Time evolution of GECAM GRD in-flight background and performance

IHEP GECAM Team
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GECAM Gamma Ray Detector(GRD) introduction

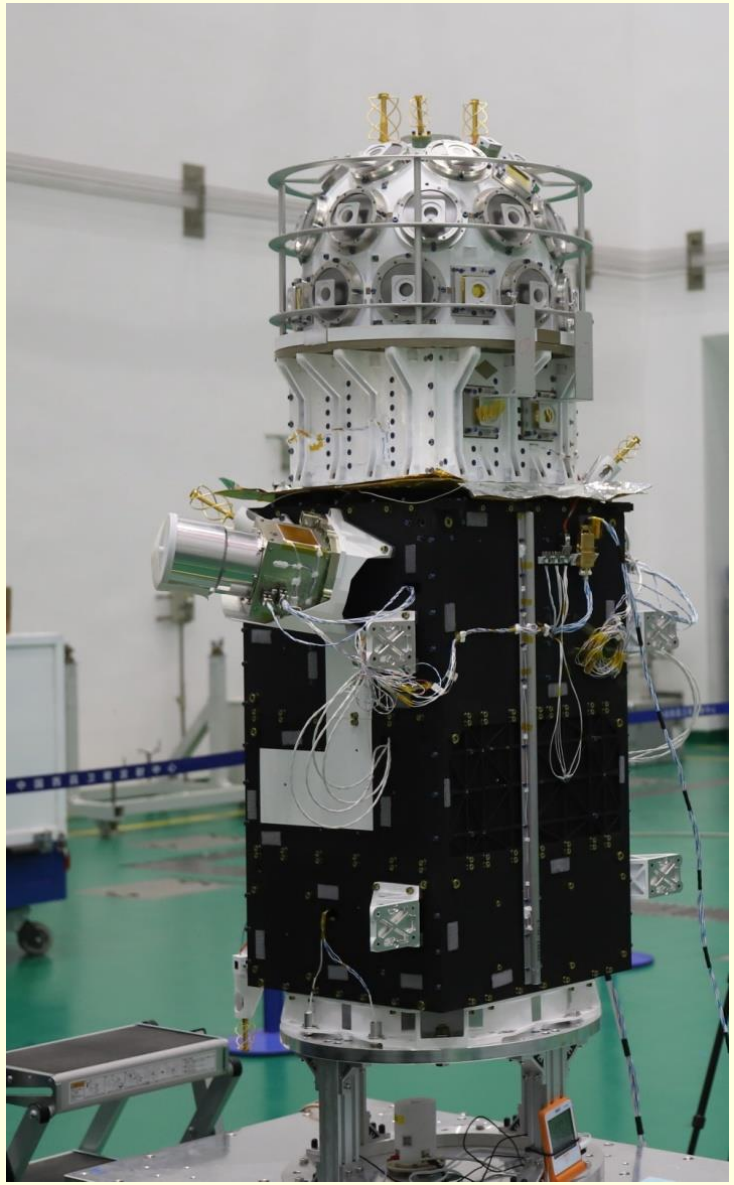
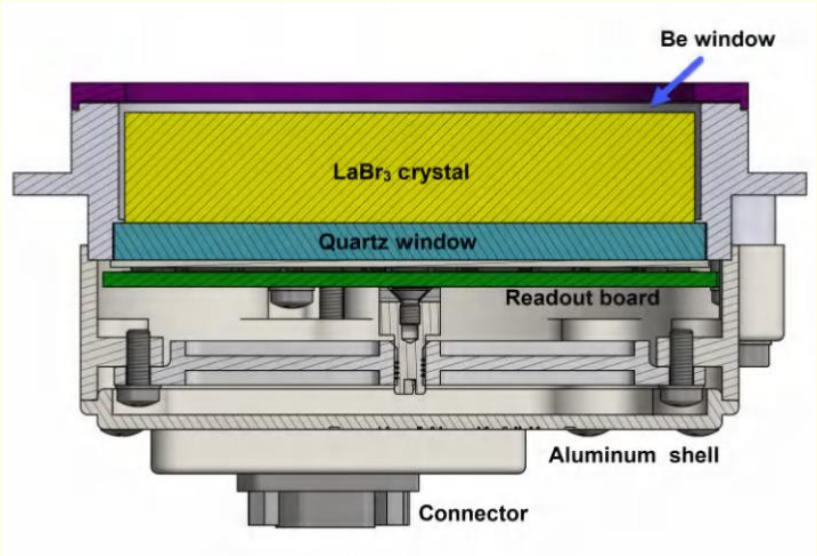


Photo of one GECAM satellite.

SiPM based Gamma Ray Detector(GRD)

SiPM array (64 chips)
SensL MICROFJ-60035-TSV-TR

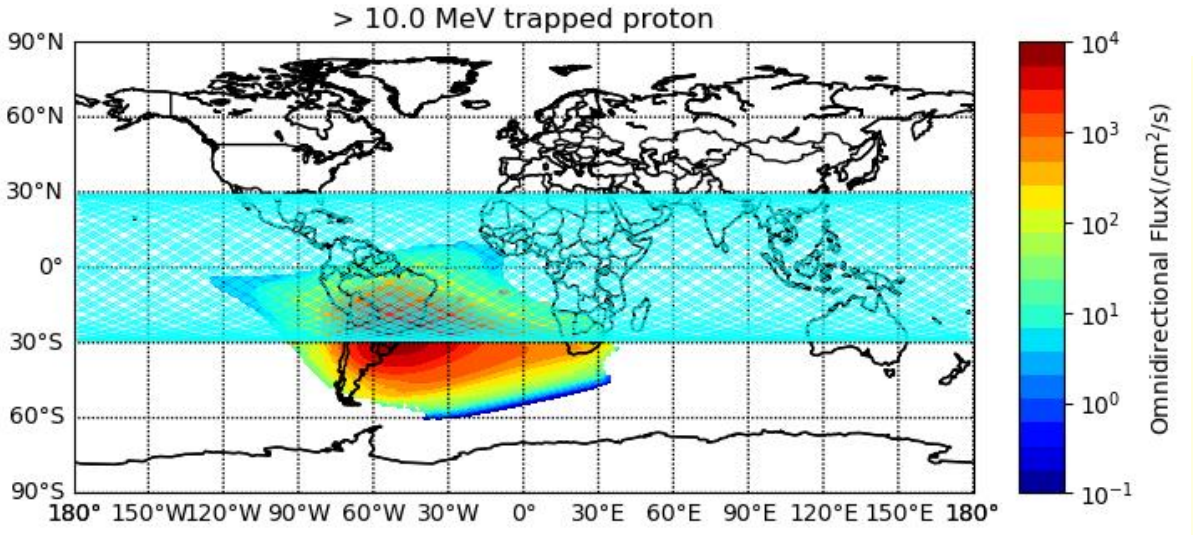


GRD structure

Parameters	Value
Detection energy range (GRD)	5.9 keV~3.9 MeV
Detection area (GRD)	> 40 cm2 (for each GRD)
Deadtime	4μs (normal events) ~70 us (overflow)
Energy resolution (GRD)	<16.93@59.5keV
Detection efficiency for Gamma-rays	>60%@8keV
Mass for each GRD	~675g
Power consumption	<0.2W

