The Status of the HCAL

2024-09-24

Qian Sen, on behalf of the HCAL Group

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The Weekly Meeting of HCAL

The Indico Page

1:00 PM → 1:05 PM **Introduction and news** Restricted

Speakers: Jianbei Liu (University of Science and Technology of China), Sen Qian (高能所)

@20240910-HCAL...

1:05 PM → 2:25 PM **sub-system progress on GSHCAL**

Conveners: Jinfan Chang (高能所), Manqi Ruan (IHEP), Sheng-Sen Sun (Institute of High Energy Physics), 伯祥 俞 (高能所), 宇广 谢 (高能所)

1:05 PM **Design** 10m

Speakers: Fangyi Guo, Hengne Li (South China Normal University)

GSHcal simulation...

1:15 PM **Glass Scintillator** 10m

Speakers: Sen Qian (高能所), Prof. 晶 任

0923 influence of c...

1:25 PM **SiPM** 10m

Speakers: 宇广 谢 (高能所), 纪锋 韩 (四川大学)

SiPM progress for ...

1:35 PM **Electronics** 10m

Speakers: Jinfan Chang (高能所), Wei WEI (高能所)

1:45 PM **Mechanics** 10m

Speakers: 亚田 裴 (高能所), Quan JI, UNKNOWN 张俊嵩

CEPC桶部强子量能... HCAL 端部初步的结...

1:55 PM **Detector Layout** 10m

Speakers: 伯祥 俞 (高能所), Yunlong Zhang (University of Science and Technology of China)

GS单元设计.pptx

2:05 PM **Software** 10m

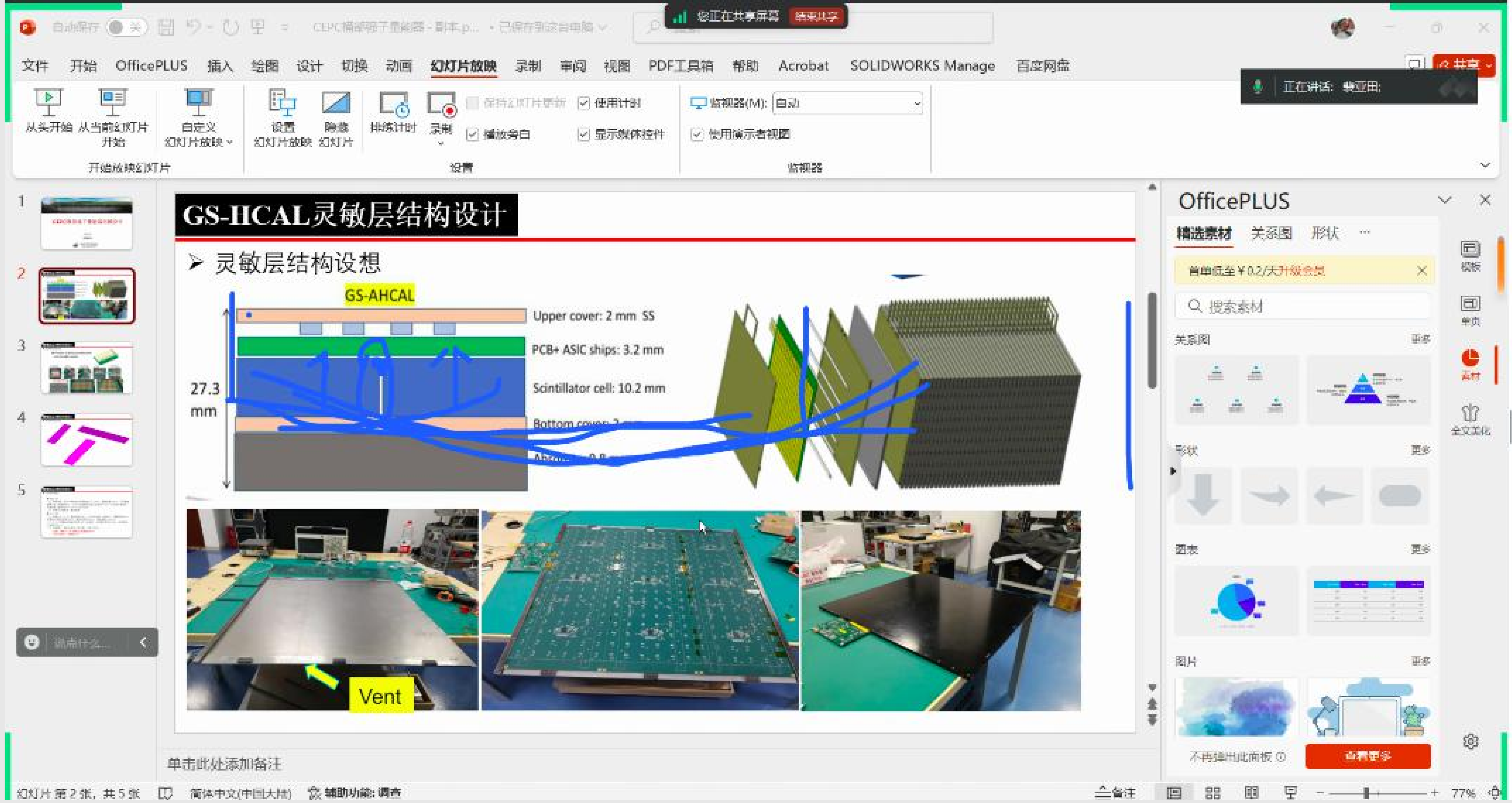
Speaker: Sheng-Sen Sun (Institute of High Energy Physics)

2:15 PM **Physics** 10m

A new mail list will be done:

cepc_det_ref_tdr_HCAL@maillist.ihep.ac.cn

Mechanics: 20240916 19:00-21:00   by Pei Yatian.



Discussed the GS cell, the electronics, the calbs and the cooling.

invite Prof. Shang from ZhengZhou Uinversity join us for the thermal analysis

Recent plans for GS-HCAL--Design

--by Fangyi Guo & Hengne Li

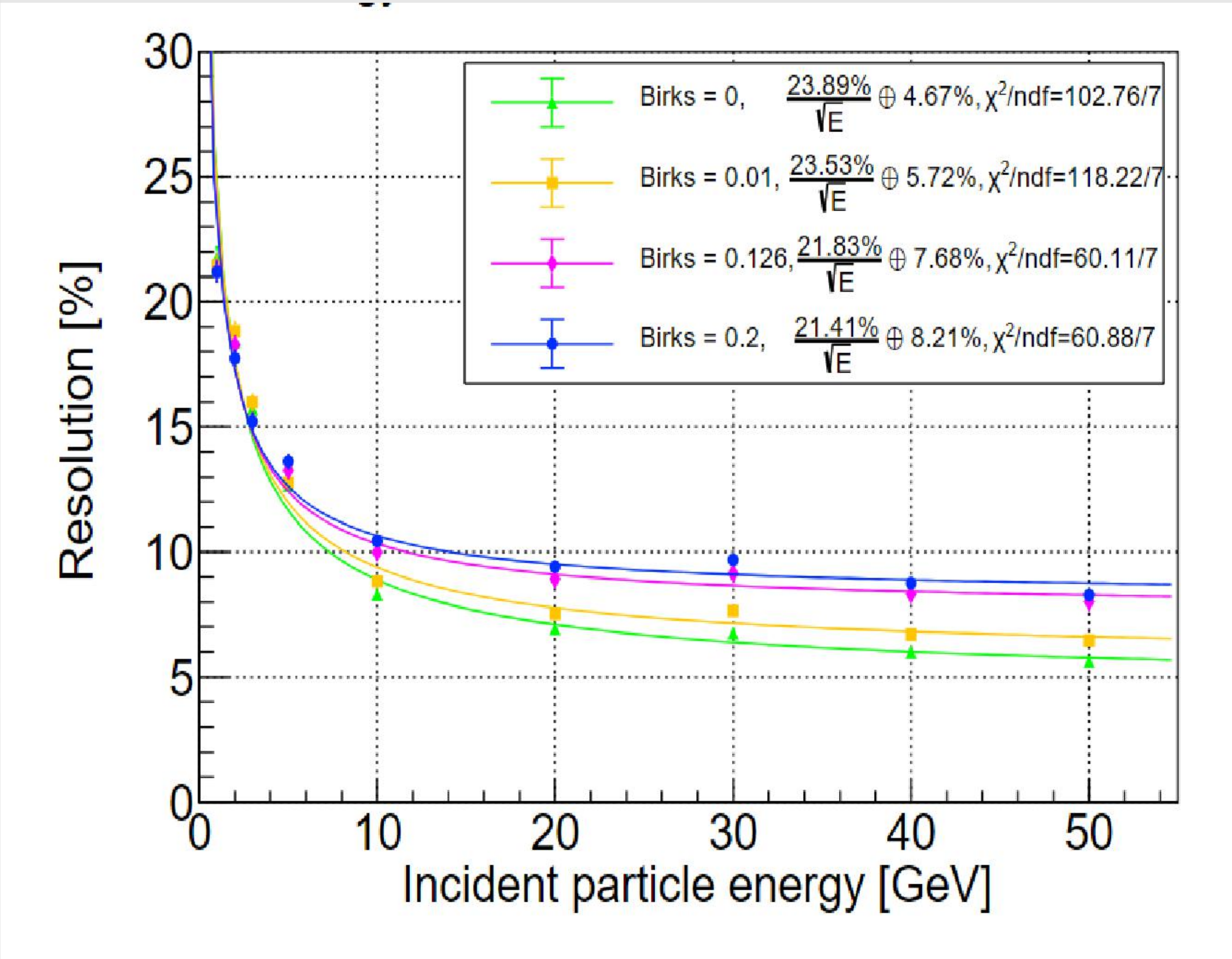
- Address key parameters to energy resolution:

	Simulation			Digitization				Design	Data rate
Terms	Leakage	Sampling fraction	Birks effect	Light yield	Attenuation length	SiPM response: saturation, dynamic range, noise, etc.	Electronics: precision, threshold, etc.	Geometry optimization	Beam background simulation; signal occupancy
Last Week	Done	Done	Doing	Doing	Doing	Todo	Todo	Todo	Doing
Status	Done	Done	Done	Done	Done	Doing	Doing	Todo	Todo

- Impacts from Birks effect, light yield, threshold, attenuation length / tile non-uniformity and dynamic range are studied (in following slides).
- Still missing: SiPM noise, electronic system precision and noise, data rate.
- Parameters for full digitization model is under discussion in group for final decision.

Recent plans for GS-HCAL--Design

--by Fangyi Guo & Hengne Li



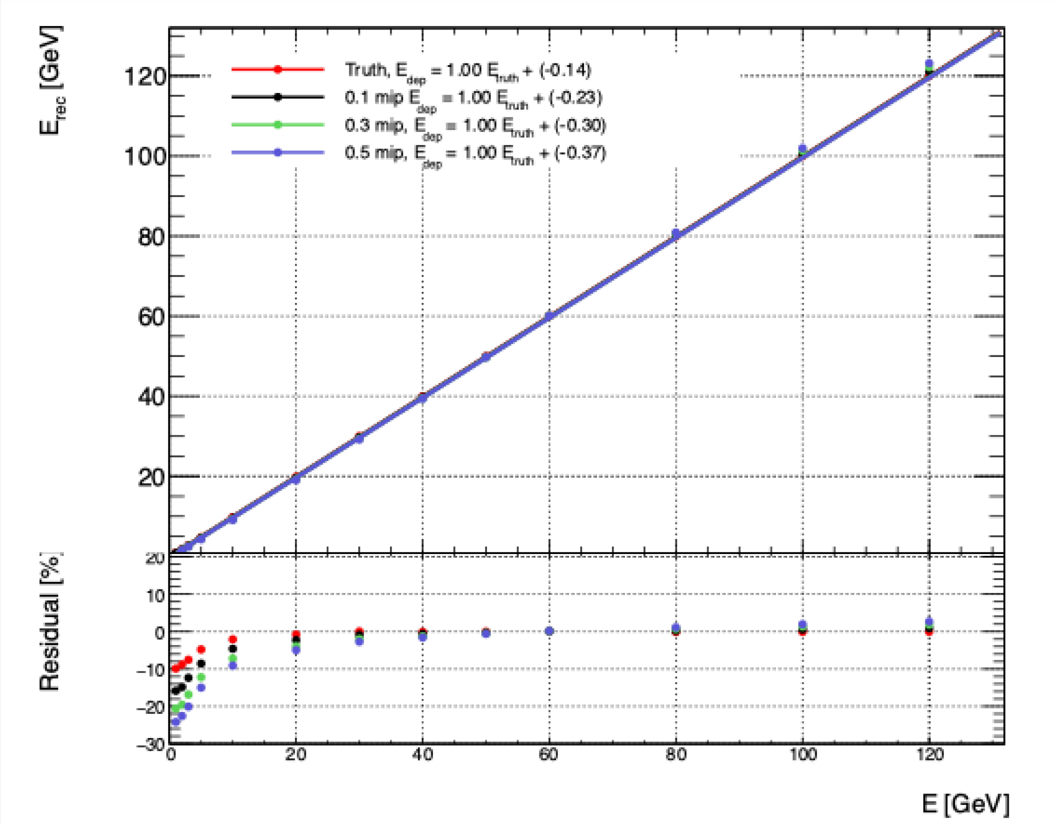
- **Scintillator non-linearity in light output caused by quenching**
  - $E_{vis} = \frac{E_{step}}{1+C_{birks}\cdot(E_{step}/Length)}$, C_{birks} is Birks constant.
  - For BGO: C_{birks}~0.008. For PS: C_{birks} = 0.126 (used for GS before)
  - Birks constant has significant impact to energy resolution. Need input from experiments / investigations.

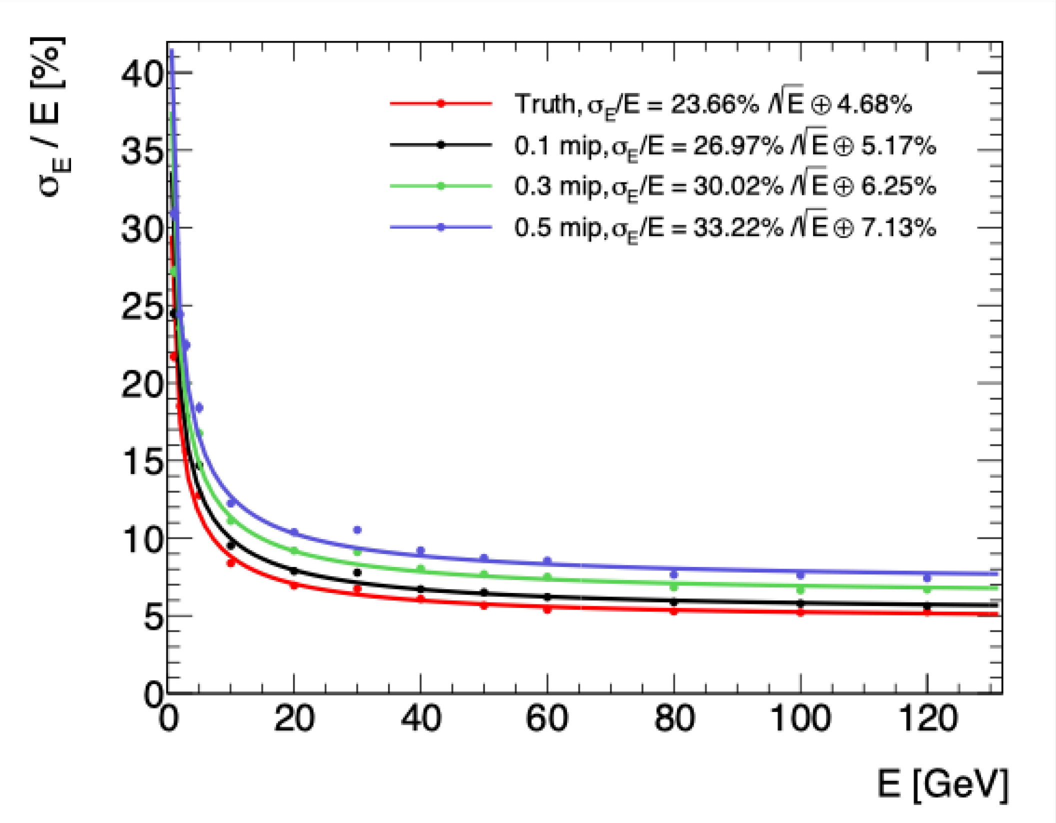
Simulation in CEPCSW:
$\theta = [85°, 95°], \phi = 0$ (module center)
Physics list: QGSP_BERT_EMV
No digitization, no threshold.

