CEPC Scintillator-Steel HCAL: cost estimates

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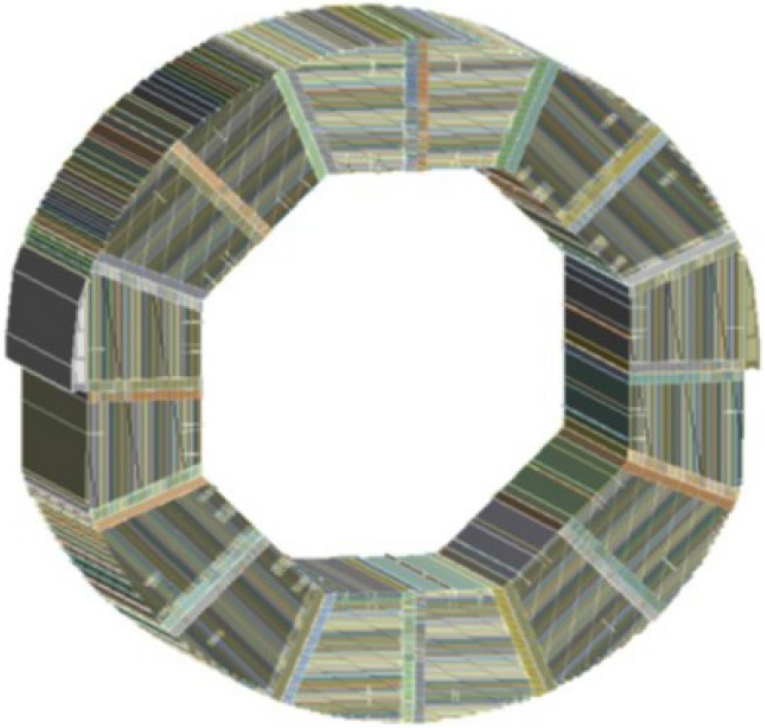
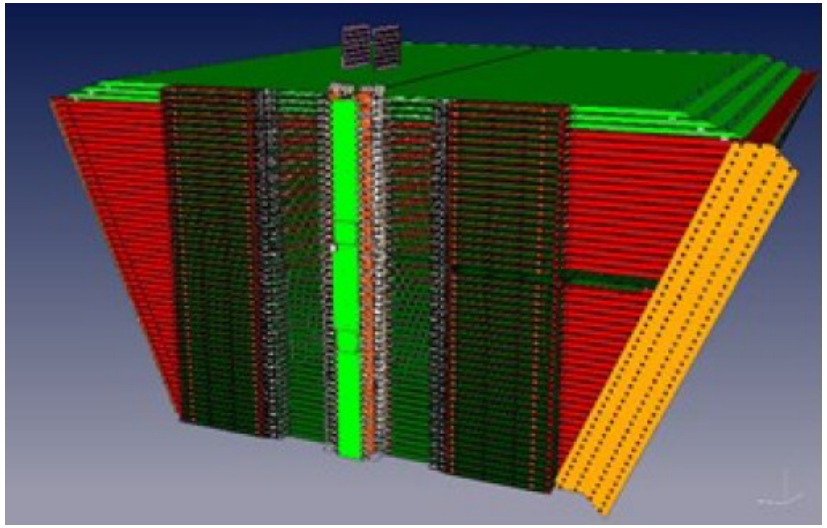
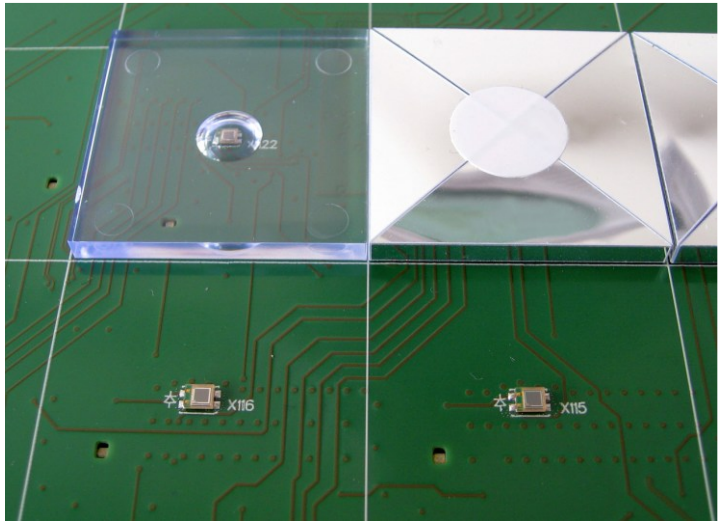
Scintillator-Steel Hadron Calorimeter: AHCAL



ILD-like AHCAL



Barrel segments



Detector Units

Expected prices of major components

Scintillator-Steel Hadronic Calorimetry is conventionally referred to Analogue HCAL (AHCAL)

Based on the Table III-7.3 (page 306) in Ref. [1]

Material	Cost (EUR in 2018) [*]	Comments (in 2013)
Stainless Steel	5 /kg	processing costs to be added (1-4 EUR/ kg)
Photosensor (e.g. SiPM)	1 /piece	based on manufacturer extrapolation, current price 7-10 EUR/piece
Front-End Electronics (ASIC)	0.22 – 0.25 /ch	Current price 0.5 EUR/ch
PCB	1800 /m²	for AHCAL extrapolated from the CALICE AHCAL prototype price of 10800/m²

[*] As quoted in Page 135 in Ref. [2]: The DBD costing had been made in an ”ILC currency”, the ILCU, in an effort to have a costing coherent between ILD, SiD and the accelerator…. 1 DBD ILCU turns out to be equivalent to 1 Euro(2018).

