Tracking WG Status Update

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EIC Detector 1 Global Detector / Integration WG

06 June 2022

Meetings organisation & Information

- The Tracking WG meetings will take place bi-weekly on Thursday at 11am EDT.
- Indico category: https://indico.bnl.gov/category/404/
- Mailing list: https://lists.bnl.gov/mailman/listinfo/eic-projdet-tracking-l
- Please subscribe if you have not done so yet.
- **Coordination with other WGs - Contact liaison are being identified for**
  - DAQ/Electronics/Readout: Kondo (MPGD), Jo (TBC, Si)
  - Computing & Software/Simulation Production & QA WG: Matt, Nicholas
  - PID: Laura (AC-LGAD), more TBC

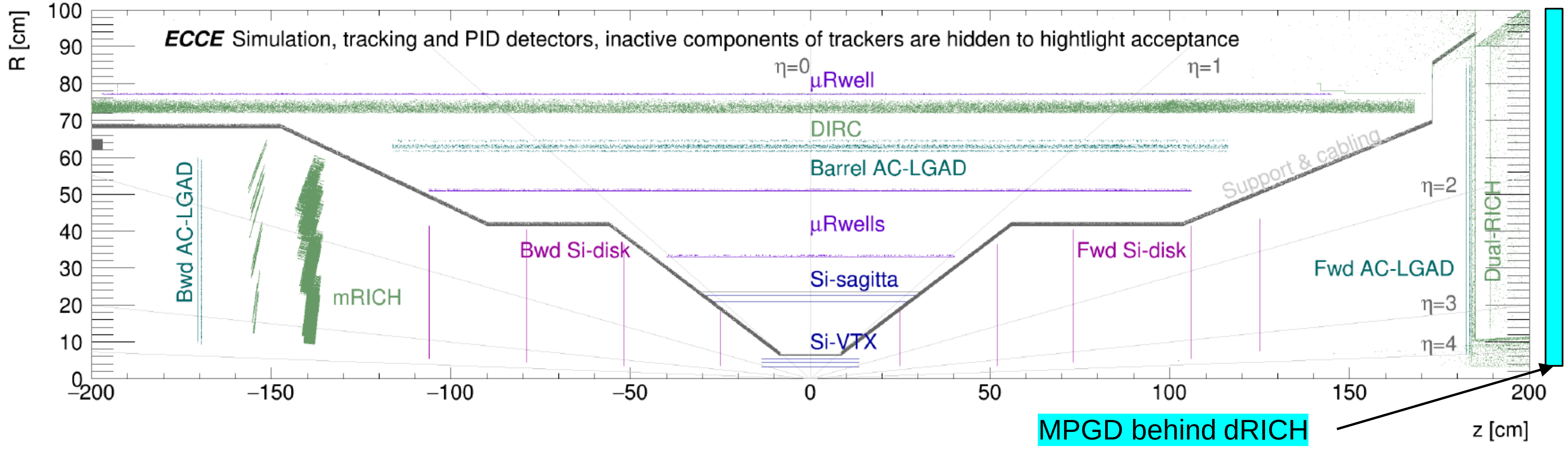
EIC detector 1 tracking detector layout

Si vertex & tracker:

- Vertex layers:
  - 3 layers
- Barrel tracker:
  - 2 sagitta layers 0.05% X0 per layer ➔ 0.55% X0 / layer
  - 1 AC-LGAD layer (between DIRC & uRWELL layer
- Electron end cap tracker:
  - 4 MAPS disks
  - 1 AC-LGAD layer behind mRICH disks
- Hadron end cap tracker:
  - 5 MAPS disks
  - AC-LGAD layer in front of dRICH

MPGD layers:

- 2 Tracking layers:
  - 2 Cylindrical / curve tiles layers between the Si sagitta and hpDIRC:
  - complement the Si trackers at larger radius for tracking performance
- 3rd layers ➔ hpDIRC MPGD support tracker
  - Impact point for DIRC ring seeding ➔ Tracking / PID integration
- Hadron end cap layer: dRICH MPGD support tracker?
  - Impact point & for dRICH ring seeding ➔ Tracking / PID integration



