HIGH RESOLUTION CHARGE-EXCHANGE REACTIONS WITH A SECONDARY TRITON BEAM AND THE S800

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The S800 spectrograph is capable of 1 part in 10,000 energy resolution for a 1 mm object spot size, independent of the energy spread in the primary beam. The energy spread in the primary beam is compensated for by dispersion matching of the spectrograph with the analysis beam line. This operation is routinely achieved for use with stable primary beams. It is interesting to see how well dispersion matching can be achieved for secondary beams. In this contribution we describe high resolution, dispersion matched, operation with a secondary triton beam. The energy spread of the triton beam was 3.5 MeV, yet 200 keV resolution for a (t,^{3}He) charge-exchange reaction was achieved.

A project to use the (t,^{3}He) charge-exchange reaction in an (n,p)--type reaction at intermediate bombarding energies at 0º was initiated a few years ago at the National Superconducting Cyclotron Laboratory [1,2]. It was concluded that this reaction is competitive with (n,p) reactions as a tool to study spin-isospin excitations in neutron--rich isobars including investigation of low--lying Gamow-Teller strength and the general characteristics of spin--dipole, quadrupole and monopole resonances. In these experiments, a secondary triton beam was produced by fragmentation of α-particles on a thick Be production target. The first stage of the A1200 beam-analysis system was used to direct the energy--dispersed triton beam to the target at an intermediate dispersive image. The second stage was used to focus the ^{3}He particles from the (t,^{3}He) reaction onto the focal plane. An energy resolution of 780 keV full-width-at-half-maximum (FWHM) was achieved [1,2]. Experimental details are given in Ref. 2. Gamow-Teller strength from the (t,^{3}He) reaction on targets of ^{9}Be, ^{10}B, ^{11}B, ^{12}C, and ^{13}C has been extracted and discussed, and mirror-symmetric T=1 states excited by the $\sigma\tau$ operator have been established in the A=10 system [1]

The present work describes an experiment where significantly better energy resolution was obtained in a (t,^{3}He) experiment using the S800 magnetic spectrograph [3,4,5]. The S800 high--resolution magnetic spectrometer, newly installed at NSCL to study nuclear reactions with radioactive beams [3,4,5], was used in the present improved (t,^{3}He) experiment. The triton beam was produced by fragmentation of 560-MeV α-particles, slightly lower in energy than in the previous experiments [1], on a thick Be production target (9.25 g/cm^2). A beam intensity of (0.5--1.0)x10^6 tritons/s was obtained. The triton beam with a mean energy of 350 MeV was selected with the A1200 fragment separator and transported in the dispersive mode to the target position of the S800.

The secondary triton beam was transported with an energy spread of about 1 %. This resulted in a vertical energy-dispersed beam spot at the target position of 5 cm in height. The S800 spectrometer was set at 0 degrees to detect the ^{3}He particles. The opening angles of about 7.0 degrees vertically (dispersive) and of about 10 degrees horizontally (non-dispersive), were defined by the geometry of the S800 dipole. Dispersion matching was employed to obtain (t,^{3}He) energy spectra with excellent energy resolution in the focal plane of the S800 spectrometer. The focal--plane detection system consisted of two cathode-readout drift chambers (CRDC), which permitted ray-tracing, and two scintillators [6.] Based on the ray-tracing information, the scattering angles at the target position were reconstructed using the inverse matrix element determined from the field mapping of the spectrometer [4,5].

Fig. 1 shows the two-dimensional scatter plots of (a) non-dispersive angle and (b) scattering angle as a function of excitation energy for a polystyrene target with a thickness of 5.6 mg/cm^2. The

loci for the p(t,^{3}He)n and ^{12}C(t,^{3}He)^{12}B reactions are clearly observed. Events corresponding to the p(t,^{3}He)n reaction follow a parabolic line due to the large kinematic shift as a function of the angles, whereas those for the ^{12}C(t,^{3}He)^{12}B reaction are straighter. The observed and calculated kinematic shifts for the hydrogen and ^{12}C in the polystyrene target agree to within 0.2 degrees.

