MPGD production and R&D at the University of Virginia

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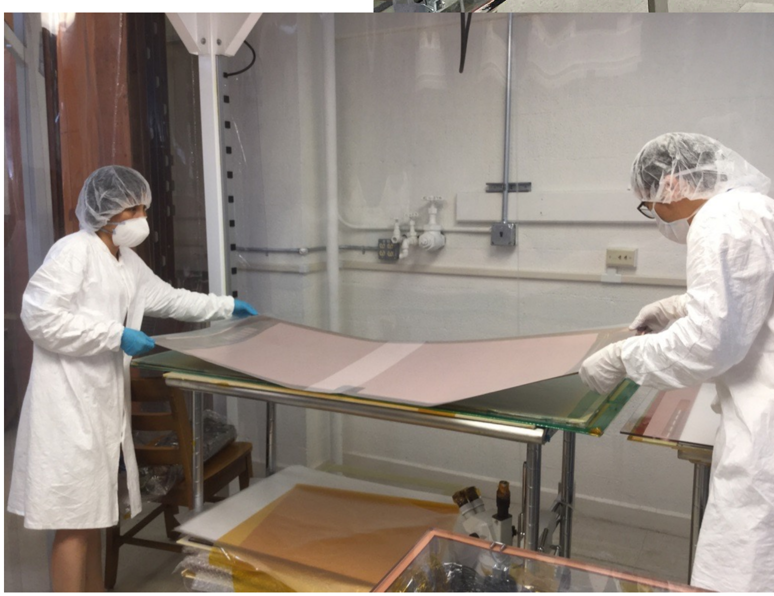
University of Virginia

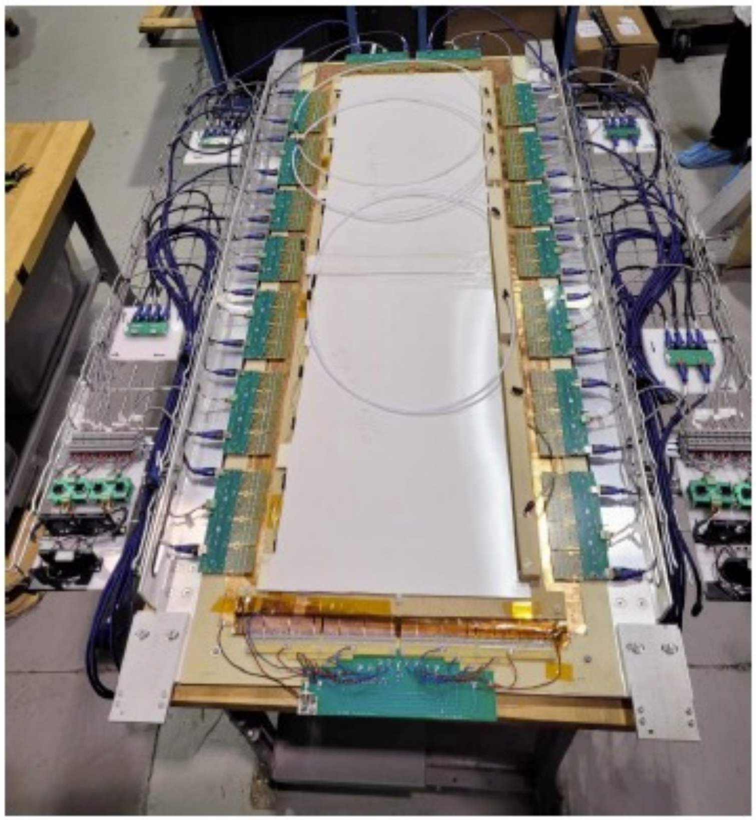
Tracking needs for Jefferson Lab Hall A experiments

- **Some of the highest luminosity experiments ever: up to about 5 x 10^{38} ! With open spectrometers and direct line of sight to target**
  - Rates at the tracker approaching MHz/cm^2
  - Need to cover large areas: 10s of m^2
  - Need to tolerate high radiation doses.
  - require good spatial Resolution: ~0.1 mm
  - Lower energy particles compared to LHC: ~ few GeV: need low material thickness
  - Relatively small experiments with relatively small budgets: need a cost-effective solution: silicon is not cost effective in most cases
- GEM and other MPGDs are a natural choice.
- Jlab SuperBigbite Spectrometer GEM project: largest in the world in the pre-CMS GEM project days.
- Very lucky to get Kondo to lead this project.



SBS GEM trackers

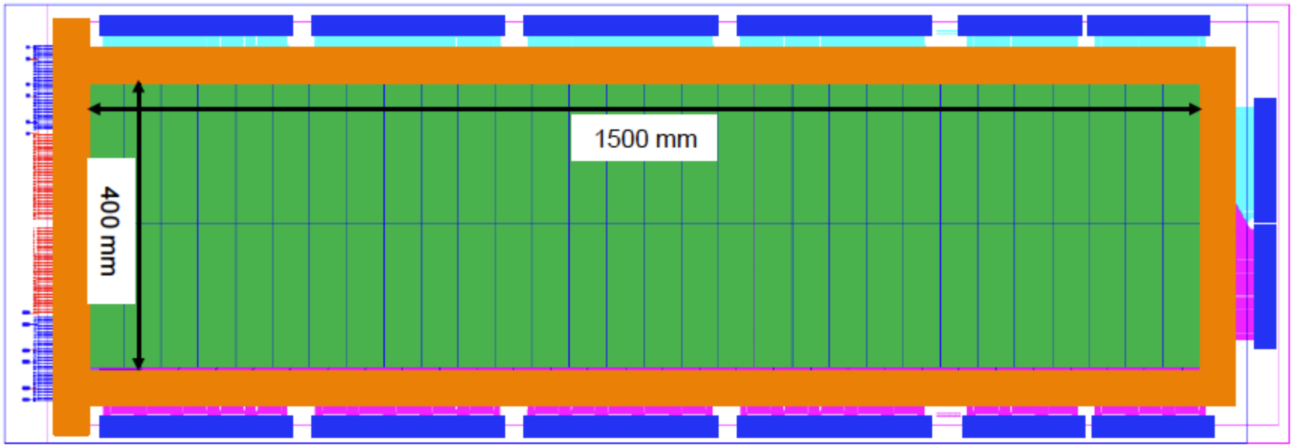
- 50 cm x 60 cm GEM modules for SBS rear tracker: 50 modules built: 48 modules operational – 40 have been in beam, 8 spares
- 150 cm x 40 cm large GEM modules for SBS front tracker: 6 modules built ; all 6 operational – all in beam

