CEPC Calorimeter Options: Input Materials (Template)

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Performance

Items	Priority	Results / Status	Remarks
Boson Mass Resolution	A	~3.6% (vv_gg)	BMR < 4%
Intrinsic EM/hadronic energy resolution	A	26.5%/sqrt(E) + 8.3%	
Separation power			gamma/gamma, gamma/hadron, hadron/hadron
Lepton ID in jets			
Timing capability			
π^0 reconstruction			
Pile-up at Z-pole			

- Priority/importance for performance requirements: (A) must-have; (B) plus; (C) not essential

Cost

Cost table template for GSHCAL

Parameter Name	Barrel	Endcaps (x2)	Sum
Inner Radius for HCAL	2050 mm ~~1900 mm + $24X_0$~~	400 mm	NA
Length for barrel; Outer radius for endcap*	4600 mm ~~6100 mm~~	1900 mm + $24X_0 + 6\lambda_I$	NA
Longitudinal Depth	$5\lambda_I$ ~~$6\lambda_I$~~		NA
Modularity	8 modules in phi, #rings along Z	Assuming any ideal geometry if no design?	NA
Material Volume (m^3)	GS 46 m^3 / Steel 64 m^3		
Readout channels	$2.9x10^6$		
Power dissipation (kW)			
Cost: sensitive materials	GS:1~10 CNY/cc / Steel: 0.4 CNY/cc		2.3e8 / 2.6e7
Cost: electronics	SiPM: 40 CNY/piece / Ele: 20 CNY/channel		1.2e8 / 0.6e8

* Endcaps encompass barrel

Please also consider to indicate in extra or supporting materials

- Unit cost for key components and materials
- References for unit cost or estimates
- Uncertainty or risks if applicable

Technical readiness level

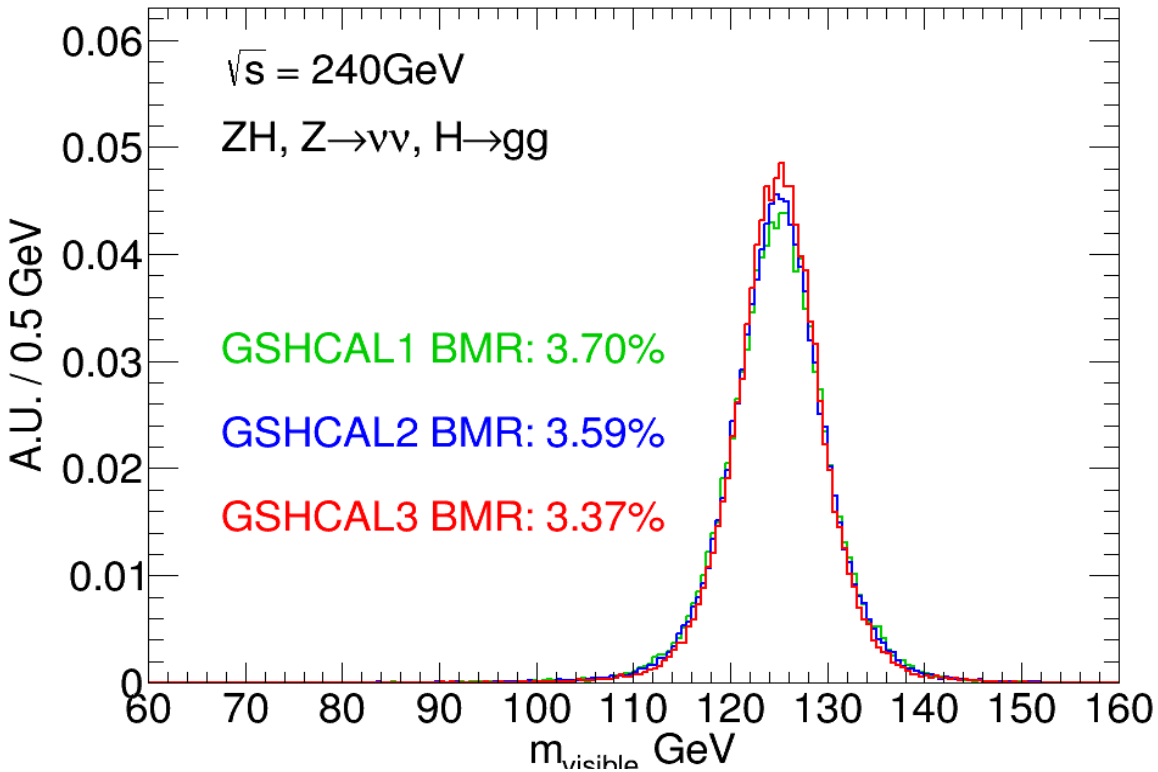
- Status and plans of simulation studies and R&D (a table template)
- Person power: Peng Hu, Du Dejing, GS collaboration colleagues

