SHMS GEM Tracker
Status Update

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Hall C Collaboration Meeting
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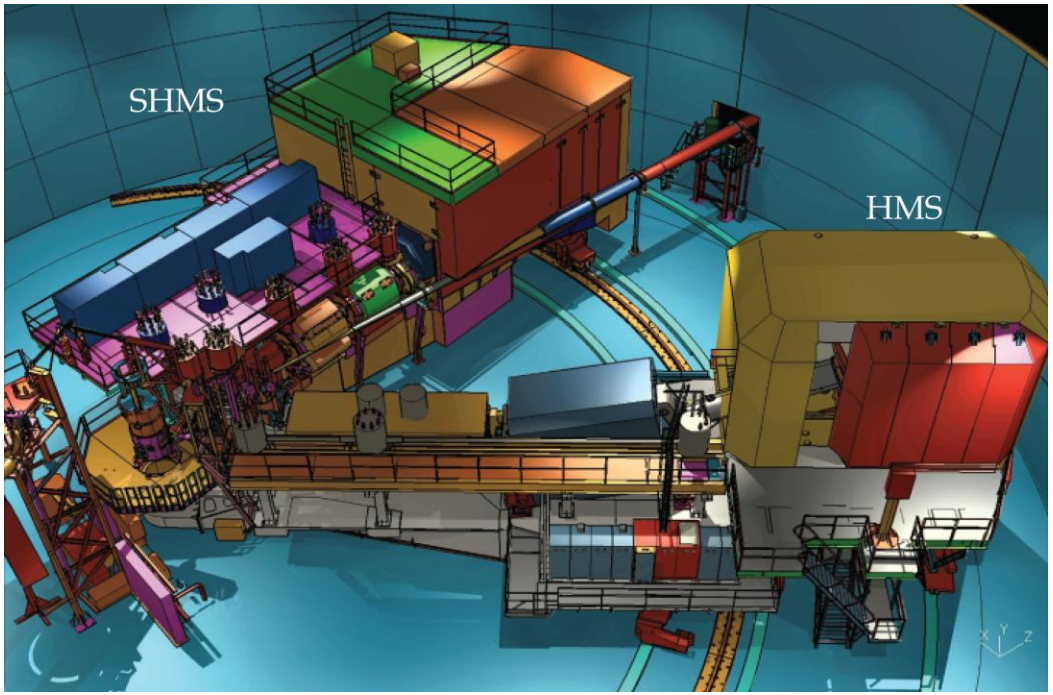
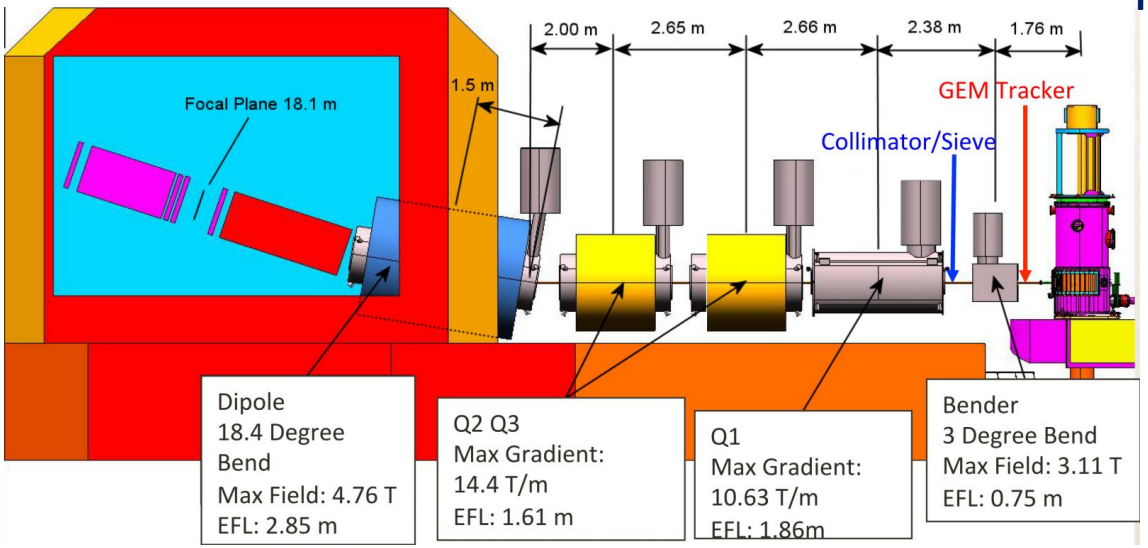
12 GeV Upgrade – the SHMS



In order to reach forward scattering angles of 5.5° and to increase the solid angle of the spectrometer, a 3° horizontal bend superconducting dipole magnet has been placed in front of the first quadrupole magnet (Q1), at ~1° to the beam-line.

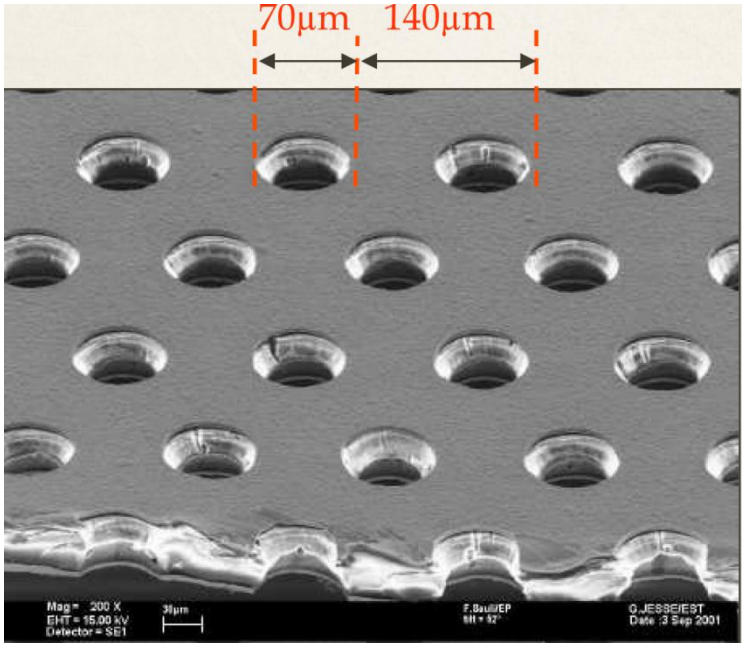
- An active collimation system is needed
- A pair of interchangeable collimator & sieve slit will be permanently attached in front of the first quadrupole magnet.
- In addition to the fixed collimators a **GEM tracker** will be added in front of the **horizontal bender (HB)**.
  - The tracker is **for optics calibration only**, hence will be used for very low beam current (~50nA).
  - It defines the initial position of the particle trajectory entering the horizontal bend magnet & acts as an active sieve slit.
  - The tracker and the sieve slit in front of the Q1 can be used to map out the transport properties of the entire SHMS within the geometrical acceptance defined by the fixed collimator.

