

# **GECAM**载荷正样地面标定情况

GECAM标定与模拟组

彭文溪

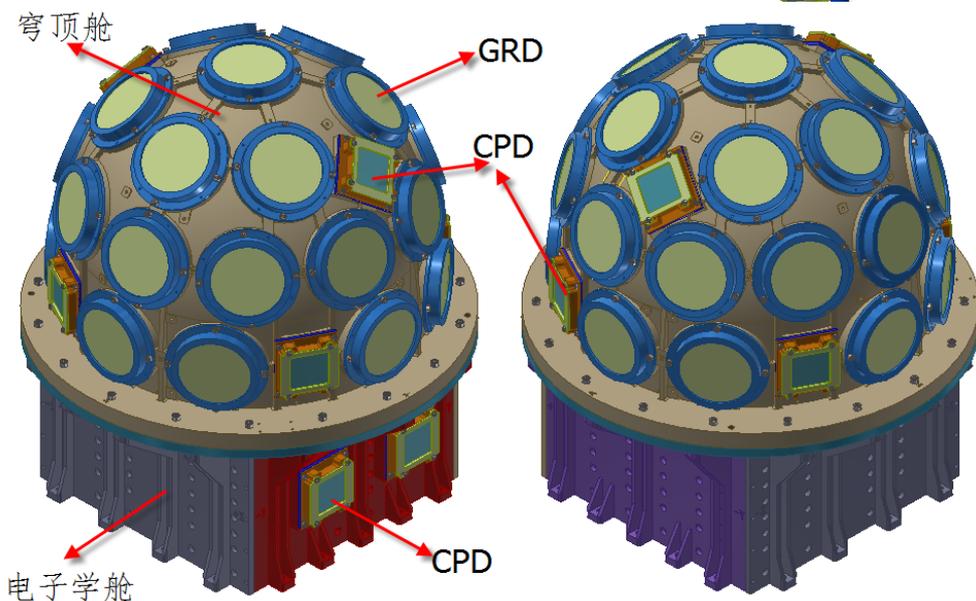
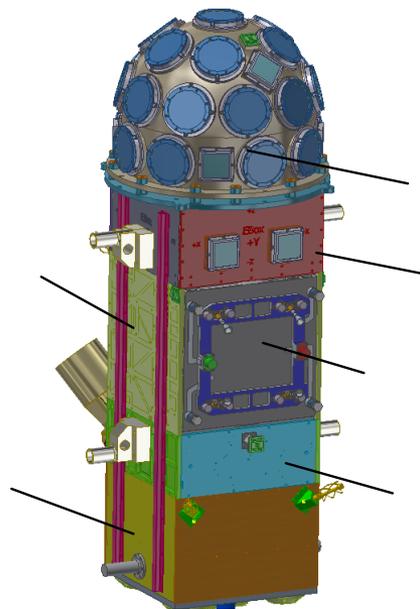
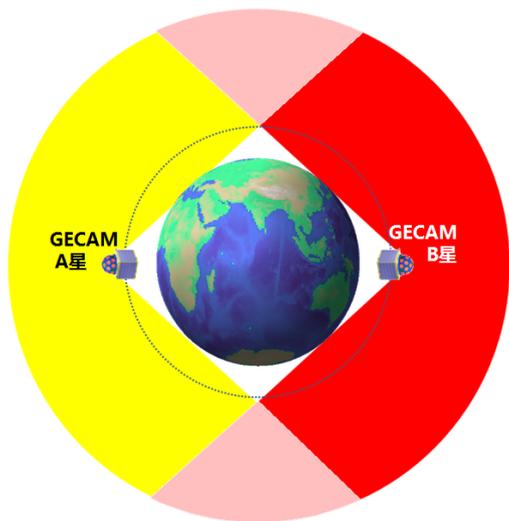
2020.11.01

# 提纲

- **1. GECAM载荷概述**
- **2. GRD标定**
- **3. CPD标定**
- **4. 在轨标定**
- **5. 总结**



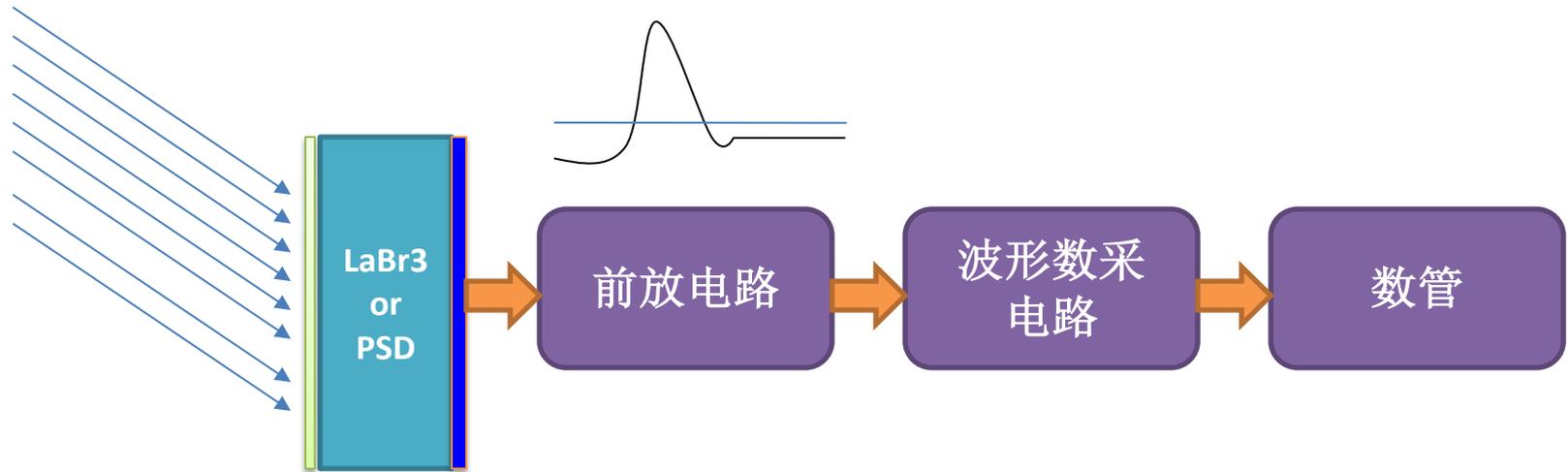
# 1. GECAM载荷概述



- 低轨道双星
  - 成本、可行性
  - 轨道相同，反相位，形成100% 全天覆盖
  - 600 km, 29度倾角，空间环境和SAA区满足要求
- 每颗星的探测器配置
  - 25个伽玛暴射线探测器(GRD), **黄色圆形,  $\text{LaBr}_3 + \text{SiPM}$**
  - 8个荷电粒子探测器 (CPD), **蓝色方形,  $\text{PSD} + \text{SiPM}$  (携带  $\text{Am-241}$ 源)**
  - 视场224度
  - 均匀指向不同方向
  - 定位、能谱、时变测量

# GRD & CPD

$F(E_i, t)$  (/cm<sup>2</sup>/keV/s)



- GRD与CPD的区别: 1) GRD LaBr<sub>3</sub>, CPD为 PSD  
2) GRD分为高低增益, CPD为单增益通道

# 载荷技术指标

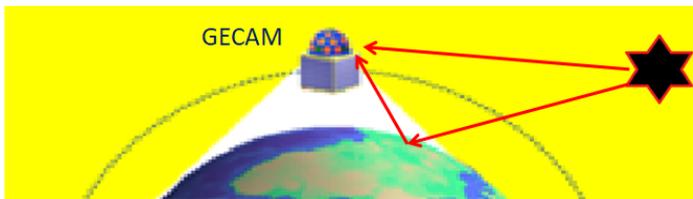
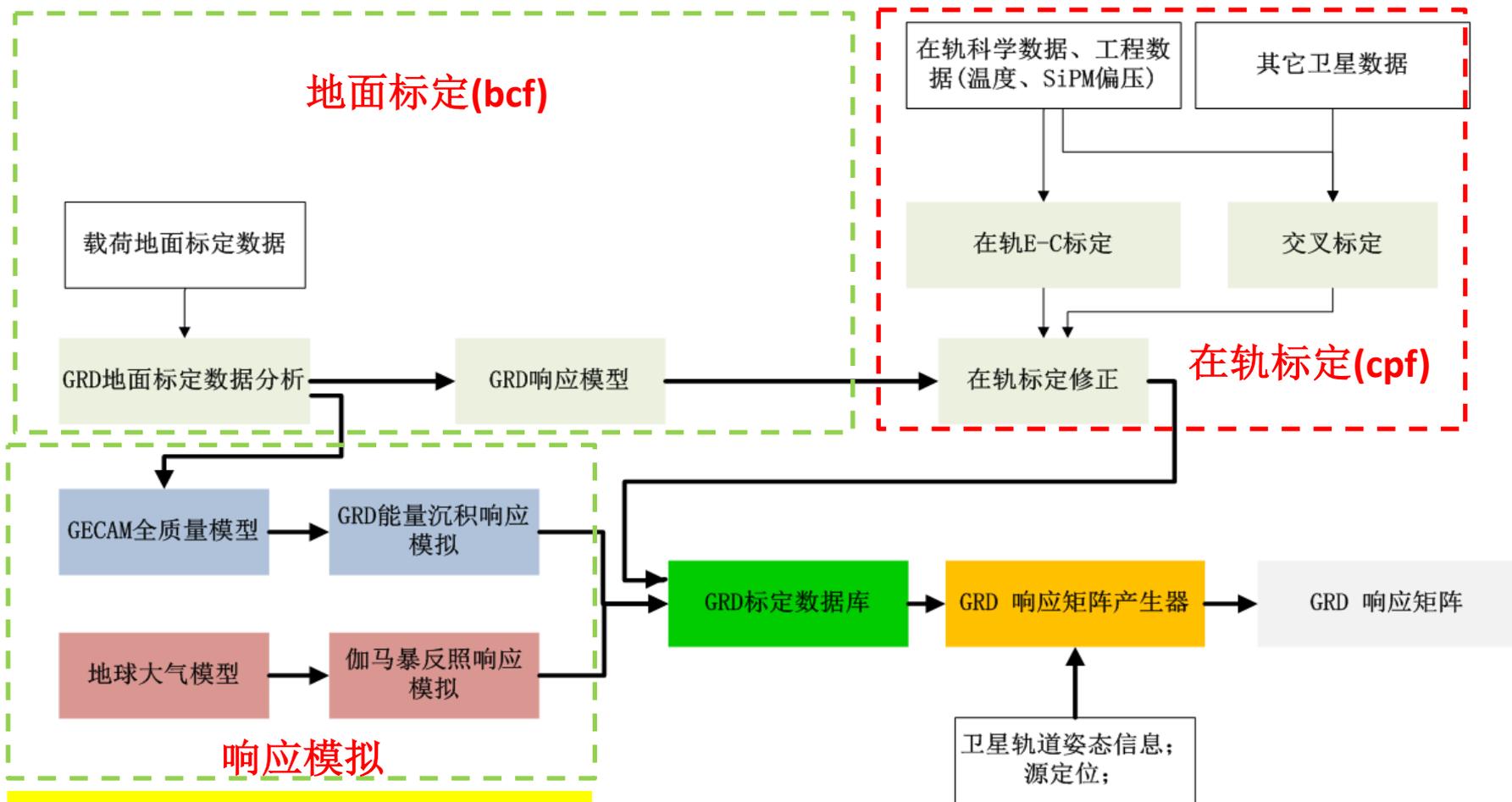
- **GRD:** 探测伽马射线(能量、时间、流量), 同时也测量空间带电粒子(电子)

GRD性能指标	要求
探测能区	8keV~2MeV
探测面积	> 40 cm <sup>2</sup> (单个探头)
死时间	≤5 μs
能量分辨	< 18%@59.5 keV
伽马射线探测效率	>50%@8keV

- **CPD:** 主要测量空间带电粒子(能量、时间、流量), 对伽马射线效率低, 识别粒子暴

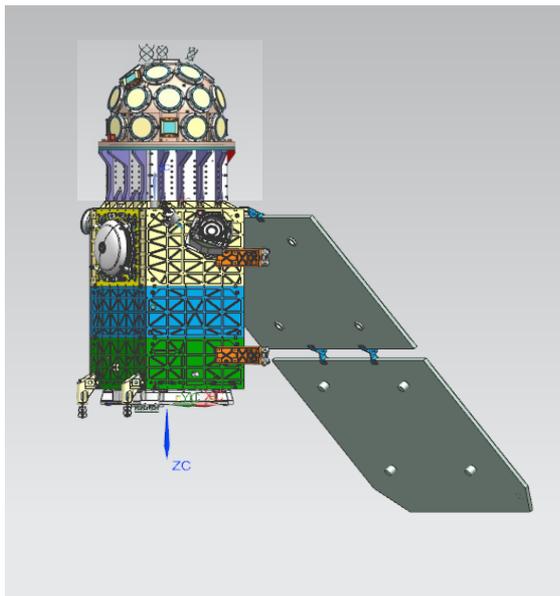
CPD性能指标	要求
探测面积	>15 cm <sup>2</sup> (单个探头)
探测能区	300 keV~5 MeV (电子)
伽马射线探测效率	<20%@ (8keV~2MeV)
死时间	≤5 μs

