Laboratori Nazionali di Frascati

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A 250-MEV ELECTRON-POSITRON STORAGE RING: THE "À d A"

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(presented by C. Bernardini)

I. INTRODUCTION

In the last few years, interest has grown in the possibility of exploring the realm of high-energy physics by means of colliding-beam machines. Electron-electron colliding beams were first proposed by the Princeton-Stanford group[1]. Two separate projects of electron-positron storage rings are presently under development in Frascati. The first project[2] (called A d A, from the Italian: Anello di Accumulazione) is intended to obtain colliding beams of e^- and e^+ of 250 Mev (500 Mev total centre-of-mass energy). The second project (Adone, which in Italian means "big A d A") should produce beams of higher energy, possibly up to 1.5 Gev (3 Gev total c.m. energy), if this can be shown to be technically feasible.

Electron-positron colliding beams seem to offer a wide range of experimental possibilities, mainly related to electrodynamics and strong interactions. Some aspects of weak interactions could also be studied by this means.[3]

In this paper we shall report on the progress of the small e^+e^- single-ring storage machine in Frascati.

General characteristics have been given already[2]; for convenience we list, briefly, some of the significant parameters (see Figs. 1, 2, 3):

Maximum energy (per beam)	250 Mev
Radio frequency	147 Mc
RF harmonic number	2
Weak-focusing magnet, n-value	0.55
Number of straight sections	4
Radius of principal orbit in the quadrants	58 cm
Vertical pole gap	4.8 cm

We started operations (March 1961) with the following program in mind:

(a) check the properties of stored beams;

(b) improvements of injection system;

(c) observation of e^+e^- reactions.

II. STORED BEAM LIFETIME AND SHAPE

The first point concerns checking the calculated beam lifetime and shape. At this stage, the injection procedure is as follows: the 1 Gev γ-ray bremsstrahlung beam from the synchrotron arrives at the internal target of the ring, 2 cm off the principal orbit. A wide spectrum of e^+e^- pairs is produced, but only an extremely small fraction of lucky electrons is accepted, since radiation damping is not very effective in helping to avoid the target (even for a particle with suitable energy and direction). Nevertheless, a single circulating electron produces synchrotron light that can be detected (it can be even seen by eye). A photomultiplier at the end of a tangent sleeve of the doughnut teceives this light and the output corresponding ro a stored electron can be registered as a step current (clearly distinguishable above the background). A typical record is shown in Fig. 4, taken when the vacuum was quite poor (2×10^{-6} mm Hg) because of the need of having a flexible doughnut for target movements, large windows, etc.

The rate at which "good" electrons enter is about a factor of 10 less than foreseen (generally 0.2 electrons/sec is observed). This we ascribe to bad target profile and positioning; these are minor troubles because we plan to use an essentially different injection method.

The mean life can be deduced and it agrees with the calculated one (mainly due to the bremsstrahlung on the residual gas) at this pressure. Moreover, the statistical character of the particle loss has been checked for a large

