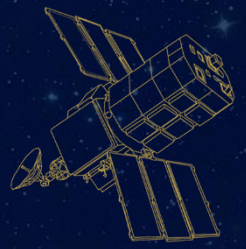


Update about the GRID-03B & GRID-04 and Future Planning

Ming Zeng, Hua Feng

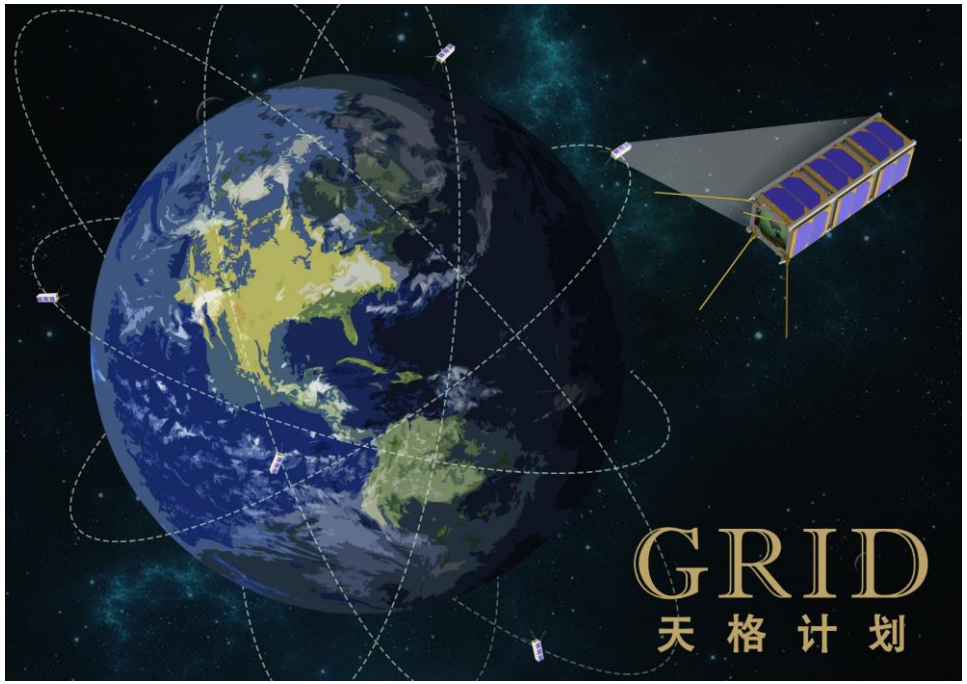
on behalf of the **GRID** collaboration

Tsinghua University, Beijing, China

GRB NanoSats Monthly Teleconferences

02 June 2022

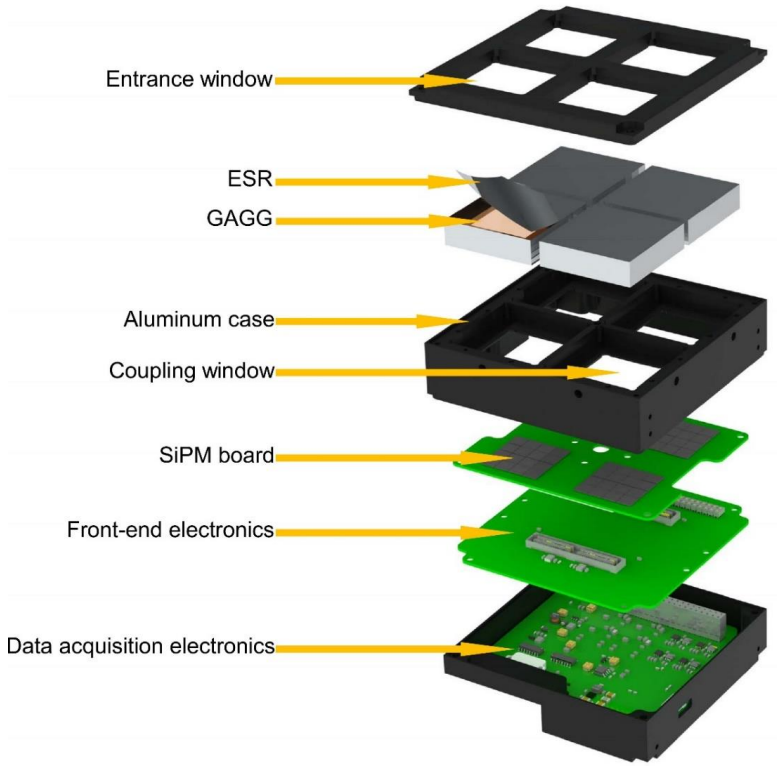
The GRID Project and Detector



Gamma Ray Integrated Detectors (GRID) concept: [1]

