R&D proposal for an Endcap TOF and TRD for Identifying electrons at EIC

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DEPARTMENT/DIVISION	**BNL/USA and USTC/China**	**DATE**	**07/12/2014**
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TITLE OF PROPOSAL	**GEM based TRD for Identifying electrons at EIC**

PROPOSAL TERM (month/year) From **01/2014** Through **07/2014**

SUMMARY OF PROPOSAL

Resubmission with status report and no additional fund request in July 2014.

In the last few months, we have accomplished the following.
1) prepare a NIMA paper on the results of cosmic ray test for submission
2) use the available fund to partially support a postdoc on continuing the test and collaboration between BNL R&D and USTC R&D. focus on obtaining results on tracking and material effect using the GEM modules (GMT) installed in STAR.
4) report status on large-area thick GEM test in USTC
5) plan
(move the temporary lab for TRD test back to the renovated lab in the physics department)

Description of Project (in the initial proposal):

Electron identification is crucial in an EIC detector for identifying the out-going scattered electrons from the incident electron beam. Furthermore, precise kinematics from these electrons are necessary to determine the (x, Q^2) of the interaction. We propose to study the combined functionality of a Time-of-Flight detector (TOF) and a Transition Radiation Detector (TRD) at forward direction ($-3<\eta<-1$) behind low-material tracking detector to provide electron identification with high hadron rejection ($\sim>10^3$) over a wide momentum range (0.2 GeV/c<p<~10 GeV/c). In addition, the configuration also provides start time for the produced hadrons in TOF detectors in other locations and additional precise tracking points for hadron reconstruction in the case that the struck particle is a hadron.

We propose an R&D project to use GEM detector with $Xe+CO_2$ for detection of transition radiation and multi-gap resistive plate chamber as TOF detector. The goals are: a) study the GEM readout performance for dE/dx (TR) signals and its position resolution in the TPC-style readout with 3-4cm ionization chamber; b) investigate different GEM configuration (regular GEM vs Thick GEM) and its impact on tracking and dE/dx.

Expected Results:

We plan to build a prototype GEM chamber of $10x10cm^2$ sensitive area filled with $Xe+CO_2$ gas mixture and with an ionization chamber of 2-4cm. Different readout electronics will be investigated and should be able to provide multiple time bins in sequence along the drift direction. The study should provide dE/dx measurement for such a GEM chamber and assess whether it is sufficient for electron identification for EIC.

1) a draft of NIMA in preparation (see attached draft)

Our students from TRD project (Shuai Yang from USTC/China, Sabita Das from IOP/India, local high-school student Justin Hsien) have worked on a NIMA draft on the cosmic ray test on Thick GEM TRD prototype performance.

Cosmic ray test of Mini-drift Thick Gas Electron Multiplier for Transition Radiation Detector

Abstract

A thick-gas electron multiplier (TGEM) with an area of 10 cm × 10 cm having 11.3 mm ionization gap has been tested along with two regular gas electron multipliers (GEM) in a cosmic-ray test stand set up at Brookhaven National Laboratory (BNL). This TGEM is proposed as part of a transition radiation detector (TRD) for identifying electrons at an electron ion collider (EIC) detector. Through this cosmic ray test, we obtain an efficiency larger than 94% for the TGEM and spatial resolution better than 300 μm at the working high voltage(-3.65 kV). Thanks to its outstanding spatial resolution and thick ionization gap, the TGEM has excellent track reconstruction capabilities. The gain uniformity and stability of TGEM are also presented.

Key Words: EIC, TRD, TGEM, Cosmic ray test

2) Focus on using GMT installed in STAR for tracking and material effects on TRD performance

In this section, we have focused on using the GMT (the GEM chambers to monitor the TPC Tracking Calibration) as a tool to study the tracking and material effects on the combination of TPC hits and TRD hits outside the TPC. This will allow us to address the question and concerns raised by the committee about the material and tracking performance in the future TRD and TPC combination.