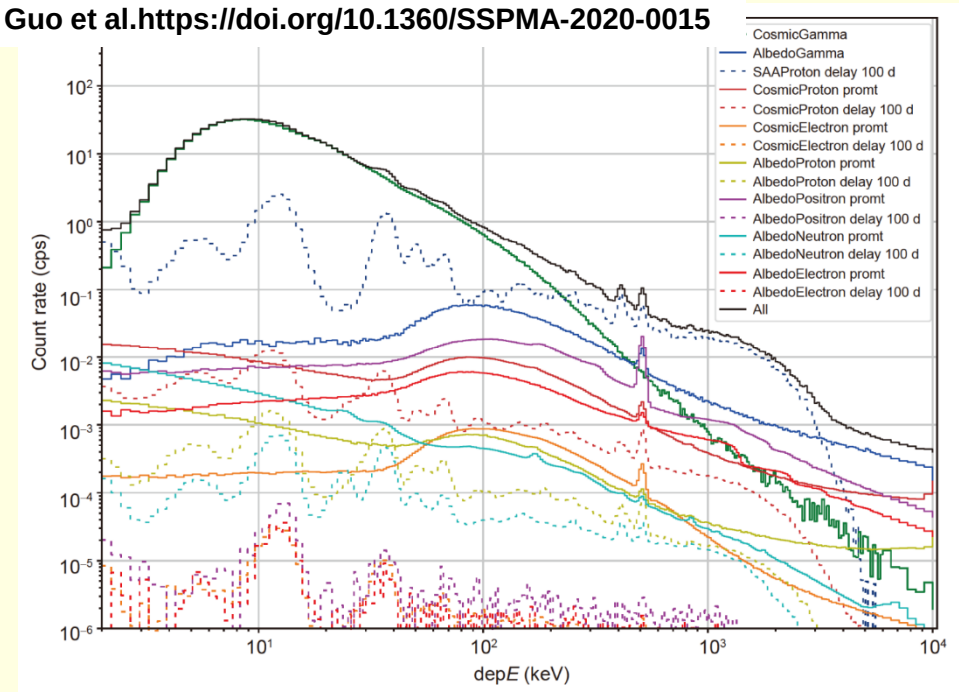
D.L.Zhang et al,NIMA,2019, https://doi.org/10.1016/j.nima.2018.12.032
Dali zhang et al.RDTM,2022,https://doi.org/10.1007/s41605-021-00282-5

In-orbit irradiation environment of GECAM

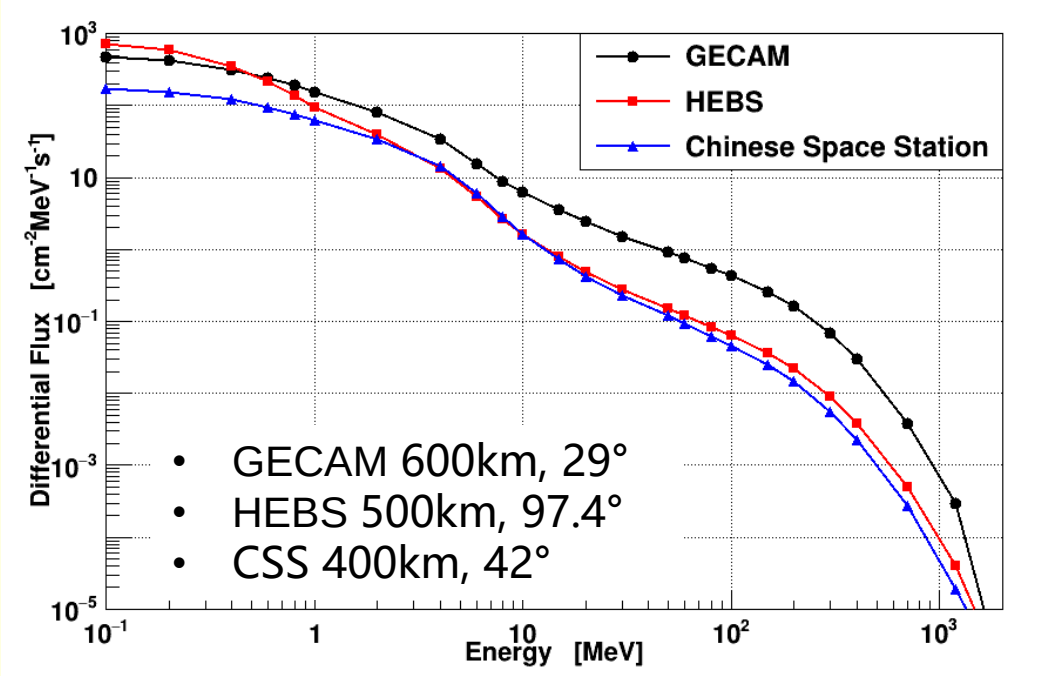


GECAM satellite orbit

DongYa Guo et al.https://doi.org/10.1360/SSPMA-2020-0015



Simulated in-orbit environment background spectrum of GRD

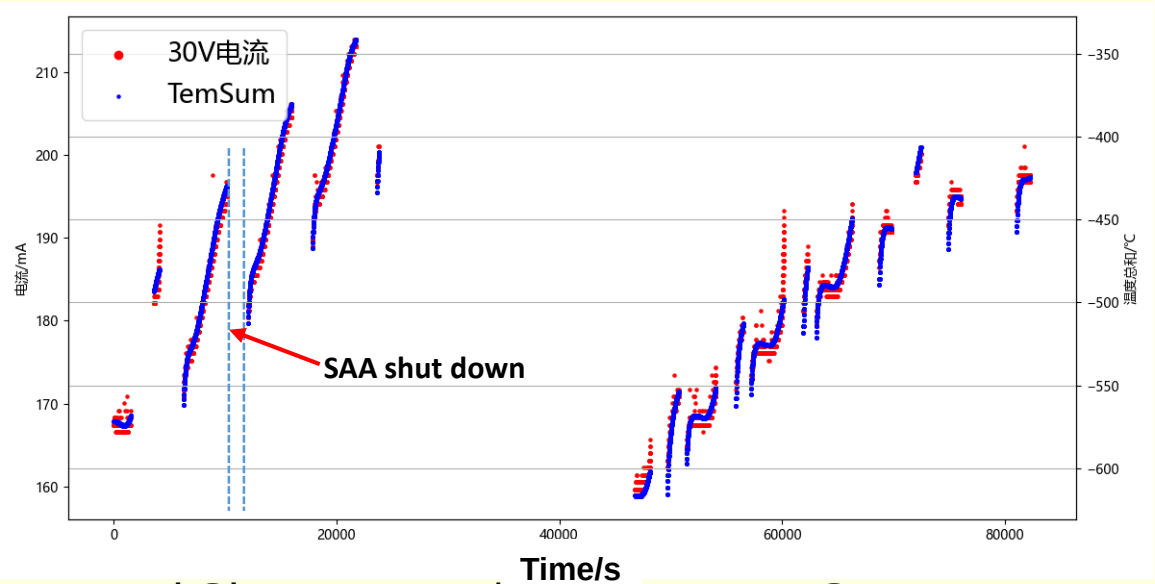


In-orbit proton spectrum (AP8)

