MEASUREMENT OF THE TRANSVERSE SPIN TRANSFER COEFFICIENT $D_{NN}(0°)$ FOR (p,n) REACTIONS AT 160 MeV

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A direct measure of the spin-flip character of a (p,n) transition is provided by the transverse spin transfer coefficient $D_{NN}(\theta)$ [or, equivalently, the transverse spin-flip probability $S_{NN} = (1 - D_{NN})/2$]. Cornelius, Moss, and Yamaya have shown that this quantity takes on distinctive values for transitions having a unique or single dominant value for the orbital angular momentum transfer.[1] In particular, GT transitions (J=1, L=0,2, S=1) should have $D_{NN}(0°) \simeq -1/3$ if L=0 dominates, Fermi (F) transitions (J=0, L=0, S=0) have $D_{NN}(0°) = 1$, and spin-dipole transitions (J=0,1,2, L=1, S=1) should have $D_{NN}(0°) = -1, 0, -2/5$, respectively, where J, L, and S are the total, orbital, and spin angular momenta transferred in the reaction. Recent measurements and analyses of the spin-flip probability in intermediate energy (p,p') reactions have also shown that D_{NN} at small momentum transfer is relatively insensitive to distortion effects and details of the transition density,[2] in contrast to other quantities such as the analyzing power.

We have made the first measurements of the transverse spin transfer coefficient $D_{NN}(0°)$ for intermediate energy (p,n) reactions. Data have been obtained for (p,n) reactions on $^{6,7}Li$ and $^{12,13,14}C$ at E_p = 160 MeV. The bombarding energy was chosen to be as high as possible to minimize L > 0 contributions to the transition amplitudes at 0°, while still maintaining the experimental energy resolution required. The targets chosen all exhibit GT transitions leading to well resolved final states with minimal interfering background and are thus suitable tests for establishing the validity of the experimental technique and the applicability of the simple predictions for $D_{NN}(0°)$. We have also obtained data for the $^{90}Zr(p,n)$ reaction and interpret these data with respect to the "benchmark" measurements obtained on the light targets.

The data were obtained using the beam swinger facility. Polarized protons with energy E_p = 160 MeV bombarded self-supporting targets with thicknesses ranging from 107 - 232 mg/cm^2. The time-of-flight (TOF) of neutrons emitted at 0° was measured over a 60 m flight path. Time resolution (including beam and target contributions) varied from 0.7 ns to 1.1 ns depending upon the target, with corresponding energy resolution of 0.7 MeV to 1.1 MeV.

The neutron polarimeter consists of six 15 cm x 15 cm x 100 cm plastic scintillators arranged in two parallel stacks of three. The long axes of the scintillators are parallel to the horizontal plane and perpendicular to the incident neutron flux. The separation between stacks is approximately 1.4 m. Neutrons are polarization analyzed by scattering from hydrogen $[^1H(\vec{n},n)^1H]$ and carbon $[^{12}C(\vec{n},n'x)]$ nuclei in one of the forward scintillators. The scattered neutrons are subsequently detected by one of the trailing scintillators, which serve as the polarimeter "arms." A thin (2.5 cm) plastic scintillator between the stacks is used to veto events caused by forward-scattered protons. Time signals derived from each end of the detectors furnish both the TOF of the incident neutron and position information from which the event may be reconstructed and characterized as a left or right scatter. Neutrons that scatter at polar angles of $14° \leqslant \theta \leqslant 31°$, azimuthal (out-of-plane) angles of $\phi \leqslant |45°|$, and with velocity $v_n'/\cos\theta \geqslant 0.91 v_n$ are accepted as valid events. The instrumental analyzing power for these conditions is $A \simeq 0.34 \pm 0.02$ and is primarily due to scattering from hydrogen.

Energy spectra for the summed yields $(N_L^+ + N_L^- + N_R^+ + N_R^-)$ and difference of yields $(N_L^+ - N_L^- + N_R^- - N_R^+)$ for double-scattered neutrons produced by (p,n) reactions on ^{13}C, ^{14}C, and ^{90}Zr are shown in Figs. 1-3. The difference spectra show positive peaks for transitions with $D_{NN}(0°) > 0$ and negative peaks for transitions with $D_{NN}(0°) < 0$. Most of the peaks in these spectra correspond to GT transitions and thus exhibit negative peaks in the difference spectra. The exceptions are the $0^+ \rightarrow 0^+$ $^{14}C(p,n)$ and $^{90}Zr(p,n)$ IAS transitions, for which

