

Laboratori Nazionali di Frascati

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Report n. 8: ACTIVITY AT THE NATIONAL LABORATORIES OF FRASCA-  
TI - DECEMBER 1959 - JUNE 1960.

COMITATO NAZIONALE PER LE RICERCHE NUCLEARI  
(National Committee for Nuclear Research)

ACTIVITY AT THE  
NATIONAL LABORATORIES OF FRASCATI

Report n° 8  

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(National Laboratories of Frascati)

COMITATO NAZIONALE PER LE RICERCHE NUCLEARI  
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Report n° 8  
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NATIONAL LABORATORIES OF FRASCATI

Compiled by the Documentation Office of  
the National Laboratories of Frascati of the CNRN  
June 24, 1960

INTRODUCTION  
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This report N° 8 will present the activity at the Frascati National Laboratories from December 1959 to June 1960. As can be seen, scientific activity at our Laboratories can be divided into three main chapters, although the spirit has been common.

A first chapter concerns the working of the electronsynchrotron, continuous changes and improvements wrought on it, and research. It should be particularly emphasised that in the last months construction of a storage ring has been undertaken (see paragraph 2). It should be borne in mind that to insure continued competence on the machine, the group of physicists and engineers directly connected with the electronsynchrotron must do some original research, each one in his own field.

The second chapter concerns the activity of the various laboratories of the Frascati center. This activity is mainly concentrated on problems connected with nuclear research done with the synchrotron or on its development and improvement. This connection is to be understood in its broadest and most liberal sense. The various laboratories in Frascati render certain services to the synchrotron and to its experimenters, but each has its own task, that may be stated as effective research; the technical side of nuclear research both in and out of Frascati obviously benefit from this. Reading about each laboratory's work will clarify this point.

In the third chapter experimental research done in conjunction with the electronsynchrotron is briefly synthetised. All experiments that have been set up in the experimental area are described, without distinction as to the origin of the experimenters. As can be seen a sizable part of these experiments have been undertaken in collaboration between physicists from

## II.

Frascati and from elsewhere. It is pleasant to note that by now the results of a few experiments have been published or are in the course of being so.

We have thought it advisable to list the names of physicists and engineers belonging to the Laboratories together with the sphere of interest of each, so as to help anybody who is interested in contacting the right person:

Amman Ing. Fernando	Electronsynchrotron laboratory
Bassetti Dr. Mario	Theoretical group
Bernardini Dr. Carlo	Experimentalist, Theoretical group
Bizzarri Dr. Ubaldo	Electronsynchrotron Laboratory
Bologna Dr. Gianfranco	Experimentalist, Magnetic measurements
Cabibbo Dr. Nicola	Theoretical group
Cerchia Ing. Renato	Building department
Corazza Dr. Gianfranco	Tecnological laboratory, Chief of persone Chief of personnel
Del Fabbro Dr. Raffaele	Electronsynchrotron laboratory
Diambrini Dr. Giordano	Experimentalist, $\gamma$ -ray beam
Evangelisti Ing. Roberto	Experimentalist's magnets laboratory
Gatto Prof. Raul	Theoretical group
Ghigo Dr. Giorgio	Electronsynchrotron laboratory, Machine director
Giannini Dr. Marcello	Electronsynchrotron laboratory
Habel Dr. Roberto	Tecnological laboratory
Infante Dr. Carlo	Electronic laboratory
Ladu Prof. Mario	Dosimetry
Massarotti Dr. Antonio	Radiófrequency laboratory
Moneti Dr. Giancarlo	Criogenic laboratory
Montelatici Dr. Vinicio	Criogenic laboratory

### III.

Murtas Dr. Giampaolo	Experimentalist, beam dosimetry
Pellegrini Dr. Claudio	Theoretical group
Puglisi Ing. Mario	Radiofrequency laboratory
Quercia Prof. I. Federico	Electronic laboratory, Vicedirector
Querzoli Prof. Ruggero	Experimentalist, Electronsynchrotron laboratory
Sacerdoti Ing. Giancarlo	Experimentalist's magnets laboratory, Magnetic measurements
Salvini Prof. Giorgio	Experimentalist, Director
Sanna Dr. Giovanni	Experimentalist's magnets laboratory, Magnetic measurements
Scaramuzzi Dr. Francesco	Criogenic laboratory
Turrin Dr. Angelo	Computing department, Theoretical group

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## Chapter I - THE ELECTRONSYNCHROTRON

### 1. SITUATION AT THE ELECTRONSYNCHROTRON

#### a) Operation of the electronsynchrotron

The situation of the electronsynchrotron in the last six months has been definitely better than the preceding period, since a certain amount of work on the machine itself and in the experimental area has been done: the results allow a more reliable operation of the machine.

In the preceding report, data on the operation of the synchrotron up to Nov. 29, 1959 has been given. During the following month of December a lot of mishaps happened to the injector: this reduced experimental activity to only 186 hours total for the whole month. In the abovementioned period all the rotating parts of the Van de Graaff had to be changed or serviced, a broken conveyor belt had also to be changed. The graph of fig. I.1 synthesizes machine activity for 1959.

From the beginning of 1960 on, the synchrotron started to work regularly again after servicing of the injector was completed: programmed machine time for experimentalists is raised according to the following schedule:

9.00	- 12.00	the machine is off for preparing experiments and for servicing;
12.00	- 13.00	the machine is started (conditioning);
13.00	- 10.45 pm	first experimental shift;
10.45 pm	- 11.15 pm	inspection to machine and experiment changeover;
11.15 pm	- 9.00 am	second experimental shift.

Weekly servicing is now limited to Monday afternoons and machine personnel is present 168 hours weekly. Consequently machine time is allotted weekly as follows:

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Allotted to research groups (13 shifts each of 9,45 hrs)	126 hrs
Preparing experiments (6 intervals of 3,30 hrs)	21 hrs
Starting machine	6 hrs
Servicing	15 hrs
TOTAL	<hr/> 168 hrs

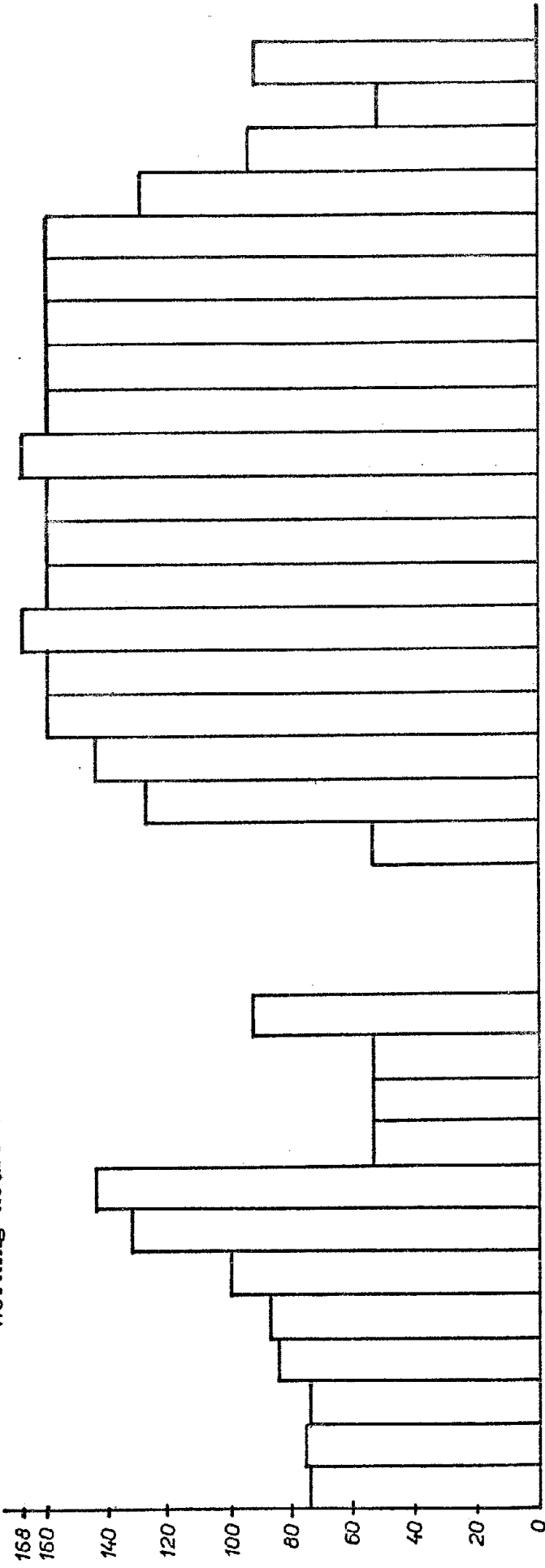
Summing up, between May 1959 and June 1960 the machine has been operating for experiments for 4,300 hrs; 1,800 during 1959 and 2,500 during 1960.

A certain improvement in the operation of the synchrotron has been due to the increase in machine personnel, that now numbers 16 persons (4 physicists, 6 qualified technicians, 6 operators) against 11 for the preceding period. This allows the continued presence at the electronsynchrotron of at least one physicist and two operators thanks to help from other physicists of the Laboratory.

During the first months of 1960 the machine has been brought to a hard-to-beat average, since out of 126 hours of allotted time, 102 have been used by the experimentalists.

Starting from 1960 complete data relative to failures has been collected and analyzed: a complete picture of the synchrotron operation follows. Apart from the trouble with the injector, relevant failures have been experienced with the RF<sub>2</sub>: particularly a crack developed in the quartz tube of the cavity's vacuum system together with troubles in the coaxial cables feeding the cavity. The rest of the off time is shared between searching for the beam and small failures in the control system. During the month of May a week long halt was decided on, for work on the power supply, on the vacuum system and on the injector. The main reason for the halt was because the collectors of the supply motors needed machining, due to abnormal wear: future longer halts may be due to the same reasons. During the same week the eastern quadrant of the vacuum chamber was changed, main

— working hours of machine personnel



— machine hours used by experimenters  
- - - beam hours used by experimenters

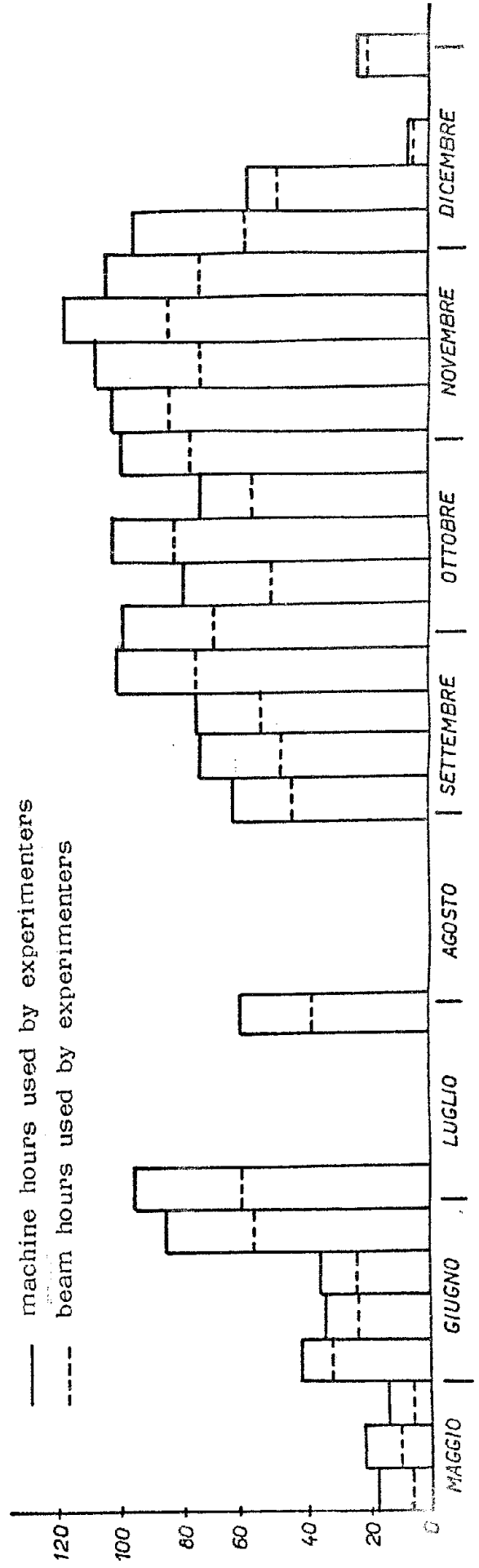


Fig. I.1 - MACHINE FUNCTIONING FROM MAY 11, 1959 TO JAN. 3, 1960

working hours of machine personnel

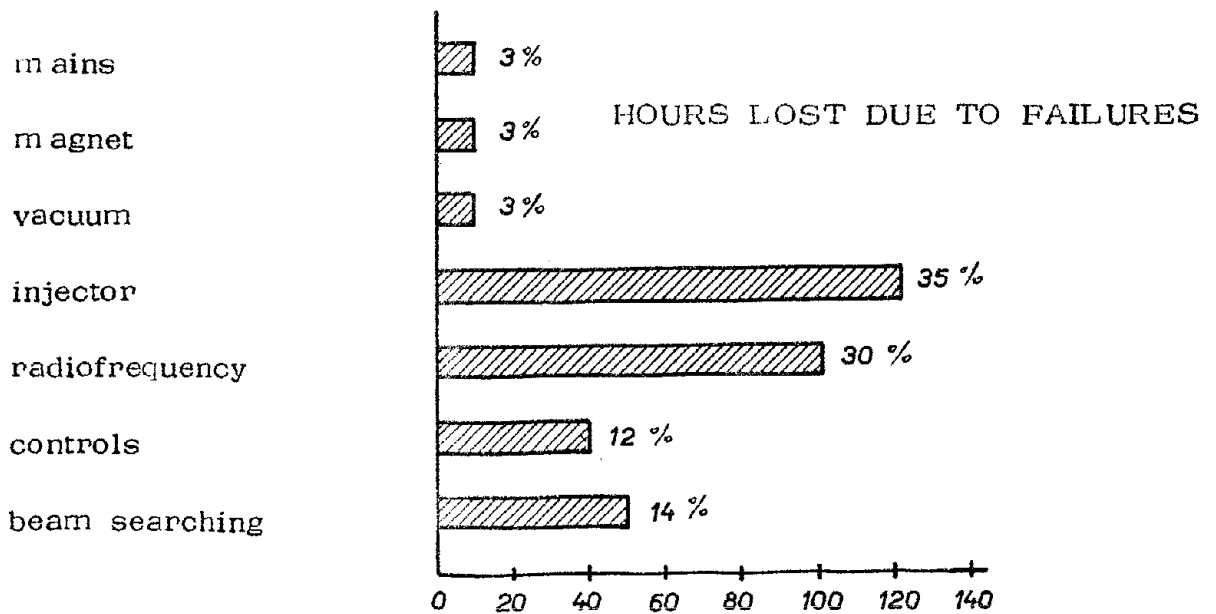
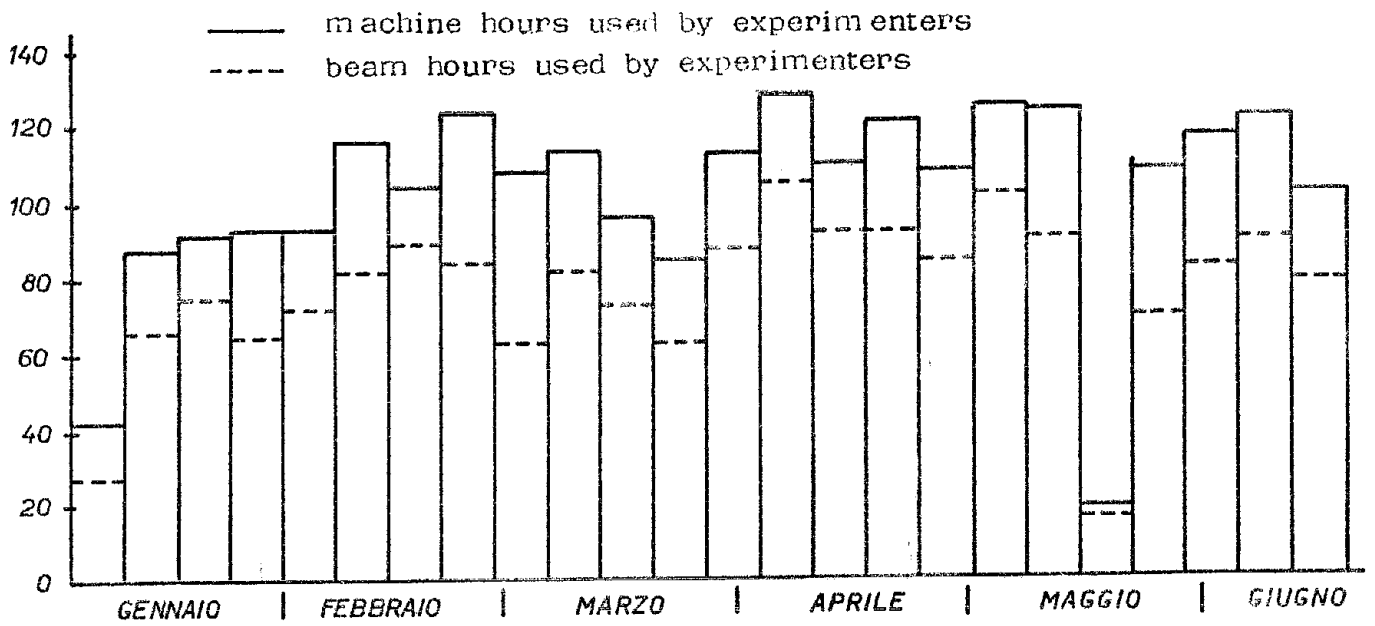
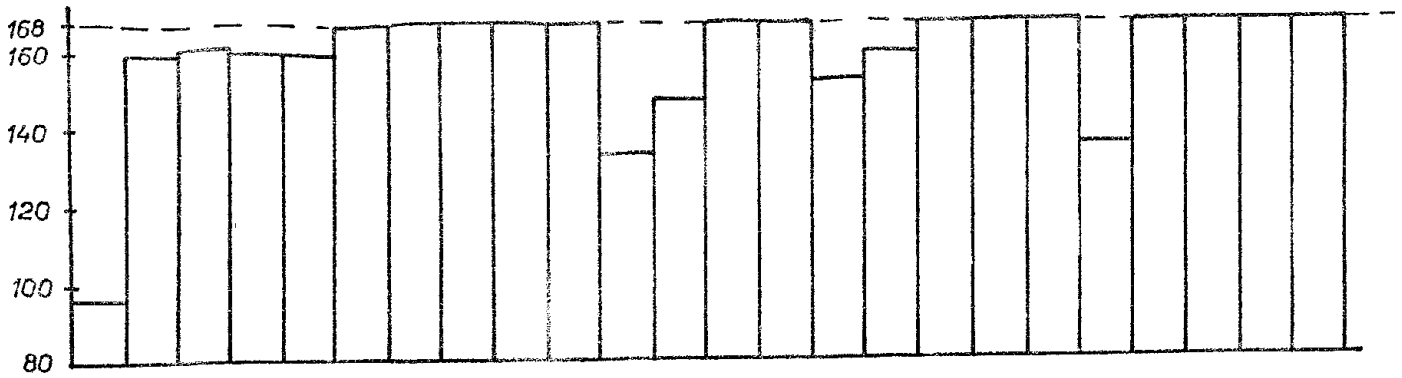


