Alternative Vertex Layout

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FCC-ee vertex detector R&D workshop – Pisa october 2025

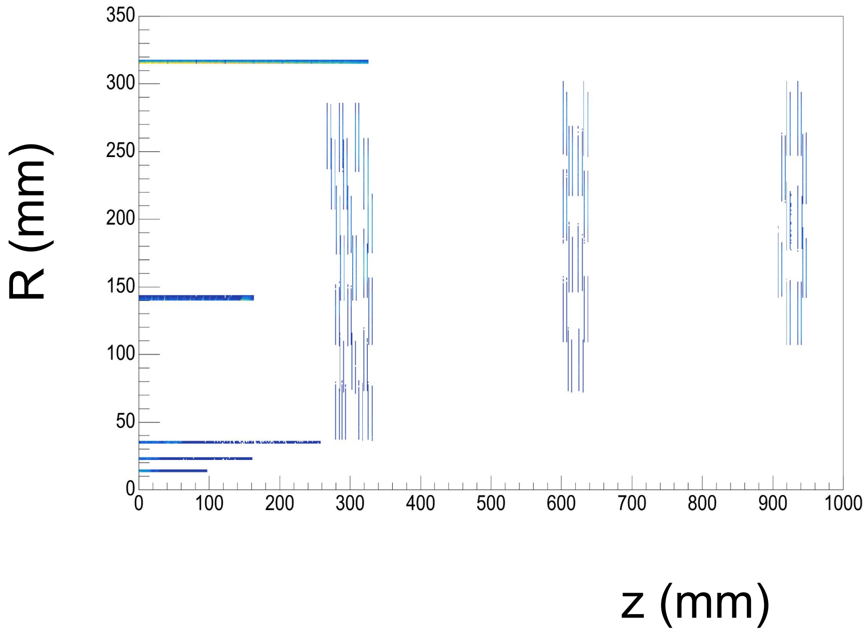
Default IDEA Vertex Detector

Default configuration

- Reference geometry: *five layers (barrel)* with innermost radius ~13.7 mm and 3 disks
- Magnetic field: **2 T** (baseline).
- Simulation based on **Delphes fast simulation** smeared according to covariance matrix.

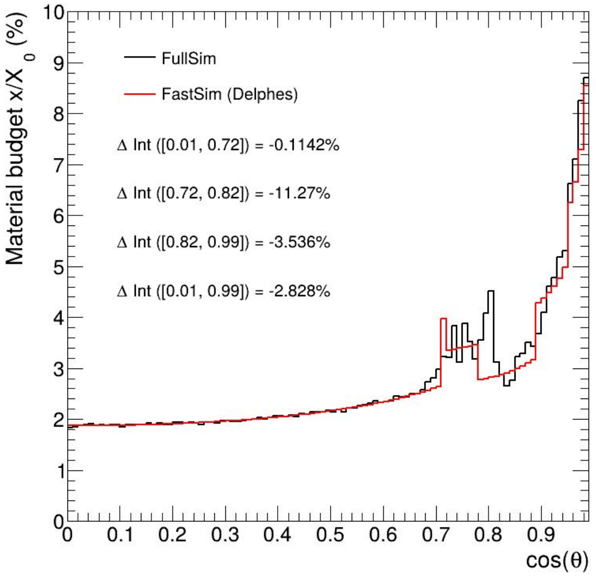
Goal: study various alternative layouts

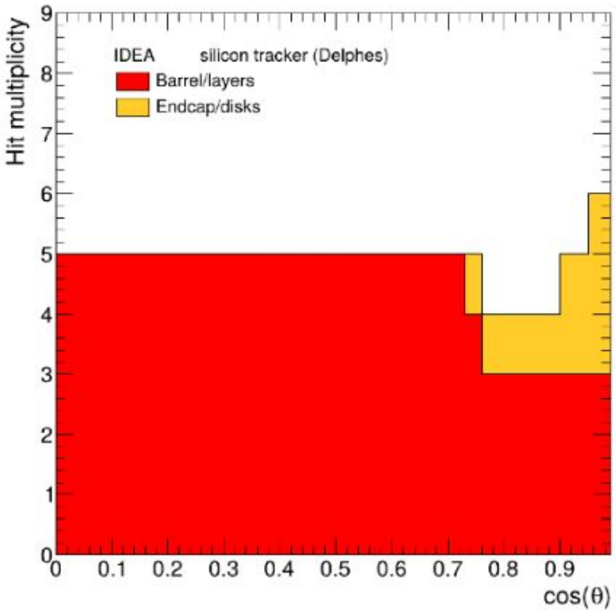
Using single muons originating from interaction point (0,0,0), evaluate terms of d0/dz/p resolutions.



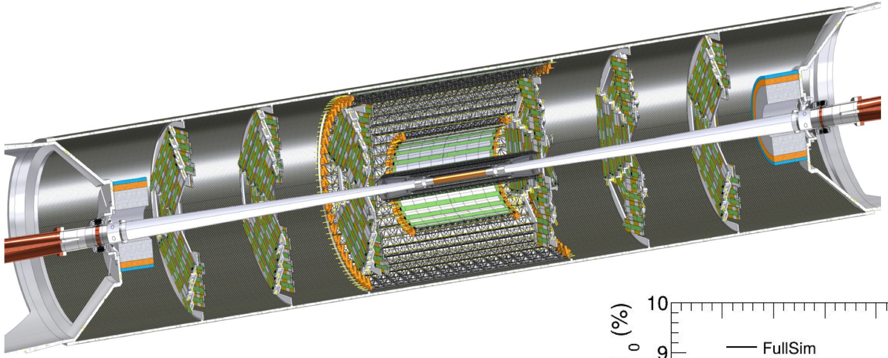
All these delphes plots can be studies following Jan's tutorial
https://indico.cern.ch/event/1564836/timetable/#31-delphes-tutorial

