GEM Detector and DAQ Status

Nilanga Liyanage
University of Virginia

PRad Collaboration Meeting, Newport News, 03/03/2025

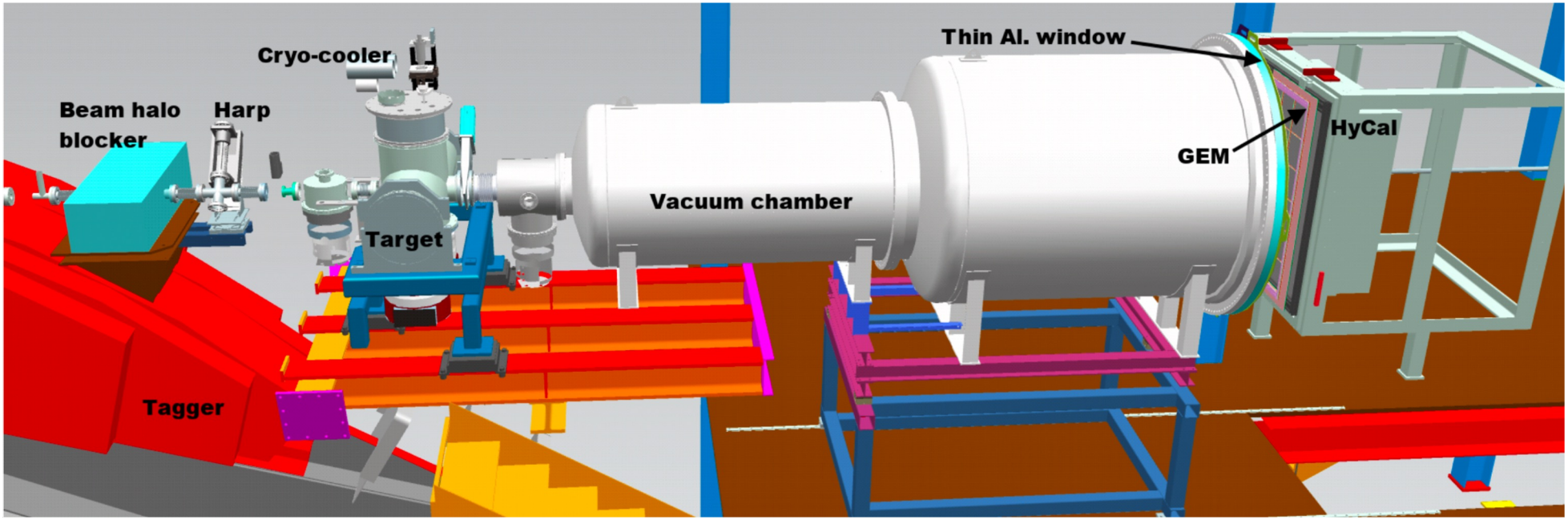
Outline

- ❏ GEMs in PRad Experiment
- ❏ PRad-II GEM chamber Status
- ❏ DAQ Preparation
- ❏ Summary

PRad

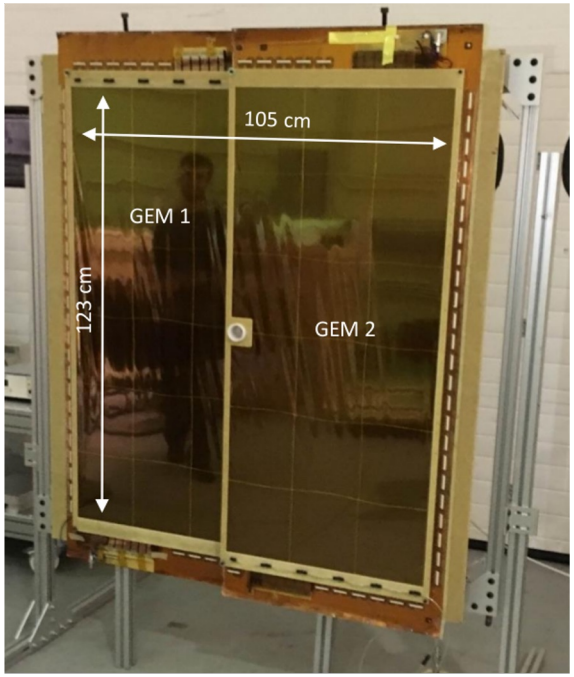
GEM Detectors in PRad Experiment

- Two major detectors: HyCal + GEM
- World largest GEM detector by then:, 120 cm X 102 cm

