PROGRESS IN THE MEASUREMENT OF C_{NN} AND A_y FOR THE $\vec{p}(\vec{n},d)\gamma$ REACTION AT $T_n = 183$ MeV

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The goal of this experiment is to observe, at a lower bombarding energy than ever before, explicit meson exchange and isobar current effects in np radiative capture. The normal-component spin correlation coefficient, C_{NN}, is expected to be particularly sensitive to such effects, due to its strong dependence on the np state in the entrance channel. Radiative np capture at low energy ($E_{c.m.} \leq 40$ MeV) is dominated by an electric dipole transition from ^3P np states to the $^3S_1$ state of the deuteron. The ^3P states give non-negative values for the spin correlation: $^3P_2$ gives $C_{NN} = 2/5$, $^3P_1$ gives $C_{NN} = 0$, and $^3P_0$ gives $C_{NN} = 1$. At higher energies, meson exchange and isobar current effects are expected to contribute. These additional currents will drive the magnetic dipole transitions $^1S_0 \rightarrow {}^3S_1$ and $^1D_2 \rightarrow {}^3D_1$. All singlet np states give a value of $C_{NN} = -1$, so this observable should become more negative as these effects begin to contribute significantly at higher energies. This simple argument is borne out by the calculations of Jaus and Woolcock[1,2] and by those of Arenhövel,[3] which additionally suggest that the cross section and analyzing powers are considerably less sensitive to these additional currents than is C_{NN}. We intend to measure C_{NN} to an absolute uncertainty of ± 0.05 and the neutron and proton analyzing powers to ± 0.025 to distinguish between the various levels of inclusion of mesons and isobars in the calculations of Jaus and Woolcock and of Arenhövel.

In the past year, significant progress has been made toward the completion of this experiment. In August 1990 we tested our complete apparatus (except for the polarized target) in beam for the first time. Based on the success of this run, we collected our first statistically significant sample of spin correlation data during a two week run in October 1990. During this long run, a number of problems remaining in our experimental setup were revealed, and we spent some of this beam time trying to understand these problems. We were able to clearly identify the radiative capture events, but the count rate of these good events was significantly lower, and at the same time the level of background was somewhat higher than expected. Also, the system we had installed for measuring the target polarization behaved unreliably. We spent the next several months analyzing the data to identify the sources of these problems. The number of problems turned out to be rather large, so we will only discuss two of the major ones here.

The polarity of the magnet which is used to sweep protons out of the neutron beam before they reach the neutron collimator had been reversed from time to time during the October run, in order to remove a potential systematic error associated with in-plane

polarization components of the neutron beam. Reversing the polarity of the magnet had the effect of averaging out these components. Unfortunately, the tune of the primary proton beam could only be matched to one of these polarities, with the result that our wire chamber leakage currents and background rates depended on the sweep magnet polarity. After some study, we have found that the largest possible systematic error of the sort described, under *very* conservative assumptions, is 25 times smaller than our statistical error goal, and so we no longer plan on reversing the sweep magnet polarity. We can thus tune the primary beam for the lowest background rates for a given sweep magnet setting and leave things that way.

The polarized target was placed farther downstream than was the the target in our test run of September 1989, to allow for the detection of photons at back angles. The neutron beam was larger in cross section at this location, such that the density of neutrons hitting the hydrogenic portion of the target was ~7% lower than we expected, and a significant fraction of the neutron beam was hitting the target frame. The background/signal ratio was thus higher than expected, closer to 12% rather than the 7% of our test run. This required two changes: 1) a new collimator to eliminate the portion of the beam hitting the target frame, and 2) operating at higher primary proton beam currents, in order to recover the lost neutron flux density. Operating at higher currents required that we run the wire chambers at lower voltages, in order to keep the leakage currents at a reasonable level. Previously we had plateaued the chambers for fast protons, but we realized it was sufficient to plateau them for deuterons.

A final development run in March 1991 to test our solutions to these and other problems was very successful. Running at only one sweep magnet polarity kept the wire chamber leakage currents and background rates low. Our new collimator had the desired effect of preventing any significant amount of beam from hitting the target frame. Whereas we had run only up to 100 nA of primary beam in October, we found that with our lower wire chamber voltages we could run at currents as high as 220 nA, with each chamber more than 98% efficient for deuterons. After some improvements, our system for measuring the target polarization is now very reliable.