STAR has installed 8 GEM chambers with thin GEM foils and identical module configuration and readout as described in our prototype for TRD. The 8 modules were installed in STAR outside of the TPC outfield cage with 4 modules at around eta=0 and 4 at eta~=1. The picture shown with GMT modules inserted into 4 Time-of-Flight trays before the trays were installed in STAR outside of the TPC. Although the location is different from what the proposed TRD will be, the material budget and tracking quality are close to what we would expect for the future TRD at TPC endcap with new TPC readout design.

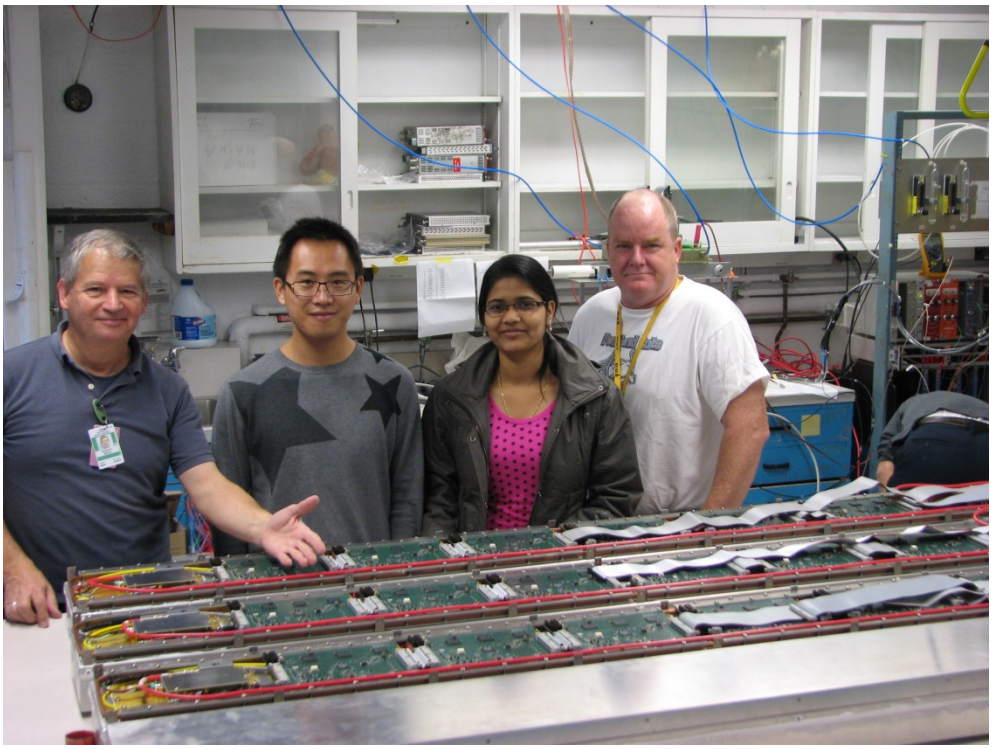


Figure 1. GMT modules inserted into the TOF trays at the TRD lab before installation in STAR.

GMT modules and TRD modules have been tested together extensively at the lab using cosmic ray. Performance of the GMT modules has been presented by the student at the RHIC/AGS and other meetings. See for example, poster by Sabita Das:
https://drupal.star.bnl.gov/STAR/system/files/gmt_poster_rhicags_21stJune_v2_0.pdf

The spatial resolution from GMT has been measured to be about 130um using cosmic ray test setup in the lab. Eight GMT modules have been installed in STAR. Their main purpose is to monitor the TPC calibration and correct the space-charge effect on TPC tracking. Since one of the main concerns is the tracking performance with the combination of TRD and TPC hits, we have focused in studying this impact using the existing GMT installed in STAR for the last two RHIC runs. Our newly hired postdoc (Dr Xin Li since April 2014) has focused his effort with other members in setting up the software infrastructure and constructing hits from GMT in association with track projection from TPC. For RHIC run 15, GMT has taken data in all three collision species (Au+Au at 15 and 200 GeV, and 3He+Au at 200GeV) at about 50Hz. The average hits in a RHIC Au+Au collision event is about 1 hit per module.
Fig.2 shows one of the event display of 3He+Au collisions with a track (in red) pointing to one of the GMT module.