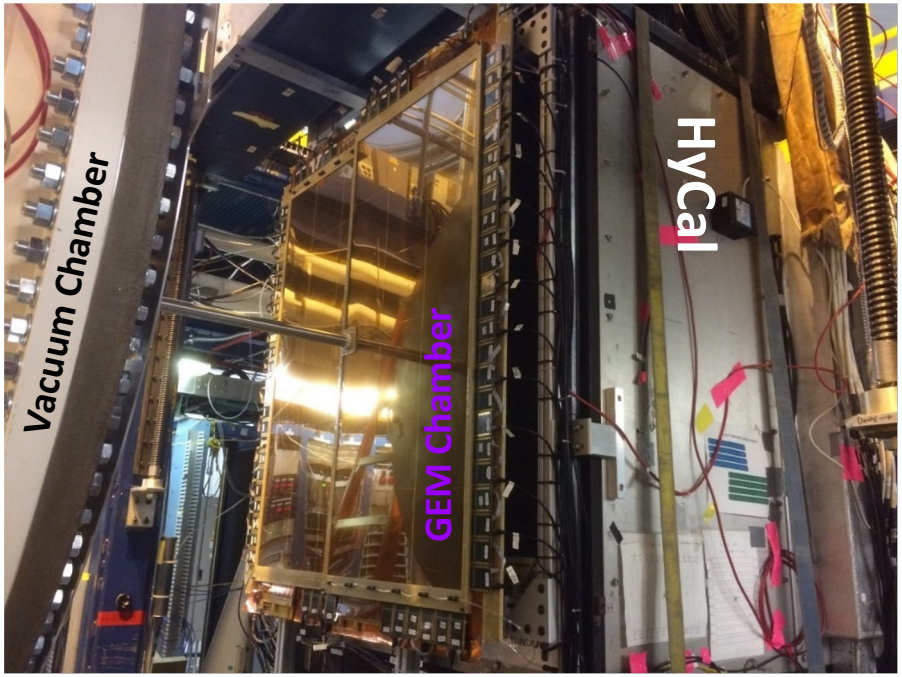


GEM Detectors in PRad Experiment

- Designed and Constructed in UVA in 2015

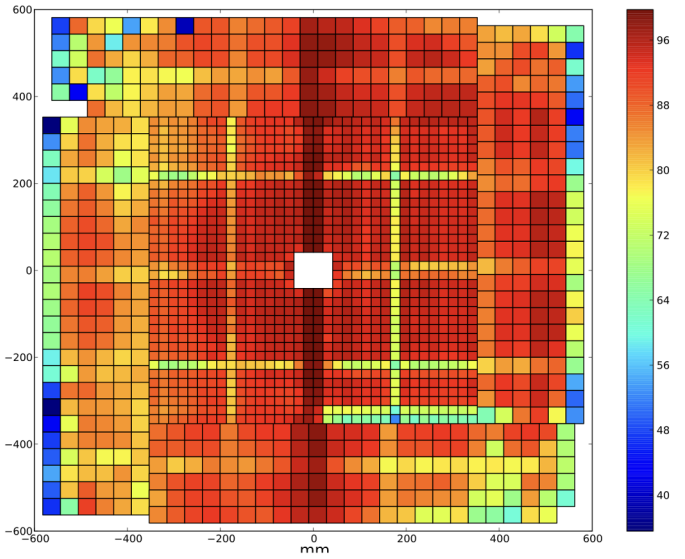


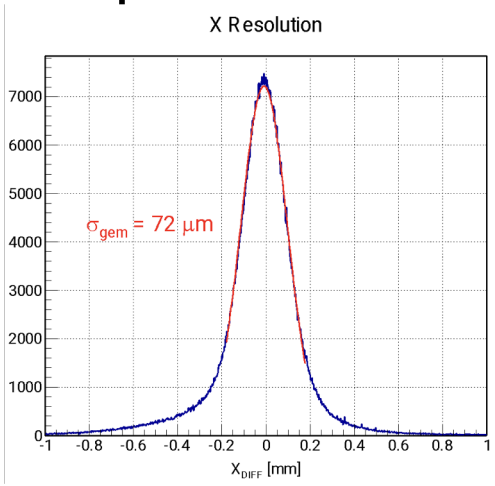
- Installed in Hall B beamline in 2016

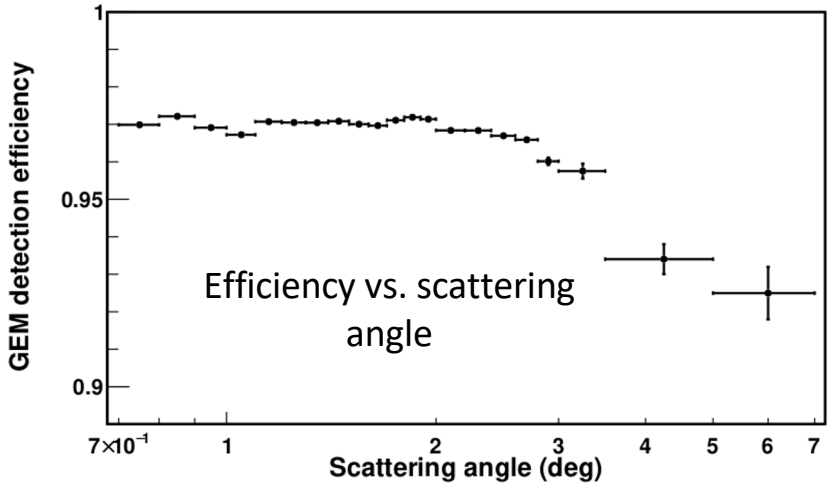


Efficiency and Resolution – PRad Experiment

- 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



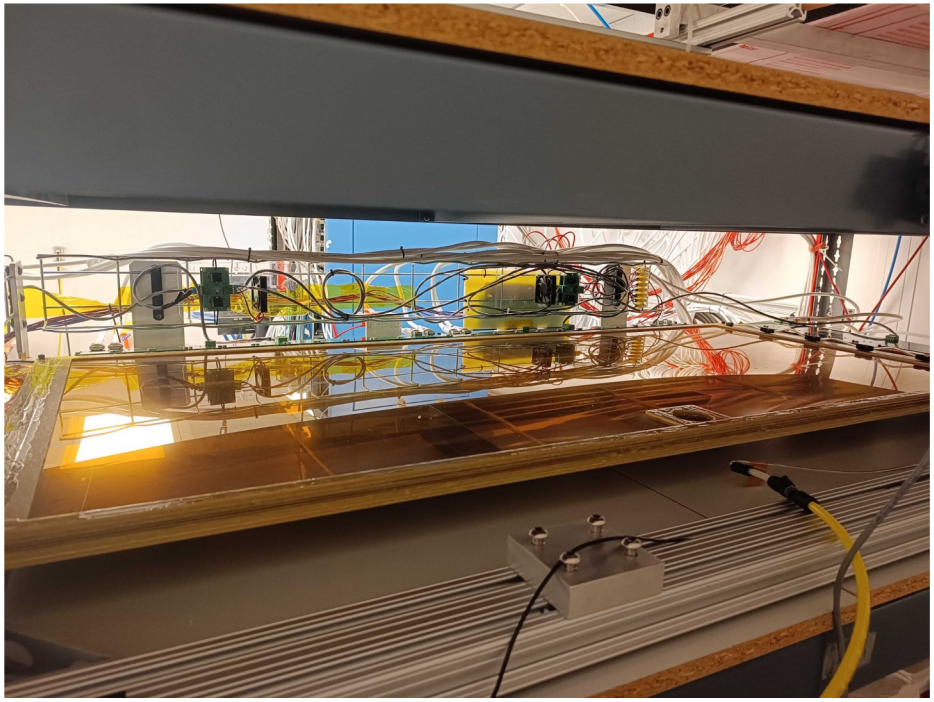




PRad GEM Detectors – Current Status

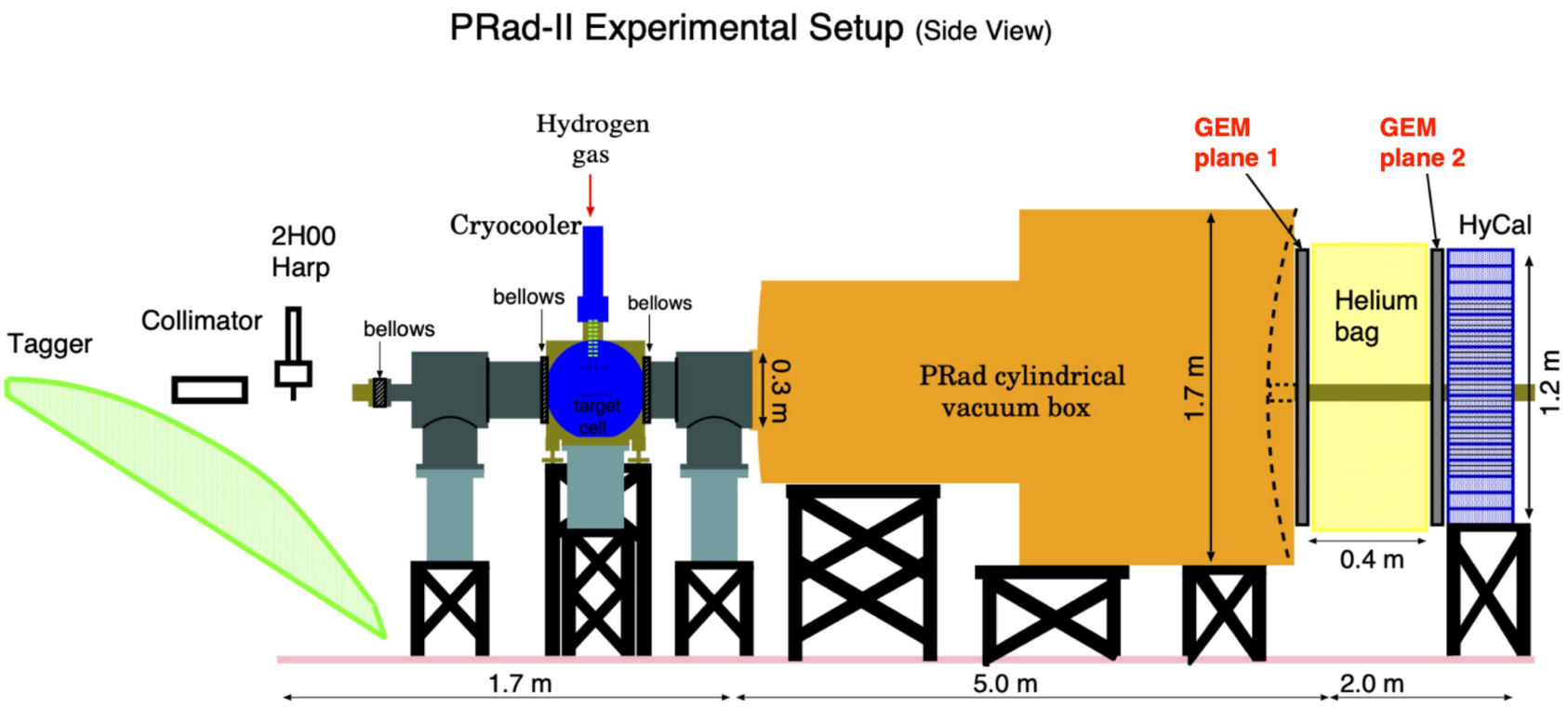
- PRad GEM Detectors will be used in LAD experiment in Hall C
- Will be used as **spare GEM detectors** for PRad-II (LAD will be completed by PRad-II running)

X-ray test for LAD (UVA)



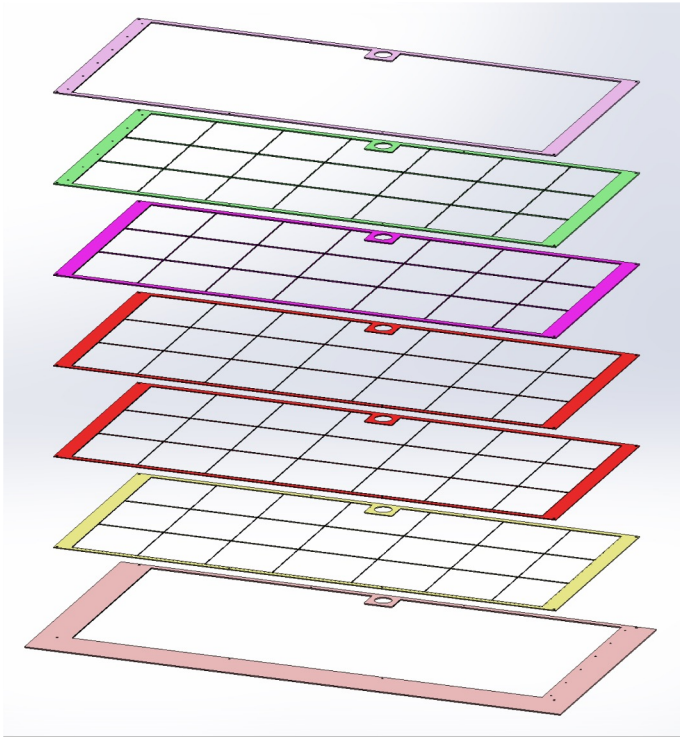
Cosmic test for LAD (JLab)