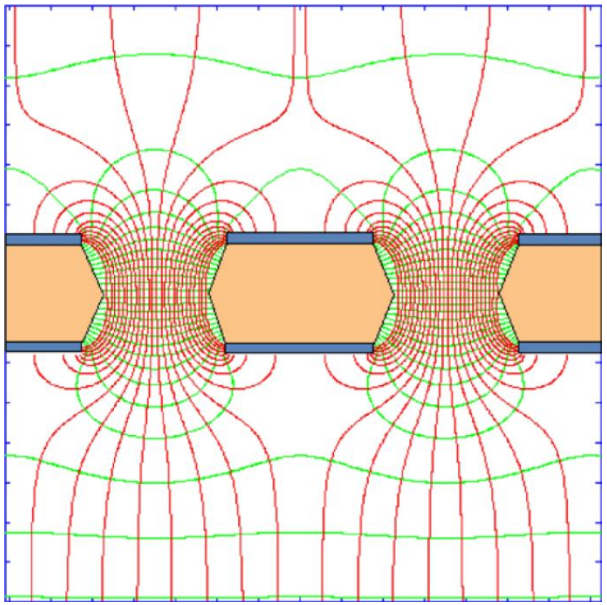


Gas Electron Multiplier (GEM)

GEMs provide low cost solutions for high resolution (~ 50 µm) & high rates (up to 10 MHz/cm2) tracking over large areas.

Thin, **metal-coated polymer foil with a high density of holes**. When applying a voltage difference, **each hole acts as an individual proportional counter**, and electrons released on the top side drift into the hole, multiply in avalanche, and get transferred to the other side.





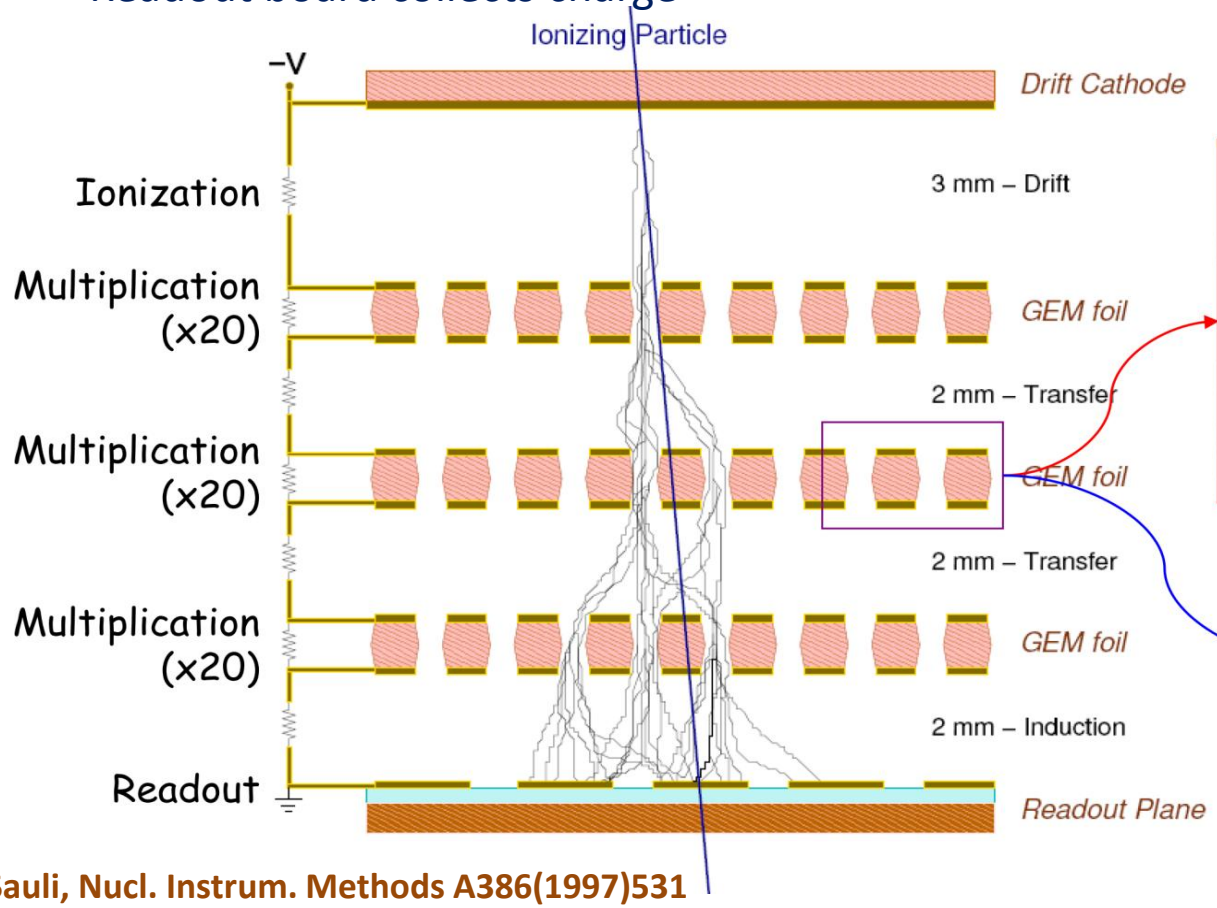
Typical geometry:

- 5 µm Cu on 50 µm Kapton
- 70 µm holes at 140 µm pitch
- 50 - 100 Independent Proportional counters/cm^2

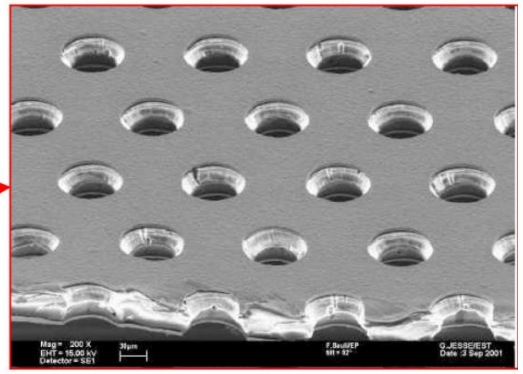
F. Sauli, Nucl. Instrum. Methods. A386(1997)531

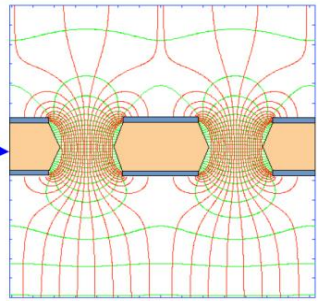
How GEM Works

- Charged particles ionize gas in the drift volume
- Primary electrons drift to the GEM holes following the E-filed lines
- Electron multiplication due to the strong E-field in the holes
- Use of two to three layers in cascade results in high gain (up to 10^5 in triple GEM)
- Readout board collects charge



GEM foil: 50 μm Kapton + few μm copper on both sides with 70 μm holes, 140 μm pitch

