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ABSTRACT

Total cross-section measurements for π^- collisions with protons are presented for the pion momentum range 2 to 5 BeV/c, where data have been meager. Comparison with other data for pion momenta slightly below 2 BeV/c suggests either a disagreement or an unexpected variation in cross sections. Cross sections for π^+ and π^- collisions with carbon nuclei are also compared.

TOTAL CROSS SECTIONS OF NEGATIVE PIONS IN THE MOMENTUM RANGE 2 TO 5 BeV/c*

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Few accurate data are presently available on the total π^--p cross section in the momentum range 2 to 4.5 BeV/c. We present here the results of measurements in this range using counter techniques. In addition, cross sections in good geometry for π^--carbon scattering were measured at 3 and 4 BeV/c in order to investigate a discrepancy between the π^+-C cross sections previously measured by the authors[1] and the π^--C cross sections of Wikner.[2]

The experimental arrangement is shown in Fig. 1. The pion beam was used simultaneously by the University of Michigan spark chamber group to measure π^--p differential cross sections. After passing through their 18-in.-long hydrogen target, the beam was refocused by Q_2 and used for our measurements. The π^--p cross sections were measured by using a CH_2-C subtraction with carefully matched polyethylene and graphite targets, the former containing 2.9 g/cm^2 of hydrogen. Incident pions were counted by measuring $M_1M_2CM_3M_4$ coincidences. The numbers of transmitted pions were measured with three different geometries simultaneously by means of counters S_1, S_2, and S_3, which were respectively 12.0, 10.6, and 9.0 in. in diameter. Measurements were made with two different target positions so that the total range of solid angles covered was 1.7 to 5.8 msr. The quadrupole Q_2 was tuned to produce an image of M_2 at the position of S_3 in order to reduce multiple Coulomb scattering corrections. Muons in the beam were eliminated by rejecting particles that passed through a 36-in.-long iron block with an "anti" counter A, as was done by von Dardel et al.[3]

*Work done under the auspices of the U. S. Atomic Energy Commission.

Total cross sections were obtained by extrapolating the measured cross sections linearly to zero solid angle. This extrapolation represented a correction of approx 0.4 mb to the measured values. At 2.0 BeV/c, a small correction for multiple Coulomb scattering was made to the point at 1.7 msr. Corrections of approx 0.6 mb were made at 2.0 and 3.0 BeV/c for electron contamination in the beam, which was measured with a gas Cerenkov counter. At 2.0 BeV/c it was also necessary to apply a small correction for low-energy muons that stopped in the iron block and thus were not "antied" out. The quoted errors include uncertainties in these corrections as well as the statistical errors.

At each momentum an average of five measurement cycles was made at different times during the experiment, each consisting of a sequence of two runs with the carbon target, four runs with the polyethylene, and two more runs with carbon. The reproducibility of repeated runs was within statistics. Accidental coincidences were monitored constantly and were always negligible. The momentum of the beam was determined from the kinematics of events observed in the Michigan spark chamber experiment. The uncertainty in momentum is about ± 2 %.

The measured cross sections are given in Table I and compared with the results of other experiments in Fig. 2. At the higher momenta our results agree well with those of von Dardel et al.[3] Near 2 BeV/c, however, our result is considerably higher than previous results at somewhat lower momenta.[4,5] Our point at 2.0 BeV/c is an average of five measurements made at different times during the experiment with very good reproducibility, and we believe that no systematic error on our part could explain the difference. We therefore suggest that further studies be made in this momentum region to investigate the possibility of structure in the π^--p total cross section. It is interesting to note that a "bump" near 2 BeV/c is appropriate to the reappearance of the Regge pole for the 600-MeV π-N resonance. See Table I.

Table I. Measured π^--p cross sections.

Momentum (BeV/c)	$\sigma(\pi^-\text{-p})$ (mb)
2.00	35.7 ± 0.8
2.95	30.9 ± 0.9
4.00	30.8 ± 1.0
4.90	28.7 ± 1.0

