Calibration Status of Hard X-Ray Modulation Telescope (Insight-HXMT) Mission

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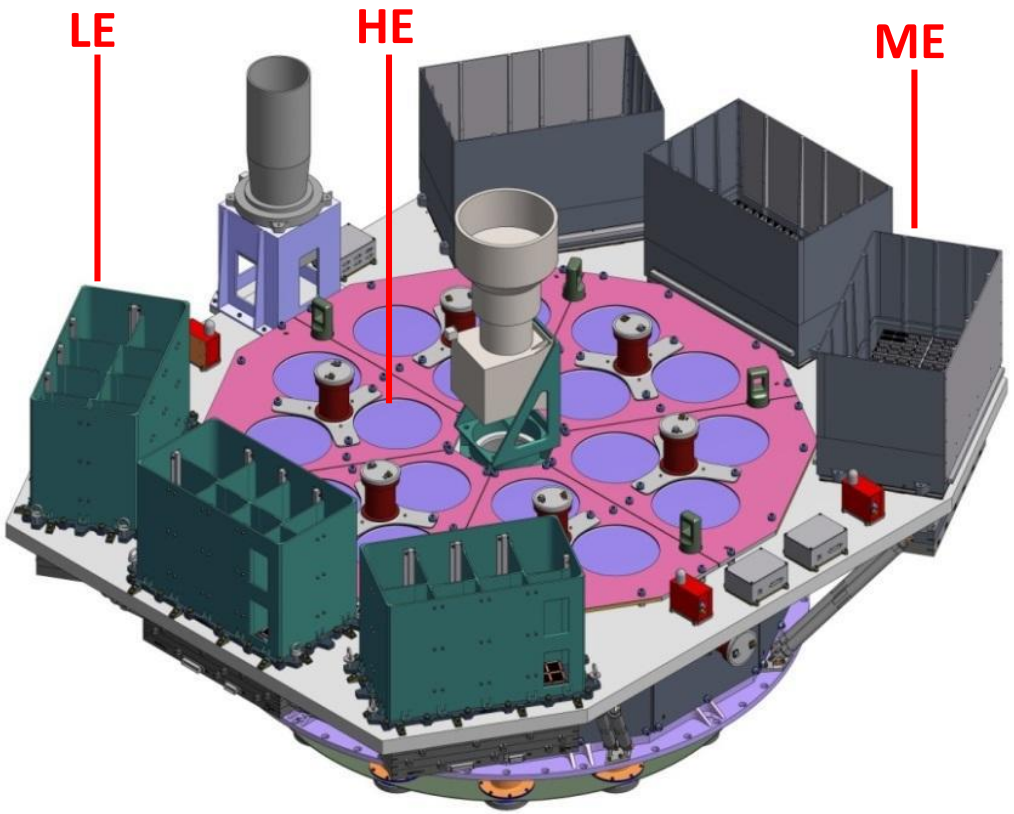
Outline

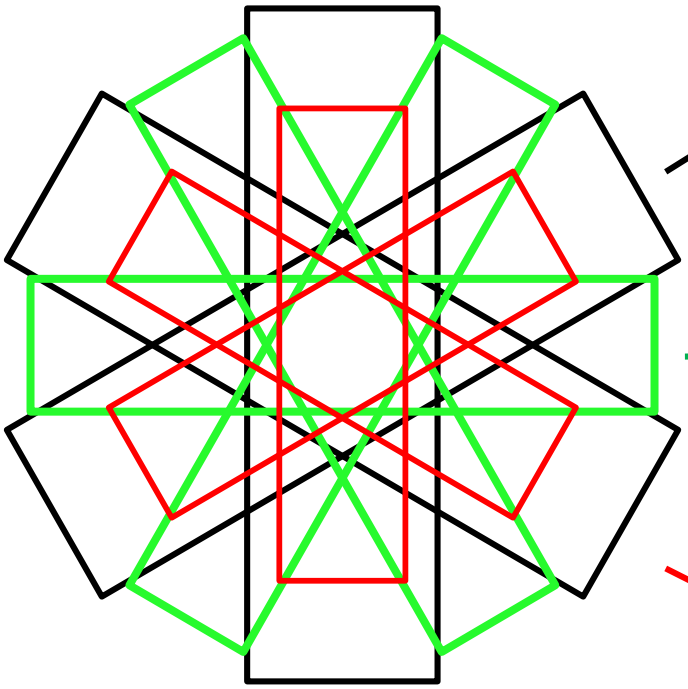
1. **Introduction of the Insight-HXMT**
   - Payloads
   - Observation Modes
2. **Calibration Status of HXMT mission**
   - Energy gain and resolution
   - ARF
   - Background model
3. **Summary**

1. HXMT introduction

- **Launched at Jiuquan on June 15. 2017**
- **Designed lifetime:** 4 years
- **Orbit:** circle, 550 km
  orbital period: ~96 mins
  orbital inclination: 43°
- **Instruments:**
  HE : 5000cm^2, 20-250keV
  18 NaI/CsI phoswich
  ME: 952cm^2, 5-30keV
  1728 Si-Pin
  LE : 384cm^2, 1-15keV
  96 SCD



1.1 Field of View



LE: 3.2 °×12 °

Energy resolution: <192eV@5.9keV

Time resolution: 1 ms

HE: 2.2 °×11.4 °

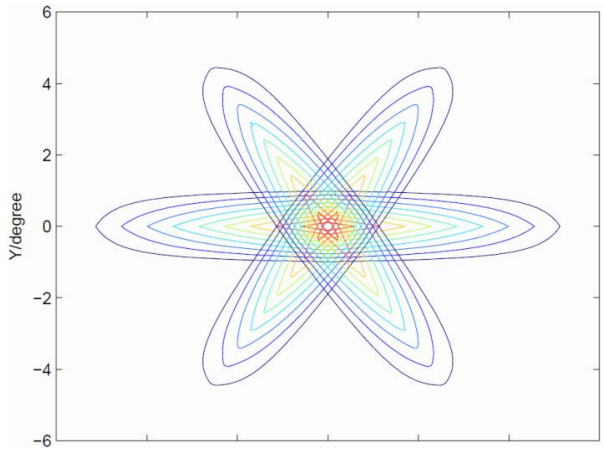
Energy resolution: 17.3%@60keV

Time resolution: 2 us

ME: 2 °×8 °

Energy resolution: 3kev@20keV

Time resolution: 276 us



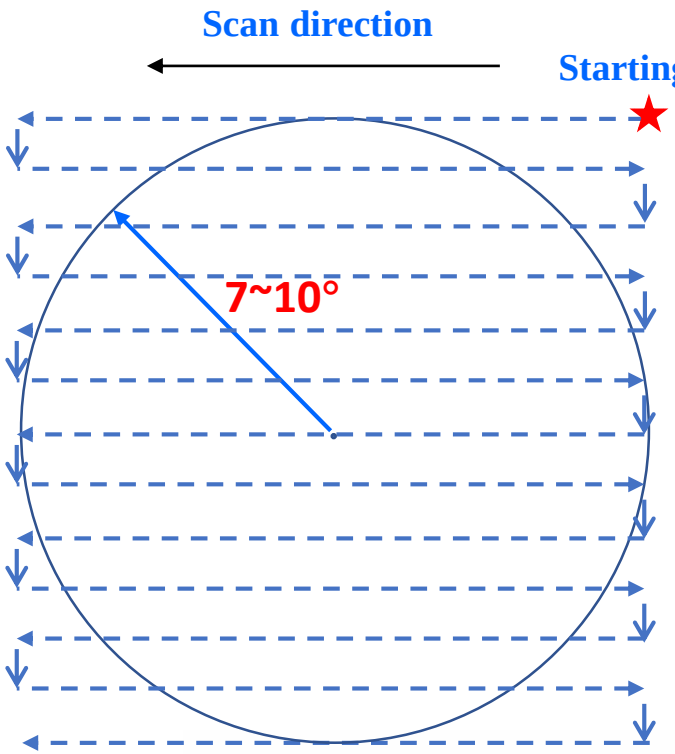
Point spread function (PSF)
for 15 HE detectors with small FOV

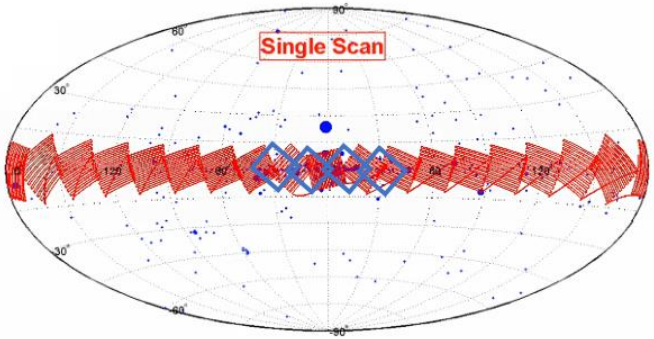
1.2 Observation Modes

- **Pointing Observation:**
  - Spectrum
  - Light Curve
- **Small Area Scan:**

  A square area of 14*14~20*20
  - Scan radius: 7~10 degree
  - Scan velocity: 0.01, 0.03, 0.06 deg/s
  - Scan step: 0.1~1 degree
  - Complete scan time: 2 hours ~ 5 days
  - Galactic Plane Scan

    ~ 1/3 of total observation time





Galactic Plane: (20°*20°)*18 + (20°*20°)*4

1.2 Observation Modes

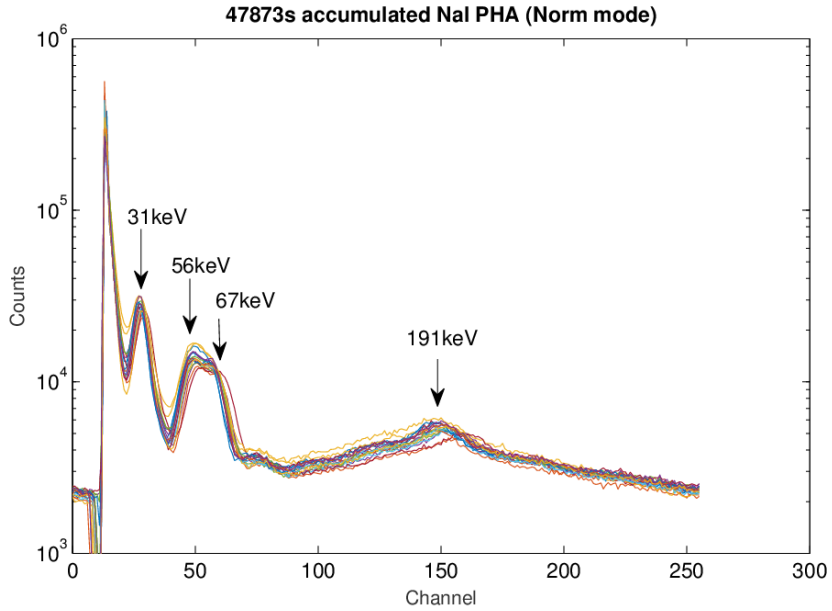
- **GRB Mode:** designed for HE
  - In this mode, the high voltage of PMT is reduced, so that the measured energy range of CsI goes up to 0.2-3 MeV.
  - Unique high-energy gamma-ray telescope to monitor the entire GW localization area and the gamma-ray counterpart, with the large collection area (~1000 cm^2) and microsecond time resolution.
  - ~ 30-40% of the observation time: during Galactic Plane Scan and earth occultation of Point observations

