ATHENA tracking

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EIC users group meeting

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Outline

- Introduction
- Baseline configurations and beyond
- Technology choice
- Conclusion

Introduction

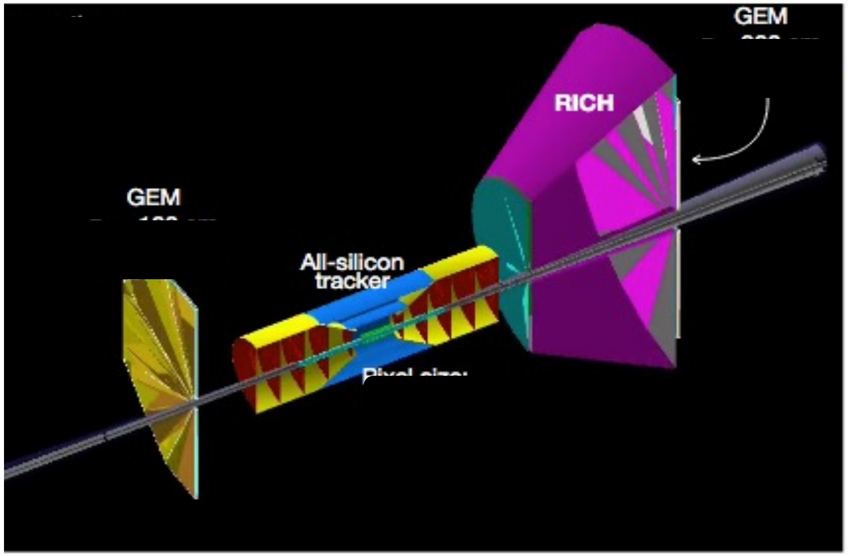
- The goal is to develop a vertex and tracking detector to meet the requirements of the YR with the 3T magnet

Tracking requirements from PWGs						
			Momentum res.	Material budget	Minimum pT	Transverse pointing res.
η						
-3.5 to -3.0	Central Detector	Backward Detector	σp/p ~ 0.1%×p ⊕ 0.5%	~5% X0 or less	100-150 MeV/c	
-3.0 to -2.5					100-150 MeV/c	dca(xy) ~ 30/pT µm ⊕ 40 µm
-2.5 to -2.0			σp/p ~ 0.05%×p ⊕ 0.5%		100-150 MeV/c	dca(xy) ~ 30/pT µm ⊕ 20 µm
-2.0 to -1.5					100-150 MeV/c	
-1.5 to -1.0					100-150 MeV/c	
-1.0 to -0.5		Barrel	σp/p ~ 0.05%×p ⊕ 0.5%		100-150 MeV/c	dca(xy) ~ 20/pT µm ⊕ 5 µm
-0.5 to 0						
0 to 0.5						
0.5 to 1.0						
1.0 to 1.5		Forward Detector	σp/p ~ 0.05%×p ⊕ 1%		100-150 MeV/c	dca(xy) ~ 30/pT µm ⊕ 20 µm
1.5 to 2.0					100-150 MeV/c	
2.0 to 2.5					100-150 MeV/c	
2.5 to 3.0			σp/p ~ 0.1%×p ⊕ 2%		100-150 MeV/c	dca(xy) ~ 30/pT µm ⊕ 40 µm
3.0 to 3.5					100-150 MeV/c	dca(xy) ~ 30/pT µm ⊕ 60 µm

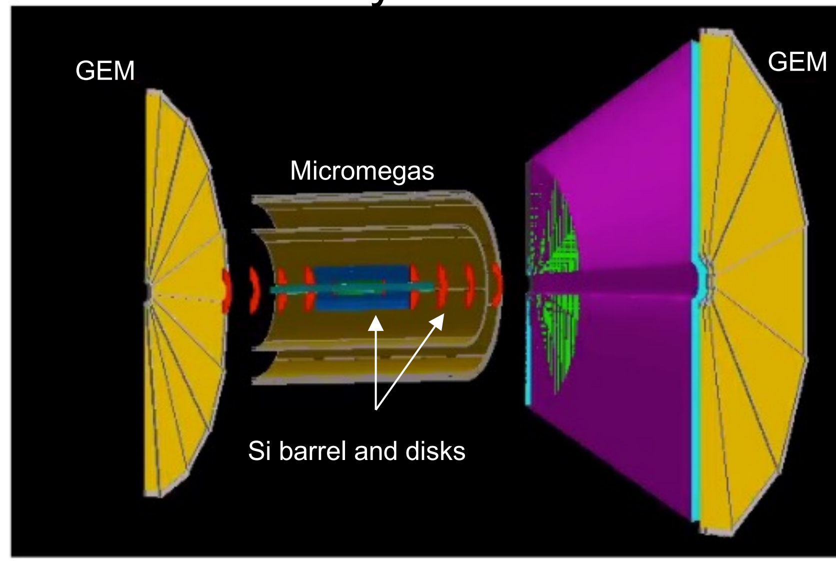
- The conclusion from the YR tracking working group serves as starting point
  - Currently two minimal (baseline) configurations developed based on the YR all-silicon and hybrid concepts
    - Develop software implementation, test overall detector integration and perform preliminary physics benchmark studies
  - Simulations continue in Fun4All given previous expertise
    - Currently starting switch to full simulation using ATHENA software

Minimal configurations

All-silicon



Hybrid

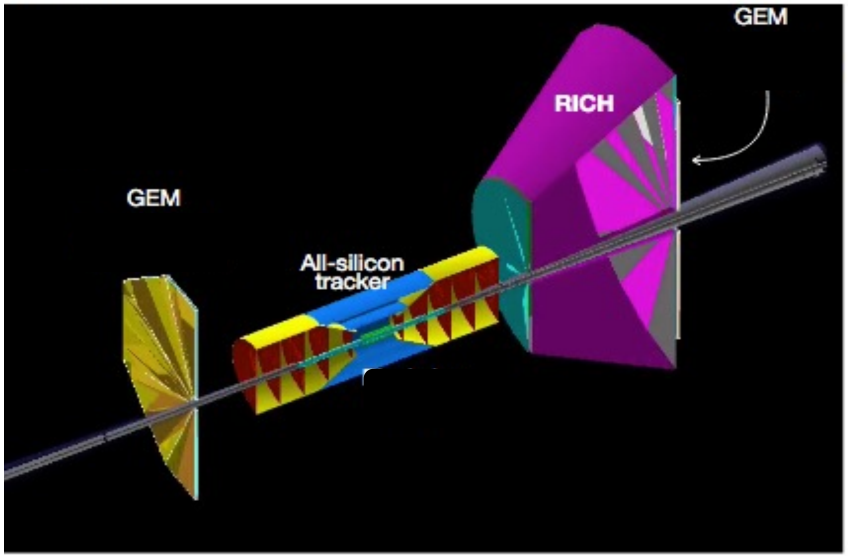


- Same silicon and GEM technologies in both concepts, micromegas barrel layers in the hybrid concept; different layout configurations
- Validated in Fun4All
  - Used truth seeding with hit smearing (detector resolution) and ATHENA solenoidal field map, comparisons with various field maps available (solenoidal, Helmholtz, uniform 3 T)
  - Hybrid: *https://indico.bnl.gov/event/12293/contributions/51958/* & https://indico.bnl.gov/event/12295/contributions/52521/
  - All-silicon: *https://indico.bnl.gov/event/12293/contributions/51959/* & https://indico.bnl.gov/event/12295/contributions/52526/

