Applications of MPGDs at an EIC

Matt Posik
Temple University

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College of
Science and Technology
TEMPLE UNIVERSITY®

Outline

- ❑ Where do MPGDs fit into the EIC?
- ❑ Applications in the Central Region
- ❑ Applications in the Endcap Region

This presentation will focus on EIC MPGD R&D work being carried out within **eRD6** by

1. Brookhaven National Lab (BNL)
2. CEA Saclay (Saclay)
3. Florida Inst. Of Technology (FIT)
4. INFN
5. Stony Brook University (SBU)
6. Temple University (TU)
7. University of Virginia (UVa)

And **eRD22**

1. Jefferson Lab (JLab)
2. TU
3. UVA

EIC R&D: https://wiki.bnl.gov/conferences/index.php/EIC_R%25D

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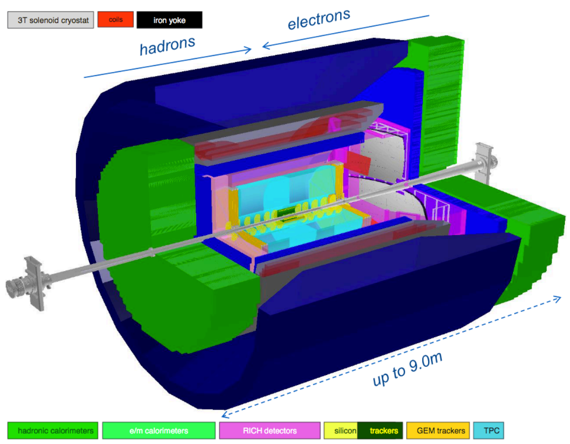
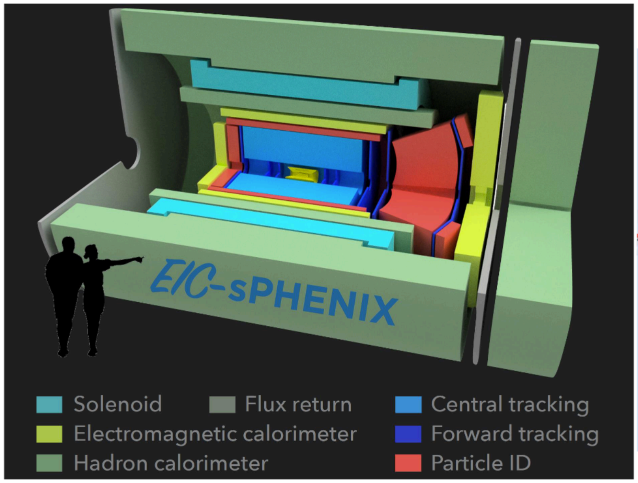
EIC Detector Envelope Concepts

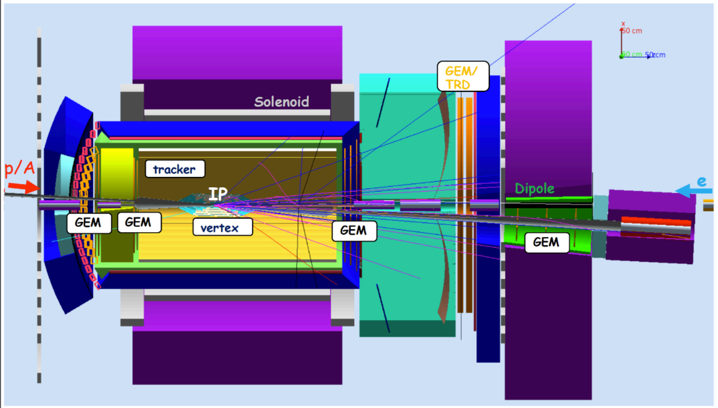
BeAST



ePHENIX



JLEIC



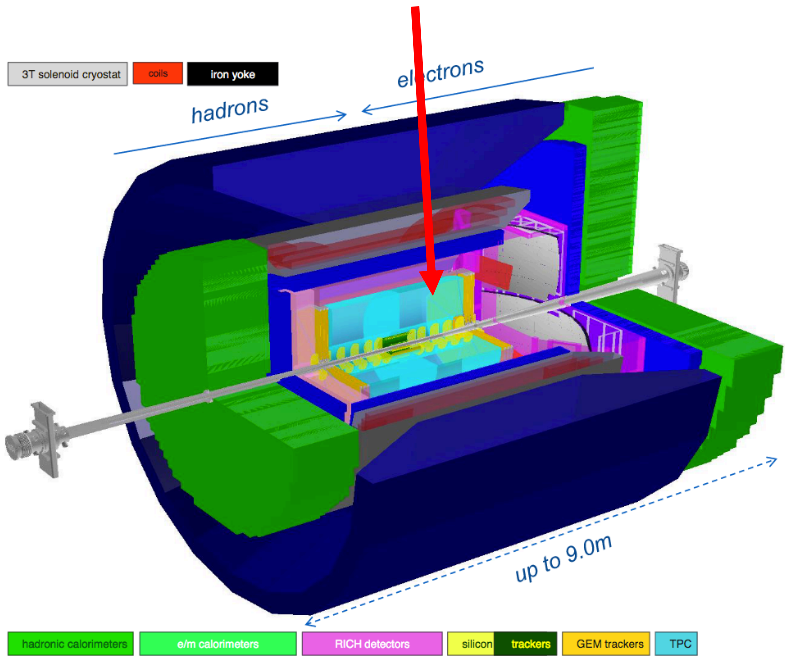
- ❑ 3 working EIC envelope place holders: BeAST (BNL), ePHENIX (BNL), and JLEIC (JLab)
  - Common features
    - vertex + central + forward/backward endcap
    - 4π hermetic acceptance to few degrees from beamline
    - Require low material budgets
    - Good momentum resolution
    - Solenoidal field
- ❑ Ideally EIC would have 2 detectors

Outline

- ❑ Where do MPGDs fit into the EIC?
- ❑ Applications in the Central Region
- ❑ Applications in the Endcap Region

Central Region: Fast Cylindrical $\mu RWELL$ Layers

Central Region



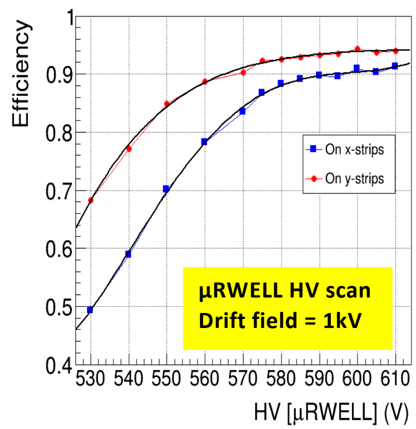
- Central Region
  - **TPC**
  - Silicon
  - Micromegas
  - TPCC
- **Fast cylindrical $\mu RWELL$ layer**
  - Located just before and after the TPC field cages
  - High space point resolution to aid in TPC calibration (correct *scale distortions*)
  - Provide fast timing (few ns) for bunch crossing identification (with TPC+MAPS config)
  - Low mass, large area, low cost detector
  - Detector assembly simpler than triple-GEM
  - Operating in μTPC mode provides tracklet information

Central Region: Fast Cylindrical $\mu RWELL$ Layers

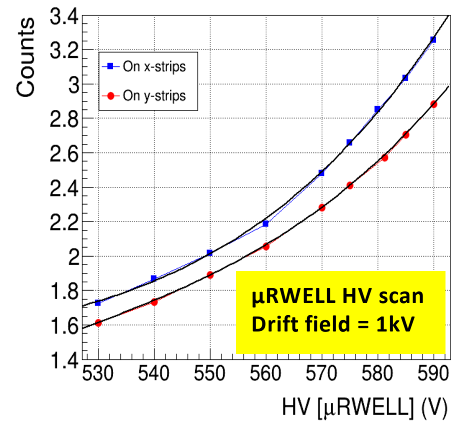
- **Planar 10 x 10 cm² $\mu RWELL$**
  - Tested by **UVa** in cosmics and FNAL proton beam
  - Tested in ArCO2 (70:30)
  - Used APV25 SRS readout
  - X-Y strip pitch = 400 μm
  - X (Y) strip width = 80 μm (340 μm)
  - Good **charge sharing** X-Y correlation at 0.8
  - **Track residuals** of 50 and 43 μm in X and Y