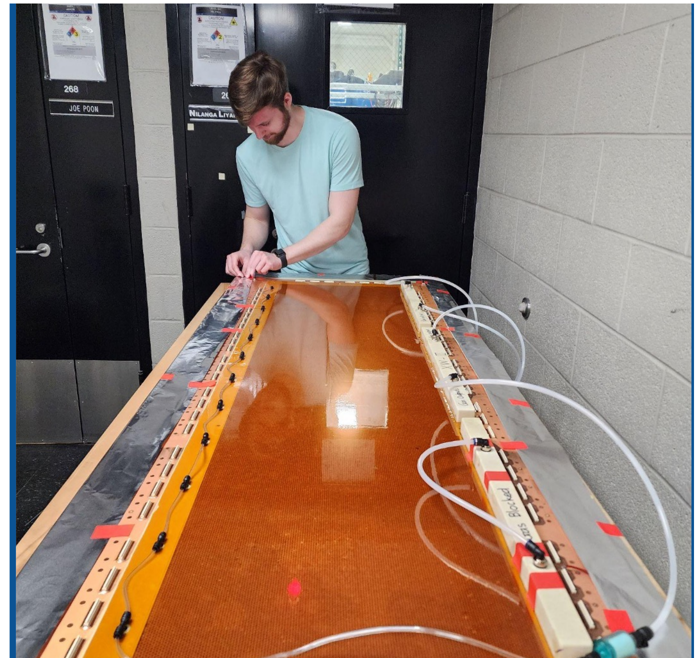


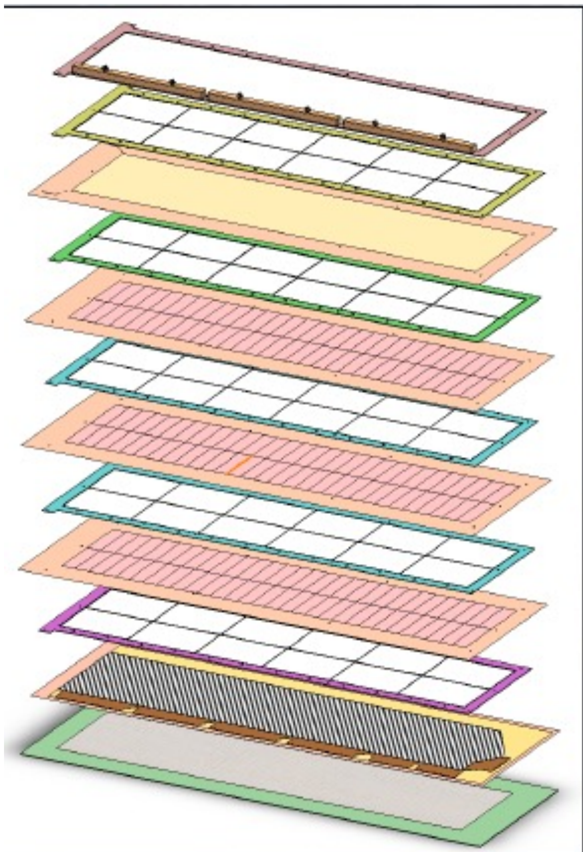
UV (shown)
40 x 150 sq.cm
Single module

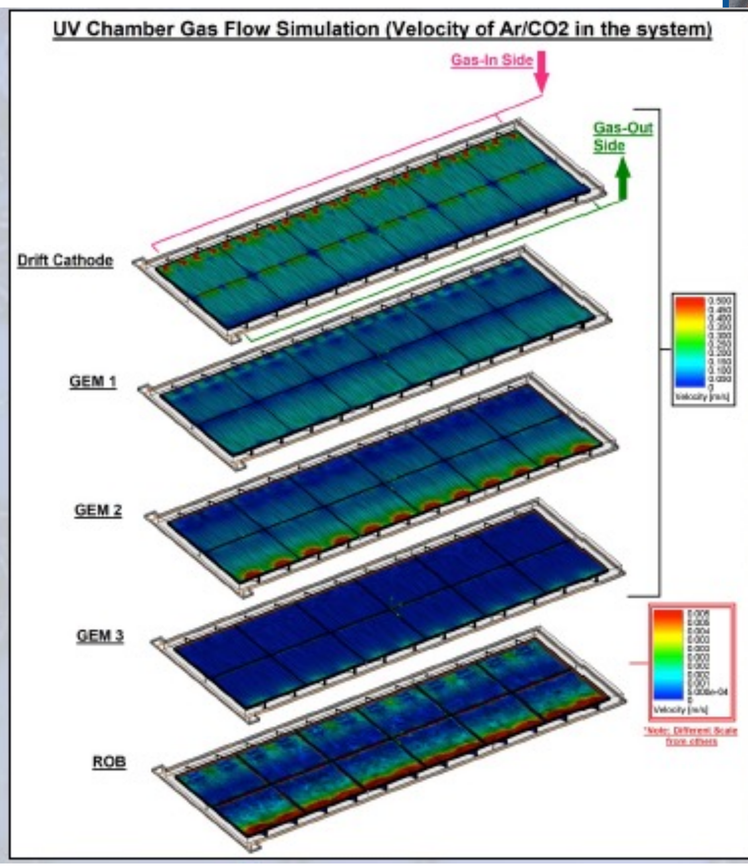
XY (shown)
60 x 200 sq.cm
4 modules

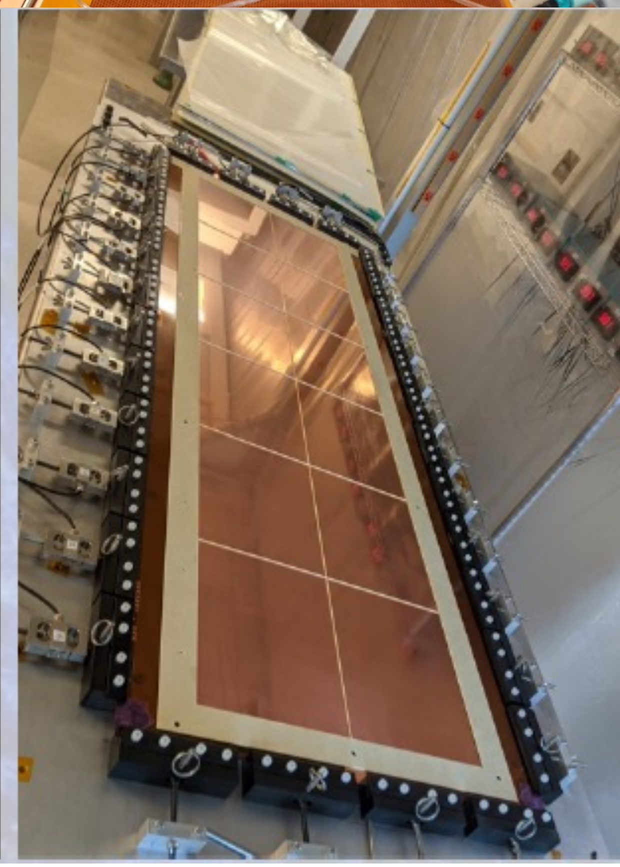
SBS Large GEM construction

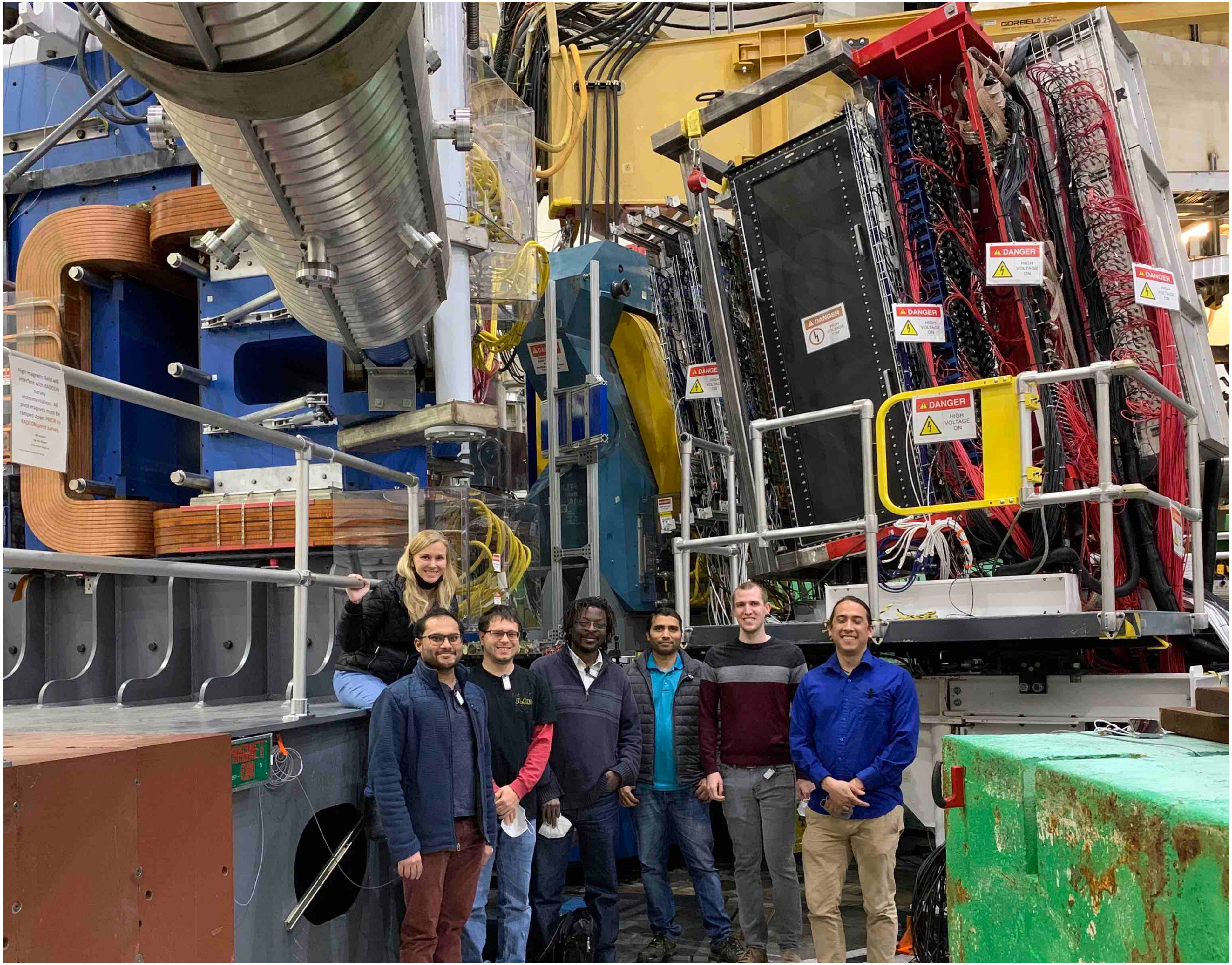








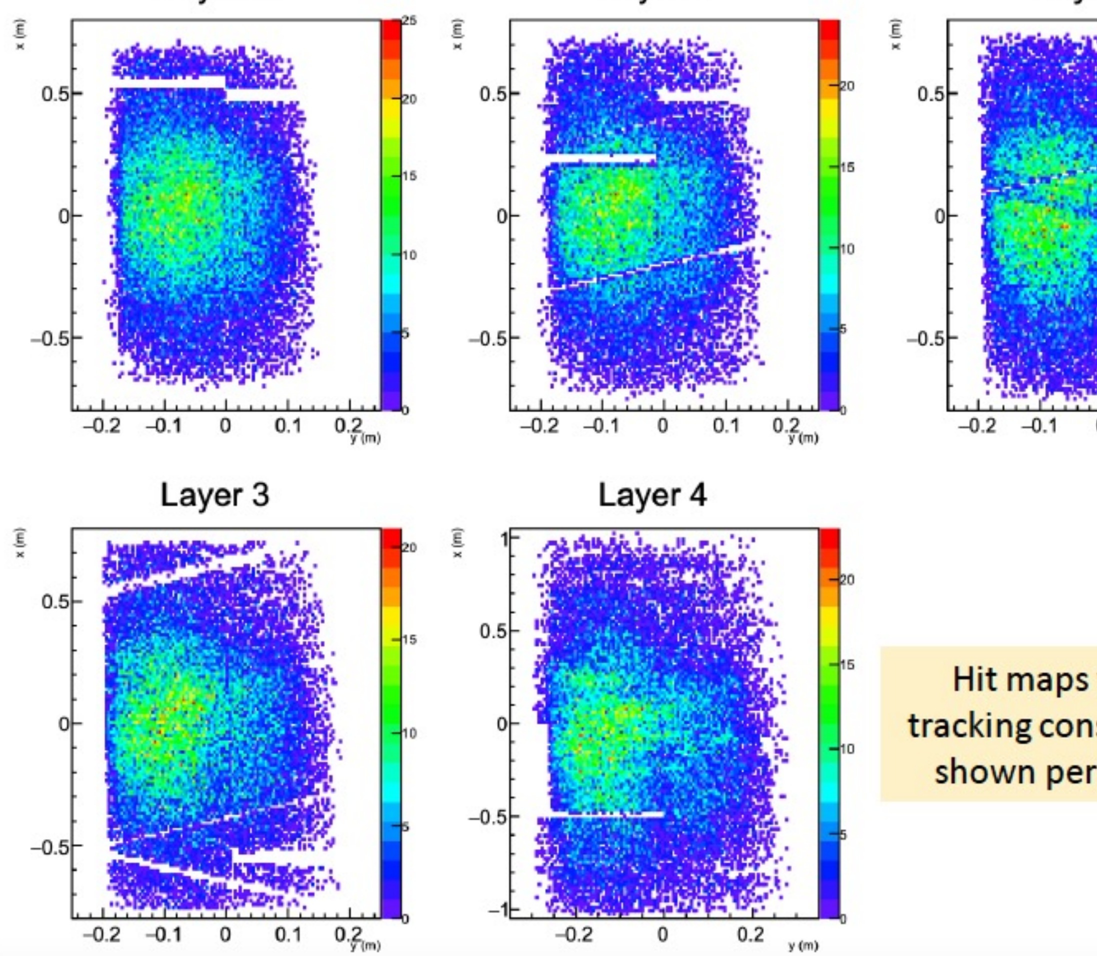



DANGER
HIGH VOLTAGE ON
GORBEL

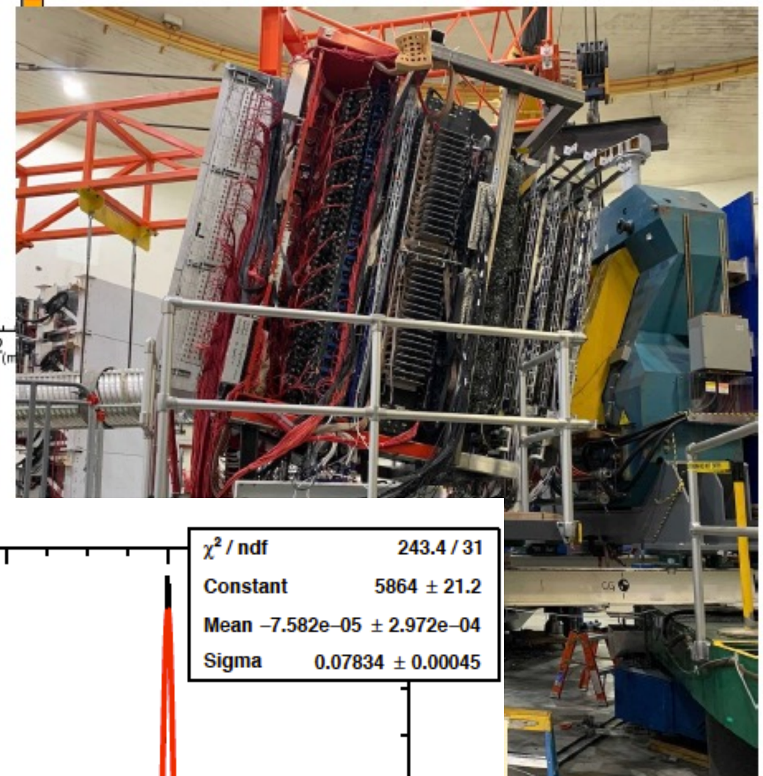
16 layers of SBS GEM installed in experiment:

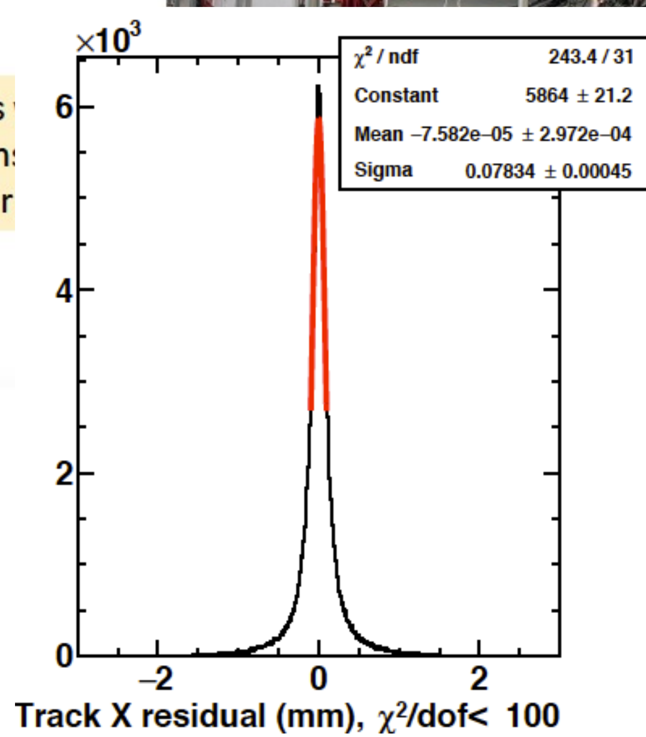
- Forty 50 cm x 60 cm GEM modules in 10 layers
- Six 150 cm x 40 cm large GEM modules

