On ground calibration results of Insight-HXMT/ME

Tan Ying
Instituteof high energy phsics,Chinese academy of sciences

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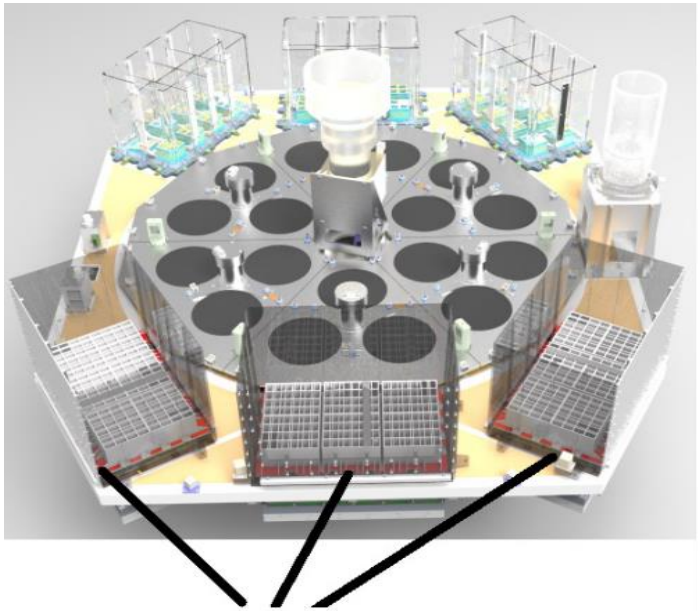
Outline

- Introduction of the medium energy X-ray telescope(ME)
- Preliminary calibration experiment at PANTER
- Calibration Results at LXCF
- Calibration using ^{241}Am and ^{57}Co

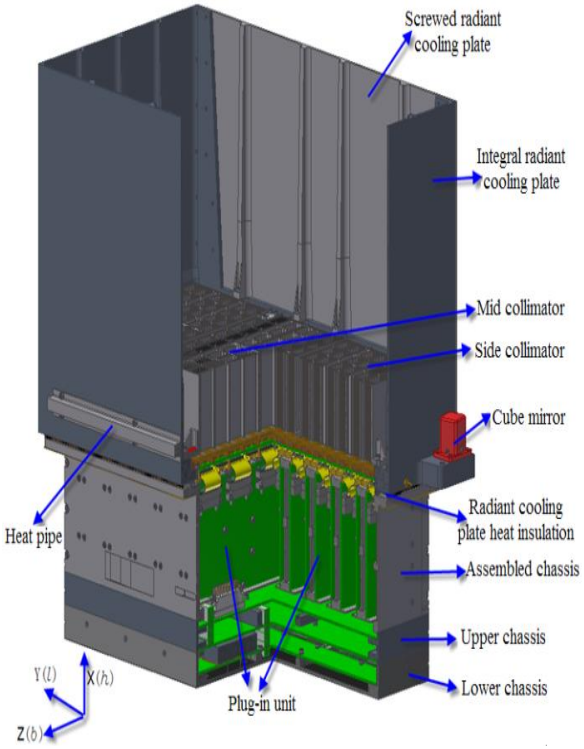
The medium energy X-ray telescope: ME

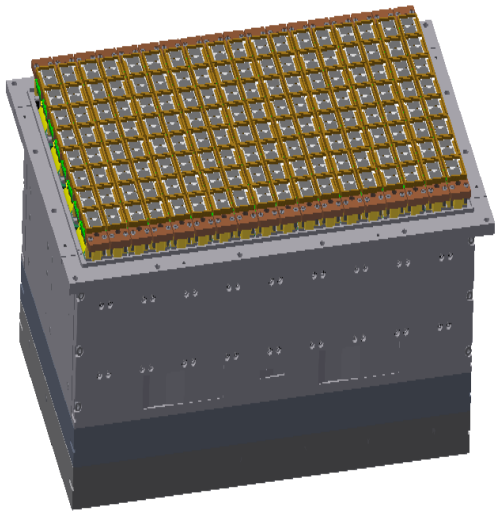


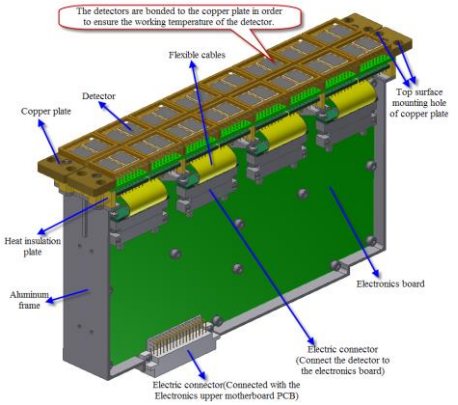
ME Detector Boxes (MED)

