Silicon vertex and tracker status

F. Bossù, K. Gnanvo, L. Gonella, X. Li

GD/I WG meeting

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Introduction

- For today the tracking WG was asked to "*report about the current status of the implementation of the silicon tracking in ePIC*".

- Work on the implementation of the silicon vertex and tracking detector proceeds through:
  - Performance simulations in the EPIC tracking WG;
  - Technology development in the EICSC.

- The process of implementing this detector is an iterative one, where simulations and R&D feed into each other and further optimisations are implemented when physics requirements and technology choices are finalised.

Transition from reference detector to baseline

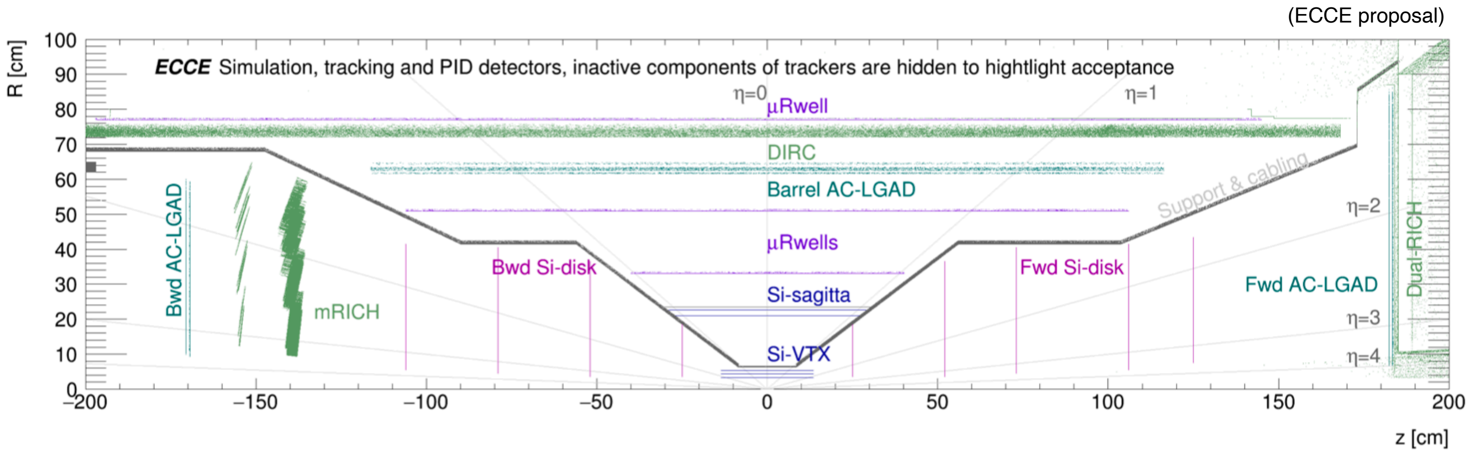
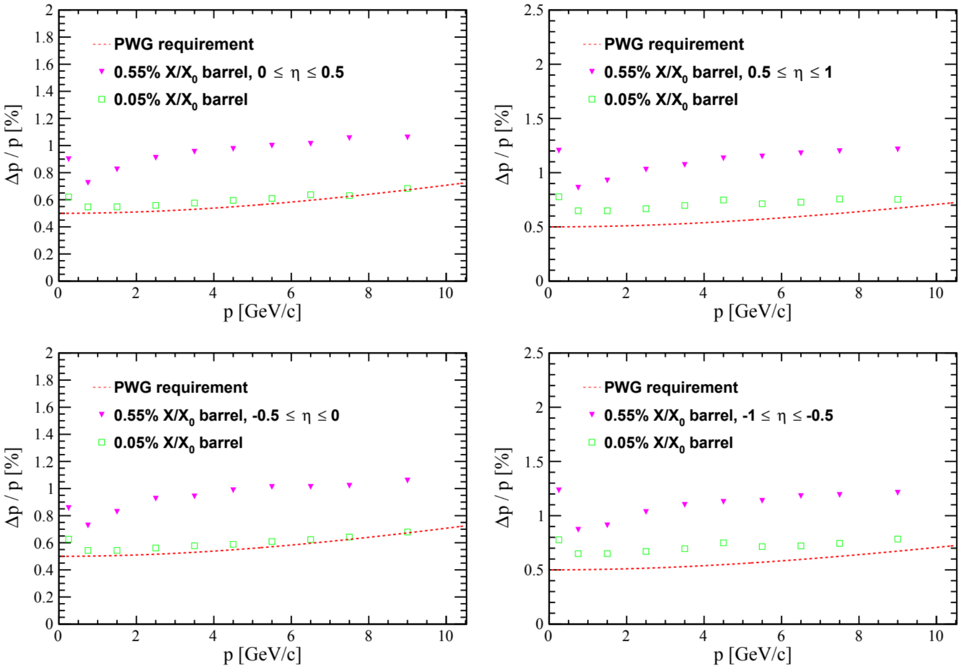


Figure 2.5: Schematic view of the ECCE tracker, including silicon, μRWELL, AC-LGAD, DIRC, mRICH and dRICH detector systems.

- The collaboration settled on a barrel update for the initial general simulation campaign on 23 June https://indico.bnl.gov/event/16261/
- Since then, the magnet situation has improved bringing an increase in overall field to an overall ~1.7 T.
- Changes to the disks are also being implemented following changes to the barrel and considering basics aspects of tracking at high eta.
- Many aspects remain open, but good progress has been made towards meeting YR requirements.

Some of the work that led to where we are

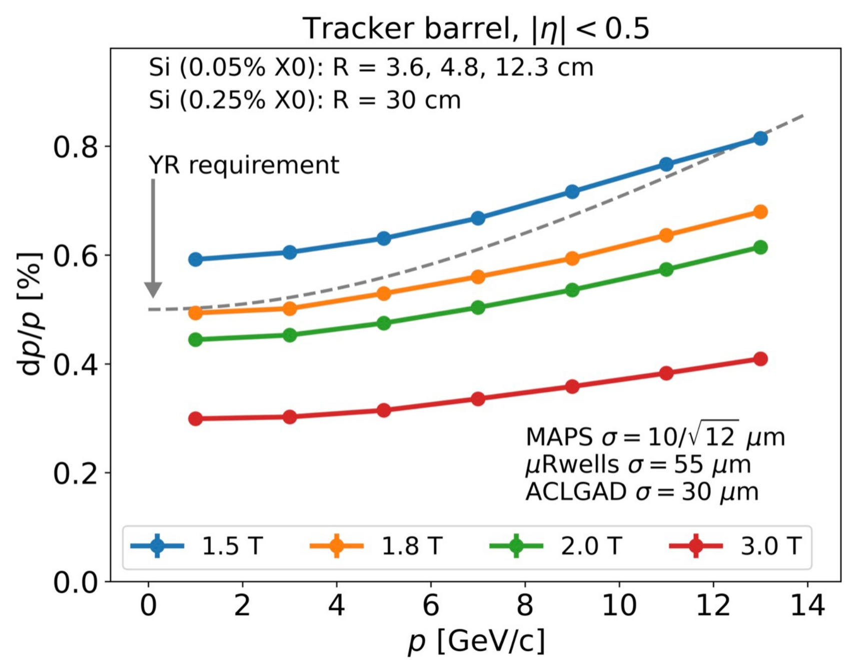


Reference detector with updated material estimates for sagitta layers showed optimisations to recover momentum resolution at mid-rapidity were needed.

