corrections necessary to convert the yields obtained using the geometry of Fig. 1 into cross sections.

We concluded this experiment by making a preliminary measurement of the analyzing power in the reaction $^{11}\text{B}(\vec{p},\pi^{0})^{12}\text{C}$(g.s.), with the pion having an energy of 3.6 MeV in the center of mass. The geometry used is illustrated in Fig. 6. It has an efficiency response function which is peaked for pions emitted at about 60° to the right in the center of mass. The azimuthal angle is localized to within 30°, while the efficiency in the polar coordinate in the center of mass is nonzero only in the forward hemisphere, has its centroid at about 53°, and a width of about 60°. If one integrates the true asymmetry over $\cos\theta_{\pi}^{\text{cm}}$, weighting it with the appropriate efficiency function, one obtains an observed average asymmetry over that region, of

$$\langle A(\theta)\rangle = -0.58 \pm 0.22$$

The results from Expt. 18 are being prepared for publication.

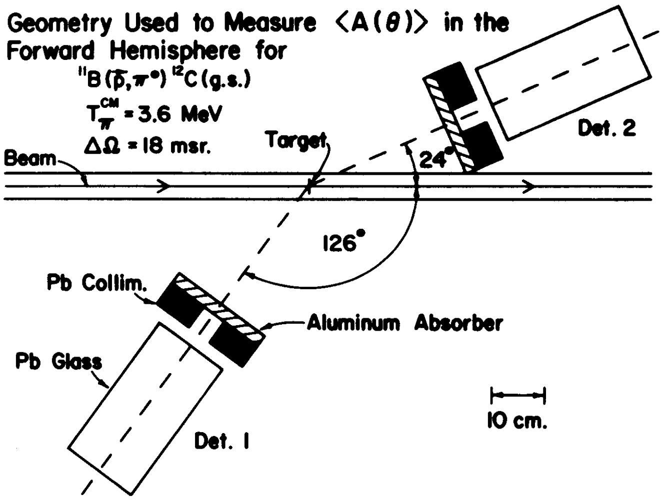

Figure 6. Geometry used to measure $(\vec{p},\pi^{0})$ *asymmetry for scattering angles near* 60°*.*

As a followup to the first successful $(\vec{p},\pi^{0})$ asymmetry measurement reported above, this group has proposed and been allocated time for Expt. 127, "Determination of Analyzing Powers for Neutral Pion Production Near Threshold." In this experiment we plan to complete our study of the reaction $^{11}\text{B}(\vec{p},\pi^{0})^{12}\text{C}$(g.s.), and perhaps examine a few other targets. The basic approach will be the same as that used in Expt. 18; however, we plan to improve both our energy resolution and angular resolution by moving our detectors out of the plane. This will permit us to do measurements at energies above the thresholds of excited states, to about 15 MeV above the ground state threshold, as well as giving us the capability of making measurements on excited states that are well separated from neighboring states. We plan to have this experiment completed by the fall of 1980.

STUDIES OF π^{0} PRODUCTION NEAR THRESHOLD

D. Jenkins, O.P. Gupta, and D. Long
Virginia Polytechnic Institute, Blacksburg, Virginia 24061

A. Bacher, G. Emery, and M. Pickar
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

P. Debevec
University of Illinois, Urbana, Illinois 61801

We have begun a series of measurements which will measure the cross section for (p,π^{0}) reactions on a range of nuclei with both unpolarized and polarized beams. The energy and angle of the π^{0} is inferred from its decay gammas by a measurement of the angle and energy of each gamma.

To analyze the (p,π^0) experiments, we expand the differential cross section in the center of mass assuming only s and p waves in an unpolarized beam

$$\frac{d\sigma}{d\Omega} = a+b \cos \theta + c \cos^2\theta$$

The angular distribution of gammas in the lab can be related to the parameters for this differential cross section. By measuring the angular distribution of gammas in the lab and fitting their distribution to obtain the parameters a,b, and c, we obtain the angular distribution of pions in the center of mass. Since we are not reconstructing each event to obtain the π^0 distribution in the center of mass, an energy measurement is not required but is useful in discriminating against background events.

The counter arrangement is shown in Fig. 1. Pions in the target decay to gammas which are detected in the gamma counters. The system measures the angles θ_1 and θ_2 relative to the direction of the incident proton and the opening angle Ω between the two gammas. To measure the angle of the gamma, we use the technique described by Heusch[1] and illustrated in Fig. 2. The gamma is converted in a piece of lead glass (ΔE counter) and the trajectory of the converted electrons is measured with wire chambers (W1, W2, W3, W4 counters). The track is extrapolated back to the converter to find the interaction point. The gamma angle can be determined once an interaction point is known relative to the target. A sample distribution of opening angles is shown in Fig. 3.