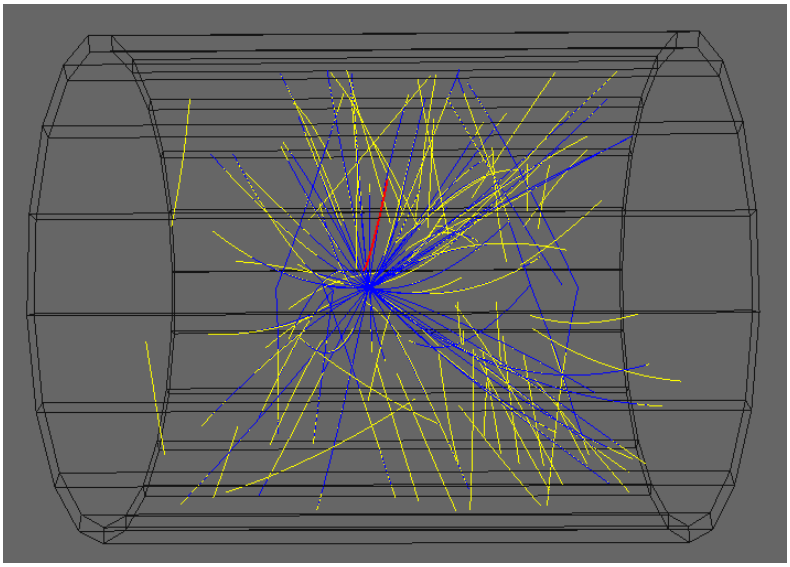


Figure 2. event display of 3He+Au collision with the track in RED pointing to one of the GMT module.

Fig.3 shows the geometry in x, y and z-axes in STAR detector coordinate system, and depicts the locations of the 8 GMT modules, and local coordinate shown in Fig.4 (local x and y axes).