# GRD能量响应矩阵产生流程

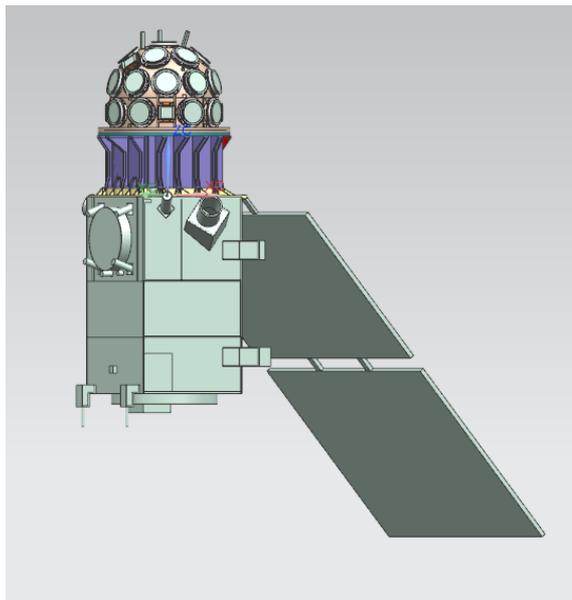


# GECAM卫星能量响应模拟

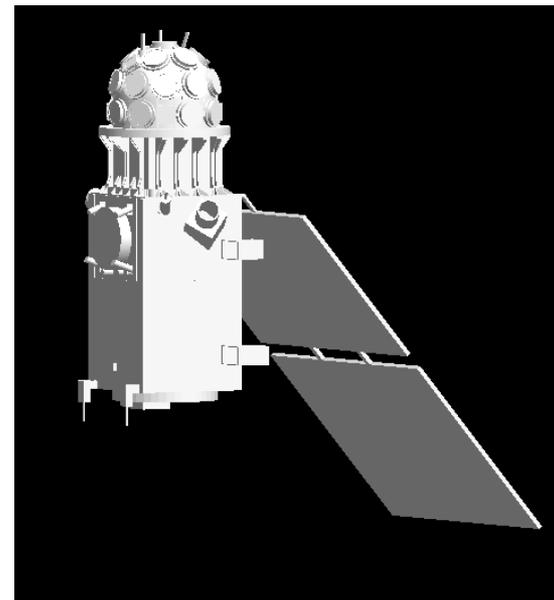
原始CAD



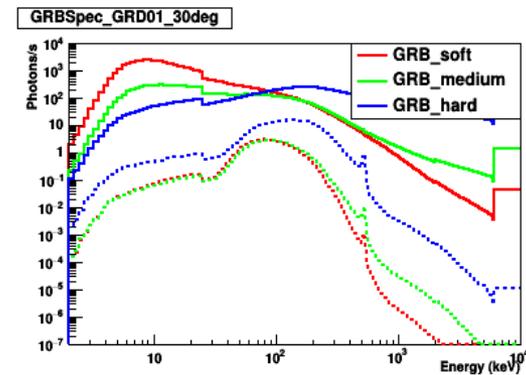
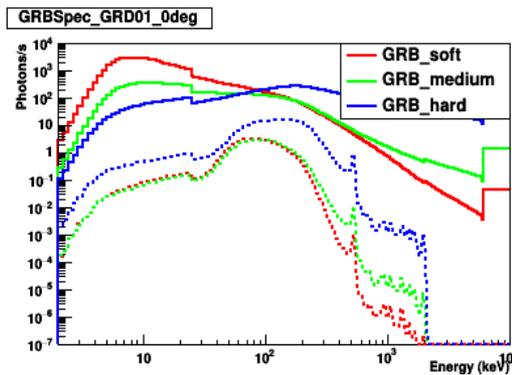
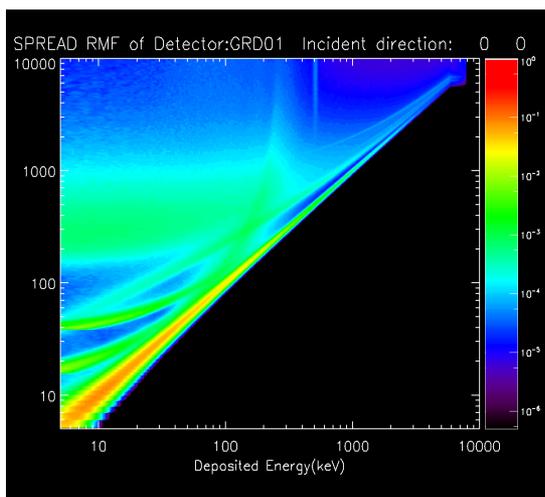
简化后CAD



模拟程序



► 整星建模与整星预估质量偏差 < 2% (目前根据正样状态修正)



# 2.GRD标定

**标定目的：** 探测器响应规律(能量、空间、时间、流量)、验证质量模型、性能指标验证

**标定方案：** 参考HXMT, Fermi-GBM, 并根据GRD的特点制定

2.1 能量响应标定

2.2 探测效率标定

2.3 空间响应标定

2.4 死时间/高计数率响应

2.5 温度偏压标定

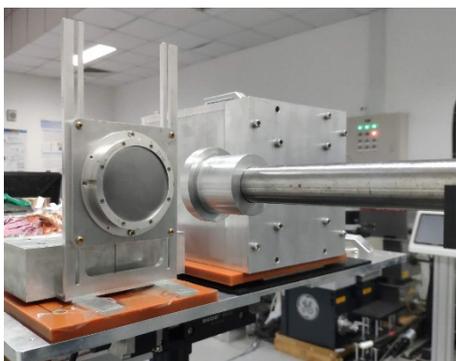
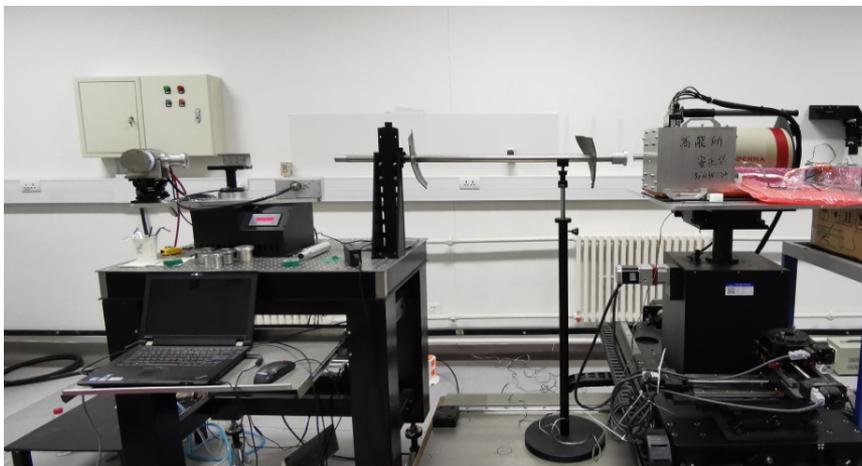
2.6 电子能量响应

2.7 时间精度

# 2.GRD标定

## 2.1 能量响应标定

	能区	标定内容
X射线束线标定	8~160keV (>20个能点)	能量EC, 能量分辨、均匀性、
放射源	390keV~1.8MeV (6个能点)	能量EC, 能量分辨



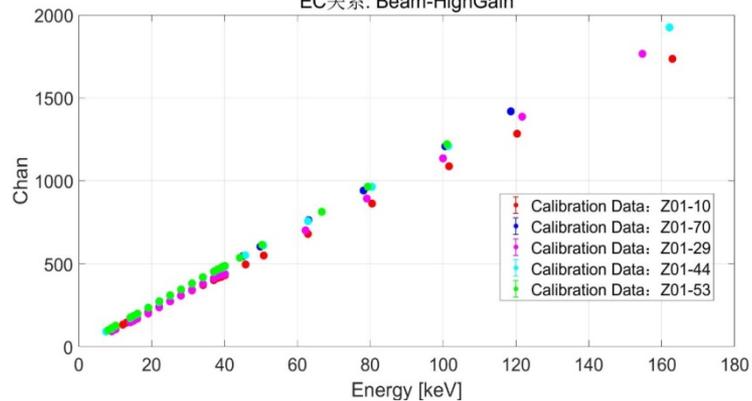
序号	核素	半衰期 (d)	能量(keV)	相对强度(%)	活度(Bq)	参考日期
1	Cs-137	10968.25	661.657	85.10%	1.99E+06	2020/9/15
2	Co-60	1923.915	1173.228	99.85%	3.50E+06	2020/9/15
			1332.492	99.98%	3.50E+06	
3	Sn-113	115.09	391.698	64.97%	6.64E+04	2020/9/15
4	Y-88	106.626	898.042	93.70%	9.89E+05	
			1836.063	99.20%	9.89E+05	2020/9/15

# 2.GRD标定

## 2.1 能量响应标定

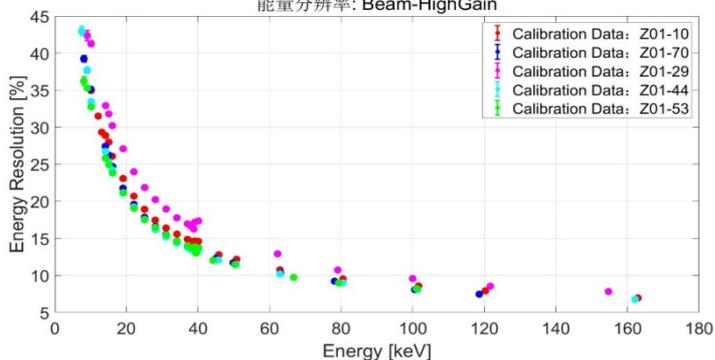
### 高增益通道(8~200keV)

EC关系: Beam-HighGain



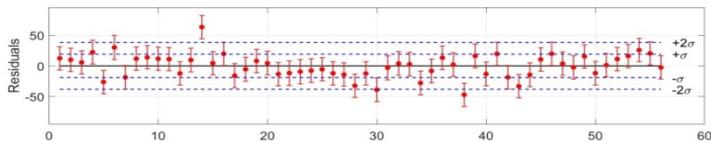
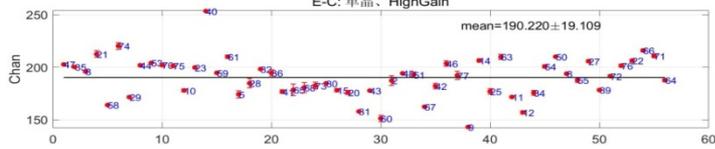
Energy [keV]

能量分辨率: Beam-HighGain



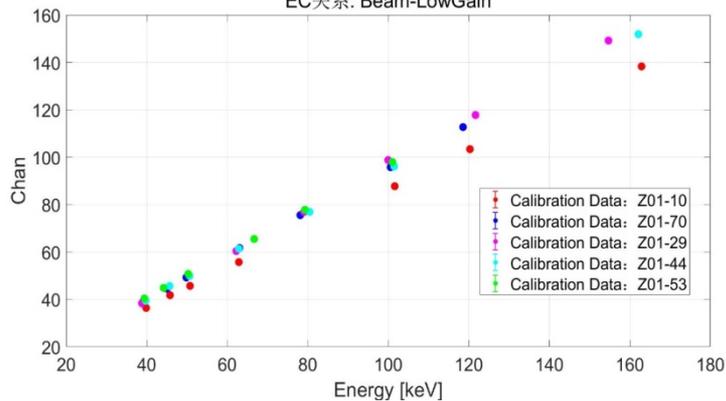
Energy [keV]

E-C: 单晶、HighGain



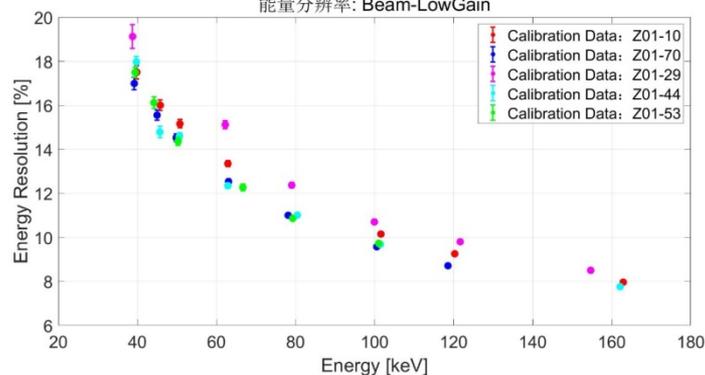
### 低增益通道(40keV~4MeV)

EC关系: Beam-LowGain



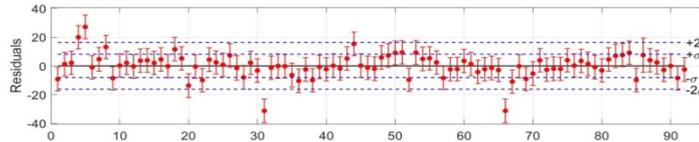
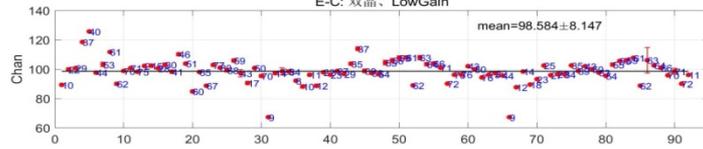
Energy [keV]

能量分辨率: Beam-LowGain



Energy [keV]