Figure 1 shows the experimental setup we now employ. Deuterons are detected in the series of in-beam counters (ΔE and E scintillators, and four planes of wires (X1, Y1, X2, Y2)) shown. The large flux of protons from elastic *np* scattering are vetoed by the scintillator paddle downstream of the E. Coincident photons are detected in an array of 160 Pb-glass Čerenkov detectors. Two flux monitor detector pairs now independently measure the relative flux of neutrons that pass through our setup. The upstream flux monitor also serves as a charged particle veto for the main detector arrangement. The beam and target polarizations are determined from *np* elastic scattering using the proton detector telescope on beam left in coincidence with the segmented neutron detector tank on beam right. The neutron beam polarization is independently measured using the downstream neutron polarimeter (shown), while the primary proton beam polarization is also monitored continuously via polarimeters in the high energy beam lines (not shown).

The data from the October run were analyzed for the spin observables of interest, although the statistics are not yet sufficient to have any physics impact. Presently we use

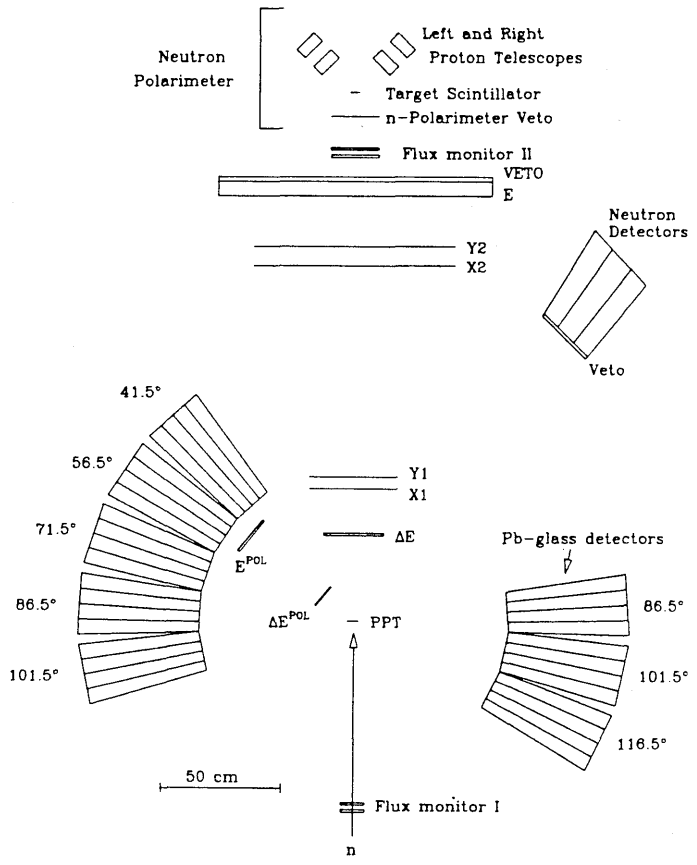

Figure 1. Scale rendering of the experimental setup for E328. The left-right asymmetric photon detector setup is dictated by concerns about γ attenuation in passage through the support posts of the superconducting magnet assembly built into the polarized proton target (PPT).

six software cuts (listed below and displayed in Figures 2 and 3) to define radiative capture events.

1) Target spot: Using the wire chamber information, we observe the distribution of intersections of the traceback rays with the target plane, in the X and Y directions, and make cuts on each axis (Figure 2(a)-(b)).

2) Particle identification: We compare the pulse heights from the E and ΔE detectors, to determine if the particle was a proton or a deuteron (Figure 2(c)).

3) E_γ: A cut is made on the pulse height distribution from the Pb-glass detectors. There are many low pulse height events, probably due to scattered neutron interactions in the Pb-glass, which appear as accidental coincidences. This cut rejects most of these events (Figure 3(a)).

4) t_γ: Coincidences between the charged particle detector arm and the Pb-glass detectors are collected for events where the charged particle and the γ-ray came from the same beam burst ("trues") and for events where the γ-ray came from the subsequent beam burst ("accidentals"). The "accidental" sample is subtracted from the "true" sample, to remove the effect of the underlying accidental events (Figure 3(b)).

