Test of Hadron Blind Detector and GEM Tracker for the J-PARC E16 Experiment

K. Aoki* for the J-PARC E16 Collaboration

RIKEN Nishina Center, Wako, Saitama 351-0198, Japan

December 12, 2011

1 Introduction

The J-PARC E16 experiment[1] measures the e^+e^- decays of vector mesons in nuclei and modification of the invariant mass spectra systematically in order to explore the breaking and restoration of the chiral symmetry at finite density. The stage-1 approval was obtained in 2007, and the detector R & D has been performed.

Here we propose a test of two types of GEM (Gas Electron Multiplier) detectors, Hadron Blind Čerenkov Detector (HBD) and GEM Tracker, which are the main detectors of the experiment. These have been tested with electron beam at ELPH, Tohoku Univ., and SPring-8/LEPS, however, test using pion beam should be performed since hadron beam is known to be severe in terms of stability of GEM operations compared to electron beam. Of course, we also have to check the pion rejection power of the HBD, which is used to distinguish electrons from pions.

We would like to use the K1.1BR beam line. We expect ~ 1 GeV/c π^- beam with an intensity of $10^5 \sim 10^6$/spill with a duty factor of about 10% for the test of the stability of GEM stacks in HBD and GEM chamber. HBD response curves for the electron and the pion beams are also measured. The two detectors can be located in-line at the beam line. Six days of beam time is requested as described below. The first day of the beam time should be later than April 15, 2012.

*Contact person, kazuya.aoki@riken.jp

2 Detectors

2.1 Gas Electron Multiplier

Gas Electron Multiplier (GEM) is a thin insulating foil which have thin electrodes on both sides and many of small holes, developed at CERN[3]. Typical thickness of the foil and the electrodes is 50 μm and 4 μm, respectively. The typical hole size is 70 μm and the distance between holes is 140 μm. A high voltage, typically 300-400 V, is applied between the electrodes in amplification gas, then the electrons are amplified by the strong electric fields in the small holes.

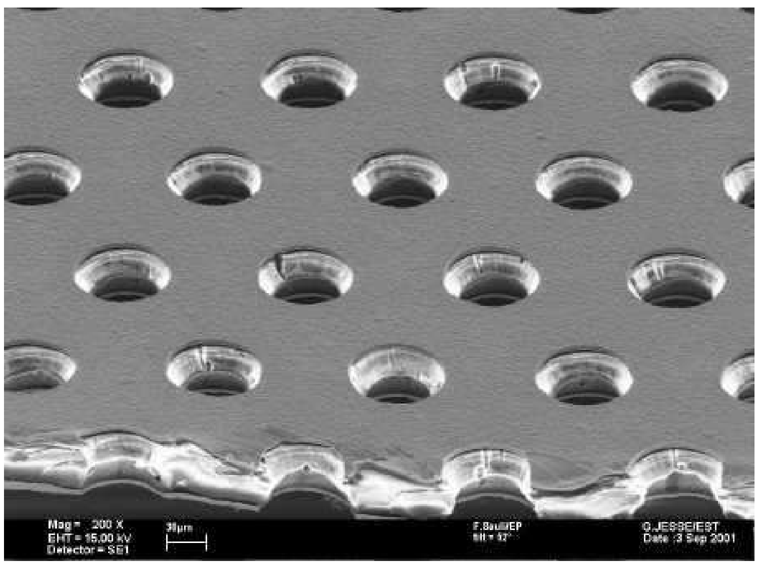

Figure 1: Photograph of typical GEM.

2.2 Hadron Blind Detector

HBD is a mirror-less windowless Čerenkov detector [2] and is used for electron identification from pion in the experiment. CF_4 is used as the radiator and amplification gas. CsI evaporated GEM serves as a photocathode. We use LCP (Liquid Crystal Polymer) GEM which has the thickness of 100 μm.

