CLD overview and recent results on ECAL optimisation

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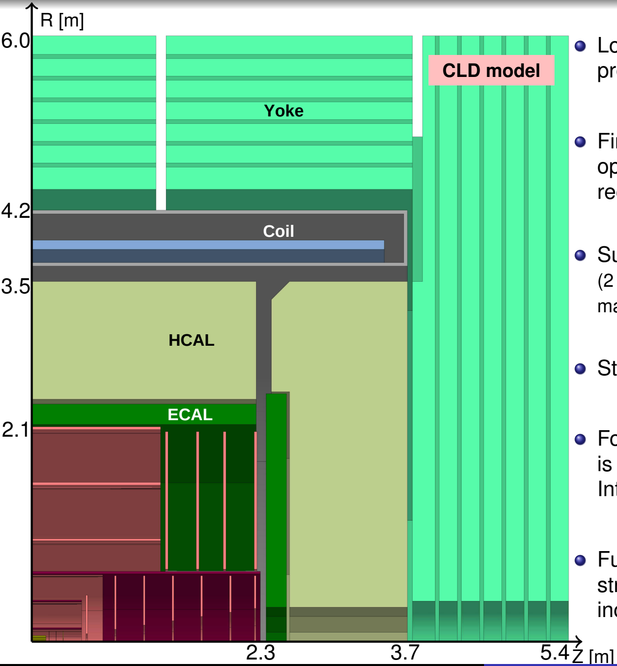
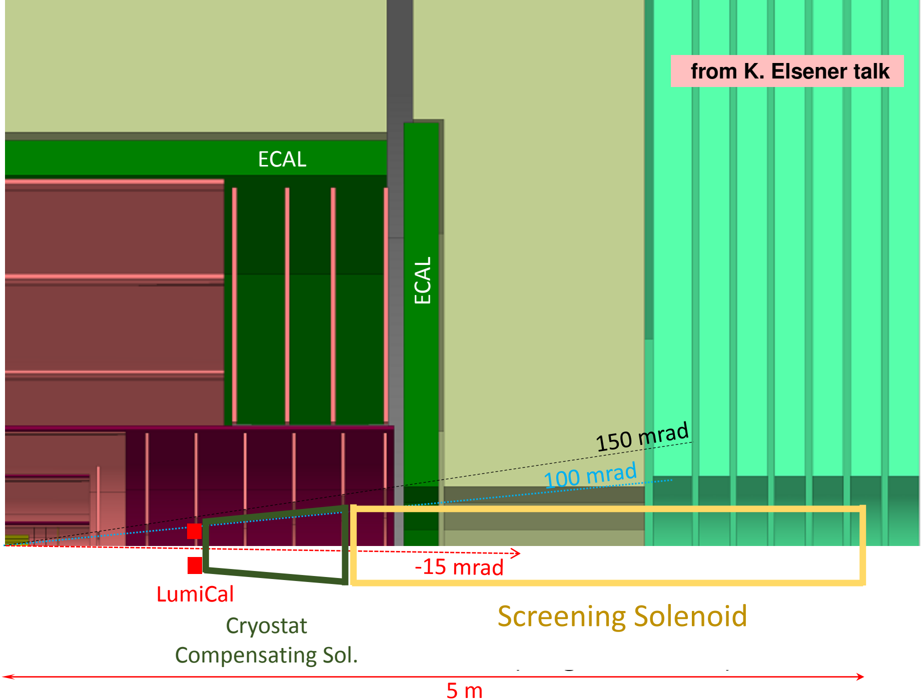
Detector Design Meeting