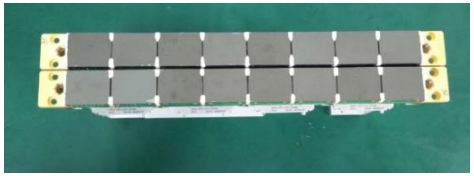
- Energy 5-30keV
- Detector type Si-PIN
- Pixel size 12.5mm×4.5mm
- Sensitive zone thickness 1mm
- The total number of pixels 1728
- Detection area 952cm^2
- Energy reolution 2.96keV@20keV
- Detector working temperature -50 ℃~-5 ℃
- Time resolution 255 μs
- Maximum count rate allowed 2.2×104 cts/s
- Power 155 W

Modular Design of ME





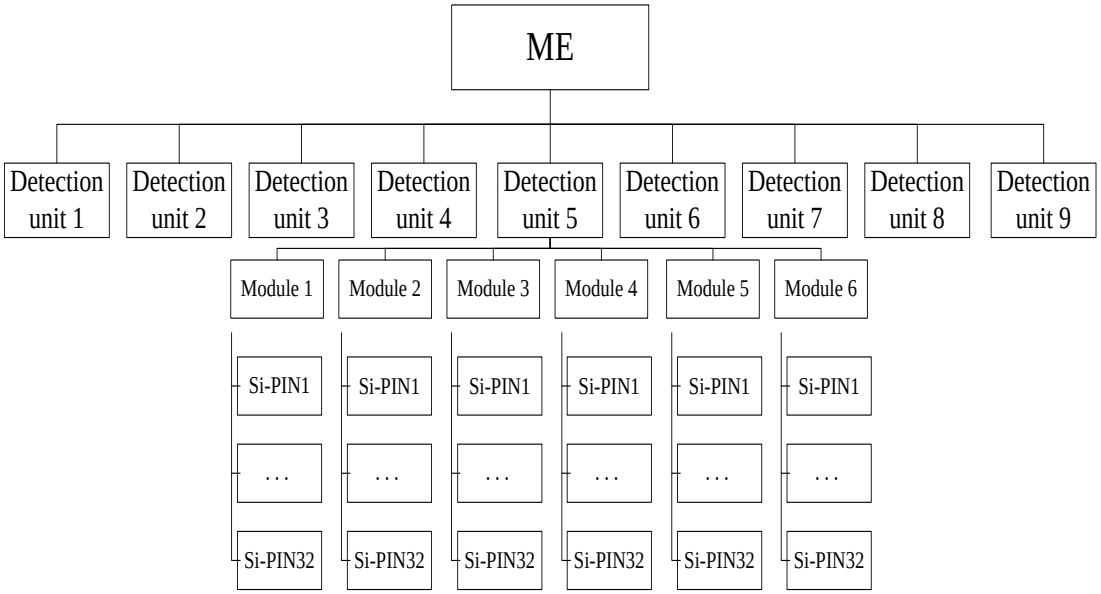




The ME system contains 432 Si-PIN detector. Each Si-PIN detector has four pixels and therefore 1728 readout electronic channels are needed.

We manufactured 54 pieces of ASIC chips containing 32 channels of each to fulfill the readout system of detectors. the whole system, modular design was adopted and each module can work independently.

