



CPAD 2025 at Penn

Plans for EIC generic R&D based on MPGD technology

Sourav Tarafdar (on behalf of EIC MPGD generic R&D consortium)

 Jefferson Lab

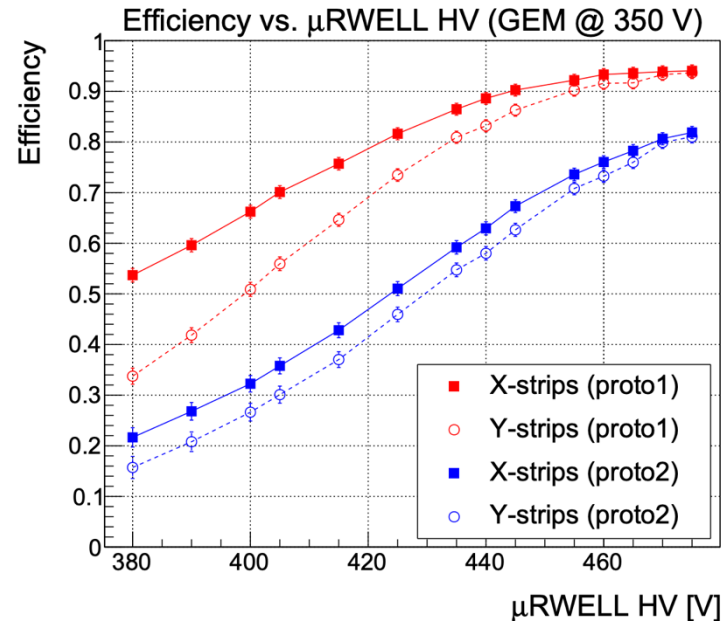
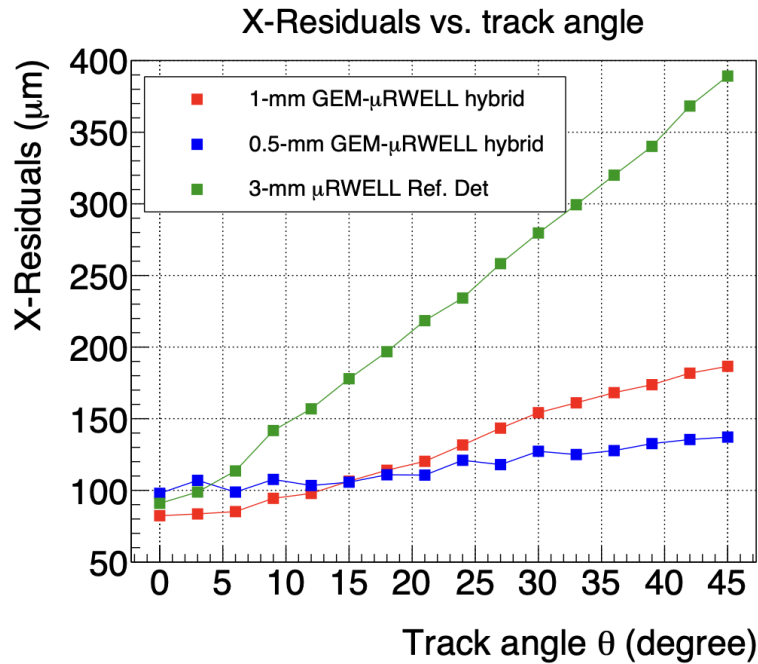
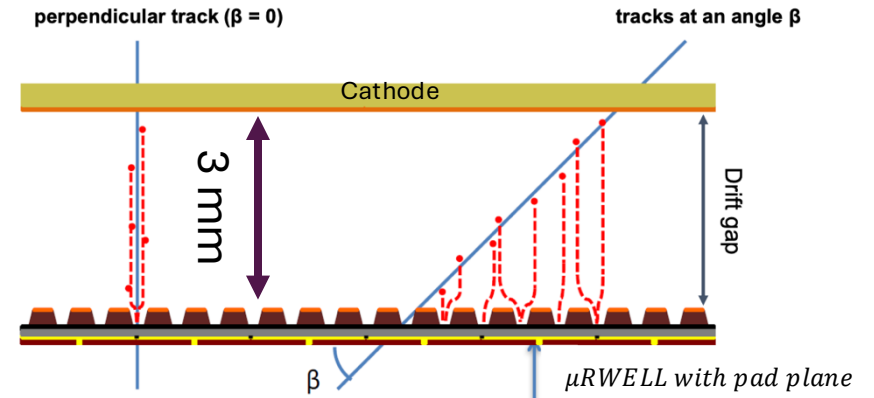
10/09/2025

Outlines

- Consortium :
 - University of Virginia, USA : Prof. Huong Nguyen, Prof. Nilanga Liyanage
 - Thomas Jefferson Accelerator Laboratory, USA : Dr. Xinzhan Bai , Dr. Kondo Gnanvo, Dr. Seung Joon Lee, Dr. Sourav Tarafdar
 - Florida Institute of Technology, USA : Prof. Marcus Hohlmann, Pietro Iapozzuto
- EIC generic R&D program introduction
 - Past MPGD based generic R&D for EIC
 - Current MPGD based generic R&D for EIC
- Details on ongoing generic MPGD R&D for EIC
- Prospect of future generic R&D for EIC
- Conclusion

Background (FY 23)

- Deterioration of Spatial resolution with larger track angle.
- Can be mitigated by reducing standard $\geq 3\text{mm}$ drift gap for MPGD trackers.
- First generic R&D proposal on thin drift gap MPGD tracker during FY 23 with **Jlab, UVA, FIT, VU, TU, Yale** as participating institutes. (*details in talk by K.Gnanvo*)



• First test beam studies for track angle dependency on MPGD spatial resolution in Fermi Lab test beam facility during FY 23 .

- Multiple MPGD structures (triple GEM, GEM+ μ RWELL, GEM+MicroMegas) with multiple gas mixtures (ArCO₂ -80:20 , KrCO₂-90:10)
- Prototypes had 10 cm x 10 cm active area
- Both spatial resolution and detector efficiencies were studied at various track angle. **Extremely encouraging results**

More questions

- Possibility of assemble large size tracker with 1 mm drift gap without stability issues ?
- Possibility of using double drift gap for possible track-let information

Ref: <https://doi.org/10.1016/j.nima.2025.170791>

Goals for FY 24 and FY 25

➤ FY 24:

- Design and assemble double drift gap MPGD trackers
 - Prototype 1 : 30 cm x 30 cm prototype to study feasibility of large size thin drift gap tracker
 - Prototype 2 : 30 cm x 30 cm prototype to study feasibility of assembling detector without gluing frames to GEM and drift foils.
 - Prototype 3 : 10 cm x 10 cm prototype with multiple pad geometries with various capacitance for high rate studies and extremely good spatial resolution ($< 50 \mu\text{m}$).

