CLD Tracker and HNL studies

Jeremy Andrea, Gaelle Sadowski, Auguste Besson, Ziad El Bitar

Thanks to Leonhard Reichenbach, Andre Sailer, Juraj Smiesko

4th FCC / DRD France Workshop, November 2023

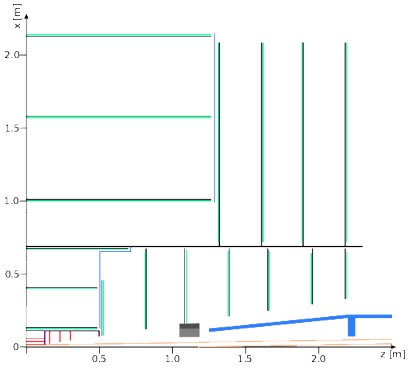
Introduction and motivation

Objectives:

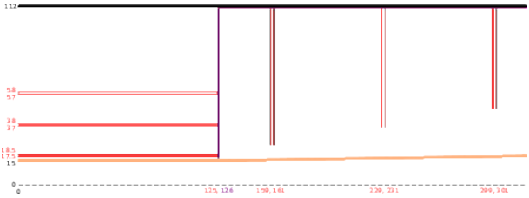
- Define different geometries and design options of Vertex Detector
- Candle for physics performance : increasing level of complexity (Tracking, Vertexing, flavour tagging, full analysis)
- Chosen approach: full simulation, for more precise results, use of CLD here.

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

CLD tracker geometry



- **Vertex Detector** with 25 μm pixels, 3 μm spatial resolution



- **Inner and Outer Silicon Tracker**, mostly 50 μm pitch strips
  - 3 short and 3 long barrel layers, 7 inner and 4 outer endcaps
  - 200 μm Silicon thickness, 50 μm × 0.3 mm cell size, 7 μm × 90 μm single point resolution (except first inner tracker disk, 5 × 5 μm^2)

More details on CLD_o1_v04 geometry CLD Paper

More information on CLD goemetries see this talk by A.Sailer

Performance plots

BeamPipe geometry – CLD_o1_v04 & CLD_o2_v05

- Difference between CLD_o1_v04 and CLD_o2_v05 = smaller BeamPipe with different material and adapted Vertex Detector

CLD_o1_v04

- BeamPipe **radius**: **15** mm
- BeamPipe **material**: Beryllium
- BeamPipe **thickness**: **1.2** mm + 5 μm gold
- **X/X0** = **0.45 %**

CLD_o2_v05

- BeamPipe **radius**: **10** mm
- BeamPipe **material**: AlBeMet 0.35 mm + paraffin 1 mm + AlBeMet 0.35 mm
- BeamPipe **thickness**: **1.7** mm + 5 μm gold
- **X/X0** = **0.61 %**

More details on CLD_o1_v04 geometry CLD Paper

More information on CLD goemetries see this talk by A.Sailer

Tracking resolution

- Simulate **particle gun** events
  - Only done with muons here, but needs to be done with electrons and pions
- Matching reconstructed tracks – simulated particle
- Calculation of resolution: $\sigma(\ \Delta = \text{reco - true})$
  - For p and pT, resolution: $\sigma(\ (\Delta = \text{reco - true}) \ / \ \text{true}^2)$

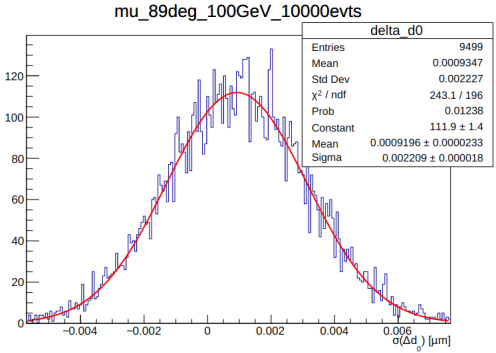


Figure: Δd0 distribution

- Calculate resolutions by changing VTX resolution
  - defined as the smearing for simulated hits with resolution VTX values (3 μm, 5 μm,...) as the Gaussian width, see code here

Performance plots

D0 resolution – single μ^- – CLD_o1_v04

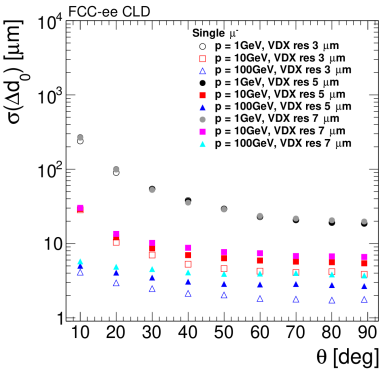


Figure: D0 resolution (10k events)

