national accelerator laboratory

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USE OF THE NAL ELECTRON BEAM FOR PION EXPERIMENTS

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1. INTRODUCTION

As the energy of the NAL accelerator increases, there will be a corresponding demand for secondary beams of higher energy than the ∿ 250 GeV now available in the Meson Lab. In addition, there is a need for high flux pion beams (10^8 - 10^{10}/pulse) to carry out experiments with incident pions that are now done with primary proton beams (for example, inclusive production studies). This latter type of experiment needs not only a large flux, but often small final spot size, so that beam optics problems are not negligible.

We have studied the NAL electron beam[1,2] which is soon to be built in the Proton Lab, as a possible pion beam, particularly as a conventional beam of high energy, but also to see if large fluxes can be obtained.

2. ELECTRON BEAM OPTICS

To convert the electron beam to a pion beam, it is only necessary to remove the front section: proton → γ → electron. The origin of the pions is the main proton target, and magnet element positions remain as for electrons.

A schematic of the optics is shown in Figure 1 (most elements are composed of several magnets). The sweeping dipole is to remove collimator spray; the field lens increases the momentum acceptance ($\Delta p/p = \pm$ 2% with 3" quadrupoles). Dipoles D_2 are the last beam elements in the electron beam to ensure that any background is swept away from the tagging target, and also the required dipole aperture is smaller in this position. However, with this arrangement the field lens can only be effective if lenses Q_3, Q_4 are horizontally defocussing, focussing, respectively. This means that Q_1, Q_2 must be focussing, defocussing (so that the overall magnification in both planes is small), which gives a large horizontal magnification and, therefore, poorer momentum definition at the momentum collimator. (The size of the image there corresponds to $\frac{\Delta p}{p} = \pm\ 0.4\%$; if it were possible to reverse Q_1 Q_2, $\frac{\Delta p}{p}$ would $= \pm\ 0.1\%$.)

The limiting horizontal aperture is Q_1, and vertical is D_1 ($\pm$ 1"). A larger D_1, necessitating also a larger D_2, would make Q_2 ($\pm$ 1.5") the limiting vertical aperture, giving a $\sim$ 30% increase in flux.

3. TARGETING

We show schematically in Figure 2 how 0° production can be accomplished with the Proton Area targeting system. This method can be used for π^-, but only for low momentum π^+.

In Figure 3 we show a prediction(3) for the ratio of π^- flux at finite angles compared to 0°; for many experiments the loss of flux at 1 mr, for example, is not serious. (It should be noted that early NAL results show that the loss is not even as much as given in the curve.) Thus, we can consider $\sim$ 1 mr production angle suitable for many experiments; identical +ve and -ve beams are then possible. Targeting is shown schematically in Figure 4. A 1 mr production angle is currently in use in the Meson Area. The distance from target to dump is greater in the Proton Area (30 ft. cf. 20 ft.) which facilitates small angle use.

4. MAXIMUM PION FLUX

We can consider magnet placement identical to the electron beam with the distance from last dipole to experiment somewhat arbitrarily chosen as 90 ft. In Figure 5 we show the calculated spot size and momentum acceptance[(4)]. (The spot size could be reduced by making the final distance shorter.) The overall acceptance is

$$\Delta\Omega \left(\frac{\Delta p}{p}\right) = 6.3 \ \mu\text{st. } \%$$

The acceptance is limited by the dipole vertical apertures; changing all dipoles to the proposed 6-3-120 type, the acceptance becomes $\sim$ 8 μst. %. If quadrupoles are changed to 4Q120's, the acceptance would be $\sim$ 11 μst. %, while changing both dipoles and quadrupoles gives $\sim$ 17 μst. %.

