NEGATIVE-PION PRODUCTION FROM THE BOMBARDMENT OF ^{9}BE WITH 200-MeV POLARIZED PROTONS

T.P. Sjoreen†, M.C. Green, W.W. Jacobs, R.E. Pollock, F. Soga,
R.D. Bent and T.E. Ward
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

We report here the results of a measurement of the analyzing power for the reaction $^{9}Be(\vec{p},\pi^-)^{10}C$(g.s). This measurement, the first of a $(\vec{p},\pi^-)$ analyzing power, was made using a beam of 200.3-MeV polarized protons on a 145-mg/cm^2 target of ^{9}Be. The negative pions were detected with the QDDM magnetic spectrograph and a focal-plane detector array consisting of a position-sensitive helical wire chamber and three scintillators. The beam polarization was measured with a low-energy helium polarimeter.

The results of the analyzing-power measurement, shown in Fig. 1, have been plotted as a function of the center-of-mass pion angle θ_π^{cm}. The analyzing power is given by

$$A(\theta) = \frac{d\sigma(\uparrow)/d\Omega - d\sigma(\downarrow)/d\Omega}{P(\downarrow)d\sigma(\uparrow)/d\Omega + P(\uparrow)d\sigma(\downarrow)/d\Omega}$$

where P is the measured beam polarization, and the arrows indicate proton spin orientation. The sign convention for A(θ) follows the Madison convention. The error bars in the analyzing-power data are based on statistical uncertainties; beam-polarization uncertainties were less than 3%. The solid line in Fig. 1 is the result of a least-squares fit to the $(\vec{p},\pi^-)$ data of the form $A(\theta) = (d\sigma/d\Omega)^{-1} \times \sin\theta[b_o + b_1P_1(\theta)]$, where $d\sigma(\theta)/d\Omega = a_o + a_1P_1(\theta) + a_2P_2(\theta)$ and the $P_n(\theta)$ are Legendre polynomials.

As displayed in Fig. 1, the angular distribution of the analyzing power A(θ) for the reaction $^{9}Be(\vec{p},\pi^-)^{10}C$(g.s.) is substantially different from that for the reaction $^{9}Be(\vec{p},\pi^+)^{10}Be$(g.s.), which has been measured[1] at about the same pion energy ($T_\pi^{cm} \approx 40$ MeV). For the $(\vec{p},\pi^-)$ reaction, A(θ) is negative for $\theta_\pi^{cm} < 70°$ and positive thereafter, with a maximum value of 0.48±0.14 at $\theta_\pi^{cm} = 106°$, whereas for the $(\vec{p},\pi^+)$ reaction, A(θ) is negative over the entire angular range with a maximum absolute

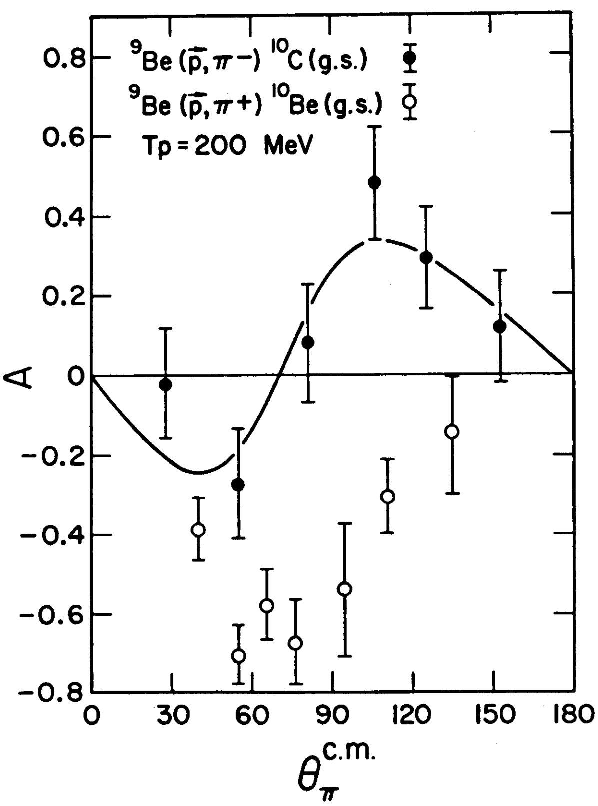

Figure 1. The results of the present measurement of the analyzing power A for the reaction $^{9}Be(\vec{p},\pi^-)^{10}C$(g.s.) at a bombarding energy of 200 MeV. The analyzing-power results for the reaction $^{9}Be(\vec{p},\pi^+)^{10}Be$(g.s.), also measured at 200 MeV, are taken from Ref. 1. The solid line is the result of a least-squares fit to the data as described in the text.