Comparison with plot made in arXiv:1911.12230v3

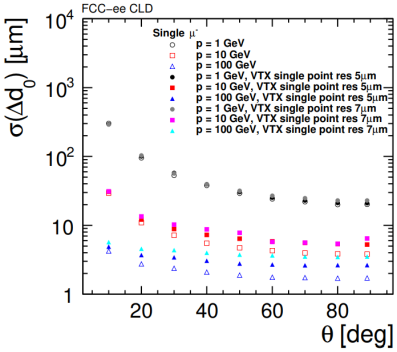
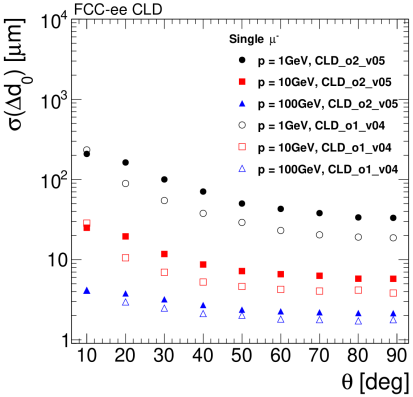


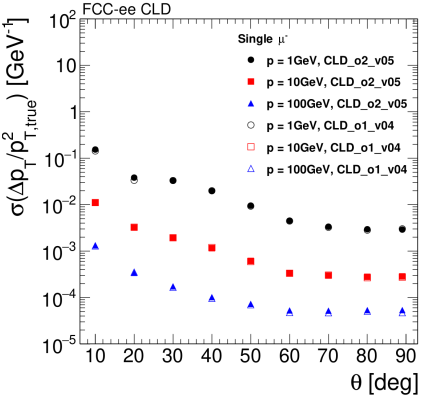
Figure: CLD paper

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

Performance plots

D0 & pT resolution – single μ^- – CLD_o1_v04 & CLD_o2_v05

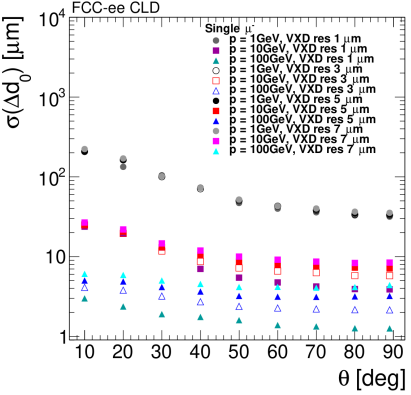


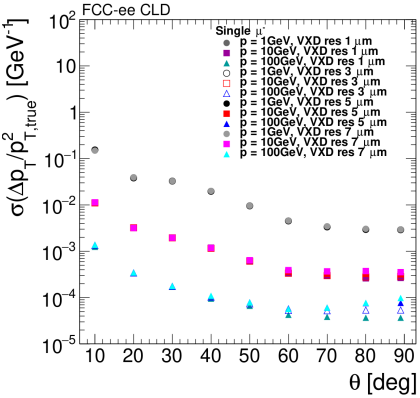


- Degradation of the d0 resolution in the new geometry observed (o2_v05), differences being investigated

Performance plots

D0 & pT resolution – single μ^- – CLD_o2_v05 (10k events)





Digitisation is currently made by smearing simulated hits with resolution values (3 μm, 5 μm,...) as the Gaussian width, see code here

Performance plots

Summary

- Study track resolution with different single point resolution and tracker (beam pipe) geometries
- Code validated by reproduced CLD paper results (geometry o1_v04)
- Also for 1 micron resolution, to test extreme case (while probably not realistic)
- Degradation of the d0 resolution in the new geometry observed (o2_v05), differences being investigated
- Need to investigate the effect of material budget

The procedure used to produce these plots:

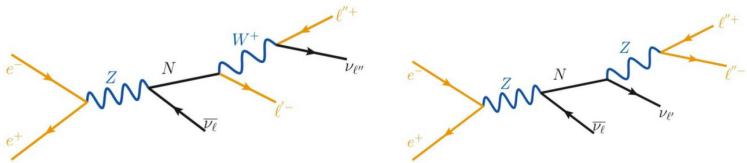
Sim & Rec

Plots

HNL studies

See talk by J.Andrea G.Sadowski

- Generation of Long Lived Particle within the Heavy Neutral Lepton model
- Inherits from FCCee paper (Alimena&al arXiv:2203.05502v4)



- Production made in the di-electron channels ($m_N = 50$ GeV)
  - 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

Selection steps

- HNL generated with **MadGraph** and simulation/Reconstruction with **CLD full simulation**
- Isolated electrons with minimum pT cuts
  - P cut 5 GeV
- Exactly two opposite signs electrons
- Di-electron invariant mass incompatible with a Z boson
  - $m_{ee} > 96$ && $m_{ee} < 86$ GeV
- Attempts for reconstruction of vertex from electron pairs
- The shape of reconstructed electron pT matched the MC distribution, while the normalisation is lower ⇒ electron reconstruction efficiency to be investigated

