PROPOSED LAYOUT FOR THE 45 GeV SYNCHROTRON

PROJECT EXPERIMENTAL AREAS

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1 - INTRODUCTION -

The nominal intensity of the french 45 GeV synchrotron in project is 10^{12} protons per second |1| . In order to reduce radiation damage to components and induced radioactivity in the tunnel we studied extensively the use of external proton beams with a high extraction efficiency. The external beam will be used in strongly shielded target rooms.

In the present paper we shall describe beam sharing and target room, shielding problems and experimental areas using this type of target room.

As we shall see it is interesting to use the concept of target room in the case of internal targets.

2 - EXTERNAL PROTON BEAM TRANSPORT -

The proton beam is extracted in a long straight section and the same magnetic channel used for driving the beam in both cases of slow and fast extraction. The beam which has been raised above the ground level is distributed to the experimental area. We use switching magnets with a short rise time in comparison with the duration of the flat-top, and also beam splitting magnets.

2.1 - RAISING THE BEAM -

The beam raising system must be achromatic. With a transfert matrix T, the dispersion terms are :

$$T_{13}(s) = T_{12}(s) \int_0^s \frac{T_{11}}{\rho}\, d\sigma - T_{11}(s) \int_0^s \frac{T_{12}}{\rho}\, d\sigma$$

$$T_{23}(s) = T_{22}(s) \int_0^s \frac{T_{11}}{\rho}\, d\sigma - T_{21}(s) \int_0^s \frac{T_{12}}{\rho}\, d\sigma$$

where ρ is the curvature radius in the bending magnets, s the curvilinear abscissa. The achromatic conditions are :

$$\int_0^s \frac{T_{12}}{\rho}\, d\sigma = 0 \quad \text{and} \quad \int_0^s \frac{T_{11}}{\rho}\, d\sigma = 0$$

These two conditions are satisfied in the case of an n-periodic structure, with a phase shift of $2\pi/n$, where $n > 2$.

It can be shown that the total number of magnets in the case of the beam raising can be reduced by using a deflection system made of two parts with opposite curvature separated by a rectilinear part.

In such a structure the length of the tunnel is not fixed, therefore the length of the central part is determined by cost optimization. The chosen structure (Fig. 1) is made of two lattices with bending magnets $2(\frac{Q}{2}\ 3M\ Q\ 3M\ \frac{Q}{2})$ two lattices without bending magnets and again two more with bending magnets. Each lattice gives a $\pi/2$ phase shift. In such a case, it is possible to use small aperture elements ; the magnets and quadrupoles are 5 cm in diameter.

The raising system described is 75 m long, with the tunnel crossing inhomogeneous soil of slightly changing mechanical characteristics. Therefore it is planned to control and correct automatically the position of the quadrupoles.

2.2 - BEAM SPLITTING -

One beam splitting system (Fig. 2) allows two prime experiments to run at the same time with only one extraction system in operation. Therefore the beam losses inside the ring are kept as small as possible.

In order to reduce losses on the horizontal magnetic septum the vertical dimension of the beam is increased in a first section. A symetrical system is used after splitting to bring the beam back to its initial dimensions. Three target positions can be used in our design, but only two can be operated at the same time.

Bending magnets insure the adjustements of the beam position in relation with the septum. They are placed on either side of the splitting magnet and have a servosystem to regulate the division of beam current. After the septum, magnets are used for directing the beam on to the targets and the whole system is designed to be achromatic.

2.3 - DIFFERENT SCHEMES FOR HOUSING THE BEAM TRANSPORT -

We have compared for a given efficiency three different ways to shield the beam transport :

- tunnel underground,
- trench with movable concrete roof,
- Apron area with a complete movable concrete shield.

The various solutions are shown in Fig. 3, the relative costs are given for a minimum shielding equivalent to 2 meters of ordinary concrete. We can remark that the cost increases with increasing flexibility, the earth being the cheapest shielding.

We can observe that the relative costs would scale up when the shield thickness increases.

3 - THE TARGET ROOM -

3.1 - PHYSICAL ASSUMPTIONS FOR SHIELDING CALCULATIONS -

Experimental studies have shown the usefulness of the concept of cascade propagator "virtual source". The neutron propagators of energy above 200 MeV are emitted from the region of primary proton interactions. For 3 GeV protons the differential production can be given as a function of θ, the angle with respect to the beam direction, expressed in radians. We then have :

$${}_{3\ \text{GeV}}\left(\frac{dN}{d\Omega}\right)_{200\ \text{MeV}} = .11 + 4.6e^{-5.2\theta}$$

The integration over θ shows that 2/3 of the neutrons are emitted isotropically and 1/3 in a forward cone with half angle aperture $\pi/6$.

