Study of nuclear correlation effects via $^{12}C(p,n)^{12}N(g.s.;1^+)$ reaction

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Nuclear correlation effects are of considerable interest in nuclear physics. At large momentum transfers of $q \simeq$ 1–3 fm^{-1}, Alberico *et al.* [1] have shown that the isovector response of the spin-longitudinal (pionic) mode should be enhanced due to nuclear correlation effects, while that of the spin-transverse (rho-mesonic) mode should be quenched. The enhancement of the pionic mode has attracted much interest in connection with the precursor phenomena of the pion condensation [2]. Some experiments [3–6] have been made in order to assess these theoretical predictions. In the measurement of quasielastic (p,n) reactions [7], the enhancement of the pionic mode has been observed, which supports the existence of nuclear correlations. However, the enhancement of the rho-mesonic mode has been also observed, which contradicts the prediction. Thus, we measured the Gamow-Teller (GT) $^{12}C(\vec{p},\vec{n})^{12}N(g.s.;1^+)$ reaction in order to investigate (1) whether there is another evidence of the pionic enhancement in nuclei, and (2) whether the discrepancy in the rho-mesonic mode is a unique phenomenon of the quasielasitic (p,n) reaction.

In this experiment, a complete set of polarization transfer coefficients was measured for the first time in order to separate the cross section into pionic (ID_q), rho-mesonic (ID_p), and the other (ID_n and ID_0) polarized cross sections. The proton beam energy was 296 MeV where distortion effects become minimum and GT transitions are predominantly excited. The neutron energy and its polarization were measured by the neutron detector/polarimeter NPOL3 [8].

Figure 1 shows the excitation energy spectrum for $^{12}C(\vec{p},\vec{n})^{12}N$ at momentum transfer $q_{c.m.}$ = 1.7 fm^{-1}. The high energy resolution of 500 keV FWHM was realized by NPOL3, which enabled us to resolve the GT 1^+ state from the neighboring states clearly. We performed peak fitting to extract the yield of the GT 1^+ state (see Fig. 1). The peak fittings at all momentum transfers were satisfactory for extracting the GT 1^+ state.

Figure 2 shows the experimental results for ID_q and ID_p. We compared the experimental results with DWIA calculations using the computer code CRDW [9] in order to investigate nuclear correlation effects. The dashed curves represent DWIA results with the free response function (= without nuclear correlations). Significant differences between experimental and theoretical results are observed especially at large momentum transfers of $q \simeq$ 1.5 fm^{-1}. The solid curves represent DWIA calculations with RPA response functions (= with nuclear correlations). Nuclear correlation effects predicted by these calculations are observed in both ID_q and ID_p, however, these calculations still underestimate at $q \simeq$ 1.5 fm^{-1}.

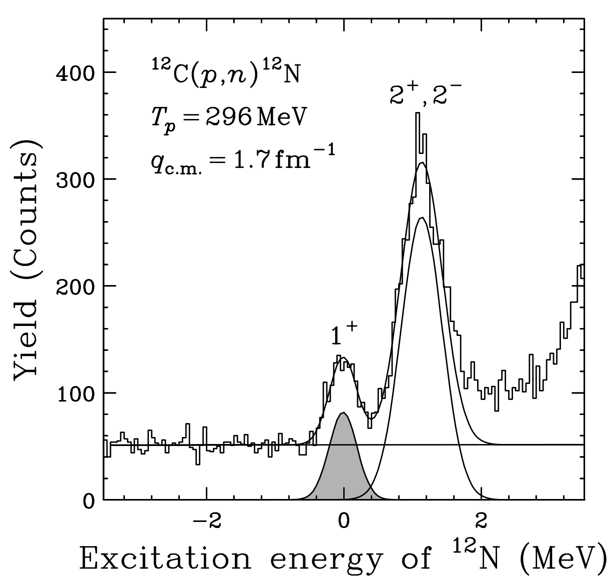

Figure 1: Excitation energy spectrum for $^{12}C(\vec{p},\vec{n})^{12}N$ at 296 MeV and $q_{c.m.}$ = 1.7 fm^{-1}. The solid curves show the reproduction of the spectrum with Gaussian peaks and a background.

