The Status of the HCAL

2025-01-07

Qian Sen, on behalf of the HCAL Group

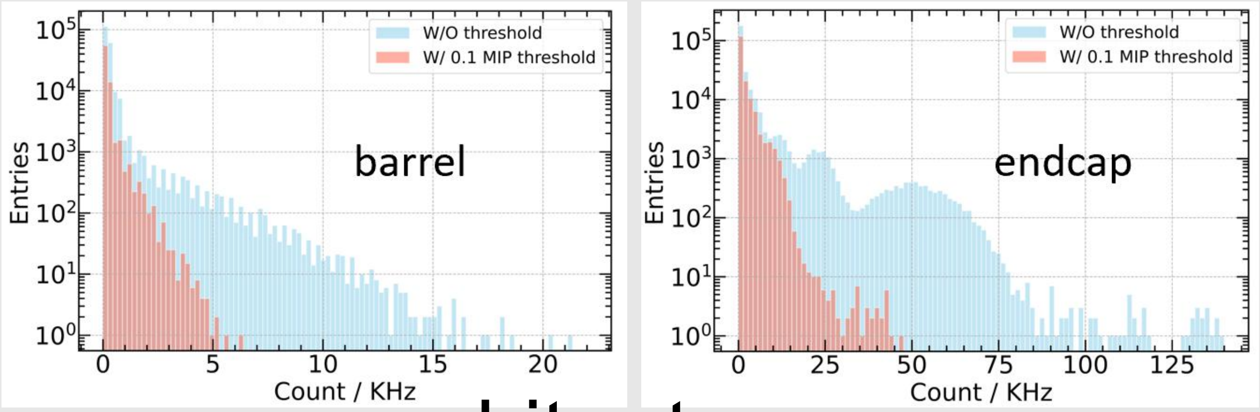
qians@ihep.ac.cn

Current status of the GS-HCAL Simulation

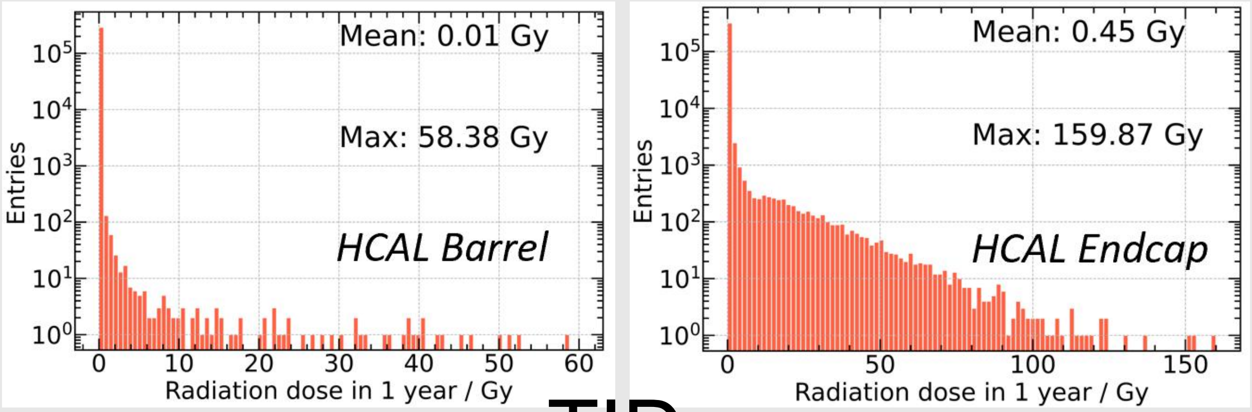
--by Weizheng Song

Beam induced background simulation

- The current HCAL BIB results are based on simulation during CEPC 2024 workshop in the Higgs mode.
- The HCAL BIB results will be updated soon:
  - including Higgs, Low Luminosity Z, and High Luminosity Z modes.
  - considering pair production and single beam BIB (Touschek effect, BeamGas scattering, Beam-Thermal Photon).
  - based on the latest designs of the collimator, shielding, and detector geometry.
  - including hit rate, occupancy, and TID (Total Ionizing Dose).