Category	Status	Design 1	Other Alternative Design (if any)
Technical Readiness Level	Full Simulation (system level)	6 lambda, ongoing	10mm GS+ 13.8mm steel, 5lambda Finished
	Full Simulation (module level)	ongoing	finished
	Prototyping R&D (common)	Ongoing within GS collaboration	Ongoing within GS collaboration
	Prototyping R&D (modules, units)	40x40x10 mm^3 unit Ongoing	ongoing

Cost

Nominal Setup

Parameter	GSHCAL1	GSHCAL2	GSHCAL3
Readout	Analog	Analog	Analog
Number of layers	40	40	40
Layer thickness	0.125 lambda (3mm GS +18.8mm Steel)	0.125 lambda (10mm GS +13.9mm Steel)	0.125 lambda (29.7 mm GS)
Total Nuclear Interaction Length	5 lambda	5 lambda	5 lambda
Transverse Cell Size	40x40 mm^2	40x40 mm^2	20x20 mm^2
Sensitive Material Density	6 g/cm^3	6 g/cm^3	6 g/cm^3
HCAL Thickness	873 mm	962 mm	1218 mm
HCAL Volume	13 m^3(GS) 81 m^3(Steel)	46 m^3(GS) 64 m^3(Steel)	159 m^3(GS)
Number of Cells	2.7×10^6	$\mathbf{2.9\times10^6}$	5.4×10^7



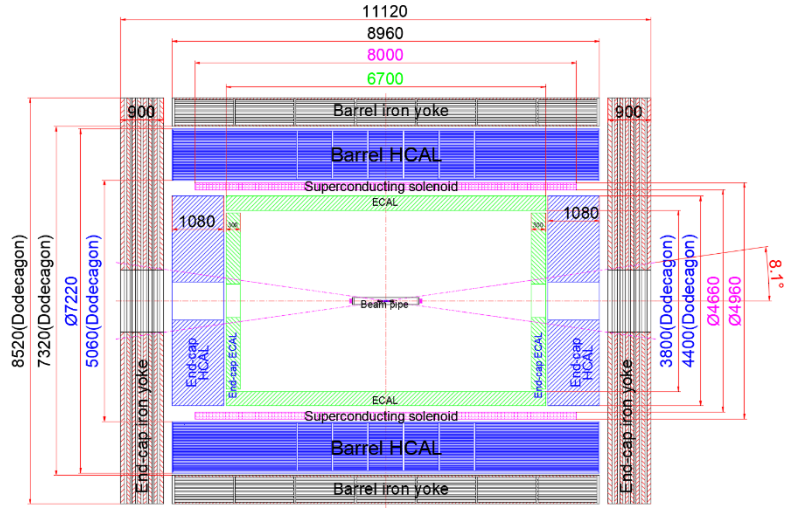
*Gaussian fitting range: Mean +/- 2 RMS

Cost

	Total Glass	Total Steel	Total SiPMs	Total Readout Channels
Value	88.8 m^3	122.9 m^3	$5.55x10^6$	$5.55x10^6$
Unit Price (RMB)	3/c.c	16500*3/ton	40/piece (国产SiPM)	20/channel (50% SiPM price)
Total Price (RMB)	$2.65x10^8$	$4.87x10^7$	$2.22x10^8$	$1.11x10^8$

