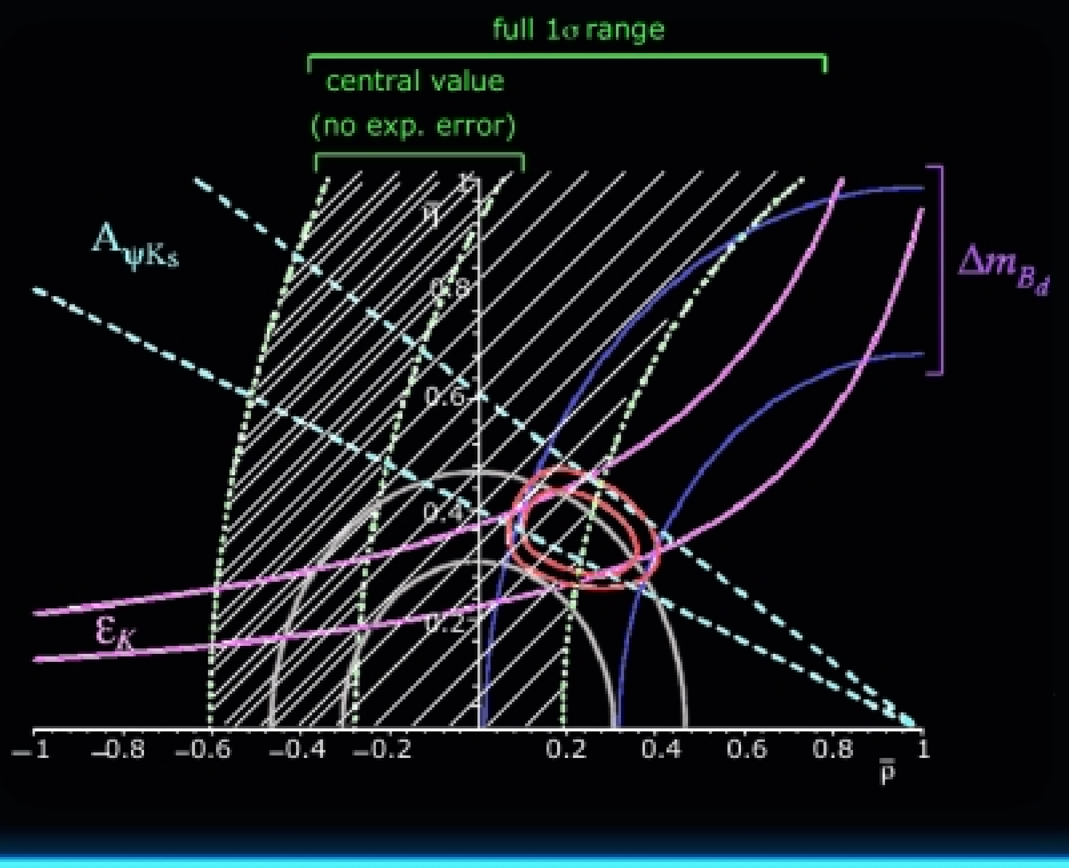
istituto nazionale di fisica nucleare
laboratori nazionali di frascati

2001

ANNUAL REPORT



Cover: Impact of rare Kaon decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ on the CKM unitarity triangle. See report from the LF-21 group.

Cover artwork by C. Federici

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FOREWORD
THE FRASCATI NATIONAL LABORATORIES

Sergio Bertolucci
Director

2001 has been a pretty good year for the LNF.

The main reason in support of this statement comes from the impressive improvement of the performances of DAΦNE, which has not only reached a peak luminosity in excess of 5 10^{31} $cm^{-2}s^{-1}$, but has also delivered about 200 pb^{-1} of data to the experiments, thus surpassing the year 2000 performances by an order of magnitude. Moreover, the vast improvement in the understanding of the machine and the introduction of new hardware and software tools will allow the continuation of the positive trend in the year 2002 and beyond.

KLOE and DEAR experiments have greatly profited of the improvements, producing new measurements, which have been shown in various international conferences, while the third approved experiment, FINUDA, is being rapidly assembled and is preparing to roll-in.

Three synchrotron light lines (IR, VUV, soft x-rays) have been also brought to operation. The IR line, due to the very high current of DAΦNE, is among the most intense beams worldwide.

A Test Beam Facility, using the DAΦNE Linac has also been brought to operation.

A particular mention is to be reserved to NAUTILUS, the Gravitational Ultracryogenic Antenna, which is consistently improving its sensitivity.

New ideas for the short and mid-term future on accelerator developments at LNF have been examined, and a proposal for the construction of a very high brilliance injector, associated to a matching undulator, has been submitted to the Italian Ministry of Research, in reply to a competitive call. This project is intended to represent the preliminary R&D for a larger enterprise, presently included in the National Research Plan, which envisages the construction of a X-Ray Free Electron Laser in the nanometer wavelength. Consequently, a rather large group has been actively working in the setting up the case study for an x-ray FEL, in preparation of a call for proposals, expected early in year 2002. The LNF Accelerator Division has also contributed the design study for the transfer lines, Delay Loop and Combiner Ring of the CTF3 initiative at CERN, as well as the construction of a number of prototypes of critical components. LNF has also participated to the TESLA TDR, presented in March 2001 to the international community at DESY.

Experimental research activities at other laboratories, involving about 50% of the lab resources, have progressed smoothly. LNF experimental groups are presently collaborating to leading experiments at LNGS, CERN, DESY, SLAC, TJNAF, ESRF, FERMILAB, EGO, as well as in astroparticle physics for space missions.The activities, covering a very broad range, from detector design to data analysis (passing through construction and commissioning), are very well documented in the report.

A small but very active theory group has continued the support and stimulation of the lab research, and has played a central role in the setting up of a large European network on Phenomenology, which has been granted EU support.

Concerning Europe, the Transnational Access to Research Infrastructures (TARI) program, initiated in year 2000, has proceeded very satisfactorily, granting more than 1500 hours of access to LNF research facilities.

Finally, LNF has staged a sizeable program for training and dissemination of science, which has met a large and enthusiastic participation.

Laboratori Nazionali di Frascati dell'INFN

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1 Introduction

The first phase of the realization of DAΦNE, the new double ring electron-positron collider of the Frascati National Laboratory was completed on Sunday, March 1st, 1998, when the first interactions between the two beams circulating in the two rings of the machine were observed. From that moment on the main task of the LNF Accelerator Division staff members, who have designed and built the facility, has been the improvement of its performance which, after the installation of the KLOE detector during the first three months of 1999, allowed to observe the production of the first Φ resonances and its CP violating decays.

DAΦNE has been therefore the first "electron-positron factory" in operation. With this name we call the storage rings for electrons and positrons delivering a high rate of mesons for high resolution experiments requiring an extremely large number of events. In order to reach such high rates, the factories are designed to work at the energies of the meson resonances, where the production cross section peaks. Examples of such resonances are the Φ near 1 GeV, the J/ψ around 3 GeV and the Y near 10 GeV, which decay into mesons containing the "strange", "charm" and "beauty" quarks respectively. However, it is not sufficient to exploit the high cross section to obtain the required production rate: it is also necessary that the collider luminosity (the number of events per unit time of the reaction under investigation divided by its cross section weighted by the acceptance of the detector) is very high, between one and two orders of magnitude larger than that obtained in the conventional colliders with a single ring where electrons and positrons run on the same orbit in opposite directions.

DAΦNE is the heart of a system consisting of a double ring collider, a linear accelerator (LINAC) an intermediate damping ring to make injection easier and faster and 180 m of transfer lines connecting these machines. The geometry of this accelerator complex has been designed to reuse the buildings hosting ADONE (the 3 GeV center of mass electron-positron collider in operation at LNF from 1969 to 1993) and its injector, a LINAC used both to refill the collider and to perform nuclear physics experiments.

The reason why a double ring collider can deliver a much larger luminosity than a single ring one is the following: in an electron-positron storage ring both beams consist of a number N of short "bunches". Since in a single ring the bunches, due to the invariance of the Lorentz force in the absence of electric fields with respect to particles of opposite charge and velocity, follow the same trajectory, they cross in 2N points. The maximum obtainable luminosity is limited by the electromagnetic beam-beam interaction. The effects of this interaction can be reduced with a very strong focussing (called "low-β") at the points where the beams cross, obtained by means of quadrupole doublets or triplets in the interaction region (IR). These magnetic structures require space and excite chromatic aberrations which must be corrected elsewhere in the ring. It is clear that in a small machine like DAΦNE only two of these regions can be realized, and therefore only a single electron bunch and a single positron one could be stored in a single ring. A larger number of bunches could be stored only if more low-β points would be available, twice the number of bunches stored in each beam.

This limitation does not hold for a double ring collider, consisting in two separate rings crossing in two low-β points. The number of bunches that can be stored in such a collider is limited only by the geometry of the IR's.

In DAΦNE the trajectories followed by the two beams cross at the interaction point (IP) at an angle of 1.5 degrees in the horizontal plane. A positron bunch leaving the IP after crossing an electron one will reach the following electron bunch at a distance of half the longitudinal separation between bunches from the IP. However, due to the horizontal angle between the trajectories of the two beams, the distance in the horizontal direction between the two bunches is equal to the horizontal angle times half the longitudinal distance between the bunches in the beam. The beam-beam interaction can be harmful to beam stability even if the distance in the horizontal direction between bunches of opposite charge is of the order of few bunch widths at points where the β function is high and this sets a lower limit on the bunch longitudinal separation and therefore on the number of bunches which can be stored in the collider. For DAΦNE the minimum separation is 80 cm, and the maximum number of bunches to be stored in each ring is 120. This number determines the frequency of the radiofrequency cavity which replaces at each turn the energy lost in synchrotron radiation, which must be 120 times the revolution frequency. The luminosity of the collider can therefore be up to 120 times larger than that obtainable in a single ring with the same size and optical functions.

Crossing at an angle could in principle be a limitation to the maximum single bunch luminosity. In order to make the beam-beam interaction less sensitive to this parameter and similar to the case of single ring colliders where the bunches cross head-on, the shape of the bunches at the IP is made very flat (typical r.m.s. sizes are 30 mm in the longitudinal direction, 2 mm in the horizontal and 0,02 mm in the vertical one).

Of course the double ring scheme with many bunches has also important drawbacks: the total current in the ring reaches extremely high values (5 A in the DAΦNE design) and the high power emitted as synchrotron radiation ($\approx$50 KW) needs to be absorbed by a complicated structure of vacuum chambers and pumping systems in order to reach the very low residual gas pressure levels necessary to avoid beam loss. In addition, the number of possible oscillation modes of the beam increases with the number of bunches, calling for sophisticated bunch-to-bunch feed-back systems.

Somebody may ask why such a simple solution to improve the luminosity of electron-positron colliders has not been adopted in the past: the answer is that two machines of this kind has been built (DORIS at DESY and DCI at LAL-Orsay) but they were not able to reach a good performance. The reasons why this happened are now well understood and the new machines have been designed taking into account this experience. In addition to DAΦNE, two other colliders at the energy of the Υ resonance (PEPII at SLAC and KEK-B in Japan) have been realized with the double ring scheme and are presently in operation.

The structure of the collider consists of two rings. Both rings lay in the same horizontal plane and each one consists of a long external arc and a short internal one. Starting from the IP the two beams travel together inside a common vacuum chamber and their distance increases until it becomes $\approx$12 cm at the level of the magnetic separators called "splitters" (SPL). These are special magnets with two regions of opposite field which deflect the two beams in opposite directions, allowing them to reach the separate vacuum chambers of the long and short arcs. Each arc consists of two "almost achromatic" bends (deflecting the beam by 81 degrees in the short arc and 99 degrees in the long one) similar to those frequently used in synchrotron radiation sources, with a long straight section in between. Each bend consists of two dipoles, three quadrupoles, two sextupoles and a wiggler. This structure is used for the first time in an electron-positron collider and it has been designed for the particular requirements of DAΦNE: the amount of synchrotron radiation power emitted in the wigglers is the same as in the bending magnets and the wigglers can be used to change the transverse size of the beams. The increase of emitted power doubles the damping rates for betatron and synchrotron oscillations, thus making the beam dynamics more stable, while the possibility of changing the beam sizes makes the beam-beam interaction parameters more flexible.

The straight section in the long arc houses the pulsed magnets used to store into the rings the bunches coming from the injection system, while in the short arc straight there are the radiofrequency cavity and the equipment for the feed-back systems which are used to damp longitudinal and transverse instabilities.

The most delicate part of the whole structure are however the IR's. The collider can host two experiments, even if up to now only one at a time can get useful luminosity. Three detectors have been realized, KLOE, DEAR and FINUDA. The first two have been installed in the two IP's, while the third is being assembled in its pit inside the DAΦNE hall and will take data in the near future in the IR now occupied by DEAR. The detectors of KLOE and FINUDA are surrounded by large superconducting solenoid magnets for the momentum analysis of the decay particles and their magnetic fields represent a strong perturbation on the beam dynamics. This perturbation tends to induce an effect called "beam coupling", consisting in the transfer of the betatron oscillations from the horizontal plane to the vertical one. If the coupling is not properly corrected, it would give a significant increase of the vertical beam size and a corresponding reduction of luminosity. For this reason a superconducting solenoid magnet with half the field integral of the detector one and of opposite direction is placed near each splitter in such a way that the overall field integral in the IR's vanishes.

However, this is not sufficient to obtain full compensation of the beam coupling induced by the main solenoids. In the case of KLOE the low-β at the IP is realized by means of two quadrupole triplets. Due to the flat shape of the beam at the IP, the low-β is realized only in the vertical plane. The quadrupole cannot be of the conventional electromagnetic type for two reasons: the first is that the iron of the joke would degrade the flatness of the magnetic field in the detector and the second is that the overall transverse size of a conventional quadrupole is at least twice its useful aperture. Therefore quadrupoles realized with permanent magnets have been built, which exhibit a surprisingly good field quality, very small transverse size and are fully transparent to external fields. The region of space around the IP occupied by machine elements, which is unavailable for the detection of decay particles by the experiment consists in two cones with the vertex at the IP and a half aperture of only 9 degrees. In order to obtain a good compensation of the above mentioned coupling effects induced by the solenoids, these quadrupoles are rotated around their longitudinal axis by angles between 10 and 20 degrees and are provided with actuators to finely adjust their position and rotation. If one takes into account the fact that the whole structure is completely embedded inside the KLOE detector, it is easy to imagine how complicate is this realization from the engineering point of view.

The structure of the FINUDA IR is quite similar. Since its superconducting solenoid magnet has half the length (but twice the field) of the KLOE one, the low-β focusing at the IP is obtained by means of two permanent magnet quadrupole doublets inside the detector and completed with two other conventional doublets outside. The DEAR experiment, which is presently installed on the IR opposite to KLOE, does not need magnetic field and therefore only conventional quadrupoles are used. Two synchrotron radiation lines, one from a bending dipole and the other from the wiggler have also been realized by the DAΦNE-LUCE group.

The vacuum chambers of the arcs have been designed to stand the high level of radiation power emitted by the beams (up to 50 KW per ring): they consist of 10 m long aluminum structures built in a single piece: its cross section exhibits a central region around the beam and two external ones, called the antechambers, connected to the central one by means of a narrow slot. In this way the synchrotron radiation hits the vacuum chamber walls far from the beam and the desorbed gas particles can be easily pumped away. The chambers contain water cooled copper absorbers placed where the radiation flux is maximum: each absorber has a sputter ion pump below and a titanium sublimation pump above.

The single cell copper radiofrequency cavities, one in each ring, are capable of running at 250 KV and are designed with particular care to avoid high order modes which could induce longitudinal instabilities in the particular multibunch structure of the beams. This is obtained by means of external waveguides terminated on 50Ω loads. A sophisticated longitudinal feedback has however been built to mantain a reasonable safety margin on the threshold of multibunch instabilities. The system is based on the digital signal processing technique and acts on each single bunch individually. Additional feedback systems on the vertical betatron motion have been also realized following the observation of coherent instabilities during the collider operation.

The correct superposition of the beams at the IP is of course of critical importance for the luminosity of the ring. For this reason, 46 beam position monitors are available in each ring and 31 small dipoles can be used to steer the beam and correct orbit distortions caused by alignment errors or wrong currents in the magnetic elements by means of sophisticated software procedures implemented in the Control System of the collider. Additional beam diagnostics are two synchrotron radiation outputs, from which the transverse and longitudinal size of the beam can be measured, total beam current monitors and strip-line pickups delivering the charge of each bunch.

The DAΦNE Control System is based on a three level architecture, where the third level consists of a large number of CPU's placed along the rings and the power supply halls. These CPU's perform all kinds of control tasks on the corresponding devices and are linked by means of a mailbox system (the second level) to the computers in the Control Room, where high-level procedures allow to control and tune all machine and beam parameters. A luminosity monitor based on single beam-beam bremsstrahlung, delivering a fast response to machine parameter changes is also used to optimize the collider performance, while the absolute value of the luminosity is directly measured by the experiments. The original system is all based on MacIntosh computers.

In a low energy electron-positron collider, such as DAΦNE, the lifetime of the stored current is mainly limited by the Touschek effect, namely the particle loss due to the scattering of the particles inside the bunches. In the present operating conditions it is of the order of half an hour. It is therefore necessary to have a powerful injection system, capable of refilling the beam without dumping the already stored one. In addition, flexibility of operation requires that any bunch pattern can be stored among the 120 available buckets. The injection system of DAΦNE is therefore designed to deliver a large rate of particles in a single bunch at the working energy of the collider. It consists of a linear accelerator with a total accelerating voltage of 800 MV. In the first section, electrons are accelerated to ≈250 MeV before hitting a tungsten target (called positron converter) where positrons in a single bunch at the working energy of the collider. It consists of a linear accelerator (LINAC, see Figure 1) with a total accelerating voltage of 800 MV. In the first section, electrons are accelerated to ≈250 MeV before hitting a tungsten target (called positron converter) where positrons are generated by bremsstrahlung and pair production with an efficiency of ≈1%. The positrons exit from the target with an energy of few MeV and are then accelerated by the second section of the LINAC to their final energy of ≈0.51 GeV. The positrons are then driven along a transfer line and injected into a small storage ring, called Accumulator (see Figure 1 again), at a frequency of 25 Hz. Up to 19 positron pulses are stacked into a single bucket of the Accumulator, then injection stops and the bunch damps down to its equilibrium beam size and energy spread, which are much smaller than the LINAC ones. Damping takes ≈0.1 seconds and then the beam is extracted from the Accumulator and injected into the positron main ring at an overall repetition rate of 1 Hz. A powerful and flexible timing system allows the storage of any desired bunch pattern in the collider. In the electron mode, the converter is extracted from the LINAC and electrons are directly accelerated to 0.51 GeV and injected into the Accumulator in the opposite direction with respect to positron operation. They are then extracted like in the positron case and injected into the electron main ring through the second transfer line.

The Accumulator has been introduced for the following reasons. The first is that the LINAC can deliver pulses of 10 ns with a charge of ≈1 nC. Since the design charge of the main ring at the maximum luminosity is 1.5 μC and the longitudinal acceptance of the main rings is only 2 ns, the number of pulses necessary to fill the ring is of the order of 104. In order to avoid saturation it is therefore necessary that at each injection pulse a fraction smaller than 10^{-4} of the already stored beam is lost, and this is not easy to achieve. The Accumulator instead can work with a lower frequency RF cavity and therefore with a larger longitudinal acceptance. In this way the full charge coming from the LINAC can be stored. The number of pulses into the Accumulator is only 19, and after damping the whole charge stacked into an Accumulator bunch can be stored into the main ring. In this way a single main ring bucket can be filled with only one pulse from the Accumulator, reducing to 120 the number of injection pulses into each main ring. As an additional benefit, the transverse beam size and energy spread of the beam coming from the Accumulator are at least one order of magnitude smaller than those of the LINAC beam, and this strongly reduces the aperture requirements of the main ring and, as a consequence, the overall cost of the collider.

2 DAΦNE history

The construction of DAΦNE was approved by INFN in June 1990. The engineering design started in spring 1991, based on the assumption of using the buildings of ADONE, which of course needed some important modifications to house the new facility. ADONE was shut down at the end of April 1993 and the DAΦNE hall was ready for installation in January 1996.

Commissioning of the injection system started in January 1996, with the first electron beam acceleration. In June the first electron beam was stored in the Accumulator, while in July also positrons were available from the LINAC. The rings were completed and under vacuum in August 1997: the first electron beam was stored in DAΦNE in October and the positron one in November. The first collisions were detected in March 1998: the machine was running in a commissioning configuration, called "DAY-ONE" without any magnetic detector. The low-β at the IP's was obtained by a symmetric arrangement of seven quadrupoles, with the central one sitting on the IP. A luminosity of $1.6\,10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ in the single bunch mode was reached in November with stored currents of ≈20 mA, and a first attempt of multibunch operation with 13 bunches in each beam yielded a luminosity of $\approx 10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$.

In the first months of 1999 the KLOE detector was installed, and commissioning in the new configuration with the strong solenoid, superconducting compensators and permanent magnet quadrupole triplets was resumed in April, with particular care dedicated to coupling correction. The vertical beam size was minimized by tuning the main solenoid field, the compensator currents and the excitation of skew quadrupole correctors around the ring. The result was better than design (the vertical emittance was reduced to less than 1% of the horizontal one). However the single bunch luminosity was less than $2\,10^{29}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, much smaller than what obtained in the "DAY-ONE" configuration.

At the end of the year a period of approximately one month was dedicated to KLOE operation: working with stored currents of 300÷400 mA in 30÷40 bunches, with peak luminosity in the range of $5\,10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and beam lifetime of the order of one hour, $\approx 2.5pb^{-1}$ were delivered to the experiment.

After a two-months shut down in January and February 2000 for some important modifications to the injection kickers, a long period of operation was dedicated to the improvement of the storage ring performance. The beam coupling was further reduced to less than 0.5% and the corresponding single bunch luminosity reached $5\,10^{29}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. The single beam stored current exceeded 1 A in both rings and with multibunch operation in collision with 30 bunches and 0.35 A per beam the luminosity was increased up to $1\,10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. The whole month of July was dedicated to KLOE data taking, with a total integrated luminosity of $\approx 4pb^{-1}$. However, the operation of the machine was characterized by a high rate of beam induced background and short luminosity lifetime. It was necessary to inject the beams frequently with data acquisition stopped because of too frequent trips of the KLOE drift chamber during injection.

After the summer shutdown, a two and a half month period from mid-September to the end of November was shared between KLOE data taking and machine development aimed at increasing the integrated luminosity and reducing backgrounds by means of scrapers placed upstream the IR's and closed orbit and optical functions optimization. As a result of this work, the loss rate during injection decreased to a level which allowed to refill the beams without switching off the KLOE drift chamber. Data acquisition was synchronized with the DAΦNE timing system in order to inhibit data acquisition for 50 msec around the injection pulse, thus reducing to a negligible fraction the loss in efficiency during injection. Therefore, the beams were refilled more frequently, leading to an average luminosity close to the maximum one.

At the end of the year the typical bunch pattern for KLOE data taking operation was between 45 and 48 bunches per beam with one empty bucket interleaved with a full one, and a 20% empty gap to avoid ion trapping in the electron ring. The beams were separated vertically in the DEAR IR. The current per bunch was up to 15 mA in the positron ring and 12 mA in the electron one, with total currents of ≈0.75 A and 0.55 A respectively. The best peak luminosity reached $1.8\,10^{29}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, smaller by ≈ 30% with respect to the single bunch luminosity times the number of stored bunches, due non uniform filling and parasitic crossing effects. During 2.5 months of operation interleaved with machine development shifts at a share near 50%, $24pb^{-1}$ were delivered to the experiment with a signal to background ratio significantly improved with respect to the shifts in July.

The first two weeks in September and the last two in December were dedicated to DEAR with the aim of improving the signal to background ratio, also in this case by optimizing the closed orbit and optical functions near the IR, and the position of the scrapers in both rings. The final improvement was a factor 20 with respect to the data collected in 1999. A local luminosity monitor based on the detection of charged K's from the decay of the ϕ resonance was brought in operation, allowing the calibration of the DAΦNE fast monitor, which detects photons from beam-beam bremsstrahlung. During DEAR operation the beams were vertically separated in KLOE: an attempt to run the machine with beams interacting in both IR's led to a substantial reduction in luminosity.

3 Year 2001 activity

During January and February 2001, DAΦNE was shut down with the main task of performing maintenance operations on the refrigeration system for the KLOE superconducting magnet. In addition, the helium refilling procedure of the two compensator magnets, which was done manually losing about three hours every two days, was updated to be remotely controlled during the normal operation of the collider. Following the indications of measurements with the beam and numerical simulations, the scrapers placed near the splitter magnets, which reduce machine induced backgrounds in KLOE and DEAR, were dismounted and substituted with new ones with a different profile. These scrapers are tapered by a Cu-Be shield to avoid large contributions to the vacuum chamber impedance, but the simulations show that the shield decreases the efficiency of the scrapers. Therefore, new shields were realized, with a slot at the level of the beam. New power amplifiers for the vertical feedback system were installed, increasing the total available power to the beam. During the shutdown, the assembly of the FINUDA detector inside the superconducting magnet was started.

Important steps in understanding the non linear behaviour of the machine lattice were realized in the last months of year 2000 and the first ones of 2001. It had been observed from the very beginning of DAΦNE operation that the dependence of the betatron frequencies versus the energy of the beam with sextupoles off was not linear as expected, indicating the presence of strong non linear terms in the ring lattice. Therefore the machine shifts in fall 2000 interleaved with KLOE data taking were dedicated to the search of such terms. Measurements of the betatron tunes as a function of horizontal beam displacement, localized in the achromatic bends, revealed the presence of a strong octupole-like term in the wigglers of both rings, which is excited by the combination of a decapole term in the wiggler field, combined with the oscillating trajectory of beam inside the wiggler itself. The result of these measurements is shown for the positron ring in Fig. 1.In order to estimate the contribution of the wigglers to the overall non-linearity of the machine, a lattice with wigglers off was realized, where the betatron functions in the achromats were similar to those with wigglers on, in spite of the absence of the vertical focusing provided by the wigglers. With this lattice the dependence of the betatron tunes versus beam energy with sextupoles off comes out to be practically linear, as shown in Figure 1, indicating that the main contribution to high order non linear terms in the DAΦNE lattice comes from the wigglers.

These results were confirmed with a new technique implemented on DAΦNE, namely the acquisition of the beam position on a turn-by-turn time scale. A coherent oscillation of the beam center of mass is excited by a single pulse on the injection kicker, and the position of the beam at each revolution is then recorded on a digital oscilloscope. If the betatron frequency depends on the oscillation amplitude, the spread of horizontal positions corresponding to the beam size translates into a mixing of betatron phases that rapidly damps down the oscillation amplitude of the beam center of mass. The corresponding decay time is related to the tune shift on amplitude coefficient measured in a steady state configuration, as described before. Figure 3 shows the result of this measurement with wigglers on and should be compared to Figure 4, which is the corresponding one with wigglers off. The difference is striking, also taking into account the different horizontal scales in number of revolutions, and demonstrates again on a different physical quantity, the dependence of the betatron frequency on the betatron amplitude, that the main source of non-linearity comes from the wigglers.

Numerical simulations show that the beam-beam performance of the collider is strongly affected by non linear contributions coming from high order terms in the magnetic field. Their effect is proportional to the value of the betatron functions β at the locations where the non linearity is present. As a first countermeasure, a new lattice with smaller β's at the wigglers was designed. In addition, since the normal KLOE operation is performed with the beams separated at the DEAR IP, there is no necessity for two low-β points in the ring. The new lattice, called "detuned" because of the reduced strength of the quadrupoles in the DEAR IR has high horizontal and vertical β's ($\approx$1 m and $\approx$17 m respectively) at the DEAR IP. In this way, a much larger vertical separation of the beams, of the order of $\pm$10mm can be obtained with smaller currents in the vertical "C" corrector magnets near the splitter, which contribute a significant sextupole effect proportional to their excitation; the vertical displacement of the beams inside the splitter magnets, where the vertical aperture is small, is reduced to a negligible amount.

In order to fight the effect of the nonlinearities in the wiggler, on a longer time scale, two initiatives were undertaken. The first, and easier, one is to build two sets of four lumped octupoles to be inserted into proper locations of the ring lattices. In this way it is possible to compensate the overall nonlinearity seen by the stored particles at each revolution in the rings. Each octupole has its own power supply, so that the whole system has a wide range of tunability. The eight octupoles have been designed and commissioned to a magnet factory in France. They have been delivered to LNF at the end of the year. The second countermeasure is much more challenging from the technical point of view, but has the advantage of correcting the nonlinearity in the wiggler locally, by eliminating the perturbation to the ideal flat field inside the poles. This can be obtained by changing properly the shape of the poles by means of shims, directly applied on the pole surface. Of course, it is not reasonable to find the optimum shape of the shims on the wiggler of the machine, since this means stopping the collider for a very long time, because this shape comes out from a converging procedure using magnetic calculations, realization of the shims on a milling machine, and magnetic measurements. Therefore a spare wiggler, exactly equal to those installed on the rings, has been ordered to the same factory which has built the other ones. The nonlinearity free wiggler will be therefore realized offline, and the modification to all wigglers in DAΦNE will be undertaken later.

After the winter shut-down, the shifts in March and April were mainly dedicated to machine development, with the KLOE detector on to check luminosity and backgrounds. The result of this work with the detuned lattice was a maximum single bunch luminosity of $1.0\,10^{30}\text{cm}^{-2}\text{s}^{-1}$ with 20 mA in each beam, a multibunch luminosity of $2.1\,10^{31}\text{cm}^{-2}\text{s}^{-1}$, with 47 bunches in each beam, and a maximum integrated luminosity per day of $1.2pb^{-1}$. The second half of April was fully assigned to KLOE data taking and $9pb^{-1}$ of useful data were collected.

The whole month of May was dedicated to DEAR. With respect to the results of the preceding year, a factor 2 was gained in peak luminosity, which reached $1.0\,10^{31}\text{cm}^{-2}\text{s}^{-1}$, while the signal to background ratio remained unchanged. Unlike KLOE, however, DEAR was not able to operate during the injection of the beam and therefore, due to the short beam lifetime, the integrated luminosity per day was much smaller, the best result being $0.24pb^{-1}$. The total integrated luminosity in four weeks was $3pb^{-1}$.

In the following two months, June and July, KLOE had a long and uninterrupted run during which $\approx 55pb^{-1}$ were collected with acceptable background rates. The peak luminosity exceeded $3\,10^{31}\text{cm}^{-2}\text{s}^{-1}$, while more than $1.5pb^{-1}$ were collected in a single day of operation.

After the summer shut down, DAΦNE started again delivering beam time to KLOE. However, some shifts were dedicated to machine development aimed at further increasing the luminosity. The efforts were in two directions: the single bunch luminosity by changing the optical functions at the crossing point, and the total stored current by improving the beam stability control systems. The vertical β function at KLOE was reduced in steps from the design value of 4.5 cm down to 3.2 cm, while the average value of the dispersion in the bending dipoles was increased in order to have a larger momentum compaction factor, which helps in raising the threshold for a longitudinal quadrupole instability (at twice the synchrotron frequency), observed mainly in the electron ring. This kind of instability cannot be directly controlled by means of a feedback system like those acting on the longitudinal and transverse dipole modes. In addition, it was observed to interact with the bunch-by-bunch longitudinal feedback and, after careful observations, it was found that running the feedback with a slight delay with respect to the ideal timing was beneficial to the quadrupole instability threshold. The instability could also be cured by increasing the RF voltage, but this is in contrast with a synchro-betatron resonance, again observed mainly in the electron ring, which enlarges the vertical size of the beam, and is reduced when the RF voltage is low.

Both the peak and integrated luminosity per day increased steadily during two and a half months of operation, as can be seen from Figure 5 and Figure 6.

At the end of November, the maximum single bunch luminosity reached $1.2\,10^{30}\text{cm}^{-2}\text{s}^{-1}$, while in multibunch operation the best result was $5.2\,10^{31}\text{cm}^{-2}\text{s}^{-1}$, with 47 stored bunches in each beam and total stored currents above 1 A in each beam. It should be noticed that the multibunch luminosity was very close to the single bunch one, times the number of stored bunches. The best integrated luminosity per day exceeded $3pb^{-1}$. The stored current without interactions in the positron ring reached 1.25 A, the corresponding one in the electron ring was 1.42 A, the highest ever obtained in an electron storage ring. From mid September to the end of November $\approx 120pb^{-1}$ were collected by KLOE, bringing the total integrated luminosity in 2001 to $\approx 185pb^{-1}$, to be compared to the $\approx 24pb^{-1}$ collected in the preceding year.

Since the impressive improvement in luminosity has been obtained by increasing the total stored current, the background rate in KLOE starts to be an important limitation: the absolute counting rate in the KLOE end caps increased by ≈70% from April to November, in spite of a continuous effort to minimize it by tuning the position of the scrapers, the position of the beam and the intensity of the sextupoles. However, if the ratio of background to luminosity is taken into account, than a gain by ≈40% has been obtained. Simulation of background rates from Touschek scattered particles have shown that additional scrapers in the wigglers could be helpful in reducing backgrounds. Additional scrapers to be installed at these locations have been realized and will be installed during the shutdown scheduled for January 2002.

Before the Christmas shutdown, two weeks were allotted to DEAR, with the main task of changing the optics in order to improve the luminosity in the second IR. During the preceding shifts the vertical β function at the DEAR IP was 7 cm. A new lattice has been designed with a β value equal to that of the KLOE IP, namely 3 cm. In agreement with the progress obtained for KLOE, the momentum compaction factor was increased as well. The new lattice was tested in both rings and beam-beam interaction parameters were adjusted and measured. A crucial item for DEAR operation is the separation of the beams at the KLOE IP, which was only 2.5 mm, limited by the increase of coupling for larger separations. This problem needs further study and optimization. The luminosity was measured by means of the DEAR kaon monitor and exceeded $10^{31}\text{cm}^{-2}\text{s}^{-1}$, with stored currents between 0.5 and 0.6 A per beam. The signal to background ratio was of the same order as that measured in May. A total integrated luminosity of $0.6pb^{-1}$ has been delivered during these shifts.

In parallel with the operation of DAΦNE, several other activities have been pursued by the Accelerator Division. The most relevant are:

- The design of the FINUDA interaction region, to be installed at the end of 2002, where the four permanent magnet quadrupoles around the IP can be rotated by 90 degrees, so that it will be possible to run the collider also with the FINUDA solenoid off. With this range of rotation it will be also possible to change the sign of the quadrupole focussing, thus allowing to realize again a detuned lattice when running with a single interaction point. Also the four conventional quadrupoles between the solenoid and the compensators will be equipped with rotating supports, allowing rotation in a range of 23 degrees, corresponding to the difference between solenoidal field on and off. Inside each permanent magnet quadrupole, a trim quadrupole realized with a printed circuit technique will allow fine tuning and measurement of the β functions near the IP.

- The design of a new interaction region for KLOE: in order to guarantee the maximum flexibility to the operation of the collider, it is also foreseen to run with the KLOE solenoid off. Therefore, the six permanent magnet quadrupoles of the KLOE IR will be able to rotate by any angle between the horizontal symmetry plane of the ring and that corresponding to the full field of the solenoid. Printed circuit trim quadrupoles will be inserted in the quads nearest to the IP. The vacuum chamber will be modified with a new structure in beryllium alloy (AlBeMet) similar to the existing one but shorter, in order to allow the insertion of two new beam position monitors.

- Design, specification, purchase and installation of the octupoles for the correction of nonlinearities in the wigglers, and their power supplies.

- Modification of the design, specification and purchase of the spare wiggler and its power supply, equipped with all items necessary to determine the optimum shape of the shims to correct the decapole term.
- Two third harmonic RF cavities to control the bunch length, and therefore the lifetime, have been realized and equipped with power supplies and controls, and are ready for installation into the rings.
- Cool-down and test of the superconducting magnet of FINUDA.
- The vertical feedback systems have been upgraded in both rings by increasing the power up to 2×250 W on the kicker.
- The new scrapers near the wigglers have been realized and equipped with new absolute encoders and interfaced with the DAΦNE Control System.
- The Control System has been improved with a new operating system, a new third level processor and several supported items such as the streak camera on the synchrotron light monitor, which allows to measure the bunch length, the new power supplies for the octupoles, and the Wall Current Monitors in the Transfer Lines.

4 Publications

1. M. Preger for the DAΦNE Team: "Status of DAΦNE", presented at HEACC2001, 18th International Conference on High Energy Accelerators, 26-30 March 2001, Tsukuba, Japan.
2. M. Preger: "Activities and Future Plans at LNF", presented at HEACC2001,18th International Conference on High Energy Accelerators, 26-30 March 2001, Tsukuba, Japan.
3. A. Drago, A.Stella: "The Dynamic Tracking Acquisition System For DAΦNE e+/e- Collider", DIPAC 2001, 13-15 May 2001, Grenoble, France, to be published.
4. S. Guiducci *et al*: "Status Report on DAΦNE", Particle Accelerator Conference PAC2001, 18-22 June, 2001, Chicago, USA, p.353.
5. M. Zobov *et al*: "Beam-Beam Experience at DAΦNE", Particle Accelerator Conference PAC2001, 18-22 June, 2001, Chicago, USA, p.3540.
6. C. Vaccarezza *et al*: "Non Linear Beam Dynamics at DAΦNE", Particle Accelerator Conference PAC2001, 18-22 June, 2001, Chicago, USA, p.443.
7. C. Milardi *et al*: "Effects of Nonlinear Terms in the Wiggler Magnets at DAΦNE", Particle Accelerator Conference PAC2001, 18-22 June, 2001, Chicago, USA, p.1720.
8. A. Gallo *et al*: "The DAΦNE 3rd Harmonic Cavity", Particle Accelerator Conference PAC2001, 18-22 June, 2001, Chicago, USA, p.885.
9. M. Boscolo *et al*: "Experience with Beam Induced Backgrounds in the DAΦNE Detectors", Particle Accelerator Conference PAC2001, 18-22 June, 2001, Chicago, USA, p.2032.
10. A. Drago *et al*: "High Current Multibunch Operation at DAΦNE", Particle Accelerator Conference PAC2001, 18-22 June, 2001, Chicago, USA, p.3543.

11. C. Sanelli *et al*: "Technical Layout of the TESLA Damping Ring", LNF-01/003, 18/1/2001.

12. M. Boscolo, for the DAΦNE Team: "DAΦNE Status Report", 23rd Advanced ICFA Beam Dynamics Workshop on High Luminosity e+e- Colliders, Cornell University, Ithaca, USA, October 2001, to be published.

13. M. Boscolo: "Effects of non linear elements on backgrounds at DAΦNE", 23rd Advanced ICFA Beam Dynamics Workshop on High Luminosity e+e- Colliders, Cornell University, Ithaca, USA, October 2001, to be published.

14. For The DAΦNE Transverse Feedback Systems", ICALEPCS 2001, 27-30 November 2001, San Jose', USA, physics/0111209.

15. F. Murtas, G. Mazzitelli, P. Valente: "The KLOE/DAΦNE Status Logging,Analysis and Database System", ICALEPCS 2001, 27-30 November 2001, San Jose', USA, hepex/0111088.

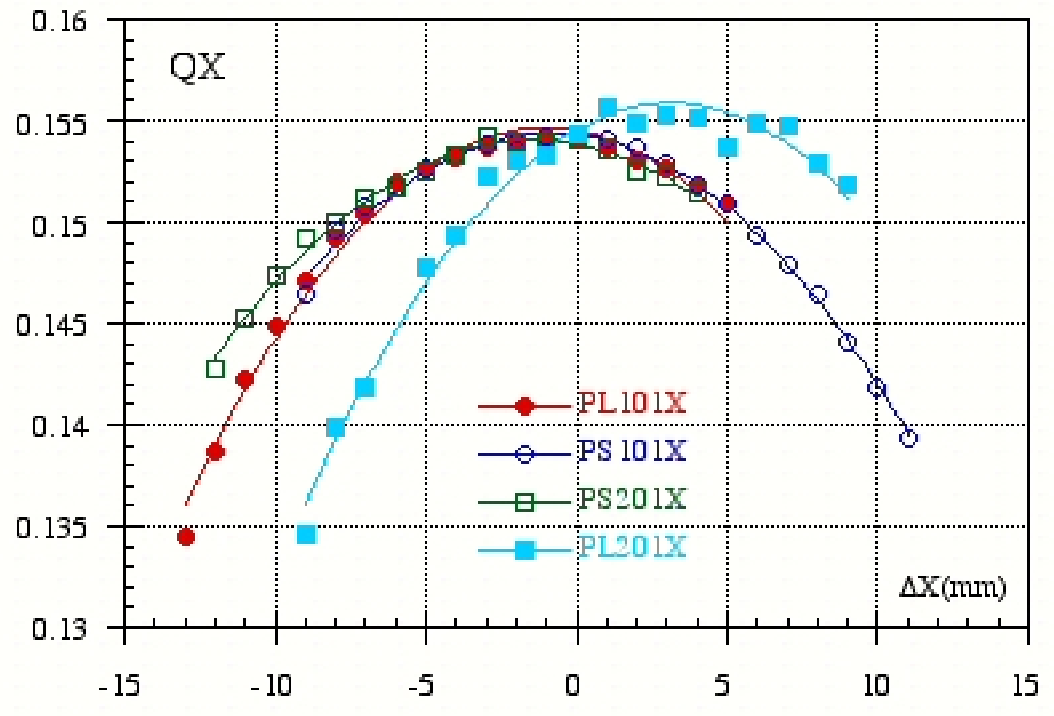

Figure 1 - Horizontal betatron tune versus horizontal displacement of the beam for the positron beam.

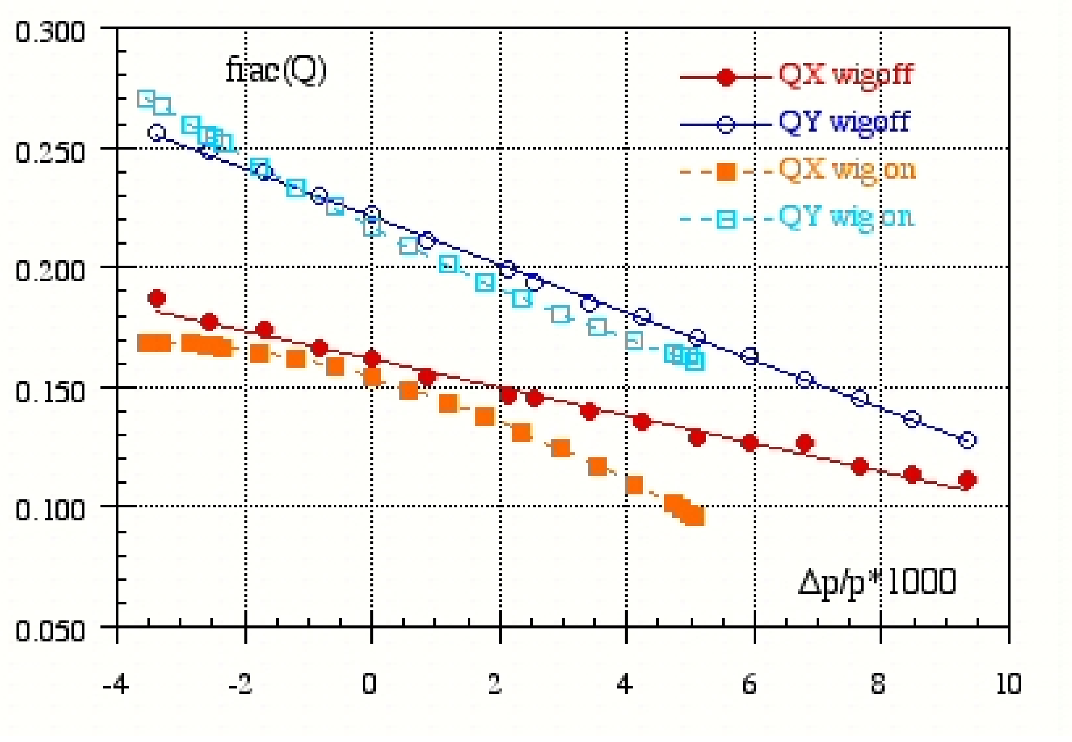

Figure 2 - Betatron tunes versus relative energy change with wiggler on and wigglers off.

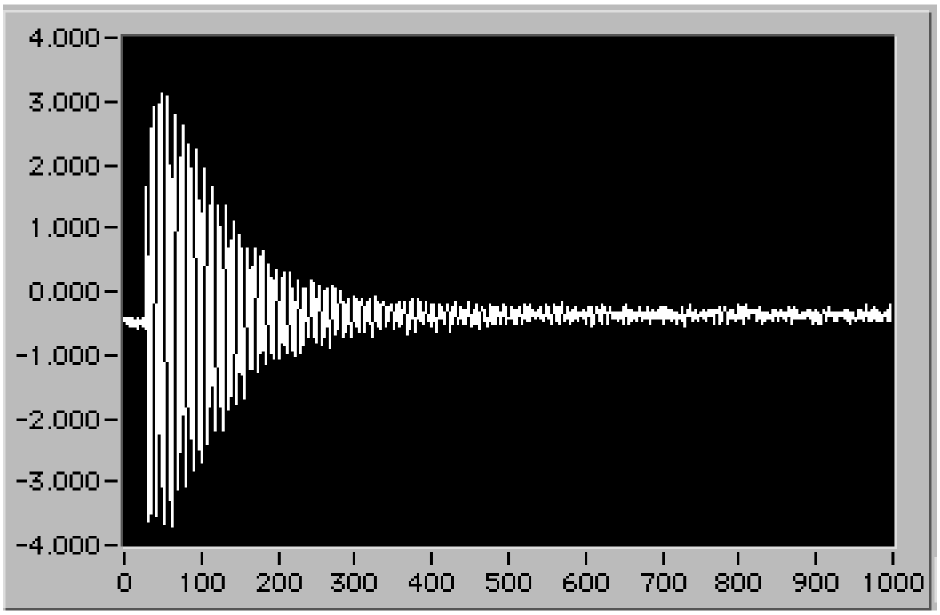

Figure 3 - Decay of the betatron amplitude of the beam after being kicked in the horizontal plane with wigglers on.

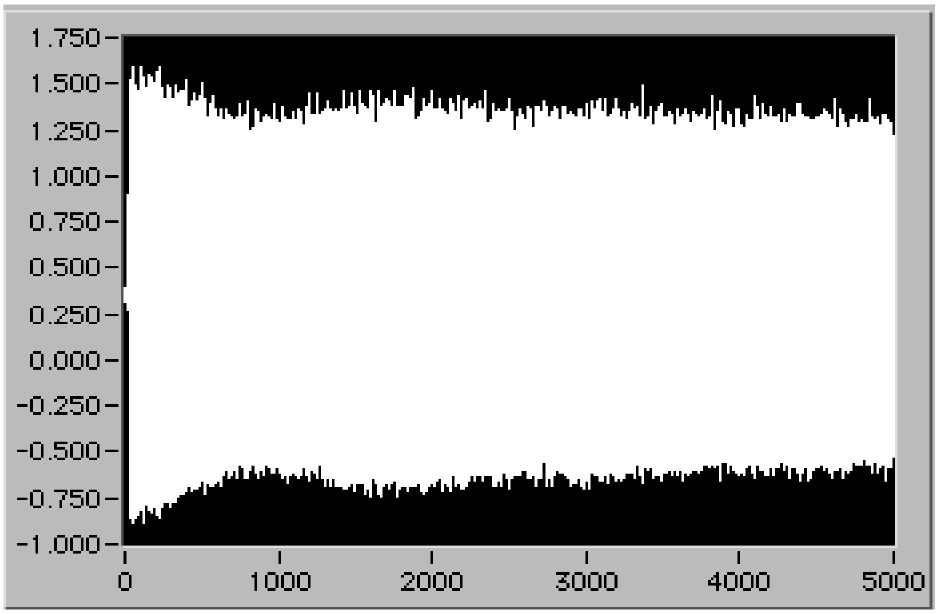

Figure 4 - Decay of the betatron amplitude of the beam after being kicked in the horizontal plane with wigglers off.

