The Role of Micro-Pattern Gas Detectors in a Hybrid EIC Tracking System

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Center for Frontiers in Nuclear Science
Workshop series

Opportunities with Heavy Flavor at the EIC - a CFNS Ad hoc Workshop

Nov. 6, 2020

College of Science and Technology
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Outline

- ❑ Detector Overview
- ❑ A Hybrid Detector
- ❑ MPGDs in the Central Region
- ❑ MPGDs in the Endcap Regions
- ❑ Photo-Sensitive MPGDs
- ❑ Summary

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

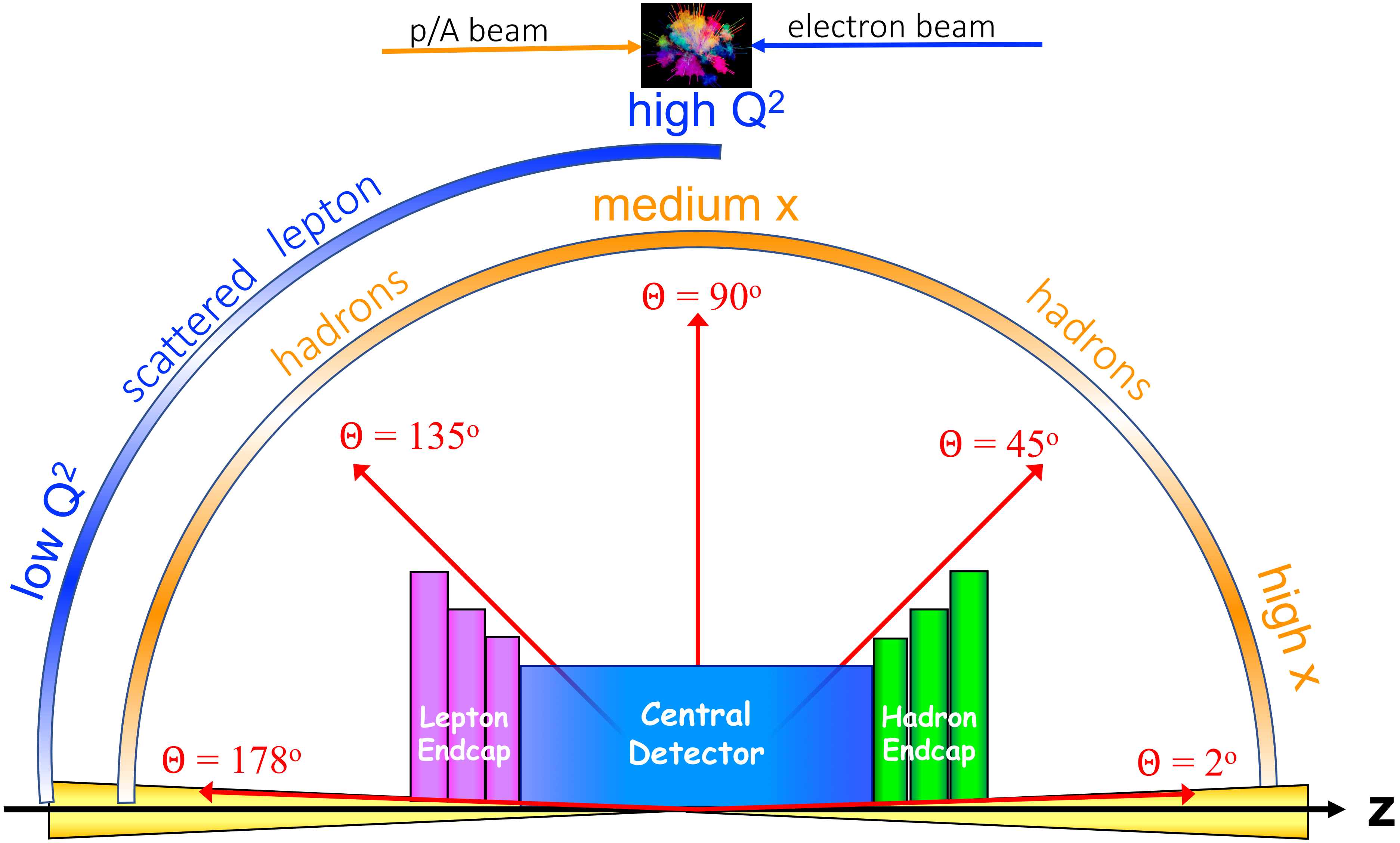
1. Brookhaven National Lab (BNL)
2. CEA Saclay (Saclay)
3. Florida Inst. Of Technology (FIT)
4. INFN
5. Stony Brook University (SBU)
6. Temple University (TU)
7. University of Virginia (UVa)
8. Yale University (YU)

And **eRD22**

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

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

EIC Kinematics



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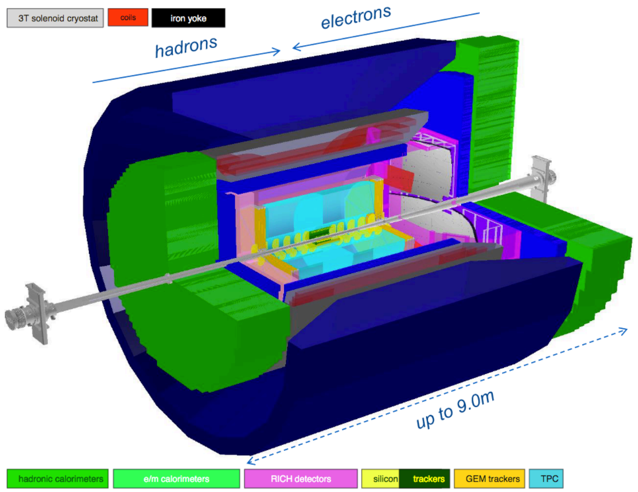
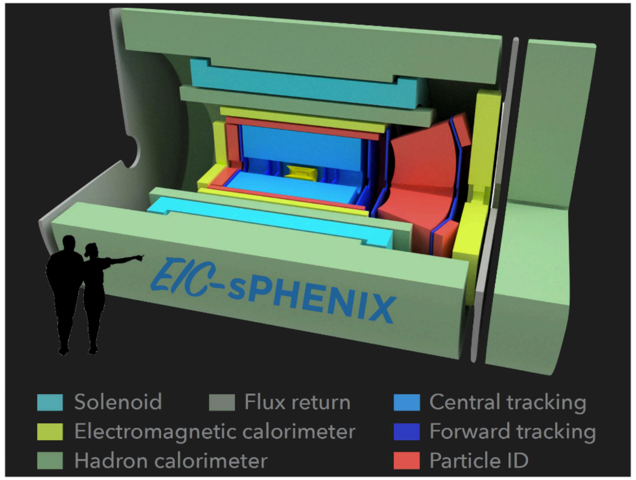
- 4 working EIC envelope place holders: BeAST (BNL), ePHENIX (BNL), JLEIC (JLab), TOPSide (ANL)
  - Common features
    - vertex + central + forward/backward endcap
    - 4π hermetic acceptance to few degrees from beamline
    - Require low material budgets
    - Good momentum resolution
    - Solenoidal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

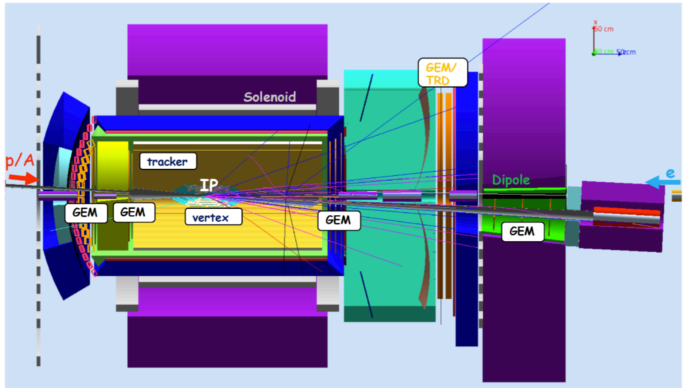
BeAST



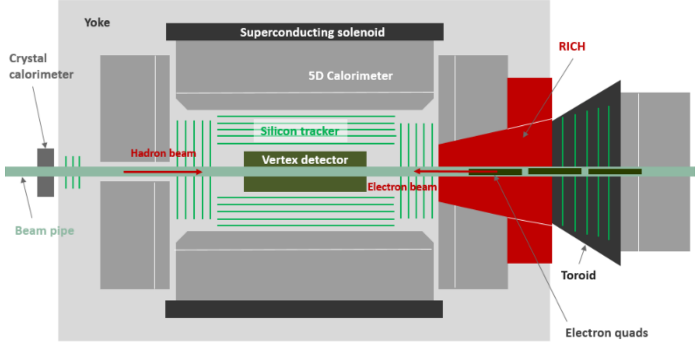
ePHENIX



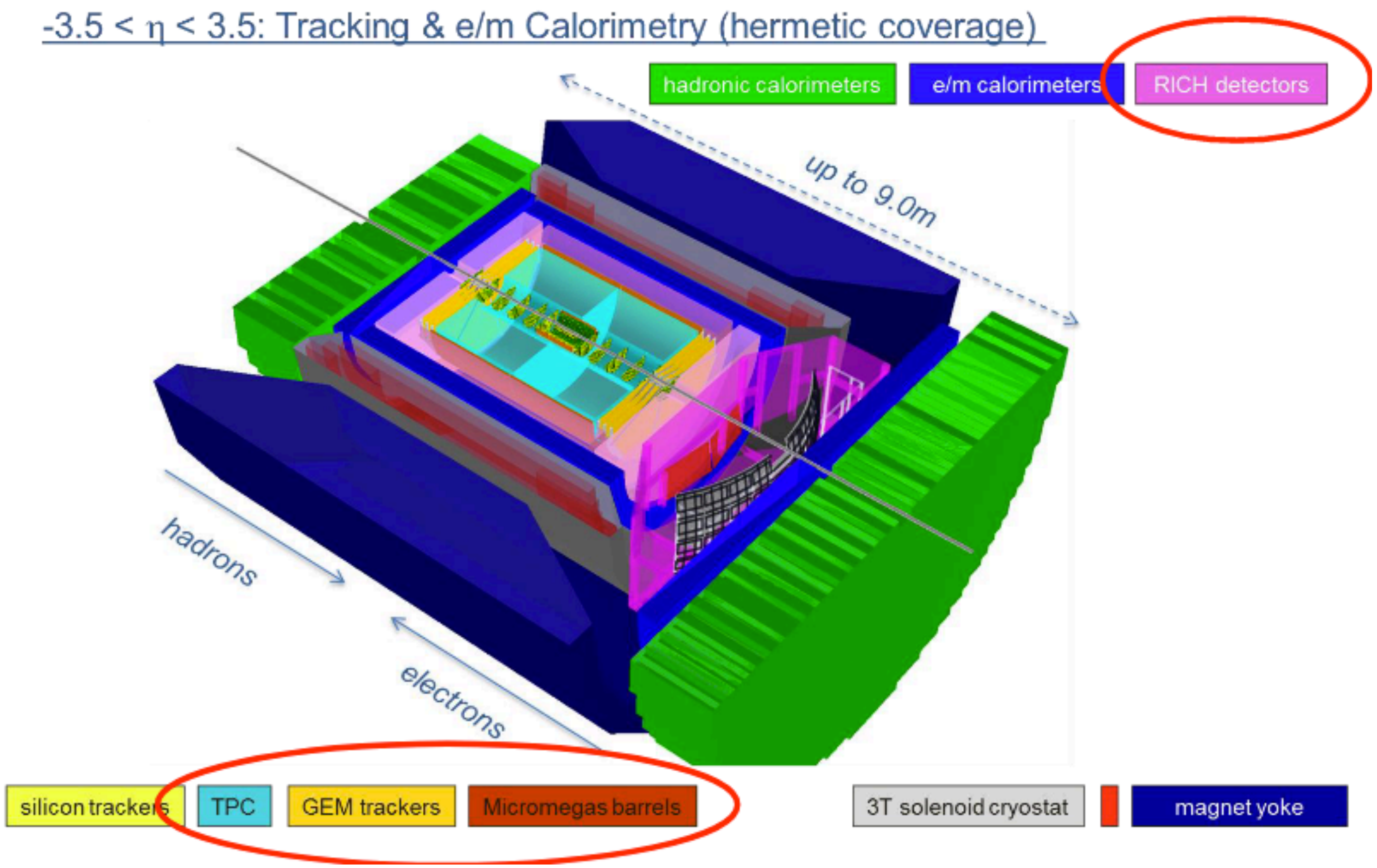
JLEIC



TOPSiDE

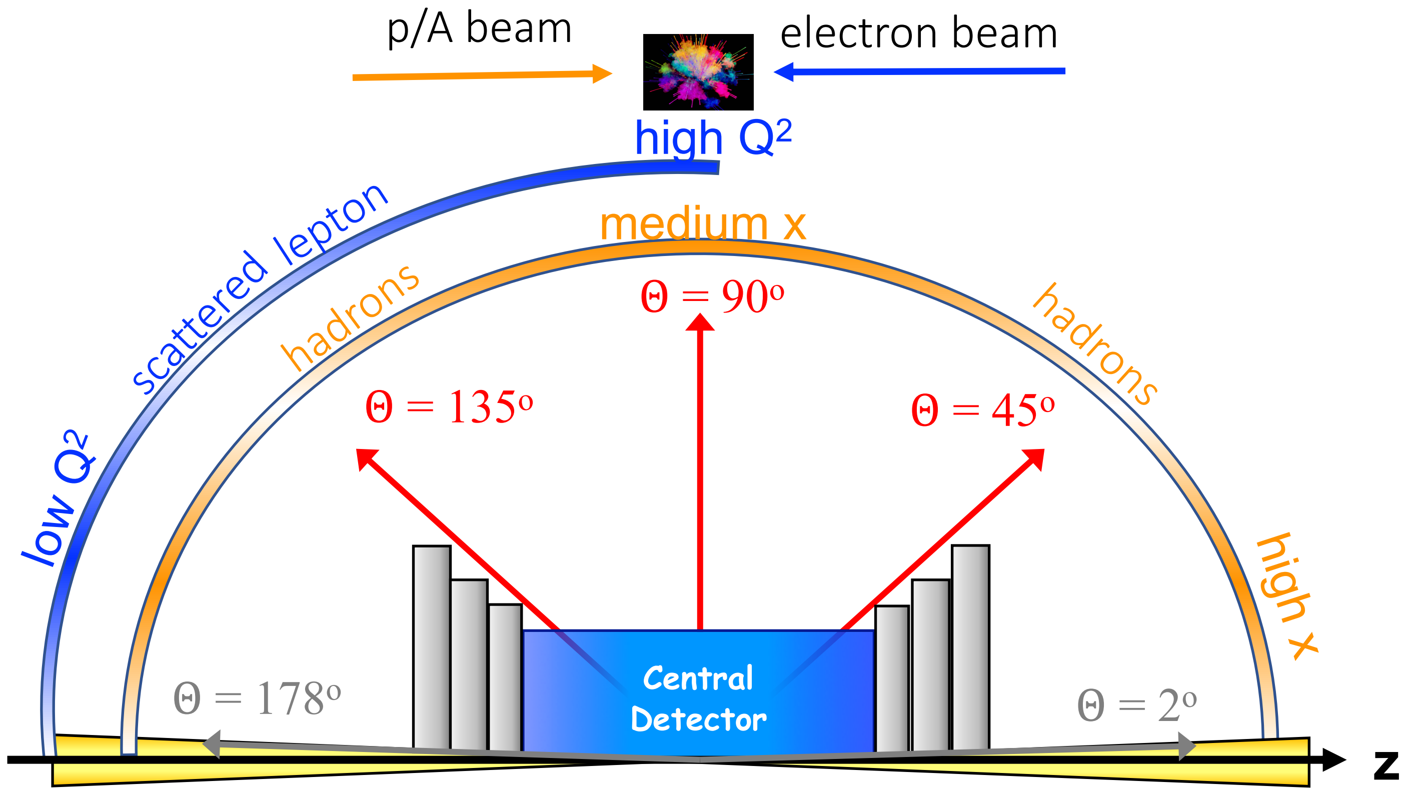


❑ Where can MPGDs fit in?



