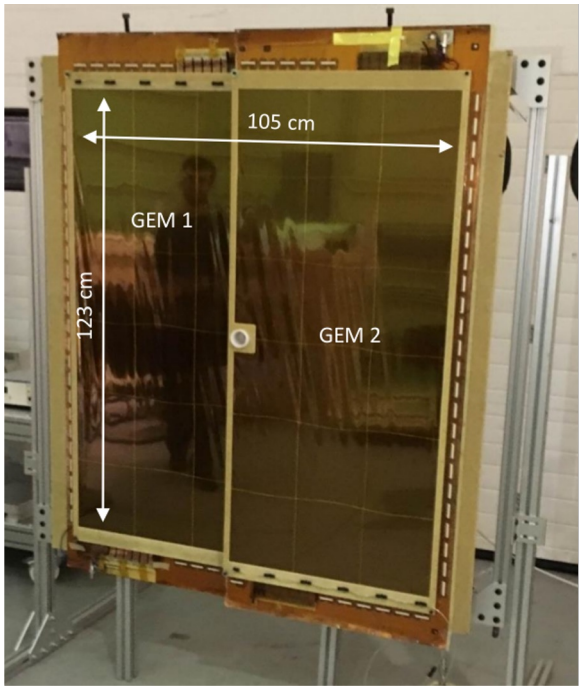
GEM Detectors for Prad-II

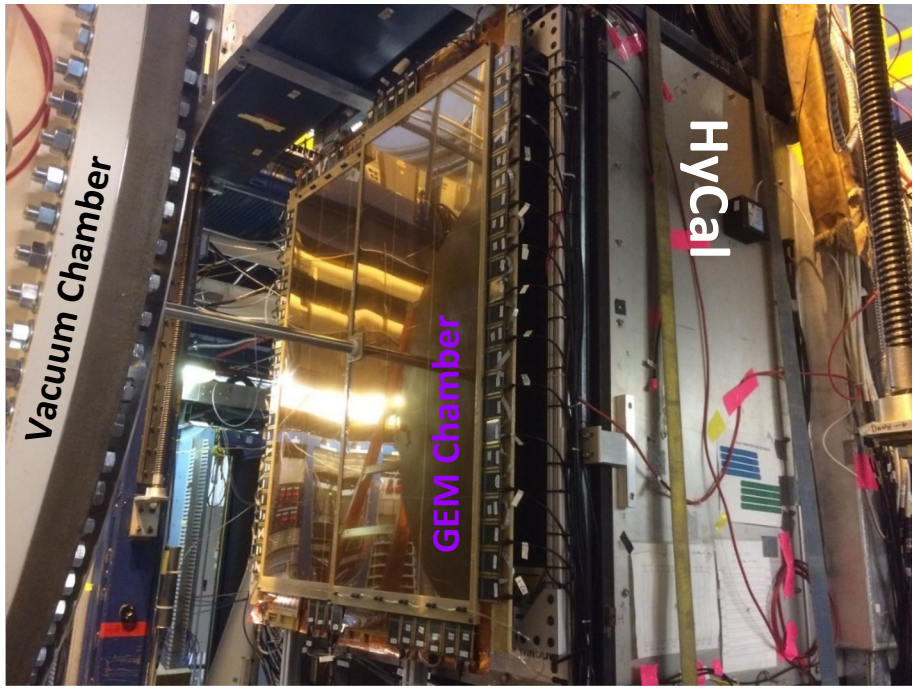
Nilanga Liyanage
University of Virginia
For Prad-II, X-17 GEM working group