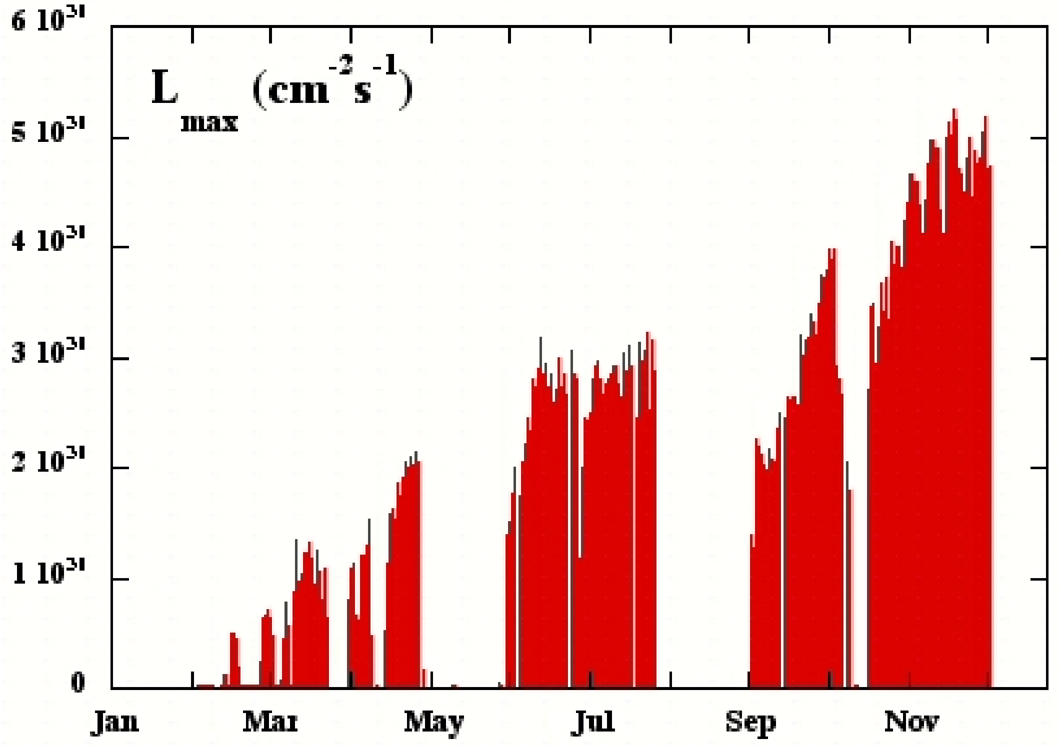

Figure 5 - Peak luminosity per day in the KLOE configuration.

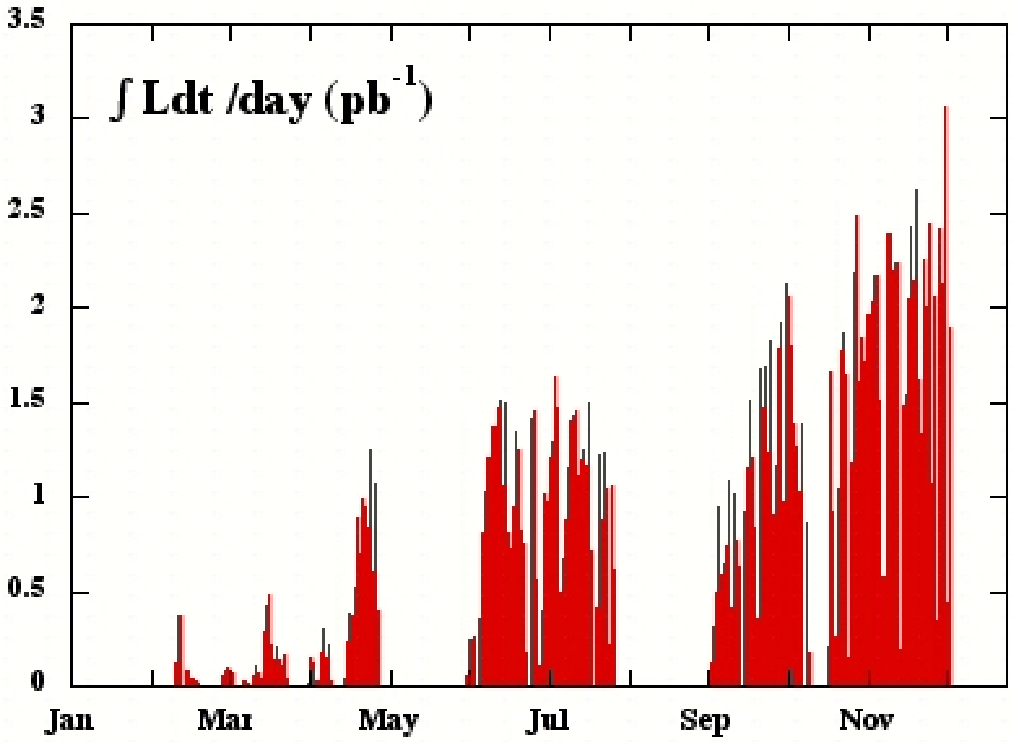

Figure 6 - Integrated luminosity per day in the KLOE configuration.

ALEPH

A. Antonelli, M. Antonelli , G. Bencivenni , G. Bologna (Ass.) , F. Bossi
P. Campana , G. Capon (Resp.) , V. Chiarella , P. Laurelli , G. Mannocchi (Ass.)
F. Murtas , G. P. Murtas (Ass.) , L. Passalacqua

1 Introduction

The data taking at Lep ended in November 2000; shortly after began the detector dismantling.

The dismantling of the hadronic calorimeter and of the muon chambers was under the Frascati responsibility; the long and complex operation terminated in July 2001.

In the mean time the activity for completing the physics analysis of all the data collected did continue.

All the Lep1 data went through a final reprocessing with improved lepton identification, track reconstruction and dE/dx analysis in the TPC.

New or updated results were produced for B_s oscillations; for b and c quarks Forward Backward Asymmetry, for Higgs and Susy particles search.

2 Physics results

For B_s oscillations the final analysis is based on three different complementary event samples : fully reconstructed B_s (low statistics but high purity sample), $D_s - lepton$ sample and inclusive lepton sample. The data are analyzed with the amplitude method; the fitted amplitude versus frequency spectrum is shown in fig. 1; from it a lower limit of $\Delta M_s > 10.9ps$ (95 % C.L.) is obtained [1].

The whole sample of Lep1 data has also been reanalysed to improve the estimate of the Forward Backward Asymmetries in $Z \to b\bar{b}$ and $Z \to c\bar{c}$. The two asymmetries are determined by a simultaneous fit to the data. Events containing the semileptonic decays of the heavy quarks have been selected and multivariate analysis methods have been used to discriminate between b and c initiated jets and between the direct $b \to l$ decay and the cascade one $b \to c \to l$.

The observed angular distributions are shown in fig. 2, the corresponding asymmetries are then [2] :

$$A^b_{FB} = 9.98 \pm 0.40(stat) \pm 0.17(syst)\%$$

$$A^c_{FB} = 7.32 \pm 0.53(stat) \pm 0.37(syst)\%$$

corresponding to a value of the effective weak mixing angle of:

$$sin^2\theta_W = 0.23188 \pm 0.00046$$

the same analysis yields also the value of the average mixing parameter for the neutral B mesons :

$$\chi = 0.1196 \pm 0.0049(stat) \pm 0.0047(syst)$$

The search for the Standard Model Higgs has been refined using the reprocessed data, the final values of the Lep energy, more MonteCarlo statistics and improved algorithms for background rejection [3].

The results are only marginally different from the first original analysis. In the two data streams - the Cut one and the Neural Network based one - the events excess is :

$$\text{Cut stream : } 3.04\ \sigma \text{ (was 3.06)}$$

$$\text{NN stream : } 2.82\ \sigma \text{ (was 2.96)}$$

The observed limit on the Higgs mass is 111.5 GeV at 95 % C. L.

The same analysis updates also the limits for the neutral MSSM Higgs bosons.

The searches for supersymmetric particles have also been updated. Here there have been important contributions from Frascati:

1) Looking for gauge mediated SUSY breaking (GMSB) topologies (acoplanar photons or leptons, non pointing single photons, heavy stable charged sleptons, etc.) no evidence for new phenomena is found. A scan of a minimal GMSB parameter space yields a mass limit for the next-to-lightest supersymmetric particle of 54 GeV/c^2 [4].

2) Searches for the scalar top, scalar bottom have also been performed; in particular the stop four-body channel decay has been investigated for the first time. The negative results have been translated into exclusion domains in the framework of the minimal supersymmetric model.

3) The single top production analysis has been extended to the full data sample; 24 candidate events are found to be compared with 20.1 expected from Standard Model processes. This corresponds to an un upper limit BR($t \rightarrow Zc + Zu$) $< 14\%$.

3 List of Publications

Here follows the list of papers quoted in the text, the full list of Aleph papers can be found on the Aleph Web page.

References

1. Aleph collab., CERN EP/2002-016 (Submitted to European Physics Jou. C)
2. Aleph collab., CERN/EP2001-97 (Submitted to European Physics Jou. C)
3. Aleph collab., CERN EP/2001-095 (Submitted to Physics Letters)
4. Aleph collab., CERN/EP2002-21 (Submitted to European Physics Jou. C)

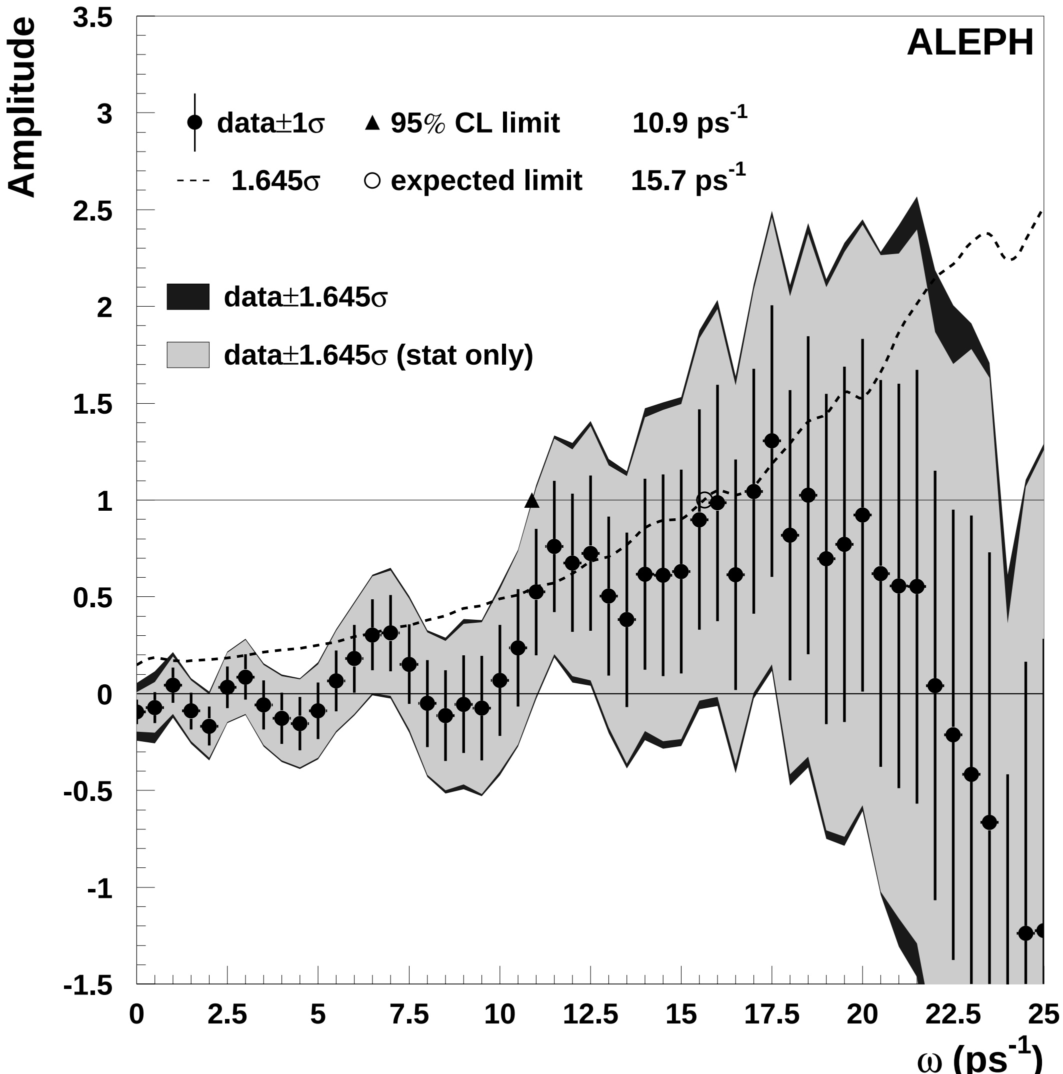

Figure 1: *Amplitude spectrum versus frequency.*

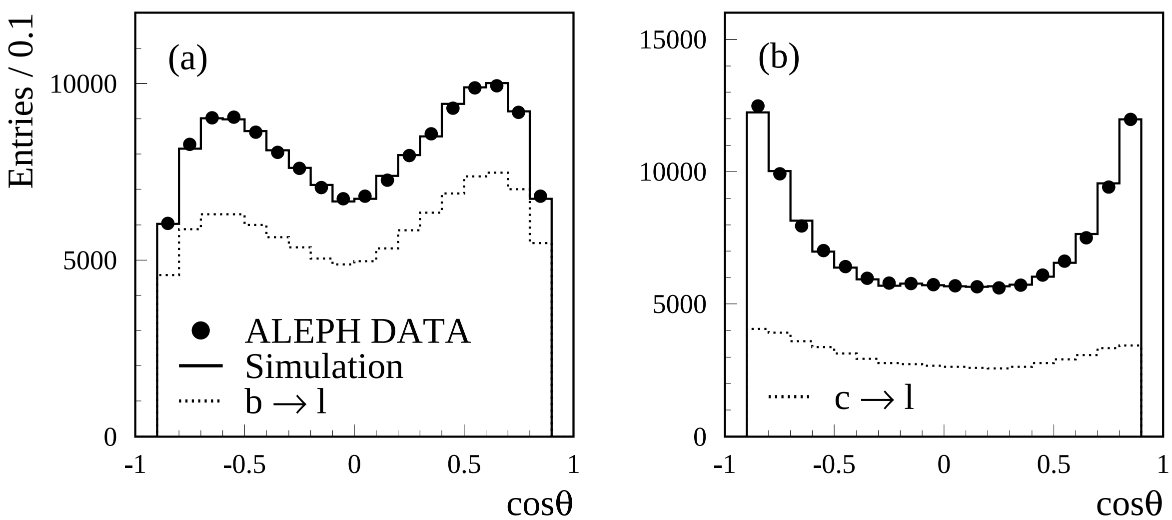

Figure 2: *Observed angular distributions for b candidate jets (side a) and c candidates jets (side b).*

ATLAS

M. Beretta, S. Bertolucci, H. Bilokon, S. Braccini, E. Capitolo (Tecn.),
V. Chiarella, M. Curatolo, B. Dulach, B. Esposito (Resp.), G. Felici,
M.L. Ferrer, P. Laurelli, G. Maccarrone, A. Martini, G. Nicoletti, E. Pace,
G. Pileggi (Tecn.), B. Ponzio (Tecn.), V. Russo (Tecn.), A. Sansoni

1 Introduction

The ATLAS experiment is aimed at exploiting the full physics potential of the LHC and is based on a general purpose detector of unprecedented size, complexity and performances. The ATLAS detector has been designed and is being built by a world-wide collaboration of more than 150 Institutions. In order to cope with the complexity of the events, the background conditions and the radiation environment, challenging requirements are put on the detector performances and characteristics. R&D programs were necessary on all the sub-detectors. The Frascati group has given an important contribution to the design and development of the precision tracking chambers of the ATLAS muon spectrometer [1)], and has taken the commitment of the construction of about 10% of the chambers. The ATLAS muon spectrometer has been designed to achieve very good momentum resolution in stand-alone mode. It consists of super-conducting toroids, instrumented with very high precision tracking chambers, the so called MDT (Monitored Drift Tubes) chambers, and RPC and TGC chambers for triggering. The MDT chambers are large area (about 5000 m^2 to be covered) high precision (about 80 microns intrinsic resolution) detectors, based on assembly of high pressure drift tubes. The design project requires the wires to be positioned at less than 20 micron r.m.s. precision. The Frascati group has contributed with the design of the assembly jig [1)] (Fig. 1), necessary to achieve such a mechanical precision, and the design of a fully automated wiring machine [2)] (Fig. 2). Also an automated leak test station (Fig. 3) and a wire tension-meter (Fig. 4) have been designed and built by the Frascati group [2)].

2 Activity in the year 2001

2.1 Chamber production

Following the construction and test of the "module zero" chamber in the year 2000, at the beginning of the year 2001 some optimization of the production facilities has been done and in April the first series chamber has been built. After the successful check of that chamber at the CERN X-ray Tomograph, the series production has been resumed at the beginning of June and carried on smoothly for the rest of the year. The series production was characterized by a "learning phase" in the first few months, with a chamber produced every 15 working days approximately. After that period the assembly procedure has been optimized and the rate achieved became one chamber produced every 7 working days, as presented in Fig. 5. A total of 16 chambers have been produced, as reported in Table 1. The resolution of three of these chambers was measured at the CERN X-ray Tomograph. The results are presented in Table 2. They show that the 20μm ATLAS specification is well met in a stable way in the series production.

The tube production in the year 2001 is shown in Fig. 6. Fig. 7 shows the daily rate of tube production and quality control measurements: wiring, wire tension measurement, dark current measurement, gas leak measurement, second wire tension measurement (before the assembly in the chamber). The results of the quality control measurements are shown in Fig. 8. The percentage of tubes outside of the strict Atlas limits is at the level of a few percent.

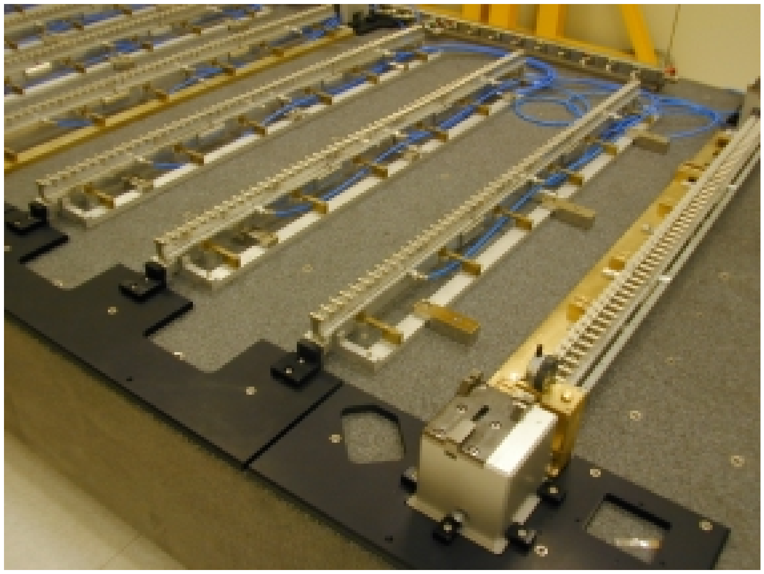

Figure 1: *The high precision jig for the positioning of the tubes.*

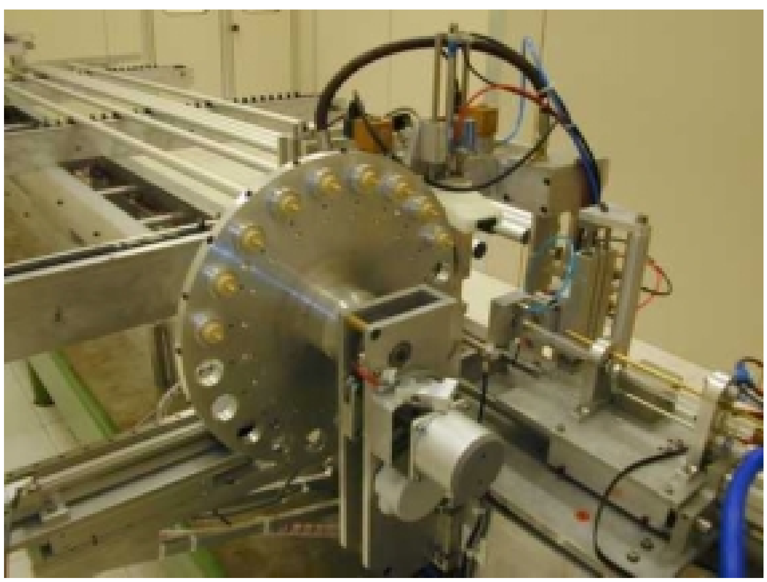

Figure 2: *The "Tub-o-matic" fully automated wiring machine.*

Figure 3: *The gas leak test station based on a helium spectrometer.*

Figure 4: *The wire tension meter (WTM) station.*

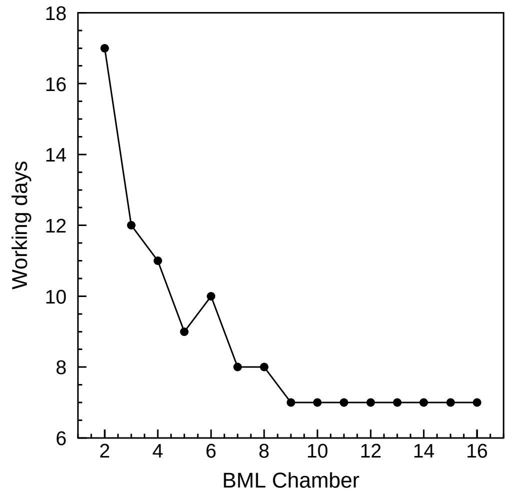

Figure 5: *The number of working days needed to assemble each BML chamber.*

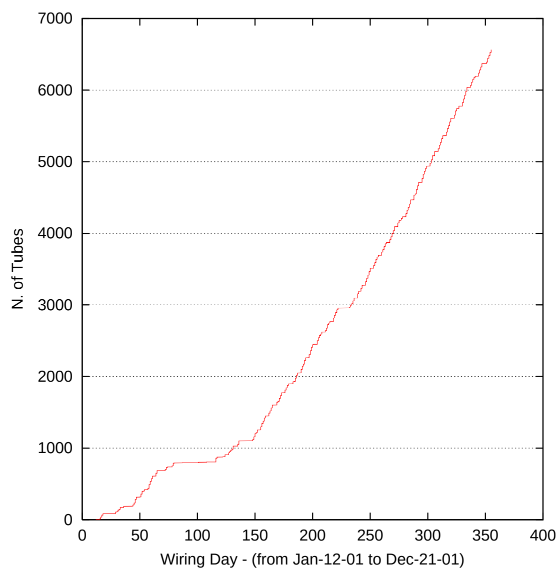

Figure 6: *The total number of wired tubes as a function of time in the year 2001.*

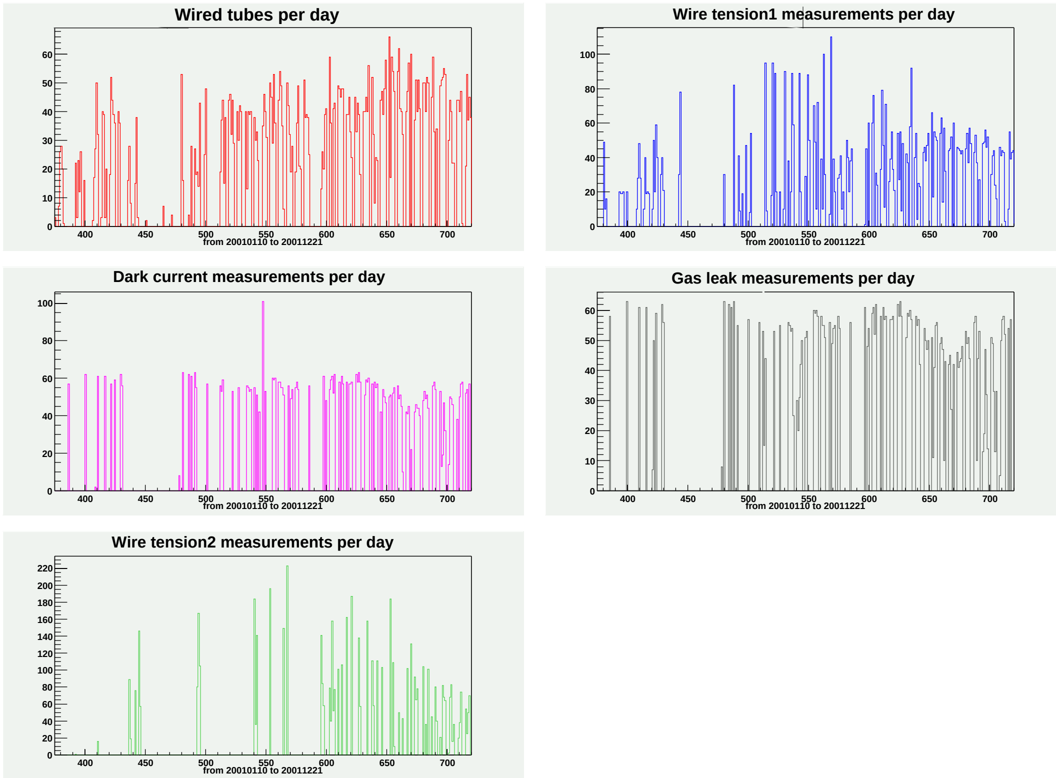

Figure 7: *The tube wiring and the quality control measurement rates per day.*

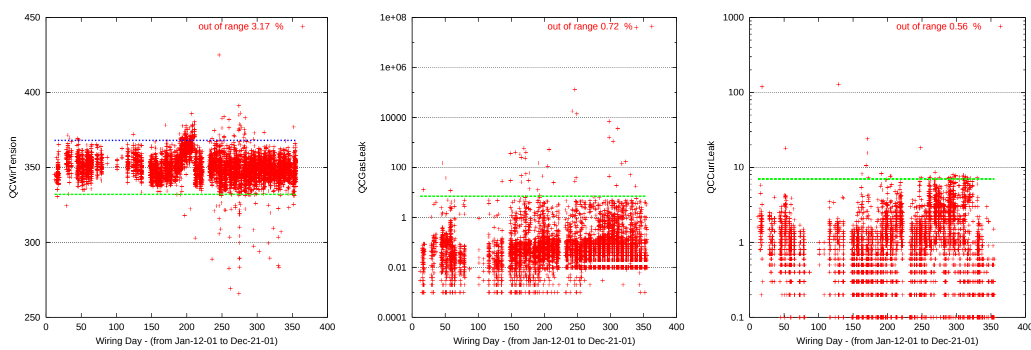

Figure 8: *The quality control measurements.*

Figure 9: *The "module zero" chamber at the H8 test beam facility at CERN.*

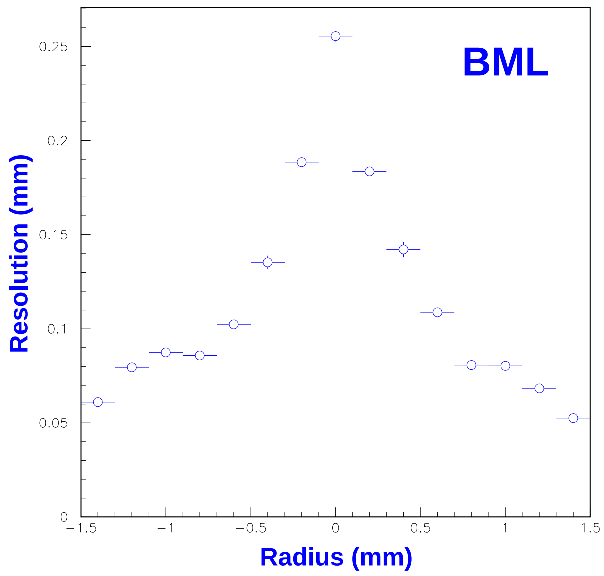

Figure 10: *Spatial resolution of the drift tubes as a function of the distance from the wire.*

BML Chamber	Tubes per layer	Begin date	End date	Working days
01	56	15/02/01	23/04/01	
02	56	07/05/01	08/06/01	17
03	56	13/06/01	28/06/01	12
04	56	09/07/01	24/07/01	11
05	56	27/07/01	08/08/01	9
06	56	09/08/01	05/09/01	10
07	56	06/09/01	17/09/01	8
08	56	18/09/01	27/09/01	8
09	56	28/09/01	09/10/01	7
10	56	09/10/01	18/10/01	7
11	56	18/10/01	29/10/01	7
12	56	29/10/01	08/11/01	7
13	56	08/11/01	19/11/01	7
14	56	19/11/01	28/11/01	7
15	56	28/11/01	07/12/01	7
16	56	07/12/01	18/12/01	7

Table 1: The BML chambers produced in the year 2001.

2.2 Test beam activity

In the second half of the year 2001 a test beam activity was started by ATLAS, in order to perform a system test of the muon detector. The Frascati group provided a chamber, installed it at the CERN H8 test beam and operated it. The setup is shown in Fig. 9, and the resolution of the chamber, measured at the test beam is shown in Fig. 10.

2.3 Cosmic ray station

A cosmic ray test stand at LNF has been in preparation, in order to perform a test of all the produced chambers.

2.4 Program of activity for the year 2002

In the year 2002 the series production will continue, about 30 MDT chambers are foreseen to be built. The cosmic ray station for the test of the chambers will become operative. A large system test will be installed at the CERN H8 test beam, with a complete ATLAS muon MDT chamber sector. The Frascati group will provide two chambers of the middle station (BML).

BML Chamber	Resolution (μm)
01	15.9
04	13.7
05	12.5

Table 2: The average resolution on the positioning of the wires measured by the X-ray Tomograph at CERN.

3 Publications

S. Braccini, *on behalf of the ATLAS Frascati Group*, "Monitored Drift Tube Chamber Production at Laboratori Nazionali di Frascati", proceedings of the 7th International Conference on Advanced Technology and Particle Physics, Como, Italy, October 2001;
G. Avolio *et al.*, "First results of the 2001 MDT chambers beam test", ATL-COM-MUON-2001-022.

References

1. H. Bilokon *et al*, ATL-MUON-95-081;
   P. Benvenuto *et al*, ATL-MUON-97-152;
   A. Ackermann *et al*, ATL-MUON-97-153;
   S. Cerioni *et al*, ATL-MUON-99-007.

2. P. Benvenuto *et al*, ATL-MUON-98-200;
   A. Balla *et al*, ATL-MUON-98-26.

BaBar

F. Anulli(Ass.), R. Baldini Ferroli, A. Calcaterra, L. Daniello(Tecn.), R. de Sangro
G. Finocchiaro, P. Patteri, I. Peruzzi(Resp.), M. Piccolo, Y. Xie(Ass.), A. Zallo

1 Introduction

BaBar is the experiment running at the SLAC asymmetric B-factory PEP-II; the physics program is centered on, but not limited to, the study of the CP violation effects in the decay of neutral B mesons. The B system is the best suited to study CP violation because the expected effects are large, should appear in many final states and, most importantly, can be directly related to the Standard Model parameters. The large data sample now being collected will also allow significant advances in a large number of topics in B, charm and top quark physics.

2 Activity

PEP-II is a two-ring e^+e^- storage ring, colliding 9 GeV electrons with 3.1 GeV positrons, energies chosen to maximize the production of B mesons. The c.m. energy corresponds to the mass of the $Y(4S)$ resonance which decays 50% in B^+B^-, 50% in $B^0\overline{B}^0$. The energy asymmetry is necessary in order to boost the B mesons momentum, so that the decay length can be measured with the accuracy needed to prove the CP violation effects. The machine commissioning ended on schedule, and data taking started in October 1999. The experiment took data without long interruptions in 2001, and will continue until the end of July 2002. The luminosity recorded in the year 2001 has reached $40fb^{-1}$ (fig. 1). The design peak luminosity, 3x10^{33} cm^{-2} sec^{-1}, has been reached; in October 2001 a record of 4.1x10^{33} cm^{-2} sec^{-1} has been achieved. The plans for an upgrade to 10^{34} and beyond are being actively addressed. The BaBar Collaboration includes more than 500 physicists, with contributions from 72 Institutions in 9 countries in North America, Europe, and Asia. Approximately half of the group are physicists from U.S. Universities and Laboratories, with the largest foreign contribution coming from Italy, with 12 INFN Institutions and approximately 85 people.

The BaBar detector has been designed primarily for CP studies, but it will also serve well for the other physics objectives of the experiment. A schematic view is shown in fig. 2. The asymmetry of the beam energies is reflected in the detector design: the apparatus is centered 37 cm ahead of the collision point, along the direction of the high-energy beam, to increase forward acceptance. All services are placed on the opposite side of the detector, in order to minimize multiple scattering in the forward direction. The momentum of the charged tracks is obtained from the curvature in a solenoidal field of 1.5 T and is measured in a low mass Drift Chamber. Different species of hadrons are identified in the DIRC, a dedicated device of a novel kind, based on the detection of Čerenkov light. Excellent photon detection and electron identification is provided by a CsI crystals electromagnetic calorimeter.

Muons and neutral hadrons are identified in the iron magnet's yoke, where a total thickness of 65 cm of Fe plates has been segmented in 18 slabs of graded thickness (from 2 to 10 cm) and instrumented with Resistive Plate Counters. This system, made of a 6-sided barrel, 2 endcaps and a double cylindrical layer inside the magnet coil, is called Instrumented Flux Return, or IFR. The final ingredient in the CP asymmetry measurements, the distance between the two decay vertices, is measured by a state of the art vertex detector, with five layers of double sided silicon strips.

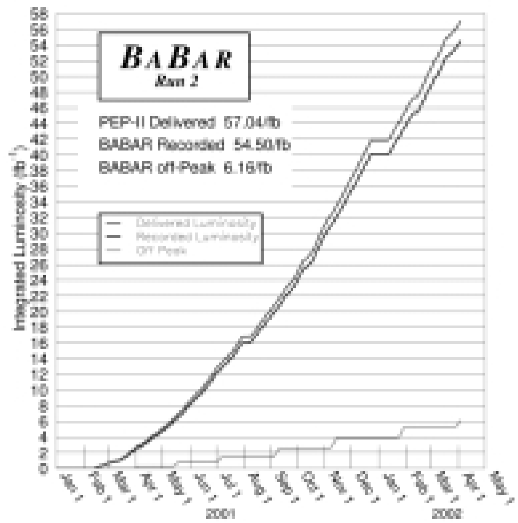

Figure 1: *Integrated Luminosity from Jan 2001 to Mar* 31^{st}*, 2002; the blue line indicates luminosity delivered by PEP-II, the red one luminosity recorded by BaBar .*

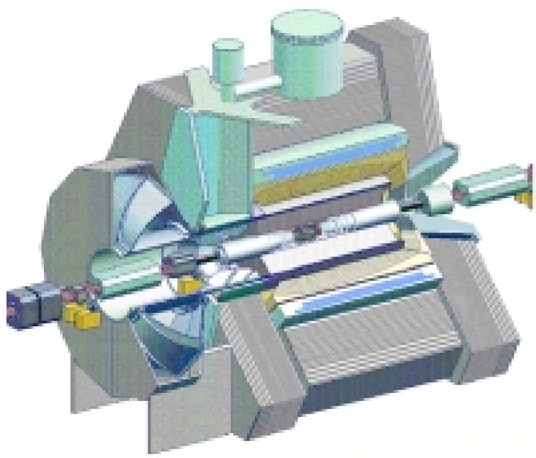

Figure 2: The BaBar Detector.

Figure 3: The LNF testing facility at the RPC factory.

BaBar has published a number of measurements during the year 2001; these include time-dependent CP-violating asymmetries, proportional to $\sin(2\beta)$ in the Standard Model; the value measured by BaBar for $\sin(2\beta)$, $(0.59 \pm 0.14(stat.) \pm 0.05(syst.)$, establishes CP violation in the B^0 meson system. Other important BaBar results include measurements of B meson lifetimes [6] and branching fractions [3, 9, 10].

The Frascati group has played a major role in the design of the IFR, construction, testing and operation of the RPC's. The system consists of 330 RPC chambers equipped with a two dimensional readout on external aluminum strips etched on a plastic support foil. Each chamber is made of 3 RPC modules in the central region and two RPCs in the doors, for a total of approximately 800 modules (total surface 2000 m^2).

The modules are operated in limited streamer regime; the gas used is a mixture containing approximately 60% Argon, 36% Freon 134a (1,1,1,2 tetrafluoroethane) and 4% isobutane. This choice satisfies the security requirements for flammability and does not contain environment damaging Freon. The mixture is drawn from a 760-liter mixing tank which is filled on demand by the combined flow from three mass-flow controllers, each adjusted to provide the desired fraction of the corresponding component gas. Samples are extracted from the mixing tank periodically and analyzed to verify the correct mixture.

During the year 2001, a strong R&D program has been pursued in several Institutions, including Frascati, to understand the mechanism of the efficiency loss appeared after the overheating of summer 1999, and find operating conditions to alleviate and possibly solve the problem. After the decision to replace all chambers in the Forward Endcap, taken at the end of the year 2000, the Frascati group has taken the responsibility to build a test setup at the RPC factory (fig. 3). This facility, that is now operational, has the capability to read out cosmic rays passing a stack of 10 finished IFR chambers; the expected impact point on each one being predicted by two additional trigger chambers, 2-dimensional efficiency maps will be obtained for all chambers before shipping to SLAC. This is the first time that a full-size testing Lab has been installed on the site of a commercial firm, *i.e.* at a non-INFN, and non-High Energy Physics, location.

The ability of the IFR for identifying muons was not seriously affected by the loss in efficiency of the RPCs, thanks to the large number of layers and the redundancy of information. Different values of the cut on the likelihood ratio of the muon and pion hypotheses give different levels of muon efficiency and pion misidentification probability, which are used in different analysis according to the needed level of purity. Examples of muon efficiency as a function of momentum obtained with control samples of $\mu^+ \mu^- e^+ e^-$ and using respectively looser and tighter cuts are shown in fig. 4.

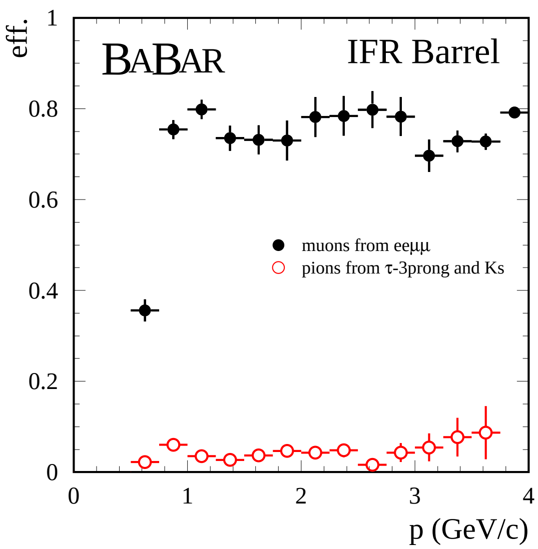

Figure 4: muon ID in BaBar with the IFR.

After the commissioning of the detector, the Frascati group has contributed, together with other Institutions, to its maintenance and running; specific responsibilities include the HV and LV distribution systems, the database maintenance, the IFR software validation and releases. In the software sector, the biggest part of our contribution has regarded writing and optimizing the code dedicated to find and identify "Neutral Hadron" interactions. K_L and other neutral hadrons interact in the iron of the IFR producing one or more clusters of hits in the RPC's. Monte Carlo simulations predict that about 64% of K_L from the most interesting physics channels produce at least 1 cluster with 2 or more layers hit. The main goal of these studies is the measurement of the CP asymmetry in the decay $B^0 \to J/\psi K_L$: this channel produces an event sample comparable to that of the "gold-plated" $B^0 \to J/\psi K_S$ and contributes convincing evidence for any observed CP asymmetry since K_L and K_S have opposite CP eigenvalues and asymmetries.

The signal reconstruction is obtained by first considering all the clusters that are not associated with any charged track. These three dimensional (3D) clusters are reconstructed separately in the 6 barrel sextants, the cylindrical RPC and the top, middle and bottom sections of the end-caps, starting from the strip hits in the various layers. Each single 3D cluster is characterized by its position, which is given by the center of gravity of all the strips it is made of, and by other information that is stored with it, like the number of hit layers, number of strips hit, etc. Since the IFR segmentation does not provide a sufficient sampling of the energy deposition of the hadrons, no measurement of the energy of the incident particle is obtained.

Since a significant fraction of K_L initiate their shower in the electromagnetic calorimeter before reaching the cylindrical RPC and IFR, a degradation of the resolution on the direction is observed unless one includes the information from the calorimeter. This is done by associating to each neutral hadron a calorimeter cluster if their directions are sufficiently close in space. In this case we require that the probability of the χ^2 of the match be $\leq$1% For neutral hadrons that have a calorimeter cluster associated to them, the direction is computed using the position of the calorimeter cluster.

In fig. 5 we show the angular resolution obtained from Monte Carlo $J/\psi K_L$ events showing a clear improvement when the calorimeter information is used (bottom) or not used (top) to determine the K_L flight direction. In fig. 6 we show for real data the distribution of the $\Delta\varphi$ between

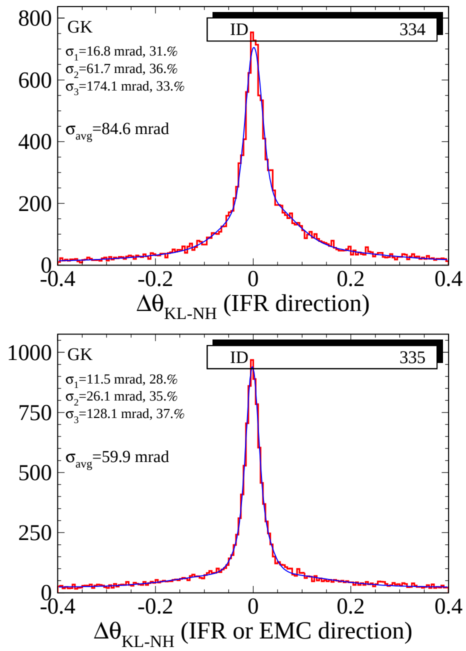

Figure 5: Neutral Hadron angular resolution.

the missing momentum in all inclusive J/ψ events and the direction of the Neutral Hadron. The peak at zero shows that indeed part of the missing momentum is accounted for by the Neutral Hadron.

In 2001 the detailed Monte Carlo study initiated in September 2000 to optimize the reconstruction of neutral hadrons in the IFR for the detection of K_L from the $B \to J/\psi K_L$ decay was completed, and the results have been summarized in an extensive document [11].

The analysis method for reconstructing the final state $J/\psi K_L$ relies on the measurement of the K_L direction, coupled with the kinematics constraints; these are sufficient to eliminate most of the combinatorial background for $J/\psi K_L$ candidates. The J/ψ is reconstructed in the dilepton final states and a momentum in the $Y(4S)$ c.m. frame in the 1.4 to 2.0 GeV/c range is required. The K_L direction is taken from the J/ψ vertex to the centroid of the neutral hadron cluster. Control samples used to check the K_L efficiency obtained by Monte Carlo have been proposed by the Frascati group and include the inclusive J/ψ decays and the process $e^+e^- \to \phi\gamma$. The result obtained on the $J/\psi K_L$ signal is shown in fig. 7. The inclusion of the K_L channel reduces the error on $\sin(2\beta)$ by $\approx 10\%$.

Two new analyses have recently been started inside the Frascati group.

The first one is the study of the CP violating decay $B \to \chi_{c1} K_L$, whose expected branching ratio is $3.7\ 10^{-4}$. This channel will provide another measurement of $\sin(2\beta)$ which can be combined with all the others to improve the overall statistical error on the measurement of this important Standard Model parameter. The measurement is more difficult than in the $J/\psi K_L$ final state case because the χ_c is reconstucted via its decay into a J/ψ and a photon. This introduces an additional efficiency factor with some increase in the background. This work is in its preliminary stage of Monte Carlo evaluation of the signal and background.

The other analysis recently started inside the Frascati group is the measurement of the sign

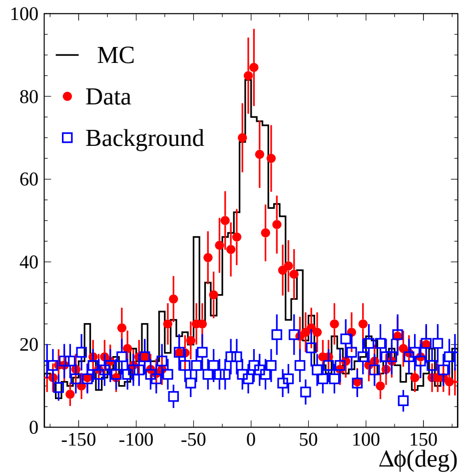

Figure 6: Between Neutral Hadron and missing momentum.

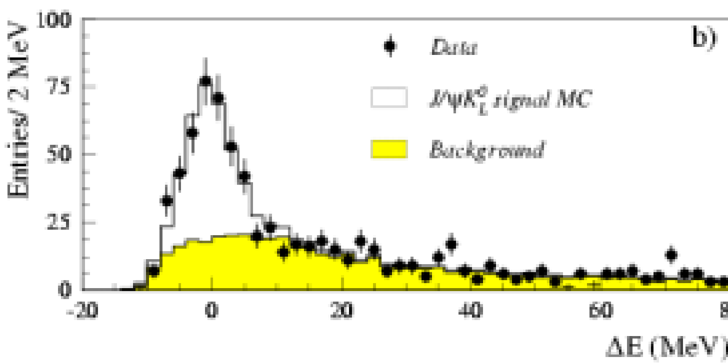

Figure 7: Results on the $J/\psi K_L$ signal.

of $\cos(2\beta)$ using the interference between $B^0 \rightarrow J/\psi K^0$ and $B^0 \rightarrow J/\psi \overline{K}^0$.

It has already been emphasized that the sign of $\cos(2\beta)$, possibly obtained in a model independent way, is needed to get β. In fact, $\sin(2\beta) \sim 0.6$ is consistent with both $\beta \sim 18°$ and $\beta \sim 72°$, that is with two quite different CP violation scenarios. It has been proposed to identify the processes $B^0 \rightarrow J/\psi K^0$ and $B^0 \rightarrow J/\psi \overline{K}^0$ looking for cascade mixing in K semileptonic decay or K^0_S regeneration. By means of these processes it is possible to detect a $K_{\rm S} - K_{\rm L}$ interference and to have access to a model independent measurement of the sign of $\cos(2\beta)$.

An additional way for identifying these processes has been proposed and is being pursued by us, namely looking for inelastic interactions with definite strangeness on the inner part of BaBar (beam pipe, SVT and DCH inner wall). Reconstruction of a $\Lambda \rightarrow p\pi^-$ decay or identification of a K^- would tag negative strangeness (therefore a $\overline{K}^0$), while the K^0 would be signalled by a K^+. In both cases the detected particles would be produced by the interaction of a neutral particle in the BaBar inner part. In principle it is not needed, for the measurement of sign(cos(2β)), that the efficiency for detecting positive and negative strangeness are well known. It turns out that the fraction of interaction length in this region is small, but not vanishing, and there are chances to get a ~ 2 standard deviations measurement of sign(cos(2β)) collecting $\sim 100 \mathrm{fb}^{-1}$.

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CDF

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1 Introduction

The CDF experiment at the Fermilab TeVatron Collider has collected data until the spring of year 1996 integrating a luminosity of about 120 pb^{-1}.

The TeVatron, with the new Main Ring, has been upgraded to achieve a $p\bar{p}$ collision energy up to 2 TeV in the centre of mass system and to increase the instantaneous luminosity delivered to the experiments up to $2 \times 10^{32}\ cm^{-2} sec^{-1}$. During the Run IIa (officially begun in march 2001 and that will be lasting until 2004) we expect to integrate 2 fb^{-1} of data. As the end of year 2001 the experiment has collected ~ 10 pb^{-1} and it is steeply increasing during the first months of data taking of the year 2002 (see Figure 1).

The CDF group of the Frascati laboratory was historically responsible of the construction and maintenance of the central hadronic calorimeter during Run I operations; the lead-scintillator based calorimeter in the central region has been retained for Run II operations having worked satisfactory in Run I.

The commissioning of the central calorimeters played an important role in driving the commissionig and tuning of the new sub-detectors of CDF. The central calorimeters are now ready to acquire data with the required quality for the first physics publications in the summer 2002.

Furthermore, the group is still active in Run I data analysis playing an important role in the measurement of the top production cross section and in a detailed analysis of the heavy flavor quarks content of the $W+$ jets sample and in the low p_T lepton sample. This analysis resulted in the observation of an excess of events with heavy flavor quarks undergoing semileptonic decays with an anomalous rate with respect to the known Standard Model processes.

