EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN/ISRC/69-37
27 May 1969

INTERSECTING STORAGE RINGS COMMITTEE

PROPOSAL FOR THE STUDY OF GENERAL FEATURES OF INELASTIC p-p INTERACTIONS WITH THE ISR BY MEANS OF NUCLEAR EMULSIONS

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(Revised version of proposal submitted
4 December 1968)

1. INTRODUCTION

It is important to have data on the angular distributions and spectra of secondary particles soon after the starting of operation of the ISR. In addition to pure physics, such data are also important for the planning of future experiments.

In this paper we propose a simple emulsion experiment to study the general features of pp interactions in the ISR.

Irradiation time being very short, the essential cost is connected with the necessity of constructing a simple chamber with windows. The results can be obtained in a short time, due to the presence of a large and qualified team of physicists and scanners in our laboratory.

2. PHYSICS

The purpose of the experiment is to obtain information about the following average general features of inelastic pp interactions at 55.5 GeV CMS available energy.

2.1 $d\sigma/d\omega$ i.e. angular distribution of secondary particles

It is proposed to perform 16 measurements of $d\sigma/d\omega$ for polar angles $\theta = 15° - 90°$, counting about 10^4 particles (statistical error of 1%) at each angle. This should give an angular distribution which would allow us to distinguish between various models of multiple meson production such as: Fermi statistical model (isotropy), Landau hydrodynamical theory (angular distribution which is Gaussian in log tan $\theta^*/2$ coordinates), Hagedorn thermodynamical model or fire-ball model (two-hump angular distributions). Fig. 1 presents as an example the angular distribution, $d\sigma/d\alpha$ (see Fig. 1 for the definition of α) expected on the basis of the fire-ball model for the value of Lorentz factor of fire balls $\bar{\gamma} = 1.5$. Fig. 2 shows the comparison of angular distributions in log tan $\theta^*/2$ (θ^* is C.M. angle) coordinates for several models. It may be hoped that with the expected accuracy of measurement it will be possible to distinguish between various predictions of this type.

2.2 $d\sigma/dp$ i.e. momentum distribution of secondary particles

It is proposed to perform momentum measurements for 10^3 particles at four angles. The momentum spectra would be compared with various predictions. Fig. 3 shows as an example spectra of pions produced at three values of the angle α, calculated according to the fireball model.

2.3 Mean multiplicity of charged secondaries

Integrating over $d\sigma/d\omega$ one may tentatively obtain the average multiplicity of charged secondaries n_s at 1650 GeV. This would help to answer the question of the increase in multiplicity with increase of primary energy. The existing machine and cosmic-ray data do not permit the two possibilities: $\langle n \rangle \sim \log E$ or $\langle n \rangle \sim E^{\alpha}$ to be distinguished although the third possibility, saturation of n_s, does not seem to be excluded. One has also to bear in mind that cosmic-ray data are always heavily contaminated with nucleon-nucleus interactions which tend to increase, in a way difficult to estimate, the average value of n_s. The knowledge of multiplicity at 1650 GeV lab. momentum combined with machine results up to 70 GeV can solve the problem. However, the difficulties in extrapolating $d\sigma/d\omega$ into the region $\alpha < 15°$ and in monitoring the number of interactions may make this last point impossible.

2.4 The information obtained in points 1 and 2 will be useful also from the points of view of planning future experiments devoted to much more detailed study of pp interactions with the help of ISR.

3. EXPERIMENTAL

Fig. 4 shows a general view of the layout of the experiment. Emulsions, glass-mounted, protected from light by a black coating, should be installed on two very light stands in the horizontal plane 1.46 m above the floor at the circumference of a circle of 2 m radius, centered at the point of beam intersection on the side of the C.M. motion. A special thin-window vacuum chamber should be installed for the purpose of this experiment in one of the low-quality interaction regions of the ISR.

3.1 Vacuum chamber

The main purpose of this experiment is the relative measurement of the flux of secondary charged particles at various angles α. Therefore the geometry of the vacuum chamber should assure the visibility of the whole diamond by each detector (emulsion plate). A wide region of angle α from 15° to 90° should be covered by the detectors to enable the integration of dσ/dα for the estimation of the total multiplicity. The transmission geometry of the thin window should be nearly independent of angle for this whole region of angles α. The chamber shown in Fig. 5 satisfies all these conditions. Two cylindrical windows for the small angle region (15° – 40°) and the large angle region (45° – 90°) should be made of 0.5-mm stainless-steel foil. Figs 7 and 3 show that for ~ 95% of the expected momentum spectrum of secondary particles such a foil would introduce an average scattering deflection smaller than the acceptance angles for tracks defined as the "effect" (see section 3.2). The possibility of the construction of the cylindrical chamber with a 0.5 mm window was discussed with the ISR Division, E. Fischer and R. Calder.

3.2 Emulsions

For the purpose of the measurement of track density dσ/dα we propose to use Ilford G5 emulsions mounted on glass and coated with black paint. Such plates could be used without any additional light protecting boxes. The plates should be placed at a distance of 2 m from the centre of the interaction diamond at the angles A 15°, 20°, 25°, 30°, 35°, 40°, facing the small-angle window and at angles B, 45°, 50°, 55°, ...85°, 90°, facing the large-angle window. For 50-μ-thick emulsions inclined 26.5° to the horizontal plane the secondary particles will produce tracks with length (100 ± 1) μ.
The limit of error corresponds to the height of 1 cm of the diamond of interaction. The largest error in the horizontal direction is ± 7° (for α = 90°), it corresponds to the length of the diamond. All tracks fulfilling these criteria of length and direction will be counted as the "effect". All other tracks correspond to the "background" (Fig. 8).

For the purpose of the momentum distribution measurements dσ/dp we propose to use 600-μ G5 Ilford plates mounted on glass and used in pairs of two plates faced emulsion to emulsion. They could be placed on the same circumference as the $d\sigma/d\alpha$ plates at the intermediate values of α in a precisely horizontal position (Fig. 8). In such a position the "effect" tracks will in principle go through the whole length of the plate making possible good scattering measurements of momenta (Fig. 8). The dimensions of all the plates should be 1" x 3" placed with the longer side in the radial direction (Fig. 8).