hit rate

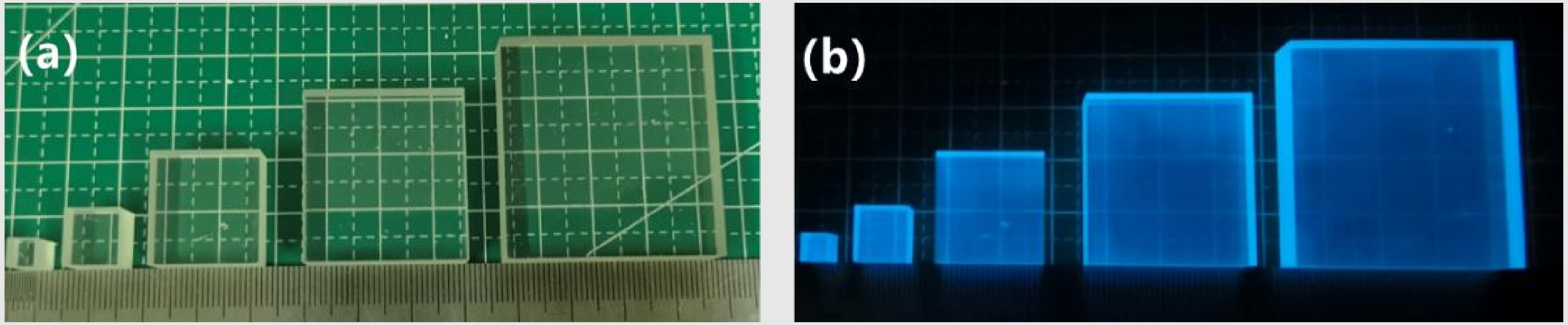


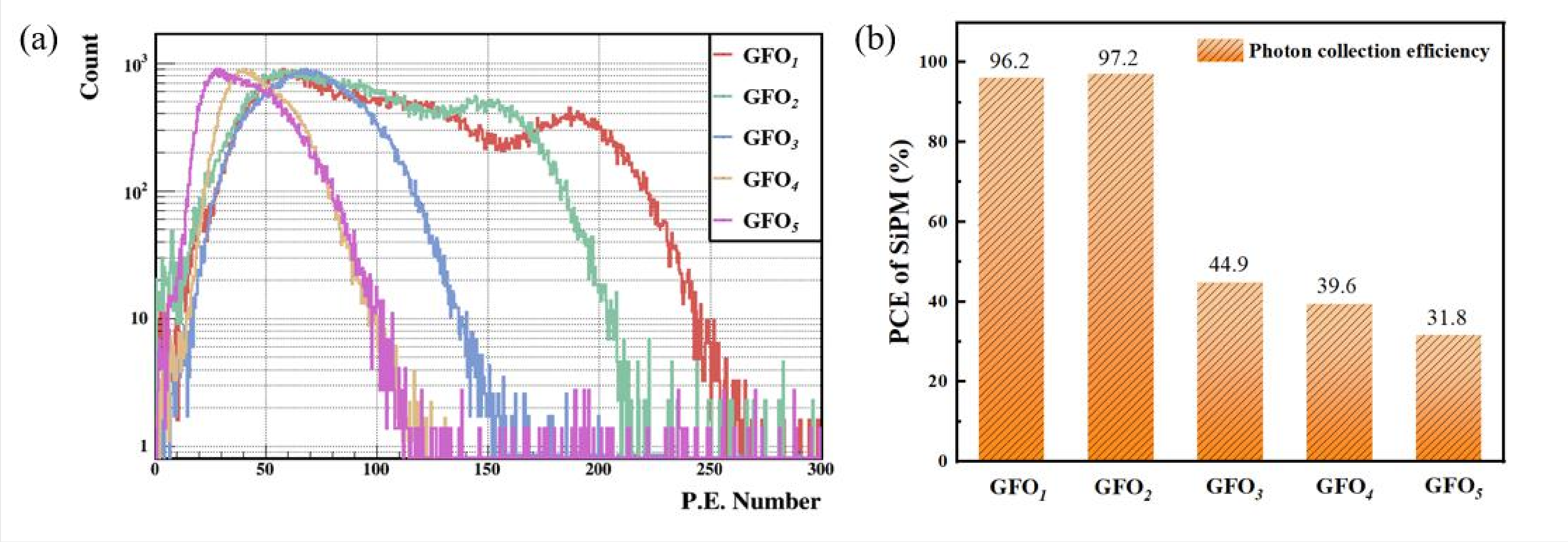
TID

Current status of the GS-HCAL PCE of GS+SiPM

--by Jing Ren

Glass scintillators, 5×5×5, 5×5×10, 10×10×10, 20×20×10, 40×40×10 mm³, from small to large named GFO_x (x=1, 2, 3, 4, 5)