❑ Central tracking detector configurations

- Si vertex + TPC
- Si Vertex + MPGD Barrel



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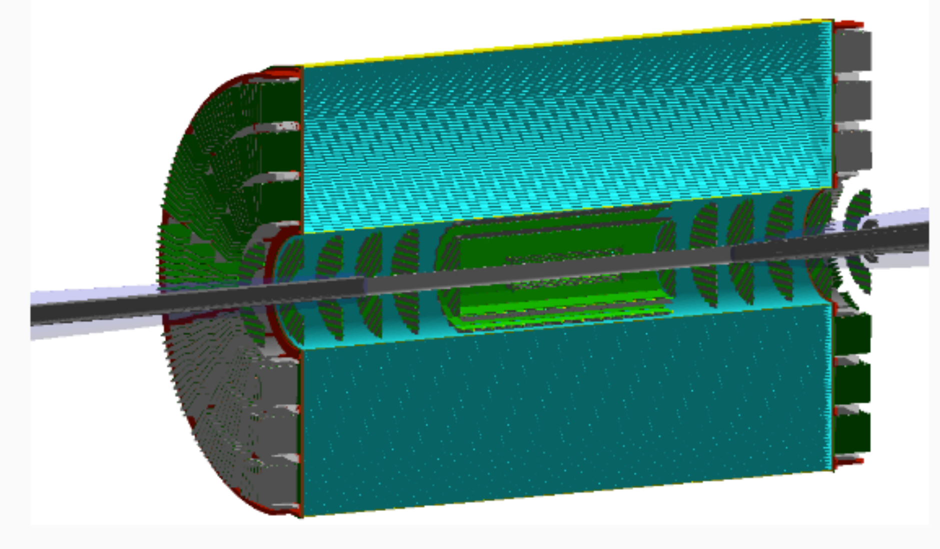
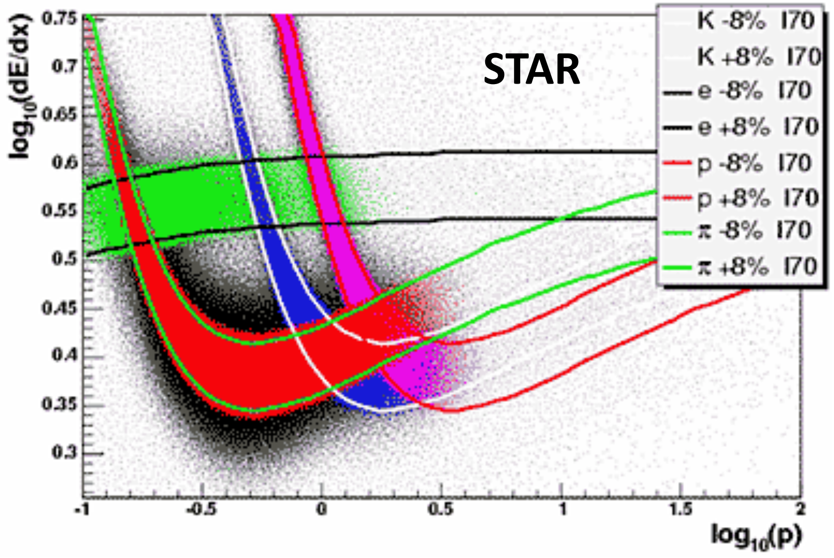
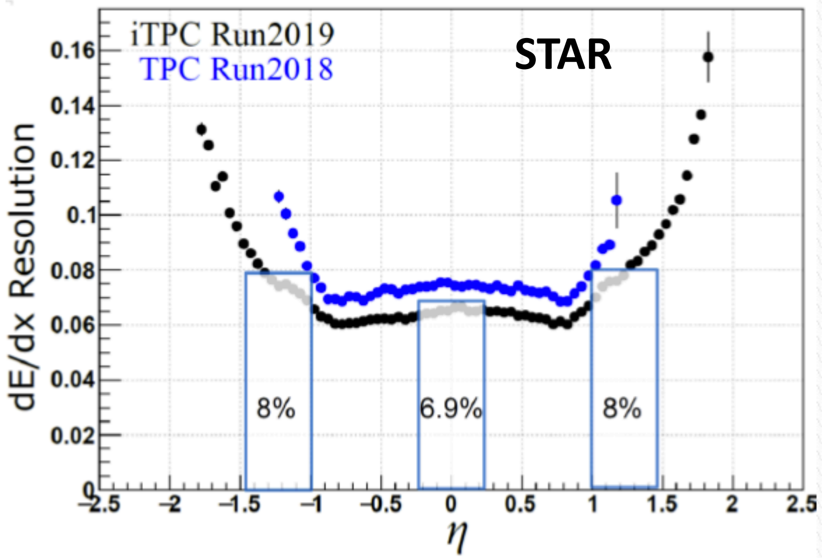
❑ TPC

- Compact: radial volume = 60 cm
  - STAR - 150 cm, ALICE - 162 cm
- Samples many space points to provide
  - Particle momentum and charge ID
  - dE/dx for PID – important for EIC
- Low material in tracking volume
- Paired with Si vertex tracker



https://www.bnl.gov/rhic/news/081208/story1.asp

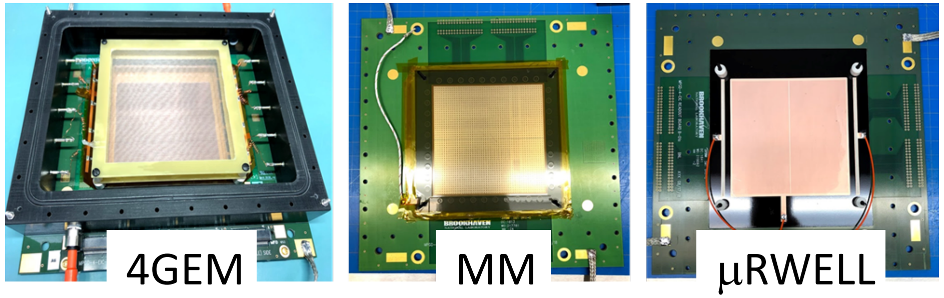


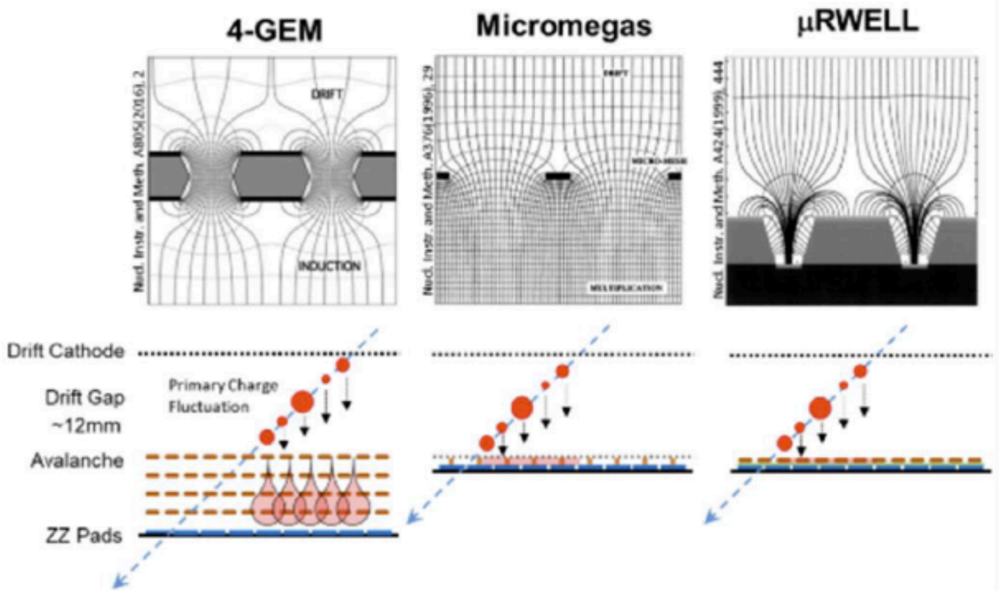


STAR iTPC Upgrade (RHIC S&T review, Caine)

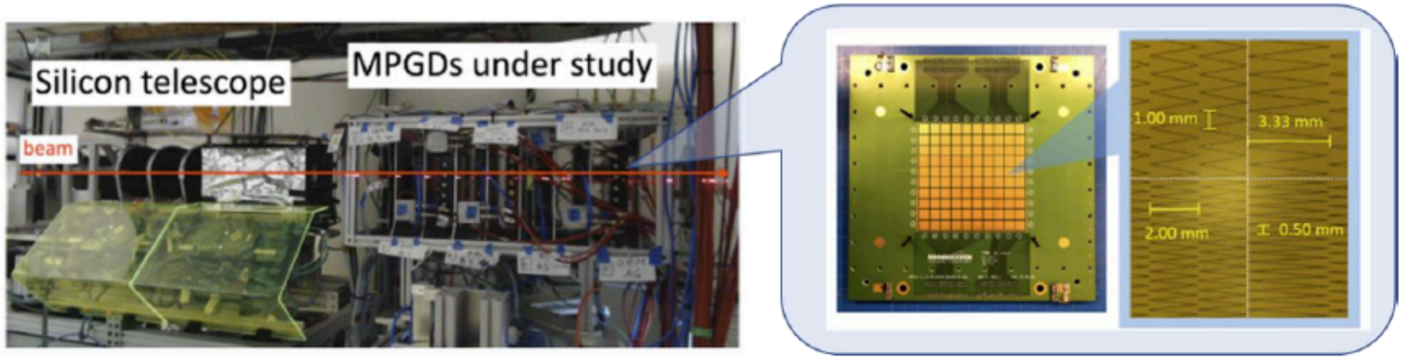
TPC MPGDs

- MPGD based avalanche structure with zigzag readout for TPC
- Variety of zigzag patterns tested
- Tests provide a baseline measure of performance for each avalanche scheme and reveal optimal parameter sets
- Not exhaustive test
  - gas mixtures were not tested
  - Field configuration not optimized





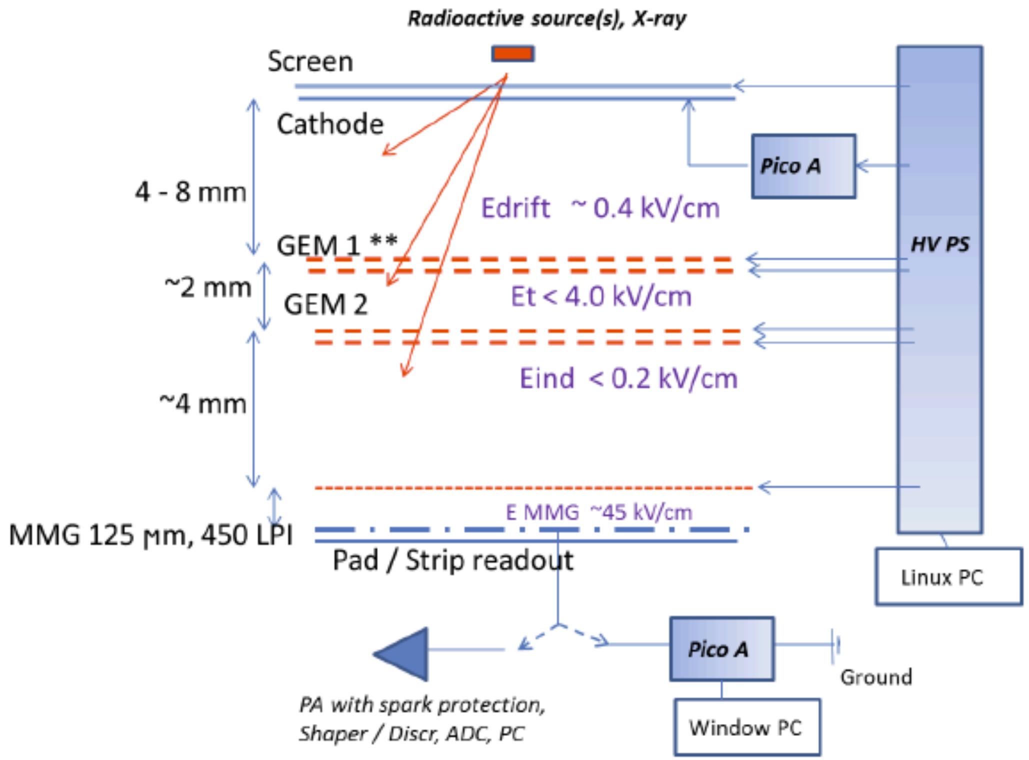
eRD6: BNL, SBU

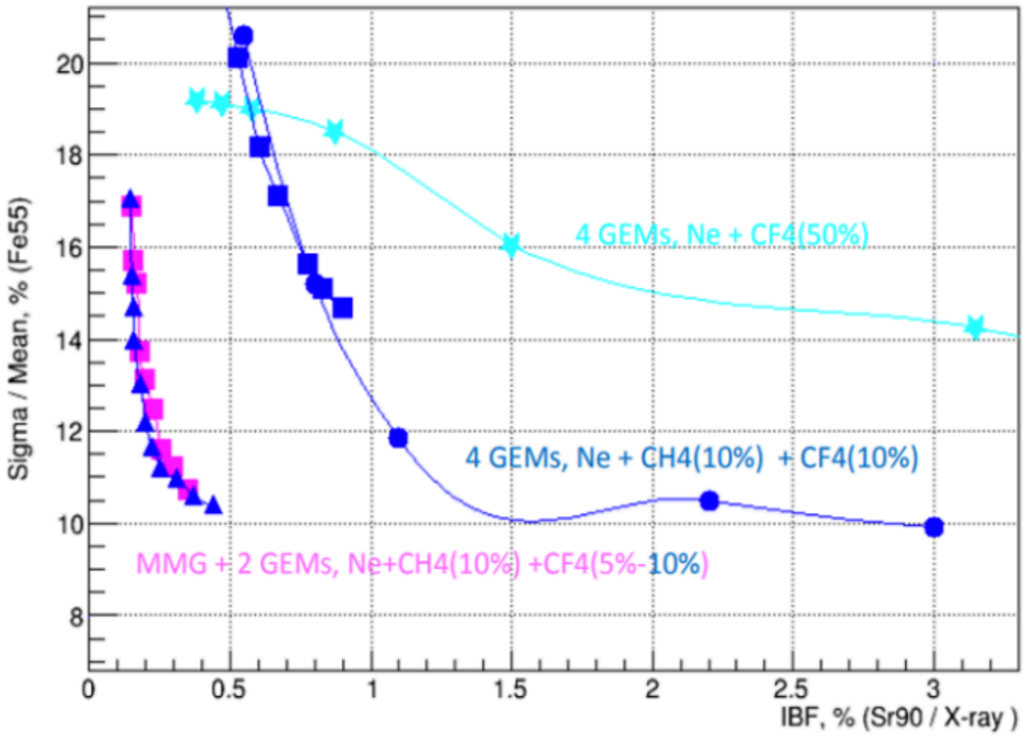


TPC MPGDs

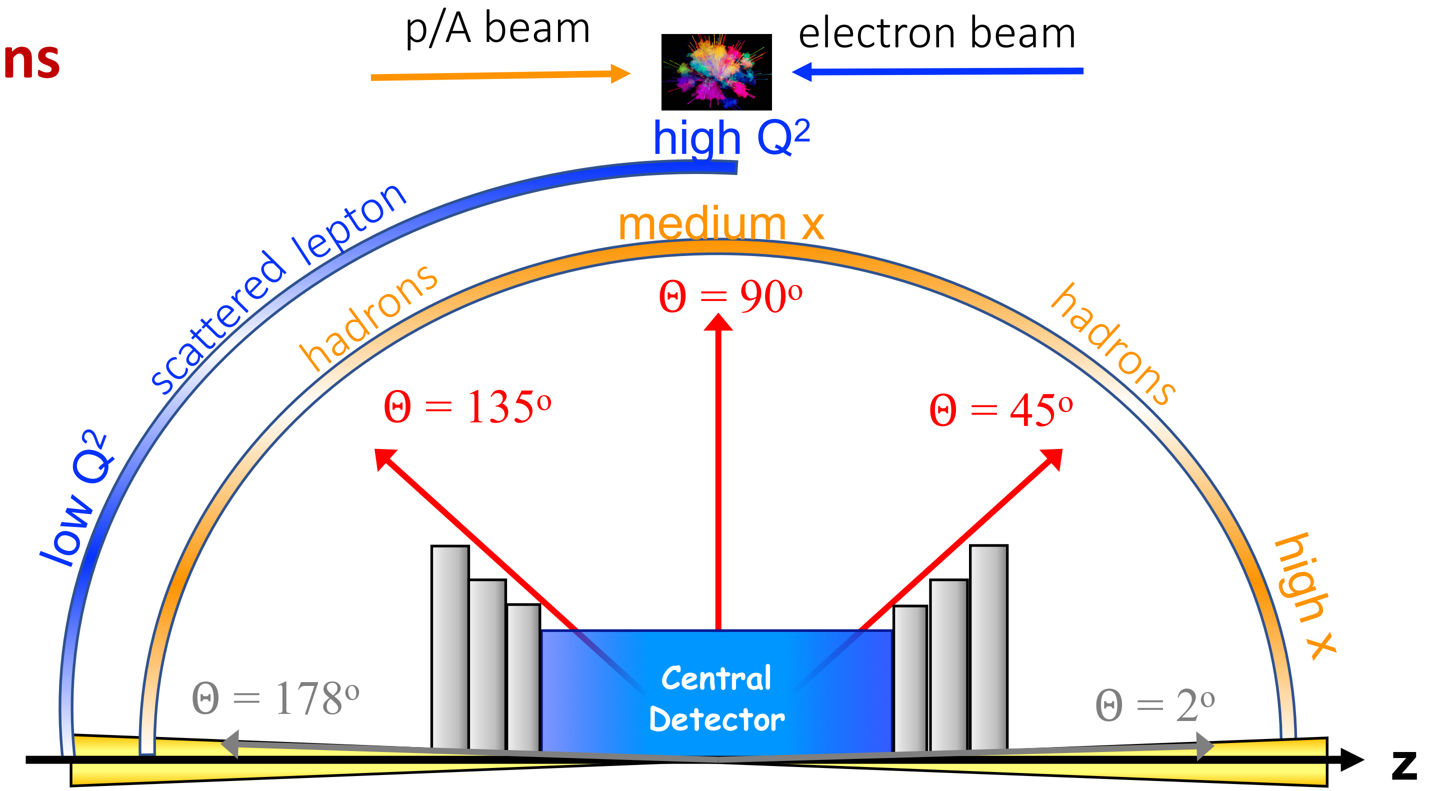
- Investigation into IBF and dE/dx in Hybrid MPDG based TPC readout
  - Minimize IBF and maximize dE/dx

eRD6: YU





- ❑ **Central tracking detector configurations**
  - o Si vertex + TPC
    - ➢ Fast cylindrical MPGDs
  - o Si Vertex + MPGD Barrel



