

Towards CLD Tracker optimisation

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Thanks to Leonhard Reichenbach, Andre Sailer, Alvaro Tolosa, Briec Francois, Michele Selvaggi

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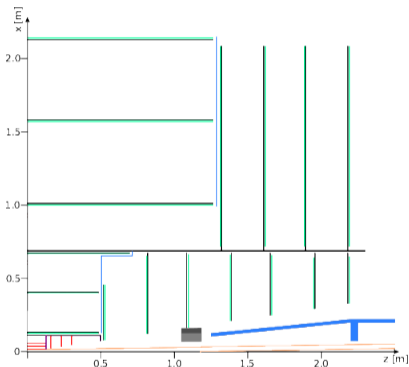
Introduction and motivation

Objectives:

- 2 Vertex and tracker optimisation for different geometries
- 2 Guideline for R&D on full silicon tracker
- 2 Candle for physics performance : increasing level of complexity (Tracking, Vertexing, flavour tagging, full analysis)
- 2 Chosen approach: **full simulation**, for more precise results, use of **CLD** here

- 2 Outline:
 - ∩ Study of tracking resolution for different CLD geometries
 - ∩ First attempts for long lived particle reconstruction (Heavy Neutral Lepton)

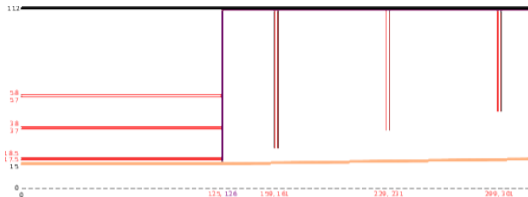
CLD tracker geometry



More details on [CLD_o1_v04](#)

More CLD geometries on [talk](#) by A.Sailer

2 Vertex Detector with 3 1m spatial resolution pixels



2 Inner and Outer Silicon Tracker, mostly $50\text{ }1\text{m}$ pitch strips

- 3 short and 3 long barrel layers, 7 inner and 4 outer endcaps
- 200 1m Silicon thickness, $50\text{ }1\text{m}$ \times 0.3 mm cell size, $7\text{ }1\text{m}$ \times $90\text{ }1\text{m}$ single point resolution (except first inner tracker disk, $5\text{ }1\text{m}$ \times $5\text{ }1\text{m}^2$)

2 Tracking optimisation with full silicon tracker

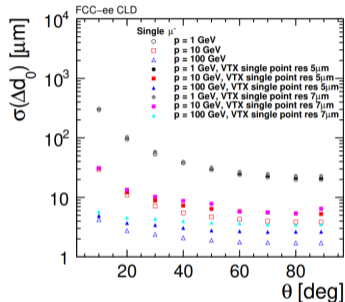
- robust technology
 - high single point resolution
 - tune to sustain higher particle rate
- material budget
 - No space for PID

Tracking Performance

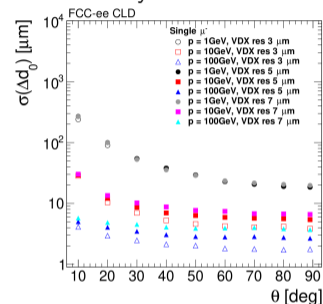
First step: reproduce performance plot with different framework – CLD_o1_v04 geometry

CLD - A Detector Concept for the FCC-ee

arXiv:1911.12230v3



Current study



2 New implementation of the performance plots gives comparable results than the CLD paper

2 Study of new geometries is possible

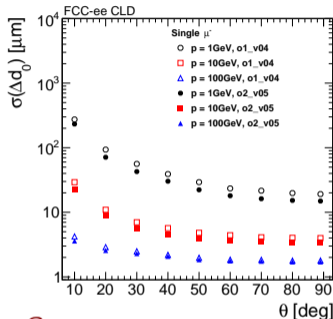
✓ Smaller and more realistic **beampipe**, and adapted **vertex detector**

✓ Add of **PID** and shortened **trackers**

✓ **fast / full** simulation comparisons for prompt tracks

Effect of shortened vertex detector and BeamPipe material budget

BeamPipe and Vertex geometry – CLD_o1_v04 & CLD_o2_v05 = smaller more realistic BeamPipe, adapted Vertex



2 Improvement of the d_0 resolution in the new geometry (o2_v05)

i Smaller vertex radius compensates fully for the increased material budget in beam pipe

