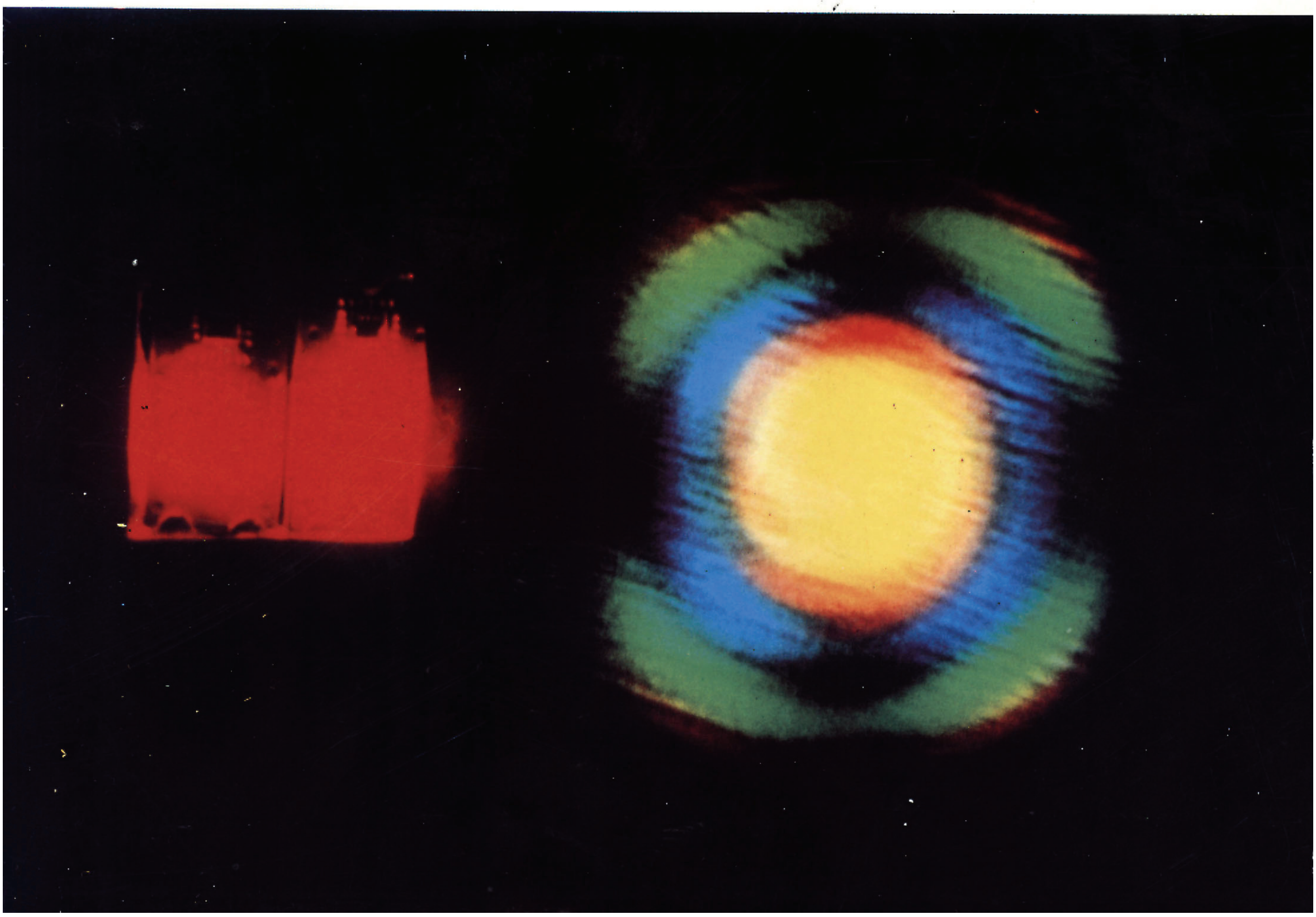
ISTITUTO NAZIONALE DI FISICA NUCLEARE

LABORATORI NAZIONALI DI FRASCATI

ANNUAL REPORT 1983



ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

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Cover photograph: light from the undulator (PULS)

INTRODUCTION

This report is divided into three parts according to the three divisions of LNF: Research Division, Accelerator Division and Technical Division.

The Research Division supervises the experimental and theoretical research programs within the guidelines of INFN research policy and the management of the activities of the LEALE, LADON, PULS and PEPR facilities. All High Energy esperiments are at present carried out in foreign laboratories e.g. CERN, Fermilab, SLAC and Orsay. LNF physicists are involved in large collaborations working in these laboratories. In particulary LNF is heavily involved in one of the LEP experiments.

LNF also carries out less conventional experiments in Passive Physics in underground laboratories viz. the proton decay experiment in the Mont Blac Tunnel and preliminary studies for monopole search in the Gran Sasso Laboratory.

Intermediate energy Physics experiments are run locally on the beams at the LINAC and LADON in Frascati and abroad on the ALS Accelerators in Saclay and at LEAR in CERN.

A new LADON beam is under construction at the Brookhaven laboratories.

In the theoretical field activities cover a wide field from collider physics, to cosmology and Solid State Physics.

In General Physics work is progressing in Synchrotron Radiation (PULS, PWA) activities along existing and new lines.

The Accelerator Division is operating and improving the current machines. Its research program includes studies on the Free Electron Laser, electron cooling for LEAR and the European Synchrotron Radiation Project.

The Technical Division provides essential support for the above activities. In particular the construction of semiautomatic devices for the assembly of plastic tube detectors is significant for present and future collaboration with other laboratories.

CONTENTS

RESEARCH DIVISION

1. - SUBNUCLEAR PHYSICS

1.1. - ALEPH

Aleph is one of the four approved experiments at LEP.

During 1983, in Frascati, the development of the hadronic calorimeter and the definition of the detector components characteristics continued. A test module was built, now on a test beam at the CERN SPS, which reproduces the longitudinal development of the calorimeter. The module is made-up of 23 layers of streamer tubes interleaved with iron slabs 100x100x5 cm^3. A double layer of tubes with X-Y reading has been put at the end of the calorimeter for μ detection. For the first time "coverless" tubes have been successfully used. Results on the linearity of the charge response of the module, obtained in December 1983, are shown in Fig. 1.

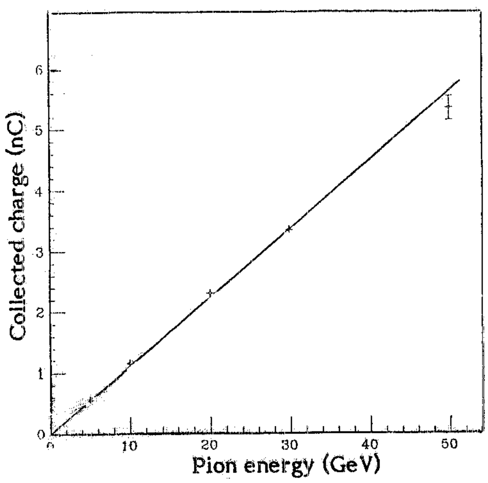

FIG. 1

Preliminary results on energy resolution give:

$$\sigma_E/E = (0.83 \pm 0.05)/\sqrt{E}.$$

The group is now continuing the test at CERN and is working on the machinery necessary for the large scale production of the hadron calorimeter streamer tubes, which will begin in the second half of 1984.

In parallel, part of the group is working on the gas system and on the read-out electronic prototypes. Work is going on the development of data acquisition and control software, together with Montecarlo programs for the generation of hadronic showers, their analysis in the calorimeter and algorithm definitions for best μ/π separations.

ALEPH Frascati group:
R. Baldini, G. Beck, G. Bologna (Ass.), G. Capon, F. Celani, A. Ciocio (Ass.), B. D'Ettorre-Piazzoli (Ass.), G. Felici (Ass.), P. Laurelli, G. Mannocchi (Ass.), G.P. Murtas (Ass.), M. Pallotta and P. Picchi (Ass.)
Technicians: M. Anelli, G. Corradi, U. Denni, G. Mazzenga and G. Nicoletti.

Collaboration with:
Athens, Bari, Clermond-Ferrand, Copenhagen, Dortmund, Ecòle Polytecnique, Edinburgh, Glasgow, Heidelberg, Imperial College, Lancaster, Marseilles, Max-Planck Institute, Orsay, Beijing, Pisa, Rutherford, Saclay, Sheffield, Siegen, Trieste, Westfield College and Wisconsin.

1.2. - CDF (Collider Detector Facility)

The Collider Detector Facility (CDF) is planned to explore the physics opportunities of the Fermilab Tevatron I project. The design, construction and initial use of this facility is being carried out by a consortium of physicists from various Universities.

It is the responsibility of INFN and the University of Purdue to construct and put into operation the hadron calorimeter (Figs. 2 and 3). INFN is also providing the vertex mini-detector and, in collaboration with the Rockfeller University, the small angle silicon spectrometers to measure the elastic scattering, σ_T and the diffractive production.

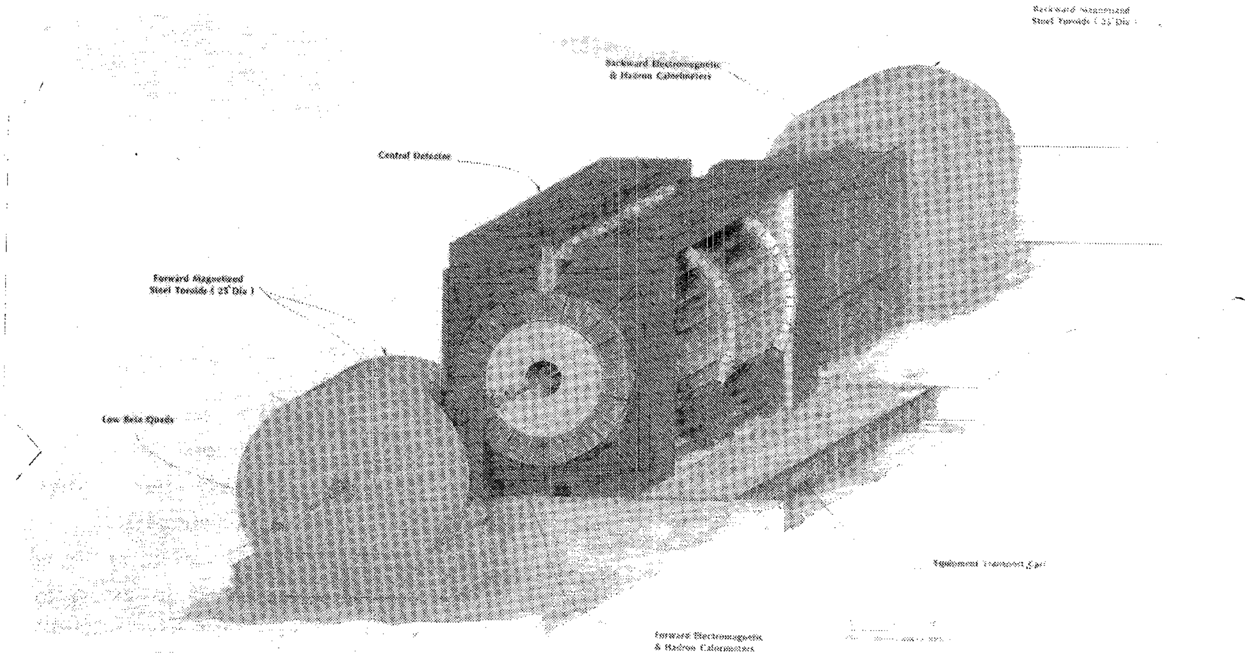

FIG. 2

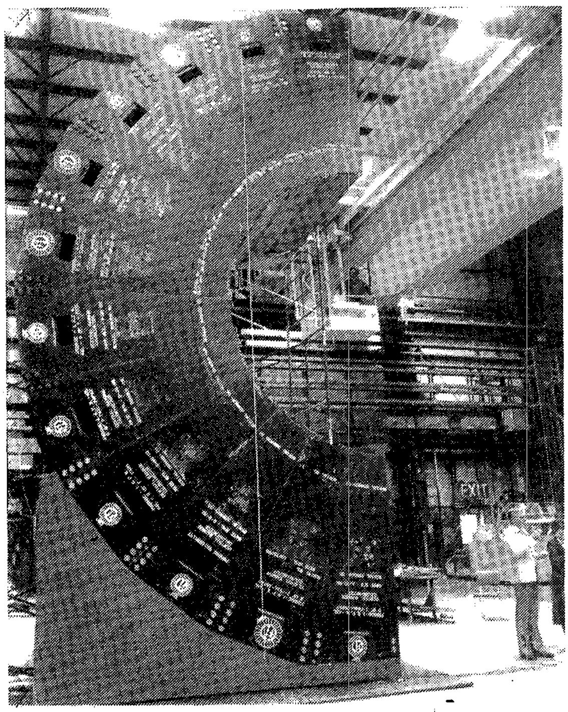

FIG. 3

The construction of the hadron calorimeter finished in Frascati at the end of January 1984. The assembly and the test of the calorimeter will continue in Fermilab up to the end of 1984.

The first prototype of the 7 vacuum pots to contain the silicon spectrometer is under construction in Frascati, while construction of silicon detectors has started in Pisa.

CDF Frascati group:
Physicists: S. Bertolucci, S. Bartalucci, M. Cordelli, M. Curatolo, B. Esposito, P. Giromini, S. Miozzi (L.), M. Pallotta and A. Sansoni (Ass.).
Technicians: M. Biagioli, R. Dal Molin, S. Mengucci, A. Rutili.

Collaboration with:
Argonne, Berkeley, Brandeis, Chicago, Fermilab, Harvard, Illinois, KEK, Pennsylvania, Pisa, Purdue, Rockfeller, Rutgers, Texas, Tsukuba and Wisconsin.

1.3. - DM2

DM2 is the only experiment which is still working on e^+e^- storage ring in the energy range 1200÷3000 MeV and, with the Mark III experiment, the only which is collecting new high statistics data at the J/ψ mass.

Concerning low energy, work was completed in 1983 and the analysis of the process is going to be published:

1) Kaon (Fig. 4) and proton (Fig. 5) form factors;
2) $e^+e^- \to \pi^+\pi^-\pi^0$ (Fig. 6) and $\pi^+\pi^-\pi^+\pi^-$ (Fig. 7).

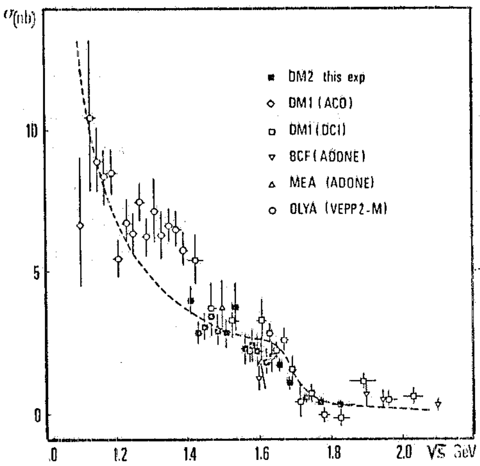

FIG. 4 - $e^+e^- \to K^+K^-$ cross section.
Dashed line: ϱ, ω, ϕ tail plus $\varrho', \omega' \phi'$.

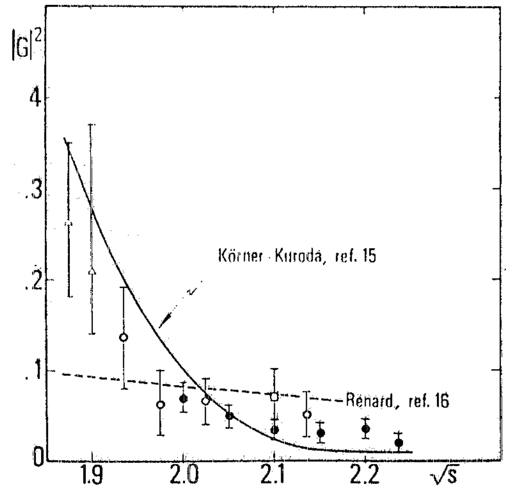

FIG. 5 - Proton form factor.

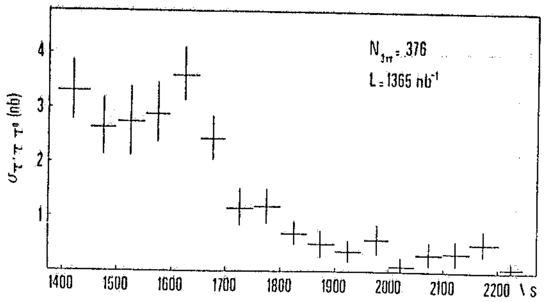

FIG. 6 - $e^+e^- \to \pi^+\pi^-\pi^0$ total cross section.

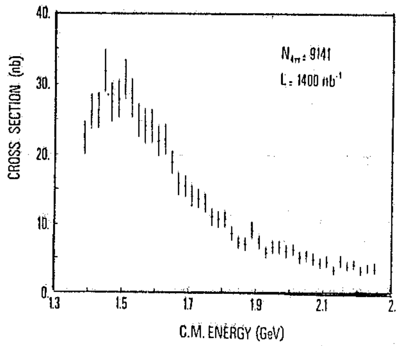

FIG. 7 - $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$
total cross section.

For other processes (as $e^+e^- \to K^0_S K^0_L$, 5π and 6π, $e^+e^- \to K\bar{K}\pi$ and $K\bar{K}\pi\pi$) and for the total cross section the analysis is in progress.

The behaviour of the analyzed cross sections shows that a further extension of lower energies is needed, overlapping with Novosibirsk and Orsay data, if we want a coherent pattern of ϱ, ω and ϕ recurrencies.

Concerning the study of the J/ψ decay the integrated luminosity (~ 3 milions of J/ψ hadronic events) was almost doubled in 1983 and we plan for ~ 8 milion in 1984.

DM2 is now the experiment with highest statistics in the world. It is well know that J/ψ radiative decays are a suitable source of standard and non-standard meson spectroscopy. For example Mark III has detected an unexpected structure in the $J/\psi \to \gamma K^+K^-$ decay at $M_{K\bar{K}}$ = 2200 MeV, whose width is compatible with the experimental resolution. DM2 results concerning 1.6 milions collected $J\psi$ are shown in Fig. 8.

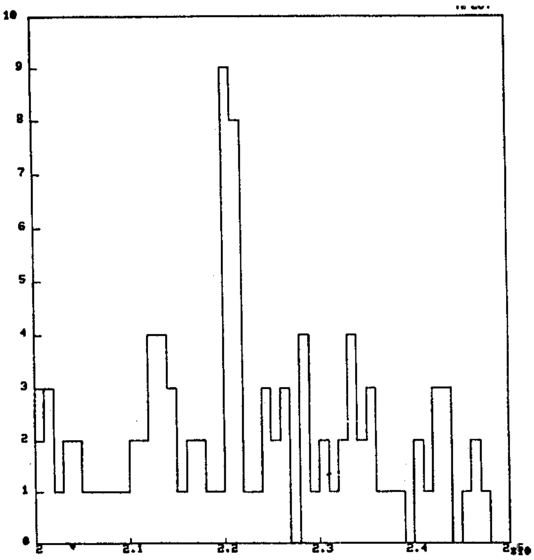

FIG. 8 - $M_{K\bar{K}}$ for $J/\psi \rightarrow \gamma K^+K^-$ around $M_{K\bar{K}} = 2.2$ GeV.

DM2 Frascati group:
A. Antonelli (Ass.), R. Baldini, S. Calcaterra (Ass.) and G. Capon.

Collaboration with:
Clermont-Ferrand, Orsay and Padova.

1.4. - FLATEV (E687)

The aim of this experiment is the study of the photoproduction of states containing heavy quarks, charm and beauty using a multiparticle spectrometer and a vertex detector equipped with live targets.

The experiment is scheduled to run with the wide band photon beam in the "Proton East Area".

The specific objectives of this experiment are:

1) study of the beauty photoproduction cross section;
2) investigation of specific beauty decay modes;
3) measurement of specific beauty decay modes;
4) measurement of the lifetimes and branching ratios of final states with charms as F-decay modes (including those involving τ's); decay modes of charmed baryons Λ_c, Σ_c and Σ_c^*; masses and decay modes of barions bearing both charm and strangeness; lifetime measurements Cabibbo suppressed hadronic decays; Cabibbo supposed semileptonic decays; rare decays; exotic four-quark charmed mesons etc;
5) search for new phenomena.

The initial phase of the experiment will give us an initial indication of the level of the beauty cross section with the measurement of events with many muons in the final state as

$$\begin{aligned}\gamma + N \rightarrow\ & \mu^+ \mu^+ + X \\ \rightarrow\ & \mu^- \mu^- + X \\ \rightarrow\ & \mu^+ \mu^- \mu^- + X \\ \rightarrow\ & \mu^+ \mu^+ \mu^- + X \\ \rightarrow\ & \mu^+ \mu^+ \mu^+ \mu^- + X.\end{aligned}$$

From the knowledge gained of the semileptonic branching ratios measured at CESR it is possible to measure the photoproduction cross section in these processes.

For the study of the mass and lifetime of the beauty we use special hardware and software triggers given by the vertex detector.

The Frascati National Laboratories have in this collaboration the responsibility for the construction of one of the two electromagnetic calorimeters foreseen for the E687 experiment.

The calorimeter consists of 30 phases of 1 cm thick scintillator strips. Consecutive scintillator phases are 90° rotated with respect to each other and the lead layers sandwiched in between correspond to $\sim$ 20 r.l.

Along the beam direction the calorimeter is split into 3 independent blocks with 10 scintillator each. In each block the light, from the strip, having the same X or Y coordinate is collected by 5 plexiglass light pipes and conveyed onto the photomultipliers. A pre-sampling block of 2 planes of scintillator strips sandwiched with lead helps in increasing the π-e rejection factor.

The calorimeter has been designed to identify and measure the energy of γ in the 1-10 GeV range and to identify electrons $\lesssim$ 25 GeV.

During 1983, using a Montecarlo program especially conceived for the photoproduction of beauty events (LNF-83/22), where the longitudinal and trasversal segmentation of the calorimeter was optimized, the mechanical project was designed. We have also studied the gain variations of different photomultiplier types for high values of the injected currents. In this way we have been able to select particularly stable photomultipliers.

About 600 light guides were constructed. We have also started to cut $\simeq$ 2500 polypop strips using a conventional milling machine instead of the laser one. In fact, for our purposes the conventional milling machine gives better quality results.

The first test at Fermilab are foreseen for July 1985.

FLATEV Frascati group:
S. Bianco (L), M. Enorini (Ass.), F.L. Fabbri, A. Maccari (L), G. Rivellini (Ass.) and A. Zallo
Technicians: L. Daniello, M. Giardoni, L. Passamonti and V. Russo.

Collaboration with:
Bologna, Colorado, Fermilab, Milano and Pennsylvania.

1.5. - FRAM

1.5.1. - NA1 Exaperiment

During 1983 the FRAM layout was modified with the installation of the germanium monolitic target. This new type of target is able to measure the charged multiplicity of the decay products of D states with a resolution of 50μ which increases the sensibility of the measurable lifetime on the 10^{-13} sec region.

The analysis of the data collected during 1983 is in progress.

1.5.2. NA7 Experiment

The measurement of the pion form factor in the time-like region for q^2 values between 0.1 $(GeV/c)^2$ and 0.18 $(GeV/c)^2$ has been done.

Existing information on the pion form factor in the time-like region below a q^2 of 0.5 $(GeV/c)^2$ is poor and in the range covered by the present experiment only one point has been measured at a q^2 of 0.16 $(GeV/c)^2$, and with a 20% error. Other data at lower q^2 comes from indirect measurements and are model dependent. The importance of a measurement of the pion form factor in the low q^2 region has been stressed several times, not only to measure the coupling of the time-like photon to the hadronic current in this region, but also to improve the hadronic correction to the calculation of (g-2) for the muon.

In this experiment the form factor has been easily determined by measuring simultaneously the cross sections for the reactions $e^+e^- \to \pi^+\pi^-$ and $e^+e^- \to \mu^+\mu^-$ since

$$|F(q^2)|^2 = C(q^2)\sigma(e^+e^- \to \pi^+\pi^-)/\sigma(e^+e^- \to \mu^+\mu^-)$$

where C is a factor dependent only on the π and μ masses and on q^2, but which includes radiative corrections. However, the predominant terms in the radiative corrections cancel out in this ratio and only minor contributions, of the order of a few percent, remain.