4 UV and 1 XY have been running successfully in BigBite since 2021

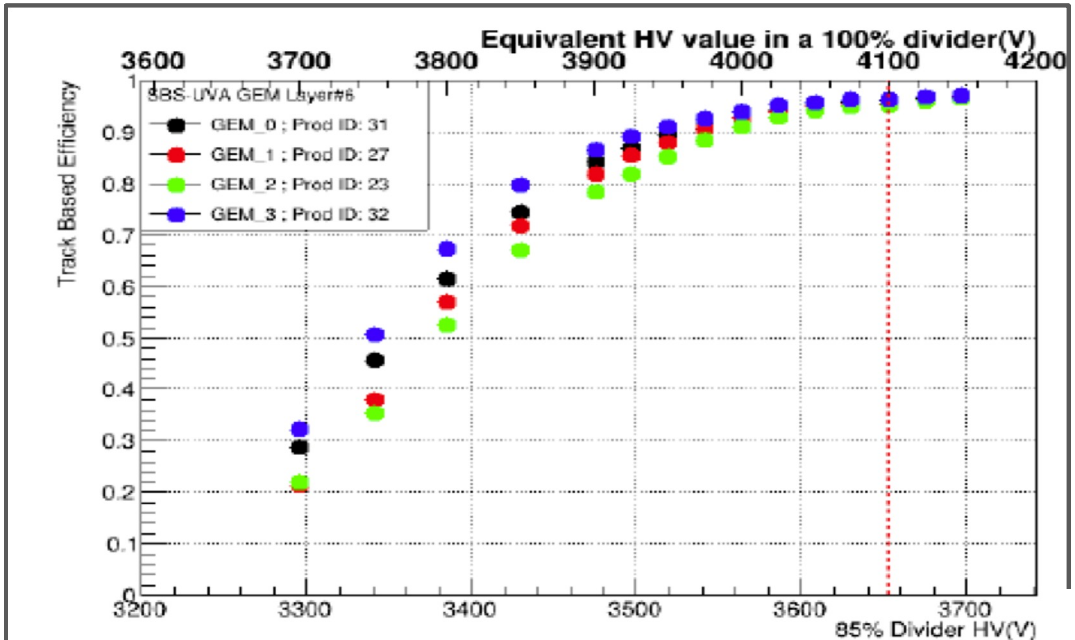


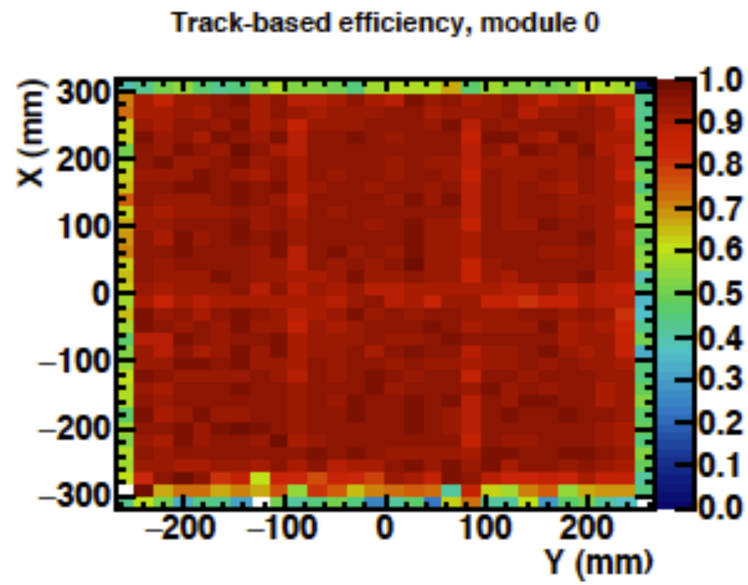
Hit maps
tracking con
shown per



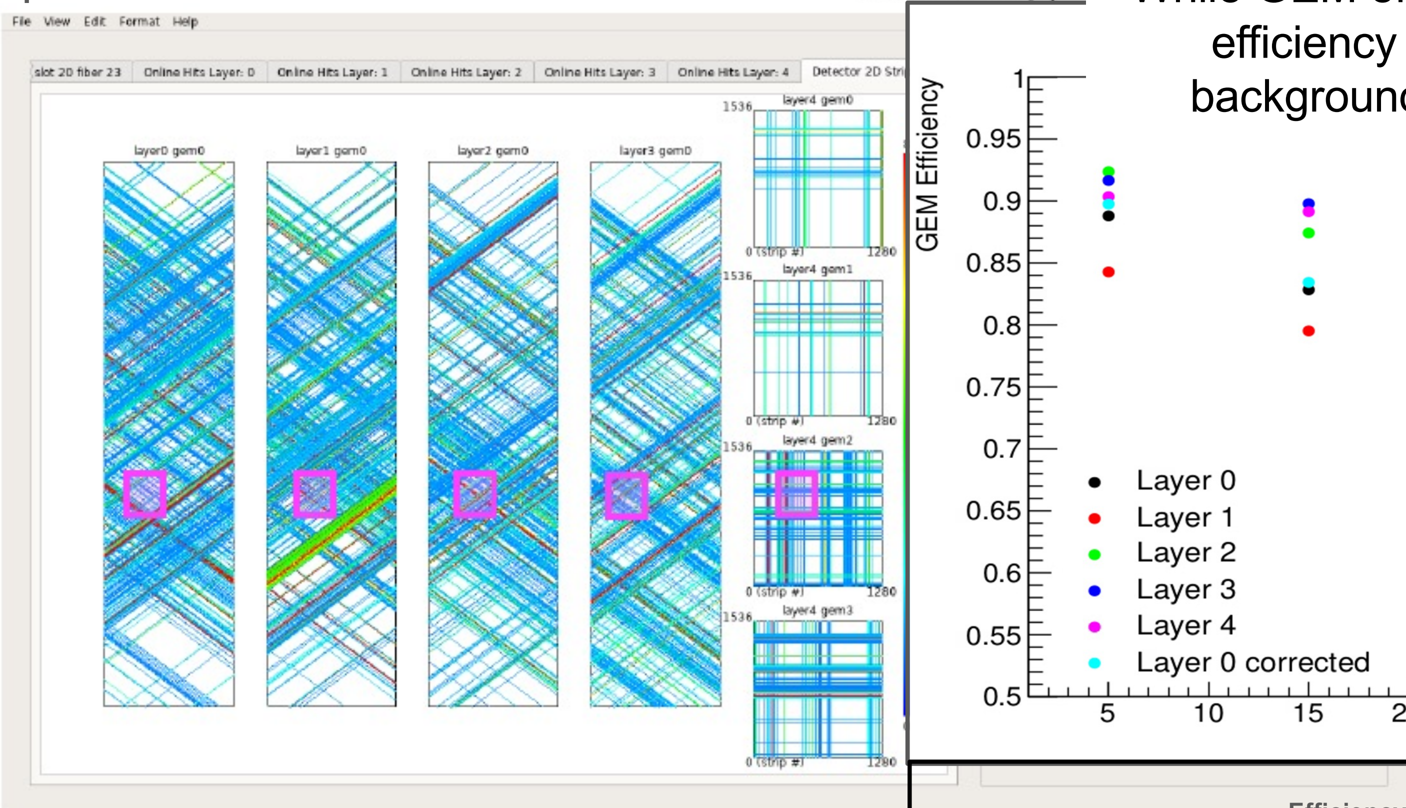


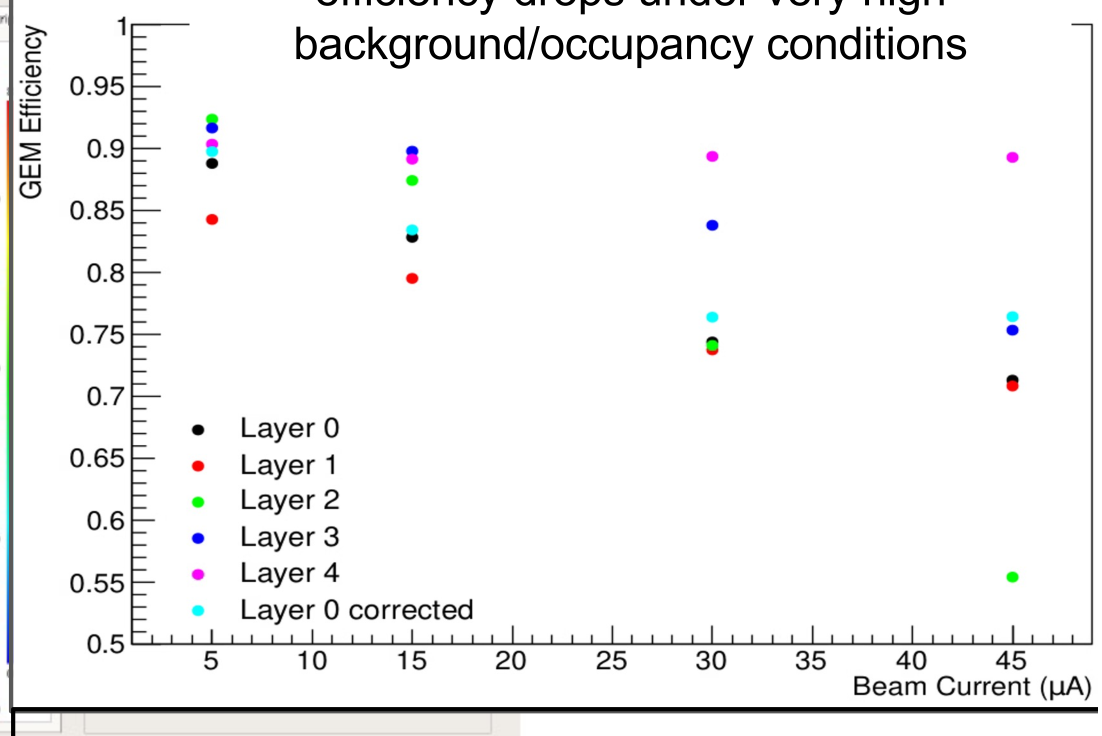
Tracking resolution
76 μm





While GEM efficiency is > 95%, tracking efficiency drops under very high background/occupancy conditions

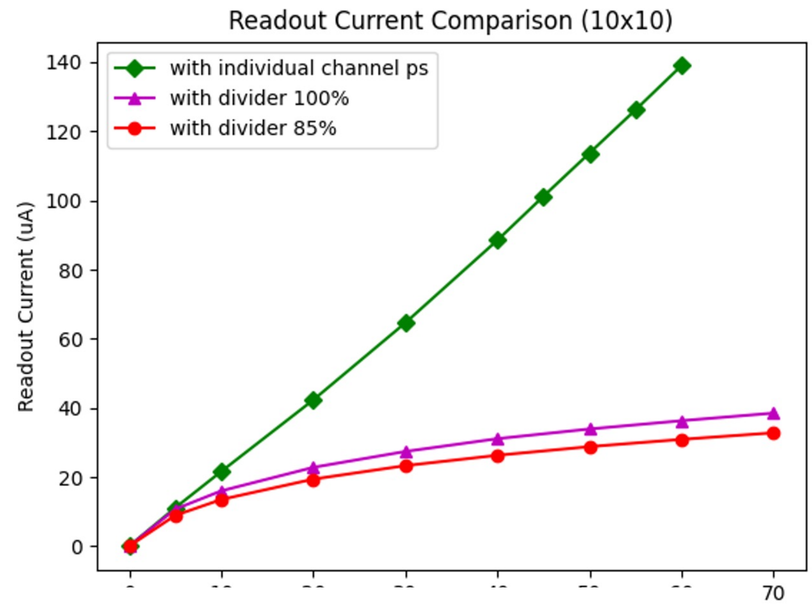


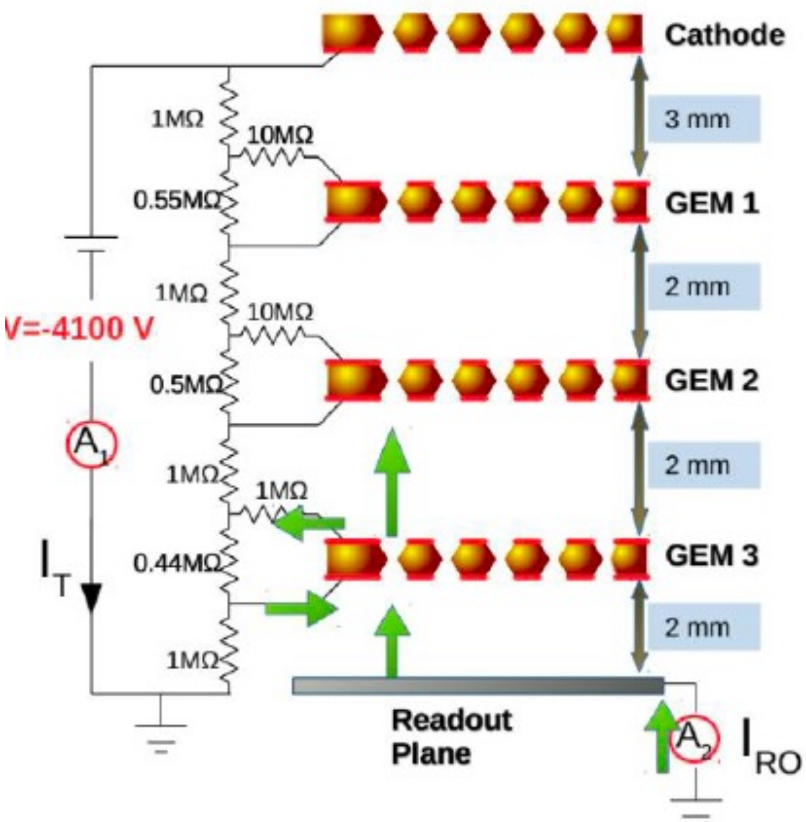


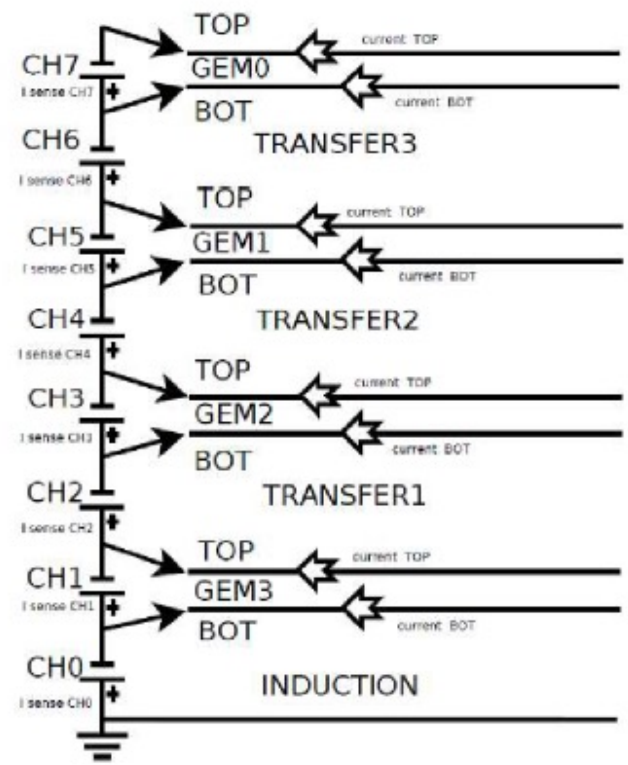
Efficiency vs. Beam Current

Another major issue doe to high charged hit rates: large current draw by the GEMs.

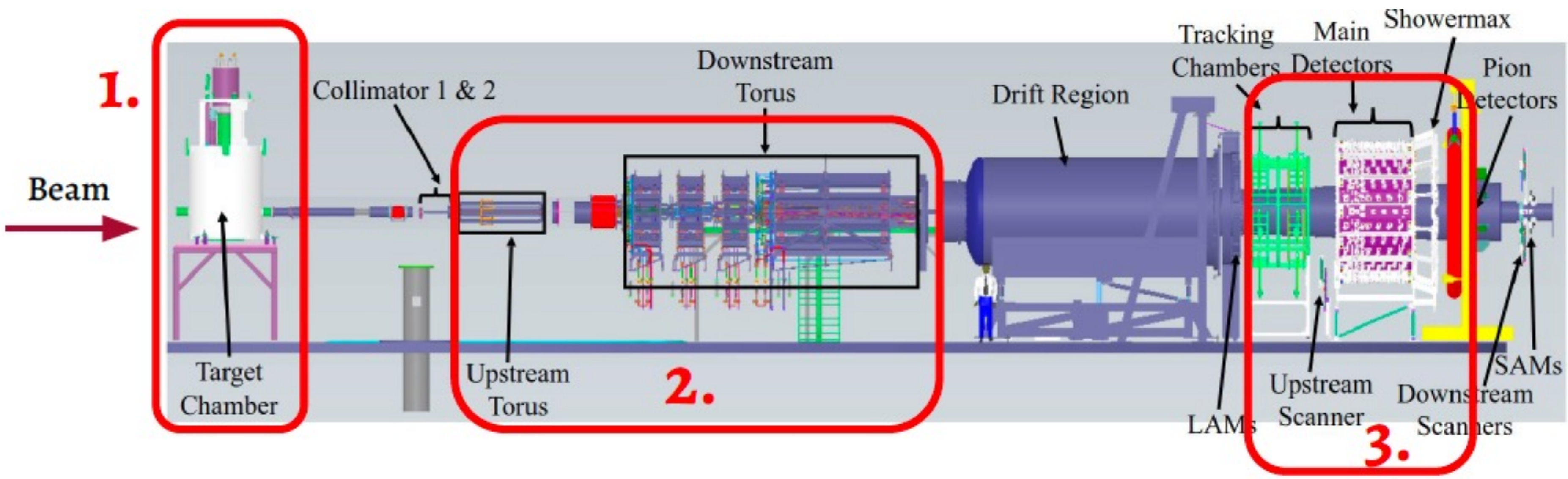
- As much as 500 μA drawn by G3
- High current draw from resistive divider reduces the voltages to the GEMs: major gain drops with increasing luminosity.
- Solution: use of CAEN multichannel GEM HV supply. Now installed for all SBS GEMs



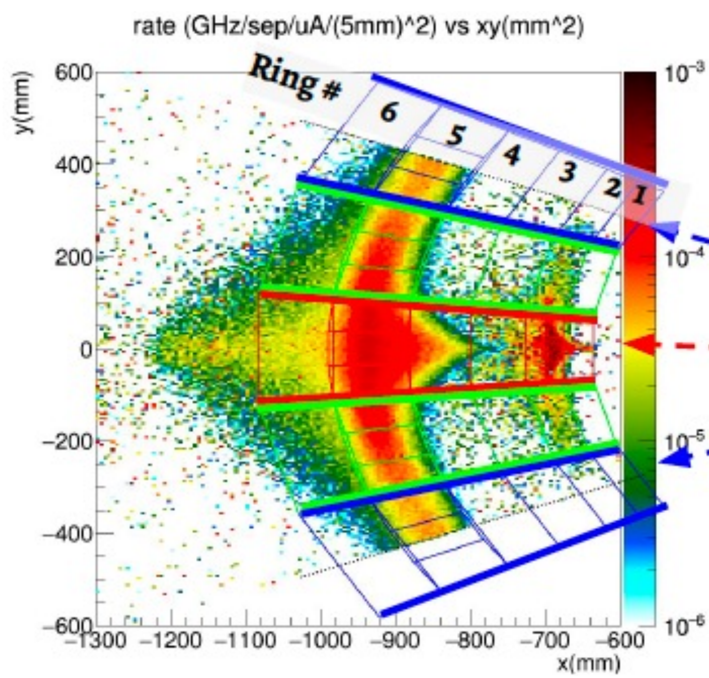


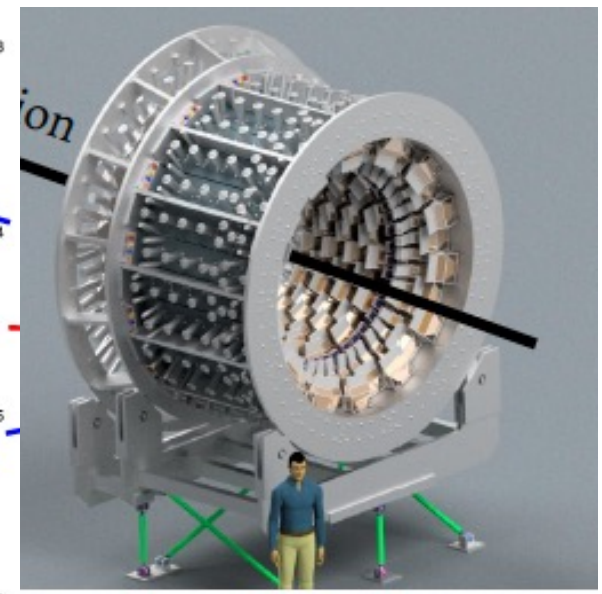


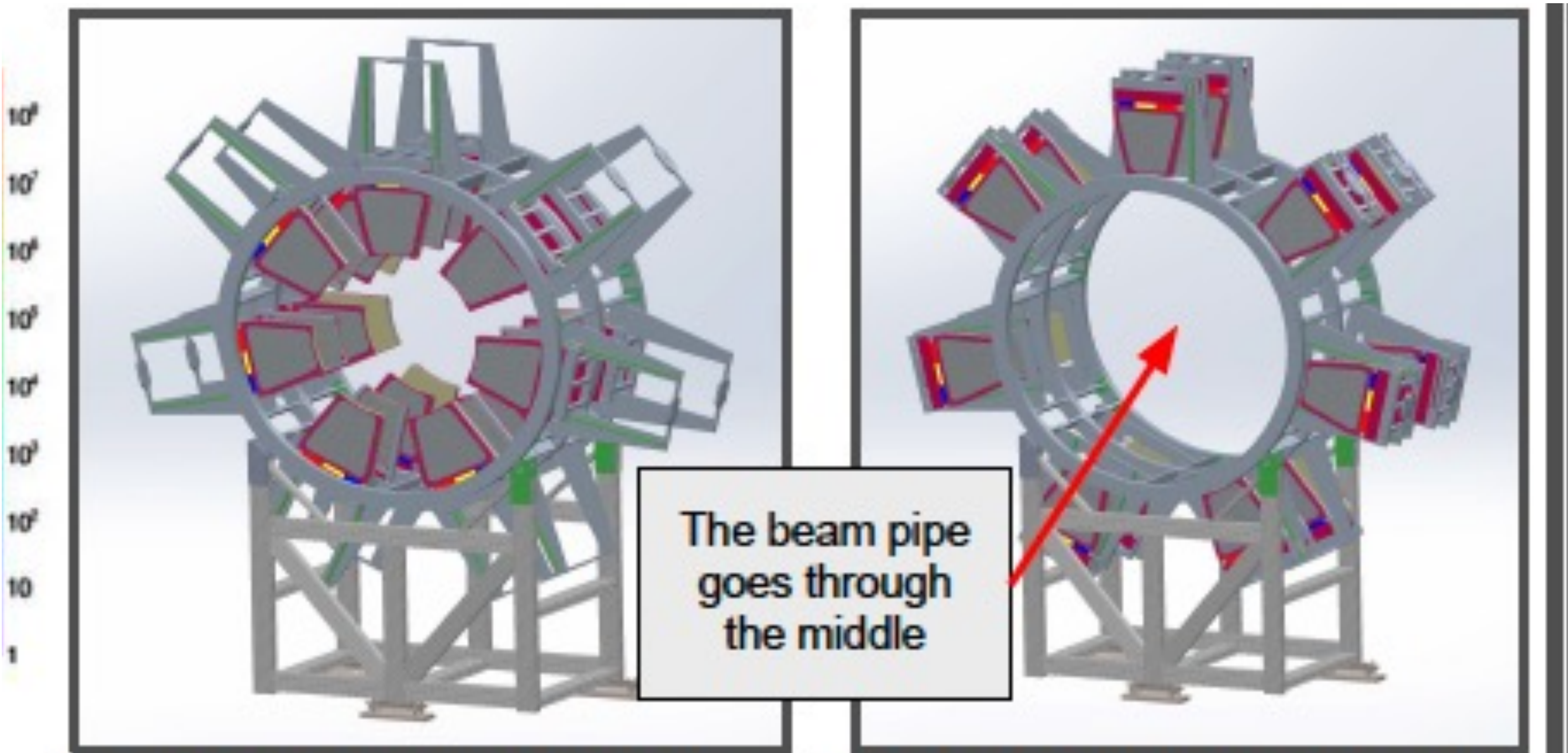
GEMs for MOLLER experiment at Jefferson Lab



