Comparison of the ^<40>Ca (e, e'p) Cross Section at Low Momentum Transfer Region with Relativistic Calculations(I. Nuclear Physics)

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Comparison of the ^{40}Ca(e, e′p) Cross Section at Low Momentum Transfer Region with Relativistic Calculations

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The (e, e′p_0) cross section of ^{40}Ca measured using a 199.53 MeV continuous electron beam is compared with theoretical calculations based on the relativistic distorted-wave impulse approximation (RDWIA). The theoretical values overestimate the experimental ones by a factor of 2 when the spectroscopic factor is obtained from the (e, e′p) experiment in parallel kinematics, or by a factor of 1.4 when spectroscopic factor is obtained in constant (ω, q) kinematics.

§1. Introduction

Recently, the (e, e′p) reaction in the quasi-elastic region and the (γ, p) reaction above the giant resonance region have been investigated in the relativistic framework [1-3]. The contributions of meson exchange currents (MEC) and the choice of the one-body current operator were discussed in Refs. [1, 2].

In previous reports [4-6] we compared the reduced cross section obtained from ^{12}C(e, e′p_0) and the differential cross section obtained from ^{16}O(e, e′p_0) with theoretical calculations based on the relativistic distorted wave impulse approximation (RDWIA). Both experiments were performed at a low momentum transfer region: energy transfer $\omega = 60$ MeV and momentum transfer $|\vec{q}| = 105.2$ MeV/c. The result of these reports was that RDWIA overestimates the experimental data by a factor of 2. A large contribution of the two-body seagull term was observed at high missing momentum region.

To investigate this reaction mechanism further, we choose ^{40}Ca as a target and performed the experiment. The ^{40}Ca(e, e′p_0) cross section obtained from this experiment is compared with calculations based on RDWIA.

§2. Experiment

The experiment was performed at Laboratory of Nuclear Science, Tohoku University (LNS) using a 199.53 MeV continuous electron beam from the stretcher-booster (STB) ring. Incident electrons were scattered with a natural calcium target of 19.0 mg/cm^2 thickness. Scattered electrons were analyzed their momentum at $\theta_e = 30°$ by a magnetic spectrometer (LDM) and detected with a vertical drift chamber (VDC) placed on the focal plane of the spectrometer and with a backup counter, layered three plastic scintillators behind the VDC. In this setup, ω is 60.0 ± 4.2 MeV and $|\vec{q}|$ is 105.2 MeV/c. Knocked-out protons were detected by SSD telescopes, which consisted of three layers of 1mm-thick SSD's. In order to degrade the energy of protons, a 6mm-thick aluminum disk was put in front of each telescope.

The normalization of our measured (e, e'p) cross section was performed by comparing the elastic scattering cross section with that of Ref. [7]. We measured the elastic scattering cross section at $\theta_e =$ 58.5°. The form factor of our experiment corresponds to that at $\theta_e = 46.0°$ with a beam energy 249.3 MeV of Ref. [7].

§3. Result and Discussion

The measured cross sections are shown in Table 1 and Fig.1. The $^{40}Ca(e, e'p_0)$ cross section obtained from our experiment is compared with theoretical calculations based on RDWIA [8]. The RDWIA treatment is same as in Refs. [1, 2]. The bound state wave function is a solution of a relativistic Hartree-Bogoliubov equation using parameters NLSH [9]. The EDAD1 optical potential parameters [10] are used for calculations of the scattering wave function. As the choice of the electromagnetic operator is arbitrary, three current conservation operators, cc1, cc2 and cc3, are used in the calculations.

