First observation of elastic electron scattering from online-produced radioactive target†

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Electron are one of the most powerful and reliable probes for exploring the internal structure of atomic nuclei, given its decoupling from the strong nuclear force ambiguities and its well-understood interaction mechanism.[1)] Elastic electron scattering determines the spatial charge density distribution of the nucleus, which is a critical feature linked to the sum of squares of all proton wave functions. Investigating unstable nuclei through elastic electron scattering yields important and direct insights into their internal structures. This technique determines the size as well as the shape by measuring the diffraction pattern of the form factors. Despite its effectiveness, electron scattering has not been applied to unstable nuclei due to difficulty for preparing thick target.

We have been developing the Self-Confining RI Ion Target (SCRIT)[2)] and, have achieved a milestone: The world's first electron scattering on unstable nuclei has been successfully measured with an online-produced radioactive target of ^{137}Cs. Cesium nuclides were produced through the photo-fission of uranium by irradiating 28 g of uranium with a 15-W electron beam and ionized using a surface ionization-type ion source at the electron-beam-driven RI separator (ERIS).[3)] The cooler-buncher, a fringing-RF-field-activated dc-to-pulse converter (FRAC),[4)] accepted the pre-pulsed ^{137}Cs ion beam with little or no loss; the FRAC stacked the beam for 4 s by repeating the injection and cooling by colliding with a pressure-controlled neon buffer gas, and ejected it as a pulsed beam at a frequency of 0.25 Hz. The purity of the ^{137}Cs beam was over 99.5%. Approximately 10^7 ^{137}Cs ions/pulse were delivered into the SCRIT with 1.9 s trapping, achieving the luminosity of approximately 0.9×10^{26} cm^{-2}s^{-1}. An electron beam with an energy of 149.3 MeV was stored in the storage ring, and the stored beam current was approximately 200 mA on average. Although ^{137}Cs has a relatively long lifetime of 30 years, this experiment perfectly emulates electron scattering from short-lived unstable nuclei produced online.

Figure 1 shows obtained angular dependences of elastic scattering for both ^{137}Cs and the residual gas background. On the vertical axis, L$d\sigma/d\Omega$ (cm^{-2}s^{-1})(cm^2/sr) is presented, where L and $d\sigma/d\Omega$ denote the luminosity and the differential cross section, respectively. The slope of ^{137}Cs is steeper than that of the residual gas, indicating a radius difference between ^{137}Cs and the residual gas nuclei. The solid lines in the figure are derived from calculations using DREPHA,[5)] a phase shift calculation code employed to calculate the cross section of elastic electron scattering from a spherical nucleus. Currently, the achieved luminosity is below the design value of 10^{27} cm^{-2}s^{-1} required for determining the charge density distribution of medium-heavy nuclei. In the next facility upgrade within a few years, we will increase the power of the ISOL driver from 15 W to 2 kW. Following the upgrade, the signal-to-noise ratio is expected to significantly improve, enabling the investigation of the charge density distribution of various short-lived unstable nuclei, such as ^{132}Sn and its isotopes.

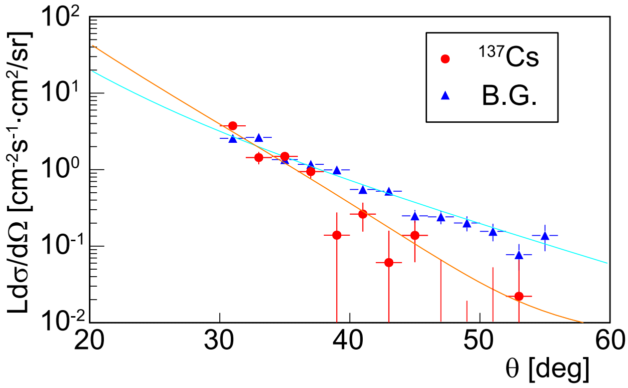

Fig. 1. Angular distributions for ^{137}Cs and the background.

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