$^{13}C(p,n)^{13}N$ AT INTERMEDIATE ENERGY

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Neutron energy spectra from $^{13}C(p,n)^{13}N$ were measured at E_p=80, 120, and 160 MeV at scattering angles from 0° to 26°. From these spectra differential cross sections have been obtained for $^{13}C(p,n)^{13}N$(g.s.) and $^{13}C(p,n)^{13}N$(3.5 MeV) for E_p=120 and 160 MeV. The transition to the 3.5 MeV excited state is $1/2^- \rightarrow 3/2^-$ and has an angular distribution characterized by a rapid monotonic fall-off with increasing angle, similar to other cases of spin-flip, isospin-flip transitions. The large 0° cross section also indicates that this state contains most of the GT strength for $^{13}C \rightarrow ^{13}N$. The ground state transition, which is $1/2^- \rightarrow 1/2^-$, shows a structured angular distribution with a sharp minimum at about 20°. These results have been analyzed using DWIA calculations with an interaction taken from the work of W.G. Love and derived from the free N-N force.

Within the context of this analysis the sharp minimum results from interference between J=1 central and tensor components of the force. This interference is not observed in the transition to the 3.5 MeV state because the central component dominates. In the ground state transition, which is $p_{1/2} \rightarrow p_{1/2}$, the central component is weaker. The J=0, spin independent isospin term in the interaction, which also contributes incoherently to the ground state transition, exhibits a monotonic fall-off with angle in the calculations.

1) W.G. Love in "The (p,n) Reaction and the Nucleon-Nucleon Force", edited by C.D. Goodman, S.M. Austin, S.D. Bloom, J. Rapaport and G.R. Satchler, Plenum, New York, 1980, p. 23.

HIGH-SPIN STATES IN NUCLEI EXCITED VIA THE (p,n) REACTIONS

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In our October 1979 run, we studied the excitation of high-spin states in the $^{12}C(p,n)^{12}N$ and $^{16}O(p,n)^{16}F$ reactions at 99 MeV bombarding energy. This was the first run to use a second detector station with the beam swinger facility which permitted access to laboratory angles from 24° to 48.5°. We used a 0.52 m^2 x 10 cm thick detector array at 68.0 m in the first detector station (0° to 24.5°) and a 0.77 m^2 x 10 cm thick detector array at 76.3 m in the second detector station (24° to 48.5°). Overall energy resolutions of 260 keV and 230 keV were achieved at the first and second detector stations, respectively, for neutrons of about 80 MeV from the $^{12}C(p,n)^{12}N$ reaction. The 23 mg/cm^2 C target contributed ∿ 150 keV to these observed resolutions.

Figure 1 shows the 48.5° spectrum of neutrons from the $^{16}O(p,n)^{16}F$ reaction. At this angle a single peak at 6.4 MeV excitation dominates the ^{16}F spectrum. We interpret this peak to be the 4^- state with a $(d_{5/2}, p_{3/2}^{-1})$ proton-particle neutron-hole "stretched" configuration predicted by Moffa and Walker.[1] As seen in Fig. 2, the angular distribution for this state has a characteristic L=3 shape consistent with the $J^{\pi}=4^-$ interpretation; i.e., the angular distribution peaks near the momentum transfer $q = L/R = 3/(1.15\ A^{1/3}\ fm) = 1.035\ fm^{-1} (\theta_{CM} \sim 35°)$. The error bars shown in Fig. 2 reflect statistical errors only. Systematic errors of about 20 percent in this experiment are dominated by an uncertainty in the neutron

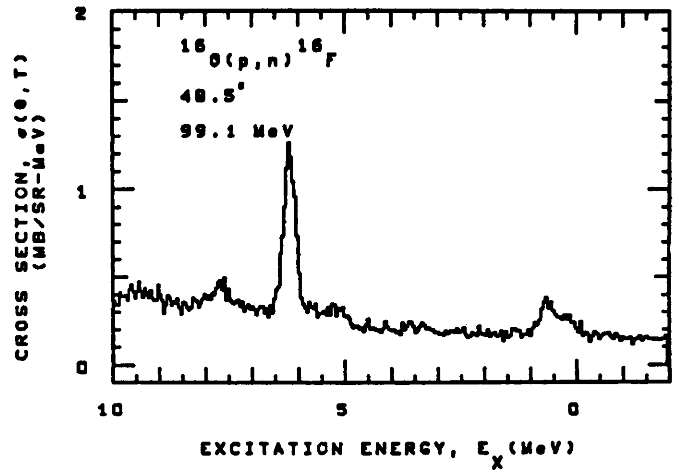

Figure 1. The neutron energy spectrum at a laboratory angle of 48.5° from the $^{16}O(p,n)^{16}F$ reaction at 99.1 MeV.

