The Status of R&D of the GS

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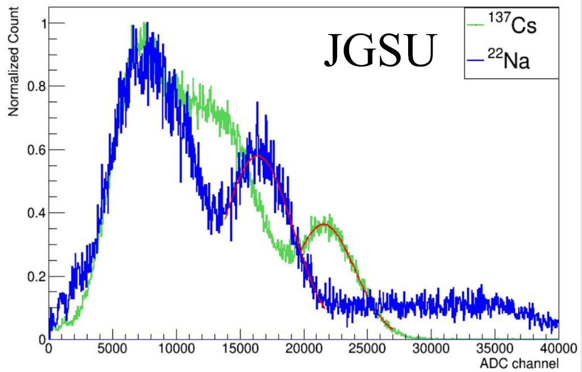
The Institute of High Energy Physics, CAS

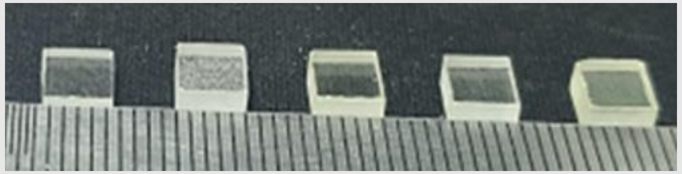
2023. Feb. 22th

1. Borosilicate Glass（Gd-Al-B-Si-Ce^{3+}）

- Density~6.0 g/cm³
- LY>1000 ph/MeV
- ER=49.55%

- Density~4.5 g/cm³
- LY=802 ph/MeV
- ER=26.77%

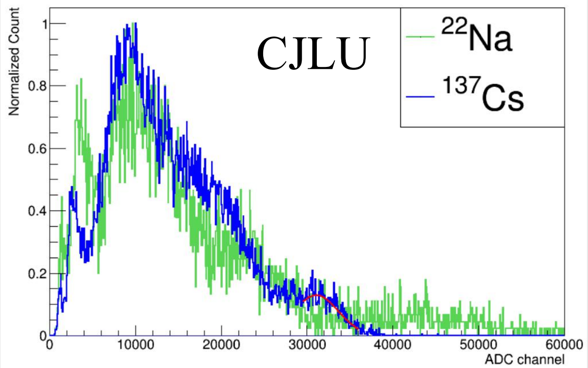


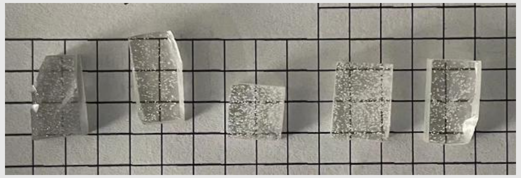


(2022.05)Opt. Mater. 2022(130): 112585

2021.11

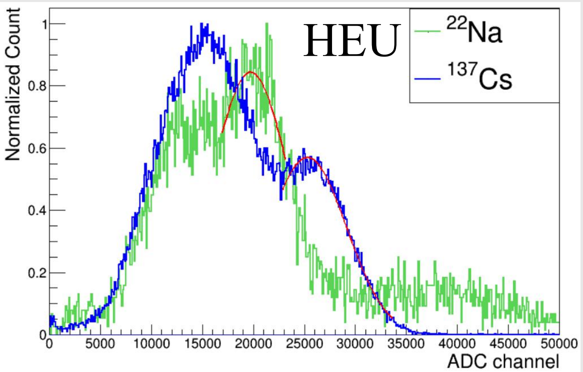
- Density~4.0 g/cm³
- LY>1200 ph/MeV
- ER=23.22%