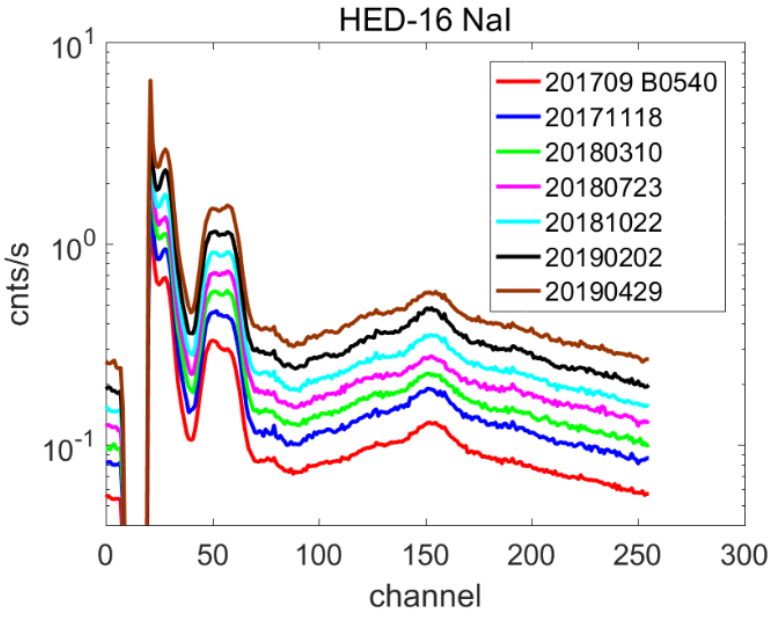
Working Mode	NaI energy band (keV)	CsI energy band (keV)	Detector Setting
Regular mode	**20-250**	**40-600**	Normal HV
GRB mode	**100-1250**	**200-3000**	Lower the PMT HV, turn off the AGC

2. Current Status of HXMT Mission

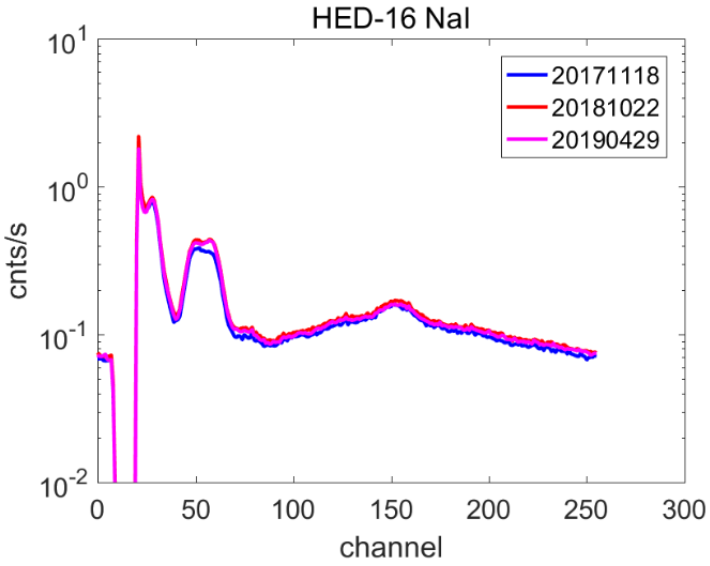
1. Energy gain and resolution
2. ARF
3. Background model
4. Some spectrum results of simultaneous observations with NuSTAR

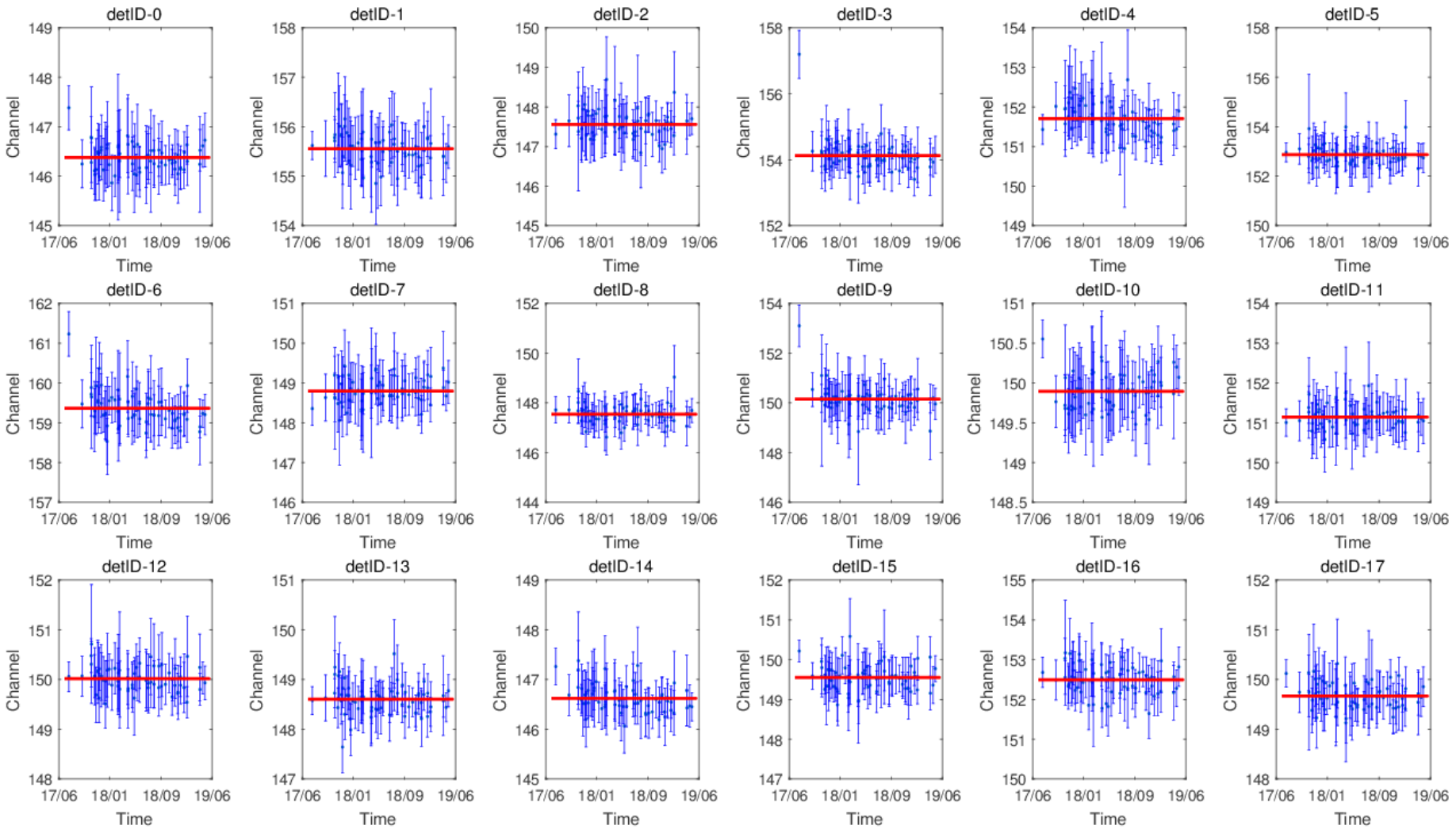
2.11 HE/NaI Energy gain calibration





- The background of HE is dominated by internal activation effects. Prominent background lines due to activation of iodine by cosmic and SAA protons are seen at 31, 56, 67 and 191 keV. These four lines can be used as the energy scale calibration combined with the ground calibration results.





- 191keV line will be used to monitor the stability of energy scale month by month.

2.12 HE/NaI energy resolution Cal.

- Deliquescent NaI on ground made the energy resolution worse. After 3 month in orbit, the resolution has kept almost same.

AGC @59.5keV
before launch

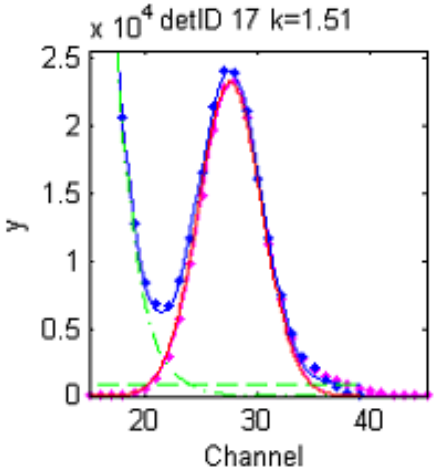
detID	201512 23	201612 21	201705 07	20170 622	20170 717	20170 828	20170 920	20171 101	20171 205
HED-1	15.30	17.35	17.48	18.46	18.72	17.77	17.69	17.85	17.68
HED-2	14.38	18.49	19.47	20.97	17.79	17.49	17.76	17.94	17.74
HED-3	14.60	16.87	16.97	18.34	17.89	17.59	17.46	17.35	17.41
HED-4	14.49	17.41	18.13	19.54	19.49	17.85	17.75	17.87	17.94
HED-5	14.71	18.13	18.46	19.92	17.91	17.81	17.77	17.49	17.90
HED-6	14.97	17.09	17.73	18.68	18.18	17.16	17.28	17.04	17.30
HED-7	14.39	21.59	23.82	27.06	21.72	19.46	19.47	19.26	19.70
HED-8	14.78	16.12	16.01	16.94	16.86	16.67	16.66	16.64	16.74
HED-9	15.90	17.13	17.46	18.21	18.26	17.90	17.75	18.05	18.13
HED-10	14.77	18.56	18.76	20.21	20.53	19.93	18.87	18.89	19.0
HED-11	14.17	15.34	15.59	16.20	16.42	15.92	15.83	15.70	15.98
HED-12	14.42	16.08	16.35	16.89	16.83	16.77	16.57	16.67	16.63
HED-13	14.83	16.07	16.36	17.28	17.09	16.92	16.88	17.07	17.01
HED-14	14.39	15.14	14.94	16.08	16.18	16.10	16.11	15.84	16.08
HED-15	14.51	15.68	15.98	16.87	16.93	16.67	16.62	16.82	16.76
HED-16	14.09	15.85	15.91	16.77	16.97	16.69	16.51	16.31	16.63
HED-17	14.26	16.92	16.92	18.28	17.93	17.39	17.49	17.43	17.69
HED-18	14.44	15.45	15.66	16.64	16.65	16.49	16.45	16.51	16.65