Fig. I.2 - MACHINE FUNCTIONING FROM JAN. 4, 1960 TO JUNE 6, 1960

- 1 - SANITA'  $\pi^0$
- 2 - PISA  $\pi^0$
- 3 - MONOCRYSTAL
- 4 - GENOVA
- 5 - ROMA  $\pi^+$
- 6 -  $\mu$  PAIRS
- 7 - FRASCATI  $\pi^0$
- 8 - BOLOGNA
- 9 - ROMA  $K^+$
- 10 - ANNIHILATION

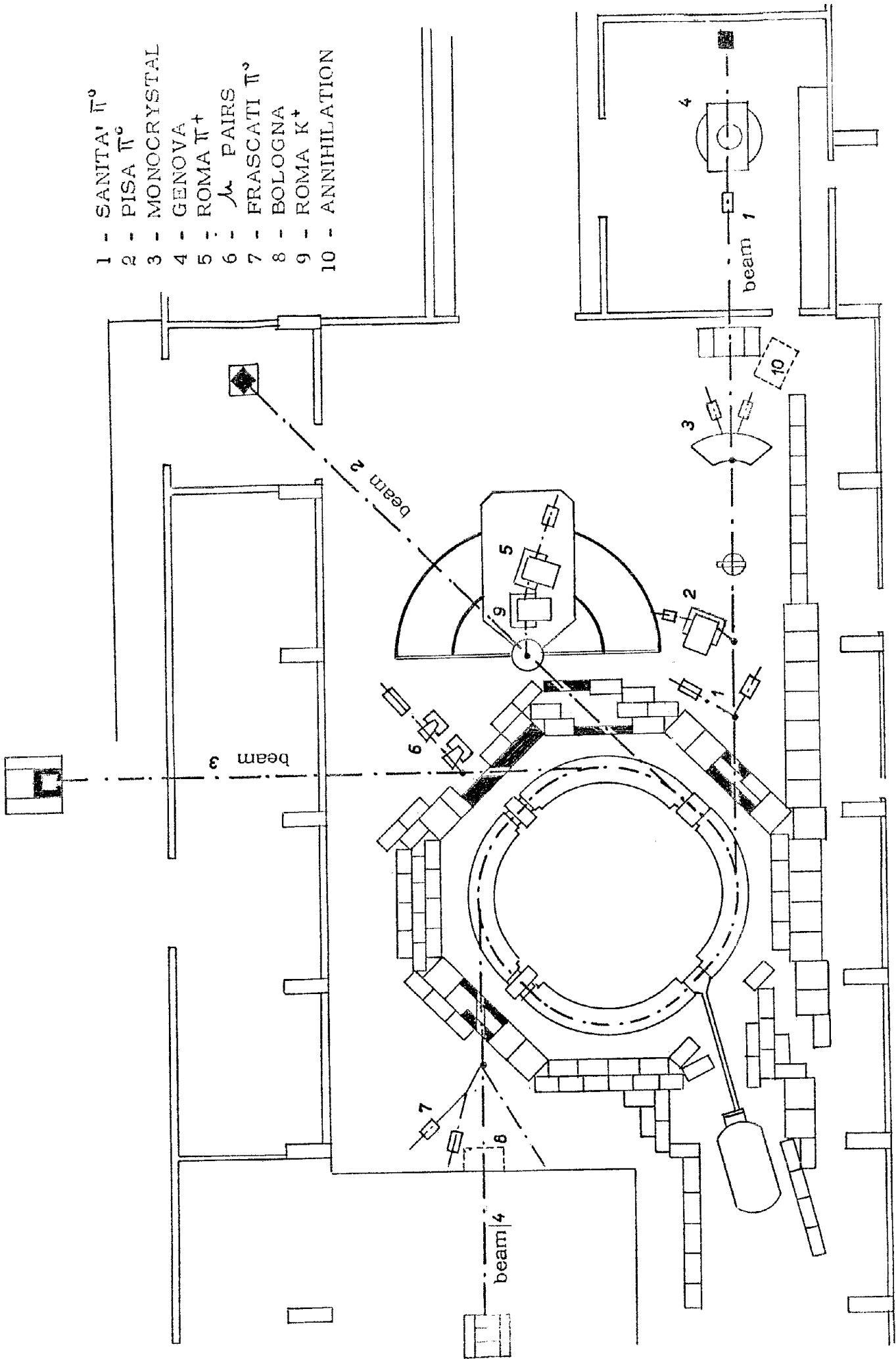


Fig. 1.3 - SYNCHROTRON BUILDING: EXPERIMENT'S LAYOUT

ly to check the gaskets and the araldite: both stood up very well. The Van de Graaff accelerating tube, that had been working for 5,000 hrs and had been dented by discharges, was also changed. With the purpose of improving the magnetic field at the  $RF_1$ , a stainless - steel tube (seat of parasite currents) has been replaced by a similar tube in araldite. After this halt a temporary lowering of the intensity due to the new accelerating tube (new electron source optics) and to the need for searching for the new values of the correction currents (replacement of steel tube).

Maximum intensity of the machine is now slightly higher and has reached  $6 \times 10^{11}$  Q/min at 1,000 MeV: normal operation is at  $4 - 5 \times 10^{11}$  Q/min with an injected current of 20 - 30 mA. During the last months the technique of changing the V. de G. filament has been improved (filaments last an average 250 hrs) during the allotted maintenance day (monday).

In fig. I.2 the graph summarizes machine activity for the first semester of 1960 showing also the distribution of lost machine time due to failures.

Recently 3 new experiments have had experimental area allotted to them for the first tests, so that the number of simultaneous experiments in the area is now 10 (see fig. I.3).

#### b) Electronsynchrotron development

During the next months experimental conditions will improve markedly since the enlargement of the counting room will be completed: a certain number of fixed cables connecting the counting room to the experimental area will be laid.

Nearly all of the building blocks of the new water supply system for the magnets to be used during the experiments have been received: this will allow simultaneous operation of a number of magnets and will speed switching from one operation to another.

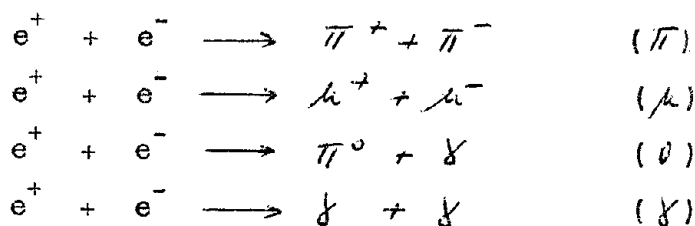
Large covered areas are also being built: this will help clearing the experimental area and allow more complicated experiments (bubble chambers, magnets) to be prepared under the best conditions.

As regards the machine practically all the improvements to the controls and to the machinery that were necessary to ensure reliable and continuous operation, have been completed. By the end of June we will receive a new stainless steel tank: this tank is the vacuum chamber for a new RF cavity that will raise the maximum energy to 1.100 MeV.

During time left free from the operation of the machine we try to improve our knowledge of the phenomena that limit the intensity of the machine: these are notoriously many and very complex, but we hope to shortly achieve results that can enable us to raise the intensity of the machine.

## 2. STORAGE RING

Following a proposal made by B.F. Touschek, certain preliminary considerations on the opportunity and possibility of building a "storage ring" (AdA short for Anello di Accumulazione) for electron pairs, have been made. This would allow the observation of  $e^+ e^-$  interactions with 400-500 MeV in the center of mass. The obvious advantage of such a device would be in allowing the observation of two-body processes such as



of obvious interest.

Having concluded that the proposal might have some chance of being carried out in Frascati, detailed calculations and designs have started, with special emphasis to the following subjects:

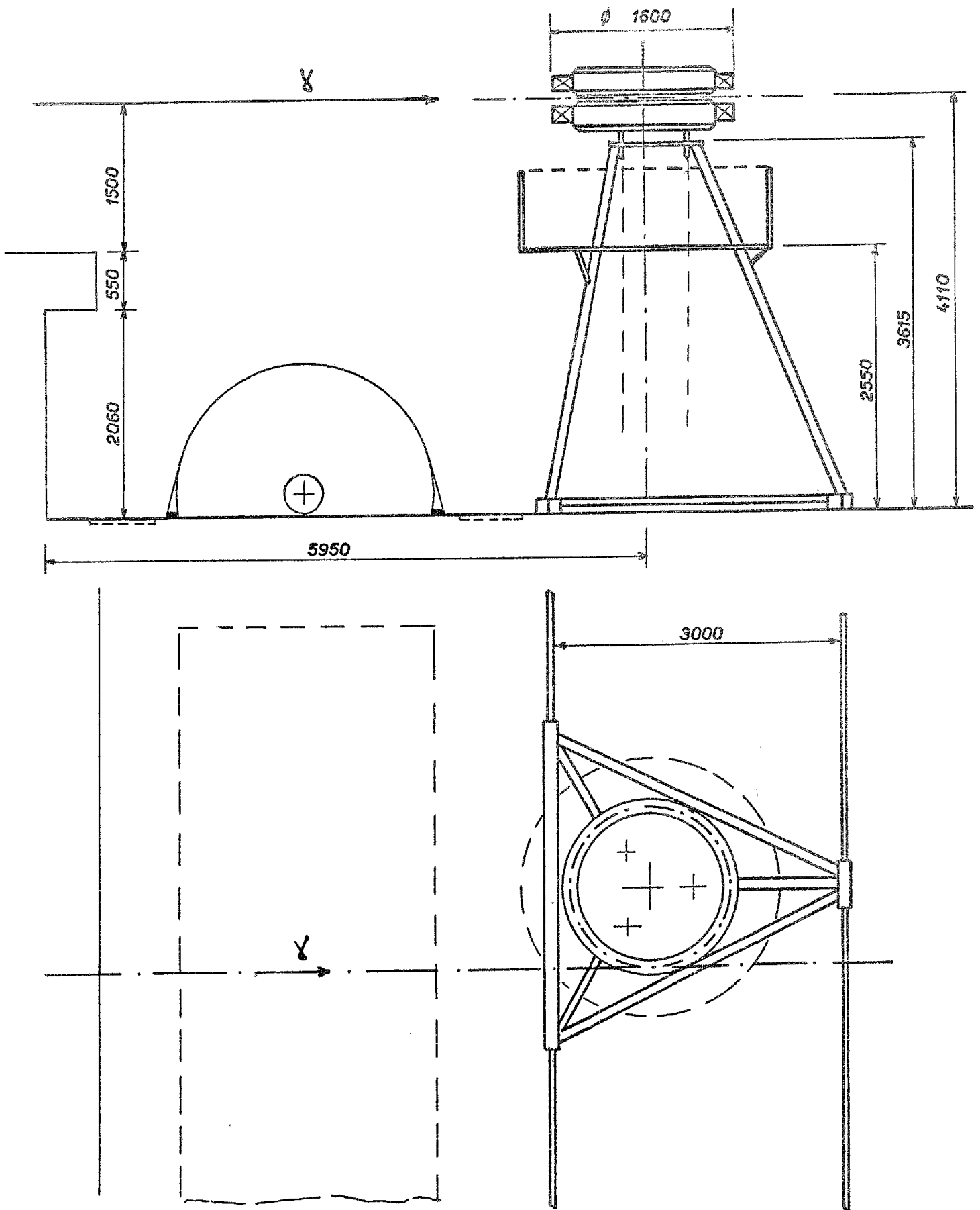


FIG. 1.4



## a) Mean life of accumulated beams.

Under steady state conditions, beam lifetime in the AdA might be of the order of one hour if the pressure of the residual gas is about  $10^{-8}$  mm Hg: losses are due to scattering, bremsstrahlung and fluctuations in radiation losses.

## b) Injection mechanism.

We are thinking of sending a  $\gamma$ -ray beam (bremsstrahlung spectrum at 1,000 MeV) from the electronsynchrotron on two diametrically situated targets, alternatively; the electron pairs thus produced in the inside of AdA could be made use of in the cinematically correct energy band. There would be no long-lived electrons if we couldn't ensure an effective spirali- zation; for this, we should strengthen the effect of betatron-oscillation indu- ced dampings somehow: At the present we are studying a few injection me- thods: their effectiveness is hard to evaluate at the present moment, but we hope to succeed.

The machine is in the advanced design stage at the various competent laboratories (magnetic laboratory, technological laboratory, radiofrequency): during the next autumn the various building blocks will be finished: on these more details will be given in another part of the report (Chap. II).

AdA will be set up for the first injection tests in the machine room of the synchrotron building, as can be seen in fig. I.4. The result of prelimina- ry estimates is that reactions like ( $\pi$ ) and ( $\mu$ ) should be observable in poor geometry with a reasonable frequency. Reaction ( $\gamma$ ) observed in a tangential direction to the beams, would be used as monitor.

## Chapter II - ACTIVITIES OF THE LABORATORIES

### 1. CRIOGENIC LABORATORY

During the months ranging from December 1959 to May 1960 850 liters of hydrogen have been liquified to supply the four hydrogen targets now in use at the electronsynchrotron.

Since January 1960 a fourth target of the "Wilson type" is in use; wall-thickness of the steel hydrogen-container is 25 ; the steel is glued on 25 -thick Mylar with araldite.

A "Wilson type" target for deuterium is now in the advanced building stage, while a more complex target for  $H_2$  or  $D_2$  is being designed. We are also tooling up for the recovery of deuterium.

Targets W1 and W2 have been modified, and a modification of the L target is being built for the K-meson photoproduction experiment.

The low-temperature group of the University of Rome, guests of our laboratory, continues its experiments on the diffusion of Ne, HT and  $He^4$  in liquid hydrogen.

The first test with liquid helium of the bubble chamber of the Rome Section of the I.N.F.N.

250 liters of liquid helium have been sent to the University of Padova; a first consignment of 15 liters has been sent to the University of Genova.

### 2. "RAFELE" (JOINT RADIOFREQUENCY-ELECTRONIC) LABORATORY

The radiofrequency and electronic laboratories have in this period worked in part on the improvement and the servicing of the electronsynchrotron, and in part on the design and the building of instruments and devices of interest to the experimenters.

Particularly to developed activity in the last-mentioned field it was thought

advisable to pool the specific competence and experience of the two laboratories in a single "Rafele" laboratory.

For the electronsynchrotron this laboratory has developed a program of improvements of the control circuitry and of the characteristics of the power radiofrequency. For the latter, a resonating cavity designed so as to furnish 150 kV peak is under construction after studies and tests on models: its accompanying driver stage is also being built.

A magnetic system to prevent "multi pacting" in resonating cavities, has been studied and calculated numerically.

For the experimentalists, fast amplitude discriminators have been studied and built. The assembly of a 20-channel fast amplitude analyzer of the Phalco<sup>(1)</sup> type has started and has made good progress: the analyzer is now undergoing tests.

A distributed amplifier with a large dynamic range has been built. We have started the systematic study and realization of fast transistorized circuitry. A new engineer has become recently part of the Rafele family: his job is just to transistorize circuitry.

For the future we plan to complete and to set up the new radiofrequency system and to put the multichannel analyzer in such a shape so that it can be tested in an experiment with the electronsynchrotron.

Three graduate students are preparing their theses in the laboratory: two more have started a thesis on circuitry to be used in conjunction with missiles.

