NAL PROPOSAL NO. 149

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A Survey Measurement of Charged Hyperon Fluxes, Including a Search for New Particles in the Mass Range up to 5.5 GeV/c^2, of Proper Life-time Larger than $3 \cdot 10^{-11}$ Seconds.

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July 15, 1971

Proposal for Experimental Research at the
National Accelerator Laboratory

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ABSTRACT

We propose to measure the yield of charged hyperons, and to search for new particles at NAL in a short unfocussed beam, using a Cerenkov counter technique. We will detect charged particles of proper lifetime $\geq 3 \cdot 10^{-11}$ seconds, and of mass between 1 and 5.5 GeV/c^2. We hope to answer the following questions:

a) What are the production rates of the known hyperons and in particular do the relative production rates of baryons of strangeness = 0, -1, -2 and - 3 exhibit any regularity?

b) Can a useful flux of Σ^+ hyperons be identified? If it can, such a "Σ^+ beam" would be unique to NAL since this possibility is excluded at lower energy accelerators. This question has important implications for planning a specific experiment on $\Sigma^{\pm} \rightarrow \Lambda\ e^{\pm}\nu$ which is a test for the existence of a second class current in the weak interactions.

c) What are the optimum conditions for the design of a high intensity hyperon beam?

d) Finally, are there additional hyperons of mass larger than the Ω^- particle of either plus or minus charge?

We believe that an early answer to these questions would enhance future hyperon experiments at the National Accelerator Laboratory.

Physics Justification:

Introduction

There is at present mounting interest by our group and many others in hyperon beams.[1-17] These beams are expected to be used for (a) elastic and inelastic hyperon proton scattering,[2-8,10-15] (b) non-leptonic hyperon decay[9,16] investigation, and (c) semi-leptonic decay studies of hyperons.[2,12] Although (a) and (b) might be done in less than optimum intensity beams and without on line particle identification (tagging), we feel the very low branching ratios for beta decays dictate a tagged beam of optimum intensity.

Both the increased flux, and the higher energy afforded by the NAL offer unique advantages in net hyperon flux, and especially the ability to create both Σ^+ and Σ^- beams. Further, at NAL the Σ^+/p ratio in the positive beam should be much more favorable than at any other accelerator. Therefore we have begun work on an experimental design for an accurate measurement of the rates of $\Sigma^\pm \to \Lambda e^\pm \nu$, which is a test for the presence of second class currents in the weak interactions. We have designed a high resolution, large acceptance Cerenkov counter that will identify on line the $\Sigma^\pm$ hyperons at NAL energies. Further progress in our experimental design (and we imagine all other proposed hyperon experiments) would be greatly aided by an early measurement of hyperon fluxes at NAL. We need to know especially the Σ^+/p ratio which cannot be extrapolated reliably from lower energies. A detailed study of hyperon production could be performed using the Cerenkov counter described below, and this instrument would allow a search for additional short lived particles (proper life $\geq 3 \cdot 10^{-11}$ sec) up to a mass of 5.5 GeV/c^2.

We therefore propose to make an early study of the production fluxes of all charged particles of mass between 1 and 5.5 GeV/c^2, and proper lifetime $\geq 3 \cdot 10^{-11}$ sec. In the sections that follow we shall outline an efficient technique using a short (6 meters) unfocussed beam channel and a differential Cerenkov counter.

Physical Mechanism of Hyperon Production

At NAL, hyperons will be produced most copiously via strong interaction associated production by incident proton beams. At high energies diffraction like particle production is expected to become increasingly important. It is already known that certain N*'s have associated (strange particle) decays, and it has been proposed that one of the main sources of hyperons will be from nucleon resonance diffractive reactions such as:[18,19]

$$\begin{array}{l} p + N \rightarrow N^{*+} + N \\ \qquad\qquad \hookrightarrow Y^{+} K^{0},\ Y^{0*} K^{+} \\ \qquad\qquad\qquad\qquad\quad \hookrightarrow Y^{-} \pi^{+} \end{array} \tag{1}$$

where Y is an s = -1 hyperon. In addition, hyperons may be produced in a one step "fireball" for example:

$$p + N \rightarrow N + Y^{-} + K^{0} + 2\pi^{+} \tag{2}$$

or via a two step process such as

$$\begin{array}{l} p + N \rightarrow p + N + \pi^{\circ} + K^{0} + \bar{K}^{0} \\ \qquad\qquad \text{with, } \bar{K}^{0} + n \rightarrow Y^{0} + \pi^{\circ} \\ \qquad\qquad\qquad\qquad\quad \rightarrow Y^{-} + \pi^{+} \end{array} \tag{3}$$

In figure (1) we show the prediction of Grote, Hagedorn and Ranft[19] concerning the Σ(fireball + diffraction dissociation) and the Ξ(fireball only). Reaction (1) will tend to produce forward Y's at close to the beam energy. Reaction (2) (fireball) tends to peak the Y momentum much lower, as would also be the case from 2-step reactions (3). In a first measurement of the hyperon system we cannot hope to disentangle the production details well enough to know exactly what is happening inside the target. However, we can answer some questions of physics interest, these are:

a) Is there any regularity in the production rates of particles of strangeness 0, -1, -2, and -3? There have been suggestions, based on the dual resonance model and Lorentz covariance arguments, that for large transverse momentum, the relative abundances vary slowly with mass for heavy particles, almost independent of strangeness.[20] This would be relatively easy to check at NAL energies.

b) Is there a new particle beyond the Ω^-? All three models of hyperon production indicate that our measurements would be sensitive to the production of previously unreported hyperon-like particles; do these exist?

In addition, our measurements should produce data on hyperon fluxes to aid designs of hyperon beams for specific experiments.

Experimental Method

(a) General description:

Hyperons will be produced by a high energy proton beam incident on a heavy element target. A short (6 meter) unfocussed magnetic channel of inherent momentum spread $\Delta p/p_0 \approx 20\%$ set at the momentum $75 < p_0 < 150$ Gev/c will deflect and define the secondary beam. We will further restrict the beam with scintillation counters using the correlation of position and angle to specify $\Delta p/p_0 \approx 5\%$ on line. We have designed a special differential Cerenkov counter of unique optical construction that will then identify the hyperons in the presence of high fluxes of π, k, p in the beam. The expected yields of particles at a distance of 12 meters from the target is shown in fig. 2.