3.3 Irradiation time and conditions of microscopic measurements

Assuming as the rate of pp interactions in the whole diamond the value 1.6×10^5 interac./sec, the average multiplicity $<n_s> = 10$ and isotropic distribution of secondary tracks, we obtain about 3 secondary tracks per second going perpendicularly through the area of 1 cm^2 at a distance of 2 m from the centre of the diamond. In a 1 h time of irradiation this will produce about 10^5 effect tracks in each of our $d\sigma/d\alpha$ plate. This is 10 times more than needed for the 1% precision of the $d\sigma/d\alpha$ measurement. On the other hand this density of tracks corresponds to about two tracks per field of view in the microscope in normal scanning conditions (10 x 30 magnification) which is a quite reasonable density for counting effect tracks and resolving them from background tracks.

During the same irradiation time (1 h) we expect in each of our $d\sigma/dp$ pair of plates about 3000 effect tracks. This is 3 times more than the assumed number of tracks for which we want to perform the scattering measurements of momenta.

In conclusion the time of irradiation of 1 h seems to assure quite satisfactory conditions for measurements and good statistics.

3.4 Remote handling of emulsion plates

In order to avoid the collection of unnecessary background tracks the plates should be present at the irradiation site only for 1 hour after the finishing of the formation of beams and before the beginning of beam dumping. It would be profitable also to irradiate a similar set of plates in the condition with beams shifted in the vacuum chamber so that they do not interact (see 4) just after or before the irradiation of the main set of emulsions. All this needsa system of remote handling of emulsion plates. Such a system could be solved rather simply taking into account that the plates could be mounted on two independent very light and flat plastic or aluminium stands A and B having the dimensions of $\sim 170 \times 27$ cm^2 and $\sim 100 \times 17$ cm^2 (Fig. 4). Such stands could be easily transported to proper positions and removed from there to a shielded area by a simple mechanical device with string control. There exists also a possibility to use the round holes in the outer wall of the main ISR tunnel to remove both stands into a radiation free area behind the wall.

The stands and the remote handling mechanism can be prepared in the workshop in Cracow after the final decision concerning the irradiation site.

4. BACKGROUND

There are two types of background which should be discussed in connection with this particular experiment.

a) The background producing the general blackening of emulsion, coming from the beam-residual-gas interactionsin the upstream region and from the beam-wall collisions upstream. The numbers given by Hyams (CERN 68 ISRU/121) are: 10^7 int./sec from the first, $10^7 - 10^8$ int./sec from the second source, respectively, for a 20 m source.

It seems that in this particular experiment it is possible to reduce this background to a non-dangerous level by suitable shielding, installed closely to the vacuum chamber (see Fig. 9).

b) Background of tracks from beam-gas and beam-wall interactions in the low-pressure region. According to Hyams we have to expect $\lesssim 2.10^5$ int./sec from a 20 m source. Our angular resolution permits to select tracks coming from the interaction region only; its length being ~ 0.5 m, the number of interactions reduces to $\sim 5.10^3$ int./sec. This last number should be compared with expected number of $\sim 10^5$ useful interactions per sec; assuming that angular distributions and numbers of produced particles are not drastically different for background and effect we obtain a ratio of effect tracks to background tracks of ~ 20.

All these estimations are rough and we feel that the experimental study of the background conditions by the emulsion method at the PS is highly advisable; this is particularly important because the ISR is most unlikely to operate at full design intensity from the beginning and the background density accompanying a given density of wanted interactions increases with decreasing circulating current.

In the near future we expect to use the bubble chamber data collected by the Scandinavian group to evaluate the background on the basis of experimental angular and momentum distributions at $\sim$ 20 GeV.

In order to subtract the background of the type "b", it is important to repeat the experiment with only one beam circulating (during the injection period?) or with beams shifted in the vacuum chamber so that they do not interact.

5. ESTIMATION OF THE TIME OF DATA ANALYSIS

Taking into account the large capacity and experience of the Cracow emulsion group and our last experience with the 60-GeV π^- events in the emulsion irradiated in Serpukhov, we estimate that the time of measurements of 16 points for $d\sigma/d\alpha$ (10^4 tracks per point) and 4 $d\sigma/dp$ distributions (10^3 tracks per distribution) is of the order of six months. The preliminary results with 10 times lower statistics could be available in about 1 month.

6. FIGURE CAPTIONS

Fig. 1 Angular distribution of secondary charged particles $dN/d\alpha$ expected in the ISR by the fireball model for the Lorentz factor $\bar{\gamma}$ of fireballs in the C.M.system equal to 1.5. A and B are the angular regions in which we expect to do measurements. 1,2 and 3 show the angles for which the momentum spectra were calculated and are presented in Fig. 3.

Fig. 2 Angular distributions of secondary particles shown in log tan $\theta^*/2$ variable expected by various models for p-p collisions with the laboratory energy in the region 10^{12} eV - 10^{13} eV. (Curve for Hagedorn Thermodynamical Model based on: R. Hagedorn and J. Ranft, N.C. Suppl. 3, 147 (1965) and CERN Report TH 715 (1966) and the calculations by J. Klosinski, TPJU - 13/67 (1967)).

Fig. 3 Momentum spectra of secondary particles expected by the fireball model for $\bar{\gamma}$ = 1.5.

Fig. 4 General lay-out of the experiment showing the vacuum chamber and two stands A and B for the emulsions.

Fig. 5 Plan of the suggested vacuum chamber.

Fig. 6 Side view and the bracing of the base plates of the vacuum chamber.

Fig. 7 Mean scattering angle in the stainless-steel window of the vacuum chamber for pions as function of their momentum.

Fig. 8 Typical effect tracks – and background tracks ______ in thin and thick emulsions in this experiment.