AHCAL: geometry and #channels

AHCAL detector unit: 30×30×3mm³

Configurations	AHCAL in ILD		AHCAL for CEPC	
Model	IDR-S	IDR-L (DBD in TDR)	CDR Baseline	Depth for 380GeV
Barrel R_in	171.5 cm	205.8 cm	205.8 cm [*]	
Barrel Depth	128.7 cm, 48 layers		40 layers	48 layers
Barrel Segments	2 in Z, 16 in phi; z_max=235 cm		idem	
Barrel #channels	3.73 M	4.27 M	3.59 M	4.27 M
Endcap R_max	287.6 cm	322.6 cm	301.2 cm	322.6 cm
Endcap R_min	35 cm		40 cm	
Endcap Depth	128.7 cm, 48 layers		40 layers	48 layers
Endcap Segments	16 in phi; 2 endcaps		idem	
Endcap #channels	2.74 M	3.44 M	2.49 M	3.43 M
Total #channels	6.47 M	7.71 M	6.08 M	7.70 M

[*] CEPC CDR: SiW-ECAL inner radius R=184.3 cm, with a total depth of 24X0 (30 sampling layers, the first 20 layers with 2.1mm W, 10 with 4.2mm W); 0.5mm thick silicon layer; 2.1mm 14-layer PCB (CALICE SiW prototype); no cooling plates yet. This value 205.8 cm is taken from Ref [1], the same as ILD.

Cost breakdown for an HCAL option: AHCAL for CEPC

Item	Cost (M€) for CDR baseline [*]	Cost (M€) for 380 GeV
Absorber	4.1	5.2
Module production	2.7	3.4
Cassettes	1.7	2.1
Scintillators	1.2	1.5
Reflective Foil	0.9	1.2
Photosensor (SiPM)	6.1	7.7
Cooling system[**]	1.4	1.8
Sum AHCAL	**36.7**	**45.7**

Item	Cost (M€) for CDR baseline [*]	Cost (M€) for 380 GeV
ASIC	1.4	1.8
Readout Board	10.4	13.2
Readout	1.8	2.3
Cabling, connections	0.8	1.0
HV/ LV supplies	0.8	1.0
Tooling, testing	**0.5**	**0.5**
Assembly, installation	**2.8**	**2.8**
DAQ	0.2	0.2

[*] The cost is estimated with a simple scaling law by applying the unit price for each of most items. Note that there are still a few items that may not be scaled (at least non-trivial at the current CDR knowledge level).
[**] The cooling is estimated for passive cooling; CMS-HGCAL ~7M CHF for ~1k m^2 area cooling with dual-phase CO2

AHCAL cost reduction: further R&D and investigations

- Photosensor
  - A new option for SiPMs from a local Chinese vendor (Novel Device Lab, aka NDL)
  - Can be a significant cost saver
- Front-end electronics
  - Currently no existing ASIC that is designed and verified for the PFA calorimeters at CEPC (continuous working mode, fast readout, minimal dead time).
  - Thus no solid information on the power consumption, but only knowledge from ASICs designed for ILD at ILC. Further info could be learned from the “HGCROC” for CMS HGCAL.
  - **Requires further R&D, especially in China**
  - Can be a significant cost saver
- Active cooling system
  - The current cost estimate of cooling is from ILD, which requires no active cooling. So this part can be very likely to be significantly underestimated.
  - Need thorough R&D studies in a scalable way towards the final system level, and identify the items that can not be scaled.

[*] Disclaimers: these are my personal remarks and understandings. All the errors are mine.

Notes and references

- Notes
  - The cost estimate of scintillator-steel HCAL for CEPC is based on the ILC TDR for the ILD detector, as these two designs are very similar.
  - PFA-calorimetry prototyping within the CALICE collaboration provides solid inputs for the cost estimate of ILD calorimetry (also for the detector for CLIC, aka “CLICdet”)
- References
  1. The International Linear Collider Technical Design Report - Volume 4: Detectors, 2013
     - https://arxiv.org/abs/1306.6329
  2. The International Large Detector (ILD) IDR (ILD Design Report), 2019
     - Only **draft version** available till now, to be reviewed within the ILD collaboration
     - https://confluence.desy.de/display/ILD/The+ILD+Design+Report%2C+IDR
  3. Cost estimate for CLICdet, 2018
     - https://edms.cern.ch/document/2027873
  4. CEPC Conceptual Design Report, 2018
     - http://cepc.ihep.ac.cn/CEPC_CDR_Vol2_Physics-Detector.pdf

Cost breakdown for an HCAL option: AHCAL in ILD

Item	Cost (kEUR)
Absorber	5200
Module production	3400
Cassettes	2100
Scintillators	1500
Reflective Foil	1200
Photosensor (e.g. SiPM)	7700
Cooling system	1800
Sum AHCAL	**45700**

Item	Cost (kEUR)
ASIC	1800
Readout Board	13200
Readout	2300
Cabling, connections	1000
HV/ LV supplies	1000
Tooling, testing	500
Assembly, installation	2800
DAQ	200

48 layers in the longitudinal direction of the AHCAL (corresponding to $6\lambda_I$) in ILD has been chosen in order to maintain the performance at 1 TeV, where typical jet energies are up to 250 GeV.