CLD_o1_v04

- 2 BeamPipe radius: 15 mm
- 2 BeamPipe material: Beryllium
- 2 BeamPipe thickness: 1.2 mm + 5 μm gold
- 2 $X/X_0 = 0.45\%$

CLD_o2_v05

- 2 BeamPipe radius: 10 mm
- 2 BeamPipe material: AlBeMet 0.35 mm + paraffin 1 mm + AlBeMet 0.35 mm
- 2 BeamPipe thickness: 1.7 mm + 5 μm gold
- 2 $X/X_0 = 0.61\%$) + 33% material budget

Vertex Barrel [mm]	R_1	R_2	R_3	L
o1_v04	17.5	37	57	125
o2_v05	13.0	35	57	109

More details on [CLD_o1_v04](#)

More CLD geometries on [talk](#) by A.Sailer

Effect of vertex spatial resolution

d_0 & p_T resolution single σ CLD_o2_v05 (10k events)

2

p_T

Effect is smaller, some effect at high impulsion barrel

2

d_0

As expected, very sensitive to intern layer, particularly at high p_T

Material budget is dominant for low p_T

2

e_i & $1/4$

Digitisation is made by smearing simulated hits with spatial resolution values as the Gaussian width

CLD with PID

Tracker geometry [CLD_o2_v05](#) & [CLD_o3_v01](#) = ARC and adapted trackers

doi.org/10.1016/j.nima.2018.08.078

AE) Need space

Outer Tracker Barrel [mm]	R ₁	R ₂	R ₃	
o2_v05	1000	1568	2136	
o3_v01	1000	1446.8	1849.2	
Outer Tracker Endcap [mm]	Z ₀	Z ₁	Z ₂	Z ₃
o2_v05	1310	1617	1883	2190
o3_v01	1310	1547	1752	1990

Inner tracker endcap was shrunk as well

$$\phi_{D0} j_{res} \frac{1}{4} p \frac{3^{3/4} \Delta}{N \Delta^5} \frac{v}{t} \frac{1 \text{ \AA} \frac{8r_0}{L_0} \text{ \AA} \frac{28r_0^2}{L_0^2} \text{ \AA} \frac{40r_0^3}{L_0^3} \text{ \AA} \frac{20r_0^4}{L_0^4}}{s}$$

$$\frac{\phi_{PT}}{p_T} j_{res} \frac{1}{4} \frac{12^{3/4} \Delta p_T}{0.3 B_0 L_0^2} \frac{5}{N \Delta^5}$$

-) lever arm reduced by 10 %
-) p_T res should degrade by ¼20%

CLD with ARC see this [talk](#) by A.Tolosa

CLD with PID

Tracker geometry CLD_o2_v05 & CLD_o3_v01 = ARC and adapted trackers

relative di	10 \pm
10 GeV	10,5 %
100 GeV	15 %
relative di	89 \pm
10 GeV	17.8 %
100 GeV	15.5 %

- 2 p_T resolution depend mainly on lever arm
- 2 Differences observed are compatible with analytic formula
- 2 For $\mu = 50 \pm$, tracks fall into a crack in the tracker geometry

CLD with ARC see this [talk](#) by A.Tolosa

Comparison with Fast Simulation

Full Sim & Fast Sim tracking performance impulsion resolution
Full Sim

Fast Sim

10 GeV $89^\pm = 7\%$ difference

10 GeV $70^\pm = 3\%$ difference

- 2 Impulsion resolution is comparable for FCC-CLD fast and full simulation

Comparison with Fast Simulation

Full Sim & Fast Sim tracking performance d_0 resolution

Full Sim

Fast Sim

10 GeV 89^\pm = 6.7 % difference

10 GeV 70^\pm = 6.9 % difference

2 d_0 resolution is comparable for FCC-CLD fast and full simulation

Tracking performance

Summary

- 2 Study track resolution with different single point resolution and tracker (beam pipe) geometries
- 2 Code validated by reproducing CLD paper results (geometry CLD_o1_v04)
- 2 Several spatial resolution for vertex tested, also for 1 micron, to test extreme case (while probably not realistic)
- 2 Improvement of the d_0 resolution in the new geometry (CLD_o2_v05) with smaller beam pipe
- 2 $\frac{1}{4}$ 20 % degradation of σ_{τ} resolution in CLD_o3_v01 with ARC
- 2 Track resolutions are comparable for FCC-CLD fast and full simulation, for prompt tracks

HNL studies

See [talk](#) by J.Andrea G.Sadowski

2 Generation of Long Lived Particle within the Heavy Neutral Lepton model

2 Inherits from FCCee paper (Alimena & [arXiv:2203.05502v4](#))

2 Production made in the di-electron channels

- Allows for some comparisons with fastsim potentially

- Benefits from existing expertise

- Analysis possibly to be ported on other LLP models,

- Some events to play with. . .