These numbers can be compared to other beams:

Meson Lab M1	(3" quads)	$\lesssim$ 4 μst. %
Guiragossián & Rand[(5)]	(3" quads)	9.5 μst. %
Cronin Special Purpose Beam[(6)]	(4" quads)	100-200 μst. % (depending on final spot size)

Fluxes obtainable in this beam can be predicted when sufficient NAL particle production data is available. The data of Appel et al[(7)] indicates that a 10 μst. % acceptance would give $\sim 10^{-5}$ π^-/proton at 0^o for 150 GeV/c π^- with 300 GeV/c protons incident on a 1" tungsten target.

5. USE OF DIFFERENTIAL CERENKOV COUNTERS FOR PARTICLE IDENTIFICATION

Schematic beam optics including a parallel section for a differential Cerenkov counter (of the type to be used in the Meson Lab M1 beam) is shown in Figure 6. We have taken the beam upstream of the parallel section as identical to the electron beam.

The required parallelness depends on the details of the Cerenkov counter. For a 100' counter, a Cerenkov angle of 7.5 mr can be used. This leads to a beam divergence requirement for 450 GeV/c π -K separation of better than 0.07 mr, otherwise the counter will be inefficient. (Note that Liouvilles Theorem says that for a $\pm$ .04" production target, $\pm$ 1 mr beam acceptance angle, the divergence at a point in the beam where the beam size is $\pm$ 1" will be $\geqslant$ .04 mr.)

In Figure 7 we show histograms of the beam divergence at the Cerenkov counter. Although not quite as good as desired, it can be improved as shown by cutting the momentum bite and/or the production target size, at the expense, of course, of flux.

6. MAGNET REQUIREMENTS

At 300 GeV/c, the number of magnets required is the same as the electron beam, with an additional 4 quadrupoles if a Cerenkov parallel section is used. If we take 500 GeV/c as a design upper momentum limit, the magnets needed are given in Table 1. Also shown in the Table are the number of 4Q120 quadrupoles and 6-3-120 dipoles needed if these are used to increase the acceptance.

7. LAYOUT

A layout of the Tagged Photon Hall at the end of the electron beam is shown in Figure 8 for a high flux beam, and in Figure 9 for a beam with a parallel Cerenkov section. In each case the number of magnets shown is for 300 GeV/c.

For some experiments, such as pion total cross sections or elastic scattering, for instance, a tunnel of $\sim$ 250' length would be required extending from the downstream end of the hall.

8. REFERENCES

1. C. Halliwell et al, Nucl. Instr. & Methods, 102, 51, 1972.

2. T. Nash - Private communication.

3. C. L. Wang, BNL Report No. 17522, 1972, p. 151.

4. Using the Beam Program of J. D. Fox, BNL, Modified by C. T. Murphy.

5. Z. G. T. Guiragossián and R. E. Rand, Nucl. Instr. & Methods, 107, 237, 1973.

6. J. Cronin, 1973 NAL Summer Study - to be published.

7. J. Appel et al, - Phys. Rev. Letters 32, 428, 1974.

TABLE 1

MAGNET REQUIREMENTS

PRESENT TYPE MAGNETS	300 GeV/c	500 GeV/c
3Q120 Quadrupoles	9	13
4-2-240 Dipoles	2	3
5-1.5-120 Dipoles	7	10
Additional 3Q120 Quadrupoles for Parallel Section	4	3

FUTURE TYPE MAGNETS	300 GeV/c	500 GeV/c
4Q120 Quadrupoles	9	11
6-3-120 Dipoles	10	15
Additional 4Q120 Quadrupoles for Parallel Section	1	3

