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Discrepancy of Cross Sections in *pd* Breakup Reactions at $E_p = 250$ MeV

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Abstract In our previous inclusive experiment on ^{2}H$(p, p)pn$ at 247 MeV, the measured cross section at forward angles is about twice larger than $3N$ calculation with $\pi\pi$ 3NF. Therefore, we have made an exclusive experiment on ^{2}H$(p, p_1p_2)n$ at the same energy. The preliminary data suggest that the cross section was enhanced at forward angle of θ_1 and θ_2.

1 Introduction

Existence of two pion exchange three nucleon force ($\pi\pi$3NF) predicted by Fujita–Miyazawa [1] was confirmed from ^{3}H binding energy [2] and cross section minimum of pd elastic scattering [3]. Nowadays, $\pi\pi$3NF models, for example, Tucson-Melbourne [4] and Urbana IX [5], have been proposed, and the differential cross section of Nd elastic scattering below 140 MeV is well reproduced.

However, the differential cross section of Nd elastic scattering at 250 MeV were not reproduced by $3N$ calculation with $\pi\pi$3NF [6,7]. The experimental cross section at backward angles is about twice larger than the calculation. Also the cross section of inclusive ^{2}H$(p, p)pn$ breakup reaction at 247 MeV angles is about twice larger than the calculation at forward angles as seen Fig. 1 [8]. Short-range 3NFs, for example, $\pi\rho$- and $\rho\rho$-exchange type, may be possible origins for the enhancement. We have measured the cross section of exclusive ^{2}H$(p, pp)n$ at $E_p = 247$ MeV to microscopically investigate the enhancement.

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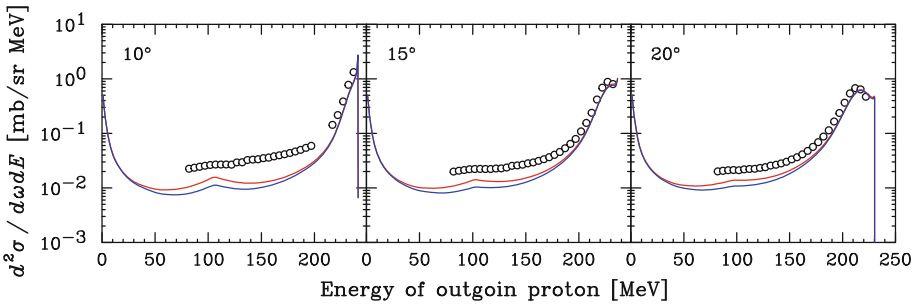

Fig. 1 *Open circles* represent the cross section of inclusive *pd* breakup at 247 MeV. The *red* and *blue curves* stand for $3N$ calculations with and without TM 3NF, respectively

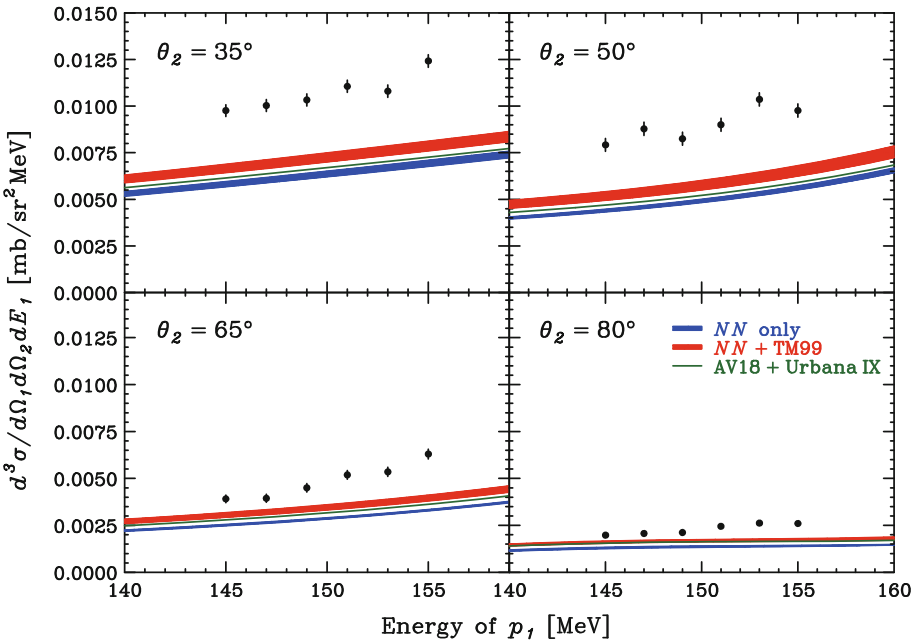

Fig. 2 *Solid circles* show preliminary data for exclusive ^{2}H$(p, p_1p_2)n$ cross section at 247 MeV with $\theta_1 = 15°$ (fixed). *Red and blue bands* represent $3N$ calculations with and without TM99 3NF, respectively, using various realistic NN potentials. The *green solid curve* stands for $3N$ calculation by H. Witała using AV18 potential with Urbana IX 3NF

