THE PRESENT SITUATION AT ADONE, FROM THE POINT OF VIEW OF THE MACHINE AND OF THE EXPERIMENTS.

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I. MACHINE. -

As all of you know, a beam was first injected into Adone at the end of 1967: more than one year after, no experiment has yet been performed.

This is due to some unexpected problems which rose up in making the machine work: although this situation is not new, being in common with the first operation time of any new accelerator, the dead time of Adone appears to be somewhat longer than usual. However, we must remember that storage rings are still a field of investigation. The radiation damping compelles the beam density in these machines to very high values even when the total circulating current is of the order of a few milliamperes: as a consequence, the beam becomes instable, the instabilities being in general of a coherent nature.

A lot of work has been carried out during last year at Adone, in parallel with the work performed at ACO, in order to understand and overcome the instabilities: my impression is that most of the problems are now understood, so that experiments will be able to start soon.

Since the machine experts among you are certainly familiar with the situation of Adone, and the others are presumably not interested to details, I will give in the following only a short summary of what seems more relevant to me. I recall that I am not at all a machine expert: I am talking about work performed by the machine people, and about which detailed reports are or will be soon available.

Three main kinds of instabilities wave been observed in Adone, i.e.

a) phase instabilities
b) transverse betatron instabilities
c) beam-beam instabilities

The so-called resistive wall instabilities(1), already observed in the e^-e^- Princeton-Stanford ring, are expected to appear at a current higher than the design one.

a) - Phase instabilities. -

These are coherent synchrotron oscillations of the bunch around the synchronous phase, and appear to be particularly important as more than one bunch is present in the machine. Their theory has been developed by Littaner, Pellegrini, Sands and Touschek[2]: a simplyfied version can be found in the paper presented by F. Amman to the Washington conference a few days ago[3].

The instabilities are due to an interaction between the beam and the R.F. cavity. Proper tuning of the cavity can avoid the single bunch oscillations, while the multi-bunch phase oscillations can be stabilized by decoupling the bunches through the insertion in the machine of a small R.F. cavity, working on an armonic of the revolution frequency but not of the main R.F. frequency. A stable beam up to a total of 150 mA in the three bunches has been obtained in this way in Adone.

b) - Transverse betatron instabilites. -

They show up both as radial and as vertical coherent oscillations: their phenomenology appears to be connected with the structure of the vacuum chamber, and is therefore different in some points from machine to machine.

I quote the main features of the instabilities observed in Adone:

- the threshold beam intensity at which instabilities appear was observed to depend on energy as shown in Figs. 1 and 2.
- The instability affects each bunch independently of the others. When more than one bunch is present in the machine, the threshold for instabilities in a bunch is independent of the current in the others. Accordingly to wether or not bending electrostatic electrodes were present in the machine, the threshold was observed to depend on the longitudinal density in each bunch (i/l) or on the current itself.
- The center of mass of the bunch is involved in the instability.
- The raise-time is of the order of 100 msec.

The idea of interpreting these instabilities as being due to an head-tail interaction of the particles in the bunch (e regeneration mechanisme being provided by the synchrotron oscillation mechanism) is due to C. Pellegrini, M. Sands and B. Touschek: a detailed theory has been developped by C. Pellegrini[4]. The damping mechanism of these instabilities appears to be the Landau damping: due to the non-linearities (octupolar terms) in the machine, the betatron frequency of each particle depends on its betatron coordinate; an oscillation which starts as a coherent one, tends to become incoherent due to the phase-shifts produced on the particles by the beam dimensions.

It has actually been observed that the threshold current depends on octupolar terms as shown in Fig. 3: the asymmetric behaviour is also well explained by theory. Making profit of the fact that the center of mass of the bunch is involved in the instability, an active feedback has been used to stabilize the beam. The method appeared to be effective. A resonant feedback was able to stabilize a single bunch in the machine up to a current of at least 65 mA. A fast feedback (taking the signal from one bunch and acting on the same bunch) was also successfully used: in this way the 6 bunches (3 bunches e^+ and 3 bunches e^-) can be stabilized.

When the center of mass of the bunch is not involved in the instability (as in the ACO case) the feedback stabilization cannot be used. However, accordingly to the head-tail theory(4), which mode is excited depends on the chromatism of the machine (sextupolar terms). Addition of a sextupol to the machine should thus be able to turn the instability mode to the center of mass one.

c) - Beam-beam instability. -

The first preliminary measurements of luminosity have been recently performed with Adone using beam-beam single bremsstrahlung. Depending on the dimensions of the beams, a maximum luminosity is obtained at which beam-beam (space-charge) instabilities occur (Amman-Ritson effect). The first preliminary measurements of ΔQ (the maximum allowed betatron frequency shift produced by beam-beam interaction) give values in agreement with the data obtained at Stanford and Orsay. ($\Delta Q \sim$ some 10^{-2}).

The next step will be to separate the e^+ and e^- beams (but in the interaction region) in order to obtain a crossing angle: in this way the space-charge effect is pushed to higher current values, and in addition a smaller interaction region (few centimeters) will be obtained.

I would like to mention another point, the positron injection rate: without an accurate optimization of the positron beam in the Linac and in the transport system, the maximum storage rate obtained was 200 μA (normal rate 100 μA) per pulse, injecting at 300 MeV on one bunch out of three: this allows to reach the design current (100 mA) in a few minutes.

Since the major machine problems seem to be solved, or near to a solution, we expect to be able to get the first results on particle physics during this year.