Modular Design of ME



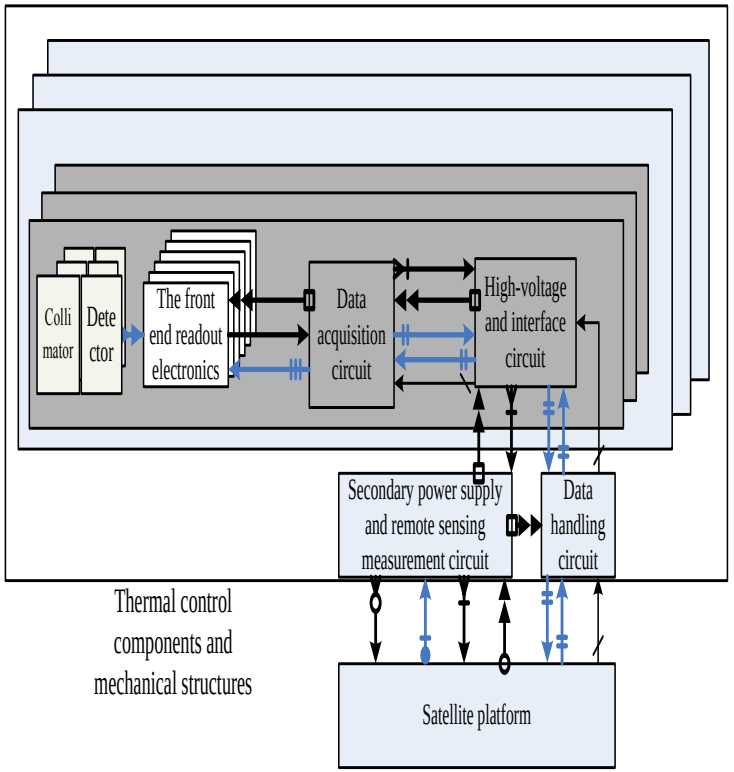
ME has three MEDs and each MED contains three identical detection units.

All the detectors in a detection unit share a set of data acquisition module and high voltage power supply module.

A detection unit is further divided into six detection modules.

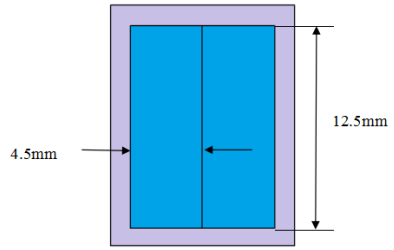
Each module has eight 4-pixel Si-PIN detectors, the ASIC, and the auxiliary circuit.

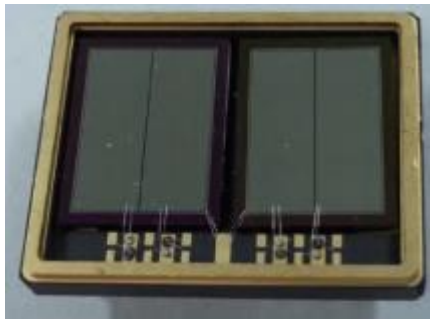
The functional block diagram of ME

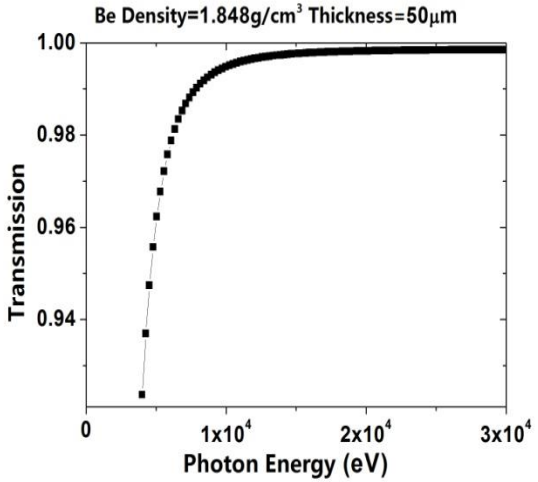


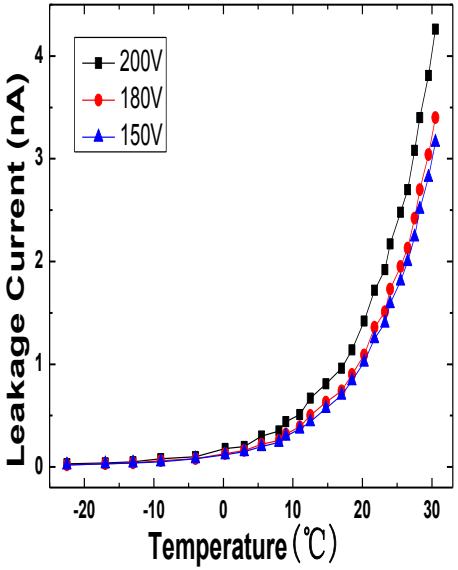
1) Detecting the X-ray photons, converting the photon energy and arrival time information into digital signals, and sending them to the electronic control box;
2) Receiving the controlling commands from MEB;
3) Generating engineering data and transmitting them to MEB;
4) Receiving the clock and reset signals from MEB;
5) Transmitting the analog and digital telemetry signals to MEB;

