THE ^{208}Pb($\vec{p}$,$\vec{n}$)^{208}Bi REACTION AT 135 MeV

J.W. Watson, Marco R. Plumley, B.D. Anderson,
A.R. Baldwin, and R. Madey
Kent State University, Kent, Ohio 44242

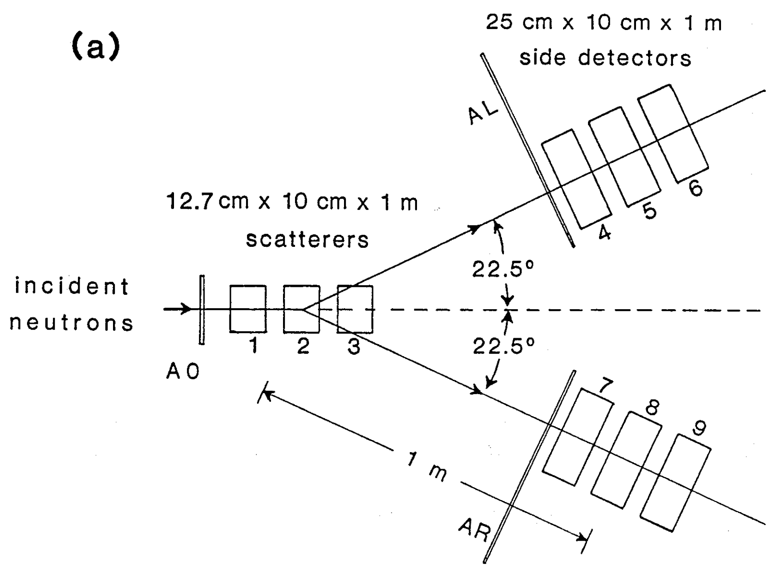
P.J. Pella
Gettysburg College, Gettysburg, Pennsylvania 17325

C.C. Foster
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

For nucleon inelastic scattering, i.e. (p,p′), (p,n), (n,p) or (n,n′) reactions, spin modes of nuclear exictation play an important role at medium-energies. Because of the special character of purely isovector transitions, we are interested in measuring spin-observables for (p,n) reactions at medium energies. These measurements include analyzing powers, $A_y(\theta)$, reaction polarizations, $P(\theta)$, and transverse polarization-transfer coefficients, $D_{nn}(\theta)$, as well as differential cross sections, $\sigma(\theta)$. These four observables are sensitive to different aspects of the reaction: $\sigma(\theta)$ is sensitive to ΔL; $A_y(\theta)$ is sensitive to whether the transition involves $j = l \pm 1/2 \rightarrow j = l \pm 1/2$ or $j = l \pm 1/2 \rightarrow j = l \mp 1/2$; $D_{nn}(\theta)$ is sensitive to Δ J and $\Delta\pi$; P − A_y is sensitive to non-localities. Previously, we reported measurements of $A_y(\theta)$[1,2] and $D_{nn}(\theta)$[3,4] for the ^{40,48}Ca(p,n)^{40,48}Sc reactions at 135 MeV. In this paper, we report on measurements of $D_{nn}(\theta)$ for the ^{208}Pb($\vec{p}$,$\vec{n}$)^{208}Bi reaction at 135 MeV.

We developed a high-efficiency neutron polarimeter that utilizes the analyzing power of n-p scattering from hydrogen nuclei in BC-517L mineral-oil scintillator; BC-517L has an H:C ratio of 2:1. The physical layout of this polarimeter is shown in Fig. 1: the operation and performance are described in Ref. 5. We obtained calibration data from the ^{12,14}C($\vec{p}$,$\vec{n}$)^{12,14}N reactions at 65, 100 and 135 MeV. In Figs. 2 and 3, we show data for the effective analyzing power, $\bar{A}_y$ and for the efficiency, ε, of the polarimeter as a function of the neutron kinetic energy E_n. At 130 MeV, the effective analyzing power, $\bar{A}_y$ is +0.375 ± 0.014 and the efficiency ε is 0.17%; thus, the figure-of-merit, $\eta = \bar{A}_y^2 \cdot \varepsilon$, is nearly 50% higher that for our earlier polarimeter design [6] which used NE-102 plastic scintillators.