A previous measurement, by the authors,[1] of π^+ cross sections for several nuclei at 3 BeV/c disagreed with the results of Wikner for negative pions at 4 BeV/c.[2] It appeared that the absorption cross sections for π^- and π^+ scattering on nuclei were substantially the same, but that the total cross sections for negative pions were consistently 30% larger. This difference would imply a breakdown of charge symmetry at high energies. We therefore made measurements of π^--C cross sections at 3.0 and 4.0 BeV/c. The results are given in Fig. 3 along with our previous results for π^+-C scattering. The π^+-C results at 3.0 BeV/c are slightly lower than those for π^--C at 3.0 BeV/c. This is probably explained by the fact that there are more charged secondaries (i.e., protons) formed in π^+-C inelastic scattering than in π^--C. Some of these strike the transmission counter, thus increasing the apparent transmission and lowering the apparent cross section. This difference would be expected to diminish as the solid angle subtended by the transmission counter is decreased. By extrapolating the measured cross sections linearly to zero solid angle (as was done with hydrogen) we can estimate the total cross section. This yields a total cross section of 292 mb for π^+ scattering at 3 BeV/c and 294 mb for π^- scattering. This excellent agreement is somewhat fortuitous, but in any case, there is no evidence for a violation of charge symmetry. For π^--C scattering

at 4.0 BeV/c we find a total cross section of 281 mb, in contrast to Wikner's result of 386 ± 20 mb. We also made measurements with a Be target and again found good agreement between the π^+ and π^- results.

ACKNOWLEDGMENTS

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FOOTNOTES AND REFERENCES

† Now at Physics Department, University of Michigan.

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FIGURE CAPTIONS

Fig. 1. Experimental arrangement. The π^- beam was taken off at 0 deg from a target in the Bevatron. The first quadrupole and bending magnet are not shown. The vertical scale is exaggerated twofold for clarity.

Fig. 2. Total π^--p cross sections vs momentum.

Fig. 3. Pion-carbon cross sections as a function of the solid angle subtended by the transmission counter.