On ground:

$$\mathrm{R(Ch)} = \frac{a + b * Ch + c\sqrt{Ch}}{Ch}$$

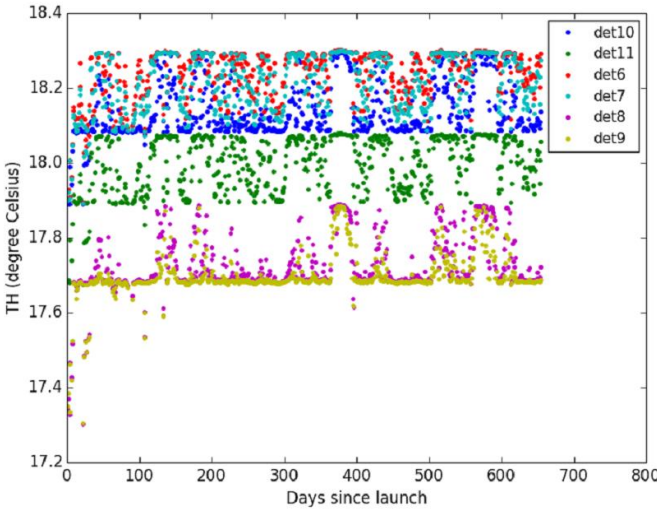
In orbit:

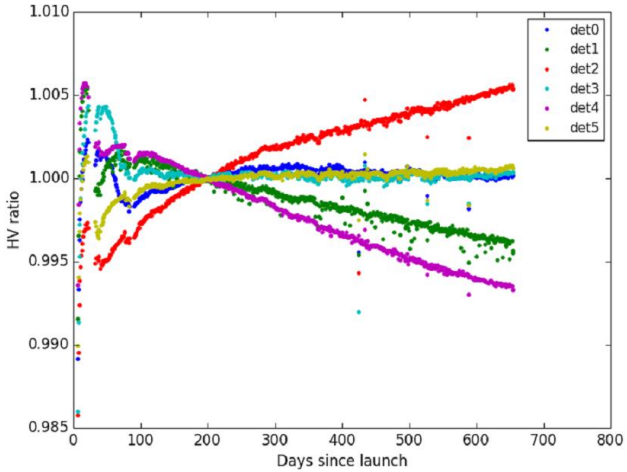
$$\mathrm{R(Ch)} = \frac{a + b * \frac{Ch}{kres} + c\sqrt{\frac{Ch}{kres}}}{\frac{Ch}{kres}}$$

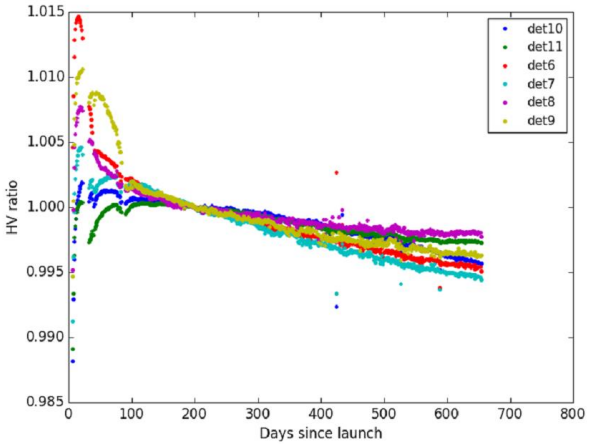


The energy resolution for 31keV will be used to estimate the energy resolution (kres) in orbit.

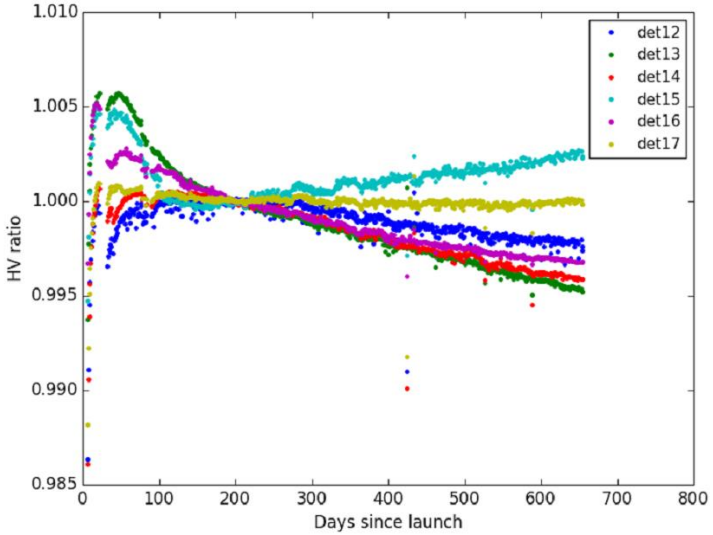
2.13 Temperature and HV of HE







- The temperature of HE is very stable in orbit: 0.6%-0.7%.
- Most High Voltage of the HE is decreased, only two has increased, water vapor has gradually evaporated from the NaI.



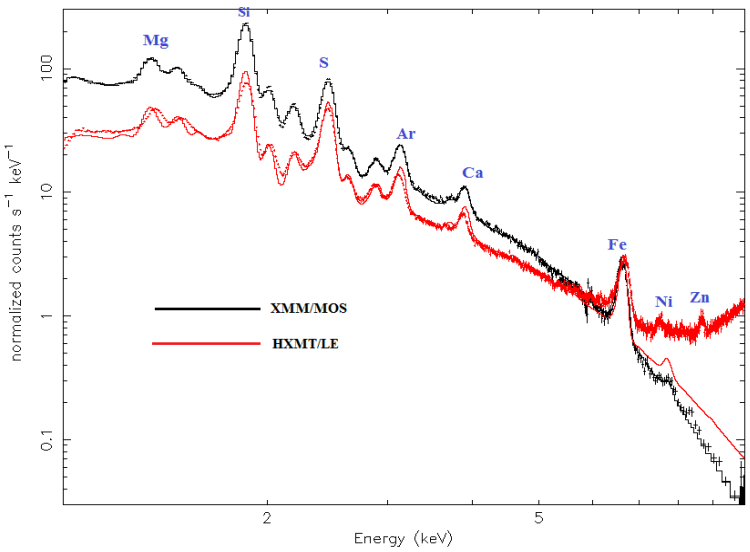
2.14 LE: energy gain and resolution calibration

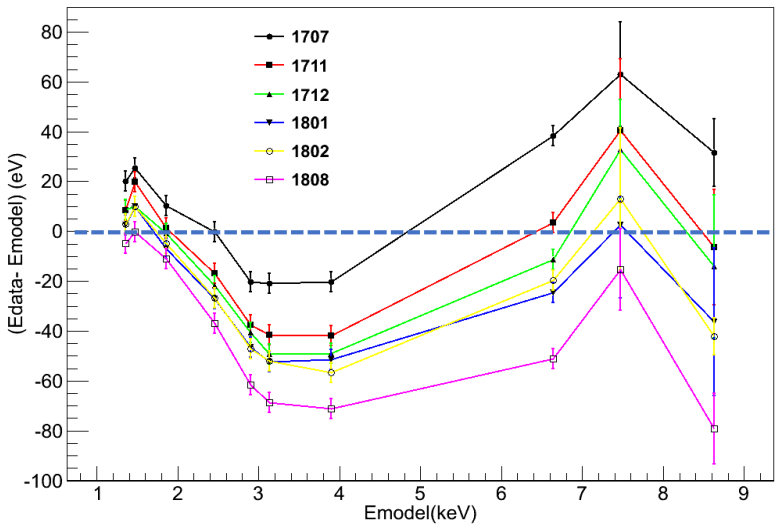
Cas A was used to calibrate the gain and resolution of LE.

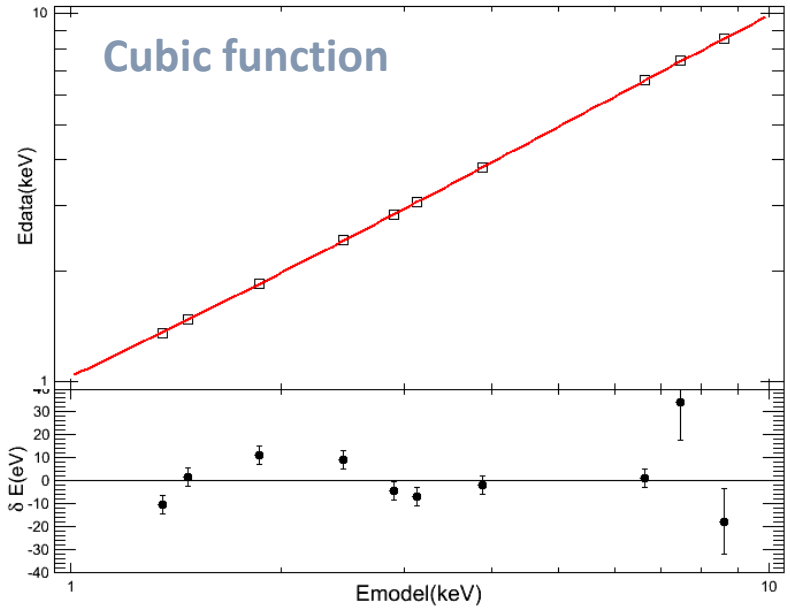
obsID	StartTime(UTC)	MJD: Days	Exp Time	Eff. Time(s)	Sun Angle
32601	2017/07/08	27.0261	100ks	23647	85
32603	2017/07/15		50ks	11739	88
32604	2017/11/06	145.083	50ks	15866	123
32605	2017/11/07		50ks	16260	123
32606	2018/01/31	239.144	200ks	45815	81
32607	2018/02/17		50ks	12051	72
32608	2018/07/30	423.898	50ks	22133	96
32609	2018/08/20		100ks	25669	103
32610	2018/08/24		100ks	29972	105
32611	2018/09/29	471.333	20ks	5361	120