Cosmics

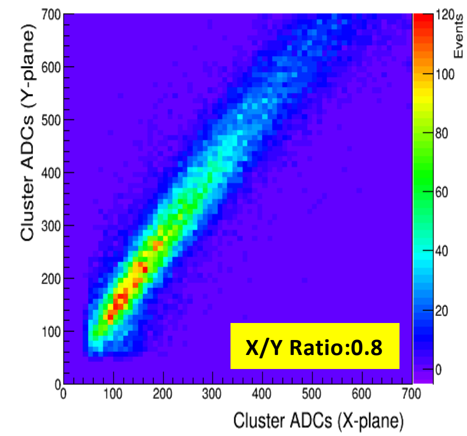
Efficiency vs. amplification



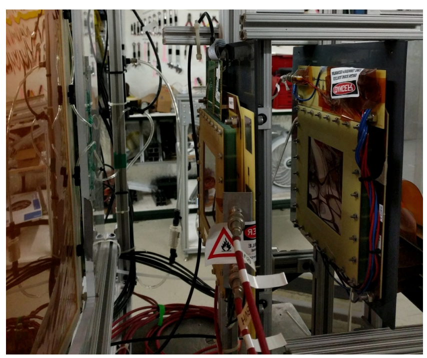
Cluster size vs. amplification

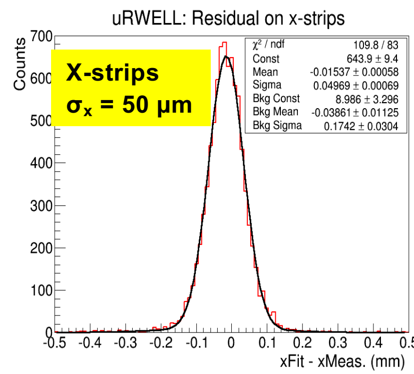


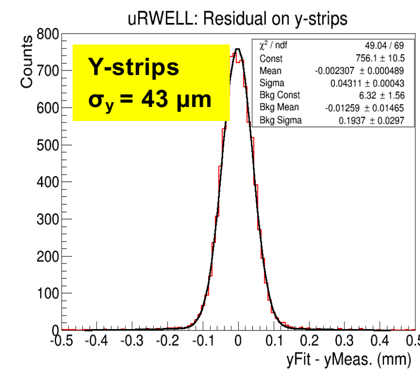
X-Y strips charge sharing



uRWELL position residuals from track fit with GEMs @FNAL







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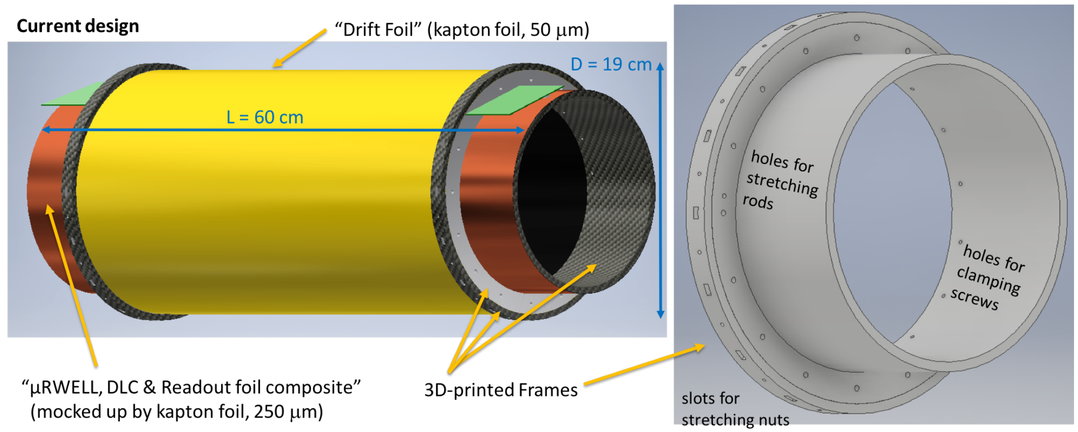
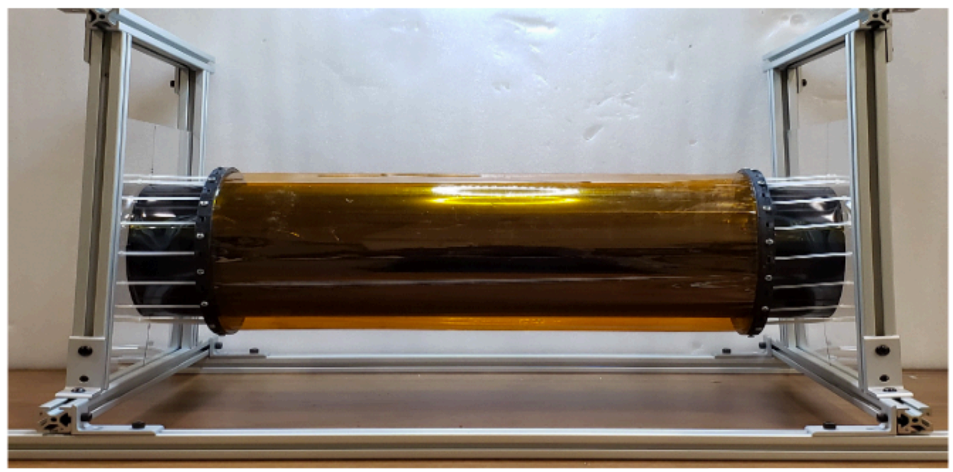
Central Region: Fast Cylindrical $\mu RWELL$ Layers

- **Mechanical Support structure mockup for fast cylindrical $\mu RWELL$ layers**
  - Kapton foils
  - 3D printed frames
  - Nylon stretching rods
  - Total Length: 60.3 cm
  - Inner Kapton diameter: 16.2 cm
  - Outer Kapton diameter: 19.6 cm



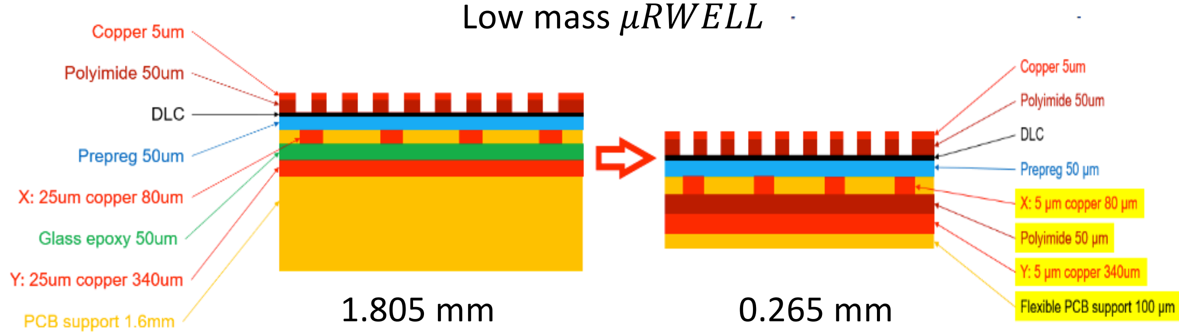
FIT



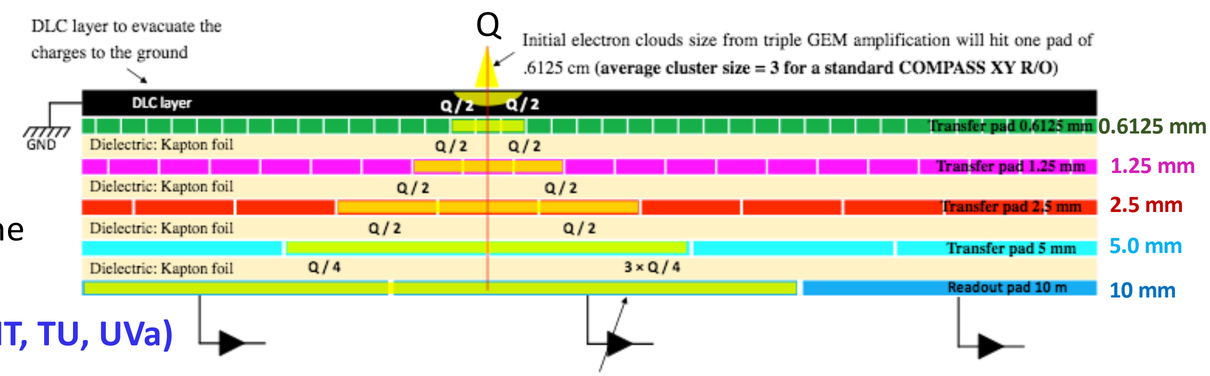
Central Region: Fast Cylindrical $\mu RWELL$ Layers

- ❑ **Investigating low mass $\mu RWELL$ (UVa)**
  - Reduce R/o Cu strips from 25 μm to 5 μm
  - 1.6 mm PCB to 100 μm Kapton
  - Drift foil Al-Kapton ($5/25\ \mu m$)
  - Entrance window Al-Kapton ($5/25\ \mu m$)
  - Exit window Kapton ($25\ \mu m$)
- ❑ **High resolution and large pad readout (UVA)**
  - Reduce channel number
  - Capacitive-sharing pad anode readout
  - Cu-pad layers separated by 50 μm Kapton foils
  - Position is weighted average of charge on large pads
  - Can be used with other MPGDs (GEMs in the endcap regions)
- ❑ **Like to build Cylindrical $\mu RWELL$ prototype (FIT, TU, UVa)**
  - Small scale: (r = 10 cm, length = 55 cm)
  - Low mass $\mu RWELL$
  - Large anode readout pads (~$1-2\ cm^2$)

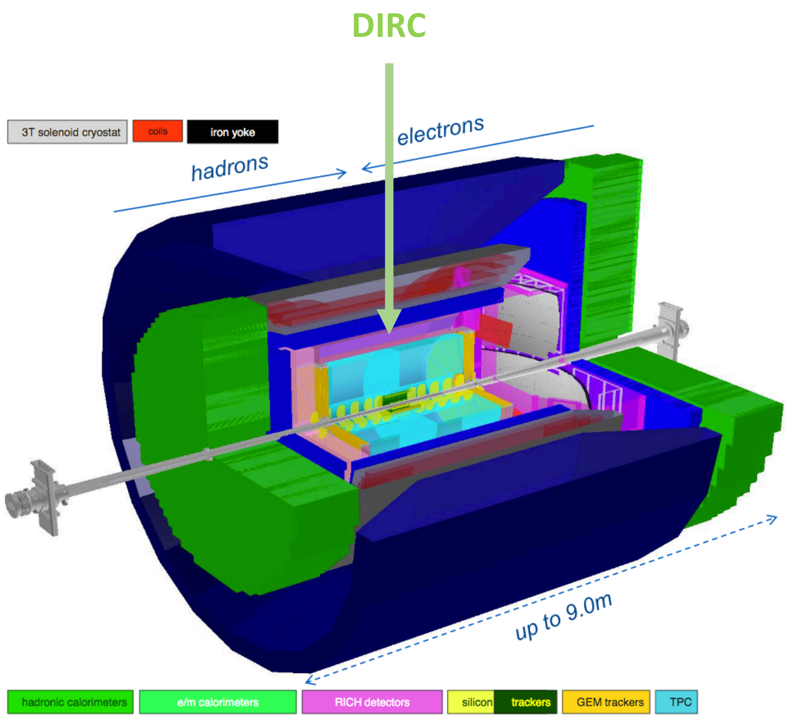
Low mass $\mu RWELL$



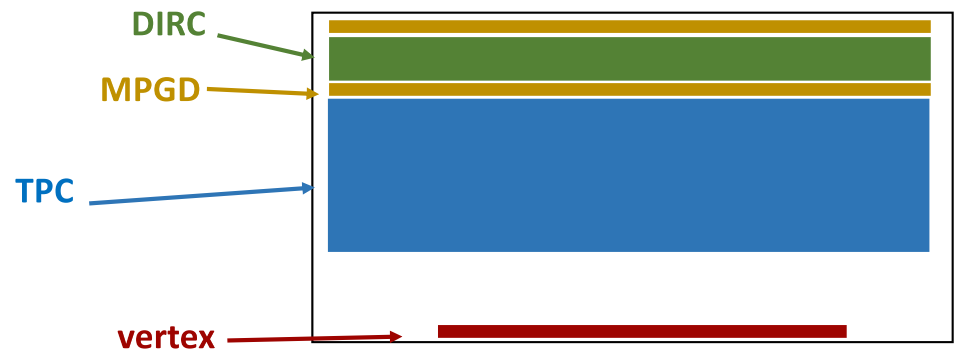
Capacitive-sharing and large-pad anode readout



