From these two results and a knowledge of the Σ^+ and Σ^- lifetimes, we also obtain the ratio of the two partial widths:

$$R = \Gamma(\Sigma^- \to \Lambda e^- \nu)/\Gamma(\Sigma^+ \to \Lambda e^+ \nu) = 1.6 \pm 0.7$$

to be compared with the value $R = 1.64$ obtained under the assumption that the strangeness-conserving weak current transforms as an isovector.

We would like to thank the operating crews of the alternating-gradient synchrotron and the 30-in. bubble chamber at Brookhaven National Laboratory for their help during the experimental runs. We are also very grateful to the scanning and measuring staffs at Columbia University and Stony Brook for their untiring efforts.

†Research supported in part by the U. S. Atomic Energy Commission.

*Sloan Foundation Fellow: 1967-1969.

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[4]The Σ^+ distribution function is obtained by interchanging the lepton variables in the expression for Σ^- decay.

[5]If we leave α free in the likelihood calculation, we obtain $\alpha = +0.8 \pm 0.3$.

[6]This result should be compared with previous measurements as summarized by J. Cronin, in Proceedings of the Fourteenth International Conference on High Energy Physics, Vienna, 1968 (CERN Scientific Information Service, Geneva, Switzerland, 1968), p. 289. A complete set of references to previous measurements is given in this article.

[7]$\vec{\alpha} = (\hat{e} + \hat{\nu})/|\hat{e} + \hat{\nu}|$, $\vec{\beta} = (\hat{e} - \hat{\nu})/|(\hat{e} - \hat{\nu})|$, $\vec{\gamma} = \hat{e} \times \hat{\nu}/|\hat{e} \times \hat{\nu}|$, as defined in W. Alles, Nuovo Cimento 26, 1429 (1962).

[8]For normalization, we counted the number of Σ^- produced and computed the number of Σ^+ produced using a production rate of $\Sigma^+/\Sigma^- = 0.465$, as given by W. E. Humphrey and R. R. Ross, Phys. Rev. 127, 1305 (1962).

ENERGY DEPENDENCE OF THE 180° $\pi^- p$ CHARGE-EXCHANGE CROSS SECTION

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We present preliminary data which demonstrate that the $\pi^- p$ charge-exchange differential cross section at 180° in the momentum region between 1.8 and 5.0 BeV/c is quite similar in shape to the elastic $\pi^\pm$ differential cross sections at 180°.

Data reviewed by Bellettini[1] indicated that the energy dependence of the differential cross section at 180° for $\pi^- p$ charge exchange ($\pi^- p \to \pi^0 n$) differed in shape from the differential cross sections at 180° for π^+ and π^- elastic scattering ($\pi^\pm p \to \pi^\pm p$).[1] We present preliminary data here which demonstrate that the differential cross section at 180° for charge exchange is quite similar to those for elastic scattering.

The experiment was performed in the 17° negative pion beam at Argonne National Laboratory. The experimental configuration is shown in Fig. 1. The momentum slit was set to transport a $\Delta p/p$ of 0.75%. A series of counters B_1, $\check{C}$, B_2, B_3, and B_4 define the incident pion beam. $\check{C}$ is a Čerenkov counter which eliminates K^- and p^- particles and also is used to measure the electron and muon contamination. B_1, B_2, B_3, and B_4

