EIC Detector 1 Tracking Detector Updates and Plan

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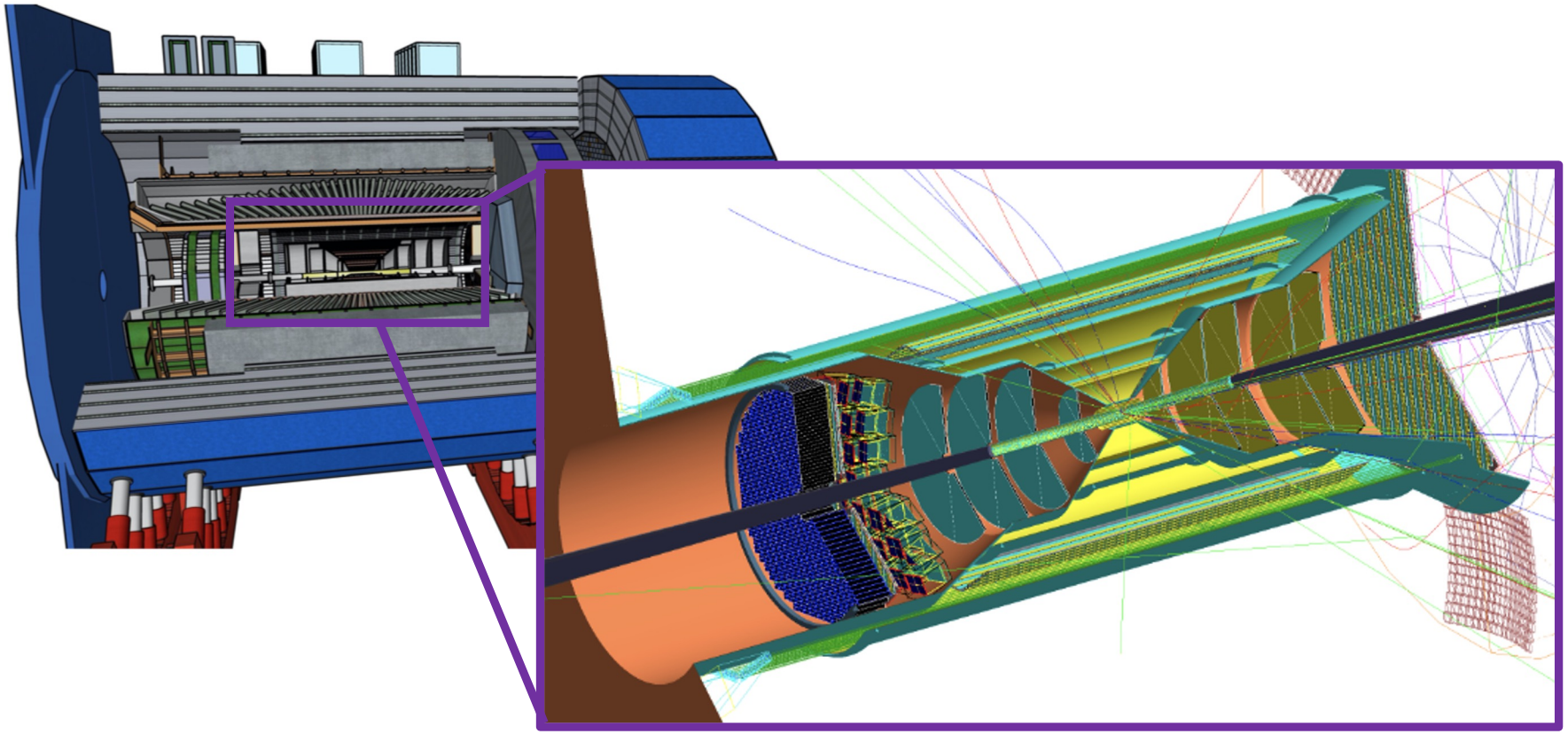
on behalf of the EIC Detector 1 Tracking Working Group

Outline

- EIC reference tracking detector design and performance.
- EIC Detector 1 tracking detector updates:
  - Goal and work status
  - Recent update highlight: detector geometry optimization and performance validation.
  - Technology option developments
- Plan towards the technical report preparation

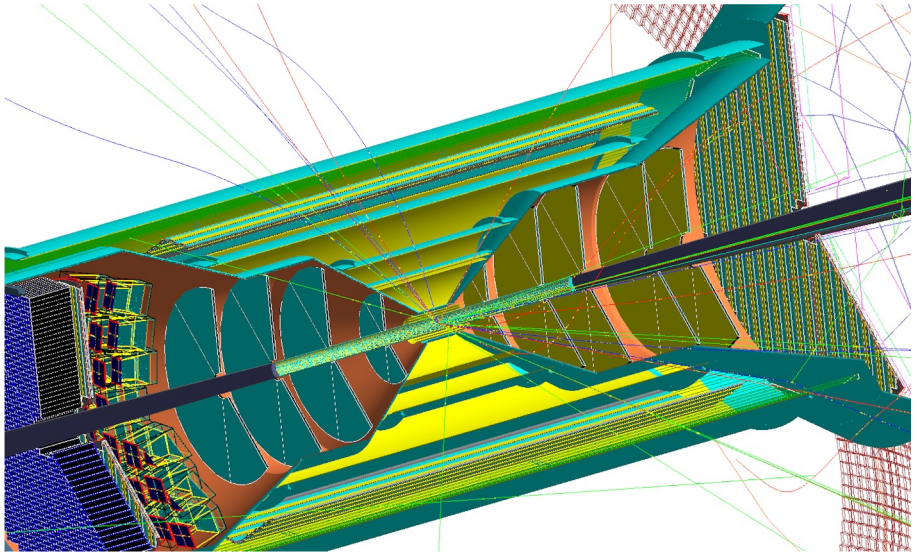
Detector 1 reference tracking detector design (I)

- The EIC reference tracking detector consists of integrated MAPS, MPGD (e.g., µRwell) and AC-LGAD tracking detectors. Detailed detector segmentation and service parts have been implemented in the Fun4All framework.