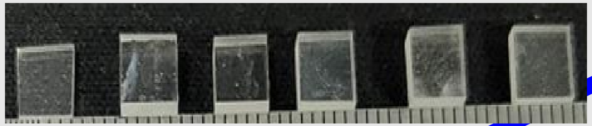




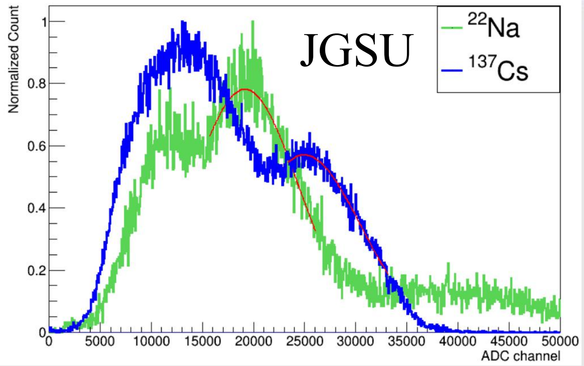
2022.06

- Density~5.5 g/cm³
- LY=1117 ph/MeV
- ER=35.80%



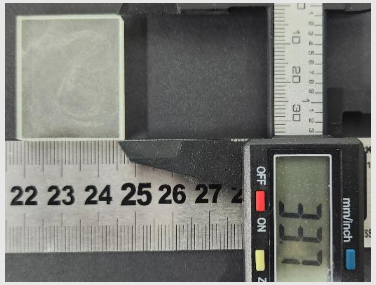


2022.10

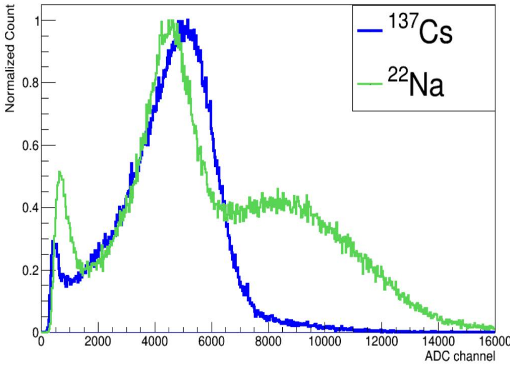


2022.11

Density=5.1 g/cm³
LY=660 ph/MeV



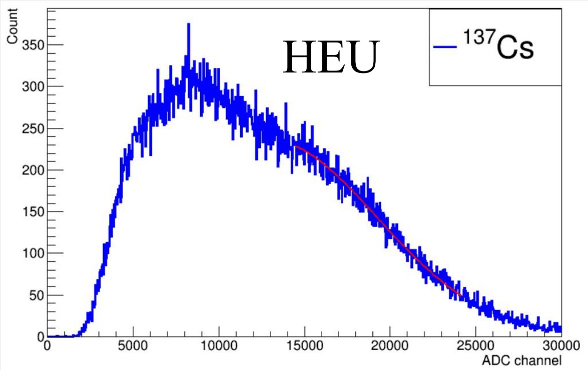
26mm*34mm*4mm



2. Glass Ceramic（Gd-Y-K-Si-Ce^{3+}）

About Glass Ceramic could be seen in these Ref.
(2021.07) Opt. Lett. (2021), 46(14), 3448;
(2021.11) J. Mater. Chem. C, 2021, 9, 17504;
(2022.11) J. Eur. Ceram. Soc., 2022;

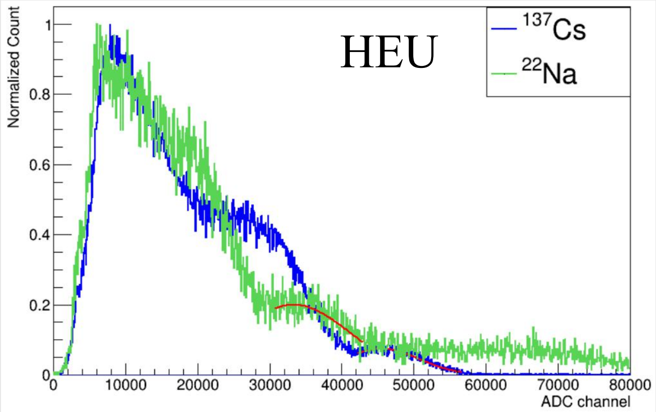
- Density~ 3.3 g/cm^3
- LY=519 ph/MeV
- ER=None



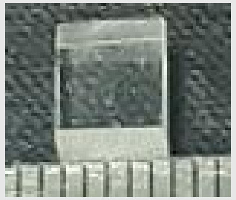
2022.04

(2022.10) J. Mater. Chem. C, 2021, 9, 17504

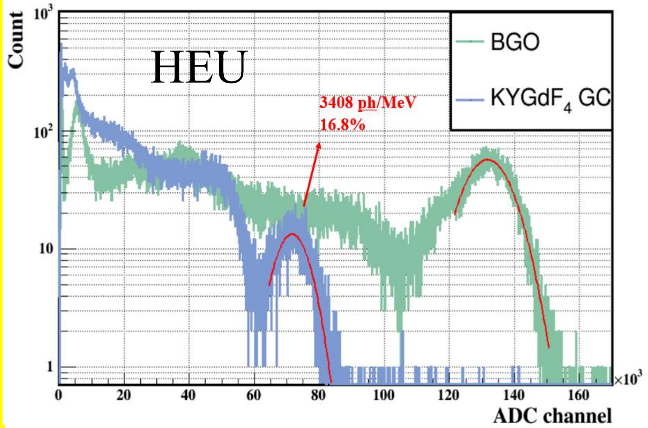
- Density~ 3.3 g/cm^3
- LY>1600 ph/MeV
- ER=27.27%



