In-orbit calibration status of Insight-HXMT

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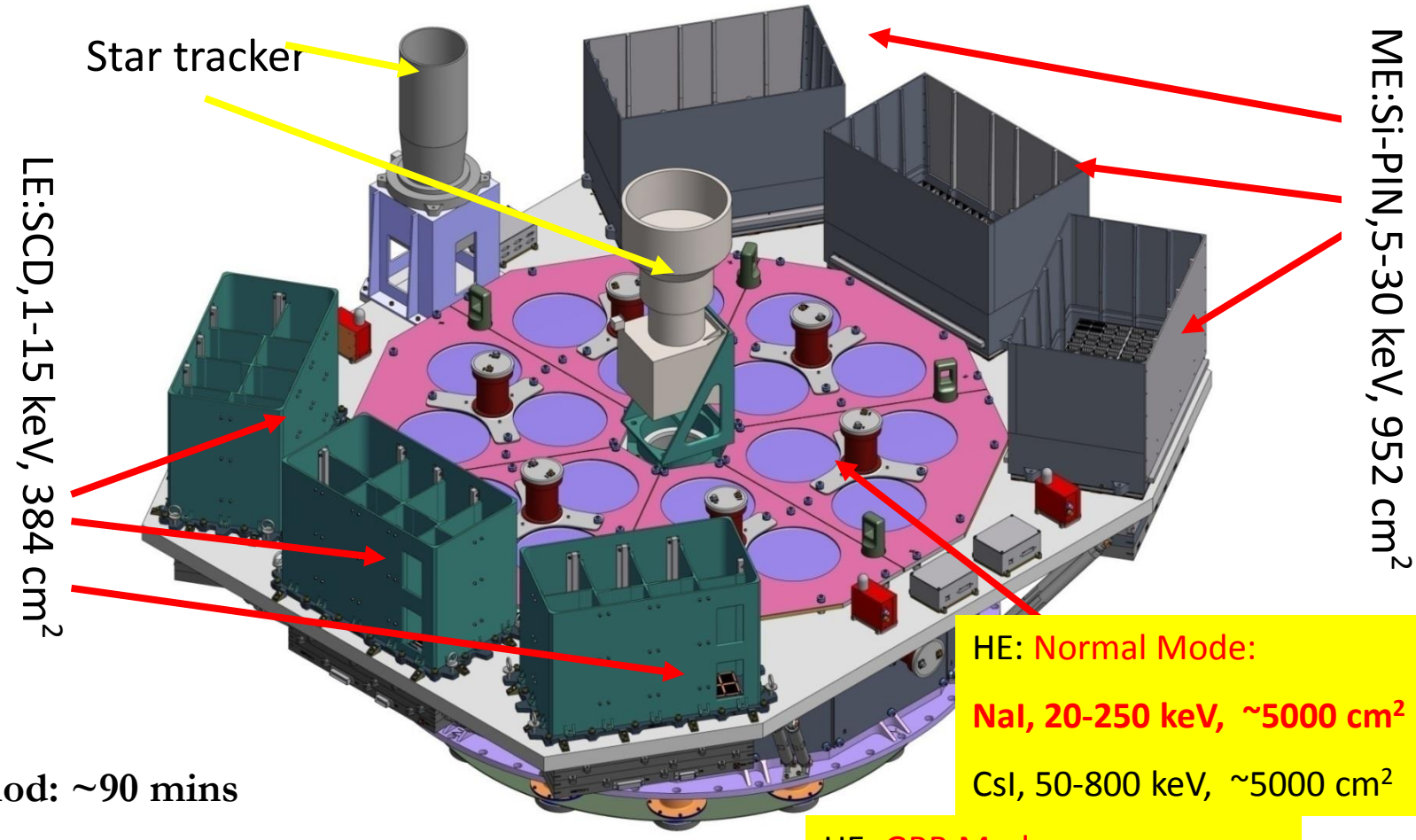
Outline

- Introduction to the payloads of Insight-HXMT: HE/ME/LE
- In orbit calibration status
- Background model estimation
- Summary

1.Science payloads



HE: Normal Mode:

NaI, 20-250 keV, ~5000 cm²

CsI, 50-800 keV, ~5000 cm²

HE: GRB Mode

NaI, 100-800 keV, 5000 cm²

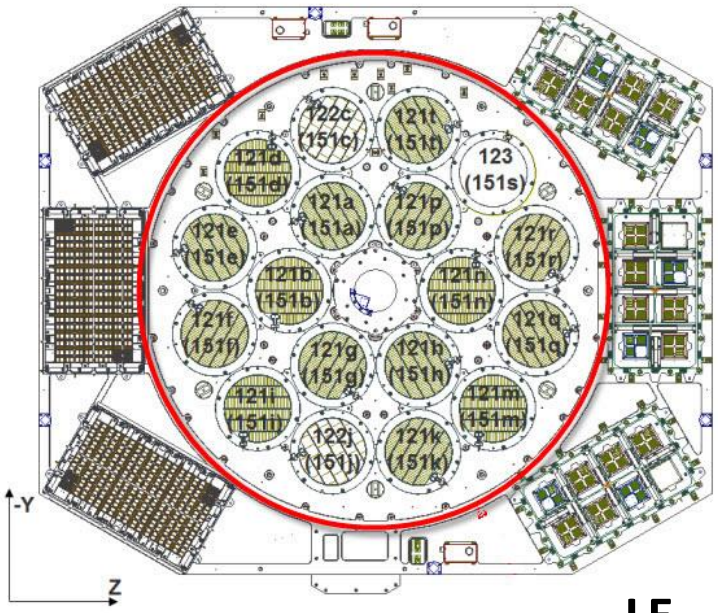
CsI, 250-3000 keV, 5000 cm²

orbital period: ~90 mins

orbital inclination: 43 degrees

Launch time：2017.6.15

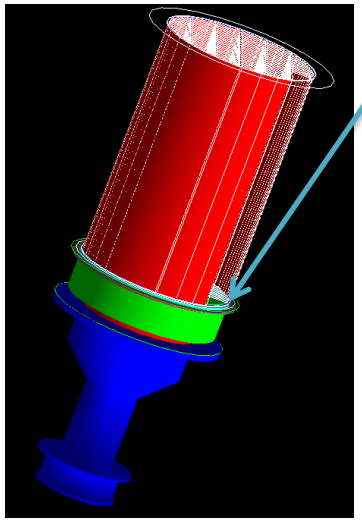
The high energy X-ray telescope: HE



ME HE LE

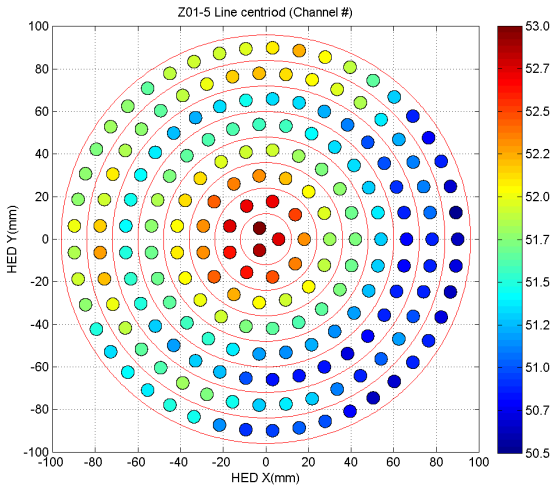
- 18 identical **NaI(Tl)/CsI(Na) PHOSWICHs**, a collimator is equipped in front of each phoswich to form the different field of view (FOV)
- 18 anticoincidence detectors (6 top +12 lateral side)
- 18 automatic gain control detectors(AGC):
  - ^{241}Am + plastic scintillator

PHOSWICH:

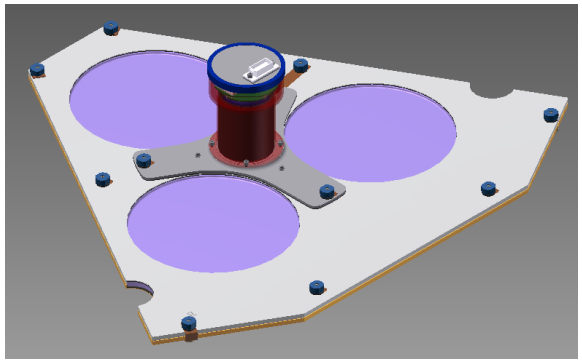


AGC:

Full energy Peak of 50 keV on 192 positions of NaI

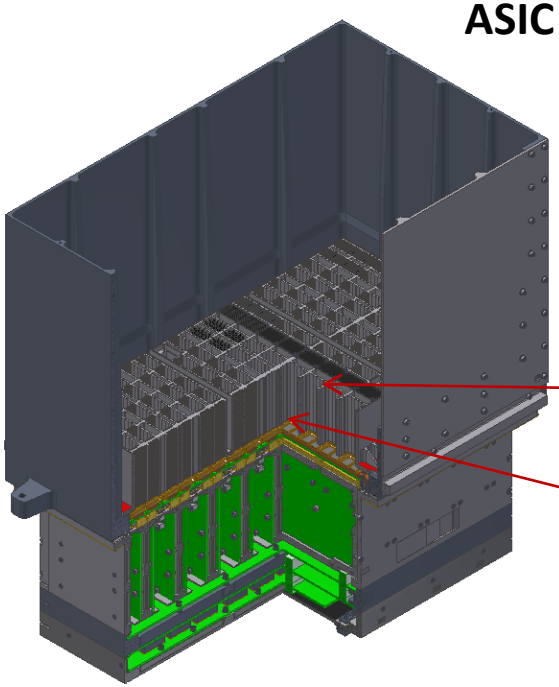


Top ACD:



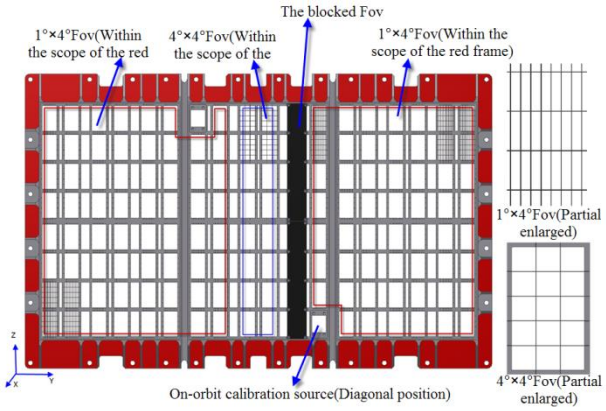
The medium energy X-ray telescope: ME

ME uses 1728 Si-PIN detectors read out by 54 ASIC (application specified integrated circuit).

