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LAYOUT OF THE 300 GeV NORTH EXPERIMENTAL AREA

A Summary of Problems and Present Ideas

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ABSTRACT

This is a revised and more complete version of the report CERN/Lab. II/EA/72-1. It summarizes the studies carried out to date with a view to determine the layout of the North Experimental Area, starting from an external proton beam at the end of tunnel TT20. A tentative layout is presented. Some elements, such as production of secondary particles, target stations and basic features of a high-energy secondary beam are considered in more detail.

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The design of the North Area (N.A.) is still in a very preliminary stage. We present, however, a list of problems and present ideas on possible solutions, merely to stimulate discussion and arrive at a reasonable compromise between potential requests by experimenters and overall technical and financial limitations.

When considering the N.A., one should bear in mind that the West Area (W.A.), with its specific features and facilities, will contribute substantially to the physics programme at the same time. Moreover, the W.A. will be fed by its own extraction system and external proton beam, so that both Areas will be completely independent (operationally) from each other.

Therefore, the ideas presented in this report are based on the assumptions that :

i) The N.A. should be considered, at least for a first period, as complementary to the W.A., namely reserved for facilities which, because of their nature, cannot or will not be constructed in the W.A. In this way the best use can be made of the limited funds available.

ii) it is not necessary to plan for the mutual independence of the various facilities to be installed in the first part of the N.A.

1. General Considerations

A 400 GeV experimental area, by its size and nature, presents problems which cannot be solved simply by extrapolation of the "comprehensive experimental hall" philosophy, adopted so far at energies up to 25 - 30 GeV. This philosophy envisages primary target, secondary beam and experiment laid down on a common floor (and mostly under the same roof), served by its extracted beam, and then surrounded by the necessary quantity of mobile shielding (concrete or iron blocks). Within limits, the position of the target and the layout of the secondary beams can then be changed rather freely. However, the price of such a flexibility becomes excessive and one can hardly envisage this solution at the highest energy of the accelerator.

The extension to 400 GeV would lead to a very large and expensive experimental floor, most of which would be permanently buried under shielding whose very quantity would reduce flexibility in the sense that a layout, once installed, would necessitate a rather long shut-down period to introduce major modifications.

The ideas outlined here do not remove the rigidity but attempt to reduce the cost of a 400 GeV beam layout, by suppressing most of the so-called mobile shielding. It has to be remembered that the cost of a given effective shielding thickness varies in the proportions 1/10/100 depending on whether it is realized with earth/concrete blocks/iron blocks.

It seems, therefore, attractive and almost compelling to locate primary target, secondary beam and experiment in different and specialized building enclosures, better adapted to the particular needs of each part.

Of course such an approach makes it necessary to understand in detail the main parts of the layout before attempting to recombine them into a coherent solution.

To date a first round of studies to present a tentative layout has been completed. Even if such a layout were acceptable for physics, more work would be necessary to assess feasibility and to elaborate detailed technical solutions.

The following sections enter into more detail on some features and problems of the various parts of the layout.

2. External Proton Beam (EPB) and Its Branches

The EPB is completely designed as a slow extracted beam with classical iron magnets for 400 GeV/c, to allow the construction of the tunnel TT20 which has started. The beam is pulsed to follow the machine cycle, thus providing the possibility of performing experiments at different energies on successive pulses. The end point of the EPB ($\sim$ 470 m from the machine tunnel and $\sim$ 590 m from the ejection point) is assumed to be the origin 0 of the area (see section 5).

It is envisaged to divide the EPB after the point 0 into branches to allow some kind of multiple use of the area. The sub-division may be obtained by switches (protons only in one branch at a time), by splitters (protons simultaneously in all branches) or by a suitable combination of both.

Since a split provides the highest degree of multiple use of the area and it is also the most demanding in terms of longitudinal space, we consider a three-way split similar to the one described in CERN/1050 (page 166 - section 13.3.6). The distance needed for the splitting section is about 150 m. A further 50 - 100 metres are needed to separate the branches by 1 or 2 metres and to focus the beams onto the targets.

It is important to stress that all targets for the layout presented below will be included in one common radiation zone, to which there will be no access whenever one target operates.

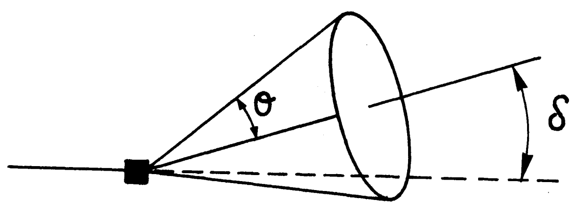
Although this limitation may give rise to some inconvenience, it is practically impossible to eliminate it since only a further considerable separation (∿ 10 m) of the EPB branches from one another would make the independence possible. This separation would require a distance of ∿ 200 - 300 m, limiting therefore even more the length available to the experiments before the river, and a considerable amount of money (∿ 3 MSFr. per branch).

3. Production of Secondary Particles

Two main parameters are of interest for the design of secondary beams :

(i) The Production Angle δ

(ii) The Angular Semi-Aperture of Acceptance Cone θ



In fact, normally, with quadrupole focussing the acceptance cone has an elliptical rather than a circular cross-section, with an acceptance defined by

$$\Omega = \pi \theta_x \theta_y = \pi \theta^2$$

where

$$\theta = \sqrt{\theta_x \theta_y} \quad \text{(x,y are the two transverse coordinates)}$$

Calculations have been carried out, following the Hagedorn-Ranft thermodynamic model[1)], by means of the CERN computer library programme SPUKJ for a hydrogen target. For heavier element targets the flux will be less by a factor 1 to 2, depending on the element.

A first set of curves (Fig. 1) illustrates the well-known peaked forward characteristics of the production, which implies that with $\delta \neq 0$ the beam intensity is considerably reduced, especially at high energy. Only for an energy of the secondaries not exceeding one-half of the primary energy, is a small δ ($\lesssim$ 3 mr) still acceptable. It should be noted that the characteristics assumed in Fig. 1 (number of interacting protons, $\Delta p/p$ and acceptance) correspond to those of a realisitic beam reaching the highest energy available.

Concerning the second parameter θ , clearly the larger it is the more flux one gets (up to a certain value). Since, however, limitations are imposed on θ both by the configuration of the target stations and, above all, by financial considerations, it is important to assess values of θ which may realize the best compromise between the various requirements in each particular case. Moreover, many experiments will be intensity-limited so that it is legitimate to ask the question "what is the minimum θ necessary to collect a given flux of particles ?".

Figs. 2,3,4 and 5 attempt to answer this question. The flux of all particles of a given sign has been limited to 10^8 or 10^7. One should underline that for negative particles above a certain energy a flux of 10^8 particles (or even 10^7) is not obtained whatever the angle θ and therefore the total flux (smaller and varying with energy) is indicated. The angle θ necessary to obtain 10^8 or 10^7 total is shown where it is possible to obtain this intensity and where not possible we show the angle necessary to obtain

50% of the total flux possible. The flux of individual particles under these conditions is also shown. In Figs. 2 and 4 one should note the preponderance of protons, while in Figs. 3 and 5 the line A-A corresponds to the limiting divergence (referred back to a target of ± 1 mm) accepted by a DISC counter of 8 cm aperture with an angular divergence tolerance of 0.02 mr.

The general conclusions which can be drawn are :

(i) In principle, all beams should be designed for $\delta = 0$ over the widest possible momentum range. This allows the most efficient use of protons.
However, to be able to vary in some cases the flux of secondary particles at "low" and "medium" energies and to obtain positive secondaries at the highest energy, the range $0 \leq \delta < 4$ mr should be available.

(ii) $\theta \lesssim 1$ mr seems to be adequate for $p_{sec} \gtrsim 100$ GeV, even if a total flux of 10^8 ppp is required.

(iii) A beam of given acceptance produced at $\delta = 0$ collects considerably more particles at high momentum than several beams arranged to receive roughly equal shares of flux at $\delta \neq 0$.

4. Target Stations

Various schemes for deriving charged secondary beams from targets placed in branches of the EPB are being studied with the aim of providing the following conditions :

i) zero production angle δ for the secondary particles, but range $0 \leq \delta < 4$ mr available (see conclusions of section 3),

ii) fixed beam lines, independent of the sign of the charge and the momentum of the secondary particles selected.