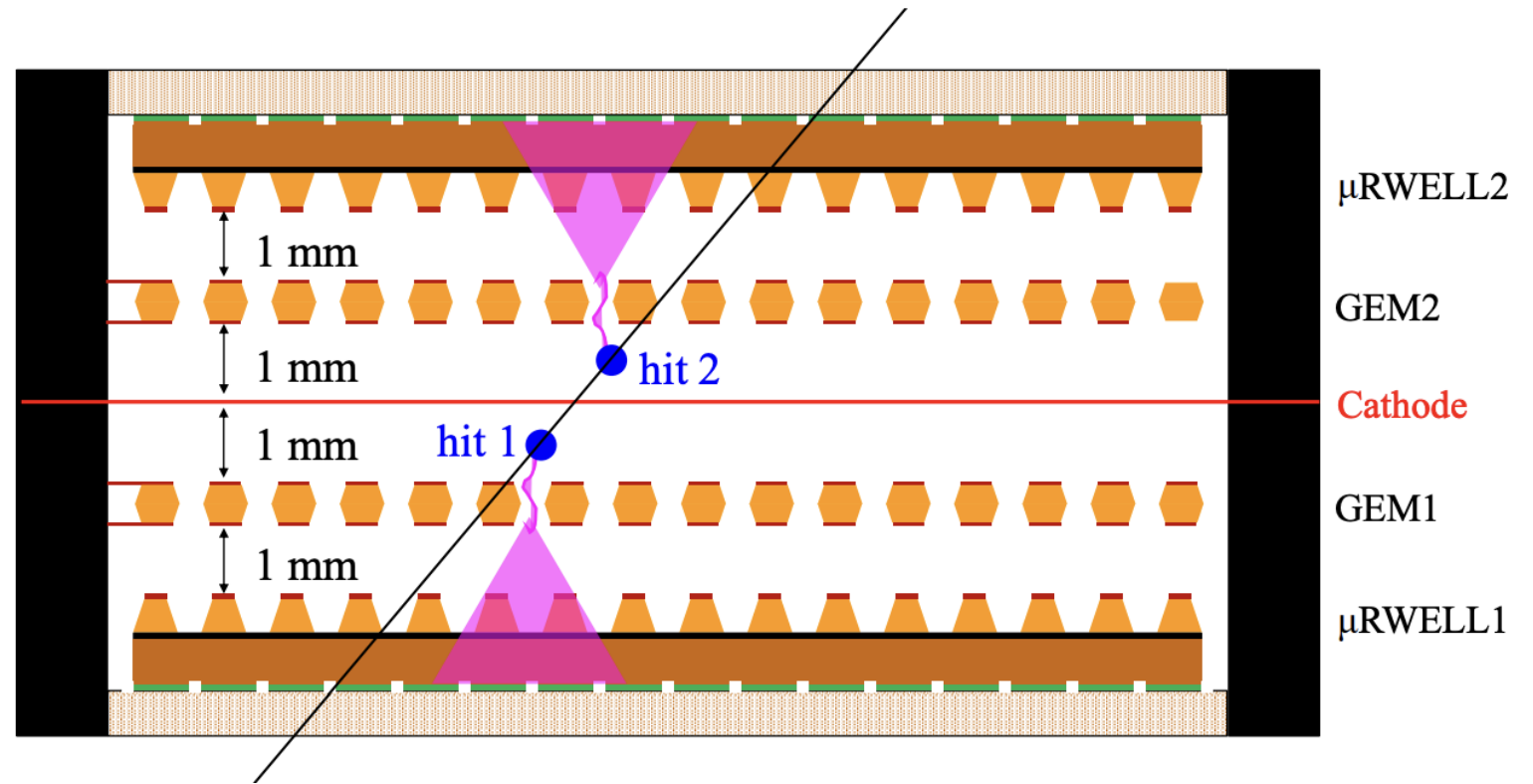
➤ FY 25 :

- Performance studies using pi/muon beam
 - Spatial resolution
 - Efficiency for both single and double hits
 - Detector stability
- Performance studies in 1.5 T magnetic field using pi/muon beam
 - Spatial resolution
 - Efficiency for both single and double hits
 - Detector stability

Extremely useful for ePIC @ EIC

Double sided thin gap GEM + $\mu RWELL$ tracker

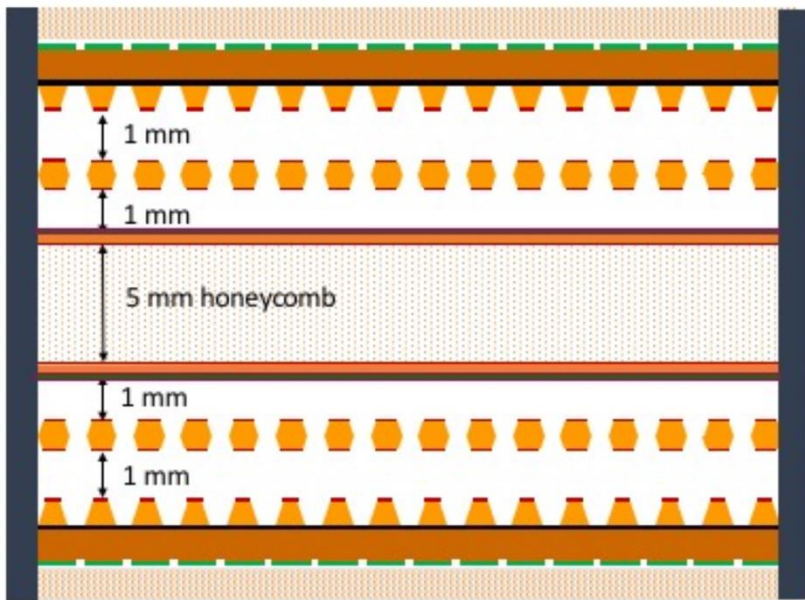
- Proposals submitted during FY 24 and FY 25 to further develop thin gap GEM + $\mu RWELL$ tracker
- Two 1 mm drift gap with two drift cathodes sandwiched between two amplification units (GEM + $\mu RWELL$).
- Expected increased probability/efficiency of $\geq 92\%$ by registering hit from either one of the layers in ArCO₂(80:20)
- Probability of registering simultaneous hits in both layers $\geq 84\%$ in ArCO₂(80:20)
- Low operating voltage , high efficiency, more stability



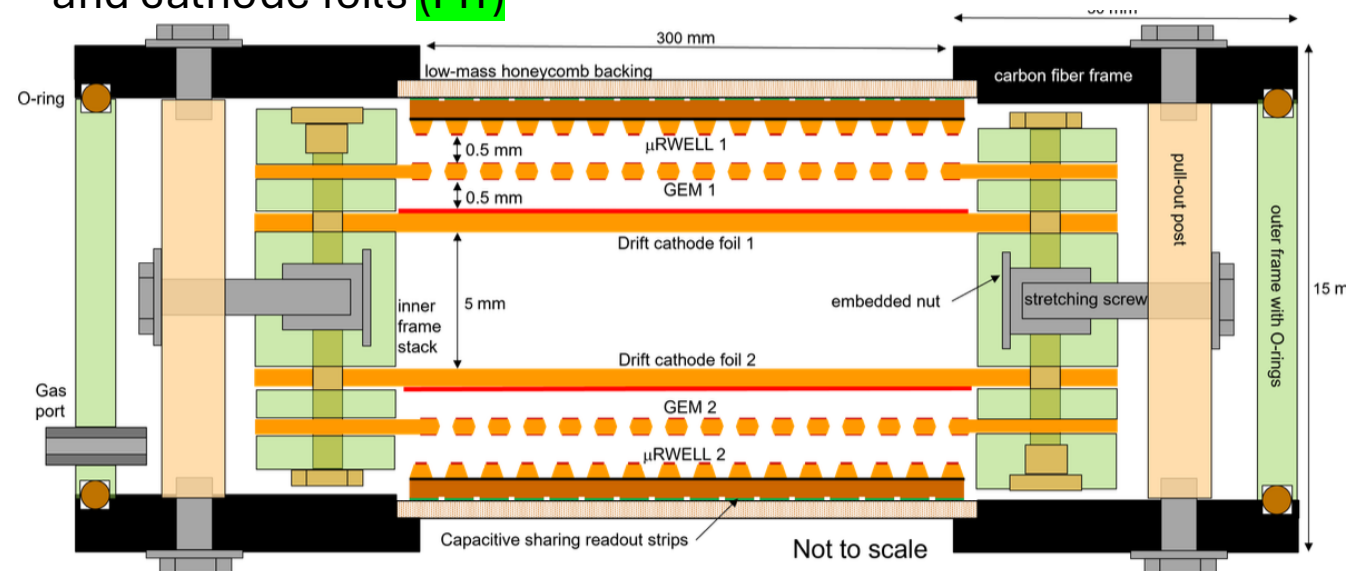
Current status

- Proposals submitted during FY 24 and FY 25 to further develop thin gap GEM + $\mu RWELL$ tracker
- Two 30 cm x 30 cm active area double sided thin gap GEM + $\mu RWELL$ tracker assembly using two different methods
- One 10x10 cm active area double sided thin gap GEM + $\mu RWELL$ tracker with different R/O pad sizes