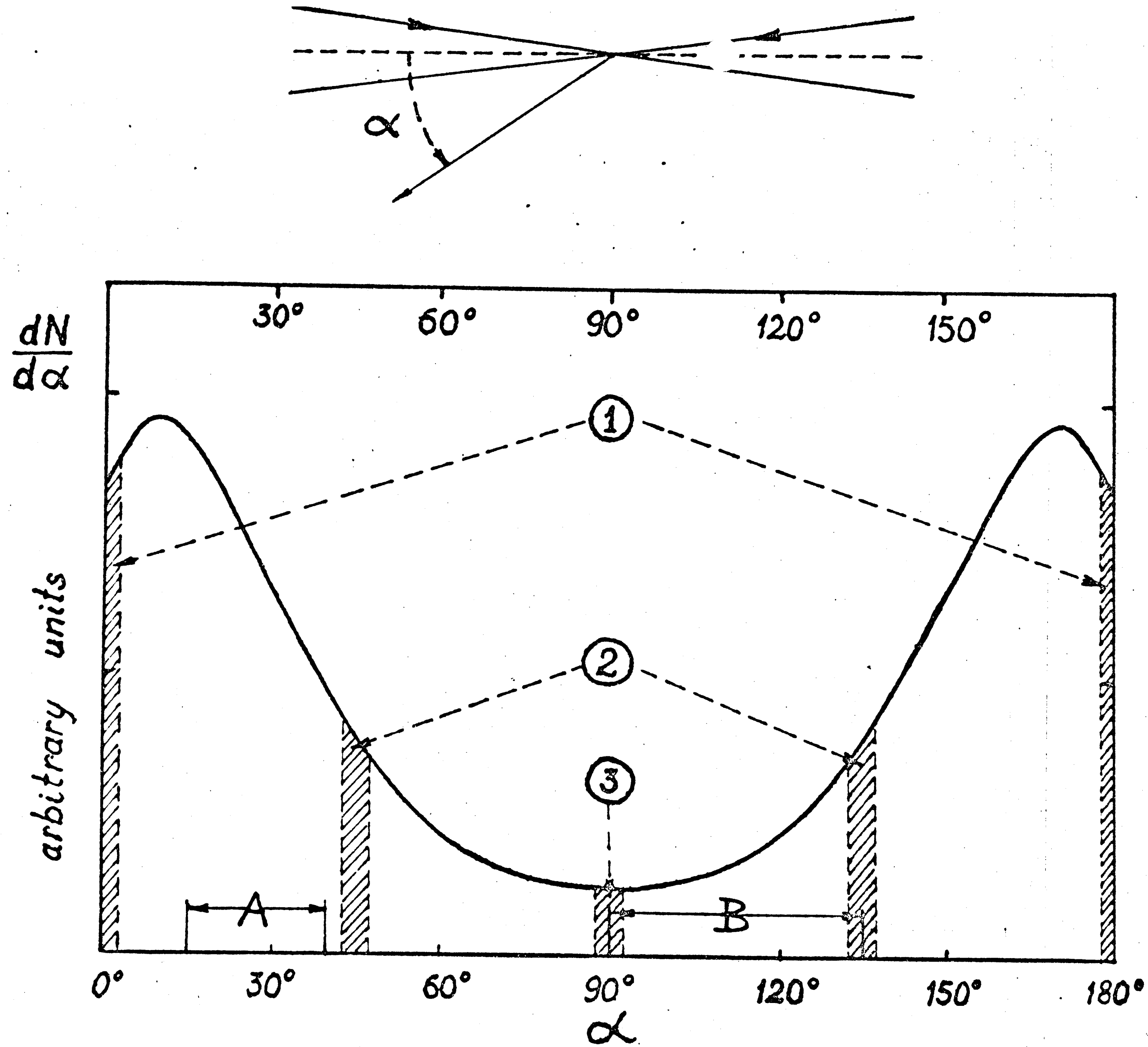

α
dN/dα
arbitrary units
30° 60° 90° 120° 150°
0° 30° 60° 90° 120° 150° 180°
α
1
2
3
A
B

