Background estimation and operation test of the GEM detectors for the J-PARC E16 experiment

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In the proposed J-PARC E16[1)] experiment, we will use a 30 GeV primary proton beam at the J-PARC high-momentum beam line. Because the beam intensity will be $\sim 1 \times 10^{10}$ per spill and expected particle counting rate is 5 kHz/mm^2 at most, we will use two types of GEM detector: the GEM tracker[2)] and the Hadron Blind Detector (HBD)[3)]. These detectors need to be operated in high-rate background environment during the experiment. In a test experiment using the 1.0 GeV/c pion beam at the J-PARC K1.1BR beamline, several breakdowns were observed with HBD (30 cm $\times$ 30 cm $\times$ 100 μm^t LCP GEM in CF_4 gas, 3×10^3 gain). The breakdowns are considered to be caused by hadronic background such as neutrons or slow hadrons, because we did not observe such breakdowns with electron beams. In addition, no breakdowns were observed with the GEM trackers (10 cm $\times$ 10 cm $\times$ 50μm^t PI GEM in Ar/CO_2 gas, 1×10^4 gain). Therefore we estimated the background particles and their energies for the E16 experiment and performed an operation test of the GEM detector in the high-rate neutron background.

The background particle counting rate was estimated using the Geant4 simulation. The simulation employed the physics list of "QGSP_BERT_HP",[4)] which includes high-precision treatment of low-energy neutrons ($E_{kin} < 20$ MeV). The validity of this simulation for estimation of background particle counting rate was checked by comparing the background calculation with PHITS[5)] calculation[6)] at the K1.1BR area; both agreed within a factor of 2. For example, the neutron rate was 0.01 Hz/mm^2 at the broken GEM of K1.1BR case.

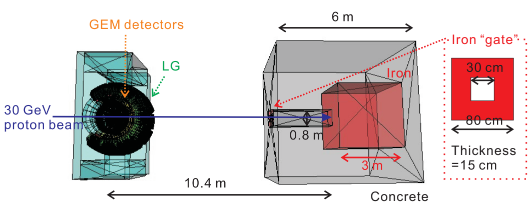

Fig. 1. Schematic model of the E16 experiment used in the simulation. The area is surrounded by concrete blocks, and is filled by air.

The model used in the E16 background simulation is shown in Fig. 1. Using this model, we estimated the particle rate at the detector position, which is located at approximately 120 cm from the target surrounded by the lead-glass calorimeters. Fig. 2 shows the energy spectra from the beam dump and the target, and reveals that the main contribution is by neutrons of several hundred keV. By integrating these spectra, we estimated the neutron counting rate of the E16 detector to be in the order of 0.1 kHz/mm^2 for the beam-dump origin and 0.01 kHz/mm^2 for the target origin.

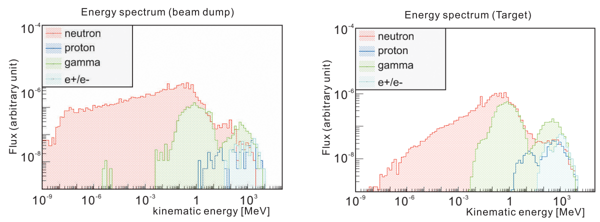

Fig. 2. Energy distribution of the background particles from the beam dump (left panel) and the target (right panel).

We performed an operation test of the GEM detector at AVF cyclotron room in the RIKEN RI beam factory. The detector includes triple-stack 30 cm $\times$ 30 cm $\times$ 50 μm^t PI GEMs in the CF_4 gas. This is the same configuration as that employed in the E16 experiment. During the operation, a 12 MeV deuteron beam with an intensity of 10 pμA was used in the room. The dominant energies of the neutrons were 0.1-10 MeV according to the Geant4 simulation, and the GEM detector was operated in the room background. The neutron radiation level monitored during the operation was 87 mSv/h on average, which is in the order of 1 kHz/mm^2. The counting rate of the GEM itself was approximately 10 Hz/mm^2. The GEM could be stably operated for 15 h without breakdowns with $V_{gem} = 510$ V, which corresponds to a gain of 2×10^4. The total amount of neutrons corresponds to the 2-month operation in the E16 experimental area. From the test operation, we can confirm that PI GEMs can work stably in high neutron background. Further study is necessary to clarify the reason for stable operation.

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References
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