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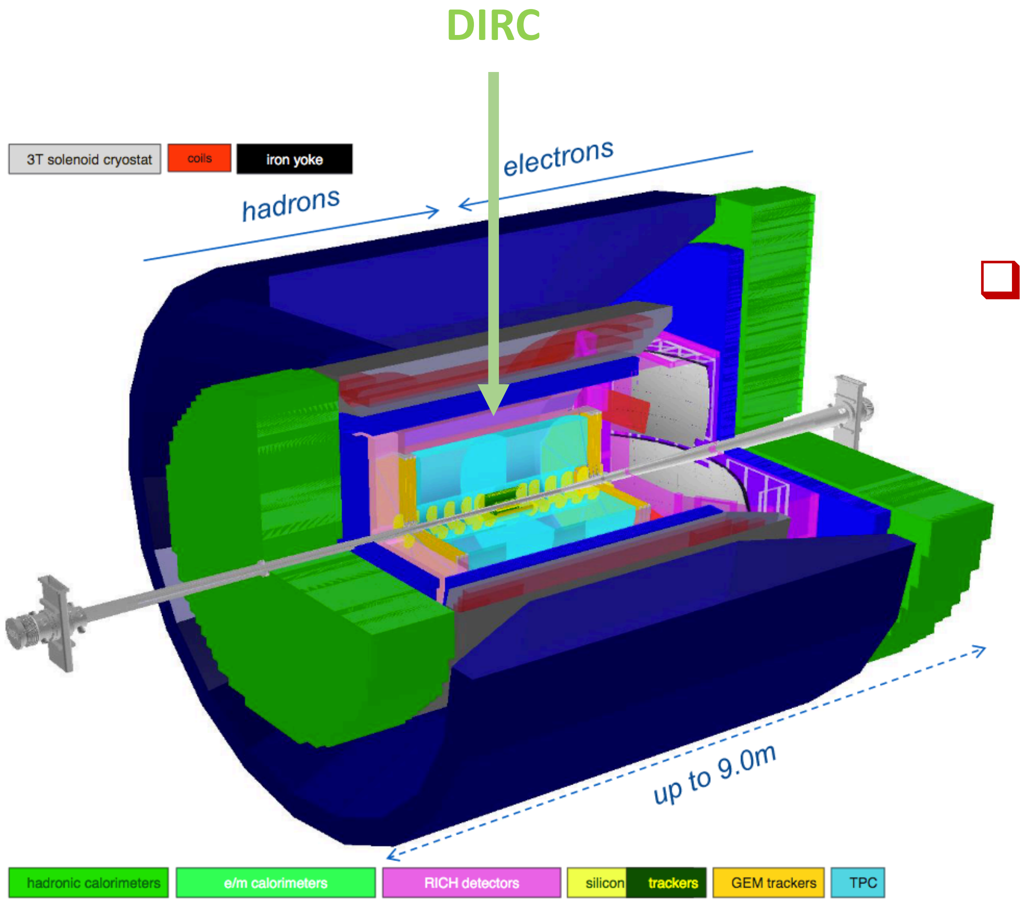
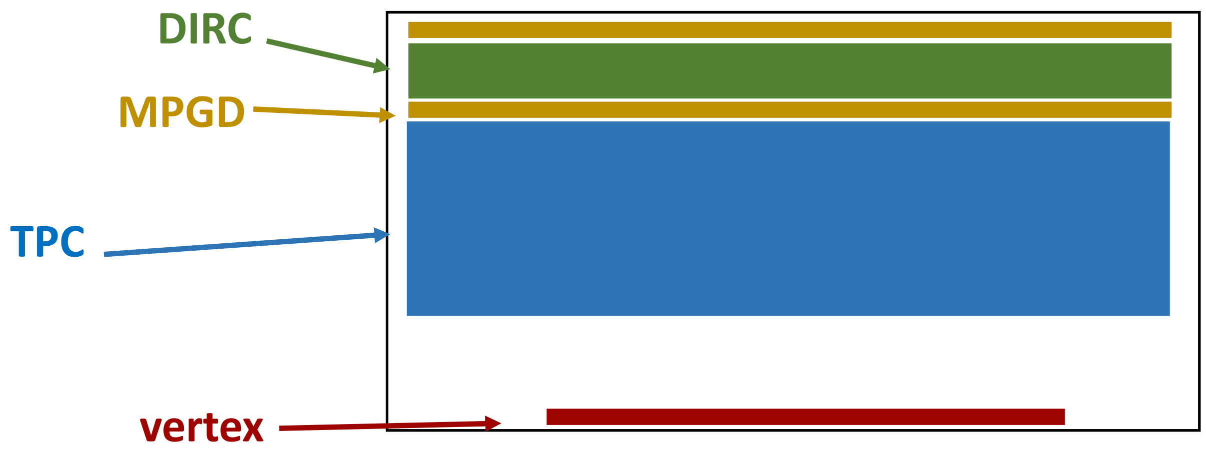


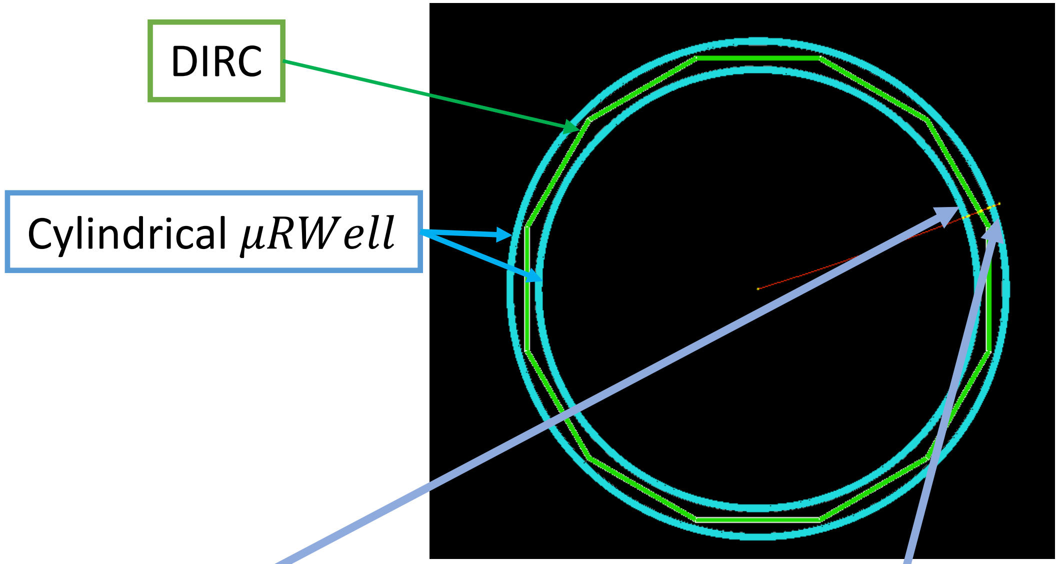
- **Fast Cylindrical $\mu RWELL$ layer**
  - Located just before and after the PID detector (DIRC)
  - Improved angular resolution of the track can be used to increase PID separation of hadrons (π/K)

- **In a TPC + MAPS configuration**
  - Aid with correcting TPC distortions and calibration
  - Provide fast timing for TPC and MAPS

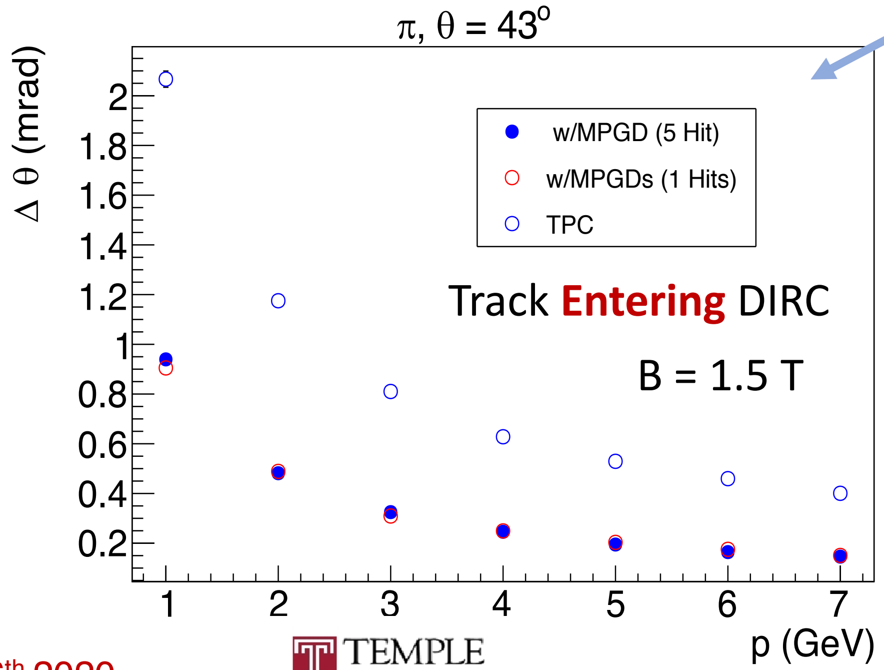


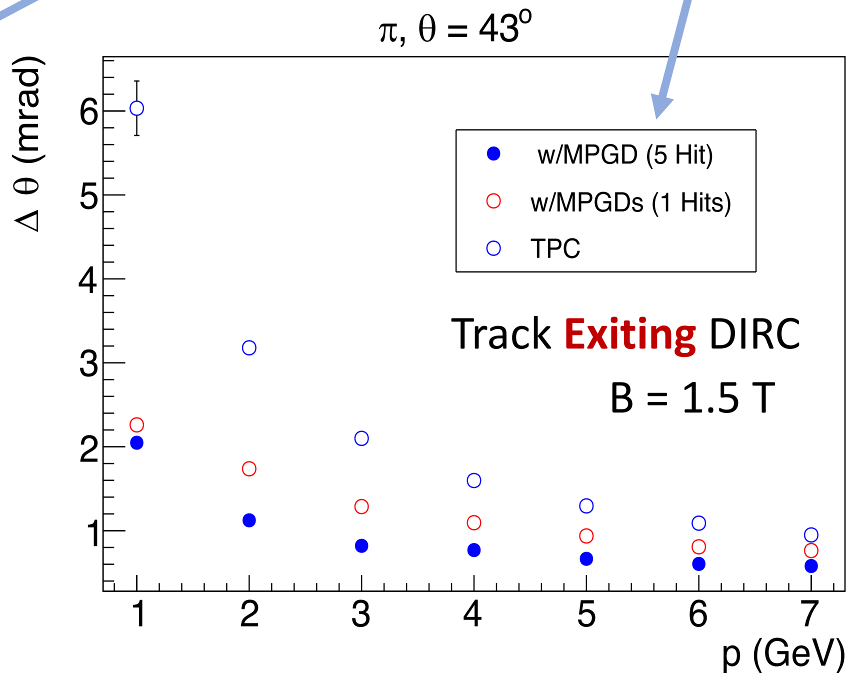
Barrel: Fast Cylindrical MPGDs

- **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



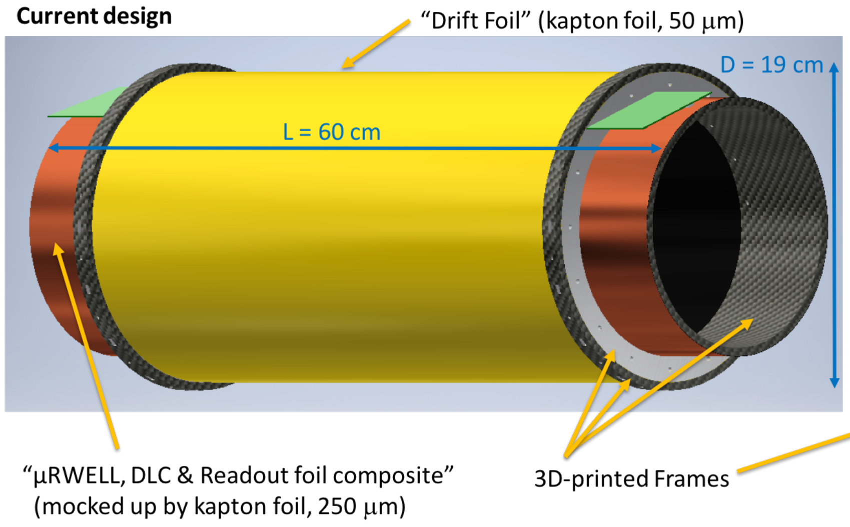
eRD6: TU

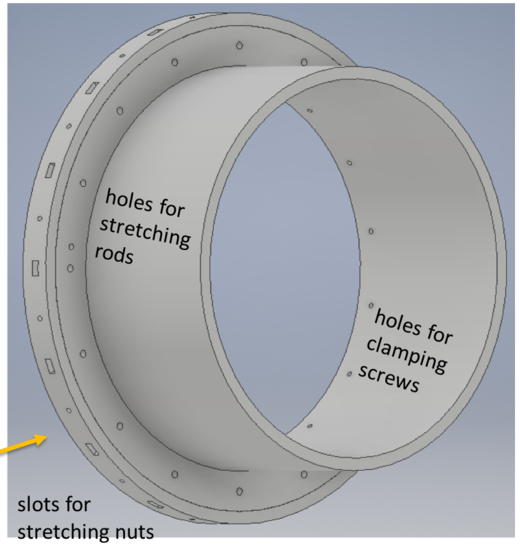




Mechanical Support structure mockup for fast cylindrical $\mu RWELL$ layers

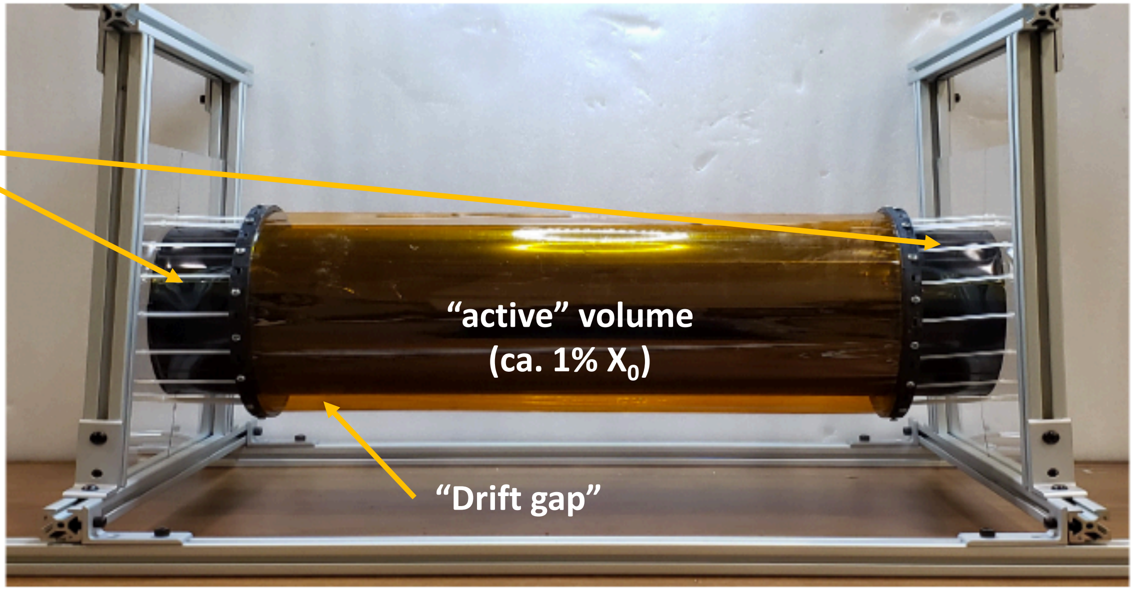
- Kapton foils
- 3D printed frames
- Nylon stretching rods
- Total Length: 60.3 cm
- Inner Kapton diameter: 16.2 cm
- Outer Kapton diameter: 19.6 cm