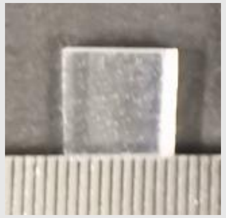
2022.10



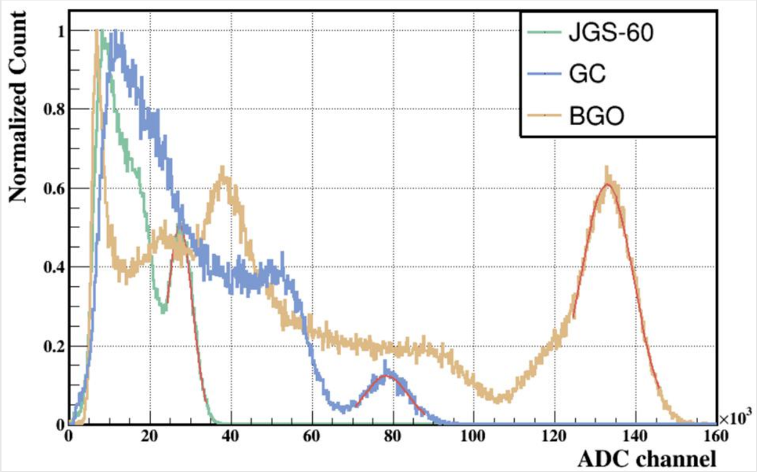
- Density~3.3 g/cm^3
- **LY>3400 ph/MeV**
- ER=16.77%