We have done our measurement using positrons of 100, 125, 160 and 175 GeV/c on a hydrogen target. The experimental layout used is the FRAM spectrometer.

The values obtained for the pion form factor are (Phys. Letters 138B, 454 (1984)) plotted in Fig. 9.

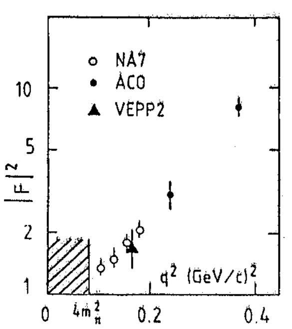

FIG. 9

Statistical errors only are shown. No deviation from a smooth trend towards F(0)=1 is suggested by our data which are in good agreement with those of previous experiments. Using the combination of the present results with the NA7 measurement of the pion form factor in the space-like region (Phys. Letters 146B, 116 (1984)) permits a realiable interpolation through the unphysical region.

FRAM Frascati group:
A. Ciocci (L), M. Enorini (Ass), F.L. Fabbri, P. Laurelli, P. Spillantini, A. Spallone (L) and A. Zallo
Technicians: G. Corradi, L. Daniello, M. Giardoni, L. Passamonti and V. Russo.

Collaboration with:
Milano, Pisa, Torino, Trieste and Westfield College.

1.6. - GRAN SASSO

The design of the new semiautomatic machines for plastic streamer tube production has continued. The machines for varnishing and cutting the plastic profiles are already working. In the mean time OFTA has prepared the machine prototypes for stretching wires and for hot gas soldering. Samples of all detector components have been produced by external firms. Optimization work is under progress, ,and the production chain is foreseen to be ready in the Summer of 1984.

As far as the laboratory tests are concerned, the sensitivity threshold for streamer tubes has been measured, thus showing the possibility of detecting single electron with high efficiency in the usual operation conditions. This also confirms the possibility of using such devices in apparata for detecting low ionizing particles. Tests of different gas mixtures have been performed. In particular, Helium and hydrocarbon mixtures have been shown to be useful for streamer tube operation. This allows the use of these tubes to detect magnetic monopoles by means of Drell-Penning effect.

In collaboration with different INFN groups, CNR and CERN, a work proposal for a large area detector (LAD) has started. Such a detector (10000 m^2.sr) should be installed in the Gran Sasso laboratory and would allow searchs for magnetic monopoles down to the Parker limit. At the same time it should provide unique features for underground cosmic ray physics (in particular μ bundle physics). This apparatus should be equipped with 10 layers of tracking devices (10 plane of streamer tubes and 4 of proportional tubes) and 2 layers of liquid scintillator, for a total height of about 2 m. This detector should also be useful as an active roof for future nuclear decay experiments. The letter of intent is in preparation.

GRAN SASSO Frascati group:
G. Battistoni, H. Bilokon, P. Campana, V. Chiarella, A. Ciocio (Ass.), A.F. Grillo, E. Iarocci, A. Marini, G.P. Murtas (Ass.), F. Ronga, L. Satta, M. Spinetti, L. Trasatti and V. Valente
Technicians: U. Denni, M. Lindozzi, G. Mazzenga, G. Nicoletti and A. Pecchi.

Collaboration with:
Bari, CERN, CNR, CNR-GIFCO, Milano, Pisa, Roma e Torino.

1.7. - MAC (Magnetic Calorimeter)

MAC (Magnetic Calorimeter) is one of the experiments which are running at PEP, one of the e^+e^- storage ring facilities of SLAC (Stanford, USA).

Due to the big increase of the machine luminosity (about a factor 5 respect to the previous year), MAC has collected data in the period October 82 - June 83 corresponding to a total integrated luminosity of 120 pb^{-1}, at a cm energy of 29 GeV.

The large statistical data available, has made possible a substantial improvement one previous measurements and the opening of new research lines.

A wide range of topics that can be usefully exploited by e^+e^- interactions have been studied: quarks hadronization and fragmentation functions, the strong coupling constant α_s, the asymmetry effects from the electro-weak interference; the inclusive lepton production and flavour tagging; lifetime and branching ratios of the τ lepton; QED tests; two photon annihilation, new particles searches, etc. The most important result obtained has been the first determination of the b quark lifetime.

The efforts of the Frascati group have been directed mainly toward the setting up of the electromagnetic calorimeter and the physics connected with electron detection. The shower chamber has been calibrated and the pulse height of each channel has been monitored through the time span of the data taking. After software corrections, the design resolution of the energy measurement for photons and electrons has been obtained: $\sigma(E)/E=5\%$ at 14.5 GeV, corresponding to 20% at 1 GeV.

From the study of the inclusive production of electrons in multihadronic events we have extracted information on the fragmentation of the heavy quarks and we have measured the semielectronic branching ratios:

$$Br\,(c \rightarrow eX) = (8 \pm 3)\% \,,$$
$$Br\,(b \rightarrow eX) = (11.3 \pm 1.9 \pm 3.0)\% \,.$$

Events from annihilation into a $b\bar{b}$ pair can be tagged through the presence of a high $p_\perp$ (respect to the thrust axis) electron or muon. A similar analysis was performed for the inclusive muon production; the distribution of the impact parameter of the lepton was then used to measure the b quark lifetime:

$$\tau_b = (1.8 \pm 0.6 \pm 0.4) \times 10^{-12}\ \text{sec.}$$

This result was the first non-zero determination of τ_b; it has important consequences for the weak interactions theory since it is connected to the quarks mixing angles; our results show that the mixing decreases with the generation number. In the "standard" model with 6 quarks this has implications on the mass of the "top" quark and on CP violation in heavy quark systems.

In Spring 1983, a new trigger was set up to detect events in which only one photon (or electron) is produced in the apparatus; we were therefore able to start a program to search for supersymmetric particles. The first result we obtained is a limit of 22.5 GeV on the selectron (the scalar partner of the electron) mass. During the Summer 1983 shutdown a small angle detector was added, which extends the solid angle coverage to 2° from the beam line. With the data that collected since the Fall 1983 it will be possible to search for selectron masses up to about 40 GeV.

More results obtained by MAC in 1983 include:

- Precise measurement of the value of R:

$$R = 3.89 \pm 0.02 \pm 0.11 .$$

The error comes essentially from the systematic uncertainties in the luminosity measurement and the evaluation of the radiative corrections.

- Electroweak interference effects. We measured the asymmetry in the muon pair production:

$$A_{\mu\mu} = -0.058 \pm 0.010 \pm 0.003$$

and the products of the coupling constants:

$$g_A^e\, g_A^\mu = 0.24 \pm 0.04 \qquad g_V^e\, g_V^\mu = 0.07 \pm 0.11.$$

- Higher order QED tests and search of excited muons. The reactions $e^+e^- \to \mu^+\mu^- \gamma\gamma$ and $e^+e^- \to \mu^+\mu^- \gamma$ were studied: the measured cross sections, charge asymmetry and invariant mass distributions agree well with the predictions of QED theory. No evidence has been found for excited muons with masses between 2.5 and 27 GeV/c^2.

- Study of acollinear μ pairs production. The results are totally accounted for by the QED processes $e^+e^- \to e^+e^-\mu^+\mu^-$ and $e^+e^- \to \mu^+\mu^-\gamma$ in which only the muon pairs are detected.

- Photon structure function. The production of multihadrons arising from photon-photon collision was studied under the so-called single tag condition, where one of the scattered beam electrons is detected.

The results agree well the simple parton model calculation; since the process resembles the deep inelastic scattering of the electron off the real photon target, this measurement also constitutes a measurement of the structure function of the photon as a function of Q^2, the four-momentum transfer squared of the electron.

MAC Frascati group:
R. De Sangro (Ass). A. Marini, I. Peruzzi, M. Piccolo and F. Ronga.

Collaboration with:
Colorado, Houston, Northeastern, SLAC, Utah and Wisconsin.

1.8. - ND (Neutrino Detector)

A search for neutrino oscillation was performed by the CHARM collaboration in the first half of 1983. Two identical set-ups measured the ν_μ and ν_e fluxes at two different distances from the source. The results of this experiment have not yet been published. Afterwards the experiment operated with the normal wide band neutrino beam (WBB) for a run essentially dedicated to the ν_μ-e scattering measurements.

The items concluded in 1983 are the following:

1) x-distributions in semileptonic neutral-current neutrino reactions (Phys. Letters 128B, 117). Neutral-current (NC) differential cross sections as a function of the scaling variable x for deep inelastic neutrino (antineutrino)-nucleon scattering were measured. The data have been corrected for the experimental resolutions using a novel unfolding procedure. The x-distributions determined in NC reactions are found to be compatible with the results obtained in charged current reactions, as expected by the quark model of the nucleon and by the standard model of the weak interactions.

2) Search for decays of heavy neutrinos (Phys. Letters 128B, 361). A search for heavy neutrinos was conducted in the neutrino beam produced by the 400 GeV proton beam-dump and in the normal WB neutrino beam. A heavy neutrino associated with the τ lepton was searched in the beam-dump experiment. No assumption on the nature of heavy neutrinos was made in the WBB experiment. The search was made for neutrinos decaying into two electrons and a light neutrino. Since no events were observed, an upper limit on the square of the neutrino mixing angle of $\approx 10^{-10}$ was obtained for neutrino masses greater than 180 MeV in the beam-dump exposure. From the WBB a limit of $\approx 10^{-6}$ was obtained for masses greater than 250 MeV.

3) Beam-dump. Preliminary results of the analysis of the data collected in 1982 have been presented at various Conferences, but not yet published. Basically the results of the previous experiment have been confirmed: in particularly, the ratio ν_e/ν_μ remains far from unity.

The experiment will run in 1984 with the narrow band beam (NBB) for an accurate measurement of the ratio neutral-current/charged-current cross sections.

ND Frascati group:
G. Barbiellini and V. Valente

Collaboration with:
Amsterdam, CERN, Hamburg, Moscow and Roma.

1.9. - NUSEX

The NUSEX experiment, located in the Mont Blanc tunnel, is designed to measure nucleon lifetime up to about 5×10^{31} years. The apparatus consists of a digital tracking calorimeter, for a total mass of 150 tons. The experiment has been active since June 1982; data acquisition has been going on during 1983. On average the life over total ratio has been about 85%. Data analysis is mainly devoted to those events which are contained in the fiducial volume, in order to discriminate possible nucleon decays against atmospheric neutrino interactions (CERN-EP/83-92). Total collected data correspond to a period of 190 years; 16 contained events have been found. Only one is compatible with a photon decay in the $p \to \mu^+ K^0$ channel. Limits on τ/B.R. so far obtained are all about 10^{31} years, at 90% confidence level. These results agree well with those of other current experiments (CERN-EP/83-147).

Since the second half of 1983, NUSEX apparatus has been also equipped with a new triggering device in order to search for heavy magnetic monopoles. In fact, with this apparatus, it is possible to identify with good efficiency particles with $\beta \gtrsim 2\times10^{-4}$ and specific ionization down to 1% of minimum ionizing particles. In this range of velocity and ionization a limit of $\varphi \leq 7.1\times10^{-13}$ cm^{-2} sr^{-1} s^{-1} has been obtained at 90% confidence level.

In the meantime the analysis concerning cosmic ray physics goes on.

NUSEX Frascati group:
G. Battistoni, P. Campana, V. Chiarella, A. Ciocio (Ass.), E. Iarocci, G.P. Murtas (Ass.), L. Trasatti and L. Satta
Technicians: U. Denni, G. Mazzenga and G. Nicoletti

Collaboration with:
Milano, CERN and Torino.

1.10. - R-110 ISR(Study of high mass electron pairs, high p_t phenomena, direct PP $P\bar{P}$ comparisons and accelerated ion beam collisions)

The apparatus shown in Fig. 10, consists of a superconducting solenoid with a magnetic field of 1.4 Tesla enclosing a drift chamber system (8-10 radial points of lecture) and four lead-scintillator modules for showers measurement. Each module, cylindrically shaped, subtends 50° in azimuth and ±1.1 unit of rapidity Y (centered at y_0=0) and is segmented azimuthally in 8 counters equipped with photomultipliers at both extremities.

The electromagnetic showers rivelation is completed by two lead glass modules composed of 168 blocks outside the magnet, in the angular region not covered by the lead scintillator shower counters, each of them subtends 57° in azimuth and ±0.6 units of rapidity.

The lead glass thickness is 21 radiation lengths and the thickness of lead scintillator modules is 14

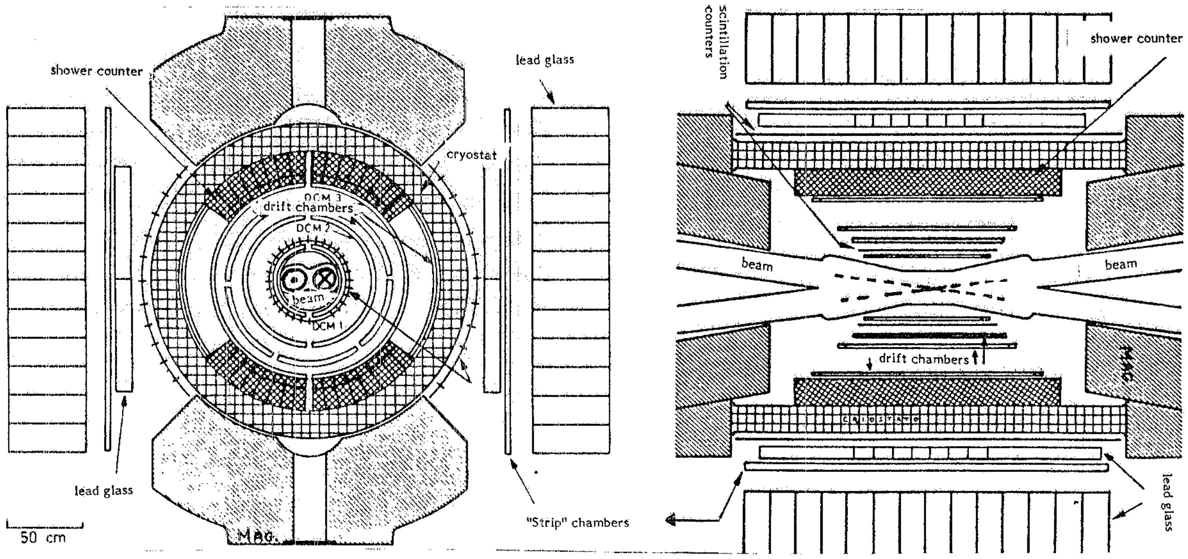

FIG. 10 - The R-110 apparatus at the CERN ISR.

radiation lengths, the energy resolution is $(4.3/\sqrt{E}+2)\%$ and $16\%/\sqrt{E}$ (E in GeV) respectively.

The lead glass modules are divided in two parts, the first one of 4 radiation lengths and the lead scintillator modules are also divided in two parts (3.7 radiation lengths the first one). A 32 scintillator counter hodoscope is placed between the first two drift chamber cylinders and two others (each one of 12 counters) are placed immediately outside the magnet just in front the lead glass modules.

Finally between the first and the second part of the lead glass wall (on each side of the magnet) two multiwire proportional chambers (MWPC with cathodic read-out) are interposed for a better shower localization.

Among the results already obtained are:

- A comparison of the production of π^0-mesons in PP and P$\bar{\text{P}}$ interaction at the CERN ISR (Phys. Letter 118B, 217). In this paper we present a direct comparison of PP and P$\bar{\text{P}}$ interactions at $\sqrt{s}=52.7$ GeV at the CERN ISR; the quantities which are compared are the multiplicities, the total transverse energy (F_t) up to 12 GeV, the inclusive cross section of π^0 production up to 5 GeV/c P_t. No significant differences are founded (Fig. 11 and 12).

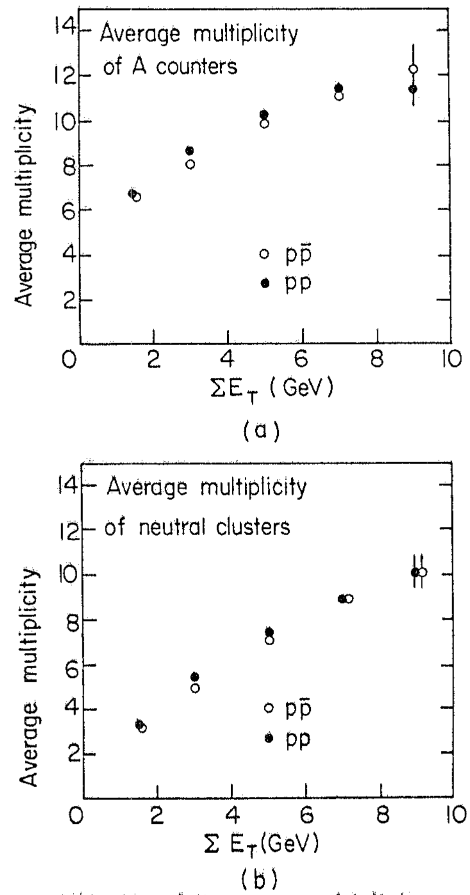

FIG. 11 - a) the mean multiplicity as a function of E_t ; b) the mean multiplicity of neutral clusters as a function of E_t.

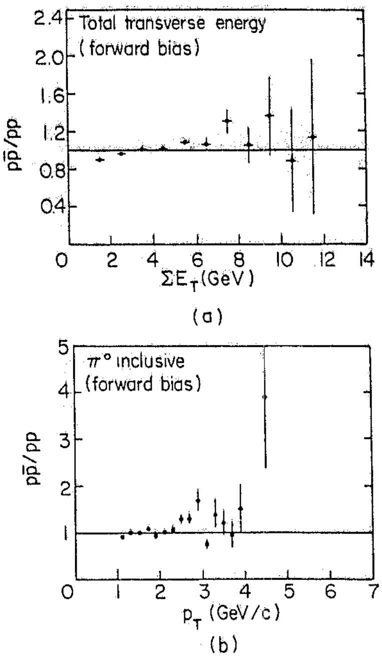

FIG. 12 - a) the ratio of E_t spectra in P-P and P-P̄ interactions; b) the ratio of the cross sections of π^o productions in the same interactions.

\- Observation of jet structure in high transverse energy events at the CERN Intersecting Storage Rings (Phys. letters 126B, 132). In this paper we presented the dN/dE_t^o spectrum (E_t^o = transverse neutral energy). The measurement made at $\sqrt{s}$=62 GeV in PP interaction is in the range of E_t^o from 10 to 30 GeV. The evidence of a large fraction of jet type events, this fraction growing with E_t^o. (Fig. 13) is stressed.

\- High P_t π^o production from $\alpha\alpha$ and αp collision at the CERN ISR (Phys. Letters 116B, 379). In this paper we presented the cross section of π^o production in $\alpha\alpha$ and αp interaction up to transverse momentum of 7 GeV/c and 8 GeV/c respectively. These results are compared with π^o production in pp interaction at the same value of $\sqrt{s}$/nucleon and the variation of A dependence with P_t is stressed (Fig. 14).

The following results was presented at the Brighton U.K. Conference, in July 1983, and will be published soon:

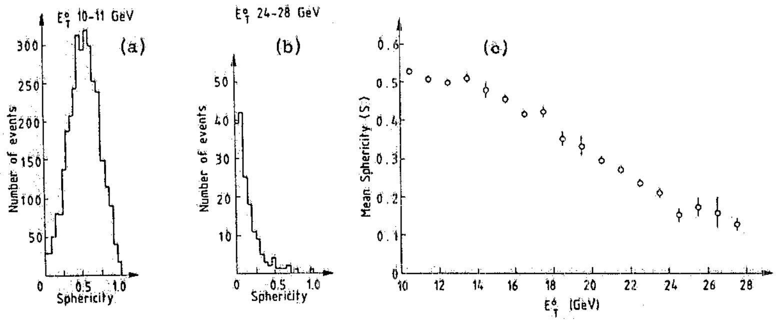

FIG. 13 - a) the sphericity distribution for events in the energy range E_T^o 10-11 GeV; b) the same in the range 24-28 GeV; c) sphericity mean value distribution as a function of E_T^o.

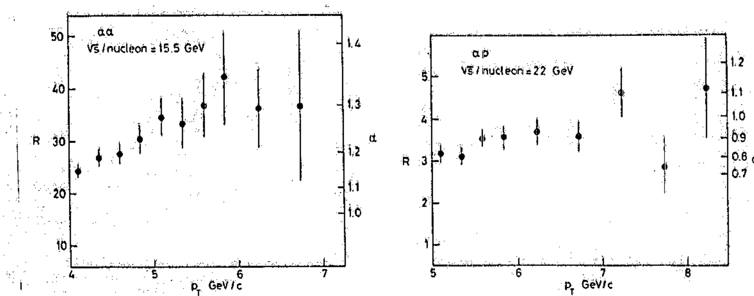

FIG. 14 - Results for R and α obtained with $\alpha\alpha$ beams at $\sqrt{s}$=15,5 GeV/nucleon and with α-p at 22,2 GeV/nucleon. R is the ratio of the cross-sections and α= ln R/ln A_1 A_2 where A_1 and A_2 are the atomic numbers.

- Electron pairs at masses greater than 11 GeV/c^2 (mass spectrum, P_t spectrum and associated particles).

- Total neutral energy trigger (total transverse energy E_t^o up to E_t^o=35 GeV and confirmation of our results (1982) on jets dominance above 20 GeV.

- The comparison of PP and P$\bar{P}$ collisions at $\sqrt{s}$=52. No evidence for difference in π^o production up to $P_t \simeq 9$ GeV/c. The ratio of E_t^o in the two interactions is measured up to 18 GeV and at the end of the spectrum this ratio deviates from the unit of about 20%.

At the Brookhaven Conference (Quark Matter Conference 1983) a comparison work of $\alpha\alpha$ and P$\bar{P}$ collisions which showed for the same value of $\sqrt{s}$/nucleon a ratio of four orders of magnitude in the total neutral energy, was presented.

Even at the highest energy values the $\alpha\alpha$ events shows isotropicity.

R-110 ISR component:
G. Basini

Collaboration with
CERN, Michigan, Oxford and Rockfeller (CMOR).

1.11. - R421

The purpose of the experiment R421, performed by the BCF Collaboration at the ISR with the Split Field Magnet Facility, is the study of a new method to investigate the multiparticle systems produced in low-p_T hadronic interactions, (pp) and ($\bar{p}$p) at the ISR). The results show that striking similarities do exist between (pp) and (e^+e^-) (Fig. 15), in contrast with the usual results of the standard analysis, which does not take into account the leading proton effects.

During this year the analysis has been extended to the study of:
- the scale breaking effects;
- the correlation properties;
- the comparison with lepton Deep Inelastic Scattering (DIS) processes.

This new series of results provides evidence of further analogies with (e^+e^-) in the scale breaking effects and in the correlation properties, and shows a

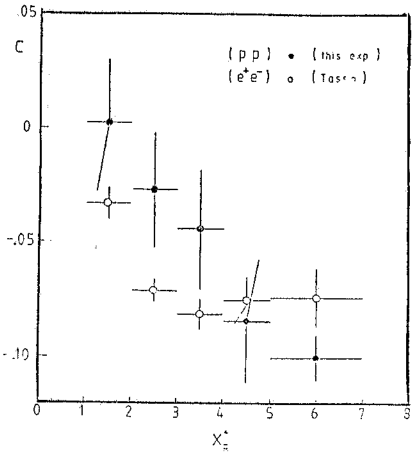

FIG. 15 - The values of the coefficient C vs. x_R^*, as measured in (pp) interactions (this experiment) and in (e^+e^-) annihilation. This is a way of measuring scale-breaching effects.

new surprising feature of (pp) interactions: in fact it has been found that (pp) interactions do produce the same results as the lepton DIS processes (i.e. (νp), ($\bar{\nu}$p), (μp) scattering) when analysed in the correct way.

The comparison with DIS processes has been studied in terms of the following quantities:

1) the average charged particle multiplicity;
2) the forward and backward average charged particle multiplicities;
3) the fractional energy distributions.