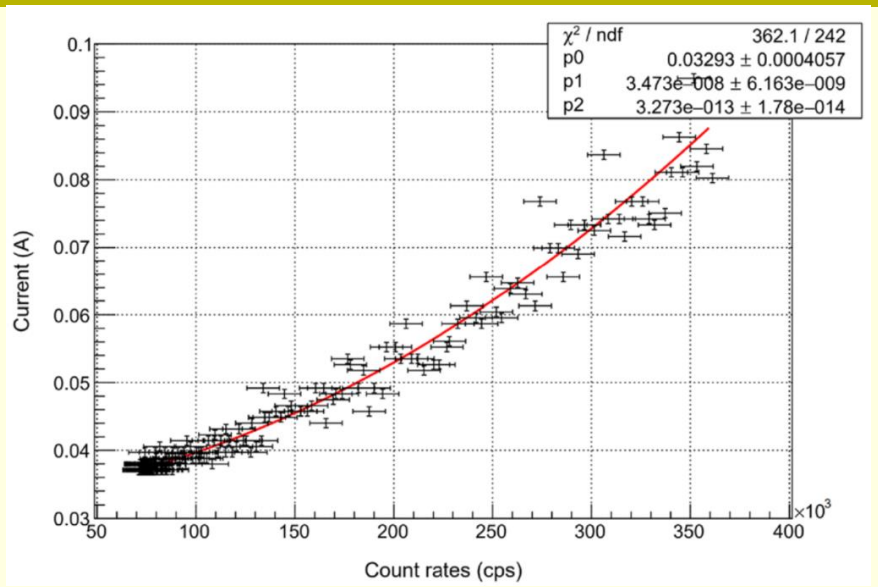
	Dose_IEL	Dose_NIEL
GRD_$LaBr_3$	708 rad	3.27E5 MeV/g
GRD_SiPM	456 rad	2.41E5 MeV/g
CPD_BC408	1330rad	2.15E6 MeV/g
CPD_SiPM	680 rad	4.12E5 MeV/g

Absorbed dose in 1 year （Dose = edep/mass）

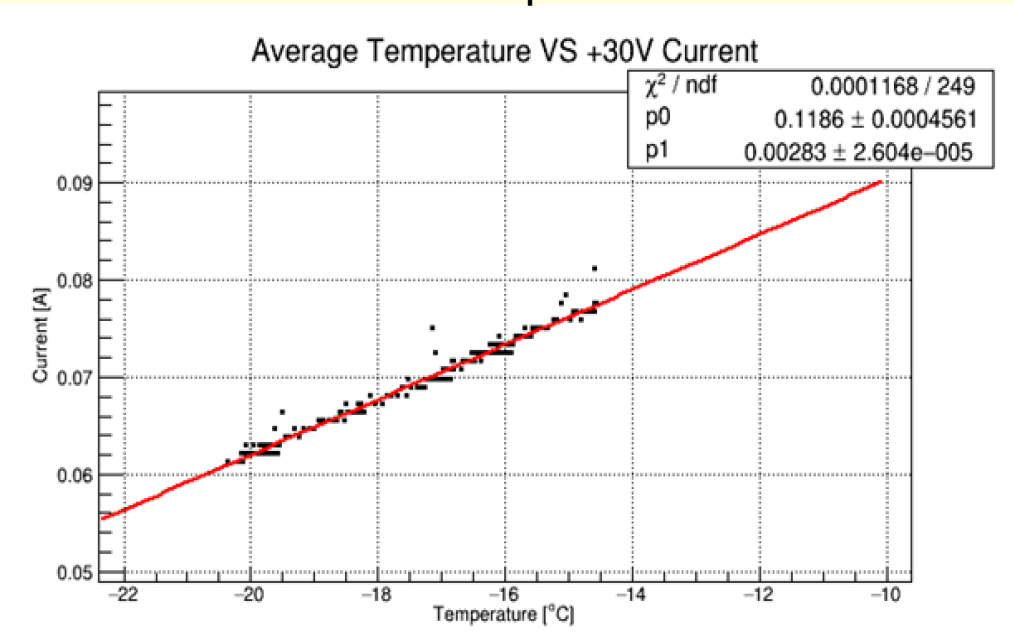
Time evolution of GRD SiPM Current



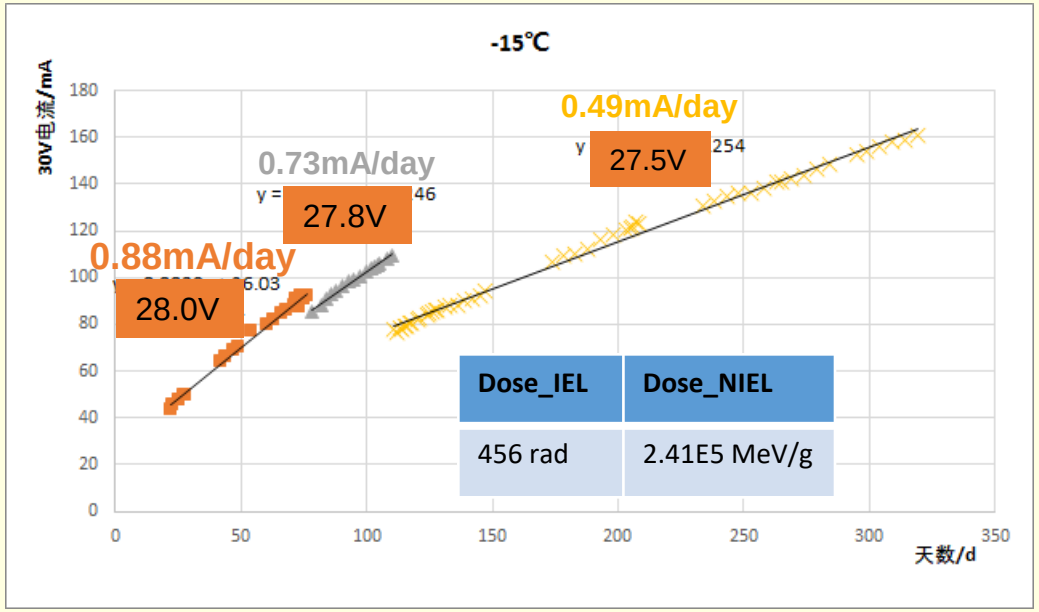
Total SiPM current / temperature VS current