GEM Detectors in PRad Experiment

- Designed and Constructed at UVA in 2015

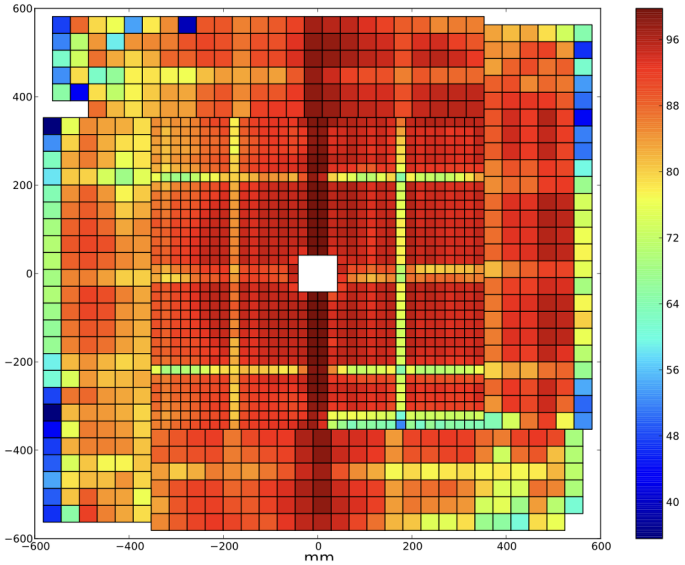


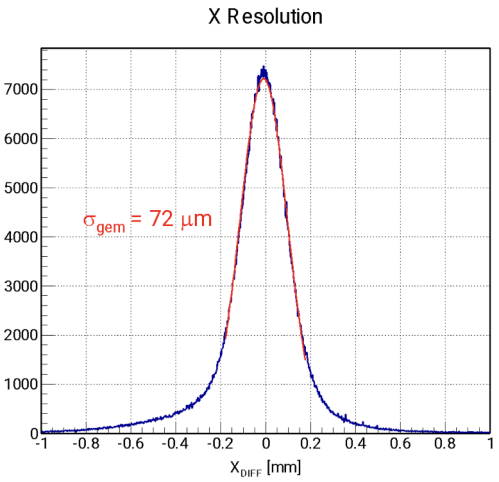
- Installed in Hall B beamline in 2016

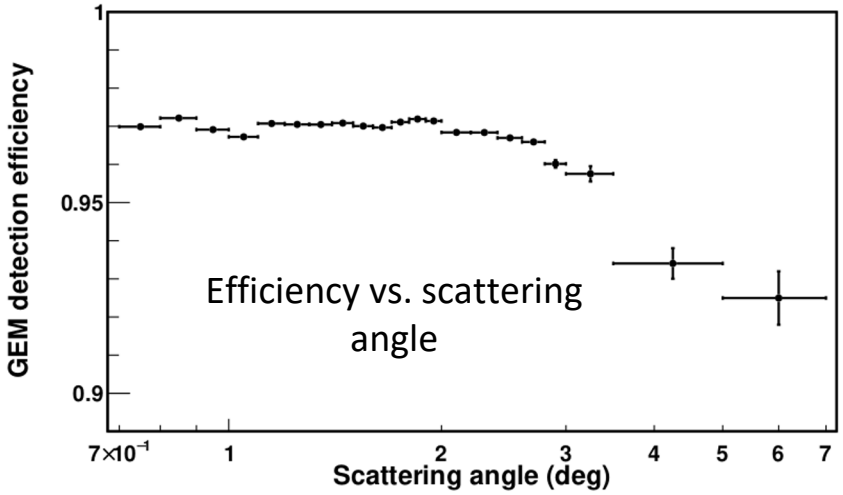


Efficiency and Resolution – PRad Experiment

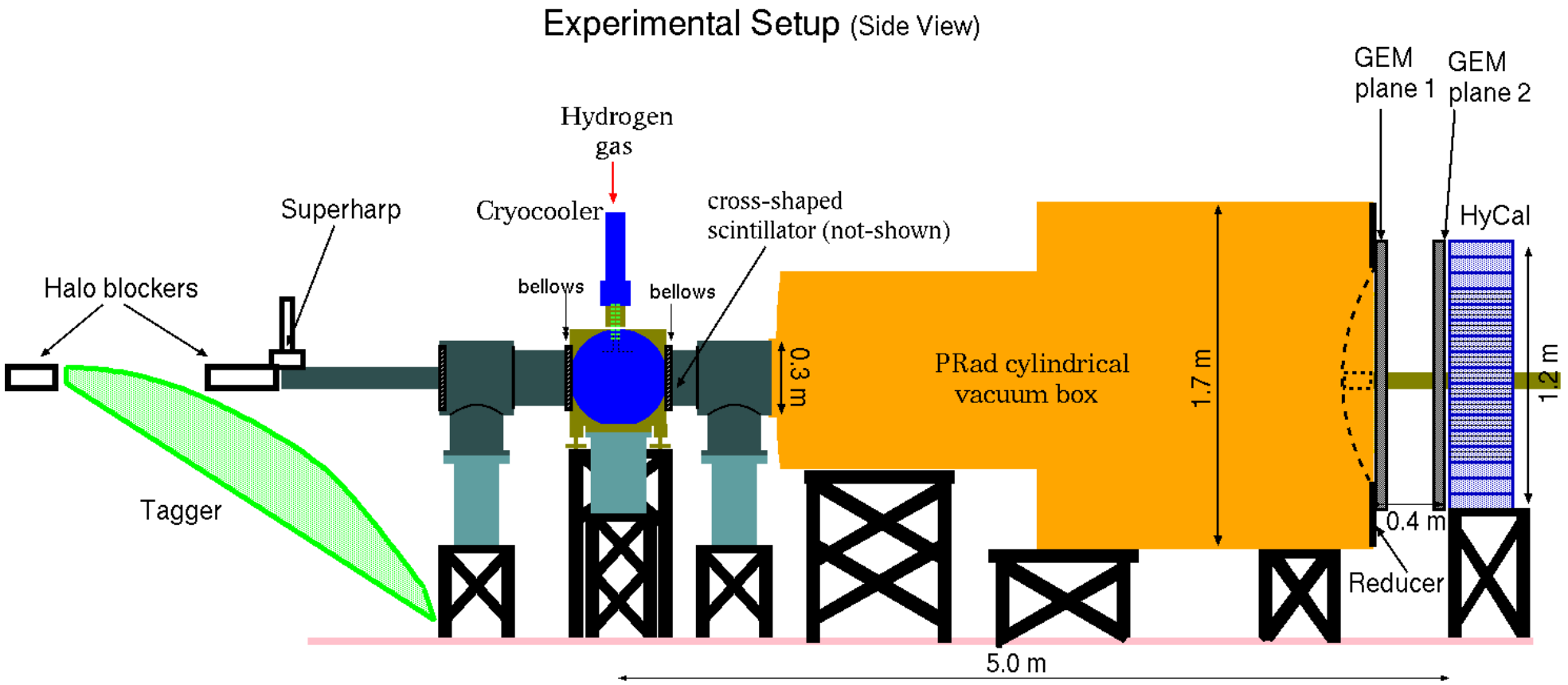
- Efficiency drop from dead area: 2% (spacers, high voltage sector, dead area)
- High efficiency in overlapping area: 99.2%
- Average efficiency: 97% in small angle region
- Performance stable over time





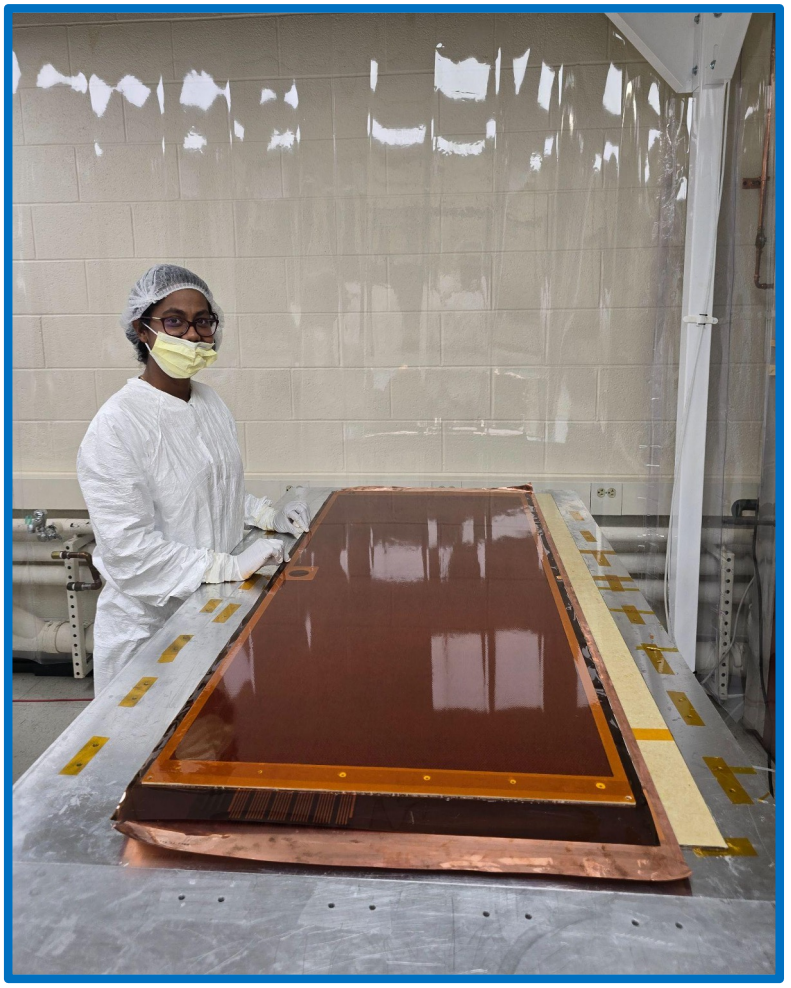


PRad-II – Add a second Layer of GEM detector



Design of the New Chambers for PRad-II

- 4 new chambers to compose 2 layers
- Overall share the same design with PRad-I but with some improvements
  - New spacer location
  - Optimized design for GEM foil, drift foil
- Same outer dimension