Figure 3 GMT Global Position in STAR Detector Global Geometry

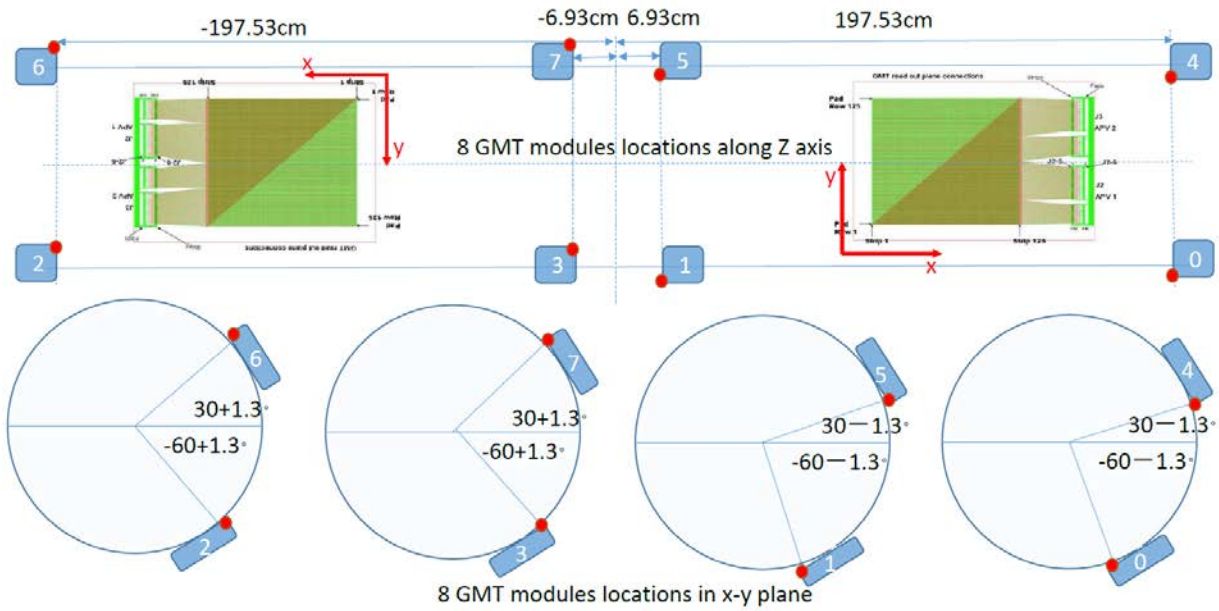


Figure 4. shows the correlation between position from TPC track projection and GEM hit cluster position. Seven of the eight modules are shown to work. With all the software and machinery setup, the next step is to align the modules relative to the TPC preciously, and optimize the best cluster algorithm for hit position. After this has been completed, we will then carry on with the performance of track pointing resolution and impact of material on combining TPC and TRD hits for tracking.

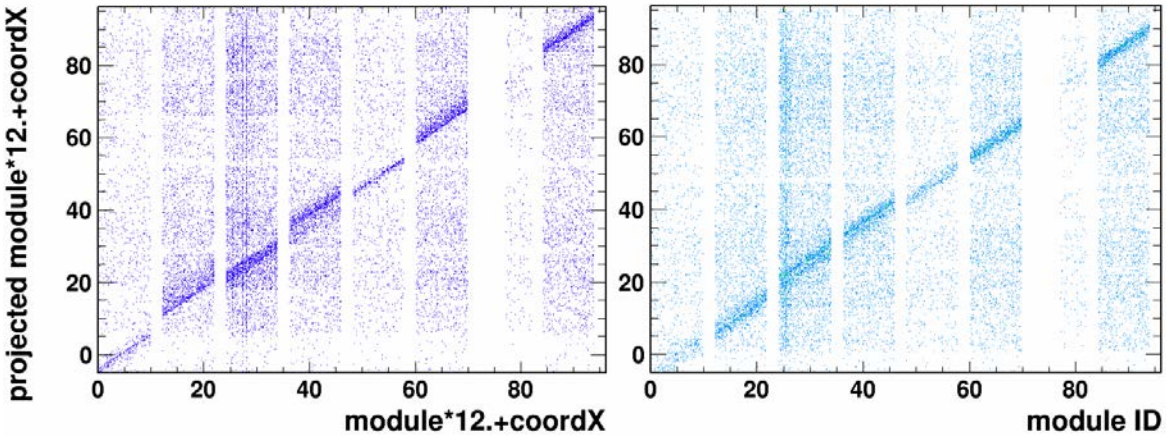


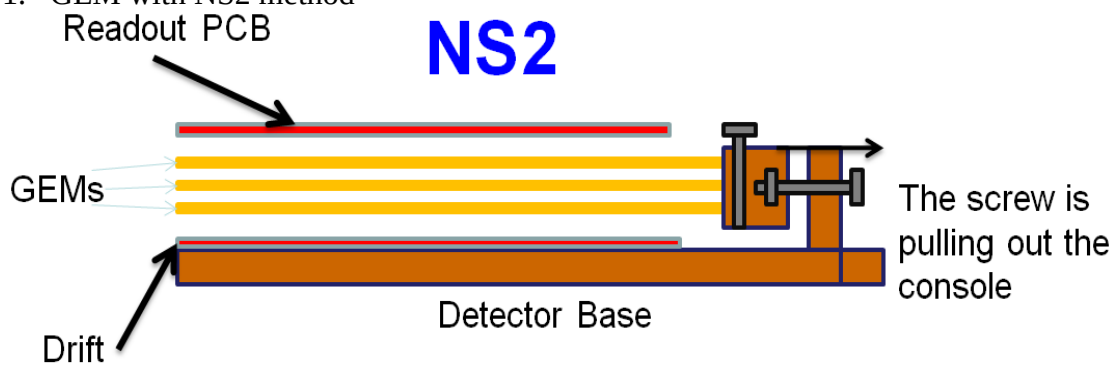
Figure 4. left panel: projected position (module ID*12+x) in cm vs the actual position from GMT hit (ID*12+x) in cm. Right panel is for the y-axis in the local module coordinate sytstem.

