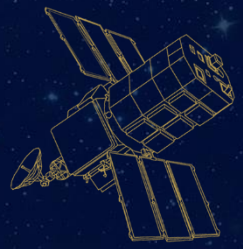


Educational experience with the GRID mission

Ming Zeng, Hua Feng, Zhi Zeng, Yang Tian, Benda Xu

on behalf of the GRID collaboration

Tsinghua University, Beijing, China

Monitoring the high-energy sky with small satellites

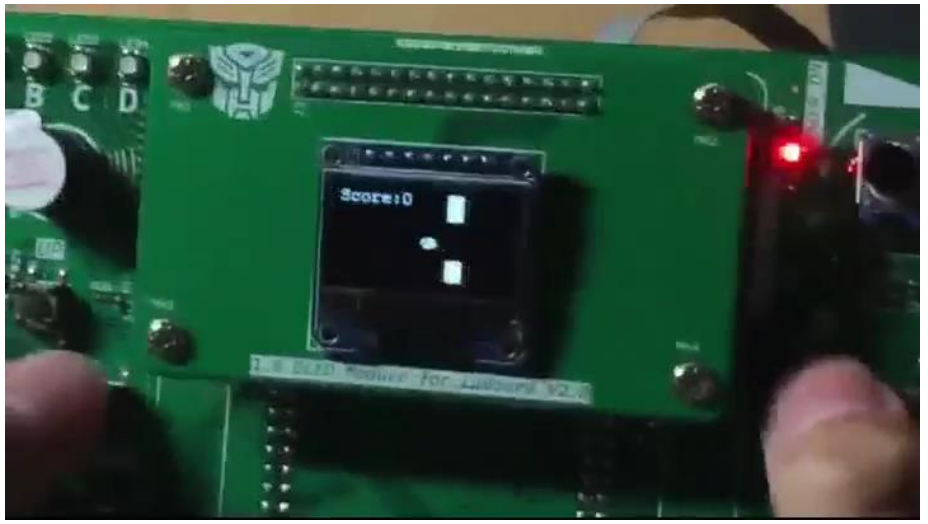
07 September 2022

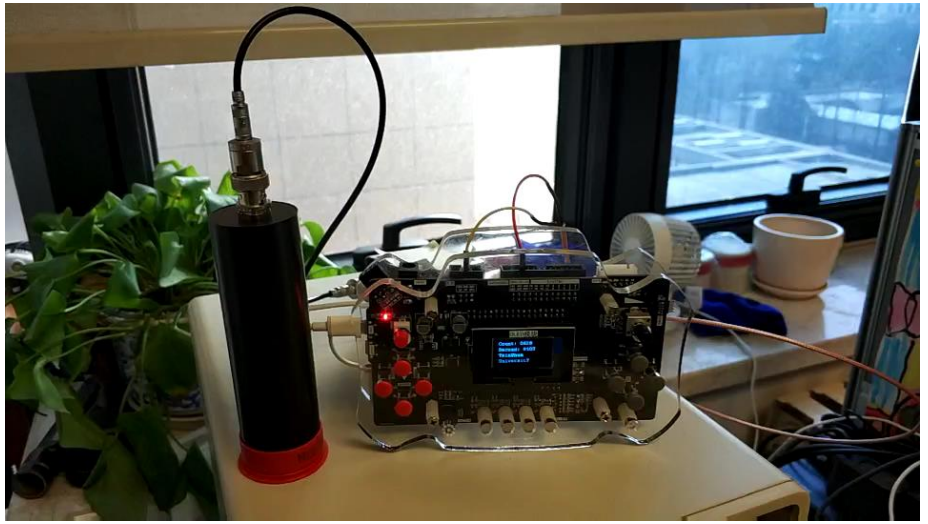
History of GRID since 2016

- The GRID concept was first proposed in October of 2016 by a group of undergraduate students, inspired by discussions with several professors.
- The first four detectors (GRID-01/02/03B/04) have been launched in Oct. 2018, Nov. 2020, and Feb. 2022, respectively.
- 25 universities and institutes in China have joined the GRID collaboration.

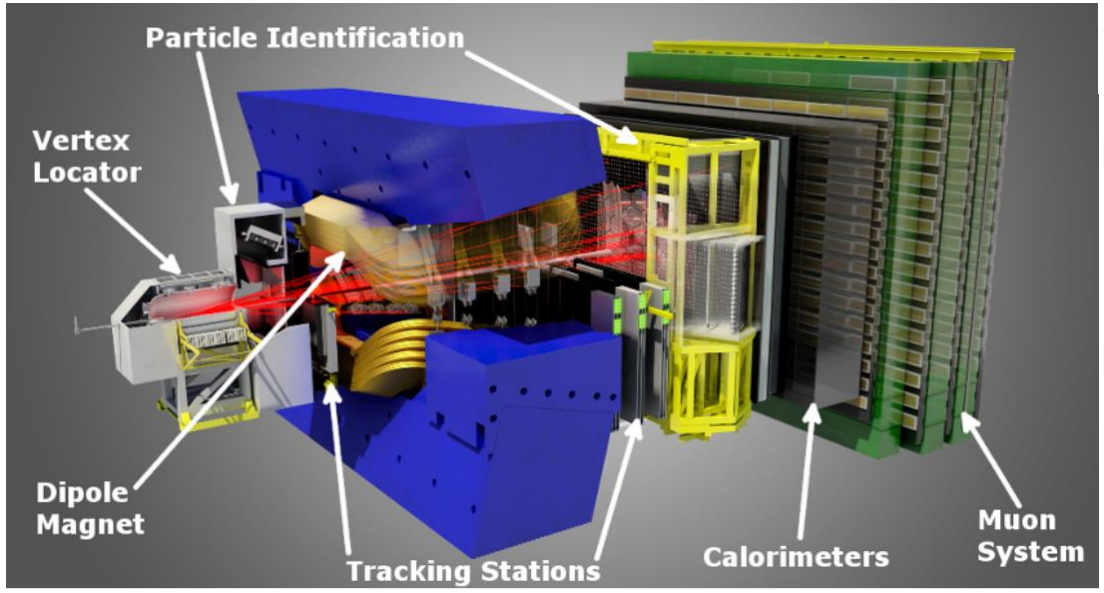
How to make it more attractive?

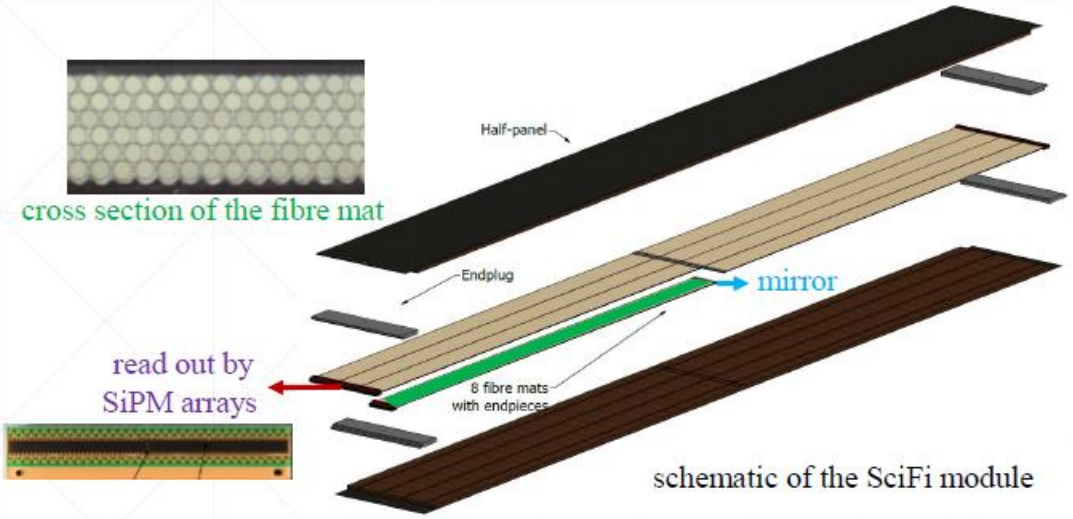
MOOCs

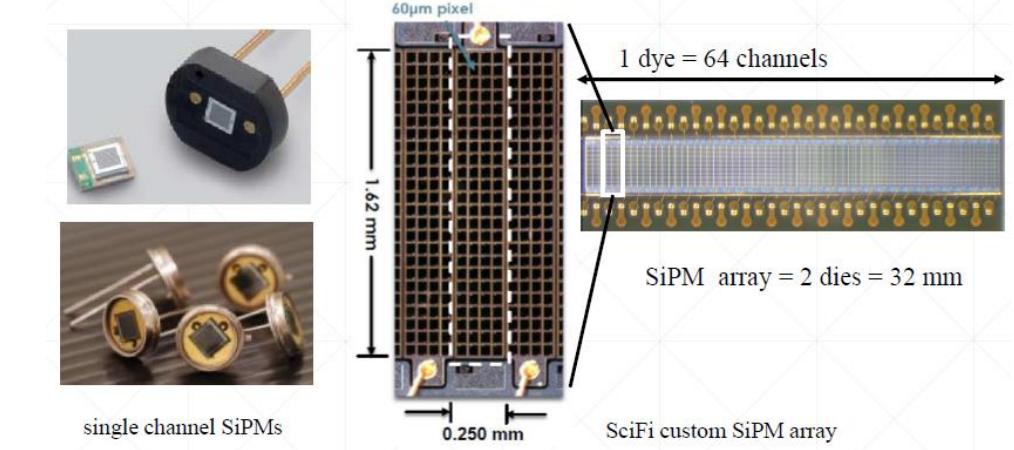




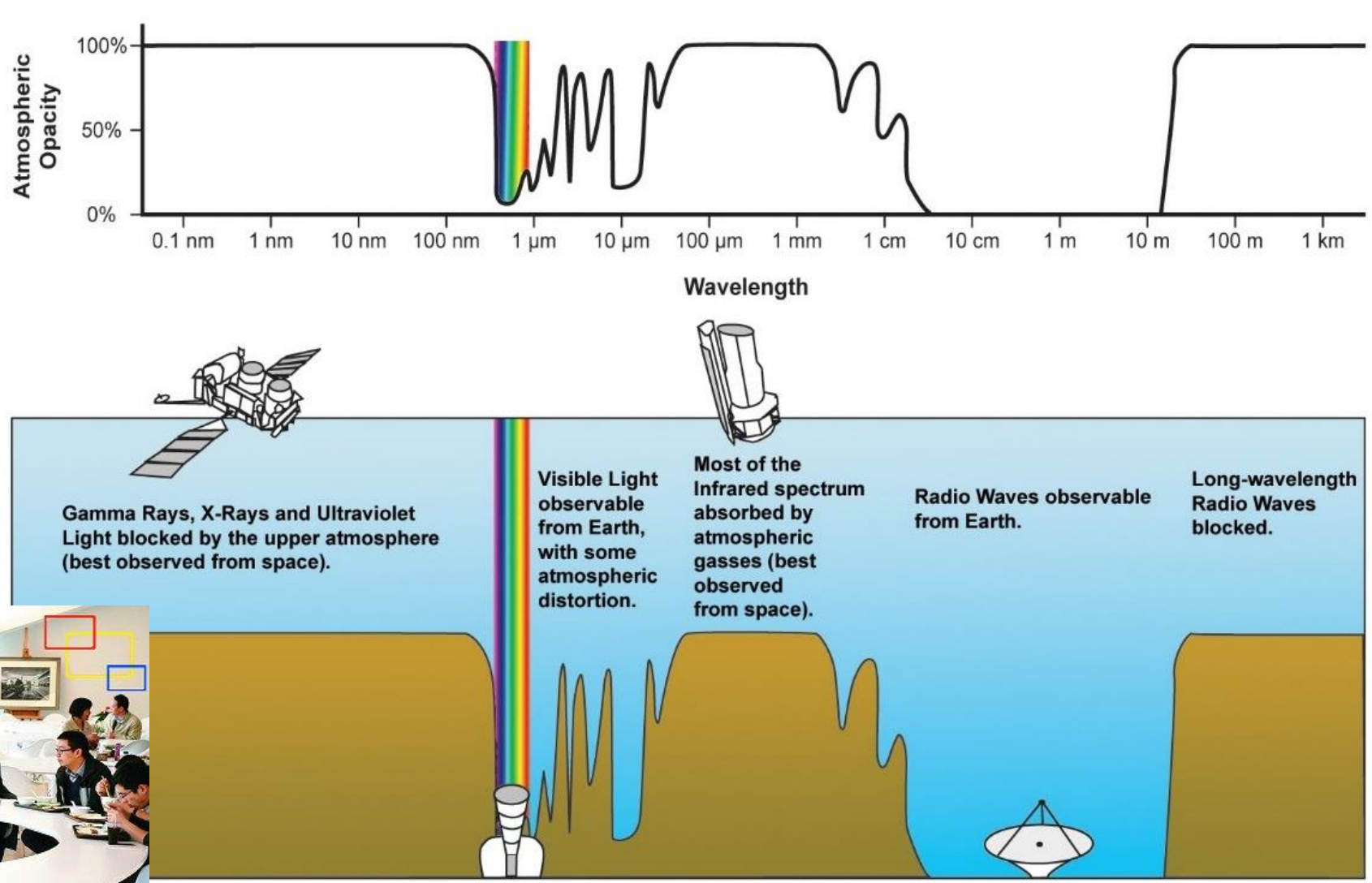
From courses to particle physics experiments