If we suppose the same angular distribution at 45 GeV and take account of the variation of cascade propagator multiplicity as determined by gray tracks in nuclear emulsions we obtain

$${}_{45\ \text{GeV}}\left(\frac{dN}{d}\right)_{200\ \text{MeV}} = .61 + 26\ e^{-5.2\theta}$$

The isotropic part of the virtual source is the only one important for the side shield. On the other hand calculations and experimental work put in evidence that a fluence rate of cascade propagators equal to .9 $\text{neutrons.cm}^{-2}.\text{s}^{-1}$ corresponds to 2.5 mrem/h, taking account of the contribution to the dose of secondaries in equilibrium with cascade propagators.

In the calculations presented here we used a value of attenuation mean free path in light materials, like ordinary concrete ($d = 2.2$) or earth ($d = 1.8$)n, equal to 145 g.cm^{-2}.

3.2 - EVALUATION OF SIDE SHIELD WITH A TARGET -

The side shield is fixed by the attenuation of strongly interacting particles. If we use for this purpose movable blocks of concrete ($d = 2.2$) placed only 2 meters from the target a thickness of 8.7 meters is needed. In the case of use of earth ($d = 1.8$) covering a room 8 meters high an earth thickness equal to 8.6 meters must be added to the concrete vault which is itself one mean free path thick.

These solutions are compared in Fig. 4. The earth covered target room is large enough to allow the simultaneous use of various beams and inside this room the handling of magnets, quadrupoles and collimators is easier.

3.3 - EVALUATION OF THE BEAM STOPPER -

After the target the surviving proton beam is separated from a secondary beam and stopped in a heavy material block, placed about 15 m downstream the target. It is then possible to place channels in the block, for the secondary beams. The size of the block in the forward direction is fixed to stop most of the muons. This effect is reinforced by lead or uranium core, (Fig. 5).

An other use of the beam stopper is to localize the induced activity resulting from the proton beam losses.

3.4 - THE WALL BETWEEN THE TARGET ROOM AND THE EXPERIMENTAL AREA -

The beam stopper placed inside the target room has been designed in such a manner to be a neutron source of second order in comparison with the targets themselves. The end wall placed after this beam stopper needs only to be 7.2 meters thick (d = 2.2).

The material used is ordinary movable concrete block to maintain maximum flexibility.

3.5 - ACCESSES TO THE TARGET ROOM -

In order to minimize the radiation level on the site from neutrons leaving the target room through the access for heavy material we designed large curved corridors with a "blind alley". With this complex design an attenuation comparable to the side shield attenuation is obtained.

4 - USE OF TARGET ROOMS FOR DIFFERENT TYPES OF EXPERIMENTAL AREAS -

The same general structure of target room can be used for various solutions.

This target room which is large enough to provide various secondary beams, is constituted of three parts with increasing width. Transverse cranes with the possibility of transferring load from one to another are installed in each part of this target room. The movable wall is outside the target room so that the handling of blocks is easy using a special transverse crane.

4.1 - GENERAL PURPOSE EXPERIMENTAL AREA -

This experimental area (Fig. 6) is designed for electronic experiments as they are presently conceived and for small bubble chamber experiments. The beam raised to the ground level and split produces in the target room various secondary beams. The secondary beams are used in a hall 50 m wide, 100 m long. Two 25 Tons cranes with a hook height of 10 meters which can be paired, service this area.

The distributions are made in box girders. Two of these girders are placed on each side of the hall at 8 m high, two underground and others transversally underground. The hall is surrounded by a 25 m wide concrete apron.

In the present project on the St Aubin site the hall housing the Saturne accelerator and associated experimental areas will be used as a general purpose experimental area.

4.2 - LONG BEAM EXPERIMENTAL AREA -

This area (Fig. 7) has been designed for a 35 GeV/c pion beam radio-frequency separeted and transported to a large bubble chamber. Up to the end wall of the target room the elements are the same as described above. After the end wall, we have chosen an open air concrete area . Separators and magnetic elements of the beam line are housed in light barracks.

