# Overview of ongoing MPGD Development for the ePIC Detector

Matt Posik
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*On behalf of eRD108*


Brookhaven National Laboratory | Infn | cea | FLORIDA TECH | Jefferson Lab | TEMPLE UNIVERSITY | University of Virginia | VANDERBILT UNIVERSITY | Yale University

# eRD-108

**eRD-108:** DOE funded project dedicated MPGD R&D for the EIC ePIC detector


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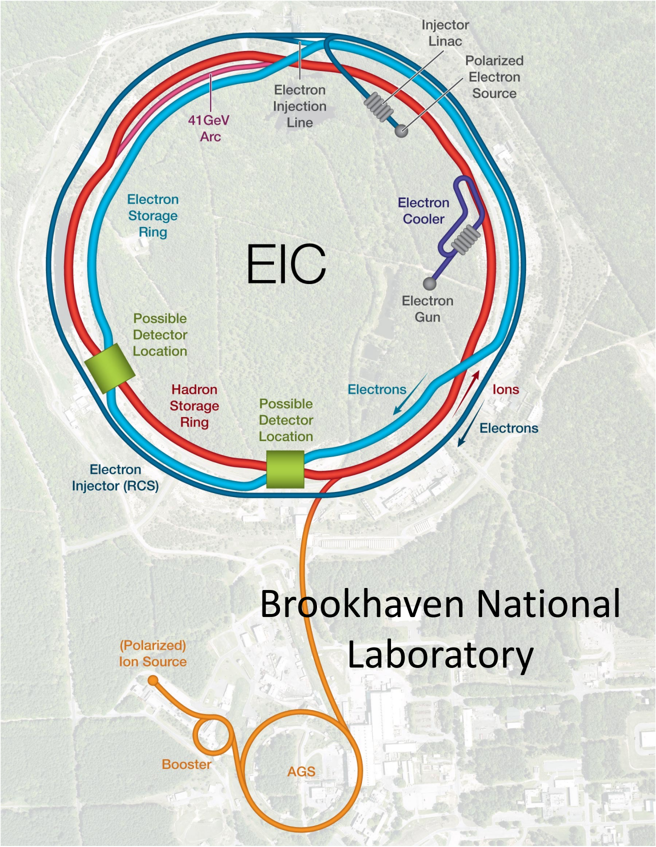
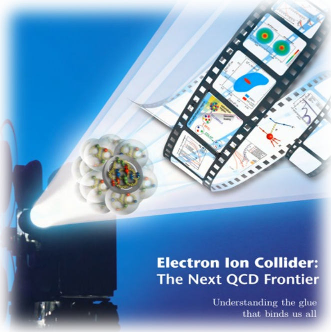
# Electron Ion Collider (EIC)

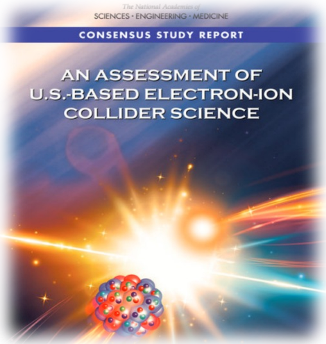
## Project Design Goals

- High Luminosity: L= $10^{33} - 10^{34} cm^{-2} sec^{-1}$, 10 – 100 $fb^{-1}$/year
- Highly Polarized Beams: 70%
- Large Center of Mass Energy Range: $E_{cm}$ = 29 – 140 GeV
- Large Ion Species Range: protons – Uranium
- Large Detector Acceptance and Good Background Conditions
- Accommodate a Second Interaction Region (IR)







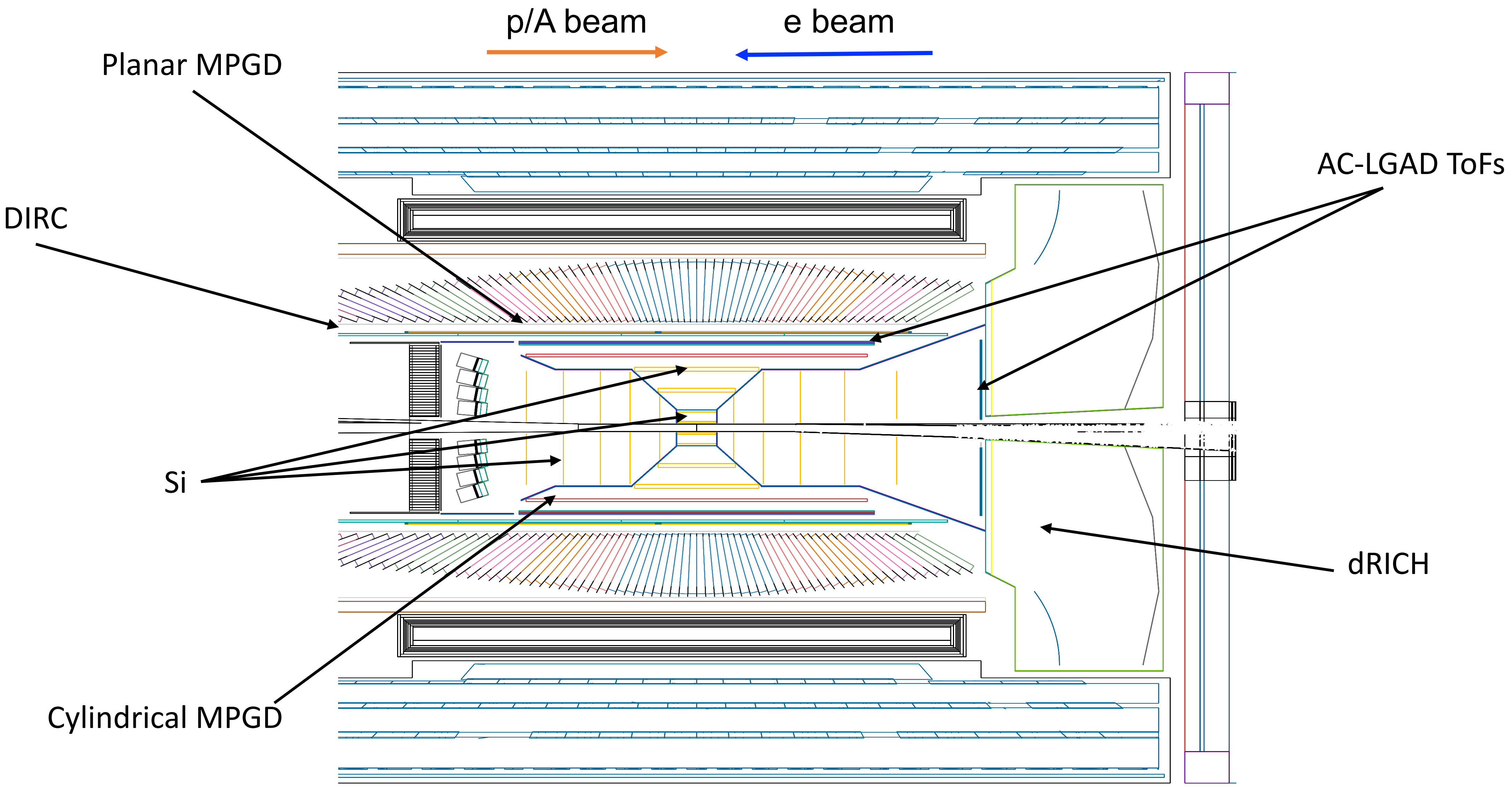




**p: 41 GeV, 100 to 275 GeV** | p/A beam → | ← e beam | **e: 5 GeV to 18 GeV**



[Slide from RHIC User Meeting]