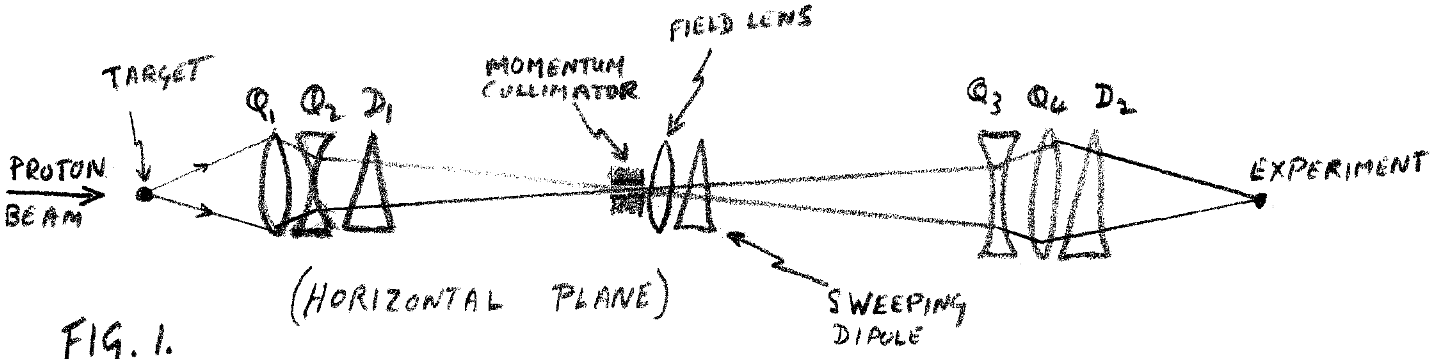


FIG. 1.

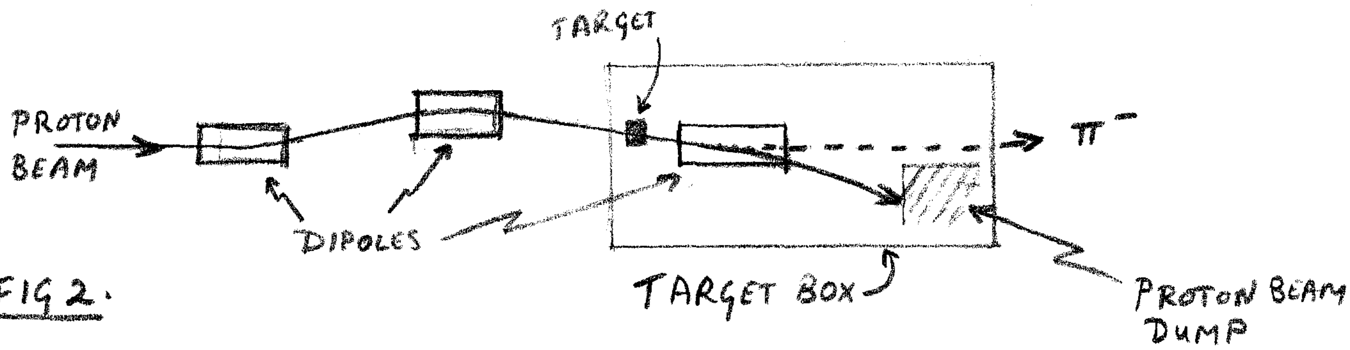


FIG 2.

