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# $\pi^-p$ INTERACTIONS AT 200 GeV/c

D. Bogert, R. Hanft, F. R. Huson, D. Ljung,
C. Pascaud, S. Pruss, and W. M. Smart
National Accelerator Laboratory
Batavia, Illinois

G. Abrams, B. Daugeras, C. Friedberg, G. Goldhaber,
D. Johnson, J. Kadyk, G. Trilling, and F. Winklemann
Lawrence Berkeley Laboratory
Berkeley, California

and

H. Bingham, D. Chew, W. Fretter, W. Graves,
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University of California at Berkeley
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Lawrence Berkeley Laboratory, Berkeley, Calif. 94720

H. Bingham, D. Chew, W. Fretter, W. Graves,
L. Stutte, G. Yost

University of California at Berkeley, Berkeley, Calif.94720

## ABSTRACT

Preliminary results give an average multiplicity of 8.0±.17 and a total cross section of 24.0±.5. We find that approximately 20% of the 4-prong events fit the hypothesis $\pi^-p \to p\pi^-\pi^+\pi^-$ and that essentially all of these are either beam diffraction into $\pi^-\pi^+\pi^-$ or target diffraction into $p\pi^+\pi^-$.

## INTRODUCTION

This experiment was performed in the 30-inch Hydrogen Bubble Chamber at the National Accelerator Laboratory. The unseparated hadron beam to the chamber was tuned to give 205.2 GeV/c negative particles. The beam on the target was 303 GeV/c protons from the accelerator. There were 48,000 pictures taken of which 22,758 were used for the data for this paper. Of the 22,758 pictures, 14,385 containing 93,941 beam tracks were defined usable.

Some considerations on corrections and errors that we have made are as follows:

1. Beam. The muon contamination in the beam was measured to be 2.1±0.3%. It was estimated by use of a Čerenkov Counter that the beam contained 2% kaons and 0.3% antiprotons. These two effects just cancel in cross section considerations and give an error 0.2%. There was less than 0.5% electrons in the beam.

2. Scanning. The film was scanned once by physicists and once by scanners. Any difference in events found in the two scans was rescanned. Most of the beam track count was also rescanned. Combining this with fiducial volume gives an error of 0.5%.

3. Odd Prong Events. There were 25 odd prong events found. These were correlated with secondary events too close to the primary interaction to separate. For these events we subtracted 5-prongs since that was the average multiplicity on fast secondaries.

4. Gammas and Vees. By the scanning rules used we found 119 gammas, 200 vees and 350 ambiguous gammas or vees. By studying the distance distribution between the interaction and the ambiguous gammas and vees, we determined that of the 350, 240 were gammas and 110 vees. It was also determined that 20 gammas and 23 vees were sufficiently close to the interaction to be called prongs. The correction for the gammas as a function of multiplicity was $P_\gamma(n)=.024 \times (2+.4n)$ and for vees $P_v(n)=.135$ (See Figure 1).

5. Missed 2-Prongs. By measuring all 2-prong events and trying 4 constraint kinematic fitting, we were able to separate the elastic events. From the t distribution (slope of $9.2\pm.8$ GeV$^2$) we determined that we missed 52 elastic events; all with $t<.03$ GeV$^2$. From this and the t distribution for 2-prong inelastic events, we found we missed 10 inelastic 2-prong events.

6. Hydrogen Density. We obtained the density of the hydrogen in the bubble chamber by measuring the muon length of pion-muon decays. This gave a density of 0.0625 gr/cm$^3$ with 0.6% error.

Other errors that we have considered are of the order of a few tenths of a percent.

Table I lists the topological cross sections. In the 4-prong channel the beam and target diffraction was determined by measuring the events and applying a 4 constraint kinematic fit. The beam diffraction in the 2-prong channel was estimated by looking at the measured data for each event. The total cross section was $24.0\pm0.5$ mb. where the errors considered are listed in Table I. The

