MeV in the energy spectrum (Fig. 2) derived from the time spectrum in Fig. 1(a). Further analysis is required to sort all of the available $CD_2$ data, to optimize the time corrections based on the time differences between phototubes at the two ends of each scintillator, to optimize the software rejection of cosmic ray or photon background events, to perform an accurate C(p,n) subtraction, and to convert the measured yields to absolute doubly differential cross section limits on dibaryon production. For missing masses near 2 GeV/$c^2$ and particle intrinsic widths $\lesssim$500 keV, we expect the 0° $^2$H(p,n)$X^{++}$ cross section limits to be of order 0.1-1 $\mu$b/sr.

## ISOSPIN RESPONSE OF THE $^4$He CONTINUUM

B.A. Raue, L.C. Bland, D.S. Carman, B.C. Markham, D.W. Miller,
R.K. Murphy, S.F. Pate, G.M. Huber, and J.A. Templon
*Indiana University Cyclotron Facility, Bloomington, Indiana 47405*

D. Dehnhard, S.M. Sterbenz, and B. Brinkmoeller
*University of Minnesota, Minneapolis, Minnesota 55455*

Experiment 307 is a study of the angular correlation of particles, $X(X = p, d, t, {}^3\mathrm{He})$, emitted from unbound states of $^4$He excited by low momentum transfer (q$\simeq$1fm$^{-1}$) proton scattering. The primary emphasis of this experiment is to provide data complementary to photoabsorption experiments. Those experiments have provided conflicting evidence that the ratio of charge-symmetric proton and neutron decays of the $^4$He dipole resonance is much larger than expected from coulomb induced isospin mixing.[1] If correct, those results could imply the necessity of including a large charge-symmetry violating component to the strong interaction. The present experiment is designed to minimize most of the systematic errors present in the earlier comparisons of $\sigma(\gamma, n)$ and $\sigma(\gamma, p)$ by detecting the residual tritons and helions resulting from the $^4\mathrm{He}^\star$ with the same apparatus. In order to determine whether the proton inelastic scattering yield in the region $25 \leq E_x \leq 35$ MeV arises from excitations other than the dipole response, we have measured complete angular correlations at three proton scattering angles, $\Theta_p$= 24, 30, and 35°, which are expected to be near the peak of the $\Delta$L=1 angular distribution for the (p,p′) reaction at $T_p$= 100 MeV. This report discusses the apparatus developed for the experiment and preliminary results on apparatus performance for a run that took place in the spring of 1989.

Figure 1 displays the setup used for the experiment. We discuss here only the modifications made to the previously described[2] target/detector system. The most notable differences include the replacement of the upstream position-sensitive silicon detector (PSD) of the "ejectile arms" by x,y position measuring drift chambers (EADC); the addition of a pair of dipole magnets in the target chamber to improve delta-ray suppression; and changes