See talk by Stephen at https://indico.bnl.gov/event/15659/

Reference detector with an updated barrel configuration vs B-field showed YR requirements are satisfied with B ~ 1.8 T.

Work by Rey



Changes to vertex layers

- Vertex layers radii needed to be increased
    - Beam pipe bake out requirement, 5 mm clearance needed.
    - Constraints from anticipated ITS3 sensors reticle size.

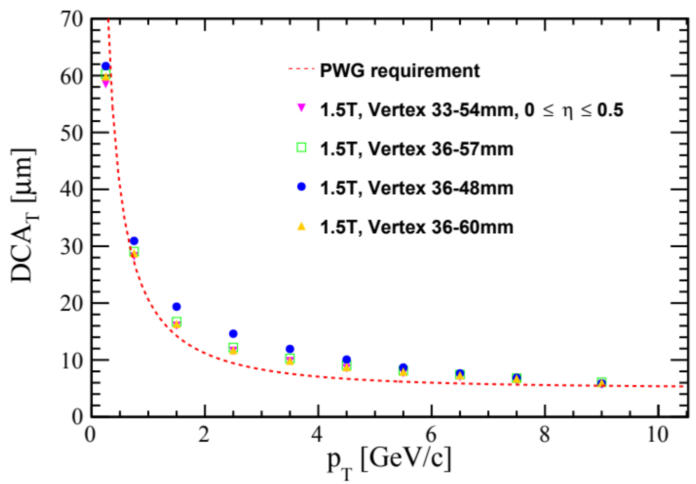
- Reference: r = 33/43.5/54 mm
- Reference + 5 mm clearance = 36/46.5/57 mm.

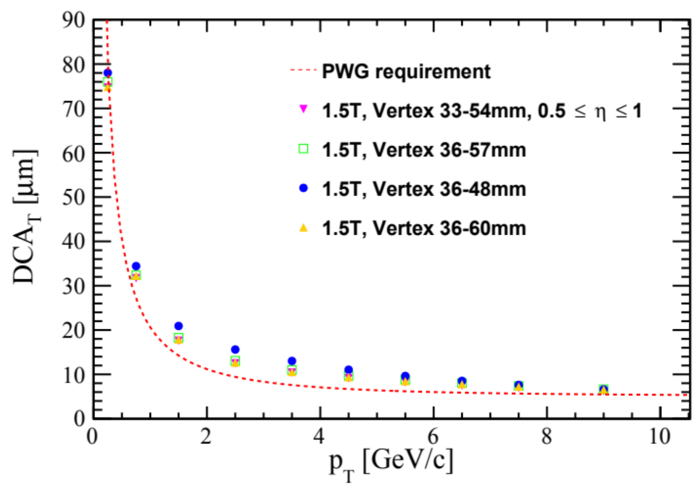
→ Both the above not possible with ITS3 reticle size.

- 5 mm clearance w/ ITS3 sensor: 36/48/60 mm → good performance and can be built with ITS3 reticule size ✅
- 5 mm clearance w/ modified ITS3 sensor size: 36/42/48 mm → Worse performance (smallest L2 – L1 distance), not worth the effort to change ITS3 sensor stitching plan.

	Reference	Updated
Layer 1 radius [mm]	33	36
Layer 2 radius [mm]	43.5	48
Layer 3 radius [mm]	54	60

See talk by Stephen at
https://indico.bnl.gov/event/16261/

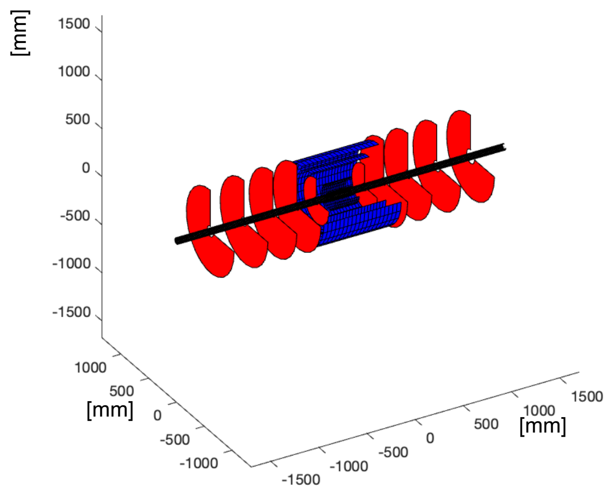


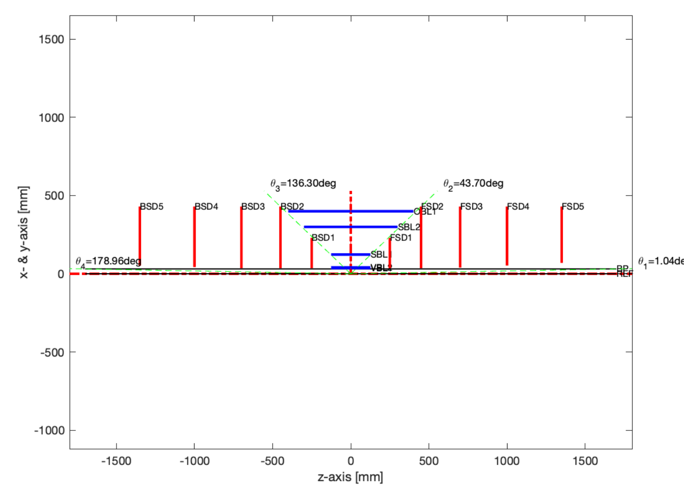


Approach to recover YR mid-rapidity performance in 1.7 T with ePIC

- Increase the radius of the outermost vertexing layer while preserving its length of approximately 27 cm.
  - The goal is to have it contribute more/better to the momentum measurement.

- Replace the two sagitta layers with a more conventional stave-based design.
  - One layer made of two half-lengths of X/X0 ~ 0.25% (or less, if feasible) at a radius of approximately r ~ 0.2 m, and optimize this radius.
  - Complemented with a layer at large-radius ~ 40 cm, with an overall length of ~80 cm – this radius follows from basic considerations on tracking and YR requirements.



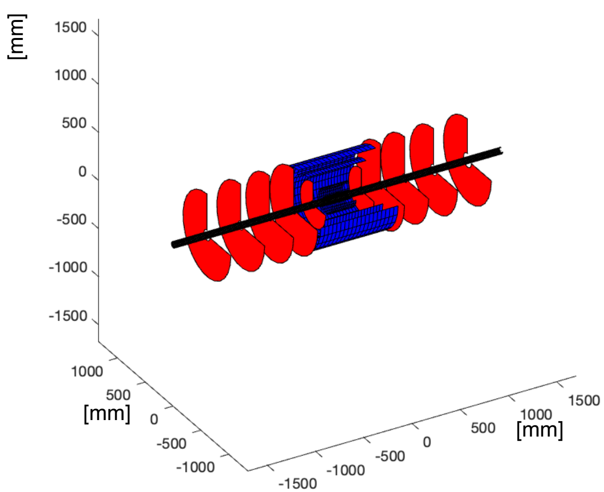


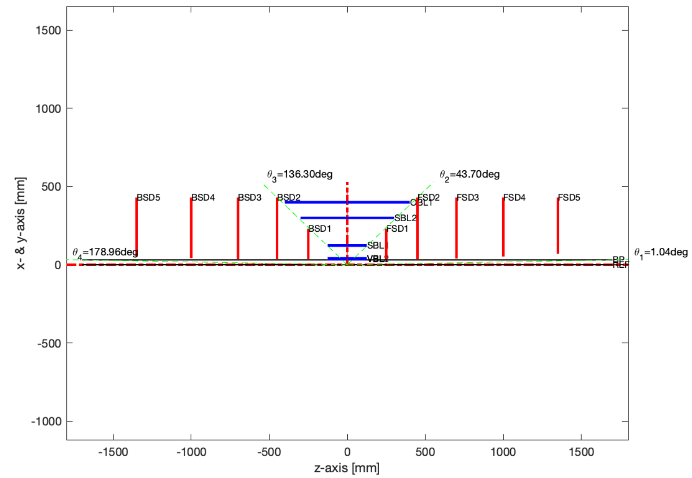
See talks by Ernst at
https://indico.bnl.gov/event/16261/ https://indico.bnl.gov/event/16582/