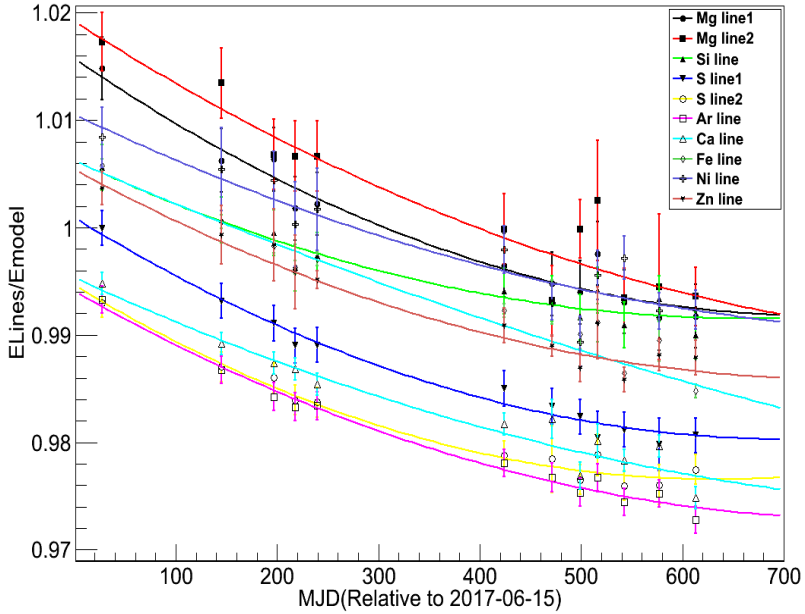
obsID	StartTime(UTC)	MJD: Days	Exp Time	Eff. Time(s)	Sun Angle
32612	2018/10/26	499.045	100ks	33467	124
32613	2018/11/12	516.278	100ks	21920	121
32614	2018/12/01	542.17	114ks	33562	114
32615	2018/12/15		100ks	39547	108
32616	2019/01/06	577	100ks	30711	96
32617	2019/01/17		100ks	26667	89
32618	2019/02/17	613.142	100ks	39186	72
30201	2017/12/28	196.837	30ks	19550	101
30202	2017/12/29		15ks		100
30203	2018/01/18	217.634	40ks	15960	89

