Within the sample of spallation hyperfragments produced by the interaction of both 800-MeV/c and 1.5-BeV/c K^- mesons, the three examples of mesonic decay in Table I were accompanied by ~1100 nonmesonic disintegrations. This may not be inconsistent with a nonmesonic/mesonic ratio of order 100 as given recently in a preliminary estimate[6] for a hypernucleus of mass $A \approx 100$.

We are grateful to Professor R. H. Dalitz, Professor M. Demeur, and Professor V. Telegdi, and to Dr. J. Reignier for many valuable discussions. The Brussels group wishes to thank the members of the K^- European Collaboration, with whom part of this work was done, for helpful cooperation. We wish to express our gratitude to both the Bevatron and CERN proton synchrotron staffs for the exposures of the stacks.

*Research supported by the U. S. Air Force Office of Scientific Research, Contract No. AF 49(638)-209.

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[1]B. D. Jones, B. Sanjeevaiah, J. Zakrzewski, M. Csejthey-Barth, J. P. Lagnaux, J. Sacton, M. J. Beniston, E. H. S. Burhop, and D. H. Davis, Proceedings of the Aix-en-Provence Conference on Elementary Particles, 1961 (C. E. N. Saclay, France, 1961); Phys. Rev. 127, 236 (1962).

[2]By a similar approach, Kenyon has recently obtained $B_\Lambda < \sim 57$ MeV for a comparable selection of hypernuclei [I. R. Kenyon (to be published)].

[3]Both upper limits on B_Λ obtained above could be, in fact, underestimated owing to the following effects: (a) the presence of spallation hypernuclei off the nuclear stability line, having separation energy B_N or $B_P \neq 8$ MeV, contrary to what was assumed, and (b) the possibility that such hypernuclei were produced in excited states and that they did not reach the ground state before undergoing mesonic or nonmesonic disintegration. These uncertainties are assumed to involve an error of ~±2 MeV in the quoted B_Λ values.

[4]R. G. Ammar, L. Choy, W. Dunn, M. Holland, J. H. Roberts, E. N. Shipley, N. Crayton, D. H. Davis, R. Levi Setti, M. Raymund, O. Skjeggestad, and G. Tomasini (to be published).

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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

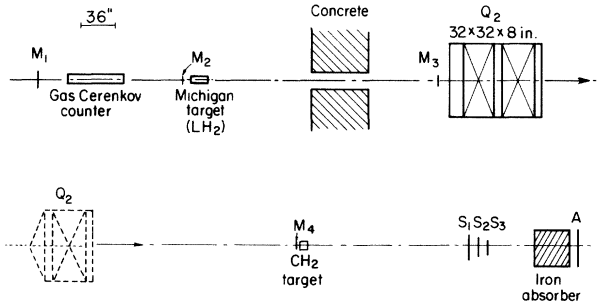

FIG. 1. Experimental arrangement. The π^- beam was taken off at 0 degrees from a target in the Bevatron. The first quadrupole and bending magnet are not shown. The vertical scale is exaggerated twofold for clarity.

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]

Total cross sections were obtained by extrapolating the measured cross sections linearly to zero solid angle. This extrapolation represented a correction of approximately 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 approximately 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 Cherenkov 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, the existing data, as a whole, seem inconsistent. Due to this uncertainty

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

Momentum (BeV/c)	$\sigma(\pi^-$-$p)$ (mb)
2.00	35.7 ± 0.8
3.10	30.9 ± 0.9
4.10	30.8 ± 1.0
4.90	28.7 ± 1.0

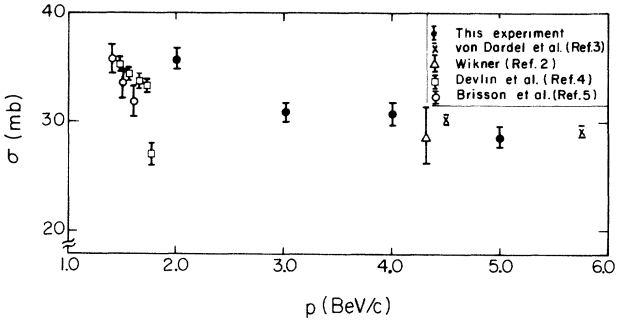

FIG. 2. Total π^--p cross sections vs momentum.

in the data around 2 BeV/c and the scarcity of data between 2.0 and 3.0 BeV/c, further measurements in this region are desirable.