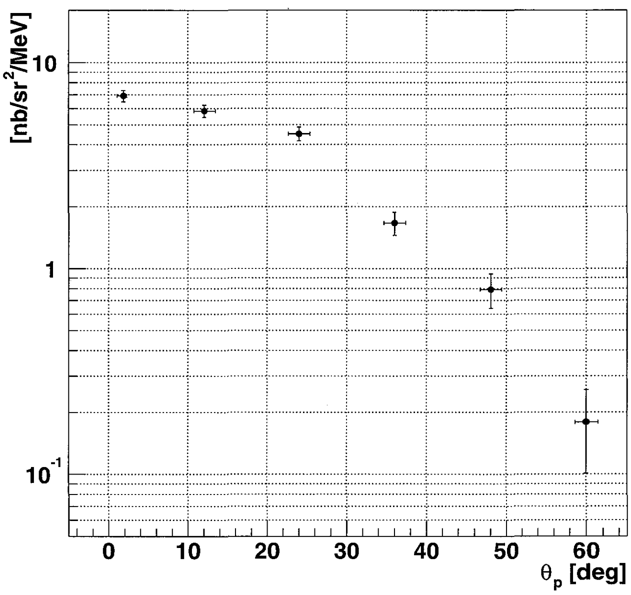

Fig.1. The $^{40}Ca(e, e'p_0)$ cross section.

The spectroscopic factor $Z(d_{3/2})$ was obtained from analysis of the quasi-elastic (e, e'p_0) reaction [11], which included the results of two different kinematics, parallel kinematics and constant (ω, q) kinematics. The factor was calculated for the three current operators on each kinematics. The spectroscopic factors obtained from parallel kinematics and constant (ω, q) kinematics are listed in Table 2. The present data are compared with

Table 1. Differential cross section of the $^{40}Ca(e, e'p_0)$ reaction.

θ_e	Cross section [nb/MeV/sr^2]
0°	6.901 ± 0.427
12°	5.832 ± 0.392
24°	4.512 ± 0.347
36°	1.662 ± 0.213
48°	0.791 ± 0.150
60°	0.179 ± 0.078

Table 2. Spectroscopic factors for three current operators in two kinematics.

	parallel kinematics	constant (ω , q)
cc1	0.627	0.446
cc2	0.713	0.594
cc3	0.766	0.701

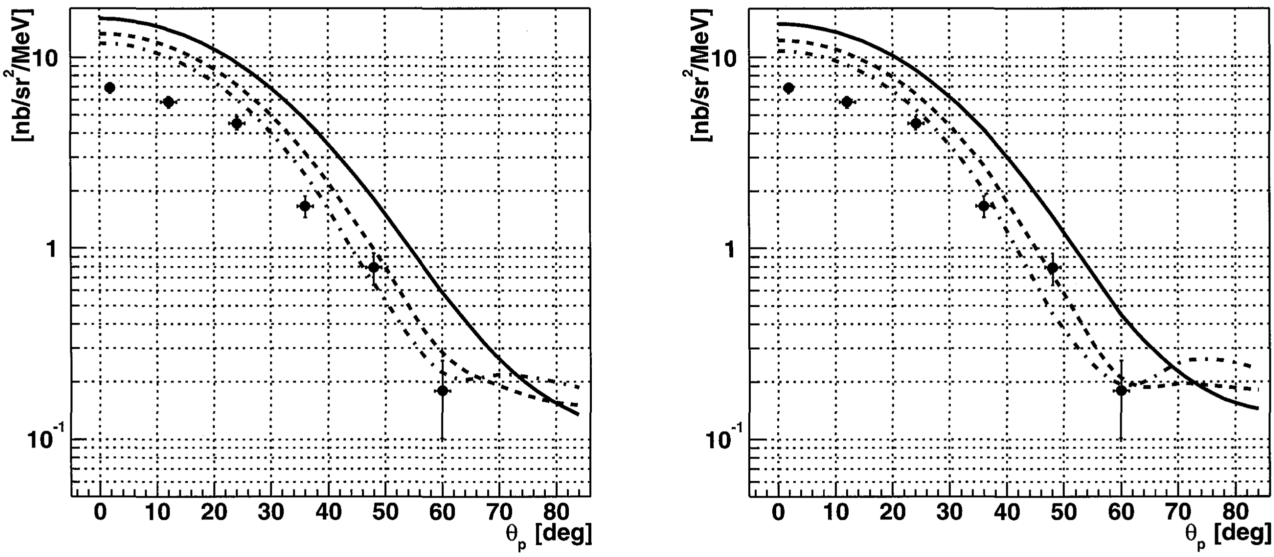

Fig.2. The $^{40}Ca(e, e'p_0)$ cross section compared with theoretical calculations, using spectroscopic factors obtained from the (e, e'p) experiment in the parallel kinematics. Calculations include the MEC effect in the left panel, and does not in the right panel. Closed circles show the present data, and solid, dashed, and dot-dashed lines represent theoretical calculations with cc1, cc2, and cc3 current operators, respectively. θ_p is the out-going angle of the proton.