We studied the ^{208}Pb($\vec{p}$,$\vec{n}$)^{208}Bi reaction at 135 MeV with this new polarimeter. For angles of 0°, 3°, 6°, and 9°, we measured the polarization-transfer coefficient $D_{nn}(\theta)$; the spin-flip probability $S = \big(1 - D_{nn}(\theta)\big)/2$. Figure 4 shows S spectra for the ^{208}Pb($\vec{p}$,$\vec{n}$)^{208}Bi reaction at 0° along with data from the ^{48}Ca($\vec{p}$,$\vec{n}$)^{48}Sc and ^{40}Ca($\vec{p}$,$\vec{n}$)^{40}Sc reactions.[3] The Gamow Teller Giant Resonances (GTGR), 0^+ isobaric-analog states, 1^- (non-spin-flip) components of the dipole resonance, and other known 1^+, 2^+, and 2^- states are indicated. For Q-values larger than 20 MeV (E_n < 115 MeV), the isovector spin-response is essentially identical for all three nuclei, suggesting a common mechanism for production of the continuum at large Q-values. The solid and dashed lines in Fig. 4 are spin-flip probabilities for free p-n scattering calculated from phase shifts and from the Bonn potential, respectively, with the computer code SAID.[8] These free p-n spin-flip probabilities were obtained from the observable D_t as S = (1 − D_t/2). D_t, the polarization transfer from the projec-



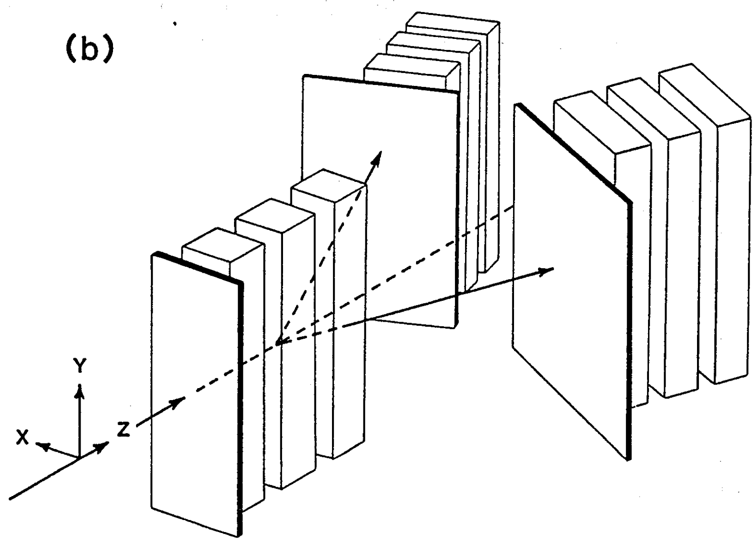


Figure 1. The configuration of the neutron polarimeter (a) as seen from above and (b) in perspective. AO, AL and AR are anti-coincidence detectors.