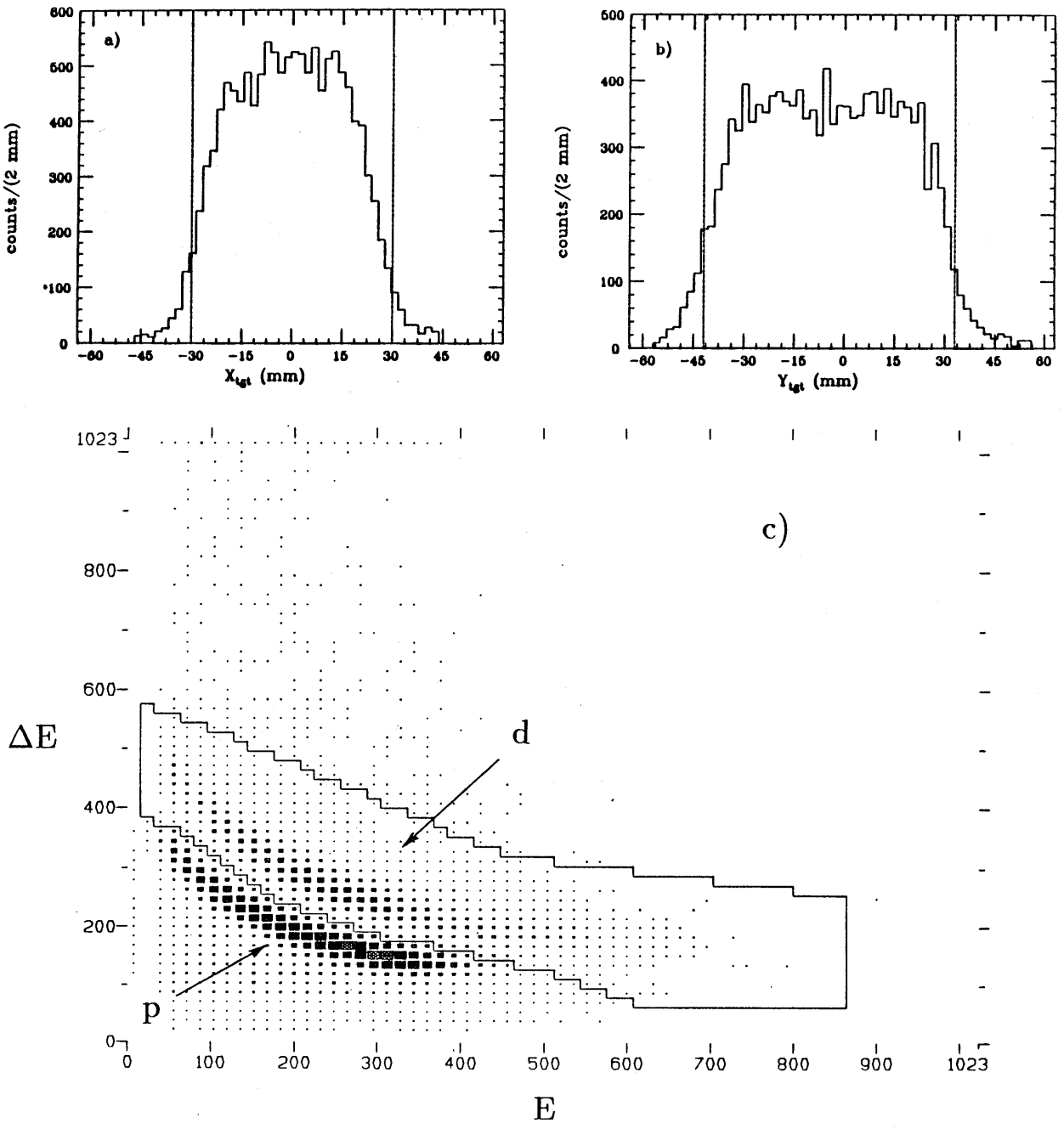

Figure 2. Spectra from runs with the polarized target, from the October 1990 run. Distribution of ray-trace intersections in the plane of the target, for the (a) X and (b) Y axes. (c) Particle identification spectrum, showing the ΔE-E loci for protons and deuterons.