Detector 1 reference tracking detector design (II)

- The EIC reference tracking detector consists of integrated MAPS, MPGD (e.g., μRwell) and AC-LGAD tracking subsystems. Detailed detector segmentation and service parts have been implemented in the Fun4All framework.
- The tracking detector layout:
  - Barrel: 5 MAPS layers, 3 μRwell layers and 1 AC-LGAD layer. Inner Radius: 3.3 cm, Outer Radius: 77.0 cm.
  - Hadron endcap: 5 MAPS planes and 1 AC-LGAD plane. Minimum z: 25 cm, Maximum z: 182 cm.
  - Electron endcap: 4 MAPS planes and 1 AC-LGAD plane. Minimum z: -155.5 cm, Maximum z: -25 cm.



EIC Detector 1 Tracking Detector Working Group Information

- About the EIC detector 1 tracking working group:
  - Conveners: Xuan Li (xuanli@lanl.gov), Kondo Gnanvo (kagnanvo@jlab.org), Laura Gonella (laura.gonella@cern.ch), Francesco Bossu (francesco.bossu@cea.fr)
  - Email mailing list: eic-projdet-tracking-l@lists.bnl.gov
  - We have weekly meetings scheduled at 11:00AM US eastern time every Thursday and the meeting indico link: https://indico.bnl.gov/category/404/
  - Mattermost channel: https://eic.cloud.mattermost.com/main/channels/tracking
  - WIKI page: https://wiki.bnl.gov/eic-project-detector/index.php/Tracking#EIC_Project_Tracking_Working_Group
- Welcome new collaborators to join us!

EIC Detector 1 tracking work plan and goal

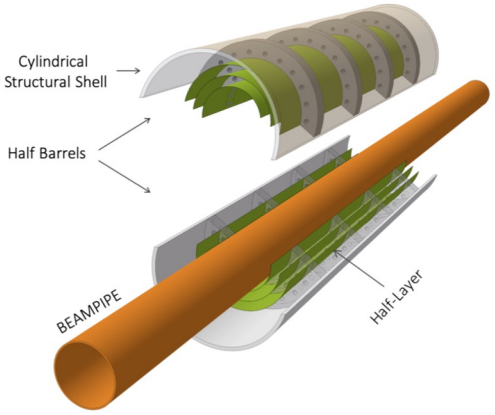
- Simulations:
  - Simulation task break down and priority list in https://docs.google.com/spreadsheets/d/1Jp1-V7MavZFejn2SG185YarbMIpGCByGfF7yz4Y-Azc/edit?usp=sharing
- Technology review:
  - Complete review of the choice of tracking technologies.
  - Identify risks & fallback solutions for each technology.
  - Establish the timelines to CD2/3A.
  - Close coordination with the detector consortia (EIC-SC, eRD108).
- EIC Tracking Detector configuration:
  - By July EICUG, the baseline configuration "***aka advanced conceptual design***" of the tracking detector is established.
- Validate the tracking performance based on inputs from the physics WGs:
  - List of key tracking requirements such as momentum resolution, vertex and projection spatial resolutions.

EIC Detector 1 Tracking work status

- Reported progresses and updates:
  - Simulation software introduction about Fun4All and DD4HEP. Decided the simulation tasks and the priority list.
  - Ongoing background studies and how to progress study of background impact on the tracking performance.
  - Detector technology inputs from EIC Si consortium and MPGD consortium.
    - Plan to invite eRD groups (e.g., eRD108, eRD 111, eRD112) to present their updates.
  - Tracking performance evaluation with different geometry optimizations.
- Upcoming meetings will focus on:
  - Continue optimisation of overall (Si+gas) vertex & tracking detector
  - Tracking pattern recognition developments.
  - Detector integration with other detector subsystems.
  - Physics study feedback.
  - …

Geometry optimization and simulation studies for the silicon tracker

- Vertex layers
  - The radii need to be adjusted as 5 mm clearance from the beam pipe are needed because of beam pipe backout and constraints from ITS sensor size
- Tracking layers
  - The material assumed in the Reference Detector proposal is 0.05%X/X0 per barrel layer.
  - This low value cannot be achieved by the technology and needed update.
  - Also, check the impact on momentum resolution by repositioning the sagitta layers.



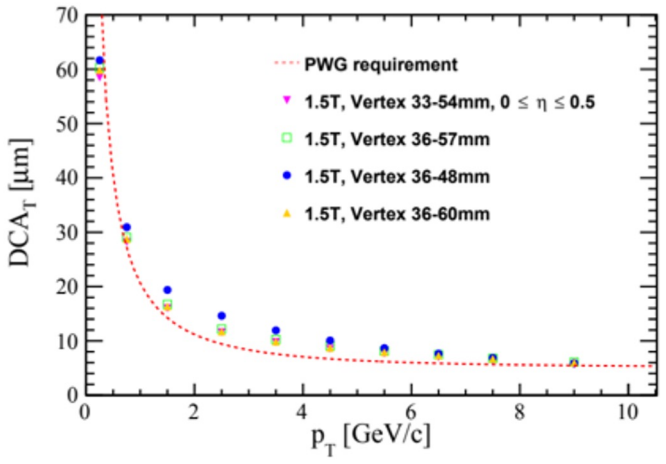
- Disks
  - The last disk on both side in the Reference Detector design is currently floating and not supported. Service cone needs updating to make the required support connections.
- Hits per track as function of rapidity and p_T/momentum
  - The average number of hits per track in the electron going direction is more than 4 hits on average.
  - Needs further verification in simulations with events including background.
- EIC background impact on the tracking performance needs evaluation (urgently)