### 3. ELECTRONIC SHOP

The electronic shop has continued the normal servicing of electronic apparatus in use at the electronsynchrotron: some of the latter have been

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(1) A. Alberigi, C. Bernardini, I.F. Quercia - Nucl. Instr. 3, 201 (1958)

changed with improved circuitry.

Part of the activity of this department has been the assembly of circuits for experiments with the electronsynchrotron.

In the development of assembly-techniques and in the use of new components, studies and tests have been made on printed circuitry. In conjunction with the Electronic Division of the C.N.R.N., standards for such circuitry have been set up: a photomechanical laboratory is being set up to build small production runs.

In view of the increase of the responsibilities which this department will shoulder it is foreseen that in the near future the electronic laboratory will be composed of the following subdepartments:

- a) design, drafting and recording blueprints;
- b) search and tests on special components;
- c) servicing of electronic instruments;
- d) electronic assembly;
- e) small mechanical shop.

#### 4. EXPERIMENTALIST'S MAGNETS LABORATORY (ME)

The activity at the ME group from December 1959 to June 1960 has been very intense to face requests for designs, assemblies and measurements both from people in Frascati and elsewhere.

Theoretical activity has been concerned mainly with problems connected with pulsed magnets: results of this study will appear shortly in an internal report. Particle containers have been also studied: these studies will shortly lead to a proposal for an experiment; calculations have been made (in collaboration with the Turin University) for a magnetic analyzer consisting of two quadrupoles.

Design activity has been devoted to the design of various magnets: in the following the salient characteristics are given:

- a) an analyzer magnet of 18 tons for 800 MeV/c particles, of the strong focussing type, solid angle  $0,7 \times 10^{-2}$  rad, and its support;
- b) a magnet for the storage ring of about 8 tons weight; particle-orbit diameter is about 645 mm while the air-gap is 50 mm at the gap center;
- c) a magnet for solid state physics experiments of about 4 tons; 20.000 gauss may be reached;
- d) two quadrupoles for the Bologna University (each of about 1.5 tons in weight);
- e) a 4 ton magnet for the Trieste University;
- f) a few magnets of small size (for vacuum pumps etc.).

In this period part of the magnet for the magnetic analyzer for polarized neutrons of the CNRN has been built.

The quadrupoles for the Bologna University and the model for the analyzer magnet are in the state of advanced assembly. A magnetic analyzer for 150 MeV/c ions has been completed: the analyzer is made up of two quadrupoles and of a magnet with orientable end poles.

Equipment for winding coils has been in part built. In collaboration with the users two coupled analyzer magnets have been magnetically calibrated for the University of Rome, the calibration of the magnetic analyzer for ions (in this case the orbits have been also studied using the floating wire technique). We have also recently started trial assemblies of equipment for magnetic measurements.

## 5. TECHNOLOGICAL LABORATORY

During the period December 1959 - June 1960 work designed to improve the electronsynchrotron vacuum system has continued: as mentioned in the preceding report the heat exchangers have been eliminated: these exchangers used alcohol and were mounted on the diffusion pumps.

This was made possible by connecting the cooling units directly to

the traps and expanding freon directly into the traps.

During the month of May a quadrant of the doughnut has been changed due to loss of vacuum in a gasket. The changeover was also made to check the damage undergone by the doughnut after a year of continuous exposure to the beam. After an accurate examination no damage was found, neither in the internal steel lining nor to the quartz and araldite wall. During the execution of this work some changes were wrought on the piece of doughnut of the straight section that crosses the first radiofrequency cavity; this was done for the reasons mentioned in paragraph 1a) chapter I.

In collaboration with the machine and radiofrequency groups a new cavity has been studied: the new cavity will replace the old one so as to reach a maximum energy of 1.100 MeV. The mechanical design is completed and assembly has started both of the vacuum container and of the cavity proper. We think that device will be ready for electrical tests by the end of the month of August 1960.

In collaboration with a group of the Electronic Division of the CNRN at Frascati a prototype of a d. c. amplifier and power supply has been studied and built, to be used in conjunction with ionization gauges. This instrument, now undergoing tests, will allow pressures in the range  $10^{-2}$  -  $10^{-12}$  mm Hg to be measured.

One of the main characteristics of the instrument is that it can be used with the principal triodes that are commercially available.

Right now a three-stage Bennett-type mass spectrometer using radiofrequency is in the design state: this will be used to search for vacuum losses in containers.

After the decision taken during March 1960 to build a storage ring (described in paragraph 2 chapter I), the study of the vacuum chamber and of the vacuum system has been undertaken.

At the present a first type of doughnut is being built to be used during the experimental phase; a titanium vacuum pump has been designed and tested: this pump will allow vacua of the order of  $10^{-8}$  mm Hg to be achieved.

Also for the vacuum pumps we are passing from the experimental prototypes to the final assemblies.

## 6. COMPUTING DEPARTMENT

This department is active since July 1, 1959. Its task lies in executing computing tasks for any type of problem of interest to the Laboratory (for experiments, for the design of magnets, for the solution of electronic problems, for the computation of trajectories, for cinematics etc.).

Awaiting installation at Frascati of a very modern electronic computer of average capacity (IBM 1620 or OLIVETTI ELEA 6001) large-scale numerical computations have been made on existing computers in Rome (FERRANTI of INAC; IBM 650 of the Scientific Computing Center of IBM) programmed by persons belonging to the Frascati computing department or to the theoretical group.

In the following we shall summarize briefly the computing work done and under way:

For the design of a magnetic analyzer for low energy mesons for the experiment of Profs. Amaldi and Ageno, calculations have been made to find the conditions for double focalisation in a pair quadrupoles and to determine the optics of such a system. This program has been also used by groups from the Universities of Trieste, Torino and Bologna.

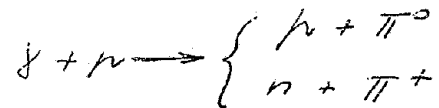
The group that worked on the calibration of the  $\gamma$ -ray beam of the Laboratory has been helped by a computation of trajectories in the pair spectrometer. This program can be used for computing trajectories in any

magnetic field with a symmetry plane.

The group experimenting with single crystals has had the help of the department in the computing of cross sections for pair production, and of the bremsstrahlung polarization in a silicon single crystal.

This program can be used for any other single crystal.

On the basis of phenomenological models proposed by Wilson and Peierls and extended by Pellegrini - Stoppini for the interpretation of the resonance which takes place at about 700 MeV in the reaction



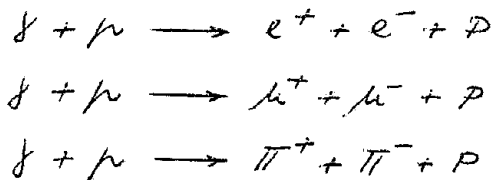
we have tried to estimate the cross-sections and the polarization of the recoil proton.

An analysis of the dispersion relations in  $\pi^0$  photoproduction is being made: specifically theoretical formulae deduced by Chew, Goldberger, Low and Nambu are compared with experimental data on the  $\gamma + p \rightarrow p + \pi^0$  reaction.

Certain unknown terms present in the formulae are estimated and seem to possess peculiar dependences.

Cinematical tables have been computed and have been used in the design of the experiment with pairs of muons.

The considered reactions were:



Efficiency of counters for the experiment on the proton polarization in the photoproduction of neutral mesons is computed evaluating a set of



triple integrals by Monte Carlo methods. The program may be used to evaluate integrals with any integrand function and any order of multiplicity.

The attenuation of the internal beam of the electronsynchrotron due to radiation effects has been evaluated, programming formulae derived from various mathematical approximations.

Calculations on the coupling circuits between a radiofrequency amplifier and its 150 kV cavity have been made.

The first phase of a computation relating to inhibiting multipacting in a resonating cavity by use of a static magnetic field has been made.

A computing program pertaining to trajectories at injection of the storage is at an advanced stage.

Double focussing conditions for a couple of strong-focusing magnets together with the optics of the system are being programmed.

A short course on the automatic programming of electronic computers is being programmed. This course will be repeated every 2 - 3 months.

## 7. RADIATION SHIELDING AND MONITORING GROUP

At present the radiation shielding around the machine seems very effective. No modifications seem necessary even at an intensity two or three times the present one. In the control and in the counting areas, normally occupied by operators and experimentalists,  $\gamma$ -ray intensity is less than 1 mr/hr while the fast neutron dose is less than half the maximum permissible amount. Radiation monitoring by means of filmbadges is extended to 106 units according to the following: 50 units are controlled monthly while 36 are controlled bi-weekly, all for  $\gamma$ -ray radiation. 10 are checked against  $\gamma$ -rays and fast and slow neutrons, while 10 more can be checked if necessary for doses between 10 and 600 r. The check against fast and slow neutrons is made only for machine personnel, while high-dose film

14.

badges are issued to persons whose work takes them to zones where even a small possibility of overexposure exists.

Radiation maps in areas accessible to personnel are periodically taken. Certain points of the control and counting areas are monitored with film badges. Equipment used for ambient monitoring is serviced by the group, as are the stylus dose meters that are used to monitor personnel who has not been issued, for any reason whatsoever, a personal photographic dosimeter.

Research intended to improve photographic monitoring of slow neutrons is being done by personnel of the group; research is also being carried out on ionisation chambers with walls both of equivalent tissue and of graphite.

On these subjects two theses have been issued.

## 8. BUILDING DEPARTMENT

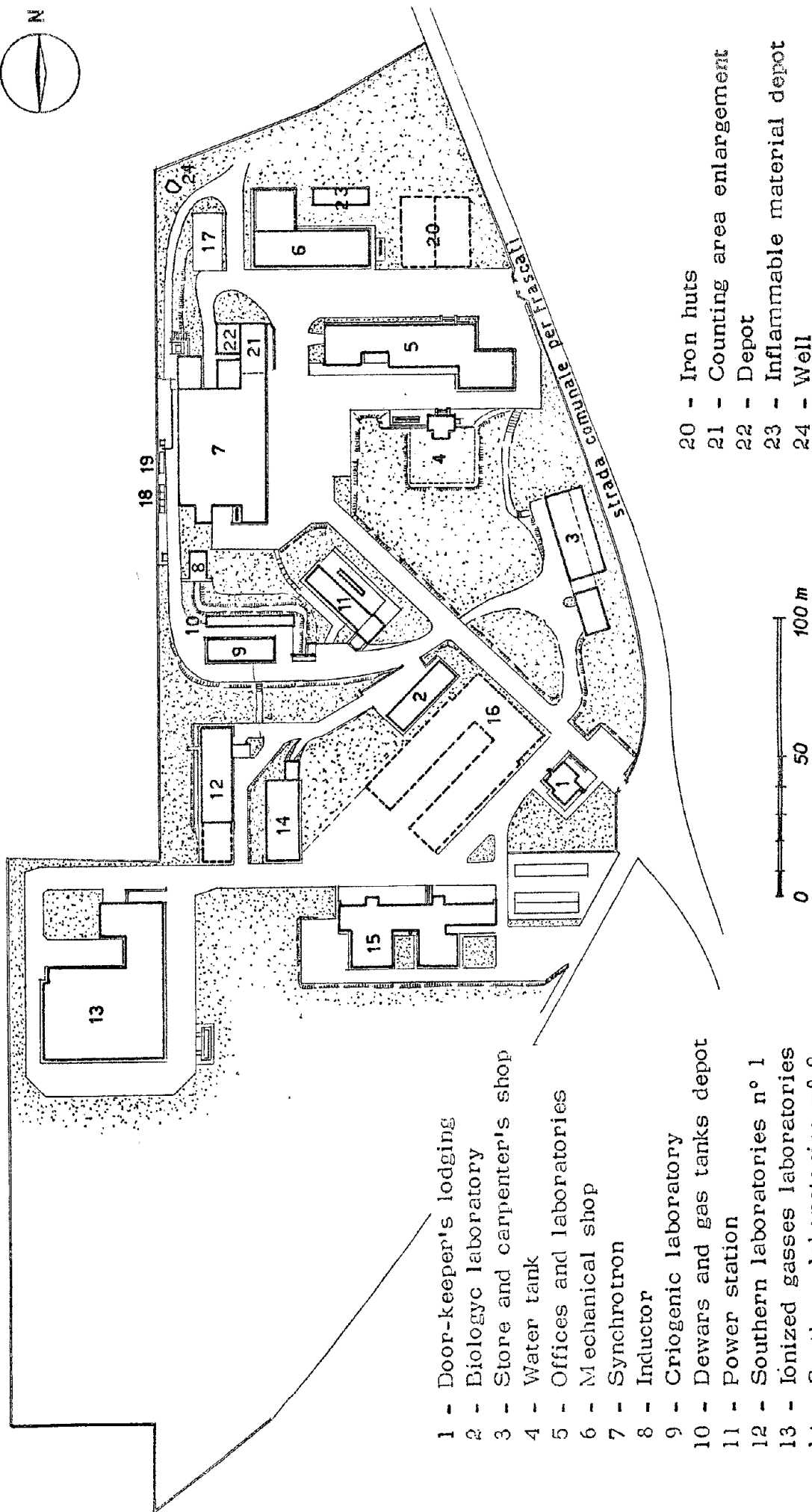
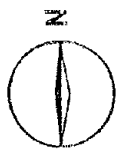
With reference to fig. II.1, bearing in mind that the buildings numbering up to 12 were already completed last December, in the last six months the building for the ionized gasses was erected (1,816 sq m, 14,821 cub m): of this building a first part including the mechanical shop, the central laboratory (experimental area), the store and the spectroscopy laboratories and other which shall be assigned to group activities.

Awaiting completion, direction, offices, studies and part of the laboratories will find a temporary arrangement.

The new building will be taken over by the group, it is foreseen, on June 30, 1960.

The building entitled "Southern laboratories n° 2" (N° 14) in the plant) inhabited by the machine group has been finished during the month of February: building it took 120 work-days.

In the finishing stage are the enlargement of the counting area in the "synchrotron building" (N° 21) for a total of 145 sq m, a depot (N° 22) and



- 1 - Door-keeper's lodging
- 2 - Biologic laboratory
- 3 - Store and carpenter's shop
- 4 - Water tank
- 5 - Offices and laboratories
- 6 - Mechanical shop
- 7 - Synchrotron
- 8 - Inductor
- 9 - Criogenic laboratory
- 10 - Dewars and gas tanks depot
- 11 - Power station
- 12 - Southern laboratories n° 1
- 13 - Ionized gasses laboratories
- 14 - Southern laboratories n° 2
- 15 - Mess-sejourn
- 16 - Electronics laboratories
- 17 - Concrete blocks depot
- 18 - Refrigerating columns
- 19 - Deuterium tanks and compressor

Fig. II.1 - LABORATORIES GENERAL LAYOUT OF



- Risultati preliminari della determinazione dello spettro di bremsstrahlung dell'elettrosincrotrone di Frascati  
G. Diambri, A.S. Figuera, B. Rispoli, A. Serra - NI n° 20 - 12, 3, 1959
- Risultati preliminari di un'esperienza di produzione di coppie di elettroni ad alta energia in un monocristallo di silicio  
G. Bologna, G. Diambri, G.P. Murtas - NI n° 21 - 12, 10, 1959
- Connessione tra fotoproduzione e scattering dei pioni ad alta energia  
C. Pellegrini, L. Tau - NI n° 22 - 12, 11, 1959
- La polarizzazione del protone di rinculo nel processo  $\gamma + p \rightarrow \pi^0 + p$   
R. Querzoli, G. Salvini, A. Silverman - NI n° 23 - 12, 11, 1959
- Esperienza sulla produzione di coppie di mesoni  $\mu$  nella reazione  
 $\gamma + \text{nucleo} = \text{nucleo} + \mu^+ + \mu^-$   
A. Alberigi, C. Bernardini, M. Pretis, G. Stoppini - NI n° 25 - 12, 11, 1959
- A generalization of the Foldy-Wouthuysen transformation  
G. Morpurgo - NI n° 26 - 12, 12, 1959
- Un sistema a molti canali per la misura della polarizzazione dei protoni  
W. Blampied, B. McDaniel, R. Querzoli, G. Salvini - NI n° 27 - 12, 12, 1959
- Calcolo della polarizzazione dei fotoni di rinculo nel processo  
 $\gamma + p \rightarrow \pi^0 + p$   
C. Pellegrini, G. Stoppini - NI n° 28 - 12, 14, 1959
- Specifiche tecniche di due magneti analizzatori e di un impianto di piastre rotanti  
R. Toschi - NI n° 29 - 1, 27, 1960
- Electron pair production at high energy in a silicon single crystal  
G. Bologna, G. Diambri, G.P. Murtas - NI n° 30 - 1, 9, 1960
- Proposta per un ciclotrone per elettroni da 150 - 800 MeV  
G. Sacerdoti - NI n° 31 - 4, 8, 1960
- Teoria e calcolo dell'ottica per una coppia di quadrupoli  
S. Costa, R. Evangelisti - NI n° 32 - 4, 11, 1960
- On the connection between scattering and photoproduction of pions at high energies  
C. Pellegrini, L. Tau - NI n° 33 - 4, 21, 1960
- On the quantum losses in an electron synchrotron  
C. Bernardini, B. Touschek - NI n° 34 - 4, 27, 1960

a building for the enlargement on the "cryogenic laboratory" (N° 10) where the mechanical shop and the depot for gas tanks and batteries will be moved to make place for the new hydrogen liquefiers.

