# Test of Lead-glass EMC and GEM Tracker for the J-PARC E16 Experiment

Y. Aramaki[1,*], K. Aoki[1] , H. En'yo[1] , H. Hamagaki[2] , J. Kanaya[1] , K. Kanno[3] , D. Kawama[1] , A. Kiyomichi[4] , Y. Komatsu[3] , S. Masumoto[3] , R. Muto[5] , W. Nakai[3] , M. Naruki[5] , Y. Obara[3] , K. Ozawa[5] , F. Sakuma[1] , S. Sawada[5] , M. Sekimoto[5] , T. Shibukawa[3] , K. Shigaki[6] , T.N. Takahashi[1] , Y.S. Watanabe[3] , S. Yokkaichi[1] (J-PARC E16 Collaboration)

[1] *RIKEN Nishina Center for Accelerator-Based Science, Wako, Saitama 351-0198, Japan*

[2] *Center for Nuclear Study, Graduate School of Science, University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan*

[3] *Department of Physics, University of Tokyo, Hongo, Bunkyo, Tokyo 113-0033, Japan*

[4] *Japan Synchrotron Radiation Research Institute 1-1-1, Kouto, Sayo-cho, Sayo-gun, Hyogo 679-5198 Japan*

[5] *KEK, High Energy Accelerator Research Organization, Tsukuba, Ibaraki 305-0801, Japan*

[6] *Hiroshima University, Kagamiyama, Higashi-Hiroshima 739-8526, Japan*

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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 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 tests of GEM (Gas Electron Multiplier) Tracker, and lead-glass calorimeter (LG). We have already performed some test experiments with electron beam at ELPH, Tohoku Univ., SPring-8/LEPS and with pion beam at J-PARC.

*Contact person, yoki.aramaki@riken.jp

We would like to use the K1.1BR beam line. We request the beam time for six days. It takes 1.5 days to perform the setup and the second beam tuning. Our detectors are tested with the following beam: $\pi^-$ beam of 1 GeV/$c$ for 84 hours, $\pi^-$ beam of 0.4 GeV/$c$ for 12 hours, $\pi^+$ beam of 1 GeV/$c$ for 9 hours, and $\pi^-$ beam of 0.7 GeV/$c$ for 3 hours.

All the detectors can be located in-line at the beam line. Six days of beam time is requested as described above. We expect that the requested beam time should be on December 2012.

# 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 $\mu$m and 4 $\mu$m, respectively. The typical hole size is 70 $\mu$m and the distance between holes is 140 $\mu$m. 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.

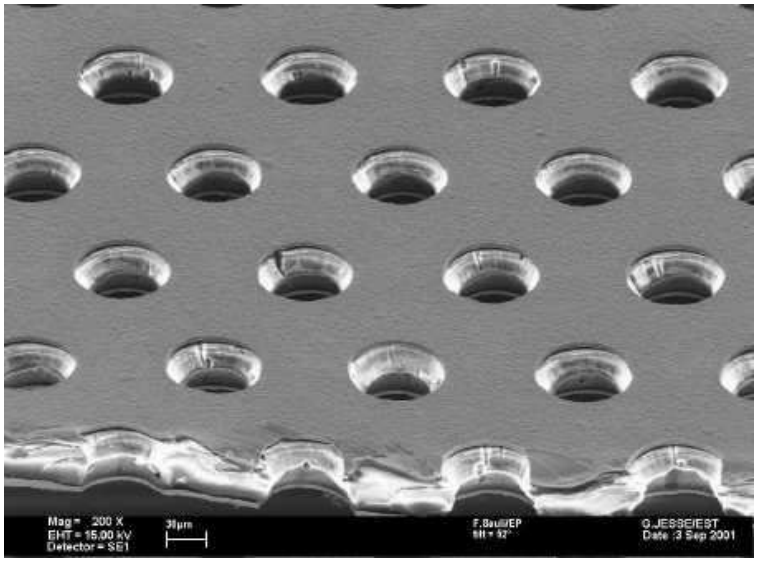


Figure 1: Photograph of typical GEM.

## 2.2 GEM Tracker

GEM Tracker consists of three layers of position-sensitive GEM chambers, whose size is 100 mm × 100 mm, 200 mm × 200 mm, and 300 mm × 300 mm for each.

As shown in Fig. 2, three standard-type GEMs made with polyimide are stacked in a chamber to amplify electrons. The amplification gas is $Ar/CO_2$ (70/30) mixture and the typical operation gain is $1 \times 10^4$. The signal readout is used with the thin two-dimensional strips. Our required position resolution, 100 $\mu$m, has already achieved for the electron beam with an intensity of $\sim$ 100 Hz/cm$^2$ in the test experiment at ELPH and for the different incident angles up to 30 °.