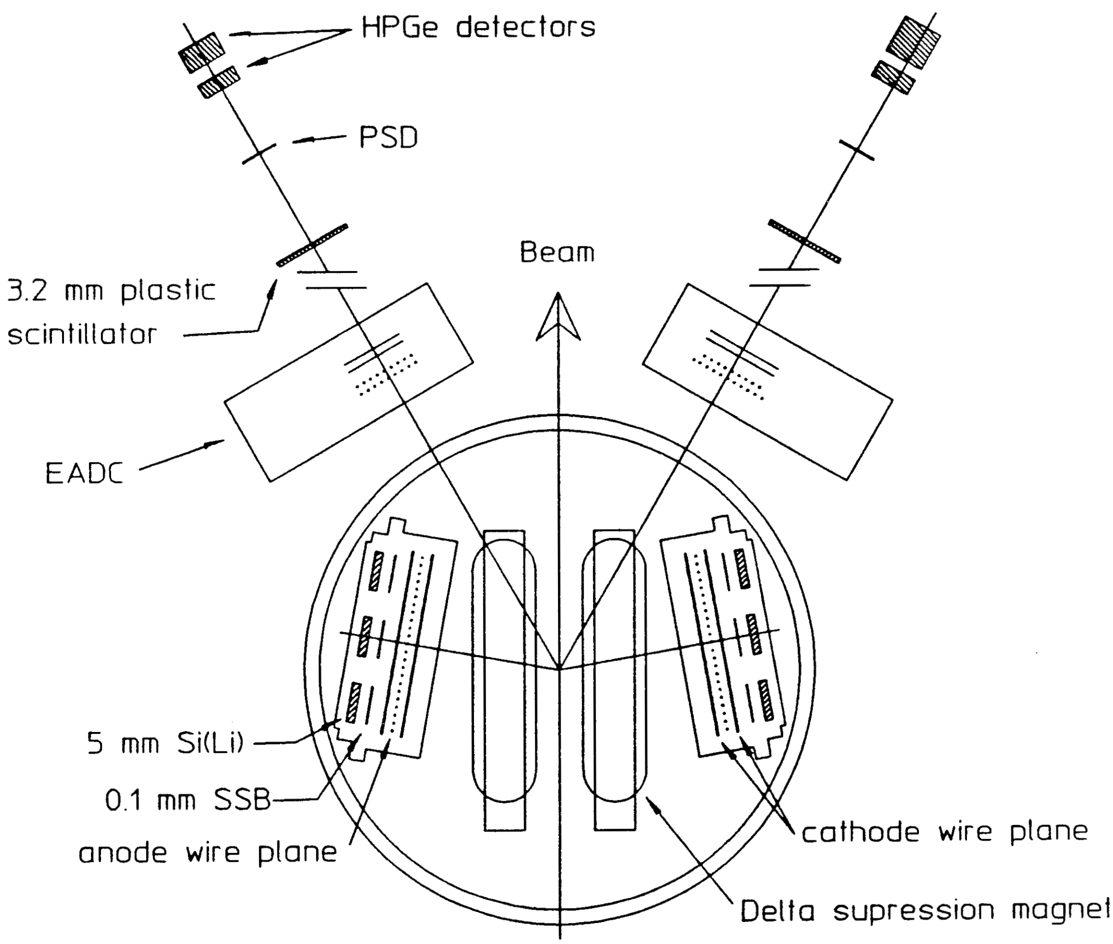


*Figure 1.* Schematic of E307 detector apparatus. All distances are to scale except separation between EACE and scintillator.

to the electrodes of the recoil arm drift chambers (RADC) used to measure the position and energy loss of the low energy, mass-3 ions.

The reaction vertex is reconstructed by ray-tracing using information from a pair of position-sensitive detectors. Determination of position along the extended source of the gas target requires a measurement of position and track slope of the scattered proton. In the original setup this was done with two 0.1 cm thick silicon PSD.[2] To improve traceback resolution we have replaced the upstream PSD by a multiwire horizontal drift chamber (EADC). This reduces multiple-scattering limitations in reconstructing the track's slope.

The EADC measures electron drift times in two offset wire planes having alternating anode and cathode wires (wire spacing 0.5 cm, plane spacing 0.53 cm). The distance from vertically- (horizontally-) oriented wires is then proportional to the drift-time difference. The detectors were run with isobutane bubbled through n-propyl alcohol at pressures of 250 and 340 Torr (changed during the experiment). The chamber bias was sufficiently large to plateau the efficiency for 100 MeV protons and to saturate the electron drift velocity. At present, the position resolution is limited by the calibration procedure to $\sim$0.4 mm. Limitations include difficulties in dealing with trajectories of non-normal incidence on the wire planes and energy dependent corrections to the drift times.

In addition to the position information from the EADC and PSD, knowledge of the beam position is required to reconstruct the reaction vertex. The latter is calibrated utilizing $p + d$ and $p + \alpha$ kinematic coincidences and is continuously monitored throughout the experiment with left–right ejectile arm coincidences which determine the reaction vertex independent of the beam position. Figure 2 displays the vertical traceback to a "point source" (solid target) for two beam positions known to differ by 3.6 mm. The resolution in the vertex reconstruction is $\leq$4.0 mm (FWHM). In addition to vertex reconstruction the PSD and EADC enable ray tracing to the high-purity germanium detector stack. This permits rejection of events where protons escape from the detector stack.