The plan is to use this for study of hit reconstruction, its resolution, and the combination of TPC hits and hits from GEM outside TPC. It is also possible to install a module at the endcap position where the actual TRD may locate.

3) Recent progress on large-size GEM R&D

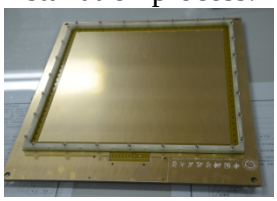
1. Keep on optimizing the NS2 method to construct large-size (30*30 cm^2 active area) GEM prototypes. New prototypes are produced and tested.
2. Gas gain and energy resolution scan over the whole active area of the GEM prototypes.
3. New readout (strip) PCB is designed with 2.5mm pitch to test the spatial resolution of GEM prototypes.
4. Preparation of building a large THGEM prototype (30*30 cm^2 active area) and new readout PCB design (0.8mm pitch, compatible with the test setup at BNL).

1. GEM with NS2 method



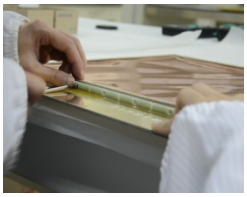
a) Fast – the whole construction procedure can be finished in 2 hours (rather than 3-4 days by using glue method)
b) Homogeneous – no inner supporter or structure within the NS2 frame, no dead area.
c) Replaceable – easy to maintain, reduced cost.

Installation process:

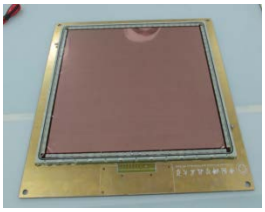


Install the NS2 frame

Mount the GEM foil to the NS2 frame



Tighten the foil



(Near-)finished module

2. Gain and Energy resolution test results

The HV chain is shown below. The active area of GEM prototype is divided into 36 pads (5*5 cm^2 each). The gas gain in Ar/CO_2(70/30) is measured with a scalar and a pico ammeter. In our test the HV varies from ~3700V to ~4400V. 1 pad is found to be problematic, while all other pads work normally. For areas of these 35 pads the HV can be up to 4400V, achieving a gas gain of 10^5. The gain uniformity at 4000V is good, with a standard deviation of 7.6%.

The energy resolution is also measured with a MCA. At 4000V the resolution is around 20%. The uniformity (standard deviation) is 5.2%.