# ePIC Reference Detector



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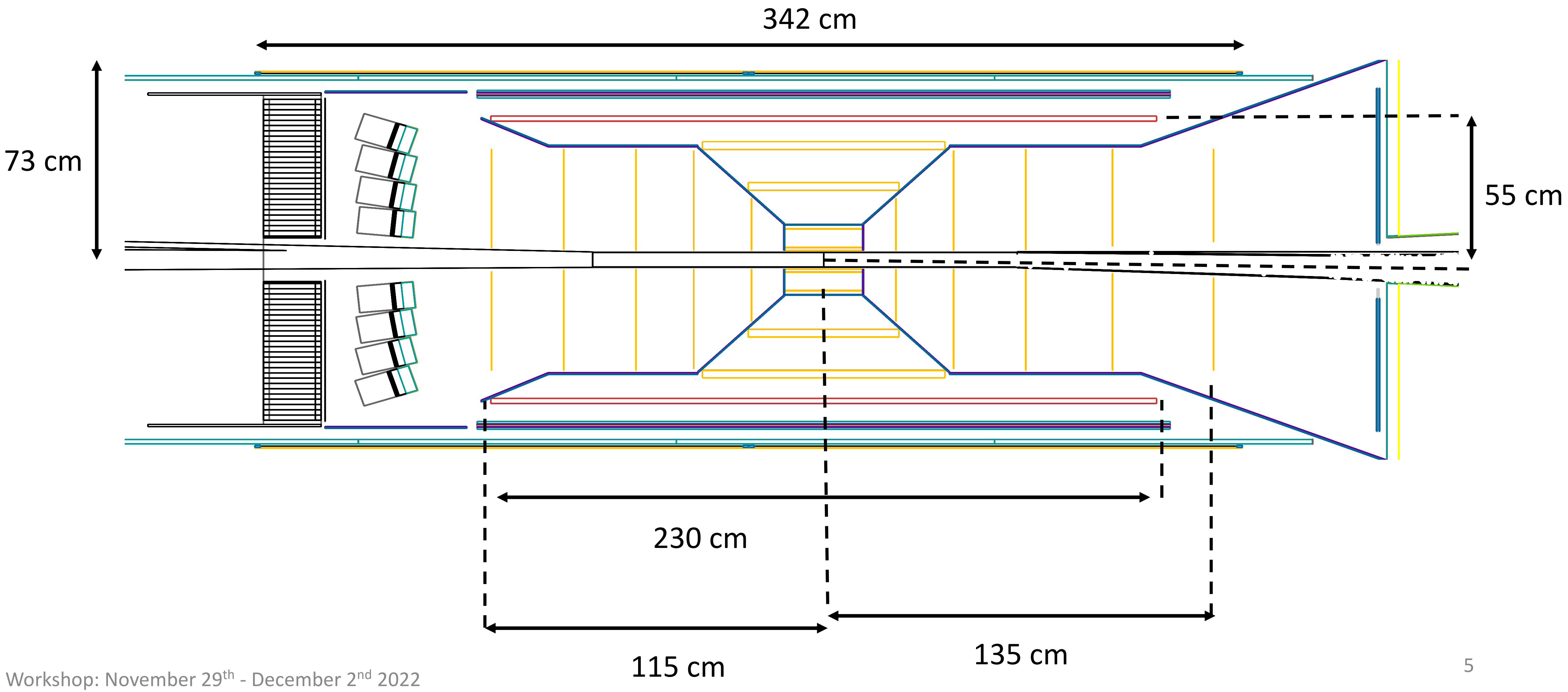
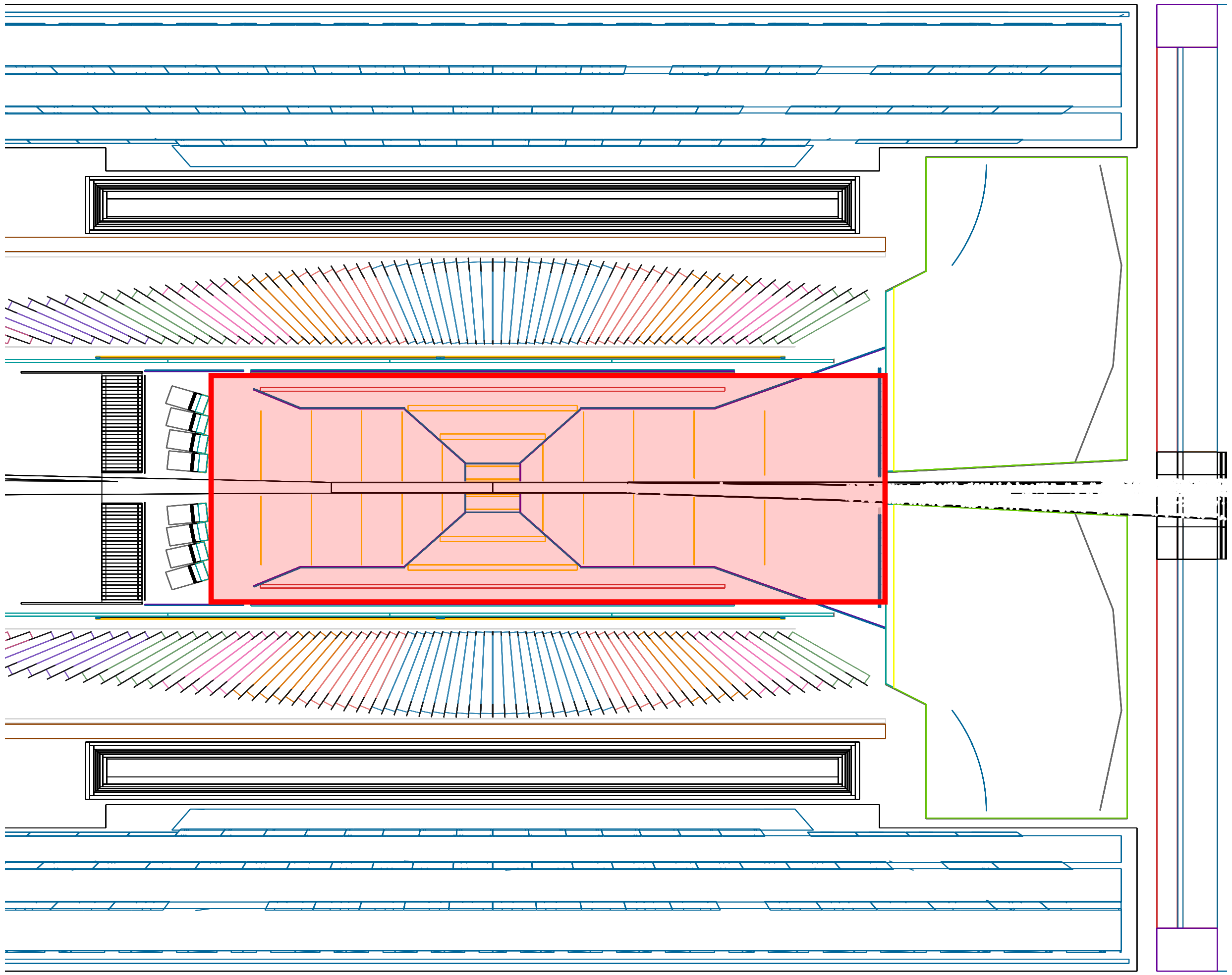


# Potential Roles of MPGDs in ePIC

## Two main MPGD applications:

- **Track reconstruction**
  - Complement the Si layers by providing additional hit points for pattern recognition and aid in track finding
  - Generally located at larger radii outside of the Si layers
  - Cylindrical geometry in barrel region



