GEM Detector and DAQ Status

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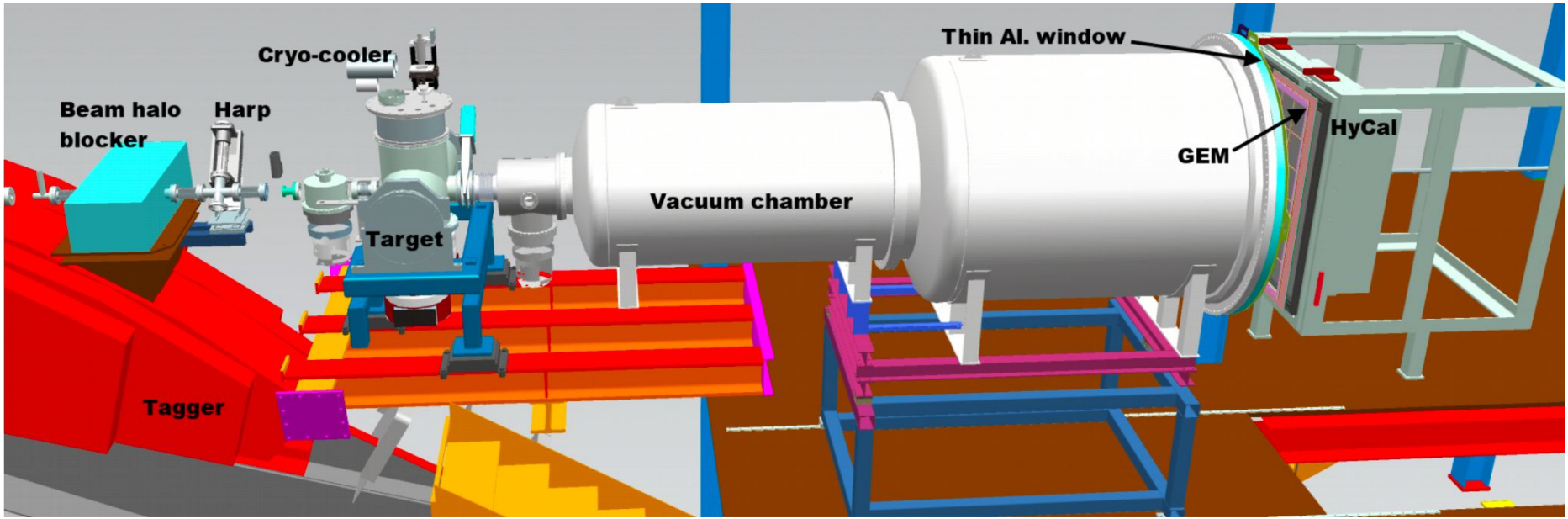
Outline

- ❑ PRad Experiment
- ❑ PRad-II GEM chamber Status
- ❑ DAQ Preparation
- ❑ Summary

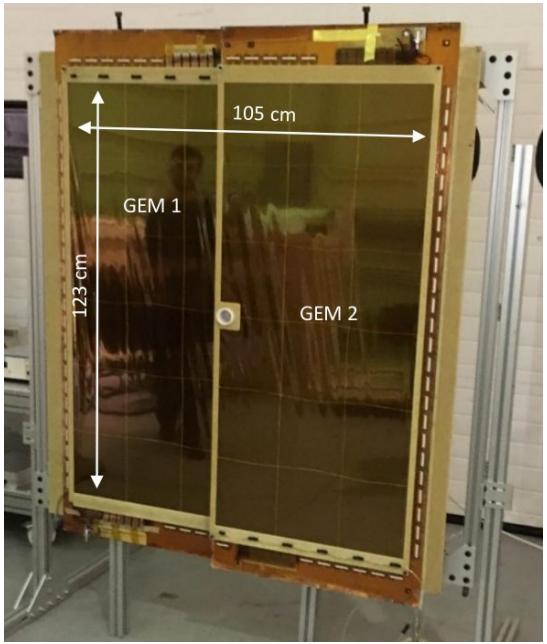
GEM Detectors in PRad Experiment

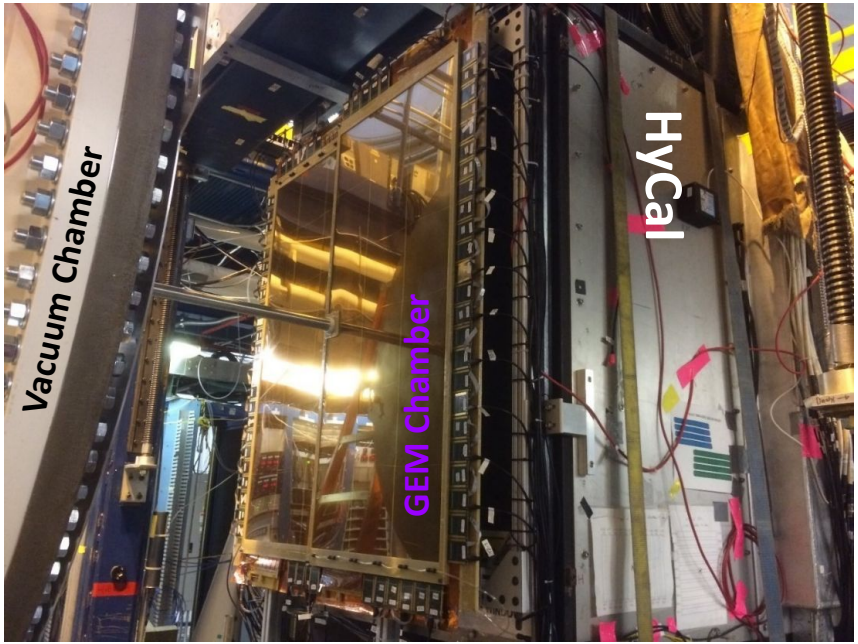
- Two major detectors: HyCal + GEM
- World largest GEM detector by then:, 120 cm X 102 cm



GEM Detectors in PRad Experiment

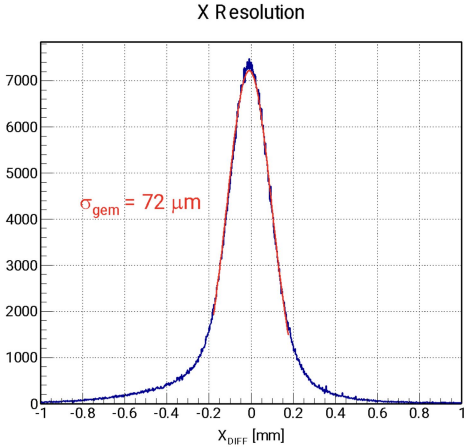
- Designed and Constructed in UVA in 2015
- Installed in Hall B beamline in 2016