Default IDEA Vertex Detector

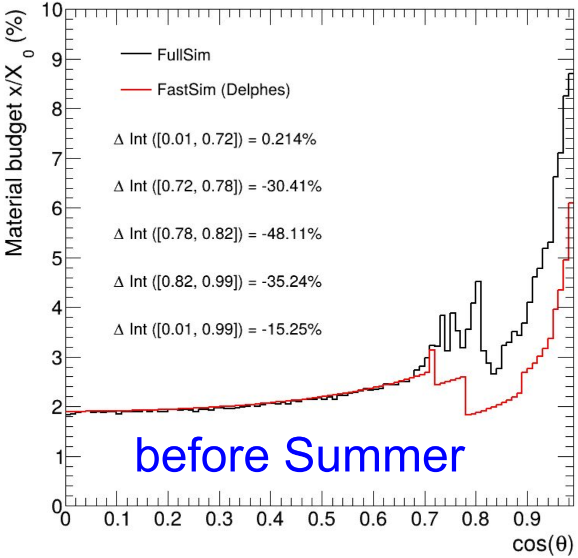




Made the fastSim more accurate



See details Jan’s PR
delphes/delphes#171



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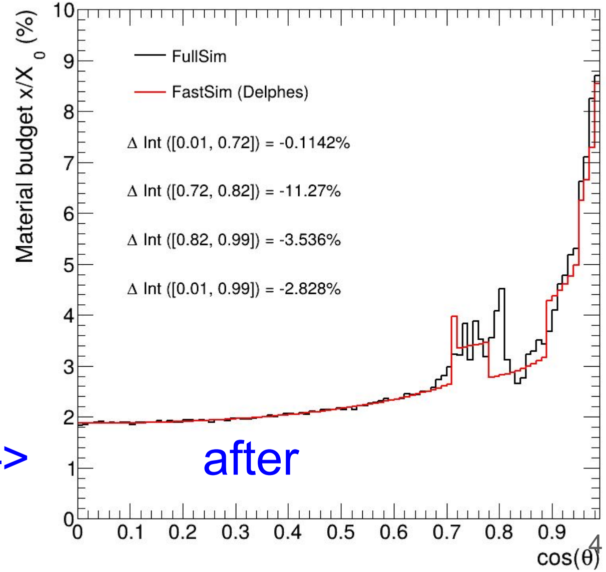
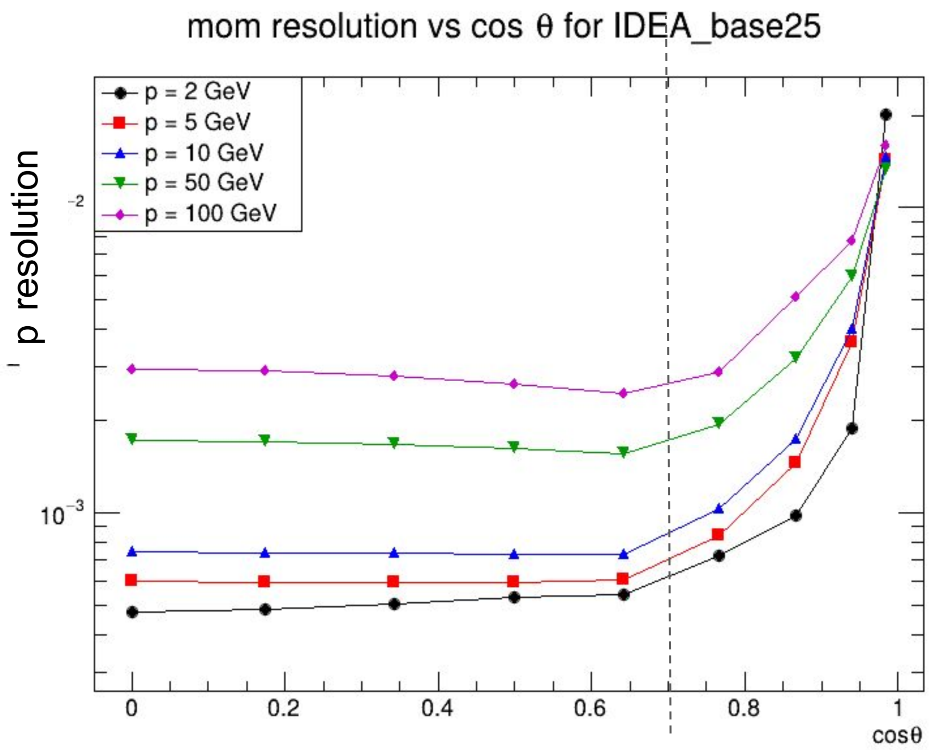