(b) Cerenkov counter.

The Cerenkov counter is described in detail in reference 21, but we will review here its main characteristics. The counter length and Cerenkov angle, were chosen as described below. For example at p = 150 Gev/c a three way light splitter divides the Cerenkov light into bands $\Theta_1 < 9.4$ mrad ("under"), $9.4 \leq \Theta_2 \leq 10.6$, and $10.6 < \Theta_3$ ("over").[22] The pressure is adjusted such that the hyperon of interest counts in Θ_2. Θ_1 and Θ_3 are then anticoincidence channels. The light is directed from each band of angle into the photomultiplier tubes with a "light funnel."[23] Such a counter need only be 5 to 6 meters long, has an expected efficiency of $> 99\%$ and a calculated rejection of $\sim 10^{-6}$ for unwanted on momentum particles. Due to the relatively small Cerenkov angle (10 mrad) we gain two advantages over other differential Cerenkov counters with similar characteristics;[24] (a) dispersion is relatively small and need not be corrected thus the counter is less complicated and cheaper to build. (b) angular acceptance is an order of magnitude larger, which is extremely important in an unfocussed beam.

Due to the efficient anticoincidence counting of beam particles, a false count from a beam particle is not a troublesome background. However we expect that particles not associated with the beam can traverse the counter and count in the differential section while failing to anti. One way for this to happen is for a muon to produce light in the glass envelope of the differential photomultiplier tube. If, at the same time, a false beam trigger were to occur (perhaps due to afterpulsing in the trigger counters), then a false event would be recorded. We plan to take the following precautions to guard against this type of failure:

1) Reduce beam trigger false coincidences to the minimum possible by using nonoverlapping light pipes for the scintillators, and specially chosen low-after-pulse photomultipliers.

2) Place four photomultipliers instead of one on the differential light funnel of the Cerenkov counter, so arranged that each sees only one quadrant of the differential mirror (see figure 3). Our trigger will demand two opposite photomultipliers in coincidence. This reduces both stray background and far off-axis particles that fail to anti due to anti inefficiency.

3) Stagger the four differential photomultiplier tubes so that it is unlikely for any one particle coming from near the production target to hit two opposite tubes.

4) Surround the tubes with an anti-counter.

With these techniques we hope to hold our beam failures to no more than one per 10^4 true beam triggers, and our accidental rate in the four Cerenkov counter differential tubes to 10^5/sec, for a 10^7/sec beam rate. Then the number of false events, assuming a 5×10^{-9} sec coincidence resolving time, is given by the product of the false differential rate

$$\frac{10^5}{\text{sec}} \times \frac{10^5}{\text{sec}} \times 10^{-8}\text{sec} = 10^2/\text{sec}$$

and the beam failure rate.

$$10^{-4} \times 10^7 = 10^3/\text{sec}$$

The net false events are

$$\frac{10^2}{\text{sec}} \times \frac{10^3}{\text{sec}} \times 10^{-8} = \frac{10^{-3}}{\text{sec}} \quad .$$

For a beam of 1 sec spill this is then 1 false event per 10^3 pulses. If we include a safety factor of 10 then our estimate of the background counting rate is 1 false event per 10^2 pulses.

(c) Optimization of the Cerenkov Counter Design.

We have studied the optimum conditions for the use of a differential Cerenkov counter in an unfocussed beam.[25] Figure 4 shows the intensity I, as a function of γ of the particle and $\Delta\Theta$ the acceptance of a Cerenkov counter in such a beam.

The line $\partial I/\partial(\Delta\Theta) = 0$ for constant γ shows the best tuning that can be obtained at any γ. The intersection of the line $\partial I/\partial\gamma = 0$ shows where the maximum intensity occurs. Note that the curve of constant counter length ℓ_c = 5.5 meters closely approximates the optimum curve. This fact suggest the proper counter length and tuning conditions. Therefore, only $\Delta\Theta$ should be changed to correspond to a change in γ. We conclude that the following design parameters are appropriate: length about 5 to 6 meters, Cerenkov angle Θ_c = 10 mrad, and angular acceptance $\Delta\Theta_c$ = 1.2 mrad full width (chosen for Σ, Ξ separation at 150 GeV/c).

(d) Monte Carlo Studies of Cerenkov Counter Rejection.

In Reference 21 we have computed the rejection for an idealized beam with angular divergence close to the counter angular acceptance, and a small uncorrelated momentum acceptance. The proposed NAL hyperon beam is substantially larger in divergence and momentum spread than the counter acceptance. We have written a Monte Carlo program which tests the Cerenkov counter performance for one possible configuration of the NAL hyperon beam. Particles are generated randomly in momentum, angle and position in a 1 mm square target, at the entrance to the magnetic channel. The channel is 6 m long, with a 30KG magnetic field. The entrance and exit apertures are 2 x 2 mm and 6 x 6 mm respectively. Discrete apertures are inserted at 1.5 m intervals, to represent the walls of the channel. The increase in width of the apertures is proportional to the distance from the target. For a central momentum of 150 Gev/c, the output of the channel is a beam with $\Delta p/p = 12\%$ (fwhm), vertical divergence of 1 mrad (fw), and a horizontal divergence of 2.4 mrad (fwhm).

