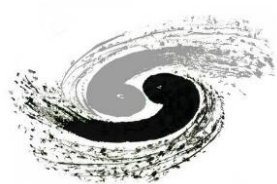


CEPC Ref-TDR ECAL updates

Yong Liu (IHEP) for the CEPC Ref-TDR ECAL team
CEPC Reference Detector TDR Weekly Meeting
October 15, 2024





Latest updates

- CEPC ECAL Weekly Meeting on TDR
 - Agenda on Oct. 11, 2024: <https://indico.ihep.ac.cn/event/23803/>
 - Online note: <https://note.ihep.ac.cn/cTyoJQbeT3WDTfY6mm2LZw>
- Routine agenda
 - *Part 1* on updates/status: electronics, mechanics, software, backgrounds, etc.
 - *Part 2* on Cost Estimates

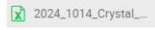
Electronics, mechanics, physics and software: Updates and Planning

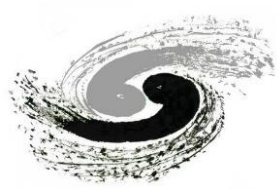
Conveners: Jinfan Chang (高能所), Manqi Ruan (IHEP), Shaojing 侯少静 (高能所), Sheng-Sen Sun (Institute of High Energy Physics)

2:05 PM	Calorimeter electronics	10m
Speakers: Jinfan Chang (高能所), Wei WEI (高能所), Xiongbo 严雄波 YAN Xiongbo (高能所)		
2:15 PM	Calorimeter mechanics and cooling: barrel and endcaps	15m
Speakers: Haijun Yang (Shanghai Jiao Tong University), Jiebing Yu (Institute of High Energy Physics, Chinese Academy of Sciences), Qian Ji, Shaojing 侯少静 (高能所), Sheng-Sen Sun (Institute of High Energy Physics), UNKNOWN 张俊嵩, Weizheng Song (Institution of High Energy Physics), 亚田 裴 (高能所)		
		
2:30 PM	Calorimeter software: geometry, simulation, digitisation and reconstruction	10m
Speakers: Dejing Du (IHEP), Fangyi Guo, Hengne Li (South China Normal University), Ji-Yuan Chen (SJTU), Sheng-Sen Sun (Institute of High Energy Physics), Weizheng Song (Institution of High Energy Physics), Zhiyu Zhao (TDLU/SJTU), 洪滨 刁 (中国科学技术大学)		
		
2:40 PM	Beam-Induced Backgrounds	10m
Speakers: Fangyi Guo, Sheng-Sen Sun (Institute of High Energy Physics), Weizheng Song (Institution of High Energy Physics)		
2:50 PM	Calorimeter performance studies: physics and beamtests	10m
Speakers: Baohua Qi (IHEP), Dejing Du (IHEP), Manqi Ruan (IHEP), Yong Liu (Institute of High Energy Physics), Zhiyu Zhao (TDLU/SJTU)		

CEPC Reference Detector TDR: Document preparations for the Chapter 6 (ECAL)

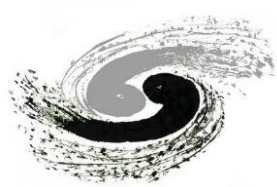
Convener: Dr Yong Liu (Institute of High Energy Physics)

3:00 PM	General updates	3m
Speaker: Dr Yong Liu (Institute of High Energy Physics)		
		
3:03 PM	ECAL requirements	3m
Speakers: Haijun Yang (Shanghai Jiao Tong University), Jianbei Liu (University of Science and Technology of China), Manqi Ruan (IHEP), Dr Yong Liu (Institute of High Energy Physics)		
3:06 PM	Survey of ECAL technical options: SiW-ECAL, ScW-ECAL, crystal	3m
Speakers: Haijun Yang (Shanghai Jiao Tong University), Huaqiao ZHANG (IHEP), Jianbei Liu (University of Science and Technology of China), Dr Yong Liu (Institute of High Energy Physics), Yunlong Zhang (University of Science and Technology of China)		
3:09 PM	Technical challenges: beam backgrounds, radiation damages, calibrations	3m
Speakers: Baohua Qi (IHEP), Fangyi Guo, Weizheng Song (Institution of High Energy Physics), Zhiyu Zhao (TDLU/SJTU)		
3:12 PM	Crystal ECAL R&D activities and highlights: addressing critical issues	3m
Speakers: Baohua Qi (IHEP), Dejing Du (IHEP), Fangyi Guo, Huaqiao ZHANG (IHEP), Ji-Yuan Chen (SJTU), Dr Yong Liu (Institute of High Energy Physics), Zhiyu Zhao (TDLU/SJTU)		
3:18 PM	Mechanics and Cooling	3m
Speaker: Shaojing 侯少静 (高能所)		