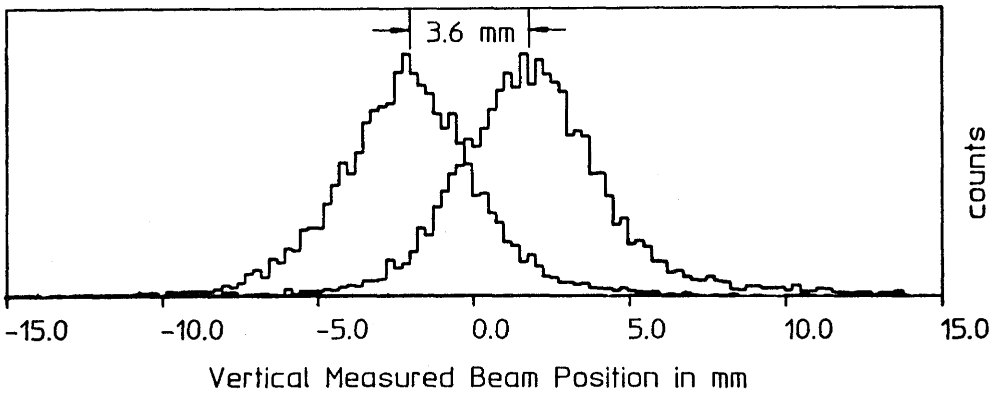


*Figure 2.* Vertical beam position as measured by ejectile arm ray tracing for a solid target. This figure shows two peaks corresponding to two beam positions known to be offset by 3.6 mm vertically.

One of the major problems discovered during in-beam tests in 1987 was the existence of a large flux of delta-rays incident on the RADC which limited the performance of these detectors. To eliminate this problem a pair of dipole magnets were placed in the target chamber. The $\int \vec{B} \cdot d\vec{l}$ had a minimum value of 1.9 mT·m, sufficient to sweep the beam induced delta ray flux away from the RADC. There was no evidence of significant pileup probability for the RADC linear signals.

Another problem with the original RADC design was manifested in the anode pulse shape. The original electrode structure of the RADC[2] was an alternating anode (biased to positive high voltage) and cathode (ground) wire plane sandwiched between grounded cathode wire planes. The cathode plane wires were grouped onto two busses each associated with the left or right of the anode wires. It was observed that the anode pulse had two components: a fast risetime component resulting from collection of secondary ionization produced between the cathode planes and a smaller amplitude slow risetime component resulting from collection of charge outside this region. To eliminate the latter contribution, the cathode wire planes were modified to permit the application of negative high voltage, thus screening the anodes from electrons produced beyond the cathode wire planes. The modification significantly improved the anode timing resolution over a broad pulse height range. In making this modification we also achieved significantly improved pulse height resolution in the cathode wire planes.

The performance of the modified RADC was extensively studied during bench tests using alpha particles from an $^{241}$Am source. The sum of the left/right cathode pulse height was found to be proportional to the energy loss with a resolution of 9% (FWHM). The left/right ambiguity associated with the drift-time position measurement is resolved by taking the difference in the left/right pulse heights. This difference was 7.6% of the summed pulse height. Analysis of in-beam performance indicate sufficient cathode difference resolution to eliminate the left/right ambiguity for energy losses down to at least 250 keV. The drift-distance resolution was determined during the bench tests by comparing anode drift times to crude position measurements obtained from a Si PSD. The position resolution was found to be better than 0.8 mm with the measurement limited by non-linearities in the crude positions obtained from the PSD.

In-beam performance of the RADC has been found to be comparable to the bench tests. The $\Delta$E information from the cathodes will enable A and Z identification for particles that range out in the upstream silicon detectors of the recoil arms after path length corrections are applied to the measured pulse heights. The position information from the RADC and knowledge of the reaction vertex determined by the ejectile arm ray tracing provide the essential trajectory information. The recoil arm energy and trajectory information combined with energies and angles measured by the ejectile arm uniquely determines the three-body final state kinematics.

During production measurements the apparatus was fully operational with two notable exceptions. First, one of the beam-left HPGe detectors was found to have a substantial dead layer limiting the energy resolution of the left ejectile arm. The second major problem was with the silicon PSD of both ejectile arms. It was discovered that the charge division for the PSD depended on whether the incident ion ranged out in the detector thus negating the utility of earlier position calibration using alpha particles from $^{241}$Am. An attempt was made to calibrate the position response using in-beam kinematic-coincident elastic scattering and an aluminum mask with small holes.[2] At this point only the right side PSD has been successfully calibrated. It is likely that the PSD performance was compromised by radiation damage from earlier (low flux) in-beam tests and/or an improper storage environment.

Production measurement target pressure was 225 Torr of helium with a beam current of $\sim$5 nA for 24 and 30° ejectile arm settings and $\sim$20 nA for 35° setting. For each ejectile arm position prescaled ejectile and recoil singles data was taken along with the coincidence data. The coincidence trigger consisted of at least any two of the four arms: ejectile–ejectile, ejectile–recoil, recoil–recoil, or any three or all four arms triggered.