A schematic drawing of the photocathode is shown in Fig. 2. A Čerenkov photon is converted into a photoelectron by the CsI which is evaporated on top of the GEM. Then the photoelectron is amplified by the stack of GEMs and the signals are readout with the pads. A mesh is placed over the top GEM and is used to manipulate the field between the mesh and the top GEM. The field is called the bias field. When reverse bias field is applied, electrons

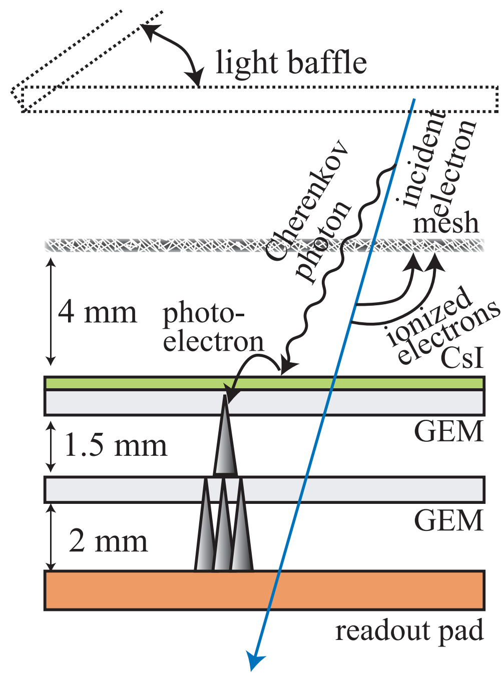

Figure 2: Schematic drawing of the photocathode.

between the mesh and the top GEM are swept into the mesh. Since photoelectrons are produced near the GEM surface, most of them drift to the GEM holes and are readout even in the reverse bias field. In this way, the HBD is sensitive to photons while is insensitive to ionization electrons from energy loss. The radiator length is 50 cm. In the PHENIX experiment, about 20 photoelectrons are observed and the rejection power of 100 is achieved with a threshold at about 16 photoelectrons. We also expect a similar performance for our prototype.

The oxygen and water contamination should be kept at ppm level since they absorb ultraviolet light of interest. The water contamination of 10 ppm is expected to absorb about 5% of the Čerenkov radiation.

A new chamber which is used in the test experiment, is being constructed whose design is almost the same as the chamber used for the real experiment. Its shape is similar to the first prototype in Fig. 3. The new chamber has improved gas-tightness compared to the first one. It also serves as a glovebox as in Fig. 3 for deliquescent CsI phototachode to be handled in dry environment.

Figure 4 is a picture of a CsI photocathode evaporated on 100 mm GEM. The evaporation was done by Hamamatsu photonics and done by ourselves. The quantum efficiency of CsI photocathode is displayed in Fig. 5. The green points show quantum efficiency for an old photocathode. By adjusting the evaporation parameters, improved photocathodes were

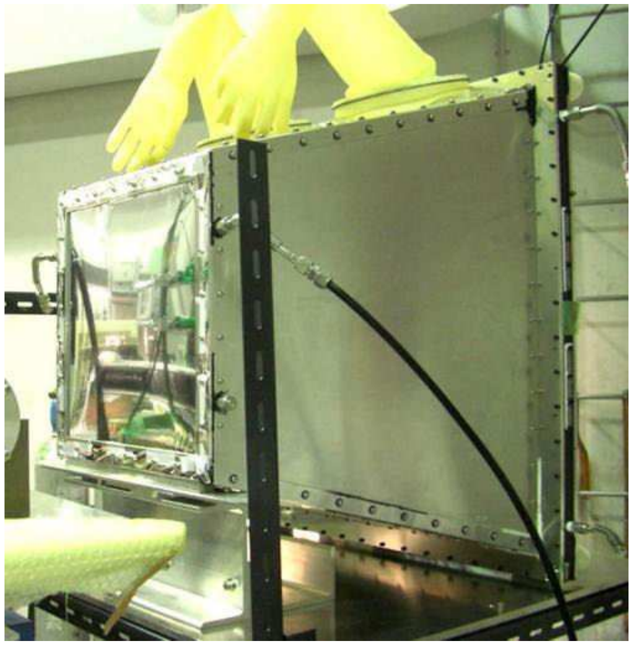

Figure 3: 1st version of prototype of HBD. A pair of gloves are equipped so the chamber itself can serve as a glovebox.