Approach to recover YR mid-rapidity performance in 1.7 T with ePIC

- Inner cone angle of ~45 degrees, at least for now.
  - See Rey's studies https://indico.bnl.gov/event/12595/
  - Note: this cone is (or should be) projective to the nominal interaction point (until more detailed studies inform otherwise).

- Constrain changes to be consistent with wafer size and anticipated sensor reticle size.

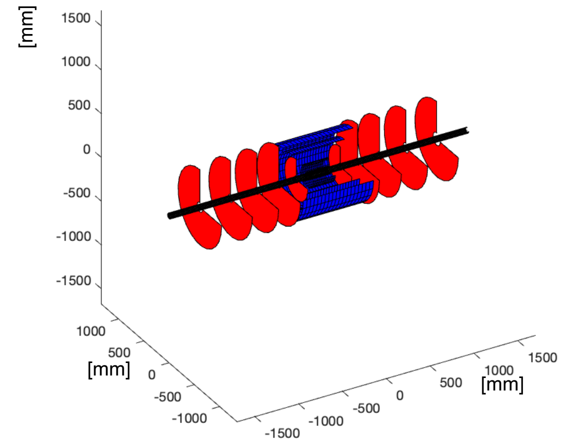




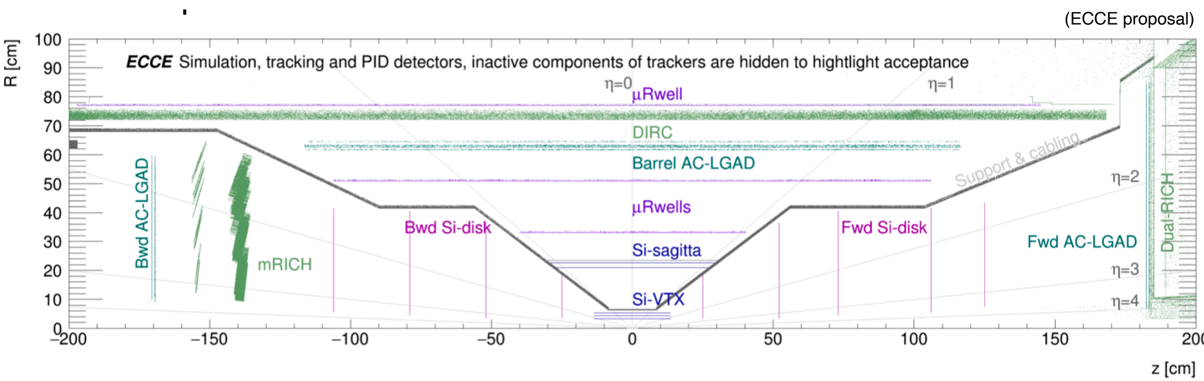
See talks by Ernst at
https://indico.bnl.gov/event/16261/ https://indico.bnl.gov/event/16582/

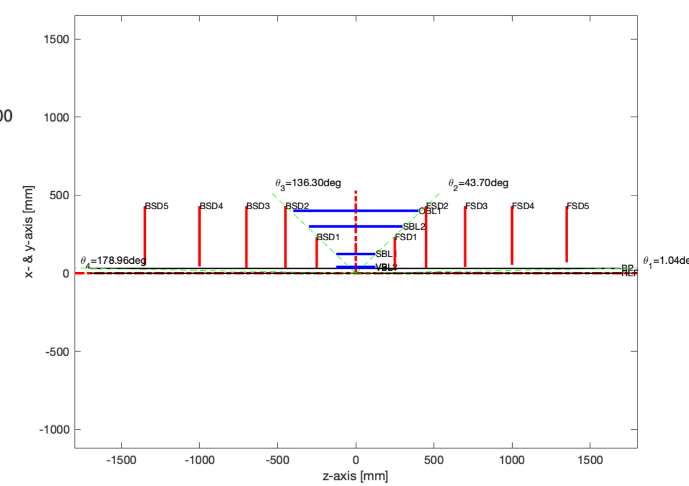
End-caps optimisations

- Increase the number of disks in both directions to improve acceptance at high eta/increase number of points on track.
  - At |eta| >= 3 in the electron going direction, hits on three disks only.
  - Not sufficient considering noise and inefficiency.



- Use all available space in z to increase lever arm.





See talks by Ernst at
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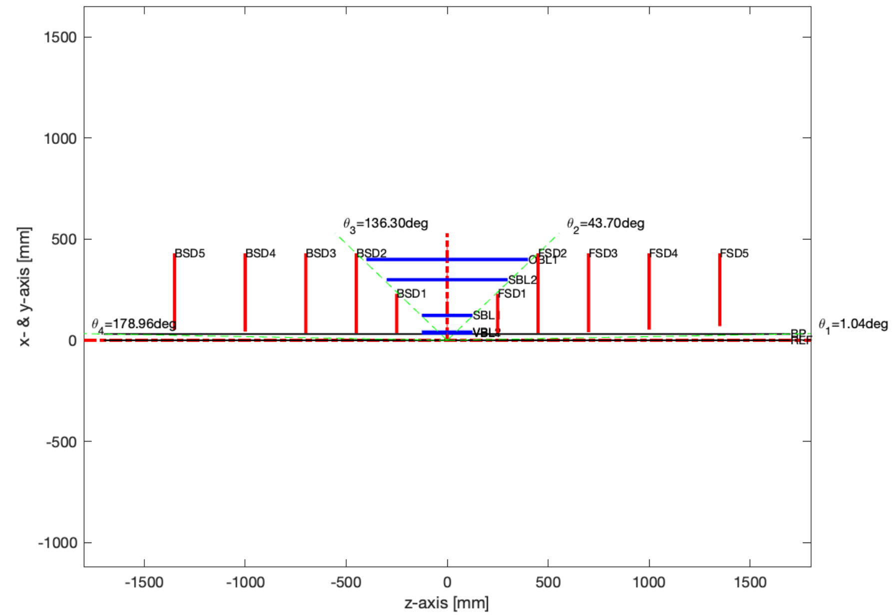
https://indico.bnl.gov/event/16582/

Current configuration (as of 25 August 2022)

Barrel:

	r [mm]	l [mm]	X/X0 %
Layer 1	36	270	0.05
Layer 2	48	270	0.05
Layer 3	120	270	0.05
Layer 4	270	540	0.25
Layer 5	420	840	0.55



