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HYPERON AND ANTIHYPERON FLUXES IN THE FERMILAB CHARGED HYPERON BEAM

Krzysztof Doroba

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The yields of hyperons and antihyperons in the Fermilab charged hyperon beam,[1] which is now under construction is an important question. The previous flux prediction was done in 1976[1,2] and was based on low energy experiments (below 30 GeV) which was the only data available at that time. The recent results from CERN SPS charged hyperon beam[3] allow me to update those predictions.

Figures 1 and 2 (taken from Ref. 3) present the CERN hyperon yields for 200/210 GeV/c incident protons in the forward direction from light target as well as the results from other experiments.[4] Although there is an apparent inconsistency in the low energy data, the CERN high and low energy points show scaling. One may assume this scaling and the CERN parameterization to compute hyperon fluxes for 400 GeV/c incident protons. If this scaling assumption is incorrect then the hyperon fluxes will be even larger. Knowing the antihyperon to hyperon ratios one can also compute the yields of antihyperons.

The values of lifetimes and masses of the hyperons used in the calculations are those from Ref. 5, except for Ω^- lifetime where the new value, τ = $(0.82 \pm 0.06)\ 10^{-10}$ sec, has been used.[6] The π^+/π^- and p/π^+ experimental ratios have been taken from Refs. 7 and 3 respectively. The values of the Σ/π; Ξ/π ratios used as an input for the calculations are from a $(1 - x)^n$ parameterization of the data shown in Fig. 1.[3] The antihyperon to hyperon ratio has been assumed to be equal to $(1 - x)^m$. This kind of parameterization is in agreement with the existing data on the $\overline{\Lambda^o}/\Lambda^o$ ratios.[8] The value of the power m has been determined for $\overline{\Sigma^+}/\Sigma^+$ and $\overline{\Xi^-}/\Xi^-$ ratios using the only two existing data points at $x = 0.47$. For the $\overline{\Sigma^-}/\Sigma^-$ ratio the same power as for the $\overline{\Sigma^+}/\Sigma^+$ has been assumed. Because of the particle charges one should expect at large x in pp collision the $\overline{\Sigma^-}/\Sigma^-$ ratio to be higher than for $\overline{\Sigma^+}/\Sigma^+$. Because of this the prediction for the $\overline{\Sigma^-}$ yields is probably pessimistic.

When looking at the antihyperon to hyperon ratios as a function of strangeness (Fig. 2) one may guess that the $\overline{\Omega^-}/\Omega^-$ ratio should be close to 1 near $x = 0.47$. We have assumed this ratio to be exactly one for all x, e.g. $m = 0$. The amount of Ω^- itself has been determined assuming that for all x, the cross section behavior is given by

$$A \cdot \frac{\Omega^-}{\Xi^-} = \frac{\Xi^-}{\Sigma^-}$$

where the value of the constant A (6.64) has been defined using the only measured data point for Ω^- (at $x = 0.47$).

The fluxes of positive and negative hyperons and antihyperons produced in the forward direction at a distance of 10 m from the light target are shown in Fig. 3a and b. The expected numbers of other particles are also presented, once again using $(1 - x)^n$ parameterization from Ref. 3. The numbers are given per 10^6 outgoing beam particles at this distance.* The length of the E497 targetting magnet is 7 m and a total distance of about 10 m would allow for wire chamber to determine the position and angle of beam particles as well as distance for a small Cerenkov detector. It does not allow for quadrupoles to make the beam parallel. This could be done with superconducting energy doubler/saver quadrupoles. With three such magnets one will need an additional 6 m to render the beam parallel up to 350 GeV/c. To illustrate how this additional distance will affect the fluxes, Fig. 4 a and b show the expected fluxes 20 m from the target. Comparing the expected amounts of pions with predictions of the Wang formula[9] one may estimate the number of incident protons required to obtain the desired beam intensity. This proton beam intensity for a magnetic channel with $dp/p \cdot d\Omega$ equal to $4.31 \; 10^{-8}$ sr and one interaction length light target is given in Fig. 5.

The possibility of targetting 1000 GeV protons from energy doubler /saver at an early date raises the question of what fluxes could be obtained using this hyperon channel. The increase of proton energy should improve especially the antihyperon fluxes because they are mostly

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*Since the beam must pass through drift chamber, the intensity is limited to about 10^6 per second.

produced at small x. The expected fluxes 10 (20) m from target are presented in Fig. 6 (7) a and b. The required incident proton intensity is given in Fig. 8.

The calculated fluxes of hyperons and antihyperons are bigger than previously[2] expected. Even with the recently measured Ω^- lifetime this beam would allow the measurement of many Ω^- properties. The fluxes of Σ^- are extremely large and even with the uncertainty of Σ^- parameterization at large x they should indeed be the major component of our high energy beam.

REFERENCES

[1] Fermilab Proposal E497.

[2] S. Ecklund and J. Lach, Fermilab 1976 Summer Study, Vol. 2, p. 317. Edited by J. Lach, Fermilab.

[3] Particle and Antiparticle Production by 200 and 210 GeV Protons in the CERN SPS Charged Hyperon Beam, M. Bourquin et al., paper submitted to the Tokyo Conference (1978).

[4] J. Badier et al., Phys. Lett. 39B, 414 (1972); V. Hungerbühler et al., Phys. Rev. D 12, 1203 (1975); P. Skubic et al., to be published in Phys. Rev. D.

[5] C. Bricman et al., Phys. Lett. 75B, 1 (1978).

[6] Measurement of the Lifetime and Branching Ratios of the Ω^-, M. Bourquin et al., paper submitted to the Tokyo Conference (1978).

[7] J. R. Johnson et al., Phys. Rev. D 17, 1292 (1978).

[8] T. Devlin et al., Nucl. Phys. B123, 1 (1977).

[9] C. L. Wang, BNL Preprint 18798.

FIGURE CAPTIONS

Fig. 1. Particle ratios at production target as a function of Feynman x at different energies. a) the Σ/π ratio and b) the Ξ^-/π^- ratio. Figure has been taken from Ref. 3. The low energy data are those from Ref. 4.

Fig. 2. Particle ratios as a function of strangeness - from Ref. 3. The $\overline{\Lambda^o}/\Lambda^o$ point is from Ref. 4 (P. Skubic et al.).

Fig. 3. Expected fluxes 10 m from target irradiated with 400 GeV protons. a) negative particles and b) positive particles.

Fig. 4. Expected fluxes 20 m from target irradiated with 400 GeV protons. a) negative particles and b) positive particles.

Fig. 5. Flux of 400 GeV/c protons at one interaction length target required to obtain 10^6 outgoing particles at given distance. The channel has $dp/p \cdot d\Omega = 4.31\ 10^{-8}$ sr. For positive particles results for 10 and 20 m are practically the same.

Fig. 6. Expected fluxes 10 m from target irradiated with 1000 GeV protons. a) negative particles and b) positive particles.

Fig. 7. Expected fluxes 20 m from target irradiated with 1000 GeV protons. a) negative particles and b) positive particles.

Fig. 8. Flux of 1000 GeV/c protons required to obtain 10^6 particles at given distance. Parameters of the channel are the same as for Fig. 5. Results for 10 and 20 m are practically the same.

