Simulation of HBD response in the J-PARC E16 experiment based on test results

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A hadron blind detector (HBD) has been developed for the J-PARC E16 experiment.[1)] The E16 experiment aims to investigate the origin of QCD mass through the spectral change of a ϕ meson in a nucleus. The mass spectrum is reconstructed through electron-positron decays. A detector for electron identification is required. The HBD is utilized in the E16 experiment for this purpose. The HBD identifies electrons by converting Čerenkov photons emitted by an incident electron in a CF_4 radiator into photoelectrons using a CsI photocathode. These photoelectrons are amplified by gas electron multiplier[2)] (GEM) foils and are subsequently read out as an electric signal. Other charged particles apart from the electron do not emit Čerenkov photons in the momentum region where we perform the measurement, 0.4–3 GeV/c. With this scheme, the HBD distinguishes electrons from the other charged particles.

We have constructed a prototype of the HBD and performed a test experiment using a positron beam of 1.0 GeV/c at Research Center for Electron Photon Science, Tohoku University. We successfully observed 11 photoelectrons per incident positron with the prototype[3)] when the incidence angle to the beam was 0°. This result was consistent with the expected result calculated based on the performance of each detector element. However, only HBD response to an electron was obtained in this beam test, and the response to a pion is also required to determine the pion rejection power for a given electron detection efficiency. We estimated the HBD response to a pion through simulation.

For this simulation, we used the HBD response to a pion that has already been obtained with another prototype. This prototype has a smaller pad readout and longer gap lengths between GEM foils. Taking into account of the differences between the prototype and another prototype, we performed the simulation to evaluate the prototype response to a pion. With this simulation, we estimated an electron detection efficiency of 85% with a pion rejection factor of 50 for 1.0 GeV/c electrons and pions at the threshold of 6.5 e when the incidence angle was 0°. In the actual J-PARC E16 experiment, charged particles including electrons and pions are emitted from a target and the incidence angle of these particles to the HBD is approximately 0–45°. Furthermore, these charged particles move along a curved line because of the magnetic field in the spectrometer used in the experiment, resulting in a larger incidence angle to the HBD.

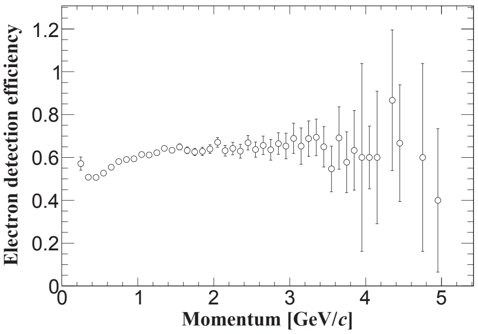

Fig. 1. Electron detection efficiency as a function of electron momentum.

To evaluate the electron detection efficiency in the offline analysis, we performed another simulation by including the possible momentum and incidence angle distribution of electrons from ϕ meson decays. In the simulation, ϕ mesons were generated by a 30 GeV/c proton-induced reaction using the nuclear cascade code JAM.[4)] These ϕ mesons decay into electrons and positrons, and then electrons move according to the magnetic field. We assumed pion samples had the same track as the electron samples. The HBD responses to an electron and a pion were estimated based on the result of the beam test and the simulation mentioned in the previous paragraph. The electron detection efficiency as a function of electron momentum with a pion rejection factor of 100 is shown in Fig. 1. The efficiency decreases in the region of 0.4–1.5 GeV/c. This fact reflects that the signal amplitude of a pion increases with decreasing momentum. A pion sample having lower momentum has a larger curvature in a magnetic field and consequently has a larger incidence angle to the HBD, namely, a larger signal amplitude. The large errors in the high-momentum region are due to availability of limited statistics. The overall efficiency is 60% with a pion rejection factor of 100 at the threshold of 7.5 e, which meets the requirement of the experiment.

As the next step, we will measure the response to a pion, which has been simulated, using a pion beam with GEM foils and the readout pad configuration for the production type of HBD.

References

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