Tracking with the CLIC-inspired detector for FCC-ee

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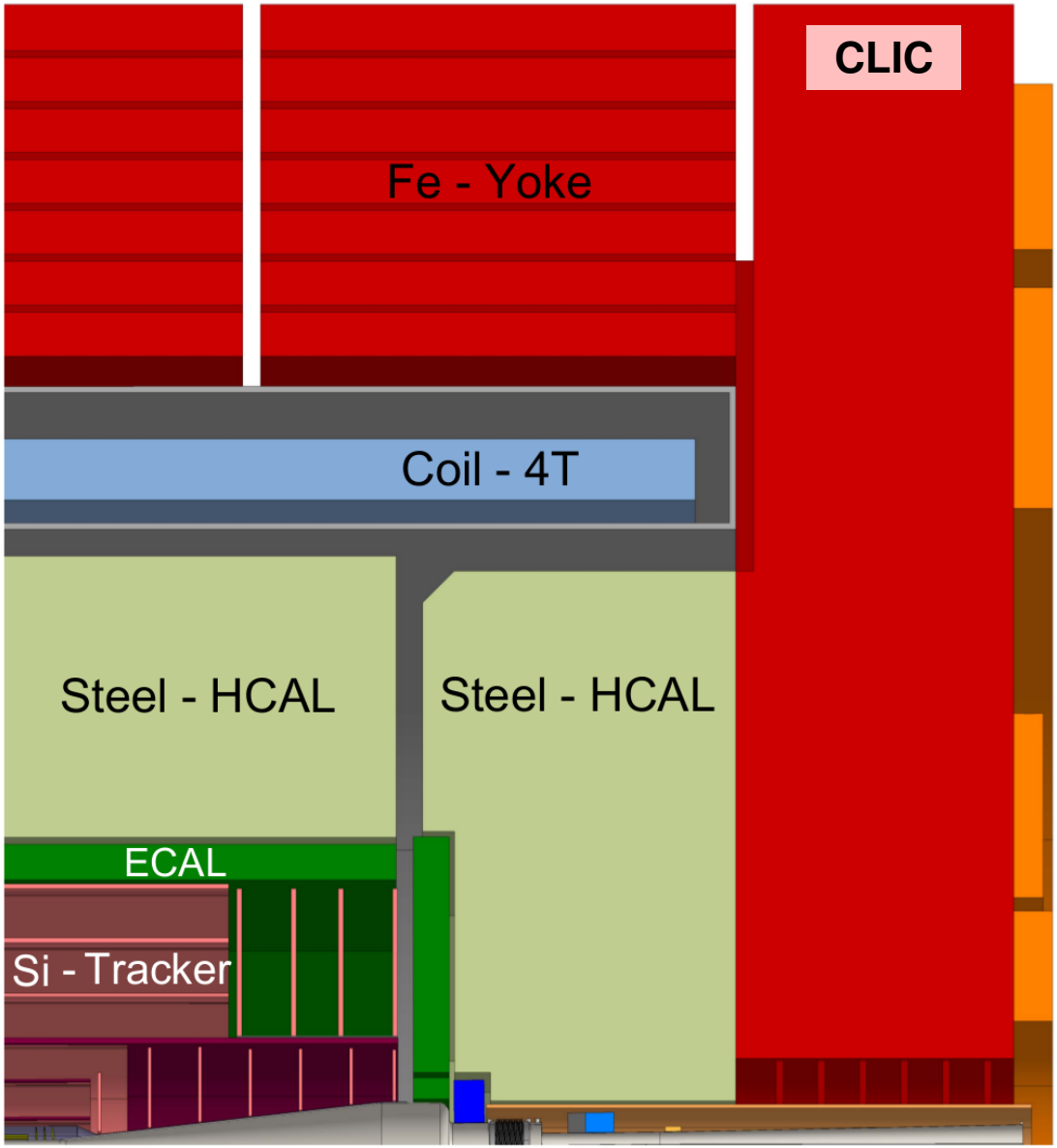
Introduction

- This talk covers an update on the CLIC-inspired detector for FCC-ee
- An overview of the CLIC detector together with the layout of the detector for FCC-ee has been shown by Emilia in a previous Detector Design meeting
- The main focus of this presentation is the layout of the VTX and Tracker subsystems and the overall tracking performance



Subdetectors

- Full silicon VTX and Tracker: $\geqslant$12 hits per track
- W-Si ECAL and Fe-Scint HCAL
- Coil is outside of the calorimeter; 4 Tesla magnetic field
- Steel return yoke with 6 RPC muon chambers

Detector requirements

- Momentum resolution (at 500 GeV): $\sigma_{p_T}/{p_T}^2 \simeq 2 \cdot 10^{-5}$ GeV^{-1}
- Lepton ID efficiency: $> 95\%$
- Impact parameter resolution: $\sigma_{d_0} = a \oplus \frac{b}{p\ sin^{3/2}\theta}$ $a \leqslant 5\mu$m, $b \leqslant 15\ \mu$m GeV
- Jet energy resolution: $\sigma_E/E \simeq 3.5\ \%$

FCC-ee detector model

- Latest version of the detector, FCCee_o5_v03, is based on the latest CLIC model (CLIC_o3_v12), which makes it compatible with the latest ILCSoft and CLIC subdetector drivers.
- All future bug-fixes of drivers and updates of algorithms will work for both CLIC and FCC-ee models.
- Intensive testing and verification of the detector model were done to make sure that simulation and reconstruction work as expected.

