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Present Status of the Frascati National Laboratories

P. Laurelli

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NUCLEAR PHYSICS A

Present status of the Frascati National Laboratories

P. Laurelli
Laboratori Nazionali di Frascati, Via E. Fermi 40, 00044 Frascati, Italy

The Frascati National Laboratories are the largest INFN laboratory, with a long standing tradition in constructing and operating e^+e^- storage rings and large size detectors. The present status of the experimental programs is reviewed, with special emphasis to $DA\Phi NE$ and its experiments.

1. THE LNF

The Frascati National Laboratories are the place where in 1961, A.d.A., the first e^+e^- storage ring, was conceived and constructed. Since then their destiny is associated with accelerator and high energy physics, although the spectrum of experimental programs in Frascati is nowdays much wider. In 1969 ADONE, A.d.A. successor, started to operate, giving birth to a generation of experiments pioneering e^+e^- collisions and synchrotron light. Today the laboratory has grown and hosts a large community: 88 researchers, 55 technologists, 158 technicians, 34 administratives, about 100 long term visitors/year and 300 guests/year. Much of the present effort is devoted to $DA\Phi NE$, the high luminosity Φ factory under construction.

2. THE $DA\Phi NE$ MACHINE

$DA\Phi NE$ (the acronym stands for *D*ouble *A*nnular Φ *F*actory for *N*ice *E*xperiments) is a complex made by a 550 MeV e^+, 800 MeV e^- Linac, a 510 MeV accumulator and the $DA\Phi NE$ main rings. A selection of the machine design parameters is reported in Table 1. It is foreseen to reach a luminosity of about 10^{33} cm^{-2} s^{-1} by making collide, at two intersection points, 120 bunches of 510 MeV electrons and positrons. The luminosity per bunch will be about 4.4 10^{30} cm^{-2} s^{-1}, very similar to the value already obtained by the VEPP-2M machine at Novosibirsk.

The Linac is presently under commissioning. It has been built by Titan Beta (USA) under LNF specifications and completely assembled by the end of 1995. The first tests have been very satisfactory. The e^- commissioning has been completed in 1996 and a 500 mA, 700 MeV beam, with less than 1% energy spread, has been successfully brought up to the Linac end. A 4.2 mA current of 435 MeV positrons has also been achieved

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Table 1
$DA\Phi NE$ main design parameters

Parameter		Parameter	
Energy (MeV)	510	Maximum number of bunch	120
Trajectory length (m)	97.69	Minimum bunch separation (cm)	81.4
Emittance, $\varepsilon_x, \varepsilon_y$ ($mm \cdot mrad$)	1/0.01	Bunch average current (mA)	43.7
Beta function, β_x^*, β_y^* (cm)	450/4.5	RF Voltage (kV)	250
Beam-beam tune shift, ξ_x, ξ_y	5.13/ 6.10	Bunch length σ_z (cm)	3.0
Betatron tune ν_x/ν_y	5.13/6.10	RF frequency (MHz)	368
Damping time τ_E/τ_x (ms)	17.8/36.0	Synchr. radiation loss (keV/turn)	9.3

by impinging 1.5 A of 80 MeV electrons on a tungsten converter. The increase of the electrons energy of up to 250 MeV, the increase of the electron current to about 4 A and the optimisation of the positron transport efficiency will allow to obtain the desired 35 mA positron current.

The Accumulator ring is also under commissioning since 1996. It has been built by Oxford Instruments (UK) under LNF specifications and assembled in mid 1996. The first beam has been accumulated on June 30, 1996 with excellent performances. A 75 mA electron current from a single 520 MeV bunch, about 750 μm (H) × 320 μm (V) in size, has been stored with all sextupoles working and a poor vacuum inside the pipe. This value constitutes about 60% of the 120 mA design current. A synchrotron light picture of the first beam stored in the accumulator is shown in Fig. 1. The full electron commissioning and the positron commissioning will be ended by the beginning of 1997.

The two main rings are not completed yet. A series of civil engineering works was needed to prepare the old ADONE hall to host the new machine. The full installation will be completed around mid 1997. A pilot run will follow immediately afterwards.

3. *DAΦNE* EXPERIMENTS

Three experiments will use $DA\Phi NE$ collisions: KLOE, FINUDA and DEAR. Essentially all of them will use the kaons from Φ decays as much as fixed target experiments can use an exceptionally good kaon beam. Nevertheless the physics goals of the experiments are quite different.

