

CPAD Workshop



CPAD Workshop 2023

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SLAC

MPGD as tracker for EIC

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On behalf of

EIC-eRD108 MPGD consortium



EIC-eRD108 MPGD consortium

The eRD108 Consortium

Project ID: eRD108

Project Name: Development of EIC ePIC MPGD Trackers.

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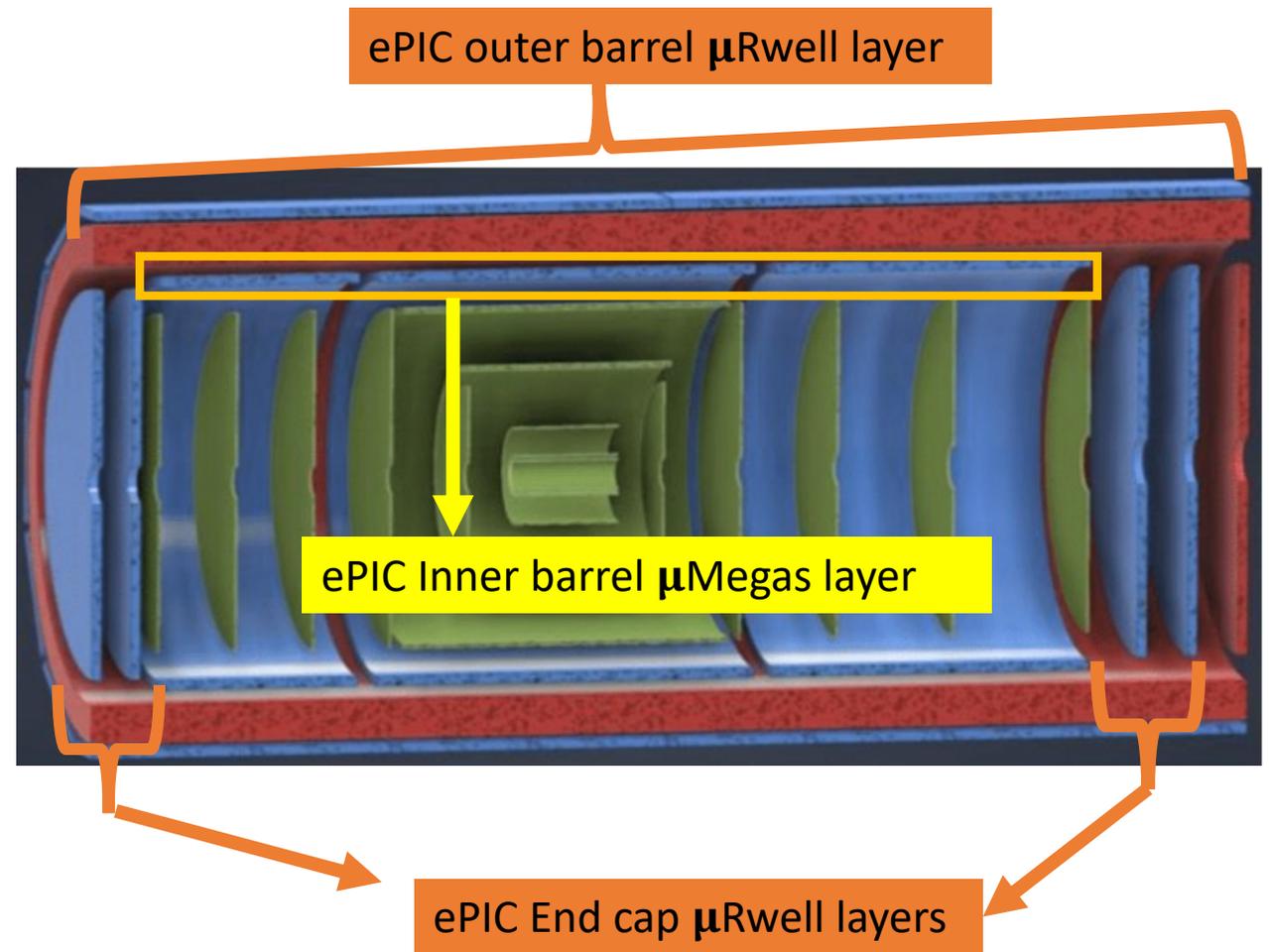
MPGD R&D program for EIC

□ Goals for ePIC detector in EIC

- **Inner barrel** : Low mass large size cylindrical detector based on μ Megas technology .
- **Outer barrel** : Large size, low channel count planar detector based on μ Rwell technology to provide additional space point for pattern recognition and to aid DIRC for PID.
- **End caps** : Disc shaped low channel count based on μ Rwell technology to compliment Si hits for pattern recognition along with background rejection due to better timing resolution compared to Si trackers.

□ Future upgrade of ePIC or second detector in EIC

- Address the issue of deterioration of spatial resolution on track angle and EXB effect.