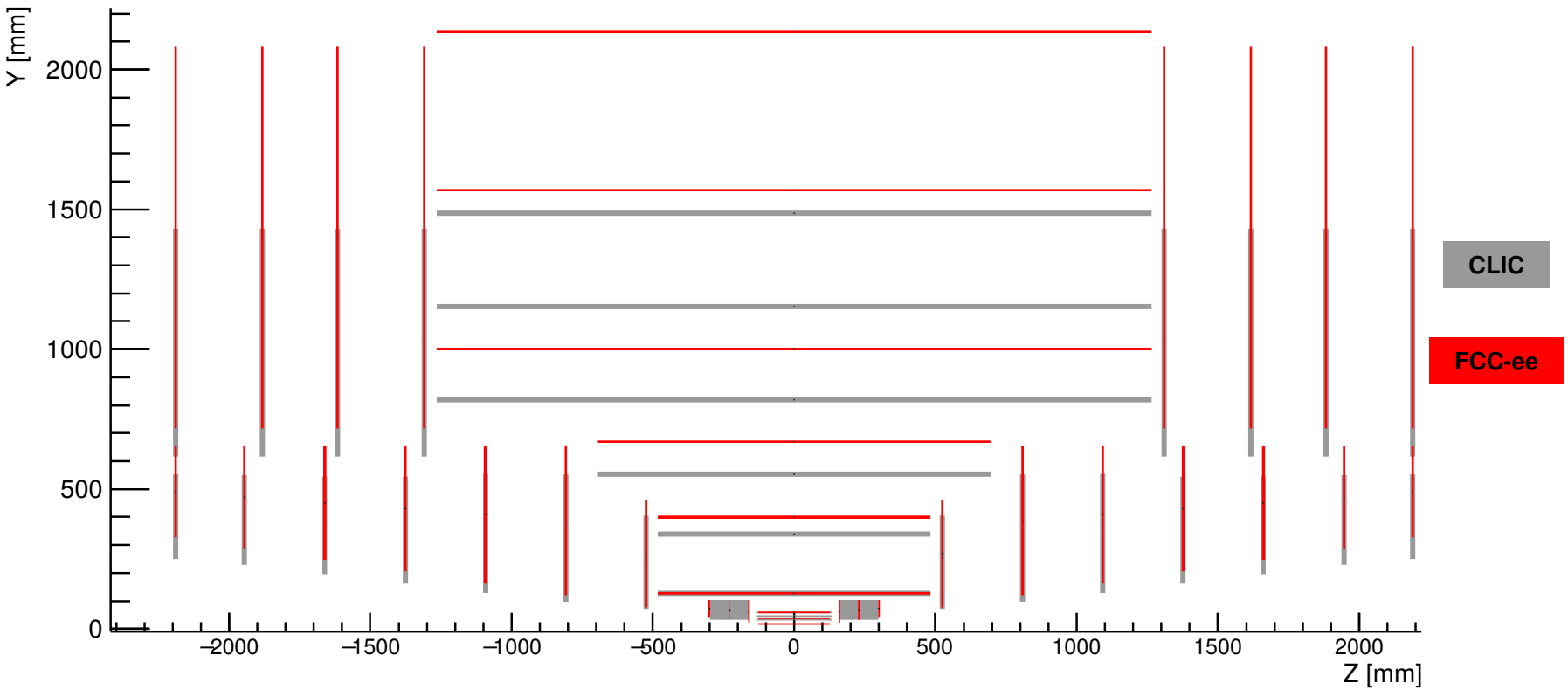
Overall dimensions of CLIC and FCC-ee detectors

	CLIC		FCC-ee
VTX Barrel	31-60 mm	$\Longrightarrow$	17-59 mm
VTX Endcap	Spirals	$\Longrightarrow$	Disks
Tracker radius	1486 mm	$\Longrightarrow$	2100 mm
ECAL thickness	40 layers, 22 X_0	$\Longrightarrow$	40 layers, 22 X_0
HCAL thickness	60 layers, 7.5 λ_I	$\Longrightarrow$	44 layers, 5.5 λ_I
Yoke thickness	1989 mm	$\Longrightarrow$	1521 mm
MDI (forward region)		$\Longrightarrow$	$<$ 150 mrad
Solenoid field	4 Tesla	$\Longrightarrow$	2 Tesla