These particles are then examined to see if they would trigger the Cerenkov counter. The Cerenkov angle is calculated from the particle velocity and the index of the gas. The actual number of photoelectrons produced by each particle is randomly chosen from a Poisson distribution, where the average number of photoelectrons is equal to $100 \cdot \sin^2\Theta_c \cdot L$, (L is the length of the counter in cm). These photoelectrons are then distributed randomly in azimuth and over a small range of Cerenkov angle, appropriate for the dispersion of Helium gas ($\Delta\varepsilon/\varepsilon = 0.016$). The photoelectrons (which represent detected photons) are then propagated through the spherical mirror and the light splitter using geometrical optics, and the number falling on each photomultiplier is counted. One photoelectron in a photomultiplier is considered sufficient for detection. The differential mirror is divided into 4 quadrants and there is one "over" and one "under" photomultiplier, for a total of six (see figure 3). The outputs of the six PMT's are examined to determine the successful counts. A success is

$$(\overline{\text{over}}) \cdot (D1 \cdot D3 + D2 \cdot D4) \cdot (\overline{\text{under}}).$$

where D1 thru 4 are the 4 quadrants of the differential mirror, · means AND, + means OR, and $\bar{x}$ means no count in x.[26]

The results are summarized in Table I. The $\Delta\Theta$ is chosen as large as possible without directly including the undesired particle. Unwanted (wrong mass) particles that count are, for most part, sufficiently off-momentum to simulate a particle of the desired mass. Better rejection can be obtained by narrowing the momentum acceptance and divergence of the beam to be compatible with the counter.

Experimental Objectives

A. Hyperon Production Measurements.

The objective of the first measurements is to survey the production of the Σ^+, Σ^-, Ξ^- and Ω^- particles. In order to accomplish this, we shall measure fluxes at an incident proton energy of 200 GeV as a function of:

a) Secondary beam energy, in three steps p = 150, 110, 75 GeV/c.

b) Secondary beam angle with respect to the primary beam, in three steps of 0°, 5 mrad, and 10 mrad.

We shall record both beam and non-beam background. Such a study would provide useful hyperon flux data for beam and experiment design, as well as for physical understanding of hyperon production mechanisms.

The average expected flux[13,19] in our apparatus, is about 10^{-7} $\Sigma^{\pm}$/incident proton, 10^{-9} Ξ^{-}/proton, and 10^{-11} Ω^{-}/proton. Thus while we could begin tuning at perhaps 10^{7} incident protons/pulse, we would need about 10^{13} to 10^{14} protons total for our survey of the known hyperons.

B. Mass Search.

The mass search will be over the same kinematic variables as Section A. The mass variation will be over 17 points at $\Delta m/m = .2$ GeV/c^2 between 2 and 5.5 GeV/c^2. For a sensitive mass search we wish to take 10^3 pulses per point, with at least 10^9 incident protons/pulse. Thus we need about $3 \cdot 10^{14}$ protons on target. Figure 5 shows beam acceptance and mass resolution for a counter modified for a mass search. Figure 6 shows the sensitivity vrs. mass and life time, based on a lower limit of one false count per 100 pulses, assuming a flux of 10^{-5} Σ^{-}/incident proton, which we expect in our apparatus at 150 GeV/c, 0°.

C. Tuning and Set Up.

In addition to the above requirements we need a minimum of two weeks for the set up and tuning of our equipment.

Experimental Equipment

We will use an unfocussed magnetic channel and differential Cerenkov counter close to the production target (6 meters) to study charged particle fluxes. The hyperon beam will be defined to $\Delta p/p_0 \approx 5\%$ by scintillation counters, and fast logic. In addition, in order to understand the counter performance, proportional wire chambers will be used in test runs to measure the beam divergence. For every particle accepted by the Cerenkov counter we will record the pulse-height of the counter photomultiplier tubes signals.

We shall need the following equipment:

Beam . The short charged beam located at the end of the diffracted proton beam m2 required for NAL experiment # 97, is suitable for our study. This beam is currently scheduled for operation in the middle of 1972. Our estimates are based on a channel width of 2 x 2 mm input and 6 x 6 mm output, appropriately curved so that the central ray at 30 KG magnetic field is 150 Gev/c.

Cerenkov Counter. We will build the Cerenkov counter. We estimate that this will take from 6 to 9 months for constuction and testing, and will be ready early in 1972. We will also supply equipment to measure the index of refraction of the Cerenkov radiator. Either a laser interferometer or a microwave refractometer would be capable of the required precision of about 3×10^{-6}.

Beam Instrumentation. Scintillation counters and fast logic are required to define a suitable beam. In addition, at least 4 small wire proportional counters are needed for some of the measurements. We can easily provide the relatively modest amount of equipment needed.

Data Recording. The small amount of data per event does not demand a computer based system. We expect to use a digital tape recorder, with a small input buffer memory to provide high rate capability. This can be constructed and tested in 2 months, and will be ready when needed.

REFERENCES

1) There are, by our count at this time of writing, three hyperon beams in construction and testing, as well as two additional proposed beams.

These are:

CERN Laboratory; 1 neutral, 1 charged beam

Brookhaven Laboratory; 1 charged beam

all in construction or testing phase, and

NAL; 1 neutral, 1 charged beam proposed.

In addition, there is some interest in a possible neutral hyperon beam at the Argonne National Laboratory.

Some of the papers describing these beams are included in references 2 through 17.

2) T. A. Romanowski, "Hyperon Beams at the 200 GeV Weston Accelerator and Possible Experiments with these Beams", NAL Summer Study 1968 Book 3, page 17.

3) M. Webster, "Separated Σ^- Beam for Bubble Chambers", NAL Summer Study 1968, Book 2, p. 217.

4) D. Berley, J. Lach, A. Maschke, and T. Romanowski, "Hyperon Beams at a 200 GeV Accelerator", NAL Summer Study 1968, Book 2, p. 233.

5) D. Cline, "Tagged High Energy $\bar{n}$, Hyperon, and Anti-Hyperon Beams at NAL", NAL Summer Study 1968, Book 2 p. 255.

6) D. Berley, G. Bingham, and G. Conforto, "A Hyperon Beam in Target Area-2", NAL Summer Study, 1969, Book 1, p. 63.

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7) R. H. March, "A Short Lived Neutral Beam," NAL Summer Study, 1969, Book 1, p. 173.

8) R. H. March, "Λ^-p Total Cross Section, and Small Angle Elastic Cross-Section Measurements." NAL Summer Study 1969, Book 4, p. 307.

9) R. H. March, "Search for the $\Delta S = 2$ Decay $\Xi^o \rightarrow p\pi^-$" NAL Summer Study 1969, Book 4, p. 313.