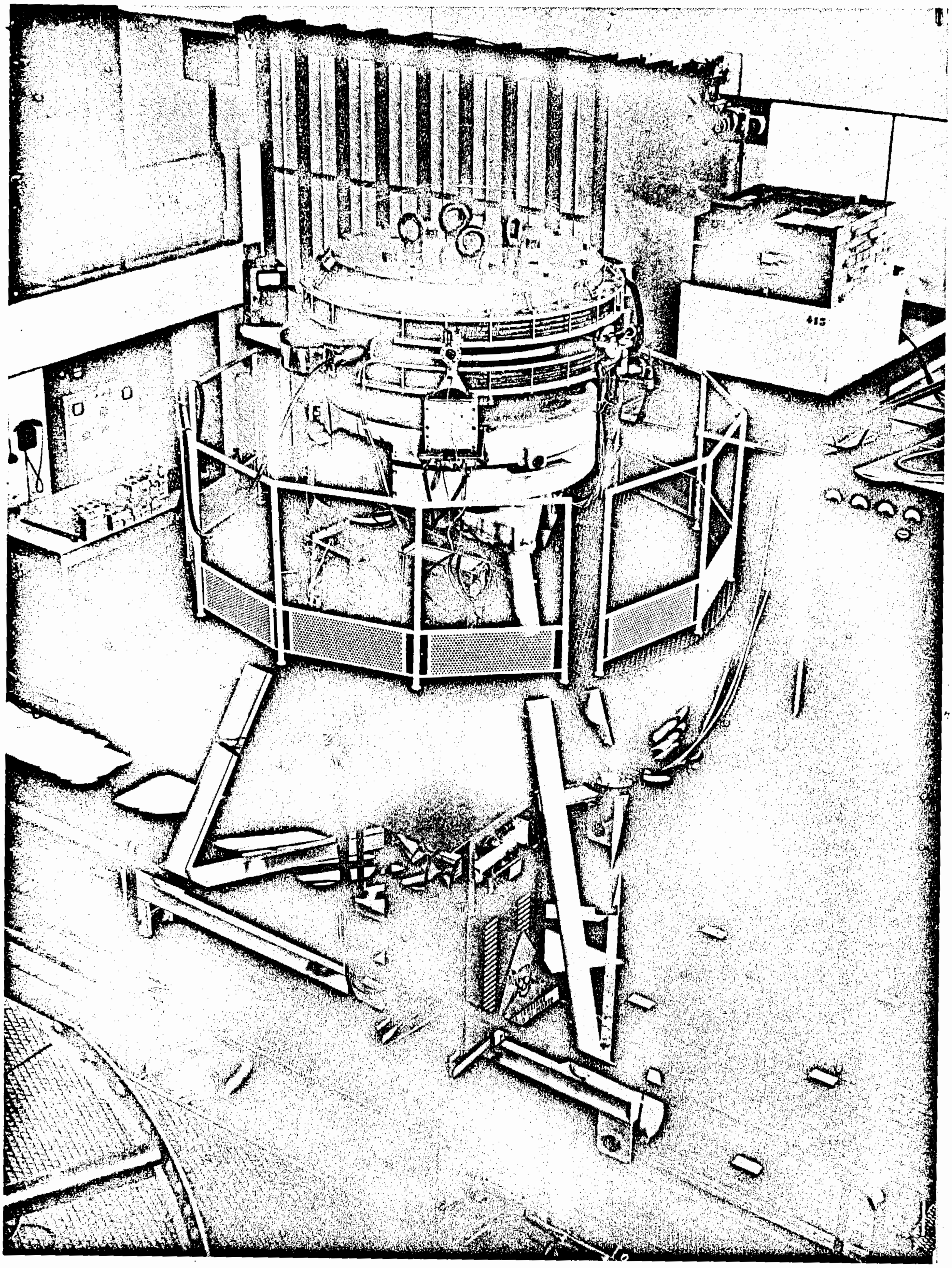

Fig. 1 View of the ring.

number of samples and it seems possible to say that there is no appreciable loss due to magnet ripple, improper rf voltage, or other troubles in the system. It must be said, however, that the lifetime is still very short (because of poor vacuum), compared to what we hope to achieve, and only a small number of tracks last more than one minute. It may be of interest to mention that the field can be changed, and the whole magnet can be displaced on the rails, without disturbing the stored particles.

We have looked at the beam cross section with a Polaroid camera replacing the phototube. In absence of x-z coupling, the vertical dimensions should be determined, chiefly, by scattering, whereas the radial size is affected by scattering and radiation fluctuations. This seems to be the case and the observed shape corresponds to the expected one, to the limit of uncertainties in the mean pressure and field-index value. The photograph in Fig. 5 shows a typical 1-minute exposure record.

We expect to go further with these tests, mainly by using a doughnut in which the vacuum can be lowered to about 10^{-9} mm Hg.