Recent plans for GS-HCAL--Design

--by Fangyi Guo & Hengne Li

- **Energy threshold: 0.1 MIP is preferred.**
  - Simulation: $\theta = [85°,\ 95°], \phi = 0$ (module center), $C_{birks} = 0$
  - No other digitization terms.

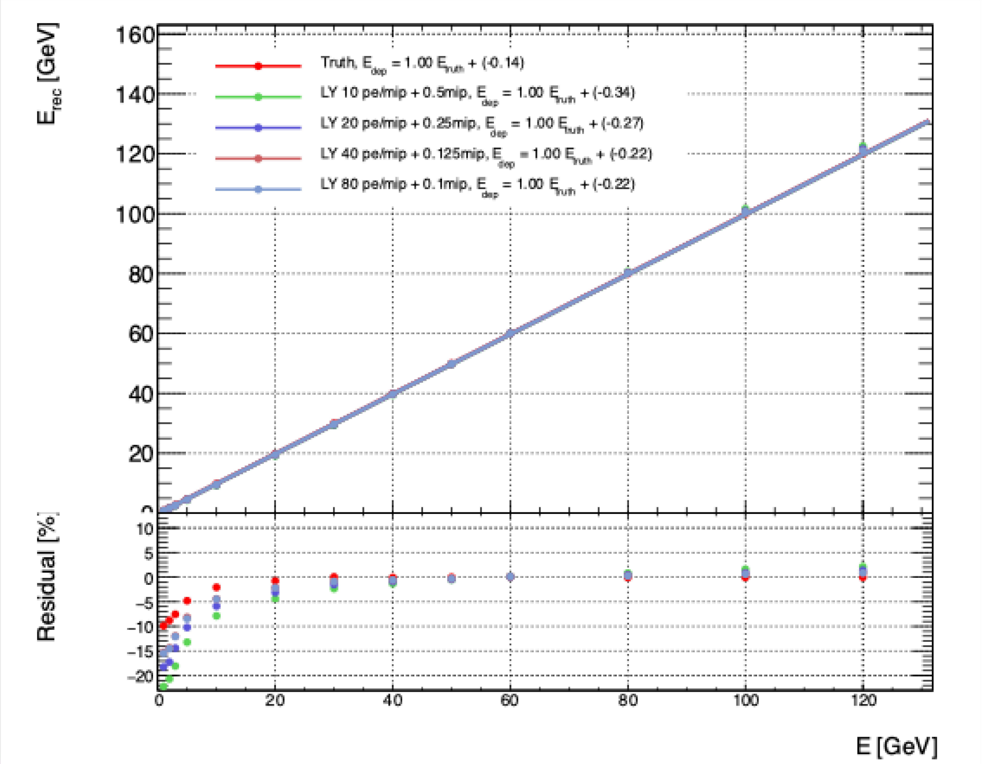


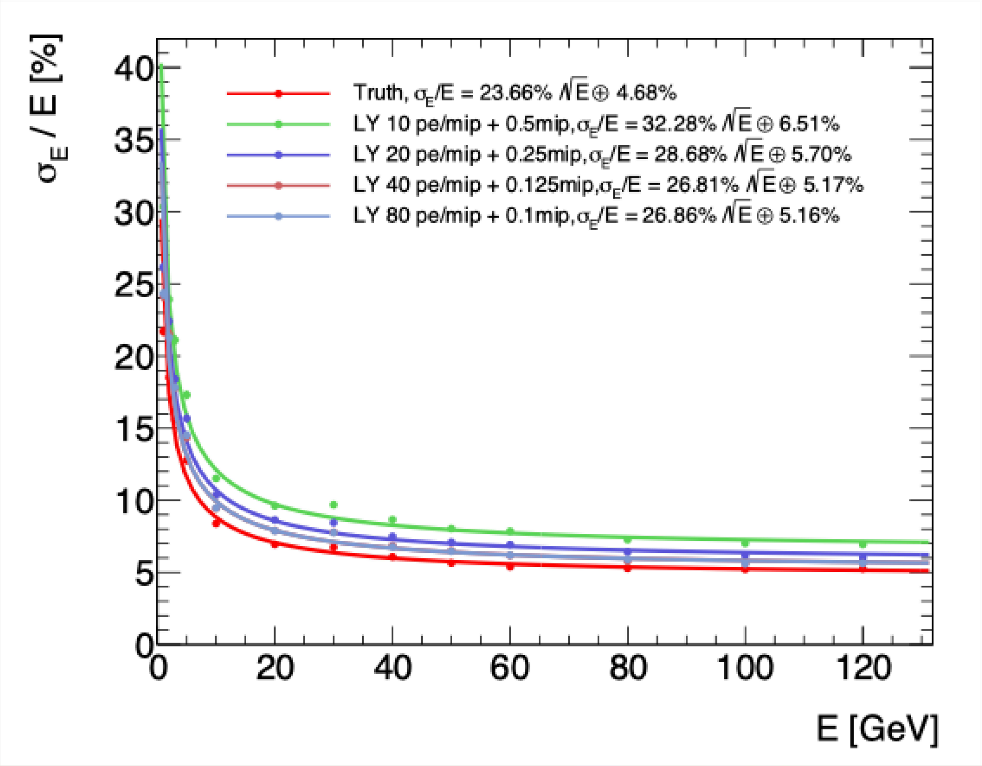


Recent plans for GS-HCAL--Design

--by Fangyi Guo & Hengne Li

- **Light yield and threshold (in p.e.) are correlated**
  - LY requirement depends on the minimum p.e. can be detected.
  - **Suppose electronic threshold 5 p.e., 0.1 MIP ⇨ LY>50 p.e./MIP**
  - Simulation: module center, $C_{birks} = 0$, no other digitization terms