In an attempt to show how these requirements might be met, we consider schematically two different types of target station and discuss briefly some of their basic features and limitations. We indicate, but do not yet pretend to have solved, some of the problems associated with their realization in practice.

End Target Station

The greatest degree of freedom is evidently obtained with a target station where no further use of the EPB branch is required after the target, i.e. at the end of an EPB branch. The principle of such a target station is illustrated in Fig. 6 a :

The EPB is incident on a target T which is followed by an analysing magnet M; a beam of secondary particles of chosen central momentum ± p produced at zero angle is deflected through an angle α to emerge along a fixed line OS independent of p; the unused EPB will be deflected through an angle ε ($\varepsilon_1 \geq \varepsilon \geq -\varepsilon_2$) and emerges in a direction OP which depends on the choice of p.

Fig. 7 shows a possible example of a target station of this type; an additional (C - type) magnet M_c is used to increase the separation of the secondary beam line from the extreme EPB trajectory at P_1. In this example positively or negatively charged particles of momentum p in the range :

$$+ 0.8\ p_o \gtrsim p \geq - 0.9\ p_o \quad \text{(in principle } - p_o \text{ is possible)}$$

can be selected at zero production angle from the target.

Two alternative locations of the target along the incident EPB line may be considered :

i) EPB focussed on target at T (using quadrupoles Q_p) - followed by quadrupoles Q_1 - Q_3 in front of magnet M. In this case the acceptance angles for secondary particles are defined by the section Q_1 - Q_3 and can be made as large as practicable. This section will, however, be common to any other beam derived from the target.

ii) EPB focussed on target at T' (using Q_p, Q_1 - Q_3) immediately in front of magnets M - M_c - followed by quadrupoles Q_1' , Q_2' ; these then limit the acceptance of the beam. In this case, the magnet system can be used to select particles of given momentum correlated to production angle; in particular a diffracted proton beam ($p = p_o$) can be derived at a scattering angle of $\sim$ 3 mr along a trajectory T'P'S. The analysing system M can furthermore be regarded as a sweeping magnet which would allow a neutral beam (n, K_L^o, $\gamma \rightarrow e^{\pm}$) to be derived along a line T'N at zero (or near-zero) production angle from the target at T'.

Transmission Target Station

In order to increase the utilization of a given EPB branch without incurring the loss of flexibility inherent in deriving several beams from a single target, we consider the design of a target station which will allow the EPB to serve more than one target in series. This will in general require a system of 3 magnets (or "wobbling" section) to return the EPB to a fixed line independent of the momentum of the secondary beam derived. There are advantages in avoiding the use of special magnets and in leaving greater spatial freedom for the secondary beam if the target is located immediately in front of the last magnet (M_3) of the wobbling section. The principle of such a target station is illustrated in Fig. 6 b.

The secondary beam (of central momentum ± p) and the unused EPB leave the analysing magnet M_3 along fixed lines OS and OP respectively, at angle α to each other, independent of p; the trajectory ABT of the incident EPB and the lateral position of the target T can be varied between two limits given by T_1 and T_2 ($\varepsilon_1 \geq \varepsilon \geq -\varepsilon_2$) according to the choice of p. Fig. 8 shows a possible example of a target station of this type in which positively or negatively charged particles of momentum p in the range

$$+ 0.6\ p_o \geq p \geq -p_o$$

can be selected at zero production angle from the target with an acceptance defined by the quadrupoles Q_1 - Q_4. Positive particles of momentum $p > 0.6\ p_o$ can be collected at non-zero production angle if an additional (C-type) magnet is inserted between M_3 and Q_1. It should be noted that the initial angle of deflection of the secondary beam and hence the momentum dispersion introduced by the analysing magnets M_3 will be a function of momentum p; this can be taken into account in designing the secondary beam. The scheme permits the beam of protons not consumed in the target to be refocussed by the quadrupoles Q'_p essentially independently of the operation of the secondary beam. Only marginal (∿ 20%) loss of possible secondary particle flux is incurred by restricting the target length to allow roughly equal utilization of the transmitted protons on a second target in series*).

Comparison of Target Stations

Some parameters relating to the examples of the two types of target station (Figs. 7,8) are compared in the following table :

	End target station (i) Target at T	End target station (ii) Target at T'	Transmission target station
Limiting angles : α (mr)	25		10
Limiting angles : ε_1	∿ 20		15
Limiting angles : ε_2	22.5		5
Maximum momentum of secondary beam [1)] for + ve particles : p_1(GeV/c)	∿ + 320 (280)[4)]		+ 240(200)[4)]
Maximum momentum of secondary beam for − ve particles : p_2(GeV/c)	− 360		− 400
Acceptance of secondary beam [2)] (μster)	∿ 2.2	∿ 0.8(∿1.5)[4)]	∿ 2.2 (∿ 3.1)[4)]
Total bending power [3)] (T.m) required for p_1	∿ 32.0		60.0
Total bending power (T.m) required for p_2	36.0		46.7

1) For momentum of EPB, p_o = 400 GeV/c

2) Assuming "slim" quadrupoles, aperture 80 mm (useful aperture ∿ 65 mm), and maximum field on pole face ∿ 1.0 T.

3) Assuming conventional magnets of gap ∿ 50 mm and maximum field $\gtrsim$ 1.6 T.

4) The numbers in brackets illustrate the correlation between the acceptance of the secondary beams and the maximum momentum of positive particles collected at zero production angle. For example, in the case of an End target, the acceptance almost doubles if the maximum positive momentum is limited to 280 GeV/c instead of 320 GeV/c.

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*) It may be noted that the r.m.s. scattering angle introduced by the presence of as much as one interaction length of material in the EPB at 400 GeV/c is small (∿ 0.05 mr for Be, ∿ 0.15 mr for Cu) compared with a typical divergence of ∿ ± 0.5 mr for the focussed EPB.

For both types of station, additional charged secondary beams could be derived along lines at different angle α from the analysing magnet. They would in general be at a lower momentum which would be coupled in sign and (to some extent) in magnitude to that of the principal beam. However, the increase in pole width of the analysing magnet entailed and the additional requirements on space around the target station may make this facility of limited use for a practical layout.

It should be noted that the target station schemes considered here are based on the use of iron magnets of conventional type, in the belief that these offer the greatest degree of simplicity, reliability and resistance to radiation under the specially severe conditions close to a target. These factors will be paramount in continuing the study towards practical designs of target stations.

5. Tentative Layout

In addition to the complementarity of the N.A. with respect to the W.A., already mentioned, our studies have been guided by the following considerations and assumptions :

(i) We limit ourselves to the first half of the area extending to about 1.4 km from point 0 (see section 2). In fact all experimental facilities discussed so far can be contained in this part. In any case it would be wrong to plan now facilities occupying the entire area; it is more advisable to reserve the rest for future development, either of the primary proton energy beyond 400 GeV or for second generation experiments still at 400 GeV,

(ii) Only slow extraction,

(iii) About six beams operating simultaneously and making the most efficient use of protons (all capable of reaching zero production angle).

As mentioned in section 1, it is our belief that it is advantageous and almost compelling to locate the various parts of the layout (beam splitter and primary targets, secondary beams, and experimental zones) in different and specialized building enclosures adapted to the particular needs of each part.

Fig. 9 shows a possible layout.

The targets, placed in the various EPB branches, are at level of 441,2 m ($\sim$ 10 m below the natural ground level). The charged secondary beams rise to the main experimental zone (Exp. Zone 1), located at a level much closer to the surface (beam height 451.2 m). On the other hand the muon-neutrino beam(s) rise(s) more gently with an inclination of $\sim$ 10 mr, to a specialized experimental zone (Exp. Zone 2) reserved for muon and neutrino detectors beyond the river "Le Lion". In addition to the secondary beams already mentioned, a possible continuation of the EPB to other experimental zones is also indicated. It can be fed by either the first (from top) or the second EPB branch.

The justification for such a layout is as follows :

(i) The primary targets, which are designed to receive globally 10^{13} ppp, must be shielded transversely by an amount of material of $\sim$ 1600 - 1800 gr/cm^2. In addition the forward muon cone, whose range in earth is $\sim$ 400 m from the target, has also to be stopped. By placing the targets at 441.2, both shields are obtained in a rather natural and inexpensive way; the former by filling back the earth on top of the target enclosure (some additional volume is needed however), the latter by the untouched earth below the rising secondary beams.