- 10 ~ 24 CubeSats scattered in low Earth orbits
- Compact gamma-ray detectors

3D model of the GRID detector [2]



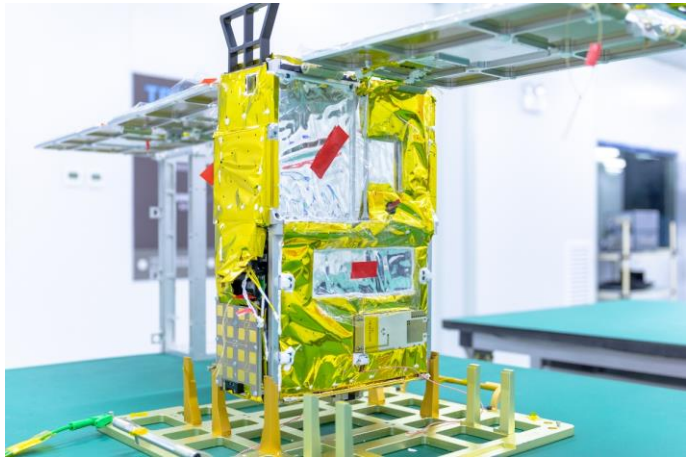
Specifications of GRID-02

Size	< 0.5U (9.4×9.4×5 cm^3)
Weight	~ 780 g
Power consumption	Typ. 2 W Max. 2.8 W
Geometric area	~ 58 cm^2
Field of view	2π
Energy range	Lower threshold < 15 keV Upper threshold ~ 2 MeV
Dead time	~ 20 us
Background count rate	Norm. ~ 2000 cps SAA > 8000 cps
Telemetry	~ 1 GB/day

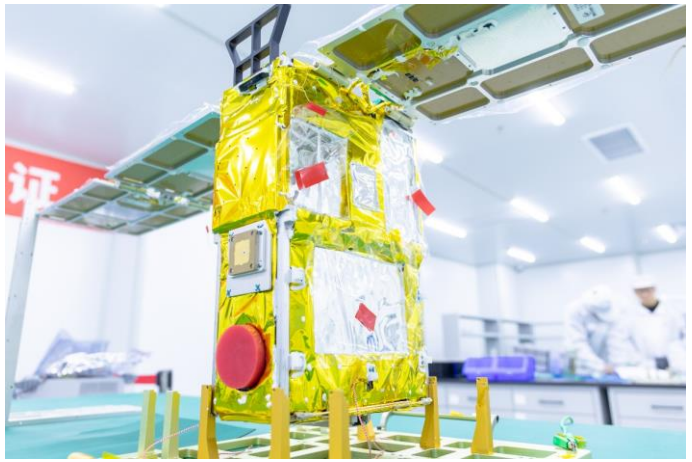
[1] Wen, J., Long, X., Zheng, X. *et al.* GRID: a student project to monitor the transient gamma-ray sky in the multi-messenger astronomy era. *Exp Astron* **48,** 77–95 (2019)
[2] Wen, JX., Zheng, XT., Yu, JD. *et al.* Compact CubeSat Gamma-ray detector for GRID mission. *NUCL SCI TECH* **32,** 99 (2021)

