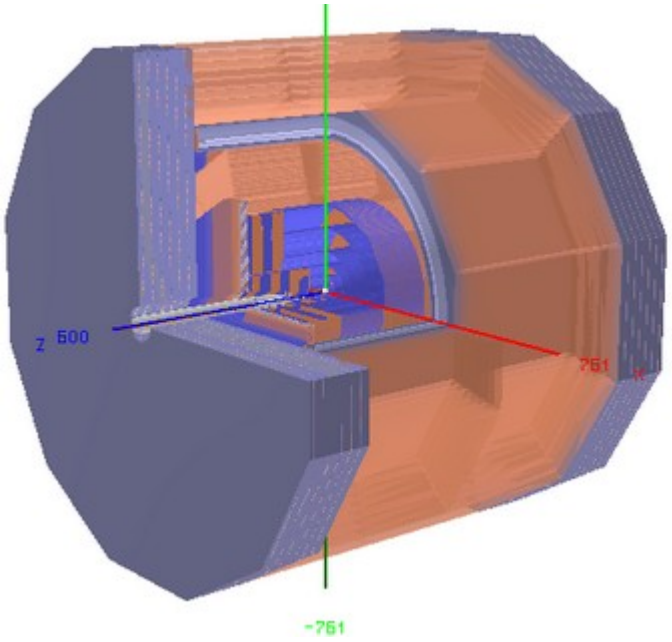
Full and fast simulations of the CLD detector concept and its future improvement

September 23, 2024

S.Chekanov, A.Paramonov, J.Zhang

ANL, USA



Introduction

About the group

Long standing expertise on collider experiments like ZEUS, CDF and ATLAS, experience and facility for silicon detector, calorimetry, electronics, TDAQ, software and computing.

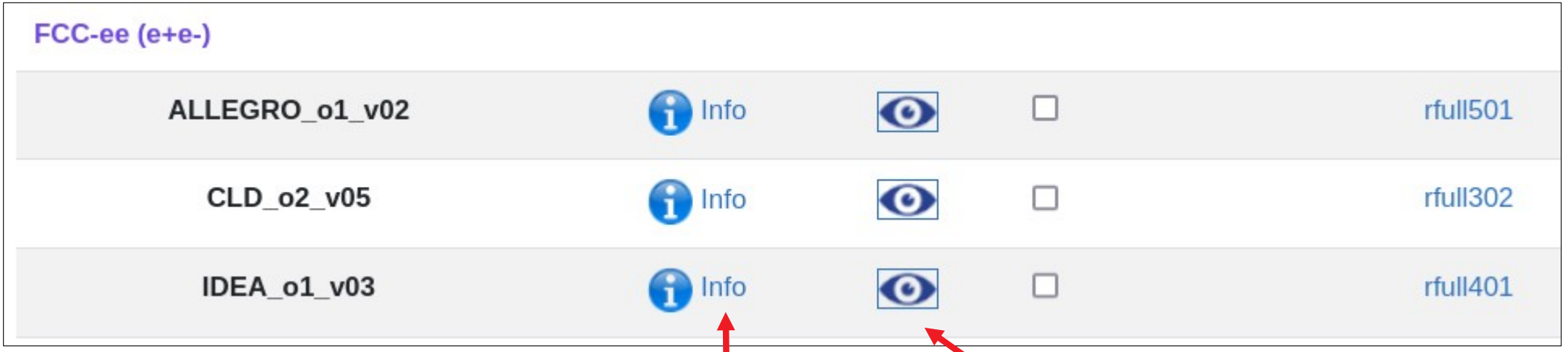
Contributions to TESLA, ILC, CLIC and FCC-hh conceptual designs, work on MC simulations, physics, tracking, calorimetry and TDAQ

Motivation

- Verify performance of the CLD_o2_v05 detector using Geant4 sim/rec
- Focus on tracking resolution, detector response at Z peak
- Verify the recent simulation/reconstruction using key4hep
- Compare with initial Delphes simulation (v3.5 using IDEA cards)
  - Calculate the Z-boson line shape & tracking resolutions
- Tune Delphes simulations and develop CLD-Delphes card
- Future: Help producing a TPC version of tracking

CLD_o2_v05 integration with HepSim

- CLD, Alegro, IDEA were integrated in HepSim together with detectors from ILC, CLIC etc. https://atlaswww.hep.anl.gov/hepsim/detectors.php



explore compact XML files

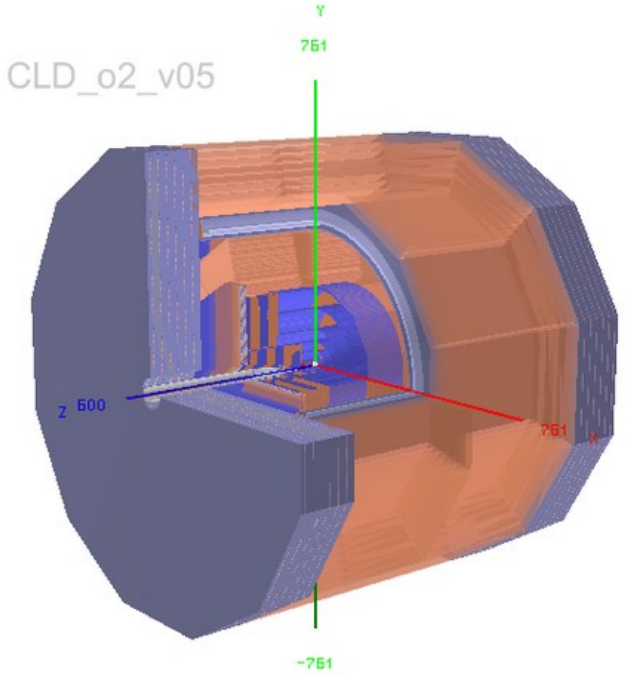
Visualize in interactive 3D viewers compact

CLD_o2_v05 integration with HepSim

https://atlaswww.hep.anl.gov/hepsim/detectorinfo.php?id=CLD_o2_v05

Summary

Name:	*CLD_o2_v05*
Title:	*FCCee detector model option 2 version 05 (updated Beampipe and VXD)*
Author:	*Andre Sailer*
Status:	*development*
Version:	*5*
Level:	Geant4 simulation and full event reconstruction
Summary:	view
3D View:	
GeoManager:	
Last modified:	July 01, 2024