Disks:

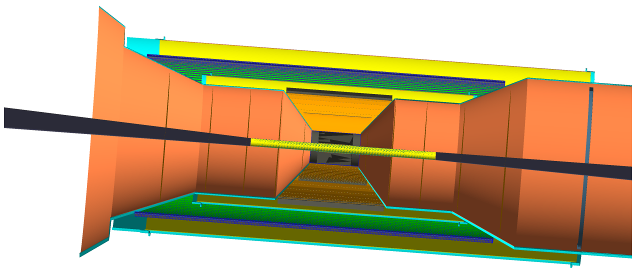
- Suggested |z| = 250, 450, 700, 1000, 1350* mm.
- r_{out} = 430mm** at |z| > 430mm, ~230 mm at |z| = 250mm
- X/X0 ~ 0.24% per disk
- r_{in} ~ 5mm away from beam pipe
- Outer support / service cylinders for 450 < |z| < 1350* mm

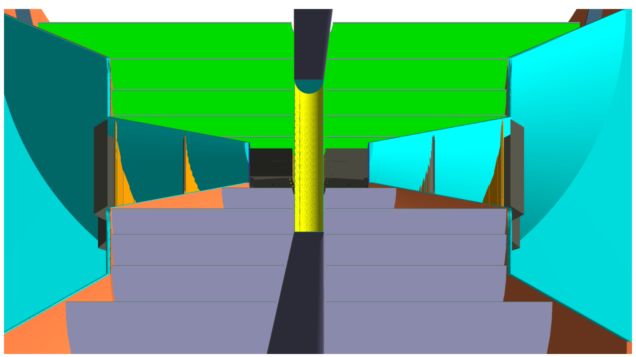
* z=1350 mm would put the last disk right against the mRICH in the e- direction; TBC pending checks with project engineers/up-to-date CAD drawing.

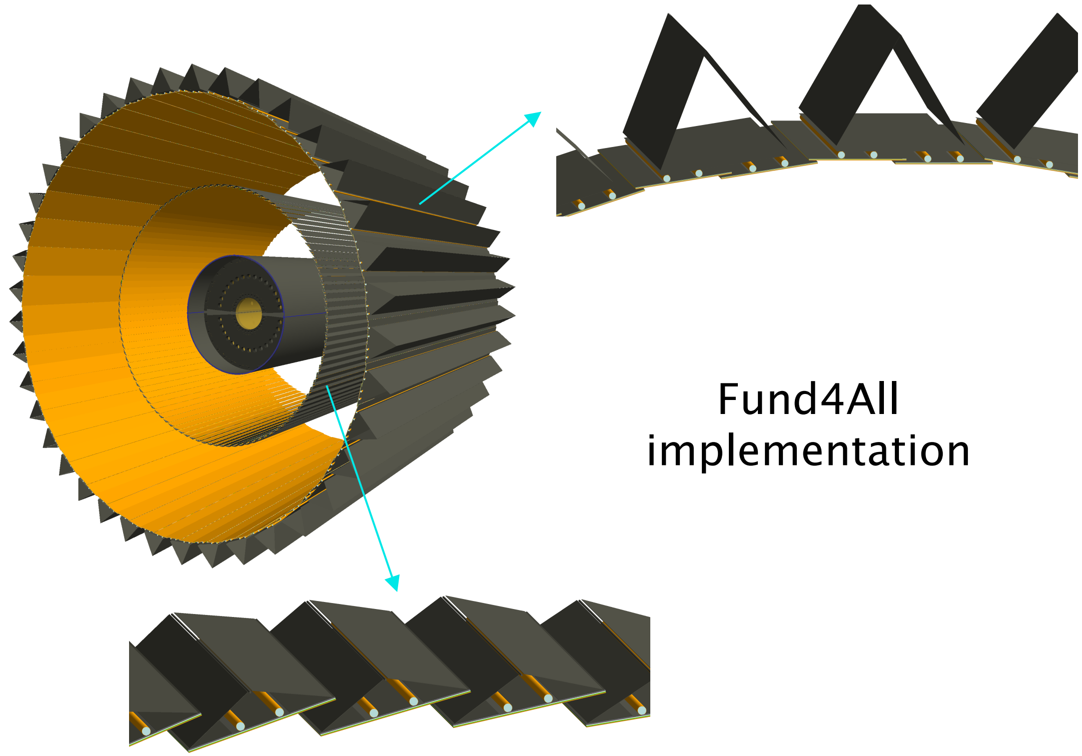
See talk by Ernst at https://indico.bnl.gov/event/16582/

Implementation for simulations

- The current configuration is being implemented in DD4Hep (Shujie) and Fun4All (Nicholas) and both are quite advanced.
  - Fun4All still in use for fast feedback on impact of geometry optimisations on resolutions.







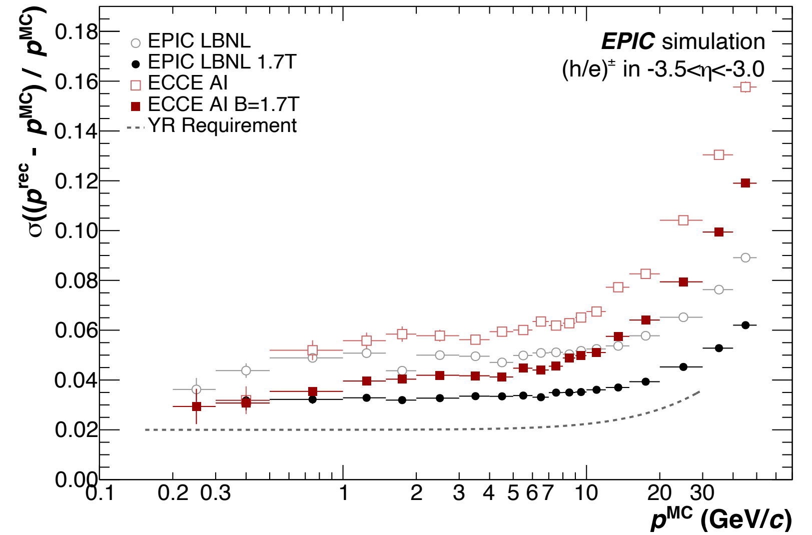
Comments:

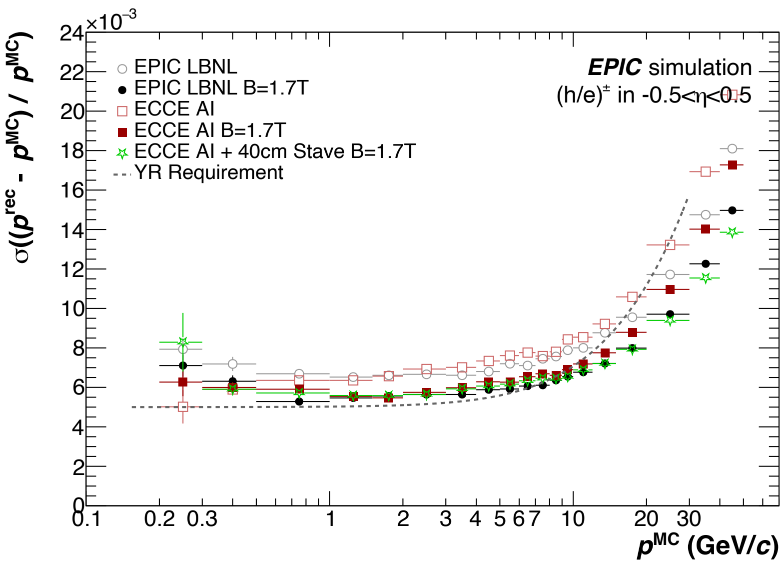
- 5th disk with r = 59/53 cm in FWD/BWD direction to fit into the current support design.
- Checking inner cone projectivity and correct beam pipe implementation.