III. INJECTION SYSTEM

We are going to improve injection by means of a pulsed magnetic field. A two-coil system will be placed (above and below the median plane) at ¼ wavelength from the target. In this way, an injected electron can be given the proper angle to reduce the betatron-oscillation amplitude, provided the perturbation on stored particles is small enough. Since the pulse duration is limited to a few turns, in the A d A (13 nanosec/turn), the method has a small duty cycle unless the γ-ray beam from the synchrotron is conveniently shortened in time. In the synchrotron, a 200–300 nanosec γ-ray pulse has already been obtained by a pulsed-coil device.

A second improvement will be made by converting γ-rays as close as possible to the synchrotron and then transporting e^+e^- to the A d A by a suitable magnetic channel. Here, the method of injection will be essentially similar to the Princeton-Stanford one. We are now arranging to build the magnetic channel (two quadrupole pairs) as soon as possible. The gain by this method is due to the reduction of primary beam spread and presumably better matching of the source to the A d A.

Many possibilities are still open. For instance, one could use the positron flux from the internal target of the synchrotron. Positrons are naturally extracted by the synchrotron field itself.

A substantial improvement could be obtained by using a suitable high-energy linac, but, at

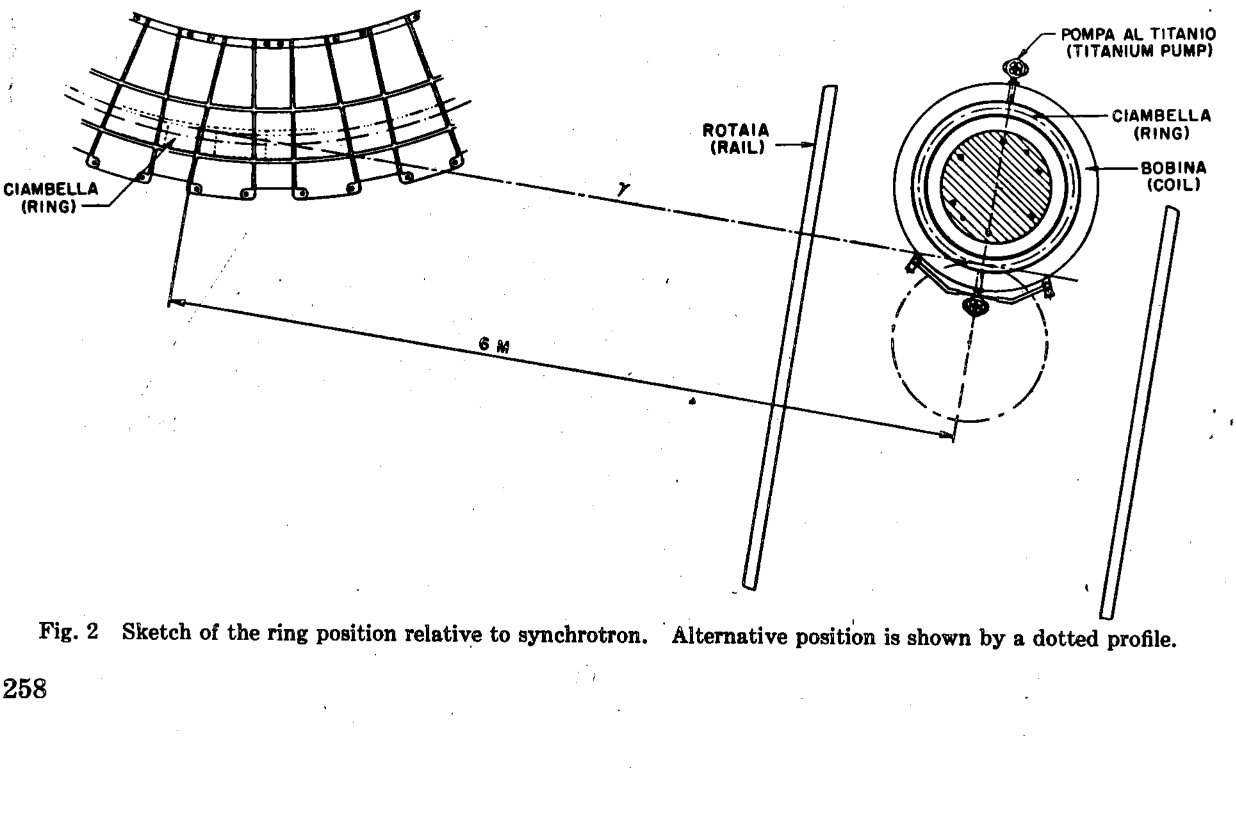

Fig. 2 Sketch of the ring position relative to synchrotron. Alternative position is shown by a dotted profile.

present, this would require transporting the A d A to another laboratory.

IV. OBSERVATIONS OF e^+e^- REACTIONS

Let $N_\pm$ be the number of stored $e^\pm$, and S the area of the cross section of the two oppositely moving beams (assuming they completely overlap). To observe conveniently (at 200 Mev per beam, for instance) the reaction:

$$e^+ + e^- \rightarrow 2\,\gamma \text{ (monitor reaction)}$$

we need

$$\frac{N_+N_-}{S} \simeq 5 \times 10^{18}\ \text{cm}^{-2}$$

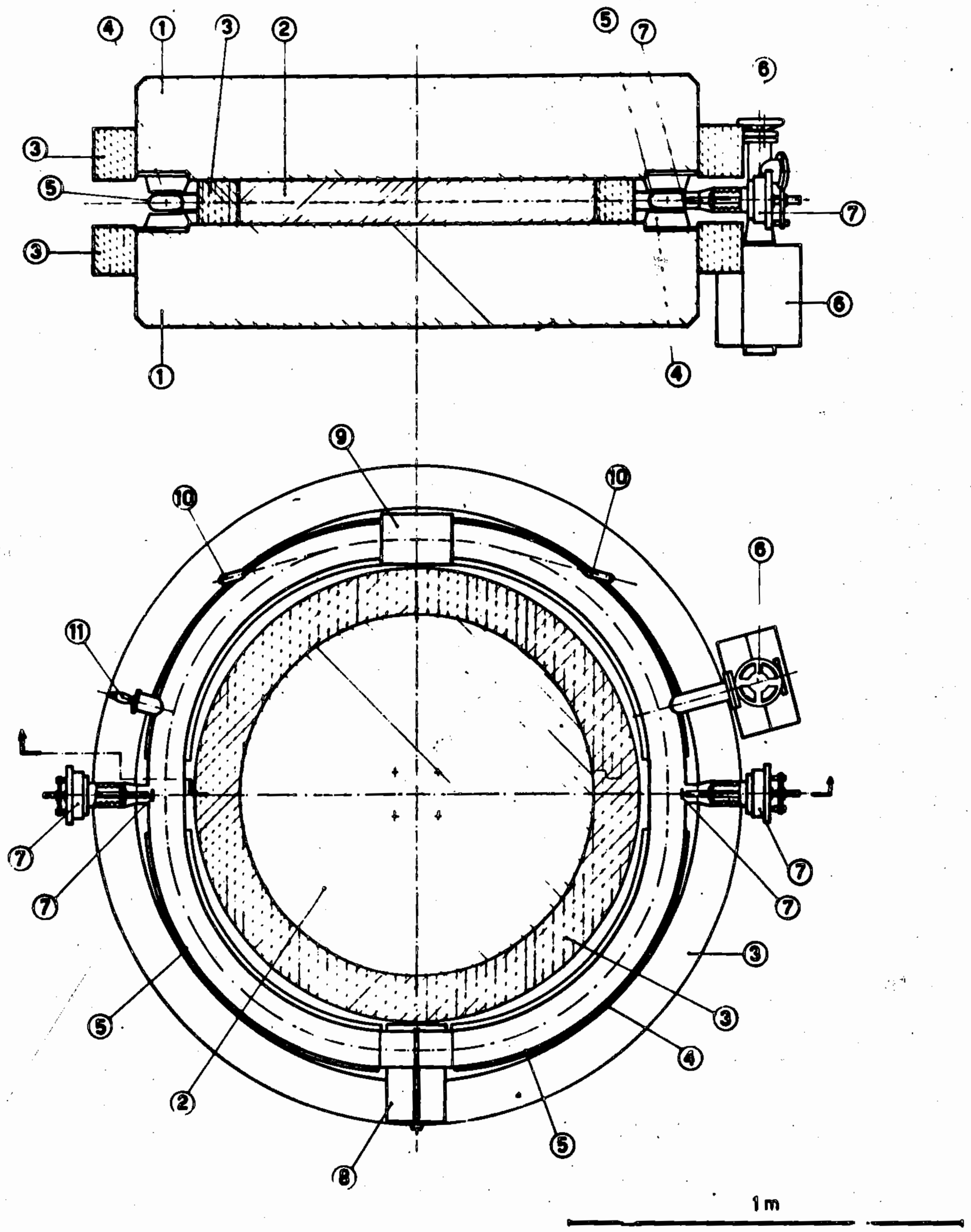

Fig. 3 Details of the magnet: (1) magnet yoke; (2) core; (3) coils; (4) pole pieces; (5) doughnut; (6) titanium pump; (7) target port; (8) rf cavity; (9) experimental area; (10) synchrotron-light windows; (11) vacuum gauge.

We consider this figure to be a threshold intensity for experiments. It corresponds to the rate of one monitor event every 10 minutes. At present, we are very far from the