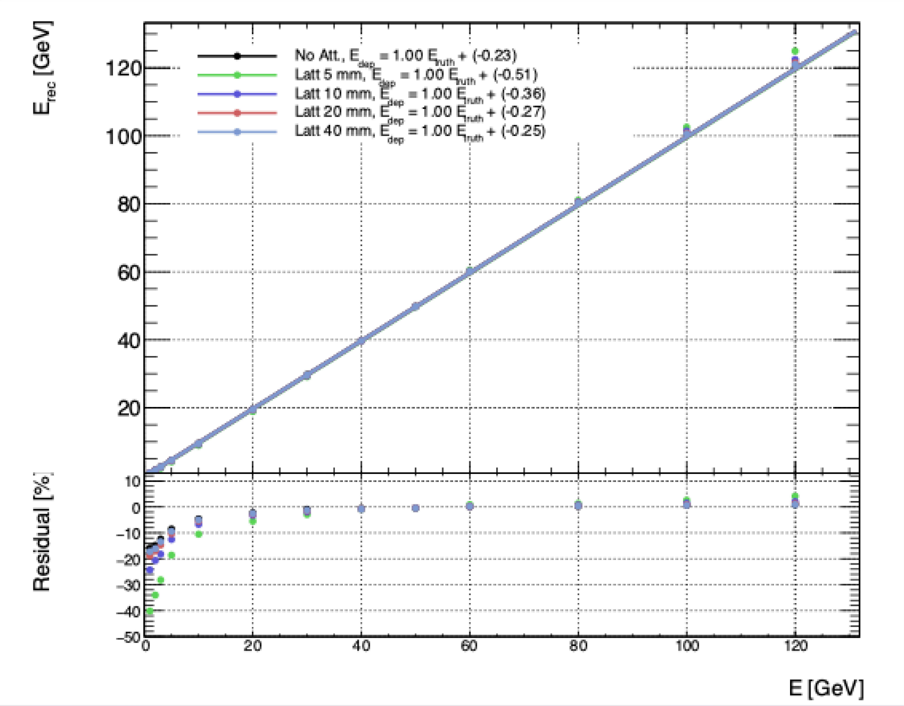


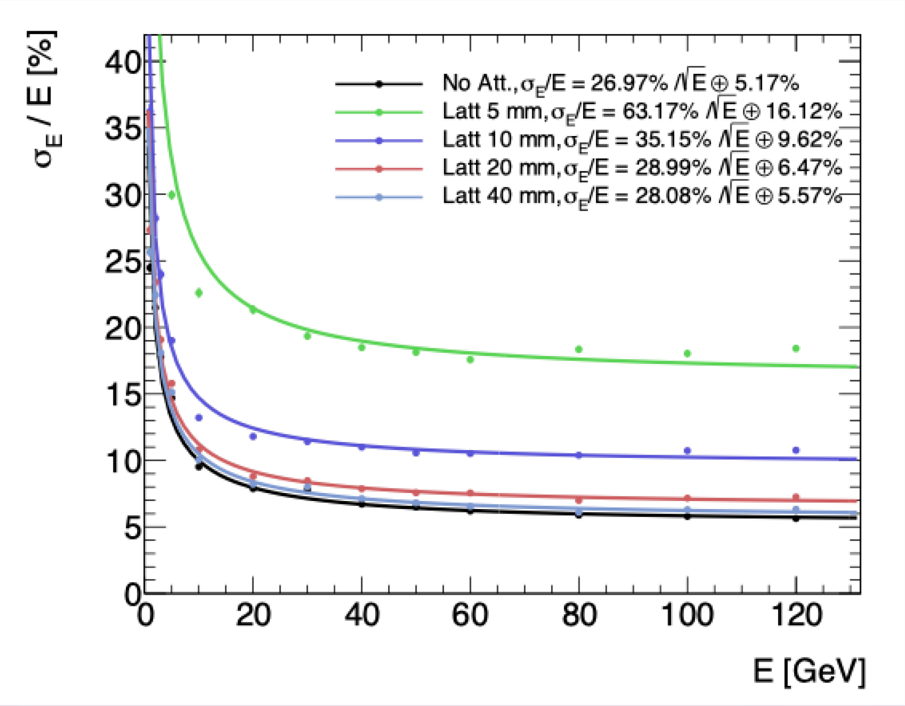


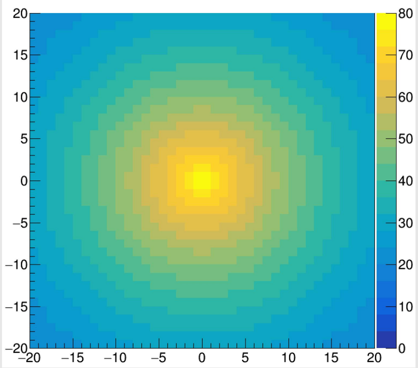
Recent plans for GS-HCAL--Design

--by Fangyi Guo & Hengne Li

- **Glass non-uniformity / effective light attenuation length**
  - Extract the effective L_{att} from glass tile non-uniformity scan at DESY: $L_{att} = 17.7\ mm$
  - Significant impact to energy resolution. **Need $L_{att} < 20\ mm$ or better readout scheme (~better uniformity)**
  - Simulation: module center, $C_{birks} = 0$, threshold 0.1 MIP, LY 80 p.e./mip





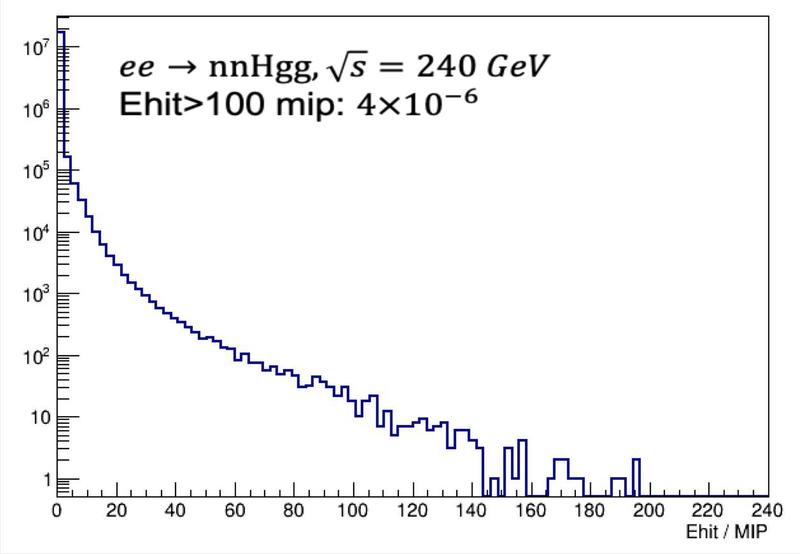


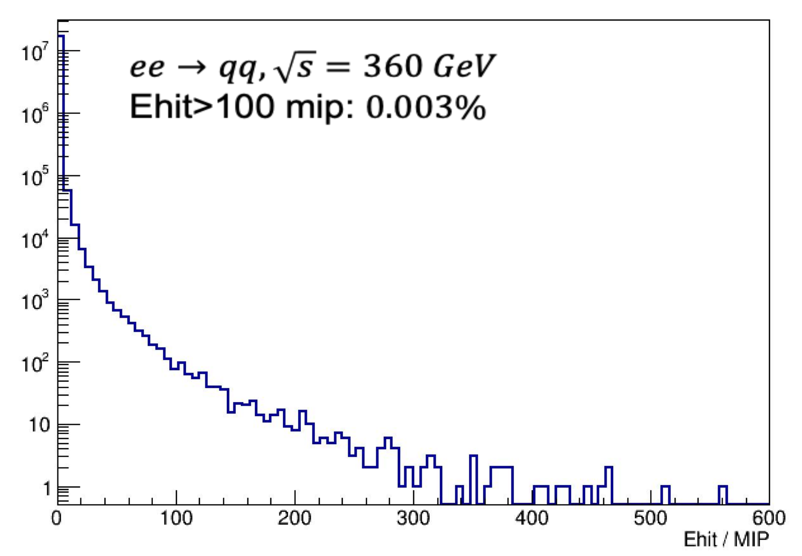
Toy model: tile response for $L_{att} = 20mm$.
Edge response ~ 24.3% of center.

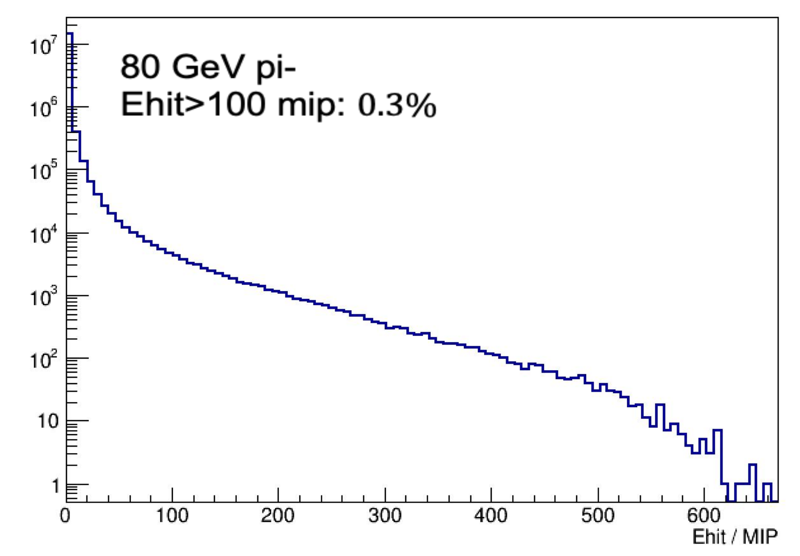
Recent plans for GS-HCAL--Design

--by Fangyi Guo & Hengne Li

- Dynamic range: check the hit energy
  - Suppose 0~100 MIPs, can cooperate with ECAL/Muon electronic system for common demands.
  - Not sufficient for possible high energy beam test.





