Ernst Sichtermann
EIC Si.Cons. June 6, 2022

Proposed ECCE Tracker – now reference for Detector 1

(ECCE proposal)

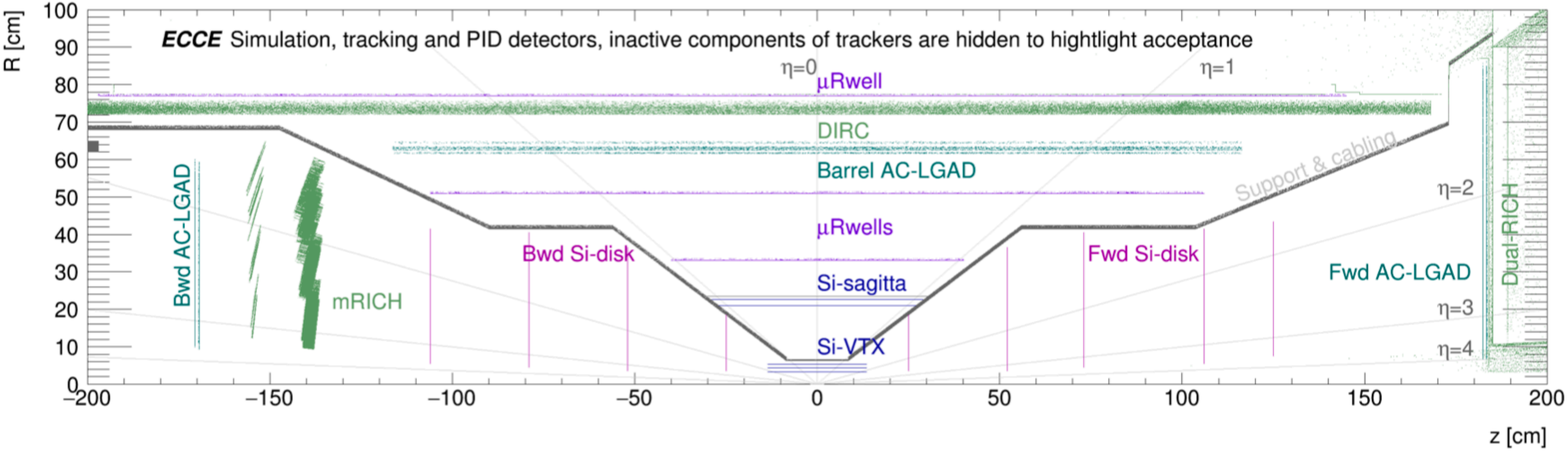


Figure 2.5: Schematic view of the ECCE tracker, including silicon, μRWELL, AC-LGAD, DIRC, mRICH and dRICH detector systems.

- Transition from reference to baseline will entail, if not require, refinement of the tracker configuration and layout,
- Consider in this group, so as to prepare.

A reminder of Yellow Report Table 11.2

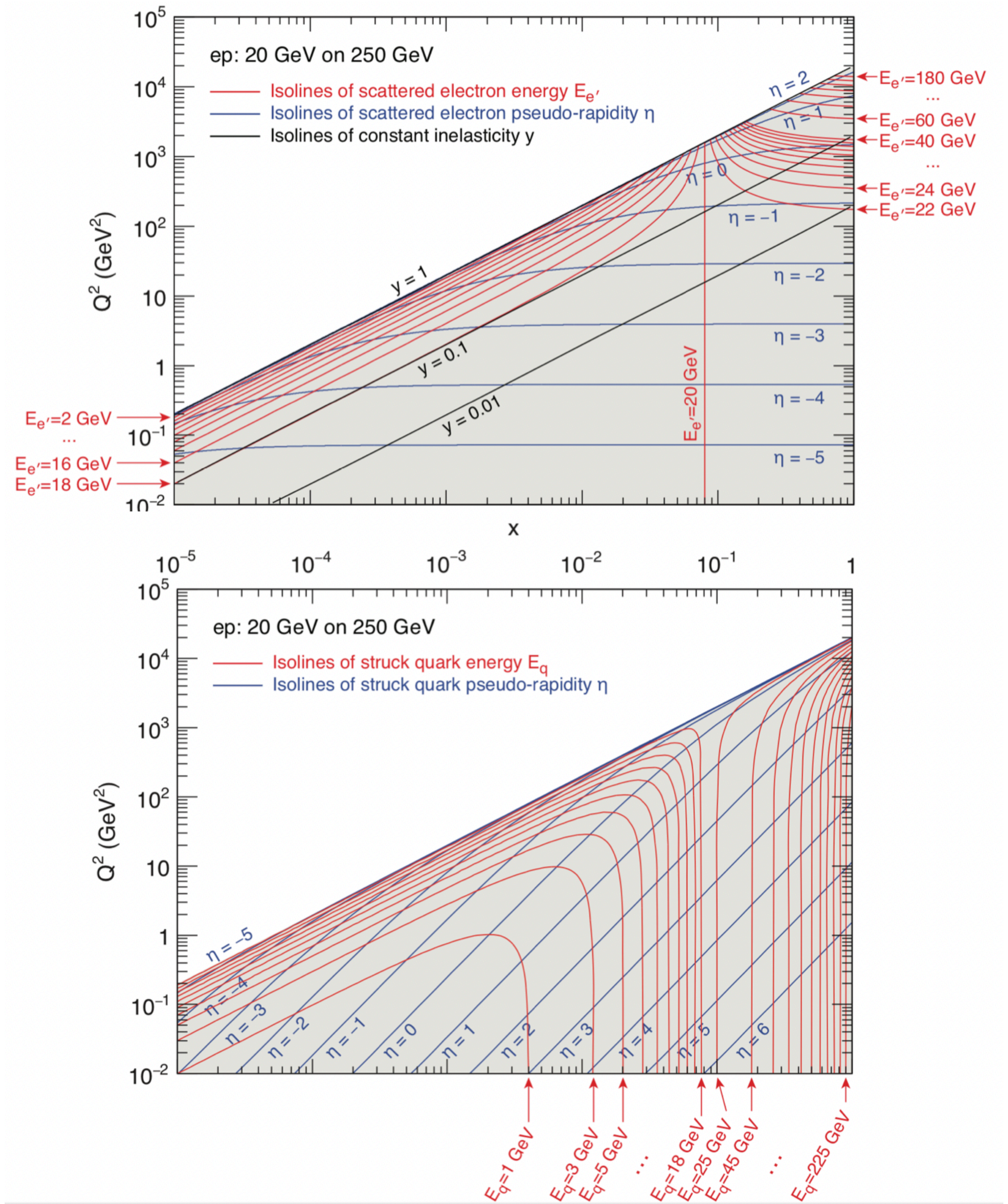
Table 11.2: Requirements for the tracking system from the physics groups.