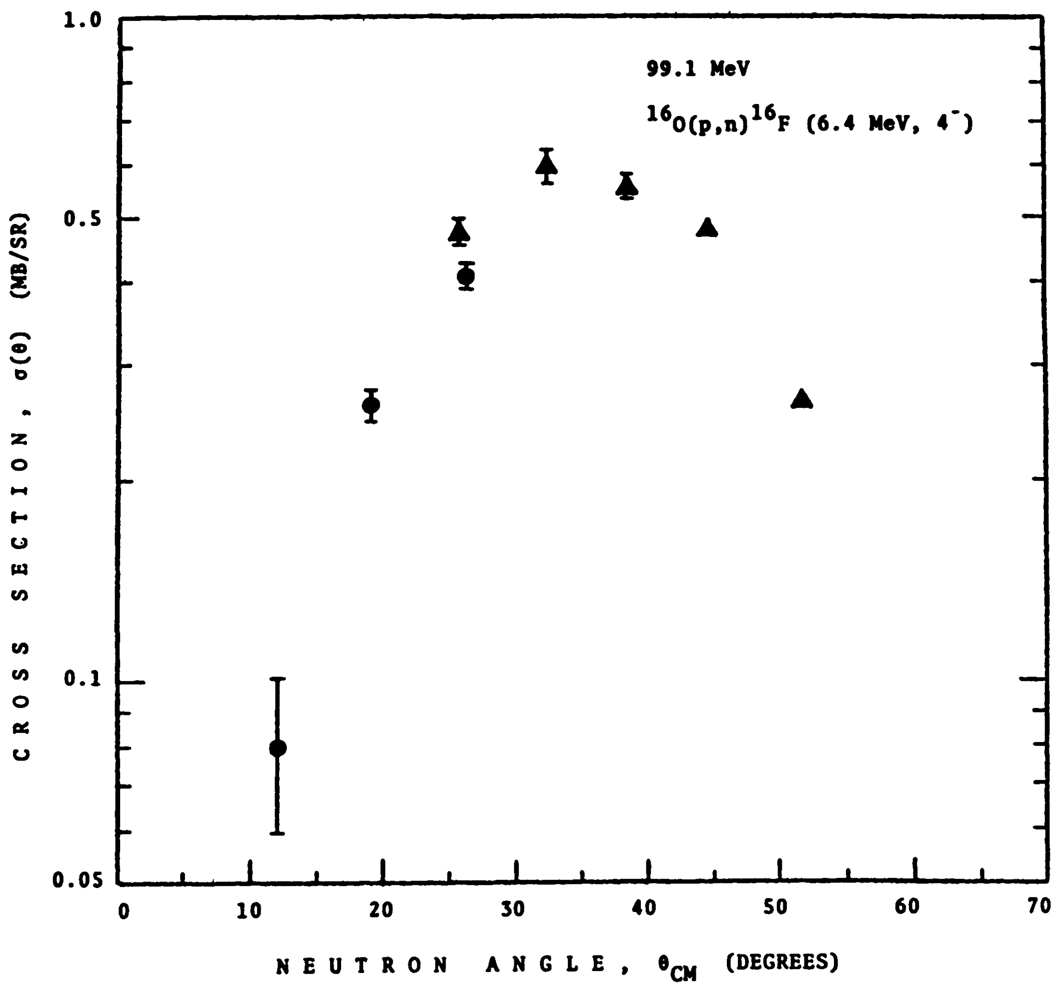

Figure 2. The angular distribution of the high-spin state in ^{16}F from the $^{16}O(p,n)^{16}F$ (6.2 MeV) reaction at 99.1 MeV. The circles represent cross sections that were extracted from the first detector station; the triangles, from the second.