2022.11

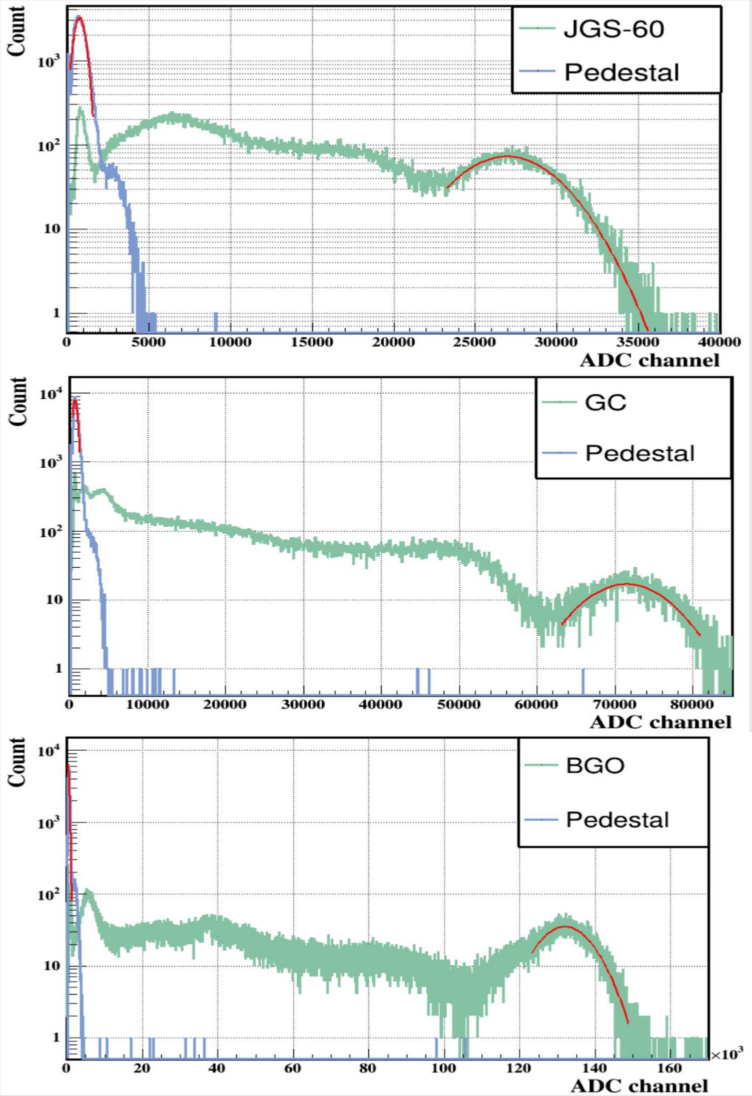


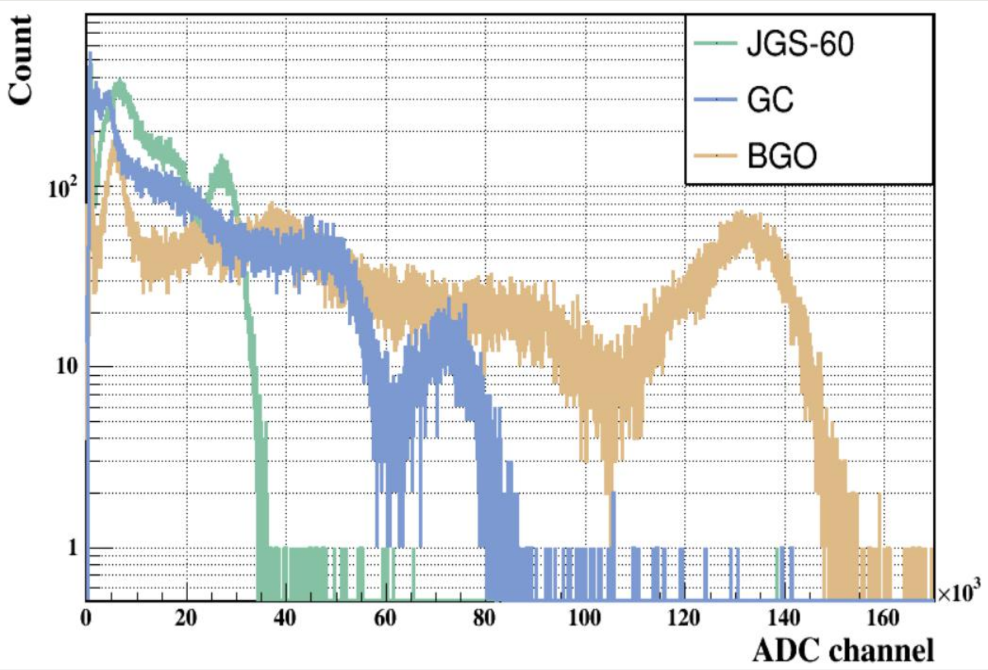
3. Check the test methode of Light Yield



	LIght Yield (ph/MeV)	Energy Resolution
GS	1279	26.9%
GC	3455	16.4%
BGO	8126	11.7%

High Threshold to cut the noice without the pedestal, short time for data acquication.



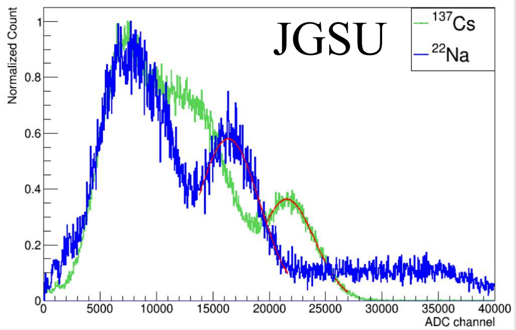


	LIght Yield (ph/MeV)	Energy Resolution
GS	1261	25.2%
GC	3408	16.8%
BGO	7478	12.2%

Low Threshold to keep the Noice pedestal, long time for data acquication.

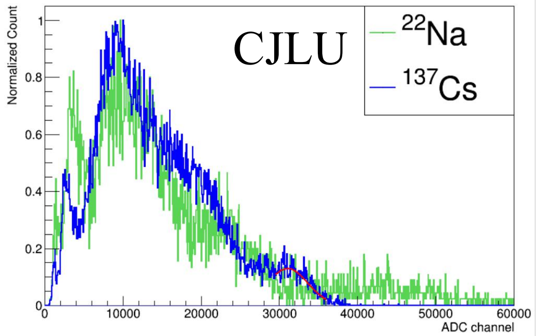
4. Borosilicate Glass（Gd-Al-B-Si-Ce^{3+}）