Si-PIN detectors





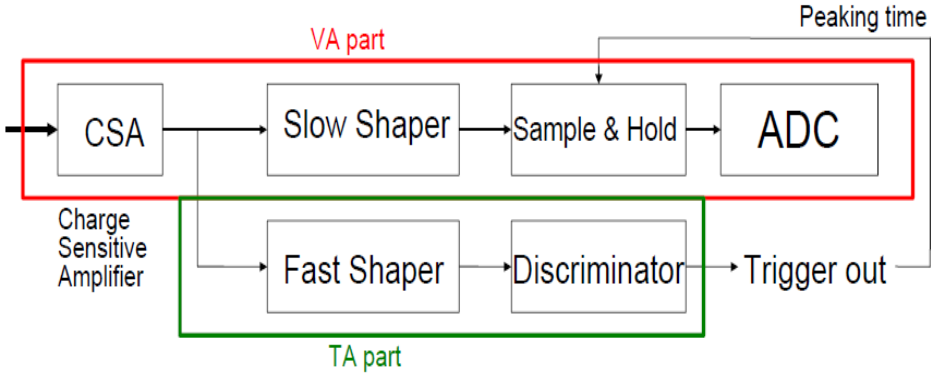




- The Si-PIN detector used by ME has a pixel size of 56.25 mm2 (12.5 mm × 4.5 mm) and a thickness of 1 mm. One guard ring has been shared by two pixels on a silicon chip
- the leakage current of Si-PIN detectors reach ~7 pA at -20 ℃ (the typical in-orbit working temperature of ME) with a bias voltage of 170 V.

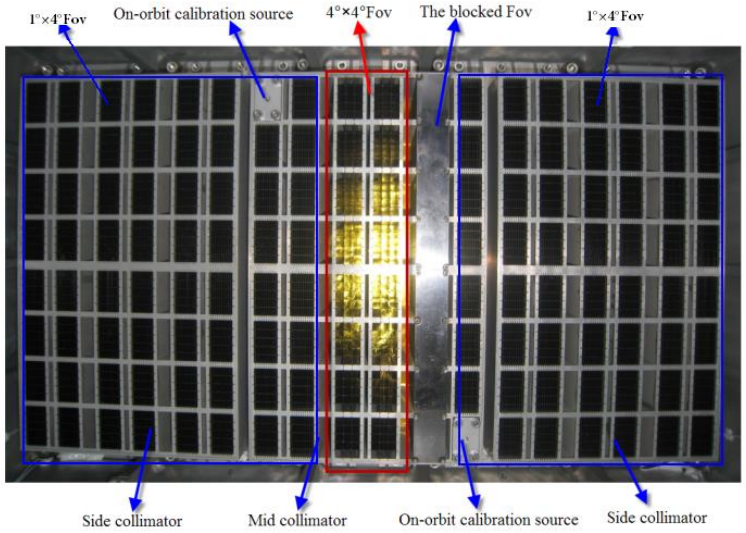
- A 50 μm beryllium (Be) window has been pasted to the ceramic package.
- 96% of the 5 keV X-rays can penetrate the Be window

ASIC and Collimators



- The ASIC used in MED is an improved version of VA32TA6 . It is a low power and rad-hard chip with 32 channels of low-noise charge sensitive amplifier (CSA)-shaper circuits.
- The ADC used in MED is Wilkinson type 10-bit ADC, which can digitize all channels in parallel.

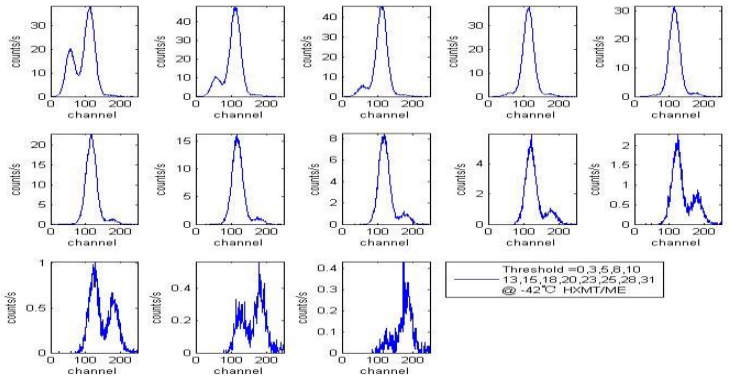
- The collimators are mounted on the top of the plug-in units to limit their FOVs.
- There are three kinds of FOVs, i.e., 1°×4°, 4°×4°, and the blocked ones,