(ii) The Experimental Zone 1, which is meant for general purpose, should be as close as possible to the surface and indeed it can be so since, in general, only beams carrying $\lesssim 10^8$ ppp will be admitted into it. An exception will be the attenuated proton beam, which could go up to 10^{10} ppp by taking appropriate precautions.

(iii) As a consequence of (i) and (ii), the secondary beams must cover a difference in level of 10 m, and for practical reasons, must be horizontal again in the Experimental Zone. It therefore appears most natural to use the two bending sections required for momentum selection, measurement and recombination[2)]. The secondary beams can be achromatic in both transverse and angular coordinates at entry in the Exp. Zone.

(iv) The muon-neutrino beam(s) cannot follow the same path as the other secondary beams for at least two reasons. The first is that the neutral line (prolongation of the EPB branch) must reach the Exp. Zone for a wide-band neutrino beam. The second is that the beams must pass under the river at sufficient depth to comply with the radiation safety regulations.

The secondary beams A, B, C and D are charged beams and should be determined in relation to a possible experimental programme.

However, as an illustration of what could be done, the following set of beams seems to be mutually compatible :

A - Attenuated proton beam ($\lesssim 10^{10}$ ppp) to be brought onto a target in Exp. Zone 1 to produce, e.g. beams of short-lived particles.

B - Charged beam ($\pi^{\pm}$, $K^{\pm}$, $\bar{p}$) with good resolution and DISC counter for particle identification.
Momentum range $+ 240$ GeV/c $\gtrsim p_{sec} \gtrsim - 400$ GeV/c.

C - Electron beam (by conversion of γ's from target). Can be reconverted to tagged photon beam in Exp. Zone 1.
Electron momentum ≤ 200 GeV/c.

D - Charged beam ($\pi^{\pm}$, $K^{\pm}$, $\bar{p}$) similar to B.
Momentum range $+ 300$ GeV/c $\gtrsim p_{sec} \gtrsim - 400$ GeV/c.

Of course, a gradual development of the N.A. is possible. The muon-neutrino facility could be started first and beams A, B, C, D follow in due course.

One has, however, to be aware of the fact that the civil engineering of the target enclosure and of the best part of the tunnels housing the beams A, B, C and D has to be completed prior to any utilization of the area.

Finally it is worthwhile noting that a layout including the same beams, but with all the parts at the same level, chosen to be intermediate between 441 m and 451 m (e.g. 446 - 447 m) was also considered in some detail. The incentive of such a study was the belief that this solution might be more flexible. It was found that this one-level solution is disadvantageous in many respects, since :

(i) the targets would have to be placed further downstream and hence the available distance to the river would be reduced by ∿ 50 - 100 m,

(ii) the width of the Exp. Zone 1 should be wider by 30 - 40 m for the same number of facilities, since the offset necessary in the secondary beams to provide the required momentum resolution should be horizontal instead of vertical,

(iii) the background at the experiments produced by the primary targets may be greater and such as to limit the freedom of placing experiments in the Exp. Zone 1,

(iv) a higher cost may be incurred because of the greater total excavation needed by the depth of the large Exp. Zone 1,

(v) finally, we do not believe this one-level solution to be more flexible. The basic "inflexibility" is given by the separate building enclosures and the earth shielding, whose transverse thickness must be the same in either solution. As mentioned earlier, we believe that a "comprehensive hall" simply cannot be afforded and would also be inflexible when buried by concrete and iron blocks.

6. Some Features of a High-Energy Charged Secondary Beam

In order to acquire some ideas on the distance needed between targets and Exp. Zone 1 and on a possible beam layout, we undertook to design a high-energy charged beam with the characteristics indicated below. Clearly, should such a beam be of interest, these characteristics should be revised and more clearly defined in the light of proposals for specific experiments.

i)	Particles/ Flux/ Momentum	:	$\pi^{\pm}$, $K^{\pm}$, p, $\bar{p}$ with maximum fluxes of $\sim 10^6 - 10^8$ ppp over a wide range of momenta extending as high as possible towards the primary momentum (p_o = 400 GeV/c) of the EPB. $\Delta p/p \sim 1\%$.

ii) Background : acceptable fluxes of hadrons and muons accompanying the beam at positions where detectors may be placed.

iii) Momentum selection/recombination : high intrinsic resolving power of the beam at the position of momentum-defining slits.

iv) Momentum (energy) measurement on individual particles : detector spacing allowing resolution of $\sim \pm m_\pi c/2 \simeq \pm 70$ MeV/c at the highest possible momentum.

v) Particle identification : velocity measurement permitting π - K separation at the highest possible momentum, ($\Delta\beta_{\pi K} \sim 10^{-6}$ at 300 GeV/c).

vi) Matching of the beam size and divergence to the experimental set-up.

If produced from an End Target Station similar to Fig. 7, the following set of parameters could be obtained :

i)	Maximum momentum :	$\lvert p_{max} \rvert$ = 400 GeV/c
ii)	Production angle :	δ = 0 for + 320 GeV/c $\gtrsim p_{sec} \gtrsim$ - 360 GeV/c $\delta \simeq$ 3 mr p = + 400 GeV/c
iii)	Acceptance from a target of 2 mm Ø :	$\theta_x \simeq \pm$ 0.8 mr $\theta_y \simeq \pm$ 0.3 mr $(\Delta p/p)_{FWHM}$ = 1.2% $\Omega \cdot \Delta p/p \simeq$ 1 μsr.%
iv)	Fluxes :	shown in Fig. 10
v)	Resolution for momentum measurement :	∿ 2800 (or ± 70 MeV/c at 400 GeV/c)
vi)	Velocity measurement :	DISC counter set for π/K identification up to $\lvert p_{max} \rvert$ and accepting $\gtrsim$ 80% of particles in beam [3].
vii)	Design emittance at experiment :	horizontal (x) plane ∿ ± 1.0 mm.mr vertical (y) plane ∿ ± 0.6 mm.mr
viii)	Total length :	∿ 500 m

It should be noted that to comply with vi) and vii) above, it is necessary to correct systematically the chromatic aberrations along the beam [4].

A more complete description of the optics of such a beam is in preparation [2].

7. Conclusions

It may be noticed that some important questions are not adequately answered or even mentioned in this report. They concern mainly the experimental zones themselves, civil engineering solutions for the various parts of the layout, radiation problems, beam elements, construction of targets, etc. Many of these questions have not yet been studied in sufficient detail to justify a meaningful presentation.

We consider it also essential to obtain very soon more information on possible experimental detectors in order to assess in a better way the facilities needed in the Experimental Zones.

Finally a general comparison can be made between the West and the North Areas. The North Area has the following distinctive features (with respect to the W.A.) :

i) The EPB energy can always be equal to the maximum accelerator energy;

ii) The maximum length available to secondary beams and experiments between targets and maximum extension of Exp. Zone 1 is ∿ 900 m (three times more than in the W.A.);

iii) The secondary beams become longer (higher energy) and are more rigidly fixed (at least in the first part);

iv) However, the experiments are less likely to be disturbed by background, and their location may be more independent of the primary targets and may thus be changed more freely;

v) There are ample possibilities of extension to the second part of the area.

It is therefore our belief that the utilization of both the N.A. and the W.A. will allow a comprehensive and versatile experimental programme to be carried out.

8. Discussion (following the talk at Tirrenia)

8.1. High intensity primary target as a source of short and special beams (e.g. neutron beam)

The remark was made that in the tentative layout no provision exists for such cases.

Indeed it is very difficult and expensive to provide such a facility in the immediate neighbourhood of the target enclosure. It was thought, however, that since such a facility can be inserted easily in the West Area, one could avoid constructing it in the North Area from the very beginning. Obviously, in a second phase of the N.A. development, it would be possible to combine it with the EPB continuing to the second part of the area.

It was also stressed that the attenuated proton beam ($\lesssim 10^{10}$ ppp) which can reach the Exp. Zone 1 via, e.g. beam A, will already be very useful for the production of hyperon beams and of beams of short-(and long-) lived neutrals.

8.2. High intensity proton beam traversing a (liquid hydrogen) target and observation of events at large transverse momentum

This requires the observation of particles produced, in the laboratory system, in a cone,whose angular semi-aperture may extend up to $\sim$ 100 mr or so.

In principle, this could be done in the primary target enclosure itself, but the main difficulty will be to install sizeable experimental equipment in a zone which is the heart of the N.A. (it should be in operation practically whenever the machine operates) and which contains hot equipment.