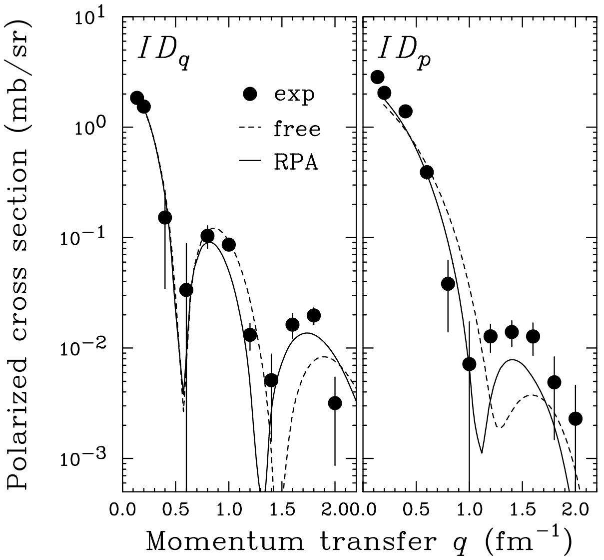

Figure 2: Measured polarized cross sections ID_q (left) and ID_p (right) for $^{12}\mathrm{C}(\vec{p},\vec{n})^{12}\mathrm{N}(\mathrm{g.s.};1^+)$ at 296 MeV. The solid and dashed curves are the DWIA results with RPA and free response functions, respectively.

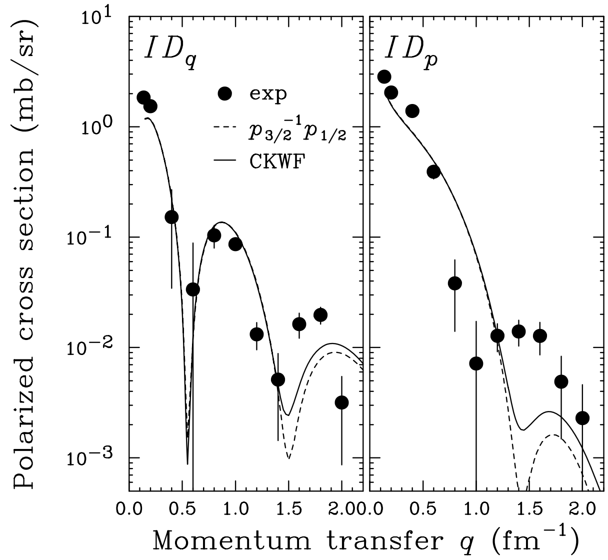

Figure 3: Configuration dependence of DWIA calculations. The solid and dashed curves represent the DWIA results employing CKWF (4 configurations) and the pure $p_{3/2}{}^{-1}p_{1/2}$ configuration, respectively.

The observed underestimations are likely to be due to a restricted one–particle one–hole configuration for $^{12}\mathrm{C} \rightarrow ^{12}\mathrm{N}(\mathrm{g.s.})$ (almost pure $p_{3/2} \rightarrow p_{1/2}$) because realistic transitions deduced from the Cohen–Kurath wave functions (CKWF) [10] consist of several configurations. Thus we performed DWIA calculations with CKWF by using the computer code DW81 [11], and the results are shown in Fig. 3. The solid curves are the DWIA results with CKWF employing 4 configurations between $p_{3/2}$ and $p_{1/2}$, and the dashed curves are the DWIA results employing the pure $p_{3/2}{}^{-1}p_{1/2}$ configuration. These calculations indicate the enhancements of both ID_q and ID_p at $q \simeq 1.7$ fm^{-1} by using more realistic wave functions (CKWF) in ^{12}C and ^{12}N. Both these effects and nuclear correlations seem to be important to reproduce the experimental data.

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