PRad-II – Add a second Layer of GEM detector



Design of the New Chambers for PRad-II

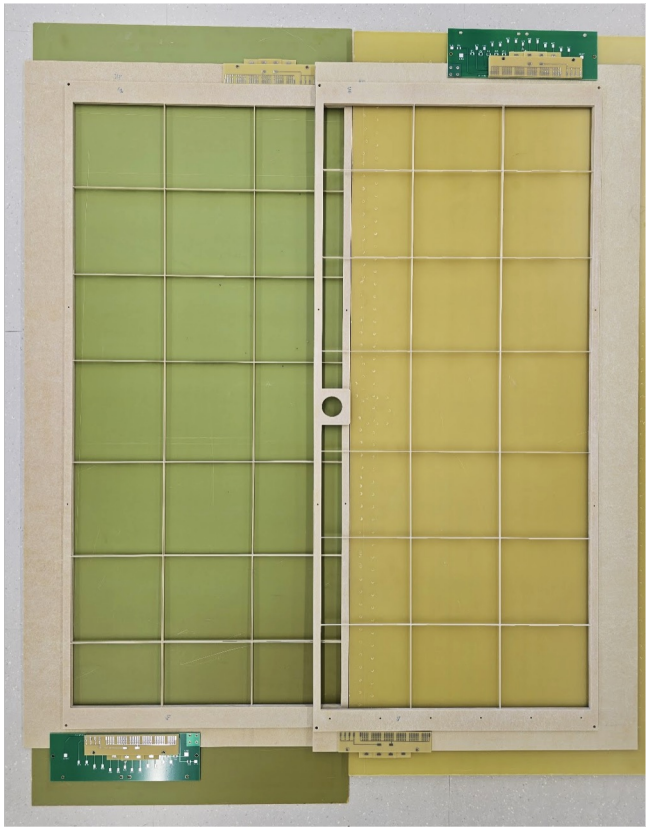
- 4 new chambers to compose 2 layers
- Overall share the same design with PRad-I but with some improvements
  - New spacer location
  - Optimized design for GEM foil, drift foil
- Same outer dimension

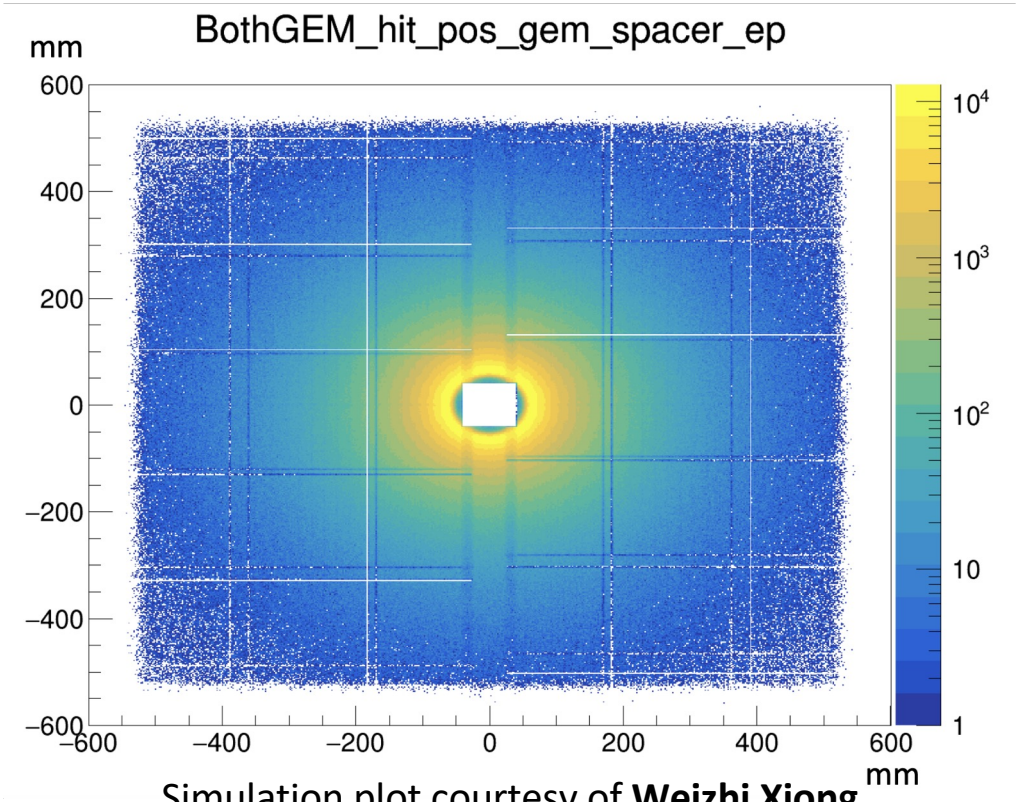


New detector frame design

New Spacer Location

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



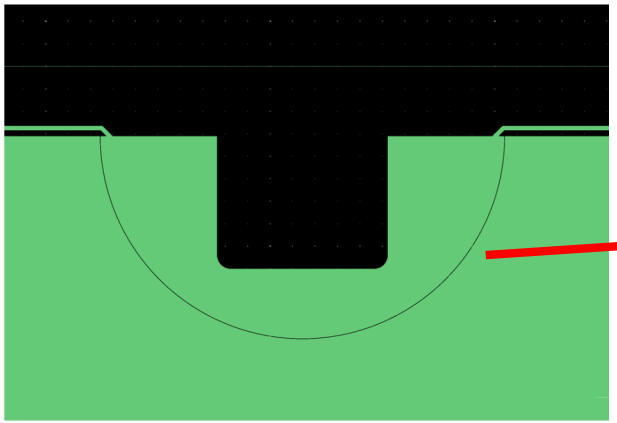


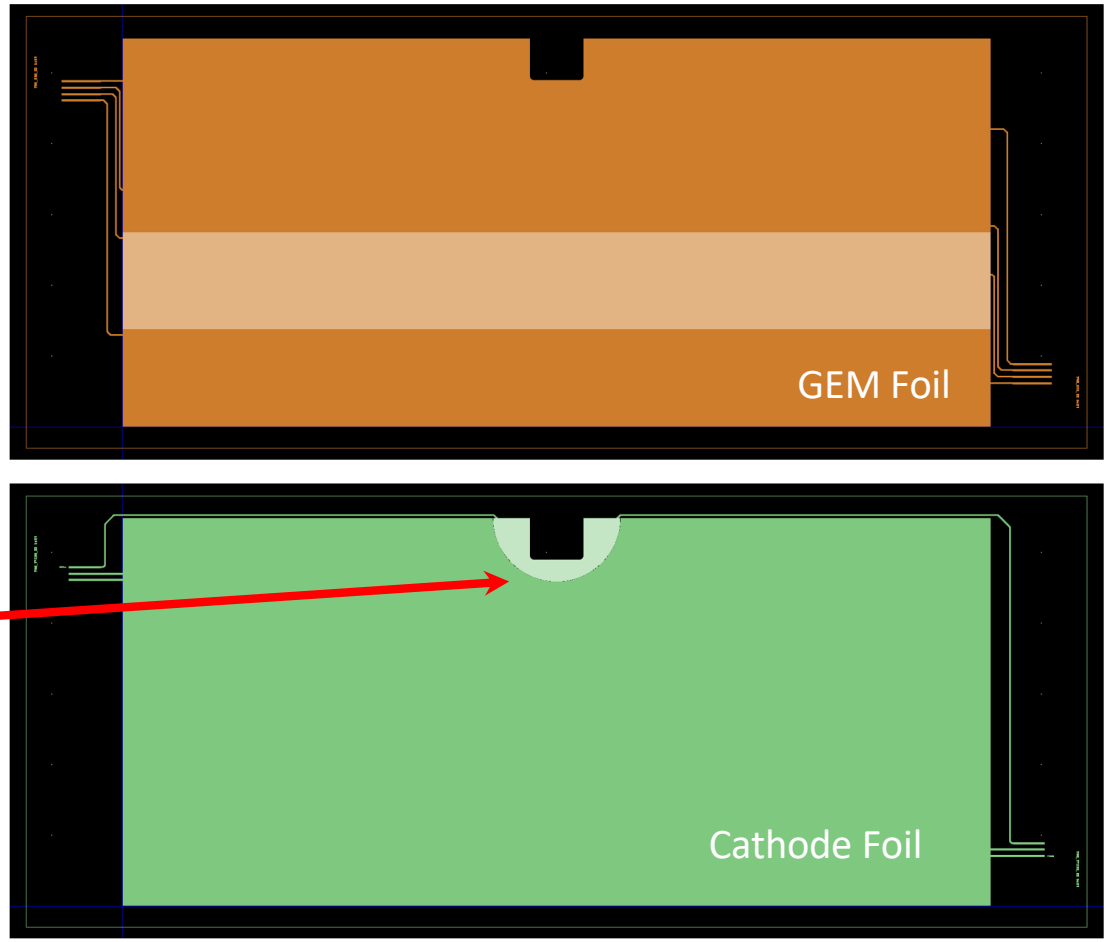
Simulation plot courtesy of **Weizhi Xiong**