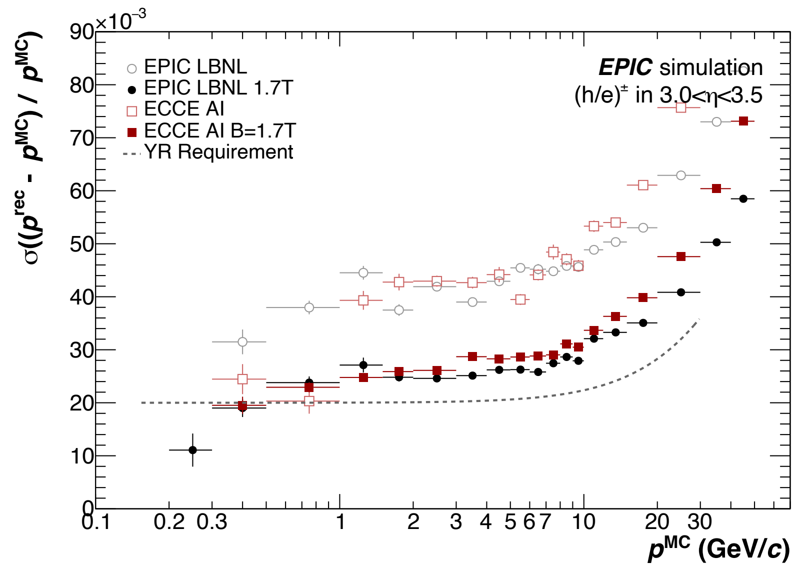
See talk by Nicholas at https://indico.bnl.gov/event/16685/

Example of ongoing studies

- Clear improvement of p resolution with higher magnetic field (1.7T).
- Additional MAPS disk in e- direction significantly improves p resolution.
- Optimised barrel radii design improve high p resolution.
- Larger z extent in fwd direction improves high momentum performance.

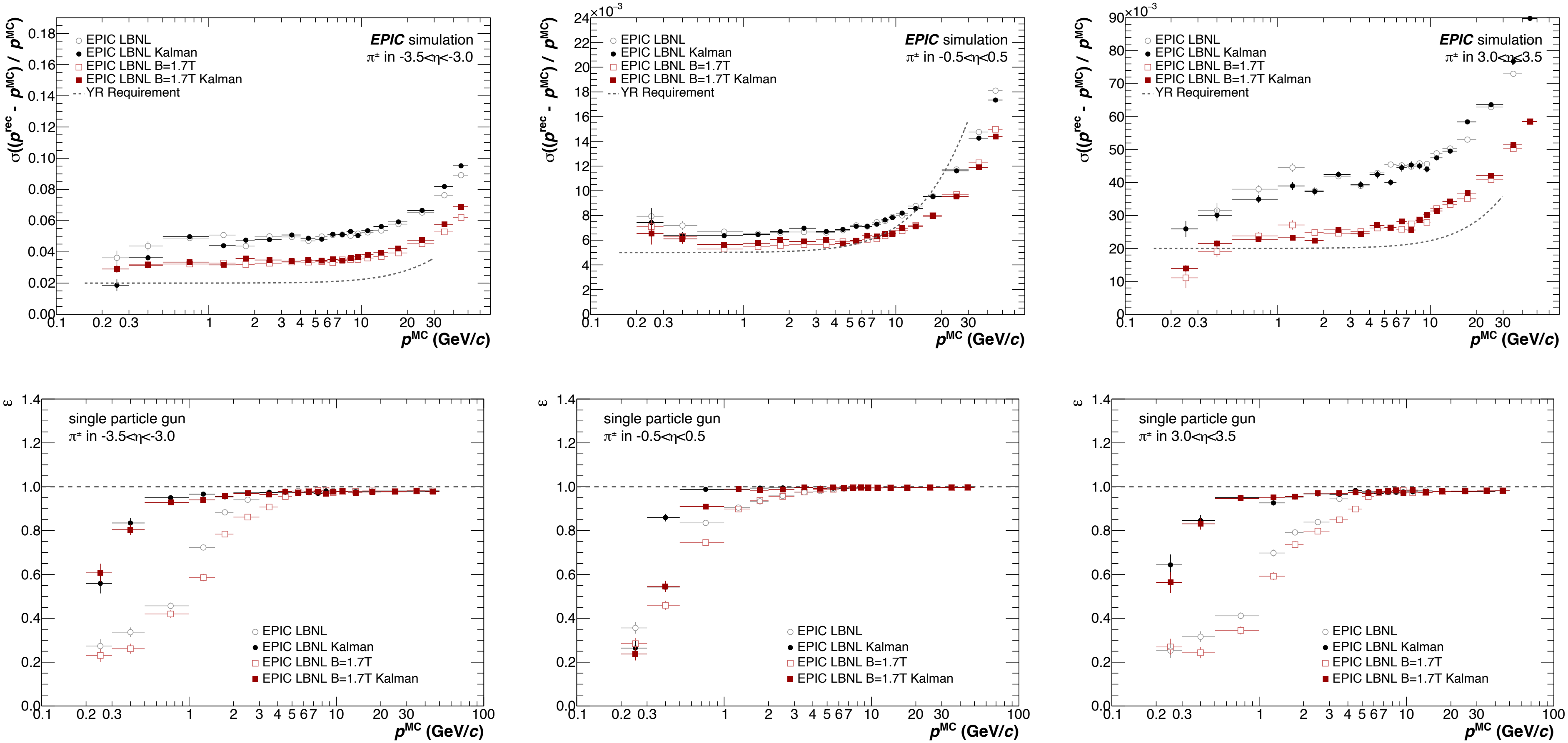






See talk by Nicholas at https://indico.bnl.gov/event/16685/

Updated results with better track fitter



See talk by Nicholas at https://indico.bnl.gov/event/16582/

Services and integration

- Material on the essential service cylinders is being worked out (Shujie) to be added soon to the geometry description.
- Explore different routing scenarios.
- Justify/revisit the double cone and step structure for the service in the current design.
    - Explore the ATHENA's solution: only one "services exit cone at eta~1.1", routing of disk services towards the cone

(ECCE proposal)