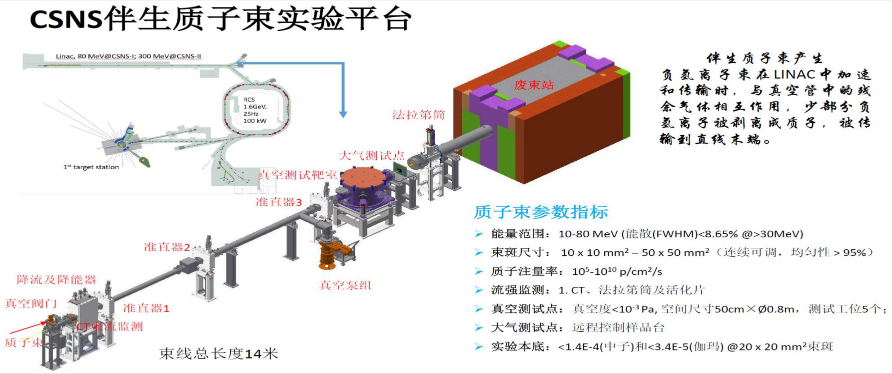


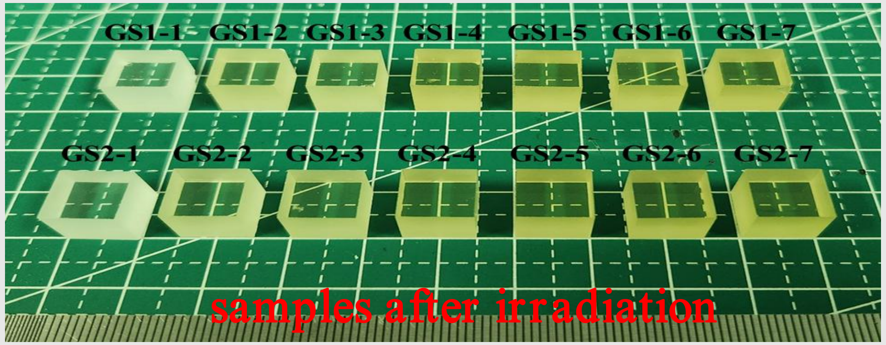
- As the surface area of the glasses increases, more scintillation light escapes from being detected by the SiPM, which results in blurred full-energy peak and decreased light yields.
- The PCE of SiPM decreased from 96.2% to 31.8%, mainly determined by the surface area rather than the thickness of the glasses.

Current status of the GS-HCAL GS

--by Peng Hu

GS irradiation test at CSNS APEP Platform



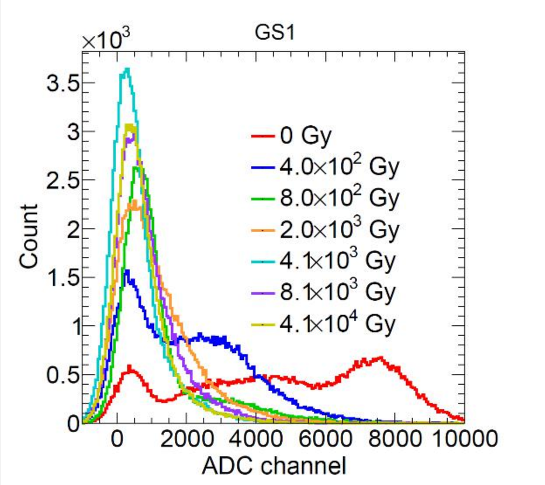


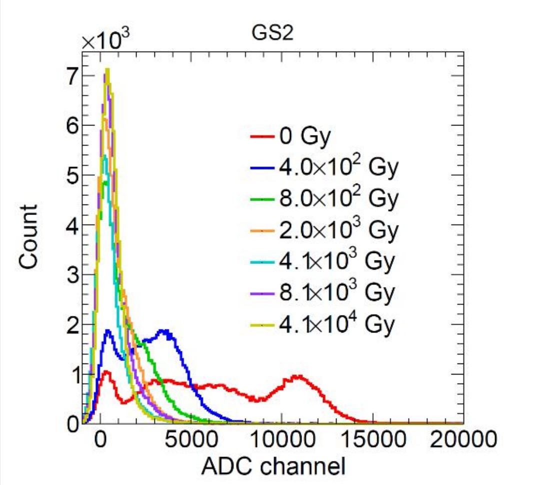
Group ID	Samples	proton flux ($p/cm^2/s$)	Irradiated time	Absorbed dose (Gy)
1	GS1-1 GS2-1	0	0	0
2	GS1-2 GS2-2	4.86×10^9	1 m 16 s	$\sim 4.0 \times 10^2$
3	GS1-3 GS2-3	4.86×10^9	2 m 33 s	$\sim 8.0 \times 10^2$
4	GS1-4 GS2-4	4.86×10^9	6 m 24 s	$\sim 2.0 \times 10^3$
5	GS1-5 GS2-5	4.86×10^9	12 m 49 s	$\sim 4.1 \times 10^3$
6	GS1-6 GS2-6	4.86×10^9	25 m 38 s	$\sim 8.1 \times 10^3$
7	GS1-7 GS2-7	4.86×10^9	2 h 8 m 12 s	$\sim 4.1 \times 10^4$
8	GS1-8 GS2-8	4.86×10^9	4 h 16 m 24 s	$\sim 8.1 \times 10^4$
9	GS1-9 GS2-9	4.86×10^9	21 h 22 m 3 s	$\sim 4.1 \times 10^5$

Group 8 & 9 are still reserved at APEP due to strong proton induced activation background

