CHARGE EXCHANGE REACTIONS

THE ENERGY DEPENDENCE OF STRETCHED STATES EXCITED IN (p,n) REACTIONS

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We studied excitation of "stretched" particle-hole states in (p,n) reactions at 100, 200, 300, and 400 MeV. This project utilized the beam-swinger (p,n) facility[1] at the IUCF for measurements at 100 and 200 MeV and the new "Chargex" (p,n) facility[2] at TRIUMF for measurements at 200, 300, and 400 MeV.

In stretched state, the particle and the hole are both in "stretched" orbits ($j_p = \ell_p + \frac{1}{2}; j_h = \ell_h + \frac{1}{2}$) and their angular momenta are coupled to the maximum possible $J = \ell_p + \ell_h + 1$. Such states have quite large spins and are unique within 2 $\hbar\omega$ of excitation so that there is relatively little mixing with other particle-hole configurations. For isovector nucleon inelastic scattering processes such as the (p,n) reaction at large momentum transfers (1 to 2 fm^{-1}) where high-spin stretched states are excited, the dominant term in the effective nucleon-nucleon interaction driving the reaction is the isovector-tensor term $t_{T\tau}$. Because isovector stretched states have a single dominant 1p$-$1h configuration and are excited primarily by a single term in the nucleon effective interaction, they should in principle provide a powerful tool for studying both the reaction mechanism and nuclear structure.

For the present project, we have chosen to study the energy dependence of the excitation of the $J^\pi = 6^-(\pi f_{7/2}, \nu d_{5/2}^{-1})$ state excited in the ^{28}Si(p,n)^{28}P(4.95 MeV) reaction and the $J^\pi = 9^+(\pi g_{9/2}, \nu g_{9/2}^{-1})$ state excited in the ^{88}Sr(p,n)^{88}Y(1.48 MeV) reaction. The former is a "1 $\hbar\omega$" excitation with the (proton) particle and the (neutron) hole in different orbits; analogs of this reaction were seen in (p,p$'$)[3], (e,e$'$)[4] and (π, π')[5] reactions, as well as in the (n,p) reaction. the latter reaction is a "0 $\hbar\omega$" excitation with the particle and hole in the same orbit; because of the Pauli principle, the only inelastic scattering process that can excite such states is an isospin-lowering, charge-exchange, reaction on a nucleus with a neutron excess. Such 0 $\hbar\omega$ stretched states are seen quite commonly[6,7] in medium-energy (p,n) reactions on medium-mass and heavy nuclei, but they have no analogs in (p,p$'$) and (e,e$'$) reactions. As noted by Anderson, et al. in Ref. 7, 0 $\hbar\omega$ stretched states have normalizations for Distorted Wave Impulse Approximation (DWIA) calculations that are always $\geq 1/2$, whereas 1 $\hbar\omega$ stretched states have DWIA normalizations that are always $\leq 1/2$; presumably, this result is a nuclear structure effect and we chose to study one transition of each type to investigate this point. In Fig. 1 we present differential cross sections as a function of momentum transfer for the ^{28}Si(p,n)^{28}P(6^-, 4.95 MeV) reaction. the data at 133 MeV are from Fazely, et al.[8] In comparing the cross section for this reaction with the analog ^{28}Si(p,p$'$)^{28}Si(6^-,16.4 MeV) reaction, charge symmetry requires that σ(p,n) $= 2\ \sigma$(p,p$'$); indeed, the (p,n) data at 100 and 133 MeV agree with (p,p$'$) data in Ref. 3. Our data (from TRIUMF) was normalized so that our 300 MeV cross sections agree with (p,p$'$) data (multiplied by 2) at 333 MeV in Ref. 9. In fig. 2 we present data for the ^{88}Sr(p,n)^{88}Y(9^+, 1.48 MeV) state. At TRIUMF, a single point at the two sets of measurements together, and to establish the overall reliability and consistency of the complete set of data.

