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

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The (p,n) charge-exchange reaction offers two important differences for the study of high-spin states in comparison with inelastic proton or electron scattering. First, the (p,n) reaction on self-conjugate nuclei necessarily populates only T=1 isospin states, whereas (p,p') and (e,e') may excite both T=0 and T=1 states. This selectivity of the (p,n) reaction can be used to identify fragmented or broad T=1 strength with no interfering T=0 background. Second, the (p,n) reaction on nuclei with a neutron excess can excite particle-hole states where the particle and hole have the same ℓ and j quantum numbers. Inelastic scattering reactions cannot excite such states because the Pauli principle forbids two protons or two neutrons in the same orbital from occupying the same quantum state. If the particle and hole excited in the (p,n) reaction have $j = \ell + 1/2$ and the j's are coupled to the maximum possible angular momentum, the state is of a "stretched" configuration with (usually) an unique structure within 2 $\hbar\omega$ of excitation. Because these 0 $\hbar\omega$ stretched states involve particle and hole levels at or near the Fermi surface, they are usually not fragmented. This is in contrast to the general situation for a 1 $\hbar\omega$ type of stretched state, especially in medium- or heavy-mass nuclei. Recently we used the (p,n) reaction to take advantage of both of these opportunities provided by the (p,n) reaction.

The $^{40}Ca(p,n)^{40}Sc$ reaction was studied at 135 MeV to search for the $(f_{7/2}, d^{-1}_{5/2})$, 6^- stretched state. This 1 $\hbar\omega$ stretched state has been observed in A = 24 and 28 nuclei,[1,2] but was surprisingly "missing" in nuclei with A > 28.[3] The neutron excitation-energy spectra for the $^{40}Ca(p,n)^{40}Sc$ reaction are presented in Fig. 1. The large-angle spectra are seen to be

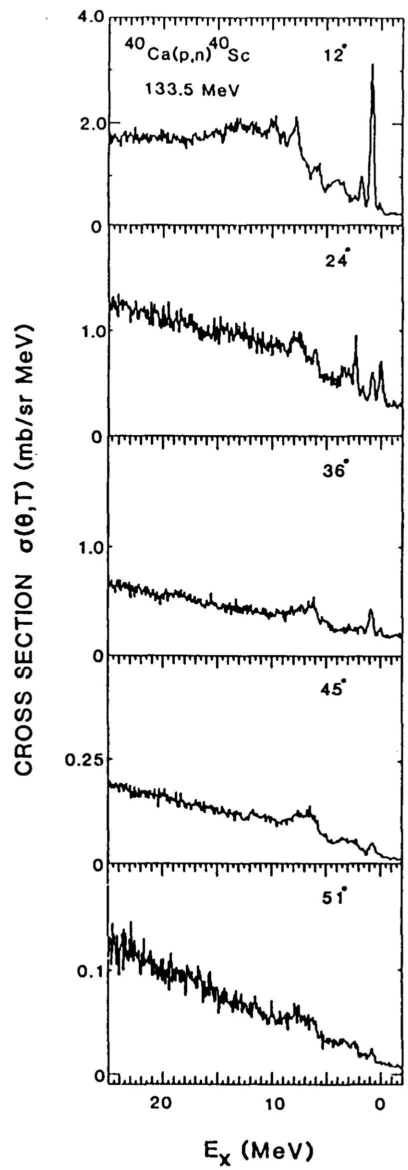

Figure 1. Excitation-energy spectra for the $^{40}Ca(p,n)^{40}Sc$ reaction at 133.5 MeV.

dominated by a broad complex of strength around $E_x = 7$ MeV. The angular distribution for this complex is consistent with that expected (from DWIA calculations) for a transition to a 6^- state. Furthermore, the excitation-energy and structure observed in this complex is consistent with that observed for the $d_{5/2}$ hole strength in ^{39}Ca observed directly in $^{40}Ca(p,pn)$ neutron knockout[4] and in $^{40}Ca(p,d)$ neutron pickup.[5] This observation of the T=1, 6^- particle-hole strength is a good example of the advantage provided by the (p,n) reaction on a self-conjugate target. The T=1 state observed here is obscured by the T=0 background in (p,p') measurements.[3]