Dark current increase with count rates



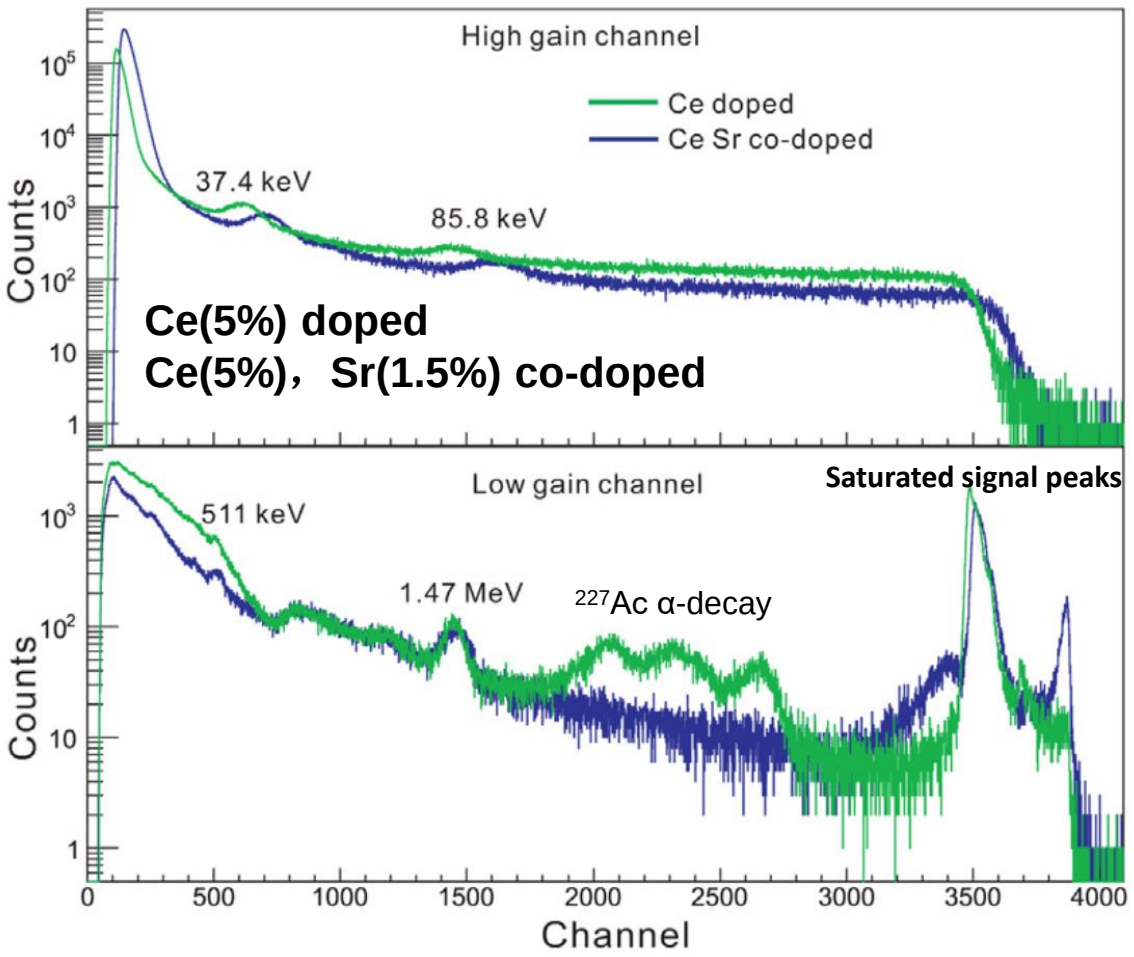
GECAM SiPM(1774chips) current VS Temperature



SiPM current increasement (-15℃/low count rate)

In-flight gamma-ray lines of GRD (in 1000 s)

In-flight background of single and co-doped GRDs

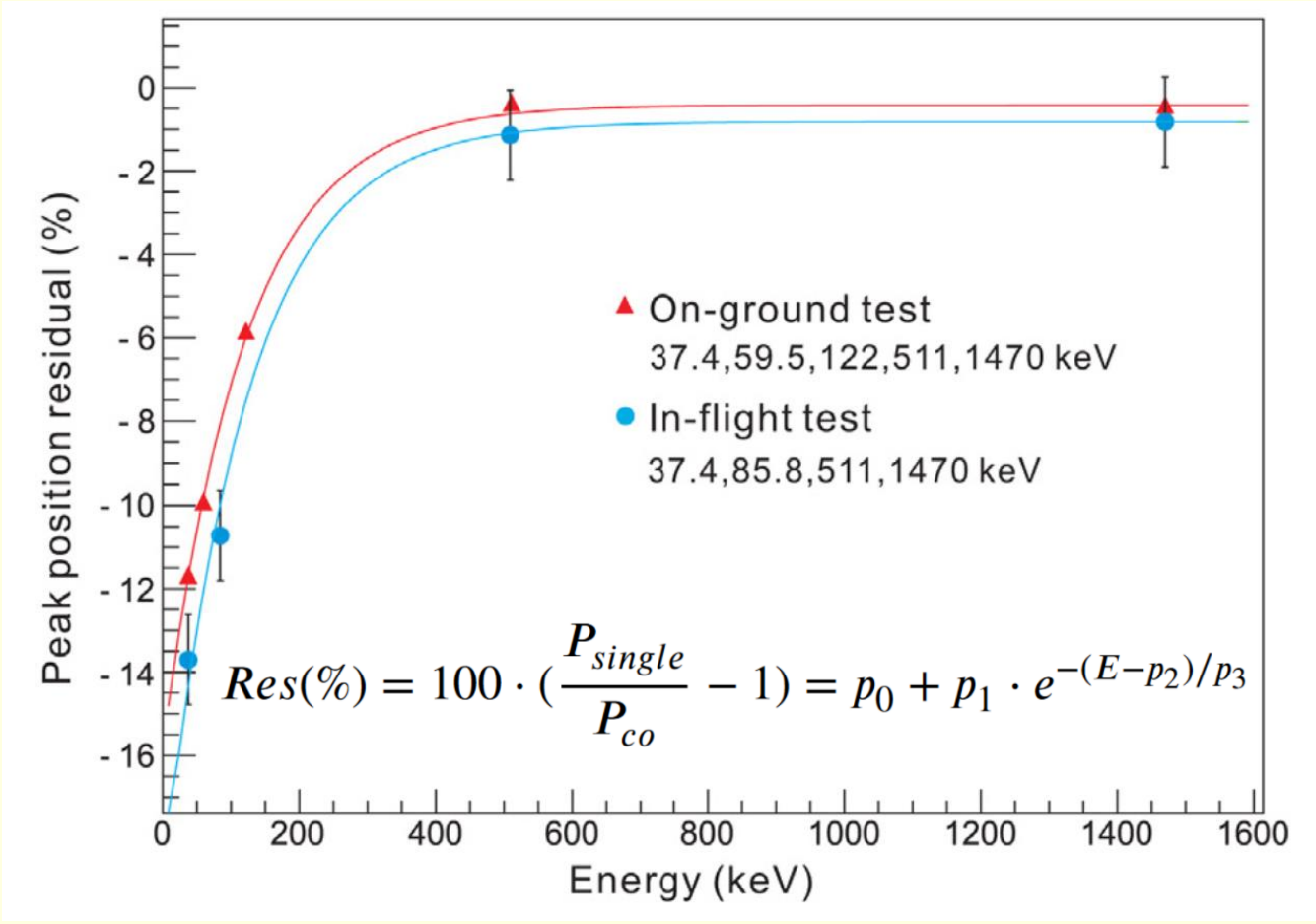


$LaBr_3$ intrinsic activity: 37.4 keV(30 cps),1470 keV(6.5 cps)

Galactic gamma-ray line: 511 keV(12.2cps)

Radiation activation line: 85.8 keV(12.5 cps)

Peak position residual between single and co-doped GRD

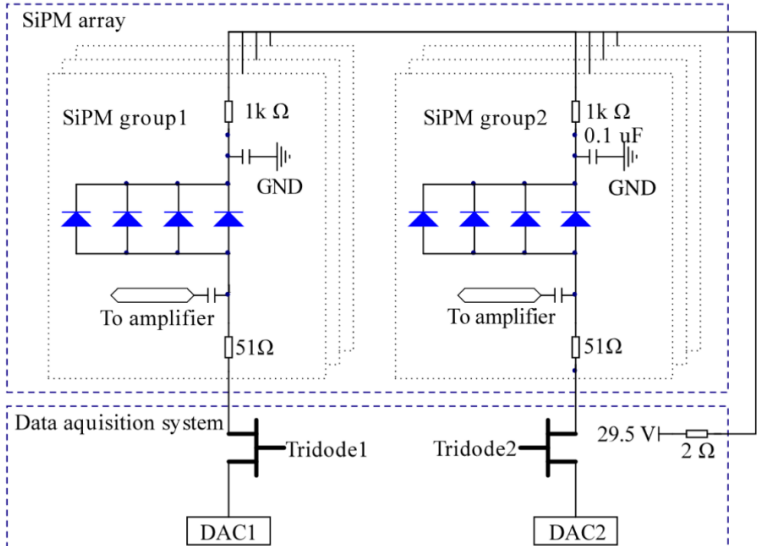


Co-doped $LaBr_3$ indicates reduced non-linear quenching in low energy.