- Two large-size (4x4x1 cm^3) glass samples produced by the GS collaboration were processed into 9 small glass samples (1x1x1 cm^3), respectively (denoted as GS1-1 to GS1-9 and GS2-1 to GS2-9). They were irradiated at the Associated Proton beam Experiment Platform (APEP) (air test point)
- Beam conditions: 80 MeV proton, 50×50 cm^2 (spot size), ~4.86×10^9 $p/cm^2/s$, corresponding to an absorbed dose rate of 315 Gy/min in glass samples
- 8 groups of glass samples were irradiated by the 80 MeV proton beam for a minimum of 1 m 23 s and a maximum of around 21 h 22 m 3s, corresponding to an absorbed dose of around 4.0×10^2 Gy and 4.1×10^5 Gy

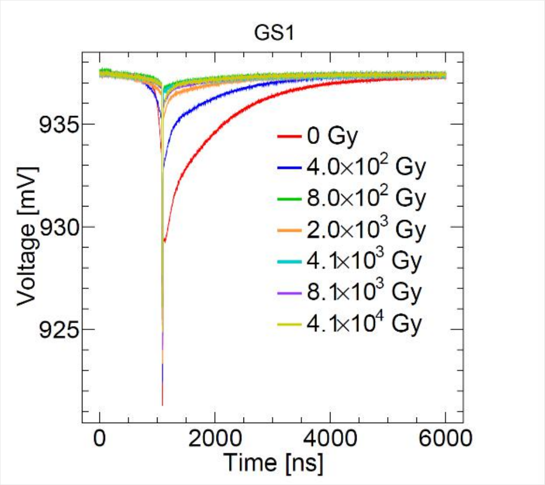
Performance evaluation before/after irradiation

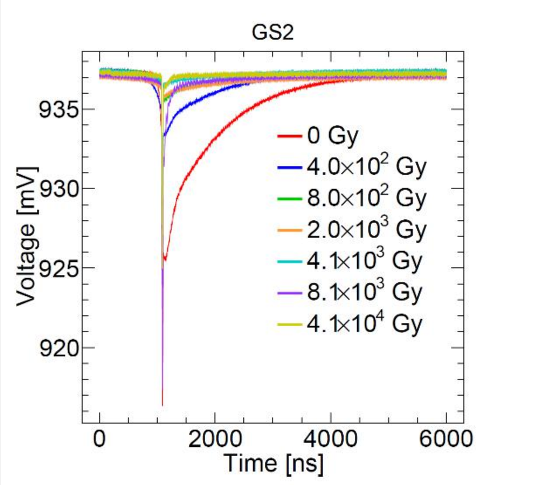




- The light output of glass sample was measured by the XP2020 PMT with a ^{137}Cs source
- **The light output of the glass sample will decrease to 1/3 of its original level after receiving a dose of 400 Gy**
- The light output is too weak to be detected when the absorbed dose is larger than 400 Gy

^{137}Cs Energy Spectrum





- The decay time is obtained by fitting the falling edge of average waveform of all events with a di-exponential function
- **The change in the fast and slow components of the decay time is almost negligible after receiving a dose of 400 Gy.** However, further studies are still needed to evaluate the situation at higher doses

Average Event Waveform

Absorbed dose rate estimation

- For a point source, the absorbed dose rate of monoenergetic gamma-rays at a certain point P under Charged-Particle Equilibrium is

$$\frac{dD}{dt} = \varphi \cdot \left(\frac{\mu_{en}}{\rho}\right) \cdot E_\gamma$$

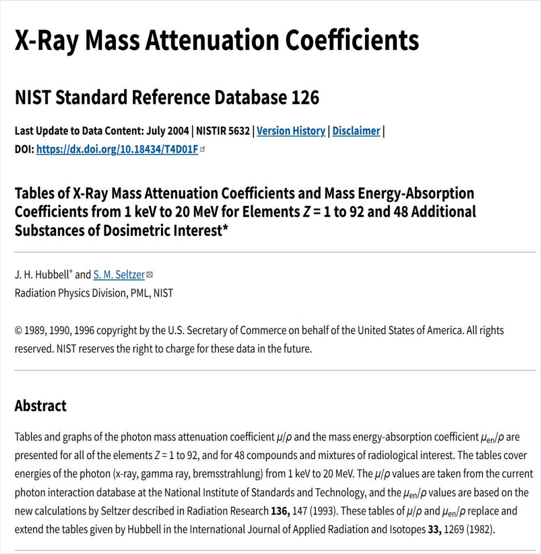
$\frac{dD}{dt}$ — the absorbed dose at point P, Gy/s

φ — the fluence rate at point P, photons/(m^2·s)

$\frac{\mu_{en}}{\rho}$ — mass energy-absorption coefficient, m^2/kg

E_γ — energy of gamma-rays, J

Gamma irradiation sources in 261



X-Ray Mass Attenuation Coefficients

NIST Standard Reference Database 126

Last Update to Data Content: July 2004 | NISTIR 5632 | Version History | Disclaimer |
DOI: https://dx.doi.org/10.18434/T4D01F