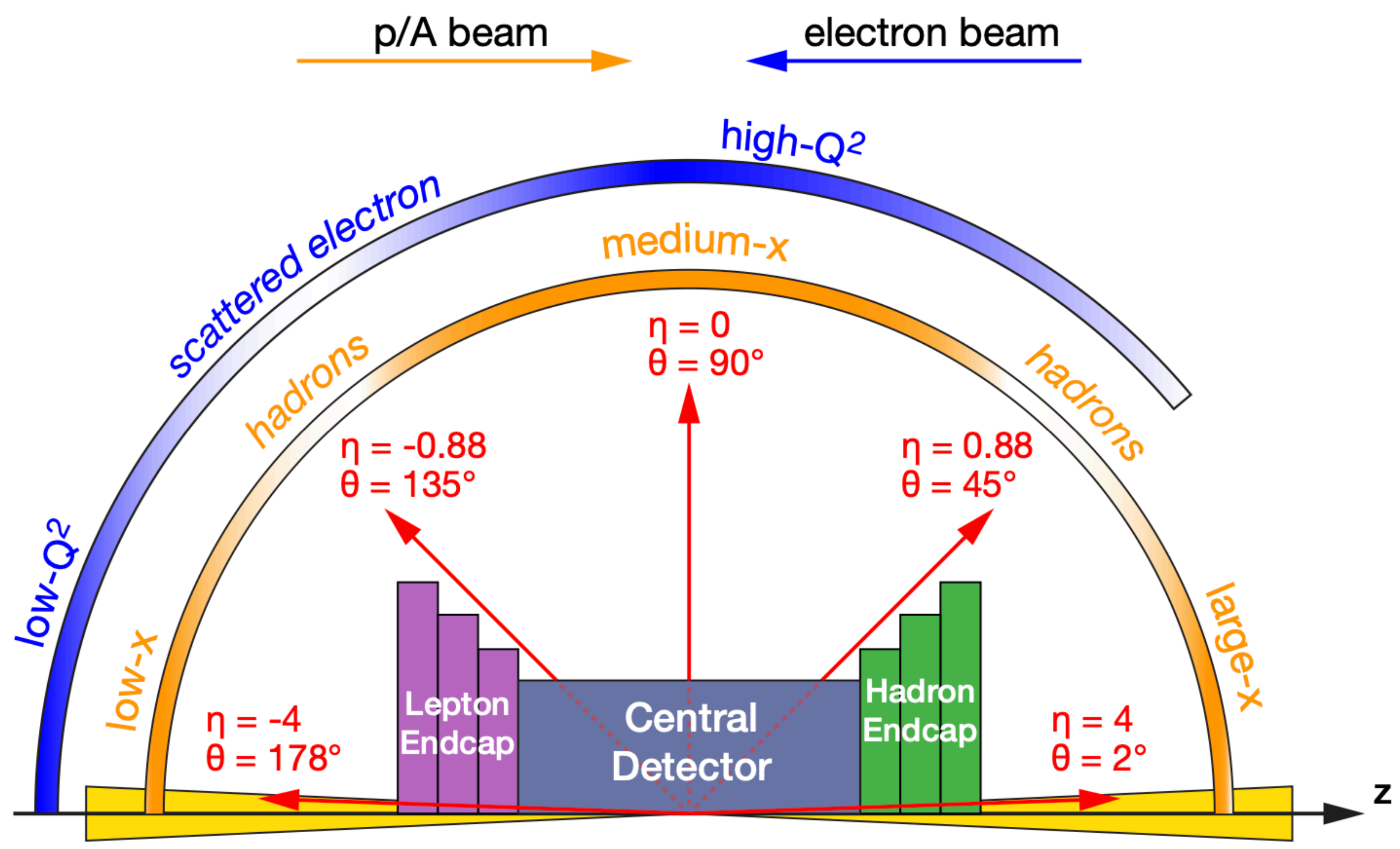
Tracking requirements from PWGs						
			Momentum res.	Material budget	Minimum pT	Transverse pointing res.
η						
-3.5 to -3.0	Central Detector	Backward Detector	σp/p ~ 0.1%×p ⊕ 0.5%	~5% X0 or less	100-150 MeV/c	
-3.0 to -2.5					100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 40 μm
-2.5 to -2.0			σp/p ~ 0.05%×p ⊕ 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 requirements for the tracking in an EIC detector are derived from the physics simulations and are represented by the detector requirements table shown in Table 11.2. The ranges in pseudorapidity are accompanied with requirements for relative momentum resolution, allowed material budget in terms of radiation length, minimum p_T cutoff, transverse and longitudinal pointing resolutions. These requirements form the basis of the designs and concepts that are presented.

