Heavy Neutral Lepton study with CLD Full Simulation

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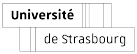
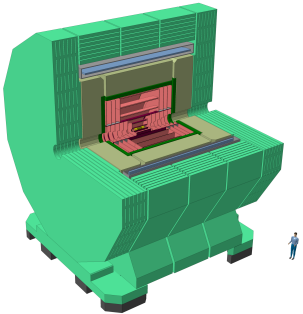
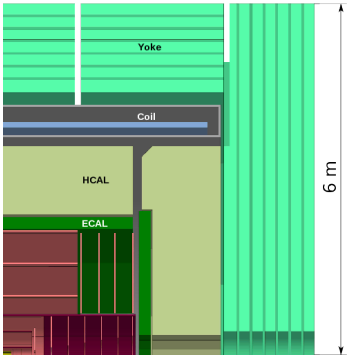
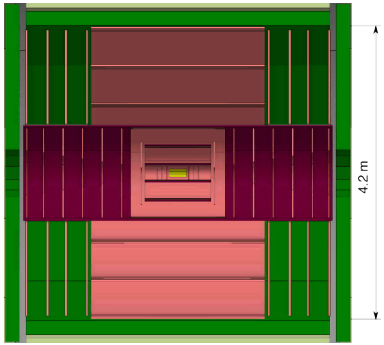


Goals

- Detector optimisation by defining different geometries for vertex and tracker
- Study detector tracking and vertexing performance for physics
- Better simulations of displaced vertices tracking with **Full Simulation**, the CLD detector is used for these studies

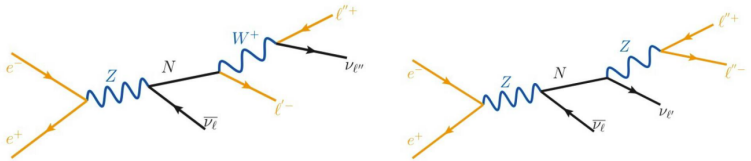






HNL study

- First attempt for physics analysis with long lived particle
  - CLD_01_v04 geometry is used, not the most recent geometry but new geometries will be tested soon
  - This analysis depends mainly on tracking
- Generation of Long Lived Particle within the Heavy Neutral Lepton model
- Reproduce the analysis from (Alimena&al arXiv:2203.05502v4) with **Full Simulation**
- Allow for FastSim / FullSim comparison
- Di-electrons channel
- The lighter the HNL particle, the longer the lifetime.



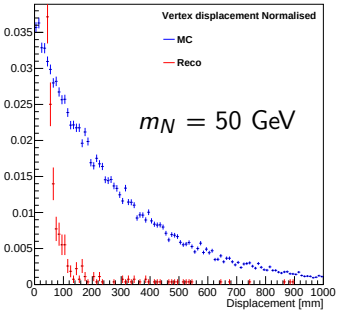
HNL study

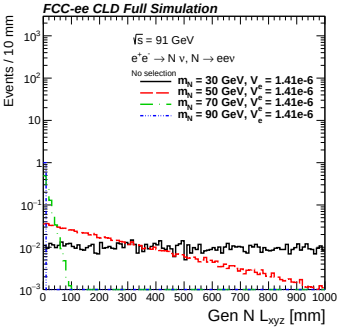
- **Object selection:**
- Gen HNL vertex r < 1500 and $|z| < 2000$, to match tracker acceptance
- Considering all reconstructed particles matched with Gen electrons ($\Delta R < 0.2$)
- Reco particles momentum > 5 GeV
- **Event selection:**
  - Exactly 2 reco particles with sum charge == 0
  - Invariant mass incompatible with a Z boson : $m > 96$ && < 86 GeV
- Vertex reconstruction with reconstructed tracks

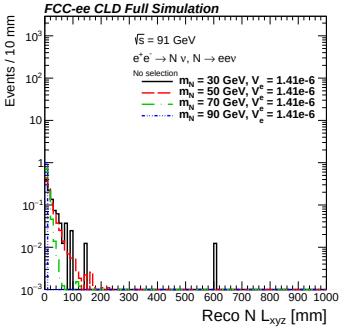
HNL study

Tracking issue for displaced tracks

- No reconstructed tracks for >10 cm displacement





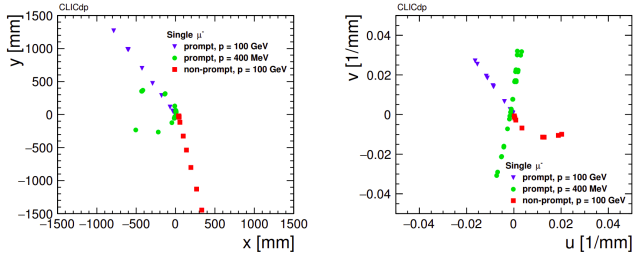


HNL study

Conformal Tracking*

- **Conformal mapping:** coordinates (x, y) in Euclidean space are converted to coordinates (u, v) in conformal space, circles passing through the origin are transformed into straight lines