Update about the GRID-03B & GRID-04

Catalog number: 51830
Launched 02/27/2022

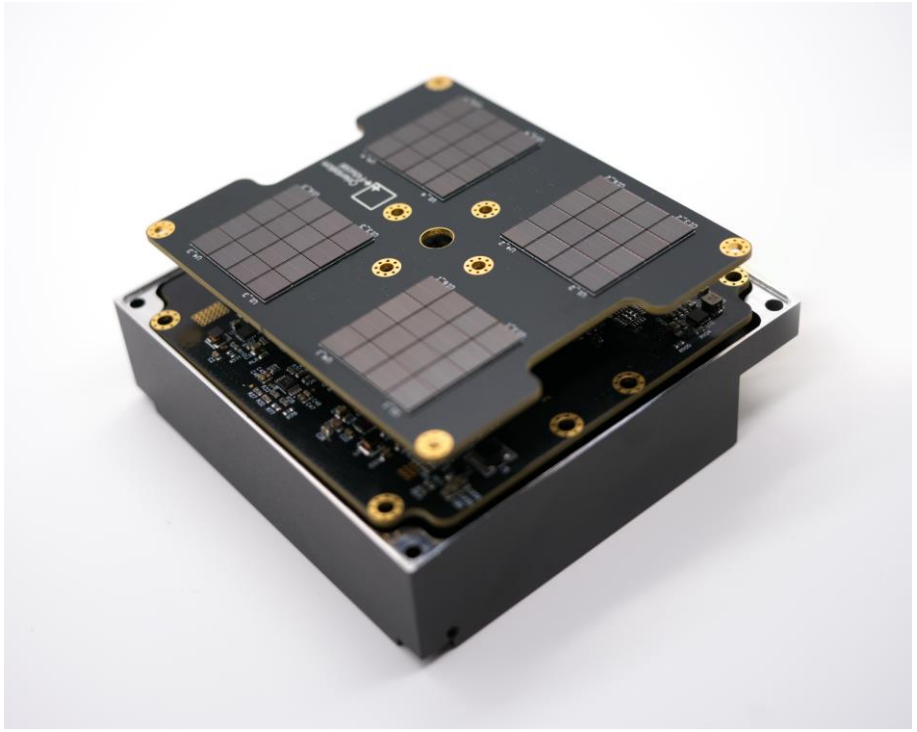


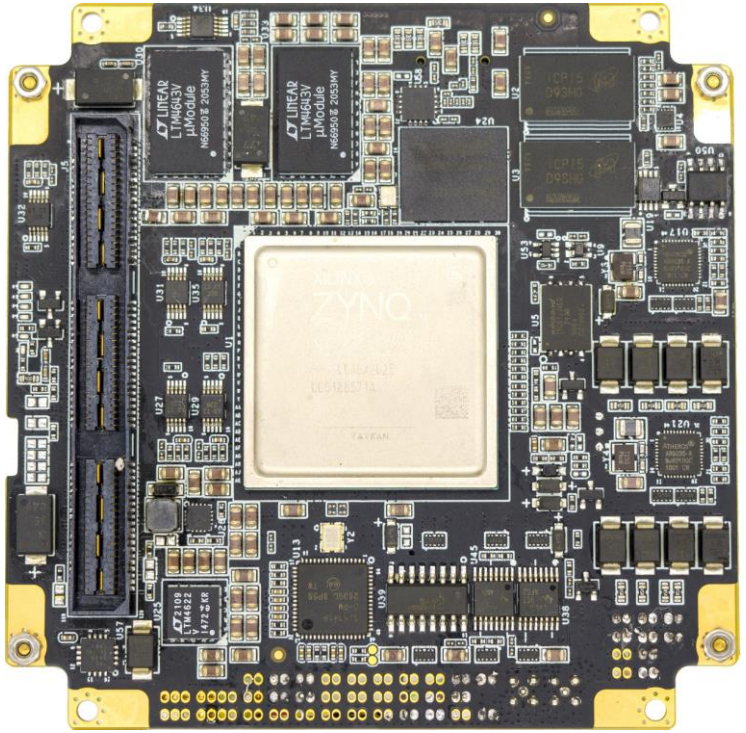
GRID-03B



GRID-04

GRID-03B New Digital Readout