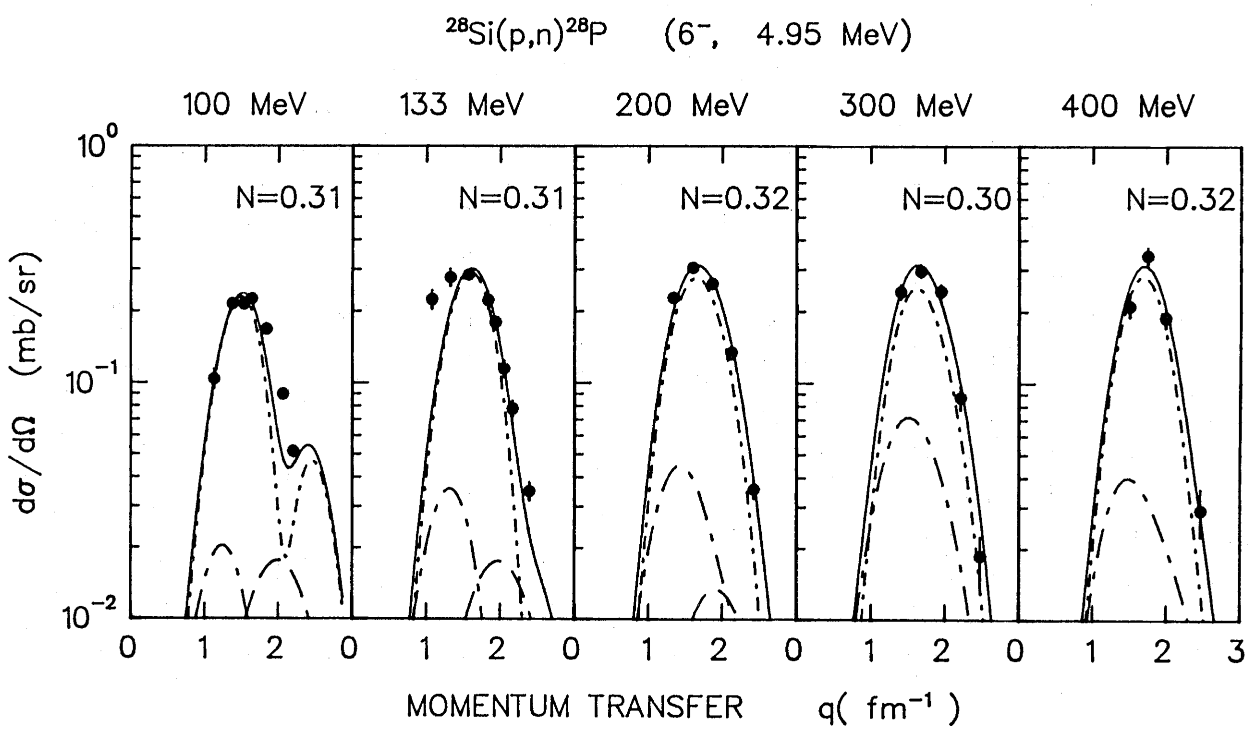

Figure 1. Momentum-transfer dependence of the cross sections for excitation of the 6− state at 4.95 MeV in the ^{28}Si(p,n)^{28}P reaction at 100, 133, 200, 300, and 400 MeV. The solid curves are DWIA calculations with the effective interaction of Franey and Love[11], and harmonic oscillator bound-state wave functions with a parameter b = 1.743 fm. Calculations for the individual tensor (- - -), spin-orbit (- · · · -) and central (– · – · –) parts of the effective interaction are shown also. DWIA normalizations ("N") are shown for each energy.

In Figs. 1 and 2 also we present DWIA calculations performed with the code DW81[10] with the nucleon-nucleon t-matrix of Franey and Love[11]. Optical potentials for ^{28}Si were taken from Refs. 3 and 12. Optical potentials for ^{88}Sr were calculated from the global parameters of Schwandt, et al.[13] for the calculations at 100, 135, and 200 MeV. For 300 MeV, the 319 MeV ^{90}Zr potentials of Nanda[14] were used. To obtain 400 MeV optical potential parameters for ^{88}Sr, we made a volume integral/nucleon (J/A) extrapolation of the energy dependence of the 100, 135, 200, and 319 MeV potentials. We assumed the simple shell model for the initial and the final states for both reactions, with harmonic-oscillator wave functions with oscillator length parameters of 1.3743 fm and 2.0 fm for ^{28}Si and ^{88}Sr, respectively. For each calculation the cross sections for the individual tensor (- - -), spin-orbit (- · · · · -) and central (– · – · –) components for the Franey-Love t-matrix are shown; we note that the excitation of these stretched states is dominated indeed by the isovector-tensor term at all five energies.