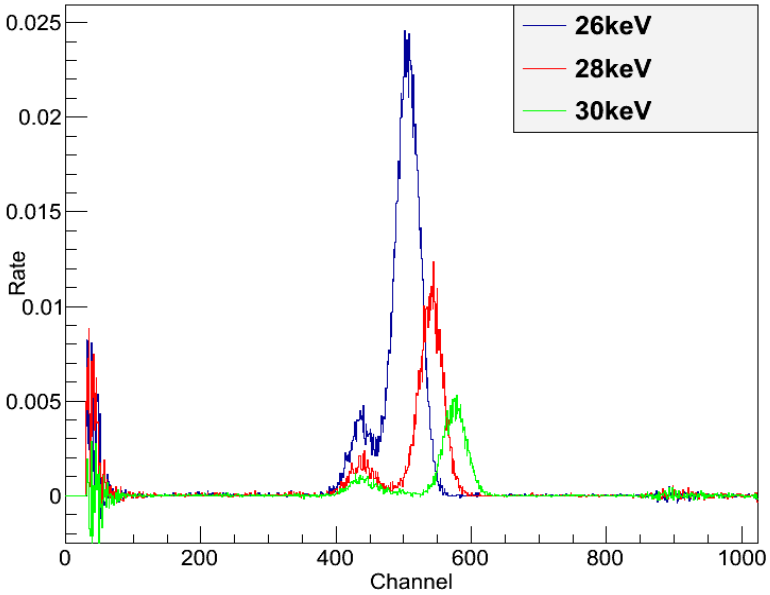


collimator

Detector (Si-PIN)



Si Pin detectors are fixed on the ceramic chip by silver(Ag) glue.



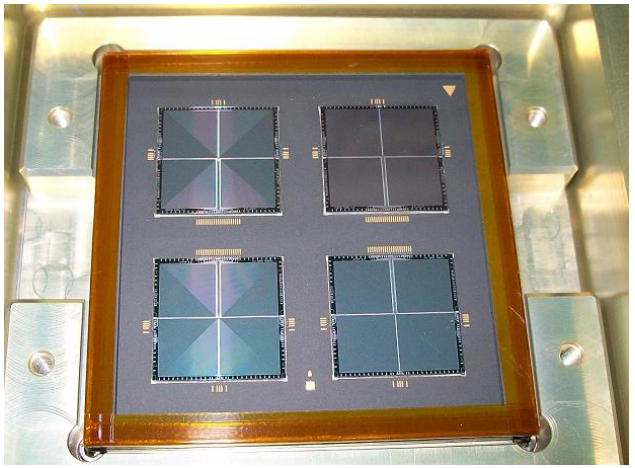
Element 47: Ag Atomic mass:

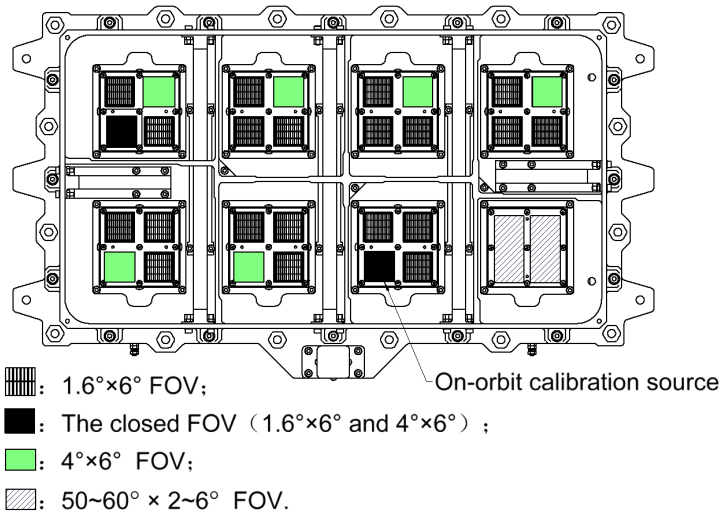
Edge	keV	A
K	25.5140	0.4859
L-I	3.8058	3.2578
L-II	3.5237	3.5186
L-III	3.3511	3.6998

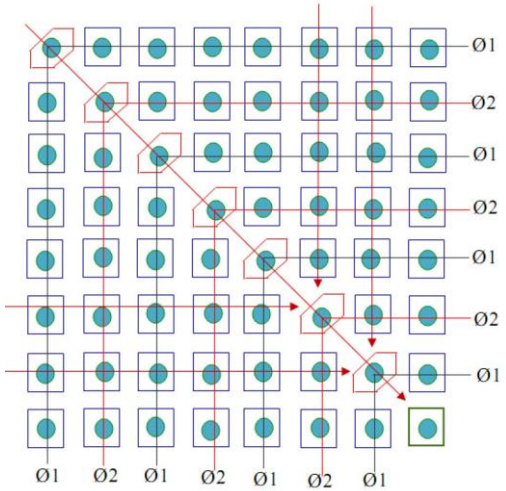
The low energy X-ray telescope: LE

LE consists of 3 detector boxes, and each boxes contains 32 CCD236.

Element Size	100 μm square
Number of elements	~40,000
Sensitive area	21.1 mm x 20.8 mm

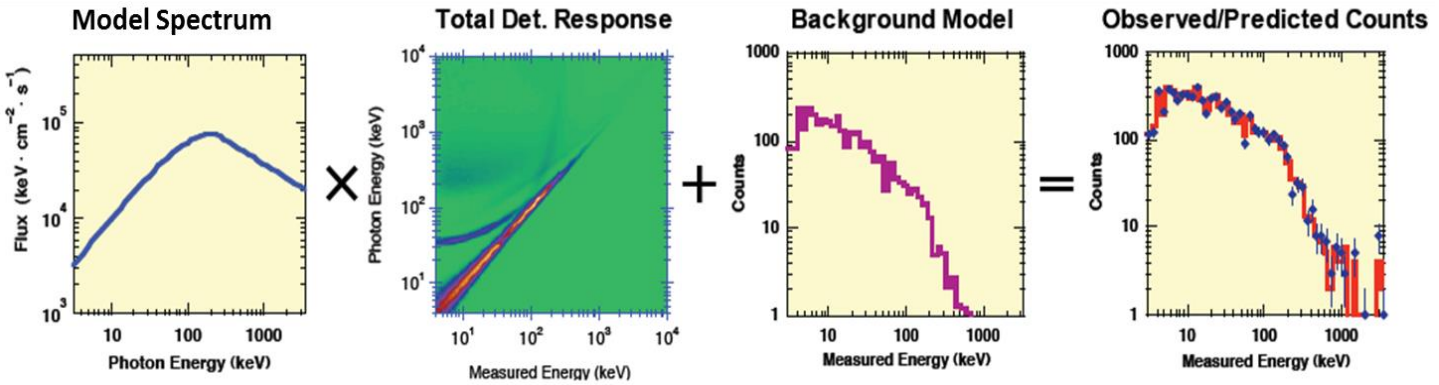






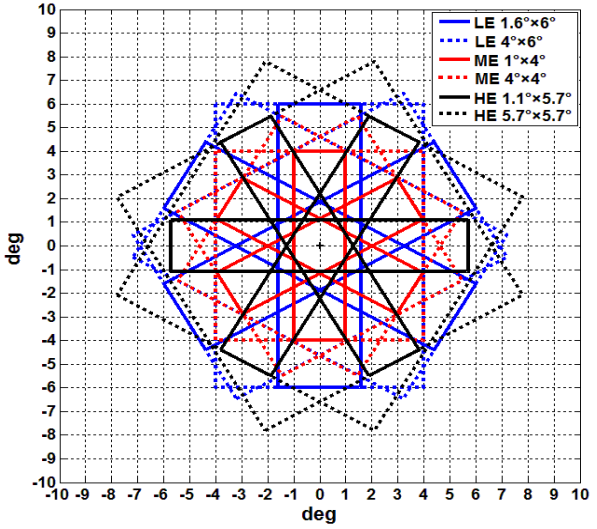
The charge transfer process will generate the split events.

