Input from eRD108 for MPGD Technology choices

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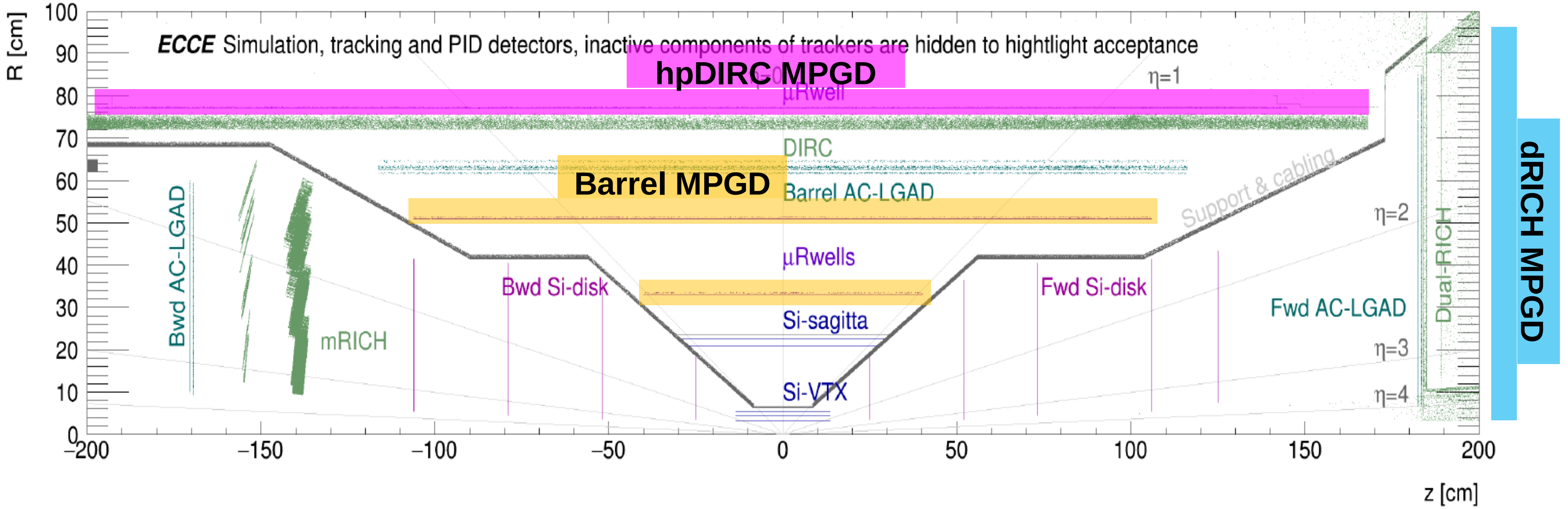
EIC Detector 1 Tracking WG

07 July 2022

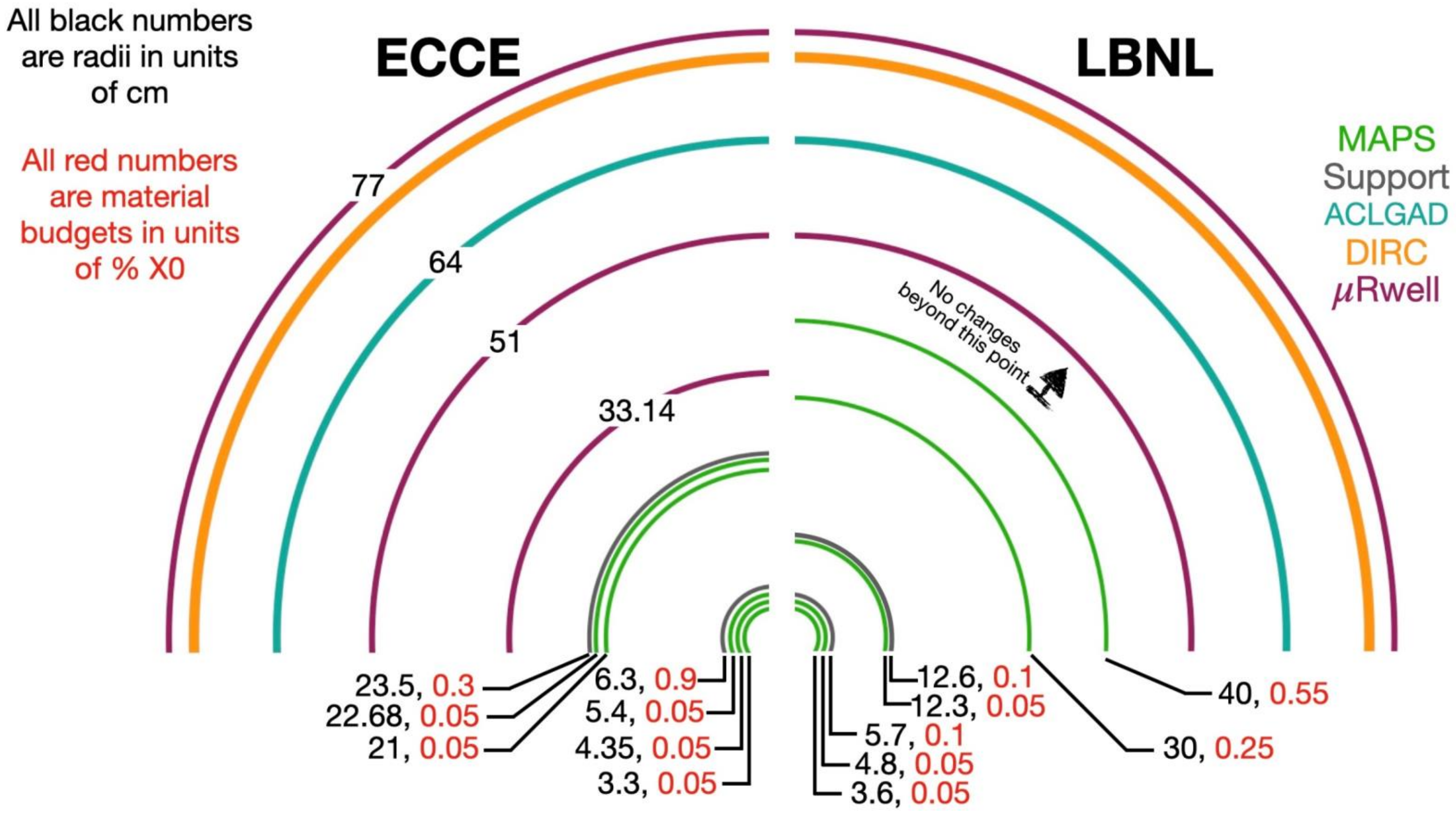
EIC detector 1 Barrel Tracker: Original layout