Fig. 1

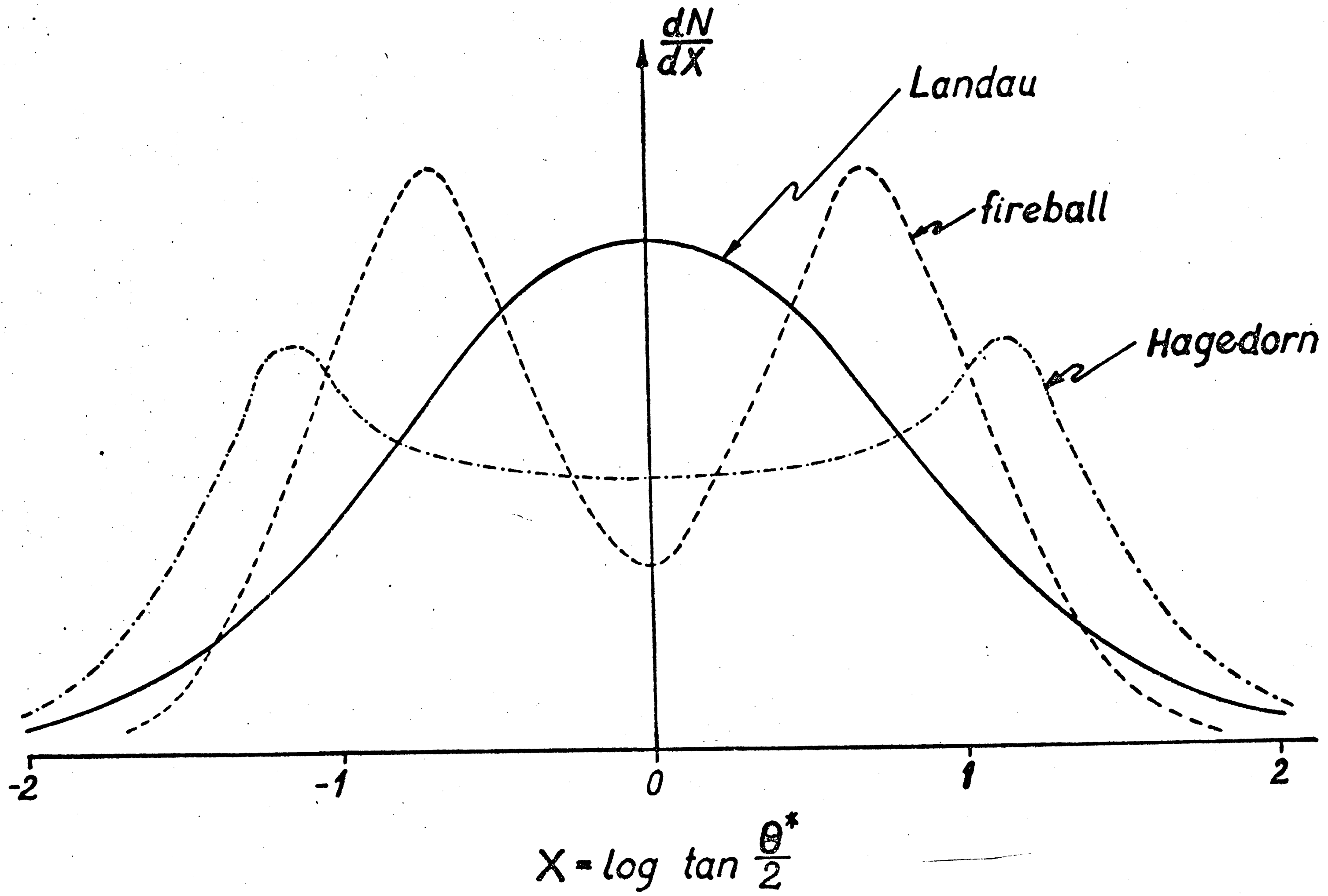
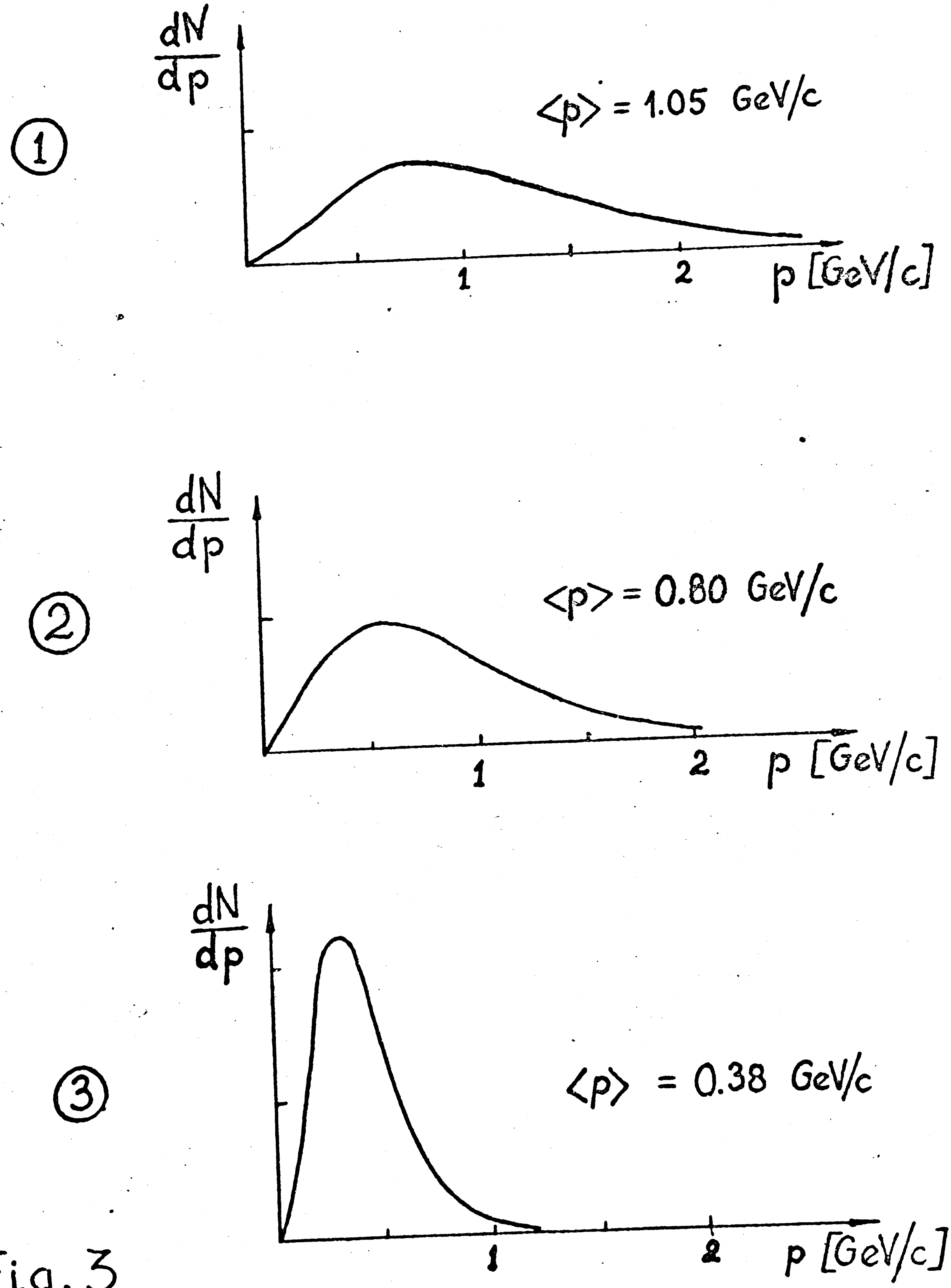


Fig. 2



①
dN/dp
<p> = 1.05 GeV/c
1
2
p [GeV/c]
②
dN/dp
<p> = 0.80 GeV/c
1
2
p [GeV/c]
③
dN/dp
<p> = 0.38 GeV/c
1
2
p [GeV/c]