KLOE is dedicated mainly to the study of CP violation in kaon decays. The simultaneous production of the monochromatic K_S^0 and K_L^0 from Φ decay makes KLOE unique among this kind of experiments and will additionally allow to study quantum interferometry. Moreover the huge production of kaons will permit to test chiral perturbation theory, to investigate rare kaon decays, to measure f_0 properties, to perform light mesons spectroscopy, etc. .

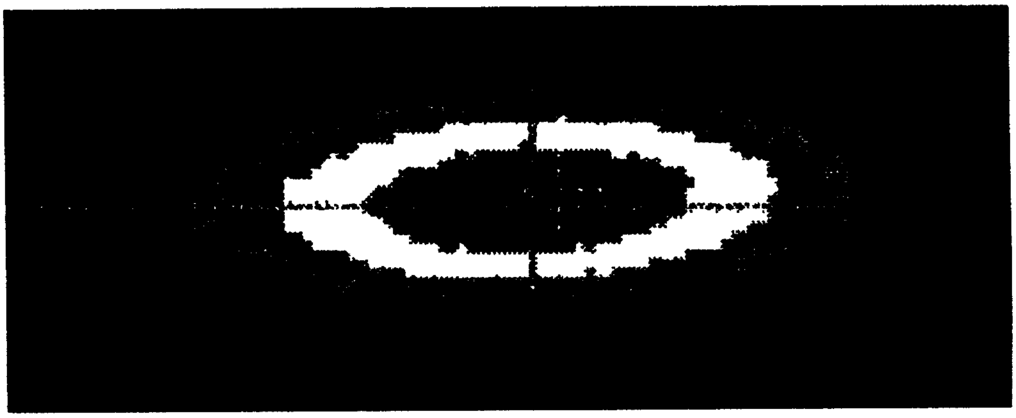

Figure 1. Synchrotron light of the first stored beam in the $DA\Phi NE$ accumulator.

Table 2
$KLOE$ main design parameters

Drift Chamber		Calorimeter	
Gas mixture	He/iC_4H_{10} 90/10	Composition	fibre/lead/glue 48/42/10
Cell size	$2 \times 2 + 3 \times 3\ cm^2$	Depth	$15\ X_0$
Stereo angle	50 - 120 $mrad$	Readout	$3.5 \times 3.5\ cm^2$
Number of layers	12+48		
Number of wires	52140	Time res.	$\delta t/t = 55\ ps/\sqrt{E(GeV)}$
K_L^0 vertex resolution	$\simeq 1\ mm$	Energy res.	$\delta E/E = 4.7\%/\sqrt{E(GeV)}$
Momentum resolution	$\delta p_T/p_T \simeq 0.5\%$	z resolution	$\delta z/z = 0.9\ cm/\sqrt{E(GeV)}$

To achieve the 10^{-4} accuracy on ϵ'/ϵ, which is the goal of KLOE, the detector needs good tracking and vertexing, good energy resolution, excellent hermeticity and uncommon efficiency in detecting low energy photons. Its main parameters are given in Table 2.

The tracking system is made of a single, very large, drift chamber with stereo wires. The chamber is designed to allow uniform tracking for the isotropic distributed pions of K_L^0 decays. The chamber is presently being wired at the LNF and will be ready mid 1997. A prototype was successfully tested with a 50 GeV beam at CERN SPS.

The KLOE calorimeter is made of scintillating fibres embedded in lead. In addition to a good energy resolution (the best ever achieved with this technique) it has a good timing resolution, which allows to reconstruct π^0s by constraining the photons flight paths to cross simultaneously onto the K_S^0 direction. Its mass construction has already been completed and the final assembly will take place in the first months of 1997. Prototype modules have been tested at the PSI facility with 100-300 MeV/c electrons and pions, and at LNF with low energy photons and cosmic rays. In all cases the design performances have been largely met.

The requirements imposed on the trigger constitute another strong challenge for the KLOE detector. At 10^{33} cm^{-2} s^{-1} the rate of events has been reduced to about 10 kHz, equally divided into 5 kHz of Φ decays and 5 kHz of background, either from Bhabha events, machine background or cosmic rays. The experiment should be able to handle about 500 Tbyte/y of information, stored on 12500, 40 Gbyte, DLTs.

The main aim of FINUDA is the spectroscopy of hypernuclear states produced following the stopping of low energy (16 MeV) K^- from Φ decays in thin ($\simeq$ 300 mg/cm^2) nuclear targets. Other goals of interest are the study of non-mesonic decays of hypernuclei ($\Lambda N \rightarrow NN$) and the production of neutron-rich hypernuclei. FINUDA will also be able to measure the $K^-p \rightarrow K^0n$ cross section for momenta of the kaon smaller than about 100 MeV/c, and to improve the error on the K_{e2} decay.