- hpDIRC MPGD: Planar MPGD rectangular module (~400 cm × 36 cm)
  - No low mass but good spatial resolution in both rphi and z?
  - Challenges: resolution vs. track angle and Lorentz angle
- dRICH MPGD: Planar trapezoidal MPGD module
  - No low mass but high spatial resolution in both rphi and z?
  - Challenges: resolution vs. track angle and Lorentz angle
- Barrel MPGD: Cylindrical MPGD layers
  - **Low mass** and high spatial resolution in both rphi and z?
  - Full cylindrical? Curved modules, planar tiles in cylindrical arrangement?
  - Challenges: resolution vs. track angle and Lorentz angle



EIC detector 1 Barrel Tracker: ECCE layout vs. LBNL layout

- **Barrel tracker layout update from EIC SC**
  - Proposed by Ernst
  - Account for realistic Si-MAPS technology with thicker material at large radius
  - Rearrangement of layers for performances optimization
- **New layout**
  - 2 Si-vertex layers
  - 3 sagitta layers with larger radius except the first one
  - MPGD @ 33.14 cm disappears
- **Adopted option for the detector geometry for the current simulation campaign**

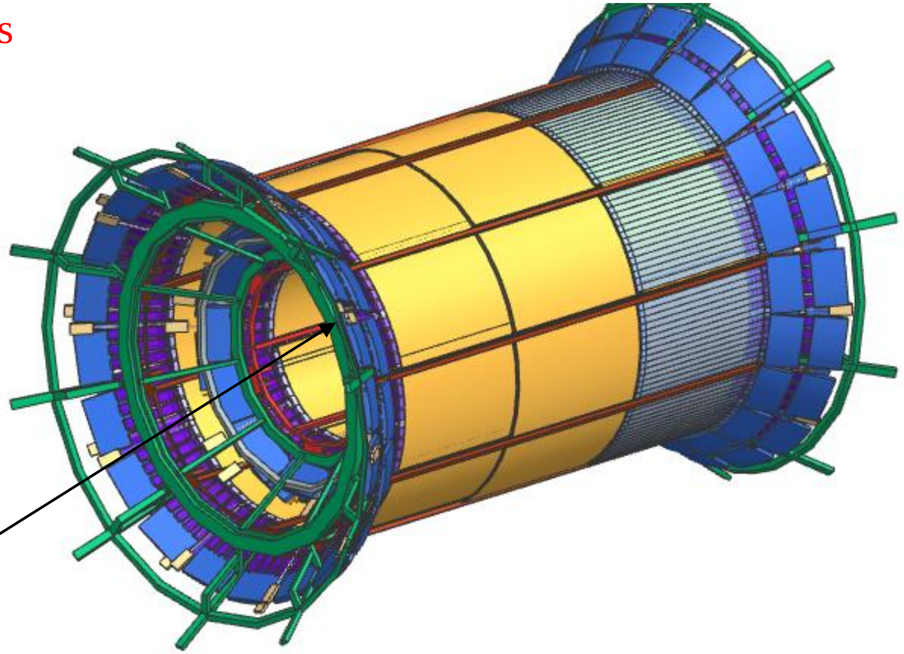


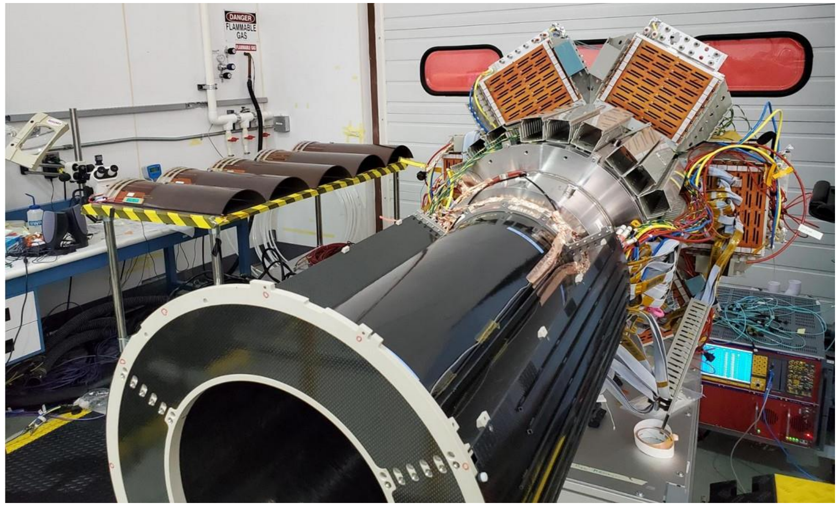
eRD108 choice for cylindrical trackers: Micromegas technology

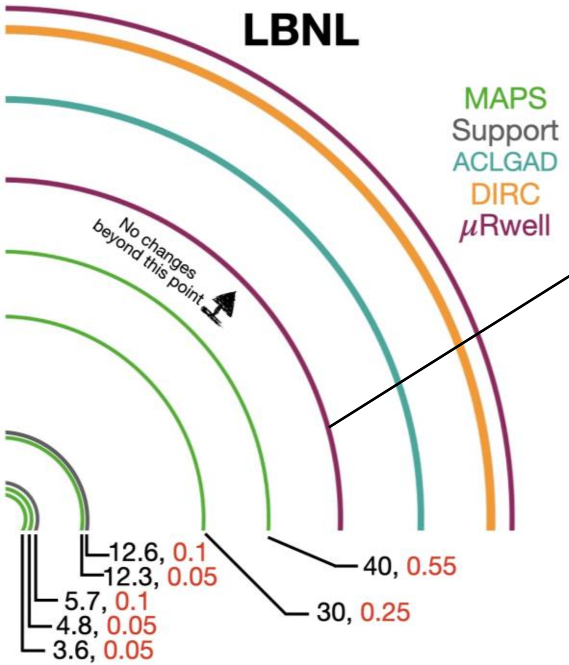
Requirements & expectations from YR & various detector proposals:

- ❖ Low mass (< 0.5% X0 / layer) is justified for this layers ➔ Starting point: CLAS12 Micromegas technology (~0.4%X0 in active area), evolution to 2D readout
- ❖ Full acceptance ➔ Arrangement of cylindrical tiles with overlaps
- ❖ Spatial resolution ➔ 50–100 μm challenging at large angle in R➔ more on following slides
- ❖ FEE close to the detectors: placement on the supporting cones?
- ❖ Backup solution: Cylindrical μRWELL (eRD108 R&D ongoing) or flat tiles

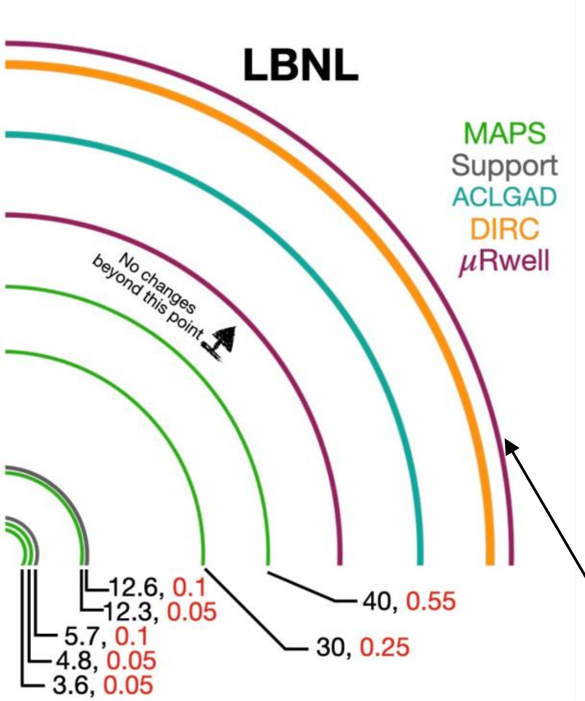
Preliminary design of micromegas tracker for ATHENA proposal