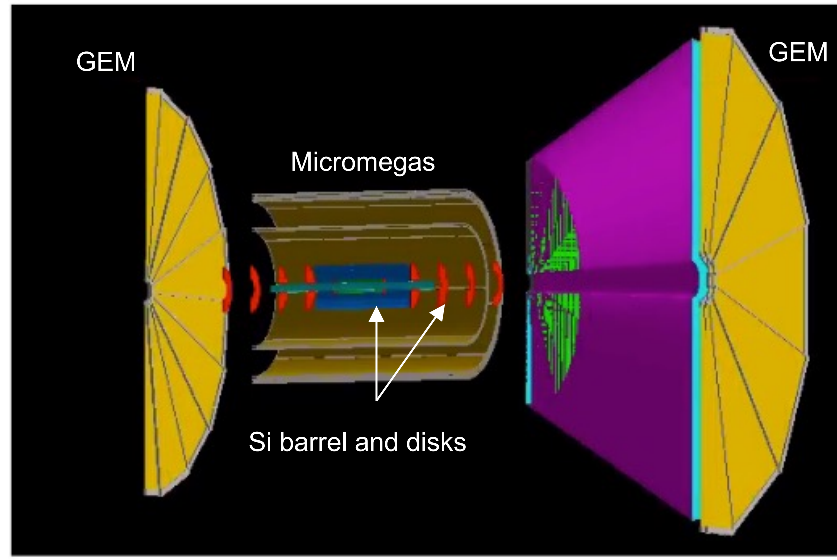
Minimal configurations: Silicon Vertex and Tracking

ATHENA

All-silicon



Hybrid

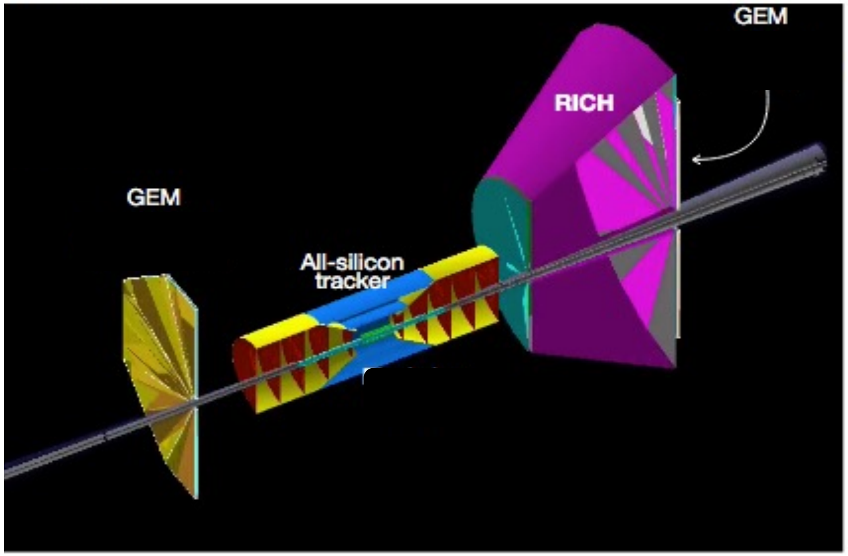


- ITS3-derived Silicon Vertex and Tracking detector
  - **10 µm** pixel pitch, **0.05% X/X0** vertex layers, **0.55% X/X0** barrel layers, **0.24% X/X0** disks

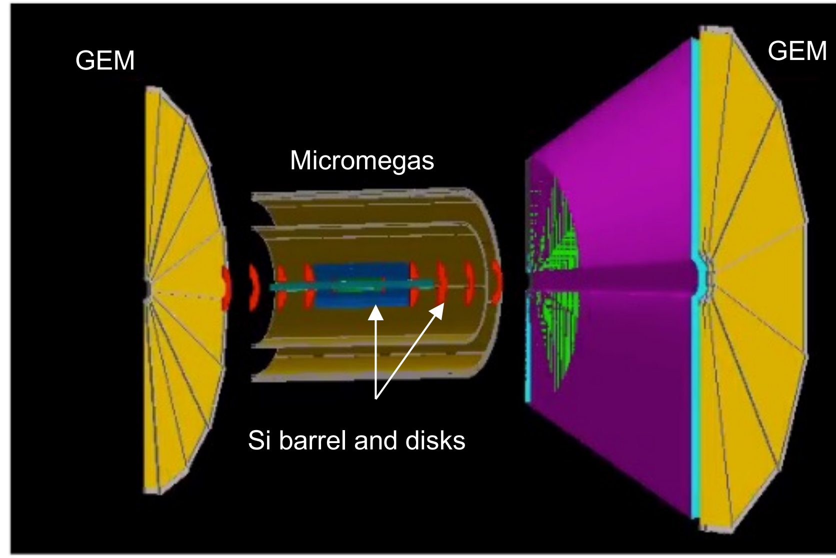
	All-Silicon	Hybrid
Vertex layers	2	3
Barrel layers	2 + 2	2
Disks	5 + 5	5 + 5