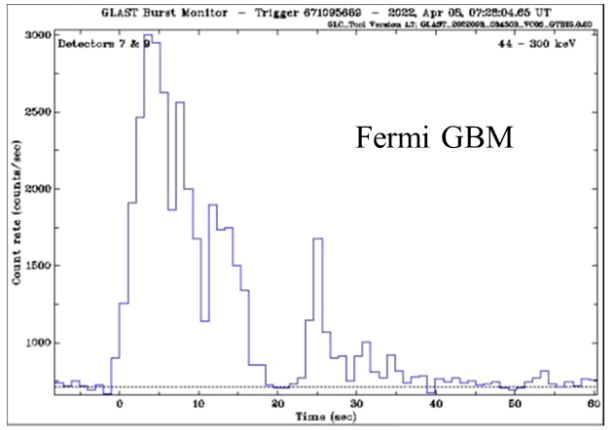


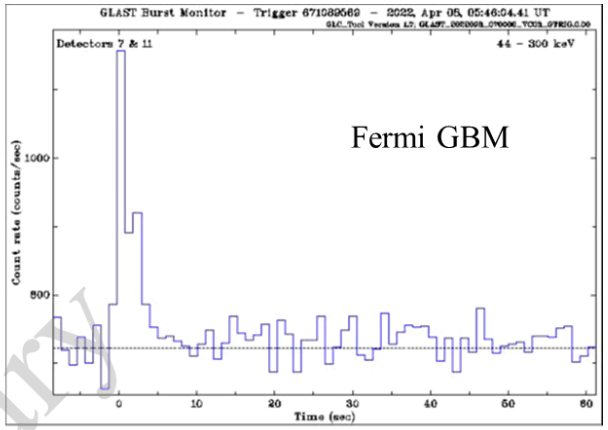


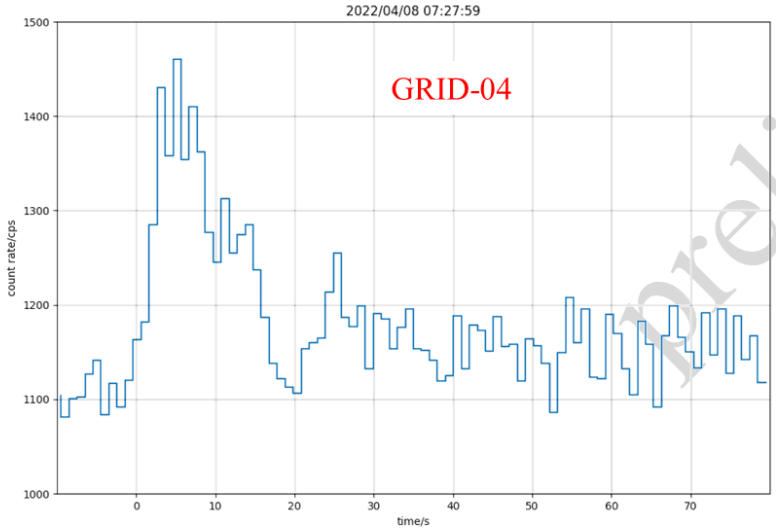
DAQ-zynq7100

星测未来 StarDetect

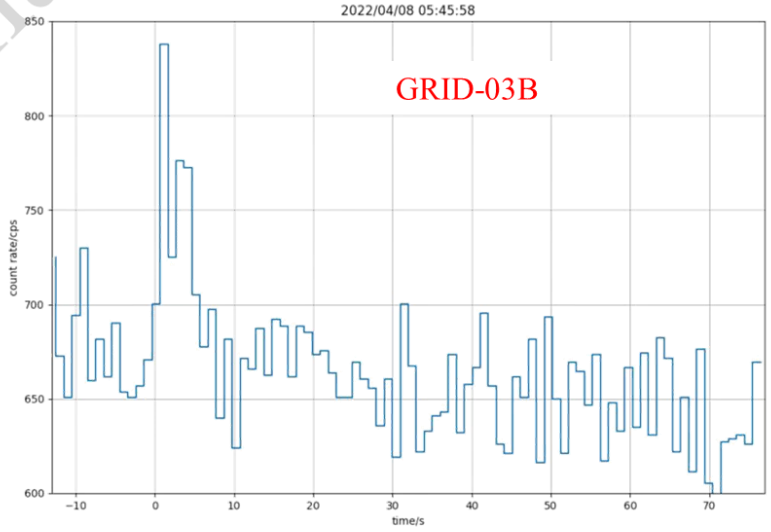
Preliminary Results from GRID-03b & GRID-04







