# LAr calorimeter R&D for FCC-ee

## Status and plans

Brieuc François (CERN)
LAr Calo for FCC working meeting
Oct. 29th, 2020

# Introduction

- Resuming the work carried out by Marina
  - Started beginning of October, still in the learning phase
  - Apologize for the mistakes, mis-phrasing, trivial statements, …
- Work organization
  - ~50% on the electrode PCB design and optimization
  - ~50% on physics related topics
    - Detector requirements and optimization of 'free' parameters from physics measurements
      - Probably start with 'simple' ECAL related key aspects of physics analyses (e.g. $\pi^0$ rejection)
      - Possibly move to a more thorough physics analysis later
    - Requires substantial FCCSW Full Sim developments beforehand
      - Clustering algorithms, physics object identification/particle flow, …
      - Optimal detector specs can only be derived within a realistic global event reconstruction

# Outline

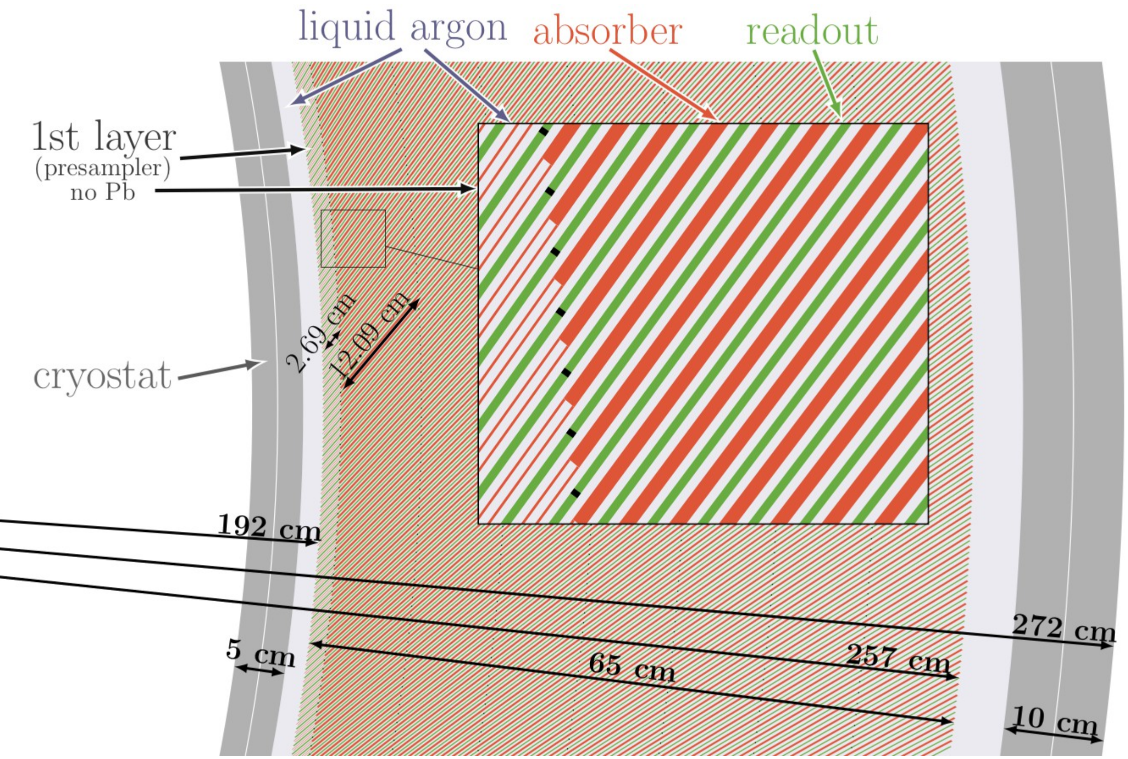
- FCC-ee LAr ECAL Geometry and FCCSW
- Update of the strategy regarding PCB design