Prototype 1 (30 cm x 30 cm) : Standard gluing of frames to GEM and cathode (JLab and UVA)



Prototype 2 (30 cm x 30 cm) : Mechanically stretched GEM and cathode foils (FIT)

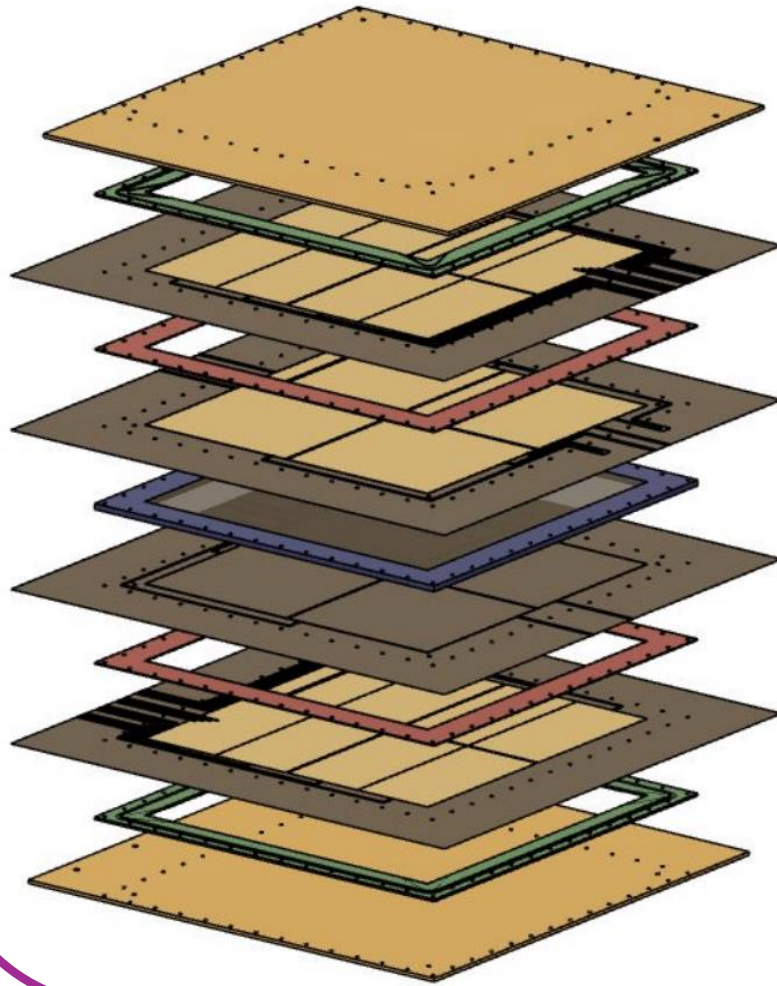


Advantages :

- Possibility of opening the detector for refurbishment
- Faster assembly

Current status - Design Features (Prototype 1)

Assembly design



μRWELL support frame

Induction frame

GEM foil

Drift frame

Drift foil

Joining honeycomb support frame

Drift foil

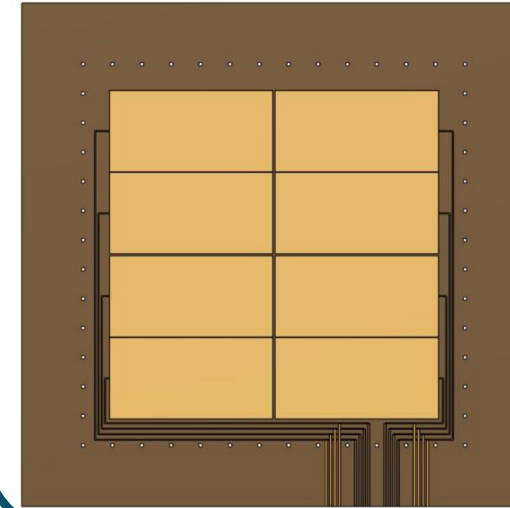
Drift frame

GEM foil

Induction frame

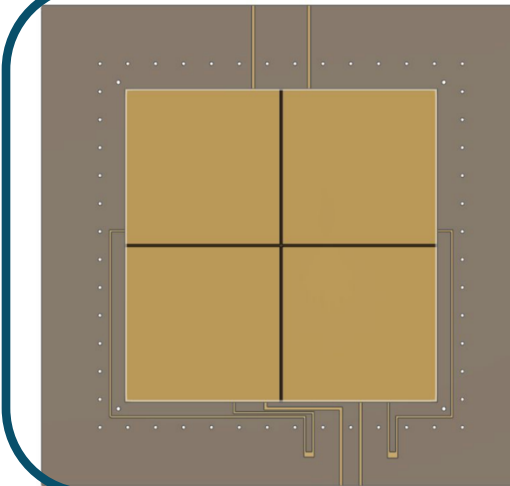
μRWELL support frame

GEM foil



- 8 sectors
- Both side segmentation

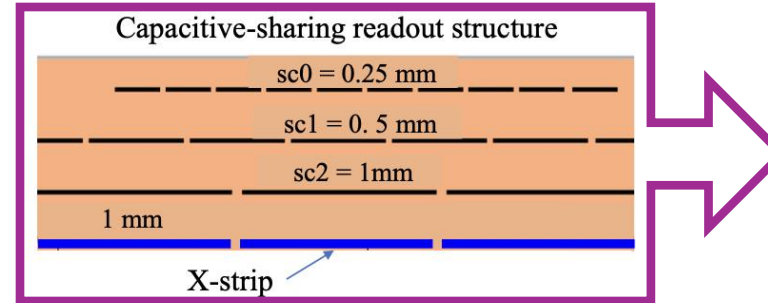
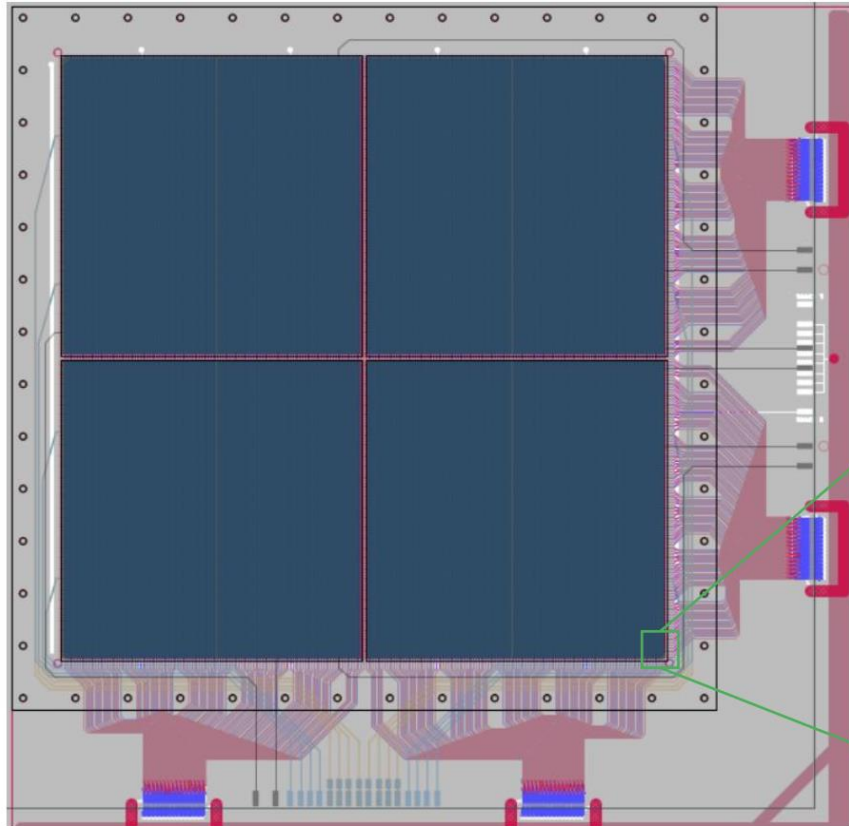
Drift cathode