The analysis of data is going on.

R421 Frascati group:
M. Curatolo, B. Esposito, M. Spinetti, G. Susinno and L. Votano
Technicians: A. Benvenuto, D. Fabbri, M. Gatta, E. Gradl, F. Masi and M. Ventura

Collaboration with:
Bologna and CERN.

1.12. - R422

The purpose of the R422 experiment is to study the associated production of heavy flavoured states in proton proton collisions at the highest ISR energy using the Split Field Magnet spectrometer and a powerful electron identification system.

Part of the apparatus was installed for a test period from May 19th to July 1st. In particular, during this period, the new lead limited streamer tubes showers detectors were thoroughly tested and found to perform according to expectations.

The complete apparatus was installed by September 8th and after final setting up, data was taken from October 31st to November 13th and from December 16th to December 23th. The integrated luminosity collected was 1.25×10^{37} cm^{-2} and the total number of events 38×10^{6}.

R422 Frascati group:
M. Curatolo, B. Esposito, M. Spinetti, G. Susinno and L. Votano
Technicians: A. Benvenuto, D. Fabbri, M. Gatta, E. Gradl, F. Masi and M. Ventura.

Collaboration with:
Bologna and CERN.

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2. - NUCLEAR PHYSICS

2.1. - FISSI/LE (Photofission of U, Bi and Au at intermediate energies).

Measurements of photofission cross sections, in the energy range 100 ÷ 300 MeV, allow the collecting of information on the fission process in an energy region where the proton is observed either by a correlated neutron-proton pair (quasi-deuteron model) or by a single nucleon (photomesonic model). Previous measurements have been performed using bremsstrahlung photon beams and are indeed in disagreement.

In a recent paper (Nucl. Intr. & Meth. 203, 227) we discussed the advantages provided, in understanding photofission processes, by the use of the LEALE quasi-monochromatic photon beam, produced by positron annihilation.

In this framework we measured production of fission fragments from Au, Bi and U nuclei, in the energy range 120 ÷ 300 MeV, with steps of 20 MeV in the positron energy.

Fission fragments were detected through glass sandwiches techniques. The total energy of the photon beam was measured by a quantameter. Furthermore, photon energy spectrum has been measured on-line, using a pair spectrometer.

Fig. 16 shows Bi fission cross section values obtained in the present experiment. In the same figure are reported values recently measured at a lower energy in Mainz, using a photon beam produced by positron annihilation.

Fig. 17 shows fission cross section values per

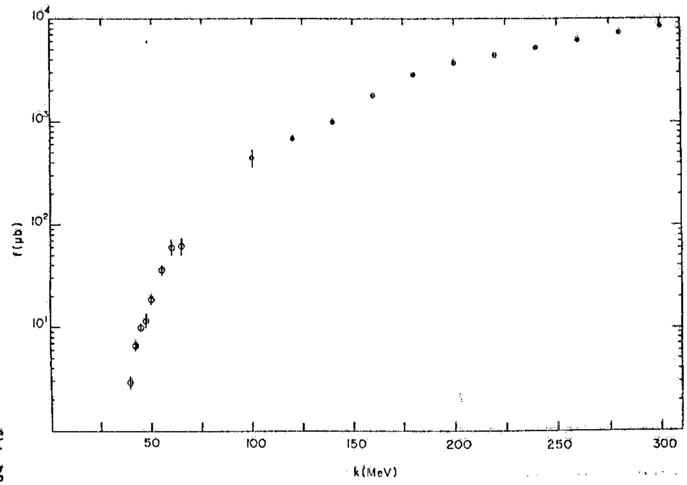


FIG. 16 - Photofission cross section values for Bismut : ● Frascati; o Mainz.

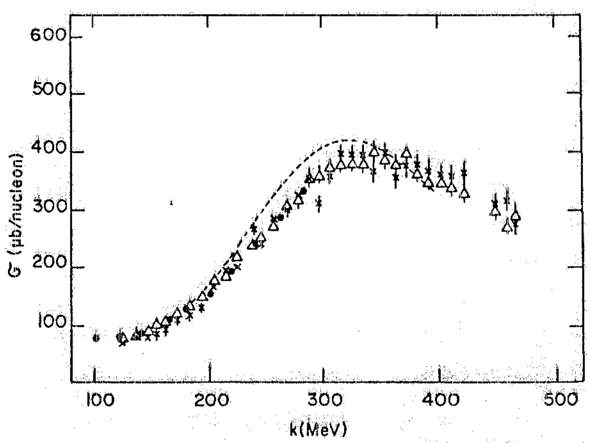


FIG. 17 - Photofission cross section values per nucleon: ● ^{238}U Frascati; Δ ^{238}U, x ^{235}U Bonn-Saclay; --- ^{9}Be photoabsorption cross section.

nucleon obtained for ^{238}U, together with preliminary values measured in Bonn for ^{238}U and ^{235}U, using a tagged photon beam.

The agreement is very good in both cases. Moreover, as shown in Fig. 17, the normalized photofission cross sections is in perfect agreement with the total absorption cross section on ^{9}Be (dashed curve).

FISSI/LE Frascati group:
E. De Sanctis, P. Di Giacomo, C. Guaraldo, V. Lucherini, E. Polli and A.R. Reolon
Technicians: M. Albicocco, A. Orlandi, W. Pesci and A. Viticchiè

Collaboration with:
Catania.

2.2. - FNNI2 (Deuteron photosintegration at intermediate energies)

The photodisintegration of the deuteron is important for the knowledge of the neutron-proton interaction and the interaction of electromagnetic radiation with nucleons. In spite of the considerable amount of effort both theoretical and experimental spent up to now on studies of this reaction, knowledge of the cross section for deuteron photodisintegration is still unsatisfactory. This is true, in particular, in the energy region between the pion emission threshold and the $\Delta(1236)$ resonance, where the reaction is increasingly influenced by mesonic effects. In fact here the range of variation of the results reported by different Laboratories is well outside any reasonable estimate of the experimental errors.

Therefore we have repeated this measure in the photon energy range $100 \leq E_\gamma \leq 260$ MeV. The experiment was carried out using the LEALE photon beam facility (Nucl. Instr. & Meth. 216, 307). The photon annihilation intensity was typically 5×10^6 γ/sec. The target was liquid deuterium contained in a mylar cylinder 9.5 cm long and 4.0 cm in diameter. Protons were detected by five dE/dx,E spectrometers, each consisting of a thin (3 mm) plastic scintillator and a cylindrical NaI crystal (11 cm diameter by 5 cm thick) having a 2.5% FWHM intrinsic resolution. Data were recorded and on-line processed on a PDP 15/76 computer.

The photon dose was measured by a quantameter. Moreover the photon energy spectrum was measured on-line with the data collection by a magnetic pair spectrometer inserted on the beam channel immediately before the deuterium target.

Proton spectra were simultaneously recorded at lab angles of 32.5°, 55°, 80°, 105° and 130° with respect to the photon beam and for six annihilation photons lab energies (100, 120, 140, 180, 220 and 260 MeV).

The preliminary results of the differential cross sections in the centre-of-mass system are plotted in Fig. 18 as a function of angle, for the given laboratory

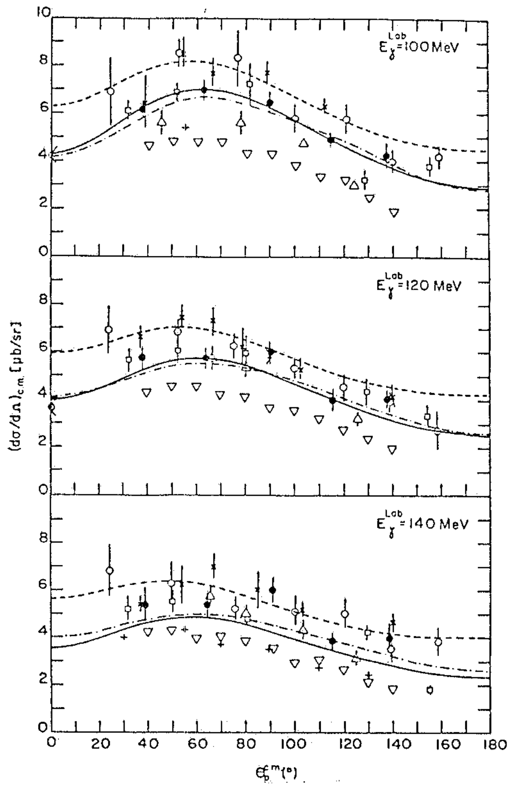


FIG. 18 - Centre-of-mass differential cross section as a function of centre-of-mass angles for the given laboratory photon energies. Our data ● are compared to the results of earlier measurements: ⊙ Hughes et al. (Nuclear Phys. A267, 329); ○ Alexandrov et al. (Soviet Phys. JEPT 6, 472); △ Keck et al. (Phys. Rev. 101, 360); □ Whalin et al. Phys. Rev. 101, 377); x Dougan et al. (Z. Physik 276, 55 and A280, 341); + Buon et al. (Phys. Letters 26B, 595); ▽ Kose et al (Z. Physik 202, 364 and to theoretical calculations by Mosconi et al. (Phys. Rev. C26, 2358) (solid line), by Arenhövel and Leideman in Workshop on "Perspectives in Nuclear Physics at Intermediate Energies" Trieste (dashed line) and by Laget (Nuclear Phys. A312, 265) (dot-dashed line).

photon energies. In the figure are also shown experimental results from other experiments and recent theoretical calculations. For older data the set showing a moderate agreement with our values are those from Illinois. The same consideration applies to the Caltech data, with the exception of data points at E_γ =100 MeV. The data of Buon et al. and Kose et al. are about 20% lower, while those of Dougan et al. are a bit higher.

The dashed curve represents a preliminary result from Arenhövel and Leidemann who extended their low energy calculation up to the pion photoproduction threshold region, adding explicit mesonic exchange current contribution beyond the Siegert operator, but neglecting inelasticities due to the opening of a real pion production channel.

The dot-dashed line is the result of a recent calculation performed by Laget using a diagram expansion technique with inclusion of final state interaction in S wave only. In this calculation Laget has used the values Λ_π=1.2 GeV, for the πNN form factor, and G_ϱ^2/G_π^2=1.6, for the ratio between the square of the ϱ- and π-baryon coupling constants.

The full line curve refers to results from Cambi, Mosconi and Ricci, who have studied the effect of higher-order contributions to the one-body (Darwin-Foldy and spin orbit terms plus relativistic correction to the wave functions) and to the two-body (one-pion-exchange both in pseudoscalar and in pseudovector πN coupling) charge densities.

All the three curves reproduce the general trend of our data: the agreement is closer for Laget and for Mosconi et al. values, while the Arenhövel and Leidemann results are roughly 20÷25% too high.

FNNI2 Frascati group:
G.P. Capitani, E. De Sanctis, P. Di Giacomo, C. Guaraldo, V. Lucherini, E. Polli and A.R. Reolon
Technicians: M. Albicocco, A. Orlandi, W. Pesci and A. Viticchiè

Collaboration with:
Genova.

2.3. - LABRO

The LABRO collaboration aims to obtain a "Ladon-type" photon beam by the 2.5 GeV X-ray storage ring placed in Brookhaven National Laboratory.

The main characteristics of this beam that one can foresee are:

- tagging system for the electrons with a resolution of ~2%;
- an energy spectrum of the produced photons between ~175 MeV and ~300 MeV;
- a good degree of polarization;
- an intensity of ~ 1×10^7 γ/sec.

The laser to be used is an Argon-Ion SP 171 working in the ultraviolet line (λ=3511 Å) with an output power of 2.5 W.

The mechanical and electronical devices employed for the alignment of the laser beam and of the optical components were designed at LNF and their accomplishment was started at Brookhaven (IEEE Trans. NS-30, 3083). We have almost finished the study of the experimental apparatus (Fig. 19) for the first foreseen experiment, consisting in the measurement of the total photonuclear cross section on different nuclei.

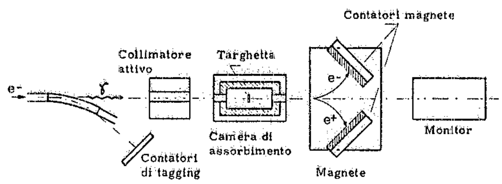


FIG. 19 - Apparatus for the measurement of the total photonuclear cross section. Active collimator: (Veto) BGO, RxH=4"x4". Anticoincidence box: Plastic scintillator NE102A (2 cm thick) and Cerenkov Silica Aerogel (10 cm thick). Counter for magnet: Plastic scintillator NE102A (2 cm thick) and Cerenkov Silicon Aerogel (10 cm thick). Monitor: NaI, RxH = 15x40 cm.

LABRO Frascati group:
Physicists: G. Giordano and G. Matone
Technicians: E. Cima and E. Turri

Collaboration with:
Roma.

2.4. - LADON (Laser on ADONE)

During the year 1983, the new laser cavity, operating in the pulsed mode-locking regime, become operational in a stable way. The power of the laser pulses is now ~ 10 times larger than in the previous set-up. Moreover, the procedures of maximization and alignment of the laser beam are completely automatized and controlled via Camac by a PDP 11/04 minicomputer. The produced γ-ray flux has achieved a net increase, reaching $\sim 6\times10^5$ γ/sec, in spite of the greater susceptibility of the new system to damage by the synchrotron radiation of the optical components.

The data acquisition is carried out by means of a PDP 11/34 minicomputer equipped with two Camac crates, each controlled by a JCC20 interface.

A new system is now under test, using Gec-Elliot interfaces and the Data Acquisition System implemented at CERN. We have also installed a CES "Firecracker" microcomputer, for speeding up the data acquisiton rate, and a CANDI microcomputer, developed in the LNF, on the magnetic pair spectrometer monitoring the γ-beam.

2.4.1. - Measure of the asymmetry factor in deuteron photodisintegration

During the current year, the LADON group continued the study of deuteron photodisintegration by measuring the angular distribution of the reaction asymmetry factor $\Sigma(\theta_n)$ at three different photon energies E_γ=19.8, 29.0 and 38.6 MeV (Fig. 20). This was done by using an experimental apparatus composed of a NE230 deuterated scintillator serving both as target and as proton counter, and of five NE213 neutron counters, capable of pulse-shape discrimination.

We also studied the function $I_o(\theta_n)$ and $I_1(\theta_n)$ which determine the photodisintegration cross section:

$$\frac{d\sigma}{d\Omega} = I_o(\theta_n) + P\, I_1(\theta_n) \cos 2\phi =$$

$$= I_o(\theta_n) \left[1 + P\,\Sigma(\theta_n) \cos 2\phi\right]$$

(P= degree of polarization of the γ-beam).

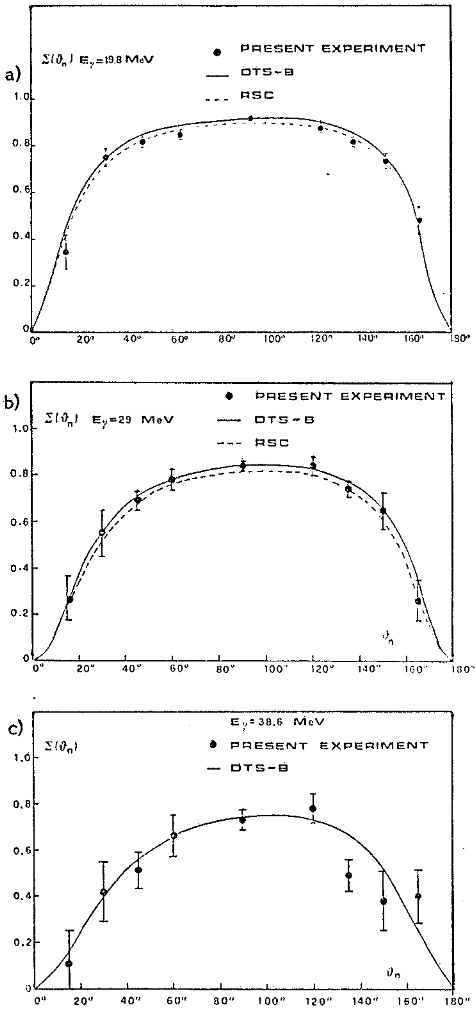


FIG. 20 - $\Sigma(\theta_n)$ versus θ_n (c.m. neutron angle) for $d(\vec{\gamma}, p)n$ at E_γ=19.8 MeV (a); E_γ=29.0 MeV (b); E_γ=38.6 MeV (c). Dashed and solid curves represent theoretical calculations with Reid soft-core and De Tourriel-Sprung potentials, respectively.

Preliminary results are shown in Figs. 21 and 22. These data were presented at the "10th Intern. Conf. on Few Body Problems in Physics" (Karlsruhe), and at the 4th Course of the "Intern. School of Intermediate Energy Nuclear Physics" (San Miniato) (LNF-83/69).

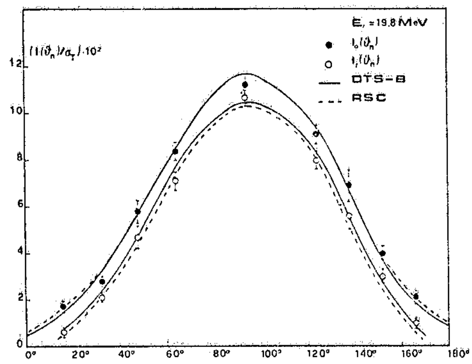


FIG. 21 - Same as Fig. 20 for $I_0(\theta_n)/\sigma_T$ (black points) and $I_1(\theta)/\sigma_T$ (circles).

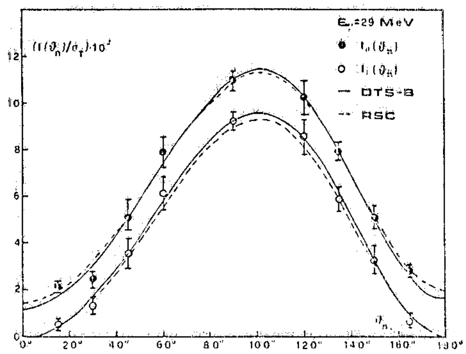


FIG. 22 - Same as Fig. 20 for $I_0(\theta_n)/\sigma_T$ (black points and $I_1(\theta_n)/\sigma_T$ (circles).

2.4.2. - Measurement of the deuteron photodisintegration total cross section

For investigating the short range nucleon-nucleon interaction, it is desirable to collect new experimental data on deuteron photodisintegration total cross section with 1-2% accuracy over a photon energy range 20-80 MeV.

This goal can be pursued taking advantage of the monochromaticity and intensity of the LADON beam. Following a preliminary evaluation of experimental feasibility, we devised the target assembly shown in Fig. 23. The gaseous deuterium is kept at high pressure

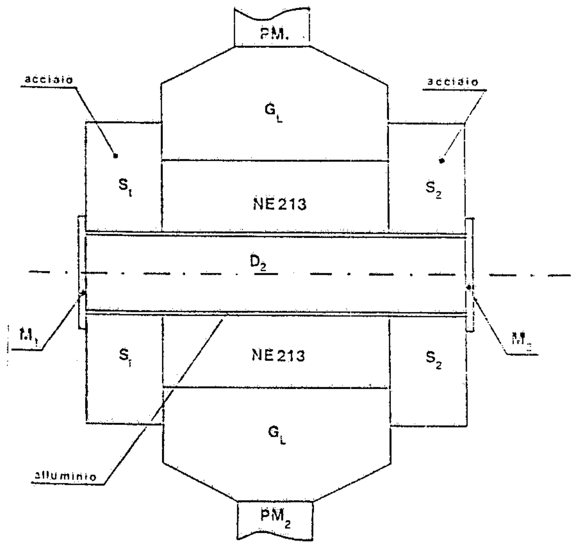


FIG. 23 - The schematic diagram of the deuterium target for the total cross section measurement of the $d(\vec{\gamma}, p)n$ reaction.

(between 20 and 100 atm) inside a 0.1 mm thick aluminum cylindric of 7.5 mm radius and 14 cm length, closed at its ends by two Macrolon plugs. The detector, surrounding the cylinder liner, is made of a NE213 liquid scintillator contained inside a glass box that is also the light guide to which two EMI 9823KB photomultipliers are optically coupled. A tomback is used to compensate the pressure between gas and liquid. An oleodynamic system allows the reaching the desired gas pressure by using two other tombacks, one for deuterium and one for hydrogen.

The use of hydrogen is meant ti improve the subtraction of e.m. - type background.

This prototype was tested under beam, but some problems arose after it was subjected to high pressure for a long time.

A new set-up, with anologous characteristics but more reliable for high pressure operation, is currently of being installed.

2.4.3. - The crystal ball

The LADON Beam intensity, although improved, is still rather low in comparison with photon sources obtained through more traditional techniques. In order to overcome this limitation, a particular effort was devoted to design a detection system with a very large solid angle, approaching 4π.

The choise fell on a NaI(Tl) crystal ball of 50 cm diameter, with a cylindric bore of 9 cm a long the beam axis, composed of 112 scintillators, each coupled to a photomultiplier. A 2 mm layer of CaF_2, placed on the face of the ball looking at the internal hole, allows pulse-shape discrimination between photons and protons. The sphere is divided into 16 section with equal $\Delta\phi$, each of them subdivided into 7 parts with equal $\Delta\cos\phi$. In this way each of the 112 crystals covers the same solid angle as viewed from a target placed in the centre of the sphere. A diagram of the apparatus is shown in Fig. 24. Preliminary tests, performed on some clusters of crystals using γ-radionuclides, gave an energy resolution of 14% at 660

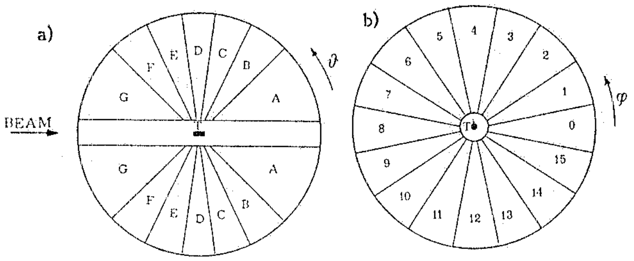


FIG. 24 - a) Longitudinal cross section of the crystal ball with a plain containing the beam axis. b) Transverse cross section perpendicular to the beam axis. Each sector corresponds to $\Delta\phi=\pi/8=22.5°$.

keV, 7.5% at 1.33 MeV and 5% at 6.1 MeV (Fig. 25). The crystal ball has been completely assembled at LNF and will soon be settled on an automatized mechanical

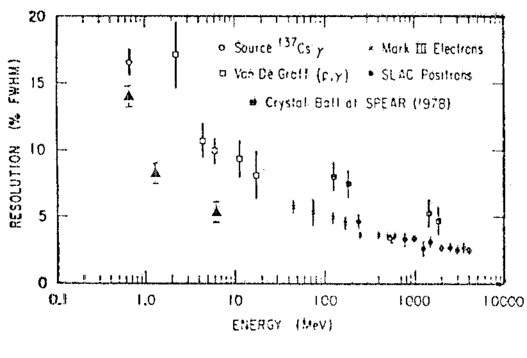


FIG. 25 - Typical resolution curve with Spear crystal ball. The triangular are the preliminary measurements of the crystal ball at the LNF.

gantry with the liquid hydrogen target. This target consists of a cell, ~60 cm from the cooling system; it has undergone the first filling trials with good results.

LADON Frascati group:
M.P. De Pascale, G. Giordano, G. Matone and P. Picozza
Technicians: E. Cima and E. Turri
Collaboration with:
Roma and Sanità.

