Spectroscopy of three-neutron system via the ^{3}H(t, ^{3}He)3n reaction

K. Miki,[*1,*2] K. Kameya,[*1,*2] N. Imai,[*3] S. Michimasa,[*3] S. Ota,[*3] M. Sasano,[*2] H. Takeda,[*2] T. Uesaka,[*2] Y. Hatano,[*4] M. Hara,[*4] H. Haba,[*2] T. Hayamizu,[*2] T. Chillery,[*3] M. Dozono,[*5,*2] N. Fukuda,[*2] J. Gao,[*6] S. Hanai,[*3] S. Hayakawa,[*3] Y. Hijikata,[*5,*2] K. Himi,[*7] J. Hwang,[*8] T. Kawabata,[*7,*2] K. Kishimoto,[*9,*2] S. Kitayama,[*1,*2] K. Kusaka,[*2] J. Li,[*3] Y. Maeda,[*10,*2] Y. Maruta,[*1,*2] T. Matsui,[*1,*2] H. Nishibata,[*9,*2] M. Otake,[*2] H. Sakai,[*2] A. Sakaue,[*3] H. Sato,[*2] K. Sekiguchi,[*1,*2] Y. Shimizu,[*2] S. Shimoura,[*3] L. Stuhl,[*8,*2] T. Sumikama,[*2] H. Suzuki,[*2] R. Tsuji,[*5,*2] S. Tsuji,[*7] H. Umetsu,[*1] R. Urayama,[*1,*2] Y. Utsuki,[*1,*2] T. Wakasa,[*9] K. Yako,[*3] Y. Yanagisawa,[*2] N. Yokota,[*9,*2] C. Yonemura,[*9,*2] K. Yoshida,[*2] and M. Yoshimoto[*2]

Can we find a nucleus that consists only of neutrons? This is a long-standing question in nuclear physics. If any signature of multi-neutron bound or resonant states exists, it is a challenge to the current description of nuclei. In particular, it has a significance on the understanding of high-isospin systems such as neutron stars. In a recent study,[1)] a candidate of the tetra-neutron resonance was found in the ^{4}He(^{8}He, ^{8}Be)4n spectrum. This peak located at $E_x = 0.83 \pm 0.65$ (stat) $\pm$ 1.25 (syst) MeV has not been understood yet with the theoretical calculations based on first principles. To investigate the simpler and more fundamental case, we focused on the three-neutron (3n) system and performed a ^{3}H(t, ^{3}He)3n experiment at the incident energy of 170 MeV/nucleon.

The schematic layout of our experimental setup is shown in Fig. 1. The primary ^{4}He beam of 200 MeV/nucleon impinged on the ^{9}Be target with a thickness of 6 cm. Among the reaction fragments, the triton beam of 170 MeV/nucleon was selected using the BigRIPS separator with a purity higher than 99%. A high intensity of 5×10^7 particles/sec was obtained owing to the cooperation of the accelerator and radiation-safety group at the RIBF. The beam was transported to the SHARAQ target position in the achromatic ion-optics mode. The beam tuning was performed with low-pressure MWDCs and PPACs installed at each focal plane of the beamline. The scattered ^{3}He particles from the target were momentum-analyzed using the SHARAQ spectrometer and detected by the CRDCs and plastic scintillators. A pair of liquid scintillation detectors were installed around the target, which counted the decay neutrons from the 3n system in coincidence with the focal plane detectors.

For the target, we have newly developed a tritiated titanium (Ti-^{3}H) target and used it for the first time at RIBF. The thickness of tritium is 3.5 mg/cm^2, which is almost two orders of magnitude larger than those used in RI beam experiments in the past. This thick target enables us to find rare process such as the production of 3n system in this study.

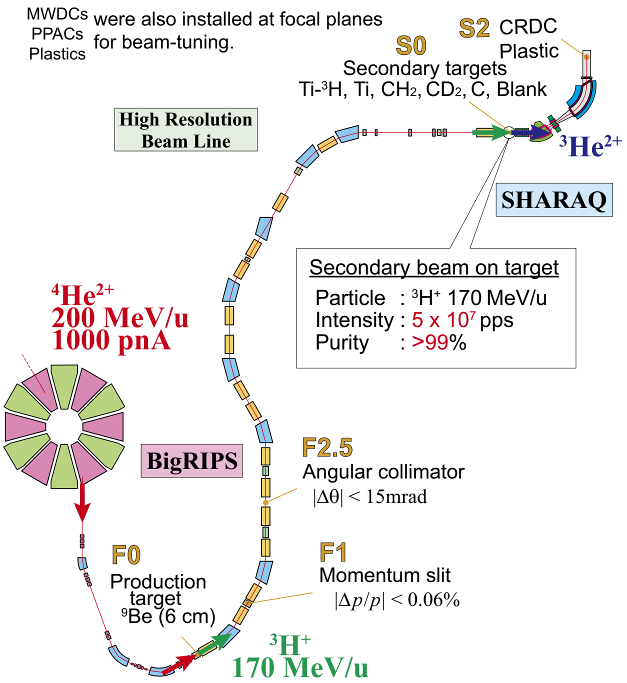

Fig. 1. Schematic layout of the experimental setup. The detector layout is similar to the previous (t, ^{3}He) experiment.[2)]

With this setup, the double differential cross section spectra for the ^{3}H(t, ^{3}He)3n reaction were obtained for the excitation energy of $0 \leq E_x \leq 20$ MeV and the scattering angle of $0 \leq \theta \leq 4$ degrees. The ^{1}H(t, ^{3}He)1n and ^{2}H(t, ^{3}He)2n spectra were also obtained in the same beamtime. This aids us to argue the 1n, 2n, and 3n systems on an equal basis. Detailed analyses are in progress.

*1 Department of Physics, Tohoku University
*2 RIKEN Nishina Center
*3 Center for Nuclear Study, University of Tokyo
*4 Hydrogen Isotope Research Center, University of Toyama
*5 Department of Physics, Kyoto University
*6 School of Physics, Peking University
*7 Department of Physics, Osaka University
*8 Center for Exotic Nuclear Studies, Institute for Basic Science
*9 Department of Physics, Kyushu University
*10 Faculty of Engineering, University of Miyazaki

References

1) K. Kisamori *et al.*, Phys. Rev. Lett. **116**, 052501 (2016).
2) K. Miki *et al.*, Phys. Rev. Lett. **108**, 262503 (2012).