The detector is composed by a tracking system made by a silicon microvertex and a series of straw tubes and drift chambers, and an outer calorimeter made by scintillators. All subdetectors are almost ready and will be assembled in the pit in 1997, after the delivering of the magnet by ANSALDO (I) in spring 1997.

DEAR is a small experiment dedicated to the measurement of the K-nucleon scattering length by the detection of X-ray transitions in kaonic hydrogen. For this purpose a low temperature, pressurised, gaseous hydrogen target of moderate density will be exposed to the low momentum monochromatic 'beam' of kaons produced by Φ decays. The transition photons will be detected by a system of CCD, the best possible device in terms of background rejection and resolution.

The experimental set-up will be ready to take data as soon as electrons and positrons will be circulating in $DA\Phi NE$. The statistics needed for the measurement will be collected in few months, after which DEAR will leave room to one of the other two detectors.

4. LIGHT FROM $DA\Phi NE$

Following a tradition inherited from ADONE, $DA\Phi NE$ can be used as source of synchrotron light. The available energy range could cover infrared light (5-5000 μm) and soft X-rays. A long list of applications might be foreseen, from the typical characterisation of material and surfaces and the development of new devices, to the investigation of electronic phenomena (e.g. insulating vs. metalling transitions in liquids), the microscopy of small and very small samples, microengineering (e.g. VLSI and LIGA Process), etc. Three beam lines can be accommodated, partially using the pre-existing facilities. The lines could became operational in a later phase of $DA\Phi NE$.

5. LNF PARTICIPATION TO H.E.P. ACCELERATOR EXPERIMENTS

The LNF maintain a strong presence in accelerator experiments operating in the biggest high energy physics laboratories around the world. A large number of physicists and technicians collaborate to five such experiments: ALEPH (e^+e^- physics) and ATLAS (pp physics) at CERN, BABAR (CP violation) at SLAC, CDF (pp physics) and E831 (c physics) at FNAL. In all these experiments the LNF have been responsible for the construction of a relevant part of the detectors, typically hadron calorimeters, e.m. calorimeters and muon detectors.

ALEPH is presently working at $\sqrt{s} > 2M_W$. Its main goals are the measurement of electroweak parameters, like M_W, ZWW coupling, etc., and the searches for Higgs and SUSY particles. In the next three years the energy of the collisions will increase up to the final 192 GeV of 1999.

CDF is presently observing the technical stop needed by the Tevatron to upgrade its main injector. The goal of the experiment is to improve the integrated luminosity from the about 110 pb^{-1} collected up to 1996, to about 2 fb^{-1}. This will permit precise studies of top and b physics, and a variety of searches for exotic phenomena.

The BABAR experiment has also a wide spectrum of physics ahead. It will investigate CP violation in the B system, but also carry out the next generation of measurements in B, D and τ physics. The detector is conceived to allow very precise particle identification in the whole energy range. This includes π,K separation and K_L^0 detection. The LNF are involved in the construction of the Resistive Plate Chambers for the hadron calorimeter and the muon system.

The primary aim of the ATLAS experiment is the search for Higgs particles. This requires large solid angle coverage and very good momentum resolution for the muons, which provide the cleanest signal signature. This is achieved with a system of high proportional drift tubes, organised in 2 multilayers of 3 layers each, placed in a toroidal magnetic field. The LNF are heavily involved in the project and construction of this huge muon spectrometer.

6. LNF PARTICIPATION TO NUCLEAR PHYSICS EXPERIMENTS

The LNF participate to several nuclear physics experiments, namely A2 at MAMI, GRAAL at ESRF, HALL B at TJNAF, HERMES at DESY, LSC at BNL and OBELIX at CERN.

A2 is an experiment which will study the Compton scattering of polarised, monochromatic photons of 200-800MeV on protons. The LNF have a small contribution, devoted to the hydrogen cryo-target and gain monitoring system.

The aim of GRAAL is the photoproduction of scalar mesons (K,η) up to about 1.5GeV

with polarised photons. Also in this case the LNF contribution is numerically modest; it is devoted to the BGO ball, the dE/dx counters and the study of rare η decays.