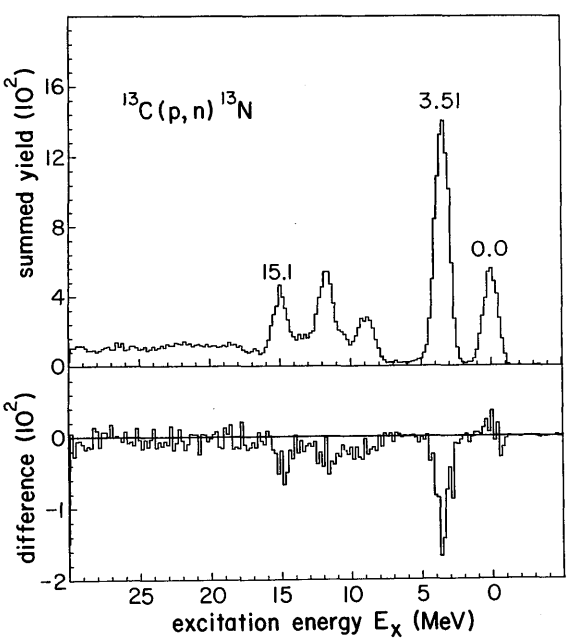

Figure 1. Energy spectra for the sum $(N_L^+ + N_L^- + N_R^+ + N_R^-)$ and difference $(N_L^+ - N_L^- + N_R^- - N_R^+)$ of yields of double-scattered neutrons produced by the $^{13}C(p,n)^{13}N$ reaction at E_p = 160 MeV and $\theta = 0°$.

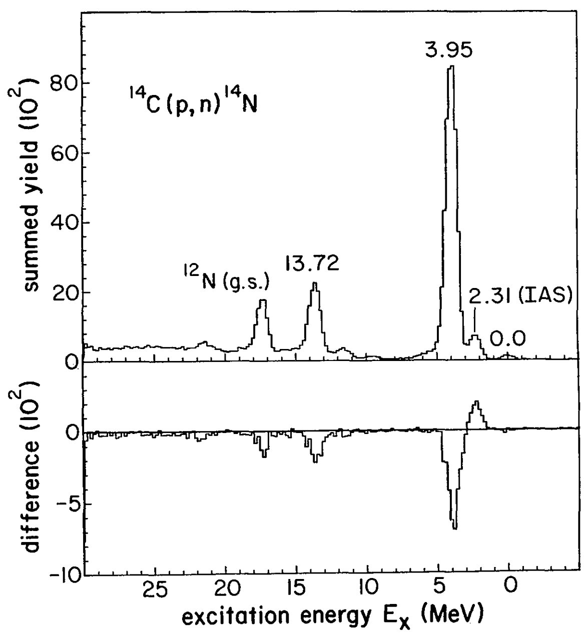

Figure 2. Energy spectra for the sum and difference of yields of double-scattered neutrons produced by the $^{14}C(p,n)^{14}N$ reaction at 160 MeV and $\theta = 0°$.

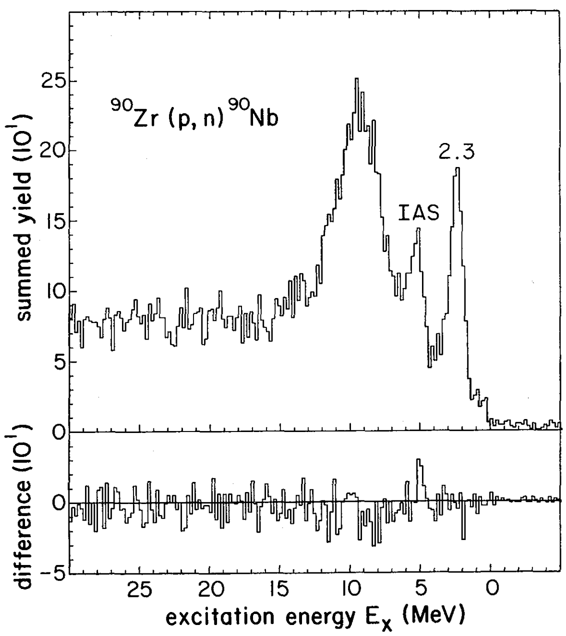

Figure 3. Energy spectra for the sum and difference of yields of double-scattered neutrons produced by the $^{90}Zr(p,n)^{90}Nb$ reaction at 160 MeV and $\theta = 0°$.

$D_{NN}(0°) = 1$, and the $1/2^- \rightarrow 1/2^-$ $^{13}C(p,n)^{13}N(g.s.)$ transition, which is a mixture of Gamow-Teller and Fermi components.