R&D on cylindrical Micromegas tracker

Motivation

- Build a full (no acceptance gaps) light-weight modular Micromegas barrel tracker to complement the silicon vertex detector

CLAS12 MM Technology

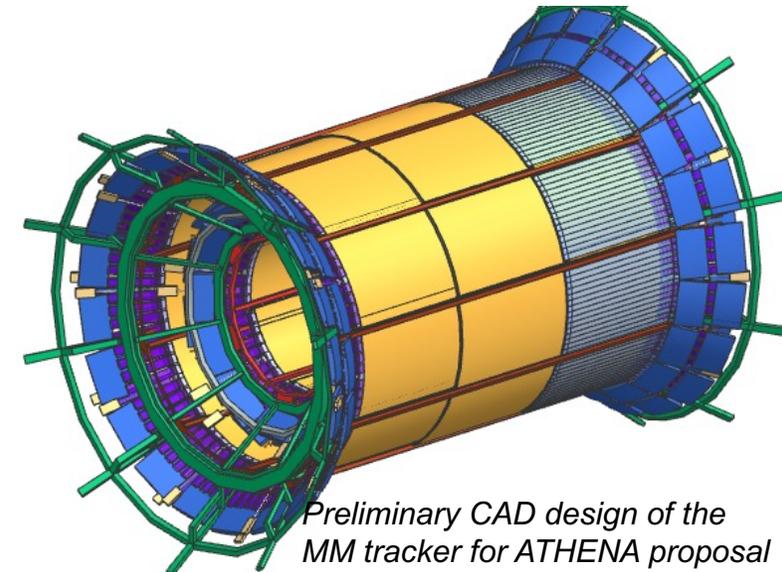
- Compact cylindrical tracker in a $B=5T$ solenoid, total active area $\sim 4m^2$
- Light cylindrical tiles ($\sim 0.4\%$ X0 per layer)
- 1D readout per tile (either phi or z coord)
- Taking data since 2017

Upgrades to fit the EIC needs:

- **Simpler construction:**
 - about one module size bent at different radii,
 - overlap tiles for no acceptance gaps
- **2D readout**
 - Resolutions 50 – 100 μm , on both directions
 - Keeping the channel count as low as possible

Objectives

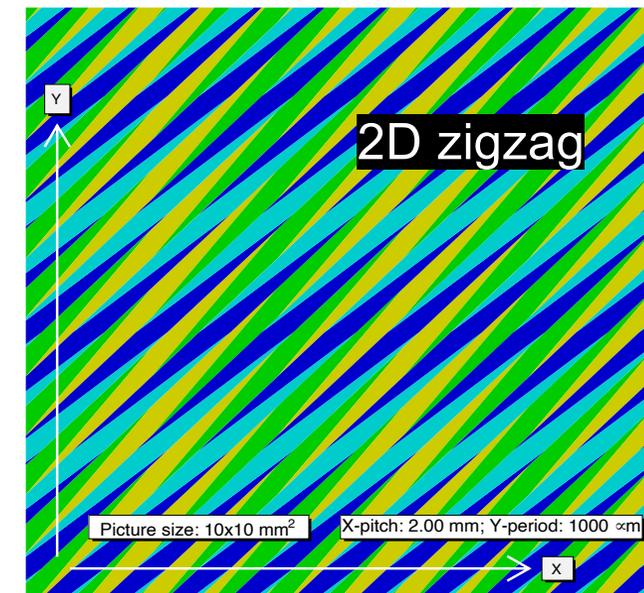
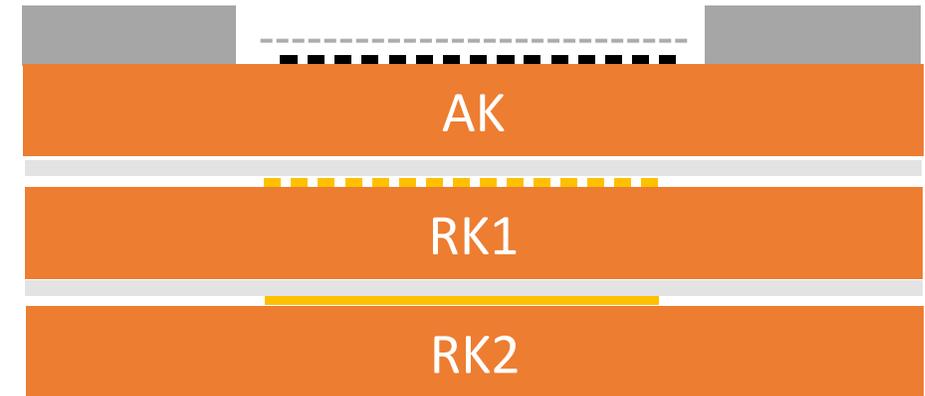
- FY22:
 - Optimization of the 2D readout for low number of channels on small prototypes
 - CAD design of the full-scale prototype
- FY23:
 - Build a full-scale prototype of a Micromegas tile ($50 \times 70 cm^2$) with the chosen 2D readout



R&D on cylindrical Micromegas tracker

R&D 2D readout

- Several small prototypes $\sim 12 \times 12 \text{ cm}^2$
- Multi stack for easy combination of different options:
 - AK: Amplification Kapton
 - Vary the resistivity, the shape, ...
 - RK: Readout Kapton
 - Different strip pitch (1, 1.5, 2 mm)
 - Vary strip type (straight, zigzag, pixel,..)
 - 2D zigzag from BNL
- Assembly in house
 - Pressing
 - 3D printed mechanics