II. - EXPERIMENTS. -

The preparation of the first generation experiments to be performed with Adone started some years ago. Most of you are therefore already familiar with them (see, for instance, the proceedings of the

Saclay meeting on electron storage rings, october 1966). The experimental apparata are now ready.

I recall that there are seven first generation experiments, listed in the following with a few comments:

1) - Study of the reaction $e^+ + e^- \rightarrow$ photons. -

The experimental apparatus consists mainly of shower spark chambers, with proper counters to trigger. A schematic drawing of the experimental set-up is shown in Fig. 4. A detailed description of the experiment can be found in ref. (5).

The aim is to explore mainly the following reactions:

a) $e^+ + e^- \rightarrow \gamma + \gamma$. The study of the angular distribution for this process can test the validity of QED for space-like momenta of the electron propagator up to some GeV(6).

b) $e^+ + e^- \rightarrow$ vector bosons $\rightarrow \pi^0 \gamma$ or $\eta \gamma$.

2) - Study of the reaction $e^+ + e^- \rightarrow \mu^+ + \mu^-$.

The experimental apparatus consists of counters, absorbers, and spark chambers. μ's of energy up to 1.5 GeV can be stopped in the apparatus.

A measurement of the absolute value of the cross section for this process allows to check the validity of QED for time-like momenta of the photon propagator up to 3 GeV.

More precisely, the product of a possible form factor in the ee vertex, in the $\mu\mu\gamma$ and of a possible modification of the photon propagator is factorized in the amplitude for this reaction.

Of particular interest are the determination of vacuum polarization effects and of other possible modifications of the photon propagator.

3) - Study of the reaction $e^+ + e^- \rightarrow$ pions, Kaons. -

Again an experimental apparatus consisting of counters and spark chambers, in order to study the production cross section of mesons both <u>on</u> and <u>outside</u> the vector boson masses.

The experimental groups involved in experiments 2) and 3) have recently joined in one single group: using a single experimental apparatus they will collect simultaneous data on all of the above reactions.

4) - Study of the decay $\phi \rightarrow K^+ + K^-$. -

The experiment is quite similar to the one being started at Orsay.

5) - Search for new vector bosons. -

An experimental apparatus consisting of four telescopes (scintillation counters, shower counters, wire spark chambers) connected on line with a small computer (DEC PDP8) will be used to search for possible new vector bosons. The energy of the machine will be modulated linearly in time and the rate for different types of observed events (colinear charged secondaries; non colinear; neutrals) will be plotted as a function of the machine energy: a resonance must show up as a pump in this distribution.

6) - Study of the reaction $e^+ + e^- \rightarrow p + \bar{p}$ at $E^+ = E^- = 1050$ MeV. -

The proton and the antiproton are stopped in thick scintillation counters: a wide gap cylindrical spark chamber surrounding the donought allows to determine the direction of flight, and wide gap spark chambers in each of the four telescopes of the apparatus allow to detect the products of the annihilation star of the antiproton.

7) - Search for leptonic quarks. -

This experimental apparatus, consisting of thick and thin counters, thin and thick spark chambers, will be able to detect, in addition to possible quarks, also most of the products from other reactions.

As I said, the experiments are ready and waiting for Adone. Although no official decision has yet been taken, it is probable that experiments 1) and 6), for which a high luminosity is required, will start after the others.

As far as a design for second generation experiments is concerned, we are of course waiting for the first experiments to give at least preliminary results.

However, it is already to be expected that the study of multibody final states will be of primary importance. For thi reason, we have already designed a large magnetic volume, filled with wide gap optical spark chambers, which surrounding one of the experimental section will be of particular utility for the above types of experiments.

This is a cylindrical solenoid, 2 m diameter and 2 m long, placed with its axis orthogonal to the beam orbit, as shown schematically in Fig. 5.

The magnetic field is therefore orthogonal to the beam orbit. To avoid strong perturbations of the orbit, along the donought within the magnet two small compensation magnets are placed. They generate a field opposit to the main field, so that $\int \vec{B} \times \vec{dl} = 0$ on the beam orbit. Sections of the magnet showing the compensators are shown in Fig. 6.

A iron structure (schematically shown in Fig. 7) insures the return of the field and gives uniformity to the field in the useful volume.

The magnetic induction in the useful volume will be 4500 gauss. The excitation is provided by a power supply 400 Volt 5000 Amperes. Additional coils in the compensators independently supplied are driven in feedback by an instrument measuring $\int \vec{B} \times \vec{dl}$ (vibrating coil): so that the interaction with the machine is continuosly kept to its minimum.

A schematic drowing of the experimental set-up which will be used in the magnet is shown in Fig. 8. I think that no particular comment is needed.

The situation with this project is now that thinks are being bought: we expect to have the object working at the end of 1970.

A detailed description of the magnet, experimental apparatus and example of experiments which can be performed with it can be found in ref. (8, 9).

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(8) - G. P. Murtas, G. Sacerdoti, M. Nigro, R. Santangelo, E. Schiavuta, D. Scannicchio, D. Grossman, G. K. O'Neill and G. Mattihiae, Frascati Report, LNF-68/7 (Int.) (1968).
(9) - W. Ash, G. Goggi, D. Grossman, G. P. Murtas, M. Nigro, G. K. O'Neill M. Placidi, R. Santangelo, D. Scannicchio and E. Schiavuta, Frascati Report, LNF-69/6 (1969).