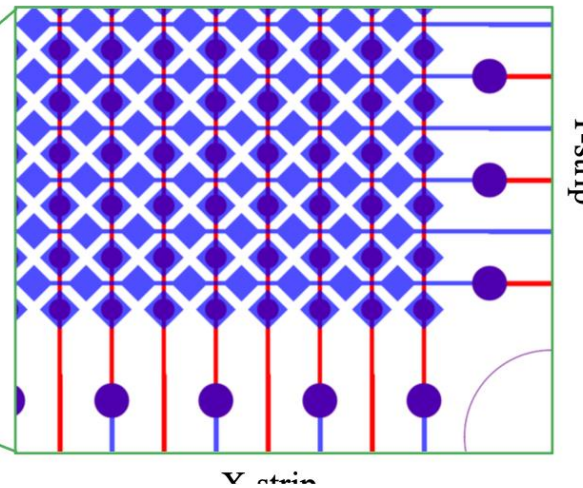
- 4 sectors
- 2 HV electrodes on each sector

Current status - Design Features (Prototype 1)

Gerber view of thin-gap GEM- μ RWELL prototype



ASACUSA-like X-Y strip readout layer



Capacitive sharing readout principle (*developed by K.Gnanvo, Jlab*)

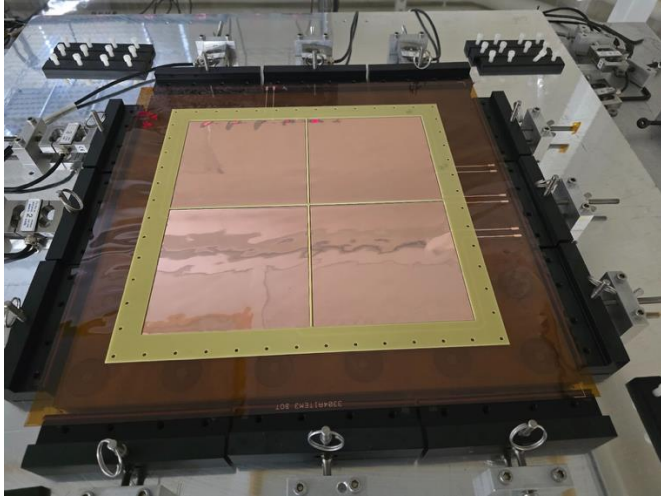
- Vertical stack of pads layers
- Charge transferred from MPGD via capacitive coupling
- Increment of pad sizes from top to bottom layers
- Transverse sharing of the charges between neighboring pads from top layer of pad.
- Allows large pitch for readout strips/pads and hence low channel count.

Ref: <https://doi.org/10.1016/j.nima.2022.167782>

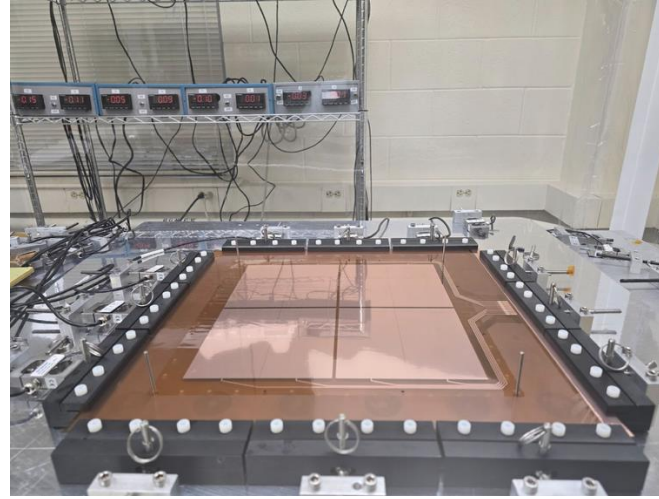
- ASACUSA X-Y type readout pads providing equal X-Y charge sharing

Current status - Design Features (Prototype 1)

Stretching of drift cathode



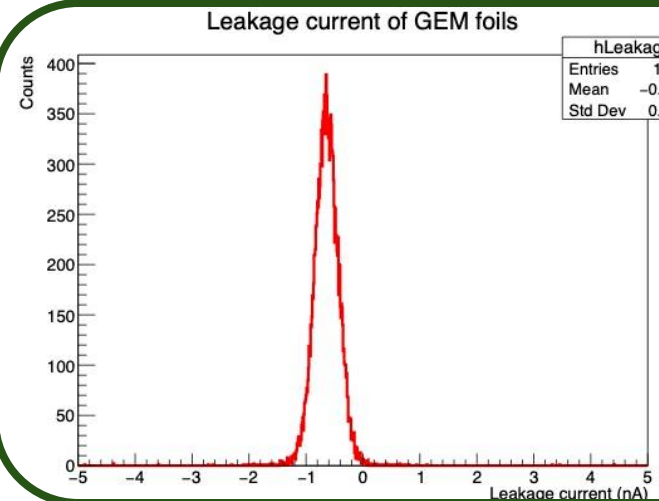
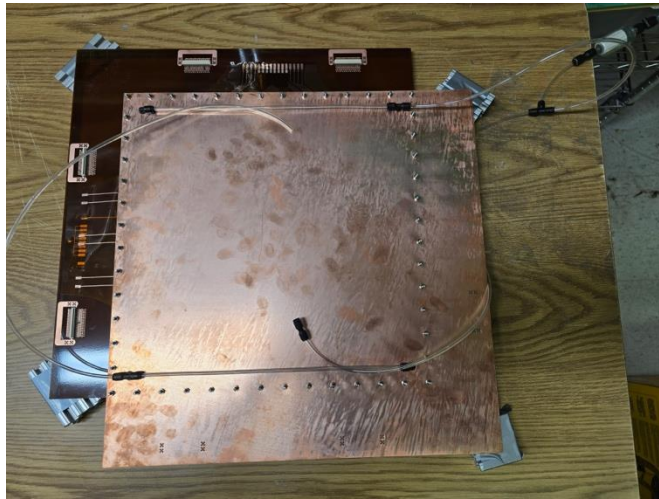
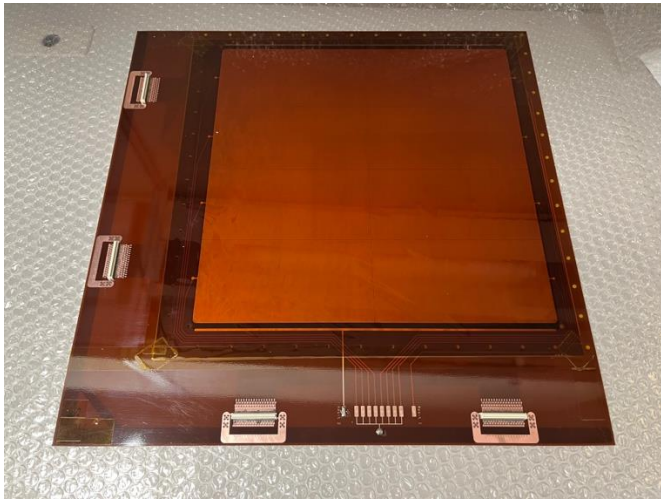
Stretching of GEM foil



Assembly procedure @ UVA:

- Stretched cathode foil glued to one side of honeycomb support.
- Drift frame glued to cathode foil and honeycomb block
- Stretched GEM foil glued to drift frame + cathode + honeycomb block.
- Induction frame glued to entire GEM+ cathode + honeycomb block.
- $\mu RWELL$ PCB bolted to the induction frame + GEM + cathode + honeycomb block.