GEM Foil Design

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

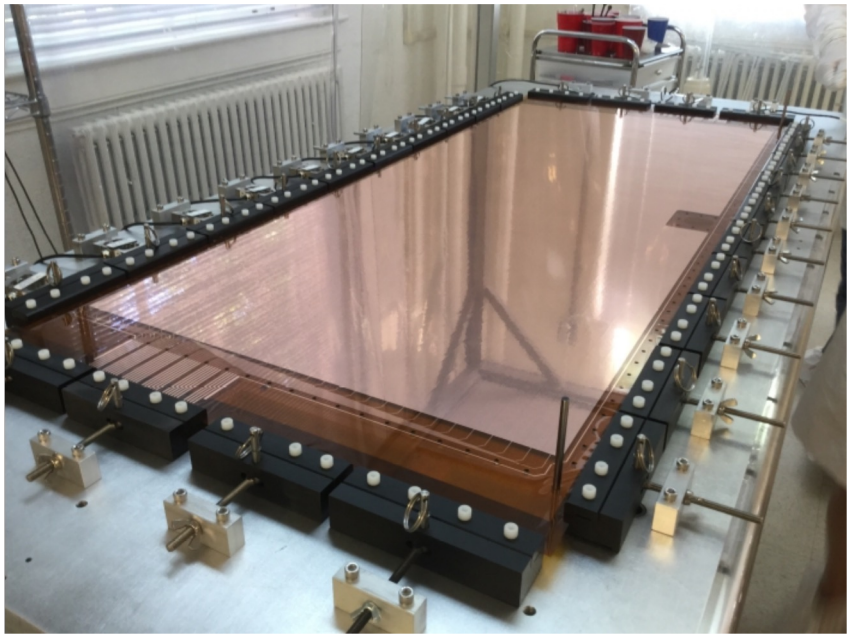
– Dedicated circular sector on cathode foil for high rate situation

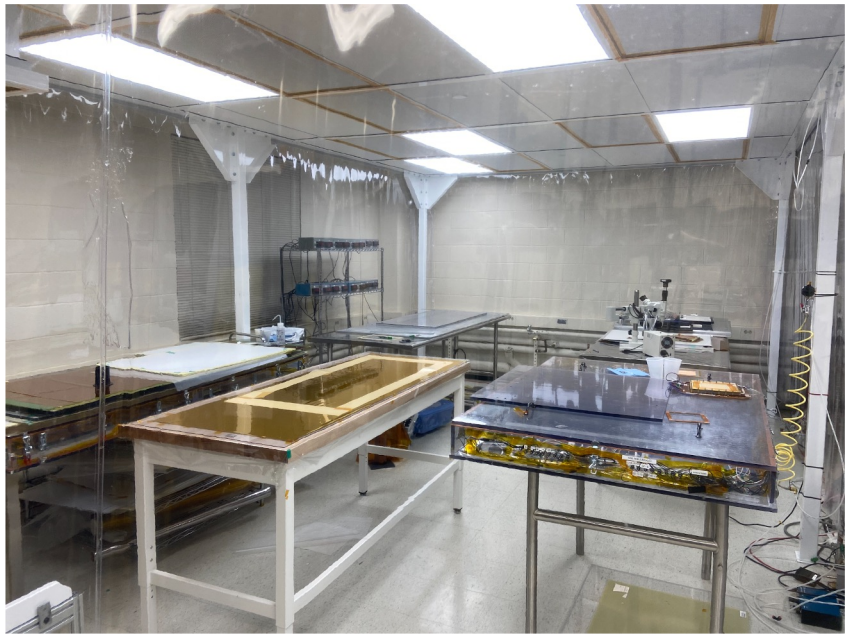




Preparation of Construction in Cleanroom

– Cleanroom transition to PRad-II project; Use the same stretcher from PRad-I detector construction

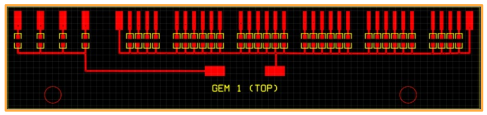


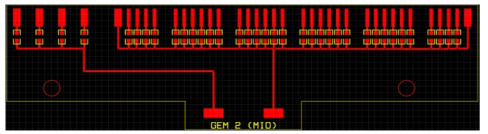


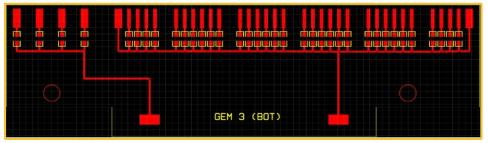
UVA cleanroom

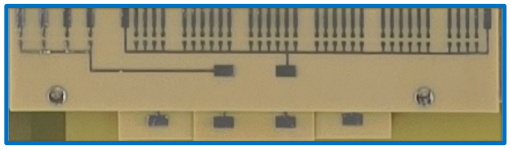
Progress on GEM Construction

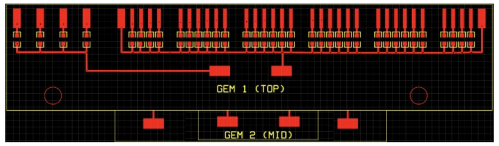
- ❏ GEM HV inspection system & GEM stretcher have been upgraded for PRad-II
- ❏ GEM construction for LAD experiment is ongoing
- ❏ All GEM frames for PRad-II have arrived and frame preparation is in progress
- ❏ Designed PRad-II HV distribution boards to match new design of GEM and cathode foils.
- ❏ All PRad-II HV distribution boards were made
- ❏ All GEM foils were shipped from CERN last week; expect here soon
- ❏ GEMs Assembly in cleanroom for PRad-II expected to start in two weeks