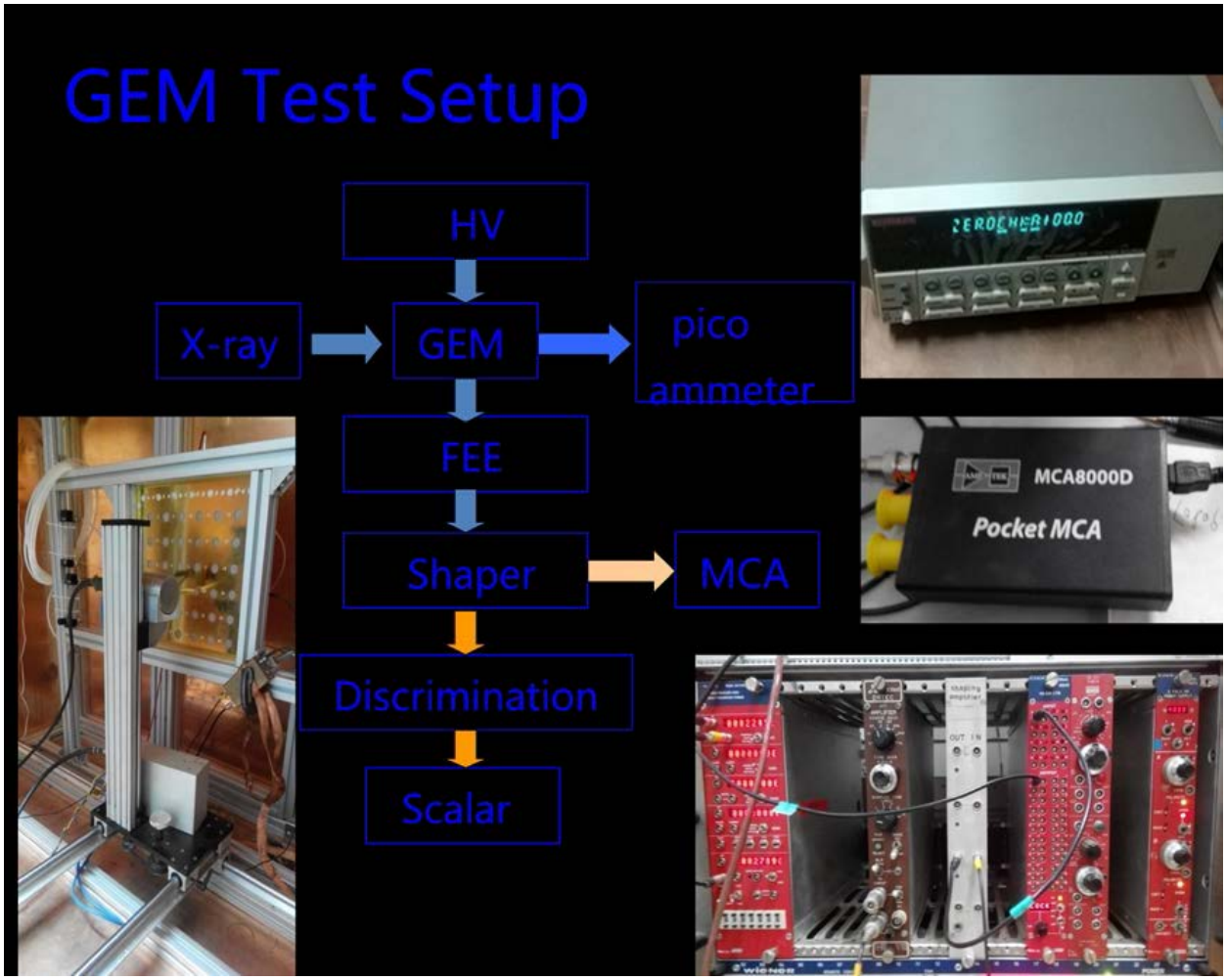


Fig: GEM test system

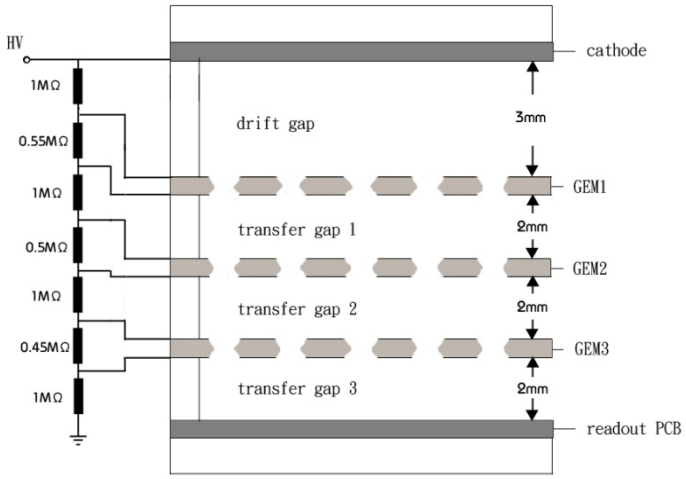