On the contrary the participation to HALL B is quite important. The experiment is designed to measure nucleon and meson form factors, few body nuclear properties, N^* properties, strange quark signals and nuclear properties. The LNF are involved in the construction of the Large Angle e.m. calorimeter and on several beam-line devices. The physics contributions are mainly related to deuteron photodisintegration, nuclear medium effect in photoabsorption and structure functions, and in the neutron magnetic form factor.

The HERMES group is also quite large. The goal of the experiment is the measurement of the spin structure of the nucleon, through the inclusive and semi-inclusive scattering of 27 GeV polarised electrons off polarised targets. The LNF have the responsibility of the construction of the e.m. calorimeter and will be involved in the study of the polarised structure function $g_1(x)$, of the semi-inclusive asymmetries and azimuthal hadron distribution and the Q^2 evolution of the GDH sum rule.

Finally a relevant contribution is also present on OBELIX. The collaboration is studying the spectroscopy of exotic and hybrid mesons, the dynamics of nucleon-antinucleon annihilation, atomic physics and Pontecorvo reactions. The LNF are active in the field of exotic meson spectroscopy in the E/ι region.

7. LNF PARTICIPATION TO NON-ACCELERATOR EXPERIMENTS

The LNF are also present in many non-accelerator experiments, namely LVD, MACRO, ROG, VIRGO and WIZARD.

LVD is a large volume liquid scintillator detector located at the GRAN SASSO Laboratories, mainly devoted to the detection of neutrino bursts from stellar collapses occurring in our galaxy or in the Magellanic Clouds. At the moment the first of the five towers of the detector is operational. The LNF are partecipating both to the installation of the last towers and to the construction of the external tracking system for the detection of penetrating muons.

MACRO is a large area underground detector, also located at the GRAN SASSO Laboratories, optimised for GUT monopoles. The detector also allows to study high energy muon fluxes and atmospheric neutrinos, and to search for gravitational collapses neutrinos. The LNF are particularly active in the search for monopoles and in the measurement of the flux of neutrinos induced by upgoing muons.

The aim of the ROG project is the search of gravitational waves with the ultracryogenic antenna Nautilus, which is hosted at LNF, and the cryogenic antenna Explorer, which is at CERN. The Nautilus antenna is steadily running at $T \simeq 100\ mK$, demonstrating the feasibility of long term operation with this technique. Since 1996, for an average temperature smaller than 50 mK, the mean duty cycle has been of about 50%. In fact it is slowly approaching the 80% design value. In addition a record temperature of T=4 mK was obtained. The LNF are also involved in research and development programs finalised to the realization of an omnidirectional ultra-cryogenic resonant detector with spherical geometry.

VIRGO is also a project dedicated to the search of gravitational waves. Its detector, a wide-base interferometric antenna, will be built near Pisa. The LNF are involved in the development of the automatic alignment system of the optical elements of the detector.

WIZARD is a collection of projects aimed to measure the flux of particles/antiparticles and nuclei in cosmic rays. The detectors constructed with the participation of LNF will either be mounted on stratospheric ($\simeq$ 40 Km of altitude) balloons, or on Russian Resurs-Arktika satellites with polar orbit at very high ($\simeq$ 700 Km) altitude as a part of the Russian-Italian program RIM. The next balloon launch is foreseen for the spring 1997 in New Mexico (USA). The LNF are mainly involved in the construction of the Si-W calorimeter and in data analysis. The next two satellite missions, NINA and PAMELA, are foreseen for spring 1997 and winter 1999. Their duration will be in both cases of the order of about 3 years.

8. THEORETICAL ACTIVITIES AT THE LNF

The LNF theory group is composed of 10 people, working on a wide spectrum of problems. Field theory, supersymmetry and superstrings, lattice gauge theories, gravity and conformal theories, high energy physics phenomenology, solid state physics, etc. A considerable effort has been put by LNF in studying the problematic of kaon and nuclear physics in view of the $DA\Phi NE$ construction. For this reason a European network of collaboration, $EURODA\Phi NE$, has been created with the financial help of the EEC. The network presently consist of 14 institutions, of which 7 from Italy. A large number of physicists has also been convened to publish a guide for $DA\Phi NE$ physics, the $DA\Phi NE$ Physics Handbook, today at its second edition, also diffused through the World Wide Web.

9. CONCLUSIONS

The Frascati National Laboratories are presently going through a phase of intense activity, in particular for what concerns the home construction of $DA\Phi NE$ and its experiments. Nonetheless the spectrum of experiments in which the LNF are involved remains large. Both conditions are fundamental to maintain competitive the technological and scientific level of the LNF and of INFN in general.

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