# Measurement of the proton elastic scattering from $^{132}$Sn at 300 MeV/nucleon

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The "neutron skin" structure is an important phenomenon in finite nuclei and is known to be strongly related with the properties of nuclear matter. In neutron-rich nuclei, excess neutrons are pushed out to the surface region, evolving the "neutron skin" structure. Many mean-field predictions indicate that the thickness of the neutorn skin ($\Delta r_{np}$), which is defined as the difference in root-mean-square radii between the proton and neutron, is strongly correlated with the equation of state (EOS) of the neutron matter. Neutron-rich doubly magic $^{208}$Pb is a benchmarking nucleus for EOS studies. Thus far, many theoretical and experimental studies on the $\Delta r_{np}$ of $^{208}$Pb have been conducted.

Proton elastic scattering is a powerful tool to extract density information and $\Delta r_{np}$. In the case of stable nuclei, we have established the method to determine neutron density distributions from proton elastic scattering at 300 MeV.[1] It is natural to expand this study to the unstable region, where large $\Delta r_{np}$ values are expected because of the large isospin asymmetry. To apply our method to unstable nuclei, we started a new project to measure the elastic scattering of protons with RI beams (ESPRI) based on missing mass spectroscopy in inverse kinematics. We developed a new device, recoil particle spectrometer (RPS), which consists of a 1-mm-thick solid hydrogen target (SHT),[2] two multi-wire drift chambers (MWDCs), two plastic scintillators, and fourteen NaI(Tl) calorimeter rods. RPS covers a wide range of momentum transfers (0.5–2.5 fm$^{-1}$) corresponding to 10°–35° in the c.m. scattering angles. We successfully performed ESPRI measurements with RPS for several light unstable nuclei.[3] We also developed a new method to determine the proton and neutron density distributions from two-energy proton elastic scattering data at 200 and 300 MeV/nucleon. Usually, the proton density distributions can be derived from the nuclear charge distributions determined by electron elastic scattering,[4] but at present, little information is available on the charge distributions of unstable nuclei. This method is based on the different energy dependences between *pp* and *pn* interactions, which was demonstrated by the proton elastic scattering data of Zr isotopes at 200 and 300 MeV/nucleon.[1]

$^{132}$Sn is another benchmarking nucleus, which has a larger isospin asymmetry than that of $^{208}$Pb. In November 2019, we successfully completed the ESPRI experiment for $^{132}$Sn at 300 MeV/nucleon (NP1512-RIBF79R1). The first part of this experiment at 200 MeV/nucleon was already completed in 2016.[5] A secondary beam around $^{132}$Sn at 300 MeV/nucleon was produced by fission fragmentation with a $^{238}$U beam at 345 MeV/nucleon. In this experiment, the purity of $^{132}$Sn was ∼20%, and the total intensity of the cocktail beam was ∼700 kcps. Since high-intensity and heavy RI beams cause critical radiation damage to and/or low efficiencies of detectors such as plastic scintillators, delay-line parallel-plate avalanche counters (DL-PPACs), and ion chambers, in place of the standard ones at BigRIPS, we have used new detectors with good radiation hardnesses and fast timing responses, namely, diamond detectors, MWDCs, strip-readout PPACS (SR-PPACs), and Xe gas scintillators.[6] The secondary beam particles were transported to F8 and finally to the SHT at F12, where RPS was installed. At F8, a CNS active target (CAT) was also installed for measurement at a forward scattering angle around 7°–10° in the c.m. angles. A new high-speed DAQ system, MOCO with parallelized VME (MPV),[7] was introduced for the first time, and it worked with a good live-time ratio under a high-data-rate condition. During the measurement, we clearly identified elastic events from the correlation of recoil proton energies and angles.

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