# Update on CLD Tracker and HNL studies

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Thanks to Leonhard Reichenbach, Andre Sailer, Juraj Smiesko

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# 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.

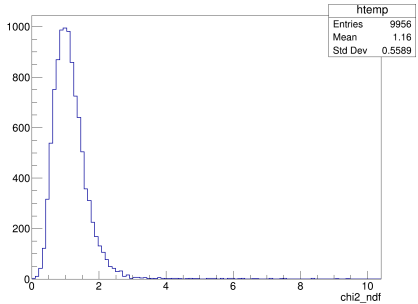
- **Outline:**
  - Update on CLD tracker studies
  - First attempts for HNL studies

# CLD geometries

- Difference between FCCee_o1_v04 and FCCee_o2_v02 = smaller BeamPipe and adapted Vertex Detector
  - ⚠ FCCee_o2_v02 geometry is bugged causing a very bad tracks reconstruction
  - CLD_o2_v05, corrected version of FCCee_o2_v02, should be used instead, but only available on nightlies for now:

    `source /cvmfs/sw-nightlies.hsf.org/key4hep/setup.sh`
- For more information on CLD goemetries see this talk by A.Sailer

- Before chi2/ndf > 10 for ≈ 50 % tracks
- New geometry gives chi2/ndf < 10 for ≈ 99 % tracks




Leonhard Reichenbach, Andre Sailer

# Performance plots

## D0 resolution – single $\mu^-$ – CLD_o1_v04

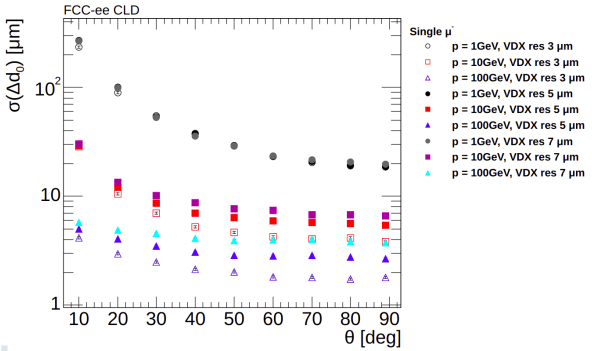



Figure: D0 resolution (10k events)

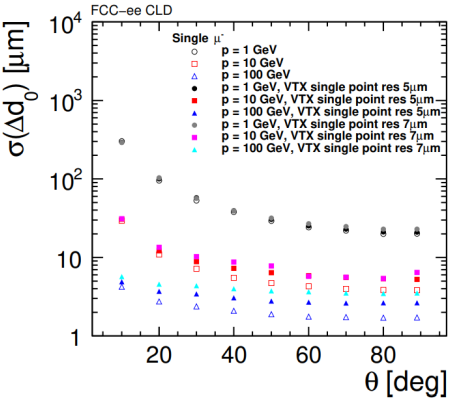



Figure: CLD paper

Comparison with plot made in arXiv:1911.12230v3

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

# Performance plots

## D0 & pT resolution – single $\mu^-$ – CLD_o2_v05 (10k events)

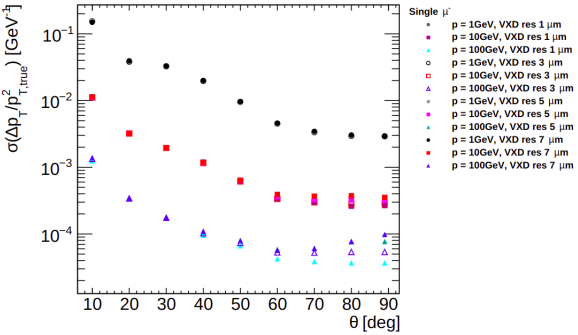



Figure: pT resolution

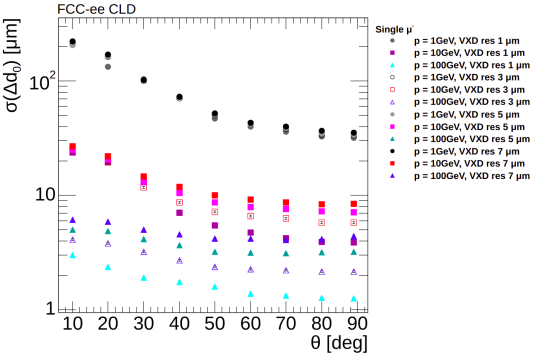



Figure: D0 resolution

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

# Performance plots

## Summary

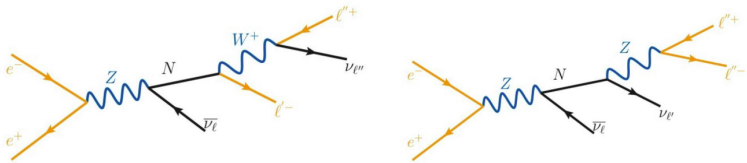
- New CLD_o2_v05 gives correct reconstructed tracks
- Test of resolution of vertex detector for the new CLD geometry
- Also for 1 micron resolution, to test extreme case (while probably not realistic).
- Still to be done : comparisons of resolution o1_V04 and o2_V05
- Effect of resolution studied, need 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

