

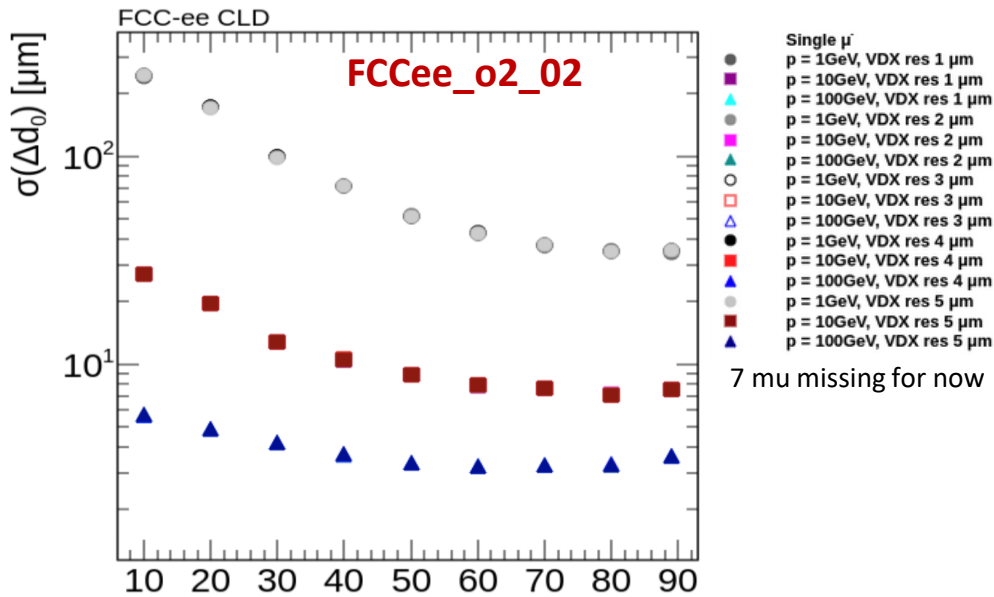
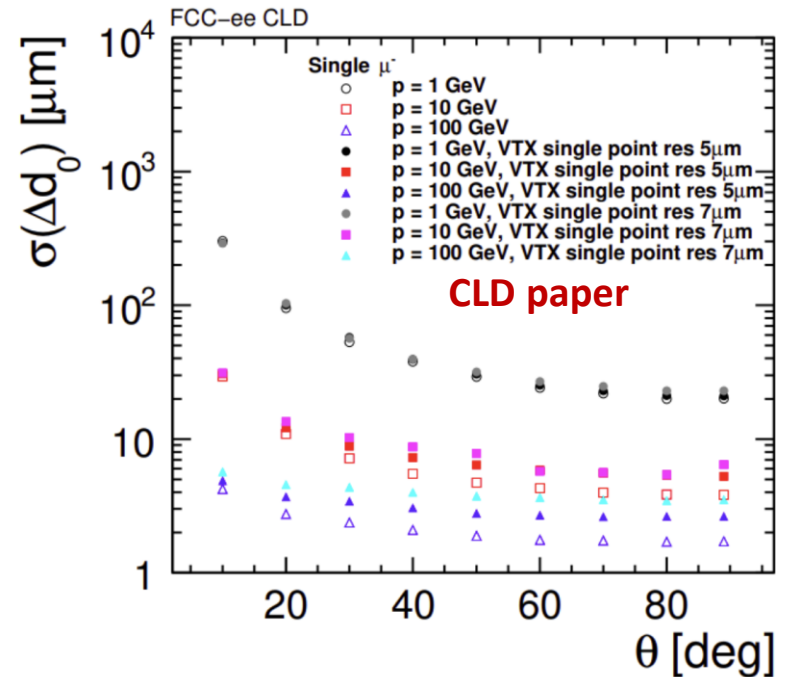
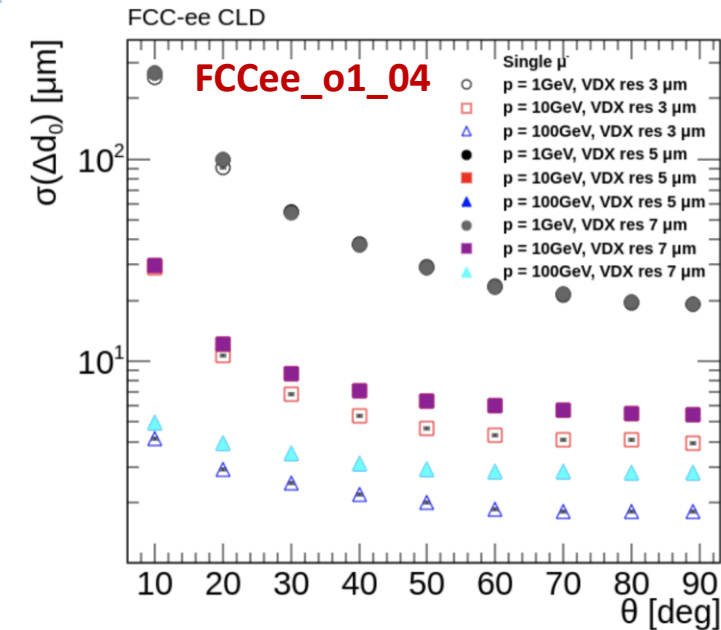
First test of Heavy Neutral Lepton fullsim with CLD