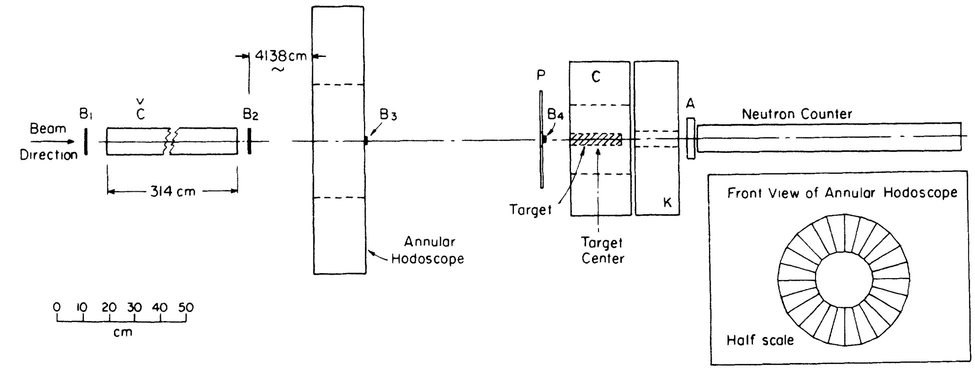

FIG. 1. Schematic showing the experimental arrangement. B_1, B_2, B_3, B_4 are scintillation counters detecting the incoming beam. $\check{C}$ is a Čerenkov counter. The liquid-hydrogen target is located at the center of an anticoincidence shield consisting of scintillation counters C, K, A, P. The π^0 is detected by the annular hodoscope and the neutron by the neutron detector.

are beam-defining scintillation counters. The beam is focused on a liquid-hydrogen target which is surrounded by an array of anticoincidence counters. The downstream and lateral counters (A, K, C) of the anticoincidence shield are constructed of alternate scintillator and lead sheets, while the upstream counter of this array (P) is composed simply of scintillator sheets. This array will detect charged particles going in all directions and gamma rays going in the forward direction. Therefore any π^0 which leaves the target at an angle of less than 90° will have at least one gamma ray interact in the anticoincidence shield.

Upstream from the hydrogen target is an annular π^0 hodoscope consisting of 24 counters, while downstream there is a neutron detector. The counters of the π^0 hodoscope and of the neutron detector are formed of alternate layers of lead and scintillator.

A "good event" triggers the beam counters B_1, $\check{C}$, B_2, B_3, B_4, and two or more of the counters in the π^0 hodoscope ring, but does not trigger the anticounters P, C, K, or A. A backward charge-exchange event will satisfy these conditions. We also record whether or not there is a coincident count in the neutron detector.

The design of the π^0 hodoscope is based on the fact that a π^0 from charge exchange at an angle very close to 180° has essentially the same energy for all π beam momenta within our range.[2] This is analogous to 180° Compton scattering and is valid for all incident π^- momenta large compared with the rest mass of the π^0. Therefore, the minimum opening angle of the two gamma rays from the π^0 and, consequently, the efficiency of the π^0 hodoscope do not vary appreciably for different beam momenta. It is possible to keep the geometry of the experiment fixed, minimizing the possibility of a systematic uncertainty in the shape of the dependence of the differential cross section on π^- momentum. The probability that a π^0 at a given laboratory angle will decay into two gamma rays each of which triggers a counter in the hodoscope does depend slightly on the incoming π^- momentum since the π^0's are not completely monochromatic. The center-of-mass detection probabilities which also include the effect of the Jacobian were calculated as a function of π^0 angle and π^- momentum by a Monte Carlo program. They are greatest for π^0's at 180° and decrease with decreasing angle. At 2.0 BeV/c 67 % of the events are in the center-of-mass cosine interval from -1.0 to -0.993, and 99 %, in that from -1.0 to -0.982. At 5.0 BeV/c 67 % of the events are in the cosine interval from -1.0 to -0.996, and 99 %, in that from -1.0 to -0.991. The cosine acceptance interval changes monotonically within our momentum region. The detection probability for the π^0 of course includes the detection probability for the individual gamma rays. Since the π^0 energy is essentially constant, the gamma rays incident on the hodoscope have energies close to 240 MeV. The efficiency for detection of such gamma rays has been measured[2] and exceeds 98 %. At this time we cannot rule out a possible systematic uncertainty in the overall scale factor for the cross sections which we are presenting, but we are confident that there is not a systematic effect dependent upon the π^- beam momentum.