Comes from a discussion



Inspiration

Properties of the GRB	Scientific requirements	Technologies
Bright	Small detection area	Scintillator detector
Rare	All-sky coverage	Constellation - triangulation & flux modulation
Associated with GW events	Localization	
Atmospheric absorption	Space-borne	CubeSat payload

IDEA

- ✓ Radiation detector: course learned
- ✓ Embedded system and electronics: course learned
- ✓ CubeSat: commercial satellite platform, developing rapidly
- ✓ Practicable for students ☺

The student team

The 2016 student team

The 2020 student team

- The first generation of team members recruited by email, about 100 students, from 7 colleges. (Engineering Physics, Physics, Material, EE, Mechanical Engineering, Aerospace Engineering)
- Student team：System Group, Hardware Group, Calibration Group, Telemetry Group, Data Group, Science Group
- Graduated Student: Polarlight CubeSat, LZ dark matter, JUNA nuclear astrophysics, LHCb, EAST tokamak, Polar2 & GECAM ……

Seminars

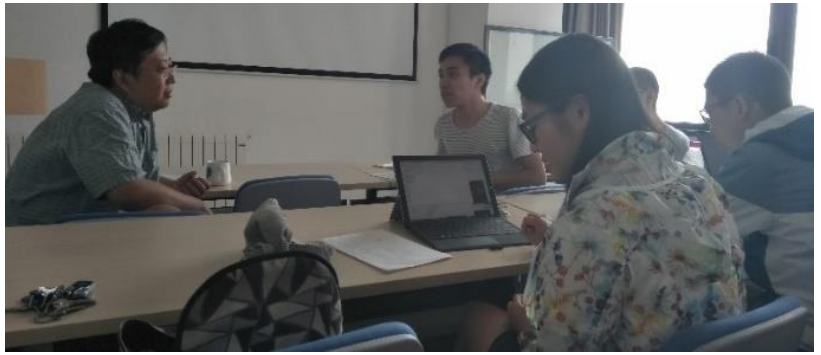
Lectures in 2016 ~ 2017 given by:

Shaolin XIONG, IHEP, PI of GECAM mission

Chen ZHANG, NAOC, PI assistant of Einstein Probe mission

Binbin ZHANG, NJU, GRB science

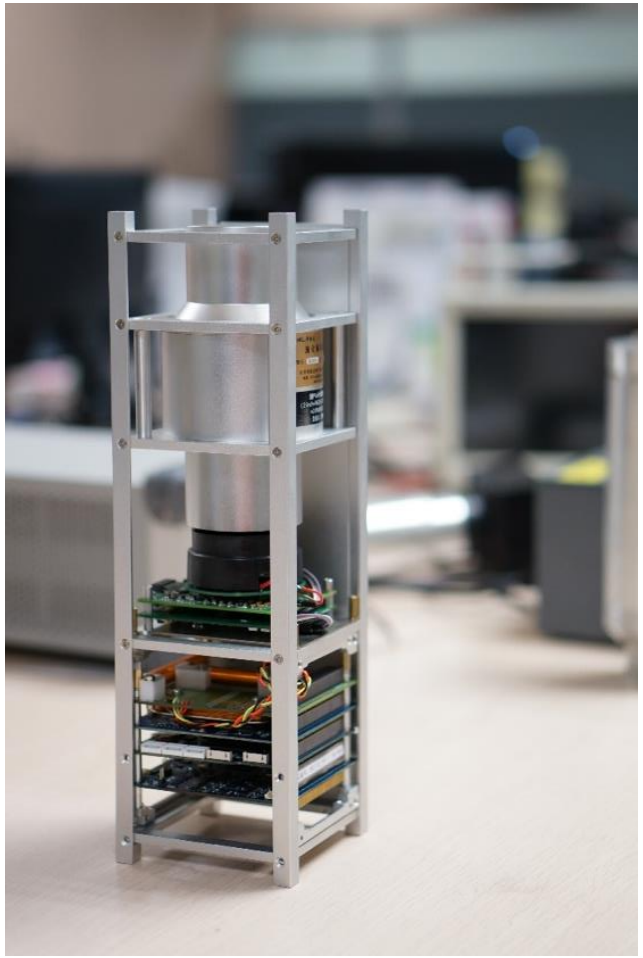
Ming ZENG, THU, particle detector and electronics



Discuss with Prof. Yanbei CHEN, Caltech
Gravitational wave detectors (e.g., LIGO)

Discuss with Prof. Enwei Liang, Guangxi University
GRB and Multi-messenger Astronomy

A draft of Scientific Reports and … 2017



After GW170817

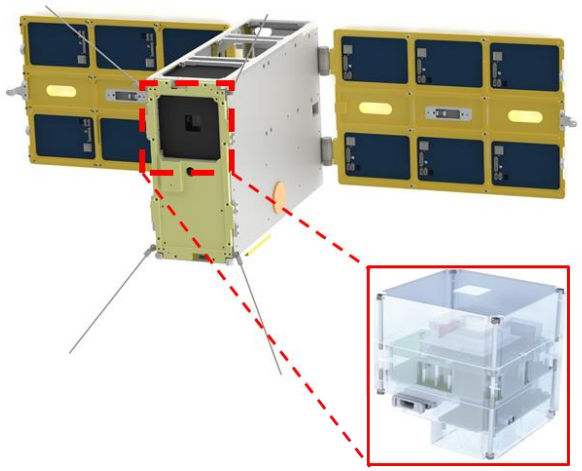
Reliability? Cost?
Scientific Value and Validity

Detector: 20 keV~2 MeV
Optimize performance

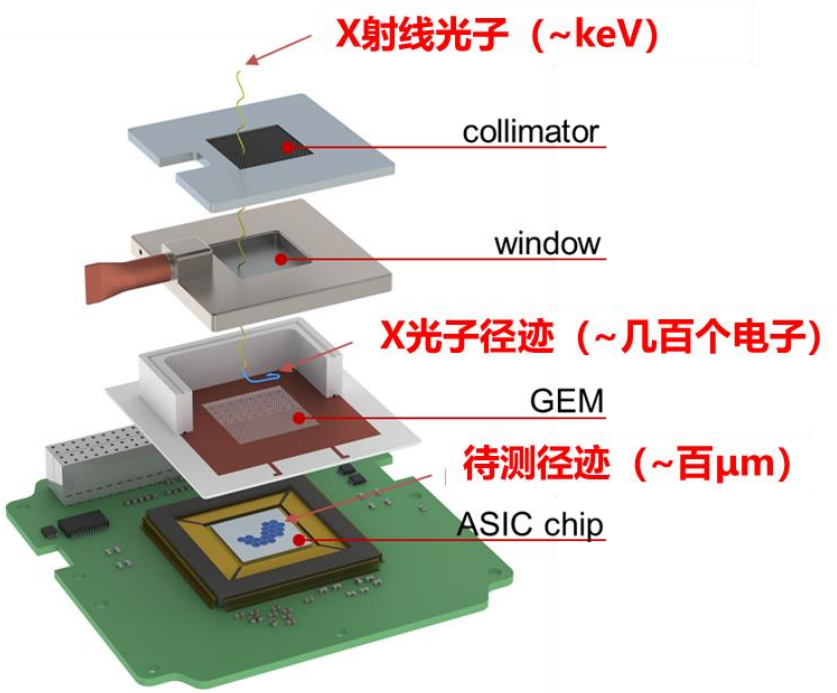
Electronics: reliable & integrated
Compress size

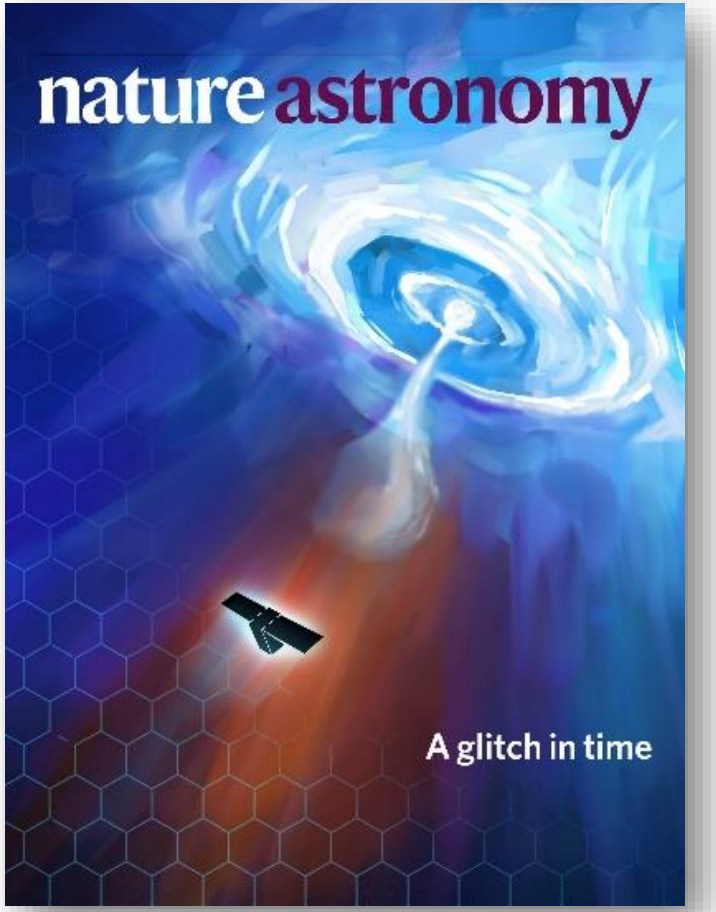
Volume: 0.5 U (10 cm×10 cm×5 cm)
palm-size

