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EP R&D Project on Noble Liquid Calorimetry

Read-Out Electrode Design and Performance Optimisation

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LAr calorimeters for Future Detectors

Calorimetry of a FCC-hh detector

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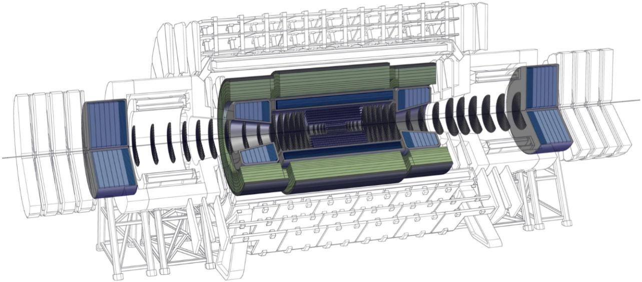
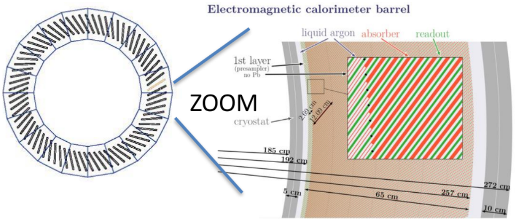


ATLAS-like calorimeter with higher granularity (PF, particle ID, PU rejection...)

- LAr in high radiation regions: ECAL + HCAL endcap and forward regions
- Tile calorimeter (stainless steel/lead and scintillating plastic tiles) in low radiation regions: HCAL and extended barrels

Electromagnetic calorimeter barrel



Fine long. and trans. granularity:

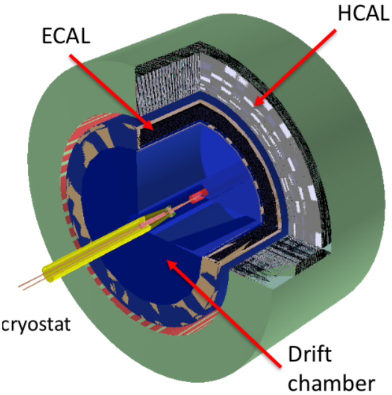
- 8 longitudinal layers
- $\Delta\eta \times \Delta\Phi \sim 0.01 \times 0.01$ (0.0025×0.02 in first layer)

$\rightarrow$ 2.5M readout channels

Possible only with straight multi-layer electrodes

- Electrode (7-layer PCB, 1.2 mm thick) and absorber (lead/steel) plates inclined by 50^o from the radial direction for readout capabilities via cables arranged at the walls of the cryostat
- LAr in the gaps

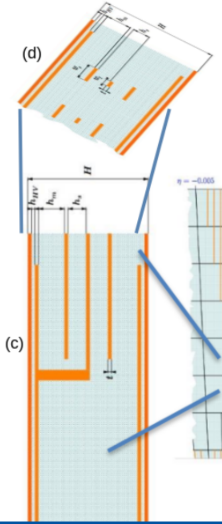
LAr calorimetry for FCC-ee

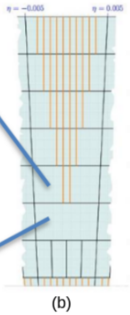


- LAr active medium for ECAL has been implemented into FCCSW for a FCC-ee experiment
- Preliminary considerations: such a calorimeter could be feasible and would fulfil physics requirements for FCC-ee

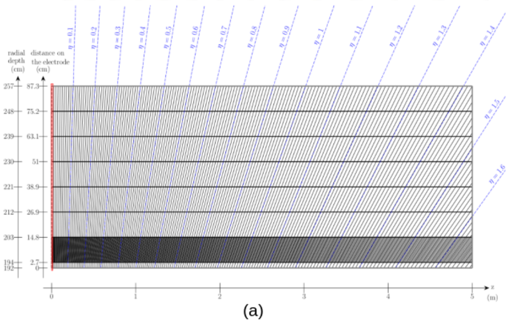
FCC calorimeters readout electrodes design

Readout electrodes for **FCC-hh** (1)

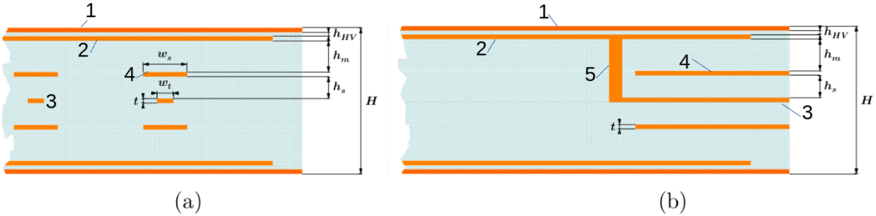




(a) Readout and cell segmentation electrodes, longitudinally (8 layers) and in pseudo-rapidity
(b) Cross-section of the first electrode. Orange lines = transmission lines for the signal extraction
(c) Cross-section parallel to the signal of the first electrode (layers 3-4)
(d) Cross-section perpendicular to the signal of the first electrode (top of layer 8)



Readout electrodes for **FCC-hh** (2)