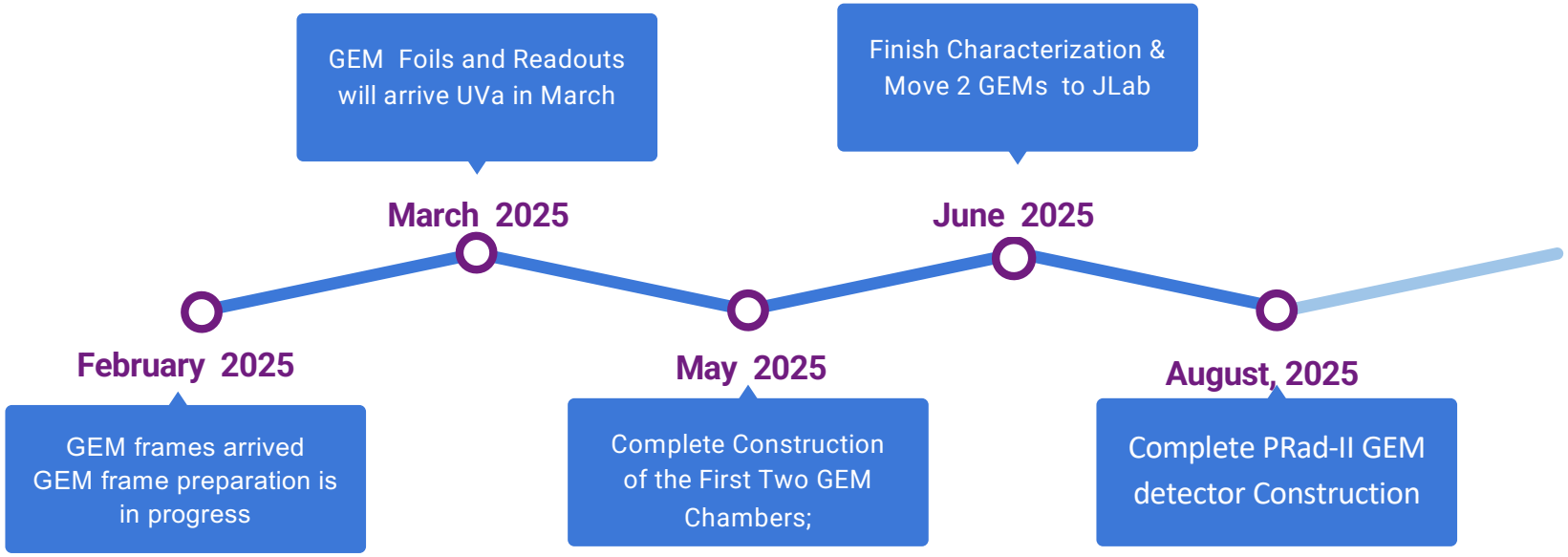






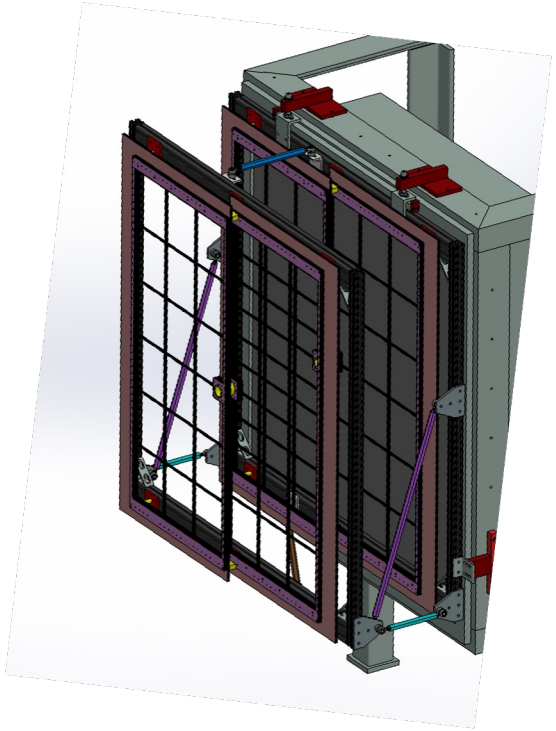


GEM Construction & Characterization Timeline

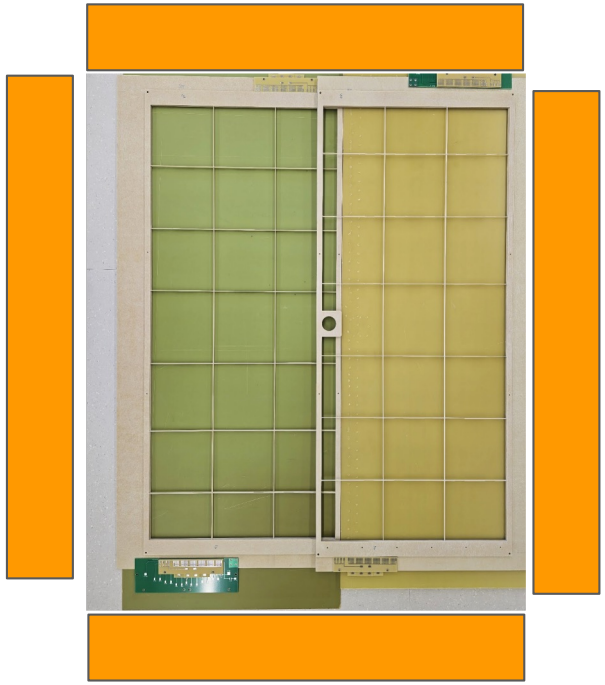


- ❑ Complete construction for two GEM chambers in May, 2025
- ❑ Finish characterization and move two chambers to JLab in June, 2025
- ❑ Compete PRad-II GEM construction and characterization in August, 2025

GEMs Installation in Hall B



❑ Current design of GEM installation frame



❑ The new DAQ scheme calls for many HDMI Cables.

❑ Need to add cable tray for HV cables, HDMI cables, gas inputs & output lines

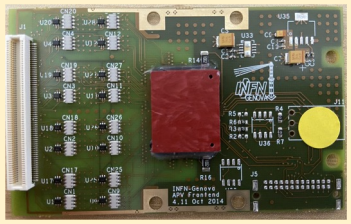
❑ Gas output is on the back of the detectors

❑ Need clearance for gas output lines

Switching to New MPD-DAQ system for PRad-II

- Currently used and well tested for all SBS experiments
- Extensive expertise for JLab DAQ group and UVA group

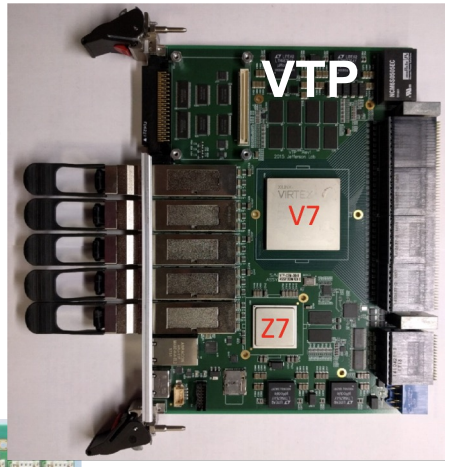
New MPD-based GEM Readout System



- ❑ **128 analog ch / APV25 ASIC**
- ❑ **3.4 us trigger latency** (analog pipeline)
- ❑ Capable of sampling signal at 40 MHz
- ❑ Multiplexed analog output (**100 kHz readout rate**)

MPD modules designed for SBS Program

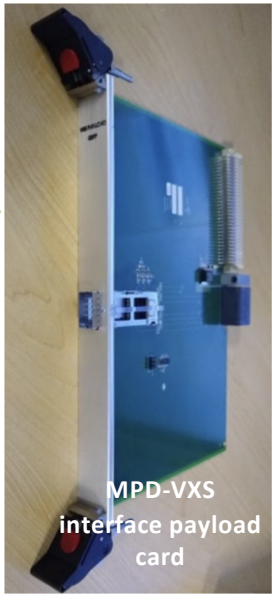
- ❑ Up to 15 APV cards on a single module
- ❑ 2 ns time resolution (APV clock synchronization)
- ❑ Arriga GX FPGA 128 MB DDR2-RAM
- ❑ **Online zero suppression**

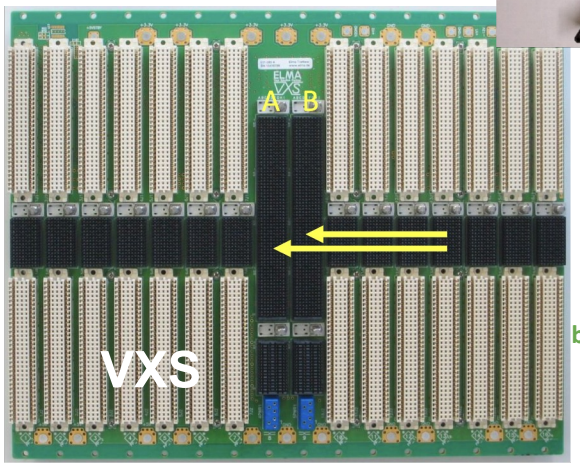


HDMI

Paolo, Evaristo (INFN)

Optical fiber 2Gbps



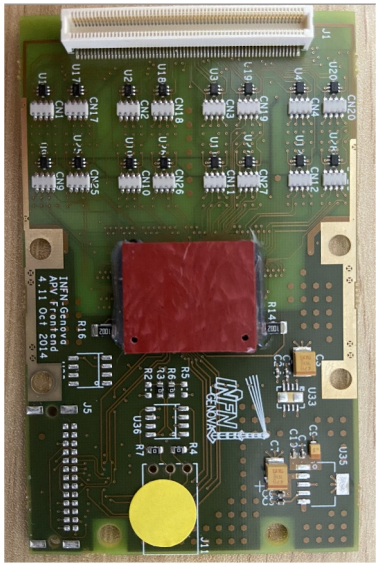


VXS bus – 20 Gbps bandwidth (4 lanes)