$\mu RWELL$ With ASACUSA readout Completely assembled prototype

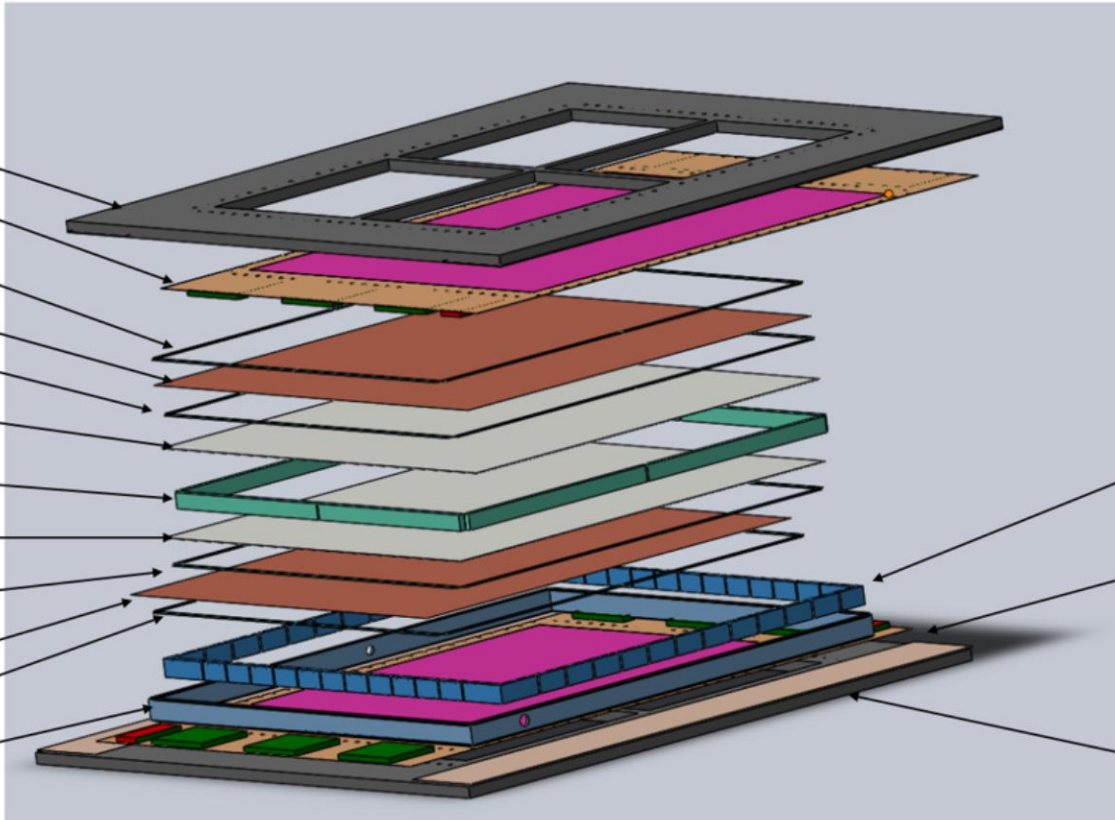


- Measured leakage current from each sectors of GEM foil < 1 nA in N_2 after complete assembly
- Need to do the same for $\mu RWELL$.

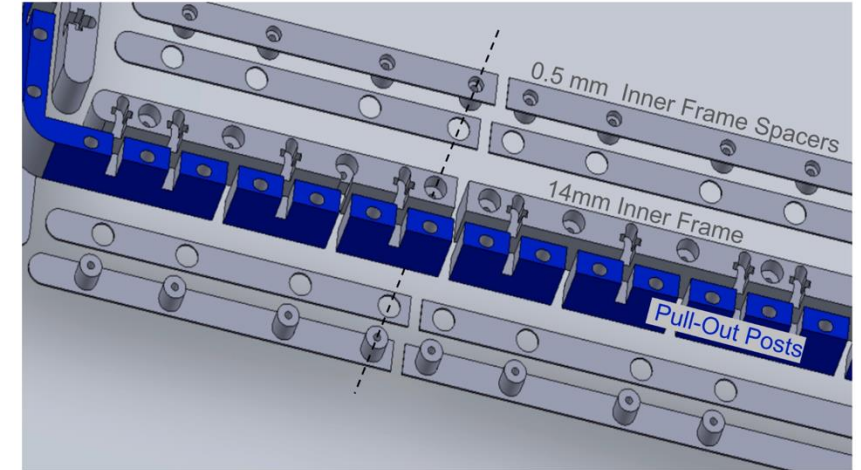
Current status - Design Features (Prototype 2)

Assembly design

Carbon Fiber Frame
 μ RWELL (Flipped)
0.5 mm Inner Frame
GEM
0.5 mm Inner Frame
Drift Foil
14mm Inner Frame
Drift foil
0.5 mm Inner Frame
GEM
0.5 mm Inner Frame
O-Ring Spacer



Spacer frame and pull out posts design

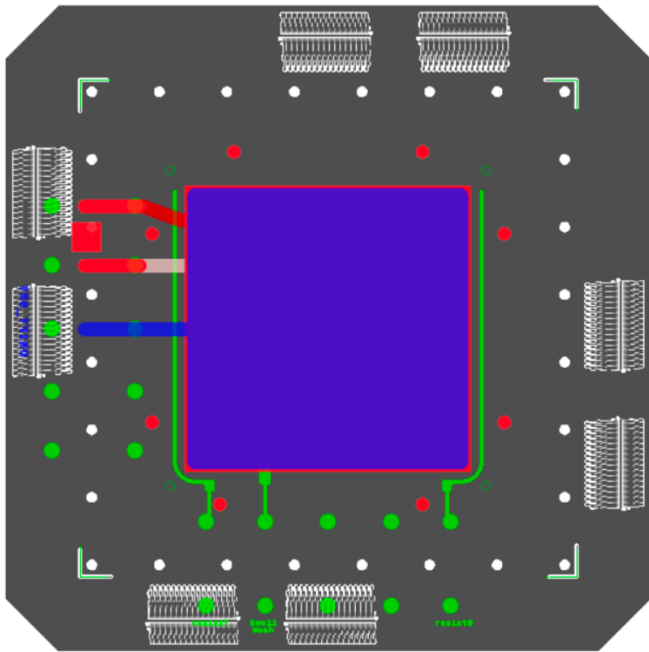


Pullout Blocks
 μ RWELL
Carbon Fiber Frame

Current status - Design Features (Prototype 3)