Polarlight - the X-ray polarimetry

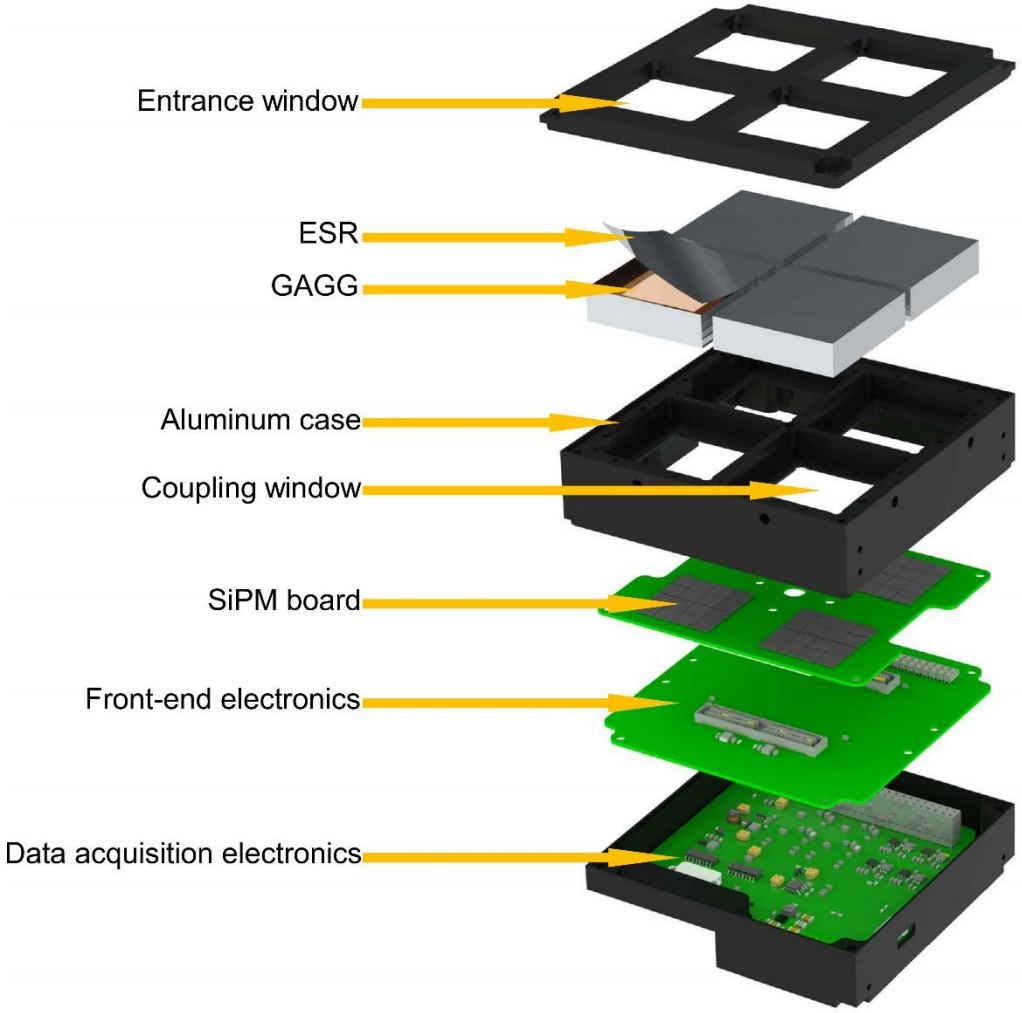


Polarlight





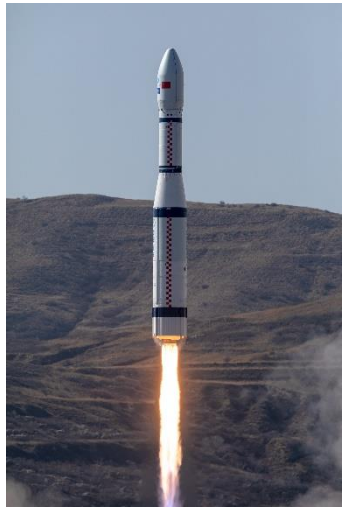
The GRID detector



Specifications of GRID-02

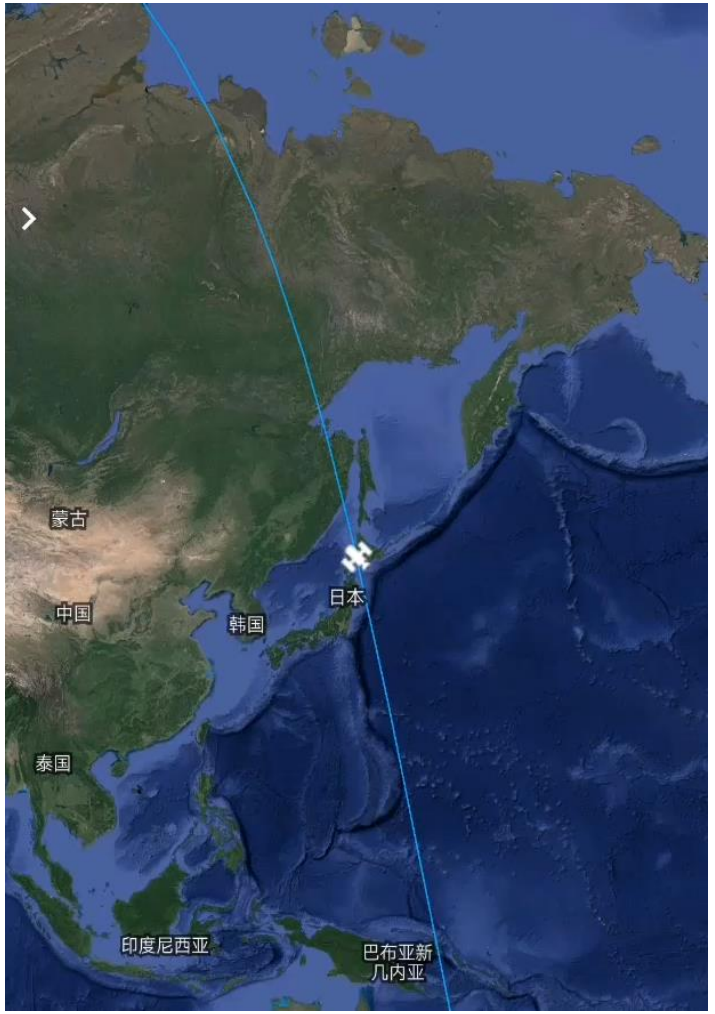
Size	< 0.5U (9.4×9.4×5 cm^3)
Weight	~ 780 g
Power consumption	Typ. 2 W Max. 2.8 W
Geometric area	~ 58 cm^2
Field of view	2π
Energy range	Lower threshold < 15 keV Upper threshold ~ 2 MeV
Dead time	~ 20 us
Background count rate	Norm. ~ 2000 cps SAA > 8000 cps
Telemetry	~ 1 GB/day

The GRID-01 & GRID-02

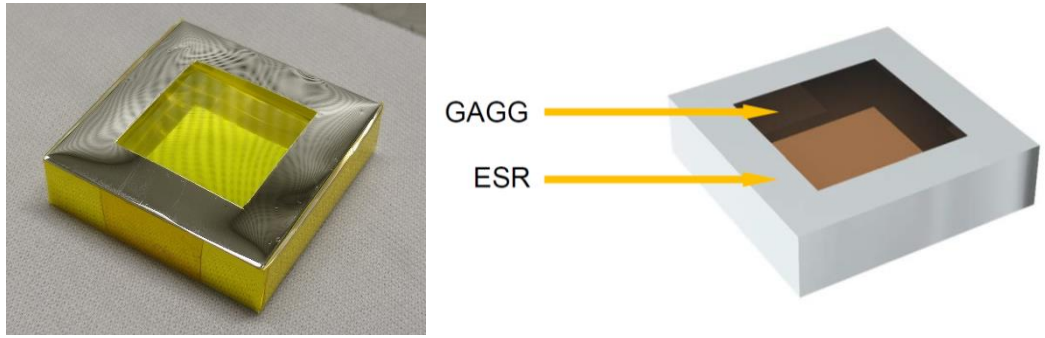


NORAD ID: 43663
Int'l Code: 2018-083B
Perigee: 511.9 km
Apogee: 528.7 km
Inclination: 97.5 °
Period: 94.9 minutes
Semi major axis: 6891 km
RCS: Unknown
Launch date: October 29, 2018
Source: People's Republic of China (PRC)
Launch site: Jiuquan Satellite Launch Center, China (JSC)

NORAD ID: 46838
Int'l Code: 2020-079M
Perigee: 471.1 km
Apogee: 481.2 km
Inclination: 97.3 °
Period: 94.0 minutes
Semi major axis: 6847 km
RCS: Unknown
Launch date: November 6, 2020
Source: People's Republic of China (PRC)
Launch site: Taiyaun Space Center, China (TSC)



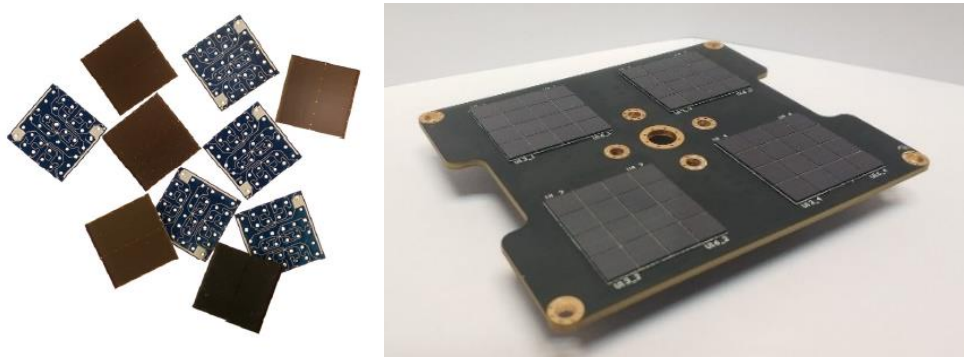
GAGG + SiPM



Bottom view of a GAGG:Ce scintillator with the ESR package

Crystal size	38×38×10 mm^3
Light yield	46000 ph/MeV
Density	6.63 g/cm^3
Effective Z	54
Energy resolution	6% @662 keV
Hygroscopic	No