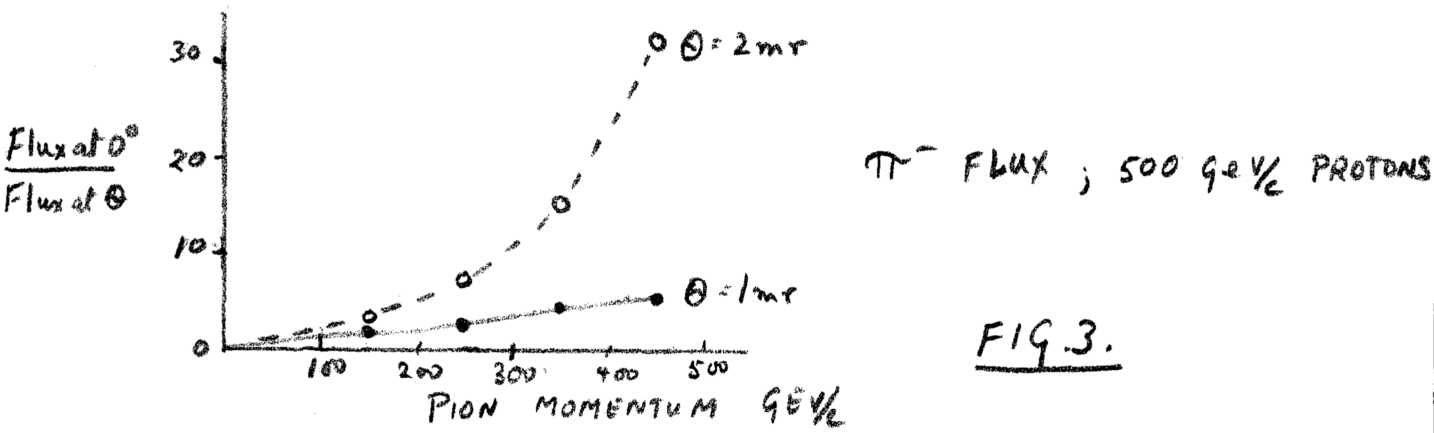
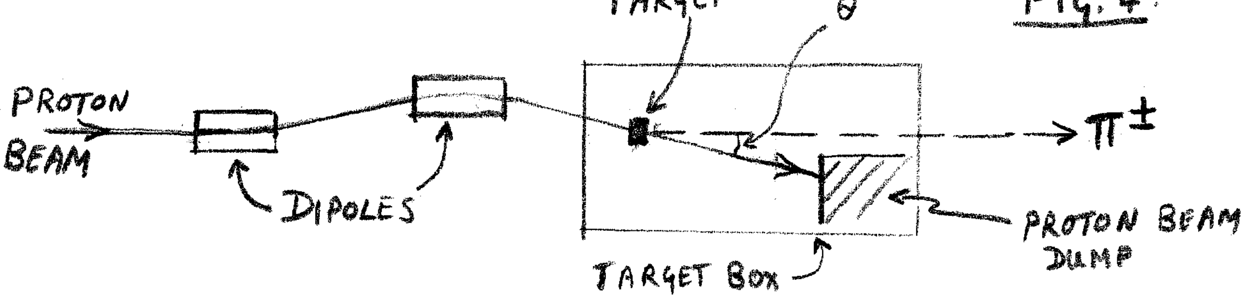


FIG 3.

FIG. 4.