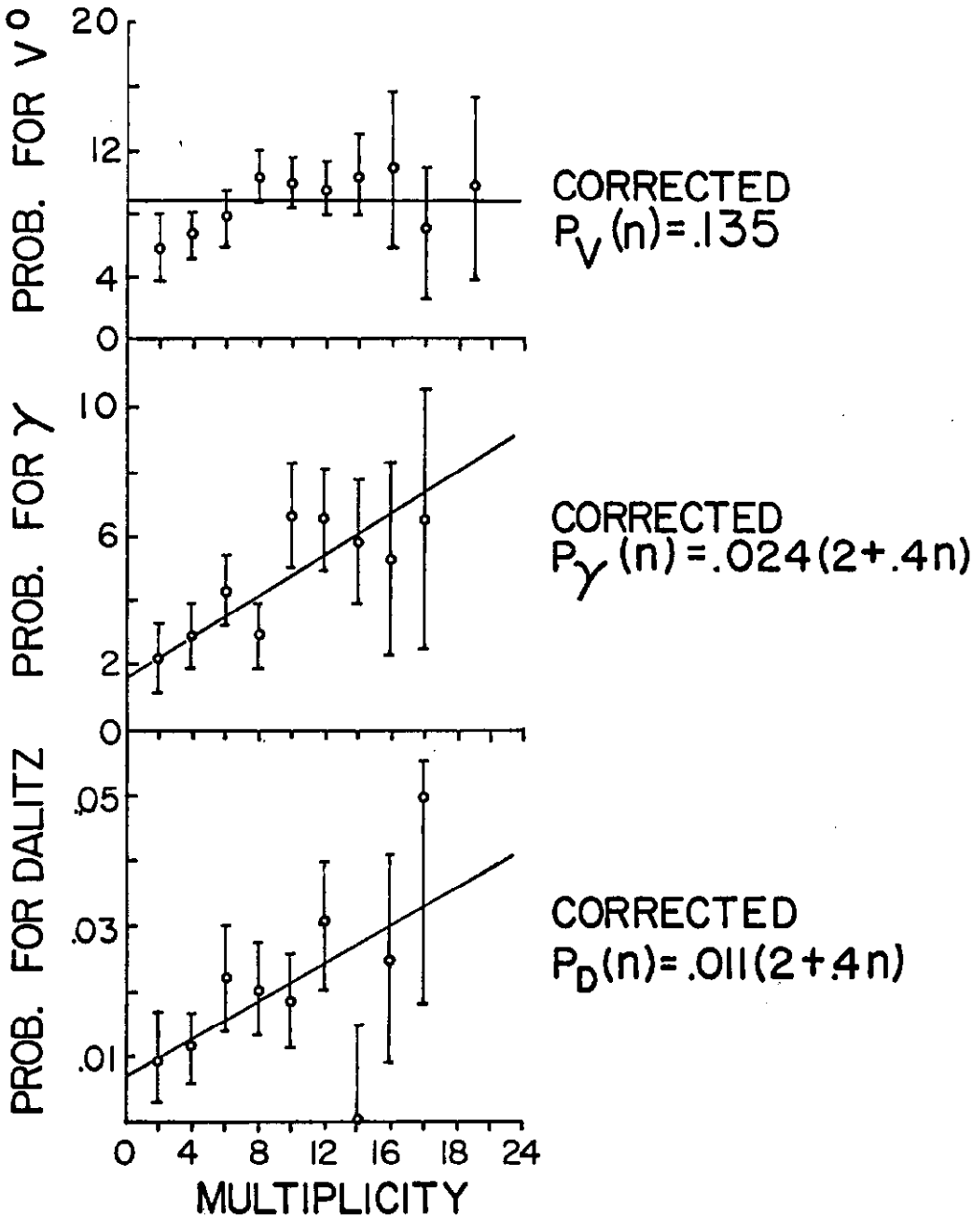


FIGURE 1.

(a) Probability event has an identified vee.
(b) Probability event has an identified gamma.
(c) Probability event has an identified Dolitz Pair.

TABLE I

| Prongs | | Events | | σ | | Δσ |
|---|---|---|---|---|---|---|
| 0 | | 2 | | .02 | | .01 |
| 2 | Total | 666 | | 4.95 | | .19 |
| | Elastic | | 439 | | 3.26 | .32 |
| | Inelastic | | 227 | | 1.69 | .25 |
| | A diff. | | 61 | | .42 | |
| 4 | Total | 463 | | 3.43 | | .16 |
| | A diff. | | 57 | | .42 | .07 |
| | N* diff. | | 32 | | .24 | .05 |
| 6 | | 515 | | 3.82 | | .17 |
| 8 | | 543 | | 4.02 | | .17 |
| 10 | | 455 | | 3.37 | | .16 |
| 12 | | 292 | | 2.16 | | .13 |
| 14 | | 161 | | 1.19 | | .09 |
| 16 | | 72 | | .53 | | .06 |
| 18 | | 40 | | .30 | | .05 |
| 20 | | 11 | | .08 | | .02 |
| 22 | | 7 | | .05 | | .02 |
| 24 | | 1 | | .01 | | .01 |
| | | 3228 | | 24.0 | | .5 |

ERRORS CONSIDERED FOR TOTAL CROSS SECTION

| | |
|---|---|
| Statistics | 1.76% |
| Density | .60% |
| Scan | .50% |
| 2 Prong | .50% |
| Muon | .30% |
| Miscellaneous | .60% |

topological multiplicity is plotted as a function of incident momentum in Figure 2. The moments for the multiplicity distribution are given in Table II.

TABLE II

MOMENTS FOR MULTIPLICITY

| | Charge Prongs | | Negative Prongs | |
|---|---|---|---|---|
| | 50 GeV/c [4] | 205 GeV/c | 50 GeV/c | 205 GeV/c |
| $\langle n \rangle$ | 5.79±.2 | 8.00±.17 | 2.89±.1 | 4.0±.1 |
| $\langle n(n-1) \rangle$ | 35.2±1.6 | 71.0±1.9 | 7.3±.4 | 15.8±.4 |
| $f_2 = \langle n(n-1) \rangle - \langle n \rangle^2$ | 1.6±1.1 | 7.0±1.2 | -1.0±.3 | -.25±.3 |
| $D = \frac{\langle n \rangle}{\sqrt{\langle n^2 \rangle - \langle n \rangle^2}}$ | 2.12 | 2.06±.1 | | |

In Figure 3 the $f_2$- is plotted for various incident momenta to indicate that it is going through O at about 200 GeV/c. This permits a good fit for a Poisson distribution in pion pairs at our mementum, however, at other momenta it does not fit. Figure 4 shows the multiplicity plot using KNO[1,2]scaling. It appears that the pions start scaling at about 50 GeV/c. Figure 5 shows the average charge multiplicity for pions[3,4] and protons[5].

The total cross section of 24.0±0.5 mb. is shown in Figure 6. Figure 7 presents antiproton, proton, pion and kaon cross sections with curves predicted by the Impact Picture[6]. Our data point has been added to the Figure. The elastic cross section is shown in Figure 8. Using the optical theorem, the elastic cross section is consistent with our total cross section.

As mentioned above the 4-prong events were measured and a 4 constraint kinematic fit was attempted. Of 293 events, 62 fit $\pi^- p \to p\pi^-\pi^+\pi^-$. As indicated in Figure 9 and 10, 37 of these events are consistent with beam diffraction and 23 with target diffraction. There maybe a small background of events with a missing $\pi^0$, however, we believe it to be small since the majority of these events fall into the 2 diffraction channels. Table III is a comparison of these diffraction cross sections with