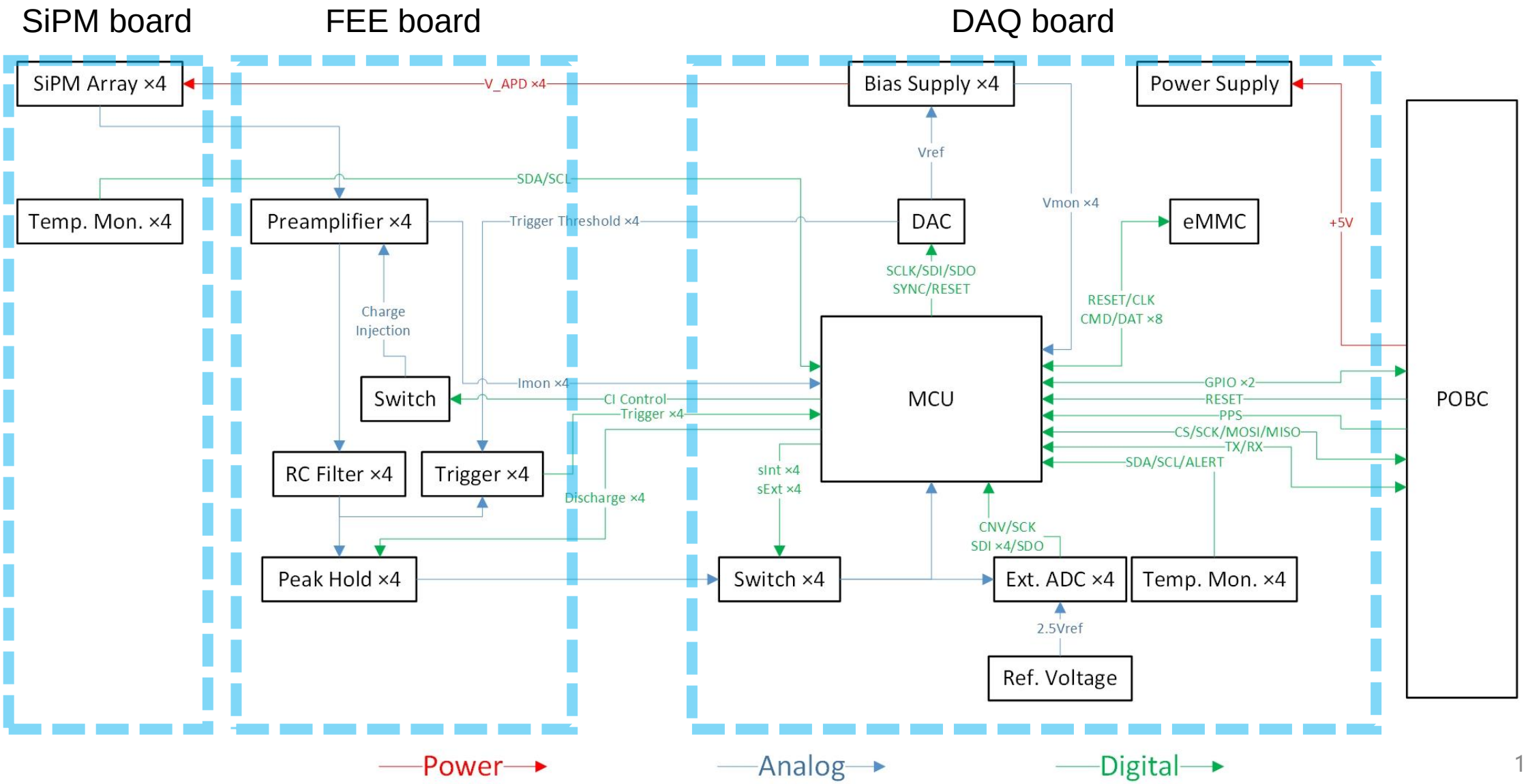
Values from C&A Corporation



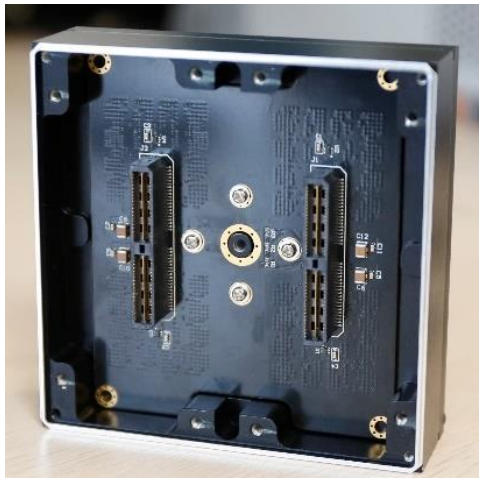
SensL MicroFJ-60035 SiPM chip (left) and the GRID SiPM array board (right)

Operation voltage **(No H.V. needed)**	~ 30 V
Photon detection efficiency	> 25%
Dark count rate	~ 150 kHz/mm^2
Temperature dependence of V_{br}	21.5 mV/℃

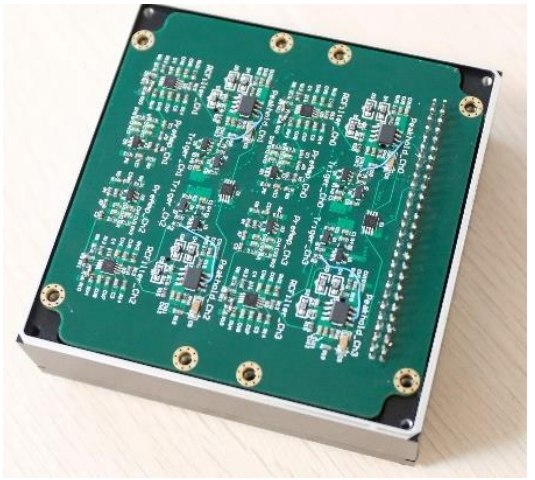
Functional block diagram of DAQ



The electronics



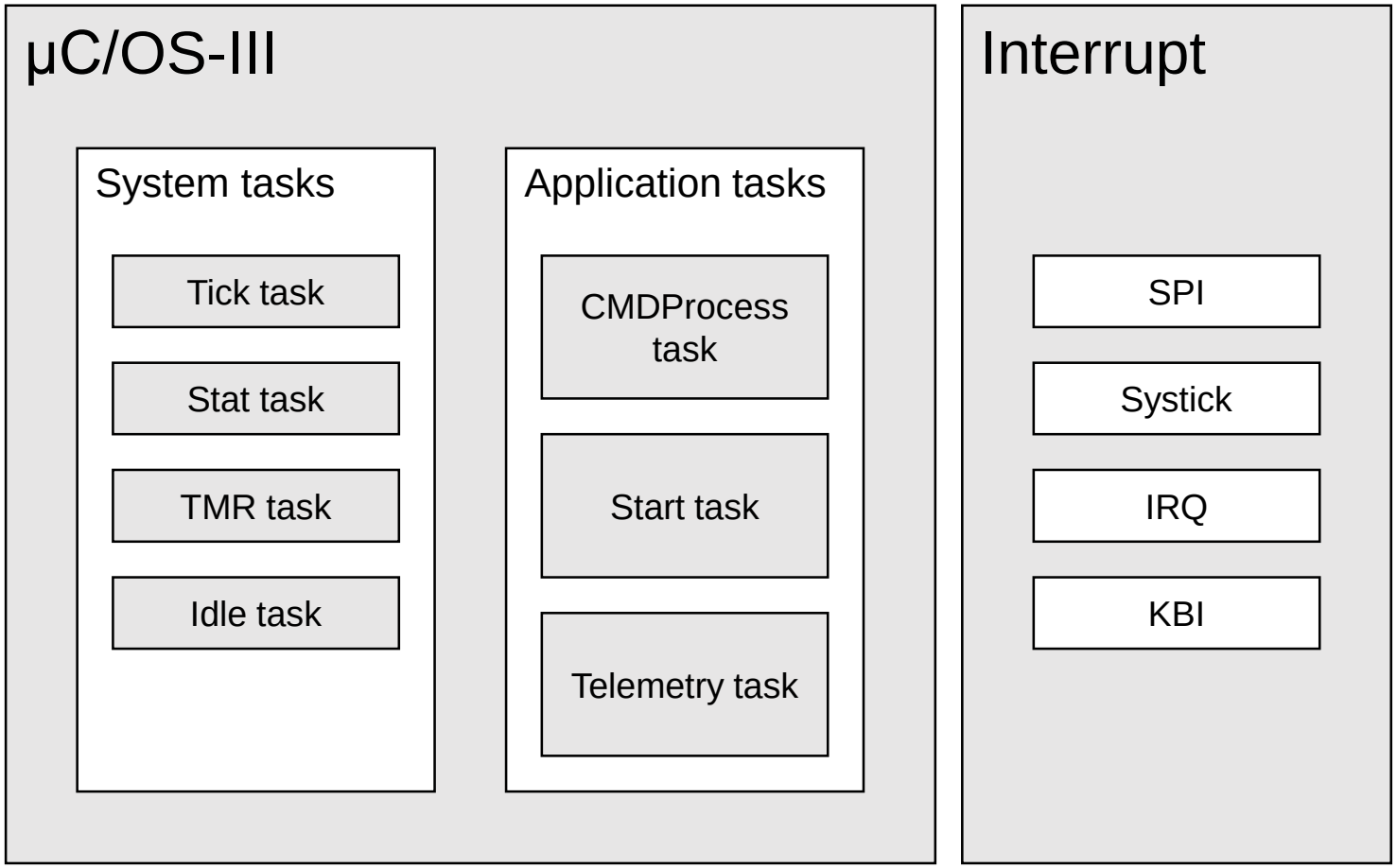
SiPM Array



Front-end electronics (FEE)

Back-end electronics (BEE) & Control electronics (CE)

Firmware based on uC/OS-III

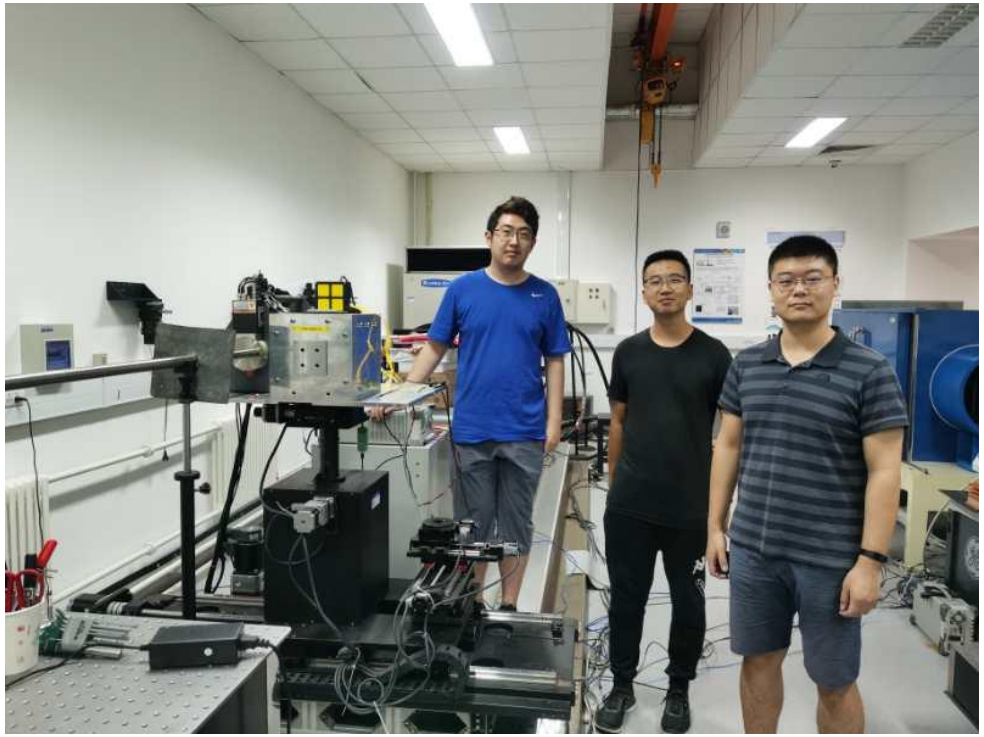


µC/OS™ RTOS and Stacks

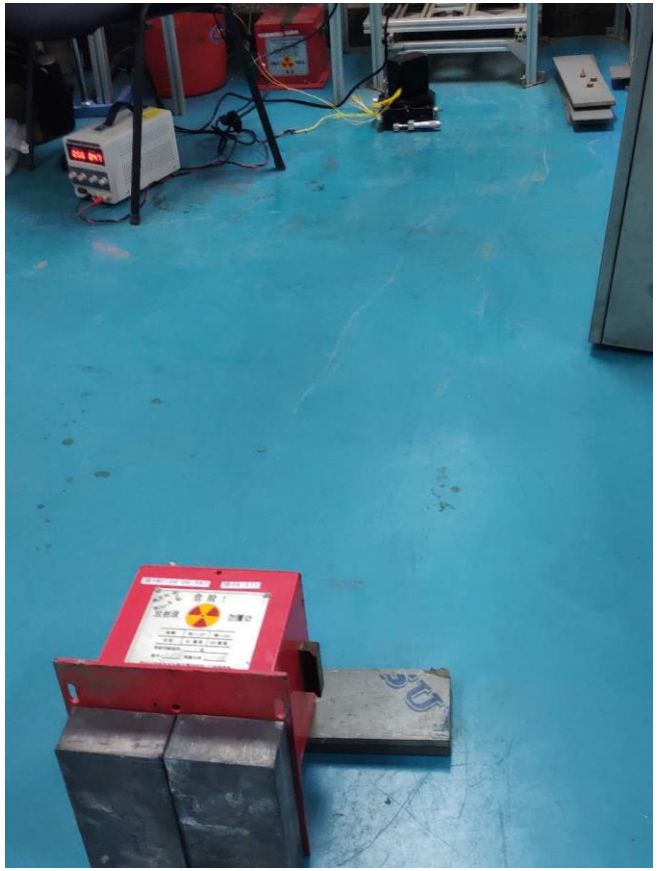
Real-Time Kernels: µC/OS-II and µC/OS-III

µC/OS-II and µC/OS-III are preemptive, highly portable, and scalable real-time kernels. Designed for ease of use on a huge number of CPU architectures, these kernels are a key component of the µC/OS real-time operating system.