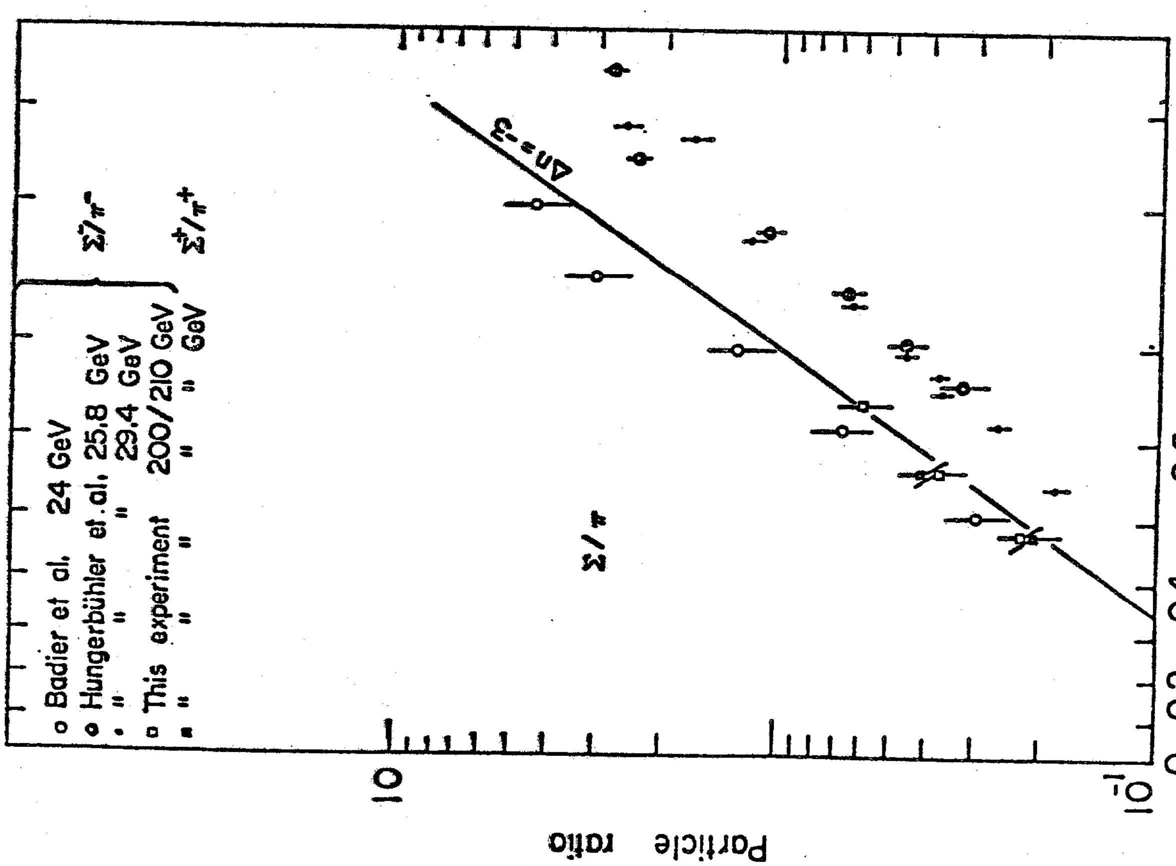

Badier et al. 24 GeV
Hungerbühler et al. 25.8 GeV
" " 29.4 GeV
This experiment 200/210 GeV
" " " GeV
Σ^-/π^-
Σ^+/π^+
Σ/π
$\Delta n=-3$
Particle ratio
10
10^{-1}
0
0.2
0.4
0.6
0.8
x

Fig.1 a

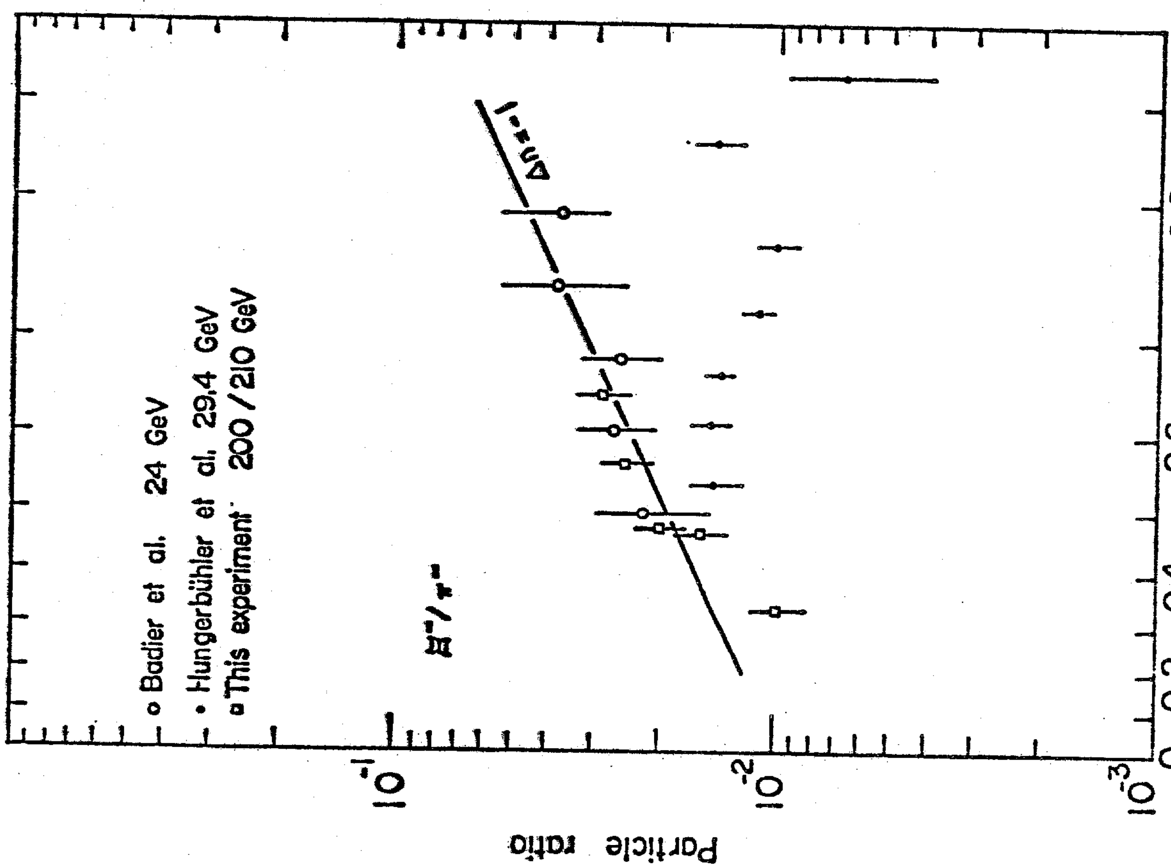
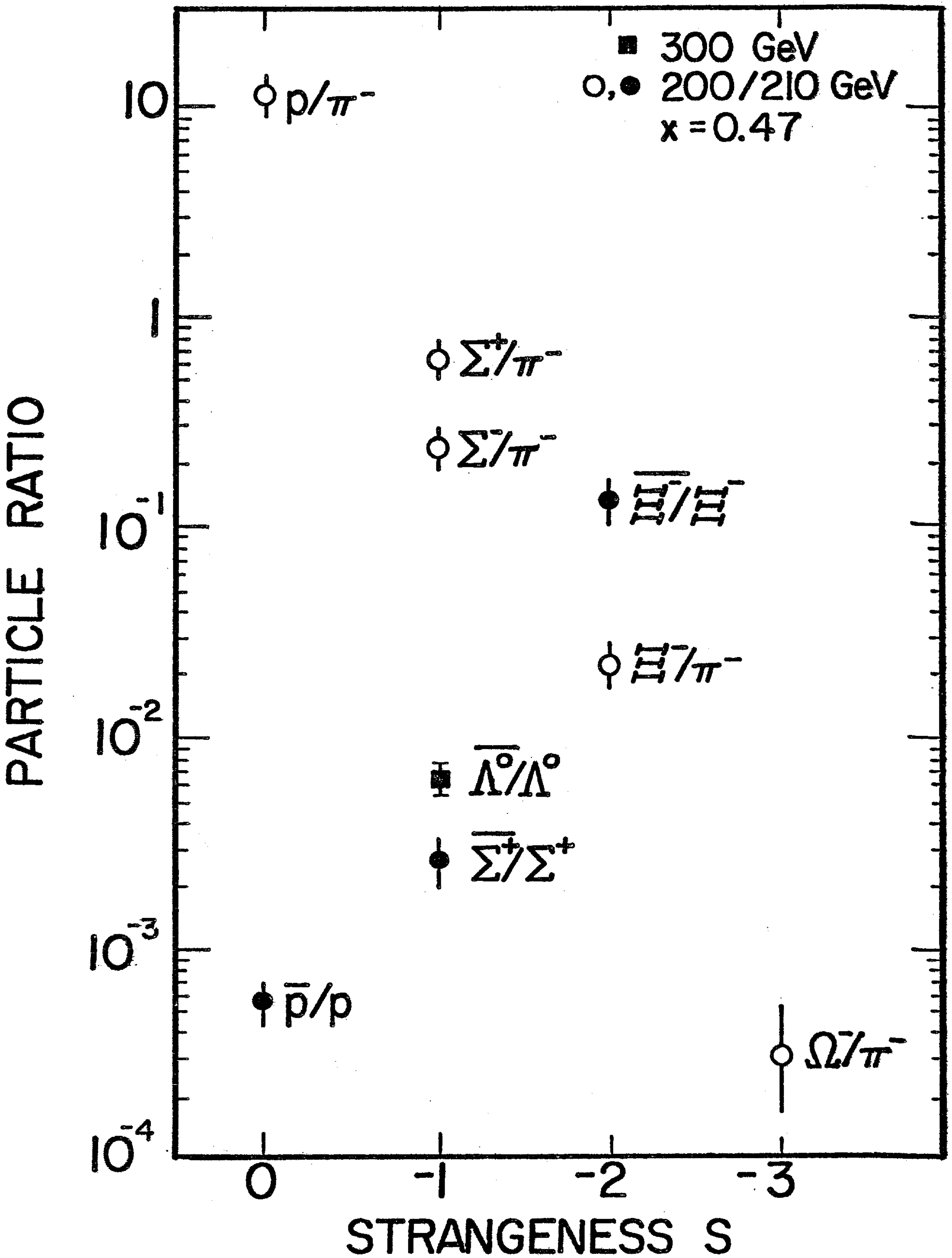

