Tutorial #5: FCC-ee Noble Liquid Calorimeter Full Simulation

Brieuc François (CERN)

FCCSW Hands on tutorial
October 2022

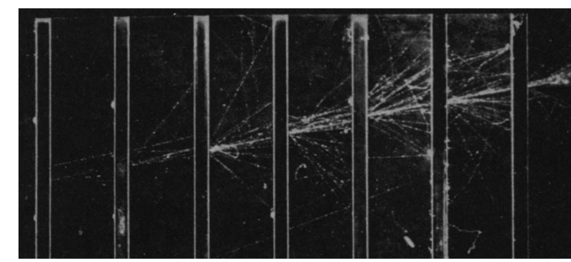
This tutorial

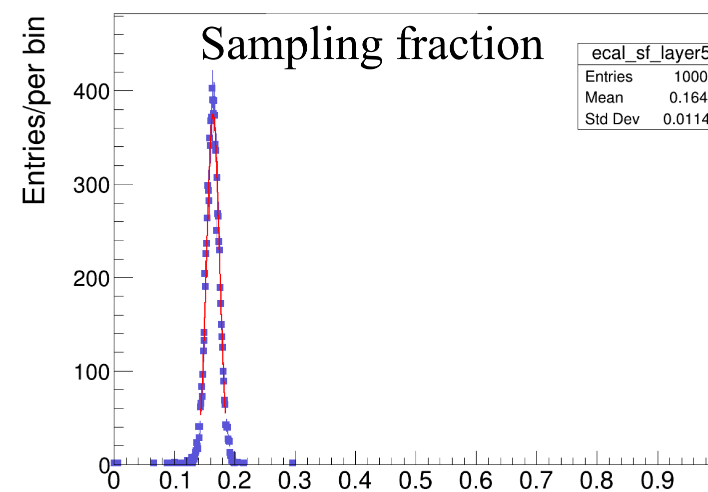
- This morning you will get the chance to run the **Full Simulation of the High Granularity Noble Liquid Calorimeter for FCC-ee**
- **You will see how to**
  - **Generate** particle gun events
  - **Run** the calorimeter **reconstruction**
  - Evaluate **performance**
  - Apply **corrections**
  - Simulate **noise**
  - **Modify** the detector **geometry**
  - **Profile** the code (per module computation time)
  - …
- But first, some basics about calorimetry that will help you answering the quiz!

Calorimetry basics

- **Schematic** explanation about sampling calorimetry
  - The EM cascade typically starts in the dense (non-sensitive) absorbers
  - What is read-out is the energy deposited by ionization in the Noble Liquid
  - For a fully contained shower (neglecting electrodes):
    - $E_{Tot} = E_{Absorber} + E_{Noble\ Liquid}$

      Not measured — Measured
  - We can know, on **average**, the **ratio between $E_{Noble\ Liquid}$ and E_{Tot}**, this is the **sampling fraction (SF)**
    - $E_{Tot} = E_{Noble\ Liquid} / SF$
  - The ratio $\mathbf{E_{Noble\ Liquid} / E_{Tot}}$ is a **random variable** $\rightarrow$ smearing!
  - The higher the sampling fraction the better the resolution