Tables of X-Ray Mass Attenuation Coefficients and Mass Energy-Absorption Coefficients from 1 keV to 20 MeV for Elements Z = 1 to 92 and 48 Additional Substances of Dosimetric Interest*

J. H. Hubbell⁺ and S. M. Seltzer
Radiation Physics Division, PML, NIST

Abstract

Tables and graphs of the photon mass attenuation coefficient μ/ρ and the mass energy-absorption coefficient μ_{en}/ρ are presented for all of the elements Z = 1 to 92, and for 48 compounds and mixtures of radiological interest. The tables cover energies of the photon (x-ray, gamma ray, bremsstrahlung) from 1 keV to 20 MeV. The μ/ρ values are taken from the current photon interaction database at the National Institute of Standards and Technology, and the μ_{en}/ρ values are based on the new calculations by Seltzer described in Radiation Research **136,** 147 (1993). These tables of μ/ρ and μ_{en}/ρ replace and extend the tables given by Hubbell in the International Journal of Applied Radiation and Isotopes **33,** 1269 (1982).

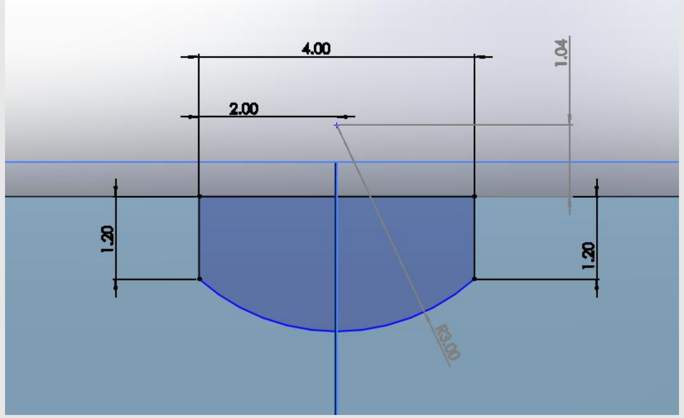
- The φ of ^{60}Co at 10 cm is ~ 2.94×10^{12} photons/(m^2·s)
- The $\frac{\mu_{en}}{\rho}$ of 1.1732 MeV and 1.3325 MeV gamma-rays for latest glass samples is ~ 0.0264 and ~ 0.0249 cm^2/g
- Then the total absorbed dose rate at 10 cm is ~ 3×10^{-3} Gy/s or 10 Gy/h

- $\frac{\mu_{en}}{\rho}$ is obtained from the NIST database (XAAMDI)

Current status of the GS-HCAL SiPM

--by Yuguang Xie, Guang Luo

To be simulated for different groove cross-sections



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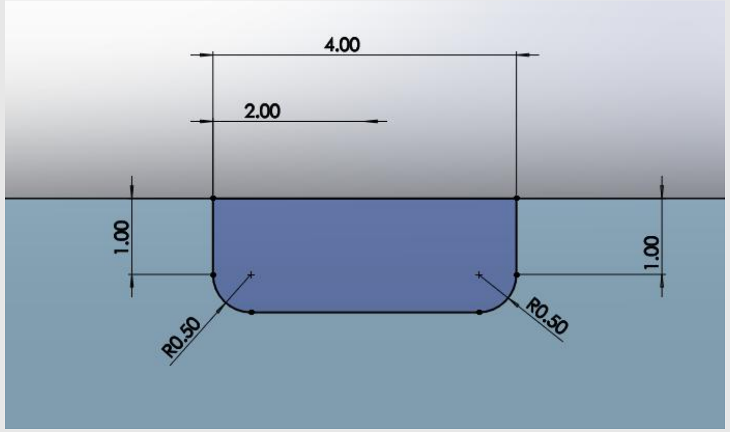