Minimal configurations: Micromegas

All-silicon



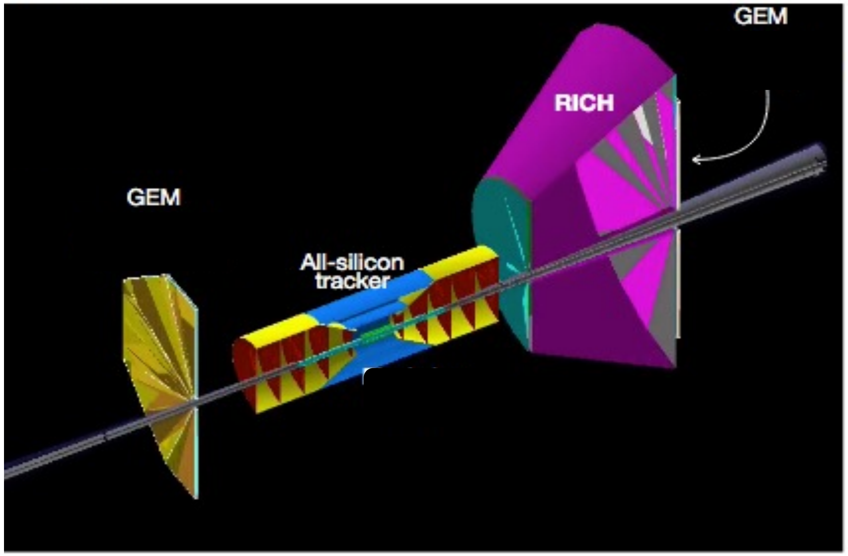
Hybrid



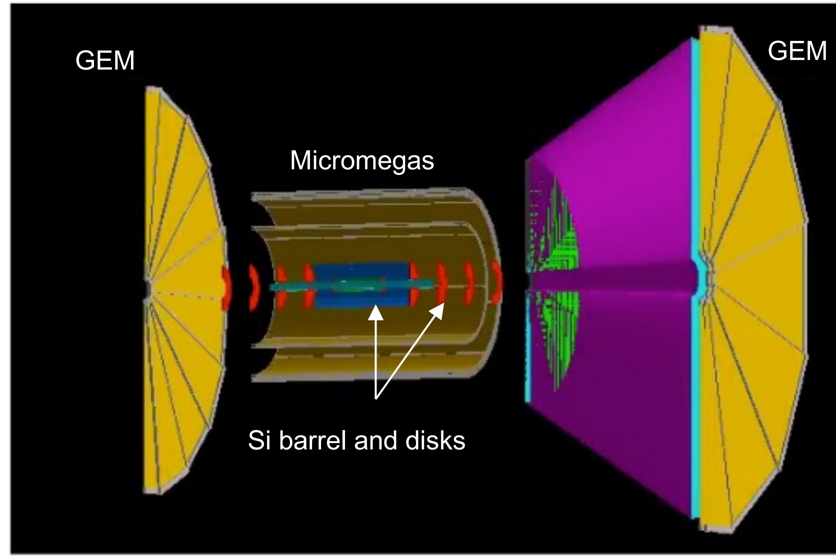
- Micromegas barrel layers to complement silicon tracking at central rapidity
- 2+4 layers, 0.4% X/X0
- 150 μm in z
- 150 μm in Rϕ

Minimal configurations: GEM

All-silicon



Hybrid



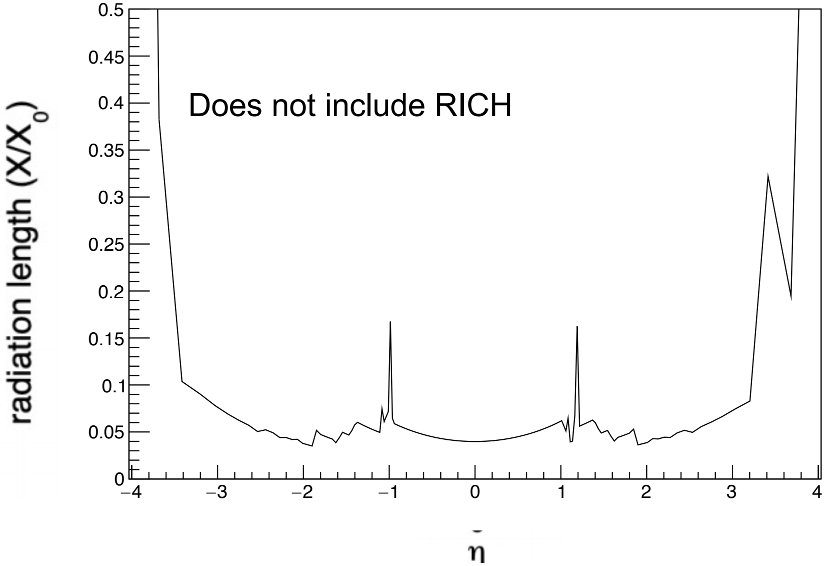
- Common technology with 0.4% X/X0 per layer, 250 μm in R, 50 μm in Rϕ

	All-Silicon	Hybrid
Hadron direction	1	2
Electron direction	1	1

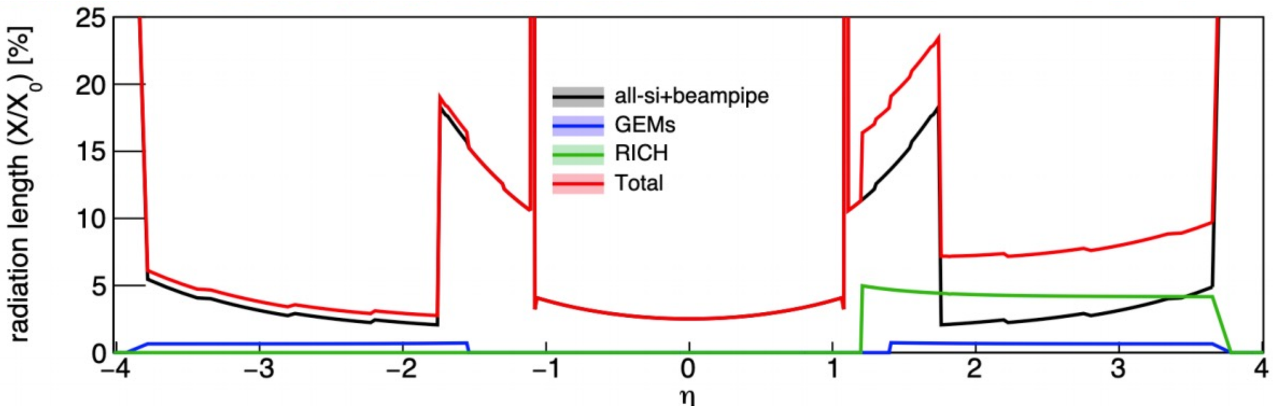
Material scans

- In addition to the active material, the minimal configurations include
  - Simplified service material estimate (e.g. support cone) in all-silicon baseline
  - GEM support frames and MM supports (i.e. dead area material) included in hybrid baseline