Steps in GEM Construction & Characterization

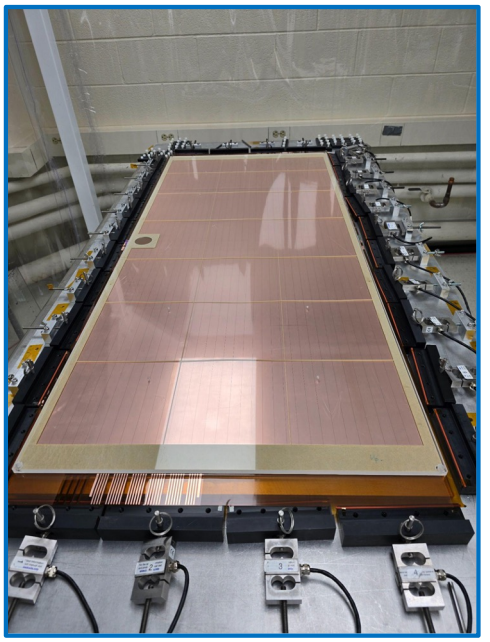
Pre-Cleanroom Activities

- **Honeycomb Plate Fabrication**
  - Used for RO support & gas window
  - Enhances mechanical robustness while maintaining low-material requirement
- **Preparations of GEM frame**
  - Sanding and washing frames with deionized water
  - Applying varnish to block dust and reduce outgassing

Steps in GEM Construction & Characterization

Cleanroom Activities

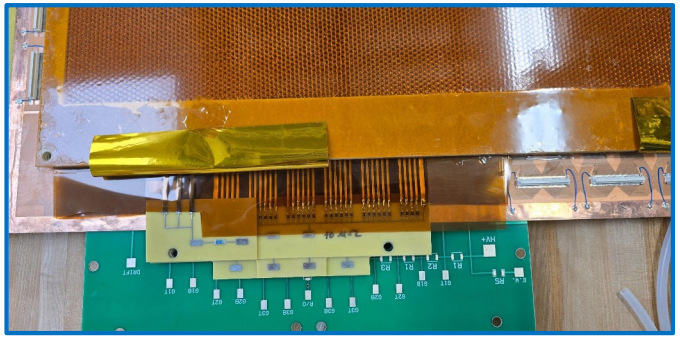
- **Inspection of GEM foils & RO boards**
  - Optical inspection for the specs of GEM holes and RO strips
  - HV sector test of GEM foils conducted in three stages: Raw foil, Framed foil & Chambered foil
- **GEM foil assembly**
  - Stretch and glue the foil on the frame
  - Attaching the framed foil to the chamber stack

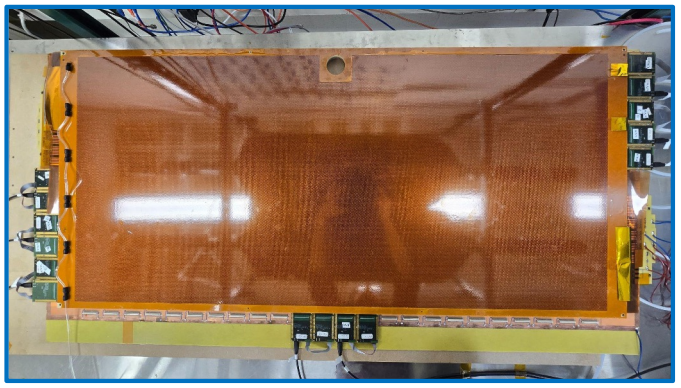


Steps in GEM Construction & Characterization

Post-Cleanroom Activities

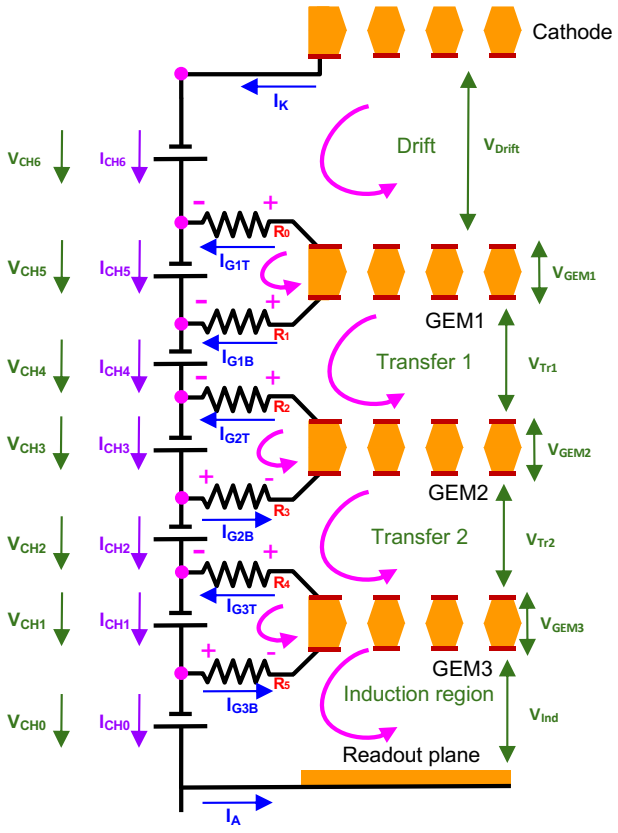
- **Mounting HV boards & Grounding RO connectors**
  - Eight HV boards to power each GEM cathode sector
  - One HV main board for HV distribution
  - Grounding RO connectors to prevent electronic noise
  - Done by Larry St.John (an electrician at UVa Physics)
- **Characterizing GEM Modules**
  - HV scan to check module stability
  - Characterize with SRS DAQ with X-Ray & Cosmic
  - Characterize with MPD DAQ in ELL 125 (Led by Xinzhan)