Fig. 3

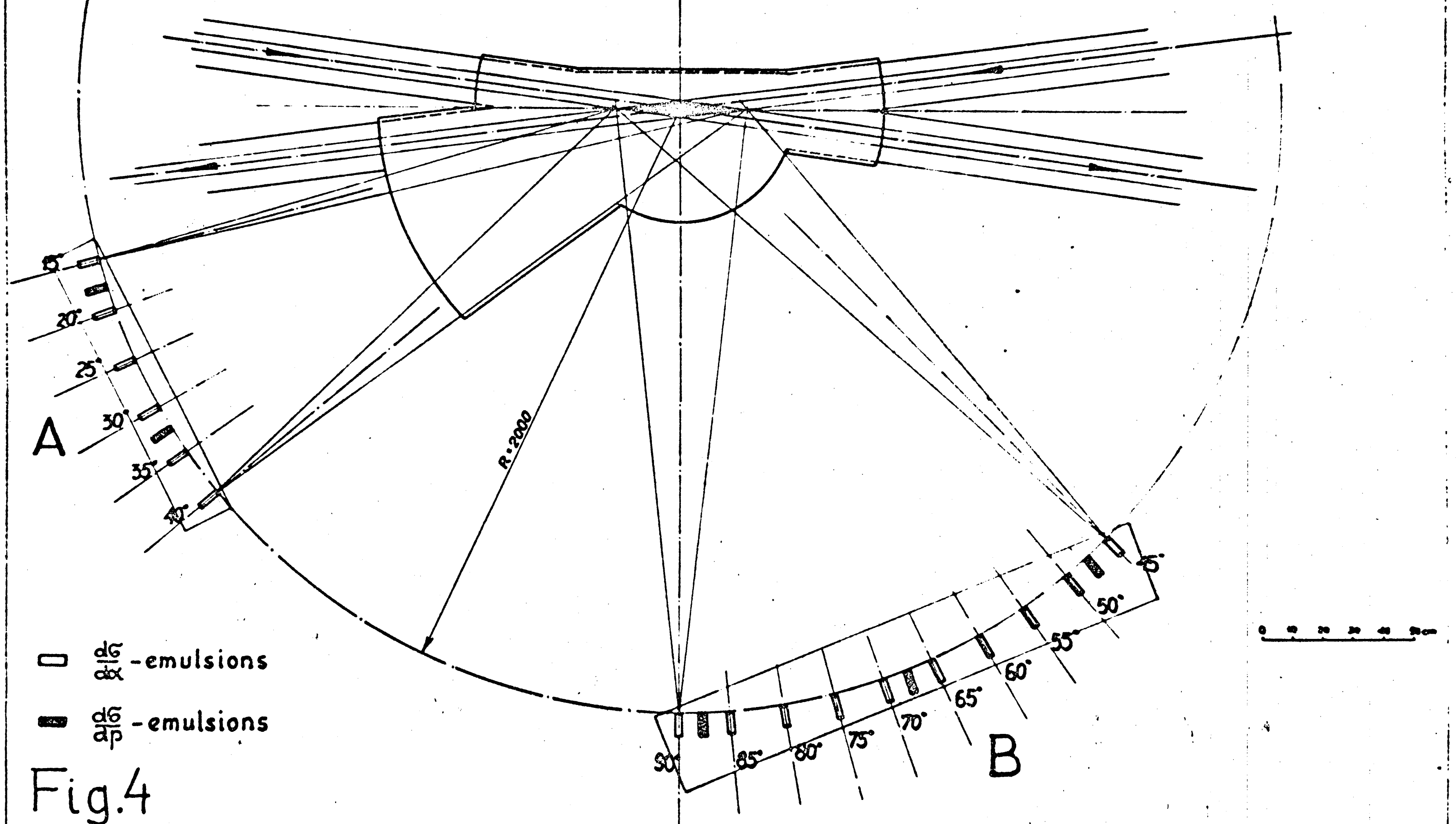

A
B
R=2000
15°
20°
25°
30°
35°
40°
45°
50°
55°
60°
65°
70°
75°
80°
85°
90°
$\frac{d\sigma}{d\alpha}$ -emulsions
$\frac{d\sigma}{dp}$ -emulsions