$$u = \frac{x}{x^2 + y^2}, \quad v = \frac{y}{x^2 + y^2}$$



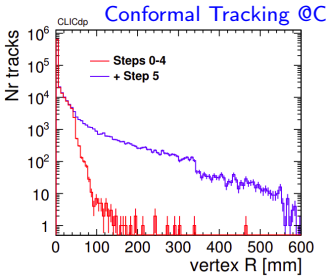
- Conformal Tracking makes hypothesis that tracks are prompt
- **Cellular Automaton Track Finding:** for pattern recognition

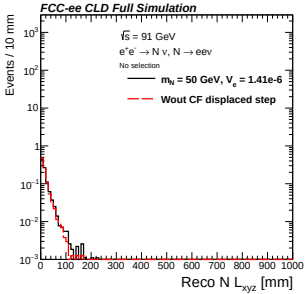
*Conformal Tracking @CLIC

HNL study

Investigation in conformal tracking

- **VXDBarrel:** build track seeds in the vertex barrel
- **VXDEndcap:** extend track seed through the vertex endcaps
- **LowerCellAngle1:** build track candidates with tight cuts for high-p_T tracks
- **LowerCellAngle2:** build track candidates with looser cuts to reconstruct low-p_T tracks
- **Tracker:** extends all existing partial tracks through the tracker
- **Displaced (step5):** build additional tracks with optimised cuts for displaced tracks from all the leftover hits





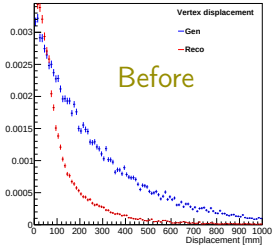
⇒ In latests reconstruction, the Step5 does not provide the expected tracking efficiency

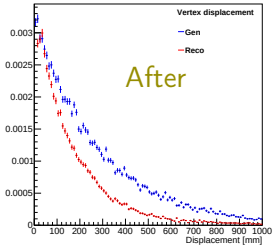
HNL study

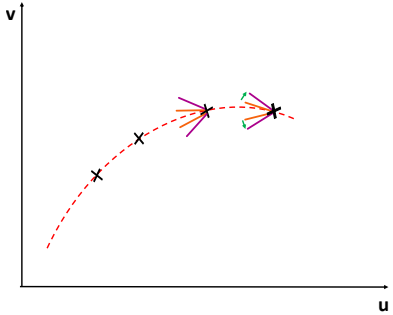
Investigation in conformal tracking

Parameters in step 5:

- **MaxCellAngle:** 0.1 ⟶ **0.5**
- **MaxCellAngleRZ:** 0.1 ⟶ **0.5**
- Chi2Cut
- MinClustersOnTrack
- MaxDistance
- SlopeZRange
- HighPTCut







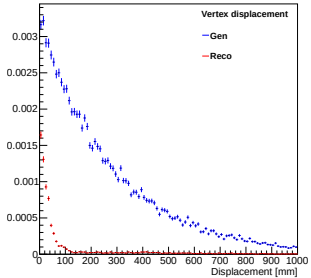
×2 vertices, window for extension to next hit was too small for the displaced step in conformal tracking [a]

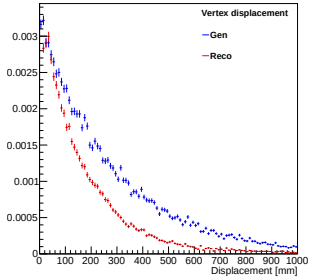
[a] The value of 0.5 was used for testing the impact of a wider window. A proper optimization is ongoing. see bug report

HNL study

Track - Cluster association issue

- Issue with electron reconstruction
  - Electrons reconstruction efficiency
    top plot → HNL vertices with reconstructed electron tracks
    bottom plot → HNL vertices with all reconstructed tracks
  - Tracks are present
  - Pandora particles are mainly photons
    ⇒ e^- are not reconstructed properly
  - Issue also observed for prompt tracks CLDConfig/issues/43