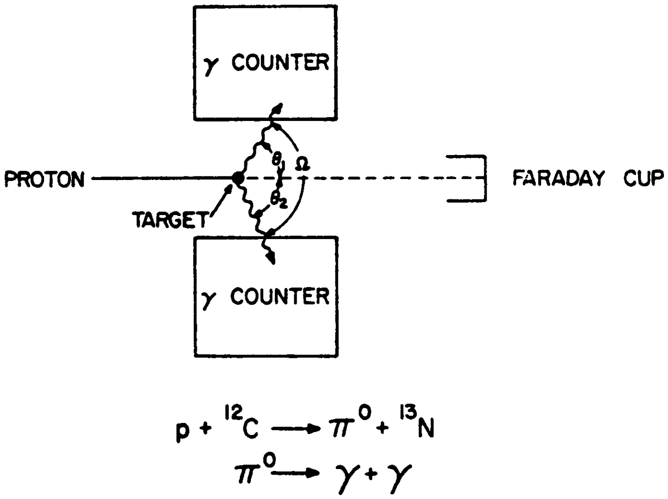

Figure 1. Counter arrangement for (p,π^0) reaction. Protons incident on the ^{12}C target produce a π^0 which subsequently decays into two gammas. The experiment measures the angles θ_1, θ_2 and Ω of the gammas.

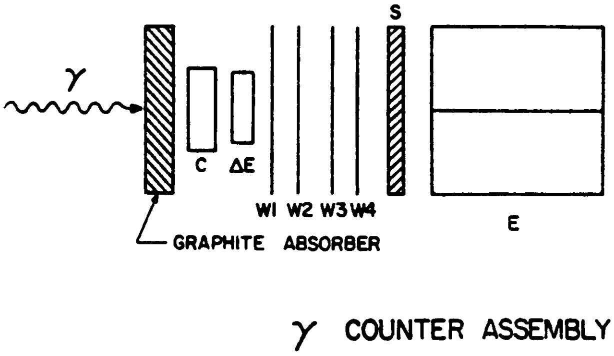

Figure 2. The incident gamma ray is converted in the ΔE counter. The position of the conversion is found by extrapolating the electron tracks from the wire chambers.

Large lead glass counters (E counter) behind the wire chambers measure the remaining energy of the converted electrons which can be added to the energy recorded in the converter to obtain a crude energy measurement and complete the identification of the gamma. The total energy resolution is about 40% and the solid angle is 0.38 sr.

During the past year we had two runs which collected data on beryllium and oxygen at different energies; however rates in the wire chambers limited the beam intensity to about 20 nA. We have completed our analysis of the 144.1 MeV ^{9}Be data. The data (226 points) was subjected to a maximum likelihood fit which yielded the following preliminary values for the parameters a,b, and c respectively: 0.978, -0.505 ± 0.176, 0.065 ± 0.045.

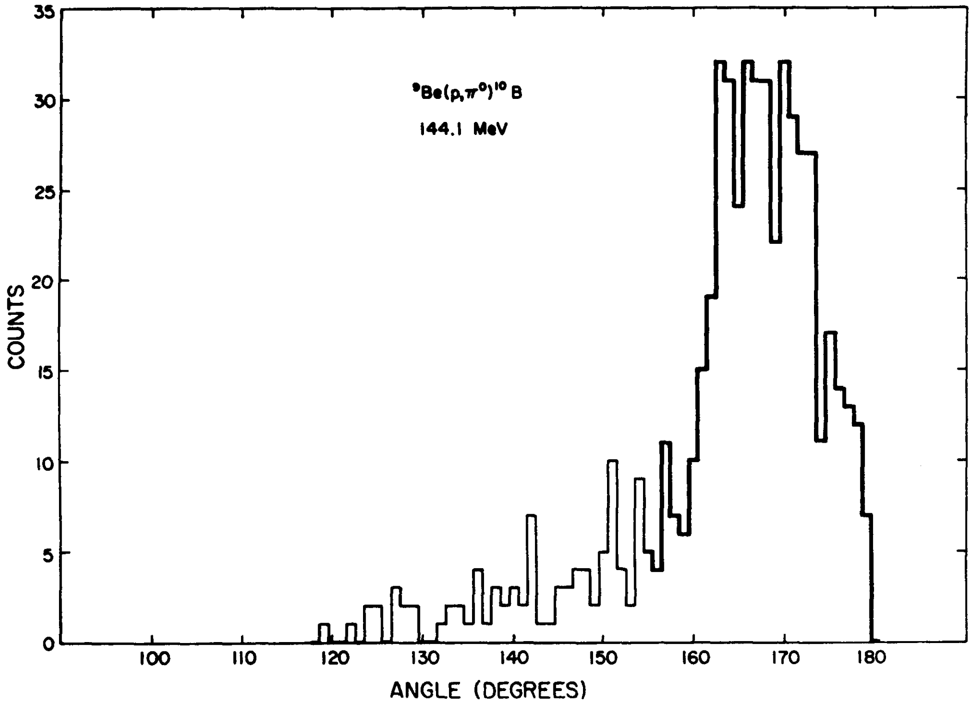

Figure 3. Opening angle distribution for the two coincident gammas from the $^{9}Be(p,\pi^{0})^{10}B$ data at 144.1 MeV. The heavy line indicates the angular range predicted by kinematics.