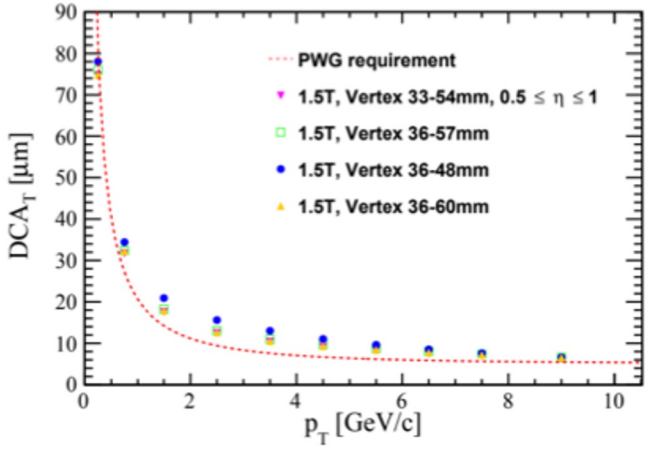
Tracking geometry optimization (Silicon vertex/tracking) I

- Silicon vertex optimisation

Stephen Maple

	L1/L2/L3 radii [mm]
Reference design	33/43.5/54
Reference design + offset so first layer at 5mm from beam pipe	36/46.5/57
ITS3 sensor design as is	**36/48/60 → chosen**
Modified ITS3 sensor size (i.e. modified stitching plan)	36/42/48





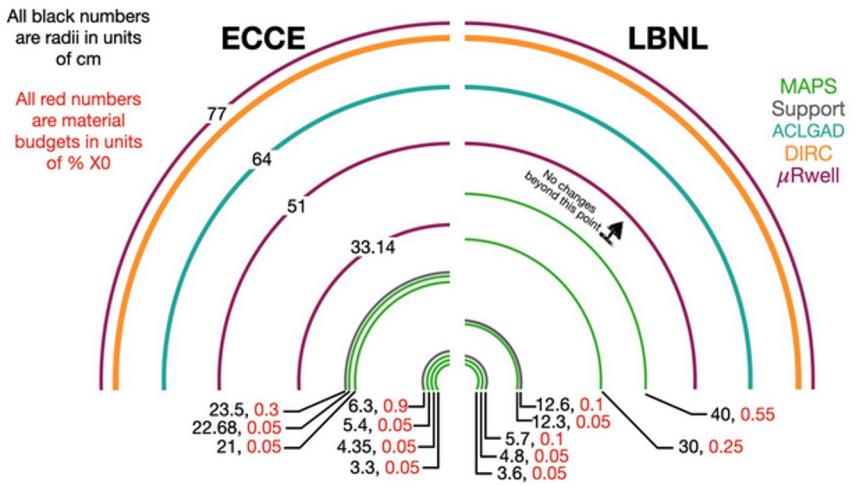
- Reference design and reference design + offset not achievable with ITS3 reticule size (i.e. basic unit that is repeated in x and y to form wafer-scale stitched sensor).
- Using the ITS3 sensor design as is gives better performance than what can be achieved by changing the stitching plan and it is cheaper as no extra design work is needed.
- **YR requirements still not met at pt < 6 GeV**

Tracking geometry optimization (Silicon vertex/tracking) II

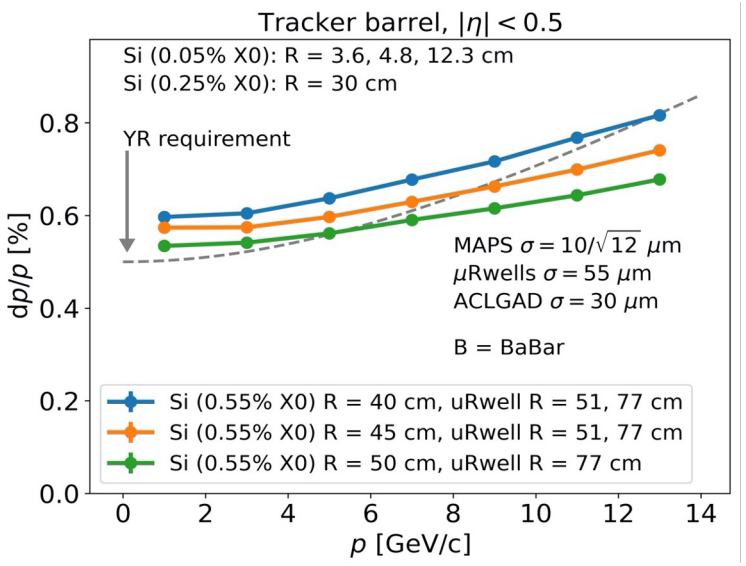
- Silicon vertex and sagitta layer optimization

Updated Silicon barrel geometry in simulation:

	r (cm)	length (cm)	X/X0
1	3.6	27	0.05%
2	4.8	27	0.05%
Support	5.7	15.4	0.1%
3	12.3	27	0.05%
Support	12.6	30.6	0.1%
4	30	77	0.25%
5	40	104	0.55%



Ernst Sichtermann, Rey Torres



- Reconfiguration of vertex and sagitta layers position and material budgets implemented in MC.
- Moving out the 3rd vertex layer and the sagitta layers can help improve the tracking momentum resolutions to get close the EIC YR requirements., but **requirements are still not met at pT < 6 GeV**