(and update on tracking resolution)

Jeremy Andrea, Auguste Besson, Ziad El Bitar, Gaelle Sadowski,
(IPHC, CNRS, Strasbourg)

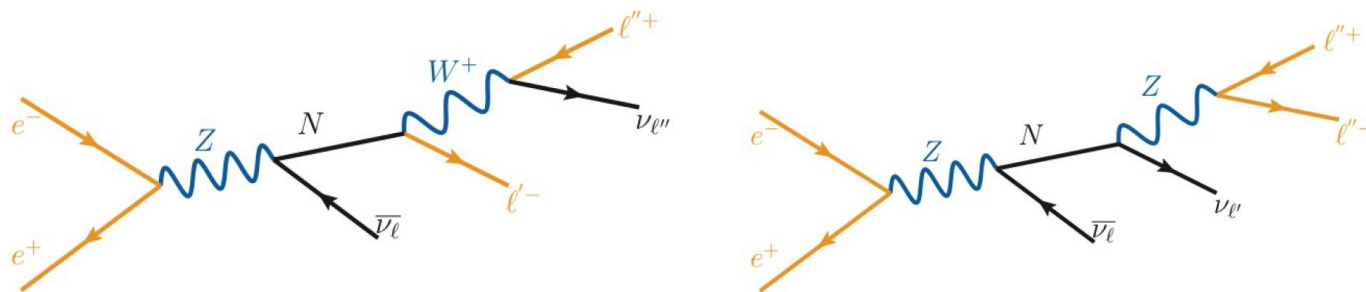
Thanks to Andre, Briec, Juliette, Juraj, Leonhard !

- **Motivations** : Optimisation of CLD tracker geometry and resolution.
- **Change of designs of the tracker, and estimate the impact on detector performances using 2 different approaches** :
 - Study of “objects” resolutions : tracking, vertexing, flavour tagging,
 - Physics performances from a physics case => long lived particles.
- **All based on full-simulation.**
- **Outline** :
 - Tracking performance => update,
 - Full simulation of Heavy Neutral Lepton (HNL) => firsts results.



- Good agreements of current results with CLD paper for geometry o1_04.
- Effects of changing sensor resolution
 - from 5 to 7 microns clearly visible,
 - Changes from 5 to 3 visible in CLD paper,
 - No visible differences below 5 microns for the current results.
- Some more investigation required³.

- Generation of Long Lived Particle within the HNL model.
- Inherits from FCCee paper (Alimena&al [arXiv:2203.05502v4](https://arxiv.org/abs/2203.05502v4)).

