Test of GEM Tracker, Hadron Blind Detector and Lead-glass EMC for the J-PARC E16 experiment

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§1. Introduction

The J-PARC E16 experiment[1)] measures the e^+e^- decays of light vector mesons in nuclei and modification of the invariant mass spectra systematically for the purpose of exploring the breaking and restoration of the chiral symmetry at nuclear density. The stage-1 approval was obtained in 2007, and the detector R&D has been performed, including some test experiments with electron beam at ELPH, Tohoku Univ., SPring-8/LEPS and with pion beam at J-PARC (T43 and T47).

Here we propose tests of GEM (Gas Electron Multiplier) Tracker, Hadron Blind Detector (HBD) and lead-glass electro-magnetic calorimeter (LG). We request to use the K1.1BR beam line with the beam time of 7 days. The requested time includes 1.5 days for the detector setup and the second beam tuning, and 5.5 days of the detector test with beams. The detail of the beams are as follows: π^- beam of 1 GeV/c for 100 hours, π^- beam of 0.8 GeV/c for 24 hours and π^- beam of 0.4 GeV/c for 44 hours.

All the detectors can be located in-line at the beam line. We expect that the requested beam time should be on the latter part of June 2013.

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§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.[2] Typical thickness of the foil and the electrodes is 50 μm and 4 μm, respectively. The typical hole diameter is 70 μm and the hole pitch is 140 μm. A high voltage, typically 300-500 V, is applied between the electrodes in amplification gas. Therefore the electrons are amplified by passing through the small hole in which the strong electric fields exists. GEM is a key apparatus for our experiment which requires the data taking under very high rate condition such as 5 kHz per mm^2.

2.2. *GEM Tracker*

GEM Tracker consists of three layers of position-sensitive GEM chambers. In order to track the particles in the magnetic field, we are planning to use three types of GEM Tracker, whose sizes are 100 mm$\times$100 mm, 200 mm$\times$200 mm, and 300 mm$\times$300 mm for each.

As shown in Fig. 2.2, three standard-type GEMs made with polyimide are stacked in a chamber to amplify electrons. The amplification gas is Ar/CO2 (70/30) mixture and the typical operation gain is 1×10^4. The signal readout is used with the thin two-dimensional strips. Our requirement for the position resolution, 100μm, has already achieved for the electron beam with an intensity of about 100 Hz/cm^2 in the test experiment at ELPH and for the different incident angles up to 30 degree. Through the previous experiments at J-PARC K1.1BR beam line (T47 on Dec. 2012 and Jan. 2013), we confirmed that required position resolution (less than 100 μm) is achieved with new readout system (APV25-S1+APVDAQ)[6] and a beam incident angle of 30 degree.

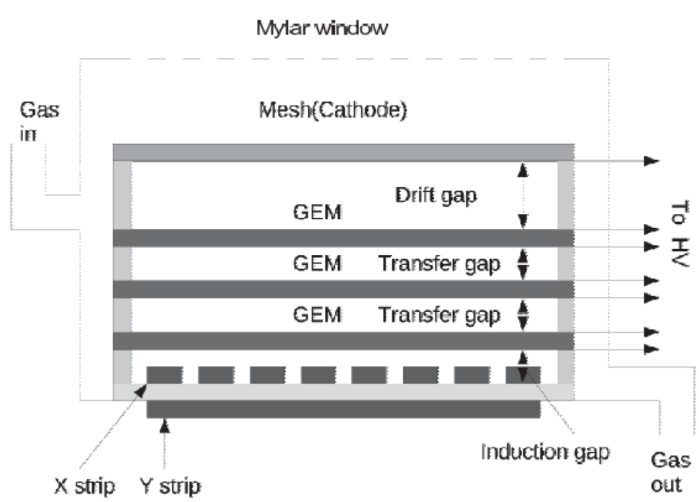

Fig. 1. Schematic view of the GEM chamber for the GEM tracker.

2.3. *Hadron Blind Detector*

The Hadron Blind Detector (HBD) is a gas Cherenkov counter for hadron rejection. The HBD uses CsI photocathode GEM detectors to detect Cherenkov photons produced by relativistic particles in a CF_4 radiator in order to separate electron/positron and other particles.

A schematic drawing of the photocathode is shown in Fig. 2.3. The CF_4 radiator length exists on the top side of this figure with the thickness of 50 cm. A generated Cherenkov photon in the radiator is converted into a photoelectron by the CsI evaporated on top of the GEM. The thickness of GEM is 50 μm 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 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.

In the previous J-PARC T47 experiment, we made a new readout pad which can distinguish the photoelectron by the Cherenkov light from the ionization signal of pions more easily using the charge cluster size. From the result, it was confirmed that we can achieve a rejection power of 100 with an efficiency of 70 %.