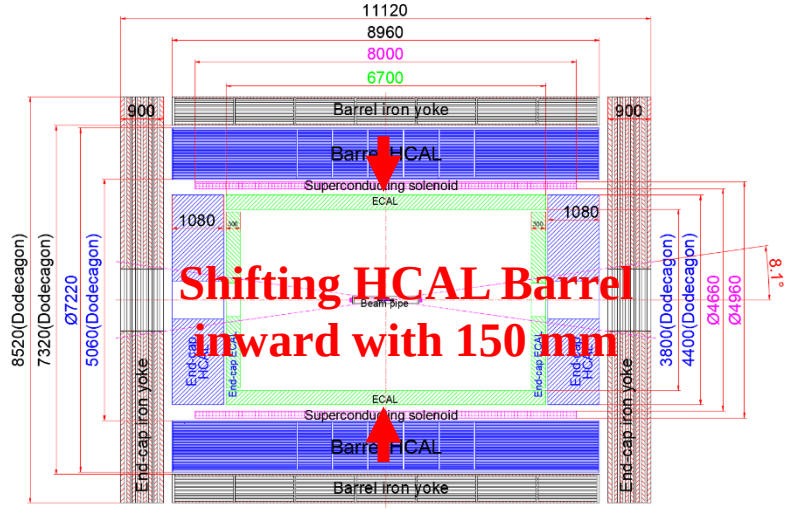
GSHCAL Total Cost: $6.47x10^8$ RMB

*Specification: 10 mm Glass + 13.8 mm Steel per sampling layer

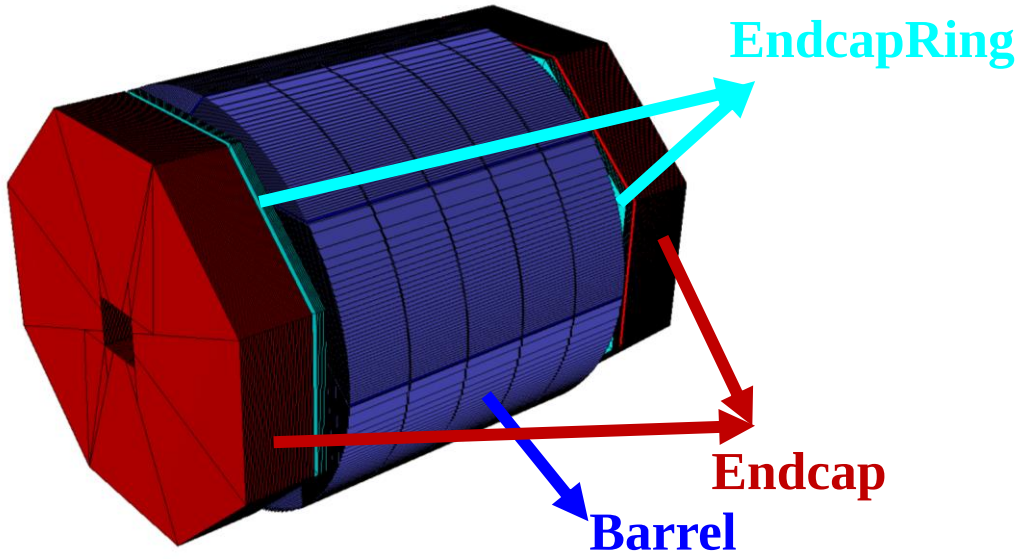


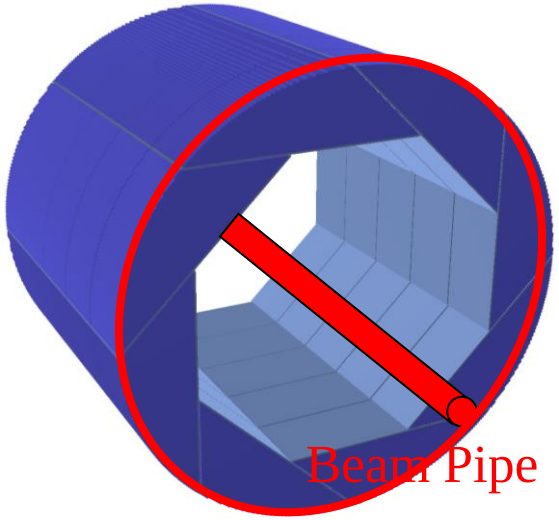
	Total Glass	Total Steel	Total SiPMs	Total Readout Channels
Value	85.1 m^3	117.9 m^3	$5.32x10^6$	$5.32x10^6$
Unit Price (RMB)	3/c.c	16500*3/ton	40/piece (国产SiPM)	20/channel (50% SiPM price)
Total Price (RMB)	$2.55x10^8$	$4.67x10^7$	$2.13x10^8$	$1.06x10^8$