Badier et al. 24 GeV
Hungerbühler et al. 29.4 GeV
This experiment 200/210 GeV
Ξ^-/π^-
$\Delta n=-1$
Particle ratio
10^{-1}
10^{-2}
10^{-3}
0
0.2
0.4
0.6
0.8
x

Fig.1 b



■ 300 GeV
○,● 200/210 GeV
x = 0.47
p/π⁻
Σ⁺/π⁻
Σ⁻/π⁻
Ξ̄⁻/Ξ⁻
Ξ⁻/π⁻
Λ̄°/Λ°
Σ̄⁺/Σ⁺
p̄/p
Ω⁻/π⁻
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
PARTICLE RATIO
0
-1
-2
-3
STRANGENESS S

Fig.2

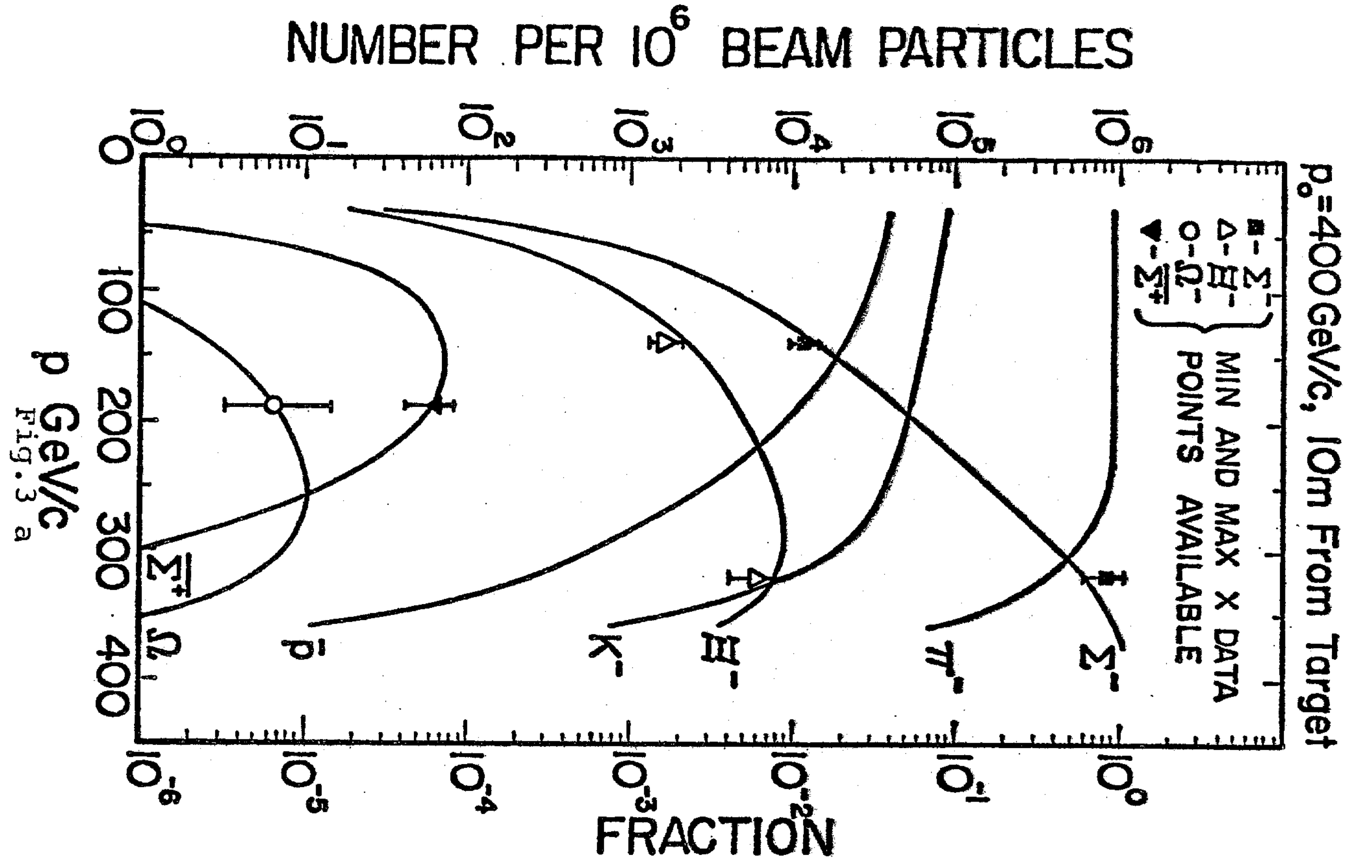