Calibration

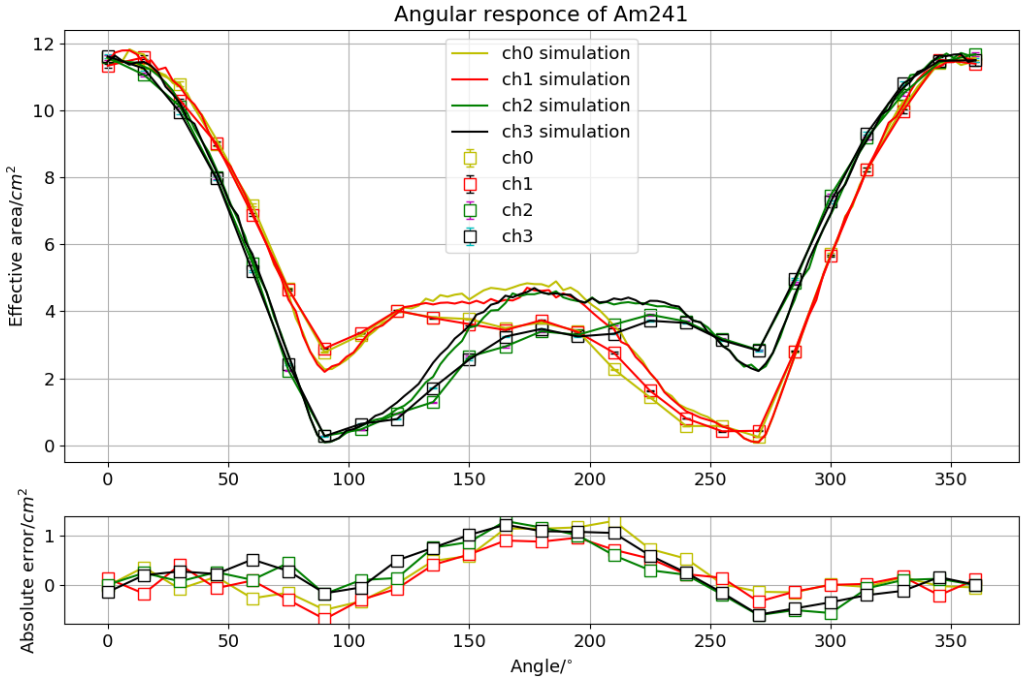


X-ray beam test

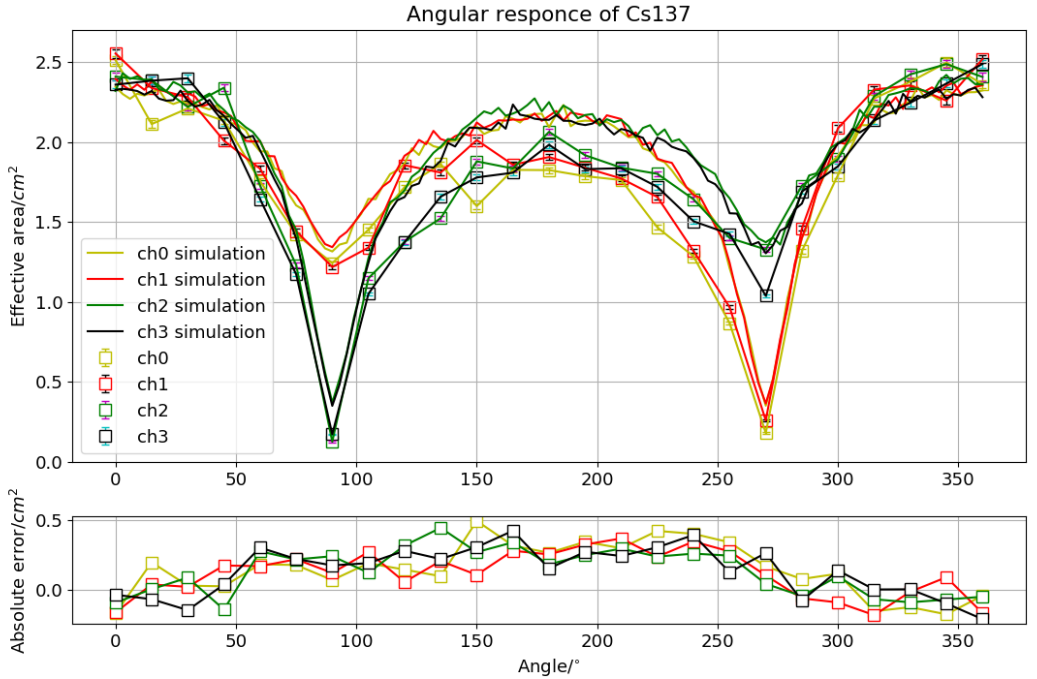


Angular response experiment

Calibration



Angular response - Am-241

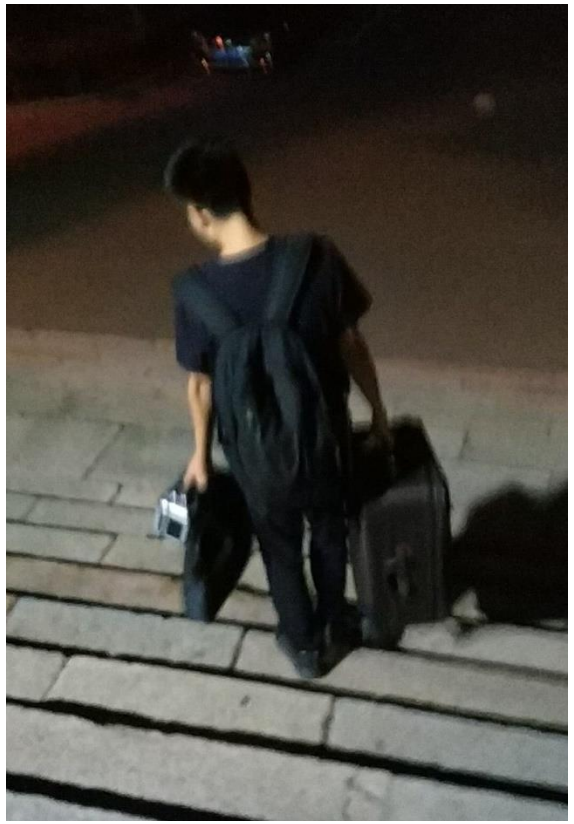


Angular response - Cs-137

Development

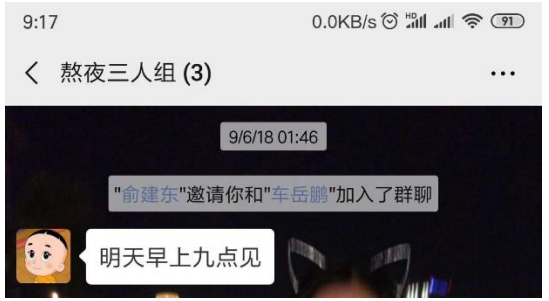
- GRID_DAQBoard
- GRID_DAQBoard_20180225
- GRID_DAQBoard_20180324
- GRID_DAQBoard_20180524
- GRID_DAQBoard_20180717
- 多道
- 立方星2号电路板
- 立方星2号电路板-5四通道-ADC、PD
- 立方星2号电路板-20170826
- 立方星2号电路板-20170830
- 立方星2号电路板-20170831
- 立方星2号电路板-20170903
- 立方星2号电路板-20170908
- 立方星MCA板（地面调试版） - 副本
- 立方星MCA板（地面调试版）无盲孔

Tens of iterations



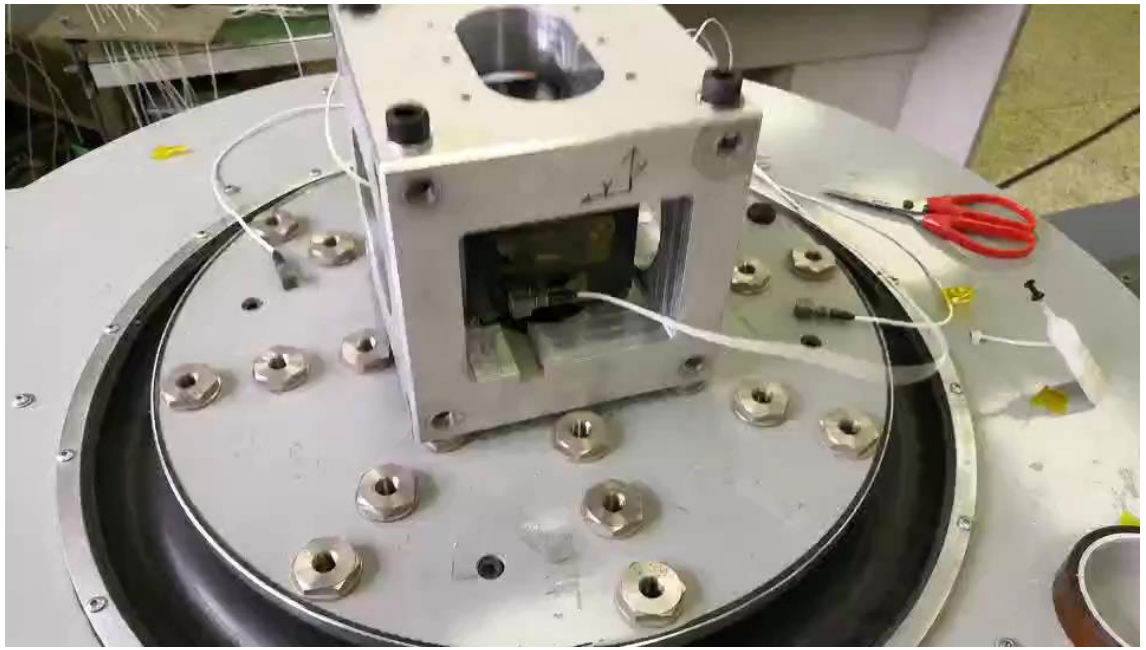
2018/9/13 1:05 a.m.
Outside the department hall