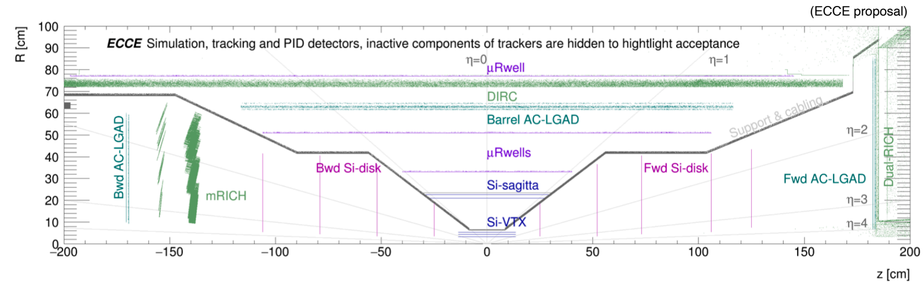
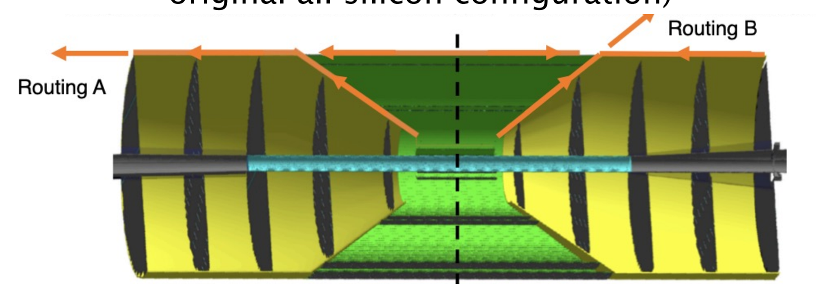
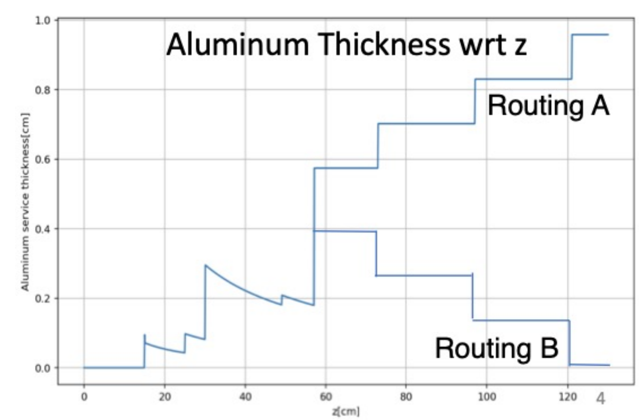


Figure 2.5: Schematic view of the ECCE tracker, including silicon, μRWELL, AC-LGAD, DIRC, mRICH and dRICH detector systems.

Services routing scheme (drawn on top of the original all-silicon configuration)





Further studies & optimisations – Si and beyond

- Study effects of backgrounds on pattern recognition and dp/p.
  - Impact on number of layers/disks, their resolution (i.e. what technology) and location.
- Barrel
  - Quantify role of MPGD and AC-LGAD in pattern recognition.
    - How many layers of MPGD are needed and with what resolution? Are more Si layers needed?
  - Depending on decision on ECAL technology, more space might be available for tracking if imaging ECAL is chosen. What can we do better with this space?
- End-caps
  - z-extent / 6th disk in the hadron-direction.
  - Optimise disks inner radii for best acceptance.
  - Disk layout underway (see next slides), needs completion to refine X/X0.
  - Are 5 Si disks enough for pattern recognition?
  - Quantify role of AC-LGAD in endcap dp/p and pattern recognition.
- How well do tracker+EMCAL reconstruct scattered electron in electron endcap?

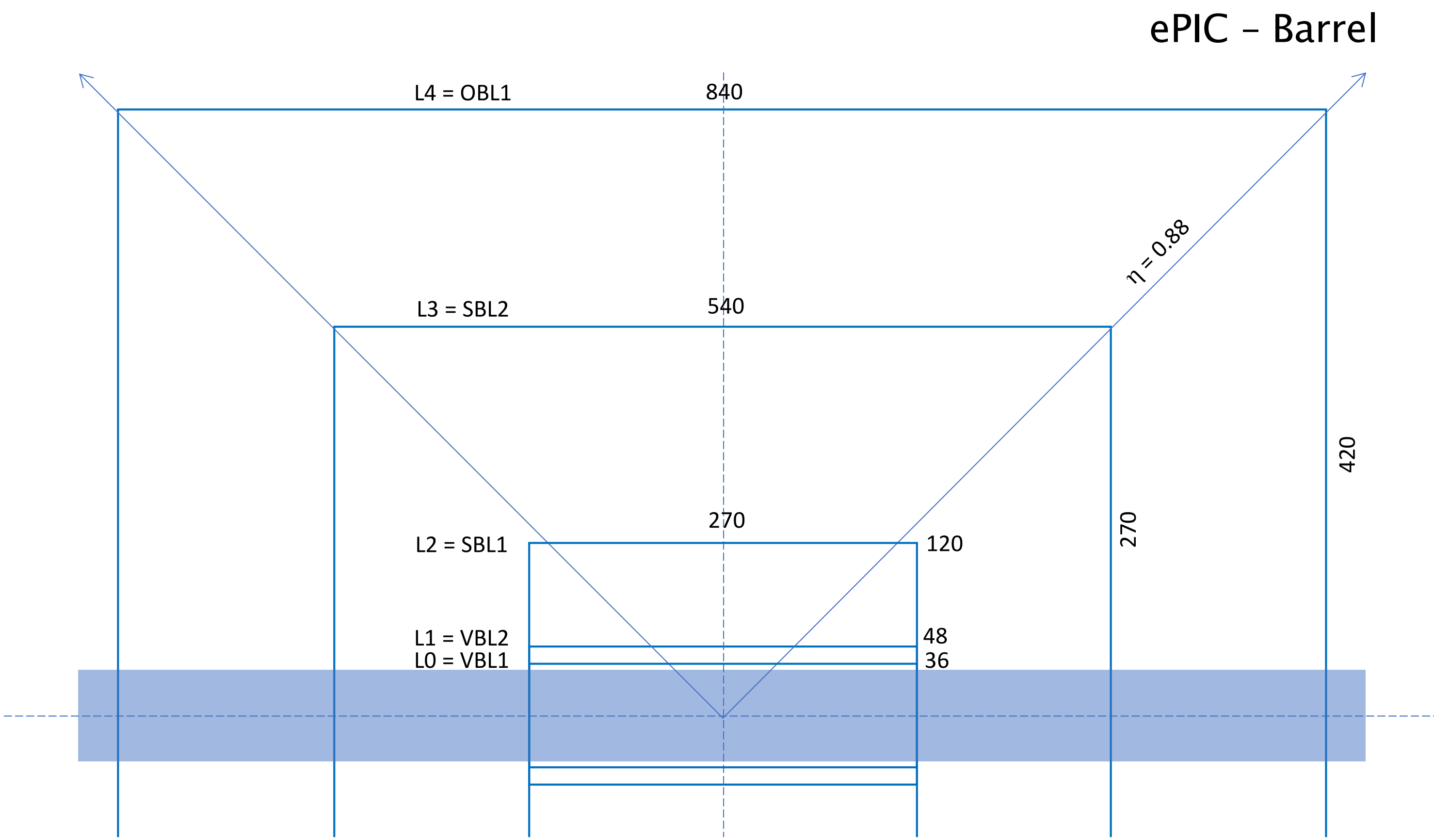
Inputs from Barbara and talk by tracking WG coordinators at https://indico.bnl.gov/event/16068/

EIC Sensors – Vertex, Barrel & Disks

- EIC Vertex Layers
  - Use ITS3 curved wafer-scale sensors.
  - Now comprises 2 vertex layers and 1 (first) sagitta layer.
  - Radii = 36 mm, 48 mm and 120 mm.
  - Note beampipe outer radius = 31.75 mm.
- EIC Sagitta Layers
  - Use smaller format ITS3 sensor (i.e. stitched not wafer-scale) on staves → EIC Large Area Sensor (LAS)
  - Comprises 1 (second) sagitta layer and 1 (outer) barrel layer.
  - Radii = 270 mm and 420 mm.
- EIC Disks
  - Requires smaller format sensors for improved yield and tiling flexibility.
  - Multiple sensor formats needed – changes to stitching plan & periphery.
  - Studying optimum tiling geometry.