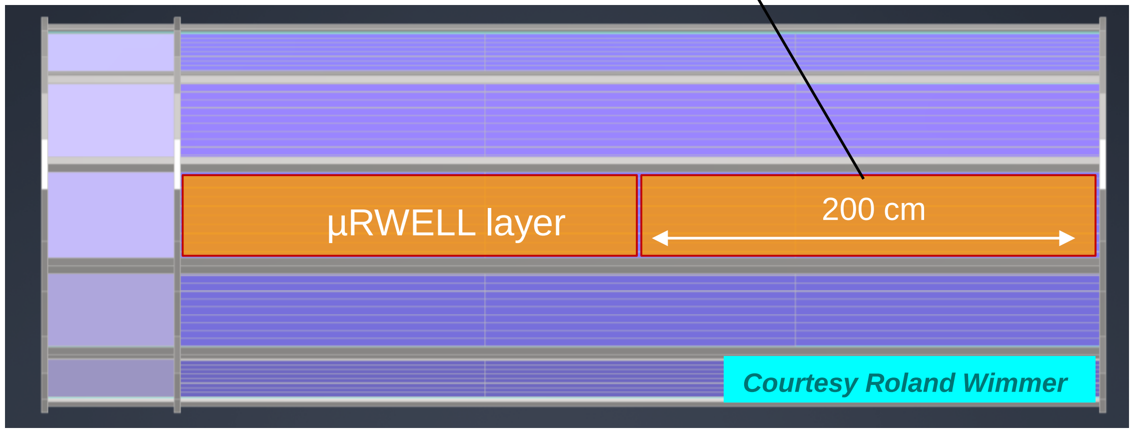
eRD108 choice for planar trackers: µRWELL technology



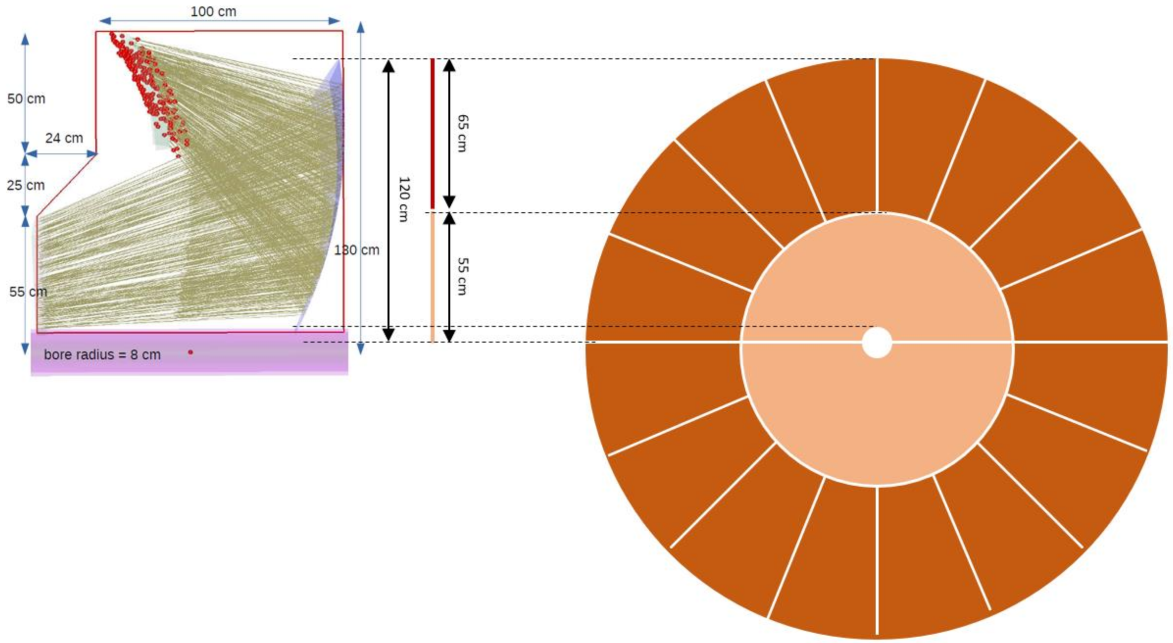
Requirements & expectations from YR & various detector proposals:

- Low mass (< 1% X0) not justified here ➔ **1% to 2% X0** in front of EM Cal. is not an issue
- But space limitation for layer behind hpDIRC ➔ 2 cm thick box space for MPGD layer
- Spatial resolution (50 - 100 µm) in both phi and z (or R for the disc layer behind dRICH)
- FEE close to the detectors: placement on hpDIRC support structure?
- Backup solution: Given space limitation MM for the hpDIRC, GEM or MM behind the dRICH

