High resolution study of Spin Dipole Excitations in ^{16}F via the (^{3}He,t) Reaction at 140 MeV/nucleon

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Our present understanding of the N-N force at intermediate energies is that it is mediated by exchanging mesons and that the dominant part at long range is originates from one pion exchange. Model calculations predict that the effects of meson exchange are mainly reflected in the momentum transfer dependence of the spin-longitudinal response, which is inaccessible by electro-magnetic probes. It is, therefore, of considerable interest to measure the nuclear response to a transition with a parity change and no total spin change, that is a 0^- transition. This corresponds to the intrinsic J^π of pion and corresponds to a pure spin-longitudinal transition. In order to study this transition, the excitation from the ground states of ^{16}O to the ground state of ^{16}F by charge exchange reaction is useful, since these states have J^π values of 0^+ and 0^-, respectively.

In order to study the 0^- transition, high resolution ^{16}O(^{3}He,t)^{16}F experiment was performed at RCNP by using a 140 MeV/nucleon ^{3}He beam in February 2002 (E159). In order to achieve high energy and horizontal scattering angle resolutions, *lateral* and *angular dispersion matching* techniques were applied [1]. As diagnostics of the the matching and focusing conditions, the *faint beam method* [2] was used. A thin polyethylene terephthalate film target of 3.3 mg/cm^2 thickness was used to reduce an energy broadening effects. Scattered particles were momentum analyzed by the Grand Raiden magnetic spectrometer [3]. The tritons were detected by two multi-wire drift-chambers (MWDC) [4] and two plastic scintillation detectors placed along the focal plane of the spectrometer. A measured spectrum covered excitation energies up to about 20 MeV. For a good angle resolution in the vertical direction, the *over-focus mode* [5] of the Grand Raiden spectrometer was applied. In combination with *angular dispersion matching*, precise measurements of the scattering angles in both horizontal and vertical directions were realized. As a result of the software correction, good energy resolution of 65 keV was achieved. Data was taken in the scattering angular range from 0° to 14°. In order to determine optical potential between ^{16}O and ^{3}He, the cross sections of elastic scatterings were also measured in the scattering angle range from 7° to 24° in laboratory frame. Since widely spread dispersive beam can escape the Faraday cup in the D1 magnet which was used for the 0° (^{3}He,t) measurements, cross sections at 0° were confirmed by an additional measurement performed in May 2004 using achromatic beam.

For the determination of transition strengths, peak intensities were derived by a peak deconvolution software. The well isolated and strong peak of the Gamow-Teller transition to the ^{12}N ground state by ^{12}C(^{3}He,t) reaction was used as the reference peak shape. Obtained cross sections were compared with the DWBA calculations. In order to evaluate the validity of the calculations, not only the 0^- ground state, but also the 1^- state at 0.193 MeV, the 2^- state at 0.424 MeV, the 3^- state at 0.721 MeV, and the stretched 4^- state at 6.373 MeV were studied. Wave functions for DWBA calculation were determined by using the code OXBASH [6]. The full model space up to f orbit by using the SPSDPF model space was assumed and the WBP interaction was applied. Transition up to $1\hbar\omega$ was taken into account. Almost pure ($s_{1/2}$, $p^{-1}_{1/2}$) configuration was obtained for the transitions to the 0^- and 1^- states. The wave function of the 2^- and the 3^- transitions were strongly dominated by the ($d_{3/2}$, $p^{-1}_{1/2}$) and ($d_{5/2}$, $p^{-1}_{1/2}$) configuration, respectively, and for the 4^- state stretched ($d_{5/2}$, $p^{-1}_{3/2}$) configuration. The optical potential parameters for ^{3}He were determined to reproduce the angular distribution

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of the cross section in the ^{3}He elastic scattering by using the code ECIS88 [7]. For the outgoing triton, by following the arguments given in Ref. [8], well depths were multiplied by a factor of 0.85 keeping the same geometrical parameters. For the effective projectile-target interaction of the composite particle ^{3}He, following the form derived by Schaeffer [9] through the folding procedure, ranges of 1.415 fm and 0.878 fm of the Yukawa potential were applied for the central and tensor force, respectively. Since $LS\tau$ term in (^{3}He,t) reaction is not known well, potential range R_τ^{LS} was treated as a free parameter.