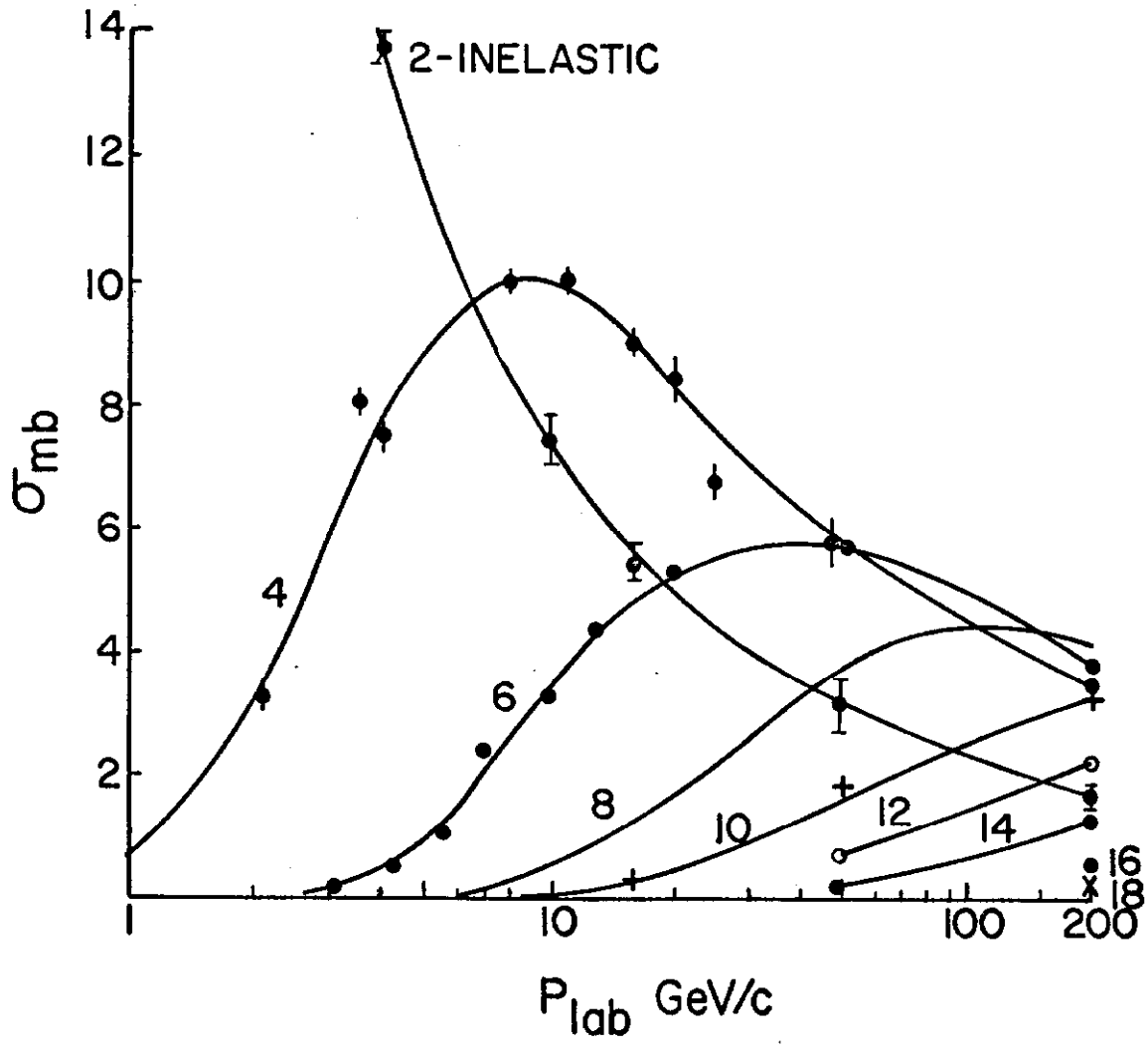


FIGURE 2.