For co-doped $LaBr_3$, the peak position of ^{227}Ac α-decay nucleus shifts to the right in double doped. The low energy peak is higher at 37.4 keV.

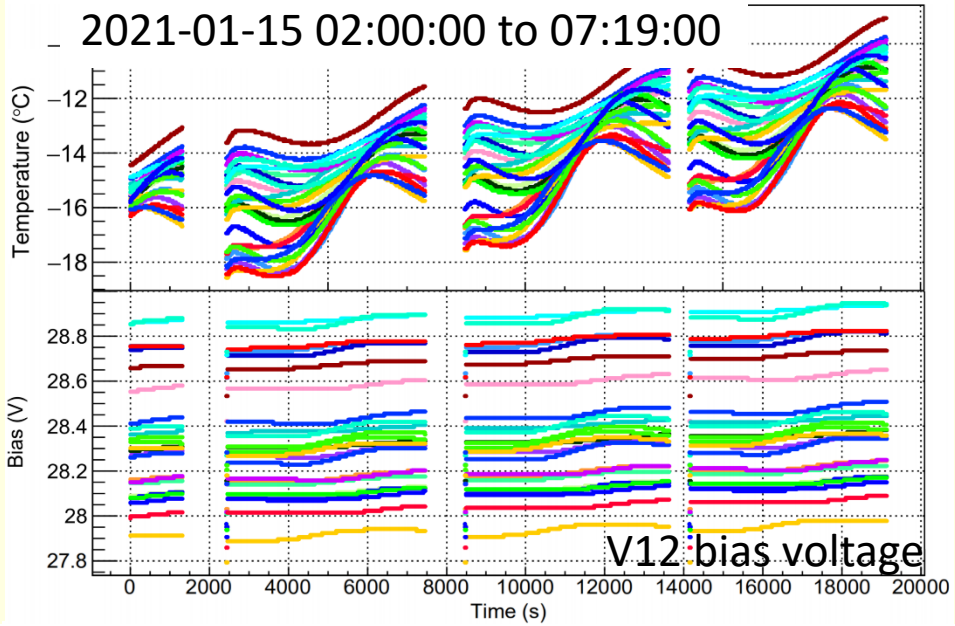
Dali zhang et al.NIMA,2022,https://doi.org/10.1016/j.nima.2018.12.032

In-flight GRD gain stability with temperature flux

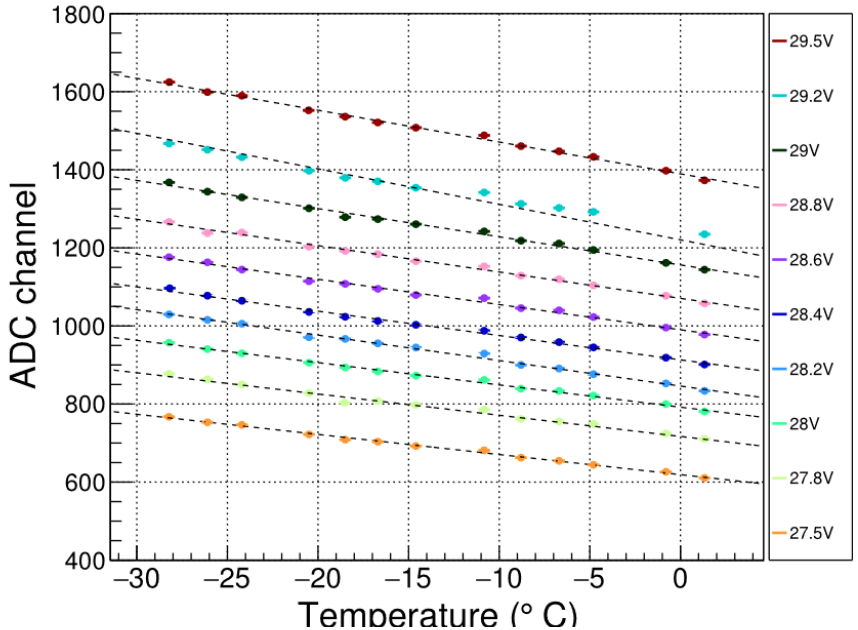


Block scheme of SiPM array and power supply

Adaptive SiPM power supply:
Voltage range: 27.5-29.5 V
Adjustment step： 0.5 mV
Refresh time: 1 s
Temperature range:−45 to 45 ◦C