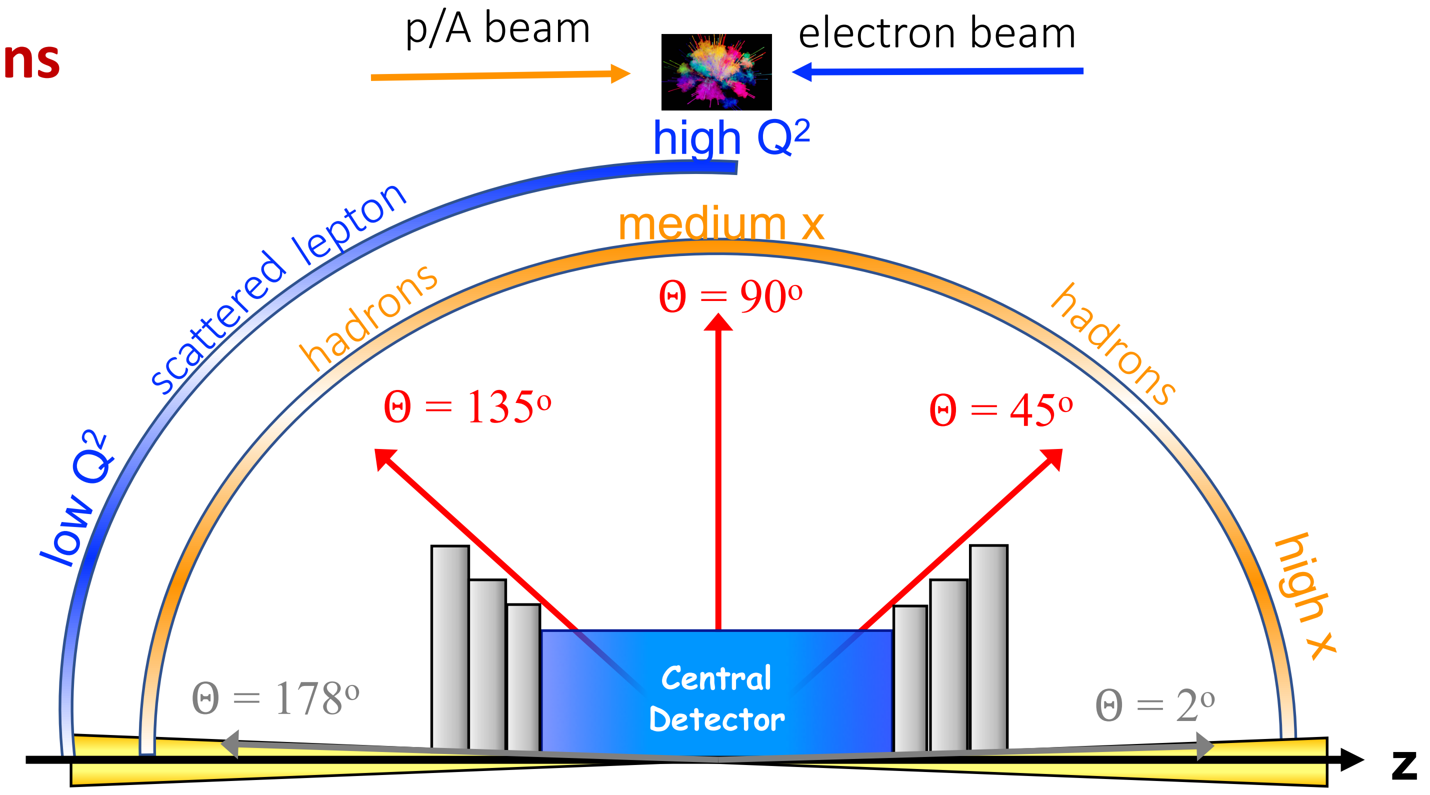
eRD6: FIT

Support area for connectors & cables



❑ Central tracking detector configurations

- ○ Si vertex + TPC
- ○ Si Vertex + MPGD Barrel
    - ➢ **Micromegas**



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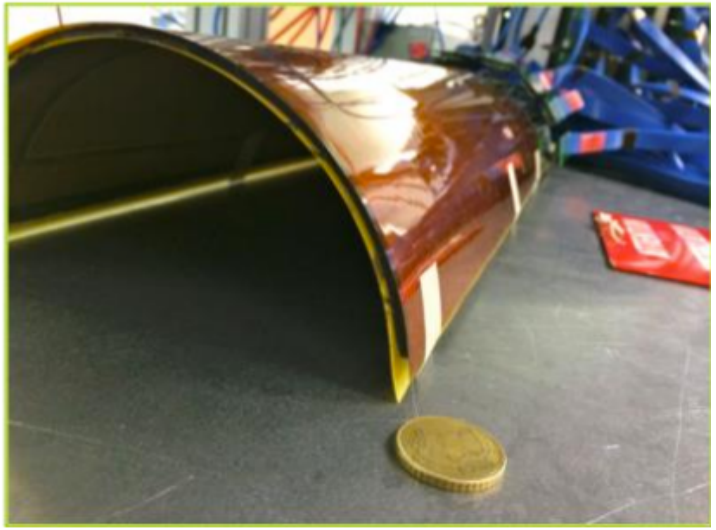
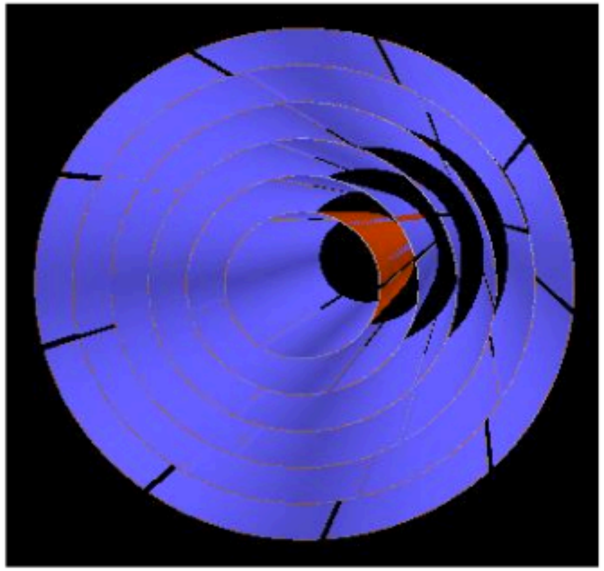
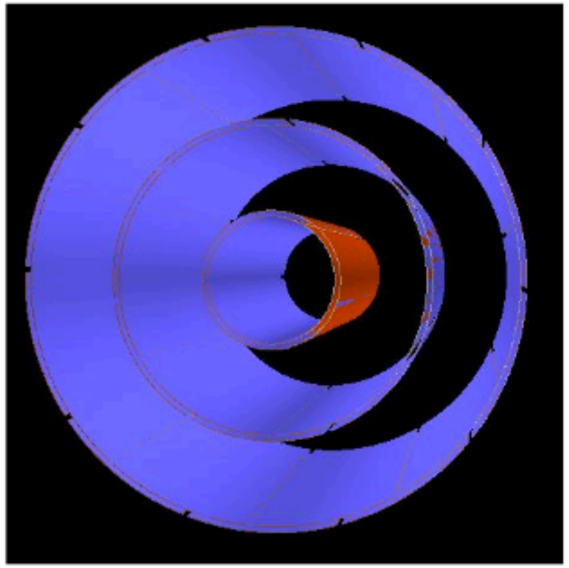
Barrel: Si Vertex + Cylindrical MPGD Barrel



Qinhua Huang, et al: CEA Saclay



6 equidistant layers

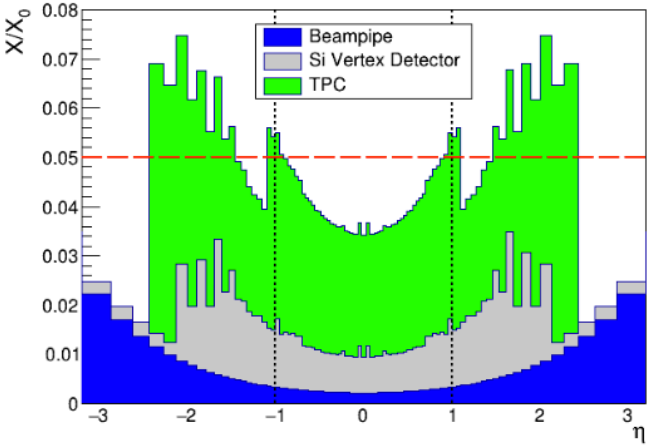


6 layers arranged as 3x2

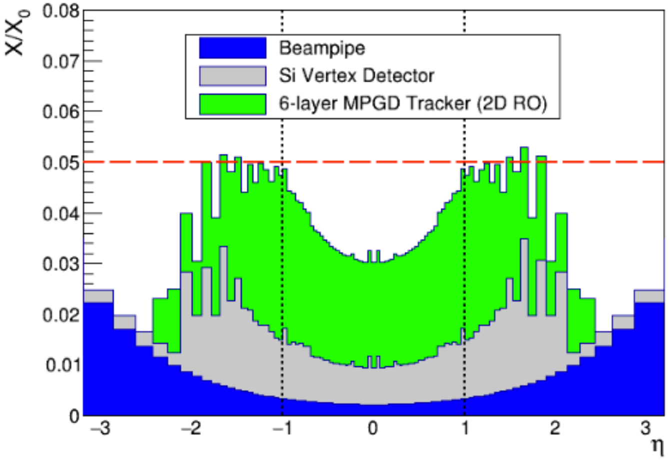
❑ Micromegas Barrel Tracker

- Two barrel configurations are being studied
- Radius: 20-80 cm
- Material budget for TPC and micromegas barrels meet $\frac{\chi}{\chi_0} < 5\%$ central region requirement

TPC



6-layer 2D RO MPGD tracker



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- **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

Qinhua Huang, et al , CEA Saclay

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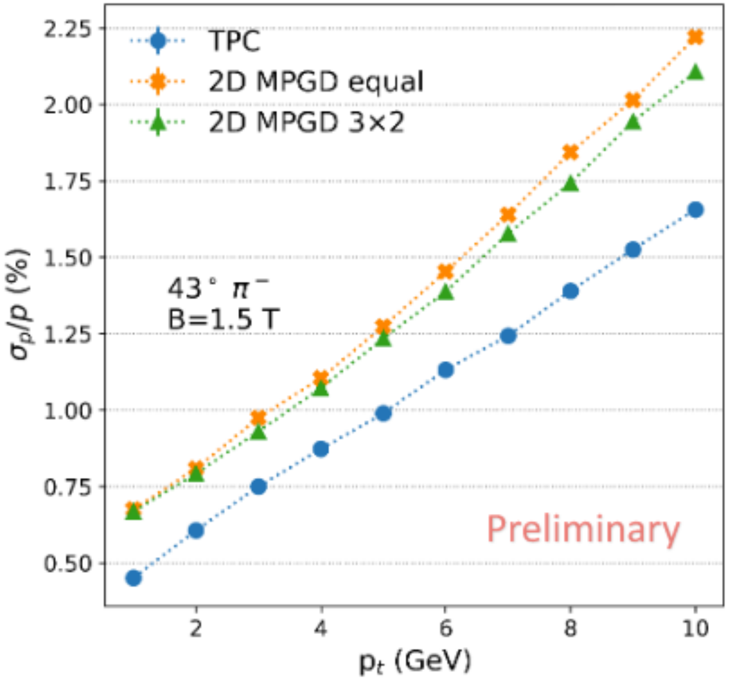
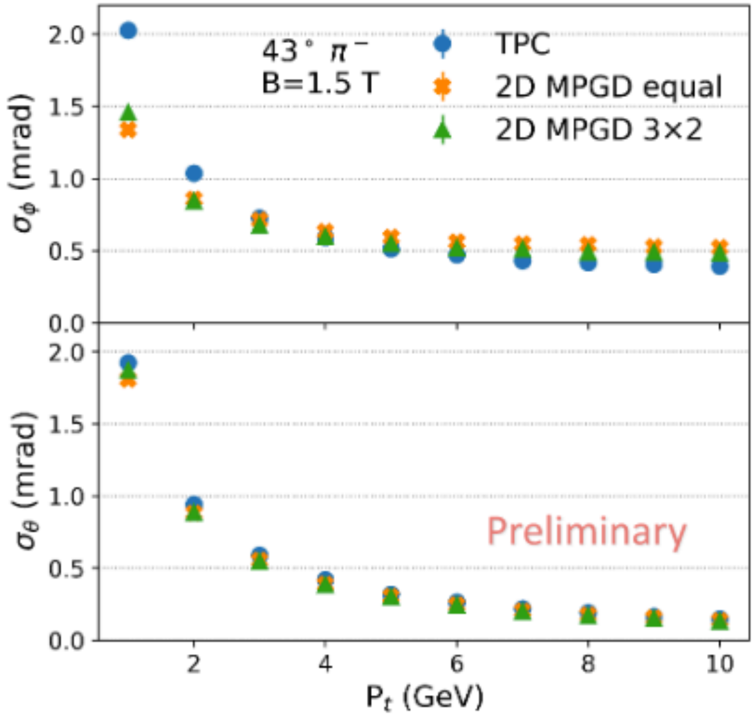
Scalay





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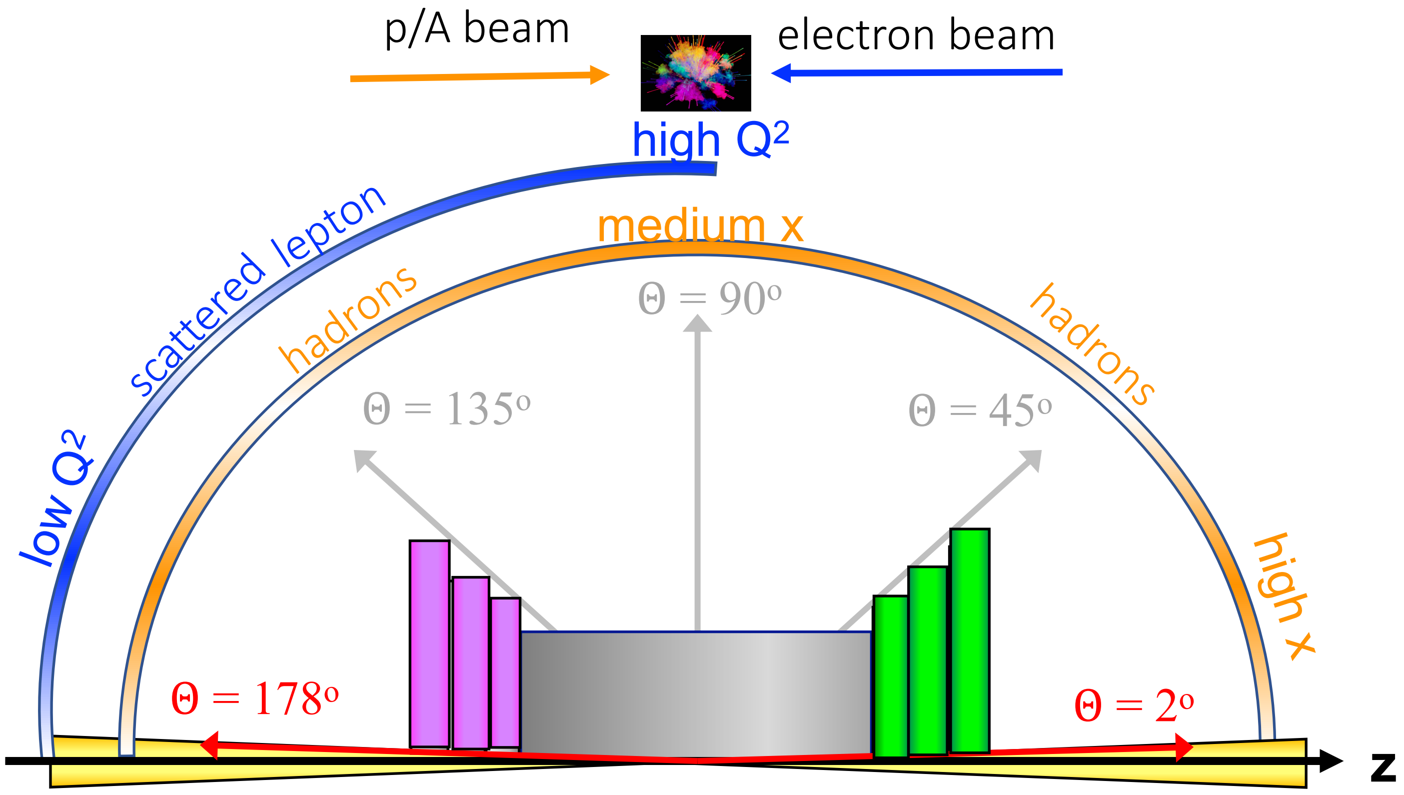
- **Endcap tracking detector configurations**
  - Si + MPGD disks
  - Si disks + MPGD-TRD



