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

H. Fujita[a], Y. Fujita[b], J. Rapaport[c], T. Adachi[b], G. P. A. Berg[a], K. Fujita[a], H. Fujimura[a], K. Hara[a], K. Hatanaka[a], K. Hosono[d], T. Ishikawa[e], J. Kamiya[a], T. Kawabata[a], K. Nakanishi[a], N. Sakamoto[a], Y. Sakemi[a], Y. Shimbara[b], Y. Shimizu[a], M. Uchida[a], T. Wakasa[a], M. Yoshifuku[b], and M. Yosoi[e]

[a]*Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan*
[b]*Department of Physics, Osaka University, Toyonaka, Osaka 560-0043, Japan*
[c]*Department of Physics, Ohio University, Athens, OH 45701 USA*
[d]*Himeji Institute of Technology, Ako, Hyogo 678-1297, Japan*
[e]*Department of Physics, Kyoto University, Sakyo, Kyoto 606-8224, Japan*

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.

A clear way to study this transition is to find resolved nuclear transitions in which the quantum numbers of the relevant nuclear states uniquely select these components. For this purpose, the transition between the ground states of ^{16}O and ^{16}F by charge exchange reaction is useful, since these states have J^π values of 0^+ and 0^-, respectively. In addition, the ^{16}O target is spin saturated and in first order one does not expect any Gamow-Teller strength. Thus the $\Delta L = 1$, $\Delta S = 1$ transitions are the lowest multipoles to be excited. Although they are weak transitions at forward angles, they can be clearly distinguished without being disturbed by GT or Fermi transitions that are dominant for other nuclei. The difficulty, however, is that the 0^- ground state, the 1^-, $E_x = 0.193$ MeV state, and the 2^-, $E_x = 0.424$ MeV state in ^{16}F form a close triplet. In order to get a reliable angular distribution, these states should be separated.

Although difficult, efforts have been concentrated on ^{16}O target to study 0^- states via charge exchange (p, n) reactions. In order to achieve energy resolutions good enough to separate these states, the ^{16}O(p, n) reactions were performed at low incoming energies of 35 MeV [1] and at 79 MeV [2]. In these experiments, a momentum range between 0 - 2 fm^{-1} was covered. Unfortunately the low energy of 35 MeV in the experiment of Ref. [1] questions the validity of the reaction mechanism being direct, making the interpretation of their results difficult. The energy of 79 MeV in the experiment of Ref. [2] chosen to be able to resolve these transitions via time-of-flight measurement, is not high enough for a direct reaction mechanism and also the reported data may be questioned about the peak fitting analysis needed to separate the three transitions.

We measured the angular distribution of the 0^-, g.s. in the ^{16}O(^{3}He,t)^{16}F reaction at RCNP using 420 MeV incident energy in the scattering angular range from 0° to 14° corresponding to a momentum transfer of q = 0 - 2 fm^{-1}. For the realization of *lateral* and *angular dispersion matching* conditions at the target, a newly constructed WS beam line [3] was used for the beam transportation.

In order to diagnose these matching conditions as well as the *lateral dispersion matching* technique, the *faint beam method* was used [4]. For a good angle resolution in vertical (y) direction, the *over-focus mode* of a spectrometer [5] was used. Thin 3.3 mg/cm^2 of Mylar target was used to avoid energy broadening effects. Scattered particles were momentum analyzed by the Grand Raiden magnetic spectrometer. As a result, an energy resolution of 60 keV was achieved. The spectrum of ^{16}O(^{3}He,t) measurement at 0° is shown in Fig. 1.

For the determination of transition strengths, peak intensities were derived by a peak deconvolution software. The well isolated and strong GT transition to the ground state of ^{12}N was used as the reference peak shape. In the peak deconvolution analysis, broadening of a peak width Γ caused by the particle decay was also taken into account in the form of Breight-Wigner function combined with the shape of the reference peak. From the preliminary analysis of 0° spectrum, Γ values larger than the known value of > 40 keV was obtained for the 1^- state.

Derived cross sections of transitions to the 0^- state (g.s.) of ^{16}F is shown in Fig. 2 as function of the momentum transfer q, with preliminary DWBA calculated angular distribution. In the calculation, the transition to the 0^- state was assumed to be pure $(s_{1/2}\ p^{-1}_{1/2})$ configuration. For the effective projectile-target interaction of the composite particle ^{3}He, the form derived by Schaeffer through the folding procedure was used. Results of DWBA calculation was normalized to have the same cross section as that of 0° spectrum ($q \approx 0.2$ fm^{-1}). At the region of $q > 1$ fm^{-1}, cross sections of 0^- transitions show enhancement relative to DWBA calculated values.

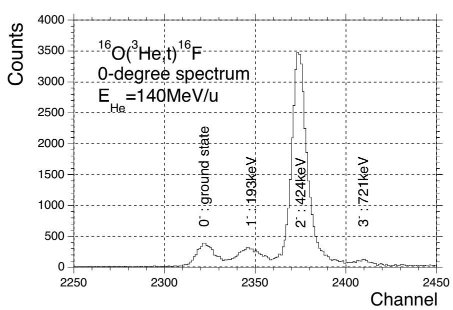

Figure 1: 0-degree spectrum of the ^{16}O(^{3}He,t) measurement. Ground state, 1^-, 2^-, and 3^- states were clearly resolved owing to high energy resolution of 60 keV.

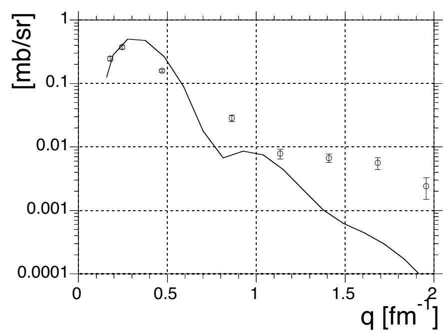

Figure 2: Momentum transfer dependence of cross section of transitions to the 0^- state (g.s.) of ^{16}F. Results of DWBA calculation is shown together.

References

[1] H. Orihara *et. al.*, Phys. Rev. Lett. **49** 1318 (1982).
[2] R. Madey *et. al.*, Phys. Rev. C **56** 3210 (1997).
[3] T. Wakasa *et. al.*, Nucl. Instr. Meth. A **482** 79 (2002).
[4] H. Fujita *et. al.*, Nucl. Instr. Meth. A **484** 17 (2002).
[5] H. Fujita *et. al.*, Nucl. Instr. Meth. A **469** 55 (2001).