µRWELL layer behind hpDIRC

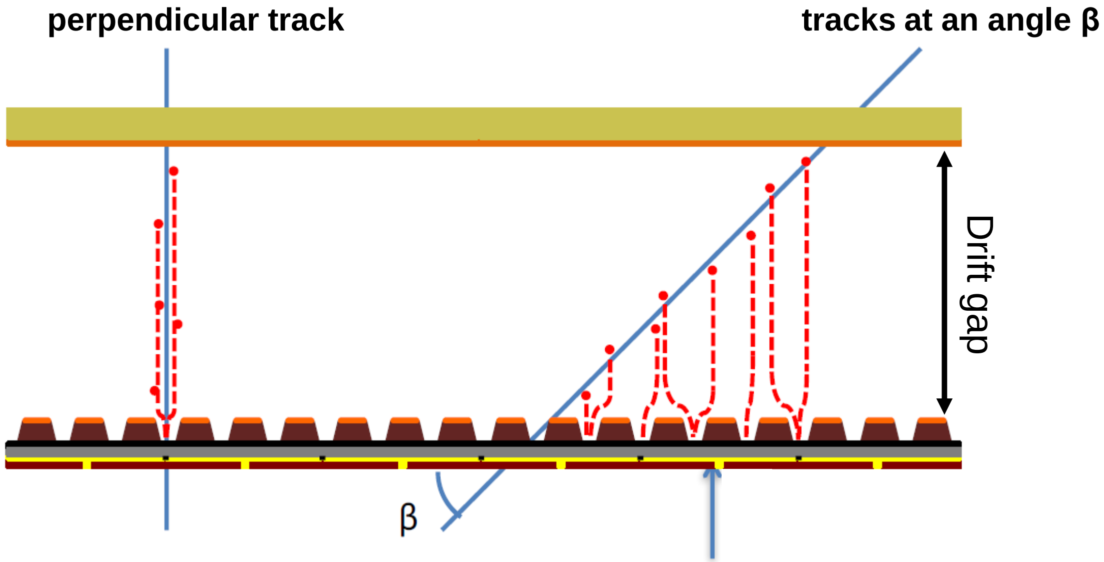


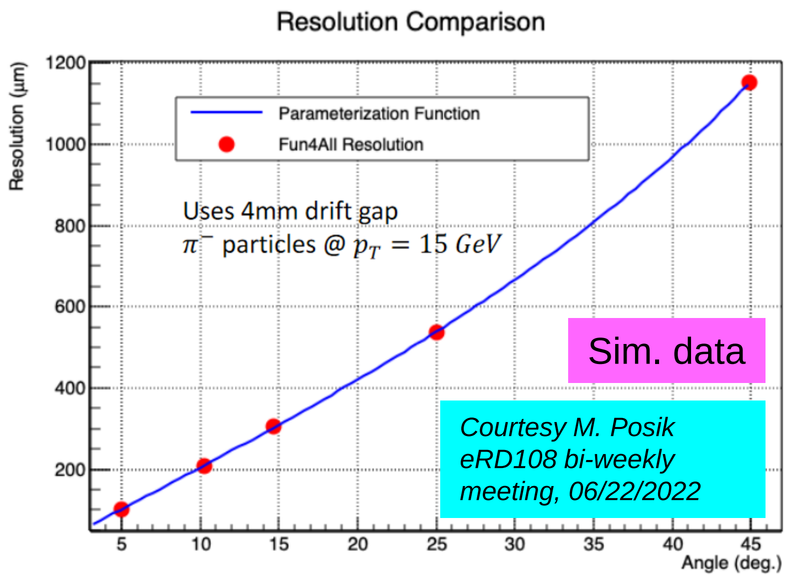
µRWELL layer behind dRICH

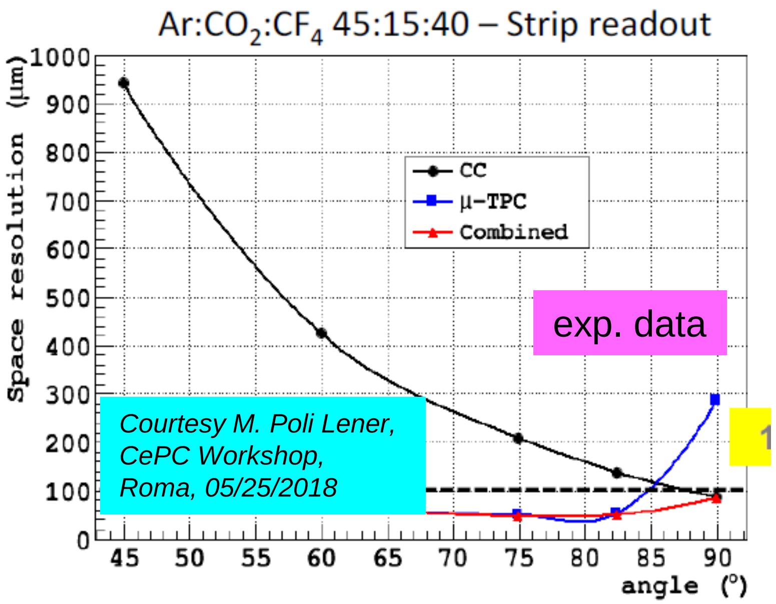


Spatial resolution: issues to address

- **Nominal position resolution:** hits from **tracks perpendicular to detector** plane.
  - Depends on technologies, readout structures & pitch (strips, pads, ZZ…), gas properties
  - Ranging between 50 – 100 µm for MPGD trackers
- **Incoming track at large angle**
  - Ionization in drift generates signal **on too many strips** Nb of strips increases linearly drift gap
  - COG no longer valid way, spatial resolution ~ d / $(\cos(\beta) \times \sqrt{12})$ ➔ determined by drift gap
- Two approaches under consideration to partially recover resolution performance
  - Micro-TPC (µTPC) ➔ increasing the drift gap (from 3 mm to 10, 20 mm)
  - Thin gap MPGDs ➔ reducing the drift gap (**from 3 mm to 1 mm or less**)