In our most recent experimental run to study stretched states, we studied the (p,n) reaction on the medium-mass and heavy-mass nuclei ^{58}Ni, ^{88}Sr, and ^{208}Pb. We did not observe any clear indication of concentrated 1 $\hbar\omega$ type excitations in these reactions, but did observe some highly-fragmented 1 $\hbar\omega$ strength in the $^{58}Ni(p,n)^{58}Cu$ reaction [consistent with (e,e') observations[6] of M8 strength in ^{58}Ni]; however, we observed strong 0 $\hbar\omega$ stretched-state excitations in the $^{88}Sr(p,n)^{88}Y$ and $^{208}Pb(p,n)^{208}Bi$ reactions. Large-angle excitation-energy spectra are shown for these targets in Fig. 2. We could describe these results briefly by saying that, in general, we see strong 0 $\hbar\omega$ type transitions for medium- and heavy-weight targets, but find it difficult to identify 1 $\hbar\omega$ strength in these nuclei. The reasons for these results appear straightforward. The 0 $\hbar\omega$ transitions generally are observed at low excitation energies and involve particle and hole states at or near the Fermi level in these nuclei; consequently, these 0 $\hbar\omega$ transitions generally are observed at low excitation energies and involve particle and hole states at or near the Fermi level in these nuclei; consequently,

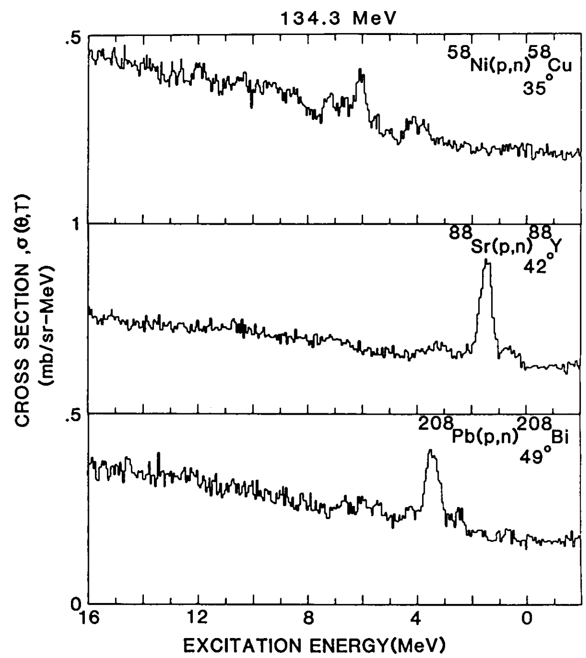

Figure 2. Large-angle excitation-energy spectra for the (p,n) reaction on ^{58}Ni, ^{88}Sr, and ^{208}Pb.

these 0 $\hbar\omega$ states are concentrated into single, sharp states seen in the (p,n) reaction. The 1 $\hbar\omega$ transitions, on the other hand, are observed at higher excitation energies and involve hole and/or particle states far from the Fermi level. These particle and hole levels are generally broad and fragmented resulting in broad and fragmented 1 $\hbar\omega$ strength.

The 0 $\hbar\omega$ stretched-state excitations seen in these various reactions are important for understanding the structure of these nuclei. Because 0 $\hbar\omega$ stretched transitions are more often concentrated into a single state, the strengths observed are primarily a measure of the target wavefunction, whereas the 1 $\hbar\omega$ strength is often highly fragmented and provides a formidable experimental task in simply identifying all of the stretched-configuration strength. Thus, a logical way to proceed in studying stretched particle-hole strength for a specific nucleus is to first measure and understand the 0 $\hbar\omega$ transition, and then to proceed to search for the (usually) fragmented 1 $\hbar\omega$ stretched strength.

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ANALYZING-POWER MEASUREMENTS FOR (p,n) REACTIONS

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We measured the analyzing power[1] for the $^{16}O(p,n)^{16}F(4^-, 6.37\ \mathrm{MeV})$ reaction at 134.0 MeV and the differential cross section for the same reaction at 135.2 MeV. The shape of the cross section for the transition to this unnatural parity stretched state is described well by a distorted-wave impulse-approximation calculation using a $(\pi d_{5/2}, \nu p^{-1}_{3/2})_{4-}$ configuration and the effective interaction derived by Love and Franey from nucleon-nucleon phase shifts. The analyzing power from this calculation reproduces all of the qualitative features of the data and supports the use of the impulse approximation as an excellent starting point for describing the reaction mechanism.

We measured the analyzing power for the $^{28}Si(p,n)^{28}P(6^-, 4.95\ \mathrm{MeV})$ reaction at 133.5 MeV and the differential cross section for the same reaction at 135.2 MeV. Work is still in progress on the comparison of our results with similar measurements of Yen et al.[2] of the analog reaction $^{28}Si(p,p')^{28}Si(6^-, T=1, 14.35\ \mathrm{MeV})$.

The above studies represent a portion of the doctoral dissertation of A. Fazely.[3] Dr. Fazely received his Ph.D. degree in August 1982.

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