The downstream neutron detector could provide an additional coincidence requirement to reduce accidentals in the case of high background rates.

For a neutron passing directly through the neutron counter, we calculate the detection efficiency to be 96 %. This efficiency should be almost independent of momentum from 1.8 to 6 BeV/c.[3] A check on this efficiency can be made by calculating our cross sections with or without requiring the neutron signal. Such a calculation shows that the above detection efficiency is of the order of 96 % and is independent of incoming π^- momentum. However, the results quoted in this paper do not use the neutron signal. The use of the neutron signal would result in a smaller statistical error than that quoted here, but pending an independent measurement of the efficiency of the neutron detector, we do not use the neutron information in calculating our cross sections.

Our accidental rates were less than 20 % of our full target rates. They were the same for full target as for empty target and therefore probably arose mainly from interactions in B_3 whose product particles registered in the π^0 hodoscope in accidental coincidence with B_4.

A crucial question in this experiment is the possible inclusion in the data of inelastic events. The major contribution of these possible inelastic events would be expected to come from the reaction $\pi^- p \rightarrow n\pi^0\pi^0$. We have three pieces of evidence that the contribution to our data from this reaction is negligible.

The first of these is the measured correlated angular distribution of the π^0's in this reaction.[4] This work shows that if one π^0 goes in the backward hemisphere, the second π^0 usually is emitted at nearly zero degrees. Obviously, in this experiment, this second π^0 would veto the event.

The second piece of evidence is a calculation of the kinematical limits in two-π^0 production. The π^0 hodoscope will only detect π^0's in the backward direction whose momentum ranges from 675 down to 270 MeV/c. For the π^- energies included in this experiment, this implies the following kinematic correlation on the two-π^0 production: If one π^0 comes off at 180° and is detected by our hodoscope, the second π^0 will most likely come off at an angle less than 90° and hence would veto the event. This result has been obtained from a Monte Carlo calculation in which all backward angles consistent with detection by the hodoscope were permitted the first π^0. Phase space was used for the correlation between the π^0's and the neutron. This is a pessimistic choice since the experimental measurements indicate a much more forward peaking of the π^0's than that predicted by phase space. The calculation shows that less than 0.1 % of our events can come from this two-π^0 source.

The third piece of evidence which indicates that we do not have any multiple-π^0 contamination in our sample comes from the correlated events in our hodoscope. If multiple-π^0 events were present, we should have events where more than two gamma rays were detected by the hodoscope. After we subtract our empty-target results from our full-target data, within statistics no events with more than two gamma rays remain. Any one of the above arguments would indicate that the multiple π^0 contribution is small in our data, and the combination of all three makes the possibility of such contributions negligible. The arguments are even stronger if the production of more than two π^0's is considered. A backward-going η^0 has much too large an opening angle to be detected by our equipment.

Figure 2(a) is a graph of our data. The solid line is the backward elastic π^+ data[5] and the dashed line is the π^- data.[6] Note that our data have a structure qualitatively similar to the π^- and π^+ data. There is an extremely marked dip at 2.1 BeV/c and a pronounced peak at 2.6 BeV/c. The errors shown are purely statistical. As noted above, systematic errors should not change the shape of the curve. However, systematics can alter the absolute scale. A detailed study of the systematics has not yet been made, but there are indications that they are of the order of 10 %.

Figure 2(b) displays the same data with the spark-chamber results of Crouch et al.[4] also plotted. The excellent agreement between the two measurements, done by totally different techniques, is a measure of the reliability of the absolute values of the cross sections. The data referred to in Ref. 1 are in disagreement with both sets of data in Fig. 2(b). However, a recent publication by the same authors[7] presents new data that are in substantial agreement with the data in Fig. 2(b).