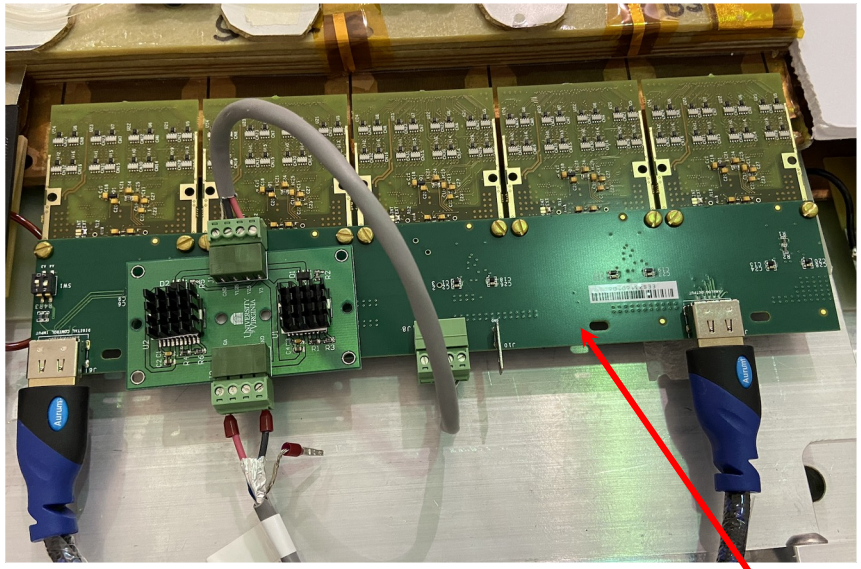
Aurora Protocol

CODA

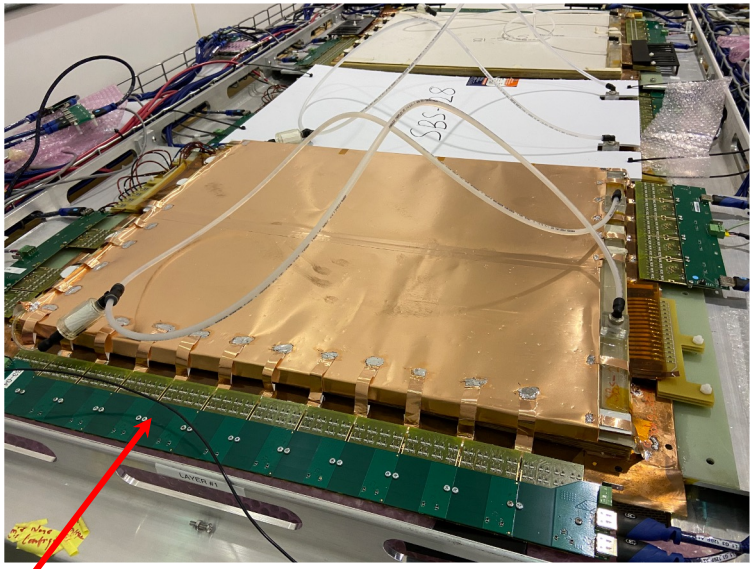
GEM Readout – APV Electronics



APV Hybrid



APV Hybrid installed on Backplane



Backplane installed on GEM chamber

Backplane

GEM Readout – APV Data

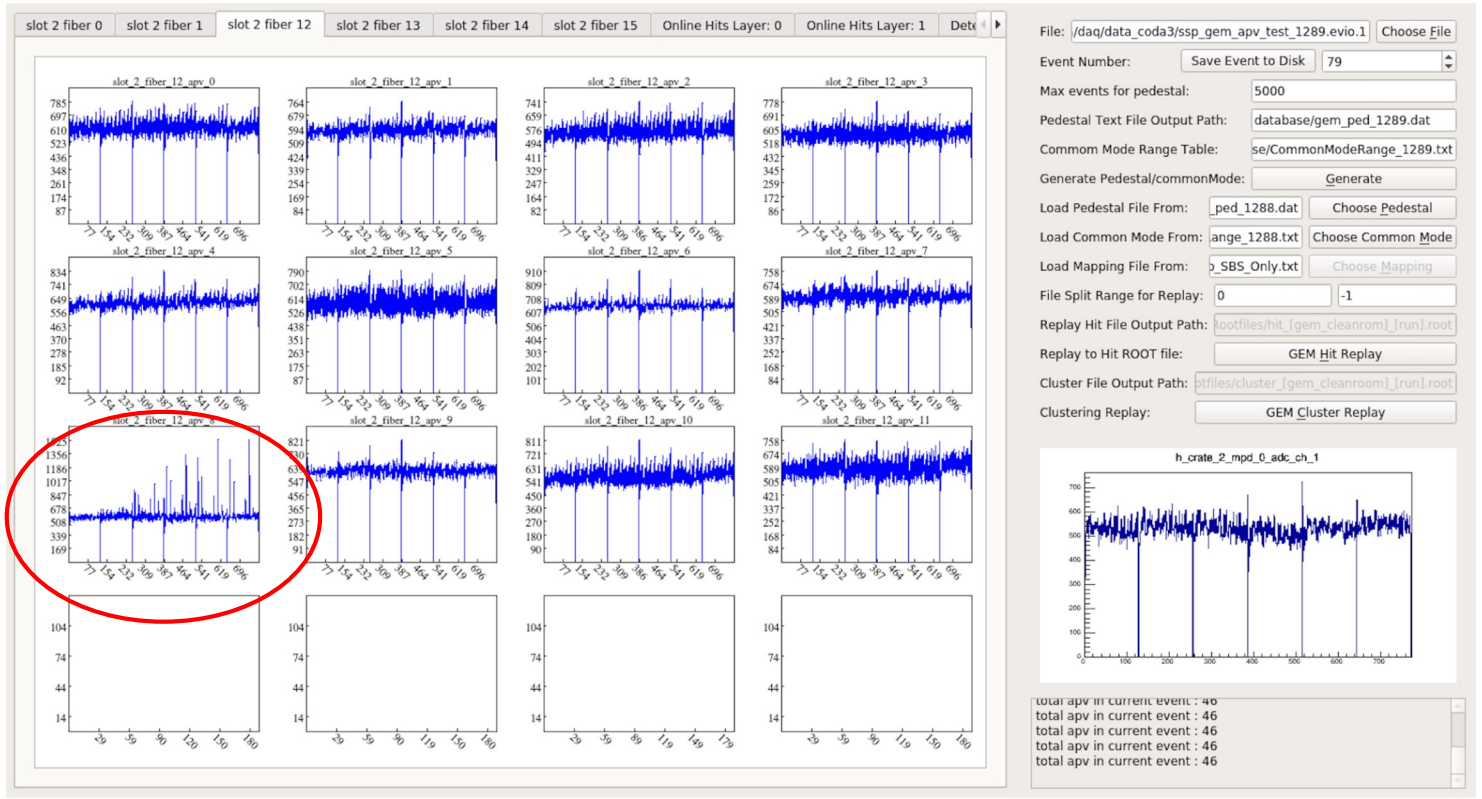
A typical event from cosmic data – 12 APVs

Every 25 ns take one sample, 6 time sample, 128 channels per sample

For cosmic events, most strips record pedestal data

Same situation for PRad experiment, > 90% data are APV pedestal data

Remove online or offline

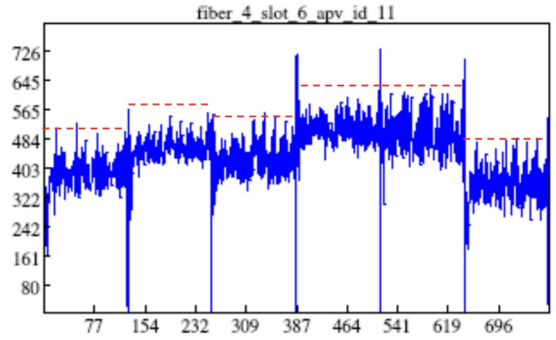


Online Zero Suppression

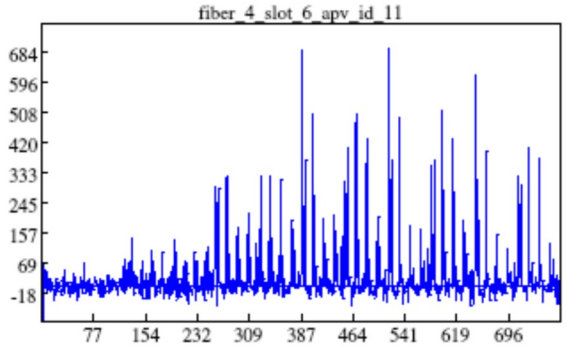
Online zero suppression algorithm implemented on VTP **on-bard FPGA**

