THE KENT STATE "2π" NEUTRON POLARIMETER

J.W. Watson, Q.-Q. Du, B.D. Anderson, A.R. Baldwin,
L.A.C. Garcia, X.-D. Hu, D.L. Lamm, R. Madey,
Y. Wang, B. Wetmore, and W.-M. Zhang
Kent State University, Kent, Ohio 44242

C.C. Foster and E.J. Stephenson
Indiana University Cyclotron Facility, Bloomington, Indiana 47408

R. Kurmanov
Omsk Railway Engineering Institute, 644046 Omsk, Russia

P.J. Pella
Gettysburg College, Gettysburg, Pennsylvania 17325

We report here the performance of a medium-energy neutron polarimeter of a new design. Over the past decade, the Kent State group has undertaken a series of studies[1–4] at IUCF of spin-obervables for the (p,n) reaction with the neutron polarimeter described in Ref. 5. The observables we measured were the analyzing power $A_y(\theta)$, the induced polarization $P(\theta)$, and the transverse polarization transfer coefficient $D_{NN'}(\theta)$, which are the only spin observables that can be measured with a beam polarized normal to the reaction plane. IUCF now has the capability of delivering proton beams of all three polarization states, and we developed our new polarimeter to utilize this capability. As with the design of our earlier polarimeter,[5] this new polarimeter utilizes the analyzing power of n-p elastic scattering from the H nuclei of organic scintillators. Figure 1 shows the laboratory differential cross section $\sigma(\theta)$, the analyzing power $A_y(\theta)$, and the product $A_y^2(\theta) \times \sigma(\theta)$ (which is the standard "figure of merit" for polarization analyzing reactions) for n-p elastic scattering at 130 MeV. The desired features that motivated the design of our new polarimeter were: (1) that it should be capable of measuring both normal and sideways components of polarization simultaneously for obtaining full sets of polarization transfer obersvables from (p,n) reactions, (2) that the scatterers present a compact face to the neutron production target, so that neutron spin-rotation magnets of modest aperture could be placed between the target and the polarimeter, and (3) that the photomultiplier tubes should be gain-stabilized to reduce instrumental asymmetries.

In Fig. 2 we show the design chosen for this device. The scatterers are four 0.102 m $\times$ 0.102 m $\times$ 0.508 m BC-404 plastic scintillators. Scattered neutrons are detected with an azimuthally symmetric array of twelve 0.102 m $\times$ 0.254 m $\times$ 1.016 m BC-400 plastic scintillators at a central scattering angle of 20.0°, which is near the angle of maximum value for ${A_y}^2\sigma$ for n-p scattering in the energy range of 100-200 MeV. Because of the full azimuthal coverage, we call this the "2π" Polarimeter. All 16 detectors are mean-timed, with a fast 50.8-mm phototube (XP-2020) on each end of the scatterers, and a fast 227-mm phototube (XP-2041 or R-1250) on each end of the 12 back detectors. Gains for all 32 phototubes are stabilized with stand-alone microprocessor-based pulser systems utilizing high-stability blue LEDs.