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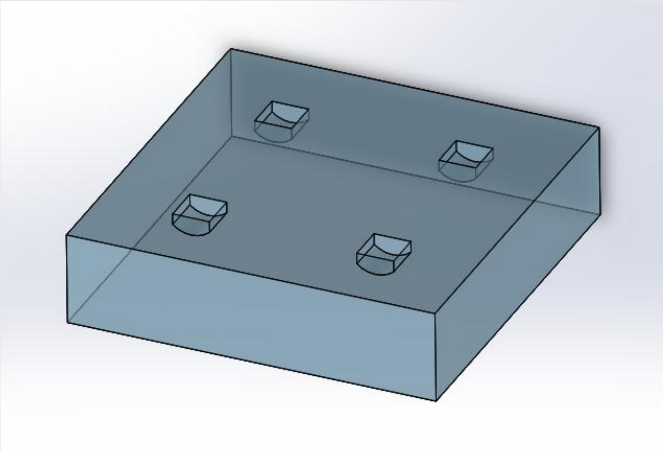
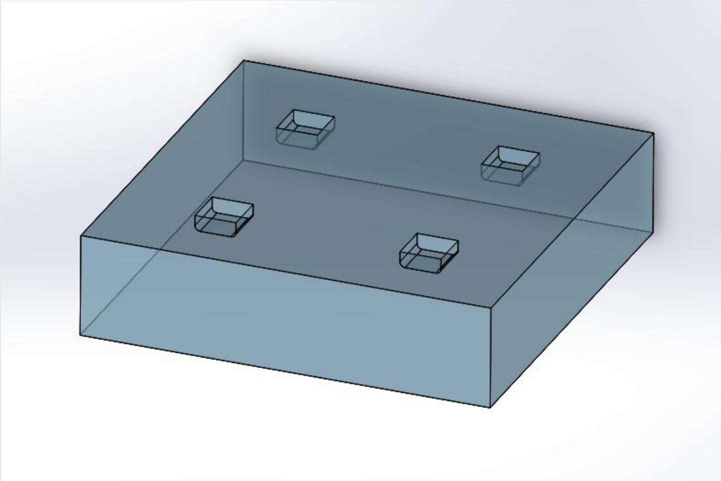