Reconstruction tags

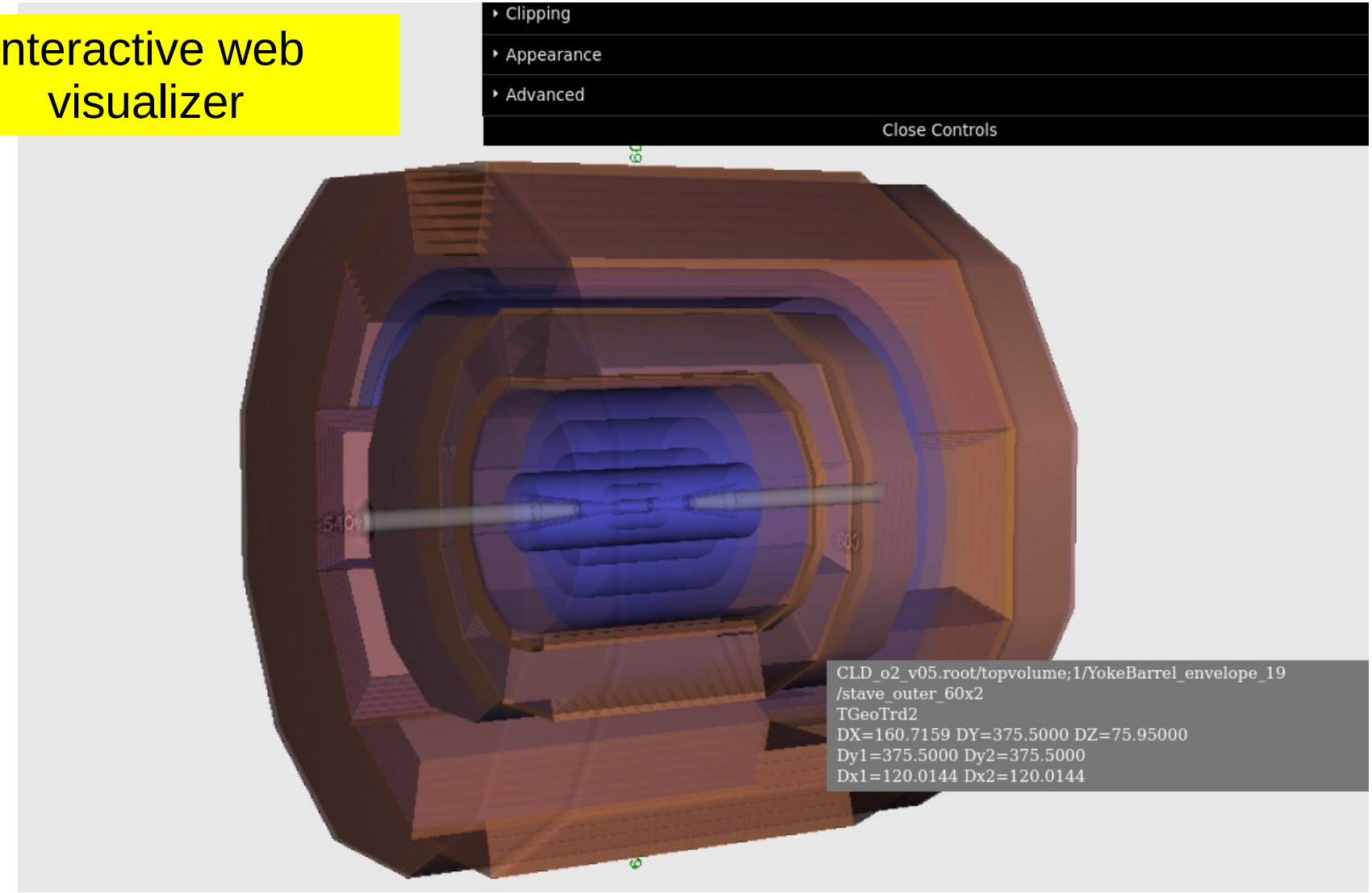
Tag lists: rfull302

Use for visual inspection in 3D

CLD_o2_v05 integration with HepSim

https://atlaswww.hep.anl.gov/hepsim/viewdet.php?det=CLD_o2_v05

Interactive web visualizer



Creating Monte Carlo event samples

- Created truth-level samples at 91 GeV using Pythia8:
  - Z→ all; Z→ e+e-; Z→mu+ mu- (~1 M events)
- Create EDM Geant4 simulations using Key4hep of a fraction of truth events:
  - Uses /cvmfs/sw-nightlies.hsf.org/key4hep/setup.sh -r **2024-08-01**
  - Geometry: CLD_o2_v05
- Create EDM Delphes fast simulation using the card for the IDEA detector (initial dummy for further modifications for CLD)
- Truth level, full simulations and fast simulations are registered in HepSim and available for downloads:

Searching for: **91gev**
Found 3 results

	Dataset Name	Generator	Description	EVGEN	Fast simulation	Full simulation
1	gev91ee_pythia8	PYTHIA8	Info	URL	rfast302 (info)	rfull302 (info)
2	gev91ee_pythia8_ee	PYTHIA8	Info	URL	rfast302 (info)	rfull302 (info)
3	gev91ee_pythia8_mm	PYTHIA8	Info	URL	rfast302 (info)	rfull302 (info)

https://atlaswww.hep.anl.gov/hepsim/

Files with Geant4 and Delphes simulations

https://atlaswww.hep.anl.gov/hepsim/info.php?item=381

Dataset: gev91ee_pythia8_mm%rfull302

https://mc.hep.anl.gov/asc/hepsim/events/ee/91gev/pythia8_91gev_mm/rfull302

Download: hs-get gev91ee_pythia8_mm%rfull302

	File name	Size
1	gev91ee_zboson_mm_001_CLD_RECO_edm4hep.root	50.27 MB
2	gev91ee_zboson_mm_002_CLD_RECO_edm4hep.root	51.8 MB
3	gev91ee_zboson_mm_003_CLD_RECO_edm4hep.root	51.52 MB
4	gev91ee_zboson_mm_004_CLD_RECO_edm4hep.root	51.93 MB
5	gev91ee_zboson_mm_005_CLD_RECO_edm4hep.root	52.14 MB
6	gev91ee_zboson_mm_006_CLD_RECO_edm4hep.root	50.99 MB
7	gev91ee_zboson_mm_007_CLD_RECO_edm4hep.root	49.16 MB
8	gev91ee_zboson_mm_008_CLD_RECO_edm4hep.root	50.48 MB
9	gev91ee_zboson_mm_009_CLD_RECO_edm4hep.root	51.17 MB
10	gev91ee_zboson_mm_010_CLD_RECO_edm4hep.root	53.73 MB
11	gev91ee_zboson_mm_011_CLD_RECO_edm4hep.root	47.98 MB
12	gev91ee_zboson_mm_012_CLD_RECO_edm4hep.root	53.7 MB
13	gev91ee_zboson_mm_013_CLD_RECO_edm4hep.root	51.49 MB
14	gev91ee_zboson_mm_014_CLD_RECO_edm4hep.root	52.65 MB
15	gev91ee_zboson_mm_015_CLD_RECO_edm4hep.root	48.23 MB

Dataset: gev91ee_pythia8_mm%rfast302

https://mc.hep.anl.gov/asc/hepsim/events/ee/91gev/pythia8_91gev_mm/rfast302

Download: hs-get gev91ee_pythia8_mm%rfast302

	File name	Size
1	gev91ee_zboson_mm_001_delphesCLD_EDM.root	73.78 MB
2	gev91ee_zboson_mm_002_delphesCLD_EDM.root	73.65 MB
3	gev91ee_zboson_mm_003_delphesCLD_EDM.root	73.66 MB
4	gev91ee_zboson_mm_004_delphesCLD_EDM.root	73.69 MB
5	gev91ee_zboson_mm_005_delphesCLD_EDM.root	73.72 MB
6	gev91ee_zboson_mm_006_delphesCLD_EDM.root	73.65 MB
7	gev91ee_zboson_mm_007_delphesCLD_EDM.root	73.62 MB
8	gev91ee_zboson_mm_008_delphesCLD_EDM.root	73.52 MB
9	gev91ee_zboson_mm_009_delphesCLD_EDM.root	73.64 MB
10	gev91ee_zboson_mm_010_delphesCLD_EDM.root	73.75 MB
		0.719 GB

Some bugs in **k4SimDelphes** haves been reported (DelphesROOT_EDM4HEP)
Does not start the loop! Fixed by Thomas Madlener

Basic studies: Full vs Fast simulations

C++ analysis code: https://github.com/chekanov/FCCPana Runs on full & fast simulations and creates invariant masses. Selections: pT>0.1 GeV, |y|<2.5

Full (Geant4) simulation:

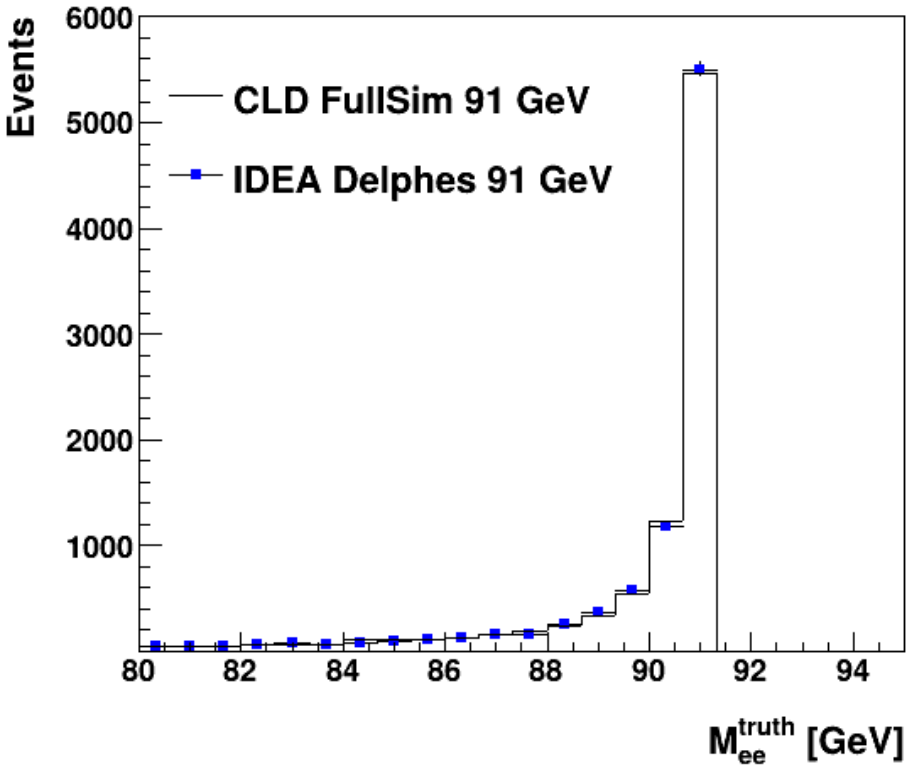
- Use **"PandoraPFOs_"** from EDM and find identified electrons & muons
- Analyzer's high-end variable (more complex than just tracks), but more relevant for final physics analysis. "Tracks" are not available in final EDM (?)
- pass Tight selection
- Require charge (tracking information)
- Require opposite charge for invariant masses

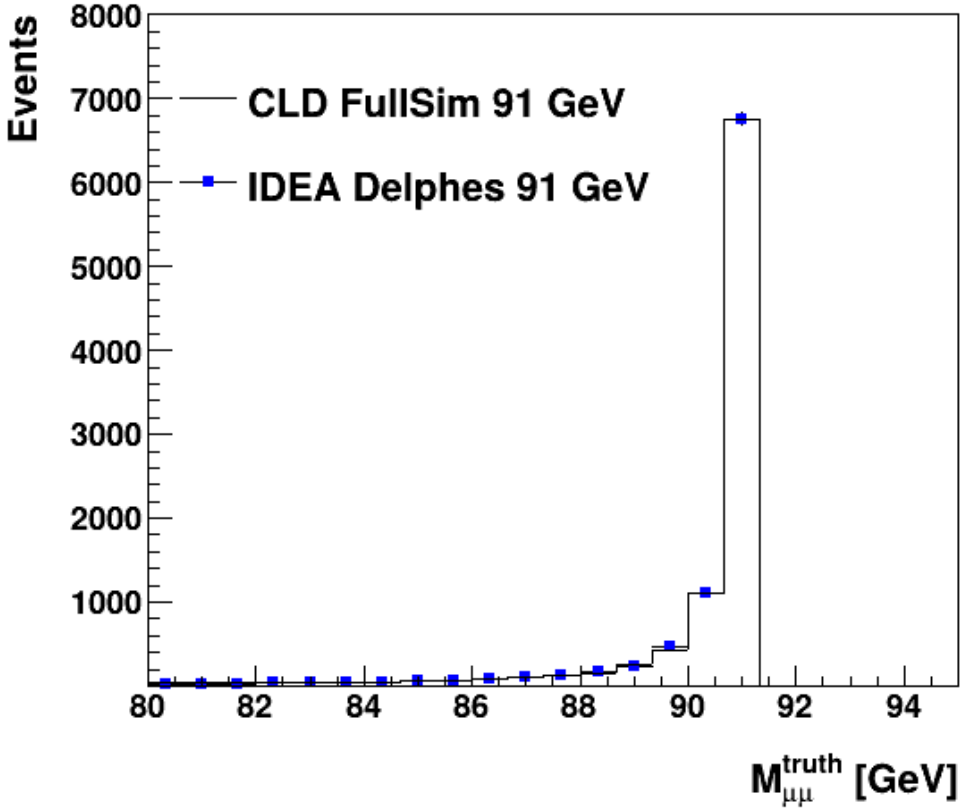
Fast (Delphes) simulations:

- Use **"*ReconstructedParticles*_"** from EDM and find identified electrons & muons
- Require charge (tracking information)
- Require opposite charge for invariant masses

Z line shape studies: Truth-level particles

C++ analysis code: https://github.com/chekanov/FCCPana
Runs on full & fast simulations and creates invariant masses