FIGURE CAPTIONS. -

FIG. 1 - The threshold current (in a bunch) at which radial instabilities appear as a function of machine energy. In this situation bending electrostatic grids where present in the machine: the threshold current was independent on external termination of the grids.

FIG. 2 - The threshold current behaviour after removing the electrostatic grids. Both radial and vertical threshold is shown.

FIG. 3 - The behaviour of the threshold current for radial instabilities as a function of the current in an octupole added to the magnetic structure of the machine. E = 305 MeV. For $i_{ott} = 3A$ the octupolar terms in the machine are compensated by the external octupole. Grids not present.

FIG. 4 - a) Perspective view of the experimental apparatus for the study of reactions $e^+ + e^- \rightarrow$ photons.

b) Vertical section of the experimental apparatus along the beams direction. Scintillators S_A, S'_A are intended to be used to anticoincidence cosmic rays not passing through the interaction region.

FIG. 5 - Schematic drawing of the solenoid: the beam travels along the Z-axis.

FIG. 6 - Schematic views of the magnet: 6a) from top; 6b) from side, orthogonal to the beam orbit (along the magnet axis).

FIG. 7 - The iron structure of the magnet.

FIG. 8 - a), b) - Experimental apparatus. Mc: Solenoid; VP: beam pipe; CP: magnetic field compensator; ESC: external spark chambers; ISC: internal spark chambers; C1, C2: cylindrical wire spark chambers; C3: wire plane chamber; GCS: gas control system; M: mirror; TG: trigger external counter; EL: electronic logic.

c) Trigger system.

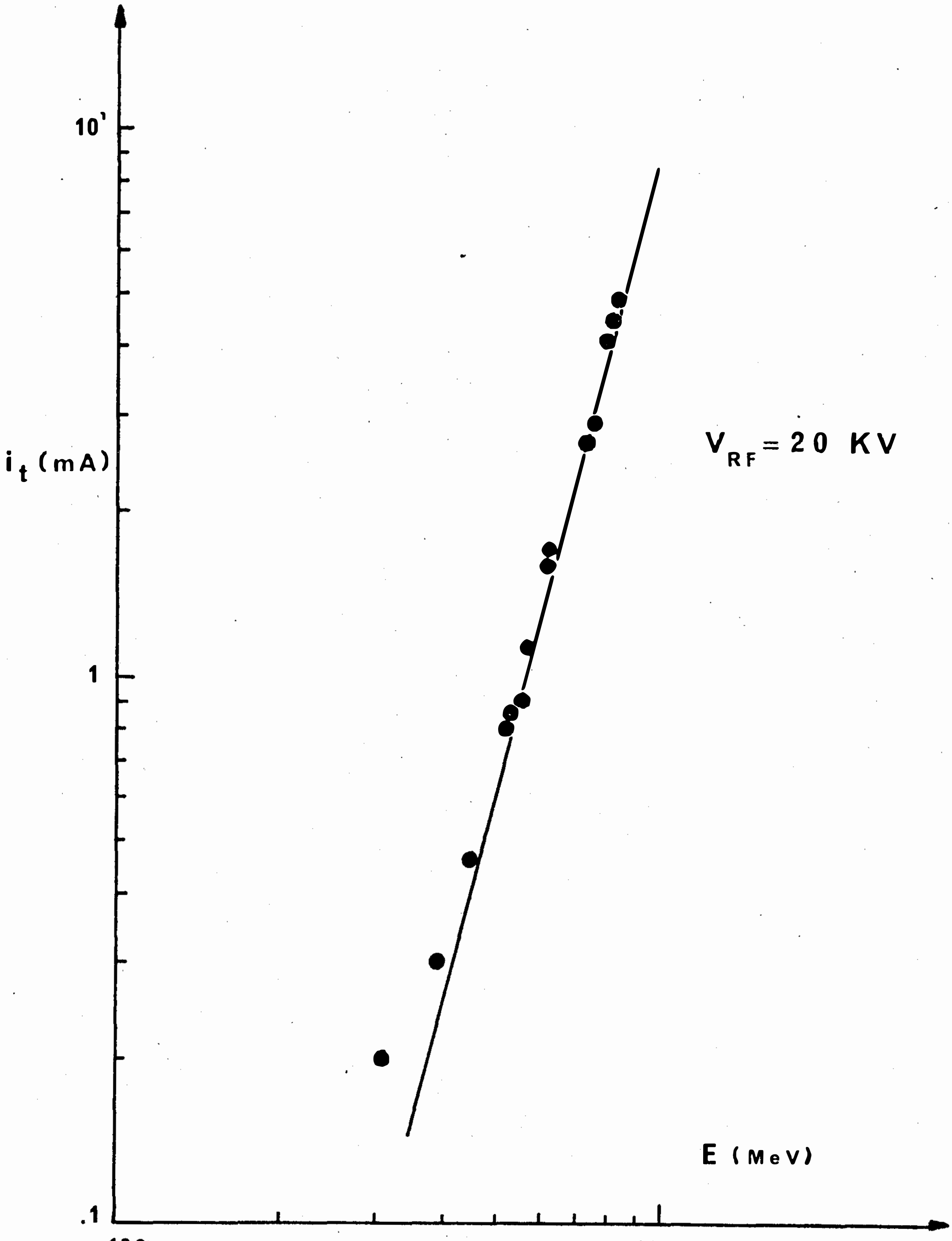
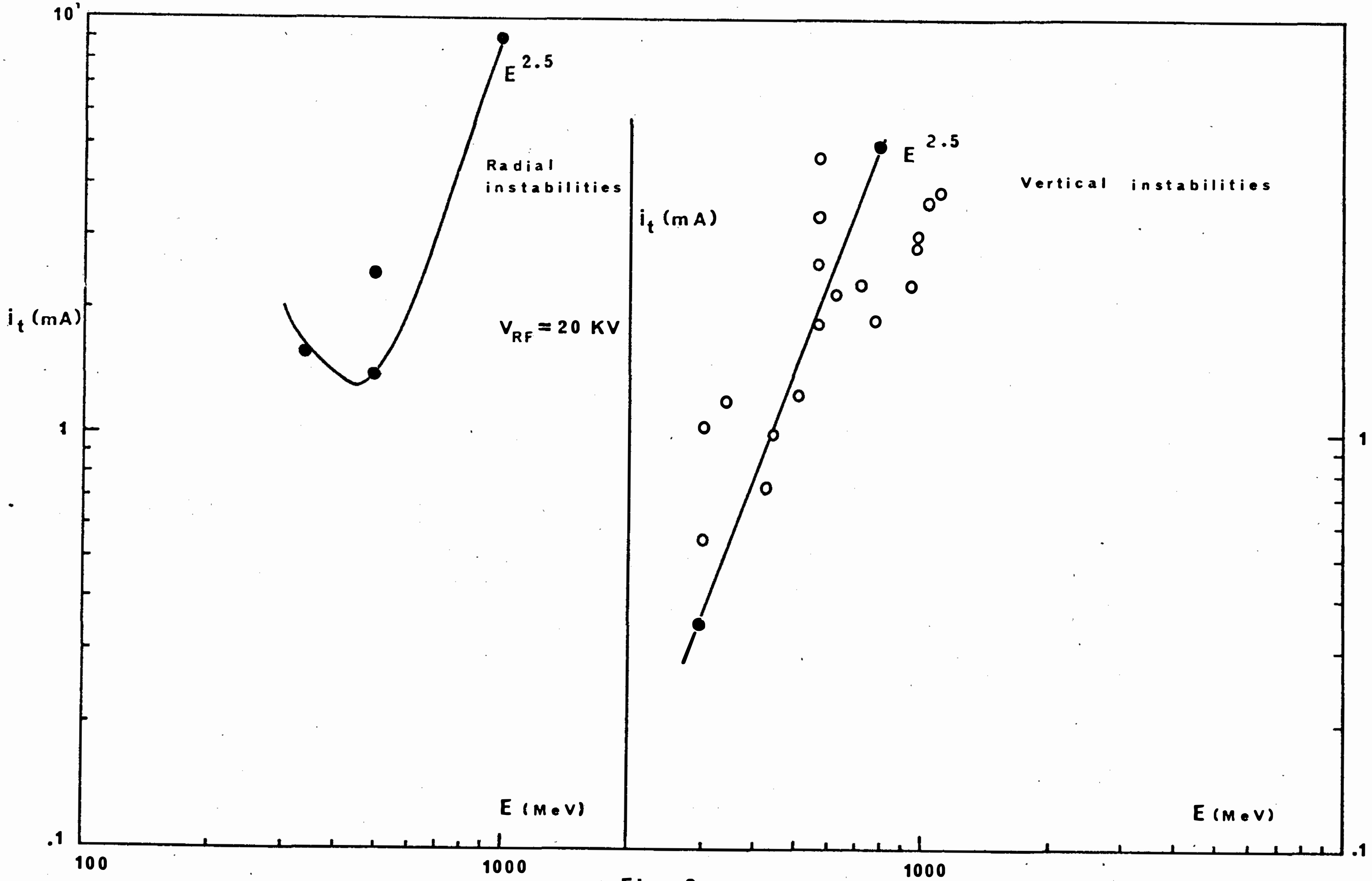