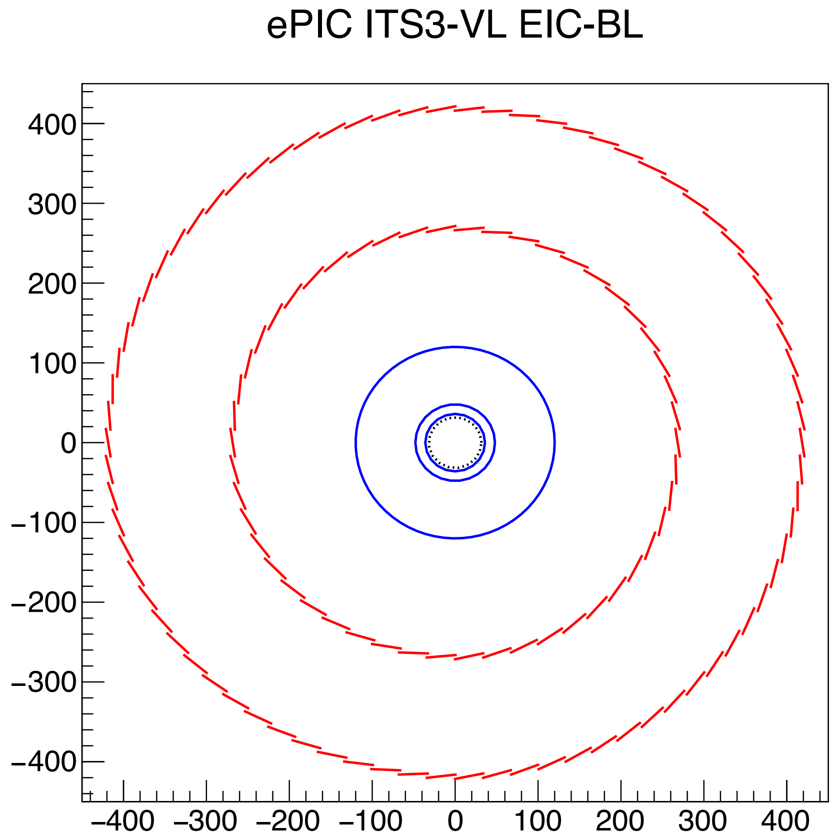
What I will show in the following slides is part of an ongoing study by Peter, to be presented soon, in full, at the EIC SC general meeting.

Conceptual design of barrel layers



Note: radii and lengths work with a reticle size of 18.85 x 30.00 mm^2.
Length of L0, L1 and L2 is made of one 270 mm sensor: read out at ONE end.
Length of L3 is made of two 270 mm sensors: read out at BOTH ends.
Length of L4 is made of four 210 mm sensors: read out at BOTH ends + services along the staves to reach 2nd and 3rd sensor.

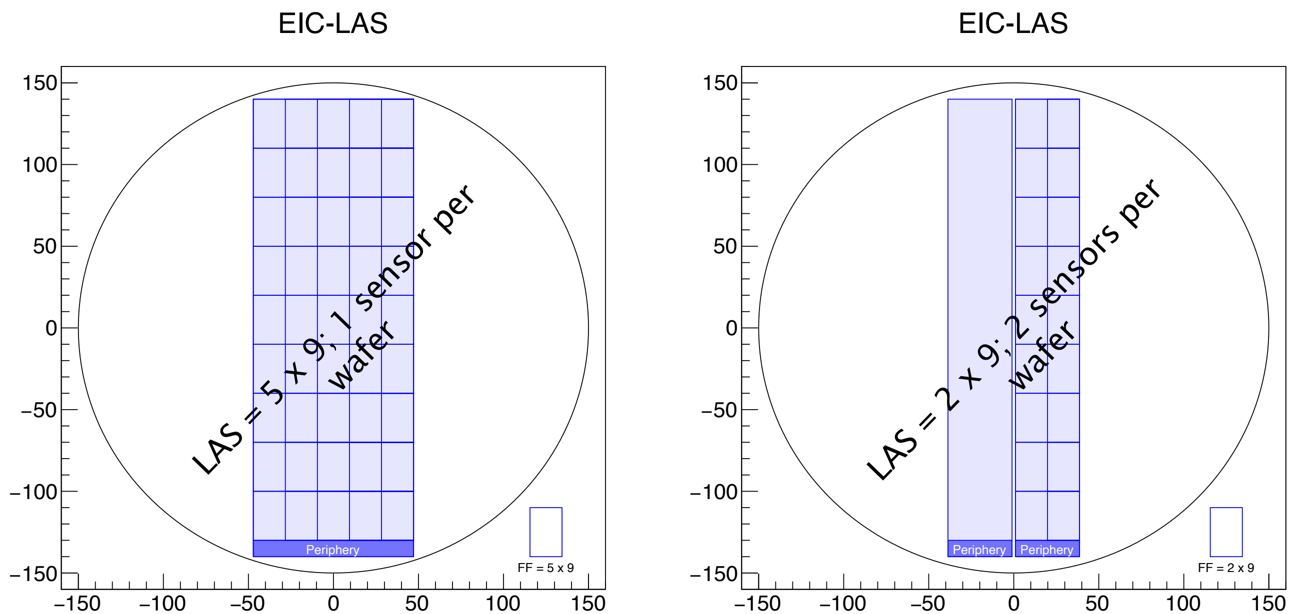
Conceptual design of barrel layers



L3 = SBL2; R = 268.4 mm; LAS = 2 x 9; 100 sensors; rϕ olap = 3.5 mm
L4 = OBL2; R = 418.5 mm; LAS = 2 x 7; 312 sensors; rϕ olap = 3.5 mm
Overlap represents an increase in silicon area of 11%
Overlap of ALICE-ITS2 MBL and OBL staves is 4.3 mm

Example of implications on sensor design

L3 (r = 270 mm) as an example:

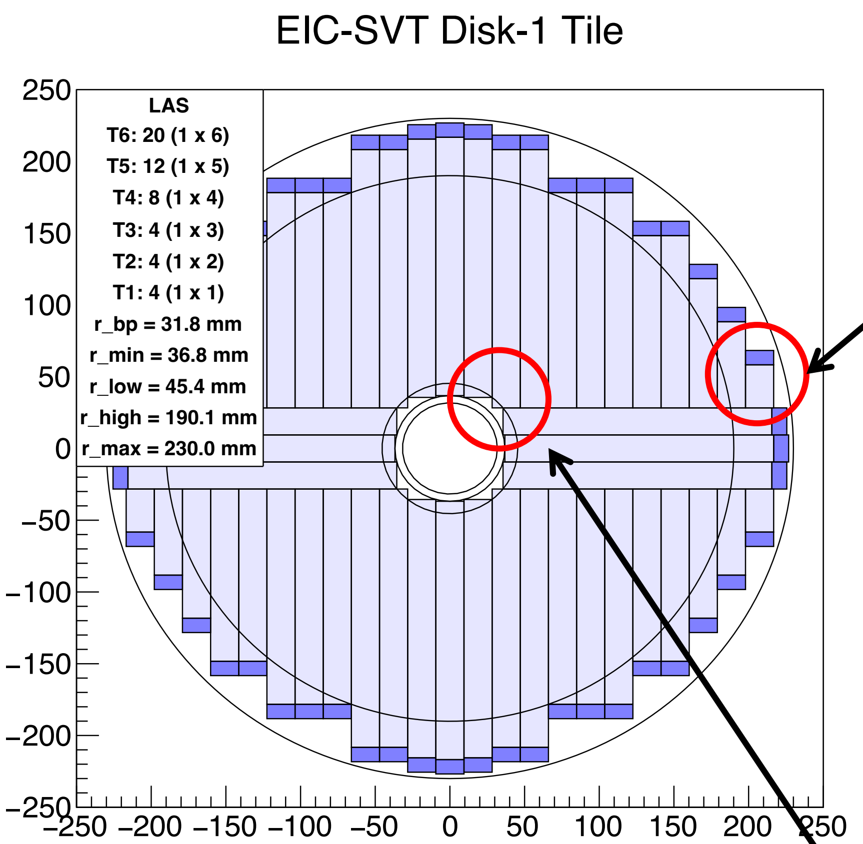


Note #1: more efficient use of silicon to make stave modules from two 1 x 9 sensors (5 per wafer) rather than 2 x 9 sensors (2 per wafer).

Note #2: Dependent on being able to have an independent periphery for each column.

Disk tiling studies

- Example: Disk 1

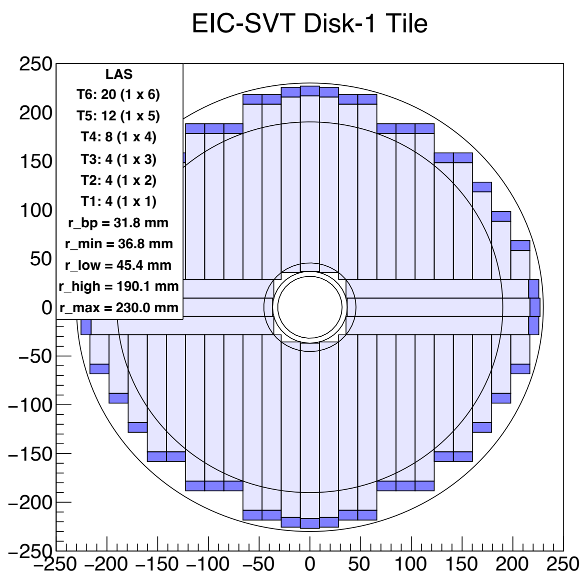


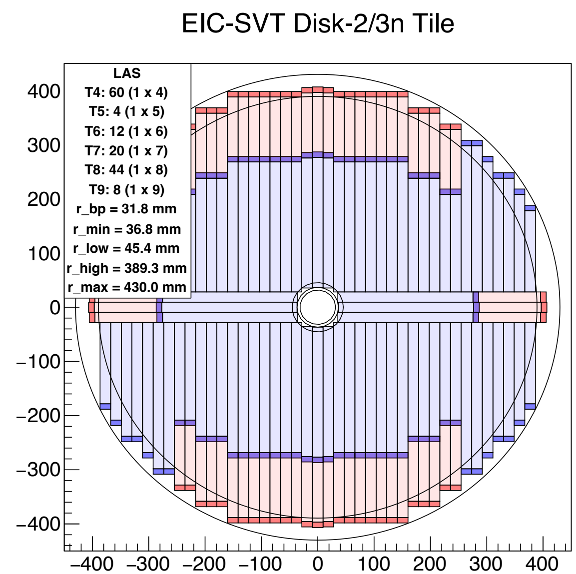
z = +/- 250 mm
Cruciform = 3 x 3 sensors

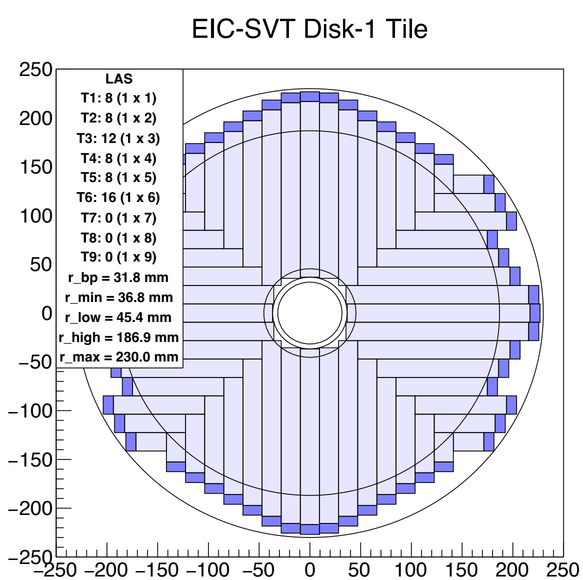
The algorithm

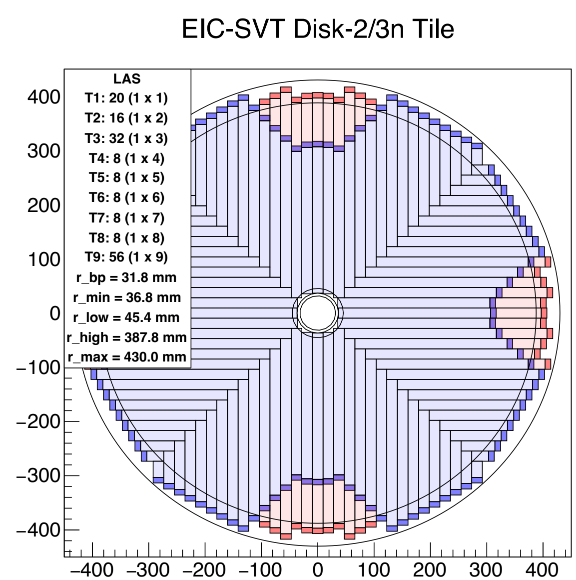
- Aim to keep periphery to larger radii
- Two designs, each based on a central cross pattern smaller than the inner diameter of the disk
- Design #1 = vertical tiles (shown)
- Design #2 = herringbone (alternating vertical and horizontal tiles)
- Limits on the max and min sensor length can be applied
- Study the number of sensor variants that are needed
- The minimum radius (r_min) is 5 mm larger than the beam pipe (r_bp) for bake out purposes
- Sensor and periphery must be contained within the min and max radii of the disk (r_min and r_max).
- For each disk, the algorithm calculates the smallest and largest radii with full acceptance (r_low and r_high)
- The algorithm does not permit any sensor overlap
- Acceptance at small radii could be improved by allowing some sensor overlap; placing overlapping sensors on the reverse side of the disk (in progress)

Some configurations under study as an example









Comments on ongoing disk tiling study

- Multiple sensor formats needed – requiring changes to stitching plan & organisation of the digital periphery.

- Attempt to minimise the number of formats by restricting the maximum and/or minimum sensor length.
    - Central cross-pattern configurations considered to accommodate the (various) beam openings.

- Physics simulations to inform acceptance needs at small radii (Stephen).

- Mechanical and material budget considerations to inform if disks can be stave-like or require monolithic disk halves.

- Power dissipation of the peripheries, in particular, to inform the need for any liquid cooling.

Backup