GSHCAL Total Cost: $6.21x10^8$ RMB



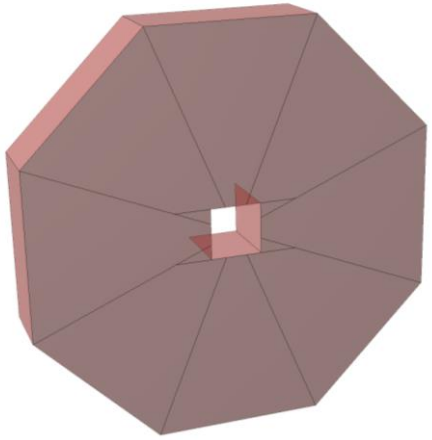
GSHCAL Overall Structure



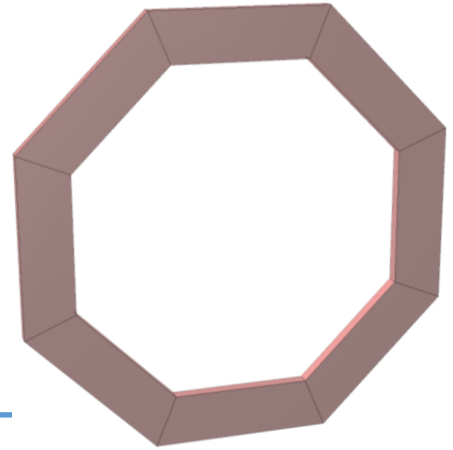


- The overall structure of the GSHCAL consists of three parts: the Barrel, Endcap and EndCapRing
  - Thickness of the Barrel: ~1 m
  - Outer radius of the Barrel: ~3 m
  - Length along beam direction: ~4.7 m
  - **Number of Layers: ~40**
  - **GS/Steel Volume: ~46/64 m^3**
  - **Number of SiPM readout Channels: ~$3x10^6$**