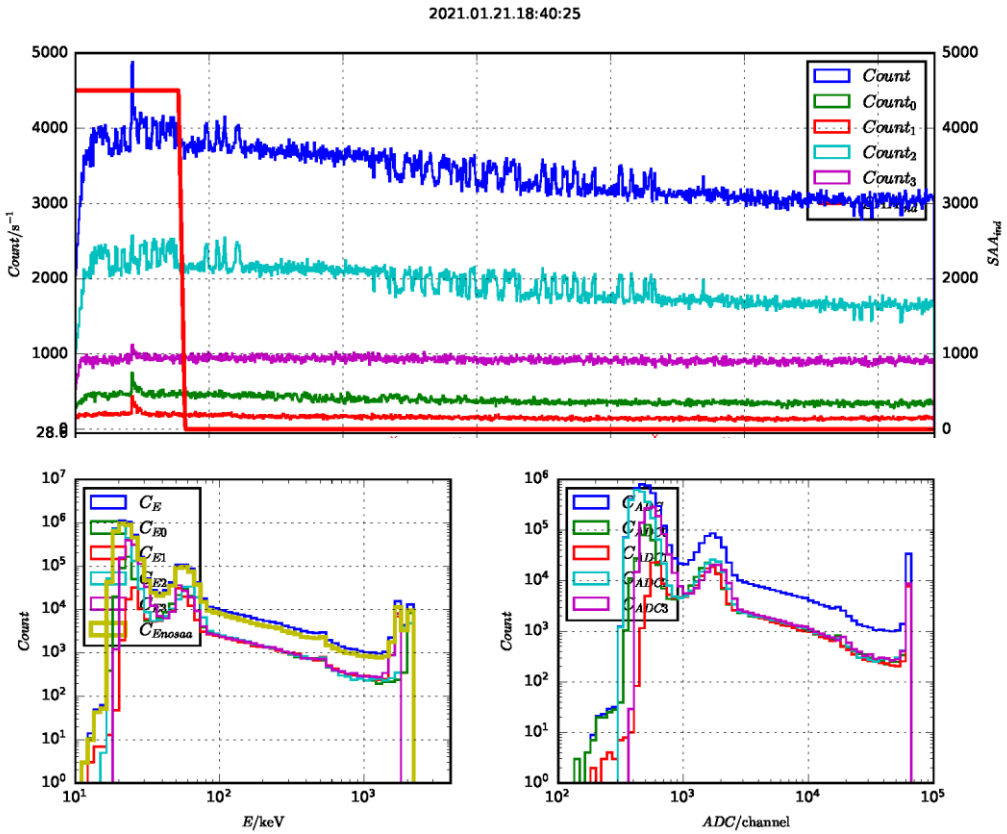
GRB 220408B



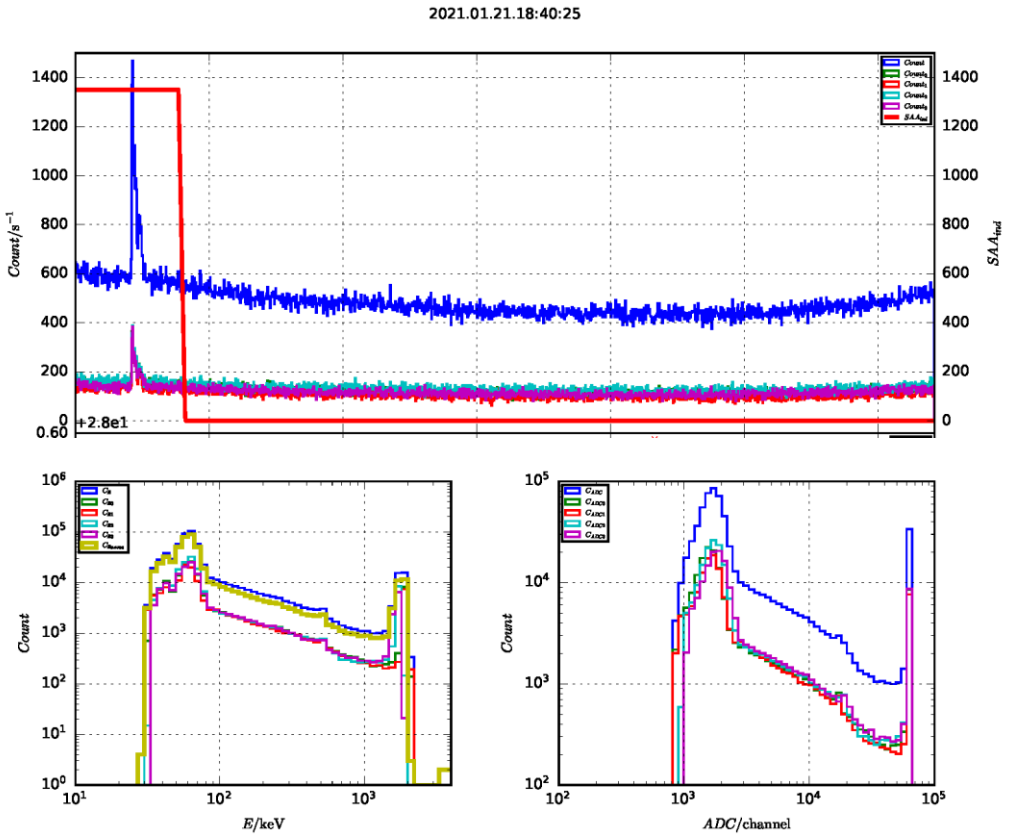
GRB 220408A

Draft paper available on arXiv 2205.10506

Example： GRB 210121A (GRID-02)