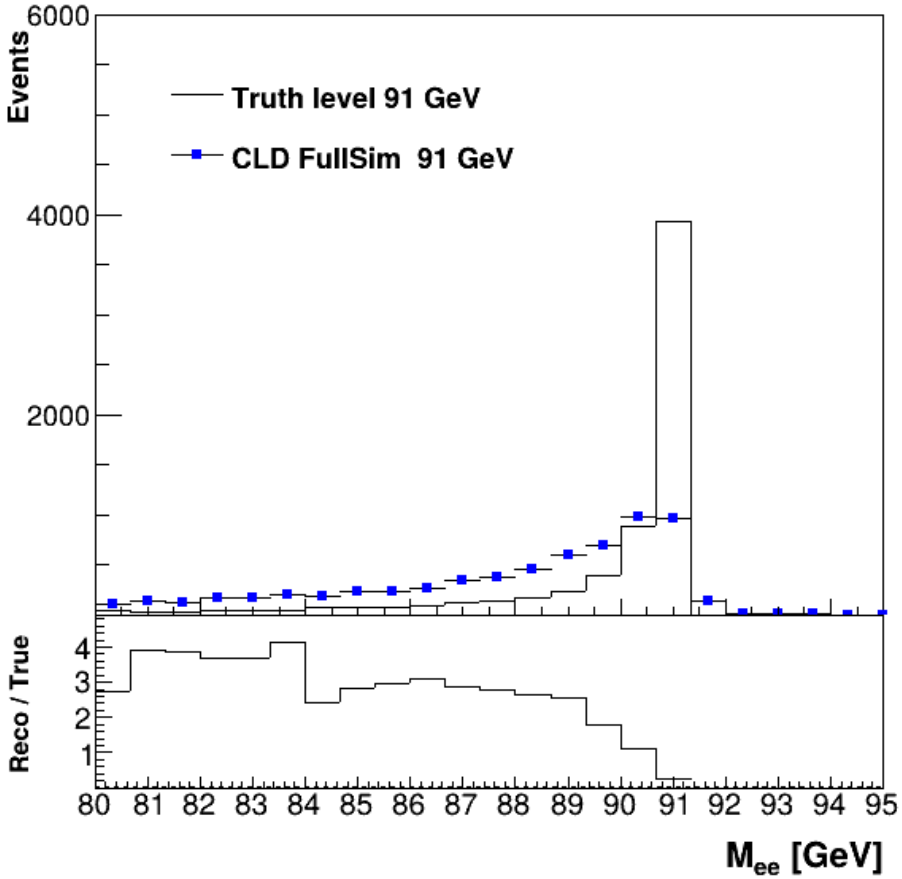


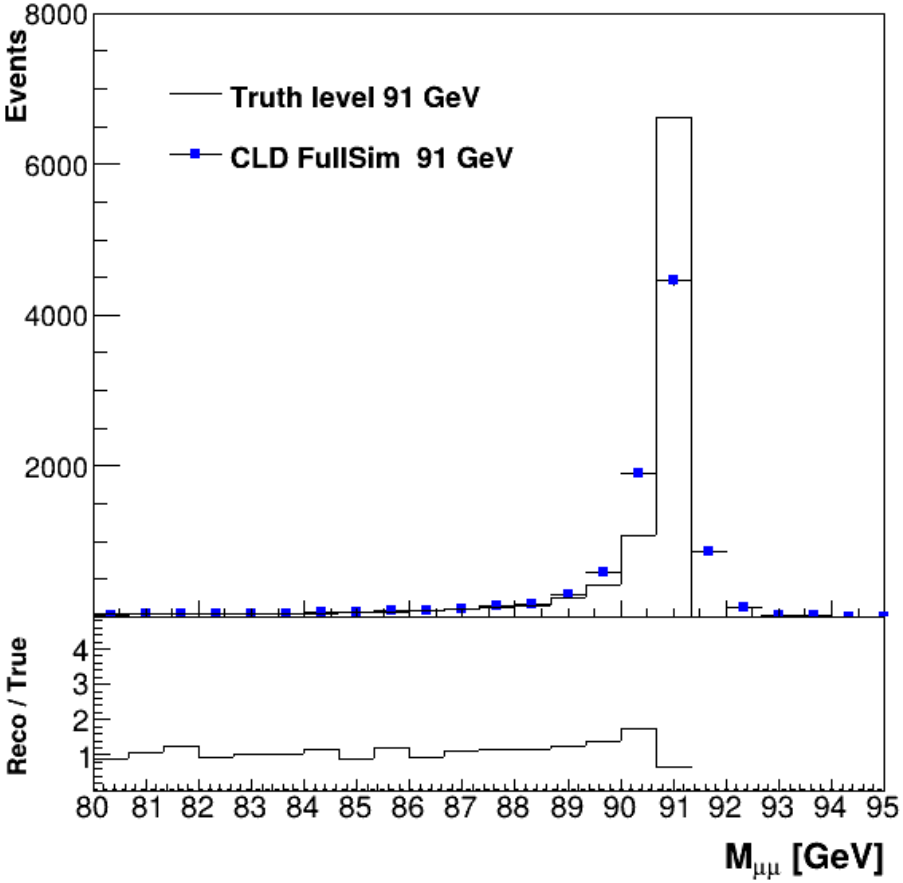


Truth-level information agrees for fast and full simulation in the EDM files. As it should.

Basic studies: Full vs Truth

C++ analysis code: https://github.com/chekanov/FCCPana
Runs on full & fast simulations and creates invariant masses

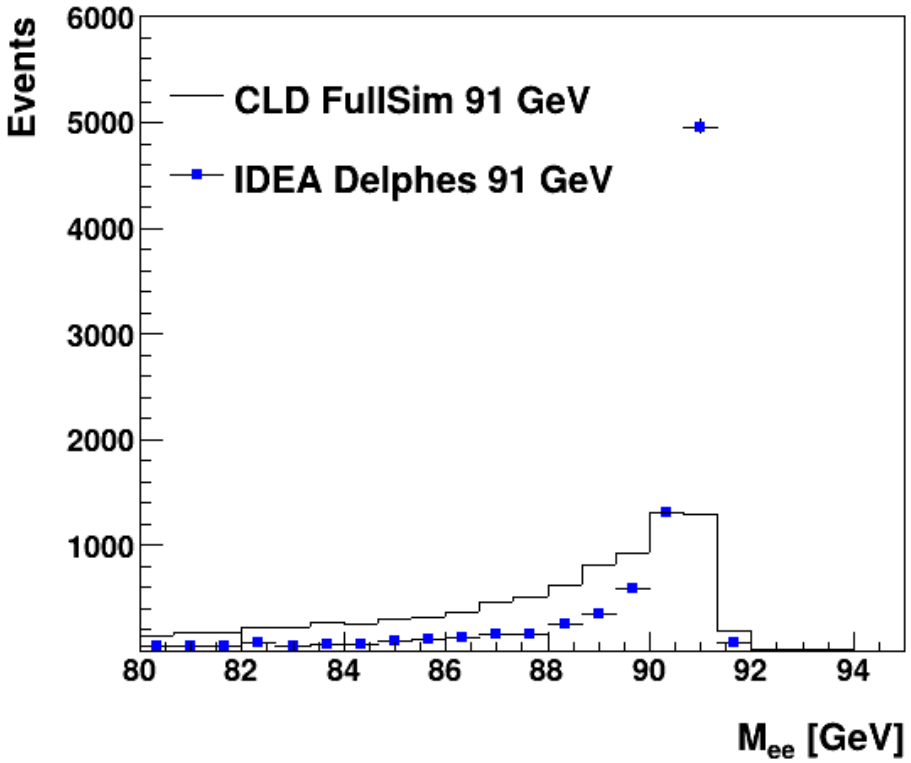


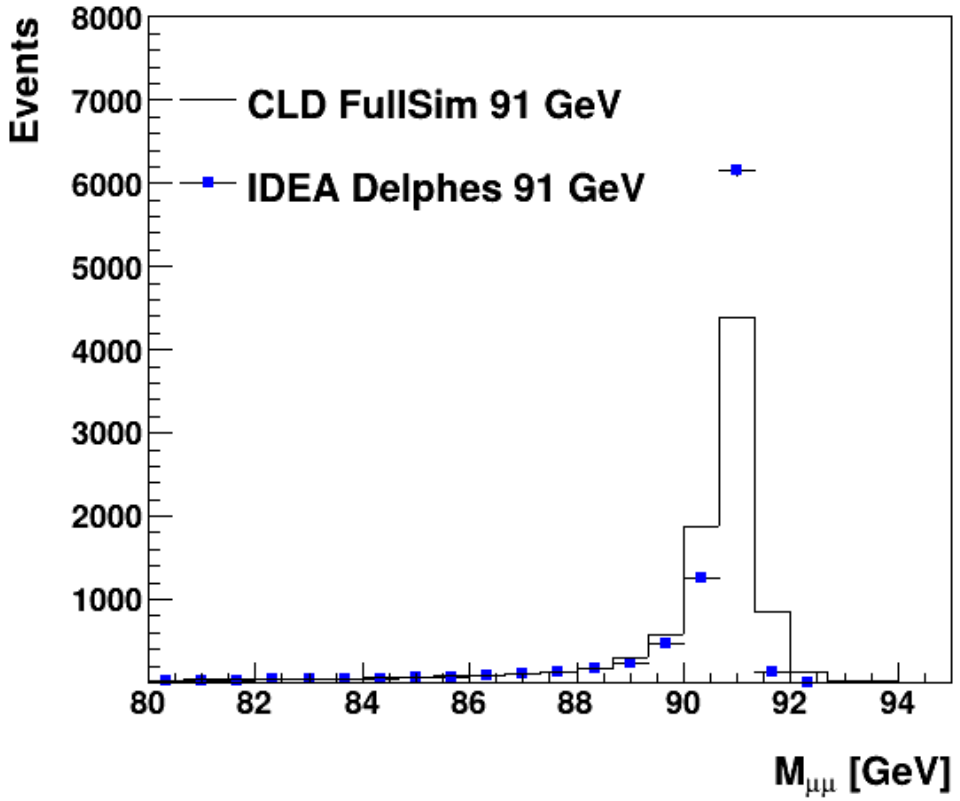


- Performance is worse for electrons
- Expected, assuming muon reconstruction is dominated by muon detection layers.