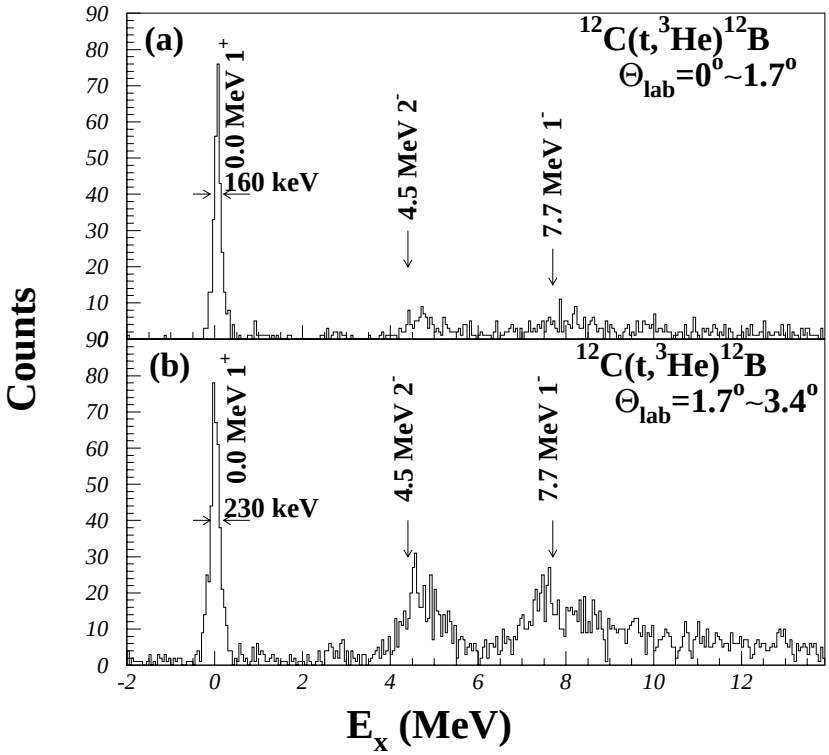

Figure 1: (a) Two-dimensional scatter plot of non-dispersive laboratory angle versus excitation energy for ^{3}He particles from the (t,^{3}He) reaction at E_t=350 MeV on a polystyrene target. Events along the strongly curved parabolic line are due to the p(t,^{3}He) n reaction. Events for the 1^+ ground state in ^{12}B excited by the ^{12}C(t,^{3}He)^{12}B reaction are seen as a slightly curved vertical line. The excited 2^- and 1^- resonances are also observed. (b) Similar two--dimensional scatter plot of scattering angle versus excitation energy.

Fig. 2 compares two spectra for the ^{12}C(t,^{3}He)^{12}B reaction at scattering angles from 0 to 1.7 degrees and from 1.7 to 3.4 degrees. Both spectra display a sharp peak for the transition to the 1^+ ground state and two broad bumps for the transitions to the 2^- and 1^- resonances. The energy resolution for the ground state of ^{12}B is 160 keV (FWHM) in Fig. 2a and 230 keV (FWHM) in Fig. 2b. The slightly increased value at larger scattering angles is due to the relatively increased kinematic broadening due to the incoherent angular spread in the triton beam. After corrections are made for the relative solid angles (increased by a factor of three for the large-angle spectrum), it is observed that the yield for the 1^+ Gamow-Teller state excited with the angular momentum transfer L=0 decreases strongly with scattering angle whereas those for the 2^- and 1^- spin--dipole resonances excited with L=1 increase weakly with scattering angle.

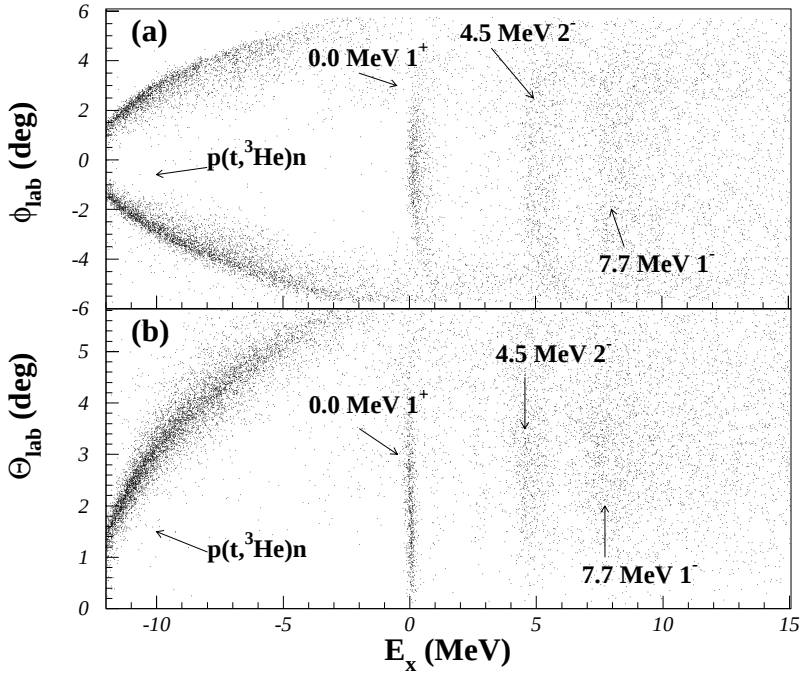

Figure 2: Spectra for the $^{12}C(t,^3He)^{12}B$ reaction for scattering angles in the range (a) 0 to 1.7 degrees, and (b) 1.7 to 3.4 degrees, respectively. The energy resolution for the transition to the ground state is indicated in both spectra. The broad bumps are for resonances at 4.5 MeV and 7.7 MeV in ^{12}B. The relative solid angle for Fig. 2(a) is three times smaller than that for Fig. 2(b).

In summary, a radioactive triton beam of energy 350 MeV was produced by fragmentation of a-particles, and it was used to measure $(t,^3He)$ charge--exchange reactions with the S800 magnetic spectrometer. Excellent energy resolution of 160 keV or $\Delta E/E$ of about 4.6×10^{-4} (FWHM) was achieved. This illustrates that the S800 can be used for high resolution studies using secondary beams. In addition, this is the best resolution for any (n,p) or (n,p)--like charge--exchange experiment except for the earlier low--energy $(t,^3He)$ data, which were obtained using a primary triton beam. A new powerful tool for studying (n,p)--like charge--exchange reactions at intermediate energies has thus become available.

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