injection rate needed to reach this threshold but there seems to be no obstacle, in principle, to reach it.

Since γ-rays of the monitor reaction are confined in a narrow cone around the line of flight of the primary electrons (the classical m/E aperture angle), it will be possible to

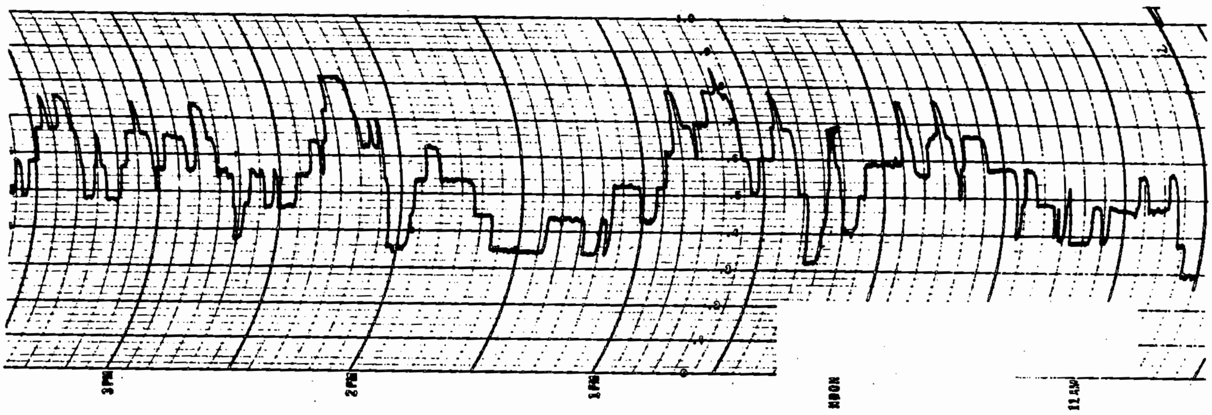

Fig. 4 Typical record of the photomultiplier looking at synchrotron light emitted by circulating electrons. Data for this trace are: average number of circulating electrons, 2.3; mean lifetime, 21 sec; time scale, 10 sec/div; energy, 218 Mev.