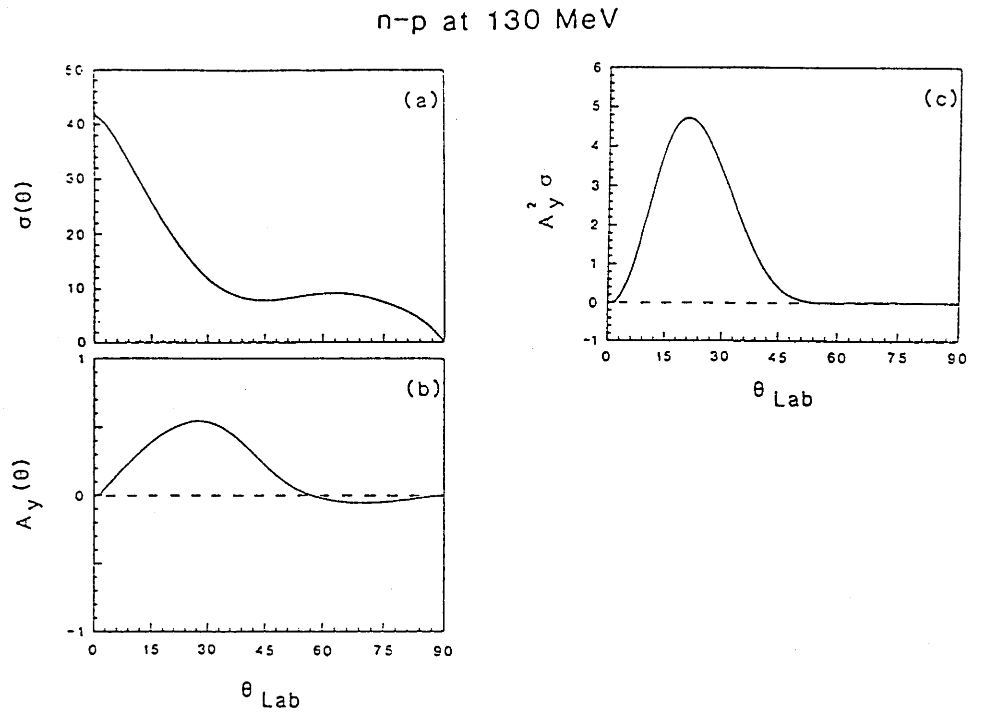

Figure 1. (a) The differential cross section $\sigma(\theta)$, (b) the analyzing power $A_y(\theta)$ and (c) the "figure-of-merit" $A_y{}^2\sigma$ versus the laboratory scattering angle for neutron-proton elastic scattering at 130 MeV.

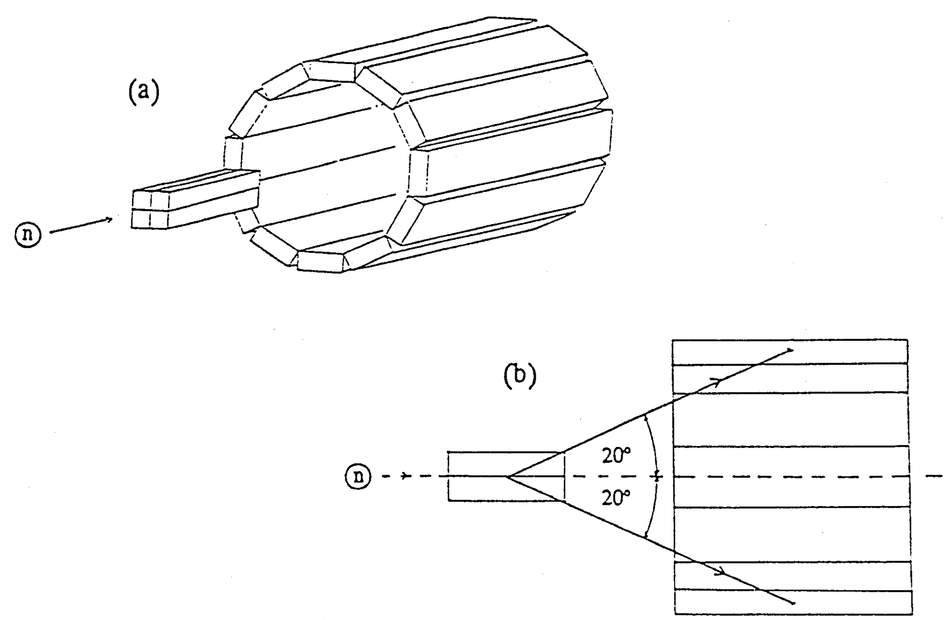

Figure 2. The new "2π" neutron polarimeter. (a) Isometric View. (b) From above.

