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PROPOSAL OF A SYNCHROTRON WITH A DOUBLE VACUUM CHAMBER

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§ 1.- The diameter of the beam of particles which is accelerated in a synchrotron is a function, among other variables, of the energy of these particles. In fact the theory indicates that:

- The amplitude of the betatron oscillations varies as $H^{-1/2}$ (H is the flux density)(1).
- The amplitude of the synchrotron oscillations is damped in time at a rate proportional to $E^{-1/4}$ (E, total energy)(1).
- The betatron oscillations which are due to the atomic collisions with the residual gas are important only at low energies.
- The effect of eddy currents, inhomogeneities etc. is mainly important at low energies.

On the other side, the reduction in diameter of the beam as its energy increases is an observed experimental fact. For instance in Brookhaven the beam has a final diameter of only 1" (2,3). This diameter does not change appreciably during the spiralisation of the beam toward the target(2), notwithstanding the beam makes 4,000 turns during that time.

§ 2.- On the basis of these considerations we suggest a synchrotron with two different gaps (or chambers) and two different acceleration stages.

The cross section of such a machine is illustrated in fig.1. The operation goes as follows:

a) The particles are injected through a deflector into the chamber A and accelerated up to a moderate energy: for instance particles electrons, injected at 2-3 MeV, are accelerated in A up to 60 MeV; with a radius of the synchrotron of 3.3 meters the flux density in A reaches about 600 gauss. The dimensions of our drawings refer to such an example.

b) As soon as the particles reached this energy (for instance, just 60 MeV) the beam shall slide from chamber A to chamber B: such a sliding will be possible if the flux density H in the median plan will follow the law:

$$B = B_0 \left(\frac{r}{r^{o}} \right)^{n} \qquad 0 < n < 1$$

in both chambers A and B at the same time. The sliding may be obtained for instance by interrupting the Radio Frequency in the resonant cavity as the flux density increases (we suppose that the chamber A is on the outside) or by controlling the frequency and amplitude modulation of the Radio Frequency. On the basis of what we reported in § 1 the sliding should not spoil the beam. As soon as the beam reaches the chamber B, a new resonant cavity or the same one with a different frequency will keep the beam in B, and the particles will be accelerated up to the maximum flux density (for instance, following our example, 10,000 gauss, corresponding to 1,000 MeV). During this time the increase of the field in A may be stopped or slowed down without danger for the beam, since we do not need the chamber A any more.

§ 3.- In a conventional synchrotron the dimensions of the gap (or at least its vertical dimension) remain the same during all the acceleration process although we need large dimensions during the first part of the acceleration only (§ 1). With our proposol we hope to reduce the large amounts of Iron and excitation energy required to obtain the maximum flux density in a gap of the dimensions of chamber A (fig.1); in fact high flux density will be reached in chamber B only, and this chamber may be much smaller.

In table I we compare one weak focusing synchrotron, which has a gap of the dimensions of chamber A with the two-chamber synchrotron we propose here; as we see, the saving in material and cost may be of a factor three or more. This factor does not depend critically on the value we choose for the ratio between the dimensions of the chamber A and the radius of the synchrotron.

In fig.2 we sketched the cross sections of a conventional synchrotron (fig. 2a) and of that which we propose here, giving in fig.2b) and 2c) two of the possible alternatives. Since the sections are in the same scale and for the same supposed radius, the possible advantages in cost and dimensions are quite evident.

We cannot exclude that the hypotetical machine we are considenring here could compete with the strong focusing synchrotron in the 10 BeV region.

§ 4.- Among the fundamental questions to be solved we recall the following:

a) The shape of the magnetic field. The magnetic field has to be almost vertical and uniform ($0 < n < 1$) in both chambers A and B. This is possible in theory, and may be solved in practice by putting the right ampere-turns difference between the equipotential surfaces (magnetic poles) defining the chambers A and B. A possible schema of the excitation may be for instance the following, if the dimensions of our example in fig.1 are used:

Current-turns in the coil R = 9 f(t)
Current-turns in the coil S = -6 f(t)
Current-turns in the coil T = -3 f(t)

f(t) is a convenient function of time.

As the beam entered in B the coils L and M will bring the flux density in B to the maximum value (for instance 10,000 gauss). Of course this is a schematic division, and the same coils may be used for different purposes in different times.

To have a first confirmation on the possibility of reaching at the same time the almost uniform magnetic field we need in the chambers A and B, we made a map of the field with a conjugate model similar to the electrolitic tank method. This method has been developed by Dr. F.Amman and will be discussed elsewhere(4). The results of this preliminary approach were even better than we could hope; in fact when we used parallel poles for A and B (n = 0) the flux density resulted to be uniform in both chambers A and B, including the transition region, in the limits of a few percent. The lines of flux are indicated in fig.1.

b) Vacuum chamber. The doughnut will result od an unusual and difficult shape. The possibility of using stainless steel could solve the problem. The effect of the eddy currents is reduced as the flux density increases, and could be already small when the beam enters the chamber B ; therefore the doughnut could consist of stainless steel at least in B.

c) Radio Frequency acceleration. The klystron-type cavities in the straight sections may probably be cut in a way which allows the passage of the doughnut.

