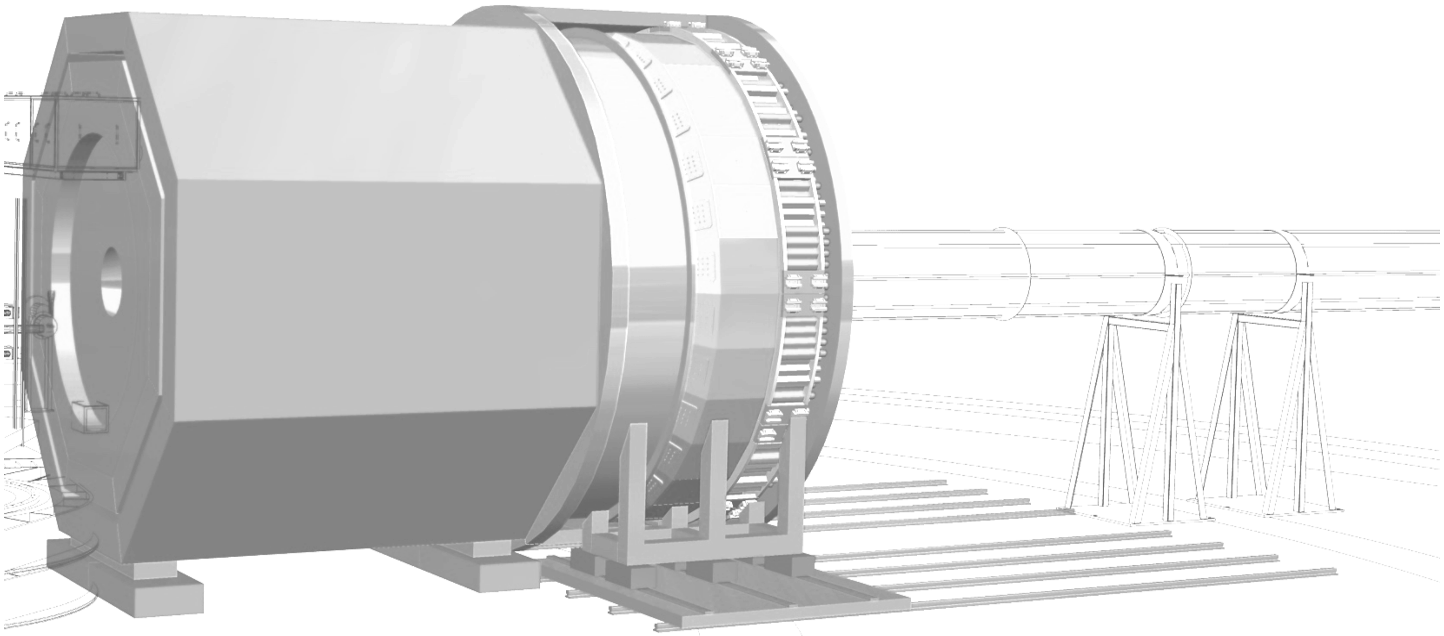
Gas Electron Multiplier (GEM) Tracker



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SoLID GEM Group
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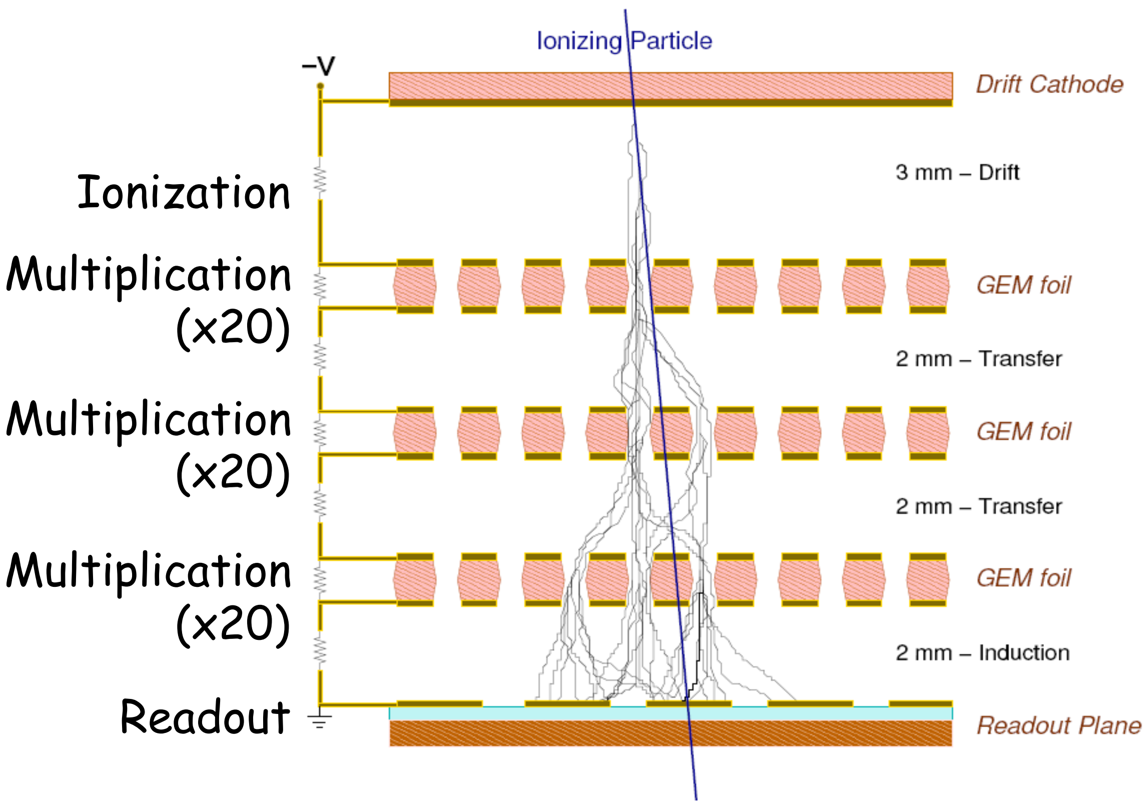
Outline

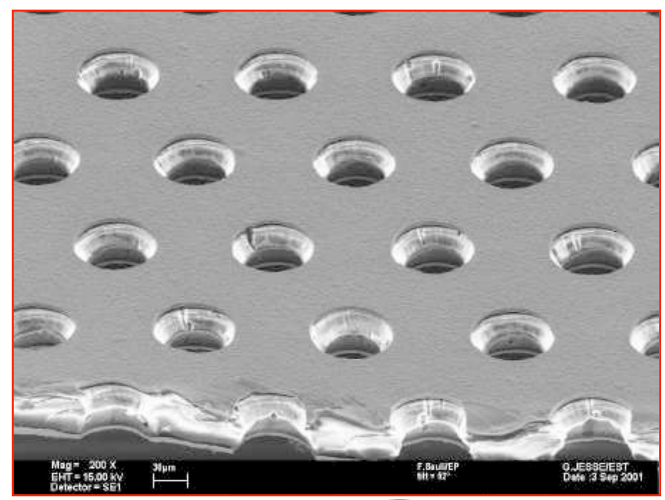
1. Why GEMs for SoLID ?
2. Requirements and Design
3. Ongoing large GEM activities at Uva
4. MuRwell R&D.

Why GEMs

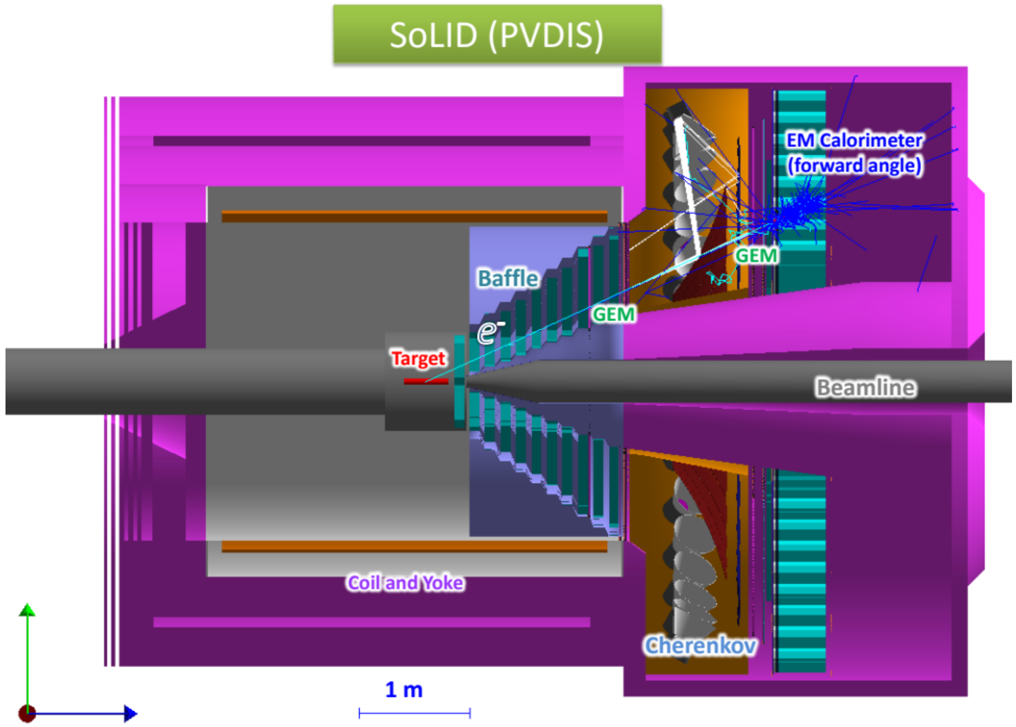
- SoLID concept leads to need for high rate trackers with good position resolution.
- GEMs: cost effective for high resolution tracking under high rates over large areas.
    - Rate capabilities higher than many MHz/cm^2
    - High position resolution (< 75 μm)
    - Ability to cover very large areas (10s – 100s of m^2) at modest cost.
    - Low thickness (~ 0.5% radiation length)
- Used for many experiments around the world: COMPASS, CMS upgrade, ALICE TPC, pRad, SBS etc.

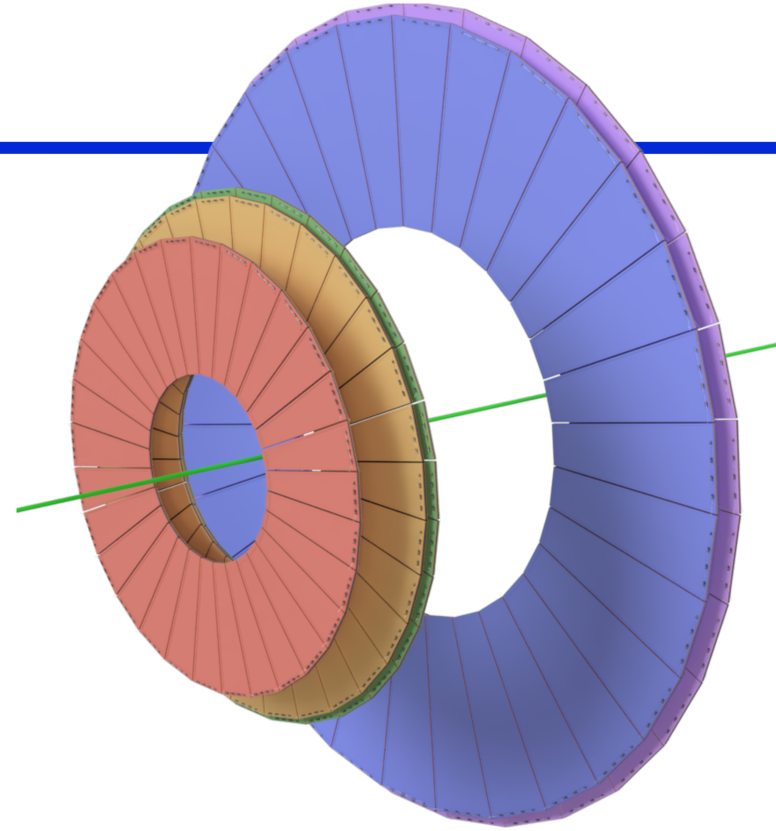


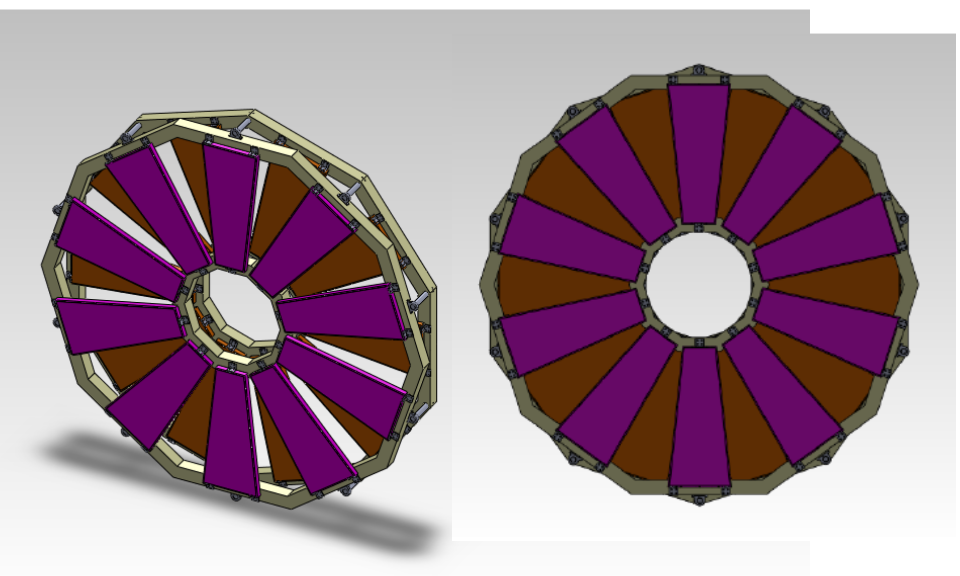
GEM foil: 50 μm Kapton + few μm copper on both sides with 70 μm holes, 140 μm pitch