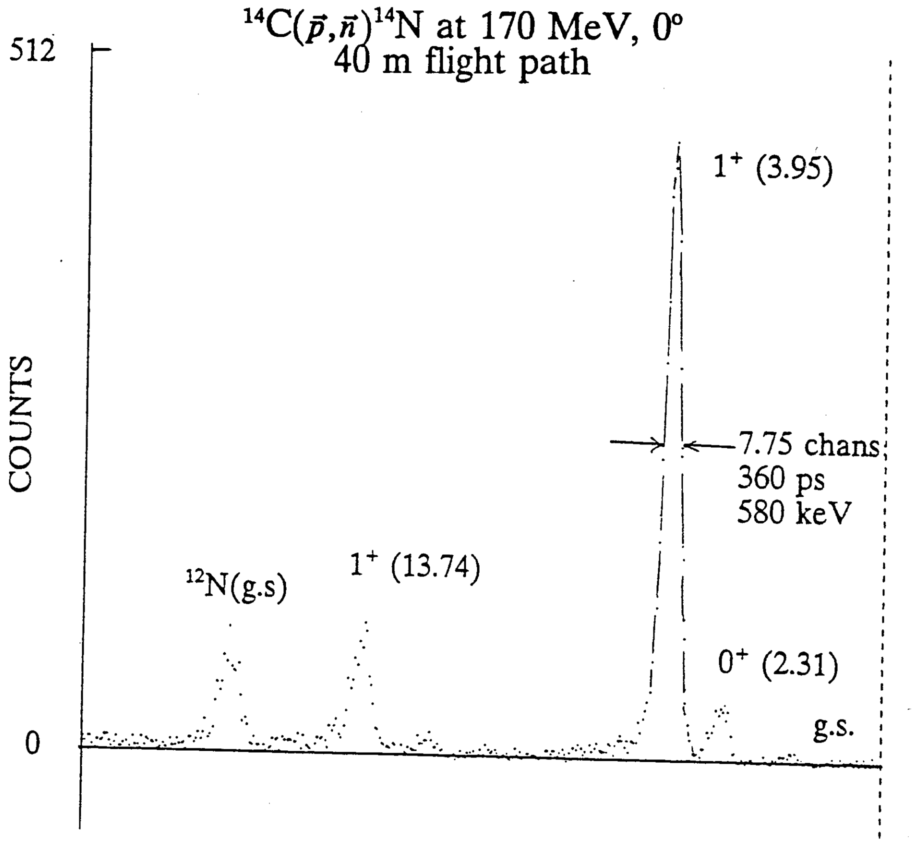

Figure 3. Flight-path-corrected neutron time-of-flight spectrum measured with the "2π" polarimeter for the $^{14}C(\vec{p},\vec{n})^{14}N$ reaction at 170 MeV and 0° for a flight path of 40 m.

We measured the performace of the scatterers with cosmic rays. Using techniques similar to those described in Ref. 6, we obtained 122 ± 6 ps (FWHM) for the intrinsic time resolution, and 17 ± 2 mm (FWHM) for the position resolution. We used the $^{14}C(p,n)^{14}N$ reaction at 135 and 170 MeV at IUCF to calibrate the polarimeter. The flight path was 40 m. Figure 3 shows the 170-MeV 0° neutron time-of-flight spectrum (for double scattering events) after event-by-event flight-path correction using position information from the scatterers. The overall time resolution is 360 ps (580 keV). This 360-ps overall time resolution is due primarily to the 300-ps beam burst width of the cyclotron. As indicated above, the intrinsic time resolution of the scatterers is 122 ps; also, the 17-mm position resolution (Δx) contributes only ($\Delta x/v$) = 109 ps to the overall time resolution.

We used the data from the $^{14}C(\vec{p},\vec{n})^{14}N$ reaction at 135 and 170 MeV also to calibrate the analyzing power of the polarimeter. For these measurements, the proton beam was in a pure normal state, with mean polarization $p_N = 0.71$. The beam polarization was reversed every 30 s. The double scattering yield should vary as $I(\phi) = I_0(1 + p_{N'}\overline{A_y}\cos\phi)$, where the neutron polarization $p_{N'} = D_{NN'}p_N$ and $\overline{A_y}$ is the analyzing power of the polarimeter. After applying "velocity ratio" cuts[5] (to eliminate events from reactions on carbon nuclei in the scatterers), we combined the spin-up and spin-down yields for pairs of back detectors differing in azimuth by $\Delta\phi = \pi$ to obtain the asymmetry ξ as a function of ϕ. Since $D_{NN'}$ is known ($D_{NN'} \equiv 1$ for the 2.31-MeV state; $D_{NN'} = -0.29 \pm 0.02$ for the 3.95-MeV