Default IDEA Performances

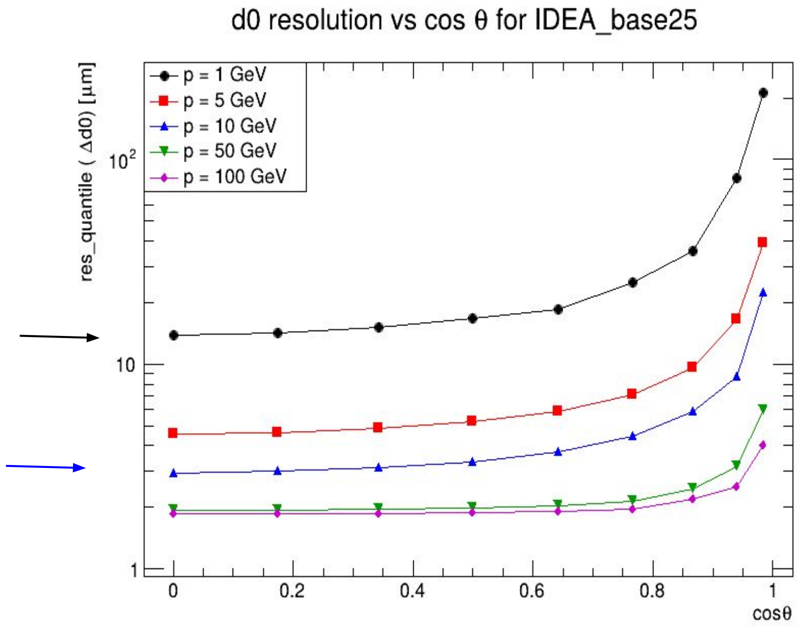
$d\sigma(p)/p \sim p / B$

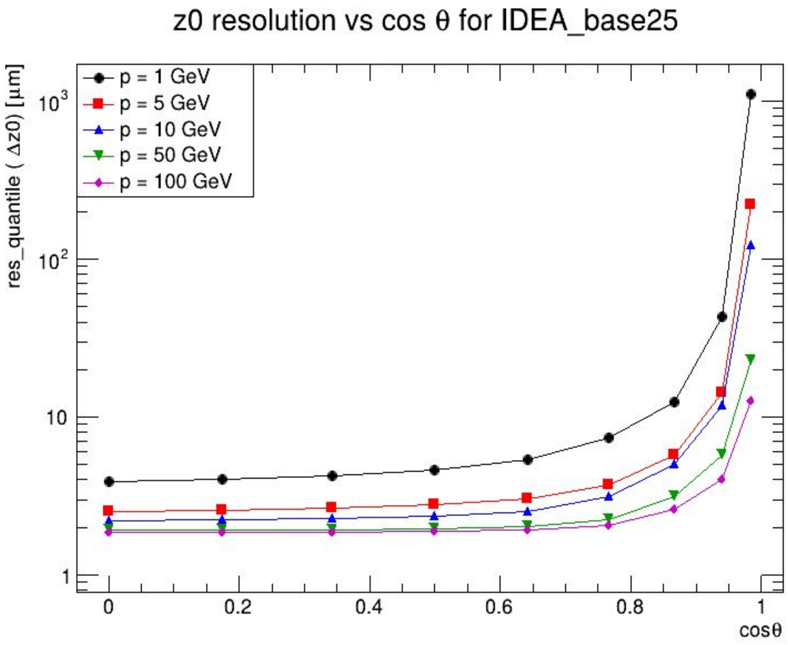
worst at high momentum

p resolution dominated by the Drift chamber
beyond cos(θ)> 0.7 larger material from Drift



Default IDEA Vertex Performances





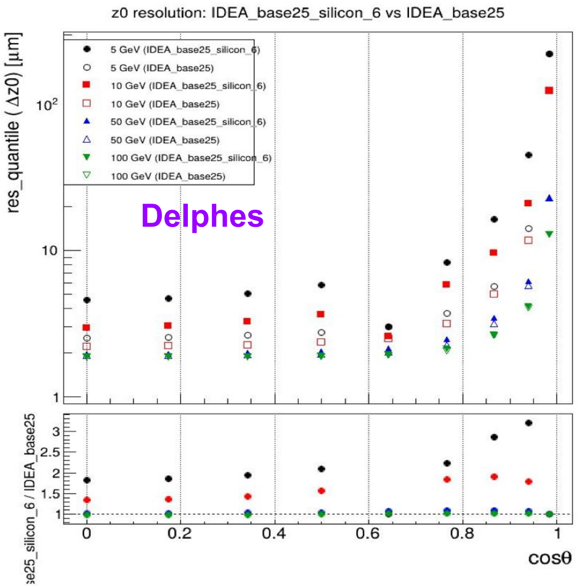
Resolutions at low p_T dominated by multiple scattering and material effects.
d0 : 1 GeV ~ 15 μm ; 10 GeV ~ 3 μm
dZ : 1 GeV ~ 4 μm ; 10 GeV ~ 2.5 μm

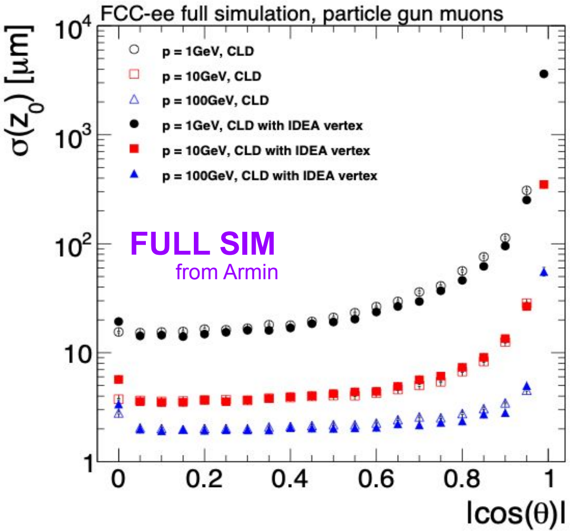
To NOTE at low momenta: the dZ is much better at d0, is this expected ?

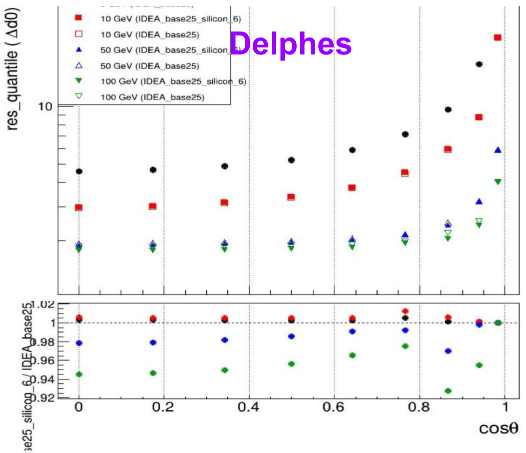
Full Sim validation

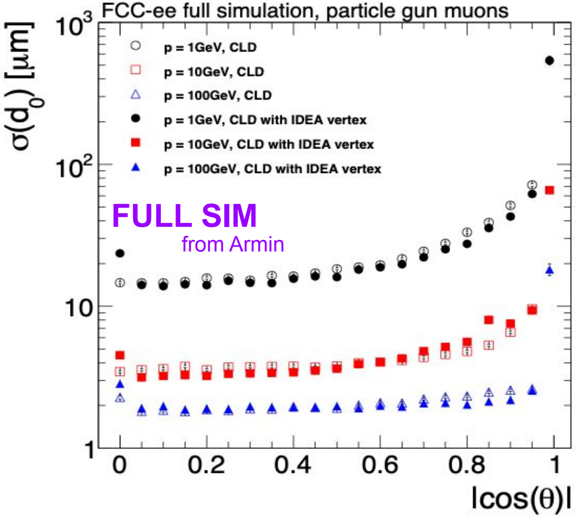
Hybrid scenario: idea VTX with Silicon Tracker (a la CLD) to reuse the CLD tracking.