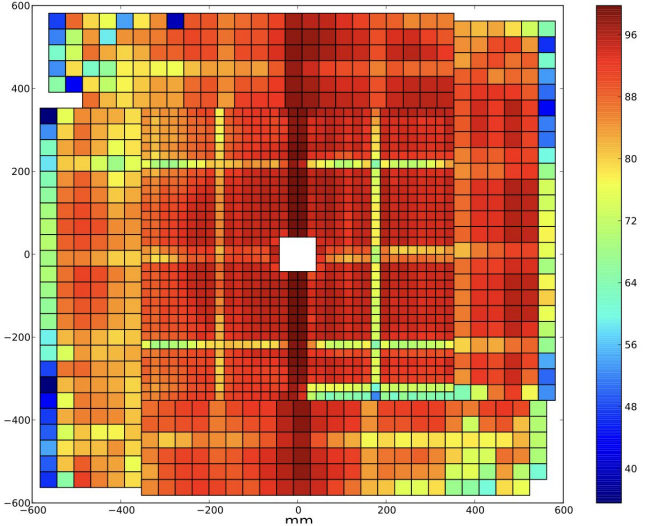


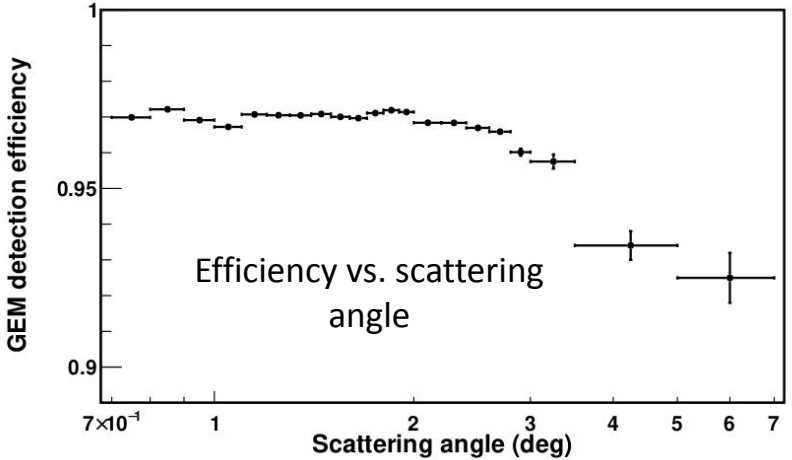


Efficiency and Resolution – PRad Experiment

- 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



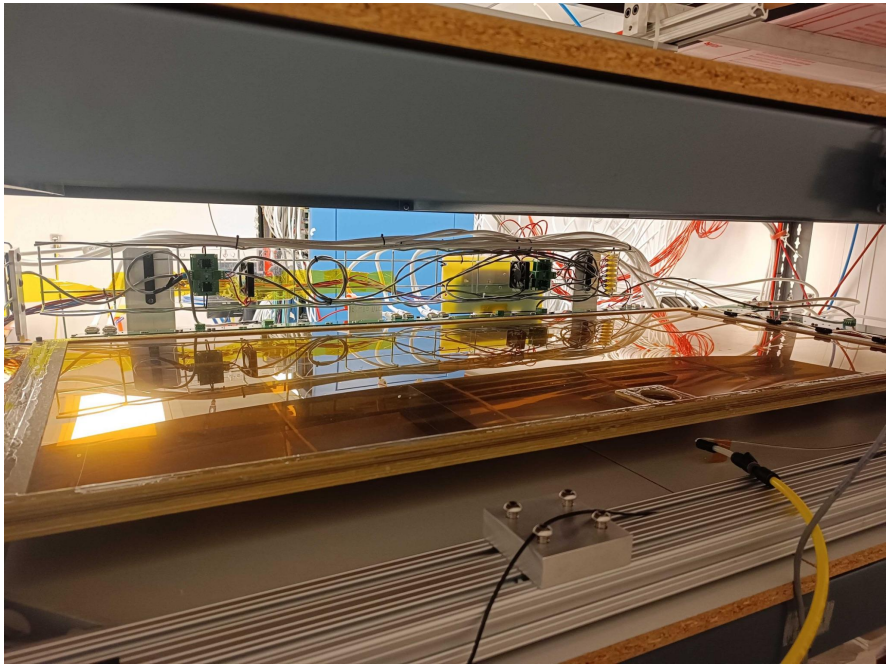




PRad GEM Detectors – Current Status

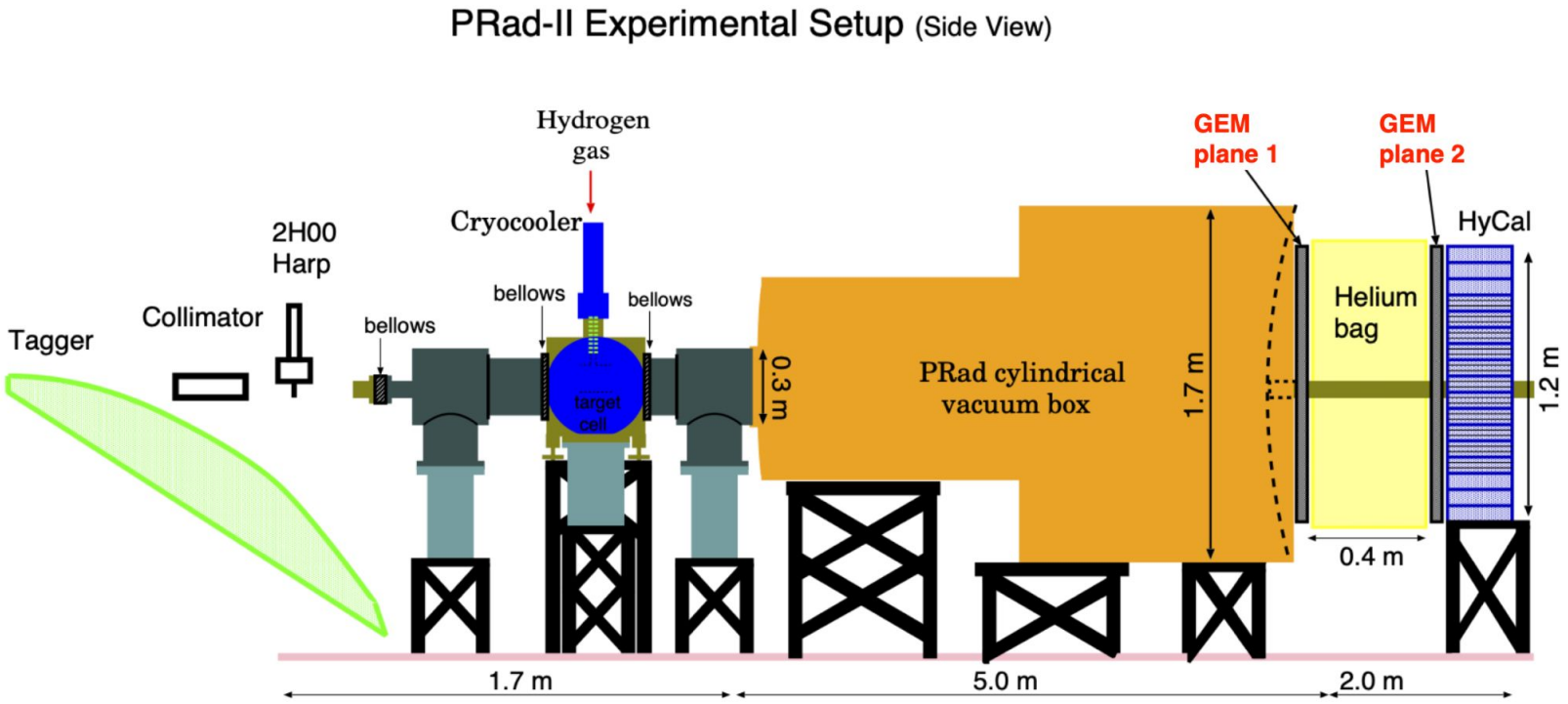
- PRad GEM Detectors will be used in LAD experiment in Hall C
- Will be used as **spare GEM detectors** for PRad-II (LAD will be completed by PRad-II running)

X-ray test for LAD (UVA)



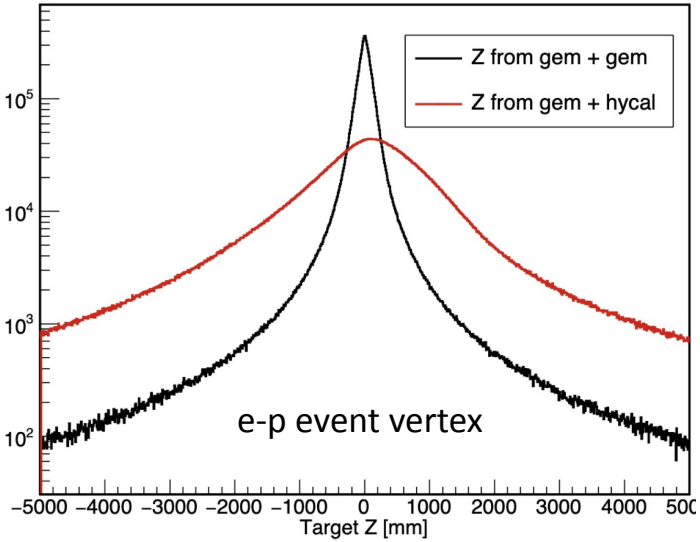
Cosmic test for LAD (JLab)