Raw Data

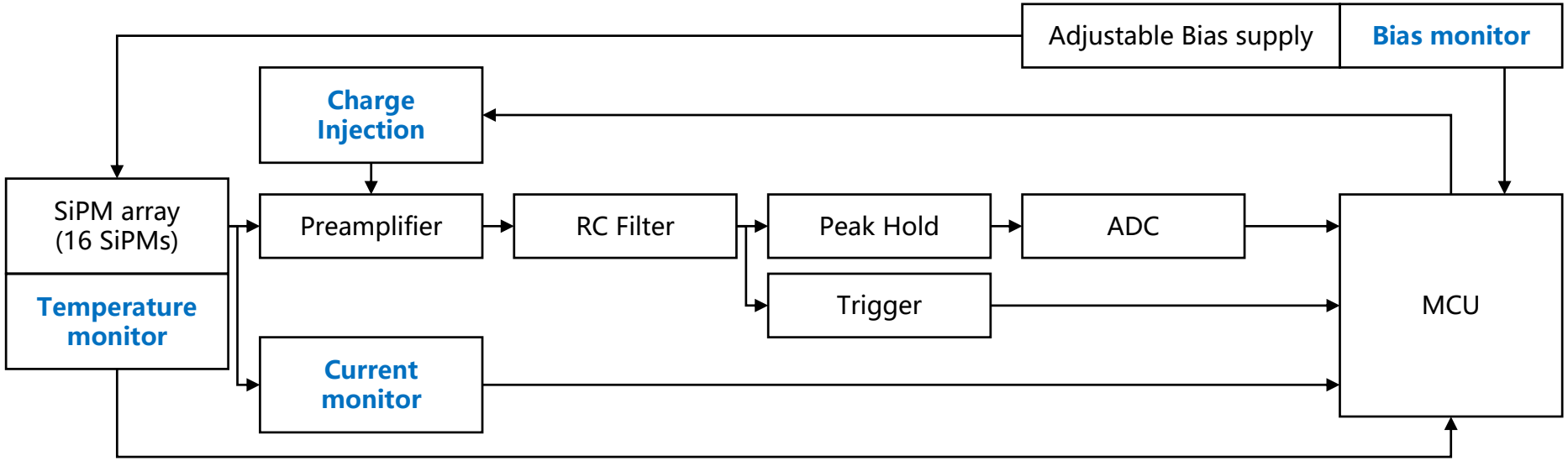


With dark count noise cut-off (6σ)

Draft paper available on arXiv (http://arxiv.org/abs/2205.10506)

In-orbit radiation damage characterization of SiPMs in GRID-02 CubeSat detector

In-orbit Characterization Setup and Methods



Housekeeping data:
- Timestamp
- Bias voltage
- Current
- Temperature

Block diagram of the front-end electronics and characterization circuits of one channel in GRID detector. Details about GRID instrument design can be found in [2].

Scientific observation: ~20k seconds (5 ~ 6 hours) per day
- Housekeeping data recorded to analyze SiPM dark current

Daily characterization experiments:
- I-V measurement at different bias voltage
- Charge injection test without and with bias voltage

[2] Wen, JX., Zheng, XT., Yu, JD. *et al.* Compact CubeSat Gamma-ray detector for GRID mission. *NUCL SCI TECH* **32,** 99 (2021)