value as large as ~0.7. A negative A(θ) is a feature of nearly all $(\vec{p},\pi^+)$ analyzing-power measurements[1,2].

The spin-averaged differential cross sections of the present $^9Be(\vec{p},\pi^-)^{10}C$(g.s.) measurement are plotted in Fig. 2 as a function of momentum transfer q in units of MeV/c. The error bars are statistical only and the error in the absolute cross section is estimated to be ±15%. Also included in this figure are the results of the measurement of the same reaction at 185 MeV proton bombarding energy.[3)]

The backward peaking in the present $^9Be(p,\pi^-)^{10}C$(g.s.) differential cross-section distribution is a feature which has not been observed in previous (p,π^-) distributions. As shown in Fig. 2, the earlier measurement[3)] of the reaction $^9Be(p,\pi^-)^{10}C$(g.s.) at a bombarding energy of 185 MeV did not cover a sufficiently large range of angle or momentum transfer to identify this feature. The other (p,π^-) angular distributions measured near threshold

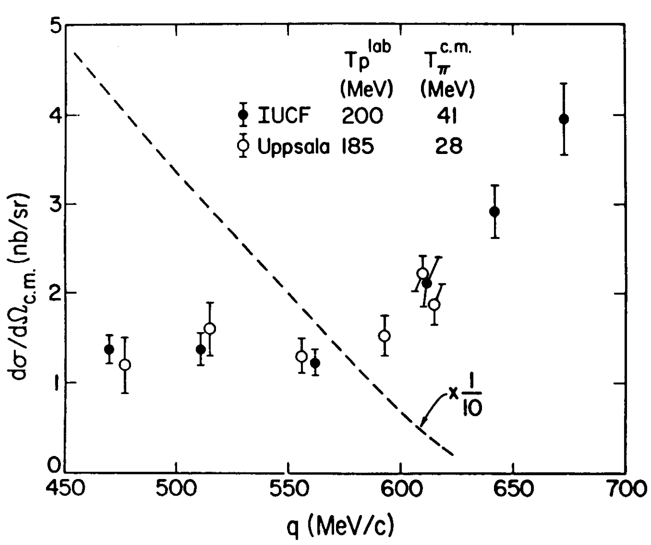

Figure 2. The spin-averaged differential cross sections of the present $^9Be(\vec{p},\pi^-)^{10}C$(g.s.) measurement plotted as a function of momentum transfer. The 185-MeV results are taken from Ref. 3. For comparison, the dotted line is a least-squares fit of Legendre polynomials to the $^9Be(p,\pi^+)^{10}Be$(g.s.) cross sections at 185 MeV bombarding energy of Ref. 3.

($T_\pi^{cm} < 50$ MeV) are isotropic. Thus, the present angular distribution measurement may signify a stronger (p,π^-) state dependence near threshold than indicated previously.

The excellent agreement between the present 200-MeV differential cross sections and those measured at 185 MeV at overlapping momentum transfer indicate that the shape and, hence, the backward peaking in the $^9Be(p,\pi^-)^{10}C$(g.s) distribution is most likely determined by the momentum transfer. The near-threshold energy dependence of the (p,π^-) reaction will be investigated in future experiments.

Although several theoretical models have been used to calculate (p,π^-) angular distributions, calculations of the $(\vec{p},\pi^-)$ analyzing power have been made only with the model proposed recently by Gibbs,[4)] in which it is assumed that the production process is dominated by direct knockout from the nuclear pionic field. Preliminary calculations with this model for the reaction $^9Be(\vec{p},\pi^-)^{10}C$(g.s.) at 200 MeV bombarding energy yield analyzing powers which are positive over the entire angular range and have maximum values ranging from 0.4 to 0.6. Thus, there is qualitative agreement between experiment and theory at back angles, but disagreement at forward angles, where A(θ) is observed to be small and negative.