Region	Layer index	technology	radius	minimum z	maximum z	pixel pitch
barrel	1	MAPS	3.3 cm	-13.5 cm	13.5 cm	10 μm
⋮	2	⋮	4.35 cm	-13.5 cm	13.5 cm	10 μm
⋮	3	⋮	5.4 cm	-13.5 cm	13.5 cm	10 μm
⋮	4	⋮	21.0 cm	-27 cm	27 cm	10 μm
⋮	5	⋮	22.68 cm	-30 cm	30 cm	10 μm
Region	Layer index	technology	radius	minimum z	maximum z	strip pitch
barrel	1	μRWELL	33.14 cm	-40 cm	40 cm	400 μm
⋮	2	⋮	51 cm	-106 cm	106 cm	400 μm
⋮	3	⋮	77.0 cm	-197 cm	145 cm	400 μm
Region	Disk index	technology	z location	inner radius	outer radius	pixel pitch
e-endcap	1	MAPS	-25 cm	3.5 cm	18.5 cm	10 μm
⋮	2	⋮	-52 cm	3.5 cm	36.5 cm	10 μm
⋮	3	⋮	-79 cm	4.5 cm	40.5 cm	10 μm
⋮	4	⋮	-106 cm	5.5 cm	41.5 cm	10 μm
Region	Disk index	technology	z location	inner radius	outer radius	pixel pitch
h-endcap	1	MAPS	25 cm	3.5 cm	18.5 cm	10 μm
⋮	2	⋮	49 cm	3.5 cm	36.5 cm	10 μm
⋮	3	⋮	73 cm	4.5 cm	40.5 cm	10 μm
⋮	4	⋮	106 cm	5.5 cm	41.5 cm	10 μm
⋮	5	⋮	125 cm	7.5 cm	43.5 cm	10 μm

Specific charge for Tracking WG

- Simulations:
  - Break down of simulation tasks in https://docs.google.com/spreadsheets/d/1Jp1-V7MavZFejn2SG185YarbMIpGCByGfF7yz4Y-Azc/edit?usp=sharing
- Technology reviews *(back up slides)*
  - Identify risks & fallback solutions for each technology
  - Establish the timelines to CD4
  - Close coordination with the detector consortia (EIC-SC, eRD108)
- EIC Tracking Detector configuration *(back up slides)*
  - By July EICUG ➔ the baseline configuration "*aka advanced conceptual design*" of the tracking detector is established
    - We know which technology goes where and basic performance expectation
- Requirements inputs from the physics WGs
  - List of key tracking requirements such as momentum resolution, vertex and projection spatial resolutions.

Considerations on the Si vertex and tracker

- Vertex layers
  - The radii need to be adjusted as 5 mm clearance from the beam pipe are needed because of beam pipe backout.
- Tracking layers
  - The material assumed in the ECCE proposal is 0.05%X/X0 per barrel layer This need to be updated to 0.55% X/X0 that is what is suggested by the EIC SC.
  - Also, check the impact on performance by switching the sagitta middle layers with the ATHENA design (i.e. smaller radii).
- Disks
  - The last disk on both side in the ECCE design is currently floating and not supported. Service cone needs updating to make the required support connections.
- Hits per track as function of rapidity and p_T/momentum
  - The average number of hits per track in the electron going direction is 3 hits on average.
  - Needs further verification in simulations.

Tracking Integration with the AC-LGAD ToF

- ❖ We plan to have joint meetings with the AC-LGAD ToF WG and here is the list of questions about the detector integration.
  - For the tracking and ToF integration, any space limitations in x-y-z for the proposed ToF in the barrel, hadron-endcap and electron-endcap regions? ➔ This is needed for the tracking geometry optimization in parallel with the ToF geometry updates.
  - We would like to get the latest hit spatial resolution of the ToF layer / disk into simulation and get the values implemented in simulation ➔ this will help us evaluate the integrated tracking performance including the ToF layer/disk.
  - Any specific tracking performance or matching or projection requirements from the ToF WG?

Considerations on the Barrel MPGD inner layers

Requirements & expectations from YR & various detector proposals:

- Low mass < 0.5% X0 per layer for all barrel MPGD layers
- Spatial resolution (50 µm – 100 µm) for all barrel MPGD layers in both phi and z directions
- Full coverage in eta and phi ➔ no dead area

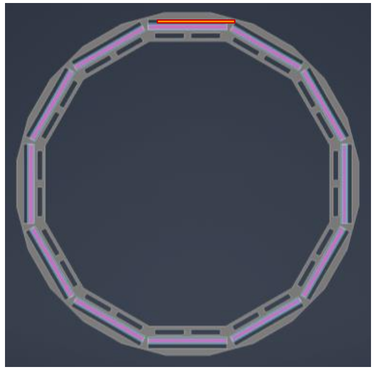
> - We will have to revisit some of these expectations and relax the constraints where possible
> - This should come from tracking simulation results and physics requirements
> - The technologies are known (micromegas or µRWELL) but actual design strongly depends on requirements