HNL studies

Simulation issue

- 2 We had issues to simulate displaced vertices, HNL vertices were simulated at IP (0,0,0)
- 2 We have tried with **HEPMC2** format with MadGraph, but simulation compatible with **HEPMC3**
- 2 Madgraph is not interfaced with **HEPMC3**. Solution : generate the event (parton) with MadGraph, then run pythia standalone to produce **HEPMC3** le
 - ï Simulation of displaced vertex require status code 2 for the HNL, while it is status 22 out of pythia => script to change by hand the status in **HEPMC3**

$$m_N = 70 \text{ GeV}$$

$$m_N = 50 \text{ GeV}$$

HNL studies

Reconstruction issue

2

Reconstruction issue with CLD_o2_v05 geometry, smaller radius for first double layer in vertex detector required re-optimisation of track seeds

- Larger distance between first and second double layer caused a difficulty to extrapolate tracks to second double layer. Corrected by changing maximum distance to 0.05 in Conformal Tracking*
- CLD_o1_v04 geometry used in this HNL study

* Leonhard Reichenbach, Andre Sailer

HNL studies

Reconstruction issue

- 2 Reconstruction issue with CLD_o2_v05 geometry, smaller radius for first double layer in vertex detector required re-optimisation of track seeds
 - ï Larger distance between first and second double layer caused a difficulty to extrapolate tracks to second double layer. Corrected by changing maximum distance to 0.05 in Conformal Tracking*
 - ï CLD_o1_v04 geometry used in this HNL study
- 2 No track reconstruction is observed beyond a displacement of 100mm. Whereas, Conformal Tracking previous study with CLIC detector [arXiv:1908.00256v1](https://arxiv.org/abs/1908.00256v1) suggests a significantly effective reconstruction of displaced tracks
 - ï Attempt to re do without displaced step (step 5) in Conformal Tracking gave the same result...

0: no sel
1: ≥ 1 eⁱ
2: $= 2$ eⁱ opposite signed

* Leonhard Reichenbach, Andre Sailer

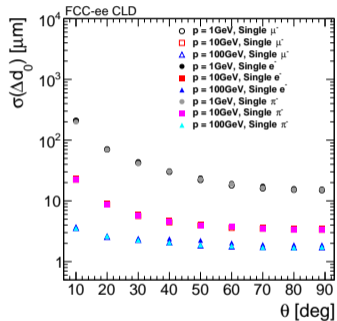
Summary & Outlook

- 2 Method to generate HNL events with correct displacement implemented and tested
- 2 Absence of reconstructed tracks after 100 mm displacement
- 2 Next steps
 - ï Debug Conformal Tracking
 - ï Study electron/track reconstruction efficiencies
 - ï Study displaced vertex reconstruction efficiency
 - ï Reproduce fast sim analysis
 - ï Study impact of tracker geometry on physics performance

Backup

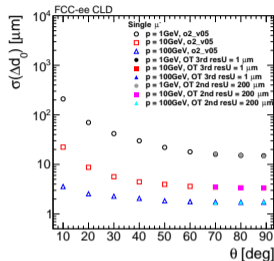
Tracking performance

Tracking for electrons and pions



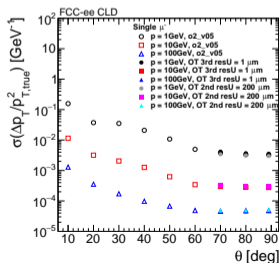
Tracking Performance

Tracker geometry – CLD_o2_v05



$$\sigma_{d_0} \approx \frac{1}{N} \sqrt{\frac{3}{4} r_A^2} \frac{1}{\sqrt{A}} \frac{1}{L_0} \frac{8r_0}{L_0} \frac{28r_0^2}{L_0^2} \frac{40r_0^3}{L_0^3} \frac{20r_0^4}{L_0^4}$$

$$\frac{\sigma_{p_T}}{p_T} \approx \frac{1}{N} \sqrt{\frac{3}{4} r_A^2} \frac{1}{\sqrt{A}} \frac{12}{0.3 B_0 L_0^2} \frac{p_T}{5}$$



- 2 p_T resolution depend mainly on lever arm
- 2 increase resolution on only one layer does not have a big effect on total resolution