Topological Multiplicity For π-p

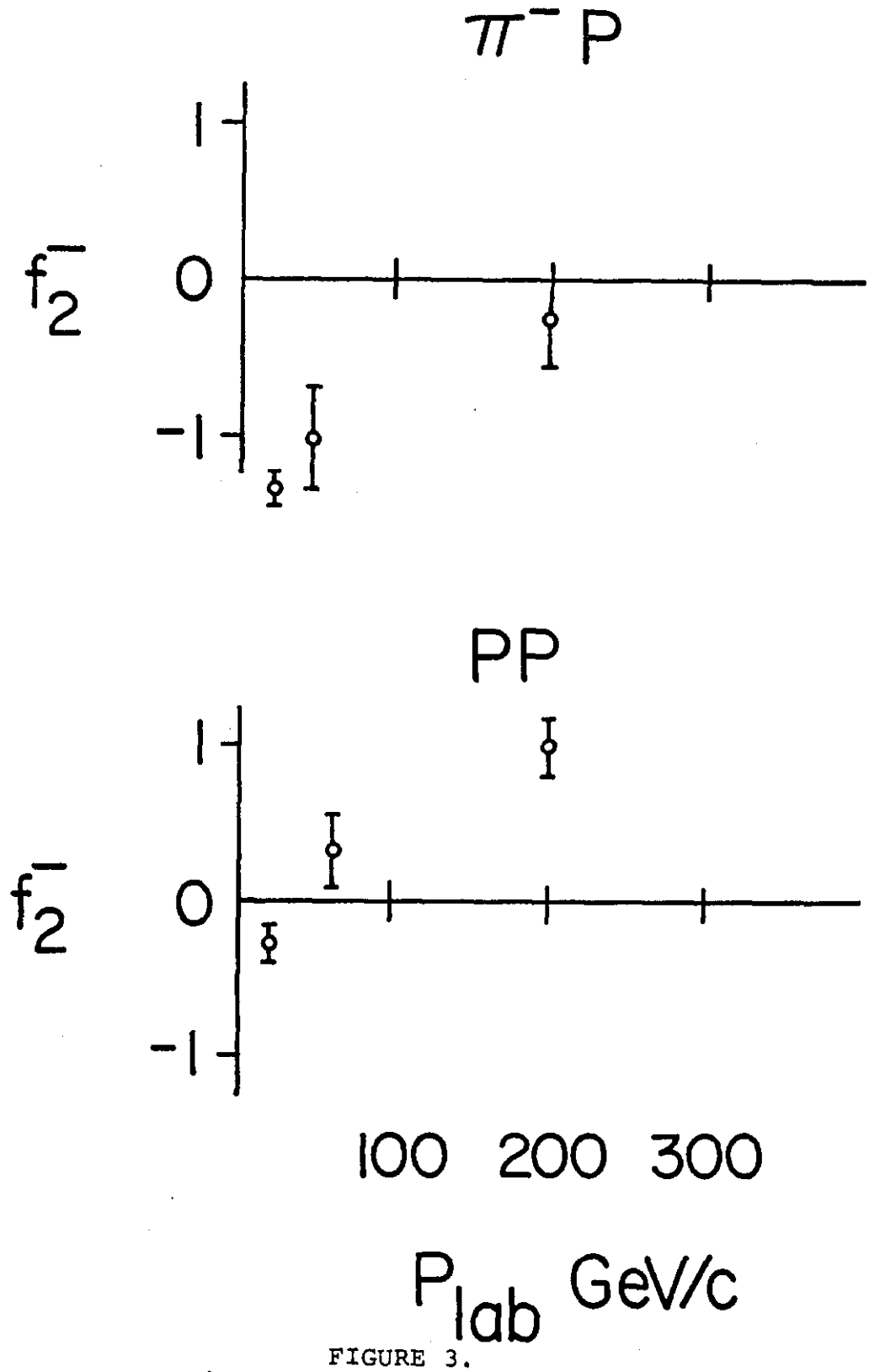


FIGURE 3.

$f_2^- = \langle n(n-1) \rangle - \langle n \rangle^2$ for $\pi$-p and pp interactions.

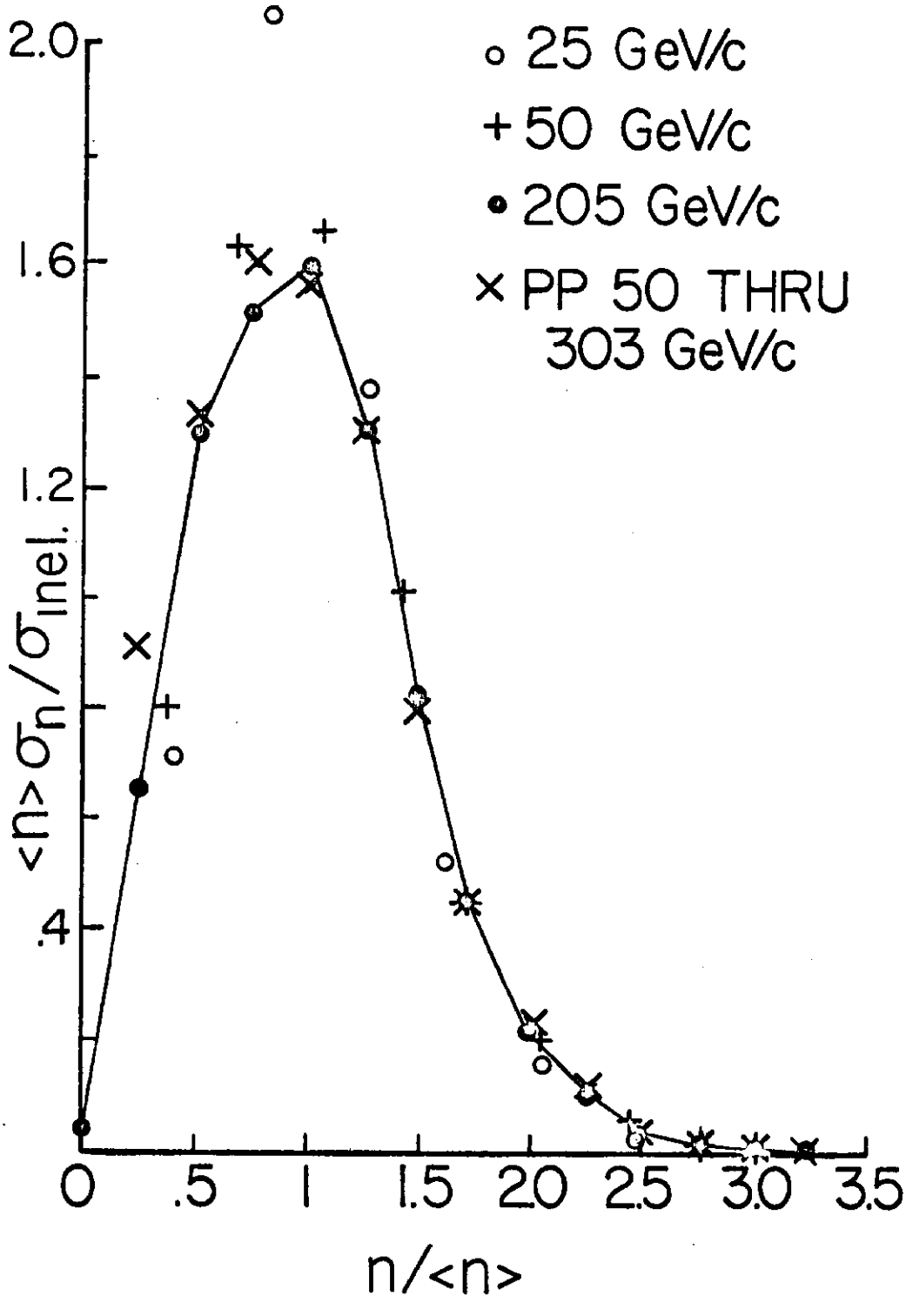


FIGURE 4.