NUMBER PER 10^6 BEAM PARTICLES
p₀=400 GeV/c, 10m From Target
MIN AND MAX X DATA POINTS AVAILABLE
p GeV/c
FRACTION

Fig. 3 a

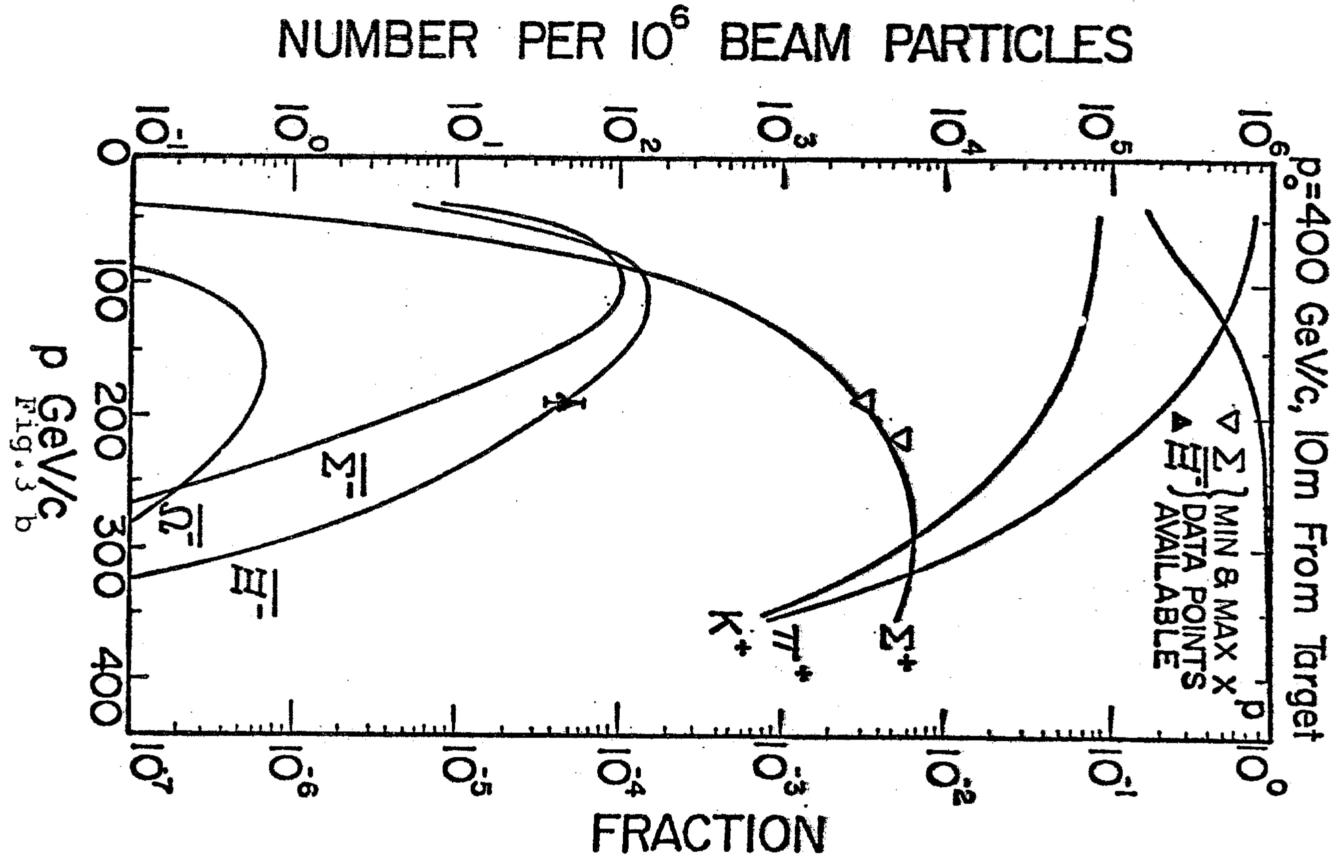

NUMBER PER 10^6 BEAM PARTICLES
p₀=400 GeV/c, 10m From Target
MIN & MAX X DATA POINTS AVAILABLE
p GeV/c
FRACTION

Fig. 3 b

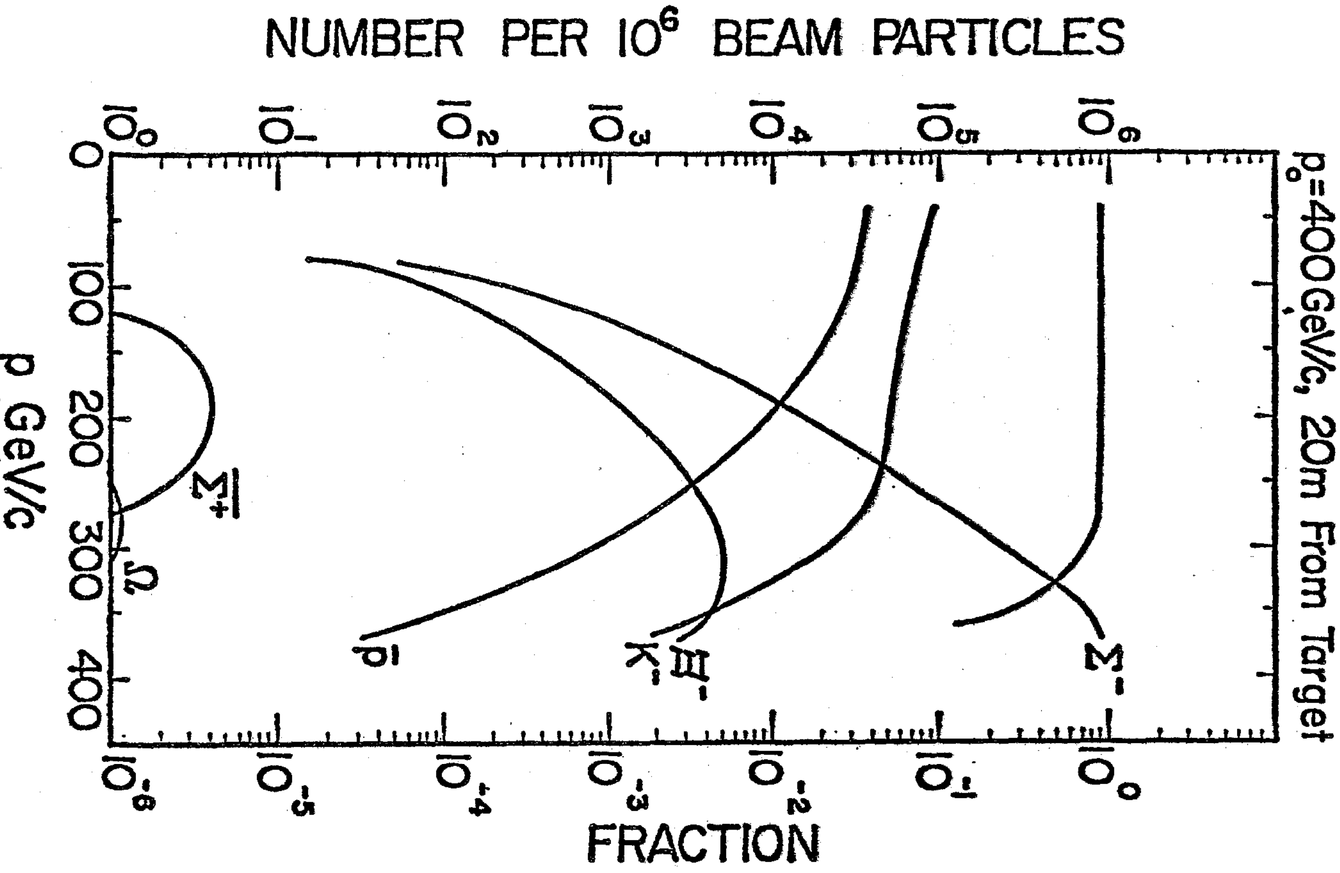

NUMBER PER 10^6 BEAM PARTICLES
p_o=400GeV/c, 20m From Target
p GeV/c
FRACTION
Σ̄+
Ω
p̄
K⁻
Ξ⁻
Σ⁻

