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HADRON PRODUCTION AT 0.8 MRAD BY 300 GeV PROTONS INCIDENT ON A THICK ALUMINUM TARGET

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Abstract

Hadron ($\pi^{\pm}$, $K^{\pm}$, p, $\bar{p}$) production was measured by using the Fermilab muon beam as a double-bend spectrometer, with the addition of threshold Cerenkov counters for particle identification. The measurement was made at 0.8 mrad with 300 GeV protons incident on a thick aluminum target.

Introduction

We have measured the yields of positive and negative pions, kaons, and protons produced at a laboratory angle of 0.8 milliradians relative to an incident 300 GeV proton beam colliding with a thick aluminum target.

Figure 1 shows the experimental arrangement. Protons extracted from the 300 GeV Fermilab synchrotron are incident upon a 30 cm long aluminum target in the neutrino targetting area. The 1 cm diameter beam spot is small compared with the 2-inch square cross section of the target. Two secondary emission monitors (SEM) measured the incident proton flux. A collimator (C_H), two scintillation counter pairs (S_{12} and S_{34}), and two bending magnets (D1 and D2, normally serving as part of the muon transport system) constitute the spectrometer used to count the total secondary particle yield. The acceptance, determined by the horizontally limiting 2.8 cm wide collimator C_H and by the one inch square overlap of S_{12}, is given by $\Delta\Omega\Delta p/p = 2.24\text{x}10^{-11}$ steradians ($\Delta p/p \simeq 1\%$). The counter pair S_{34} having a 2" x 2" area of overlap is not a limiting aperture but serves to reject counts due to halo scattering into S_{12}. Because of the compensating bend D2 the dispersion at S_{34} is nearly the same as at S_{12}. Two threshold Cerenkov counters, C_1 and C_2, each containing a 200-foot length of helium or air radiator, were used for particle identification.

A salient property of the apparatus is its simplicity resulting in a minimum of systematic bias to the results. Thus, particle identification is done with threshold Cerenkov counters, rather than differential counters, to avoid problems with counter and mirror alignment. Because the spectrometer does not use quadrupoles, the geometrical acceptance is easy to determine and to check and understand during operations. Whenever possible, scintillation counters were used in place of collimators to avoid problems in measuring slit scattering. These simplications made the spectrometer easy to operate, giving direct on-line results for particle yields and ratios.

During the run, counts were recorded for the coincidences $B=S_{12}\cdot S_{34}$, $B\cdot C_1$, $B\cdot C_2$, and $B\cdot C_1\cdot C_2$. The accumulated B counts normalized to the SEMs gave directly the total charged particle yields into the acceptance of the spectrometer, subject to the corrections discussed below. These measurements are shown in Figure 2. At each secondary momentum setting (determined by D1) a sweep was made in the setting of D2 to insure acceptance matching of the two legs of the spectrometer. In separate runs at fixed settings of the spectrometer momentum the Cerenkov counter pressure was varied to measure the relative yields of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$. The pressure curves are shown in Figure 3 and 4.

Cerenkov counter efficiencies for pressure settings well above threshold were typically 80% and 95% for C_1 and C_2, respectively. Where feasible the Cerenkov count rates were corrected for efficiency as inferred from the redundant measurements: $(B\cdot C)_{corr} = (B\cdot C_1)\cdot(B\cdot C_2)/B\cdot C_1C_2$. ($C_1$ was rendered ineffective by the high fluxes encountered at the highest momentum settings in the positive beam, and was not used there.)

The following corrections were applied to the data: (1) Multiple Coulomb scattering caused some mismatch between the acceptance of S_{34} and that of S_{12}. The size of the effect was inferred from three separate methods of calculation and direct measurements with the beam. The correction factor varied from 1 at 225 GeV/c to 5.5 at 25 GeV/c; (2) The production spectra were corrected for π and K decay to obtain the yields at the target; (3) A correction was made for absorption by material in the beam path which was about 15% in most cases; (4) Corrections were applied for accidentals in the B-Cerenkov coincidences. The subtraction amounted typically to 1%; (5) Muons remaining within the acceptance of the system measured about 10%. An error in the normalization is due to the uncertainty in the effective target thickness due to extraneous material in the beam near the target area. Rates measured with the target removed were about 30% of those with the target in place.