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- **Track reconstruction**
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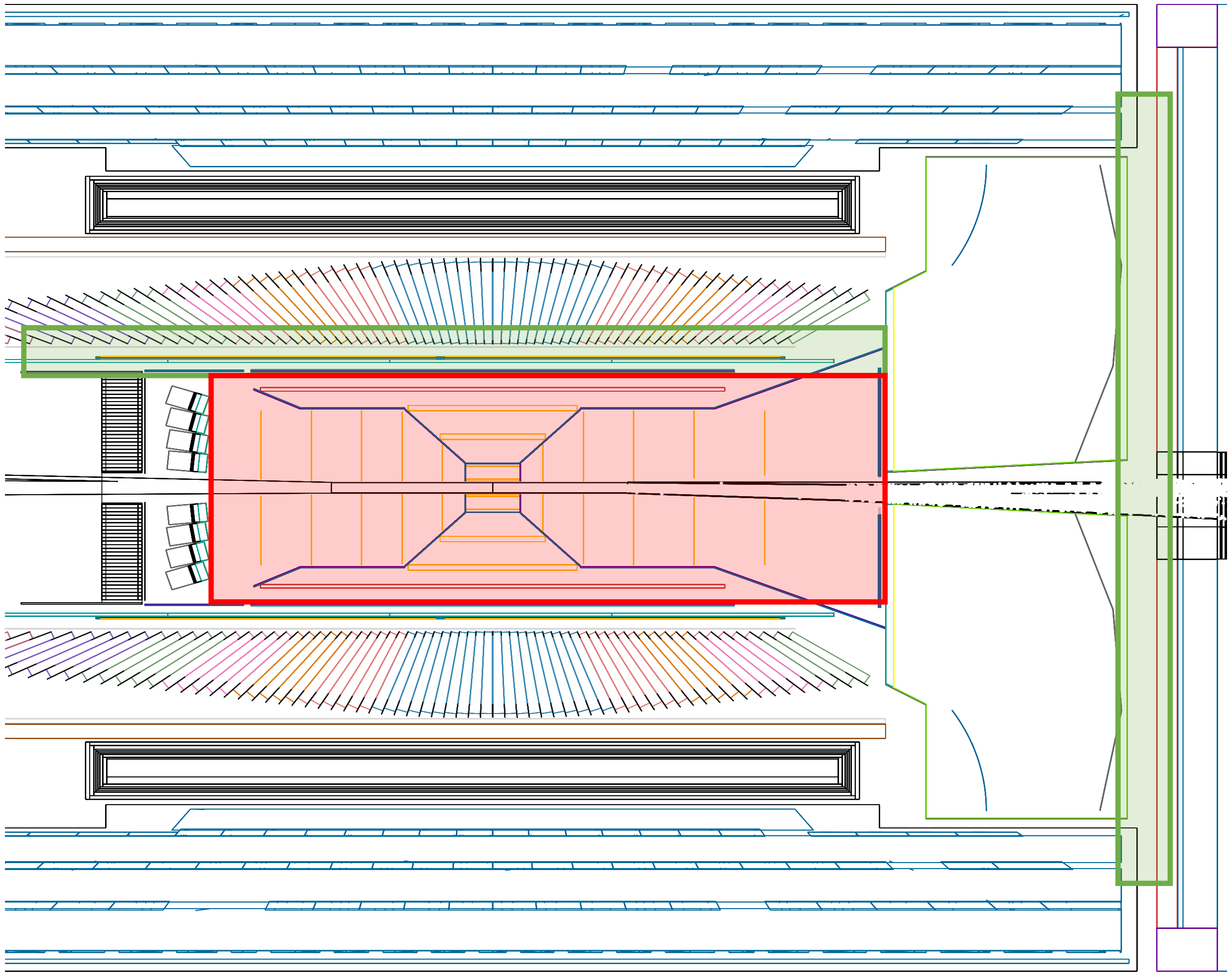
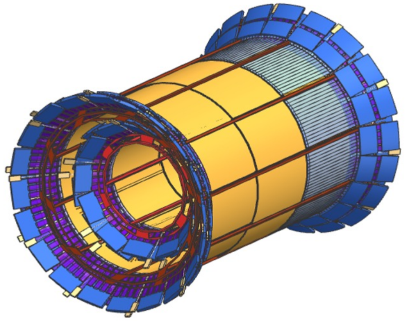
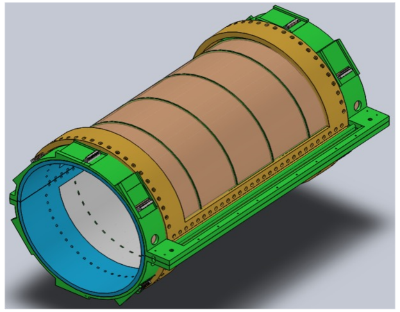
- **Aiding PID Systems**
  - Precision trackers used to provide angular information about the track passing through the PID detector.
  - Help seed Cherenkov ring reconstruction
  - Thin gap MPGDs with planar/disk geometry



# Cylindrical MPGDs

## Development of cylindrical MPGD for ePIC central tracker





1. **Ongoing effort:** Cylindrical MPGD with ~3 mm drift gap and provides single space point
   - Technology of choice: Micromegas (CEA Saclay, Yale U., BNL)
   - Fall back Technology: $\mu$RWELL (Florida Tech, BNL, Jlab, Temple U.)
   - R&D focus: Large area, low mass, 2D readout structures

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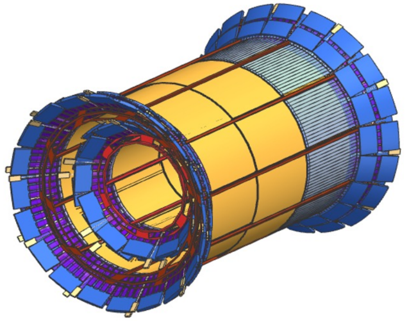

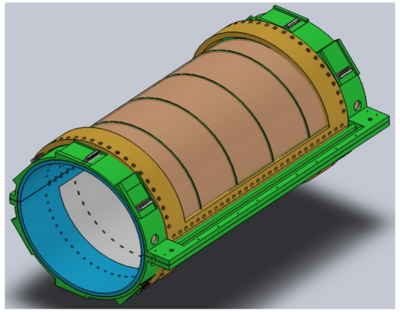

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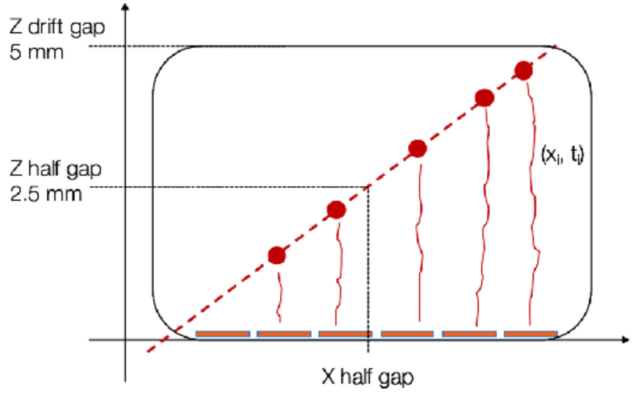
2. **Alternative approach:** Cylindrical MPGD operating in $\mu$-TPC mode to measure vector information of the track
   - Attractive option for pattern recognition layer in central barrel tracker
   - Single detector provides vector information of the track rather than just single point
   - R&D focus: Demonstrate proof of principle concept with a small cylindrical prototype




https://doi.org/10.1109/NSSMIC.2017.8532927

# Cylindrical MPGDs: Micromegas

## Motivation

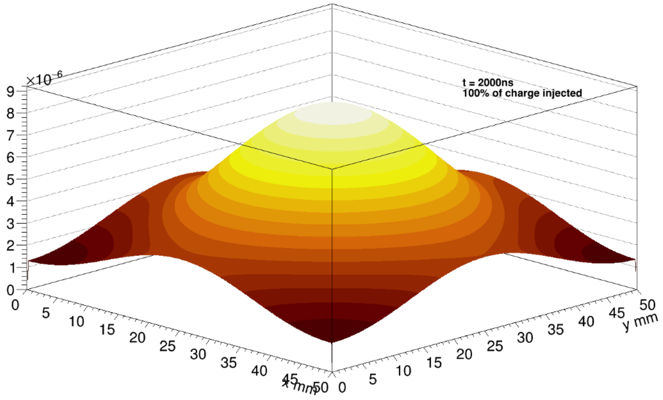
- Build a full (no acceptance gaps) light-weight modular Micromegas barrel tracker to complement the silicon vertex detector
- Take the existing 1D MM technology from CLAS12 and upgrade it to be **2D readout**

## Objectives

- Optimization of the 2D readout to reach resolutions of ~150um with the fewest possible number of channels on small prototypes
- Design and construction of several small prototypes with different r/o patterns and different resistivity values