2.15 LE: energy gain calibration

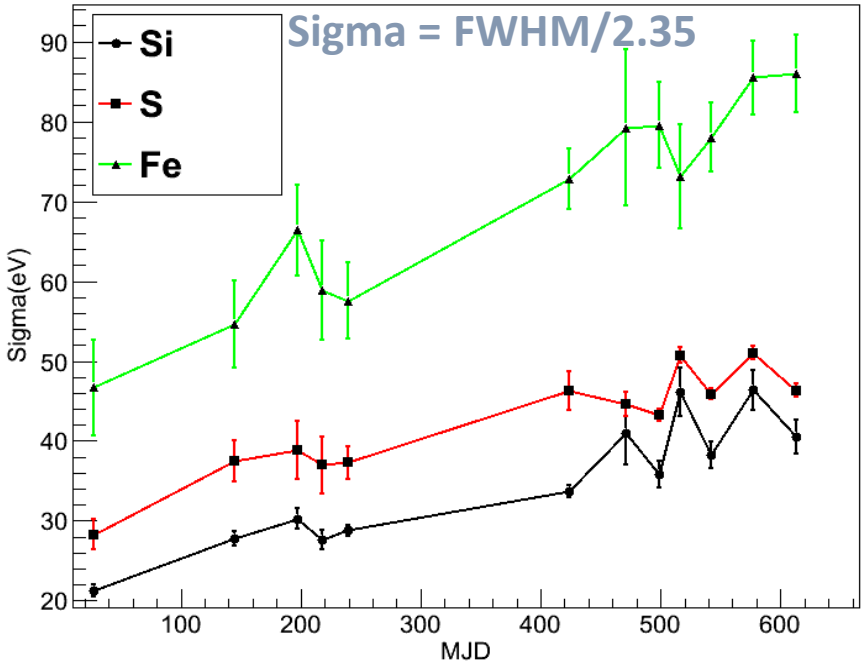


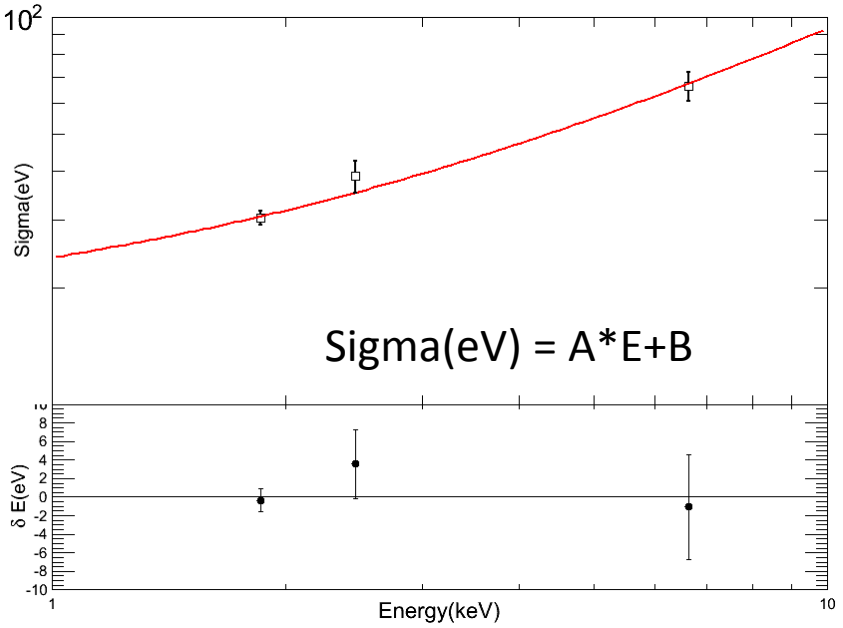






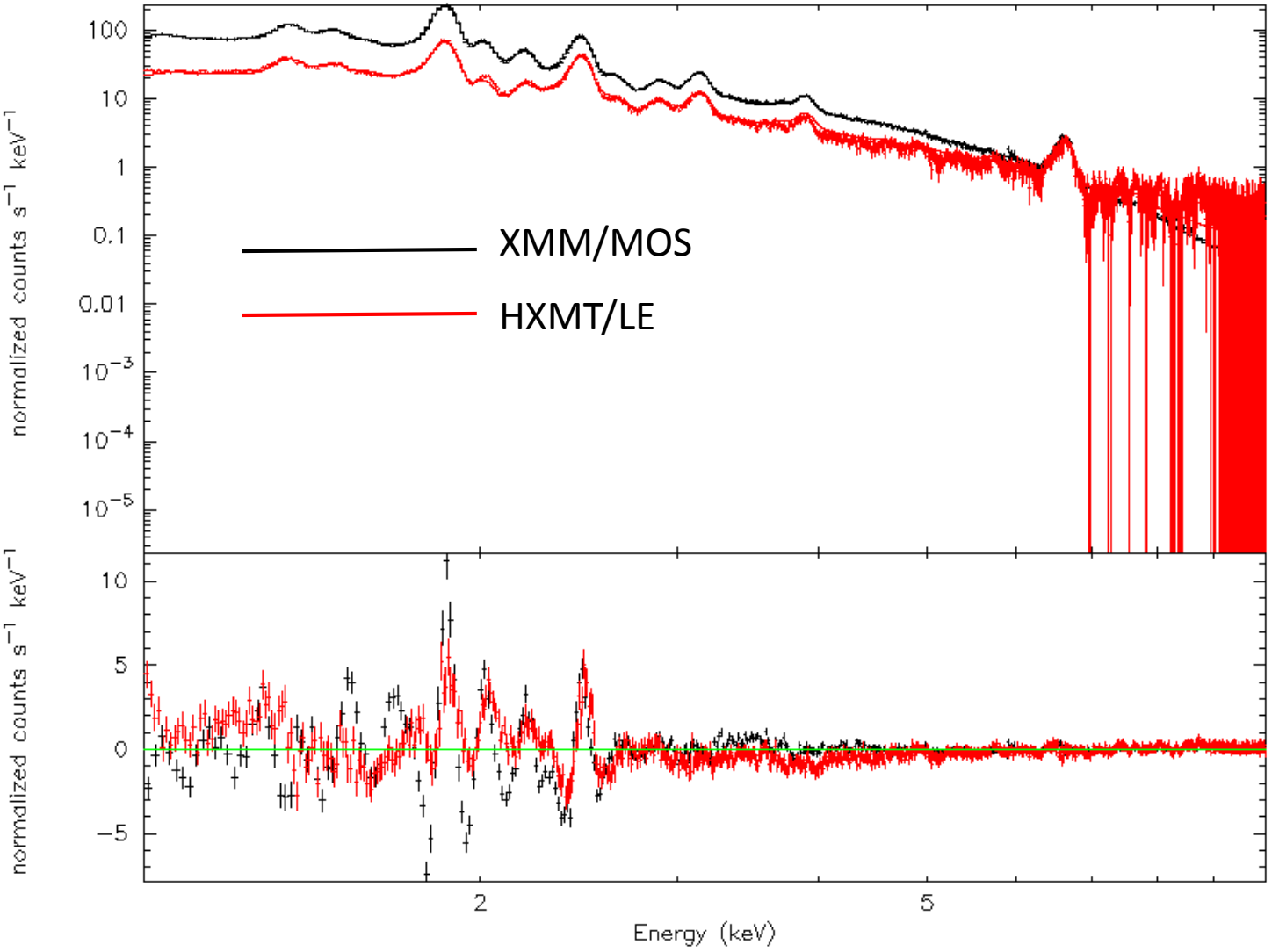
2.16 LE: energy resolution calibration





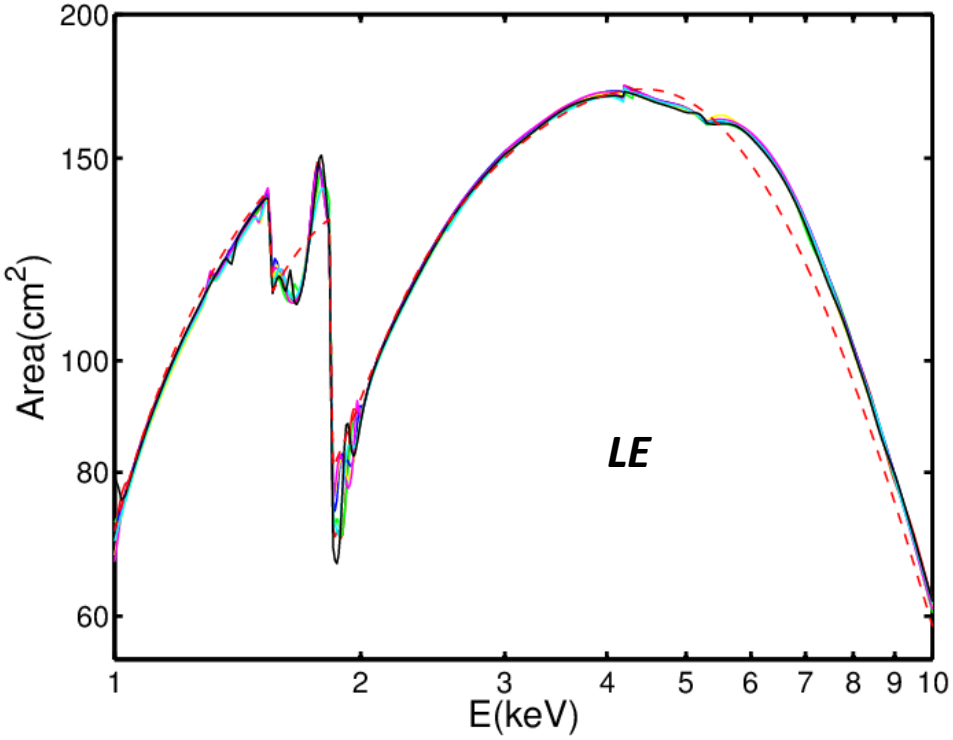
- Jointly fit the Si, S, Fe width of XMM and LE in different time to get the extra broadening of three lines.
- The energy resolution has changed compared with the pre-launch calibration. A extra broadening is required to spread the resolution underground.
- A function (Sigma(eV) = A*E+B) was used to fit the extra broadening using the 3 lines.

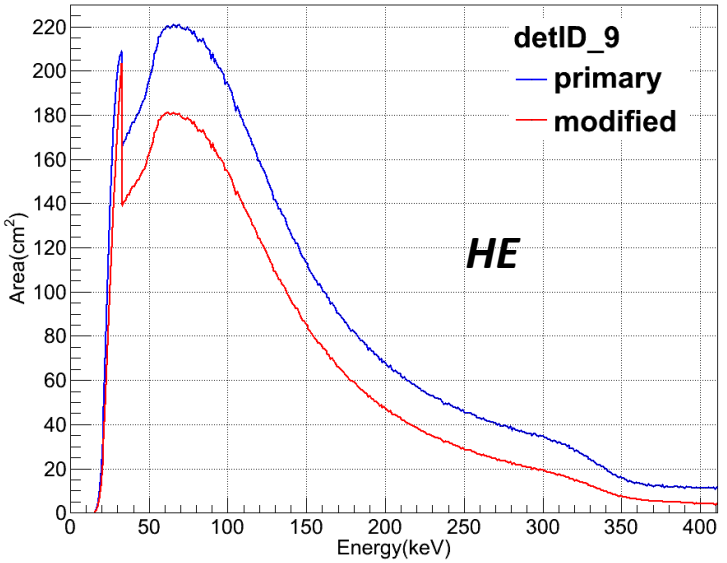
2.17 Cas A

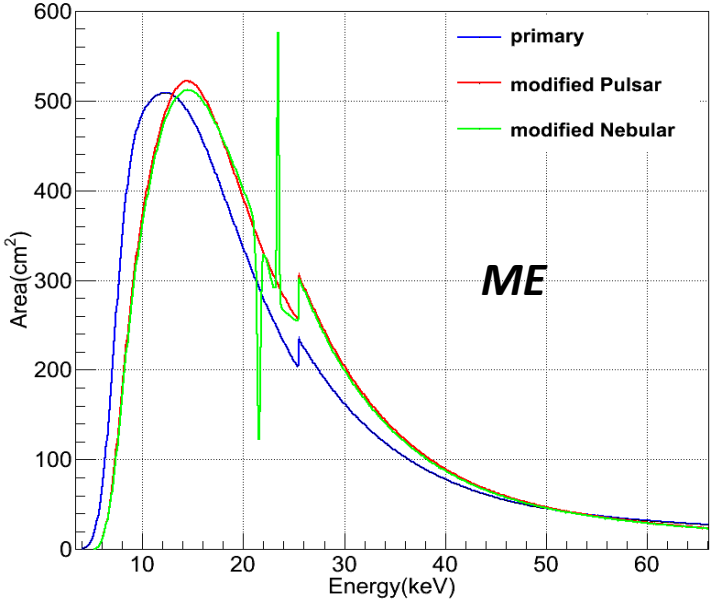

XMM/MOS
HXMT/LE
normalized counts s^{-1} keV^{-1}
normalized counts s^{-1} keV^{-1}
Energy (keV)

2.2 ARF calibration

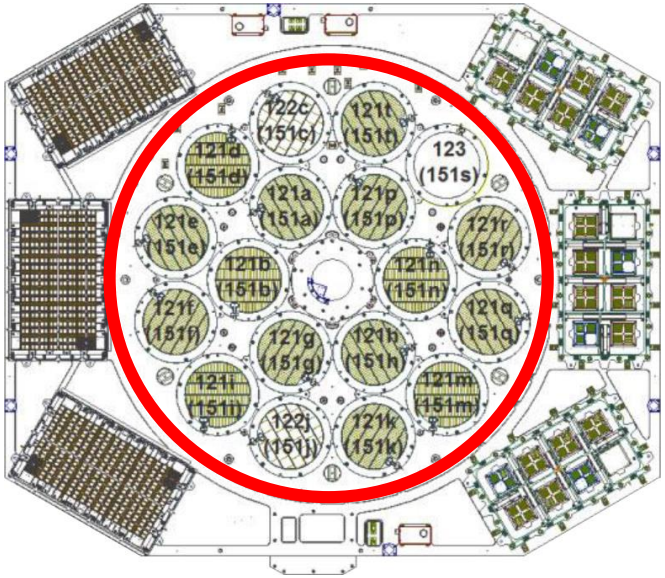
- Crab nebular was used to calibrate the ARF(NH=0.36, Norm=9.71, index=2.11)
- The dashed line is the simulated effective areas of LE.