§ 5.- Application of similar concepts to a synchrotron working with alternate gradient magnets (strong focusing) is under consideration.

TABLE I

Comparison between a conventional weak focusing synchrotron (column I) which has a gap of the dimensions of our chamber A (fig.1, 2), and the synchrotron we suggest here (column II). The numbers in column I and II refer to the example of an electron synchrotron that we give in the text

	I	II
Maximum energy (MeV)	1,000	1,000
Average radius (cm)	330	330
Weight of Iron (Kg)	$7\mathrm{x}10^4$	$\sim 1.6\mathrm{x}10^4$
Weight of copper (Kg)	$1-2\mathrm{x}10^4$	$\sim 5\mathrm{x}10^3$
Total energy stored in the gap (Joules)	$\sim 2.4\mathrm{x}10^5$	$\sim 5\mathrm{x}10^4$

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2) M.Hildred Blewett: R.S.I., 24, p.725 (1953)

3) C.E.Swartz, R.S.I., 24, p.851 (1953)

4) This method mainly consits in drawing the equipotentials in a field of currents traversing a thin aluminum foil whose boundaries are the boundaries of the chambers A, B.

Fig. 1.- Cross section (orthogonal to the beam) of the synchrotron with two separate chambers. The lines in chambers A and B indicate the field we obtained (§ 4) with an electric model.

Fig. 2.- Comparison (in the same scale) between the dimensions of a conventional synchrotron (fig. 2a) with a gap of the dimensions of our chamber A, and the synchrotron with two chambers (fig. 2b). In fig. 2c another solution for the shape of the two-chamber synchrotron is indicated.

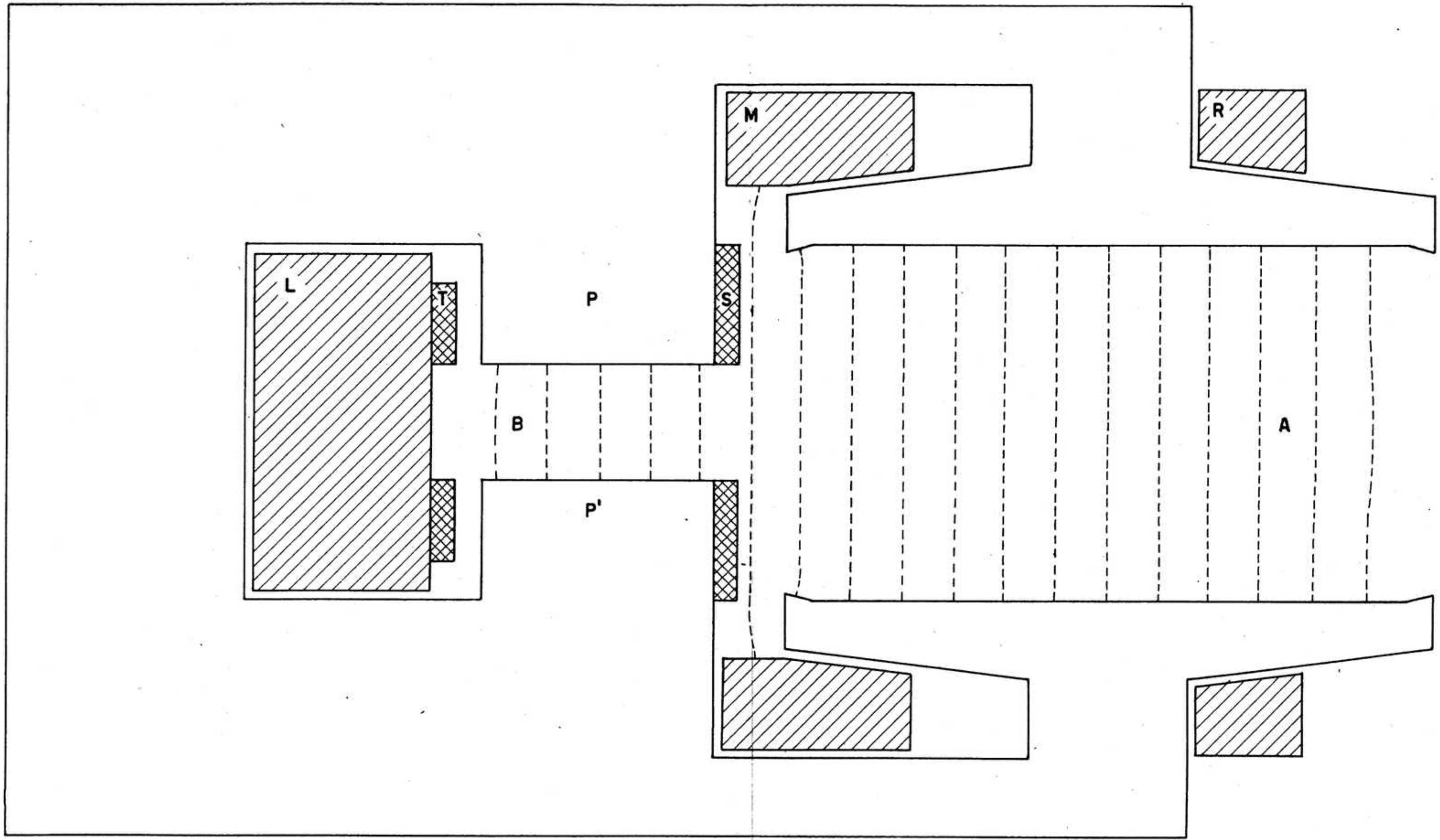
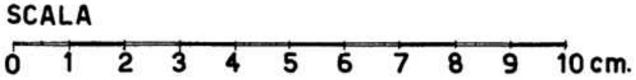