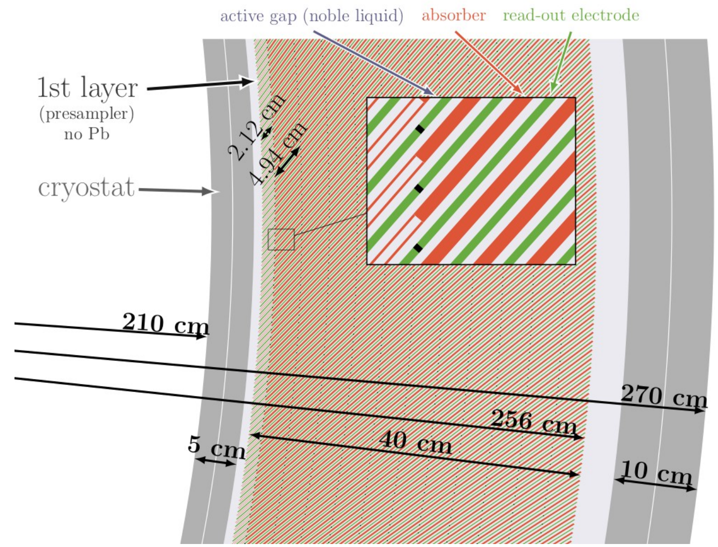




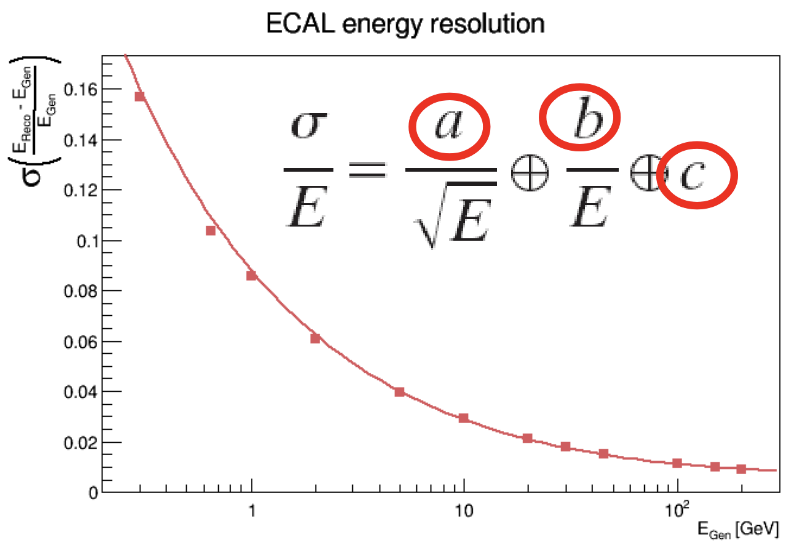
Calorimetry basics

- Inclined **rectangular** absorbers and readout electrodes
- Everything else filled with noble liquid
- Inner radius circumference smaller than the outer radius one

    → consequence on the ratio between sensitive and non-sensitive material?



- Calorimeter energy resolution can be parametrized
    - a = sampling term: depends on the ratio sensitive/non-sensitive
    - b = noise term: linked to... the noise (electronics + pile up). Dominates at low energy
    - c = constant term: linked to detector non-uniformities, shower leakage, dominates at high energy



Time to get your hands dirty!

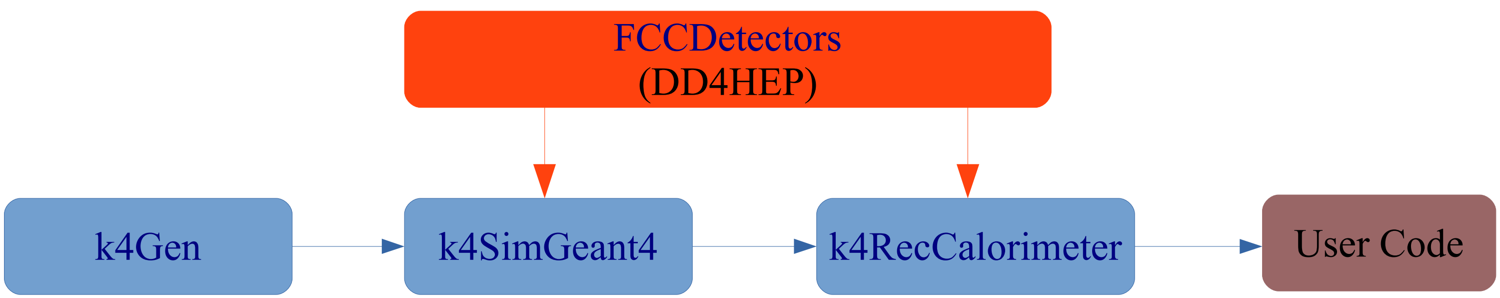
- There are 6 exercises and a bonus exercise for advanced user

Link to the tutorial introduction: here

  - Don't rush, go at your own pace and take time to understand how the code works
    - i.e. avoid copy pasting everything without asking yourself what the commands do
  - Every exercise has a quiz
    - Answers are provided (hidden by default) but try of course to find them yourself before to display the spoilers
  - It's ok if you don't do everything today, the tutorial will remain available if you want to finish it later
  - Make sure you **read carefully instructions and do every step** from every exercise otherwise some won't work (some exercises assume a given status of the code!)
    - Exception: **10 minutes before the end** of the tutorial, make sure you **jump to the exercise "Preparing for the next tutorial"**
      - This one should be self consistent
- Let's start: follow **instructions from here**
  - Feel free to call us for any question, we will do our best to answer them

Simple simulation and performance

- Various Key4hep repositories will be at play
  - Produce 10 GeV γ gun events, run calorimeter reconstruction on it and produce energy resolution plots
  - Modify detector geometry xml to replace liquid Argon by liquid Krypton
  - Assess the difference between the two scenarios and witness the need for correction



k4Gen

Monte Carlo Generation

Physics collision or Particle Gun

k4SimGeant4

Detector description

Particle interaction and propagation

Energy deposits

k4RecCalorimeter

Energy deposits per physical cells/readout channel

Noise

Corrections (sampling fraction, dead material correction)

Clusterings

User Code

Performance studies

Partially provided

Applying corrections

- Some energy is deposited in non-sensitive regions
  - Simple scaling can recover the correct energy response but
  - Stochastic nature of the amount of energy deposited in a given region smears the energy response and degrades the energy resolution
  - With a finely segmented calorimeter, we can do better!
  - **Strong correlation** between energy in first(last) sensitive layer and energy deposited upstream(downstream)
- You will learn how to apply this event by event correction for energy deposited in dead (non sensitive) material and witness its effect
  - Adding new algorithms to the sequence
  - Modifying the content of the output collection