1. d0 and dz similar resolution both fullsim/delphes
2. high p similar results between delphes and full Sim
3. low p d0 silicon tracker worst than Drift and dz better

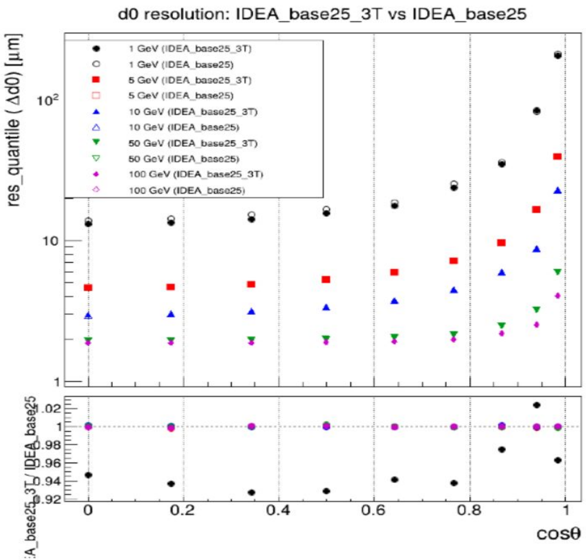


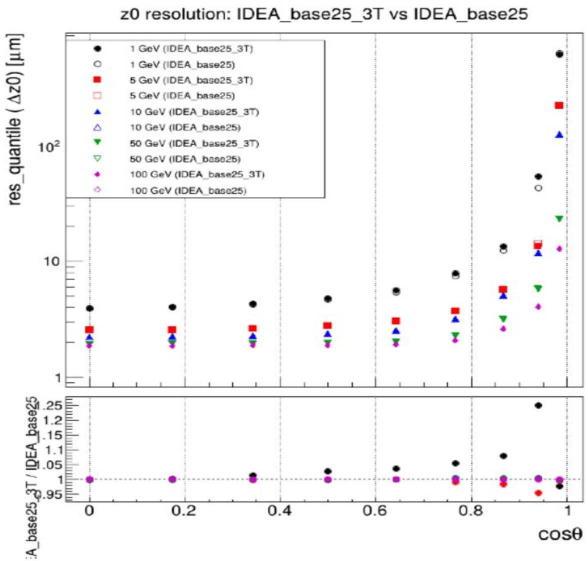






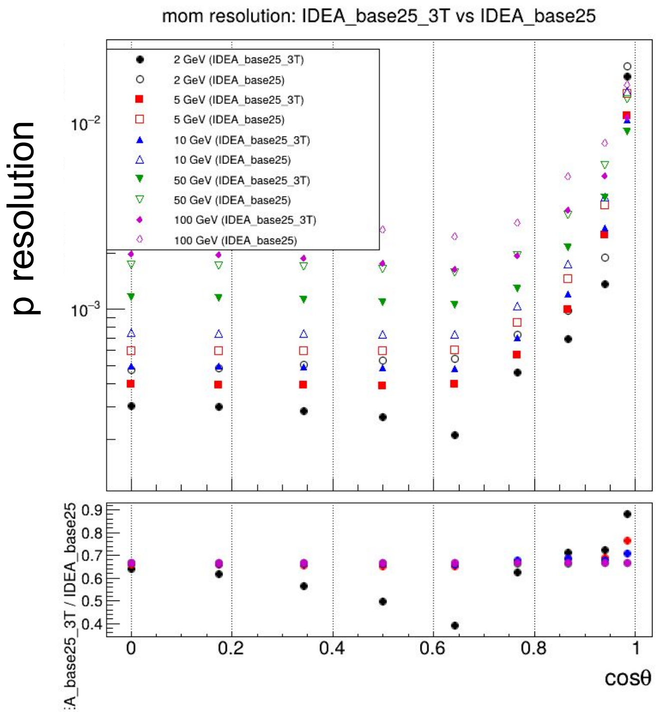
Magnetic Field Dependence (2 T → 3 T)





At **low momentum (~1 GeV)**, better curvature improves transverse impact parameter (d_0), but slightly worsens longitudinal (z_0) resolution (likely due to helical trajectory geometry and pattern recognition effects).

Magnetic Field Dependence (2 T → 3 T)