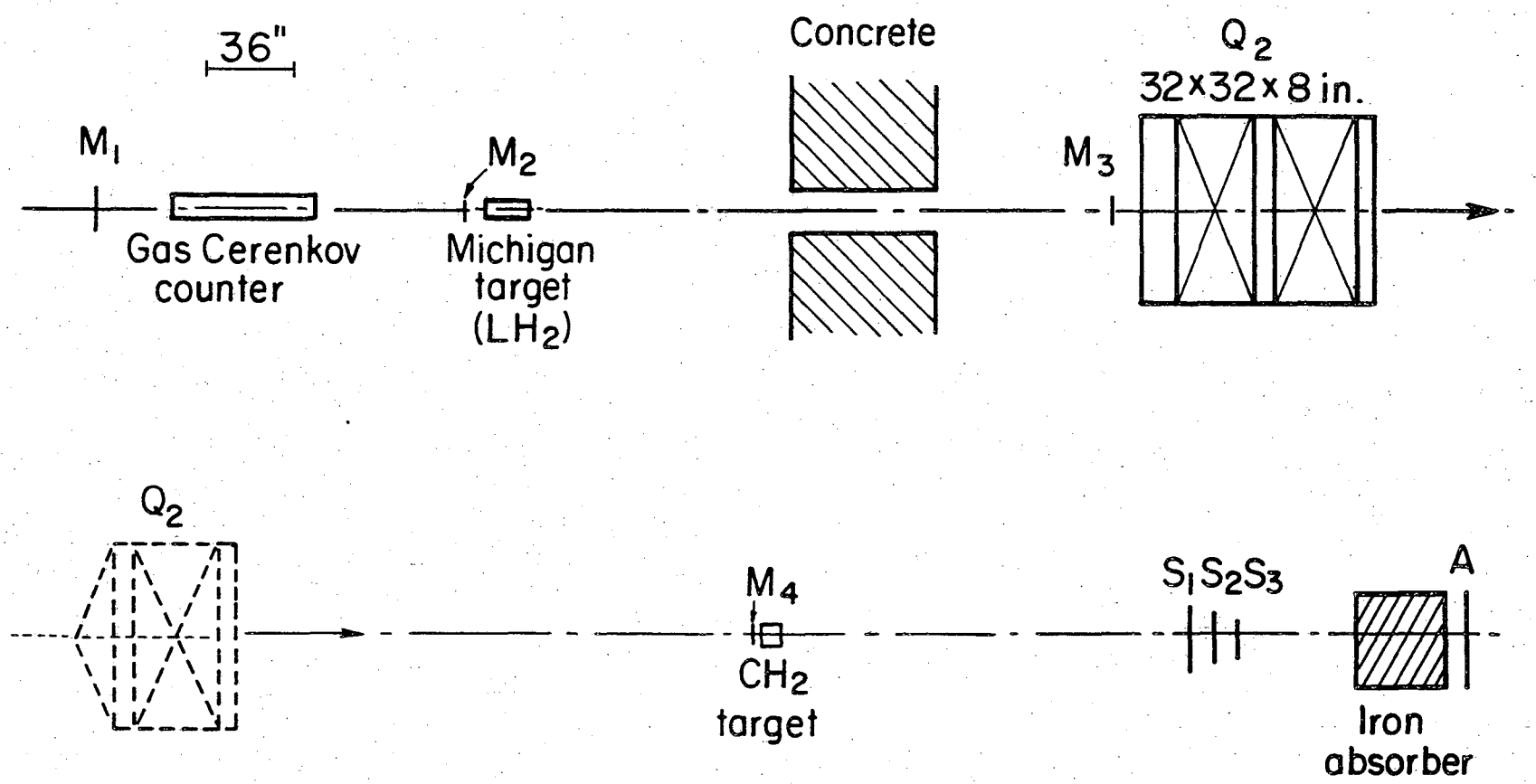

Fig. 1.

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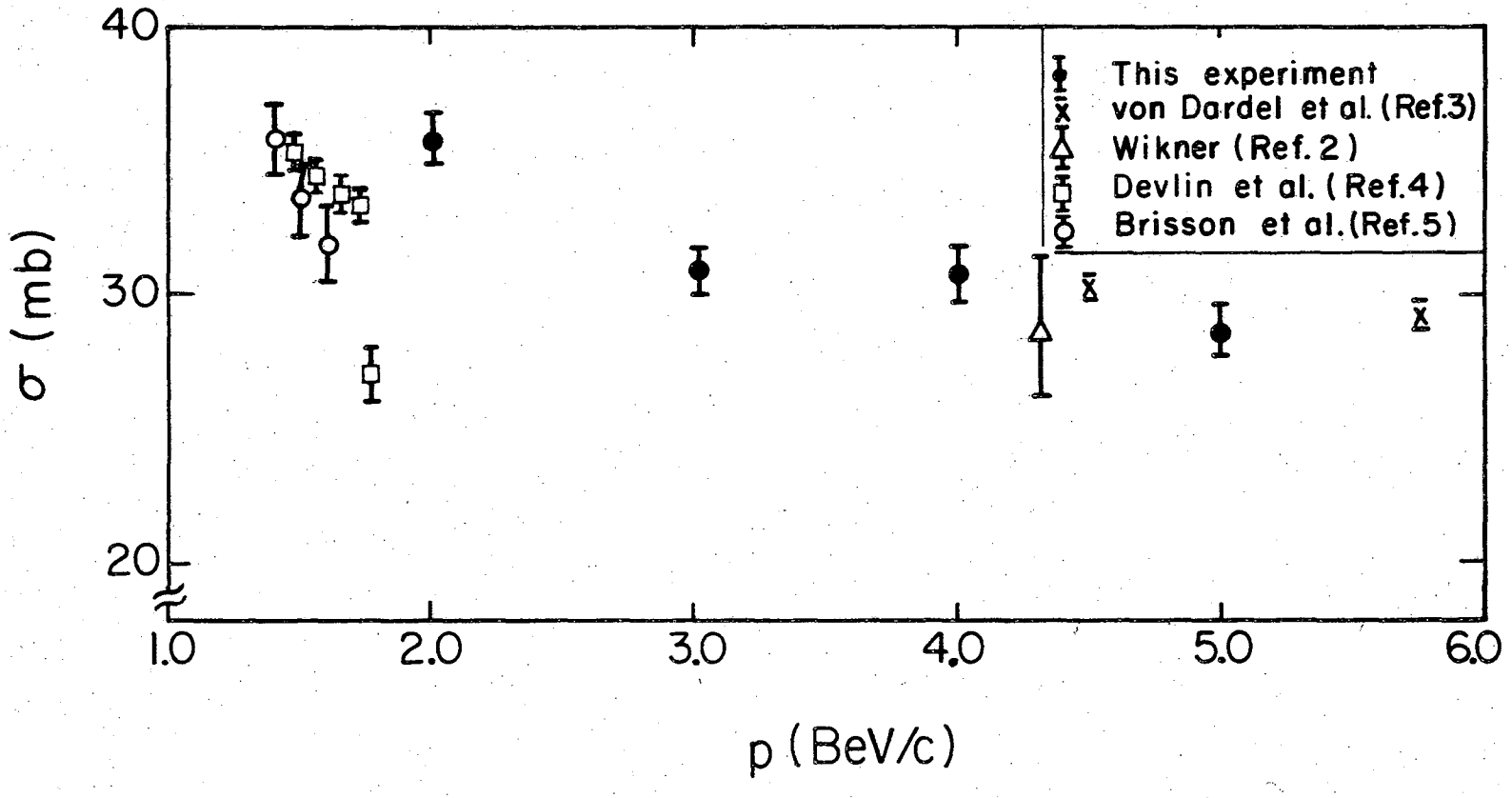

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Fig. 2.