MPGDs Aiding PID

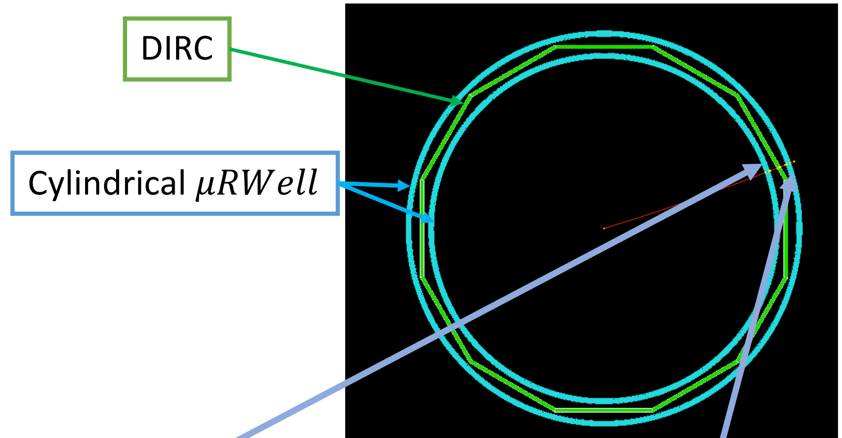


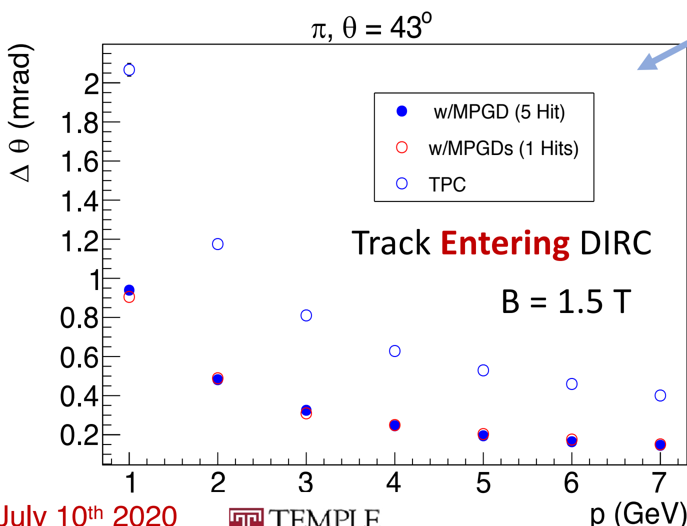
- ❑ Central Region
  - TPC
  - Silicon
  - Micromegas
  - TPCC
- ❑ **Assisting central PID detectors**
- ❑ **Cylindrical $\mu RWELL$ layer**
  - Located just before and after the PID detector (DIRC)
  - Same design as fast cylindrical $\mu RWell$ detectors
  - Improved angular resolution of the track can be used to increase PID separation of hadrons (π/K)

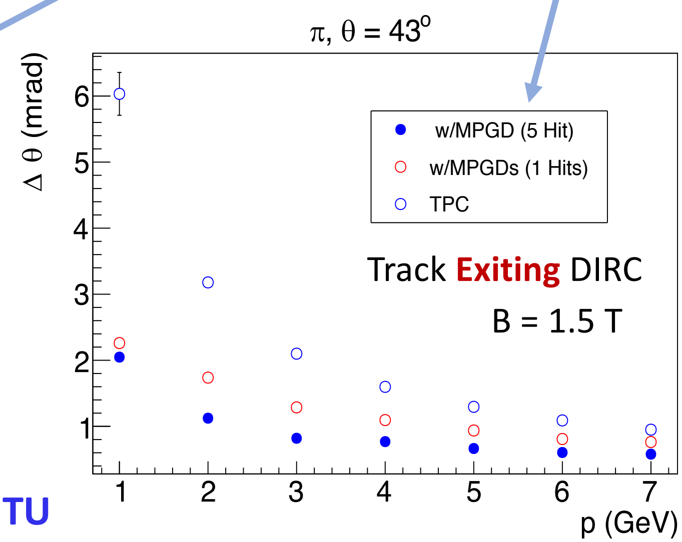


MPGDs Aiding PID: DIRC

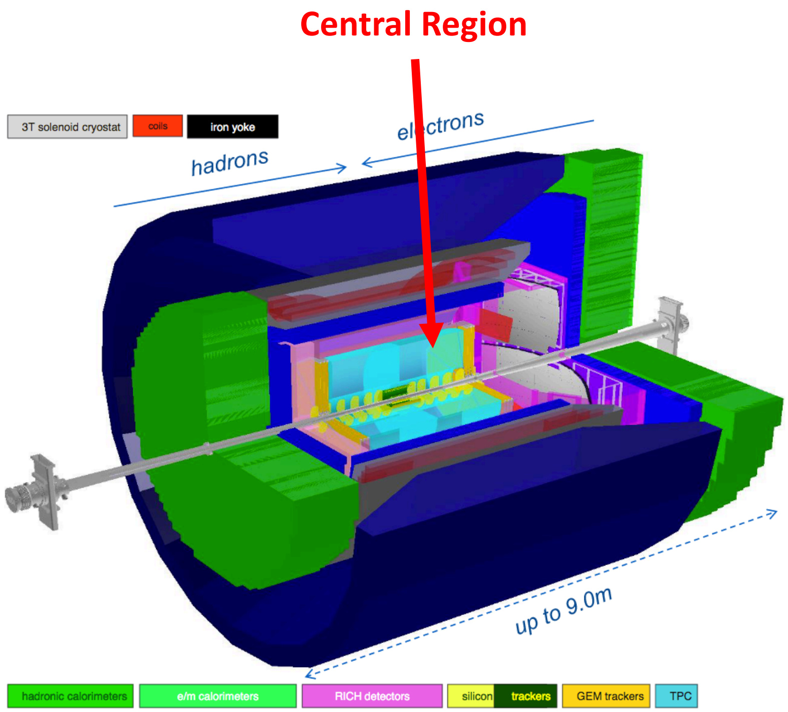
- **Cylindrical $\mu RWELL$ layer assisting PID (simulation)**
  - Simulated detectors: SVTX, TPC, and $\mu RWELL$ cylindrical layers
  - Angular resolutions compare projected track to truth value
  - Preliminary simulations show clear improvement in angular resolution
  - Prelim. results suggest some improvement if $\mu RWELLS$ are operated in μTPC mode







Central Region: Micromegas Barrel Tracker

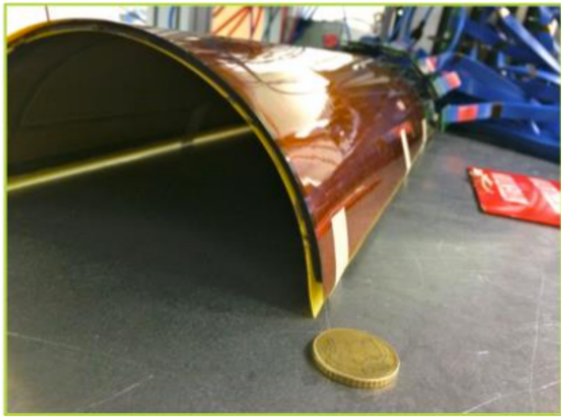


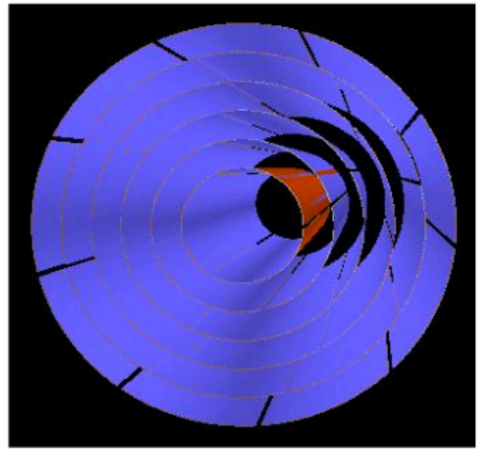
- Central Region
  - TPC
  - Silicon
  - **Micromegas**
  - TPCC

- **Micromegas Barrel Tracker**
  - Replace TPC with several layers of micromegas trackers
  - Low mass budget (χ/χ_0 = 0.3% per layer)
  - Cylindrical micromegas technology is used in CLAS12
  - Radial coverage from 20-80 cm
  - Operating in μTPC mode could provide more information (i.e tracklets)

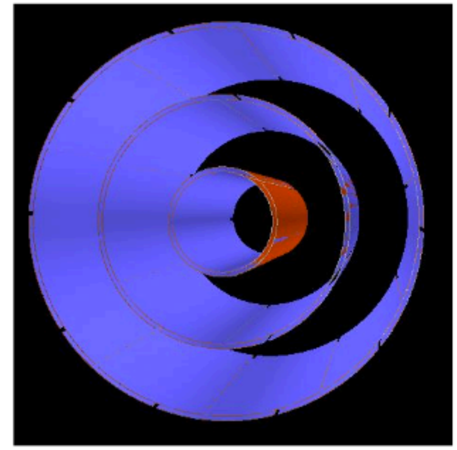
Central Region: Micromegas Barrel Tracker