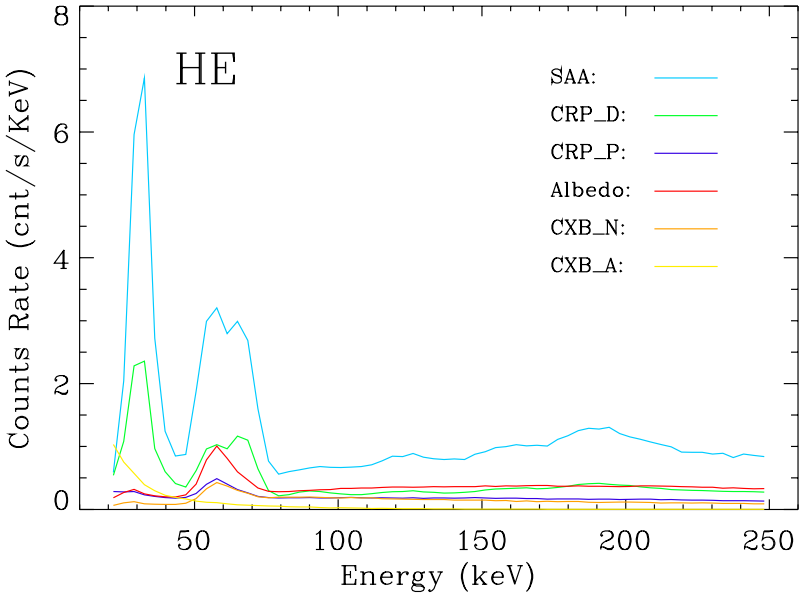






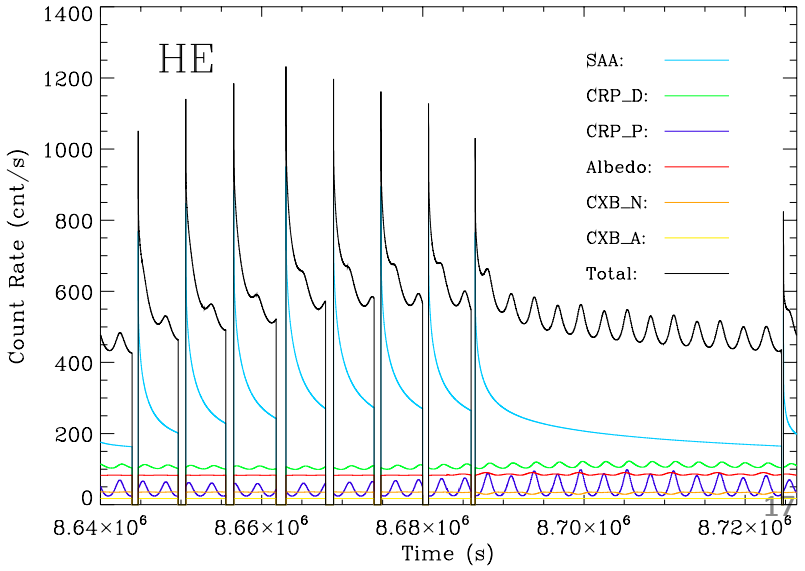
2.3 HE Background



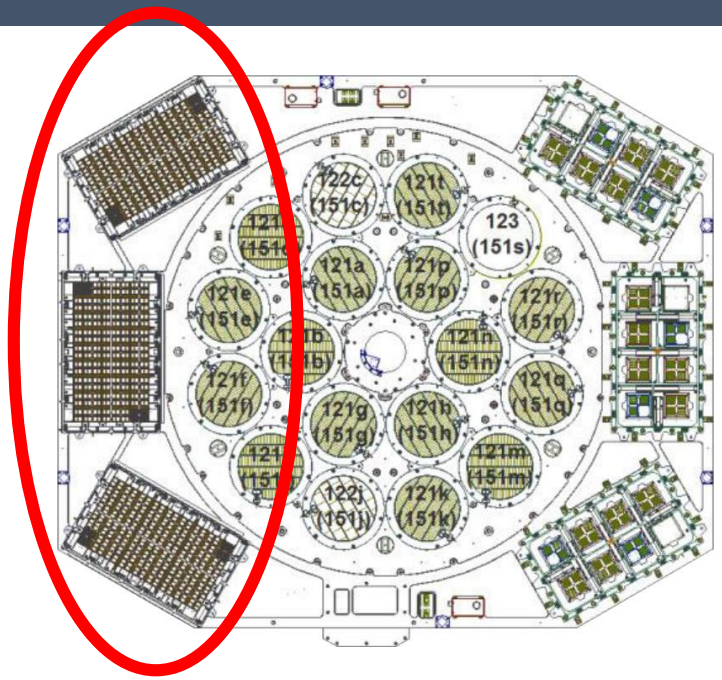


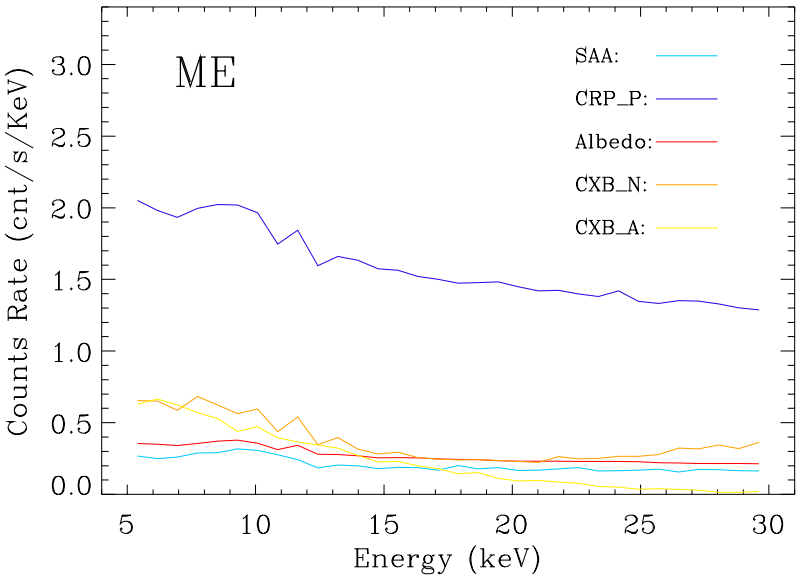
Delayed BKG (dominant):
Activated by Cosmic ray proton,
SAA proton (> 100 MeV)

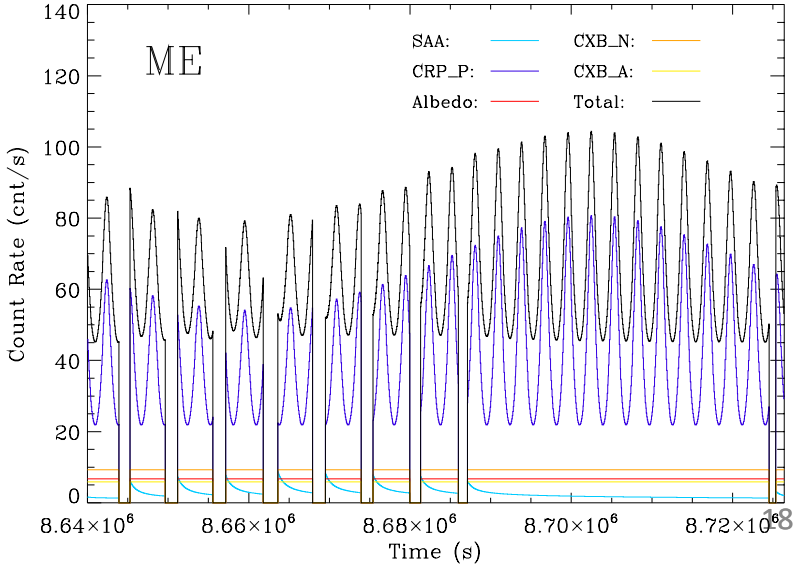
Prompt BKG:
Cosmic ray proton, Albedo
Gamma-Ray, CXB



2.3 ME background

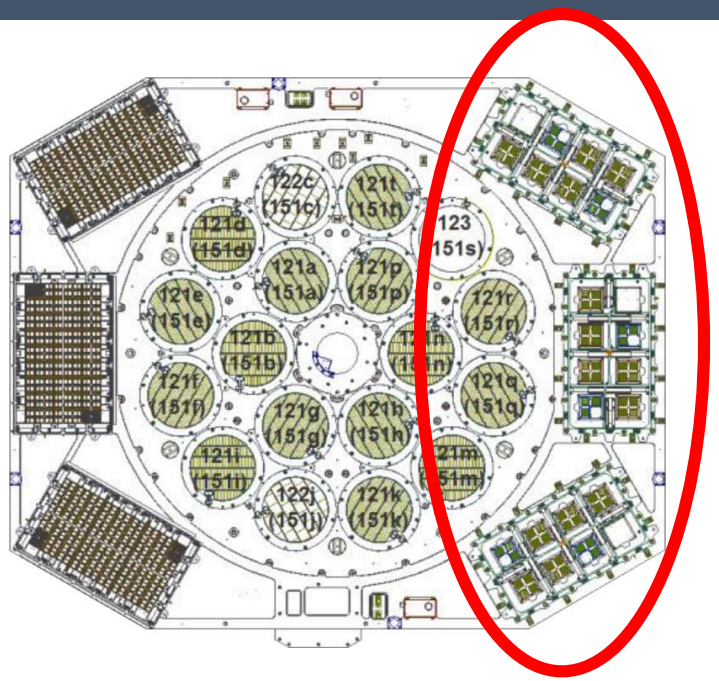


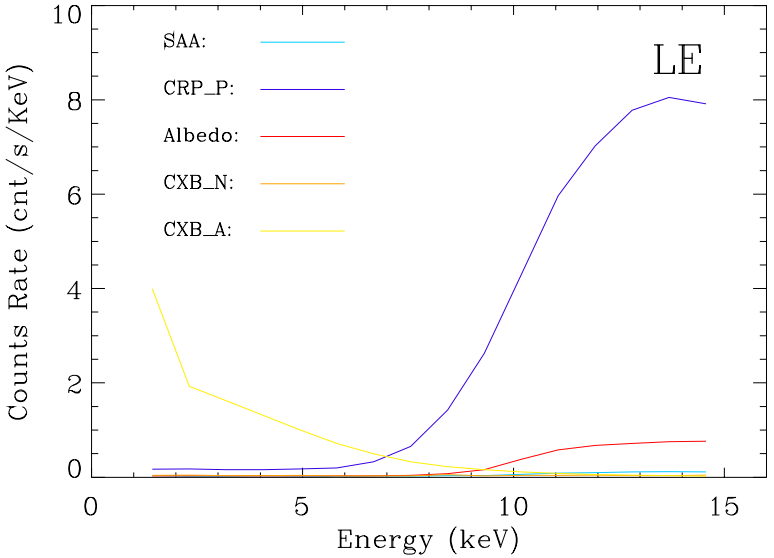


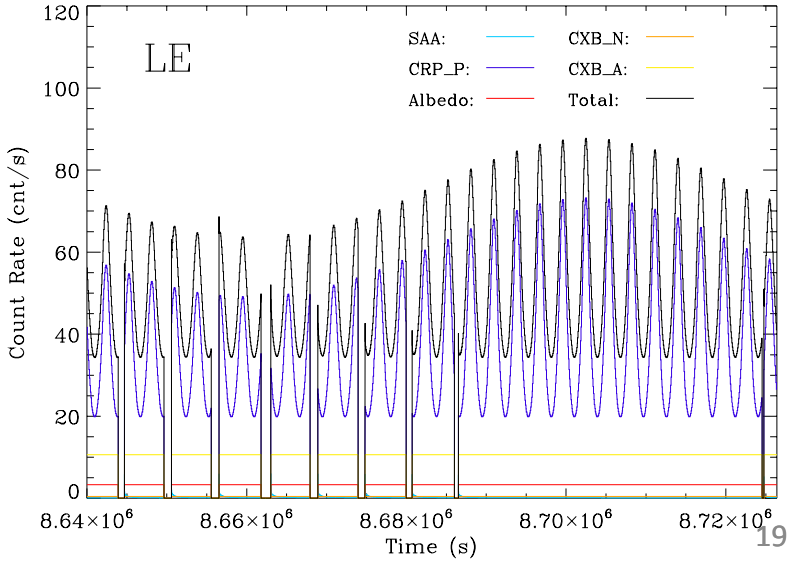


Prompt BKG:
CRP(dominant), CXB,
Albedo Gamma-Ray,

2.3 LE background







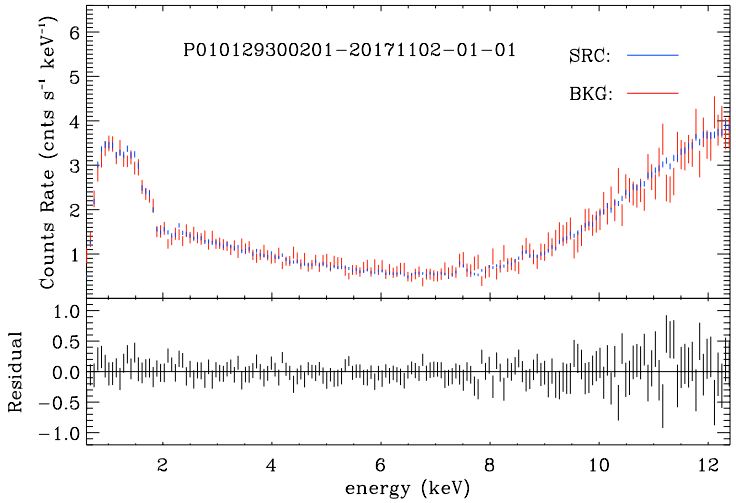
Particle BKG:

CRP (dominant > 7 keV)