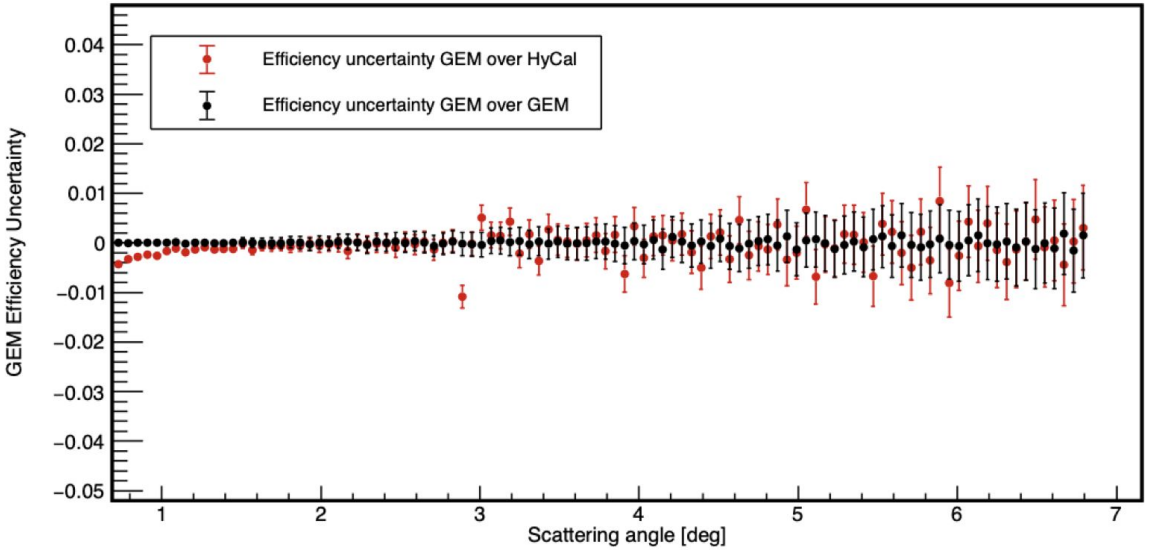
PRad-II – Add a second Layer of GEM detector



PRad-II – Add a second Layer of GEM detector

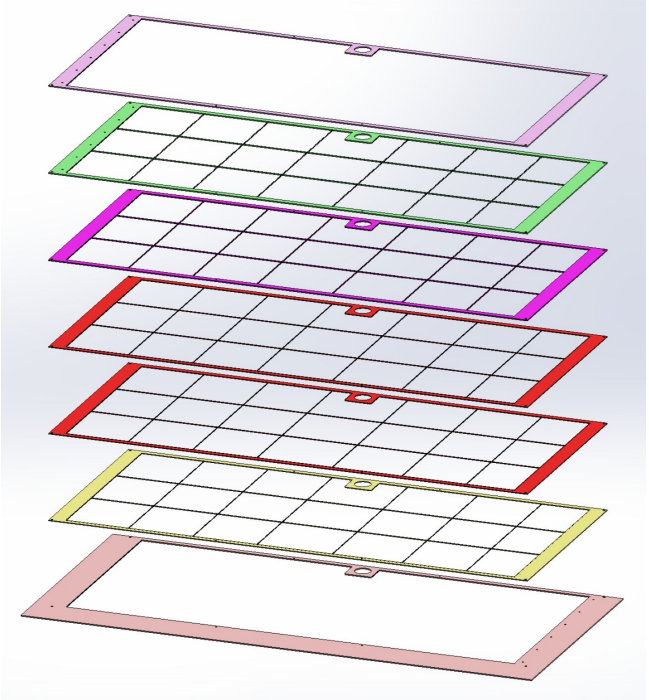
Adding a second layer GEM detector significantly improves vertex reconstruction and Efficiency uncertainty





Design of the New Chambers for PRad-II

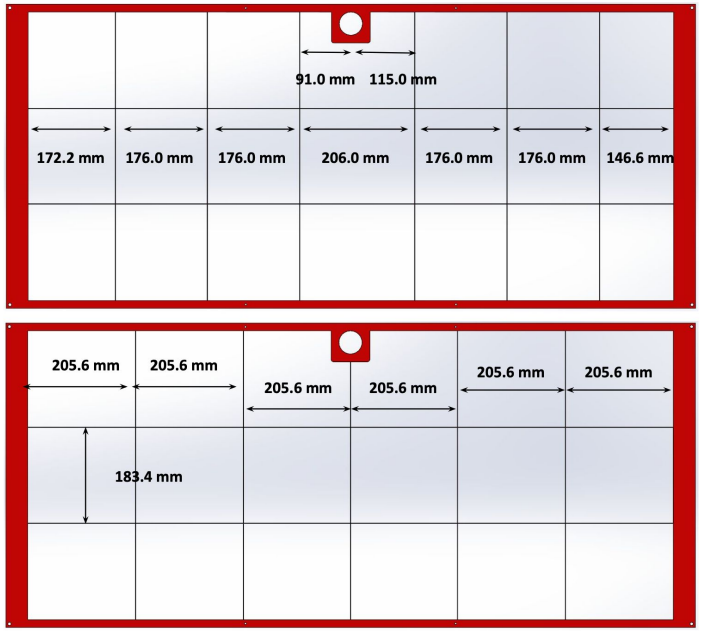
- 4 new chambers to compose 2 layers
- Overall share the same design with PRad-I but with many improvements
  - New spacer location
  - Optimized design for GEM foil, drift foil
  - Replace top Kapton gas window (very fragile) with large area honeycomb board (thanks to new technology)
- Same outer dimension

