Study on neutron-neutron correlation in Borromean nuclei via the (p, pn) reaction with the SAMURAI spectrometer

Y. Kubota,[*1,*2] A. Corsi,[*3] G. Authelet,[*3] H. Baba,[*2] C. Caesar,[*4] D. Calvet,[*3] A. Delbart,[*3] M. Dozono,[*1] J. Feng,[*5] F. Flavigny,[*6] J.-M. Gheller,[*3] J. Gibelin,[*7] A. Giganon,[*3] A. Gillibert,[*3] K. Hasegawa,[*8] T. Isobe,[*2] Y. Kanaya,[*9] S. Kawakami,[*9] D. Kim,[*10] Y. Kiyokawa,[*1] M. Kobayashi,[*1] N. Kobayashi,[*11] T. Kobayashi,[*8] Y. Kondo,[*12] Z. Korkulu,[*13] S. Koyama,[*11] V. Lapoux,[*3] Y. Maeda,[*9] F. M. Marqués,[*7] T. Motobayashi,[*2] T. Miyazaki,[*11] T. Nakamura,[*12] N. Nakatsuka,[*14,*2] Y. Nishio,[*15] A. Obertelli,[*3] A. Ohkura,[*15] N. A. Orr,[*7] S. Ota,[*1] H. Otsu,[*2] T. Ozaki,[*12] V. Panin,[*2] S. Paschalis,[*4] E. C. Pollacco,[*3] S. Reichert,[*16] J.-Y. Roussé,[*3] A. T. Saito,[*12] S. Sakaguchi,[*15] M. Sako,[*2] C. Santamaria,[*3] M. Sasano,[*2] H. Sato,[*2] M. Shikata,[*12] Y. Shimizu,[*2] Y. Shindo,[*15] L. Stuhl,[*2] T. Sumikama,[*8] M. Tabata,[*15] Y. Togano,[*12] J. Tsubota,[*12] T. Uesaka,[*2] Z. H. Yang,[*2] J. Yasuda,[*15] K. Yoneda,[*2] and J. Zenihiro[*2]

Dineutron correlation is one of the specific phenomena expected to appear in neutron drip-line nuclei. It has been explored through indirect studies such as the determination of the $E1$ cluster sum rule via the Coulomb breakup reaction.[1] In order to directly determine the momentum distribution of two valence neutrons of the Borromean nuclei ^{11}Li, ^{14}Be, and ^{17,19}B, a kinematically complete measurement was performed at the RIKEN RIBF for the quasi-free (p, pn) reaction on these nuclei.[2] The opening angle between the two neutrons was reconstructed from the measured momentum vectors of all the particles.

The experiment was carried out by using the SAMURAI spectrometer[3] combined with the liquid hydrogen target system MINOS.[4] The beam momentum was determined from the time-of-flight (TOF) between focal planes F7 and F13. The trajectory was measured using the beam drift chambers (BDCs). The momentum vectors of a decay neutron, a knocked-out neutron, and a recoil proton were determined from the TOF and position respectively measured by the NEBULA, the WINDS, and a recoil proton detector (RPD). The position and the angle of a heavy fragment at the entrance and the exit of the SAMURAI spectrometer were measured by the forward drift chambers (FDCs). The rigidity was determined so as to reproduce the set of the tracking information by using the calculated magnetic field.

The resolution of each momentum vector, estimated from the detector responses and angular straggling around the target, is summarized in Table 1. The momentum resolution of the recoil proton was dominated by the angular straggling, while that of the knocked-out neutron was limited by the time resolution of the WINDS. The required resolution of about 20 MeV/c was achieved.

Table 1. Estimated resolution of momentum vectors deduced from the detector responses and angular straggling. The unit is MeV/c.

Particle	Detector	σ_{Px}	σ_{Py}	σ_{Pz}
Beam ^{11}Li	BigRIPS+BDC	0.08	0.08	8
Recoil p	RPD	12	10	12
Knocked-out n	WINDS	15	16	15
Decay n	NEBULA	0.2	0.2	5
Fragment ^{9}Li	FDC	0.1	0.1	12
Total		20	19	25

Figures 1 (a), (b), (c), and (d) show the difference of the sum of the four-vectors of all the particles between the initial and the final states projected onto the x-, y-, and z-direction and the energy, respectively. Owing to the momentum and energy conservation law, in each spectrum the peak should be centered at zero; this is a test of the consistency of both the reconstruction and measurement. The widths of the spectra are consistently explained by the estimated resolution.

Data analysis is currently in progress.

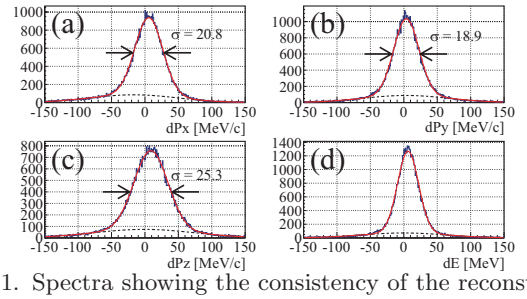

Fig. 1. Spectra showing the consistency of the reconstruction in the (a) x-, (b) y-, and (c) z-direction, and (d) the energy via the verification of the momentum and energy conservation.

*1 Center for Nuclear Study, University of Tokyo
*2 RIKEN Nishina Center
*3 CEA, Saclay
*4 Department of Physics, Technische Universität Darmstadt
*5 Department of Physics, Peking University
*6 IPN Orsay
*7 LPC Caen
*8 Department of Physics, Tohoku University
*9 Department of Applied Physics, University of Miyazaki
*10 Department of Physics, Ehwa Womans University
*11 Department of Physics, University of Tokyo
*12 Department of Physics, Tokyo Institute of Technology
*13 MTA Atomki
*14 Department of Physics, Kyoto University
*15 Department of Physics, Kyushu University
*16 Department of Physics, Technische Universität München

References

1) T. Nakamura *et al.*: Phys. Rev. Lett. **96**, 252502 (2006).
2) Y. Kubota *et al.*: RIKEN Accel. Prog. Rep. **48**, 52 (2015).
3) T. Kobayashi *et al.*: Nucl. Instr. Meth. B**317**, 294 (2013).
4) A. Obertelli *et al.*: Eur. Phys. Jour. A**50**, 8 (2014).