37.4 keV peak position stability with temperature

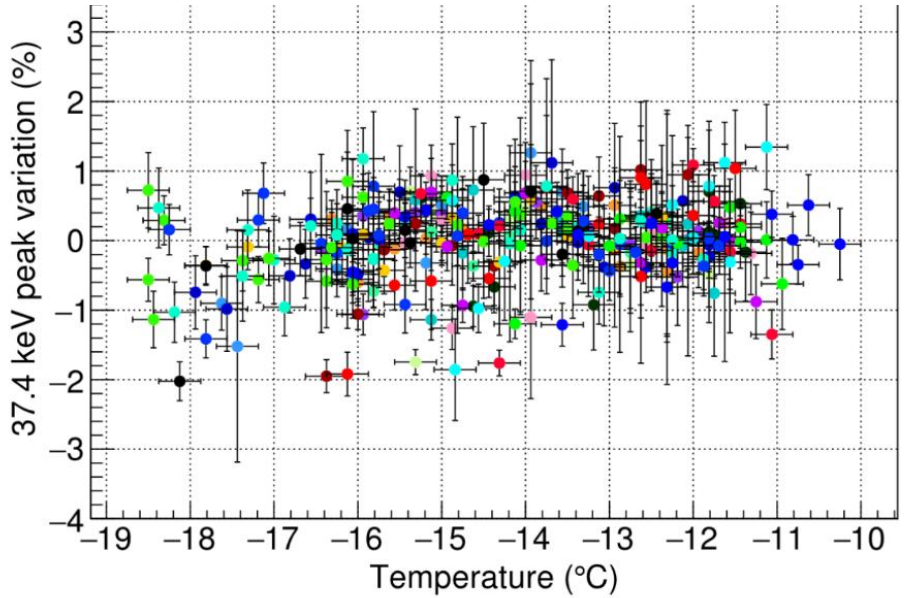


GRD temperature dependence

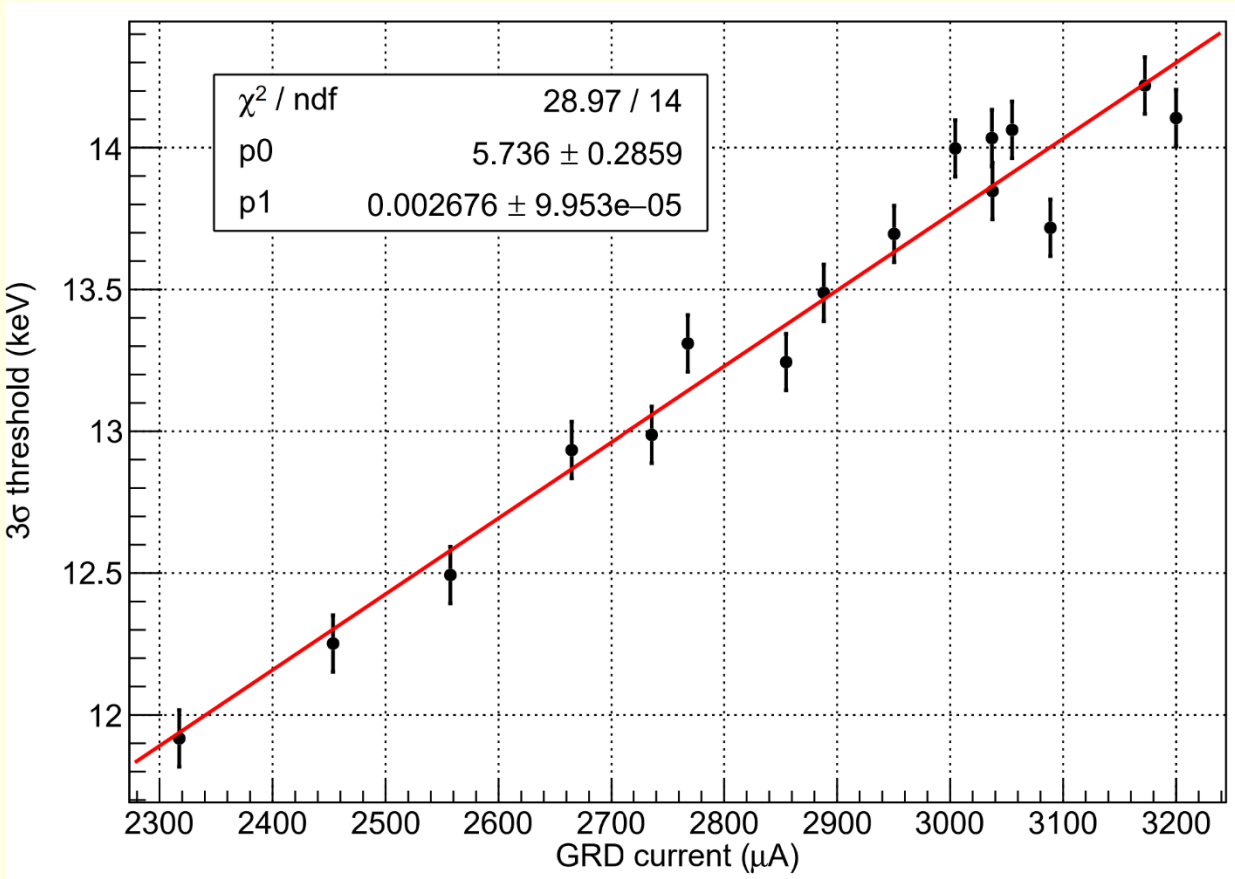
Constant SiPM overvoltage

$$V_{bias} = V_R + \alpha \cdot (T - T_R)$$

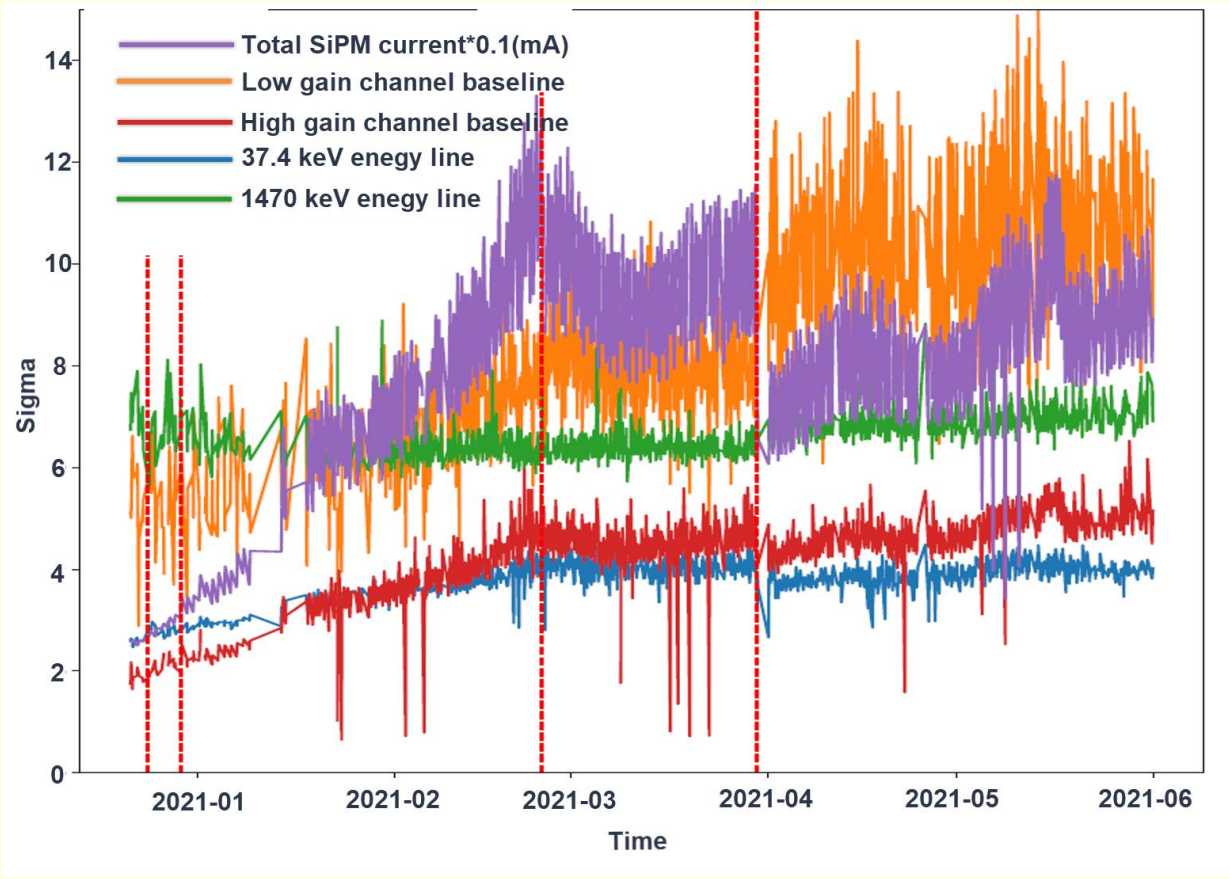
V_R is around 28 V
T_R: 20 ◦C
α: 18 mV/◦C