Dark Current Increase

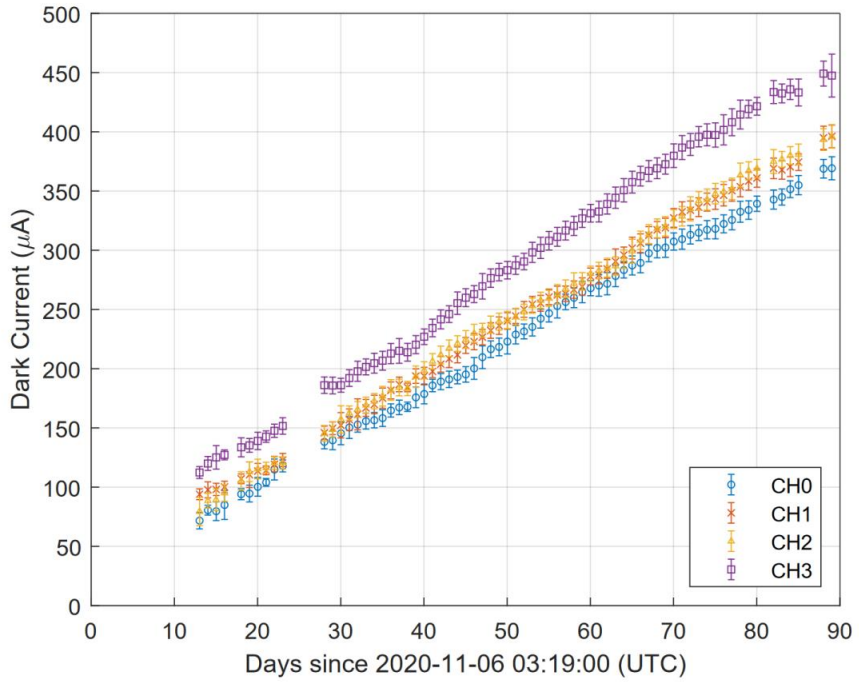


Figure 5: SiPM dark current (I_{dark}) at 28.5 V bias voltage as a function of time. are the sum of 16 SiPMs in the same channel and are unified to 5°C.

- Linear relationship between I_{dark} and radiation damage (dose or particle fluences) is found (model MicroFJ-60035-TSV):

GRID-02: ~ 93/96/98/110 μA / (year · chip) @5 ℃ & 28.5 V
~ 50 μA / (year · chip) @-20 ℃ & 28.5 V
SIRI-1: ~ 132 μA / (year · chip) @28.5 V, temp. not mentioned (22 ℃?) [4]

- An approximate empirical equation around room temperature:

$$I_{\mathrm{dark}}(\mu\mathrm{A}) = 16 \cdot (0.26 \cdot Time(\mathrm{Days}) + 1.96) \cdot e^{0.03428 \cdot (T - 273.15 - 5)}$$

- **with SHIELDOSE-2 model, SPENVIS calculates cumulative dose:**

$$I_{\mathrm{dark}}(\mu\mathrm{A}) = 16 \cdot (1.9 \cdot Dose(\mathrm{rad}) + 1.96) \cdot e^{0.03428 \cdot (T - 273.15 - 5)}$$

Table 3: Measured and estimated dark current increasing rate of SIRI-1 and GRID-04.

Mission	Operating temperature (°C)	Operating voltage (V)	Orbit	Dose in silicon (rad)	Dark current increasing rate per SiPM chip (μA/year)	
					Measured	Estimated
SIRI-1	7.75	28.5	567 × 589 km 97.7°	90	132	188
GRID-04	5	28.5	523 × 550 km 97.5°	90	182	171