Status of GEM Production

Cleanroom Activities

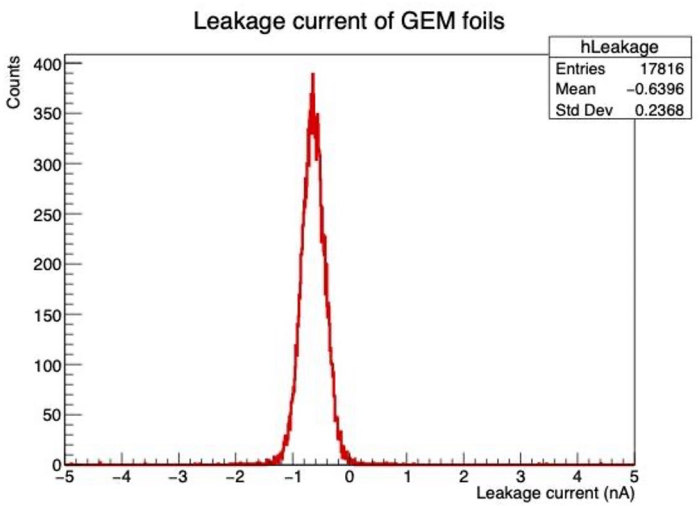


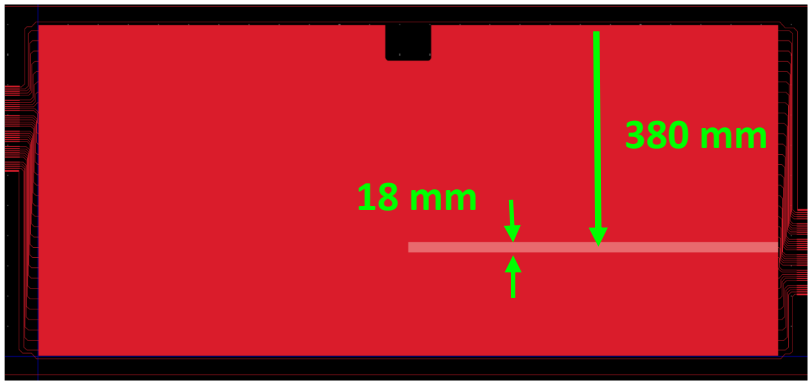
- **Modification in Cathode structure**
  - First two chambers
    - Cathode has GEM-hole structure
    - Gas coming from the top of cathode foil
    - Thickness of the chamber: ~17 mm
  - 3rd & 4th chambers
    - Solid cathode without holes
    - Gas coming from the top of 1st GEM foil (under the cathode foil)
    - Thickness of the chamber: ~15 mm
- **Finished assembly 4 GEM chambers in the cleanroom**

Status of GEM Production

Outside Cleanroom Activities

- **Outside cleanroom activities**
  - Grounding Panasonic connectors on the RO boards
  - Identifying dead sectors
    - Leak current I < 3nA at HV = 550V in N2
- **The first two chambers**
  - Completed outside-cleanroom activities
  - Pedestal noise is suppressed
  - One dead sector on each chamber: same location
- **3rd & 4th chambers**
  - The 3rd: in the process of grounding connectors
  - The 4th: in the process of identifying dead sectors

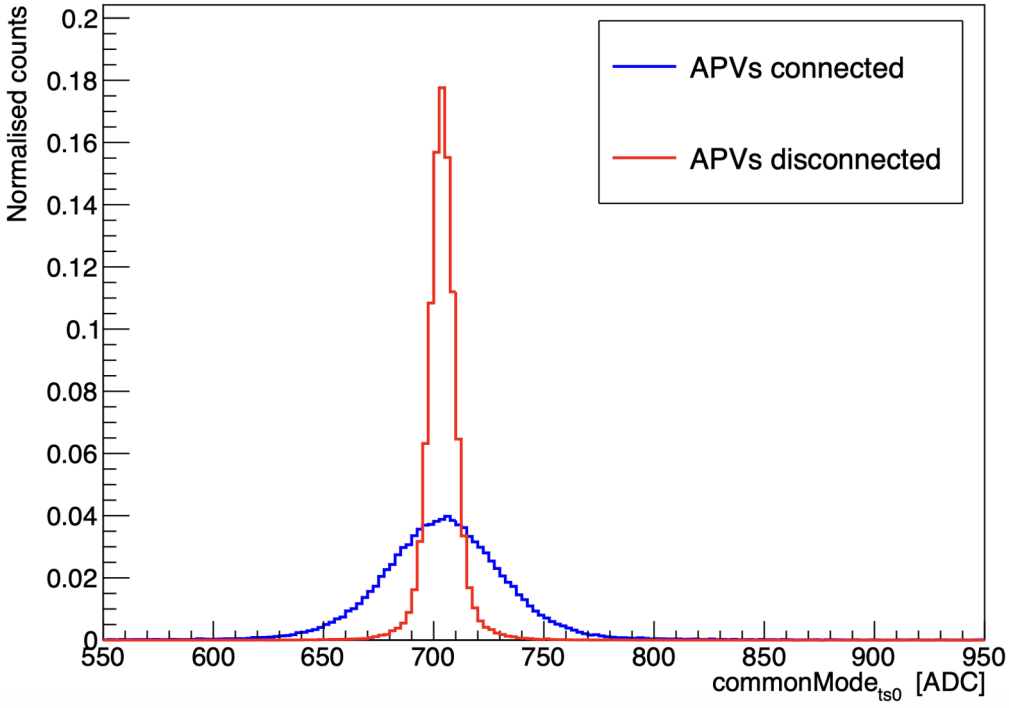




GEM Testing at UVA

Noise Testing

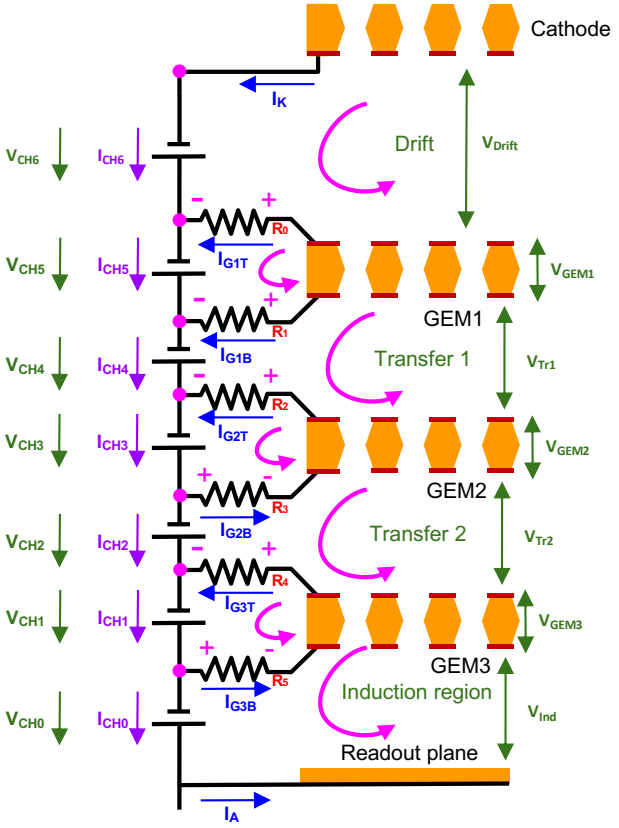
- Common-mode noise distributions using the PRad backplane were compared:
  - **APVs connected to the detector**
  - **APVs disconnected from the detector**
- Noise behaviour is acceptable – however, RF shielding is likely needed for operation in the hall