Hybrid

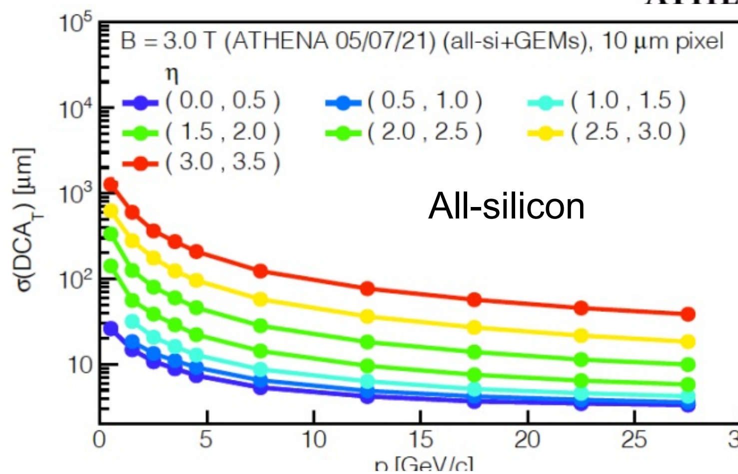


All-silicon

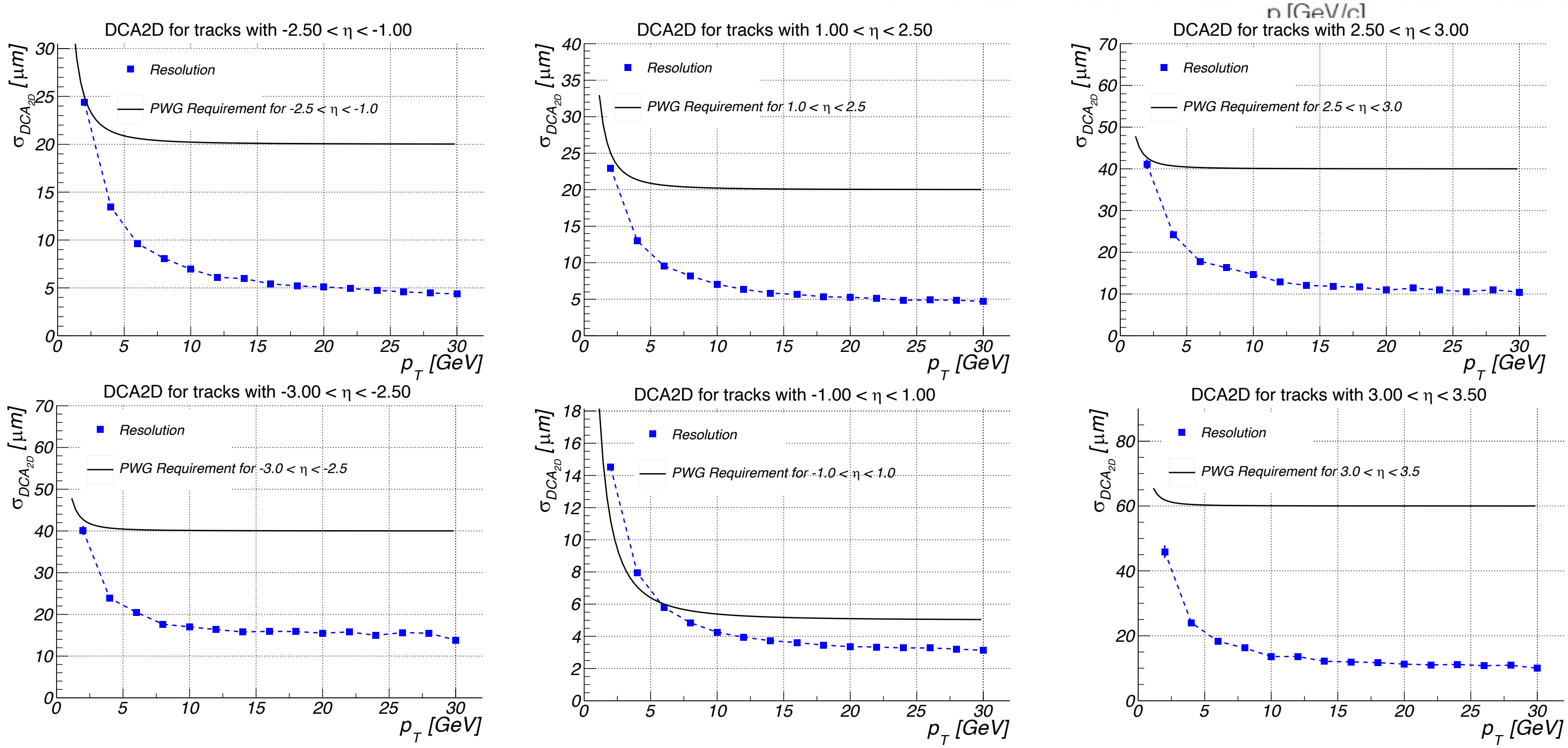


Pointing resolution

- Transverse and longitudinal pointing resolutions for both baseline concepts meet YR PWG requirements at all eta
    - Only transverse shown here