Testing

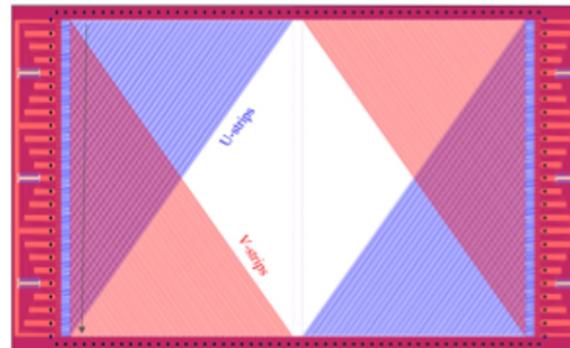
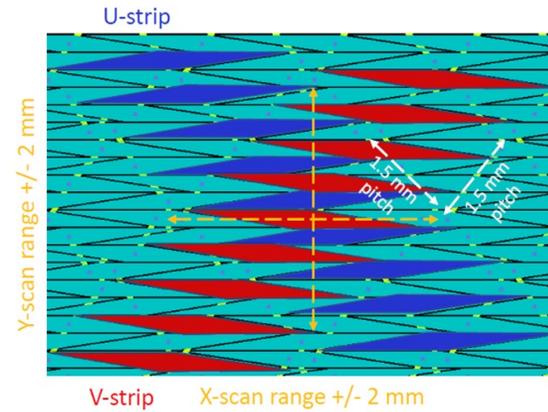
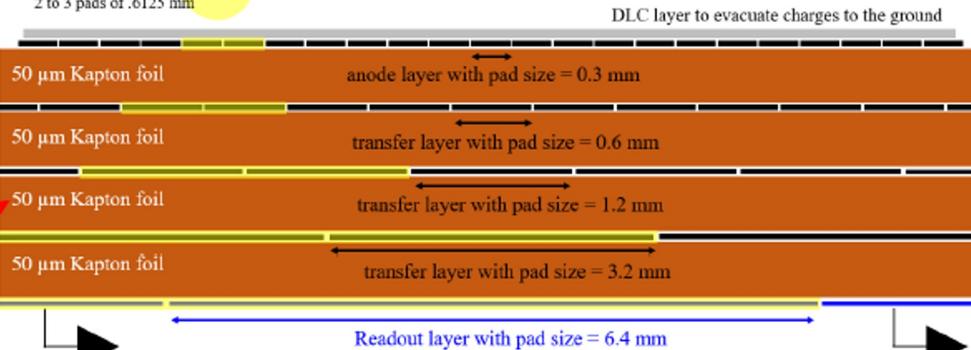
- ^{55}Fe Cosmic rays test bench in Saclay
- X-rays gun tests in BNL
- Beam test in 2023

Cylindrical μ -RWELL prototype

- Each half of prototype were based on capacitive sharing principle with U-V strips readout pattern
 - One half straight capacitive sharing U-V pattern by JLab
 - Other half chevron capacitive sharing U-V pattern by BNL

Cross section of capacitive-sharing pad readout with 6.4 mm \times 6.4 mm pads

Initial electron clouds size from triple-GEM will hit on average 2 to 3 pads of .6125 mm



gap

Outer clamp

Cathode foil

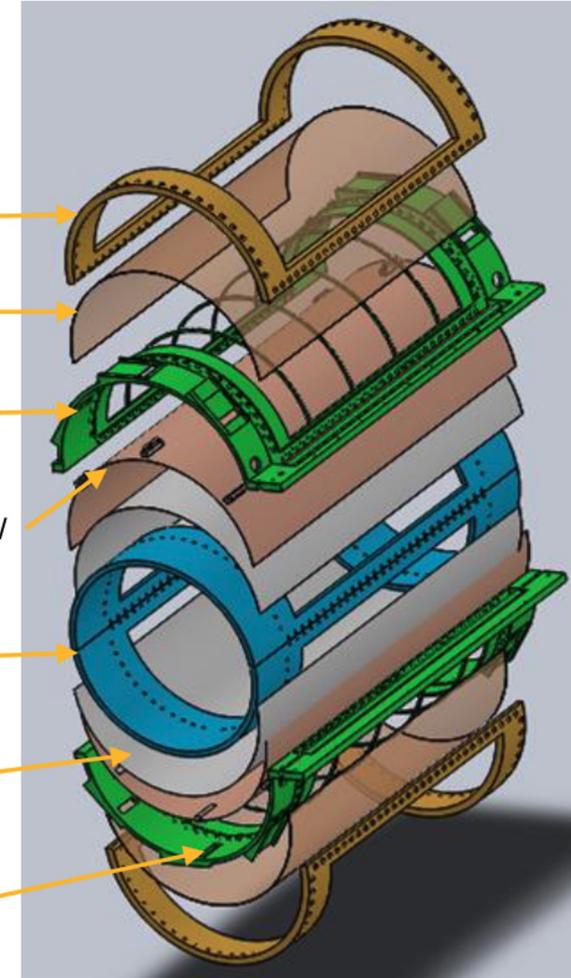
Main frame

μ RWELL-R/O composite foil (w/ FE connectors)

Inner clamp

Prepreg base (0.2-1mm thick)