A better solution could be to combine this facility with the one mentioned under 8.1, e.g. on the EPB continuing onto the second part of the area.

8.3. Use of a secondary beam for more than one experiment

The remark was made that, since high-energy beams are long, costly and necessarily limited in number, it would be quite appropriate to use them for more than one experiment at a time.

It certainly looks feasible to have two experiments, e.g. one data-taking and the other setting-up, at the end of any of the beams A,B,C,D. The beam could then be shared in time between the two experiments as appropriate.

Whether or not more sophisticated schemes could be applied (more than two experiments, more elaborate particle sharing, etc.) will be studied in due course, when actual experiments are designed.

8.4. Provision of a pion beam of the highest possible intensity

Interest was expressed in deriving a beam of $\gtrsim 10^9$ π's at medium energies (100 - 200 GeV/c) for experiments in which detectors would be placed outside the beam to observe reaction products at large transverse momentum.

The similarity of these requirements with those of the muon beam included in the layout (large acceptance, wide momentum-band transmission, possibly common detector system, natural earth shielding around Exp. Zone 2) suggests that a combined π/μ beam facility might merit closer study.

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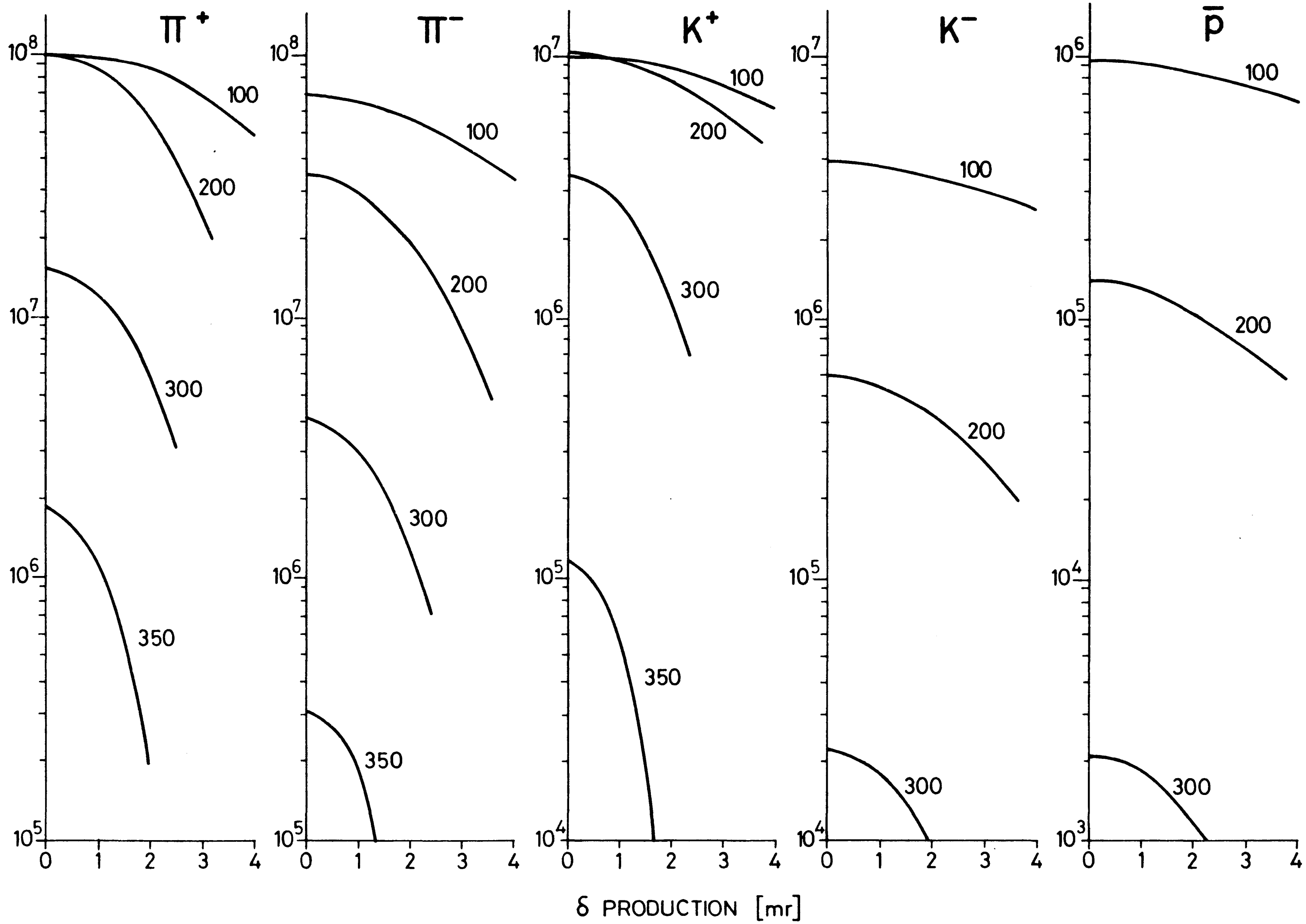
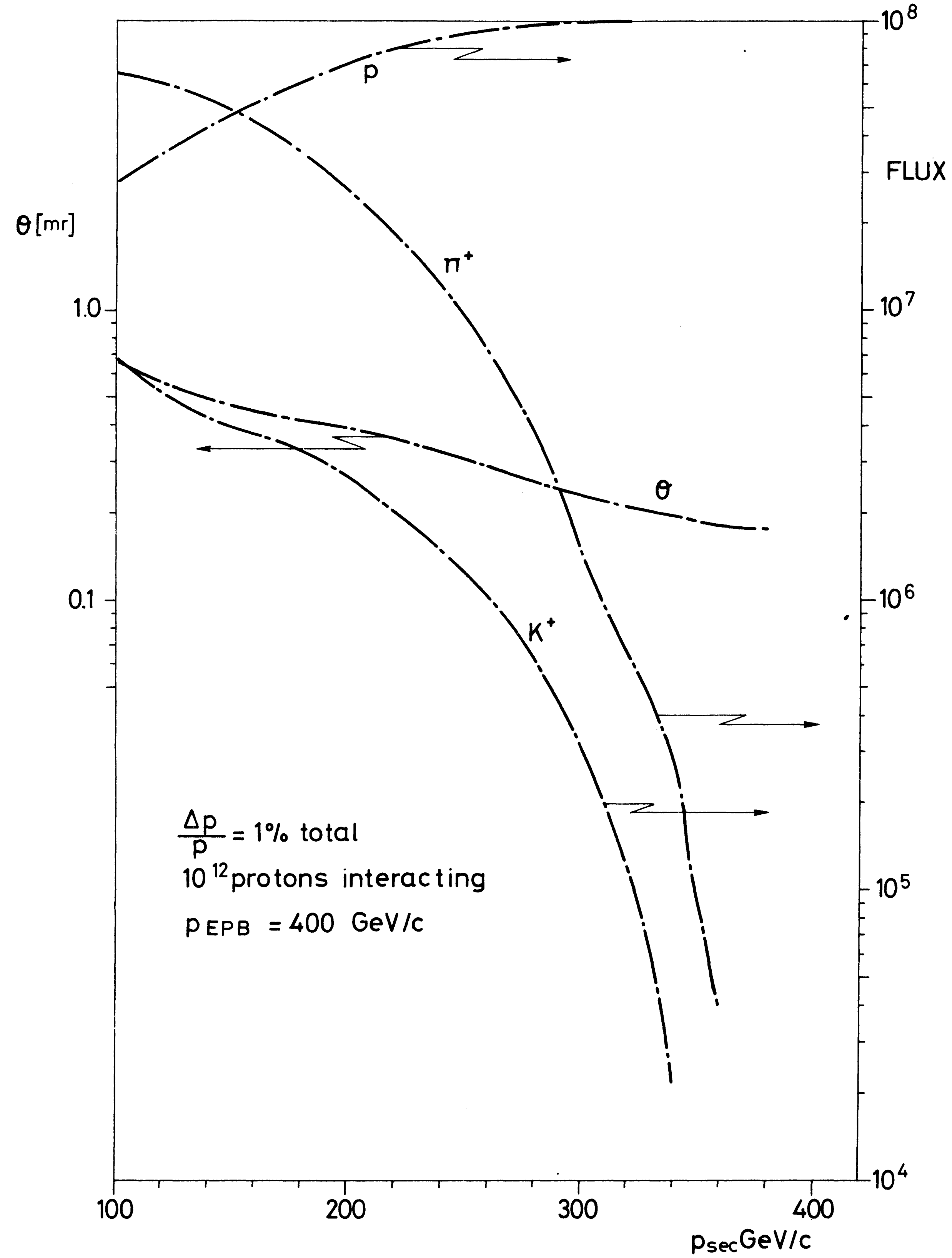
PRODUCTION CHARACTERISTICS OF SECONDARY PARTICLES