A weekend in 2017
Meeting in the corridor

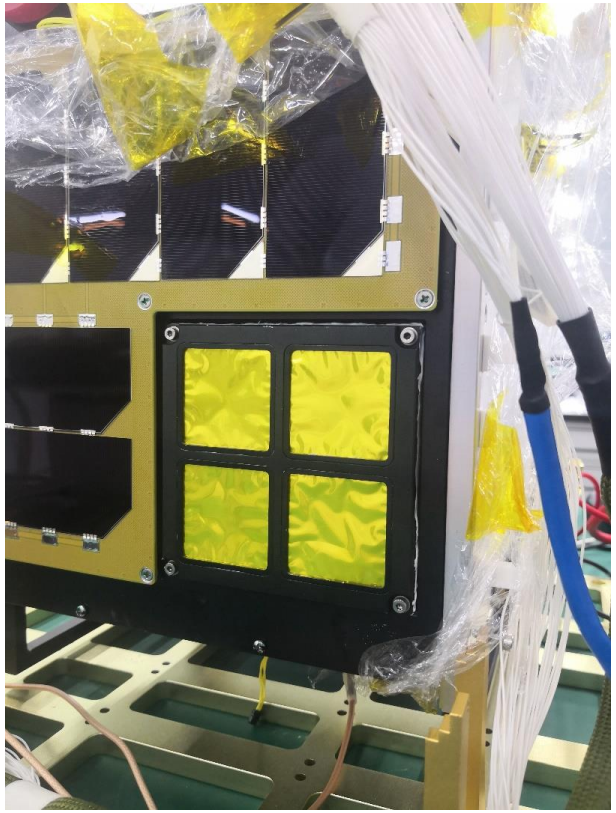


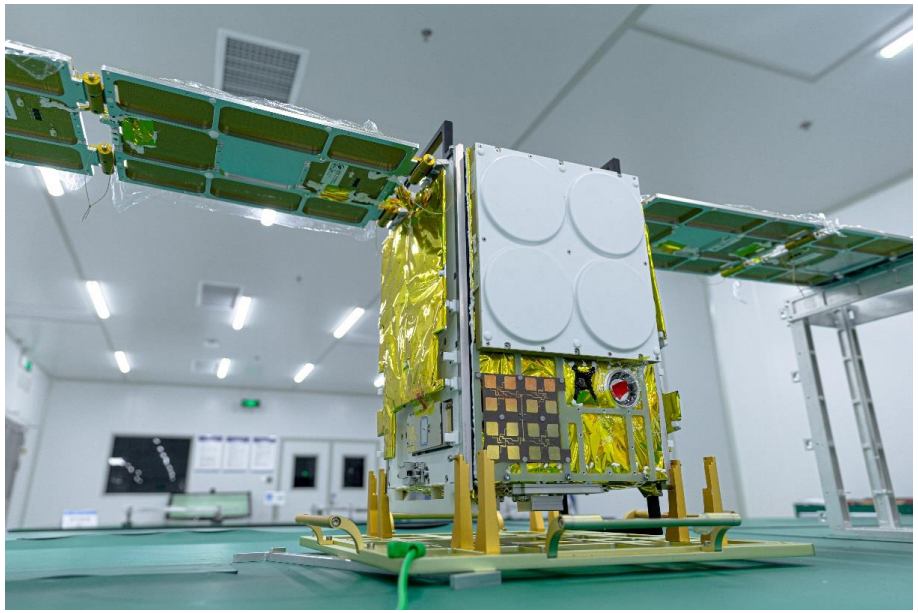
2018/9/6 1:46 a.m.

Shock test and Vibration test



The GRID-02 flight model



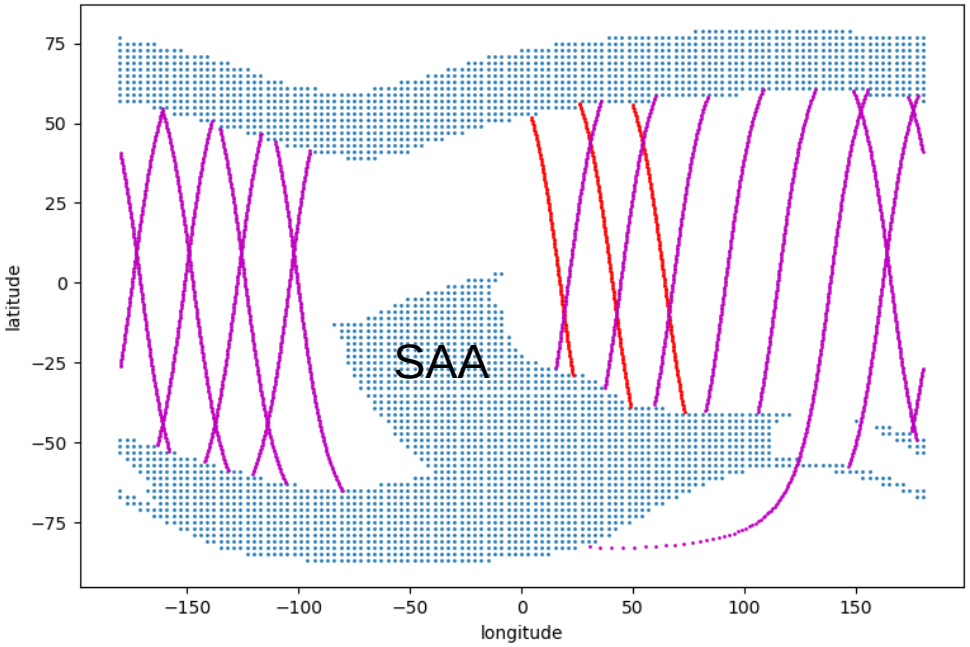


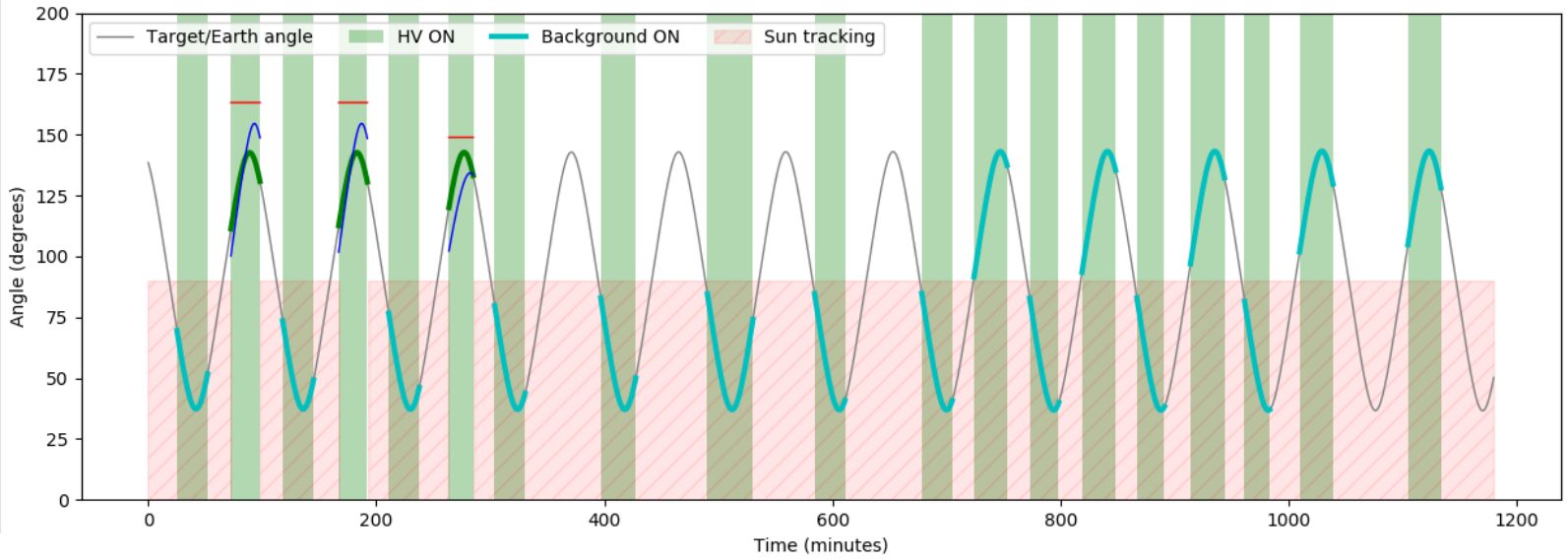
Scientific observation

- Undergraduate students on duty make observation plan every day
- 10 ~ 20 observations per day, 20 ~ 40 minutes each (depends on other payloads and CubeSat platform)
- Shutdown in South Atlantic Anomaly (SAA) and high-latitude region

✓ Targeting observation: point to Crab (Inertial pointing mode)

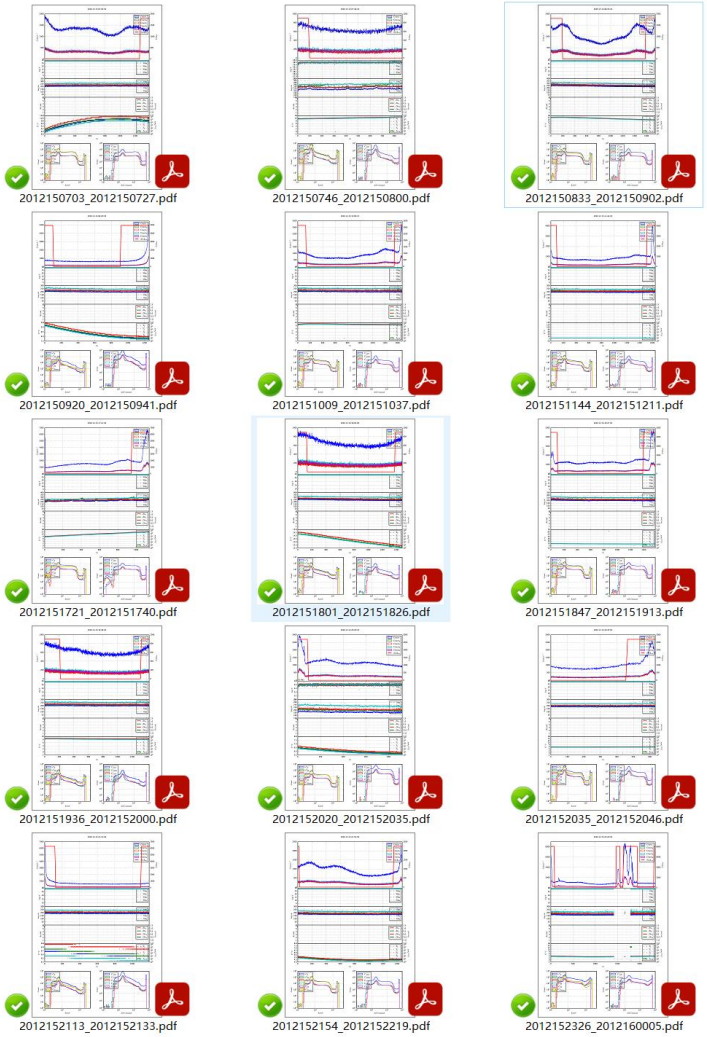
✓ Non-targeting observation: random orientation (Inertial or magnetic sun tracking mode)

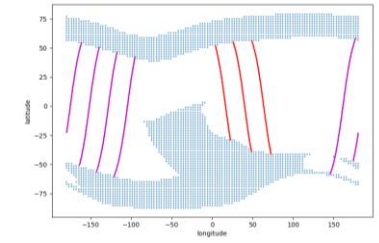


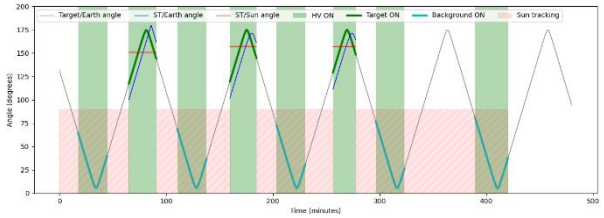


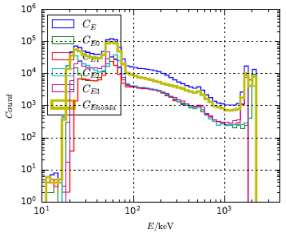
Example observation plan during Nov. 29 2020 17:00 ~ Nov. 30 2020 12:30 (UTC)