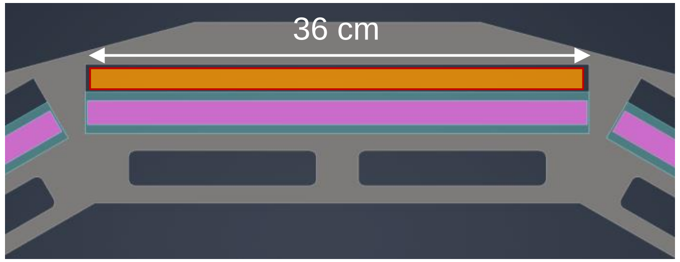
Challenges ➔ No showstopper

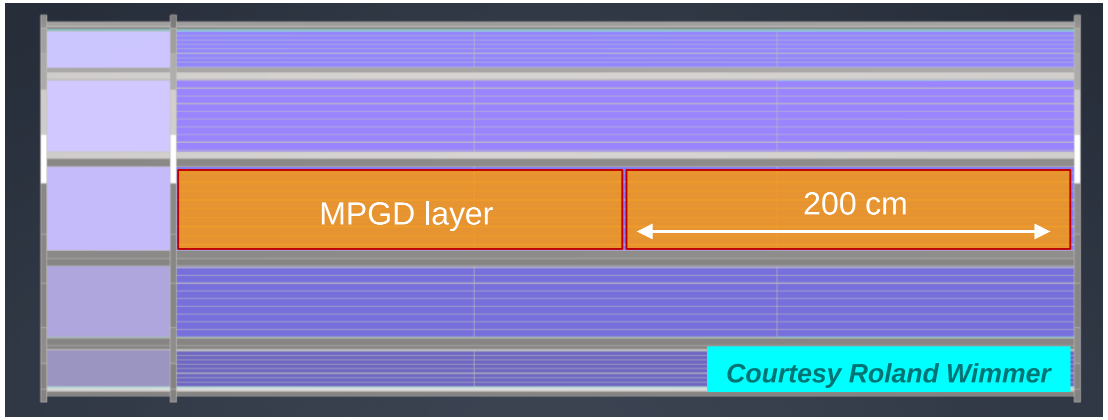
- **Large area & low mass** ➔ < 0.5% X0 will be very challenging
- **Low mass & 2D readout** ➔ at this level of low mass, material budget of readout is a major contribution to the overall thickness regardless the MPGD technology
- **Spatial resolution** ➔ degradation of resolution with incoming track angle
  - Main concern is the spatial resolution requirements at large angle in z direction
  - 50 µm–100 µm will be extremely challenging (quasi impossible with MPGDs) at large angle ➔ more on following slides
  - excellent spatial resolution (50 µm–100 µm) uniform across the range in phi direction

Considerations on the MPGD support layers for PID

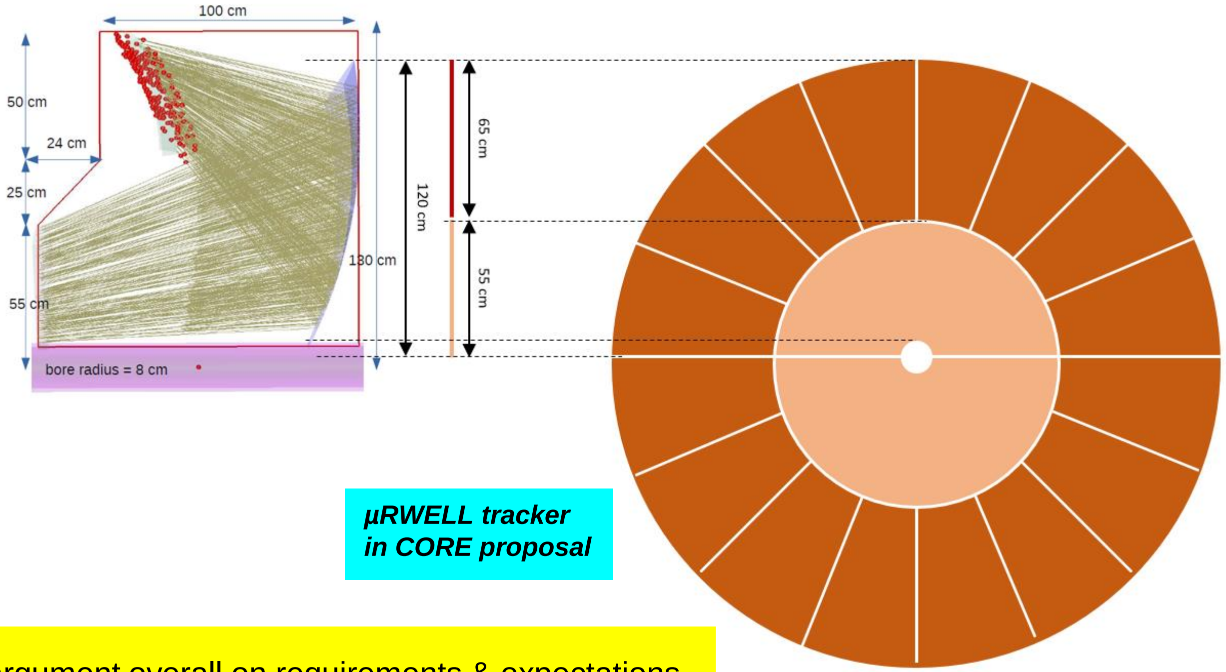
MPGD layer behind hpDIRC: Ring reco. seeding