2 Run II activities

The increase of the luminosity, together with the shortening of the time interval between two adjacent bunch crossings, required an upgrade of the CDF detector. CDF essential components, like the central tracking chamber, the silicon secondary vertex detector and the forward regions of the calorimeter nedeed to be built *ex novo*. The central electromagnetic and hadronic calorimeters are the only devices, together with the muon chambers, that are still working properly in the new Run after the renewal of all the Front-End electronics; indeed the integration time of charge signals has to be completed within the 132 $n$sec window of the new machine clock (during Run I it was of 3.5μsec).

The Frascati group had also designed and built the new fast discriminator for the TDC's of the hadronic calorimetry, ASD. During year 2000 and 2001 the boards have been built, their thresholds have been set on a test-stand and then installed on the detector's crates.

To analyze collisions data the group developed software packages, integrated in the official CDF standard (that uses C++ and AC++ framework). Preliminary studies of the timing behaviour of the hadronic calorimeter have been carried on in order to test the discriminators and TDC functionality. The debugging of the installation and the verification of the thresholds have been pursued through the analysis of the first "engineering" collisions runs acquired by CDF since april 2000. Moreover, the dependence of the timing on pulse-height has been studied and parametrized. This slewing correction has then been applied to all channels.

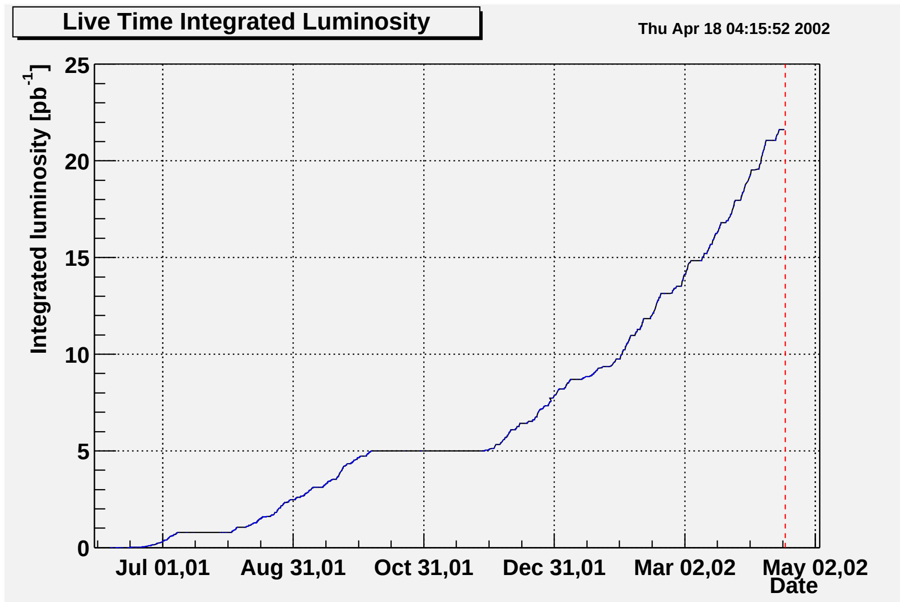

Figure 1: *Live integrated Luminosity vs time*

After the fullfillment of the installation of the discriminators system in all the hadron calorimeters (CHA, WHA, PHA), we realized that the WHA calorimeter was affected by a pick-up noise in the cabling from the PM's to the crate where the ASD boards are plugged in. In Figure 2 it is shown the time distribution of the TDC hits stored in the HATD bank, for all the events, for events with only one hit, for events with only two hits and for events with more than two hits. The level of noise was covering the peak for the collisions expected at around $\sim$ 550 ns. In order to reduce this high rate noise ($\sim$ MHz) we adopted the solution of inserting decoupling transformers along the PM's - ASD boards chain. To do this we had to redesign and rebuild new transition boards to fed the dinode signals of the PM's into the backplane of the ASD crate where for each channel is inserted a 1:1 transformer.

During year 2001, the new transition boards have been produced and installed on the detector. The effect of this operation is shown in Figure 3 where we plot the time distribution for both west and east side of the WHA calorimeter. The collision time is now clearly visible together with smaller structures due to few remaining noisy channels.

To test the behaviour of the resolution as a function of energy we report in Fig. 4 the distribution of timing with an applied energy cutoff (0.6, 0.9, 1.2, 1.5, 1.8, 2.1 GeV); the resolution improves with energy as expected as shown in Figure 5.

The time reconstruction is useful for cosmic rays rejection. In Figure 6-top the calorimeters towers time distribution is shown for a sample of di-muon trigger. In red it is evidenced the contribution of cosmic rays. In the bottom plots it is shown the time difference between all towers; the sample clearly shows the discriminating power of the time information for cosmic with two legs ($\Delta t \leq 5n$sec).

Another important activity carried on during 2001 has been the re-establishment of the absolute calorimeter energy scale. The usage of a short integration gate generated a $\sim$ 6% loss due to long tails in the scintillation light. Furthermore in order to recover the light yield losses of the

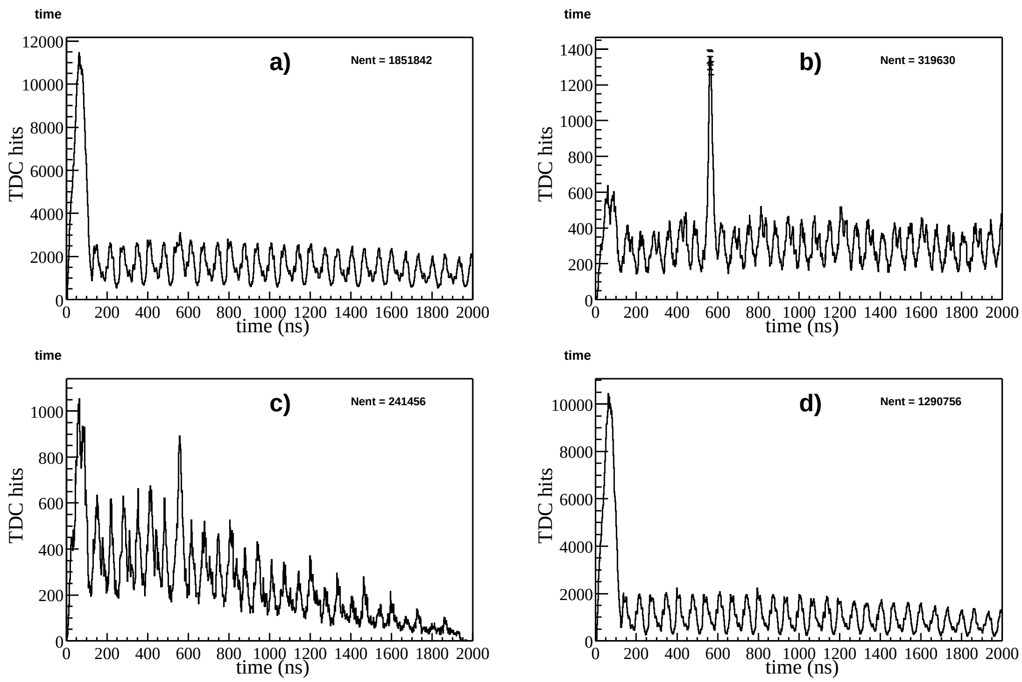

Figure 2: *WHA calorimeter: time distribution of all the TDC hits in the HATD bank (a), for events with only one TDC hit (b), for events with two hits (c) and more than two hits (d).*

scintillator, due to aging phenomena, we have acquired a set of runs with Cs^{137} sources with the magnetic field on and off. During these calibration runs we have evaluated the effect of the LED conditioning system on PM's. In Figure 7 the Linear Energy Response

$$LER = \frac{Cs(test - beam)e^{-\Delta t/\tau}}{Cs(today)}$$

is shown for the WHA calorimeter, before (dashed) and after the LER equalization around 1 obtained adjusting the HV values of the PM's. Before the HV adjustment the average of the LER was ~ 1.2 thus corresponding to a light yield decrease of $\sim 20\%$ from 1995 to date.

As a test of the energy calibration, in Figure 8 we show the energy distribution for Minimum Ionizing Particles, MIP, in a sample of muon candidates. We compare the spectra obtained in Run II before and after LER calibration with the one of Run I.

3 Run I data analysis

The commitment of the group for the analysis of Run I data consists in a detailed study of the production cross-section of $t\bar{t}$ pairs in the lepton+jets channel. For this analysis, the requirement of "tags" based on the location of the secondary vertex, located by SECVTX and JPB algorithms, has been used in order to identify the hadronic-jets coming from b quarks decay. The yield of the number of events as a function of the jet multiplicity is reported in Fig. 9 for the whole statistics of Run I; the value of the derived cross-section is also shown.

In the $W+2$, 3 jets topology, we observed an excess of events with characteristics far from the expected Standard Model predictions. The main difference consisting of having b jets tagged by

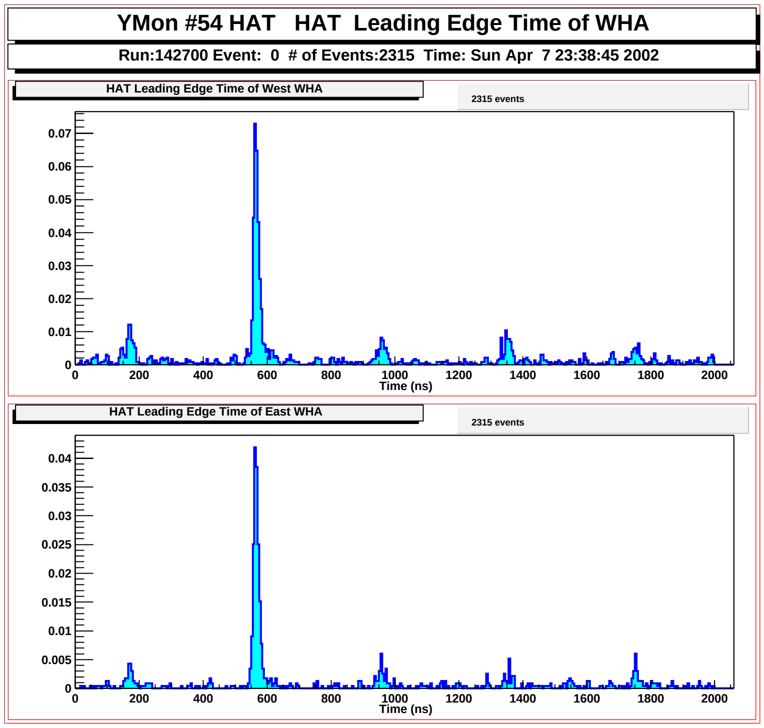

Figure 3: *Timing distributions for the two sides of WHA calorimeter after the introduction of the new transition boards with decoupling transformers.*

SECVTX undergoing semileptonic decays, detected by the Soft Lepton Tagging algorithm (SLT), with an anomalous rate. The observed effect represents a deviation from Standard Model ranging between 4.1 ÷ 4.8 sigma. This result is exemplified in Figure 10 where the breakdown of observed jets with multitags (SECVTX+SLT) with respect to the expectation is drawn. This analysis has been published in Phys. Rew. D. Events with similar behaviour have been searched for also in the low p_T lepton sample. In this sample we select event with the trigger lepton, e or μ, contained in a jet with $p_T > 15$ GeV, called lepton-jet, and another jet recoiling against the lepton jet, called away-jet. This sample is naturally enriched in heavy flavor since the $p_T \geq 8$ GeV trigger lepton is likely coming from the semileptonic decay of heavy quarks. To enhance the b and c quark content, the two jets in the event are required to contain secondary vertices located by SECVTX and JPB. The semileptonic decay rate is measured looking at the rate of SLT tags in the away jets and it is found much higher than expectations as shown in Figure 11. This analysis under scrutiny by the CDF collaboration.

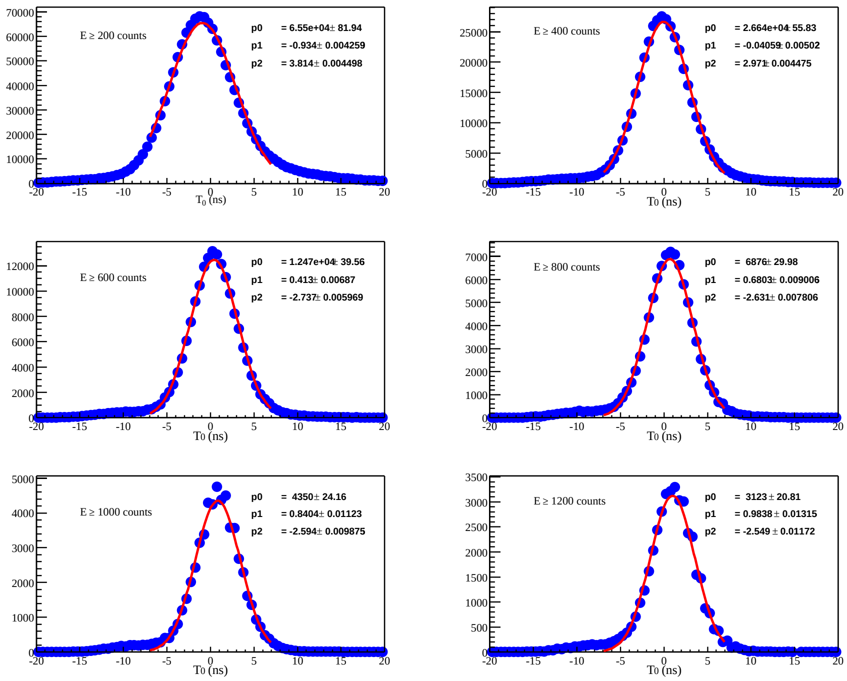

Figure 4: *Timing distributions for the CHA calorimeter after slewing corrections in different energy windows.*

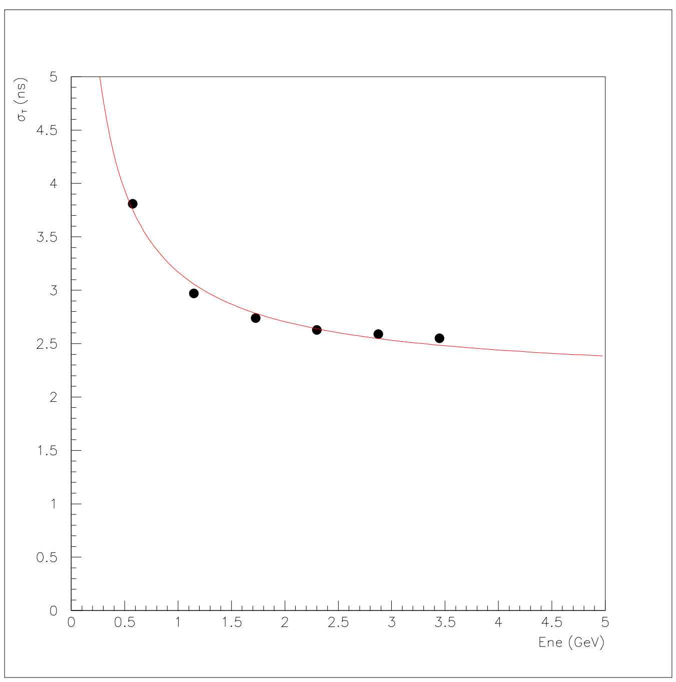

Figure 5: *Timing resolution as a function of the reconstructed tower energy in the CHA.*

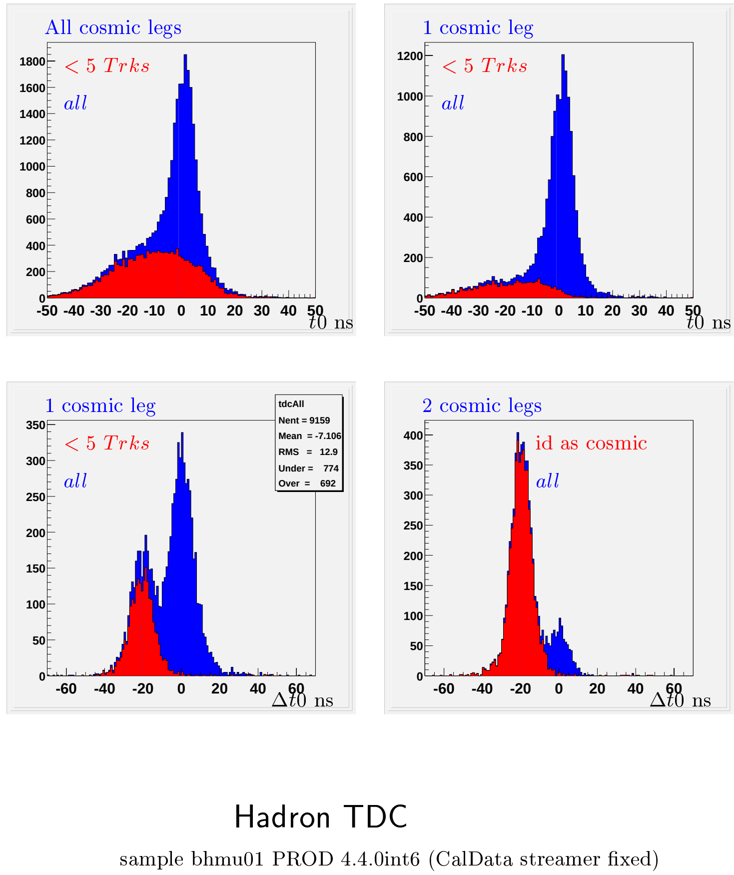

Figure 6: *Time distribution of the calorimeter towers for a di-muon sample (a) and (b); Distribution of time difference for a di-muon sample with one (c) and two (d) cosmic legs.*

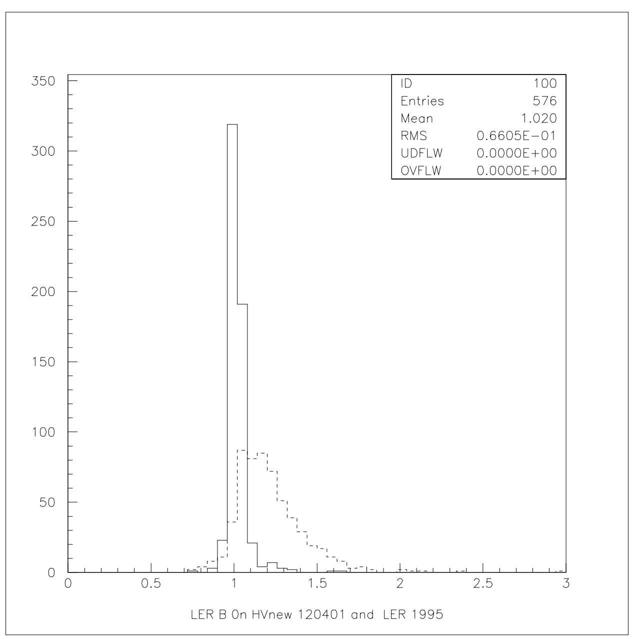

Figure 7: *LER distributions for WHA calorimeter with B on before (dashed) and after (solid) the PM's HV adjustment.*

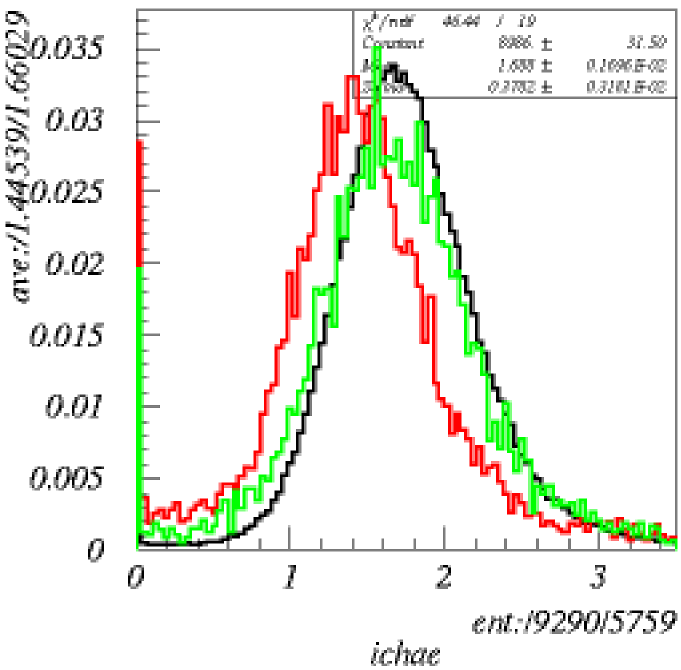

Figure 8: *MIP adronic energy distributions for muon candidates in Run I (black) in Run II before the energy scale calibration (red) and after the calibration (green).*

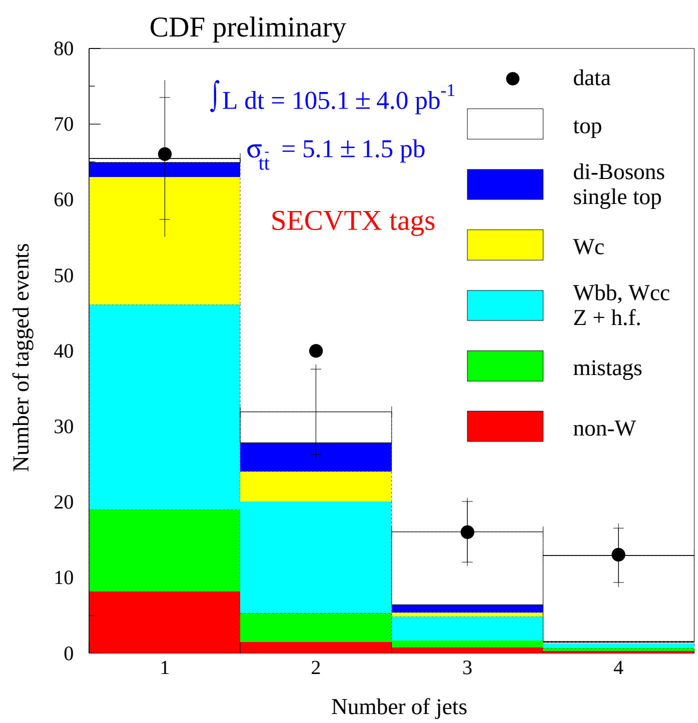

Figure 9: *Number of SECVTX tags in W+ jets events*

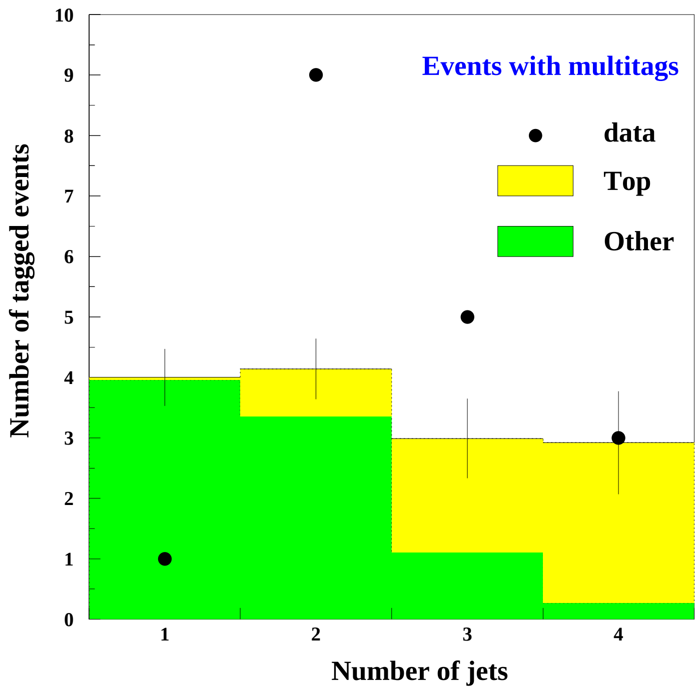

Figure 10: *Number of SECVTX+SLT tags in W+ jets events.*

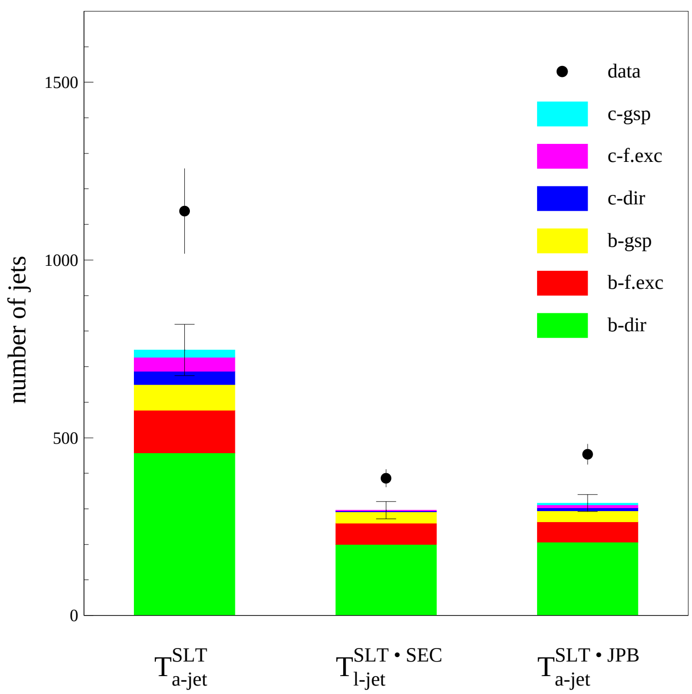

Figure 11: *Rates of SLT tags in away jets without secondary vertex tag (T^{SLT}_{a-jet}) and tagged by SECVTX ($T^{SLT \cdot SEC}_{a-jet}$) and JPB ($T^{SLT \cdot JPB}_{a-jet}$).*

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9. The CDF Collaboration (T.Affolder et al.): “CHARGED PARTICLE MULTIPLICITY IN JETS IN $p\overline{p}$ COLLISIONS AT $\sqrt{S} = 1.8$ TEV”, Submitted to Phys. Rev. Letters (Jul 2001);

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12. The CDF Collaboration (T.Affolder et al.): MEASUREMENT OF THE $t\overline{t}$ PRODUCTION CROSS-SECTION IN $p\overline{p}$ COLLISIONS AT $\sqrt{S} = 1.8$ TEV”, Submitted to Phys. Rev. D (Jan 2001);

E831 FOCUS

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FOCUS (Experiment 831 at Fermilab, www-focus.fnal.gov) studies photoproduction and decays of charm mesons and baryons at Fermilab. In FOCUS, a forward multi-particle spectrometer is used to measure the interactions of high energy photons on a segmented BeO target. The FOCUS detector is a large aperture, fixed-target spectrometer with excellent vertexing, particle identification, and reconstruction capabilities for photons and π^0's.

FOCUS is a considerably upgraded version of a previous experiment, E687, and it amply surpassed the goal of collecting ten times the E687 sample of fully reconstructed charm decays, i.e. a sample of over 1 million fully reconstructed charm particles in the three major decay modes: $D^0 \to K^-\pi^+,\ K^-\pi^+\pi^-\pi^+$ and $D^+ \to K^-\pi^+\pi^+$.

The FOCUS Italian groups (Milano, Pavia and Frascati) hold full responsibility for the μ-strip detector, the Hadron calorimetry, and the Outer em calorimetry respectively, and coordinate about half of the software-related projects. The Frascati group also coordinates the calorimetry working group, and is responsible for the first level selection process in physics analyses utilizing em calorimetry.

1 Activity during year 2001

The activity in 2001 has been focussed on the data analysis, optimization of montecarlo simulation codes, and presentation at conferences. The data analysis studies were centered on spectroscopy.

Heavy Quark Symmetry and Heavy Quark Effective Theory predict a rich spectrum for the excited charm mesons. FOCUS presented precise new measurements of D_2^* masses and widths at EPS-HEP 2001, Budapest ICHEP. Evidence for an insofar unobserved broad state (possibly the D_0^* as predicted by HQET) was also shown. Work continued on the search for radial excitations.

Light quark diffractive physics is a surprise for a heavy quark experiment. Thanks to a dedicated trigger FOCUS has collected a very significant sample of diffractive events, thus starting studies of interest in hadronic physics and predictions of χQCD. During 2001, FOCUS published evidence for a narrow dip structure in diffractive photoproduction of the 6π final state. When interpreted as a new resonance interfering with the diffractive continuum, the structure has $1.911 \pm 0.004\,\mathrm{Gev/c^2}$ mass and $29 \pm 11\,\mathrm{Mev/c^2}$ width.

1.1 Conference Organization

During 2001, members of the FOCUS Frascati group have participated in the organization of the conference:

1. Frontier Science 2002: The physics of D, B and CP, Frascati, Italy, October 2002.

1.2 Seminars

1. S. Bianco, New Light quark results from FOCUS, Bloomington, Indiana, November 2001.

1.3 Memberships in International Advisory Committees

During 2001, members of the Frascati group served as members in International Advisory Committees of the following conferences:

1. 10th Conference On Calorimetry In High Energy Physics (CALOR 2001)
2. 1st Int. Conf. on Heavy Quarks and Leptons (HQL2K2)
3. 21th Physics In Collision Conference

2 Outlook

The activity in 2002 will be focussed in searching for radial excitations, including channels with γ and π^0 in the final state. In the light quark sector, we plan to continue the study to seek confirmation of the six pion structure found out of a larger data sample, and to study f_0 production and $\eta - \eta'$ mixing from our diffractive sample.

3 Conference Talks in 2001

1. S. Bianco, Heavy- and Light-Quark Spectroscopy Results from FOCUS, EPS-HEP Budapest, July 2001.
2. A. Zallo, Light quark results from FOCUS, PEP-N Work., Stanford, USA, May 2001.
3. S. Bianco, Fisica del Charm, relazione su invito Congresso SIF, Milano, Ottobre 2001.

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KLOE

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1 Introduction

DAΦNE, the Frascati ϕ-factory [1], is an e^+e^- collider working at the ϕ resonance peak. The ϕ meson, produced practically at rest, decays with a probability of 33.8% into a K_SK_L pair. DAΦNE collisions are thus a source of nearly monochromatic, back-to-back K_S-K_L beams.

The KLOE experiment [2] is primarily designed to study CP and CPT violation in the K^0-$\overline{K}^0$ system. The unique feature of KLOE is the possibility to perform these studies by measuring the interference patterns in the relative time distributions of the K_SK_L pair decays (the pair is produced in a $J^{PC} = 1^{--}$ quantum state) into various final states [3]. Another complementary and more traditional way to measure $\Re(\epsilon'/\epsilon)$ at KLOE is the double ratio method based on the relation:

$$\frac{R_L}{R_S} \simeq 1 + 6\Re(\epsilon'/\epsilon) \tag{1}$$

where

$$R_{S,L} = \frac{BR(K_{S,L} \to \pi^+\pi^-)}{BR(K_{S,L} \to \pi^0\pi^0)} \tag{2}$$

As an example of the statistics needed for these studies, the measurement of $\Re(\epsilon'/\epsilon)$ with an accuracy $O(10^{-4})$, considering the double ratio method for simplicity, requires an integrated luminosity of about 10 fb^{-1}. This corresponds, at the design luminosity $L = 5 \cdot 10^{32}$ cm^{-2} s^{-1}, to about two years of running.

In 1999 the KLOE integrated luminosity was $\sim$ 2pb^{-1}, while during year 2000 was more than 20pb^{-1}. In year 2001 the DAΦNE luminosity reached $5 \cdot 10^{31}$ cm^{-2} s^{-1} and KLOE collected $\sim$ 180pb^{-1}, the vast majority of which in the last three months. In year 2002 further progress in the luminosity is expected.

Even though the statistics of the current data set is not adequate for the precision studies of fundamental symmetries, however it is suitable for the study of other topics, which are part of the KLOE physics program. In fact a sample of about 17pb^{-1} of good data, collected during the year

2000, has been used to obtain the results on K_S decays and on radiative decays of the ϕ meson presented in this report.

2 The KLOE detector

The KLOE detector, shown in Fig.1, consists mainly of a large volume drift chamber surrounded by an electromagnetic calorimeter. A superconducting coil provides a 0.52 T solenoidal magnetic field.

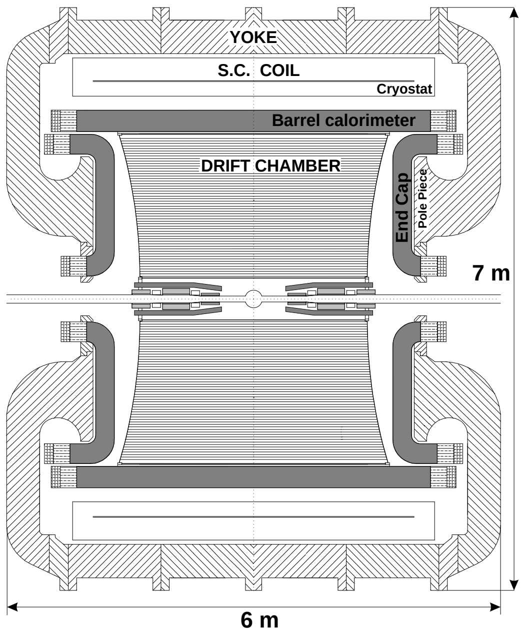

Figure 1: Schematic view of the KLOE detector.

The fine sampling lead-scintillating fiber calorimeter [4] consists of 24 barrel modules with 4.3 m active length and 23 cm thickness ($\sim 15X_0$) and 2×32 C-shaped end-cap modules of various lengths and same thickness as barrel modules, with photomultiplier read-out at both sides. The solid angle coverage is 98%. The energy resolution measured using $e^+e^- \to e^+e^-\gamma$ events is $\sigma_E/E = 5.7\%/\sqrt{E(\mathrm{GeV})}$. The time resolution measured using $e^+e^- \to e^+e^-\gamma$ and $e^+e^- \to 2\gamma$ events is $\sigma_t = 54$ ps$/\sqrt{E(\mathrm{GeV})} \oplus 50$ ps, after the subtraction of the finite bunch-lenght effect.

The tracking detector is a 4 m diameter and 3.3 m long cylindrical drift chamber [5] with a total of $\sim$ 52000 wires, of which $\sim$ 12000 are sense wires, in an all-stereo geometry. In order to minimize multiple scattering and K_L regeneration and to maximize detection efficiency of low energy photons, the chamber works with a helium based gas mixture and its walls are made of light materials (mostly carbon fiber composites). The momentum resolution for tracks produced at large polar angle is $\sigma_p/p \leq 0.4\%$ while spatial resolutions are $\sigma_{r,\phi} \approx 150\mu$ m and $\sigma_z \approx 2$mm.

3 Tagging of K_S decays

At KLOE a K_S is tagged by identifying the interactions of the K_L in the calorimeter. In fact about 50% of the produced K_L's in $\phi \to K_SK_L$ events reach the calorimeter before decaying;

their associated interactions (called "K_L-crash") are identified by a high-energy ($E \geq 200$ MeV), neutral (i.e. not associated to any track in the event) and delayed (the interaction time of a K_L with $\beta \sim 0.218$ is delayed of ≈ 30 ns with respect to the one due to a $\beta = 1$ particle coming from the interaction region) cluster in the calorimeter.

The position of the K_L-crash, exploiting the two body decay kinematics, provides the momentum of the K_S. Moreover in about 40% of the events the K_L-crash alone indipendently satisfies the trigger conditions, thus facilitating the trigger efficiency studies.

4 BR($K_S \to \pi^+\pi^-$)/BR($K_S \to \pi^0\pi^0$)

The measurement of R_S constitutes a part of the double ratio method for measuring $\Re(\epsilon'/\epsilon)$.

In the sample of K_L-crash events the $K_S \to \pi^+\pi^-$ decay is identified by requiring the presence of two tracks of opposite charge coming from the interaction region (IR) which satisfy loose cuts on momentum, p, and polar angle, θ. These cuts define the acceptance for the decay; the corresponding efficiency is obtained from Monte Carlo simulation (MC). The single-track reconstruction efficiency in bins of (p, θ) is obtained directly from subsamples of $K_S \to \pi^+\pi^-$ events themselves.

The $K_S \to \pi^0\pi^0$ decay is identified by requiring the presence of at least three "prompt" clusters (i.e. originated by photons coming from the IR: $|T_{cl} - R/c| \leq 5\sigma_t$, where R and T_{cl} are the measured distance from the IR and the time of the cluster, respectively) which satisfy cuts on energy and polar angle.
The photon detection efficiency is evaluated from a sample of $\phi \to \pi^+\pi^-\pi^0$ events, in which the kinematic variables of one photon can be constrained by the detection of the two pions and the other photon in the event.

In both $\pi^+\pi^-$ and $\pi^0\pi^0$ cases, the probability that the K_S (K_L-crash) detection fully or partially satisfies the trigger conditions can be evaluated using events in which the K_L-crash (K_S) alone triggers. Thus the trigger efficiency is evaluated as the combined probability of K_S and K_L-crash to satisfy the trigger conditions.

The preliminary KLOE result is:

$$R_S = 2.192 \pm 0.003_{\text{stat}} \pm 0.016_{\text{syst}} \tag{3}$$

This result has a statistical significance never reached before by a single measurement and has to be compared to the world average [6] $2.197 \pm 0.026_{\text{stat}} \pm 0.013_{\text{syst}}$. The systematic error will be further reduced in the analysis of 2001 data, partly because the error on some efficiencies are currently dominated by the statistics of control samples, and partly because of an improved selection of K_L-crash events in 2001 data.

5 BR($K_S \to \pi e\nu$)

Assuming CPT and the $\Delta S = \Delta Q$ rule, the $K_S \to \pi e\nu$ branching ratio is calculated from the equality $\Gamma(K_S \to \pi e\nu) = \Gamma(K_L \to \pi e\nu)$. Using the measured values of BR($K_L \to \pi e\nu$) and τ_S/τ_L [6], BR($K_S \to \pi e\nu$) $= (6.70 \pm 0.07) \cdot 10^{-4}$ is obtained. At present only one direct measurement exists [7] obtained with 75 ± 13 observed events: BR($K_L \to \pi e\nu$) $= (7.2 \pm 1.4) \cdot 10^{-4}$.

At KLOE the $K_S \to \pi e\nu$ events are selected in the sample of K_L-crash events by requiring the presence of a vertex with two tracks of opposite charge in the IR. The observation of the K_L-crash determines the momentum of the K_S. The invariant mass at the vertex is calculated assuming both tracks are from pions, and the total momentum at the vertex is calculated in the K_S rest frame. Loose preselection cuts, which mainly eliminate $K_S \to \pi^+\pi^-$ events, are imposed on these quantities. The preselection efficiency is evaluated by the MC.

The $K_S \to \pi e \nu$ decay is identified by making the correct π/e assignment to the two tracks. In order to use time-of-flight π/e identification, both tracks from the vertex must be associated to calorimeter clusters. The difference $\delta_t(m) = T_{cl} - L/c\beta(m)$ is calculated for each track by using the measured cluster time, the track length L, and by applying the mass hypotheses $m = m_e$ or $m = m_\pi$ to derive the velocity β from the track momentum. In order to be independent from the absolute time zero determination, the difference $\Delta = \delta_t(m)_1 - \delta_t(m)_2$ is evaluated. For the correct mass assignment, this difference is expected to be around zero. Therefore a cut at $|\Delta| \leq 1$ ns is applied to select the signal. In the end, events are kinematically constrained at the K_S vertex finding the neutrino energy E_{miss} and momentum P_{miss}. The difference of these two variables is plotted in Fig. 2. The observed peak around zero is due to the $K_S \to \pi e \nu$ decays, while the residual $K_S \to \pi^+\pi^-$ background populates the region above zero. The histogram corresponds to $\sim 17\text{pb}^{-1}$ of data of year 2000, while crosses are the results of a fit to the sum of the MC spectra for signal and background events. The free parameters of the fit are the independent normalizations of the signal and background distributions, and the finite MC statistics has been taken into account in the likelihood function. As a result of the fit, 627 ± 30 signal events are observed.

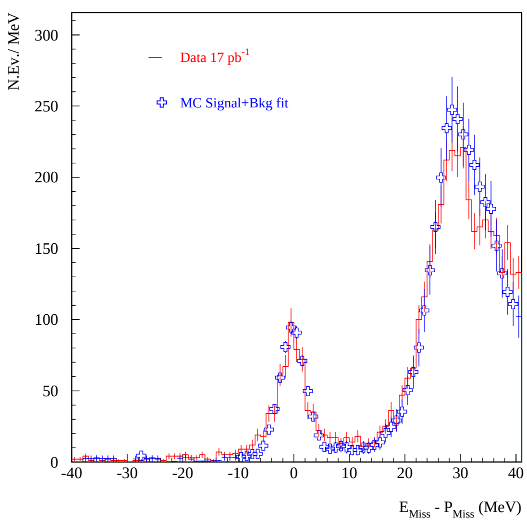

Figure 2: Spectrum of $E_{miss} - P_{miss}$ for $K_S \to \pi e \nu$ candidate events; data (histogram) are compared to MC (crosses).

The vertex reconstruction, π/e identification and trigger efficiencies can be evaluated from a clean and unbiased sample of $K_L \to \pi e \nu$ events in which the K_L decays near the IR, thus simulating a $K_S \to \pi e \nu$ decay. The track-cluster association efficiency is evaluated using proper samples of $\phi \to \pi^+\pi^-\pi^0$, $K_S \to \pi^+\pi^-$ and $K_L \to \pi e \nu$ events. Therefore from these events the probability that a given particle (π^+, π^-, $\mu^\pm$ or $e^\pm$) reaching the calorimeter deposits enough energy to register a cluster and that the track and cluster are then correctly associated can be obtained.

The result:

$$\text{BR}(K_S \to \pi e \nu) =$$

$$(6.79 \pm 0.33_{\rm stat} \pm 0.20_{\rm syst}) \cdot 10^{-4} \quad (4)$$

is obtained by normalizing the number of signal events to the number of $K_S \to \pi^+\pi^-$ events in the same data set and using the present experimental value for BR($K_S \to \pi^+\pi^-$). This result is in agreement with the expectation of the $\Delta S = \Delta Q$ rule. The relative uncertainty on the KLOE measurement is less than a third of that on the only existing measurement [7]. From the analysis of year 2001 data both the statistical and systematic errors should be reduced and a competitive test of the $\Delta S = \Delta Q$ rule could be performed.

6 BR($\phi \to \eta'\gamma$)

The branching ratio of the decay $\phi \to \eta'\gamma$ is particularly interesting since its value can probe the $|s\bar{s}\rangle$ and gluonium content of the η' [8, 9, 10]. In particular, the ratio of its value to the one of $\phi \to \eta\gamma$ can be related to the $\eta - \eta'$ mixing parameters and determine the mixing angle in the flavor basis φ_P, offering an important point of comparison for the description of the $\eta - \eta'$ mixing in chiral perturbation theory [11].

The decay chains considered are:

- $\phi \to \eta'\gamma$ with $\eta' \to \pi^+\pi^-\eta$ and $\eta \to \gamma\gamma$
- $\phi \to \eta\gamma$ with $\eta \to \pi^+\pi^-\pi^0$ and $\pi^0 \to \gamma\gamma$

In both cases the final state is $\pi^+\pi^-\gamma\gamma\gamma$, resulting in several systematic errors cancellation in the measurement of the ratio BR($\phi \to \eta'\gamma$)/BR($\phi \to \eta\gamma$). For both channels events are selected requiring the presence of three prompt photons and two tracks of opposite charge with a vertex near the IR. Then a preliminary kinematic fit is performed requiring total energy and momentum conservation, the constraint $\beta = 1$ for all photons, without any invariant mass constraint on intermediate particles. Simple kinematic cuts eliminate the background mainly due to $\phi \to \pi^+\pi^-\pi^0$ events in which a spurious cluster is present, and to $\phi \to K_S K_L \to \pi^+\pi^-\pi^0\pi^0$ events in which one photon is lost.

The energy spectrum of the photons gives no combinatorial problem: the radiative photon is the hardest one in $\phi \to \eta\gamma$ events ($E_{rad} \simeq 363$ MeV), while is the softest in $\phi \to \eta'\gamma$ events ($E_{rad} \simeq 60$ MeV), the other two photons being generated in π^0 and η decays, respectively. Hence η' events are disentangled from η background by proper cuts on the energy spectrum of the two hardest photons γ_1 and γ_2.

The distribution of the invariant mass of $\pi^+\pi^-\gamma_1\gamma_2$ for the $\phi \to \eta'\gamma$ events is shown in Fig.3, where a small residual background is observed in the η' peak region. The shape of the background is obtained from sidebands of the signal region in the γ_1 and γ_2 energy distribution. The number of signal events, as obtained from the simple fit shown in Fig.3, is $124 \pm 12_{\rm stat} \pm 5_{\rm syst}$. The ratio BR($\phi \to \eta'\gamma$)/BR($\phi \to \eta\gamma$) is obtained by normalizing to the number of $\phi \to \eta\gamma$ observed events and correcting for detection efficiency taken from MC.

The KLOE preliminary result is:

$$\frac{{\rm BR}(\phi \to \eta'\gamma)}{{\rm BR}(\phi \to \eta\gamma)} = (5.3 \pm 0.5_{\rm stat} \pm 0.4_{\rm syst}) \cdot 10^{-3} \quad (5)$$

from which the corresponding value for the mixing angle can be extracted [9, 11]:

$$\varphi_P = (40^{+1.7}_{-1.5})^\circ \quad (6)$$

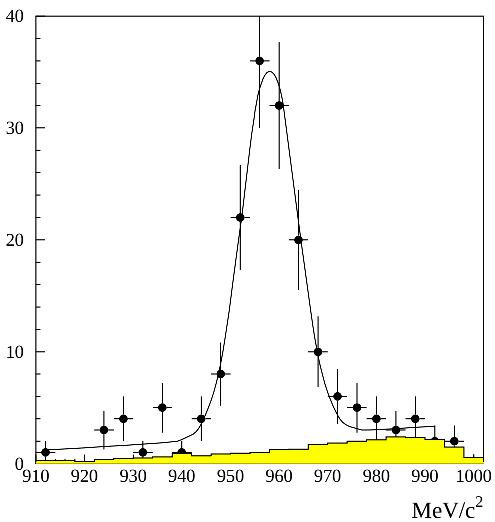

Figure 3: The $\pi^+\pi^-\gamma_1\gamma_2$ invariant mass distribution for candidate events $\phi \to \eta'\gamma$. The shaded area represents the residual background. The continuous line is the result of a gaussian plus linear fit.

Making use of BR($\phi \to \eta\gamma$) value from Ref. [6], it is obtained:

$$\mathrm{BR}(\phi \to \eta'\gamma) = (6.8 \pm 0.6_{\mathrm{stat}} \pm 0.5_{\mathrm{syst}}) \cdot 10^{-5} \tag{7}$$

which is the most accurate measurement to date. The value obtained disfavours a very large gluonium content of η', while leaves still room for an $O(10\%)$ admixture.

7 BR($\phi \to f_0\gamma$) AND BR($\phi \to a_0\gamma$)

Several models proposed to explain the nature of the f_0 and a_0 mesons: ordinary $q\bar{q}$ meson, $q\bar{q}q\bar{q}$ state, $K\overline{K}$ molecule, make different predictions of BR($\phi \to f_0\gamma$), BR($\phi \to a_0\gamma$) and their ratio [12]. Therefore a precise measurement of BR($\phi \to f_0\gamma$) and BR($\phi \to a_0\gamma$) would clarify the interpretation on the nature of these mesons. Up to now only the VEPP-2M experiments have studied these decays [13, 14].

At KLOE the following decay chains are considered:

- $\phi \to f_0\gamma$ with $f_0 \to \pi^0\pi^0$
- $\phi \to a_0\gamma$ with $a_0 \to \eta\pi^0$ and $\eta \to \gamma\gamma$

In both cases the final state is 5γ's. Several backgrounds are present: the main contributions come from the resonant process $\phi \to \rho^0\pi^0$ with $\rho^0 \to \pi^0\gamma$ or $\rho^0 \to \eta\gamma$, and the continuum process $e^+e^- \to \omega\pi^0$ with $\omega \to \pi^0\gamma$ or $\omega \to \eta\gamma$. There are also contributions from the 3γ's final states in which two clusters are spurious, and from 7γ's final state in which two clusters are lost.

The events are identified by requiring five prompt photons within loose acceptance cuts. Then a preliminary kinematic fit is performed requiring total energy and momentum conservation with the additional constraint $\beta = 1$ for all photons, thus refining the measured cluster positions, energies, and times. The best photon pairing is then obtained assuming each one of the possible decays, e.g. $\phi \to \pi^0\pi^0\gamma$, $\phi \to \eta\pi^0\gamma$, and $e^+e^- \to \omega\pi^0$. For each of them, a second kinematic fit is then performed with additional constraints on the masses of intermediate η's and π^0's. Finally the $\phi \to \pi^0\pi^0\gamma$ and $\phi \to \eta\pi^0\gamma$ events are isolated by means of cuts on kinematic variables and on the χ^2 probability values obtained in the second series of kinematic fits.