2.5. - LION

The first part of the analysis of the inclusive data taken at 7 GeV/c with the α beam on p, d, ^{3}He, ^{4}He targets has been carried out (Fig. 26). The main item

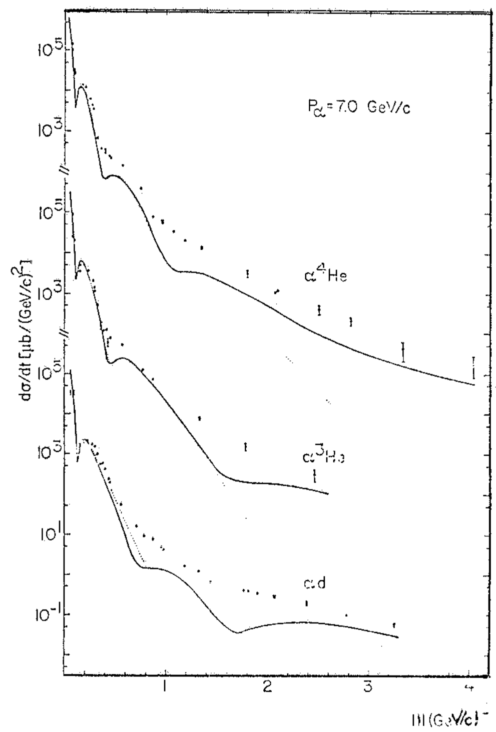


FIG. 26 - Differential cross sections for α^4He, α^3He, αd as a function of t. Continuous line: Cryzx and Maximore model. Dotted line: rigid projectile approximation.

considered in the analysis was the elastic scattering. The obtained angular distributions extend up to t ~ 4 GeV^2/c^2. Over this transferred momentum range the cross sections fall from the barn to the nanobarn level. By those measurements the same process, in identical experimental conditions, is studied on nuclei of growing A. There is a clear indication that multiple scattering dominates at high momentum transfer, but the theory accounts for these data at best qualitatively.

During the year we begun to examine the possibility of lowering the present limit on charge symmetry conservation through the measurement of the dd→ ^{4}He π^o reaction. The existing limit for the cross section of this process is 20 pbarn/sr, and was established by the same collaboration ten years ago at the Saturne I. The characteristics of the beams extracted from the Saturne II, and the performances of the new experimental apparatus are such that a new limit of 0.1 pbarn/sr for the dd→ ^{4}He π^o reaction seems not out of reach. For this purpose a γ detector for the π^o's photons must be put in coincidence with the magnetic spectrometer.

In Frascati a modular lucite-lead γ detector has been designed, and the first element will be tested on the deuteron beam in Saclay early in 1984.

A careful study of the background on the focal plane of the spectrometer was carried out in the planned kinematical conditions of the measurement.

As a byproduct of this study the η production in the reaction dd→ ^{4}He η has been observed, with a c.m. cross section of 300 pbarn/sr. With this result a more realiable calculation of the cross section for dd→ ^{4}Heπ^o (which can proceed via π^o-η mixing) can be carried out, giving a better reference value to which can be compared the experimental limit.

LION Frascati group:
M. Se Sanctis and L. Satta
Collaboration with:
Orsay and Saclay.

2.6. - SFR

2.6.1. - Exclusive deuteron electrodisintegration at high neutron recoil momentum

In the continuation of our previous ^{2}H(e,e'p)n expriment (Nucl. Phys. A365, 349), new measurements have been recently made at Saclay, in order to reach higher recoil neutron momenta between 300 and 500 MeV/c. In fact it is in this momentum region, where D-state is dominant, that the deuteron wave functions computed from various nucleon-nucleon potentials have the largest differences. To explore this region with reasonable counting rates, it is necessary to perform the measurements at small electron scattering angles. This leads to work at high energy but low momenta transfer, that is in kinematical conditions where the contributions from the Δ-isobar exchange current (IC) are quite substantial (Nucl. Phys. A314, 253).

The experiment was performed using the Saclay ALS accelerator and the two-spectrometer setup of the HE1 endstation. Electrons of 500 MeV were incident on a liquid deuterium target consisting of a 1.5 mm diameter vertical stainless steel cylinder, of wall thickness 0.02 mm. Electrons, scattered at 25°, where detected in the "900" spectrometer operating at a fixed field corresponding to a momentum of 360 MeV/c. These kinematical conditions give an excitation energy of the neutron-proton pair E^{np}_{cm} = 179 MeV and a transferred momentum $|\vec{q}_{cm}|^2$ = 1.66 fm^{-2}.

Protons were detected in the "600" spectrometer set at seven different angles and central energies in order to measure the neutron recoil momentum distribution. An automatic system enabled us to fill the target quickly with liquid hydrogen or deuterium, in order to make normalization measurements on elastic scattering cross sections. The statistical accuracy of the data is about 5% while the uncertainty in the normalization factor is 7%.

The Fig. 27 shows the comparison of our results

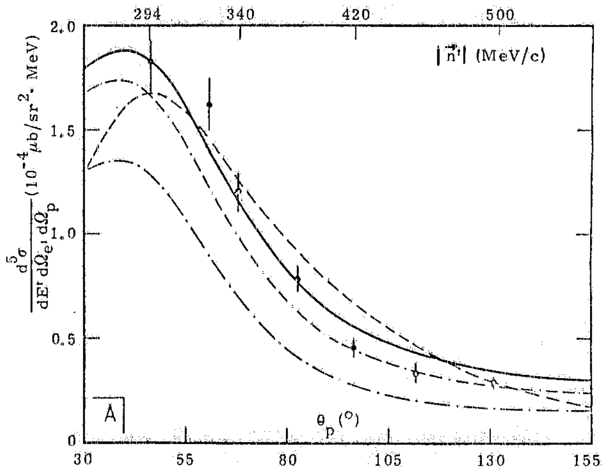


FIG. 27 - Experimental results compared with Arenhövel's calculation: --- BA: calculation using nucleon plane wave functions; -.-.- N: BA + final state interactions (FSI); --.--: N + isobar configurations (IC); — N + MEC + IS, complete calculation including explicit meson exchange currents (MEC) and isobar configurations.

with Arenhövel's (Nucl. Phys. A384, 287) non relativistic calculations, using a Reid soft core potential (which gives a D state percentage value P_D=6.47%). The BA curve corresponds to the calculation using nucleon plane wave functions. It includes also the direct neutron knock-out contribution with the detection of the spectator proton. The different corrections to BA are also shown: final state interactions (FSI) decrease the cross section down to 60% in contrast with exchange currents which increase it up to a factor of 2 (+65% for IC, +25% for MEC). In spite of the relativistic compensation of these interaction effects, the Born approximation is clearly insufficient in these kinematics. Nevertheless, there subsists a slight difference between the experimental and theoretical shapes of the angular distributions. This is also the case if other potentials are used as the Paris one (P_D=5.77%) or the De Tourriel and Sprung one (P_D=5.91%) which better reproduce the high momentum part of the distribution.

SFR Frascati group:
G.P. Capitani and E. De Sanctis

Collaboration with:
Saclay and Sanità.

2.6.2. - Monte Carlo calculation of final state interactions in (e,e'p)

One of the open problems in the study of quasi-free (e,e'p) reactions concerns the final state interactions between the outgoing proton and the residual nucleus. These interactions are usually taken into account by distorting the outgoing proton's wave by means of an optical nuclear potential. Protons absorbed by the imaginary part of the potential are considered lost from the reaction under consideration. On the other hand, a proton coming from another channel and whose momentum is changed during the interaction with the residual nucleus, may reach the detector. These protons, if misinterpreted as produced by a pure quasi-free reaction, give rise to false values of missing energy and recoil momenta.

As a consequence of this fact the energy weighted sum rule (Phys. Rev. Letters 28, 182), connecting the average kinetic energy $\langle T \rangle$ and the average separation energy $\langle E \rangle$ to the total binding energy per nucleon is not fulfilled when $\langle T \rangle$ and $\langle E \rangle$ are extracted from experimental functions obtained from (e,e'p) reactions (Nucl. Phys. A262, 461).

We made a Monte Carlo calculation (MULDIF code) which simulates completely an (e,e'p) reaction in a given nucleus, taking into account all the interactions to which the scattered proton in crossing the residual nucleus undergoes. The goal of the program is to produce as output a distorted spectral function from an undistorted one given as input.

The calculation was carried out for the $^{16}O(e,e'p)^{15}N$ process. The result of the calculation can be summarized as follows:

a) the effect of final state interaction is quite sizeable: about 50% of the knock-out nucleons undergo a second scattering;

b) final state interactions distort largely the missing energy spectrum displacing protons from the low to the high missing energy regions;

c) the shapes of distorted momentum distributions are not very different from the undistorted ones.

In Fig. 28 is shown the result of the calculation for the missing energy spectrum.

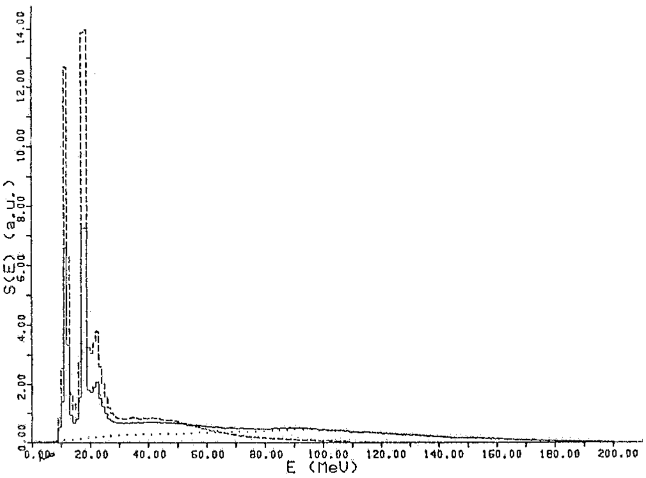


FIG. 28 - Calculated missing energy spectrum for the $^{16}O(e,e'p)^{15}N$ process, with (full line) and without (dashed line) multiple interactions. The curves have been normalized to the same area in order to emphasize the distortion effects.

By using the results of MULDIF we have calculated the quantities < T >, < E > and E_z/Z from the measured spectral functions (Nucl. Phys. A373, 381), and from the "undistorted" one. We have found a lower < E > value for the latter, while the < T > value kept quite unchanged. Consequently the E_z/Z value showed a better agreement with the mass formula prediction, although it still did not reach a saturation behaviour.

SFR Frascati group:
G.P. Capitani, E. De Sanctis and P. Levi Sandri.

2.7. - TOFRADUPP (Interaction of low energy antiprotons with nuclei).

The physical aims of the experiment is the study of the interaction of low energy antiprotons with atomic nuclei (^{2}H, ^{3}He, ^{4}He, Ne) at LEAR momenta (600 MeV/c, 300 MeV/c), down to zero energy, by means of a self-shunted streamer chamber in a magnetic field (CERN/PSCC 83-34 PSCC/P17-M164).

The apparatus takes advantage of low density gas targets, 4π acceptance of the streamer chamber, the possibility to trigger on selected events and the presence of the magnetic field. It allows the recording of elastic, inelastic and annihilation events; to measure cross sections, angular distributions and charge prong multiplicities; to detect and recognize very low heavy particles. Also neutral particles such as K^0_s can be detected with high efficiency through their decay products.

Bubble chamber data on ($\bar{p}$, ^{2}H) interaction in flight exist down to 260 MeV/c (below this momentum the interactions are considered at rest) and their analysis presents some ambiguities. The present measurements above 300 MeV/c and at low momenta allow the following relevant results:

a) a more precise evaluation of the ($\bar{p}$, ^{2}H) and ($\bar{p}$, n) cross sections. The improvements are mainly due to the good beam energy definition and to the possibility of selecting the events with a visible low energy spectator proton.

b) Information of the ($\bar{p}$, p) scattering amplitude. It has been shown that a forward-backward asymmetry in the spectator proton distribution is proportional to the ratio between the real and the imaginary part of the ($\bar{p}$, p) scattering amplitude and could give indication on the existence of poles in the ($\bar{p}$, p) scattering amplitude and of broad resonances in the ($\bar{p}$, ^{2}H) system.

We will measure for the first time the ($\bar{p}$, ^{3}He) interaction. Moreover, no other data exist on the ($\bar{p}$, ^{4}He) interaction beside those obtained on antiprotonic atoms. In particular, the study of the ($\bar{p}$, ^{4}He) annihilation is of great importance for clarifying some open cosmological questions. It could help to understand the origin of the observed abundance of the elements in the universe and in evaluating the quantity of antimatter present in its early stages.

Total cross section data for the interaction of antiprotons with complex nuclei (Be, C, O, Al, Cu, Ag) exist only between 500 and 1000 MeV/c. As far the Neon nucleus is concerned, no data exist up to now. We intend to study the ($\bar{p}$, Ne) interaction through the measurement of elastic, inelastic and annihilation cross sections; pion and heavy particles multiplicities, angular distributions. The research will be performed in two steps:

1) Measurements of the ($\bar{p}$, Ne) cross sections.
2) Studies of nuclear matter in higly excited states.

The study of antiproton absorption in nuclear matter allows the obtaining of information on different annihilation mechanisms. When the annihilation occurs on the surface of the nucleus (annihilation at rest) several pions enter the nucleus simultaneously, and each can interact independently (incoherent multipion-nucleus interaction). It is also possible that mesonic resonances are generated in the process and that subsequently they interact with nuclear matter, with emission of two fast correlated nucleons. The $\bar{p}$ can also be absorbed by correlated pairs of nucleons, with subsequent emission of high energy pions and nucleon pair. In this case information can be deduced about nucleon-nucleon correlations at distances where the effects of the quark structure may contribute in an essential way. More properly, the absorption must be considered to occur on a six-quark configuration.

In the case of annihilation in flight, when the $\bar{p}$ annihilates deep in the nucleus, in the region of high nuclear density, a "fireball" developes and travels into the nuclear matter and can give rise to interesting exotic phenomena: I) excited nuclear matter and II) quark-gluon plasma formation. The phenomena do not depend on the size of the nucleus, so that they can occur for each of the nuclei we plan to study. However, with a complex nucleus such as Neon, one should expect not only a high kinetic energy of nuclear fragments but also a high heavy particle multiplicity, that is a nuclear "explosion". This fact increases the probability to detect those exotic phenomena by means of specific additional triggers of the streamer chamber (lateral detectors) (CERN/PSCC 83-36 PSCC/P17-Add. 4).

From October 25th to November 9th 1983, during the first runs with a 610 MeV/c antiproton beam from LEAR machine, the following part of the experimental program was performed:

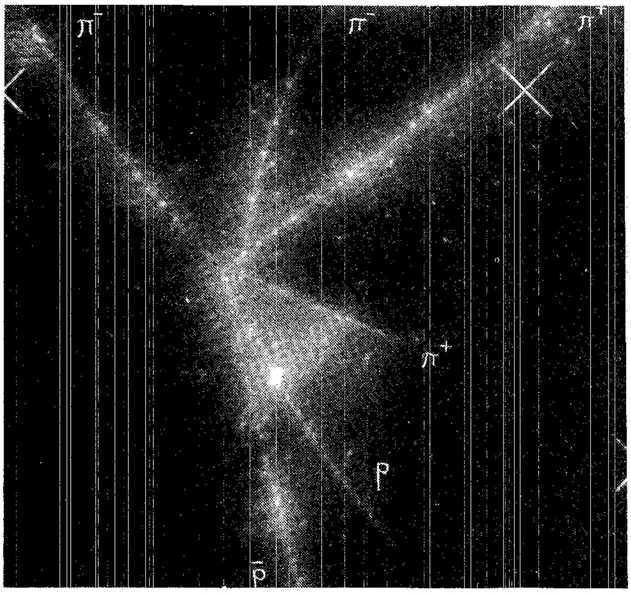
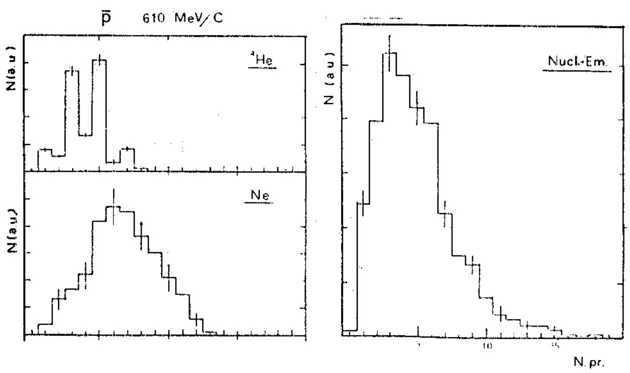


FIG. 29 - Typical annihilation event of a 610 MeV/c antiproton in ^{4}He. A K^o_s candidate is visible.



- The streamer chamber (90x70x18 cm^3) placed in a magnetic field of 0.8 T and exposed to the $\bar{p}$ beam was initially fluxed with ^{4}He (gas purity > 99%). About 19.000 photographs of $\bar{p}$ interaction on ^{4}He were taken. The absorption events analyzed at the end of December were 918 (absorption ≡ charge exchange + annihilation + inelastic). One absorption event every twelve photographs was found. The number of K^o_s candidates was 19 (~ 2% of the absorption events).
- The streamer chamber was subsequently fluxed with Ne. About 6600 photographs of $\bar{p}$ interaction on Ne were taken. The absorption events analyzed at the end of December were 300. One absorption event every six photographs was found. The number of candidates was 6 (~ 2% of the absorption events).

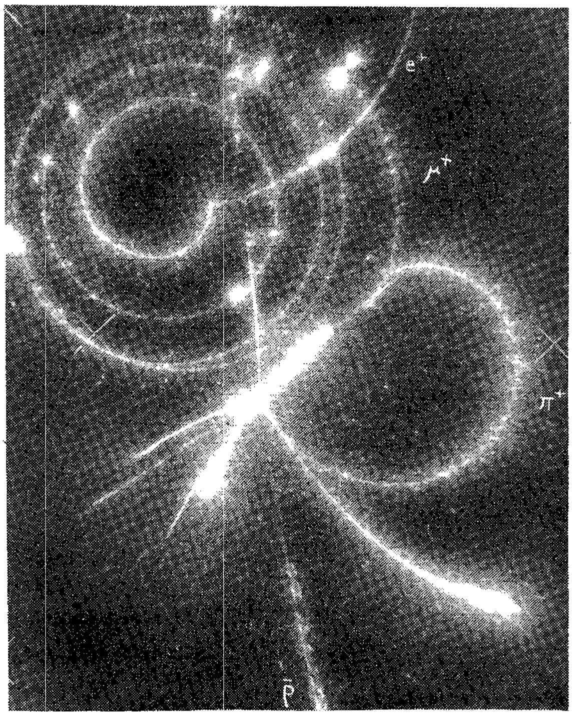


FIG. 30 - Typical annihilation event of a 610 MeV/c antiproton in Ne.

FIG. 31 - Distribution of the number of ionizing tracks for ^{4}He, Ne and nuclear emulsion.

- Also 4.6×10^5 antiprotons were stopped in one stack of 50 nuclear emulsions (10 cm x 20 cm x 100 μm), to be developed and measured at JINR (Dubna). The absorption events analyzed at the end of December were 1000.

In Figs. 29 and 30 two typical annihilation events in ^{4}He and in Ne, respectively, are shown. Fig. 31 shows the distribution of the number of ionizing tracks, for ^{4}He, Ne and nuclear emulsion.

TOFRADUPP Frascati group:
C. Guaraldo and A. Maggiora

Collaboration with:
Dubna, Padova, Pavia and Torino.

2.8. - HUNTING THE ANOMALONS

During 1983 we designed an experiment (LNF-82/23) to search, in the relativistic fragments originated by heavy ions, for an anomalous component with a very high cross section (anomalons).

The evidence of the existence of these objects has come up till now from measurements with emulsions exposed to cosmic rays or to heavy ion beams. The proposed experiment uses instead solid state and , μ-strip detectors and is able to measure both the lifetime and the production cross section of these fragments.

The design study has been completed and we foresee the start of the experiment in 1985.

Frascati group:
S. Bianco (L), M. Enorini, F.L. Fabbri and A. Zallo.

3. - THEORETICAL GROUP

The theory group is working on a variety of problems, ranging from Collider Physics to cosmology, through nuclear and solid state physics and Lattice Gauge Theory.

Collider Physics

Various phenomenological and theoretical analyses have been performed. In particular, the following problems have been studied:

1) Multihadronic distribution functions, KNO scaling violations and correlation between single pion mean transverse momentum and multiplicity;
2) infrared radiative corrections to Z_o mass and width distributions;
3) anomalous radiative Z_o decays and their interpretation in terms of excited lepton decays;
4) W and Z_o transverse momentum distribution in terms of soft and hard gluon bremsstrahlung;
5) jet production and the three gluon coupling.

Field Theory

The properties of vacuum in the Wess-Zumino massless model have been studied in the c $-\infty$ limit. Radiative corrections in abelian gauge theories have been discussed in the presence of periodic boundary conditions. It was found that under such conditions the theory is compatible with a new parameter, in addition to the mass and the coupling constant. This introduces in the theory a new energy scale.

Nuclear Physics

Study of the two rotors model of heavy deformed nuclei and the spin-isospin excitations of light deformed nuclei has continued, in particular in connection with the experimental activity. Theoretical calculations have been performed in connection with Richter experiments on ^{156}Gd which has confirmed the model predictions, as well as on ^{20}Ne for the spin-isospin excitations.

Solid State and Statistical Mechanics

Using high energy techniques and insight, two well known solid state problems have been discussed and partly solved: the problem of 1/f noise has been interpreted as due to soft QED radiation and discussed using the Bloch-Nordsieck type summation. Production of chiral particles near a monopole and quantized Hall effect have been studied using the analogy between the theory of superconductivity and non-abelian gauge fields ebt. In the framework of the Synchrotron Radiation project, a generalization of the multiple scattering method has been formulated for the calculation of the X-ray Absorption Structure in condensed matter, which allows the elimination of the so called muffin-tin approximation.

As a by-product a simplication of the matricial Numerov method for the solution of systems of coupled differential equations arising from the Schrödinger problem in three dimensions has been derived, which allows a much faster computation of the solutions.

Finally, in order to elucidate the connection between coordination geometry and X-ray Absorption Near Edge Structure, the study of simple molecular systems (C_2H_n series, n=2,4,6) has been undertaken. The condition DetM=0, where M is the multiple scattering matrix, has been used to obtain an implicit relation between the multiple scattering resonance in the continuum and C-C bond length. The conditions under which this relation is valid have been discussed and the theoretical predictions compared with the experimental results.

Lattice QCD

Results from Montecarlo simulations have used the largest lattice employed so far in this kind of study. Calculation of matrix elements of relevant operators in Weak non-leptonic decays are very encouraging. Also, quark-loop effects for $\varrho - \omega$ mass splitting show that contribution to the action is of the same order of magnitude as the kinetic energy term in the pure gauge. Paquette-plaquette correction functions have been evaluated for a mixed SU(2) theory with satisfactory results.

Cosmology and Underground Physics

The problem of the cosmological production of monopoles has been studied. Monopole-antimonopole annihilation has been proposed as a mechanics which could reduce monopole density. Also physical and astrophysical neutrino production has been studied, in connection with experiments proposed for the Underground Laboratory under the Gran Sasso Mountain.

Contributors:
V. Ascoltì, G. De Franceschi, E. Etim, S. Ferrara, A. Gargano, M. Greco, A.F. Grillo, G. Martinelli, A. Nakamura, C. Natoli, F. Palumbo, G. Pancheri, G. Parisi and Y.N. Srivastava.

4. - GENERAL PHYSICS

4.1. - CANDI 2

During the year 1983 the CANDI 2 group has terminated the industrialization of the system. CANDI 2 is now assembled and commercialized by SEA (Strumentazione Elettronica Avanzata, Roma). Eight systems were delivered during the year, mostly to INFN sections.

In the meantime, work has continued on upgrading the system with peripherals. The floppy disk-winchester hard disk coprocessor is almost ready to be delivered and a memory expansion board containing 8 ADC channels has been tested and defined.

On the communication side, a prototype board for HDLC/X25 protocols is under test, and an agreement has been reached with OLIVETTI (Ivrea) to develop Ethernet on the CANDI system. This powerful local area network is becoming increasingly popular, and the possibility to access it will dramatically increase the capabilities of the CANDI 2 system.

CANDI Frascati group:
M.L. Ferrer and L. Trasatti
Technicians: O. Ciaffoni

Collaboration with:
ENEA -Frascati.

4.2. - CARIOPEPR

We are studying the possibility of using the PEPR apparatus (Precision Encoding and Pattern Recognition) to classify chromosomes and to detect chromosome aberrations.

Our aim is to set up an automatic system for biological dosimetry of ionizing radiation.

Exposure of living organisms to radiation causes chromosome damage: by counting the aberrations in lymphocytes derived from samples of blood the radiation dose to which the individual has been exposed can be determined. This counting is usually done by an expert cytologist using optical microscopes and this limits the applicability of the method.