E-C: 双晶、LowGain

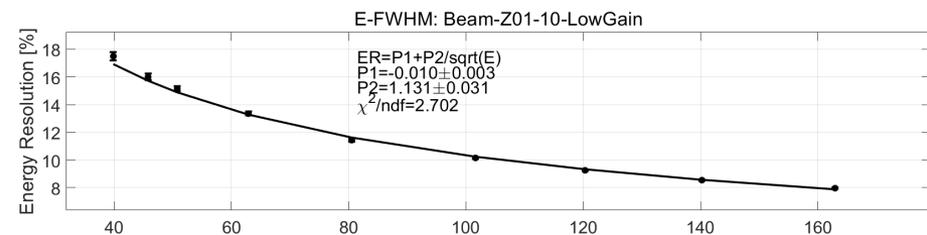
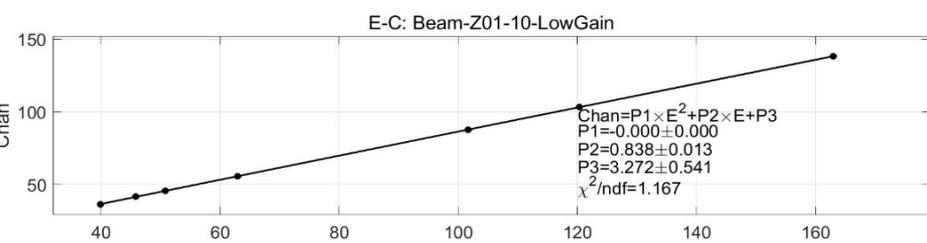
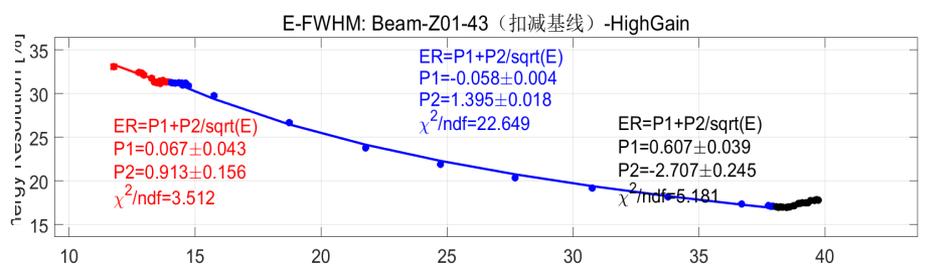
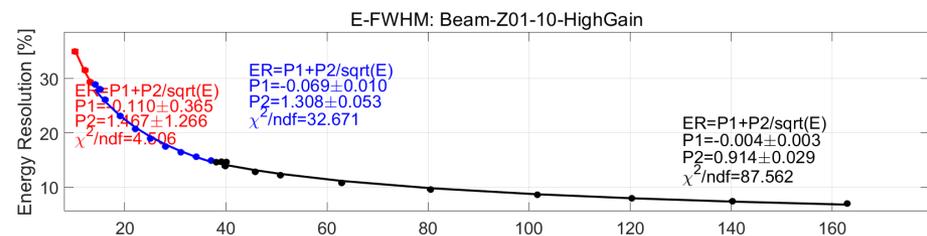
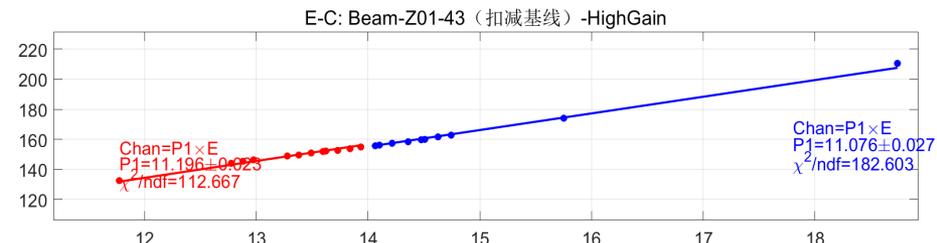
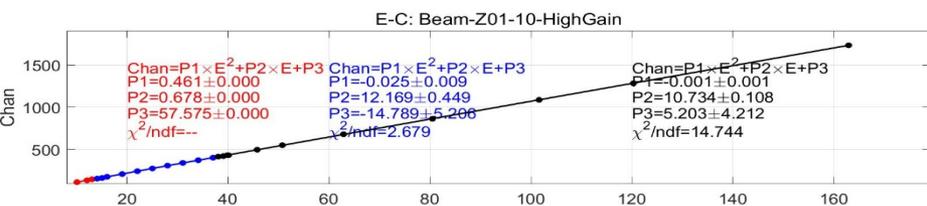


# 2.GRD标定

## 2.1 能量响应标定

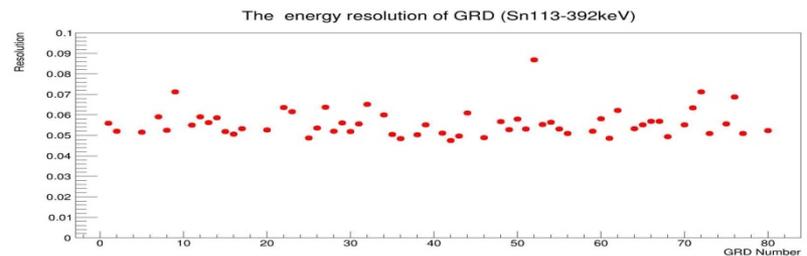
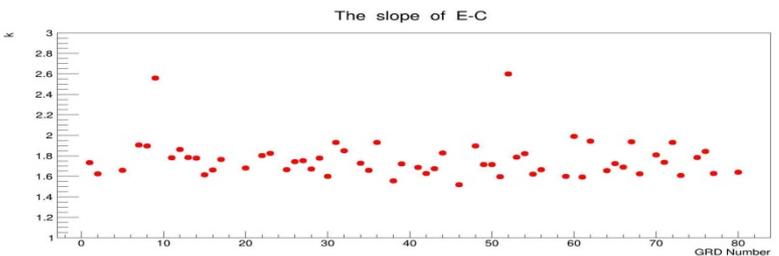
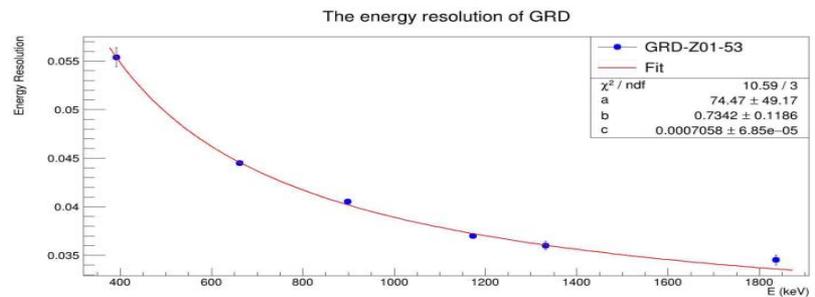
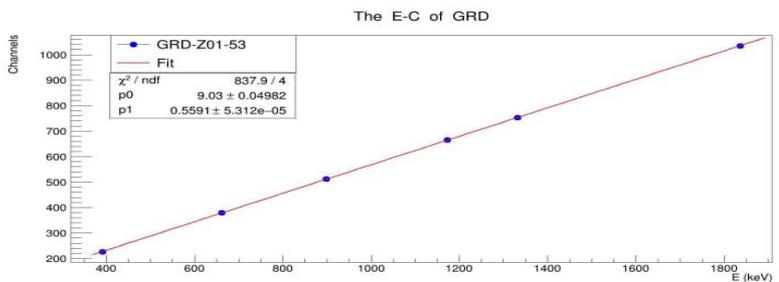
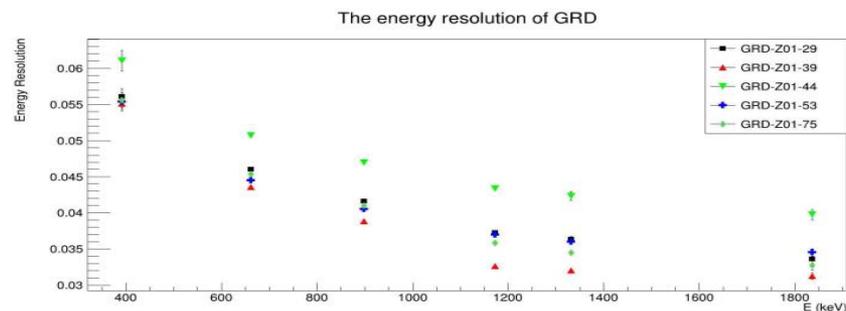
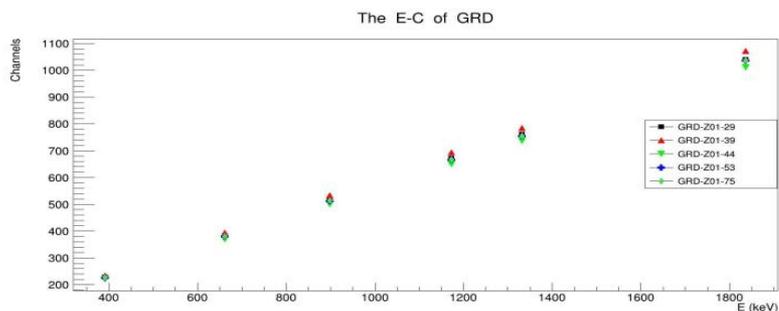
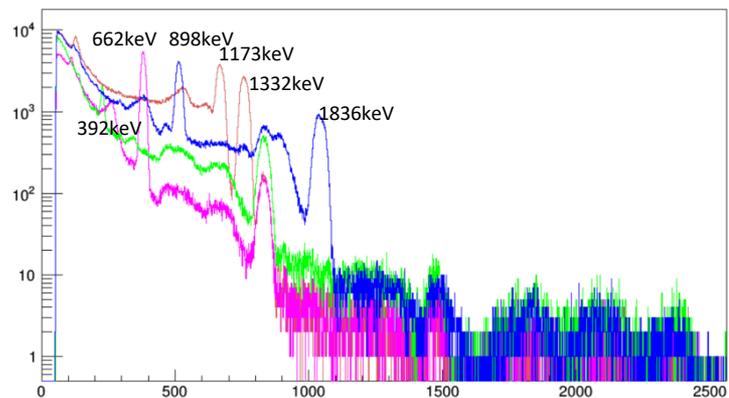
高低增益-EC, 能量分辨曲线分段拟合

吸收边精测(1keV步长)



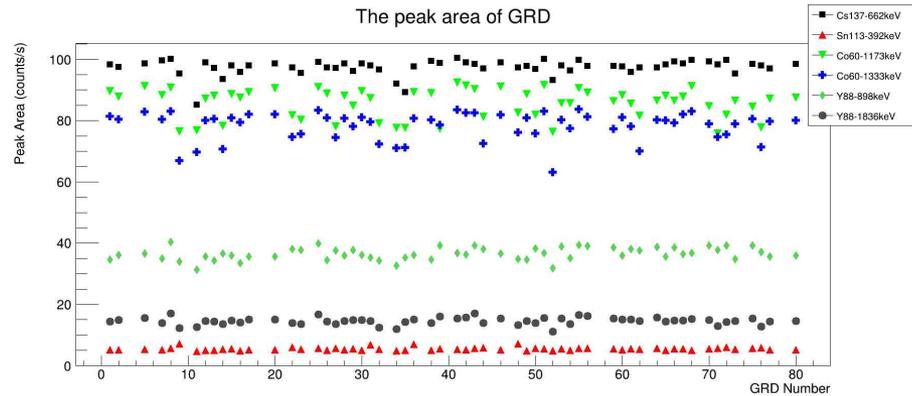
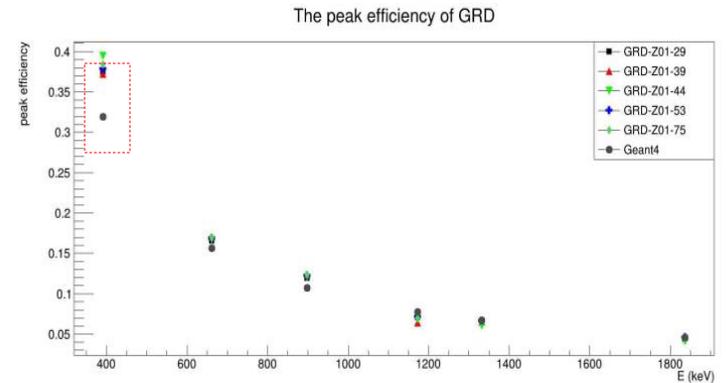
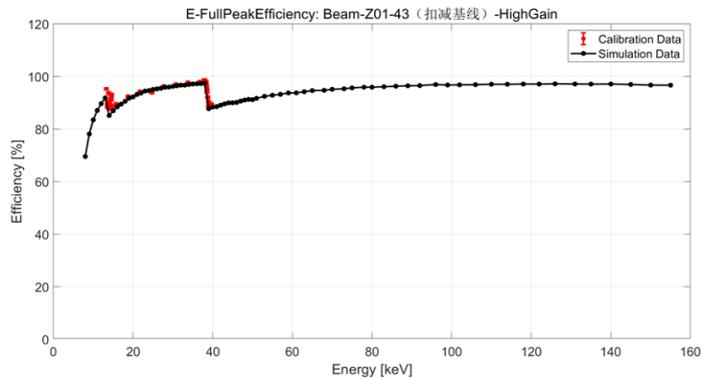
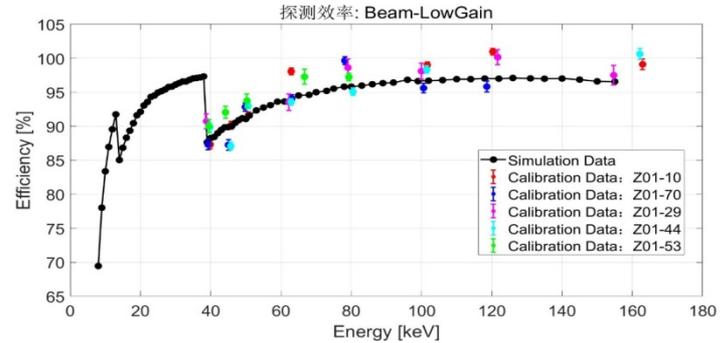
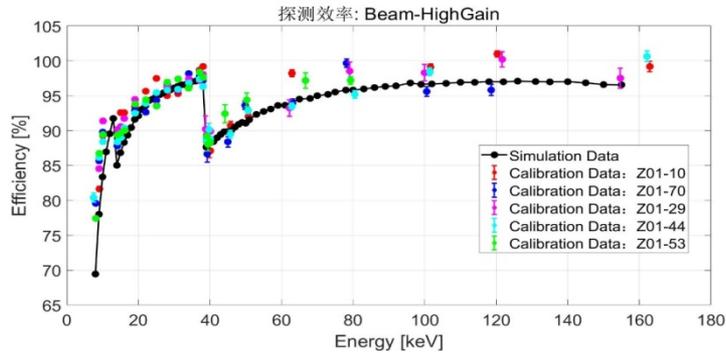
# 2.GRD标定