2. The response of Insight-HXMT

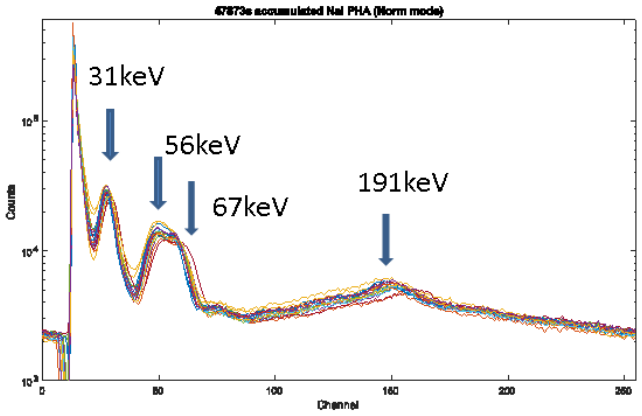


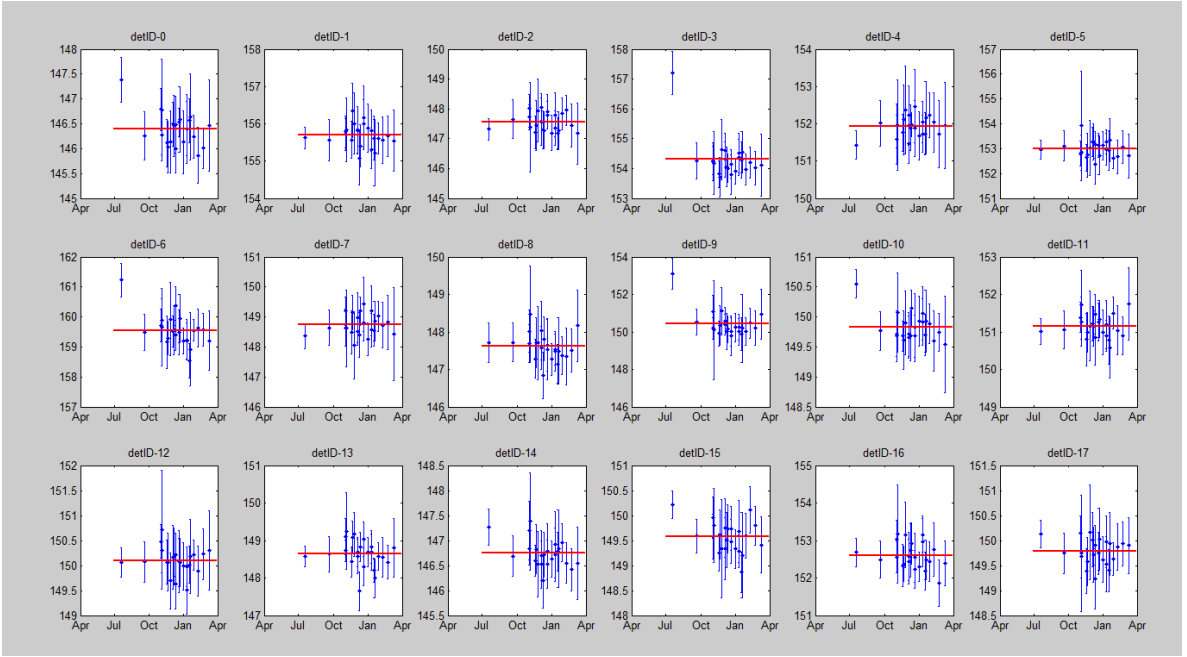
$$\mathrm{f(E,\alpha,\beta)} * \mathrm{PSF(E,\alpha,\beta)} * \mathrm{ARF(E)} * \mathrm{RMF(E,\alpha,\beta,C)} \cdot T + \mathrm{B(C)} = \mathrm{S(C)}$$

- PSF: Point Spread Function, response of the collimators.
- ARF: Ancillary Response File, effective areas
- RMF: Redistribution Matrix File, probability density distribution in observed channels.
- T: exposure time



HE/NaI: Energy-Channel Calibration





- Four lines can be found in blank sky observation. They will be used as the EC and energy resolution calibration.
- 191keV and 31keV line will be used to monitor the long stability of EC relation.

HE/NaI: energy resolution

- Air-slaked NaI on ground made the energy resolution bad. After 3 month in orbit, the resolution has kept almost same.

AGC @59.5keV
before launch

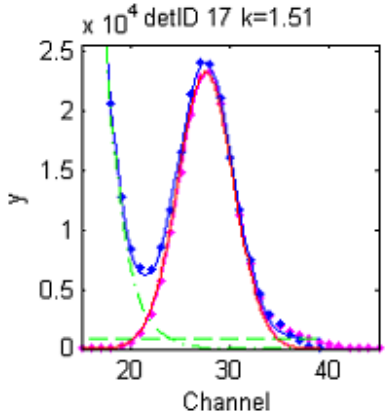
detID	201512 23	201612 21	201705 07	20170 622	20170 717	20170 828	20170 920	20171 101	20171 205
HED-1	15.30	17.35	17.48	18.46	18.72	17.77	17.69	17.85	17.68
HED-2	14.38	18.49	19.47	20.97	17.79	17.49	17.76	17.94	17.74
HED-3	14.60	16.87	16.97	18.34	17.89	17.59	17.46	17.35	17.41
HED-4	14.49	17.41	18.13	19.54	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:

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

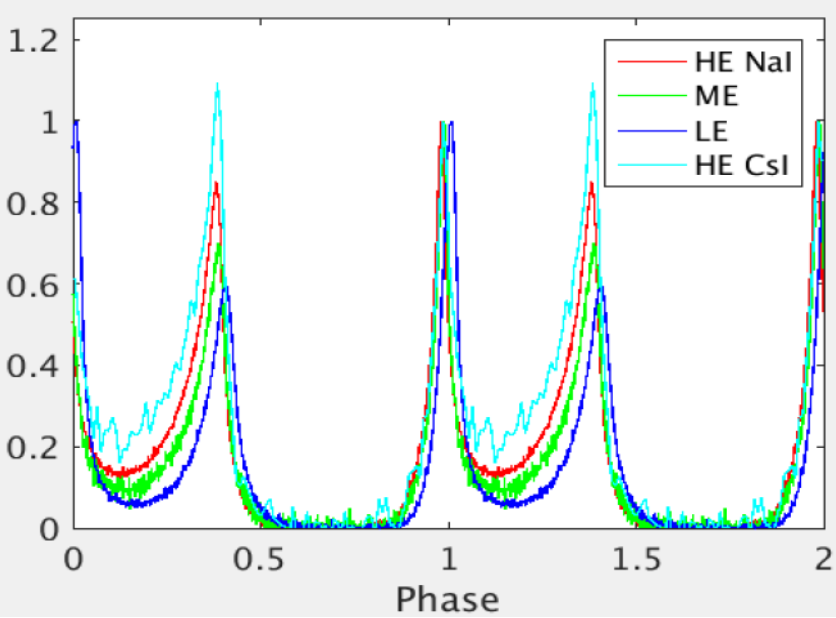


The energy resolution for 31keV will be used to estimate the energy resolution (kres) in orbit.

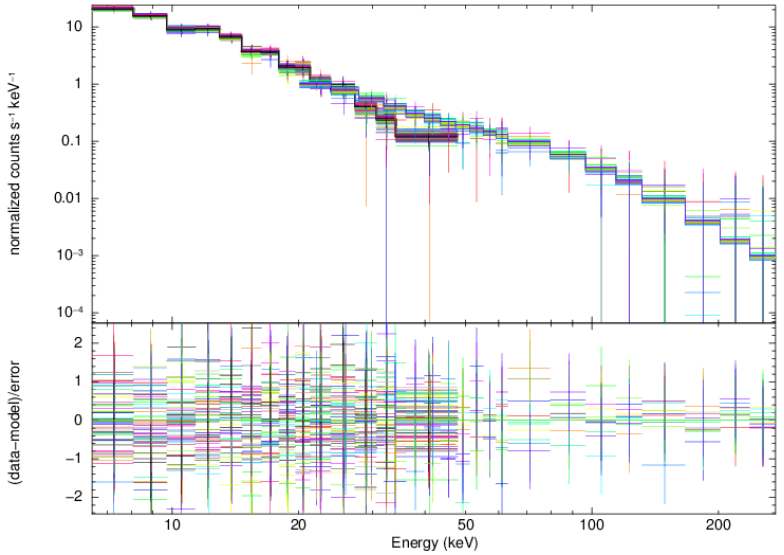
HE/NaI: ARF calibration

- Crab pulsar was used to calibrate the ARF in order to avoid the influence of background.
- Pulse off: 0.6-0.8 as background;

Pulse profile of Crab

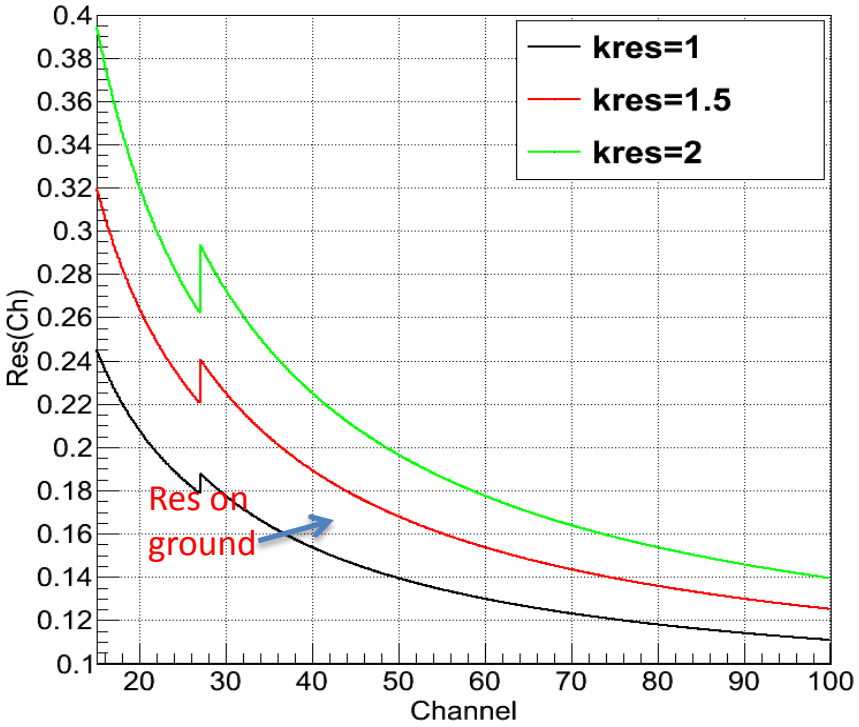


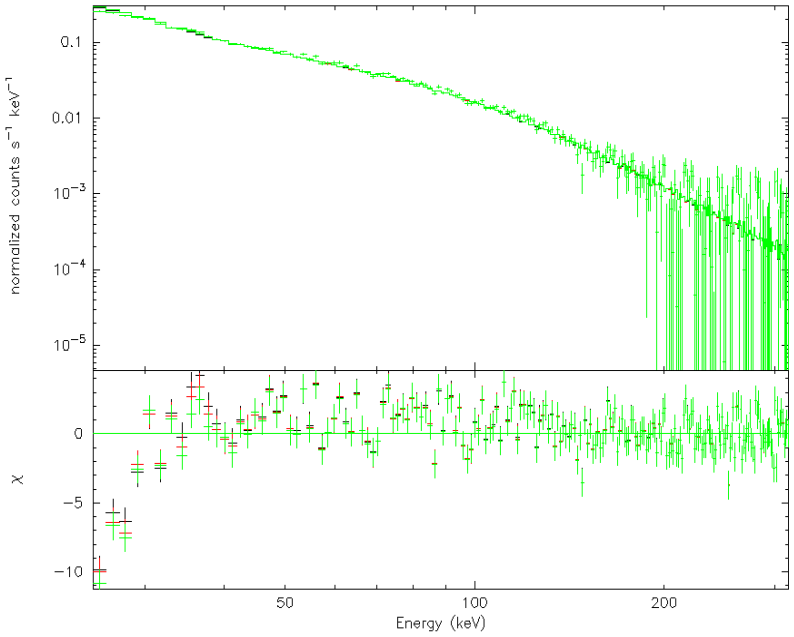
RXTE/PCA and HEXTE 2011 obs.