FIG. 1



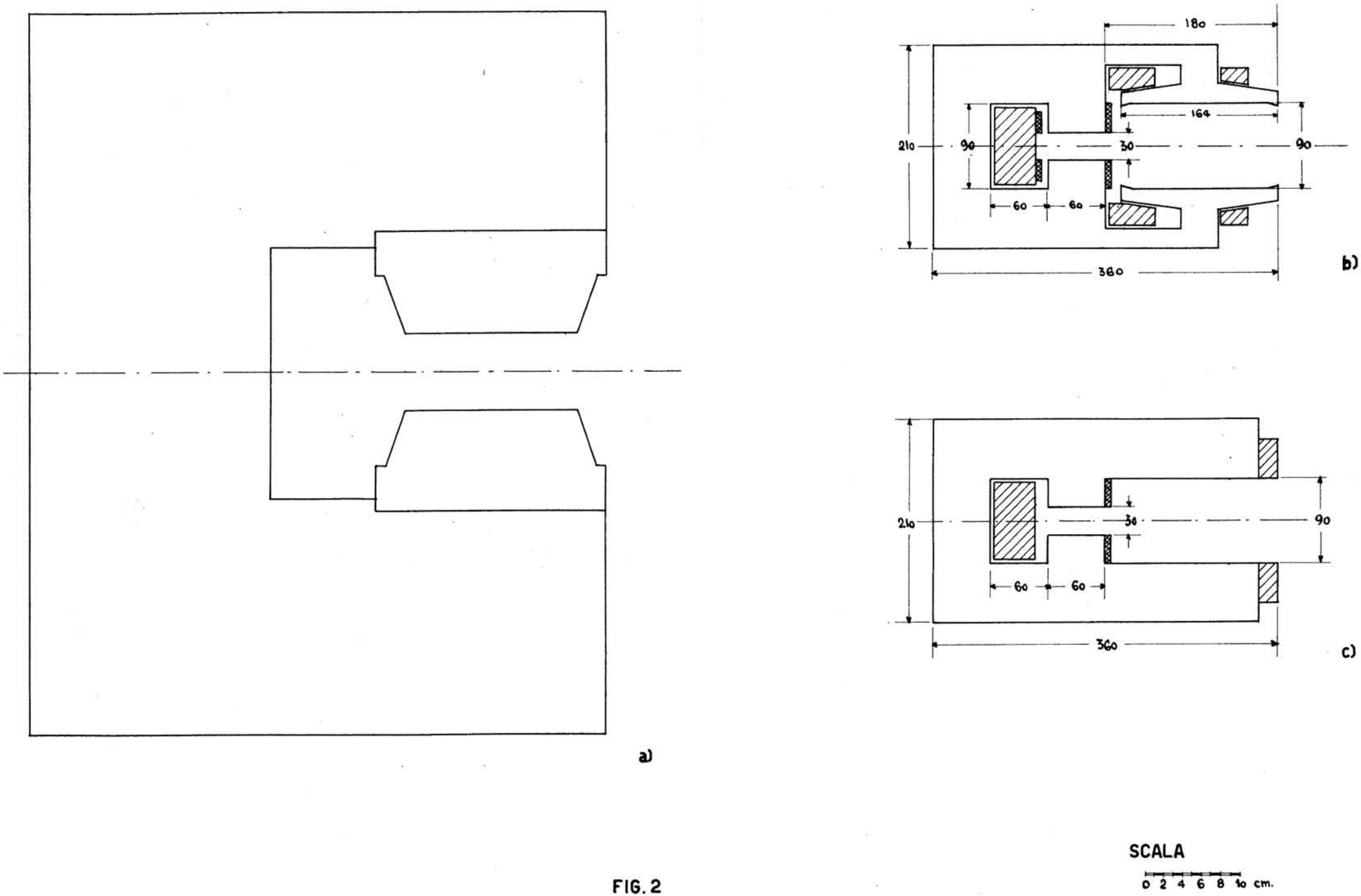

a)
180
164
210
90
30
90
60
60
360
b)
210
30
90
60
60
360
c)
SCALA
0 2 4 6 8 10 cm.

FIG. 2