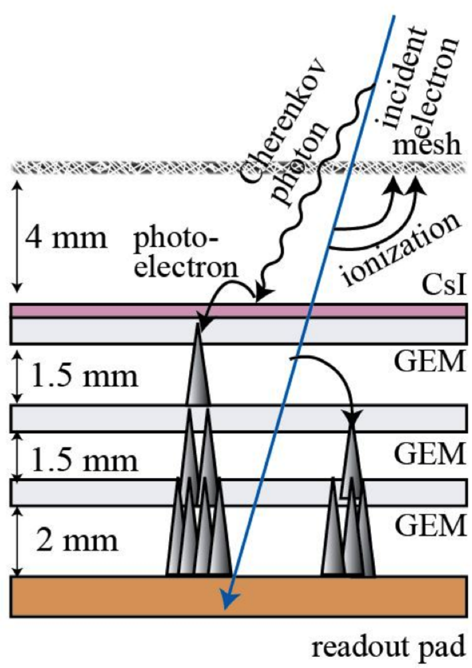

Fig. 2. Schematic view of the HBD detector.

2.4. *Lead-glass calorimeter*

The LGs, which were employed in the TOPAZ experiment at KEK-TRISTAN have been reused for the J-PARC E16 experiment. They have been kept in KEK after the deconstruction of the TOPAZ spectrometer.

One LG is composed of five parts: a lead-glass block, light guide, flange, photomultiplier (PMT), and 2 mm thick magnetic shield case made of PB permalloy. PB is a nickel iron soft-alloy containing 40-50% nickel. All the lead-glass blocks have an identical shape: they are 340 mm in length, 122 mm by 113 mm in the front, and 122 mm by 135 mm at the back. The lead-glass material is SF6W. The radiation length of the block is 1.7 cm (equivalent to 20 radiation lengths). The other physical properties and chemical components of the blocks are described by Kawabata *et al.*[5) The end face of a block was glued to a ange made of 20 mm thick high manganese steel, and the lead-glass block was supported by the only glue joint.

In the T47 expriement, we took data of the LG counters with the hadron beam. As shown in Fig. 2.4, the LG counter was placed on the rotation table and estimated e/π separation power changing the beam incident angles. From this data, we confirmed a rejection factor of 10 for the 0.4 GeV/c electron.

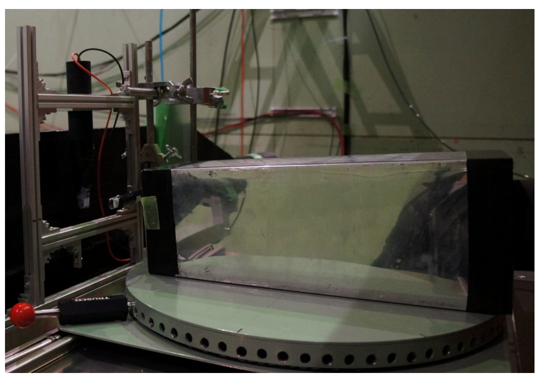

Fig. 3. Picture of the LG counter in the T47 experiment.

§3. Test experiment

3.1. *Experimental setup*

Figure 3.1 shows the setup of the experiment. Two Gas Cerenkov counters, GC1 and GC2, and trigger scintillators, GS1 and GS2, the scintillator to measure the time-of- ight, TOF1 are located upstream of the test setup followed by the setup of the GEM Tracker, HBD and LG. Two scintillators, S1 and S2, are placed on in front and in rear the GEM Tracker. The GEM chamber is located between Silicon Strip Detectors (SSDs), and the hit position on the chamber is determined by the detectors.

The beam positions on the GEM Tracker, HBD and LG are defined by each finger counters, S1-3, HS1-3 and LS1-2. We assume that the beam rate of 5×10^5/spill for π^-. According to the results for our test experiments, J-PARC T43 and T47, e^-/π^- ratio is about 1/3, thus we can take the data for electron and pion at the same time. The rate capability of DAQ prepared for test experiment is several 100 Hz. Therefore, the triggered event rate would be determined by our DAQ capacity.

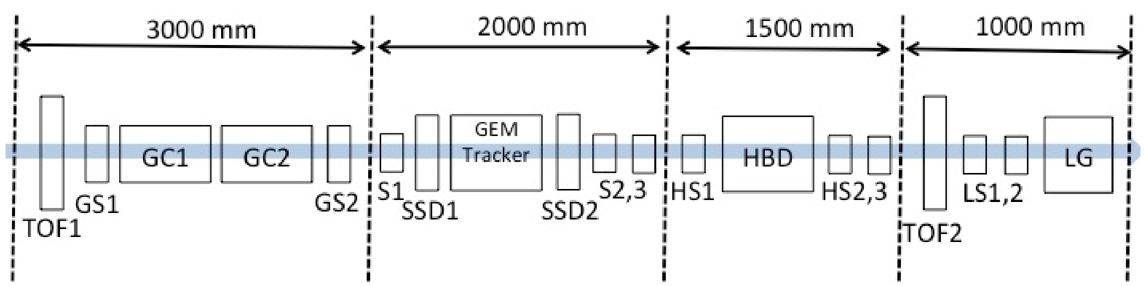

Fig. 4. Schematic of experimental setup for the proposed experiment.