Fig.4 a

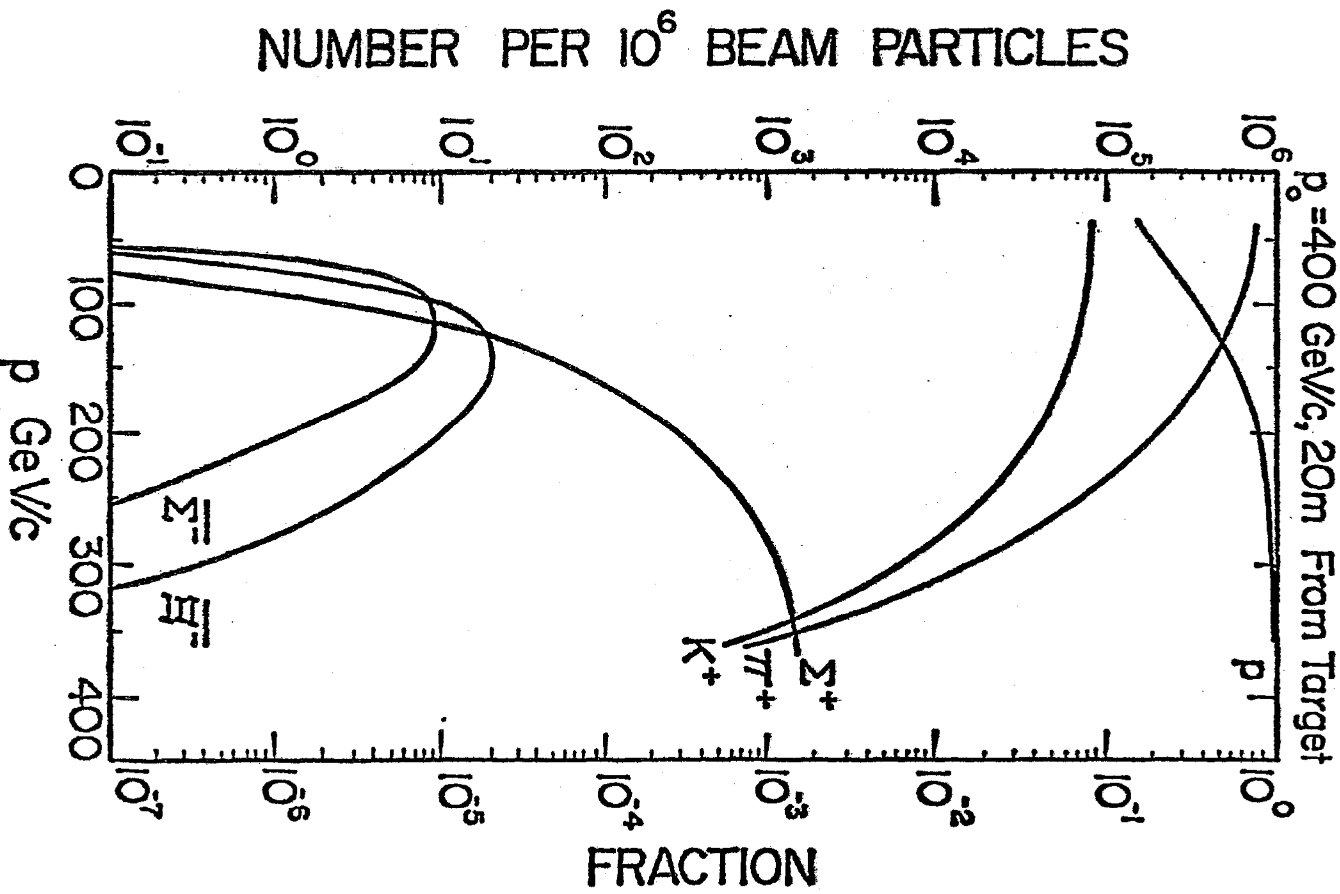
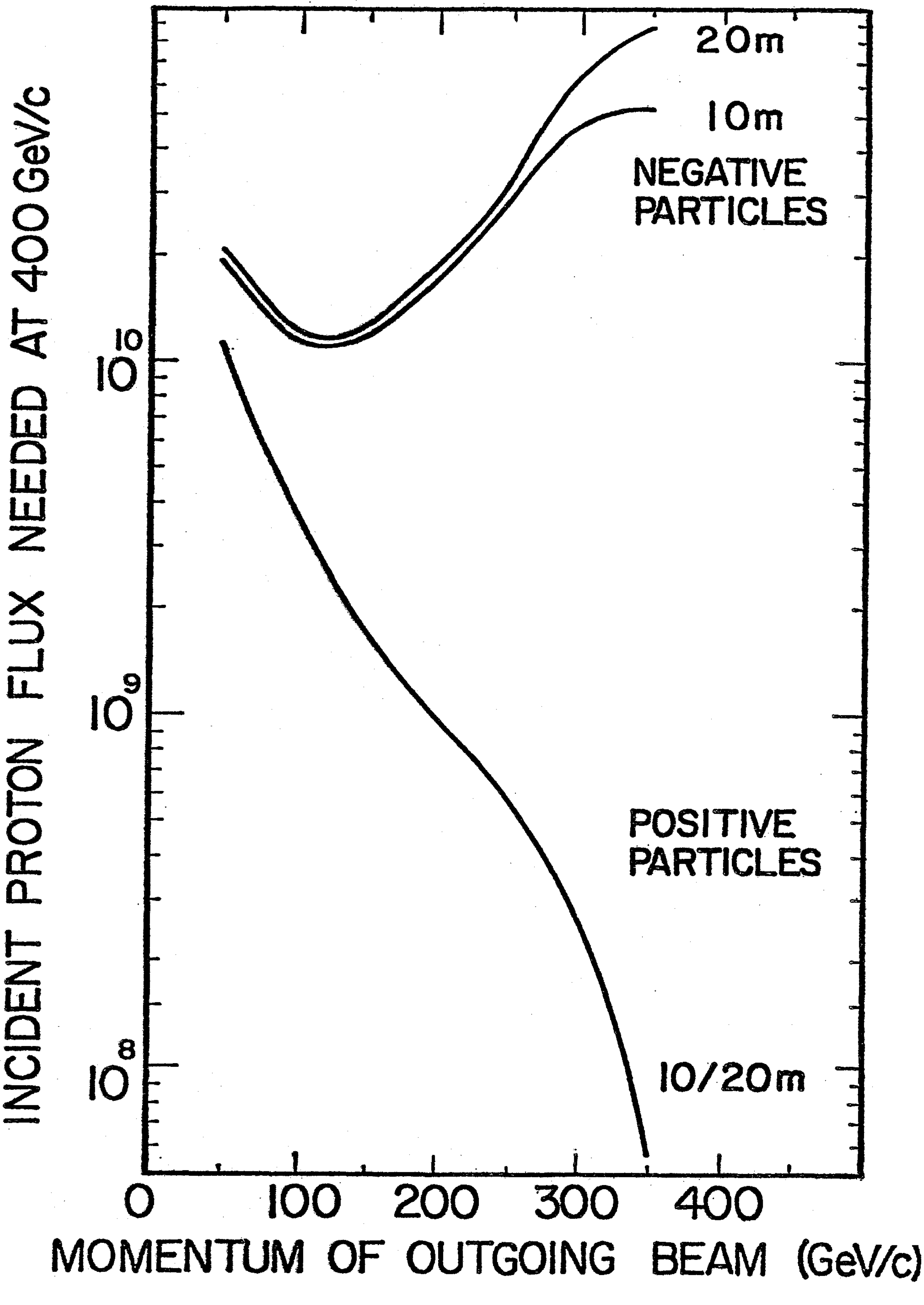