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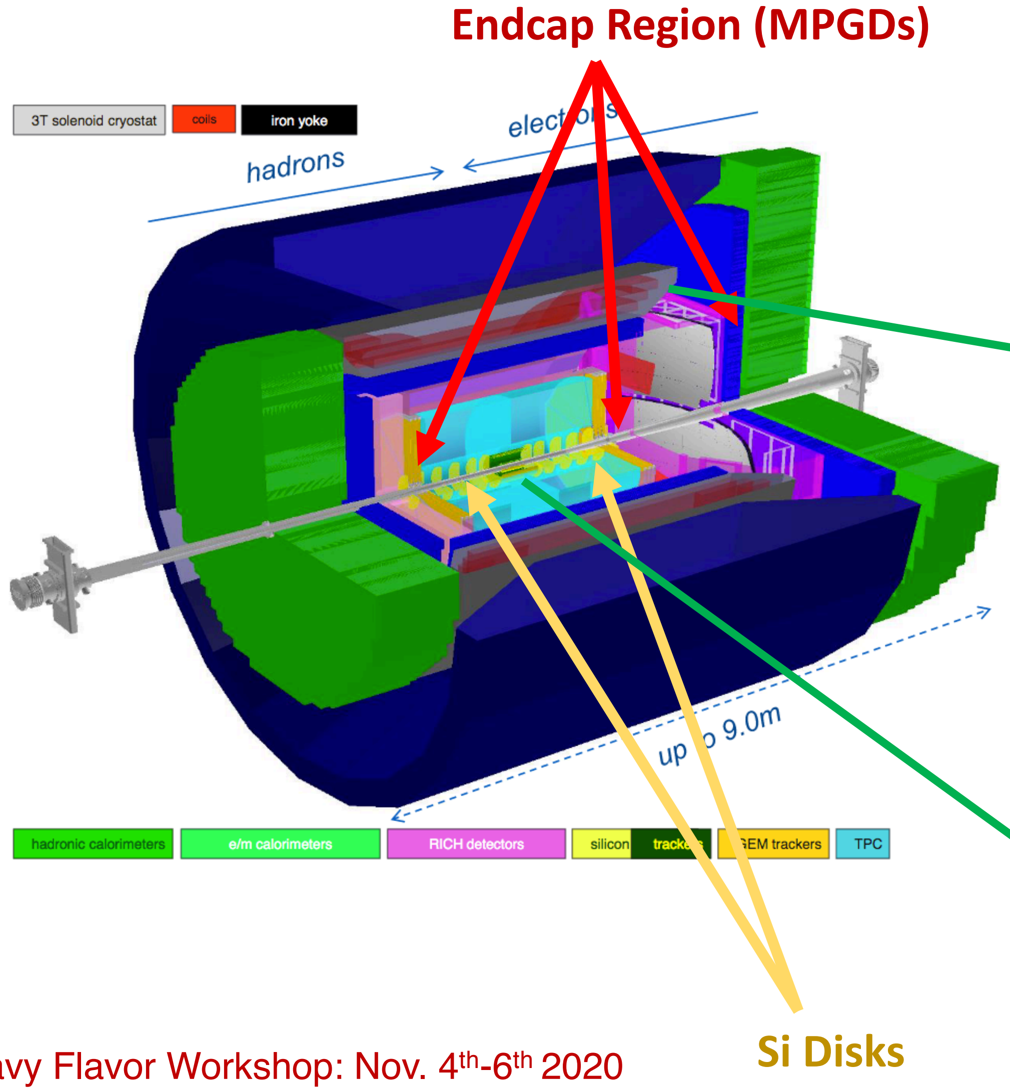
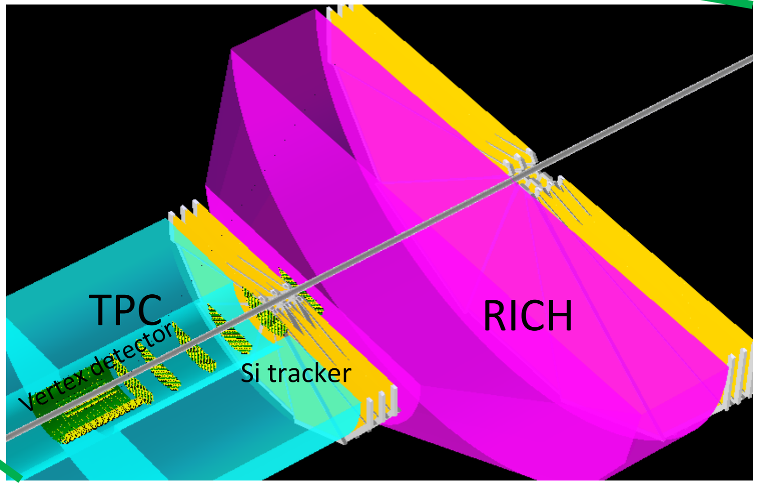
Endcap: Si + MPGD Disks

❑ Si + MPGD disks

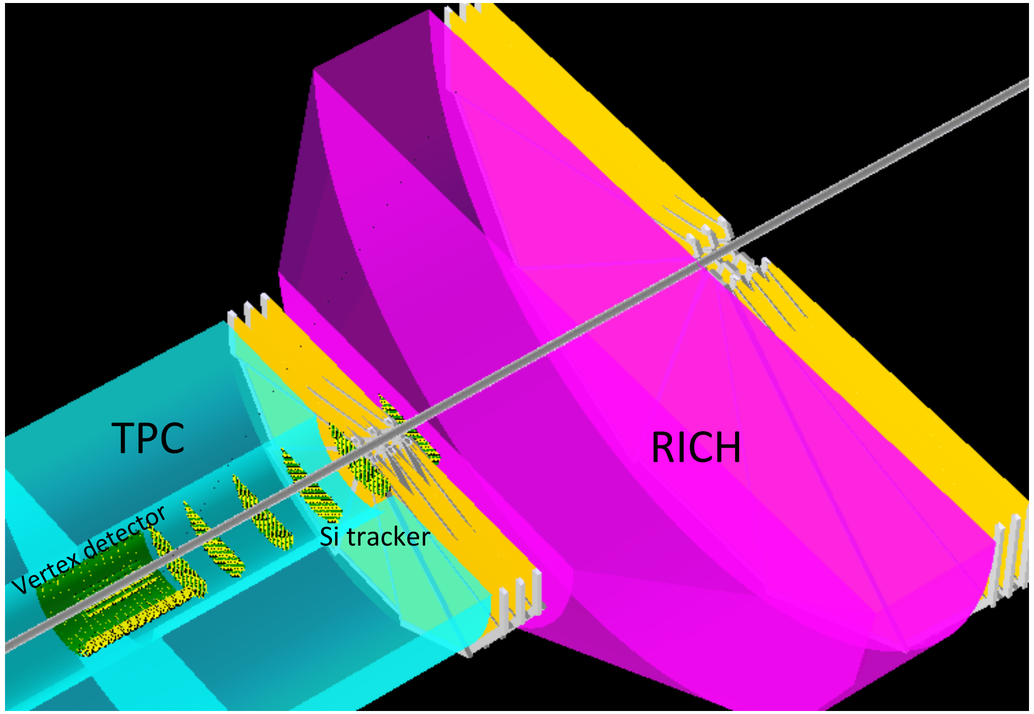
- Small Si disks in barrel region
- Medium MPGD disks in endcap
- Large GEMs behind the RICH
  - Improve angular resolution
  - Provide additional information to aid in Cerenkov ring reconstruction





❑ Simulated Detectors

- 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

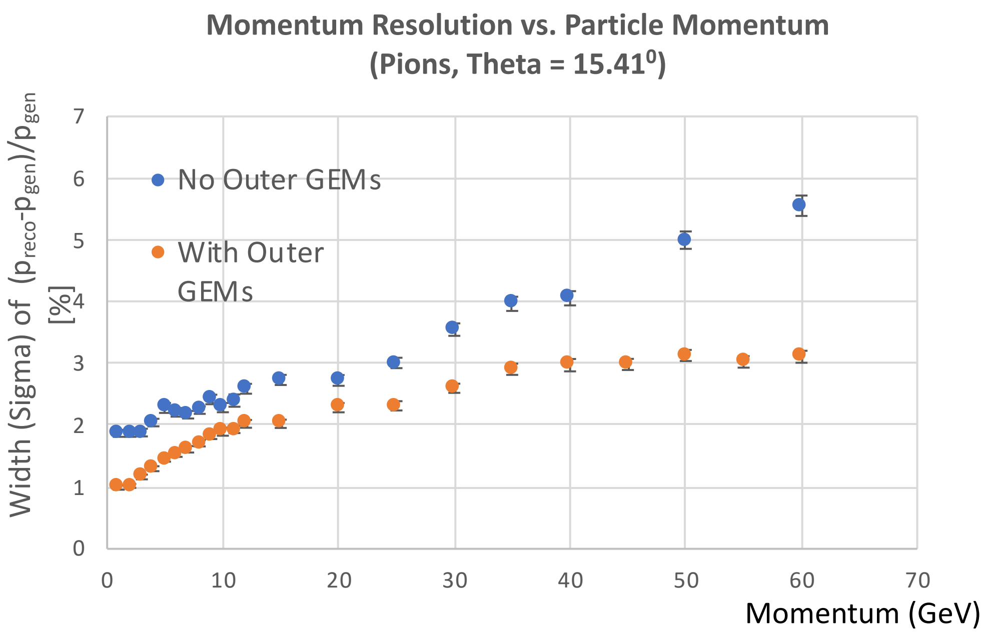


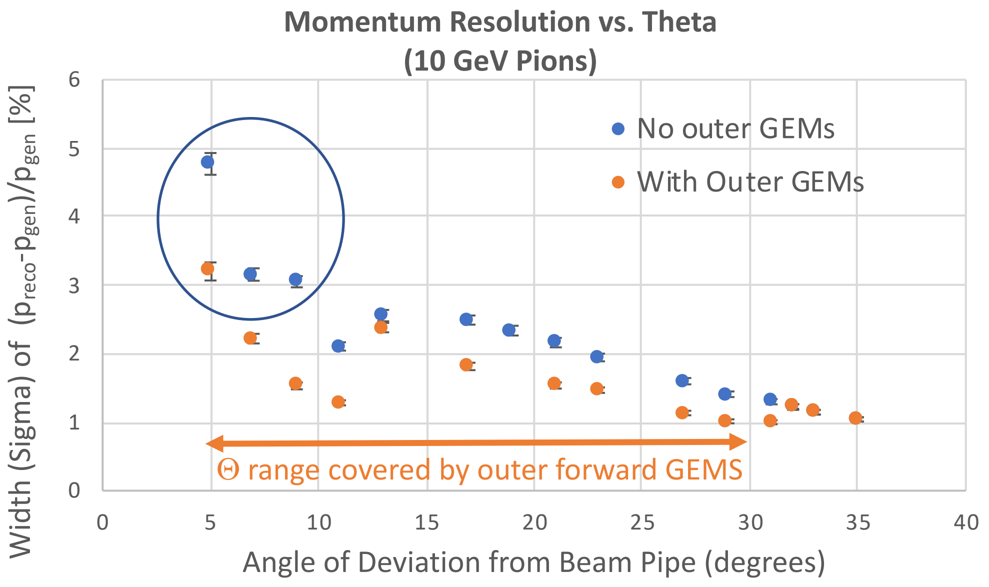
Endcap: Si + MPGD Disks

❑ Endcap Outer GEMs (simulation)

- Significant improvement is seen at
  - Large momentum
  - Small angle

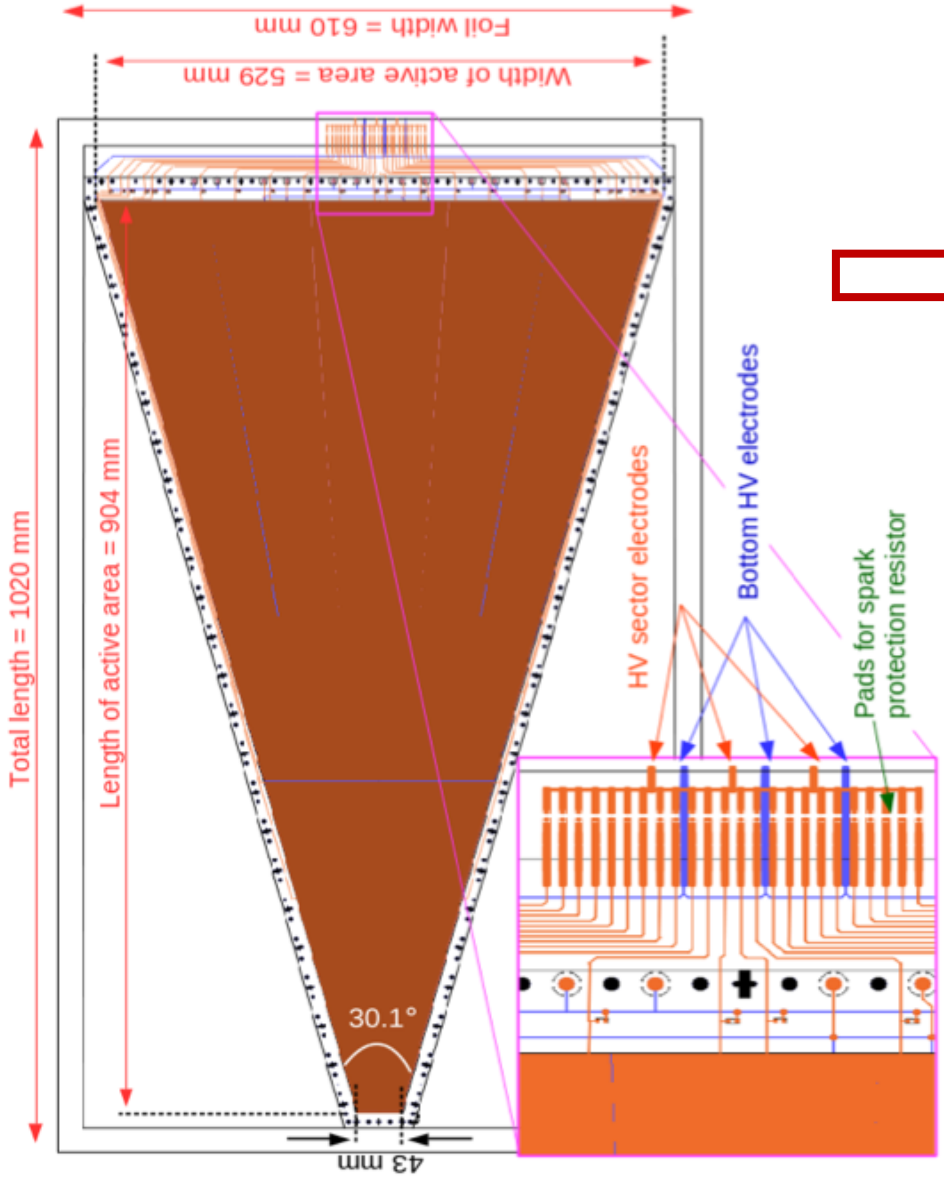
eRD6: FIT





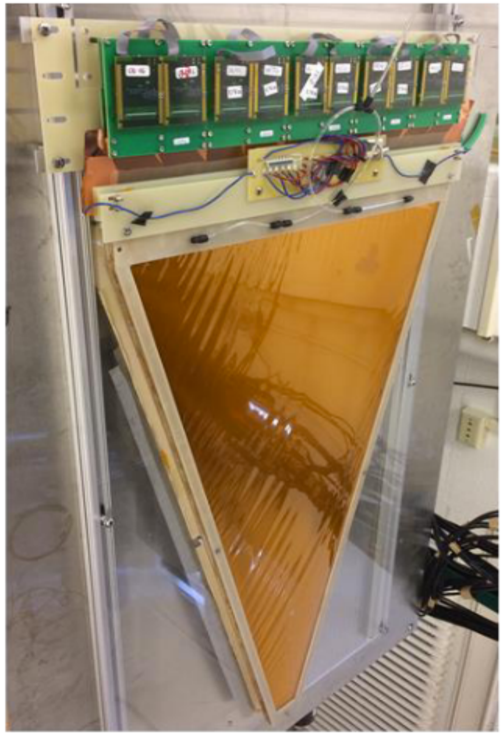
eRD6, FIT, TU, UVa

- **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

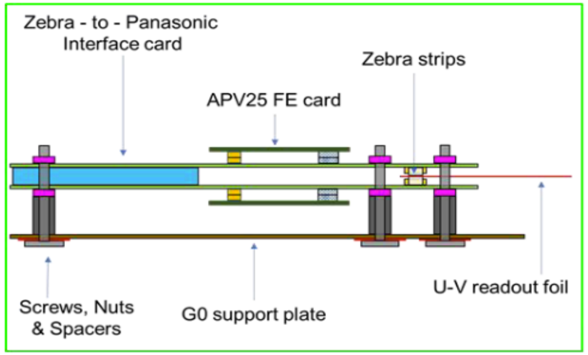


Low mass detector prototype

- All GEM foils, drift cathode, and U-V readout layer Kapton foils
- No rigid PCB or honey comb material in active area
- All connectors at outer radius