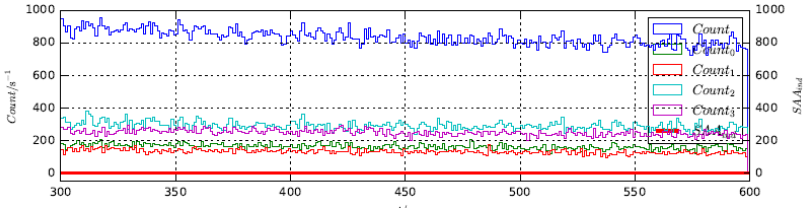
Scientific observation

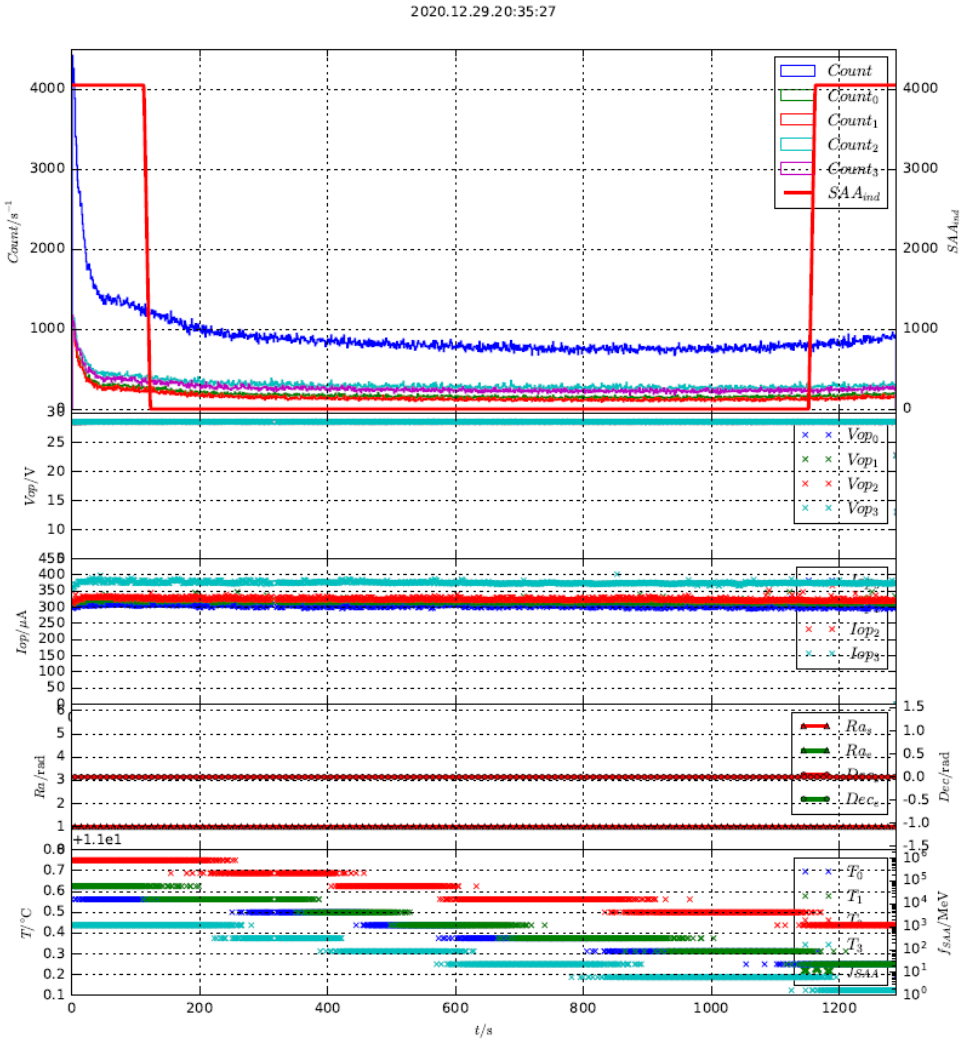












Open hardware and data


【证书号 第 QGX2021001 号】

科学数据汇交凭证

项 目 名 称："天格计划"二号卫星空间伽马射线暴探测数据研制

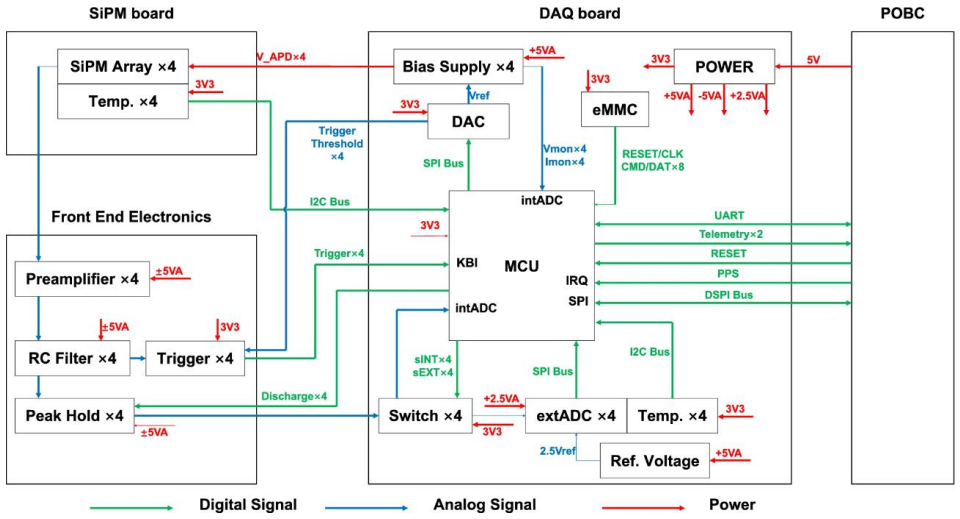
项 目 编 号：2020702001

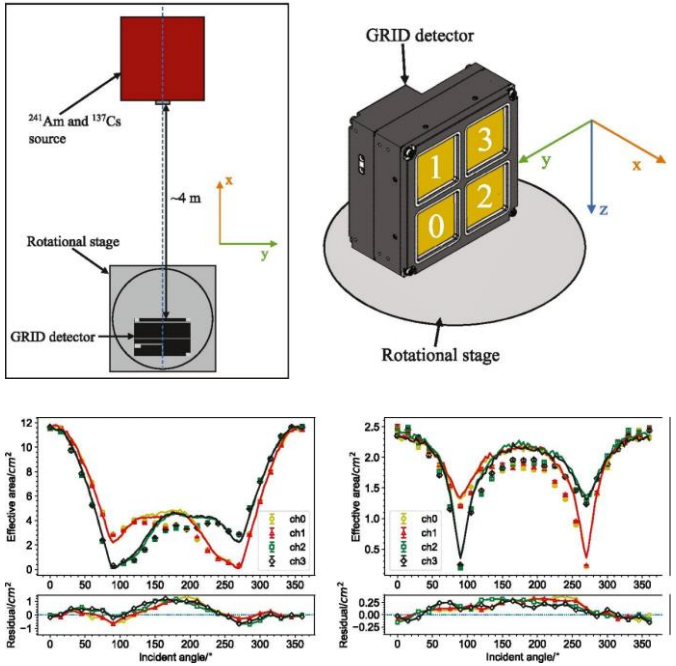
所属计划（专项）：清华大学大学生学术研究创造计划

项目牵头单位：清华大学

经国家空间科学数据中心审核，项目汇交"天格计划"二号卫星探测产生的科学数据集6个，数据质量符合科学数据管理汇交要求；该数据按国家空间科学数据中心收录，依据相关数据政策向科学界开放共享。

主任 郭自明





The first paper published by students

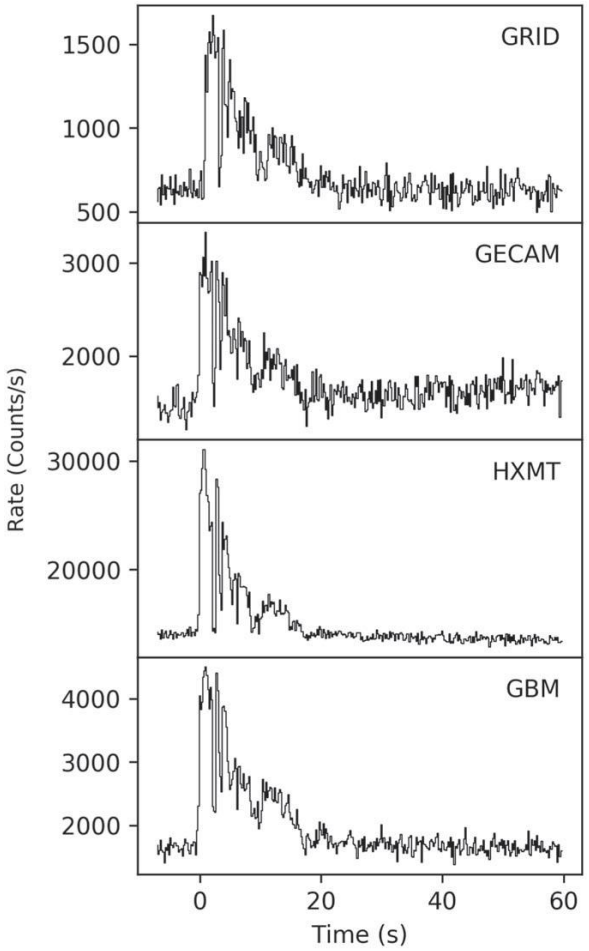
GRID: a Student Project to Monitor the Transient Gamma-Ray Sky in the Multi-Messenger Astronomy Era

Jiaxing Wen, Xiangyun Long, Xutao Zheng, Yu An, Zhengyang Cai, Jirong Cang, Yuepeng Che, Changyu Chen, Liangjun Chen, Qianjun Chen, Ziyun Chen, Yingjie Cheng, Litao Deng, Wei Deng, Wenqing Ding, Hangci Du, Lian Duan, Quan Gan, Tai Gao, Zhiying Gao, Wenbin Han, Yiying Han, Xinbo He, Xinhao He, Long Hou, Fan Hu, Junling Hu, Bo Huang, Dongyang Huang, Xuefeng Huang, Shihai Jia, Yuchen Jiang, Yifei Jin, Ke Li, Siyao Li, Yurong Li, Jianwei Liang, Yuanyuan Liang, Wei Lin, Chang Liu, Gang Liu, Mengyuan Liu, Rui Liu, Tianyu Liu, Wanqiang Liu, Di'an Lu, Peiyibin Lu, Zhiyong Lu, Xiyu Luo, Sizheng Ma, Yuanhang Ma, Xiaoqing Mao, Yanshan Mo, Qiyuan Nie, Shuiyin Qu, Xiaolong Shan, Gengyuan Shi, Weiming Song, Zhigang Sun, Xuelin Tan, Songsong Tang, Mingrui Tao, Boqin Wang, Yue Wang, Zhiang Wang, Qiaoya Wu, Xuanyi Wu, Yuehan Xia, Hengyuan Xiao, Wenjin Xie, Dacheng Xu, Rui Xu, Weili Xu, Longbiao Yan, Shengyu Yan, Dongxin Yang, Hang Yang, Haoguang Yang, Yi-Si Yang, Yifan Yang, Lei Yao, Huan Yu, Yangyi Yu, Aiqiang Zhang, Bingtao Zhang, Lixuan Zhang, Maoxing Zhang, Shen Zhang, Tianliang Zhang, Yuchong Zhang, Qianru Zhao, Ruining Zhao, Shiyu Zheng, Xiaolong Zhou, Runyu Zhu, Yu Zou, Peng An, Yifu Cai, Hongbing Chen, Zigao Dai , Yizhong Fan, Changqing Feng, Hua Feng, He Gao, Liang Huang, Mingming Kang, Lixin Li, Zhuo Li, Enwei Liang, Lin Lin, Qianqian Lin, Congzhan Liu, Hongbang Liu, Xuewen Liu, Yinong Liu, Xiang Lu, Shude Mao, Rongfeng Shen, Jing Shu, Meng Su, Hui Sun, Pak-Hin Tam, Chi-Pui Tang, Yang Tian, Fayin Wang, Jianjun Wang, Wei Wang, Zhonghai Wang, Jianfeng Wu, Xuefeng Wu, Shaolin Xiong, Can Xu, Jiandong Yu, Wenfei Yu, Yunwei Yu, Ming Zeng, Zhi Zeng, Bin-Bin Zhang, Bing Zhang, Zongqing Zhao, Rong Zhou, Zonghong Zhu (collapse list)