Support for FE cards



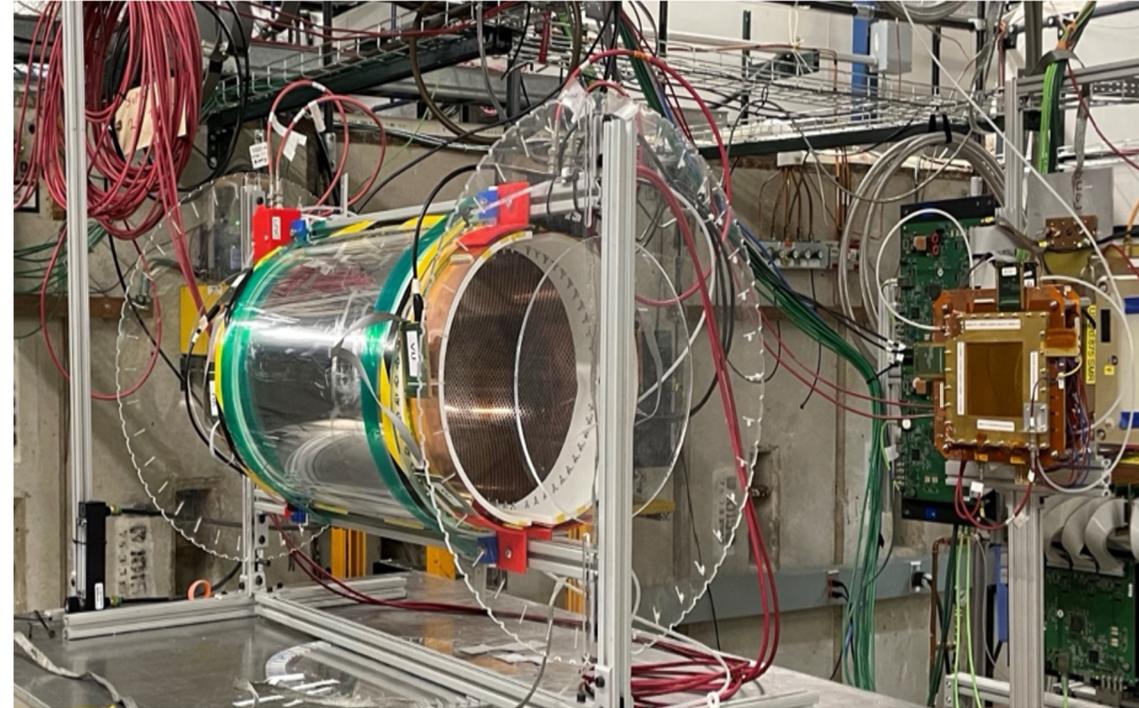
- Mechanical support structure was developed by FIT

☐ June 2023 Fermilab Test beam

- Prototype was installed on rotational mount
- 120 GeV pion beam with the motivation to study spatial resolution along with efficiency and stability of detector.

☐ Unable to collect data

- FNAL shut down due to safety/security issue elsewhere onsite.
- Intending to test the prototype next year (2024) at the earliest test beam opportunity at Fermilab test beam facility.



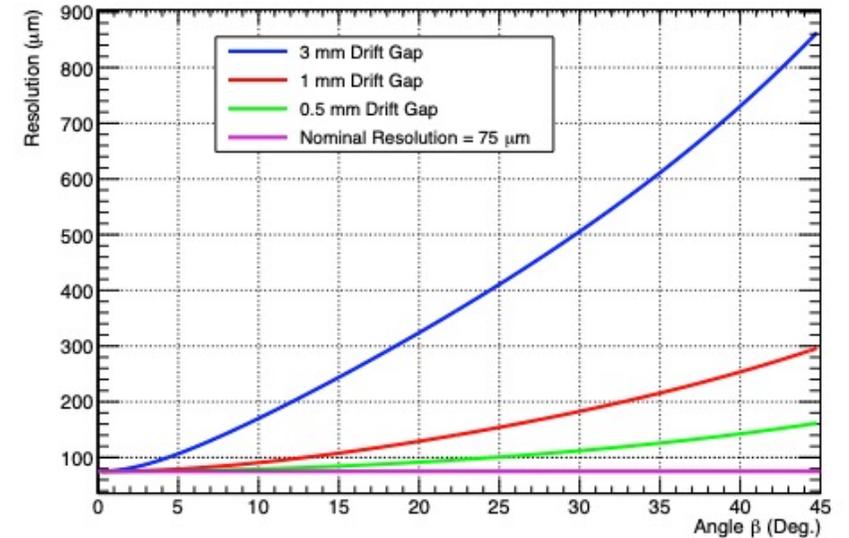
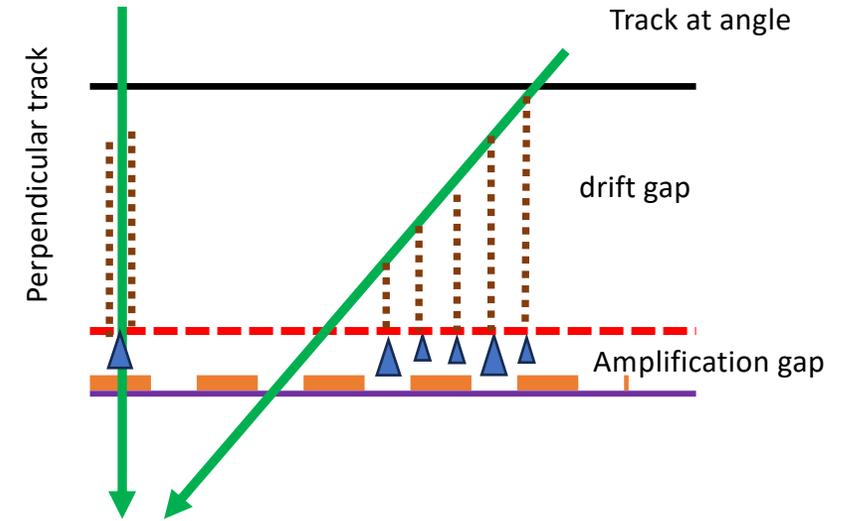
Cylindrical μ Rwell in 2023 Fermilab Test Beam Facility

Current challenges with MPGD trackers

- Deterioration of spatial resolution with track angle .
- Minimization of E x B effect inside magnetic field.