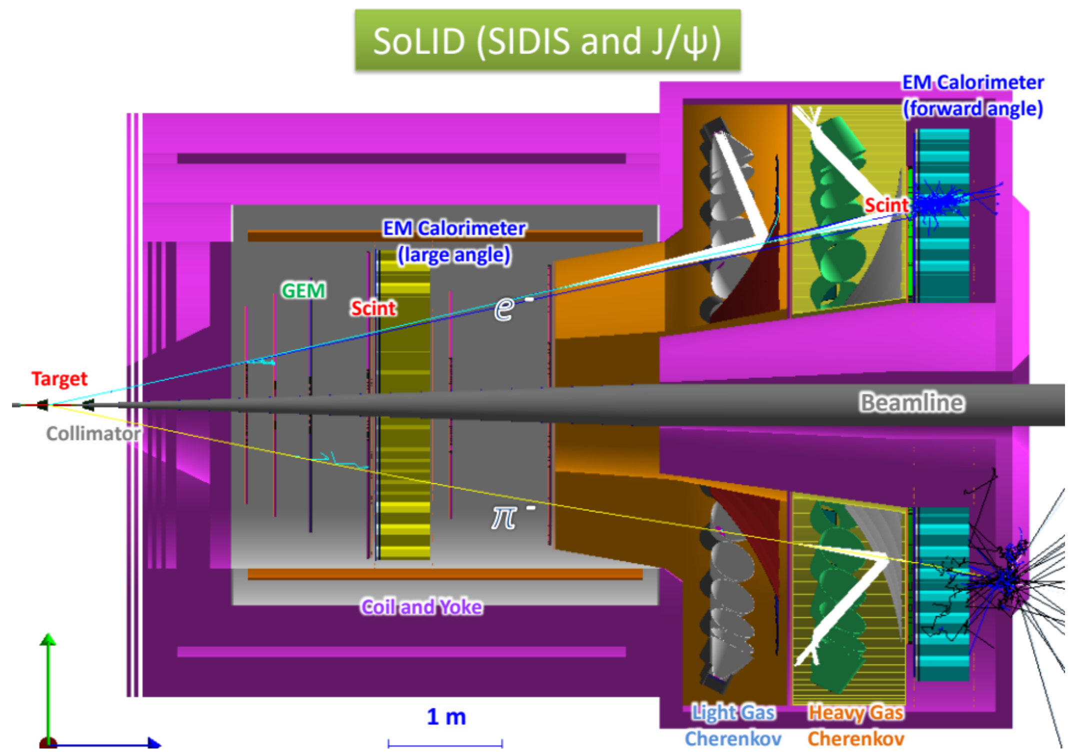


GEM Overview





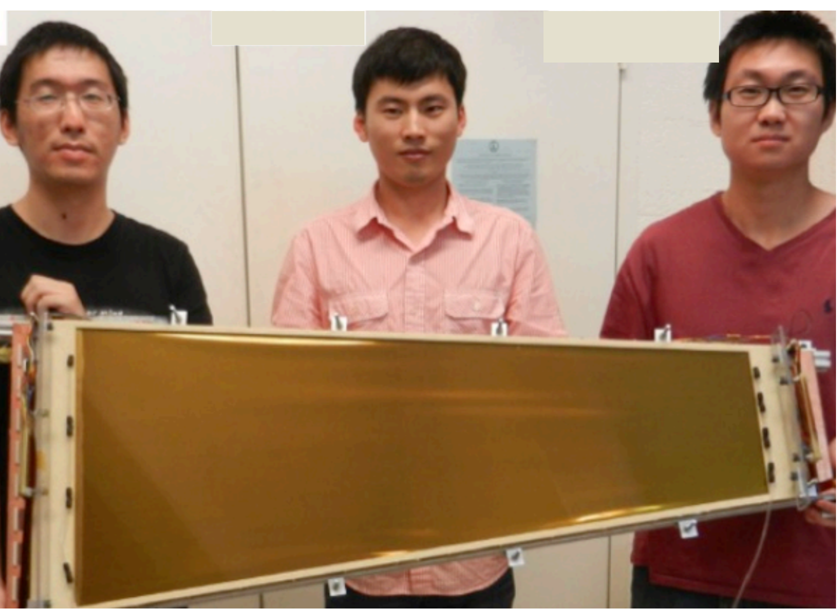


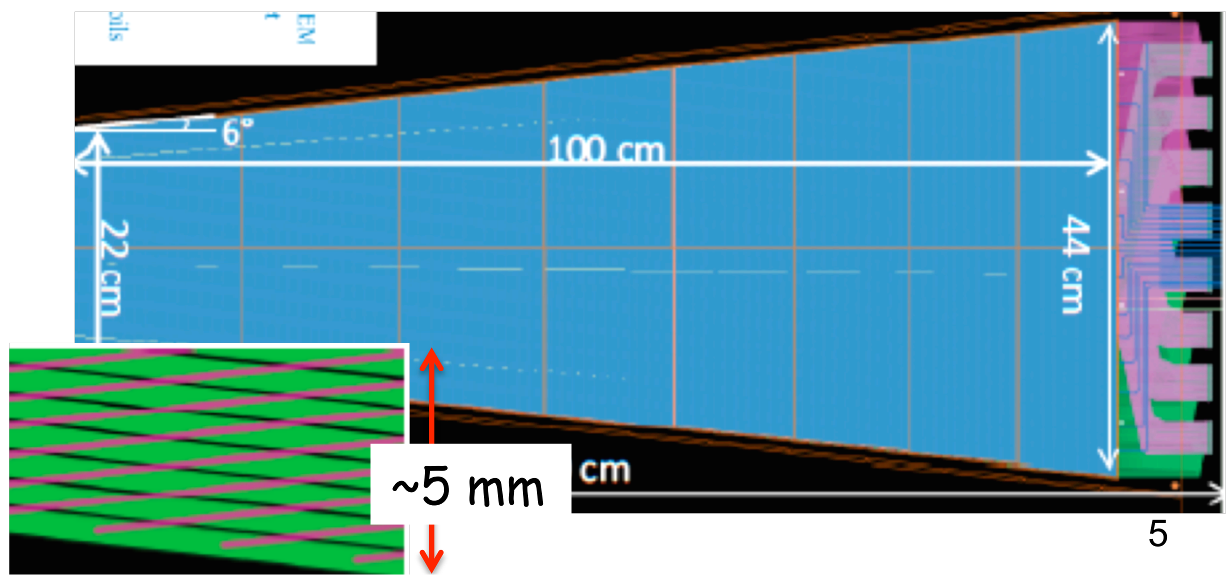


GEM Requirements: for all experiments

- Good position resolution
  - 100 μm (1 mm) in azimuthal (radial) direction.
    - 2D U-V readout with 12-degree stereo angle between strips
    - 400 μm (600 μm) strip pitch for layers 1-3 (5-6)
    - The high occupancy at layer #1: split each readout strip into two channels
    - Total number of channels ~ 215 k (with 15% spares)
- 92 % overall GEM-module efficiency.
- modules with a trapezoidal geometry, with 12^{o} angular width
- All readout electronics located at the outer edge: Given radiation exposure map.
- Side frames need to be very narrow: minimize material thickness in active area (especially for SIDIS, J/Ψ)

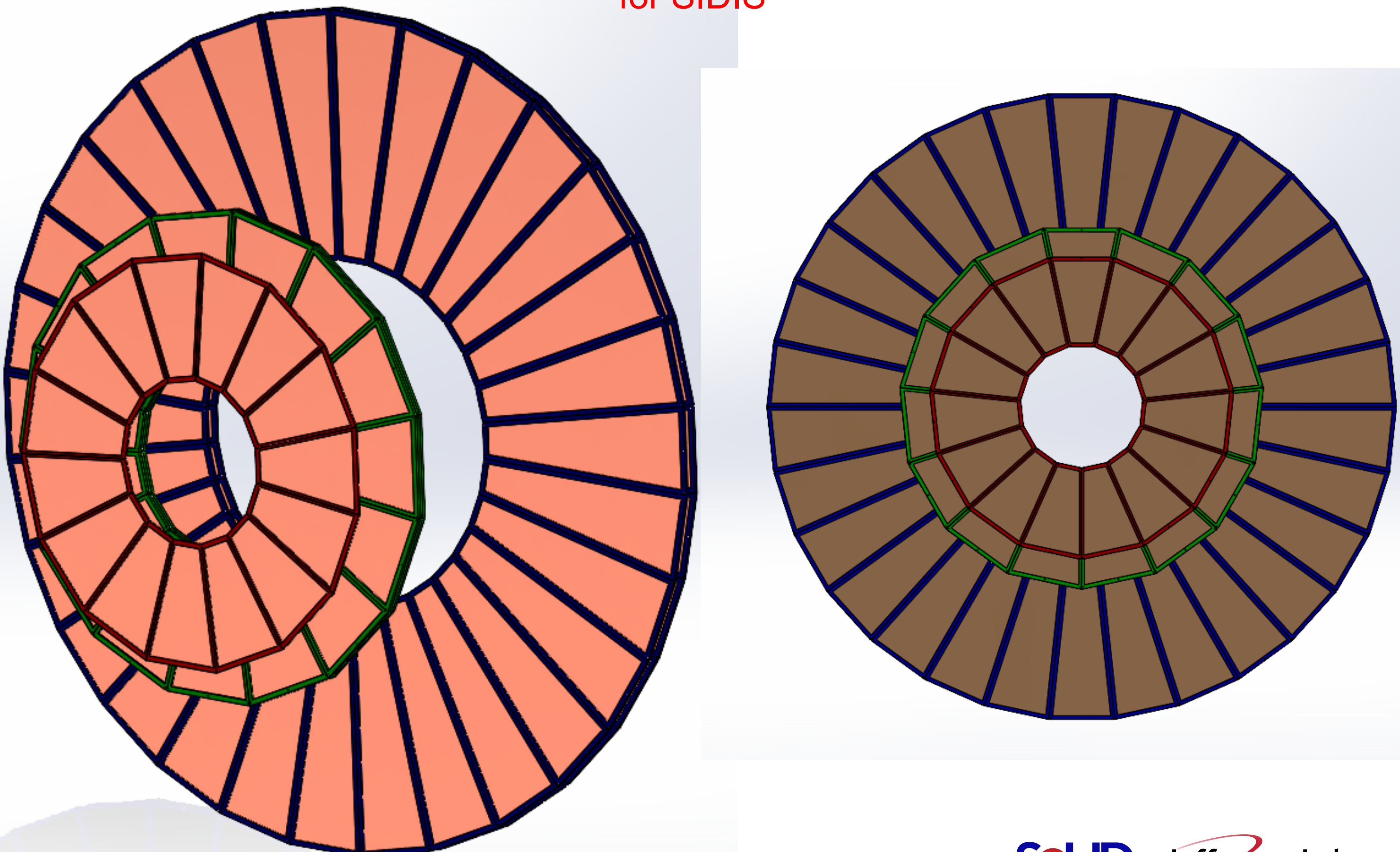
All requirements follow from tracking and neutron/radiation dose simulation to meet SoLID conditions.