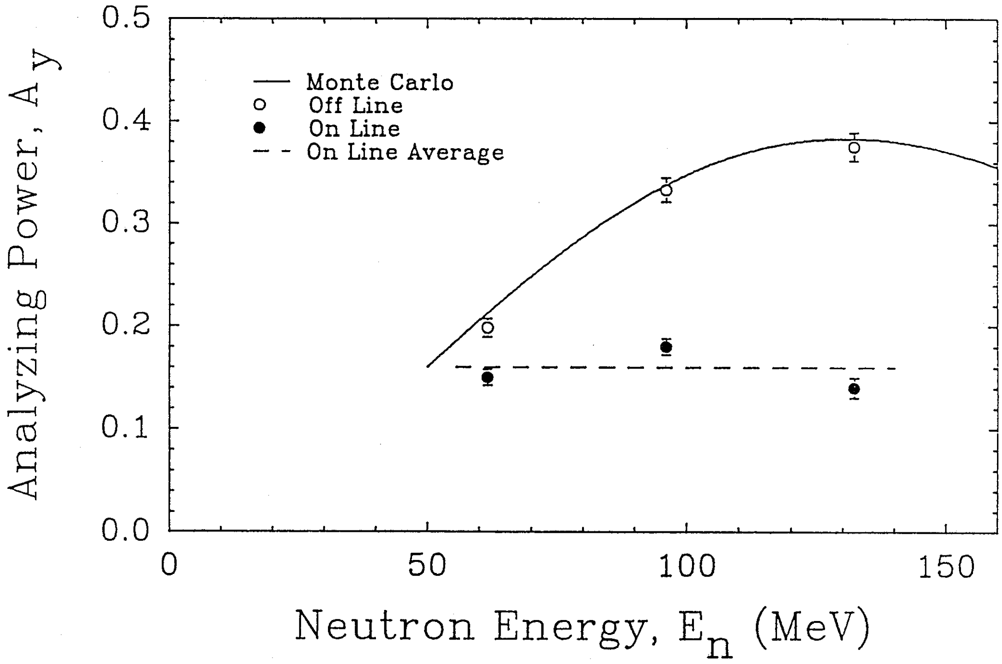


Figure 2. The analyzing power of $\bar{A}_y$ of the neutron polarimeter with mineral-oil scatterers as a function of the incident neutron kinetic energy E_n. Shown are on-line results, off-line results for the final software cuts, and results from a Monte-Carlo simulation assuming n-p scattering alone.

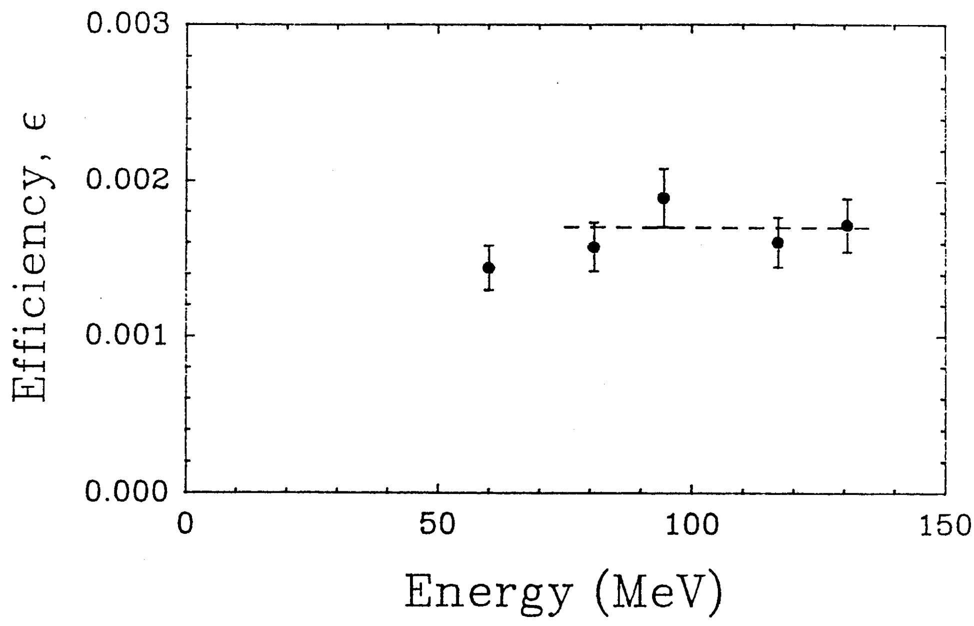


Figure 3. The efficiency of the polarimeter with (BC-517L) mineral-oil scatterers as a function of the incident neutron kinetic energy E_n. These efficiencies were determined from the $^{12}C(p,n)^{12}N$ (g.s.) and $^{14}C(p,n)^{14}N$ (3.95 MeV) reactions with the final choice of software cuts. The weighted average of the four highest energy points = 0.17%.