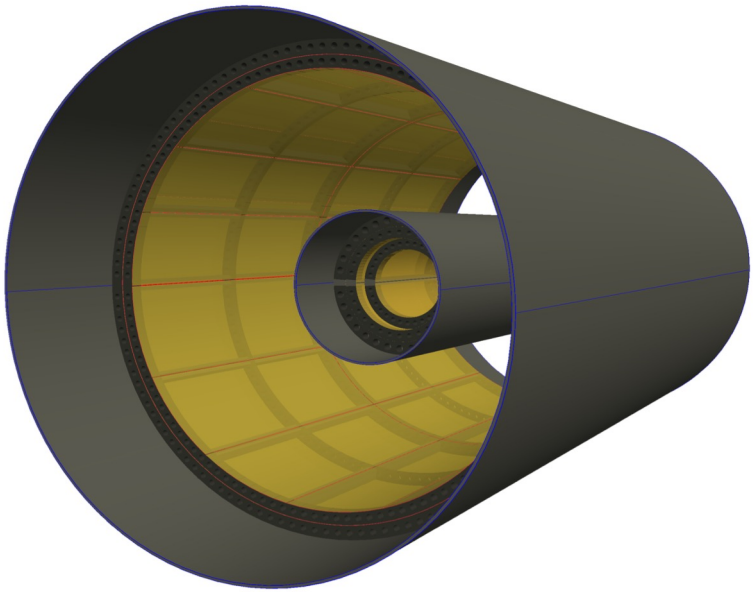
Tracking geometry optimization (Silicon vertex/tracking) III

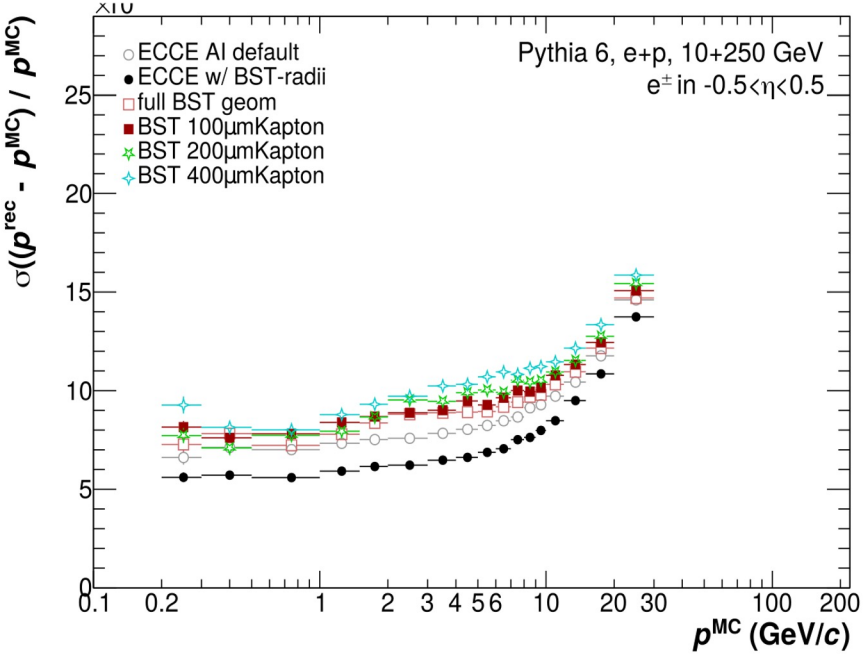
- Silicon vertex and sagitta layer optimization

Vertex layer	radius [mm]	sensors (half shell)
0	36.16	113.1x250mm
1	48.22	2 * 75.5x280mm
2	60.19	2 * 94.3x280mm
Sagitta layer	**radius**	**sensors (half shell)**
0	198.3	5 * 94.3x280mm + 2 * 75.5x280mm
1	210.3	7 * 94.3x280mm

Nicolas Schmidt

- 3 vertex layers with 0.05% X /X0
- 2 sagitta layers with optional kapton foil **0.11% X /X0**
- radii of layers based on ITS3 sensor sizes
- all 5 layers curved



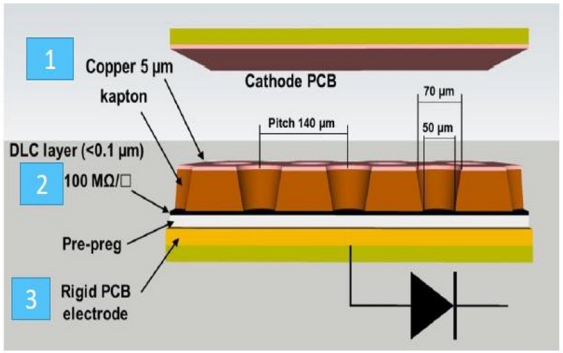


Key points of ongoing Si tracker optimization

- Two solutions explored that could recover momentum resolution once constraints from beam pipe backout, achievable sensor size and material budget are folded in.
- Both propose 5 layers of silicon.
  - **Note that this will need to be re-evaluated when simulations are done with events including background to understand if 5 layers are enough.**
- One solution (slide 10) has been implemented in the first simulation production
  - R&D needs to achieve 0.05%/0.25% in the layers at 12.3/30 cm can be met with eRD104/111.
- The other solution (slide 11) will be carried forward under the generic R&D program.