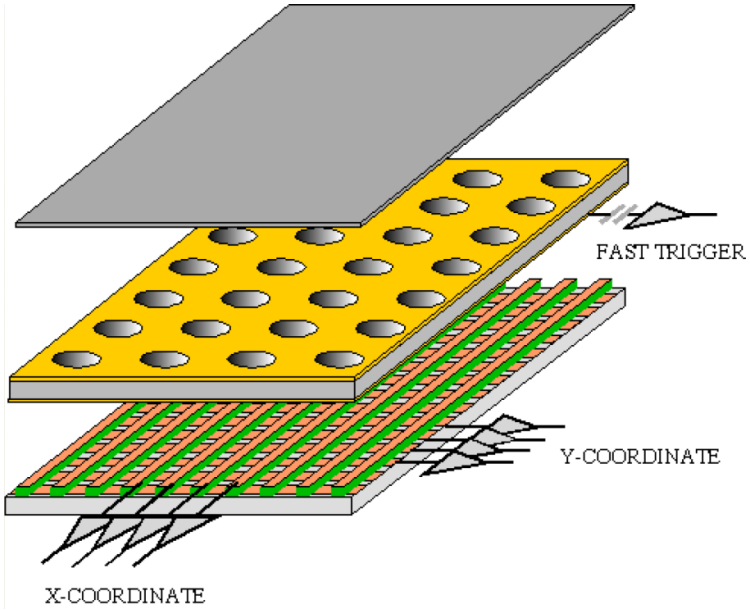


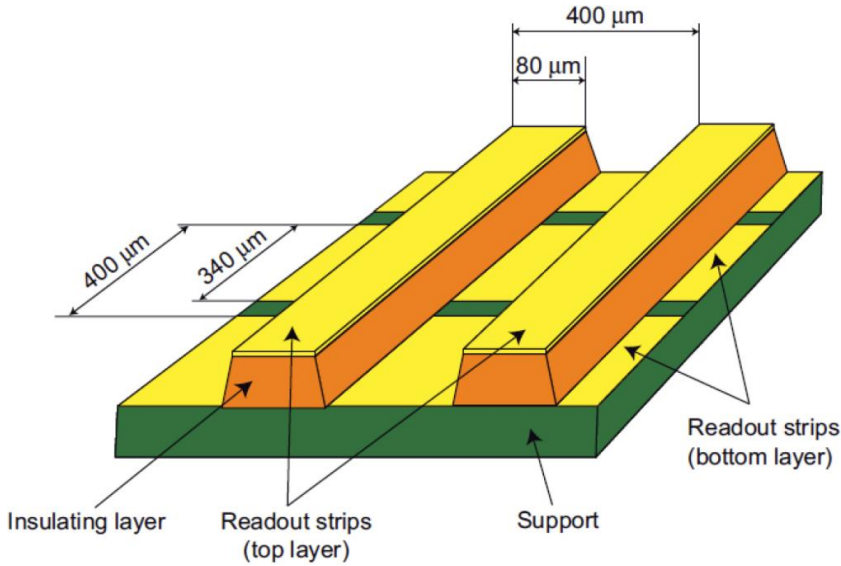


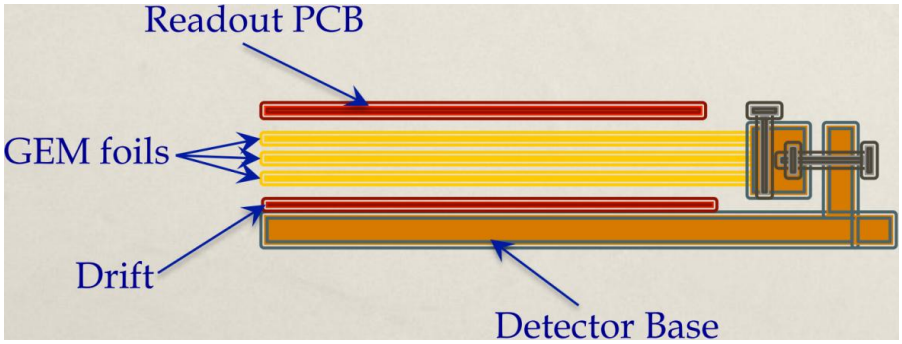
Strong electrostatic field in the GEM holes

F. Sauli, Nucl. Instrum. Methods A386(1997)531

GEM Readout







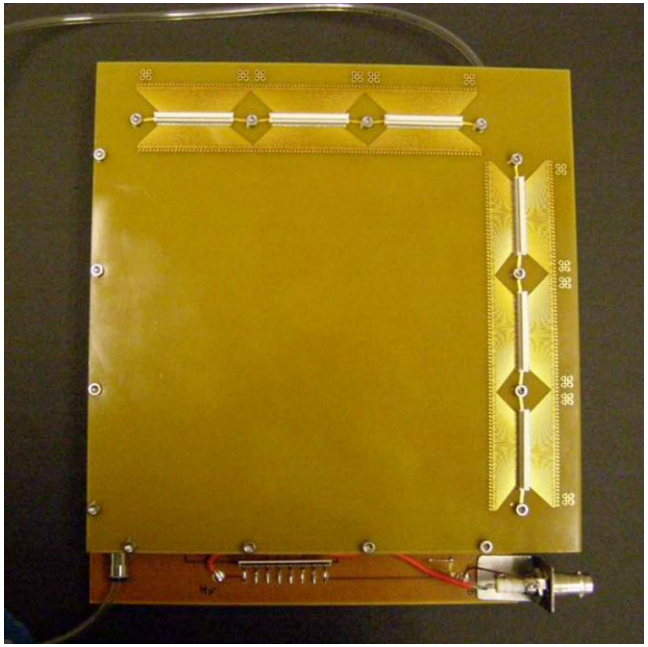
A. Bressan et al, Nucl. Instr. and Meth. A425(1999)254

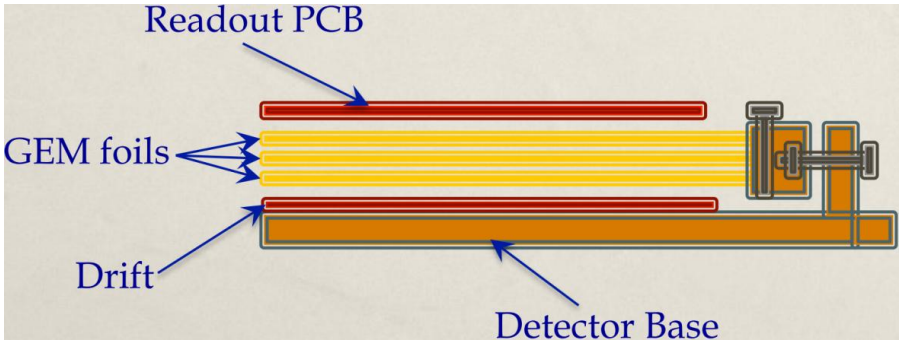
- Electrons are collected on patterned readout boards. A fast signal can be detected on the lower GEM electrode for triggering or energy discrimination.
- **Two orthogonal sets of parallel copper strips** at 400µm pitch engraved on 50µm Kapton; 80µm wide on upper side, 340µm wide on lower side (for equal charge sharing)
- Width of the strips optimized to provide close to equal charge sharing between the two layers.
- All readout electrodes are at ground
- Potential.

GEM Readout

GEM tracker is a triple GEM chamber
(Gas Mixture Ar/CO2 (70/30))

- 3 GEM foils : 160mm x 160mm (153.6mm x 153.6mm active area)
- External dimension: 240mm x 240mm x 16mm
- Readout board 400µm pitch X and Y
- Panasonic connectors (128 pins per axis)





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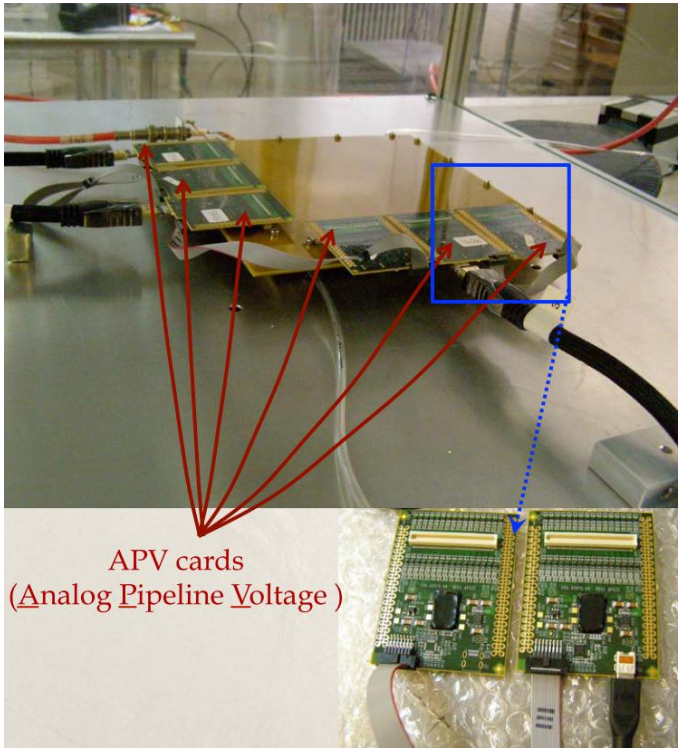
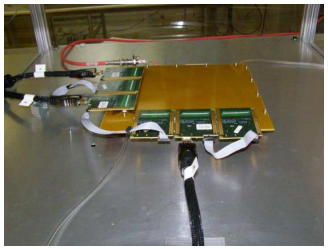