GEM Testing at UVA

HV Configuration & Stability

- **GEM Operation for PRad-I vs. PRad-II**
  - **100% HV configuration used for PRad-I**
    - Voltage ratios on GEM foils and gap regions from Drift -> RO 1.0/ 0.55/1.0/0.5/1.0/0.45/1.0
  - **85% HV configuration used for PRad-II**
    - Reduce the field in gap region to 85%, keep the fields cross GEM the same: 0.85/ 0.55/0.85/0.5/0.85/0.45/0.85
    - Increase the HV stability in high rate environment
- **Performed HV stability test on two GEM chambers and both chambers passed the test**
- **Will use HV Parallel Power Supplies for GEM PRad-II**
  - Allow optimizing HV operation for each chamber independently



GEM Testing at UVA

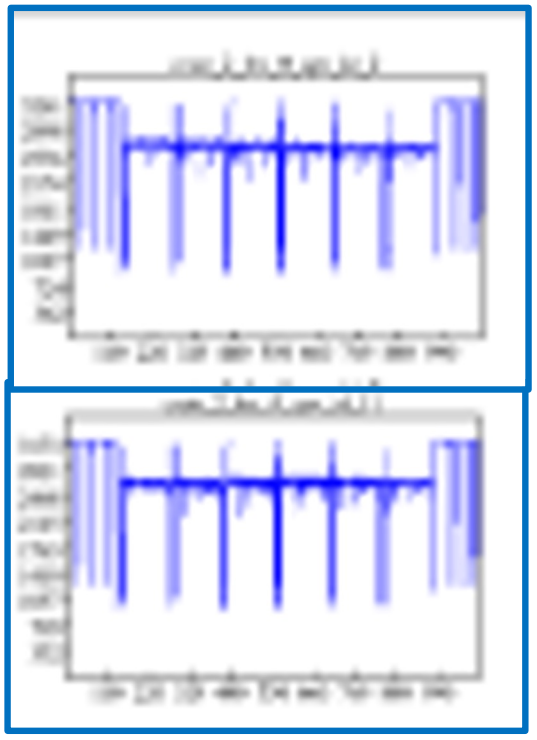
Cosmic Test with ArCO2 (70/30) Gas Mixture

- **Set up for Cosmic test at UVa**
  - Setup scintillators to test GEM area read by 14 APV

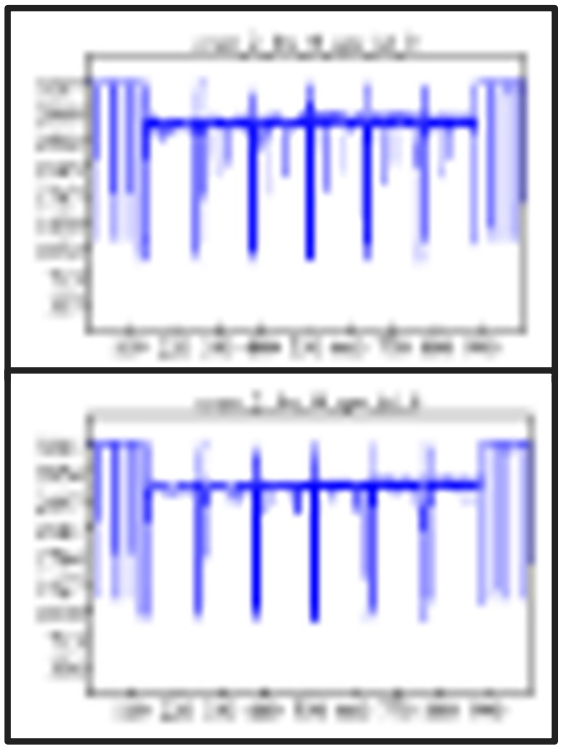
- **Goals of UVA cosmic test**
  - Verifying the HV stability with ArCO2
  - Check the APV raw signals to verifying gas circulation
  - Check signal size vs. HV setting to to give a handle for Cosmic test in EEL building

GEM Testing at UVA

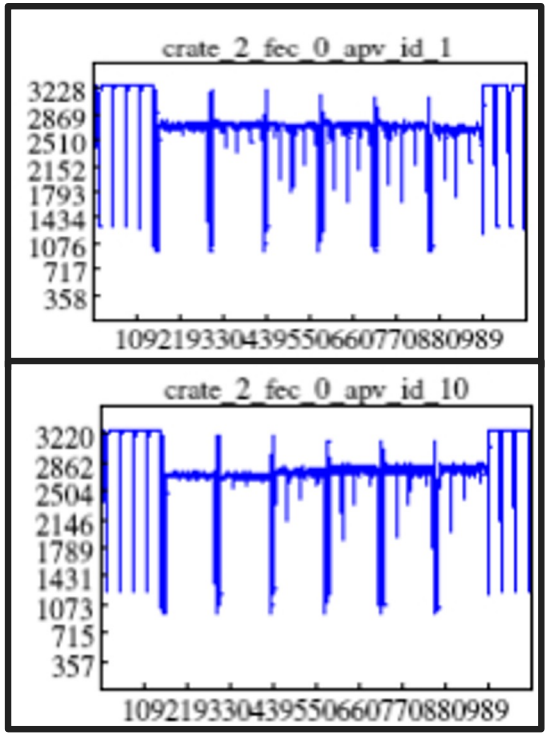
Cosmic Test with ArCO2 (70/30) Gas Mixture



HV= 3563 V (~4000 V)



HV= 3608 V (~4050 V)

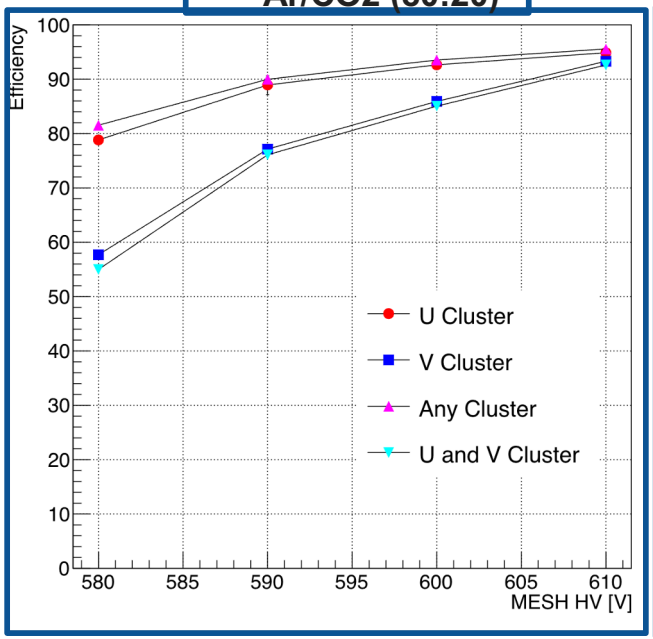


HV= 3652 V (~4100V)