Time evolution of GRD performance in long period



GRD threshold vs SiPM array dark current

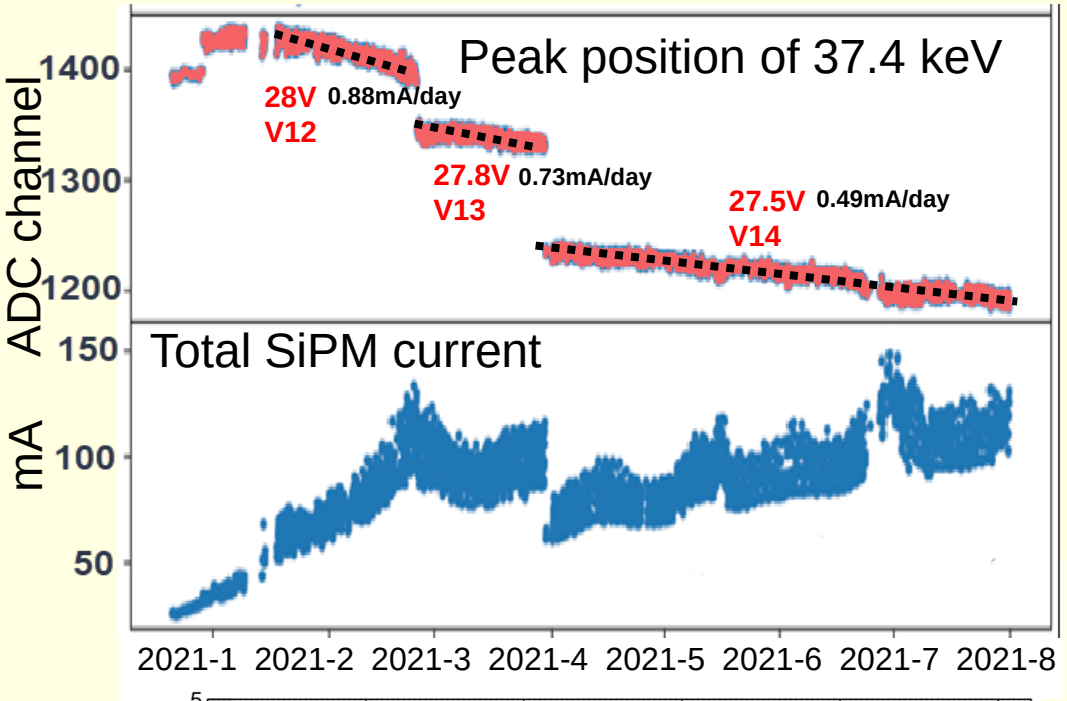


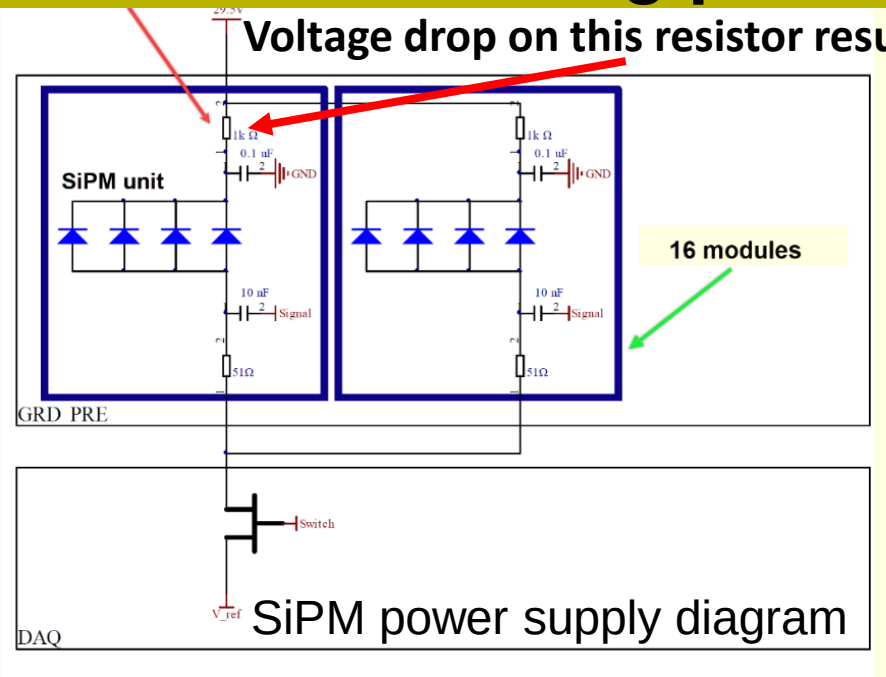
Sigma evolution of gamma-ray lines

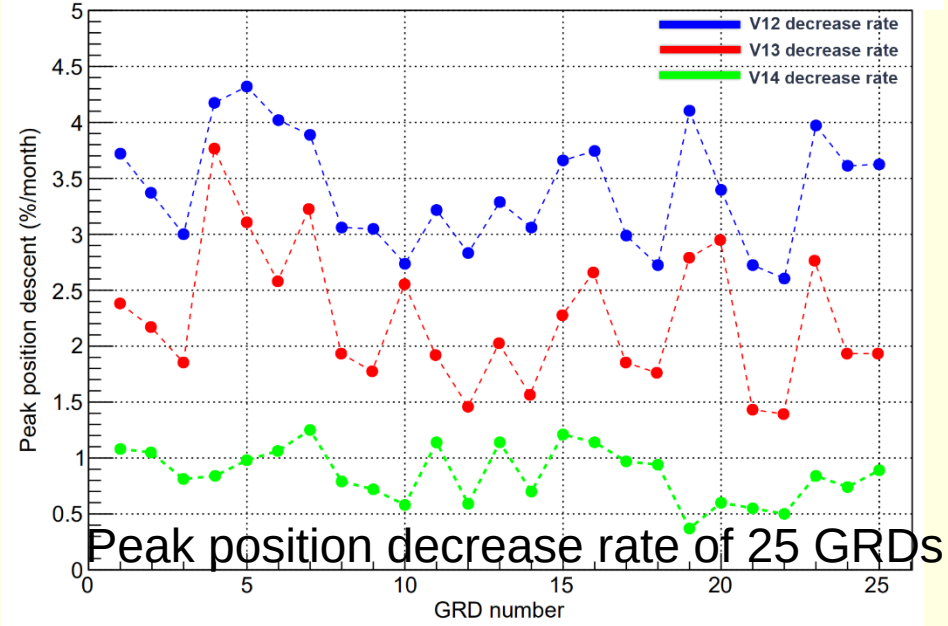
D.L.Zhang et al,RDTM,2021,https://doi.org/10.1007/s41605-021-00282-5

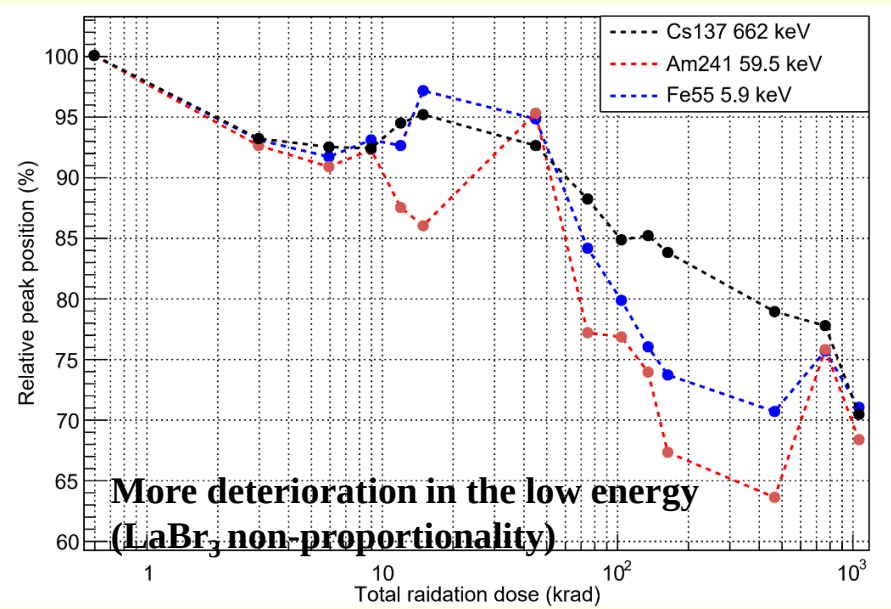
Due to the continuous radiation damage of SIPM in orbit, the SiPM current, sigma of gamma-ray lines and baseline broadening will rise.
The sigma of the 37.4 keV and 1470 keV are increased by 23% and 12% respectively.