2	wabs	nH	10^22	0.220000
3	logpar	alpha		1.52041
3	logpar	beta		0.139402
3	logpar	pivotE	(scale)	1.00000
3	logpar	norm		0.448593

The influence of energy resolution：

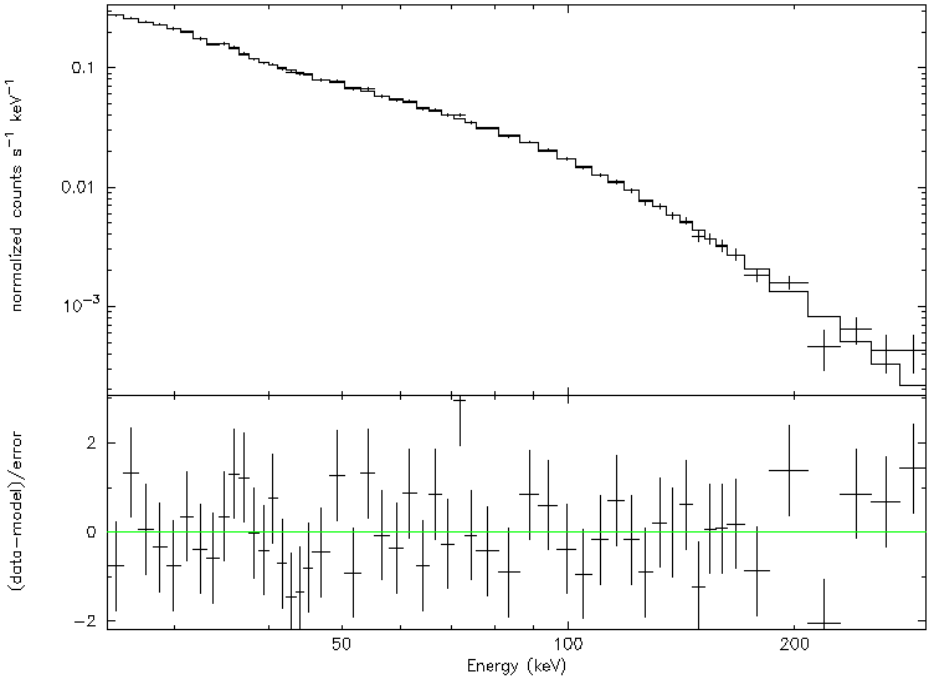


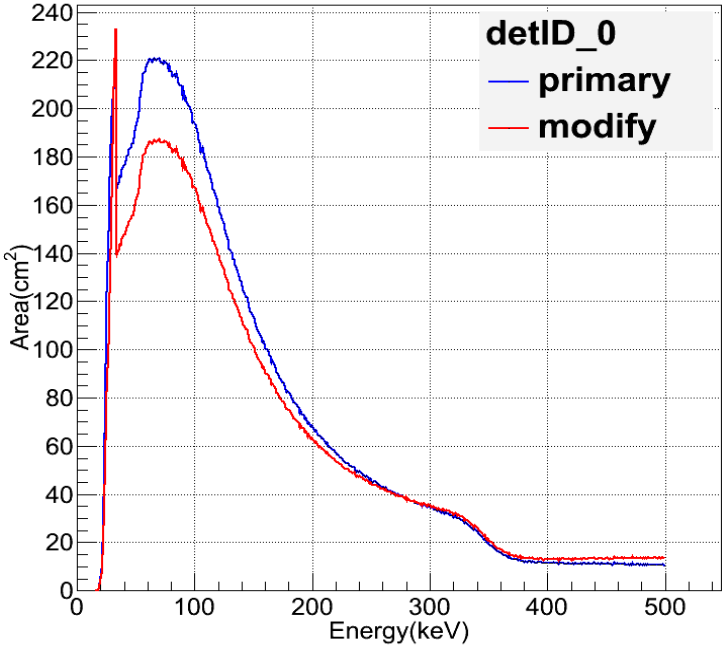


Fix the parameters of Crab pulsar from RXTE, residual of HE changed little at different Res in RMF.

Black: kres=1
Red: kres=1.5
Green: kres=2

New ARF of HE

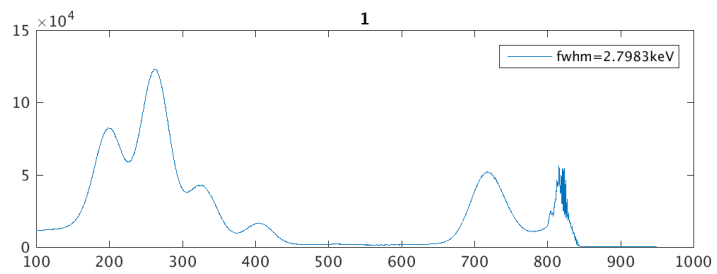


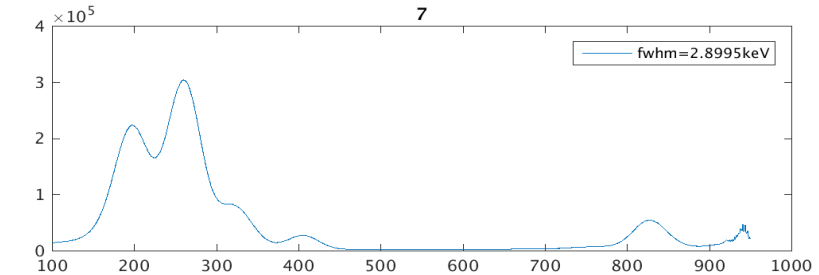


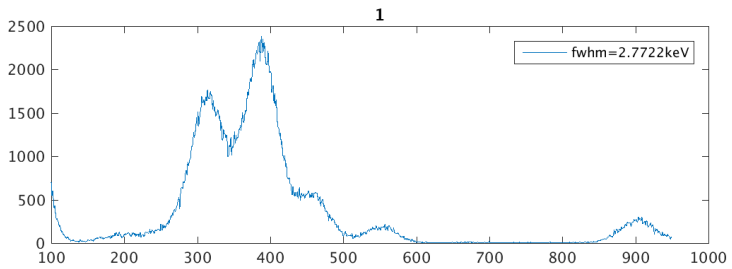

```
=========================================================================
Model hemutipoly<1>*logpar<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   hemutipoly A1                 7.58061E-03  +/-  2.06274E-03
   2    1   hemutipoly B1                 -0.378736    +/-  0.113034
   3    1   hemutipoly C1                 5.39503      +/-  1.53044
   4    1   hemutipoly A2                 1.29342E-06  +/-  2.52970E-06
   5    1   hemutipoly B2                 2.57114E-04  +/-  4.72537E-04
   6    1   hemutipoly C2                 0.823749     +/-  1.89933E-02
   7    2   logpar     alpha              1.52000      frozen
   8    2   logpar     beta               0.139000     frozen
   9    2   logpar     pivotE     (scale) 1.00000
  10    2   logpar     norm               0.448000     frozen
```

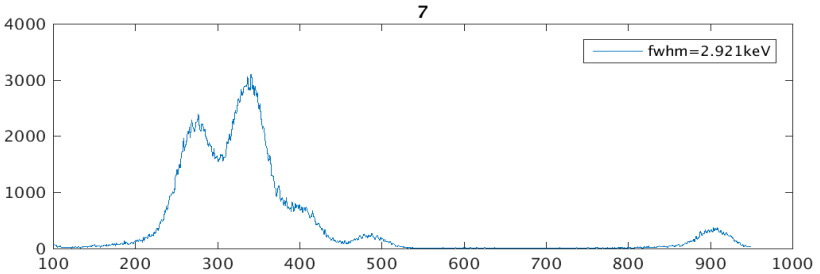
- A empirical function f(E) has been introduced to modify the ARF.
- The new ARF will be: ARF*f(E)
- f(E) is quadratic function of two segment below and above 33.17keV.

ME: Verification of FWHM and EC in orbit

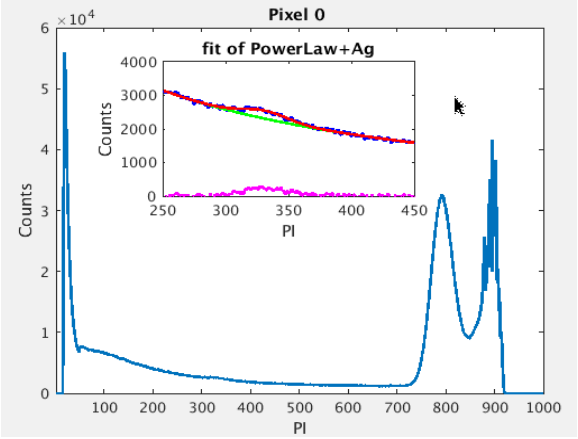




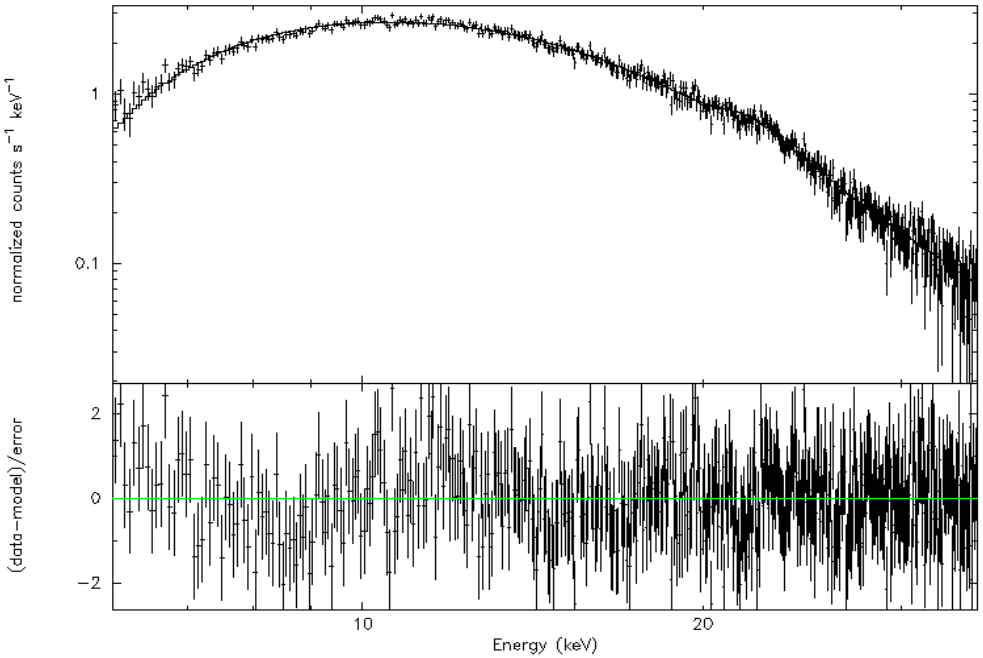




- The pixels carried ^{241}Am in orbit can also be used to estimate the change of FWHM in orbit. FWHM is almost same with ground.
- The EC is almost same as on ground using the Ag line in orbit.
- The RMF of ME is same as on ground.