Since these data represent only half of the approved experiment, further data will be acquired in the next months and a detailed publication on the completed experiment will be forthcoming. At that time we will discuss in detail theoretical interpretation of the data. At this time we will confine ourselves to two brief remarks. First, since the charge-exchange and the elastic differential cross sections at 180° are all related to the $T=\frac{1}{2}$ and $T=\frac{3}{2}$ amplitudes by charge independence, we can determine the relative phase and modulus of these amplitudes within our momen-

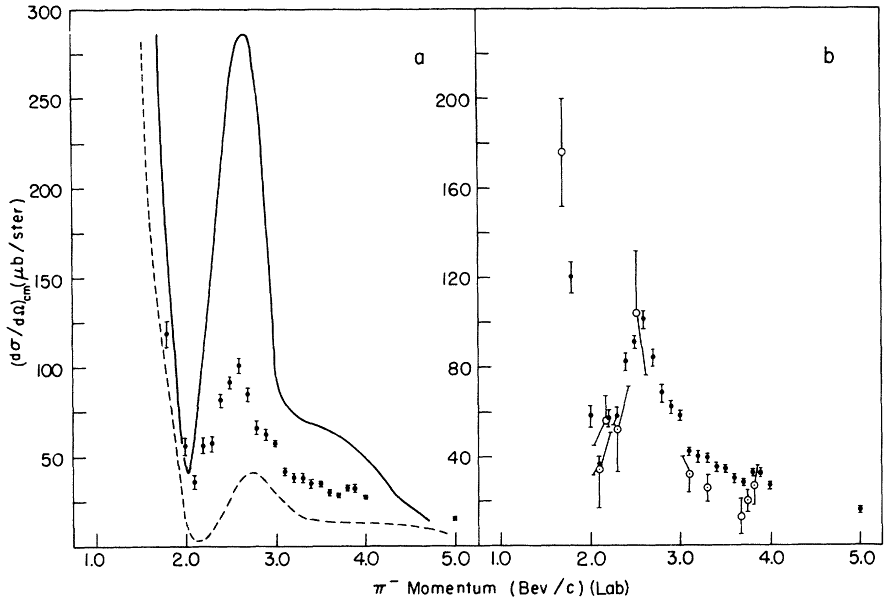

FIG. 2. (a) Center-of-mass differential cross section for charge exchange at 180° as a function of π^- laboratory momentum. The uncertainties shown are statistical. Systematic effects are the same for all momenta. The uncertainty of the absolute values of the cross section due to systematic effects is estimated to be 10%. The solid curve is a smooth curve drawn through the $\pi^+p \rightarrow \pi^+p$ data from Ref. 5. The dashed curve is a smooth curve drawn through the $\pi^-p \rightarrow \pi^-p$ data from Ref. 6. (b) The open circles give center-of-mass differential cross sections for charge exchange at 180° from Ref. 4. The closed circles are the same data as given in (a). Note the change in ordinate between (a) and (b).

tum region wherever reliable π^+ elastic and π^- elastic data are also available. Second, the dip in the differential cross sections at ~2.1 BeV/c can be explained by the $T=\frac{1}{2}$ resonance at 2190 BeV/c^2 and the maximum at ~2.6 by the $T=\frac{3}{2}$ resonance at 2420 MeV/c^2. We see some indication of the next maximum expected at 3.85 BeV/c corresponding to the $T=\frac{3}{2}$ resonance at 2850 MeV/c^2.

We wish to thank the staff of the Argonne National Laboratory accelerator and high-energy physics divisions for their outstanding assistance, without which this study could not have been performed. In addition we would like to thank Professor A. Wattenberg and Professor D. Frisch for the loan of valuable equipment. We would also like to thank Mr. S. Humphries for his aid in the initial stages of this experiment and Mr. G. H. Schulze for the development of the electronics for the data readout. One of us (I.A.P.) would like to thank the Massachusetts Institute of Technology for a special financial grant which permitted him to participate in this work.

*Work supported in part by the U. S. Atomic Energy Commission.

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