4.3 - COMBINATION EXPERIMENTAL AREA -

This target room which can be adapted for use with internal targets (Fig. 8) allows to save the movable concrete needed in the case of a side wall along the main ring. It is difficult to cross this wall with beam at grazing incidences. This target room can also be used with an external proton beam. The length of the room is fixed by placing the movable end wall as close as possible to the main ring. The end wall and the experimental hall are constructed in the same manner as the general experimental area.

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REFERENCE

|1| - Avant-projet d'un synchrotron à protons, 45 GeV, 10^{12} protons par seconde
GESyN (Saclay) - Février 1967.

DISCUSSION (Condensed and reworded)

F. Bonaudi (CERN): [Question re experimental hall and shielding.]

J. Parain: The present Saturn experimental hall will be for general use. A target room will be ahead of the experimental hall. Eight meters of concrete shielding will cover the target room which is 6 meters from the target. Movable shielding will be used between the target room and the experimental hall.

H. Hahn (BNL): Did you provide for pre- and post-momentum analysis?

Parain: The separation of momentum is in the target room in the first part of the beam.

Bonaudi: What is the total length of the beam and the distance between the separators?

Parain: The length from target to bubble chamber is 330 m and the distance between separators is 150 m.

J. Kirchgessner (PPA): How fast is the switching between beam runs?

Parain: Changes in switching can only be made slowly.