10) S. Aronson, R. Winston, J. Lach, A. Roberts, R. Meunier, L. Pondrom and T. Romanowski, "Hyperon Beta Decays at NAL," NAL Summer Study, 1970, p. 337.

11) L. Pondrom, "Compatibility of the Charged and Neutral Hyperon Beams," NAL Summer Study, 1970, p. 343.

12) A. Aronson, R. Winston, R. Meunier, L. Pondrom, T. Romanowski, J. Lach and A. Roberts, "Feasibility of a Survey of Negative Hyperon Intensities in a Beam of Moderate Length," NAL Summer Study, 1970, p. 345.

13) J. Sandweiss and O. Overseth, "Some Considerations on a High Intensity, High Energy, Negative Hyperon Beam at NAL," NAL Technical Memo TM-199 (1970).

14) T. Ferbel, "Proposal for a Study of Antiparticle Production and for a Possible Source of $\bar{\Lambda}^o$ Beams", BNL Summer Study on AGS Utilization 1970, p. 246.

15) J. Peoples, "Forward Λ Production in K^-p Interactions and Its Use in the Study of Λp Scattering," BNL Summer Study on AGS Utilization 1970, p. 353.

16) W. Willis, "Search for the $\Delta S = 2$ Decay of the Ξ^o", BNL Summer Study on AGS Utilization, 1970, p. 366.

References (continued)

17) Earlier proposals to use hyperon beams at NAL are: A. Atac, C. Dolnick, P. Gollen, J. Lach, J. MacLachlan, A. Roberts, R. Stefanski, D. Theriot, H. Kraybill, J. Marx, P. Nemethy, J. Sandweiss and W. Willis, "NAL Proposal 97 - Elastic Scattering of the Hyperons," (1970); R. H. March, L.G. Pondrom and O.E. Overseth, "NAL Proposal 8 - Experiments in a Neutral Hyperon Beam," 1970.

18) See D. Cline reference 5 and also T.M. Knasel, "The Production of the Λ Hyperon at Very High Energies in Proton Nucleon Collisions," Enrico Fermi Institute Preprint, EFI 71-19 (1971); for details of the coupling $N^* \to K\Lambda$, see F. Wagner and C. Lovelace, TH-1227 CERN (1970).

19) H. Grote, R. Hagedorn, and J. Ranft, "Atlas of Particle Production Spectra," CERN Geneva, 1970.

20) R. C. Arnold and E. Berger, "Produced Particle Fluxes at High Energies," ANL/HEP 7125, and R.C. Arnold and S. Fenster, "Notes on the Dual Resonance Model for Single Particle Spectra," ANL/HEP 7122.

21) R.L. Sumner, T.M. Knasel, E.C. Swallow, and R. Winston, "Design of a High Rejection Self-Collimating Cerenkov Counter for the NAL Hyperon Beam," EFI preprint 71-18 (1971).

References (continued)

22) R.L. Sumner, "Multiway (2 to 5) Light Splitter for Cerenkov Light," (unpublished).

23) H. Hinterberger and R. Winston, "Efficient Light Coupler for Threshold Cerenkov Counters," Review of Scientific Instruments, 37, 1094 (1966).

24) For example, the CERN DISK (Differential Isochronos Self-collimating) Counter, see R. Meunier "DISK Counters" NAL Summer Study, 1970, p. 85.

25) T. M. Knasel, R. Sumner and E.C. Swallow, "Optimum Tuning of a Differential Cerenkov Counter in an Unfocussed Beam," Enrico Fermi Institute preprint.

26) We wish to point out that the Cerenkov counter described in Reference 21 can be modified to make a tagging counter for a decay spectrometer. For this application higher acceptance is desired and less rejection can be tolerated. A success can be defined as

$$(\overline{\text{over}}) \cdot (D1 \cdot D3 + D2 \cdot D4) \cdot (\overline{\text{under}})$$
$$+ (D1 + D2 + D3 + D4) \cdot (\text{under})$$

with the restriction that the polar angle $\leq \Delta\Theta_C$ (the polar angle is the angle between the particle direction and the counter axis, and $\Delta\Theta_C$ is the full width of the differential mirror). The Monte Carlo results for this mode of operation are

References (continued)

Mass A	Mass 2	Θ mrad	$\Delta\Theta$(fw) mrad	acceptance for Mass A	$\frac{\text{acceptance Mass B}}{\text{acceptance Mass A}}$	
Ξ^-	Σ^-	10.0	1.2	45%	6.3%	These can be reduced to <1% "off line".
Ξ^-	Σ^-	13.0	1.0	45%	5.6%	

The conditions are the same as in Table I. Most of the errors occur in a very narrow (0.2 mrad) angular region at the largest channel bending angle. These can easily be rejected after the fact, leaving < 1% contamination.

TABLE 1

Monte Carlo Results

P = 150 Gev/c, channel 6m long, 2 x 2 mm entrance, 6 x 6 mm exit

B = 30 KG, target 1 x 1 mm

Counter is tuned to mass A

Successful count = $(\overline{\text{OVER}}) \cdot (D1 \cdot D3 + D2 \cdot D4) \cdot (\overline{\text{UNDER}})$