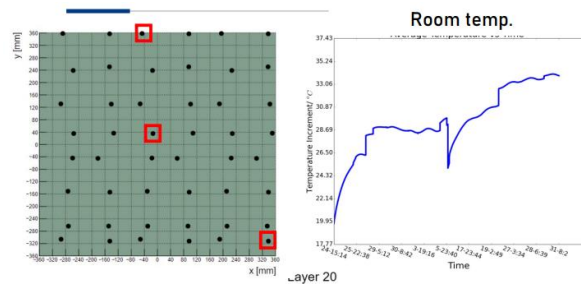
Latest Status: a brief summary

- ECAL mechanics
 - Updated design and FEA simulation, carbon fiber prototyping;
 - A separate progress report to be presented by Shaojing
- Beam-induced backgrounds
 - Ongoing studies to evaluate the impacts to EM performance
- Software
 - Updated digitisation in simulation: temperature,
- Cost estimates

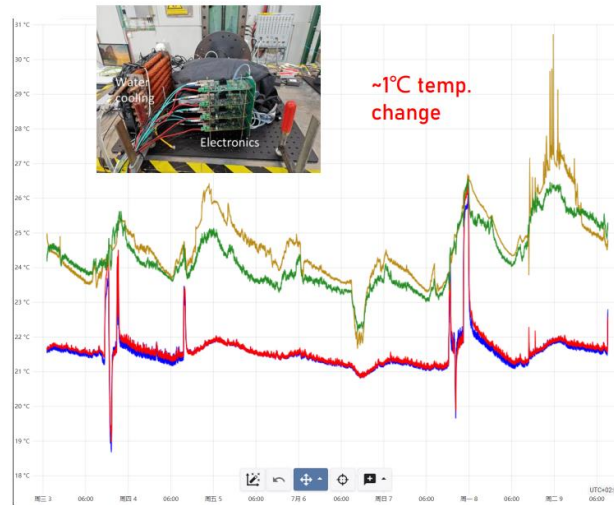


Digitisation updates

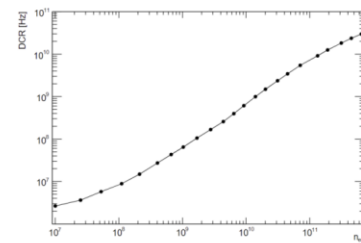
- Experiences: temperature gradient and fluctuation in prototypes during beamtests
- Temperature coefficients implemented in CEPCSW digitisation
 - Crystal (intrinsic light yield), SiPM (DCR, gain)
- Temperature field in CEPCSW
 - A simple model based on current FEA simulation: 1D linear interpolation within Tmin and Tmax
 - Missing Detailed map of temperature gradient (and fluctuations) in the full detector



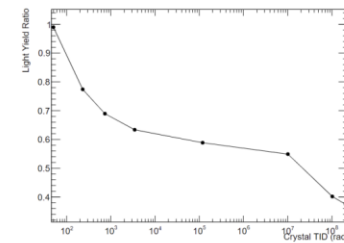
• Temperature of crystal module(box), air and water cooling



Conditions	Parameters	Value	Note	Prototype value
Temperature	Temperature gradient	3K	Specification?	<1K within 1 week
	Global temp. dynamic range	1K	Uniform distribution	
	Crystal light yield	-1.38%/K	doi:10.1007/s11433-014-5548-4	
	SiPM gain	-3%/K	doi:10.1016/j.nima.2016.09.053	
Radiation damage	SiPM DCR	$DCR_0 \cdot 10^{\frac{3.34}{80} \Delta T}$	doi:10.1016/j.nima.2016.09.053	
	Crystal TID	<50 rad	No damage now	
	SiPM NIEL	<1e+6	No damage now	



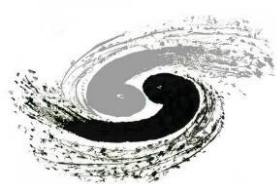
<https://doi.org/10.1016/j.nima.2022.167488>



[doi:10.1088/1742-6596/1162/1/012022](https://doi.org/10.1088/1742-6596/1162/1/012022)

- CEPC AHCAL, no active cooling
- Temperature gradient is almost constant

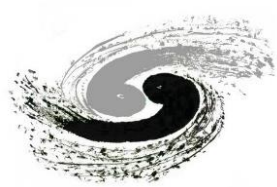
- It is better to have the maps of both temperature and radiation dose in ECAL
- Currently, the energy shift cause by temperature and radiation can be calibrated without any uncertainty.