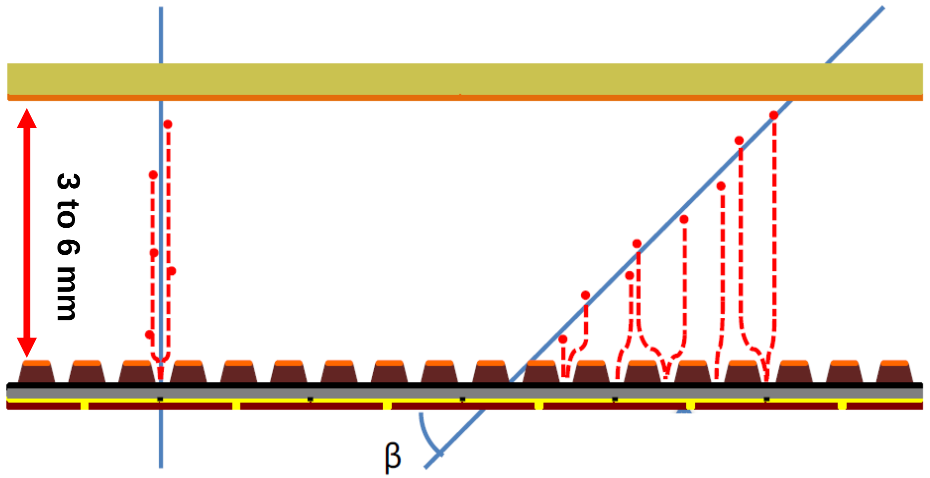


Solutions for improving resolution: Thin Gap MPGD

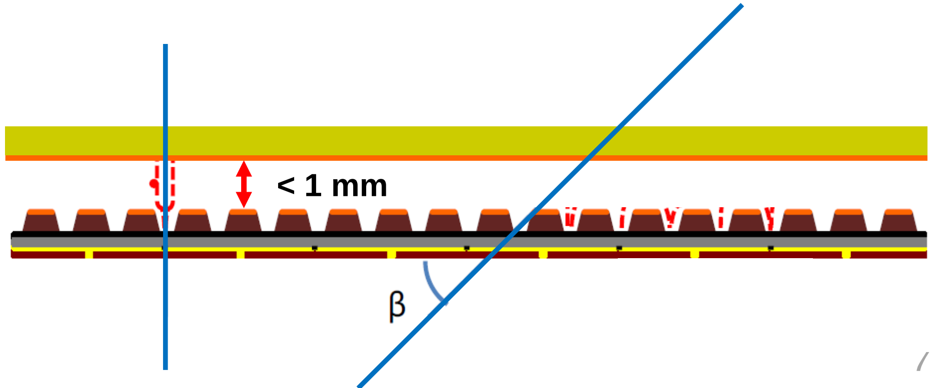
- **idea:** Narrow drift gap from 3 mm (or more) to 1 mm (or less)
  - Improve spatial resolution demonstrate better 150 um for 45 º tracks with 1 mm drift gap
  - Thin Gap MPGDs will also minimize Lorentz angle effect on resolution performances

- **Cons / challenges**
  - Will require high density gas like Xe, Kr etc .. ➔ cost
  - Needs R&D to develop and test prototypes to validate the idea
    - Reduce the average number of primary ionization cluster to 1 and compensate by higher gain ➔ hybrid amplification
    - Recover full efficiency with twin readouts configuration