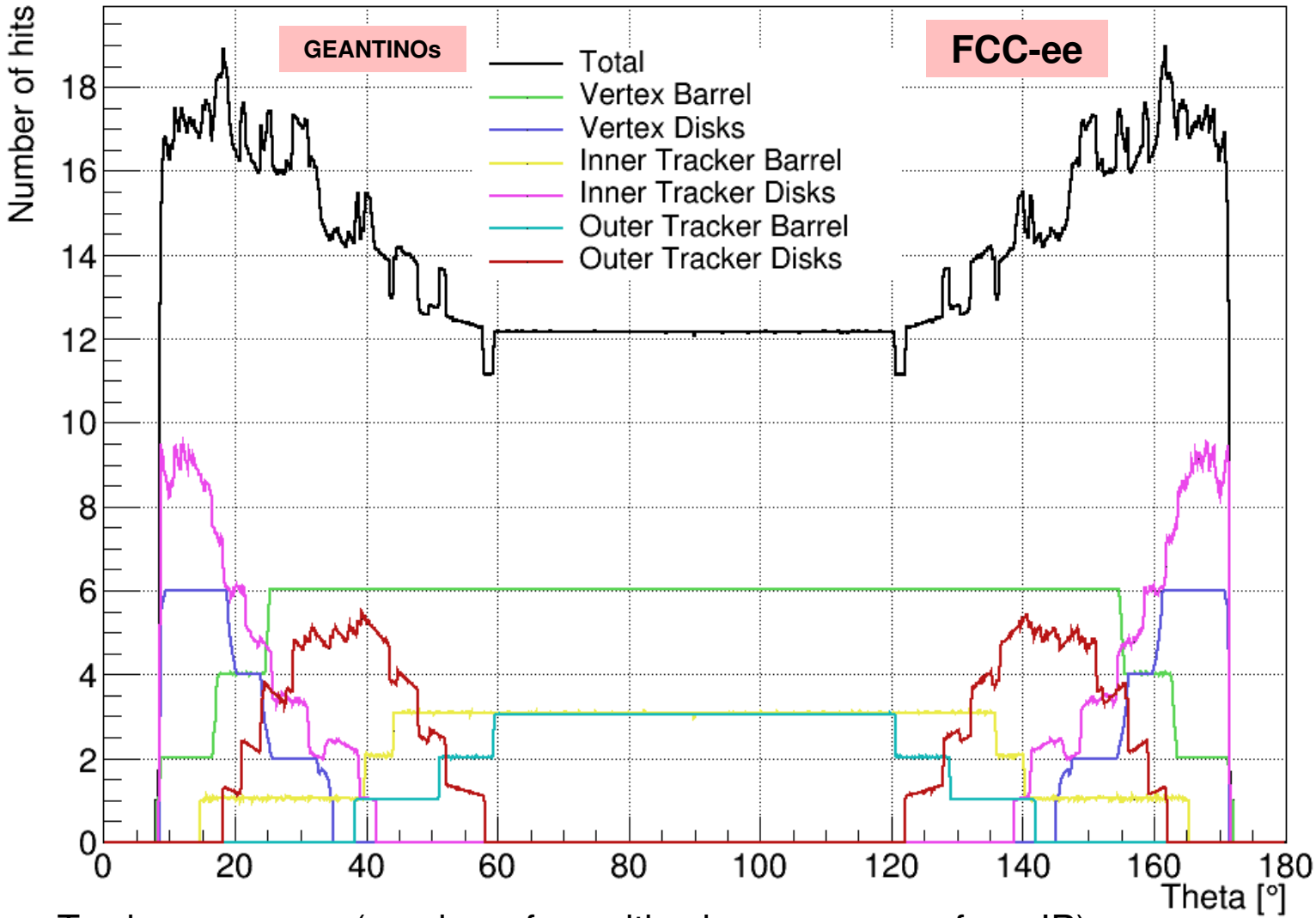
VTX and Tracker layout

- Overall structure of VTX and Tracker is the same as in the CLIC detector
- VTX barrel is a scaled version of the CLIC VTX barrel
- VTX endcaps consists of disks (while CLIC has spirals, to allow air cooling)
- Tracker radius is increased to compensate for smaller magnetic field
- Minimum radius of the IT disks is adjusted to the MDI region, 150 mrad

Comparison of the CLIC and FCC-ee tracking system



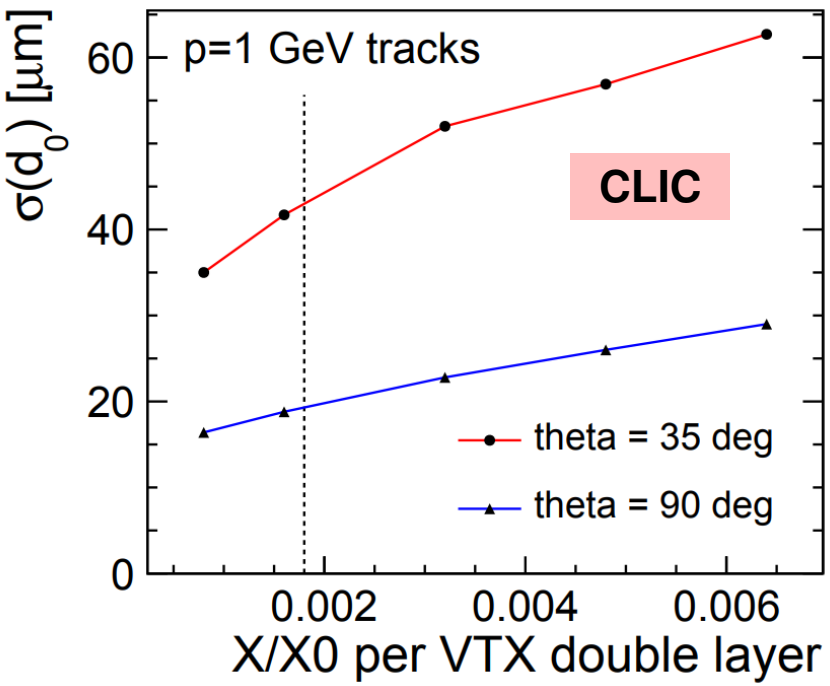
Coverage of VTX and Tracker detectors



- Tracker coverage (number of sensitive layers as seen from IP).
- More than 12 hits over theta range 8.6° - 171.4°