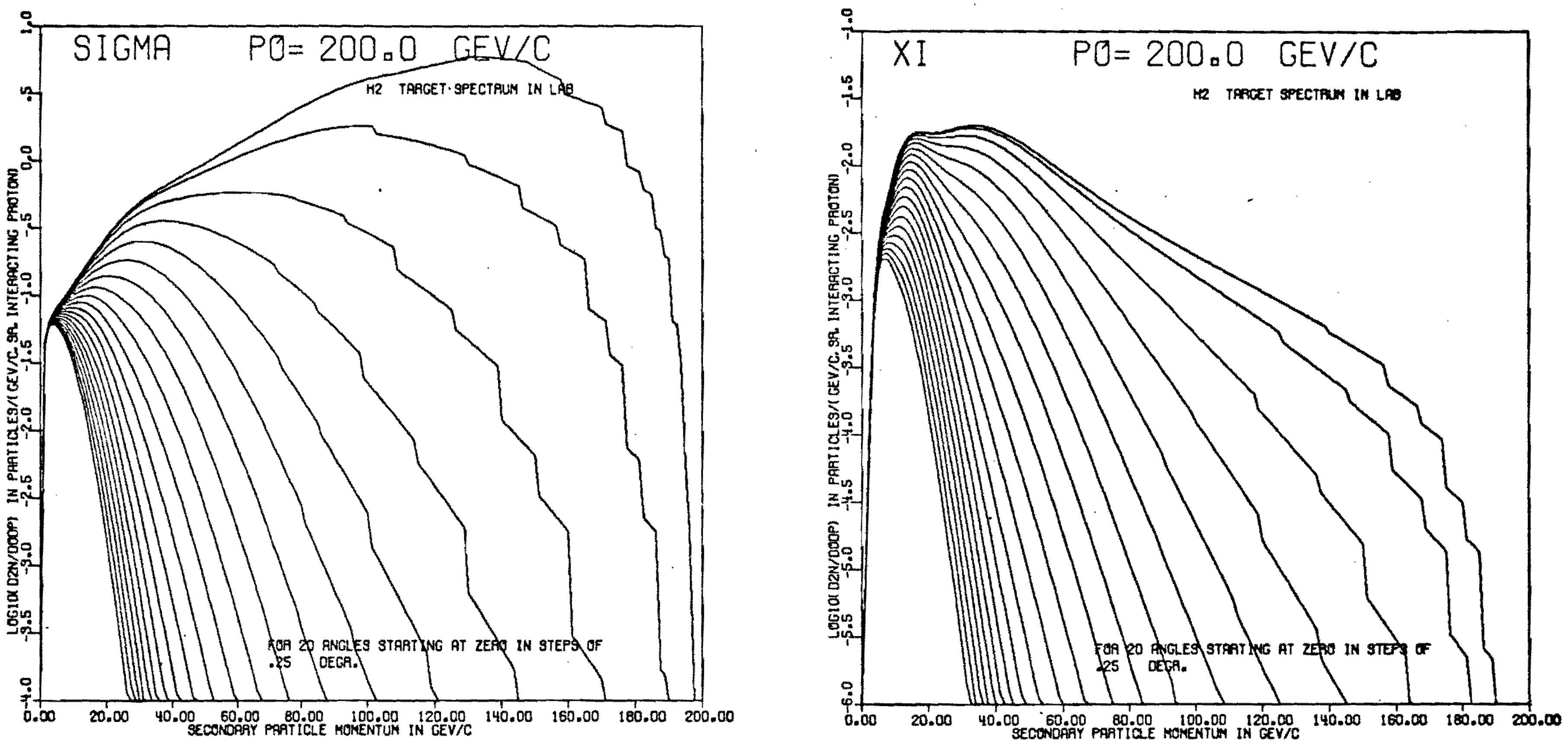
Cerenkov angle = 10 mrad, counter length = 6 m

Mass A	Mass B	$\Delta\Theta$(fw) mrad	acceptance for Mass A	$\frac{\text{acceptance Mass B}}{\text{acceptance Mass A}}$
$K^{\pm}$	$\pi^{\pm}$	0.8	16%	1.9% (19 events)
Σ^{+}	p^{+}	2.0	49%	0.5% (5 events)
Ξ^{-}	Σ^{-}	1.2	25%	2.9% (29 events)
Ω^{-}	Ξ^{-}	4.0	70%	0.3% (3 events)

The acceptance of Mass A is based on 1000 successful events.