The results of these measurements have been published.[5)]

†Present address: Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830.

1) E.G. Auld, A. Haynes, R.R. Johnson, G. Jones, T. Masterson, E.L. Mathie, D. Ottewell, P. Walden, and B. Tatischeff, Phys. Rev. Lett. 41, 462 (1978).

2) P.H. Pile, T.P. Sjoreen, R.E. Pollock, W.W. Jacobs, H.O. Meyer, M.C. Green, F. Soga, and R.D. Bent, Bull. Am. Phys. Soc. 24, 614 (1979), and to be published. See also IUCF Scient. and Techn. Report 1979, p. 63, and contribution to the present report.

3) S. Dahlgren, P. Grafström, B. Höistad, and A. Åsberg, Nucl. Phys. A204, 53 (1973).

4) W.R. Gibbs, LASL Report No. LA-8303-C, 1980 (unpublished), p. 232, and private communication.

5) T.P. Sjoreen et al., Phys. Rev. Lett. 45, 1969 (1980).

MEASUREMENT OF THE $^2H(\vec{p},\pi^\circ)^3He$ THRESHOLD CROSS SECTION AND ANALYZING POWER

M.A. Pickar, R.E. Pollock, H.-O. Meyer, A.D. Bacher, and G.T. Emery
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

Differential cross sections and analyzing powers have been measured for proton induced neutral pion production from deuterium at three energies within 4 MeV of threshold, T_{th} = 198.70 MeV. These data should prove useful in making a less ambiguous study of the reaction mechanism for (p,π), as the initial and final states are better understood than those of heavier systems.

To perform the measurement we used the QDDM spectrograph set at, or near, 0° to detect the recoiling ^{3}He in coincidence with either one or both of the decay γ-rays emitted in the π° decay. The high-energy photons were detected using lead glass detectors placed on the left and right of the CD_2 target. From the energy of the recoil ^{3}He the scattering angle was deduced. The flight time of the ^{3}He between target and focal plane was used to determine whether it was emitted to the right or the left (TOF is an approximately linear function of the projected horizontal angle at which the recoil enters the spectrograph). We were thus able to measure the angular distribution of both the cross section and the analyzing power of the reaction.

Because the experiment was done with the QDDM at or near 0°, a special Faraday cup had to be placed within the dipole magnet of the QDDM. The high rates in the QDDM focal plane arising from background generated by this cup made it necessary to use a 14 element high-rate scintillator hodoscope constructed for this purpose to act as the focal plane detector. To tag each event with one or both of the γ-rays from the decaying π°, it was necessary to assemble two large lead glass detector arrays, each composed of 4 pieces of Schott F2 glass, 15 cm x 15 cm x 30 cm. The 24" scattering chamber for the QDDM had to be replaced with a smaller chamber, 2.50" in diameter, and a stable detector support to allow positioning the large lead glass detectors as close to the target as possible.

The experiment was completed in the summer of 1980 and consisted of measurements of the differential cross section and asymmetry at proton energies T_p = 199.53, 201.26, and 203.01 MeV, corresponding to pion center-of- mass energies of $T_\pi{}^{cm}$ = 0.48, 1.53, and 2.59 MeV. Figure 1 shows our preliminary results for the $T_\pi{}^{cm}$ = 2.59 MeV cross section. It is important to note that the large forward to backward ratio indicates the p-wave amplitude plays an important role even at these low energies. Our measurements made at lower energy show cross sections becoming more isotropic as one approaches threshold, but even at $T_\pi{}^{cm}$ = 0.48 MeV we observe a forward-to-backward ratio of about 2 to 1.

We are presently in the process of evaluating the necessary corrections to the data and the various uncertainties in the final result. The principal effects one must consider in such an analysis are:

1) the beam energy uncertainty
2) the acceptance of the QDDM