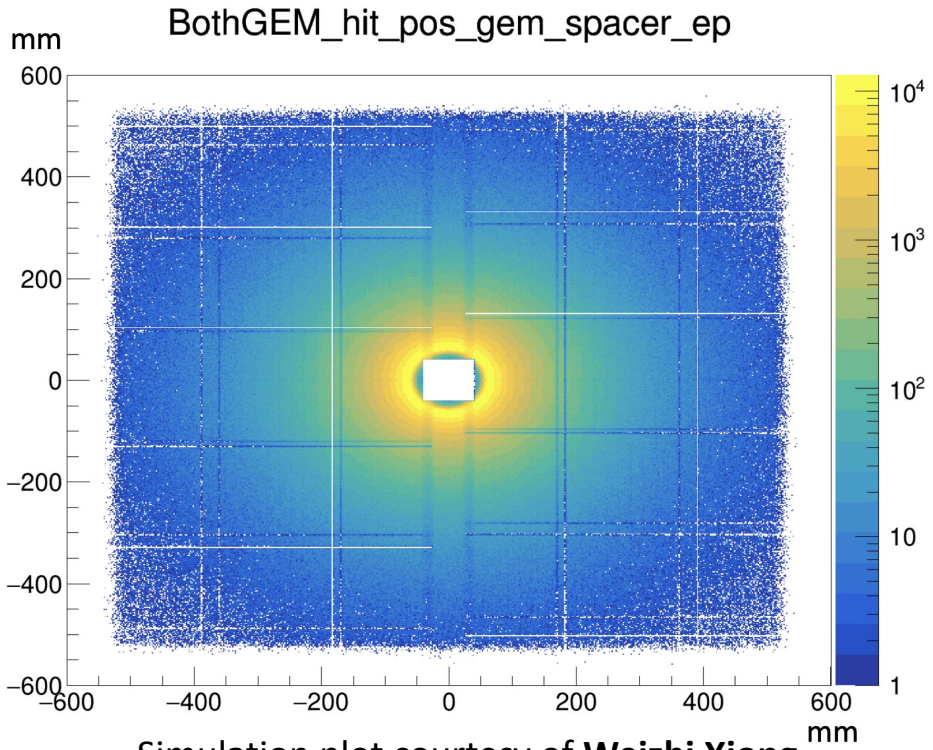


New detector frame design

New Spacer Location

Asymmetric Spacer Location to minimize projected overlap area



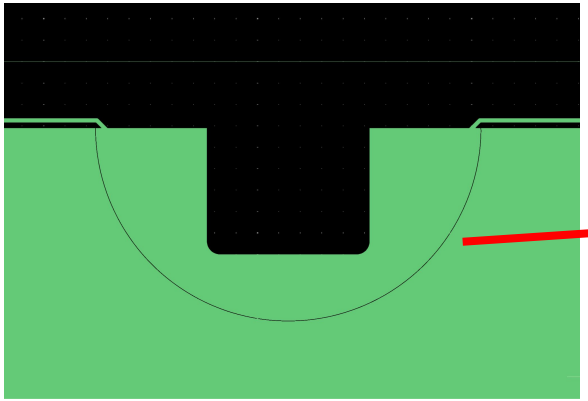


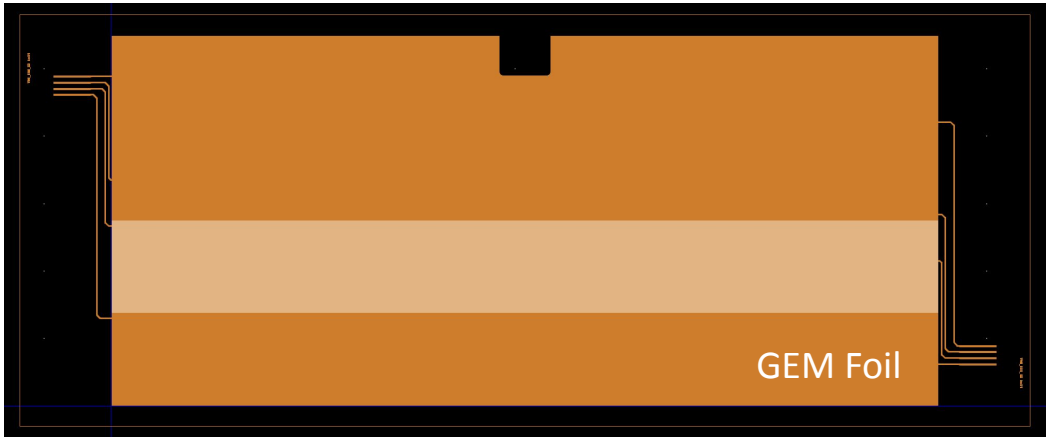
Simulation plot courtesy of **Weizhi Xiong**

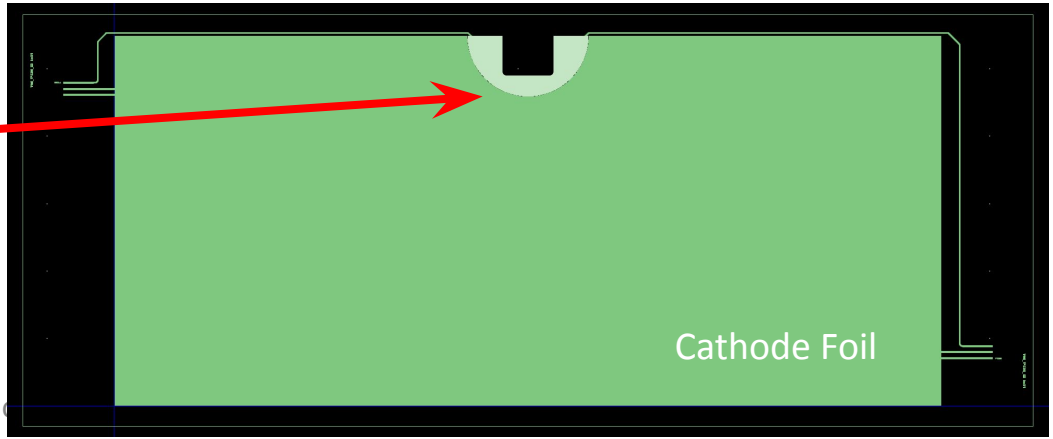
GEM Foil Design

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

– Dedicated circular sector on cathode foil for high rate situation

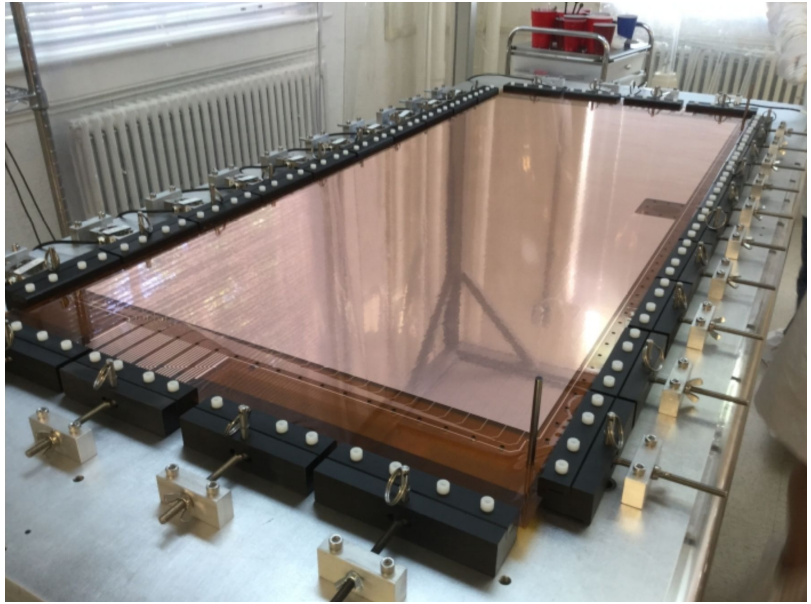






Preparation of Construction in Cleanroom

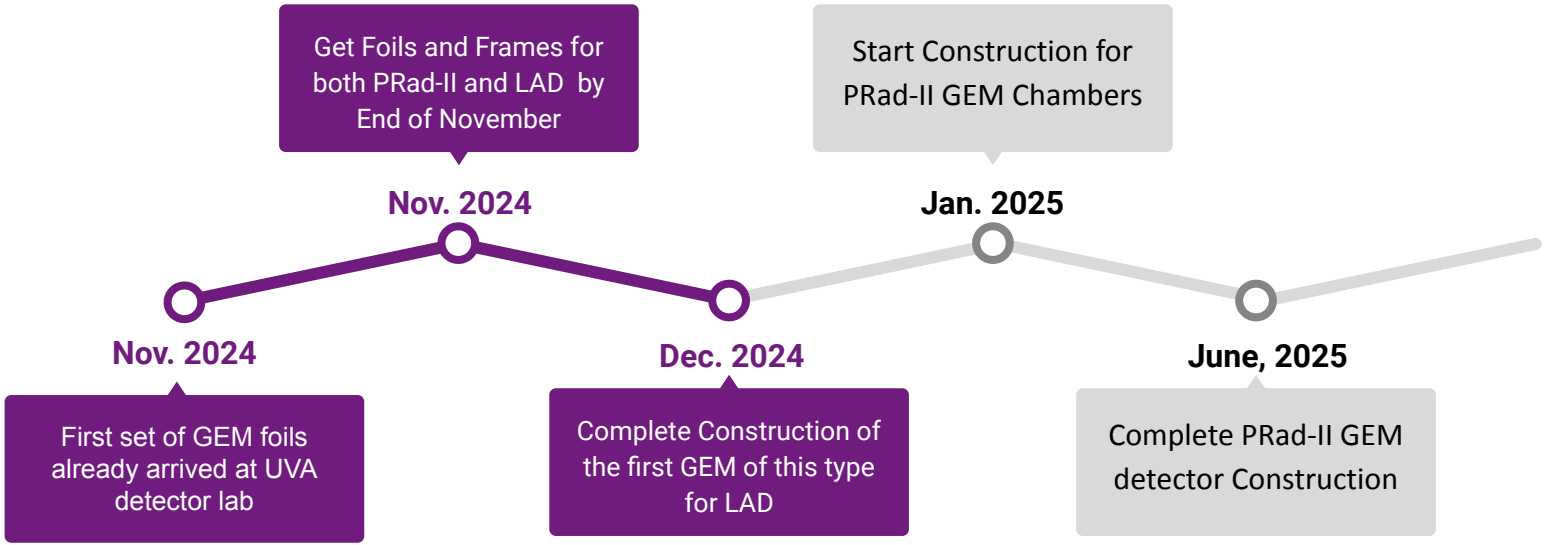
– Cleanroom transition to PRad-II project; Use the same stretcher from PRad-I detector construction