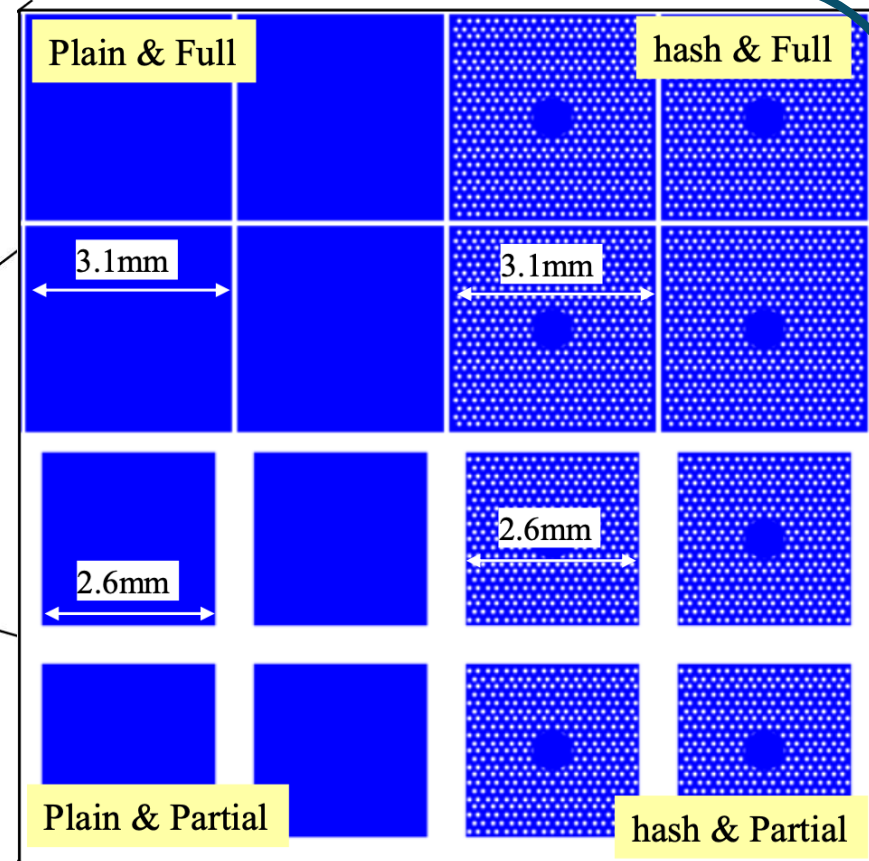
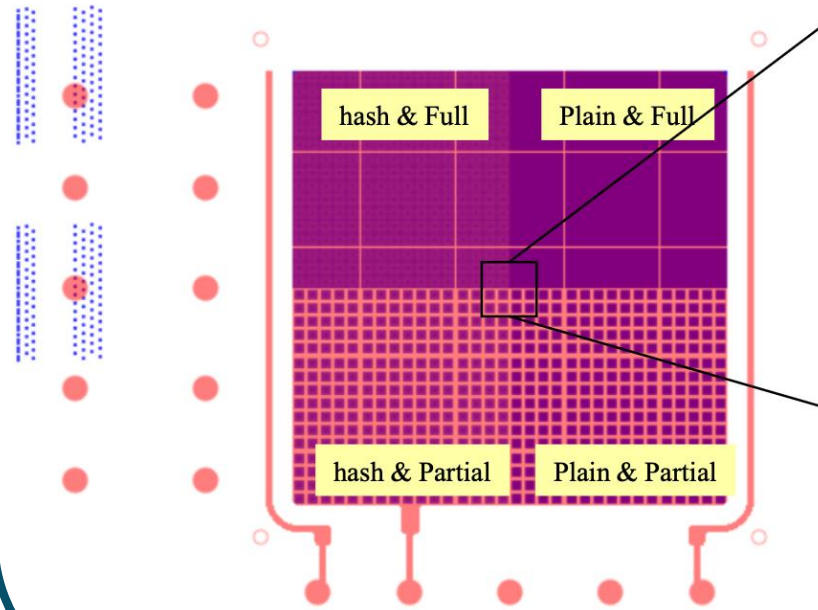
- Assembly process same as prototype 1.
- Active area – 10 x 10 cm with 4 different readout pad geometries
- Assembled and already underwent cosmic test and beam test in JLAB