The $p\alpha$ elastic scattering coincident events were hardware prescaled by placing an upper limit threshold on the downstream high-purity germanium detector (HPGe) pulse height. Monte-Carlo simulations of the experiment give a $\sim$1% probability for ejectile particles to escape the detector stack. However, because the acceptance of the detectors is much larger for $p\alpha$ kinematic coincident events, there are a significant number of triggers corresponding to elastic events with incomplete energy information obtained for the proton. These events have been cleanly identified during replay using a combination of ejectile arm pulse-height cuts, recoil arm pulse-height and timing cuts, and ray-tracing information. A similar problem (although not as severe) has been encountered with $p\alpha \rightarrow d^3$He events with incomplete energy information for the deuteron.

For both three-body final states of interest, the same ejectile telescope and target acceptance cuts are made to ensure that the yields for tritons and helions are obtained with minimal systematic errors. Fig. 3 show the three-body phase space for inelastically scattered protons in the ejectile arm (central angle of 30°) and tritons in the forward angle recoil telescope using the above mentioned cuts along with recoil arm particle identification. The analogous distribution for helions is equally clean, thus demonstrating the ability to clearly distinguish three-body final states from other reactions. There have been no energy loss corrections yet applied to the pulse heights measured in the recoil arm detectors. This will be required so that complete kinematic reconstruction can be performed. In the current state of analysis, indications are that the ratio of the charge-symmetric final-state yields, $Y(p\cdot{}^3H)/Y(p\cdot{}^3He)$, strongly resembles previously presented results.[3]

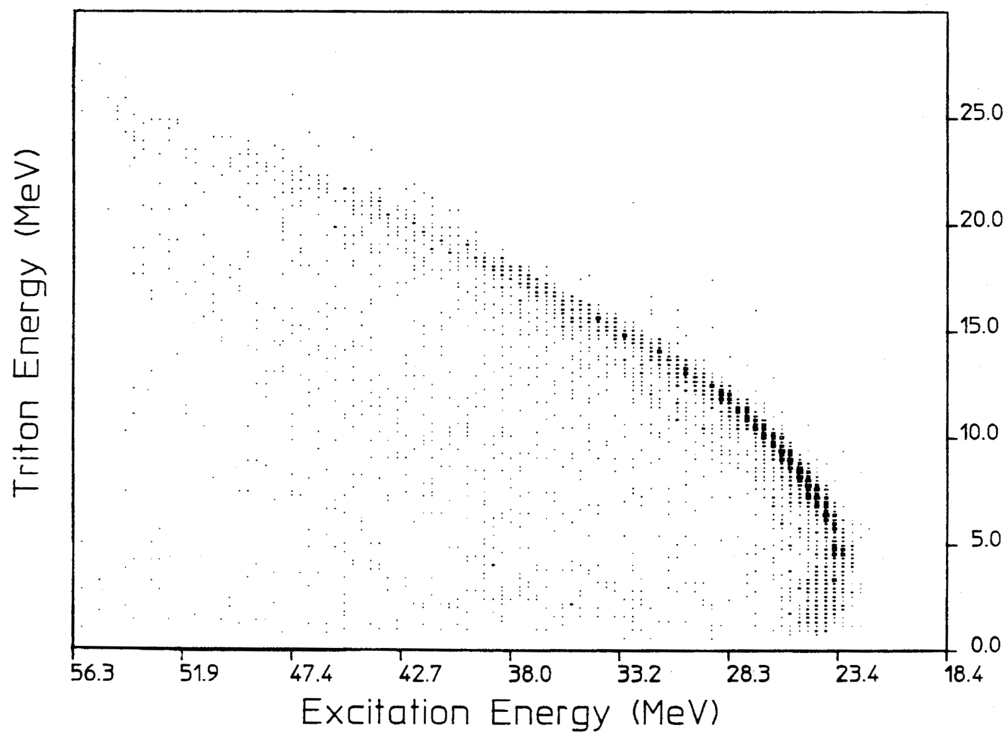


*Figure 3.* Locus for three-body kinematics for tritons in the forward angle recoil telescope and the ejectile arm at 30° with a source cut, $-2.5 \leq Z \leq 0.5$ cm.


1. J.R. Calarco, B.L. Berman, and T.W. Donnely, Phys. Rev. **C27** (1983) 1866.
2. L.C. Bland, B. Markham, D.W. Miller, R.K. Murphy, B.A. Raue, J.A. Templon, D. Dehnhard, and S.M. Sterbenz, *IUCF Scientific and Technical Report* 1987-88, p.11.
3. L.C. Bland, J. Breeden, K. Murphy, W.W. Jacobs, B. Raue, J. Sowinski, J. Templon, S. Vigdor, and J. Wilkerson, *IUCF Newsletter* 40 (1987) p.6.