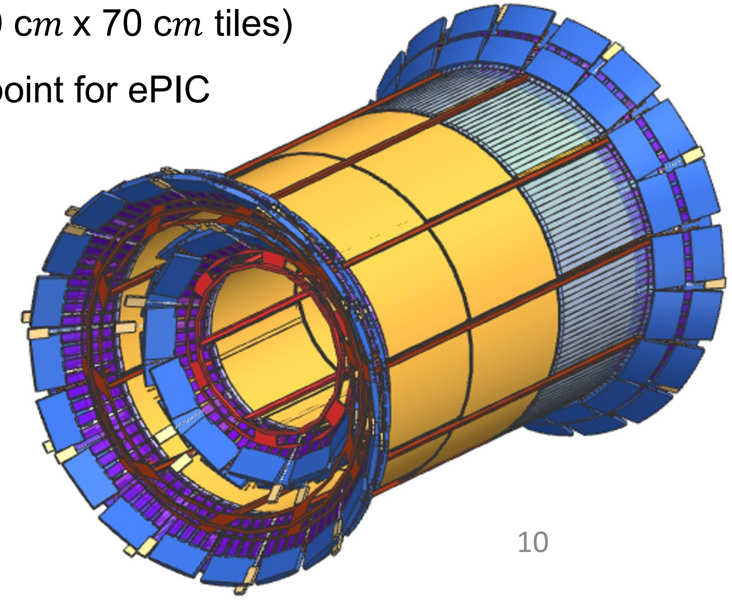
## Main activities

- **Finite difference element simulation of the resistive layer** coupled with Garfield++ output
- This tool will be calibrated with prototype results




*Example of the charge density on the resistive surface 2µs after injection*

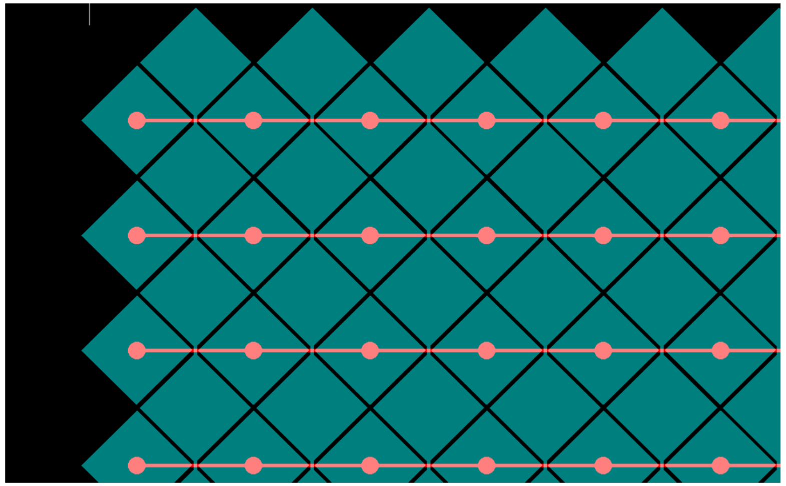
- First **CAD design** of the whole Micromegas tracker for the ATHENA proposal (50 $cm$ x 70 $cm$ tiles)
- Being used also as starting point for ePIC



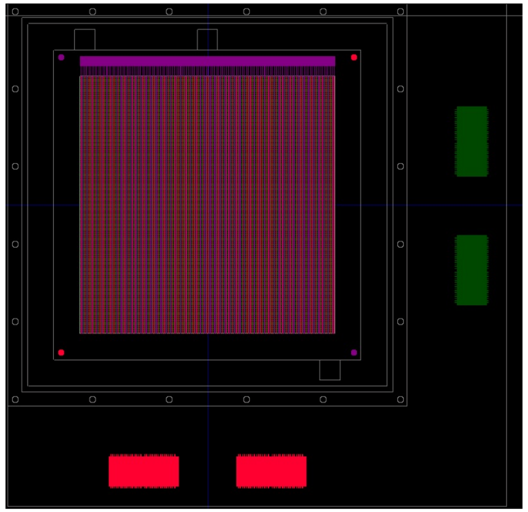
## Prototype design and R&D

- **Amplification Kapton (AK)**: a Kapton foil with resistive paste stretched on a carbon fiber frame and then bulk with a micromesh
  - AKs with different resistivity will be glued together with Kapton foils with 2D readout patterns
  - First tests are promising: holding up to 900V between resistive layer and the mesh in air
- **2D readout patterns:**
  - Orthogonal strips
  - ASACUSA like readout