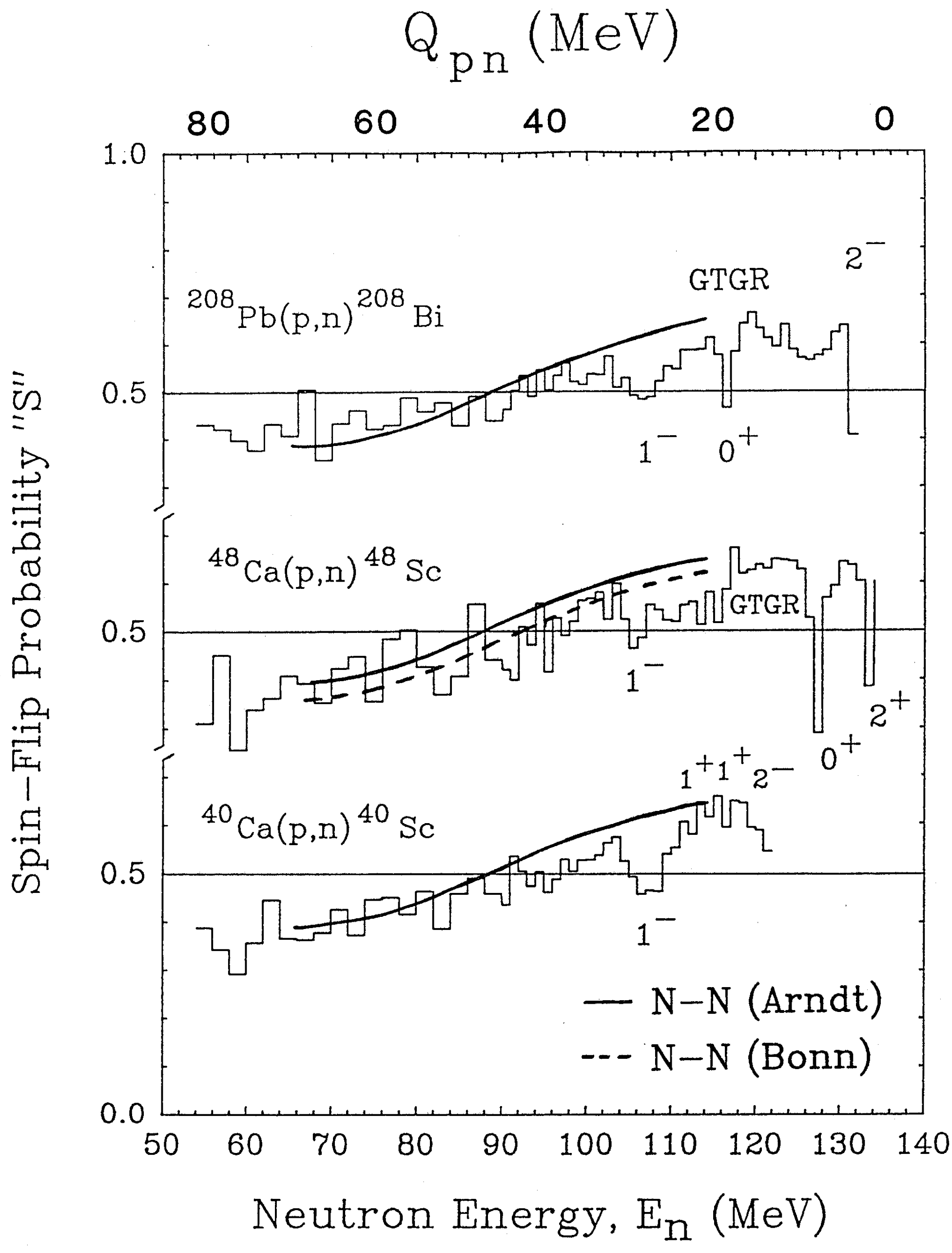
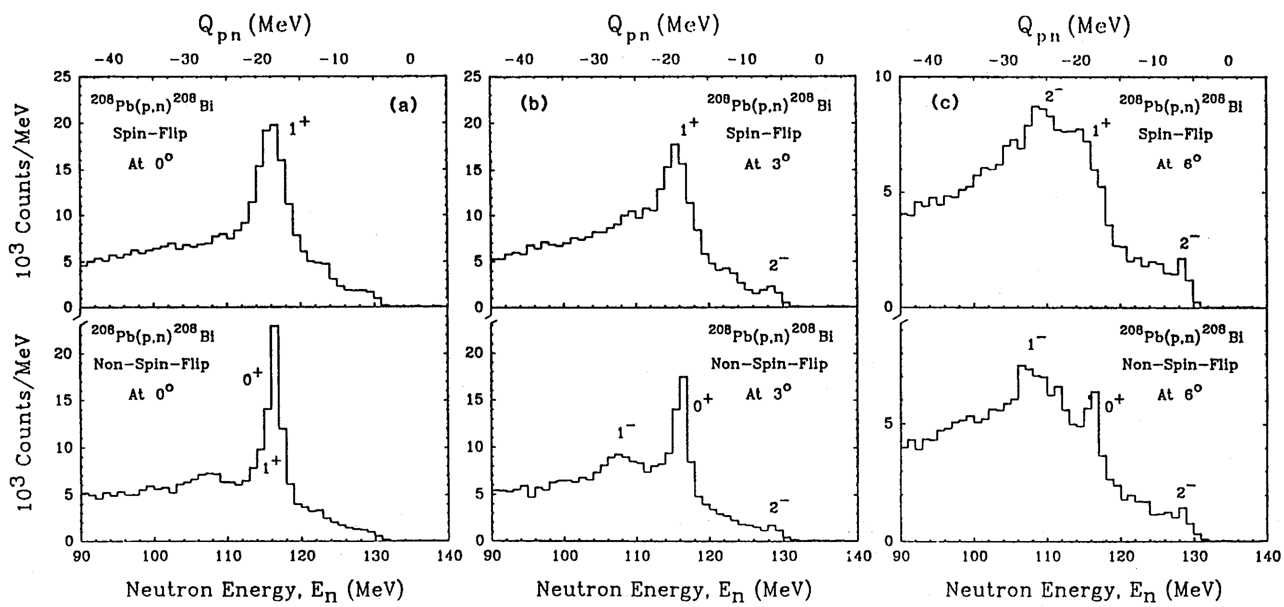