Performance of Large-area µRWELL in Isobutane Gas Mixture

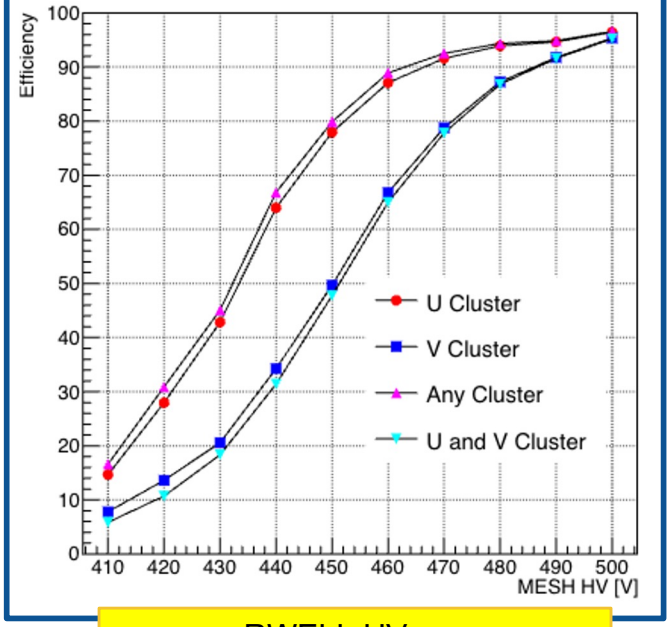
Plots from Rafayel Paremuzyan

Ar/CO2 (80:20)



uRWELL HV scan

Ar/C_4H_{10} (90:10)

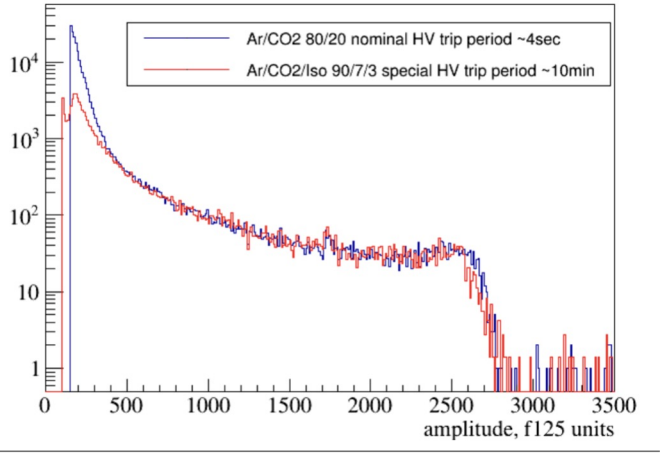


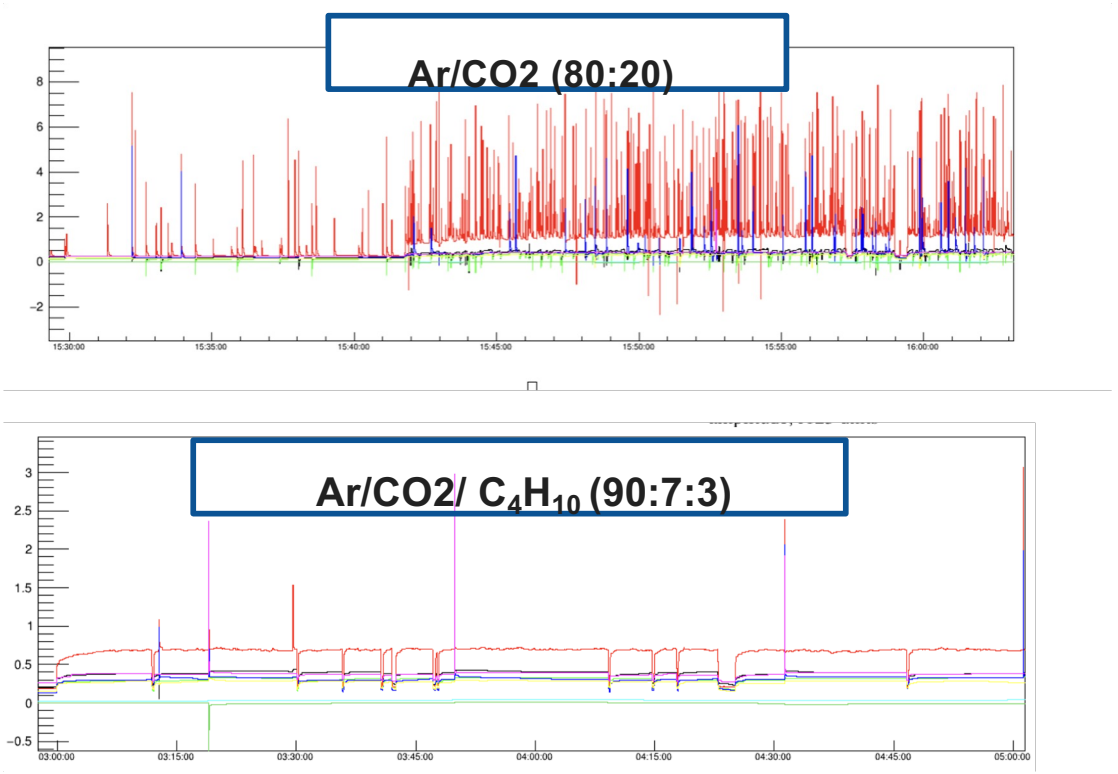
uRWELL HV scan

- **Prototype reached 90% efficiency in Ar/C4H10 (90:10) at a much lower HV (490 V vs. 600 V) => operated much more stably**

Performance of GEM-TRD in Isobutane Gas Mixture

- **At the same gain Isobutane gas mixture shows two orders of magnitude less GEM discharge**
- **Isobutane has great potential to stabilize PRad-II GEM detector performance under high rate**





Plots from Lubomir Pentchev

Operating PRad GEM with Isobutane Gas Mixture

A backup plan to accommodate high rate environment

- Use Ar:CO2 (75:25) as our baseline
- Isobutane stabilizes detector performance under high rate
- Test 3 Isobutane gas mixtures in EEL
  - Ar:CO2:Iso (70:28:2)
  - Ar:CO2:Iso (75:23:2)
  - Ar:CO2:Iso (80:18:2)
- A promising improvement for PRad-II GEM detector operation for X17

Prad GEM detector preparation timeline

- Week of September 8:
  - Gather DAQ components in EEL 125.
  - Bring GEM chambers 1 and 2 to the EEL building

- Week of September 15:
  - Arrange the N2 gas supply in EEL room 125
  - Connect the two GEM chambers to N2 supply
  - Setup the GEM DAQ system.
  - Arrange low voltage and high voltage power for the GEMs
  - Install APV backplanes and APV cards on the two GEMs
  - Cable up the detectors
  - Test the 25 kHz trigger rate.
  - Arrange Ar/CO2 gas supply and switch the two GEMs to that gas mixture