Material budget of VTX and Tracker

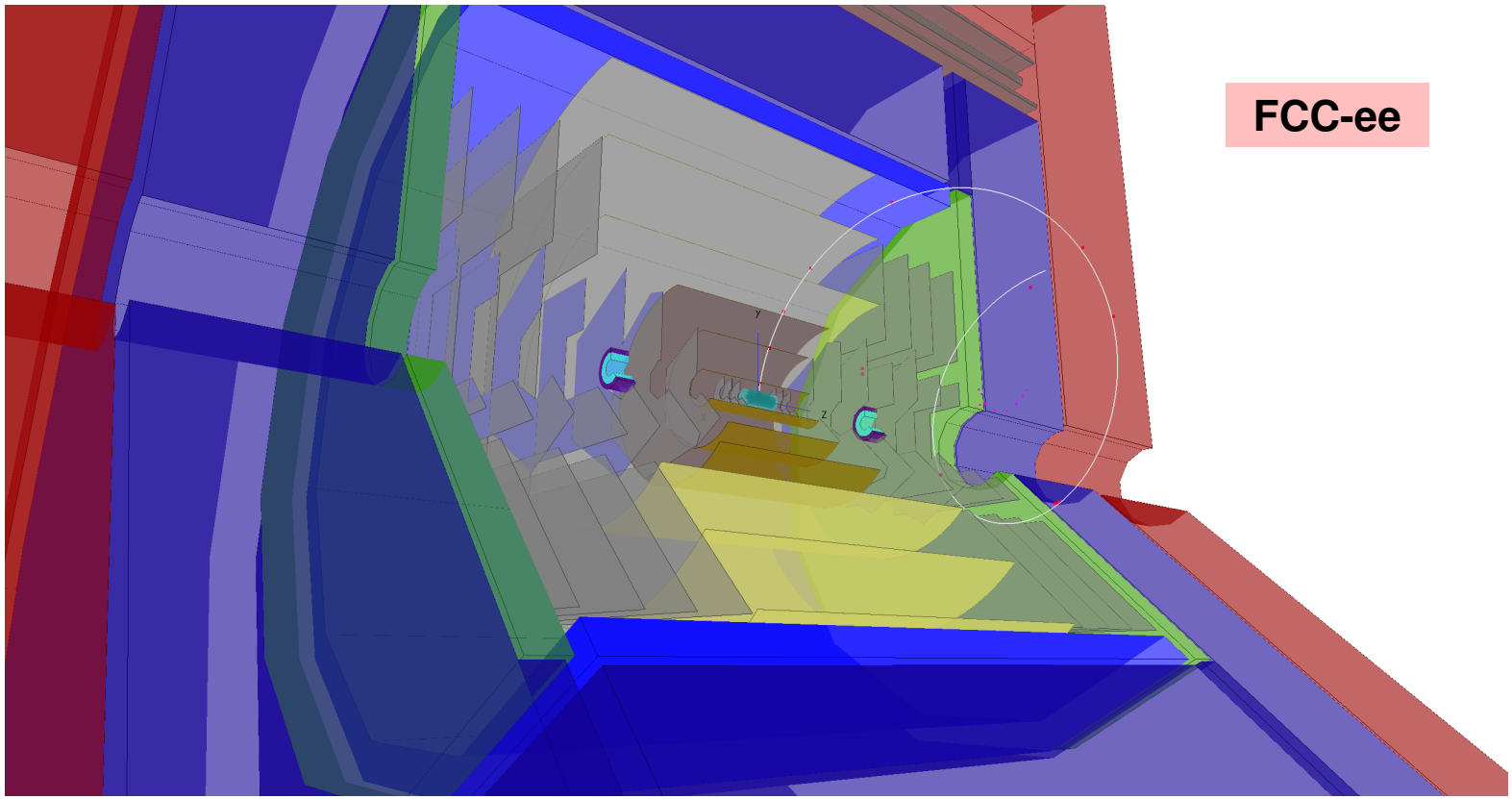
- Due to power-pulsing, CLIC VTX can be cooled by air flow. Since power-pulsing is not suitable for FCC-ee operation the material budget of the VTX has to be revised.
- The study of the effect of increased material budget in VTX on impact parameter and momentum resolution is ongoing.



- Current FCC-ee model doesn't contain support structures and cables (while it is implemented in CLIC model)... will be added soon