Steps for addressing the above issues

- Reduce drift gap to circumvent dependence of spatial resolution on track angle.
- Use various gas mixtures to optimize the detector performance in terms of stability and efficiency.



Development of Thin Gap MPGD Trackers for EIC Trackers

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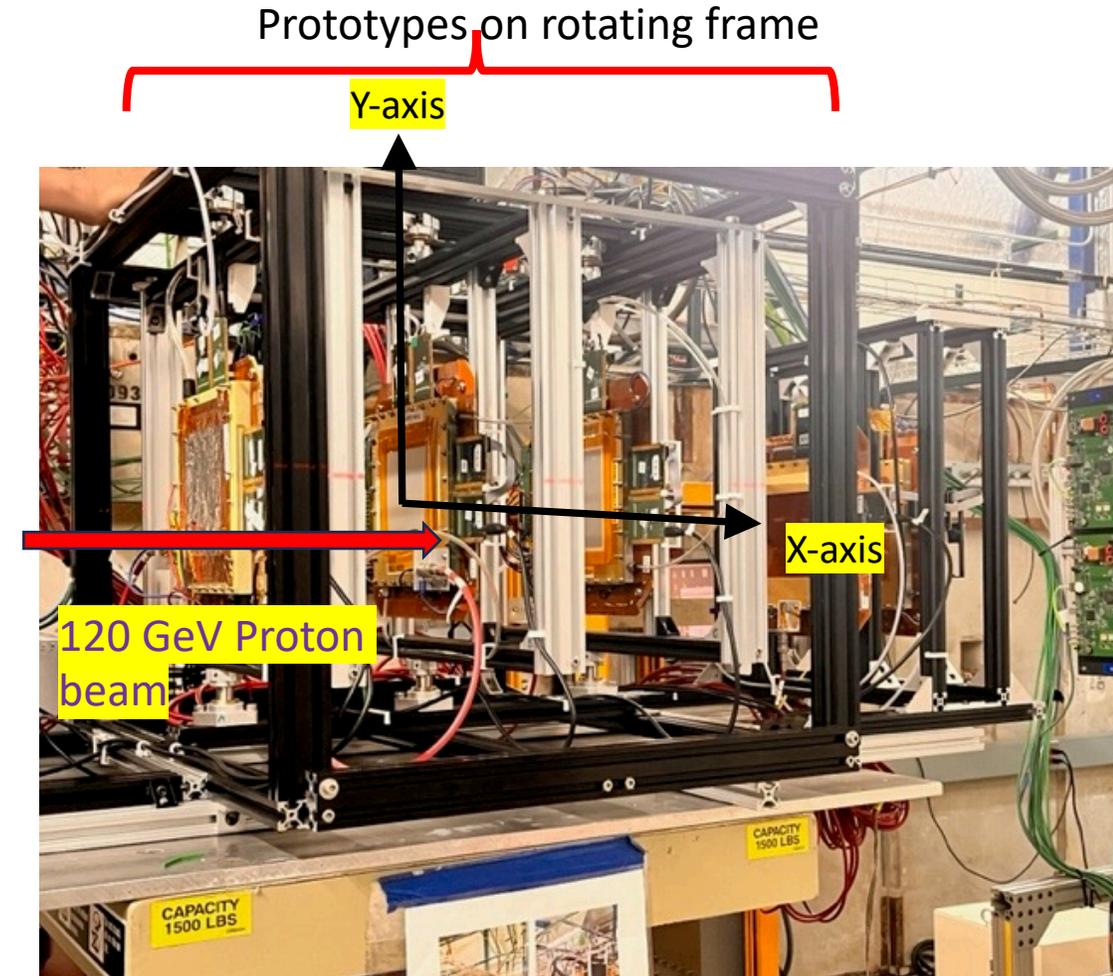
⁴Vanderbilt University, Department of Physics and Astronomy, Nashville, TN 37240, USA

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Submitted EIC generic R&D proposal during FY 22 and got approved