P_{EPB} = 400 GeV/c, 10^{12} INTERACTING PROTONS, $\Delta p/p = 1\%$ TOTAL ACCEPTANCE ELLIPSE $1\,mr \times \frac{1}{2}\,mr$

Fig. 1



θ [mr]
1.0
0.1
10^8
10^7
10^6
10^5
10^4
FLUX
p
π⁺
θ
K⁺
$\frac{\Delta p}{p}$ = 1% total
10^{12} protons interacting
p_{EPB} = 400 GeV/c
100
200
300
400
p_{sec} GeV/c

Fig. 2

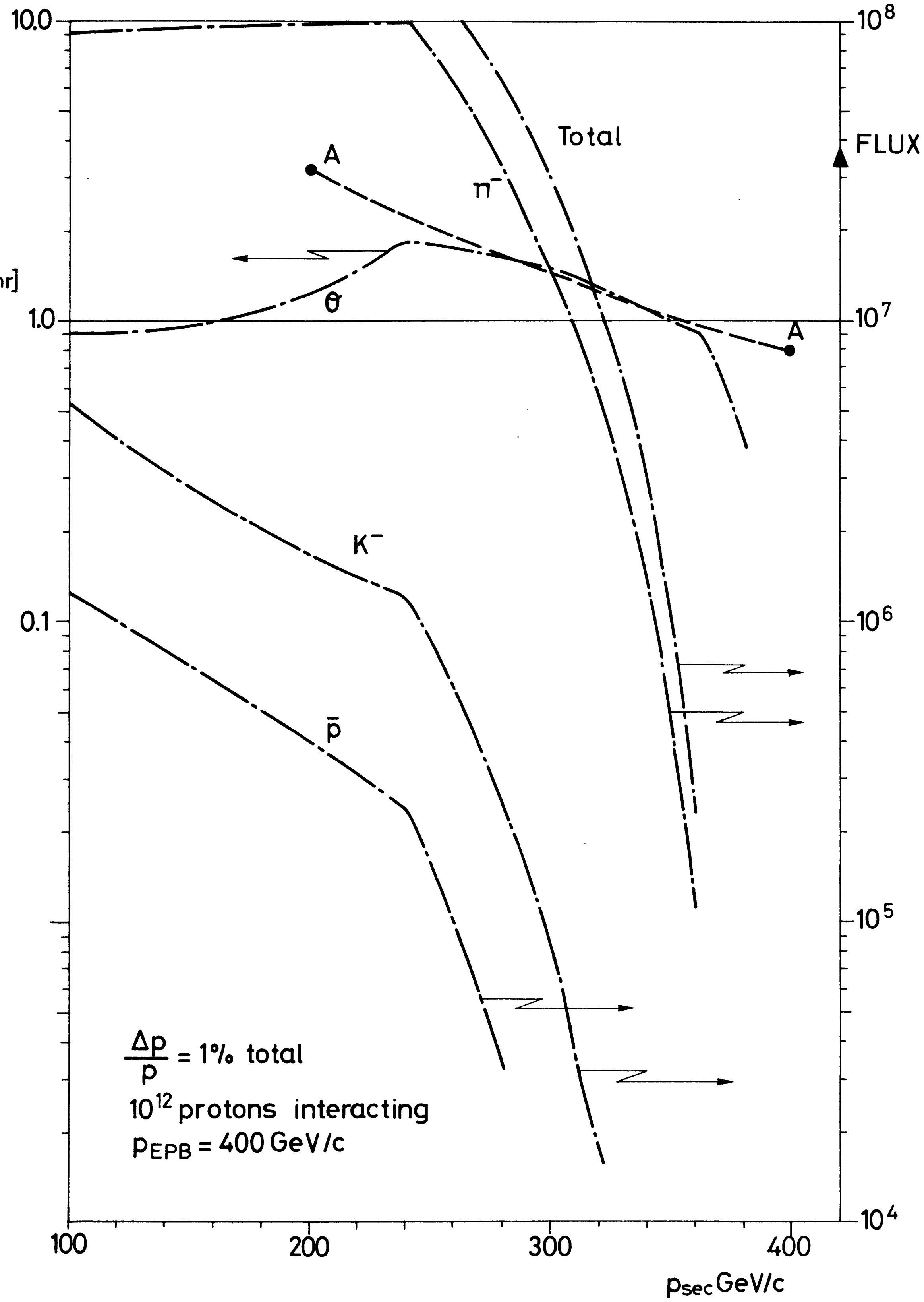
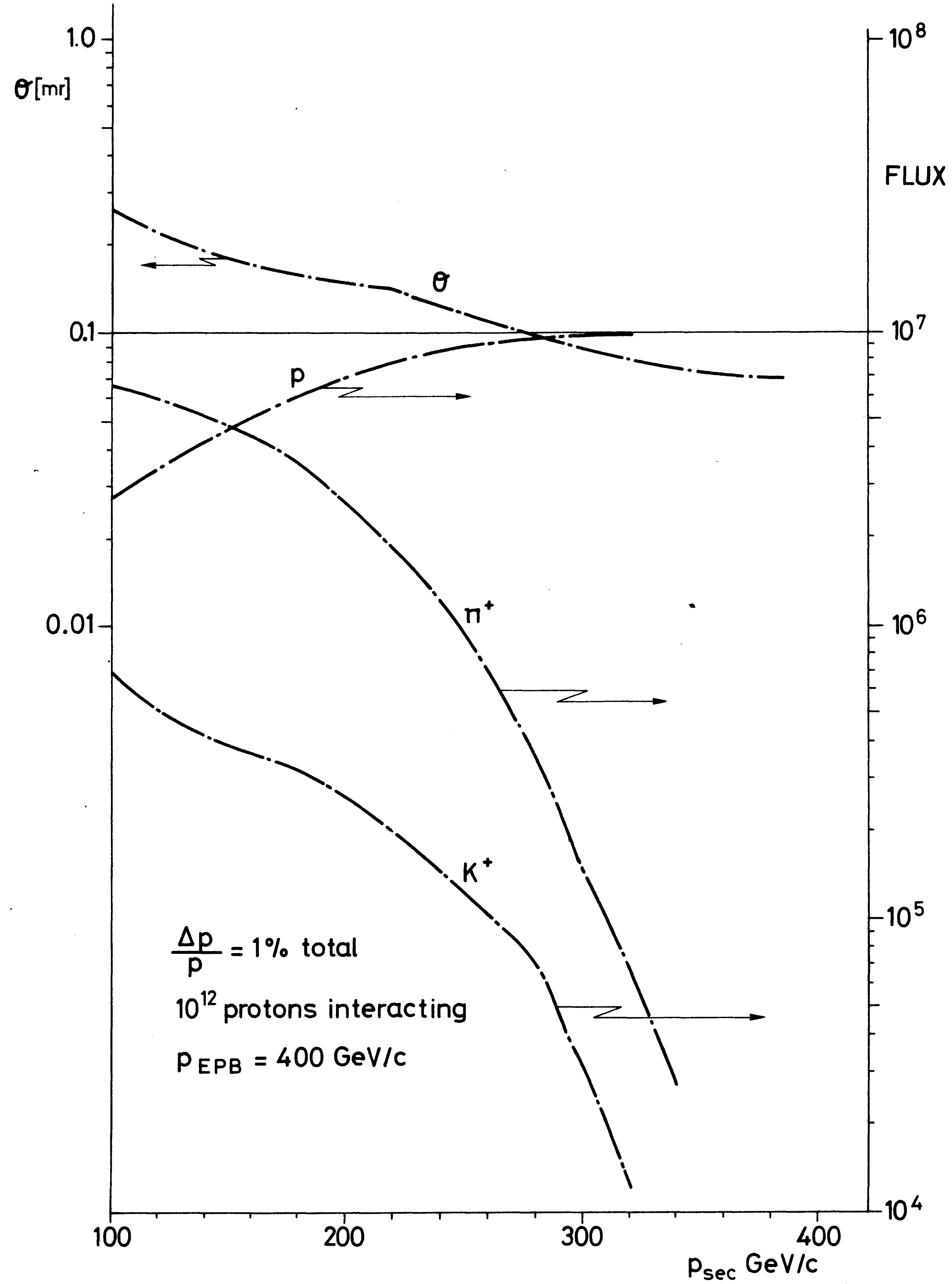
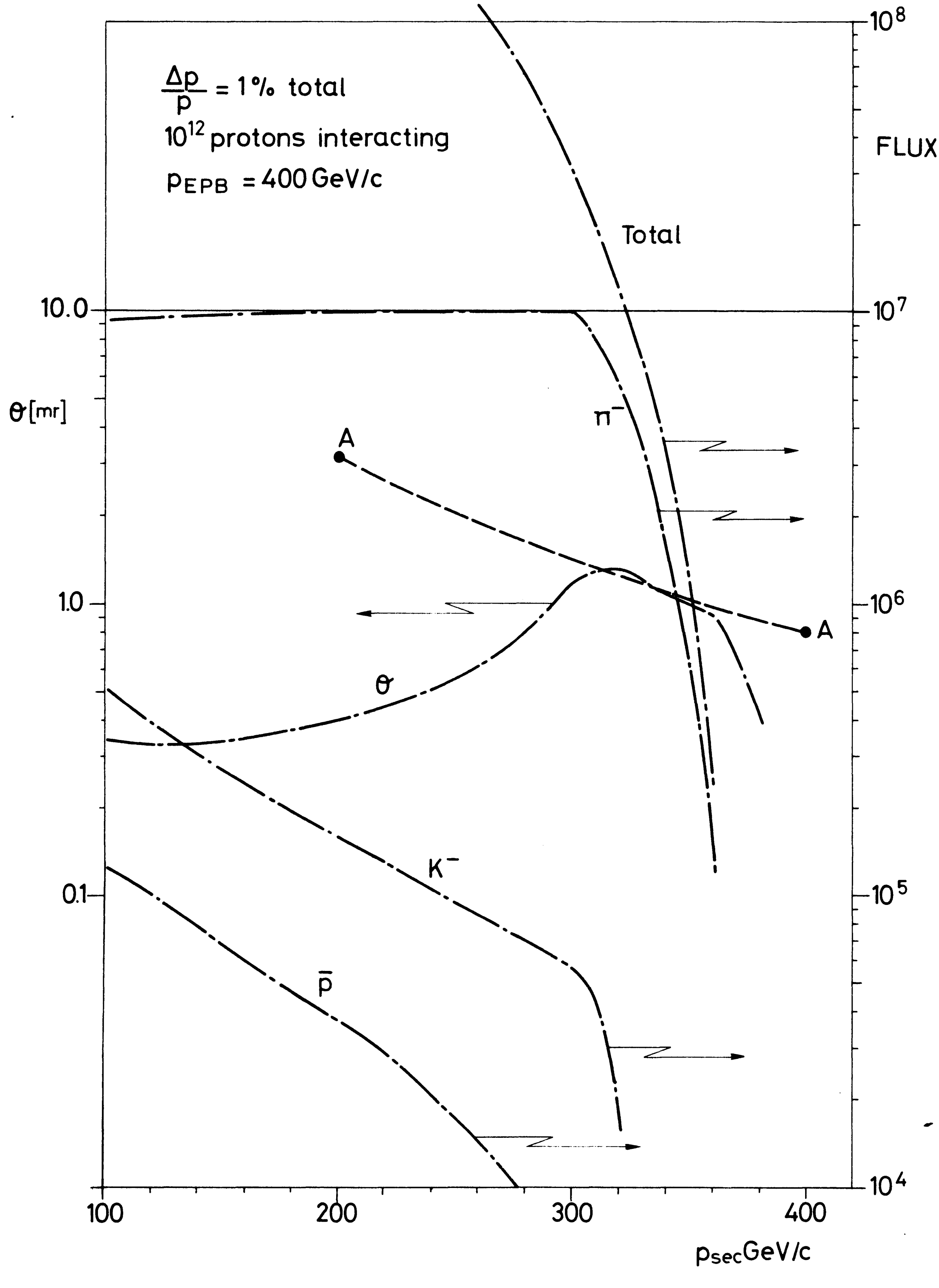