- The rate during production in GHz: need integrating detectors.
- But Precision coordinate detection is needed for calibration of the Setup.
- GEMs: a good choice
- Calibration to be done with ~ 100 nA beam; highest local rates around 100 kHz/cm^2
- GEMs need to be moved out of the way to avoid damage during production







GEM Module Rotator Orientation during Calibration runs

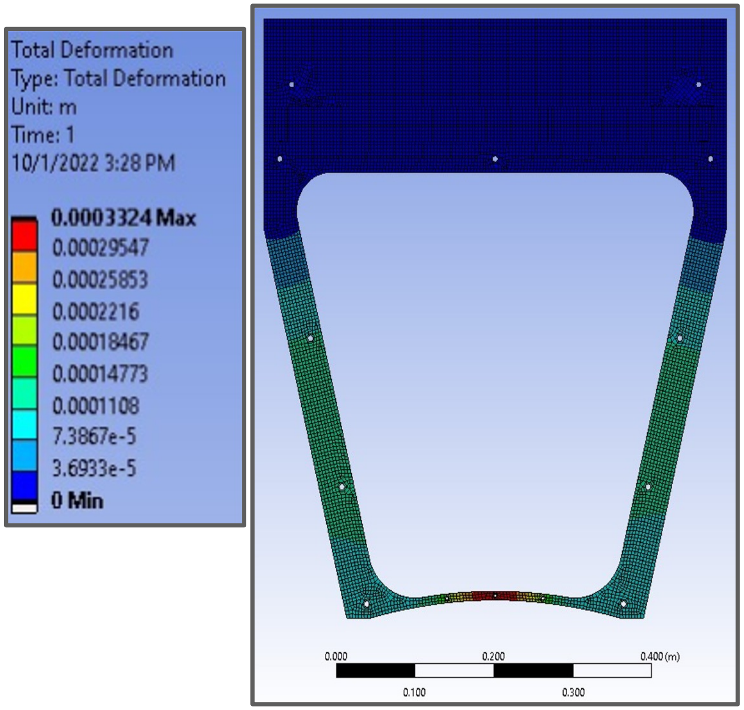
GEM Module Rotator Orientation during Production runs

- 4 GEM tracking layers, **7 trapezoidal shaped** detectors at each layer
- Only 50% azimuthal coverage cuts down overall costs
- GEM layers can be rotated around the beam pipe axis
- Pulled out during production runs (as shown above)
- Different geometric requirements for each layer - one single design to match with all 4 layers

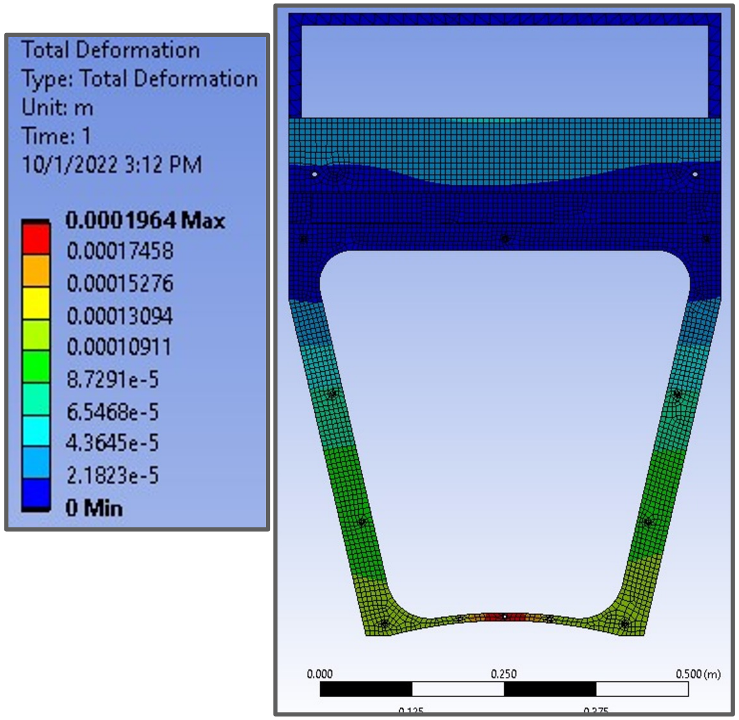
The work at UVa

- **Engineering Design** of GEM tracking detector module
- **Prototyping and Testing** of GEM tracking Modules
- Engineering Design of GEM **Polarimeter**
- **Mass fabrication** of **16** (+2 spares) out of **28** (+4 spares) total tracking detector modules
- **Fabrication** of **2** GEM Polarimeters
- **Commissioning, Operation** and **Data Analysis**

'Rotator' Image courtesy - Chandika Annasiwatt



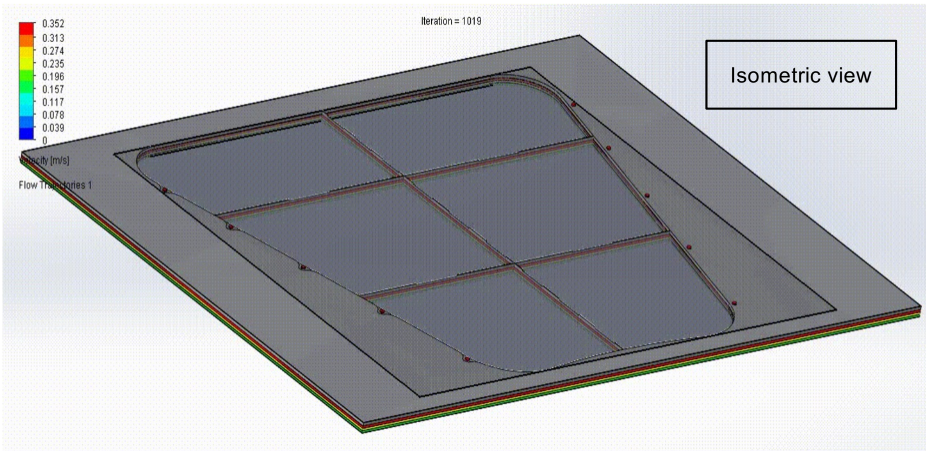
Deflections of the module
under 3(safety factor) times total foil stress
(without the Carbon fiber mounting frame)

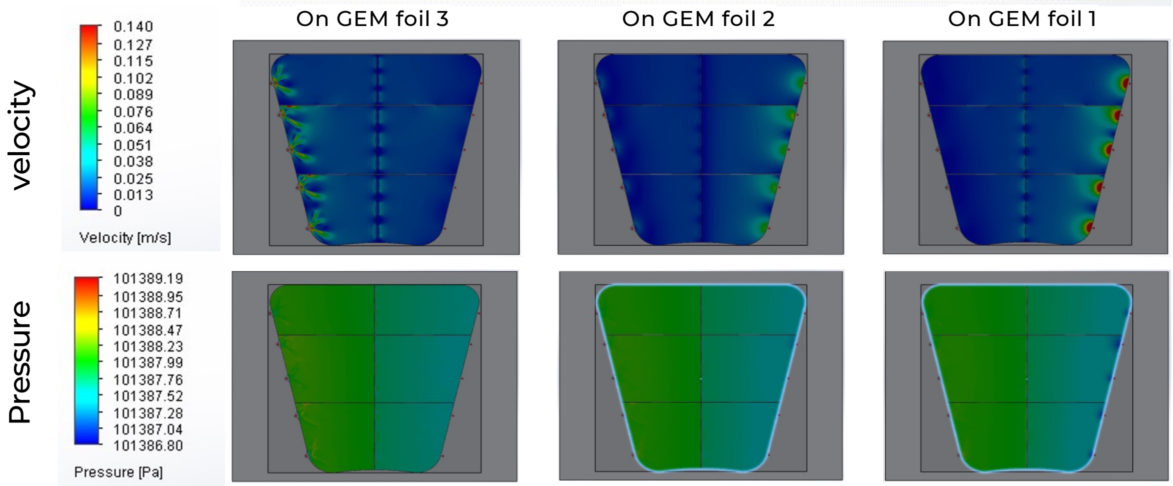


Deflections of the module
under 3(safety factor) times total foil stress
(with the Carbon fiber mounting frame)

Beam side of the frame has to be very thin and curved not to miss any acceptance. We did a FEA calculation to study the distortion of the thin inner arc under stress from the GEM foil tension. For this arrangement the deformation was 340 microns; within acceptable limits.

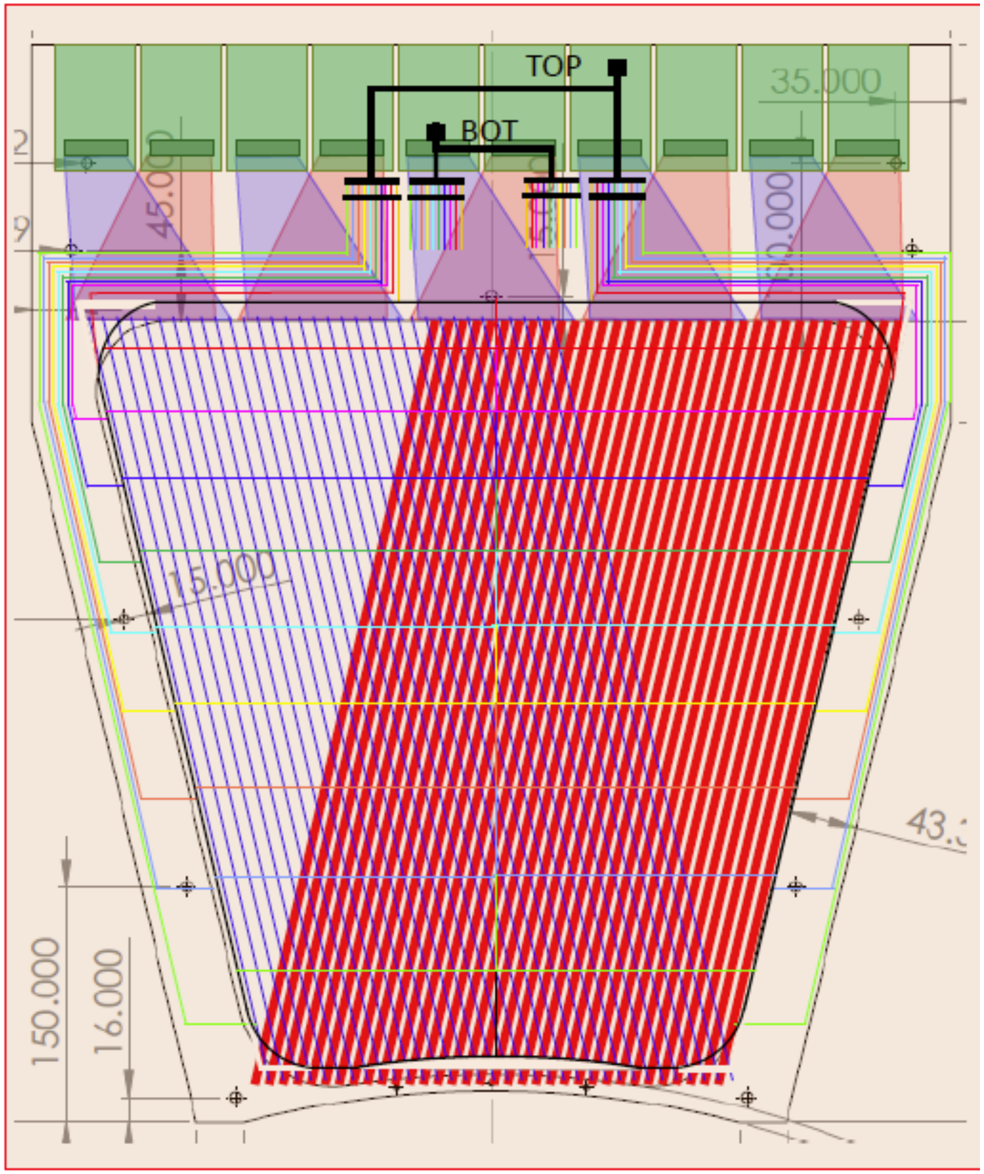
3-D CFD Simulation study of the internal Gas Flow

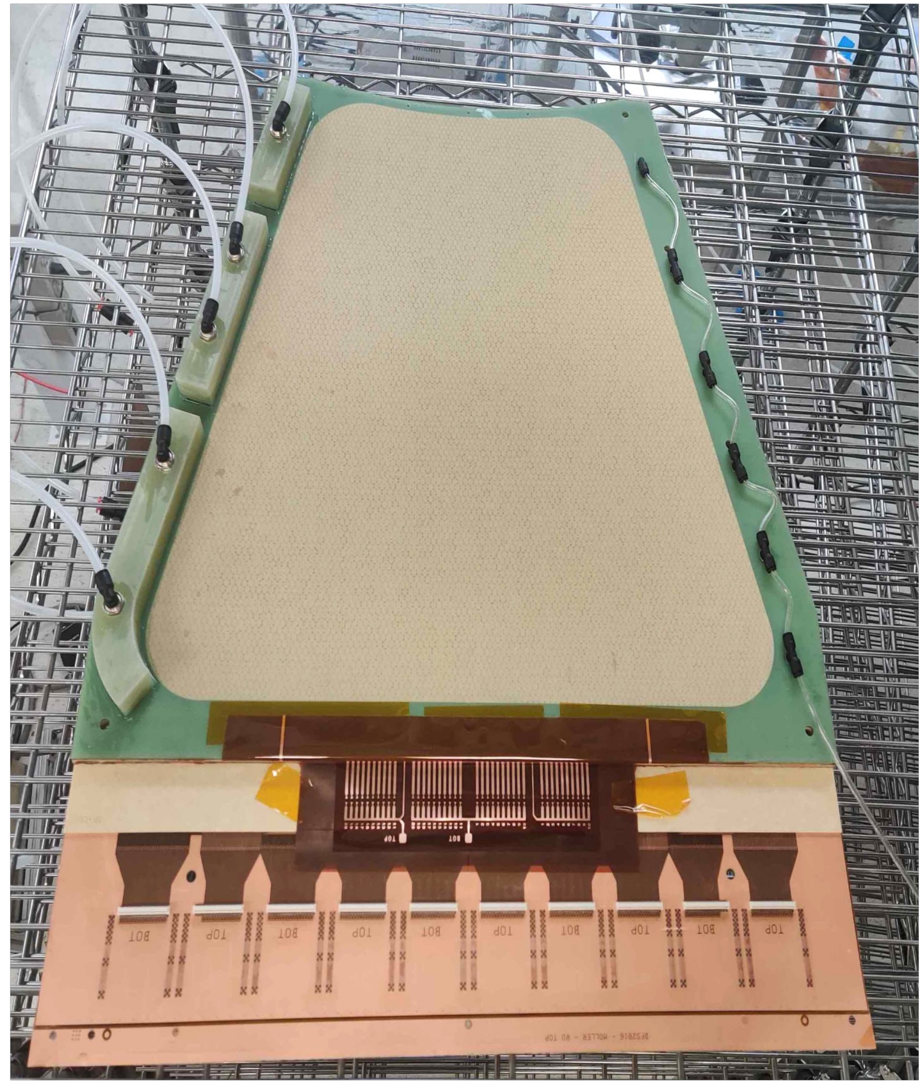




- Gas used: A mixture of 70% Argon and 30% Carbon dioxide
- Smooth gas flow is necessary for good chamber uniform efficiency
- Regions with lower gas circulation will likely lead to lower efficiency and increased aging.