standard Gap µRWELL



Thin Gap µRWELL

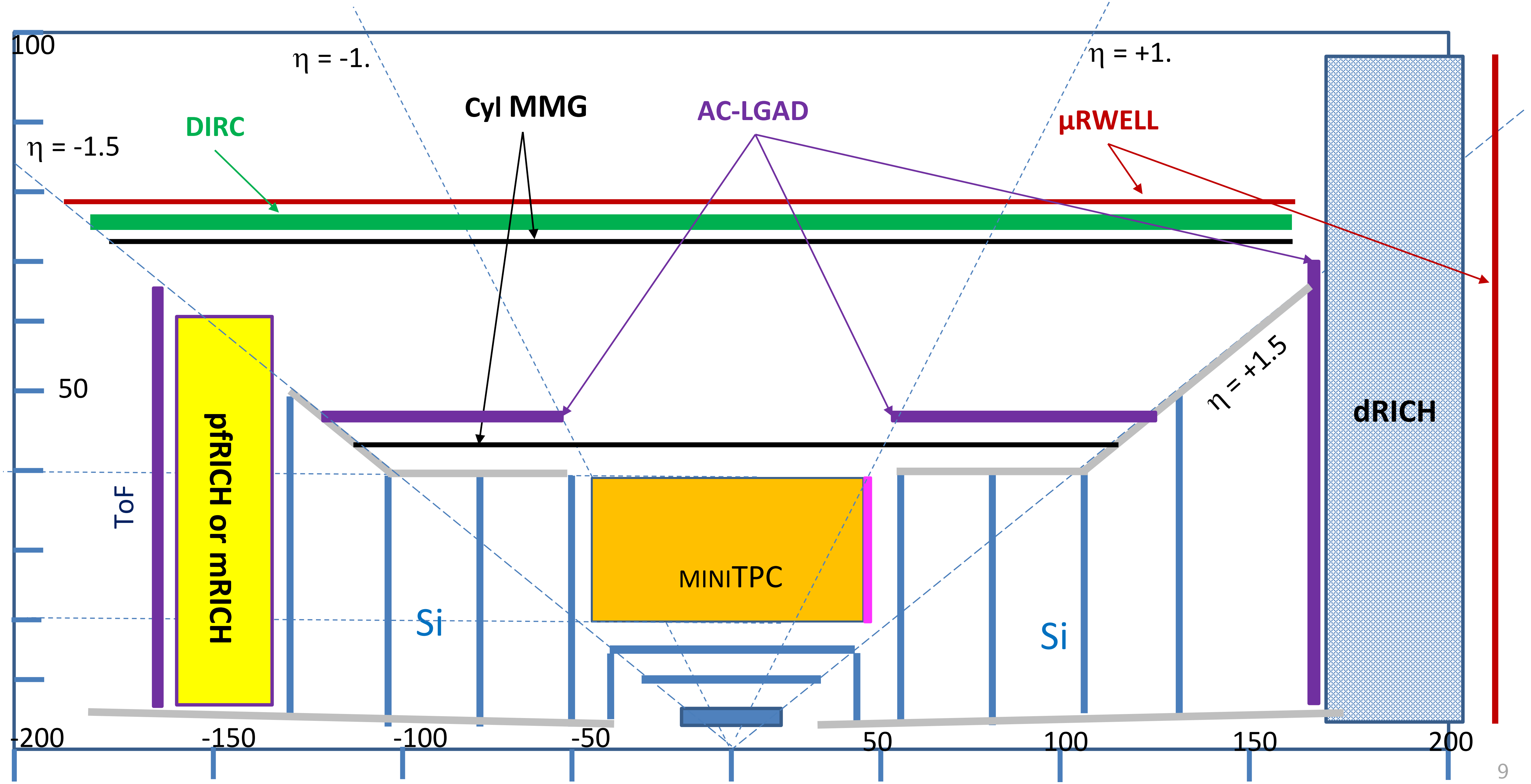


EIC detector 1 Tracking: Open questions on tracking / PID requirements

Concerns expressed by Nikolai Smirnov and shared by many people

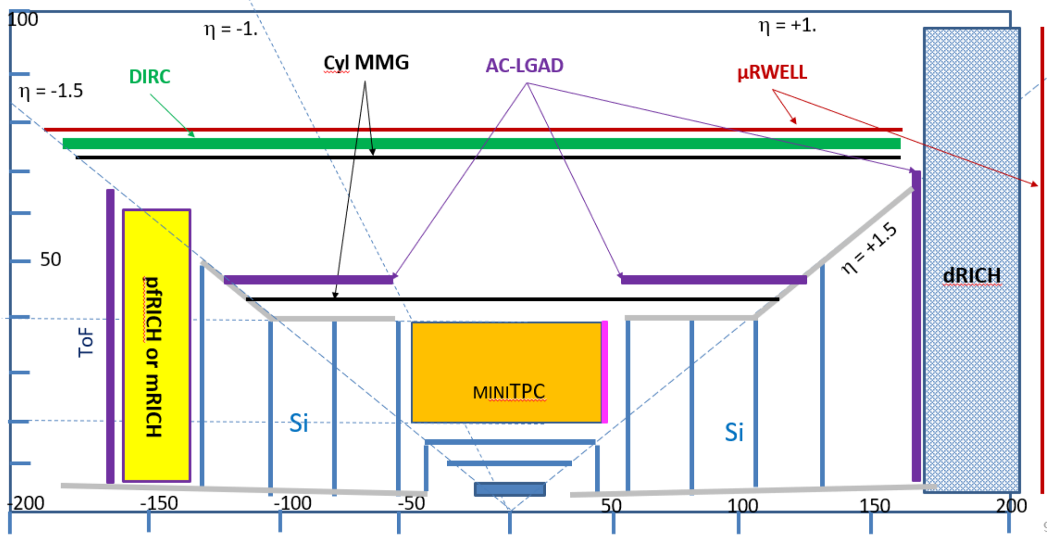
- Original ECCE tracking / PID setup does not fit the YR request.
- "Fast" simulations were done using unrealistic material thickness and hit smearing parameters with a misleading conclusion.
- BaBar magnet, 1.4 T B-field is not good enough for high precision momentum reconstruction.
- Very small number hits / track is extremely "sensitive" to background.
- PID (ToF) proposed R-position does not work up to 0.3 GeV/c (~30% of all particles in +/- 1.5 rapidity).
  - Need input from Physics WGs if there is a needs for PID below 0.3 GeV/c
- A lot of barrel tracking simulation were done for (1. – 20.) GeV/c. The optimization should be done for (0.1 – 1.0) GeV/c (>85% of all (hadron) particles).
- It should be checked / simulated the option of the barrel (+/- 1 rapidity) with mini TPC on (low mass, very good PID up to 0.7 GeV/c, ~large number of hits / track – exactly fits all demands for low momentum particle track finding and reconstruction)
- and "projective" setup for +/- (1. – 1.5) rapidity. (Alexander's original idea; see next slide).
- 4. Expedite the production of the "spare" magnet with ~(2. – 2.5) T B-field.

