Status of CEPC Ref-Detector TDR ECAL software in CEPCSW

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Introduction

- CEPC Ref-Detector TDR Calorimetry System:
 - Aim to achieve an unprecedented Boson Mass Resolution(BMR) of 3-4%
- Homogeneous crystal ECAL:
 - Optimal intrinsic EM resolution: $\sigma_E/E < 3\%/\sqrt{E}$
 - High granularity in 3D: compatible with PFA
 - Minimal longitudinal dead material: orthogonal arranged bars



Simulation Framework in CEPCSW

Simulation:

- Critical for design, optimization and performance study of detectors.
- Simulation chains includes: physics generator, detector simulation and digitization.
- DD4hep is adopted to provide the full detector description with a single source of information
 - Consists of C++ constructors and XML based compact files
- Different detector options are managed in a git repository.
 - Easy to setup detectors and compare between different options.







Detector description of ECAL barrel

Boundary and # modules of ECAL barrel

Parameter	Value / mm			
Radius of incircle	1830			
Regular 16-sided polygon	2130			
Length	5800			
# modules in phi	32			
# modules in Z	15			



--- 1830 mm 3000 2000 2130 mm 1000 ۲ / mm 0 1830 mm -1000 -2000 -3000 1000 2000 3000 -3000 -2000 -1000 0 X/mm



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Detector description of ECAL barrel



Why angle between leg and direction of interaction point not equal 0: avoid from energy leakage



Detector description of ECAL barrel

Unight		Value / mm			
	пеідіі	Inverted Isosceles trapezoid	Isosceles trapezoid		
	# Layer	28	28		
Each layer	Crystal	9.6	10		
	ESR wrapping	0.2	0.2		
Top of module	РСВ	1	1		
	Cu cooling	1	1		
	Al cooling and electronics components	10	10		
	Carbon fiber cover and ring	TBD	TBD		
Bottom of module	Carbon fiber cover	TBD	TBD		
	Sum	286.4	297.6		



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	Geometry	Shape and size	Material	Schematics	Software implementation
ſ	Vechanic supporting	R-phi: one step in ecah layer, 2.5mm in one side Z: 2.5mm in one side and 20mm at Z=+-2900mm Reforcing ribs 50-50*10mm	CarbonFiber		Absent: supporting at z=+-2900mm and reforcing ribs
Side	PCB and ASIC	thickness: 3mm	PCB F24		Update: reduce unnecessary pcb & asic and update material
	Cu cooling	thickness: 1mm	Cu		Done
	Gap between Cu & shell	thickness: 1mm	Air	5	Absent
	Carbon firber shell	TBD	CarbonFiber		Absent
Top and bottom	Al cooling tubes	4 tubes: 10mm*40mm, 2mm thickness	AI		Absent
	Electronics components	Sharing with Al cooling tubes	TBD		Update: material
	Cu cooling	thickness: 1mm	Cu	8	Absent
	РСВ	thickness: 1mm	РСВ		Update: thickness
	Top & Bottom cover	TBD	CarbonF		Absent
each layer	Sipm	3mm*3mm*0.8mm, two in one side	Si		Done, inside ESR
	ESR wrapping	thickness: 0.1mm*2	ESR		Done
	Crystal	height, length, width & numbers & abnormal cells	ength, width & numbers & abnormal cells BGO		Update: study of abnormal cells
	Cable	TBD	TBD		TBD

	Inverted Isosceles trapezoid		Isosceles trapezoid			Inverted Isosceles trapezoid		Isosceles trapezoid	
Layer	Length / mm	N bar	Length / mm	N bar	Layer	Length / mm	N bar	Length / mm	N bar
1	287.5	36	406.1	36	15	374.7	36	374.2	36
2	293.7	27	403.8	39	16	380.9	37	371.9	35
3	299.9	36	401.5	36	17	387.1	36	369.6	36
4	306.2	29	399.2	39	18	393.4	37	367.3	35
5	312.4	36	397.0	36	19	399.6	36	365.1	36
6	318.6	31	394.7	37	20	405.8	39	362.8	35
7	324.9	36	392.4	36	21	412.0	36	360.5	36
8	331.1	31	390.1	37	22	418.3	41	358.2	35
9	337.3	36	387.8	36	23	424.5	36	355.9	36
10	343.5	33	385.6	37	24	430.7	41	353.7	33
11	349.8	36	383.3	36	25	436.9	36	351.4	36
12	356.0	33	381.0	37	26	443.2	43	349.1	33
13	362.2	36	378.7	36	27	449.4	36	346.8	36
14	368.4	35	376.4	35	28	455.6	43	344.5	33





Detector description of ECAL endcap

- Key issues in design of ECAL endcap:
 - Effective proportion
 - Avoid from energy leakage
 - Few types of module
- Detector description of ECAL endcap
 - > Work in progress
 - Be a circle as much as possible
 - ✓ Angle between leg and direction of interaction point > 11°
 - ✓ 6 types



Digitization and Energy resolution

- Digitization model: from beam test
 - Crystal scintillation: 100 p.e./MIP (single end detected)
 - SiPM gain calibration: 1 p.e. = 5 ADC, with noise
 - Electronics: 12 bits ADC with precision 0.2%, 3 gain modes
 - Threshold: 0.1 MIP

• Energy resolution with full digi: $\sigma_E/E = 1.4\%/\sqrt{E} \oplus 0.3\%$ (in barrel module center)



CyberPFA: CrYstal Bar ECAL Reconstruction

- Key issues in ECAL reconstruction to be addressed:
 - shower overlap
 - multi-particle ambiguity





Ghost hits

- Task list in CyberPFA:
 - clustering
 - pattern recognition
 - shower splitting for overlap
 - ambiguity removal
 - full PFA





Physics performance

- Close-by particle separation:
 - $\gamma \gamma$ separation : 22 mm @ 100% efficiency.
 - $\gamma \pi$ separation : 100 mm @ 100% efficiency.
- Physics process $ee \rightarrow ZH \rightarrow \nu\nu\gamma\gamma$ in higgs mode
 - Full simulation and digitization. Energy correction in crack region has been applied.

Efficiency / %

- Physics process $ee \rightarrow ZH \rightarrow \nu\nu gg$ in higgs mode
 - Full reconstruction in CEPC detector: Silicon + TPC tracker, crystal ECAL, glass tile HCAL.
 - BMR = 4.11%
 - with truth tracker: BMR = 3.73%



Summary

ECAL software in CEPCSW is available:

- Complete software tools: simulation, digitization and reconstruction, has been used for jet reconstruction and beam background studies.
- Appreciate the inputs from mechanics, electronics, beam test group.

Next step:

- Implementation and optimization of geometry description:
 - Detailed mechanics / cooling / cable structure.
- Energy correction for energy leakage.
- Detector design optimization:
 - BMR study at 1.5cm*1.5cm*40cm geometry.



backup