10.0
1.0
0.1
θ[mr]
10^8
10^7
10^6
10^5
10^4
FLUX
Total
A
A
π^-
θ
K^-
$\bar{p}$
$\frac{\Delta p}{p}$ = 1% total
10^{12} protons interacting
p_{EPB} = 400 GeV/c
100
200
300
400
p_{sec} GeV/c

Fig. 3



1.0
θ [mr]
0.1
0.01
10^8
FLUX
10^7
10^6
10^5
10^4
θ
p
π⁺
K⁺
$\frac{\Delta p}{p}$ = 1% total
10^{12} protons interacting
p_{EPB} = 400 GeV/c
100
200
300
400
p_{sec} GeV/c

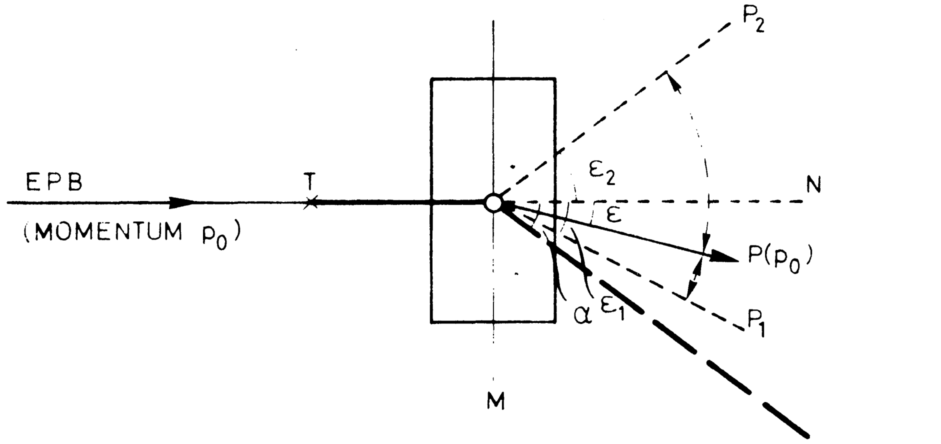
Fig. 4



$\frac{\Delta p}{p}$ = 1% total
10^{12} protons interacting
p_{EPB} = 400 GeV/c
FLUX
Total
10.0
1.0
0.1
θ [mr]
π⁻
A
A
θ
K⁻
p̄
100
200
300
400
p_{sec} GeV/c
10^8
10^7
10^6
10^5
10^4

Fig. 5

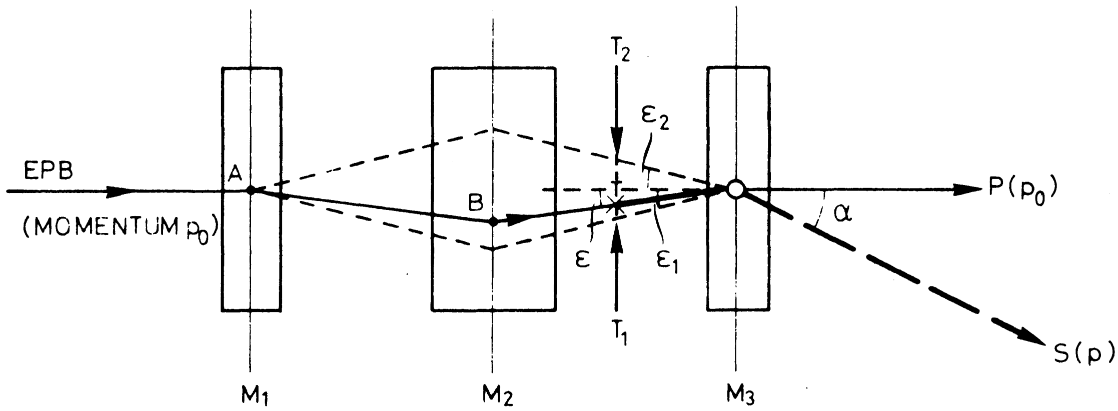
(a) END TARGET STATION



SECONDARY BEAM : MOMENTUM $p = \left(\frac{\varepsilon}{\alpha}\right) p_0$

$$\frac{\varepsilon_1}{\alpha} \geqslant \frac{p}{p_0} \geqslant \frac{-\varepsilon_2}{\alpha}$$