# Geometry in FCCSW

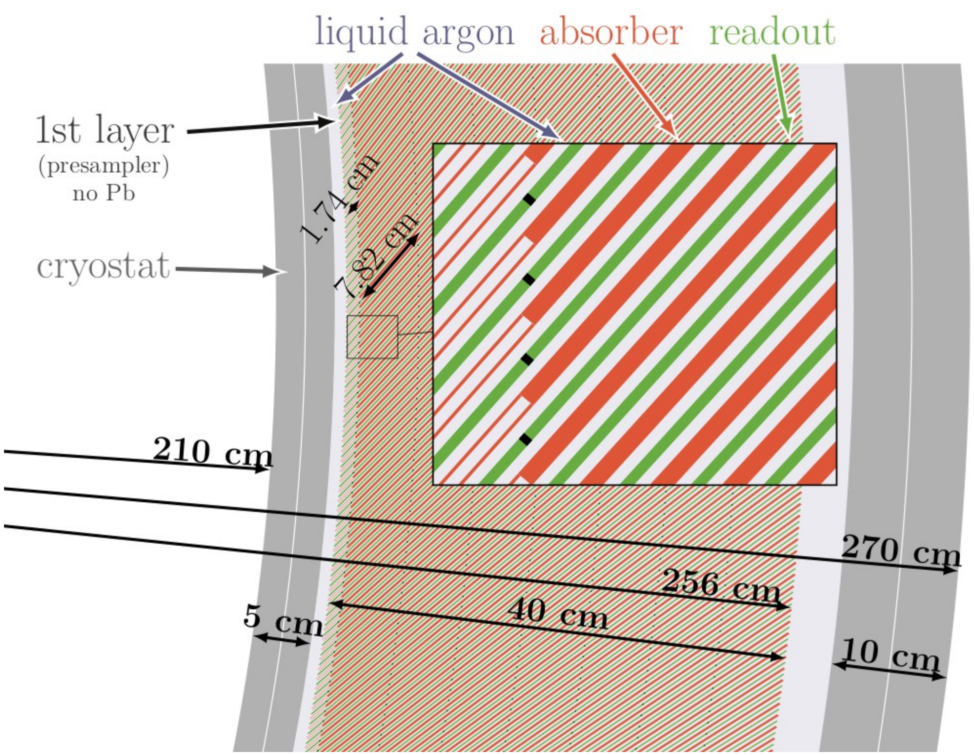
- Main geometry changes in FCC-ee w.r.t. FCC-hh
  - Bigger tracker → inner cryostat radius pushed further (185 cm → 210 cm)
  - Less energetic particles → sensitive region shrunk (30 $X_0$ → 22 $X_0$)
- New geometry already propagated to the FCCSW framework by Jana (thanks for the very nice documentation!)
  - Further modifications to align on the latest baseline scenario
    - Go from 8 to 12 longitudinal layers in the readout segmentation
    - Fine-tuning
      - Cryostat starts at 2.1 m instead of 2.06 m (leaves 10 cm between the end of the outer tracker and cryostat), 1 cm services after inner cryostat, 4 cm after, …
      - 'z' coverage: current 2.2 m (at 2.16 m from the beam pipe it results in an angular coverage of 27$^{o}$ on both sides of the radial direction)
      - Gap thickness of 1.2 mm instead of 1.8 mm
    - This baseline scenario will anyway be optimize based on simulation studies
    - NB: need to update the sampling fractions/upstream material corrections and re-derive the noise for most of the geometry modifications

- New geometry is being implemented in the **technical drawings** (thanks Anna for the source code!)
  - 1552 cells in total (abs-gap-readout-gap unit), 60 cm radial depth including cryostat → ~22 $X_0$ and 53 cells crossed by a straight trajectory at θ=90°