- dp/p is a combination of the constant and proportional term,
- Both matter over most of the EIC range, but the trade-offs can be different,
- E.g. in the central barrel, the terms are balanced for p = 10 GeV/c; in the (very) forward region this is for p = 20 GeV/c, and in the backward region for p = 5 GeV/c.
- Transitions are, of course, not as hard as suggested by the table.

A reminder of DIS kinematics



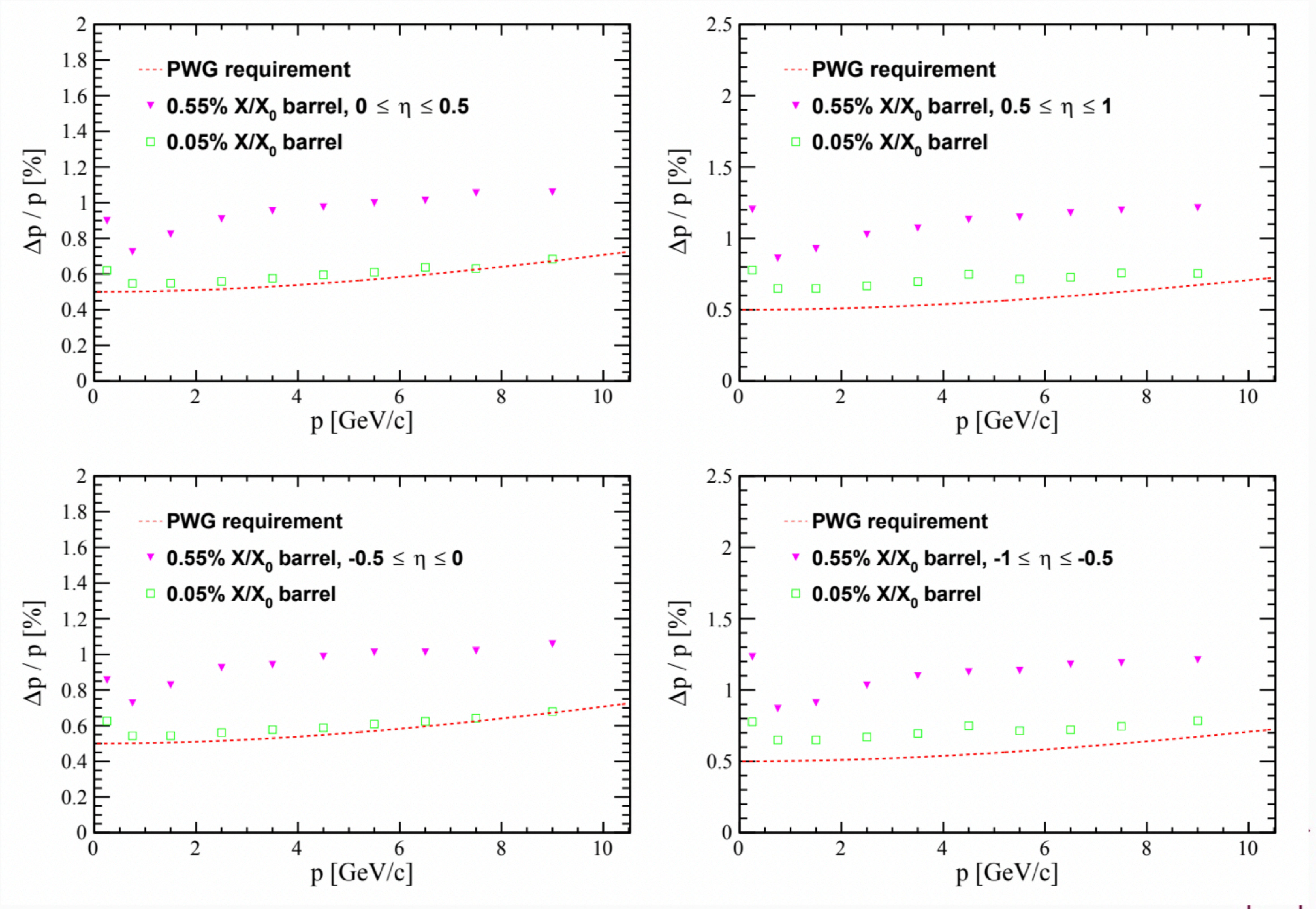


- The DIS cross-section typically goes as $1/Q^4$
- High momenta, be they electron or hadron, are typically associated with large *x* processes,
- Physics in all areas of this (these) kinematic plane(s),
- Trade-offs, in parts, probably “a matter of taste.”

Fun4All simulations - Stephen Maple (U. of Birmingham), May 19 Tracking WG mtg.