ME: ARF calibration




```
========================================================================
Model logpar<1>*memutipoly<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   logpar     alpha              1.52000      frozen
   2    1   logpar     beta               0.139000     frozen
   3    1   logpar     pivotE     (scale) 1.00000
   4    1   logpar     norm               0.448000     frozen
   5    2   memutipoly A1                 3.00024E-04  +/-  3.26638E-05
   6    2   memutipoly B1                 -1.95678E-02 +/-  1.34605E-03
   7    2   memutipoly C1                 0.420733     +/-  1.70674E-02
   8    2   memutipoly D1                 -1.79662     +/-  6.65122E-02
   9    2   memutipoly A2                 3.65752E-03  +/-  9.54846E-03
  10    2   memutipoly B2                 1.06672      +/-  0.283890
------------------------------------------------------------------------

Fit statistic : Chi-Squared =         415.18 using 494 PHA bins.

Test statistic : Chi-Squared =          415.18 using 494 PHA bins.
 Reduced chi-squared =        0.85079 for    488 degrees of freedom
 Null hypothesis probability =   9.925823e-01
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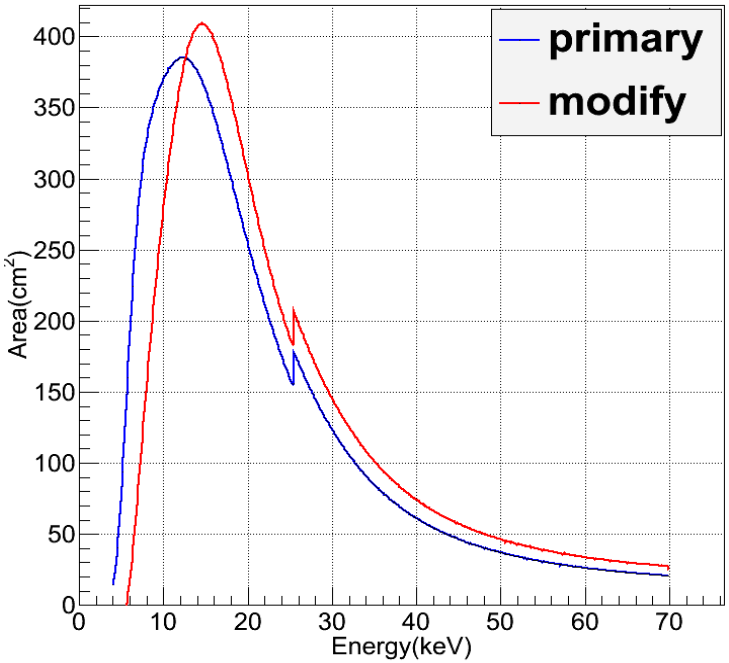
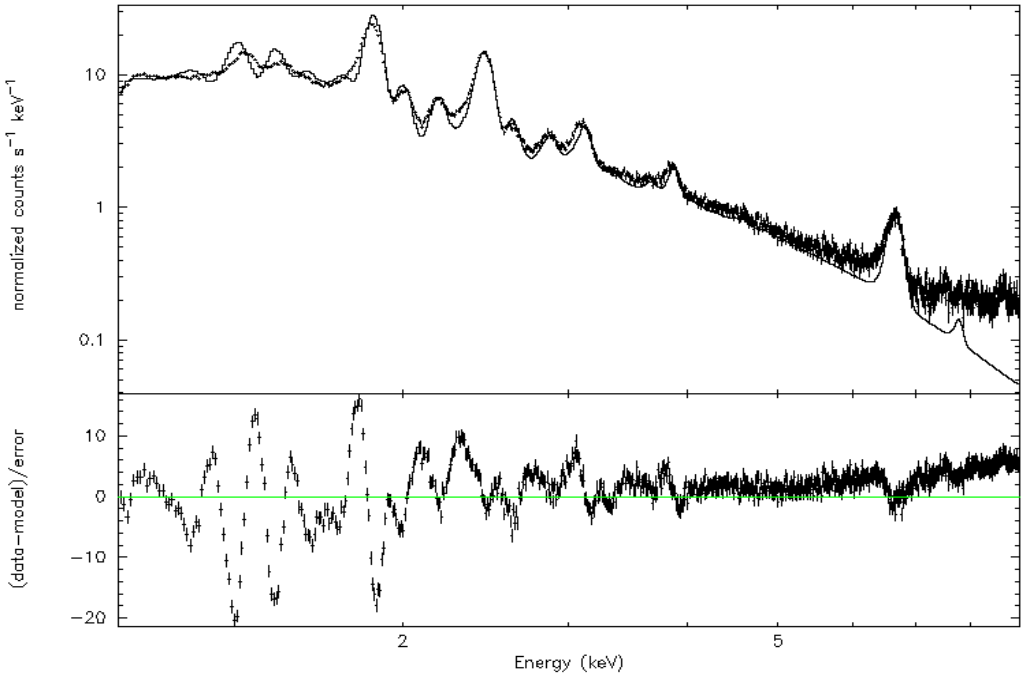
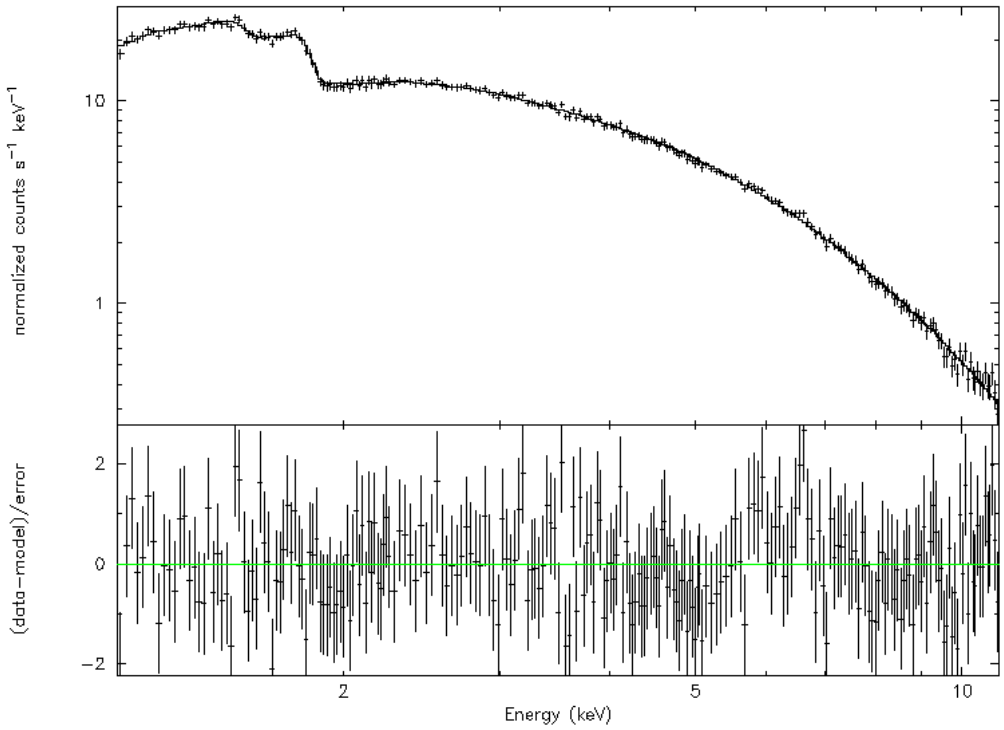


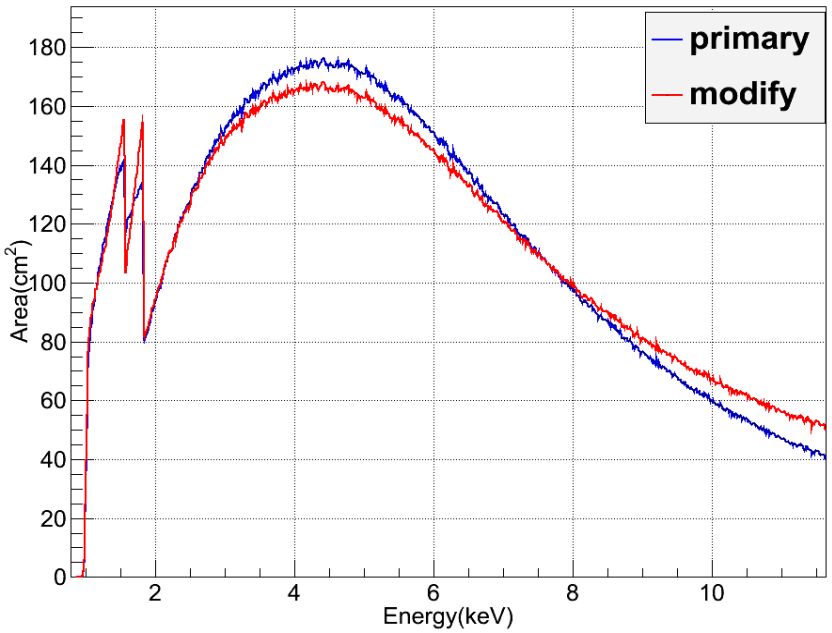
LE: Verification of EC in orbit

- Use the EC underground to convert the PHA spectrum of CasA to PI spectrum (black dot). The background has not subtracted from the PI spectrum.
- Use CasA model convoluted the RMF and ARF to fit the PI spectrum.
- The EC in orbit has changed little.

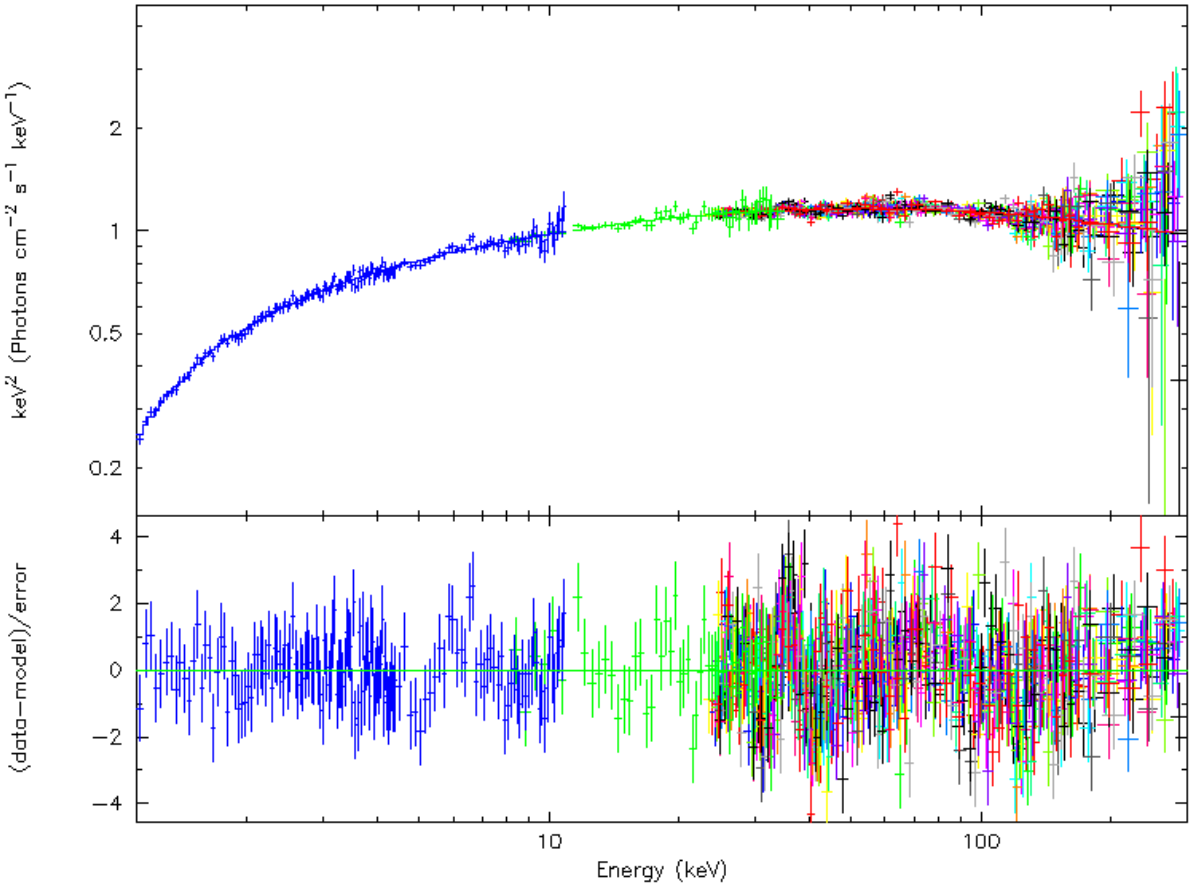


LE: ARF Calibration



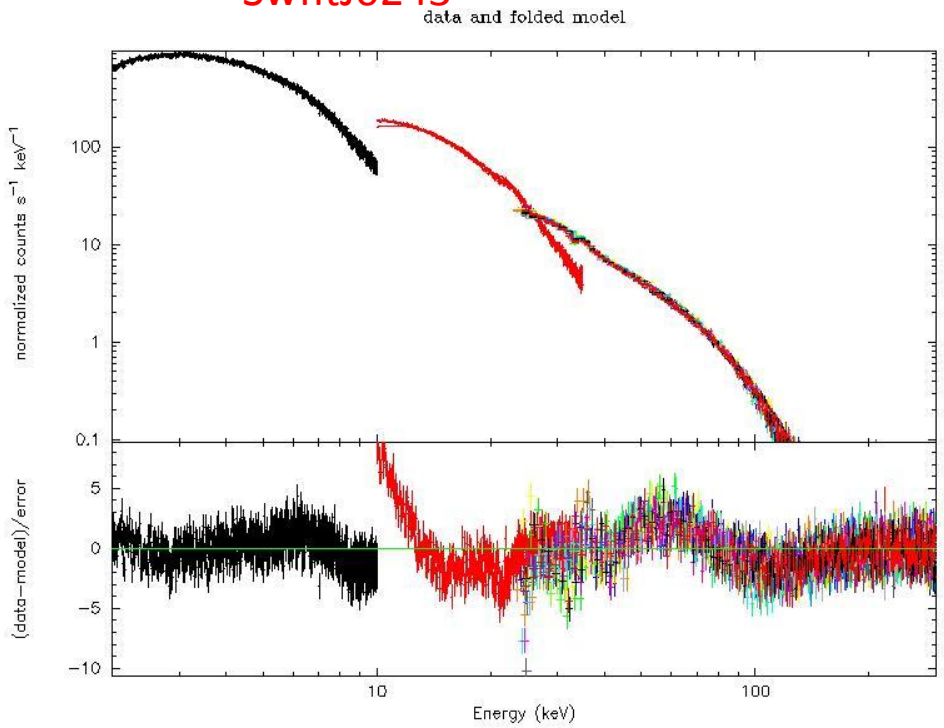


Residuals of Crab pulsar using the new ARF

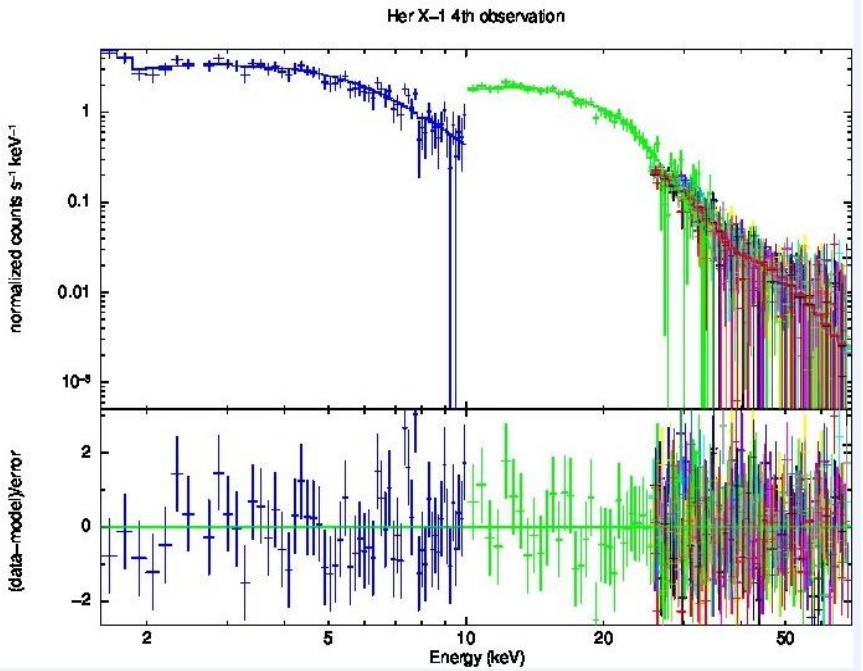


Pulsar of SwfitJ0243 and Her X-1

SwfitJ0243

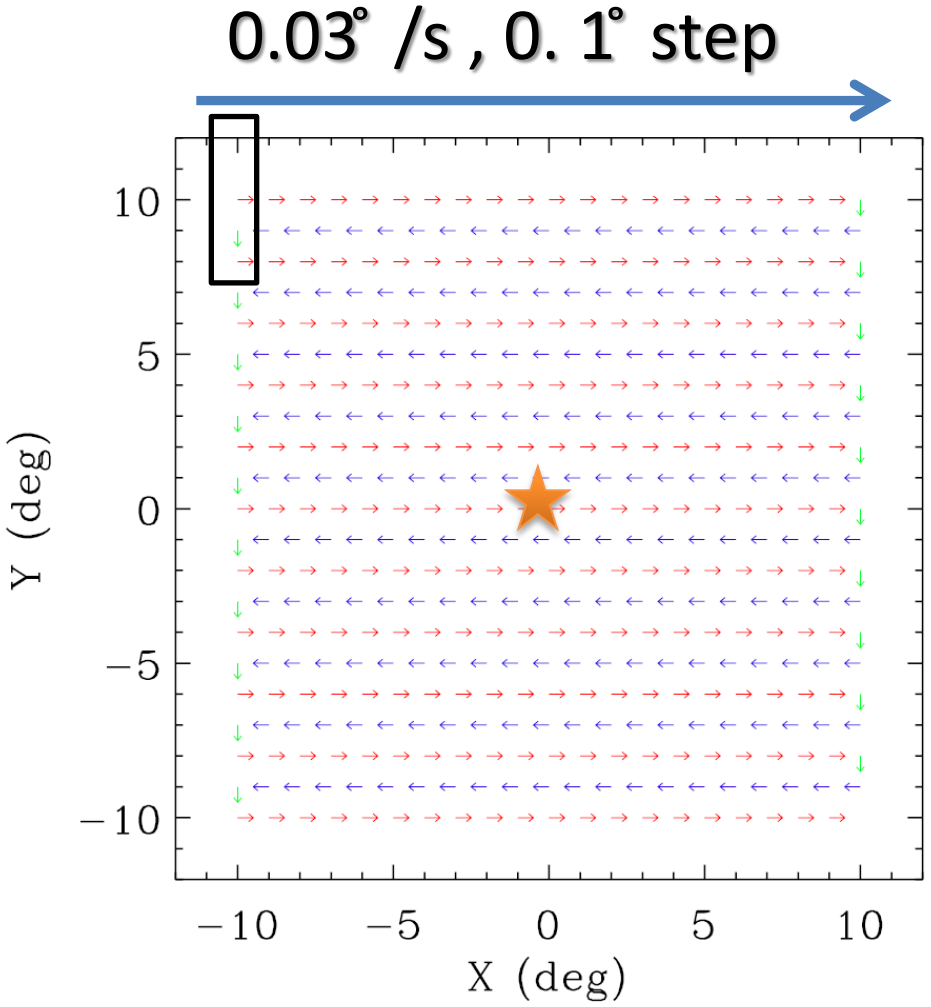


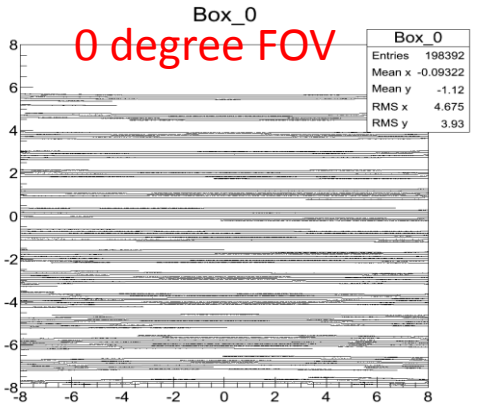
Her X-1

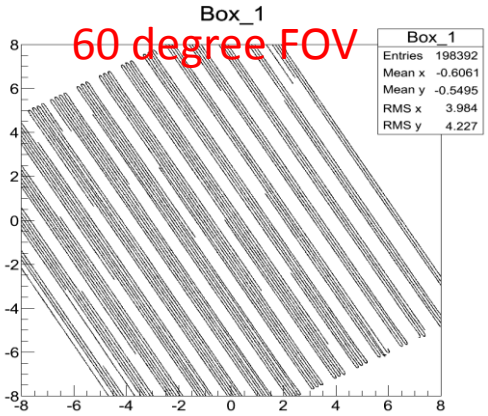


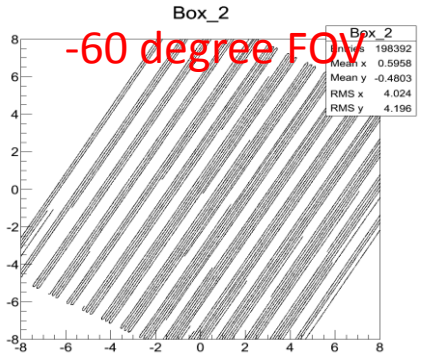
- The statistic of SwiftJ0243 pulse component is about 100 times higher than that of crab pulsar.