NUMBER PER 10^6 BEAM PARTICLES
p_o=400 GeV/c, 20m From Target
p GeV/c
FRACTION
Σ̄⁻
Ξ̄⁻
K+
π+
Σ+
p

Fig.4 b



20m
10m
NEGATIVE PARTICLES
POSITIVE PARTICLES
10/20m
10^{10}
10^{9}
10^{8}
0
100
200
300
400
INCIDENT PROTON FLUX NEEDED AT 400 GeV/c
MOMENTUM OF OUTGOING BEAM (GeV/c)

Fig.5

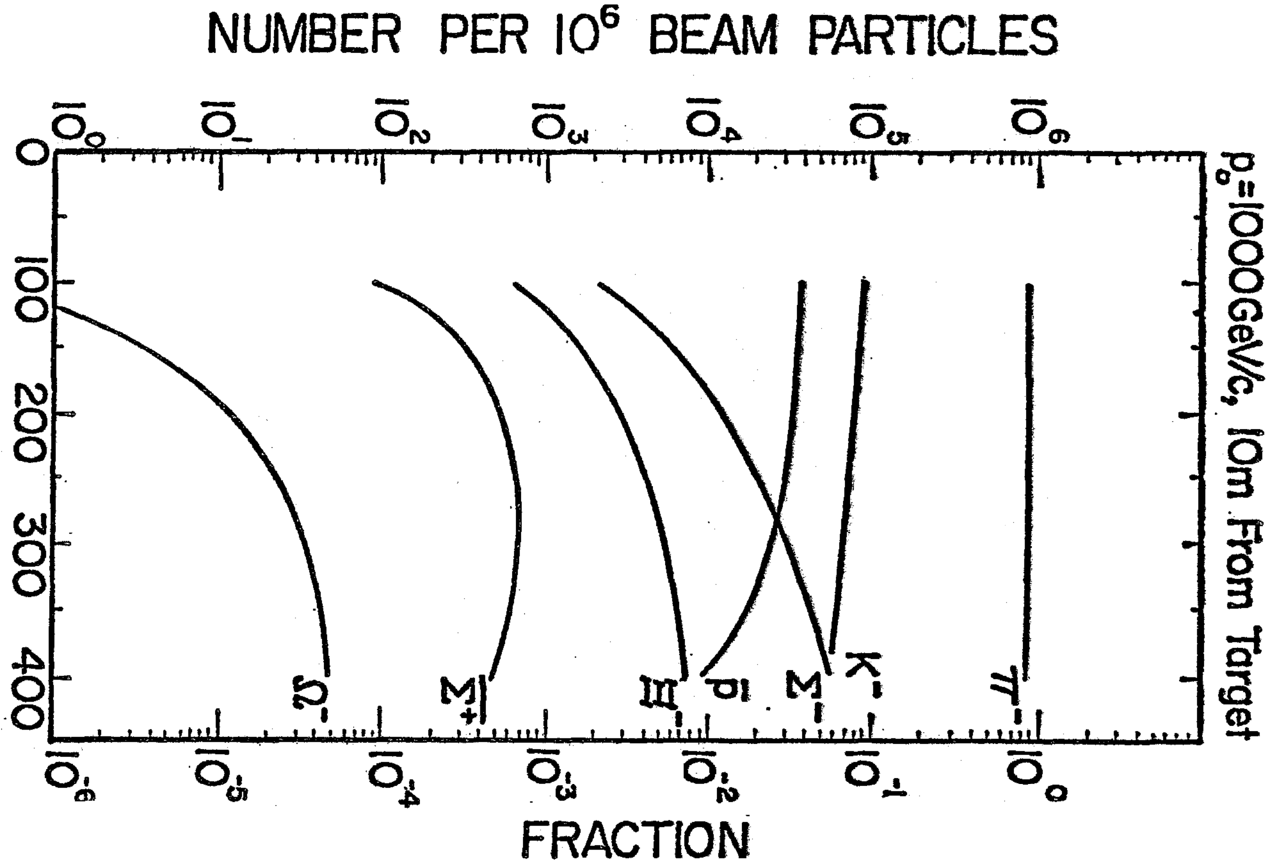

NUMBER PER 10^6 BEAM PARTICLES
p₀=1000GeV/c, 10m From Target
p GeV/c
FRACTION
Ω⁻
Σ̄⁺
Ξ̄⁻
p̄
Σ⁻
K⁻
π⁻