Fig.4

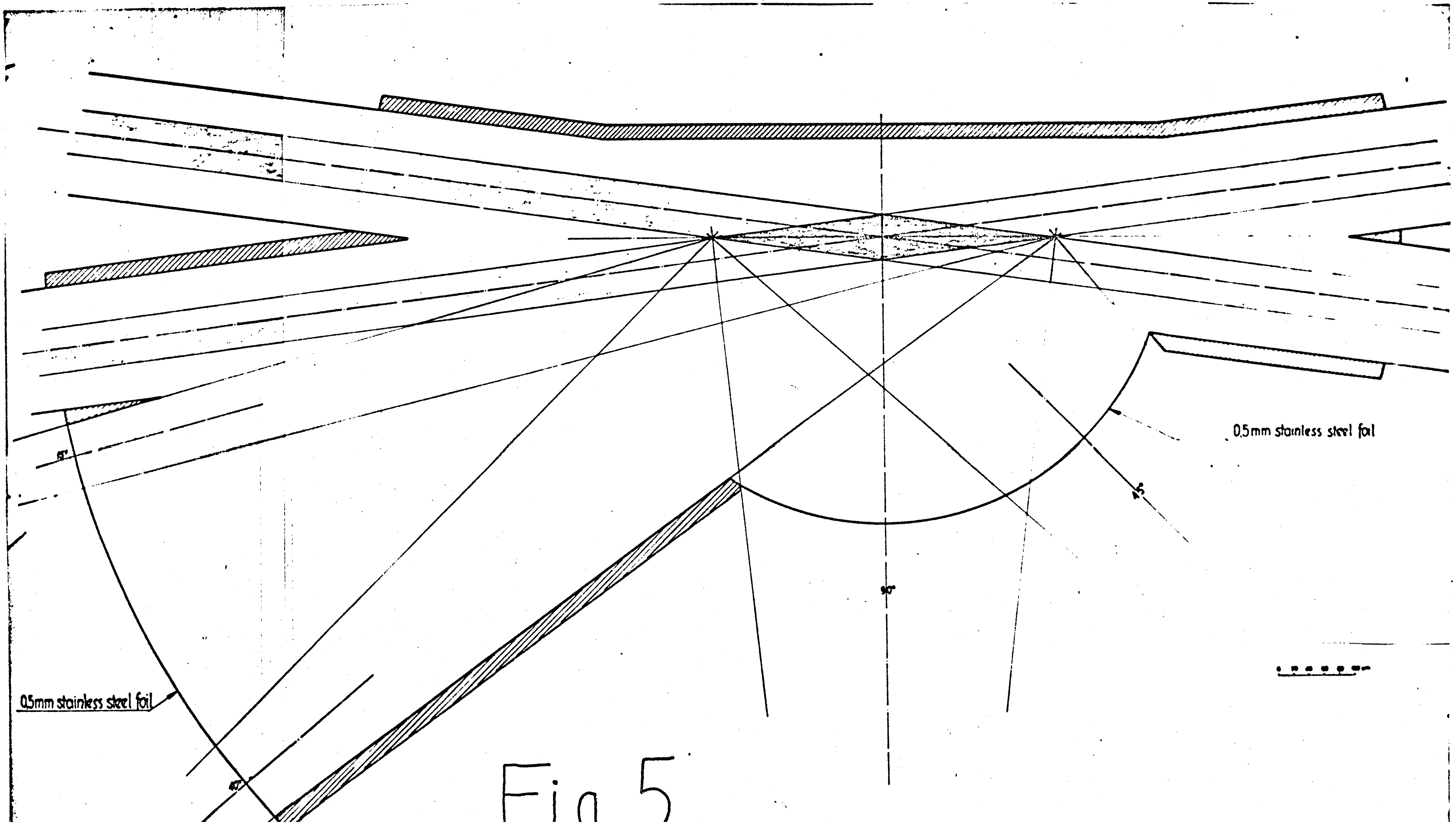

0.5mm stainless steel foil
0.5mm stainless steel foil
90°
45°
40°

Fig 5

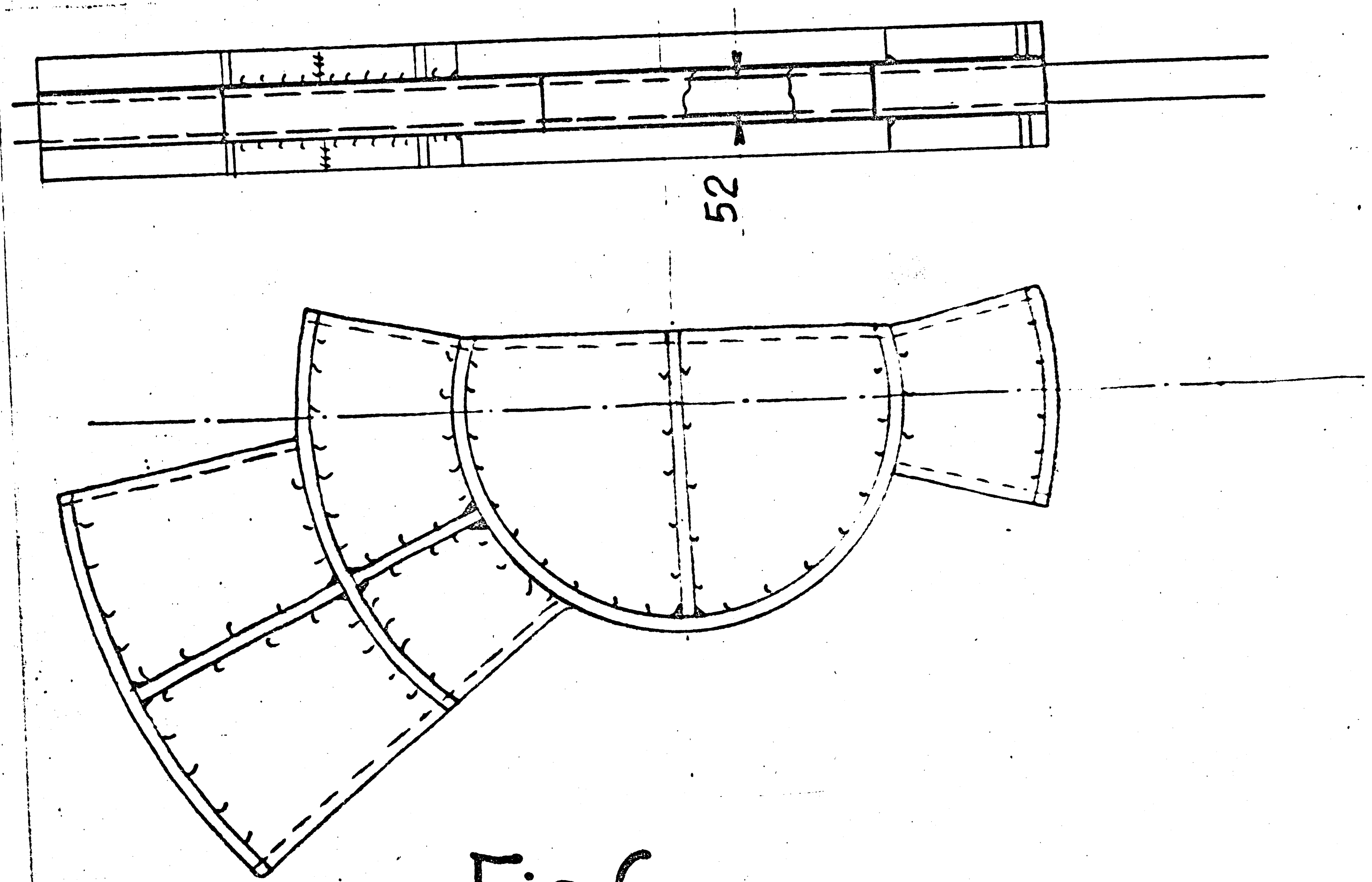


Fig.6

Multiple scattering angle for pions
(0.5 mm Stainl. Steel)