- No additional systematic error : 2% will be good for fitting.

PSF calibration: Small area scan of Crab





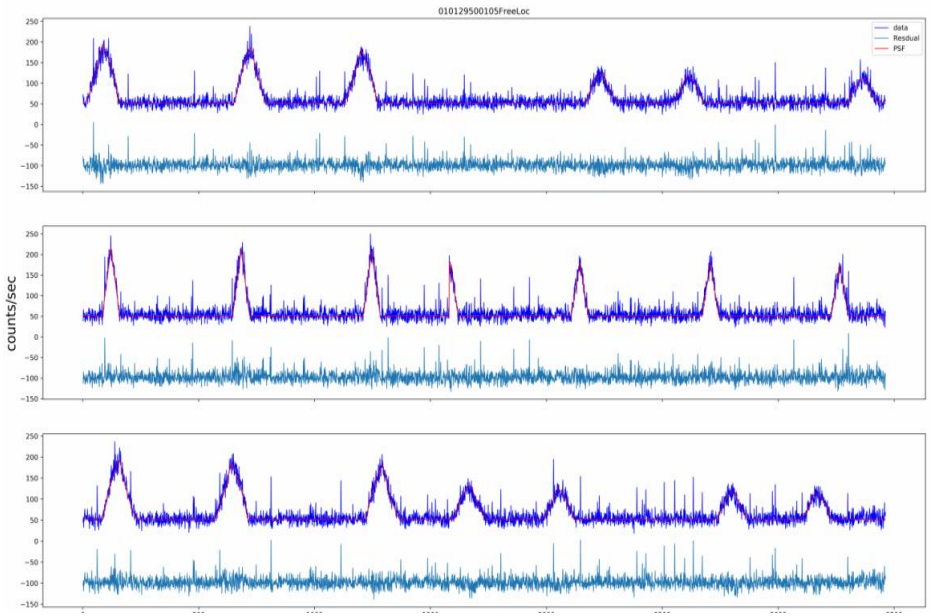




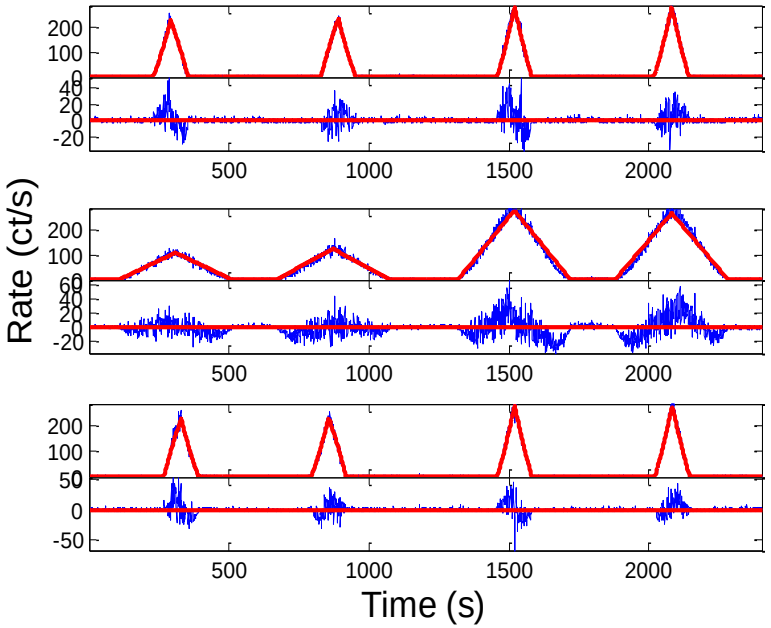
- The position of the Crab in different FOVs.

Light Curve fit of scanned data of Crab

HE



LE



- PSF model is correct and collimators did not distort when launch for HE and ME.
- The PSF of LE has some distortion. And we has modified the model of LE.

3.Background Estimation of HXMT/HE

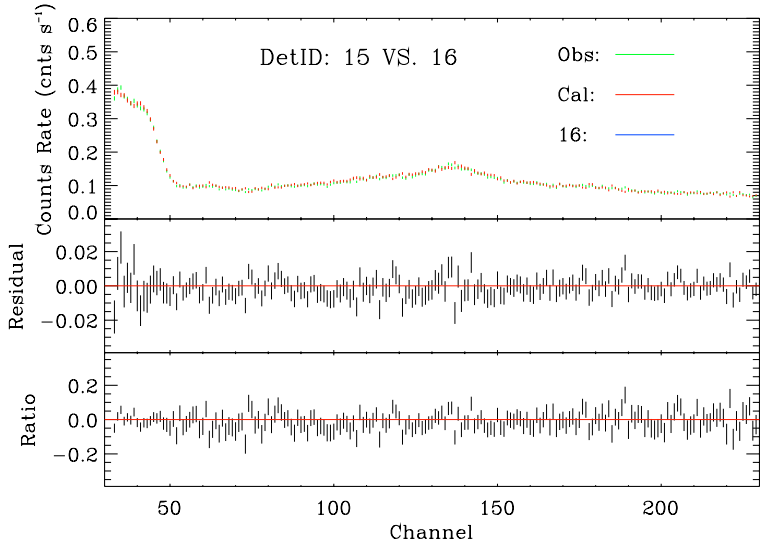
$$y = a + bx + (0, \epsilon^2),$$

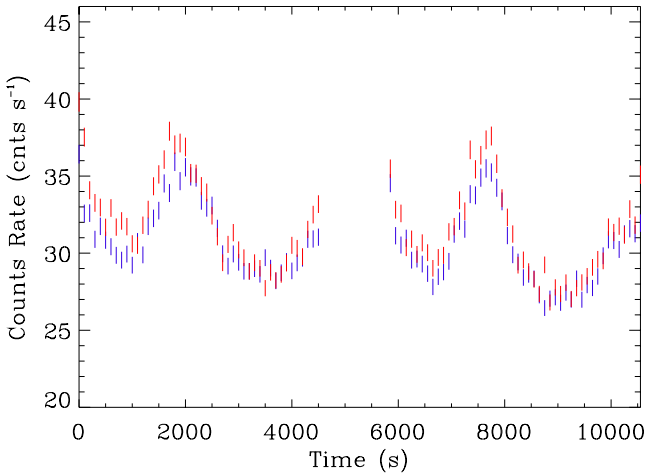
x: BKG in BGK detector

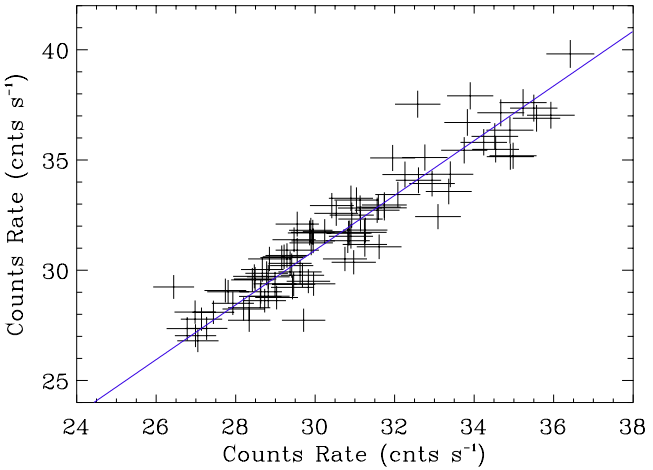
y: BKG in source detector

Linear correlation model:

model parameters: a & b.







Very good correlation, the validity and stability need to be confirmed

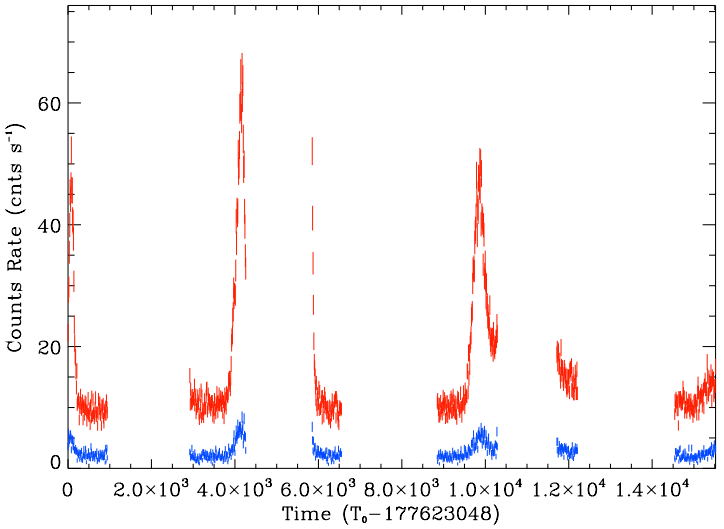
If the model parameter is stable, thus we can use it to estimate the BKG anytime!

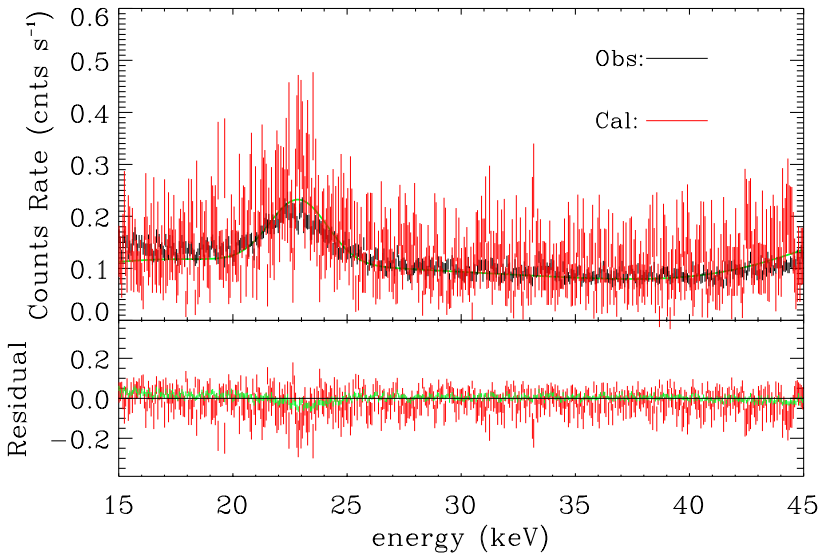
Background Estimation of HXMT/ME

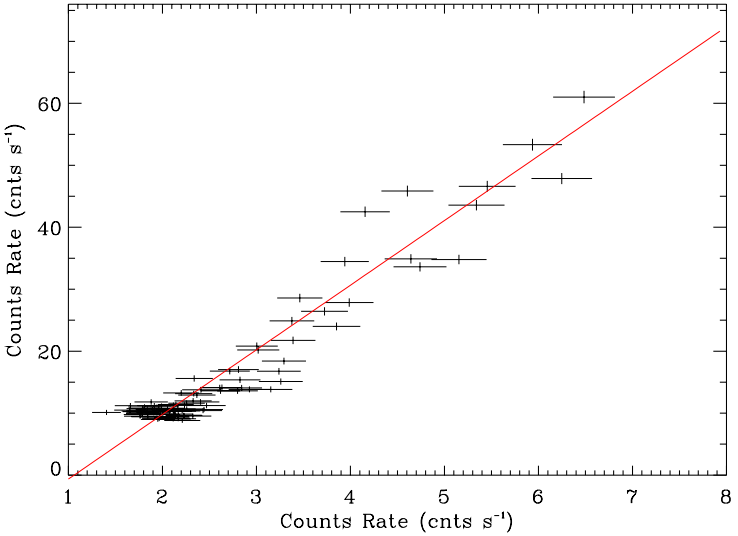