Fig.1



10'
E 2.5
Radial instabilities
i_t (mA)
V_RF = 20 KV
1
E (MeV)
.1
100
1000
i_t (mA)
E 2.5
Vertical instabilities
1
E (MeV)
1000
.1

Fig. 2

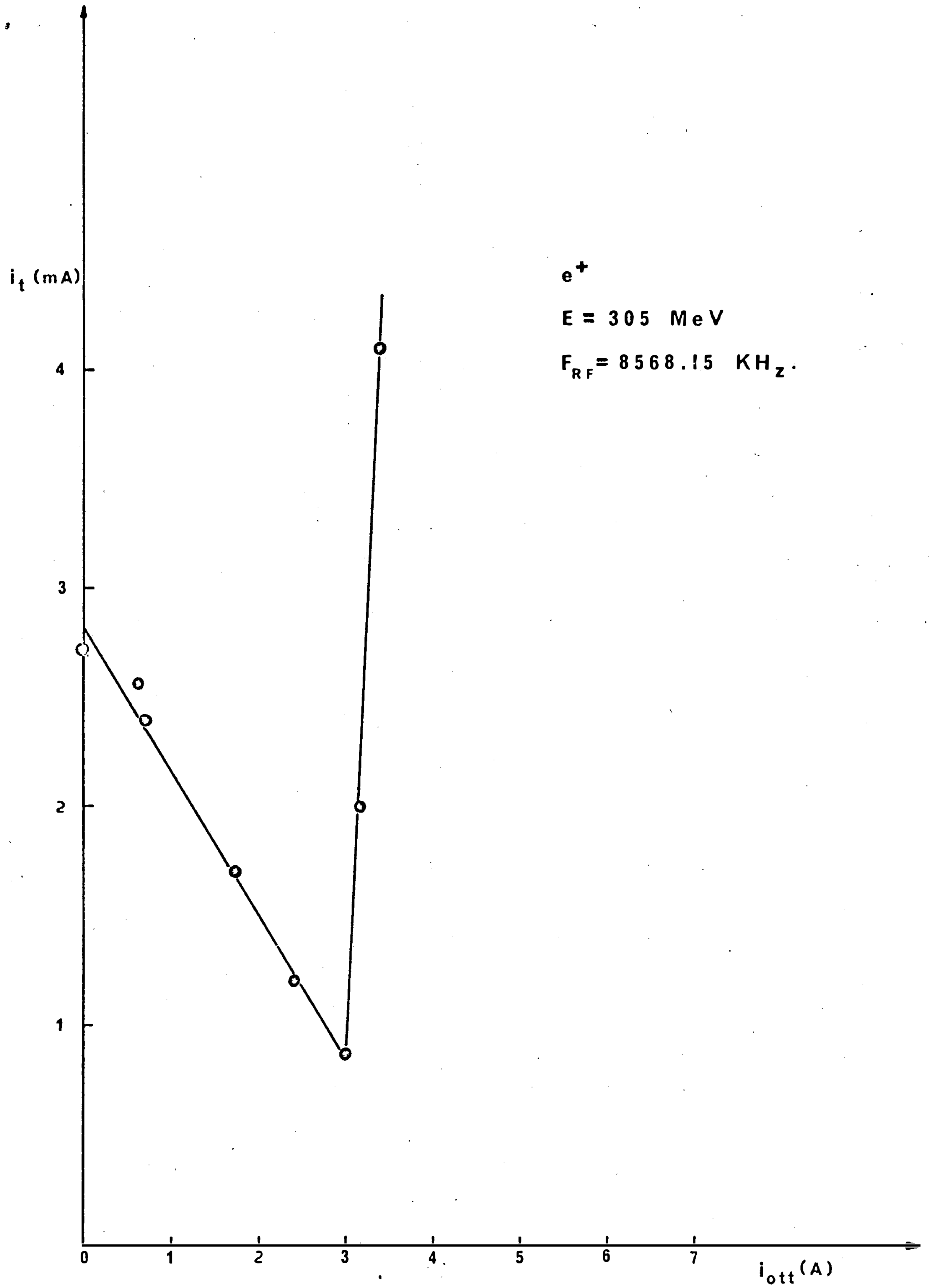
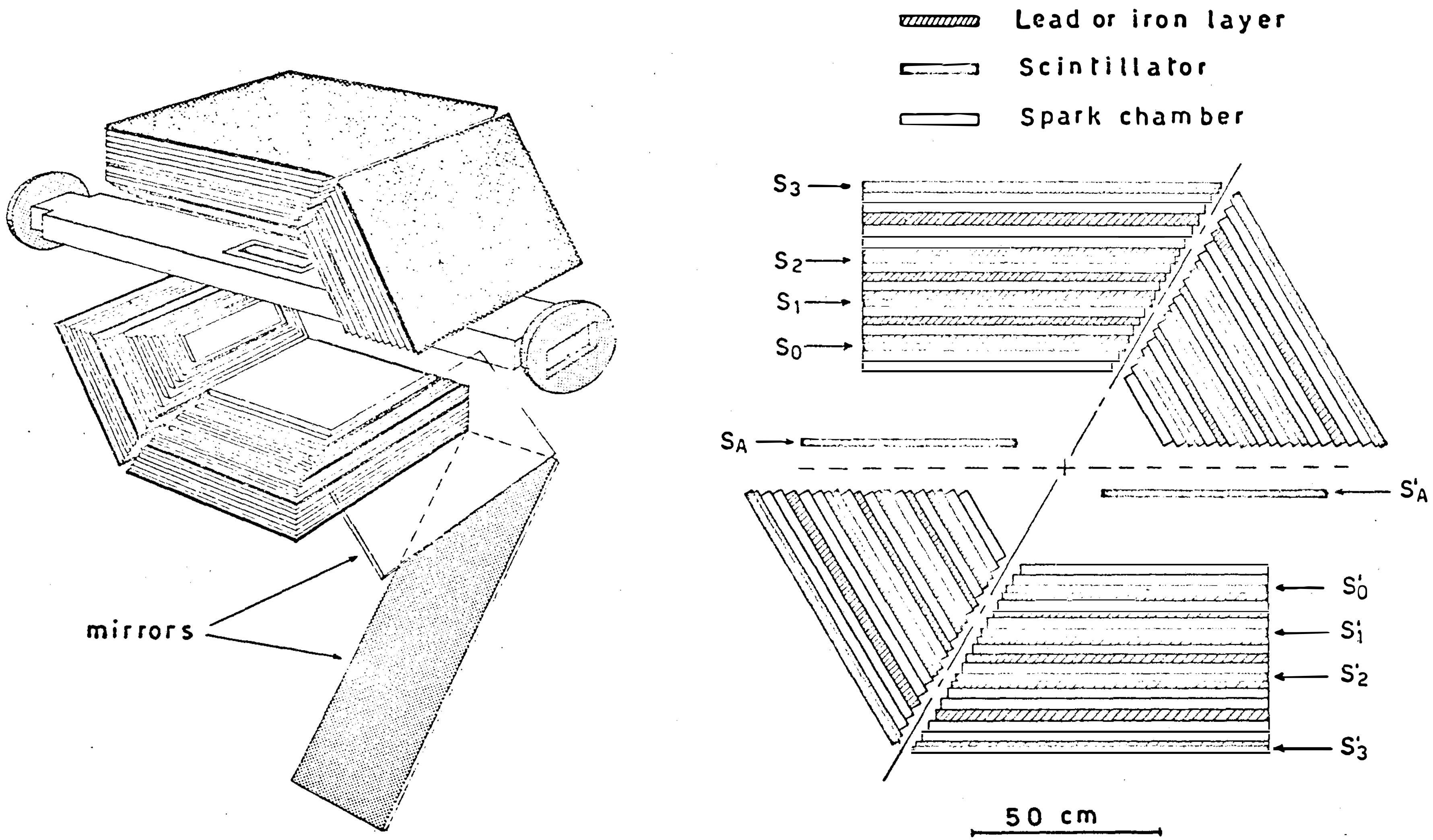