The results are presented in Table I and Figures 5, 6 and 7. The sources of the quoted errors are uncertainty in the multiple scattering correction to the acceptance, in the fits to the Cerenkov pressure curves, and statistical uncertainties. In addition, the long term instability of the SEMs and the presence of sources near the target contribute an overall normalization uncertainty of ±30%.

We have compared our results with measurements at a 3.5 milliradian production angle and proton energies of 200 and 300 GeV by Baker, et al.[1] Within the rather large normalization errors of both experiments, the P1 dependence of the production rates is consistent with the scaling law proposed by F. T. Dao et al.[2]

1 W.L.Baker et al., Physics Letters, Vol. 51B #3, page 303, August 1974.

2 F.T.Dao et al., Phys. Rev. Letters, Vol 33 #6, page 389, August 1974.

P (GeV/c)	$d^2N/(\frac{dP}{P})d\Omega$ (Sγ Incident Proton)$^{-1}$					
	π^+	K^+	P	π^-	K^-	$\bar{P}$
25	363±25%	-	-	371±25%	-	-
50	529	51.3±30%	128±25%	355	25.7±30%	10.9±25%
75	688	81.6±25%	367	350	23.7±25%	9.49
100	719	83.0	671	308	19.4	5.67
125	605	85.3	1125	252	14.6	3.27
150	487	89.2	1571	179	8.48	1.37
175	394	-	2301	115	4.61	.489±35%
200	223	-	2887	56.9	1.86	.124±55%
225	84	34.0±45%	3534	22.2	-	-

P (GeV/c)	PARTICLE RATIOS					
	P/π^+	K^+/π^+	K^-/π^-	$\bar{P}/\pi^-$	π^-/π^+	K^-/K^+
25	-	-	-	-	0.92±15%	-
50	0.24±1%	0.10±20%	0.073±20%	0.031±5%	0.67±10%	0.50±30%
75	0.53	0.12±10%	0.068±10%	0.027±10%	0.51	0.29±20%
100	0.93	0.12	0.063	0.018	0.43	0.23
125	1.86	0.14	0.058	0.013	0.42	0.14
150	3.23	0.18	0.047	0.0077	0.37	0.095
175	5.84±3%	-	0.040	0.0043±25%	0.29	-
200	13.0±7%	-	0.033±10%	0.0022±50%	0.26±15%	-
225	42.2±12%	0.41±40%	-	-	0.27	-