MPGD layer behind dRICH: Ring reco. seeding



- ❖ Same argument overall on requirements & expectations
- ❖ But planar configuration and moderate "low mass" requirements makes these layer less challenging

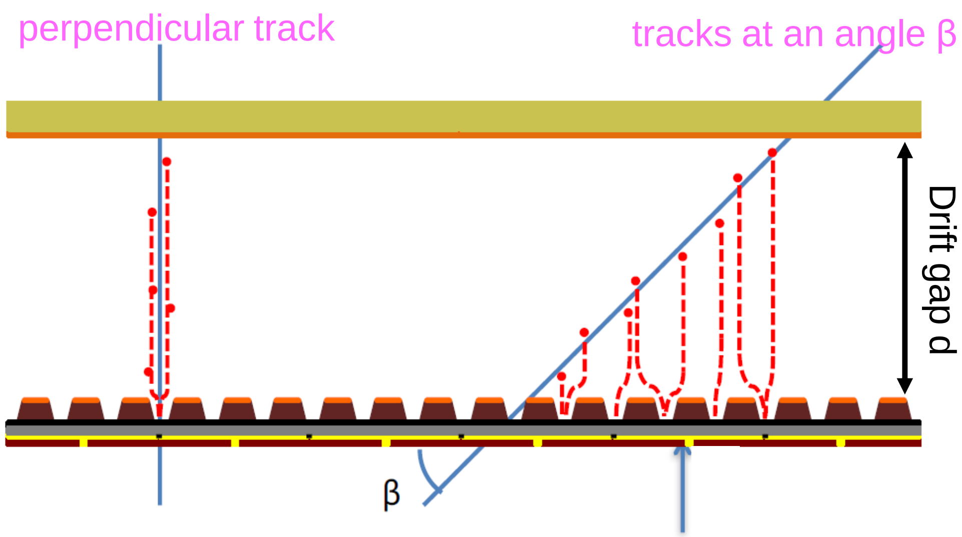
Requirements & expectations from YR & various detector proposals:

- ❖ Low mass (< 0.5% X0 / layer) is **really not** justified for this layers ➔ **1% to 2% X0** MPGD layer right in front of EM Cal. is not an issue
- ❖ But space limitation for layer behind hpDIRC ➔ 2 cm thick box space allocated for MPGD layer
- ❖ Spatial resolution (50 µm – 100 µm) for all barrel MPGD layers in both phi and z directions (or R for the disc layer behind dRICH
- ❖ Spatial resolution ➔ 50 µm–100 µm will be extremely challenging at large angle in R direction ➔ more on that on following slides

Spatial resolution: issues to address

❖ **Nominal position resolution:**

- Determined with hits from **tracks perpendicular to the detector** plane.
- Depends on technologies, anode readout structures & pitch (strips, pads, ZZ…), gas properties
- **This is what we usually refer to** when talking about the position resolution performances of MPGD detectors.
- Ranging between 50 µm – 100 µm for MPGD trackers (3 mm drift gap, & various readout technologies) when position is calculated using center of gravity (COG) / charge centroid (CC) method
- Still valid if track angle w.r.t detector plane axis is small (< 10^{o})



❖ **Incoming track at large angle**

- Ionization in drift volume generates signal **on too many strips** on the anode readout
- Number of strips with hits ➔ increases linearly drift gap d
- COG no longer valid way, spatial resolution ~ $\mathbf{d/\sqrt{12}}$ ➔ determined by drift gap
- Two approaches to recover spatial resolution performance under consideration
    - Micro-TPC (µTPC) ➔ increasing the drift gap (from 3 mm to ~ 1 - 2 cm)
    - Thin gap MPGDs ➔ reducing the drift gap (from 3 mm to 1 mm or less)