Lesser works, such as the erection of a platform as a depot for shielding blocks (N° 17), foundations for refrigerating towers (N° 18), iron structures with alluminum overheads (N° 19) where the deuterium tank and compressor will find place: road works and external finishing-up are to be considered as complementary to the abovementioned buildings. During 1960-1961 we contemplate building two huts with iron structure and volute roofing each supplied with 15 ton cranes (N° 20), of a building that will house the radiofrequency and electronic groups, together with the technological and high energy research groups (N° 16) and to enlarge the southern laboratory n° 1. Design of these buildings has been undertaken at Frascati.

## 9. DOCUMENTATION OFFICE

The laboratory owns a library, a duplicating machine, photocopying equipment and an eliograph machine.

In the following the present-day supplies and the recent increase are summarized:

Books: 1,900 volumes; increase 400.

External reports: (microfilm included): 4,600; increase 800.

Magazines: 85 subscriptions; increase 20.

Internal reports: in the last six months about 20 papers have been printed: apart from these about 10 papers have been published or are in course of being so, by personnel belonging to the Laboratories.

In the following a list of papers published by Frascati personnel is given.

- High energy bremsstrahlung from a silicon single crystal  
G. Bologna, G. Diambri, G.P. Murtas - NI n° 35 - 4, 28, 1960
- The collection of light from thin large area scintillators  
A.C. Odian, T. Yamagata - NI n° 36 - 5, 27, 1960
- Pulse height discriminator employing distributed amplification  
C. Infante - NI n° 37 - 5, 27, 1960
- Costruzione e sperimentazione di un rotatrone quale separatore di isotopi (proposta di esperienza)  
M. Puglisi, G. Sacerdoti - AS 10 - 6, 15, 1960
- Remarks on neutral pion photoproduction in the high energy region  
C. Pellegrini, G. Stoppini - NI n° 38 - 6, 24, 1960
- Dosimetria fotografica di raggi X,  $\gamma$  e dei neutroni  
M. Ladu - Minerva Nucleare, 3, 399 (1959)
- Risultati preliminari della determinazione dello spettro di bremsstrahlung dell'elettrosincrotrone di Frascati  
G. Diambri, A.S. Figuera, B. Rispoli, A. Serra - Nuovo Cimento, 15, 500 (1960)
- Electron pair production at high energy in silicon crystal  
G. Bologna, G. Diambri, G.P. Murtas - Physical Review Letters, 4, 134 (1960)
- A generalization of the Foldy-Wouthuysen transformation  
G. Morpurgo - Nuovo Cimento, 15, 624 (1960)
- Un grosso magnete per una camera a diffusione  
G. Sacerdoti - L'elettrotecnica, 47, 239 (1960)
- High-energy bremsstrahlung from a silicon single crystal  
G. Bologna, G. Diambri, G.P. Murtas - Physical Review Letters, 4, 572 (1960)
- Proprietà ottiche di un quadrupolo magnetico elicoidale  
G. Sacerdoti - L'elettrotecnica, 47, 322 (1960)
- Photostar production between 500 and 1100 MeV  
C. Castagnoli, G. Ghigo, M. Muchnik, R. Rinzi - Nuovo Cimento, 16, 683 (1960)
- The collection of light from thin large area scintillators  
A.C. Odian, T. Yamagata - Submitted to Review of Scientific Instruments for publication

18.

Pulse height discriminator employing distributed amplification

C. Infante - Submitted to Nuclear Instruments for publication

Remarks on neutral pion photoproduction in the high energy region

C. Pellegrini, G. Stoppini - Submitted to Nuovo Cimento for publication

Symmetry between muon and electron

N. Cabibbo, R. Gattà - Submitted to Physical Review Letters for publication



Chap. III - PRESENT-DAY EXPERIMENTS WITH THE ELECTRONSYNCHRO  
TRON.

In the following a brief resume, compiled by the authors, is given of the various experiments that have started their run in Frascati. The order of presentation follow the arrangement around the electronsynchrotron (see fig. 1.3).-

1.  $\pi^0$  MESON PHOTOPRODUCTION EXPERIMENT (Sanità  $\pi^0$ )

G. Cortellesa, A. Reale  
 Istituto Superiore di Sanità, Roma

The group of the "Istituto Superiore della Sanità" is in course of measuring angular distribution in  $\pi^0$  photoproduction, at various  $\gamma$ -ray energies between 500 and 1,000 MeV, with special reference to the zone of the second maximum. In this energy range strong discrepancies exist between the data of various experimenters, specially for  $\pi^0$  angles close to  $0^\circ$  or to  $180^\circ$  (CM). The result is a marked uncertainty in the determination of parity, angular momentum etc. of the resonance. Aim of the experiment is to determine whether disagreement between data is due to poor angular and energy resolution in preceding experiments. Experimental disposition is shown in fig. III.1.

A time coincidence between the recoil proton and one of the decay gamma rays due to the  $\pi^0$  meson defines an event. The proton is detected with a 5 - counter telescope with suitable adsorbers between scintillators. The counters are 5 mm in thickness and have an area of 15 x 15 sq cm, excepting the first one that measures 10 x 10 sq cm and defines the solid angle. In measurements made to date, the telescope subtends an angle of  $\pm 1^\circ$  in the laboratory. The decay gamma is detected by a Cerenkov counter (glass + Pb) preceded by a counter analogous to the abovementioned ones, in anticoincidence. Energy resolution of the system is  $\pm 30$  MeV in

the energy of the incident gamma ray, and has been achieved by suitably shaping the adsorbers.

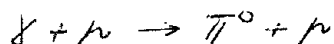
To date the group has made measurements relative to an angle of  $56^\circ$  (CM) for the  $\pi^0$  and a measurement at an angle of  $90^\circ$  is now under way.

Experimental results are summarized in fig. III.2. These preliminary data seem to indicate a very sharp resonance centered at the same energy of the resonance in  $\pi^+$  photoproduction.

## 2. EXPERIMENT ON THE POLARIZATION OF THE RECOIL PROTON IN THE PHOTOPRODUCTION OF SINGLE $\pi^0$ MESONS IN HYDROGEN (Pisa $\pi^0$ )

L. Bertanza, P. Franzini, I. Mannelli, V.Z. Peterson<sup>(x)</sup>, G.V. Silvestrini  
Istituto di Fisica dell'Università, Pisa

We have used a bubble-chamber (ethane - propane gas - liquide mixture) to measure the asymmetry in elastic scattering from carbon of magnetically selected protons from the reaction



The use of a visual technique permits detailed knowledge of each scatterer, and an internally - consistent correction for the rather large number of inelastic scatters which are present. Magnetic selection determines the photon energy interval and excludes higher energy protons and neutral particles from entering the bubble chamber. The experimental arrangement is shown in fig. III.3 .

The counter telescope distinguishes protons from minimum particles. The bubble - chamber operates reliably at 4 pulses/second, and thus uses

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<sup>(x)</sup> Cal. Inst. of Technology, Pasadena