TABLE I

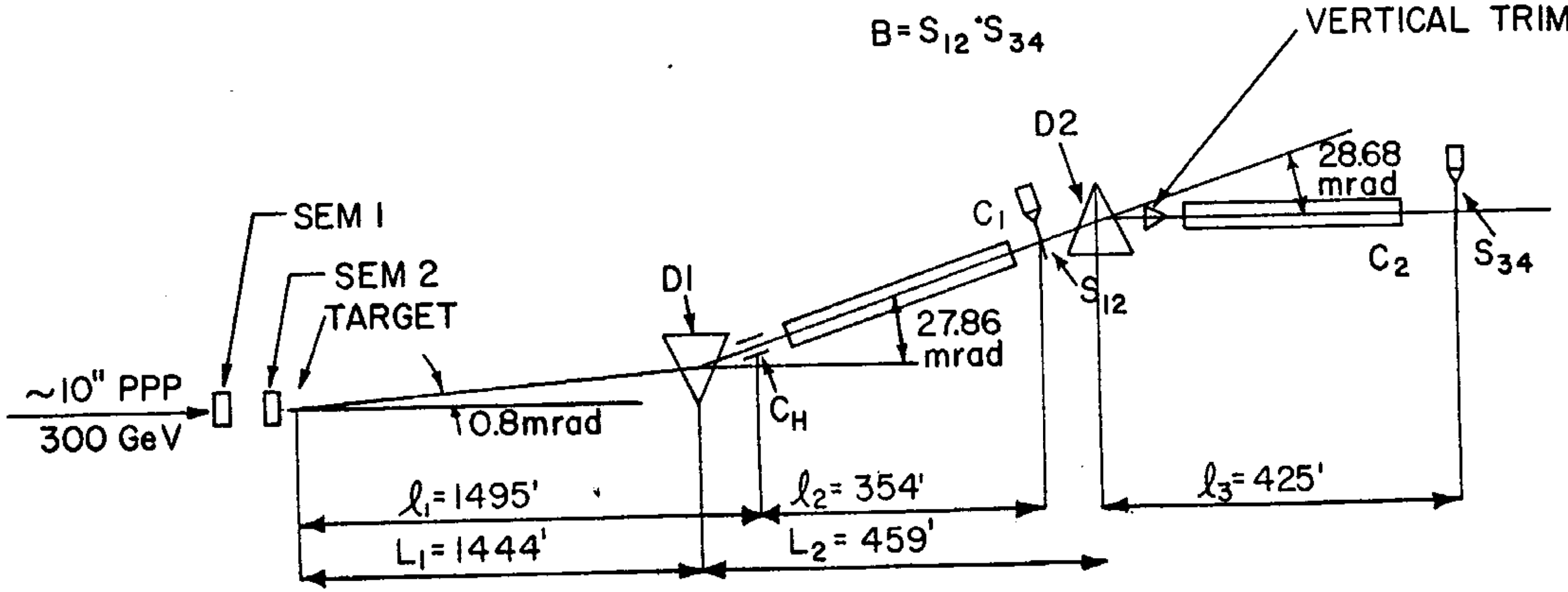

Figure 1: Schematic diagram of the double-bend spectrometer used for the particle yield measurement.