PEPR is an apparatus studied for the analysis of photographs from bubble chambers: it recognizes the tracks of ionizing particles and analyses high energy physics events.

By slightly modifying the hardware and software of this apparatus it may be possible to use it for the recognition and classification of chromosomes.

CARIOPEPR Frascati group:
I. Laakso, E. Righi, A. Rindi and L. Votano
Technicians: D. Fabbri, M. Gatta, F. Masi and M. Ventura
Collaboration with:
ENEA-Roma and USL RM29.

4.3. - PESS-PEPR

The goal of this experiment is to obtain a measure of the concentration of radon and its daughters by the use of CR39 plastic nuclear track detectors. As deployment of a great number of detectors is foreseen, automation of the image data acquisition is necessary. For this end the applicability of the PEPR system of our laboratory was investigated.

We tested an automatic scan procedure based on the detection at local maxima. Each object thus revealed underwent an analysis of form in order to recognize it as a particle track. More details were presented in the 12th Inter. Conf. on "Solid State Nuclear Track Detectors" in Acapulco (LNF-83/70). The first comparison thus obtained with other automated systems applied to these kinds of problems recommends PEPR.

The pattern recognition problem of the tracks, which appear as more or less elliptical forms, boils down to the determination of the principal parameters: orientation of the major axis, and the lengths of the minor and major axis. This was reached by the use of a scan by an orientable line-element. The optical density profiles of the tracks appear to be quite complex, and thus the use of threshold be comes critical in the determination of the minor axis. A procedure was developed to evaluate the background density at the track location. Thus, a threshold at a constant fraction between this and the track maximum can be used. The best results were obtained by employing the hardware of quadruple threshold, which allows approximation of the density profile with a parabola, and obtain an estimation of the width at the background level.

In Fig. 32 we show a readout result from a sample irradiated in a calibrated radon atmosphere. On the x-axis we plot the eccentricity of the track and on the y-axis the minor diameter after elimination of the minor axis ellipticity correlation.

PEPR Frascati group:
L. Votano
Technicians: P.L. Benvenuto, D. Fabbri, M. Gatta, E. Gradl, F. Masi and M. Ventura
Collaboration with:
Roma and Sanità.

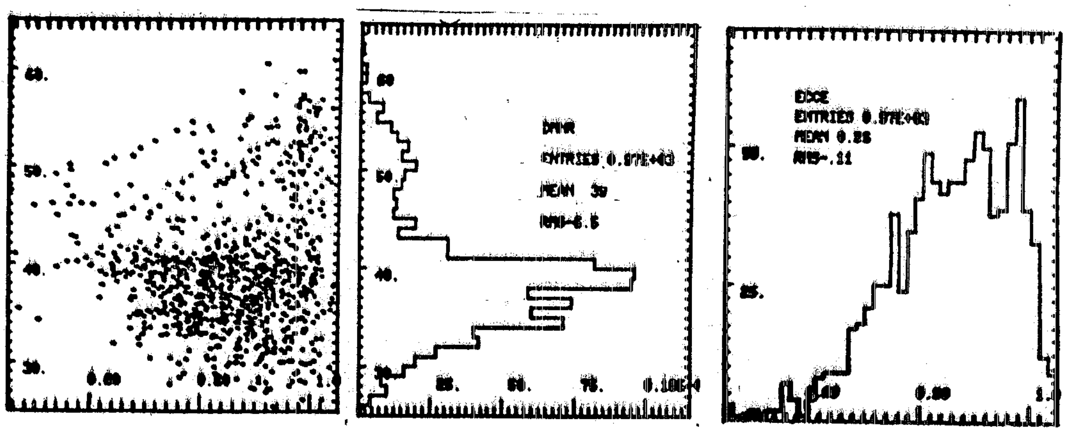


FIG. 32

4.4. - E3S (Esone Standard System Specification)

During 1983 the group participated in the work of the ESONE Committee on the standardization of a multimaster data acquisition system.

A proposal for a standard was presented to the ESONE AGA (Berlin, May 1983). The standard is a bus independent system applied to the existing hardware busses that are being presented by various industries.

One of the most promising standards which is now becoming available is the VME (Motorola, Mostek, Signetic, Thompson), which is now officially supported by CERN.

We have bought a small VME system and we are planning to have it working in Frascati in the near future. Software development on such a system will be very important to solve the interesting problems generated by an environment of many intelligent objects sharing the same resources (bus, and therefore memories, peripherals, etc.).

Two reseachers from Pakistan, working with an international grant, are working on the problem.

The group is also following the other developments of the ESONE Committee, i.e. Local Area Network, Computer Aided Design etc, and planning to participate in the organization of the next ESONE General Assembly (AGA), which will be held in Legnaro in the fall.

E3S Frascati group:
M.L. Ferrer, M. Serio, F. Tazzioli and L. Trasatti
Technicians: O. Ciaffoni.

4.5. - INFNET

The software allowing the INFNET network to access the national computer centers of Rome and Bologna (with UNIVAC and CDC machines respectively) and the CERNET network at CERN, has been completed.

This software offers the following facilities for all the INFNET nodes:

1) Access to CERNET for files transfer, job submission to the IBM and CDC computers with automatic sending out of print-outs.

2) Seminteractive use of the CERN IBM computer (Wylbur system) from each INFNET node, without remote login on the gateway).

3) Interactive work with the national CDC computer center.

4) Job submissions to the UNIVAC and CDC computers with automatic sending out of the print-outs.

The experimentation on the above software and the whole activity in the INFNET program will be finished at the end of this year.

A new experiment, HEPNET, has been proposed which studies the possibility to construct a universal software gateway among networks of several countries participating in the LEP programs.

The first gateway project has been already produced.

INFNET Frascati group:
M.L. Ferrer

Collaboration with:
INFN-Rome.

4.6. - PILOC

We are carrying out a feasibility study of a hodoscope-spectrometer for neutrons of energy between about 15 and 100 MeV.

The main aim of such an apparatus is to be the localization of the π^- stopping region in tissue for radiation therapy purposes. Moreover, it can be used also for Nuclear Physics and Health Physics applications.

We completed the simulation study of the apparatus with a Montecarlo computer program: this allowed us: a) to optimize the model of multiwire chambers used as detectors; b) to optimize the geometry of the apparatus; c) to check its efficiency and the precision of the image localization.

In order to decrease the cost of the associated electronics we are studying a simpler method of wire reading that uses no delay lines nor single wire amplifiers. We also started the study of the software for a PDP 11 computer which will be used on line for the stopping region image reconstruction.

PILOC Frascati group:
L. Figliozzi (L), A. Rindi, I. Speranza (L) and L. Tana (L)
Technicians: M. Lindozzi and A. Pecchi.

4.7. - PULS (Programma Utilizzazione Luce di Sincrotrone)

During 1983 the PULS staff members have been mainly involved in experimental activities on the three working beam line and in the completion of the soft X-ray "Grasshopper" beam line. (Table I).

The staff activity can be divided into: Technical-management part (improvement of instrumentation and management of beam-lines); and Scientific research part.

TABLE I - Spectral range of the Synchrotron Radiation Lines installed behind the bending magnet.

Lines	Energy Range	N_{max}/sec, monochromatic photons x mA of electron current stored	$\Delta E/E$	Greating type	$\Delta\lambda$ (Å)
X-ray	2.4 keV-14 keV	5×10^7	1.3×10^{-4}	Crystals: Si(111)	2.3×10^{-4} (at $\lambda = 1.77$ Å)
Grasshopper	40 eV-800 eV	10^8	2×10^{-3}	600 lines/mm	0.2
Jobin-Yvon	15 eV-80 eV	3.5×10^8	6×10^{-3}	600 lines/mm	2
Hilger and Watts	3 eV-35 eV	10^8	10^{-3}	1440 lines/mm	0.7

4.7.1. - Technical-management part

A. - Works on beam-lines

A.1. - X-ray beam line

The line, in its fourth year of full activity, can perform experimental measurements of types:

- EXAFS, Extended X-ray Absorption Fine Structure, both by absorption and X-ray fluorescence;
- SAXS, Small Angle X-ray Scattering, using a drift chamber detector.

During the year the following work was done:

1) Change of X-ray monochromator and ionization-chamber windows to extend the useful energy. At present the beam line covers a spectral range of 2.4 KeV - 14 KeV;

2) Test of a new fluorescence system which uses four NaI scintillators placed at 45° on a horizontal plane and is equipped with suitable filters. Such a system allows EXAFS measurements on a biological solution diluted up to a few mM (see Fig. 33);

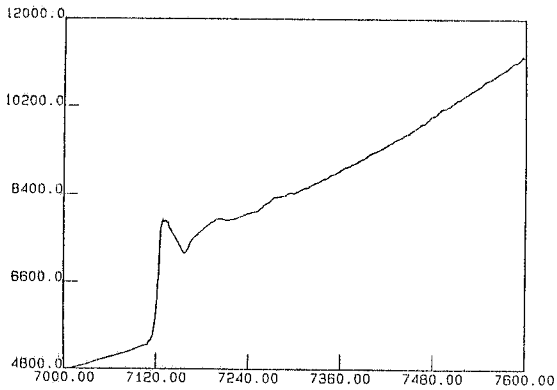


FIG. 33 - X-ray fluorescence spectrum on the K edge of Fe in native C-cytochrome in 5 mM solution. Recording time of the spectrum: ~1h.

3) Modifications of the SAXS diffractometer, equipped with a bidimensional drift chamber detector, and its instrumentation. In particular: a) the beam stop entrapping primary beam on the drift chamber has been replaced by a new one with double micrometric

movement, x and y, orthogonal to the beam; this makes the alignment easy in each measurement and allows the accurate position of zero angle scattering, which is necessary for a good data analysis; b) the data acquisition system has been modified improving the MCA performances; at present it is possible to do acquisition of spatial spectra on bidimensional maps XxY of 128 x 64 = 8192 channels, enganging the whole MCA memory: for instance, the spatial intensity of small angle scattering of Ag spherical particles having a diameter of 93 Å is shown in Fig. 34.

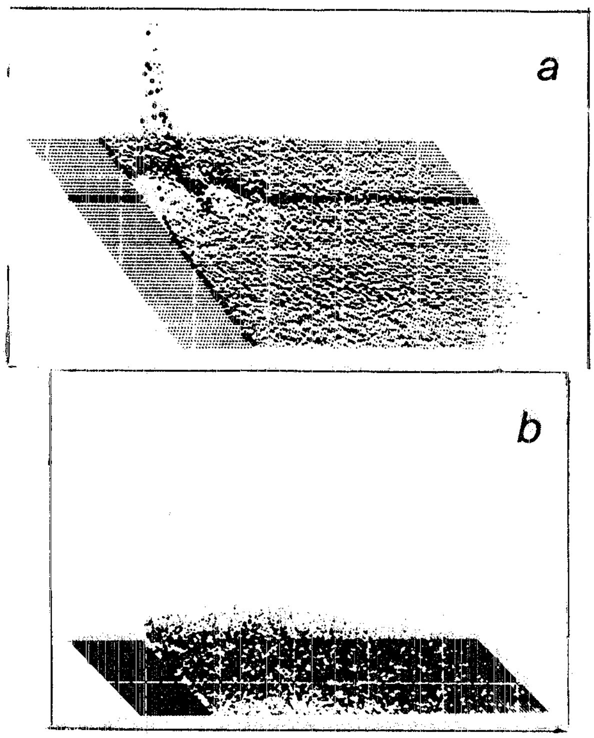


FIG. 34 - Spatial intensity of small angle scattering of Ag particles, of mean diameter d=90 ± 10 A, observed following two different position of half space 2θ≥0. The analysis of b) spectrum in Guinier approximation gives d=93 A.

A.2. - Grasshopper beam line

The "Grasshopper" monochromator and the electron analyser of the photoemission experimental chamber have been interfaced with a minicomputer connected to a PDP 11/34.

Four encoders for the control of the laboratory of the S_2 mirror placed in the Adone storage ring hall (see for instance Activity Report of 1981) have been installed. The position reading error is 10 μm. We have taken some sets of measurement of absorption, partial yield and photoemission to test the whole system (focusing system, monochromator, photoemission experimental chamber). Fig. 35 shows the incident radiation intensity on the sample versus the photon energy (the monochromator is equipped with a 600 lines/mm greating and $\Delta\lambda$=0.2 Å). The maximum intensity is at 3×10^8 photons/sec mA. The monochromator calibration in the energy range 200-800 eV has been done by measuring the $L_{2,3}$ absorption threshold of transition metals. For instance, Ti threshold measured in partial yield is shown in Fig. 36.

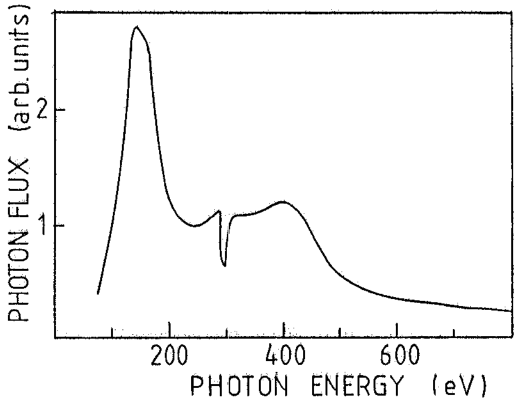


FIG. 35 - Photon flux at exit of Grasshopper monochromator equipped with greating of 800 lines/mm and spectral resolution $\Delta\lambda$=0.2 A. Electron circulating current in Adone storage ring was ~5 mA at 1,2 GeV of energy.

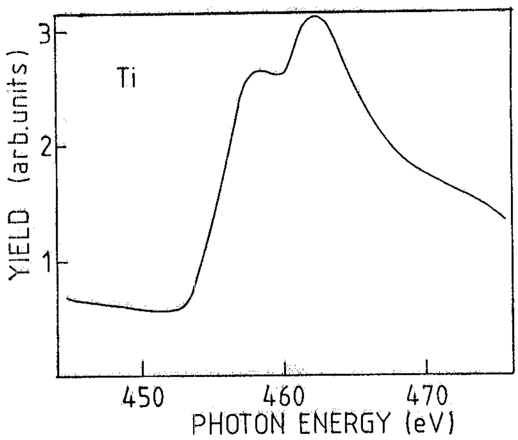


FIG. 36 - $L_{2,3}$ threshold of absorption of Ti measured in partial yield.

A.3. - Jobin-Yvon beam line

This low-energy photoelectron-spectroscopy line is in its second year of full activity. During the year a new toroidal grating has been installed in the Jobin-Yvon monochromator to replace the old one damaged by severe radiation. The new grating has a blaze angle which gives an energy cut off at 80 eV photon energy. The spectral range of available energy in this beam line at the present is 15-80 eV with a intensity shown in Fig. 37.

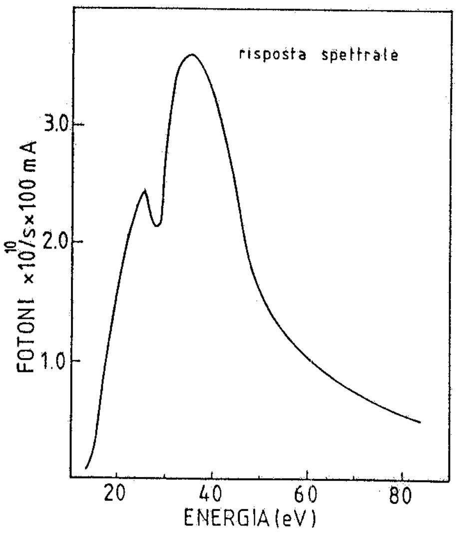


FIG. 37 - Photon flux at exit of Jobin-Yvon monochromator equipped with toroidal greating of 600 lines/mm and spectral resolution $\Delta\lambda$=2 Å. Electron circulating in Adone storage ring was 100 mA.

A.4. - Hilgher and Watts line

We replaced the SHW and S1 mirrors, damaged by use in order to improve the luminescence count rate. We mounted an AT 2244 RCA photomultiplier solar-blind, with LiF window in the reflectometer on a turning arm, so that it can cover the whole spectral range given by HW (30-300 nm) in a single run. For this purpose we mounted on a linear vacuum feedthrough, behind the HW exit splits, a tungsten grid and a LiF window at 45°. The light reflected by the latter towards a second AT 2244 RCA photomultiplier gives the reference signal between 110 and 300 nm.

B. - Development of new detectors

With regard to the development of X-ray detectors, we have studied a drift chmaber detector with a calculated energy resolution of ~10% at 6 keV.

In particular we have built, in collaboration with the Scodet group, a transimpedance amplifier with input impedance of 15Ω, bandwith of 1,2 GHz, gain of 4, very suitable for analyzing the electronic current pulses produced at zero time by the anode avalanche discharges. By performing an amplitude analysis of these current pulses (two order of magnitude higher than those currently occuring by measuring the ion pulses) at zero time, we hope to obtain the calculated 10% energy resolution. The final test of this detector on the X-ray line of the Synchrotron Radiation Facility is scheduled for Autumn 1984.

C. - Use of the machine time shift

In 1983 PULS staff had 158 machine time shifts. Of those, 52 shifts were not used because of machine fault; 45 shifts were used with the machine operating at 1,2 GeV and 61 shift at 1,5 GeV (maximum machine energy). The shifts were divided as follows:

a) - X-ray line

19 shifts	upkeep and tests;
9 shifts	EXAFS on experiments of biology;
58 shift	EXAFS on experiments of solid state;
16 shifts	SAXS;
1 shift	Safety Physics Service.

b) - Grasshopper line

60 shifts	system tests and control measurements for the Safety Physics Service;
46 shifts	absorption, photoemission, partial yield experiments.

c) - Jobin-Yvon line

14 shifts	tests;
34 shifts	experiments on interfaces;
12 shifts	experiments on chemical detectors;
14 shifts	experiments on layered compounds;
18 shifts	experiments on amorphous materials.

d) - Hilger and Watts line

During the year the line was mainly used for luminescence and spectroscopy experiments. The 128 machine time shifts, 22 in parassitic mode operation, were divided so:

35 shifts tests on reflectometer (8), and on luminescence (10), lifetime (8) and luminescence phase-sensitive (9) apparatus;
30 shifts reflectivity experiments;
44 shifts luminescence experiments;
19 shifts phase-sensitive luminescence experiments.

4.7.2. - Research scientific part

The scientific activity worked out by the members of the PULS group in collaboration with the day-users was dedicated to study electronic and structural properties in inorganic and biological systems.

We list only the subjects and the topic of the many researches performed in our laboratory. We refer to the pubblications for detailed description and results.

- EXAFS of concentrated electrolyte solutions;
- EXAFS of phase transition in liquid crystals;
- EXAFS of metal-semiconductor phase transition;
- EXAFS, XANES, photoemission of semiconductor and hydrogenated amorphous alloys (Si and Ge);
- EXAFS of Fe-Pd metallic glasses;
- Determination of chemical state of metals in atmospheric, aerosols by means of X-ray spectroscopy;
- Structural modifications in native c-cytochrome and carboximethileted by EXAFS;
- Fe site in trasferrine by EXAFS;
- Ca site in proteins linking Ca by EXAFS and XANES;
- Thresholds of rare earths (LaO_5, Y_6O_3, $CePd_3$, ...);
- Determination of dimensions of metallic small particles by SAXS;
- L and M thresholds of transition metals (Co, Ti, Fe, Ni, ...);
- Study of EXAFS dichroism and of structures near to thresholds in layered compounds like TiSr, GaS, GaSe, ...;
- Study of the empty electronic states and valence bands by absorption and resonant photoemission in intercalary compounds such as $NiPS_3$, $FePS_3$, ...;
- Resonant photoemission from surface state in GaP;
- Study of ZnSe-Ge and GaP-Si interfaces by photoelectronic spectroscopy;
- Study of Schottky barriers between Au and amorphous Ge and hydrogenated amorphous Ge by photoelectronic spectroscopy;
- Study of MIS hydrogen sensor, (Pd$|SiO_x|$ a-Si:H), by photoelectron spectroscopy;
- Study of Ga 3d levels and In 4d in Ga S_{1-n} Se_x and Ga_{1-x} In_x Se mixed layered compounds by photoelectron spectroscopy and VUV reflectivity.
- Study of intrinsic luminescence and impurity induced luminescence in Tl doped potassium halides;
- Study of fluorescence lifetime of color centres in NaF;
- Study of optical properties in discontinue films for 10-500 Å thickness, forming metallic clusters of few tens Å of diameter;
- Study of optical properties of Cd_x Mn_{1-x} Te mixed compounds and similars;
- Study of fluorescence times of biological molecules.

For details see LNF reports 83/31, 59, 63, 68, 98, 99 and the pubblications in Nucl. Instr. & Meth 219, 227; Surface Sci. 136, J. Vacuum Sci. and Techn. A1, 650; Phys. Rev. B27, 1161 and B28, 4882; Solid State Commun. 46, 367, 871 and 875; 49, 749; Nuovo Cimento 2D, 1281; J. Phys. E16, 83; J. Mol. Byology 165, 125; Phys. Rev. Letters 50, 1949.

PULS Frascati group:
A. Congiu-Castellano (Ass), M. De Crescenzi (Ass), I. Davoli (Ass), M. Iannuzzi (Ass), A. La Monaca, S Mobilio, F. Patella (Ass.) and A. Savoia
Technicians: R. Bolli, F. Campolungo, L. Sangiorgio and V. Tullio

Collaboration with:
Camerino, CNR, Roma I and Roma II.

4.8. - PWA (Programma Wiggler Adone)

The synchrotron radiation emitted from the wiggler magnet during 1983 has been utilized up to now still inside the machine hall; consequently due to the space limitations for the experimental apparatus and the special personnel protection requirements the experimental activity has been strongly reduced.

The work done on the facility has been the following:

a) Many experimental works by several external groups during the time dedicated to the synchrotron radiation activity;

b) The first part ($\simeq$ 5 m) of the second X-ray beam line, so-called BX_2, has been connected to the storage ring;

c) The photon flux available at the BX_2 has been measured and compared with the one emerging from the BX_1; from the first results obtained it is clear that the two photon fluxes are practically the same;

d) the first X-ray beam has been prolonged from 15 m to 30 m and its final checks into the new dedicated laboratory are scheduled at the end of the 1984;

c) the experimental activity inside the new dedicated laboratory very probably will start in February of 1985 with two X-ray beam in operation.

The experiments in progress at the wiggler facility mainly concerning absorption spectroscopy measurements (XANES and EXAFS) both in solid state physics and biophysics are the following:

- In order to observe the behaviour of the nearest, neighbour distance contraction versus cluster diameter of gold evaporated, small metal clusters were studied by X-ray absorption spectroscopy on L_3 Au edge.

- The fine structures at the X-ray L absorption edges of Sb in crystalline antimony and in antimony sulphoiodide were analysed and compared with the density of states calculated for the conduction bands.

- In order to understand the microscopic structure of the glassy state in particularly the consequences of the introduction of the various oxides into the network of the glass former B_2O_3, X-ray absorption measurements were performed for the first time at the A_gL_3 edge on glasses $Ag_2OnB_2O_3$ (n=2, 3, 4) and an crystalline Ag_2O.

- In order to reveal the difference of the Fe-side structure between the foetal and adult deoxy Hb, iron X-ray absorption spectra (Near Edge Structures) were measured.

PWA Frascati group:
E. Burattini (Ass) and A. Reale (Ass.)
Collaboration with:
L'Aquila, Napoli, Roma and Trento.

4.9. - RIBEX

In 1983 a conclusive paper was published on the results obtained on the binding of Mn ions to ATP molecules, by means of fine structure analysis of X-ray absorption spectra (EXAFS and XANES), at the K-edge of Mn using the synchrotron radiation (Nuovo Cimento D2, 1281-1904).

This paper refers to the first part of the experiment, (RIBEX I), which was limited to the study of an important and comparatively simple biological molecule such as ATP.

The 5'-ATP molecule, in fact, acts as an activator in several important enzymatic reactions, and requires the presence of divalent metal ions for its action. The structure of the Mn-ATP complexes in aqueous solutions has therefore been extensively studied with various methods because of its intrinsic biological relevance as well as for its value as a simple model for the investigation of metal-nucleic acids binding.

