

EXCITATION OF 2p-1h HIGH-SPIN STATES IN THE
 $^{45}\text{Sc}(p,n)^{45}\text{Ti}$ REACTION AT 136 MeV

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The motivation for this experiment is to see if the (p,n) reaction can excite one of the 2p-1h stretched states observed to be excited in (p, π^-) reactions near threshold.¹ The (p, π^-) double charge-exchange reaction is believed to proceed through the interaction of the incident proton with a target neutron in such a way as to capture the proton and convert the target neutron into a proton (which results in an emitted π^-), thereby producing a two proton particle, one neutron hole state. Because of the large momentum mismatch in the (p, π^-) reaction, the highest-spin state is preferentially excited. In order to excite this kind of state in the (p,n) reaction, which produces a proton-particle, neutron-hole state, it is necessary to find a target that already has an odd proton in the orbital of interest. This requirement is difficult to satisfy, in general, but is available for the $^{45}\text{Sc}(p,n)^{45}\text{Ti}$ reaction, which can excite the same states as does the $^{44}\text{Ca}(p,\pi^-)^{45}\text{Ti}$ reaction. Both reactions are believed to occur on the excess neutrons in the $f_{7/2}$ orbital. The highest spin state allowed is thus $19/2^-$ (the $21/2^-$ state is not allowed by the Pauli exclusion principle).

Although it seems clear that the (p, π^-) reaction does preferentially excite these 2p-1h high-spin states, it would be desirable to excite them also in another reaction, to help confirm their character; furthermore, although there does exist a simple model of the reaction mechanism for the (p, π^-) reaction, it can predict only relative strengths, so that absolute spectroscopic information is unavailable. The (p,n) reaction, if it can also excite these states, is known to be described reasonably well by the DWIA, so that absolute spectroscopic information may be available in the same way as it is for the various 1p-1h stretched states observed with the (p,n) reaction² [and which can be compared with (p,p') and (e,e') excitations].

Neutron time-of-flight (TOF) spectra for the $^{45}\text{Sc}(p,n)^{45}\text{Ti}$ reaction at 136 MeV were obtained with the beam-swinger system at the IUCF. Neutrons were detected in large-volume, mean-timed neutron counters³ placed in three detector stations at 0° , 24° , and 45° with respect to the undeflected beam line; the flight paths were 131.0, 131.1, and 81.3 m, respectively. Overall time resolutions of about 800 ps were obtained, which provided energy resolutions of about 320 keV in the first two detector stations and 520 keV in the third one. Neutron TOF spectra obtained at 15 angles between 0° and 63° were converted to excitation-energy spectra.

The excitation-energy spectrum at 45° is shown in Fig. 1; it is dominated by a single peak at $E_x = 4.4$ MeV. The angular distribution for this peak is shown in Fig. 2. The angular distribution, although peaked at a wide angle as expected for a high-spin state, cannot be fit well by a DWIA calculation for a $19/2^-$ excitation alone. As shown, if we assume that there is also an unresolved $17/2^-$ state in the peak shown in Fig. 1, then