UVA cleanroom

Remaining Tasks for Construction and Timeline

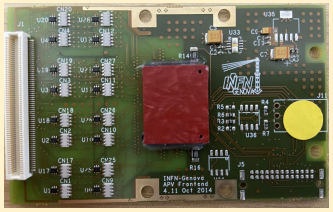
➢ PRad-II GEM detector construction expected to be completed by June, 2024



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

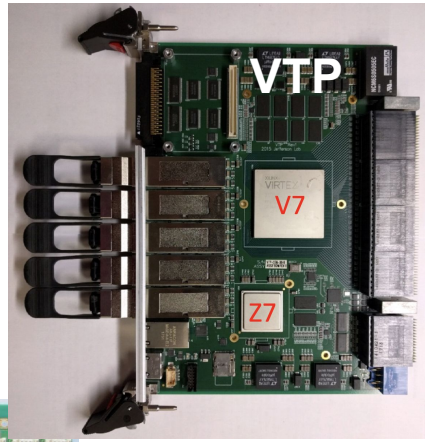
New MPD-based GEM Readout System



- **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**)

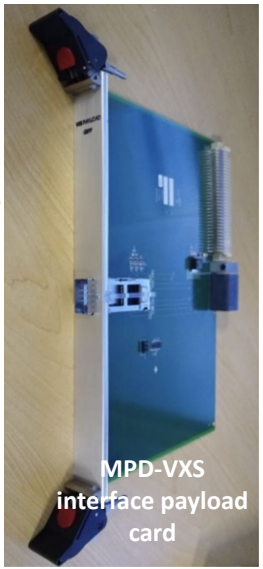
MPD modules designed for SBS Program

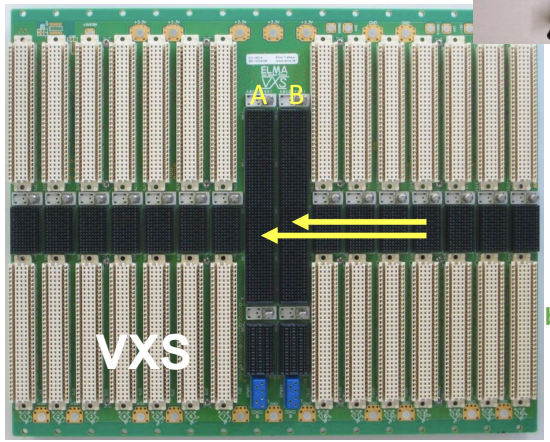
- Up to 15 APV cards on a single module
- 2 ns time resolution (APV clock synchronization)
- Arriga GX FPGA 128 MB DDR2-RAM
- **Online zero suppression**



HDMI

Optical fiber 2Gbps





VXS bus – 20 Gbps bandwidth (4 lanes)

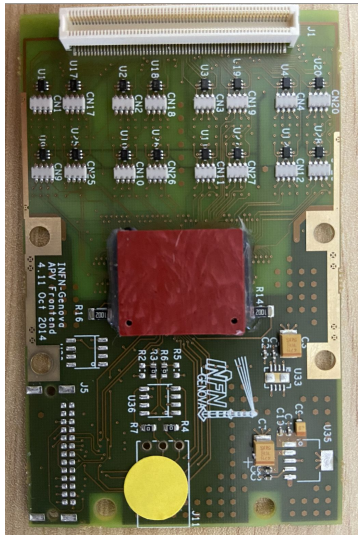
Aurora Protocol

CODA

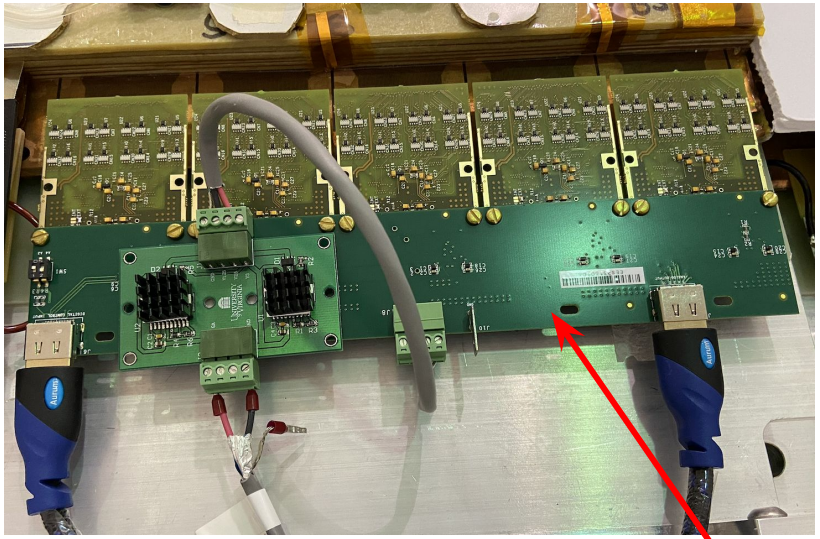
Paolo, Evaristo (INFN)