Scalay





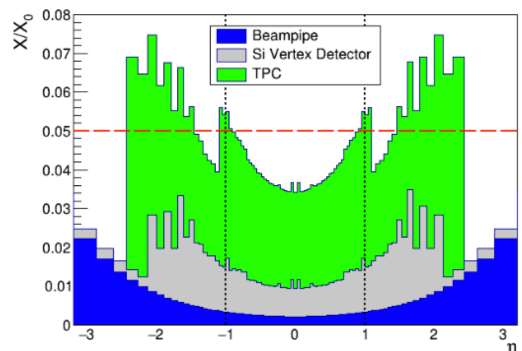
6 equidistant layers



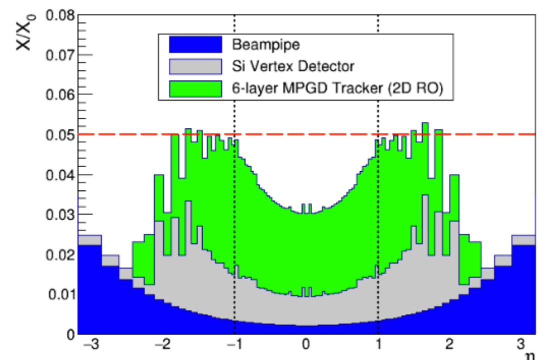
6 layers arranged as 3x2

- **Micromegas Barrel Tracker**
  - Two barrel configurations are being studied
  - Material budget for TPC and micromegas barrels meet $\frac{\chi}{\chi_0} < 5\%$ central region requirement

TPC



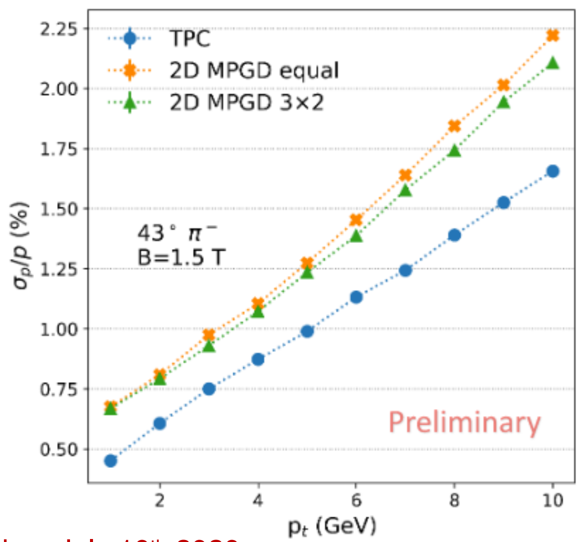
6-layer 2D RO MPGD tracker



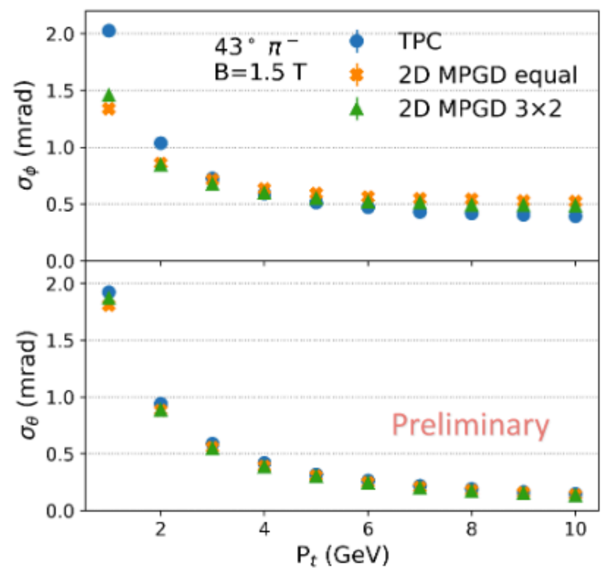
Central Region: Micromegas Barrel Tracker

❑ Preliminary performance comparisons (simulations)

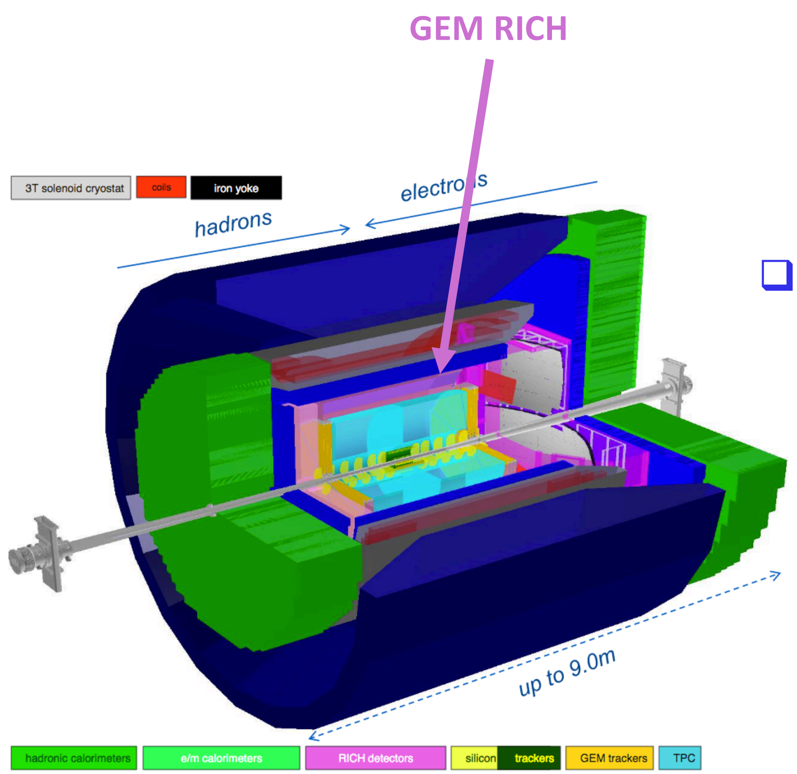
- Momentum and angular resolutions compared at r = 81.5 cm from beamline
- Simulation includes:
  - SVTX: $\sigma(R\ /\phi/Z) = 5\mu m$
  - TPC: $\sigma(\phi) = 200\ \mu m, \sigma(Z) = 500\ \mu m$
  - Micromegas: $\sigma(\phi/Z) = 150\ \mu m$
- TPC has slightly better momentum resolution
- Angular resolutions are comparable
- Potential improvement of operating in μTPC mode ongoing



Scalay



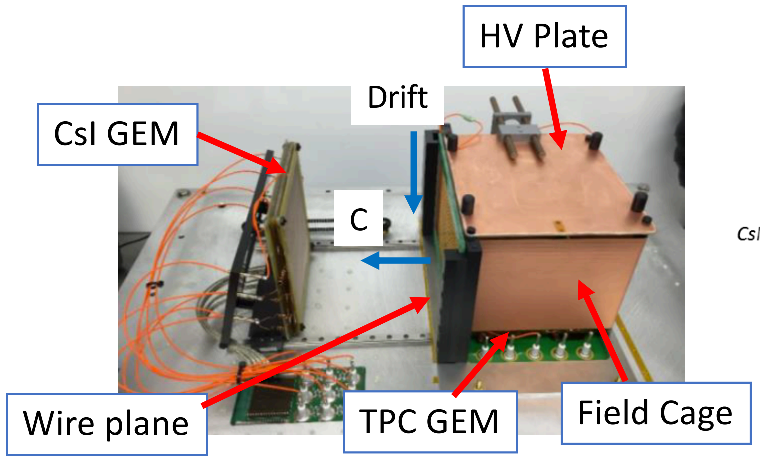
TPCC Tracker



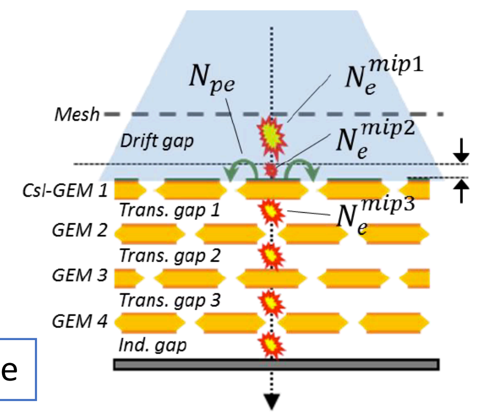
- ❑ Central Region
  - TPC
  - Silicon
  - Micromegas
  - **TPC-Cerenkov**
- ❑ **TPC-Cerenkov (TPCC) Tracker**
  - TPC-Cerenkov quadruple-GEM combination
  - Provides tracking and PID for to separate electrons from hadrons
  - Tracking
    - Tracking is done in μTPC (mini-drift) mode
    - Quadruple-GEM
  - PID
    - Windowless proximity focusing Cerenkov
    - Quadruple-GEM with CsI coating

TPCC Tracker

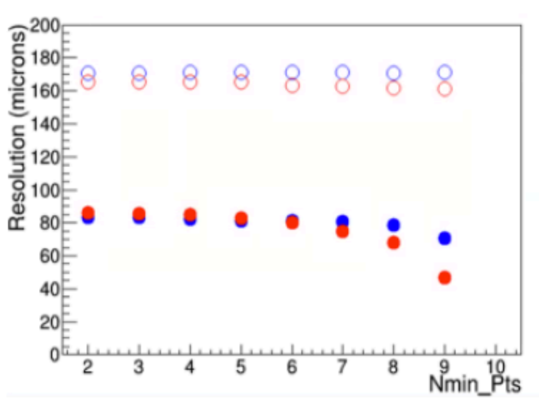
- TPCC Tracker
  - Tested at Fermilab test beam facility
  - CF_4 gas
  - Tracking
    - 10 x 10 x 10 cm^3 field cage
    - 10 x 10 cm^2 4-GEM
    - 2 x 10 mm^2 zigzag pads
  - PID
    - 10 x 10 cm^2 readout plane
    - Segmented in 3x3 pads

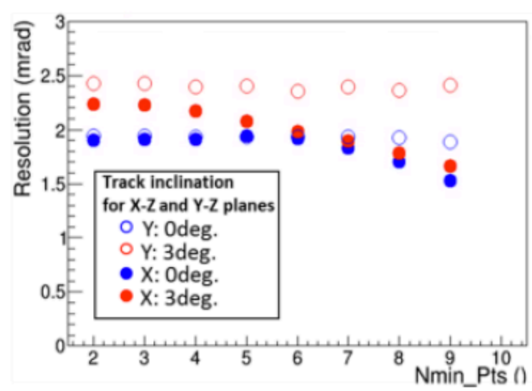


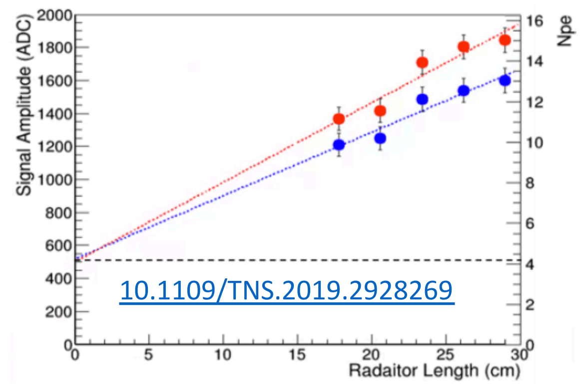
Cerenkov GEM



  - Plan to study high pressure Ar radiator with Capacitive-sharing and large-pad anode readout







