Hadron blind detector using a finely segmented pad readout†

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We developed a hadron blind detector (HBD) using a finely segmented pad readout for the J-PARC E16 experiment.[1)] The HBD is a Cherenkov detector that does not require mirrors or transparent windows.[2)] Our HBD is used to identify electrons and to reject pions in the momentum region of 0.4–3.0 GeV/c. The finely segmented pad readout enabled us to perform an advanced analysis using the number of signal-detecting pads in addition to the usual analysis with the total amount of collected charge. With this advanced analysis method, the pion rejection factor is increased while keeping the electron detection efficiency.

Our HBD consists of a 50-cm-long CF_4 radiator, a mesh electrode, a CsI photocathode, three layers of GEM foils and a pad readout. The mesh and three layers of GEM foils are stacked together onto the readout pad. The CsI photocathode is evaporated on the top surface of the top GEM foil to detect Cherenkov photons and convert them into photoelectrons. An incident electron emits Cherenkov photons, whereas an incident pion does not in the momentum region of interest. Thus, a pion can induce a signal only through the ionization electrons. However, this signal is greatly suppressed by controlling the electric field of the gap between the mesh and the top GEM foil such that the ionization electrons produced in the gap are swept into the mesh. The pad readout consists of 25 square pads. The size of each pad is 10×10 mm^2. This size is smaller than that of the circular image of the Cherenkov photons, which is 34 mm in diameter in our HBD. Thus, an incident electron is expected to induce multiple signal-detecting pads, whereas an incident pion is expected to leave no signal-detecting pad. The pion rejection factor is expected to be improved by applying a threshold on the size of a charge cluster. This analysis method is called cluster size analysis.

To measure the responses of the detector to electrons and pions, we performed a beam test at J-PARC K1.1BR with a negatively charged secondary beam at 1.0 GeV/c containing approximately 20% electrons. A signal-detecting pad was defined as a pad with the induced charge larger than that of the pedestal by 7σ, corresponding to 0.22 e. The cluster size is defined as the number of neighboring signal-detecting pads. Two pads which share at least a corner are considered as neighbors. Our HBD was operated under a reverse bias of 5 V/mm. The mean primary charge for incident electrons and pions is 7.3 e and 0.7 e, respectively.

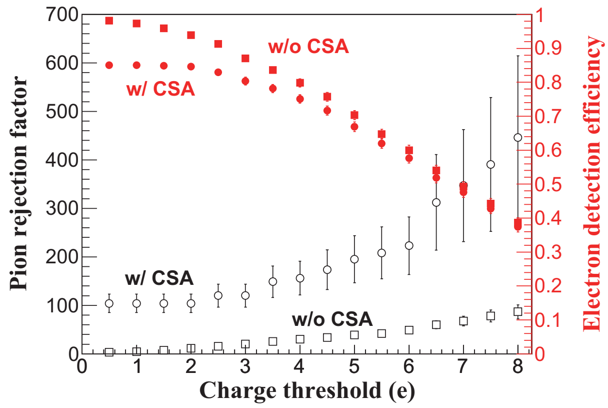

Fig. 1. Electron detection efficiency and pion rejection factor with and without the cluster analysis as a function of the threshold on the primary charge. The notation "CSA" represents the cluster size analysis. The open and closed symbols represent the pion rejection factor and electron detection efficiency, respectively.

This mean primary charge for incident electrons was consistent with the expected result calculated based on the performance of each detector element including the quantum efficiency of the CsI photocathode. Thus, the primary charge induced by an incident electron was considered to be due to photoelectrons. The mean cluster size for incident electrons and pions was 4.3 pads and 0.5 pads, respectively. An electron had a larger cluster size than a pion.

We calculated the electron detection efficiency and the pion rejection factor with and without the cluster size analysis as shown in Fig. 1. We achieved an electron detection efficiency of 83% with a pion rejection factor of 120 when we applied a threshold of 2.5 e on the primary charge and required a cluster size of three or more. The pion rejection factor with the cluster size analysis was improved by a factor of approximately five.

Based on this result, we constructed a production model of the HBD for the J-PARC E16 experiment with hexagonal pads with a side length of 10 mm. The pion rejection factor of the HBD was evaluated as 160 with a simulation, which satisfies the requirement of the experiment.

References
1) S. Yokkaichi et al.: In this report.
2) W. Anderson et al., Nucl. Instr. and Meth. A **646**, 35 (2011).

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