UNIVERSITY of VIRGINIA

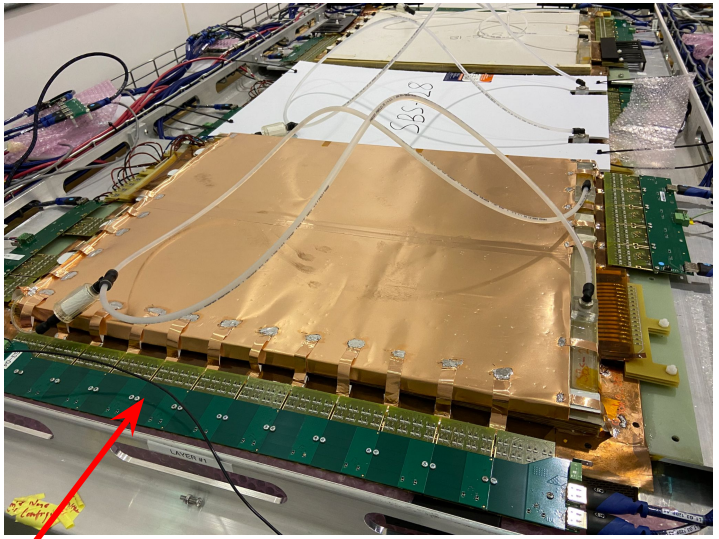
GEM Readout – APV Electronics



APV Hybrid



APV Hybrid installed on Backplane



Backplane installed on GEM chamber

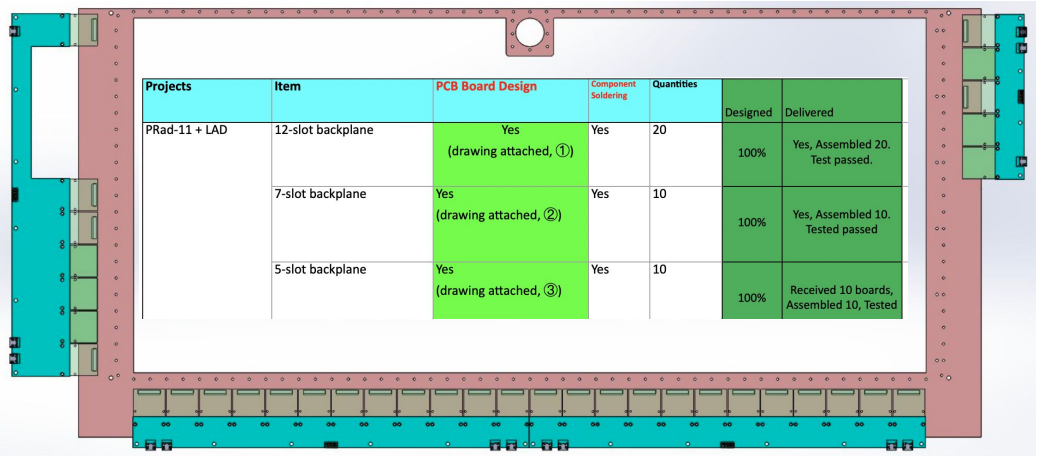
Backplane

PRad-II Backplane Design

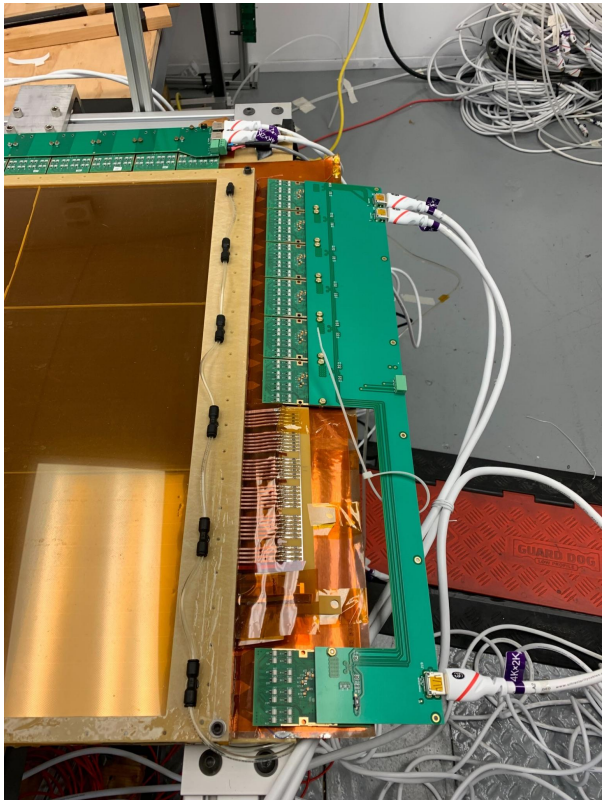
Only Backplane needs to be customized for chamber

All backplanes for PRad-II have been **completed**, and tested in old PRad GEM chamber – designed and fabricated by **Jeff Wilson** and **Mark Taylor** from **JLab FE group** (**Chris's group**)

Currently taking cosmic data in JLab



Projects	Item	PCB Board Design	Component Soldering	Quantities	Designed	Delivered
PRad-11 + LAD	12-slot backplane	Yes (drawing attached, ①)	Yes	20	100%	Yes, Assembled 20. Test passed.
	7-slot backplane	Yes (drawing attached, ②)	Yes	10	100%	Yes, Assembled 10. Tested passed
	5-slot backplane	Yes (drawing attached, ③)	Yes	10	100%	Received 10 boards, Assembled 10, Tested



GEM Readout – APV Data

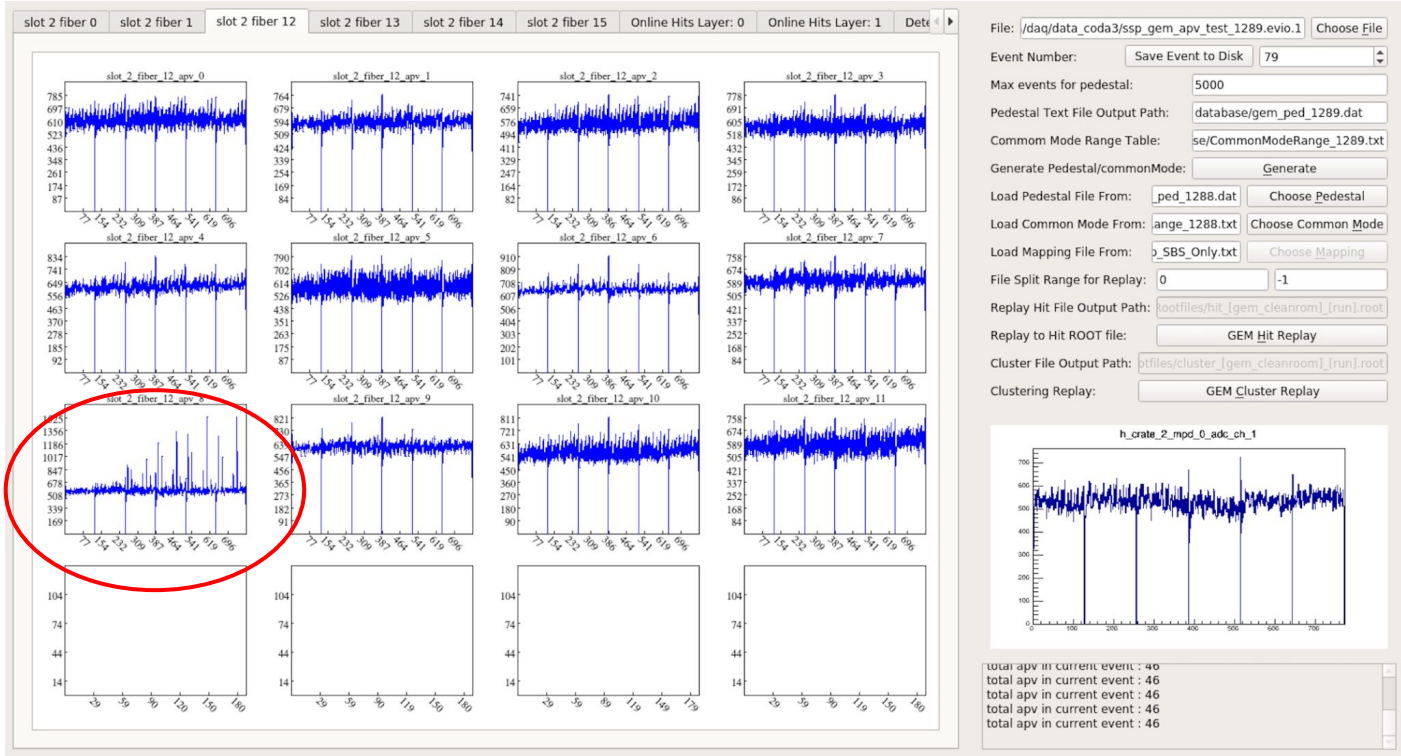
A typical event from cosmic data – 12 APVs

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

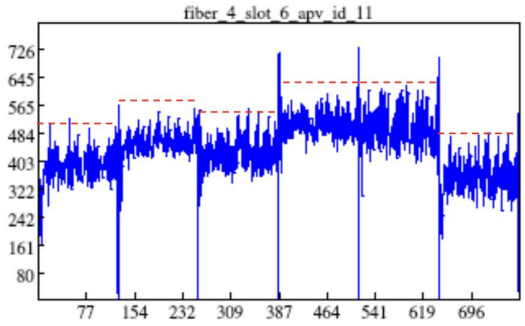


Online Zero Suppression

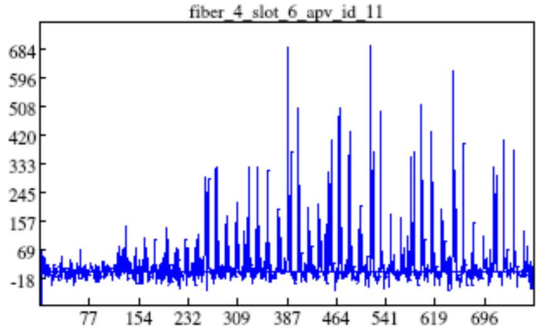
Online zero suppression algorithm implemented on VTP **on-bard FPGA**

3 different algorithms available (Sorting, Danning, Histogramming)