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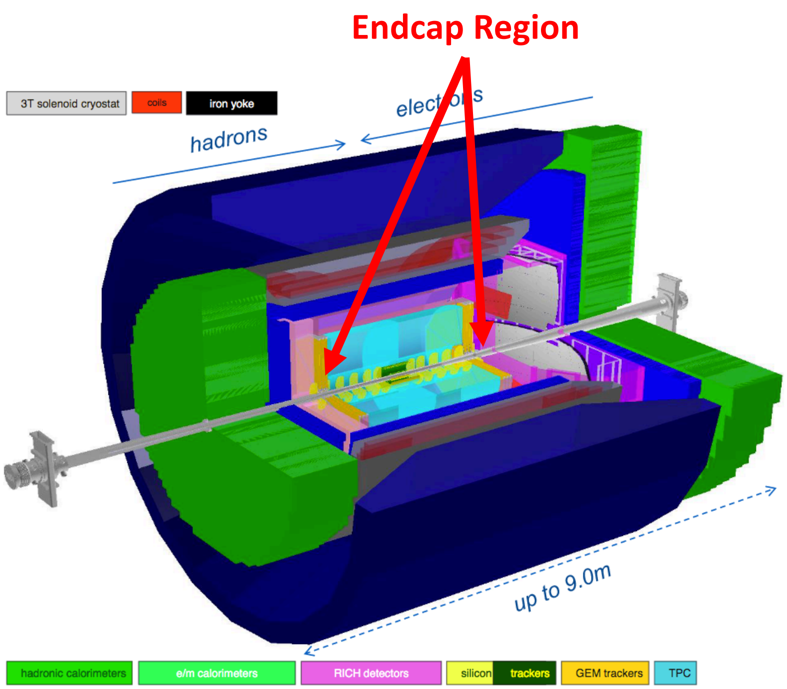
- ❑ Applications in the Central Region
- ❑ Applications in the Endcap Region

Endcap Regions: GEM Trackers

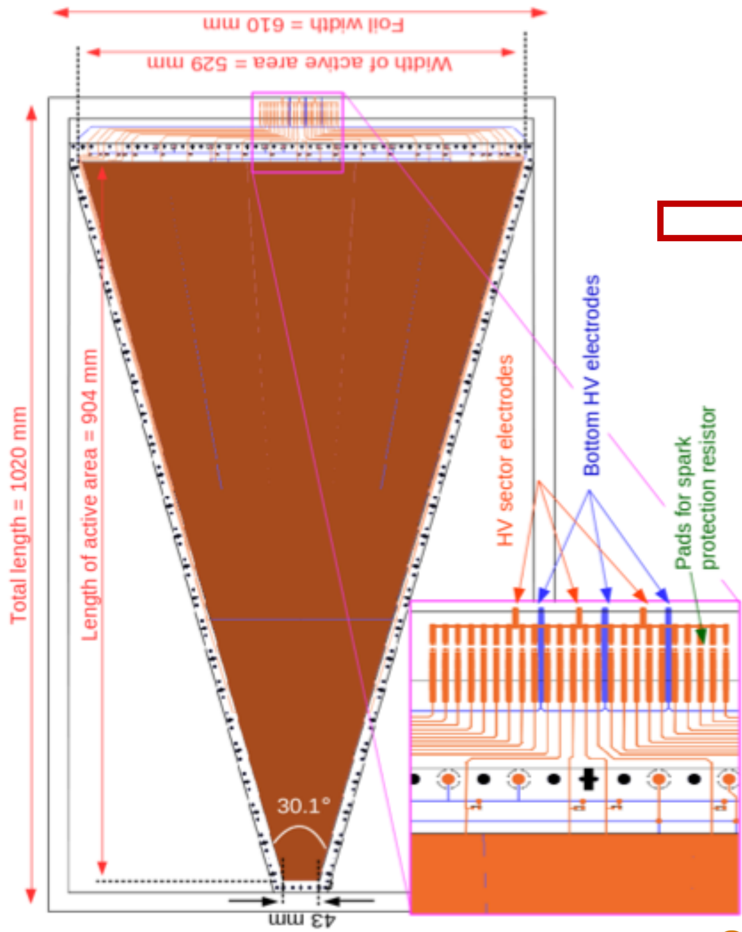


- ❑ Endcap Region
  - Triple-GEM Trackers
  - GEM-TRD Trackers
  - Hybrid MPGD RICH

- ❑ **Triple-GEM Trackers**
  - Implemented in forward and backward endcaps
  - Low material budget
  - Large area
  - Low cost
  - Several assembly and readout techniques investigated

Endcap Regions: GEM Trackers

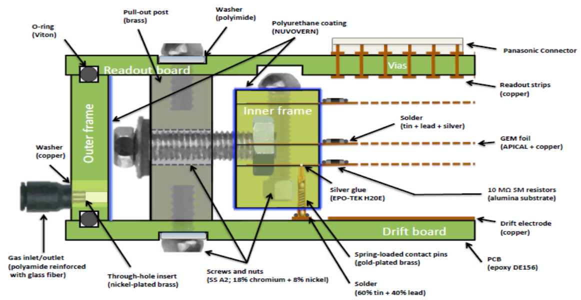
- **Developed common 1 m long GEM foil**
  - All electronics, HV, and gas connections outside of active area
  - Opening angle of 30.1°
  - 8 HV sectors along r (inner)
  - 16 HV sectors along ϕ
  - HV area = ~107 cm^2
  - Active area ~2,584 cm^2

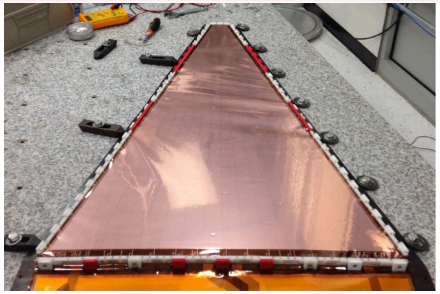


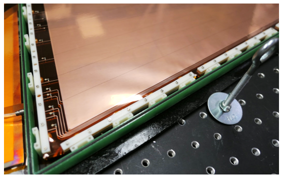
Endcap Regions: GEM Trackers

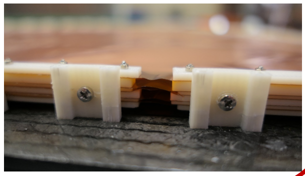
- **Investigated different assembly procedures**
  - Low mass version of CMS mechanical stretching
    - Carbon fiber frames and 3D printed materials
    - No spacers in active area!
    - Some technical issues with tension (under investigation)
  - G10 frames and gluing
    - Requires spacers in active area
  - Use of Kapton rings over G10 spacer grids
    - Initial results show similar dead area as grids

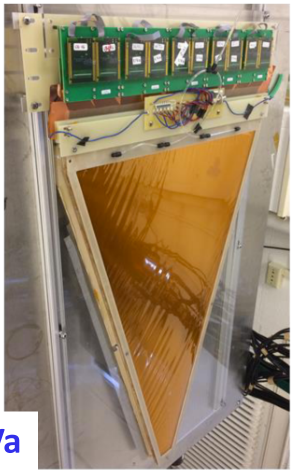
FIT



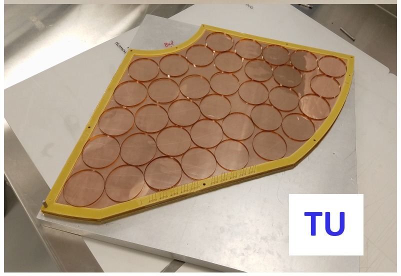








UVa

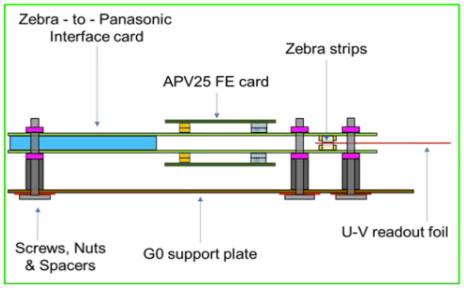


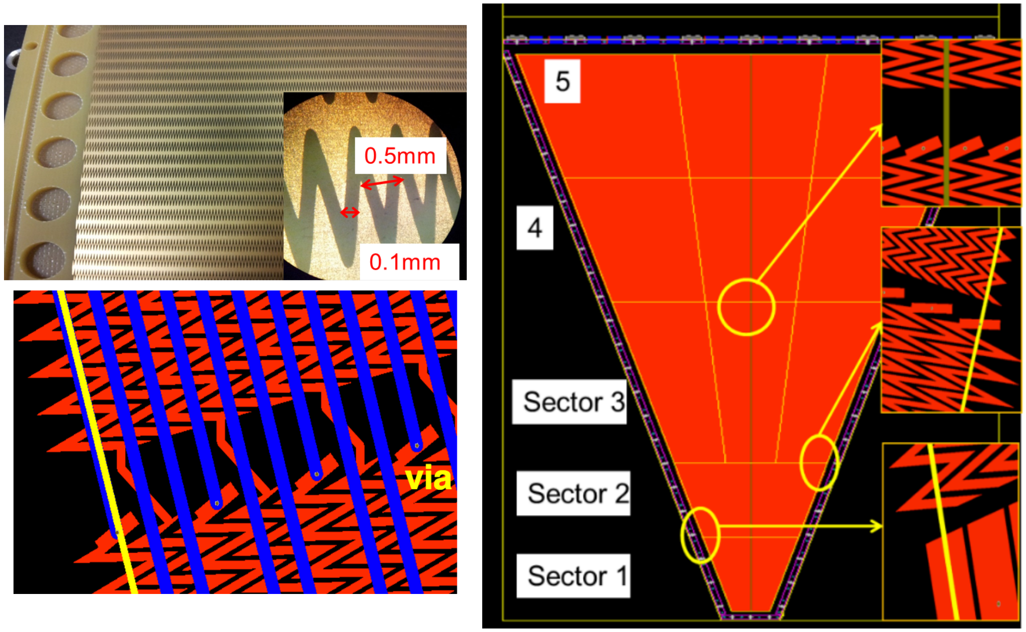
TU

Endcap Regions: GEM Trackers

- **Investigated different readout schemes**
  - Zig-zag
    - $\sigma(\phi) = 100\ \mu m$ (expected)
  - U-V with double sided Zerbra strip
    - $\sigma(\phi/\ r) = 100\ \mu m\ /\ 500\ \mu m$ (expected)