Values of $D_{NN}(0°)$ extracted from these spectra are given in Table I, along with results for ^6Li, ^7Li, and ^{12}C. Significantly, all of the pure GT transitions, such as $^6Li(p,n)^6Be(g.s.)$, $^{12}C(p,n)^{12}N(g.s.)$, $^{13}C(p,n)^{13}N(3.51\ MeV)$, and $^{14}C(p,n)^{14}N(3.95\ MeV)$, exhibit values of $D_{NN}(0°)$ close to the expected value of $\simeq -1/3$. Large systematic deviations from this value would be indicative of unexpectedly large L=2 amplitudes at 0° or failure of the assumed single-step direct-reaction mechanism.

Having established that $D_{NN}(0°) \simeq -1/3$ is a definite signature of GT transitions, we can attempt to interpret the results for $^{90}Zr(p,n)$. The values obtained for the $^{90}Zr(p,n)$ transitions represent the summed strength in the energy region indicated, i.e. no "background" has been subtracted. The value obtained

Table I. Transverse spin transfer coefficient $D_{NN}(0°)$ for (p,n) reactions at 160 MeV.

Reaction	E_x (MeV)	$D_{NN}(0°)$
$^6Li(p,n)^6Be$	0.0	-0.38 ± 0.04
$^7Li(p,n)^7Be$	0.0 + 0.43	-0.28 ± 0.06
$^{12}C(p,n)^{12}N$	0.0	-0.25 ± 0.03
$^{13}C(p,n)^{13}N$	0.0	0.05 ± 0.086
"	3.51	-0.34 ± 0.05
"	15.1	-0.36 ± 0.08
$^{14}C(p,n)^{14}N$	0.0	-0.30 ± 0.17
"	2.31[a,b]	1.0
"	3.95	-0.29 ± 0.02
"	13.72	-0.34 ± 0.04
$^{90}Zr(p,n)^{90}Nb$	0.0 - 4.2	-0.21 ± 0.15
"	4.3 - 6.3[b]	0.24 ± 0.18
"	6.4 - 13.1[c]	-0.28 ± 0.09
"	13.2 - 17.3	-0.11 ± 0.14

[a] Calibration transition.

[b] Isobaric analog state (IAS).

[c] Giant Gamow-Teller resonance.

for the region of the giant GT resonance is consistent with that expected for a pure L=0 GT transition and thus indicates that nearly all of the strength observed in this region has the same GT-type spin transfer signature. Note that $|D_{NN}(0°)|$ for the region of the T=5 state[3] ($13.2\ MeV \leq E_x \leq 17.3\ MeV$) is significantly less than 1/3, indicating that GT strength is not the dominant component in this region of excitation. The value obtained for the IAS + background is consistent with $D_{NN}(0°) = 1$ for the IAS transition and $D_{NN}(0°) \simeq -1/3$ for the background.

In summary, measurements of the transverse spin transfer coefficient $D_{NN}(0°)$ have been made for (p,n) reactions on $^{6,7}Li$, $^{12,13,14}C$, and ^{90}Zr at E_p = 160 MeV. These measurements reveal that most GT transitions exhibit values of $D_{NN}(0°)$ close to the expected nominal value of -1/3. This observable may therefore be a useful means of characterizing features observed in (p,n) spectra. In particular, the results obtained for $^{90}Zr(p,n)$ suggest that there is very little background in the region of the giant Gamow-Teller resonance. Additional data on this target should help resolve the question of whether there is significant GT strength at higher excitation energies.

1) W.D. Cornelius, J.M. Moss, and T. Yamaya, Phys. Rev. C 23, 1364 (1981).

2) S.J. Seestrom-Morris et al., Phys. Rev. C 26, 2131 (1982).

3) D.E. Bainum et al., Phys. Rev. Lett. 44, 1751 (1980).

THE $^{19}F(p,n)^{19}Ne$ and $^{39}K(p,n)^{39}Ca$ REACTIONS AT INTERMEDIATE ENERGIES

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The (p,n) reaction on ^{19}F and ^{39}K targets has been studied at 120 MeV and 160 MeV using the IUCF beam swinger facility. States with up to 12 MeV excitation energy have been observed for which GT strengths have been obtained. In Fig. 1 are presented the zero-degree spectra observed for the $^{19}F(p,n)^{19}Ne$ reaction at 120 and 160 MeV, while in Fig. 2 similar spectra for the $^{39}K(p,n)^{39}Ca$ reaction are shown. A total integrated B(GT) = 2.0 ± 0.06 has been obtained for the $^{19}F(p,n)^{19}Ne$ reaction while a total B(GT) = 1.02 ± 0.12 has been obtained for the $^{39}K(p,n)^{39}Ca$ reaction.