FCC-hh



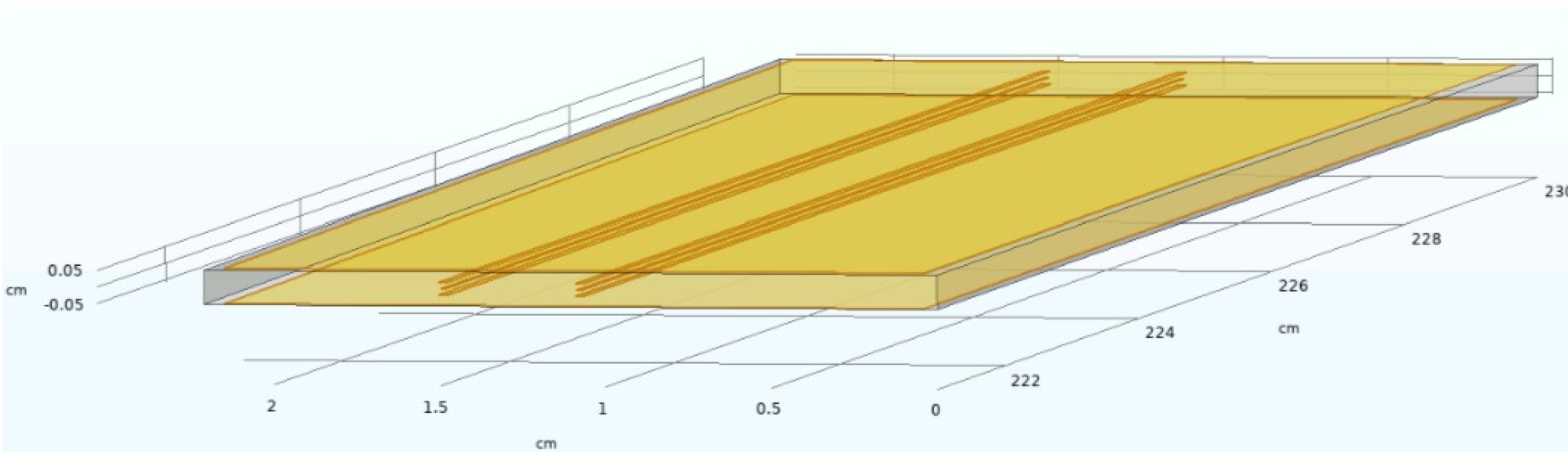

FCC-ee



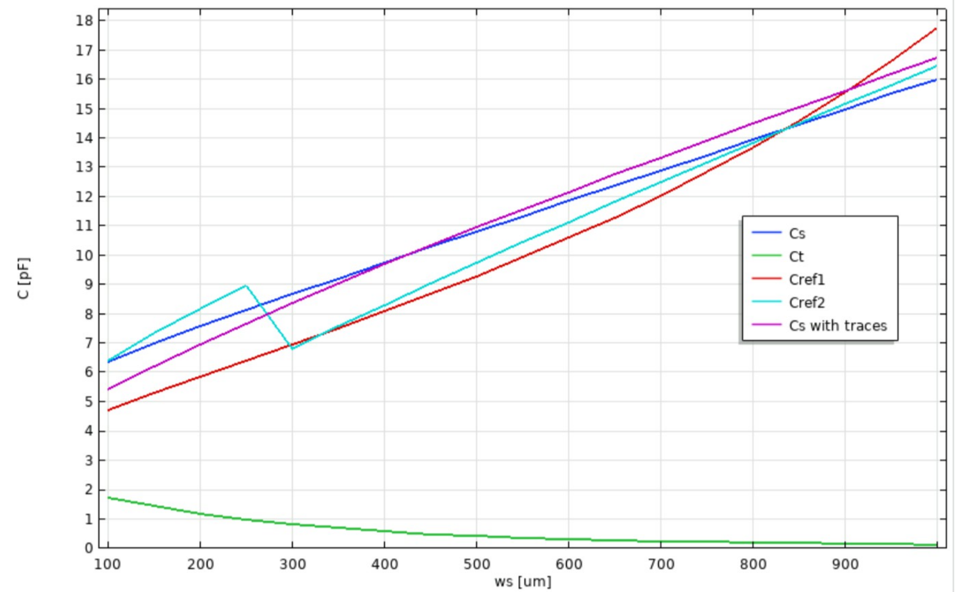
# FCCSW development

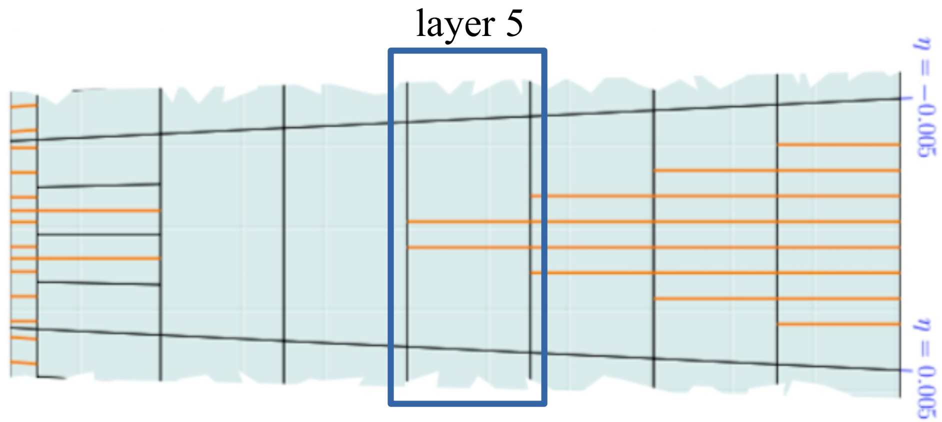
- Once the fine tuning of the baseline geometry is implemented in FCCSW, one can already start to do simple studies such as ECAL resolution as a function of granularity, absorber thickness, etc
- FCCSW development needed for further studies
  - Fix the topoClustering algorithm (so far only managed to run it with the FCC-hh geometry)
  - Implement new clustering algorithms (e.g. CMS CLUE)
  - Implement a machine learning based $\pi^0$ identification algorithm
  - …
- Currently learning the FCCSW Full Sim framework to be able to contribute (thanks Valentin for the help!)
  - Will start with the migration of topoClustering to EDM4hep (probably needs some refactoring)
    - Implies to also migrate all the input ingredients (G4CaloHits, CaloCells, calibration tools, etc.)