$d\sigma(p)/p \sim p\,/\,B$

improve with higher B Field

Geometry Variations Overview

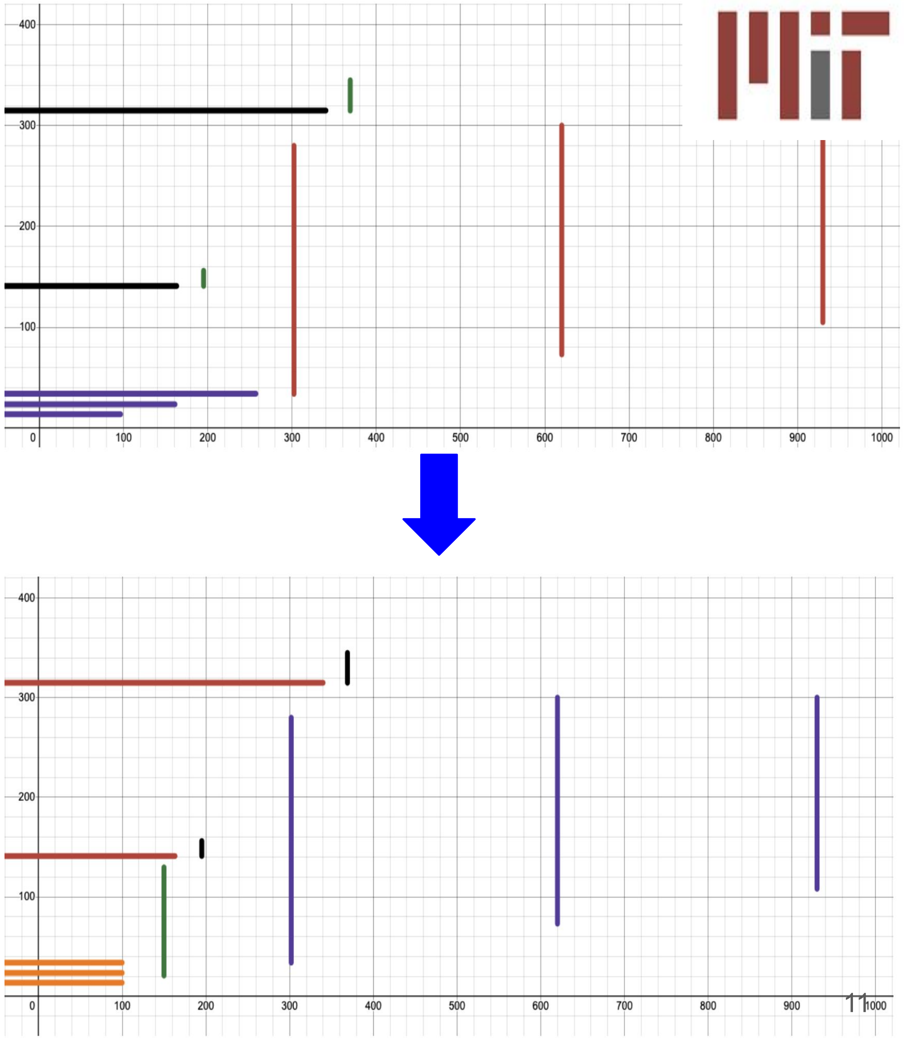
Investigated configurations:

1. **Short Barrel Geometry** (aiming to use bent stitched MAPS)
   a. Reduced barrel length (~10 cm).
2. **First Layer on Top of Beam Pipe**
   a. Moves first layer closer to IP (without entering the beam pipe).
3. **First Layer Inside the Beam Pipe**
   a. More aggressive layout, innermost radius moved to 8–10 mm.
   b. Requires re-engineering of beam pipe and cooling strategy.

Short + Light barrel

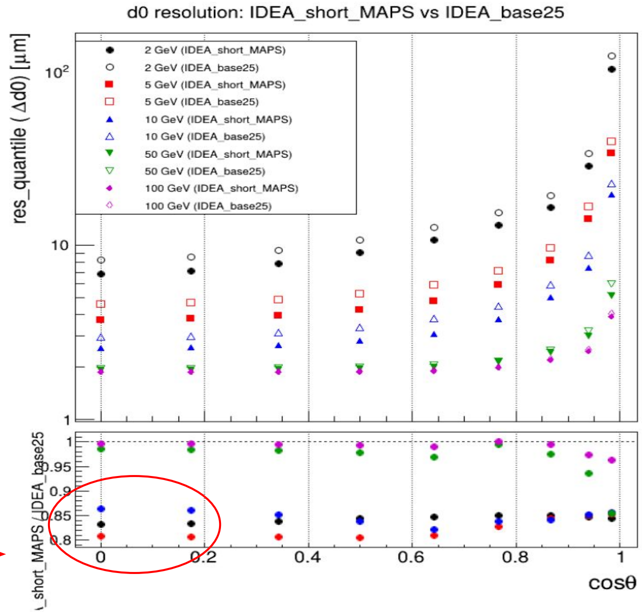
Design changes:

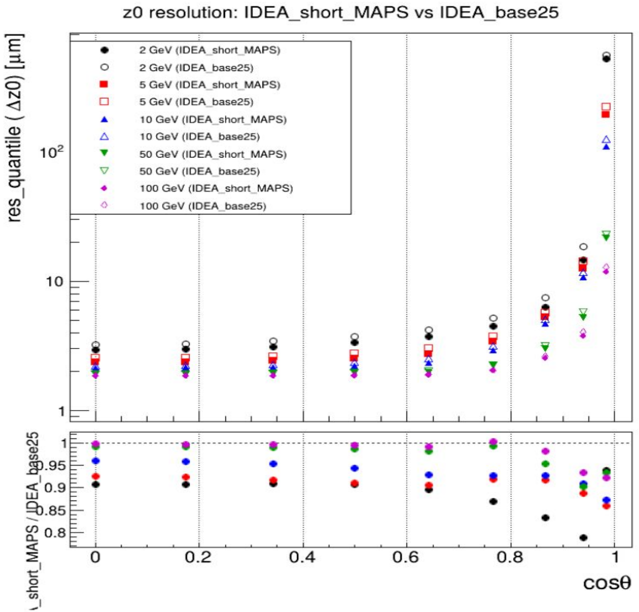
- Barrel shortened to **~10 cm**.
- Material budget of the first 3 barrel layers reduced from 1 X_0 to 0.4 X_0