Figure 4. Spin-flip probabilities for the ^{208}Pb($\vec{p}$,$\vec{n}$)^{208}Bi, ^{48}Ca($\vec{p}$,$\vec{n}$)^{48}Sc and ^{40}Ca($\vec{p}$,$\vec{n}$)^{40}Sc reactions at 135 MeV and 0°. The solid and dashed lines are for free p-n scattering calculated from phase shifts, and the Bonn potential, respectively.

tile to the target, is the free p-n observable corresponding to $D_{nn}(\theta)$ for a (p,n) reaction. These calculations assume that the (p,n) reaction can be described as p-n scattering from stationary, bound neutrons. For a series of binding energies, two-body kinematics were used to determine the final-state laboratory neutron kinetic energy E_n, the momentum transfer q, and the final state p-n c.m. energy; D_t was then calculated for these latter two kinematic variables. The spin-flip probabilities calculated in this simple model agree remarkably well with the data for Q-values < -30 MeV; for neutron energies as small as half the beam energy, the continuum clearly carries the spin-flip signature of free p-n scattering. This simple model is equally successful in describing data for $Q < -30$ MeV for the $^{208}Pb(\vec{p},\vec{n})^{208}Bi$ reaction at 3°, 6°, 9°, and $(\vec{p},\vec{n})$ data for other targets at other energies reported by other groups.[8] Similar calculations do not seem to do a good job of fitting medium-energy $(\vec{p},p')$ data,[9] apparently[10] due to the presence of strong, collective, isoscaler, $\Delta S \doteq 0$ resonances which deplete non-spin-flip strength in the continuum.