3 different algorithms available (Sorting, Danning, Histogramming)

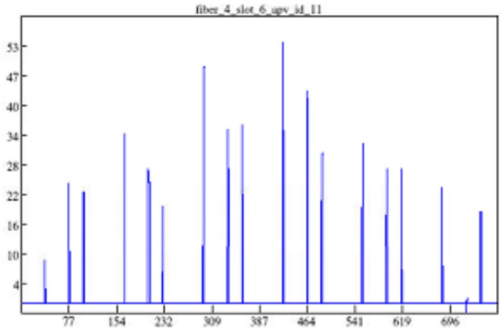
- ❏ Sorting, Danning algorithm from UVA group
- ❏ Danning Algorithm has been successfully implemented on the FPGA firmware – production algorithm for GMn, GEn experiments – Ben Raydo, JLab
- ❏ Histogramming algorithm (Andrew Puckett, UConn) to be implemented for GEp experiment – optimization for unexpected polarity-inverted "signals"



Raw APV Data Frame



Offset & Common Mode Correction



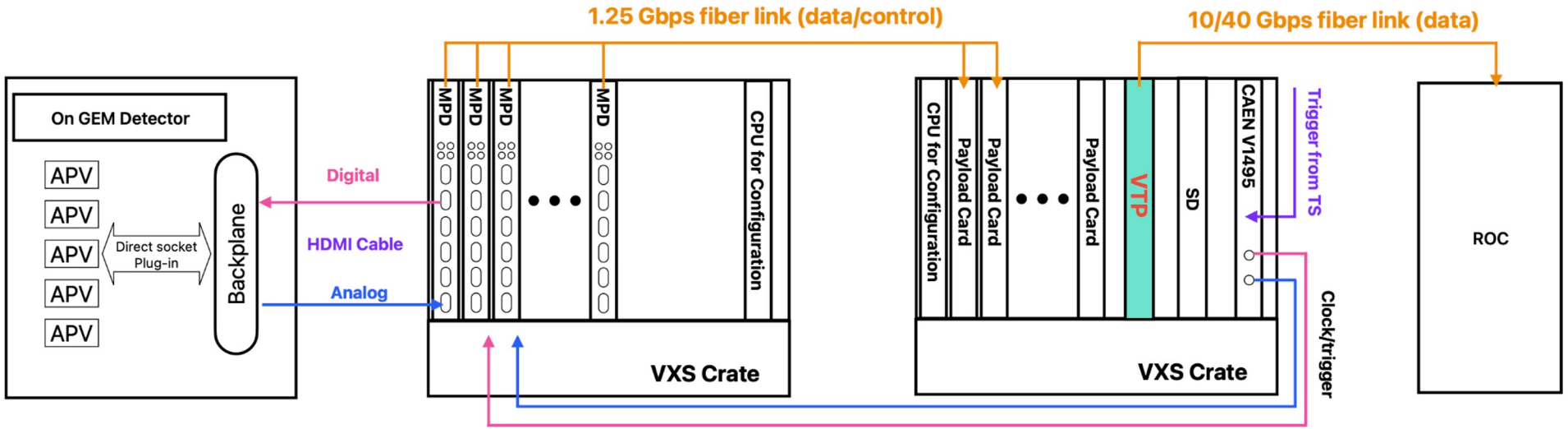
Zero Suppression

VTP/MPD DAQ System

- VTP-MPD system used in SBS program, 4 KHz event rate > 90% live time, 15 APVs per MPD module
- Bottleneck on MPD limited data bandwidth with 1.25 Gbps, MPD transfer all APV raw frames to VTP for zero sup

  ~~Option 1: Process zero suppression on MPD, new version MPD ordered~~

  Option 2: Reduce the APV load per MPD (15 APVs to 3 APVs)



VTP/MPD DAQ System

- A working VTP/MPD system for upcoming PRad-II GEM Detector working at UVA
- Use the same system to test new MPDs, new firmware, and the 25 KHz event rate
- Move the setup to Hall B for integration to PRad-II overall DAQ

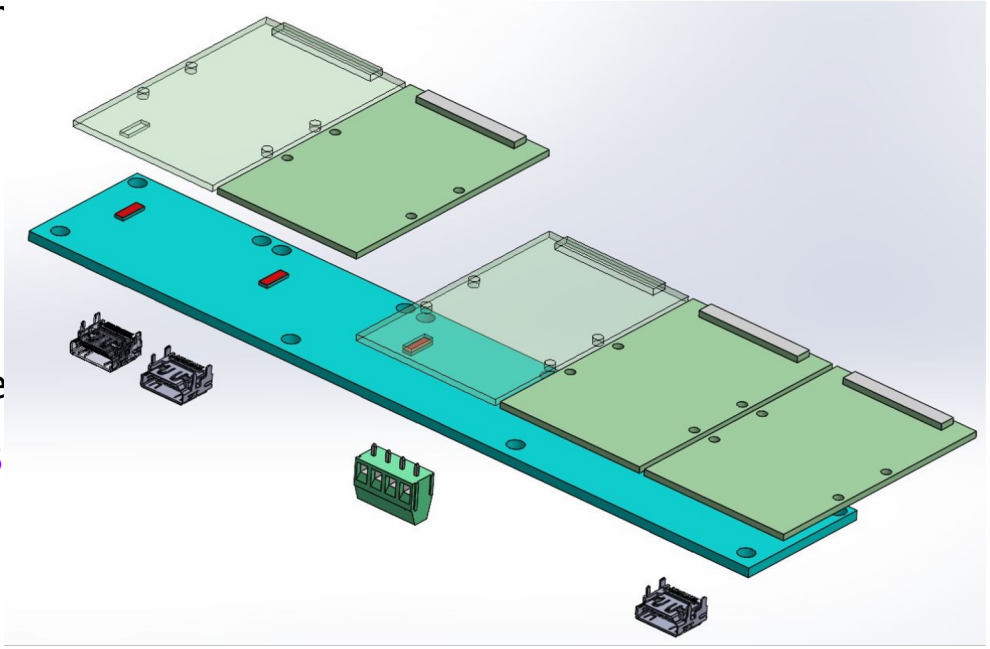
VTP/MPD DAQ System

We were hoping to get the newly improved version of MPD. However, these units will not be ready or time for Prad-II

Given this we are switching to the backup plan – use only 3 APV per MPD:

Current version can also achieve 25 KHz event rate

- ❑ Redesign backplane, make them all 2~3 slot (more MPD modules needed)
- ❑ **Backplane designed and fabricated by Jeff Wilson, Mark Taylor – JLab FE group (Chris's group)**