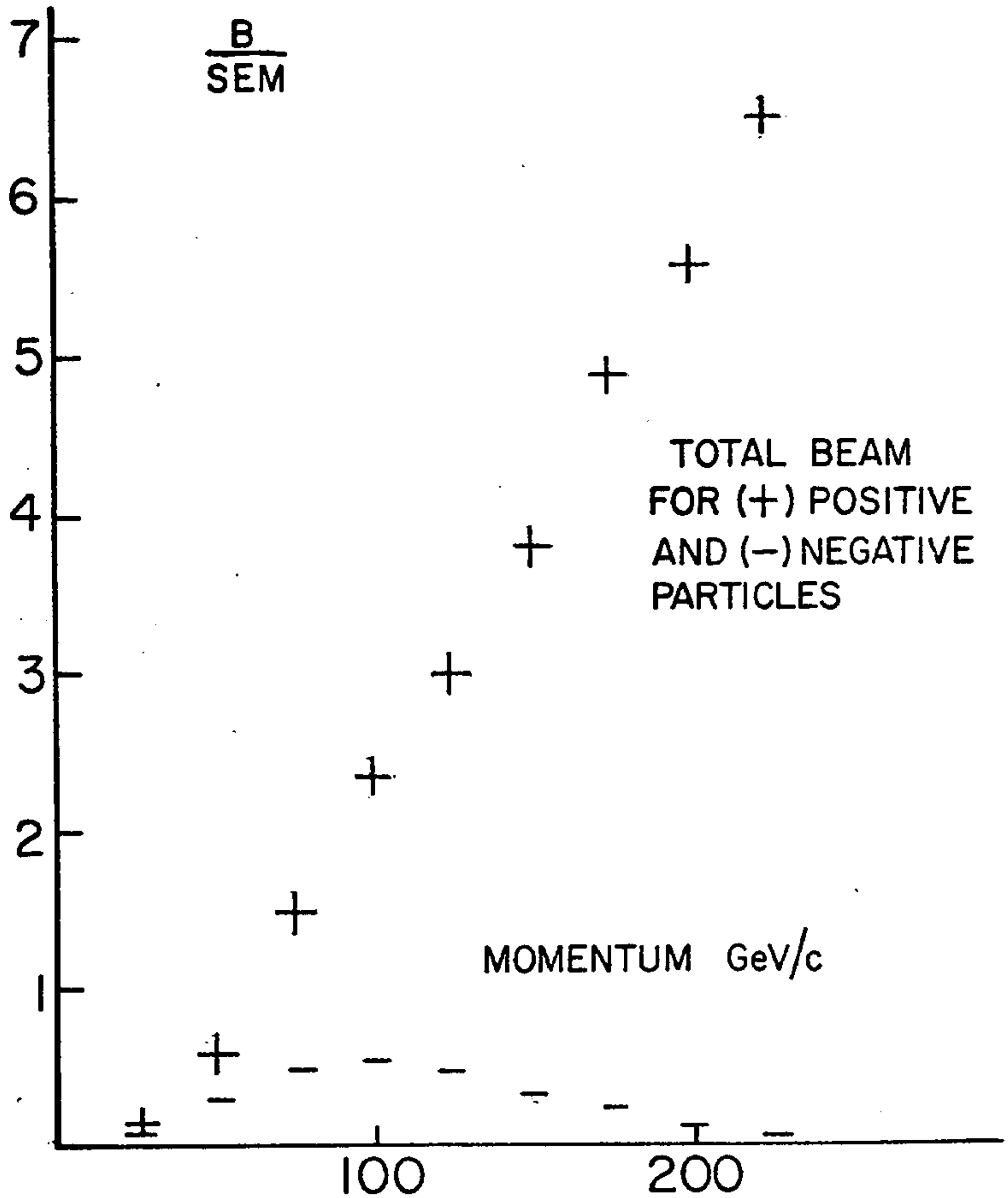

Figure 2: Total number of particles in the beam as a function of beam momentum. The SEMs were calibrated in one count per 10^9 protons. B is defined in Figure 1.