KNO Scaling

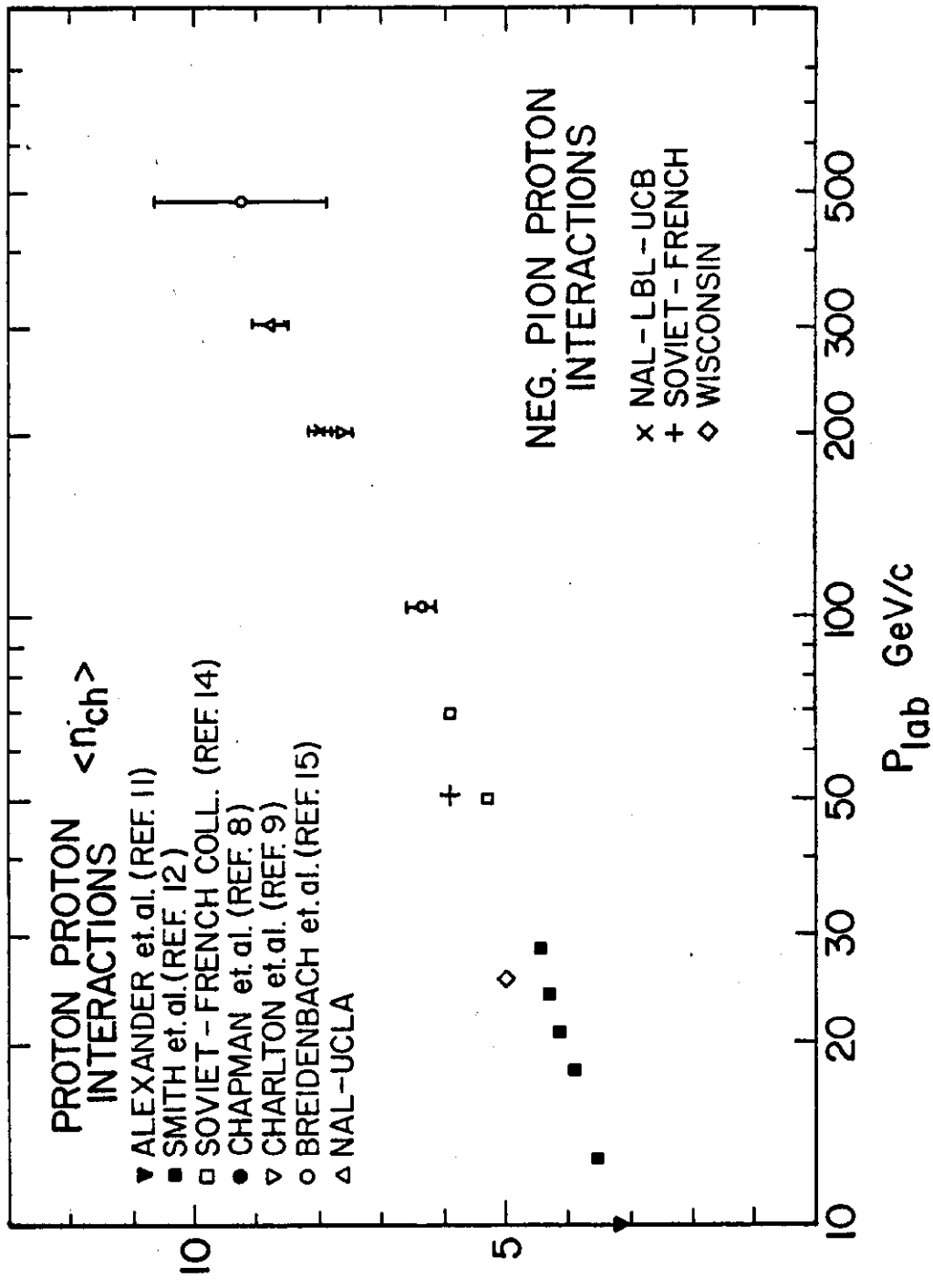


FIGURE 5.

Average Charge Multiplicity
vs.
Momentum for Pions and Protons[3]