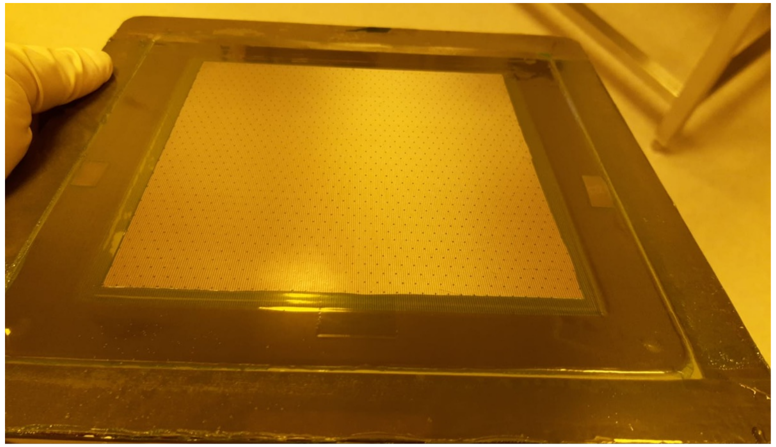
ASACUSA-like readout



Orthogonal strip readout



Bulked Kapton foils with a resistive layer

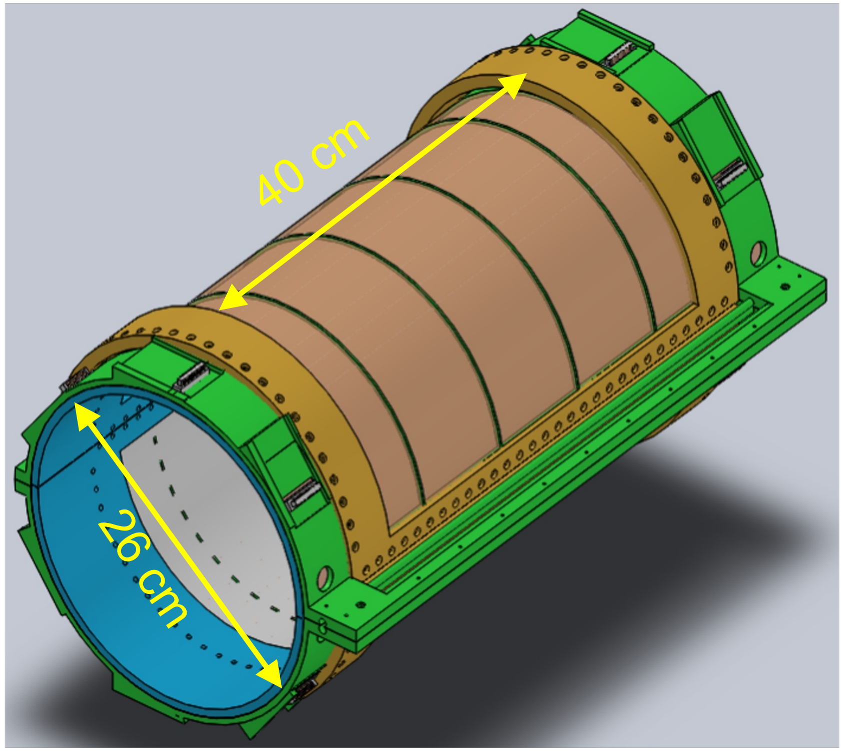


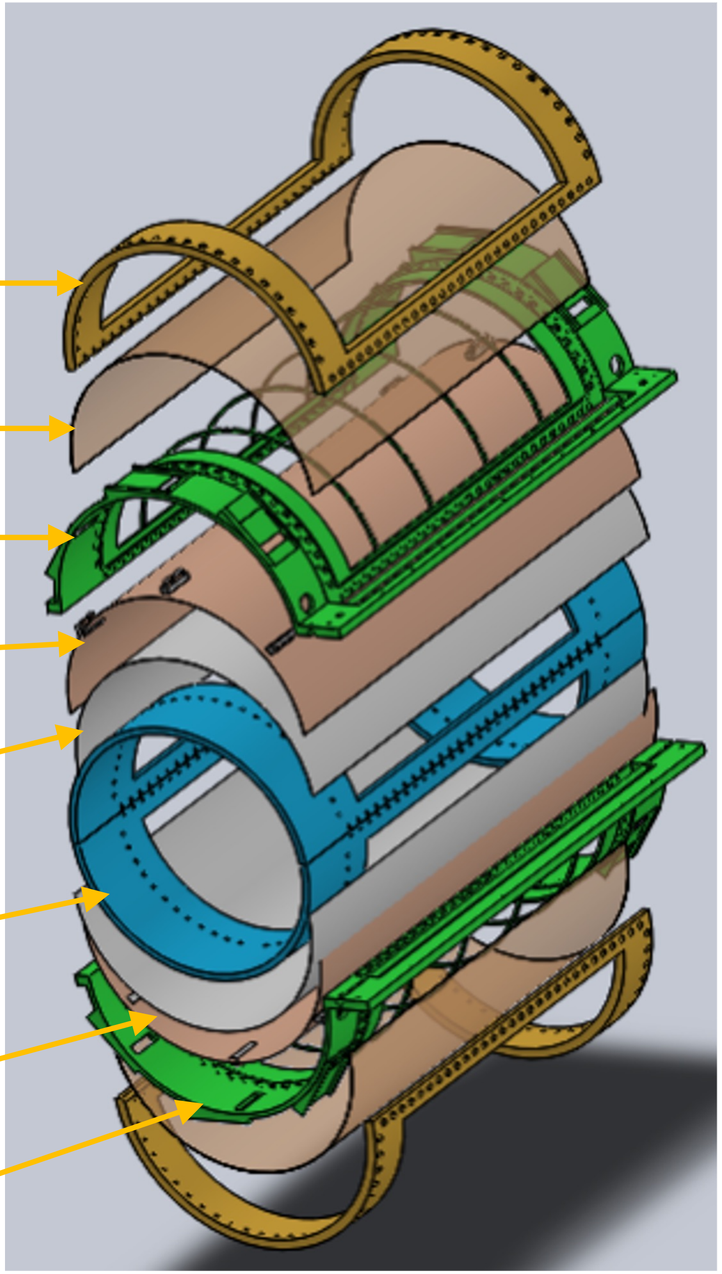
# Cylindrical MPGDs: $\mu$RWELL



## Design of mechanical structure for the cylindrical $\mu$RWELL prototype with 3mm drift gap

- Prototype consists of 2 half cylinder chambers with different readout structures
  - **CapaSh-$\mu$RWELL:** $\mu$RWELL /readout foil with U-V capacitive-sharing readout
  - **Zigzag-$\mu$RWELL:** $\mu$RWELL /readout foil with U-V zigzag readout
- Set of three support frames per half-cylinder (main frame + 2 clamps)

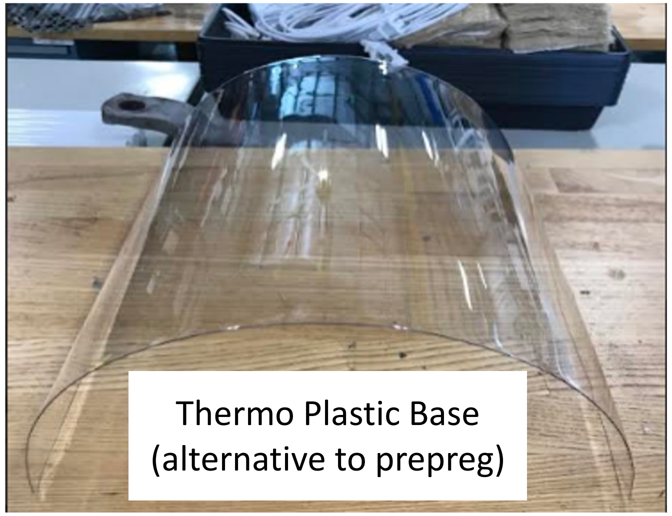


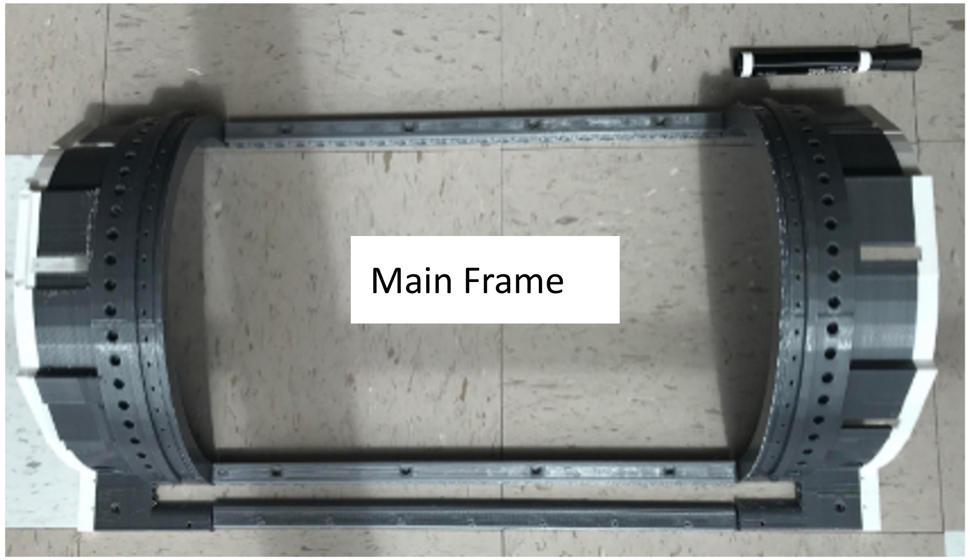
# Cylindrical MPGDs: $\mu$RWELL

## Very early 3D printed prototypes

Mock-up assembly of a half-cylinder with the inner & outer clamps, the main frame, and a Kapton "drift" foil



Thermo Plastic Base
(alternative to prepreg)



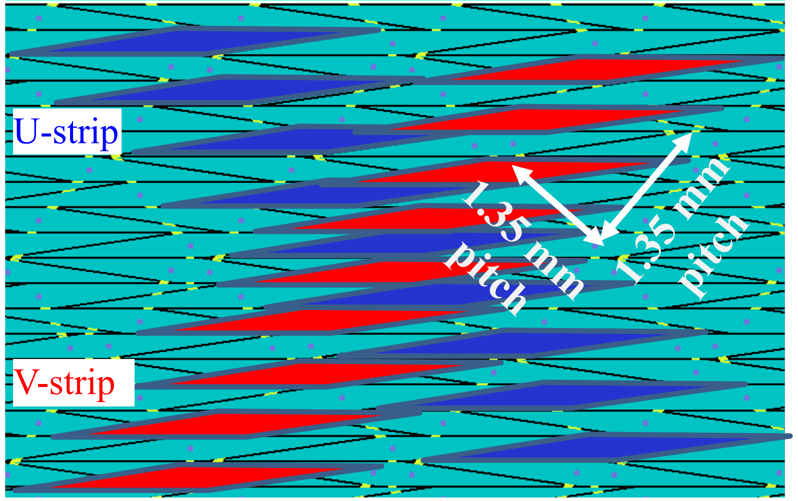
Main Frame

# Cylindrical MPGDs: $\mu$RWELL Readout Structures

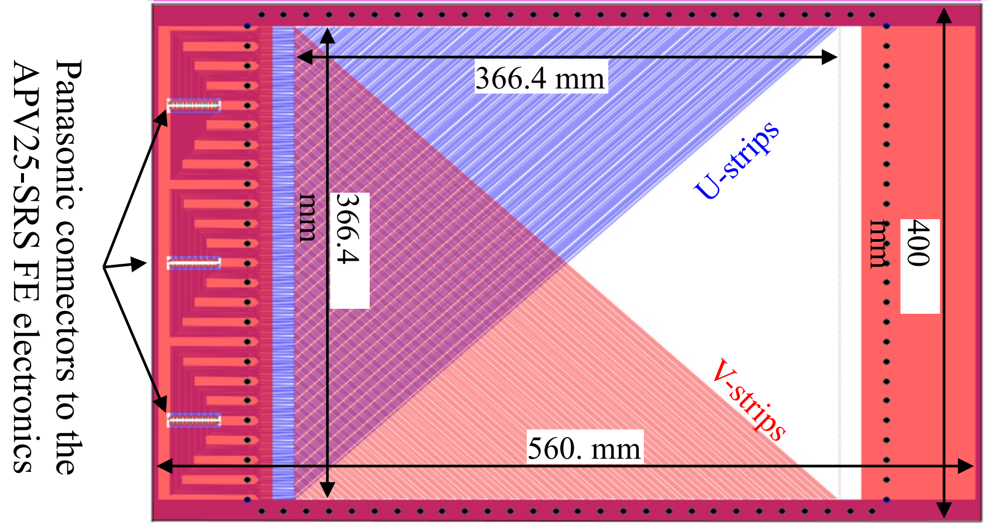
## Design of $\mu$RWELL readout composite foil structures