Basic studies: Full vs Fast simulations

C++ analysis code: https://github.com/chekanov/FCCPana
Runs on full & fast simulations and creates invariant masses



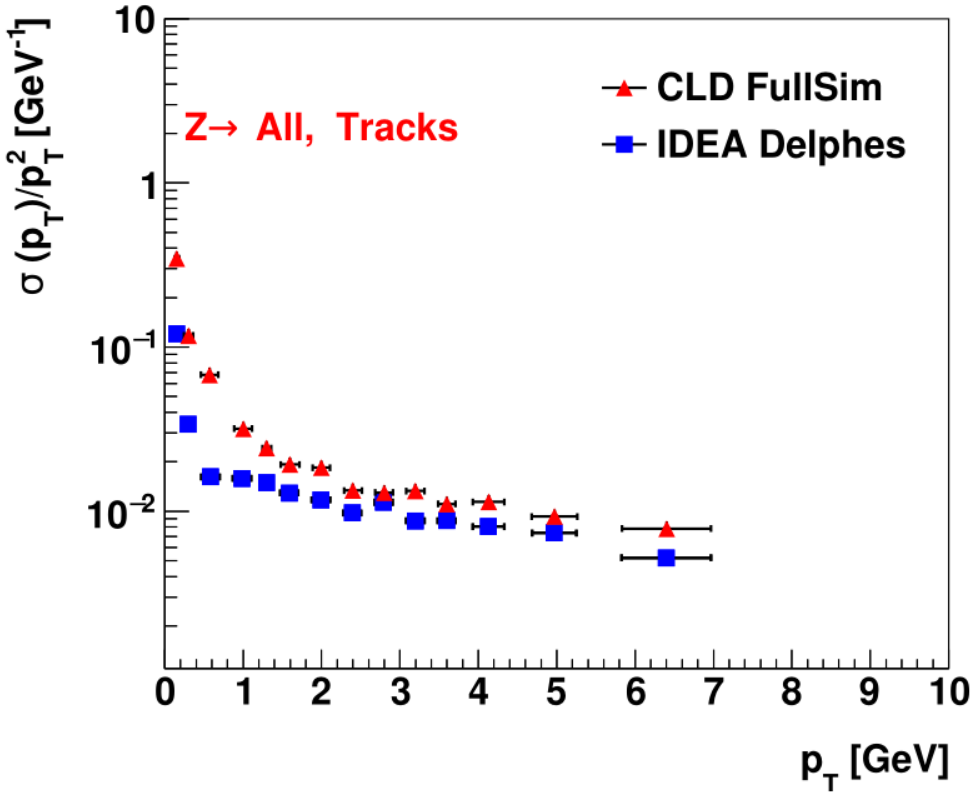


Delphes is unrealistically different from full simulations

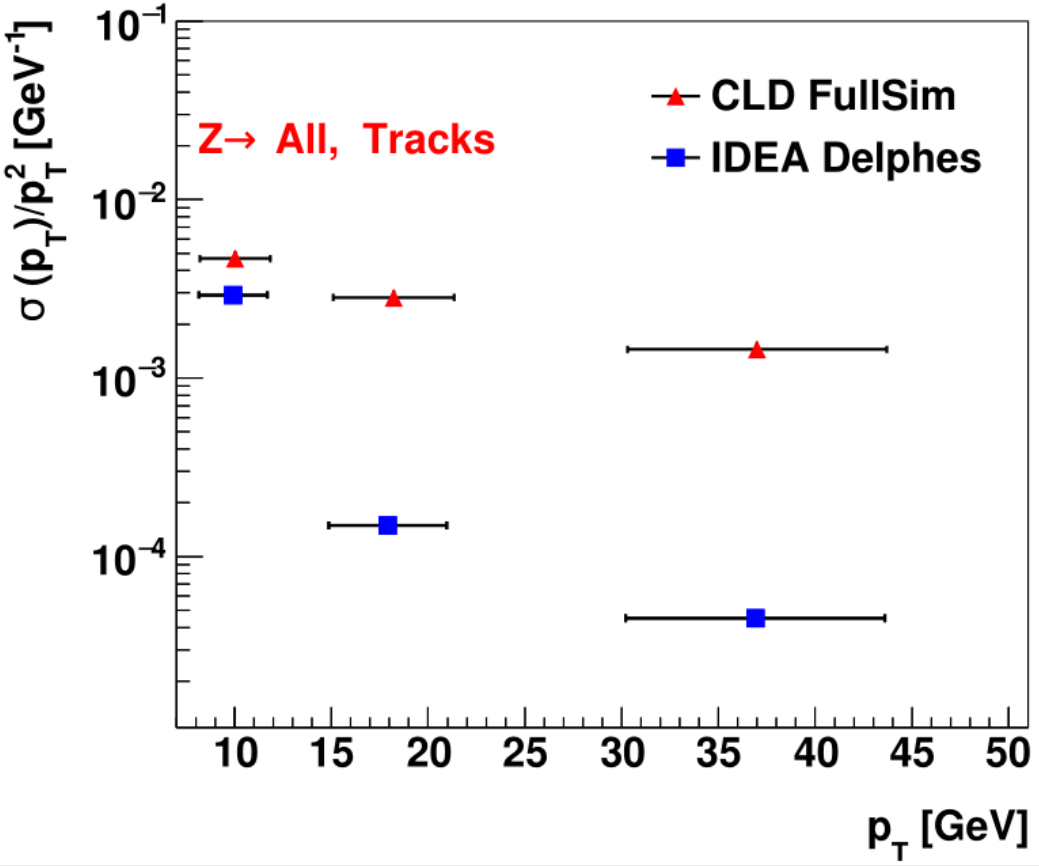
Resolution using Z→ all

- **Use a cone in ϕ-y with the size 0.05 to match a true particle with a track**
- **Use RMS for pT(reco)/pT(true)**

