# Measurement of $pd$ radiative capture at $E_d$=200 MeV

T. Yagita,[a] K. Sagara,[a] M. Kondo,[a] S. Minami,[a] T. Ishida,[a] K. Hatanaka,[b] T. Wakasa,[b] J. Kamiya,[b] D. Hirooka,[b] T. Noro,[b] H. P. Yoshida,[b] E. Obayashi,[b] K. Takahisa,[b] M. Yoshimura,[b] and H. Akiyoshi[c]

[a] *Department of Physics, Kyushu University, Fukuoka 812-8581, Japan*
[b] *Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan*
[c] *Institute for Chemical and Physical Research (RIKEN), Wako, Saitama 351-0106, Japan*

So far possible evidences of 3-nucleon force (3NF) have been reported in the 3N bounding states and in the $pd$ scattering state above $E_p$ = 65 MeV ($E_d$ = 130 MeV). The $pd$ radiative capture, which is the transition between the 3N bound state and the $pd$ scattering state, is therefore considered to be suitable to find the evidence of 3NF. Hence we have made precise experiment of H($\vec{d}$,$^3$He)$\gamma$ reaction at $E_d$ = 200 MeV. The cross section and analyzing powers $A_y$, $A_{yy}$ and $A_{xx}$, were measured to search the 3NF effects in various kinds of observables.

Due to small cross section of the $pd$ capture reaction ($< \sim 1\mu$b/sr), there have been a few precise experiments and some experiments have been made only at $\theta_{lab} = 90^\circ$ where the cross section is relatively large. Above $E_d$ = 95 MeV, no measurement of the analyzing powers has been reported.

In the present experiment, the cross section, $A_y$, $A_{yy}$ and $A_{xx}$ of the $pd$ capture were measured in a wide angular range. Since $^3$He particles from H($\vec{d}$,$^3$He)$\gamma$ reaction are emitted at very forward angles within 85mr in the laboratory frame, we detected the $^3$He particles using the large acceptance (horizontally $\pm$60mr and vertically $\pm$100mr) spectrograph (LAS). The measurement in the vertical reaction plane was made with LAS at 0°, and that in the horizontal plane with LAS at 0° and at 3°. Detection of $^3$He's instead of $\gamma$-rays was very effective to obtain high detection efficiency and to decrease backgrounds.

We used a liquid hydrogen target[2] of about 1.5 mm in thickness with the beam entrance and exit windows sealed by aramide foils of 4.4$\mu$m in thickness. The A/H (A=C,O,N,etc.) atomic number ratio of this target is about 1/150 whereas the ratio of a $CH_2$ foil target is 1/2, hence the backgrounds from A(d,$^3$He) reactions in the target materials were greatly reduced. The energy loss of $^3$He from the $pd$ capture in the liquid target is about 1.5 MeV. The target pressure was kept below 0.6 atm to reduce swelling of the window foils by the inner pressure.

The $d$-beam polarization ($p_y$ and $p_{yy}$) was measured during the experiment by a polarimeter using $d + p$ scattering[1] which was calibrated just before the present experiment.

By placing LAS at 0°, $A_{xx}$ and $A_{yy}$ were simultaneously measured in the vertical and horizontal reaction plane, respectively, with a vertically polarized $d$-beam, and the $d$-beam was stopped on the Faraday cup after passing through an aperture in the yoke of LAS. When LAS was placed at 3°, $A_y$ and $A_{yy}$ were measured in a horizontal plane and the $d$-beam was stopped on a Faraday cup in the scattering chamber.

Typical $^3$He spectra on the focal plane measured by two VDC's and a plastic scintillator are shown in figure 1. The spectra were well reproduced by the simulation using the computer code RAYTRACE, and the CM angle of H($\vec{d}$,$^3$He) reaction was well determined. The background were estimated from the separate measurement with a thick aramide target and were carefully subtracted from the spectra.

The preliminary results are shown in figure 2 together with Faddeev calculations by H. Kamada[3]. Calculations in Siegert approximation (dashed curves) may be somewhat unreliable at the present rather high energy, and we compare the experimental results to the

calculations including the meson-exchange current (MEC)[4] based on $AV_{18}$ NN potential (solid curves). The MEC calculations with $2\pi$3NF at 80°, 120° and 140° and are also shown by dots.

The experimental results of $A_y$, $A_{yy}$ and cross section fairly well reproduced by the MEC calculation. The small discrepancy between the experiment and the MEC calculation in $A_y$ and $A_{yy}$ at around 100° is reduced by the inclusion of 3NF. However, very large discrepancy was found in $A_{xx}$. The 3NF effects in MEC calculation is much smaller than the observed discrepancy. The large discrepancy is also seen if the data are compared with the Siegert calculation or with the MEC calculation based on Bonn-B NN potential.

Since the relation $A_{xx}+A_{yy}+A_{zz}=0$ holds, $A_{zz}$ has the similar discrepancy of opposite sign, and the discrepancy is most enhanced in $A_{xx} - A_{zz}$ $(= X_2)$. In the deuteron induced reactions, $X_2$ has been known to be sensitive to the tensor interaction. It is possible therefore the present discrepancy has a relation with the D-state NN interactions.

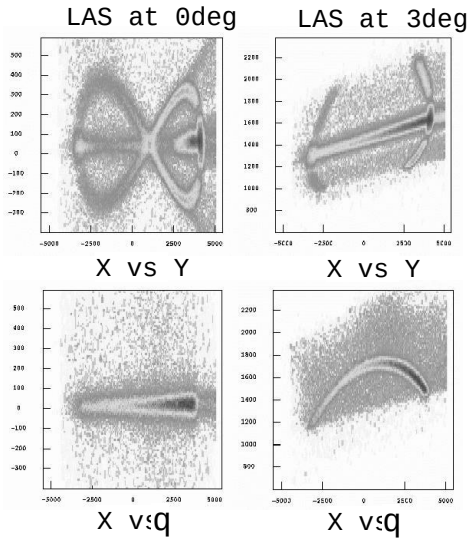


Figure 1: Typical $^3$He spectra on the focal plane

It is very interesting to see whether the large discrepancy is caused by a new type 3NF, or by the shortage in the D-state NN interactions used in the calculations, or by other reaction mechanism so far neglected in the calculations.

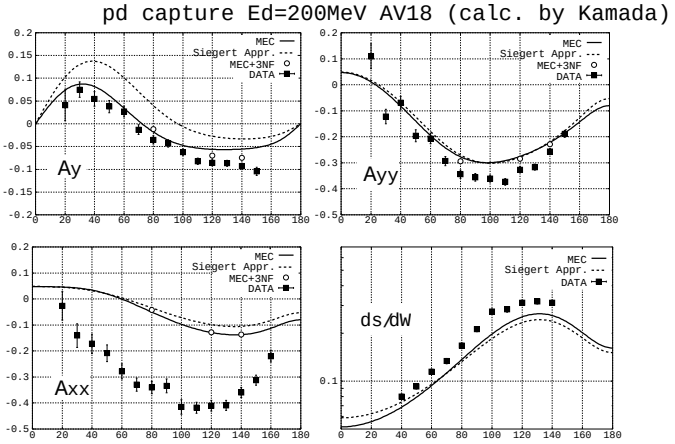


Figure 2: The preliminary results of $A_y$, $A_{yy}$, $A_{xx}$ and $d\sigma/d\Omega$

## References


[1] T. Yagita *et al*, RCNP Annual Report 2000.
[2] K. Sagra *et al*, KUTL Report-**6** (1997) 157
[3] H. Kamada, private communication.
[4] J. Golak *et al* Phys. Rev. C **62** (2000) 054005