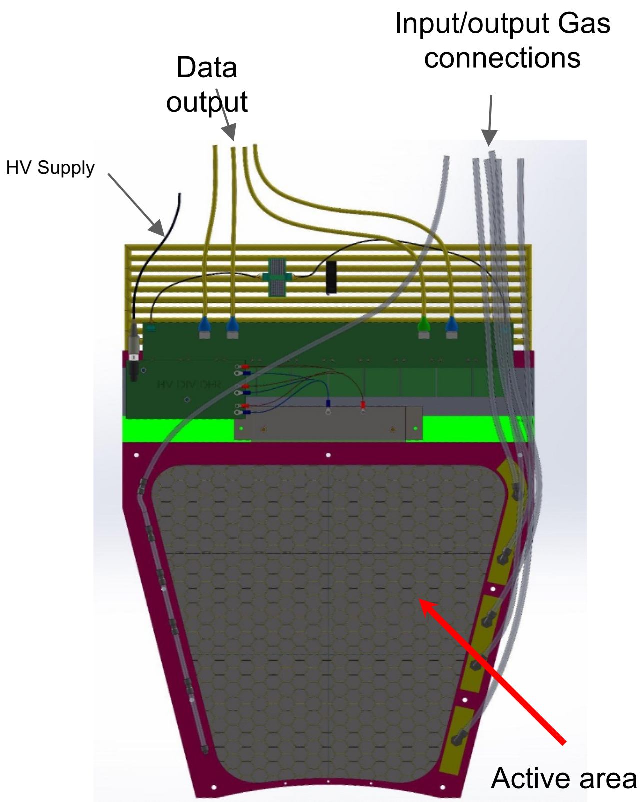
GEMs for MOLLER



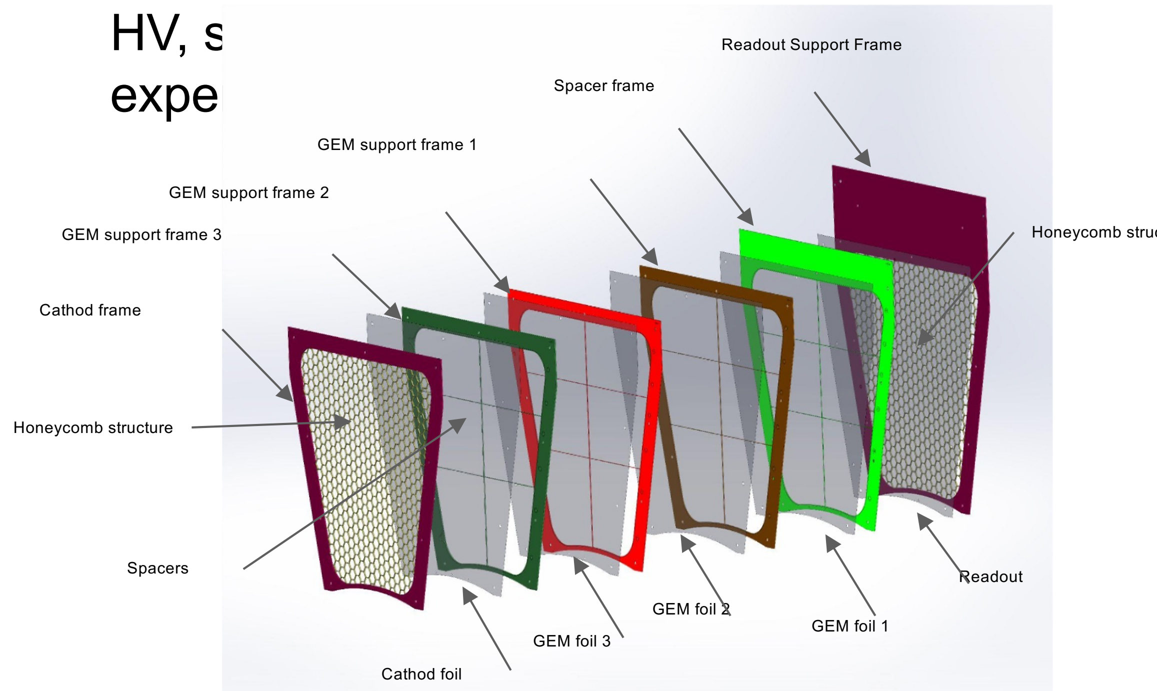


MOLLER coordinate GEM prototyping progress

- The CAD design based on the SBS GEM design.
- Improvements to module design, gas flow, HV, s
expe



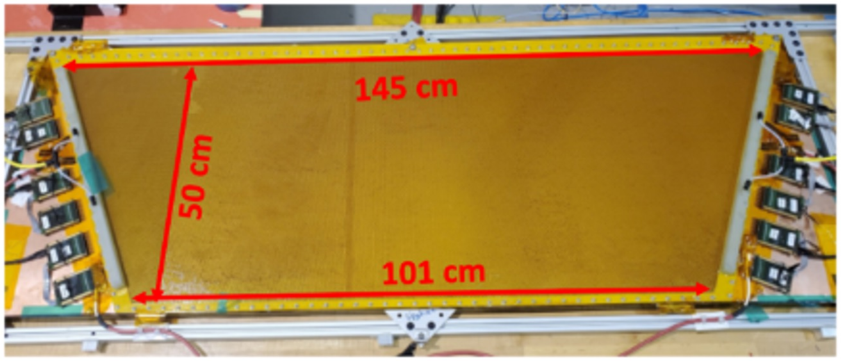
Module Front View with Components

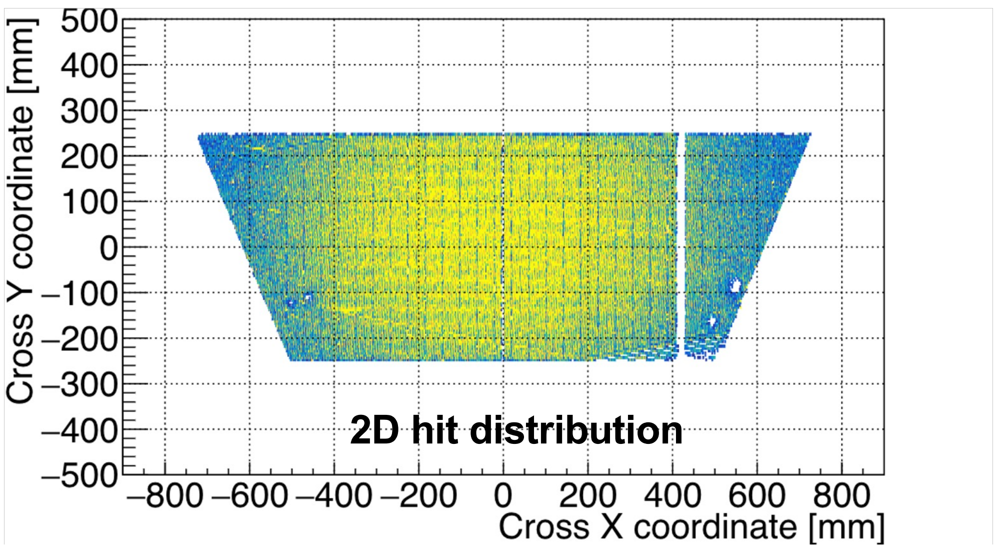


Exploded View with Basic Components

Jefferson Lab

Large-area µRWELL Prototype for CLAS12 at JLab

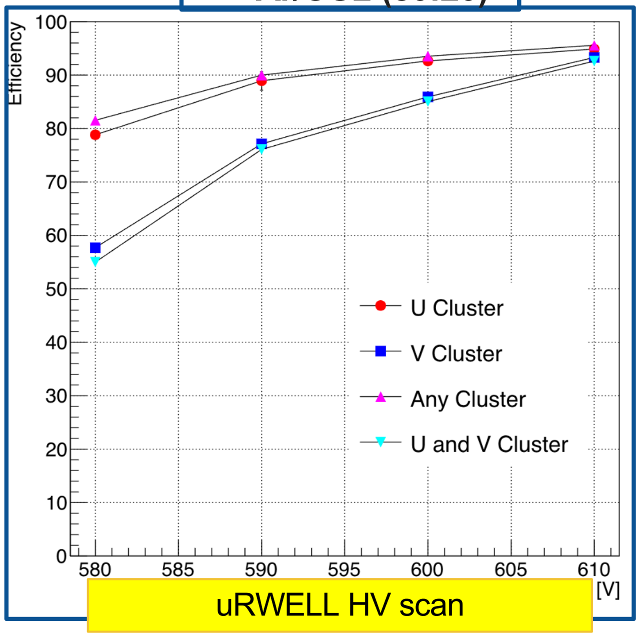




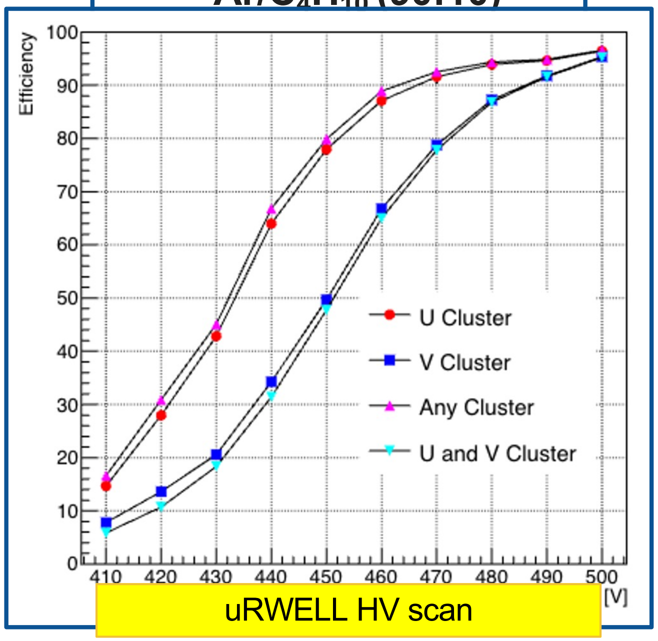
- **Large-area µRWELL with 2D-strip readout**
  - Active area: 50 cm x (101 cm x 145 cm)
  - U and V readout layers oriented 10° with respect to the base of the detector
  - Primarily built to study the impact of its large size and long readout strips on the overall performance of the detector
- **Studied intensively with cosmic**
  - 98% of the detector active area is functional
  - Overall gain is reasonably uniform

Efficiency of Large-area µRWELL Prototype

Ar/CO2 (80:20)



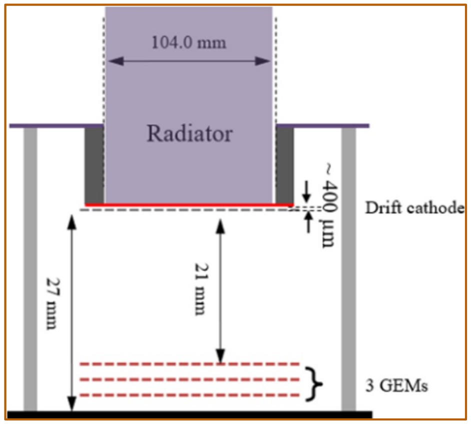
Ar/C_4H_{10} (90:10)

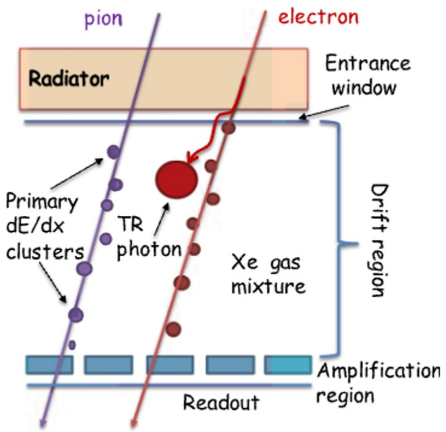


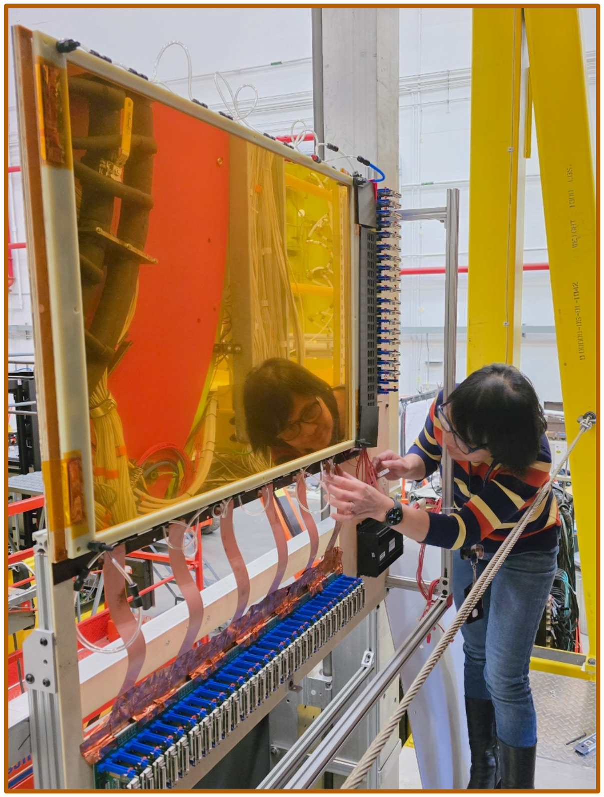
- ❖ **Detection efficiency of the bottom readout layer is significantly lower than top readout layer**
- ❖ **Prototype reached 90% efficiency in Ar/C4H10 (90:10) at a much lower HV (490 V vs. 600 V) => operated much more stably**

- ❖ **Plan to install the detector into Hall B to take beam data and check its high-rate capability.**
- ❖ **In discussion of building a new version of the large detector as a pair of 1D detectors facing each other, each with the same trapezoidal active area (145 cm × 101 cm) × 50 cm**