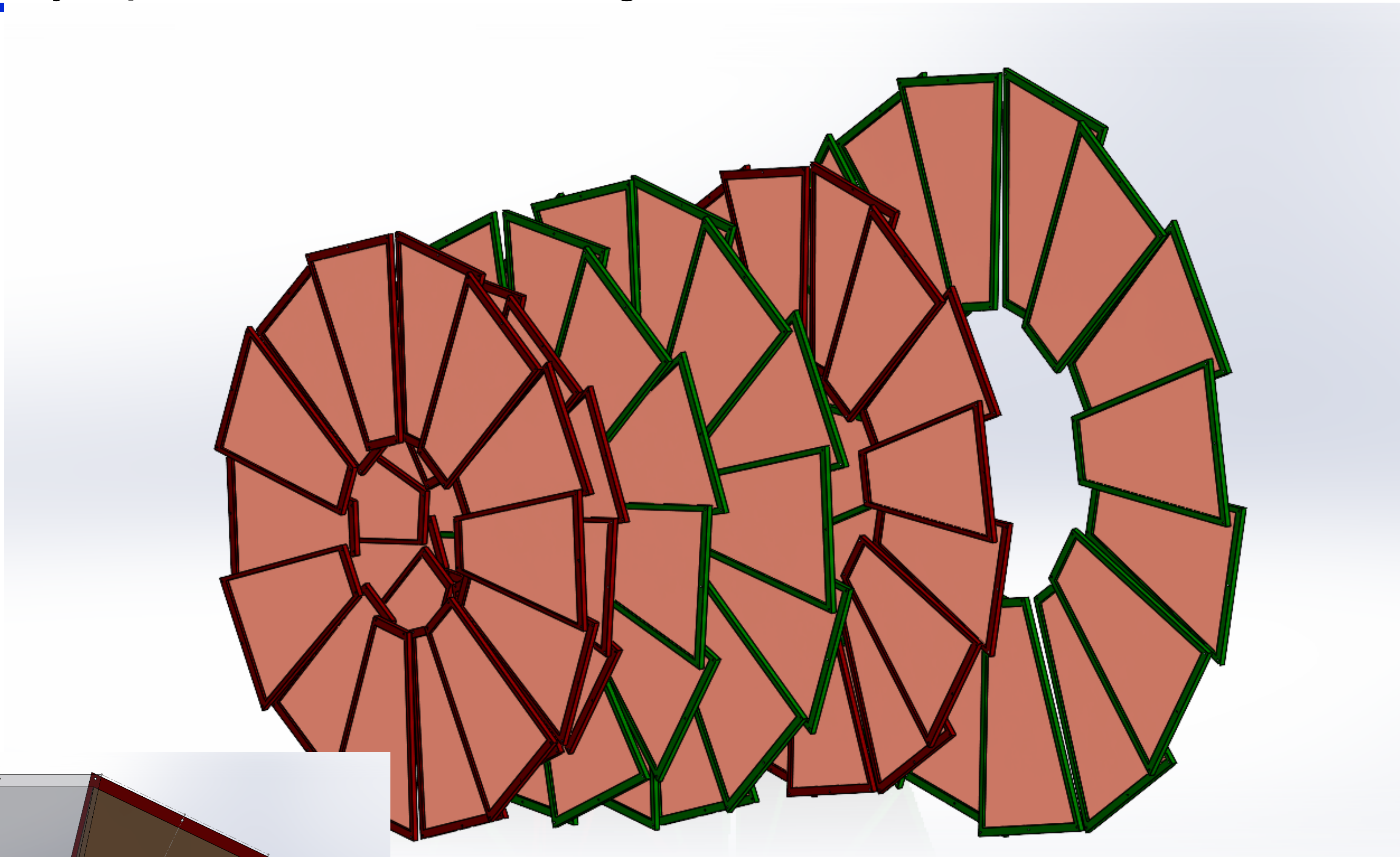


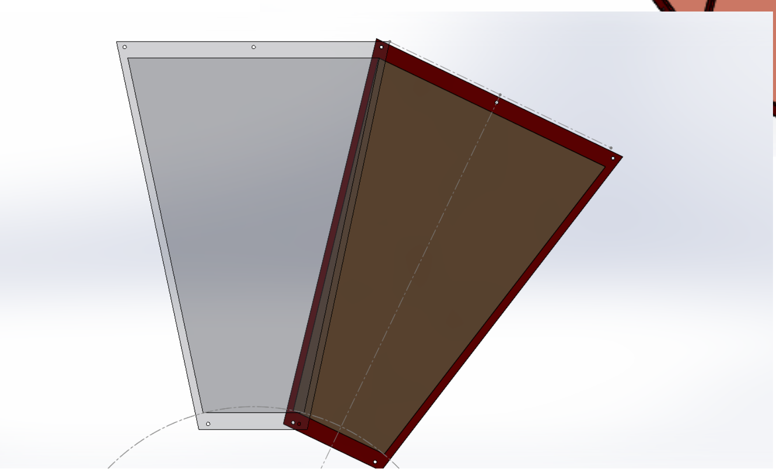
Recently optimized GEM configuration - PVDIS

First 3 layers optimized to have only 15 modules:
minimizes the number of frames in the active area for SIDIS

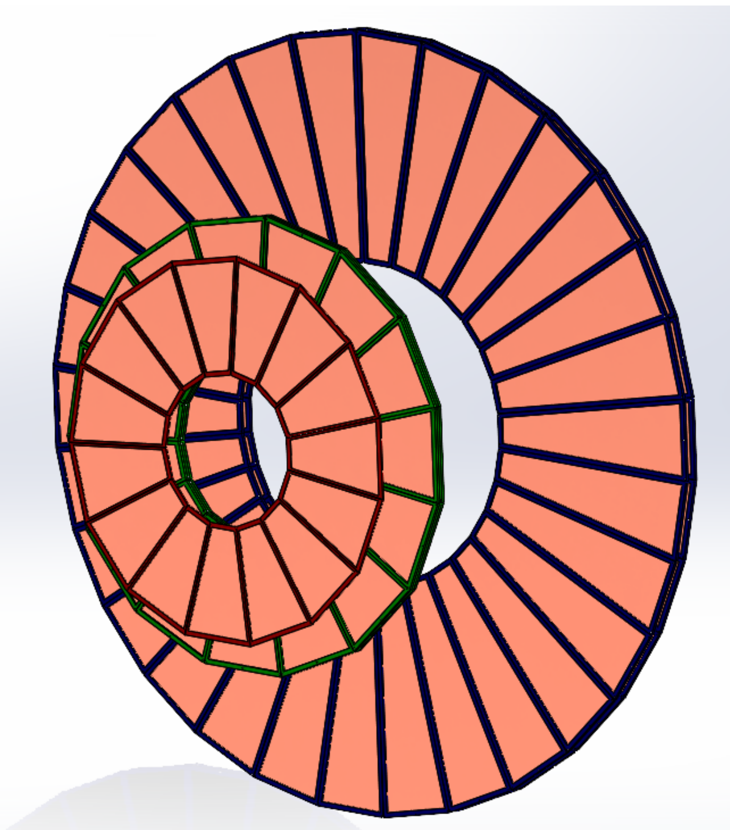


Recently optimized GEM configuration - SIDIS

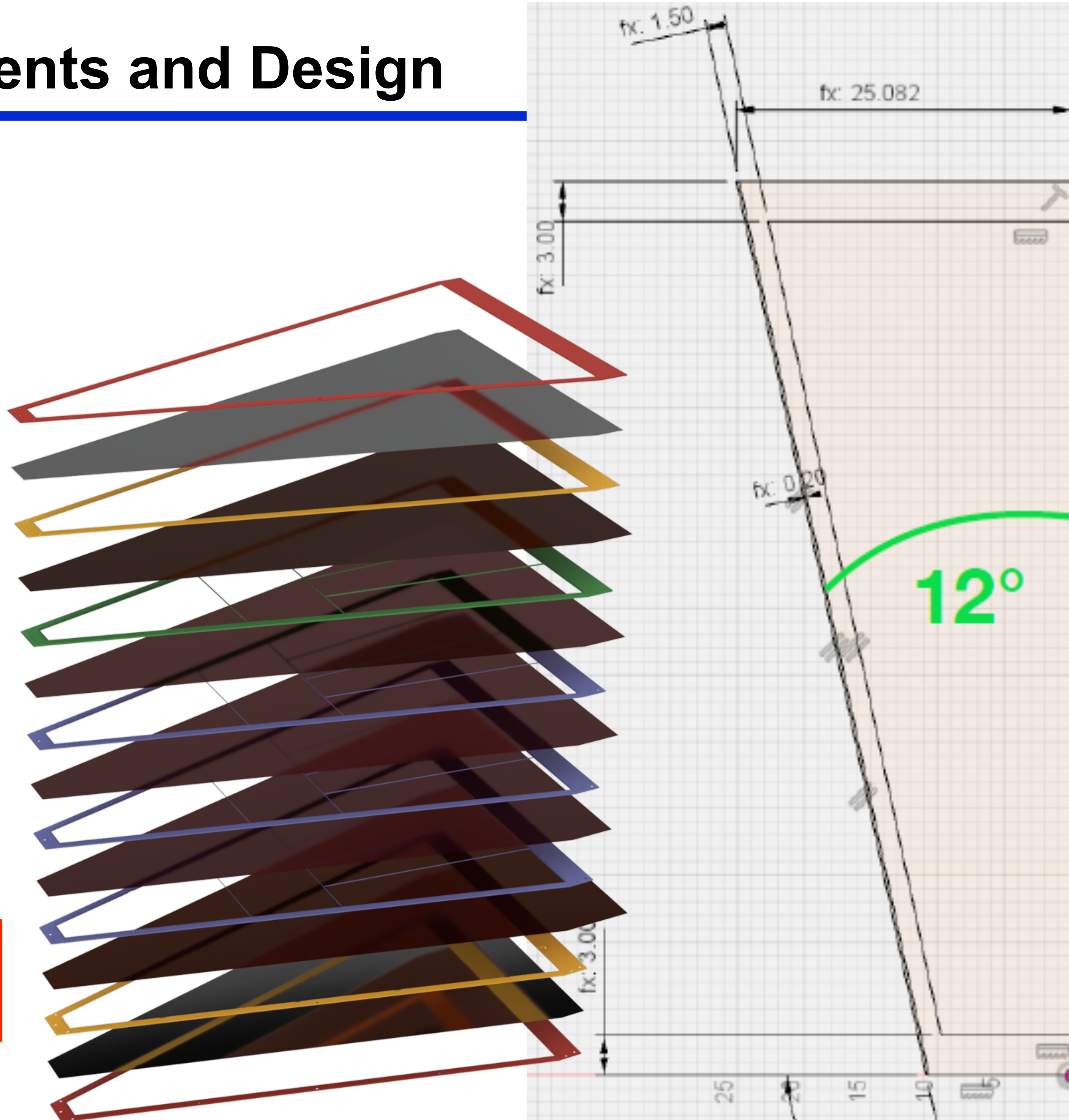




GEM Requirements and Design



PVDIS GEM tracker arrangement

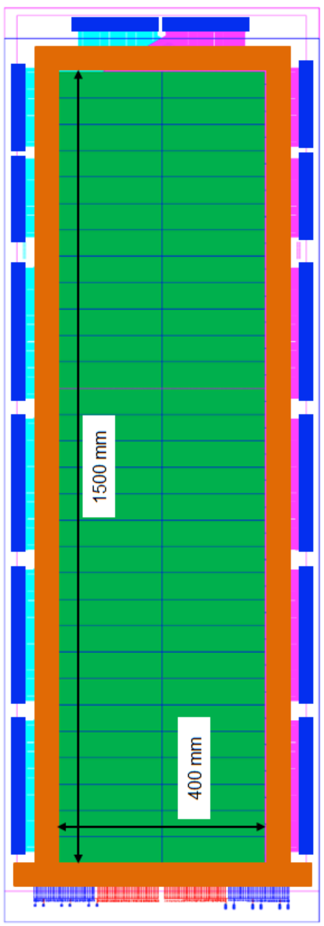


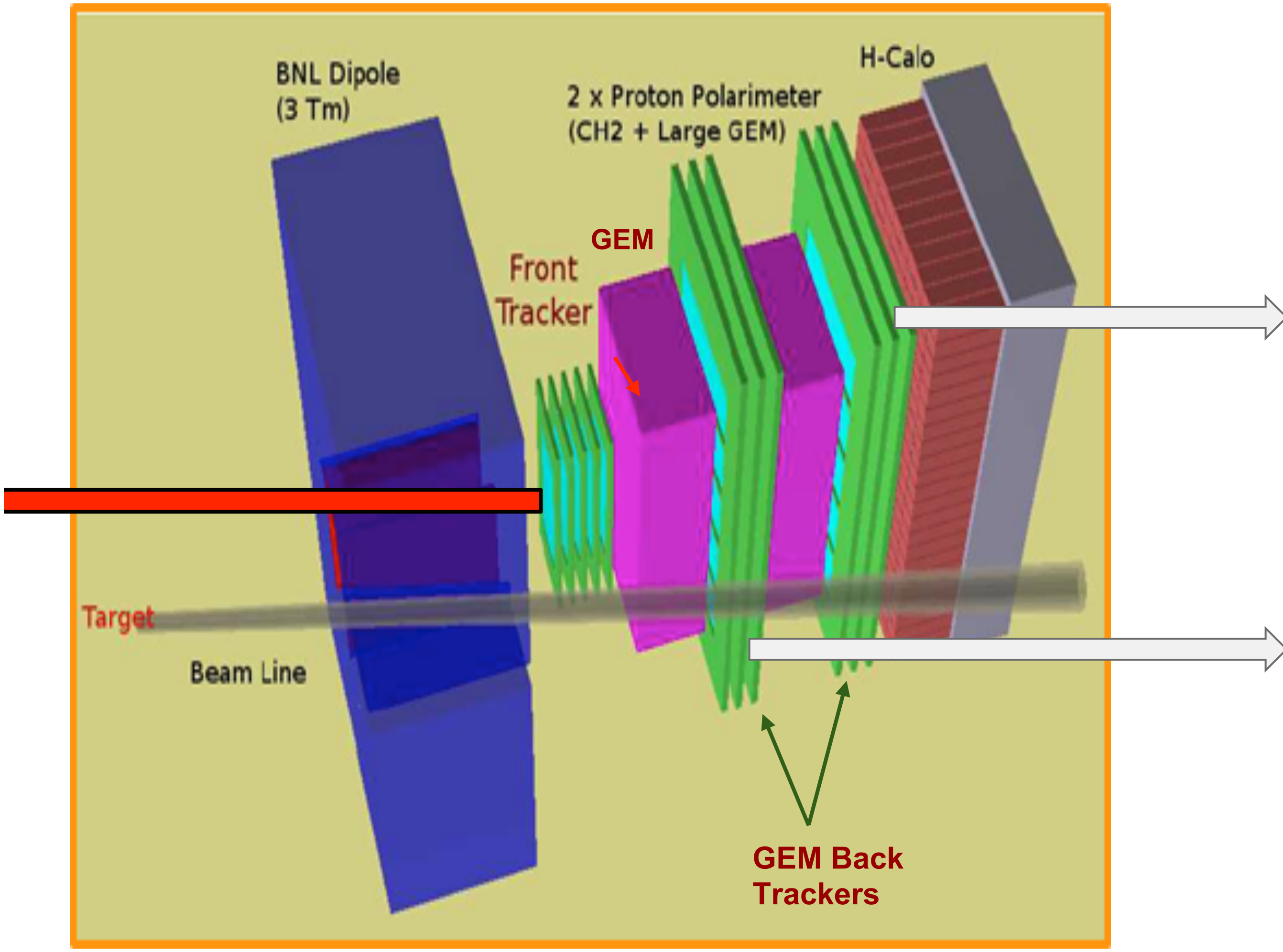
CNC-ready CAD design for a single GEM module for SoLID.

