MPGD as tracker for EIC

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*On behalf of*
EIC-eRD108 MPGD consortium
The eRD108 Consortium

**Project ID:** eRD108

**Project Name:** Development of EIC ePIC MPGD Trackers.

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- CEA Saclay: Francesco Bossù, Maxence Vandenbroucke
- Florida Institute of Technology (FIT): Marcus Hohlmann
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- University of Virginia (UVA): Huong Nguyen, Nilanga Liyanage
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**Project Members:**

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Goals of MPGD R&D in EIC
- Provide low mass, low channel count tracking detector.
- Address the issue of deterioration of spatial resolution on track angle and EXB effect.

MPGD for ePIC detector in EIC
- **Inner barrel** : Low mass large size cylindrical detector based on ρMegas technology.
- **Outer barrel** : Large size, low channel count planar detector based on ρRWELL technology to provide additional space point for pattern recognition and to aid DIRC for PID.
- **End caps** : Disc shaped low channel count based on ρRWELL technology to compliment Si hits for pattern recognition along with background rejection due to better timing resolution compared to Si MAPS tracker.
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 (data taking since 2017)
• Compact cylindrical tracker in a B=5T solenoid, total active area \( \sim 4m^2 \)
• Light cylindrical tiles \((\sim 0.4\% \, X_0 \, \text{per layer})\)
• 1D readout per tile (either phi or z coord)

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 \( \mu \text{m} \), on both directions with low channel counts

Objectives
• Optimization of the 2D readout for low number of channels on small prototypes
• CAD design of the full-scale prototype
R&D on cylindrical Micromegas tracker

**R&D 2D readout**

- Several small prototypes ~12x12 cm²
- 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)
    - ASACUSA pattern
- Assembly in house
  - Pressing
  - 3D printed mechanics

**Testing**

- $^{55}$Fe Cosmic rays test bench in Saclay
- Beam test in 2023 in MAMI facility using 880 MeV electron beam.
Cylindrical $\mu$-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 2D zigzag U-V pattern by BNL

- Design with only foils in the active area. Mechanical support structure was developed by FIT

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Ref: K. Gnanvo et al., NIM A, 1047 (2023) 167782
June 2023 Fermilab Test beam

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

Unable to collect data

- Use of substantial beam time to address HV stability issue.
- FNAL shut down due to safety/security issue elsewhere onsite.
- Intending to test the prototype at the earliest test beam opportunity at Fermilab test beam facility.
Thin Gap MPGD tracker for EIC

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.

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

Development of Thin Gap MPGD Tracker for EIC Trackers

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

• Recently (June 2023) concluded Fermilab test beam.

• 10 prototypes from Jlab, UVA and VU
  ✓ Jlab: Hybrid GEM+$\mu$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 + $\mu$RWELL and GEM + $\mu$Megas with 2D zigzag (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 ArCO$_2$ (80:20) and KrCO$_2$ (80:20) gas mixtures at different track angles.
Thin Gap MPGD tracker for EIC

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

**JLAB prototype**

- **µRWELL HV scan**
- **ArCO$_2$ (80:20)**

**UVA prototype**

- **Efficiency vs. Gas mixture**
- **GEM HV scan**

**VU prototype**

- **1.6 mm pitch**
- **Resembles X-Y straight strips pattern**

**Cluster size in GEM + µRWELL hybrid detector**

- **Entries**: 9905
- **Mean**: 1.592
- **Std Dev**: 0.8583

Mostly single strip hit making difficult to decipher hot channel with real hit.
Double-sided Thin-Gap MPGD tracker for EIC-FY23

- **Double-sided thin-gap GEM-µRWELL hybrid**
  - Double amplification with hybrid GEM-µRWELL is the most promising approach for thin-gap MPGD
  - With double-sided, we recover full detector efficiency

- **Operation with Argon based gas mixture**
  - Affordability and availability than Xe / Kr
  - 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-\(\eta\) and FF regions

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Submitted EIC generic R&D proposal during FY 23 and got approved.
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-µRWELL 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 of frame structure for GEM and drift foil stretching allowing to adjust foil tension during assembly of detector : FIT
  - Final assembly at UVA : FIT, Jlab, TU, UVA, VU, YU

Conceptual design by Florida Inst. of Technology

- Low-mass honeycomb backing
- Carbon fiber frame
- Drift cathode foil 1 & 2
- Embedded nut
- Stretching screw
- Capacitive sharing readout strips
- Gas port

11/8/23 CPAD Workshop-2023
Conclusions

• Substantial R&D is in progress related to design of mechanical structure of large size cylindrical $\mu$-RWELL and planar $\mu$-RWELL.

• Promising R&D results from cylindrical large size Micromegas and awaiting results from 2023 test beam.

• Promising preliminary result from June 2023 Fermilab test beam for thin gap hybrid ($\text{GEM + } \mu$-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 tracklet information.

• Future R&D plans on large size thin gap MPGD tracker will provide answers for detector stability (both mechanical and High Voltage).