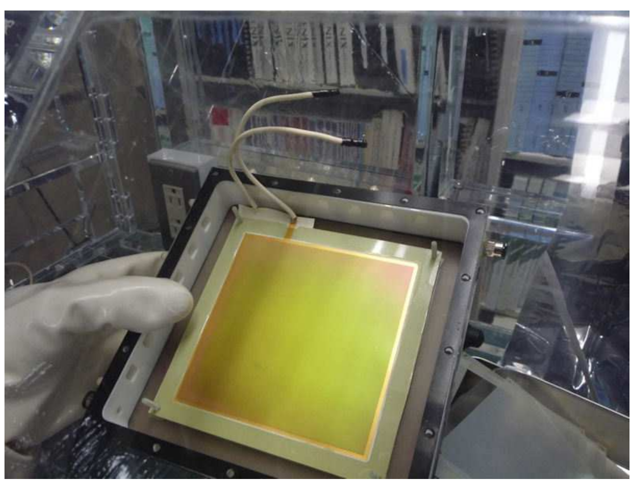

Figure 4: Picture of a CsI photocathode evaporated on 100 mm-GEM.

obtained with better quantum efficiencies shown with the red and the orange points. Their efficiencies are comparable level as that of the BNL photocathode.

A test experiment using electron beam was performed at ELPH. We successfully observe

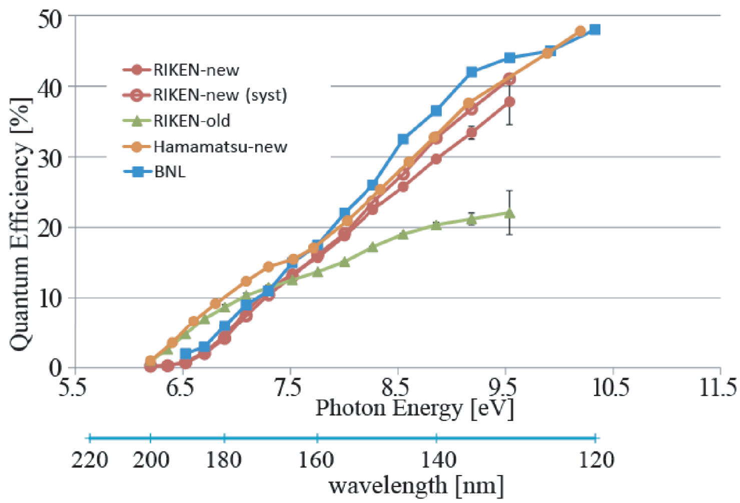

Figure 5: Quantum Efficiency of the photocathode.

Čerenkov radiation with 100mm GEM.

For the test experiment, we prepare 300 mm GEM and its design is the same for the real experiment. Figure 6 shows 300 mm LCP-GEM which works successfully in the laboratory.

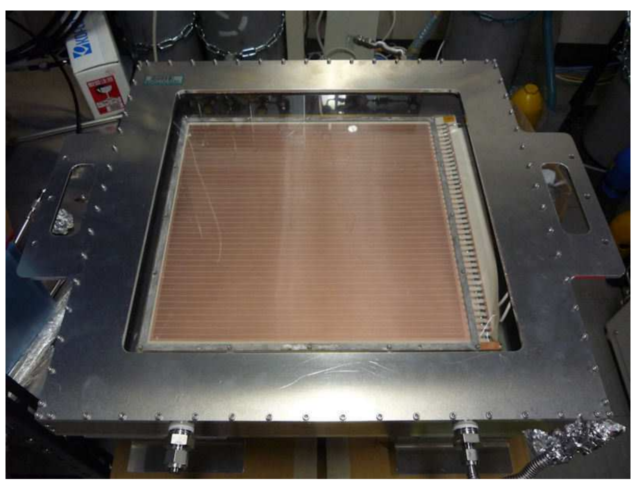

Figure 6: 300 mm LCP-GEM in a test chamber.

2.3 GEM Tracker

GEM Tracker consists of three layers of position-sensitive GEM chambers. As shown in Fig. 7, three standard-type GEMs made with polyimide (PI) are stacked in a chamber to amplify the electrons. The amplification gas is Ar/CO_2 (70/30) mixture and the typical operation gain is 1×10^4. The signal read out with the thin two-dimensional strip read-out board. Required position resolution of 100 μm is already achieved for the electron beam with an intensity of $\sim$ 100 Hz/cm^2 in the test experiment at ELPH.