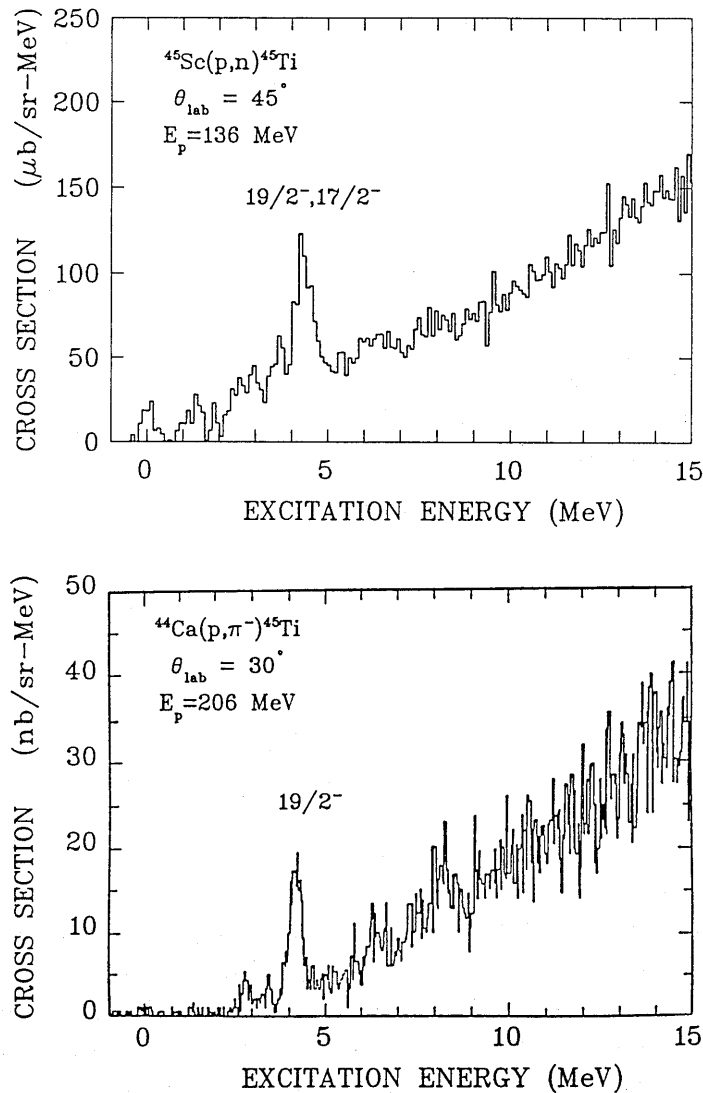


Figure 1. Excitation-energy plots for the $^{45}\text{Sc}(p,n)^{45}\text{Ti}$ reaction at 135 MeV and 45° and for the $^{44}\text{Ca}(p,\pi^-)^{45}\text{Ti}$ reaction at 206 MeV and 30° .

the sum of the two DWIA calculations can describe the angular distribution well. Note also that the normalization factors required for the DWIA calculations are consistent with unity, the DWIA calculations use one-body transition densities (OBTDs) obtained from a 1f-2p shell model calculation. This calculation considers five particles in the 1f-2p shell with no restrictions; the ^{40}Ca core is assumed to be closed. This calculation also predicts a $19/2^-$ state at $E_x = 4.6 \text{ MeV}$, which is within 0.3 MeV of the state we observe at large angles (vis., at 4.3 MeV). This same shell model calculation also predicts a $17/2^-$ state at 4.2 MeV, which is within 0.4 MeV of the predicted $19/2^-$ state; if these two states are actually this close in energy (or closer), we could not resolve them in this experiment.

$^{45}\text{Sc}(p,n)^{45}\text{Ti}$ (4.4 MeV $19/2^-, 17/2^-$)

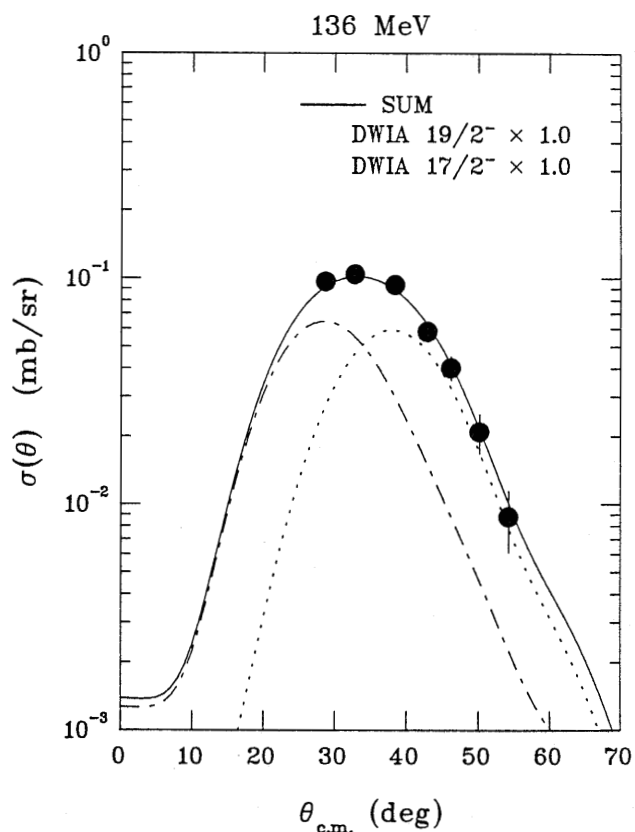


Figure 2. Angular distribution for the excitation of the complex at $E_x = 4.4$ MeV in the $^{45}\text{Sc}(p,n)^{45}\text{Ti}$ reaction at 135 MeV.