At J-PARC K1.1BR beam line on June 2012, we comfirmed that 1) the newly developed large-size thin readout board (mesh type) works well, and that 2) our required position resolution, 100 $\mu$m, is kept using a preamp board which has shorter time constant (80 ns) than that of the formerly used one (1 $\mu$s). The shorter time constant is needed to avoid the pile-up of signals for the most forward region at the E16 experiment where the hit rate of 700 kHz is expected for a readout strip.

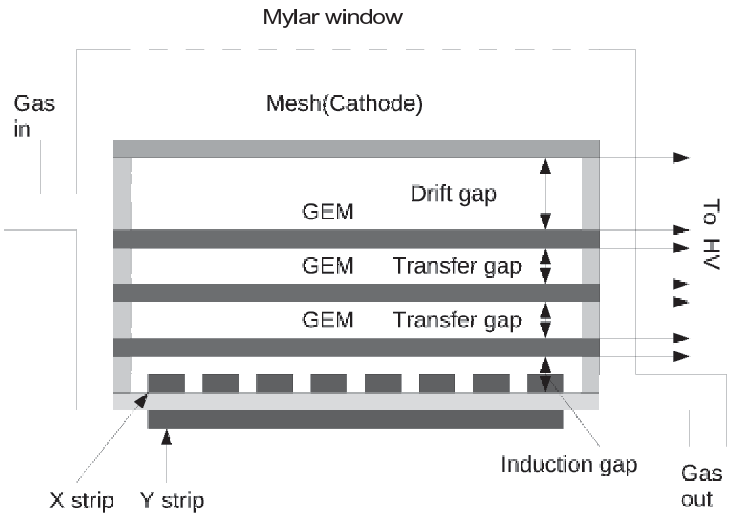


Figure 2: Schematic view of the GEM chamber.

## 2.3 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 in Ref. [4]. The end face of a block was glued to a flange made of 20 mm thick high manganese steel, and the lead-glass block was supported by the only glue joint. More detailed information on the LG is available in Ref. [4].

# 3 Test Experiment

## 3.1 Experimental Setup

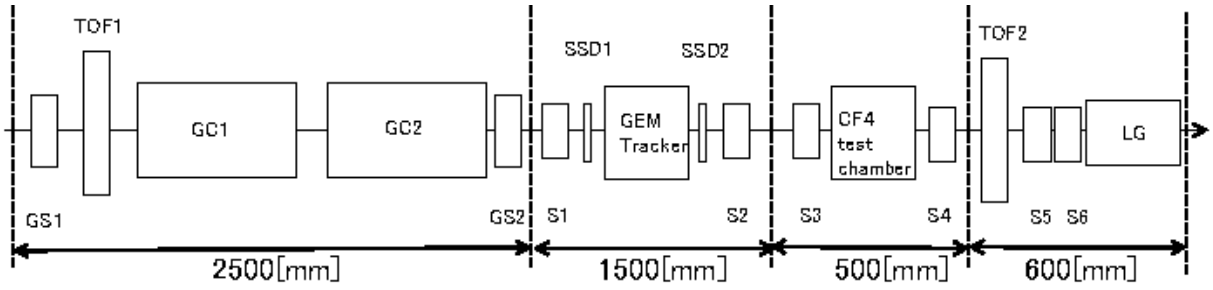


Figure 3: Setup for the test experiment.

Figure 3 shows the setup of the experiment. Two Gas Čerenkov counters, GC1 and GC2, and trigger scintillators, GS1 and GS2, the scintillator to measure the time-of-flight, TOF1 are located upstream of the test setup. Then, the setup of the GEM Tracker and LG follows. 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. Then two scintillators, S3 and S4, are placed on the $CF_4$ test chamber as well. In order to define the small beam size, the scintillator, S5 and S6, is placed on the LG. TOF2 is in front of the S5 and S6 counter.

We are going to ask KEK and TREK group to borrow GCs, GS1, GS2, TOF1, and TOF2. The beam size incoming on the surface of the LG is defined by 1 cm $\times$ 1 cm trigger scintillator, S5 and S6, in front of the LGs.

We assume that the beam rate of $5\times10^5$/spill for $\pi^-$. According to the results for our test experiment, J-PARC T43, $e^-/\pi^-$ 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 about 100 Hz. Therefore, the triggered event rate would be determined by our DAQ capacity.