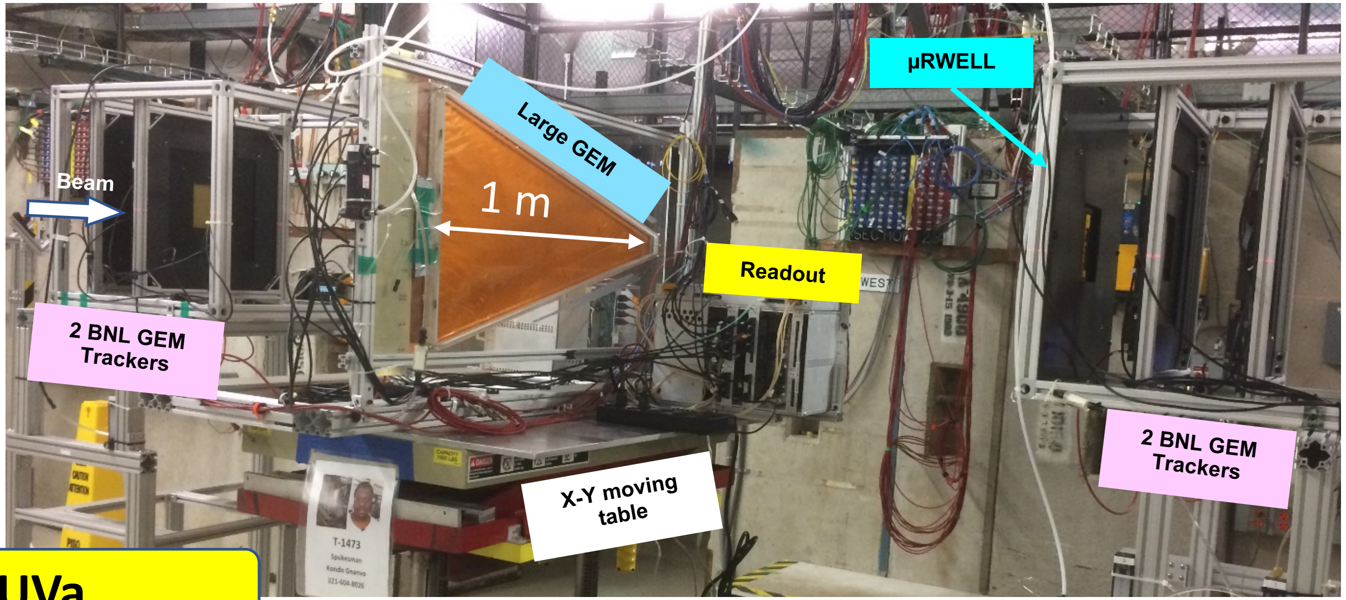
eRD6: UVa



❑ Low Mass Large Area GEM Tracker Beam Test

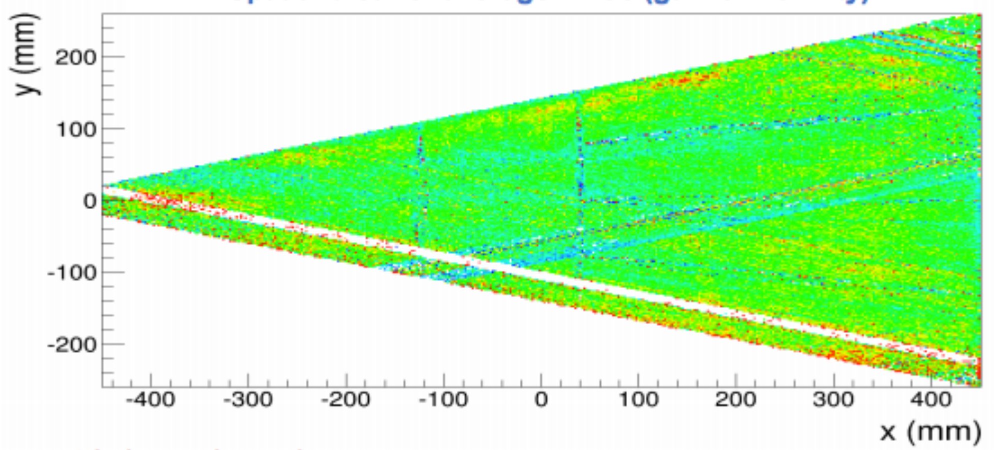
- **UVa** tested GEM tracker with FNAL proton beam
- Detector radiation length = 0.41%
- Excellent X-Y resolution measured
  - $\sigma_x = 426\ \mu m$
  - $\sigma_y = 115\ \mu m$

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

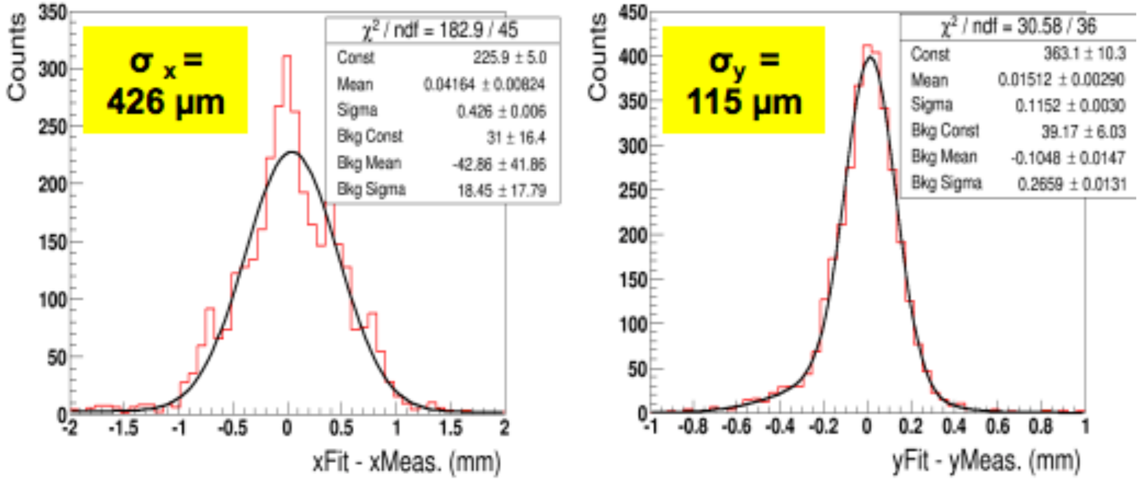


eRD6, UVa

Spatial distr. of average ADCs (gain uniformity)



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

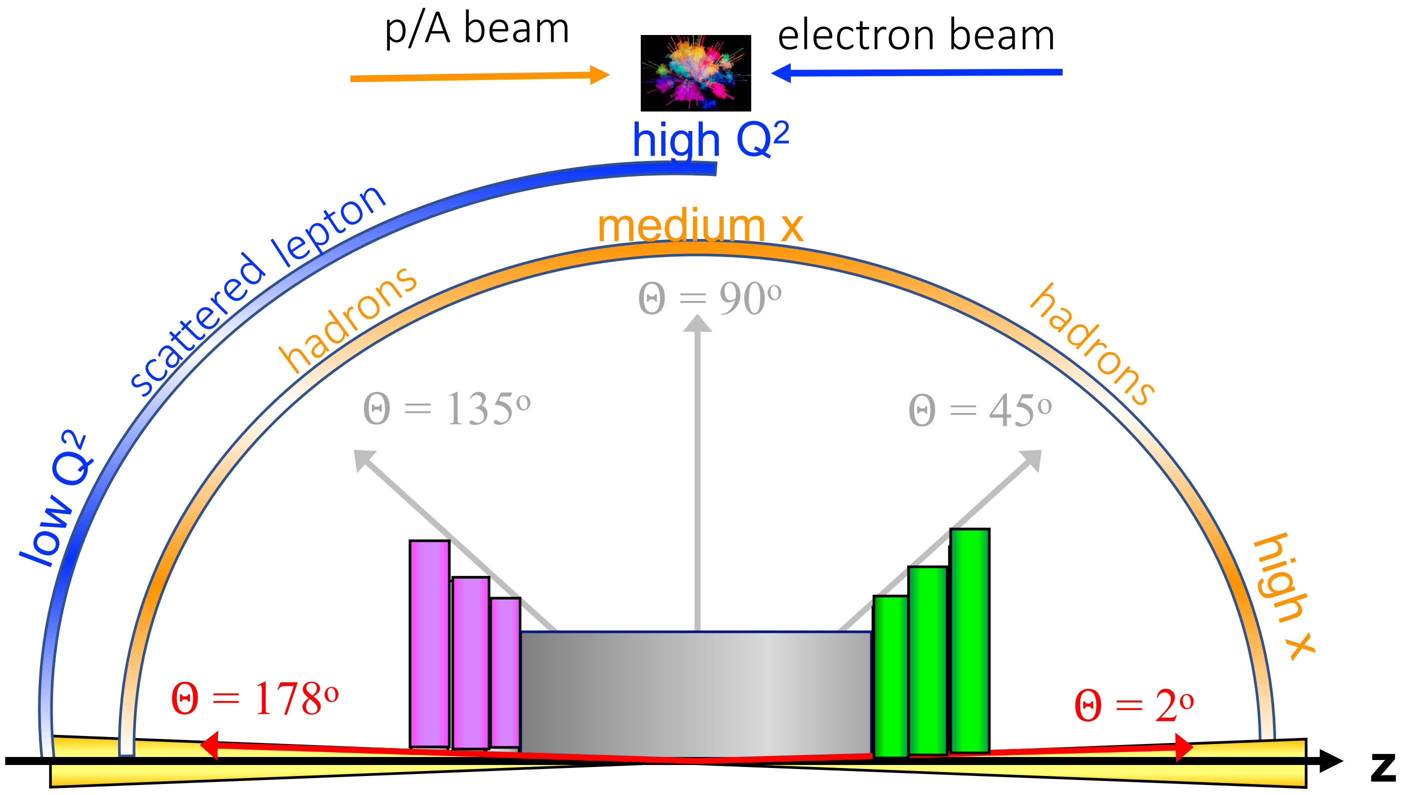


PRELIMINARY

Endcap Region

❑ Endcap tracking detector configurations

- Si + MPGD disks
- Si disks + MPGD-TRD



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❑ Endcap tracking detector configurations

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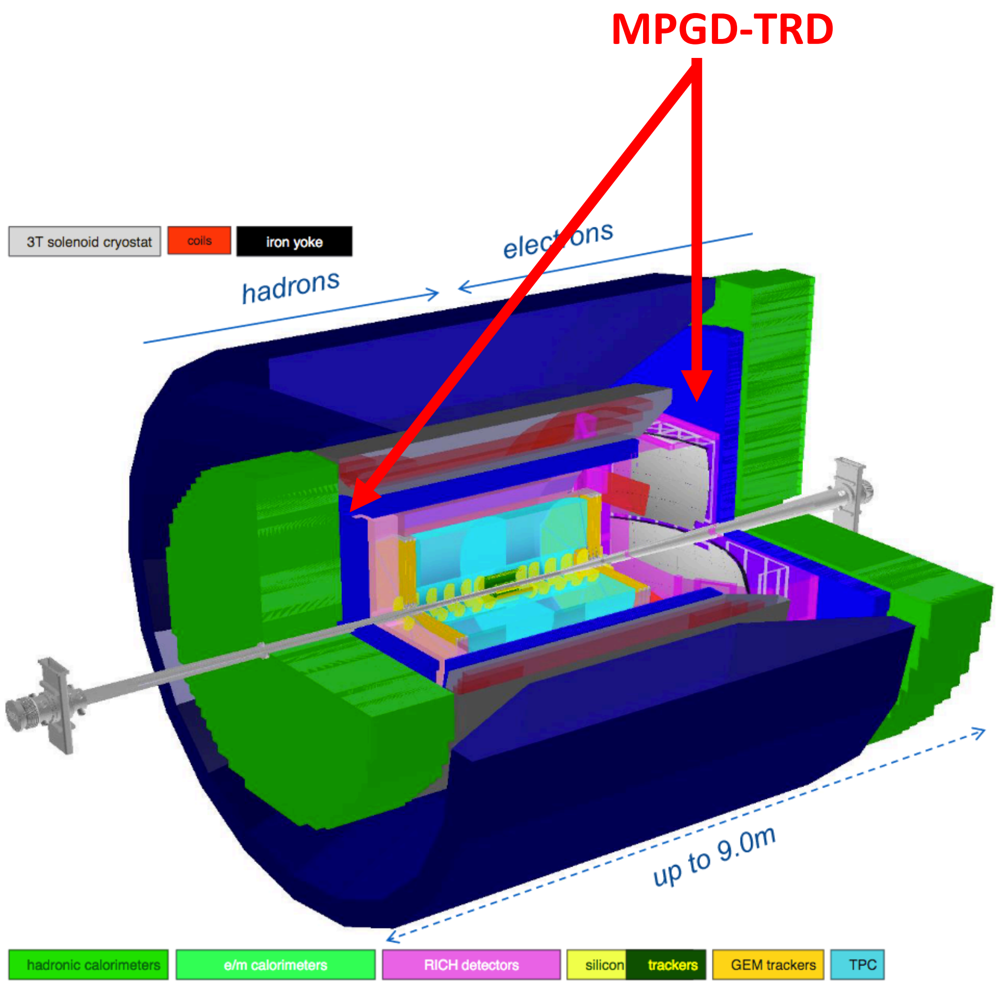
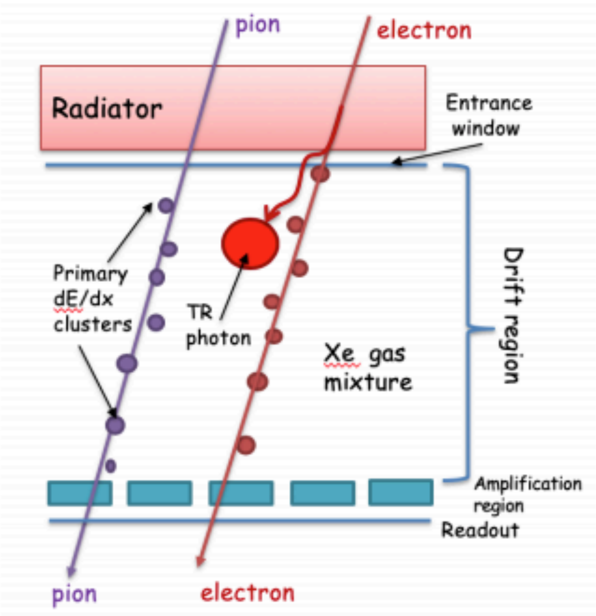