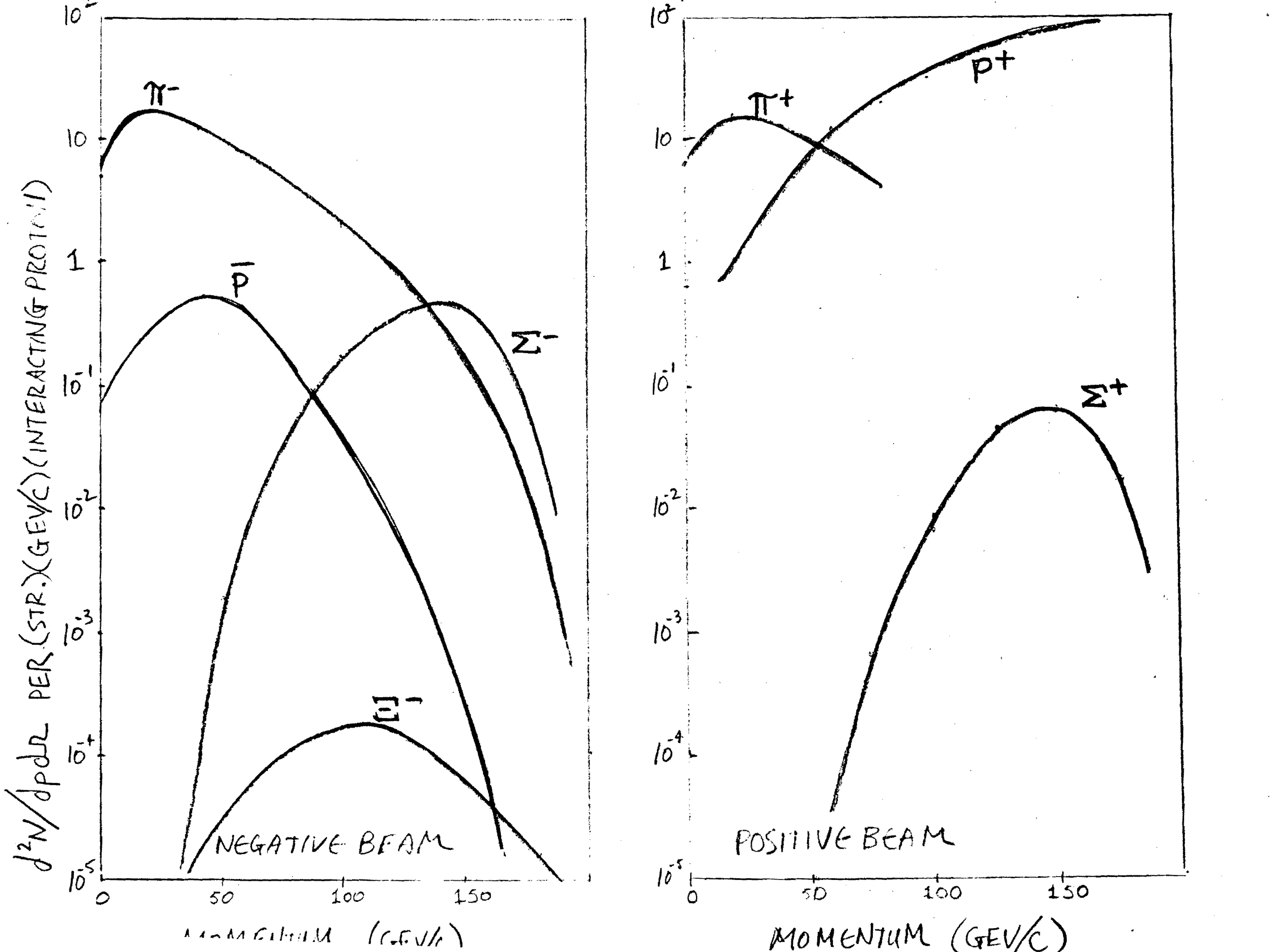
FIGURE 1   HYPERON YIELDS AT TARGET

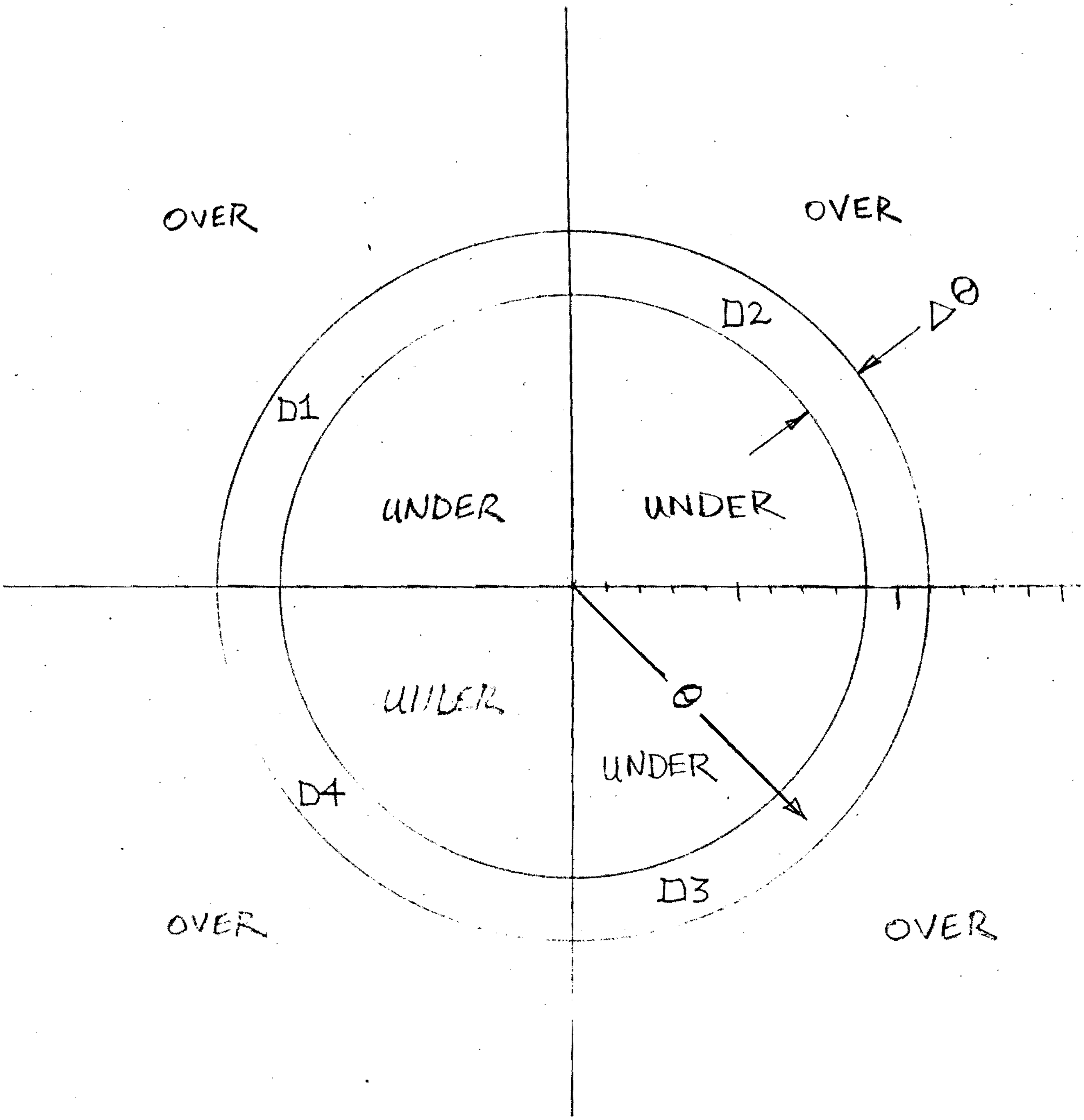
$\Sigma \equiv \frac{1}{3}\left[\Sigma^{+} + \Sigma^{\circ} + \Sigma^{-}\right]$ $\Xi \equiv \Xi^{\circ} = \Xi^{-}$



PREDICTED PARTICLE PRODUCTION IN $p + p \rightarrow \Sigma\ (\Xi) + \text{ALL}$.
FROM GROTE, HAGEDORN, & RANFT, REFERENCE 19.