## 2.1 能量响应标定



# 2.GRD标定

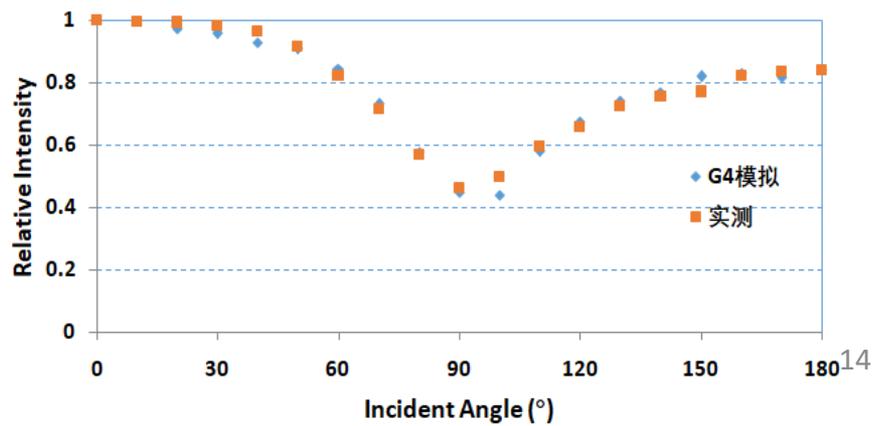
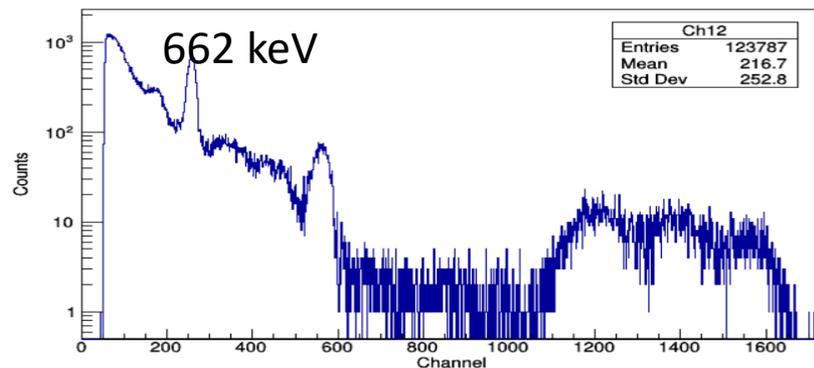
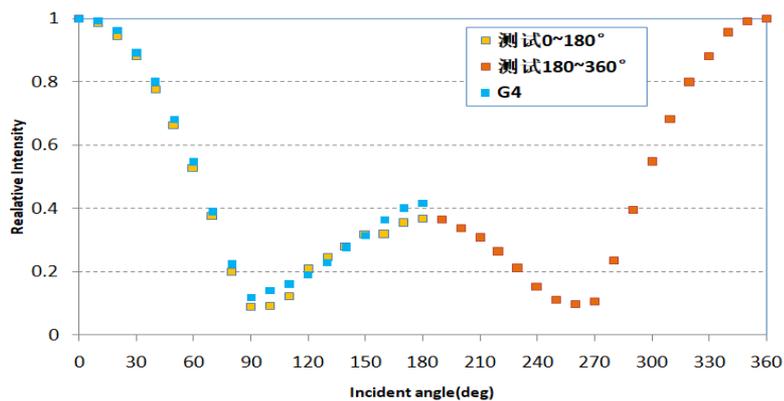
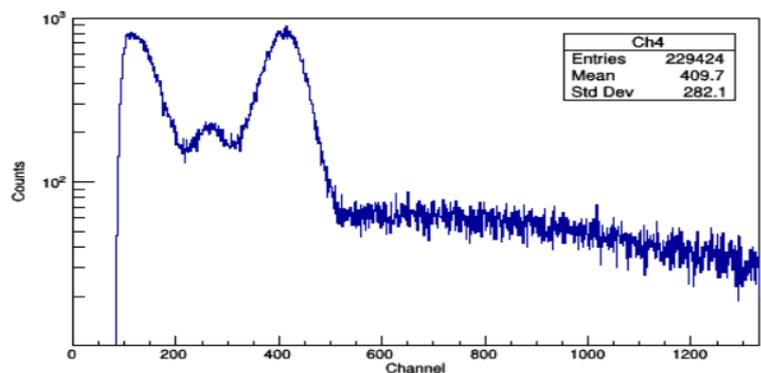
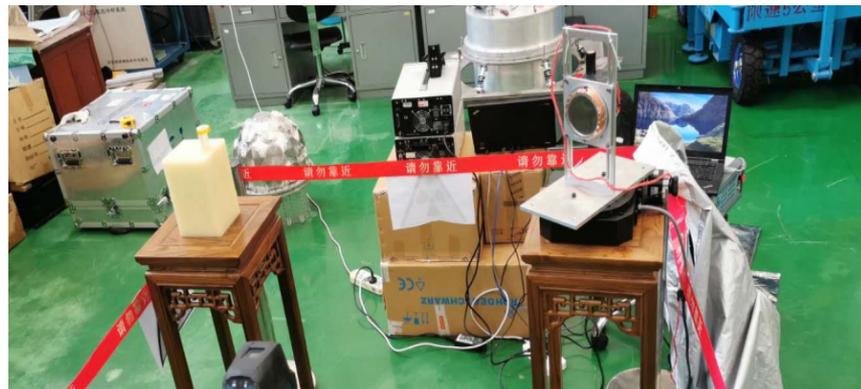
## 2.2 探测效率标定



# 2.GRD标定

## 2.3 空间响应标定:

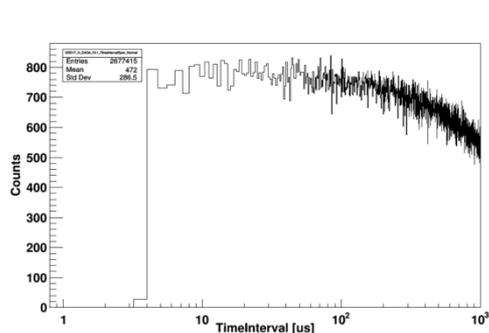
- 放射源Am-241(59.5keV), Cs-137(662keV)
- 入射角:  $0\sim 180^\circ$  , 每 $10^\circ$  一个点



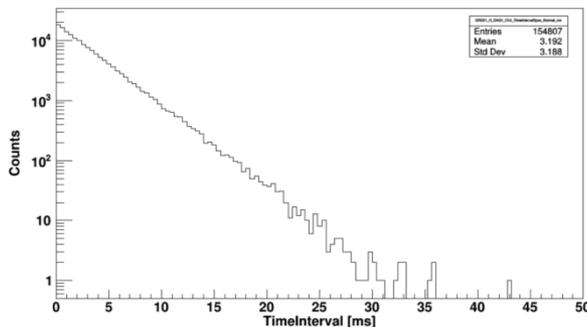
# 2.GRD标定

## 2.4 死时间/ 高计数率响应

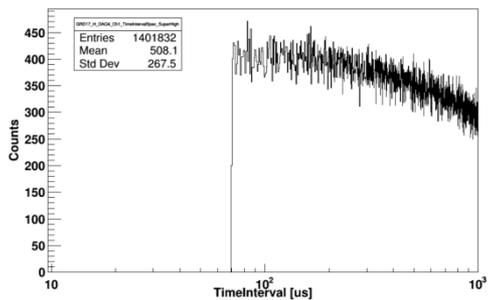
正常事例: 4us



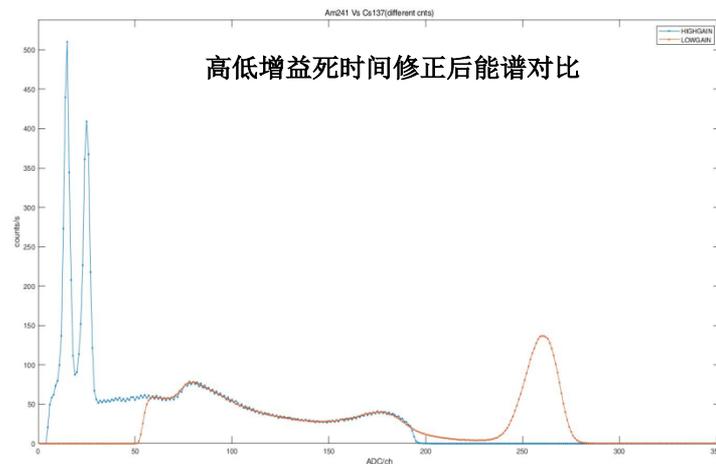
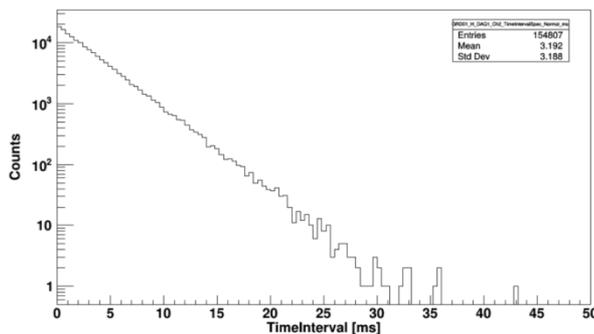
GRD01\_H\_DAQ1\_Ch2\_TimeIntervalSpec\_Normal\_ms



超高事例: 70us



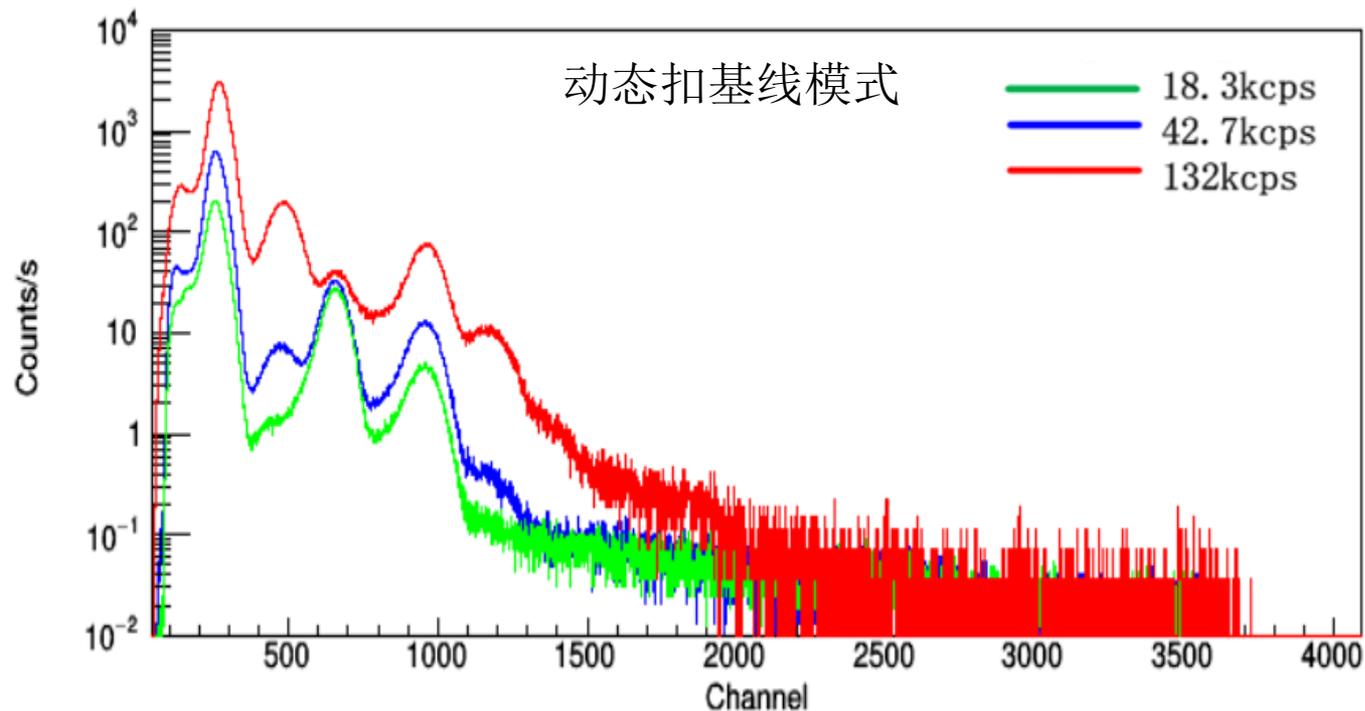
GRD01\_H\_DAQ1\_Ch2\_TimeIntervalSpec\_Normal\_ms