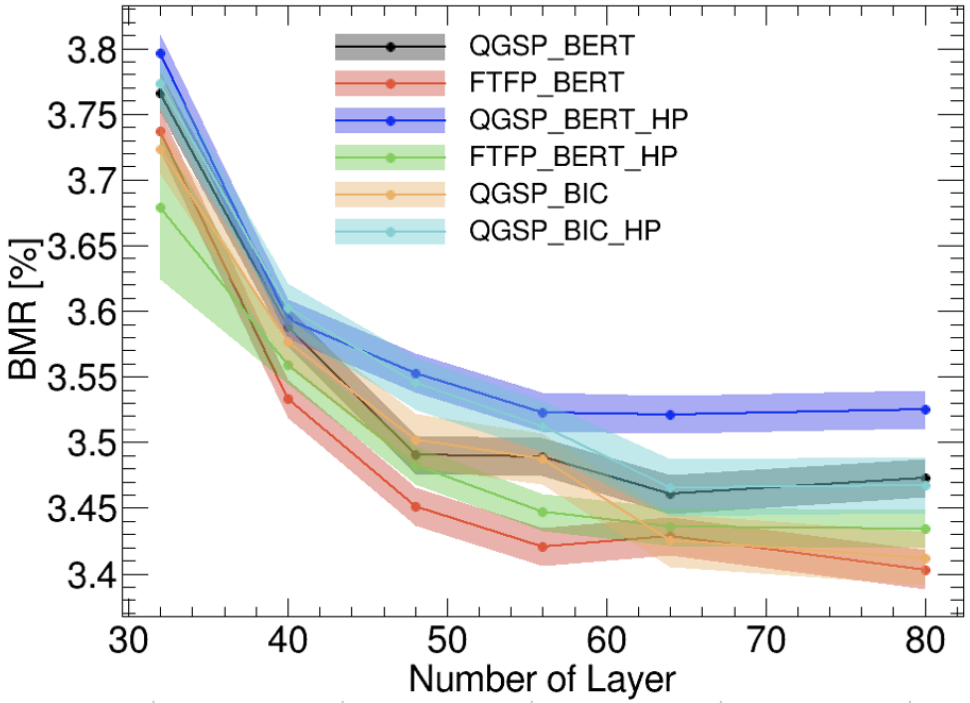
Endcap



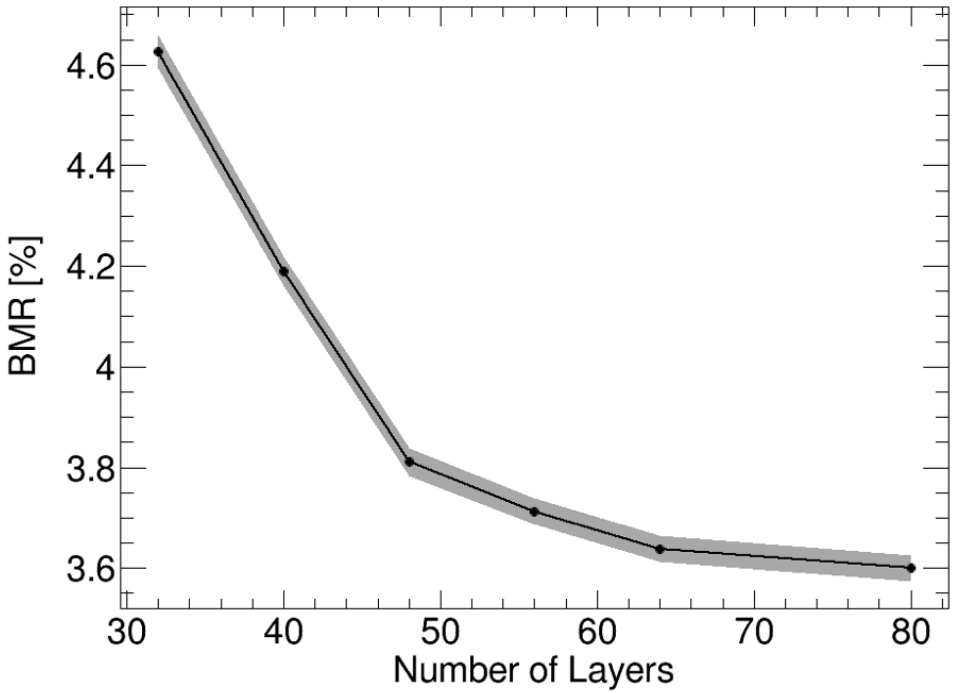
EndcapRing



240 GeV e+e- → $\nu\bar{\nu}$H (H → gg)



360 GeV e+e- → $\nu\bar{\nu}$H (H → gg)



☐ These parameters are fixed

Glass Cell Size	**40×40×10 mm^3**
NIL of Sampling Layer	**0.125 λ**
Glass Density	**6 g/cm^3**
Readout Threshold	**0.1 MIP**

Nuclear Interaction Length

Geant4 Source Code

```
void G4Material::ComputeNuclearInterLength()
{
  const G4double lambda0  = 35*CLHEP::g/CLHEP::cm2;
  const G4double twothird = 2.0/3.0;
  G4double NILinv = 0.0;
  for (G4int i=0; i<fNumberOfElements; ++i) {
    G4int Z = (*theElementVector)[i]->GetZasInt();
    G4double A = (*theElementVector)[i]->GetN();
    if(1 == Z) {
      NILinv += fVecNbOfAtomsPerVolume[i]*A;
    } else {
      NILinv += fVecNbOfAtomsPerVolume[i]*G4Exp(twothird*G4Log(A));
    }
  }
  NILinv *= amu/lambda0;
  fNuclInterLen = (NILinv <= 0.0 ? DBL_MAX : 1./NILinv);
}
```

General Definition

The nuclear interaction length λ characterises the interactions in calorimeter; exactly it is the mean free path of particle between two inelastic interactions. This variable is different for various particles. It depends on the inelastic nuclear cross section σ like:

$$\lambda = \frac{A}{N_A \cdot \sigma \cdot \rho} \tag{1}$$

where A, ρ are the atomic weight and density of the target, N_A is the Avogadro number.

The interaction length for pions and protons in TileCal was calculated in [2]:

pions:	λ_π=251 mm
protons:	λ_p=206 mm
	λ_π/λ_p=1.22

PDG DataBase

- Nuclear collision and interaction cross sections based on Glauber model are calculated using code by Sergei Striganov (FNAL). Table entries are for 200 GeV/*c* neutrons. Cross sections are reasonably independent of momentum over this region, as shown in the figure.