Geometry optimization and simulation studies for the MPGD tracker

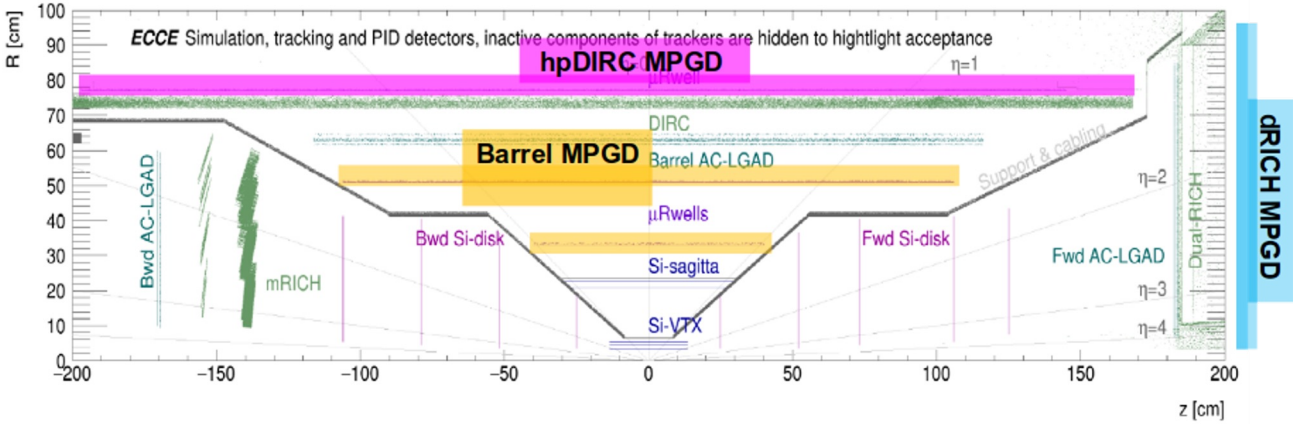
- Updating the reference detector
  - Redundancy vs number of hits per track
    - Synergy with the Silicon tracker
  - Addition of a MPGD layer behind the dRICH:
    - Help improving the angular resolutions
  - Technology selection (MM, µRWELL or both): see next
- Thicknesses
  - Updating Reference Detector's design: ~0.3%X0 not achievable
    - 0.5% – 1% X0 for barrel layers
    - 1% – 2% X0 for PID layers
- Resolutions
  - Track angles impact the resolutions
  - R&D ongoing to keep resolution ~100µm



1 **a WELL** patterned kapton foil acting as **amplification stage** (GEM-like)

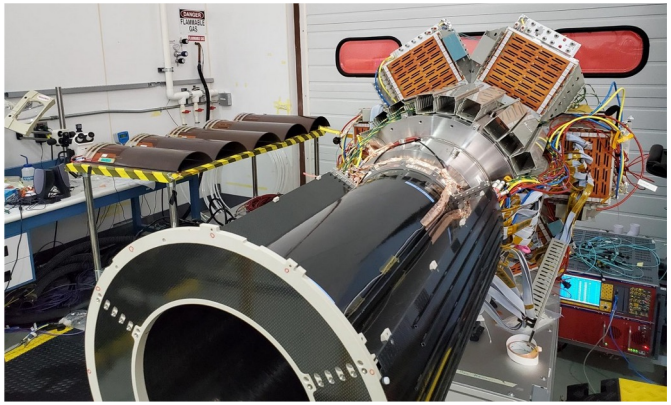
2 **a resistive DLC layer (Diamond-Like-Carbon)** for discharge suppression w/ surface resistivity ~ 50÷100 MΩ/□

3 a standard readout PCB



MPGD technology choices (from eRD108)

Barrel MPGDs



Requirements:

- Low mass (<0.5%X0)
- Full acceptance
- Spatial resolution ~100µm

Technology choice:

- Starting point: CLAS12 **cylindrical MicroMegas** (0.4% X0 in active area)
- Ongoing R&D: 2D readout choice

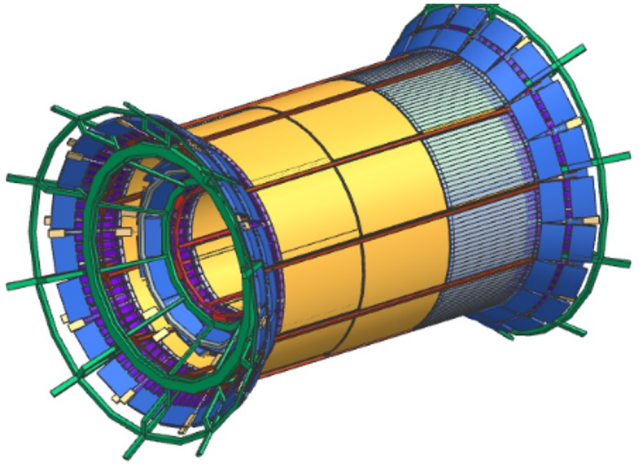
Integration:

- Arrangement of cylindrical tiles with overlaps
- Preliminary concept of support and services developed

Fallback solution:

- Cylindrical µRWELL: ongoing R&D

Preliminary design of micromegas tracker for ATHENA proposal



MPGD technology choices (from eRD108)

Planar MPGD trackers:

- Tiles behind the hpDIRC
- A layer behind the dRICH

Requirements:

- Space limitations
  - About 2cm thick boxes integrated in the hpDIRC structure
- Spatial resolutions: 50–100µm
- No strict requirements on material budget: 1%--2%X0

Technology choice:

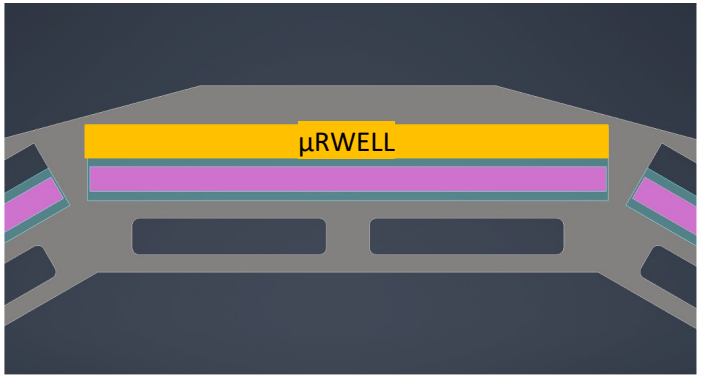
- **Planar µRWELL**
- Ongoing R&D for large area detectors and 2D readout

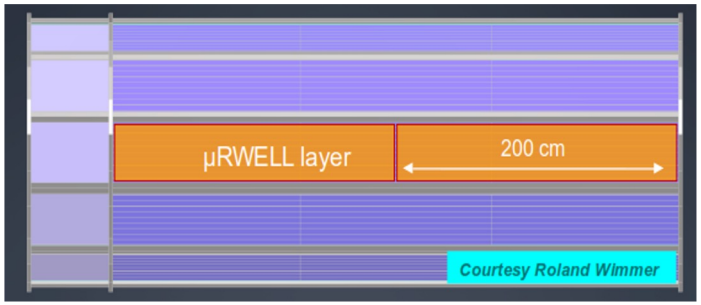
Integration:

- Tight spaces and interference with PID detectors
- Discussions will start soon

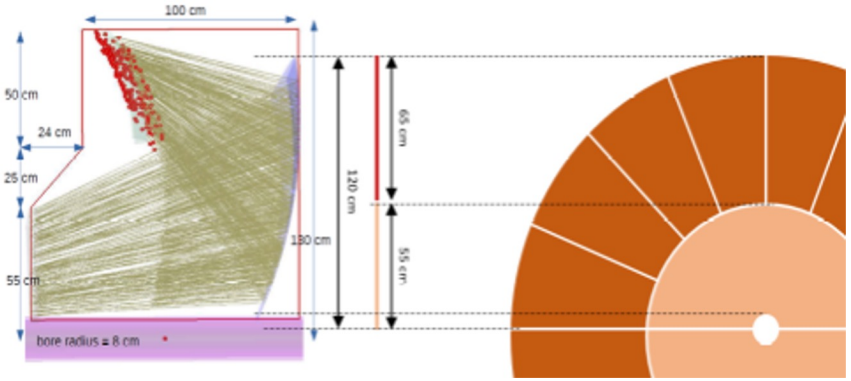
Fallback solutions:

- hpDIRC: MicroMegas
- dRICH: GEM or MicroMegas





µRWELL layer behind dRICH



Alternative technology options

Open questions: (from EIC YR)

- Is PID at low momenta (100<pT<300 MeV/c) important?
- Do we have enough hit point for track finding at low momenta?

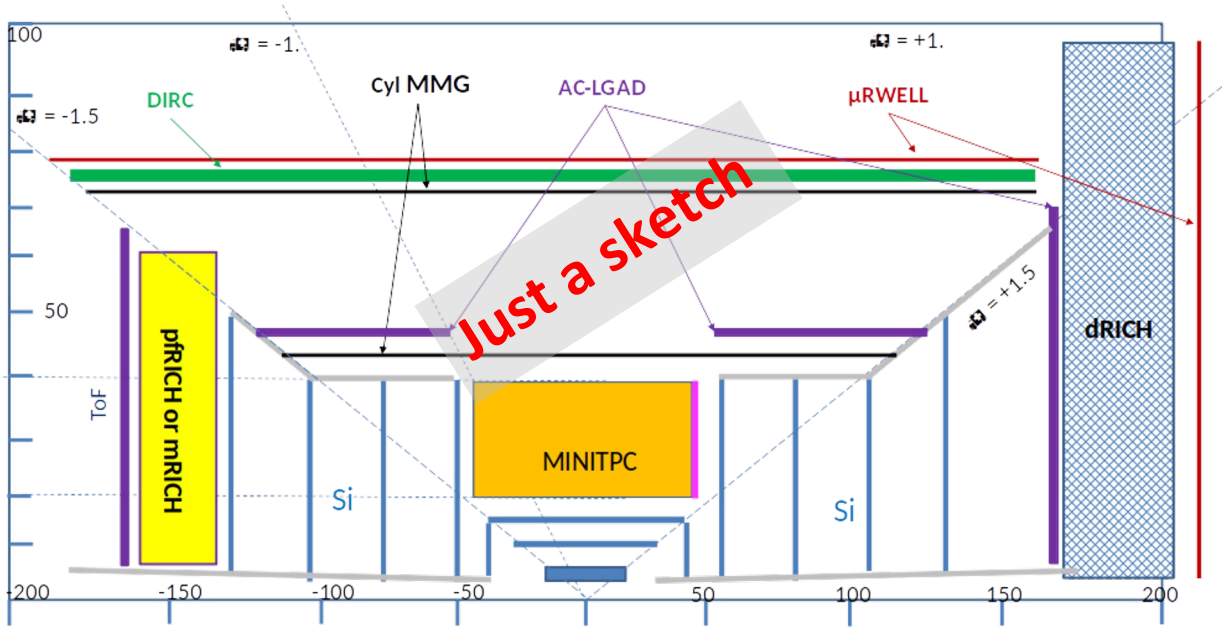
IF yes, then a possible solution is:

- **Mini-TPC with GridPix readout** is a candidate to provide more hits for track reconstruction in the barrel region.