EIC detector 1 Barrel Tracker: The eRD108 mini-TPC option



EIC detector 1 Barrel Tracker: The eRD108 mini-TPC option

- Original ECCE tracking / PID setup does not fit the YR request.
  - Developing simulation to evaluate the mini TPC options performance
- BaBar magnet, 1.4 T B-field is not good enough for high precision momentum reconstruction.
  - mini TPC option will address this question
- Very small number hits / track is extremely "sensitive" to background.
  - mini TPC option will address this question
- If PID for momentum < 0.3 GeV/c is needed
  - mini TPC option will address this question ➔ need validation with simulation
- Limited mpact of the TPC readout material budget in the hadron endcap **eta 1 to 1.5** already covered by AC-LGAD and hpDIRC
- Impact of the TPC readout material budget in barrel region -1 < **eta < 1 is smaller than for AC-LGAD option**



“Summary & Consensus” on MPGD technoloy

- ❖ MPGD community (eRD108) has a solution and clear R&D path for the current EIC detector 1 gaseous tracking layout
- ❖ Identify Micromegas for the cylindrical tracker and uRWELL for the planar layer behind hpDIRC and dRICH
- ❖ The two technologies are mutually fallback solution. GEM is still an option for the layer behind dRICH in hadron endcap
- ❖ An alternative option with mini TPC under discussion within community
- ❖ We will soon contact all institutions beside eRD108 members expressing interest in participating the EIC MPGD trackers effort to join the discussions

Backup

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

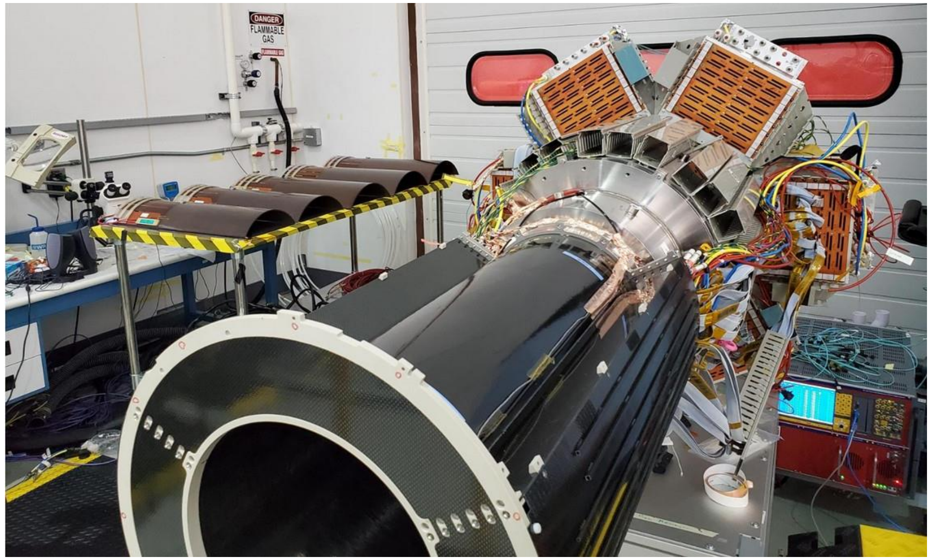
EIC needs:

- 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

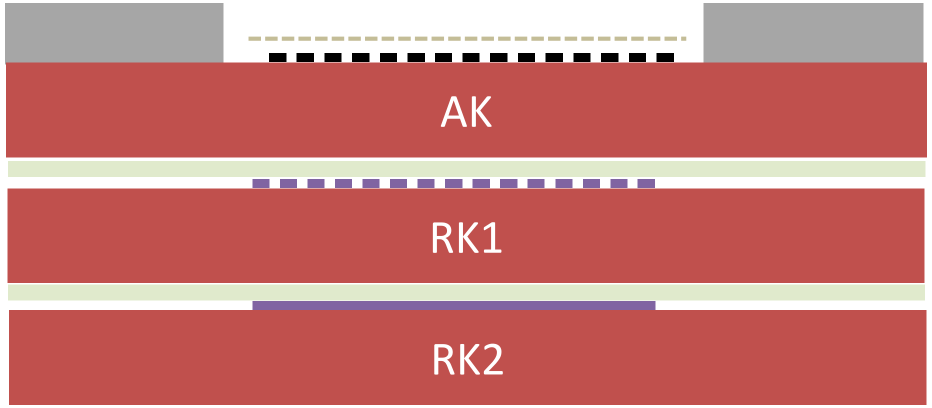
eRD108 R&D efforts

- 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