Fig.6 a

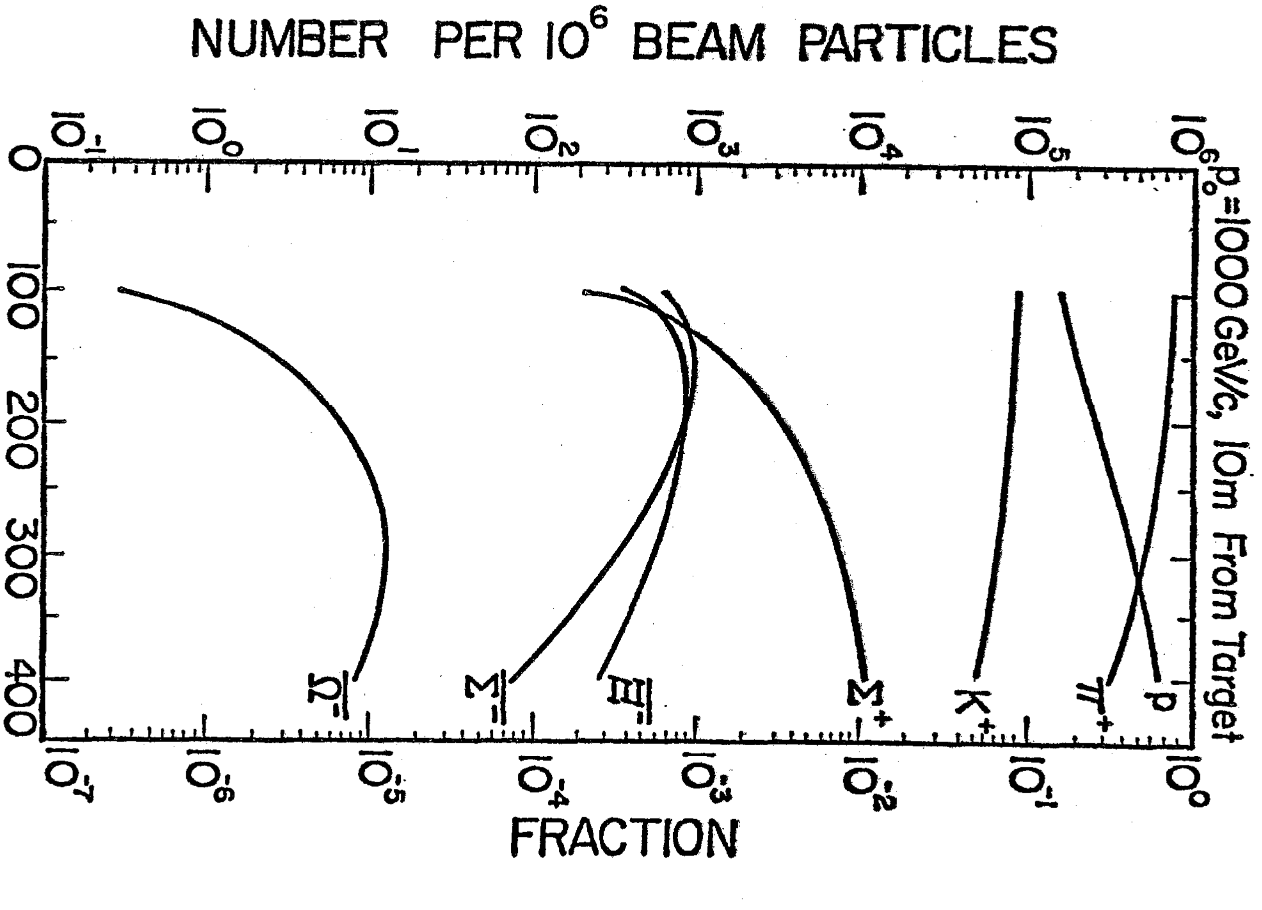

NUMBER PER 10^6 BEAM PARTICLES
p₀=1000GeV/c, 10m From Target
p GeV/c
FRACTION
Ω̄⁻
Σ̄⁻
Ξ̄⁻
Σ⁺
K⁺
π⁺
p

Fig.6 b

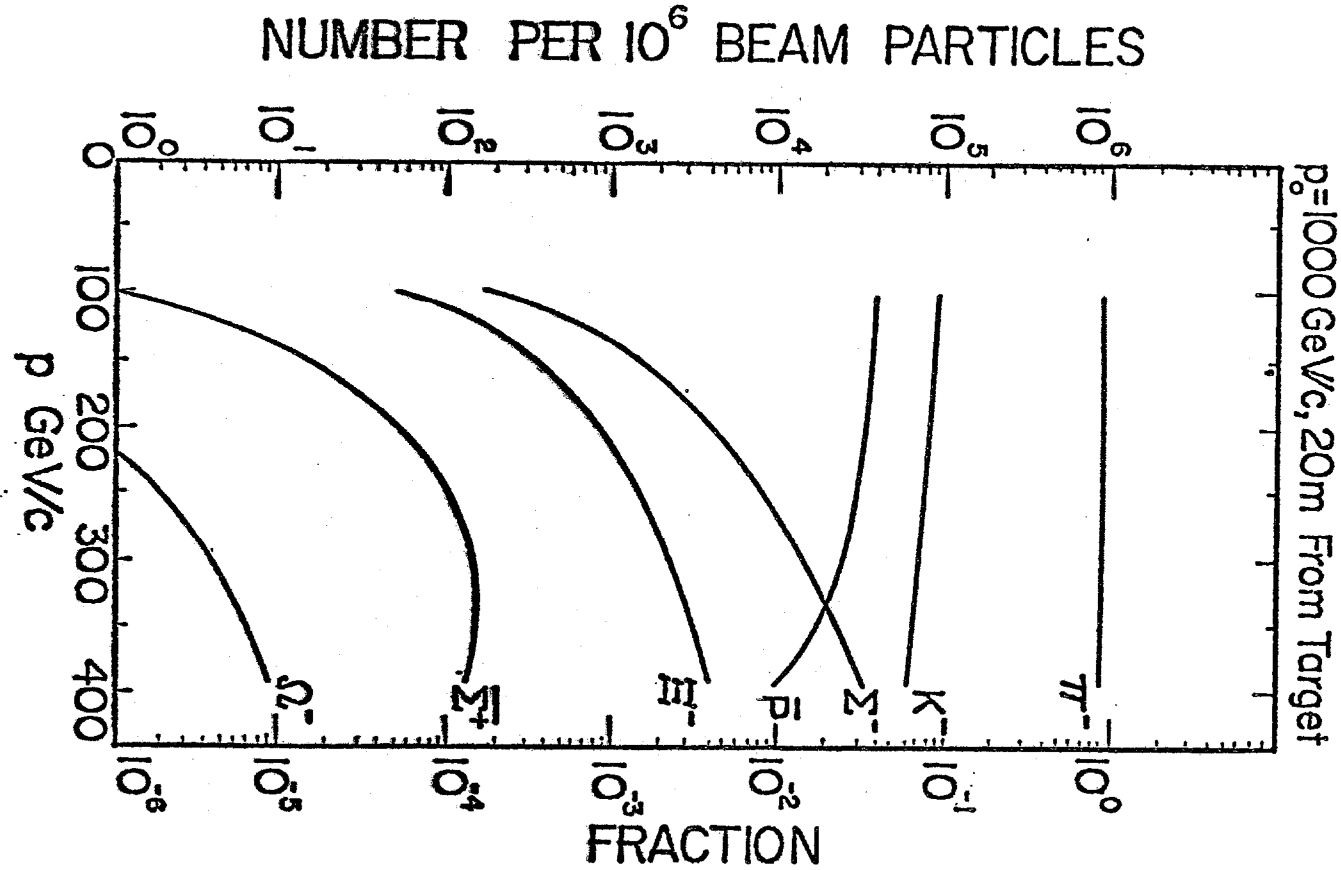

NUMBER PER 10^6 BEAM PARTICLES
p_0=1000 GeV/c, 20m From Target
p GeV/c
FRACTION
π⁻
K⁻
Σ⁻
p̄
Ξ⁻
Σ̄⁺
Ω⁻