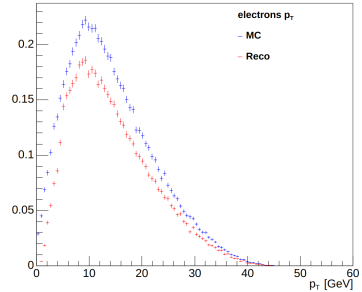


Figure: electron pT

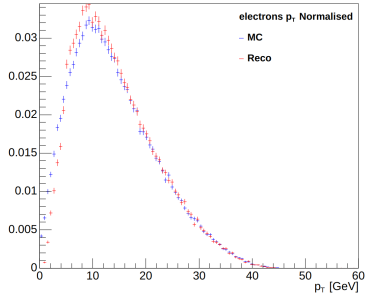


Figure: electron pT normalised

HNL studies

First results

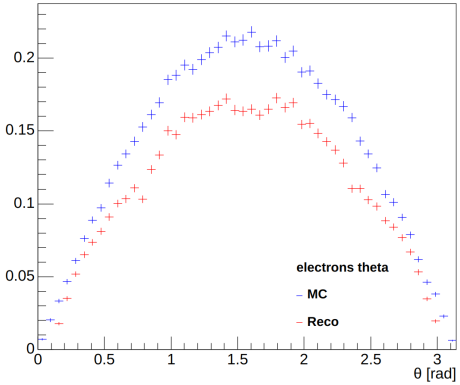


Figure: electrons theta

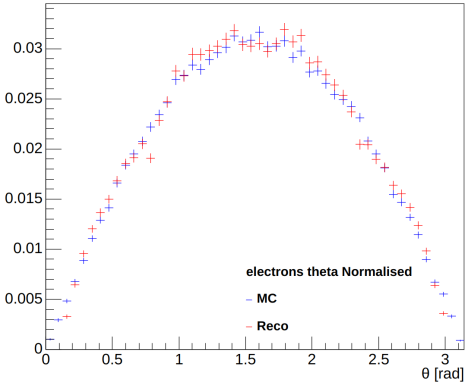


Figure: electrons theta normalised

HNL studies

First results

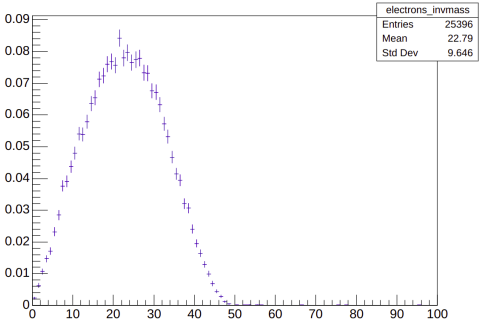


Figure: electrons invariant mass [Gev]

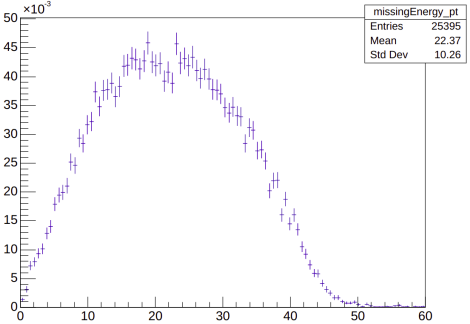


Figure: missing energy transverse [GeV]

- di-electron invariant mass and missing Et coherent with what is expected for the signal

HNL studies

Simulation issue

- We had issues to simulate displaced vertices, HNL vertices were simulated at IP (0,0,0)
- We have tried with HEPMC2 format with MadGraph, but simulation compatible with HEPMC3
- Madgraph is not interfaced with HEPMC3. **Solution :** generate lhe event (parton) with MadGraph, then run pythia standalone to produce HEPMC3 file
  - 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

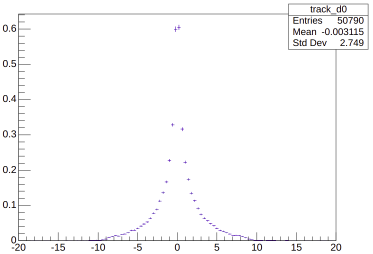


Figure: D0 electrons tracks [cm]

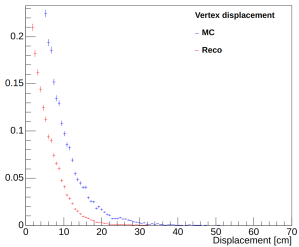


Figure: vertex displacement

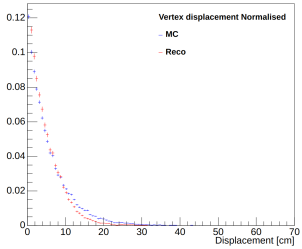


Figure: vertex displacement normalised

Summary

- Method to generate HNL events with correct displacement implemented and tested
- Degradation of the d0 resolution in the new geometry observed (o2_v05), differences being investigated
- Next steps
  - Study electron/track reconstruction efficiencies
  - Study displaced vertex reconstruction efficiency
  - Generate more signal benchmark points and backgrounds
  - Reproduce fastsim analysis
  - Study impact of tracker geometry on physics performance