- Single foil design, same $\mu$RWELL amplification, two different U-V readout structures
  - 2D zigzag readout (BNL)
  - Capacitive-sharing straight strip (JLab)
- Common readout template design
  - Strip pitch: 1.35 mm → 768 strips / half cylinder
  - **Target:** Nominal space point resolution **better than** 100 $\mu$m for perpendicular tracks

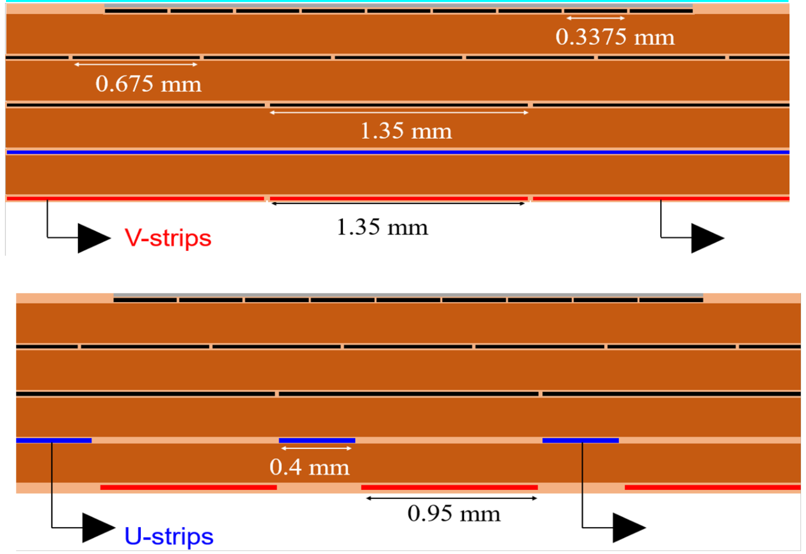
U-V zigzag readout concept (BNL)




common U-V readout template design



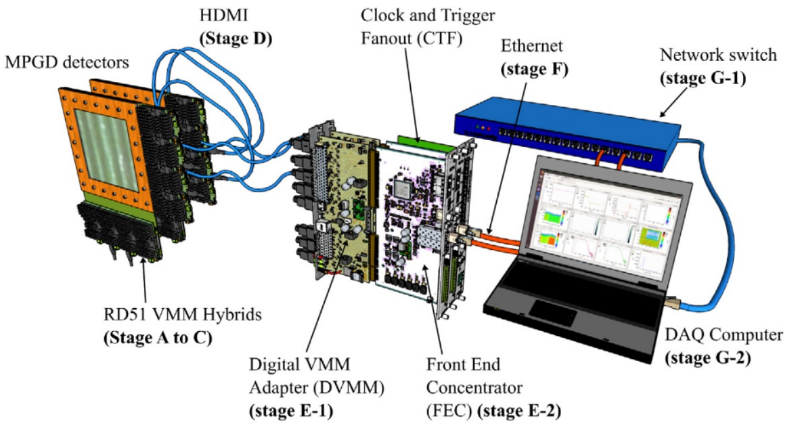

capacitive-sharing readout concept (JLab)




https://doi.org/10.1016/j.nima.2022.167782

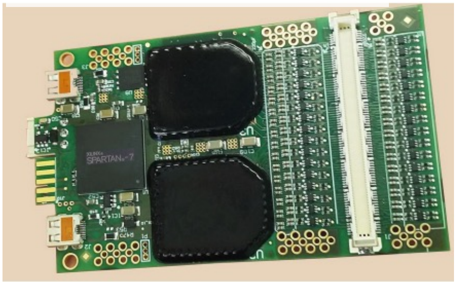
# Cylindrical MPGDs: $\mu$RWELL Readout and DAQ

## Small scale VMM-SRS electronics and DAQ system




- ❑ **Goal:** To commission a small-scale VMM-SRS system to equip and readout a portion of the μRWELL cylindrical prototype tracker with VMM3a ASICs
  - Develop VMM plugin for **RCDAQ**
  - Partially equip cylindrical μRWELL prototype with 4 VMM3a hybrids
  - Assess VMM3a as potential EIC ASIC

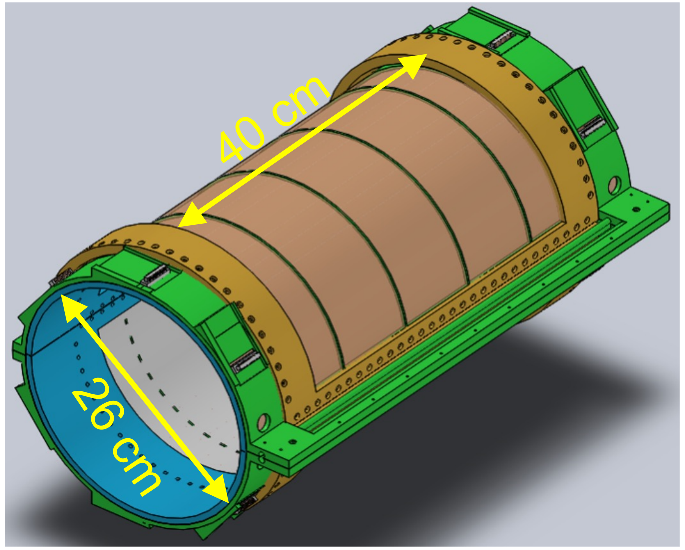

VMM hybrid card



# Cylindrical MPGDs: $\mu$RWELL in $\mu$-TPC Mode

## Design of cylindrical $\mu$RWELL prototype operating in $\mu$-TPC mode

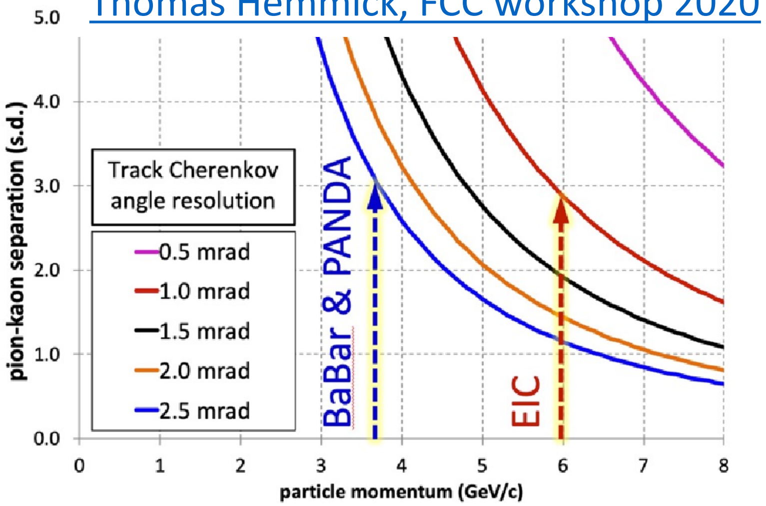
- **Motivation**
  - Single MPGD layer with larger drift gap that operates in $\mu$-TPC mode
  - Measure the tracklet direction and provide direction resolution of order 1 mrad
  - Ideal for pattern recognition to match track measured by Si-tracker
  - Smaller detector envelop than multiple MPGD pattern recognition layers (less cost and services)
- **Prototype Design**
  - Construct a third half cylinder $\mu$RWELL prototype base on the same design and mechanical structure.
  - Expand drift gap to 15 mm and reduce strip pitch to 400 $\mu m$



# MPGD Tracking Layers for PID Detectors

- **Motivation**
  - Major contributor to PID separation performance is the determination of Cerenkov angle resolution
  - Improve the measurement of direction and impact position of charged particles that hit the PID detectors by measuring a high precision hit (< 100 $\mu m$) after the particle has traversed all materials in the tracker and PID detector.