Short + Light barrel

reduced material budget results in better d0 and dz at low p





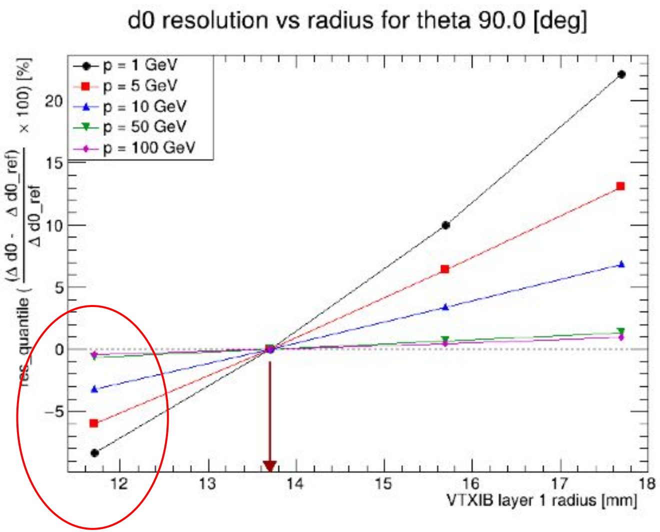
d0 20% gain at p=5GeV

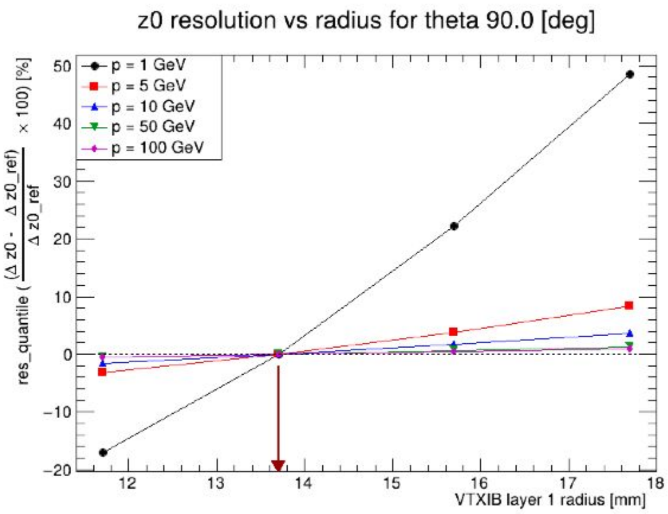
Gains more pronounced at low and intermediate p

Positioning the first layer

Current layout see the first layer at radius 13.7 mm

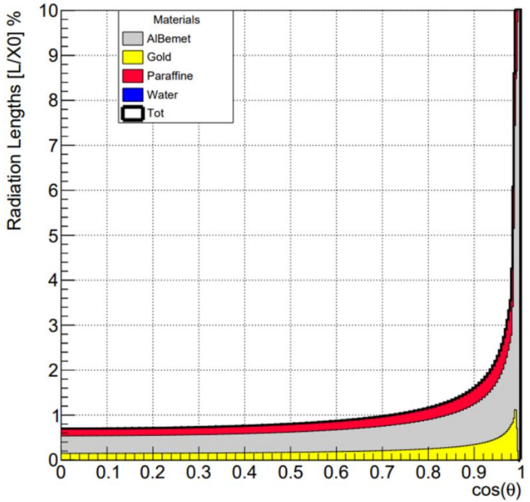
→ gain up to 10%(20%) in d0(z0) positioning the first layer on top of the beam pipe (13.7 mm → 11.7 mm)





Positioning the first layer, inside the beam pipe

current beam pipe



Move the first inner barrel layer radius from 13.7mm to 10, 9 or 8mm and scale the rest of the layers accordingly.

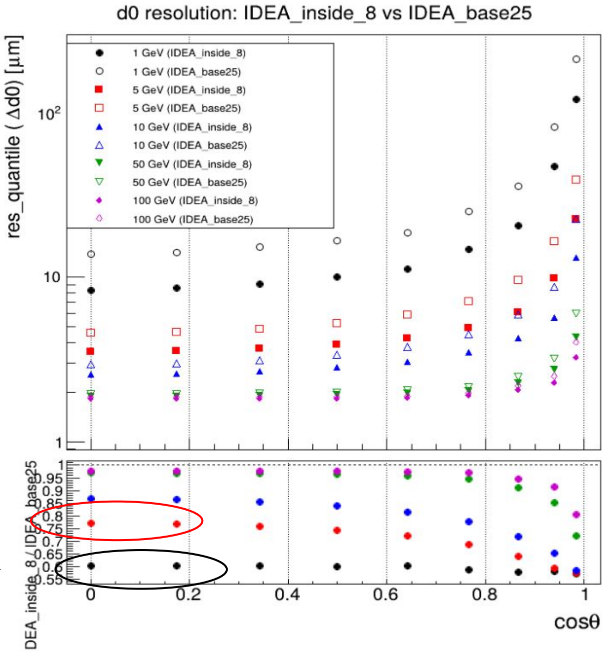
1. Remove parafine and simplify AlBeMet double layer to single. Therefore, the beampipe is reduced to 1mm in thickness
2. Instead of having a cooling layer in the beampipe, reuse the one already installed in the first layer of the inner barrel
3. 10 μm gold layer (needed for beams conduction layer + SR shield) with a material budget of 0.3% X/X0 are shown for the three configurations.

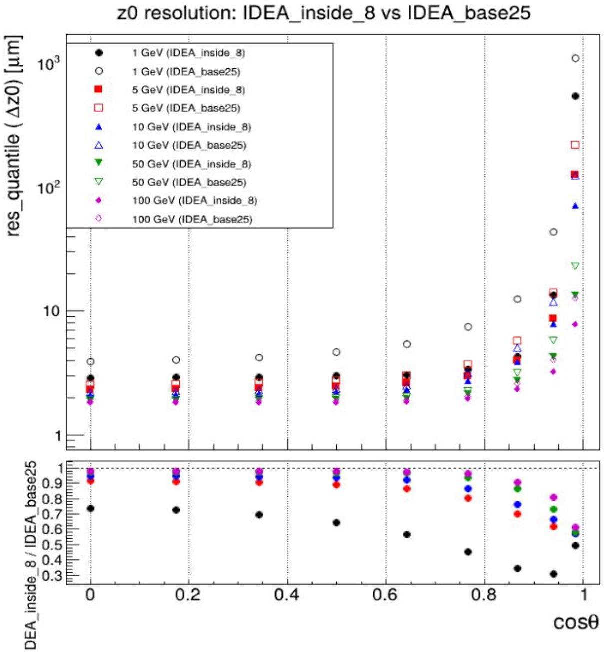
Positioning the first layer, inside the beam pipe