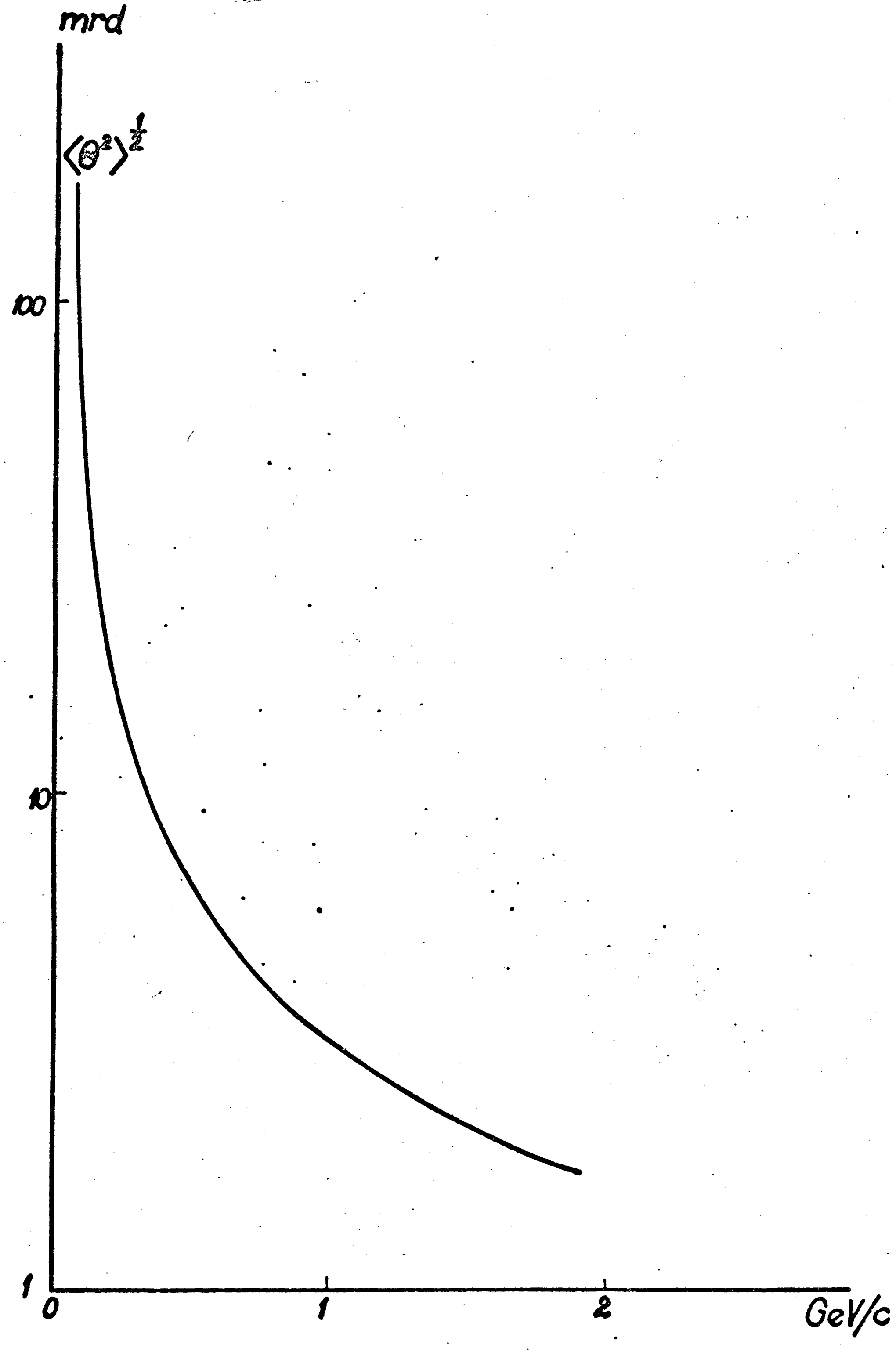


Fig. 7

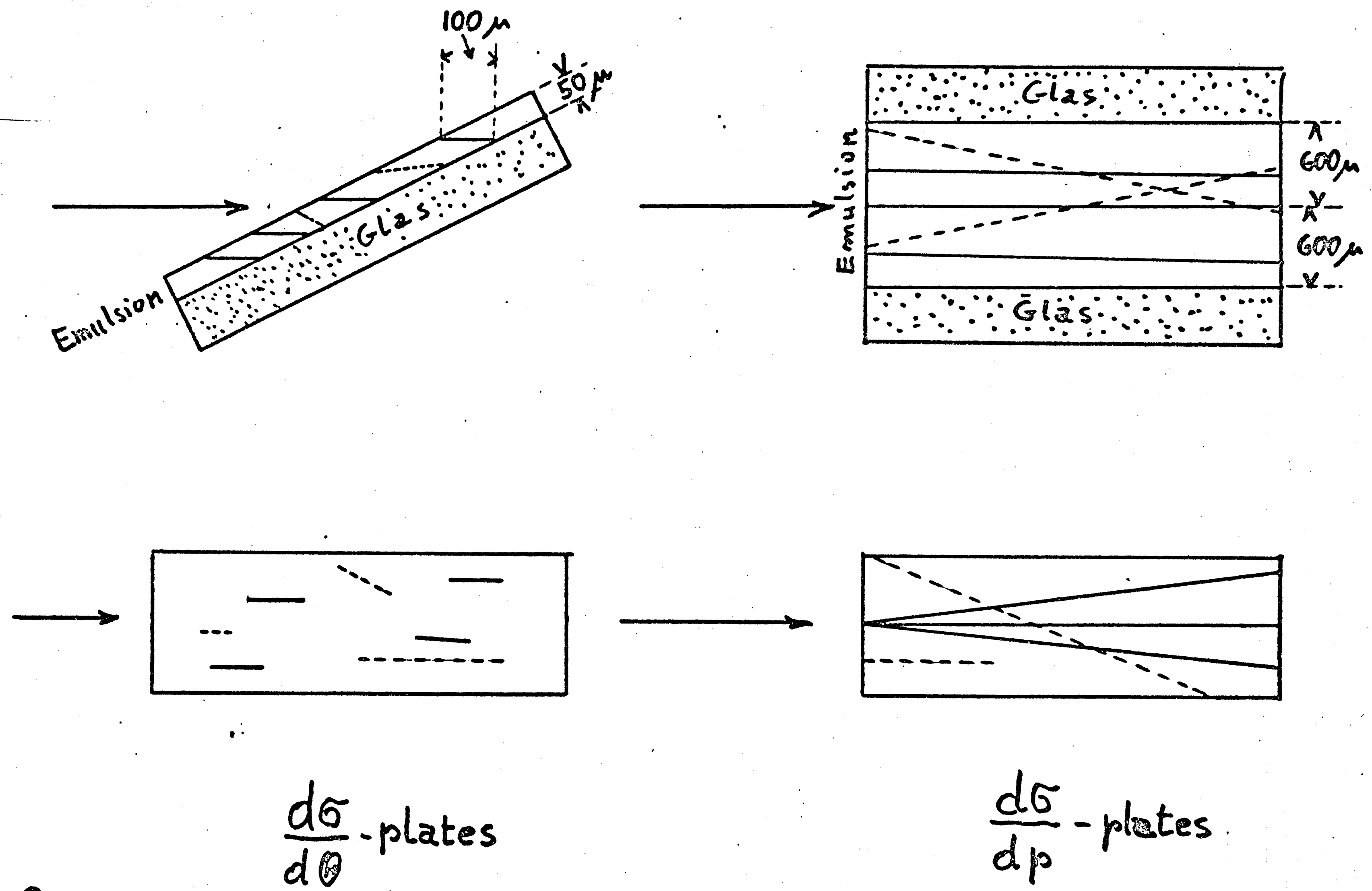

100 μ
50 μ
Emulsion
Glas
Glas
Emulsion