Thomas Hemmick, FCC workshop 2020



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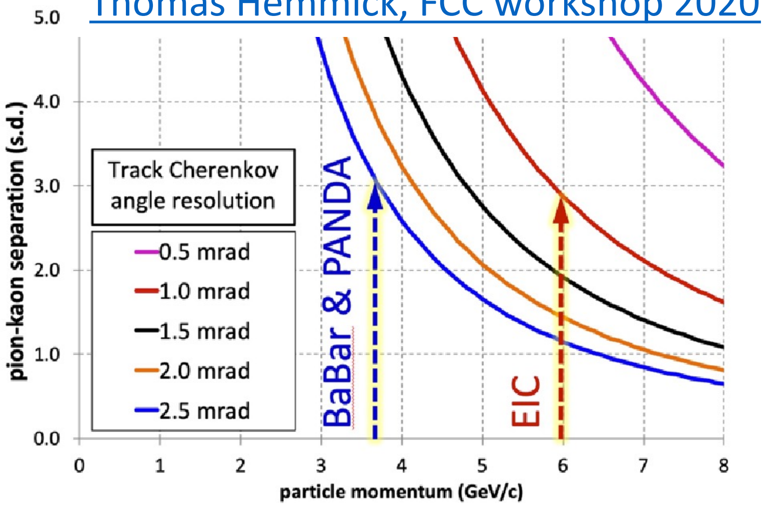
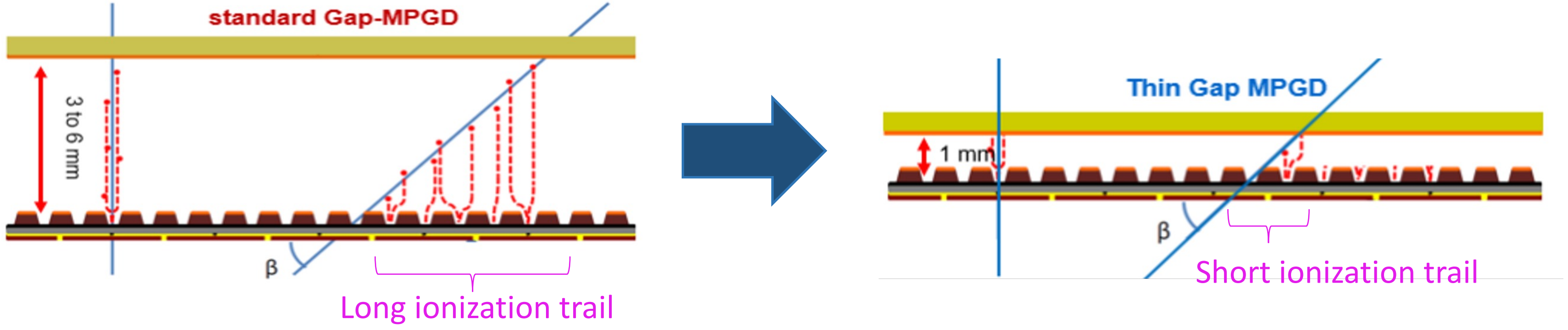
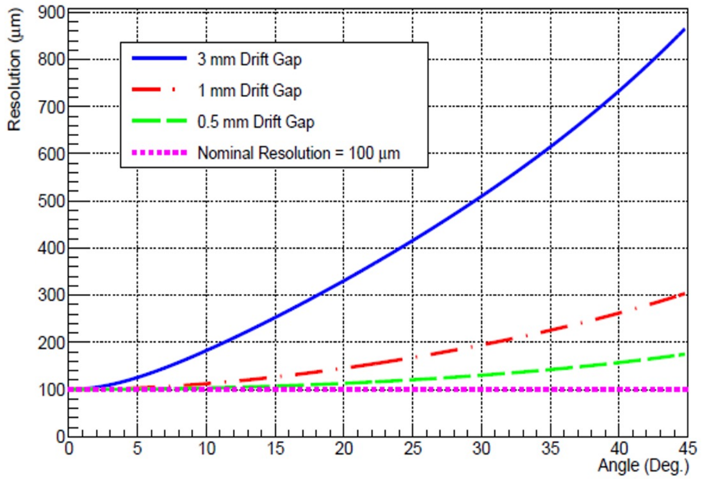
- **Prototype Design**
  - MPGD layer needs to cover a large angular acceptance, but resolution degrades with angle → General EIC issue, not just for ePIC
  - Thin-gap MPGDs/ hybrid-MPGDs could provide a solution
    - Proposal submitted to generic EIC R&D program (proposal #23)

Thomas Hemmick, FCC workshop 2020




**Spatial resolution v.s. track angle for various drift gaps**

# Summary

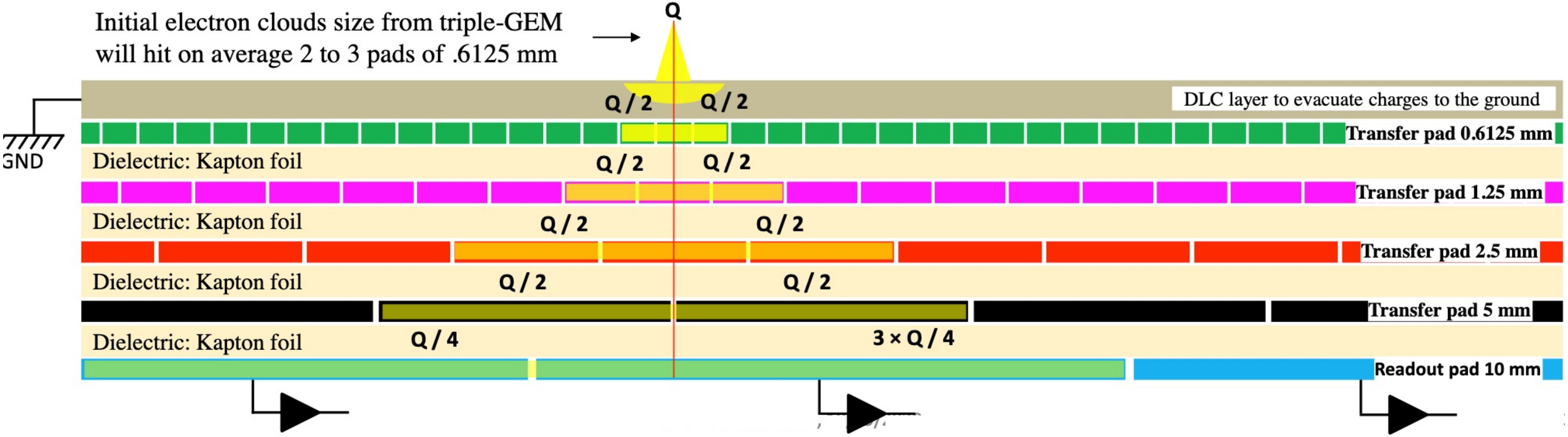
- eRD-108 is developing ePIC specific MPGDs to address two general areas:
  1. Pattern recognition for track finding/fitting
  2. Provide additional tracking information to PID systems to aide in Cerenkov ring reconstruction

- Develop large area cylindrical MPGDs based on both micromegas and $\mu$RWELL technology
  - Optimize 2D readout structures
  - Investigate cylindrical $\mu$RWELL detectors with
    - ~3 mm drift gap single space point
    - ~15 mm drift gap detector operating in $\mu$TPC mode
    - APV and VMM ASICs

- Develop large area MPGD detectors to provide precise space point resolution for aiding PID detectors
  - Thin gap hybrid-MPGDs could potentially meet this need (see EIC generic proposal #23)

# Backup

# Capacitive-Sharing Readout




[Kondo Gnanvo, RD51 Collaboration Meeting, 2020]