死时间=正常事例\*4us+超高事例\*(70+ $\Delta 1$ ) us+(超宽事例\*  $\Delta 2$ )us

# 2.GRD标定

## 2.4 死时间/高计数率响应



峰位漂移~2ADC

Counts rate(cps)	DeadTime/IntegrationTime
18.3k	8%
42.7k	17%
132k	53%

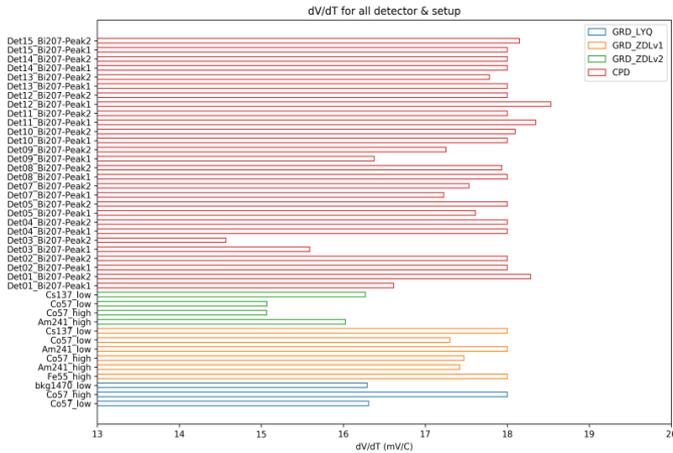
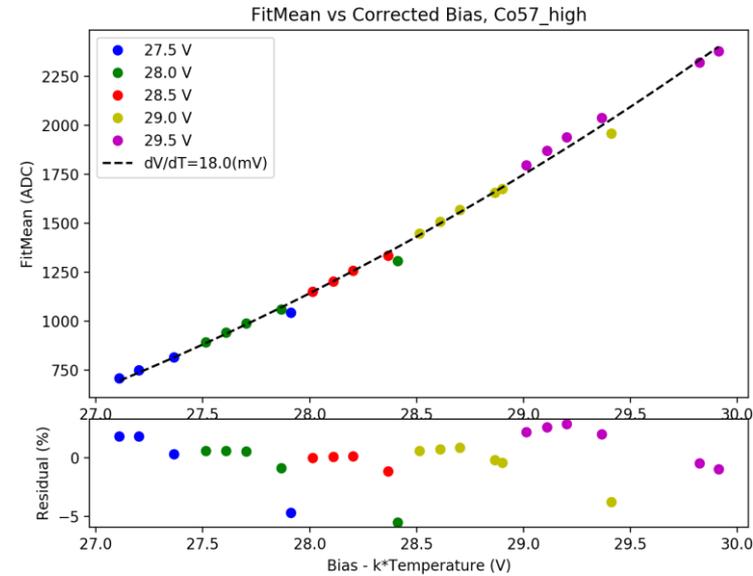
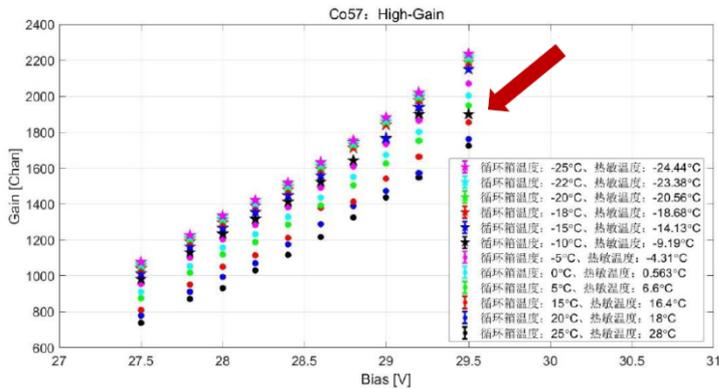
# 2.GRD标定

## 2.5 温度偏压标定:

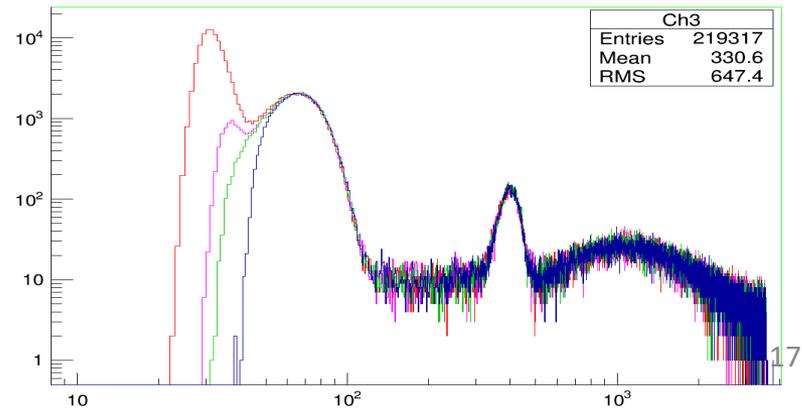
- 温度影响因素:  $V_{breakdown}$ , SiPM ( $V_{breakdown}$ , DCR), 晶体光产额, 光耦合 (热形变)

### 试验方案:

GRD测试探头 (3个), 高低温箱-25~+25°C,  
 $^{55}\text{Fe}$ 源(5.9keV),  $^{57}\text{Co}$ 源(122keV),  $^{137}\text{Cs}$ 源(662keV)  
 $V_{bais}=27.5, 28, 28.5, 29, 29.5\text{V}$



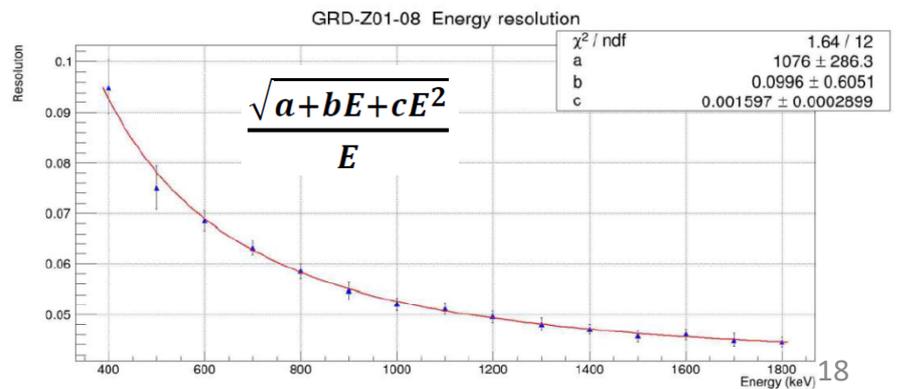
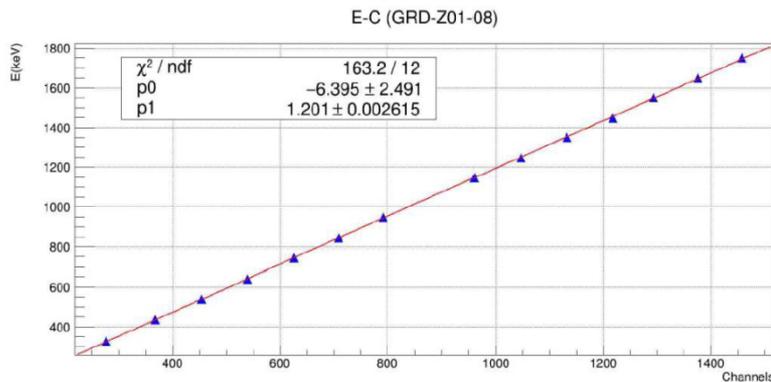
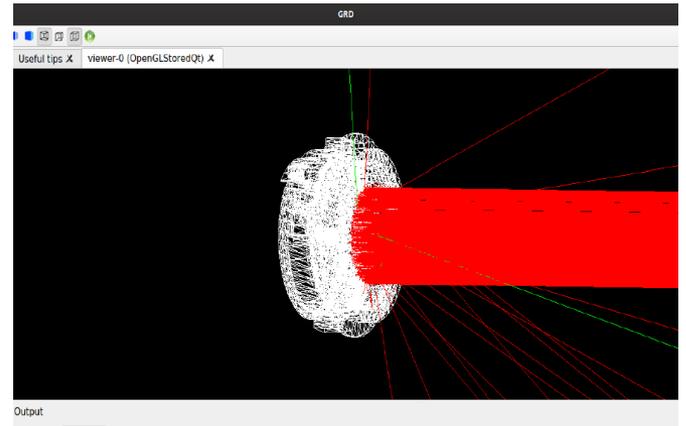
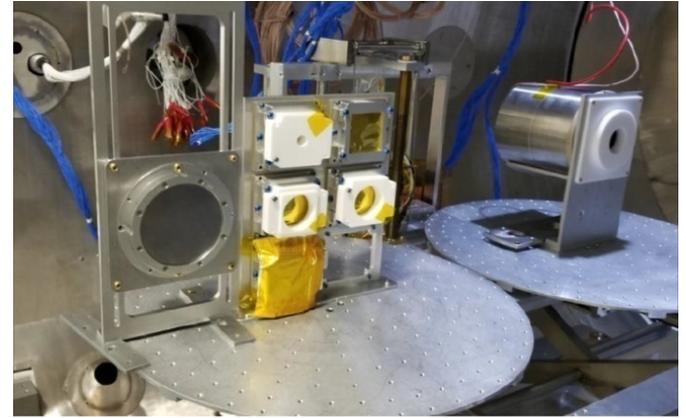
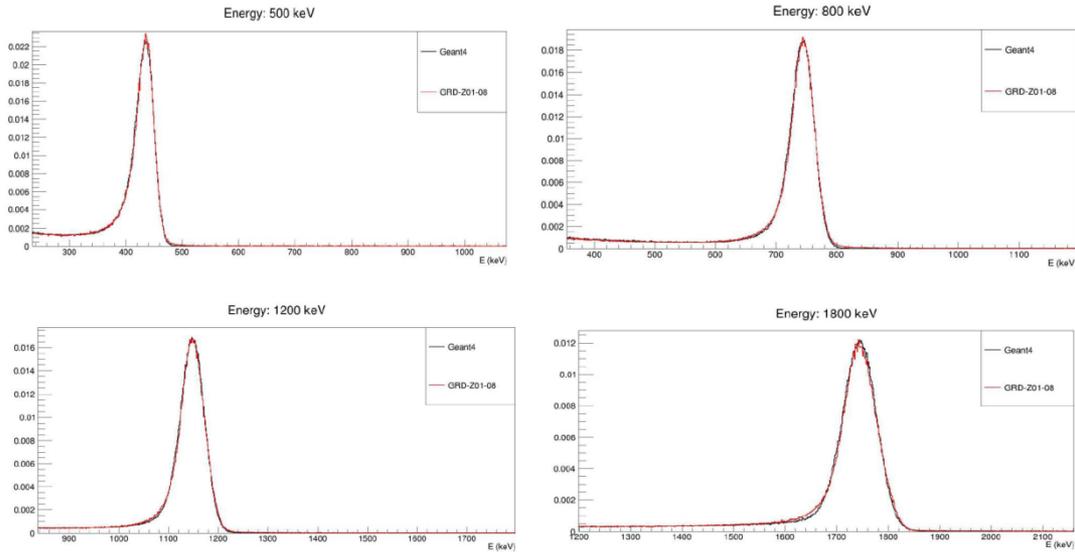
### $\text{Fe}^{55}$ (5.9keV) ,-20°C



# 2.GRD标定

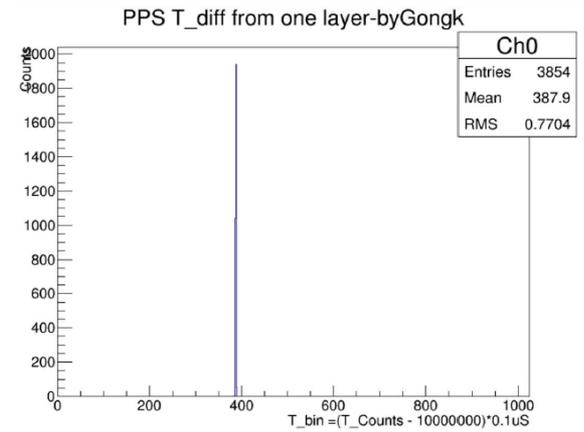
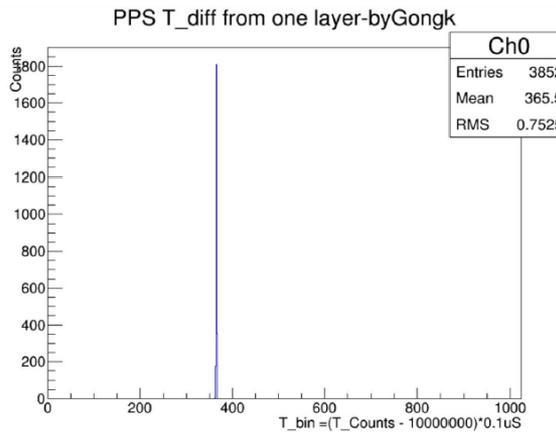
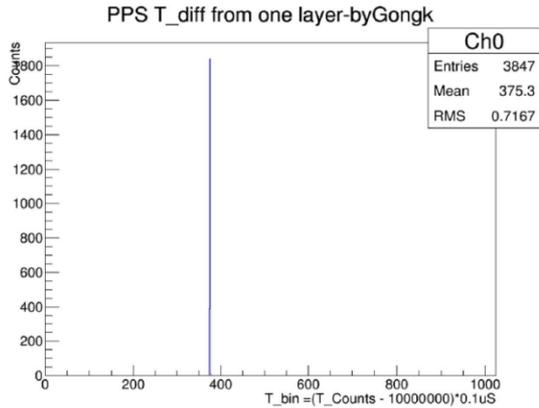
## 2.6 电子能量响应

空间中心电子束：200~1800keV, 17个点

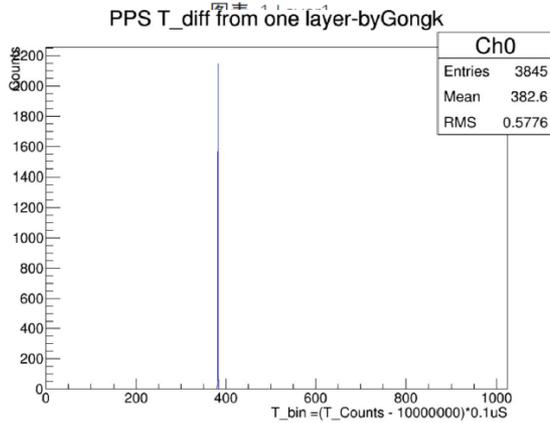


# 2.GRD标定

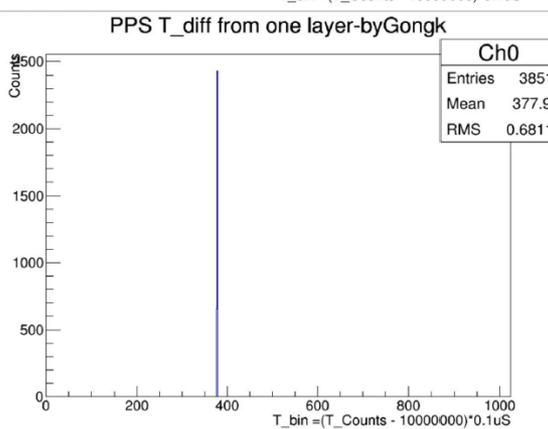
## 2.7 相对时间精度:



图表 3 Layer3



图表 4 layer\_4

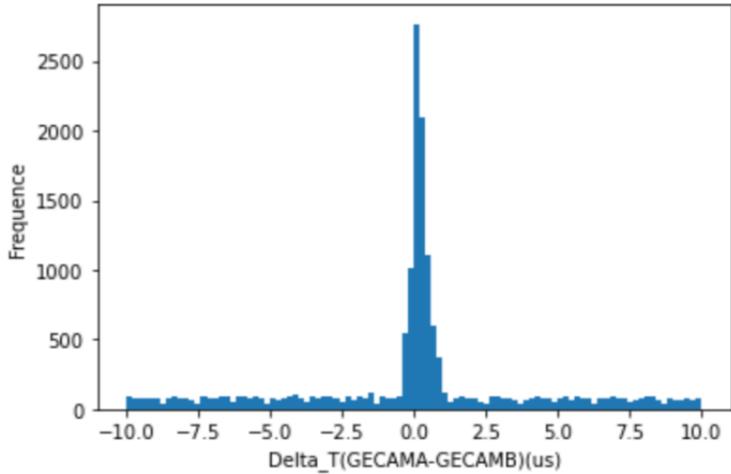


图表 5 layer5

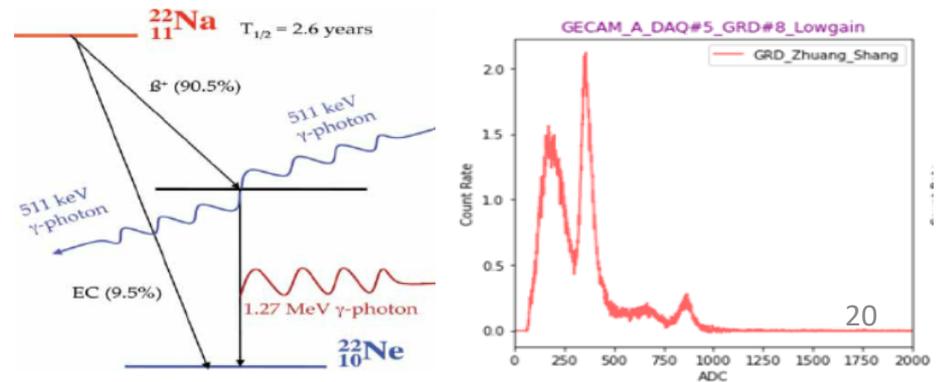
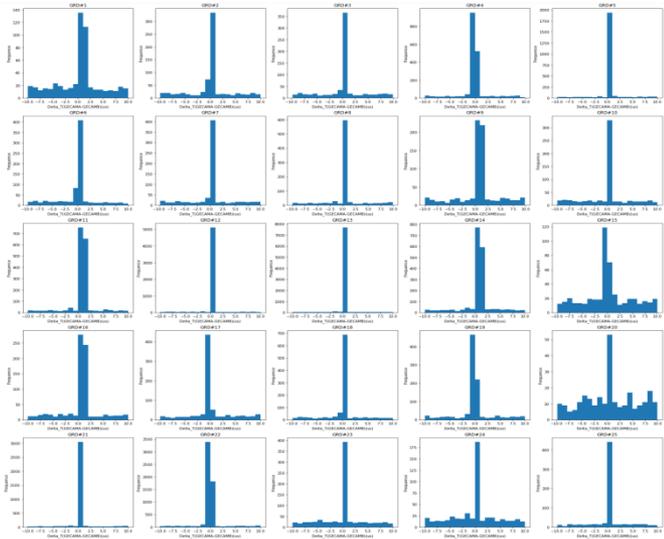
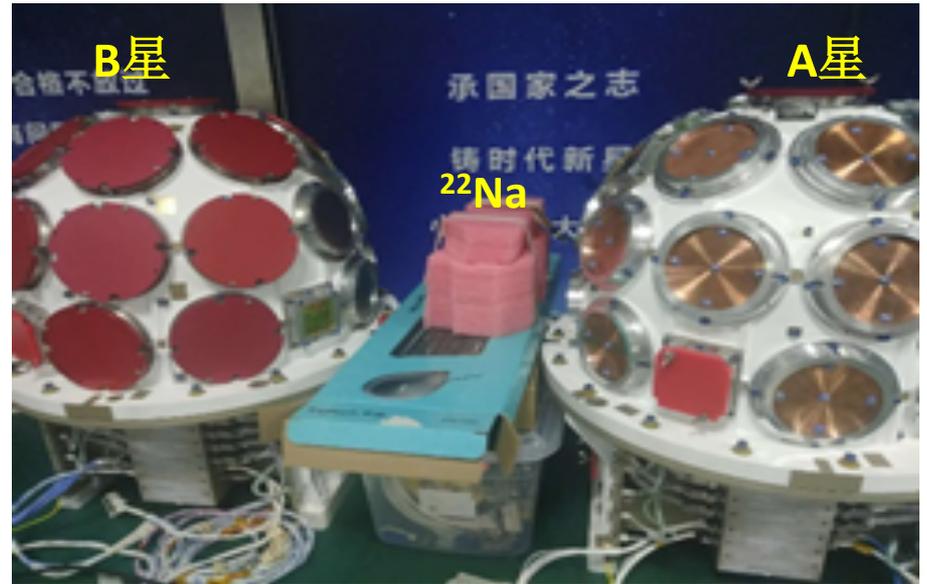
秒脉冲时间间隔谱分布宽度(RMS):  $< 0.1\mu s$

# 2.GRD标定

2.7 相对时间精度（双星）：**1Sigma < 0.5us (3sigma ~ 1us)**



判定条件：时间间隔小于10us，ADC道数200-600



# 3.CPD标定

3.1 电子能量响应标定

3.2 伽马射线探测效率

3.3 温度偏压标定

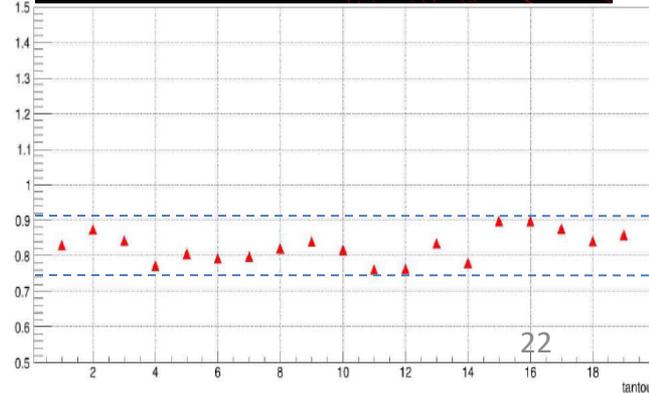
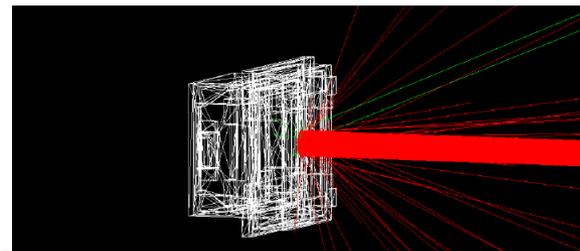
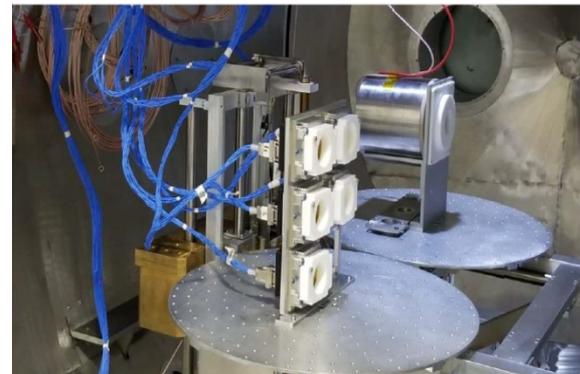
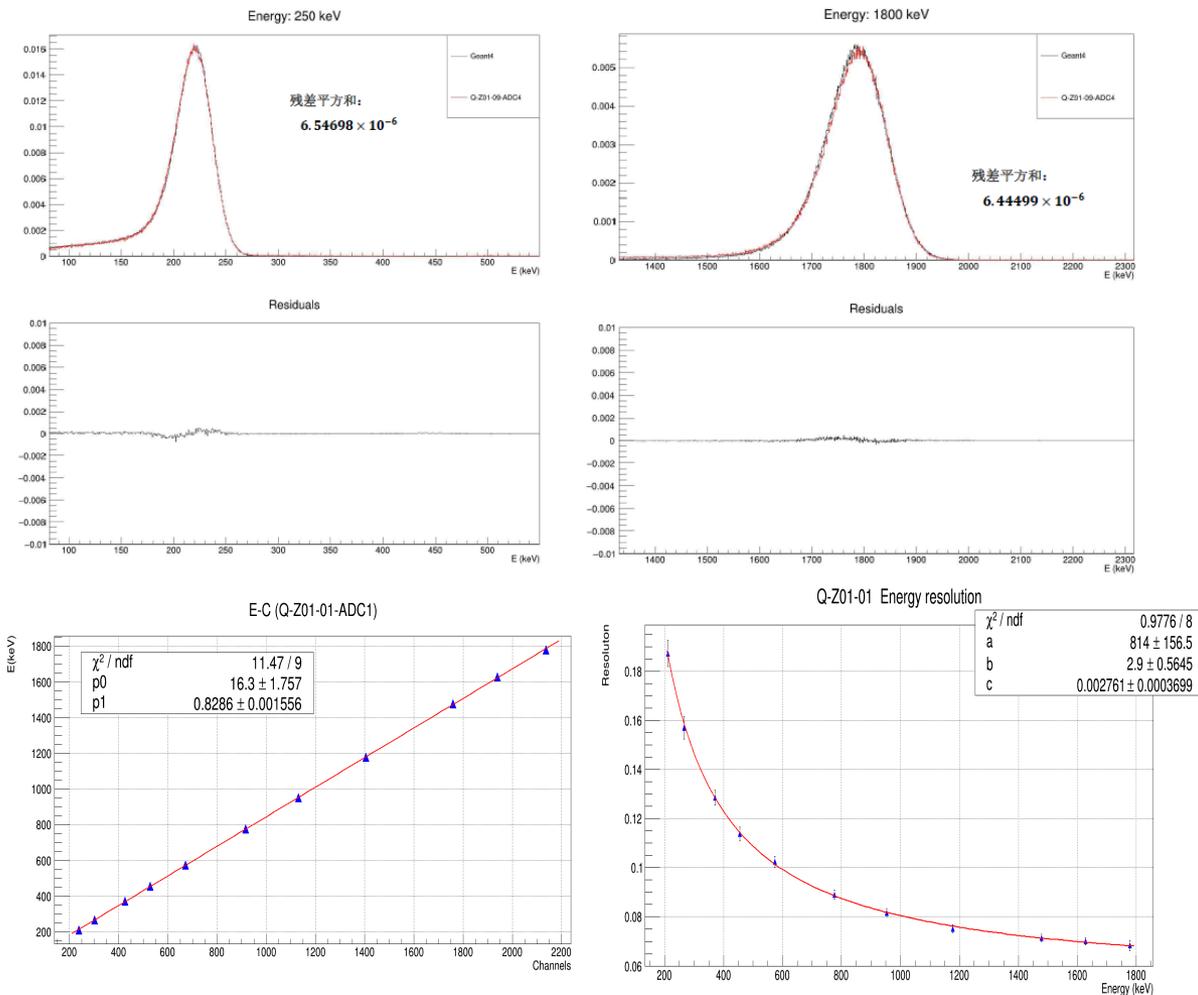
3.4 质子能量响应

3.5 死时间

# 3.CPD标定

## 3.1 电子能量响应 标定 (19个CPD: 16个装机, 3个备份)

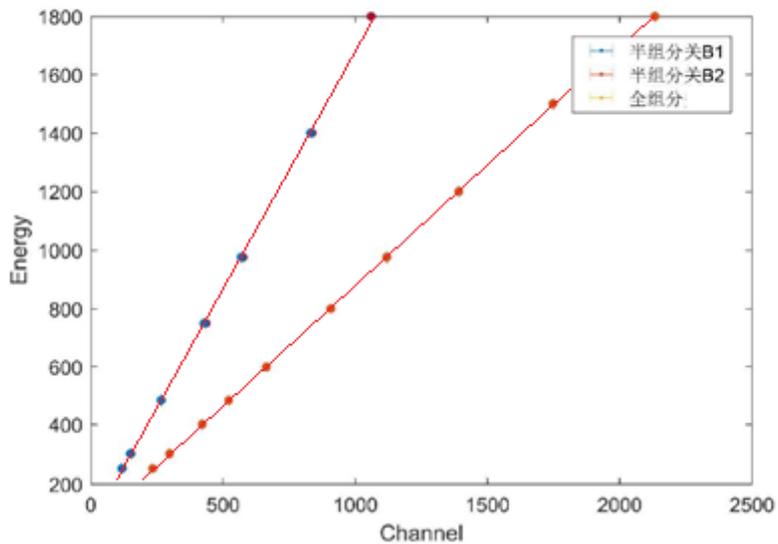
空间中心电子束: Energy=250keV~1800keV, 11个点



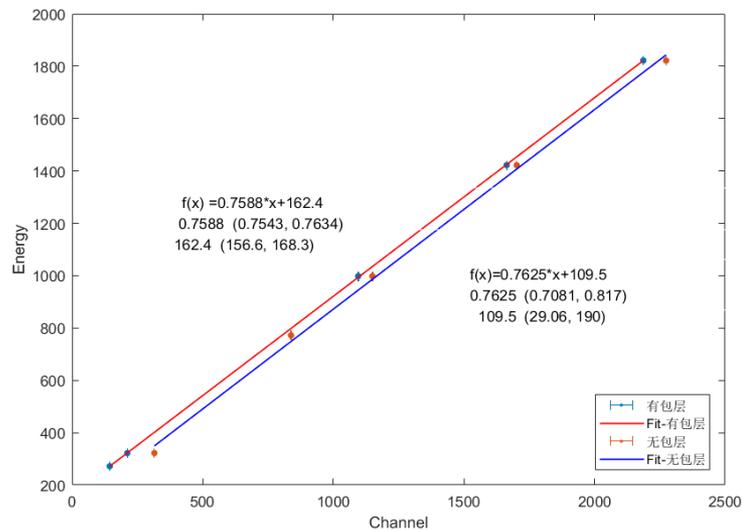
探测效率: 低计数率( $<10^4$ cps)下, 100%; 高计数率地检待测