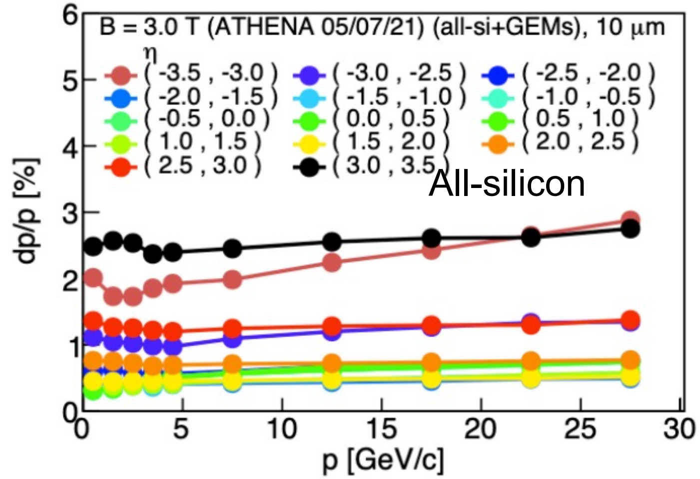


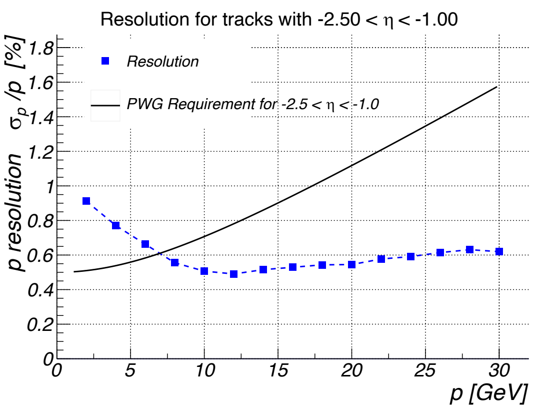
Hybrid



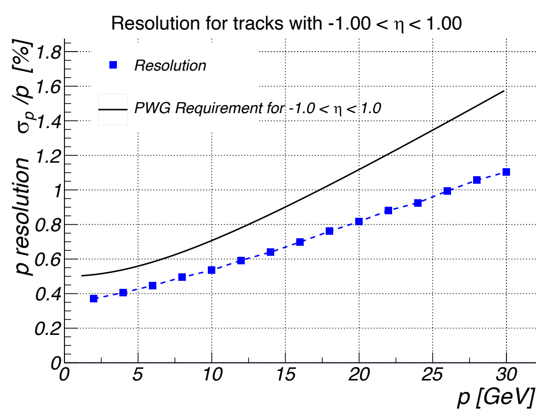
Momentum resolution

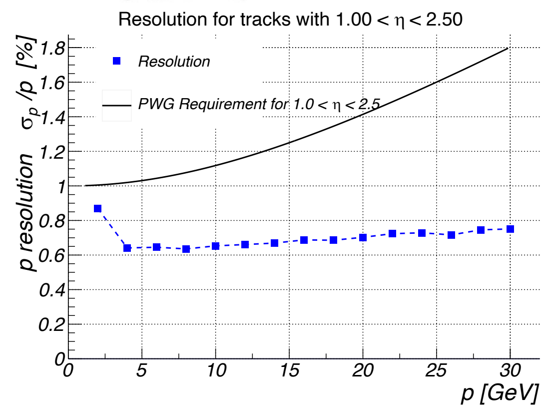
- Momentum resolution requirements fully satisfied in central region and hadron-going direction
  - further optimisations ongoing, in particular for the electron direction (tighter physics constraints)

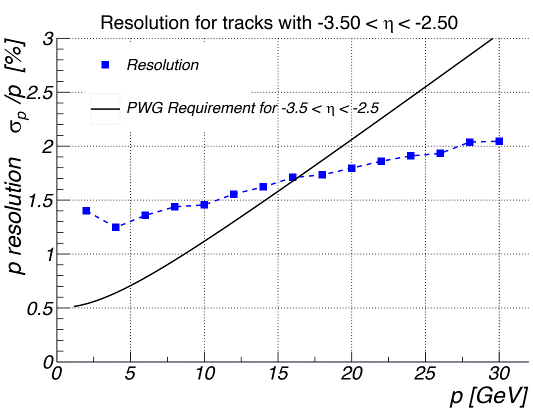


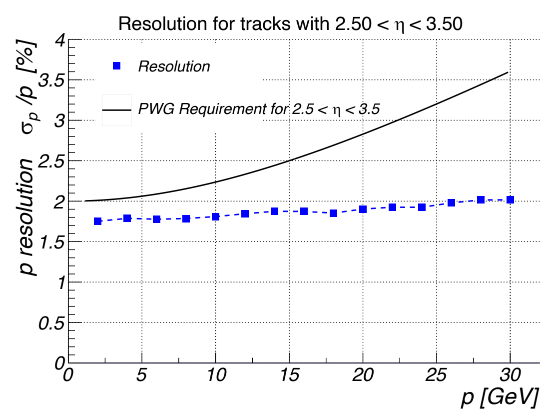


Hybrid





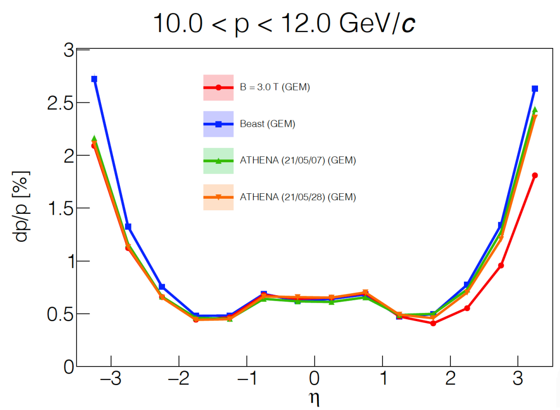




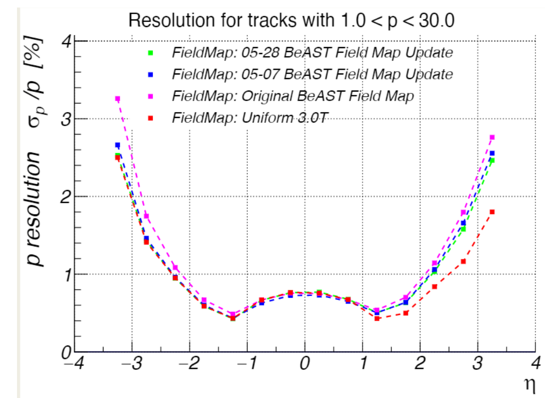
Magnetic field comparisons

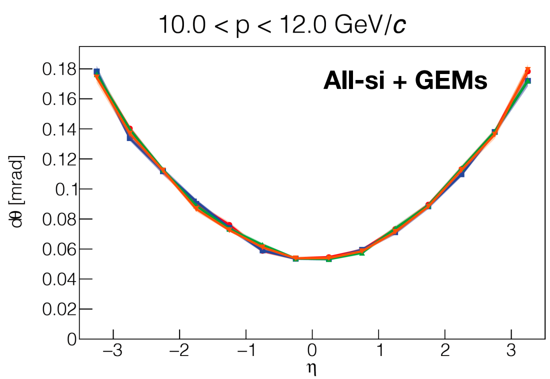
- There is no sizeable difference in performance between the two magnet configurations provided so far
- Homogeneity requirement at mid-rapidity less stringent without TPC in the tracking system