Dominated by relatively busy events
From hadronic Z decays



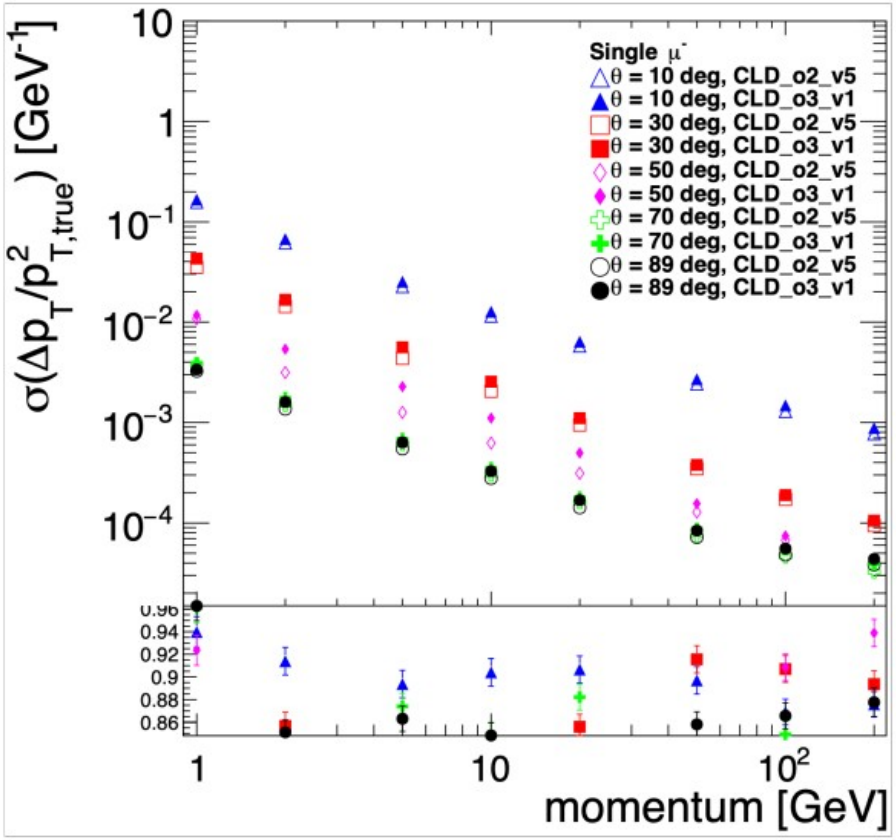
Dominated by sparse events
with e+e, mu+mu-

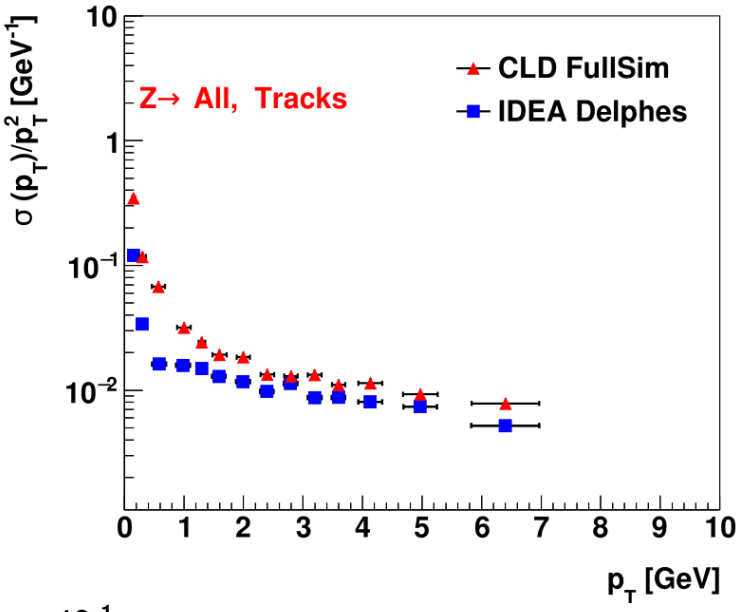


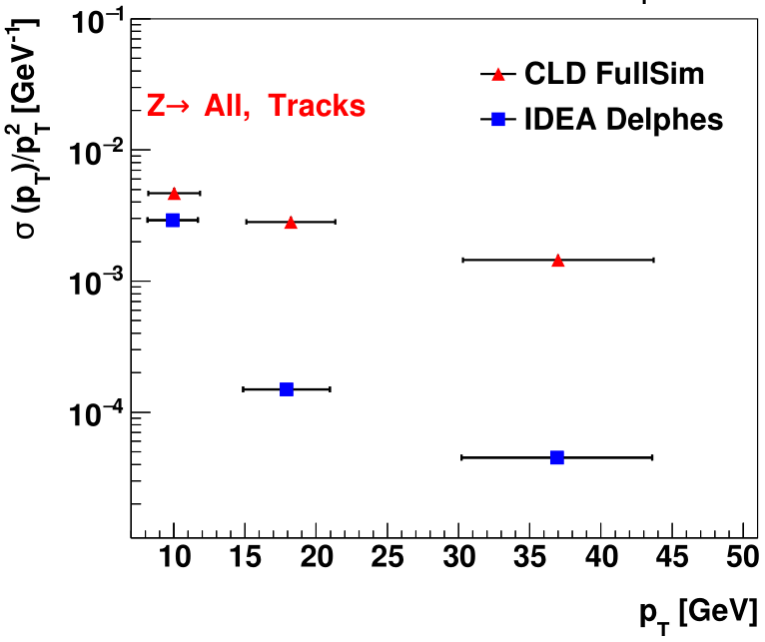
Comparisons with previous studies

CLD_o2_v05

Resolution for single muons, G.Sadowski, presented by Frank Gaede, FCCee week, 2024