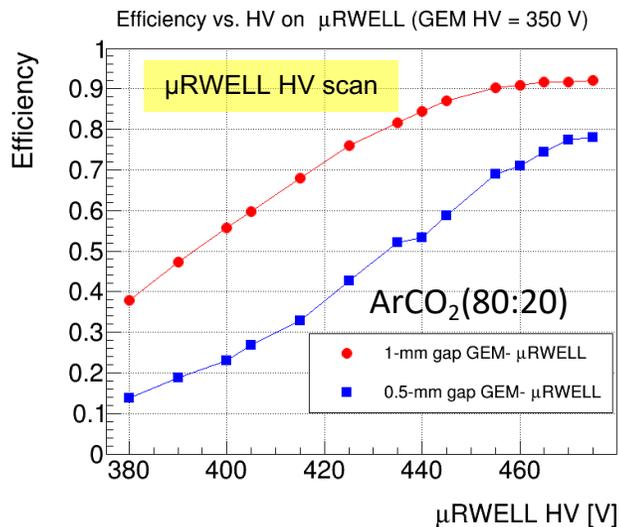
July 25, 2022

- Recently (June 2023) concluded Fermilab test beam.
- 10 prototypes from Jlab, UVA and VU
 - ✓ Jlab : Hybrid GEM+ μ Rwell with capacitive sharing X-Y strip (0.8 mm pitch) R/O board and multiple drift gap (0.5-1 mm).
 - ✓ UVA : Triple GEM with X-Y strip (0.4 mm pitch) R/O with multiple drift gaps (1-3.0 mm) and cathode based on copper-Kapton foil or copper wire mesh.
 - ✓ VU : Hybrid GEM + μ Rwell and MMG + μ Rwell with 2D chevron (1.6 mm pitch) R/O board with 1 mm drift gap.
- Rotation angle from 0 degree to +/- 45 degrees .
- 2 trackers upstream and 2 trackers downstream on a fixed separate stand.
- Data taken using both ArCO₂ (80:20) and KrCO₂(80:20) gas mixtures at different track angles.

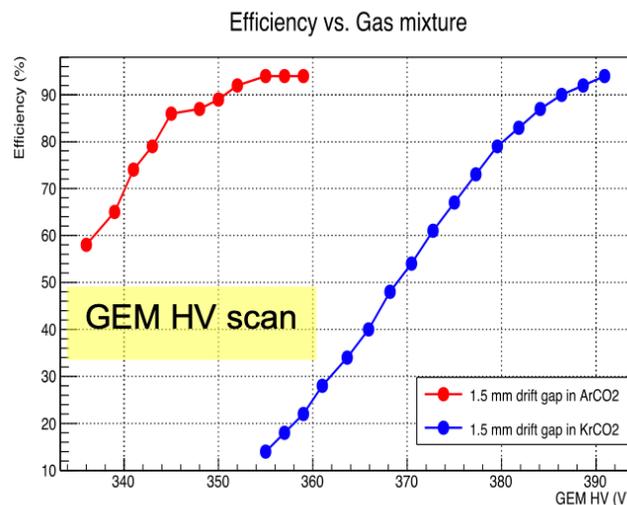


Preliminary results from ongoing analysis of June 2023 Fermilab test beam data

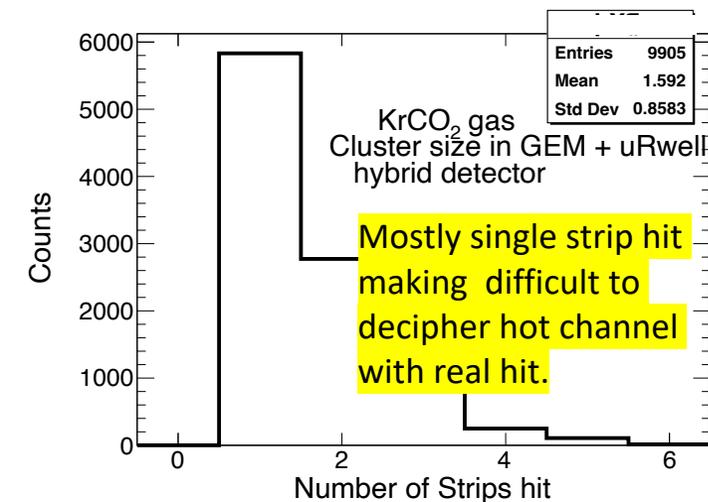
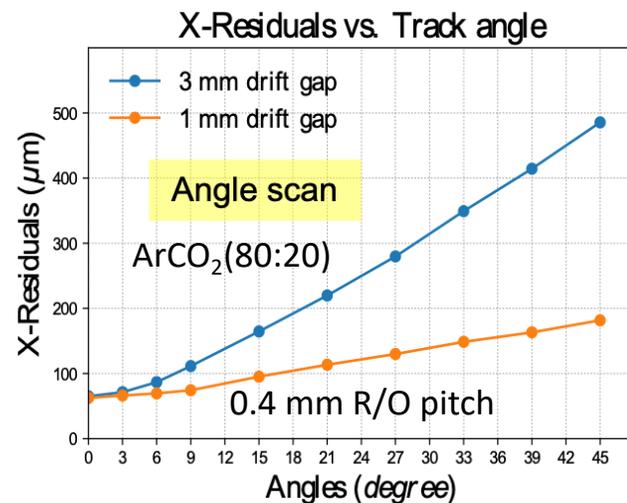
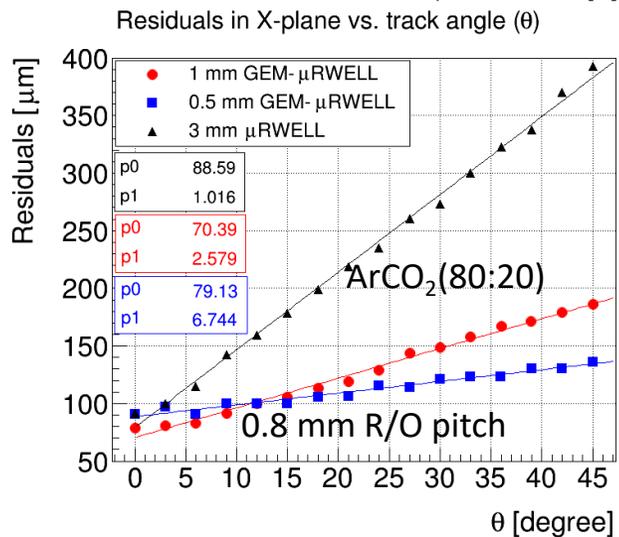
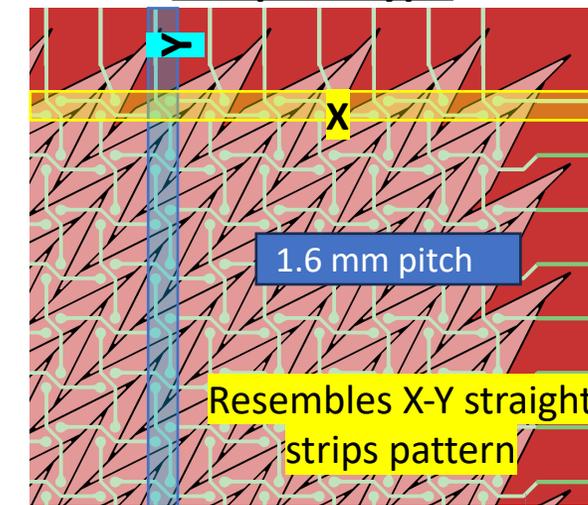
Jlab prototype



