Radioactive Isotope Physics Laboratory

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The Radioactive Isotope Physics Laboratory was established as one of the institutes laboratory in 2005 when Hiroyoshi Sakurai was appointed as a Chief Scientist. Since then, the Laboratory has functioned as one of the core research groups conducting programs at the world-leading heavy-ion accelerator facility, the RIKEN "RI Beam Factory (RIBF)."

The Laboratory explores exotic nuclear structures and dynamics in exotic nuclei that have never been investigated before, such as those with large imbalanced proton and neutron numbers. Our aim is to develop new experimental techniques utilizing fast radioactive isotope (RI) beams at RIBF and to discover new phenomena and properties in exotic nuclei.

Research subjects covered by the Laboratory are the shell evolution in exotic nuclei, the r-process nucleosynthesis, and the equation of state (EOS) in asymmetric nuclear matter.

The shell evolution has been investigated via in-beam gamma spectroscopy and decay spectroscopy. The two spectroscopy methods complement each other: in-beam gamma spectroscopy is a good method for finding yrast states, while decay spectroscopy gives information on non-yrast states as well. A major experimental site of in-beam gamma spectroscopy is the "ZeroDegree" spectrometer,[1] where reaction products are identified in coincidence with de-excited gamma-ray measurement at a NaI array called "DALI2."[2] The first spectroscopy at RIBF was organized as a day-one campaign in 2008 for the island-of-inversion region. The ^{48}Ca beam was utilized to produce very neutron-rich nuclei in the region. Not only the high primary beam intensity but also unexpectedly large production cross sections caused surprisingly intense secondary beams, which gave very efficient organization in managing the day-one programs. The first data on ^{32}Ne were published in PRL in 2009.[3] Since then, multitudes of programs have been conducted under the SUNFLOWER collaboration. One of the highlights is "the discovery of a new magic number 34," which was published in Nature.[4] The SEASTAR collaboration was formed as a subset of SUNFLOWER in 2014 to observe the first excited states in even-even neutron-rich isotopes, and it finished its campaign program in summer 2017. Exciting results are being published.[5]

Decay spectroscopy at RIBF was started in 2009 as a day-two campaign by utilizing a primary beam of uranium. A beta-gamma coincidence setup including four clover Ge-detectors was mounted at the end of ZeroDegree, and neutron-rich nuclei with $A \sim 110$ were implanted into active Si strip detectors "WAS3ABi." The first campaign was successfully organized for 2.5 days, and two papers on the shell evolution and the r-process path were published in PRL.[6] The first attempt made a trigger to organize the "EURICA" project, where the GSI RISING setup of Euroball-cluster Ge-detectors was coupled with RIBF. The EURICA campaign was organized from 2012 to 2016, and about 40 papers including 11 PRL papers have already been published. One of the highlights is a successful measurement of 110 half-lives of neutron-rich nuclei.[7] The measurement impacts the r-process nucleosynthesis scenario. Since 2016, the BRIKEN project of beta-delayed neutron emission probability measurement has been conducted.

The EOS in asymmetric nuclear matter at a density that of normal nuclei has been studied with heavy-ion central collisions by utilizing a large TPC, which was developed under the SπRIT collaboration.[8] In 2016, the TPC was mounted inside the SAMURAI magnet, and physics runs were organized. A huge amount of data is being analyzed to obtain $\pi^{\pm}$ yields as well as proton- and neutron-flows.

Other activities in the Laboratory were missing-mass spectroscopy with radioactive isotope beams,[9] laser spectroscopy of radioactive atoms in superfluid He, and Antarctic ice core analysis for supernova explosion events. At the occasion of a researcher leaving and new laboratories being created, their research activities were transferred to other Laboratories and other research units in Nishina Center. In 2013, a spallation reaction study with long-lived fission products was initiated by the Laboratory for the nuclear waste problem.[10] This activity was also transferred into the other group in Nishina Center in 2014.

Future projects being initiated by the Laboratory are the development of detectors such as GAGG crystals, advanced tracking Ge detectors, and silicon telescopes. Based on these detectors, new programs with decelerated radioactive isotope beams are the future research directions in the Laboratory.

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References

1) T. Kubo et al., Prog. Theor. Exp. Phys. **2012**, 03C003 (2012).
2) S. Takeuchi et al., Nucl. Instrum. Methods Phys. Res. A **763**, 596 (2014).
3) P. Doornenbal, H. Scheit et al., Phys. Rev. Lett. **103**, 032501 (2009).
4) D. Steppenbeck et al., Nature **502**, 207 (2013).
5) N. Paul, A. Corsi, A. Obertelli, P. Doornenbal et al., Phys. Rev. Lett. **118**, 032501 (2017)
6) S. Nishimura et al., Phys. Rev. Lett. **106**, 052502 (2011); T. Sumikama et al., Phys. Rev. Lett **106**, 202501 (2011).
7) G. Lorusso, S. Nishimura et al., Phys. Rev. Lett. **114**, 192501 (2015).
8) R. Shane, A.B. McIntosh, T. Isobe et al., Nucl. Instrum. Methods Phys. Res. A **784**, 513 (2015).
9) A. Matta, D. Beaumel, H. Otsu et al., Phys. Rev. C **92**, 041302 (2015).
10) H. Wang et al., Phys. Lett. B **754**, 104 (2016).