❖ We need to integrate this into simulation for tracking performance

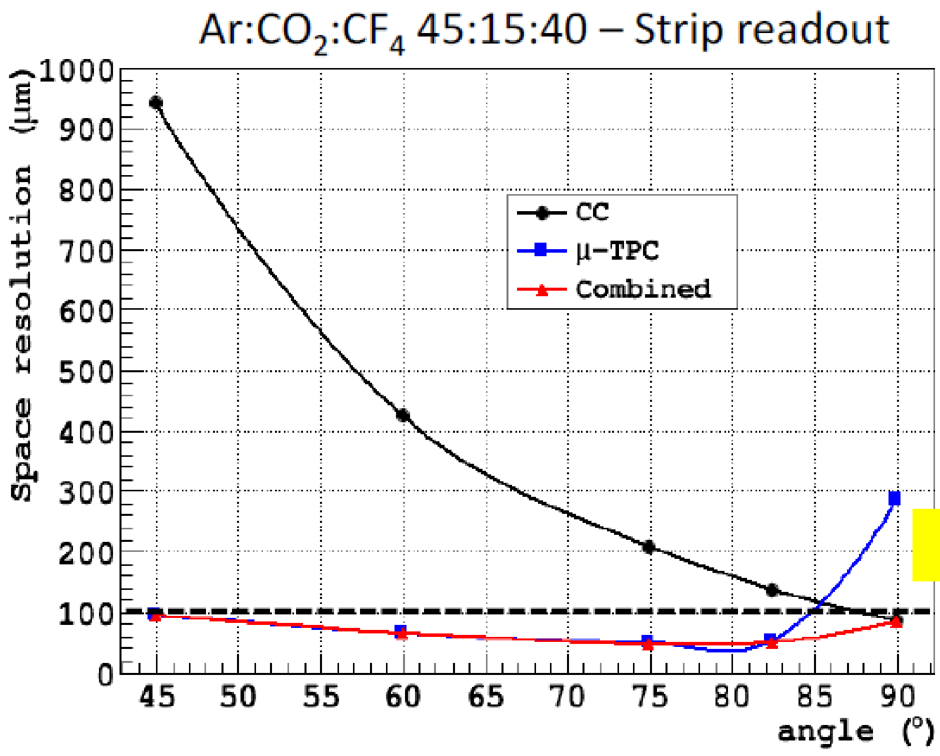
Solutions for improving resolution: MPGD-µTPC

❖ **advantage:**

- **Technique has been studied by several groups (i.e B. Azmoun @ BNL)**
- Combine COG method for small angle with µTPC for large angle
- Provide track lets track reconstruction with single detector layer
- **~100 µm spatial resolution across a wide range of angle?**
- Can be a very good option for barrel cylindrical MPGD trackers

❖ **Cons / challenges**

- Requirement on readout electronics more stringent, same situation as for GEM-TRD with eRD122
- Still, it is not clear if MPGD in µTPC mode an provide the angular resolution required for ➔ performance need to be demonstrated
- Performances in B field (Lorentz angle) need to be evaluated
- Multi-track performances need to be evaluated
- Is µTPC compatible with high performance & low channel count readout under development with eRD108?



Courtesy M. Poli Lener, CePC Workshop, Roma, 05/25/2018
https://agenda.infn.it/event/14816/contributions/26754/attachments/19109/21615/CepC_MPL_Roma_2018.pdf