The SBS GEM production at UVa

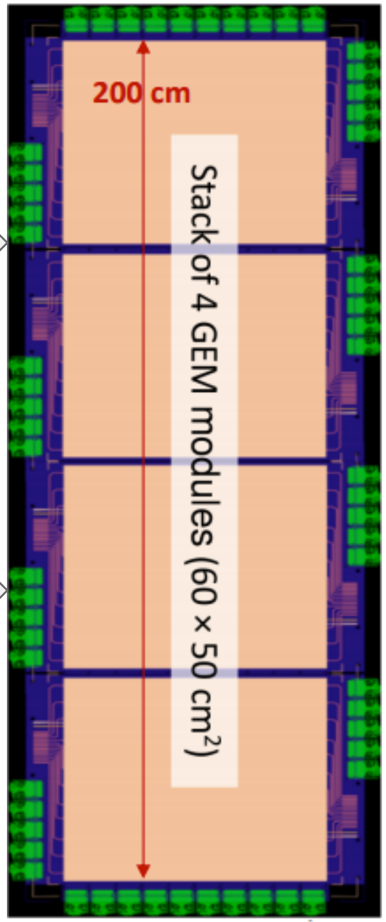
- 50 cm x 60 cm GEM modules for SBS rear tracker: 48 modules – production complete
- 150 cm x 40 cm large GEM modules for SBS front tracker: 4 modules – in production

UVA-built FT UV GEMs

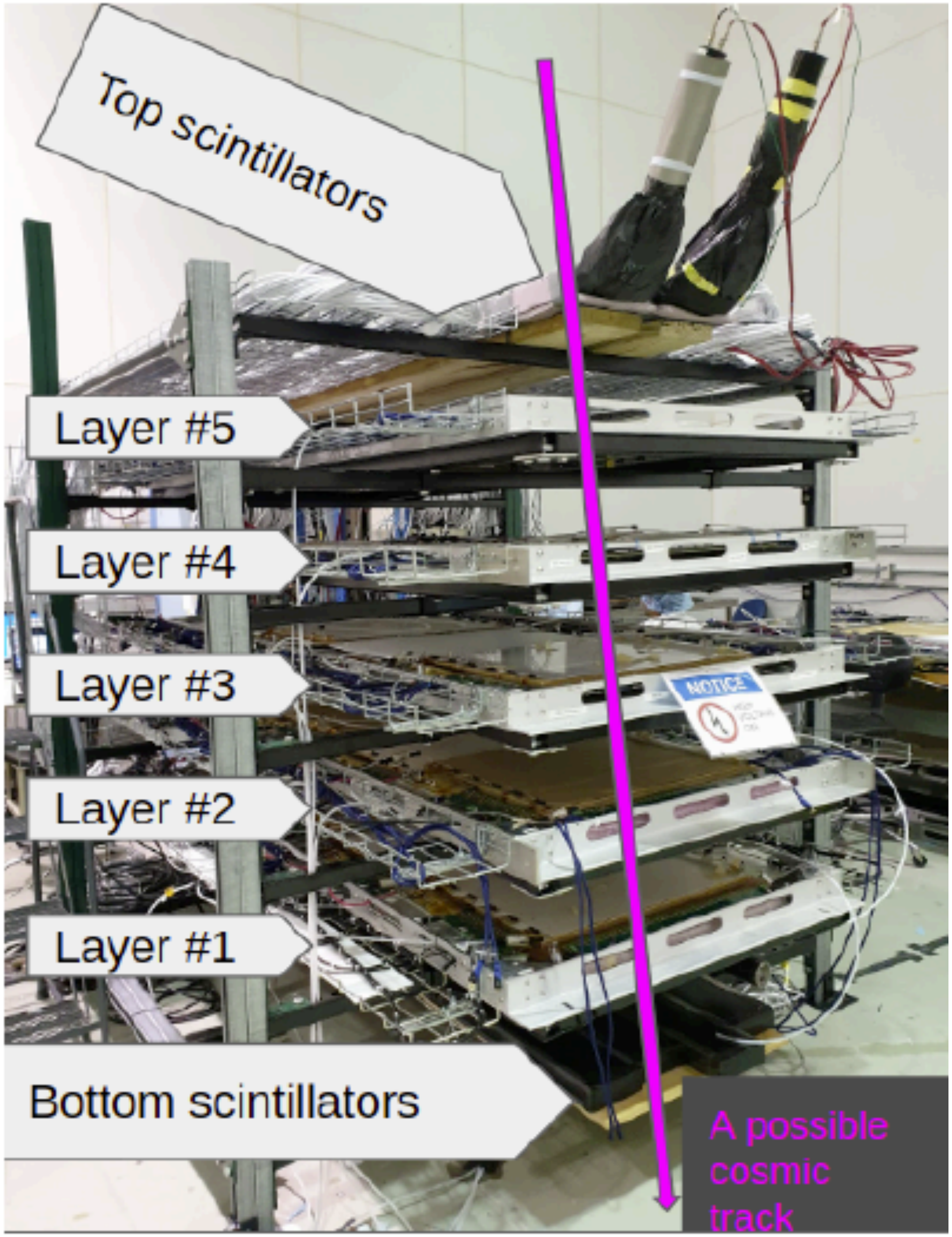


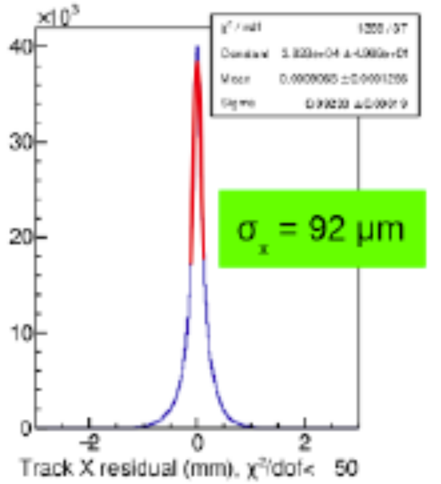


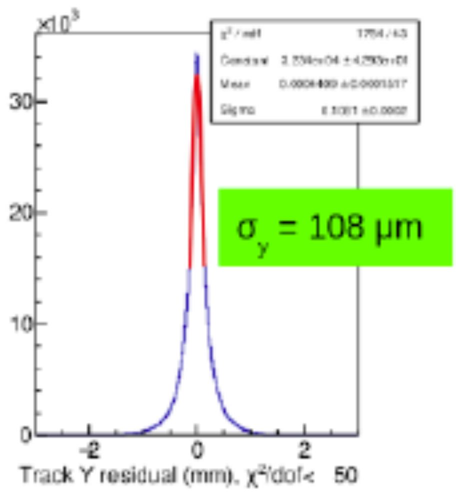
UVA-built XY Back Tracker



Experience and Expertise for SoLID GEM from SBS







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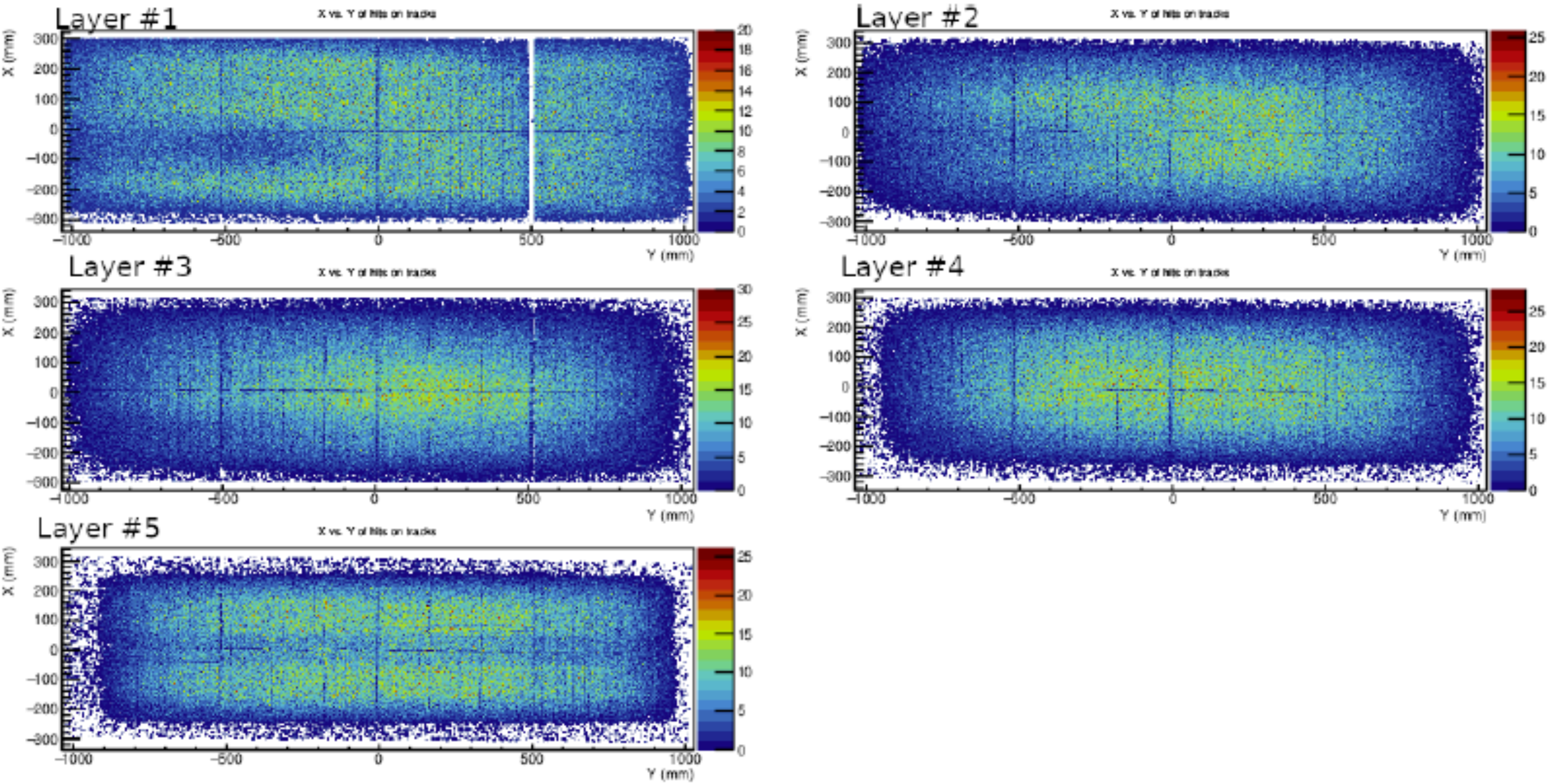
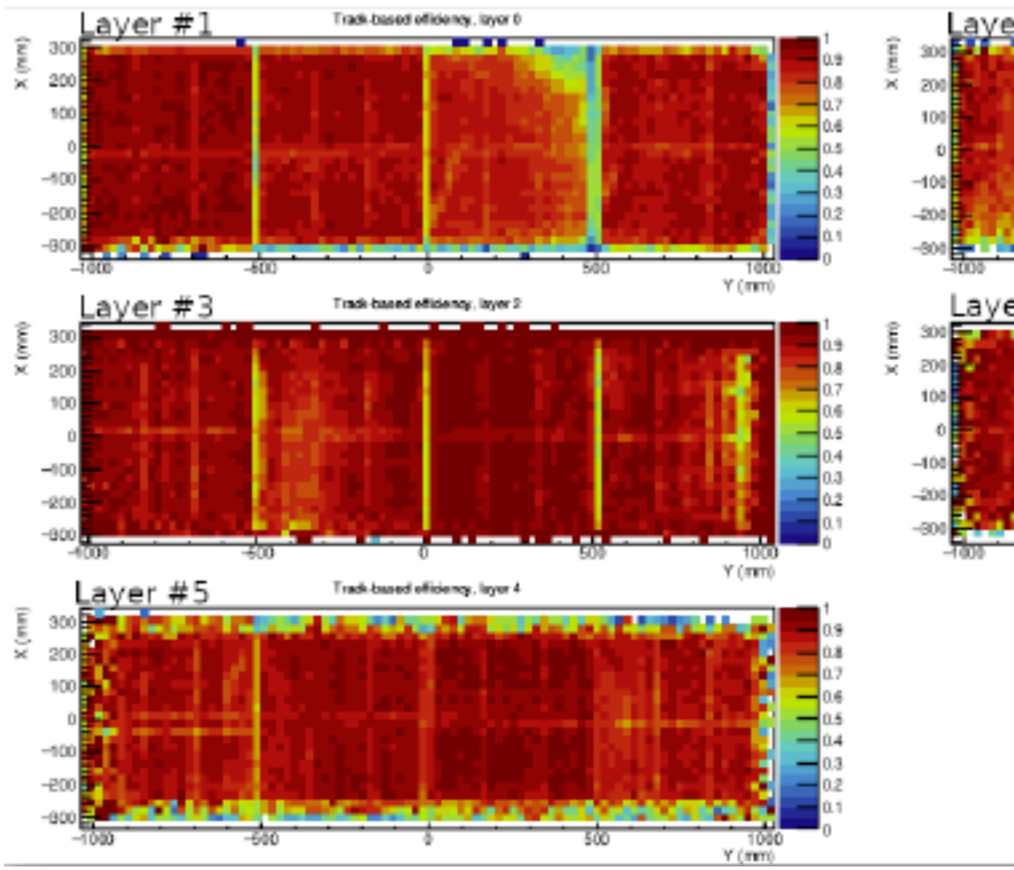
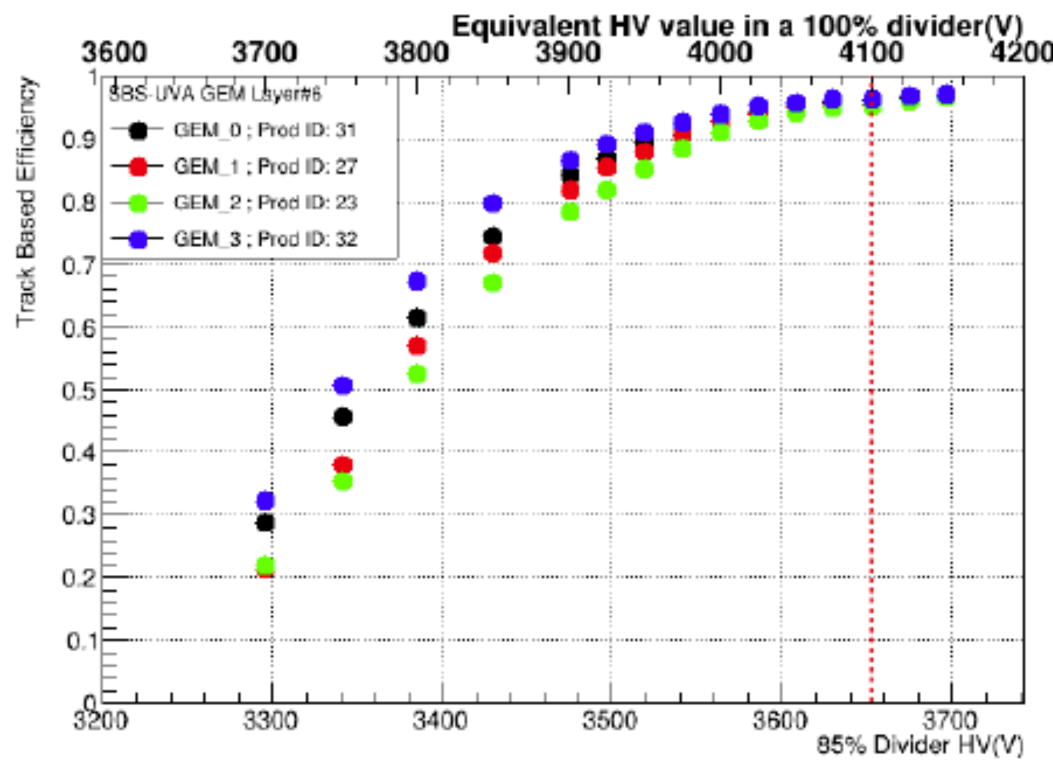