Prad GEM detector preparation timeline: EEL 125: Continued

- Week of September 22:
  - Start cosmic data taking
  - Perform efficiency studies of the two GEM detectors using cosmic data using Ar/CO2 gas mixture

- Week of September 29:

  - Continue cosmic data taking
  - Receive the SBS electronic modules from Hall A/B and complete the DAQ system

- Week of October 6:
  - Switch one GEM to the Ar/CO2/Iso-butane gas mixture when this mixture is available
  - Take cosmic data with the Ar/CO2/Iso-butane gas mixture and optimize efficiency
  - Receive GEM chamber #3 from UVa
  - Cable up this GEM and test with cosmic rays
  - Receive GEM holding frames from Bob Miller
  - Full DAQ system test

Prad GEM detector preparation timeline: EEL 125: Continued

- Week of October 13:
  - Receive GEM chamber #4 from UVa
  - Cable up this GEM and test with cosmic rays
  - Install RF shielding on the chambers

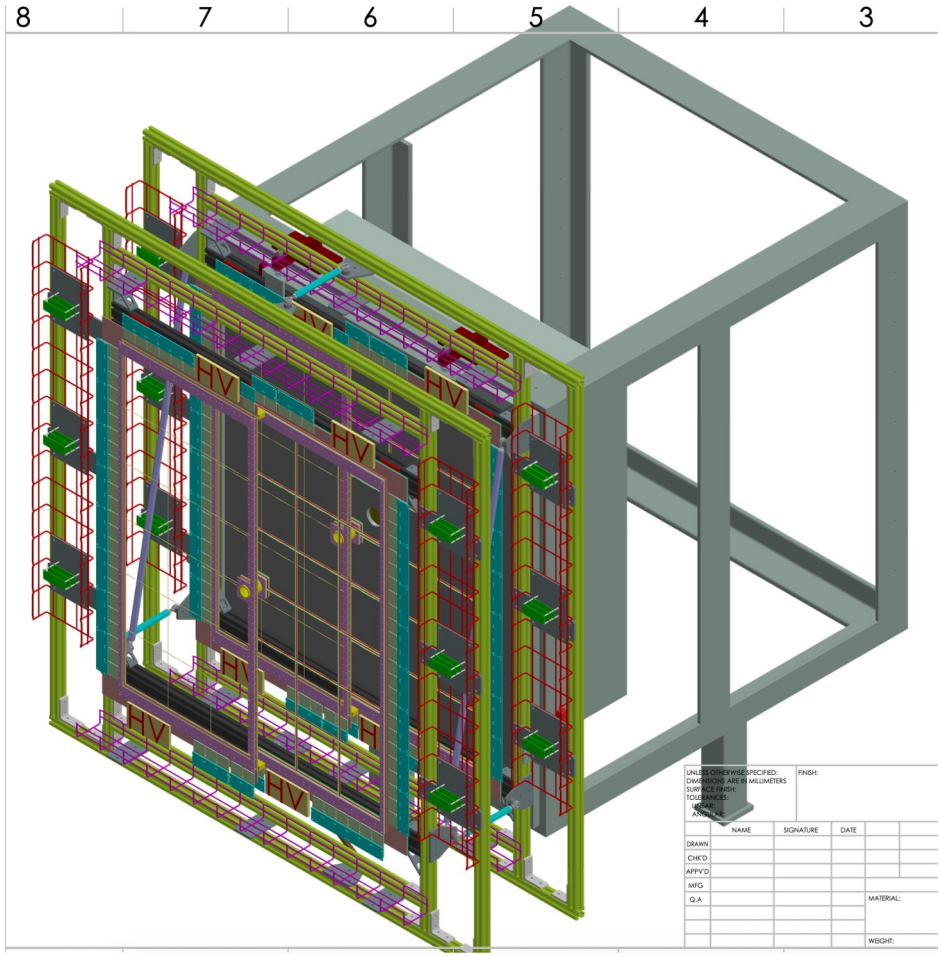
- Week of October 20:
  - Assemble GEMs #1 and 2 into the first PRad GEM holding frame
  - Install the cables into trays on the frame.
  - Continue cosmic data taking with GEM #3 and 4.

- Week of October 27:
  - Assemble GEMs #3 and 4 into the second Prad GEM holding frame
  - Assemble the GEM frames into the vertical holding structure.
  - Do a pedestal noise test with the full system

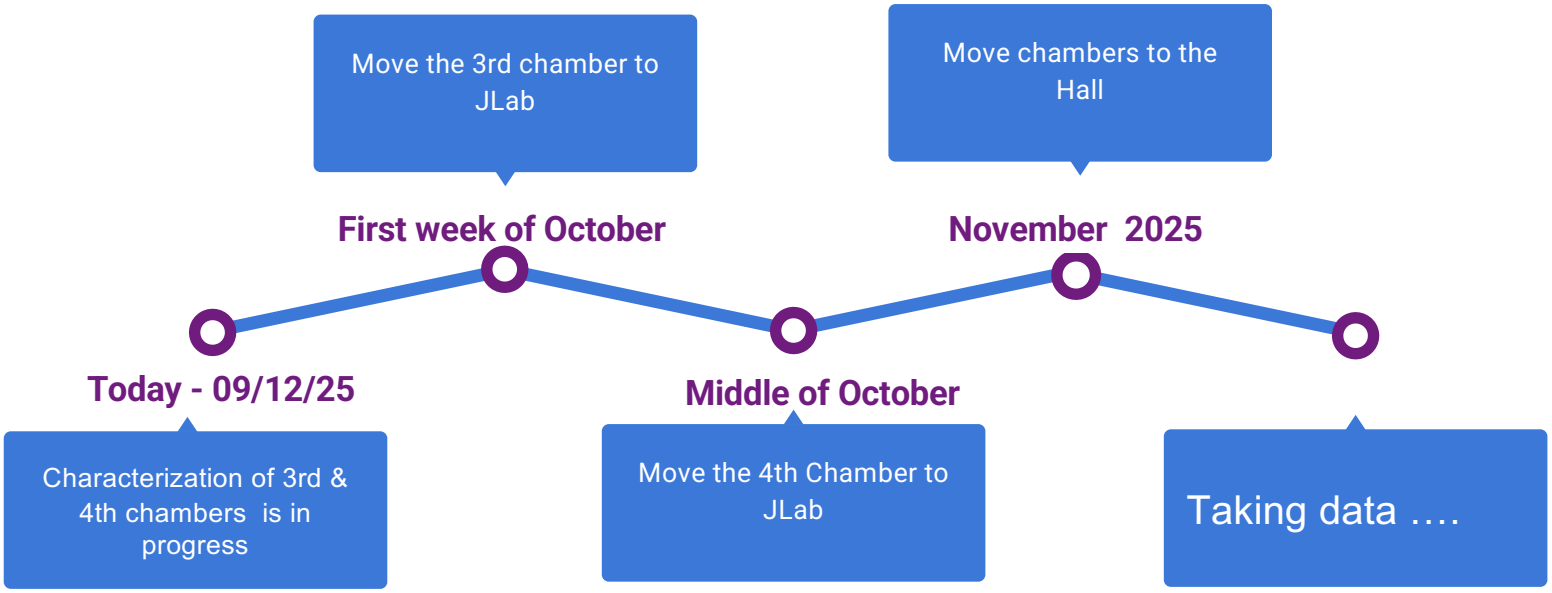
- Week of November 3:
  - Catch up
  - Get ready to move into Hall B

Installation in the Hall

- The frames will come to the hall with GEMs mounted and short HDMI and LV cables installed into the cable trays.
- Mount the frames one by one on HyCal and connect to the long cables
- It is desirable to have a scintillator mounted between the GEM to make cosmic track triggers in coincidence with HyCal.