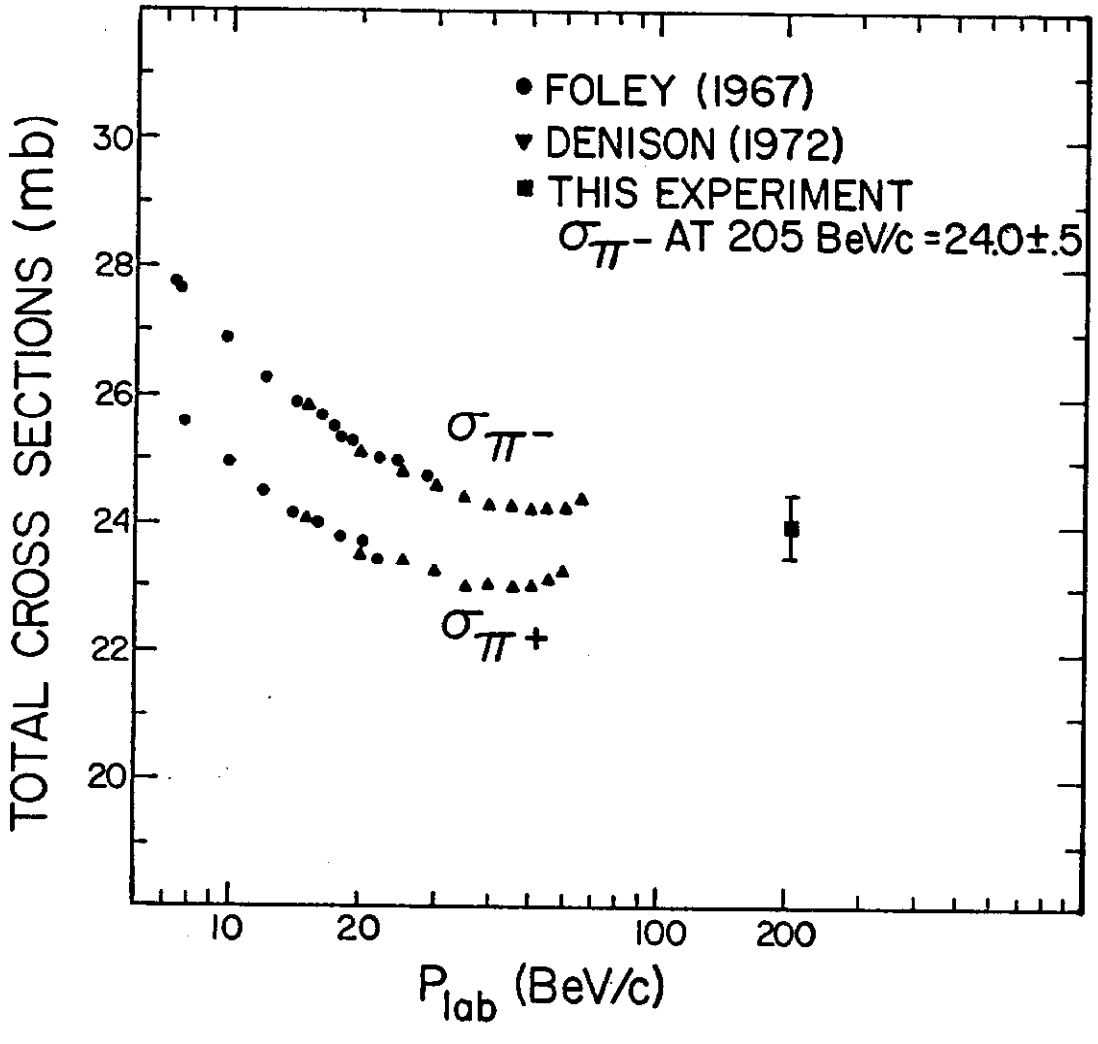


FIGURE 6.

Total Cross Section For Pions

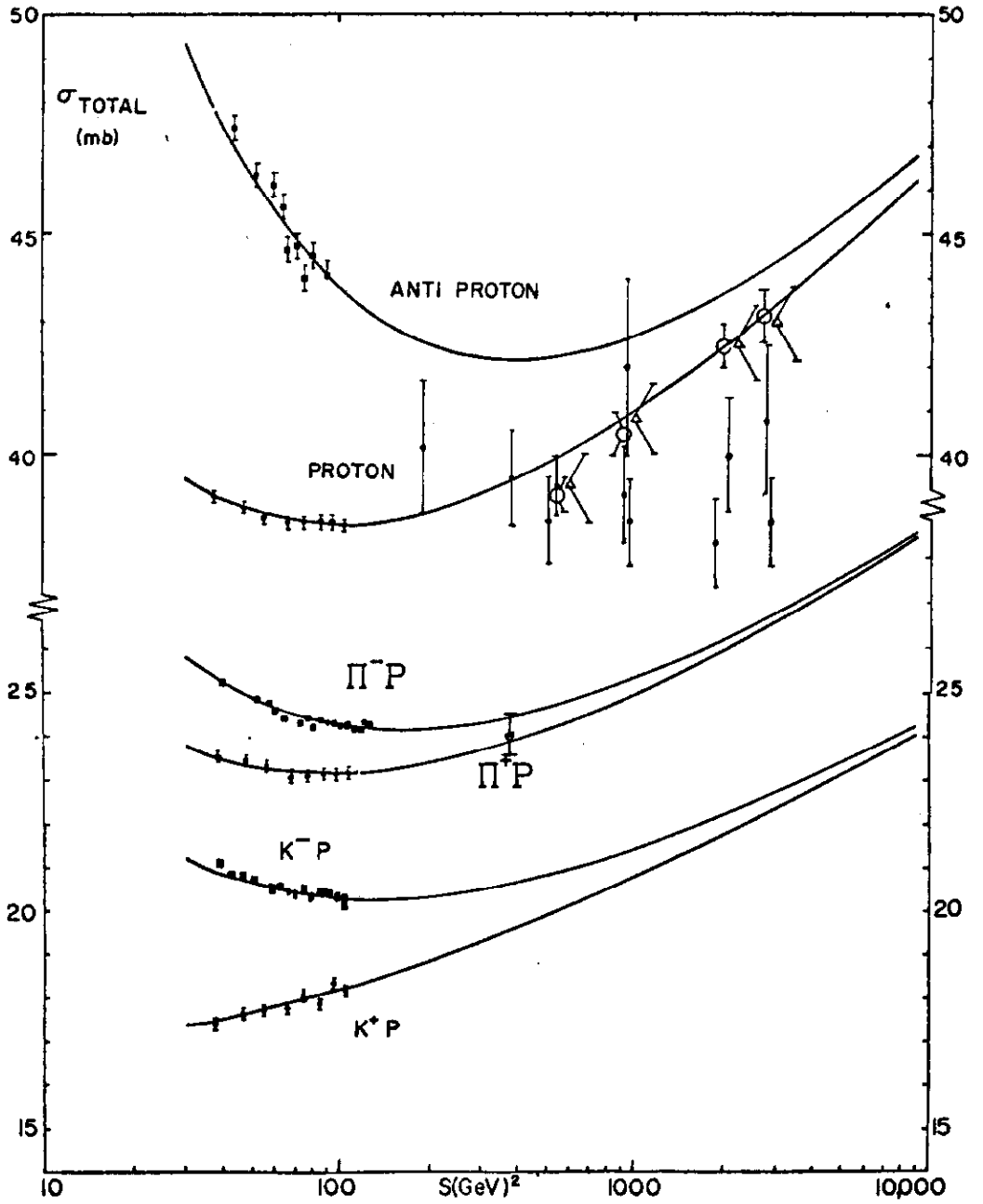


FIGURE 7.

Total Cross Section with Curves Predicted by the Impact Picture.[6] Our data point has been added.