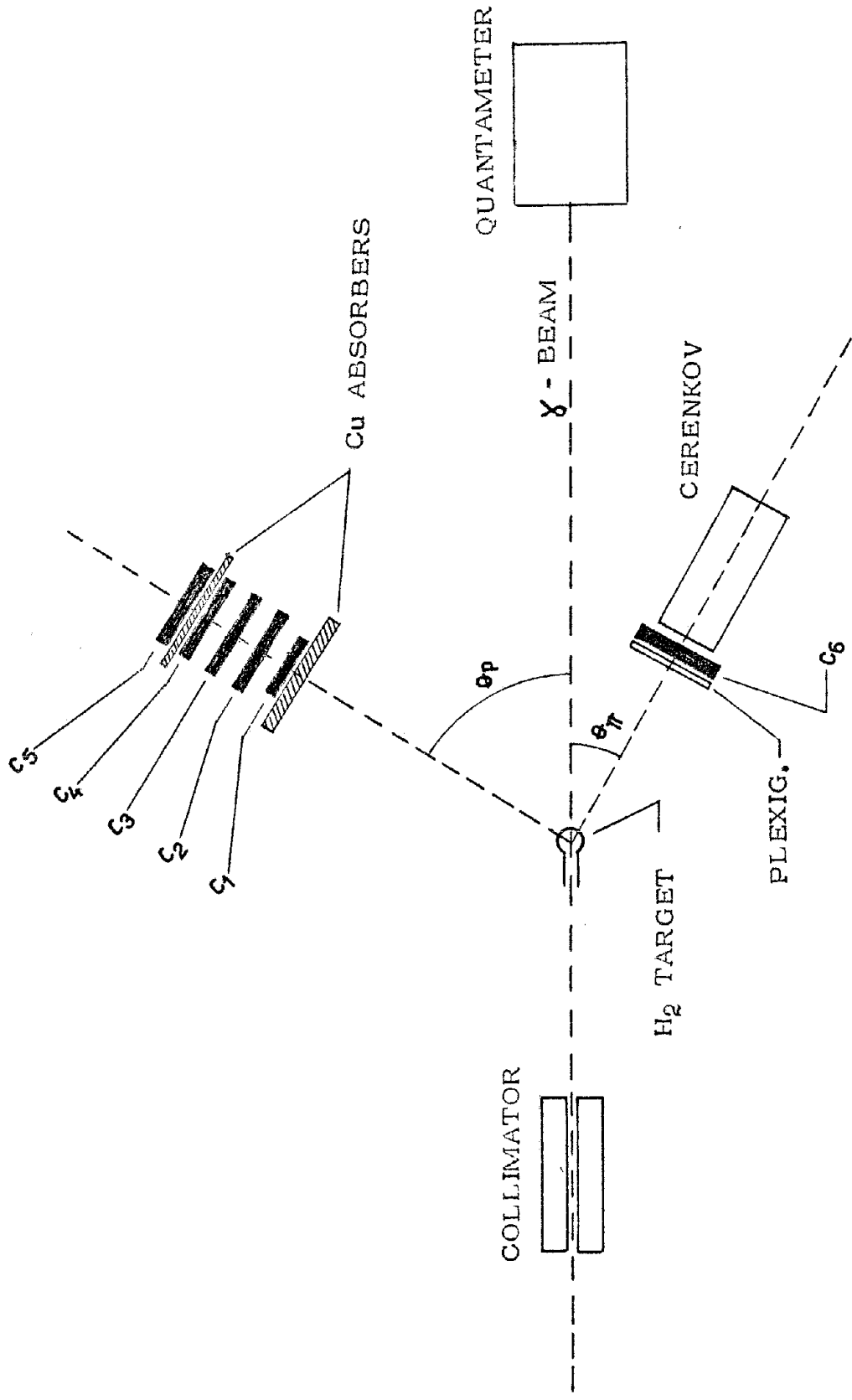


FIG. III.1

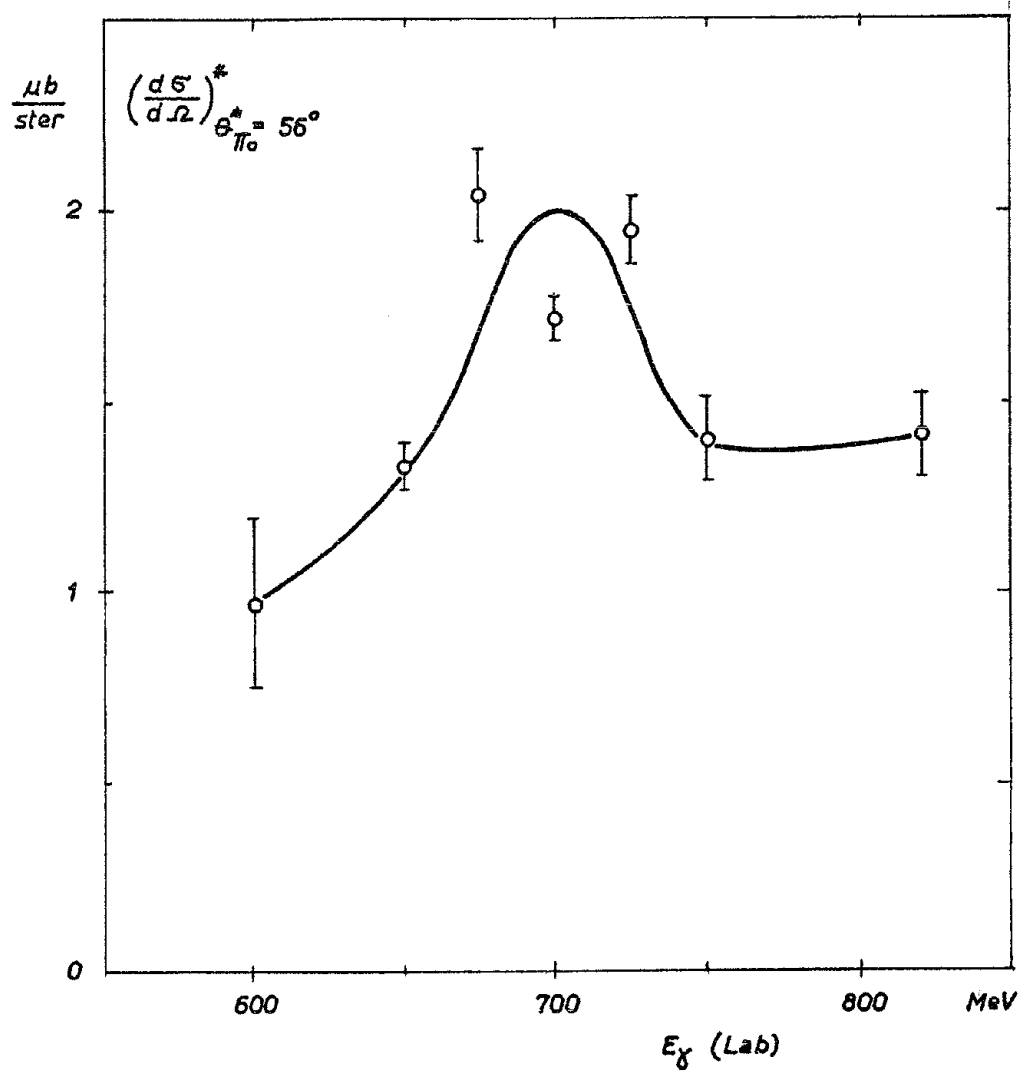


FIG. III. 2

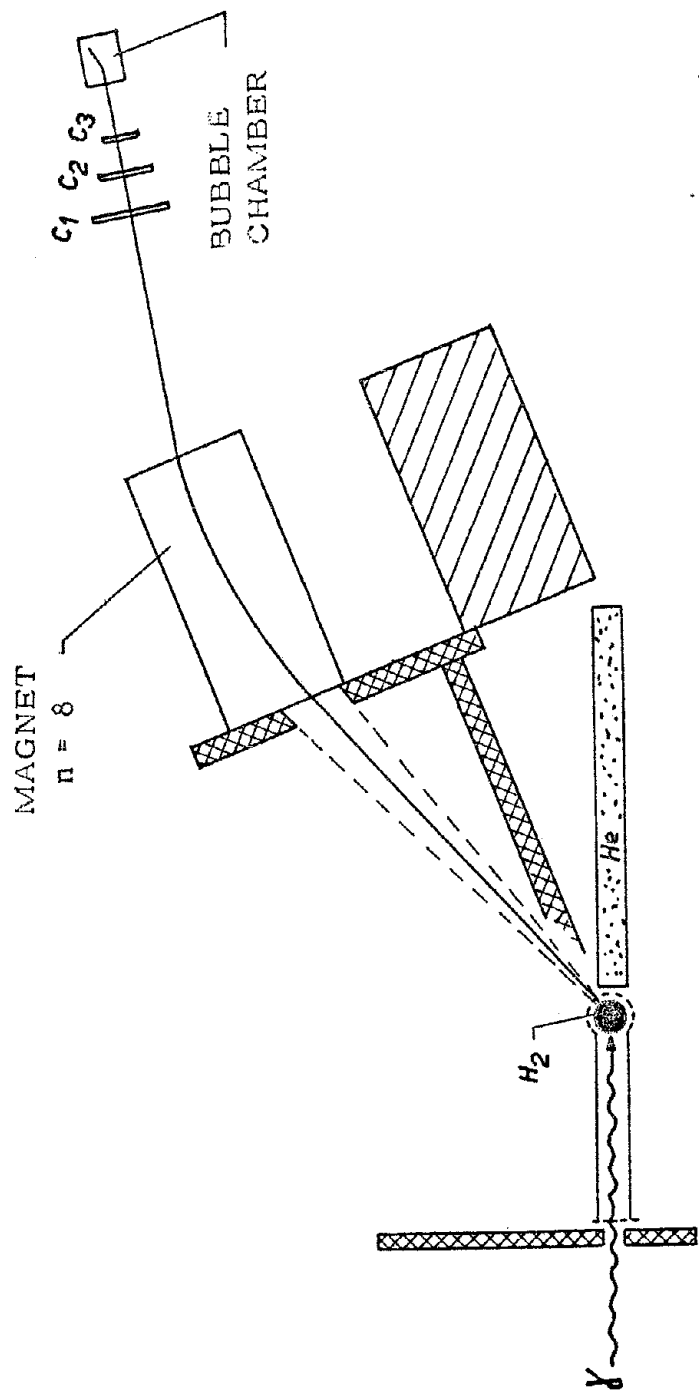


FIG. III.3

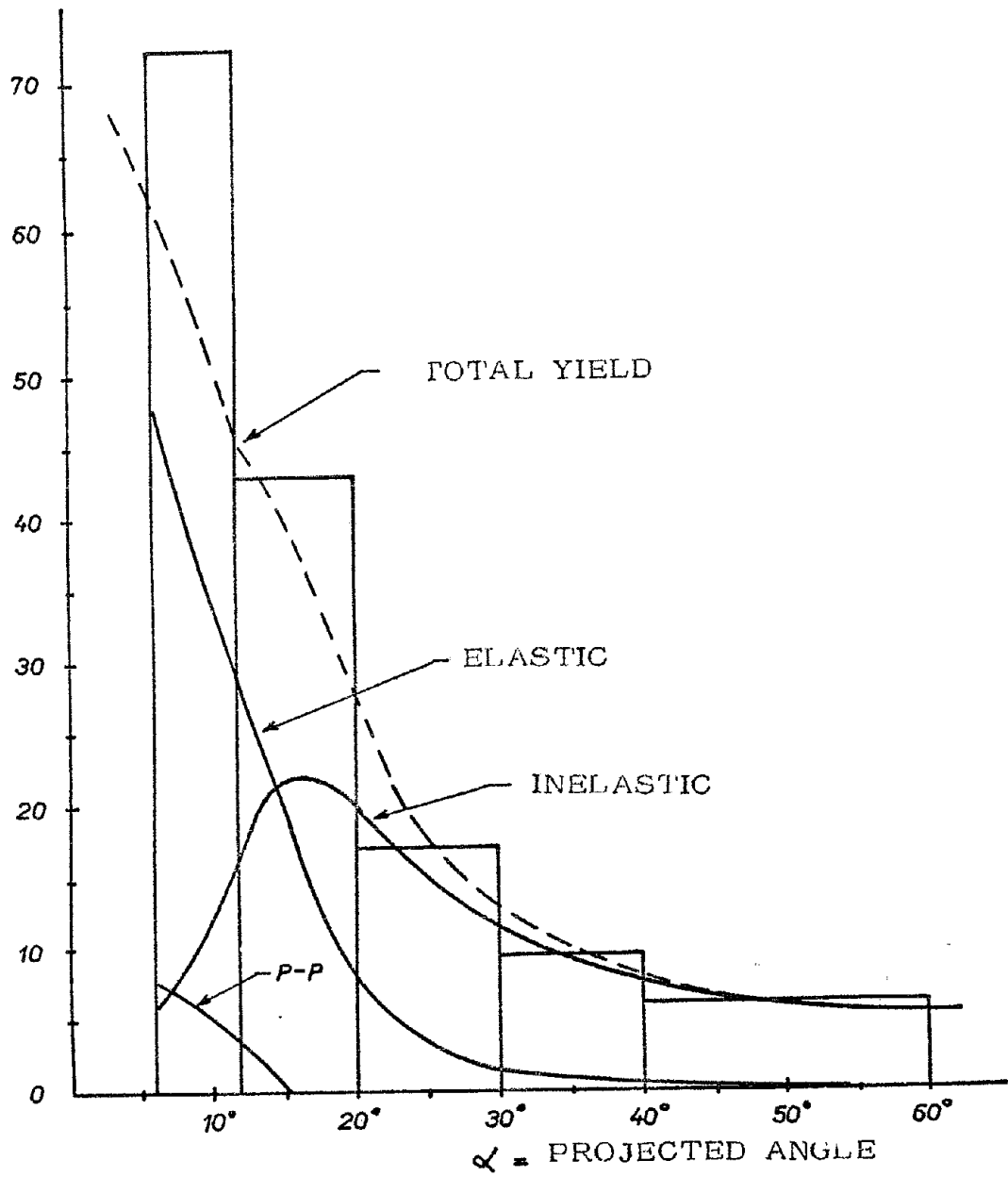


FIG. III.4

1/5 of the protons entering the chamber.

A preliminary result has been obtained for a mean photon energy  $k = 725$  MeV and pion c.m. angle of  $87^\circ$ . The results, based on 262 scatters (160 left, 102 right) in the projected angle  $6^\circ - 20^\circ$  interval, is

$$P = + 0.81 \pm 0.29$$

in the direction  $\underline{k} \times \underline{p}$  (where  $\underline{p}$  is the momentum of the proton). The proton energy resolution function, determined from kinematics and range curves, is triangular with base  $\sim 200$  MeV wide. The inelastic correction is 74 (out of the 262) events; this is determined by extrapolating the  $20^\circ - 60^\circ$  distribution (130 additional scatters) to small angles. The protons kinetic energy at the center of the chamber is 165 MeV.

The elastic and inelastic scattering yields are in good agreement with the Uppsala cyclotron data assuming that excitation energies up to only 50 MeV are involved (see fig. III.4). P - P scatters are almost entirely eliminated by kinematic tests. The quoted error in P includes statistics of subtraction and an estimate of possible systematic errors.

The present status of the experiment is to improve technique and statistics. A new hydrogen target (with less empty-target background) and stereoscopic cameras have been used for one exposure. A larger chamber (25 cm diameter) with freon (greater density, less inelastic contamination) will soon be available.

Optimum magnet orientation can be expected to improve energy resolution by momentum-angle correlation.

### 3-a. EXPERIMENT ON THE BREMSSTRAHLUNG PRODUCED BY 1,000 MeV ELECTRONS IN A SILICON SINGLE CRYSTAL

G. Barbiellini, G. Bologna, G. Diambri, G.P. Murtas  
Laboratori Nazionali di Frascati

General experimental activity has been directed in an attempt to clarify the mechanism of electrodynamic interactions at high energies (particularly bremsstrahlung and pair production) in periodic structures: following this general scope an experiment dealing with electron pair production in a single silicon crystal has been completed. This experiment has essentially confirmed theoretical previsions by Überall and has already been published<sup>(1)</sup>. In the period immediately following this the first part<sup>(2)</sup> of an experiment designed to measure the bremsstrahlung intensity produced by 1,000 MeV electrons crossing a silicon crystal, as a function of the angle  $\Theta$  between the crystalline axis and the direction of the electrons was completed. A monocrystalline sheaf of silicon,  $10^{-3}$  radiation lengths thick, has been placed inside the synchrotron doughnut and connected to a goniometric device that allows rotation around a vertical and a horizontal axis. The  $\gamma$ -beam thus produced is collimated at an angle of  $0,8 \times 10^{-3}$  rad and passes through a sweep magnet and an aluminum converter, placed in the vacuum chamber of a pair spectrometer. The symmetrical pairs of electrons thus produced are detected by a pair of plastic scintillators connected to two 6810 A photomultipliers placed in simultaneous and delayed coincidence, with a resolving time of about 6 nsec.

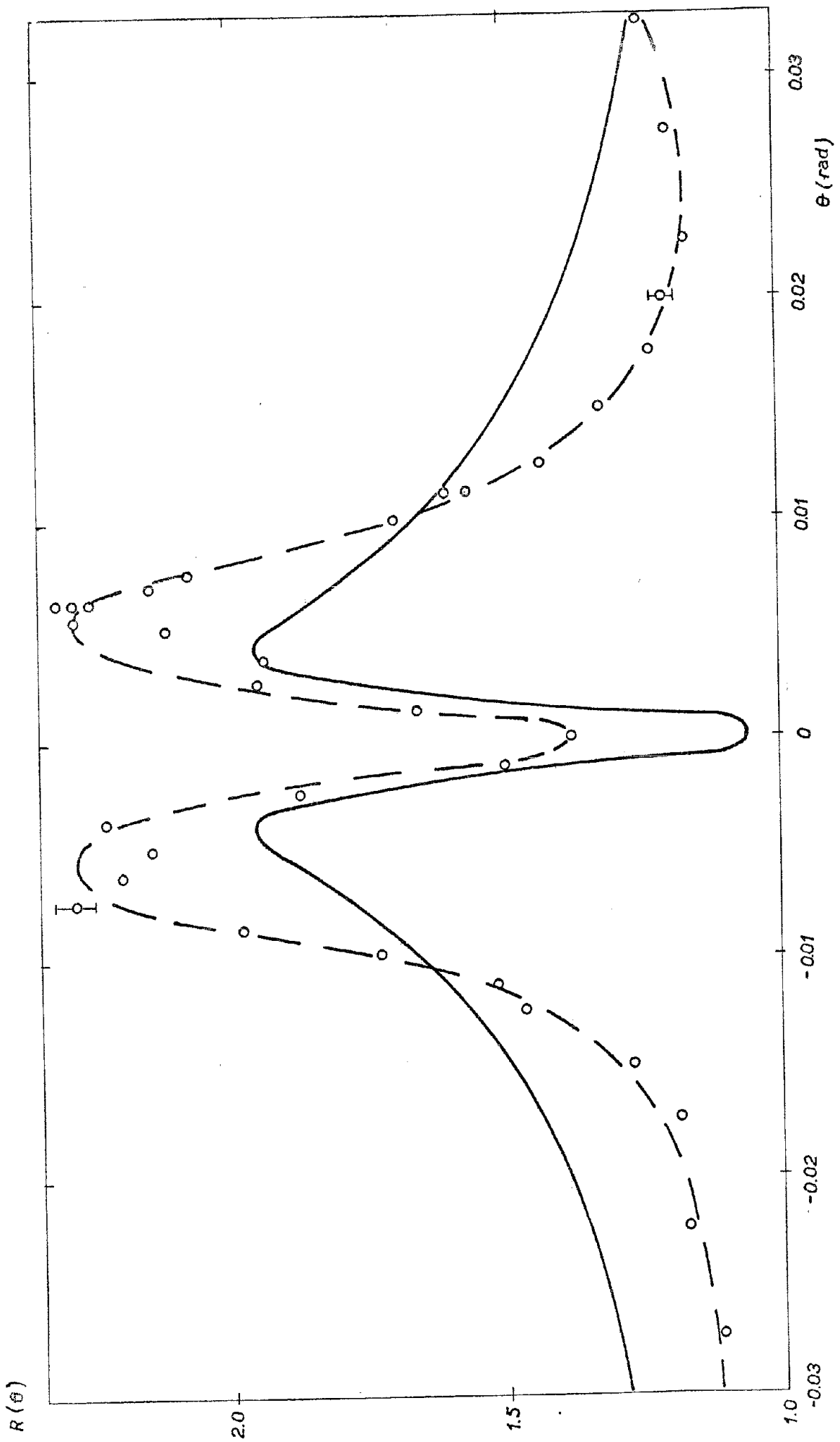
Thus the numbers  $N(\Theta, K)$  and  $N(\Theta, K_0)$  of symmetrical pairs per unit quantameter dose are measured as a function of  $\Theta$  and at the central

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(1) G. Bologna, G. Diambri, G.P. Murtas - Phys. Rev. Letters, 4, 134 (1960)

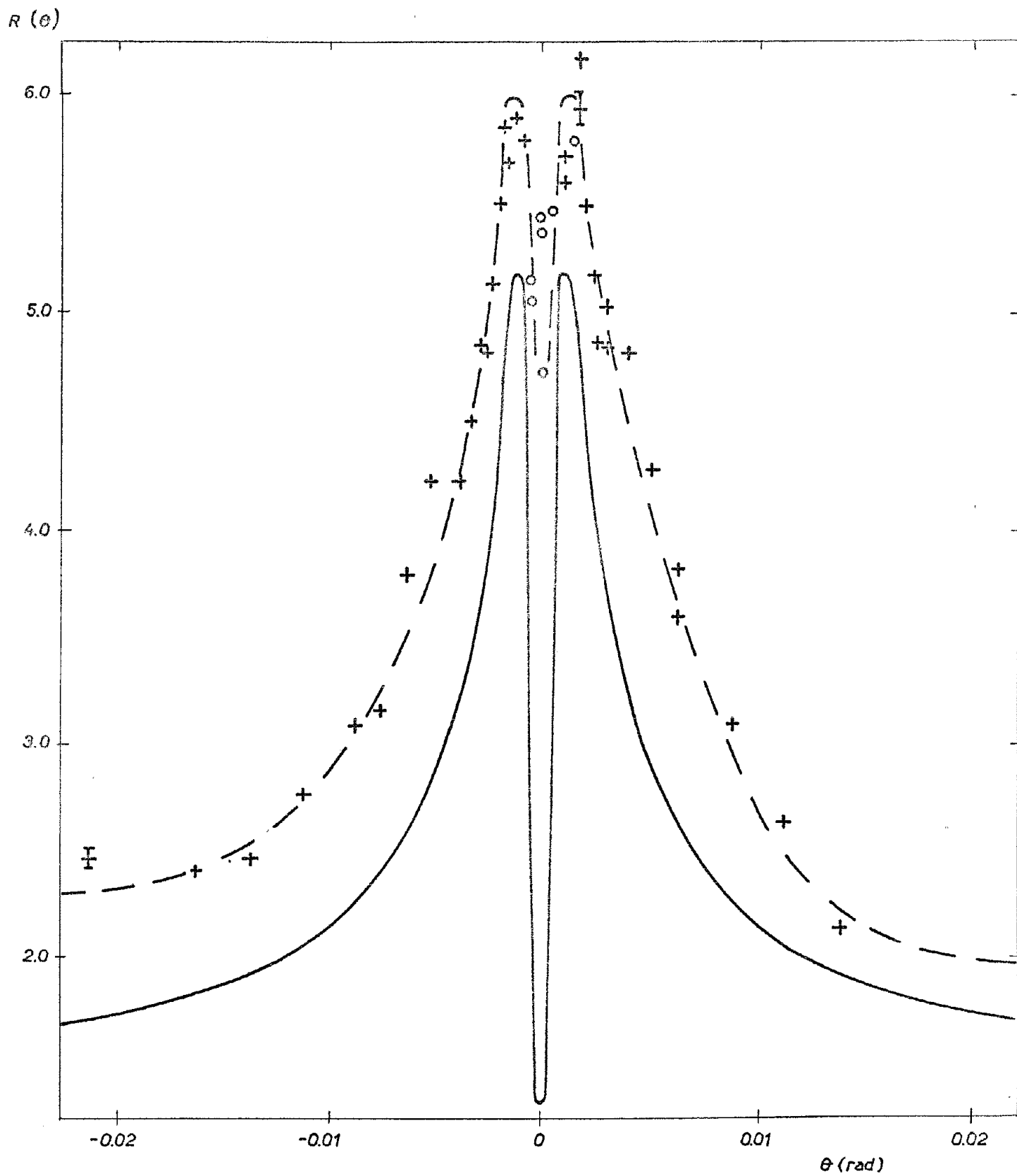
(2) G. Bologna, G. Diambri, G.P. Murtas - Phys. Rev. Letters, 4, 572 (1960)





$K = 240 \text{ MeV}$   
 $K_0 = 910 \text{ MeV}$

FIG. III.5



$K = 80 \text{ MeV}$   
 $K_0 = 865 \text{ MeV}$

FIG. III.6

energies of the photons  $K$  and  $K_0$ .

In fig. III.5 and III.6 the experimental ratios found are plotted:

$$R_{sp} = \frac{N(\theta, K)}{N(\theta, K_0)} \frac{\tilde{\sigma}_\mu(K_0)}{\tilde{\sigma}_\mu(K)}$$

where  $\tilde{\sigma}_\mu(K) dK$  is the cross-section for electron-pair production by photons of energies between  $K$  and  $K + dK$ . In fig. III.5 the data for  $K = 24 \text{ MeV}$ ,  $K_0 = 910 \text{ MeV}$  are plotted; in fig. III.6 those for  $K = 80 \text{ MeV}$ ,  $K_0 = 865 \text{ MeV}$ . The continuous curves represent the theoretical value of the ratio calculated on the basis of Überall's results.<sup>(3)</sup>

The experiment has thus shown the existence of the central minimum for  $\theta \leq 0$  foreseen by Überall, and that had not been detected by preceding experimentalists<sup>(4)</sup>.

The results of fig. III.6 indicate that also for  $K = 80 \text{ MeV}$  a central minimum exists, even if its real depth is still uncertain due to the collimation angle employed (about  $0.8 \text{ mrad}$ ). This fact entitles one to think that the correction to the Born approximation near the central minimums probably less than that computed by Schiff in a recent paper<sup>(5)</sup>.

We are now planning further measurements, done with a better angular precision, on the intensity of coherent bremsstrahlung and on its polarization.

(3) H. Überall - Phys. Rev., 103, 1055 (1956)  
H. Überall - Phys. Rev., 107, 223 (1957)

(4) O.R. Frisch, D.H. Olson, - Phys. Rev. Letters, 3, 141 (1959)  
A.N. Saxena - Phys. Rev. Letters, 4, 311 (1960)

(5) L.I. Schiff - Phys. Rev., 117, 1394 (1960)

### 3-b. MEASUREMENT ON THE BREMSSTRAHLUNG SPECTRUM OF THE FRASCATI ELECTRONSYNCHROTRON

G. Diambri<sup>(x)</sup>, A.S. Figuera<sup>(x)</sup>, B. Rispoli<sup>(x)</sup>, A. Serra<sup>(x)</sup>  
 Laboratori Nazionali di Frascati

Definite results on the bremsstrahlung spectrum of the 1,000 MeV Frascati electronsynchrotron have been obtained using two converters and two different collimations, according to the following diagram:

Tantalium converter (Radiation lengths)	Collimation: accepted angles ( x 10 <sup>-3</sup> rad)	
0.13	0.75	3.6
0.013	0.75	3.6

The experimental arrangement has already been described<sup>(6)</sup>.