Solutions for improving resolution: Thin Gap MPGD

❖ **idea:**

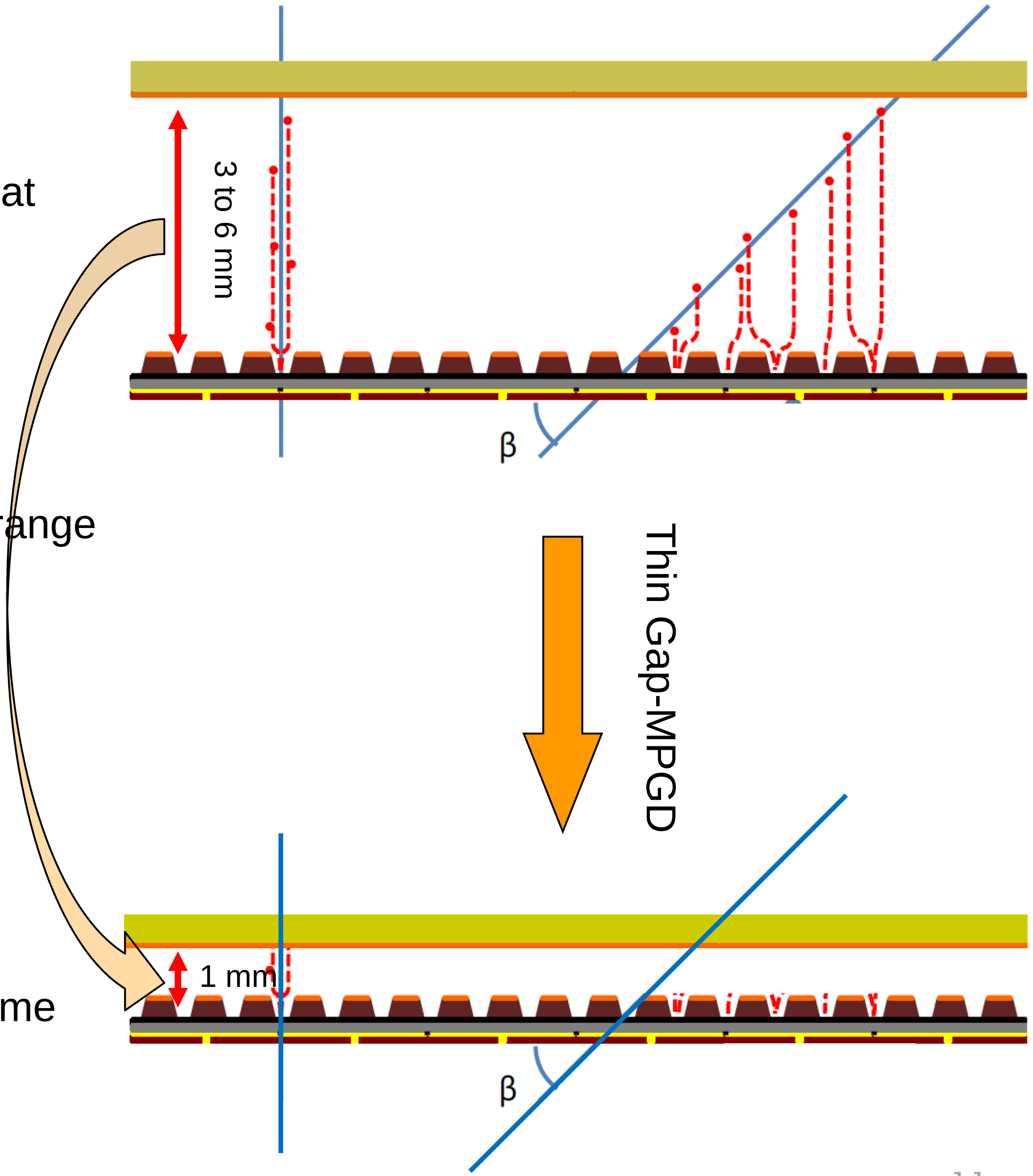
- Narrow drift gap from couples of mm (3 to 6) to sub mm level
- Spatial resolution still angle dependent but expected to be reasonable at large angle ➔ < 150 um for 30 º tracks with 1 mm drift gap

❖ **advantages:**

- Combine COG method for small angle with µTPC for large angle
- Twin TG-MPGD configuration ➔ Good angular resolution in large eta range
- Performance improvement in large B field ➔ to be demonstrated
- Should work with capacitive-sharing readout structures

❖ **Cons / challenges**

- Will require high density gas like Xe ➔ cost
- Needs extensive R&D to fully validate the idea
- Not be ideal for low mass Cyl. layer ➔ gap uniformity might require some rigid support



“Consensus” on MPGD tracking resolution

- **Resolution parameters input for tracking simulation ➔** Our starting point
  - In phi direction ➔ 50 µm (optimistic scenario), 75 µm(reasonable scenario), 100 µm (pessimistic scenario)
  - In z (for barrel trackers) or R (for end cap disks) ➔ Parameterization of spatial resolution
    - 50 µm (75, 100 µm) @ 0^{o} to 500 µm @ 45^{o} for standard gap (~3 mm) MPGDs
    - 50 µm (100 µm) @ 0^{o} to 150 µm @ 45^{o} for thin gap (1 mm) MPGDs
- **Impact of B field on resolution:**
  - We have not yet discussed in detail this aspect within eRD108
  - We will start soon and be able to provide input parameters to simulation
- **Short term ➔** Beam test in Hall D @ JLab for resolution studies:
  - Setup a beam test in Hall D @ JLab this fall to study (several eRD108 institutions to contribute)
  - Study resolution vs. track angle with standard gap µRWELL and GEM prototypes
  - Proof of principle of Thin Gap MPGD with GEM and µRWELL ➔ efficiency with Xe mixture, resolution vs track angle)