(b) TRANSMISSION TARGET STATION



SECONDARY BEAM : MOMENTUM $p = \left(\frac{\varepsilon}{\alpha + \varepsilon}\right) p_0$

$$\frac{\varepsilon_1}{\alpha + \varepsilon_1} \geqslant \frac{p}{p_0} \geqslant \frac{-\varepsilon_2}{\alpha - \varepsilon_2}$$

Fig. 6 PRINCIPLES OF TARGET STATIONS

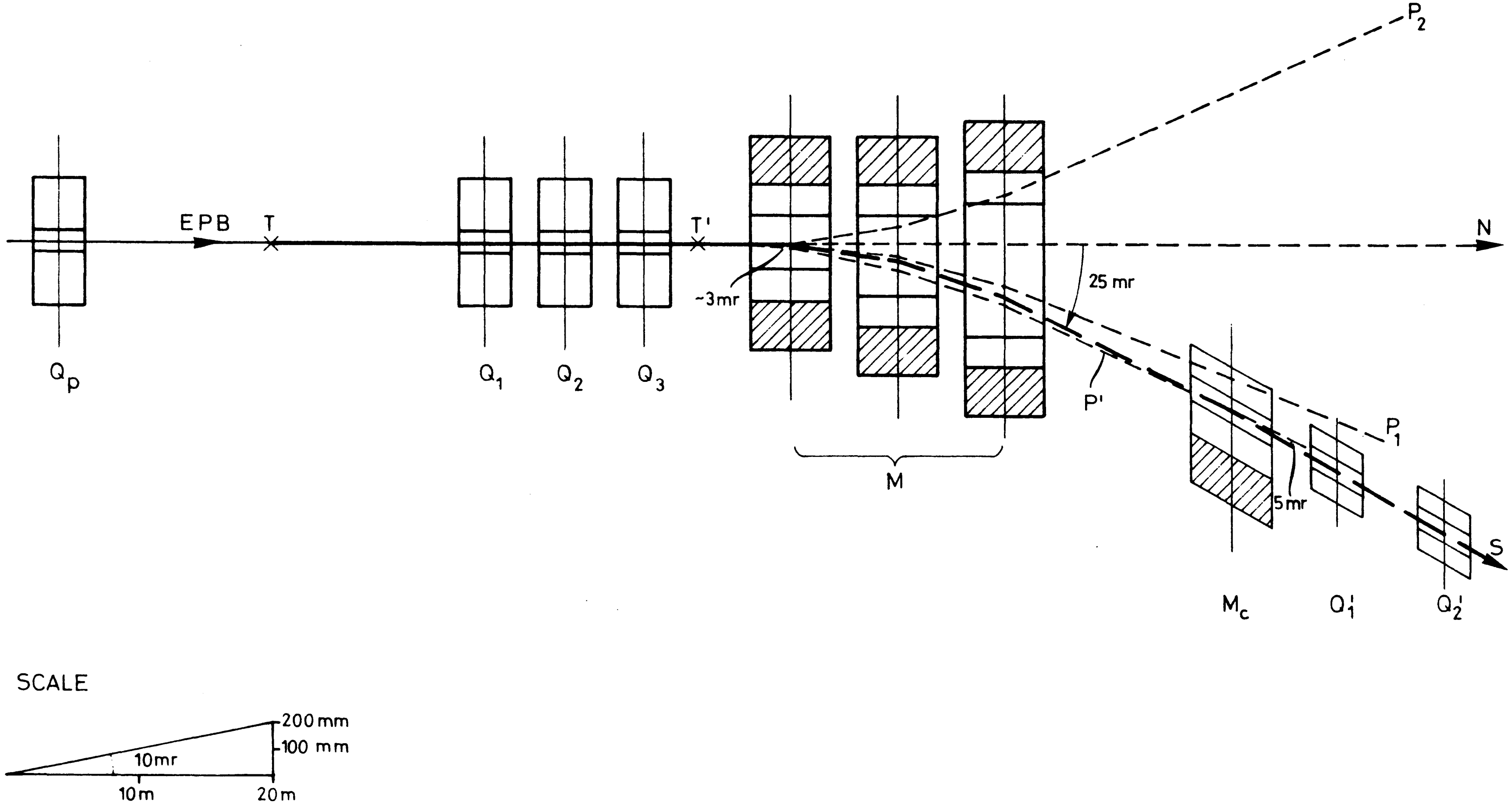


Fig. 7 EXAMPLE OF END TARGET STATION (SCHEMATIC)

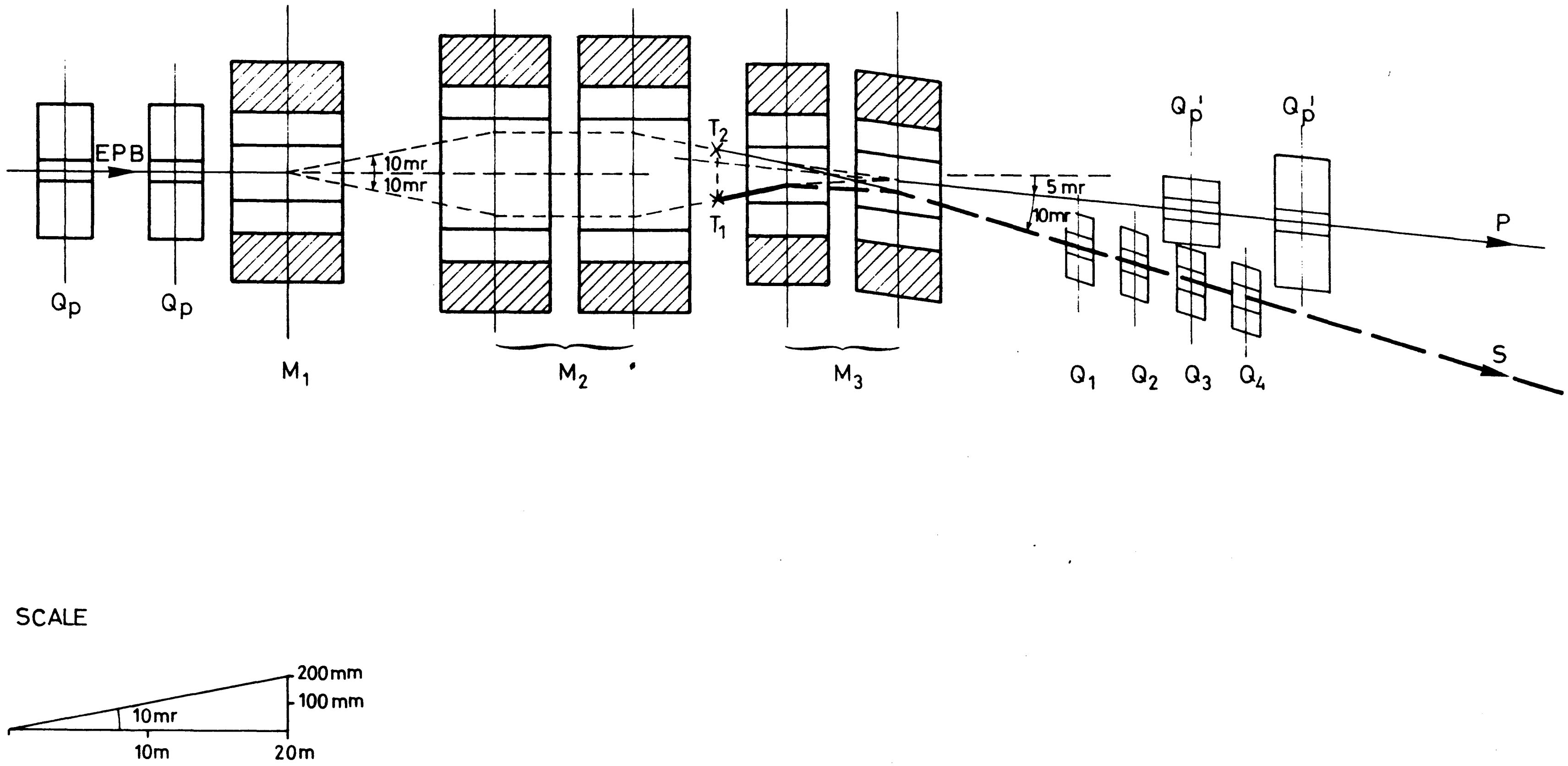


Fig. 8 EXAMPLE OF TRANSMISSION TARGET STATION (SCHEMATIC)