- Density~4.5 g/cm^3
- LY=802 ph/MeV
- ER=26.77%



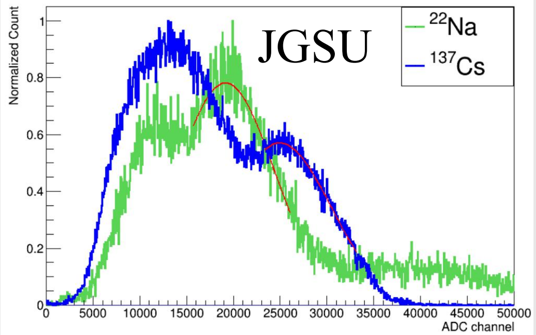
2021.11

- Density~4.0 g/cm^3
- **LY>1200 ph/MeV**
- ER=23.22%



2022.06

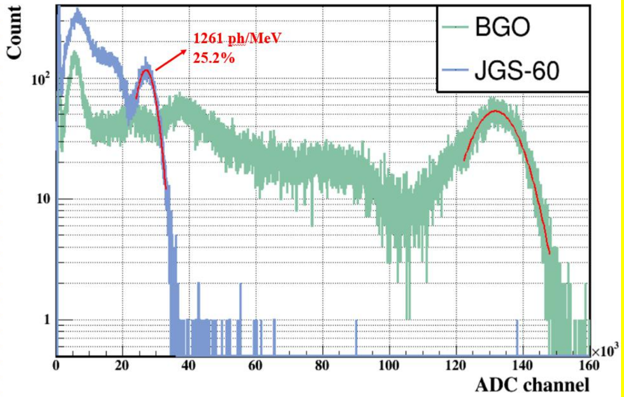
- **Density~6.0 g/cm^3**
- LY>1000 ph/MeV
- ER=49.55%



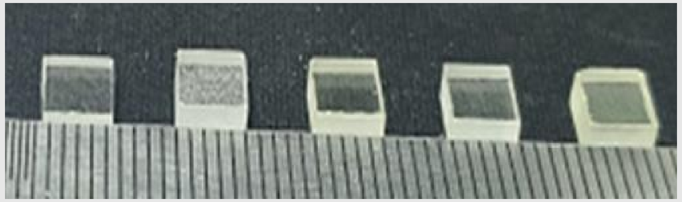
2022.11

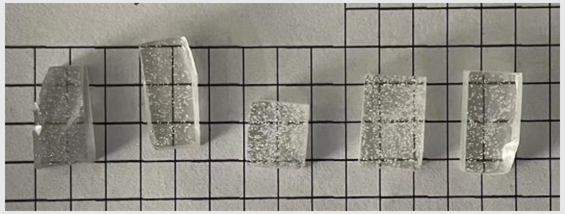
- Density~6.0 g/cm^3
- LY>1200 ph/MeV
- **ER=25.2%**