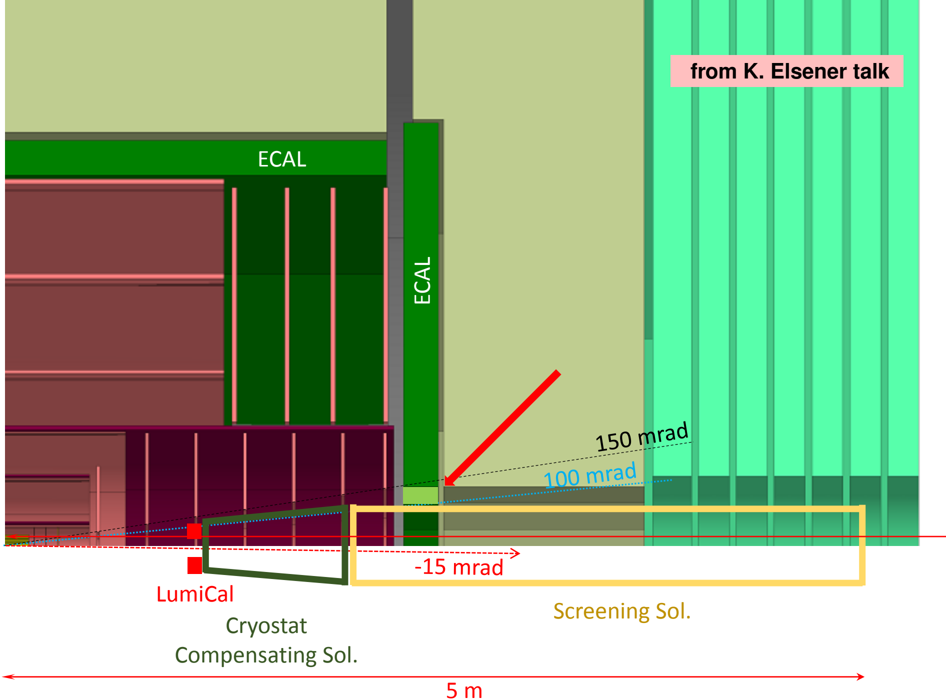
4 October 2019

CLD detector model



- Low mass silicon tracking system - provides $\geqslant$12 hits per track
- Fine-grained ECAL and HCAL optimized for particle flow reconstruction
- Superconducting solenoid (2 T magnetic field, constraint from the machine)
- Steel return yoke with muon chambers
- Forward detector region ($<$ 150 mrad) is reserved for Machine-Detector Interface (accommodates LumiCal)
- Full detector simulation with support structures, cables and services included in the model


from K. Elsener talk
ECAL
ECAL
150 mrad
100 mrad
-15 mrad
LumiCal
Cryostat
Compensating Sol.
Screening Solenoid
5 m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150 mrad
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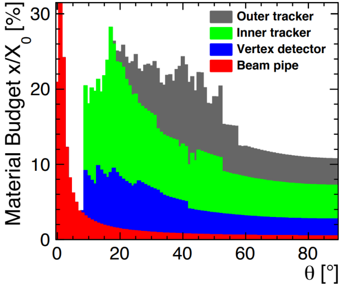
5 m

Vertex detector

- 3 double layers in barrel and endcaps
- Single-point resolution: 3 μm
- Material budget: 0.6% X_0 per double layer

Tracker detector

- Silicon pixel and microstrips detector
- Single-point resolution: 7 μm x 90 μm (except 1st IT disk: 5 μm x 5 μm)
- Material: 1.1-1.6% X_0 per layer

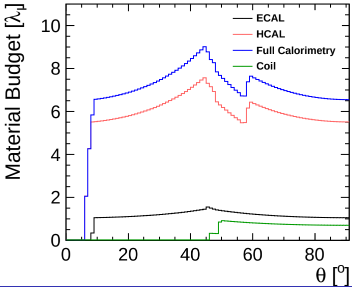


Electromagnetic Calorimeter

- Si-W sampling calorimeter
- cell size 5x5 mm^2
- 40 layers (1.9 mm thick W plates)
- Depth: 22 X_0, 1 λ_I, 20 cm

Hadronic Calorimeter

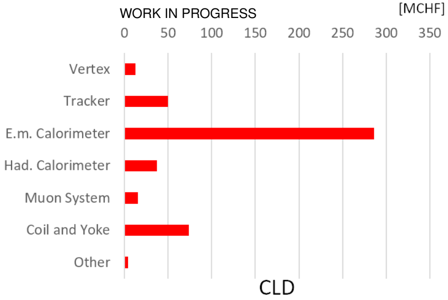
- Scintillator-steel sampling calorimeter
- cell size 30x30 mm^2
- 44 layers (19 mm thick steel plates)
- Depth: 5.5 λ_I, 117 cm (inspired by ILD)



Motivation of ECAL optimization

- ECAL is the most expensive piece of the CLD detector
- 40 layers of ECAL consist of $\sim$ 4000 m^2 of silicon
  - is $\approx$ 90 % of ECAL cost
  - is $\approx$ 50% of total cost of CLD
  - assuming 6 CHF/cm^2 for silicon
- Reduction of the number of layers will significantly affect the total detector cost

Cost of CLD



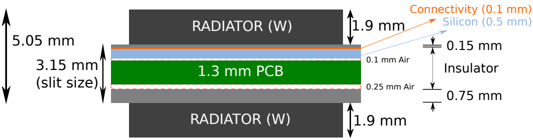
	Cost [MCHF]
Mechanics	26.46
Detectors and sensors	251.58
Power supplies	3.83
Integration and installation	4.10
DAQ	0.37
ECAL Total	**286.33**