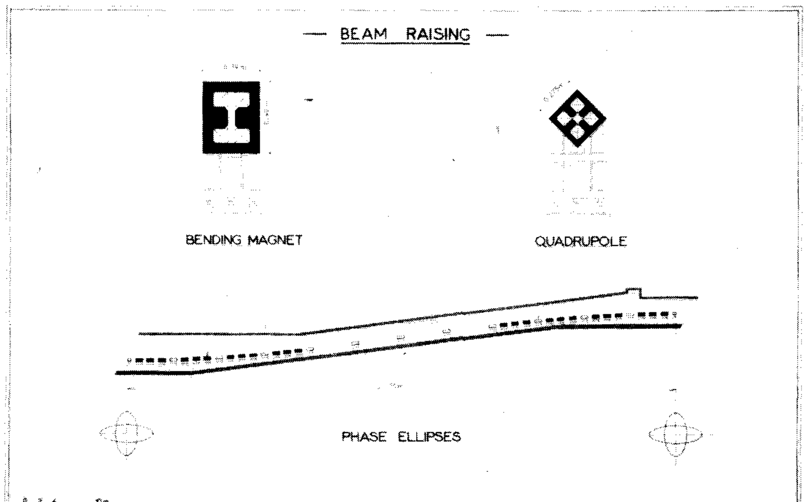

FIG. 1

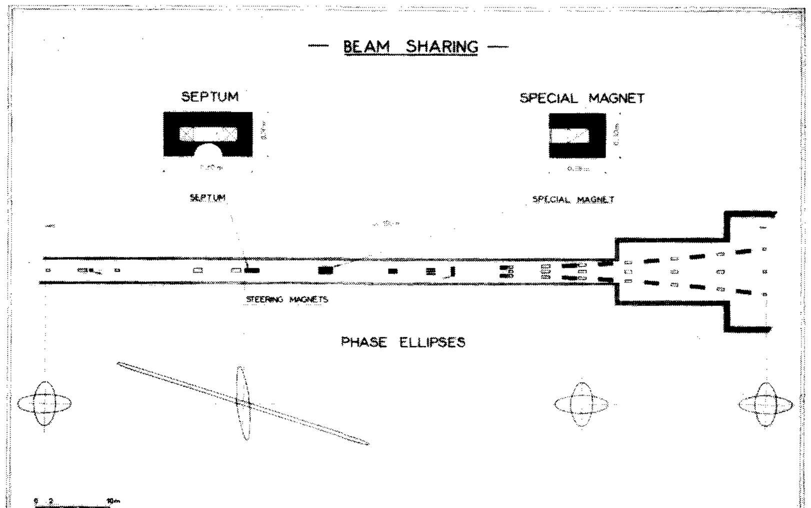

FIG. 2

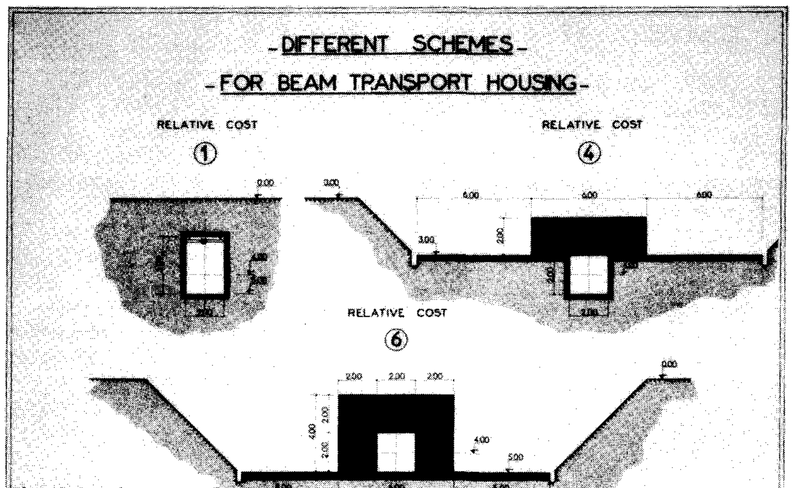

FIG. 3

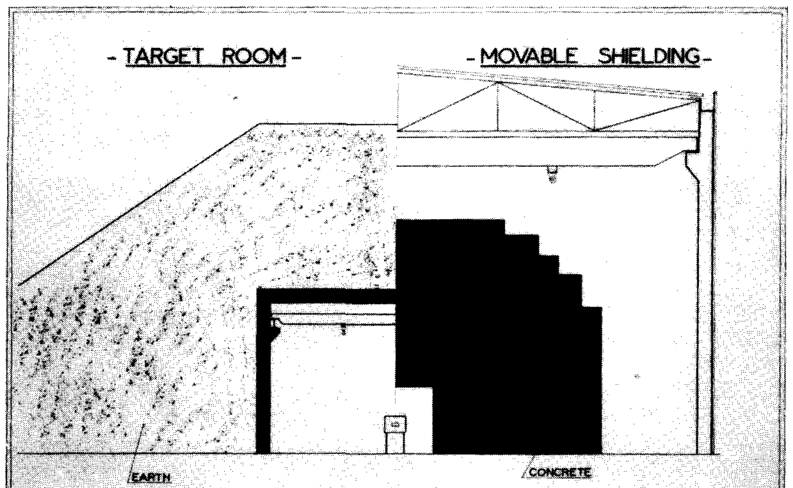

FIG. 4

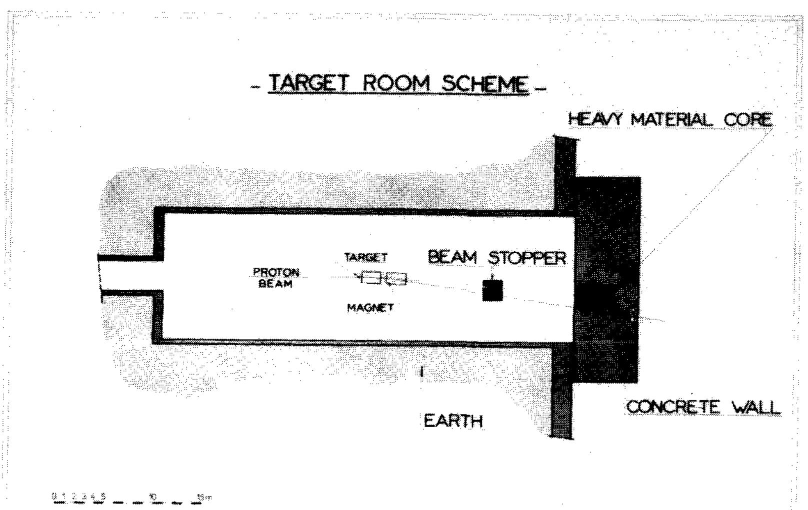

FIG. 5

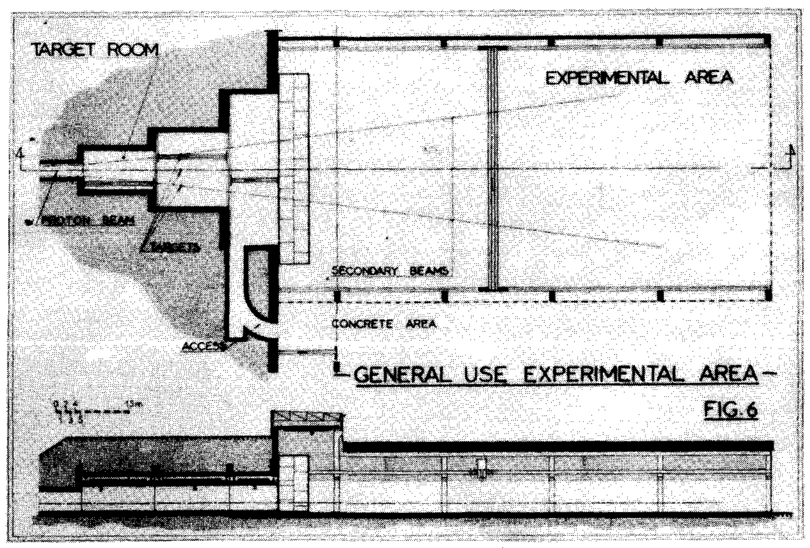

FIG. 6

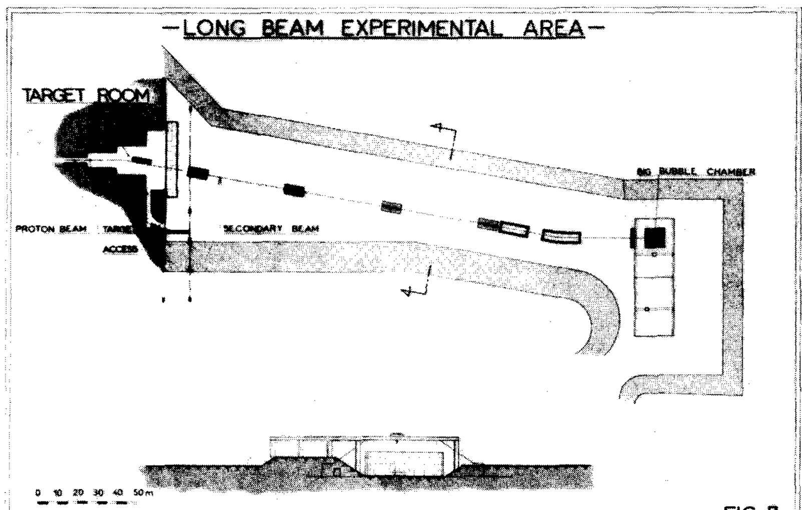