Fig. 3


mirrors
Lead or iron layer
Scintillator
Spark chamber
S3
S2
S1
S0
SA
S'A
S'0
S'1
S'2
S'3
50 cm

a) b)

FIG. 4

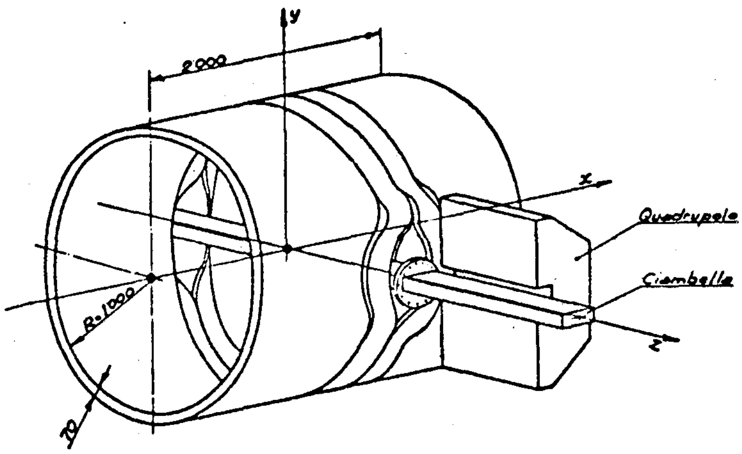


FIG. 5

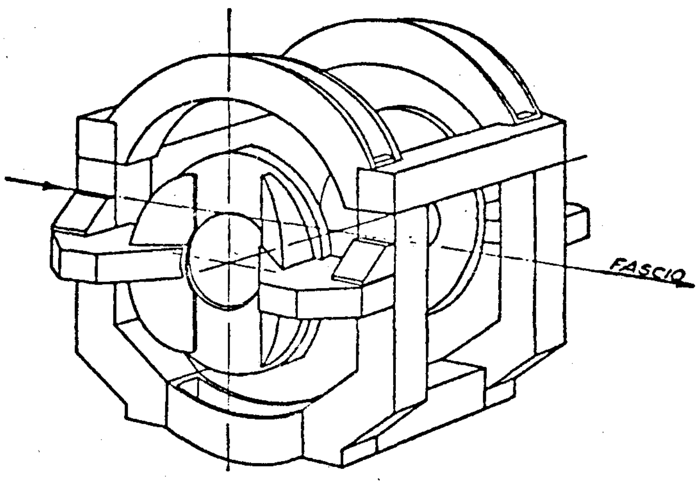
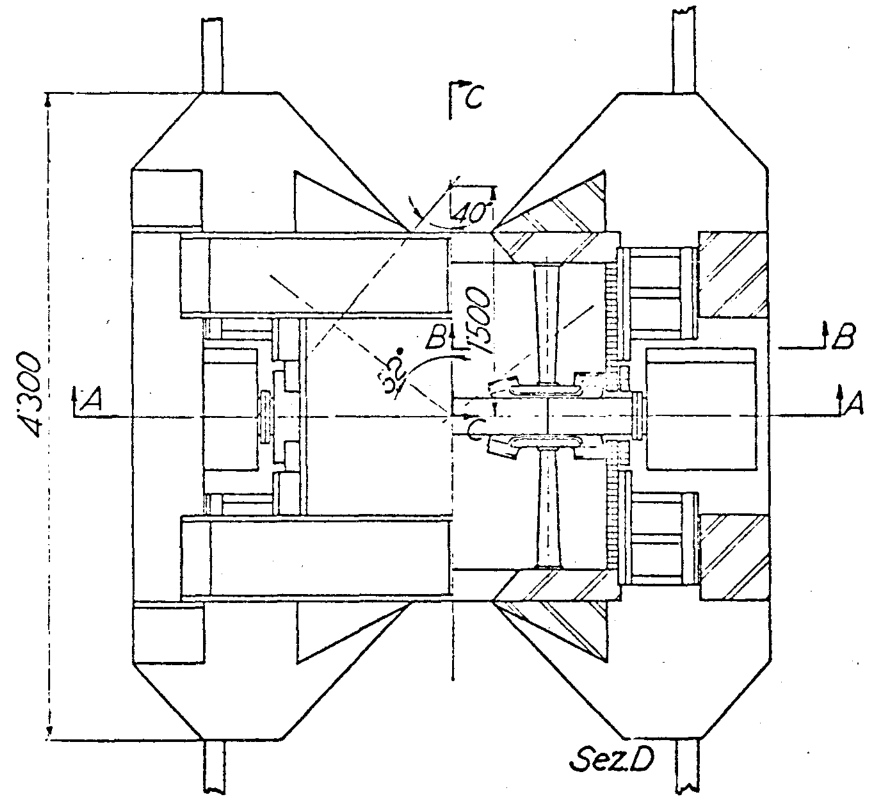
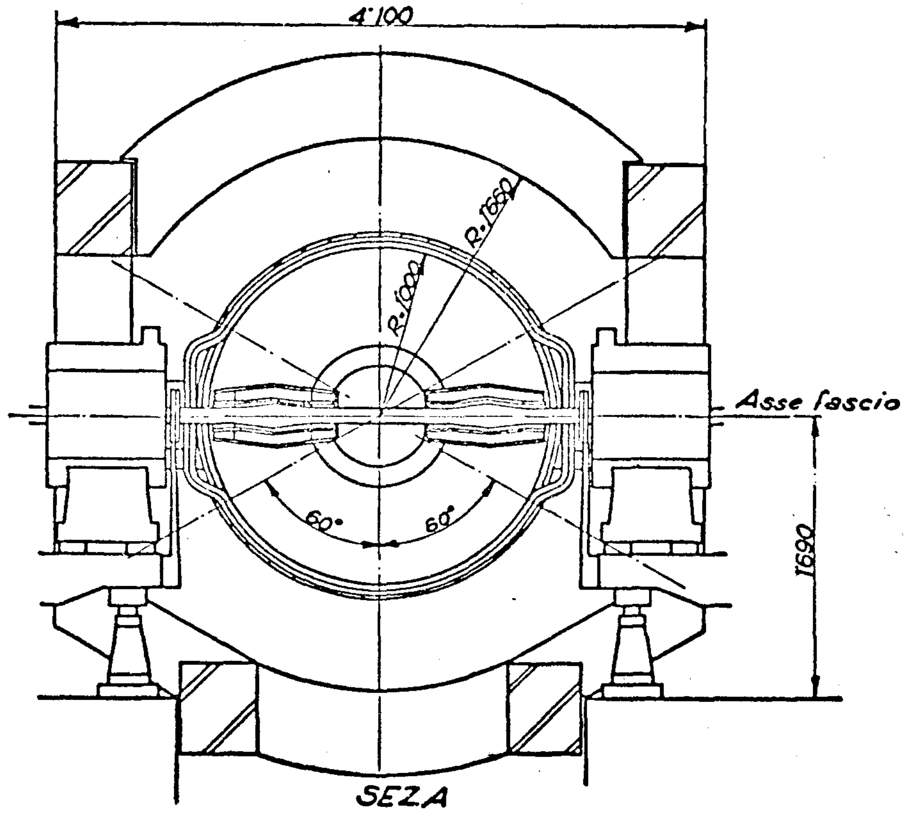


FIG. 7


C
4300
A
A
B
B
1500
40°
52°
C
Sez.D

a)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R.1660
R.1000
Asse fascio
60°
60°
1690
SEZ.A

b)