- 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

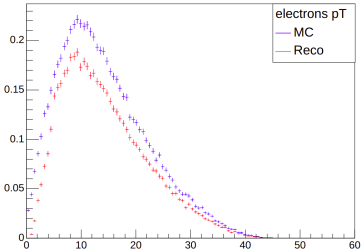



Figure: electron pT [GeV]

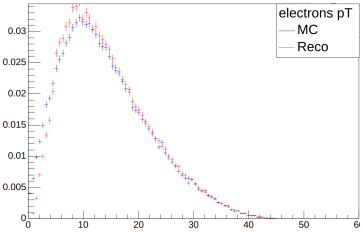



Figure: electron pT normalised [GeV]

- The shape of reconstructed electron pT matched the MC distribution, while the normalisation is lower ⇒ electron reconstruction efficiency to be investigated

# HNL studies

## First results

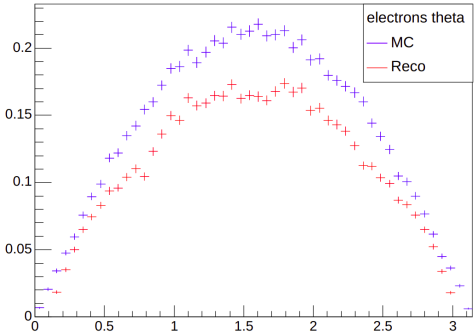



Figure: electrons theta [rad]

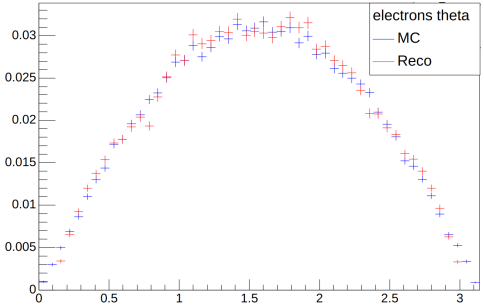



Figure: electrons theta normalised [rad]

# HNL studies

## First results

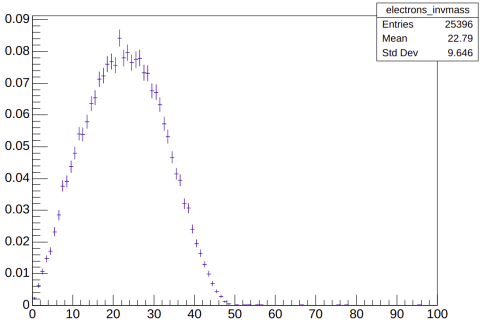



Figure: electrons invariant mass [Gev]

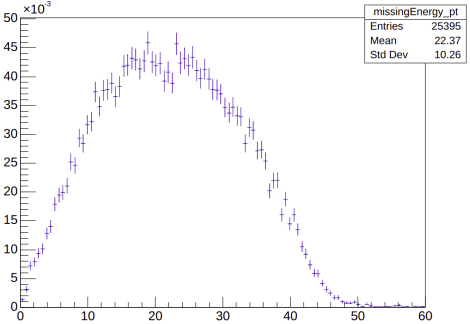



Figure: missing energy transverse [GeV]

- di-electron invariante 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), 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

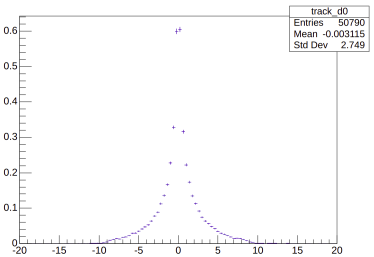



Figure: D0 electrons tracks [cm]

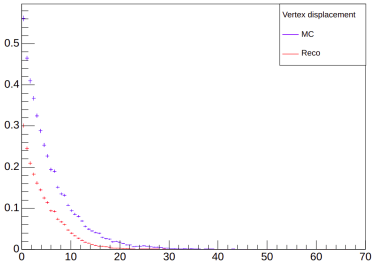



Figure: vertex displacement [cm]

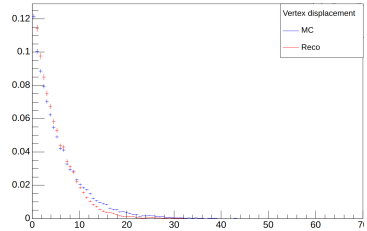



Figure: vertex displacement normalised [cm]

# Summary

- Method to generate HNL events with correct displacement implemented and tested
- New geometry o2_v05 gives better track reconstruction, allowing for proper displaced vertex reconstruction
- 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

# Backup

# K4run with EDM4Hep input available

- So far k4run was only available with LCIO input:


- It is now available with both LCIO and EDM4Hep input:
  One needs to use the new repository CLDConfig instead of the old one CLICPerformance

```
k4run CLDReconstruction.py -inputFiles outputSIM_edm4hep.root \
-filename.PodioOutput outputREC_edm4hep.root \
-n 100
```

```
k4run CLDReconstruction.py -inputFiles outputSIM.slcio \
-filename.PodioOutput outputREC_edm4hep.root \
-n 100
```

Leonhard Reichenbach, Andre Sailer, see talk