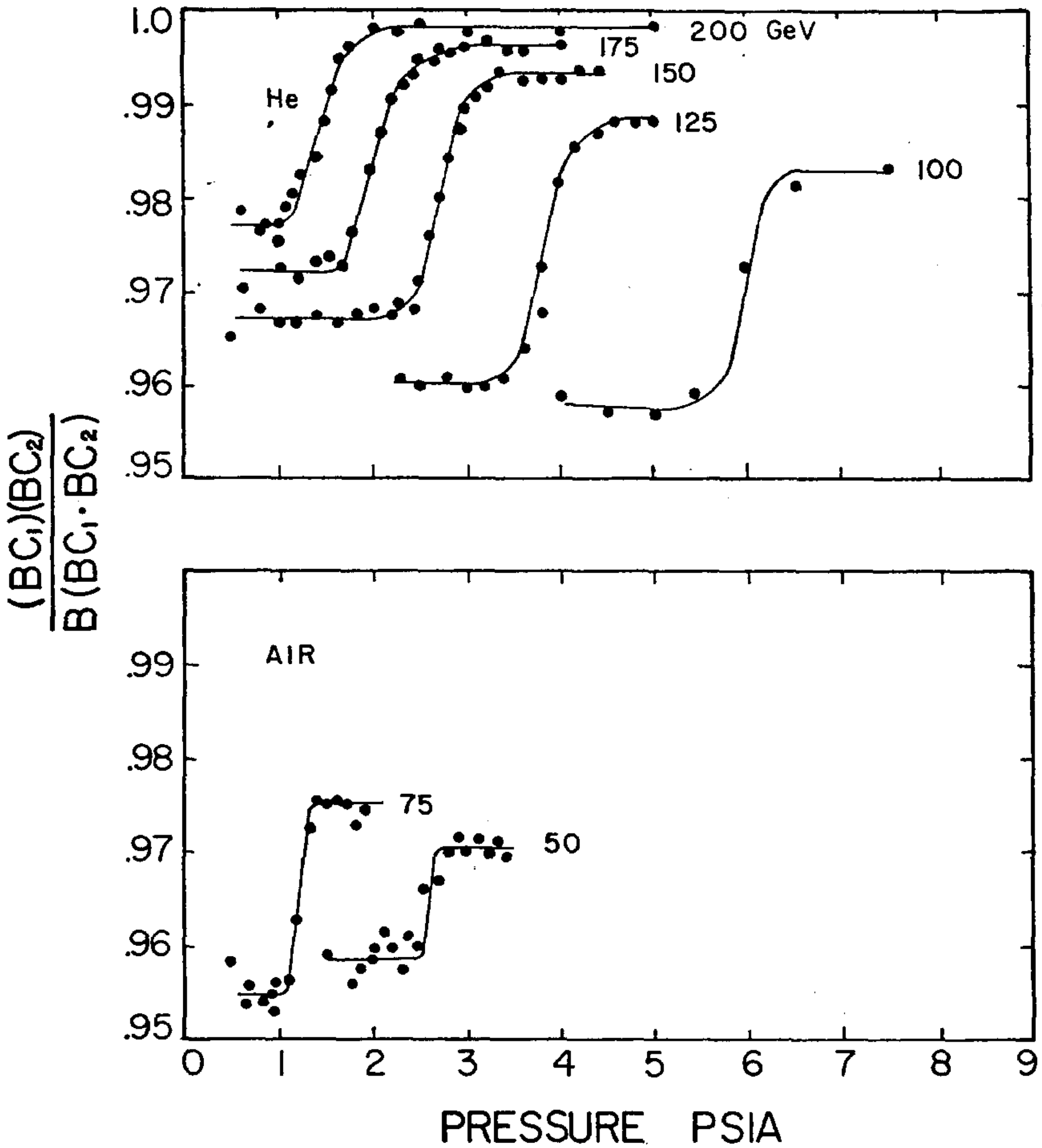

Figure 3: Cerenkov counter pressure curves, corrected for efficiency, for the negative beam. Only the region of the kaon threshold is shown for each momentum.