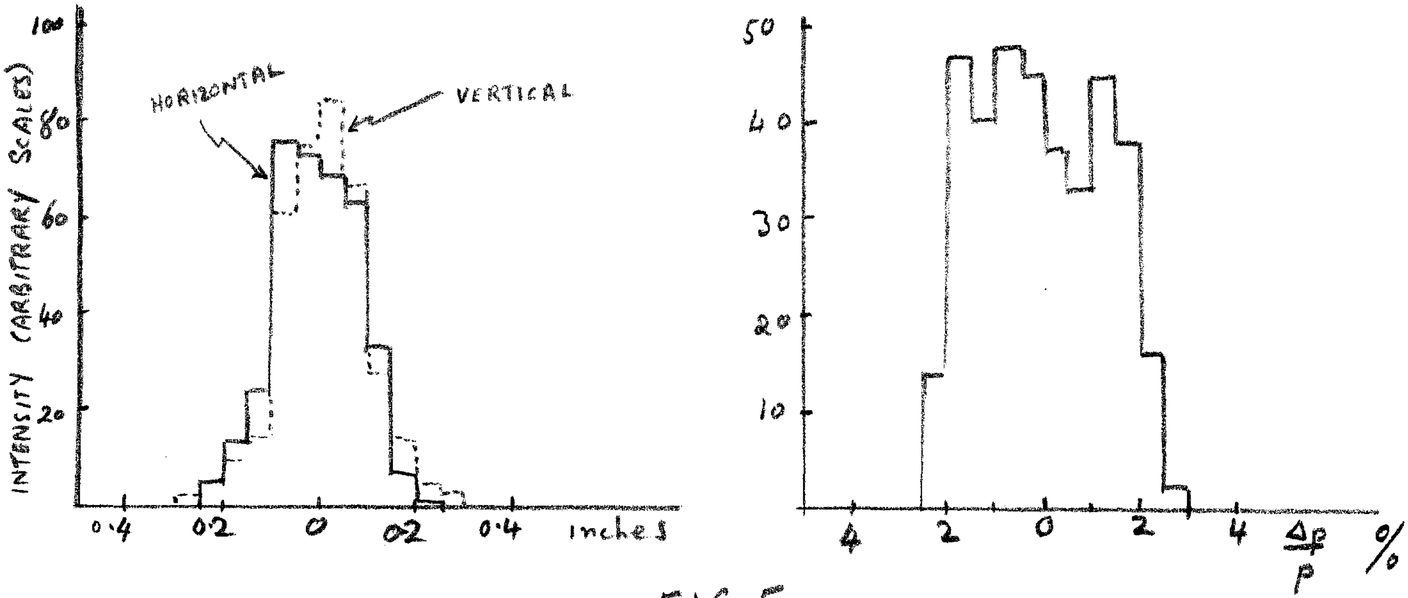


FIG. 5.

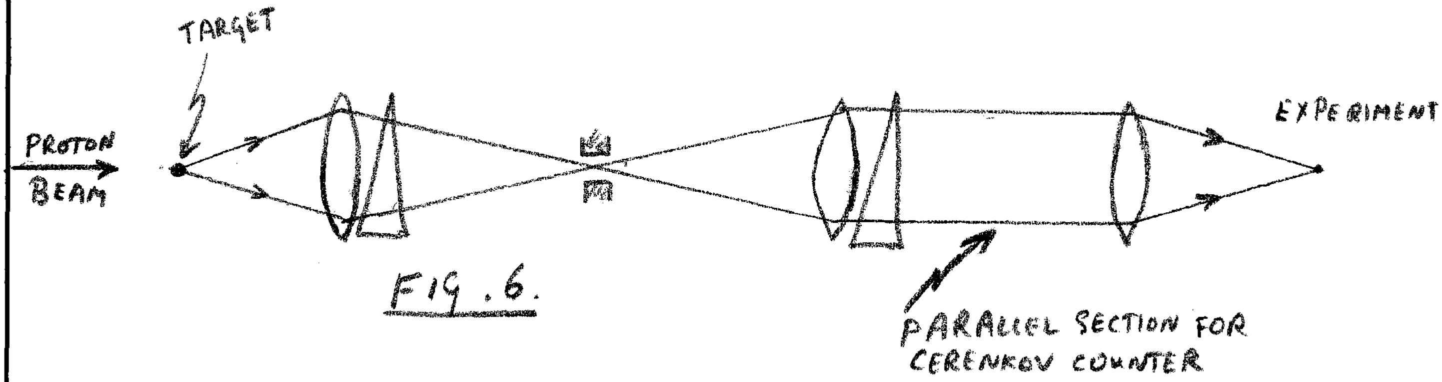


FIG. 6.