Digitisation updates

- A summary table on digitisation: ongoing validation studies

Process	Parameters	Value	Note	Prototype value
Scintillation	Intrinsic light yield	8200 ph/MeV	BGO properties (8000~10000 ph/MeV)	8200 ph/MeV
	Effective light yield	200 p.e./MIP	$LY_{Int} * LCE * PDE$, $40 \times 1 \times 1cm^3$ BGO	760/1340 p.e./MIP (module-1/2, $12 \times 2 \times 2cm^3$ BGO)
	MIP energy	8.9 MeV	5 GeV muon pass through 1cm BGO	17.8MeV (2cm BGO)
	Non-uniformity along bar	0.03%	$[(Ch1 + 2)_{max} - (Ch1 + 2)_{min}] / (Ch1 + 2)_{min}$	No this parameter (<1% in measurement)
	Difference between 2-ends	5%	$(Ch1_{max} - Ch2_{min}) / Ch2_{min}$	No this parameter (<1% in measurement)
	Light collection efficiency	1.1%	Ensure the effective light yield	3.1%/5.4%
	Photon detection efficiency	25%	<u>SiPM NDL-EQR06</u>	17%/30% (HAMAMATSU S14160-3010/15PS)
SiPM	Active area	$3 \times 3 mm^2$	<u>SiPM NDL-EQR06</u>	$3 \times 3 mm^2$ (HAMAMATSU S14160-3010/15PS)
	Pixel pitch	$6 \mu m$	<u>SiPM NDL-EQR06</u>	$10 \mu m / 15 \mu m$
	Pixel number	244719	<u>SiPM NDL-EQR06</u>	89984/57600
	DCR	2,500,000 Hz	<u>SiPM NDL-EQR06</u>	700,000 Hz
	Gain fluctuation	8%	<u>SiPM NDL-EQR06</u>	5%
	Crosstalk	12%	<u>SiPM NDL-EQR06</u>	0.5%
ADC	Time window	150 ns	Assumption	87.5 ns
	Number of gains	3	Assumption	2 (CAEN A5202, Citiroc-1A)
	Dynamic range	0.1~4885 MIP	Accurately meas. within 30 GeV	0.1~80 MIP
	Vertical accuracy	13-bit, 8192 ADC	Citiroc-1A	13-bit, 8192 ADC
	Switching point	8000 ADC	Citiroc-1A	7900 ADC
	Pedestal position	50 ADC	Citiroc-1A	40~80 ADC
	ASIC noise	4 ADC	Don't varies with gain	
	FEE noise	15 ADC	Varies with gain	



ECAL cost estimates: a first preliminary table

Crystal ECAL Parameters			Unit	Remarks	
Barrel	Inner Radius	1.83	m		
	Length	5.80	m		
	Thickness	0.27	m		
	Modularity: Z-segments	15.00	/		
	Modularity: Phi-segments	32.00	/		
	Crystal Volume (cylindrical ring)	19.33	m ³	19.334555	
	Crystal Volume (32-sided modules)	19.21	m ³	19.21055962	19.21055962
	Number of Readout Channels (estimate)	960000.00	/		On average 2,000 channels/module
Number of Readout Channels (in CEPCSW)	963840.00	/			
Endcap	Inner Radius	0.35	m		
	Outer Radius	2.10	m		
	Thickness	0.27	m		
	Crystal Volume (cylindrical ring)	7.27	m ³	(2.1*2.1-0.35*0.35)*PI()*0.27*2	
	Crystal Volume (32-sided modules)	To be updated	m ³		5.148732094
	Number of Readout Channels	387552.00		5.15*49356	
Unit Price	SiPM cost per piece	63.00	CNY	9 EUR / ch	Scaling from 1 EUR/piece based on cost projection of 1x1mm SiPM
	Front-end Electronics	15.00	CNY	2.5 EUR/ch	
	BGO Crystal Unit Cost	65.00	CNY	Quotes from SIC-CAS, (per cc, VAT included)	BSO cost saving (Estimate <6USD/cc)
Sum	Total Crystal Volume	26.48	m ³		
	Crystal Cost	16.68	100M CNY (亿元)		
	Total Number of Readout Channels	1.35	million channels		
	SiPM and FEE Cost	85.14	million CNY (百万元)		
	Total Cost (Crystal + SiPM + FEE)	17.53	100M CNY (亿元)		