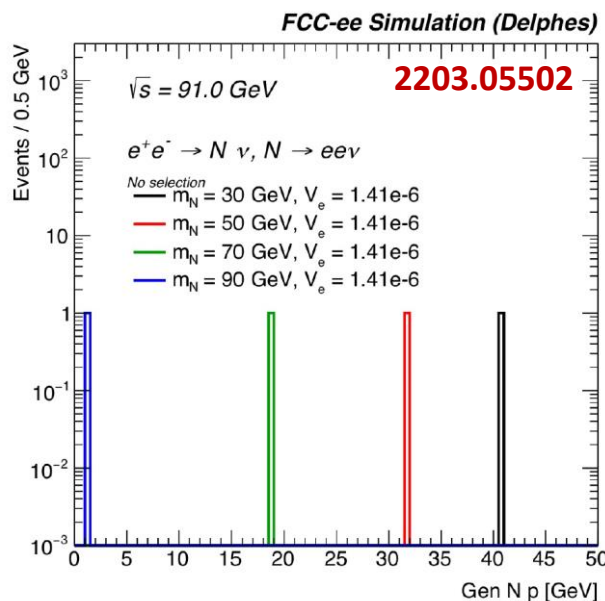
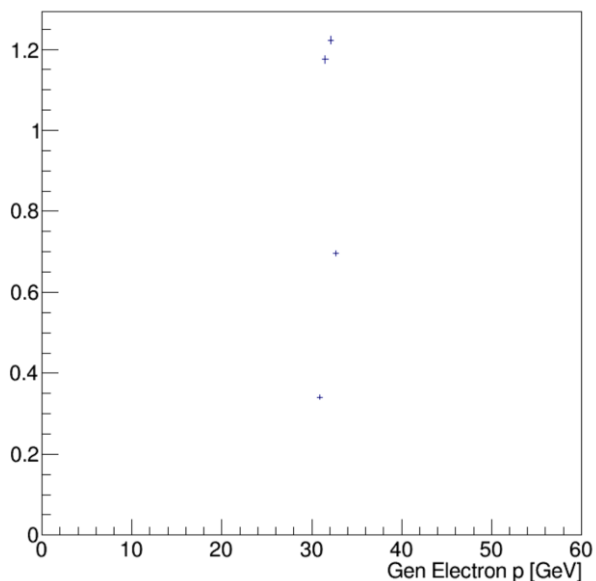
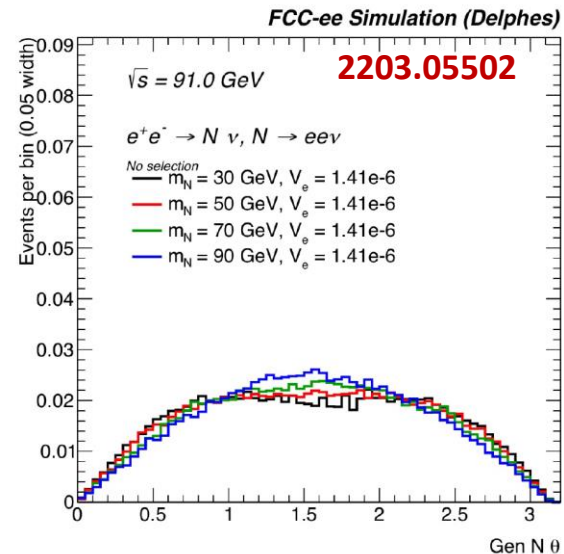
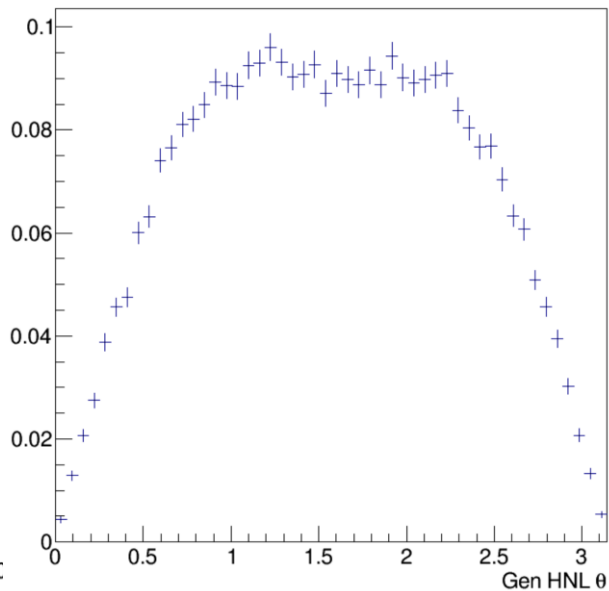
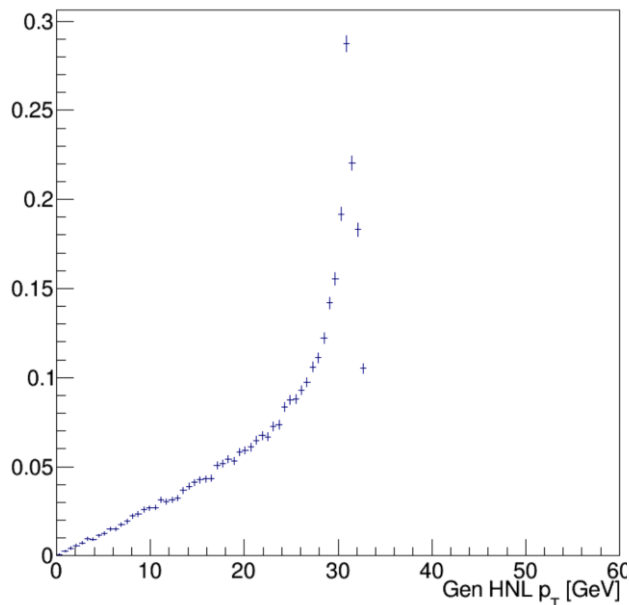