CAVEAT:

- preliminary implementation in fun4all to be done.
- Need to check performance with background
- Integration and services must be worked out

Checkout Nikolai and Tom' presentations:
https://indico.bnl.gov/event/16352/



Remaining tasks and requests

- Simulation developments
  - Background implementation for tracking performance studies.
  - Alternative technology geometry (e.g., MiniTPC) to be included in the simulation production.
- Technology readiness
  - R&D plan
  - Cost and schedule updates
- Detector integration
  - Joint studies for the detector geometry optimization and technology down selection, for example, PID and tracking requirements.
- Physics WG inputs

Summary and Outlook

- The EIC detector 1 tracking working group has been formed and focuses on the tracking detector geometry optimization, updates and implement of technical details towards the pre-CDR submission.
- The charge, plan and path forward has been defined for the EIC detector 1 tracking detector related studies.
- Good progresses have been achieved for both silicon and gas tracking geometry optimization.
- With more realistic detector implementation, it is challenging to meet the YR requirements at low momenta, unless we consider a stronger B field.
- We welcome your suggestions, inputs and feedback for the EIC detector 1 tracking developments.

Backup

EIC reference silicon vertex/tracking detector geometry

- The ECCE tracking detector geometries have been archived in the Fun4All ECCE associated repositories.

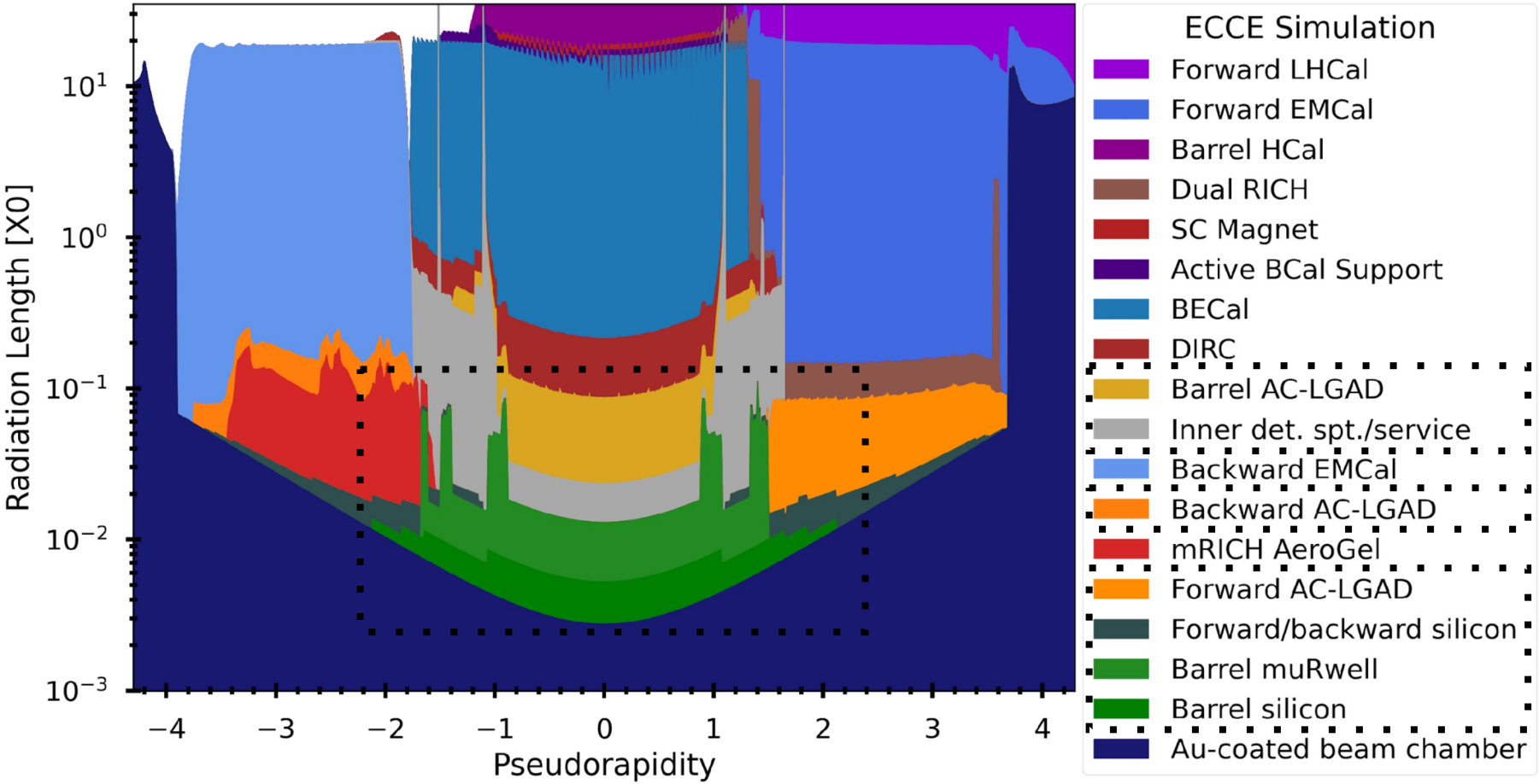
Barrel index	R (cm)	z_{min} (cm)	z_{max} (cm)
1	3.3	-13.5	13.5
2	4.35	-13.5	13.5
3	5.4	-13.5	13.5
4	21.0	-27	27
5	22.68	-30	30

H-endcap index	z (cm)	r_{in} (cm)	r_{out} (cm)
1	25	3.5	18.5
2	49	3.5	36.5
3	73	4.5	40.5
4	106	5.5	41.5
5	125	7.5	43.5

e-endcap index	z (cm)	r_{in} (cm)	r_{out} (cm)
1	-25	3.5	18.5
2	-52	3.5	36.5
3	-79	4.5	40.5
4	-106	5.5	41.5