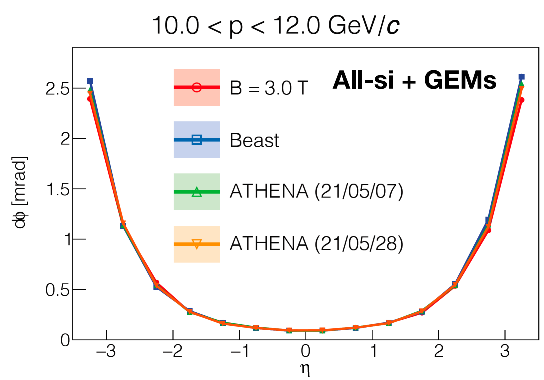
Hybrid

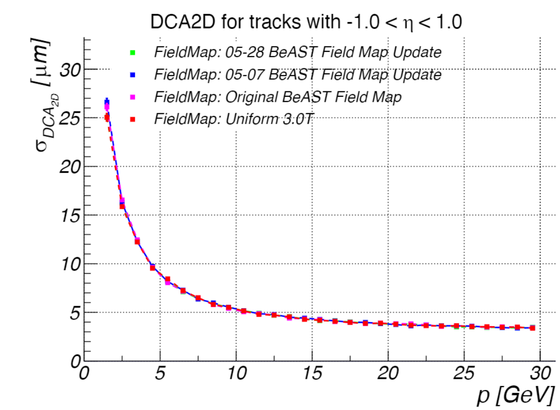


All-silicon





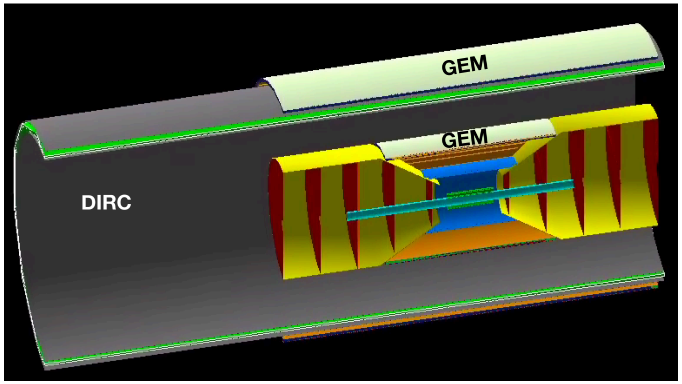




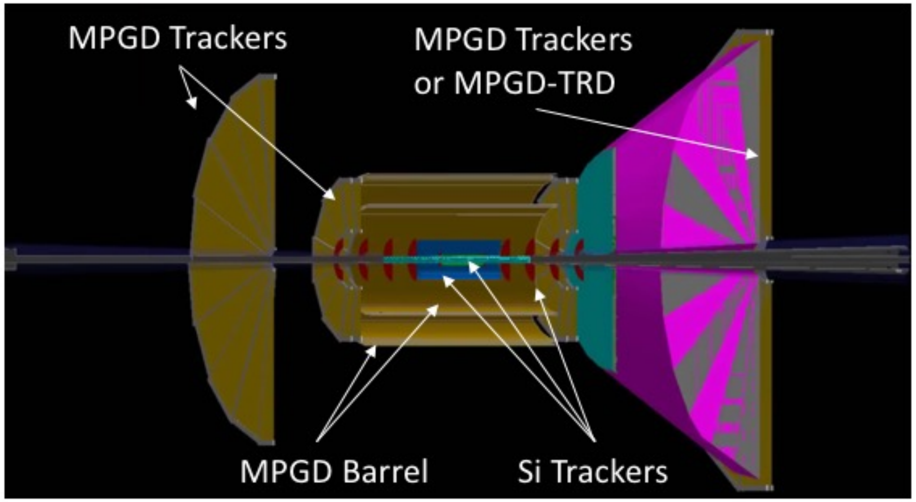
Configurations beyond minimal

- Various optimisations of minimal configurations considered

All-silicon + MPDG barrel layers



Hybrid with added MPGD trackers (or MPDG-TRD at large z)



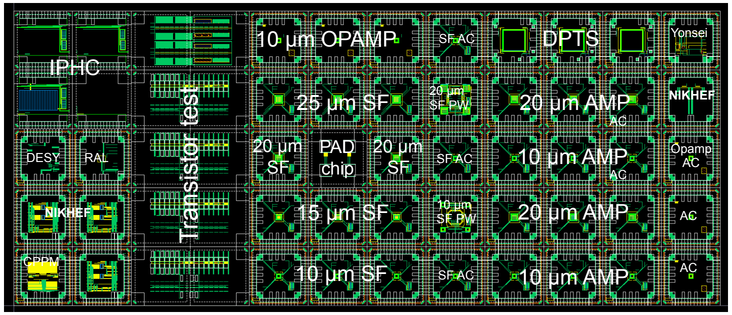
- Mini-TPC with GridPix readout also considered for barrel region
  - Low momentum PID, compact detector, affordable for a small area, high resolution tracking, low mass in electron arm
  - Readout with high power consumption on one side requires a low mass approach to services

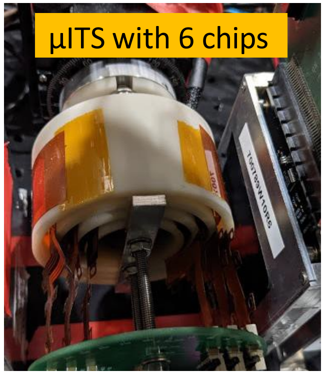
Technology choice: 65 nm MAPS

- Only technology that can satisfy the EIC requirements
- Significant benefits in exploiting synergies with ITS3

- ATHENA members actively participating to the EIC SC activities to develop technology and detector concept, and integrated into ITS3 WP

- Ongoing R&D
  - **Sensor development** (with ITS3): MLR1 test structures received, testing about to start; design of ITS3 ER1 with stitched sensor ongoing
  - **Vertex layers** (with ITS3): thinning and bending studies proceeding with super ALPIDE structure; test beam of uITS with 6 bent ALPIDE chips
  - **Barrel layers & disks** (EIC specific): work has started within the EIC SC to define disk concept; work ongoing with EIC project engineers





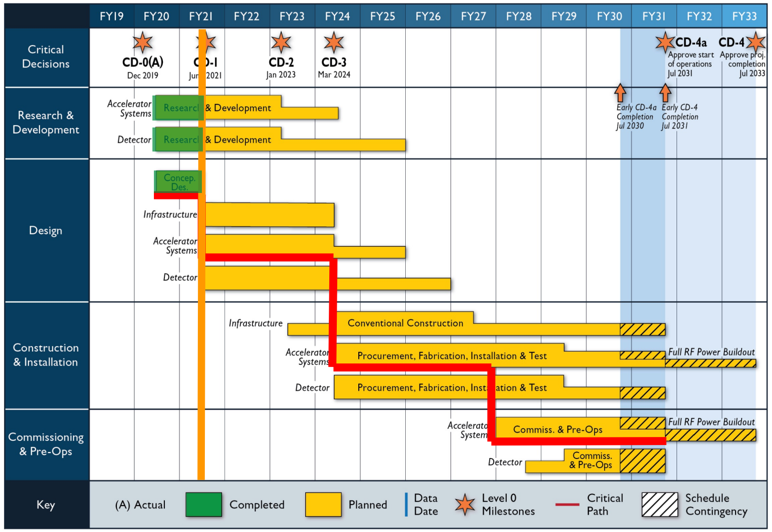
https://indico.bnl.gov/event/12512/contributions/52168/

Technology choice: 65 nm MAPS

- Fallback option
  - New MAPS sensor in 180 nm developed by the ALICE ITS3 collaboration in case of problems with the 65 nm MAPS development
  - Decision expected later this year after evaluation of MLR1

- Timeline of development
  - Largely driven by sensor development
  - Critical R&D on all aspects of detector development completed in time for TDR

Year	Main tasks
2021	Submission of the first MLR.
2022	Submission of the first engineering run (ITS).
2023	Submission of the first engineering run (EIC variant), second engineering run (ITS3).
2024	Submission of the second engineering run (EIC variant).
2025	Integration of prototype sensors into disc and stave. Possible contingency submission of EIC variant.

