# Study of spin-isospin response of $^{11}$Li (SAMURAI30 experiment)

L. Stuhl,[*1] M. Sasano,[*2] J. Gao,[*2,*3] Y. Hirai,[*4] K. Yako,[*1] T. Wakasa,[*4] D. S. Ahn,[*2] H. Baba,[*2] A. Chilug,[*5,*2] S. Franchoo,[*6] Y. Fujino,[*7] J. Gibelin,[*8] I. S. Hahn,[*9] Z. Halász,[*10] T. Harada,[*11] M. N. Harakeh,[*12,*13] D. Inomoto,[*4] T. Isobe,[*2] H. Kasahara,[*4] D. Kim,[*14] G. G. Kiss,[*10] T. Kobayashi,[*15] Y. Kondo,[*16] Z. Korkulu,[*2] S. Koyama,[*17] Y. Kubota,[*2] A. Kurihara,[*16] H. N. Liu,[*18] M. Matsumoto,[*16] S. Michimasa,[*1] H. Miki,[*16] M. Miwa,[*19] T. Motobayashi,[*2] T. Nakamura,[*16] M. Nishimura,[*2] H. Otsu,[*2] V. Panin,[*2] S. Park,[*9] A. T. Saito,[*16] H. Sakai,[*2] H. Sato,[*2] T. Shimada,[*16] Y. Shimizu,[*2] S. Shimoura,[*1] A. Spiridon,[*5] I. Stefanescu,[*5] X. Sun,[*2,*3] Y. L. Sun,[*18] H. Suzuki,[*2] Y. Togano,[*7] T. Tomai,[*16,*2] L. Trache,[*5] D. Tudor,[*5,*2] T. Uesaka,[*2] H. Yamada,[*16] M. Yasuda,[*16] K. Yoneda,[*2] K. Yoshida,[*2] J. Zenihiro,[*2] and N. Zhang[*20,*1]

The spin-isospin responses of $^{11}$Li and $^{14}$Be neutron drip line nuclei were measured in charge-exchange $(p,n)$ reactions. Until recently, only the spin-isospin collectivity in stable isotopes was investigated.[1)] There is no available data for nuclei with large isospin asymmetry factors, where $(N-Z)/A > 0.25$. The $(p,n)$ reactions at intermediate beam energies ($E/A > 100$ MeV) and small scattering angles can excite Gamow-Teller (GT) states up to high excitation energies in the final nucleus, without $Q$-value limitation. The combined setup of PANDORA[2)] and SAMURAI spectrometer[3)] with a thick liquid hydrogen target (LHT)[4)] allowed us to perform the experiment with high luminosity. In this setup,[5)] PANDORA was used for the detection of the recoil neutrons while SAMURAI was used to tag the decay channel of the reaction residues.

The secondary cocktail beam of $^{11}$Li and $^{14}$Be was transported onto the 10 mm-thick LHT.[6)] The neutron detector setup on the left and right sides of LHT consisted of 27 PANDORA and 13 WINDS[7)] plastic scintillator bars. The neutron kinetic energies were deduced by the time-of-flight (ToF) technique (1.25 m flight path). The ToF time reference was taken from SBT1,2 plastic scintillators. The left and right wings with respect to the beam line covered the laboratory recoil angular region of 47°–113° and 62°–134°, respectively, with 3.25° steps. PANDORA was optimized to detect neutrons with a kinetic energy of 0.1–5 MeV. The light output threshold was set to be 60 keV$_{ee}$. The digital data-acquisition (DAQ) of PANDORA was combined[8)] with standard DAQ of SAMURAI.

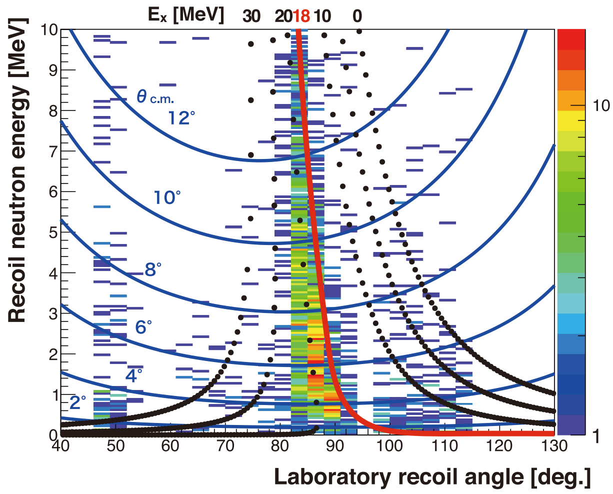


Fig. 1. Recoil neutron energy spectrum as a function of scattering angle in the laboratory frame.

The reaction residues were momentum analyzed by the SAMURAI spectrometer, using HODF24 and HODP detectors.[9)] Figure 1 shows a preliminary plot of kinetic energy as a function of laboratory scattering angle for recoil neutrons associated with $^{11}$Li beam. We required the simultaneous detection of $^{9}$Li and $d$ in HODF24 and neutron detection[10)] in PANDORA.

A clear kinematical correlation between the measured kinetic energy and the laboratory scattering angle, above 18 MeV excitation energy ($E_x$), was obtained. This forward scattering peak (2°–7° in the center-of-mass system) suggests a GT transition. The $^{9}$Li + $d$ decay channel of $^{11}$Be is observed for the first time. Reconstruction of the excitation-energy spectrum up to about 30 MeV, including the GT giant resonance region, is ongoing.

*1 Center for Nuclear Study, University of Tokyo
*2 RIKEN Nishina Center
*3 School of Physics, Peking University
*4 Department of Physics, Kyushu University
*5 Horia Hulubei Nat. Inst. of Phys. and Nucl. Eng.
*6 Inst. de Physique Nuclaire, Univ. Paris-Saclay
*7 Department of Physics, Rikkyo University
*8 LPC CAEN
*9 Department of Physics, Ewha Womans University
*10 ATOMKI, Institute for Nuclear Research, HAS
*11 Department of Physics, Toho University
*12 KVI - CART, University of Groningen
*13 GSI Helmholtzzentrum für Schwerionenforschung
*14 Department of Physics, Korea University
*15 Department of Physics, Tohoku University
*16 Dept. of Physics, Tokyo Institute of Technology
*17 Department of Physics, University of Tokyo
*18 Dépt. Physique Nucl., CEA, Univ. Paris-Saclay
*19 Dept. of Physics, Saitama University
*20 Institute of Modern Physics, Chinese Acad. of Sci.

References

1) K. Nakayama *et al.*, Phys. Lett. B **114,** 217(1982).
2) L. Stuhl *et al.*, Nucl. Instrum. Methods Phys. Res. A **866,** 164 (2017).
3) T. Kobayashi *et al.*, Nucl. Instrum. Methods Phys. Res. B **317,** 294 (2013).
4) X. Sun *et al.*, in this report.
5) M. Sasano *et al.*, in this report.
6) M. Miwa *et al.*, in this report.
7) K. Yako *et al.*, RIKEN Accel. Prog. Rep. **45,** 137 (2012).
8) J. Gao *et al.*, in this report.
9) Y. Hirai *et al.*, in this report.
10) Y. Hirai *et al.*, in this report.