Increased material in sagitta layers

- Updated the material of layer 4 and 5 of the barrel MAPS to reflect estimated material budget from SC
  - Barrel layer 4 and 5 go from 0.05% X/X_0 → 0.55% X/X_0 per layer
- Note: both sets of results are produced using the 1.5T field map



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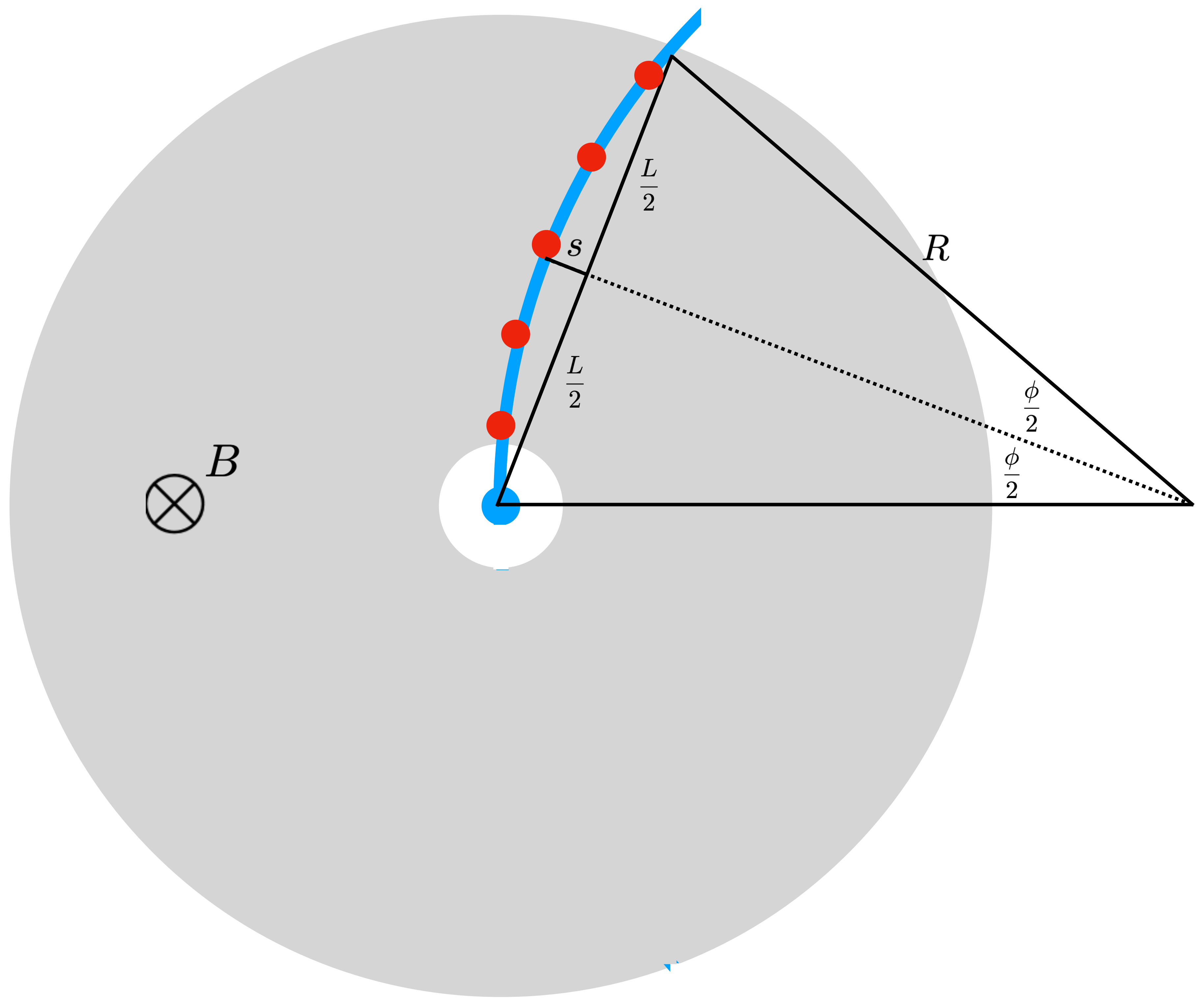
- Sagitta layers of the ECCE proposed length exceed twice the wafer size; curved silicon not realistic even if yields suffice,
- Performance implications from necessary material for a more traditional stave-based implementation are real.

A reminder of Tracking-101

The basics can be captured by straightforward considerations. Imagine a view along the beam and a helical track model inside a solenoidal field. Then,



$$p_\mathrm{T}\,[\mathrm{GeV}] = 0.3B\,[T]\;R\,[m]$$

$$s = R - R\cos\frac{\phi}{2} \approx R\frac{\phi^2}{8} \qquad \phi = \frac{L}{R}$$

Hence,

$$\frac{\Delta p_\mathrm{T}}{p_\mathrm{T}} = \frac{\Delta R}{R} = \frac{\Delta\phi}{\phi} \approx \frac{\Delta s}{L^2}\cdot\frac{8p_\mathrm{T}}{B}$$

In other words, a good (transverse) momentum resolution requires:

- a large path length *L* (scales as L^2)
- a large magnetic field (scales as *B*)
- good Sagitta measurement.

$$\Delta s = \frac{\Delta_{r\phi}}{8}\sqrt{\frac{720}{N+5}}$$ (Glückstern, 1963)