Fig: GEM structure and HV chain

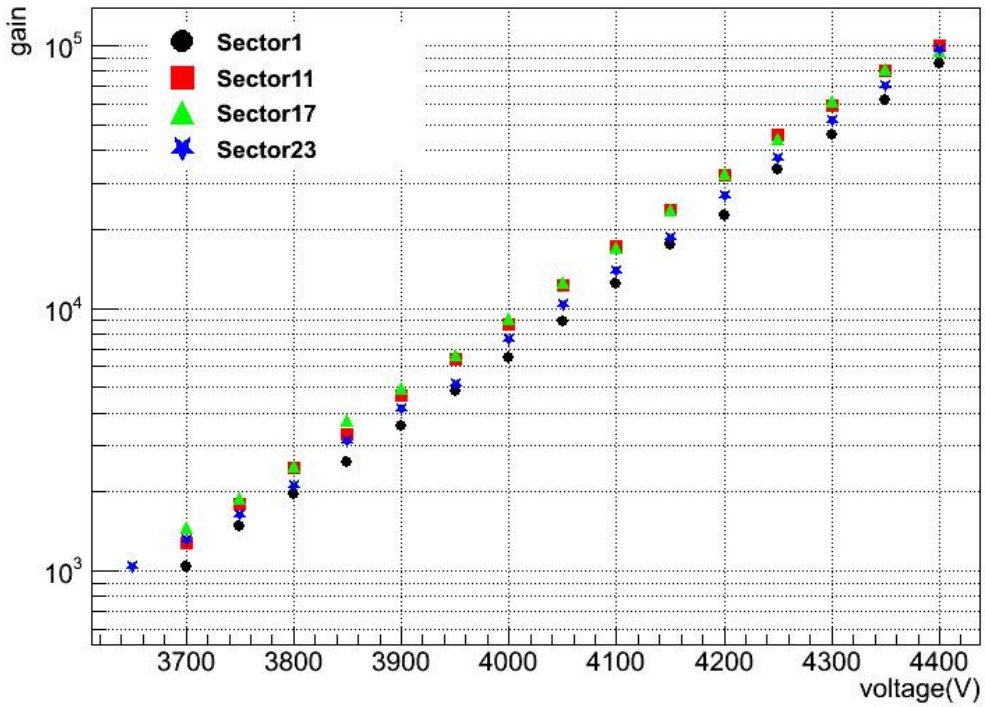
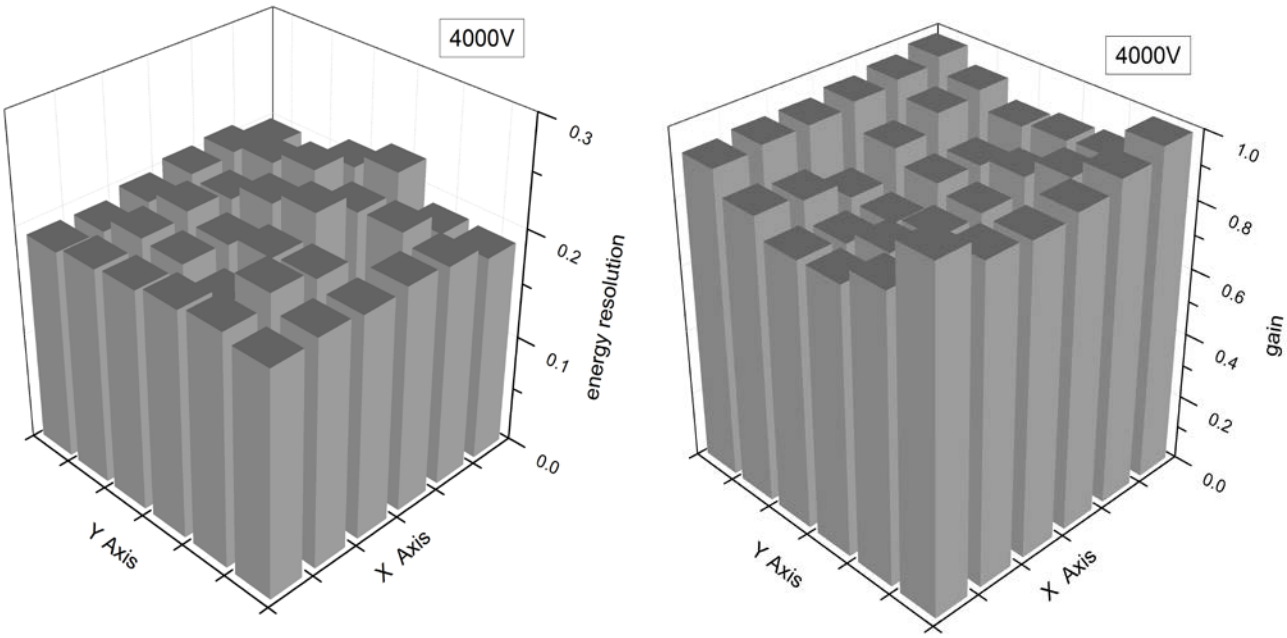