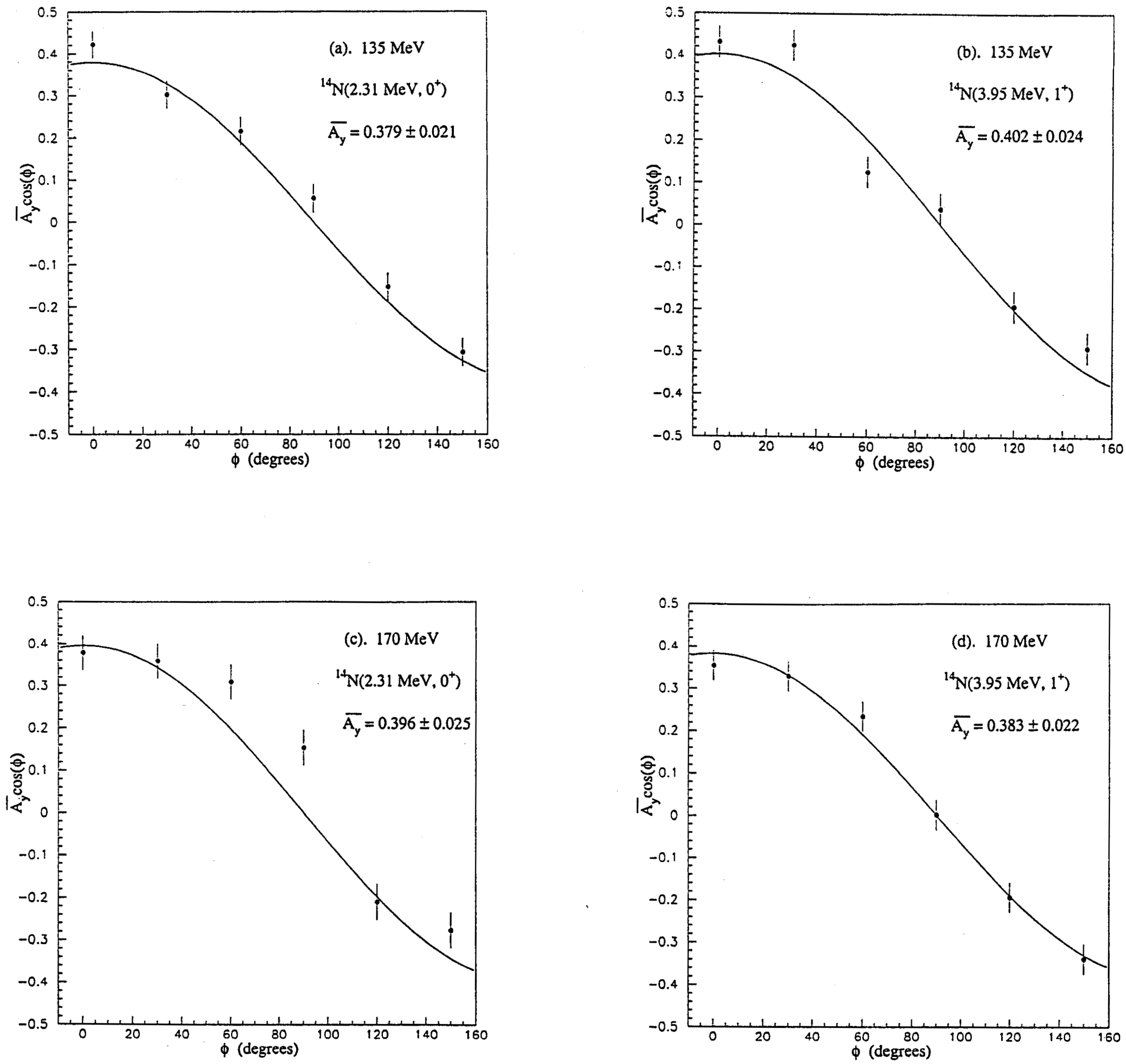

Figure 4. Data for $\overline{A_y}\cos\phi = \xi(\phi)/p_N D_{NN'}$ from the $^{14}C(\vec{p},\vec{n})^{14}N$ reaction: (a) and (b) for 135 MeV; (c) and (d) for 170 MeV.