3.2. *Test of GEM Tracker*

The basic studies for the 100 mm × 100 mm GEM using hadron beam were done in the T43 and T47 experiments. This time, we intend to operate 200 mm × 200 mm and 300 mm × 300 mm GEMs with the π^- beam. For these GEMs, we would check the stability and the position resolution changing the operation voltage of the GEM and beam hit position. The GEM is located between Silicon Strip Detectors (SSDs) and the hit position on the GEM is determined by the SSDs. In addition to these tests, the direct signal readout from the 300 mm × 300 mm GEM foil will be tested. This signal is plannning to be used as a trigger in the E16 expriment. The beam rate for this test is an order of 10^5 per spill with the trigger rate of several 10^2 Hz.

3.3. *Test of HBD*

We optimized the hole size of the GEM. It was tested in the T47 experiment and the gain was increased. At that time, the size of the GEM was 50 mm $\times$ 50 mm as a test, and it is necessary to test 300 mm $\times$ 300 mm size GEM for the prototype of the actual E16 experiment. The prototype GEM will be tested with a new chamber and CF_4 gas. The main purpose of this expriment is the operation of the 300 mm GEM with the hadron beam, and the electron efficiency and hadron rejection factor will be estimated. Though the above test will be done with the beam rate of several 10^5 per spill, operation under the high beam rate will be also tested. We are planning to operate the HBD under the almost maximum beam rate at the K1.1BR (an order of 10^6 per spill).

3.4. *Test of LG*

We took some data for e/π separation power changing beam incident angles and arrangement of two or three LGs in the T47 expriement. The radiator length of the LG used in the T47 experiment was 34 cm, and in this time we will test other LG whose radiator length is 12cm. This shorter one will also be used in the E16 experiment togather with the longer one. The basic data such as the dependency on the beam incident angle or the hit positions will be tested. The LGs is placed on the rotation table just after the TOF2 counter. The beam rate is 10^5 per spill, similar to the other detector tests. In order to estimate the rejection power for some momentum values in the E16 particle acceptance, the test will be done with the 0.4 GeV/c, 0.8 and 1.0 GeV/c beams.

§4. Requests

4.1. *Preparation area*

For the preparation, we need an area of about 12 m$\times$8 m in total for the the detector preparation and data taking. It is preferable to put them nearby experimental area. For our DAQ PC and the preparation space of the detectors, we request 5 desks of about 1.8 m$\times$0.8 m and 8 chairs. For the HBD test chamber, we bring a CLASS-1000 clean booth with a size of 2 m$\times$2 m, and build it outside the experimental area. Finally, we also request the space to put the stands for five gas cylinders just aside the K1.1BR experimental area, two for the HBD test chamber, three for GEM Tracker. We prepare the stands by ourselves.

4.2. *Experimental area*

Figure 3.1 shows the setup of the test experiment at K1.1BR. The setup is quite similar to J-PARC T43 and T47 experiments.[3),4)] We need about 2.0 m for the GEM Tracker setup, 1.5 m for the HBD setup, and 1.0 m for the LGs. In addition to the spaces mentioned above, we need about 2.5 m for two Gas Cherenkov counters and trigger counters, GS1, GS2, TOF1, and TOF2 on upper stream of K1.1BR beam line. We use Gas Cherenkov counters with dry air, thus, one dry gas cylinder and its stand is put in the area.

4.3. *Beam time*

Our beam request is summarized in Table I. We request eight days in total for the beam time in the latter part of June 2013 (run 50a). The first 36 hours of our beam time is used for circuit setup and the second beam tuning using 1 GeV/c π^- beam. Our detectors are tested with the following beam: π^- beam of 1 GeV/c for 64 hours, π^- beam of 0.8 GeV/c for 24 hours and π^- beam of 0.4 GeV/c for 44 hours. In order to reduce the multiple scattering of particles, the test of the GEM Tracker is performed with π^- beam of 1 GeV/c. The HBD and LG are operated with π^- beams of 0.4, 0.8 and 1 GeV/c which are typical momenta of the particles in the E16 experiment. In particluar, 0.4 GeV/c will be set as the trigger threshold for the momentum.

Table I. Beam time request

Particle	Momentum [GeV/c]	Time [hours]	Comment
π^-	1.0	36	Trigger and beam tuning
π^-	1.0	64	Detector test
π^-	0.8	24	Detector test
π^-	0.4	44	Detector test
total		168	

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