Proton scattering of ^{16}C at 300 MeV/nucleon

S. Terashima,[*1] T. Baba,[*2,*3] Y. Matsuda,[*2,*4] J. Zenihiro,[*2] H. Sakaguchi,[*2,*4] M. Dozono,[*2] T. Furuno,[*2,*3] S. Gotanda,[*2,*5] C.L. Guo,[*1] Y. Kanaya,[*2,*5] T. Kawabata,[*3] Y. Maeda,[*5] H.J. Ong,[*4] S. Ota,[*6] H. Otsu,[*2] W.W. Qu,[*1] H. Sakurai,[*2] M. Tsumura,[*2,*3] T. Uesaka,[*2] J.C. Yang,[*1] and G.L. Zhang[*1]

Neutron-rich carbon isotopes can provide opportunities to study the evolution of nuclear structure up to the neutron drip line. Even-even carbon isotopes have been extensively studied so far. ^{16}C was identified as an exotic structure using lifetime measurement for the first time at RIKEN[1)]. Then, the lifetime of the 2^+ state in ^{16}C was remeasured using different methods including more neutron-rich carbon isotopes, ^{18}C and ^{20}C [2–4)]. The existence of the anomalous behavior of ^{16}C is still under discussion. Proton elastic and inelastic scattering can provide unambiguous optical potential and shape information of the ground state via the coupled channel effect with the deformation parameter $\beta_{pp'}$. In addition, ^{16}C is a first step to develop a neutron skin or neutron halo up to ^{22}C. The angular distribution of elastic scattering is expected to provide us with density distribution information that includes not only the radius but also surface diffuseness.

In April 2013, an experiment the so-called Elastic Scattering of Proton with RI beam (ESPRI) setup was performed at the RIKEN Nishina Center. The ^{16}C beam with an intensity more than 10^5 Hz at approximaately 300 MeV/nucleon was produced in BigRIPS using an ^{18}O primary beam at 345 MeV/nucleon. The incident ^{16}C with a purity of 95% was selected with a set of narrow slits setting ($\pm$2 mm) at F1 and F2, and then, it was transported to the F12 area. The size of the beam spot was $\sigma = 3$ mm (5 mm) in the horizontal (vertical) direction on the secondary solid hydrogen target named SH TRICꓘ (Solid-Hydrogen Target for Recoil detection In Coincidence with INVERSE Kinematics)[5)]. The use of para-H_2 was critical in operating it safely during this experiment for one week.

Further, beam particle identification was perfermed using the energy deposit(ΔE) of a plastic scintillator and beam trajectory using beam tracking detectors at F12. The thickness and effective diameter of the secondary target that was tilted to 45○ at target center was 1 mm and 20 mm, respectively. The recoil protons were identified using time-of-flight(TOF)-ΔE-E technique by plastic scintillators and NaI(Tl)s; the scattering angle (θ_p) and energy (T_p) of the recoil proton were reconstructed using the tracking detectors, position detectors, total energy calorimeters, and energy loss calculation in passive materials.

Figure 1 shows a kinematical correlation between θ_p and T_p, and the expected kinematical curves of elastic and inelastic scattering (6 MeV). The two strong loci are observed clearly. A line at most intense locus is the ground state, which includes the first excited state. Another line corresponds to a higher inelastic channel. Figure 2 shows an angler distribution of the elastic channel and theoretical calculation using relativistic impulse approximation(RIA) and relativistic Hartree density[6)] as reference. Detailed data analysis for angular distribution of elastic and inelastic channels are currently in progress.

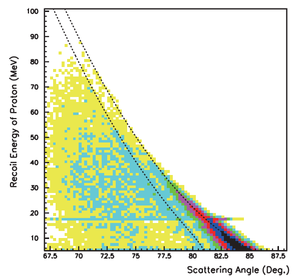

Fig. 1. Kinematical correlation of the $p(^{16}\mathrm{C},p)$ reaction. Dashed lines represent expected kinematical curves of elastic and inelastic scattering.

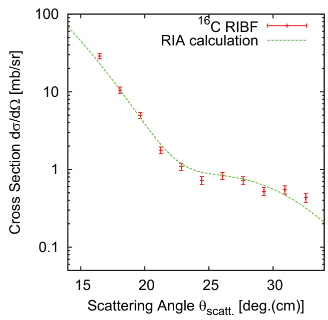

Fig. 2. Preliminary result of angular distribution of elastic channel $p(^{16}\mathrm{C},p)$ with the theoretical calculation using RIA and the relativistic Hartree density[6)].

References
1) N. Imai et. al.: Phys. Rev. Lett. **92**, 062501 (2004).
2) H.J. Ong et. al.: Phys. Rev. C **78**, 014308 (2008),
3) M. Wiedeking et al.: Phys. Rev. Lett. **100**, 152501 (2008),
4) M. Petri et al.: Phys. Rev. Lett. **86**, 044329 (2012).
5) Y. Matsuda et al.: Nucl. Intr. Meth. **A643**, p6 (2011).
6) C.J. Horowiz and B.D. Serot: Nucl. Phys. **A368**, p503 (1981).

*1 School of Physics and Nuclear Energy Technology, Beihang Univeristy, Beijing
*2 RIKEN Nishina Center
*3 Department of Physics. Kyoto University
*4 Research Center for Nuclear Physics, Osaka University
*5 Department of Applied Physics, Faculty of Engineering Miyazaki University
*6 Center for Nuclear Study, University of Tokyo