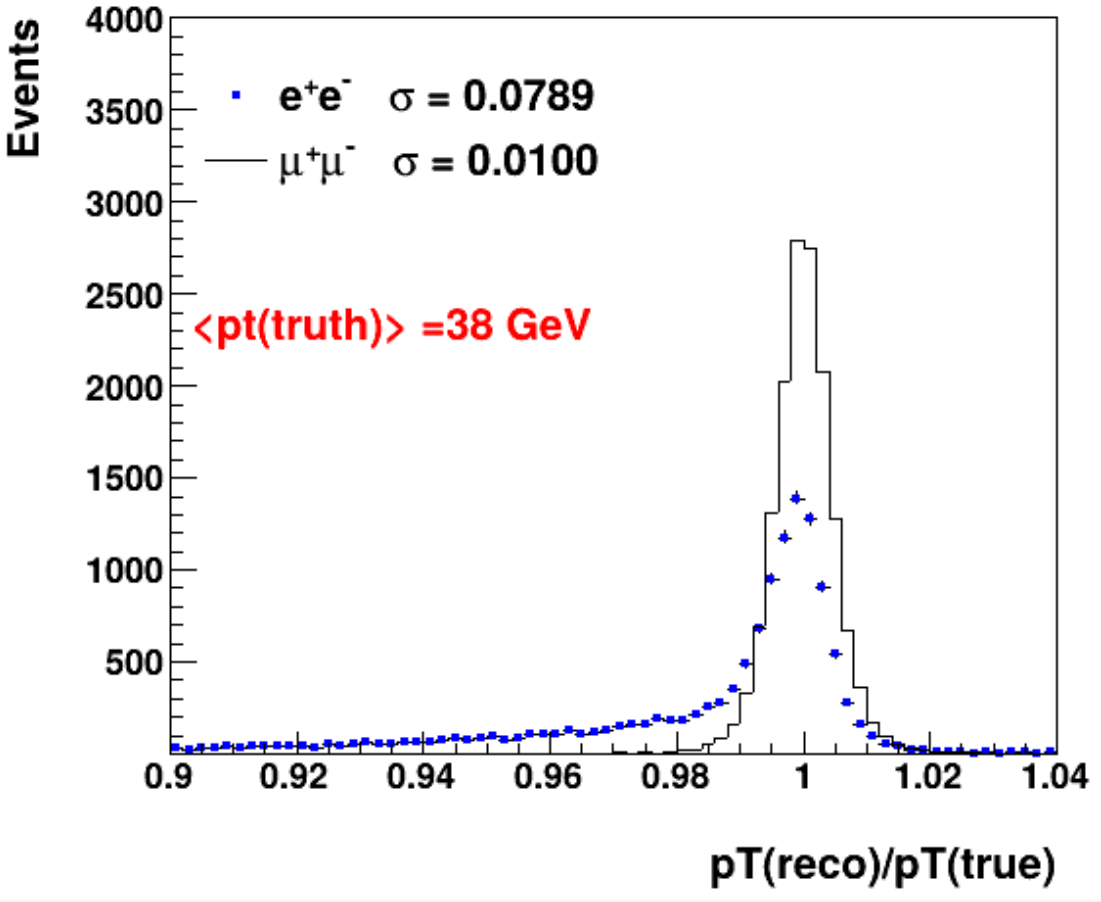


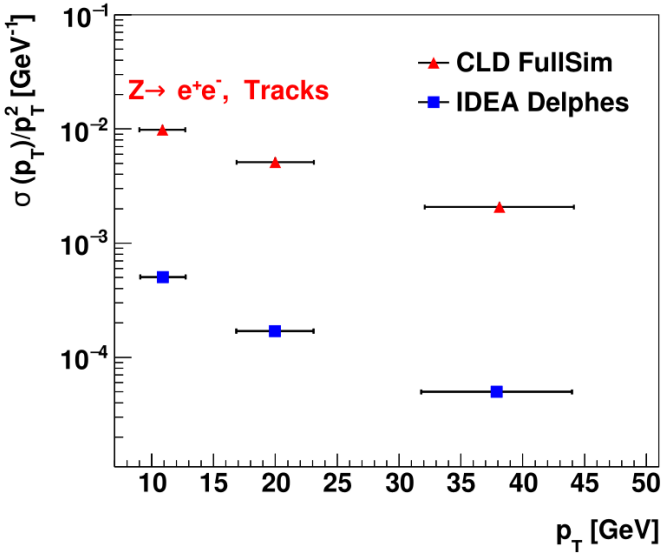


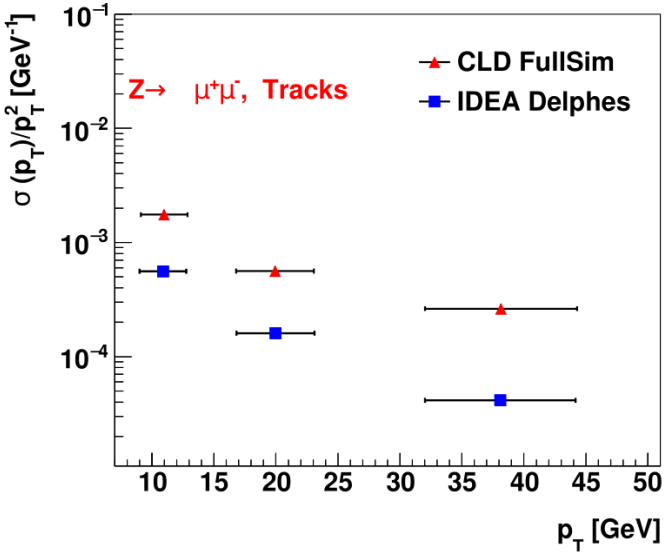
The agreement is reasonable with Z→ all, but Z boson decays cover different angles & different charged particles

Resolution using Z→ e+e-, mu+mu-

The resolution for muons is better than for electrons.
Not entirely surprising?



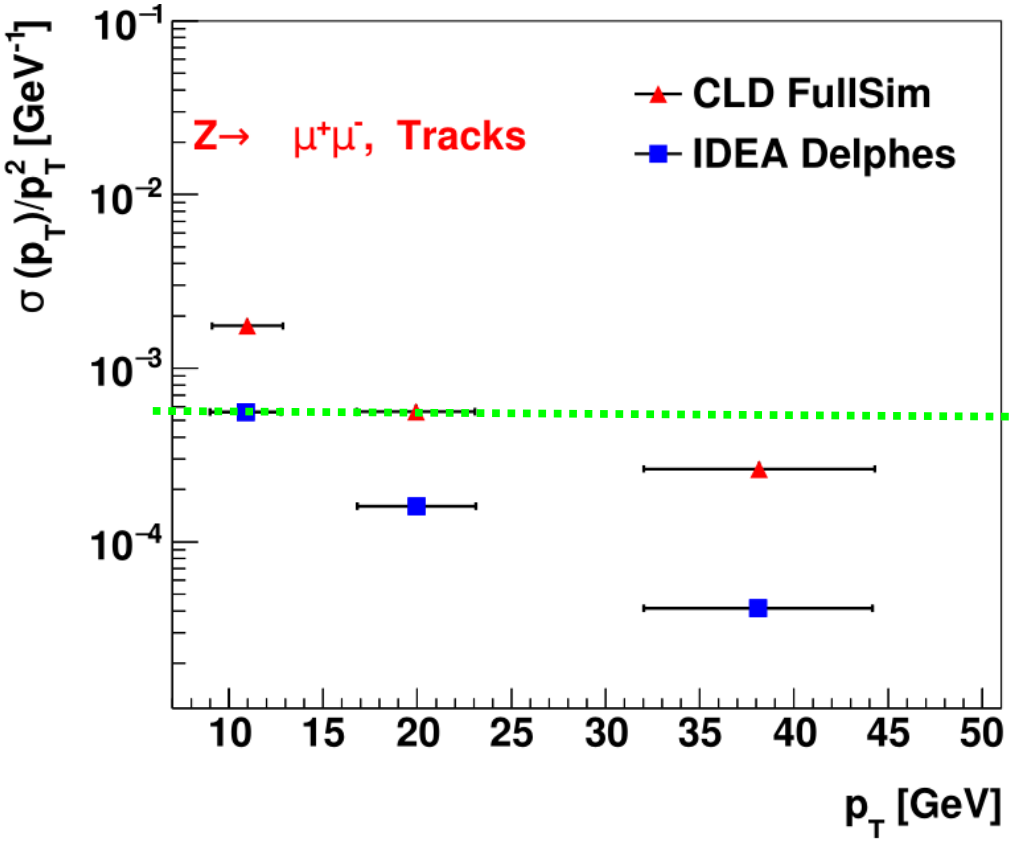


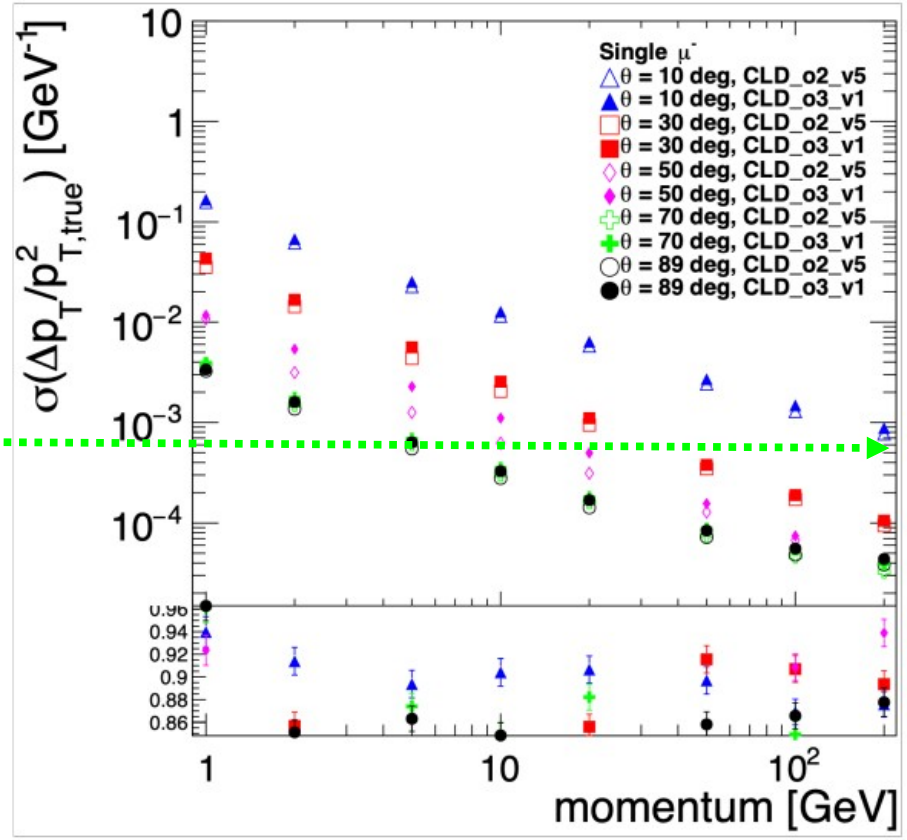


Tracking resolution using Z→mu+mu-

Comparing muons from Z vs single muons from tracks

Resolution for single muons, G.Sadowski, presented by Frank Gaede, FCCee week, 2024