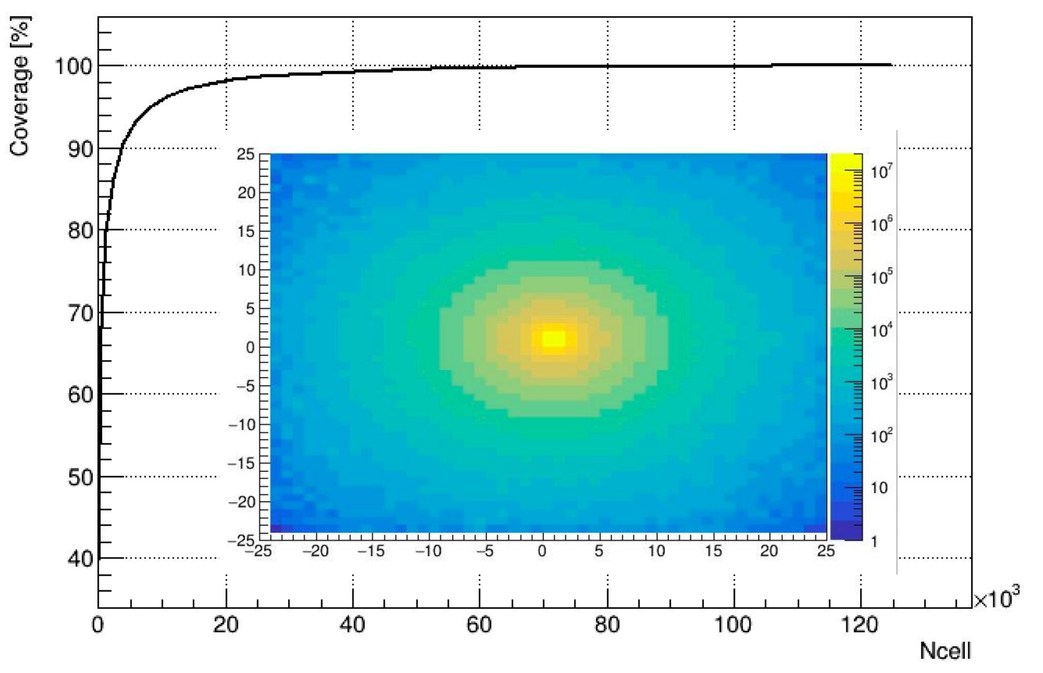


Recent plans for GS-HCAL--Design

--by Fangyi Guo & Hengne Li

- Considering a prototype for beam test: standalone simulation
  - 80 GeV proton events in a 2m*2m*1.3m (50*50*48) module for shower profile and coverage estimation

Simulation from 80 GeV proton:
coverage vs central cell number

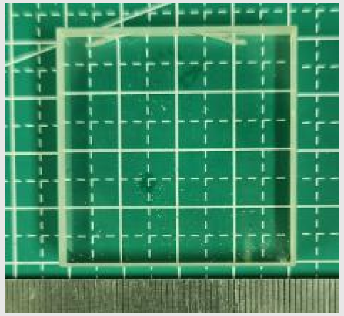


Module size [cell]	total cell number	Coverage [%]	σ_E/E @ 80 GeV[%]	Material Cost
10*10*48	4800	91.9023	7.89429	5M ¥
11*11*48	5808	93.1429	7.45489	6M ¥
12*12*48	6912	94.118	7.26531	7M ¥
13*13*48	8112	94.9576	6.90094	8M ¥
14*14*48	9408	95.6474	6.85437	9M ¥
15*15*48	10800	96.238	6.52527	11M ¥
16*16*48	12288	96.7237	6.35152	12M ¥
Full size (50*50*48)	125k	100%	5.62279	125M ¥

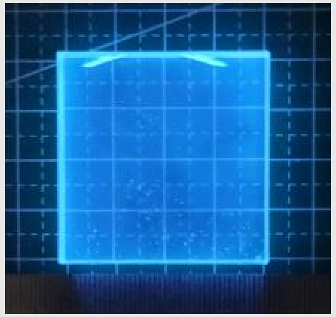
Current status of the GS-HCAL Glass Scintillator

--by Ren Jing

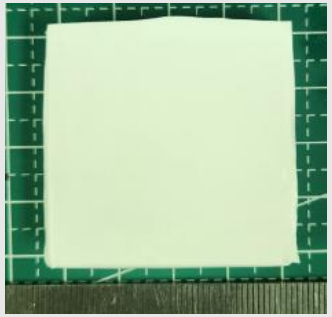
Uncovered glass



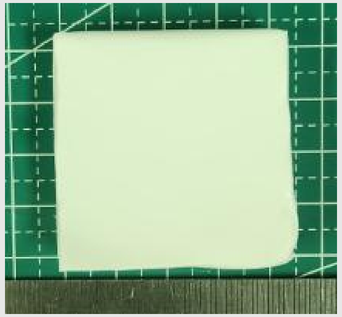
Uncovered glass under UV



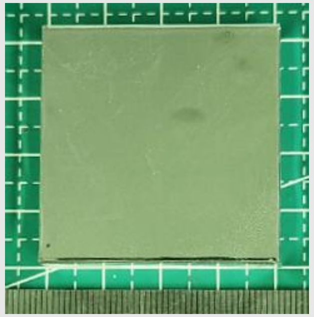
1 layer Teflon



3 layers Teflon



1 layer ESR



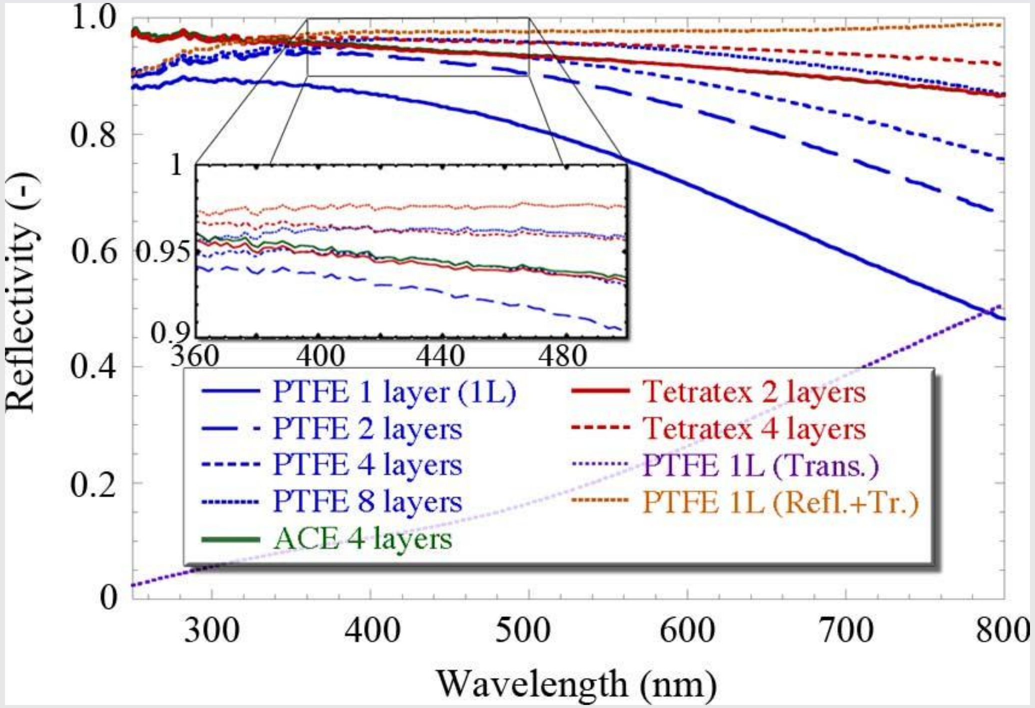
sample	P.E. Number	PCE (%)
Uncovered	58	100
1 Teflon	99	171
3 Teflon	95	164
ESR	57	98

	P.E. Number	Count rate (Hz)	PCE (%)
Uncovered	42	1.53	100
1 Teflon	44	2.94	105
3 Teflon	62	8.29	148
ESR	40	1.59	95