μ RWELL Gerber view



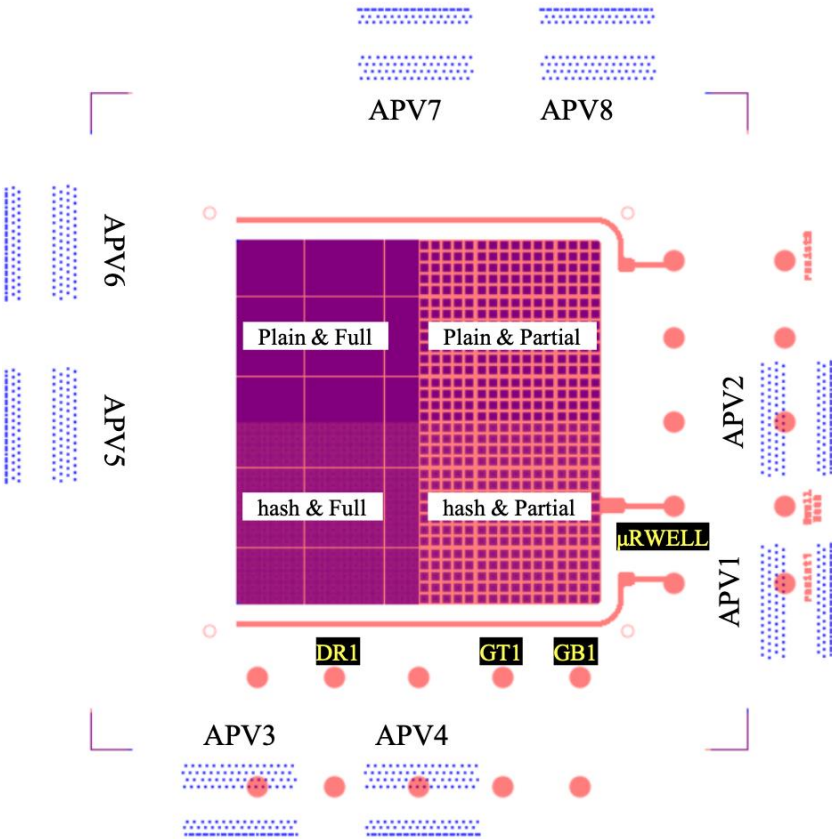
Pad readout geometry

- Same pitch different pad size
- Low capacitance study

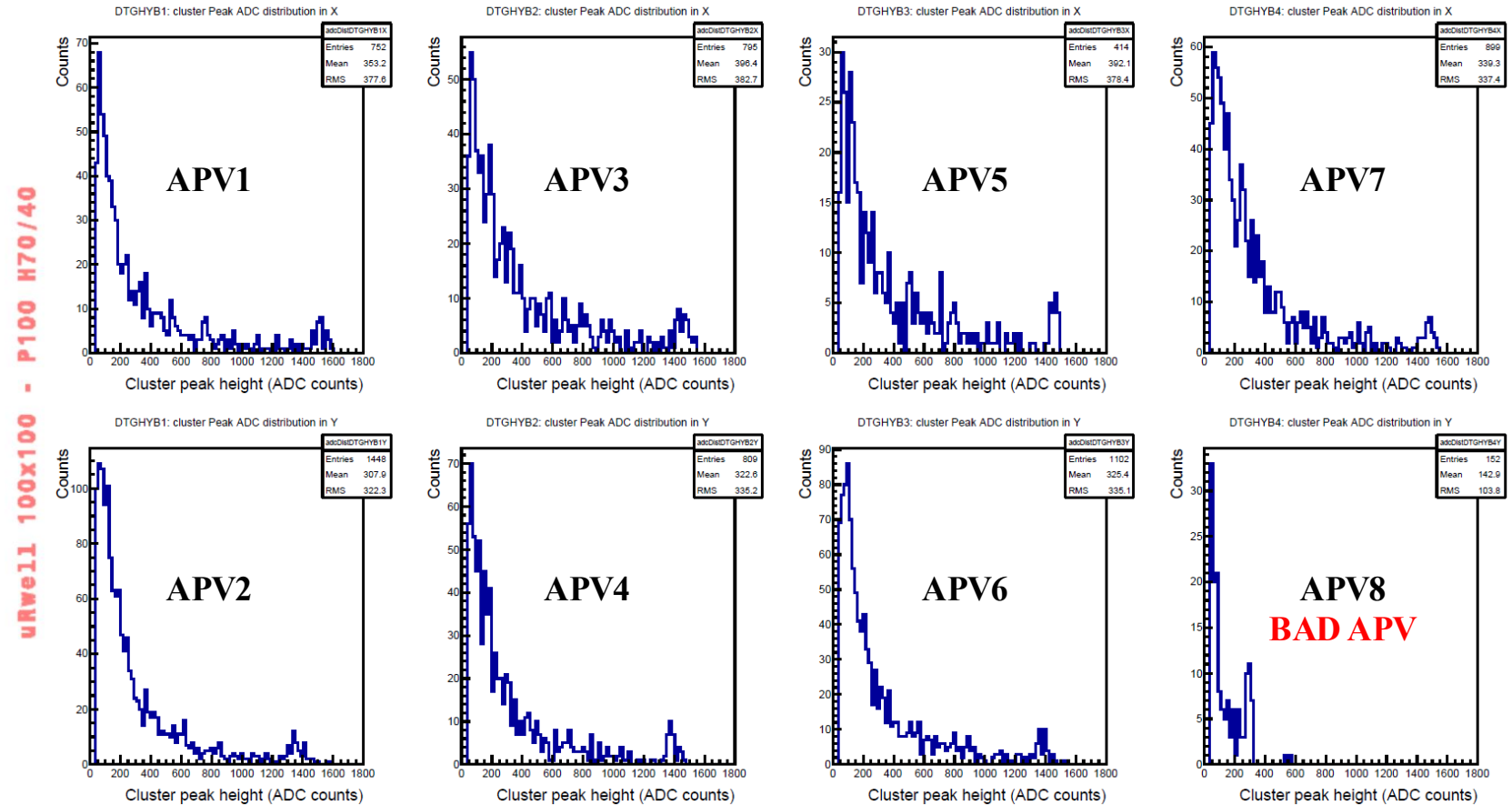


Current status – Preliminary results (Prototype 3)

- Recently conducted cosmic ray test in JLAB.
- ArCO₂(75:25) gas mixture used.



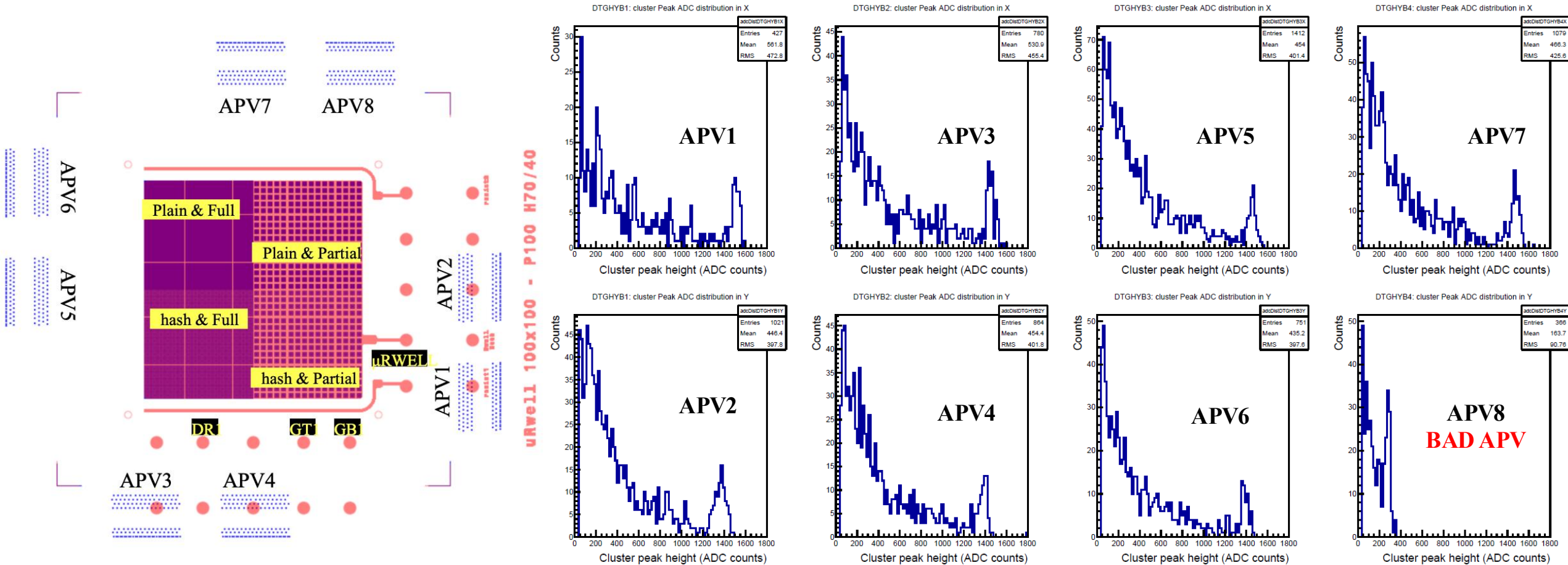
ADC distribution from top detector



Current status – Preliminary results (Prototype 3)

- Recently conducted cosmic ray test in JLAB.
- ArCO₂(75:25) gas mixture used.

ADC distribution from bottom detector

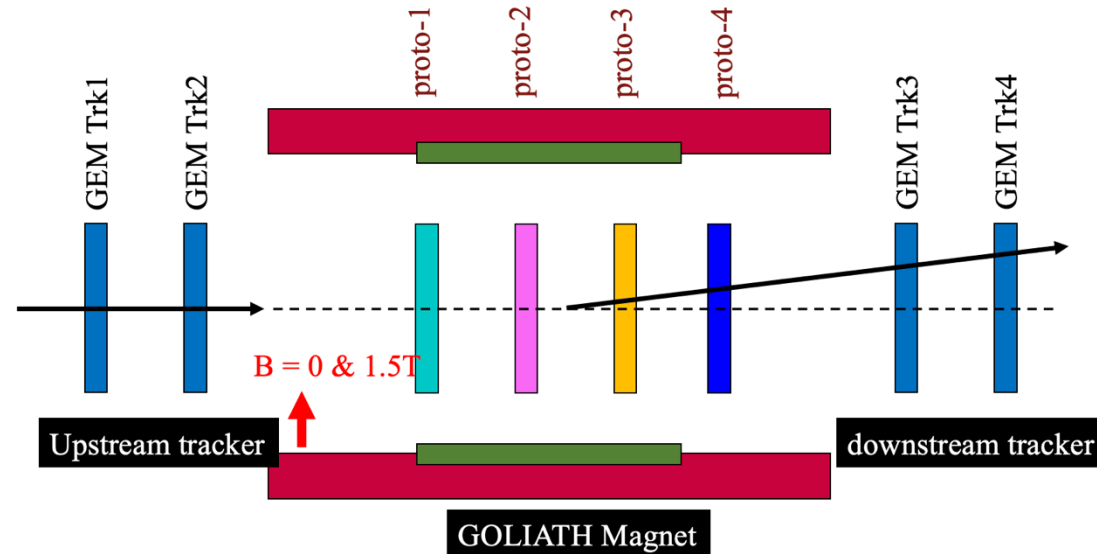


Characterization plans (Prototypes 1 & 3)

- Characterization of prototype under test beam condition at CERN during November 2025
 - Spatial resolution
 - Efficiency Studies
 - Magnetic field study