The GEM DAQ System - SRS

Compact SRS minicrate for up to 4096 channels

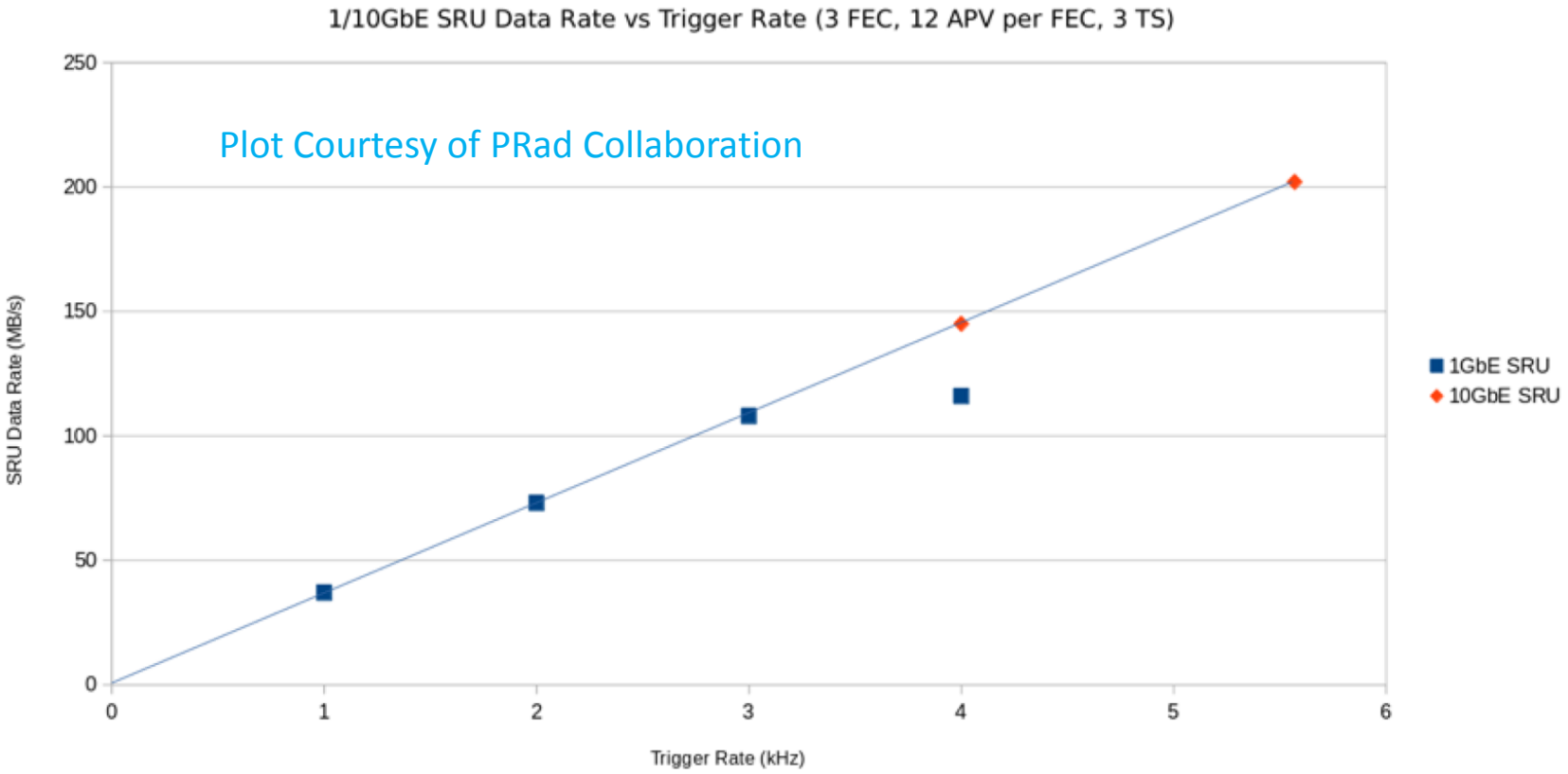


SRS provides a low-cost, common platform that can accommodate different readout chips.

- Uses the **Scalable Readout System (SRS)** developed by RD51 Collaboration (CERN)
  - Four basic parts: APV hybrids, ADC card, FEC card, SRU
- SRS-APV25 hybrid cards mounted on GEM detector, each reads 128 channels
- Data is digitized using the SRS-ADC unit and controlled by a Front End Concentrator (FEC) card.
  - Each ADC and FEC combo can handle up to 16 SRS-APV cards (The GEM tracker will use a total of 6 APV cards handled by one FEC).
- A Scalable Readout Unit (SRU) communicates with the FEC cards. We use only one FEC.
- The SRU is read out using CODA (using 10 Gb/s fiber link (originally used a 1 Gb/s copper link)

Recent Upgrades to the GEM DAQ

- Implemented by the JLab Fast Electronics and DAQ groups
- The SRU firmware was upgraded to handle a 10 Gb/s fiber based link (originally used a 1 Gb/s copper link)