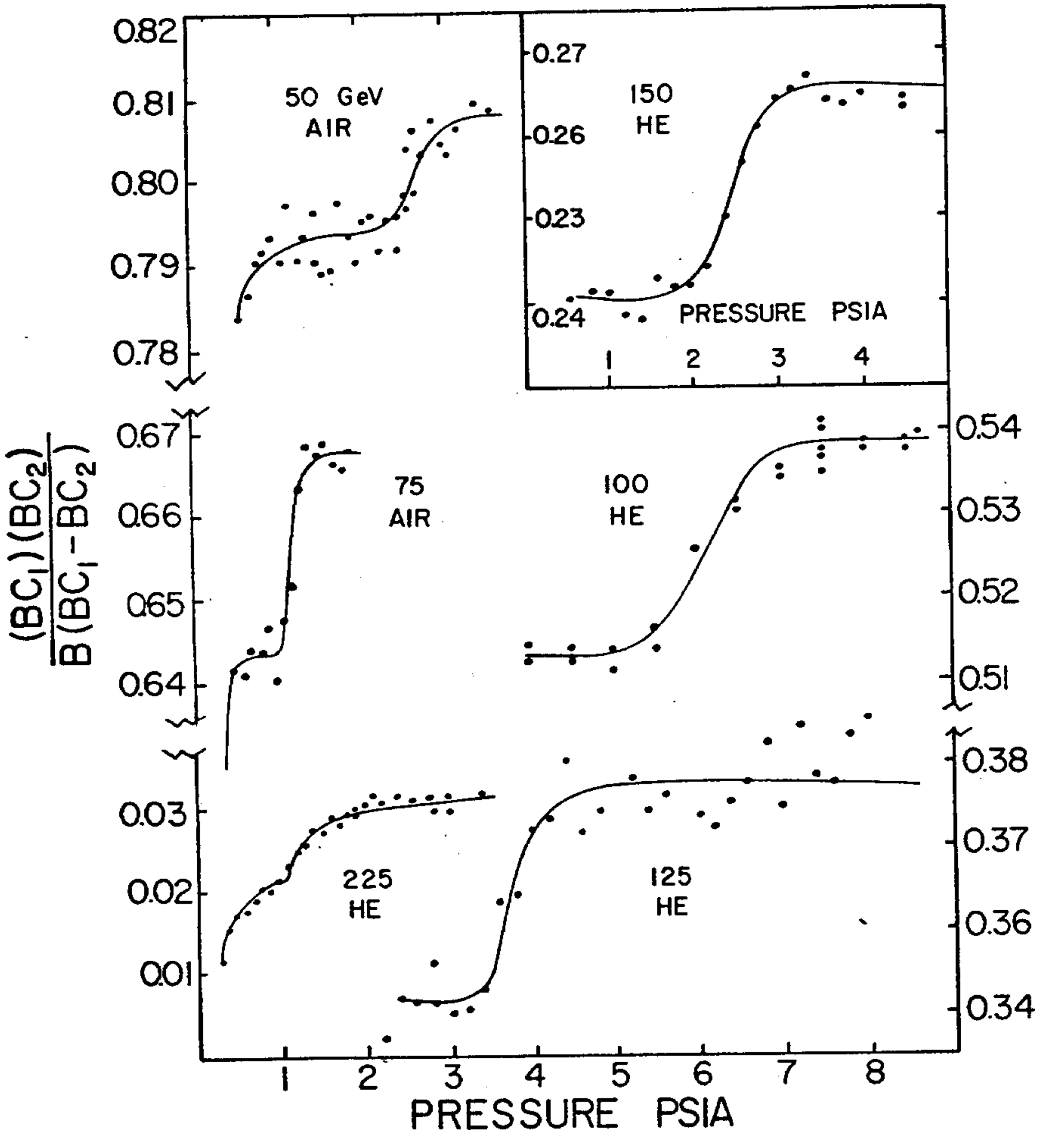

Figure 4: Same as Figure 3 for the positive beam.