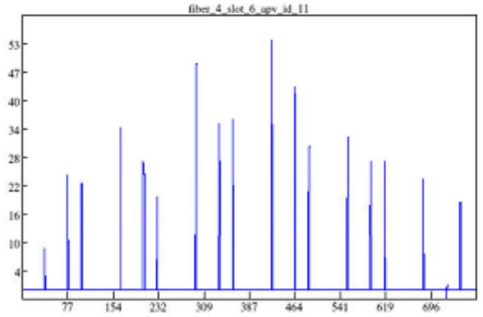
- ❑ Sorting, Danning algorithm from UVA group
- ❑ Danning Algorithm has been successfully implemented on the FPGA firmware – production algorithm for GMn, GEn experiments – Ben Raydo, JLab
- ❑ Histogramming algorithm (Andrew Puckett, UConn) to be implemented for GEp experiment – optimization for unexpected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



Raw APV Data Frame



Offset & Common Mode Correction



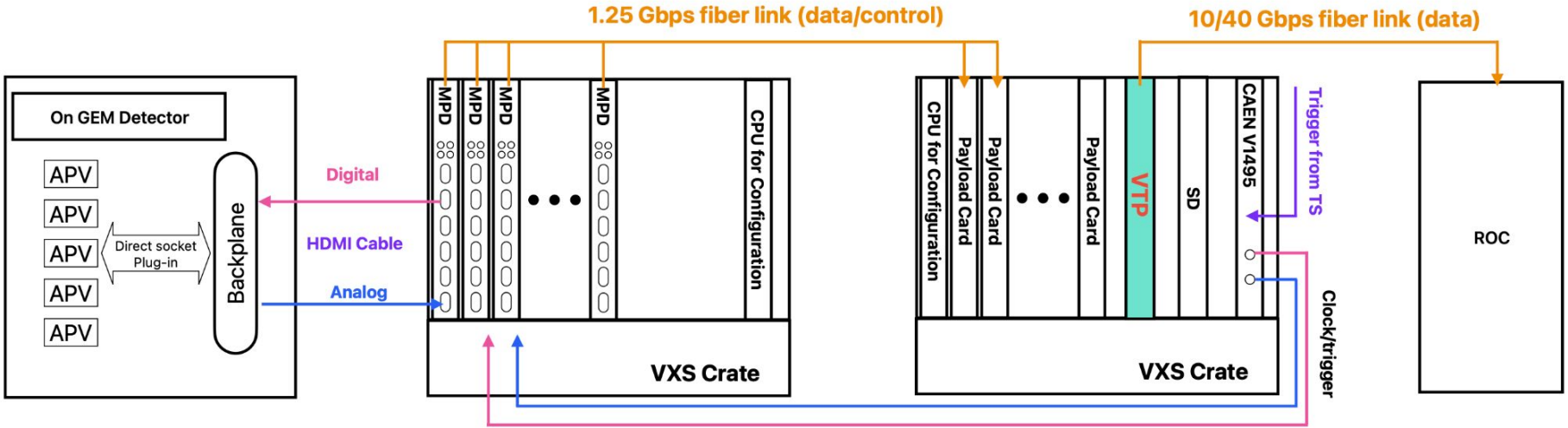
Zero Suppression

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)

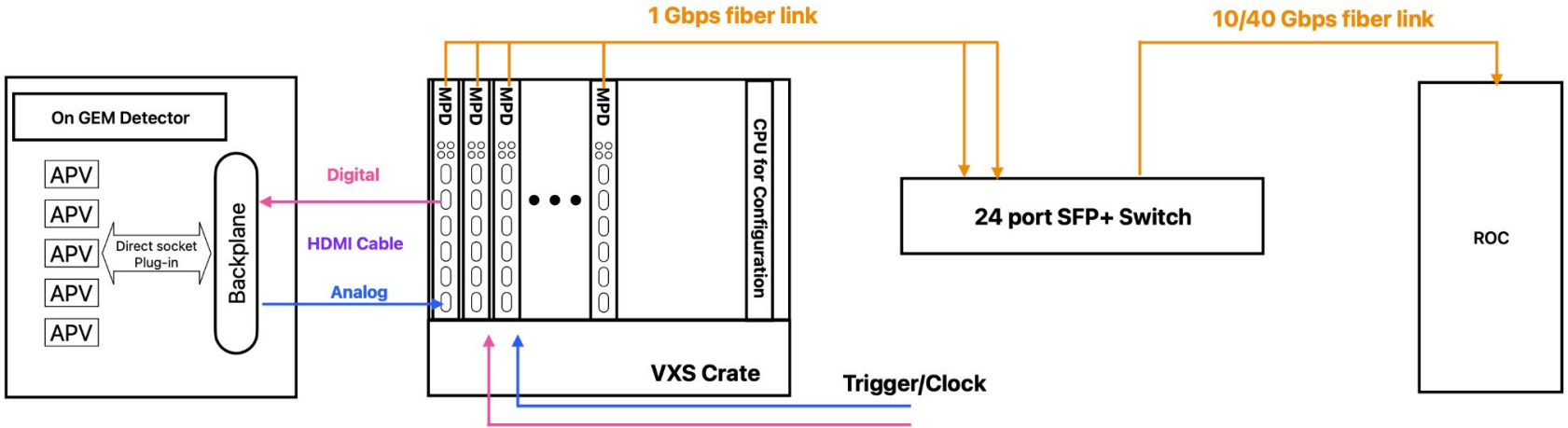


VTP/MPD DAQ System

MPD perform zero suppression : **INFN (Paolo) + JLab FE group (Chris's group)**

A possible more simplified system, VTP could be replaced by a SFP+ switch

VTP is still preferred, mature technology from SBS, **decode/reconstruction** can stay the same

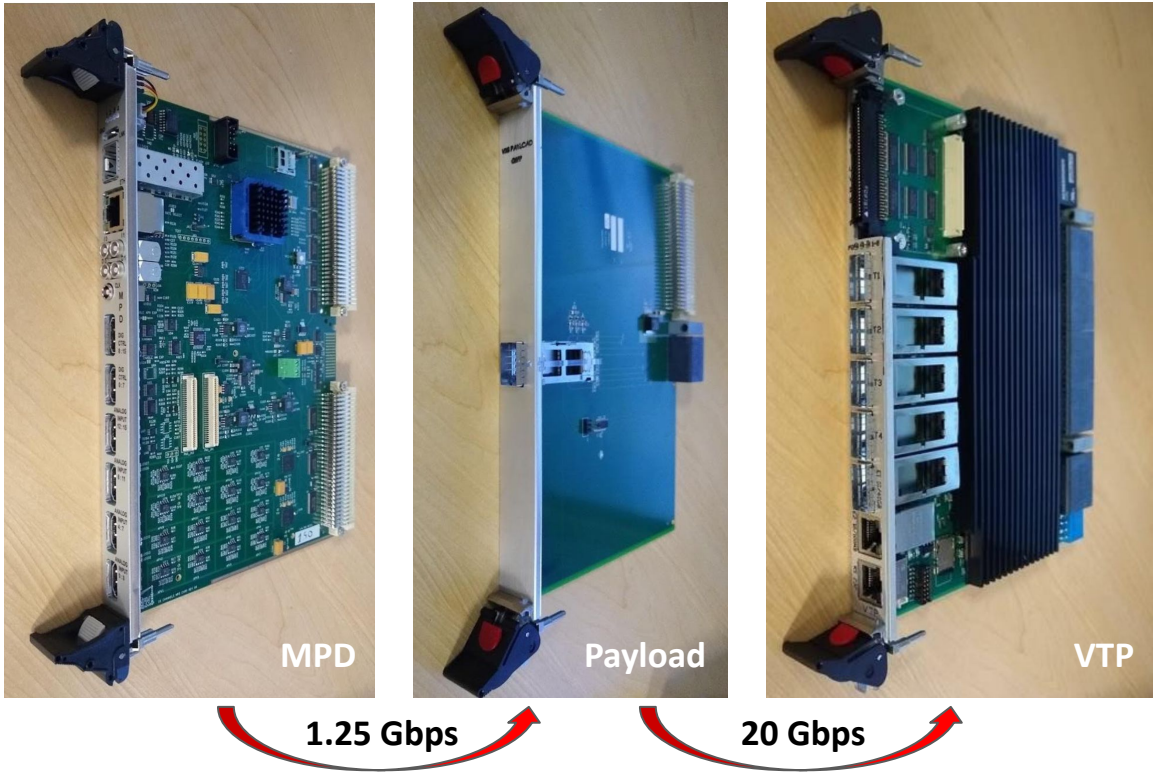


VTP/MPD DAQ System

- A working VTP/MPD system for upcoming PRad-II GEM Detector commissioning in 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