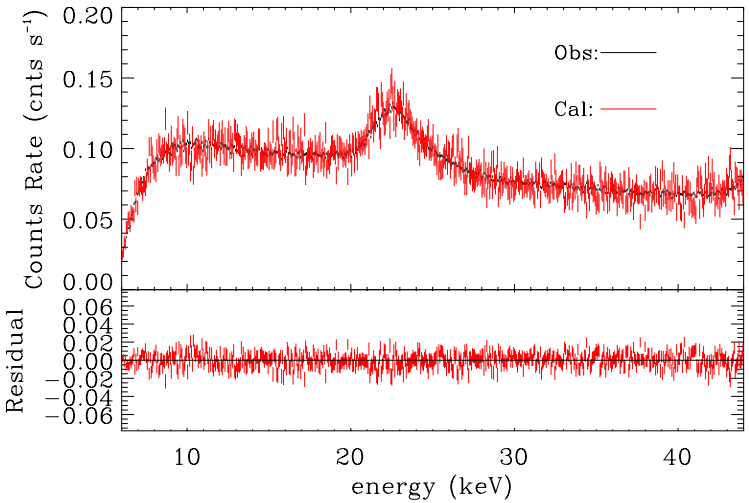
Diffused BKG:

GXB/CXB (dominant < 7 keV)

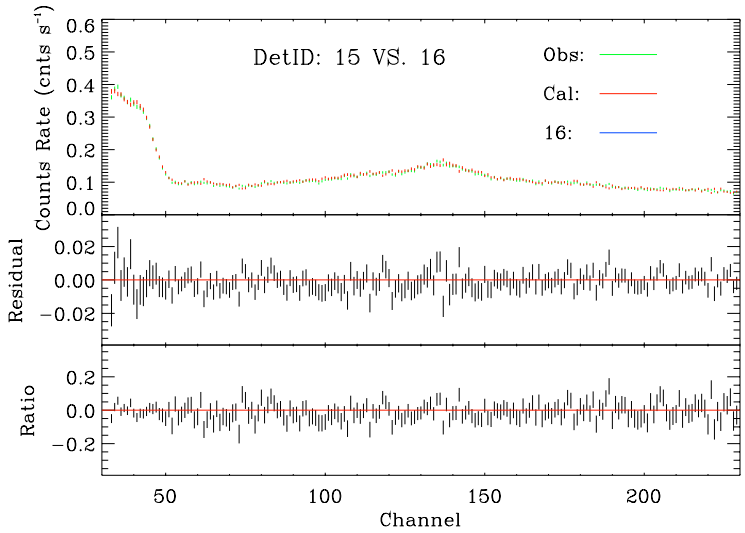
2.4 Background Model for HE/ME/LE



LE



ME

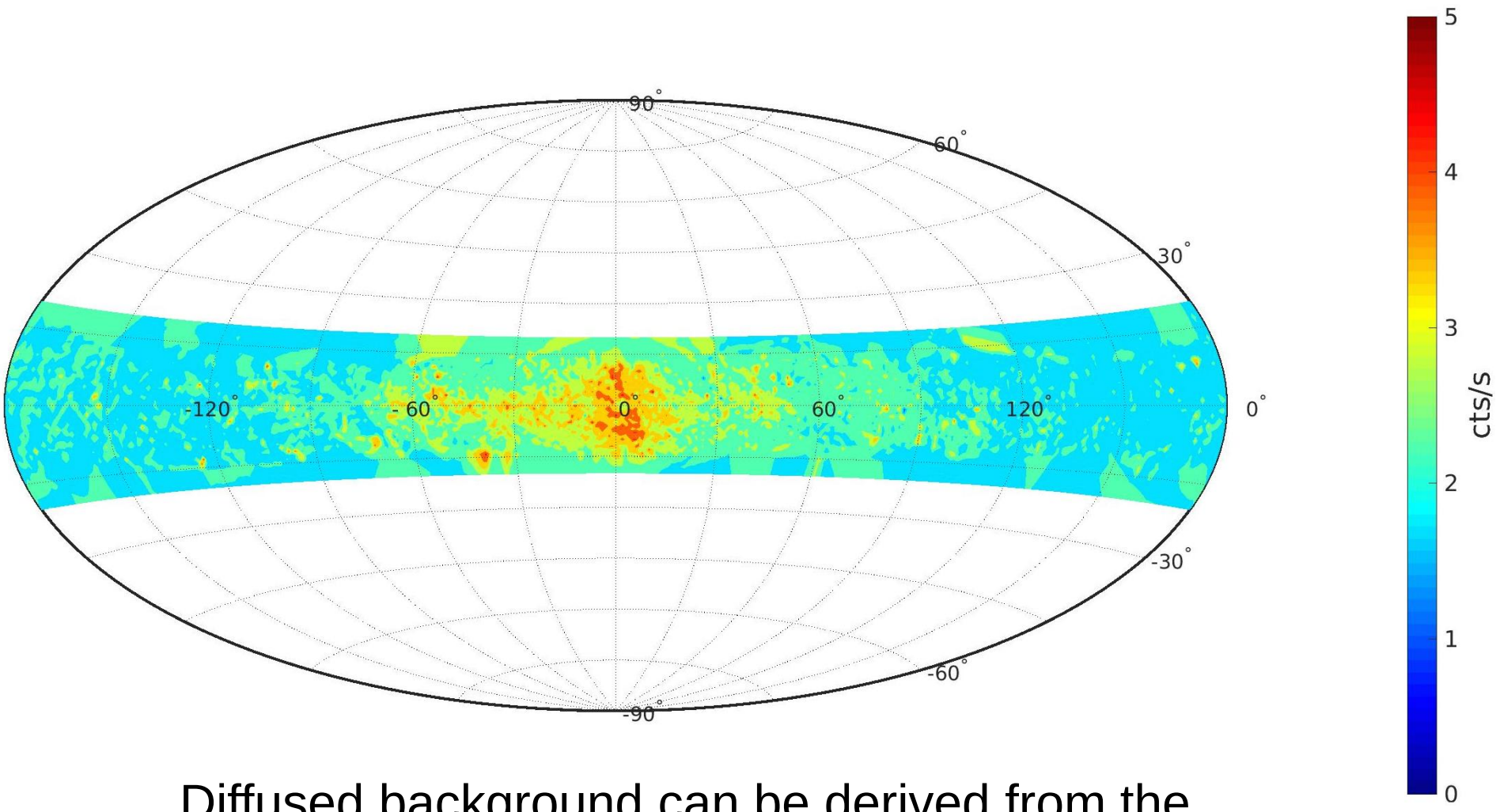


HE

The three telescopes (HE, ME, & LE) can give correct estimation of the background.

For the observation of Galactic plane, the LE BKG at the low energy band (< 7 keV) is dominant by the diffused X-ray.

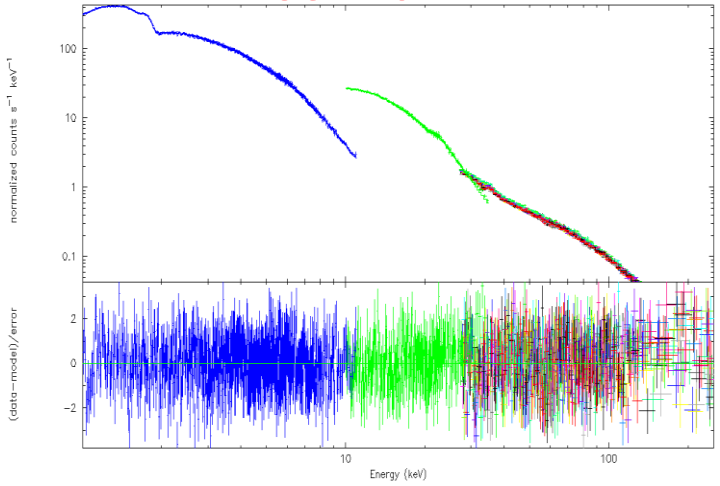
2.4 Diffused Background in Galactic Plane



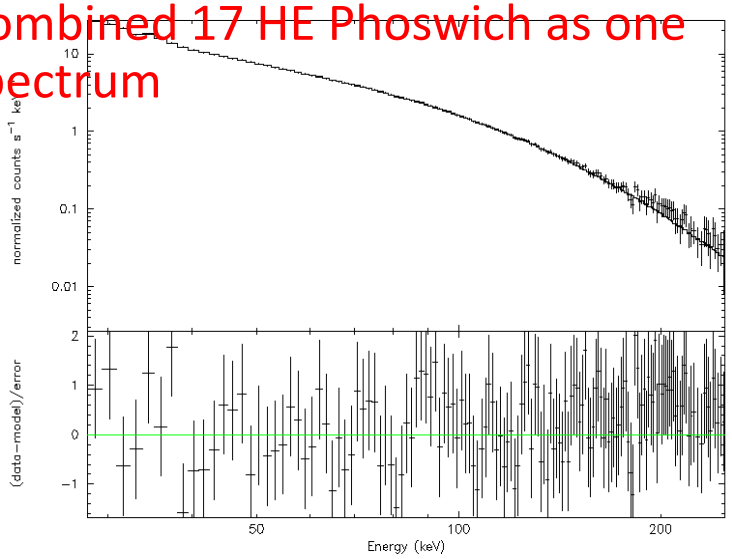
Diffused background can be derived from the galactic plane scanning survey (1-6 keV)