Fig: Gain vs. HV



standard deviation=5.2%
max variation=10.6%
minor variation=8.6%

standard deviation=7.6%
max variation=13.6%
minor variation=12.2%

Fig: Uniformity of gain and energy resolution

3. Spatial resolution test with new readout design
   We are working on the new strip readout design (2.5mm pitch) with SFE16 FEE. The spatial resolution with such a design is to be measured. The readout board and FEE are shown in the figure below. We are tuning the FEE and will begin the test soon.

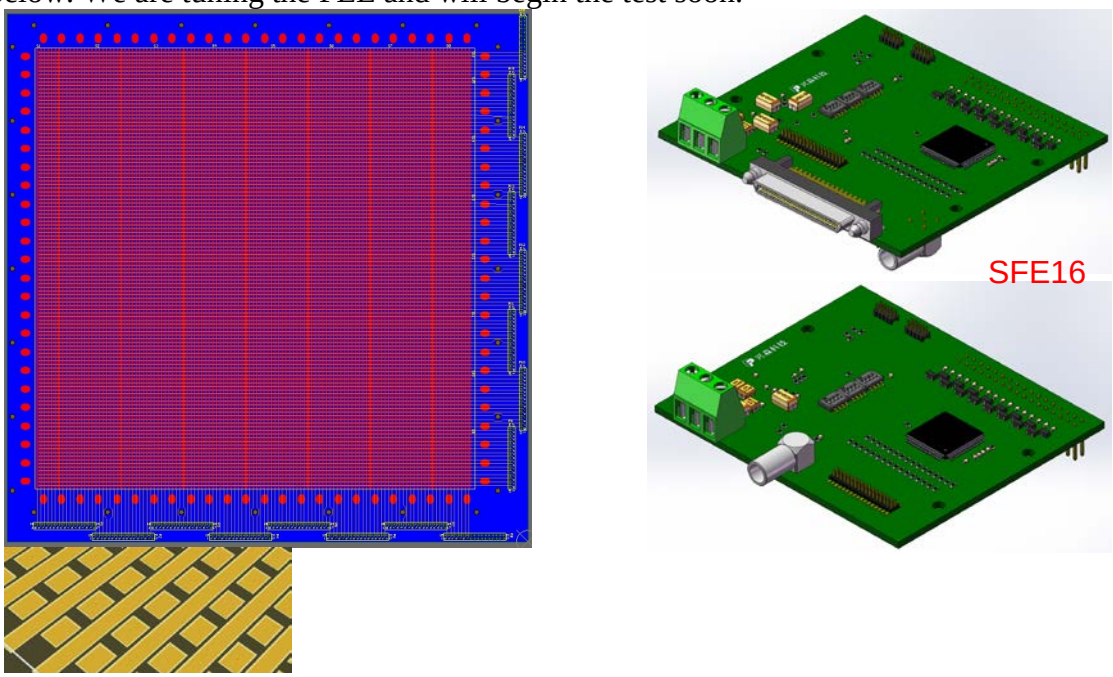


Fig: 2-D strip readout design and FEE

4. Large-size THGEM prototype
   A THGEM module with 30*30 cm^2 active area is being constructed. The THGEM is produced at CERN. When constructed this THGEM module will be tested with the same setup used for GEM modules. Also a new readout PCB design (0.8mm pitch) is underway. Such design is compatible with the test setup at BNL (with APV25 FEE).