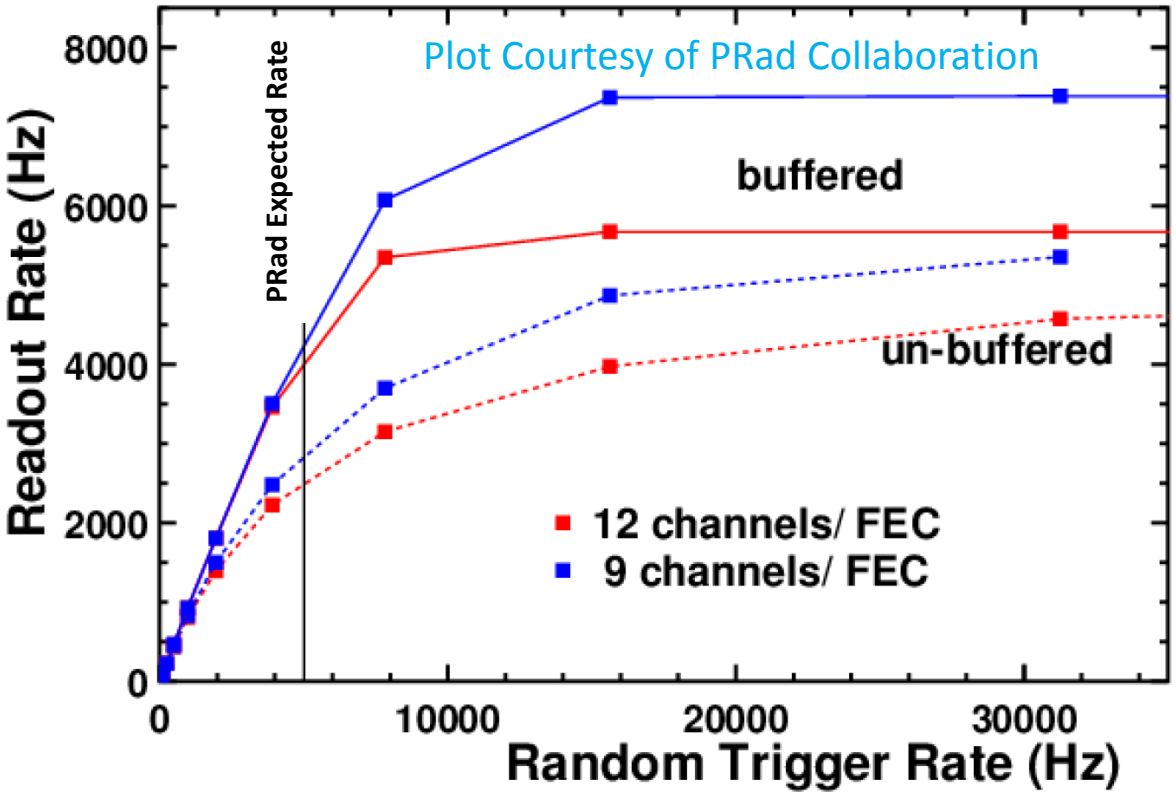


Tests indicated that the data transfer bottleneck with the 1Gb/s link has been removed with the 10Gb/s link

Recent Upgrades to the GEM DAQ

•The JLab PCI Express based Trigger Interface card (TI-PCIe) is used to integrate the SRS readout with CODA. New drivers were released by the JLab DAQ group before the PRad run (May, 2016) in Hall B.

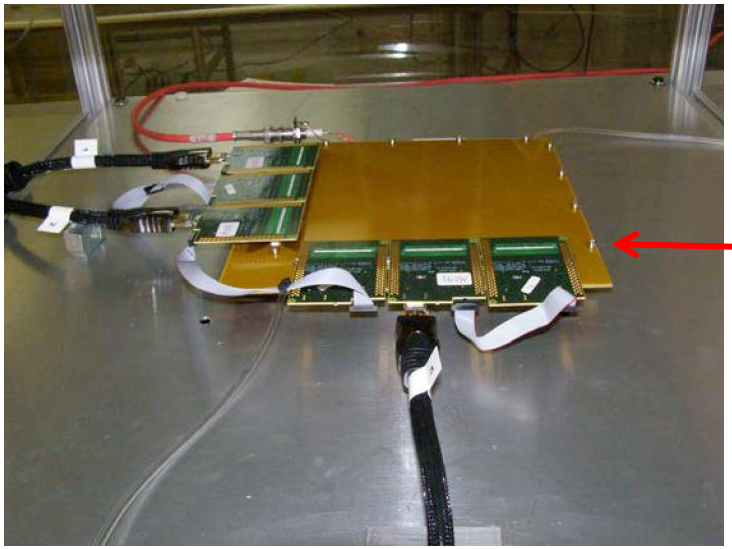
•The SRS firmware was upgraded to allow buffering (by the JLab Fast Electronics group)

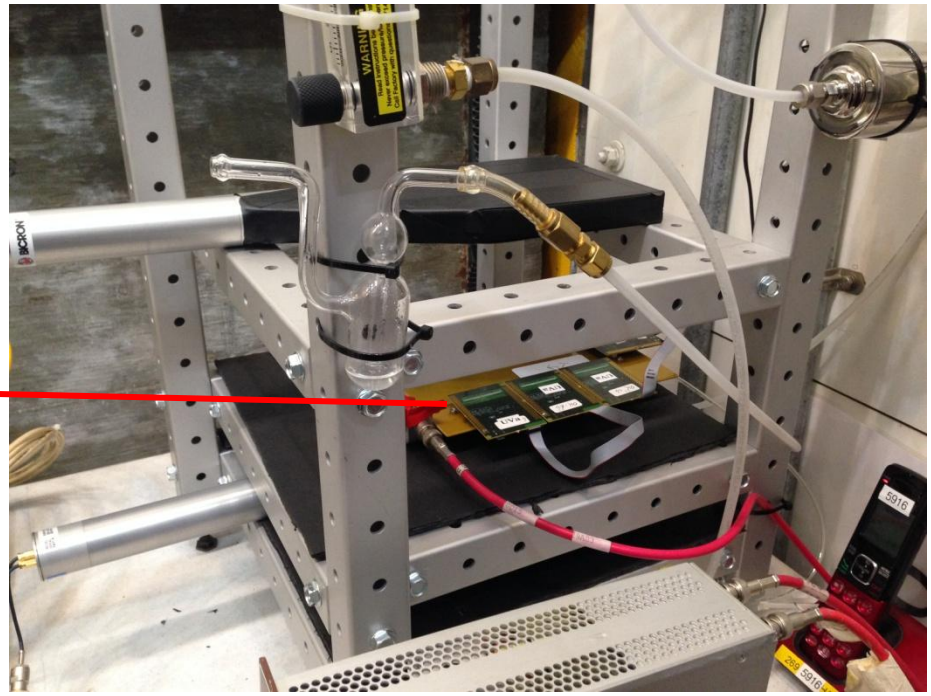


Tests demonstrates < 15% dead-time for random trigger rates of 5 kHz

We will use only **6 APVs** i.e., **6 channels /FEC** so our performance should be even better.