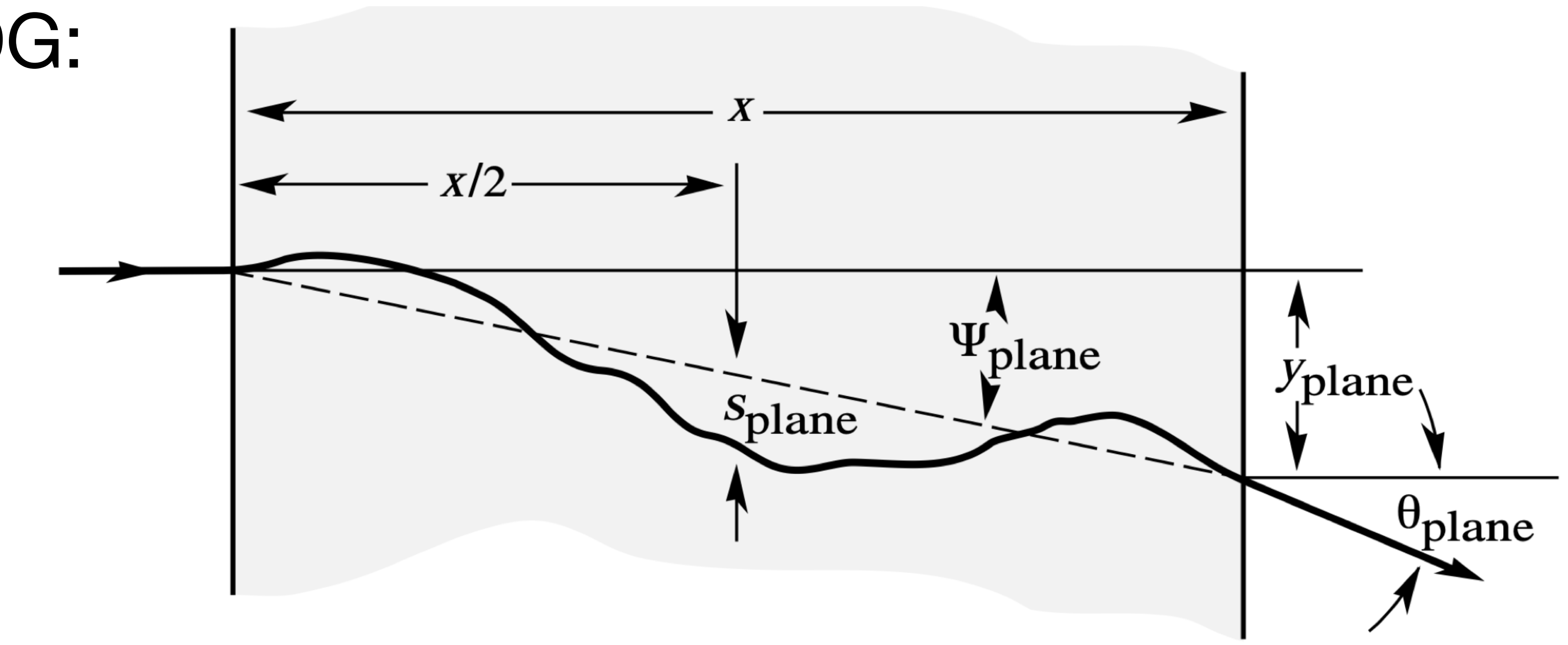
Note, however, that multiple scattering through the material *really* matters.

- The proportional term at mid-rapidity is 5 x 10^{-4}
- In a 1.4T field with 10μm pixel pitch and a reasonably small number of points, this implies L ~ r_{out} ~ 0.4 m,
- Equidistant points do *not* generally result in the optimum dp/p. However, the dependence on positioning is not very strong,
- Hard to get around this with MPGD resolutions, even state of the art, within the ECCE bore,
- Of course, one could trade off the high-momentum end.

A reminder of Tracking-101

Regarding the multiple scattering contribution,

PDG:



$$\Delta\phi \approx \frac{14\,\text{MeV}}{p}\sqrt{L/X_0}$$

$$p = \frac{p_{\text{T}}}{\tan\theta}$$

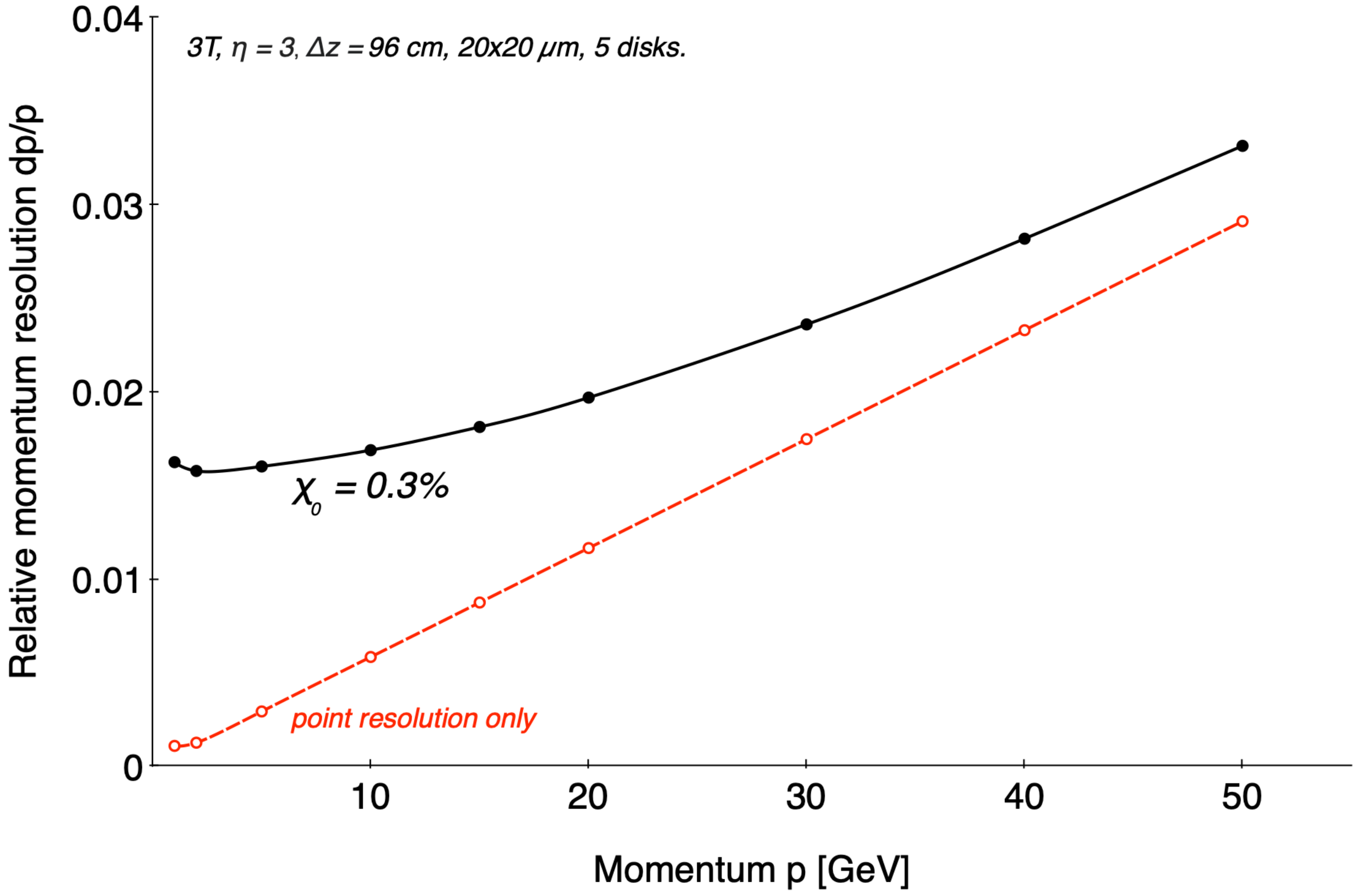
$$\left.\frac{\Delta p_{\text{T}}}{p_{\text{T}}}\right|_{\text{m.s.}} \approx \frac{14\,\text{MeV}}{p}\sqrt{\frac{L}{X_0}}\cdot\frac{R}{L} = \frac{14\,\text{MeV}}{p}\sqrt{\frac{1}{LX_0}}\frac{p_T}{eB}$$