Fig.7 a

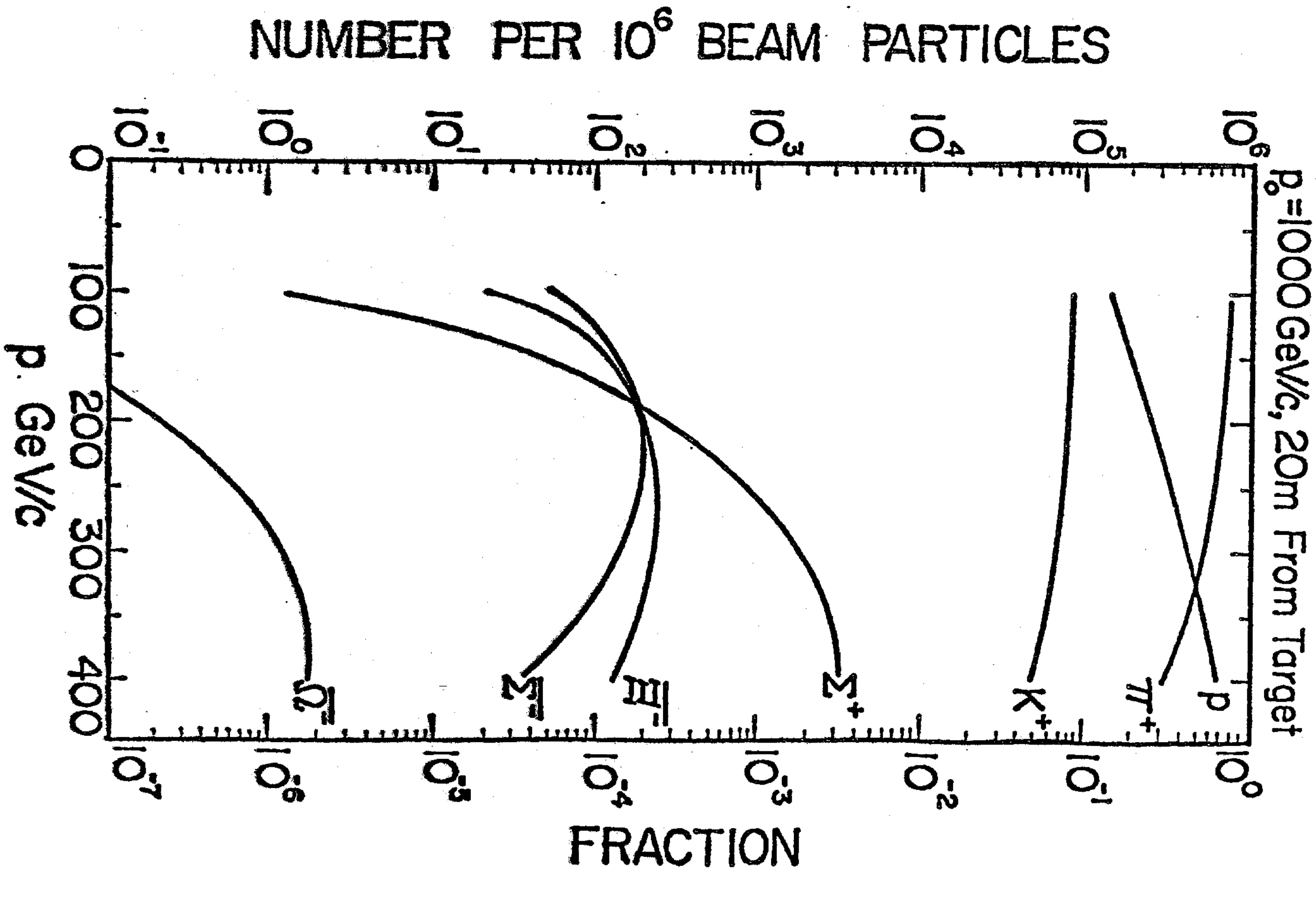
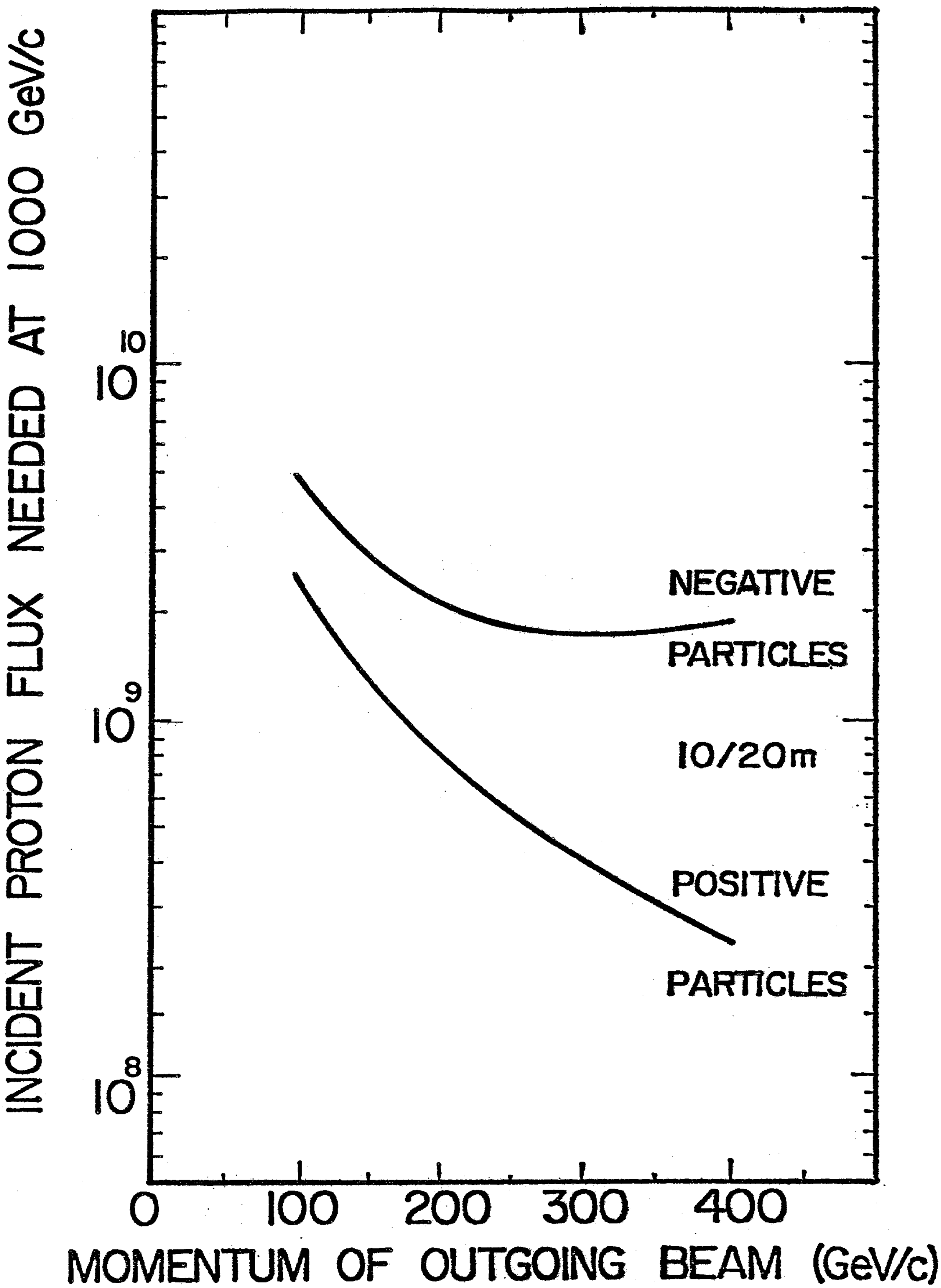

NUMBER PER 10^6 BEAM PARTICLES
p_0=1000 GeV/c, 20m From Target
p. GeV/c
FRACTION
p
π⁺
K⁺
Σ⁺
Ξ̄⁻
Σ̄⁻
Ω̄⁻

Fig.7 b



INCIDENT PROTON FLUX NEEDED AT 1000 GeV/c
10^{10}
10^{9}
10^{8}
NEGATIVE
PARTICLES
10/20m
POSITIVE
PARTICLES
0
100
200
300
400
MOMENTUM OF OUTGOING BEAM (GeV/c)

Fig.8