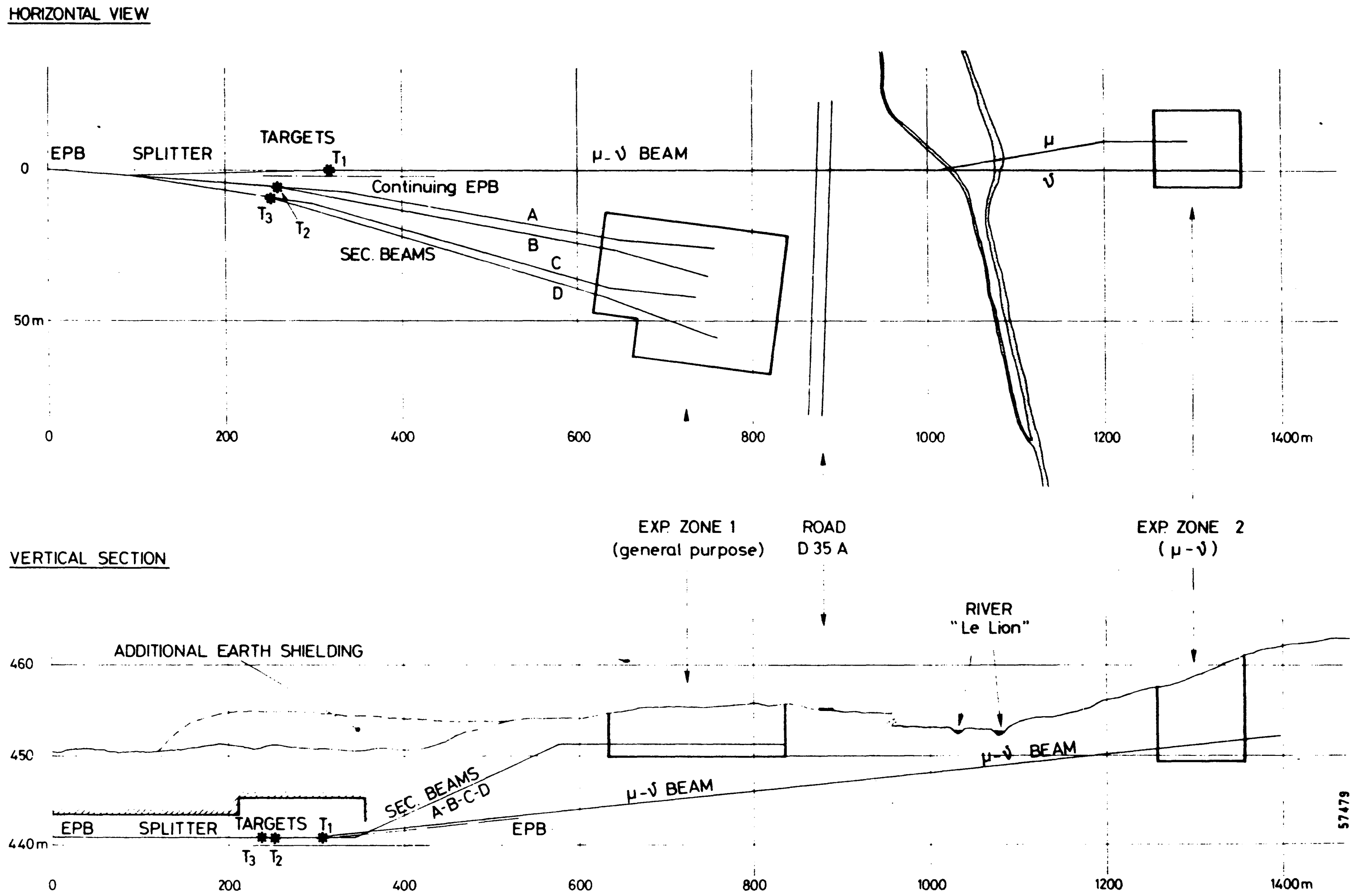
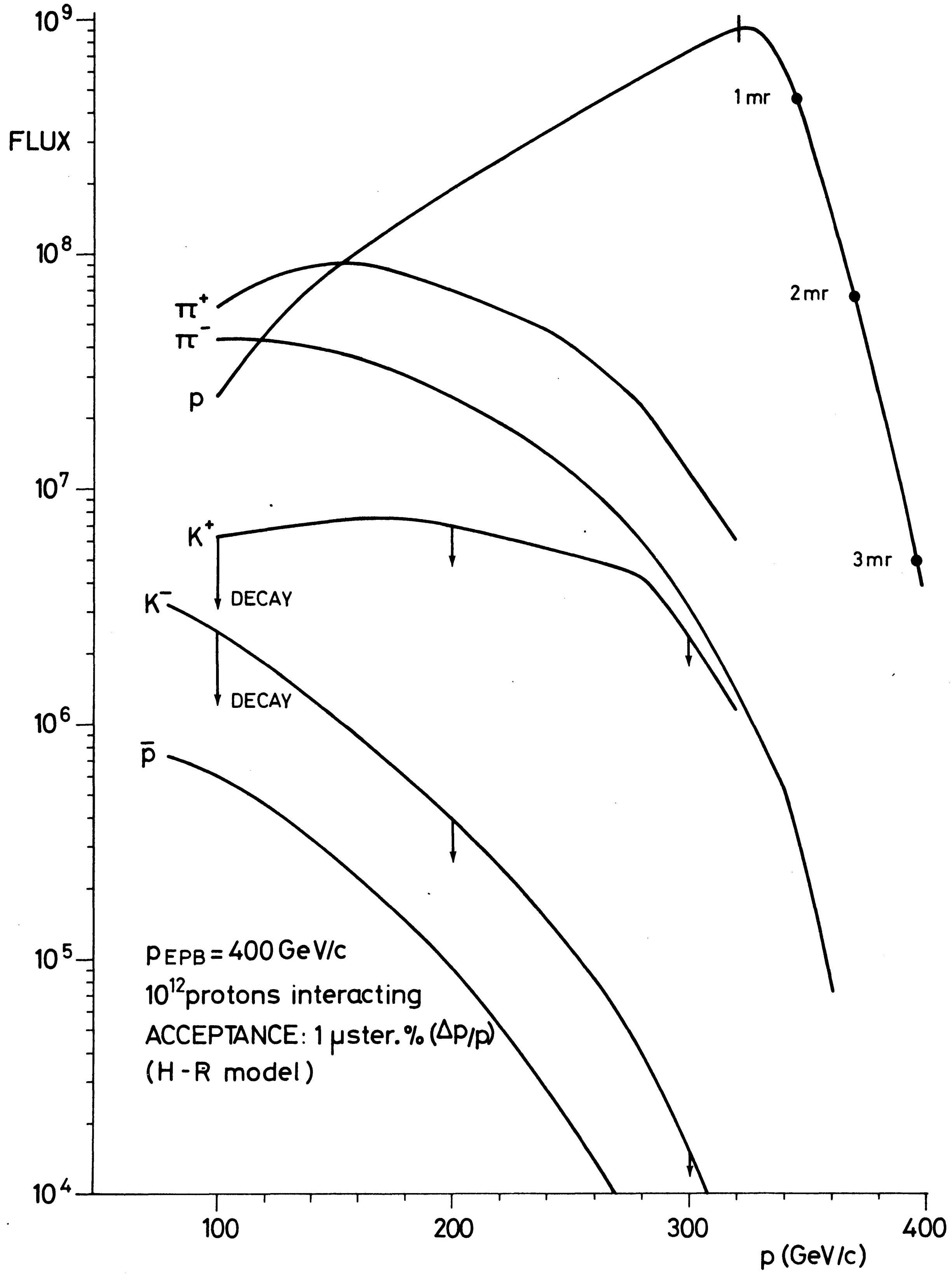


Fig. 9 NORTH AREA LAYOUT



FLUX
10^9
10^8
10^7
10^6
10^5
10^4
1 mr
2 mr
3 mr
π+
π−
p
K+
K−
DECAY
DECAY
p̄
pEPB = 400 GeV/c
10^12 protons interacting
ACCEPTANCE: 1 μster.% (Δp/p)
(H-R model)
100
200
300
400
p (GeV/c)

Fig. 10