### 3.2 Test of GEM Tracker

In the test, the GEM Tracker of 100 mm × 100 mm would be measured with new preamp board, APV25S1[1] chip. In addition to this test, we optimize the operation gain of the GEM Tracker and the drift-gap length for the preamp, and we evaluate the position resolutions as a function of the gain and different incident angles of the beam for different drift-gap lengths.

We also measure the energy loss of the pion in $CF_4$ with the $CF_4$ test chamber in which three GEMs are stacked.

### 3.3 Test of LG

In order to obtain the incident angular dependence of the $e/\pi$ separation, we perform the test for the LG.

Two or three LGs are placed on the rotating table, and we obtain the response of pion and electron for the LG. The beam rate is similar to the measurement of the GEM Tracker. In addition to the data set of 1 GeV/$c$ beam, we take the data with the beam of about 0.4 GeV/$c$ and 0.7 GeV/$c$ for the LG. For J-PARC E16 experiment, the threshold momentum of the triggered particles is assumed to set 0.4 GeV/$c$, thus we need to take the basic data for the LG. For the beam of 0.7 GeV/$c$, we don't have any data of the LGs for this momentum range, thus we expect to measure the performance of the LGs.

## 4 Requests

### 4.1 Preparation Area

For the preparation, we need an area of about 12 m × 8 m in total preparing for the $CF_4$ test chamber and the GEM Tracker and so on.

For putting the measuring equipments, we request an area of 3 m × 3 m. It is preferable to put them nearby experimental area.

For our DAQ PC and the preparation space of the GEM Tracker, we request 4 desks of about 1.8 m × 0.8 m and 12 chairs. For the $CF_4$ test chamber, we bring a CLASS-1000 clean booth with a size of 2 m × 2 m, and build it outside the experimental area.

Finally, we also request the space to put the stands for five gas cylinders in the preparation area, two for the $CF_4$ test chamber, three for GEM Tracker. Also, we prepare the stands by ourselves.

[1] Developed for the CMS silicon detector

### 4.2 Experimental Area

Figure 3 shows the setup of the test experiment at K1.1BR. The setup is quite similar to J-PARC T43 experiment [2]. We need about 1.5 m for the GEM Tracker setup, (0.5 m for the HBD setup), and 0.6 m for the LGs. In addition to the spaces mentioned above, we need about 2.5 m for two Gas Čerenkov counters and trigger counters, GS1, GS2, TOF1, and TOF2 on upper stream of K1.1BR beam line. We use Gas Čerenkov counters with dry air, thus, one dry gas cylinder and its stand is put in the area.

### 4.3 Beam Time Request

Our beam request is summarized in Table 1. We request six days in total for the beam time. The first 36 hours of our beam time is used for circuit setup and the second beam tuning. Our detectors are tested with the following beam: $\pi^-$ beam of 1 GeV/$c$ for 84 hours, $\pi^-$ beam of 0.4 GeV/$c$ for 12 hours, $\pi^+$ beam of 1 GeV/$c$ for 9 hours, and $\pi^-$ beam of 0.7 GeV/$c$ for 3 hours.

In order to reduce the multiple scattering of particles, the test of the GEM Tracker is performed with $\pi^-$ beam of 1 GeV/$c$. For the LG, $\pi^-$ beams of 0.4, 0.7, 1 GeV/$c$ are used. The trigger threshold of the momentum at E16 experiment would be set to 0.4 GeV/$c$, thus we need to take the data of 0.4 GeV/$c$ beam. We would like to evaluate the momentum dependence of the LG, thus we also need 0.7 GeV/$c$ beam. In order to understand the background particles from the beam dump, we also request $\pi^+$ beam of 1 GeV/$c$.

| Particle | Polarity | Momentum [GeV/$c$] | Time [hours] |
|---|---|---|---|
| $\pi$ | $-$ | 1.0 | 36 |
| $\pi$ | $-$ | 1.0 | 84 |
| $\pi$ | $-$ | 0.4 | 12 |
| $\pi$ | $+$ | 1.0 | 9 |
| $\pi$ | $-$ | 0.7 | 3 |

Table 1: The table of our beam request. The first 36 hours are used for the setup and the second beam tuning.

# References

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

[2] http://j-parc.jp/researcher/Hadron/en/pac_1201/pdf/KEK_J-PARC-PAC2011-07.pdf

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

[4] S. Kawabata *et al.*: Nucl. Instr. Meth., A**270**, 11 (1988).