HXMT-ME has 3-Box, and each box has a blind FOV detector

ME BKG is dominantly caused by particle (e.g., proton), thus the blind FOV detector is used as a BKG detector

Establish a correlation between the BKG detector and other detectors.



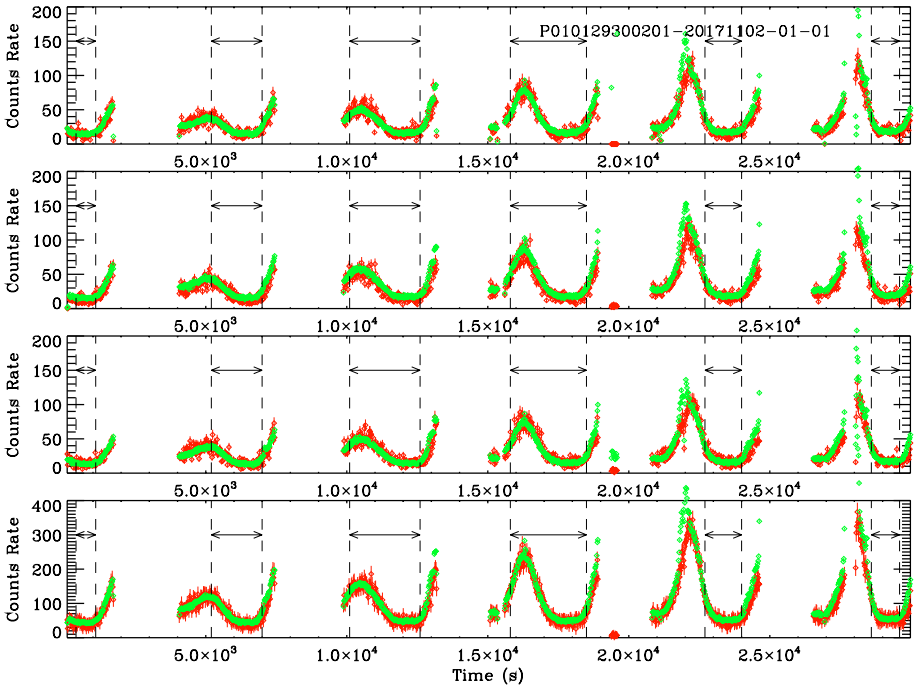




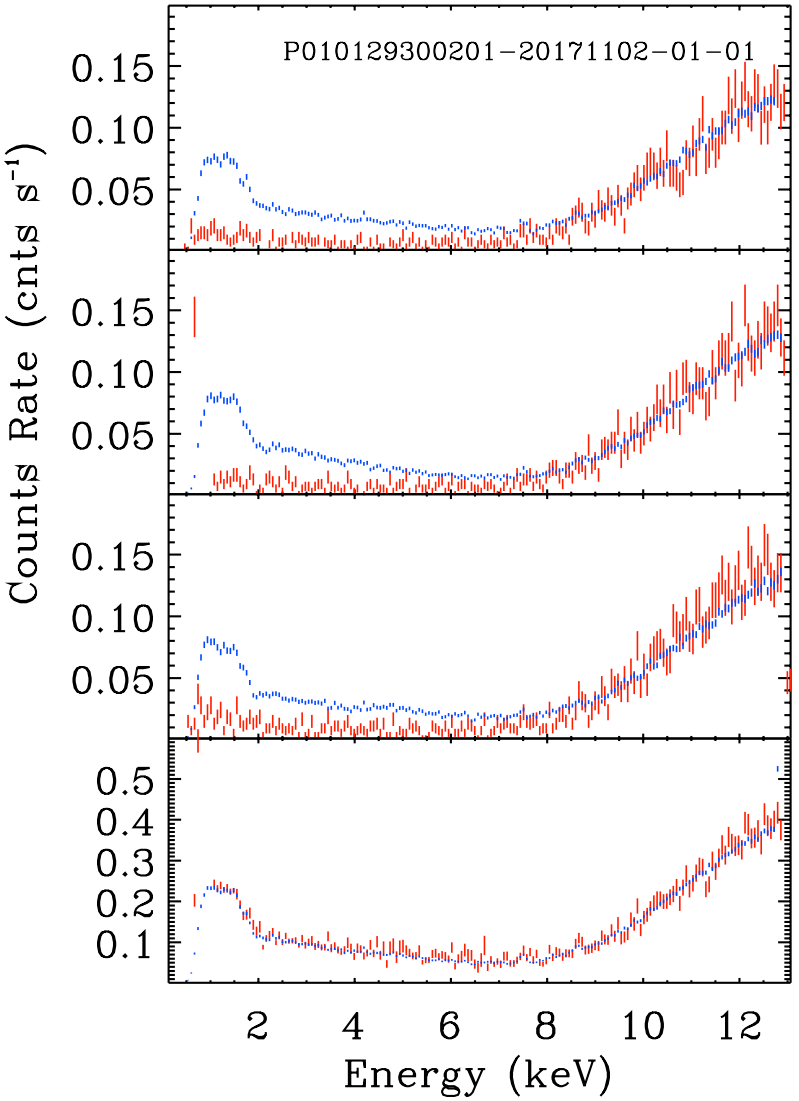
Very good correlation, the validity and stability need to be confirmed

Background Estimation of HXMT/LE

The same as the method used in ME
In high-energy band, the BKG is dominant by the particle, we can use the blind detector to estimate the BKG.
In Low-energy band, the BKG is dominant by CXB, so we must obtain the CXB sky map to estimate the BKG.



GTI



Summary

- The ARF calibration has been independently done by the crab pulsar without the BKG influence.
- The BKG has been tested through the blank sky observation. But the BKG estimation software are still under test.
- The test of Crab nebula will be done soon. The empirical function to the ARF will be given through the multiple iterations and tested through simultaneous observations.