(^{3}He,p) Reactions as a Probe of Neutron-Proton Pairing in N=Z Nuclei

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In analogy with the BCS theory of superconductivity, a pairing mechanism was invoked for nuclei to explain, among other properties, the energy gap in the spectra of even-even nuclei, odd-even mass differences, and the magnitudes of the rotational moments of inertia. Most nuclei have N>Z and the "superconducting" state consists of neutron (nn) or proton (pp) pairs coupled to angular momentum, I=0, and to isospin, T=1. For nuclei with the same numbers of protons and neutrons, pairs comprising one proton and one neutron (np) are also expected. An np pair can couple to I=0 and T=1 (isovector) as in the nn or pp case or, since they are no longer restricted by the Pauli exclusion principle, they can couple to T=0 (isoscalar). Charge independence of the nuclear force implies that T=1 np pairing should exist on an equal footing with T=1 nn or pp pairing. The possibility of strongly correlated T=0 np pairs has remained an open question and has been the subject of considerable debate.

Based on the more familiar case of quadrupole shape fluctuations, where an important measure of collective effects is provided by reduced transition proababilities, one can associate a similar role to the transition operator describing the two-particle transfer process. In fact two-nucleon transfer reactions such as (t,p), have provided a unique tool for understanding pairing correlations in nuclei [1]. The rapid quenching of np pairs as one moves away from N=Z [2] suggests that the transfer of an np pair from even-even to odd-odd self-conjugate nuclei is an outstanding tool for studying np-pairing. The cross sections for the (^{3}He,p) and (t,p) reactions for nuclei up to ^{40}Ca, as derived from the available literature, are summarized in Figure 1. This data will serve as the baseline for examining the relative strengths of pairing correlations in the T=0 and T=1 channels. However, it is clear that there are inconsistencies in the trends of the available data, probably arising from the fact that these studies were conducted under different experimental conditions by several different groups over a number of years. With this in mind, it would be helpful to revisit some of these measurements in a systematic way.

As a first step we have performed an experiment at the 88-Inch Cyclotron using the LIBERACE+STARS detector system. A ^{3}He beam, with energy of 17 MeV, was incident on a target of ^{28}Si of ~100µg/cm^2 thickness. Protons from the transfer reaction were detected in the STARS annular Si detector system set-up in a ΔE-E telescope configuration. Gamma-rays depopulating excited states from the np-pair transfer to ^{30}P could be identified in the LIBERACE array. In particular we could identify the 677 and 709 keV lines from the lowest excited 0^+ and 1^+ states in ^{30}P as shown in Figure 2. In the proton spectrum these two lines interfere making it difficult to quantify the population cross section for the individual levels. This may be the reason for the observed discontinuity in Figure 1. The relative population of these two states can be measured from the gamma-ray spectrum and the relative population of the lowest T=0 and T=1 states determined to unprecedented accuracy. Analysis is ongoing.

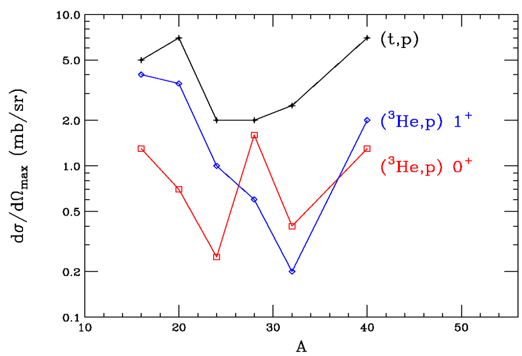

Fig. 1: Systematic behavior of the cross sections to the 0^+ (T=1) and 1^+ (T=0) states in N=Z nuclei.

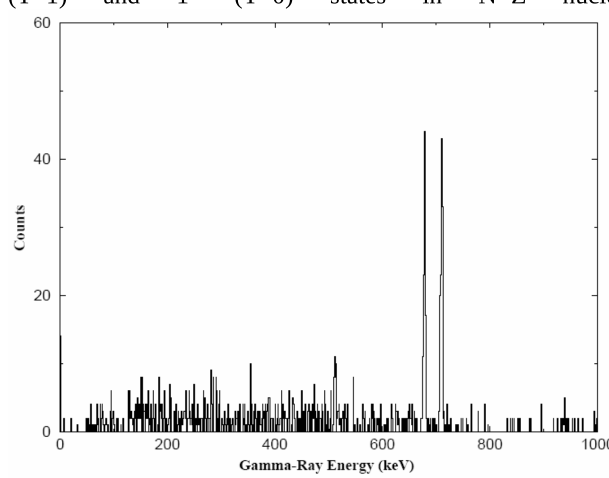

Fig. 2: Gamma-ray spectrum of the excited states in ^{30}P populated in the ^{28}Si(^{3}He,p) reaction. The 677 and 709 keV lines are clearly resolved.

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