GEM Characterization and Delivery Timeline



- ❑ Completed construction for four PRad Chambers
- ❑ Finished characterization and move the first two chambers to JLab
- ❑ Compete PRad-II GEM construction and characterization in Middle of October

Personnel availability for GEM construction, GEM and DAQ installation

GEM construction: **Huong Nguyen,** Mihitha Maithripala, Nithya Kularatne, Eric Fernandez

GEM installation, commissioning and operation: Xinzhan Bai, Asar Ahmed, Nithya Kularathne, Jacob McMurtry, Vidura Vishvanath, Huong Nguyen, Nilanga Liyanage, Florian Hauenstein, Rafayel Paremuzyan

DAQ setup: Xinzhan Bai and Ben Raydo (Jefferson Lab), UVa group

Nithya Kularatne will be a thesis student on PRad-II

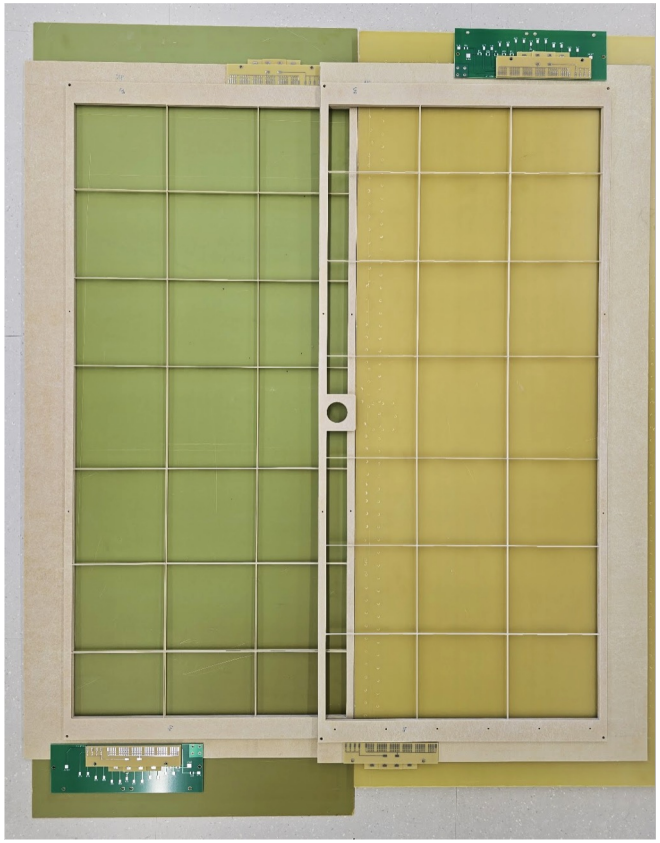
Summary

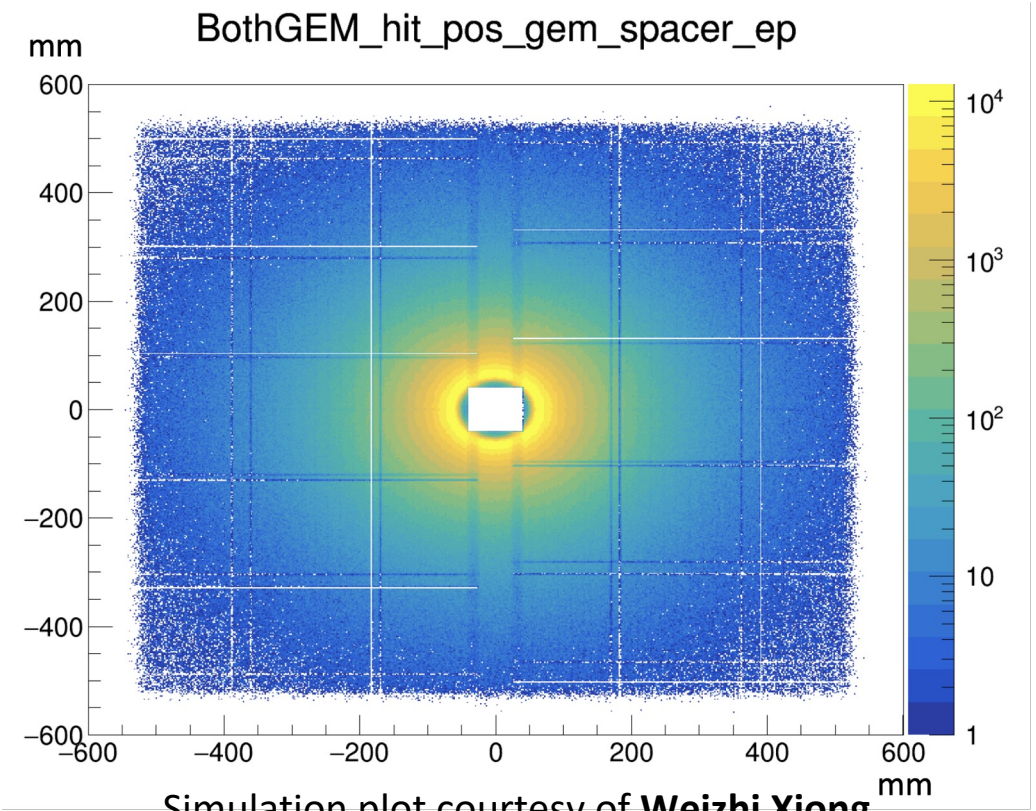
- The construction of the four GEM modules is complete
- Working on the spare GEM now
- Two GEMs at Jlab now, will send all four GEMs to Jlab by mid October
- Feasible installation and commissioning schedule.

Backup

New Spacer Location

Asymmetric Spacer Location to minimize effective dead area in the overlap region





Simulation plot courtesy of **Weizhi Xiong**

GEM Foil Design

– Segmentation on bottom side of GEM foil – great improvement on chamber robustness during operation

– Dedicated circular sector on cathode foil for high rate situation