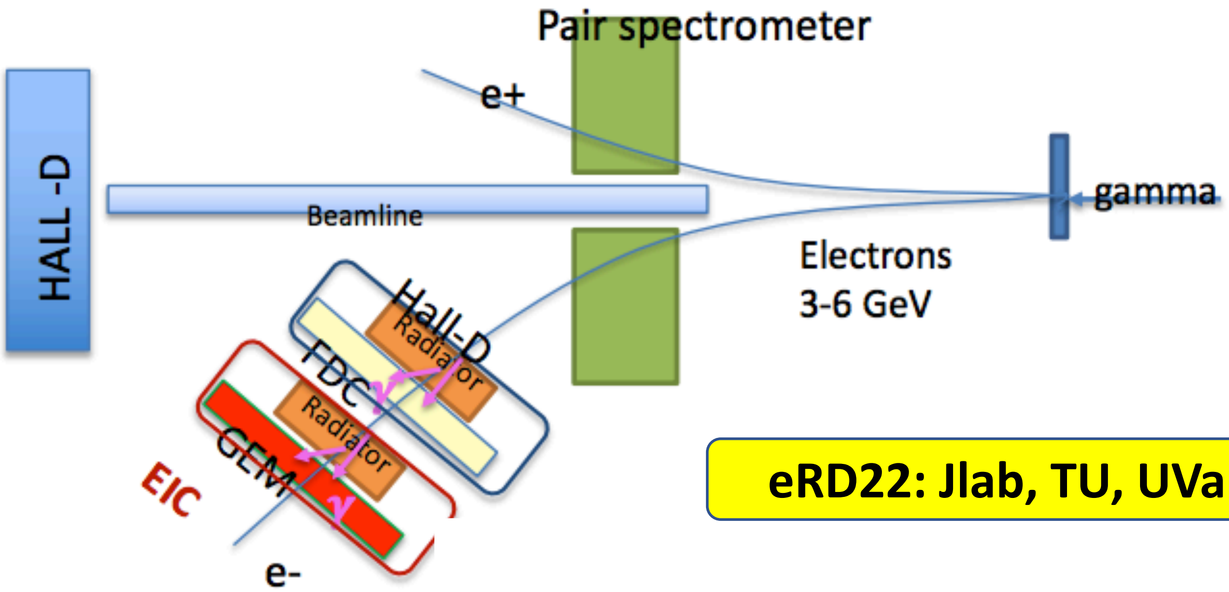
❑ Physics

- Secondary electron identification will be critical and plays a role in many process and physics
  - ➢ D and B meson, and J/ψ production
  - ➢ Spectroscopy
  - ➢ Beyond standard model physics … etc.
- High granularity tracker with e/π discrimination would be ideal

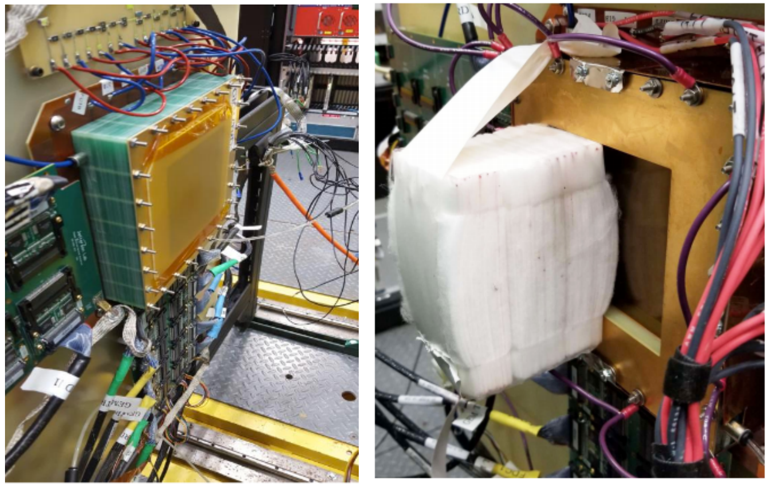
Endcap: Si + MPGD-TRD

- **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 (21 mm drift)
  - Located in the hadron endcap (behind the RICH)
  - Beam test at JLab with 3-6 GeV electron beam





eRD22: Jlab, TU, UVa

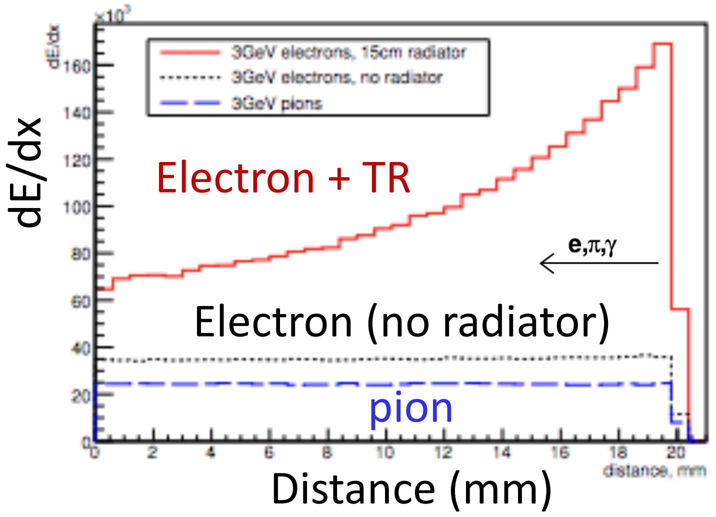


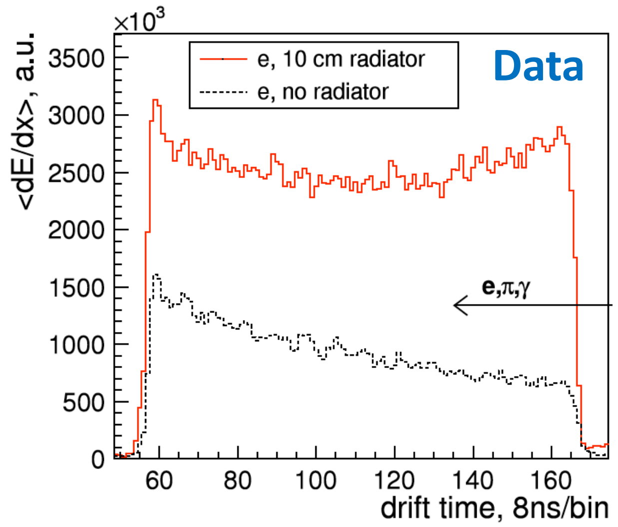
Nucl. Instrum. Meth. A 942, 162356 (2019).

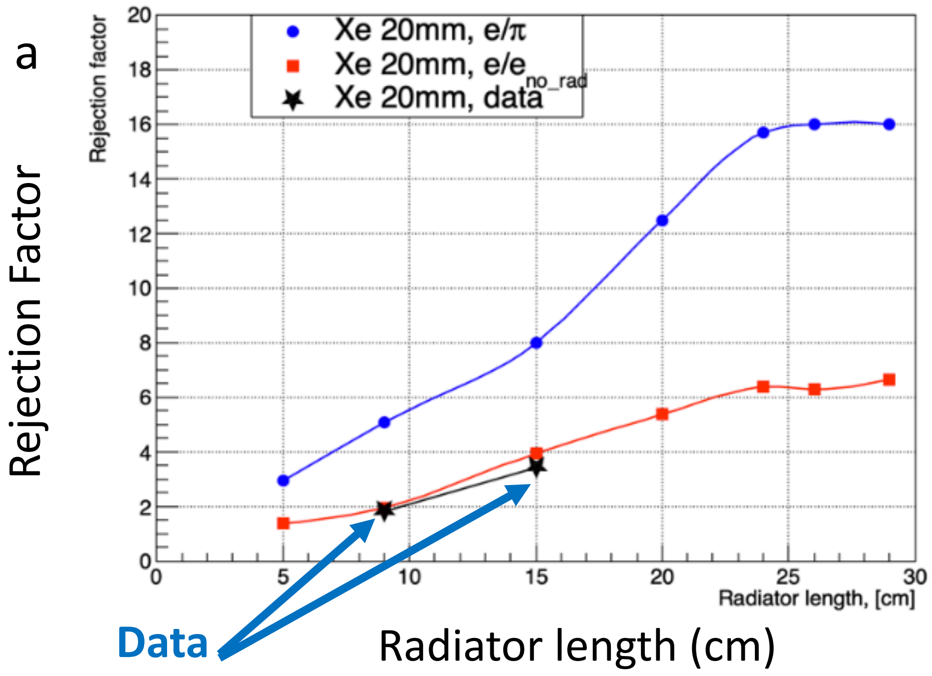
Nucl. Instrum. Meth. A 942, 162356 (2019).

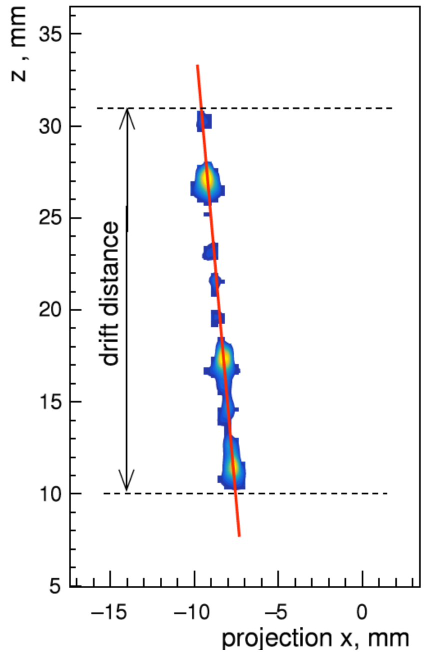
- **PID of GEM TRD Tracker**
  - Clear measurement of TR
  - Good agreement between data and simulation
  - Several data analysis and machine learning approaches were used to estimate e/π rejection factor.
  - MC suggests the prototype achieved a rejection factor of ~5-8

eRD22: Jlab, TU, UVa









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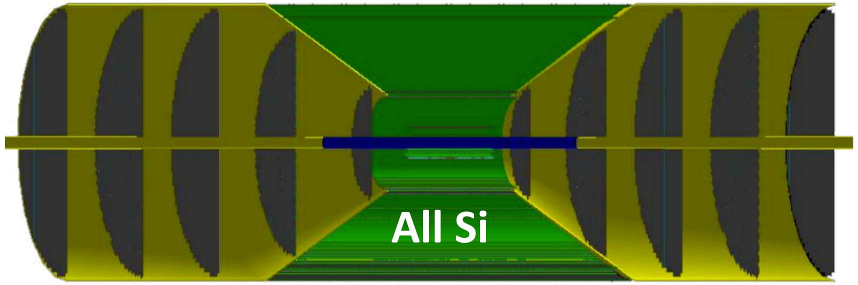
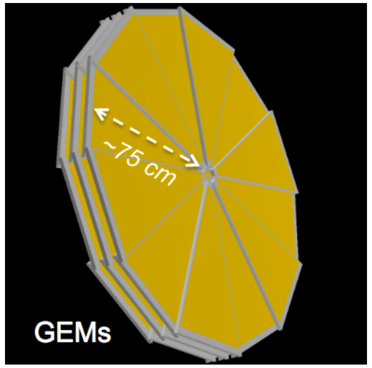
It’s All Coming Together

- **Integrated hybrid detector configurations are added to common simulation framework (Fun4All)**
  - TPC + Si disks + Si vertex
    - Including end cap material
  - MPGD barrel + Si vertex
  - Triple-GEM disks
    - Based on SBS GEMs
  - All Si detector
  - Ability to study various detector integrated configurations

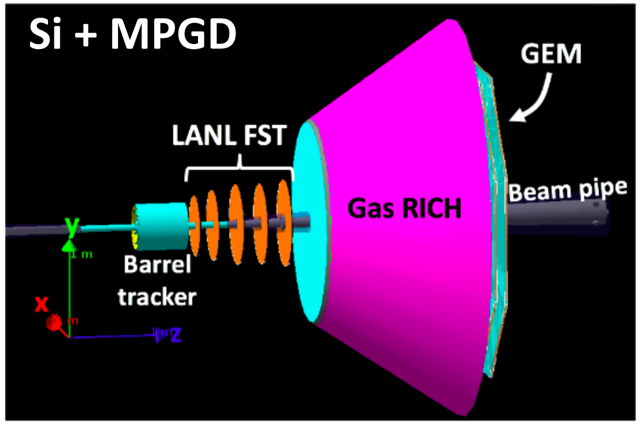
Rey Cruz-Torres et al: UCB



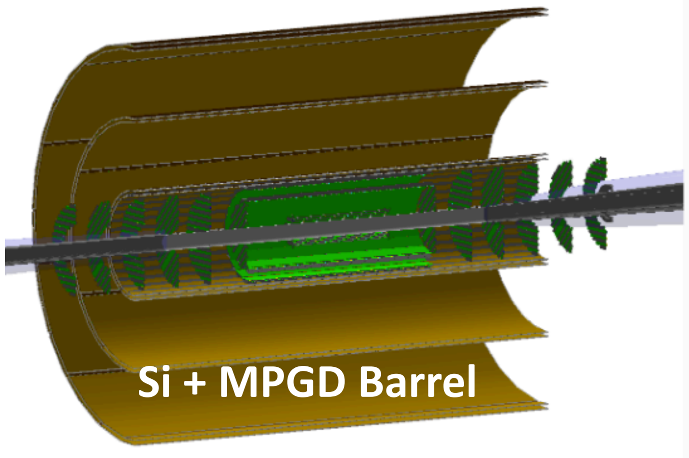
SBS GEMs



Cheuk-Ping Wong, et al: LANL



Qinhua Huang, et al , CEA Saclay



Hȧkan Wennlö̇f et al: UoB

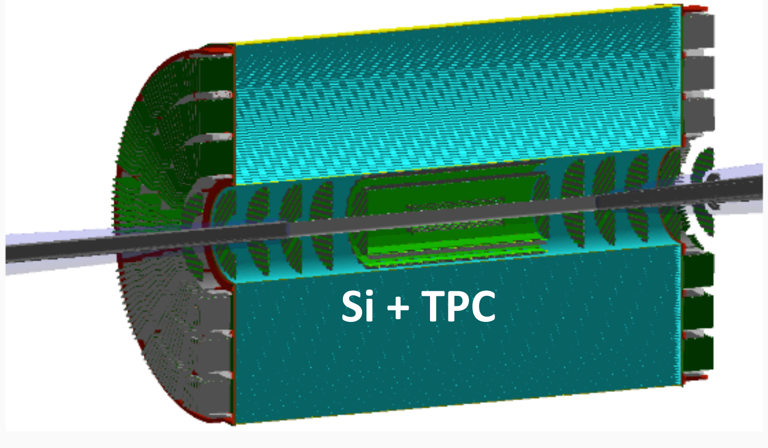
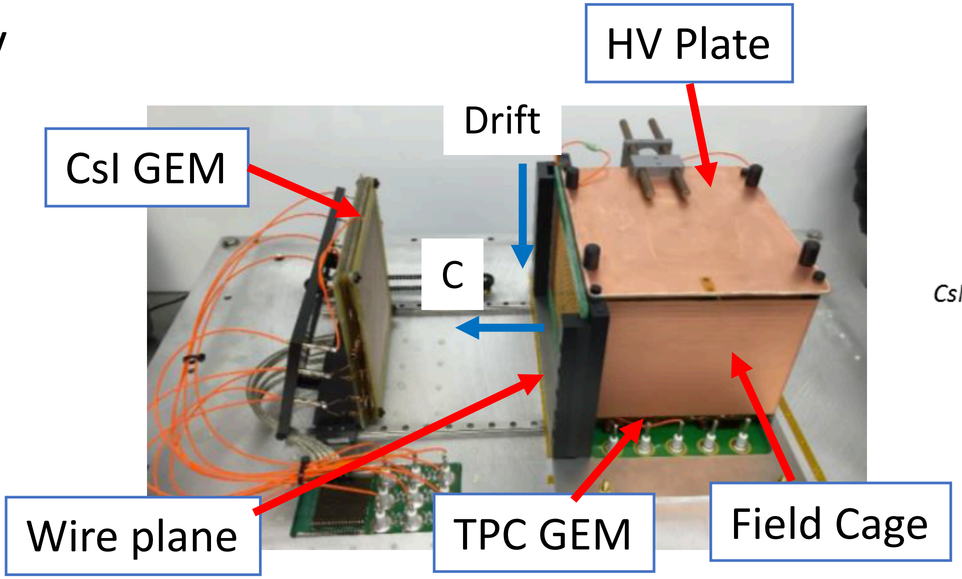
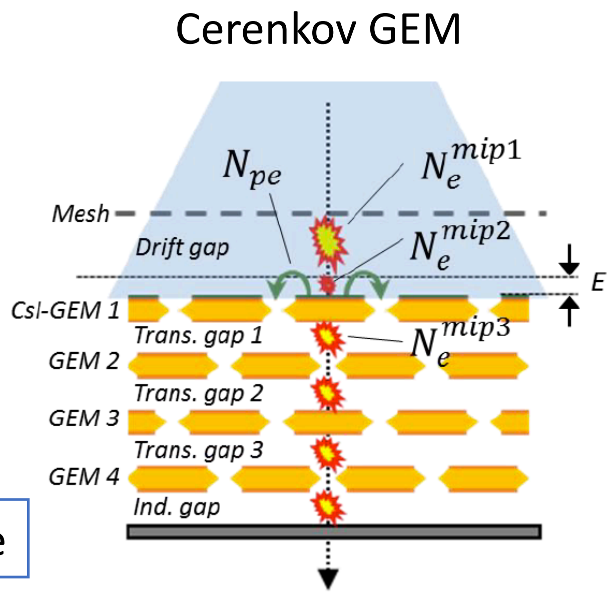
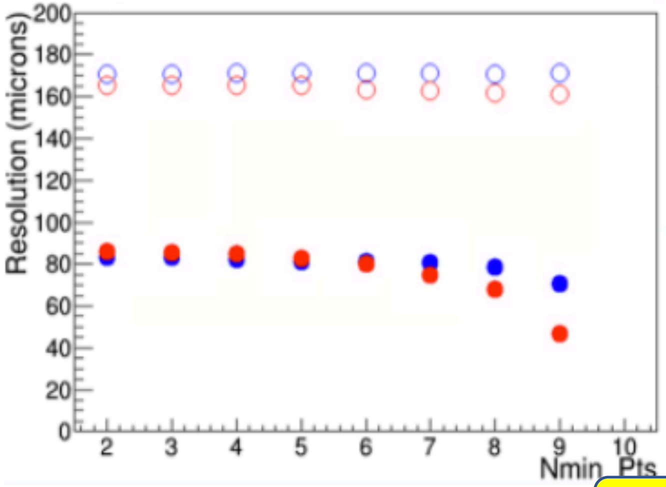