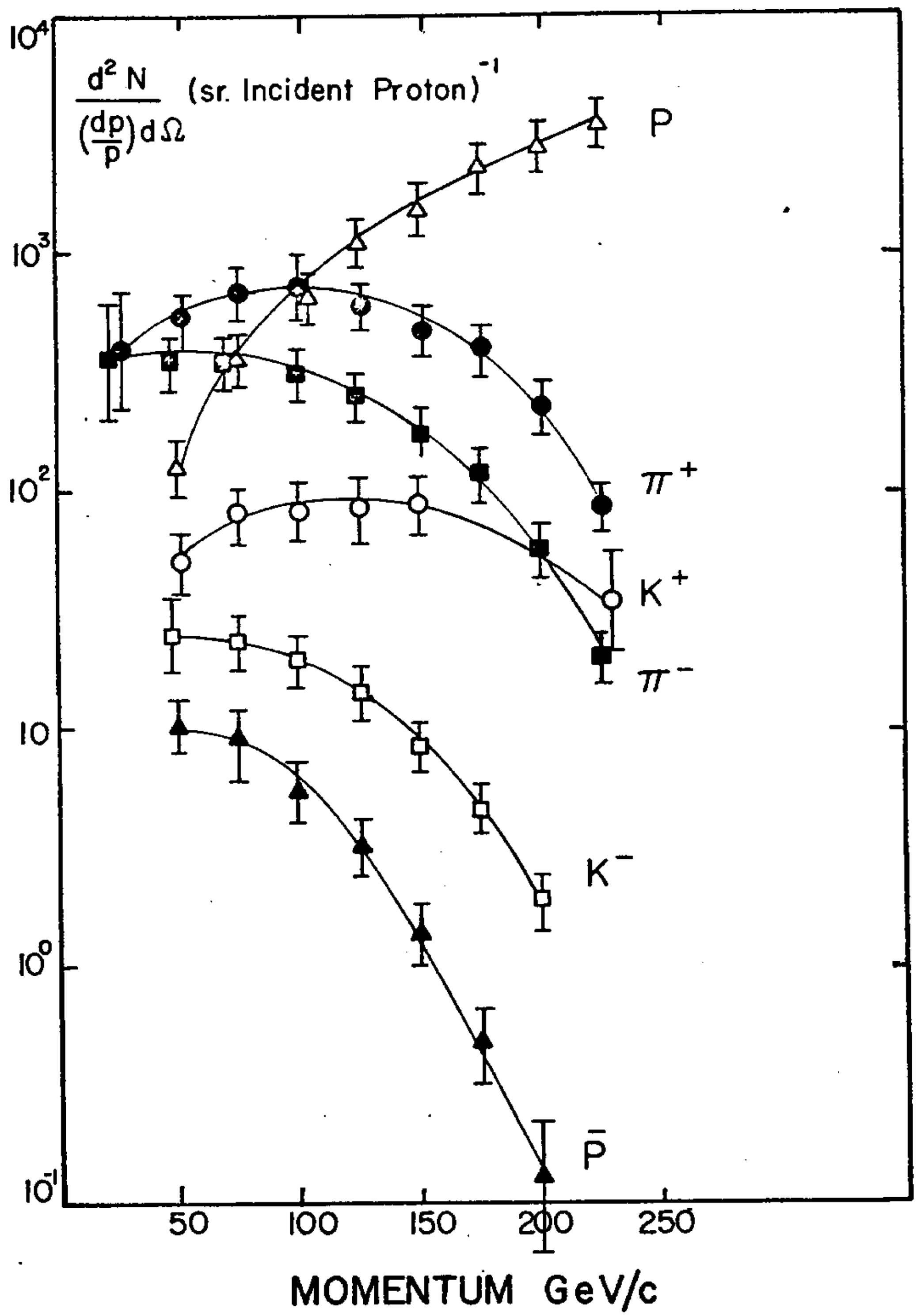

Figure 5: The absolute yields as a function of momentum.