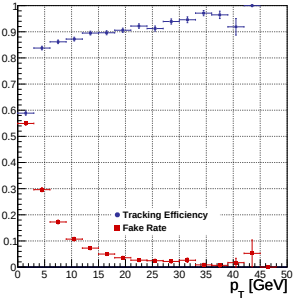
HNL study

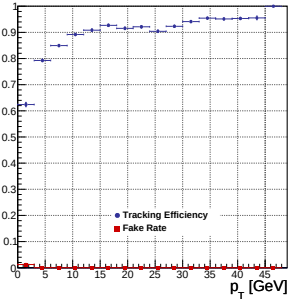
Tracking Efficiency

Tracking Efficiency defined as $\frac{GenElectronsMatched2Tracks}{AllGenElectrons}$
Fake Rate defined as $\frac{TracksNotMatched}{AllRecoElectrons}$

- Tracking Efficiency and Fake Rate for $Z \rightarrow \tau\tau$
  - Good tracking efficiency but high fake rate at low p_T
  - No cut applied
  - need to investigate

- Tracking Efficiency and Fake Rate for **HNL** $m_N = 90$ **GeV**
  - Good tracking efficiency and low fake rate





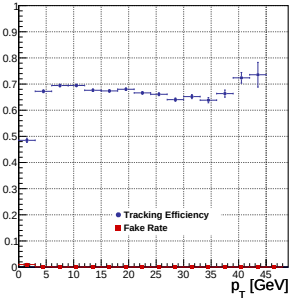
HNL study

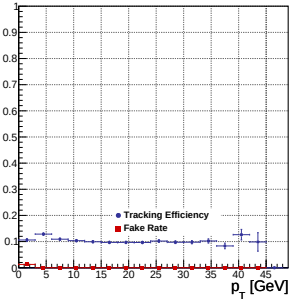
Tracking Efficiency

Tracking Efficiency defined as $\frac{GenElectronsMatched2Tracks}{AllGenElectrons}$

Fake Rate defined as $\frac{TracksNotMatched}{AllRecoElectrons}$

- Tracking Efficiency and Fake Rate for **HNL** $m_N = 70$ **GeV**
  - Lower efficiency compared to 90 GeV
- Tracking Efficiency and Fake Rate for **HNL** $m_N = 50$ **GeV**
  - The more vertices are displaced, the lower the efficiency

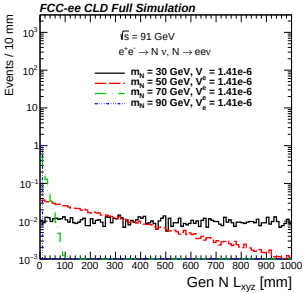


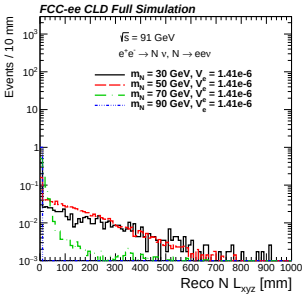


HNL study

Analysis (considering all reconstructed tracks)

- Reconstructed vertices up to 600 mm displacement, as expected from Conformal Tracking paper

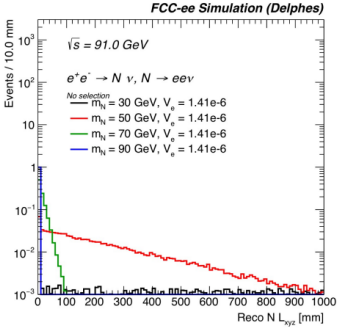


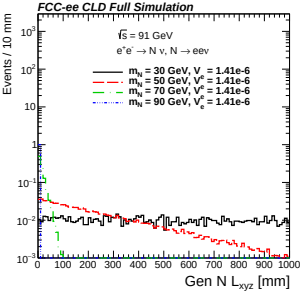


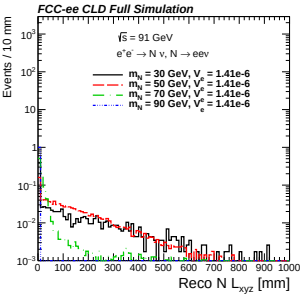
HNL study

Analysis (considering all reconstructed tracks) – Comparison with Delphes

- Delphes does not take tracking efficiency for displaced vertices into account







HNL study

Conclusion

- Displaced tracks are now correctly reconstructed
  - Further optimisation is required, for busier events
- Tracks are not associated to clusters
  - Need to investigate
- Next steps
  - Study displaced tracks/vertex reconstruction efficiency
  - Generate more signal benchmark points and backgrounds
  - Study impact of tracker geometry on physics performance