Both freeze-dried and liquid samples of the Mn-ATP complex in aqueous solutions have been investigated by our group, under different values of pH and of the stoichiometric Mn:ATP ratio.

MnO_2 and MnO have been taken as model compounds; the respective EXAFS spectra are shown in Figs. 38 and 39; an excellent agreement has been found with the known crystallographic data and with the EXAFS spectra already reported in the literature.

The near edge structures (XANES) of the absorption spectra have been investigated both on inorganic Mn compounds, and on Mn-ATP and Mn-AMP complexes. The results are shown in Fig. 40; Fig. 41 presents the Fourier transforms of the EXAFS spectra of liquid samples of Mn-ATP.

We can draw the following conclusions from our data:

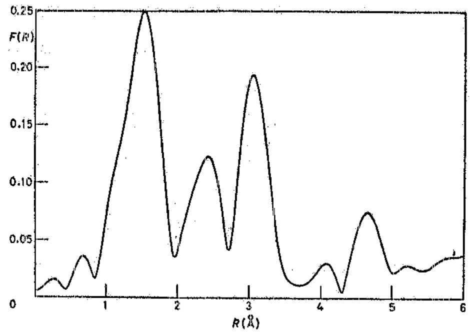


FIG. 38 - Fourier transform of EXAFS spectrum of $Mn\ O_2$.

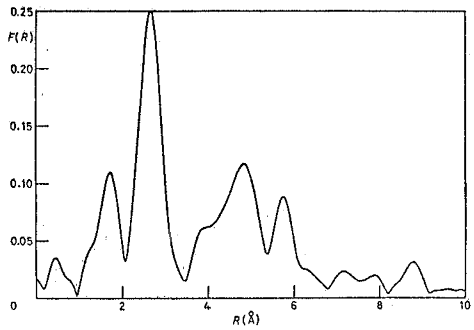


FIG. 39 - Fourier transform of EXAFS spectrum of Mn O.

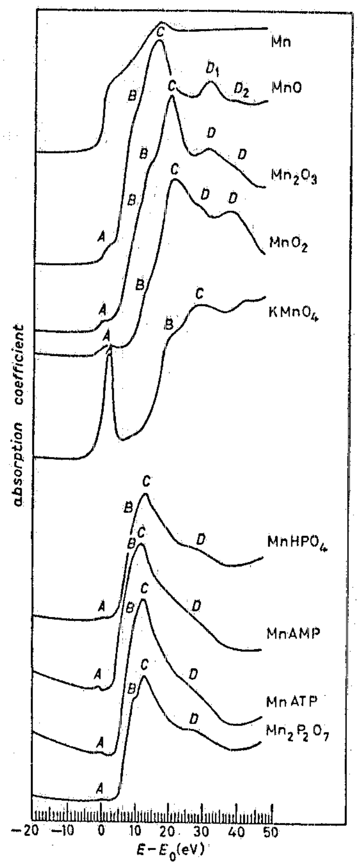


FIG. 40 - XANES spectra of various Mn compounds.

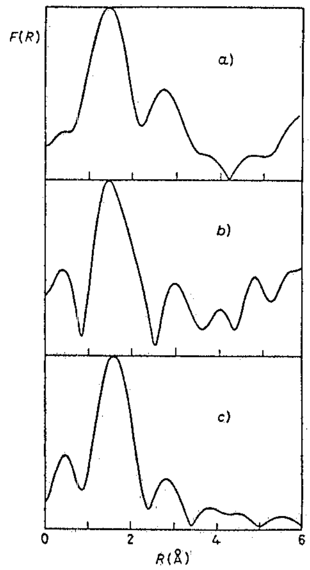


FIG. 41 - Fourier transform of $K\chi(k)$ for different Mn-ATP complexes: a) ph=9; b) ph=7; c) pH=3.

1) the Mn metal ion is in centro-symmetric position in the Mn-ATP complexes, octahedrally coordinated to the oxygen ligands;

2) the first and second shell distances appear the same in all the samples, being equal to (2.16 ± 0.05) Å and (3.40 ± 0.05) Å respectively;

3) the presence of a N-atom of the adenine ring in the first co-ordination shell seems to be excluded;

4) a $Mn(ATP)_2$=1:2 complex is formed in solution at pH=9 at room temperatures, while the Mn:ATP 1:1 complex is the most stable configuration under all other conditions;

5) a small increase of covalency in the Mn-O bond occurs with increasing pH.

Data have also been collected on the binding of Mn to some other biological molecules, such as synthetic nucleic acids and tRNA by means of XANES analysis.

tRNA has been particularly studied at various Mn:tRNA stoichiometric ratios, in order to compare these results with some studies of optical spectroscopy which attest the role of divalent metal ions in the structure of tRNA.

RIBEX Frascati group:
S. Mobilio, C.R. Natoli and A. Reale (Ass.)
Collaboration with:
Roma and Sanità.

4.10. - SCODET (Super COnducting DETector)

The aim of the experiment is to use superconducting tunnel junctions as ionizing particle detectors. The experiment is done together with the Physics Institute of the University of Salerno (Italy) where, for some years, it has been possible to get Josephson-tunnel junctions. In this Institute the junctions are developed and studied both in DC and low frequency AC conditions.

These devices are interesting from the point of view of particle detection because in a superconductor the minimum energy to get an excited state (quasi-particle) is of few meV. This value of energy is almost 1/1000 of that necessary for a conventional semiconductor detector to create an electron-hole pair (e.g. 3.6 eV in Si). In such a way it is possible to hypothesize a detector with a very good energy resolution.

We use photolitographic technics to get the junctions and then it is easy to obtain a spatial resolution of 10 μm.

There is little literature about these detectors and almost all the experiments have been performed using α particles.

We use junction Nb-Nb_2 O_3-Pb type that are rugged and have a Tc (critical temperature) of ~ 7° K. The detection system is: junction, low temperature mechanic interface, charge preamplifier, TFA (Time Filter Amplifier) when we use a conventional "static" dewar (i.e. without "window"). When we use an "experiment" dewar we do not need a low temperature mechanic interface. In such conditions, moreover, the lenght of the cable (coaxial) from the detector to the preamplifier is less than 26 cm.

The theoretic performances of such junctions (high energetic and spatial resolution, high speed) detecting ionizing particles are now still limited because of the state-of-the-art of the front-end electronic. The tunnel junctions have a low value of impedence and the value of parasitic capacitance (3μ F/cm^2) is very high. The value of parasitic capacitance, now, is difficult to decrease increasing the thickness of dioxide. Such characteristics of resistance (low) capacitance (high) speed (high) make the use of the well stabilished low noise electronic (used for the conventional semiconductor detectors) unuseful or inpracticable. Even the use of a step-up transformer (to reduce the capacitance "seen" from the preamplifier) is not efficient because of the very fast rise time of the signal.

During 1983 we continued to study the noise of the system detector-preamplifier. We studied the noise changing both preamplifier configuration (charge, current, voltage) and detector characteristic (low-high resistance-capacitance). Now we study the system in the frequency range of 10 kHz - 100 MHz, interesting in a "practical" application of such a type of detector (before we analyzed the range 10 MHz - 1 GHz). We gave a talk about some preliminary results (10 MHz - 1

GHz) during the Workshop of Superconducting Metastable Detectors, held in Paris (14-16 April 1983).

We designed a new type of very fast charge-preamplifier. The input transistor is a VMOS (MOS with vertical channel) that has a high value of gm (transconductance) and very high value of the ratio gm/Cin (Cin=intrinsic input capacitance). This value is equivalent to a BW in excess of 5 GHz and is, theoretically, well matched with the intrinsic times of the tunnel junctions.

We found experimentally that the transmission line between the junction and the preamplifier is very important to get a signal of enough good "quality". Because of that, we developped a new type of junction with a "special" geometry. Such junctions (Fig. 42) have an electrode, from which we plan to

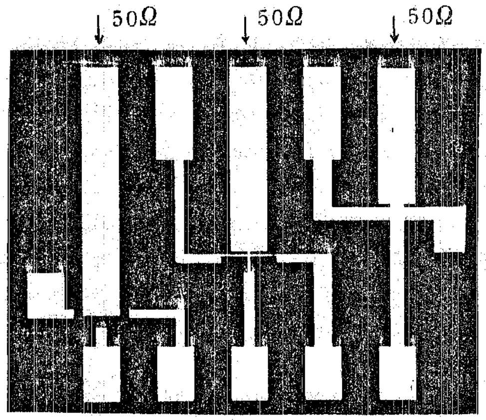


FIG. 42

collect the signal, that is a strip-line with Z_0=50 Ω. By the way, we developped such types of junctions with large ranges of absolute value of impedance (i.e. R=0.1 - 100 KΩ; c=30 pF - 30 nF). We made 2 cryostats ready, both in Frascati and Salerno, with 50 Ω transmission lines. With the use of such cryostats we can excitate the junctions with α, β, γ sources. Moreover, we can test the junctions with light coming from LED (pulse and continue mode, λ_1=565 nm; λ_2=583 nm; λ_3=635 nm) and Laser Diode (pulse mode, Tw=200 ns, λ=904 nm, ν=1 KHz, Maximum Peak Operating Power=9000 mW) using the dewar of LNF.

At the same time, we began to study the phenoma of thermodynamic equilibrium arising from ionizing radiation on superconductor electrodes of the junction. Particularly, we paid attention to the recombination and scattering time of quasi-particles and to the scattering time of phonons. Most of the literature, up till now, is about "phenomena not completely homogeneous with a not explicity time dependence and not too far from equilibrium". In our case such conditions were not verified, and, according to us, the phenomena of diffusion both of quasi-particle and phonons seem to play an important rule in understanding the true response of the device. Anyway, we have some indication, theoretic and exprimental, showing that we have to change, in the future, the compounds of the junction to get the characteristic times longer than the intrinsic time of the device.

Such chang, nevertheless, will carry with it some experimental problems because of the new compound itself (element more difficult to process then Nb-Pb) and lower value of Tc (now the temperature is about 7° K). Anyway, it will be possible to get the best performance from such a device (together with the front-end electronics) only if the non-equilibrium process arising because of ionizing particles are understood.

Up to now, the best experimental results (using α particle) shows an excitation energy of 70 meV. Although such a result is about 50 times better than Si, on the other hand it is 30 times greater than the theoretic intrinsic limit (the energy gap in a Nb-Nb_2O_3-Pb junction is of 2.2 m eV).

SCODET Frascati group:
F. Celani, B. D'Ettorre-Piazzoli, R. Falcioni (Ass.), Y.N. Srivastava, S. Pace (Ass.) and B. Savo (Ass)

Collaboration with:
Salerno and Turin.

4.11. - STELLA (Satellite Transmission Experiment Linking Laboratories)

STELLA is an experiment which aims for an experimental test practicability of data transmission both at high rate (2 Mbit/sec) and at a low value of BER (Bit Error Rate, $< 10^{-9}$) by using the satellites and fast local-area networks.

The test was performed by the most important European laboratories of Nuclear Physics and "CERN" using the OTS (Orbital Test Satellites) satellite which was offered by ESA (European Space Agency). The experiment began in 1978 and it officially expired, succesfully, at the end of 1983.

The LNF did both the "standard" transmission tests and have designed some special hardware since 1981.

The collaboration of LNF in the experiment is characterized, in the framework of European collaboration, by the development of some new hardware. This arises because of the geographical location of the antenna (located in ESA building, about 2 km far the LNF) and the on-line computer (PDP 11/44, located in CNR buildings, about 200 meters from the ESA).

During 1983 three types of circuits were developed. The first one is "in principle" a multiple input-output digital switch at high rate (2 MHz). It was developped to avoid some cross-talk problems, which arose using the conventional mechanical (although high quality) switch provided by ESA. We need such a switch because we use the antenna MODEM both for SPINE (of ESA) and STELLA expriments.

The second one is a more sophisticated version of the high frequency high power (15 V/50 Ω) digital transmitter just described in the previous "Rapporto di Attività" (LNF-83/105). We designed such a transmitter "to link" the antenna and the computer with a 50Ω standard coaxial cable. We added a circuitry to such a transmitter which allows, in real time, to detect the condition of short circuits or overload both static and dynamic (2 MHz) at the trasmitter output or along the coaxial cable. We wish to emphasize that the transmitter, LNF design, has enough power to give 15 V at 2 A. The rise and fall times (equal) are less than 3-4 ns. The stated frequency ranges from DC to 10 MHz. Taking into account that such circuitry has enough power speed and ruggedness to be a general purpose type, we think it useful to show the scheme even in this memorandum (Fig. 43).

The third circuit concerns the design of a new receiver of the signals arising from the coaxial cable. This design differs from the previous one because of a larger degree of sensibility and ruggedness against

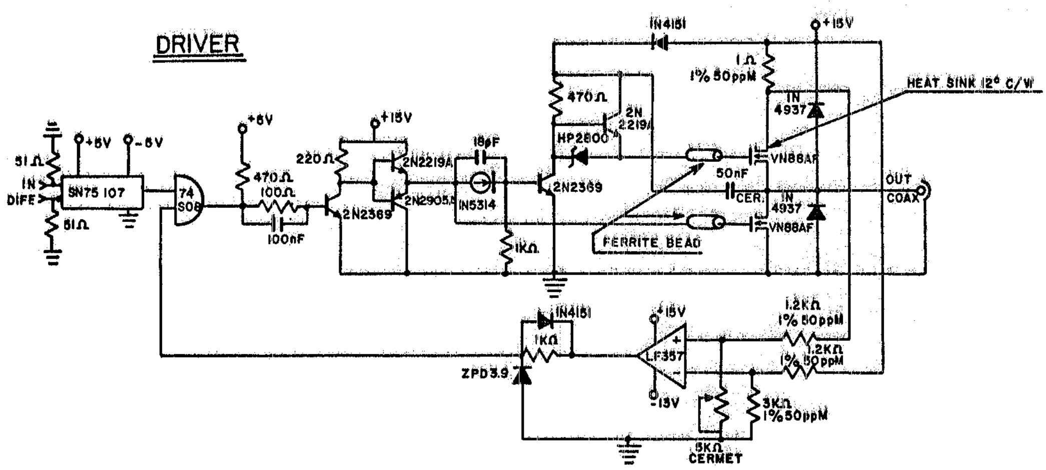


FIG. 43

unexpected events (water in the coaxial cable, lighting, power failure of only the receiver section, etc.). Its maximum operating frequency, squarewave, is 50 MHz.

STELLA Frascati group:
S. Catà (Ass.), F. Celani and M. Pallotta
Technicians: B. Bonito

Collaboration with:
CNUCE, CNR Pisa and CERN.

ACCELERATOR DIVISION

The distribution of effective beam hours to users is shown in Fig. 44.

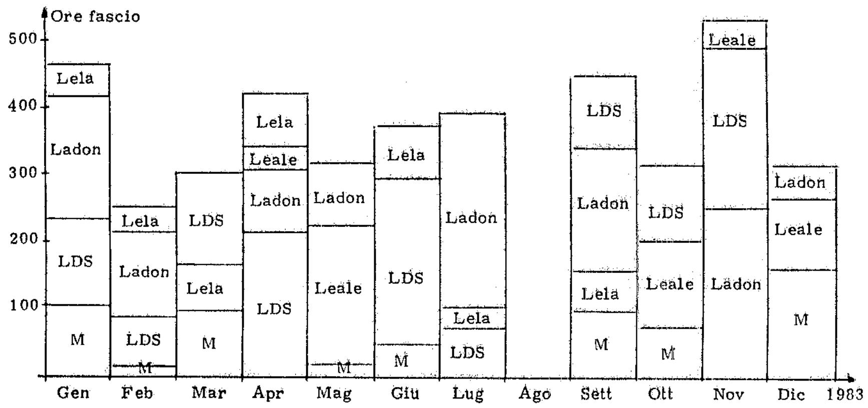


FIG. 44

The beam hours effectively used are 3600 over the 5500 assigned. The main cause of the loss of various shifts has been the malfunctioning of the control computer which has successively been practically replaced by extra maintenance during December.

1. - OPERATION SERVICE

Besides the operation of accelerators, with apparatus active for more than 6000 hours, and maintenance of electric and electronic parts, the Service has initiated the following:

- start of the construction of a prototype of the new injection system for the LINAC;
- modification of the stand-by modulator for tests on the above mentioned injection system;
- design and construction of a device for measurements on permanent magnets;
- design of a bridge-coil on the new LINAC converter;
- substitution of two 50 KVA transformer for supplying LINAC solenoids.

In collaboration with the Mechanics and Vacuum Service of the Technical Division (SMV-DT) the Operation Service has taken part in the project for the new positron converter.

During '83 a feasibility study to increase the LINAC energy by compressing the klystron pulse was started. Moreover, a study of multipacting phenomena in RF cavities (Memo RF-48) and in the LELA experiment was participated in.

Staff:
G. Baldini, M. Belli, B. Bolli, R. Clementi, M. Gentile, E. Grossi, P. Locchi, M. Martinelli, V. Pavan, S. Pella, R. Pieri, B. Spataro, S. Simeoni, P. Tiseo and M. Vescovi (Resp.).

2. - MECHANICAL SYSTEMS SERVICE

Work performed in '83 in addition to routine maintenance of the accelerators:

- Plants: new hydraulic system for RF; preparation of new heat exchangers (WCS) for the LINAC; replacement of all flexible hydraulic connections to LINAC section no. 5.
- Mechanics: completion of a lead screen for the RF cavity; assistance to LADON group; vacuum leak tests; assistance to PWA group; substitution of ADONE-PWA sectioning valve, assembly of new vacuum pipe section (in collaboration with SMV-DT); heating of ADONE vacuum chamber section after Nitrogen treatment (in collaboration with SMV-DT); modification of slits control system for LEALE; glow discharge test on RF cavity (in collaboration with SMV-DT); operations with cranes and hydraulic lifts; regeration of pumps for the LINAC; preparation of threaded connectors, adaptors and flanges for fluid plants; maintenance of electro-pumps, blowers, compressors for the LINAC; preparation of equipment for repairing LINAC belows; construction of an iron framework for RF group; assembly of new target on positron converter; preparation of connections for spectrometer head on RF cavity (in collaboration with SMV-DT).
- Vacuum and related extra works: preparation of new expansion bellows for LINAC sections, preparation of system for Nitrogen introduction before opening vacuum (in collaboration with SMV-DT); test for determining suction speed of triode pumps (in collaboration with SMV-DT); preparation of new target for the positron converter with protective and centering screens of Ta and ceramic; preparation, test and replacement of LINAC section no. 5 and converter block.
- Designs and drawing, purchasing, development activities: purchase of spare partes; drawing of LINAC monitors, design and drawing of test station and LN_2 traps for turbo-pumps; drawing of a framework for RF; technical development of ultra-high vacuum ($p < 10^{-11}$ Torr) apparatus for Electron Cooling; design of an interaction chamber for the same.

Staff:
A. Aragona, N. De Sanctis, G. Ermini, S. Faini (Resp), R. Lanzi V. Lollo, A. Maciocce, C. Marini, A. Mazzenga and G. Serafini.

3. - ELECTRONICS AND RF SERVICE

3.1. - Electronics:

Adone:

- Installation of a monitoring and warning system for the Adone electromagnets.
- The binary status of pressure switches, flowmeter, thermostats and thermoresistance bridge (the latter through an analog scanner) is monitored in each element. An Anomalous condition is signalled by a beeper and pointed by LED indicators. The system can be connected to the control computer.
- Longitudinal Schottky Detector.

Detection of shot noise related to longitudinal (synchrotron) incoherent oscillations in the electron beam, with an heterodyne converter and a Fourier Analyzer of the FFT type. Coherent oscillations are easily detected by this very sensitive system.
- Maintenance, repair, various modifications and upgrades of diagnostic and control equipment.
- Position control of the plunger turner of the synchrotron tune splitting cavity.
- This system comprises a stepping motor coupled to a micrometer for positioning, the power stage and the driving circuit, interfaced to the operator with a rotary knob/incremental encoder pulse generator.
- Design, assembly and installation of an octupolar (see Fig. 45) lens intended to raise the current threshold of "head-tail" instabilitie, especially in the Adone configuration ("4 families") suitable for the LELA exaperiment.

The octupole (air filled) is made of eight equal 24-turns coils of copper 7x1.5 mm^2 two meters long, circularly placed around a straight section vacuum chamber.

The integrated octupolar coefficient is about 15 T/m^2 and we foresee, with an iron shell, to rougly double such a value.

The octupole power supply is computer controlled.

LELA Experiment

- Electronic circuitry for the measurement of FEL gain: particular care has been exerted in low noise design of the devices and their interconnection and in

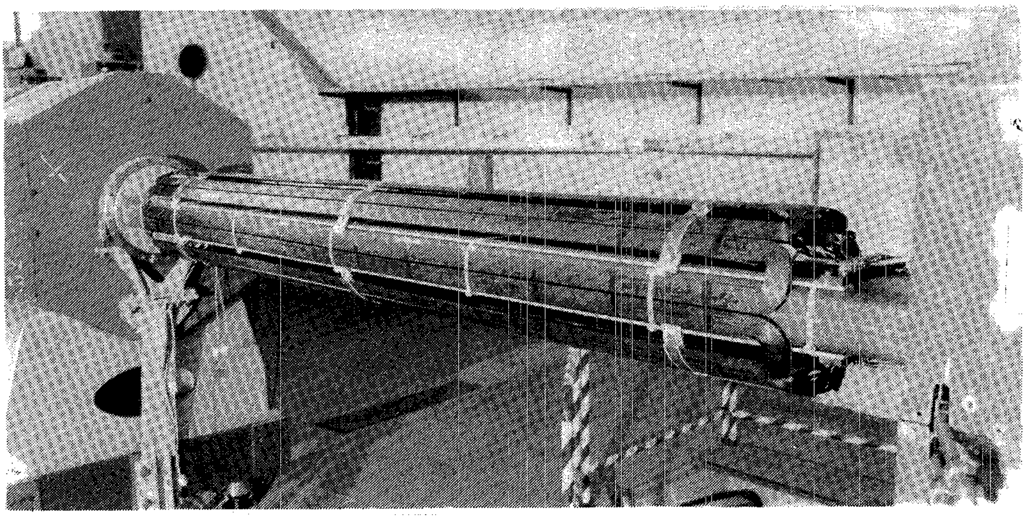


FIG. 45 - Octupolar lens for "Landau damping".

the linearity of transfer characteristics.

The measurement chain has been calibrated both electrically and versus the spontaneous radiation. The equivalent noise FEL gain level is estimated around 10^{-8}.

- Device for the measurement of the transverse intensity distribution of the Laser beam used in the FEL gain measurement.

General

- Series of 8.568 MHz (3rd harmonic of the Adone revolution frequency) low noise tuned amplifiers; gain 30 dB.
- TTL level 50 Ohm fan-out.
- Activity for the Central Electronic components store.
- IEEE 488 General purpose I/O register.

The PC has been designed by an external firm (SERP-Ivrea). It is mounted in a fraction (1/4) of the space available in a NIM module with a standard connector on rear side.

The interface provides two 8 bit registers with handshake, one for input or status read, the other for output and implements the interface functions: Source Handshake, Talker, Accepter Handshake, Listener, Remote/Local, Device Clear, Device Trigger, Service Request. With this module it is easy to integrate in an IEEE-488 environment home made devices such as DAC's, ADC's, actuators etc.

3.2. -Radiofrequency

- Study and design of a second resonant cavity under vacuum, at 51.4 MHz, to be installed on Adone, trying to solve the problems given by the actual one. In Fig. 46 is shown a section of one quadrant of the new

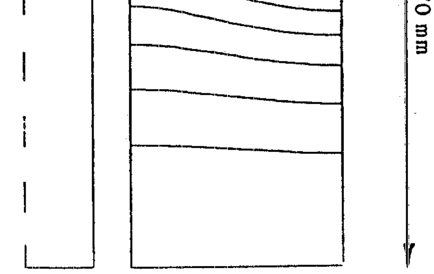


FIG. 46

resonator with the electrical field lines in the fundamental mode, traced by computer with the Superfish code.