GEM-TRD Prototype for GlueX Experiment





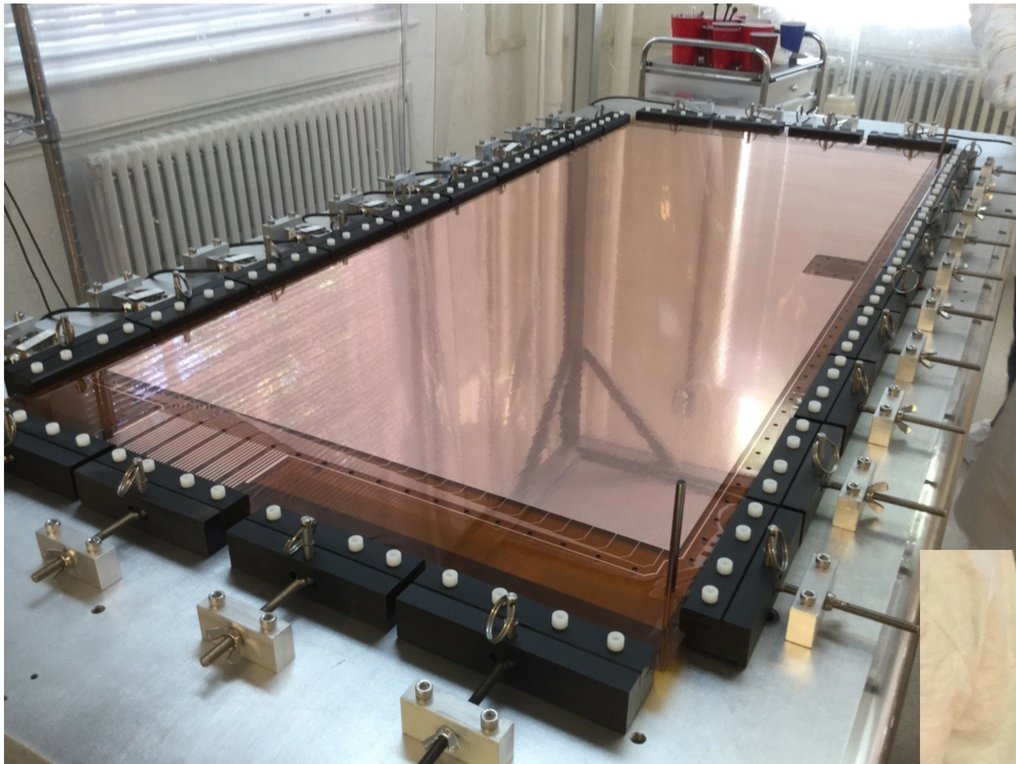


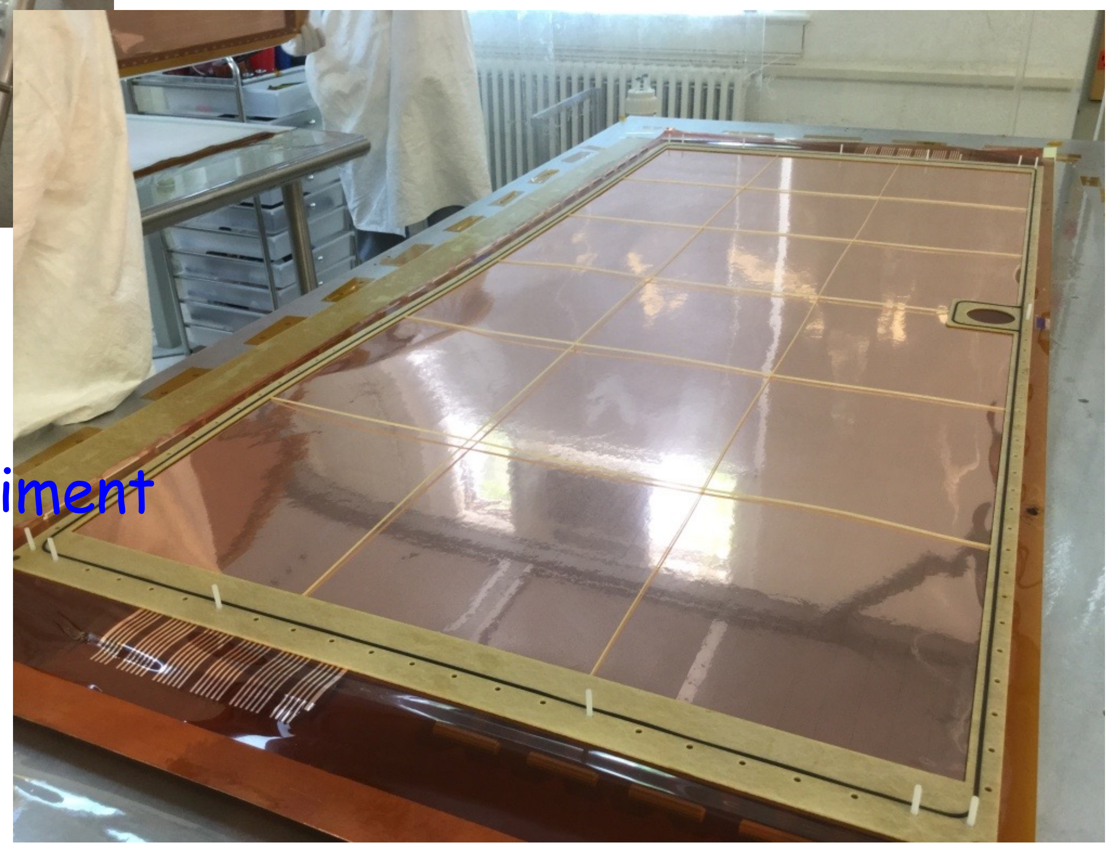
- **GEM-TRD Prototype**
  - Combination of TRD functionality with the high granularity and high-rate capability of GEM trackers for high-luminosity experiments at JLab
  - Used for electron identification or hadron suppression, particularly in high-luminosity experiments at JLab and EIC
  - Active area: 52 cm × 72 cm
  - Being tested with electrons in Hall D using a Krypton gas mixture. S

GEM-Pixel Detectors for GEn Experiment

- **Issues with intense low-energy photon background at SBS**
  - Photon conversion hits increase the occupancy of the GEM trackers
  - Problem especially severe for strip readout due to false x-y combinations
  - Too costly for fine pixel readout
  - Increased difficulty in track reconstruction and reduced the overall efficiency of the tracking system.

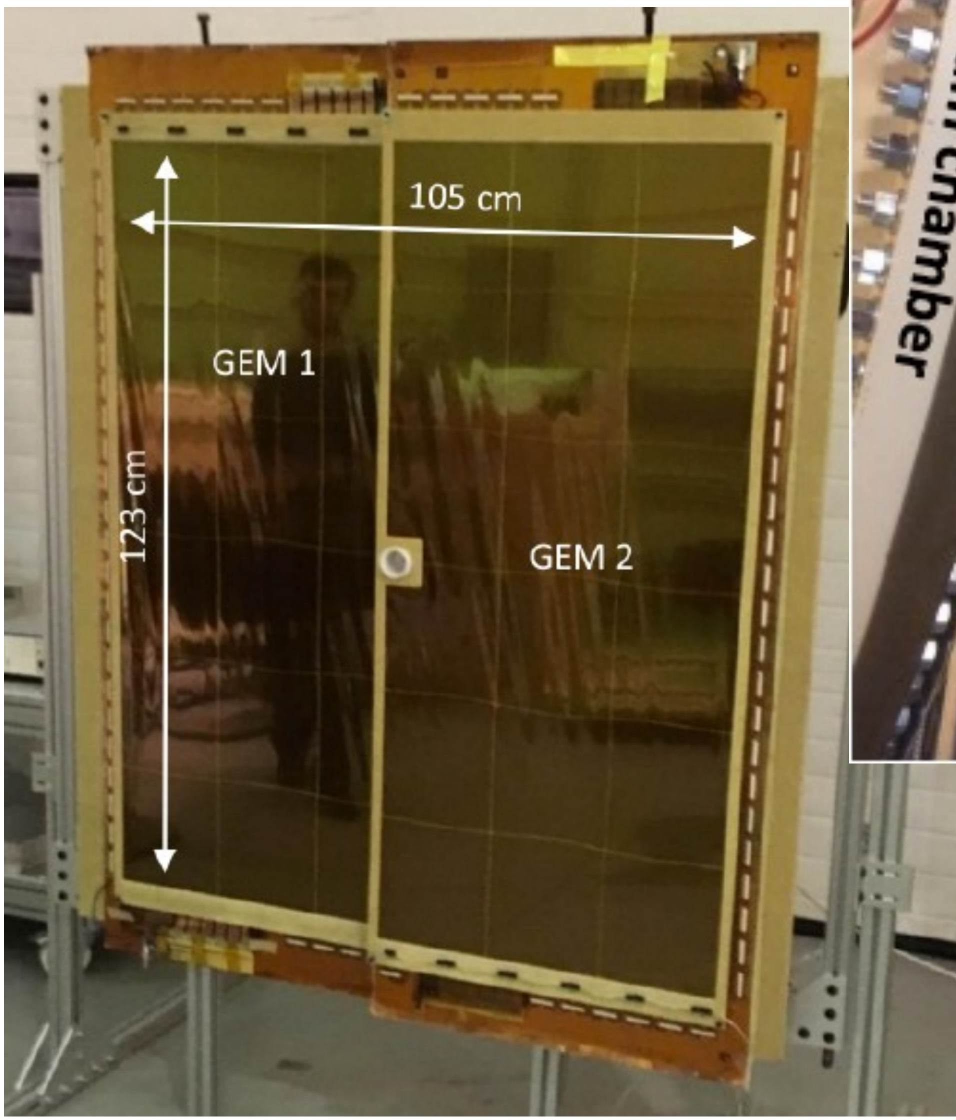
- **Solution: Adding coarse pixel detectors in combination with strips**
  - Building two GEM detectors with 9×9 mm^2 pixel readout and active area of 40×150 cm^2
  - Hits from low-energy photons tend to produce single-tracker-layer hits without correlated signals across independent tracker layers
  - Having two pixel detectors at the front and back of the SBS tracker system and applying a coincidence condition between them to differentiate random photon conversion hits rom high-energy track hits.
  - Accelerate the track-finding process by narrowing the search area for hits in the subsequent 2D-strip-readout GEM trackers

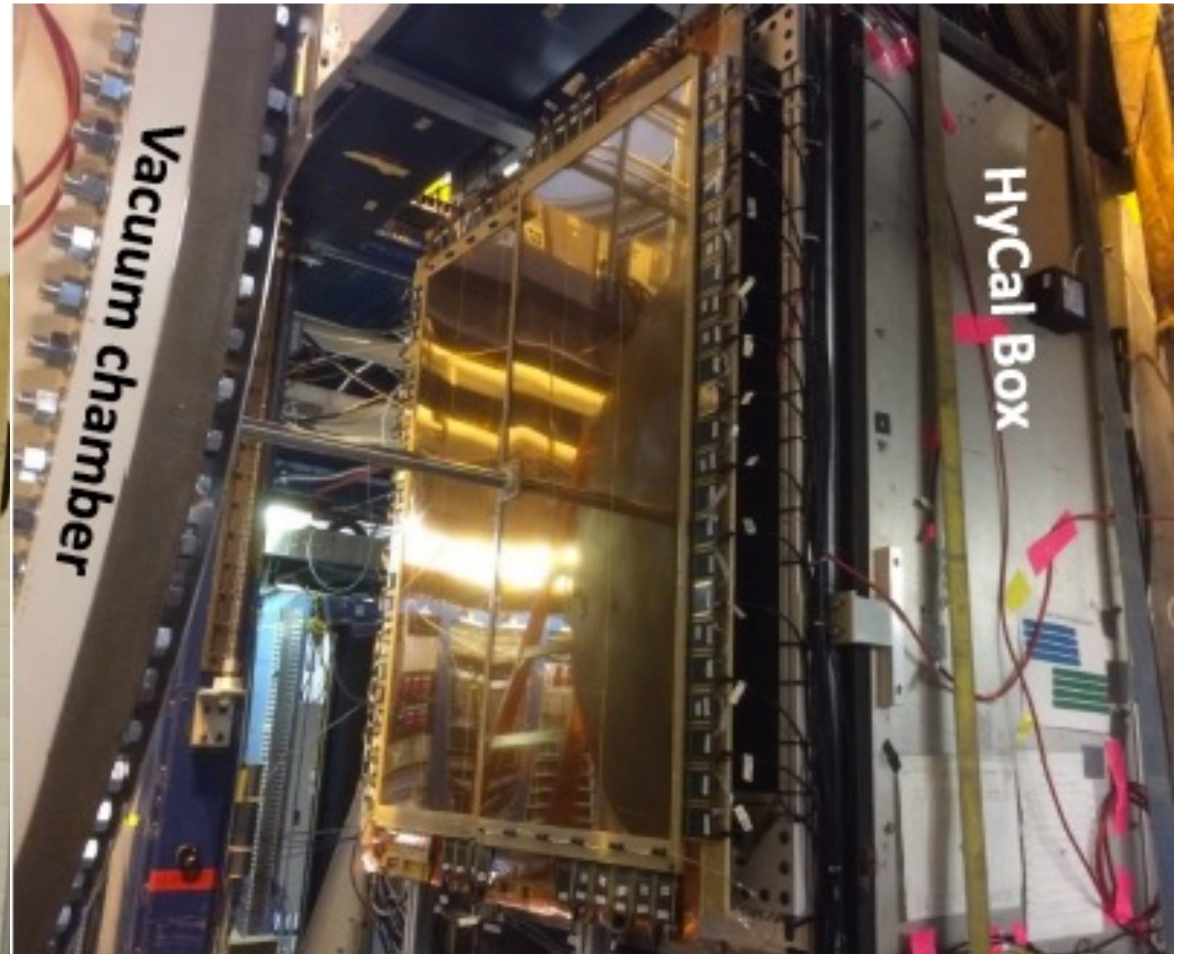




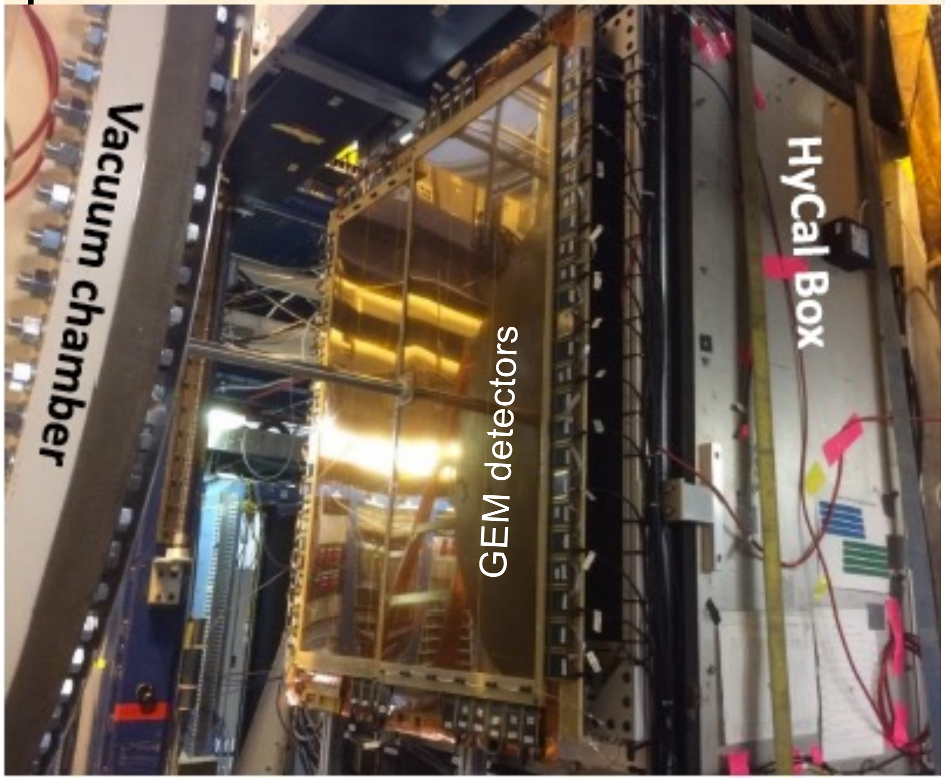
123 cm x 55 cm active area
GEM detectors for pRad experiment
during construction at UVa