Hence, the m.s. contribution depends on the dip-angle *θ*, though *not* on *p* or p_{T}, and

$$\frac{\Delta p_{\text{T}}}{p_{\text{T}}} = a \cdot \frac{p_{\text{T}}}{BL^2} \oplus b(\theta)\cdot\frac{1}{B\sqrt{LX_0}}$$

For forward angles, m.s. is the limiting component in d*p/p for much of the p range.*

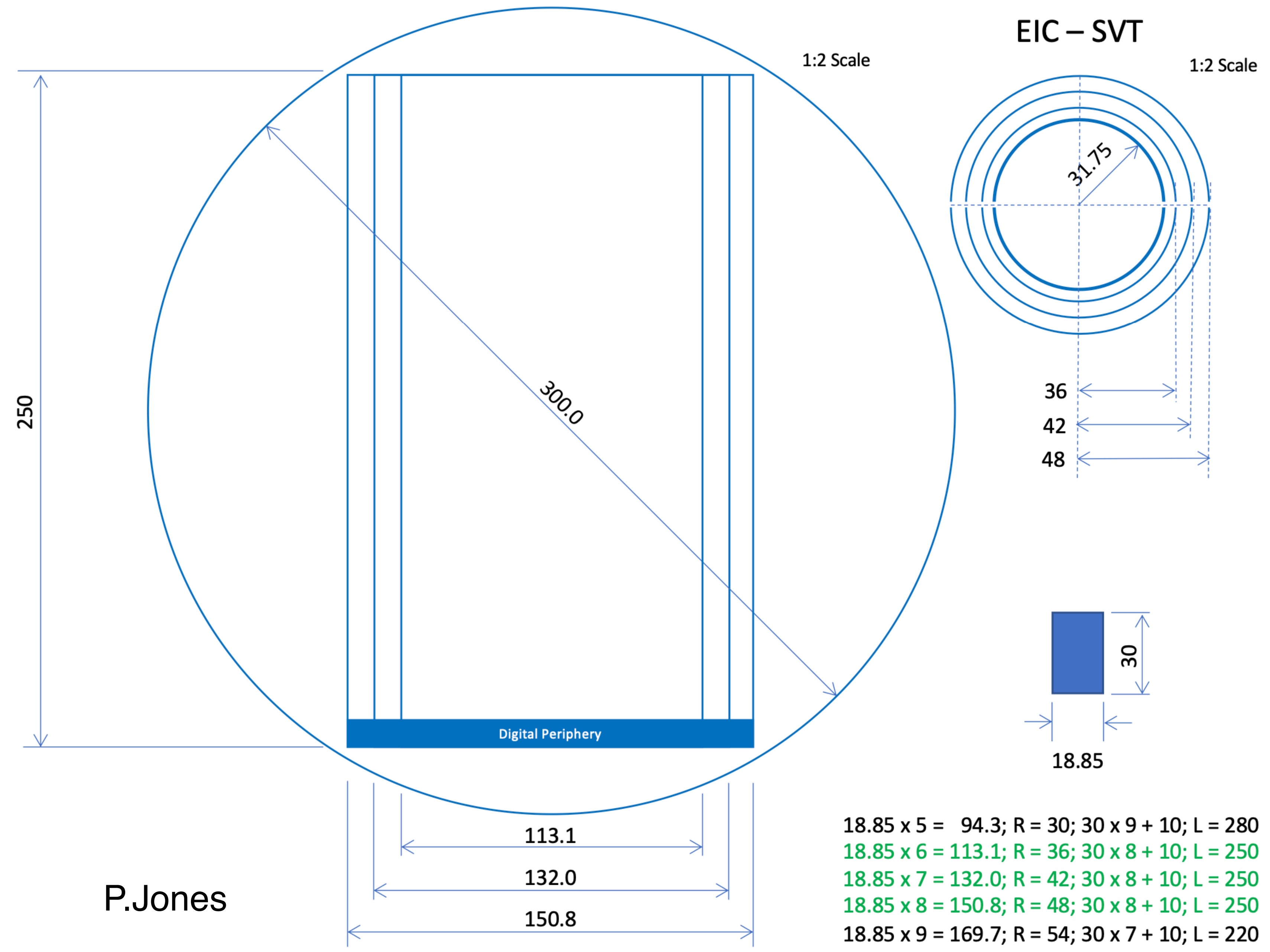
There is, indeed, a subtle correlation of m.s. and the dip angle measurement (not explicitly considered in the arguments presented here).