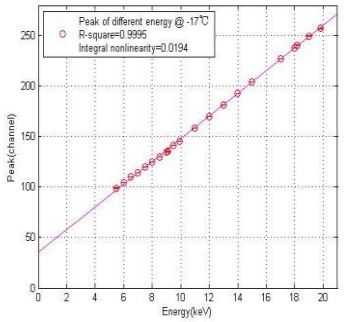


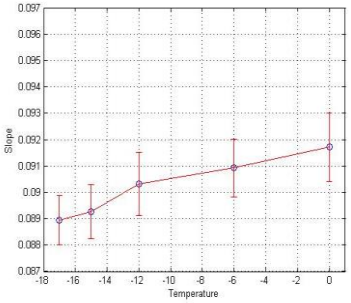
On ground calibration of Insight-HXMT/ME

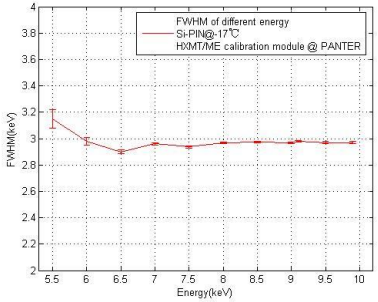
Pixel Numbers	Experiment site	Energy	Temperature	VTHR
2	PANTER	5.5-10keV	-17~0℃	13
2	LXCF	5-30keV	-38.6℃	0,9-14
1728	IHEP	^{241}Am ^{57}Co	-31~0℃	9-14

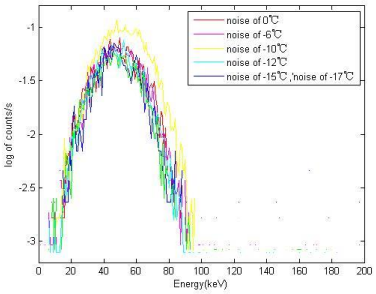
Preliminary calibration experiment at PANTER



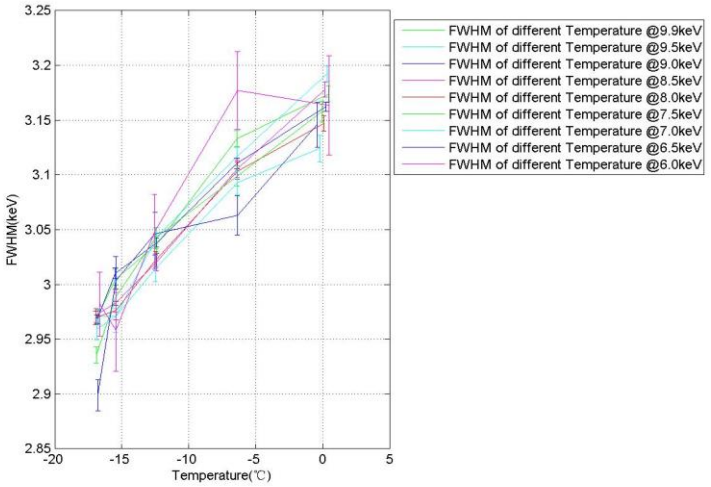








- Two pixels Si-PIN detectors with the similar readout electronics were tested on the Max Planck Institute for Extraterrestrial Physics PANTER X-ray test facility at Neuried by Munchen (Germany) in 2013.