2 Experimental and Results

The measurement of exclusive ^{2}H$(p, p_1p_2)n$ cross section was performed using a 247 MeV p-beam at RCNP (Research Center of Nuclear Physics), Osaka University. Outgoing two protons were detected by two big spectrometers, the Grand Raiden (GR) spectrometer for p_1 and the Large Acceptance Spectrometer (LAS) for p_2.

We investigated microscopically the discrepancy of inclusive ^{2}H$(p, p_1)pn$ cross section around $E_1 = 150$ MeV at $\theta_1 = 15°$ as shown in Fig. 1. GR for p_1 was fixed at 15°, and LAS was placed at 35°, 50°, 65° and 80°. Although E_1 varies from 0 to 244.8 MeV, we measured only the region of $E_1 = 150 \pm 7$ MeV. The relative azimuthal angle, $\phi_{12} = \phi_1 - \phi_2$, was set at 180°, because $3N$ calculations by H. Kamada predicted that the *pd* breakup cross section becomes maximum at $\phi_{12} = 180°$ and decreases monotonically toward $\phi_{12} = 0°$. We used a liquid deuterium target of about 200 mg/cm^2 in thickness. The target thickness was monitored during the experiment using *pd* elastic scattering.

The preliminary results are shown in Fig. 2. The error bars contain only statistical ones, and systematic errors in the absolute cross section are ±10% at present. The latter will be reduced by our future data analysis.

The experimental results are higher than $3N$ calculations with and without $\pi\pi$3NF as seen in Fig. 2. The θ_2 dependence of the cross section at $E_1 = 150$ MeV is shown in Fig. 3. Effects of $\pi\pi$3NF and relativity are

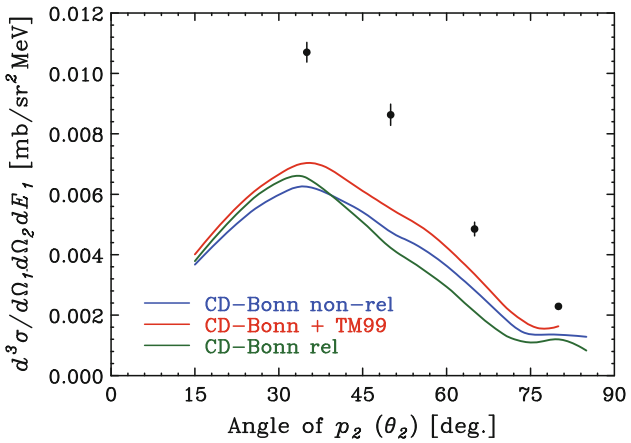

Fig. 3 *Solid circles* represent preliminary data of ^{2}H$(p, p_1p_2)n$ cross section at $E_p = 247$ MeV, measured at $\theta_1 = 15°$ and $E_1 = 150$ MeV. The *red and blue curves* show $3N$ calculations with and without TM99 3NF, respectively, and the *green curve* stands for a relativistic calculation

independently calculated. These effects are sizable, but are not enough to explain the enhancement of the *pd* breakup cross section. The enhancement becomes larger at forward θ_2 as same as the θ_1 dependence of the enhancement in Fig. 1.

We measured also the inclusive ^{2}H$(p, p_1)pn$ cross section for several θ_1 angles at the same energy in the same beam-time. The data in Fig. 1 agreed with the new data within experimental errors.

The experimental data on *pd* elastic scattering and *pd* breakup reaction at 250 MeV have been measured, and the large discrepancies of these cross sections have been found. At this high energy, magnitude of 3NFs, for example, $\pi\pi$3NF, $\pi\rho$3NF and $\rho\rho$3NF, may become larger. Also the relativistic effects should be taken into accounts. We hope information on 3NFs are obtained from the present data.

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