Development of a forward detector for the measurement of the mean square radius of the neutron distribution of unstable nuclei by electron scattering

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In nuclear physics, the nucleon density distribution is an essential physical quantity because it directly reflects the wave function of nucleons. Electron scattering provides detailed information of the nucleus's charge density distribution, dominated by the proton distribution. However, it is difficult to determine the neutron distribution by electron scattering because its contribution to the charge density distribution is less than a few percent.

It was recently suggested that the mean square radius (msr) of the neutron distribution could be accessed by measuring the fourth–order moment of the charge density distribution.[1,2] The charge form factor deduced from elastic electron scattering at the low momentum transfer can be Taylor-expanded as $F(q) \sim 1 - \frac{<r^2>_c}{6} q^2 + \frac{<r^4>_c}{120} q^4 - \frac{<r^6>_c}{5040} q^6 \cdots$, where F is the form factor, q is the momentum transfer, and $< r^n >_c$ is the nth-order moments of the charge density distribution. Figure 1 shows the q^2 dependence of the ^{132}Xe form factor and the contribution of each term of the above equation. The msr of the neutron distribution measurement of unstable nuclei by electron scattering will be obtained in a region that covers the forward scattering angle (12–25° for the electron beam energy $E_e = 150$ MeV). In the low momentum transfer region (less than 0.09 fm^{-2} in the case of Xe isotopes), the form factor is sensitive almost to only the second- and fourth-order moments of the charge density distribution.

The study of the msr of the neutron distribution of Xe isotopes (stable : $^{124–136}$Xe, unstable : $^{138,\,140}$Xe) by electron scattering is under consideration at the SCRIT facility.[3] A forward detector for measuring the fourth-order moment of the charge density distribution is under discussion. A series of background studies were performed using an alternative detector to investigate the number of background events at the new setup for the measurement in the low momentum transfer region. This is because it may not be possible for the forward detector to distinguish between the elastic scattered electrons signals from the target nuclei and the background signal if there are more or similar amounts of background events than the true one in the target region (length is 500 mm). The background study was performed with a calorimeter array of seven CsI crystals and two drift chambers, which covered a scattering angle of $18 \pm 1°$ from the center of the SCRIT device and measured the scattered electrons energy E'_e by summing energy deposits of CsIs.

Figure 2 shows the reconstructed vertex distribution of electron scattering events from the target region. The red line in Fig. 2 denotes those of $E'_e > 100$ MeV and is identified as the elastic events. These events at -450 to -200 mm are considered as the elastic scattering events of the electron beam halo from the material upstream of the target region. The forward detector cannot separate these events from the vertex distribution of the target nuclei. It needs to consider approaches to reduce background events, for example, by reducing the material around the SCRIT device.

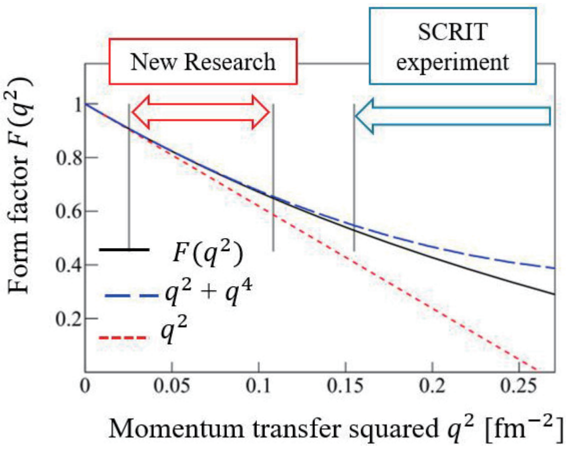

Fig. 1. q^2 dependence of the ^{132}Xe form factor obtained by the past experiment.[4] The black line shows the form factor for which all moments are calculated. The red and blue lines show the form factor up to the second- and fourth-order moment of the charge density distribution, respectively.

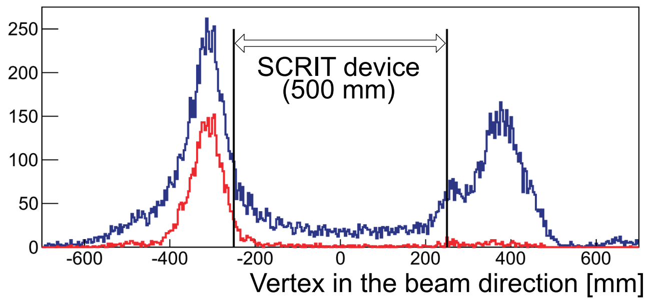

Fig. 2. Reconstructed vertex distribution of electron scattering events from the target region (blue line). The red line shows the events where the scattered electrons have kinetic energies higher than 100 MeV. The events at -450 to -200 mm are from the material upstream of the target region. The blue line shows events containing low energy.

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