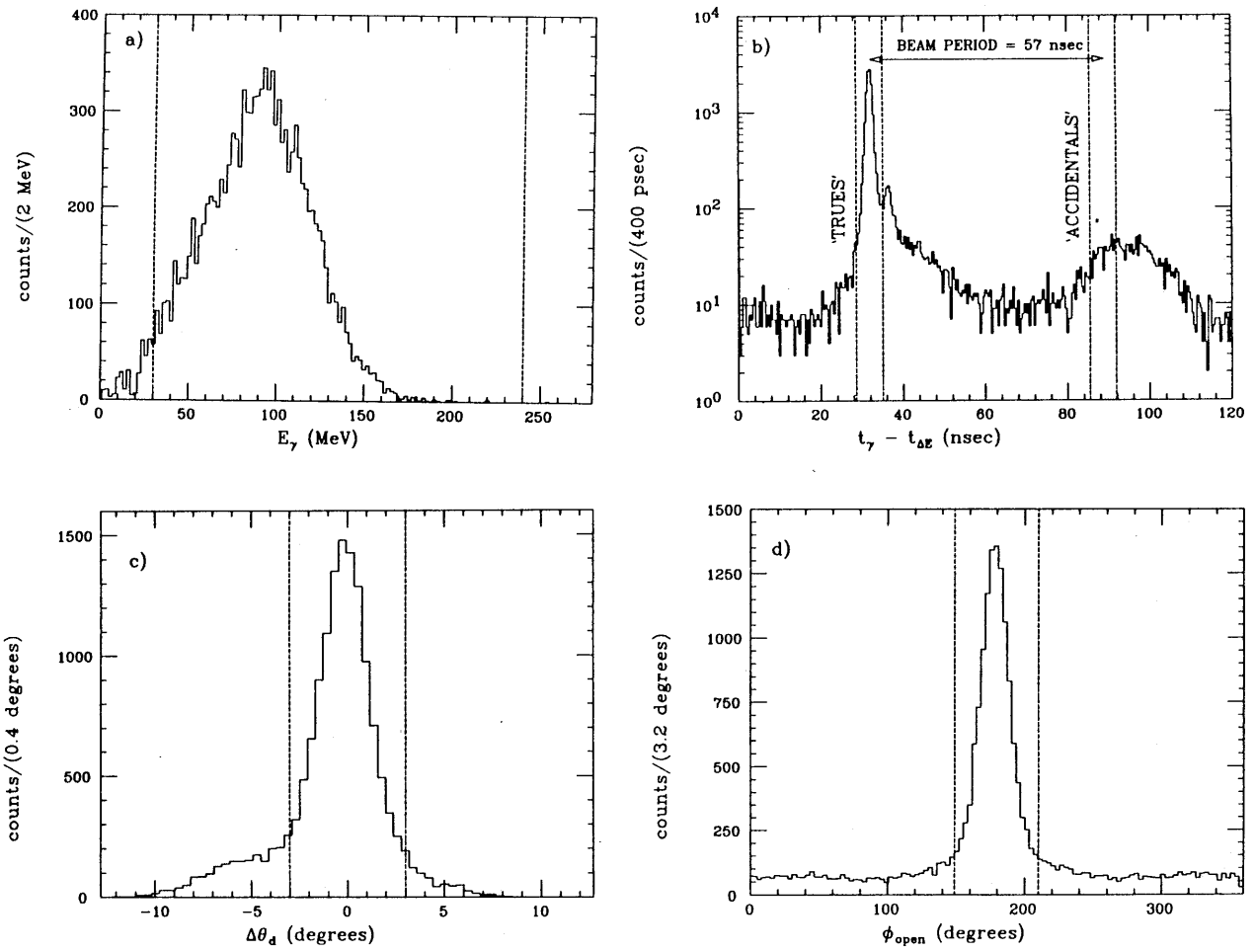

Figure 3. Spectra from runs with the polarized target, from the October 1990 run. (a) γ-ray energy. (b) t(γ)–t(ΔE). The small peak labeled 'ΔE' adjacent to the main 'true' peak arises from events which originate in the ΔE scintillator detector. (c) $\Delta\theta_d = \theta_d(traceback) - \theta_d(\theta_\gamma)$. (d) $\phi_{open} = \phi_d - \phi_\gamma$.

5) $\Delta\theta_d = \theta_d(traceback) - \theta_d(\theta_\gamma)$: We calculate the difference between the deuteron polar angle determined from the wire chamber information and that given by two-particle kinematics using the coincident γ-ray angle (Figure 3(c)).

6) $\phi_{open} = \phi_d - \phi_\gamma$: We calculate the difference between the azimuthal angles of the two particles. This cut on coplanarity and the $\Delta\theta_d$ cut reject events that do not have p(n,d)γ kinematics (Figure 3(d)).

As can be seen in Figs. 2 and 3, the signal from the radiative capture events is very clear, even with all the problems associated with the October running period. Figure 4 shows the preliminary results for the two analyzing powers and the spin correlation parameter for the October 1990 data. Since we have not yet been able to extract reliably the target polarization using the events from the np-polarimeter for this run, we have