- Production made in the di-electron channels ($m_N = 50 \text{ GeV}$).
 - Allows for some comparisons with fastsim potentially,
 - Benefits from existing expertise,
 - Analysis possibly to be ported on other LLP models,
 - Some events to play with ...

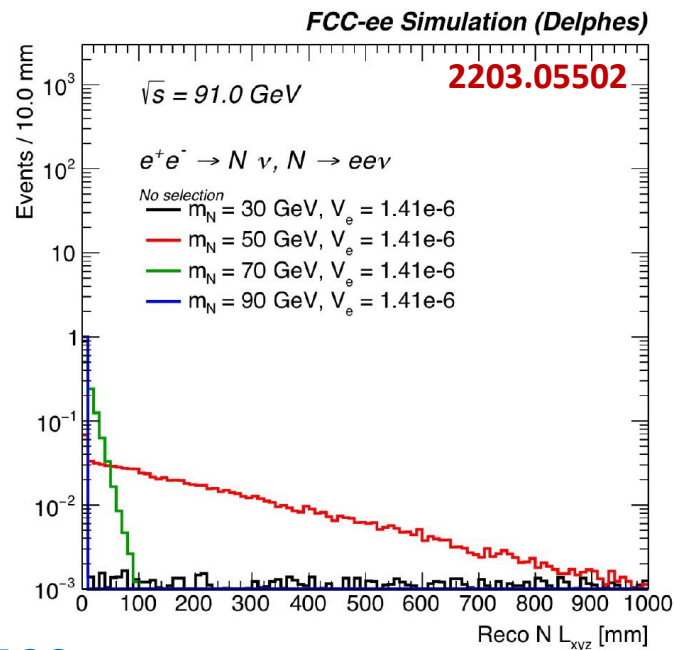
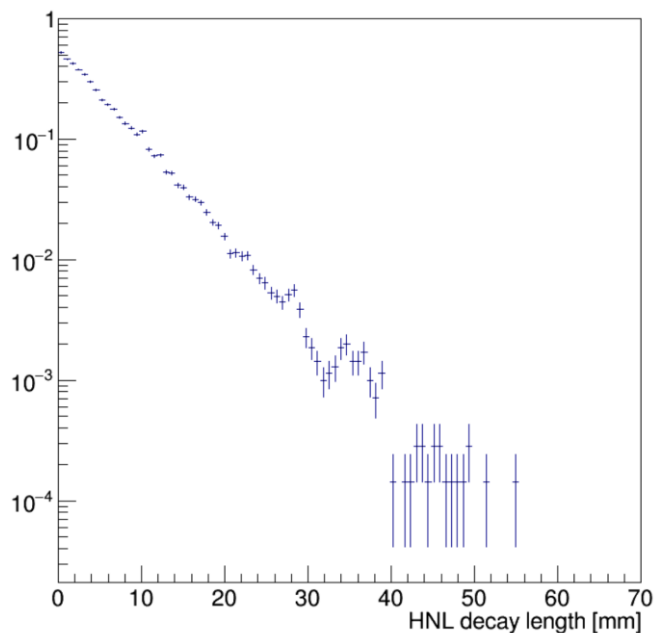
- **Generation of 50k events** in the hepMC format (using madgraph with hadronization, ISR and Parton Shower from Pythia8).
- At the Z mass energy. No beam energy spread, no beam backgrounds. How does it has to be handled at Sim level ?
- **Does Geant4 treat LLP properly “out of the box” ?**
 - Has the LLP time life to be added to Geant4 in a way or another ?
- **Follow same recipe as FCCee HNL paper :**
 - Link to the madgraph card [[link](#)],
 - Link to the madgraph HNL model [[link](#)],
 - Link to the latests madgraph version [[link](#)].