The overall detection efficiency is obtained by tuning the MC to reproduce the observed $M_{\pi^0\pi^0}$ and $M_{\eta\pi^0}$ invariant mass distributions in case of $\phi \to \pi^0\pi^0\gamma$ and $\phi \to \eta\pi^0\gamma$ events, respectively. The background in the $M_{\pi^0\pi^0}$ and $M_{\eta\pi^0}$ distributions is estimated using the MC and the cross section values for various processes directly measured by KLOE. The $\phi \to \rho^0\pi^0$ background rate is estimated from Ref. [6, 15] (the interference between this process amplitude and the signal amplitude is neglected). The background from misreconstructed 3γ's final state events is estimated by embedding accidental cluster distributions obtained directly from data into MC generated events.

The preliminary KLOE measurements are:

$$\mathrm{BR}(\phi \to f_0\gamma \to \pi^0\pi^0\gamma) = (7.9 \pm 0.2_{\mathrm{stat}}) \cdot 10^{-5} \tag{8}$$

obtained for $M_{\pi^0\pi^0} \geq 700$ MeV, and

$$\mathrm{BR}(\phi \to a_0\gamma \to \eta\pi^0\gamma) = (5.8 \pm 0.5_{\mathrm{stat}}) \cdot 10^{-5} \tag{9}$$

Assuming $\mathrm{BR}(f_0 \to \pi^+\pi^-) = 2\mathrm{BR}(f_0 \to \pi^0\pi^0)$, and full decay of the f_0 and a_0 in the $\pi\pi$ and $\eta\pi$ channels, the following value is obtained for the ratio of branching ratios:

$$\frac{\mathrm{BR}(\phi \to f_0\gamma)}{\mathrm{BR}(\phi \to a_0\gamma)} = 4.1 \pm 0.4_{\mathrm{stat}} \tag{10}$$

This value seems to favour the interpretation of f_0 and a_0 as compact $q\overline{q}q\overline{q}$ states surrounded by a virtual $K\overline{K}$ cloud [12].

The systematic error on the previous results is under study and it should not exceed 10%. Detailed analyses to fit the $M_{\pi^0\pi^0}$ and $M_{\eta\pi^0}$ distributions and to extract the f_0 and a_0 resonance parameters, also studying the contribution of the background due to $\phi \to \rho^0\pi^0$ decay (and of a possible $\phi \to \sigma\gamma$ decay with $\sigma \to \pi^0\pi^0$) with its interference with the signal are in progress.

8 Talks by LNF authors in year 2001

M. Antonelli, Physics results from KLOE, La Thuile Workshop
A. Denig, Status of KLOE, German Physical Society, Bonn
A. Denig, Measurement of the hadronic cross-section at KLOE, e+e- Workshop, SLAC
A. Antonelli, Physics results from KLOE, LAPP
C. Bloise, Prospects on e'/e at KLOE, Kaon 2001, Pisa
S. Giovannella, Searches of scalar mesons at KLOE, XII EURODAFNE Workshop, Valencia
C. Bloise, Status and physics opportunities at the phi factory, Snowmass 2001
F. Bossi, KLOE results, Lepton Photon Conference, Rome
P. Valente, KLOE physics program, Hadron 2001, Protvino
G. Lanfranchi, Detection of the radiative decays, Photon2001, Ascona
I. Sfiligoi, KID - KLOE integrated dataflow, CHEP2001, Beijing
M. Moulson, Recent results from the KLOE experiment, LEP legacy conference, Siena
G. Finocchiaro, Results from KLOE at DAFNE, SLAC seminar

9 KLOE papers in year 2001

KLOE Coll., Calibration and reconstruction performances of the KLOE electromagnetic calorimeter Nucl. Inst. Meth. A 461 (2001) 344-347
KLOE Coll., The KLOE electromagnetic calorimeter Nucl. Inst. Meth. A 482 363-385 (2002)
KLOE Coll., Status and first results of the KLOE detector to be published on proc. of Hadron Structure 2000
KLOE Coll., Results from KLOE and DAPHNE to be published on Acta Physica Polonica B
KLOE Coll., The KLOE trigger system Nucl. Inst. Meth. A 461 (2001) 465-469
KLOE Coll., The KLOE drift chamber Nucl. Inst. Meth. A 461 (2001) 25-28
G. Cabibbo, Misura di $K_s \rightarrow \pi^+\pi^-/K_s \rightarrow 2\pi^0$ con il rivelatore KLOE, Ph.D. thesis
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LHCb

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1 Introduction

During year 2000 LNF started the collaboration with LHCb participating to the activities of the muon sub-detector. In particular the Frascati group has responsibilities on the detectors, the electronics and the mechanical structure. In 2001 the group contributed substantially to the finalization of the TDR [1] of the system. A lot of R&D work has also been carried out, especially on the detectors. In the following, we will briefly describe the work performed, for each of the main items: MWPC, GEM, electronics and supporting structure of the chambers.

2 Multiwire Proportional Chambers

LHCb-LNF has the responsibility for the construction of 1/4 of the MWPCs of the muon detector. Depending on the position inside the detector, there are different chamber dimensions with different readout: anode pads, cathode pads, anode & cathode pads. We designed, collaborating with the Ferrara group, all the details of 10 different chambers types (with active dimensions ranging from 29×35 cm^2 to 27×130 cm^2). With thess characteristics 444 chambers will be assembled and tested, half in LNF, half in Ferrara. The same design will be applied to the remaining 456 chambers that will be built at CERN and in S.Petersbourg.

2.1 Brief description of MWPC

The MWPC chambers of the LHCB muon detector must fulfill stringent requirements on time response: for triggering purpose $\sim 95\%$ minimum efficiency must be exploited in 20 ns. Each chamber is constituted by 4 layers assembled as two independent bigaps with hardwired-OR of the readout. In each 5 mm gap there are 50 microns gold plated tungsten wires stretched at about 60 grams. The filling mixture is $Ar/CO_2/CF_4$ (60/20/20).

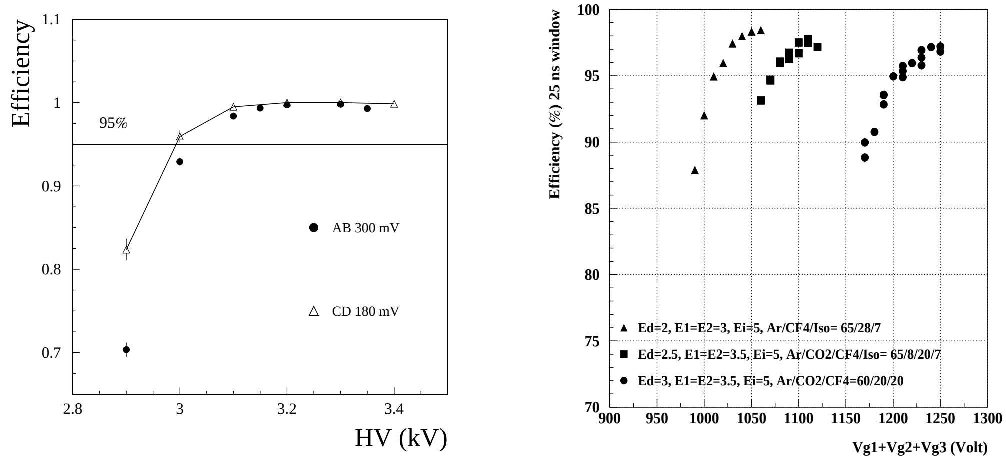

Figure 1: LEFT: MWPC cathode pad efficiency, as function of the high voltage setting, for bigaps AB and CD, determined with the first hit in time. RIGHT: GEM efficiency in 25 ns time window for a single detector.

2.2 Main goals reached in 2001

PANELS

The possibility to use poliuretanic expanse foam has been explored as an alternative to the more expensive honeycomb panels. A preliminary mould has been designed, constructed and tested; one of the two final moulds is in production. Several tests have been carried out on about one half of the 100 panels already produced. The mechanical specifications are satisfied, in particular the tolerance of $50\mu m$ in planarity needed to insure a uniform gain. Some panels have been submitted to a thermal stress, some other to radiation with a powerful Co_{60} source with a dose of $1Mrad$, corresponding to $\sim$ 10 LHC years. The effects of these stresses are within the limits tolerated.

CONSTRUCTION AND TEST OF PROTOTYPES

Several prototypes have been constructed; one of them has been tested at a CERN beam [2)]. The prototype works with high efficiency (Fig. 1, LEFT), low cluster size (1.15 at 300 mV threshold and 1.26 at 180 mV), and good time resolution (4.24 ns at 300 mV and 3.49 at 180 mV).

DESIGN AND ENGINEERING OF CHAMBER PROTOTYPES

The choice of the most appropriate construction technology has been carried out: in particular we studied the wire positioning and their soldering with a laser source, the gas tightness, the HV distribution, the signal OR-ing, the chamber assembling procedure. The construction of a full dimension chamber prototype is started.

3 Triple GEM detectors

For the innermost parts (regions R1 and R2) of the first muon station (M1), the LNF group, in collaboration with INFN-Cagliari, proposes a detector based on Gas Electron Multiplier (GEM)

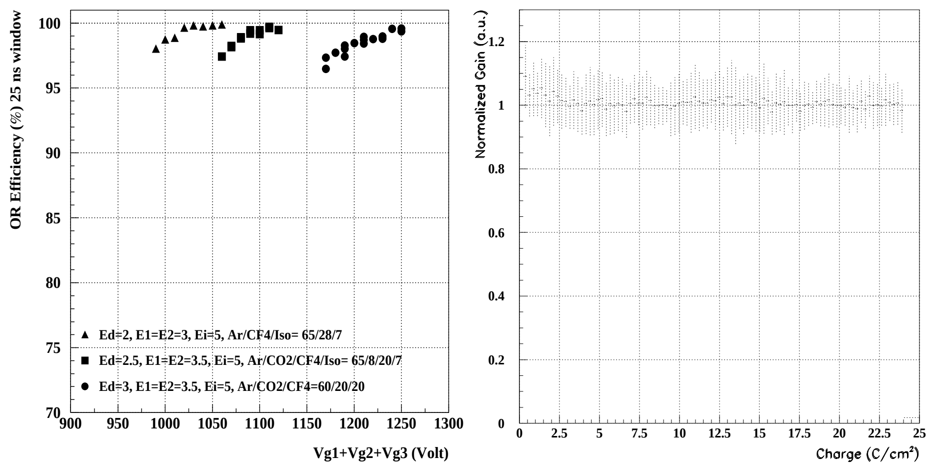

Figure 2: LEFT: GEM efficiency in 25 ns time window for two detectors logically OR-ed. RIGHT: Normalized gain versus accumulated charge for the $Ar/CO_2/CF_4$ (60/20/20) gas mixture with ΣV_{GEM} = 1230 V, corresponding to a $G_{eff} \sim 2\times10^4$.

technology. The requirements [1] are: a rate capability of ∼ 500 kHz/cm^2; an efficiency of ∼ 99% in 25 ns (two independent detector layers, logically OR-ed, are foreseen); a cluster size smaller than 1.2, for a 10×25 mm^2 pad size; a radiation hardness ∼ 6 C/cm^2 in 10 years of operation (for a gain of ∼10^4).
The GEM [3] consists of a thin (50 μm) kapton foil, copper clad on each side, chemically perforated by a high density of holes having bi-conical structure, with external (internal) diameter of 70 μm (50 μm) and a pitch of 140 μm. In safe condition, gains up to $10^4 \div 10^5$ are reachable using multiple structures, realized assembling more than one GEM at close distance one to each other.
A detailed investigation of the role played by the detector geometry and electric fields has been performed in order to optimize the time performance and the electron transparency of the triple-GEM detector [4] (the results have been presented at the "Vienna Conference on Instrumentation, Vienna, Austria, February 19-23,2001").
For the R&D we used 10×10 cm^2 triple-GEM detectors. The construction of detector prototypes required the development and realization of a special tool for the stretching of the GEM foils. The detailed description of the detector mechanics and the assembly tools is reported in [4], [5]. The readout anode was segmented in forty 10×25 mm^2 pads connected to KLOE-VTX chip based pre-amplifiers [5], [6].

Time performances [7] and efficiencies (Fig. 1, RIGHT) of triple-GEM detectors operated with three different gas mixtures have been studied at the PSI πM1 beam facility. A time resolution (r.m.s.) of 5.3 ns, corresponding to a 97.2% efficiency in 25 ns, is obtained with the $Ar/CO_2/CF_4$= 60/20/20 gas mixture, considerably improving the performance obtained with the standard Ar/CO_2=70/30 gas mixture (9.7 ns for a 89% efficiency in 25 ns) [4], [5]. Further improvements are obtained with isobutane based gas mixtures, which allow to reach excellent time resolutions: 4.9 ns (97.8% efficiency) with the $Ar/CO_2/CF_4$/iso-C_4H_{10}=65/8/20/7, and 4.5 ns (98.7% efficiency) with the Ar/CF_4/iso-C_4H_{10}=65/28/7. The requirement of 99% efficiency is achieved with two detector logically OR-ed, pad by pad (Fig. 2, LEFT). The results have been

presented at the "IEEE Conference, San Diego-California, USA, November 3-7, 2001".
Discharge studies have been performed exposing a triple-GEM chamber to both a high intensity hadron beam at PSI as well as α-particles from an ^{241}Am source. Data taken at PSI, even though do not allow to discriminate among the three gas mixtures used, permit to estimate a discharge probability for triple-GEM detectors of the order of $4\times10^{-12} \div 2\times10^{-11}$ per hadron, corresponding to $\sim 200 \div 1000$ discharges/cm^2 in 10 years at LHCb (R1,R2 of M1).
Tests with α-particles allowed to study the dependence of discharges on various detector parameters, such as GEM voltages and gas mixtures [7]. In addition, because of their ionization capability of $\sim 2\times10^4$ electron-ion pairs, α-particle tests permitted to integrate ~ 200 discharges/cm^2 (without any appreciable change in detector performance), corresponding to at least 3 years of normal operation at LHCb.
The aging properties were investigated exposing the detector to high intensity 5.9 keV X-rays. The detector was operated with the $Ar/CO_2/CF_4$=60/20/20 gas mixture at an effective gain of $\sim 2\times10^4$. After accumulating 23 C/cm^2, corresponding to about 18 years of normal operation at LHCb experiment, only a negligible gain change of $\sim 5\%$ was observed (Fig. 2, RIGHT). The results of the PSI test beam, the discharge studies and the aging tests have been presented at the "International Conference on Instrumentation for Colliding Beam Pysics, Novosibirsk, Russia, Februray 28 - March 6, 2002".

4 Electronics

During 2001 the electronics activity was mainly addressed to the tests performed on WPC and GEM. In particular, uniquely related to the test phase, the group worked on:
- optimization of the front-end boards based on ASDQ chip;
- construction of LVDS-ECL translators;
- construction of a module for thresholds and low voltage power supplies;
- design and production of front-end boards for WPC and GEM tests.

A more defined and incisive role was played by the LHCb-LNF group on the definition of the architecture of the electronics from the front-end boards to the DAQ and trigger interfaces. As a result of the collaboration with Cagliari, RomaI and Marsiglia, a strong reduction of the complexity of the system was reached. The preliminary designs of the Intermediate Boards (IB) and of the Off Detector Electronics (ODE) were developed. The complexity of the project is mainly due to the required high density and low cost boards, cables and connectors.
The design of the low voltage power supply and regulation (radiation hard) also started.
A complete test of all the electronics chain is schedule for the end of 2002.

5 Chamber supporting structure

LHCb-LNF has the responsibility for the construction of the 10 movable walls that will support the chambers in between the iron absorbers of the muon filter.

A full scale (4,5$\times$7,5 m^2) light aluminum structure was designed and constructed with the dimensions of the second station (M2). The aim of that prototype is the study of the chambers positioning procedure (the detectors will be MWPC, RPC and GEM, presumably), their integration on the system, the cable routing and the gas piping. The wall will be installed in the KLOE assembly hall during April 2002.

6 List of Conference Talks by LNF Authors in Year 2001

- Vienna Conference on Instrumentation, Vienna, Austria, February 19-23, 2001;
- IEEE Conference, San Diego - California, USA, November 3-7, 2001;
- International Conference on Instrumentation for Colliding Beam Physics, Novosibirsk, Russia, February 28 - March 6, 2002.

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ICARUS

P. Picchi (Resp.)

1 Introduction.

During the year 2001 the activity of the LNF group in the framework of the ICARUS project was devoted to $R\&D$ on aspects of the detector not yet fully defined. We focused our efforts on the problem of the trigger and T=0 signal; for both the most natural solution is the exploitment of the prompt signal due to scintillation light in liquid Argon.

2 Successful tests of scintillation light (128 nm) in liquid Argon.

During the year 2000, we already started this study using a MgF_2 window and PM in vacuum, placed in gas phase in the 50 liter chamber. Stopping muons data were taken by mean of a trigger based on the double light pulse, from the muon and the subsequent decay electron. A time interval between $2\mu s$ and $10\mu s$ was considered. A precision measurement of the muon lifetime was thus performed giving a value of lifetime of $t_{1/2} = 2.191 \pm 0.025\mu s$. This measurement took about 2 months of data taking and required the analysis of 100,000 events.

The test was successful because it demostrated the viability of a trigger based on scintillation also for relatively low energy events. Unfortunately the use of PM in vacuum coupled with MgF_2 windows turns out to be unpractical for a large ICARUS module like the T600 or more.

3 Further tests of scintillation light in liquid argon.

Being practically impossible to find commercial large photomultipliers with MgF_2 windows, sensitive to 128 nm light which work at liquid argon temperature, during the year 2000 we tested some PM (10" EMI 1864) which works at liquid argon temperature (87K). This kind of tube is not sensitive to 128 nm light so wave shifting is necessary.

We tried various ways to deposit a wave shifter that could stand the thermal contractions due to the LAr temperature. A spray of aspirin on a MgF_2 layer did not work because it was found that aspirin dissolves very easily in liquid argon. This was verified with a study under a microscope of the window, before and after operating the PM. Care was taken in this study to avoid Cerenkov light, by having the PM looking down onto the liquid argon volume.

More test were performed with P-terphenyl as wave shifter. A first MgF_2 layer was deposited on the PM to provide a structure holding on firmly to the glass. The P-terphenyl is evaporated on the MgF_2 layer. Then, a protective MgF_2 layer is added to avoid washing out of the P-terphenyl by liquid argon.

Mechanically the system seemed to behave in a very stable way when confronted with fast temperature gradients. Not so satisfactory results were reached concerning the behaviour in liquid Argon (poor stability in time and low quantum efficiency).

A new set of PM was purchased early 2001 with a sand-blasted window which proved to be very effective to mechanically hold the wave shifter in tests done in Pavia.

We developed a new method to deposit the wave shifter: first it is diluted in a chemical solvent, then the solution is sprayed on the PM window; when the solvent evaporates the wave-shifter in effectively trapped in the sand-blasted surface of the PM window. We tried this PM in liquid Argon obtaining enough quantum efficiency ($\simeq 8\%$) and good stability in time (several months with no changes).

In the second half of 2001 we performed a test were we used two wave-shifted PM's to trigger the 50 liter LAr-TPC by means of the scintillation light. Both tubes were looking into the drift volume, one from the bottom (fully immersed in LAr), the other from the top

(with the voltage divider in gas phase). This provided coincidences that allowed complex trigger-patterns with high efficiency and lower energy threshold on the electron signal. This layout allowed to obtain a cleaner sample of stopping muon in an extended time window from 0.5 to $15\mu s$. The large size of the EMI tubes allowed a larger data rate, which make it possible to study rapidly small systematics of the method. With a trigger rate of 1 event per minute and an efficiency of 0.45, we collected about 30000 true stopping muon events. The scanning is underway. A preliminary result obtained on a small fraction of events (about 3000) is shown in Figure 1. The data show a double exponential behaviour due to the fraction of negative muons that are not captured by the argon nucleus.

From the fit one can deduce the mean capture time ($0.77 \pm 0.30\mu s$) which is in agreement with published data. This *R&D* programme will continue through the year 2002.

4 Tests on Data Reduction for the ICARUS LAr-TPC.

Using the 50 liter LAr-TPC we also started a test concerning the ability to reduce on-line the data collected by the LAr-TPC. The typical event size in the T600 exceeds 200 Mbytes but only a small fraction of it contains the informations about ionizing events.

A VLSI Chip, called DAEDALUS, has been realized and mounted on the digital DAQ board to perform signal detection and zero skipping in real time.

Given the wide variety of signal shaped, the DAEDALUS has to be tuned to get the best performance in term of signal detection efficiency and rejection of false signals. About ten parameters are available to reach the goal.

The study of the best parameter set is being performed off-line on the T600 data. The outcome is then applied to the DAQ system of the 50 liter chamber, to check the performance of the whole DAQ chain (signal detection efficiency, data throughput, ...) This test is progressing also during the year 2002.

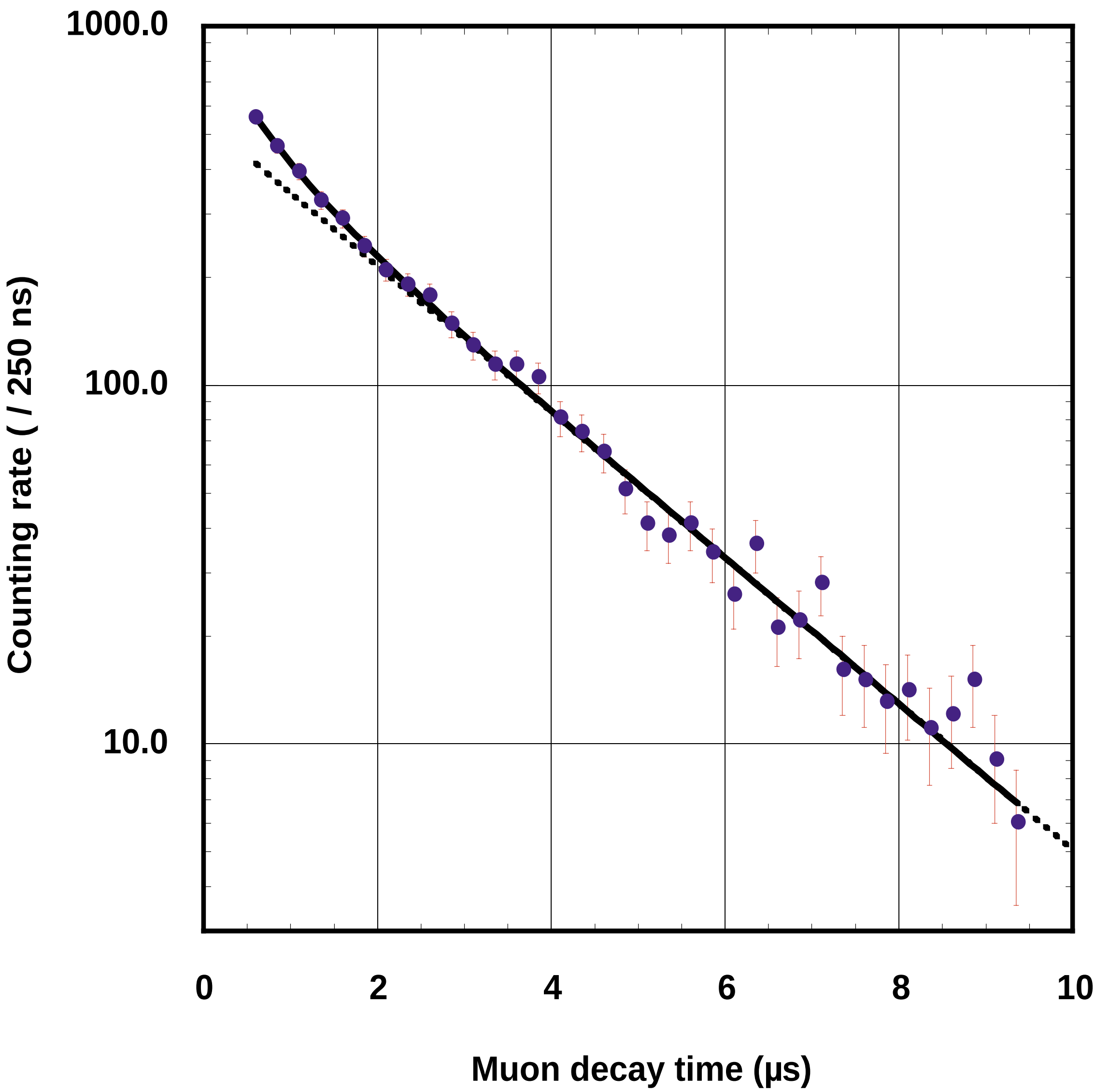

Figure 1: *Measurement of the muon lifetime, from light information in the ICARUS 50 litre prototype chamber. Two components are visible from the fit: the decay rate of positive muons* ($t_{1/2} = 2.191 \pm 0.025 \mu s$) *and that of the fraction of negative muons that are not captured by the Argon nuclei. From the latter one can deduce the mean capture time of positive muons in Argon (preliminary results* $= 0.77 \pm 0.30 \mu s$*), This measurement is performed in a background free environment.*

NEMO-KM3

M. Cordelli, A. Martini, L. Trasatti (Resp.)

In the framework of an European effort toward the construction of a kilometer cube detector for neutrino astronomy, the NEMO project has studied in detail the best possible sites in the Mediterranean sea, and produced several instruments to study the marine depths. During the year 2001 the group has participated in the ANTARES effort, and has been preparing for the Catania Test Site.

The experiment includes groups from INFN sections of Bari, Bologna, Cagliari, Catania, Genova, LNF, LNS, Messina and Roma 1. The LNF group has tested in shallow waters the prototype of NERONE, an instrument to measure with great accuracy the water transparency using measurements performed at severl distances from the source. We expect to make deep sea tests in 2002. At the same time the group has developed several prorotypes using the PIC microcontroller system, that will be used for the Catania test site slow controls.

1 Publications

LNF-01 / 029 (NT) (30 novembre 2001) M. Cordelli, R. Habel, A. Martini, L. Trasatti: NERONE: First Tests in Sea Water.

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OPERA

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1 The experiment

The aim of the OPERA experiment [1, 2]. is the observation of $\nu_\mu \to \nu_\tau$ oscillations in the parameter region indicated by Super-Kamiokande as the explanation of the zenith dependence of the atmospheric neutrino deficit. OPERA is a long baseline experiment to be located at the Gran Sasso Laboratory in the CNGS neutrino beam from the CERN SPS. The detector design is based on a massive lead/nuclear emulsion target. Nuclear emulsions are used as high resolution tracking devices, for the direct observation of the decay of the τ leptons produced in ν_τ charged current interactions. Electronic detectors locate the events in the emulsions. They are made up of extruded plastic scintillator strips read out by wavelenght-shifting fibers coupled with photodetectors at both ends. Magnetised iron spectrometers measure charge and momentum of muons. Each spectrometer consists of a dipolar magnet made of two iron walls interleaved by pairs of precision trackers. The particle trajectories are measured by these trackers, consisting of vertical drift tube planes. Resistive Plate Chambers (RPC) with inclined strips, called XPC, are combined with the precision trackers to provide unambiguous track reconstruction in space. Moreover, planes of RPC's (Inner Tracker) are inserted between the magnet iron plates. They allow a coarse tracking inside the magnet to identify muons and ease track matching between the precision trackers. They also provide a measurement of the tail of the hadronic energy leaking from the target and of the range of muons which stop in the iron. The discovery potential of OPERA originates from the observation of a ν_τ signal with very low background level. The direct observation of $\nu_\mu \to \nu_\tau$ appearance will constitute a milestone in the study of neutrino oscillations. Opera is an international collaboration (Belgium, China, Croatia, France, Germany, Israel, Italy, Japan, Russia, Switzerland, and Turkey) and the INFN groups involved are Bari, Bologna, LNF (Frascati), LNGS (Gran Sasso), Naples, Padova, Rome and Salerno.

2 Activities in Frascati

The Frascati group is responsible for the design and construction of the dipolar magnet. It also shares responsibility with CERN and INFN Padova for the construction and installation of the bakelite RPC planes (Inner Tracker). Frascati and Naples also designed and prototyped the wall support structure housing the lead/emulsion bricks and will take care of the overall support structure of the experiment in Gran Sasso.

2.1 Magnets

In 2000 a full scale prototype of part of the dipole magnet was constructed in Frascati [3]. A full survey of the magnetic properties of this device has been carried out in 2001 [4]. Measures of the field in the bulk of the spectrometer were done employing the "ballistic method" and installing pick-up coils along the spectrometer. Additional information have been extracted by Hall probes recording the fringing field in air. It turns out that the choice of the iron is appropriate to reach the nominal field and its magnetic properties are not modified by mechanical stresses. The non-uniformity of the field along the height does not exceed 5% in agreement with specifications. An average 4 ± 1 % deficit of magnetic flux is observed with respect to simulations made assuming ideal mechanical contact and complete isolation of the dipole from the hall. At the same time, in collaboration with C. Sanelli and M. Incurvati, the study of the power supply specifications has started. The full specification document will be ready for tendering in summer 2002. The procedure for the construction of the OPERA magnets started at the beginning of 2001. The tender for the iron slabs was concluded and the contract has been signed in Sep.2001. At present 150 slabs have been produced. The mechanical quality is in agreement with specifications and measurement of the magnetic properties of small samples are in progress at CERN. The tenders for return yoke production, slab machining and coil construction were concluded between Oct.2001 and Mar.2002.

2.2 Wall support structure

The wall support structure is made of thin stainless steel vertical bands welded to light horizontal trays where the bricks are positioned with a precision of one millimeter. The structure is suspended through rods and joints from the general support structure and tensioned from the bottom through a spring system. One prototype (full height and 1 m wide) was assembled at the Frascati Laboratory in 2000, suspended and loaded with dummy bricks. Long term (8 months) mechanical stability tests have been carried out in 2001. The maximum elongation was 6 mm in agreement with calculation. A second prototype (full width and 1 m high) was built and equipped with a more compact tensioning system. This prototype was sent to LAPP (Annecy) and is currently used for brick manipulator tests. Finally, a full size proytotype was built by industry as test for mass production. It will be sent to Gran Sasso in 2002 to check trasportation and handling issues.

2.3 Inner trackers

During 2000 and 2001 RPC prototypes have been tested at CERN, Frascati, Gran Sasso and Padova, as well as at the T9 test beam from the CERN PS. In particular, full size induction strips were characterised in the Frascati laboratories. Efficiency measurements of small size RPCs have been performed to test the front-end electronics and the cards developed at LNF. 12 full-size prototype are available since the end of 2001. They will be tested at CERN and LNGS in 2002.

2.4 OPERA General layout

The general structure integrated with magnets and wall system is now finalised. In particular, issues concerning wall tensioning, access to PM and cable passages have been fixed. Full sismic response has been simulated and it is in agreement with LNGS specification. The executive drawings are available.

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ROG

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collaboration with L'Aquila, Roma 1 La Sapienza, Roma 2 Tor Vergata

1 Introduction

The ROG (Roma Onde Gravitazionali) group is operating currently two cryogenic gravitational wave bar detectors: Explorer (at CERN) and Nautilus (in Frascati). The main goal of this search is the direct detection of the gravitational waves that could be emitted by astrophysical sources (Supernova, Coalescent Binaries. ecc.). Such detection could be of enormous interest for general relativity and for astrophysics.

Cryogenic resonant-mass detectors were conceived in the '70s with the aim of improving the sensitivity of room temperature Weber detectors by many orders of magnitude, by reducing the temperature of the bar to or below helium temperature (4.2 K) and employing superconducting electronic devices in the readout system.

The principle of operation of resonant-mass detectors is based on the assumption that any vibrational mode of a resonant body that has a mass quadrupole moment, such as the fundamental longitudinal mode of a cylindrical antenna, can be excited by a gravitational wave with non zero energy spectral density at the mode eigenfrequency. The mechanical oscillation induced in the antenna by interaction with the G.W. is transformed into an electrical signal by a motion or strain transducer and then amplified by an electrical amplifier. Unavoidably, Brownian motion noise associated with dissipation in the antenna and the transducer, and electronic noise from the amplifier, limit the sensitivity of the detector.

The sum at the output of the contributions due to the Brownian noise and to the electronic noise gives the total detector noise. This can be referred to the input of the detector (as if it was a GW spectral density) and is usually indicated as $S_h(f)$. This function has a resonant behaviour and can be characterized by its value at the detector resonance frequency f_0 and by its half height width. $S_h(f_0)$ can be written as:

$$S_h(f_0) = \frac{\pi}{8}\frac{KT}{MQL^2}\frac{1}{f_0^3} \tag{1}$$

where T is the antenna temperature, M is the antenna mass, Q is the quality factor of the mode. The half height width of this function gives the bandwidth of a resonant detector. The bandwidth of a resonant detector depends from the mechanical parameters of the detector and from the characteristic of the electronic amplifier and can be written as:

$$\Delta F = \frac{4f_0}{Q}\frac{T}{T_{eff}} \tag{2}$$

where T_{eff} is the noise temperature when the data are filtered to have the maximum signal to noise ratio in the case of delta like signals (like the one expected from supernova). T_{eff} decreases as the noise temperature of the amplifier decreases and as the transducer efficiency increases.

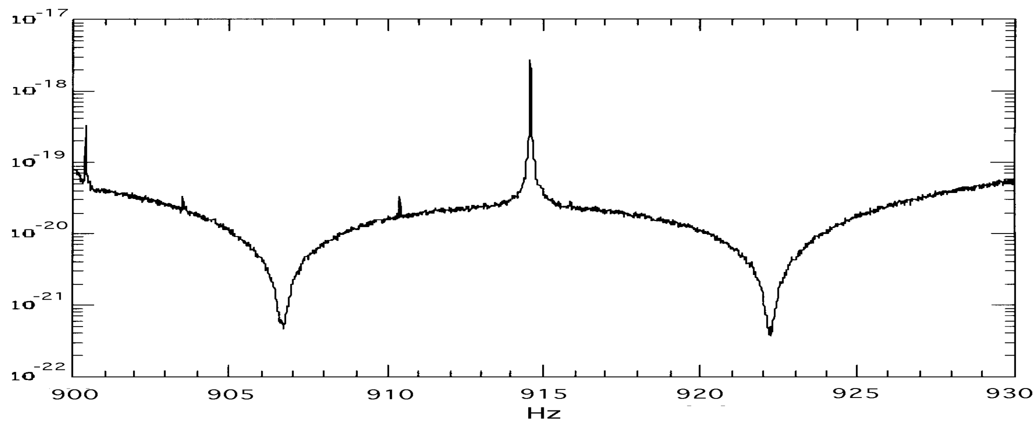

Figure 1: Nautilus strain sensitivity (input noise spectral amplitude in units of $hz^{-1/2}$). The sensitivity at the two resonances is about $4\,10^{-22}\,hz^{-1/2}$. The spectral amplitude is better than $3\,10^{-20}\,Hz^{-1/2}$ over a band of about 25 hz. The peak at 914.6 hz is a calibration reference signal fed into the dcSQUID amplifier to monitor the gain of the electronics.

These relations characterize completely the sensitivity of a resonant-mass detector. For instance, the minimum detectable (SNR=1) GW amplitude for a short burst signal lasting for a time τ_g can be written as :

$$h_0 = \frac{2}{\tau_g}\sqrt{\frac{S_h(f_0)}{2\pi\Delta F}} \tag{3}$$

We recall also that a resonant bar detector could detect also the stochastical energy density in gravitational wave. The stocastical density respect the one necessary to have a closed universe is given by:

$$\Omega = \frac{4\pi^2}{3H^2} f^3 S_h(f) \tag{4}$$

where H is the Hubble constant.

2 NAUTILUS and EXPLORER

The ultra cryogenic detector NAUTILUS [2)] is operating at the Frascati INFN National Laboratory since December 1995. It consists of an Al5056 cylindrical bar, 2300 kg in weight and 3 meters in length, cooled to a temperature of 0.1 K by means of a diluition refrigerator, and equipped with a resonant capacitive transducer and a dcSQUID amplifier. Due to the coupling of two resonators (the antenna and the transducer) the resonant frequency f_0 is split in the two frequencies around 908 and 924 hz. Moreover Nautilus is the only detector in the word equipped with a cosmic ray detector.

Nautilus has undergone, in the first half of 1998, a partial overhaul of its mechanical suspensions and thermal contacts. The results obtained since June 1998 show a considerable improvement in the rejection of non stationary noise and in the sensitivity of the apparatus. We show in Figure 1 the strain sensitivity of the detector, expressed in units of $hz^{-1/2}$, the noise temperature of the order of $T_{noise} \simeq 2$ mKelvin This sensitivity allows the detection at $SNR = 1$ of an impulsive

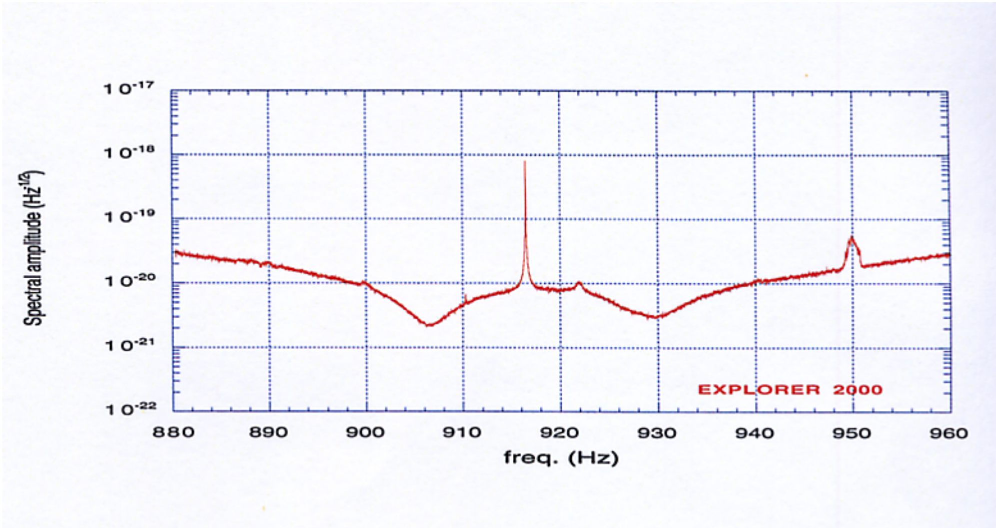

Figure 2: Explorer strain sensitivity with the new trasducer. The spectral amplitude is better than $4\,10^{-21}\,\mathrm{Hz}^{-1/2}$ over a band of about 10 hz.

gravitational wave (GW) signal of duration 1 ms at amplitudes $h \simeq 4\,10^{-19}$. We recall that a supernova in the Galactic Center should produce gravitational waves having $h \simeq 3\,10^{-18}$ much bigger than the Nautilus sensitivity.

The Explorer antenna is located in CERN and is very similar to Nautilus, but is cooled only to 2.6 Kelvin. During 1999-2000 major improvements have been done on the suspensions using solutions similar to Nautilus. A new capacitive transducer having a 10μ gap and a commercial Quantum Design D.C. SQUID are now installed in Explorer. Due to the improvement in the fraction of the energy store in the transducer there is a gain in T_{eff} and therefore in the bandwidth (see eq 2). Figure 2 shows some results. Further improvements are planned on the SQUID. During 2001 we have started to build a cosmic ray detector for the Explorer antenna. This detector will use scintillator counters taken from the Cosmo-Aleph detector that was inside the Aleph hall at LEP.

There are currently four groups in the world operating 5 bar detectors (EXPLORER, NAUTILUS, ALLEGRO at LSU (USA), AURIGA at the INFN Legnaro National Laboratories, and NIOBE (Australia) The four groups formed the International Gravitational Event Collaboration (IGEC) on July 4th 1997, at CERN, and agreed in a data exchange protocol. The data analysis o is presently focused in searching for short GW bursts.

The Frascati group has major responsibilities in the maintenance and running of Nautilus (including the production of liquid helium), in the maintenance, building and running of the cosmic ray detectors, in the development of a new superconductive transformer for the signal readout, in the data acquisition and in many items of data analysis.

3 Future

It is assumed now in the gravitational wave resonant detectors community that the next generation of resonant-mass detectors will be of spherical shape. A single sphere is capable of detecting gravitational waves from all directions and polarizations and is capable of determining the direction information and tensorial character of the incident wave. A sphere will have a larger mass than the present bars (with the same resonant frequency), translating into an increased cross section and improved sensitivity. Omnidirectionality and source direction finding ability make a spherical detector an unique instrument for gravitational wave astronomy with respect to all present detec-

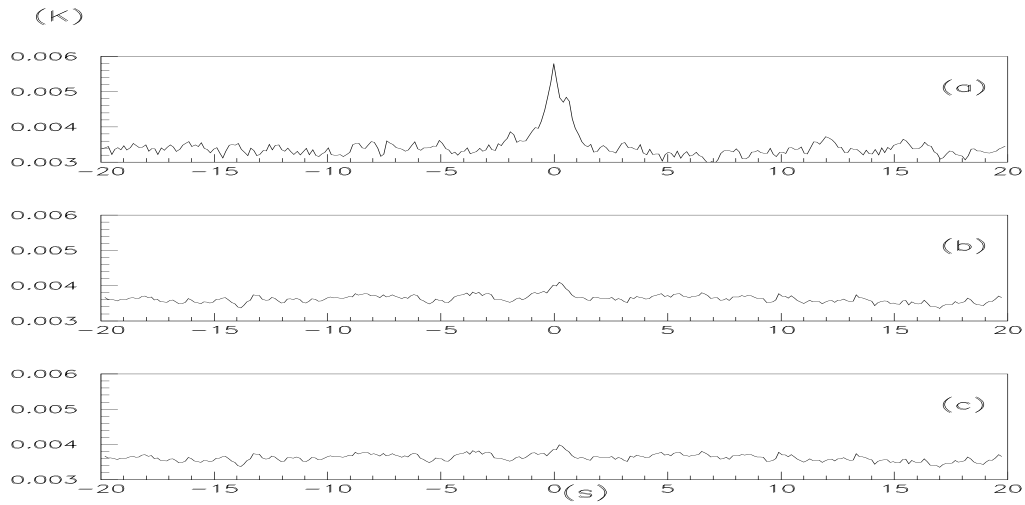

Figure 3: The energy response of NAUTILUS to the CRs passage at zero time. In fig.(a), we show the average energy (K) vs time for 308 data stretches detected during 2000, with NAUTILUS bar temperature at 0.14 K. In fig.(b), the result of the same analysis is shown for 968 data stretches detected during 2001, with bar temperature at 1.5 K. The CR showers particle density is larger than $300\frac{particles}{m^2}$ for the both periods. In the data there is one event having energy=0.5 Kelvin. Excluding from the last data this event, the average energy for 967 data stretches is shown in the fig.(c).

tors. Studies and measurements essential to define a project of a large spherical detector, 40 to 100 tons of mass, cooled to 10 mK have been made in USA, Italy, Netherland and Brasil. The R/D activity of ROG group is related in particular to the cryogenic problems, the suspensions and the effect of the cosmic rays.

A shutdown of NAUTILUS is planned during 2002 to mount a transducer similar to the one of Explorer. Recently the pulsar originated from the Supernova 1987A has been detected. This pulsar should produce gravitational waves at a frequency of about 935 HZ. The Nautilus alluminium bar will be replaced from a bit shorter bar tuned at this frequency [11]. During the 2002 we will complete the installation of the Explorer cosmic ray detector.

4 Main analysis results obtained in 2001

The main analyses using the NAUTILUS and EXPLORER data, just published or in progress, are the following:

- A search for monochromatic signal. The present sensitivity of NAUTILUS allows the detection at $SNR = 1$ of a continuous GW signal around 1 khz of amplitude $h \simeq 5\,10^{-26}$ with an observation time of 100 days [3];
- Search for coincidences between Explorer and Nautilus [4];
- Search for coincidences with gamma ray bursts;
- Detection of the excitation of NAUTILUS due to the passage of cosmic rays.

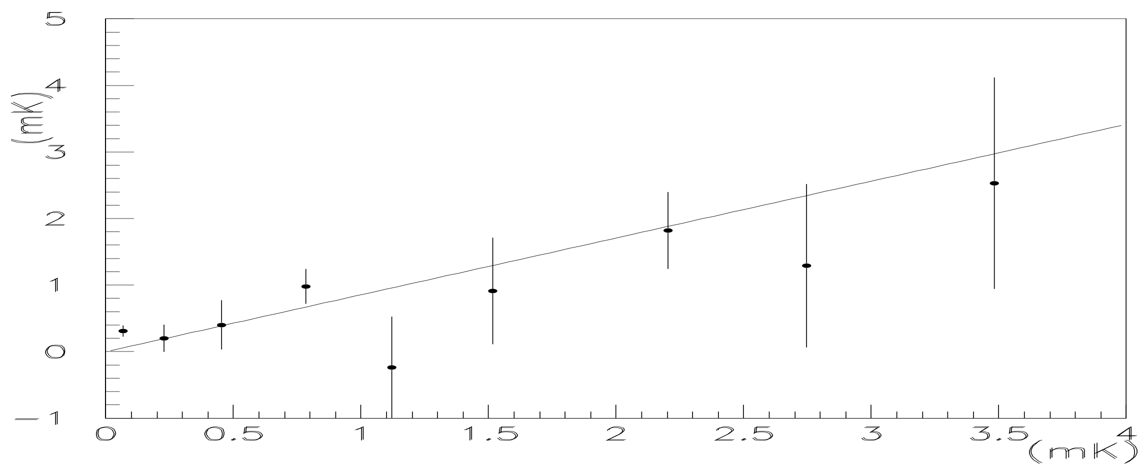

Figure 4: Experimental signal versus the expected signal due to the electromagnatic component of the CR shower. The straight line is at least square fit and the vertical bars indicate statistical errors (± one standard deviation).

time period	NAUTILUS temperature (K)	duration hours	n_c	$\bar{n}$	rate (ev/day)
Sep-Dec 1998	0.14	2002	12	0.47	
Feb-Jul 2000	0.14	707	9	0.42	
Total		2709	21	0.89	0.178 ± 0.041
Aug-Dec 2000	1.1	118	0	0.03	
Mar-Sep 2001	1.5	2003	1	0.42	
Total		2121	1	0.45	0.006 ± 0.011

Table 1: Coincidences during the years 1998, 2000 and 2001, using a coincidence window of ±0.1 s. NAUTILUS temperature, duration of the analysis period, expected number of accidental coincidences $\bar{n}$ and number of coincidences n_c.

Of particular interest is detection of the excitation of NAUTILUS due to the passage of cosmic rays. We have done the first observation of this effect. Recently [6] we have observed several anomalous unexpected signals of large amplitude (up to 60 Kelvin corresponding to 87 TeV). A resonant mass gravitational wave detector used as particle detector has characteristics different from the usual particle detectors, and it could detect new features of cosmic rays. Among several possibilities, one can invoke unexpected behaviour of superconductor Aluminium as particle detector, producing enhanced signals, the excitation of non-elastic modes with large energy release or anomalies in cosmic rays (for instance, the showers might include exotic particles as nuclearites or Q-balls). During the period 2000-2001 NAUTILUS operated at different thermodynamic temperatures. In 2000, until July, the NAUTILUS bar cryogenic temperature was 0.14 K; then, between August and December, it was brought at 1.1 K. The Aluminum is not superconductor at this temperature. In the period 1 March 2001 through 30 September 2001 NAUTILUS operated at a temperature of 1.5 K. We proceeded to apply to these data the same data analysis algorithms used for the previous runs: coincidence search and zero threshold search [9], latter being more efficient for detecting small amplitude signals. We report the result of the analysis and comparison in Table 4. This table affords evidence at about 4 σ level that the observed coincidence rate is related to the bar temperature. We are investigating this interesting effect both experimentally than theoretically.

The question arises whether NAUTILUS, operating at temperature T=1.5 K (in a normal non superconductive status) is sensitive to the CR showers as predicted by the thermo-acoustic models. For a quantitative estimation of a possible effect due to CR we proceeded as follows. We consider NAUTILUS stretches for the year 2001 corresponding to CR in various contiguous multiplicity intervals. For each multiplicity range, the measured signal (average at time 0 ± 68.2 ms) is compared with the signal we expect due to the electromagnetic component of the shower. The theoretical value is given by

$$E_{th} = \Lambda^2 \cdot 4.7\ 10^{-10}\ K \tag{5}$$

where Λ is the number of secondaries through the bar.