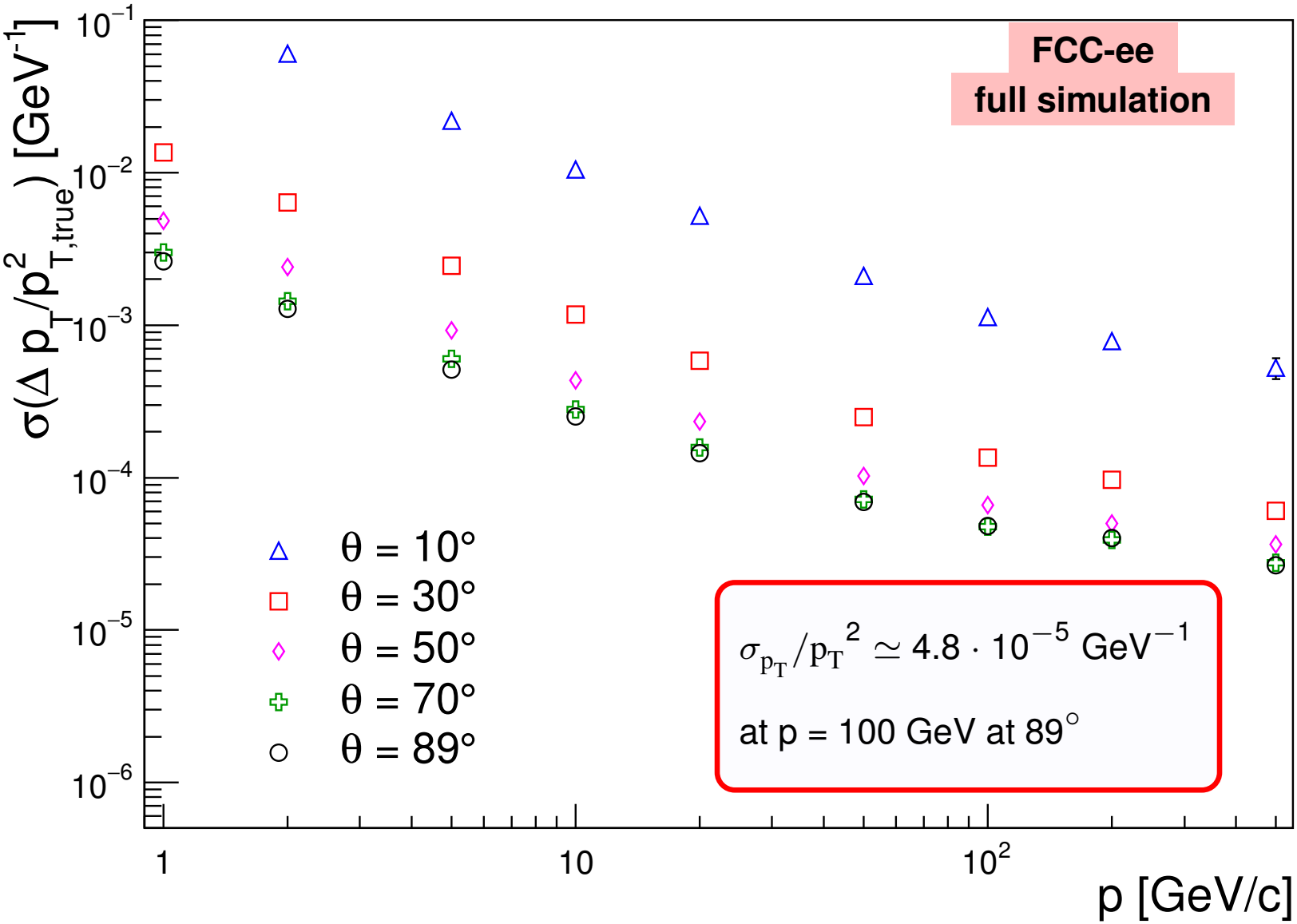
Tracking

- Two tracking algorithms are available:
  - truth tracking - track fitting is done by using all hits produced by particle (by using truth information)
  - conformal tracking - hits are found by pattern recognition algorithm in conformal space
- All results shown below are obtained with truth tracking.
- Single-point resolution (sigma): VTX - 3×3 μm; IT - 7×300μm; OT - 7×3000μm



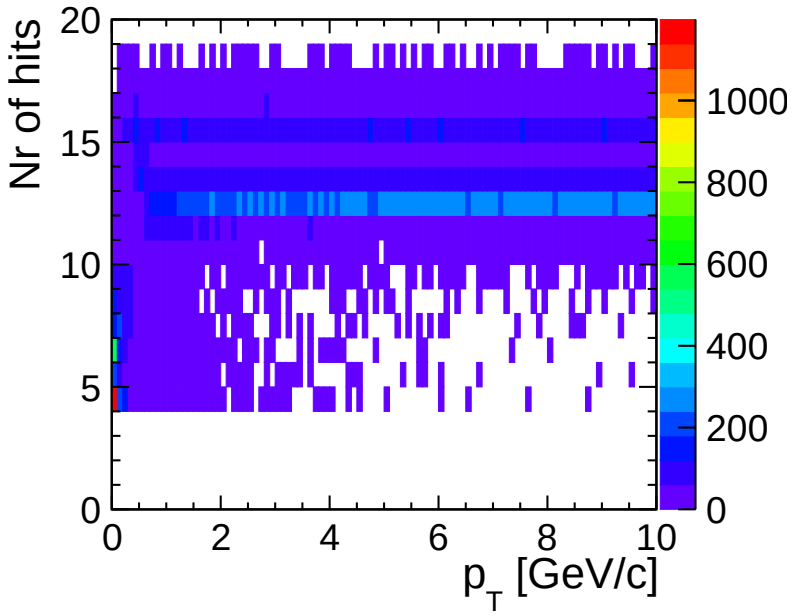
- Charged particles with $p_T > 0.65$ GeV reach calorimeter.