We normalized the DWIA calculations for each transition at each energy to provide an optimum fit near the peak of the momentum-transfer distribution. The indicated

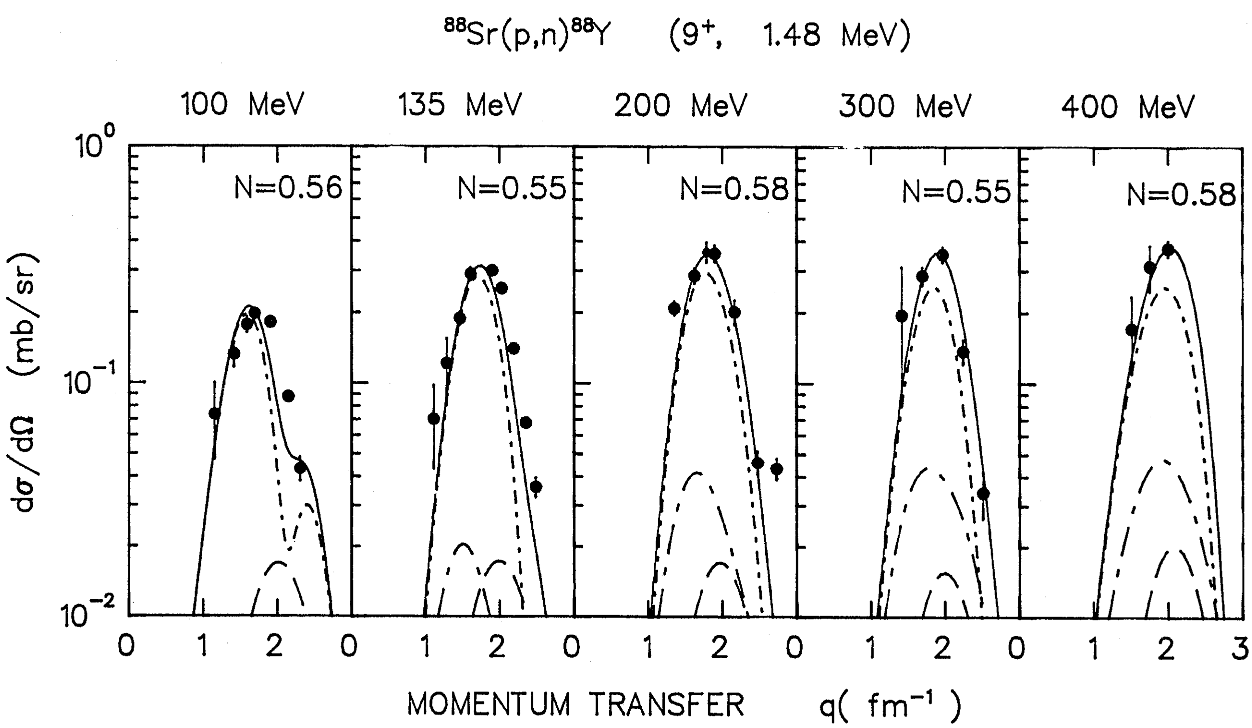

Figure 2. Momentum-transfer dependence of the cross sections for excitation of the 9+ state at 1.48 MeV in the ^{88}Sr(p,n)^{88}Y reaction at 100, 135, 200, 300, and 400 MeV. The solid curves are DWIA calculations with the effective interaction of Franey and Love,[11] and harmonic oscillator bound-state wave functions with a parameter b = 1.743 fm. Calculations for the individual tensor (- - -), spin-orbit (- · · · · -) and central (– · – · –) parts of the effective interaction are shown also. DWIA normalizations ("N") are shown for each energy.

normalizations include an $((A-1)/A)^{J-1}$ center-of-mass correction factor. We draw two important conclusions from these results. Firstly, the ratio of the ^{88}Sr to ^{28}Si DWIA normalizations is independent of energy, indicating that the systematic difference in DWIA normalizations between 0 $\hbar\omega$ and 1 $\hbar\omega$ stretched states is indeed a nuclear structure effect. Secondly, and equally important, with the Franey-Love t-matrix the normalization for each reaction is constant to within a few percent. Olmer, et al. noted in Ref. 3 that over the energy range from 80 to 180 MeV the DWIA normalization for the ^{28}Si(p,p′)^{28}Si (6^-, 16.4 MeV) reaction (to the analog of the state we observe in ^{28}P) varies with any of several different nucleon-nucleon t-matrices they tried. In contrast, with the Franey-Love t-matrix (developed since the publication of Ref. 3), we obtain a consistent and coherent picture of the excitation of stretched states over a broader energy range. Perhaps as important may be the fact that the energy-independent DWIA normalization obtained for the ^{28}Si(p,n)^{28}P (6^-) reaction ($\sim 0.31 \pm 0.01$) now agrees with the value obtained for the excitation of the analog 6^- state at 16.4 MeV in ^{28}Si by inelastic electron scattering[4].

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