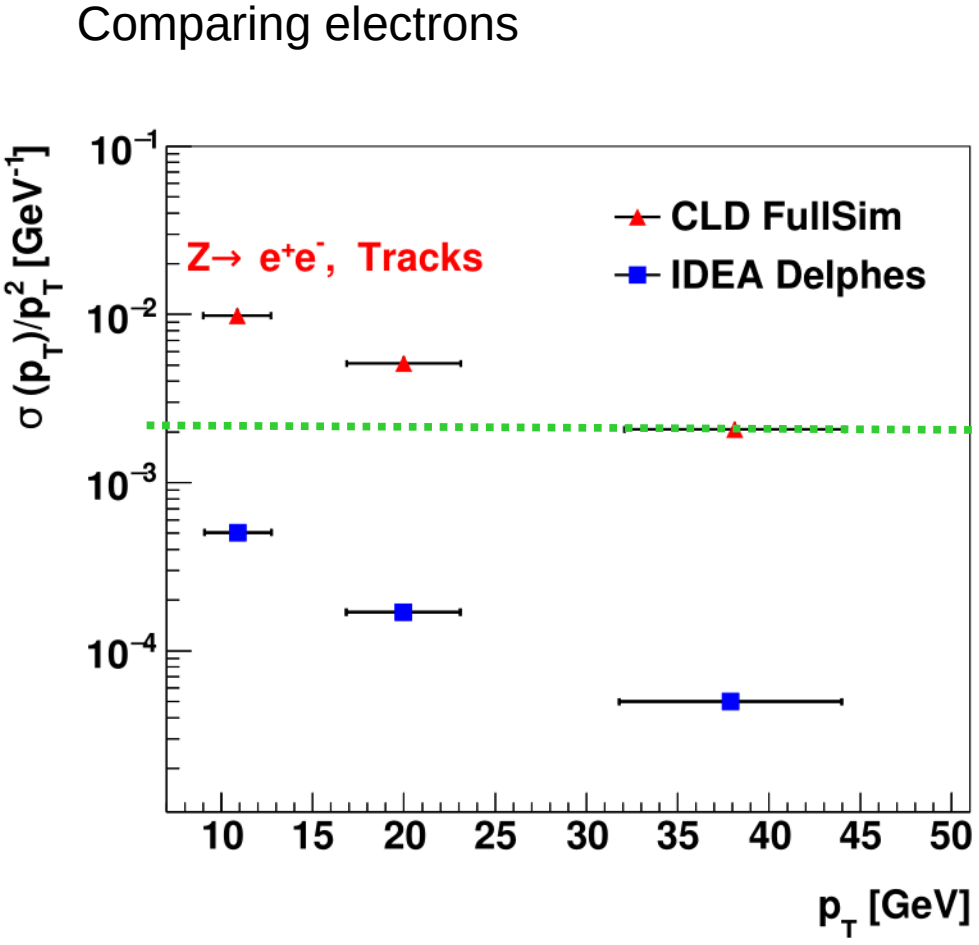


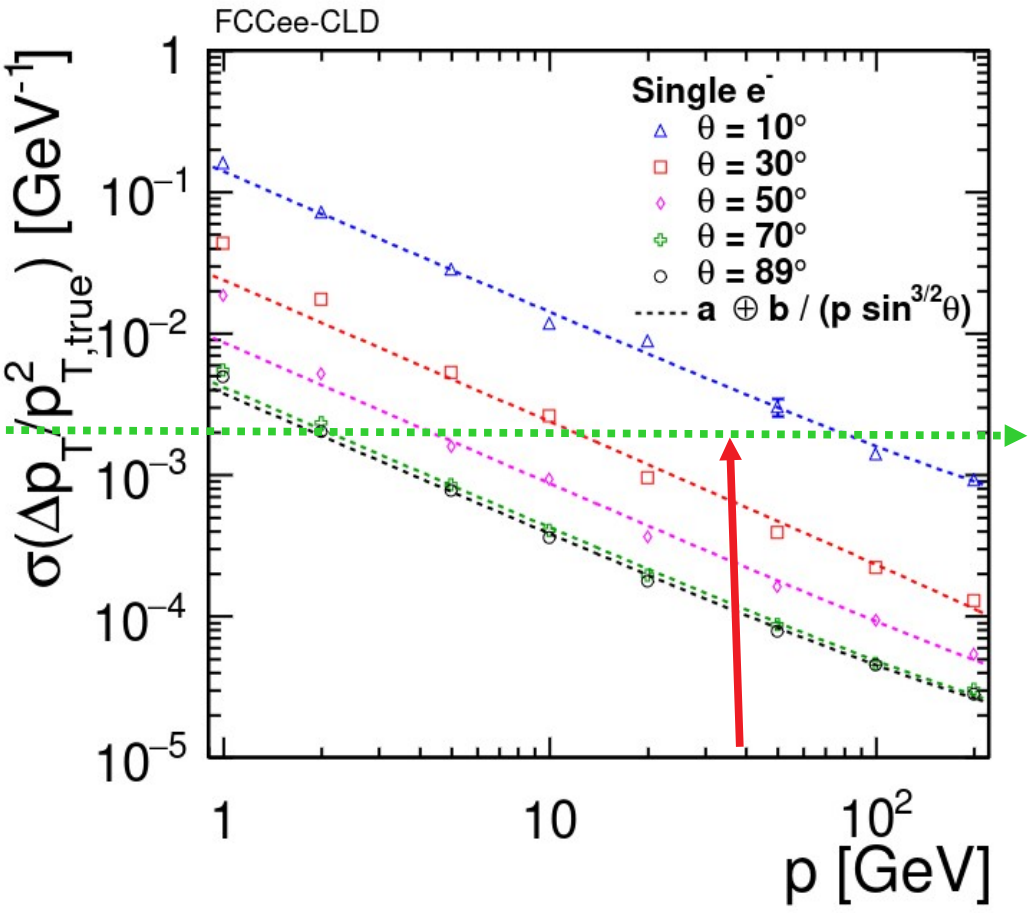
~40 GeV: sigma/pT^2 ~ 0.00026 [GeV-1]. Roughly agrees with single-particle studies

Tracking resolution using Z → e+e-

arXiv:1911.12230

Comparing electrons





Probably is somewhat larger than seen for single leptons

Summary

- Verified CLD_o2_v05 detector performance with the focus on physics-related information from **“PandoraPFOs_”** for the Z peak
- It is still difficult to compare with single particle studies, but the results look compatible with single muons (tracks)
- DELPHES fast simulation does not look very realistic
- **Future:**
  - Work on a Delphes version of the CLD detector
  - Contribute to the TPC version of tracking