- Production made with ddsim with condor @CERN.
- Script (*ProdSim4Physics.py*) and descriptions available here [[link](#)].
 - Creates on directory with .sh script and condor config,
 - Runs from ddsim from “SkipEvents” to “SkipEvents+NEventsPerJob”,
 - Version : sw-nightlies,
 - Geometry : FCCee_o2_v02.xml,
 - Copy output files on configurable directory.
- Same approach for reconstruction (*ProdReco4Physics.py*).
- Some observations :
 - Some condor jobs (~1-2%) fails with strange error :
 - condor_exec.exe: line 2: /cvmfs/sw-nightlies.hsf.org/key4hep/setup.sh: No such file or directory
 - File content different from particle gun production used for tracking resolution studies.
 - Example “SiTrack_Refitted_1” does not exist (type TrackStates). “SiTrack_Refitted” exists, but seems to be of type TrackData ?
 - Collection names changed in sw-nightlies ?
 - edm4hep2json does not provide any useful information (just edm4hep version...).

- **Hepmc** : /eos/home-j/jandrea/SampleFCCee_HNL/HNL_50_v2/tag_1_pythia8_events.hepmc
- **Fullsim (slcio)** : /eos/home-j/jandrea/SampleFCCee_HNL/HNL_50_v2/
- **Reco (root)** : /eos/home-j/jandrea/SampleFCCee_HNL/_HNL_50_v2_RECO_EDM4Hep
- Proto-analysis implemented in FCCAnalysis [[link](#)].
- Background production ongoing, but stuck with eos space quotas.



- “visual” good agreement between new production and 2203.05502.