In Fig. 4 we show the difference in mK units between the average energy at zero time delay and the background versus the expected signal due to the electromagnetic component of the CR showers. The straight line is a least square fit through the origin . The slope is $0.85 \pm 0.16 \pm 0.42$ and is in a good agreement with the thermo-acoustic model

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10. P. Astone *et al.*, “The EXPLORER gravitational wave antenna: recent improvements and performances“ Classical and Quantum Gravity Volume 19, Number 7 pag 1905, 7 April 2002

11. P. Astone *et al.*, “The next science run of the gravitational wave detector NAUTILUS“ Classical and Quantum Gravity Volume 19, Number 7 pag 1911, 7 April 2002

12. S. D’Antonio “The online data filters for Explorer and Nautilus“ Classical and Quantum Gravity Volume 19, Number 7 pag 1499, 7 April 2002

WIZARD

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ASI (Italian Space agency);
Electronic Engineering Department, University of Roma 2 "Tor Vergata";
RUSSIA: MePhi Moscow;
FIAN Lebedev Moscow;
IOFFE St Petersburg;
TsSKB-Progress Samara;
SWEDEN: KTH Stockholm;
GERMANY: Siegen University;
USA: NASA Goddard Space Flight Center;
New Mexico State University.

1 Experimental Program and Scientific Objectives

The WIZARD experimental program is devoted to the extensive study of cosmic ray spectra (particles, antiparticles, isotopes, abundances and search for antimatter) in several energy ranges achievable through different apparatus on board stratosferic balloons and long duration satellite missions. WIZARD is an International Collaboration between several Universities and Research Institutions from Russia, Sweden, Germany, USA togheter with the Space Agencies NASA, RSA (Russia), SNSB (Sweden), DLR (Germany) and ASI. The experimental activities are carried out through three main programs:
Balloon flights;
Satellite missions NINA-1 and NINA-2;
Satellite mission PAMELA.
We refer to previous editions of this report for the descrition of the activities related to the balloon flights and to the two NINA missions.

1.1 The satellite mission PAMELA

PAMELA is a cosmic ray space experiment that will be installed on board a Russian satellite (Resurs-DK1) whose launch is foreseen in the first quarter of 2003 from the cosmodrome of Baikonur, Kazakhstan. The satellite will fly for at least 3 years in a low altitude, elliptic orbit (300-600 km) with an inclination of 70.4 degrees. The PAMELA telescope consists of a magnetic spectrometer including a permanent magnet coupled to a silicon tracker, a Transition Radiation Detector, an imaging silicon-tungsten calorimeter and a time-of-flight system including anticoincidence counters [1, 2]. A sketch of the PAMELA instrument is shown in fig.1.

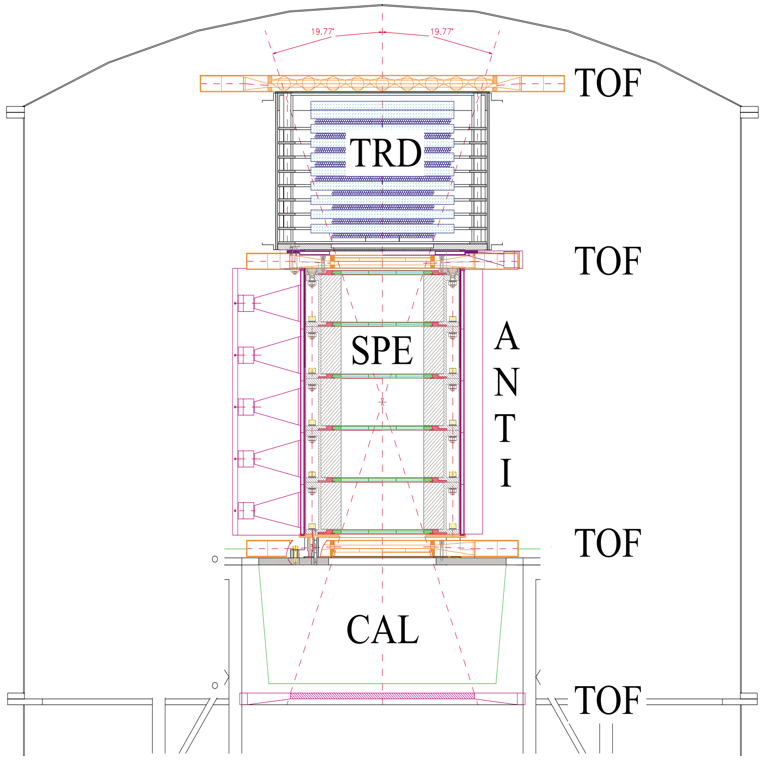

Figure 1: The PAMELA telescope and its main detectors: Transition Radiation Detector (TRD); Permanent Magnet Spectrometer equipped with silicon tracker (SPE); Silicon-Tungsten Calorimeter (CAL). Time Of Flight(TOF) and Anticoincidence (ANTI) systems are also shown.

The total height of PAMELA is 120 cm, the mass is 440 kg, the power consumption is 385 W and the geometrical factor is 20.5 cm^2 sr.

The observational objectives of the PAMELA experiment are to measure the spectra of antiprotons, positrons and nuclei in a wide range of energies, to search for antimatter and for indirect signatures of dark matter and to study the cosmic ray fluxes over a portion of the solar cycle.

The main scientific goals can be schematically listed as the following:

a) measurement of the antiproton spectrum in the energy range 80 MeV-190 GeV;
b) measurement of the positron spectrum in the energy range 50 MeV-270 GeV;
c) search for antinuclei with a sensitivity of $\sim 3 \times 10^{-8}$ in the $\overline{He}/He$ ratio;
d) measurement of nuclei spectra (He, Be, C) at energies up to 700 GeV/n;
e) measurement of the electron spectrum in the energy range 50 MeV-2 TeV.

Moreover, the PAMELA experiment will be able to address the following additional issues:

a) continuous monitoring of the cosmic rays solar modulation during and after the 23rd maximum of the solar activity;
b) study of the time and energy distributions of the energetic particles emitted in solar flares;
c) measurement of the anomalous component of cosmic rays;
d) study of stationary and disturbed fluxes of high energy particles in the Earth magnetosphere.

Activity in the year 2001 has been continued on the development of the qualification model of the instrument for each sub-detector and on the finalization of the general design of services (power supply, CPU, DAQ, telemetry, slow control etc., developed by Companies LABEN, CAEN, C.Gavazzi Space and Kayser Italia) for the Flight Model. Calibrations and beam tests have been performed at CERN PS and SPS and specific vibration, thermal and electromagnetic tests have taken place at different european facilities for space qualification. The assembly and integration laboratory, provided with two clean rooms, has been completed at the INFN Section of Roma 2 with the installation of the MGSE (Mechanical Ground Support equipment) and the computerized metrology system. New radiation hardness tests have been performed at JINR Nuclotron beam in Dubna (Russia) to verify a Flash Memory chip for Single Event Upset and Latch-up. As an example of the performance of some PAMELA detectors, in fig.2 is shown the spatial resolution of the silicon tracker during a test at PS-T9 beam with 10 GeV electrons.

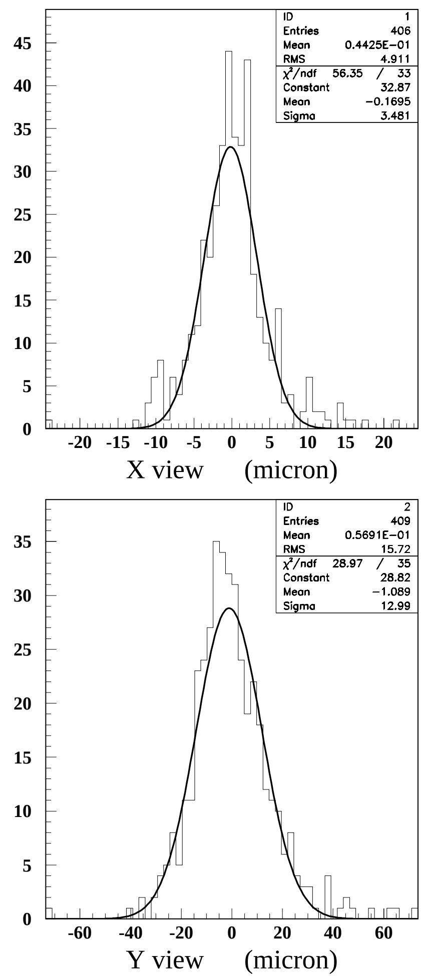

Figure 2: Spatial resolution of the PAMELA silicon tracker with 10 GeV electron beam at CERN PS; x-view is the one subjected to the bending effect of the 0.4 T field of the permanent magnet. A value of less than $3.5\mu m$ has been achieved in this view.

2 Activity of the LNF group during year 2001

The LNF WIZARD group has been fully involved in all the balloon and satellite programs. During the year 2001 the activity for the PAMELA experiment has been carried on as follows:

Responsibility of the Mechanical Ground Support Equipment (MGSE) for the assembly and integration of the whole apparatus.
Completion of the integration laboratory and clean rooms at INFN Roma 2: delivery, installation and test of the MGSE.
Organization and coordination of beam test set-up at CERN PS and SPS.
Responsibility of the counting detectors and trigger for beam tests.
Initial work on preparation of the Mass Dimensional and Thermal Model.
Vibrational tests of PAMELA Dummy Model at IABG Company, Munchen (Germany).

3 Programmed activity of the LNF group during year 2002

Final beam tests of Engineering and Flight Model model at CERN SPS/H4 and PS/T7.
Ground tests and integration of Mass Dimensional and Thermal Model.
Completion of Technical/Engineering Model.
Completion of Flight Model, integration and ground tests.
Delivery of Flight Model to Russia (4th quarter 2002).
Flight readiness tests and integration with spacecraft Resurs DK1.

4 List of Publications in 2001

"In-orbit performance of the space telescope NINA and Galactic Cosmic-Ray flux measurements', V.Bidoli et al., Ap. J. Supp. 132, 365 (2001)
"Light isotope abundances in Solar Energetic Particles measured by the space instrument NINA", astro-ph/0106390
"The cosmic-ray antiproton flux between 3 and 49 GeV" M.Boezio et al. Ap. J. 561, 787 (2001)

Proceedings of the 27th ICRC 2001 Hamburg (Germany):
"The PAMELA experiment", OG vol. 6, p.2215
"Measurement of primary protons and electrons in the energy range of $10^{11} - 10^{13}$ eV in the PAMELA experiment", OG vol. 6, p.2219
"The Transition Radiation Detector for the PAMELA experiment", OG vol. 6, p.2223
"A new measurement of muon spectra in the atmosphere" HE vol.3, p.921
"High-Energy cosmic-ray antiprotons with the CAPRICE98 experiment" OG vol 5, p. 1695
"High-energy deuteron measurement with the CAPRICE98 experiment"OG vol.5, p. 1638
"A new measurement of the primary cosmic ray spectra" OG vol 5, p.1634
"A balloon-borne experiment to measure the fluxes of cosmic-ray muons in the atmosphere", HE vol.3, p.1251

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AIACE

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1 Introduction

AIACE stands for Attività Italiana A CEbaf. It is the collaboration of the INFN groups of Frascati and Genova which participate in the physics program carried on with the CLAS detector at the 6 GeV Continuous Electron Beam Accelerator Facility (CEBAF) at the Jefferson Laboratory (JLab), located in Newport News, Virginia (USA).

CLAS [1] is the large acceptance spectrometer used to study complex reactions that occur when large amounts of energy and momentum are deposited in protons, neutrons, or complex nuclei.The broad physics program approved by the international Program Advisory Committee of the JLab covers the following fields: elementary and nuclear excitations of N^* resonances, spin structure functions of the nucleon, inclusive electron scattering on nuclei, elementary and nuclear hyperon production and decays, structure of the few body systems (few quarks or few nucleons), nuclear medium effects.

At present, the CLAS collaboration counts 140 physicists from 35 Institutions from seven Countries.

In the period covered by this report the Frascati group has carried out:

- the analysis of data collected during the 'g2 run period' for the determination of the deuteron photodisintegration cross section between 0.5 and 3.0 GeV.
- The normalization of the photon flux which involves all the experiments carried out at CLAS with the tagging system.
- The development of the Quark-Gluon String (QGS) model for the prediction of the deuteron photodisintegration cross section at small momentum transfer and the new calculations, within the same model, of the polarization observables of the recoil proton.
- The development of a new program to monitor the Large Angle Calorimeter High Voltage system, using Java application and a graphical user interface.

In addition, the Frascati group has participated to the various CLAS production runs data taking and to the relative discussions of the analysis work.

2 Deuteron photodisintegration between 0.5 and 3.0 GeV (Experiment E-93-017)

2.1 Physics motivation

One of the primary goal of nuclear physics is the study of the interplay between hadronic and partonic degrees of freedom, and of the effectiveness of the traditional nucleon-nucleon theories or QCD inspired model in describing the data. For this purpose, the deuteron reactions with real

and virtual photons are particularly well suited, because the deuteron is the simplest nucleus, and photon interaction with quarks is well known.
Deuteron photodisintegration at low energies (up to around 0.5 GeV) is usually correctly described in terms of hadronic degrees of freedom and meson exchange currents (MEC). At higher energies, the QCD structure of hadrons becomes dominant, and data are reproduced using perturbative QCD calculations. The intermediate energy region is important in order to clarify the transition from the hadronic to the partonic description of hadrons and nuclei. However, in this region perturbative QCD calculation are not applicable, thus non-perturbative methods must be used.
One obvious signature of QCD effects in the deuteron photodisintegration is a scaling behaviour of the cross section. The constituent counting rule (CCR) [3] predicts that, for sufficiently high energy and fixed angle, the differential cross section of any binary reaction must scale with the square of the total energy s:

$$\frac{d\sigma}{dt} = \frac{1}{s^{N_F-2}} f(\theta_{CM})$$

where N_F is the minimum number of microscopic fields involved in the reaction. In our case, $N_F = 13$, thus $d\sigma/dt \propto s^{-11}$.
The differential cross section of the deuteron photodisintegration for photon energy above 1 GeV has been measured only at few angles [4], [5], [6]. The experimental data show scaling only at large proton angle, $\theta_{cm} = 69°$ and $89°$, while for more forward angles the situation is less clear.
More sophisticated models have been developed for the description of the data but no one is able to reproduce all the experimental data. The Reduced Nuclear Amplitude (RNA) model [7] is able to describe the $\gamma d \to pn$ cross section with an appropriate normalization factor only for $\theta_{cm} = 69°$ and $E_\gamma > 2$ GeV. In the Hard quark Rescattering Model (HRM) [8] the agreement with the data is poor (especially at higher energies) and the uncertainty is large, due to the poor knowledge of the pn amplitude. Traditional models based on hadronic degrees of freedom are expected to fail to reproduce data at $E_\gamma > 1$ GeV. However, this approach has been extended in the few GeV region in the Asymptotic Meson Exchange Current (AMEC) model [9]. The results reproduce the energy dependence of the cross section only for $\theta_{cm} = 89°$. In any case, it is worth noticing that also this non QCD-based model is able to provide a scaling law for the cross section, with an exponent depending on the scattering angle.

In summary, it seems that at high energies, where asymptotic behaviour is expected, the nucleon-nucleon interaction is well described by the scaling behaviour of pQCD; while in the intermediate energy regime, where meson-exchange models fail and pQCD is not yet applicable, non perturbative QCD methods should be considered.

In this context, a few years ago we have derived an expression for the cross section for the reaction $\gamma d \to pn$ at small momentum transfer t and u in the framework of the QGS model and Regge phenomenology [10] (here t,u, and s are the usual Mandelstam variables). In this approach (see next par.) the cross section is a fast decreasing function of the photon energy and t. Its energy behaviour at fixed centre-of-mass angle is complex and cannot be incorporated into a simple power law of energy, in distinction from the quark counting rule which predicts a constant power s^{11} at all angles.

2.2 Experimental

The experiment of interest here (experiment E-93-017) intends to measure at the Jlab the differential cross section for the processes $\gamma d \to pn$ and $\gamma d \to p\Delta^0$ in the region of small momentum transfers and over the energy range from 0.5 to 3.2 GeV, in order to check the predictions of the Regge phenomenology and the QGS model. [11] The data are obtained with the CLAS Spectrometer of Hall B. A bremsstrahlung photon beam is produced by the continuous electron beam hitting

a thin radiator, and the tagging system [12] tags monochromatic photons with energy between 0.20 and 0.95 of the electron beam and resolution of about 0.1%. The hadrons are detected with CLAS [1], a nearly 4π spectrometer based on a toroidal magnetic field generated by 6 superconducting coils. The field was set to bend positively charged particles away from the beam line.
Data were taken with photon energy ranging from 0.5 to 3 GeV. The trigger for the data acquisition was the coincidence between signals in the tagger and in the CLAS detector (TOF). The total number of recorded triggers is about 2.5 billions.
Real photodisintegration events are selected requiring the identification of a photon in the tagger and a proton in CLAS, and then applying a missing mass cut to the reaction $\gamma d \rightarrow pX$. The CLAS acceptance has been evaluated by Monte Carlo simulations of the photodisintegration reaction, and the background contribution has been computed by a fit to the experimental missing mass distributions.
In fig. 1 the differential cross section $d\sigma/d\Omega$ is reported as a function of the proton angle in the CM frame, for fixed photon energy above 0.9 GeV. The present preliminary results are obtained from the analysis of about 30% of the accumulated statistic, corresponding to about 530 millions of triggers. Moreover, an additional cut $\theta_p^{CM} > 20°$ has been applied, that will be removed in the final analysis. The agreement with the other available data from SLAC [5] and Hall C of TJNAF [6] is good at all energies and angles. Notice that, in spite of the limited data set, the statistical error is lower than 5% for $E_\gamma < 1.5$ GeV. When the whole data set will be analysed, the statistical error will be improved by a factor 3 or more for photon energies up to 2.5 GeV.

3 Deuteron photodisintegration within the Quark-Gluon Strings model

The Quark Gluon String Model (QGSM) is a non-perturbative approach, which has been extensively used for the description of hadronic reactions at high energies [13]. Due to duality property of scattering amplitudes, it can also be applied at intermediate energies for reactions without explicit resonances in the direct channel.
The QGSM is based on a topological expansion in QCD of the scattering amplitudes in power of $1/N$ [14], where N is the number of colors N_c or flavors N_f. In the limit $N_f >> 1$ and $N_c/N_f \simeq 1$, the planar graphs give the dominant contribution to the amplitude [15].
In the space-time representation, the reaction $\gamma d \rightarrow pn$ is described by the exchange of three valence quarks in the t-channel with any number of gluons between them. This picture corresponds to the formation and break up of a quark-gluon string in the intermediate state, leading to the factorization of the amplitudes: the probability for the string to produce different hadrons in the final state does not depend on the type of the annihilated quarks, but is only determined by the flavor of the produced quarks.
The intermediate quark-gluon string can be easily identified with the nucleon Regge trajectory [13]. Actually, most of the QGSM parameter can be related to the parameters of Regge Theory, as trajectories or residues. In this sense, the QGSM can be considered as a microscopic model for the Regge phenomenology, and can be used for the calculation of different quantities that have been considered before only at a phenomenological level.
In Ref. [16], the QGSM has been applied for the description of the deuteron photodisintegration reaction, using QCD motivated non linear nucleon Regge trajectories [17], with full inclusion of spin variables and assuming the dominance of the amplitudes that conserve s-channel helicity. The interference between the isoscalar and isovectorial components of the photon has been also taken into account, leading to forward-backward asymmetry in the cross section.
The result of the calculation is shown in fig. 1 as full line, compared with previous published data and with the preliminary results of the new CLAS measurement. The agreement between data and

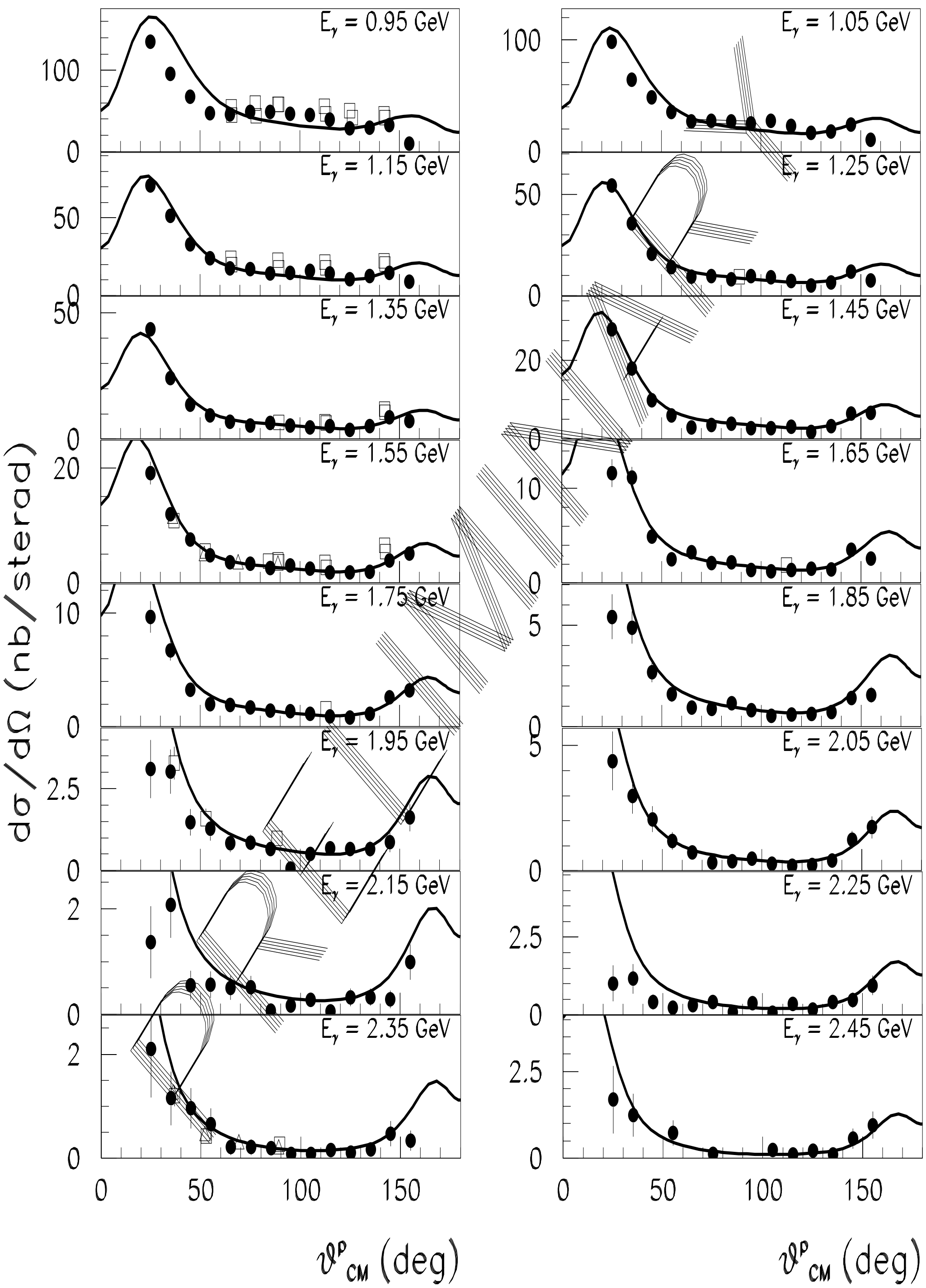

Figure 1: *Preliminary results of the deuteron photodisintegration differential cross section measured in Ha ll B of TJNAF (black circles), compared with the published data from SLAC* [5] *(open squares) and Hall C of TJNAF* [6] *(open triangles). The curve is the QGSM calculation* [16].

calculations is very good for all energies above 1 GeV: the QGSM reproduces the angular dependance of the cross section at fixed photon energy and predicts the forward-backward asymmetry showed by the data. From these plots, it results also the importance of measuring the cross section at very forward angles, in order to check the QGSM prediction that the cross section decreases for angles smaller than $10° - 20°$.
The QGSM model also predicts correctly the decrease of $d\sigma/dt$ at fixed angle as a function of the photon energy, as shown in fig. 2 for four CM proton angles. Also here, the cross section multiplied by the factor s^{11}.

4 List of Publications

1. CLAS Collaboration, R. Thompson *et al.*, The $ep \rightarrow e'p\eta$ reaction at and above the $S_{11}(1535)$ baryon resonance, Phys. Rev. Lett. **1** (2001) 1702.

2. CLAS Collaboration, K. Lukashin *et al.*, Exclusive electroproduction of ϕ mesons at 4.2 GeV, Phys. Rev. **C 63** (2001) 065205.

3. V.Yu. Grishina *et al.*, Deuteron photodisintegration within the Quark-Gluon Strings Model and QCD motivated nonlinear Regge trajectories, Eur. Phys. J. A **10** (2001) 355.

4. CLAS Collaboration, S. Stepanyan *et al.*, Observation of exclusivive virtual Compton scattering in polarized electron beam asymmetry measuremets, Phys. Rev. Lett. **87** (2001) 182002.

5. CLAS Collaboration, S. Barrow *et al.*, Electroproduction of the $\Lambda(1520)$ Hyperon, Phys. Rev. **C** (2001) in print.

6. CLAS Collaboration, M. Battaglieri *et al.*, Photoproduction of ρ_0 Meson on the Proton at large momentum transfer, Phys. Rev. Lett. **87** (2001) 172002.

7. CLAS Collaboration, R. DeVita *et al.*, First Measurement of the Double Spin Asymmetry in $e(pol)p(pol) \rightarrow e'pi + n$ in the Resonance Region, Accepted 1-6-02 by Physical Review Letters.

8. CLAS Collaboration, K. Joo *et al.*,Q2 Dependence of Quadrupole Strength in $gamma * - > Delta + (1232)$, Accepted by Physical Review Letters.

5 Presentation at Conferences

1. *Deuteron photodisintegration in the GeV region: QGSM prediction and preliminary results from E93-017 experiment.*
   Patrizia Rossi.
   Invited talk at the "XXIV Brasilian Workshop on Nuclear Physics"
   San Paulo (Brazil), September 1-5,2001.

2. *Quark-Hadron Duality in Deuteron Photodisintegration.*
   Marco Mirazita.
   Contributed talk at the "XL International Winter Meeting on Nuclear Physics"
   Bormio (Italy), January 21-26, 2002.

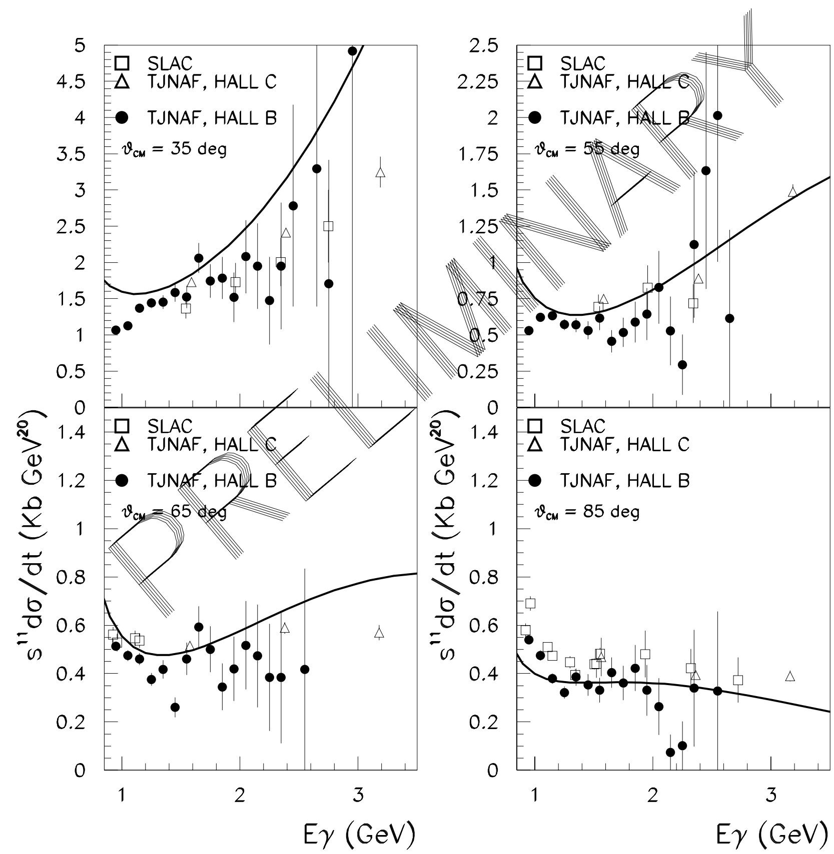

Figure 2: *Deuteron photodisintegration cross section for four fixed proton angles: preliminary results of Hall B of TJNAF (black circles) and published data from Mainz* [4]*, SLAC* [5] *and Hall C of TJNAF* [6]*. The curve is the QGSM calculation* [16]*.*

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DEAR

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1 Aim of the DEAR experiment

DEAR (DAΦNE Exotic Atom Research) will observe X rays from kaonic hydrogen and kaonic deuterium, using the "K^- beam" from the decay of ϕs produced by DAΦNE. The DEAR setup consists of a cryogenic pressurized gaseous target and Charge-Coupled Devices (CCDs) as x-ray detectors. The sketch of the experimental setup is shown in Fig. 1.

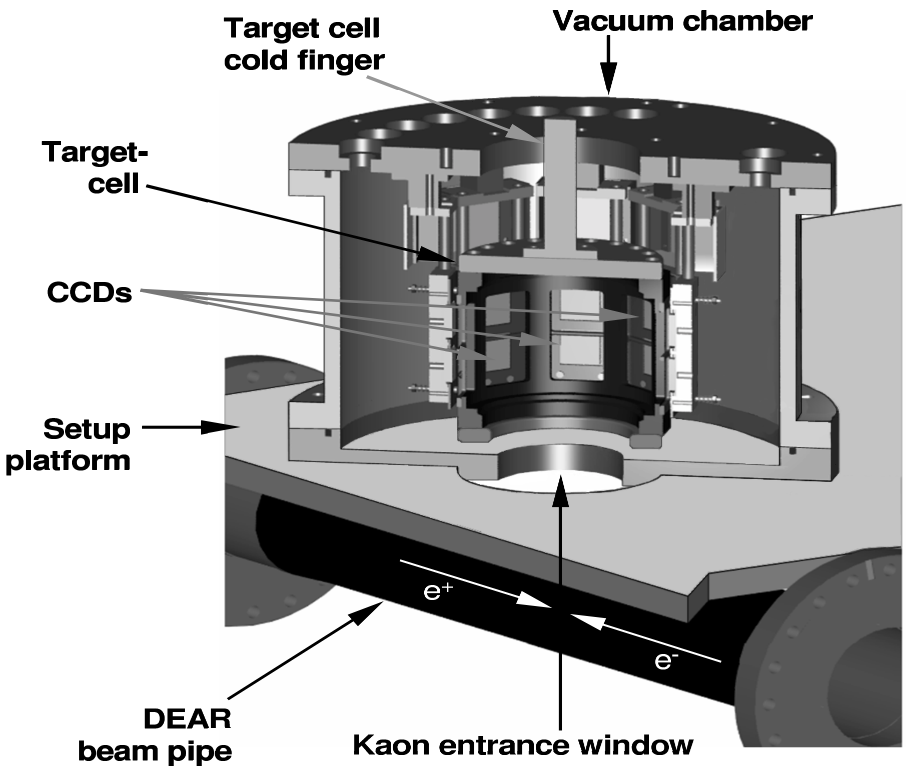

Figure 1: *Sketch of the DEAR experimental setup.*

A kaonic atom is formed when a negative kaon enters a target, loses its kinetic energy through ionization and excitation processes of the atoms and molecules of the medium and eventually is captured, replacing the electron, in an excited orbit. Three processes then compete in the deexcitation of the newly formed kaonic atom: dissociation of the surrounding molecules, external Auger transitions and radiative transitions. When a kaon reaches low-n states with small angular momentum, it is absorbed through a strong interaction with the nucleus. The strong interaction causes a shift in the energies of the low-lying levels from their purely electromagnetic values, while the decreased lifetime of the state results in an increase of the observed level width. The shift ϵ

and the width Γ of the $1s$ state of kaonic hydrogen are related in a fairly model-independent way to the real and imaginary parts of the complex S-wave scattering length:

$$\epsilon + \frac{i}{2}\Gamma = 2\alpha^3\mu^2_{K^-p}a_{K^-p} = (412\ eV\ fm^{-1}) \cdot a_{K^-p} \tag{1}$$

where α is the fine structure constant and μ_{K^-p} the reduced mass of the K^-p system. This expression is known as the Deser-Trueman formula. A similar relation applies for the case of kaonic deuterium and the corresponding scattering length a_{K^-d}.

DEAR aims a precision measurement of the shift and of the broadening, due to the strong interaction, of the K_α lines of kaonic hydrogen and kaonic deuterium. K^-d will be measured for the first time. In this way, a precise determination of the isospin dependent K^-N scattering lengths will be obtained. This will allow to determine the kaon-nucleon sigma terms. The sigma terms give a direct measurement of chiral symmetry breaking.

Presently, only estimates exist of the KN sigma terms. A measurement of K^-N scattering lengths at a percent level would enable the determination of the KN sigma terms with a precision of about 20% or less, to be compared with the 70% uncertainty of the present estimates.

The sigma terms are also especially important in connection with the strangeness content of the nucleon, that provides the SU(3) description of the nucleon beyond the SU(2) naïve picture. Indeed, the SU(3) structure of the nucleon appears more explicitly in quantities associated with chiral symmetry breaking. The strangeness fraction is dependent on both kaon-nucleon and pion-nucleon sigma terms, but is more sensitive to the first one.

2 Activity in 2001

2.1 Measurement of two unobserved transitions of kaonic nitrogen

The first stage of the DEAR scientific programme consisted in the demonstration that the scientific line based on the creation and detection of exotic atoms using the kaons of DAΦNE from ϕ–decay, entering the DEAR setup, could be followed. This indeed was obtained by measuring kaonic nitrogen, in which the yields of the transitions are much higher than in kaonic hydrogen and therefore a relatively faster observation is possible. The measurements was performed in May–June 2001, with the target cell filled with nitrogen at a pressure of about 1.52 bar and a temperature of 118 K, representing a density equivalent to about 4 ρ_{NTP}. The cryogenic setup was equipped with 8 CCD-22 and 4 CCD-05. The CCD-05 were used for background measurements, in order to compare the background level seen by the cryogenic setup with that measured in the previous configurations with the NTP setup. The data coming from 6 good CCD-22 were firstly calibrated in energy, using the Al, Fe and Zr peaks, and then further considered for the search of the kaonic nitrogen signal.

After having established which CCDs had to be considered for a further analysis, the x-ray spectrum was built with the data taken in the whole data taking period and the fit procedure started. The basic idea of the fit was to perform a global fit on the whole energy spectrum, i.e. to find that function which describes the entire x-ray spectrum. All fit results were obtained using MINUIT.

A very important first step of the fit was to establish the function describing the background. Since background was very high, describing its shape is fundamental, in order to correctly derive the kaonic nitrogen signal. Special attention was dedicated to this problem and, independently, Frascati and Vienna groups arrived at the same result. The regions free of peaks were initially considered for the fit. It was checked that one exponential, as naïvely one might think, cannot describe the behaviour of background over the whole energy range. Then, a sum of two exponential was tested for the shape of background: however, this solution could not describe the background as well (giving a bad χ^2 - inacceptable for the number of degrees of freedom present in the fit). Finally, it was tested that a sum of 3 exponentials, i.e. a function with 6 parameters, correctly describes the behaviour of the background in the peak–free regions.

As second step, after having obtained the function describing the background, the parameters describing the different x-ray peaks present in the spectrum were added to the fitting function. The criterium was to have the minimum number of parameters to obtain a good fit, namely a $\chi^2/NDOF$ acceptable for the number of degrees of freedom we had.

Finally, the function which gave a good description of the experimental data through the whole energy spectrum was obtained. The fit gave a $\chi^2/NDOF = 0.95$, representing a very good value for the number of degrees of freedom involved (127).

In Fig. 2, the background subtracted spectrum is shown. The spectrum was obtained from the global fit of the full energy spectrum out of which the function representing the continuous background was subtracted. The peaks in Figure 2 are:

1. Aluminium K_α X rays at 1.49 KeV, from the target frame;
2. Silicon K_α X rays at 1.74 keV, from the CCDs;
3. Scandium K_α X rays at 4.09 keV, from the CCD–22 ceramics supports;
4. **Kaonic nitrogen (7→6) transition at 4.6 keV**;
5. Vanadium K_α X rays at 4.95 KeV, from stainless steel (screws);
6. Chromium K_α X rays at 5.41 keV, from stainless steel (screws);
7. Manganese K_α and chromium K_β at 5.89 and 5.95 keV, respectively, from aluminium and stainless steel;
8. Iron K_α and manganese K_β X rays at 6.40 and 6.49 keV, respectively, from stainless steel and aluminium;
9. Iron K_β X rays at 7.06 keV, from stainless steel;
10. **Kaonic nitrogen (6→5) transition at 7.6 keV**;
11. Copper K_α X rays at 8.04 keV, from the cold finger of the cooling system;
12. Zinc K_α X rays at 8.63 keV, from stainless steel and CCD back support;
13. Lead L–complex and zinc K_β X rays at 9.4 and 9.57 keV, respectively, from shielding and stainless steel;
14. Lead L–complex X rays at 10.5 keV, from shielding;
15. Zirconium X rays at 15.7 keV, from zirconium foil used for energy calibration.

As it is seen from Figure 2, the peaks corresponding to kaonic nitrogen are clearly visible.

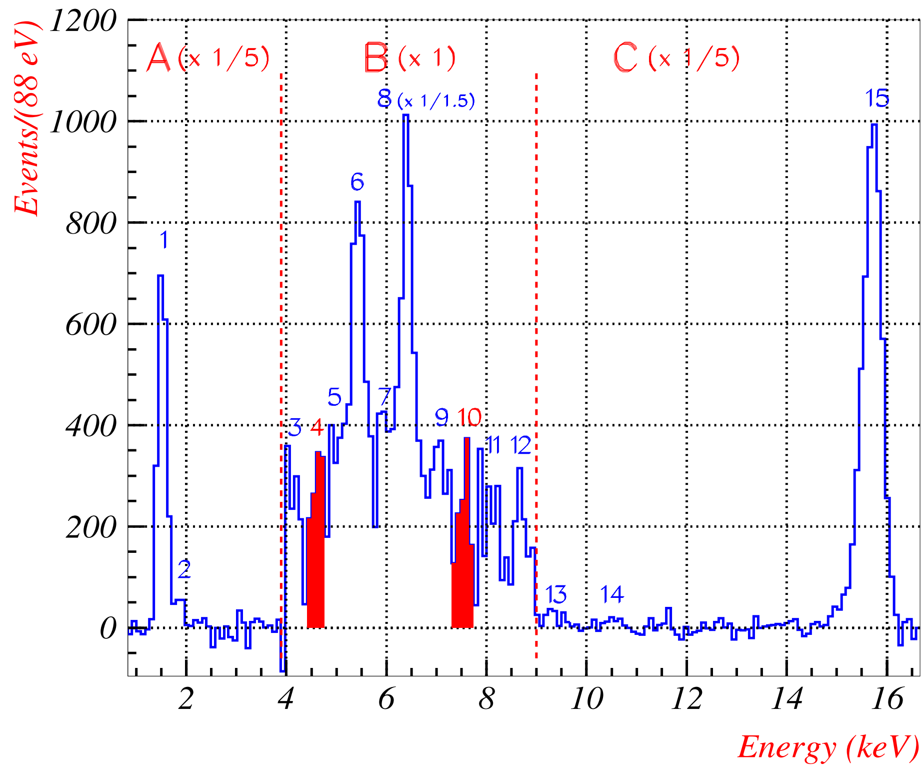

Figure 2: *The kaonic nitrogen spectrum (see text for the identification of the peaks).*

2.2 Realization of new cryogenic setup to measure kaonic hydrogen

A complete new setup was designed and realized for the measurement of kaonic hydrogen. The final setup was built by taking advantage of the experience gained in background studies on DAΦNE. In particular, the new target cell was designed following few important indications:

- as less material as possible in front of the CCDs, which means low mass target cell;
- as less material as possible behind the CCDs, which means new CCDs frames;
- improved shielding possibilities within the vacuum jacket;
- easier access to the cell and easier extraction fron the vacuum chamber.

These prescription turned out in a target done in kapton, 60μ thick, cylindrical shaped, with a diameter of 11 cm, reinforced with epoxy-fiberglass bars shown in Fig. 3. Top and bottom, in aluminium, are simply glued to the kapton cylinder, so avoiding stainless steel screws (containing iron and chromium).

The target was submitted to a test during an engineering run in December 2001 with collision in the DEAR interaction point.The test consisted in verifying that the materials by which the cell is made did not contain elements "dangerous" for the hydrogen measurement, specifically iron and manganese, present in the cell used for the nitrogen measurement. The experimental setup was the same used for the kaonic nitrogen measurement, apart the substitution of the target cell with the new one. The x-ray energy spectrum was carefully studied looking for all apparent structures.

In the measured energy spectrum very few peaks corresponding to electronic excitations of the materials appear: only the calcium and silicon lines, from the kapton target cell; the aluminium line, from the cryogenics of the cell, the zirconium peak from the foil put on the top of the target in order to have a calibration over the whole energy scale. No line in the region of interest of the measurement of kaonic hydrogen is apparent. The new cryogenic setup was equipped with a new

Figure 3: *Fiber–glass reinforced kapton target cell.*

control and acquisition electronics and as well with a new type of CCDs. Objectives and realisation of the new detection and acquisition system were:

- increase the efficiency of the setup by the use of 16 CCD-55 instead of CCD-22;
- increase the flexibility in adjusting the CCD readout parameters;
- improve the quality of readout;
- simplify the maintenance by reducing the amount of home-made electronics.

These objectives were fully fulfilled. In particular, the following performances were obtained:

- resolution and noise characteristics:
  - thermal noise of about 15 eV FWHM;
  - energy resolution at 5.9 keV: 136 eV;
  - linearity: about 10^{-4};
  - stability: fluctuation below 4 eV/month;
  - charge transport inefficiency: 10^{-4}.

Fig. 4 shows the assembly of new electronics, CCDs and cryogenics.

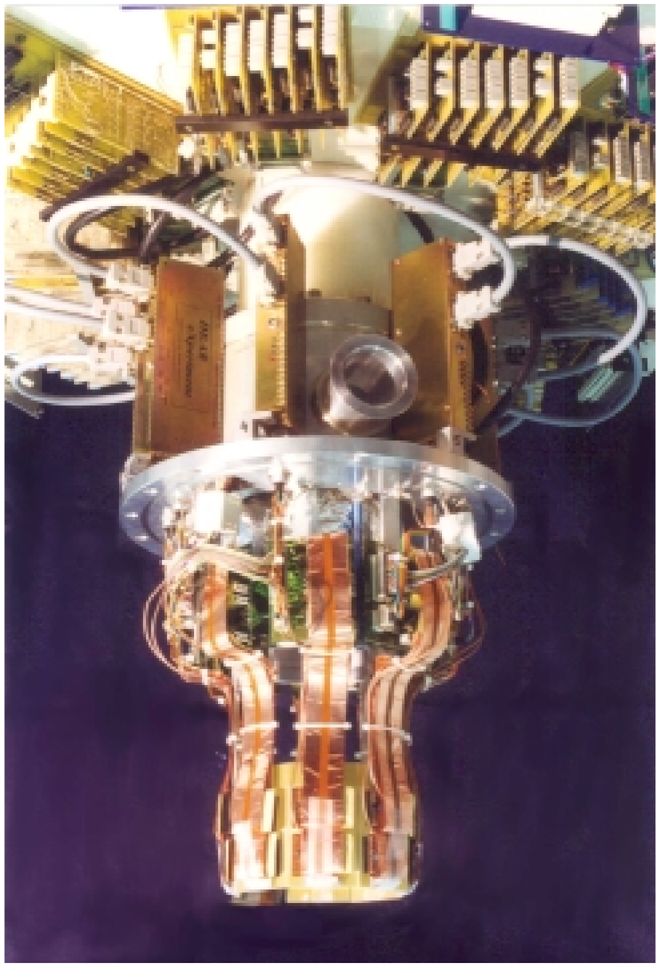

Figure 4: *CCD mounting, cryogenics and on-cell electronics.*

3 Activity in 2002

In the year 2002 the measurement of kaonic hydrogen will be finally performed. The measurement will be preceeded by a test of the new cryogenic setup - in the new machine configuration after the installation of scrapers, octupoles and with a new optics - test consisting in a re–measurement of the kaonic nitrogen spectrum. This, in order to verify the status of the experiment, in terms of signal/background ratio, resolution, integrated luminosity collected/day, etc., and to extrapolate to the case of hydrogen. The installation will be done during the winter shutdown, will be followed by a tuning of the machine and then by the study of the degrader, in order to optimize the kaons stopping points distribution.

In case of positive results, at a date to be fixed by the Scientific Committee, the kaonic hydrogen measurement will start until at least 50 pb^{-1} will be collected, necessary to reach a precision around (8-10)% with a signal/background ratio 1/20.

4 Publications 2001

4.1 Paper

1. C. Guaraldo *et al.* (DEAR Collaboration), **The DEAR experiment on DAΦNE**, Nuclear Physics **A**, Vol. 691 (2001) 278.

2. C. Curceanu (Petrascu) *et al.* (DEAR Collaboration), **The DEAR experiment on DAΦNE**, American Institute of Physics, AIP, 564 (2001) 217.

4.2 Technical Notes

1. C. Curceanu (Petrascu) and C. Guaraldo, **Some considerations about the possibility to increase the integrated luminosty/day collected by DEAR**, DEAR Note IR-38, December 10, 2001.

2. M. Bragadireanu, A. Cecchetti, C. Curceanu (Petrascu), B. Dulach, C. Guaraldo, M. Iliescu, V. Lucherini, L. Ludhova, F. Lucibello, R. Petrescu, D. Sirghi, J. Zmeskal, **Cryogenic setup for kaonic nitrogen**, DEAR Note IR-37, April 12, 2001.

3. M. Bragadireanu, C. Curceanu (Petrascu), C. Guaraldo, M. Iliescu, V. Lucherini, F. Lucibello, **Report on the run period December 2000: Kaon Monitor**, DEAR Note IR-36, February 7, 2001.

4. M. Bragadireanu, C. Curceanu (Petrascu), B. Gartner, C. Guaraldo, M. Iliescu, B. Lauss, V. Lucherini, L. Ludhova, D. Soare, **"En attendant Godot": background reduction obtained in the NTP setup in the period 16 October - 5 December 2000**, DEAR Note IR-34, January 9, 2001.

4.3 Presentations to international conferences

1. C. Curceanu (Petrascu) *et al.* (DEAR Collaboration), **The first measurement of kaonic nitrogen with DEAR at DAΦNE**, "Workshop on Hadronic Atoms - HadAtom 01", Bern, Switzerland, 11-12 October 2001.

DIRAC

P. Gianotti (Resp), M. Giardoni, C. Guaraldo, M. Iliescu, A. Lanaro (Resp. Naz.),
P. Levi Sandri, V. Lucherini, C. Oana Petrascu

1 Introduction

The DIRAC (Dimeson Relativistic Atomic Complex) Experiment at CERN will submit Chiral Perturbation Theory (ChPT) to a stringent test, by measuring, in a model independent way, the difference between the isoscalar (a_0) and isotensor (a_2) S-wave pion-pion scattering lengths with 5% accuracy. Such determination will be done through a measurement (with 10% accuracy) of the lifetime of Pionic Atoms ($A_{2\pi}$), a weakly bound $\pi^+\pi^-$ system at threshold, produced by proton-nucleus interactions at 24 GeV/c.

The present theoretical estimate of the lifetime of the ground state of the dimeson atom, from calculations performed within the framework of standard ChPT, is $(2.9 \pm 0.1) \cdot 10^{-15} s$ [1, 2, 3, 4].

The DIRAC experimental apparatus is located at the CERN PS East Hall. It consists of a double arm magnetic spectrometer, consisting of high resolution tracking and particle identification detectors. It is designed to detect with high efficiency charged pion pairs with small relative momentum ($Q < 3$ MeV/c), and small opening angle ($\simeq 0.35$ mrad). The experiment was approved in 1996, the commissioning was done at the end of 1998 and the apparatus became fully operational in the spring of 1999.

The DIRAC Collaboration includes 83 participants from 19 international Institutes. 14% of the participants are from Italian Institutes (INFN-LNF and Trieste University/INFN). About 25% of leadership roles within the collaboration is granted to INFN members. The yearly budget contribution from INFN to the Experiment amounts to ∼20% of the total budget.