Experience and Expertise for SoLID GEM from SBS





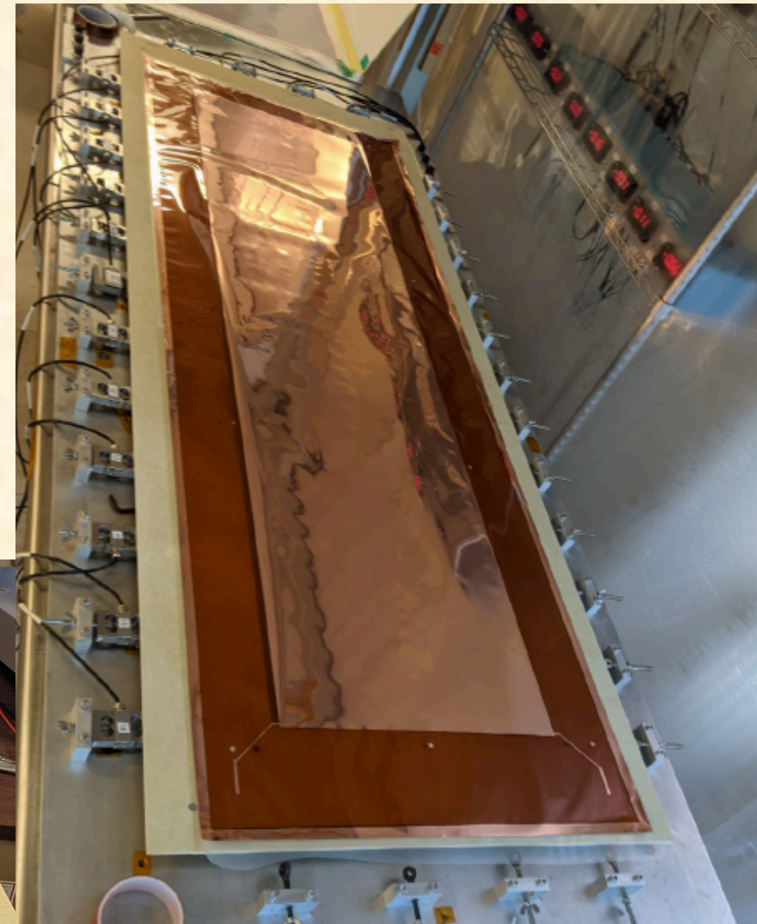
Experience and Expertise for SoLID GEM from SBS

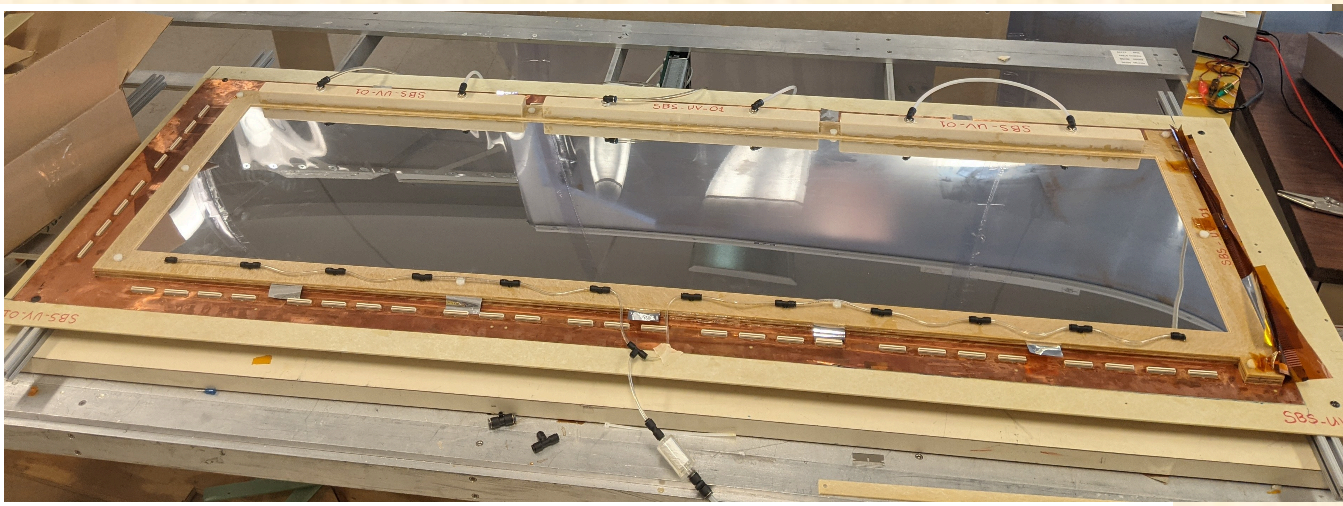
Inserting a GEM layer into the Bigbite electron spectrometer

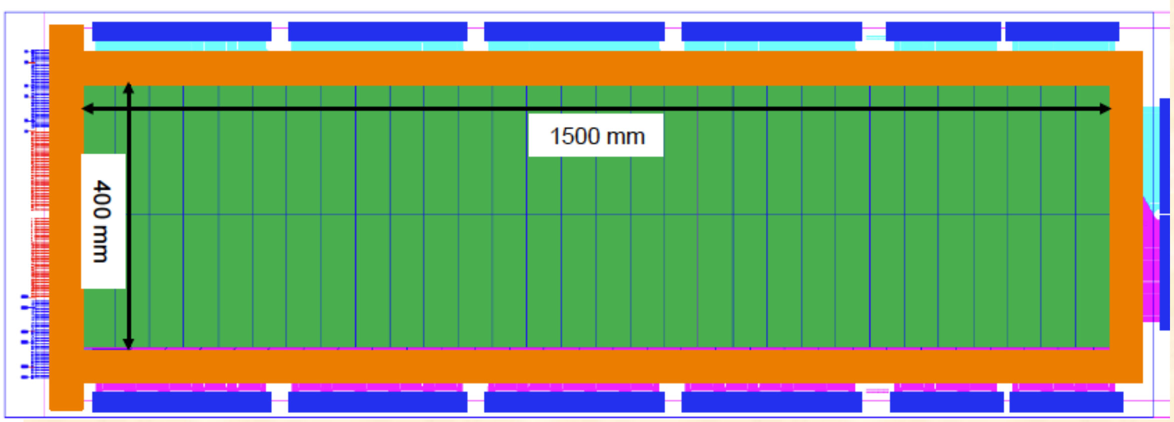
SBS GEM tracker preparations:

- 9 out of 11 SBS large GEM layers already assembled and tested with cosmics; a large dataset collected since reopening: everything looks good
- All modules fully operational with efficiencies > 90%, and resolutions ~ 90 μm
- One large GEM layer for BigBite was installed in Bigbite frame in December.

new stretcher at Uva.