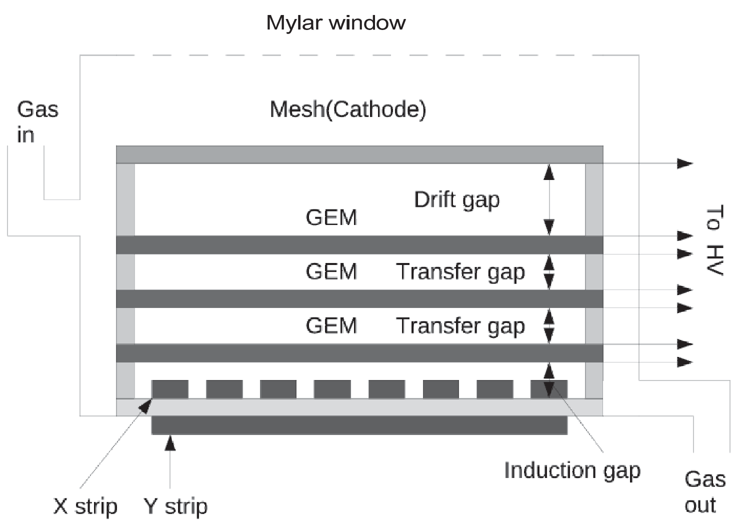

Figure 7: Schematic view of the GEM chamber.

3 Test Experiment

3.1 Test of HBD

We need π^- and e^- to understand the performance of the detector. We prepare two trigger logics, one for π^- and the other for e^-. We will obtain charge distributions for π^- and e^-, and do bias field scans to optimize the efficiency for electrons and the rejection power for pions.

Figure 8 displays the setup of the experiment. A trigger scintillator and two Gas Čerenkov counters are located upstream of the test setup. Then GEM Tracker setup and HBD setup follows. In the most downstream of the HBD setup, we place a Lead Glass Calorimeter(LG). Two stages of Gas Čerenkov counters (GCs) and LG are used for the strict identification of electron. We expect we can borrow the GCs from KEK while the LG is prepared by ourselves.

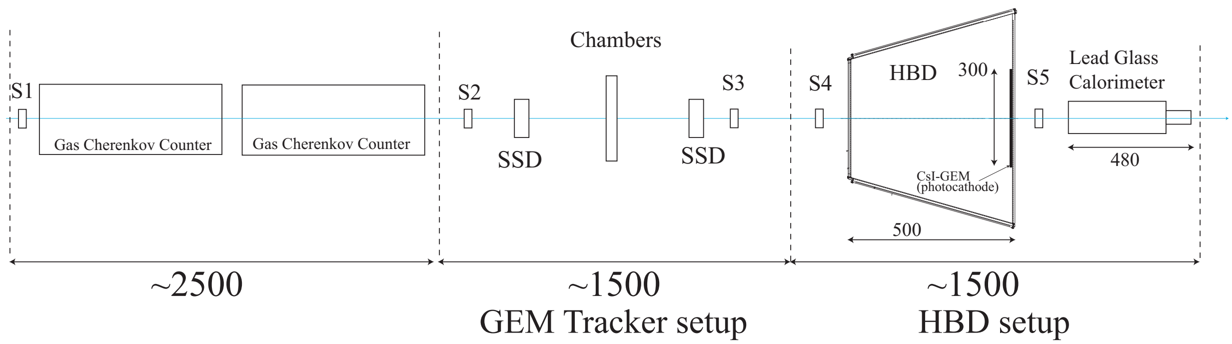

Figure 8: Setup for the test experiment.

The HBD is sandwiched by 1 cm × 1 cm trigger scintillators to restrict the beam size and contain the Čerenkov blob within the readout area. The readout pad has hexagonal shape with an edge of 17 mm and the Čerenkov blob is about the same size. The center and neighboring seven pads are readout and summed to obtain the Čerenkov radiation.

We require π^- and e^- beams with momenta of about 1 GeV/c. We assume beam rate of 5×10^5/spill for π^-, e^-/π^- ratio of about 1/100, duty factor of about 10 % and beam spot size of about 1 cm × 1 cm. Therefore, we assume 5×10^3/spill for e^-. The rate capability of DAQ prepared for test experiment is about 100 Hz. Therefore, if the assumption is correct, the rate will be determined by the DAQ capacity.

We need twelve hours of beam running for a bias field scan. Additional twelve hours will be spent with a different GEM gain. After that, we replace the photocathode with another and do the scan again. The photocathode replacement will take two days including gas flow to dry the chamber.