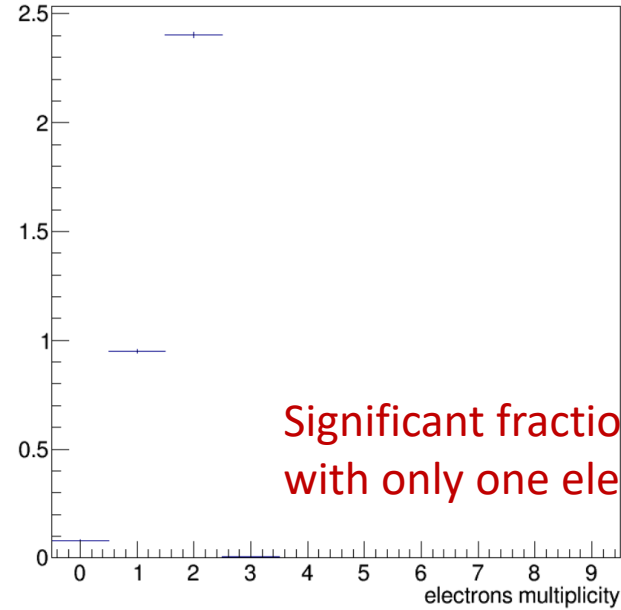
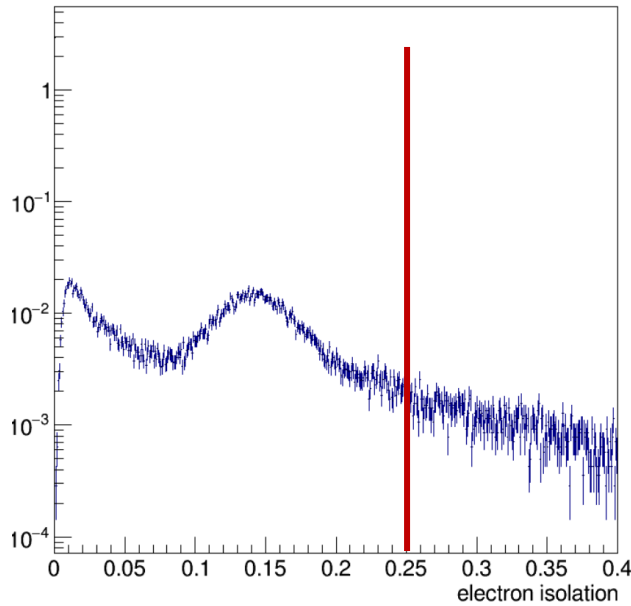
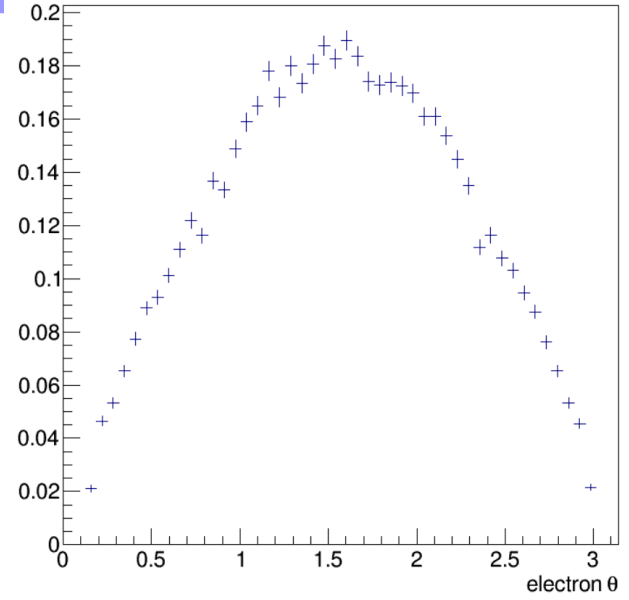
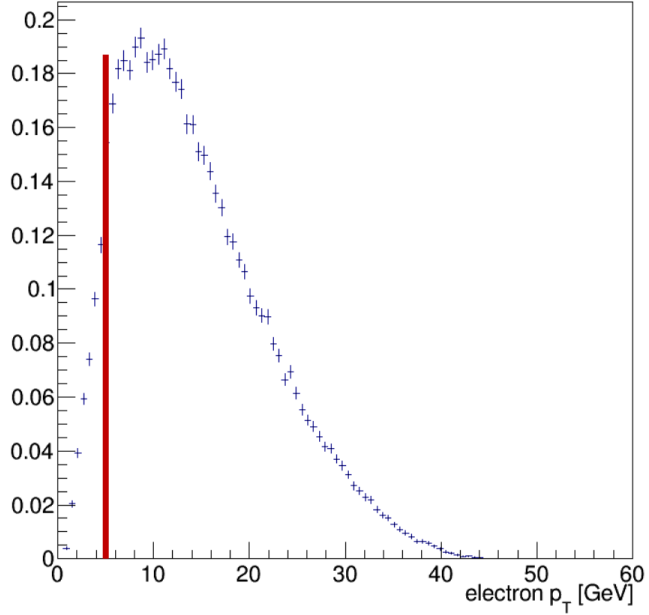


- Decay length does not match 2203.05502.