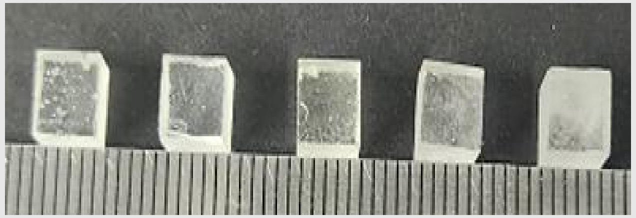
JGSU

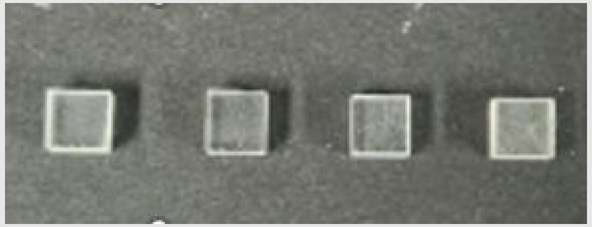


2023.02







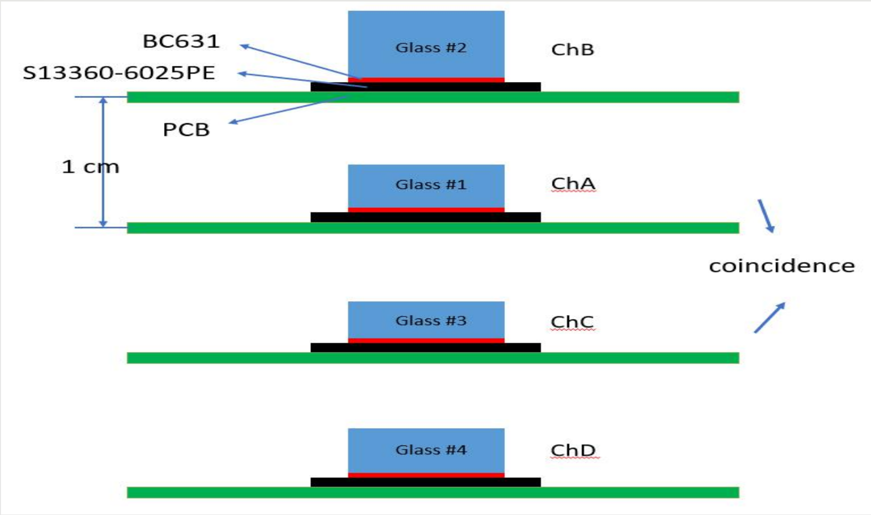


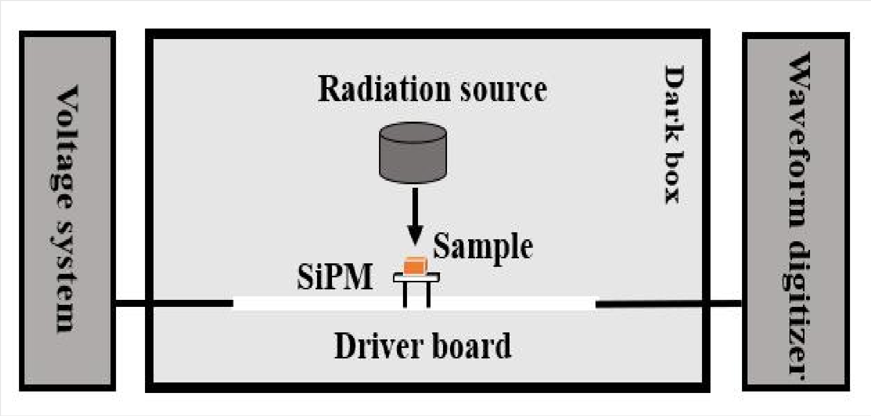
(2022.05)Opt. Mater. 2022(130): 112585

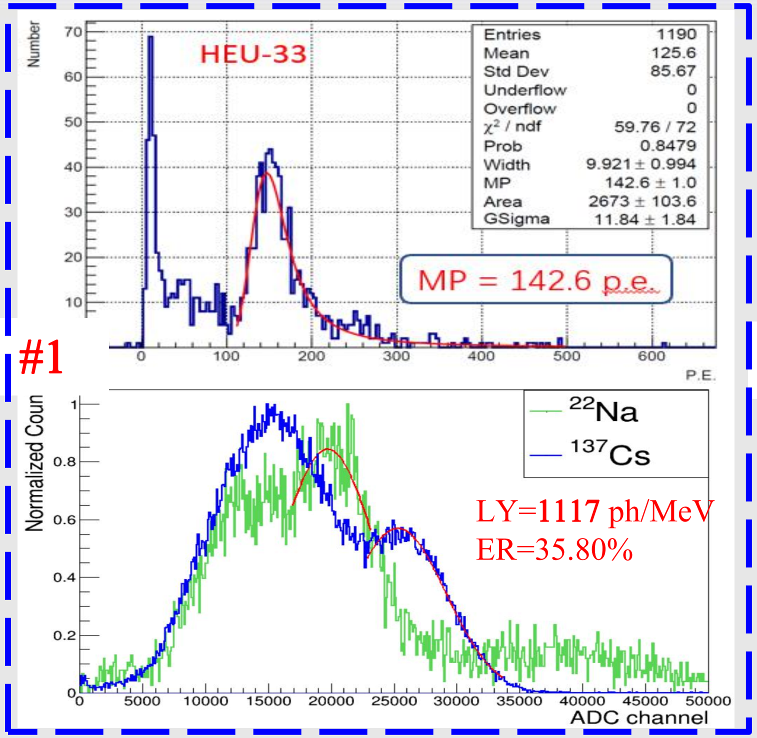
5. Target of Glass Scintillator

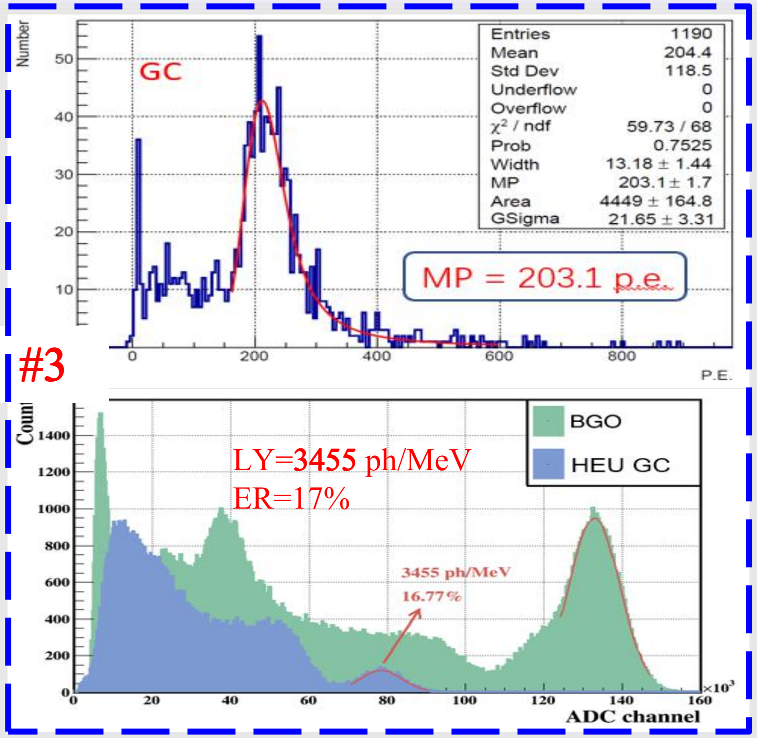
Key parameters	Value	Remarks
➢ Tile size	~30×30 mm^2	Reference CALICE-AHCAL, granularity, number of channels
➢ Tile thickness	~10 mm	Energy resolution, Uniformity and MIP response
➢ **Density**	**5-7 g/cm^3**	More compact HCAL structure with higher density
➢ **Intrinsic light yield**	**1000-2000 ph/MeV**	Higher intrinsic LY can tolerate lower transmittance
➢ Transmittance	~75%	
➢ MIP light yield	~150 p.e./MIP	Needs further optimizations: e.g. SiPM-glass coupling
➢ Energy threshold	~0.1 MIP	Higher light yield would help to achieve a lower threshold
➢ Scintillation decay time	~100 ns	Mitigation pile-up effects at CEPC Z-pole (91 GeV)
➢ Emission spectrum	Typically 350-600 nm	To match SiPM PDE and transmittance spectra