3.2 Test of GEM Tracker

The GEM Tracker consists of three GEM chambers, the size is 100 mm × 100 mm, 200 mm × 200 mm, and 300 mm × 300 mm for each.

The rate capability of GEM chambers should be tested using pion beam. The requirement is 5 kHz/mm^2 of pions which is expected at the most forward region of the proposed E16 spectrometer. The expected rate at K1.1BR is $5 \times 10^5/(\sim 4\ \text{cm}^2)$/spill $\sim$ 0.5 kHz/mm^2, which is less than the requirement. However, as the first step, we would perform the test in this occasion.

In the test, we would increase the beam rate from 10^2/spill to 10^6/spill gradually and check the stability and the position resolution. The GEM chamber is located between Silicon Strip Detectors (SSDs) and the hit position on the chamber is determined by the detectors.

4 Requests

4.1 Preparation Area

For the preparation, we need an area of 8 m $\times$ 6 m for HBD and GEM Tracker. For HBD we bring a CLASS-1000 clean booth with a size of 2 m $\times$ 2 m, and build it in the preparation area. It is preferable that the area is near the experimental area, because we want to minimize the time that HBD spends without gas flow. If such a large area is not available near the experimental area, we will need at least 3 m $\times$ 4 m area including the clean booth near the experimental area for HBD, in addition to the required area mentioned above. In the preparation room, we need non-flammable gas cylinders to dry the chamber, to protect CsI photocathode, to test GEMs, and to blow off dusts. We request stands for six gas cylinders in the preparation area, five for HBD, one for GEM Tracker.

4.2 Experimental Area

Figure 8 displays the setup of the test experiment at K1.1BR. We need about 1.5 m for HBD setup, 1.5 m for GEM Tracker setup. In addition to the spaces mentioned above, we need two Gas Čerenkov counters. We need to negotiate with the TREK group and the ArTPC group on the experimental setup. We request stands for seven gas cylinders in the experimental area, six for HBD, one for GEM Tracker.

4.3 Beam Time Request

We require π^- beam with a momentum of about 1 GeV/c. Requested beam schedule is summarized in Table 1. We define the beam coming date as D-day, which should be assigned us later than April 15, 2015. We bring our equipments to J-PARC seven days before the beam (D-7). It is preferable that three days before beam experiments (D-3), HBD chamber is placed in the experimental area with a gas flow to dry the chamber.

We require 24 hours of beam time for circuit setup (D-day). For HBD, we plan to test two photocathodes and we need two 12-hour shifts of beam running to complete a evaluation for each photocathode (HBD-1 $\sim$ HBD-4). We require 48 hours for photocathode replacement including gas flow to dry the chamber.

For GEM Tracker, we test the stability and the position resolution of three sizes of chambers, for some beam rates from 10^2/spill to 10^6/spill, with vertically injected tracks and angled tracks (0°, 15° and 30° from the perpendicular line of the GEM chamber).

First, the test of 100 mm chamber takes three 12-hour-shifts as shown in the Table 1 (Tracker-1 $\sim$ Tracker-3). After that, in the two-days of HBD gas-flow term, 12-36 hours are used to test the 200 mm $\times$ 200 mm and 300 mm $\times$ 300 mm chambers, only for a few selected combinations of beam rates and track angles (Tracker-4 $\sim$ Tracker-6).

DAY	day shift	night shift
D−7	Bring equipments to J-PARC	
D−3	HBD in exp. area.	
D−2	HBD gas flow	
D−1	Setup in experimental area.	
D-day	Circuit setup (w/ beam)	
D+1	Tracker-1	HBD-1
D+2	Tracker-2	HBD-2
D+3	Tracker-3	Tracker-4
D+4	Tracker-5	Tracker-6
D+5	HBD-3	HBD-4
D+6	Evacuate the area	

Table 1: Beam schedule.

References

[1] `http://j-parc.jp/Nucl/Part/pac_0606/pdf/p16-Yokkaichi_2.pdf`

[2] A. Kozlov *et al.*: Nucl. Instr. and Meth. **A523** (2004) 345.

[3] F. Sauli: Nucl.Instr. and Meth. **A386** (1997) 531.

[4] B. Azmoun *et al.*: IEEE Trans. on Nucl. Sci. **56** (2009) 1544.