Figure 5 shows spin-flip spectra $[S \times \sigma(\theta)]$ for the $^{208}Pb(\vec{p},\vec{n})^{208}Bi$ reaction at 0°, 3°, and 6°. In the non-spin-flip spectra, the 0^+ IAS and the 1^- natural-parity component of the spin-dipole resonance are separated clearly from the GTGR and the unnatural parity components of the spin-dipole resonance which dominate the spin-flip spectra. This ability of spin-flip measurements to identify and separate the various components of the spin-dipole resonance was noted also for the $^{40}Ca(\vec{p},\vec{n})^{40}Sc$ reaction.[3,4]

1. T. Chittrakarn, B.D. Anderson, A.R. Baldwin, C. Lebo, R. Madey, J.W. Watson and C.C. Foster, Phys. Rev. C **34**, 422 (1986).
2. B.D. Anderson, T. Chittrakarn, A.R. Baldwin, A. Fazeley, C. Lebo, J.W. Watson,



<u>Figure 5.</u> Spin-flip and non-spin-flip spectra for the 135 MeV $^{208}Pb(\vec{p},\vec{n})^{208}Bi$ reaction at (a) O°, (b) 3°, and (c) 6°.

and C.C. Foster, Phys. Rev. C **34**, 422 (1986).
3. 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. **B181**, 47 (1986).
4. J.W. Watson, B.D. Anderson and R. Madey, Can. J. Phys. **65**, 566 (1987).
5. J.W. Watson, Marco R. Plumley, P.J. Pella, B.D. Anderson, A.R. Baldwin, and R. Madey. submitted to Nucl. Instrum. Meth.
6. J.W. Watson, B.D. Anderson, A.R.Baldwin, T. Chittrakarn, B.S. Flanders, R. Madey, P.J. Pella, C.C. Foster, and I.J. van Heerden, in Nucleon and Anti-Nucleon Scattering from Nuclei, ed. G.E. Walker, C.D. Goodman, and C. Olmer (Plenum, New York, 1985) p. 371.
7. R.A. Arndt, computer code SAID (unpublished).
8. T.N. Taddeucci, Can. J. Phys. **65**, 557 (1987).
9. C. Glashausser, K. Jones, F.T. Baker, L. Bimbot, H. Esbensen, R.W. Fergerson, A. Green, S. Nanda, and R.D. Smith, Phys. Rev. Lett. **58**, 2404 (1987).
10. P.M. Boucher, B. Castel, Y. Okuhara, I.P. Johnstone, J. Wambach, and T. Suzuki, Phys. Rev. C **37**, 906 (1988).

THE ^{52,54}Cr(p,n)^{52,54}Mn AND ^{57,58}Fe(p,n)^{57,58}Co REACTIONS AT $E_p = 120$ MeV

D. Wang and J. Rapaport
Ohio University, Athens, Ohio 45701

D.J. Horen
Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830

B.A. Brown
Michigan State University, East Lansing, Michigan 48824

C. Gaarde
Niels Bohr Institute, Copenhagen, Denmark

C.D. Goodman
Indiana University, Bloomington, Indiana 47405

E. Sugarbaker
Ohio State University, Columbus, Ohio 43215

T.N. Taddeucci
Los Alamos National Laboratory, Los Alamos, New Mexico 87545

Differential cross sections for the (p,n) reaction on ^{52,54}Cr and ^{57,58}Fe have been measured for angles up to $\theta_{lab} = 10.5°$ and 14.6°, respectively, using 120 MeV protons. The observed angular distributions has been used to evaluate the location and strength of Gamow-Teller resonances. A shell-model calculation of this strength distribution has