MPD Status

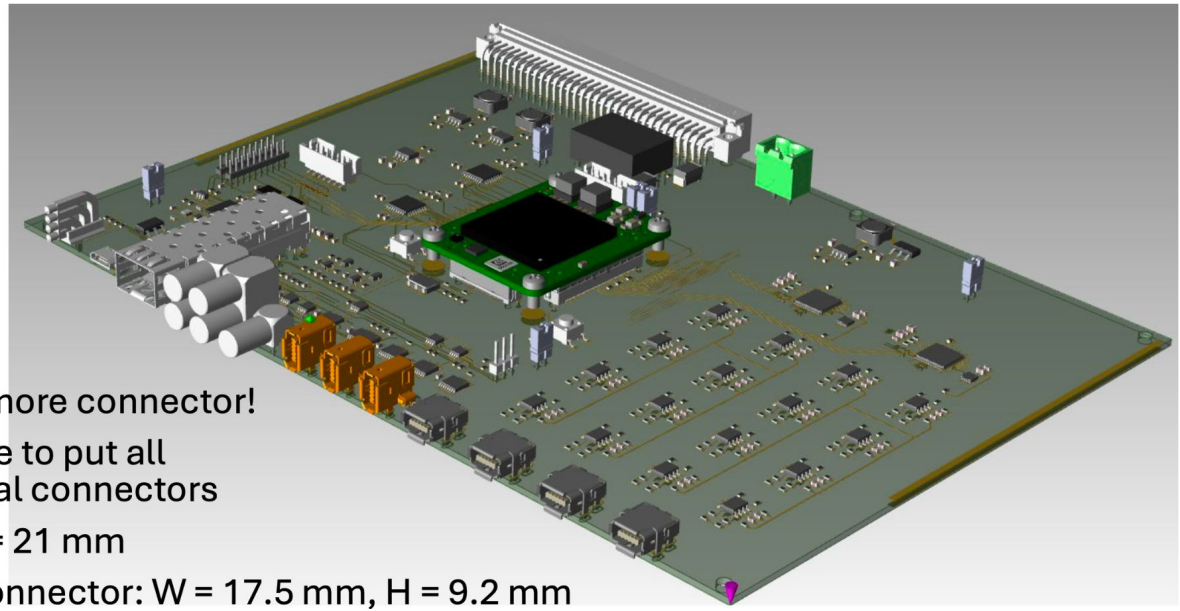
- Current SBS MPD use 1.25 Gbps link to VTP, after 8/10 bit encoding, results to 1 Gbps actual data bandwidth – 5 KHz trigger rate for 15 APVs
- Improved MPD version (2022, Ben has a couple tested), data bandwidth doubled
- Latest MPD for PRad-II, more onboard computing resources for MPD online zero suppression, vast data reduction



New MPD Design

- A more powerful on-board FPGA (**AMD/Xilinx Kintex-7 160**) for MPD online zero suppression
- Schematics design frozen
- MPD PCB boards ready – **INFN**
- Two connector versions – HDMI connector and IX connector

3D screenshot with IX



- Need 1 more connector!
- No space to put all horizontal connectors
- H Pitch = 21 mm
- Cable connector: W = 17.5 mm, H = 9.2 mm

Slide Courtesy of **Paolo Musico (INFN)**

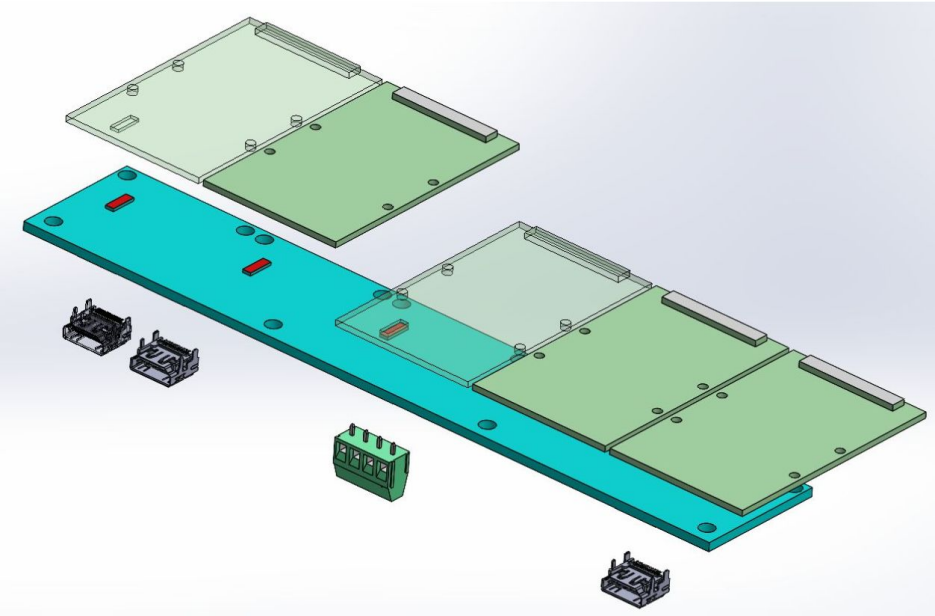
VTP/MPD DAQ System

New MPD, new firmware is currently under development by **Paolo (INFN)**

2 new version MPDs expected January, 2025

Backup plan – worst case scenario:

- 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

MPD/APV Timeline

➢ List of Modules needed by PRad-II

Module Name	Required Quantity
VXS crate	1
VME crate	1
MPD modules	12
backplanes	16
APV	144
SD	1
CAEN V1495	1
CPU	1
SFP+ network switch	1
fan-in-fan-out NIM modules	as needed (depends on module)
HDMI Cables (6 m)	56

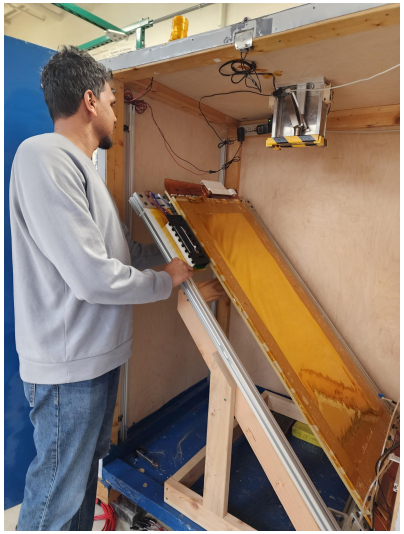
Table 1: List of Modules

200 APV cards expected in December, 2024

First 2 MPD modules expected in January, 2025

Remaining 10 MPD modules expected in April, 2025

Overall Plan



Complete construction for all 4 chambers by June

June, 2025

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

June, 2025

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

July, 2025

Move to Hall B

Nov. 2025

UVA Group for PRad-II GEM Project

Professor: Nilanga Liyanage

Research Assistant Professor: Huong Nguyen

Research Scientist / Postdoc: Xinzhan Bai, 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 foils, Frames have been ordered – first set of GEM foils already arrived in UVA detector lab
- Full construction completion expected in June, 2025
- New MPD DAQ system for 25 KHz event rate
  - 2 new MPD modules arriving next month
  - 10 remaining MPD modules arriving April, 2025
- Mature decode/reconstruction from SBS program
- 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