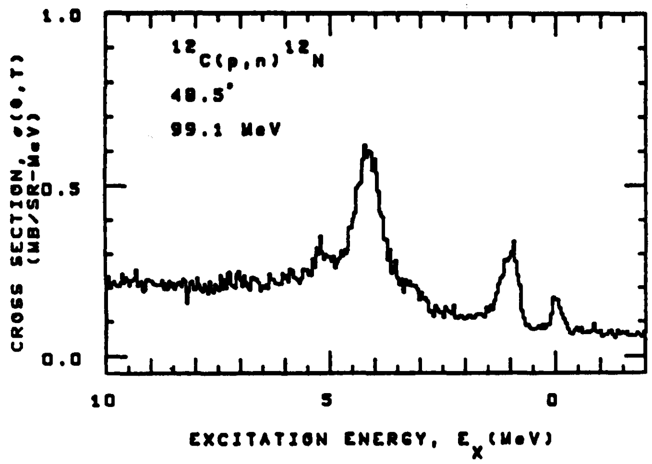

Figure 3. The neutron energy spectrum at a laboratory angle of 48.5° from the $^{12}C(p,n)^{12}N$ reaction at 99.1 MeV.

detection efficiency because the detected neutron energies are too close to the detection threshold.

Figure 3 shows the 48.5° spectrum of neutrons from the $^{12}C(p,n)^{12}N$ reaction at 99 MeV. The prominent peak at about 4.2 MeV excitation is believed to be the 4^- "stretched" state predicted by Moffa and Walker for ^{12}N. Recently, Morris et al.[2] suggested that the analog of this state at 19.65 MeV excitation in ^{12}C is one member of a highly isospin-mixed doublet of 4^- states, with the other member at 19.25 MeV. This suggestion is based on differences in the yields for π^+ and π^- inelastic scattering from ^{12}C near the (3,3) resonance energy. The observed width of the peak at 4.2 MeV excitation in Fig. 3 is substantially larger than our 230 keV resolution. Until we complete the analysis of our data at each of the measured angles from 0° to 48.5° in steps of about 6°, we are unable to comment on whether the observed peak is likely to be a single state with an intrinsic width of a few hundred keV or whether it could be two unresolved states. Since the $^{12}C(p,n)^{12}N$ reaction must populate states with $T \geq 1$, we should observe an analog of only one of the states proposed by Morris et al. It may be necessary to study this reaction again at longer flight paths and larger momentum transfers to clarify this point.

The study of these high-spin states complements studies of analog states and Gamow-Teller states by focusing on tensor terms in the nucleon-nucleon effective interaction with specific values of orbital-angular-momentum transfer. Lindgren et al.[3] showed from a systematic comparison of (e,e') and (p,p') transition strengths to unnatural parity states of "stretched" (j = maximum) configurations that the available data emphasize the isovector part of the tensor force. Since the one-particle radial form factors can be determined from inelastic electron scattering where the projectile-target interaction is known, the excitation of such "stretched" high-spin states in (p,n) and (p,p') reactions provides a moderately well-understood framework in which to study the tensor terms in various models of the effective nucleon-nucleon interaction.

In addition to studying the 4^- high-spin states in ^{12}N and ^{16}F, we extracted differential cross sections for the ^{12}N ground state ($J^\pi=1^+$) from the $^{12}C(p,n)$ data. These cross sections are presented in Figs. 4 and 5 along with DWIA calculations from Love which use an effective nucleon-nucleon interaction[4] derived from the free nucleon-nucleon force. For the ground state, the calculation agrees with the data out to about 30° and falls significantly below at wider angles; for the 0.96 MeV state, the calculation must be reduced by 35% to obtain agreement with the data at forward angles. A similar comparison[4] of DWIA calculations with the $^{12}C(p,p')^{12}C^*$ data of Comfort[5] at 122 MeV appeared on page 93 of the IUCF Technical and Scientific Report of last year. An abstract on the 99 MeV ^{12}C data was submitted to the American Physical Society for presentation at