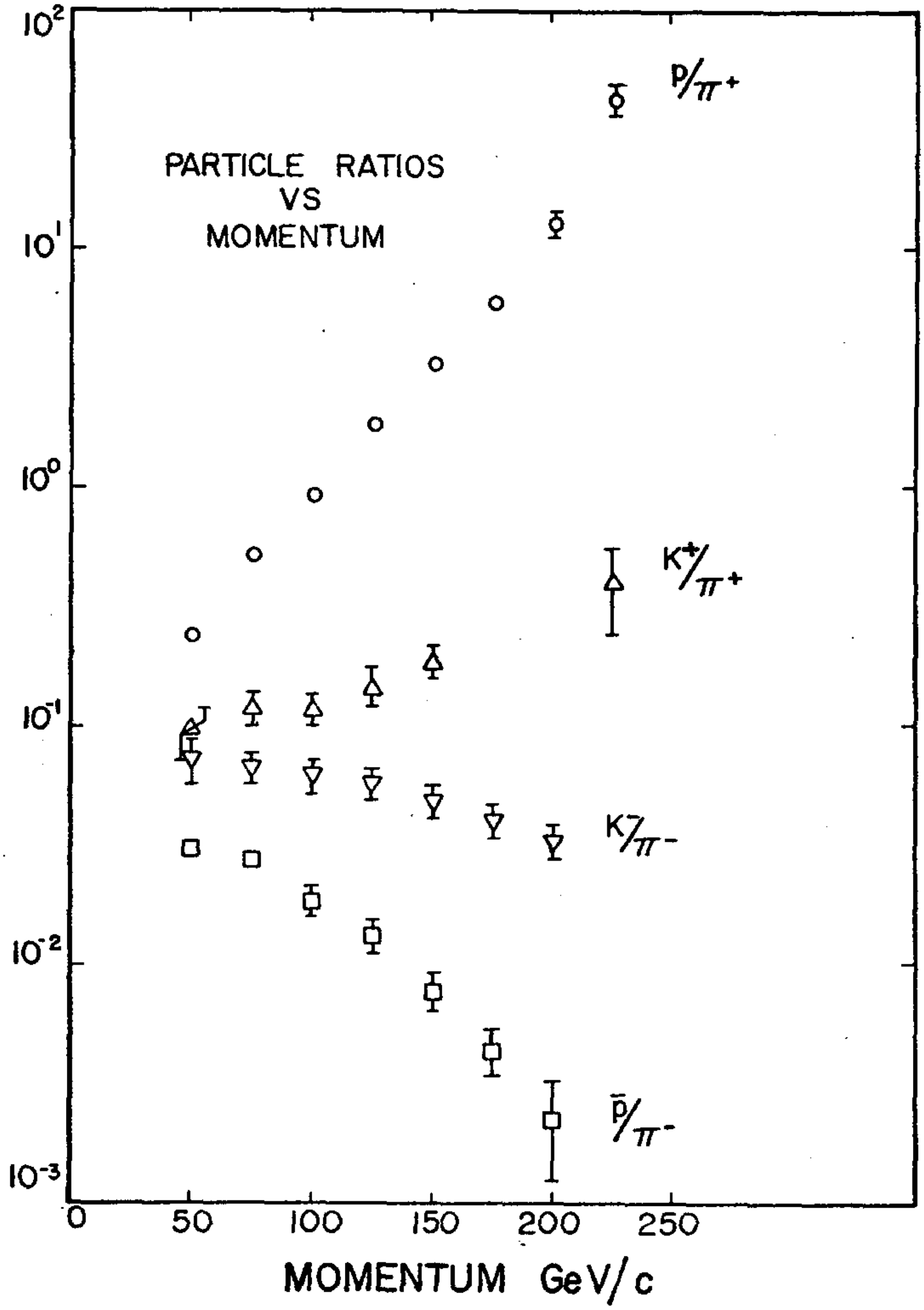

Figure 6: Particle ratios as a function of momentum for like sign particles.

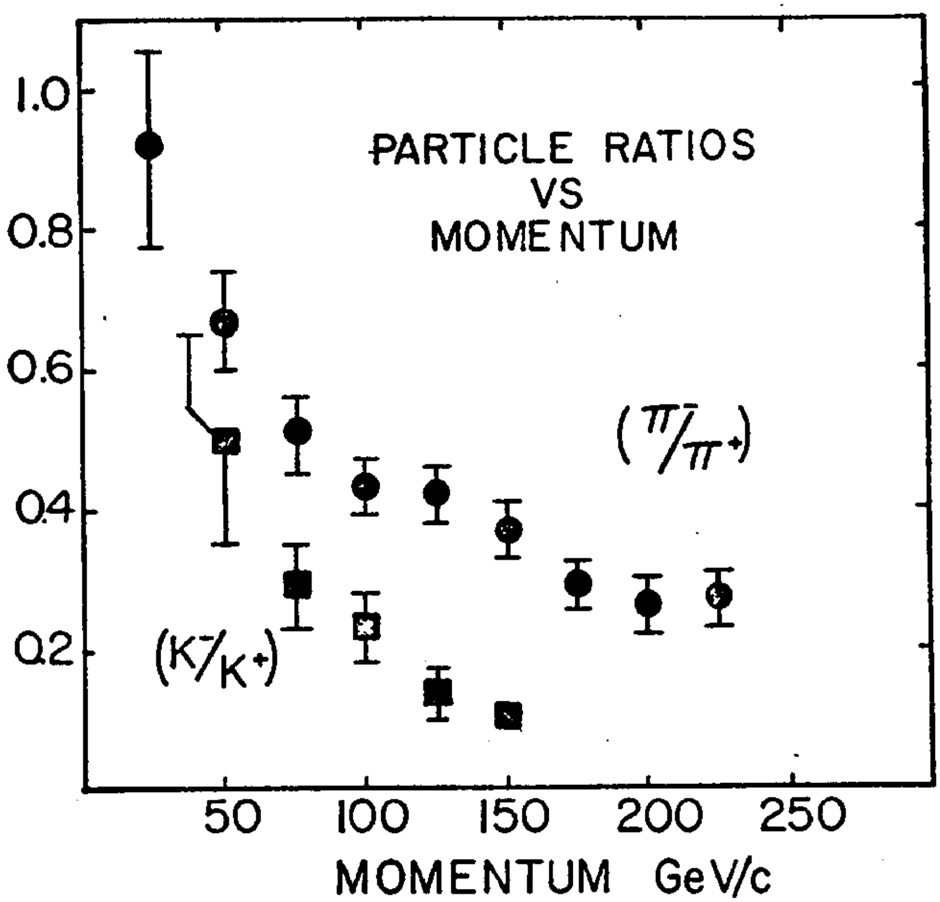

Figure 7: Particle ratios as a function of momentum for particles of opposite sign.