The LNF group has contributed to the experiment by providing 2 large threshold Cherenkov counters for e^+e^- identification. The counters use gaseous nitrogen as radiator. Each counter is equipped with 20 mirrors and 10 photomultipliers. The Cherenkov detectors ensure e^+e^- rejection at the trigger level with 99.5% efficiency, and 15 photoelectrons are on average detected in each counter.

2 Experimental activity in 2001

In 2001 the LNF-DIRAC group has contributed to the analysis of $\sim 1.5 \times 10^9$ events collected in 1999 and 2000 using Pt, Ti and Ni targets. From such analysis several hundreds $\pi^+\pi^-$ atomic pairs coming from the breakup of $A_{2\pi}$ in the target were observed.

The LNF group has also participated to the 2001 experimental data taking (from early April to the end of October), keeping the responsibility for the maintenance and performance studies of the Cherenkov and Preshower detectors. In addition, the group coordinated the off-line monitoring of the data quality.

A very large data sample ($\sim 1.4 \times 10^9$ events) was collected in 2001. A fraction ($\sim 70\%$) of this statistics was analysed and combined to the statistics of 1999 and 2000. Preliminary results presented at the CERN SPS Committee held in September showed evidence of about 5500 $\pi^+\pi^-$

atomic pairs detected in the apparatus, which allowed for an experimental determination of the $A_{2\pi}$ lifetime with a statistical accuracy of $\sim 22\%$. Fig. 1 shows the $\pi^+\pi^-$ relative c.m. momentum (Q) distribution of atomic pairs detected from Ni and Ti targets.

Including the full statistics of 2001 the expected statistical accuracy on $\tau(A_{2\pi})$ should be of the order of 14%, corresponding to a 7% uncertainty on the difference $|a_0 - a_2|$.

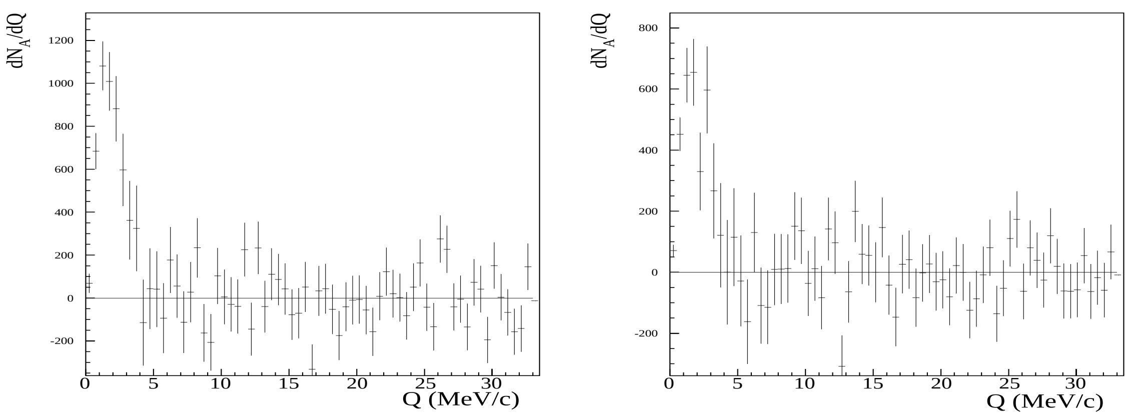

Figure 1: *Q distributions of $\pi^+\pi^-$ atomic pairs from Ni (left) and Ti (right) target data.*

The LNF-DIRAC group has continued the R&D devoted to the upgrade of the particle identification system for the simultaneous observation of $\pi^+\pi^-$ and $\pi^\pm K^\mp$ atoms [5]. At the end of May a one-week test was performed using SF_6 gas as radiator in the Cherenkov counters. This gas (n=1.0007) allows to discriminate kaons from pions with momenta above 3.7 GeV/c. The success of the test was demonstrated by providing evidence of the $\phi \to K^+K^-$ resonance decay (Fig. 2). In addition, the development of a small-size Aerogel Cherenkov detector, using Aerogel with very low index of refraction (n=1.008) manufactured by the Boreskov Inst. of Catalysis in Novosibirsk, is currently underway at LNF. This detector should provide K^+ to p separation at the trigger level.

The LNF-DIRAC group has also performed the following data analyses:

- A parameterisation of inclusive charged pion spectra from 24 GeV/c proton interactions on nuclear targets. Evaluation of proton contamination to positively charged particle sample (**DIRAC Note 2001-01**).
- Experimental determination of the size and uncertainty in position of the proton beam at the DIRAC target (**DIRAC Note 2002-02**).
- Analysis of μ-candidate events in DIRAC (**DIRAC Note 2002-03**).

3 Planned activity in 2002

DIRAC was granted 6 months of running time in the year 2002. Data taking with Ni and Ti targets is foreseen to continue in order to improve the accuracy on the $A_{2\pi}$ lifetime determination. In addition, a 2-months data taking with a segmented thin Be target, producing a very weak $A_{2\pi}$

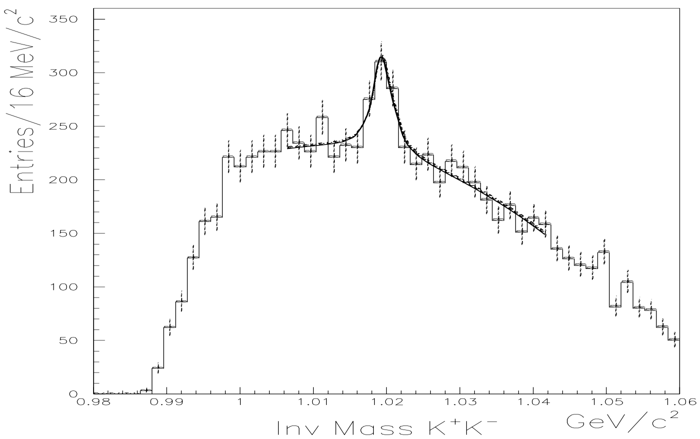

Figure 2: K^+K^- *invariant mass distribution from test beam data using* SF_6 *gas radiator.*

signal, is planned in order to perform a systematic control of the experimental procedure. The goal is to achieve the aimed accuracy on $\tau(A_{2\pi})$ with full control of systematical errors.

The LNF group will participate to the data taking shifts, to the implementation of the Be target station and to the analysis of collected data. We plan also to perform a test of the prototype Aerogel counter under construction at LNF to asses the light yield under different photo-detector configurations.

4 Publications and reports to Conferences

1. P.Gianotti et al. (DIRAC Collaboration), "First results from DIRAC experiment at CERN", S.I.F., 28 September 2001, Milano (Italy)
2. A. Lanaro et al. (DIRAC Collaboration), "πK atom: Observation and lifetime measurement with DIRAC", Proc. Int. Workshop on Hadronic Atoms [HadAtom01], 11-12 October 2001, Bern (Switzerland), Eds. J. Gasser, A. Rusetsky and J.Schacher, BUTP-2001/23, BUHE-2001-07 (2001) 16.

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FINUDA

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M. Pallotta, L. Passamonti (Tecn.),D. Pierluigi(Tecn.), F. Pompili (Bors.),
N. Quaiser (Bors.), A. Russo (Tecn.), S. Tomassini (art.23)

1 Introduction

FINUDA (meaning FIsica NUcleare a DAΦNE) is an experimental set up whose aim is the study of hypernuclei formation and decay within the same apparatus. Hypernuclei are nuclei in which a bound nucleon, baryon made of only u (up) and d (down) quarks, is replaced by a hyperon, baryon made also by s(strange) quarks. The added flavour enlarges the basic nucleon-nucleon interactions also to the strange sector: the so changed level scheme of the involved nucleus gives hence information on the modification of the properties of baryon-baryon interaction due to strangeness. High resolution hypernuclear spectroscopy can also, in principle, reveals in a more clearly way a partial deconfinement of quarks in nuclear matter.

The DAΦNE e^+/e^- collider is optimized in *Luminosity* at the *c.m.* energy corresponding to the $\phi(1020)$ meson. The huge number of ϕs, produced (almost) at rest, decay with a $B.R.$ of 0.49 into back-to-back pairs of slow (127 MeV/c)charged kaons. The K^-s, stopped by a thin target, can hence produce hypernuclei, through the reaction (inside one of the target nuclei):

$$K^- + n \rightarrow \pi^- + \Lambda \tag{1}$$

The levels of the produced hypernucleus can be obtained through an accurate measurement of the momentum of the emitted (*prompt*) π^-. Since the kaons from DAΦNE have a very low and sharp momentum, they can be stopped in very thin targets, allowing unprecedented resolution (0.3%) to be reached in hypernuclear spectroscopy. Moreover, the subsequent decay of the hypernucleus, both *mesonic* (p+π^-) and $non-mesonic$ (np or nn) can be detected by FINUDA, allowing the simultaneous study of formation and decay of hypernuclei within the same apparatus, a feature never reached in previous experiments.

FINUDA is a large acceptance magnetic spectrometer based on a medium sized superconducting solenoid (2.7 m long and 2.4 m diameter), operating at a maximum field of 1.1 T. The inner of the solenoid is equipped with tracking detectors, time-of-flight scintillator barrels and vertex detectors, also embedding a system of multiple targets. The volumes between the tracking detectors are filled with He gas in order to reduce the deterioration of resolution due to multiple scattering effects. A special and complex system of thin windows bags (He bag) is used for this purpose. A sketch of FINUDA spectrometer is shown in fig.1), which also reports the name and type of the different detectors.

The FINUDA Collaboration is formed by almost 50 physicists from LNF, several INFN sections and Universities (Torino, Bari, Trieste, Pavia, Brescia) and with the participation of researchers from TRIUMF Laboratory of Vancouver, Canada.

An extensive description of the FINUDA experiment can be found in [1], [2], and [3].

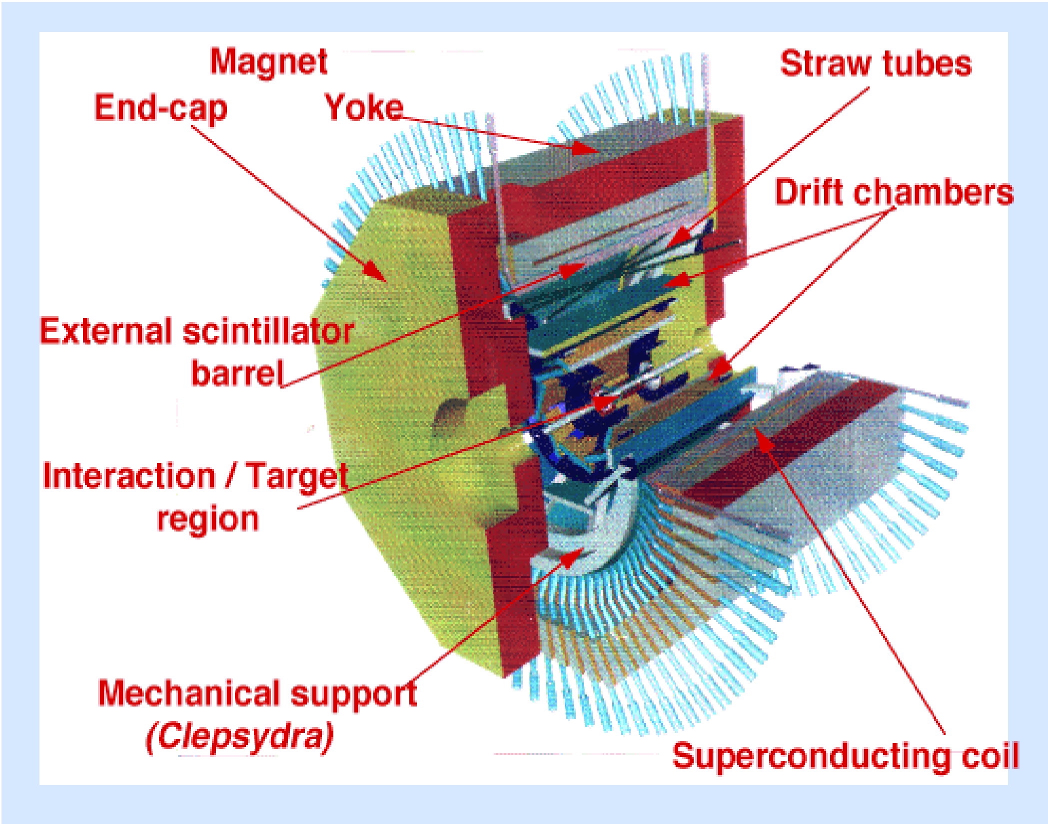

Figure 1: *Three dimensional layout of the FINUDA apparatus.*

2 Activity up to December 2001

As written in the conclusions of the LNF Activity Report for year 2000, at February 2001 the FINUDA experiment was in the following status: the magnet was installed in the FINUDA pit ready for cooling and subsequent energization; the TOFONE detector was already for three quarters installed inside the magnet; all other detectors, tested in several runs with cosmic rays, were standing in the ASTRA laboratory.

During the subsequent months of 2001, the activity of FINUDA can be divided in the following three main streams, according to the foreseen shut down periods of DAΦNE.

2.1 Activity from February 2001 up to May 2001

The mechanical structure called Clepsydra which supports all FINUDA detectors, TOFONE apart, and the beam pipe itself contains already installed and cabled the 2424 straw tubes which constitue the most external tracker of the experiment. During the first months of 2001, the main task of the FINUDA-LNF group was hence that to prepare the Clepsydra in ASTRA with all straws mounted and cabled in it for its journey from ASTRA to the pit in DAΦNE, foreseen during the one month DAΦNE shut down of August 2001. A trolley already existing at LNF was restored and readopted for that trip. At the end of April 2001 this task was ended, and the Clepsydra, ready for the transfer, was put on the trolley in ASTRA, fig.2.

Figure 2: *The Clepsydra with the straws inside it on the trolley in ASTRA ready for the transfer to the pit.*

In the meantime, the FINUDA Collaboration took advantage of two one week shut down periods of DAΦNE, in March and May 2001, to install the FEE racks, the cables on magnet to FEE racks, and to complete the TOFONE scintillators installation. At the end of May 2001, having completed ahead of schedule all the above tasks, the FINUDA Collaboration decided to use the last two days of the May week shut down to move the Clepsydra with all its straws and cables from ASTRA to the pit in DAΦNE, in front of the magnet and inserted it inside (May 19, 2001), fig.3 and fig.4.

2.2 Activity from July 30th to September 2nd 2001

During the all month of August 2001, the FINUDA Collaboration was fully engaged in installation works in DAΦNE during the foreseen shut down period. In this period several tasks were accomplished.

- Clepsydra alignment inside the magnet. The precision achieved was 0.01 degrees respect to beam axis, with a 0.5 mm centering on it.
- Completing of cabling and piping from detectors to FEE racks for straw tubes, TOFONE, outer LMDCs.
- Starting of installed detectors check out and debug.
- Begining of He-bag installation (windows and piping)
- Slow control and safety system installation
- New DAQ, using PVIC, installed and debugged.

Figure 3: *The Clepsydra with the straws inside it hanged to the DAΦNE crane.*

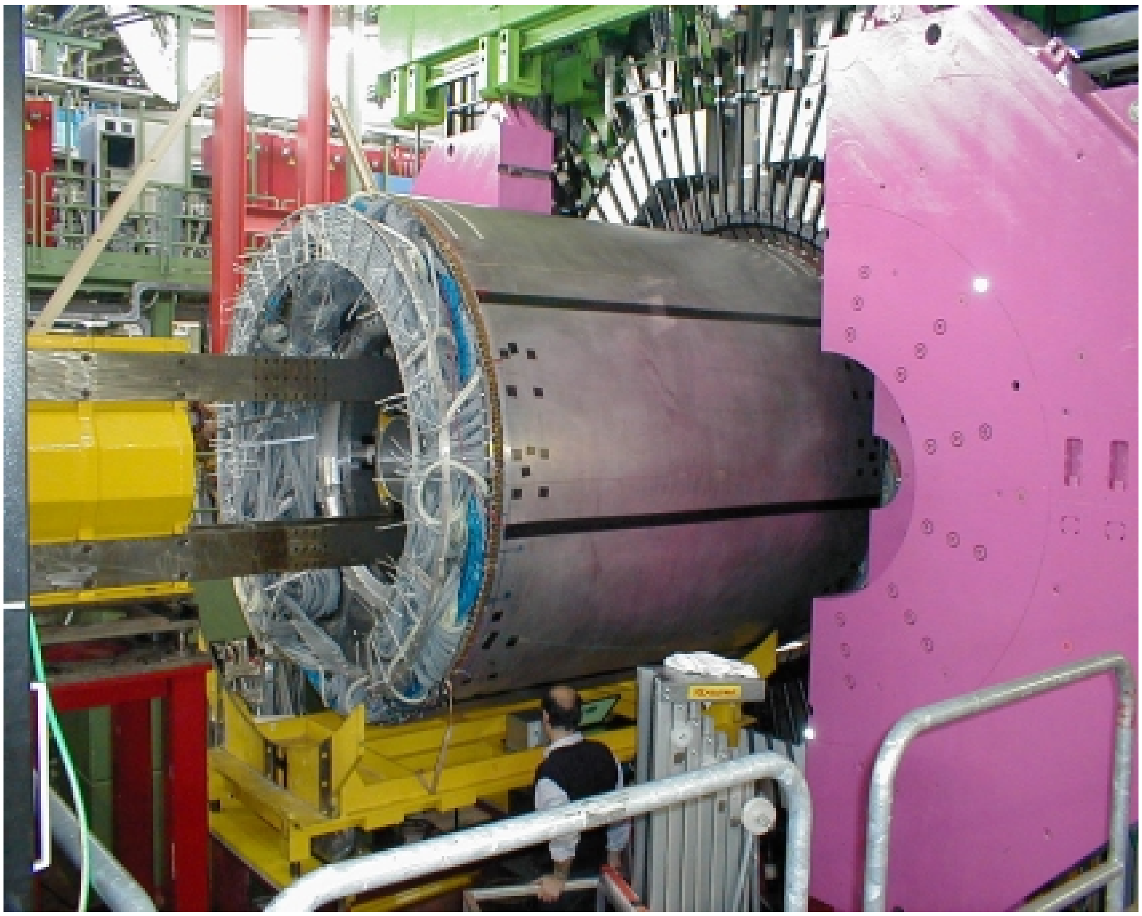

Figure 4: *The Clepsydra being inserted inside the FINUDA solenoid.*

2.3 Activity during the one week October 2001 shut down

During the last shut down period foreseen for DAΦNE in 2001, FINUDA tested the crucial closure of magnet end caps with the Clepsydra inside with all the cables and piping mounted for straws, TOFONE and outer LMDCs. Moreover, installation of μ-strips FEE was started, together with part of the corresponding cabling. He piping was also going on in this period. Finally, the laser system for TOFONE and tofino scintillators was installed. In fig.5 it is shown the FINUDA spectrometers status at the end of the year 2001.

Figure 5: *The FINUDA spectrometer with the straw tubes and external drift chambers mounted together with their electronics. The outer part of the He-bag is also visible.*

2.4 Other activities during 2001

While during the time of machine shut down, the FINUDA Collaboration activity was mainly devoted to operations in the pit, only in those periods accessible, during all other periods of the year other activities proceeded. One of the them was the installation in counting room of the racks of the electronics, the terminals and PCs for slow controls, DAQ, and safety. Another was the delicate work of selection and building of the complex system of multi targets of the experiment. Both very pure and rare material targets (as Li^6) were prepared, or their construction carefully studied. Finally a continuous refining of the software tools for the simulation of detector response and physical processes was carried out.

3 Conclusions

At the end of 2001, FINUDA has achieved on schedule all the tasks previously established for this year, having the full detectors (included cabling, piping and electronic) of the outer region of the spectrometer installed and under debugging. Moreover, the slow control system, the safety system, the new DAQ, and the installations in counting rooms were almost totally ended.

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HERMES

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(Corresp. Naz.), G.P. Capitani (Resp.), E. De Sanctis,
P. Di Nezza (Ass.), A. Fantoni, D. Hasch (Bors.), K. Hovhannisyan
(Bors.), V. Muccifora, A. Orlandi (Tecn.), W. Pesci (Tecn.), E. Polli,
A.R. Reolon, E. Thomas (Bors.), A. Viticchiè (Tecn.)

HERMES (**HER**A **ME**asurement os **S**pin) is a particle physics experiment located at the DESY research institute in Hamburg, Germany. The main aim of the experiment is to understand the internal spin structure of nucleons. Nucleons (protons and neutrons) are the basic ingredients of the matter and their most important quantum number is the spin 1/2. Since the nucleon is a composite object which can be described in terms of quarks of different flavours (up, down and strange) in different configurations (valence and sea) and gluons, it is straightforward to understand how important is to study the quark and gluon contributions to the nucleon spin. In 1987 it was found that the spin contribution of the quarks is different compared to the naive expectation at that time. The *spin crisis* was born. HERMES was designed and build to verify this result and to obtain detailed information of the spins of the quarks and gluons in the nucleon. In addition to the original main motivation of the experiment a large number of additional measurement take place with the HERMES apparatus ranging from studies of the hadronic content of the photon to the nuclear effects in fragmentation. HERMES became (after large detector upgrades) a general purpose facility for deep-inelastic scattering off nucleons and nuclei and for diffractive production of vector mesons with polarized unpolarized and nuclear targets. HERMES is an International Collaboration of $\sim$ 200 physicists from 35 Institutes from all over the world. Italy participates with 4 groups from Bari, Ferrara, Frascati and Rome. The Frascati group is responsible for the electromagnetic calorimeter, and is one of the leading group for the physics analysis having provided valuable contributions in inclusive, semi-inclusive and exclusive processes.

List of 2001 Publications

Hermes collaboration pubblications

1. Hadron Formation in Deep-Inelastic Positron Scattering from ^{14}N and ^{2}H A. Airapetian et al, Eur. Phys. J. C 20 (2001) 479-486. Eprint numbers: hep-ex/0012049 and DESY-00-191

2. Double-Spin Asymmetry in the Cross Section for Exclusive ρ^0 Production in Lepton-Nucleon Scattering A. Airapetian et al, Phys. Lett. B 513 (2001) 301-310. Eprint numbers: hep-ex/0102037 and DESY-00-189

3. Single Spin Azimuthal Asymmetry in Electroproduction of Neutral Pions in Semi-inclusive Deep Inelastic Scattering A. Airapetian et al, Phys.Rev. D64 (2001) 097101 Eprint numbers: hep-ex/0104005 and DESY-01-047

4. Measurement of the Beam-Spin Azimuthal Asymmetry associated with Deeply-Virtual Compton Scattering A. Airapetian et al., Phys. Rev. Lett. 87 (2001) 182001. Eprint numbers: hep-ex/0106068 and DESY-01-091

Talks and Invited Talks

1. Exclusive processes at HERMES N. Bianchi Workshop on Lepton Scattering, Hadrons and QCD Adelaide, Australia, Mar 26 - Apr 6, 2001
2. Nuclear medium effects at HERMES P. Di Nezza Workshop on Lepton Scattering, Hadrons and QCD Adelaide, Australia, Mar 26 - Apr 6, 2001
3. Hadron Formation in DIS in a Nuclear Environment V. Muccifora 9th International Workshop on Deep Inelastic Scattering and QCD (DIS 2001), Bologna, Italy, Apr 27 - May 1, 2001
4. Single Spin Asymmetry in Electroproduction of Exclusive π^+ E. Thomas 9th International Workshop on Deep Inelastic Scattering and QCD (DIS 2001), Bologna, Italy, Apr 27 - May 1, 2001
5. Measurement of Pion Multiplicities and Hadron Pt in DIS at HERMES P. Di Nezza 9th International Workshop on Deep Inelastic Scattering and QCD (DIS 2001), Bologna, Italy, Apr 27 - May 1, 2001
6. Single-spin azimuthal asymmetries in π^0 electroproduction D. Hasch 9th International Workshop on Deep Inelastic Scattering and QCD (DIS 2001), Bologna, Italy, Apr 27 - May 1, 2001
7. Spin Physics Working group summary N. Bianchi 9th International Workshop on Deep Inelastic Scattering and QCD (DIS 2001), Bologna, Italy, Apr 27 - May 1, 2001
8. Physics at HERMES V. Muccifora Third International Conference on Perspectives in Hadronic Physics May 7 - 11, 2001 Trieste, Italy
9. Single-Spin Azimuthal Asymmetries at HERMES N. Bianchi New Trends In HERA Physics 2001 Jun 17 - 22, 2001 Ringberg Castle, Tegernsee, Germany
10. Transversity Effects in Longitudinally Polarized Nucleons K. Oganessyan Topical Workshop on Transverse Spin Physics Jul 9 - 11, 2001 Zeuthen, Germany
11. Tagging the Collins Fragmentation Function at HERMES P. Di Nezza Topical Workshop on Transverse Spin Physics Jul 9 - 11, 2001 Zeuthen, Germany
12. Results from the Hermes Experiment A. Fantoni ECT* Conference On The Spin Structure Of The Proton, Trento, Italy, Jul 23 - 28, 2001
13. Hadron formation in a nuclear environment at HERMES V. Muccifora ECT* Conference On The Spin Structure Of The Proton, Trento, Italy, Jul 23 - 28, 2001
14. Single Spin Asymmetry in exclusive electroproduction of π^+ E. Thomas IX Workshop on high energy spin physics Aug 2 - 7, 2001 Dubna, Russia
15. Verification of the quark-hadron duality in spin structure function A. Fantoni Electromagnetic Interactions with Nucleons and Nuclei: Euroconference on Hadron Production with Electromagnetic Probes, Santorini, Greece, Oct 2 - 7, 2001
16. Hadron Formation in DIS from nuclear targets V. Muccifora Electromagnetic Interactions with Nucleons and Nuclei: Euroconference on Hadron Production with Electromagnetic Probes, Santorini, Greece, Oct 2 - 7, 2001
17. Exclusive Pion Electroproduction at HERMES D. Hasch Electromagnetic Interactions with Nucleons and Nuclei: Euroconference on Hadron Production with Electromagnetic Probes, Santorini, Greece, Oct 2 - 7, 2001

18. Exclusive meson and photon production at HERMES N. Bianchi The 3rd Circum-Pan-Pacific Symposium on "High Energy Spin Physics" Oct 8 - 13, 2001 Beijing, China

19. The Q2 dependence of the generalised GDH integral in the Hermes Experiment A. Fantoni Division of Nuclear Physics 2001 Fall Meeting (DNP 01), Maui, Hawaii, Oct 17 - 20, 2001

20. Nuclear Effects at HERMES P. Di Nezza Division of Nuclear Physics 2001 Fall Meeting (DNP 01), Maui, Hawaii, Oct 17 - 20, 2001

21. Azimuthal Asymmetries in SIDIS K. Oganessyan Talk at Hermes Collaboration Meeting, Dec 29, 2001

22. Hadron formation in DIS in a nuclear environment V. Muccifora 9th International Workshop on Deep Inelastic Scattering and QCD (DIS 2001), Bologna, Italy, Apr 27 - May 1, 2001

23. Single Spin Azimuthal Asymmetries in Electroproduction of Exclusive π^+ E. Thomas 9th International Workshop on Deep Inelastic Scattering and QCD (DIS 2001), Bologna, Italy, Apr 27 - May 1, 2001

24. A Measurement of Pion Multiplicities and Momentum Distributions in DIS at HERMES P. Di Nezza 9th International Workshop on Deep Inelastic Scattering and QCD (DIS 2001), Bologna, Italy, Apr 27 - May 1, 2001

25. Nuclear Medium Effects at HERMES P. Di Nezza Workshop on Lepton Scattering, Hadrons & QCD, Adelaide, Australia, Mar 26 - Apr 6, 2001

26. Single spin azimuthal asymmetries in neutral pion electroproduction D. Hasch 9th International Workshop on Deep Inelastic Scattering and QCD (DIS 2001), Bologna, Italy, Apr 27 - May 1, 2001

27. Results from the Hermes Experiment A. Fantoni ECT* Conference On The Spin Structure Of The Proton, Trento, Italy, Jul 23 - 28, 2001

Internal Report

1. The HERMES Dual-Radiator Ring Imaging Cerenkov Detector N. Akopov et al. (The HERMES RICH group)

2. A Large Acceptance Recoil Detector for HERMES Collaboration

3. σ(N)/σ(D) from hadron tagging N. Bianchi, P. Di Nezza, V. Muccifora

4. Nuclear attenuation of fast electroproduced pions, kaons and anti-protons in krypton N. Bianchi, P. Di Nezza, E. Garutti, V. Muccifora

5. Verification of quark-hadron duality in spin structure function A. Fantoni and N. Bianchi

LF21: PHENOMENOLOGY OF ELEMENTARY PARTICLE INTERACTIONS AT COLLIDERS

R. Escribano (Post-doc TMR), G. Isidori (Ric.), H. Pichl (Post-doc TMR), G. Pancheri (Resp.)

1 Summary of the project

The research topics investigated by this project can be divided into three main areas:

1. CP violation and rare decays;
2. Precision physics in hadronic processes at DAPHNE;
3. Quantum Chromodynamics and the rise of total cross-sections.

The first area, discussed in Section 2, concerns the possibility to perform new precision tests about the mechanism of quark-flavor mixing, within and beyond the Standard Model (SM). Other studies concerning precision physics in hadronic processes at DAPHNE will then follow in Sect. 3. An altogether different field of investigation, dedicated to reach into a much higher energy range, is the project related to the QCD description of hadronic and photonic total cross-section, which will be described in detail in Sect. 4.

2 CP violation and rare decays

CP-violating observables and rare decays, in K-, D- and B-meson systems, are very useful in order to extract precise information on the less-known elements of the Cabibbo-Kobayashi-Maskawa (CKM) matrix. These processes are also sensitive probes of possible non-standard effects. Continuing an activity started a few years ago, the sensitivity of various observables to flavour-mixing parameters of standard and non-standard origin has been systematically investigated.

In particular, G. Isidori and A. Retico have analysed scalar flavour-changing neutral currents of down-type quarks in models with two Higgs doublets, coupled separately to up- and down-type quarks, in the limit where the ratio of the two expectation values ($\tan\beta = v_u/v_d$) is large. [1)] This analysis has clarified the origin of this interesting phenomenon, both in $\Delta F = 1$ and $\Delta F = 2$ processes, showing the difference between supersymmetric and non-supersymmetric models. Moreover, it has been emphasised the unique role of the rare processes $B_{s,d} \to \tau^+\tau^-$ and $B_{s,d} \to \mu^+\mu^-$ in probing this well-motivated scenario.

In collaboration with G. Buchalla and G. Hiller, G. Isidori has also analysed the rare decays $B \to K^{(*)}\ell^+\ell^-$, $B \to K^{(*)}\nu\bar{\nu}$ and $B_s \to \mu^+\mu^-$ in a generic scenario where New Physics effects enter predominantly via Z penguin contributions. [2)] It has been shown that also this possibility is well motivated on theoretical grounds, since the $\bar{s}bZ$ vertex is particularly susceptible to non-standard dynamics. In addition, such a framework is particularly interesting at the phenomenological level since the $\bar{s}bZ$ coupling is rather poorly constrained by present data. The characteristic features of this scenario for the relevant decay rates and distributions have been investigated. In particular,

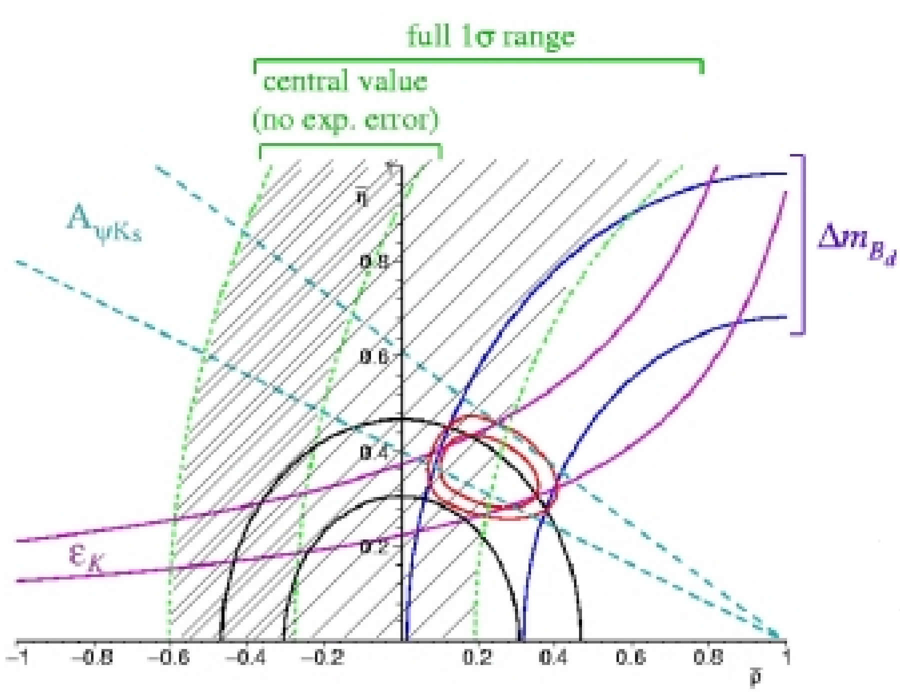

Figure 1: *Impact of* $\mathcal{B}(K^+ \to \pi^+\nu\bar\nu)$ *on the CKM unitarity triangle (or* $\bar\rho - \bar\eta$ *plane). The two ellipses denote* 68% *and* 90% *C.L. intervals obtained from* ϵ_K*,* $|V_{ub}/V_{cb}|$*,* ΔM_{B_d} *and the measurement of* $\sin(2\beta)$ *at* B *factories; the corresponding* 1σ *intervals for all these observables are also shown. The small (dense) dashed area is obtained from the central value of* $\mathcal{B}(K^+ \to \pi^+\nu\bar\nu)$*, taking into account only theoretical errors; the large dashed area denote the full* 1σ *interval derived from the BNL-E787 measurement.*

it has been shown that both sign and magnitude of the forward-backward asymmetry of the decay leptons in $\bar B \to \bar K^* \ell^+\ell^-$ are excellent probes of this general framework.

Finally, after the release of a new experimental determination of $\mathcal{B}(K^+ \to \pi^+\nu\bar\nu)$ by the BNL–E787 collaboration, an updated analysis of the impact of rare decays on the unitarity triangle has been performed. As shown in Fig. 1, where we compare the information on the CKM unitarity triangle from B physics (and ϵ_K) and $\mathcal{B}(K^+ \to \pi^+\nu\bar\nu)$, present data on the latter starts to provide an interesting constraint. The results of this analysis [and related works [3)]] have been presented by G. Isidori at Lepton-Photon 2001. [4)]

3 The Higgs mass and the stability of the electroweak minimum

If the Higgs mass is not sufficiently heavy, the Standard Model vacuum, or the minimum of the Higgs potential, could be destabilised by quantum corrections. In particular, top-quark loops decrease the Higgs self couplings and, if $m_H \lesssim 135$ GeV, a new deeper minimum appears before the Planck scale. In presence of a light Higgs mass, this argument can be used to establish

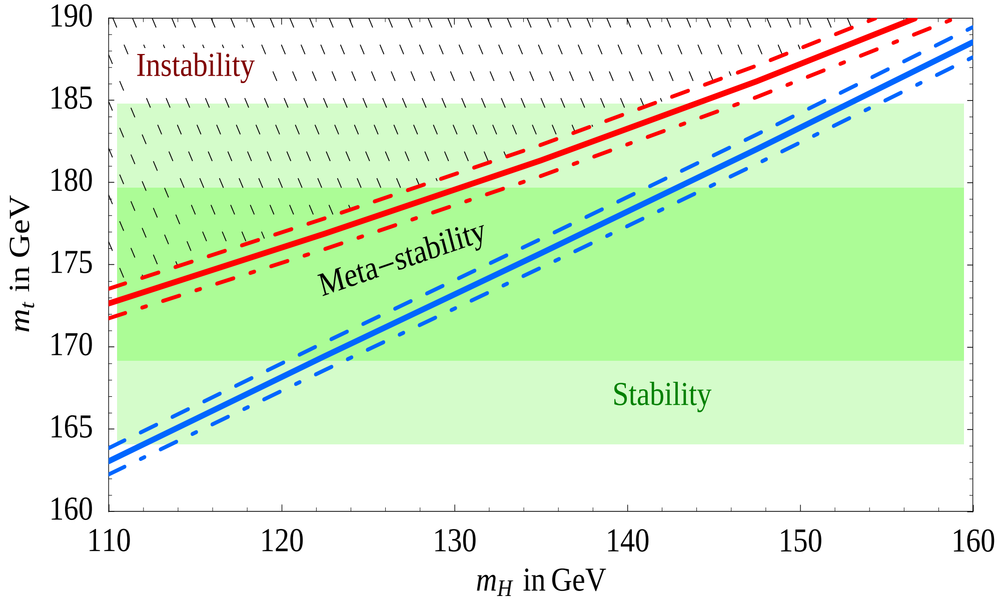

Figure 2: *Metastability region of the Standard Model vacuum in the* (m_H, m_t) *plane, for* $\alpha_s(m_Z) = 0.118$ *(solid curves). Dashed and dot-dashed curves are obtained for* $\alpha_s(m_Z) = 0.118 \pm 0.002$*. The shaded area indicates the experimental range for* m_t*. Sub-leading effects could shift the bounds by* ± 2 *GeV in* m_t*.*

unambiguously the existence of new physics below the Planck scale.

Given the recent indications of a light Higgs mass, both from precision measurements and from direct searches, this issue has been re-examined in detail. In particular, G. Isidori, G. Ridolfi and A. Strumia we have analysed the life-time of the Standard Model vacuum, under the assumption that a new deeper minimum appears at high scales. 5) By means of a complete one-loop computation of the tunnelling rate between the two ground states, it has been shown that life-time of the Standard Model vacuum is likely to be large compared to age of the Universe. Thus the appearance of a new minimum does not necessarily signal a break down of the Standard Model, which could be in a metastable regime. The results of this analysis are summarized in Fig. 2. As can be noted, even if the Higgs mass is very close to its present experimental bound (≈ 155 GeV), the Standard Model is not necessary unstable. To definitely exclude the instability region we would need either a stronger upper bound on m_H or a more precise determination of m_t.

4 Precision physics in hadronic processes at DAPHNE-old

4.1 *QCD and meson interactions below 1 GeV*

The research activity of R. Escribano, TMR post-doc with the EURPDAΦNE network, until September 30th, 2001, **old** has been devoted to the study of strong interactions at low energies in the framework of Quantum Chromodynamics (QCD) effective theories. More in particular, the phenomenology of the strong interactions among the pseudoscalar, scalar and vector mesons with masses of the order or below 1 GeV has been studied.

The research method is based on the use of the following tools: Chiral Perturbation Theory (ChPT) as the appropriate effective theory for describing the interactions among the lightest pseudoscalar mesons (π, K and η); Large-N_c expansion techniques for extending ChPT with the inclusion of the η'; the Linear Sigma Model (LσM) as a chiral model that incorporates in an explicit and systematic way the lightest scalar mesons together with their pseudoscalar counterparts; Vector Meson Dominance (VMD) as a phenomenological model for the interactions between the lightest vector and pseudoscalar mesons.

The research progress achieved along the year 2000 is summarized as follows :

Large-N_c, chiral approach to $M_{\eta'}$ at finite temperature [6]:

We study the temperature dependence of the η and η' meson masses within the framework of $U(3)_L \times U(3)_R$ Chiral Perturbation Theory, up to next-to-leading order in a simultaneous expansion in momenta, quark masses and number of colours. We find that both masses decrease at low temperatures, but only very slightly. We analyze higher order corrections and argue that large-N_c suggests a discontinuous drop of $M_{\eta'}$ at the critical temperature of deconfinement T_c, consistent with a first order transition to a phase with approximate $U(1)_A$ symmetry.

The ratio $\phi \to K^+K^-/K^0\bar{K}^0$ [7]:

The ratio $\phi \to K^+K^-/K^0\bar{K}^0$ is discussed and its present experimental value is compared with theoretical expectations. A difference larger than two standard deviations is observed. We critically examine a number of mechanisms that could account for this discrepancy, which remains unexplained. Measurements at DAΦNE at the level of the per mille accuracy can clarify whether there exist any anomaly.

Chiral loops and $a_0(980)$ exchange in $\phi \to \pi^0\eta\gamma$ [8, 9]:

The radiative $\phi \to \pi^0\eta\gamma$ decay is discussed emphasizing the effects of the $a_0(980)$ scalar resonance which dominates the high values of the $\pi^0\eta$ invariant mass spectrum. In its lowest part, the proposed amplitude coincides with the reliable and ChPT-inspired contribution coming from chiral loops. The $a_0(980)$ resonance is then incorporated exploiting the complementarity between ChPT and the LσM for this channel. The recently reported experimental invariant mass distribution and branching ratio can be satisfactorily accommodated in our framework. For the latter, a value of $B(\phi \to \pi^0\eta\gamma)$ in the range $(0.75–0.95) \times 10^{-4}$ is predicted.

5 Quantum Chromodynamics and the rise of total cross-sections

This project is developed through collaborations between G. Pancheri and Rohini Godbole [11], for what concerns strictly the Eikonal Minijet Model, Martin Block and Francis Halzen for the factorization picture which is extended up to cosmic ray energies [12], A. Grau and Y.N. Srivastava [13] for the studies of the effect of Soft Gluon Resummation on the taming of the rise of total cross-section.

The goal of this project is to obtain a QCD description of the initial decrease and the final increase of total cross-sections through soft gluon summation (via Bloch-Nordsieck Model) and QCD calculable jet x-sections, also known as mini-jets in this context. Thus, the physical picture includes multiple parton collisions and soft gluons dressing each collision.

5.1 *The Eikonal Minijet Model for protons and photons*

In the Eikonal Minijet Model (EMM) the rise can be obtained using the QCD calculable contribution from the parton-parton cross-section, whose total yield increases with energy. For a unitary description, the jet cross-sections are embedded into the eikonal formalism, where the eikonal function contains both the energy and the impact parameter distribution in b-space. The simplest formulation with minijets to drive the rise, and hadronic form factors for the impact parameter distribution, can be applied to all the available x-sections. One finds that proton-antiproton high energy data can be reproduced by this model. However it is not possible to describe both the early rise, which in proton-antiproton scattering takes place around $10 \div 50\, GeV$, and the Tevatron data, with a single set of parameters.

Photo-production data can be described through the same simple eikonal minijet model, with the relevant parton densities for the jet cross-sections, scaling the non perturbative part with VMD and quark counting factors. However, just like in the proton-proton case and in the gamma gamma case, the case for extrapolation of the EMM to higher energies is not convincing. A compilation of $\gamma\gamma$ data, including present LEP data, done for future Linear Collider studies has indicated that the EMM describes quite well the rise at present energies, but the extrapolation to even higher energies appears unrealistic and may need to be modified, as found in the proton case. A possible way to circumvent this problem is pursued through resummation of soft gluon emission from the initial state partons, a feature absent from most simple EMM.

5.2 *Soft Gluon Summation and the impact parameter distribution of partons*

A model for the impact parameter space distribution of parton in the hadrons has been developed and applied to the proton cross-sections in order to obtain a better description of total cross-section. The physical picture underlying this model is that the fast rise due to mini-jets and the increasing number of gluon-gluon collisions as the energy increases, can be reduced if one takes into account that soft gluons, emitted mostly by the initial state valence quarks, determine an acollinearity between the partons which reduces the overall parton-parton luminosity. This model can describe very well all available data for proton collisions. Work to extend this model to photon proton collisions is shown in the accompanying figure.

6 Work Program for the year 2002

In addition to continue investigations along the lines just decribed, G. Isidori is planning to investigate the metastabiity of the Standard Model vacuum. If the Higgs mass m_H is as low as suggested by present experimental information, the Standard Model ground state might not be absolutely stable. It is planned to undertake a detailed analysis of the lower bounds on m_H imposed by the requirement that the electroweak vacuum be sufficiently long-lived.

As for the other participants, most of the activity previously described in hadronic physics will be continued into the year 2002. The work on QCD and total cross-sections, a long term project, will focus mainly on discussing the normalization of total cross-sections and the impact parameter distribution of partons in both in protons and photons.

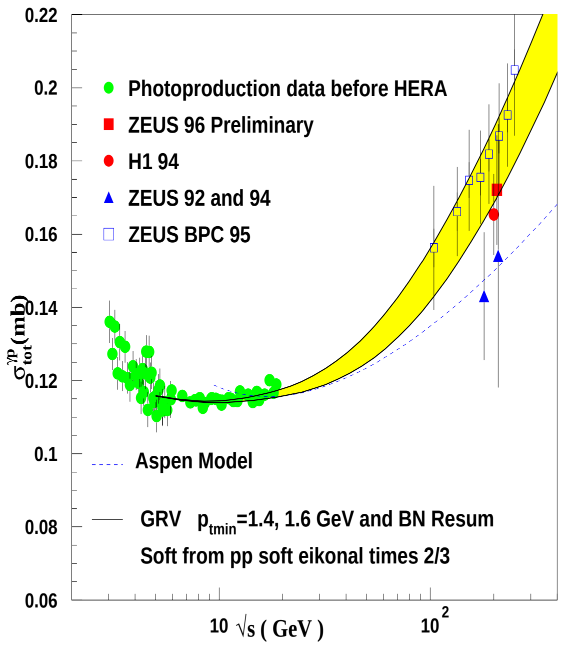

Figure 3: *Photon proton total cross section data compared with various models*

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PI-11: FERMIONIC SYSTEMS AND LATTICE

F. Palumbo (Resp.)

1 QCD at finite density

As it is well known there is no way at present to investigate the properties of QCD at finite density. We have then started a systematic study of the foundations of QCD with the chemical potential and of alternative approaches.

In connection with the first issue we have derived the Hasenfratz-Karsh form of the action from the partition function, showing that the chemical potential retains its role of a Lagrange multiplier. This derivation has been done both for Wilson and Kogut- Susskind fermions. In the latter case it has been shown that the chemical potential in the spin-diagonal basis is half that in the flavour basis. This can be of relevance when the chemical potential acquires a physical meaning.

Concerning alternative approaches, we have constructed an expansion of the quark determinant in series of the number of quark-antiquark pairs in a given sector of the baryon number, avoiding altogether the use of the chemical potential. This expansion can be used also to investigate some properties of the nucleon, like the content of the spin, and phases of QCD at very high density, like color superconductivity.

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PI-31: NUCLEAR THEORY

F. Palumbo (Resp.), M. Barbaro (Ass.), A. Molinari (Ass.)

1 Bosonization and the Interacting Boson Model

Effective bosons composite of nucleons are at the basis of the celebrated

Interacting Boson Model of Arima and Iachello. They are analogous to the Cooper pairs of the theory of superconductivity. The IBM has been succesfully developed at the phenomenological level, but until now there is no way to derive the parameters appearing in it from a "fundamental" nuclear hamiltonian. Moreover there is no general way of mapping fermionic operators into bosonic operators.

To tackle these problems we want to exploit the analogy with the BCS theory, but in such a way as to conserve the number of particles, which in nuclei is very important. To this end we use the Hubbard-Stratonovic transformation and evaluate the fermionic determinant by a saddle point expansion, which turns out to be an expansion in the inverse number of states in a shell. As a first step we have applied the outlined procedure to the pairing hamiltonian, getting the exact spectrum already to second order.

ALFAP

A. La Monaca (Resp.), G. Cappuccio (Ass.), E. Costa, G. Di Persio (Tecn.),
L. Pacciani, G. Patria (Tecn.), A. Rubini (Tecn.), P. Soffitta, N. Zema

1 Introduction

ALFAP, acronym of Advanced Large Field Astronomical Polarimeter, is a new experiment supported by G5-INFN at LNF in collaboration of CNR-IASF, CNR-ISM and CNR-ISC of Tor Vergata and Montelibretti, respectively. The experiment proposes to realize a new X-ray astronomic polarimeter, having a large field and wide area for detecting the polarization of X-rays, emitted from extreme compact astronomic sources as binary neutron stars, black holes, gamma ray bursts. The associated physics can cover a large field of research from the structure and formation of compact objects, to the acceleration of cosmic rays ($> 10^{19}$ eV) and production of neutrinos of very high energy (about 10^{14} eV).

