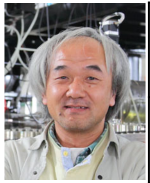
【Grant-in-Aid for Scientific Research (S)】

Precise measurement of charge density distribution of Sn unstable isotopes by advanced innovative SCRIT electron scattering



Principal Investigator	Kyoto University, Institute for Chemical Research, Professor WAKASUGI Masanori Researcher Number:70250107	
Project Information	Project Number : 23H05436 Project Period (FY) : 2023-2027 Keywords : Unstable nuclei, Electron scattering, Proton distribution, Charge density distribution	

Purpose and Background of the Research

●Outline of the Research

The world's first method for directly measuring the shape of artificially created unstable nuclei (RI), which do not exist in nature, has been developed. We call this the SCRIT electron scattering system. By trapping RIs created using an accelerator in the orbit of an electron beam circulating in an electron storage ring, naturally occurring electron scattering events are observed and consequently the proton density distribution (proton wave function) of the RIs is precisely measured.

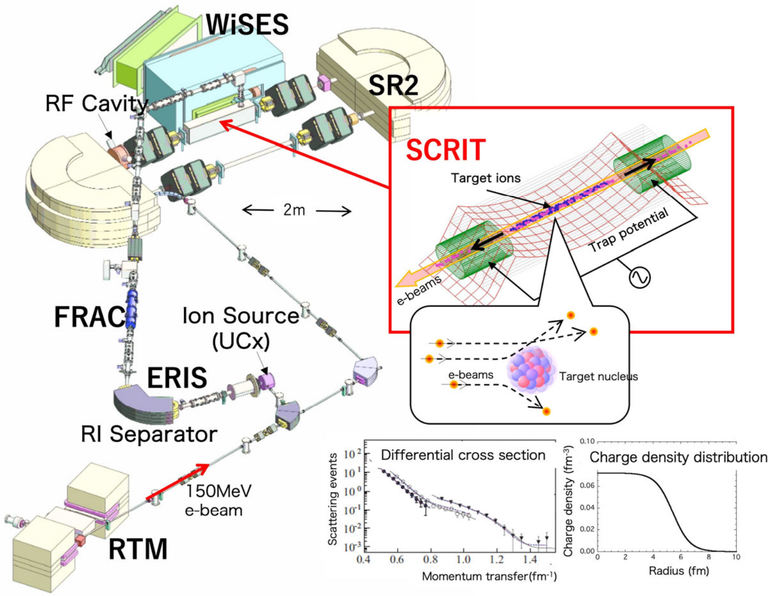


Figure 1. the SCRIT electron scattering system

●Density distribution of proton and neutron in unstable nuclei

The proton and neutron distributions in nuclei are the most fundamental physical quantities in nuclear structure research. In particular, the difference between their distributions is an important observable that determines the symmetry energy term in the equation of state of nuclear matter. Furthermore, they are the key to unlocking the secrets of elemental synthesis in the neutron star mergers. The precise measurement of the proton and neutron distribution for unstable nuclei is therefore a critical issue in physics, including a wide range of fields such as astrophysics and astronomy. Although electron scattering for measuring the proton distribution has been completely impossible, our SCRIT method has been the breakthrough.

●Upgrading the SCRIT system

SCRIT is an innovative target formation method developed to perform previously impossible electron scattering experiments on RI. SCRIT forms relatively thick targets with a small number of RIs by capturing the RI ions in the electron beam itself. The luminosities currently obtained are still an order of magnitude less for a physically meaningful discussion using experimental results. Therefore, the SCRIT electron scattering system will be improved in this study. One of them is the high stabilization of the electron beam by introducing a higher-order mode (HOM) damping cavity: the HOM causes instability of the electron beam, which reduces the luminosity. Therefore, a HOM damping cavity will be developed in this study. Another improvement is the dramatic reduction of the background caused by residual gas ions trapped together with the RI ions in the SCRIT. As the ions move back and forth in the SCRIT with a inherent frequency that depends on their mass, only the residual gas ions can be removed by applying a resonant frequency to the trapping potential. This reduces measurement data errors and improves the accuracy of cross sections.

Expected Research Achievements

● Charge density distribution measurements of neutron-rich Sn isotopes

The present study aims to achieve high precision in charge density distribution measurements and, at the same time, to establish a technical basis toward inelastic and quasi-elastic scattering studies. This will precisely determine the charge density distribution of neutron-rich Sn isotopes (indicated by the green band in Fig. 2). We have developed the SCRIT method over a long period of time. In the process, we have measured the elastic scattering cross sections of the nuclei shown in Fig. 2, including pilot experiments targeting ^{132}Xe. These demonstrate the potential of RI electron elastic scattering, and recently the elastic scattering angular distributions of on-line produced unstable nuclei (^{137}Cs) were successfully measured. We intend to increase the currently insufficient RI generation capacity by a factor of 100 and to bring electron scattering experiments for RI into full operation.

● Technical breakthroughs

In this study, two technological breakthroughs in unstable nuclei research are.

(1) The first lepton probe studies on unstable nuclei.

(2) The first practical application of fixed RI targets.

Previous studies of unstable nuclear reactions have utilised inverse kinematics methods with hadron probes, which are unsuitable for precision studies. The two breakthroughs in this work provide a method for precise nuclear reaction studies even with rare RIs, by allowing studies with pure electromagnetic probes with no ambiguity in reaction processes and with normal kinematics using high quality, high intensity probe beams.

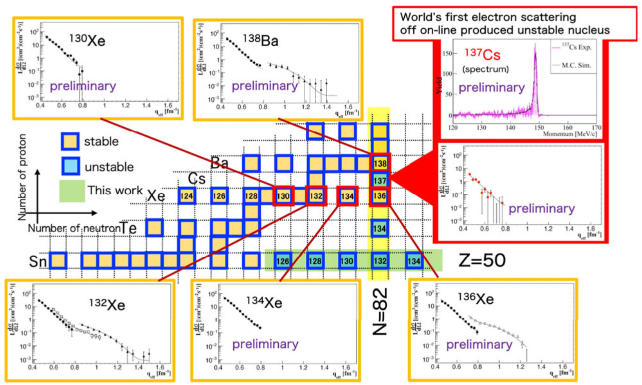


Figure 2. Measurements of cross sections for elastic electron scattering

Homepage Address, etc.	https://pbs.kuicr.kyoto-u.ac.jp/research-fields-ja/unstable-nuclear-science-by-em-probe-ja/