pRad GEMs

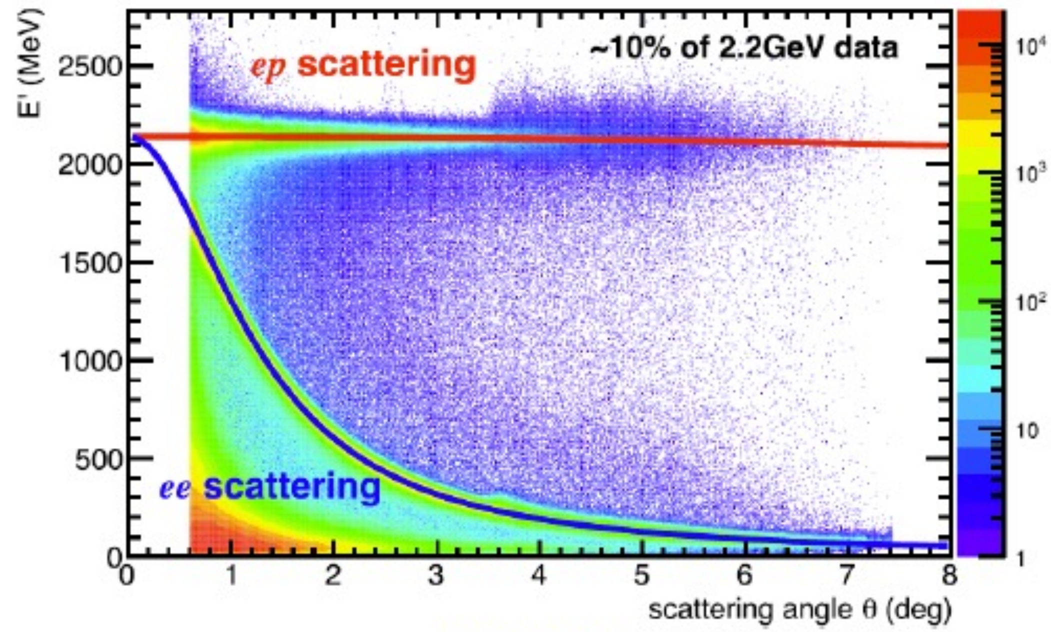




pRad GEMs - Results

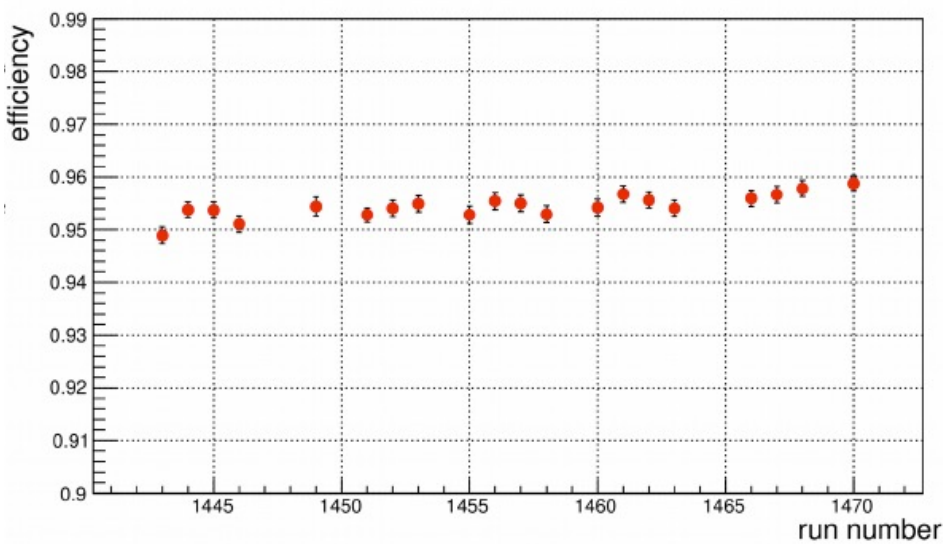


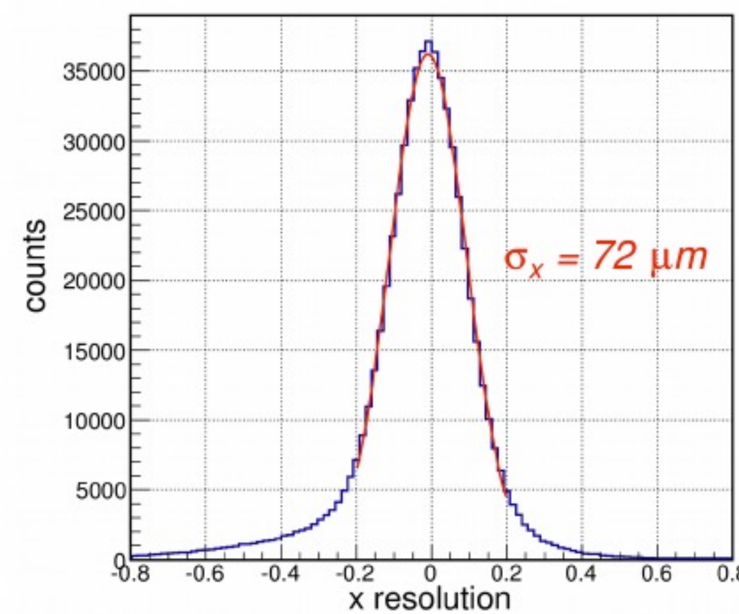
Using coordinates from GEM detectors, and energy from calorimeter.



2.2 GeV beam

GEM efficiency as a function of time



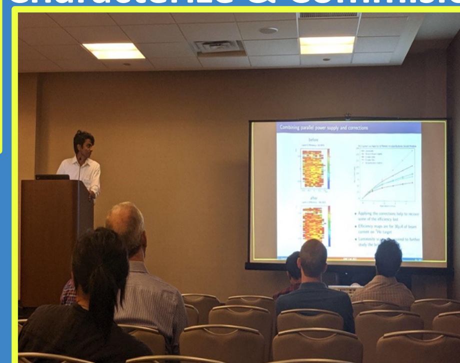


UVA MPGD Lab's Capabilities

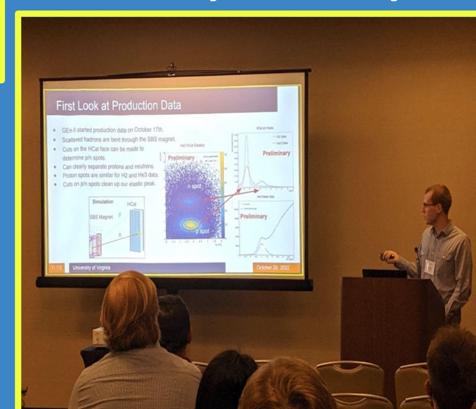
Simulations

Design & Construction

Characterize & Commision



Data & Physics Analysis



A BIG thank you to Rui and his team for providing us with excellent quality foil, readouts, valuable advise and innovation

Liyanage-Nguyen MPGD Group at UVa

- ⇨ Six (6) Grad Students & One (1) Undergrad
- ⇨ Two (2) Technicians (Mechanical & Electrical)
- ⇨ Two (2) Post-docs
- ⇨ Two (2) professors
- ⇨ And close collaboration with former colleague Kondo Gnanvo

Conclusion

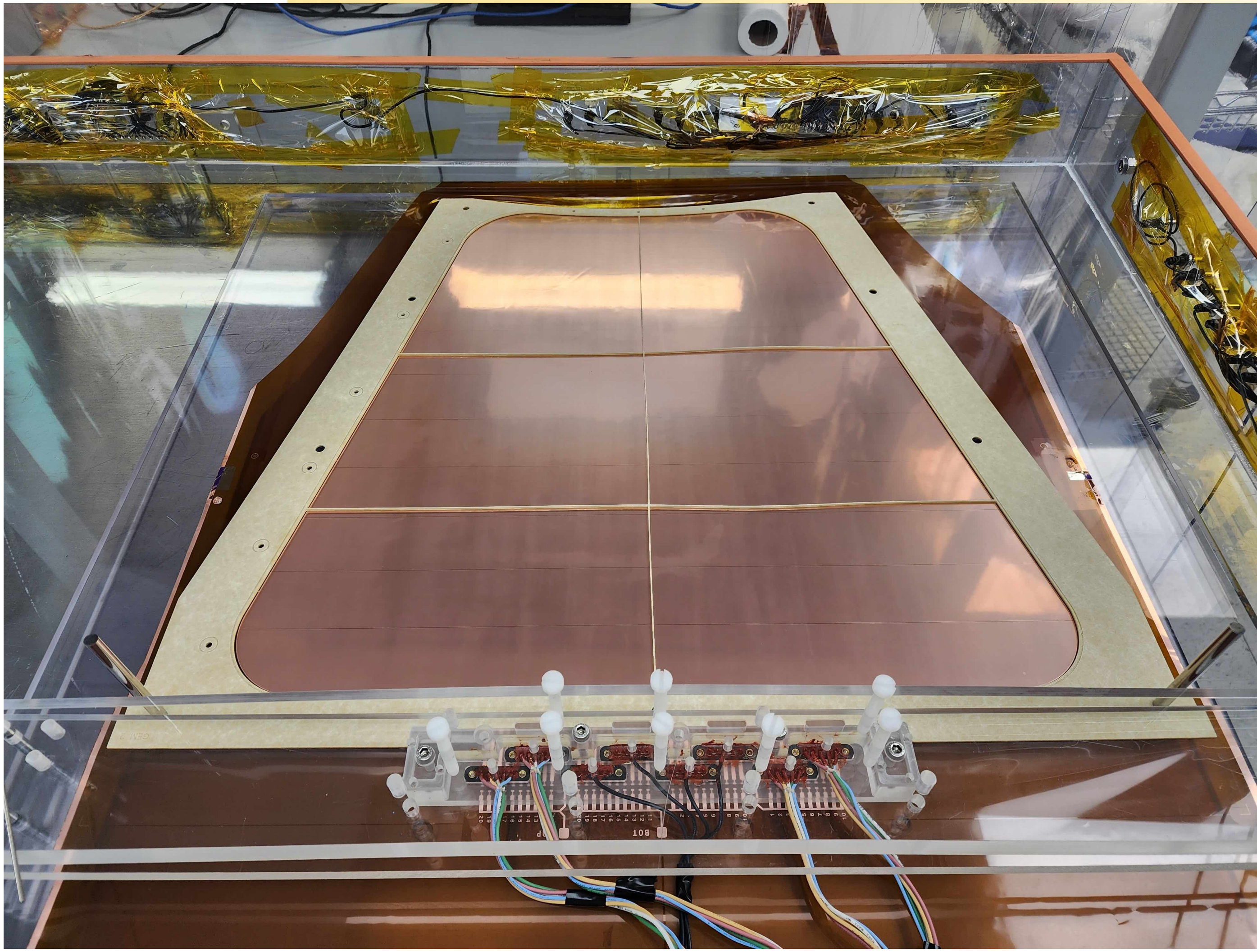
- At the University of Virginia we have a very active MPGD production and R&D program
- Traditionally our interests have been in large area MPGDs and MPGDs to work under high rates and highly ionizing conditions.
- Now we are also working in the areas of thin-gap MPGD, GEM-TRD, and wire-amplification detectors.
- We have had very close collaboration with RD51/DRD1 and looking forward to continuing this collaboration.

Backup

GEM foil quality assurance

- Visual inspection of the foil upon arrival from CERN. If there is any sign of damage:
  - inspect the area under the microscope. If damage is confirmed, set the foil aside and return to CERN.
  - If there are minor issues such as local discoloration, spots etc. refer the foil or sector for microscope and special attention during high voltage testing
- High voltage testing of all sectors at three different stages: in the raw foil, in the framed foil and the foil in the module.

GEM foil quality assurance: sector testing in dry N_2 box



- Rapid HV ramp-up to 550 V.
- Significantly higher the voltage applied in operation (~ 400 V)
- At 550 V: the initial current is a few of μA (re: capacitance of the sector).
- Then quickly drops and stabilizes to ~ 1 nA
- The test is done for raw foils, framed foils and foils in chamber

GEM foil quality assurance

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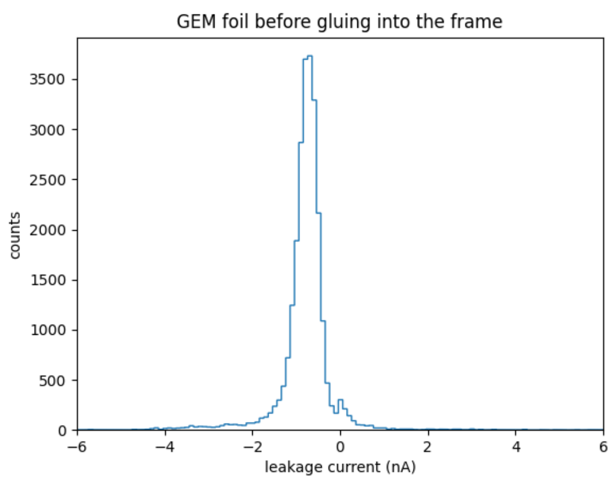
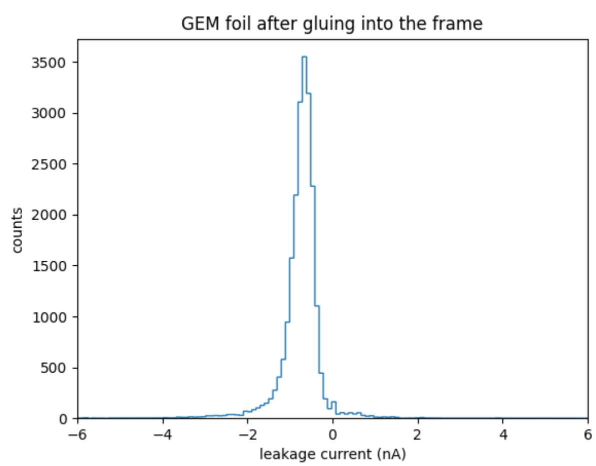
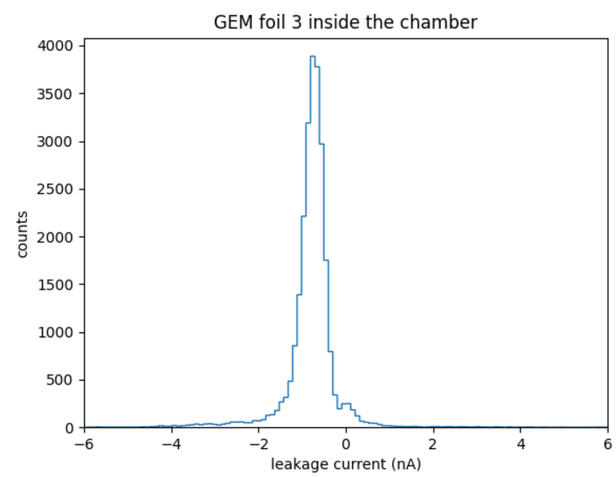
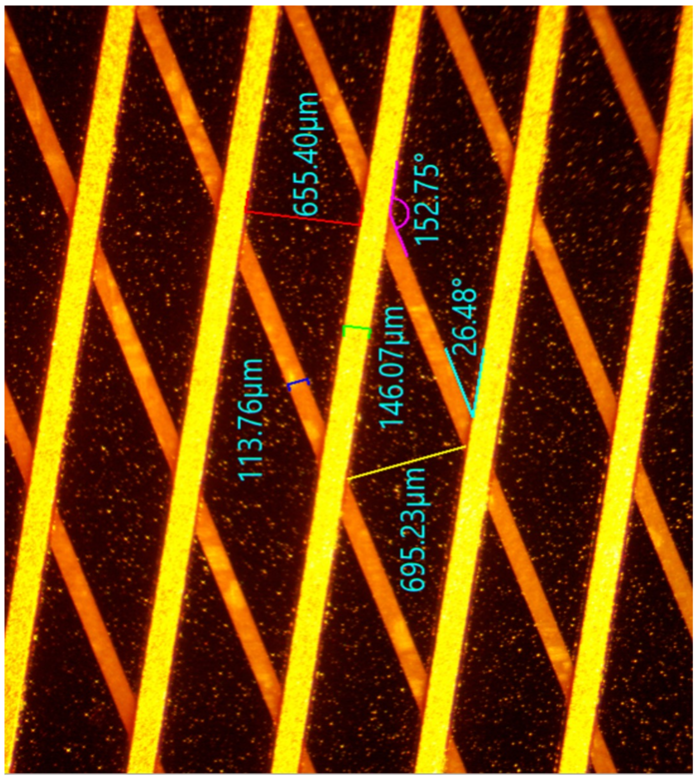
  - inspect the area under the microscope. If damage is confirmed, set the foil aside and return to CERN.
  - If there are minor issues such as local discoloration, spots etc. refer the foil or sector for microscope and special attention during high voltage testing
- High voltage testing of all sectors at three different stages: in the raw foil, in the framed foil and the foil in the module.
  - require leakage current to be less than 5 nA: if raw foil fails test, set the foil aside and return to CERN.





