Measurement of proton elastic scattering from ^{132}Sn in inverse kinematics

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The neutron skin thicknesses of medium and heavy nuclei such as ^{208}Pb are now known to be strongly correlated with the nuclear matter equation of state (EOS), especially because of the density dependence of the isospin-asymmetric term of the EOS, so-called the symmetry energy. The symmetry energy plays an essential role in the understanding of astorphysical phenomena such as neutron star structures and supernova explosions. Precise measurements of the neutron skin thicknesses are very important to constrain the symmetry energy, but are very difficult owing to the model dependences.

Proton elastic scattering is a powerful tool to study the ground-state properties of nuclei such as proton and neutron densities, radii, and neutron skin thicknesses. For stable nuclei, thus far, we succeeded in extracting the model-independent neutron density distributions and neutron skin thicknesses from proton elastic scattering at 300 MeV.[1] For the systematic study of neutron skin thicknesses with large isospin asymmetry, the measurements of proton elastic scattering from unstable nuclei as well as stable ones are necessary. For this purpose we launched a new experimental project to measure the elastic scattering of protons with RI beams (ESPRI) based on the missing mass technique. To measure recoil protons scattered by unstable nuclei with a wide range of momentum transfers ($1 \sim 3$ fm^{-1}), we developed a new device, recoil proton spectrometer (RPS), which consists of a 1-mm-thick solid hydrogen target (SHT),[2] two multi-wire drift chambers (MWDC), two plastic scintillators, and fourteen rods of NaI(Tl) calorimeters, which cover an angular range from 65° to 85° in the laboratory system. At two heavy-ion facilities, GSI and HIMAC, we have already tested the performance of RPS and successfully performed ESPRI measurements for several unstable nuclei such as ^{9}C, ^{20}O, and ^{66,70}Ni. An excitation energy resolution of $\sim$ 500 keV (σ) was achieved.[3]

In May 2016, we have performed an ESPRI measurement for ^{132}Sn (NP1512-RIBF79R1). The ^{132}Sn nucleus is a flag-ship doubly magic nucleus which has a larger isospin assymmetry than that of ^{208}Pb. The secondary beam including ^{132}Sn at 200 MeV/u was produced by a ^{238}U beam at 345 MeV/u. The intensity of the cocktail beam was very high, typically 500 kcps at F3 and 200 kcps at F7. The purity of ^{132}Sn was approximately 25%. Owing to the radiation damage and the high-rate detections with a heavy and intense RI beam, we used MWDCs and diamond detectors instead of the conventional PPACs, plastic scintillators and ion chambers. We employed a new PI technique of the TOF-$B\rho$-$B\rho$ method which was recently developed.[4]

After the BigRIPS seperater the secondary beam was transported to F8 and finally to the SHT at F12, where the ESPRI detectors were installed. Another experimental setup of NP1312-RIBF113 using a CNS active target (CAT) was also intalled at F8.[5] Since both the RIBF79 and RIBF113 experiments required a high-intensity ^{132}Sn beam, the same configuration of the BigRIPS detectors was used. A newly designed DAQ system was also introduced to achieve a high live-time ratio even under such a high-intensity beam condition.[6]

Since ^{132}Sn is known to have an isomeric state of ^{132}Sn (8^{+}) with a half life of 2 μs, this state is a possible background of this measurement. Four LaBr(Ce) detectors were installed around a beam stopper to investigate the isomer tagging system by measuring γ rays emitted from the isomeric state.[7]

The experiment has been successfully performed. Analysis to deduce the excitation energy spectrum and the angular distribution of cross sections is now in progress.

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