Subsystem	Layer ID	Radius [mm]	$\lvert z\rvert$ [mm]	$\lvert\cos\theta\rvert$ coverage
Beampipe (gold)	–	7.99	< 100000	–
Beampipe (AlBeMet)	–	13.0	< 100000	–
Inner barrel	1	8.0	< 96.5	$0 < \lvert\cos\theta\rvert < 0.997$
Inner barrel	2	21.7	< 160.9	$0 < \lvert\cos\theta\rvert < 0.991$
Inner barrel	3	32.0	< 257.0	$0 < \lvert\cos\theta\rvert < 0.992$

d0 20% (15%) gain at p=5GeV for first layer at 8mm (10mm)

up to 40% for p 1GeV





Promising Configurations

A realistic geometry change

with measurable physics performance benefits

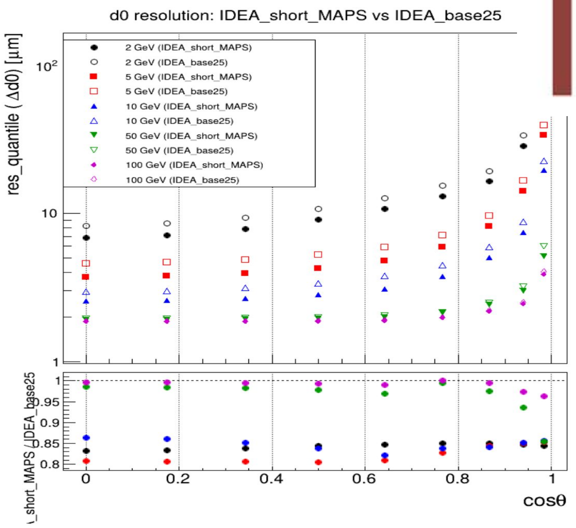
combining:

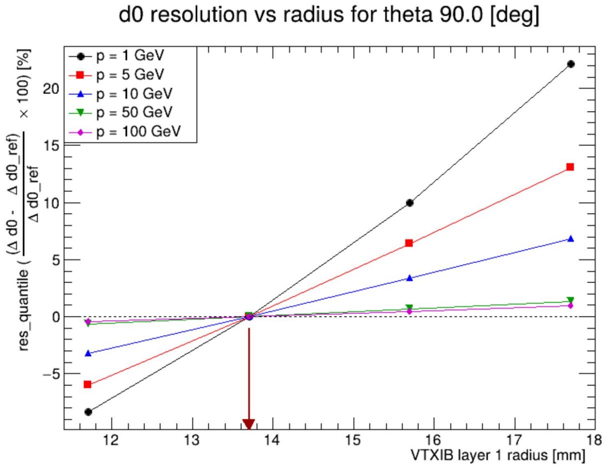
Short & light barrel designs

d0 20% gain at p=5GeV

first layer close to the beam pipe

d0 5% gain at p=5GeV



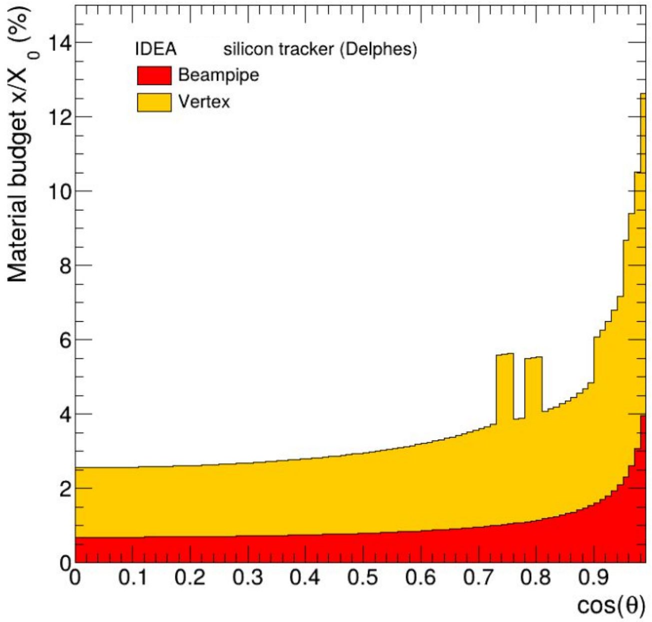


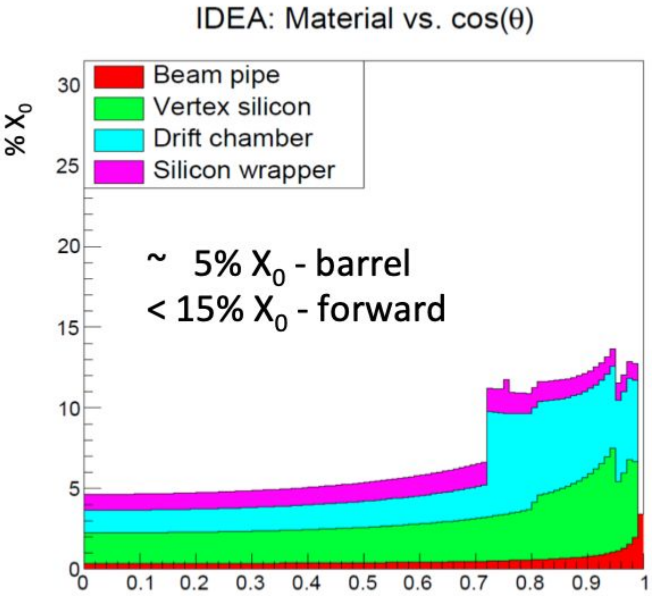
Summary

- Developed and compared several **alternative vertex detector geometries** for the FCC-ee IDEA concept.
- Demonstrated potential performance gains from:
  - **Short & light barrel designs**
  - **Closer placement of inner layer (on top or inside beam pipe)**
  - **Higher magnetic field (3 T)**
- Next phase will focus on:
  - **validation of the delphes performances** respect to the full simulation
  - **complement those scenario with realistic occupancy studies**, **with integrated digitizer and improved beam background**