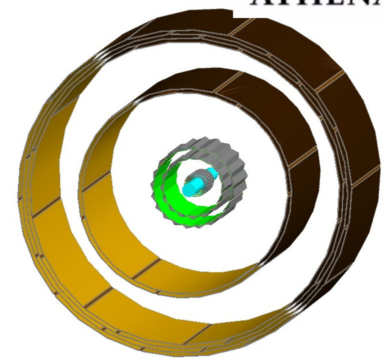


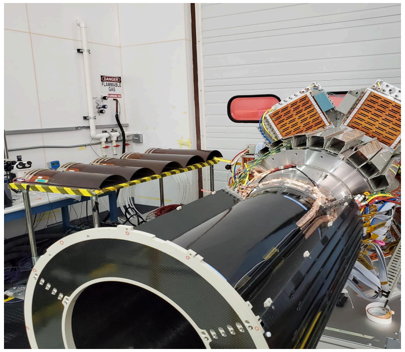
- More details at: https://indico.bnl.gov/event/11961/contributions/50340

MPDG trackers: MicroMegas

MM barrel tracker

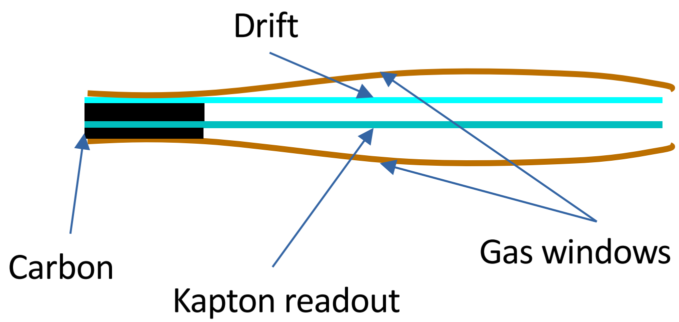
- Technological Readiness:
  - Very mature, based on CLAS12 MM, taking data since 2017
  - Fulfils the YR requirements (simulations included in YR)
- Targeted R&D:
  - 2D readout pattern, based on LDRD zigzag studies
  - A large scale 2D prototype to be built in 2023
  - Support structure





Ultra light MicroMegas

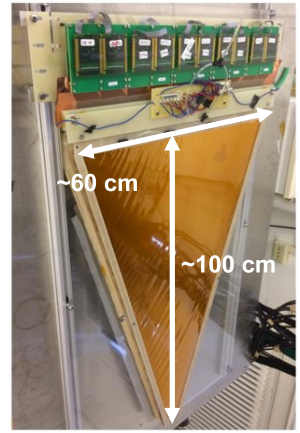
- Technological Readiness:
  - Preliminary R&D, on the timescale of EIC
- R&D goal: reach less than 0.07% of X0 in the active region
  - PCB → Just a Kapton layer (2021)
  - Inox mesh → LASER etched Al or Cu (2022)
  - Cu strips → deposited Al (2023)
  - Some of these R&Ds can be ported to the curved technology too



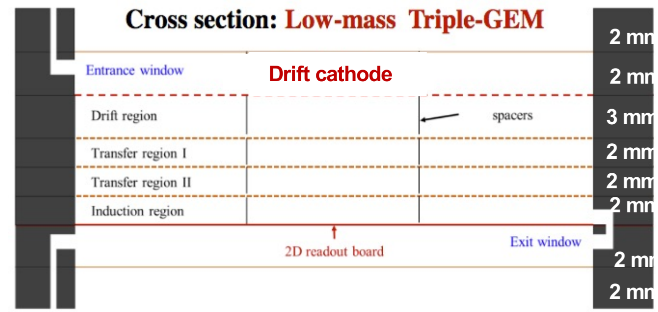
MPGD Trackers: GEMs

Triple GEM tracker

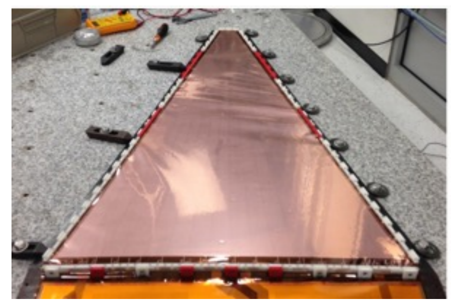
- Technological Readiness:
    - Very mature
    - Large area GEMs used in many nuclear/high energy experiments
- R&D
    - Assess two different assembly techniques to minimize material and dead area
    - Investigate two strip readout structures: U-V and Zig-Zag
    - Develop capacitive charge sharing readout based on pads and strips

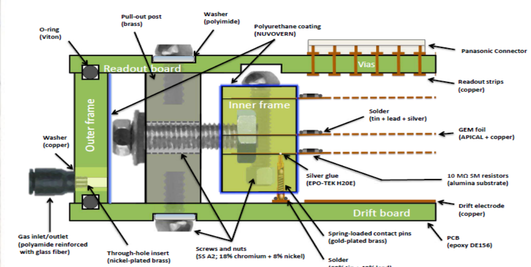


UVa Prototype



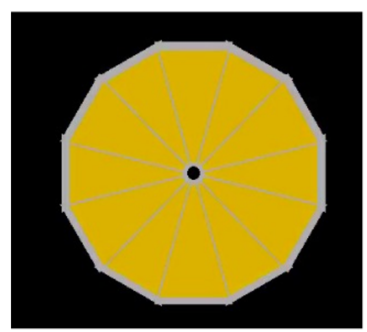
Florida Tech. Prototype





Realistic size (preliminary):

- ~12 GEM modules per disk (modified to keep top width < 55 cm)
- Active area ~0.4% X/X0

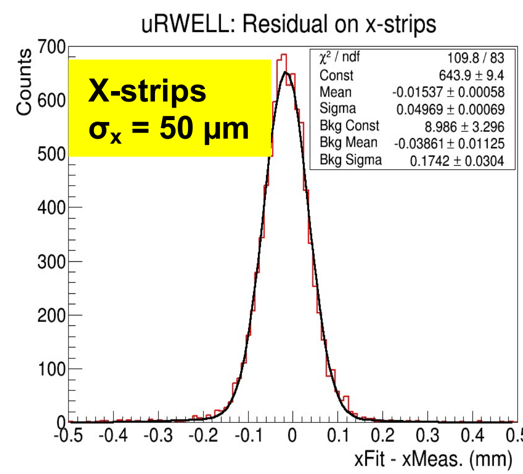


MPGD Trackers: MicroRWells

µRWell End Cap Tracker

- Technological Readiness:
  - Can be ready for EIC, but more R&D needed
  - Small (10 cm x 10 cm) standard µRWell well demonstrated in beam tests
- R&D:
  - Design a low-mass and large-area prototype
  - Optimization of readout pattern and channel count – capacitive sharing