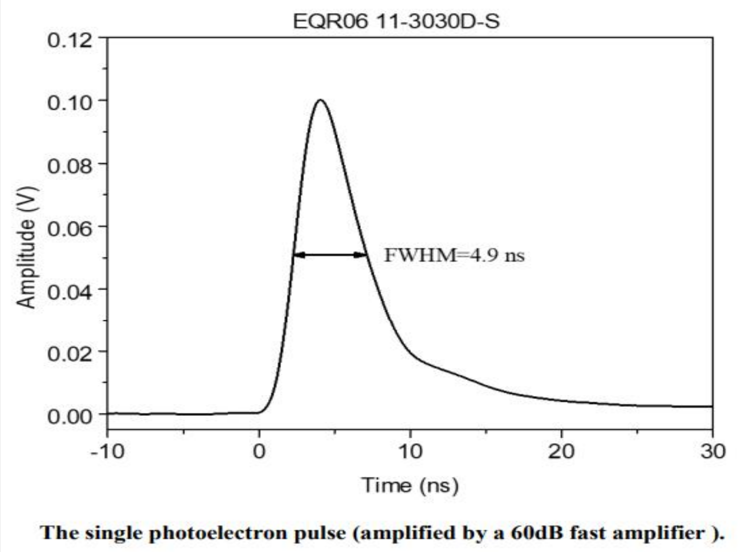


Current status of the GS-HCAL Electronics

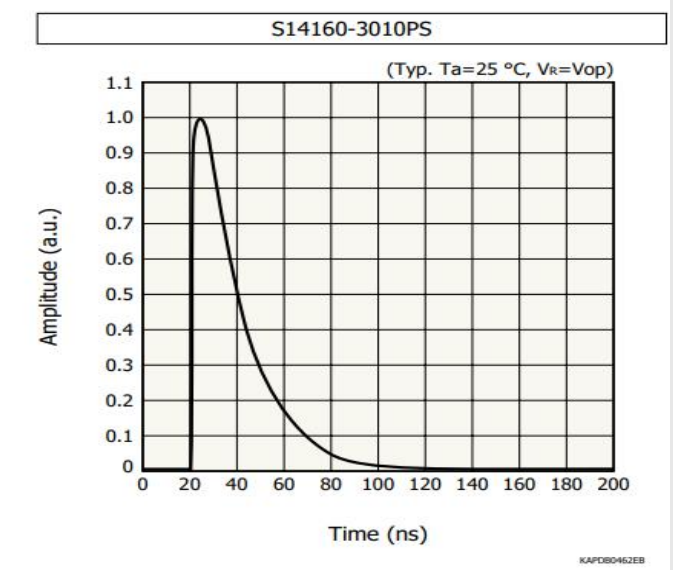
--by Jinfan Chang， Huaishen Li

Comparison of different SiPMs

NDL EQR06



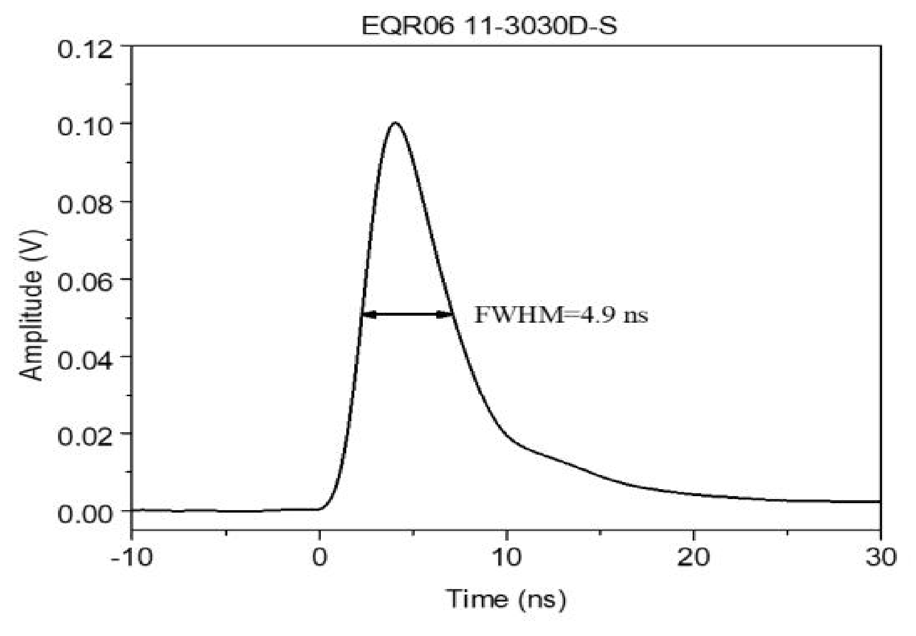
S14160-3010PS



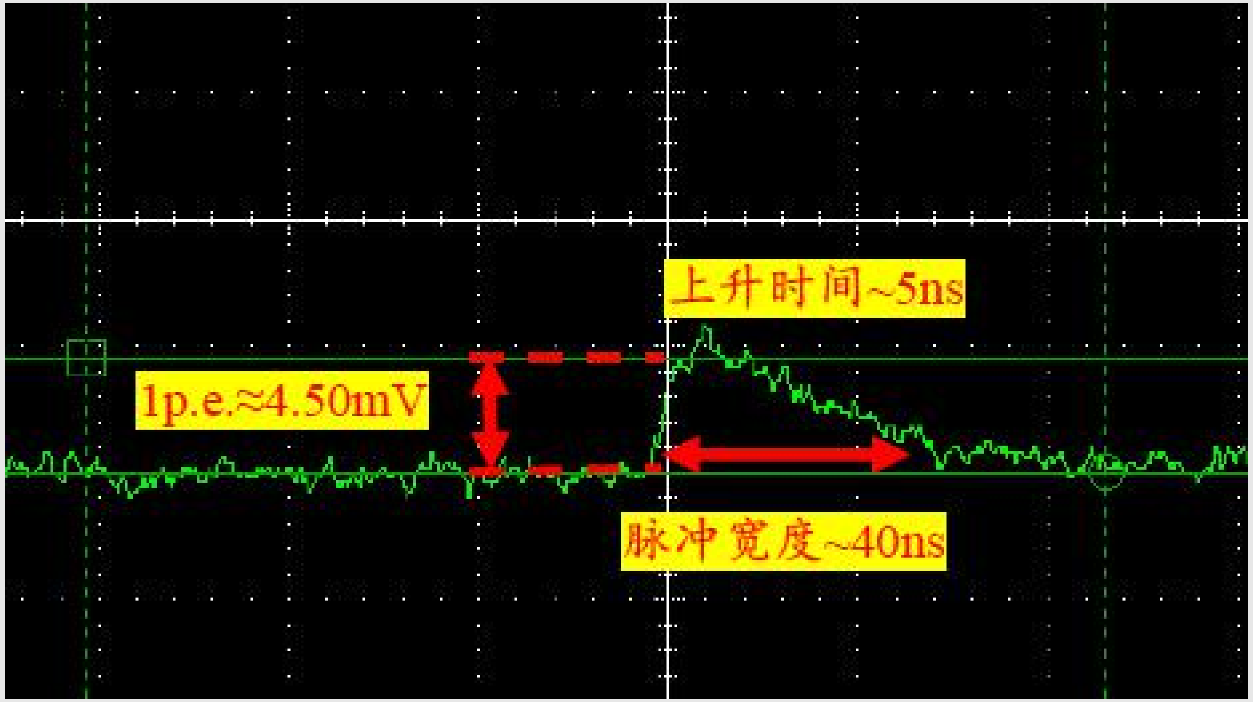
- The capacitor of the two device is about 45.9pF and 500pF, the width of the single photoelectron is different, the pulse width of NDL SiPM is about 5ns and 20ns.
- The signal of BGO/GS + NDL SiPM: The decay time is more than 300ns, so for the small signal, such as 1MIP(100P.E.) or 0.1MIP, signals will appear in a discrete state

NDL EQR06

EQR20 11-3030HS



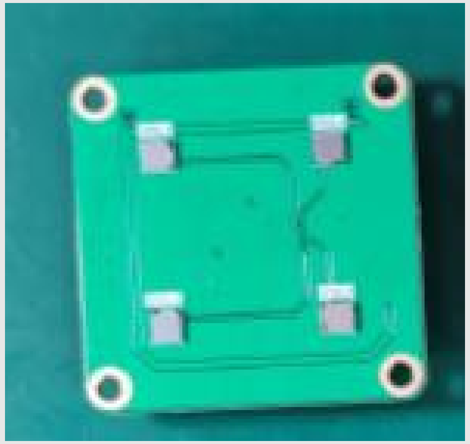
The single photoelectron pulse (amplified by a 60dB fast amplifier).