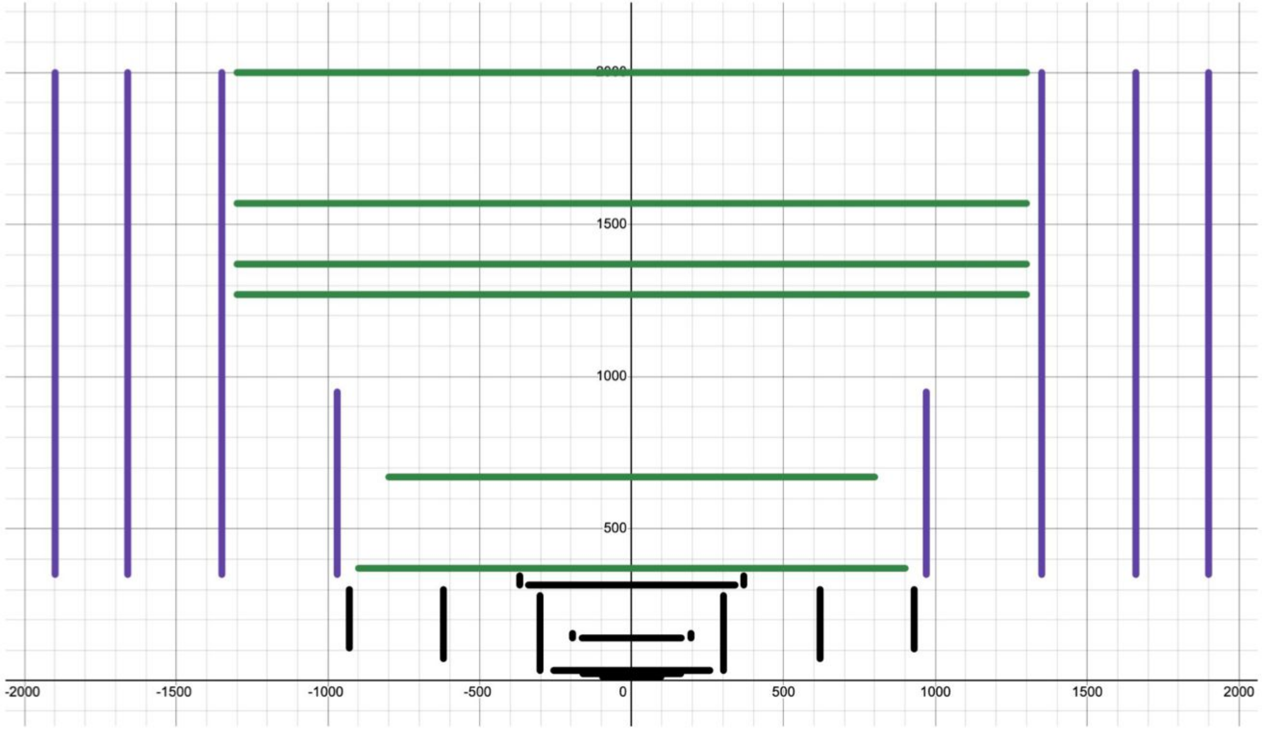
BACKUP

IDEA Material budjet



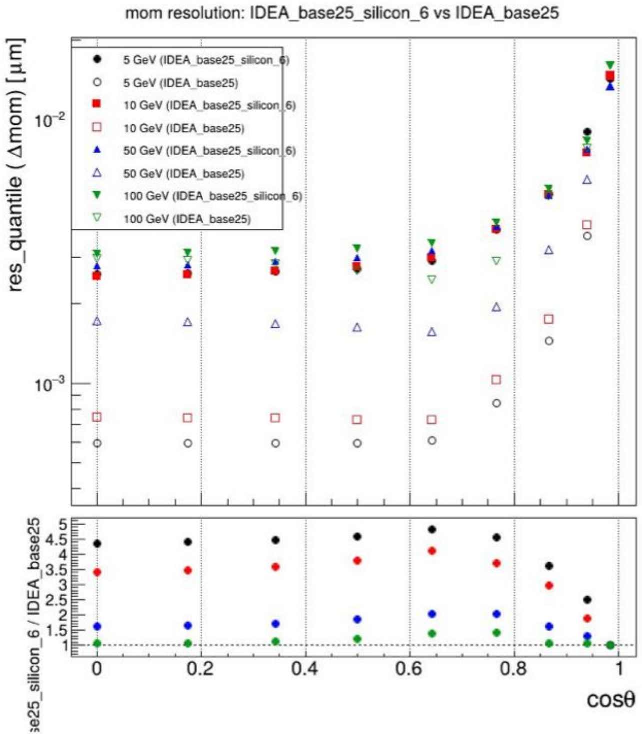


IDEA_base25: silicon tracker with 6 layers



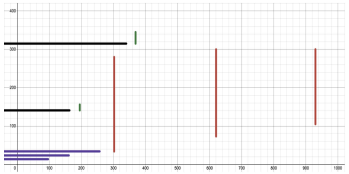
IDEA_base25: silicon tracker with 6 layers (pT)

$$d\sigma(p)/p \sim \frac{p}{B^*\sqrt{N}}$$

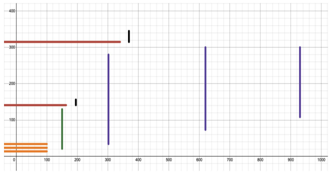


pT is worst with 6 layer silicon than gas with many/many layers; (OK expected)

IDEA Short scenario



idea reference



idea shot barrel