6. The Light Yield--Cosmic Ray VS Gamma Ray





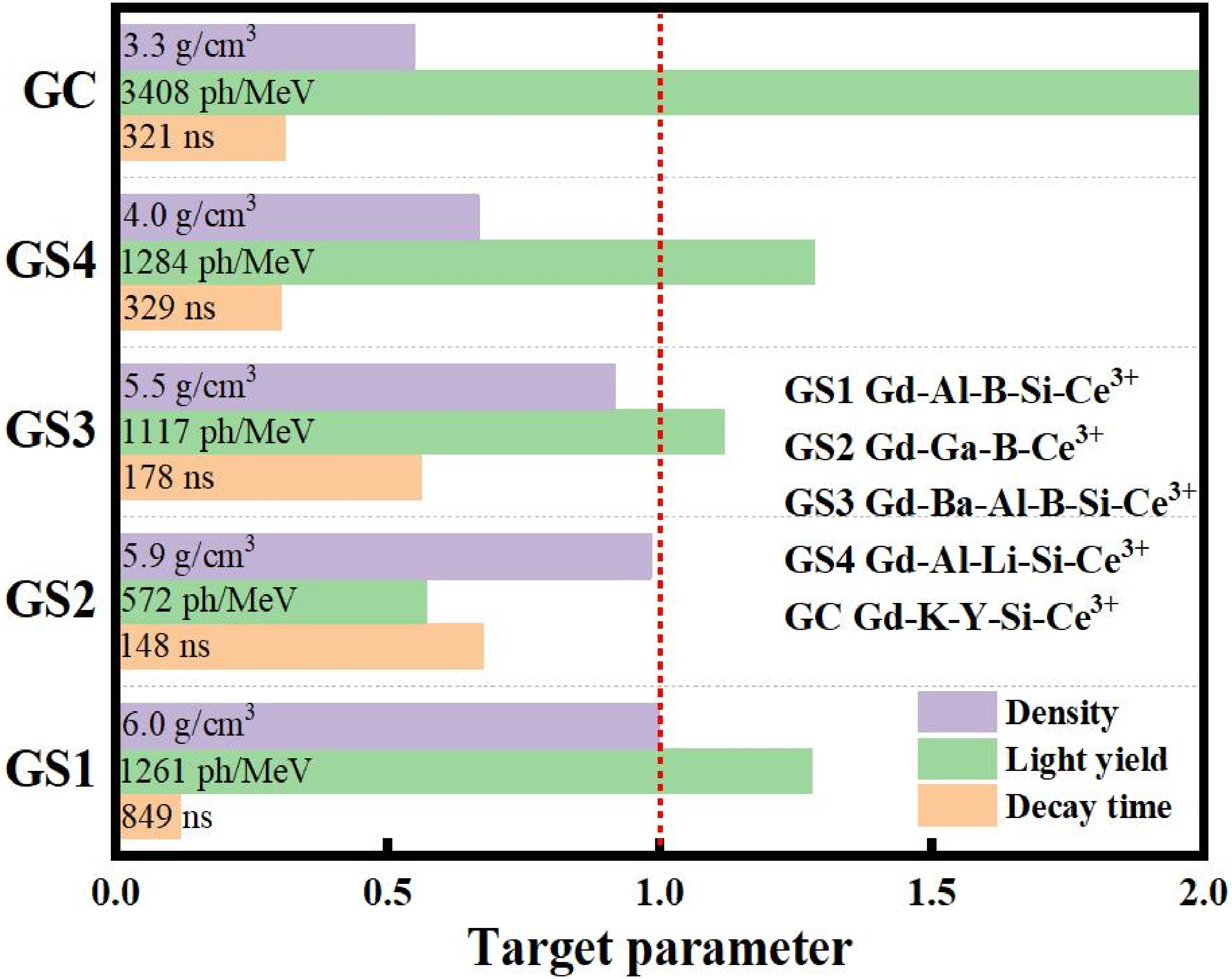




- Considering the density and thickness of the glasses, the MIP response by the cosmic ray is consistent with the light yield of the glass scintillator by gamma ray.

	MIP（p.e.）	LY（ph/MeV）	Thicknes（mm）	Density（g/cm³）	mip/(Thi*Den)	LY/MIP
#1	143	1117	2.6	5.4	10.2	**110**
#3（GC）	203	3455	2	3.3	30.6	**113**

7.1 Summary



Glass scintillator of good Energy Resolution, High Density and High Light Yield

- **6.0 g/cm^3 & 1279 ph/MeV with 26% @662keV —Gd-Al-B-Si-Ce^{3+} glass**

- Ultra-high density **Tellurite Glass**—6.6 g/cm^3
- High light yield **Glass Ceramic**—3500 ph/MeV
- Fast scintillating Decay Time—100 ns
- Large size Glass—42mm*51mm*10mm

7.2 The Scintillator data

Typy	Composition	Density (g/cm^3)	Light yield (ph/MeV)	Decay time (ns)	Emission peak(nm)	Price/1 c.c (RMB)
Glass Scintillator in Paper	Ce-doped high Gadolinium glass[1]	4.37	3460	522	431	~10
	Ce-doped fluoride hafnium glass[2]	6.0	2400	23.4	348	150
Plastic Scintillator	BC408[3]	~1.0	5120	2.1	425	60
	BC418[3]	~1.0	5360	1.4	391	80
Crystal	GAGG:Ce[4]	6.6	50000	50	560	2400
	LYSO:Ce[5]	7.1	30000	40	420	1200
	BGO[6]	7.3	8000	300	480	800
Glass Scintillator for CEPC	?	>6	>1000	< 100	350-500	~1
Stuaus of Glass Scintillator	?	~6	>1000	< 800	350-500	~?

[1] Struebing, C . Journal of the American Ceramic Society, 101(3). [2] Zou, W. Journal of Non-Crystalline Solids, 184(1), 84-92 . [3] Plastic Scintillators | Saint-Gobain Crystals. [4] Zhu, Y. Qian, S. Optical Materials, 105, 109964. [5] Ioannis, G. Nuclear Instruments & Methods in Physics Research. [6]Akapong Phunpueok, et al. Applied Mechanics and Materials, 2020,901:89-94.

8. Next Plan

Gd-(Ba/Al)-B-Si -Ce^{3+} glass will be the focus of future research.

- The glass scintillators were prepared repeatedly to ensure its performance stability;
- The properties of the glasses will be further improved through **raw material purification;**
- To reduce the scintillation decay time of the glasses (<100 ns);
- To produce the large size and mass preparation samples;
- Test the radiation resistance and mechanical properties of the glasses;
- Explore the structural properties of the glasses.

闪烁玻璃合作组
Glass Scintillator Collaboration

See the unseen
change the unchanged

The Innovation

THANKS