2 The Polarimeter

The instrument, fig.1, differs from the traditional Bragg crystal polarimeters, that can modulate only small portion (¡1%) of radiation incident at 45^o on the crystal, or from Thomson scatters of the low atomic number. It is based on X-ray photoelectron effect in the gas, it measures the photoelectron direction by its multiple ionization [1), 2), 3)] and it can get very high sensibility. ALFAP consists of modular elements assembling 25 single photoelectric polarimeter units. Each unit is a PIAP polarimeter, as built at Frascati. This has been lastly modified with a new gas scintillation chamber, a GEM (gas electron multiplier) device that produces UV light along the photoelectron track. ALFAP holds X-ray mechanical collimators and is without focussing optics. It can scan a large portion of sky under an angle of 1.8 steradiants and measure a rate of 4 GRBs/month. Because the high cost of each single polarimeter units, a minimal configuration, reduced at two modules, will be tested for the next two years.

3 Activity 2001

3.1 *Hardware*

During the first year, the group has worked on the mechanic design, on the electronics and CCD read-out systems of ALFAP project. The concept of ALFAP requires a read-out system simple, fast and modular. Therefore the commercial system heritage of PIAP project is not adequate. A new readout and control system has been designed and tested as shown in figure 2. It consists of a controller memory where it is possible to write/read the phases needed to drive CCD's vertical lines and the horizontal registers. It also directs the image data flow from the remote control memory to the local host memory. It also hosts a *sequencer* which reads out fast static memory RAM blocks storing the streams of logic states needed to drive the phases requested by the CCD. All this system is being implemented by a single FPGA (Field Programmable Gate Arrays). These items have been commissioned to suitable firms, that have partially realized them within the year. Besides, using PIAP2 bench, the assembling of one polarimeter unit module has been tested.

3.2 Monte Carlo simulations

The group has also evolved the computer simulations with progress on the topics of X polarimetry performances of the polarimeter modularly assembled to be compared to that one made of a single chamber with integrated optics and CCDs. The first system is resulted better than second one. In fact photoelectron tracks of polarized high energy X-rays detected by gas mixtures of low atomic number are extended. The need for a large field a many-pixel detecting array, including tracks of photons detected at a certain distance, is, somehow, in competition with the need of a high granularity of the detector, requested for a good definition of the track and a reliable reconstruction of the photoelectron initial direction. We have developed a software, combining a transfer code for electron microscopy and microanalysis, with dedicated routines to produce the angular distribution deriving from a polarized beam, and others including the effect of the drift in the gas and of the optics. In fig.3, we show the distribution of some of such events in neon gas. From the angular distribution of the photoelectron tracks collected on the shown plane (yz), we can measure the direction and the grade of polarization of the incident radiation and derive the modulation factor related to improve the sensibility of polarimeter. The information of the track direction of the polarized photoelectron can be get by algorithms that use either the total length of the track or the impact point localization. Different methods are applied: a) direct calculation of the track length for two orthogonal polarizations (Modulation Factor from Length (MFL)); b) recognition of the nearest extreme track point to the photon impact using skewness analysis and distance calculation from the barycentre (Modulation Factor from Length and Distance (MFLD); c) suppressing of X and Y projections of the photoelectron end path (Modulation factor from Length, Distance and Path (MFLDP).

4 Future Plans

During next year we plan to assembly two modules of polarimeter units of ALFAP and test GEMs of the scintillation chamber. Besides, we will test the electronics of control of 1) the optical camera annexed to the GEM (trigger) and 2) of the backside illuminated CCD operating in a fast readout mode to support subsecond frame readouts with low noise and a 14-bit A/D converter. Finally, according the formerly activated procedure in the agreement framework between INFN, CNR and ASI, we will completly transfer PIAP2 polarimeter to CNR Astrophysics Laboratory (IASF) for more specific astrophysics applications.

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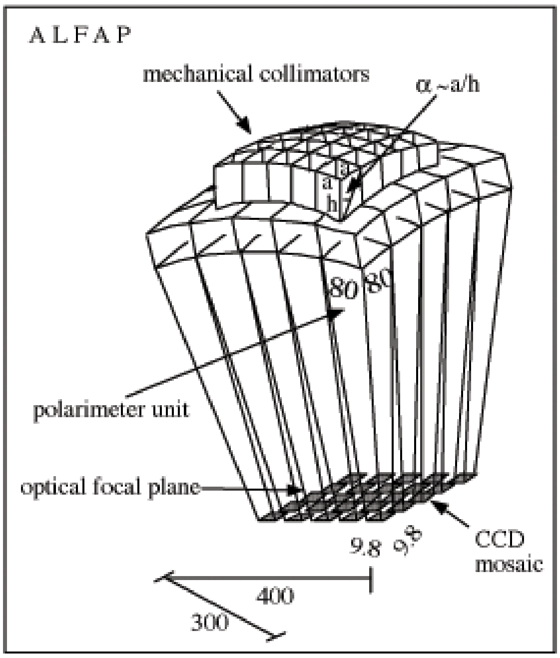

Figure 1 – ALFAP polarimeter. Field view of the polarimeter 1.78 steradiants. Field view of the collimators (5°x5°). Geometric area ~1600 cm^{2}. Demagnification on the optical focal plane ~7. Polarimeter unit of 80x80 mm^2 area and CCD of 9.8x9.8 mm^2. Number of polarimeter units 25.

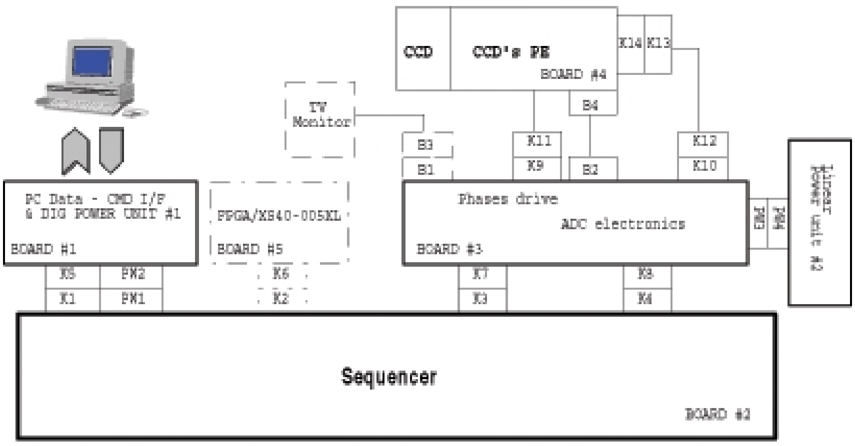

Figure 2 – New CCD read-out and control system.

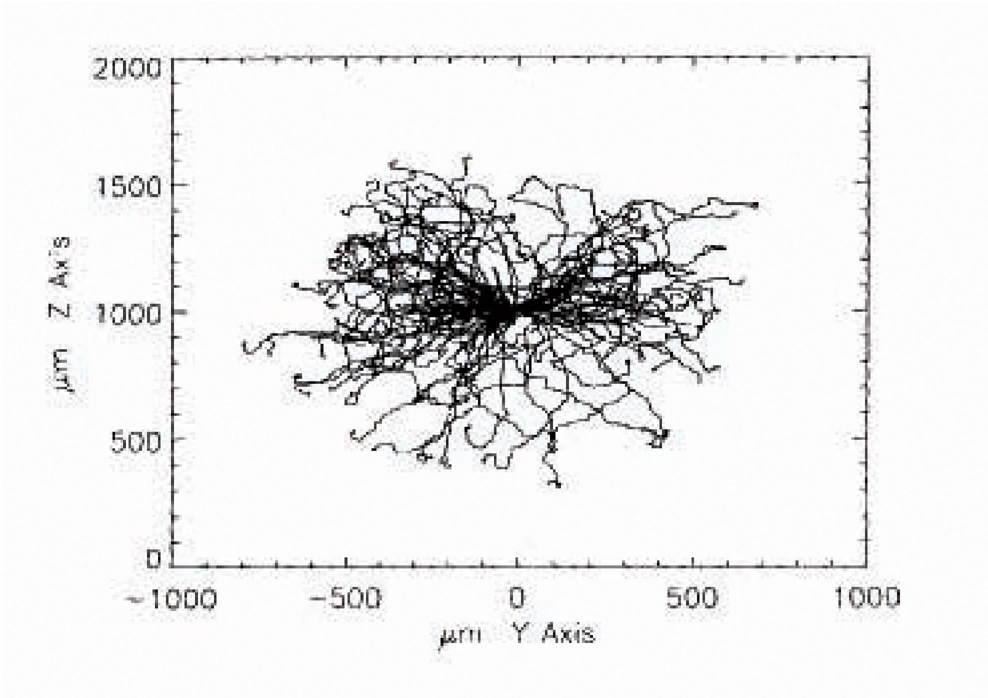

Figure 3 – Simulated distribution of 5 KeV polarized photoelectron tracks seen along x direction, whose X-ray photons come from (orthogonal to the paper).

FREEDOM

F. Celani (Resp.), A. Spallone (Ass.), G. D'Agostaro (Ass.),
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1 Introduction

The experimental task of FREEDOM (Fusion Research by Electrolytic Experiments of Deuterium On Metals) is to develop [1] highly innovative and reproducible > 60% success rate) techniques to maximise the value of Hydrogen (H), and later Deuterium (D), concentration into Palladium (Pd), the so-called "overloading", through light water (H) electrolysis (H/Pd > 0.95) with short waiting time for overloading (< 50 hours) and long stability (> 4 hours). Obviously, the final target is to transfer the "method" to heavy water (D_2O) system in order to study, in a more reliable way, some (excess heat, tritium production) of the unusual phenomena related to the so-called "Cold Fusion".

In parallel, as spin off of our experiments, we studied:

- characteristics of one of the two new bacteria from us discovered since 1999 in heavy water, from the point of view of bioremediation (using Ralstonia genera);
- new studies and methodologies in order to take full advantage of intrinsic anticancer propriety of heavy water, at concentrations (< 20%) not dangerous for human body (massive sterilisation of D_2O, by ^{60}Co source, mainly against the Stenotrophomonas genera).

2 Experimental activity

The experimental activity performed during year 2001 can be summarised as following:

- developing new electrolytic procedures to maximise H(D) loading into Palladium thin wires (diameter only $50\mu m$) at NTP: alcohol + water (5–15% concentration) solution, alkaline earth and Hg salts (both at an as-low-as micromolar concentration), pH value (4.0–5.0) optimisation and stabilisation over time.

The best same procedure found in our Laboratory at Frascati was fully reproduced, and for some aspects even improved, at Pirelli Labs in Milan ("Advanced Research" department, group leaded from Flavio Fontana). In short, the exceptionally good result obtained at Pirelli Labs was the observation of a resistance ratio (Pd wire) as low as 1.05 after a time shorter than 30 minutes from the beginning of electrolysis. The stability, versus time, was larger than 1 hour. The solution used was the same we suggested (both light ethyl alcohol and water, relative concentration close to

[1] Collaboration with: INTRABIO (LNF-INFN); EURESYS, ORIM and Pirelli Companies

azeotropic one) but the geometry of the cell was modified (optimised about homogeneity of applied electric field).

We like to note that the previous result (R/Ro=1.05) was obtained, at Pirelli Labs only once: usually, whit optimised geometry, they get R/Ro=1.20-1.30, close to results in our Laboratory.

We recall that the resistance ratio of Pd is the parameter generally adopted to evaluate the H/Pd and D/Pd ratio. In our peculiar experimental conditions, i.e. long and thin wires of Pd (typical resistance, at the beginning of the experiment, of 15 Ohm for a 30 cm long wire) and electrolytic solution of quite high values (over several thousand of Ohm) because salts and acid added at only micromolar concentrations, in is quite easy to can measure the resistance (by AC methods at proper frequency), and than the loading value, with an accuracy as good as 0.5%. Moreover, we recall that, beyond the maximum relative value of resistivity due to loading, in the "right side" of the loading curve, as such value is lower as higher is the loading. Up to now, the best value reported in the literature is 1.43 for Hydrogen and 1.6 for Deuterium, at room temperature and an applied pressure as high as 50000bar. We notify that, at present time, we are able to get, (using light H based solution) at NTP, with a success rate of the order of 60%, a resistance ratio of 1.3 and overall time stability longer than 24 hours;

- (b) steps to minimise the input power of electrolysis in order to measure excess heat, if any, at high accuracy: results very positive, up to now, with H;
- (c) steps to minimise the amount of Tritium (T) added to the solution because use of heavy water. The typical concentration of it, in a reactor grade D_2O (isotopic purity $> 99.97\%$) at low Tritium content, is of the order of 200 dpm/ml. The amount of T anomalously produced in some "lucky" experiment, as reported in the literature, is of the order of only $10^4 - -10^6$ atom/s with a production time of just 10-30 hours;
- (d) studied, in some detail, the behaviour of 1 of the 2 new bacteria discovered from our experimental group since 1999 in the heavy water. Later they were officially recognised from the International Institutions (DDBJ in Japan and NCBI in USA) involved on registration of new bacteria (cfr. the LNF-INFN Activity Report 2000 for further details). We used the Ralstonia detusculanense in the field of bio-remediation of water-soluble Uranium salt at quite large concentration (10mM). We experienced that the solution, test tube experiment, was "cleaned" from Uranium salt (uranile acetate) at a level better than 99.5% in a time shorter than 8 hours. Experiments with bacteria made, in a specific laboratory, at ENEA CR-Casaccia (from G. D'Agostaro) and analysed, by ICP-optical spectroscopy, from Centro Sviluppo Materiali at Castel Romano (Italy);
- (e) studies on anticancer proprieties of heavy water. The studies was motivated from the observation, as reported in the large (over 1500 papers) and lasting from long time (since 1938) literature, that the intrinsic anticancer properties of such compound experienced by researchers (in vitro with human cell and in vivo experiments with animals affected by cancer) are generally good at the beginning of experiments, and began worse after some time. We formed the hypothesis that such strange effect arose because increasing deleterious effect, over time, of bacteria living in heavy water. We recall that the other bacteria discovered from us are genera Stenotrophomonas, than pathogen (class 2). Because this, before the use, we sterilised massively the heavy water by gamma ray arising from ^{60}Co source. The dose given was quite large (17000Gy).

3 Reasons to use acidic water solution, with micromoles of Sr and Hg, and even alcohol-water, in electrolytic overloading of Pd with H(D)

Because the kind of research we described is quite different from usual one performed at INFN (it is largely based on electrochemistry) and we understand that even some scepticism can arise about it (because the motivation is the questioned "Cold Fusion"), we will describe again in this report some aspects in details.

The lack of reproducibility observed in "Cold Fusion" experiments is mainly connected with the difficulty in obtaining loading with atomic ratios (D/Pd) close to 1. It has been shown in fact that such a high D/Pd ratio, which is considered as a necessary condition for the production of the so called "anomalous heat", is very difficult to be obtained and in particular to be maintained for reasonably long time, except few lucky circumstances. In order to solve such a problem our group has performed a systematic campaign of experiments since 1994, starting from simpler and more economic Pd-H system, aiming to find out a protocol capable to insure a fast and reproducible loading with thin Pd wires, up to a H/Pd ratio as close as possible to 1.

The protocol, tested successfully (since 1999) in three different Laboratories (Pirelli-Labs, Milan-Italy; Stanford Research Institute International-USA; our Laboratory in two completely different arrangements of the electrolytic cells), is based (in an acidic environment, pH 4-5) on the addition of very small amount (typically few 10^{-5} moles) of alkaline-heart ions (strontium seems to be the most effective) to the re-distilled water used for the preparation of the electrolyte. We just remind that, in this kind of experiments, most of the researches adopted LiOD at a concentration of 0.1-1 molar, i.e. strong basic environment (pH 13-14). The use of re-distilled water was found to be a mandatory requirement: it has been found that the impurities normally yet present in the distilled and/or de-ionised water can negatively affect the loading process.

The following explanations are due, in large part, because very close collaboration (from long time), with electrochemistry at EURESYS company (Paolo Marini, Vittorio di Stefano, Missa Nakamura) and support, mainly for chemical and metallurgical analysis, at ORIM company (leaded by Alfredo Mancini).

The protocol is based on the following physics-chemical principle: Strontium ions (as $SrCl_2$) are added to the re-distilled water in such an amount that no precipitation as $SrCO_3$ can occur in the bulk of the electrolyte, pH slightly acid, with the carbonic ions normally, i.e. at NTP, dissolved (as H_2CO_3) in the water. Strontium carbonate is allowed to precipitate only on the cathodic surface, because of the local alkalisation produced by the flowing of the electrolytic current: it is well known that the solubility of carbonates decreases strongly following to the increase of the pH. In the cathodic process

$$2H_2O + 2e \rightarrow 2H(ads) + 2OH^-$$

the OH^- ions formed on the cathode promote the precipitation of $SrCO_3$. The atomic Hydrogen adsorbed on the cathodic surface can either be absorbed into the Pd bulk

$$a) \quad H(ads) \rightarrow (H)Pd(loading\ \ reaction)$$

or bubbled out as H_2 gas

$$b) \quad 2H(ads) \rightarrow H_2(parasitic\ \ reaction)$$

The intrinsically catalytic surface of Pd, used as cathode, promotes generally the b) reaction, deleterious to (H,D) overloading. By using our procedure, viceversa, because of the precipitation on the cathodic surface of a thin layer of $SrCO_3$ the catalytic properties are consistently reduced and the loading reaction a) turns to be dominant, thus allowing a fast achievement of H/Pd ratio equals to unity. Moreover, we have found that the addition of very small amounts of mercuric ions is also effective in maintaining the loading level over a large period of time. Hg, because its ability to form amalgams, is supposed to act as "anti-cracking agent" against Pd damage (almost permanent!!!) due to H, D absorption. When we tried to apply our protocol for D-Pd loading and H_2 was replaced by D_2 the results in terms of D/Pd were consistently lower, and/or unstable, than those obtained with light water. The reasons of such an evident failure are essentially:

- The amount of the impurities generally contained in the "as received "heavy water is too large. Foreign inorganic ions, galvanically deposited on the cathode, were found to hinder the formation of the proper $SrCO_3$ layer. Double distillation of D_2O which is very difficult to be accomplished because of its hygroscopicity (no contact with the atmosphere is required), is a necessary but not sufficient pre-treatment.

- Heavy water contains bacteria that were identified by us at ENEA-Casaccia. These bacteria belong to two new species, which were also found to form colonies on the cathodic surface. Therefore, several long treatments of the D_2O, added with $KMnO_4$ (1g/l) at a pH adjusted in sequence at $1 \rightarrow 7 \rightarrow 13 \rightarrow 7$ (i.e. addition of D_2SO_4 to get pH=1, $LiOD$ to get pH=13): several distillations under nitrogen at 90^oC and at 25degC (under vacuum), are than required for a satisfactory sterilisation and ions purification (final conductivity of D_2O as to be, at NTP, lower than 3μS/cm).

About those two new bacteria, we experienced that one of this, Ralstonia species, "metabolises" several elements including the Hg used in our procedure, than vanishing the "anti-cracking" effect. Aiming to eliminate wasting time and troublesome pre-treatments, needed to "kill" the bacteria and purify the heavy water from inorganic and organic pollutants, and taking into account that the main controlling parameter of the D-Pd loading seemed to be the ratio between the total amount of the impurities present in the electrolyte and the surface of the cathode, we realised that the problem could be matched from a completely different point of view. In order to minimise the ratio between the amount of the impurities and the surface of the cathode, two different approaches could be taken into consideration:

1. build up a very thin cell, just around the electrodes (Pd surface about 1cm2), thus containing a very small amount of electrolyte (i.e.50cc) and consequently a negligible amount of impurities;

2. fill the cell currently used in our experiments, whose volume is about 1000 cc, with a new electrolyte prepared by mixing a majority part of suitable organic solvent (i.e.950 cc) with a minority part (i.e.50 cc) of heavy water.

In both cases, with respect to the 1000 cc of D_2O normally used in our tests, the reduction to 50 cc is equivalent to a 20 times reduction of the impurities which could be deposited on the cathodic surface. The option 2) seemed to be extremely more attractive because of its simplicity (no need to build up a new and very delicate cell) and its flexibility (the ratio between the organic solvent and the heavy water can be varied over a large extent). As far as the choice of the organic solvent is concerned, the following requirements should be satisfied:

- large miscibility with water,

- very small amount of H_2O present as residual impurity (isotopic contamination of H in the D-Pd loading),

- no (or negligible) acid properties (isotopic contamination for partial dissociation and production of H^+ ions),

- boiling point not too far from 100^oC.

In relation to the above mentioned requirements, alcohol, keton, ester seem to be the most promising solvents. If the hydro-organic electrolyte could be considered an elegant solution for the problem of the impurities, the proper precipitation of $SrCO_3$ on the surface of the cathode seemed difficult to be accomplished in the new ambient: how to control the concentration of carbonic ions? Taking into account that the actual concentration, the activity, of the ions in the hydro-organic electrolyte could be remarkably higher than their nominal concentration (referred to both the components of the liquid phase), we realised that Strontium ions could be precipitated as $SrSO_4$ even though the solubility product of this compound is about 50 times higher than that of $SrCO_3$. In this case, the $SrSO_4$ precipitation in the hydro-organic ambient could be accomplished simply by controlling the amounts of Sr^{++} and SO_4^{--} ions added to the electrolyte. After several tests we found that a suitable electrolyte could be prepared just by using 1000 cc of ethyl alcohol (95% concentration, i.e. 50cc is water) and by adding to the hydro-alcoholic solution 20mg of $SrCl_2$, 1-2cc of H_2SO_4 (0.01M) and 0.5-2 cc of $HgCl_2$ (0.01M).

The electrolysis was started with the following conditions: Anode: Pt (wire, length 30cm, diameter 200μm); Cathode: Pd (wire, total length 30cm with 2 portions of 15cm, diameter $50\mu m$); electrodes parallel (inter-distance 4cm); Current: 5mA; Voltage: 20-50V; T=20degC. The loading rate of the cathode, after 1 day of "conditioning", was surprisingly high: in less than 20 minutes a H/Pd ratio very close to one (R/Ro =1.20) is currently achieved with a stability of 4-6 hours. Our results have been completely reproduced at Pirelli Labs, Italy.

Works are in progress for the application of the new protocol to a D_2O organic solvent electrolyte. Up to now, we studied in some details C_2H_5OD, the partially-heavy ethyl alcohol.

4 Publications

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2. National Centre Biology Information– GenBank (Bethesda, USA) Ralstonia detusculanense Locus: AF280433 Taxonomy ID: 148618 October 24, 200 http://www.ncbi.nlm.nih.gov/

3. National Centre Biology Information– GenBank (Bethesda, USA) Stenotrophomonas detusculanense Locus: AF280434 Taxonomy ID: 148630 October 24, 2001,

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4. Electrochemical H-D loading of Palladium wires by hydro-alcoholic electrolytes related to the new discovered Ralstonia bacteria into heavy water, Invited Paper, JCF3-5, (F.Celani et al.) at "The 3rd Meeting of Japan CF-Research Society", October 25-26, 2001 Yokohama National University (Japan) http://fomcane.nucl.eng.osaka-u.ac.jp/jcf/

5. Effetti indotti dall'acqua pesante (come tale e in associazione a raggi X) su cellule tumorali umane coltivate "in vitro" INFN Laboratori Nazionali di Frascati, LNF-01/030(IR), 19 Dicembre 2001

GEDI

A.Balerna, E.Bernieri (Resp.), M.Chiti (Tecn.), U.Denni (Tecn.)
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1 Introduction

During 2001 the realised gamma-ray spectrometer for "in situ" radioactivity measurements on glaciers and snowfields was improved, mainly in its electronic components. Data acquired in the past were analysed for publication and in order to plan future measurements and researches.

2 Activity 2001

A dedicated MOSFET-based pulse generator circuit has been built to better manage the control of the temperature with negligible power dissipation of the circuit itself. Since the output signals of the detector are low and very narrow, and are not well matched with the input requirements of the ADC card utilised (National Instruments DAQ Card 6062E), a dedicated peak detector circuit was lso realised. This circuit includes many planning skills that will be described in detail in a dedicated internal report.
The radioactivity measurements performed in the year 2000 in Himalaya were analysed in detail, in the framework of the mechanisms of global circulation of pollutants, dusts and ions in central Asia. Our results,that will be published in a short time elsewhere, show the necessity to make a deep study of the space-time distribution of radioactive contaminants in this area to understand the large scale processes of transport and diffusion.
On the basis of technical and scientific results of the GEDI experiment, that concludes its activity in 2001, the formulation of new national and international research proposal, in the field of the nuclear physics technologies applied to Earth an environmental sciences, is in progress.

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INTRABIO

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1 Experiment purpose

The main concerns of the INTRABIO research are the oncological and biophysical aspects. In this frame we are carrying out our researches on the effects of ionizing radiations in the living matter, on the biophysical properties of the LNF recently discovered bacteria, on the D_20 effectiveness in cancer therapy and on the protein analysis with the infrared radiation.

Up to year 2001, the INTRABIO group carried out a program of biodosimetric advice after real or feared radiation accidents; so we developed the dicentric and micronucleus techniques that we used also for evaluating the individual radiation sensibility in irradiated oncological patients. To validate our micronucleus technique we participated also in an international project (HUMN Project).

In collaboration with the FREEDOM Group we studied some properties of the Ralstonia detusculanense we jointly discovered in year 2000, in heavy water. We would like to evaluate the meaning of this bacterium in the oncological processes and its ability in bioremediation activity.

Because the historic literature indicates that the heavy water could be effective in some cancer therapy of animals but could rise same negative effects, our aim was to verify if the collateral negative effects are attributable to bacteria living in the heavy water. So we conducted some experiments "in vitro" to verify the effects of the sterilized heavy water in oncological cellular lineage.

As far as the last objective, we were aimed to characterize the specific behaviour of the proteins with the respect to the IR of DAΦNE synchrotron radiation. This experiment should allow qualitative and quantitative analysis of a specific protein in biological specimen after a chemical, biological or physical mutagenic damage. The first protein to study will be the p53 which has an oncological interest. The experiment will be carried out jointly with the DAΦNE LUCE Group.

2 2001 Results

It was successful the intercomparison of our micronucleus methodology with 24 world-wide laboratories, and a publication on the subject is in progress. The study of radiation sensitivity with the micronucleus test carried out among the irradiated patients in collaboration with the Radiotherapy Clinic Institute of University "La Sapienza" indicates a real subdivision of people in two radiation sensitivity categories. This is a very important result usable both for therapeutic purposes and for the radiation protection medical surveillance of exposed workers. A Report is in progress. The competence of the INTRABIO Group was asked from the ANPA to formulate a screening program to evaluate the possible dose to military personnel who operated in Bosnia and in Kossovo. Preliminary studies were carried out on the bacterium Ralstonia detusculanense to asses its ability in scavenging the environment from heavy metals and in hydrogen producing. The results seem to be very interesting. The next step is the evaluation of the bacterium health class for protection purposes through an agreement with the Istituto Superiore di Sanità (ISS).

The cytotoxic effect "in vitro" of sterilized heavy water on human lymphoma cell line was studied at various $D_2 0$ concentration. The preliminary data confirm the feasibility of the tests for cellular survival, for micronucleus induction and for apoptosis. A concentration greater than 20% produces a high lethality in this clone. A LNF report was edited on this subject. Apparatus and measure instruments to carry-out the experiment with infrared radiation was set-up; but because it was impossible during the 2001 year to get available the IR radiation beam, the experiment was interrupted.

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MUST

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1 Activity

This project is based on an European and American INFN Patent (submitted also to Japan). The idea is to manufacture more efficient curved x-ray diffractor prototypes based on the Bragg geometry (see Fig. 1) competitive with energy dispersive device and detectors. These devices are characterized by a layout capable to focus, with high resolution and large throughput, an x-ray beam and producing, at constant resolution, a gain up to one order of magnitude respect to a comparable, in terms of size, spherical or cylindrical crystal. During the 2001 we completed tests and analysis of the devices with cylindrical figure, assembled with mosaic (mica) or perfect crystals (quartz). We also started the construction and tests of the first high resolution spherical crystal spectrometers with more than 4 steps, designed for commercial apparata, and working with conventional sources, and two large devices dedicated to synchrotron radiation applications. In Fig. 1 it is shown a photograph of the first three-step spherical prototype devoted to synchrotron radiation experiments. This device is made with three quartz crystals that were set on a spherical holder using the optical contact method. During 2001 we improved the test procedures of both the crystal holder and the assembled devices before and after the crystals assembly onto the surface of the holder. We also tested crystal devices for a commercial micro-analyzer in cooperation with an industrial firm. We demonstrated the feasibility and the gain of compact systems with spherical figures, in a wide range of photon energies. We show in Fig. 2 the comparison among the diffracted intensity by a multistepped device manufactured with quartz (10-11) crystals. It not only demonstrates that the resolution is excellent but also equivalent when both one (central) step (black curve - left labels) or the whole system (4 steps) (red curve - right labels) is illuminated by x-ray radiation at the Sn L edge. Work is in progress and will be completed in the 2002 to characterize and compare all devices manufactured in cylindrical and spherical geometries. Experiments with the large spherical devices are also planned at synchrotron radiation facilities.

The results already achieved by MUST support both the feasibility of the multi-stepped design and the expected advantages both in term of resolution and focused intensity. Moreover, we also demonstrated that multi-stepped crystal devices may replace with success curved crystals with Johann or Johannson mountings, installed in standard (e.g. commercial) spectrometers working with photons or electron beams. (Additional information are available at the URL: http://www.projectx.aaanet.ru)

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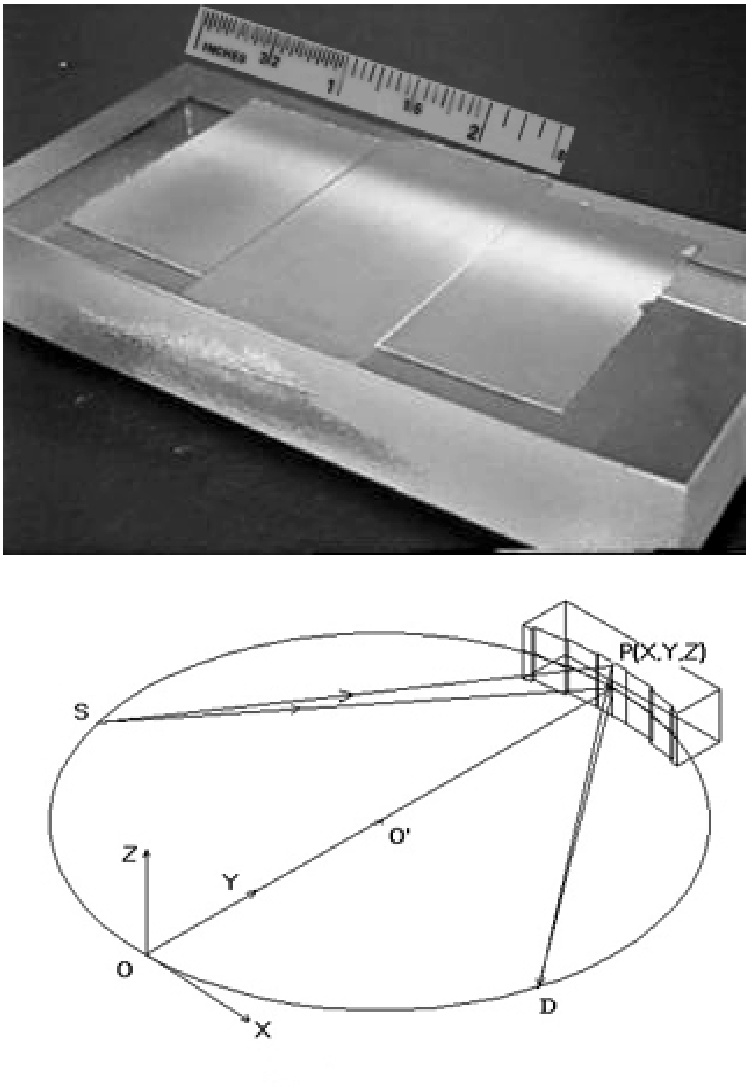

Figure 1: In the top panel the photograph of the first multistepped spherical prototype. In the bottom panel the optical layout of the diffractor geometry of a multistepped device.

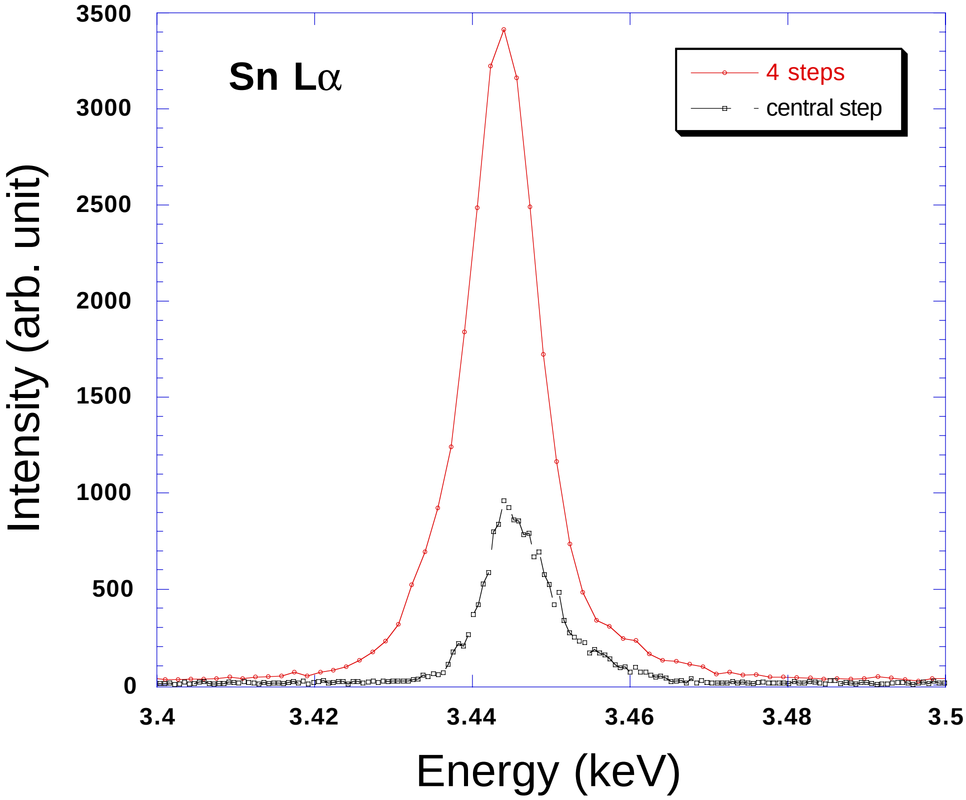

Figure 2: Comparison among the diffracted intensity by a multistepped device manufactured with quartz (10-11) crystals when or the central crystal (black curve - left labels) or the entire system e.g., 4 crystals, (red curve – right labels) is illuminated by x-ray radiation at the Sn L edge.

OBD

A. Ferrari (CERN), M. Pelliccioni (LNF) (Resp.), T. Rancati (Sez. Milano)

1 Report year 2001

The dependence of the doses at aircraft altitudes on intermediate levels of solar activity has been studied by means of simulations carried out by the Monte Carlo transport code FLUKA. The calculated results show that the linear dependence proposed in a previous work for the effective dose rate as a function of the solar modulation parameter, can be considered as an acceptable approximation, at least for vertical cut-off in excess of 3.0 GV.

In addition the depth-dose curves in the tissue equivalent ICRU sphere have been determined by the FLUKA code for a number of cosmic ray spectra. On the basis of the calculated results, a value of the depth, d, which would make the ambient dose equivalent, H*(d), a conservative predictor of the effective dose, can not be specified for cosmic radiation.

Preliminary simulations have been done in order to determine the response to cosmic radiation of a tissue equivalent ionization chamber.

2 Program for 2002

The analysis of the properties of the dosimeters in use for the monitoring in the cosmic ray environment will continue through 2002. This study aroused interest at last DOSMAX Meeting (European Community), during which M. Pelliccioni was asked to apply the results to the Concorde route.

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POLYX

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1 Experiment aims

The main aim of this project, funded by INFN - Gruppo V, is to study and to utilize polycapillary optics in X-ray applications using both conventional sources (X-ray tubes) and synchrotron radiation (SR). Polycapillary lenses allow increase the radiation density in the focal spot position. Polycapillary semi-lenses allow obtain parallel X-ray beams from divergent sources or convergent beams from parallel sources (SR). Finally straight polycapillaries (pillars) allow to match parallel beams wih X-ray detectors, monochromators, etc.

2 2001 Activities

After our successful experiments done in the year 2000 with polycapillary optics using a Cu X-ray tube, preliminary experiments with Synchrotron Radiation (SR) were carried out at the Elettra X-ray Diffraction Station (ID 5,2) at Trieste. Both a polycapillary lens and a straight polycapillary optic have been aligned using the same procedure previously developed for the Cu tube [1]. As the polycapillary lens that we utilize was not designed for a synchrotron radiation source that is characterized by a strong natural collimation, i.e. very low divergence, the focusing effect was less effective nevertheless its uses provided valuable information. One set of spot images was collected at various distances from the lens exit, in 1 cm step lengths. The mean horizontal and vertical dimensions of each spot were evaluated and through a graph, the approximate focus position was found to be 6.0 ± 0.5 mm with a spot diameter of 0.76 ± 0.02 mm. These values should be compared with that obtained using the Cu tube, i.e. focus position of 7.8 mm and spot diameter of 1.6 mm. The measured spot density gain at the focal point was $G \approx 0.2$, while according to the theory for such a lens it should be $G_{th} \approx 0.7$. The discrepancy depends on the fact that the lens alignment using SR is extremely critical, in other words in order to focus a "quasi parallel" SR beam an "ad hoc polycapillary semi-lens" must be utilized. Using 8 keV synchrotron radiation we tested also a "straight polycapillary lens", which is often called a "pillar system" (length = 50 mm, diameter = 8 mm). After a careful alignment a maximum intensity behind the pillar was obtained at the angle of $\approx 0.08^0$, which is less than the SR critical angle $\theta_c \simeq 0.25^0$ and greater than 0.012^0, which corresponds to the "non-reflecting mode" for photon propagation through the capillary channels. This result confirms three facts: (i) no "direct straight rays" pass through the pillar; (ii) total radiation capture by the microchannel walls; (iii) and a total suppression of straight nonreflected rays. As a fallout of the above mentioned experimental activities an exhaustive quantum theory of surface x-ray channeling in capillary structures was developed by our group in the course of 2001 year [2, 3, 4], and it was object of oral communications both in national and international conferences [a, b, c].

3 2002 Program

The main activity in 2002 year will be to utilize polycapillary optics: lenses, half-lenses and collimators, hold up by remotely controlled "Gimbal" mounts, on the High-Resolution X-ray Diffraction Station, which will be operative on the X-ray SR beam-line at "Dafne Light Laboratory" (LNF, Frascati). We have in mind many possible applications: (i) to improve the quality of the diffraction spectra collected using a Cu tube source with a polycapillary half-lens to reach a quasi-parallel configuration for thin solid film measurements; (ii) to increase the synchrotron radiation spot density at the entrance of the diffractometer using tapered polycapillary optics; (iii) to utilize a polycapillary full-lens for microdiffraction experiments; (iv) to improve the scintillation detector sensitivity using a polycapillary pillar optics as a collimator for the radiation diffracted by different samples like: polycrystalline powders, thin films, bulk materials.

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SAFTA

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1 Aim of the experiment

The activity of SAFTA group is mainly related to the study of the electromagnetic interaction between a particle beam and the accelerator pipe wall, the generation of the parasitic fields, the related energy loss and instability effects. Two main subjects have been investigated: the coupling impedance of LHC rings, and a parasitic diagnostic device for bunch length monitor.

The porpouse of the first activity, done in collaboration with SL/AP group at CERN, is the estimate of the impedance budget of LHC vacuum chamber, necessary for the calculation of the instability thresholds. The latter activity, in collaboration with the University of Roma "La Sapienza", concerns the development of a new bunch length monitor based on the microwave spectroscopy.

2 Main results of 2001

The LHC liner is a new-shape coaxial beam pipe with million of pumping holes. The inner part of the beam pipe shows a periodic corrugation of very small depth, which prevents from damage to super-conducting magnets due to the photo-electrons emitted by the pipe walls lighted by the synchrotron radiation. The group has developed new models for the study of the fields produced by the beam itself passing through this structure. It has been shown that the total energy loss going into heating of the outer tube, close to the superconducting magnets, stays below the loss budget steted by the cryogenic sistem. Worth of note is the new theory developed to study the effect of the inhomogeneous conductivity on the pipe walls.

Furthermore, the energy loss and the coupling impedance of several beam pipe components have been studied with the MAFIA3D code:

- electrodes BPM(Beam Position Monitors)
- strip lines BPM
- vacuum chamber of LHCb experiment
- recombination chamber at the interaction points.

In all cases the analysis of the results have suggested an optimisation of the design, in order to obtain acceptable values of coupling impedance and energy loss.Particularly interesting has been the investigation of the trapped modes in the recombination chamber, predicted and measured experimentally on a scaled prototype.

The theoretical study of a bunch length monitor based on the microvawe spectroscopy has lead to the design and construction of a prototype being tested in the laboratory.

The device is optimised for a bunch-length of 3 mm, and is taken under consideration also as transverse position monitor.

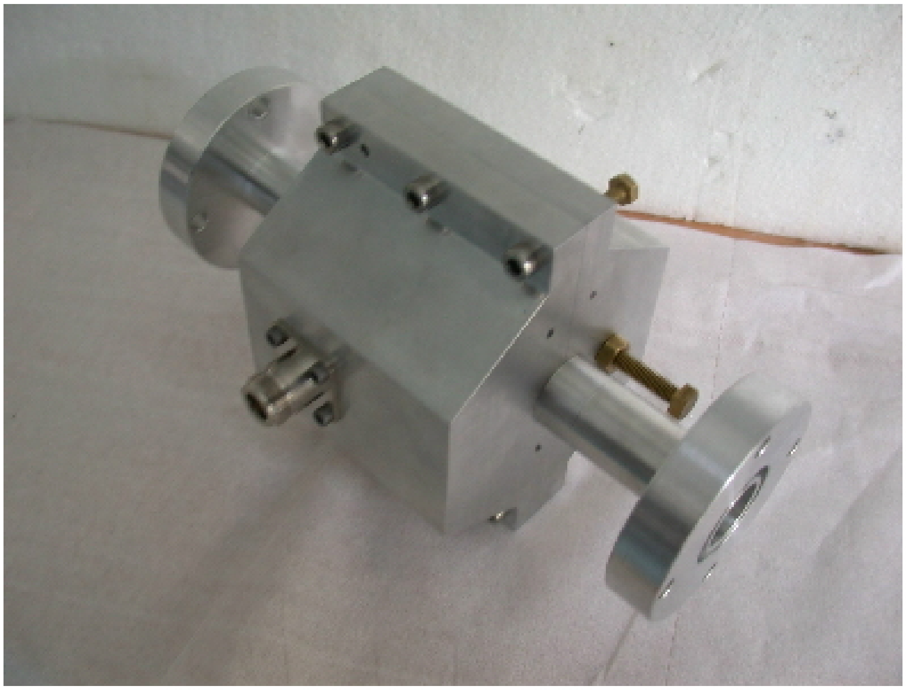

Figure 1: *Prototype of the microvawe bunch-length monitor.*

3 Activity 2002

It is foreseen the continuation of the successful collaboration with the SL/AP group of CERN in order to study few components of the LHC chamber under definition. In particular it will be investigated the beam pipe at the interaction region of the LHCb experiment.

A measurement campain is foreseen to study the behaviour of the device in fig. 1, as bunch length monitor and as beam position monitor.

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SFERA

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Collaboration with Univ. Roma1 and Roma2 and Univ. Milano

1 Introduction

The SFERA experiment at Frascati Laboratories is concerned with the study of robust electron photo-cathodes, aimed at the use in advanced particle accelerators. Two main classes of wide band gap insulators have been investigated: ferro-electric ceramics and synthetic diamond films. The Milan and Roma1 collaborators supply the ceramic samples. The Roma1 and Roma2 collaborators produce and characterize the synthetic diamond CVD films. The cathodes are illuminated by intense Nd:Yag laser harmonics with 25 ps pulse duration.

2 Activity

We have continued the study of diamond films with various crystal structures, with the addition of various doping agents and with various degrees of surface termination with Hydrogen.

Emission efficiencies comparable to those of metals have been obtained and a strategy to improve the efficiency has been devised, supported by theory. This activity will continue in the future with the additional investigation on the temporal distribution of the electron pulse.

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SIEYE2

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Participant Institutions:

ITALY: INFN LNF, Firenze, Roma2, Trieste;
RUSSIA: MePhi, IBMP, RKK"Energia" (Moscow)
SWEDEN: KTH (Stockholm)

1 Introduction

The SIEYE2 experiment has been carried out on the MIR Space Station to study, using a silicon strip segmented detector, the biophysical effects related to the radiation environment inside the Station (altitude 400 Km , inclination 51.5°) with particular attention to the phenomenon of "Light Flashes" (LF) [1]. A prototype of the detector (SIEYE1) was placed on the Station MIR in October 1995 obtaining, during its two years in operation, 25 measurement sessions with 6 different astronauts, and recording more than 50 LF's. Following the success of this mission, a new detector (SIEYE2) has been developed and built in order to have a more accurate analysis of the radiaton flux (in particular for high Z particles) in the zone of the South Atlantic Anomaly (SAA) and in the subpolar zones. The equipment of SIEYE2 provides the opportunity for a simultaneous definition of the particle trajectory and its arrival time, an estimation of its energy and the recognition of its charge. A complete description of the experiment is given in [2], [3] and [4]. SIEYE2 was delivered on board of the Space Station MIR in October 1997, and several acquisition sessions (since February 1998) have taken place with different astronauts until the reentry of MIR in March 2001 and its subsequent destruction in the Earth atmosphere.

The SIEYE2 experiment makes use of silicon strip detectors to measure the coincidence between the passage of a ionizing particle and the occurrence of a LF. The astronaut wears a helmet which holds on its side the detector box; a joystick, connected to the same detector box, and controlled by the acquisition PC, is used for LF acquisition. The system can be seen as a completely software controlled solid state instrument. Its main characteristics are: small dimensions, portability, low power consumption, user friendly interface, real time data analysis.

The detector is compact (max dim. 264 mm) and with a low mass (less than 5.5 Kg); it measures particle energy losses from 0.25 to more than 250 MeV and determines the particle trajectory with an angular accuracy of 3 degrees.

Final analysis of SILEYE2 data is in progress [5], [6], [7] while a brand new project, called ALTEA [8] is under development to install on board the International Space Station a larger telescope with the concomitant use of electroencephalography and visual stimulation, to directly correlate LF and particle crossing the head with brain activity. A preliminary version, called ALTEINO, is going to be carried on board the International Space Station by italian astronaut R. Vittori in April 2002 and is foreseen to take data for about two years.

2 Activity of the LNF group

The LNF group has taken the responsibility of the design, test and construction of all the mechanical structures and interfaces of both SIEYE1 and SIEYE2 detectors contributing also to the integration of the mechanical support for the DAQ. It participates in the beam test activity (performed at GSI-Darmstadt and TSL-Uppsala). In view of the new ALTEA experiment, the LNF group, with the support of the local Service of Development and Construction of Detectors, has taken the responsibility of the design, test and construction of the complete structure and assembly of the qualification model of ALTEINO for ground testing and calibrations.

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SUE

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F. Monti (Ass.), A. Raco (Tecn.), L. Tallone (Ass.)

1 Experimental task

The increase in the amount of UVB radiation (280-320 nm) reaching the earth surface due to the reduction of the stratospheric ozone layer has potentially significant impact on the incidence of skin cancer in humans. Task of the SUE (Solar Ultra-violet Effects) experiment is the determination of damages (cell death, micronucleus induction and oncogenic transformation) induced in cultures of human cells and their progenies by the B band of the UV radiation.

The experiment has been planned to be carried out by means of a dedicated beam line (the DXR-2 beam line at the DAFNE-Light facility), using monochromatic photon beams obtained from Synchrotron Radiation (SR) emitted at the DAFNE storage ring. The possibility to work with SR monochromatic beams in the wavelength range of 280-320 nm, with high resolution and very high intensity as compared to conventional sources, offers a presently unique experimental technique in the study of UVB biological effects.

2 Experimental set-up and activity

The SR photon beam, extracted from a wiggler under a horizontal collection angle of 15mrad, is splitted into two beams by a grazing incidence gold coated mirror, resulting in two separate beam lines; the DXR-2 beam line (deflected at about 40 mrad) collects radiation with energy below 800 eV and carries it up to an experimental hutch dedicated to cell cultures irradiation.