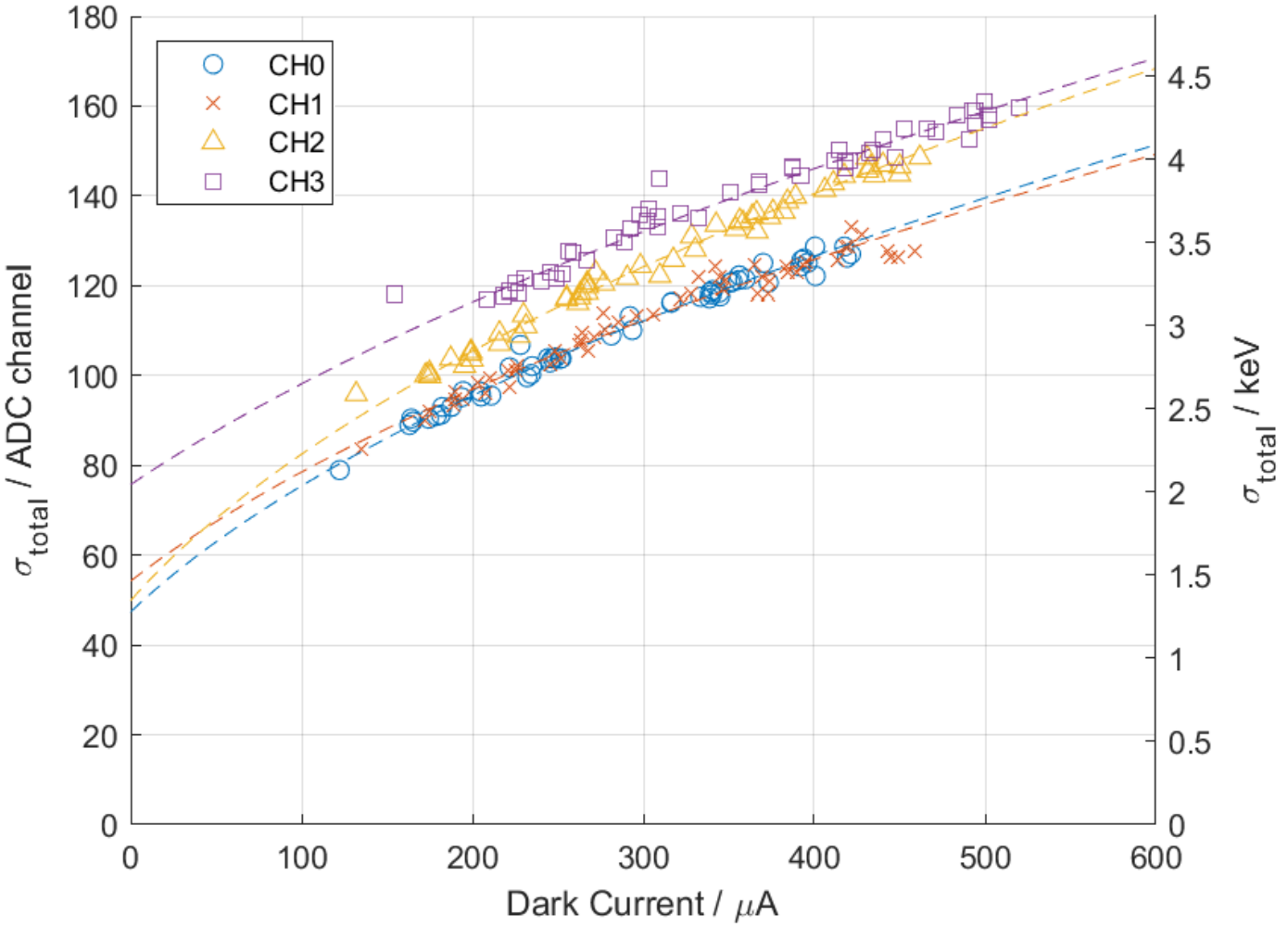
Noise Assessment Through Charge Injection

- Campbell's theorem gives

$$\sigma^2_{\text{dark current}} = DCR \cdot (Gain \cdot e)^2 \cdot \int h^2(t)\,\mathrm{d}t$$

$$\propto I_{\text{dark}} \cdot (V_{\text{bias}} - V_{\text{BD}})$$

GRID-02 energy-channel calibration result [3]



Noise (sigma) increasing rate: ~ 7.5 keV/year

[3] H. Gao, et al., GRID Collaboration, On-ground calibrations of the GRID-02 gamma-ray detector, Exp Astron. (2021).

Methods of Improve SNR

- Dominant noise for radiation damaged SiPM:

$$\sigma^2_{\text{dark current}} = DCR \cdot (Gain \cdot e)^2 \cdot \int h^2(t)\,\mathrm{d}t$$

① Lower temperature, lower DCR
- DCR reduced by half for 16℃ decrease at room temperature
- Difficult for CubeSats ?

② Lower bias voltage, lower DCR
- Trade off: Gain & PDE decrease as well
- Care must be taken to find the optimum value

③ Lower readout time constant
- Limited by scintillation decay time

Future Planning of GRID

- GRID-05B (Tsinghua Univ.)

  Prof. Ming ZENG & Hua FENG

- GRID-06B (Nanjing Univ. & Sichuan Univ.)

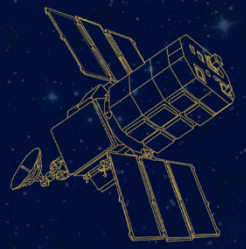
  Prof. Bin-bin ZHANG, Prof. Zhonghai WANG & Rong ZHOU

- GRID-07 (Beijing Normal Univ.)

  Prof. Lin LIN, Yuanyuan LIU, Jianyong JIANG

- GRID-08B (Nanjing Univ. & Sichuan Univ.)

  Prof. Bin-bin ZHANG, Prof. Zhonghai WANG & Rong ZHOU



Thank you !

StarDetect DAQ System architecture