UVa



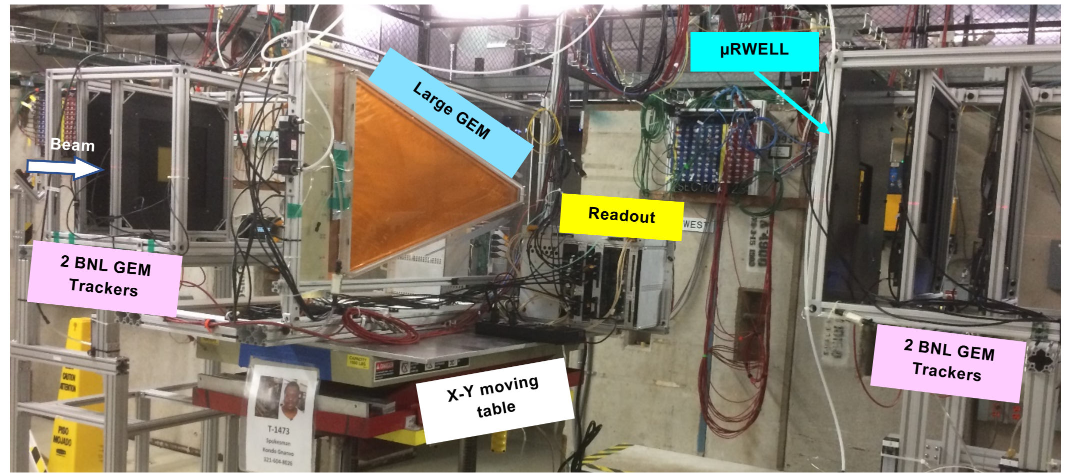


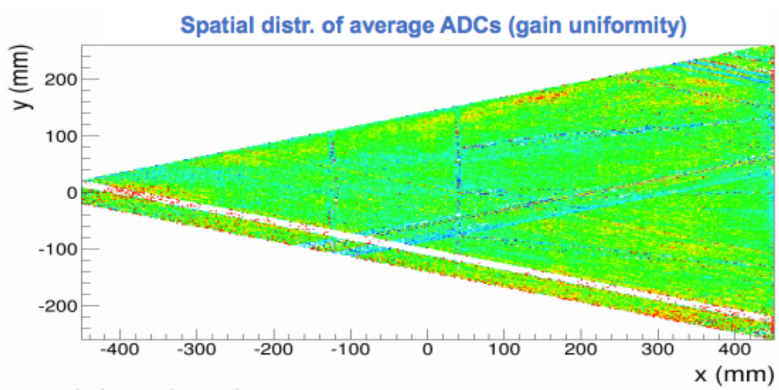
FIT

Endcap Regions: GEM Trackers

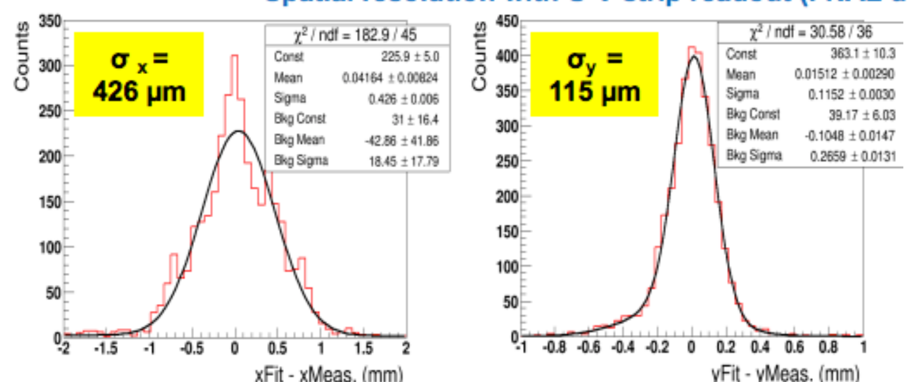
- **Low Mass Large Area GEM Tracker Beam Test**
  - **UVa** tested GEM tracker with FNAL proton beam
  - Detector radiation length = 0.41%
  - Excellent X-Y resolution measured
    - $\sigma_x = 426\ \mu m$
    - $\sigma_y = 115\ \mu m$

Large GEM Setup in MT6.2b Area at FTBF (June-July 2018)



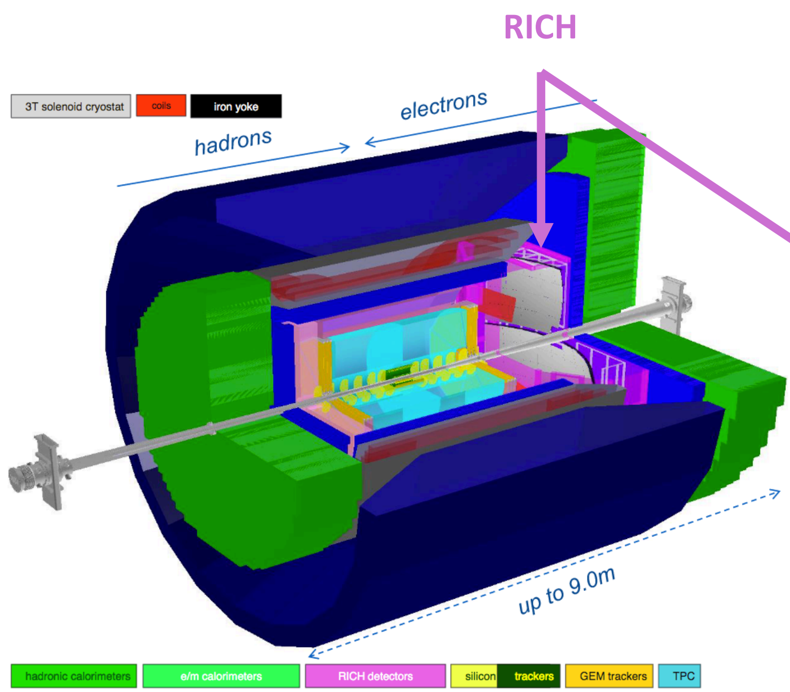


Spatial resolution with U-V strip readout (FNAL data)

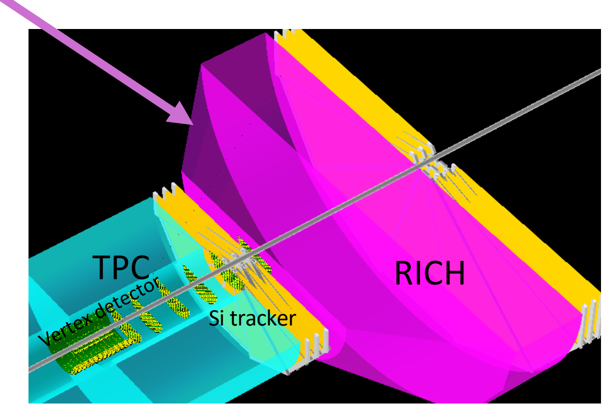


UVa

MPGDs Aiding PID

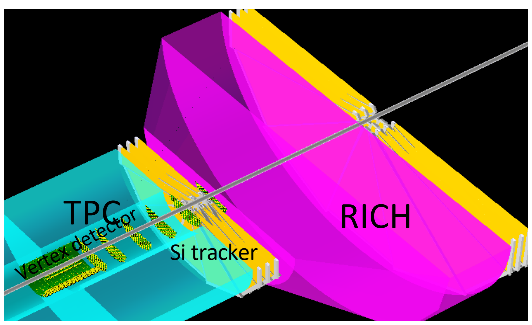


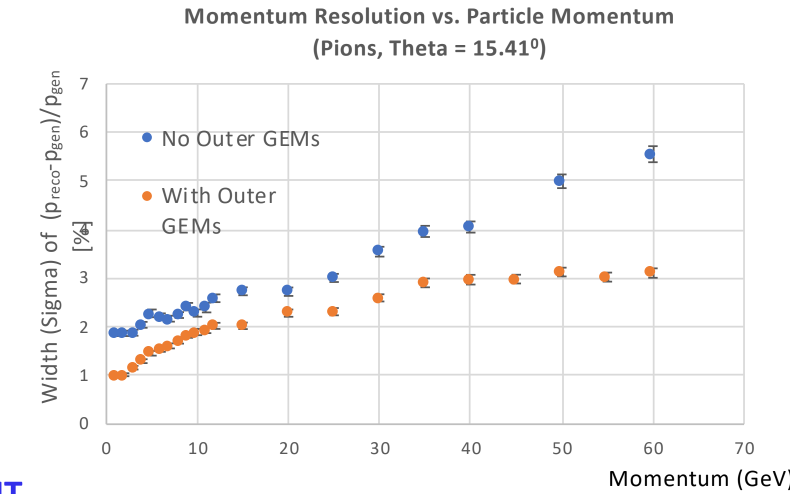
- Endcap Region
  - Triple-GEM Trackers
  - GEM-TRD Trackers
  - Hybrid MPGD RICH
- Assisting PID detectors in the endcap regions
- **Triple-GEM trackers**
  - Located behind the RICH
  - Improved angular resolution and additional information can aid in the Cerenkov ring reconstruction



MPGDs Aiding PID: RICH

- **Endcap Outer GEMs (simulation)**
  - Impact of outer forward GEM trackers on RICH ring reconstruction still under investigation.
  - Preliminary effects from **FIT** on momentum resolution have been studied.
    - Simulated detectors include
      - Vertex, silicon, and GEM trackers
      - TPC
      - RICH volume
      - Magnetic Field = 1.5 T
  - Significant improvement is seen
    - at large momentum
    - Small angle