# 3.CPD标定

半组分E-C散点图

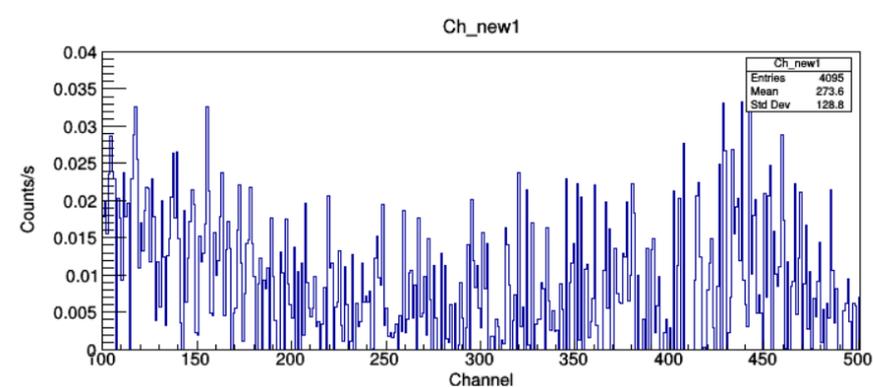
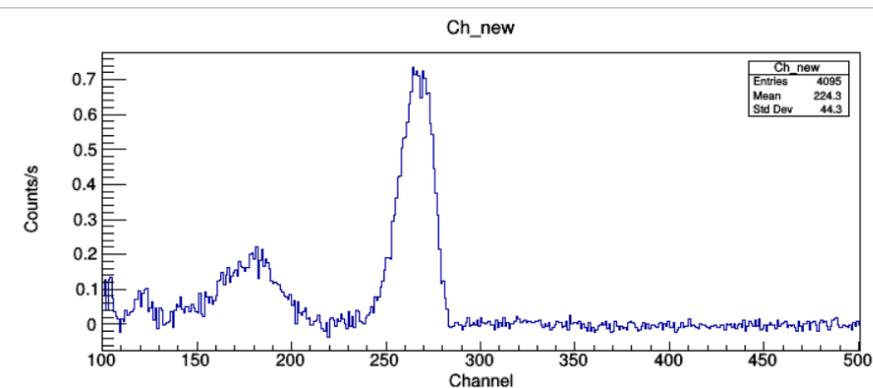
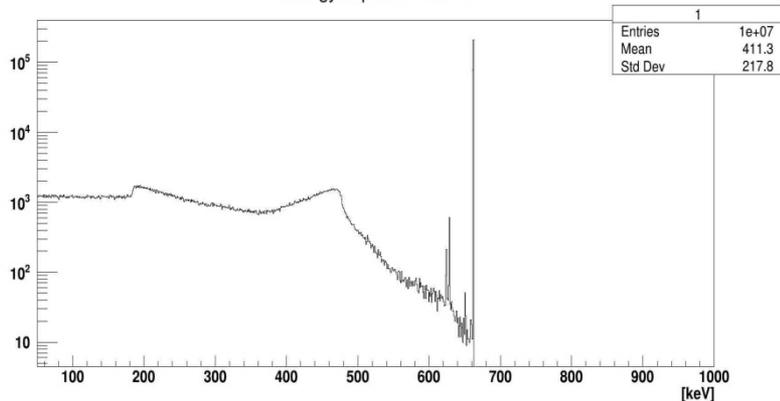
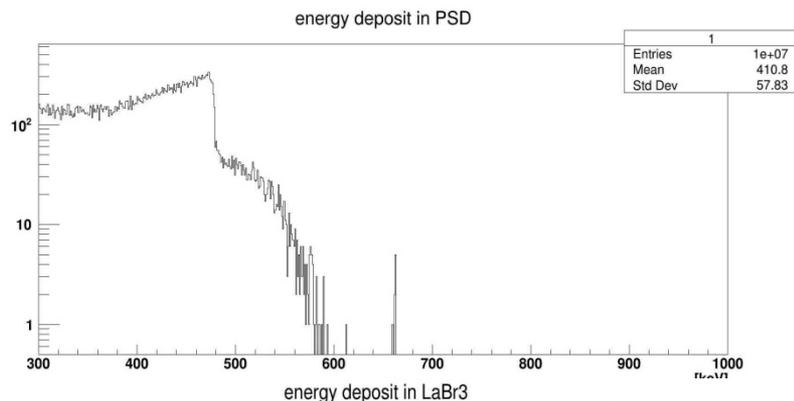


有无包层E-C关系图



# 3.CPD标定

## 3.2 伽马射线探测效率



### Cs-137(662keV)

相对探测效率  $\text{Eff\_CPD}/\text{Eff\_GRD(LG)} = 0.129 \pm 0.01$

模拟结果:  $\text{Eff\_CPD}/\text{Eff\_GRD(LG)} = 0.126 \pm 0.01$

考虑GRD对662keV全效率=77%, **CPD对662keV伽马射线探测效率=10%**

# 3.CPD标定

## 3.3 温度偏压响应

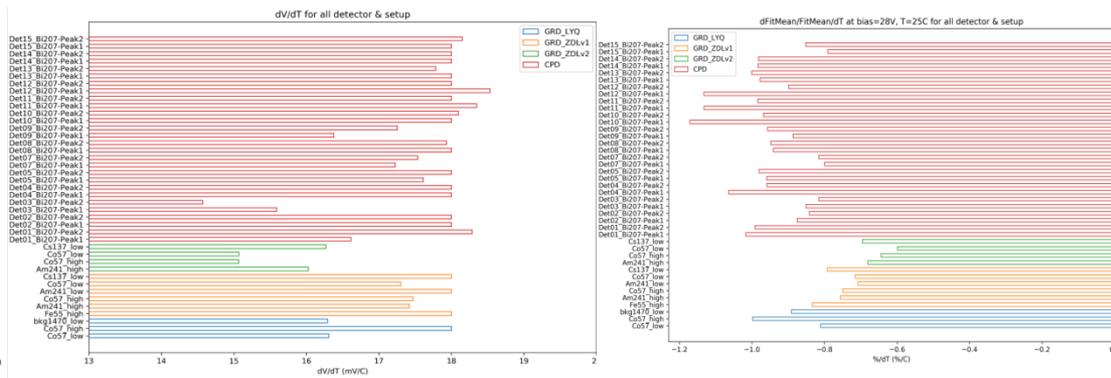
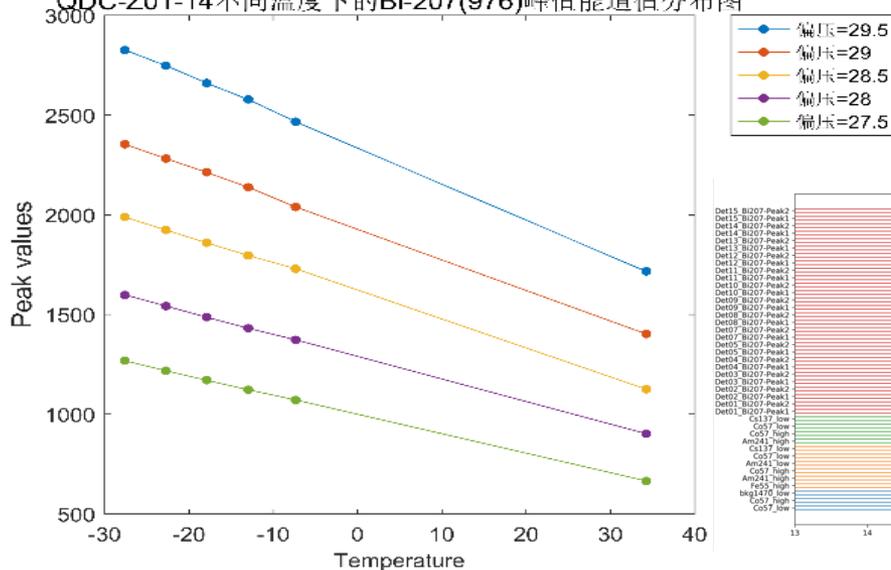
温度影响因素：

SiPM ( $V_{bd}$ , PDE, DCR), 晶体光产额, 光耦合

试验方案：

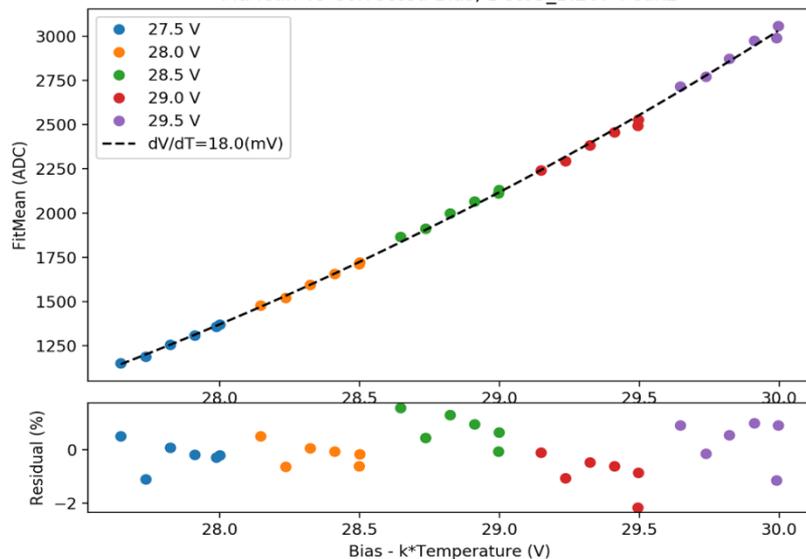
14个穹顶舱CPD, 高低温箱-30~+30°C ,  
 $^{207}\text{Bi}$ 源(482,976keV),  
 $V_{bais}=27.5, 28, 28.5, 29, 29.5\text{V}$

ODC-Z01-14不同温度下的Bi-207(976)峰值能道值分布图



大部分CPD探头 ~18mV/°C

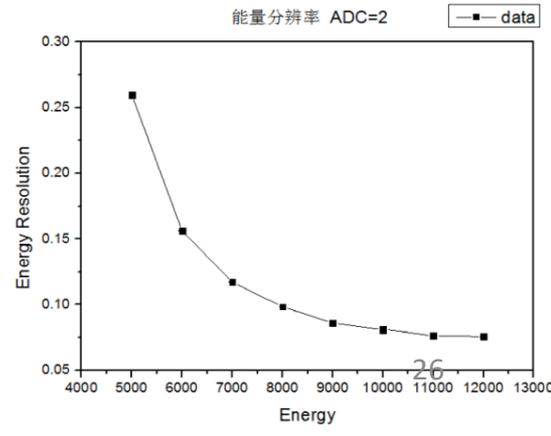
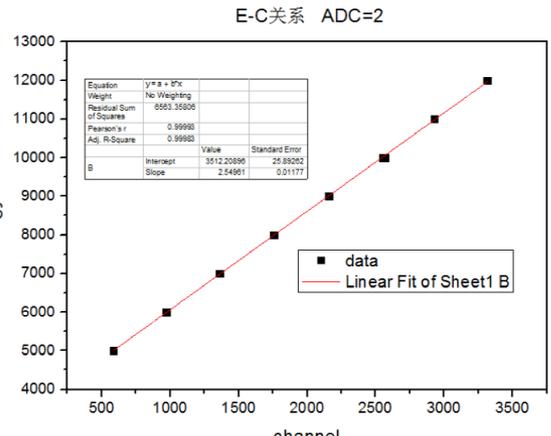
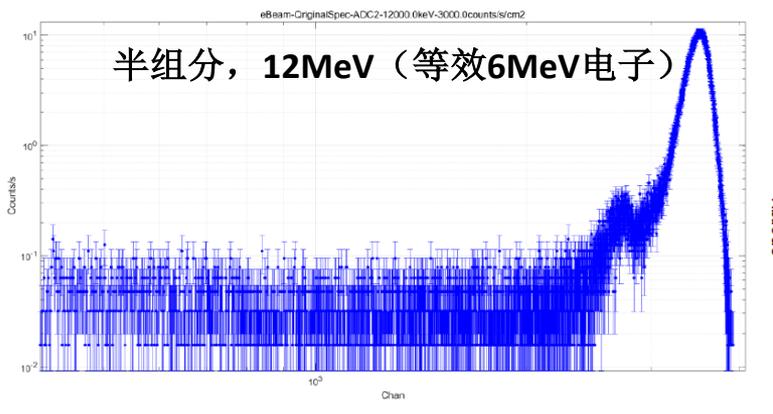
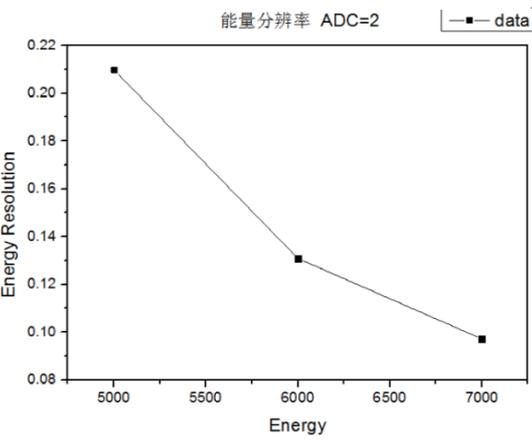
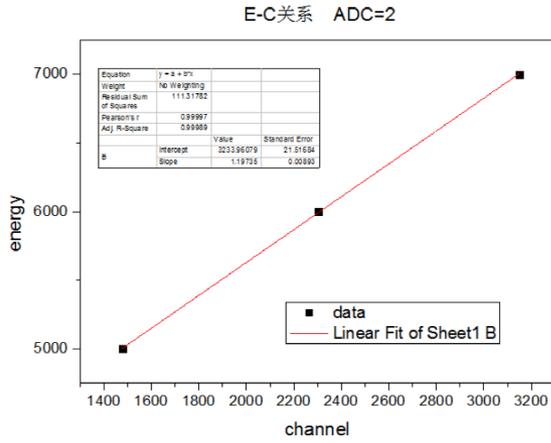
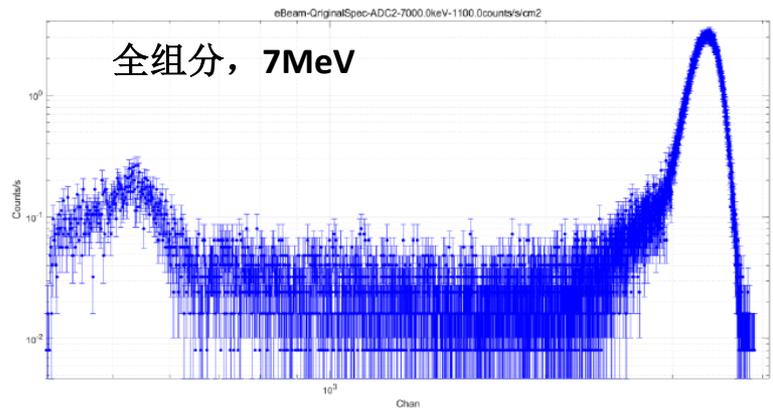
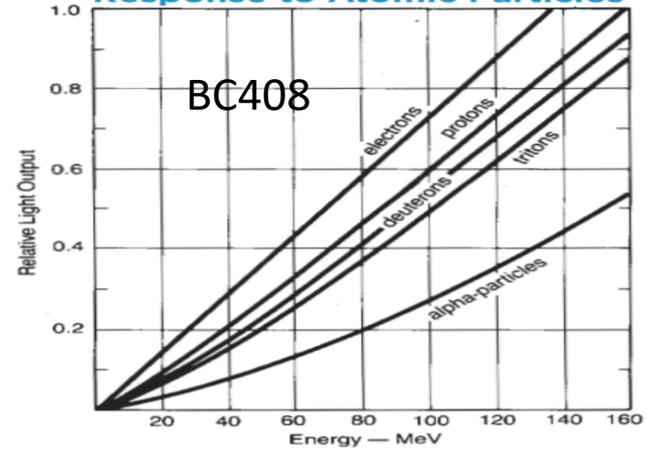
FitMean vs Corrected Bias, Det05\_Bi207-Peak2