600 μ
600 μ
Glas
$\frac{d\sigma}{d\theta}$-plates
$\frac{d\sigma}{dp}$-plates

Fig. 8

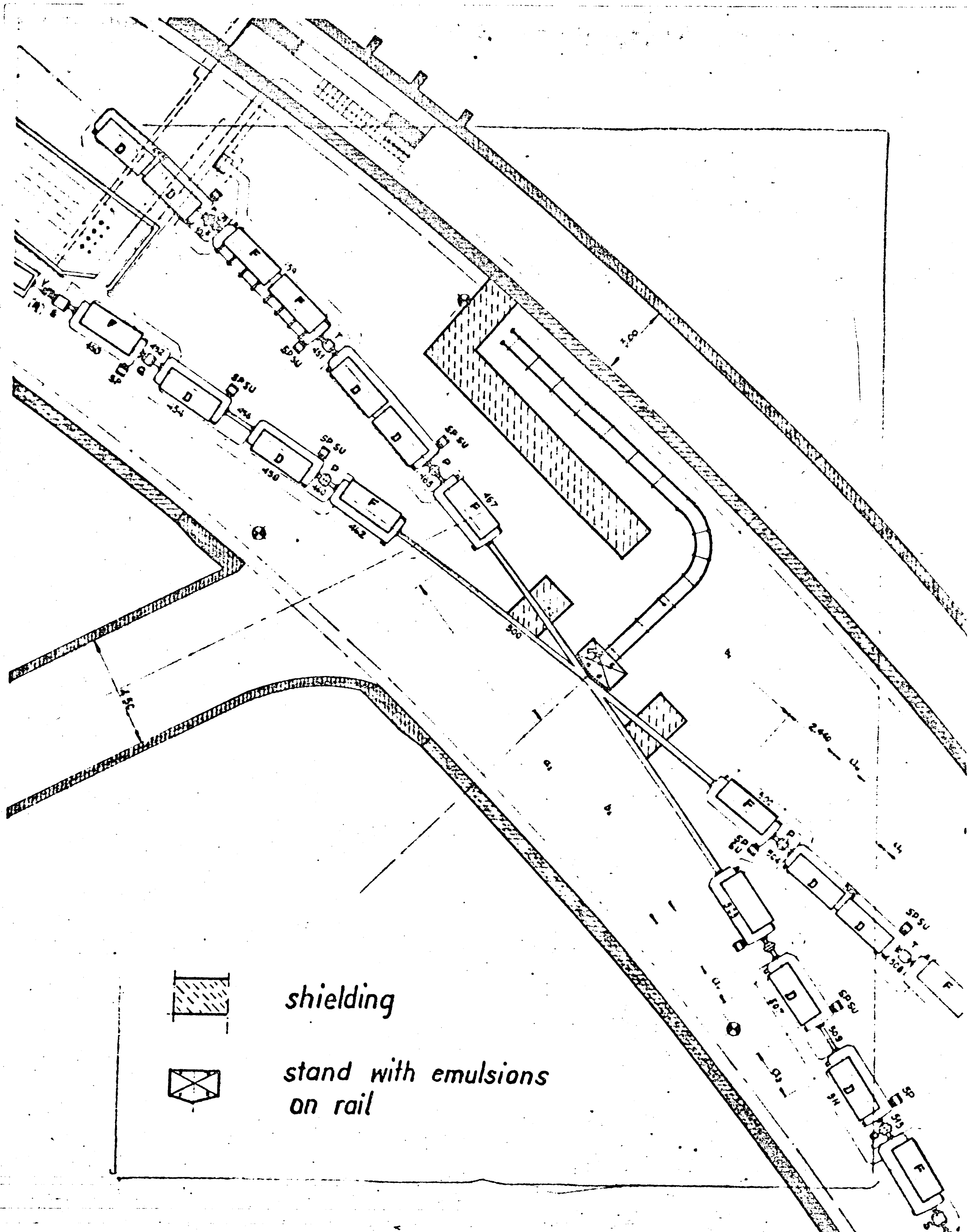


Fig. 9