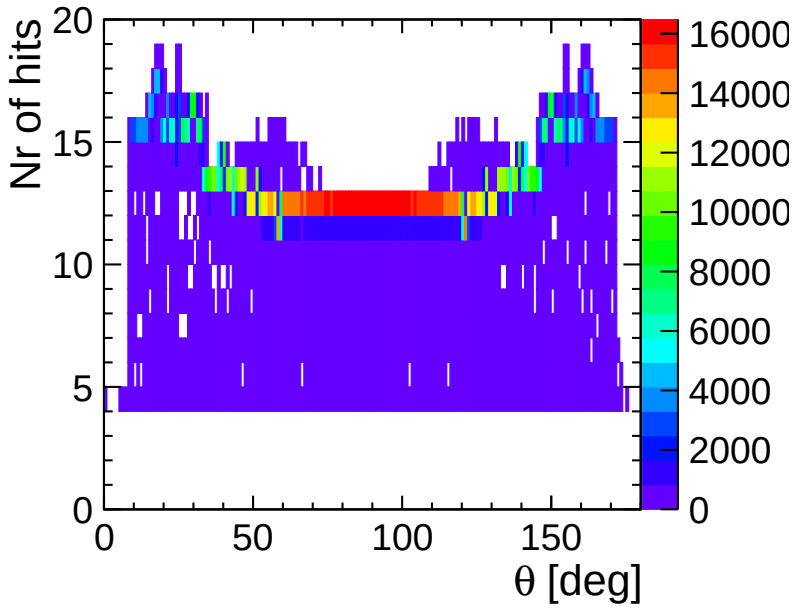
Momentum resolution

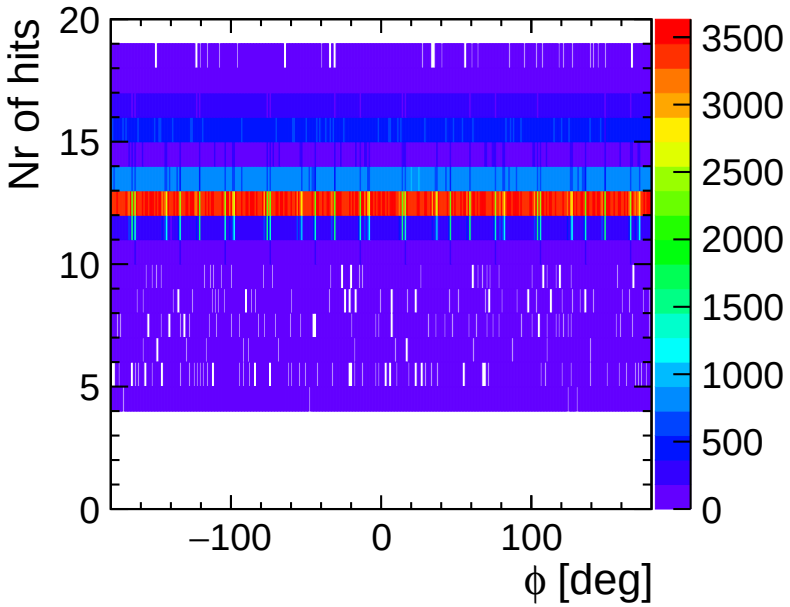


- Resolution was simulated with muons generated by particle gun

Number of hits per track

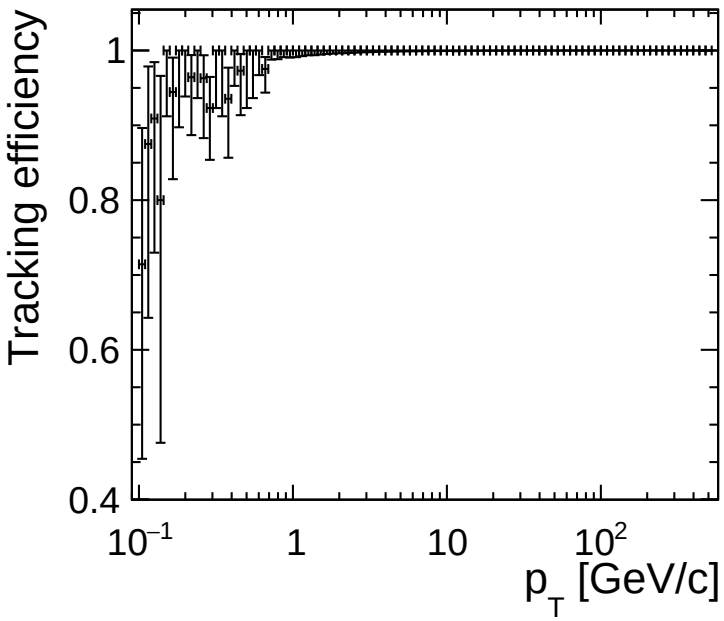


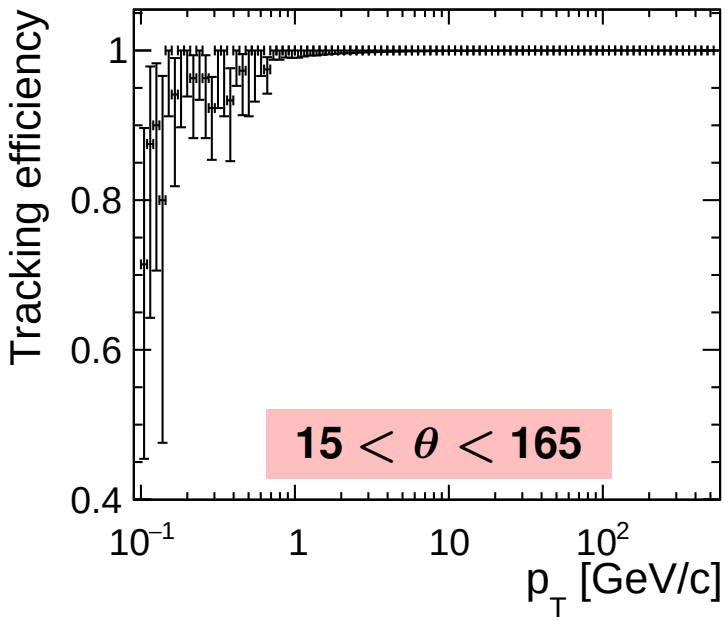




- Muons are generated with general particle source with:
  - isotropic angular distribution (uniform in $\cos(\theta)$)
  - uniform energy distribution
- 12 hits per track on average
  $\rightarrow$ all hits are used during track fitting