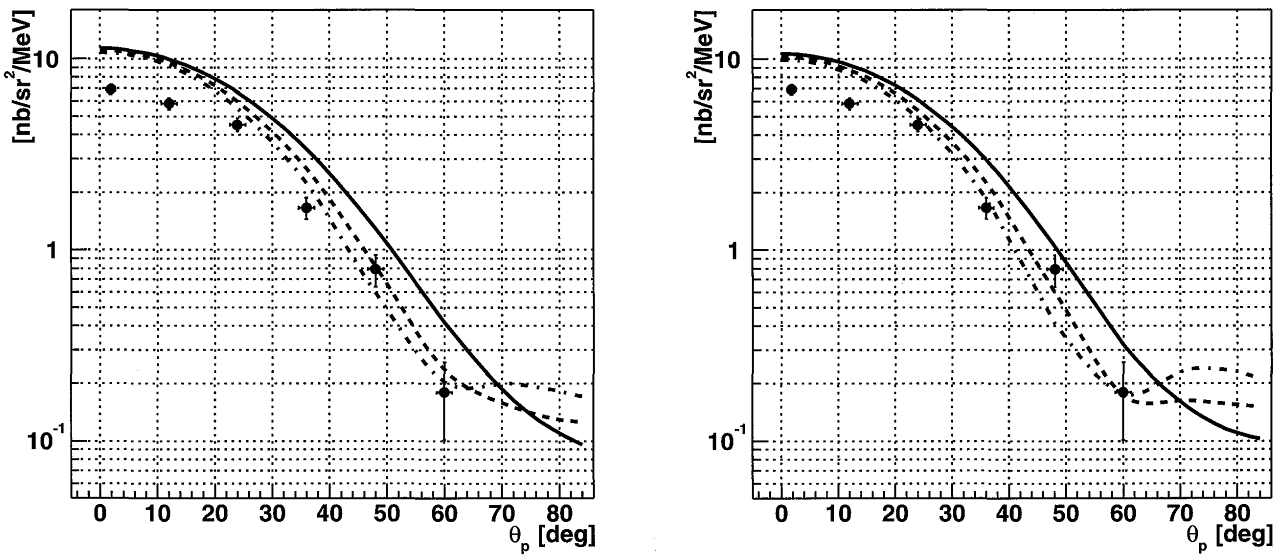

Fig.3. Same as Fig. 2, but comparison with theoretical calculations using the spectroscopic factor obtained from the (e, e'p) experiment in the constant (ω, q) kinematics.

theoretical calculations in Figs.2 and 3. The theoretical values are obtained using 3 one-body current-conservation operators and spectroscopic factors listed in Table 2. According to Figs.2 and 3, the MEC effect is not important in the small θ_p region, corresponding to the lower momentum transfer region. Calculations with spectroscopic factors obtained from parallel kinematics overestimate the data, at forward angles, and are different from each other, as shown in Fig.2. In order to fit calculations to the data, a normalizing factor 0.423 is needed for the cc1 current, and 0.523 and 0.588 for the cc2 and, cc3 currents, respectively. Thus, theoretical values overestimate the experimental ones by a factor about 2. This result is same as in previous reports [4-6]. As shown in Fig.3, calculations with spectroscopic factors obtained from constant (ω , q) kinematics also overestimate the data by a factor of about 1.4, but the calculation is equivalent to each other in the small θ_p region. The theoretical values are closer to the experimental one than using a spectroscopic factor obtained in parallel kinematics, but still too large.

§4. Summary

Both theoretical calculations using the spectroscopic factor obtained in the parallel and constant (ω, q) kinematics. overestimate the experimental cross section, about factors 2 or 1.4, respectively. The (e, e'p) experiment at the low momentum transfer in ^{12}C, ^{16}O and ^{40}Ca show some important contributions is missing in the theoretical approach.

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