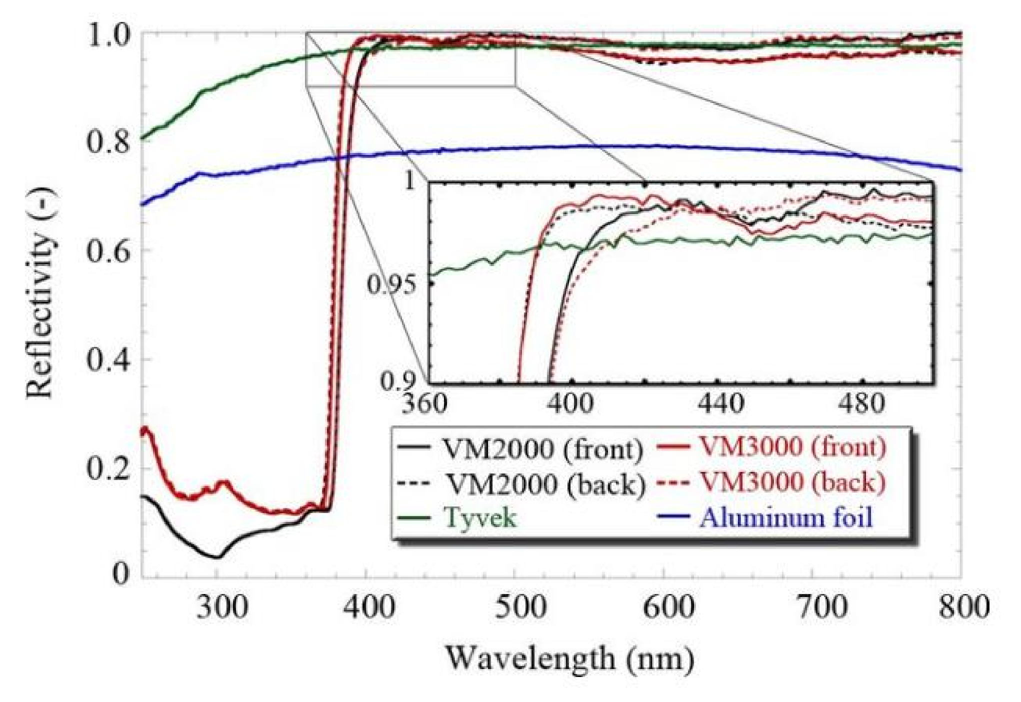
- Use of highly reflective Teflon film can help to improve the light collection efficiency (and thus P.E. number), and increase the number of covered Teflon film can improve the counting rate (Hz);
- ESR film has a low reflectivity at the Ce3+ emission waveband, it will not improve the light collection efficiency。

Current status of the GS-HCAL Glass Scintillator

--by Ren Jing



Reflectivity of Teflon film
(highly reflective in the whole Ce3+ emission waveband of 380-420 nm)



Reflectivity of ESR film
(limited reflectivity in the Ce3+ emission waveband)

- The large difference in the light collection efficiency between Teflon and ESP films can be understood from the difference in the reflectivities of two films.
- Take the reflectivity and cost of fabrication into account, it will be also reasonable to test other films such as silver or aluminum metal films。

Current status of the GS-HCAL SiPM

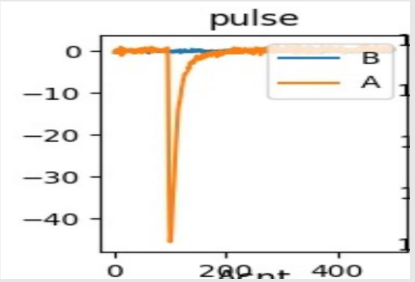
--by Yuguang Xie & Han Jifeng

➢ Primary tests of SiPM + GS(1000 LY)

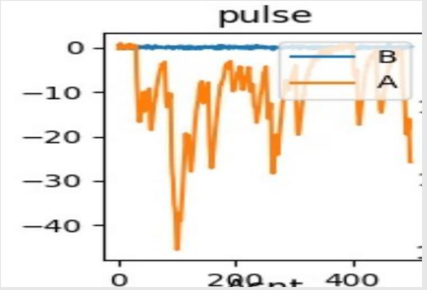
- HPK 3*3 mm, NDL 6*6mm, JBT 3*3mm
- Signal photon OK, DCRs of NDL and JBT ~200kHz
- Small GS 5*5*5mm, coupling 3*3mm SiPM not good to test
- Q spectrum and counting rate can see GS signal (CS-137)
- Big size GS 40*40*10 mm, used HPK 8*8 SiPM array, source position is corresponding to the peak position in 2D hit distribution.
- Key issue: reduce noise of SiPM and increase LY of GS
- More tests ongoing:

  1) uniformity test(with higher LY GS)