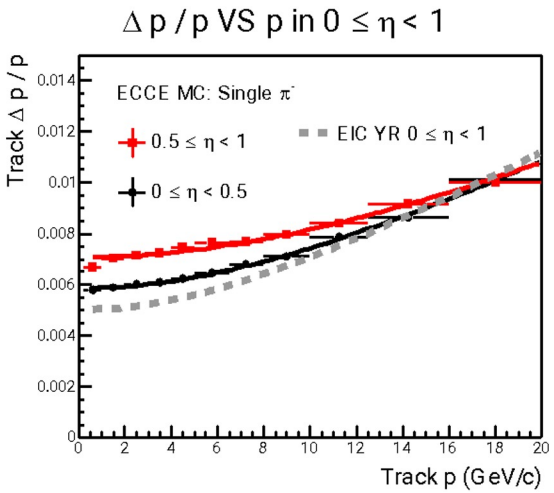
EIC reference detector material budget scan

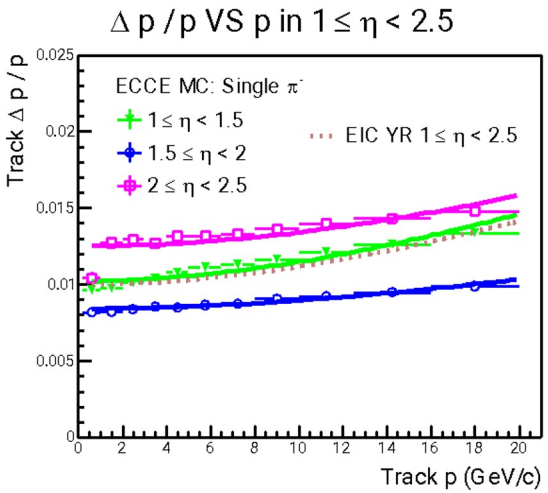
- From the Fun4All simulation, material budget scan of the EIC reference detector subsystems.

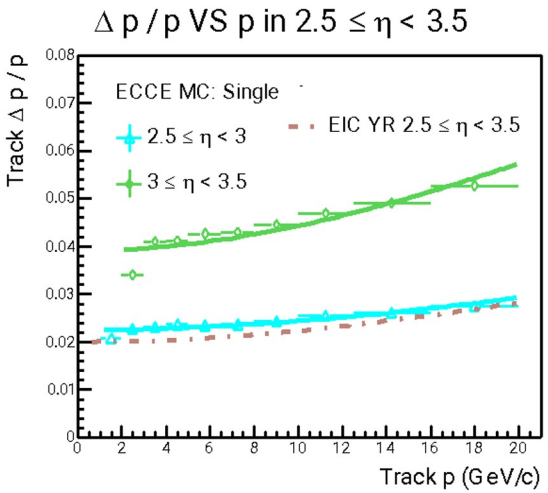


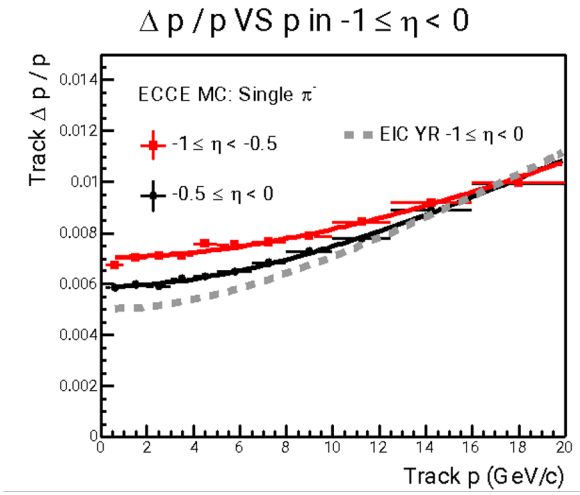
EIC reference tracking detector momentum resolution

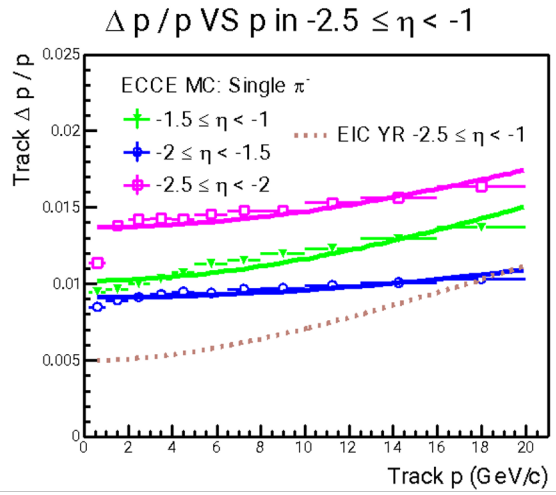
- Track momentum dependent momentum resolution.

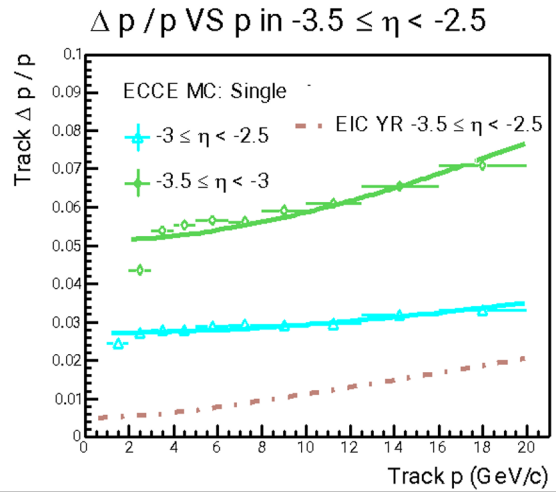












EIC reference tracking detector DCA_{2D} resolution

- Track p_T dependent DCA_{2D} resolution.