The 0^- transition is contributed by $\sigma\tau$ and $T\tau$ terms of the effective interaction. By applying the strengths $V_{\sigma\tau}$ of -2.02 MeV and V_τ^T of -3.06 MeV, the measured cross sections are well reproduced. Parameters of $LS\tau$ term were optimized to reproduce the cross section of the 2^- state, which expect no contribution from τ term. As a result, V_τ^{LS} of 0.10 MeV and R_τ^{LS} of 3.07 fm were obtained. The same procedure using the 4^- state showed a similar result. Recently the empirical ratio $R^2 = (V_{\sigma\tau}/V_\tau)^2$ in (^{3}He,t) reaction at 140 MeV/u were studied for various target nuclei [10]. Applying the estimated R^2 value of 5.2 for $A = 16$ from the mass dependence, V_τ strength was determined to be 0.89 MeV. In Fig. 1, calculated cross sections are shown for the 0^-, 1^-, 2^-, 3^-, and the 4^- state applying these parameters.

Unnatural parity transitions show better agreement with measured cross sections. The 0^- state showed the best agreement with the optimized interaction. As for the 2^- state, shape of the angular distribution was reproduced. Maximum cross section was also reproduced, which is mainly contributed by the $LS\tau$ term. The 4^- state also shows good agreement in the shape of the angular distribution and its maximum value, however, the cross sections at very forward angles are underestimated. On the other hand, natural parity transitions were not reproduced so well. Shape of the angular distribution of the 1^- state was not reproduced. Underestimation of the cross section of the 3^- state suggests that stronger $V_{\sigma\tau}$ and/or $V_{T\tau}$ terms can give better agreement, which contribute mainly at $\theta_{sc} \approx 10$ degrees.

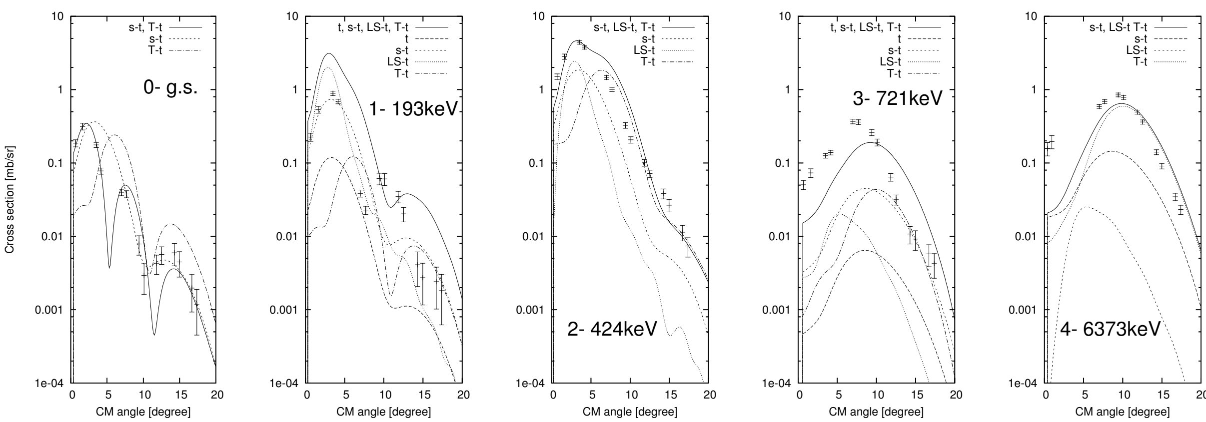

Figure 1: The values of cross sections of transitions to the 0^-, 1^-, 2^-, and 3^- states in ^{16}F. Results of DWBA calculations are also shown. For details of calculations, see text.

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