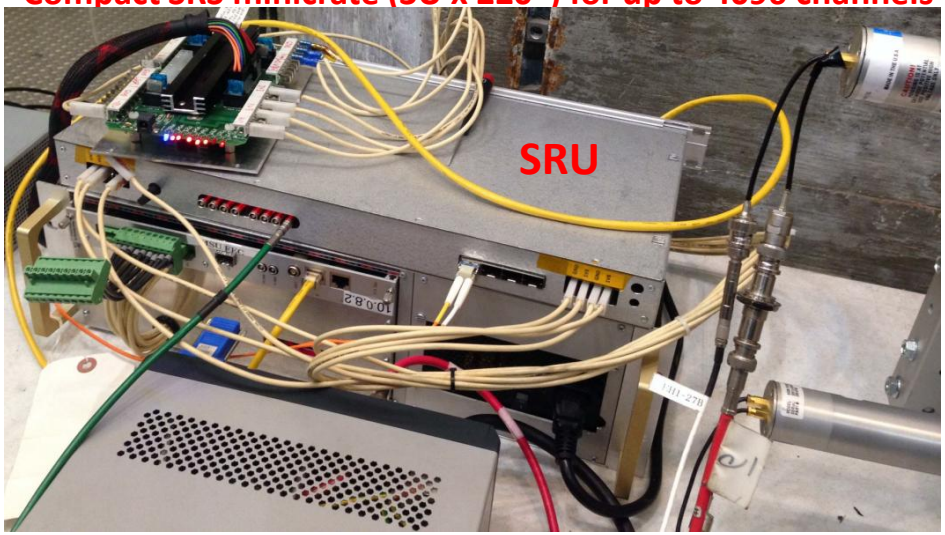
GEM Test in EEL



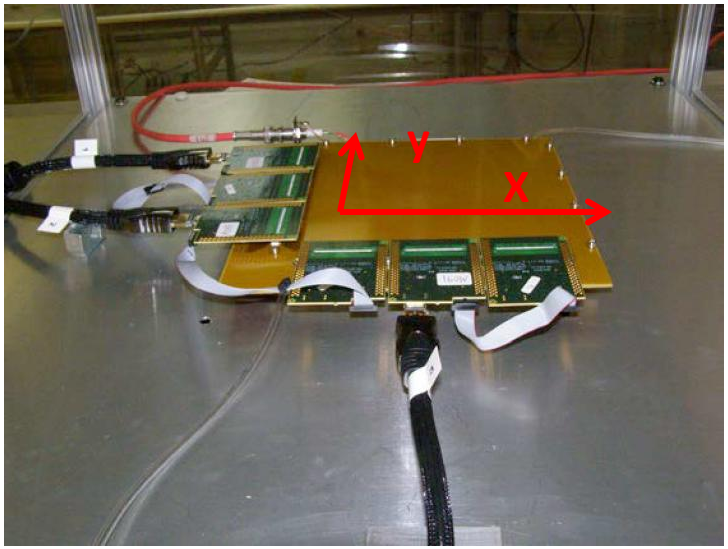


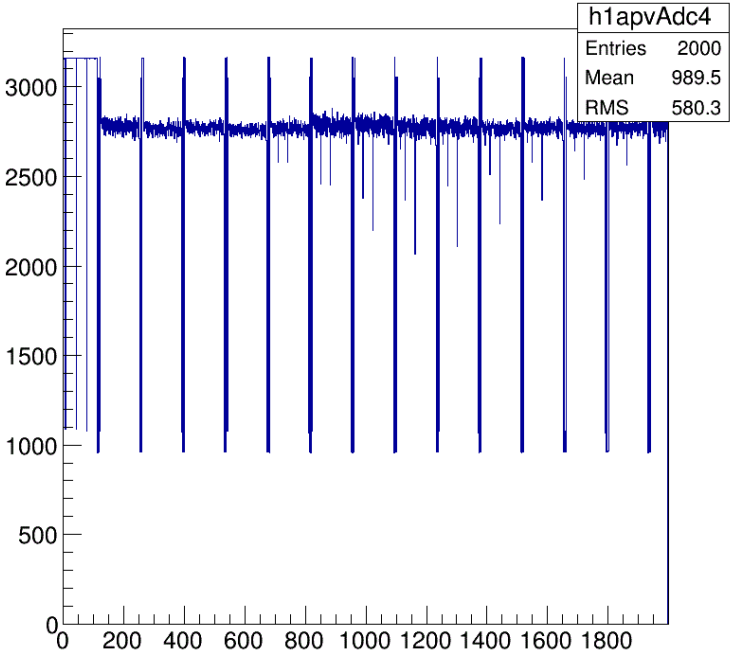
Gas Mixture Ar/CO2 (70/30)

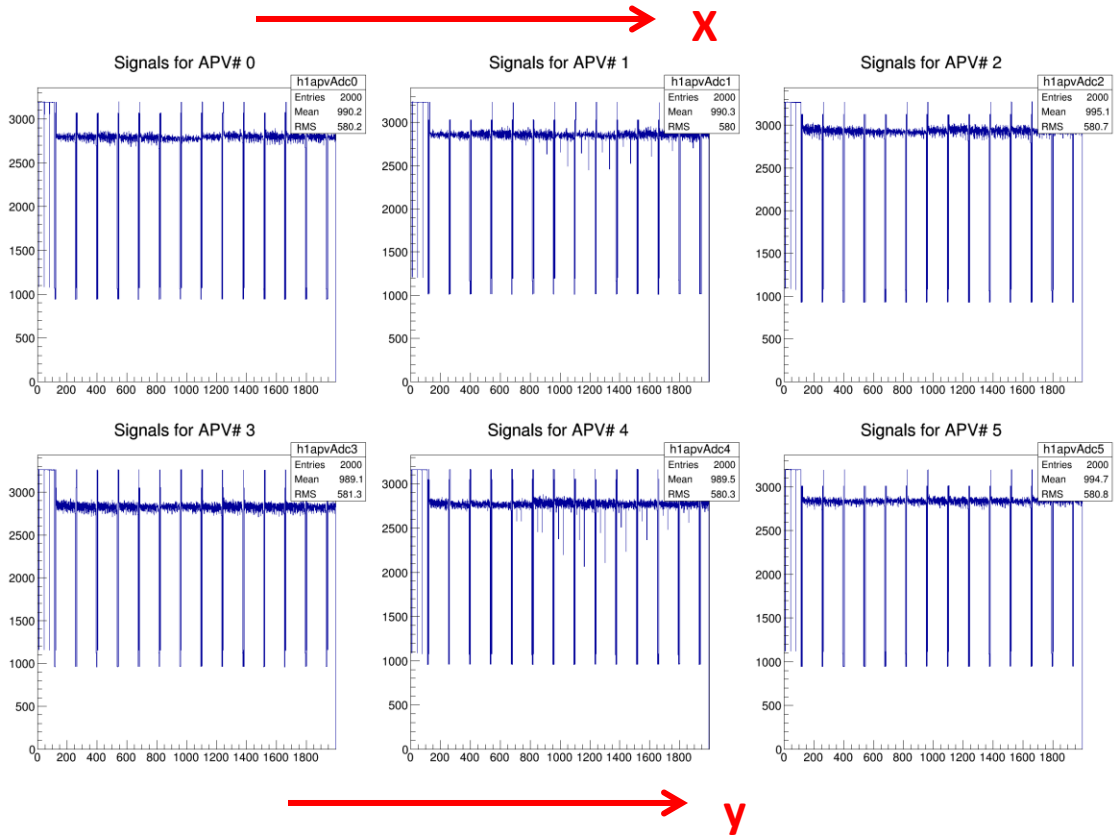
Compact SRS minicrate (3U x 220) for up to 4096 channels



GEM Test: Raw Data





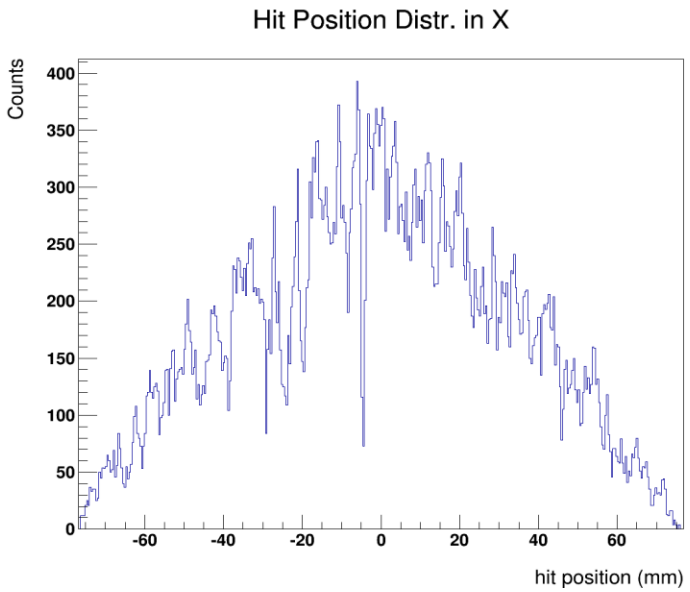


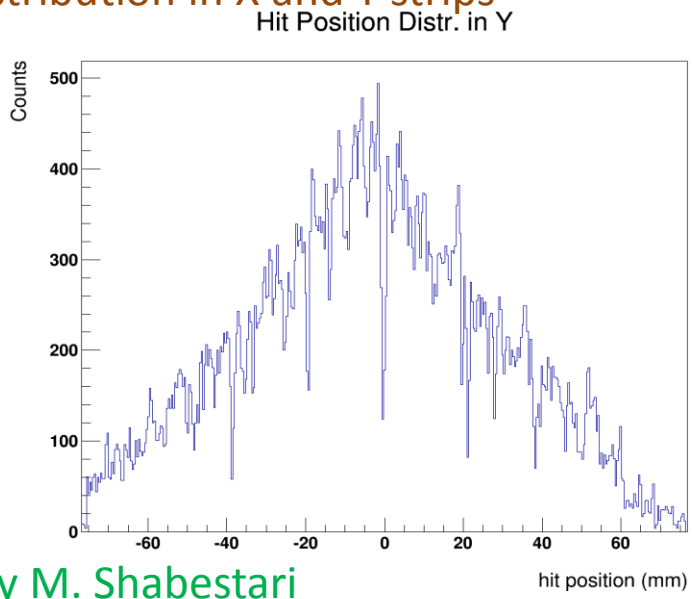
Raw data from one APV25

Each “slice” in these plots between the vertical lines contains the raw APV data for 128 channels during one 25 ns sample.