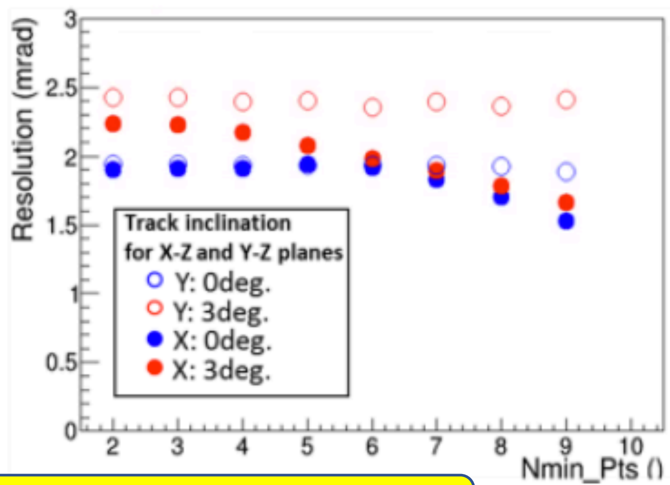
Photo-Sensitive MPGDs: TPCC Tracker

- 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
    - 50 x 10 mm long zigzag anodes
      - Arranged in 10 pad-rows
  - PID
    - 10 x 10 cm^2 readout plane
    - Segmented in 3x3 pads
  - Plan to study high pressure Ar radiator with Capacitive-sharing and large-pad anode readout









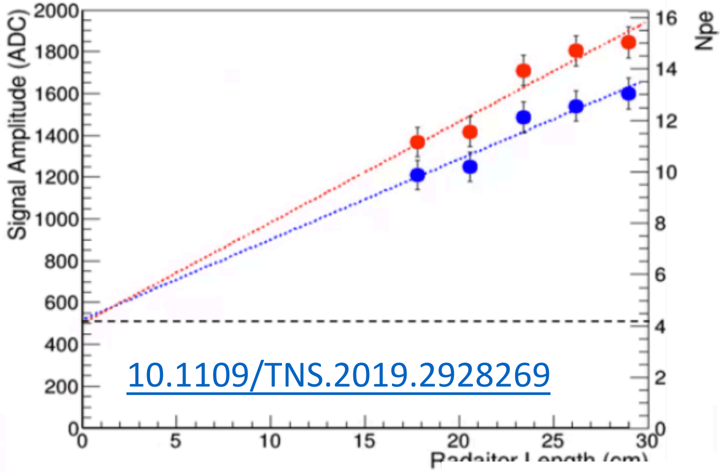
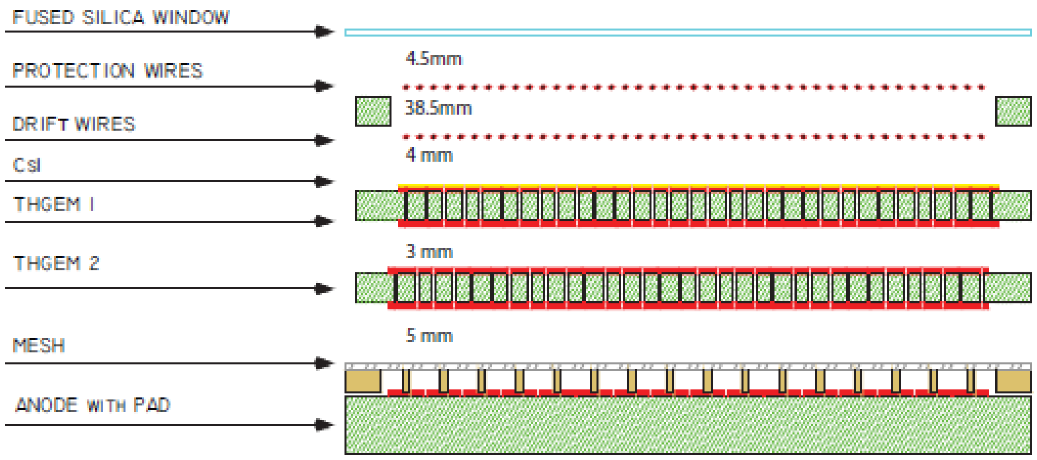


Photo-Sensitive MPGDs: Hybrid MPGD RICH

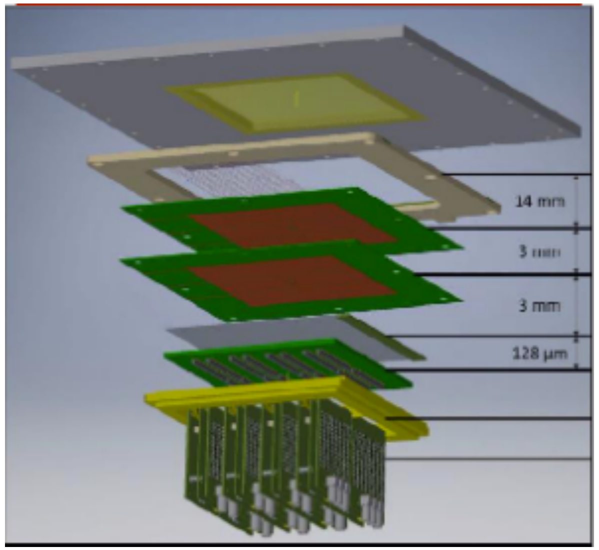
Hybrid MPGD RICH

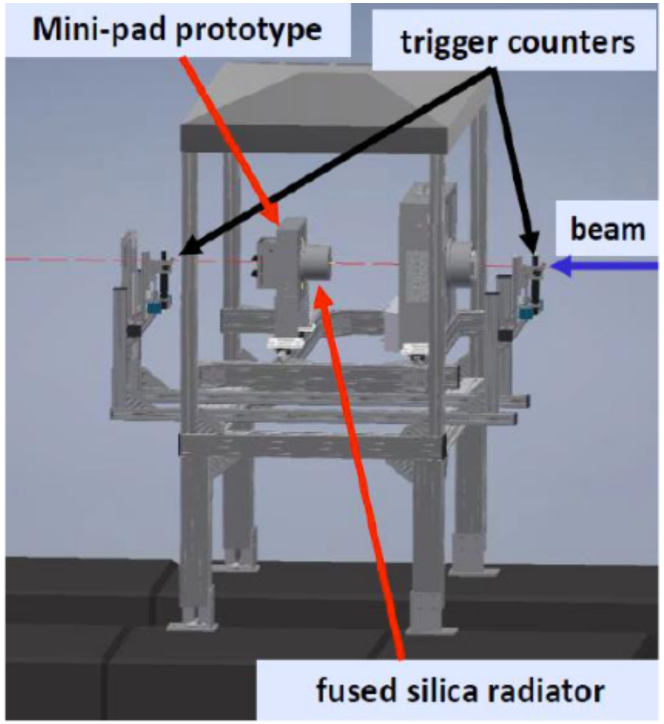
- Single-photon detection with for high-momentum RICH (above 6-8 GeV)
- Resistive thick GEM-MicroMegas hybrid detector
- Radiator gas is the detector gas
- Based on Compass design

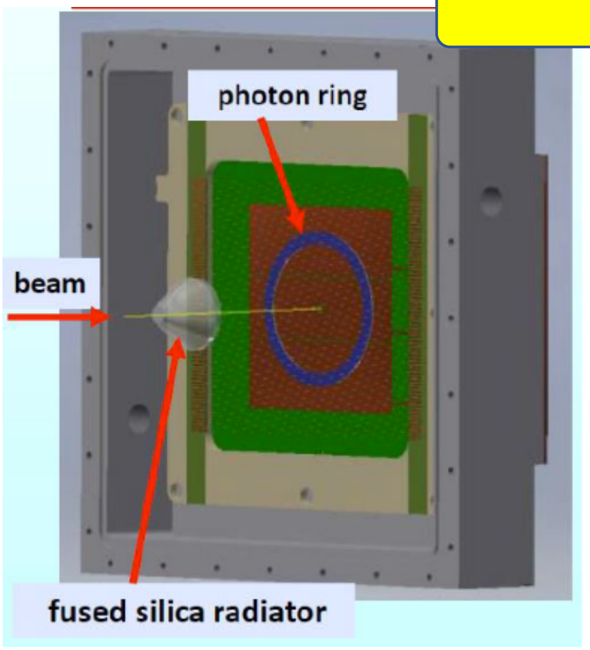


Miniature pads: 32 x 32 array, 3 mmm x 3mm, 3.5 mm pitch

eRD6: INFN

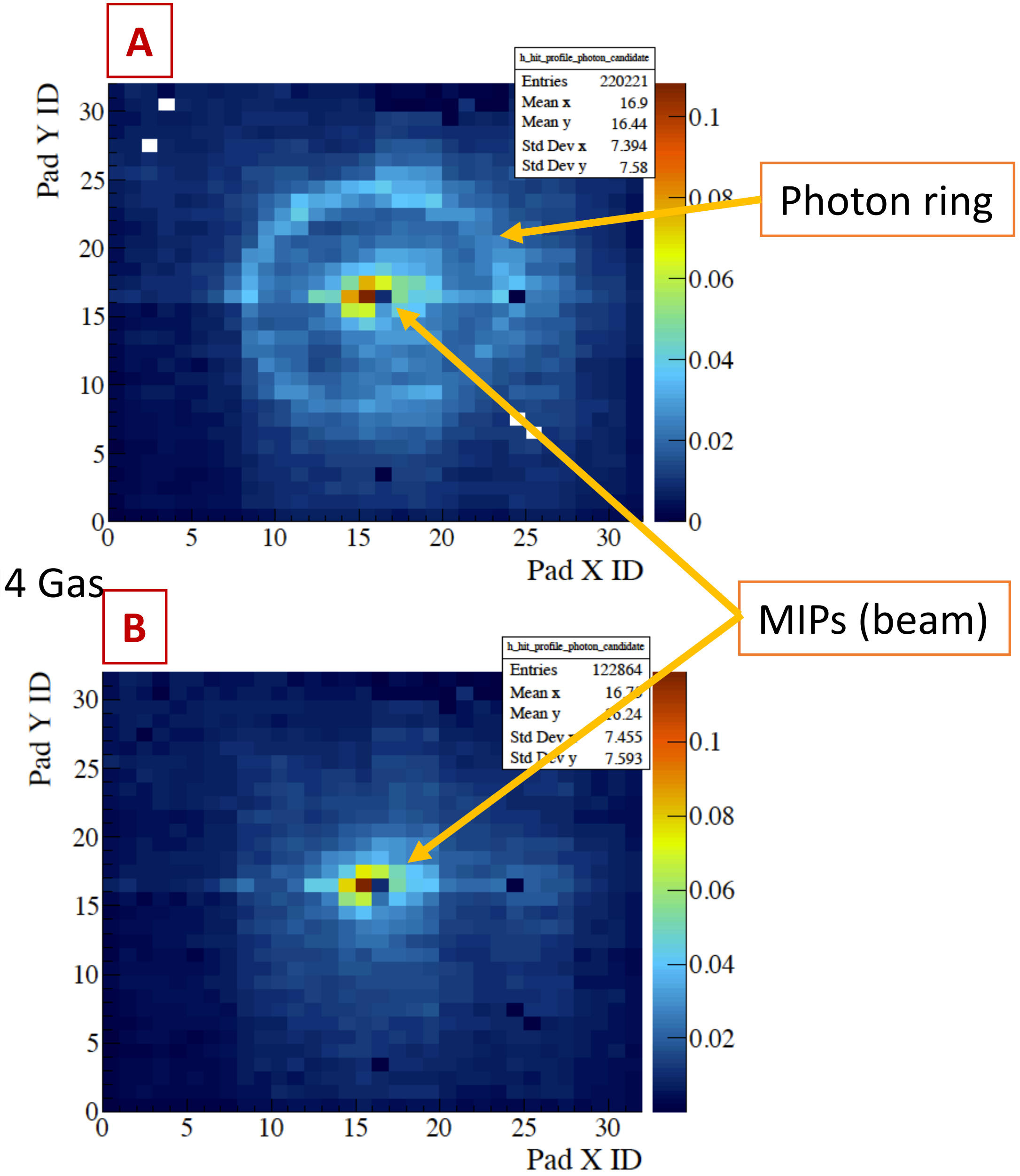




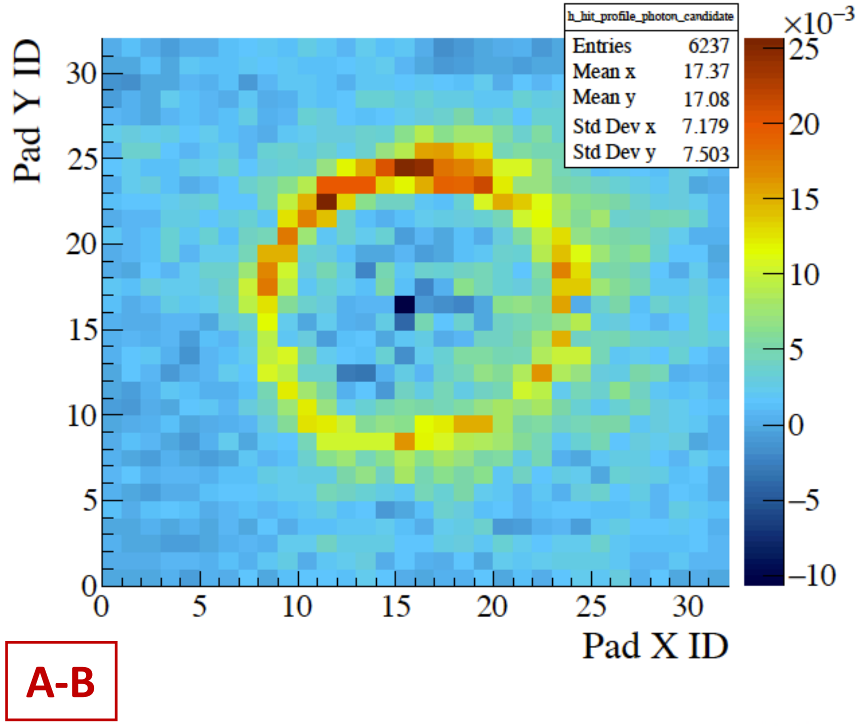


eRD6: INFN

ArCH4 Gas



- A – Shutter between detector and radiator **OPEN**
- B – Shutter between detector and radiator **CLOSED**
- A-B : Only photon ring remains



Summary

- Integration of MPGDs and silicon detectors can provide a high precision, large acceptance, and cost effective EIC tracking system.
- Many preliminary simulation studies have been done.
- Work is continuing to evolve as gas and silicon hybrid detector configurations are being added to common simulation framework
  - Allows for a consistent comparison between various studies
  - Material budgets and resolutions are being made more realistic
- Many R&D efforts being carried out in parallel to simulations
- Developing photo-sensitive MPGDs
  - RICH MPGDs