Aim of these measurements has been to contribute to the understanding of the mechanism of production of the  $\gamma$ -ray beam of the electronsynchrotron and to furnish helpful results for those photoproduction experiments that will use photons of energy close to the peak of the spectrum. Since the shape of the  $\gamma$ -ray spectrum depends essentially on the effective width of the converter, on the collimation, on the energy distribution of primary electrons and on possible multiple traversals of the converter, one must determine the effective width of the converters in use and the transmission factors of the collimators. With this in mind the angular distribution of the beam's intensity has been studied and the results compa-

<sup>(x)</sup> Divisione Elettronica, Roma

<sup>(6)</sup> G. Diambri, A.S. Figuera, B. Rispoli, A. Serra - Nuovo Cimento, 15, 500 (1960)

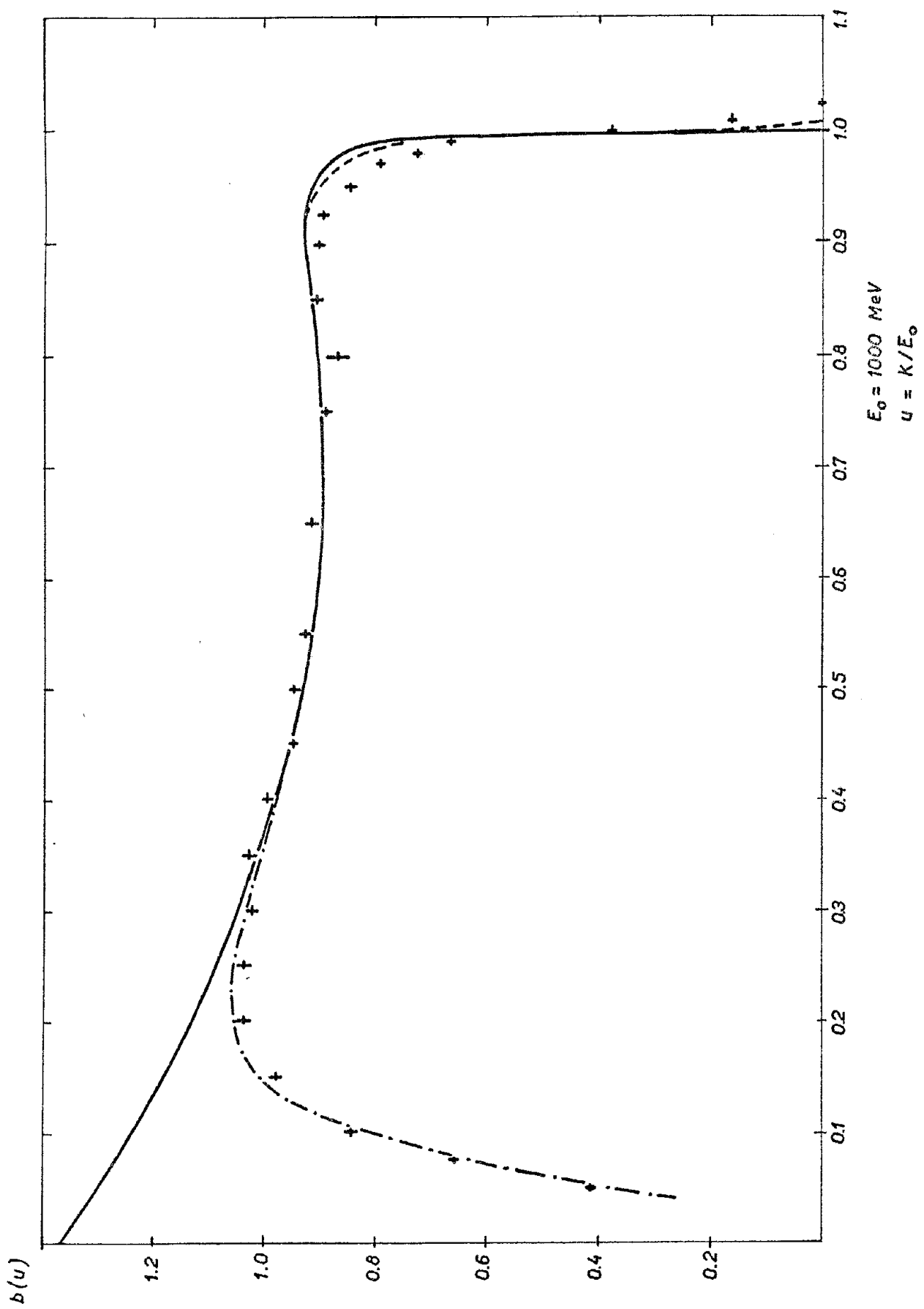
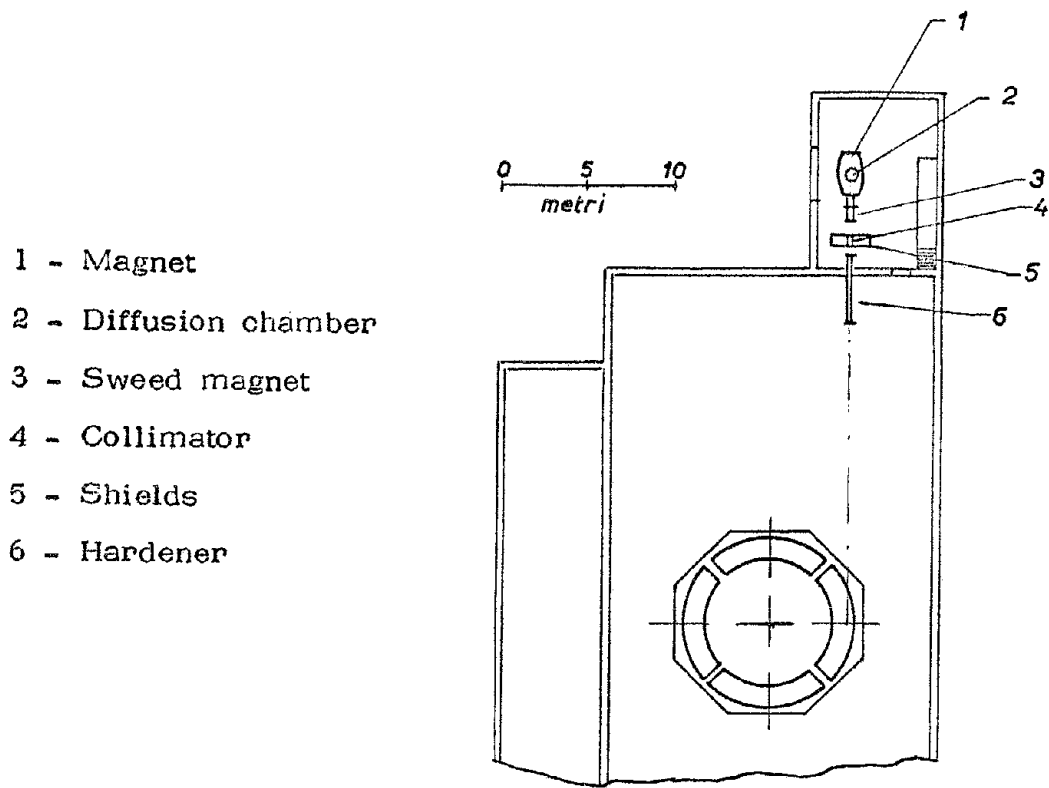


FIG. III. 7



- 1 - Magnet
- 2 - Diffusion chamber
- 3 - Sweep magnet
- 4 - Collimator
- 5 - Shields
- 6 - Hardener

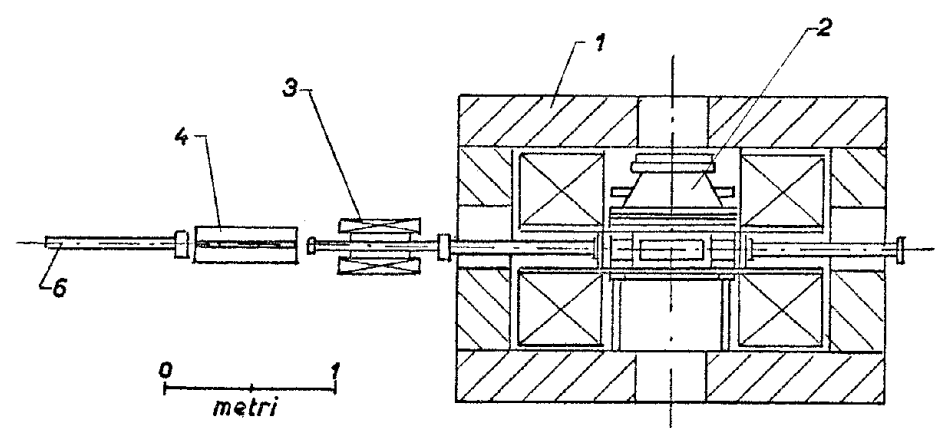


FIG. III.8

red with the theoretical angular distribution.

These results will soon be published on "Il Nuovo Cimento".

In fig. III,7 we plot a spectrum obtained with  $3.0 \times 10^{-3}$  collimation and a tantalium converter 0.013 radiation lengths thick.

#### 4. PHOTOPRODUCTION OF SINGLE AND MULTIPLE $\pi$ MESONS IN HYDROGEN AND DEUTERIUM

P.E. Argan, G. Bendiscioli<sup>(x)</sup>, V. Bisi<sup>(o)</sup>, A. Gigli, A. Piazzoli<sup>(x)</sup>, E. Picasso, G. Piragini<sup>(o)</sup>  
Istituto di Fisica dell'Università, Genova

Groups from the Universities of Genova and Turin collaborate on this experiment. To date we have achieved a final arrangement and functioning both of the diffusion chambers and of its auxiliary equipment. The arrangement of the various pieces of equipment is shown in fig. III,8.

To date, notwithstanding some trouble, now overcome, due to the malfunctioning of the cooling apparatus, we have taken a few thousand photographs, using liquid hydrogen as a target: these photographs have been used to set up scanning apparatus in Genova and in Turin, to train technicians and to check the programming of electronic computers.

Events contained in these photographs will also be used for the final statistics.

In the future we plan to use deuterium gas as a target. We are studying the possibility of repeating the experiment using a polarized gamma ray beam.

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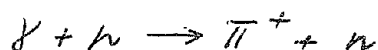
(x) Istituto di Fisica dell'Università, Pavia

(o) Istituto di Fisica dell'Università, Torino

5. SINGLE  $\pi^+$  MESON PHOTOPRODUCTION IN HYDROGEN BETWEEN 600 AND 900 MeV AT ANGLES  $\leq 90^\circ$  (CMS)

N. Beneventano, G. Finocchiaro, R. Finzi, L. Mezzetti, L. Pauluzzi, C. Schaerf  
Istituto di Fisica dell'Università, Poma

Measurements on the differential cross section of the



reaction, have been made, for energies  $E_\gamma$  between 600 and 900 MeV and in the  $\Theta_\pi = 90^\circ - 10^\circ$  angular region (CMS).

The experimental arrangement is that already described, with a few changes (see fig. III.9): a) we have added a scintillation counter ( $S_3$ ) at the end of the telescope so as to avail ourselves of an event (which we shall call briefly "quadruple") defined by  $S_1 S_2 C_a S_5 \bar{G}_1 \bar{G}_2$  specially at small angles ( $< 20^\circ S_1 B_1$ ), not as heavily affected by "spurious" and chance coincidences as event  $S_1 S_2 C_a \bar{G}_1$  (triples); b) along the magnetic analyzer we have placed some shields, so as to reduce pile up in counter  $S_1$ , that is mainly responsible for chance coincidences; c) in part of the measurements we have used "guard" counter  $S_4$ , that has a suitably dimensioned rectangular window in its center;  $S_4$  is placed at the exit of the first magnet so as not to intercept the trajectories of the pion beam defined by the target and the telescope, and to intercept (at least for the major part) eventual trajectories scattered only once from the magnet poles. The acceptance of the magnetic analyzer (determined with floating wire techniques) is approximately defined by the following parameters:

$$\left. \begin{array}{ll} \Delta\Theta \text{ (horizontal)} & \pm 35 \text{ mrad} \\ \frac{\Delta p}{p_0} & \pm 2,5 \% \end{array} \right\} \text{ for a point source}$$

Dispersion  $\sim 1\%$  per cm. Vertical cylindrical target about 50 mm in diameter.  $\gamma$ -ray diameter in the target  $\sim 36$  mm.