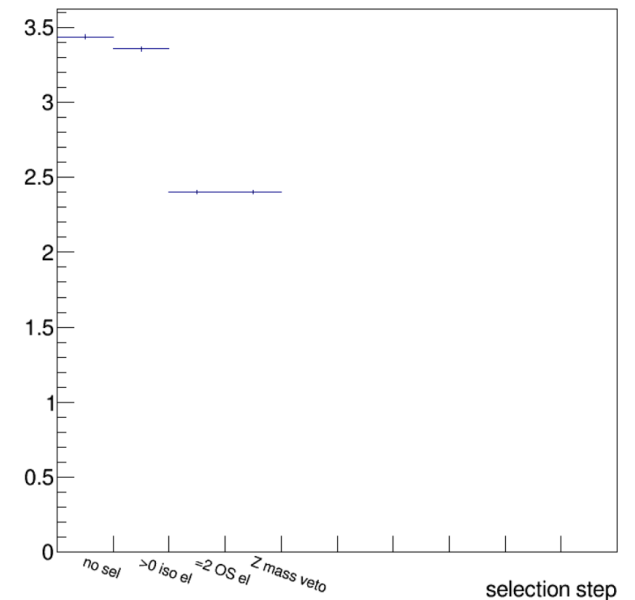
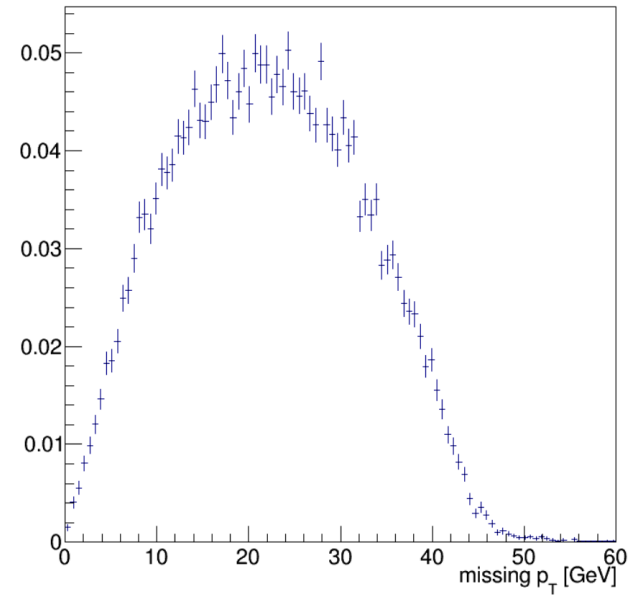
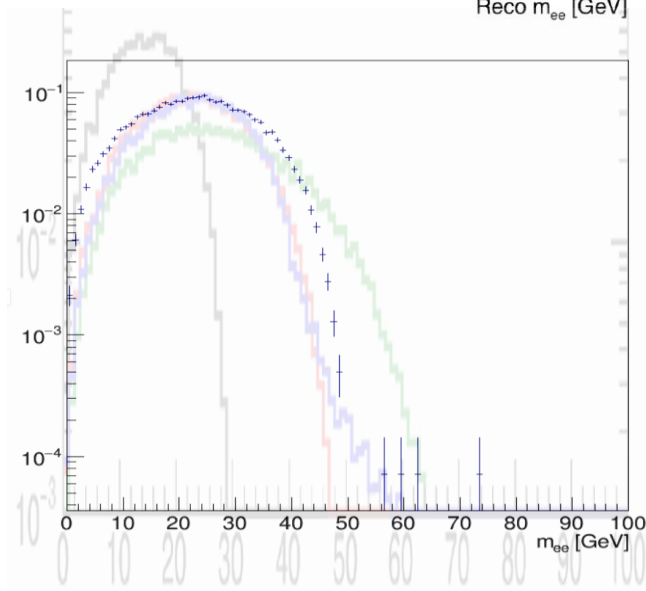
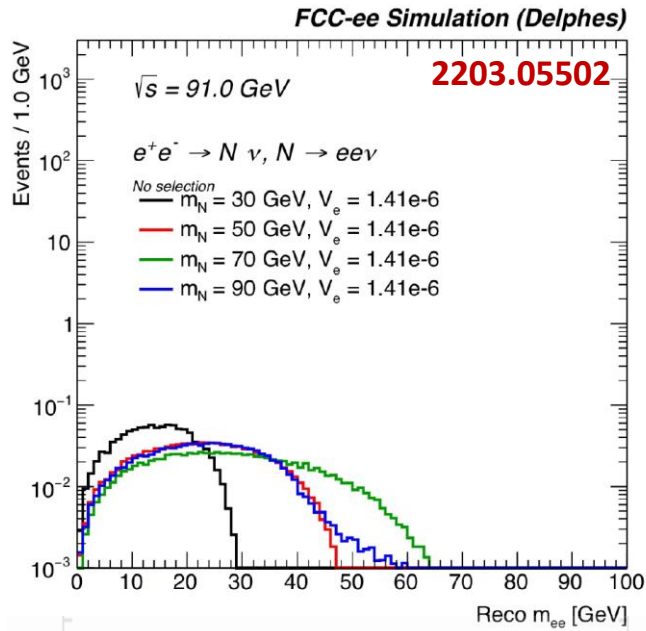
- Possible explanation : generation made with mixing angle of $1.e^{-5}$ instead of $1.41e^{-6}$.
- But the shape seems correct.
- Decay vertex position vertex position of electrons with gen status code of 23.
- Need an example of how to check the PDG ID of the parent particle. How to get MCParticle parent indices in :

```
int get_lepton_origin(const edm4hep::MCParticleData &p,
                    const ROOT::VecOps::RVec<edm4hep::MCParticleData> &in,
                    const ROOT::VecOps::RVec<int> &ind);
```