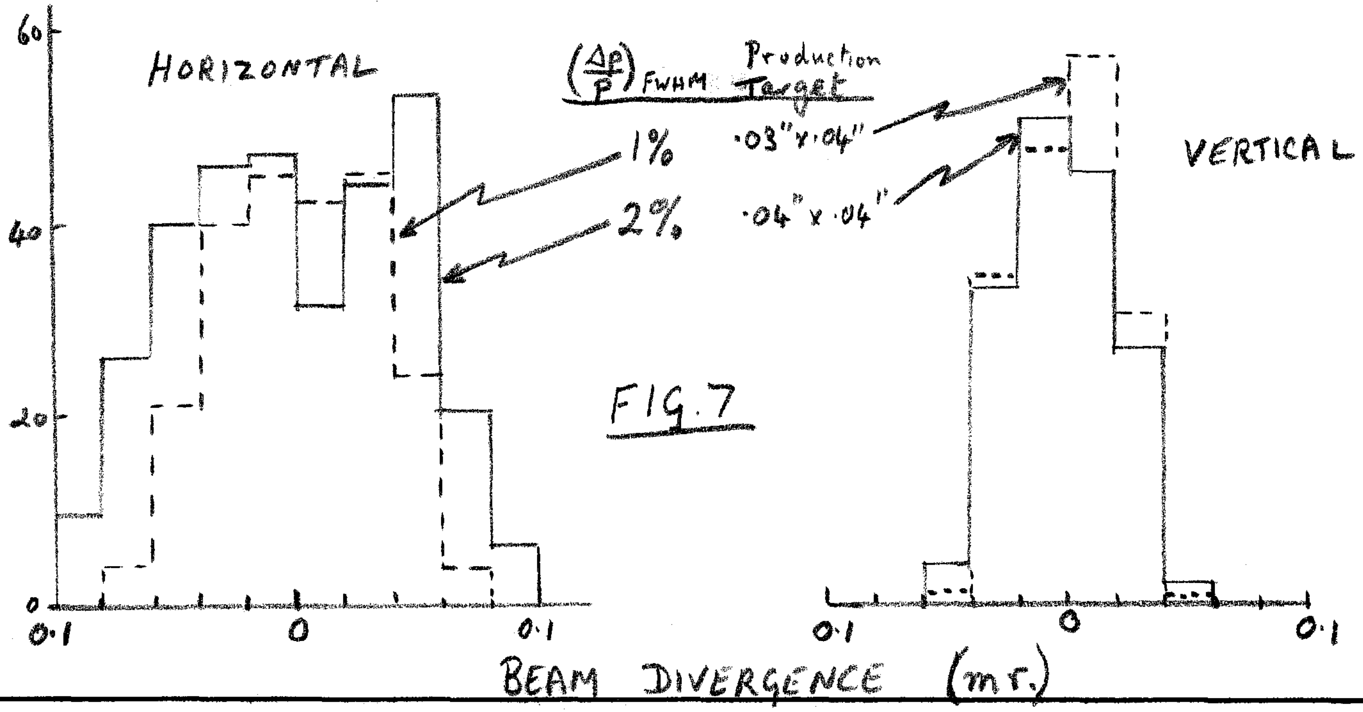


FIG. 7

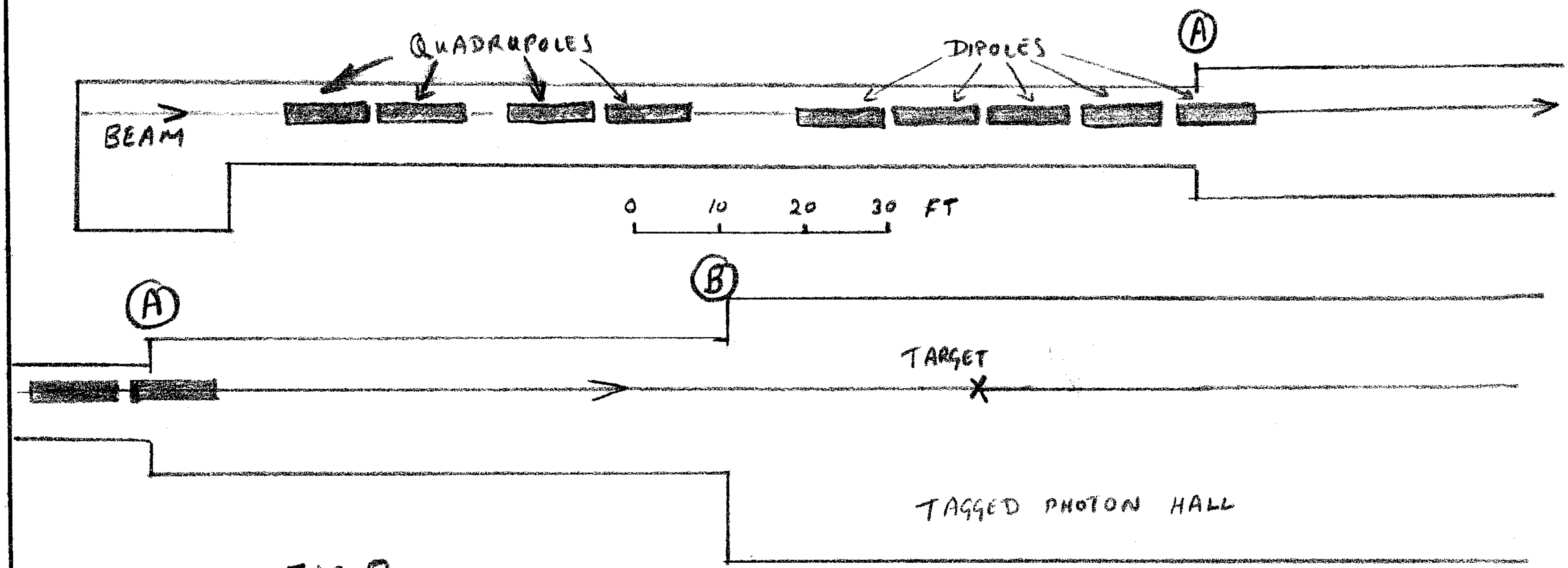

QUADRUPOLES
DIPOLES
A
BEAM
0 10 20 30 FT
B