# 3.CPD标定

## 3.4 质子能量响应标定

兰州质子束：5MeV~80MeV

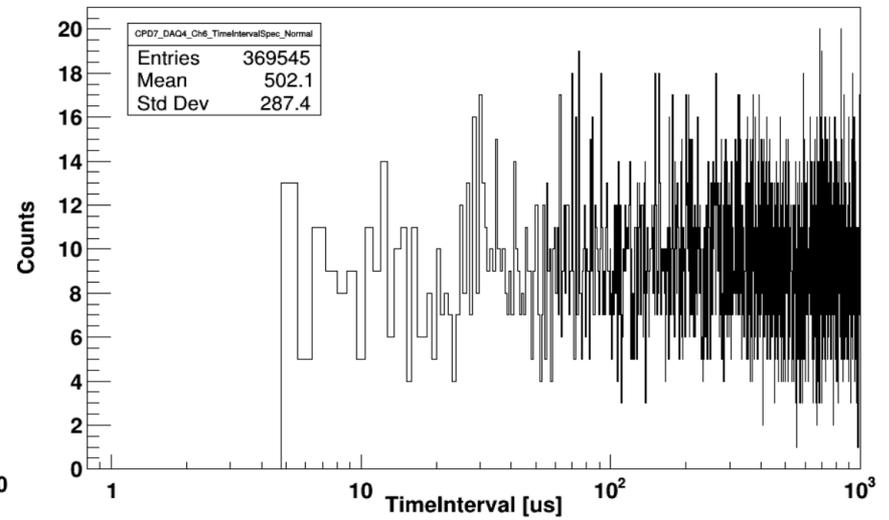
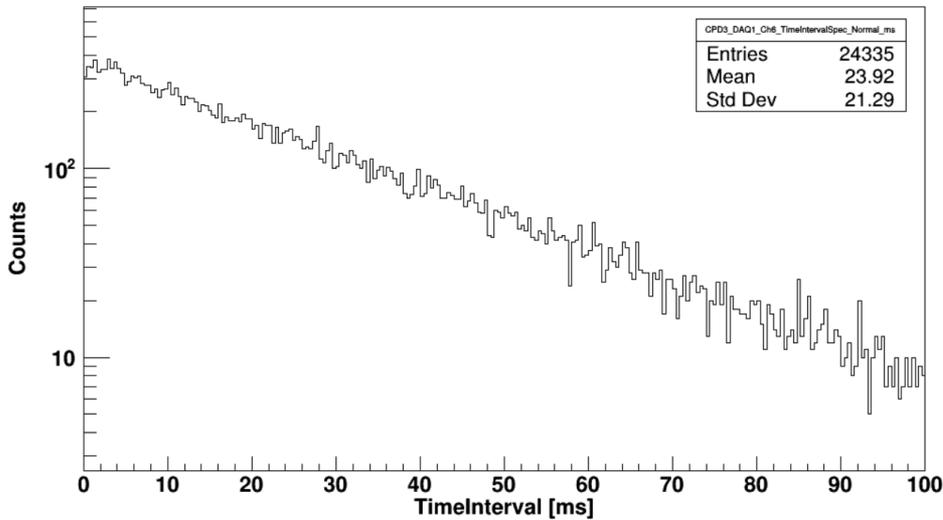


# 3.CPD标定

## 3.5 死时间

正常事例4.8us， 超高事例死时间70us

CPD3\_DAQ1\_Ch6\_TimeIntervalSpec\_Normal\_ms

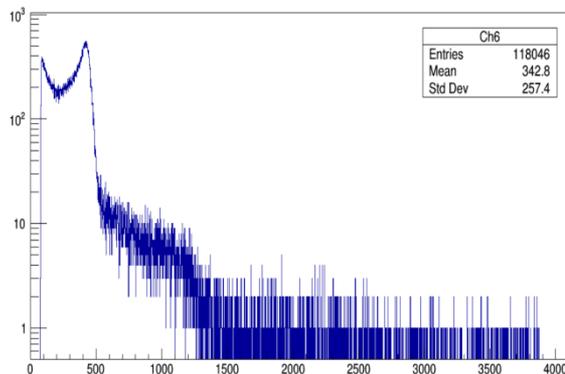
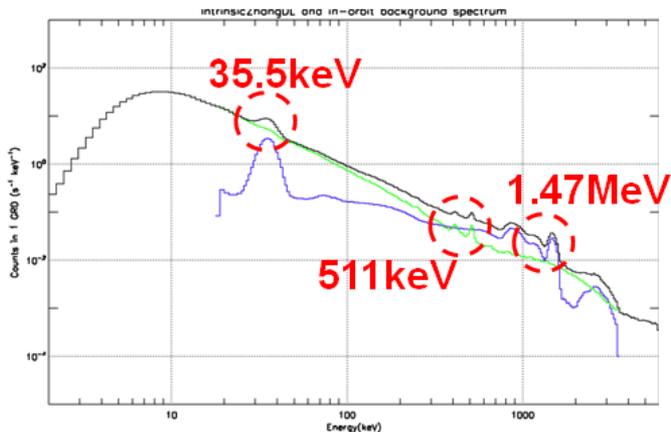


死时间=正常事例\*4.8us+超高事例\*(70+ $\Delta 1$ ) us+(超宽事例\*  $\Delta 2$ )us

# 4.在轨标定

## • 能量响应标定

利用在轨本底谱线开展标定(GRD至少有3条谱线, CPD有1条)



## • 有效面积标定

通过已知亮源掩食观测、脉冲星观测, 数据挑选, 对各个探头不同方向、能量的有效面积进行刻度。短期: 对爆发源的交叉标定。

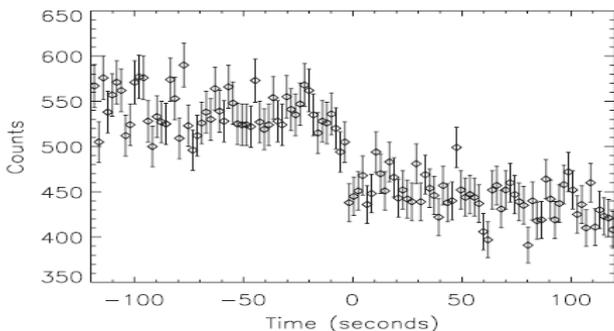


Figure 1. Single Crab occultation step seen in the CTIME raw count data of a single GBM NaI detector (NaI 2) in the 12–25 keV band with 2.048 s time bins. The Crab was 4:5 from the normal to the detector. The time window is centered on the calculated occultation time for 100 keV.

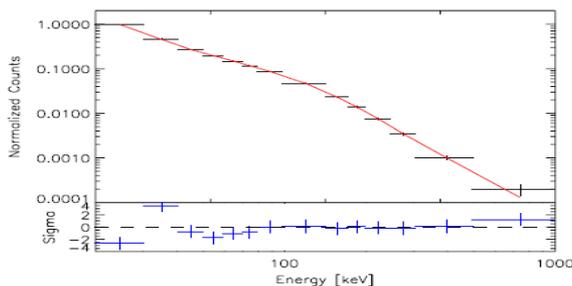
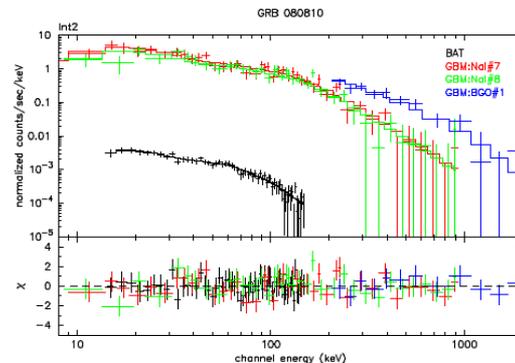


Figure 5. Fit to the Crab spectrum using 14,620 Earth occultation steps, approximately 1.7 Ms of on-source time, and 42 position bins. An average spectrum, averaged over the 69 spectra simultaneously fit, and the fit model are shown. The best-fit broken power-law model had a lower photon index of  $2.057 \pm 0.01$ , break energy of  $98 \pm 9$  keV, and an upper photon index of  $2.36 \pm 0.05$ .



# 4.在轨标定

- **定位系统误差:**

- 已知变源定位, 太阳耀斑定位
- 新源(GRB, XRB,etc): 交叉标定

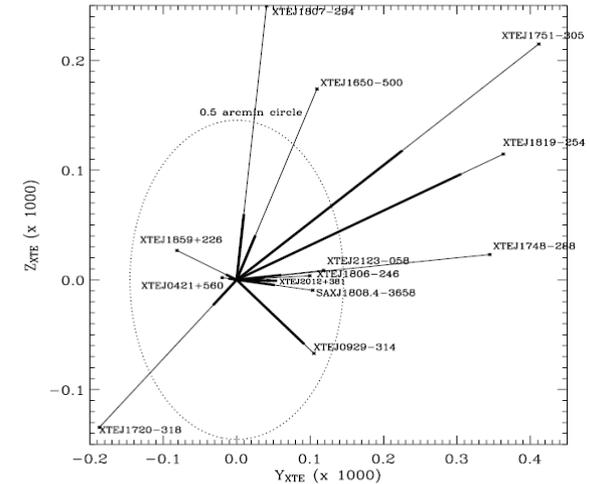
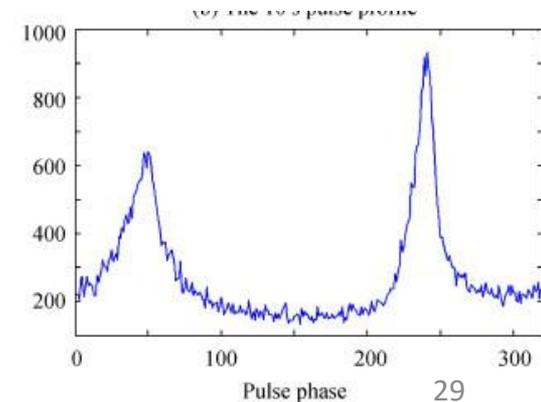


Fig. 34. Differences between PCA-derived positions of known sources and actual positions. The dark part of the offset is attributable to counting statistics; the remainder comes from source variability, ACS systematics, and inaccuracies in the collimator model.

- **时间系统:**

- 相对精度: GPS时间间隔分布宽度
- 绝对精度: 利用对脉冲星Crab等的观测, 进行太阳系质心修正和相位折叠, 获取脉冲轮廓。



# 5.总结

- **地面标定：** 已按照标定大纲要求基本完成了**GRD**和**CPD**的标定内容，获取了能量响应、有效面积、温度偏压响应及时间响应等重要参数，标定结果与蒙卡模拟基本相符，验证了 **GRD**和**CPD**质量模型的准确性。目前正在整理结果，将形成论文发表。
- **下一步：**
  - 1) 质量模型及响应矩阵库的更新；
  - 2) 在轨标定实施方案的编写和 准备

谢~谢!