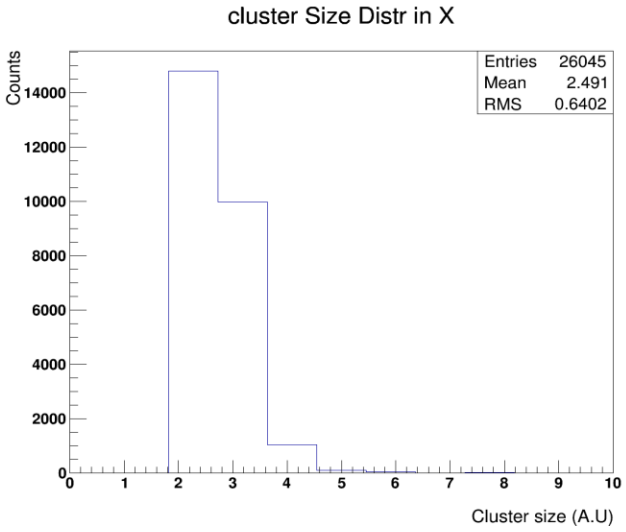
GEM Test: Cosmic Results

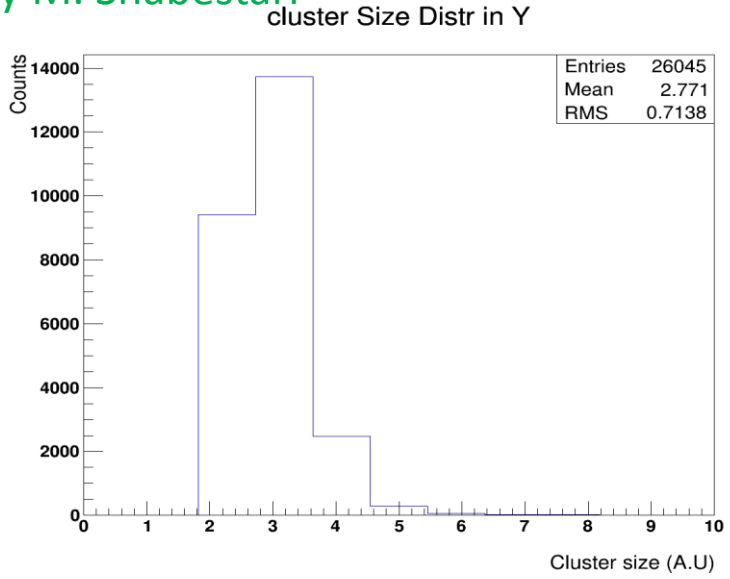
Charge distribution and cluster size distribution in X and Y strips





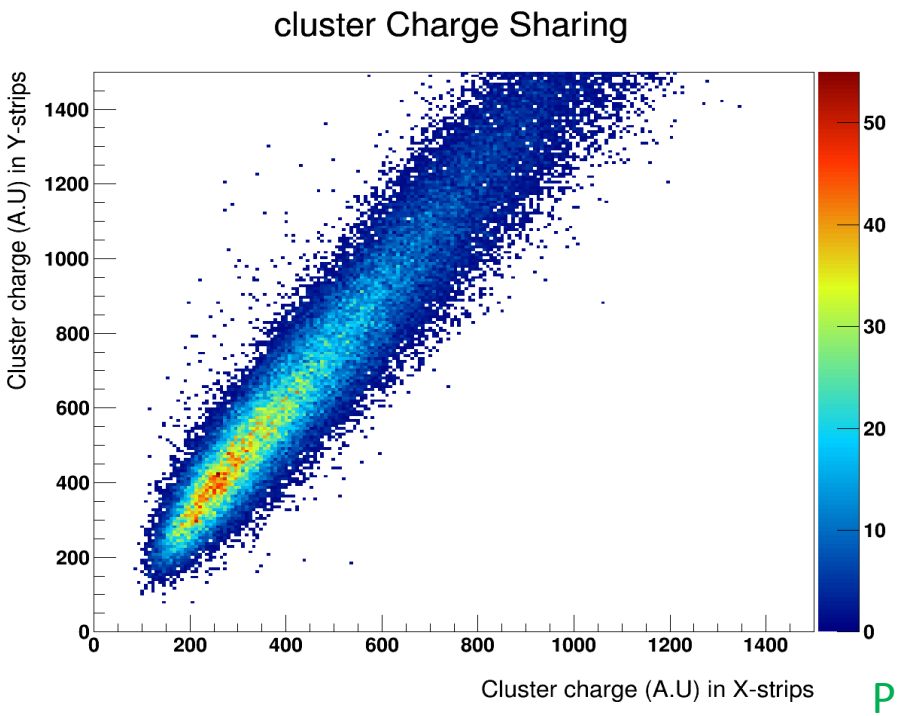
Plots by M. Shabestari

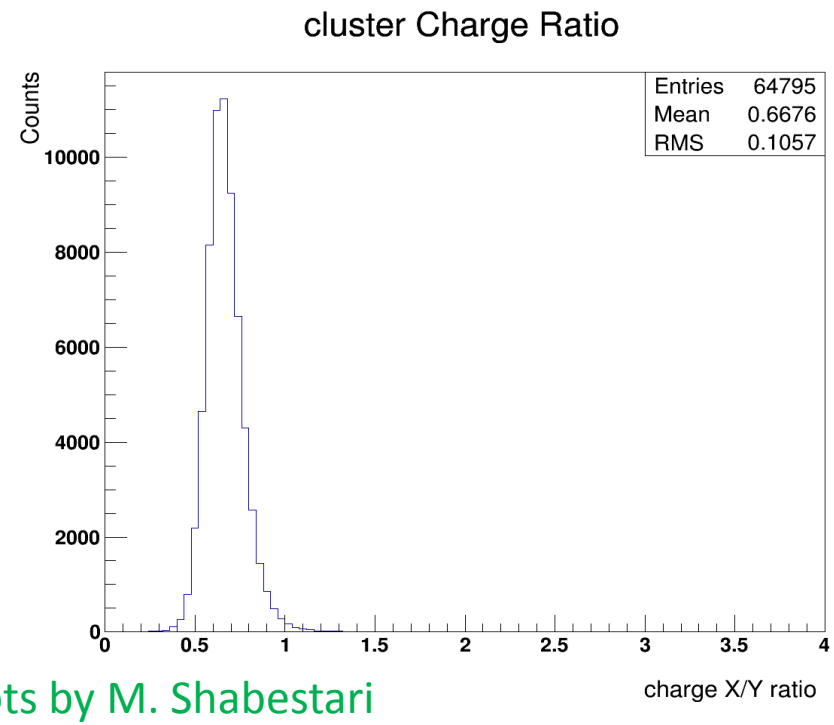




Correlation of Cluster Amplitudes

X/Y strips charge sharing correlation.