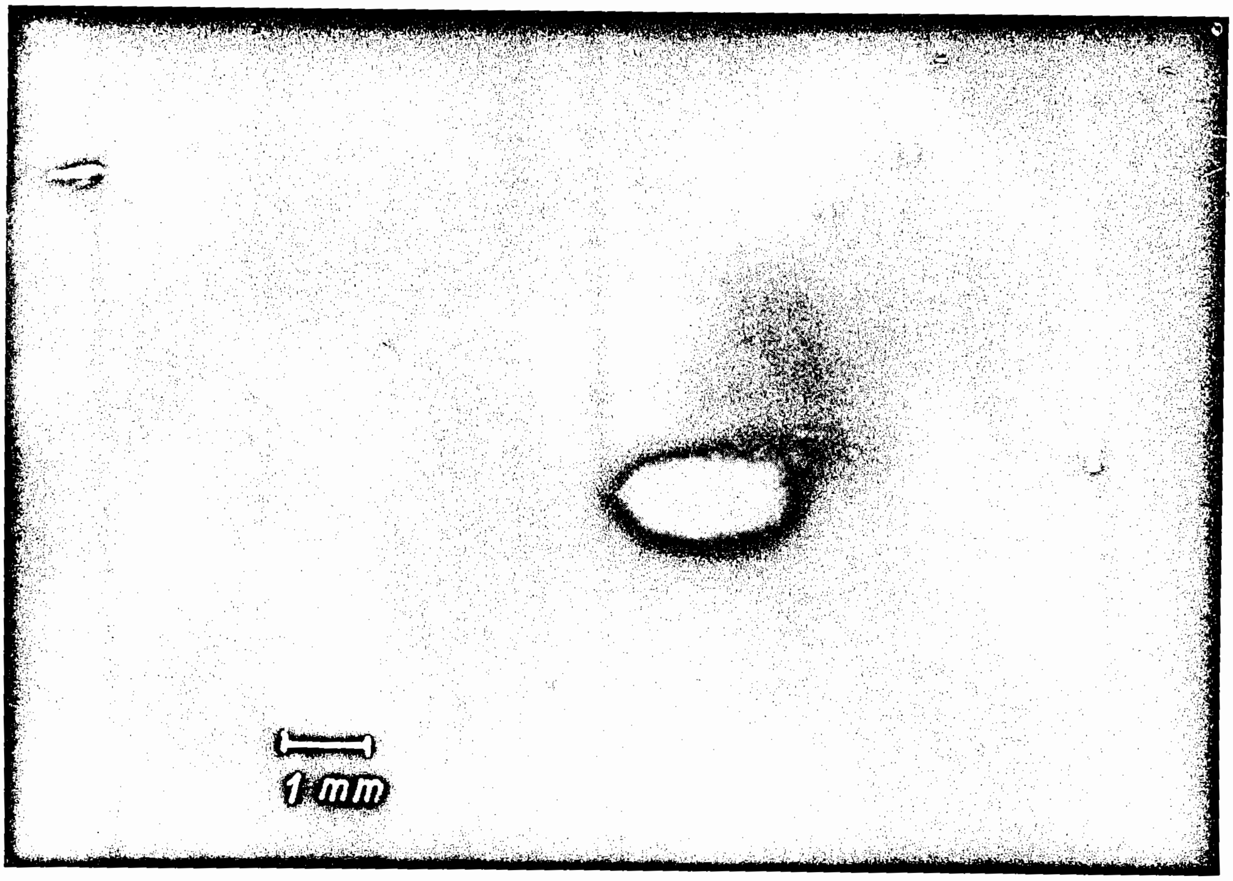

Fig. 5 Photograph of the beam cross section.

collect a large fraction of γ-rays in two small-aperture lead Cerenkov counters.

It must be mentioned that for these experiments, with the A d A, space-charge effects, which would prevent the proper overlap of the two beams, are not expected to be catastrophically large.

REFERENCES

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3. N. Cabibbo and R. Gatto, Nuovo Cimento *20*, 185 (1961).