Time evolution of GRD performance in long period



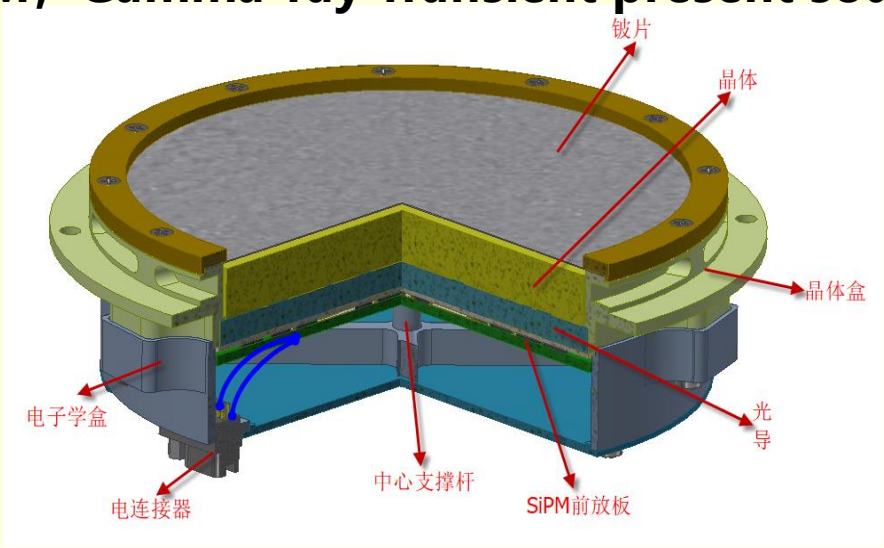




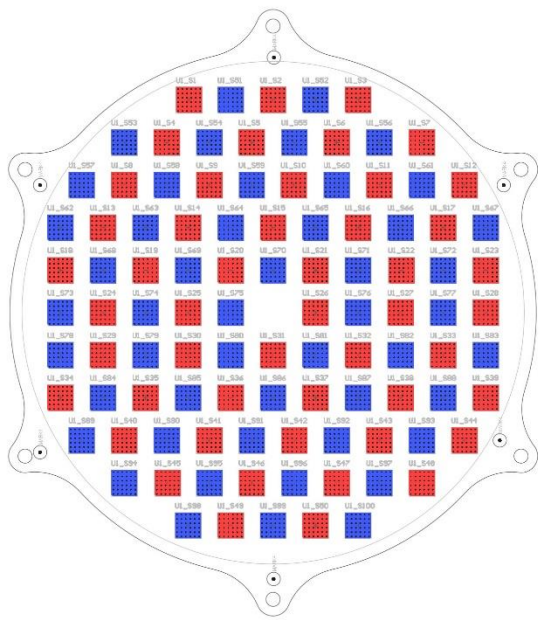


Improvement design for future SiPM in-flight application

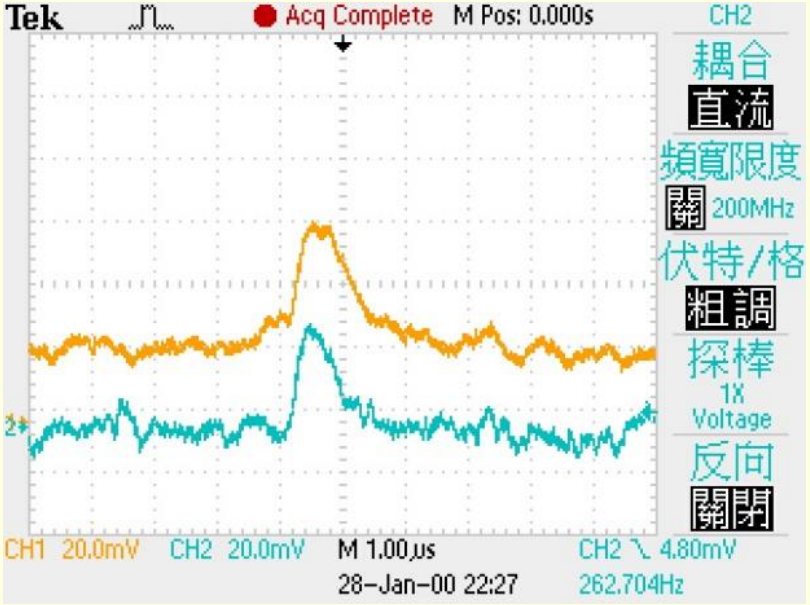
GTM，Gamma-ray Transient present source Monitor (20 keV-1.2 MeV)



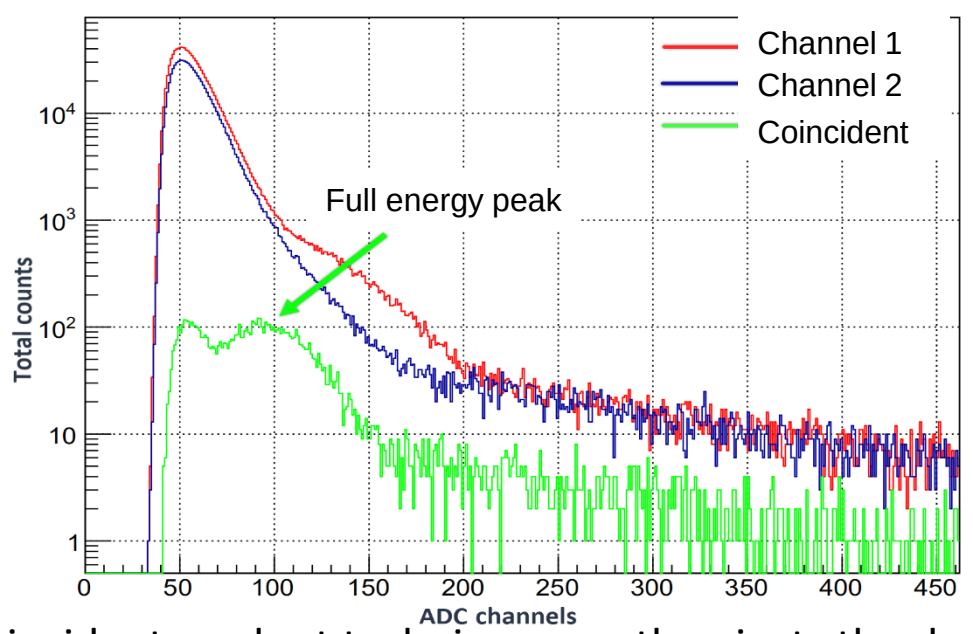
4 inch SiPM-based Gamma ray detector



SiPM array layout



Coincident SiPM outputs



Coincident readout technique greatly rejects the dark counts(0.1%)

	GECAM	GTM
SiPM bias voltage	27.5-29.5V	24.8-26.8V
SiPM density	1.45 chips/cm^2	0.98 chips/cm^2
Temperature	-20 ℃	-30 ℃
Readout	Not coincident	coincident readout

Improvements of SiPM application

Summary

1. The in-flight $LaBr_3$ activation line is around 85.8. Other gamma lines are 37.4 keV，511 keV and 1470 keV. These gamma-ray lines are useful for in-flight calibration.

2. The in-flight irradiation causes some unexpected influences on GRD. The total current of SiPM arrays is increasing all the time because of radiation damage. The performance deterioration of GRD was observed in-flight which is caused by the LaBr3 radiation damage and SiPM.

3. In GTM project, GECAM team is developing a new SiPM-based GRD with improvement design.