Understanding bremsstrahlung spatial distribution of electron scaterring in the SCRIT experiment

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The self-confining RI ion target (SCRIT) electron scattering facility has been constructed to realize electron scattering off unstable nuclei[1)]. In 2014, a luminosity monitor (LMon) was installed to measure the absolute luminosity value of electron scattering in the SCRIT experiment[2,3)]. The luminosity is determined as

$$\frac{d^2N}{d\Omega dE} = L \cdot \frac{d^2\sigma}{d\Omega dE} \tag{1}$$

where N is the number of scattered electrons, L is the luminosity and σ is scattering cross section.The angular distribution of scattered electrons is measured by the window-frame spectrometer for electron scattering(WiSES)[4)]. The required accuracy of the luminosity value is expected to be less than 5% which is comparable with the systematic uncertainty of WiSES.

To determine the luminosity with a total uncertainty less than 5%, it is necessary to measure the bremsstrahlung photon counts, energies and spatial distribution very precisely and accurately. The photon counts and energies are measured by a CsI calorimeter array. The CsI calorimeter consits of 7 pure CsI scintillators. The spatial distributions of the bremsstrahlung photons are measured by two layers of fiber scintillators. Each layer consits of 16 fiber scintillators and the cross section of each fiber is 3×3 mm^2. In the experiment, L is calculated as

$$L = \frac{N_{\mathrm{Brems.}}}{\sigma_{\mathrm{Brems.}}} \cdot \frac{1}{\varepsilon} \quad [\mathrm{cm^{-2}sec^{-1}}] \tag{2}$$

where $N_{\mathrm{Brems.}}$ is the number of bremsstrahlung photons per second and $\sigma_{\mathrm{Brems.}}$ is the caluculated bremsstrahlung cross section[5)]. Because LMon is located 7 m downstream of the vertex position and there are structures in the path of the photons such as a cryopanel in the beam chamber, it is necessary to evaluate the transmittance. ε is estimated as the number of photons detected with LMon divided by the number of radiated photons in the SCRIT calculated by GEANT4 simulations. It is important to understand several electron beam conditions such as electron beam energy and beam shape. In order to determine the parameters to be handled in the simulation, we compared experimental data and simulation data.

From 2015 to 2016, the experiment of electron scattering for ^{132}Xe and ^{208}Pb targets had been performed at electron beam energies Ee = 150 MeV, 200 MeV and 300 MeV. Figure 1 shows the experimental spatial distributions together with that calculated with GEANT4 simulations at E_e = 150 MeV. The red and blue closed circles in the upper panels in Fig. 1 represent the spatial distributions with and without target ions (Ion In and Ion Out), respectively. The lower panels show the spatial distributions of bremsstrahlung photons from ^{208}Pb estimated by subtracting Ion Out from Ion In. The systematic uncertainty of ε is estimated by varying the initial beam parameters within χ^2/ndf between exprimental data and GEANT4 spatial distributions. With a careful study of the initial beam condition, it has become possible to reproduce the spatial distributions of data by GEANT4 simulation, and the systematic uncertainty of ε was reduced to ~ 6% , significantly less than the uncertainty of ~ 10% achieved in a previous study. The key point to increase the reproducibilty and to reduce the systematic uncertainty is to understand the electron beam size according to the lattice function of the electron storage ring. In Fig. 1, the beam size is $\sigma_H \sim 2.13$ mm, $\sigma_V \sim 0.60$ mm and the spread of incident angle in the horizontal direction is +0.4 mrad in σ_H at the center of the SCRIT device.

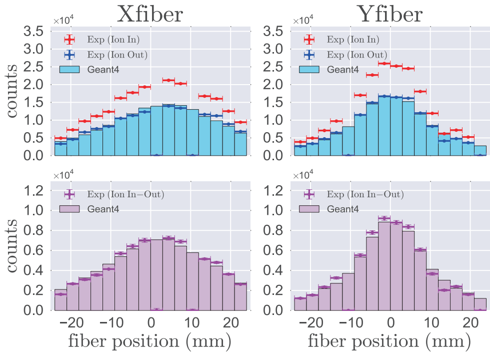

Fig. 1. Horizontal (X fiber) and vertical (Y fiber) spatial distributions. The histograms show simulation results.

In summary, we found that a careful treatment of the initial beam condition is key to reproduce the spatial distribution of bremsstrahlung photons and to reduce the systematic uncertainty in the determination of ε.

References

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