state[7]), fitting the asymmetry yields $\overline{A_y}$. Figure 4 shows the fits to the asymmetry data for both the 0^+ (2.31 MeV) and 1^+ (3.95 MeV) states at 135 and 170 MeV. For both energies, the weighted mean of the two fits yields $\overline{A_y} = 0.39 \pm 0.02$. From known cross sections for the 3.95 MeV state, and the total double scattering yields (after cuts) we obtained the polarimeter efficiency $\epsilon \approx 0.3\%$ for both energies. For a velocity ratio cut at 0.92, we obtained the maximum polarimeter figure-of-merit $(\overline{A_y})^2\epsilon$ for both energies. The data in Fig. 4 are for this cut.

1. J.W. Watson, P.J. Pella, B.D. Anderson, A.R. Baldwin, T. Chittrakarn, B.S. Flanders, R. Madey, C.C. Foster, and I.J. van Heerden, Phys. Lett. B **181**, 47 (1986).
2. J.W. Watson, B.D. Anderson, and R. Madey, Can. J. Phys. **65**, 566 (1987).
3. W.-M. Zhang, *et al.*, Phys. Rev. C **45**, 2819 (1992).
4. J.W. Watson, B.D. Anderson, A.R. Baldwin, C.C. Foster, D.L. Lamm, R. Madey, P.J. Pella, Y. Wang, and W.-M. Zhang, Nucl. Phys. **A577**, 79c (1994).
5. J.W. Watson, Marco R. Plumley, P.J. Pella, B.D. Anderson, A.R. Baldwin, and R. Madey, Nucl. Instrum. & Methods **A272**, 750 (1988).
6. R. Madey, *et al.*, Nucl. Instrum. & Methods **A214**, 401 (1983).
7. T.N. Taddeucci, *et al.*, Phys. Rev. Lett. **52**, 1960 (1984).

CALIBRATION OF A NEUTRON POLARIMETER

I. Niculescu, R. Madey, T. Eden, K. Baker, and G. Niculescu
Hampton University, Hampton, Virginia, 23668

B.D. Anderson, A.R. Baldwin, M. Elaasar, D. Keane,
A. Lai, H. Liu, R. Madey, D.M. Manley, M. Niboh, M. Olson,
R. Suleiman, J.W. Watson, W.-M. Zhang, and J. Anderson
Kent State University, Kent, Ohio, 44242

J. Cameron, E.J. Stephenson, and C.C. Foster
Indiana University Cyclotron Facility, Bloomington, Indiana, 47408

C.C. Chang, J.J. Kelly, P. Markowitz, C. Halli, and W.R. Brown
University of Maryland, College Park, Maryland, 20742

C. Howell and R. Walter
Duke University, Durham, North Carolina, 27708

We measured the average analyzing power and the efficiency of a neutron polarimeter that was designed for use in experiments to measure the electric form factor of the neutron at the Bates Linear Accelerator Center and at the Continuous Electron Beam Accelerator Facility. The experiment was performed with polarized protons at the Indiana University Cyclotron Facility. The detector station that housed the polarimeter was located outside of the beam-swinger facility on the zero-degree line at a flight path of 65.55 m from the target to the midpoint of the front analyzing detector array in the polarimeter.

Shown in Fig. 1 is the configuration of the neutron polarimeter that was calibrated. A description of this polarimeter was reported previously.[1] It consists of 20 plastic (NE102) scintillation detectors: eight front scattering analyzers and two rear arrays parallel to the central ray of the incident neutron flux. Each rear array consists of two layers of detectors; each layer is composed of three detectors stacked side by side and staggered. Each detector