Back up slides

Barrel MPGD trackers: Cylindrical design

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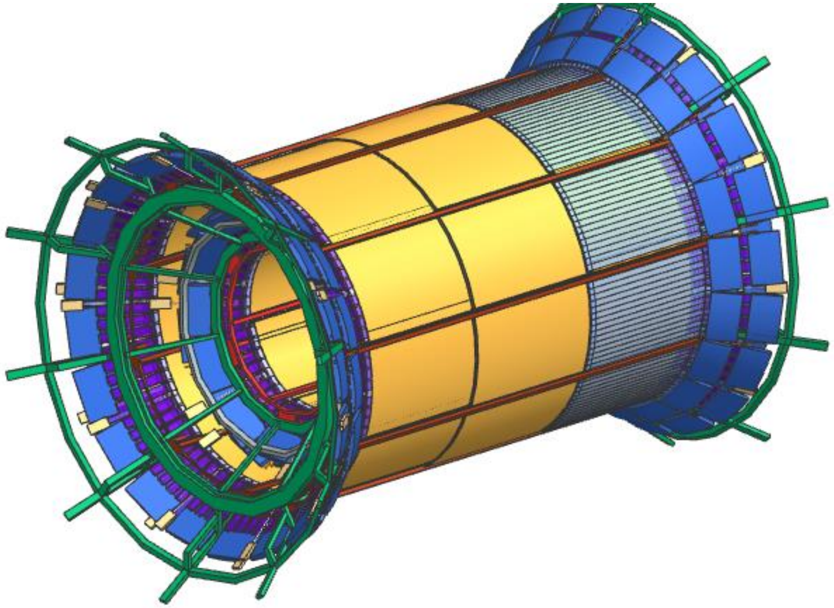
Preliminary design of micromegas tracker for ATHENA proposal



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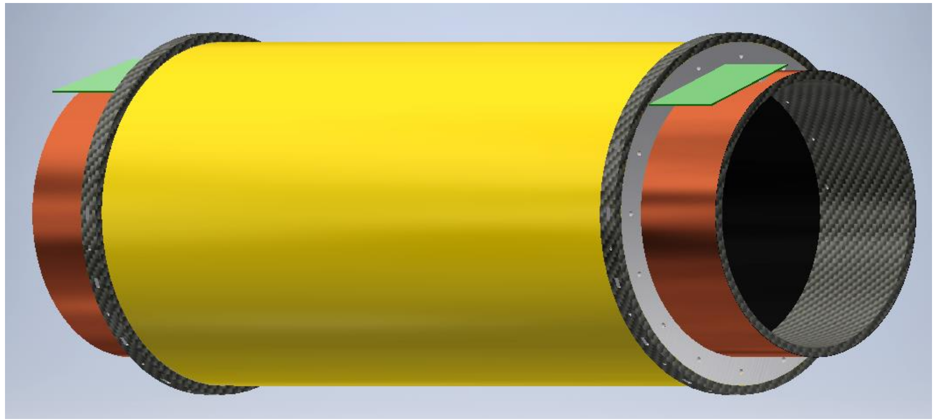
Ongoing R&D for cylindrical µRWELL (eRD108)



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  - Main concern is the spatial resolution requirements at large angle in z direction
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  - excellent spatial resolution (50 µm–100 µm) uniform across the range in phi direction

EIC detector 1: MPGD technologies - Micromegas

Technology

- Leading institutions in eRD108 and Tracking WG: **CEA Saclay, BNL, Yale, Vanderbilt U.**
- Mature technology (CLAS12 MVT, ATLAS Muon chambers, T2K TPC readout …)
- Planar and tiles modules for cylindrical trackers

CLAS12 Micromegas Vertex Tracker (MVT)

- Compact & light-weight (~0.4% X0 / layer) cylindrical tracker in a B=5T solenoid, total active area ~4m^2
- 1D readout per tile (either phi or z coord)
- Taking data since 2017

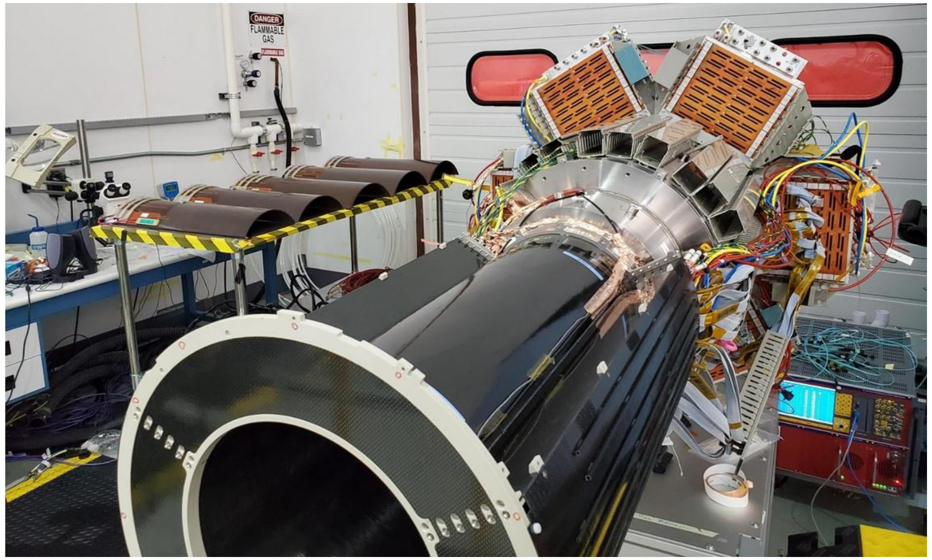
EIC needs:

- Simplify assembly of the curved tiles: one single tile module size with a fixed bending radius
  - Same module will cover different barrel layer radii
  - overlap tiles for full acceptance (no dead area gaps)
- 2D readout with **nominal resolutions 50 – 100 µm** in both directions & low channel count

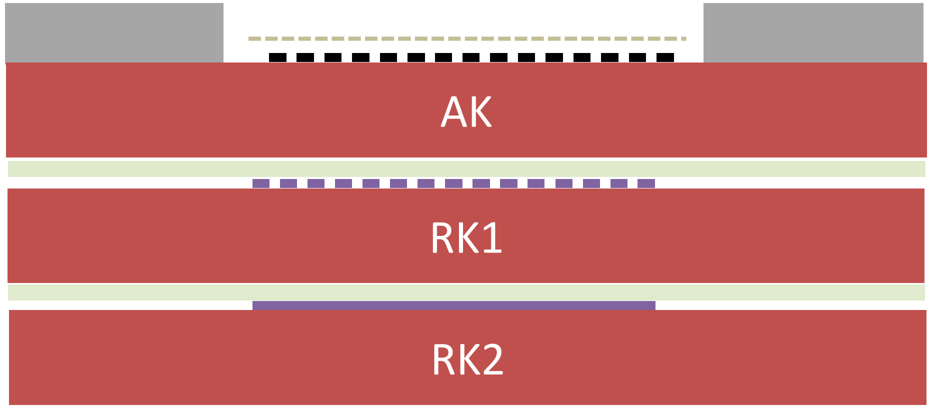
eRD108 R&D efforts

- 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 (50x70cm^2) with the chosen 2D readout

CLAS12 MVT open for maintenance



R&D on 2D Readout for Micromegas



EIC detector 1: MPGD technologies - µRWELL

Technology:

- Leading institutions in eRD108 and Tracking WG: **BNL, Florida Tech, JLab, Temple U, UVa.**
- More recent technology ➔ never deployed in an HEP or NP experiment yet
  - Simpler fabrication, low cost, flexibility, robustness
- Planar and tiles modules for cylindrical trackers, full cylindrical module for smaller radius possible

CLAS12 High Luminosity Upgrade Forward Tracker: Large-area µRWELL prototype:

- Large-area (150 cm x 50 cm) & light-weight (0.7% X0)
- Prototype completion by end 2022 and in test in Hall B in 2023
- A lot to learn from the test this prototype in early 2023

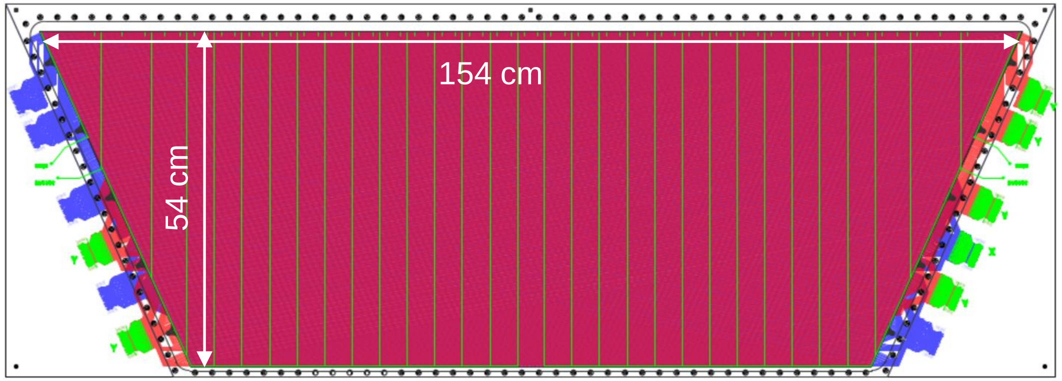
EIC detector 1 needs:

- Cylindrical tracking layers (full cylinder for most inner barrel layer & modular tiles option ala Micromegas all under consideration
- Large planar module (200 cm x 34 cm)) capability for DIRC MPGD layer
- 2D readout with **nominal resolutions 50 – 100 µm** in both directions & low channel count

Ongoing R&D efforts with eRD108:

- FY22:
  - Develop small radius (2 cm diam) cylindrical µRWELL prototype
  - Develop 2D readout for low number of channels on small prototypes
- FY23:
  - Prototype tests in beam ➔ FNAL Summer 2023 (contingent R&D funding continuation)
  - Explore options optimization of track angle dependence of the spatial resolution

Gerber view of CLAS12 High-Lumi FT µRWELL prototype



Cylindrical µRWELL: mechanical mockup

Courtesy P. Iapozzuto, Florida Tech