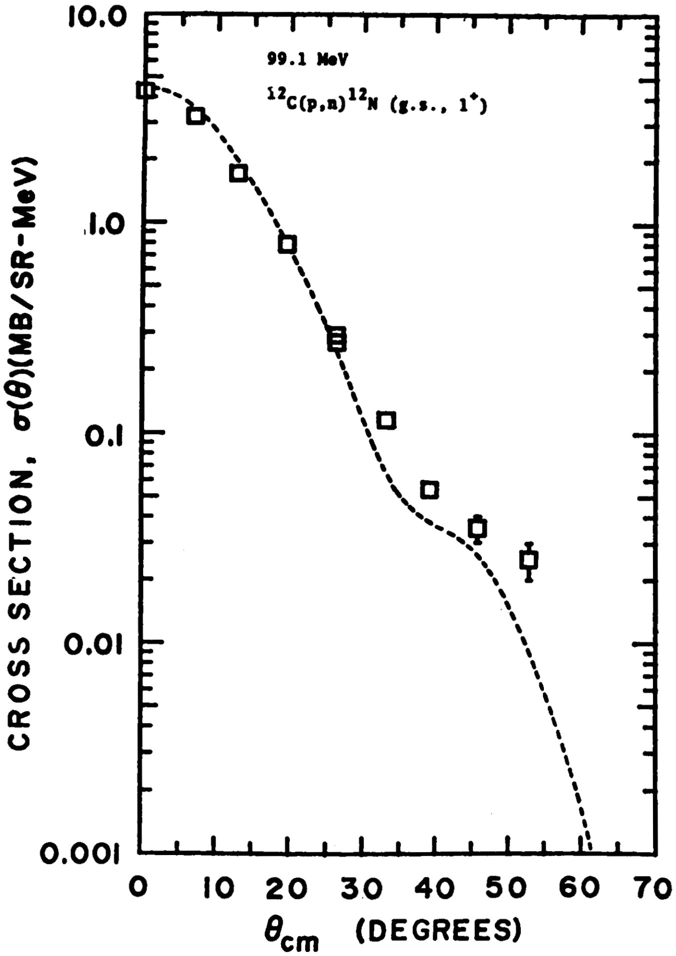

Figure 4. *The angular distribution of the* 1^+ *ground state in* ^{12}N *from the* $^{12}C(p,n)^{12}N$ *reaction at 99.1 MeV. The smooth curve is a DWIA fit with a combination of central, tensor and spin-orbit interactions including exchange terms.*

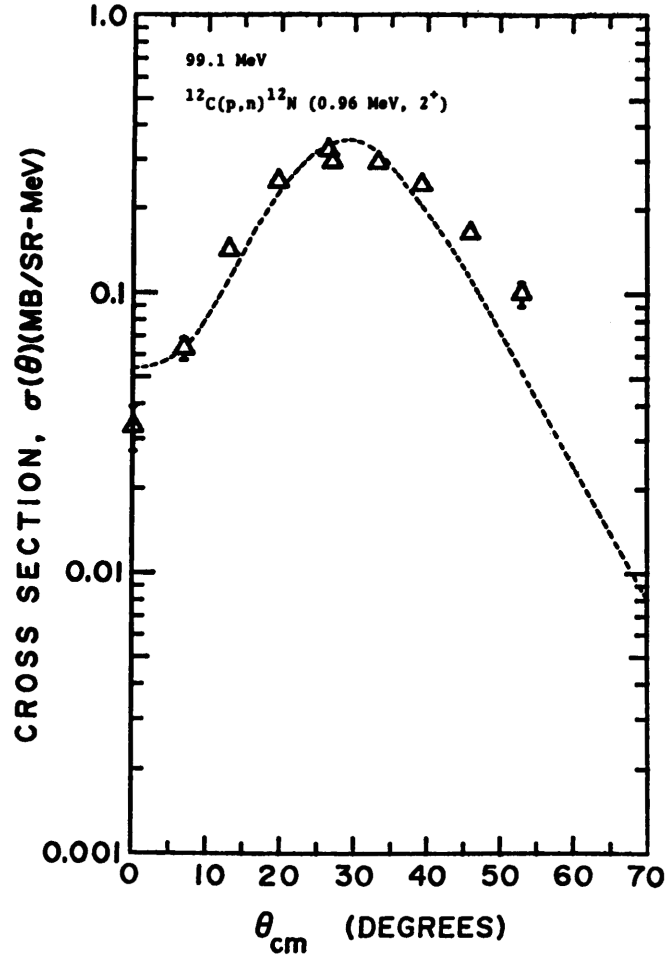

Figure 5. *The angular distribution of the* 2^+ *state at 0.96 MeV in* ^{12}N *from the* $^{12}C(p,n)^{12}N$ *reaction at 99.1 MeV. The smooth curve is a DWIA fit with a combination of central, tensor and spin-orbit interactions including exchange terms.*

the April 1980 meeting in Washington, D.C. A paper[6] comparing earlier data from the $^{12}C(p,n)^{12}N$ reaction at 62 and 120 MeV with $^{12}C(p,p')$ data was accepted for publication.

1) P.J. Moffa and G.E. Walker, Nucl. Phys. A222, 140 (1974).

2) C.L. Morris et al., Phys. Lett. 80B, 38 (1978).

3) R.A. Lindgren et al., Phys. Rev. Lett. 42, 1524 (1979).

4) W.G. Love, Conference on the (p,n) Reaction and Nucleon-Nucleon Forces (Telluride, 1979); and private communication.

5) J. Comfort et al., Bull. Am. Phys. Soc. 24, 829 (1979).

6) B.D. Anderson et al., Nucl. Instrum. Methods (in press).