- Selection steps :
 1. Isolated electrons with minimum p_T cuts.
 - From “PandoraPFOs” of type “ReconstructedParticle”,
 - Isolation definition from tutorial ([link](#)),
 - For now, loose p cut 5 GeV,
 - For now, no veto on other lepton flavour nor jets.
 2. Exactly two opposite signs electrons.
 3. Di-electron invariant mass incompatible with a Z boson : $m_{ee} > 96 \text{ \&\& } < 86 \text{ GeV}$.
 4. Missing $p_T > 15 \text{ GeV}$ => Filtering does not work, needs debugging.
 5. Attempts for reconstruction of vertex from electron pairs.



Significant fraction of events
with only one electron



- Track resolutions, comparisons with different detector resolution requires more investigation => no apparent effects of a change of vertex detector resolution below 5 microns.
- First attempt for the fullsim HNL events production with the CLD detector.
- Learning phase : generation, simulation and FCCAnalysis.
 - genParticle level seems to show meaningful distributions,
 - Generation with different mixing angle and masses to be done,
 - recoParticle level seems to show meaningful distributions,
 - FCCAnalysis framework seem to provide all is needed for the analysis.
- Some difficulties however:
 - In the determination of which branch corresponds to what objects in the tree. We progress groping, not being 100% certain of what we do sometime.
 - Code is sometime self-explaining, sometime it is not. Not always possible nor easy to find examples.
- Next steps :
 - Continue investigating track resolution,
 - Generations of more signal benchmark points and backgrounds,
 - See how to add BES, BS and beam backgrounds into the generation/simulation,
 - Tests displaced vertex reconstruction. First attempts with VertexFitterSimple provide vertices without displacement => convergence issues and/or no displacement after Geant4 ?

backups