5-slot APV-backplane CAD assembly

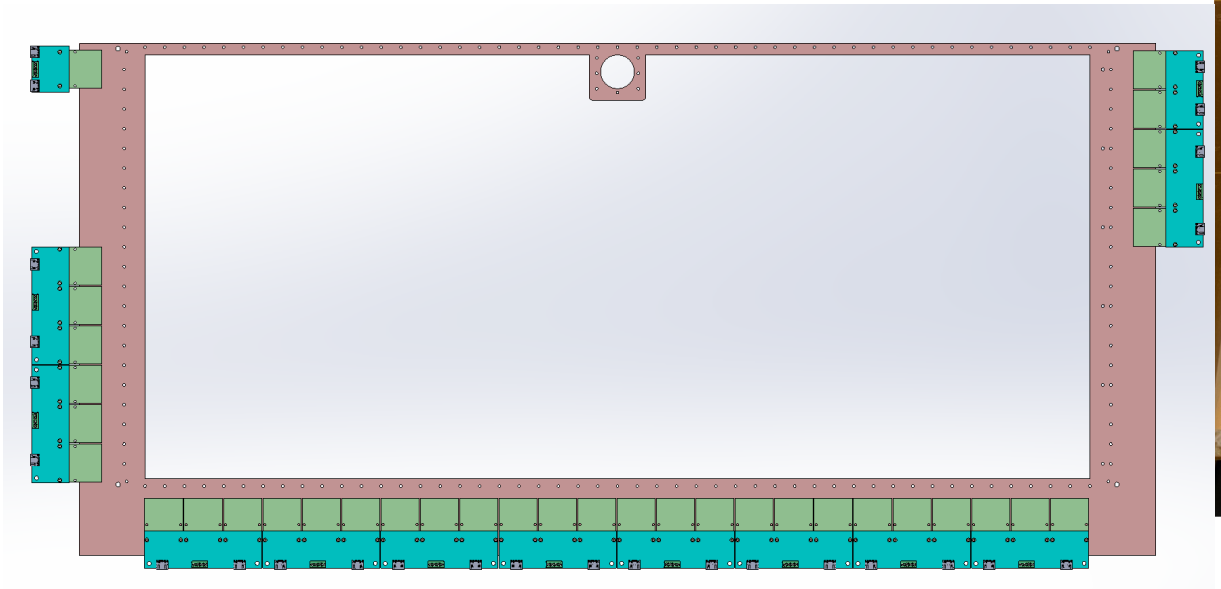
PRad-II Backplane Design

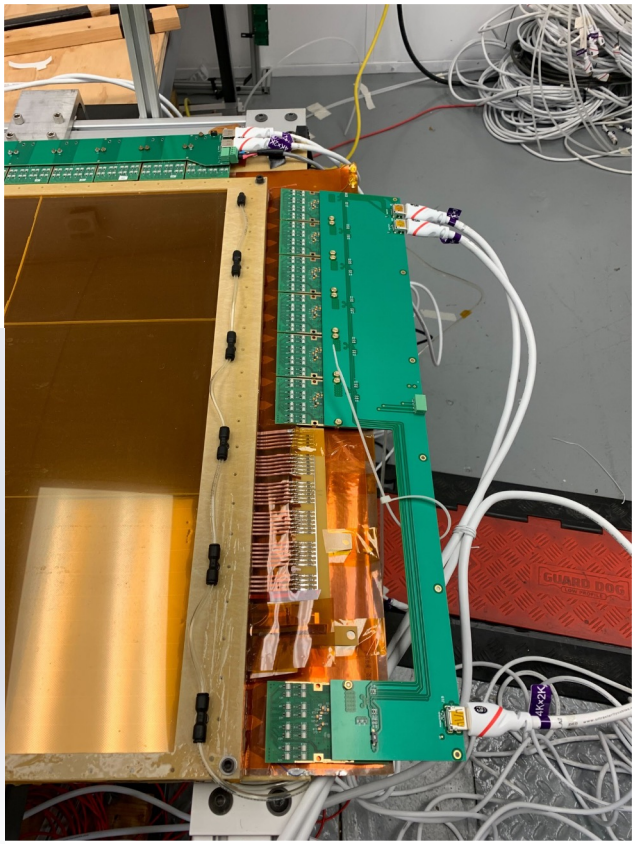
New Backplanes need to be made for the chambers, to reduce the APV load to 3 or less per MPD

44 + 6 3-slot back planes

4 + 2 2-slot back planes

4 + 2 1-slot back planes



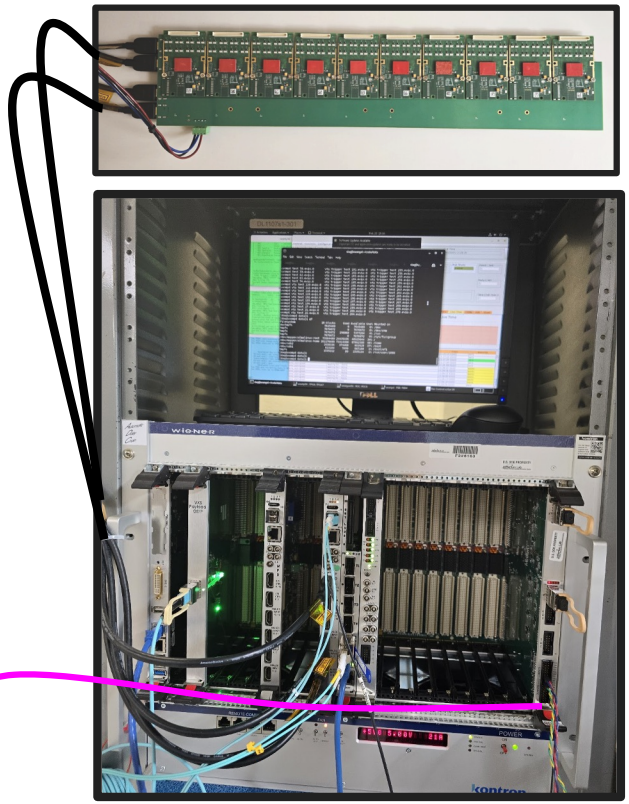


Setup for 25-kHz Event Rate Test

- .Generating external trigger
  - AWG (Siglent SDG6022X) => Discriminator =>Translator => TI
  - Fixed trigger rate: 5 kHz - 35 kHz
- VTP-MPD System
  - One MPD module
  - 1.25 Gbps link between VTP-MPD
  - Test was performed on a 10-slot APV backplane
  - APVs per MPD module: 10, 4, 3,2
- CODA-based DAQ
  - Buffer level: 4

External trigger

10-slot APV backplane



25 kHz Event Rate Test: Procedure & Results

- .Test procedure
  - Mount 10 APVs on the backplane and enable 10, 4, or 3 APVs
  - Ramp up the trigger rate and determine the maximum trigger rate (TR_max) with 95% CODA live time and the trigger rate (TR_50) when CODA live time drops to 50%
- Test Results

Number of Enabled APVs	TR-max with 95% Coda Live time	TR-50 with 50% Coda Live time
10	7.5 kHZ	8.0 kHz
4	19.0 kHz	19.5 kHz
3	**25.5 kHz**	**26.0 kHz**
2	27.5 kHZ	32.0 kHz

Next Steps for 25 kHz Rate Test

- Use the Random Trigger (instead of the fixed trigger) to further study the actual data processing delays on the APV/MPD
  - Write a python script to create an encode stream as an arbitrary waveform and then load it into current AWG to make it generate Poisson like random triggers
  - Planning to do this test this week

MPD/APV Timeline

➢ List of Modules needed by PRad-II

Module Name	Required Quantity
VXS crate	2
VME Crate	2
Payload Cards	12
MPD modules	48
backplanes	52
APV	144
SD	2
CAEN V1495	1
CPU	2
VTP	2
fan-in-fan-out NIM modules	as needed (depends on module)
HDMI Cables (10 m)	104
1-to-4 fibers	12

Table 1: List of Modules

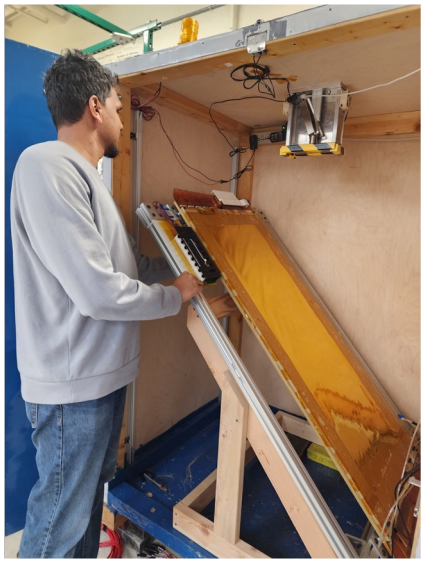
Dec, 2024

150 APV cards received in December, 2024

Aug , 2025

SBS program concluded, MPDs become available

Overall Plan



Aug, 2025

Complete construction for all 4 chambers by August

Aug, 2025

Perform test in UVA – X-ray, Cosmic, DAQ test

Sept, 2025

Move Detector and DAQ to JLab, Install and Commission in EEL Building, Test everything

Nov. 2025

Move to Hall B

UVA Group for PRad-II GEM Project

Research Assistant Professor: Huong Nguyen

Postdoc: Asar Ahmed

Graduate Students: Vimukthi Gamage, Bhasitha, Jacob McMurty, Mihitha Maithripala, **Vidhura Vishvanath, Nithya Kularatne**

Physics Technician: Eric Fernandez

Vidhura Vishvanath / Nithya Kularatne will be thesis student on PRad-II

Summary

- All GEM Frames frames arrived in February; all GEM foils arriving this week
- Full construction completion expected in August, 2025
- Use the APV MPD system for DAQ
  - Mature decode/reconstruction from SBS program
  - All APV cards arrived
- DAQ with 3 APV per MPD to go to 25 KHz event rate
  - Need to get new back planes made
  - Need to borrow MPDs from Hall A
- Currently no show-stopper to meet PRad-II timeline

Thank you !

Big thanks to:

Alexander Camsonne, Chris Cuevas, Ben Raydo, Jeff Wilson, Mark Taylor, Holly Szumila-Vance, Ching Him Leung, Bill Gunning

Paolo Musico (INFN)

and JLab Fast Electronics Group

and CERN MPGD Workshop