Tracking efficiency as function of p_T

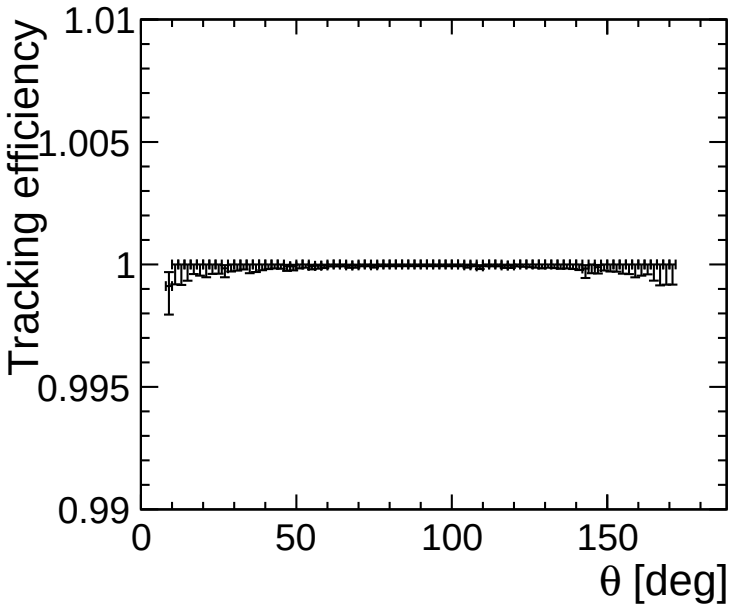


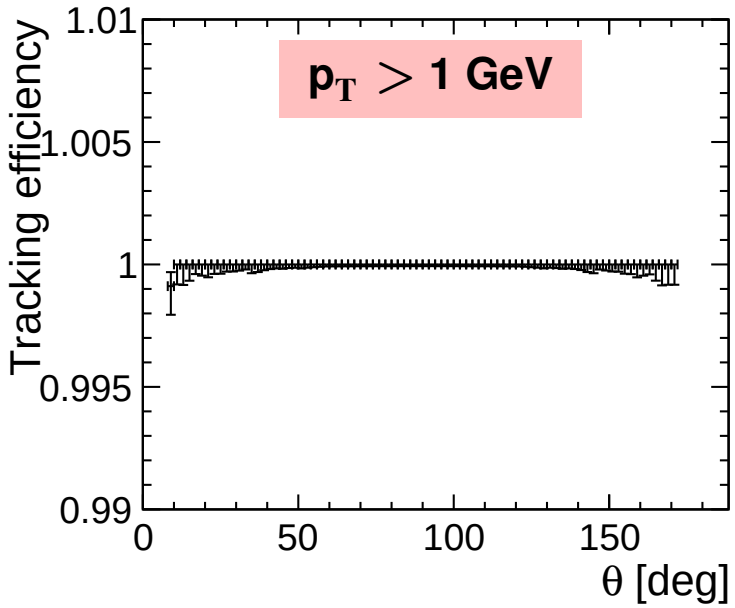


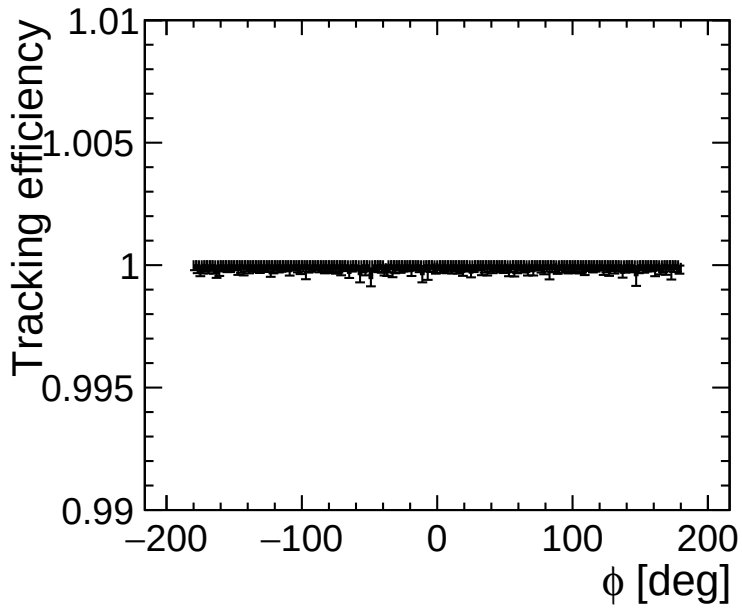
$$\text{Tracking efficiency} = \frac{N^{reconstructed}_{tracks}}{N^{reconstructable}_{particles}}$$

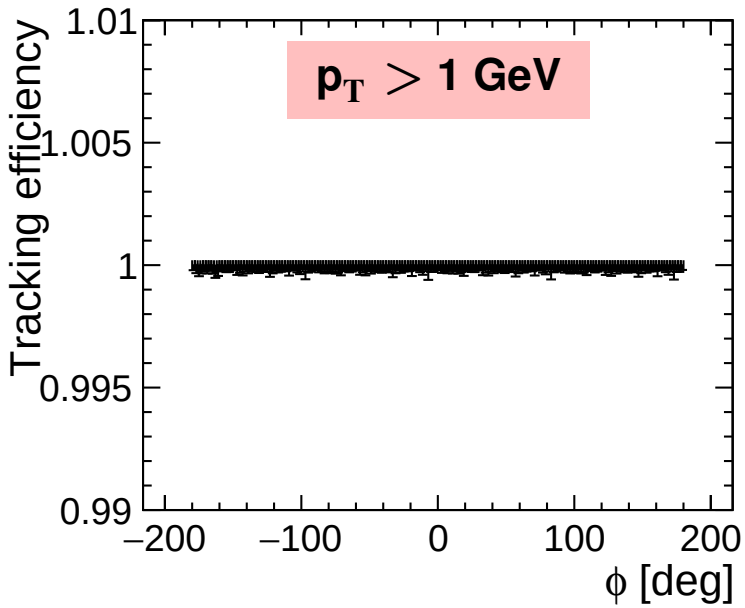
- reconstructable particles:
  - PDG ID = 13 (muon)
  - $N_{hits} \geqslant 4$
  - $|\cos(\theta)| < 0.99$
  - $p_T \geqslant 0.1$ GeV/c
  - particle track is not a loop (does not have two hits on the same layer of the same subdetector)