UVA prototype



VU prototype



Double sided Thin Gap MPGD tracker for EIC-FY23

Development of Double-sided Thin-Gap GEM- μ RWELL for Tracking at the EIC

Proposal to the FY23 EIC generic detector R&D program

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July 14, 2022

The EIC physics program requires precise tracking over a large kinematic acceptance, as highlighted in the EIC Yellow Report [1]. MPGDs provide space point measurements for track pattern recognition and momentum measurements. MPGD detectors will span a large pseudorapidity range and will see tracks entering over a wide range of incidence angles, in addition to tracks bending due to magnetic fields. The position resolution of a standard MPGD structure for a track impinging at a large angle from the normal is not determined by the detector readout structure, but instead by the gap in the ionization gas volume. As the incidence angle increases, the path length of the particle traverses before reaching the amplification stage, leading to a deterioration in the position resolution that grows with the incidence angle relative to the normal. To minimize the impact of track angle on the resolution, several medium-size prototypes with double layers of thin-gap MPGDs, where the ionization gas volume is significantly reduced with respect to typical MPGD detectors and can be operated with standard Ar/CO₂ gas mixtures at high efficiency, will be designed, built, and tested.

Submitted EIC generic R&D proposal during FY 23 and got approved

□ Double-sided thin-gap GEM- μ RWELL hybrid

- Double amplification with hybrid GEM- μ RWELL is the most promising approach for thin-gap MPGD
- With double-sided, we recover full detector efficiency
- Focusing / de-focusing of Lorentz angle in B field