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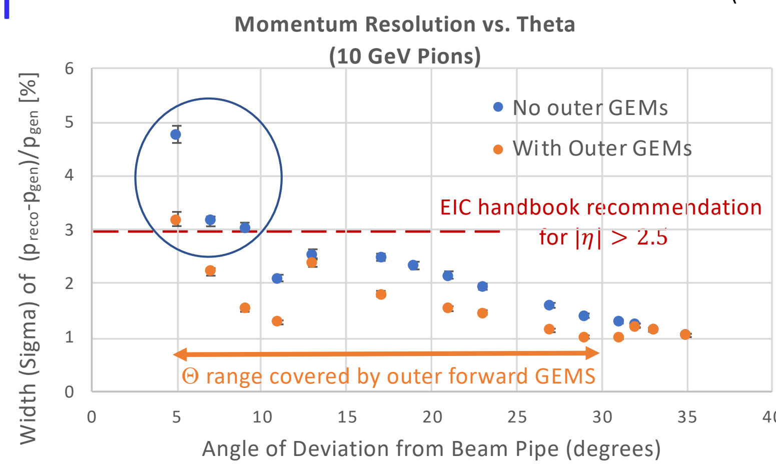
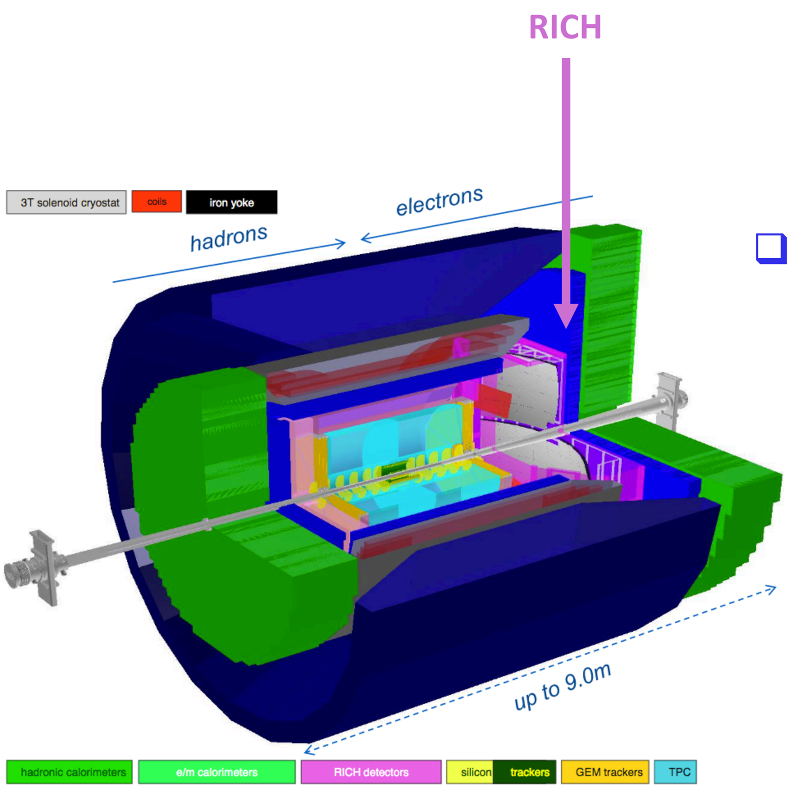
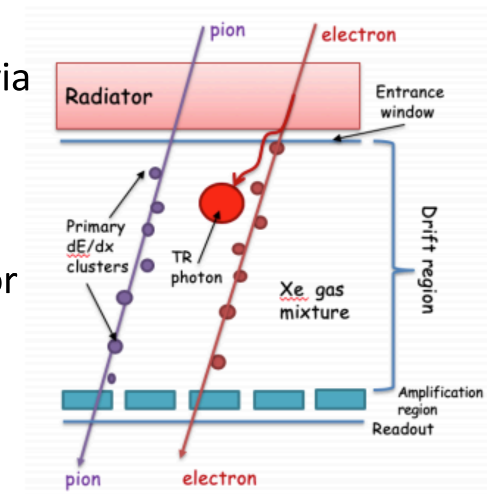


GEM-TRD Tracker

- Endcap Trackers
  - Triple-GEM Trackers
  - **GEM-TRD Trackers**
  - Hybrid MPGD RICH

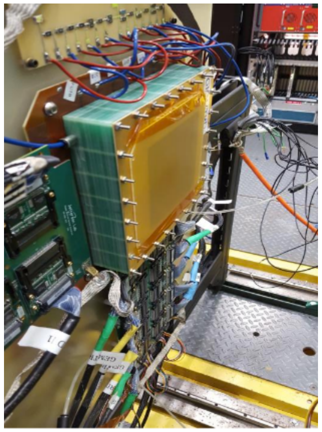


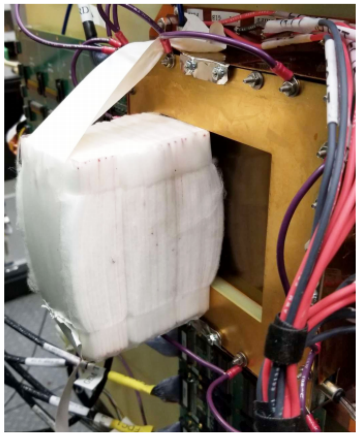
- **GEM-TRD Tracker**
  - TR allows π/e discrimination via dE/dx
  - ID electrons (p ~ 1-100 GeV) from pions
  - Triple-GEM based TRD detector
  - Operates in a μTPC mode providing tracking information
  - Located in the hadron endcap (behind the RICH)

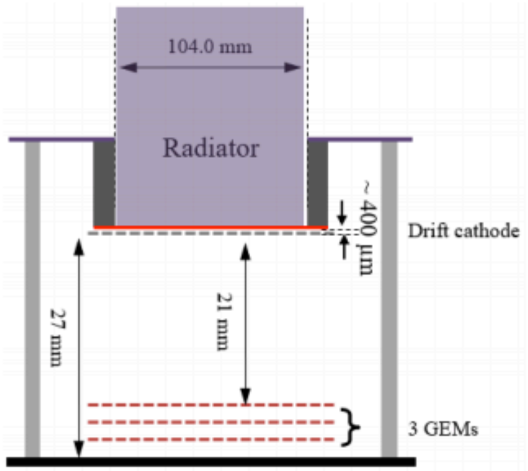


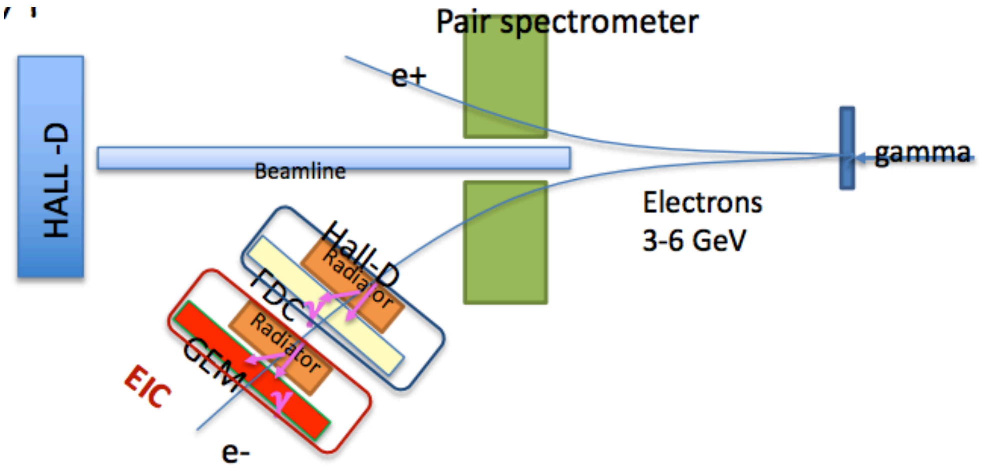
GEM TRD/Tracker Prototype (JLab, TU, UVa)

- Xe/CO_2 (70:30) gas
- Drift gap of 21 mm
- 10 cm radiator
- Flash-ADC with VME based readout
  - work in progress for streaming readout mode
- Beam test ran in JLab Hall D with 3-6 GeV electron beam
- e/π rejection can be assessed comparing dE/dx of electron with and without radiator





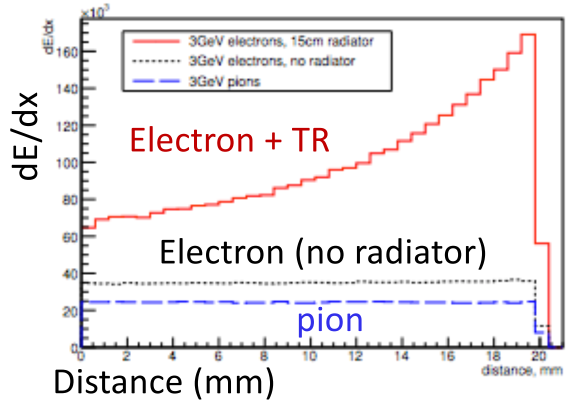


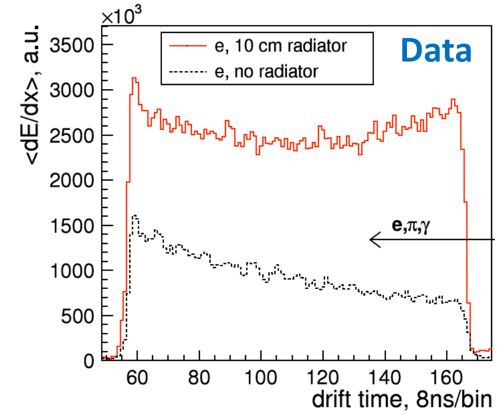


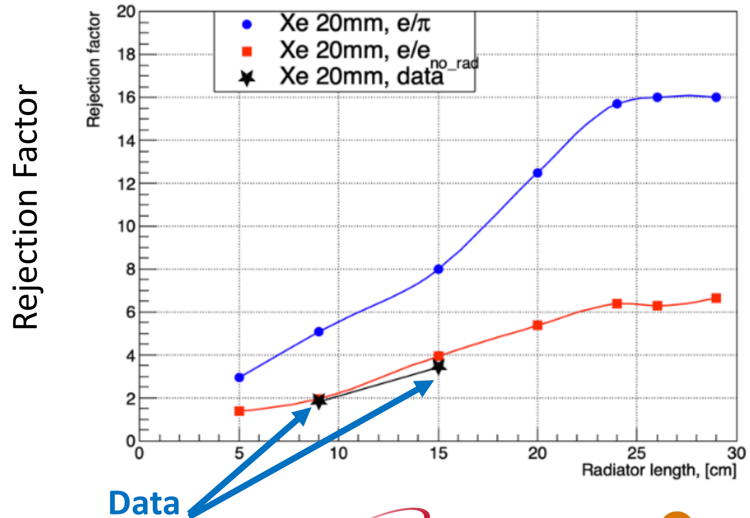
GEM-TRD Tracker: PID

Nucl. Instrum. Meth. A 942, 162356 (2019).

