Spin Isospin Laboratory

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The Spin Isospin Laboratory was started on 1st April, 2011 and, as of July 2017, consists of five staff researchers (one is concurrently appointed), nine postdoc researchers, two JRA, three IPA, four resident trainees, secretaries, and several tens of visiting researchers. The Spin Isospin Laboratory pursues research activities with a primary focus on the interplay of spin and isospin in exotic nuclei. Understanding nucleosynthesis in the universe, especially in r- and rp-processes, is another significant goal of our laboratory.

The three big pillars of our research activities are as follows: 1) direct reaction studies of nuclear matter and structure, 2) storage ring experiments for nuclear physics and nuclear astrophysics, and 3) interdisciplinary studies based on a nuclear polarization technique.

Direct reaction studies of nuclear matter and structure are being conducted mainly with the SAMURAI and SHARAQ spectrometers. We investigate spin-isospin responses in nuclei with newly developed experimental methods. Highlights from the activities are an observation of β^+-type isovector spin monopole resonances (IVSMR) in ^{208}Pb and ^{90}Zr via the $(t, {}^3\mathrm{He})$ reaction at 300 MeV/nucleon 1) and the discovery of a candidate of tetraneutron resonant state via the ^{4}He(^{8}He, ^{8}Be) reaction. 2) Another double-charge exchange reaction, (^{12}C, ^{12}Be(0_2^+)), is planned to be used to search for yet-to-be-discovered double Gamow-Teller resonances.

To investigate spin-isospin properties, the neutron-skin thickness, and the incompressibility for a single symbolic nucleus, in this case the doubly magic ^{132}Sn, we performed three experiments during 2014–2016: the (p, n) experiment to probe spin-isospin responses conducted in 2014 with the WINDS neutron detector and SAMURAI, the proton elastic scattering experiments to determine the neutron-skin thickness with the ESPRI setup, and the (d, d') experiment to extract the incompressibility performed with the CNS active target. Results from the three experiments will provide us a better understanding of isospin dependencies of nuclear-matter properties.

The laboratory hosted the MINOS setup from CEA Saclay and the NeuLAND neutron detector from GSI, and performed the SEASTAR campaigns 3) in collaboration with the RI Physics laboratory and the SAMURAI experiments to explore multi-neutron correlations in near- and beyond-dripline nuclei such as tetraneutron, ^{7}H, ^{11}Li, ^{17}B, and ^{28}O.

The second pillar consists of storage ring experiments for nuclear physics and nuclear astrophysics. In close collaboration with the Instrumentation Development Group, we have constructed a heavy-ion storage ring, the Rare RI Ring, for precise mass measurements of short-lived radioactive nuclei. Masses of the radioactive nuclei play a decisive role in the establishment of our understanding of nucleosynthesis, such as the rapid neutron capture process (r-process) and the rapid proton capture process (rp-process), in the Universe.

During 2014–2016, we accomplished two important technical achievements. One is the world's first realization of individual injection to a storage ring. 4) This technique has paved the way in the field of storage-ring science and has opened up applications in cyclotron facilities. The other is the construction of a Schottky pickup detector with the world's highest sensitivity. We have tested the newly constructed Schottky pickup detector with a ^{78}Kr beam at 168 MeV/nucleon and have confirmed that the sensitivity is twice those in other facilities. Mass measurements of radioactive nuclei will start soon.

The last pillar consists of interdisciplinary studies based on a nuclear polarization technique. We have developed a method to produce nuclear polarization using photo-excited triplet states of pentacene (*Triplet-DNP*). A distinguished feature of the Triplet-DNP technique is that it works under a low magnetic field of 0.1–0.7 T and at a high temperature of 77–300 K, in striking contrast to standard dynamic nuclear polarization (DNP) techniques working in extreme conditions of magnetic fields of several Tesla and sub-Kelvin temperatures. We have applied the technique to construct a polarized proton target system for use in RI-beam experiments and performed several experiments at RIPS and SAMURAI.

The nuclear polarization technique is now being applied to a broad field of science: a research program to apply the Triplet-DNP technique for sensitivity enhancement in the NMR spectroscopy of biomolecules started in 2016 in close collaboration with QBiC (RIKEN), Yokohama City University, the University of Tokyo, and Kansei Gakuin University. In the program, protein-protein interaction in a relatively short time scale will be investigated via two-dimensional NMR spectroscopy with sensitivity enhanced by the Triplet-DNP method. The first results will be obtained in a few years.

References

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