□ Operation with Argon based gas mixture

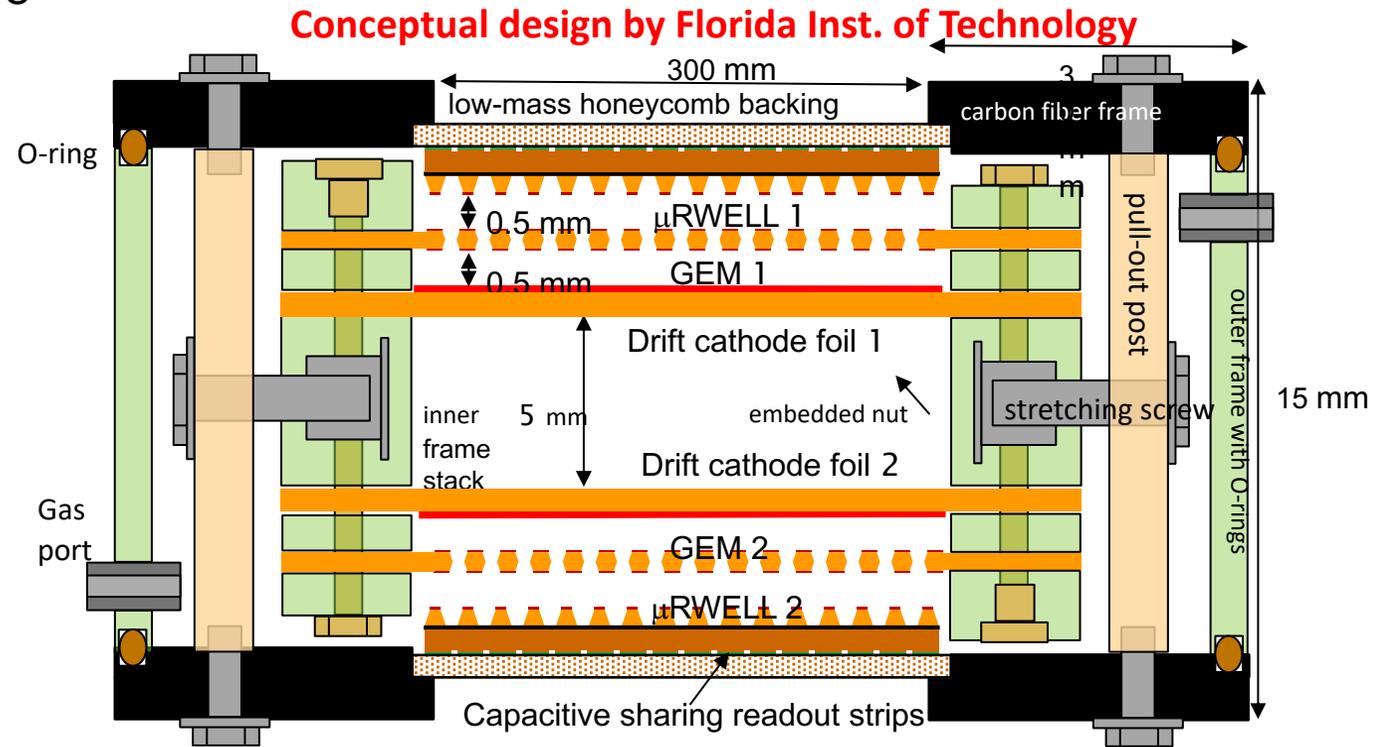
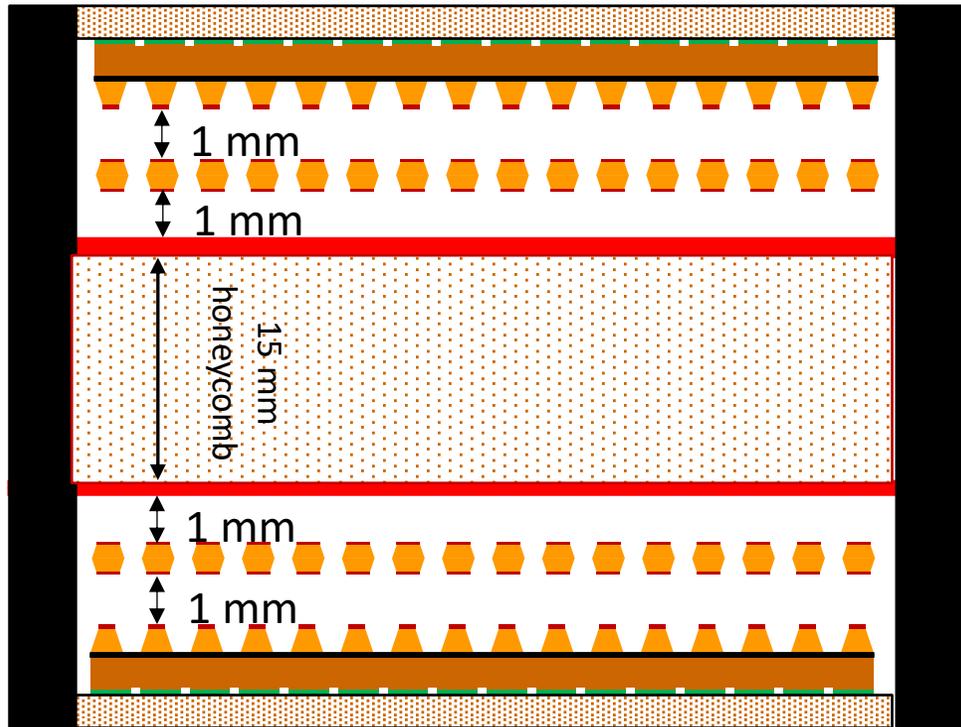
- Affordability and availability than Xe / Kr
- **Reduction of background rate in the detector**
- Improved timing resolution (~ 2 ns) for 0.5 mm gap

□ Large-area, low-mass and compact detector modules

- Outer tracker layer / disc of EIC central tracker
- Large acceptance muon chambers
- High performance trackers in high- η and FF regions

Double sided Thin Gap MPGD tracker for EIC-FY23

- ❑ Development of low mass, low channel count, double sided thin-gap 30 cm x 30 cm active area GEM- μ RWELL hybrid trackers.
- ❑ Collaborative effort from multiple Institutions.
 - Design of two capacitive sharing R/O with different pattern (X-Y and UV) : Jlab and VU
 - Design of honeycomb support structure and GEM foil : UVA
 - Design on frame structure for GEM foil stretching allowing to adjust foil tension during assembly of detector : FIT
 - Final assembly at UVA : FIT, Jlab, TU, UVA, VU, YU



Conclusions

- Substantial R&D is in progress related to design of mechanical structure of large size cylindrical **μ -RWELL and planar μ -RWELL** .
- Promising R&D results from cylindrical large size Micromegas.
- Promising preliminary result from June 2023 Fermilab test beam for thin gap hybrid **(GEM + μ -RWELL)** and thin gap triple GEM detector showing effect of track angle on spatial resolution can be mitigated by reducing drift gap of detector (improvement in spatial resolution by a factor of 3 as compared to 3 mm drift gap detector).
- Approved FY23 generic R&D funding for double sided thin gap MPGD tracker will mitigate using expensive heavier gas (Xe/Kr) along with providing tractlet information.
- Future R&D plans on large size thin gap MPGD tracker will provide answers for detector stability (both mechanical and High Voltage).