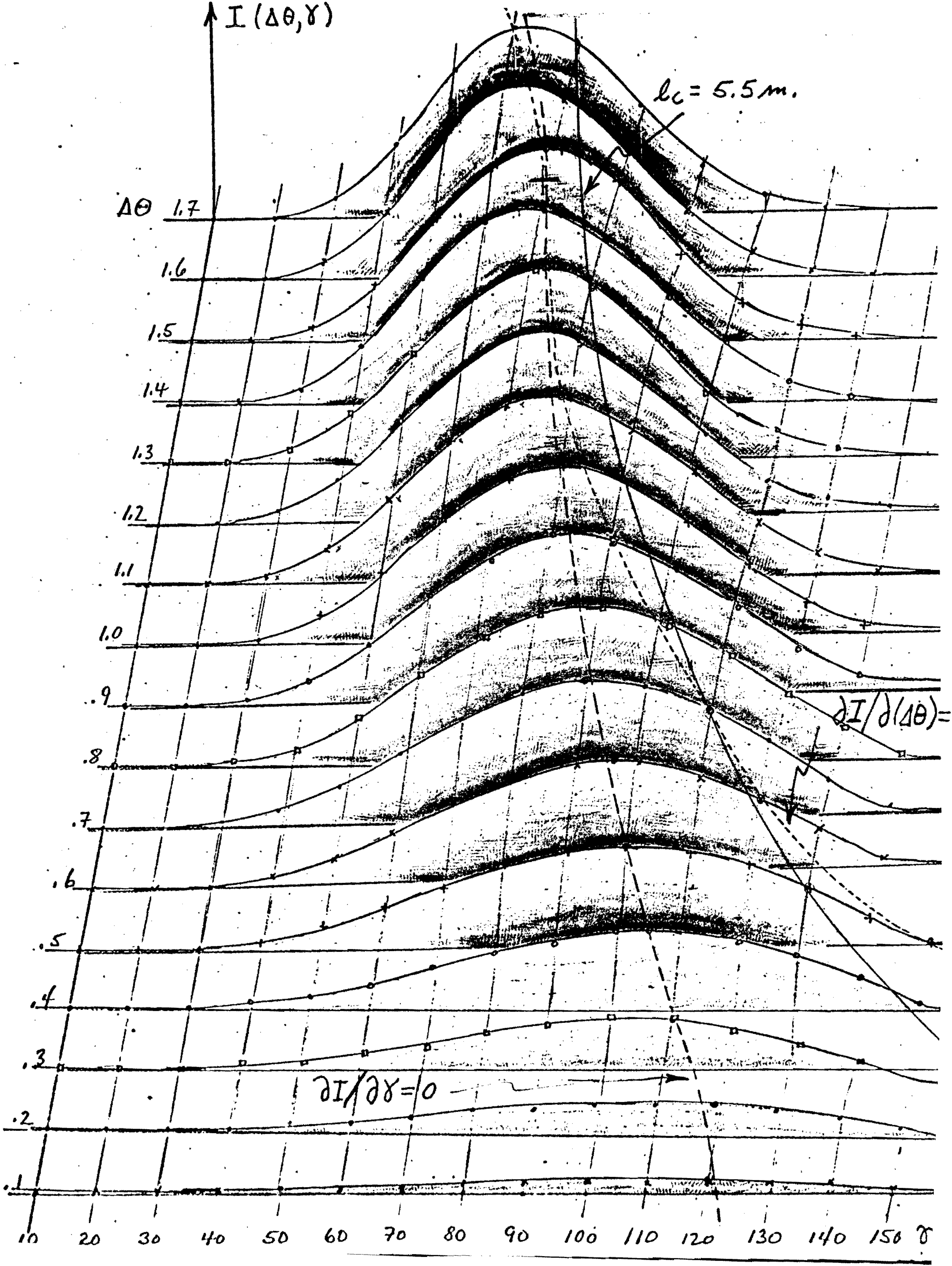
FIGURE 2. HYPERON YIELDS 12 METERS FROM TARGET (REF. AS FIG 1, 0° PRODUCTION)





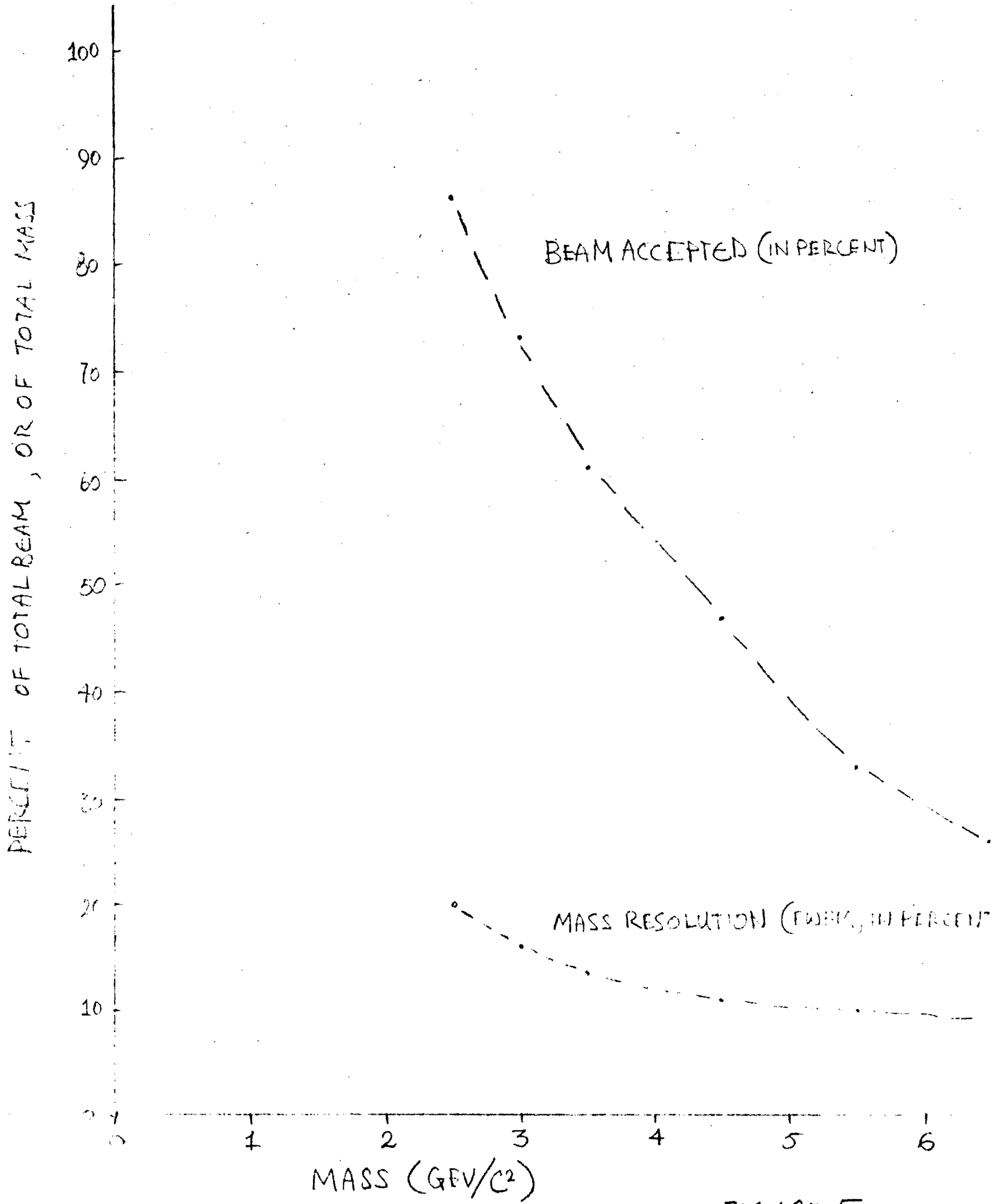
COORDINATE SYSTEM OF DIFFERENTIAL MIRROR SHOWING REGIONS VIEWED BY THE SIX PHOTOMULTIPLIER TUBES