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 transmis-

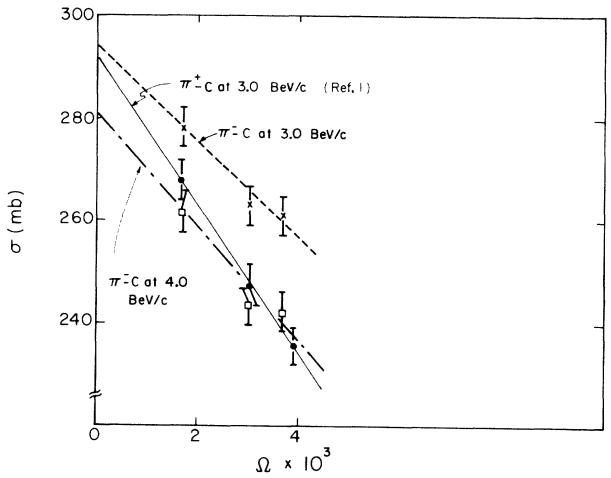

FIG. 3. Pion-carbon cross sections as a function of the solid angle subtended by the transmission counter.

sion 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.

We wish to express our gratitude to the University of Michigan spark chamber group, particularly to Dr. Lawrence Jones and Dr. Martin Perl, for their help and cooperation, which made this work possible. We are deeply indebted to Robert A. Profet for his generous assistance in the preparation and execution of the experiment.

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

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PION-PROTON ELASTIC DIFFRACTION SCATTERING AT 3, 4, AND 5 GeV/c†

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(Received October 29, 1962)

The elastic differential cross section of negative pions on protons at 3.15, 4.13, and 4.95 GeV/c and of positive pions on protons at 2.92 GeV/c has been measured in a spark chamber experiment using the Bevatron of the Lawrence Radiation Laboratory.[1] The data in the diffraction region for these momenta are reported in this Letter. The interest in these diffraction data centers about the recent theoretical developments in the field of strong interactions, which predict that at sufficiently high energies the differential cross section in the diffraction region should be an exponential function of the four-momentum transfer, and that the width of the diffraction peak should decrease with increasing energy.[2] Our data show the predicted exponential behavior for small four-momentum transfers, but no statistically significant shrinkage of the π^-+p diffraction peaks over the 3- to 5-GeV/c interval is observed. Comparison with other published π^-+p data[3-5] up to 16 GeV/c also gives little evidence of shrinkage, although this observation is strongly influenced by the data at 15.9 GeV/c which have relatively large published errors. This appears to be in contrast to the proton-proton case, where the data are in remarkable agreement with the Regge behavior.[6,7]

The experimental data are plotted on a semilogarithmic scale in Fig. 1 where the errors shown are statistical.[8] The data consist of about 1200 elastic events at each momentum, obtained from an analysis of one half of the data film. The points at $t=0$ are calculated from zero-momentum-transfer dispersion relations and the optical theorem using the recent total cross section data taken by Longo and Moyer in the 3- to 5-GeV/c range.[9] For the π^-+p data the over-all error in normalization may be ±8%. However, there are some uncertainties in the composition of our π^+ beam, and therefore the normalization error for those data may be as great as ±30%.

The Regge pole theory[2] predicts that the elastic diffraction scattering may be expressed by

$$d\sigma/dt = (d\sigma/dt)_{t=0} F(t)(s/s_0)^{2[\alpha(t)-1]}, \qquad (1)$$

if only a single Regge trajectory is involved. Here s is the square of the total center-of-mass energy; and t, the square of the four-momentum transfer, is given by

$$t = -2p^{*2}(1-\cos\theta^*), \qquad (2)$$