- Study and design of a scaled model of the new cavity, at 160 MHz, to investigate:

a) the dimensions of the tuner;

b) study of multipacting phenomena (in collaboration with INFN Section in Genoa).

- Installation of a high power 3 db coupler between the 100 KW RF amplifier and the 51.4 MHz Adone cavity, to protect the amplifier from occasional short circuits due to discharges in the cavity and also to reduce instabilities due to beam-loading effects.
- Installation of a new automatic tuning system for the 51.4 MHz cavity that has improved beam stability especially during energy ramping.
- Installation of a more efficient voltage control system for the same cavity.
- Several intervents for repairing, adjusting and maintenance of the 51.4 MHz generator.
- Normal maintanance of other plants relevant to the groups.

Staff:
P. Baldini, R. Boni, O. Coiro, E. De Simone, S. Fortebracci, U. Frasacco, L. Lucibello, C. Marchetti, F. Ronci, F.V. Rubeo, F. Sanelli, M. Serio, A. Sprecacenere, F. Tazzioli (Resp.) and T. Tranquilli.

4. - ACCELERATOR PHYSICS

The LELA Experiment: the amplification of the light emitted by an external laser due to the interaction with Adone electron beam in the field of a 20 period, 4.5 Kgauss undulator has been measured by directly detecting the gain curve as a function of the energy of the beam (see Fig. 47) with the normal Adone lattice. The maximum value obtained for the average gain was 7.5×10^{-6} with about 20 mA stored in a single bunch. The corresponding peak gain (with an RF voltage of about 25 KV) is about 10^{-4}. Further work has been done with the achromatic version of the Adone lattice (4 quadrupole families) to increase the gain. The project of the optical cavity has been undertaken (mainly at INFN and the University in Naples).

Electron Cooling: for the Electron Cooling project for the $p\bar{p}$ ring at CERN (LEAR) a prototype at 60 KV, 3 A has been made (in collaboration with ENEA in Frascati and the INFN Departments of Genova and Turin) in the pulsed mode, following the results of the SLAC Trajectory Program (Fig. 48). On this prototype measurements were performed on the optical properties of the beam and on energy recovery. Studies and measurments on the magnetic guide field were also carried out. On the basis of the obtained results, the project of the final setup at 700 KV, 10 A was undertaken.

ESRP: in July the ESRP (European Synchrotron Radiation Project) has officially began its activity at CERN. The Frascati Accelerator Physics Group contributed the largest amount of work and manpower in 1983. The lattice of the ring was studied and a solution was proposed which particularly takes into account the problems of versatility and flexibility peculiar to this kind of storage ring. Sextupolar non-linearities were carefully analyzed, with the aid of the computer programs developed at CERN for the LEP project. In collaboration with the machine physicists and engineers of other european laboratories (ENEA, Daresbury, Saclay, CERN, Nikhef, etc.) orbit corrections, tolerances of magnetic fields and alignment, and non-linear behaviour of synchrotron phase space were studied, and the design of the vacuum chamber and of the magnetic elements undertaken.

Staff:
S. Bartalucci, M. Bassetti, M.E. Biagini, S. Guiducci and M. Preger (Resp.).

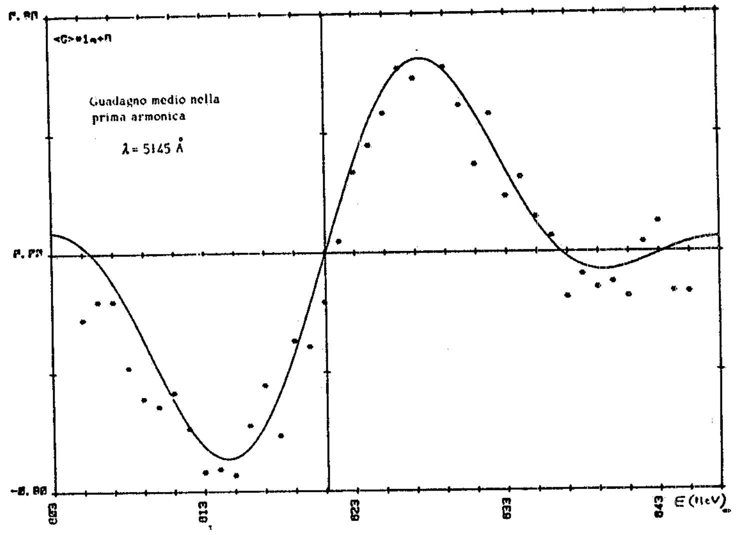

Guadagno medio nella
prima armonica
λ = 5145 Å
E (MeV)

FIG. 47

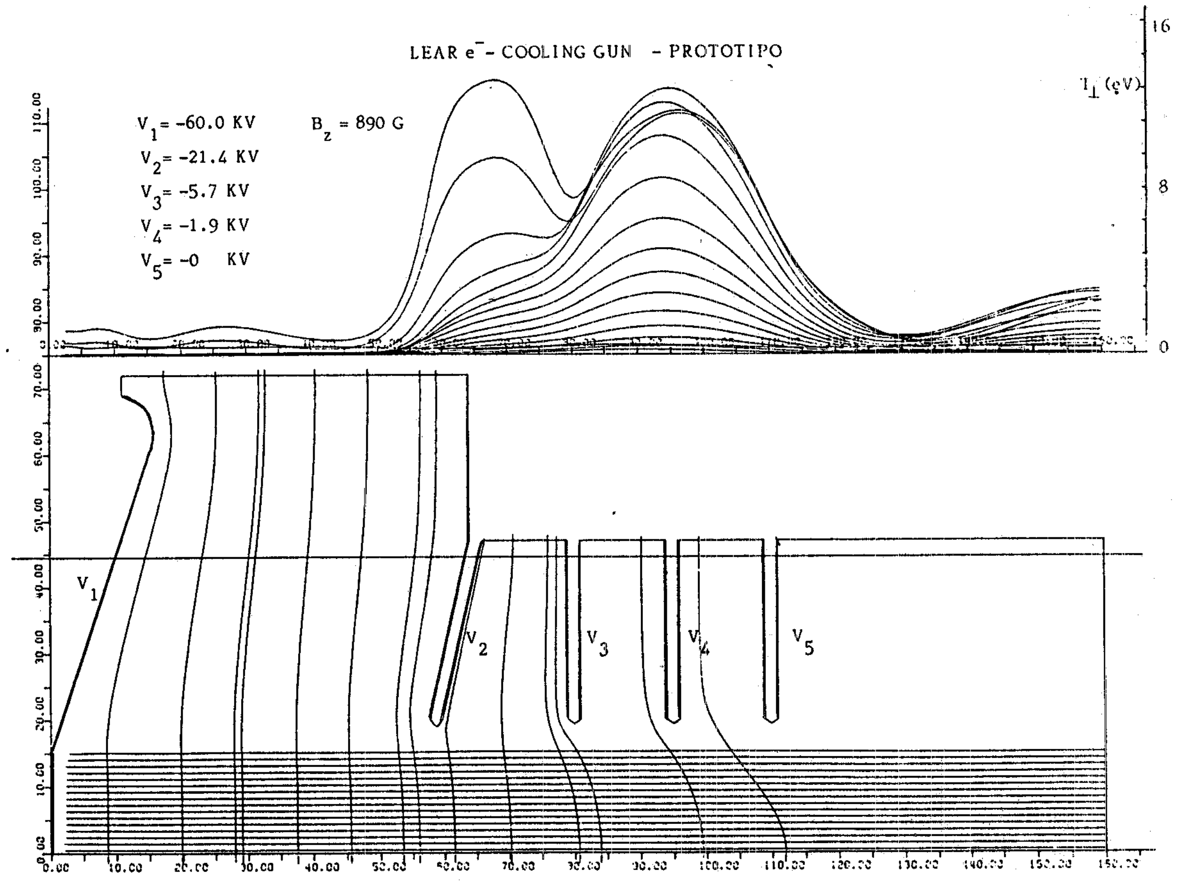

LEAR e⁻ - COOLING GUN - PROTOTIPO
V1 = -60.0 KV
V2 = -21.4 KV
V3 = -5.7 KV
V4 = -1.9 KV
V5 = -0 KV
Bz = 890 G
T⊥ (eV)
16
8
0
V1
V2
V3
V4
V5

FIG. 48

MEMORANDUM

G-50 R. Boni, S. De Simone, S. Fortebracci e M. Serio, Caratteristiche del sistema per la misura del guadagno di LELA.

M-23 S. Faini, Calcolo dei parametri del raffreddamento dei solenoidi per il nuovo sistema di iniezione del LINAC.

SC-113 M. Preger, Istruzioni per il passaggio da due famiglie di quadrupoli (struttura normale) a quattro famiglie (struttura LELA).

EC-3 M.E. Biagini, Calcolo di un campo magnetico in simmetria cilindrica a partire da una soluzione in simmetria piana (Magnet).

V-29 V. Chimenti e S. Faini, Impianto da vuoto delle macchine: LINAC. Premesse per il progetto di un nuovo impianto.

RF-48 R. Boni, B. Spataro e F. Tazzioli, Studio e dimensionamento di una seconda cavità RF a 51.4 MHz.

RF-49 R. Boni, Spira di accoppiamento per la seconda cavità a 51.4 MHz.

MM-17 M.E. Biagini e S. Guiducci, Misure preliminari sui magneti permanenti.

G-51 M.E. Biagini e M.A. Preger, Calcolo della zona di stabilità in J_x, J_s per la nuova struttura LELA.

SC-114 S. De Simone, C. Marchetti, M. Serio, F. Tazzioli e A. Vitali, Caratteristiche elettriche dei rivelatori "a bottone".

M-28 B. Dulach e F.Q. Wei, The temperature calculation of seconf RF 51.4 MHz cavity.

O-11 M. Vescovi, Posizionamento nuove targhette fosforescenti lungo l'ottica.

V-31 S. Faini e V. Lollo, Progetto esecutivo del nuovo impianto da vuoto del LINAC.

L-79 M. Vescovi, Proposta di un bridge coil per il nuovo sistema di conversione elettroni-positroni del LINAC.

RM-26 M. Preger, Resoconto turni LELA del 25/26 Luglio 1983.

G-52 M. Preger, Analogia tra le formule di trasporto per fasci laser ed il simbolismo usato per l'ottica di macchine acceleratrici.

RF-50 R. Boni, S. Fortebracci e F. Tazzioli, Relazione sui colloqui tecnici con il personale del DCI di Orsay.

RF-51 F. Tazzioli, Allungamento attivo del bunch in ADONE.

RF-52 F. Tazzioli, Appunti sulla controreazione longitudinale di baricentro.

T-119 M. Preger, Calcolo della lunghezza della traiettoria in un magnete rettangolare.

ESRP - Internal Reports

IRM-2/83 S. Guiducci, A. Jackson and M. Preger, Preliminary report of the ESRF lattice studies.

IRM-4/83 S. Tazzari, Aperture for injection.

IRM-7/83 M. Preger, A flexibile lattice for ESRP. Status report.

IRM-/83 M.E. Biagini, S. Guiducci and A. Renieri, An application of a method for distinguishing chaotic from quasi-periodic motions to the ESRP lattices.

PG-4/83 B. Buras and S. Tazzari, ESRP Workshop "Synchrotron Radiation Users Requirements for the ESRF".

TECHNICAL DIVISION

In 1983 the Technical Division significantly supported the experiments in run or in construction (for example Zeta-∅, Tofradupp, Nusex, etc.). The continuation of mechanical constructions started last year, and technical assistance "in loco" were need.

The new proposals like Gran Sasso, Labro, Flatev started, required some feasibility studies involving the design of different prototypes.

On this subject we emphasize the design, development and construction of the prototypes constituting the automatic assembly line of the streamer tubes to be produced for the future calorimeters proposed for LEP and Gran Sasso experiments.

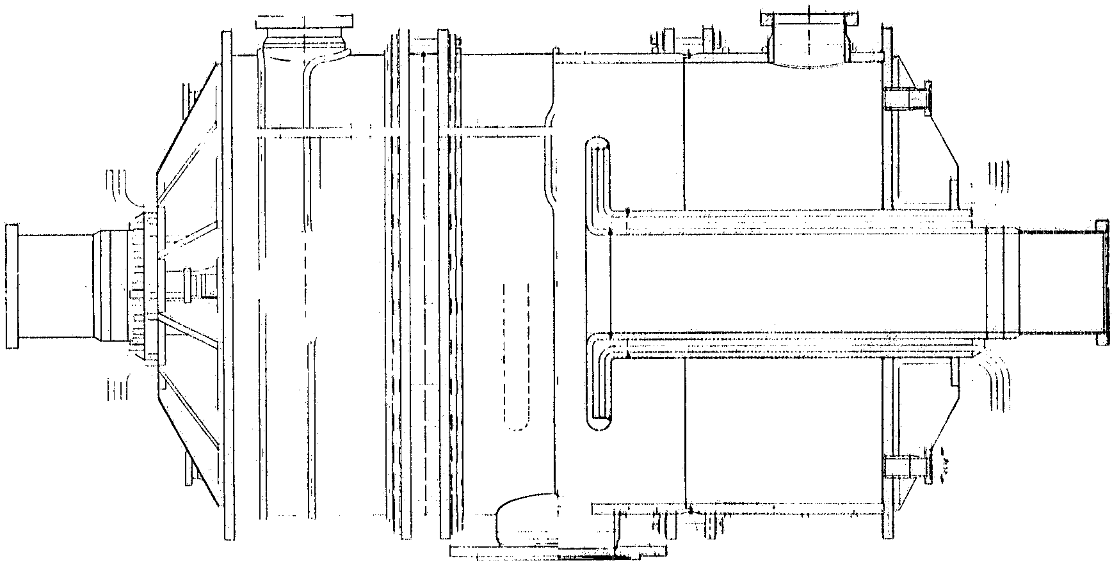
Advanced technologies involved in the study and development of new components for the Frascati accelerators have been requested: in particular a new Positron Converter with the aim of significantly reducing the build up of radiations in the surrounding area has been designed.

More details about the above subjects can be found in the following chapters devoted to the various Services of the Technical Division.

1. - MECHANICAL DESIGN SERVICE

Accelerator Division

- The assembly of a new positron beam dimension monitor for Adone.
- Modification of the targets for the beam position control in the transport channel between Linac and Adone.
- Project of the second 51.5 MHz cavity (see Fig. 49). The second cavity will be made, like the first one, from one kind of alluminium alloy (ASTM 6061 UNI 3571) which is satisfactory for electronic welding. In



order to control the frequency deviation within an acceptable limit, the temperature of the cavity was calculated and the temperature uniformity and stability of the cavity improved. (See Memo M-28). The cooling water temperature is controlled by some probes which are inserted in suitable area of the cavity. The vacuum joint was improved. The three cavity parts join together at the median outside cylinder where the superficial current is smaller. The electrical continuity at the joints depends on the pressure which reaches 100 da N/cm^2. This new project reduced some cavity dimensions, particularly the outside cylinder dimension, the capacitance plates dimension and the distance between them.

- Re-establishement of the equipment used for the Adone alignment in order to check the magnet positions which were installed 20 years ago.

Leale

- Study of a big angle vacuum chamber for double focalization spectrometry.
- New thin windows for the spectrometer vacuum chamber.

Gran Sasso

- Study of the calorimeter structure for an experiment of proton decay which will take place at the Gran Sasso Laboratory. It is a big steel block consisting of a number of horizontal steel layers with dimensions of 8000x2000x5 mm. Some 15x15 mm^2 tubolars are put between two adjacent layers to form a gap which permits the insertion of streamer tubes. The final block dimensions are 8x8x9 m^3 (see Memo M-22). The tests of the mechanical resistence of the structure and of the sensitive components have been done. Good results have been obtained (see Memo M-24). A 5 layers test block has been assembled in co-operation with SMV to check the possibility of the structure to achieve the request accuracy and to estimate the necessary time and manpower (see Memo M-27) (see Fig. 50).

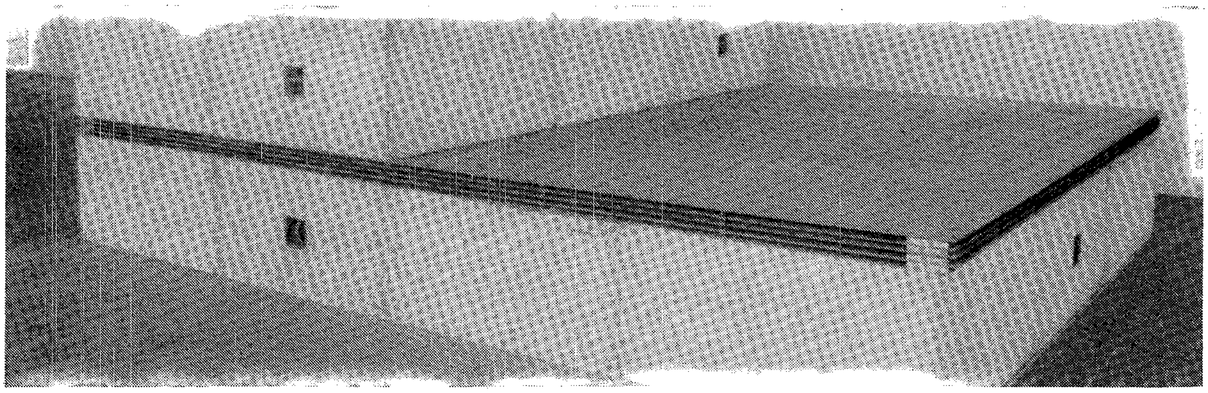


FIG. 50

Labro (see Fig. 51).

An optical bench to align the argon laser light beam on the electron beam of the machine, for the Brookhaven x-ray production facility has been designed. A technique used at LADON in Frascati has been followed. For completing the optical bench a system of the laser spatial adjustment remains to be built and an adjustable vacuum window should still be defined.

Zeta - 0

- Phototube gain control system. A photomultiplier gain control system which is installed in the adronic calorimeter of CDF (Collider Detector Facility). It allows the checking of efficiency of the phototube signals by a calibrated laser light. In Fig. 52 the block diagram of the system with each component function is shown.

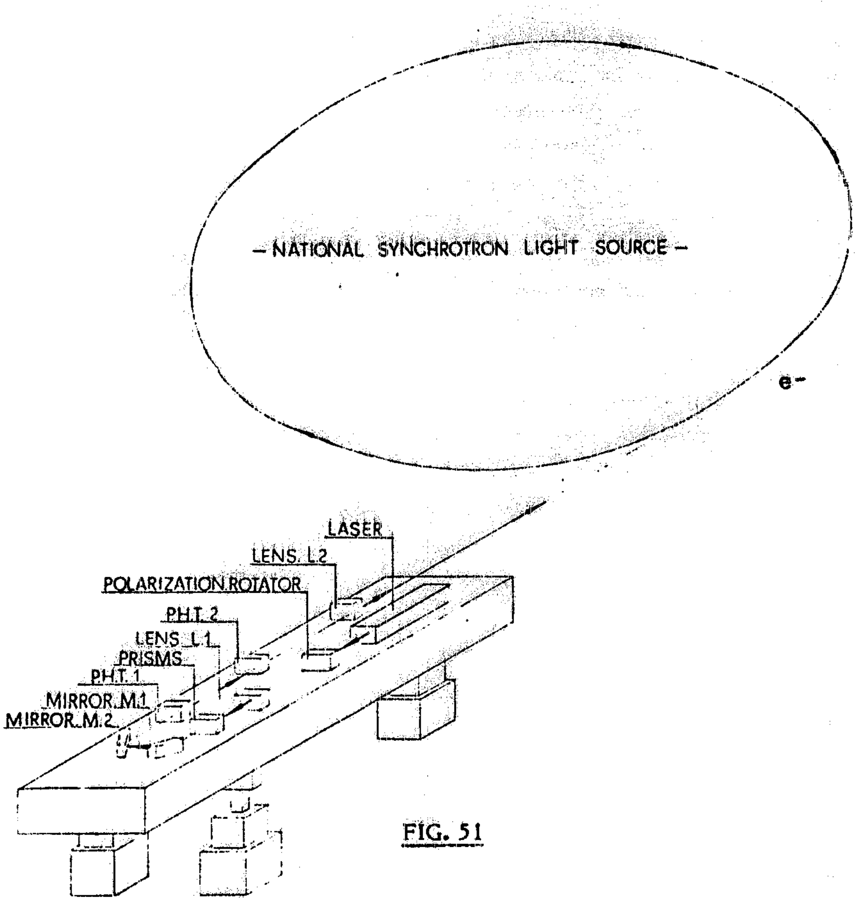

– NATIONAL SYNCHROTRON LIGHT SOURCE –
e-
LASER
LENS L2
POLARIZATION ROTATOR
P.H.T. 2
LENS L1
PRISMS
P.H.T. 1
MIRROR M1
MIRROR M2

FIG. 51

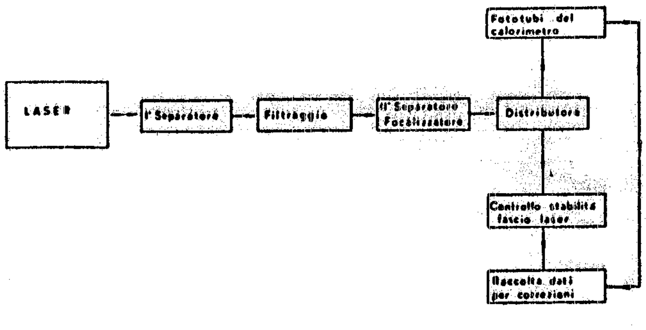

LASER
I° Separatore
Filtraggio
II° Separatore Focalizzatore
Distributore
Fototubi del calorimetro
Controllo stabilità fascio laser
Raccolta dati per correzioni

FIG. 52

- Small angle detector under vacuum. (Fig. 53). A detector constructed in seven copies is to be inserted in the vacuum channel of the proton-antiproton machine in Fermilab for luminosity measurements. The sensitive part of the detector made by metallic strips deposited on the plane area over the silicon crystal, is able to operate under ultra vacuum conditions. The configuration and precision of the sensitive strisps permit the measurement to a tolerance of ± 0.05 mm. Step motors and linear transducers assure the wanted precision of the position and the repetitiveness of the sectors. The silicon crystal is deteriorated easily by the intense beam circulating in the machine. This system is able to extract the sectors in a maximum time of two seconds, in the case of progressive beam loss.

Because of the complexity of the machine requirements the project is at a preliminary stage, but we hope that a prototype will be built in 1984.