- FIGURE 3 -


I (Δθ, γ)
ΔΘ 1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
l_c = 5.5 m.
∂I/∂(Δθ)=
∂I/∂γ = 0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
γ

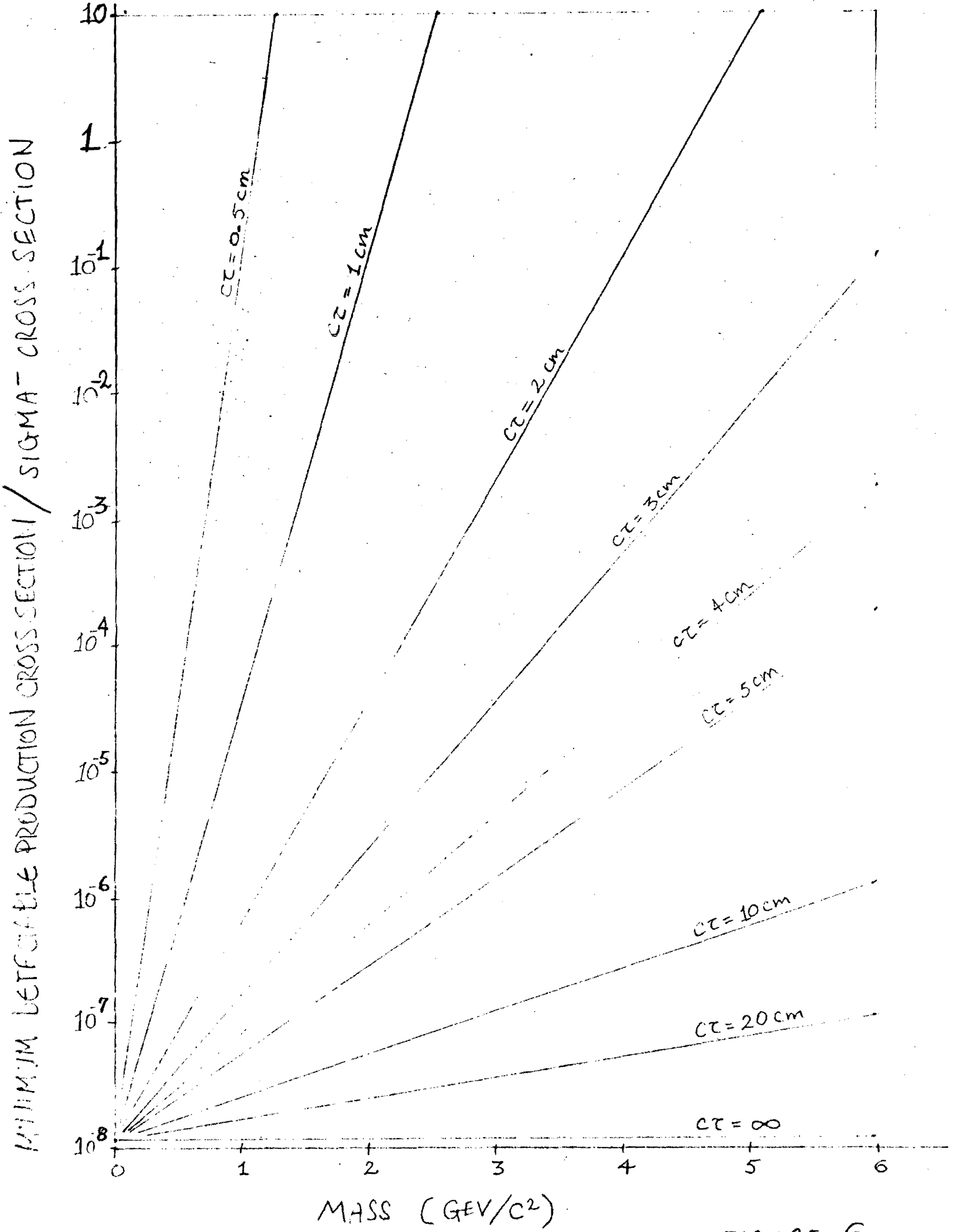
MOMENTUM = 150 GEV/C

CERENKOV COUNTER ANGLE $\theta = 15$ mrad, $\Delta\theta = 6$ mrad (fw)



-FIGURE 5-

MOMENTUM = 150 GEV/C   TOTAL BEAM LENGTH = 12 meters



-FIGURE 6