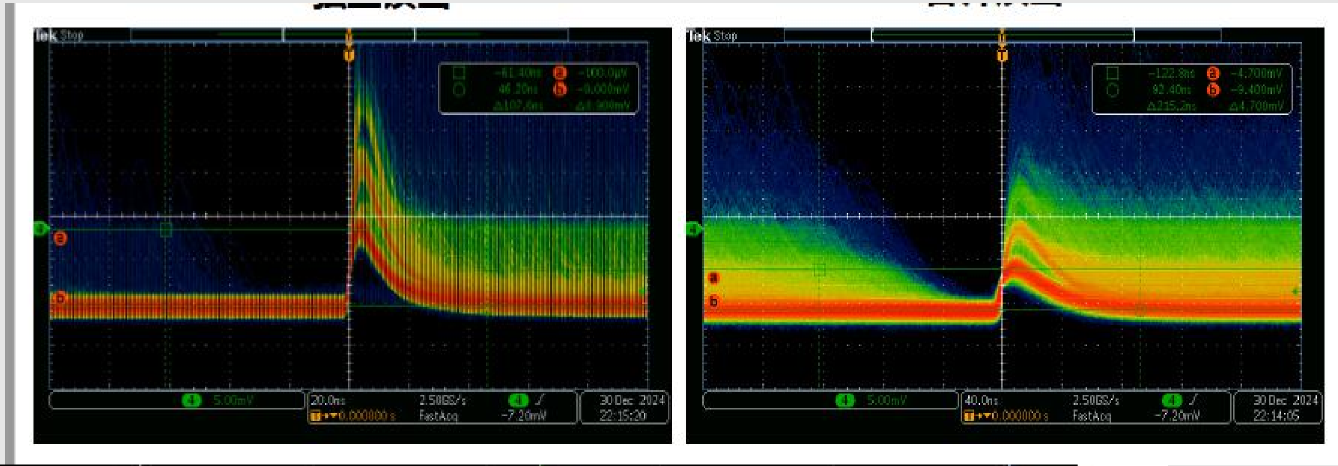
Current status of the GS-HCAL SiPM

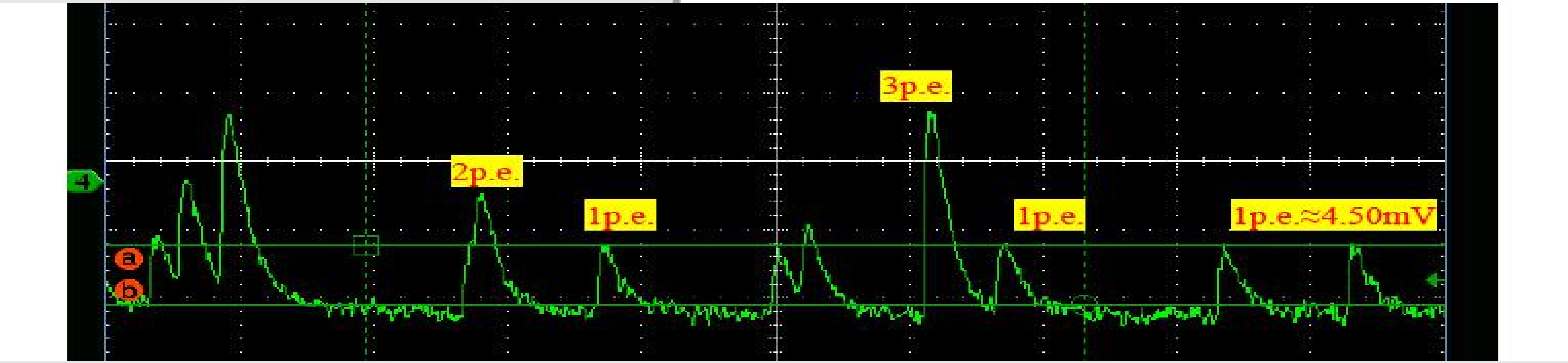
--by Xiaolong Wang

EQR20 11-3030HS



The Signal from 1 SiPM / 4 SiPM combain together





The real signal of the GS+SiPM (NDL) vs GS+SiPM (HBK)

Backup

The Manpower of the HCAL

- 1. The PS-HCAL
  - **Jianbei Liu,** Haijun Yang, Boxiang Yu， Yunlong Zhang， ……，
- 2. The GS-HCAL： Sen Qian （IHEP）
  - 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)，**
  - DAQ： **Chen Boping(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;

DAQ: Chen Boping(IHEP),

Mechanics: Yatian Pei(IHEP), Junsong Zhang(IHEP), Shang Bofeng(ZZU)

--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;