A
TARGET
TAGGED PHOTON HALL

FIG 8.

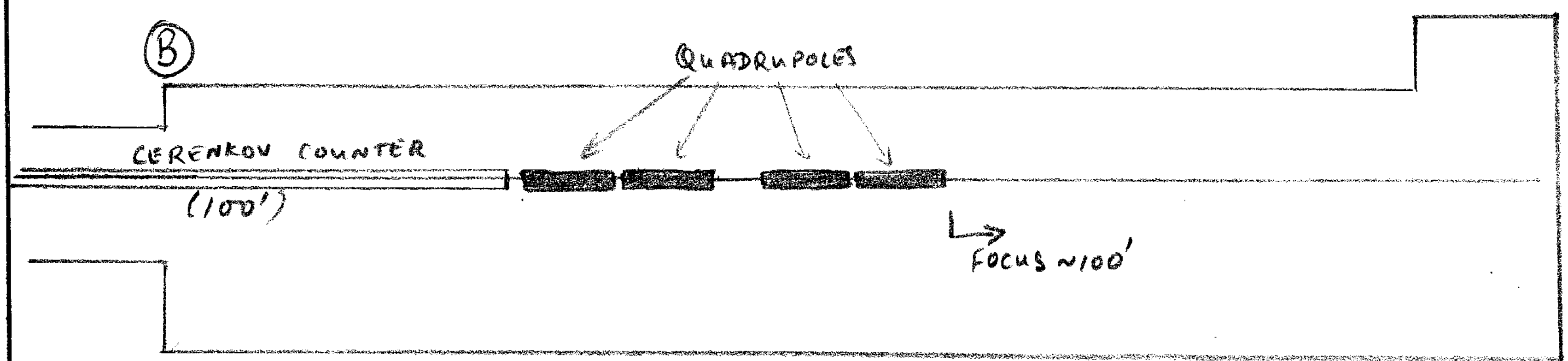

B
QUADRUPOLES
CERENKOV COUNTER
(100')
FOCUS ~100'

FIG. 9.