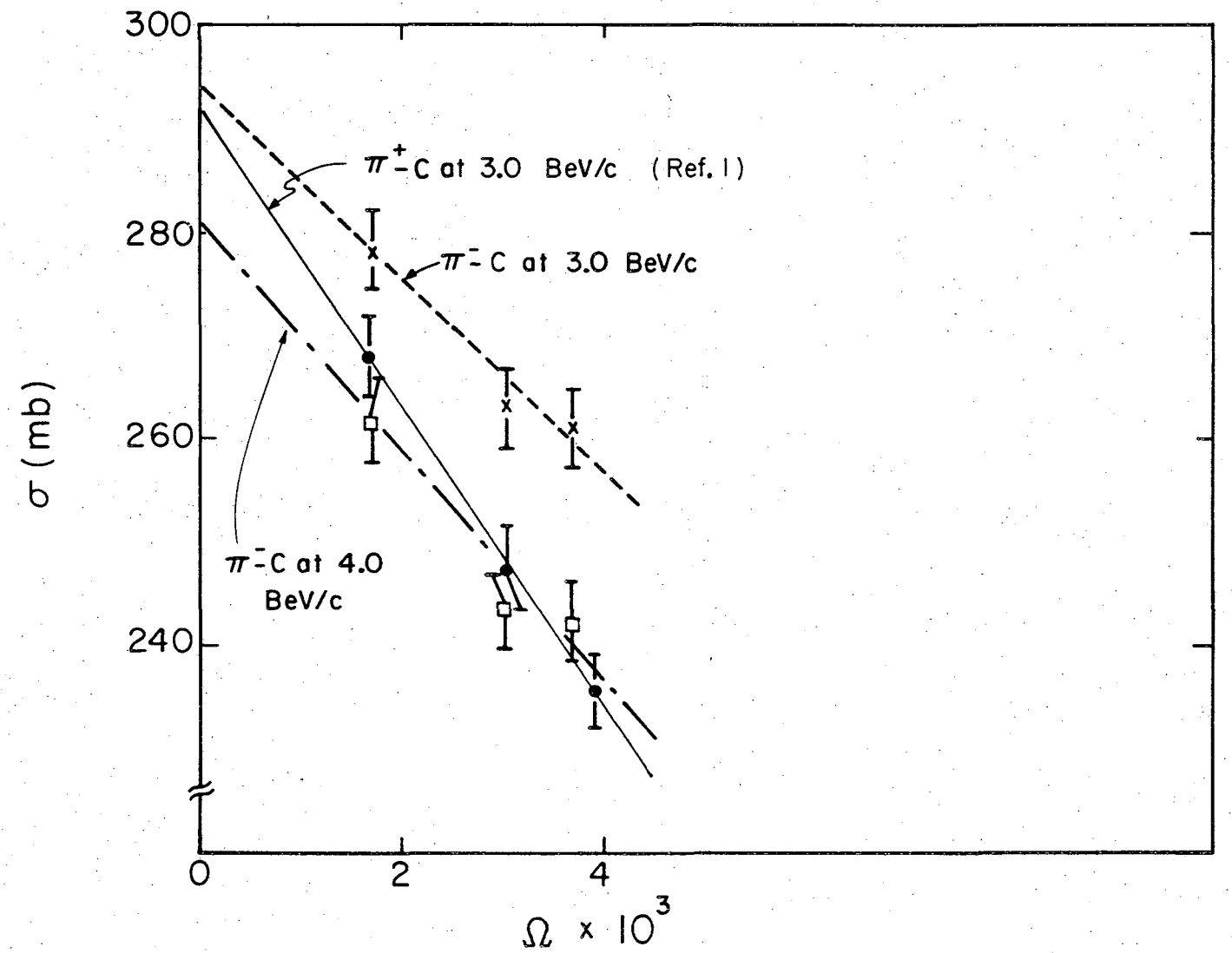

Fig. 3

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