-LONG BEAM EXPERIMENTAL AREA-
TARGET ROOM
BIG BUBBLE CHAMBER
PROTON BEAM
TARGET
SECONDARY BEAM
ACCESS
0 10 20 30 40 50m

FIG. 7

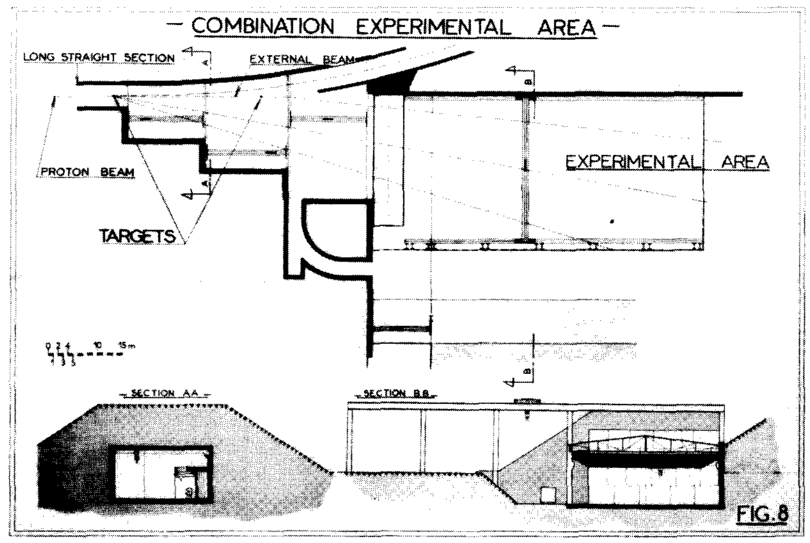
- COMBINATION EXPERIMENTAL AREA -
LONG STRAIGHT SECTION
EXTERNAL BEAM
PROTON BEAM
EXPERIMENTAL AREA
TARGETS
SECTION AA
SECTION BB

FIG. 8