- Traversed material matters,
- Traversed material motivates the transition from barrel to disks near 45° in this and other EIC tracking concepts,
- There is an additional factor though at backward/ forward angles, of B.dL falling off in a solenoidal field.

Is the YR mid-rapidity performance recoverable in 1.4T?

- Almost certainly, yes,
- How is primarily a task for the tracking working group, in combination with the global design and integration working group and this group,
- Even though we do not know the outcome, can consider scenarios and their implications for our path(s) forward.
- Personally, I think it is “optimistic” to assume there is a work-around, presumably with somewhat radii, for the thickness of the sagitta layers - a reconfiguration seems more viable to me, e.g.



- Preserve the inner cone angle of approx. 45^{o},
- Consider increasing the radius of the outermost vertexing layer while preserving its length to approximately 12 cm,
- Replace the two sagitta layers with a more conventional stave-based design with two half-lengths of $X/X_0 \sim 0.25\%$ (or 0.05%, if feasible) at a radius of approximately 21 cm,
- Complement with a large-radius, $r_{out} \sim 0.4$ m, conventional stave-based design, with an overall length of about 0.8 m,

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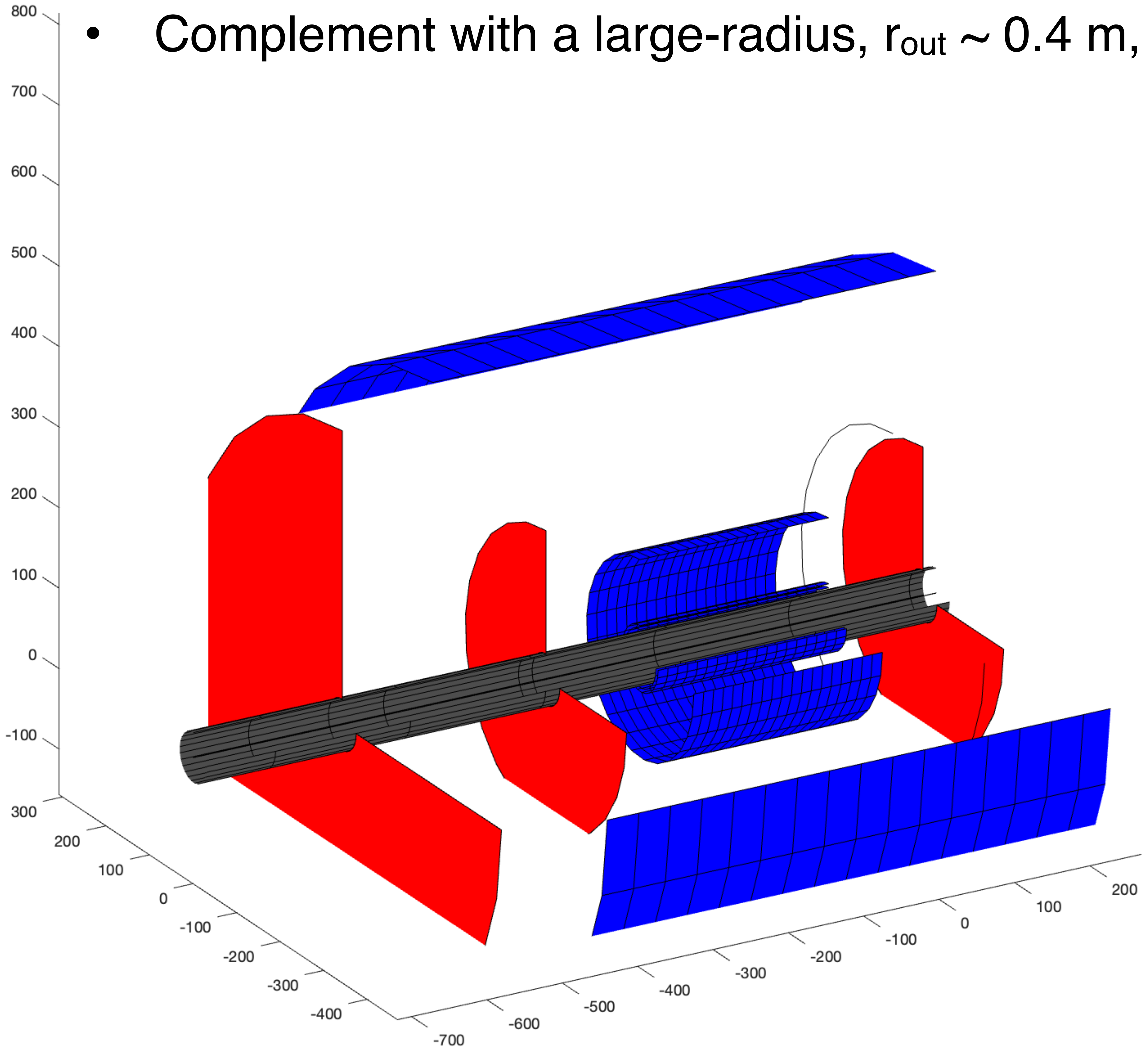