- **PID of GEM TRD Tracker (JLab, TU, UVa)**
  - Clear measurement of TR
  - Good agreement between data and simulation
  - Several data analysis and machine learning approaches were used to estimate e/π rejection factor.
  - MC suggests the prototype achieved a rejection factor of ~5-8







GEM-TRD Tracker: Tracking

- **GEM TRD Tracking (JLab, TU, UVa)**
  - Triple-GEM readout can reconstruct X-Y hit locations
  - Operating with large drift gap in μTPC also allows for reconstruction of Z coordinate
- Further beam tests are in the works to directly measure the pion rejection factor and optimize the detector

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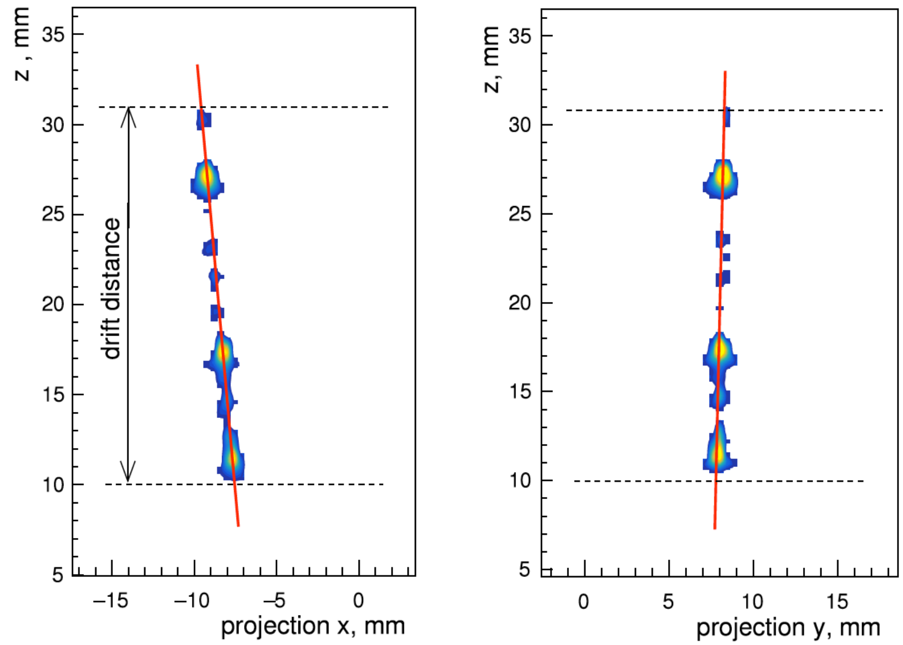
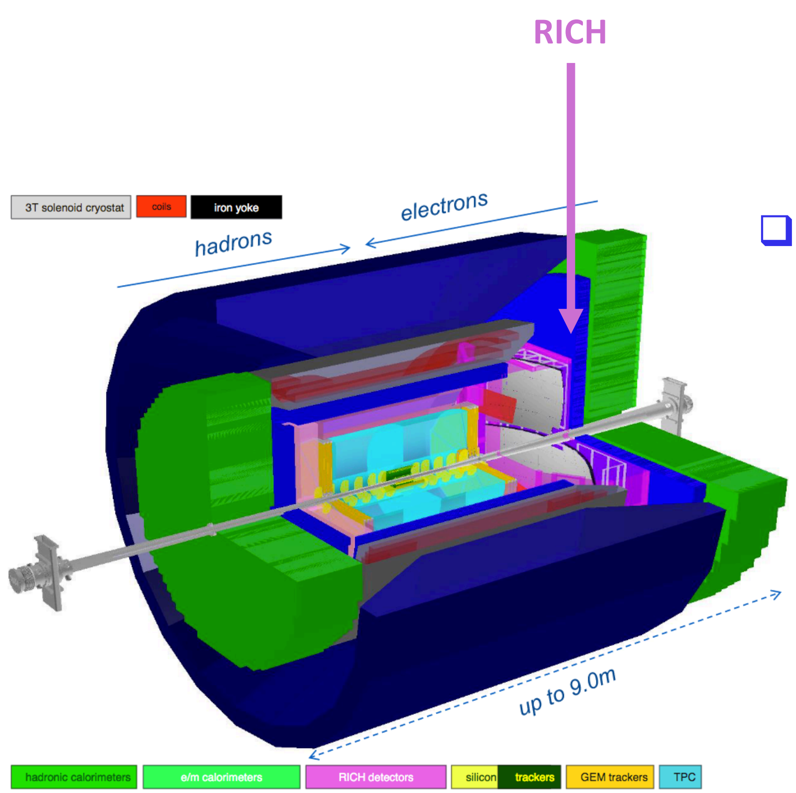
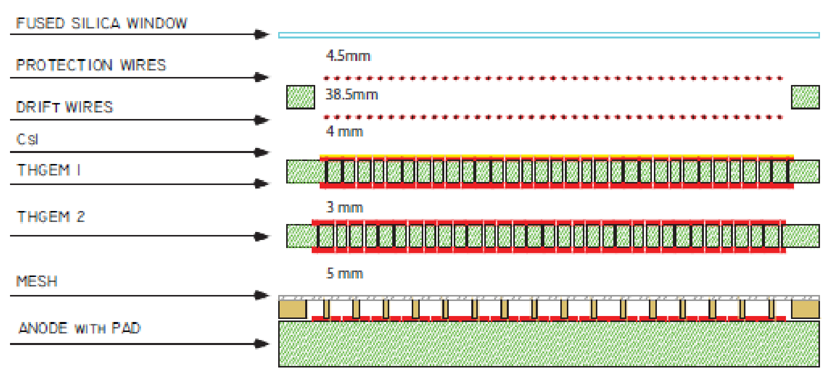


Hybrid MPGD RICH



- Endcap Trackers
  - Triple-GEM Trackers
  - GEM-TRD Trackers
  - Hybrid MPGD RICH

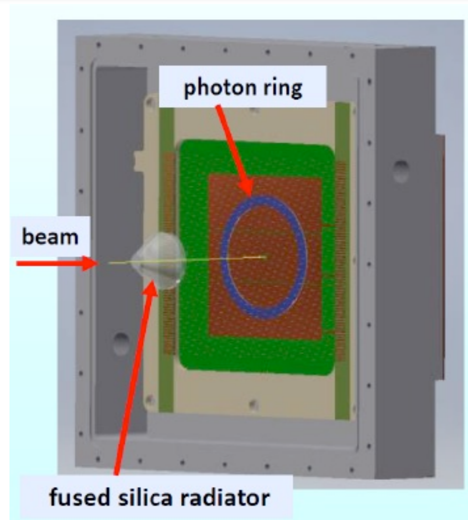
- **Hybrid MPGD RICH**
  - Single-photon detection with for high-momentum RICH (above 6-8 GeV)
  - Resistive thick GEM-MicroMegas hybrid detector
  - Radiator gas is the detector gas
  - Based on Compass design



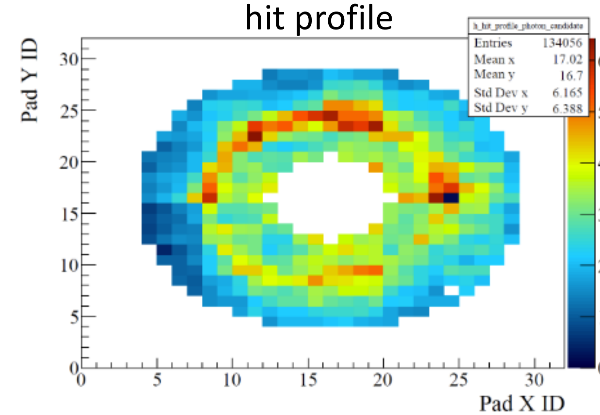
Hybrid MPGD RICH

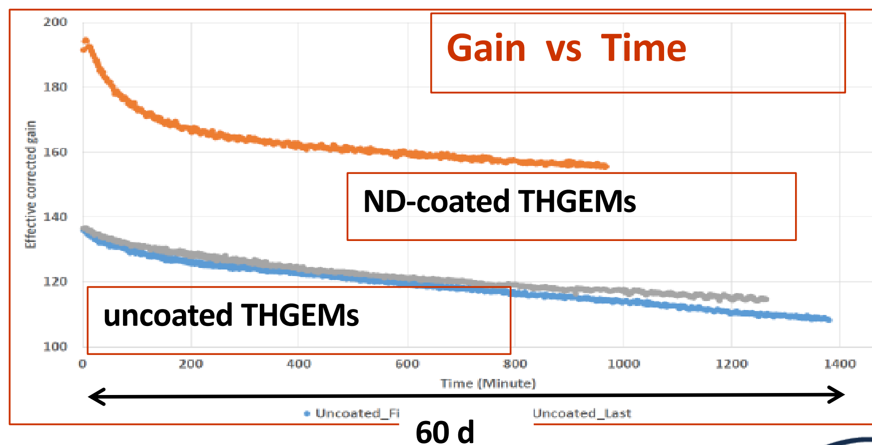
- Hybrid MPGD RICH
  - Tested in beam at CERN
  - 2 gases investigated
    - $ArCH_4$ (50:50)
    - Pure methane
  - For $ArCH_4$
    - Gain ~30k
    - Time resolution ~14 ns
  - Second version being built
    - Optimizing electronic noise
    - Implementing DCL resistive layer

- Development of new photocathode
  - Nano-diamond (ND) coating on THGEM
  - Gain increase seen with coating
  - Investigating resolution and QE of ND



Photon candidate hit profile





Summary

❑ MPGDs for an EIC

- Are under active R&D
- Can be applied to any of the initial EIC detector place holder concepts
- Can make an impact in both central and endcap regions
- Moving beyond just tracking to also provide PID