2.5 Crab nebular

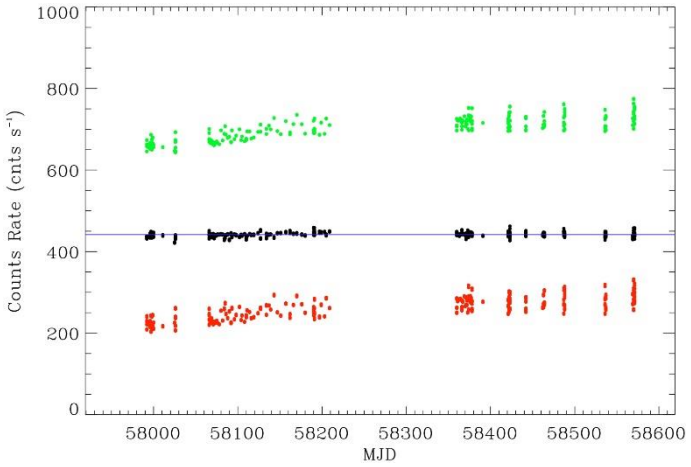
17 HE Phoswich+ME+LE



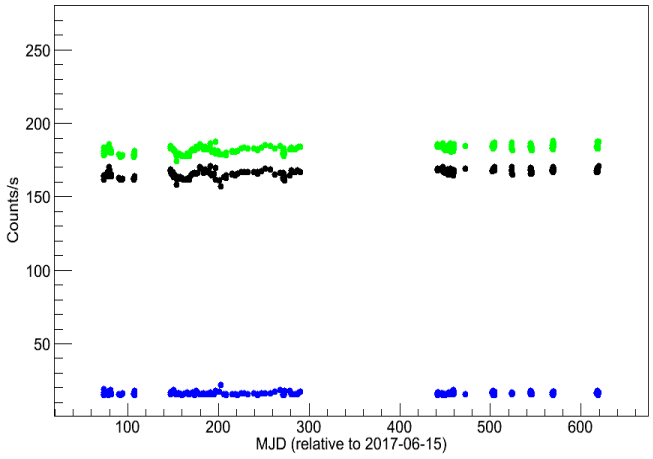
Combined 17 HE Phoswich as one spectrum

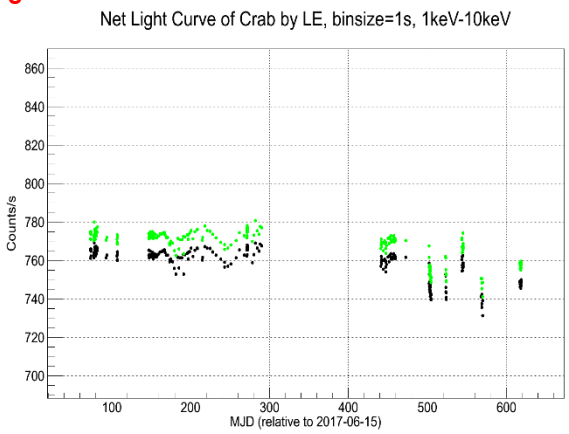


Light Curve by HE, 30-150keV, 1.2%

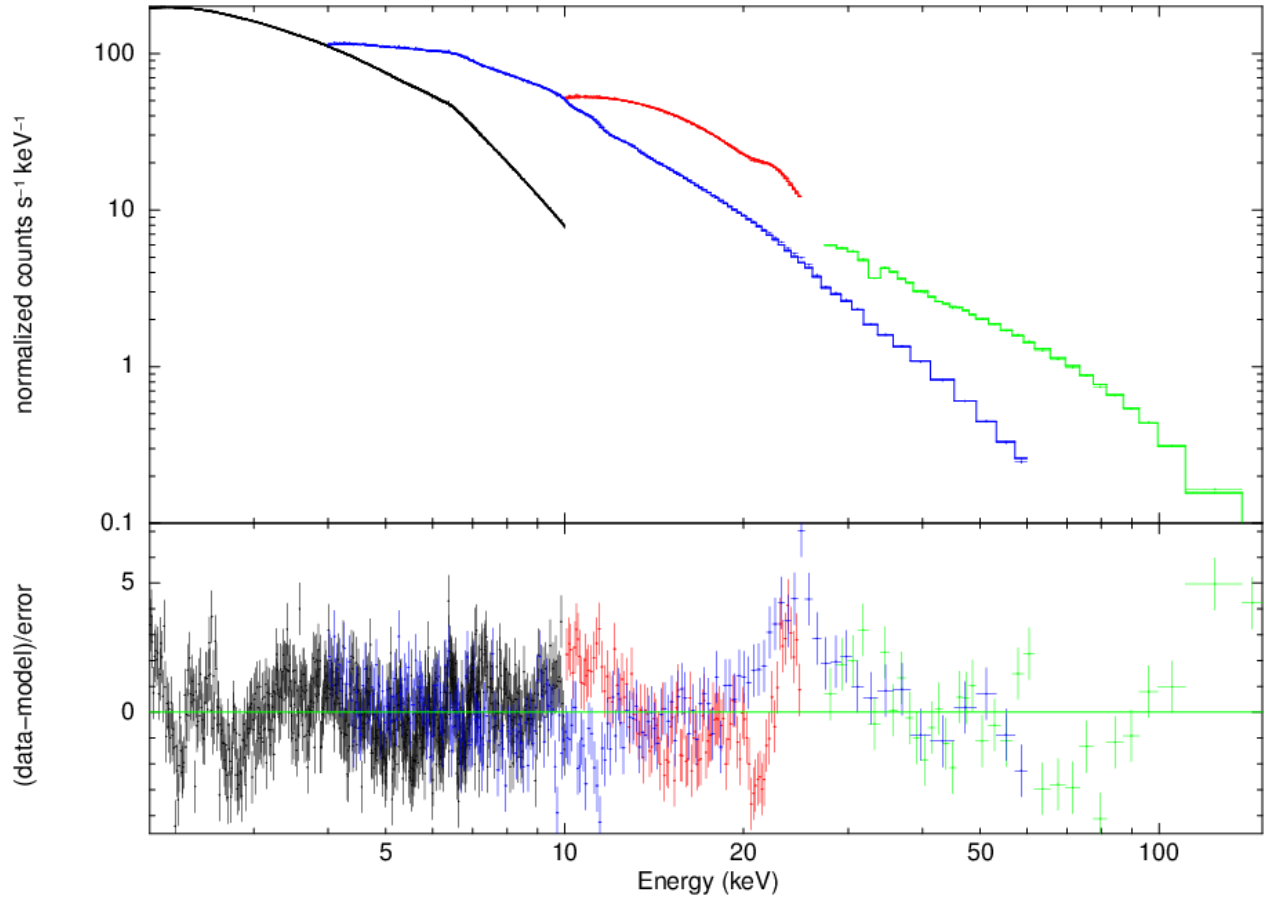


Light Curve by ME, 10-20keV, 2%



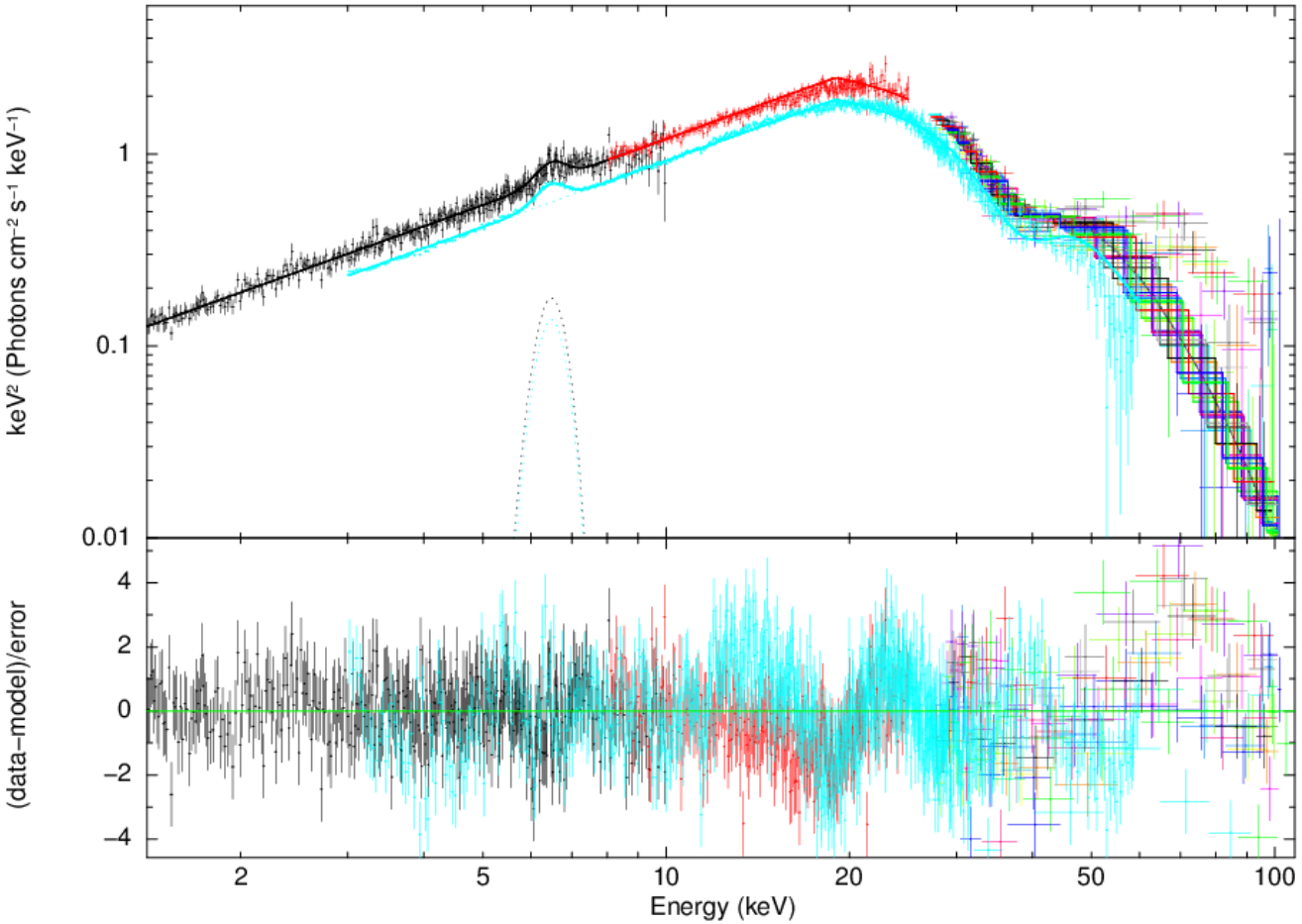


2.5 Maxi J1820+070 (~4 Crab)



- Blue: NuSTAR
- No systematic error was added, 1% will be better.

2.5 Her X-1



- From other simultaneous fit with NuSTAR and Swift/XRT(Maxi J1535-571, Swift J0243.6+6124), we know the systematic error of calibration and background for HE/ME/LE is about:1%-2%.

3. Summary

- Insight-HXMT has worked smoothly for 700 days, and all the instruments work well.
- The gain and resolution are stable for HE and ME. They have been monthly monitored. Cas A was used to calibrate the gain and resolution of LE.
- The in-orbit calibration and the BKG estimation models have been confirmed and the systematic error of three payloads is about 1%-2%.
- Homepage: http://hxmt.org

Thank you!