Draft document

- Four different ECAL configurations are considered:

Layer structure	Thickness tungsten alloy [mm]	Total thickness per layer [mm]
40 uniform	1.9	5.05
30 uniform	2.62	5.77
20 uniform	3.15	7.19
20 thin + 10 thick	1.9 + 3.8	5.05 + 6.95

- All configurations have the same total thickness of $\approx 22\ X_0$
  $\rightarrow$ vary the thickness of the tungsten layer
- Every ECAL configuration requires calorimeter recalibration (done by the iLCDirac calibration system)



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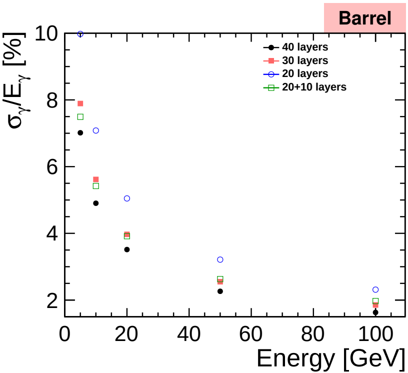
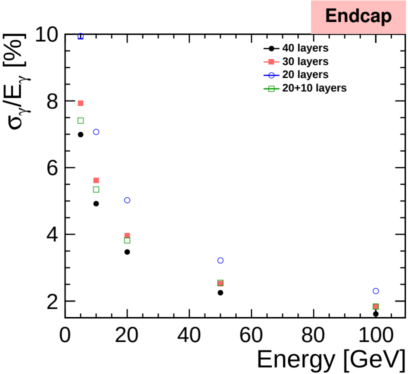
Photon energy resolution

- The number of ECAL layers strongly affects photon energy resolution.





- 40 layers configuration provides the best photon performance
- 20+10 layers configuration provides better performance at low energies compared for 30 layers which probably better fits needs of FCC-ee
- 20 layers option leads to significant degradation of photon resolution

- Jet energy resolution ($Z \to q\bar{q}, (q = u, d, s)$) is almost not affected by the number of ECAL layers

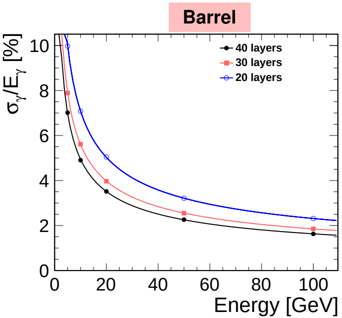
Layer structure	JER [%] $\sqrt{s} = 365$ GeV	JER [%] $\sqrt{s} = 91.2$ GeV
40 uniform	3.62 ± 0.05	4.52 ± 0.06
30 uniform	3.72 ± 0.05	4.45 ± 0.06
20 uniform	3.78 ± 0.05	4.82 ± 0.07
20 thin + 10 thick	3.67 ± 0.05	4.56 ± 0.06

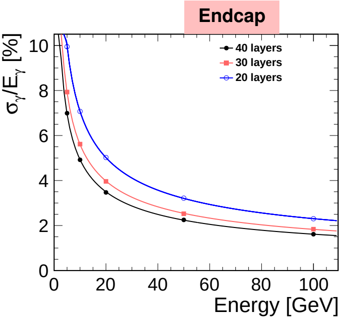
Summary

- Reduction of ECAL layers allows to significantly reduce the total cost of the detector with a moderate degradation of photon energy resolution and almost no effect on jet energy resolution.
- Configuration with 20 thin + 10 thick layers looks like a good option for a new baseline configuration of ECAL for CLD.

BACKUP

- Effect of reducing number of layers in ECAL to 30 or 20 (keeping constant depth of ECAL about 22 X_0, increasing thickness of W plates)





Barrel:

- 40 layers: $\frac{\sigma_{EM}}{E} = \frac{15.6\%}{\sqrt{E}} \oplus 0.5\%$
- 30 layers: $\frac{\sigma_{EM}}{E} = \frac{17.6\%}{\sqrt{E}} \oplus 0.6\%$
- 20 layers: $\frac{\sigma_{EM}}{E} = \frac{22.3\%}{\sqrt{E}} \oplus 0.6\%$

Endcap:

- 40 layers: $\frac{\sigma_{EM}}{E} = \frac{15.5\%}{\sqrt{E}} \oplus 0.5\%$
- 30 layers: $\frac{\sigma_{EM}}{E} = \frac{17.6\%}{\sqrt{E}} \oplus 0.6\%$
- 20 layers: $\frac{\sigma_{EM}}{E} = \frac{22.3\%}{\sqrt{E}} \oplus 0.6\%$