- Fast simulations show reasonable agreement, e.g. dp/p at 90^{o}
  - ~ 0.30% at 1 GeV/c (~0.50% YR)
  - ~ 0.43% at 5 GeV/c
  - ~ 0.67% at 10 GeV/c (~0.71% YR)
  - ~ 1.24% at 20 GeV/c (~1.12% YR)

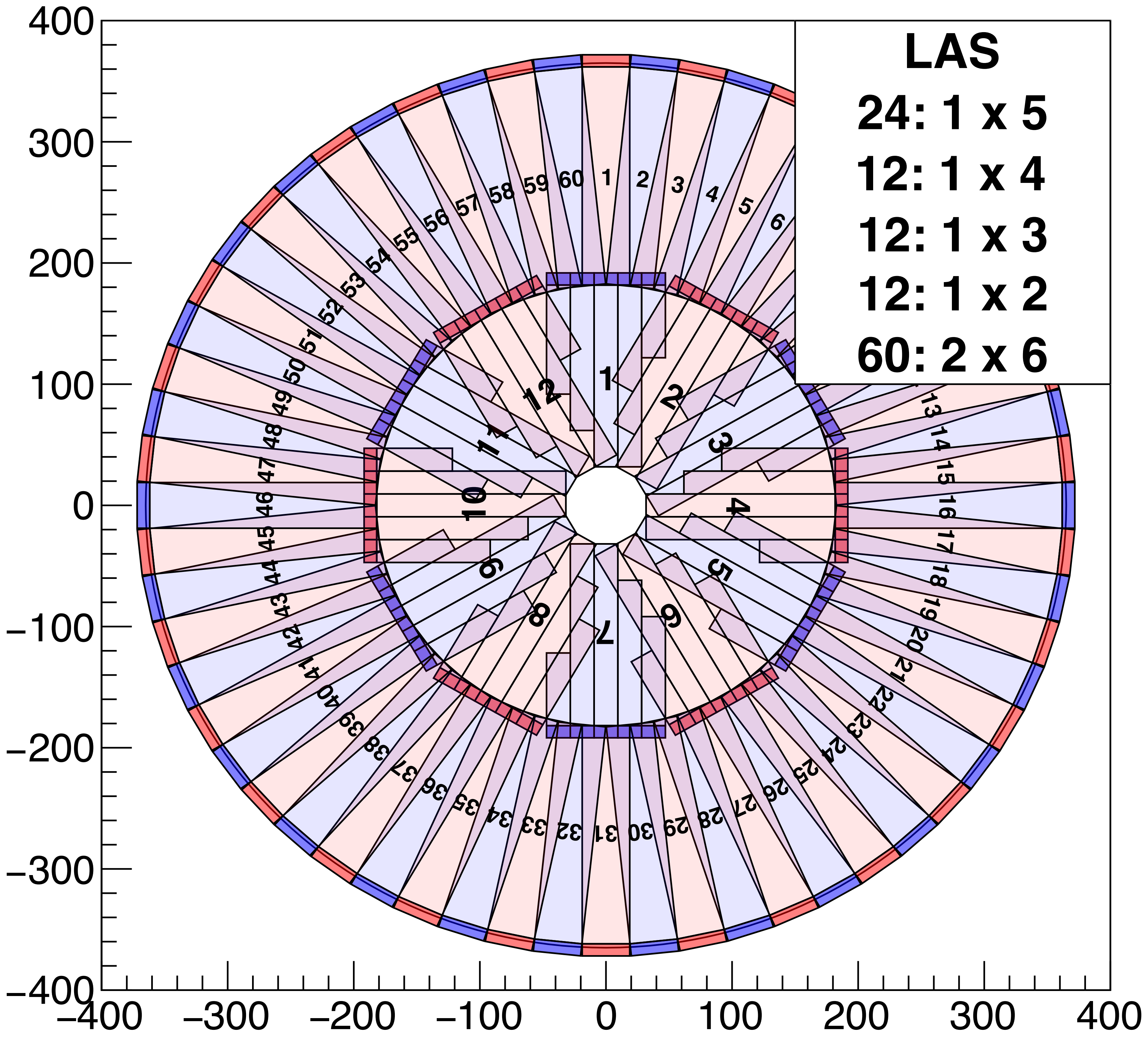
- Looking ahead, it may thus be worthwhile to consider:
  - yield for the LAS and if a low material layer at larger r is viable,
  - low material half-staves of ~0.2 m length,
  - revisit cost for outer barrel layer with radius of ~0.4 m,

Looking ahead to the forward/backward region

- Transition from reference to baseline would, to me, seem likely to involve an additional disk in the electron going direction and possibly in the hadron going direction, as well as extensions in |z|,

- May need to revisit material impact, in view of practical layout possibilities, with somewhat larger material at outer radii,

EIC-SVT Disk-2



P. Jones

- Sensor layout on disks remains an open challenge; most approaches aim at a combination of elements common to most/all disks and an element specific to the beam-pipe opening at a particular location.

- Shown on the left is a recent example, courtesy Peter, showing a possible approach and illustrating material overlaps (and, hence, additional measurement points as well as increased material budgets).