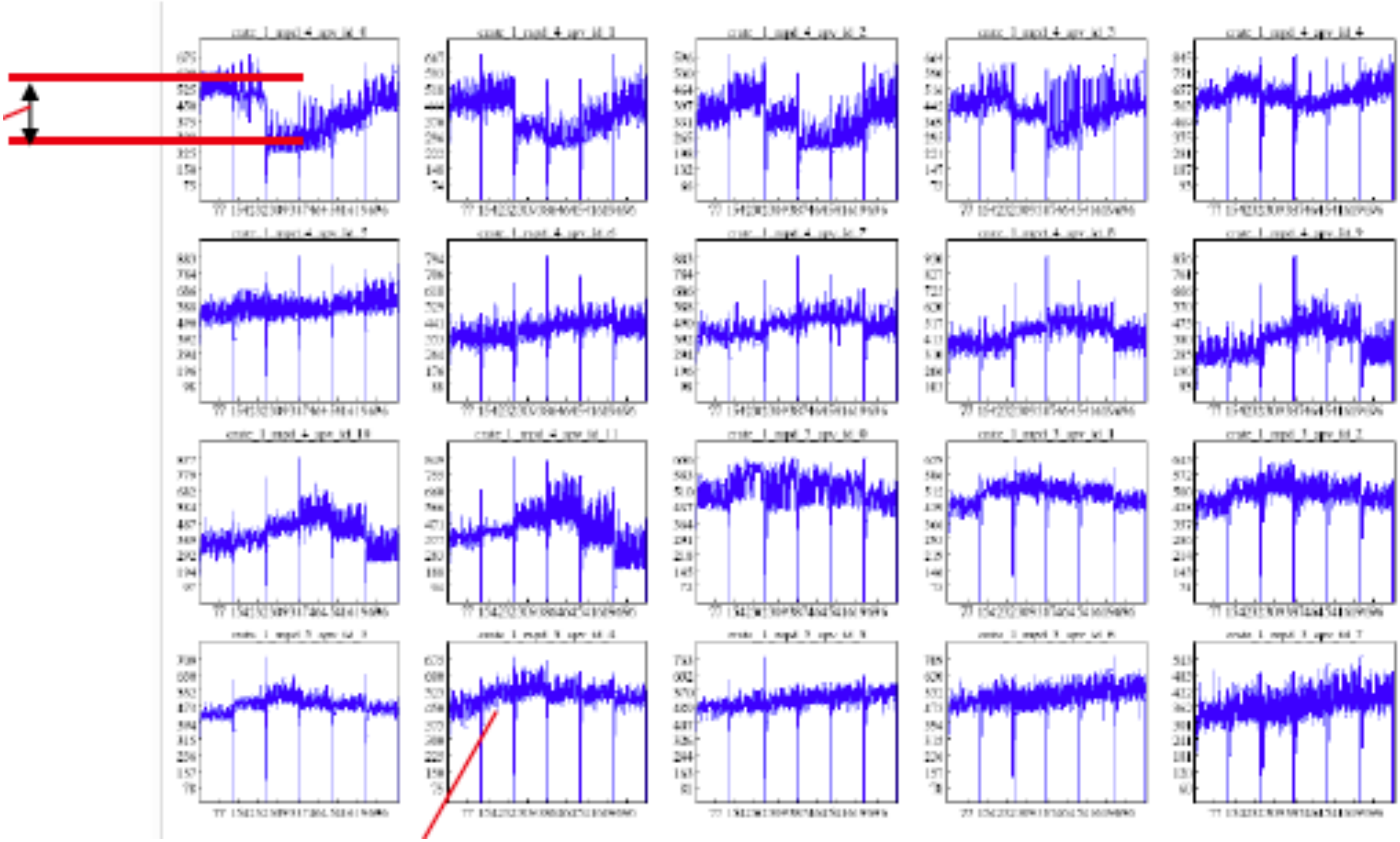


UV strip readout GEMs for SBS front tracker

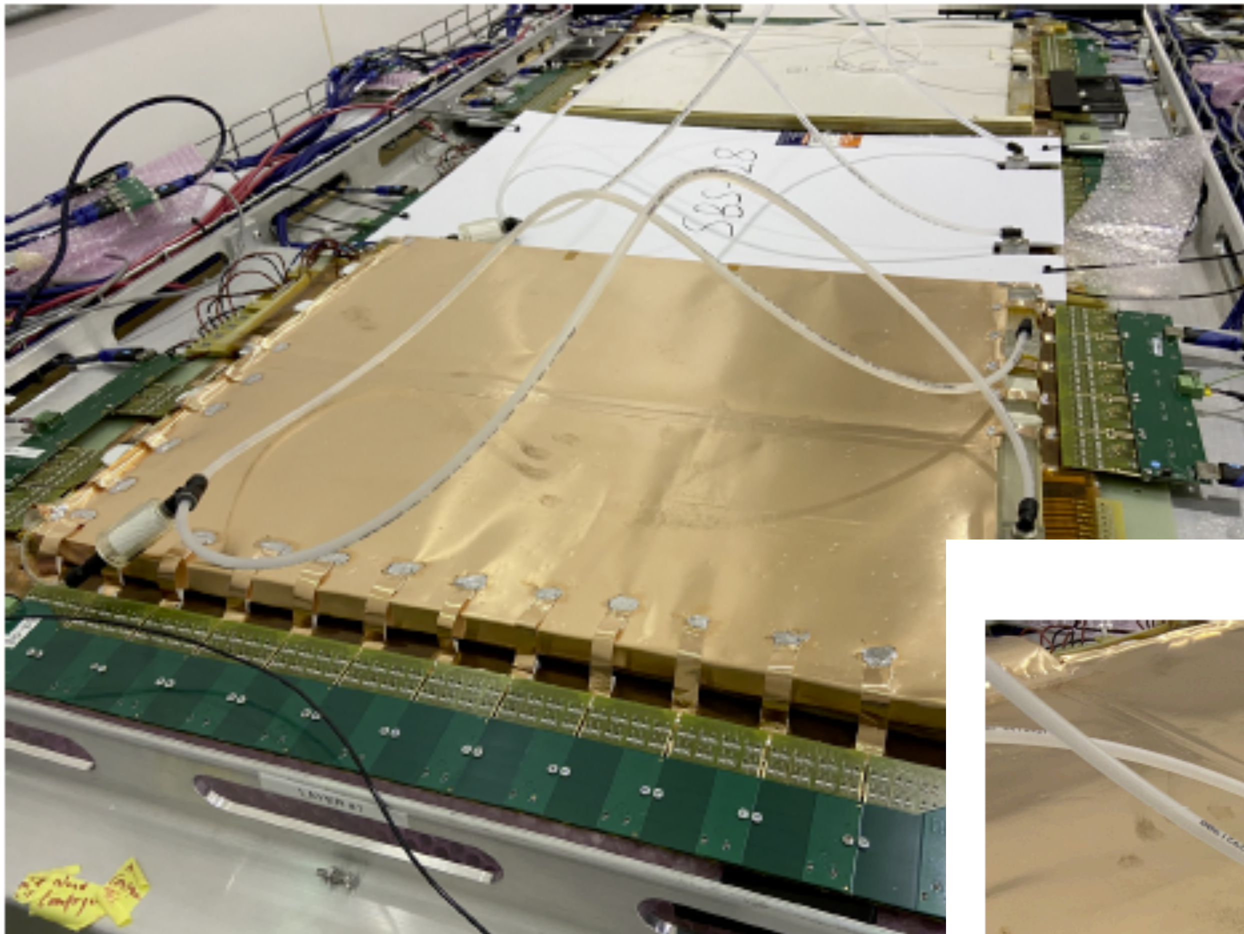
GEM building going on at UVa.

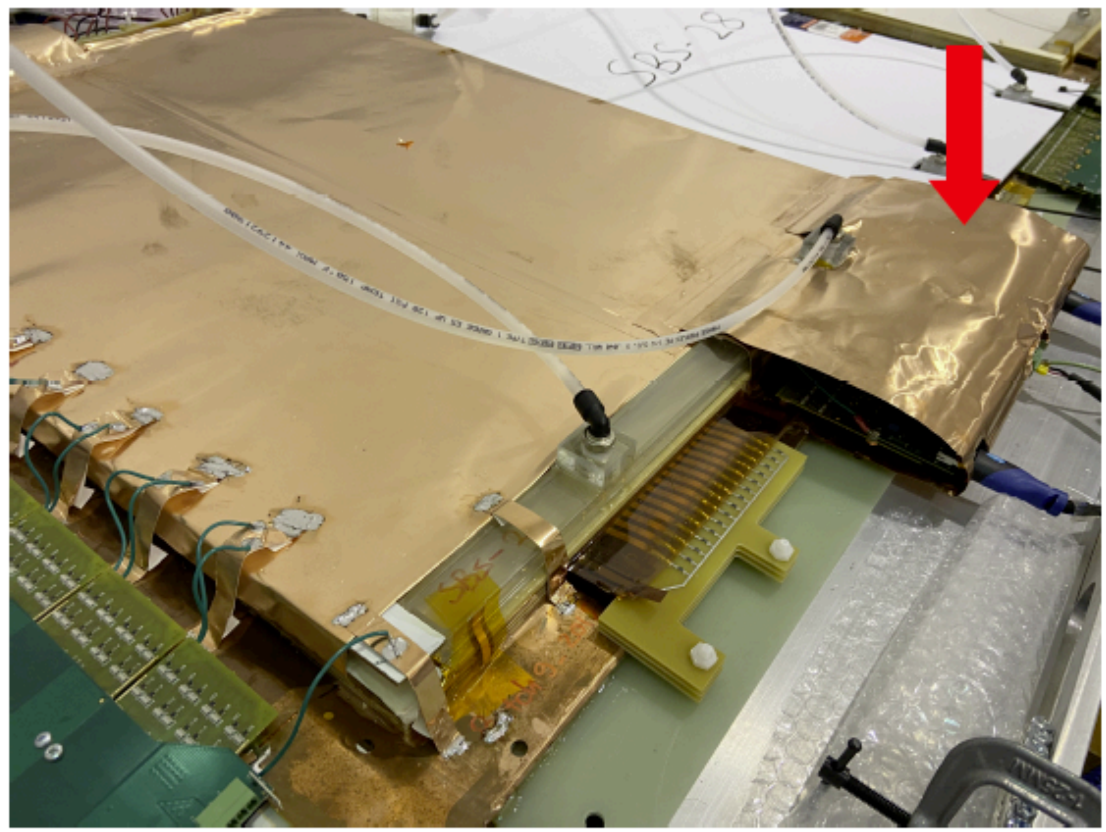
- First three chambers are completed; two moved to Jlab.
- Are be the largest GEMs in the world.
- UV and XY combination powerful in tracking under high rates.

Readout electronics pedestal fluctuation minimization

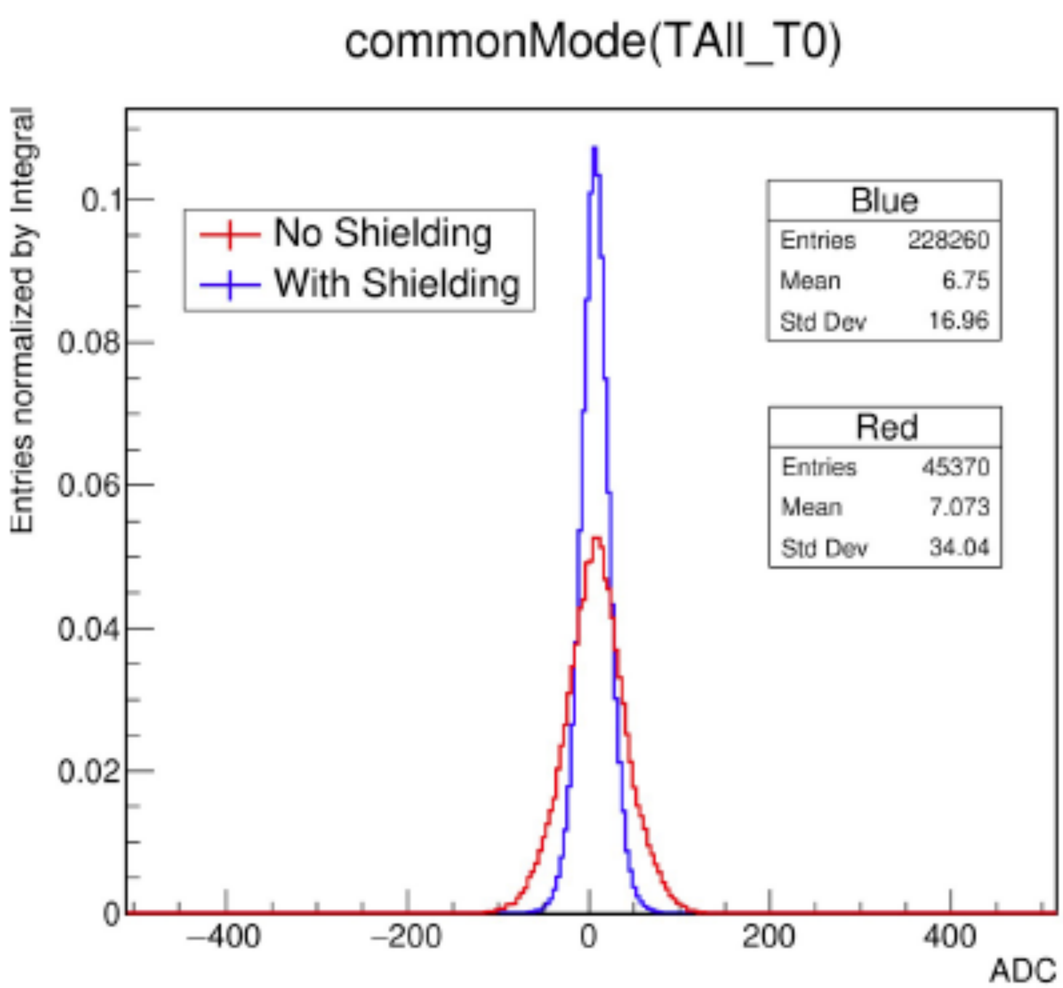


Readout electronics pedestal fluctuation minimization





Readout electronics pedestal fluctuation minimization



Resistive Micro WELL Detector: µRWELL

The µ-RWELL PCB is realized by coupling:

1. "Suitable WELL patterned Kapton foil as "amplification stage"
2. "Resistive stage" for discharge suppression & current evacuation:
   i. "Low rate" (LR) << 100 kHz/cm^2: single resistive layer → surface resistivity ~100 MΩ/
   ii. "High rate" (HR) >> 100 kHz/cm^2: more sophisticated resistive scheme must be implemented (LHCb-muon upgrade)
3. a standard readout

G. Bencivenni et al.;

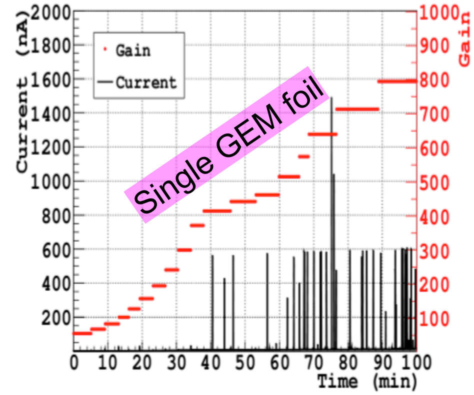


Figure 9. Monitoring of the current drawn (in black) by the single-GEM detector for different gas gain (in red). Discharge amplitudes as high as 1µA are recorded at higher gains.