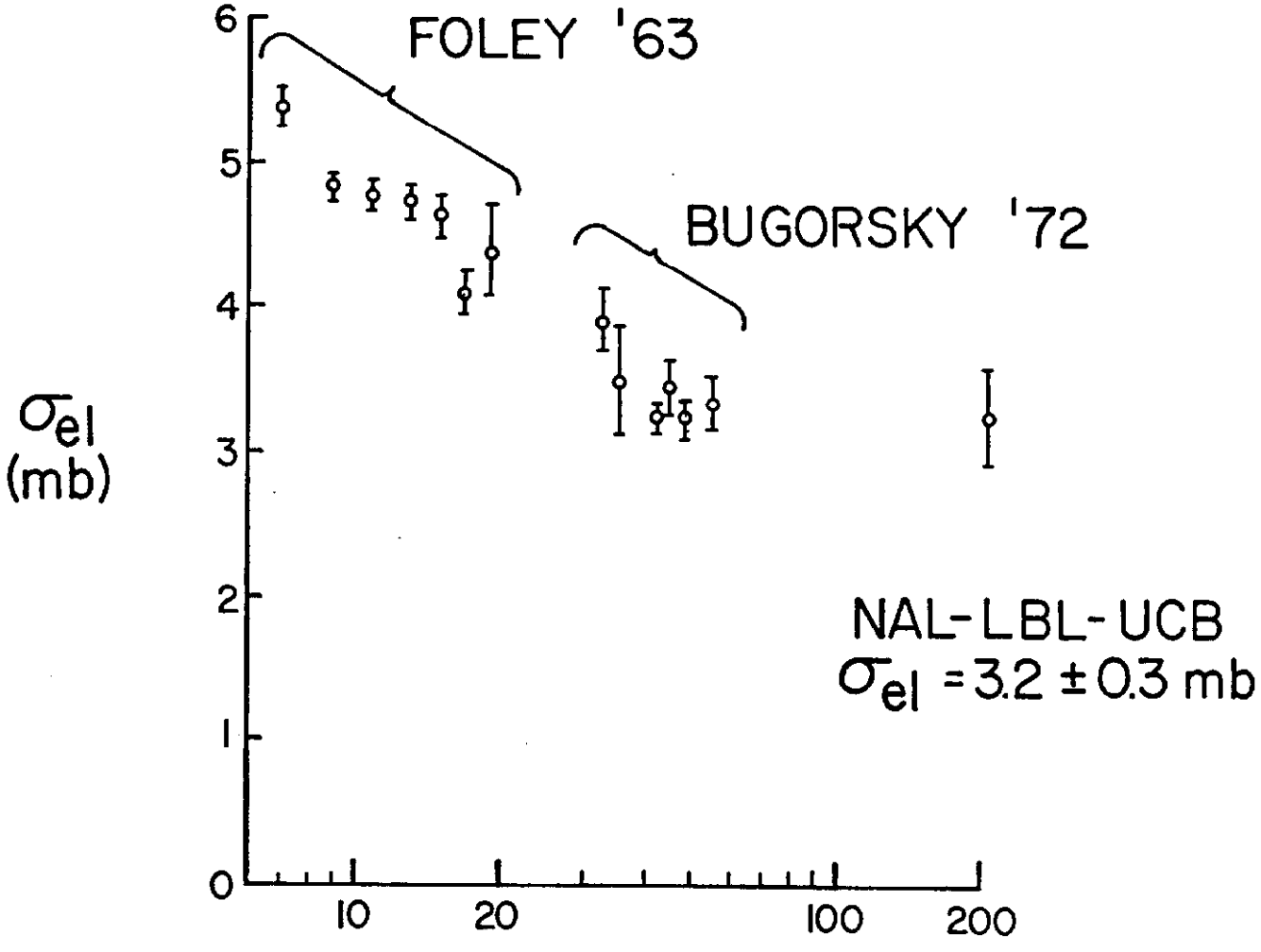


FIGURE 8.