- B-field: up to 1.5T positive and negative
- Beam: 120 GeV Muon or Pions

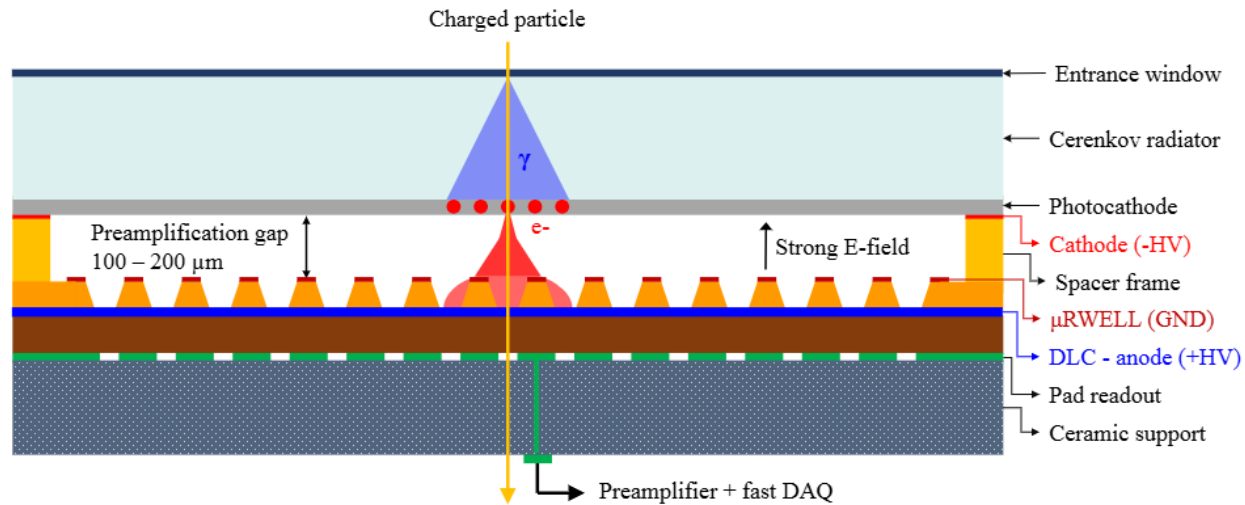


Multiple thin gap prototypes at upcoming CERN test beam will be studied

- ✓ 30 cm x 30 cm active area double sided thin gap
- ✓ 10 cm x 10 cm active area double sided thin gap
- ✓ 2 x 10 cm x 10 cm active area single side thin gap of different R/O patterns
- ✓ Primarily ArCO₂(80:20) gas mixture with the possibility of ArCO₂iC₄H₁₀(90:7:3) will be used.

Future prospects on MPGD EIC generic R&D

➤ MPGD based Picosec detector



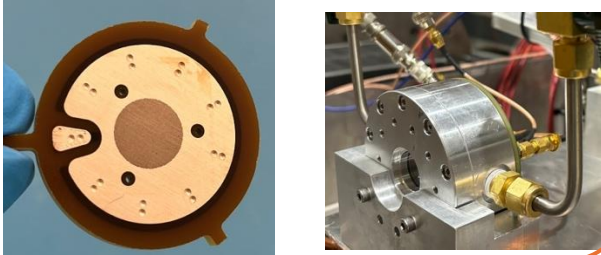
- Fast timing detector with the possibility of using as Time Of Flight PID detector
- Extensive progress in ongoing MM-PICOSEC collaboration at CERN during last one decade.
 - Proof of concept already established for 10cm x 10 cm and multi channel (100 pads) \rightarrow < 20 ps with MIPs
- Strong R&D program started in JLAB for pursuing μ RWELL –PICOSEC concept under K.Gnanvo
 - Initial funding provided by JLAB LDRD program
 - Smaller amplification gap of 50 μ m in μ RWELL as compared to 120 μ m in MM can provide better timing performance
 - μ RWELL can be segmented which is not possible for MM \rightarrow Better for large size detector with less dead area
 - Better control in gap uniformity in μ RWELL as compared to MM due to absence of pillar and stretching process

Future prospects on MPGD EIC generic R&D

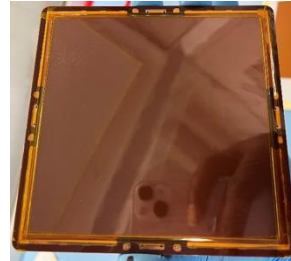
μRWELL –PICOSEC Progress

- Various hole parameters (size and shape) of μRWELL
- Capacitive sharing readout board for better charge sharing
- Both CsI and DLC based photocathode studies
- Both single pad and 100 pads prototype studies

Small Single pad prototype

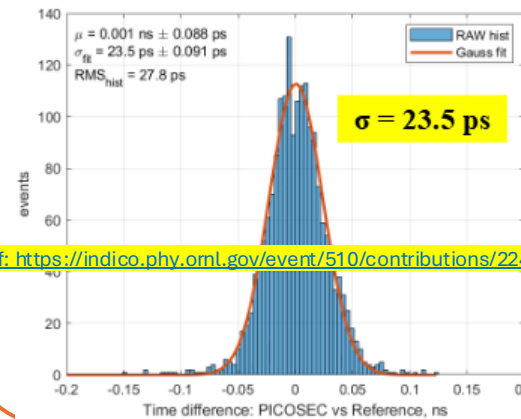


10 cm x 10 cm 100 pads proto

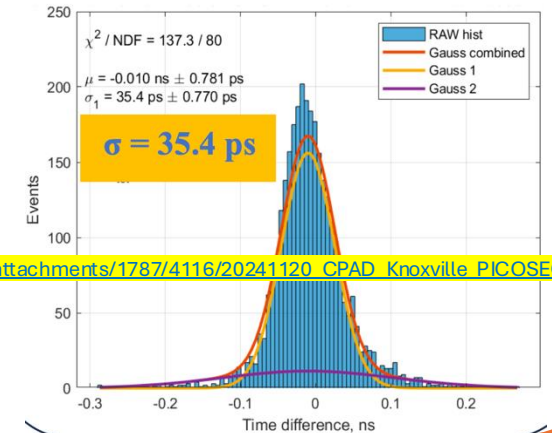


Timing performance, single channel μRWELL –PICOSEC

Circular hole optimized CsI photocathode



Circular hole optimized DLC photocathode



Ref: https://indico.phy.ornl.gov/event/510/contributions/2248/attachments/1787/4116/20241120_CPAD_Knoxville_PICOSEC_KG.pdf

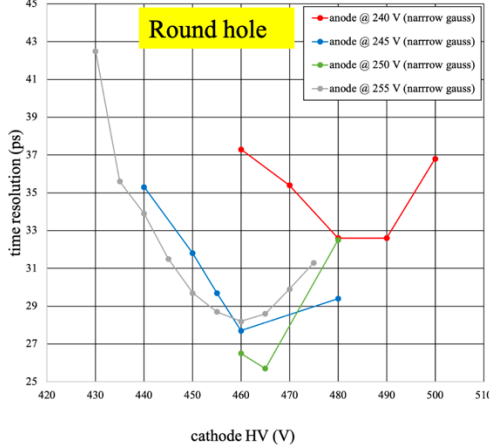
Future prospects for μRWELL –PICOSEC :

- Optimize photocathode for longevity
- Optimize large size (10cmx10cm active area) with multiple pads to be used as ToF PID.
- Optimize hole parameters
- Study eco friendly gases

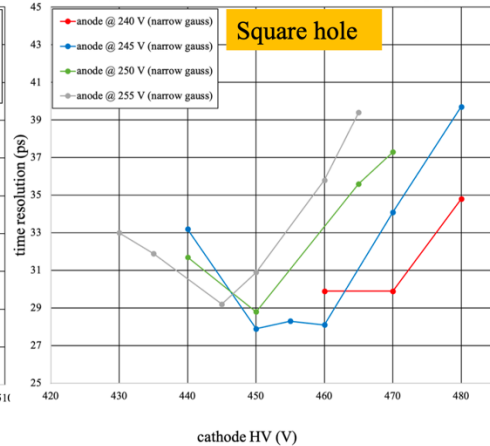
MPGD based photosensors :

- MPGDs are great candidate for photosensors
- Design modifications in for μRWELL –PICOSEC can provide us photosensors
- Modifications include increasing gain $\sim 10^7$ at the expense of timing resolution

μRWELL-PICOSEC5: Time resolution vs cathode voltage



μRWELL-PICOSEC1: Time resolution vs cathode voltage



Round hole better timing than square hole

Conclusions

- Multiple interesting results from particle tracking perspective.
- Strong dependency of track angle on spatial resolution can now be controlled.
- More new results to come.
- Strong generic R&D program even with limited funding.
- Huge possibility of MPGD R&D from point of view of Particle Identification Detectors.
- More contributions and proposals from more Institutions are welcome.
- All the results presented here are based on DOE and JLAB approved grant **DE- AC05-06OR23177, DE-FOA-0003432.**