FIG. 6

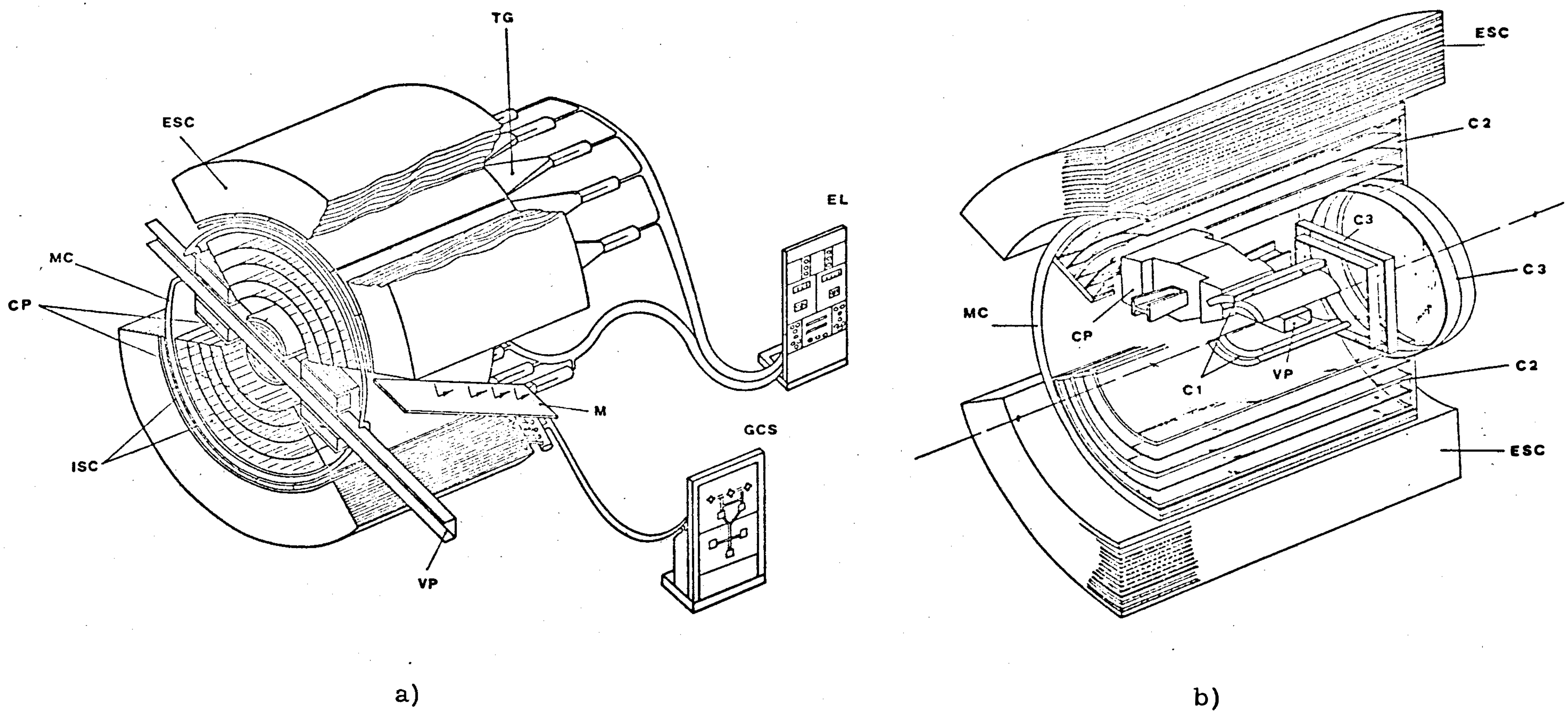

FIG. 8

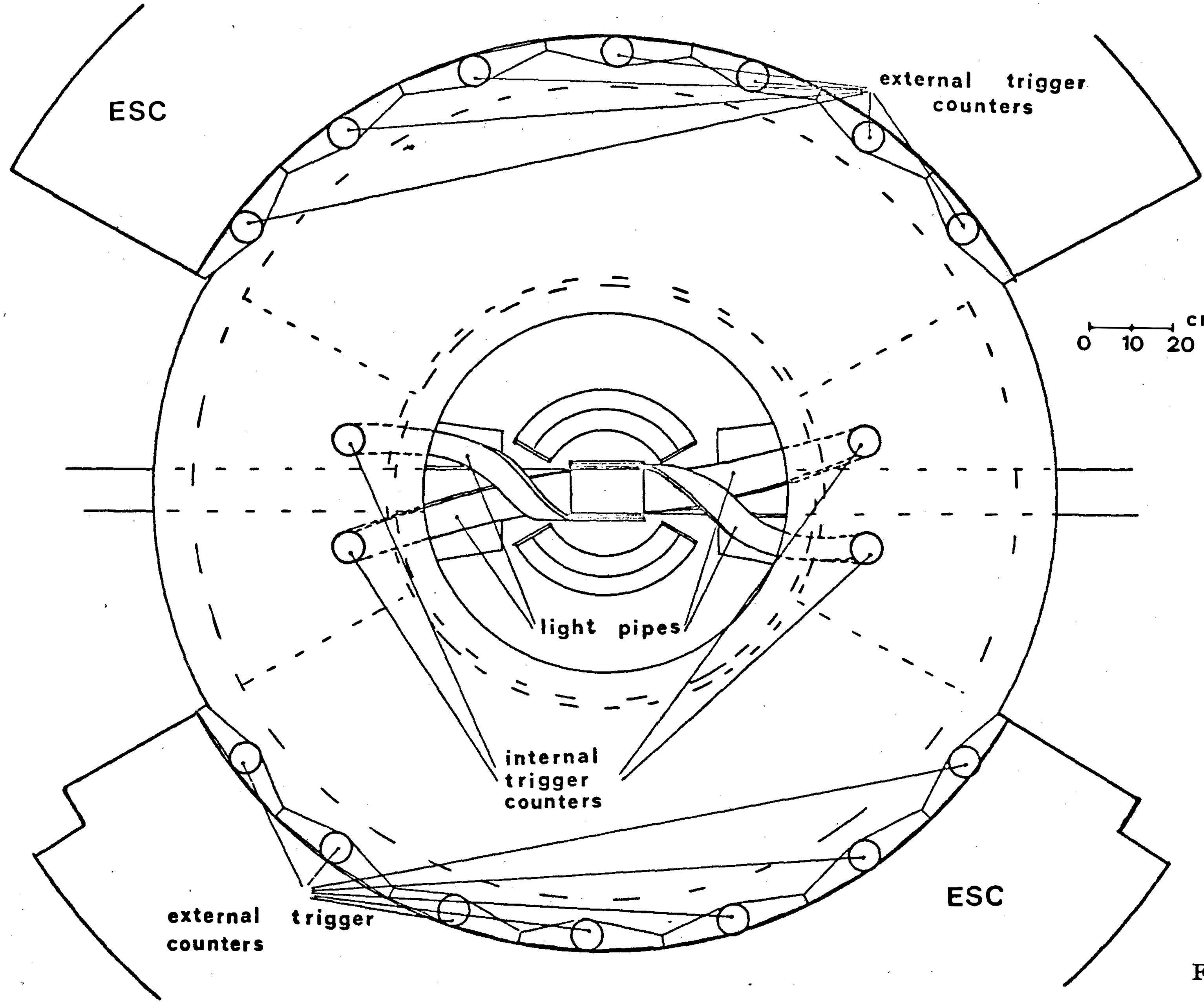
ESC
external trigger counters
cm
0 10 20
light pipes
internal trigger counters
external trigger counters
ESC

FIG. 8 c)