During these runs we noticed that the singles rates in the counters made wide fluctuations over long time intervals even though the cyclotron operator maintained what was described as a good tune. To test the beam tune and attempt to reduce the singles rates in our counters, we made a short run in November 1979 with only one of the gamma detecting telescopes. Two scintillation counters were placed on opposite sides of the beam next to the beam pipe about three feet upstream from the target position. We found that there were many stray particles passing through these counters when the operator had achieved a good tune. When the beam tune requirement included minimizing the rates in these new monitor counters, we found that the singles rates in our gamma telescope had decreased considerably and we were able to operate at beam currents over 100 nA. We expect that further beam studies should allow our operating at even higher intensities.

During the past year we also examined the possibility of using NaI counters to improve the precision of our energy measurement of the gammas. We found that for a given number of events, a more precise energy measurement can improve the accuracy with which the angular distribution parameters are determined since an ambiguity in determining the π^0 direction can be removed. The ambiguity arises when reconstructing the π^0 direction from the direction of the decay gammas because kinematics allows two directions for the π^0. This twofold ambiguity reduces the precision with which angular distribution parameters can be determined, but can be removed by a measurement of the gamma energies. Since the energy resolution of the lead-glass counters is not sufficient for this purpose, we considered the use of NaI counters. We found that the improvement in accuracy for the angular distribution parameters is approximately equivalent to the accuracy gained by doubling the number of events with the lead-glass system. Since singles rates in the NaI counter may limit the beam intensity which could be used in the experiment, the actual running time could be about the same for a NaI-detector system as compared to a lead-glass detection system which would handle higher rates. We concluded that a NaI detector system would be much more complicated than the present system and most likely not justified at this time.

We hope to take a few more shifts in the spring to further improve the proton beam focus. A modest time in studying the beam could greatly increase our data collecting rate by allowing us to run with higher beam intensities. We then plan to take more data on oxygen to improve the statistical accuracy of our measurement of the angular distribution parameters.

1) C.A. Heusch, R.V. Kline, and S.J. Yellin, Nucl. Inst. and Meth. 120, 237 (1974).

MEASUREMENTS OF (p,π^-xn) AND $(^3He,\pi^-xn)$ TOTAL CROSS SECTIONS BY ACTIVATION TECHNIQUES

M. Rickey, P. Singh, and J. Wiggins
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

In these measurements we hope to take advantage of the distinctive properties of delayed proton emitter spectra as a highly selective indicator that the reactions under study have taken place.

The initial reaction of interest is

$$^{24}Mg(p,\pi^-)^{25}Si \xrightarrow{\beta^+} {}^{25}A\ell^* \rightarrow {}^{24}Mg + p$$

with measurements of the β-delayed proton spectrum and the lifetimes of the various peaks being used to select events corresponding to the decay of ^{25}Si. If adequate signal-to-noise ratios and high counting efficiencies can be achieved, cross sections (which correspond to the production of ^{25}Si in any of its seven particle-stable states below the 3.42 MeV proton separation energy) will be measured as a function of energy. These data are intended to complement rather than replace spectrometer data. Using this target, it might also be possible to observe the production of ^{24}Si, produced by the $^{24}Mg(p,\pi^-n)^{24}Si$ reaction.

Other targets and reactions in which the production of ^{25}Si would provide the signatures are $^{25}Mg(p,\pi^-n)^{25}Si$; $^{26}Mg(p,\pi^-2n)^{25}Si$; and $^{23}Na(^3He,\pi^-n)^{25}Si$.

Among the additional possibilities for use of the apparatus we are developing are studies of this family of reactions leading to the production of ^{21}Mg[i.e., $^{19}F(^3He,\pi^-n)^{21}Mg$] and of ^{17}Ne[i.e., $^{16}O(p,\pi^-)^{17}Ne$; $^{18}O(p,\pi^-2n)^{17}Ne$; $^{14}N(^3He,\pi^-)^{17}Ne$; and $^{15}N(^3He,\pi^-n)^{17}Ne$].

It was hoped initially that counting on one target could proceed while the next was undergoing bombardment. This proved to be not possible because of background probably arising from neutron induced reactions in and near the detectors. A mechanical chopper was then designed and installed between the pre-injector and the injector cyclotron to provide convenient, clean beam pulsing on a time scale $\geq \sim 10$ m sec. The target wheel, its drive motor, and the associated detectors are presently being installed for runs in the 64" scattering chamber; and the chopper motor, target motor, and counting system control pulses are provided by a 6800 microprocessor.

Two runs have provided data useful for diagnostics and evaluation of the practicality of the technique. Figure 1 shows typical data summed over the time channels. The background present comes from the comparatively large amounts of ^{21}Mg and ^{17}Ne produced, together with that arising from continuum low energy protons and from the energy loss of the more energetic ^9C delayed protons passing through the 500 μm Si detector (which lose from 3 to 8 MeV in the detector). This background obscures the region in which the