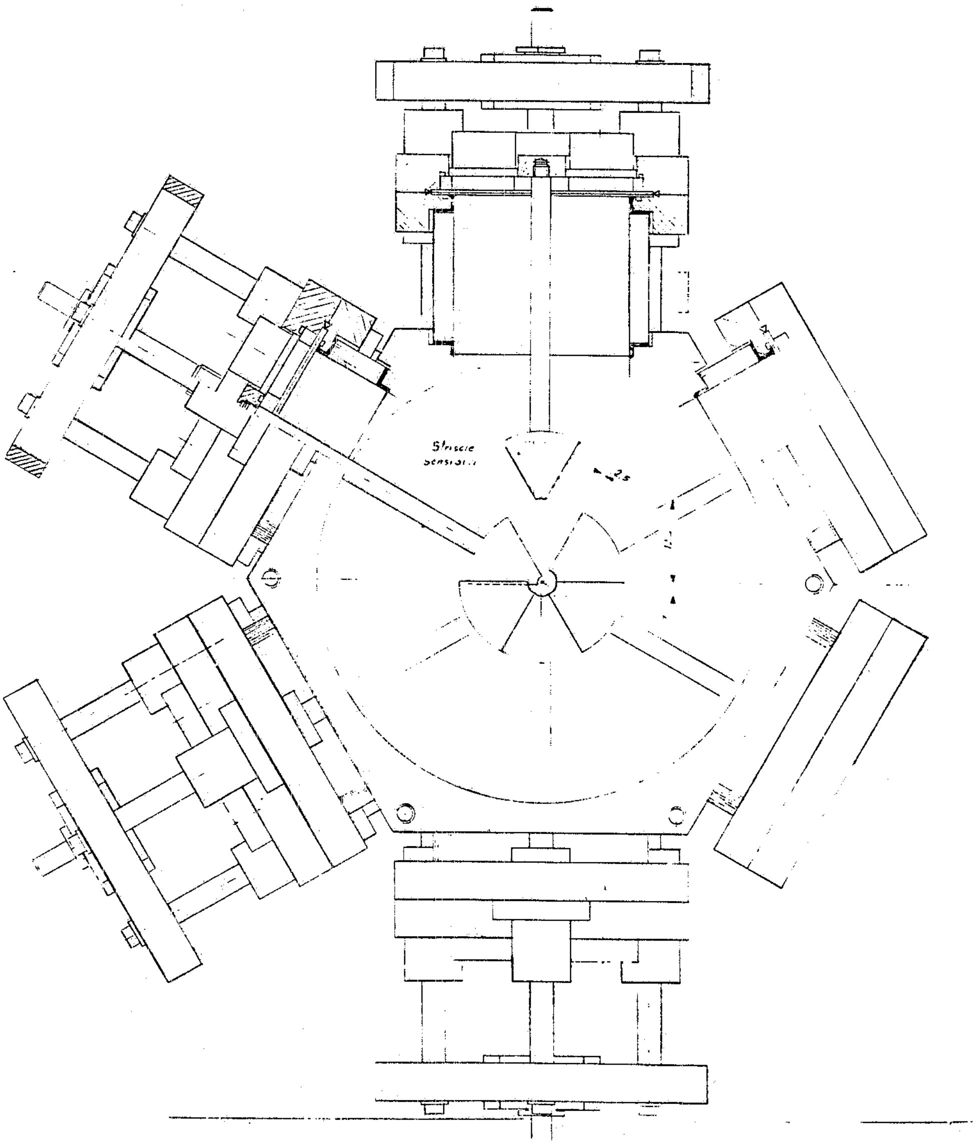


FIG. 53

Fla-Tev (Fig. 54)

- The possibility of constructing an electromagnetic calorimeter has been studied in co-operation with Fermilab. The detector will consist of 30 lead shower counters whose dimensions are 2400x2200x2.5 mm^3. There are about 4000 sticks (width 32 mm, thickness 10 mm and length 1000÷1200 mm) which make up the sensitive parts of the experiment. The calibration of the sensitive elements is obtained by translating each point of the calorimeter on the pion beam axis. The request precision is ±1 mm horizontal and ±5 mm vertical. It is possible to scale the absolute position through the stepper-motors and linear transducers. The calorimeter is designed in two symmetrical parts which can be split horizontally to reduce the difficulty of construction and installation and to permit, moreover, access to the centre part for maintenance and control. The final plan is under execution and we hope to begin the construction in the middle of 1984.

Staff:
A. Beatrici, A. Cecchetti, B. Dulach (Resp.), C. Fontana, G. Sensolini and M. Troiani.

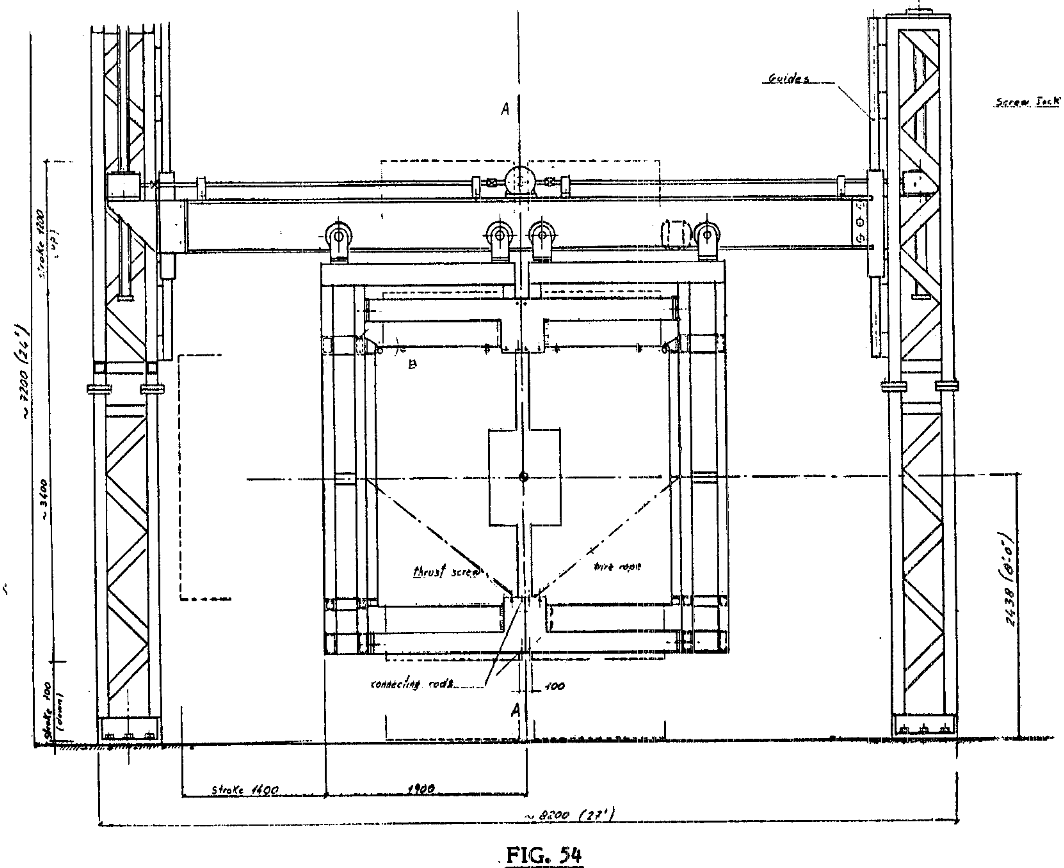


FIG. 54

2. - MECHANICAL AND VACUUM SERVICE

New Positron Converter for the Frascati Linac

The good performance of the copper-gold targets (see Memo V-27) has reduced the problem of radiation damage in the area surrounding the PC.

We decided to plan another vacuum chamber for PC matching following points:

1) The material used must show a low residual radiactivity or at least create short half-life radionuclides.

2) Vacuum flanges must be quickly demountable to let people work rapidly with short exposition to radiation.

3) The vacuum chamber must be shielded with a material with low residual readioactivity. The radioactivity must be reduced in order to avoid radiation damage to the surrounding parts when the target is working and to allow people to work around the PC with the beam stopped a short time before.

For 1) pure Al was found as the best material. In practise a commercial alloy (ASTM 6061) was chosen which contains heavy metals of low percentage and shows a low induced radioactivity, after exposition, as tested.

For 2) vacuum connections will be done using quickly demountable clamp chains with flat flanges and Al gaskets. Laboratory tests confirmed reliability and characteristics.

For 3) pure lead (without antimony) seems to be the most suitable material. Minimum thickness to be used is 5 cm.

R.F. Cavity

The aluminium 51.4 MHz cavity was installed in Adone about two years ago. Every time a RF field is applied a strong increase in pressure occurs (2 or 3 orders of magnitude from 10^{-9} Torr) which makes it difficult to start the cavity itself.

In order to study the desorption of gases due to interaction between RF fields and the internal surface of the cavity we have installed a quadrupole mass spectrometer (1-100 AMU) which can be switched on and used from the Control Room (it is not possible to work near the cavity because of the high X-ray radiation level). First measurements (see mass analysis in Fig. 55) have shown a strong emission of Oxygen from internal surfaces.

In addition to these studies on the Adone cavity we decided, together with the RF Group, to plan and build a smaller cavity, 160 MHz, just studying these phenomena in the laboratory.

During 1983 we completed the plan and within the first months of 1984 we hope to have the cavity ready for the first studies. We have planned this cavity with demountable capacitive plates for the possiblity of studying the behaviour of aluminium and other metals and the influence of different treatments.

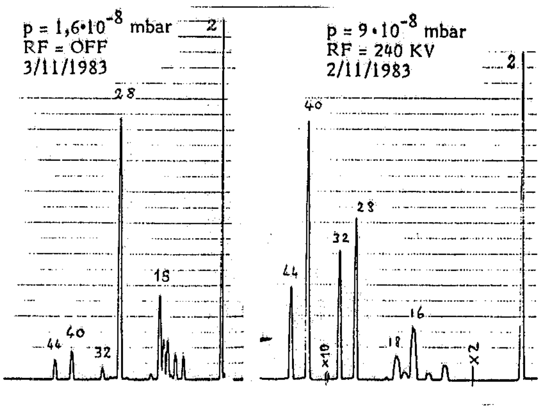


FIG. 55

Other interesting work, is outlined below:

- LEALE double focussing magnet (to be finished in 1984).
- Prototype of iron sheets structure for Gran Sasso experiment.
- New injection system for LINAC.
- Remarkable work done to create complete computer aided store management.
- IRSS experiment: after a short activity with synchrotron light we stopped because of problems with the mass spectrometer.
- Vacuum laboratory. Activity related to the usual problems of our accelerators. The "CANDI" computer has arrived together with the planned hardware and tests are in progress.

Staff:
G. Bisogni, B. Casagrande, A. Ceccarelli, V. Chimenti (Resp), R. Ciocca, M. De Giorgi, M. Di Virgilio, V. Luppino, U. Martini, M. Meli, A. Mengucci, A. Olivieri, F. Sgamma, L. Siracusano, A. Tiburzi, G. Turchetti, A. Vitali and A. Zolla.

3. - ELECTROTECHNICS SERVICE

- The theoretical study of a "distributed" sextupole for Adone has been concluded. The position of the conductors surrounding the vacuum chamber of the bendind magnet and to get the sextupole field area as wide as possible was studied. The results of the calculation, iron excluded and with a sextupole field area of 4x4 cm^2, suggested the construction of a

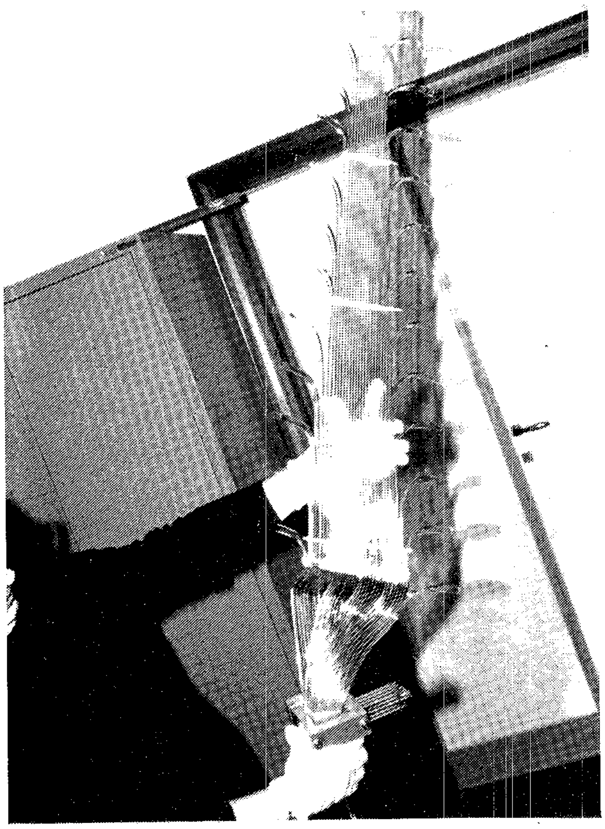


FIG. 57

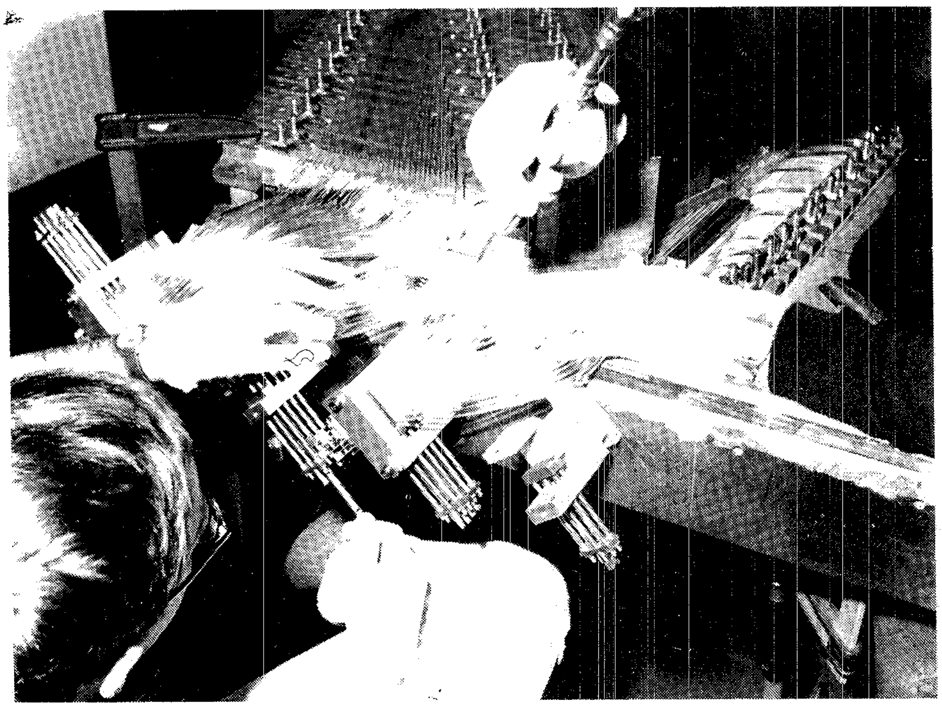


FIG. 58

model. The aim was to verify the sextupolar strength was greater than the other terms of the magnetic field (dipole, quadrupole, etc.) by a factor of 100 or more. The measurement will be done using an asymmetric rotating coil driven by a synchronous motor (3000 rev/min).

- Ladon: a new control board for the pump room, needed by the Laser Group, was installed.
- A new power supply powering the Wiggler magnet has been purchased. The electrical characteristics are:

Line volatge	3.000 V
Output voltage	0-65 V d.c.
Output current	0-5000 A d.c.
Stability	± 0.1%

The Ahsaldo will assemble the power supply whose delivery is foreseen in October 1984.

Using this "ad hoc" power supply we'll improve the working conditions of the magnet and save money on electrical energy.

- The program to improve the power distribution line is being continued increas the available power of the Adone transformation cabin, by purchasing a low voltage panel and substituting a 315 kVA with a 630 kVA transformer.
- During the next year we will install a new transformation cabin powering the new Ladon, Nusex and PEPR laboratories. With this improvement it will be possible to supply an area of the LNF not energizeable yet.
- Concerning the main transformation cabin it is noted that, after the deconnection of ENEA, we linked the 3 kV bus bars again, made maintenance on the H.V. cross connection equipments, on the under-load commutators of the main transformers, and installed the lighting protectors missing from one of the two main transformers.

Staff:
D. Cosson, G. Fuga, M. Rondinelli and C. Sanelli (Resp.).

4. - DETECTOR SERVICE

During 1983 the OFTA was mainly devoted to the realization of the 800 light-guides for the 32 layer shower counters (see Figg. 56, 57) of the CDF expriment. Some people also participated in the experiment assembly at Fermilab.

In the second half of the year the main job was the development and construction of a prototype automatic weaver machine for streamer tubes. This machine allows the simultaneous weaving of the 8-wires of each module (see Fig. 58).

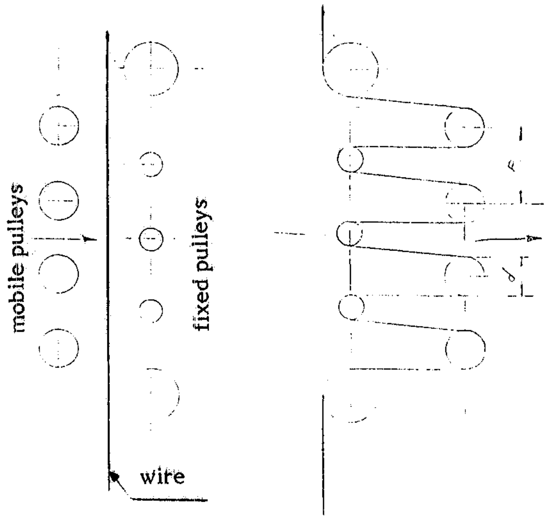


FIG. 58 - A single stretched wire coming from a spool, passes through a group of fixed pulleys and a series one mounted on a mobile arm. The relative motion (as sketched in figure) of the two groups of pulley creates the 8 wire segments necessary to built the detector module.

The wire-soldering at both ends of the module together with the loading and unloading of the modules is also automatized.

The project for the final version of the machine capable of handling 8-meter long modules is nearly completed.

Among the minor activities are construction of a Cerenkov detector for the LION experiment, the assembly of streamer tubes detectors to be put on test beams at CERN.

Work has been also devoted to the maintenance of the machinery for the construction of "NUSEX" type tubes, requested by many external groups.

The activity of the photographic and printed-board workshop has been suspended to allow a complete reconstruction of the workshops.

Staff:
R. Baldini, R. Bonini, G. Catitti, V. Chiarella (Resp.), R. Di Stefano, A. Di Virgilio, C. Federici, L. Iannotti, D. Pistoni, D. Riondino and M. Santoni.

MEMORANDUM

V-27 V. Chimenti, G. Turchetti e A. Vitali, Targhetta e^+e^- del positron converter.

M-20 B. Dulach, Sostentamento pneumatico dello spettrometro dell'esperimento TOFRA-DUPP.

V-28 V. Chimenti e G. Turchetti, Determinazione del desorbimento del naftalene dagli scintillatori plastici.

M-22 B. Dulach e M. Spinetti, Studio del castello di ferro per l'esperimento Gran Sasso.

M-24 B. Dulach e F. Sgamma, Esperimento Gran Sasso. Prove di resistenza dei componenti il castello.

M-25 B. Dulach e G. Siracusano, Leale. Finestra sottile dello spettrometro a coppie.

V-29 V. Chimenti e S. Faini, Impianto da vuoto delle macchine: Linac. Premesse per il progetto di un nuovo impianto.

SC-114 S. De Simone, C. Marchetti, M. Serio, F. Tazzioli e A. Vitali, Caratteristiche elettriche dei rivelatori "a bottone".

V-30 V. Chimenti e G. Turchetti, Filamento del cannone del Linac.

M-26 B. Dulach, Esperimento CDF.

M-27 B. Dulach, F. Sgamma e A. Vitale, Esperimento Gran Sasso - Valutazione costi dei materiali e dei tempi di assiemaggio.

M-28 B. Dulach e F.Q. Wei, The temperature calculation of second RF 51.4 MHz cavity.

M-29 F. Sgamma, Dimensionamento di una camera da vuoto di sezione generica composta di tratti rettilinei e di tratti circolari.

M-30 R. Bonini, G. Catitti, V. Chiarella, U. Denni, G. Nicoletti e D. Pistoni, Prototipo di macchina tessitrice per tubi tipo Nusex: Status al 1/8/1983.

M-31 B. Dulach, Controllo allineamento Adone.

M-32 B. Dulach, Procedura per l'elaborazione di un progetto e per lo sviluppo dei disegni costruttivi.

SERVICES

COMPUTER CENTER

At the end of 1983, the hardware/software configuration of the VAX 11/780, the local computing service, is as follows:

- Memory: 3.5 Megabytes.
- Magnetic discs: 2 RM03,1 RM80, 1 RM05, 1 RUA81 (to be installed in 1984). The total disc capabilities will be 1000 Megabytes.
- Magnetic tapes: 1 TU77, 2 TU78.
- Communication interfaces: 1 CS21 (or DH11), 3 DZ11, 1 DZS11, 1 DMC11, 2 DMF-32.
- Printers and plotters: 2 Centronics 6000 (printing 600 lines/minute), 1 HP-7221B plotter, 1 printer/plotter Versatec mod. 80.

  Software: VMS Vers. 3.3, DECNET and standard scientific libraries from CERN and SLAC laboratories.

In this configuration, the use of the CPU throughout the year was about 80% of the solar time.

The standard DEC program DATATRIEVE is now used by documentation and store-room services to catalog the existing items.

Using the printer/plotter Versatec and the program TEK from SLAC, several scientific publication were prepared by the authors in the final presentation.

The following external computing external computing resorces are accessible from LNF:

1) The CINECA center (CDC computers) using the INFNET network.

2) The CCIUR center (UNIVAC computer) using the INFNET network.

3) The CERN center (VAX, IBM and CDC computers) using the INFNET-CERNET gateway.

4) The SLAC center (VAX and IBM computers) using the TYMNET network and a link between LNF and ITALCABLE in Rome.

5) The ORSAY center (UNIVAC computer) using the EURONET network.

6) The ENEA local center (IBM computer).

7) The CNUCE center (IBM computer) using the RPCNET network from the local CNR Plasma-Spazio center.

Also in this configuration, local users needs for the year 1984, new CPU resources (equivalent to 3.5 times the VAX 11/780).

Staff:
O. Ciaffoni, M.L. Ferrer (Resp.), A. Martini, M. Pistoni and M.A. Spano.

HEALTH PHYSICS

During 1983, the activity of the Health Physics Group continued with physical surveillance in the LNF, according to present laws.

Concerning the activity of study and research, a comparison of different kind of fast neutron personnel dosimeters has been effectuated in the mixed fields of radiation around the LNF machines.

In collaboration with the USL a programme for the study of toxic gased produced near particle accelerators was established.

In addition, the study of some radioprotection problems relating to the LEP was carried on in collaboration with the Health Physics Group of CERN.

Staff:
R. Centioni, M. Chiti, A. Esposito and M. Pelliccioni (Resp.).

MEDICAL SERVICE

During 1983 the Medical Service of the LNF continued its activity of medical surveillance according to present laws.

In collaboration with other units of LNF and external scientific associations, the Medical Service carried out a programme of study in the field of occupational medicine with reference to the interests of the Institute: clinical radiopatology, medical aspects of nuclear emergency, laser light effects in biostimulation, etc.

The occupational medicine activity included also clinical research in the screening of social diseases.

Staff:
R. Centioni, V. Grisanti and E. Righi (Resp.).

SCIENTIFIC INFORMATION SERVICE

Due to financial restriction our Library had a very low increment in 1983, for only about 200 books and not more than 150 subscriptions for Scientific Reviews. The exchange of publications with about 250 italian and foreign institutes still continues.

As far as the organization of the Library and the automation of the catalog is concerned, an internal report was planned for the begining of 1984.

130 Articles were published in 1983, 30 of which were for other INFN Sections, about 65 articles have been composed and sent for publication to scientific reviews or for proceedings of various Conferences and Congresses.

Moreover, this Service has published the following proceedings:

- Internal Seminar on Nuclear War. 2nd Session: How to avoid a Nuclear War, Erice, August 1982.
- International Colloquium on Matter Non Conservation - ICOMAN '83, Frascati, January 1983.
- Italian-Soviet Symposium on Mathematical Problems of Statistical Physics, Rome, February 1983.

and has also considerably contributed in organizing the ICOMAN Conference which was held in January 1983, at the Villa Tuscolana in Frascati; Science for Peace - Galileo Galilei and Alfred Nobel Celebration, from May 1st to May 11th, 1983 in San Remo and Rome.

Staff:
L. Invidia, G. Leoni, M. Pacifici, G. Romagnoli and S. Stipcich (Resp.).

PUBLICATIONS LNF-

83/1(P) G. Battistoni, P. Campana, V. Chiarella, U. Denni, B. D'Ettorre-Piazzoli, E. Iarocci, G. Mannocchi, G. Nicoletti and P. Picchi.
INFLUENCE OF GAS MIXTURE AND CATHODE MATERIAL ON LIMITED STREAMER OPERATION
Nucl. Instr. & Meth. 217, 433 (1983).

83/2(P) Y.N. Srivastava and A. Widom:
CRITICAL VOLTAGE LAW FOR CHIRAL PARTICLE PRODUCTION NEAR A MONOPOLE.
Lett. Nuovo Cimento 37, 77 (1983).

83/3(R) M.L. Ferrer, G. Mirabelli and E. Valente:
GATEWAY INFNET-CERNET PERFORMANCES.

83/4(P) G. Battistoni, P. Campana, V. Chiarella, A. Ciocio, U. Denni, E. Iarocci, G. Mannocchi, M. Meschini, G. Nicoletti and P. Picchi:
ELECTRODELESS PLASTIC STREAMER TUBES
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