Elastic Cross Section For Pions

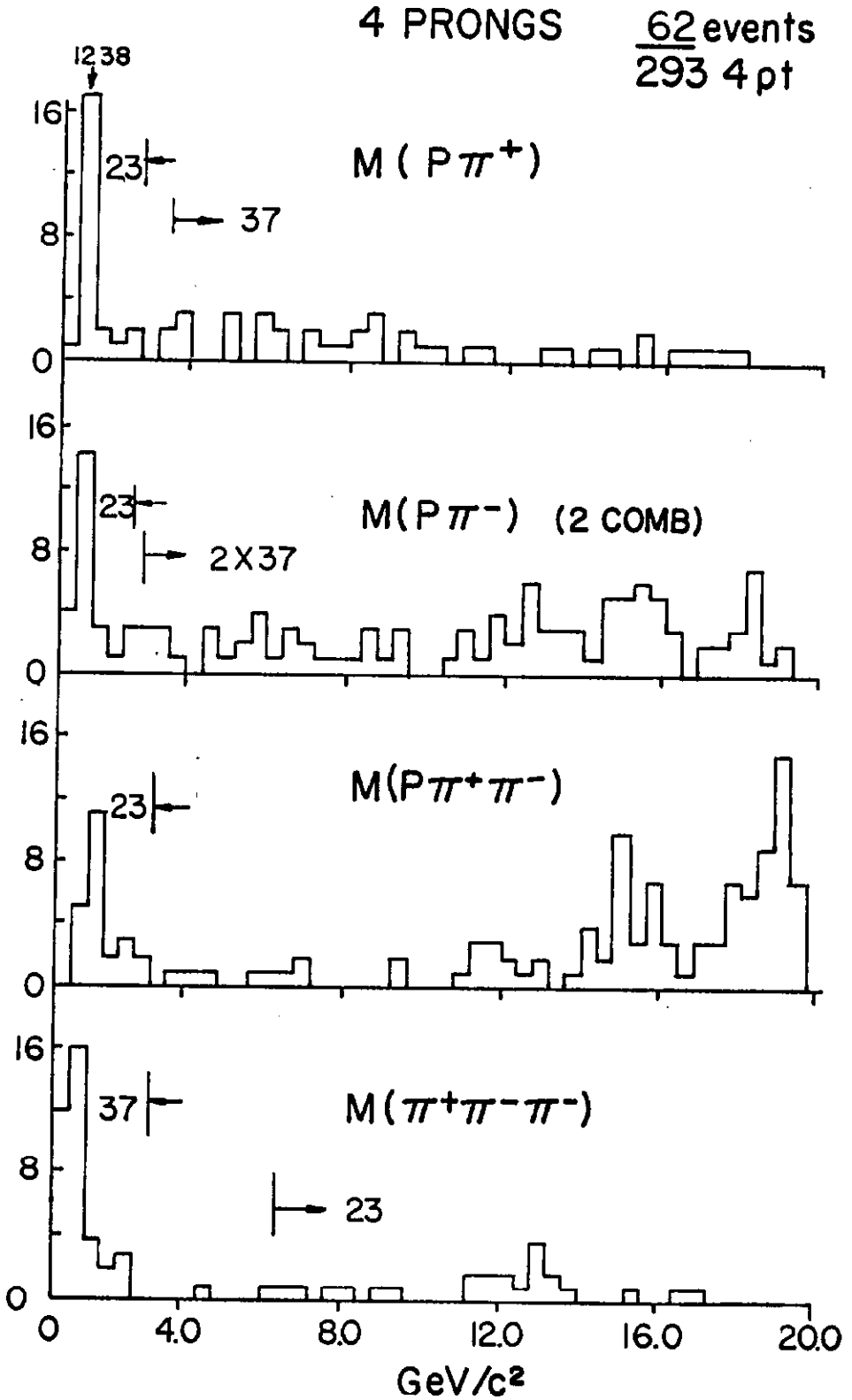


FIGURE 9.
Mass Distribution for $\pi^- p \to p\pi^-\pi^+\pi^-$

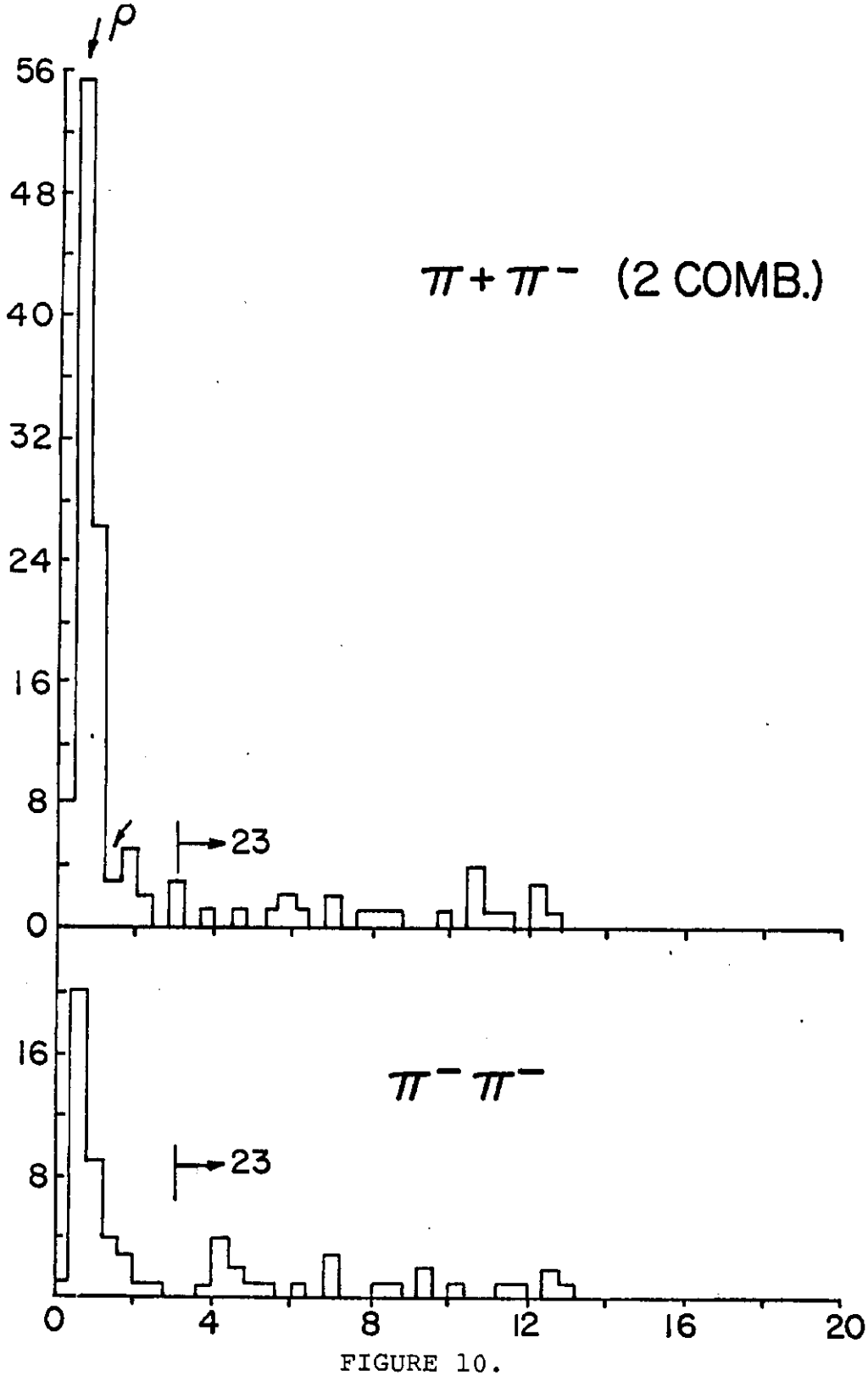


FIGURE 10.
Mass Distribution for $\pi^- p \to p\pi^-\pi^+\pi^-$

TABLE III

DIFFRACTION CROSS SECTIONS

| | 3.9[7] | 11.9[7] | 205 |
|---|---|---|---|
| $\pi p \rightarrow (\pi^- \pi^+ \pi^-) p$ | .26±.04 | .45±.08 | .42±.07 |
| $\pi^- p \rightarrow (p \pi^+ \pi^-) \pi^-$ | .39±.04 | .30±.04 | .24±.05 |

lower energy. They are all consistent with an approximately constant diffraction cross sections.

In conclusion this pion data represents a unique region of physics available at NAL. These preliminary data support KNO scaling for pions, give a total cross section of 24.0±0.5 mb. and an elastic cross section of 3.2±.3 mb. and indicate that the low multiplicities contain a large amount of beam and target diffraction. These diffraction cross sections are constant within the errors.

It is a pleasure to acknowledge the enormous effort put forth by many people at NAL to make this experiment possible.

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