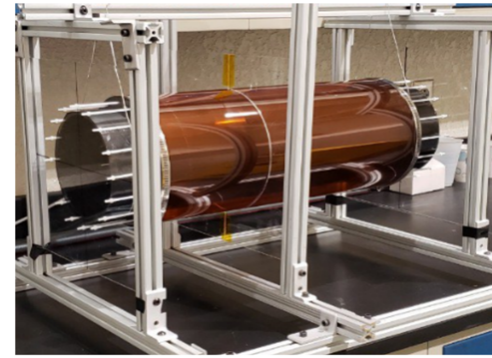
10 cm x 10 cm planar µRWELL resolution @ FNAL (UVa)



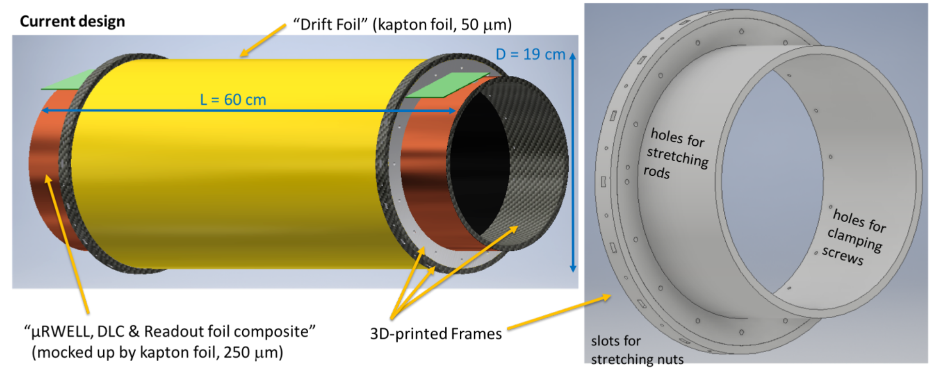
MPGD Trackers: MicroRWells

μmRWell BarrelTracker

- Technological Readiness: On the timescale of EIC
- R&D:
  - Completion of small-scale mock-up
  - Build and test of small cylindrical prototype
  - Design, build and test large radial prototype



Cylindrical μRWell mock-up (Florida Tech.)



Service estimates (preliminary):
- similar to micromegas

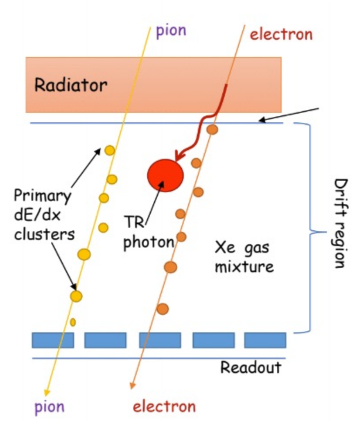
Size estimates (preliminary):
- similar to GEM for end cap
- similar to micromegas for barrel

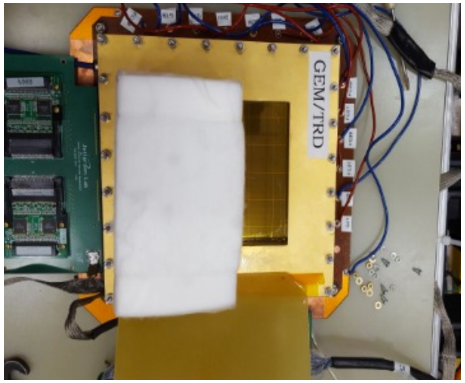
MPGD Trackers: TRD

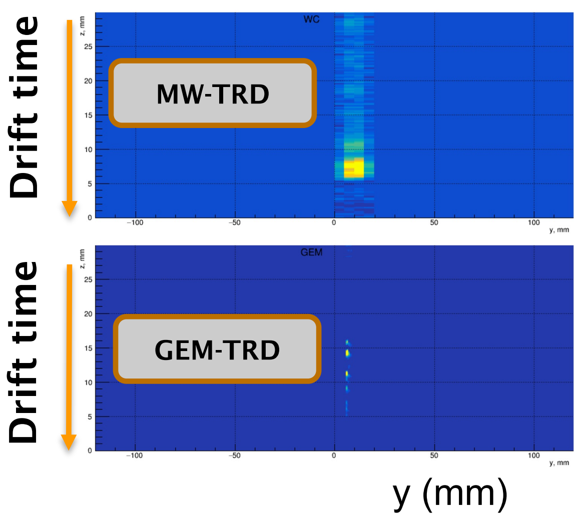
GEM-TRD (eRD22)

Triple-GEM TRD

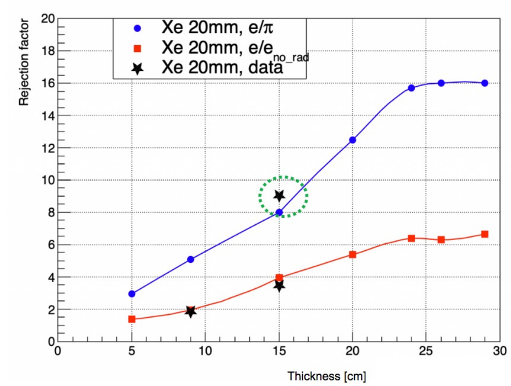
- Technological Readiness:
  - On pace for EIC readiness
  - 10 cm x 10 cm demonstrated
- R&D
  - Optimize readout architecture
  - Investigate additional radiator materials
  - Design and test a large scale prototype
- Specifications:
  - Can cover large areas (~100 cm x 60 cm)
  - Low mass TRD: ~0.4% triple-GEM + ~0.1% Xe gas + ~1.5% radiator (X/X0)
  - Provides precision tracking and e/π discrimination







PID



Conclusion

- Work is well underway to define up to two detector configurations for the ATHENA proposal satisfying YR requirements for 3T magnet
- Minimal (baseline) configurations defined to progress work on ATHENA software implementation, overall detector integration and preliminary physics benchmark studies
  - Spec sheets preliminary filled for the current baseline configurations
- Baseline technologies chosen considering experiment requirements, performance, readiness, R&D timeline to completion
- Work continues to
  - Implement (more) realistic support and services description
  - Finalising switch to Athena simulation framework
  - Continue optimisation of detector configurations following addition of passive material and feedback from PWG