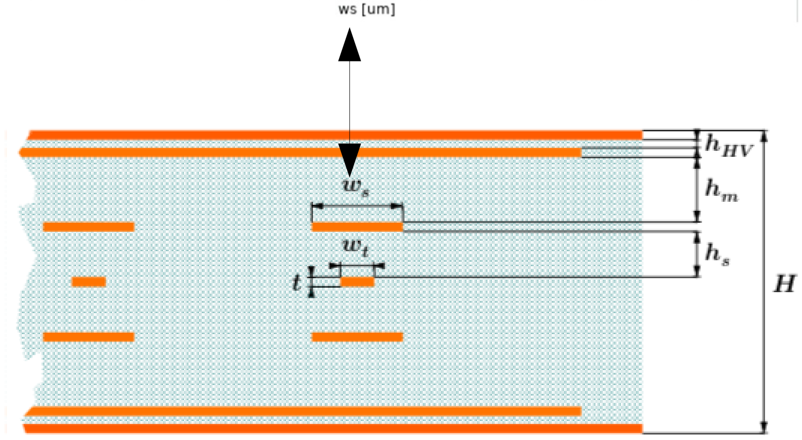
# Electrode PCB design



- Marina implemented the PCB layer 5 geometry into COMSOL, based on Finite Element Method (FEM)
  - Derived the capacitances as a function of the shield width and compared it to the analytical modeling used in FCC-hh studies
  - Reasonable agreement, slightly higher capacitance observed with FEM
  - Next steps: evaluate noise and cross-talk
  - Work taken over by IJCLab (Orsay)

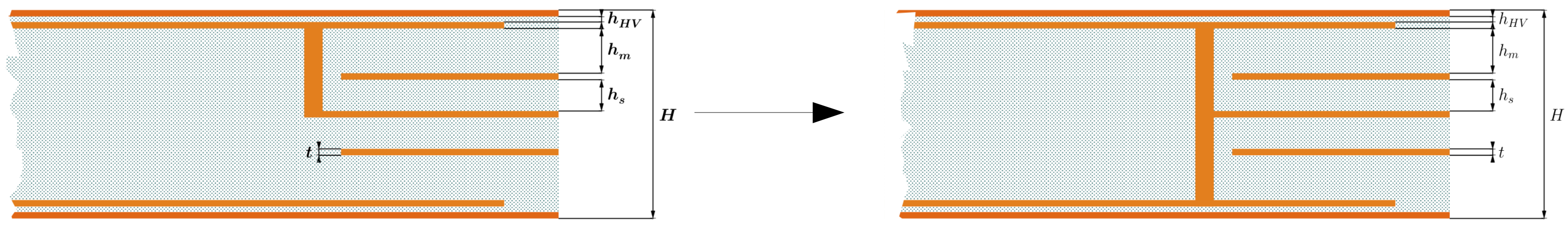


# PCB Design

- Alternative/complementary approach: use **Cadence** Design Systems together with Sigrity
- Possible to perform the model implementation through the CERN **PCB Design Office**
  - Had a first chat with them two weeks ago
  - Will meet again coming Tuesday to launch the actual implementation of the model
    - Should be a matter of days/week (relatively simple PCB for them)
- Will allow **cross validation together with the COMSOL model**
- Will implement an updated version of the electrode for FCC-ee
  - More longitudinal layers (12 vs 8) and shorter length (62 cm)
  - One signal trace reads two signal pads



# Summary

- Trying to learn all these new topics, step by step
- Playing with the FCC-ee updated detector geometry and FCCSW in general (thanks to Jana, Anna and Valentin for their precious help)
- Update of the technical drawings for FCC-ee ongoing
- PCB modeling in COMSOL performed by IJCLab (Orsay) while we carry out the implementation in Cadence with the PCB Design Office
  - New version of the baseline design

# Additional material

# Master student project

- **Master student** starting with Christos L. (Edinburgh) on LAr Calo R&D studies
  - Need a short term task that would be useful for us in the long run
  - Propose to start with **resolution studies as a function of the granularity**
    - Energy resolution w.r.t. incoming particle energy for different geometries
    - $Z \rightarrow e^+e^-$ invariant mass resolution for different detector geometries
      - Fixed Z mass (no Breit-Wigner to avoid convolution with detector resolution)
      - Maybe switch off ISR/FSR to have clean events
      - Possibly, also switch off the magnetic field to make things easier
  - More advanced studies (e.g. electron bremsstrahlung dressing, $\pi^0$ rejection, …)
  - Use **FCCSW Full Sim** with FCC-edm, time scale does not allow to move to EDM4hep
    - Report has to be written in May

# Full readout theta view