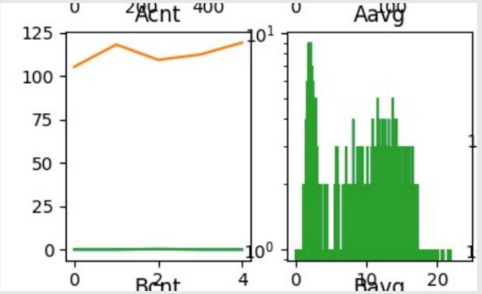
  2) new type of SiPM test



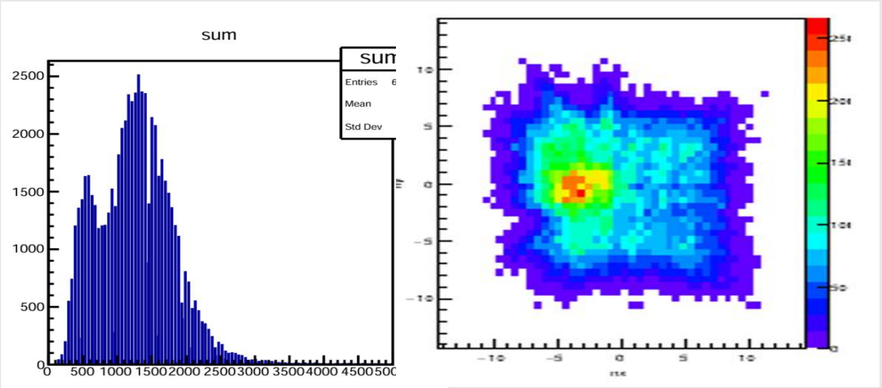
SiPM noise



GS signal



	A	B	C
1	阈值	无源	有源
2	25	5700	6800
3	30	1850	2000
4	40	170	200
5	45	52	73
6	50	16	

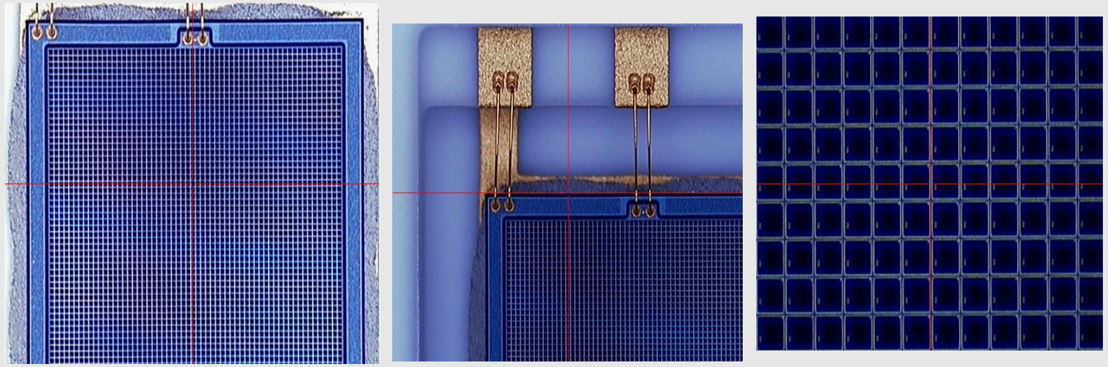


Current status of the GS-HCAL SiPM

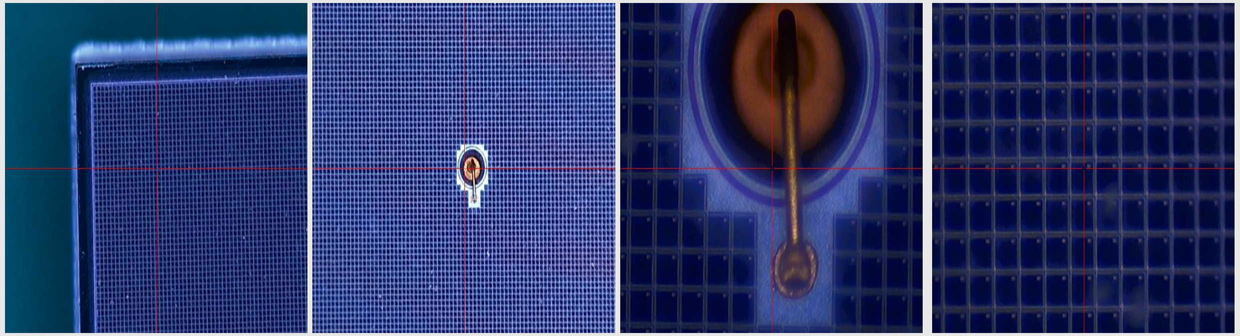
--by Yuguang Xie & Han Jifeng

- Compare SiPM difference of pixel and encapsulation (HPK, FBK, Sensl, NDL)

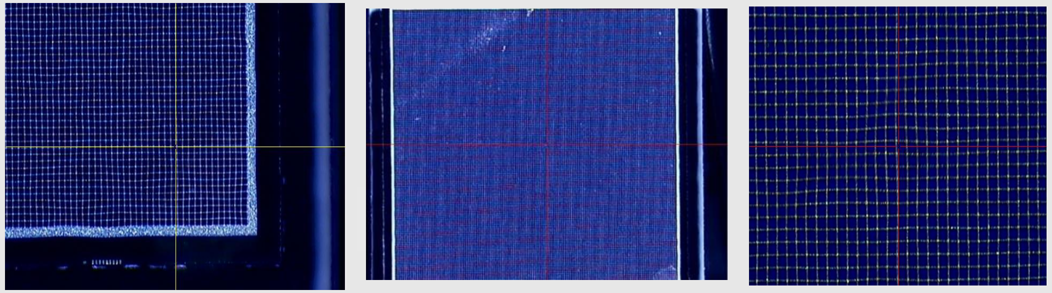
HPK33



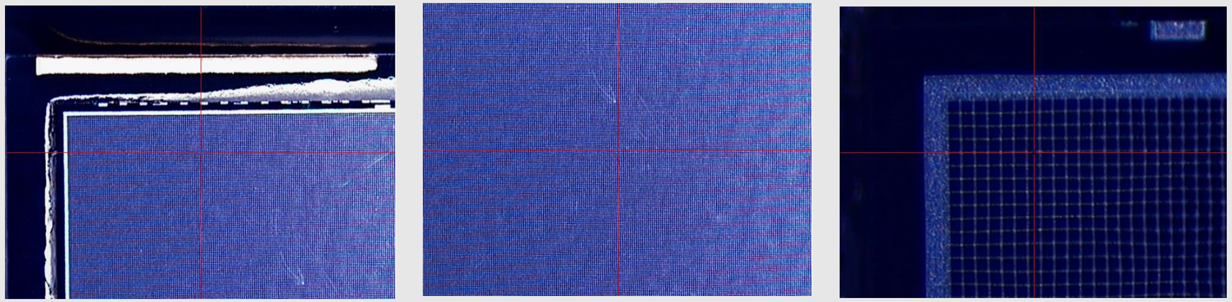
HPK66



NDL33



NDL66

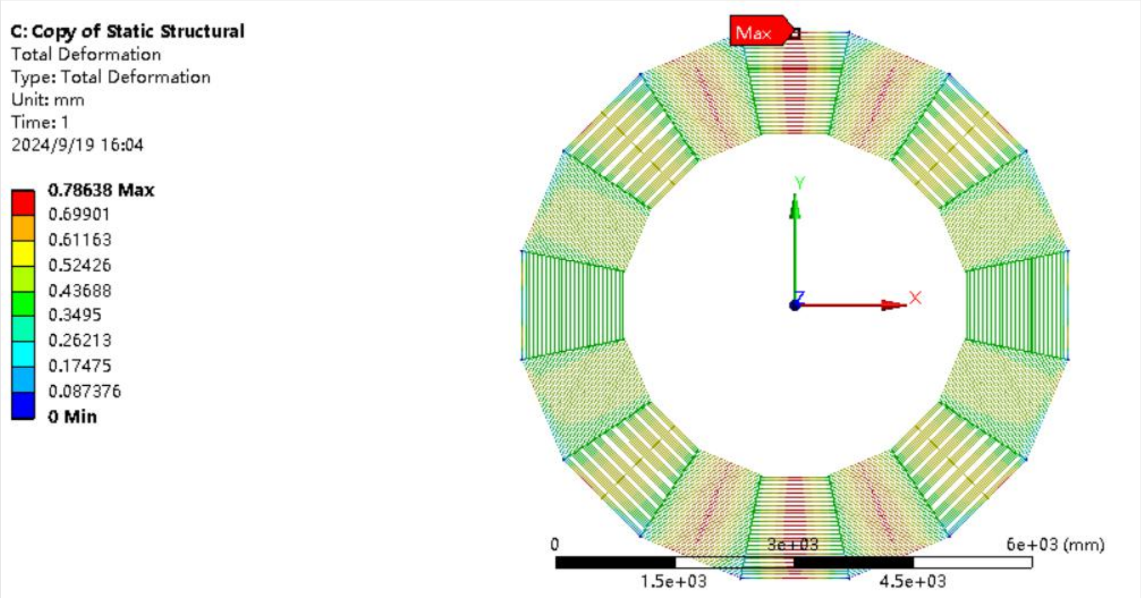


- Higher precision for import SiPMs, helps low noise, good gain uniformity.
- Encapsulation method is one way to reduce cost, discussed with HPK.
- PDE optimized at 390nm is possible, depending on demand and cost.

Current status of the GS-HCAL Mechanics

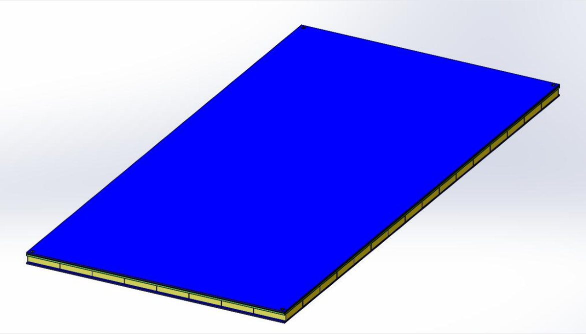
--by Pei Yatian

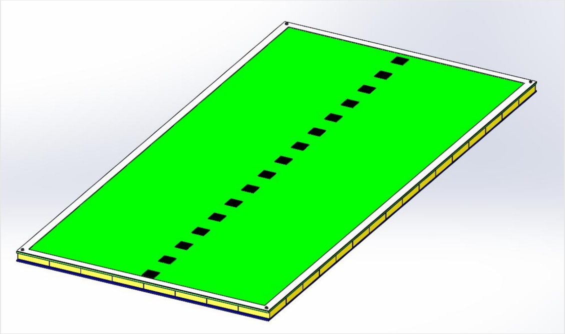
1.Absorbtion layer design



- Inserting stiffener in the middle of each 1/16 module. Maximum deformation is 0.786mm (58% of no stiffener structure)
  - Continuing optimizing the stiffener structure to meet the deformation requirement which is smaller than 0.5mm