Note that the simple reaction model for the (p,π^-) reaction predicts that the $17/2^-$ state would be suppressed severely in that reaction. The observed (p,π^-) spectrum appears to be consistent with this prediction. The observed (p,π^-) and (p,n) spectra in Fig. 3, are compared with spectra predicted from the simple (p,π^-) reaction model and the DWIA for the (p,n) reaction; both calculations use 1f-2p shell-model wavefunctions. The (p,n) spectrum is at 45° where the $19/2^-$ state is predicted to dominate (see Fig. 2). The two spectra are seen to be similar and in reasonable agreement with the theoretical predictions.

In summary, the (p,n) reaction is observed to excite the $19/2^-$, 2p-1h state in ^{45}Ti observed also in the (p,π^-) reaction on ^{44}Ca . The excitations observed in the two reactions appear to be consistent with each other, although the (p,n) reaction does not suppress the nearby $17/2^-$ state as does the (p,π^-) reaction. The (p,n) reaction provides an angular distribution that can be fit with the DWIA. It is found that if these DWIA calculations use realistic structure wavefunctions from a 1f-2p shell-model calculation, the DWIA calculations do not need to be renormalized in order to describe the experimental results.

1. T.G. Thrope et al., Phys. Rev. C **35**, 1083 (1987).
2. B.D. Anderson, J.W. Watson, and R. Madey, "Nuclear Structure at High Spin, Excitation, and Momentum Transfer," ed. by H. Nann, AIP Conf. Proc. **142**, 155 (1986).
3. R. Madey et al., Nucl. Instrum. and Meth. **214**, 401 (1983).

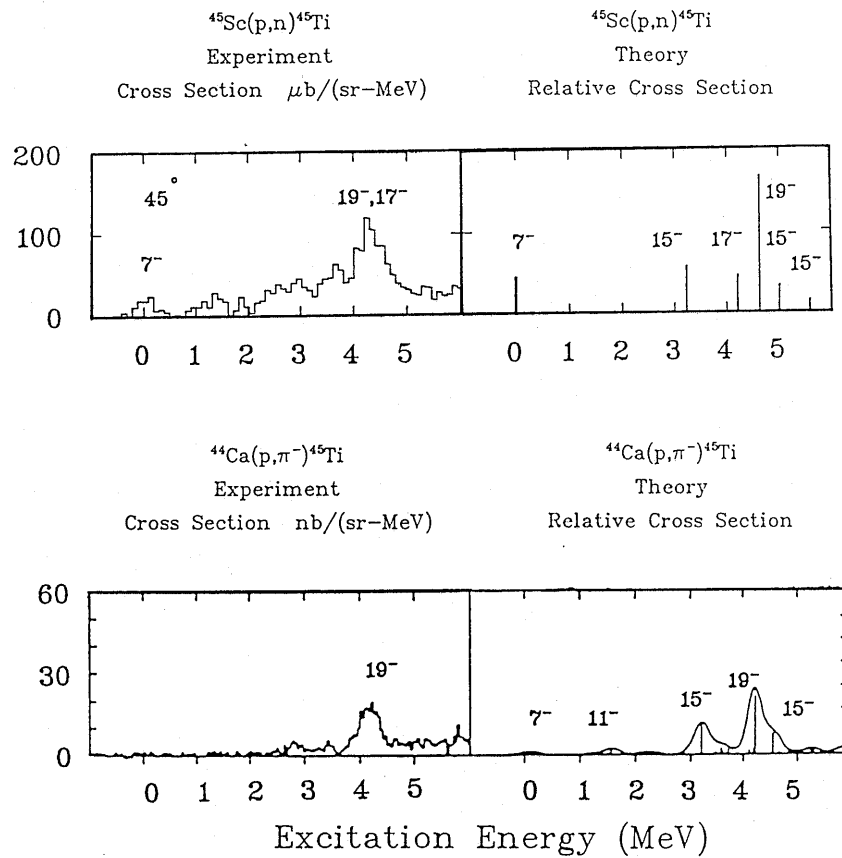


Figure 3. Comparison of the predicted and observed (p,π^-) and (p,n) spectra for the excitation of $2p-1h$ states in ^{45}Ti . (States are labeled by $2 \times J$.)