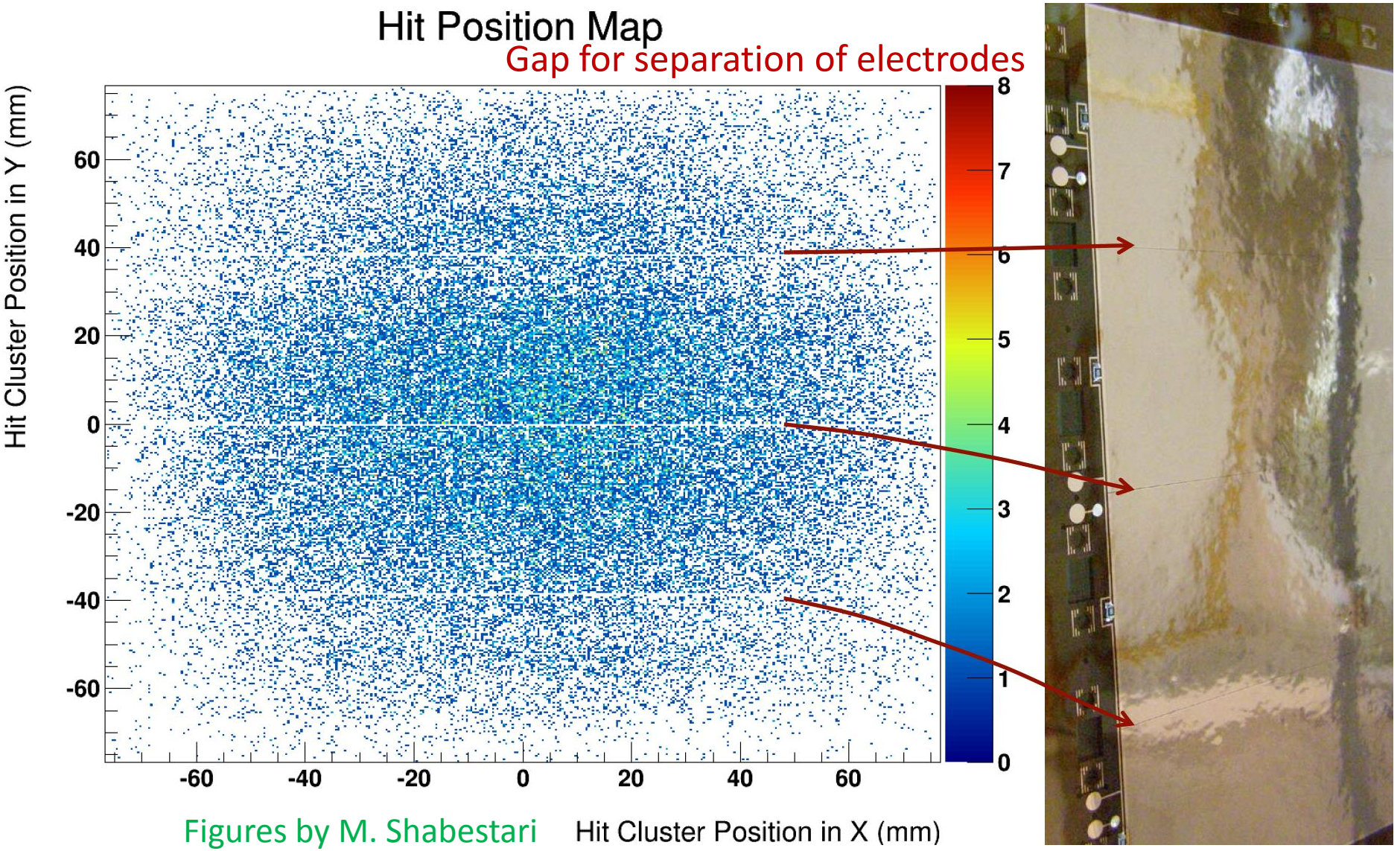




Plots by M. Shabestari

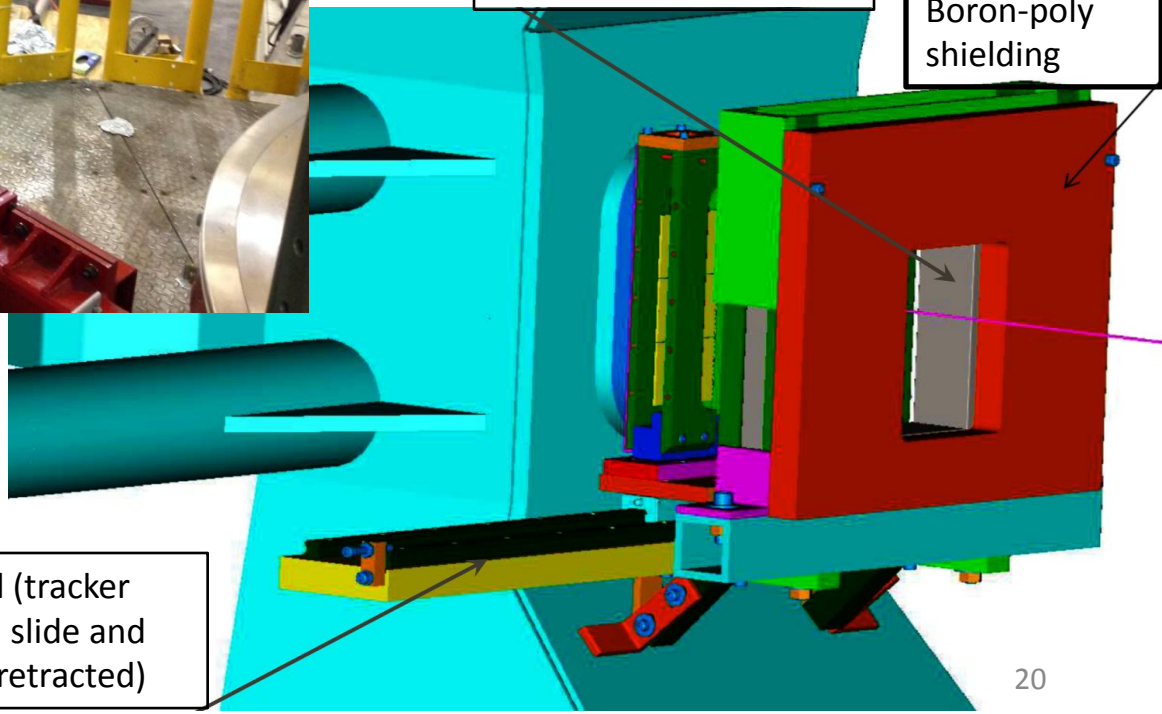
The charge sharing correlation is useful in resolving multi-track ambiguity

2-D Hit Map from Cosmic Data



Figures by M. Shabestari

GEM & Shield Holder



Summary

- Completed
  - Correct mapping for the GEM.
  - SRS integration with CODA.
  - GEM tracker test in EEL-126.
  - Assembly of the GEM holder.
- In progress
  - Setting up GEM-DAQ system in HMS platform and performing cosmic tests.
  - Move to HMS detector hut for test with DC triggers.
  - Move GEM to the SHMS.

Acknowledgement

- MEP group at MSU (D. Dutta, M. Sabestari)
- Colleagues at JLab (M. Jones, B. Sawatzky, B. Moffit, B. Raydo, S. Furches, E. Pooser)
- UVA detector lab (K. Gnanvo, V. Nelyubin, X. Bai)
- Colleagues at CERN and FIT