Tracking efficiency as function of θ and ϕ









Summary and outlook

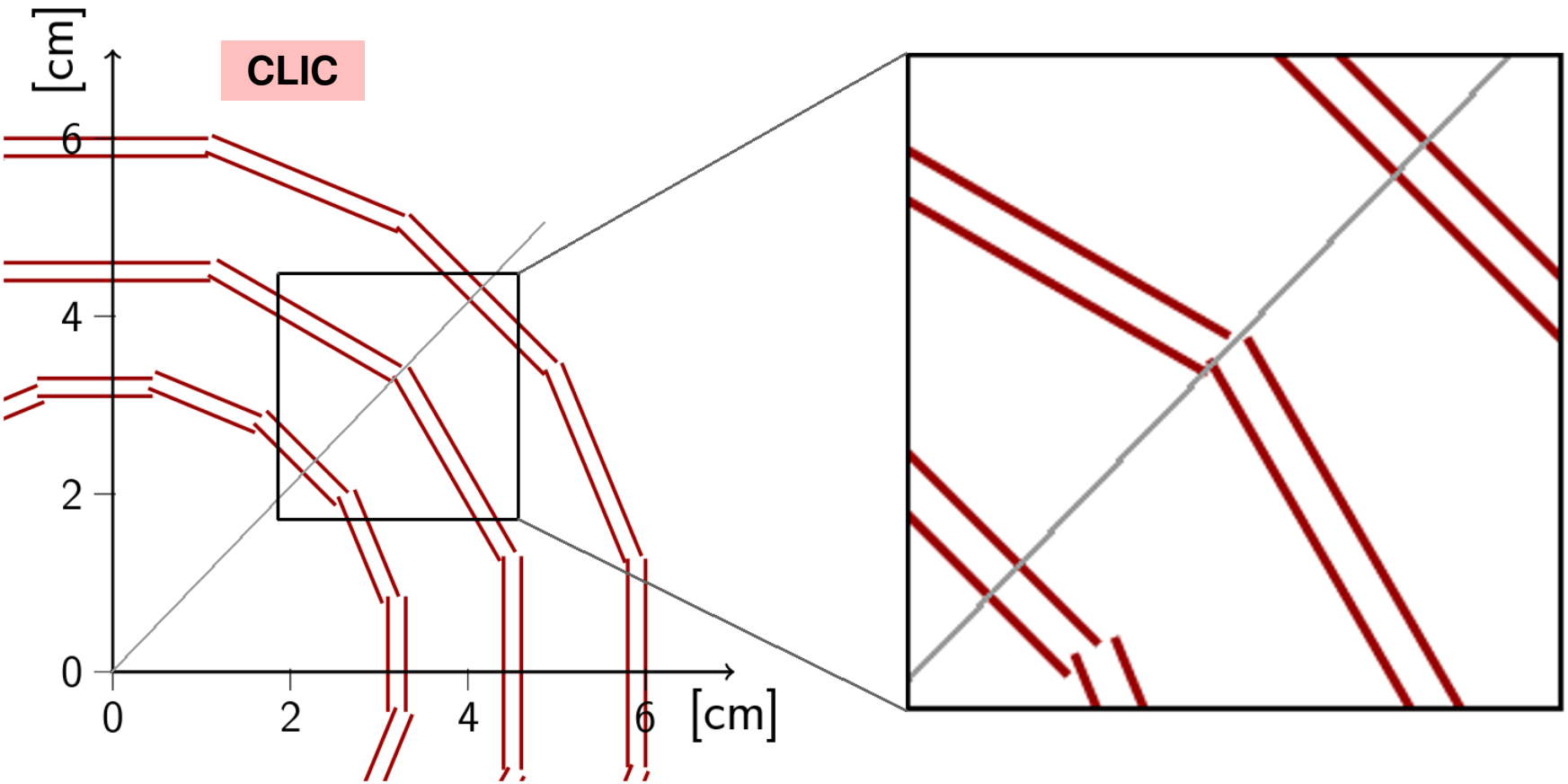
- Complete FCC-ee detector model is available for performance studies
- Tracking performance was studied with full simulation and reconstruction (truth tracking)

Next steps

- Conformal tracking performance (presently being completed for CLIC)
- Conformal tracking for complex events (e.g. $Z \rightarrow$ uds events)
- Conformal tracking with overlay of beam background
- Effect of increased material budget in VTX
- Calorimeter studies:
  - single electrons, photons, muons and pions (PID efficiency as function of pT and theta)
  - complex events - PID efficiency
  - jet energy resolution
  - all above with beam background overlaid

BACKUP

VTX barrel layout



Photon energy resolution for different number of ECAL layers