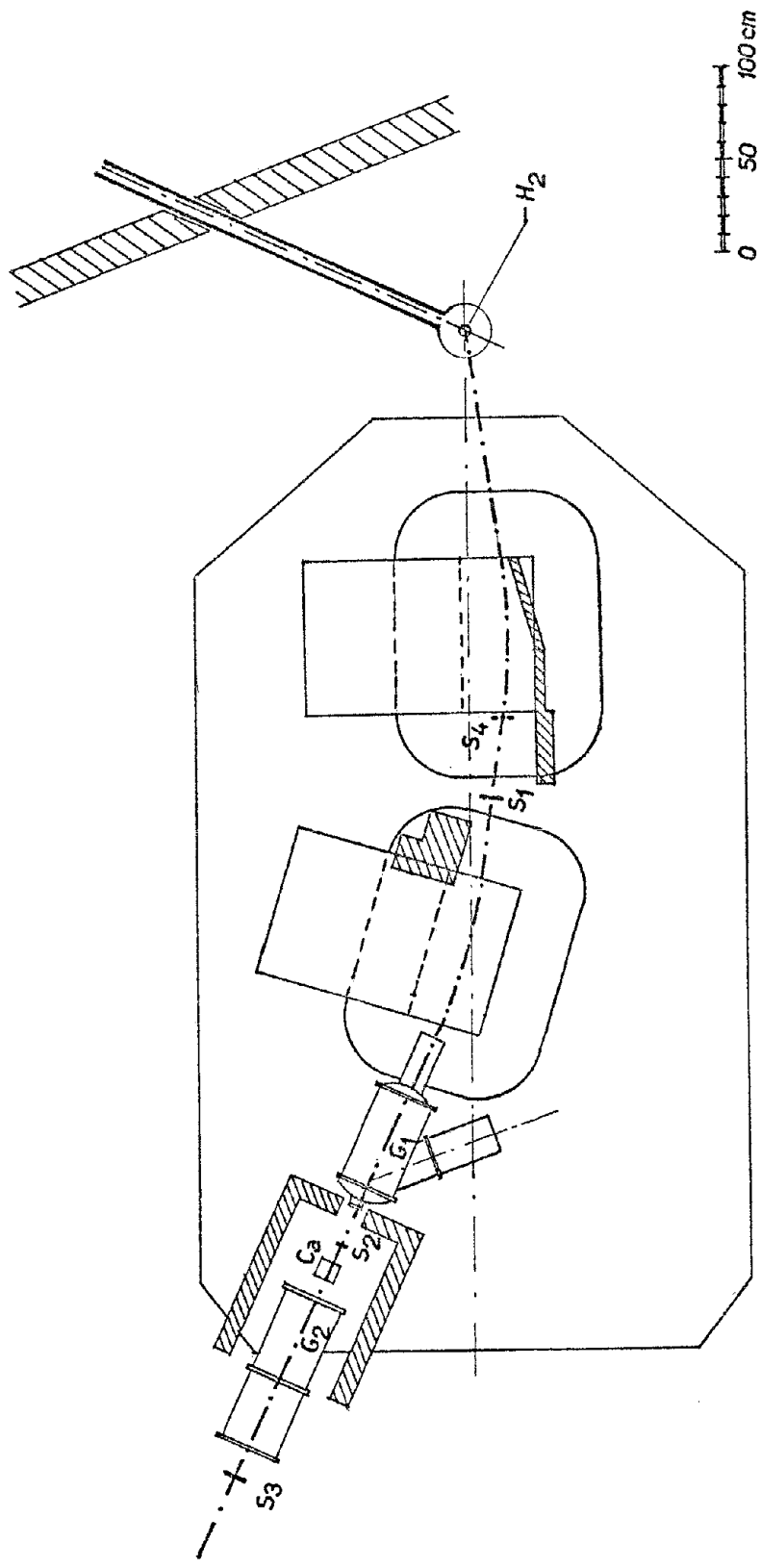


FIG. III.9

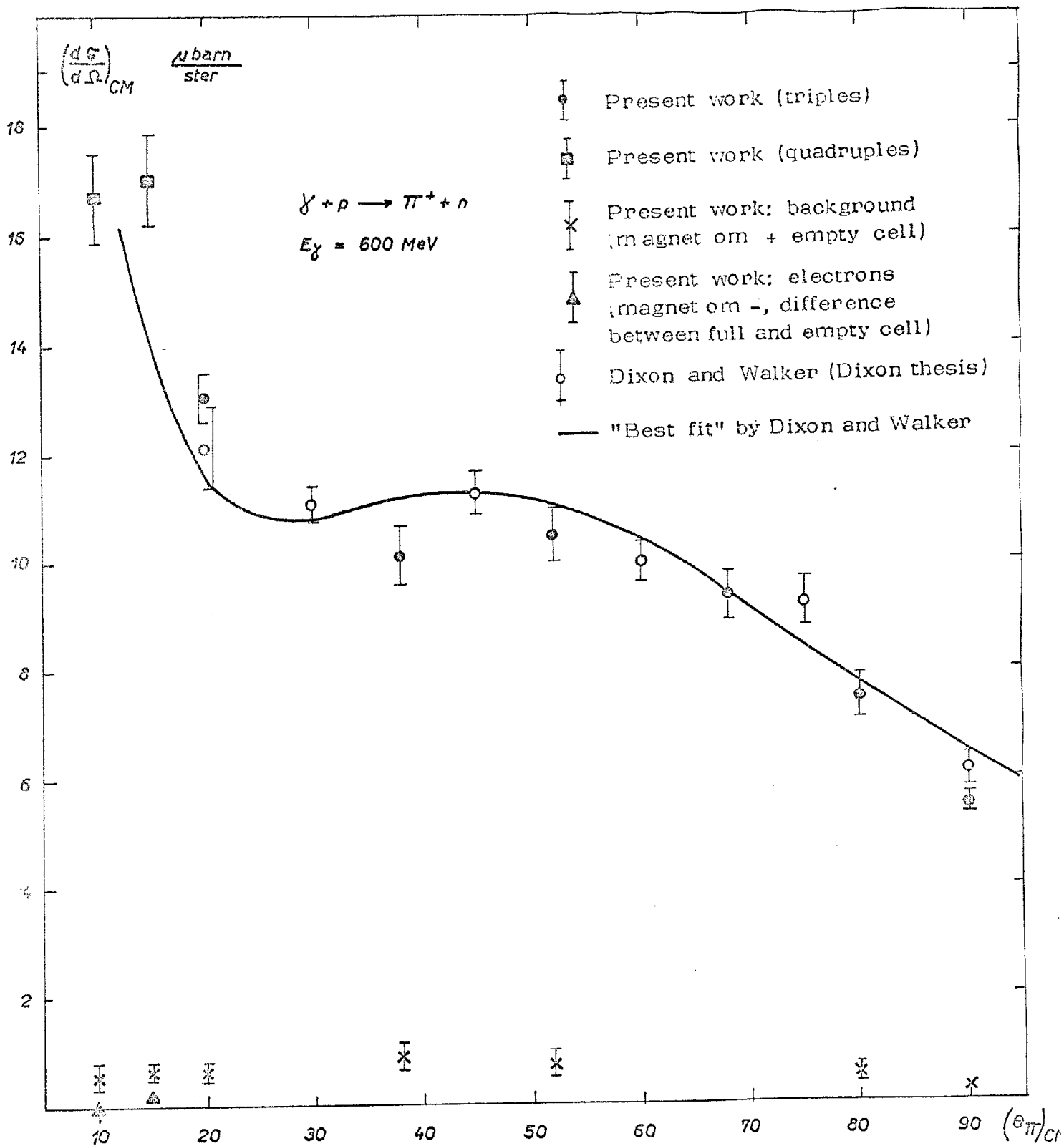


FIG. III.10

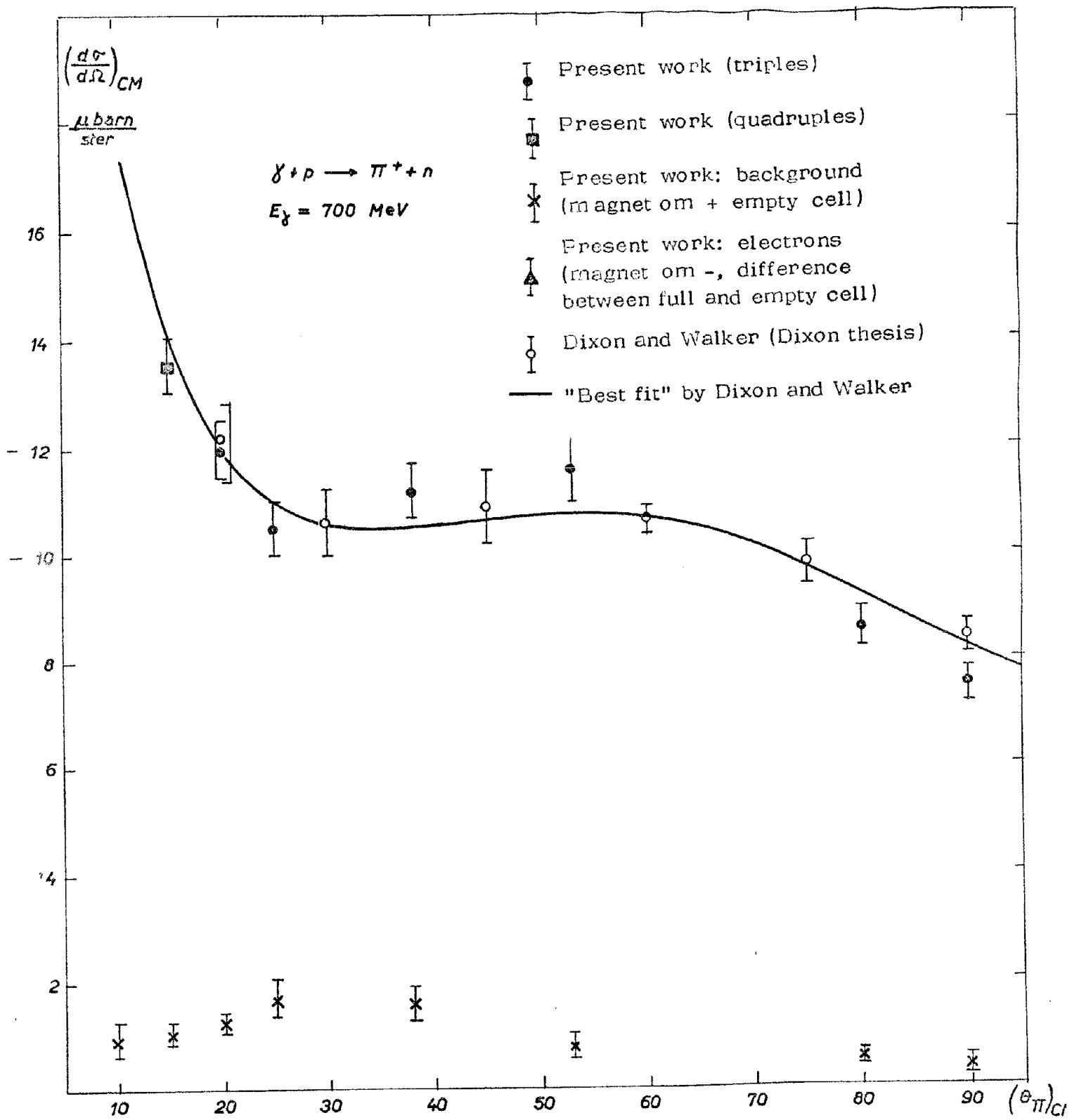


FIG. III.11

We have thus obtained points of the angular distribution at 600, 700, 800, 900 MeV chosen so as to complement published data and to extend them as far as possible towards small values of  $\Theta_{\pi}$ . The smallest value of  $\Theta_{\pi}$  practically achievable is determined in the present arrangement by the necessity to employ the mentioned radiation shields so as to keep spurious counting down. These are due, at least in great part, to complex events, presumably due to electromagnetic interactions on the magnet pole faces.

We have also measured the cross sections as functions of photon energy for  $\Theta_{\pi} = 90^{\circ}$  and  $20^{\circ}$  (CM): this has been done with the maximum possible detail compatible with the energy definition of photons (this varies from about  $\pm 20$  MeV to about  $\pm 30$  MeV at "half width" according to angles and energies).

Results are still being elaborated. In fig. III.10 and III.11 we have shown in a preliminary fashion angular distribution for  $E_{\gamma} = 600$  and  $700$  MeV, showing the experimental points of Dixon and Walker together with ours that have been suitably normalized. The indicated values are corrected for empty - target background (the latter is shown in the same graph and on the same scale) and for chance coincidences. The data have not yet been corrected for scattering on the pole faces.

The correction for in-flight-decay of pions, has not been determined. A rough estimate shows however that such a correction can not amount to more than 15 % in absolute value in the most unfavourable conditions, and does not vary by more than 4 % between extreme cases.

The normalization factor employed, for figg. III.10 and III.11 is a factor averaged on all experimental points (at all energies), by comparison with the "best fit according to Moravcsik" curves calculated by Dixon and

Walker<sup>(7)</sup>.

We are preparing a direct measurement of the acceptance factor of the analyzer to determine the absolute cross-sections. Some substantial changes on the counter telescope are being made and tested: these should allow us to extend measurements to angles  $< 10^\circ$  (CMS), possibly up to  $\Theta_{\pi^-} = 0^\circ$ .

The pressure containers of the two gas Cerenkov counters  $G_1$  and  $G_2$  have been coupled to form a single container, so as to eliminate two closing plaques: counter  $S_2$  has been placed internally, while counter  $C_2$  has been placed back, behind the  $G_1 - G_2$  assembly.

With these changes, the yield of  $G_2$  for high-energy electrons improved by a factor 20. Other changes tend to reduce as much as possible the number of chance coincidences, and above all the number of spurious counts due to complex events.

## 6. EXPERIMENT ON THE PRODUCTION OF $\mu$ MESON PAIRS

A. Alberigi<sup>(+)</sup>, C. Bernardini<sup>(\*)</sup>, G. Marini<sup>(\*)</sup>, A. Odian<sup>(x)</sup>, M. Pretis<sup>(o)</sup>, G. Stoppini<sup>(\*)</sup>

Laboratori Nazionali di Frascati

With the present arrangement we have finished a first phase relative to the determination of the frequency of

$$J + \text{nucleus} = (\text{nucleus}) + \pi^+ + \pi^- + \dots$$

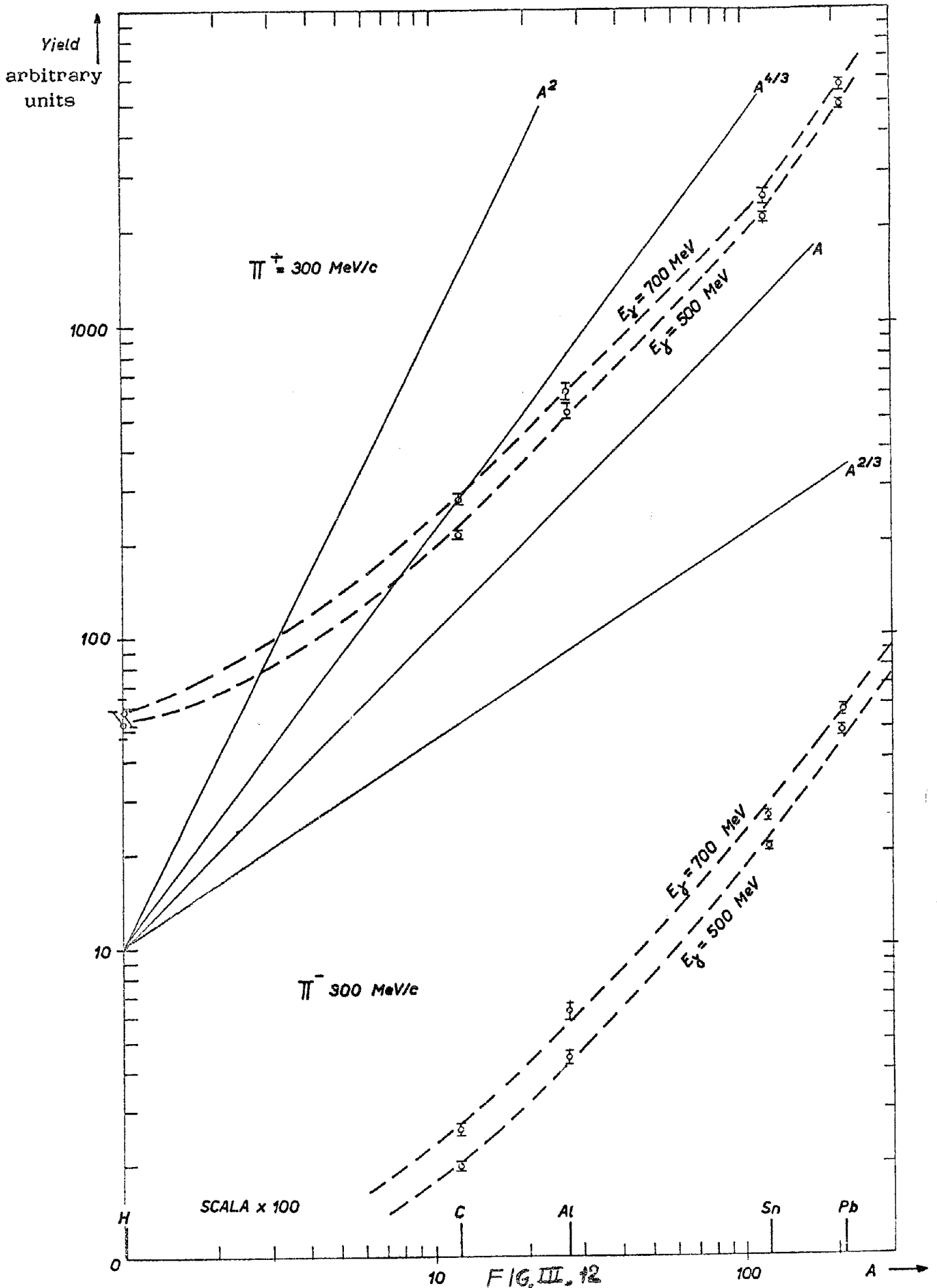
(7) Dixon - Thesis, California Institute of Technology, 1959 - The values quoted on the graph have been averaged by us over the results found by Dixon using different experimental arrangements.

(+) Istituto di Fisica dell'Università, Bologna

(\*) Istituto di Fisica dell'Università, Roma

(x) Univ. of Illinois, Urbana

(o) Istituto di Fisica dell'Università, Trieste



yield ↑  
arbitrary  
units

$E_\gamma = 900 \text{ MeV}$

1000

100

10

$A^2$

$A^{4/3}$

$A$

$A^{2/3}$

$\pi^+ 300 \text{ MeV/c}$

$\pi^+ 500 \text{ MeV/c}$

$\pi^- 300 \text{ MeV/c}$

$\pi^- 500 \text{ MeV/c}$

$\pi^- 700 \text{ MeV/c}$

SCALA x 100

H

C

Al

Sn

Pb

0

10

100

$A \longrightarrow$

FIG. III. 13

We have magnetically analyzed one of the charged pions coming from the target at an angle of  $30^\circ$  (LS); the magnet has been set up for momenta of 150, 300, 500 and 750 MeV/c. The maximum energy of the machine at which measurements have been made has been of 1,000, 900, 700 and 500 MeV. The targets we have used have been: carbonium, aluminum, tin and lead. Further, using a polyethylene target, we have deduced by subtraction the frequency of events in hydrogen so as to normalize (among others) the experimental points to the values already known of the cross-sections for single production.

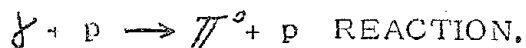
The data accumulated up to now, must be in part corrected for instrumentation effects (out-scattering in the telescope, decay in flight, contamination of low momentum electrons, etc.) that do not allow an immediate calculation of cross-sections. This normalization is still being done. We can nonetheless draw curves of yield as a function of the atomic number  $A$  of the target for measurements made in the same cinematic conditions. These curves are shown (see fig. III.12 and fig. III.13) in non final form, for the points we have analyzed to date. The ordinates are arbitrary while the interpolation curves connect points that are equivalent on a cinematic basis.

The most interesting information as regards the detection of  $\mu$  meson pairs lies in the possibility of excluding that the pion background is produced through coherent effects; these effects would give yields  $\sim A^2$ .

A further confirmation of this is furnished by coincidence measurements on two charged pions, done with a second telescope; these measurements, when compared with theoretical previsions on counting rate, seem to definitely exclude any coherent production.



## 7. EXPERIMENT ON THE POLARIZATION OF THE RECOIL PROTON IN



R. Querzoli, A. Silverman<sup>(x)</sup>, G. Salvini  
Laboratori Nazionali di Frascati

We have finished a first set of measurements of the proton polarization: the measurement (see internal report N° 23, presented at the meeting December 17-18, 1959) with an arrangement of scintillation counters in coincidence and anticoincidence (see fig. III.14); one deduces the proton polarization from the lack of left-to-right symmetry in the collision of protons with a carbonium target.

The dissymmetry

$$\mathcal{E} = \frac{R/L - 1}{R/L + 1}$$

has been measured at vario-

us energies (see fig. III.15 and accompanying table) of the incident proton, for protons emitted at 90° in the center of mass.

The value of  $\mathcal{E}$  has been corrected for chance coincidences, empty target effects, and the possible anelastic collisions in carbonium.