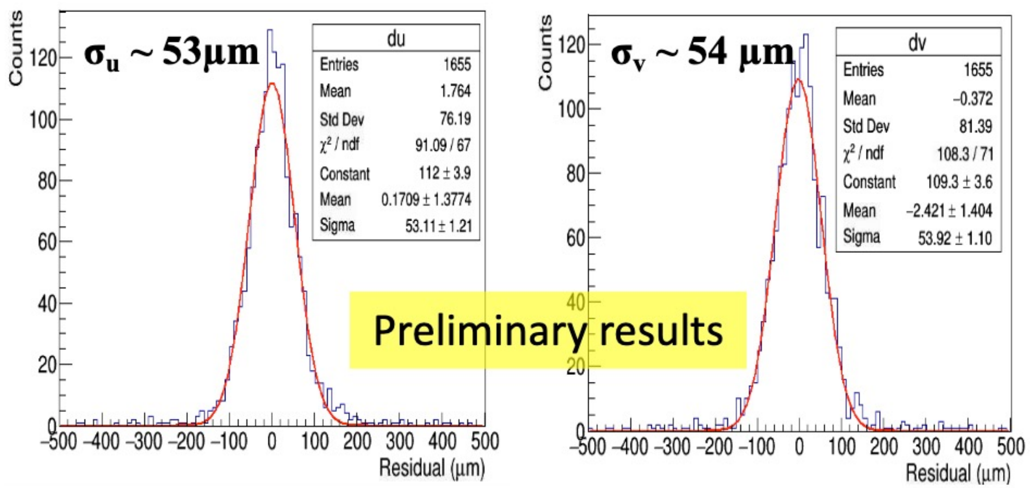
# Planar MPGDs: $\mu$RWELL Readout Structures

## 2D readout structures on small planar $\mu$RWELLs with 3 mm drift gaps

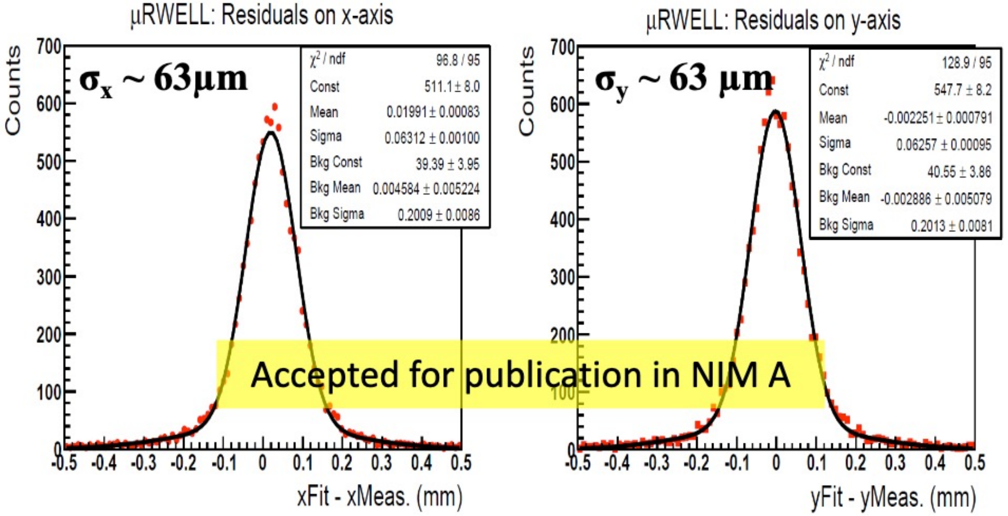
- ❑ Low channel counts and high resolution
  - o 2D zigzag readout structure →1.5 mm pitch
  - o 2D straight strip capacitive-sharing readout structure → 800 $\mu m$ pitch
  - o Suitable for large detectors
- ❑ Concepts will be applied to cylindrical $\mu$RWELL

➢ More details at [2022 RHIC AGS Users Meeting presentation]

2D Zigzag



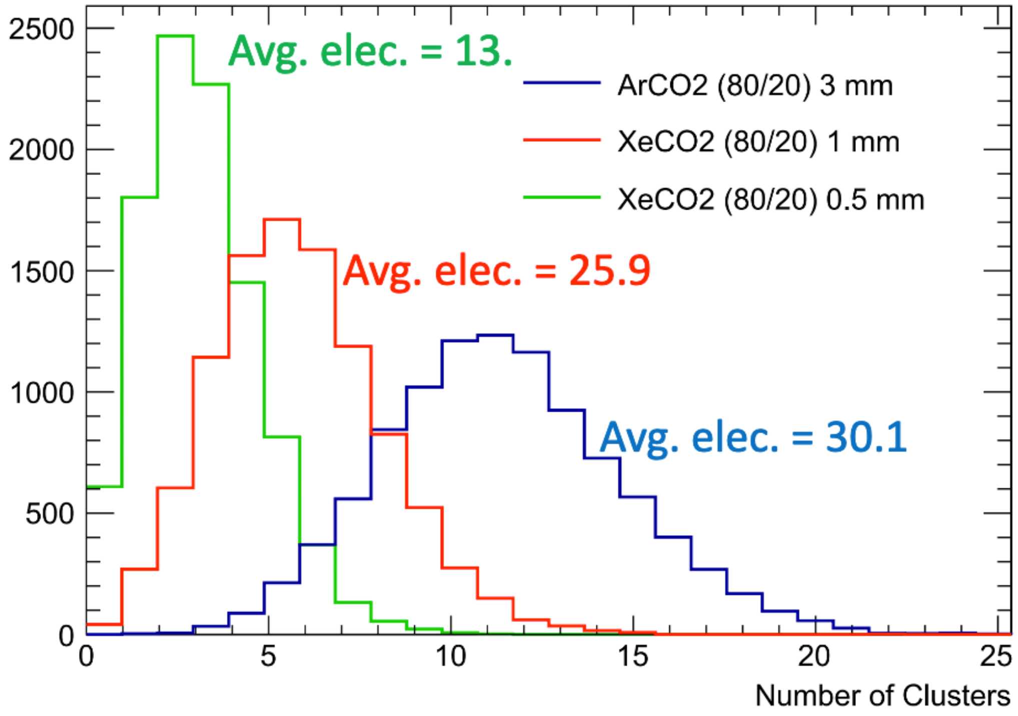

Capacitive-sharing



# MPGD Tracking Layers for PID Detector

| Gas | Z | A | δ (g/cm³) | $E_{ex}$ | $E_i$ (eV) | $I_0$ | $W_i$ | dE/dx (MeV/g cm⁻²) | dE/dx (keV/cm) | $n_p$ (i.p./cm) a) | $n_T$ (i.p./cm) a) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_2$ | 2 | 2 | $8.38 \times 10^{-5}$ | 10.8 | 15.9 | 15.4 | 37 | 4.03 | 0.34 | 5.2 | 9.2 |
| He | 2 | 4 | $1.66 \times 10^{-4}$ | 19.8 | 24.5 | 24.6 | 41 | 1.94 | 0.32 | 5.9 | 7.8 |
| $N_2$ | 14 | 28 | $1.17 \times 10^{-3}$ | 8.1 | 16.7 | 15.5 | 35 | 1.68 | 1.96 | (10) | 56 |
| $O_2$ | 16 | 32 | $1.33 \times 10^{-3}$ | 7.9 | 12.8 | 12.2 | 31 | 1.69 | 2.26 | 22 | 73 |
| Ne | 10 | 20.2 | $8.39 \times 10^{-4}$ | 16.6 | 21.5 | 21.6 | 36 | 1.68 | 1.41 | 12 | 39 |
| Ar | 18 | 39.9 | $1.66 \times 10^{-3}$ | 11.6 | 15.7 | 15.8 | 26 | 1.47 | 2.44 | 29.4 | 94 |
| Kr | 36 | 83.8 | $3.49 \times 10^{-3}$ | 10.0 | 13.9 | 14.0 | 24 | 1.32 | 4.60 | (22) | 192 |
| Xe | 54 | 131.3 | $5.49 \times 10^{-3}$ | 8.4 | 12.1 | 12.1 | 22 | 1.23 | 6.76 | 44 | 307 |
| $CO_2$ | 22 | 44 | $1.86 \times 10^{-3}$ | 5.2 | 13.7 | 13.7 | 33 | 1.62 | 3.01 | (34) | 91 |
| $CH_4$ | 10 | 16 | $6.70 \times 10^{-4}$ | | 15.2 | 13.1 | 28 | 2.21 | 1.48 | 16 | 53 |
| $C_4H_{10}$ | 34 | 58 | $2.42 \times 10^{-3}$ | | 10.6 | 10.8 | 23 | 1.86 | 4.50 | (46) | 195 |

MAGBOLTZ simulation




Heavier gas Xe and Kr produces more primary and total ionization compared to Ar. Suitable for thin gap detector.
(slide from EIC generic proposal #23)