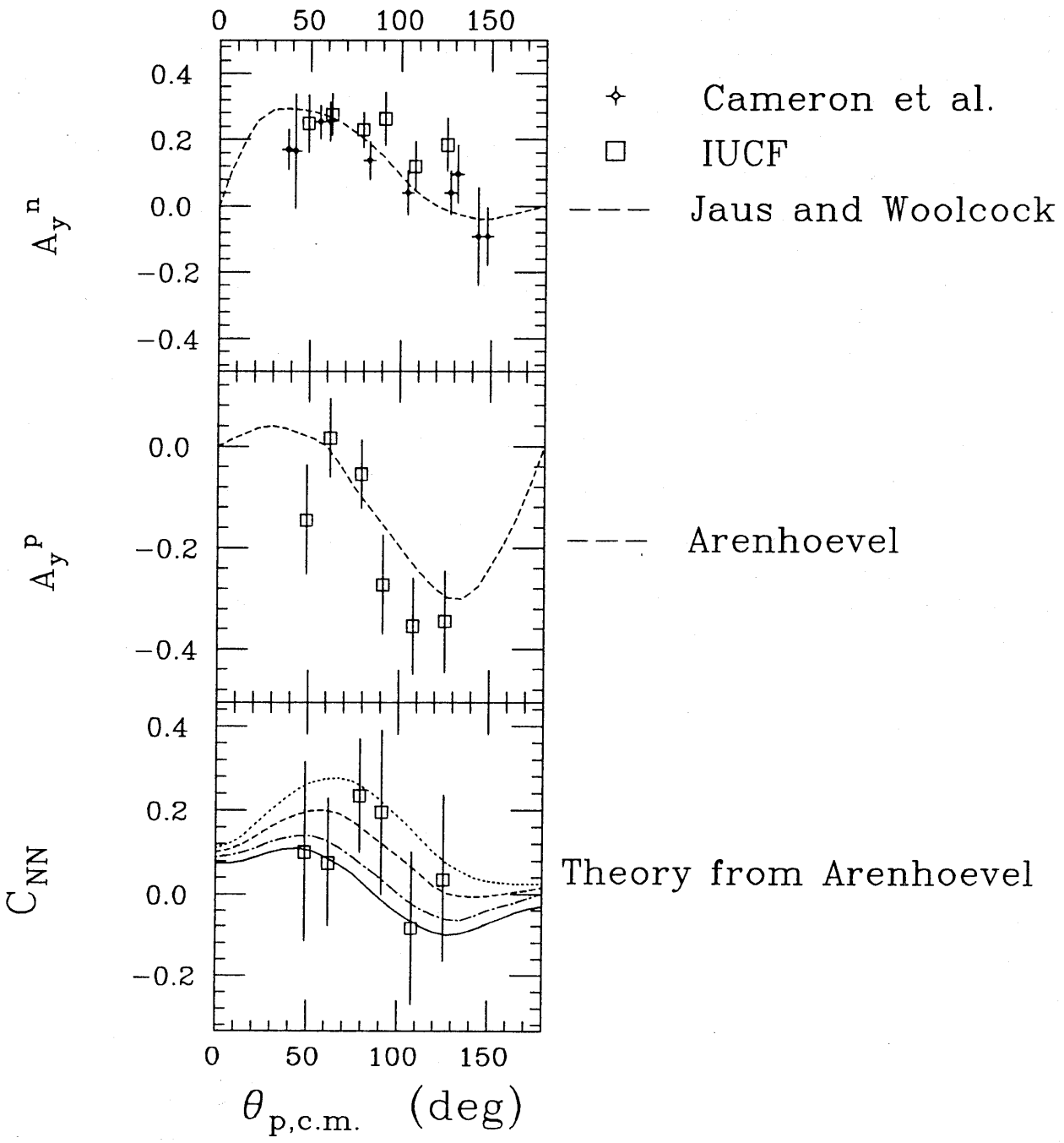

Figure 4. Preliminary results for A_y^n, A_y^p, and C_{NN}, from the October 1990 data.

assumed a value of $P_t = 0.4$, consistent with values measured using NMR techniques. The neutron beam polarization was determined from the downstream polarimeter. Our distribution for the neutron analyzing power has approximately the same shape as that of Cameron *et al.*,[4] and also a comparable statistical uncertainty per point. Our measurement of the proton analyzing power has roughly the right shape to agree with the calculations of Jaus and Woolcock and of Arenhövel. The distribution for C_{NN} is also shown; since the polarizations for the proton and the neutron are both on the order of a half, the error bars on C_{NN} will always be about twice as large as those for the analyzing powers. Other than the tendency towards an average positive value, these data do not have much to say about the spin correlation, due to the lack of statistics.

Based on the results of our March 1991 development run, we have submitted a proposal to the June 1991 PAC for sufficient beam time to complete the experiment. We expect to take half of our data during an already scheduled run this summer, and the remainder later this fall.

1. W. Jaus and W.S. Woolcock, Nucl. Phys. **A473**, 685 (1987).
2. W. Jaus and W.S. Woolcock, Nucl. Phys. **A480**, 573 (1988).
3. H. Arenhövel, 1986 CEBAF Summer Study.
4. J.M. Cameron *et al.*, Nucl. Phys. **A458**, 637 (1986).