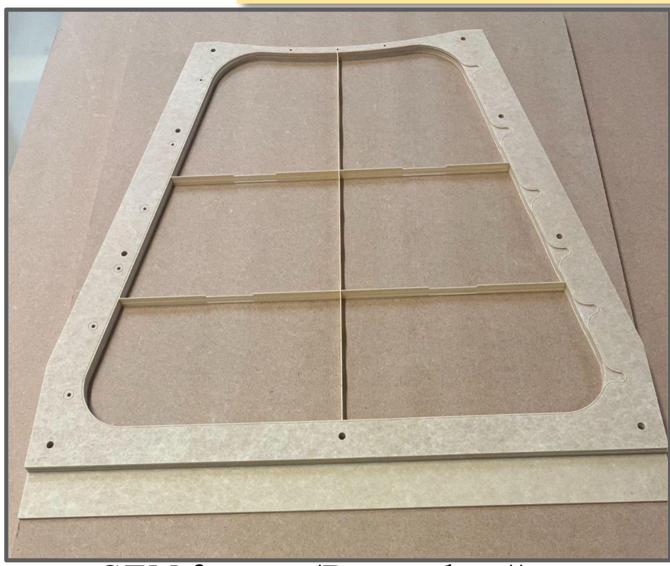


Readout foil quality assurance

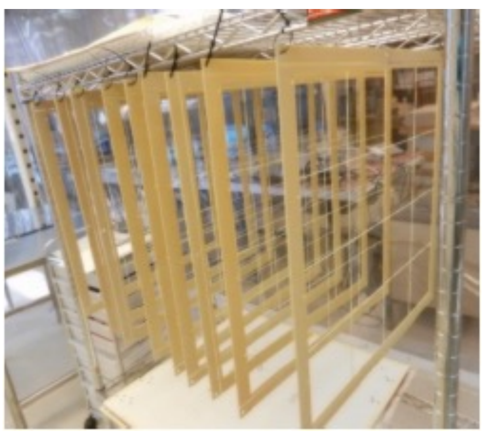


- Visual inspection upon arrival from CERN:
  - Check sensitive area and all connectors. Note any areas with possible issues for inspection under microscope.
- Inspection of readout strips under the microscope:
  - measure the readout strip width and strip pitch for both directions. Ensure that no Kapton is extending out from under the top readout strip layer.
  - If observations are not within specs, set the readout aside and return to CERN.
- Electronic pedestal noise test of the readout board:
  - Connect all connectors of the readout board to the APV-25 readout system and take pedestal data. Ensure that all channels have pedestal RMS values of 50 channels or less.

Preparation of the frames

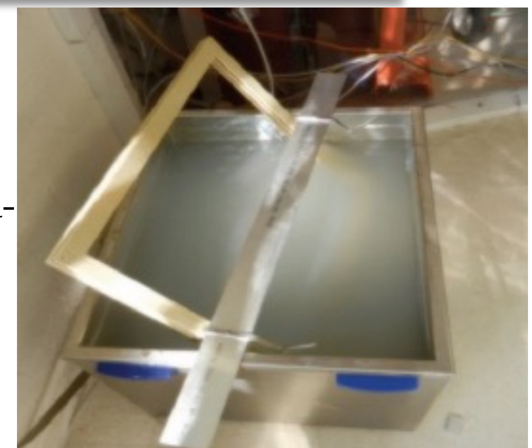


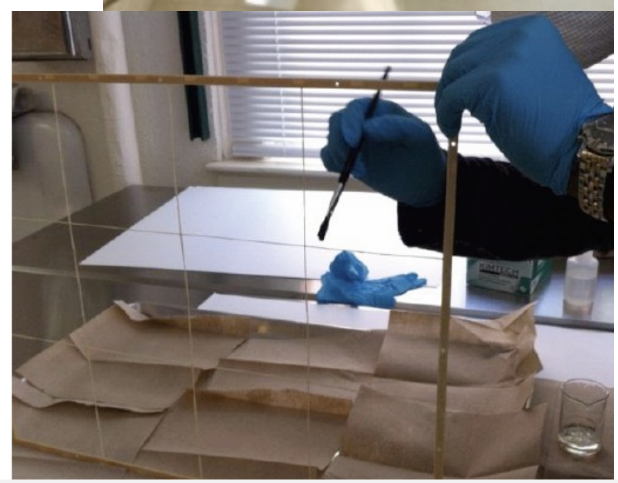
GEM frames (Permaglass))



Dried for 4 days under a filter hood .

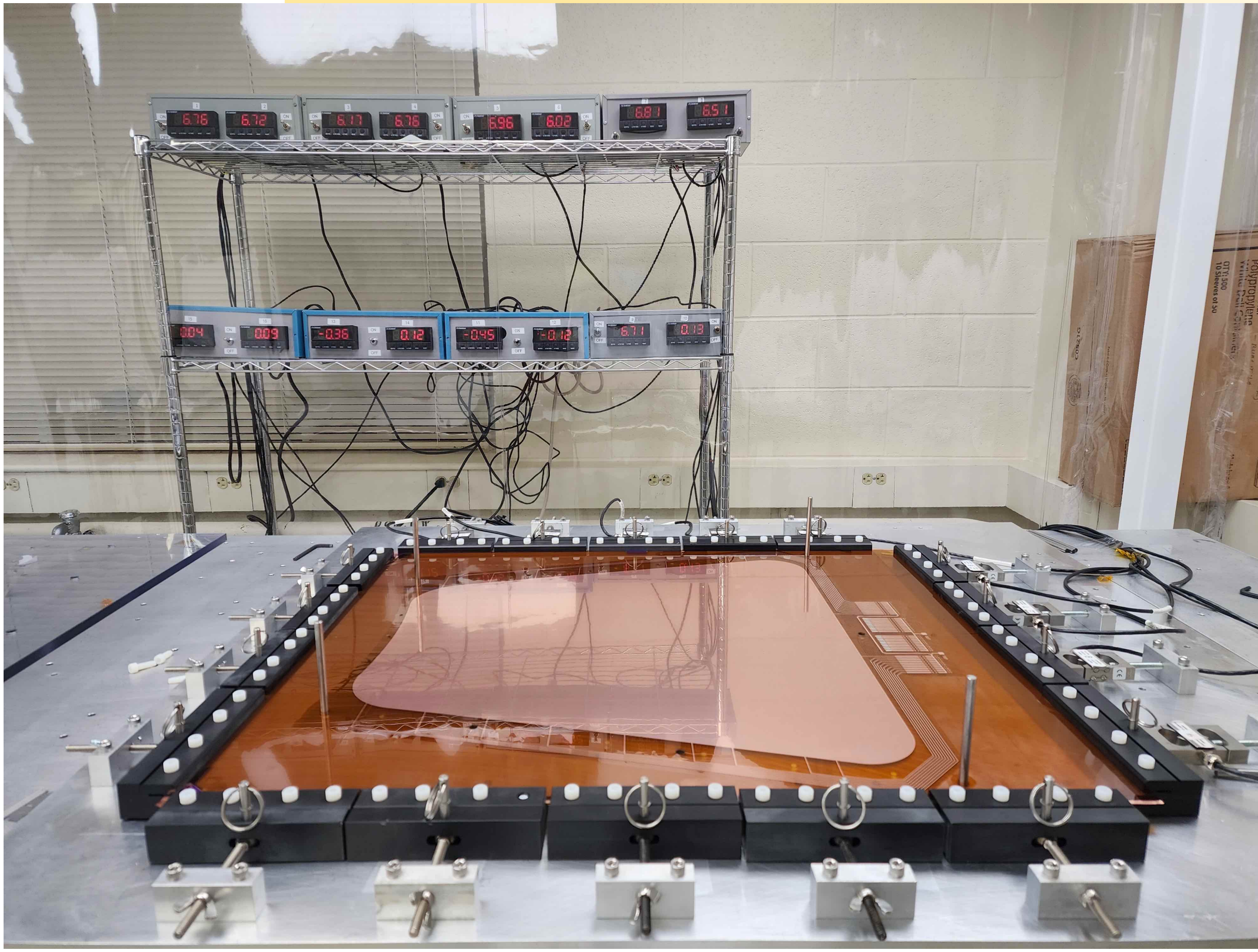
Spacers sanded, then frames cleaned in Ultra-sonic bath with demineralized Water



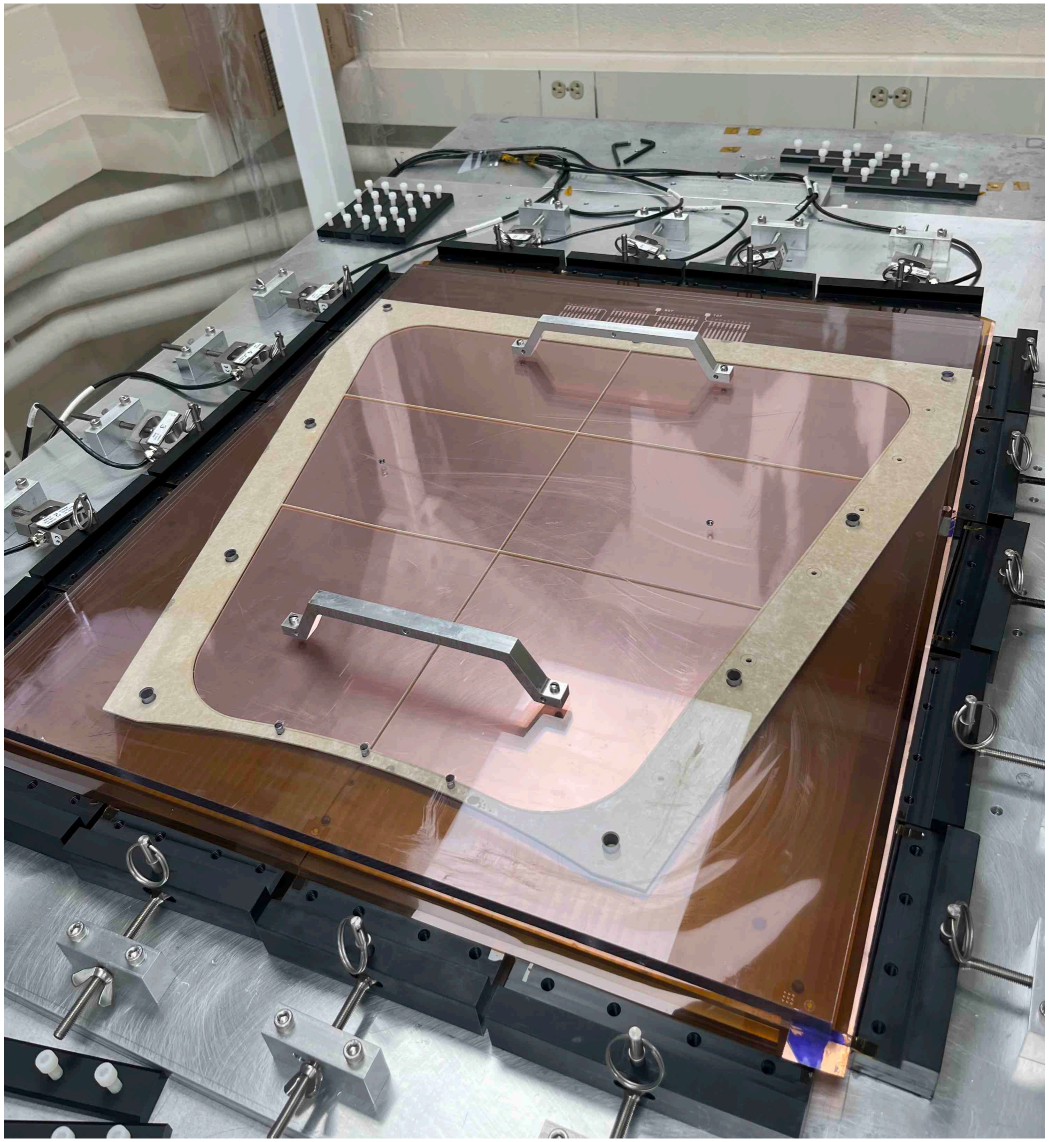


Machined surfaces sealed with a layer of polyurethane (Nuvovern LW) to prevent surface irregularities, residual fibers or sharp edges in the active area of the chamber

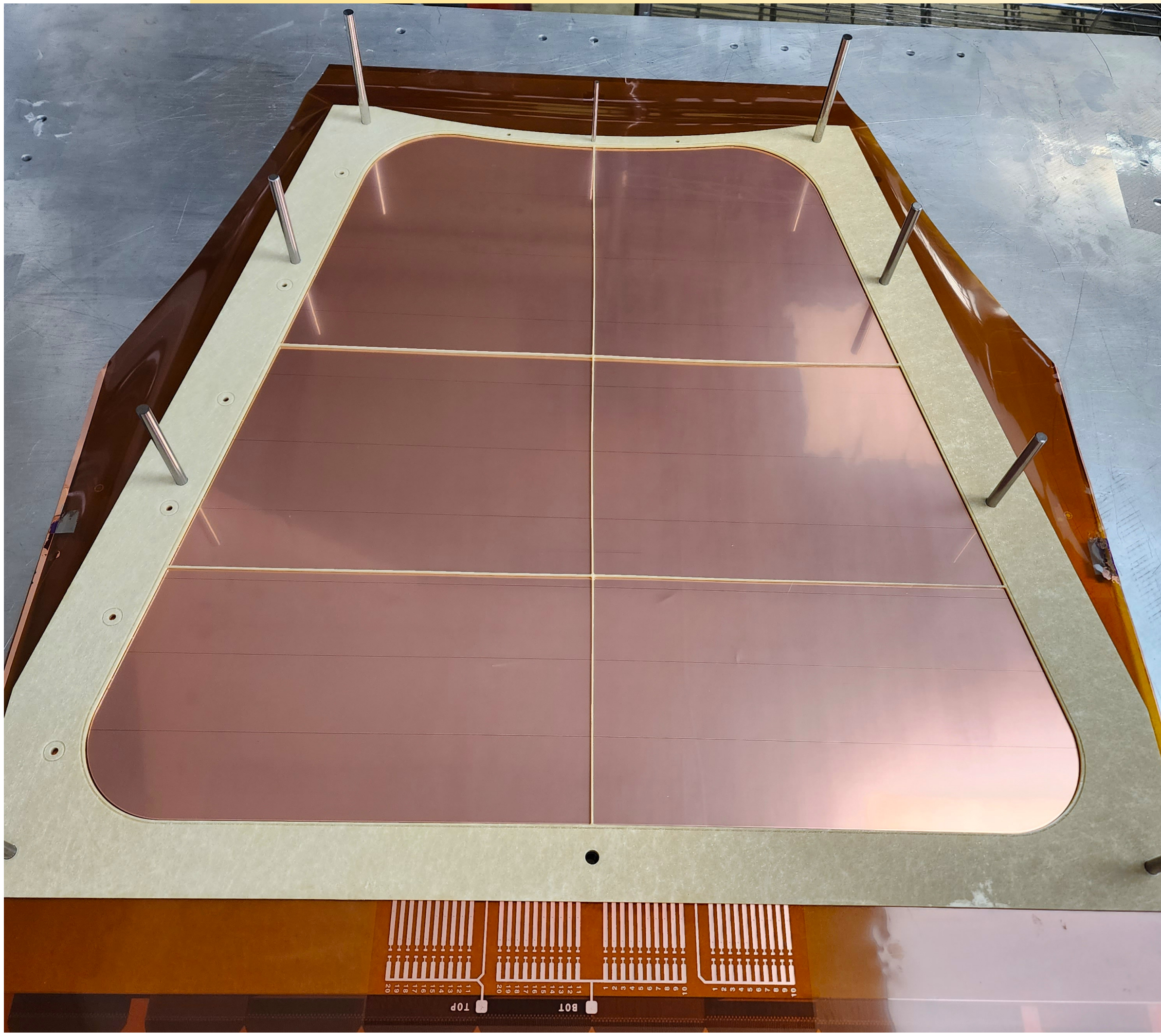
Assembly: Foil stretching



- ❑ Foil stretched to 2.5 N per cm ±10 %
- ❑ Monitored for 24 hours till the glue dries



Assembly: Gluing Framed foil to chamber



- Dowell pins used to ensure alignment to 50 micron level

Assembly: Chamber with all 3 GEM foils installed