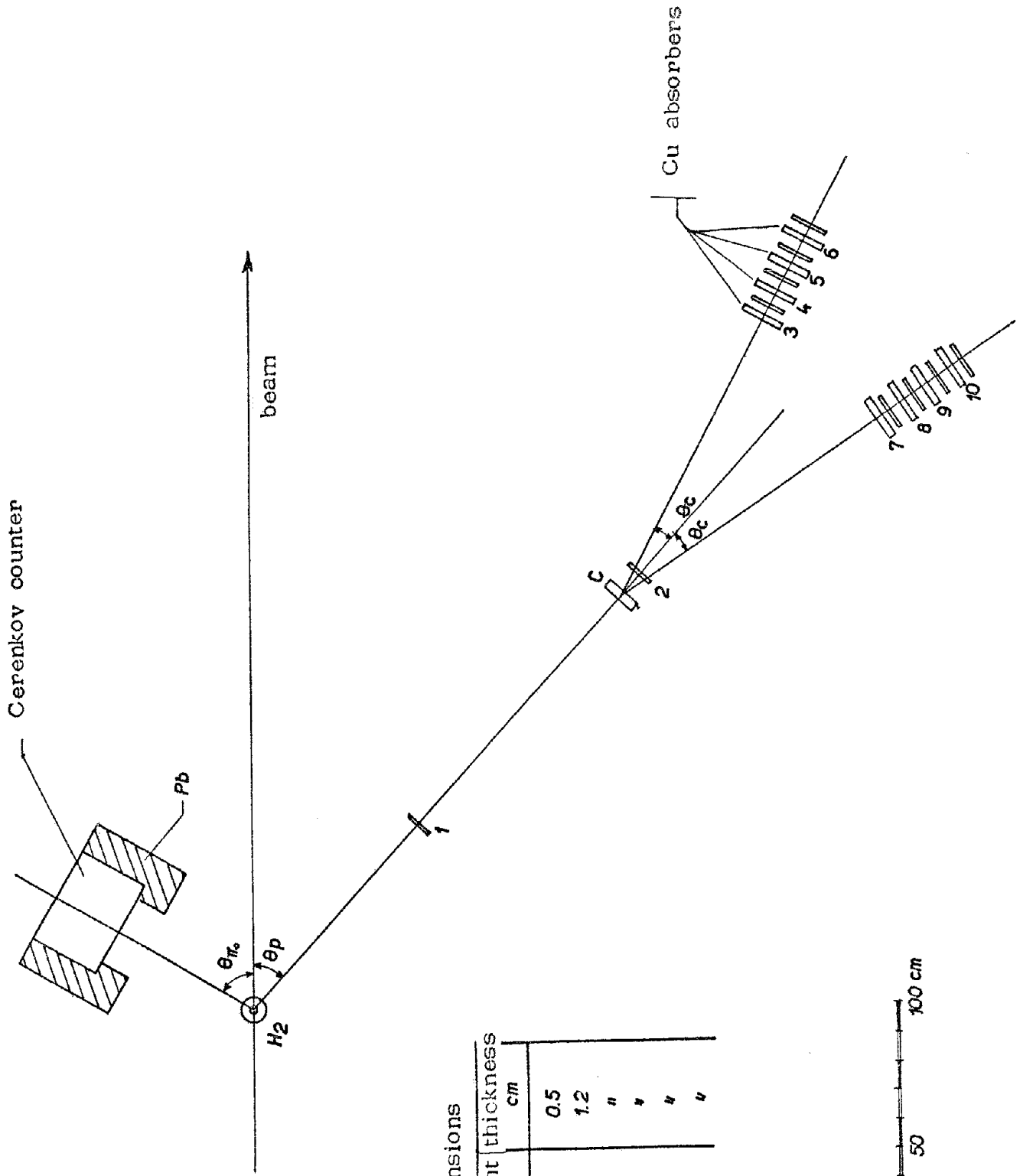
From the corrected value of  $\mathcal{E}$  (reported in the table) one can deduce the polarization of the proton calculating the analyzing power of carbonium in our arrangement. This efficiency calculation has been done employing Monte Carlo methods on an IBM 650 electronic computer.

The rather high values of polarization indicate that the second resonance has the opposite parity of the first, and should therefore be a  $P_{3/2}$  state of isotopic spin 1/2.

It is interesting to note that polarization stays quite high also after the second resonance (750 - 850 MeV energy range): this result is com

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<sup>(x)</sup> Lab. for Nuclear Studies, Cornell Univ., Ithaca



Counter dimensions

No.	width cm	height cm	thickness cm
1	9	14	0.5
2	10	25	1.2
3-7	12.5	"	"
4-8	"	"	"
5-9	"	"	"
6-10	"	28	"



Fig. III.14 - COUNTER LAYOUT

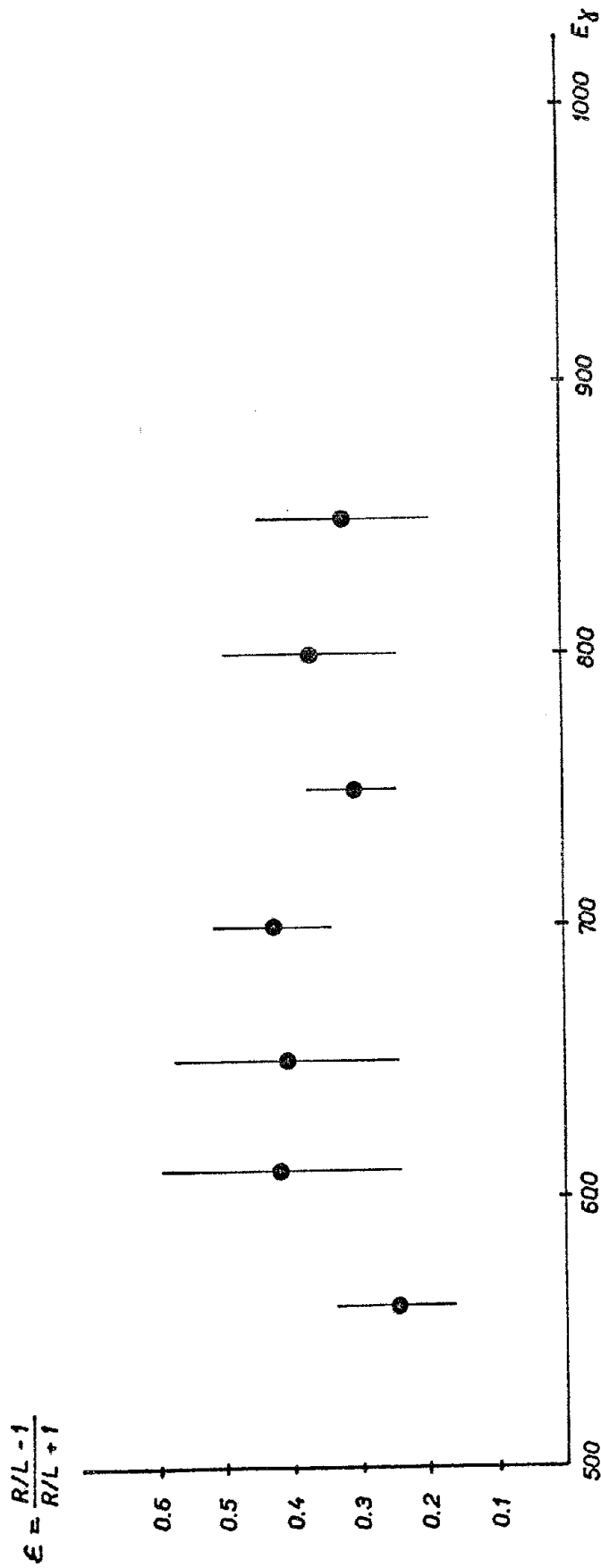


Fig. III.15 - ASYMMETRY  $\epsilon$  VERSUS PHOTON ENERGY  
(Intensity is always lower in the telescope closest to the  
-beam)

patible with the hypothesis that the third resonance interferes with the second, since these two have opposing parities. In such a case the third resonance could be a  $F_{5/2}$  state.

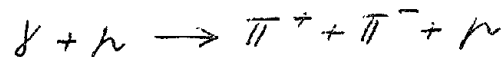
Table

$E_\gamma$	$\Sigma$	Polarization
560	$0.25 \pm 0.09$	$0.40 \pm 0.14$
610	$0.42 \pm 0.18$	$0.63 \pm 0.27$
650	$0.41 \pm 0.17$	$0.59 \pm 0.24$
700	$0.43 \pm 0.09$	$0.56 \pm 0.11$
750	$0.31 \pm 0.07$	$0.39 \pm 0.09$
800	$0.37 \pm 0.13$	( $\sim 0.5$ )
850	$0.32 \pm 0.14$	( $\sim 0.5$ )

## 8. EXPERIMENT ON PARITY CONSERVATION

E. Fuschini, A. Forino, C. Maroni, P. Veronesi  
Istituto di Fisica dell'Università, Bologna

Aim of the experiment is to verify the conservation of parity in the photoproduction reaction



We plan to detect the presence or lack of presence of a pseudoscalar term of the type  $P_\gamma = P_{\pi^+} \times P_{\pi^-}$ , in a counter experiment.  $P_\gamma$ ,  $P_{\pi^+}$ ,  $P_{\pi^-}$  are the momenta of the particles in the final state.

To define the considered event cinematically, we fix the angles and the momenta of the two pions, who, for practical reasons, are detected in coincidence at  $90^\circ$  relative to each other in a plane perpendicular to the

direction of the  $\gamma$ -ray beam. While we are awaiting a magnetic analyzer (now being built) so as to charge - select the  $\overline{\pi}$  mesons, we will run a preliminary experiment without employing the abovementioned selection. Since for statistical reasons we have to keep our counters very close to the beam, we are now searching for an adequate way of shielding our counters so as to keep background down to acceptable limits.

#### 9. EXPERIMENT ON $K^+$ PHOTOPRODUCTION AT ENERGIES CLOSE TO THE THRESHOLD OF THE $\gamma + p = \Lambda^0 + K^+$ REACTION

L. Mezzetti, L. Osborne, S. Tazzari, C. Bemporad<sup>(x)</sup>, M. Grilli<sup>(x)</sup>, P. Kussthatchner<sup>(x)</sup>  
 Istituto di Fisica dell'Università, Roma

During the period November 1959 - April 1960, the group has worked on setting up and checking the equipment necessary to the measurement (This has been described during the Frascati meeting and is synthesised in fig. III.16).

Since May 1960 we have started our first runs at the machine (for a total to date, of 6 shifts). We have made tests at angles  $\Theta_{\gamma-K} = 10^\circ - 35^\circ$ , for  $(E_\gamma)_{\max} = 1.050$  MeV.

We can say that the electronic system devised for selecting events of interest has proved satisfactory: on about 70 photographs relative to about 20 events have been observed that may be identified as K mesons. We are now making calibrations for a more accurate study of these photographs. The situation at  $\Theta_{\gamma-K} = 10^\circ$  is more complicated, due to pile up in counters in which K particles stop ( $C_6 - C_{10}$ ). We think that we can overcome these difficulties by suitably gating the stopping channels. Our future program includes, a part from the completion and perfection of the present

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<sup>(x)</sup> Istituto di Fisica dell'Università, Padova

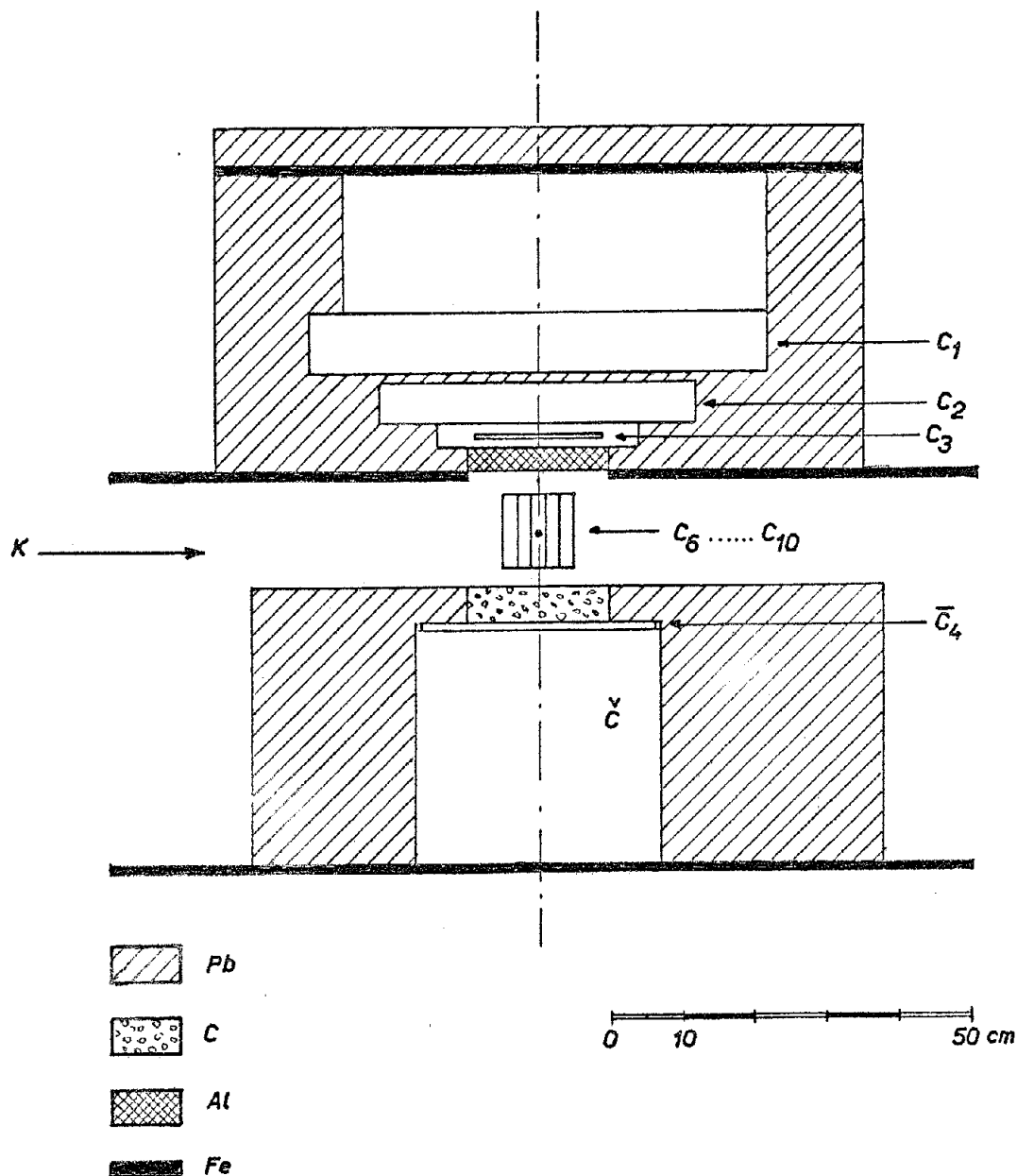


Fig. III.16 - SCHEME OF  $\gamma + p \rightarrow \Lambda^0 + K^+$  EXPERIMENT

- |                                     |   |   |
|-------------------------------------|---|---|
| C <sub>1</sub> , C <sub>2</sub>     | toluene counters                            | } $\pi^+$ detection channel ( $K^+ \rightarrow \pi^+ + \pi^0$ ) |
| C <sub>3</sub>                      | plastic counter                             |   |
| C <sub>6</sub> .....C <sub>10</sub> | plastics counters (K <sup>+</sup> stoppers) |   |
| $\bar{C}$                           | Cerenkov                                    | } $\pi^0$ detection channel                                     |
| $\bar{C}_4$                         | plastic counter                             |   |

equipment:

- 1) - The building (already under way) of a liquid hydrogen target of a special shape.
- 2) - Setting up a new arrangement, with which we plan to measure the transversal polarization of the  $\Lambda^0$ , respect to the plane of production, in the  $\gamma + p = \Lambda^0 + K^+$  reaction.

To date two graduate students collaborate at the work of the group.

## 10. ANNIHILATION EXPERIMENT

L. X. Ion, G. Poiani<sup>(x)</sup>, G. Torelli, R. Torelli Tosi  
Istituto di Fisica dell'Università, Pisa

The measurement of the total cross-section of the annihilation process  $e^+ + e^- \rightarrow \gamma + \gamma$  at high energies ( $\sim 1,000$  MeV) will provide new informations on the adequateness of electrodynamics at these high energies.

For this measurement we plan on using the  $e^+$  beam selected by the pair spectrometer magnet.

An arrangement of three coincident scintillation counters will allow us to count the incident positrons, while a total - absorption Cerenkov counter preceded by an anticoincidence will detect at least one of the two  $\gamma$ -rays produced in every event.

The coincidence system and the detectors are ready here at Frascati and they shall be shortly set up at the machine. Our Cerenkov counter is being assembled at Pisa and will be brought next to the machine within the following month.

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<sup>(x)</sup> Istituto di Fisica dell'Università, Trieste

11. MEASUREMENT OF THE POLARIZATION OF THE RECOIL PROTON  
IN THE  $\gamma + p = p + \pi^0$  REACTION USING NUCLEAR EMULSION  
TECHNIQUES

M. Grilli, I. Laboragine, G.A. Salandin  
Istituto di Fisica dell'Università, Padova

As was said in the preceding report N° 7 (December 1959) and was communicated during the meeting held at the same date at Frascati, the group has exposed a block of 120 nuclear emulsions (400  $\mu$ m, 10x12 sq cm) to study the polarization of the recoil proton in the



reaction ( $E_\gamma = 600 \pm 50$  MeV,  $\Theta_p \approx 100^\circ$  in the CM). The scanning of these emulsions is still being done at Padova.

During the month of Aprile exposures have been made at Rochester, at a polarized proton beam of known energy ( $P = 0.89 \pm 0.02$ ;  $E = 216 \pm 3$  MeV).

The latter experiment will serve to calibrate the one in Frascati. Information shall be given on both during the next months.