Here, after having crossed a sapphire window cutting off wavelengths below 180 nm, in order to avoid second order light contamination, the beam is suitably focused and deflected by means of an optical system composed of two Al coated mirrors (one spherical and one plane), and then enters into a grating monochromator providing monochromatic UVB radiation with spectral resolution of about 1 nm. The monochromatic beam is driven up to the sample holder by an optical fiber bundle coupled to the monochromator and equipped with a diverging lens, in order to assure a uniform lighting, at a distance of about 200 mm, on the sample surface (13 mm in diameter). Dosimetry and spectral intensity measurements are accomplished by means of a pre-calibrated silicon photodiode; exposure time for each dose is determined by monitoring the ring electron current.

During the year 2001 the DXR-2 line has been completed, including the apparata for the storage ring safety and the remote control of the beam line. A radiobiological laboratory equipped for preparing and maintaining the cell cultures, and for analyzing the effects induced has been got ready. Purpose-built teflon cylinders with a quartz base have been prepared for cell irradiation; plating efficiency, double time, optimal cell density have been determined for CGL1 and AG1522 cells. All the instruments and related facilities assembled in the experimental rooms have been successfully tested.

A preliminary analysis of the light intensity distribution on the sample surface has been carried out using a mercury calibration lamp as light source at the entrance of the monochromator.

The monochromatic output beam has been used to expose a radiographic plate (Kodak X-OMAT UV Film), placed at the sample position, with high spectral sensitivity in the UV region (Fig.1). The scanning of the developed film by means of a microdensitometer shows that the optical density is reasonably uniform inside the spot, with small stochastic fluctuations (within 10% of the mean value) over a sharp plateau (Fig.2).

Results achieved are promising for the next tests with the SR beam, scheduled in the first months of 2002. Afterwards, it will be possible to start the first photobiology experiments.

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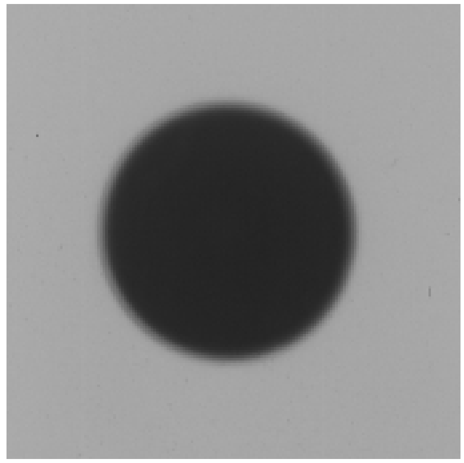

Figure 1: *Spot of monochromatic radiation (Hg line at 312.6 nm) recorded on a radiographic film placed at about 20 cm from the optical fibre beam expander.*

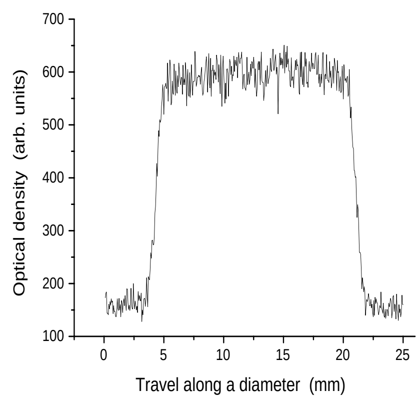

Figure 2: *Analysis of the film optical density along a diameter of the spot by means of microdensitometry.*

DAFNE-L

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A. Marcelli, C. Mencuccini (Ass.), R.M. Montereali (Ass.), F. Monti (Ass.)
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A. Raco (Tecn.) L. Tallone

DAFNE-Light is the Synchrotron Light Laboratory planned to use the synchrotron radiation emitted by DAFNE, the 0.5 GeV storage ring operational at Frascati. In 2001 important progress in the commissioning of the collider has been achieved, in particular those connected with the accumulated current that now overcomes routinely 1 A. This result actually makes DAFNE a powerful SR source for applications ranging from the soft X-ray up to the far IR range.

During the year, the commissioning of the synchrotron source have been completed, and the DAFNE experimental apparata connected to the three beamlines have been installed. Two beamlines collect the radiation emitted by one of the four wigglers of the e- storage ring. The first beamline, called DXR-1, has been designed to collect horizontally up to 5 mrad in the energy range from about 500 eV, thanks to a thin polymide window (1500 $\mathring{A}$), up to the K absorption edge of Fe. This beamline is equipped with a double-crystal monochromator, with fixed exit, to be used for absorption and fluorescence spectroscopy: working at grazing angle from 15 to 75 degrees, this device allows energy resolutions better than 10-3 and 10-4 (DE/E) already by the present equipment of Si(111) and Quartz(10-10) crystals (see Fig. 1). An high resolution diffraction station with a two axes Goniometer is also present, and the apparatus is endowed with a conventional X-ray source for preliminary alignment and test procedure, too. The end station of this beamline is a clean room (A 100 class) where an existing X-ray stepper Karl SUSS is going to be installed on its marble support for alignment to the line.

In the laboratory tunnel (point B in Fig. 2), a 75 cm long Au-coated plane mirror allows deflecting part of the wiggler radiation thus generating the photon beam for the second line DXR-2. Working at the grazing incidence of 2,2 degrees, such a mirror determines an energy upper limit of about 800 eV and collects about 2 mrad of the SR fan. The experiments planned at this beamline will be performed, independently on the operational status of DXR-1, in a dedicated experimental hutch where a grating monochromator has been installed. Mounted after a sapphire window that transmits radiation wavelengths higher than 180 nm, the Jobin Yvon HR 460 monochromator (with an holographic grating of 2400 grooves/mm) is capable of selecting photons in the spectral range between 2 and 6 eV with energy resolution of about 3The first planned experiment, SUE (Solar Ultraviolet Effects), concerns the determination of biological effects induced by the B-band of UV radiation (280-320 nm) on cultures of human cells. A dedicated laboratory where post-irradiation treatment on cell cultures will be performed in-situ, is now operative. In December, after a long data acquisition from the Radiation Protection Service devoted to know the X-ray dose released inside the X-ray hutches, the experimental area of the DAFNE-Light laboratory have been authorized. As a consequence, before the Christmas shut-down of DAFNE both the X-ray beamlines have started the alignment procedures using the synchrotron radiation beams.

The third beamline, SINBAD (Synchrotron INfrared Beamline At Dafne), collects 20 x 45 mrad of the radiation emitted from a bending magnet. SINBAD utilizes a complex optical layout formed by 6 mirrors, which collects, focus on a CVD diamond wedged window and finally transports the IR radiation at about 25 m from the source. The optical scheme has been designed to preserve the high brilliance and intensity of the photon beam. Because of the optical scheme, the radiation in the laboratory is not on the same plane of the ring and the Radiation Protection Service allowed operation without hutches. As a consequence, all the alignment operations and tests of the optics proceeded during the 2001 parasitically to the DAFNE schedule. In Fig. 3 it is shown the first intense beam observed at the end of the vacuum pipe before the final toroidal mirror.

Before the celebration of the 50^{th} anniversary of the INFN, the commissioning of the IR beamline and the interferometer has been started. In Fig. 4 the first stored interferograms using the synchrotron light focused at the entrance slit of the instruments, through an IRTRAN window, is reported.

The spectra shown in Fig. 4 refer to different circular apertures at the sample position, the diameter of which goes from no-stop up to 0.3 mm of diameter. As expected for an extremely brilliant source like the IRSR, the measured signal intensity does not scale with the source size as in the case of the black body. Actually, the accurate determination of the gain of the synchrotron radiation source, as a function of the aperture and in comparison with a black body source, is the main goal of the beamline commissioning for the 2002.

The Bruker Equinox interferometer, modified for vacuum operation and equipped for both transmittance and reflectance measurements, has been also tested under vacuum using the synchrotron radiation beam emitted by DAFNE. In Fig. 5 is shown a detail of the high resolution spectra of the CO_2 molecule in-plane band vibration. This spectra is a small region of the wide absorption spectra of the air vapor detected by the instrument working under vacuum.

Alignment procedures and test continued in December and the start up of the experimental activity at SINBAD is planned in the Spring of 2002. Next year also the experimental proposals funded in the EU framework of the TARI program will receive access to the synchrotron radiation facility of the Laboratori Nazionali di Frascati running approved experiments.

1 List of Conference Talks in 2001

1. G. Cappuccio, Invited talk Alignment procedure and divergenge behaviour in capillary optics, International Conference on X-ray and Neutron Capillary Optics POP'01 (September 8-12, 2001, Zvenigorod, Russia)
2. G. Cappuccio, Invited talk Eureka project - Surface monitor: high tech instrumentation for XRD/XRF analysis, International Conference on X-ray and Neutron Capillary Optics POP'01 (September 8-12, 2001, Zvenigorod, Russia)
3. G. Cappuccio, Invited talk Capillary optics in x-ray diffraction experiments: first results with X-ray tubes and efficiency synchrotron radiation, 31 Congresso dell'Associazione Italiana di Cristallografia (September 18-21, 2001, Parma)
4. S. Dabagov, Invited talk Features for scattering of soft synchrotron radiation by a gratings capillary surface, Annual SPIE Meeting, (July 29 August 3, 2001, San Diego, USA)
5. S. Dabagov, Invited talk Features of neutral particles channeling in capillary arrays, Annual SPIE Meeting, (July 29 August 3, 2001, San Diego, USA)
6. S. Dabagov, Invited talk Quantum theory of X-ray channeling in capillary systems, International Conference on X-ray and Neutron Capillary Optics POP'01 (September 8-12, 2001, Zvenigorod, Russia)
7. S. Dabagov, Invited Talk Wave theory of x-ray scattering in capillary structures, International Capillary Optics Meeting ICOM'01 (June 17- 21, 2001, Antwerp, Belgium)
8. A. Marcelli, Invited Talk The new laboratory DAFNE-Light, Network SINBIO Luce di sincrotrone e sistemi biologici (23 March 2001, Roma)

9. A. Marcelli, Invited talk Fisica, produzione e trasduzione degli ultrasuoni, Corso di Aggiornamento in Radioprotezione Medica Metodiche diagnostiche e strumentali (6-7 April 2001, Frascati)

10. A. Marcelli, Invited talk Infrared synchrotron radiation: from condensed matter to biology researches, XXXVI International Zakopane School of Physics (14-19 May 2001, Zakopane)

11. A. Marcelli, Invited talk The DAFNE-Light Facility, Workshop Nanotubes & Nanostructures 2001 (25-27 October 2001, Frascati)

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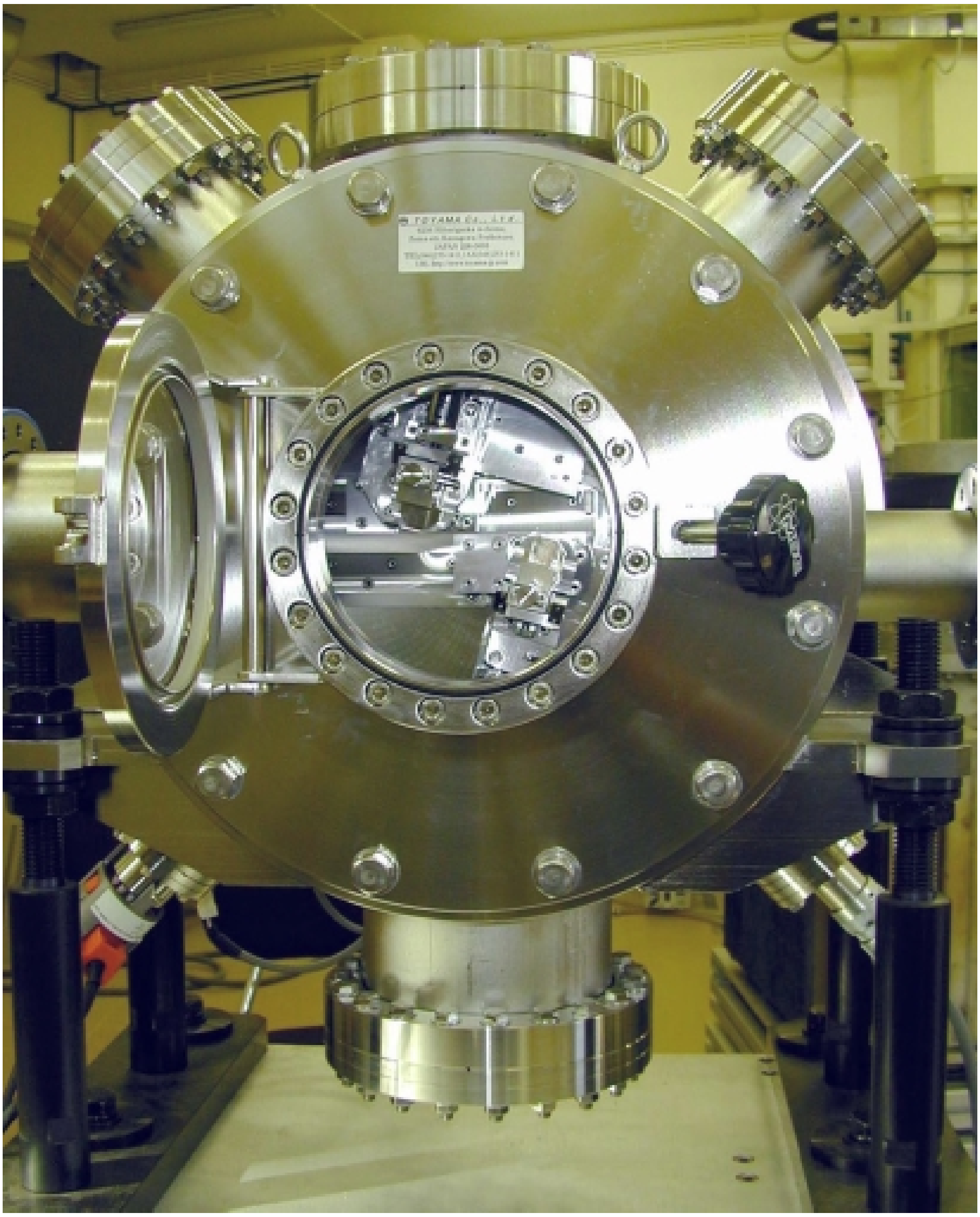

Figure 1 – The high resolution x-ray diffraction station for thin films, bulk and polycrystalline material analysis using synchrotron radiation. The Cu x-ray tube installed has been used for the preliminary alignment procedure and test.

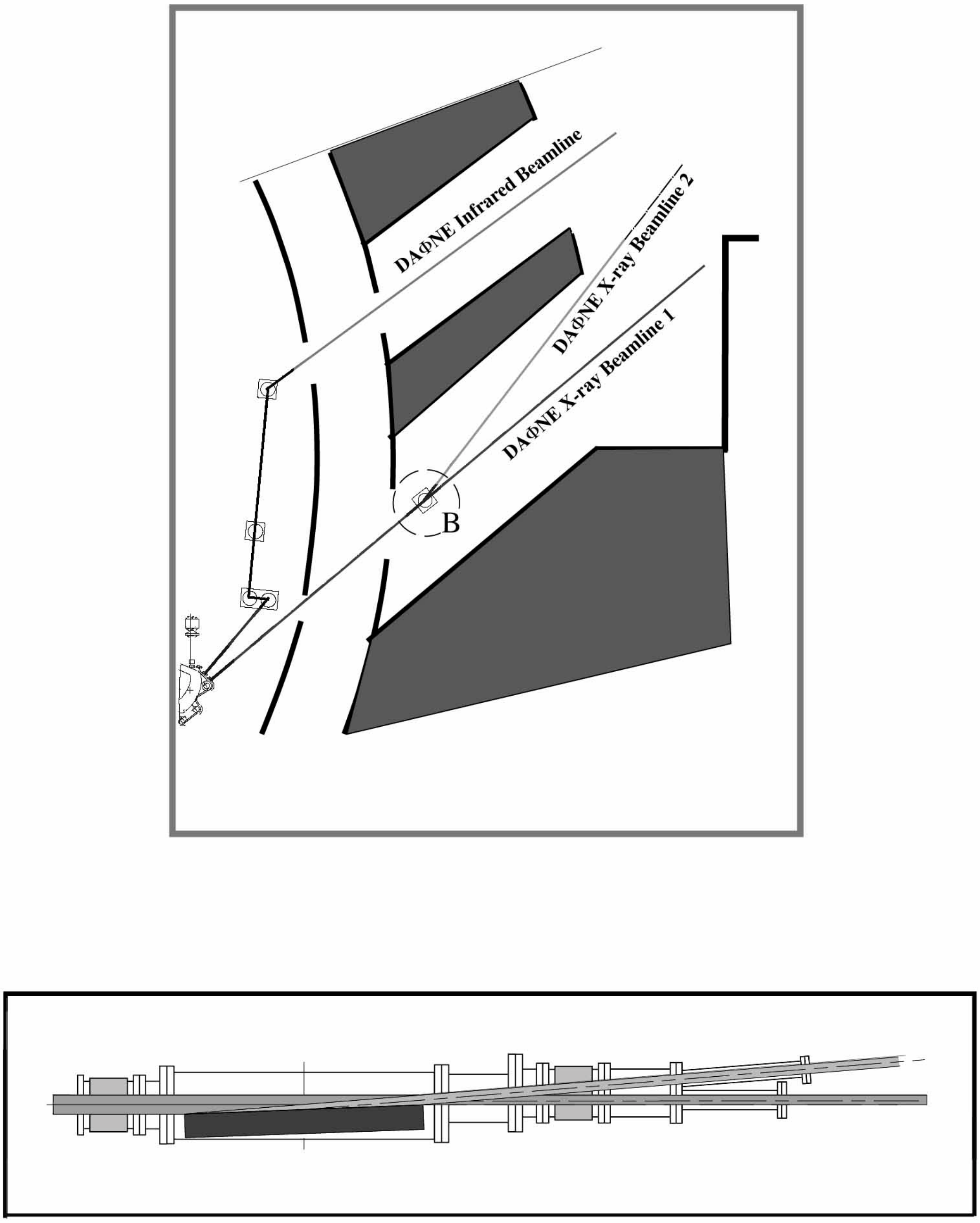

Figure 2 – In the top panel the layout of the three beamlines.In the bottom panel a view of the x-ray deflection mirror.

Figure 3 – The photograph shows the light emerging from the last plane mirror that deflects the synchrotron radiation inside the DAΦNE-Light laboratory. Here a toroidal mirror focuses the radiation at the entrance slit of the interferometer.

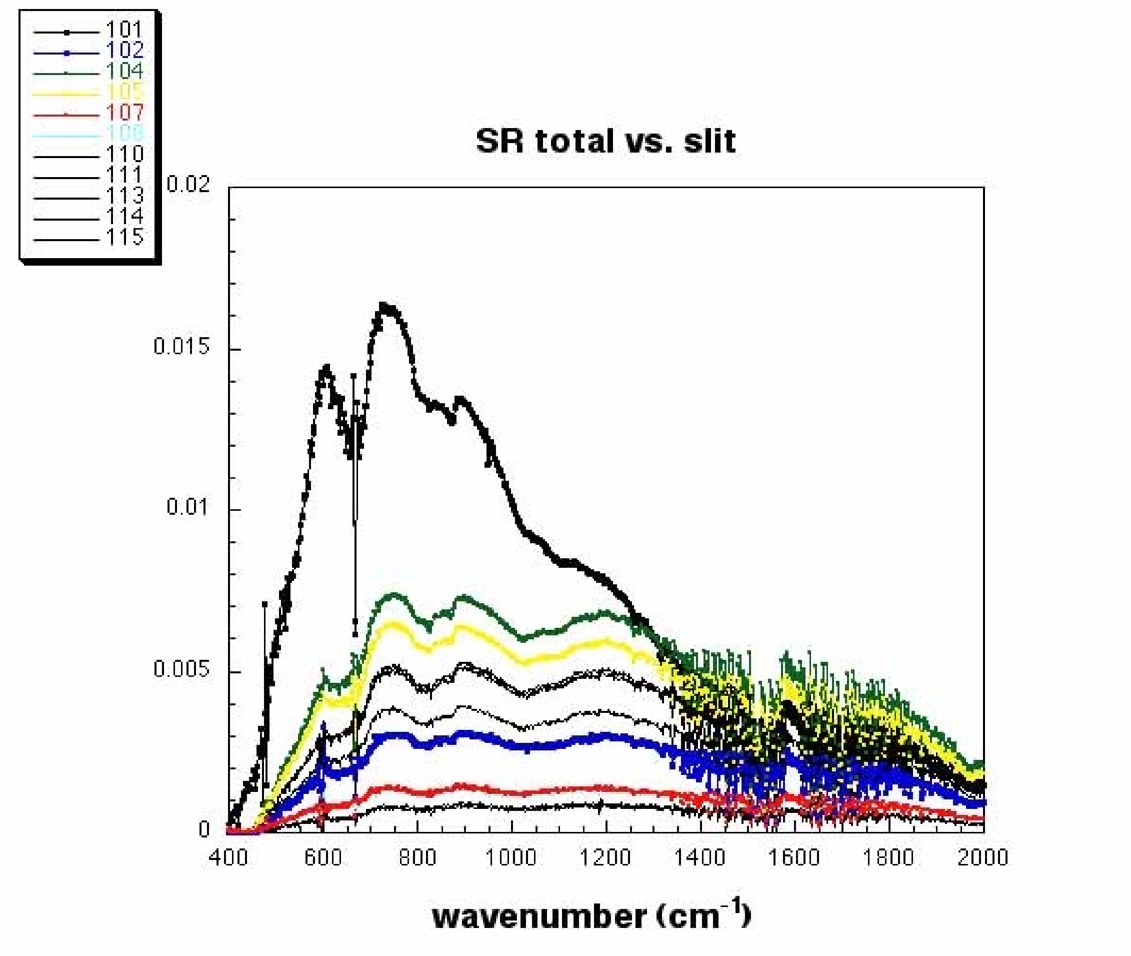

Figure 4 – Synchrotron radiation intensity measured, as a function of the radius of different circular slit, in the frequency region from 400 to 2000 cm^{-1}. In the low frequency region the cut is due to the effect of the IRTRAN window that does not transmit IR radiation.

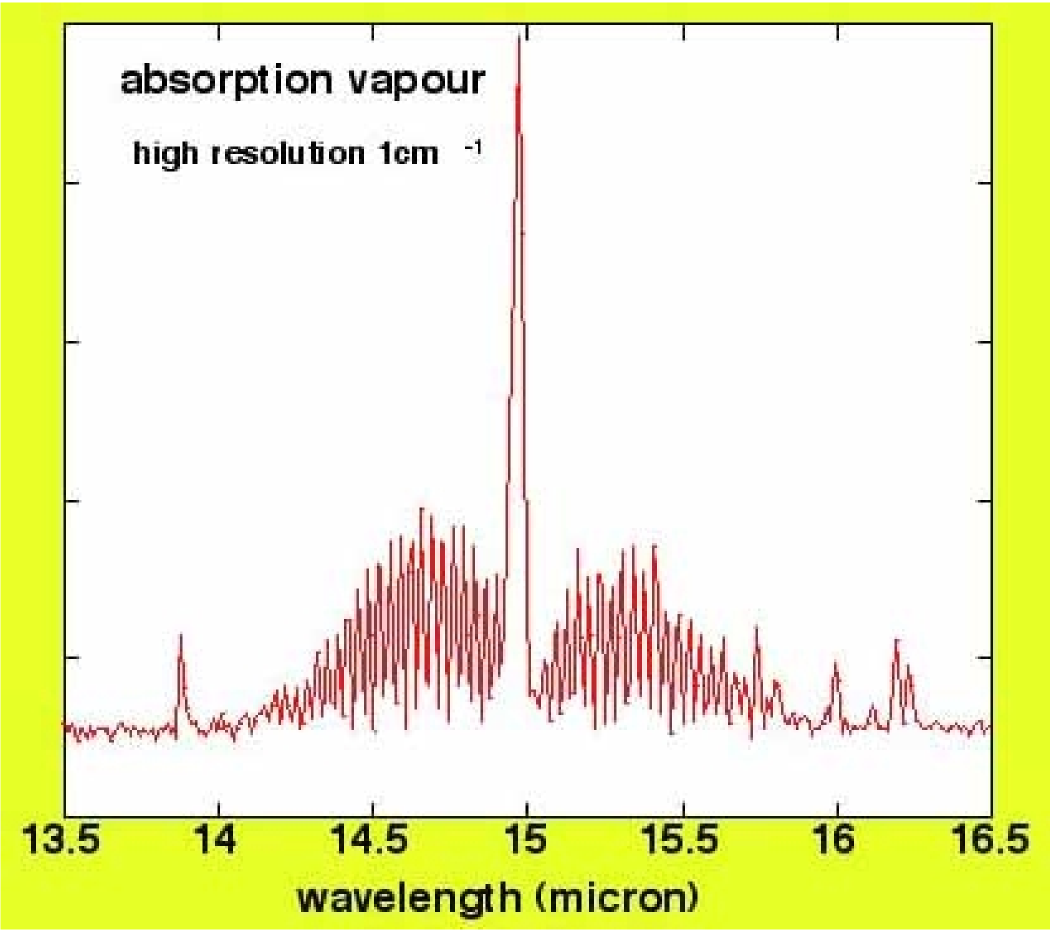

Figure 5 – The absorption spectra of CO_2 molecule collected at SINBAD at the resolution of 1 cm^{-1}.

LINAC-FEL

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1 Aim of the experiment

The proposal SPARC (Sorgente Pulsata e Amplificata di Radiazione Coerente) was prepared by the collaboration among ENEA-INFN-CNR-Università di Roma "Tor Vergata" during the month of February 2001, and submitted to the Italian University and Research Department (MIUR) in March 2001, in order to respond to a call for proposals launched by MURST within the frame of the FISR initiative (Fondo Integrativo Speciale per la Ricerca), with the aim to promote a R&D activity strategically oriented to the development of a Coherent Ultra-Brilliant X-ray Source. The total amount of funding made available by the call for proposals was 7.7 million euros.

The SPARC collaboration identified a program essentially founded on two issues considered of crucial relevance for the final goal of designing and building a Coherent X-ray Source: the generation of electron beams with ultra-high peak brightness and the generation of resonant higher harmonics in the SASE-FEL process. It is actually well known that the requirements on the electron beam quality, in terms of peak current, energy spread and normalized transverse emittance, imposed by the needs to drive a SASE-FEL instability at very short wavelengths (from 10 nm down to 1 Angstrom), typically exceed the present capability of storage rings by large factors, while they are in perspective attainable by Linacs equipped with advanced photo-injectors and compressor devices (magnetic and/or RF compressors). The benefit of such an effort, i.e. attaining such peak brightness in the electron beam, is the availability of a radiation source emitting coherent X-rays with unprecedented brightness, many orders of magnitude higher than that delivered by (present) third generation light sources.

2 Group activity in 2001

On this basis, the SPARC proposal was prepared in order to encompass the construction of an advanced photo-injector producing a 150 MeV beam to drive a SASE-FEL in the optical range.

The proposed system to be built consists of: a RF gun operated at S-band (2.856 GHz) and high peak field on the cathode (120-140 MeV/m) with incorporated metallic photo-cathode (Copper or Mg), generating a 6 MeV beam which is properly focused and matched into 2 accelerating sections of the SLAC type (S-band, travelling wave). The aim of this accelerator system is to generate, in a first phase of commissioning (before the installation of the RF compressor section), an electron beam carrying a fraction of a nC of bunch charge at 150 MeV, with a rms normalized emittance of 2 mm mrad and an energy spread of 0.1 %. The peak current will be in excess of 150-200 A and will drive a SASE-FEL experiment at 520 nm, performed with a 12 m undulator following the linac.

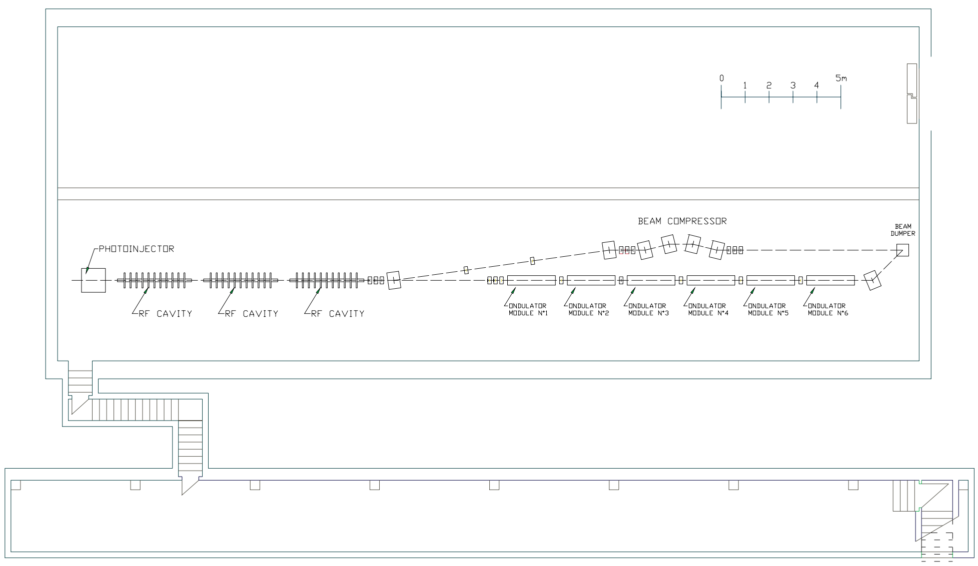

Figure 1: *Schematic Lay-out of SPARC Project.*

Main goal of this FEL experiment is to study the generation of higher odd harmonics through the resonant non-linear mechanism. The proposal was selected by the search committee to receive 85% of the available funding: in march 2002 the SPARC collaboration was informed by MIUR that the proposal was approved and funded with 6.5 million euros by MIUR.

It has been also proposed to INFN to fund the design and construction of a third section which will serve as RF compressor. This will be located just after the gun (the two others will be shifted further downstream) and it consists of a travelling wave section operated at S-band with adjustable phase velocity. Studying RF compression is one of the main objective of the SPARC. A transfer line for experiments on bunch compression through magnetic dipoles, is also envisaged. All these activities are thought to be crucial for the performances of future X-ray SASE-FEL Projects. The time table for the project foresees a commissioning of the system within 3 years: an additional year is requested to upgrade the system by installing the RF compressor section (whose design and construction has to start anyway in the very early stages of the project, in order to be available close to the end of the third year for installation).

During 2001, the group, in collaboration with CNR, ENEA and Università di Roma "Tor Vergata", was indeed involved also in the preliminary study a Linac for the SPARX (Sorgente Pulsata Autoamplificata di Radiazione X) project, based on the SPARC photo-injector, able to accelerate high brilliant beams at the energy of 2.5 GeV and to generate in the undulators a fundamental wavelength at 1.5 nm. This study was done in view of a call for a "large research infrastructure", launched by MIUR on December 2001.

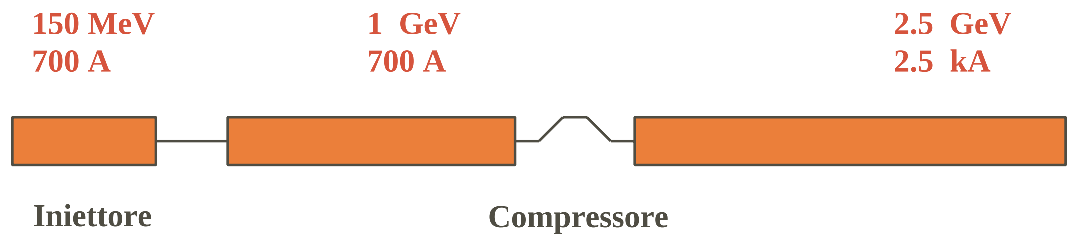

Figure 2: *Scheme of the 2.5 GeV Linac for the SPARX project.*

The Linac consists of a photo-injector at 150 MeV (SPARC) which includes the RF compressor, followed by SLAC-type accelerating sections up to 2.5 GeV. A magnetic compressor at 1 GeV brings the peak current at the required value of 2.5 kA with a moderate compression factor.

Energy	2.5	GeV
Peak current	2.5	kA
Emittance (average)	2	mm-mrad
Emittance (slice)	1	mm-mrad
Energy spread	0.1	%

The behaviour of the peak current and energy spread along the linac are reported in Fig.3.

At the end of the Linac the beam is injected inside a 30 meters long undulator where the SASE coerent radiation is expected to occur with the following features:

Table 1: *FEL perfomances at 1.5 e 13.5 nm.*

wavelength	1.5 nm	13.5 nm
saturation length	24.5 m	14.5 m
Power 1st harmonic	10^{10} W	4 10^{10} W
Power 3rd harmonic	2 10^{8} W	5 10^{9} W
Power 5th harmonic	3 10^{7} W	2 10^{8} W
Brigthness 1st	1.8 10^{31}	2 10^{32}
Brigthness 3rd	10^{29}	10^{31}
Brigthness 5th	9 10^{28}	3 10^{29}

(*Peak in photons/sec/0.1%bw/(mm mrad)^2)

3 Activity for 2002

The group will continue the work on the conceptual study for both SPARC and SPARX projects. Depending on the response to the proposals from MIUR, the activity can move to a technical

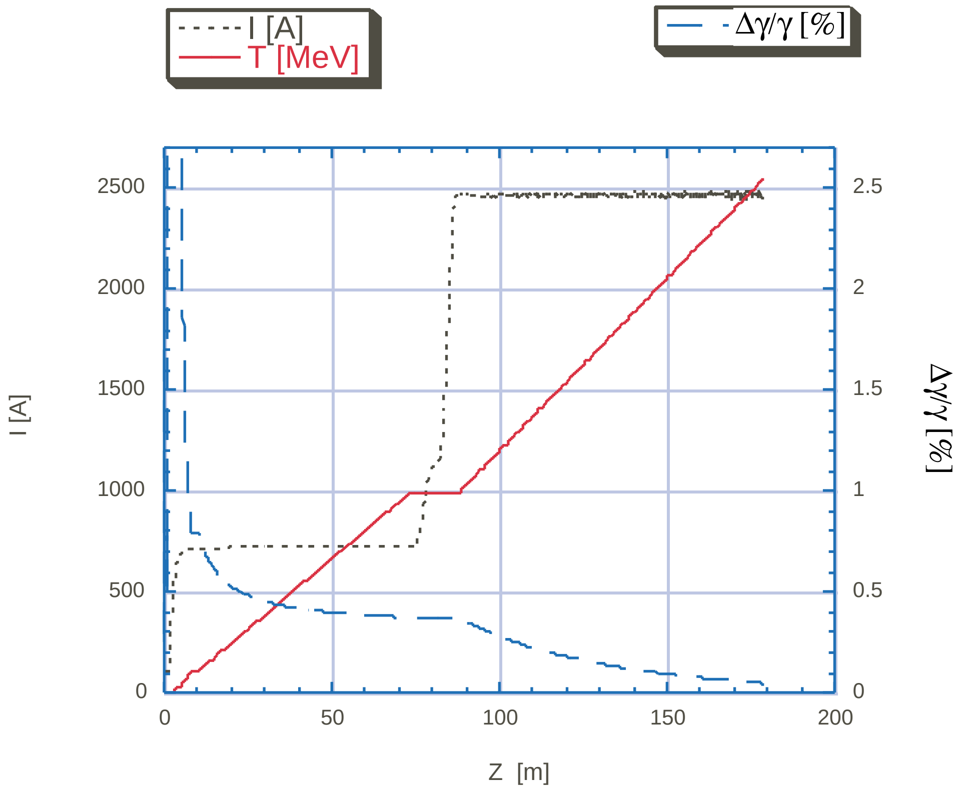

Figure 3: *Peak current and energy spread along the Linac in the SPARX project.*

design of the two accelerators.

GILDA

A. Balerna, F. Campolungo (Tecn.), S. Mobilio (Resp.), V. Sciarra (Tecn.)
V. Tullio (Tecn.)

1 Introduction

GILDA (General Purpose Italian BeamLine for Diffraction and Absorption), is the Italian CRG beamline, built to provide the Italian scientific community with an easy access to the European Synchrotron Radiation Facility to perform experiments with a high energy and brilliance X-ray photon beam. GILDA is funded by the three Italian public research Institutes: Consiglio Nazionale delle Ricerche (CNR), Istituto Nazionale per la Fisica della Materia (INFM) and Istituto Nazionale di Fisica Nucleare (INFN). Experimental stations for X-ray Absorption Spectroscopy, Anomalous X-ray Scattering and X-ray Diffraction (XRD) are present at the GILDA beamline.

2 Activity on the GILDA beamline during 2001

During 2001 a big effort was dedicated to the improvement of the beamline and of the experimental apparata. The hardware of the optical hutch and of the absorption hutch has been implemented in the new standards required by ESRF. The instruments software control of the absorption hutch under LABVIEW has been completed. Since the monochromator of the beamline was using only Si(311) and Si(511) crystals in order to achieve high energy values and high resolution, a Si(111) curved crystal has been tested. This will give the possibility, working with its third harmonic that has the same lattice parameter of Si(511), to cover the whole spectral range (5-80 keV) changing only the first flat crystal which is a relatively simple operation. At the same time the use of Si(111) crystals will push the low energy limit down to about 3.6 keV giving the possibility to study the K-edges of Ca and K.

2.1 Absorption Hutch

The experimental setup dedicated to REFLEXAS was completed with an evaporation stage and oven for thermal treatments up to 1000 C. The new system gives the possibility to evaporate metals on different substrates and then perform thermal treatments under vacuum or under gas controlled conditions. A system to hold the 13 element fluorescence detector has also been realized in order to be able to perform REFLEXAFS measurements on samples with few layers with reasonable counting times and good signal to noise ratios.

2.2 Diffraction hutch

Concerning the experimental set-up in the diffraction hutch the last year has been dedicated to the optimization of the apparatus and the improvement of data quality. The instrument is now controlled by a Labview based software, that makes it more user friendly. The improvement of the quality of the data has required an accurate work to catalog and understand the effects of various experimental parameters on the collected XRD data. As a result a new program has been developed, able to integrate the images collected with the translating image plate (TIP) taking automatically into account the main origins of the distortions. This has given the possibility to reach a very high stability on the structural parameters. Moreover a procedure for the automatic refinement of XRD patterns has been implemented. This procedure allows a huge time saving in the data handling procedure considering that translating XRD scan can provide up to 90 different diffraction patterns. ¿From the experimental point of view a reactor for in-situ XRD studies on catalysts has been developed in collaboration with the University and ICTPN of Palermo. The reactor consists of a quartz capillary open at both ends which contains the sample powder and is mounted on a goniometer head for alignment on the X-ray beam. Since capillary is open at both sides it allows to input the reaction gases at one end and to send the reaction products to a quadrupole mass spectrometer at the other end. The sample is heated by using a remote controlled heating gun. This geometry ensures the optimal experimental conditions for what concerns chemical and XRD constraints: 1) the gas flow reaches all the sample; 2) sample temperature has a uniform distribution; 3) negligible diffusion effects. The reactor has been successfully used for studying Three Way Catalysts (TWC) systems.

3 Beamtime use during 2001 and scientific outcomes

During 2001, 28 Italian experiments were performed on GILDA. Some of the results achieved during 2001 and to be mentioned were obtained in the study of : 1) Co/Ag systems, very important for their peculiar magnetic properties, like a magnetoresistance increase of about 20% called Giant MagnetoResistance (GMR),were the evidence of Co dimers at a slightly contracted distance with respect to Co bulk and in quasi substitutional structural configuration in the Ag fcc matrix were found; 2) the structural evolution of human bioapatite, a calcium phosphate major component of the mineralised part in mammalian bones, during the early stages of ossification processes; 3) Co segregation in CoCu granular alloys and its influence on the magnetoresistance; 4) Three-Way Catalysts (TWC), complex systems constituted of a metal nanophase supported on mixed oxides,designed to remove simultaneously the major environment pollutants CO, NOx and hydrocarbons (HC) from automotive exhaust gases.

4 2002 - GILDA Forseen Activity

In order to optimize the vertical focusing and proceed with the tests on the second mirror the installation of two new beam monitors in the second (diffraction) and third hutches will be completed. The instruments control software of the diffraction hutch will be fully implemented under LABVIEW. A new holder for the first crystal of the monochromator will be designed and realized. A new bender for the second crystal, needed to improve the homogeneity and dimension of the x-ray beam will be designed. In situ sample preparation systems will be developed. The collaboration with the experiment MANU2 (Gruppo II) on the comparison between the beta-decay electron spectrum and the X-ray absorption spectrum of Re will still go on.

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NTA-NF

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B. Spataro, F. Tazzioli, C. Vaccarezza, V. Verzilov

1 Description and aim of the experiment

A Neutrino Factory based on a muon storage ring is the ultimate tool for studies of neutrino oscillations, including possibly leptonic CP violation. It is also the first step towards $\mu+\mu-$ colliders. Ionization cooling of muons constitutes an important ingredient of both the performance and cost of a neutrino factory, but has never been realized in practice. This motivates a programme of R & D at international level, including an experimental demonstration. The aims of this muon ionization cooling experiment are as follows:

- to show that it is possible to design, engineer and build a section of cooling channel capable of giving the desired performance for a Neutrino Factory;
- to place it in a muon beam and measure its performance in a variety of modes of operation and beam conditions.

The concept of a muon ionization cooling experiment has been extensively studied, and an international collaboration is being set up to realize it. A section of a cooling channel assembles liquid hydrogen absorbers providing energy loss, combined with high gradient RF cavities to re-accelerate the particles, all tightly contained in a magnetic channel. Spectrometers placed before and after the cooling section perform the measurements of emittance reduction and transmission. It appears feasible to build a section of cooling channel that reduces the emittance of a muon beam by 5-10%, and to measure this emittance reduction with an absolute precision of ± 0.1%.

2 Group activity in 2001

The Neutrino Factory activity in the LNF has been done in collaboration with the CERN Neutrino Factory Working Group and INFN - Roma 2, and has been devoted to:

- study alternative schemes in the design of low frequency cavities for muon capture and cooling in a Neutrino Factory [1]. Solutions with closed and open irises have been considered. The comparison between the various solutions is based on dimensions and power per unit length, for a given accelerating gradient.
- study of beam loading compensation schemes for the muon recirculating Linac [2]. A train of 100 muon bunches, 2.2 ms long, with an average current of 0.1 A, has to be accelerated by the first recirculating linac from 2 GeV up to 10 GeV (in 4 turns) with a rms relative energy spread $\sigma_\varepsilon < 5 * 10^{-3}$. Despite the huge amount of energy stored in the 352 MHz cavities adopted for this linac (about 100 Joule at 10 MV), the energy spread induced by beam loading effects without compensation results to be $\sigma_\varepsilon = 1.4x10^{-2}$. A preliminary

study about possible schemes for beam loading compensation has been performed. Simple scaling laws are derived by means of the phasor description of beam loading effects. The code HOMDYN has been used for multi-bunch computations.

- study of beam dynamics for a muon ionization cooling experiment [3]. Two possible scenarios have been considered: the first is a subsection of the 88 MHz cooling channel in the CERN reference scheme for a neutrino factory. The second system studied is based on 200 MHz cavities as proposed in the US study II design (see fig. 1). The studies comprise a scan of input beam parameters, various optics with and without alternating solenoid polarity as well as a cross-check with an independent simulation code. An example of the performances of the 200 MHz cooling channel is shown in fig. 2.

3 Activity for 2002

For the 2002 we intend to further study the possibility of a cooling channel based on 200 MHz cavities with superconducting solenoids and liquid hydrogen absorbers, in order to verify if the achieved cooling factor (i.e. the increase of the number of particles in a given acceptance) for a 200 MeV muon beam passing through a system of 4 cavities at 7.6 MV/m is within the capability of the measurement apparatus and sufficient to gather important information for the final design of a full-scale cooling channel.

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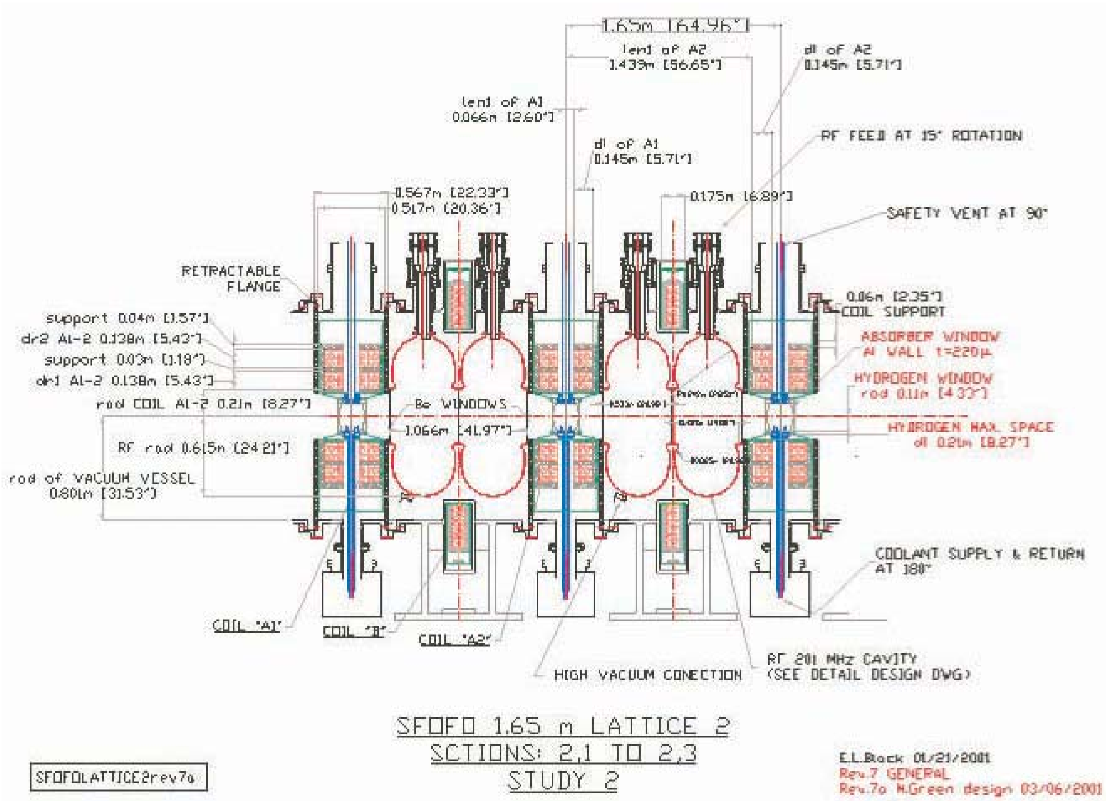

Figure 1 – Schematic layout for the 200 MHz cooling experiment.

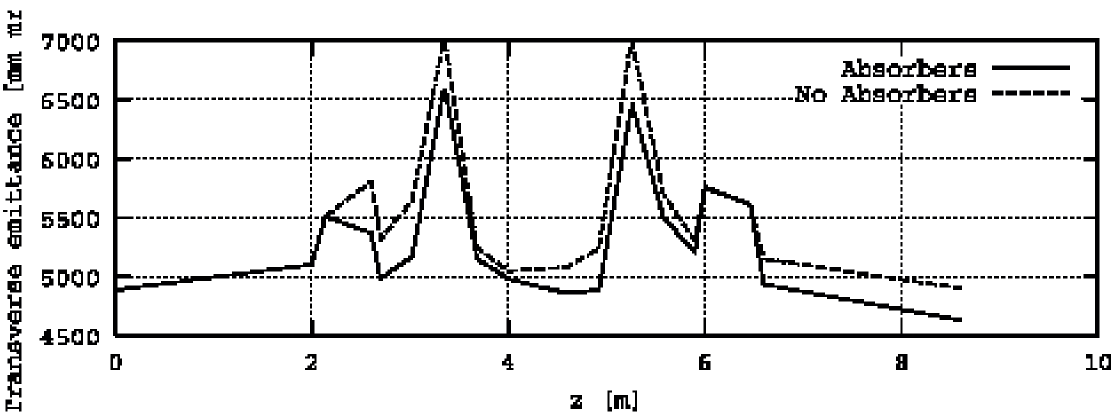

Figure 2 – Transverse rms normalized emittance along the 200MHz channel with and without absorbers.

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These are the acronyms used in each status report to describe personnel qualifications other than Staff Physicist:

Ass.	Associated Scientist
Osp.	Guest Scientist
Bors	Fellowship holder
Tecn.	Technician
Resp.	Local Spokesperson
Resp.Naz.	National Spokesperson
Ass.Ric.	Research Associate
Bors. PD	Post-Doc Fellow
Dott.	Graduate Student
Laur.	Undergraduate Student
art.23	Term Contract (Scientist)
art.15	Term Contract (Technician)