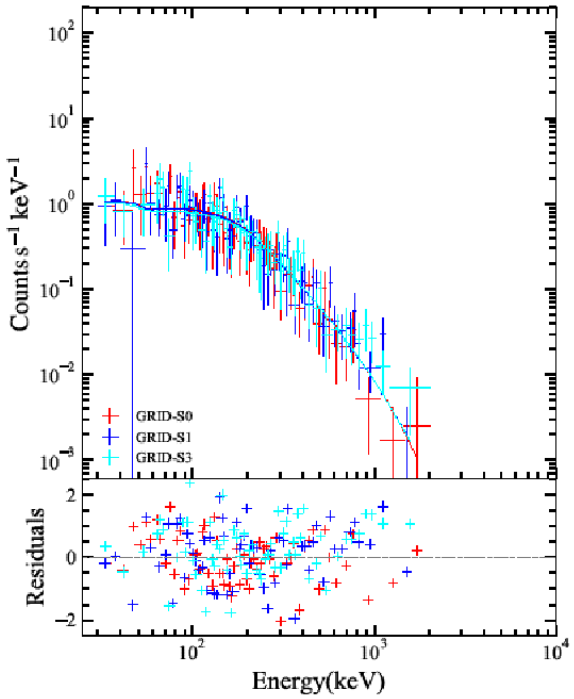
(Submitted on 16 Jul 2019)

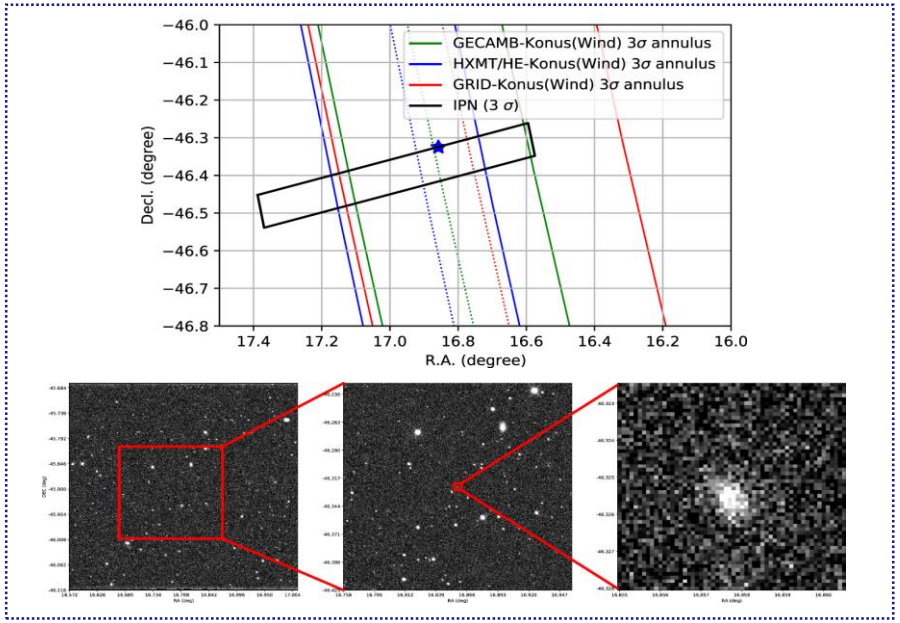
96 students from 12 universities, most undergraduates

GRB 210121A: GRID-02 detection



Light curves of the four missions





The joint localization of GRB 210121A

The GRID Collaboration

The 1st and 2nd GRID collaboration meeting

- Started since October 2016 at Tsinghua
- More than 150 Students from 17 universities have joined the GRID collaboration by now
- GRID Summer Camp since 2020
- Open Data access

Open source framework

✓ Fixed design

✓ Open hardware to member institutes

✓ Member institutes can build their own detector/ground station/satellite

The GRID Collaboration

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

Large scientific facilities

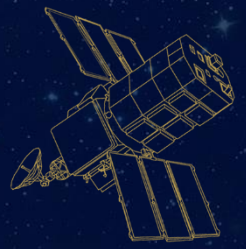
FAST

Insight-HXMT

eXTP

Conclusion

- GRID is a CubeSat mission proposed and developed by student team, with considerable contribution from undergraduate students.
- Besides GRID’s scientific goals, we hope to attract excellent students from different disciplines into astrophysics and train them, not only how to develop instruments, but also how to lead and organize an multi-discipline collaboration.
- Multidisciplinary students with teamwork together has shown extraordinary enthusiasm and execution, and successfully get crossed the gap between course knowledge to practical application.
- The students experience a real scientific project and the pressure from a space mission. "hard core“, Painful and happy, fruitful and worth remembering…
- GRID Collaboration with open hardware, open data and joint supervision.

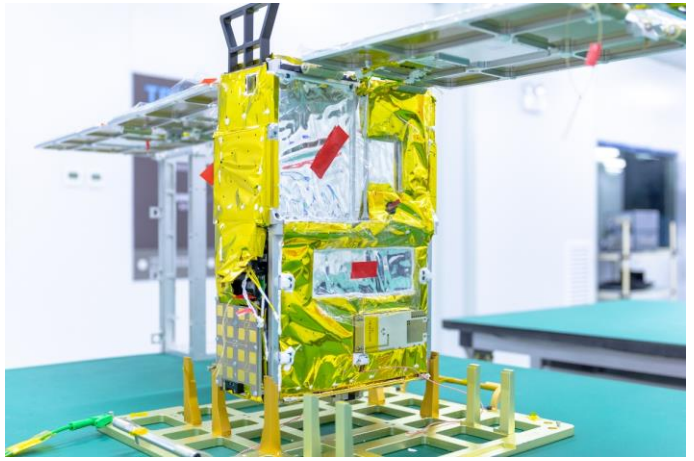


Thank you !

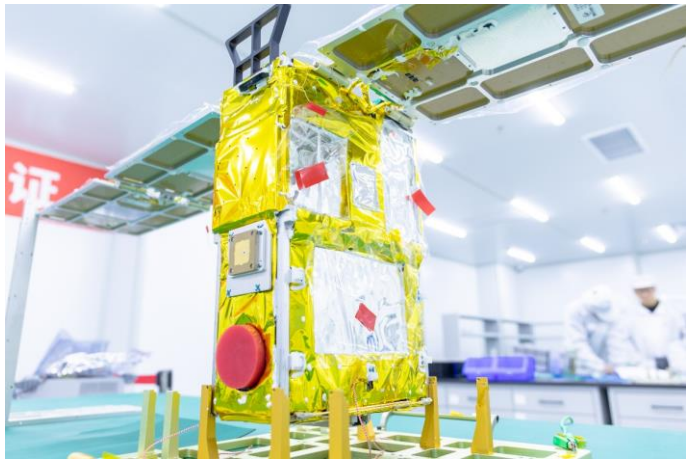
Welcome to join us. ☺

Update about the GRID-03B & GRID-04

Catalog number: 51830
Launched 02/27/2022

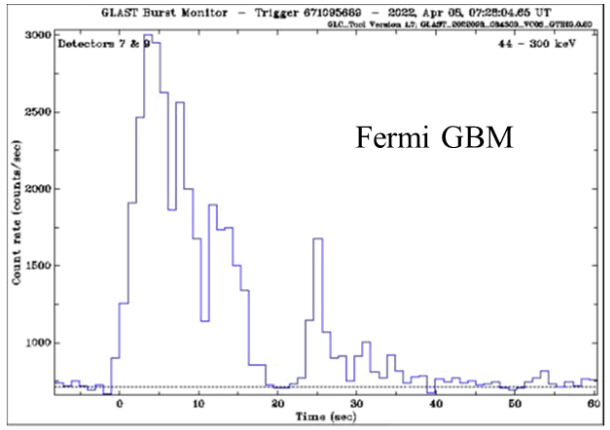


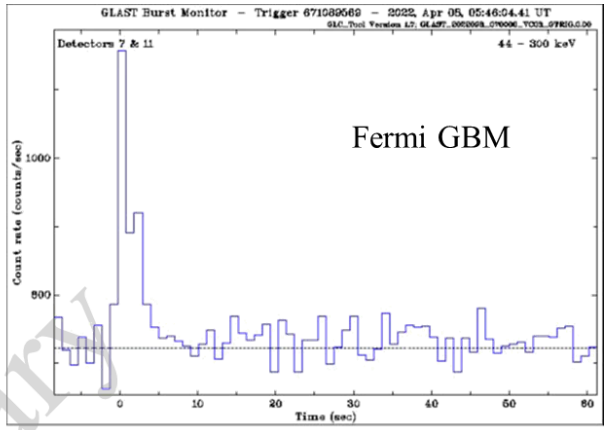
GRID-03B

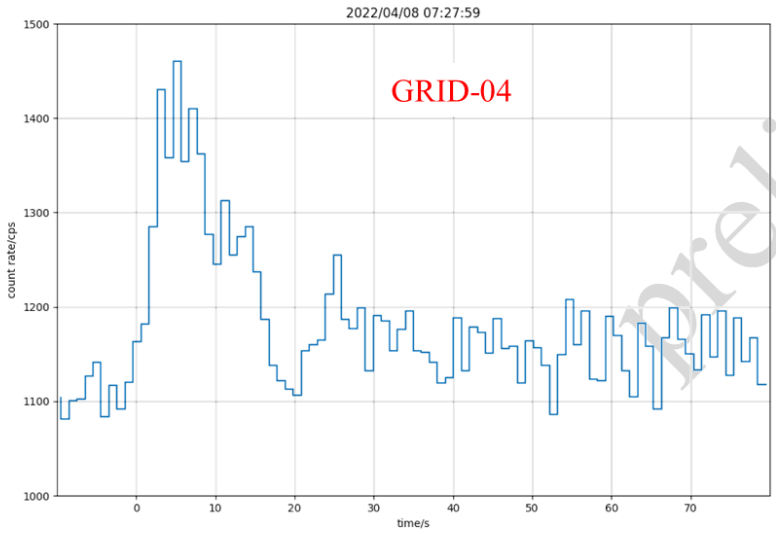


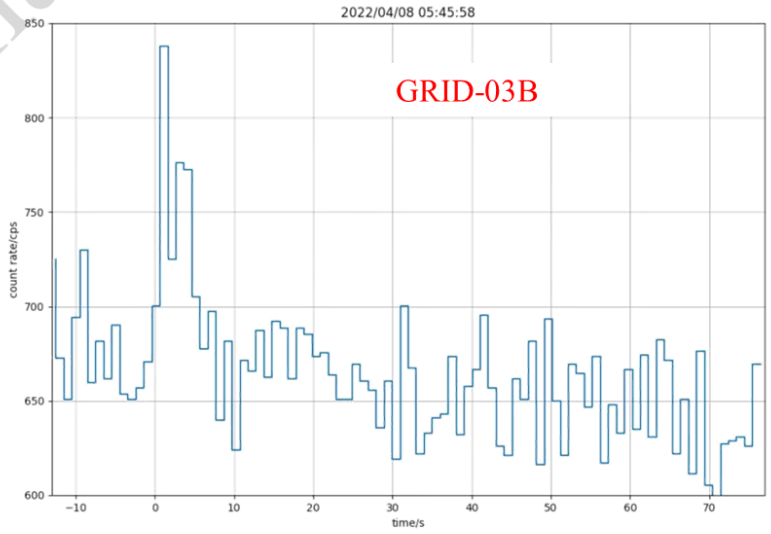
GRID-04

Preliminary Results from GRID-03B & GRID-04









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