1. Outside HV layers that produce the electric field
2. Pads that collect the signal
3. Signal traces connected with vias (5) to the signal pads
4. Ground-shields to prevent crosstalk between the trace and the pad. Shields/trace forms a $25\Omega - 50\Omega$ transmission line

Towards a design of the readout electrodes for **FCC-ee**

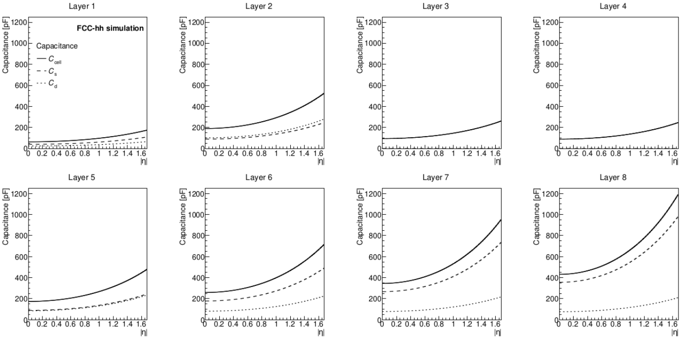
Similar design than the FCC-hh readout electrodes

FCC-ee measures low energies, therefore:

- granularity to be studied
- the electronic noise have to be minimised

$\rightarrow$ **Detector granularity and PCB readout electrodes signal-to-noise ratio have to be optimised**

Electronic noise in readout



$C_{cell} = C_d + C_s \sim 100 - 1000\text{pF}$

C_d = detector capacitance
C_s = capacitance shield-pad

C_s depends on the dimensions of the transmission line

4 – 40MeV noise per readout channel assuming ATLAS-like electronics

Noise contribution is proportional to the cell capacitance

$\rightarrow$ large shield prevents crosstalk but increases C_{cell}

$\rightarrow$ higher the granularity, more shields are needed, C_{cell} increases

$\rightarrow$ **Requires PCB optimisation**

PCBs optimisation

Milestones

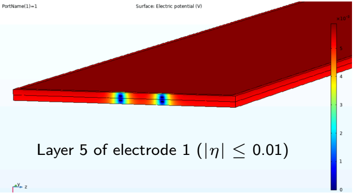
1. Study of the readout electrodes for FCC-hh LAr calorimetry
    1.1 Computation of several parameters (signal attenuation, capacitance to ground, electronic noise, crosstalk between signal pads and signal traces) and comparison with analytic approximate formulas.
    1.2 Optimisation of the PCB dimensions to minimise noise and crosstalk while maximising the readable signal
2. Design of the readout electrodes for a FCC-ee LAr calorimeter
    2.1 Participation of the particle flow implementation into FCCSW
    2.2 Study the granularity requirements of an electromagnetic calorimeter for FCC-ee
    2.3 Optimisation of the readout electrodes by studying the above mentioned parameters

Study of the readout electrodes for FCC-hh

Computation of several parameters and comparison with analytic approximate formulas
$\rightarrow$ Using COMSOL Multiphysics, a finite element tool

1. Learn COMSOL
2. Capacitance

$$C_{COMSOL} = 8.53 \text{ pF}$$



Layer 5 of electrode 1 ($|\eta| \leq 0.01$)

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Article : approximation microstrip line on top of one ground shield :

$$C_s[\text{pF/cm}] = \frac{0.26(\varepsilon_r + 1.41)}{\log \frac{5.98 h_m}{0.8 w_s + t}}$$

C_s = 6,38 pF

Schneider model :

$$C = \frac{\epsilon_r l}{60 v_0 \ln\left[\frac{8h}{w} + \frac{w}{4h}\right]} \quad \text{for } \frac{w}{h} < 1$$

$$C = \frac{\epsilon_r l\left[\frac{w}{h} + 1.393 + 0.667 \ln\left(\frac{w}{h} + 1.444\right)\right]}{120\pi v_0} \quad \text{for } \frac{w}{h} \geq 1$$

L = conductor lenght
v_0 = speed of light

C = 8,95 pF

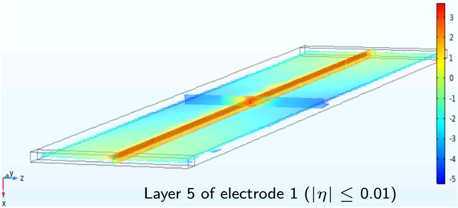
10.1109/SECON.2007.342939

Study of the readout electrodes for FCC-hh

Computation of several parameters and comparison with analytic approximate formulas
→ Using COMSOL Multiphysics, a finite element tool

1. Learn COMSOL
2. Capacitance
3. Impedance

$$Z_{COMSOL} = 52.4\ \Omega$$



Layer 5 of electrode 1 ($|\eta| \leq 0.01$)

Approximation strip line between two ground shields:

$$Z[\Omega] = \frac{60}{\sqrt{\varepsilon_r}} \log \frac{1.9(2h_s + t)}{0.8w_t + t}$$

$$Z = 49.25\ \Omega$$

The formula has an accuracy of approx. ±6%

Conclusion

- Preliminary results
- The step 1.1 should be completed soon for layer 5, the remaining will follow
  $\rightarrow$ COMSOL need to be understood first
- A lot of interesting work to do!

Thanks for your attention :)
Questions?

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