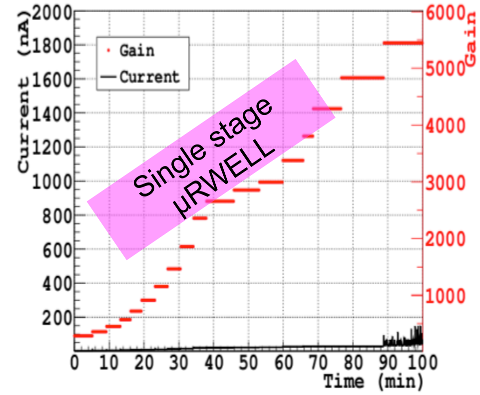
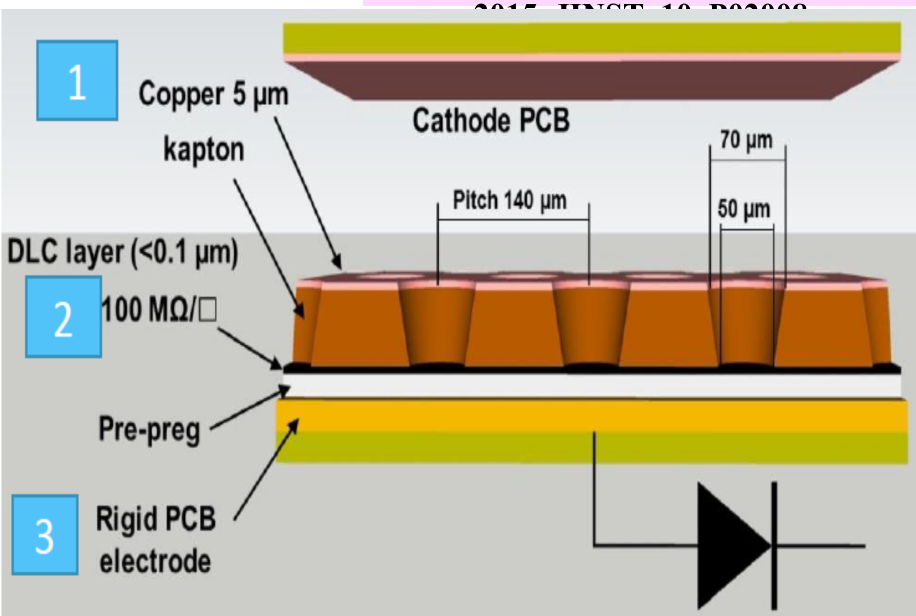
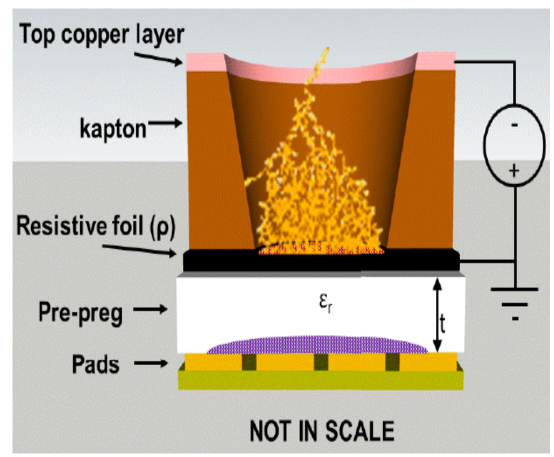
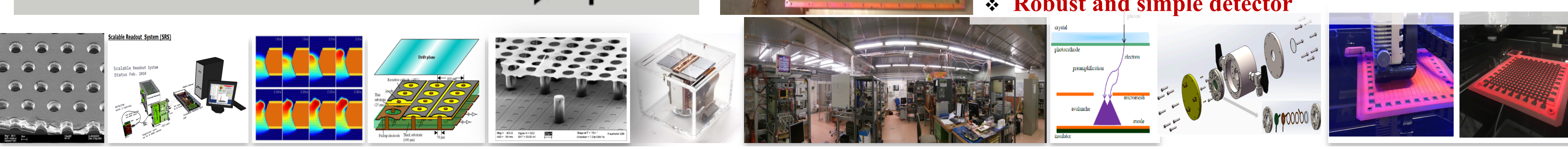


Figure 10. Monitoring of the current drawn (in black) by the µ-RWELL detector for different gas gain (in red). Discharges are quenched down to few tens of nA even at high gains.



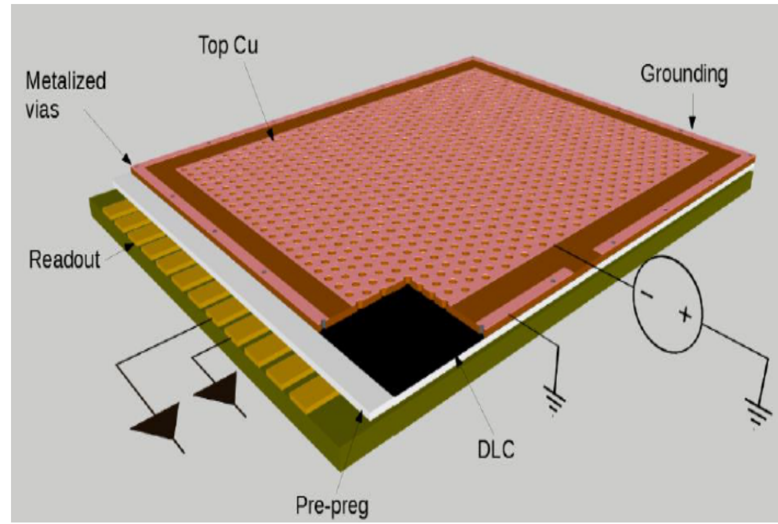


- Like Micromegas ➪ Single amplification stage, no need to stretch
- Like GEM ➪ Same base material
- **Robust and simple detector**

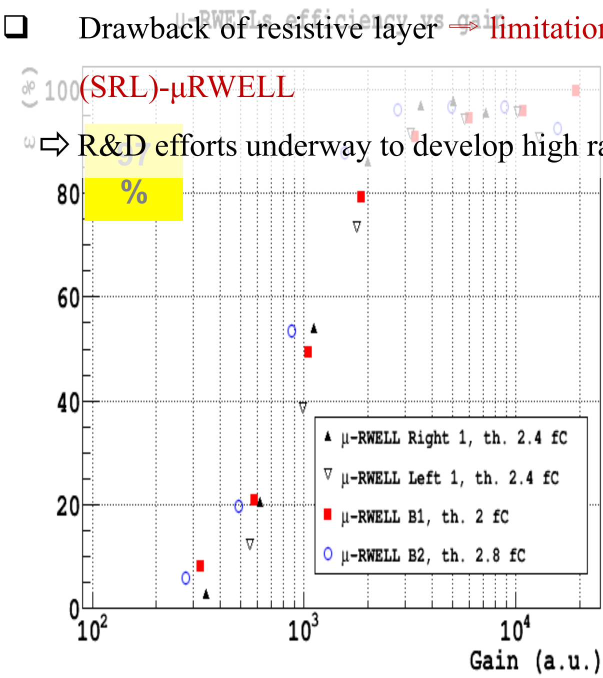


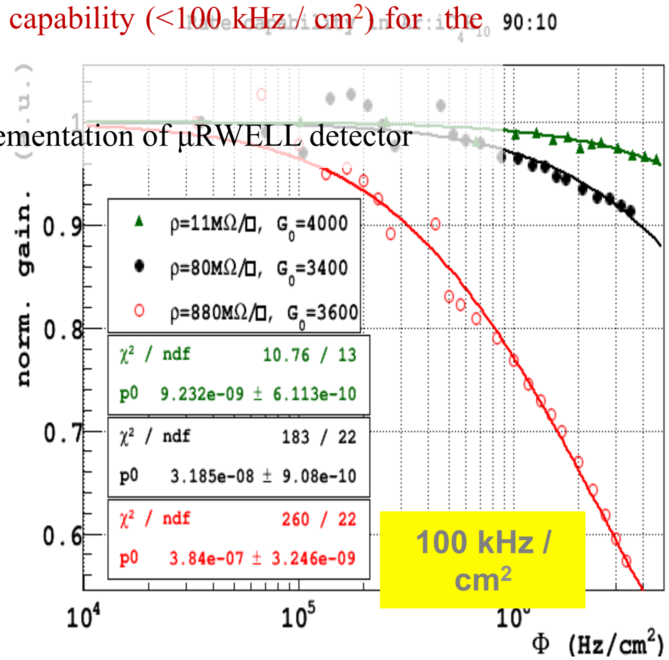
04/30/2021 - Seminar on MPGDs @ JLab

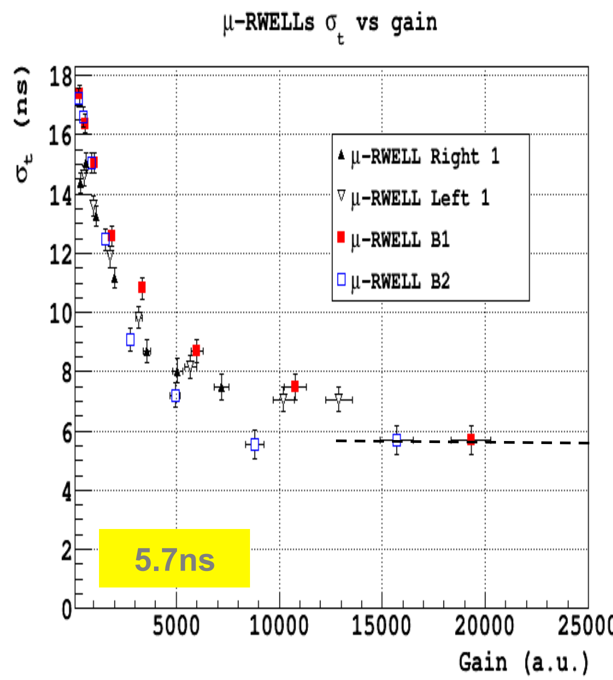
Performances of Single Resistive Layer (SRL)-µRWELL: "Low Rate" Layout



- The "Well" in the Kapton act as amplification structure (electron multiplication) just as a GEM foil
- The induced charges in the resistive layer spreads with a time constant ⇨ $\tau = \rho \times C$ with:
  - ⇨ ρ: surface resistivity of the DLC layer
  - ⇨ C: capacitance per unit area between the DLC layer and the readout plane
- The Resistive layer also ensure the quenching of the spark amplitude ⇨ spark resistant detector
- Drawback of resistive layer ⇨ limitation of rate capability (<100 kHz / cm^2) for the (SRL)-µRWELL
  - ⇨ R&D efforts underway to develop high rate implementation of µRWELL detector







https://clasweb.jlab.org/wiki/images/3/3b/The_micro-RWELL_detector_-_JLAB_-_Seminar_-_22th_Apr_-_2021_-_2nd_Year_Covid_Era.pdf

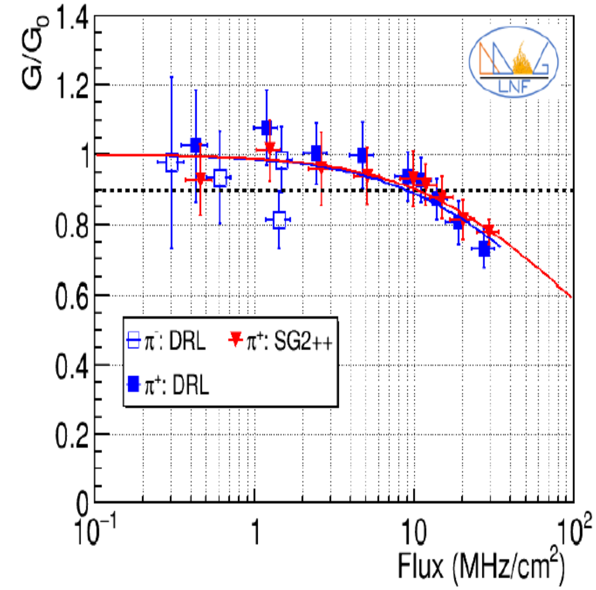
Development of high rate µRWELL detector

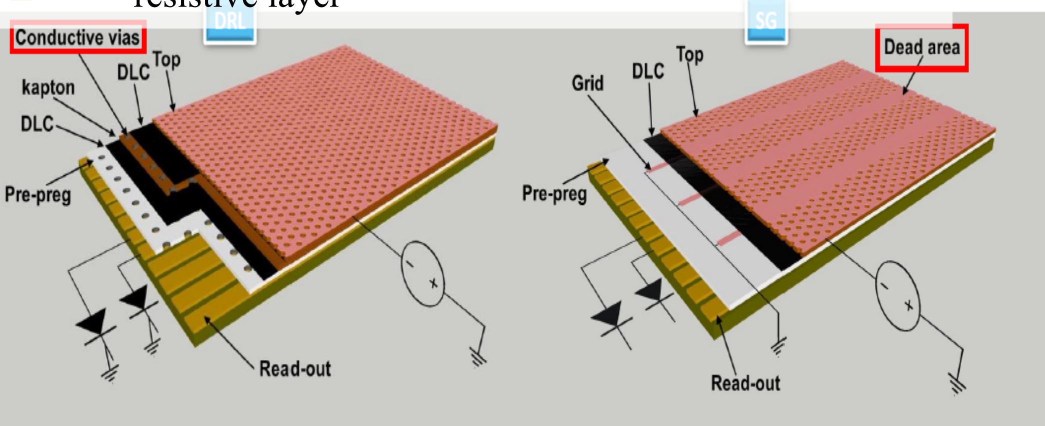
Introducing grounding network into µRWELL single resistive layer layout to overcome intrinsic rate limitation