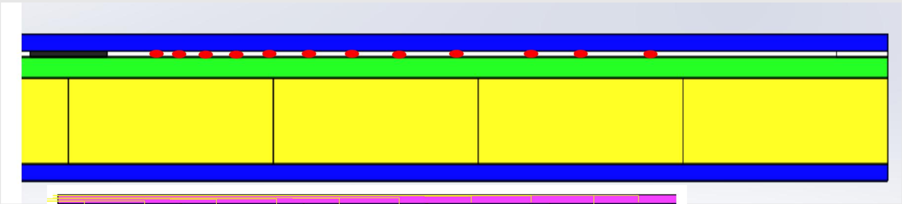
2.Active layer design



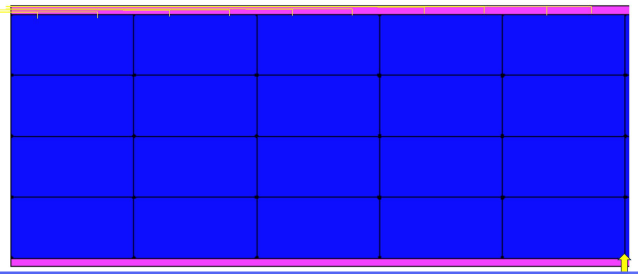


- Three kinds of module (64.6cm in length, 32cm/28cm/24cm in width)
- Adding bolts fixing structure and PTFE washer structure

3.Cabling design



- Scheme 1: cables are inserted between upper plate and PCB

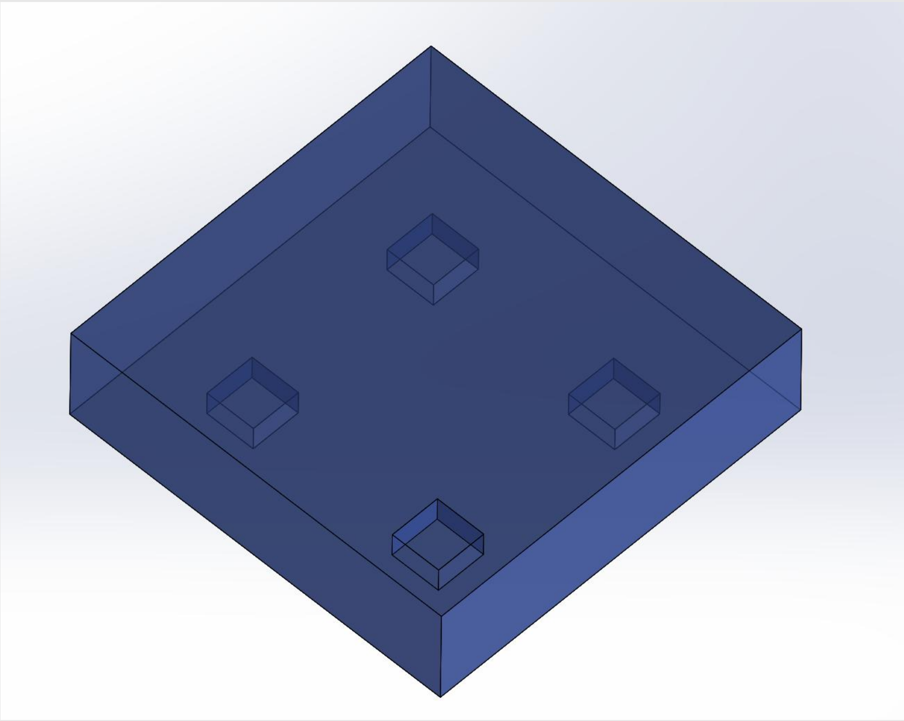


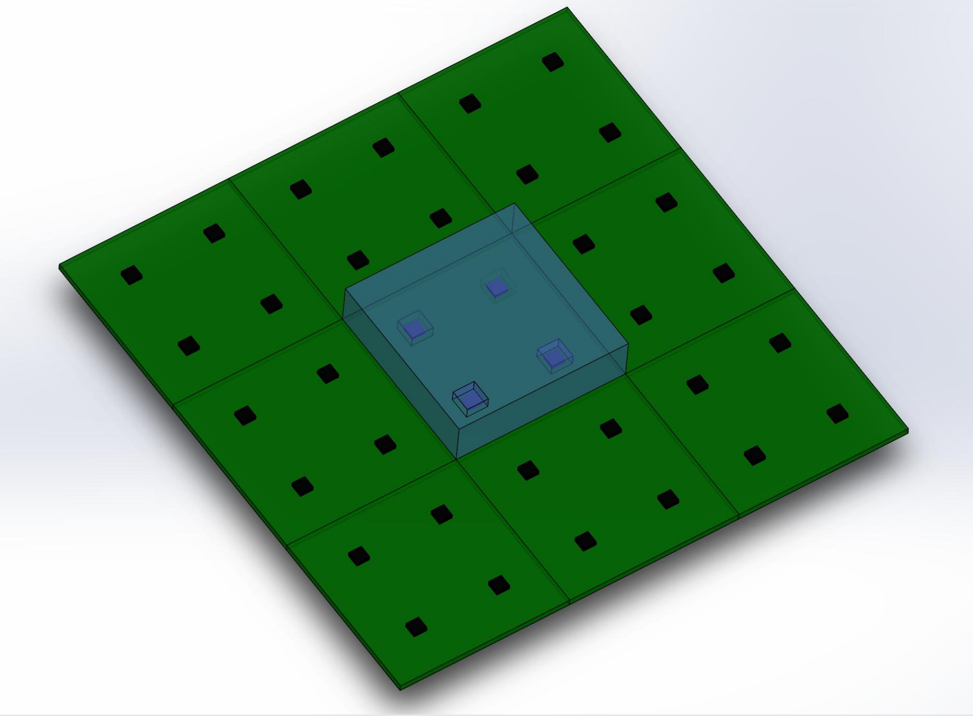
- Scheme 2: cables are lain into the gap around the edge of obsorbtion layer

Current status of the GS-HCAL Detector

--by Yu Boxiang

- For short attenuation length of GS, one scintillator is coupled with 4 SiPMs （3mm×3mm SiPM）
- GS bonded to the PCB board with optical glue was tested. The result shows that this glue is strong enough for this work.





The Manpower of the HCAL （20240910）

- 1. The PS-HCAL
  - Jianbei Liu, Haijun Yang, Boxiang Yu，Yunlong Zhang，……，
- 2. The GS-HCAL
  - Sub-system: 2 Conveners + others
  - Physics：**Manqi Ruan(IHEP)，Haijun Yang（SJU），**
  - Software: Sengsen Sun(IHEP)；
  - Design: **Fangyi Guo(IHEP), Hengne Li(SCNU)**，
  - Glass Scintillator: **Sen Qian(IHEP), Jing Ren(HEU)**，the GS collaboration Group
  - SiPM: **Yuguang Xie(IHEP), Jifeng Han(SCU)**，
  - Electronics: **Jingfan Chang(IHEP)**，
  - Mechanics: **Yatian Pei(IHEP), Junsong Zhang,**
  - Detector：**Boxiang Yu(IHEP), Yunlong Zhang (USTC)**

The Manpower of the subsystem of GSHCAL

Physics： Manqi Ruan(IHEP), Haijun Yang（SJTU）,

Software: Sengsen Sun(IHEP);

Design: Fangyi Guo(IHEP), Hengne Li(SCNU), Qingming Zhang(XJTU), Weizheng Song(IHEP), Peng Hu(261)
Dejing Du(IHEP), Hongbing Diao(SUTC), Jiyuan Chen(SJTU), ……

--to design the GS-HCAL detector based on the CEPCSW;

Glass Scintillator: Sen Qian(IHEP), Jing Ren(HEU), the GS collaboration Group;

--R&D of the GS for CEPC-HCAL, a special group independent of CEPC;

SiPM: Yuguang Xie(IHEP), Jifeng Han(SCU),Guang Luo(SYSU),

--to do the research of SiPM for CEPC-HCAL, the electronics of SiPM for the GS performance test;

Electronics: Jingfan Chang(IHEP),

--to design the ASIC and FEE for CEPC-HCAL; the power supply, the cables and so on;

Mechanics: Yatian Pei(IHEP), Junsong Zhang(IHEP),

--to design the Mechanics of the GS-CEPC-HCAL; also the cell, the module, the cooling system;

Detector：Boxiang Yu(IHEP), Yunlong Zhang (USTC)

--to study the module of the GS-HCAL with GS and SiPM, the cosmic ray test, the beam test;