⇨ Two designs with high density grounding connection network implemented and tested

⇨ Double Resistive layer (DRL) with a "3D " grounding scheme

⇨ Silver Grid (SG) grounding scheme based on single resistive layer





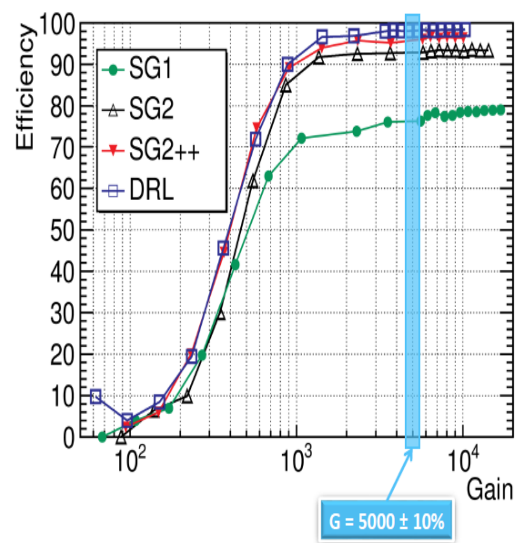
Double Resistive Layer (DRL): 3-D current evacuation scheme based on **two stacked resistive layers** connected through a **matrix of conductive vias.**

Silver Grid (SG): is based on a Single Resistive layer with the implementation conductive strips lines realized on the DLC layer. The **conductive grid** can **induce instabilities due to discharges -> introduction of a small dead zone.**

https://clasweb.jlab.org/wiki/images/3/3b/The_micro-RWELL_detector_-_JLAB_-_Seminar_-_22th_Apr_-_2021_-_2nd_Year_Covid_Era.pdf

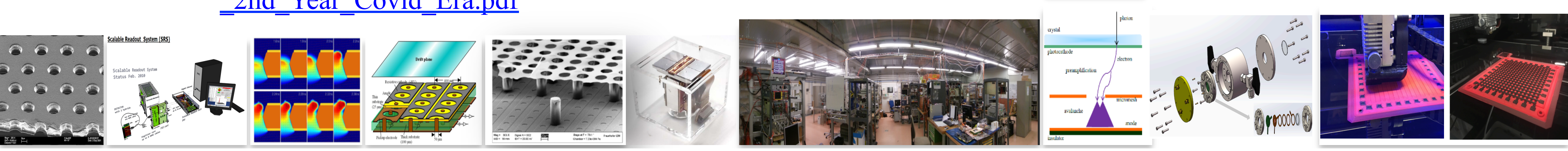
Efficiency

PAD READOUT



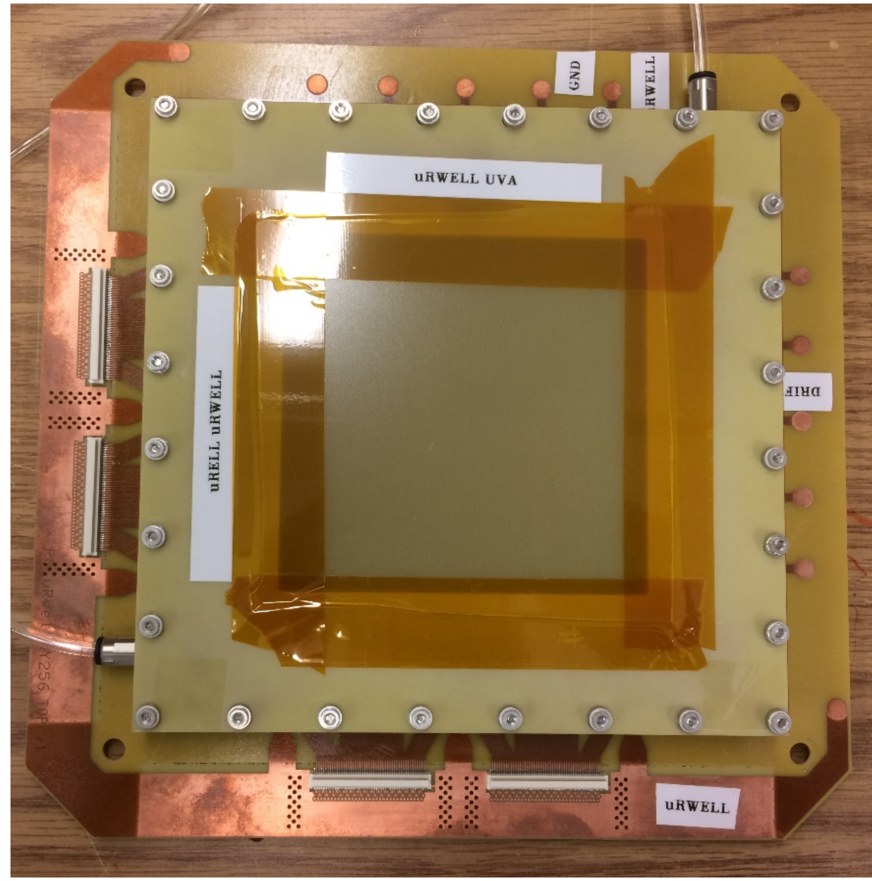
MODEL	DEAD AREA (mm)	Geometrical Acceptance	MAX measured efficiency	SG Δ%
DRL	0	100%	98%	
SG2++	0.6	95%	97%	2%
SG2	1.2	90%	93%	3%
SG1	2.0	66%	80%	14%

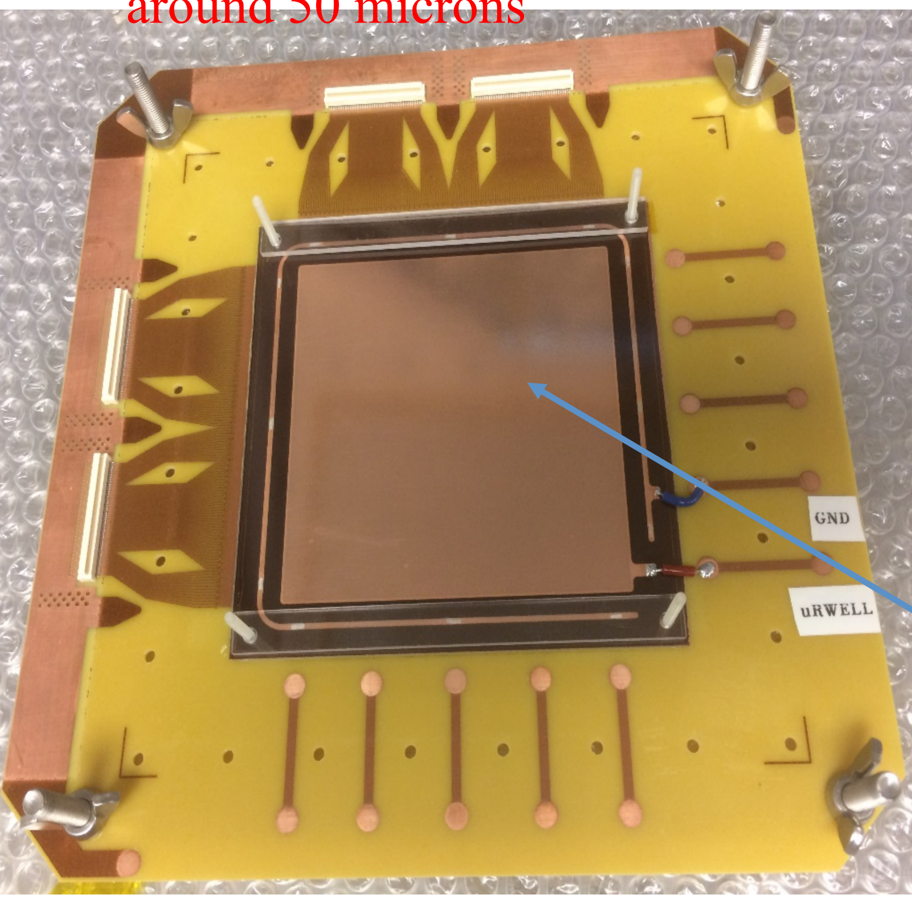
The SG chambers show a higher efficiency thanks to an **electron collection mechanism** that **reduces** the effective dead zone.



Small (10 cm × 10 cm) prototype of μRWELL detector

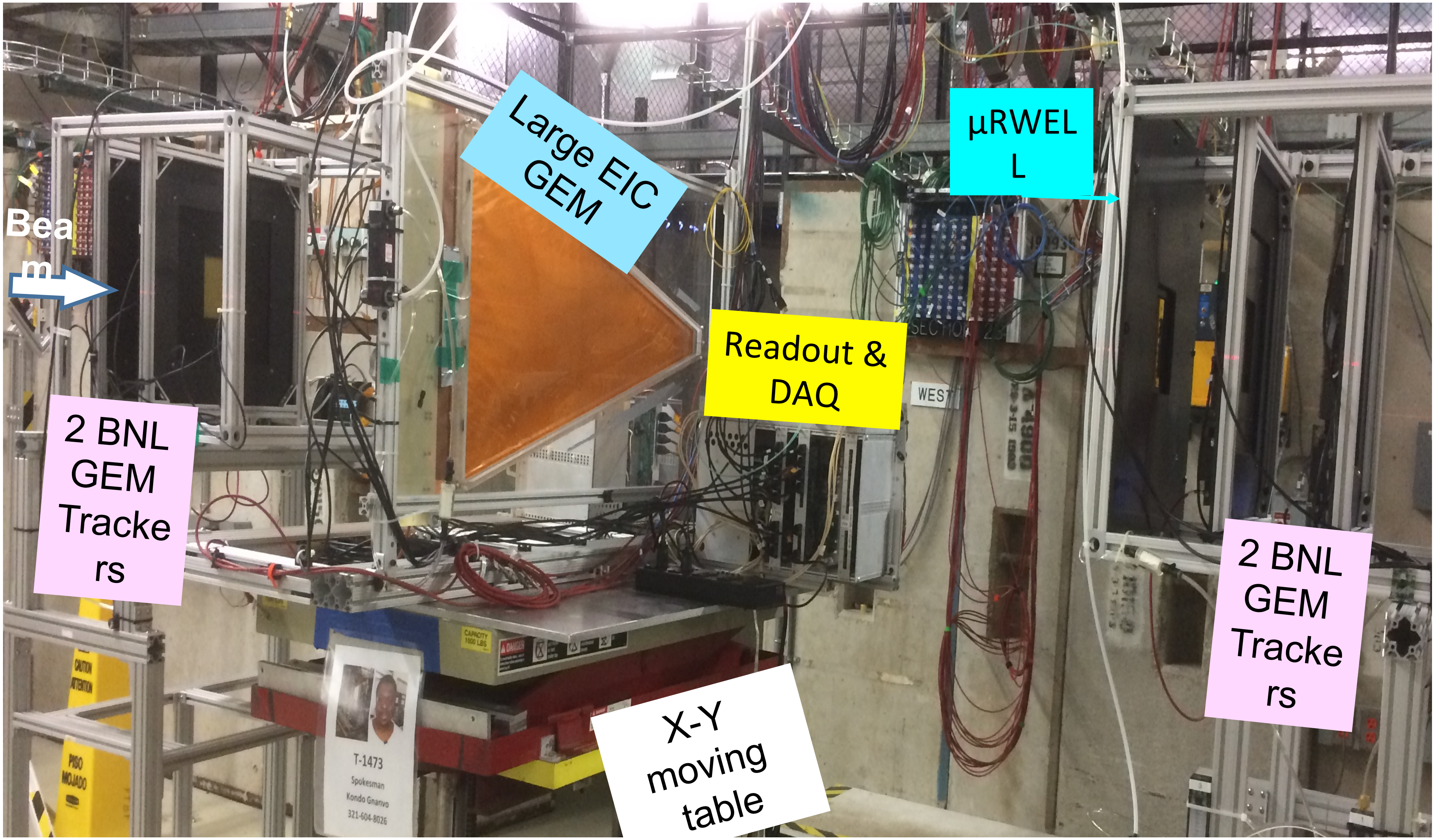
- ✓ μRWELL prototype produced by CERN with 2D "COMPASS" readout
- ✓ Going to put it together in clean room this week and test it on cosmic
- ✓ In principle, pretty simple to assemble just add the drift cathode
- ✓ Was tested in FTBF test beam: excellent resolutions around 50 microns





- Hope to build a 50 cm x 50 cm muRwell prototype this year: excellent opportunity to test with high rates in SBS
- Plan to build two very large: 120 cm x 55 cm muRwell detectors for Prad-II, CLAS-12

Large GEM Setup in MT6.2b Area at the FTBF (June-July 2018)



Production Capabilities and facilities

- SoLID requires ~ 120 GEM modules including spares.
- Will be one of the largest GEM production projects in the world.
- A second GEM lab with 20’x12’ cleanroom coming to UVa this month.
- UVa will be starting MOLLER GEM production soon, but it is much smaller project, could go parallel with SoLID GEM production.
- Two collaborating sites GWU/MIT-Bates, and Stonybrook have indicated interest for parallel GEM production with Uva.
- CERN GEM shop has indicated that they are ready to supply to components
- No issue meeting the demand for SoLID.