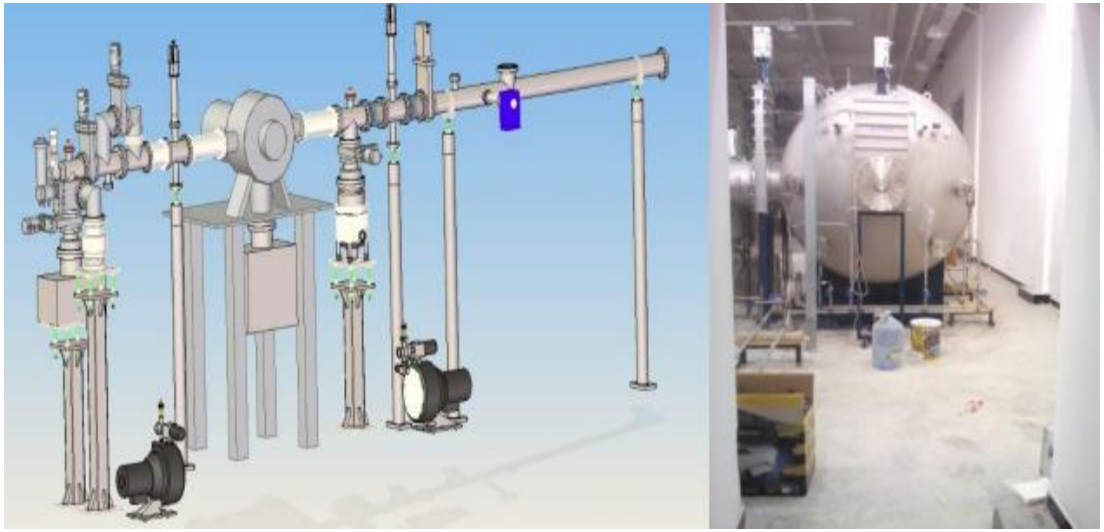


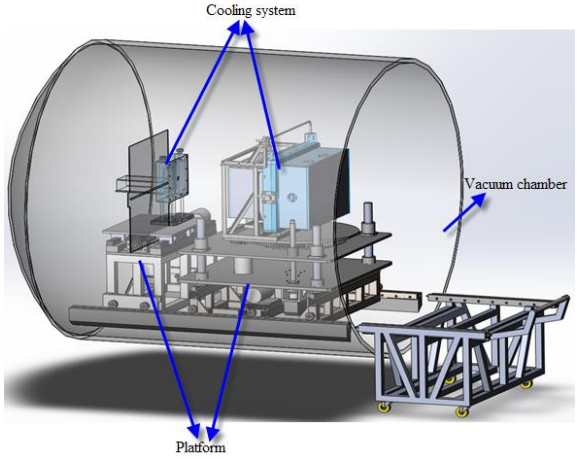
The low X-ray calibration facility (LXCF)

Characteristics	Value/range
Energy	0.929~30.23 keV
Ratio of monochromatic line	88%-99%
Beam flux	0.1-580 cts/mm^2/s
Spot size	>20×40 mm^2（for a fixed energy）
Monochromaticity	1% (4 eV eV)0.2%(16 keV keV24 keV)
Beam location accuracy	6 cm (maximum horizontal deviation)
Temperature Stability	<5%@1 h

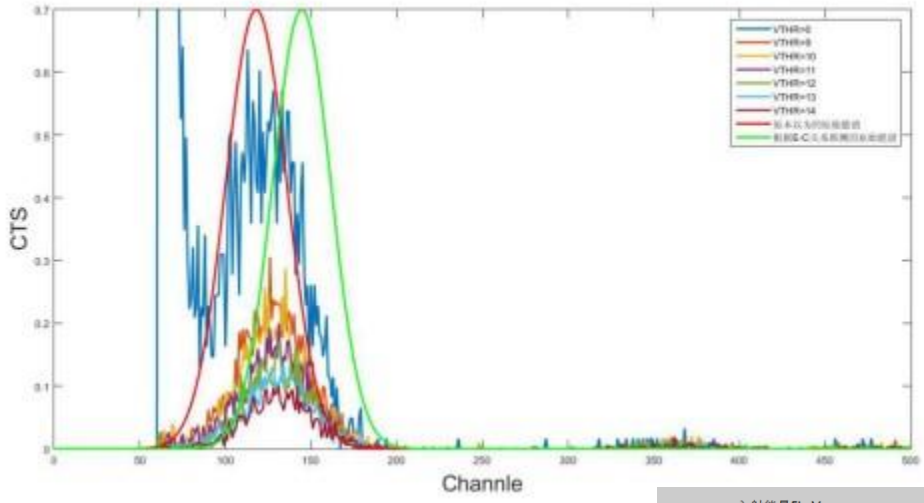
To meet the requirements of HXMT calibration experiment, we builded LXCF in 2014.

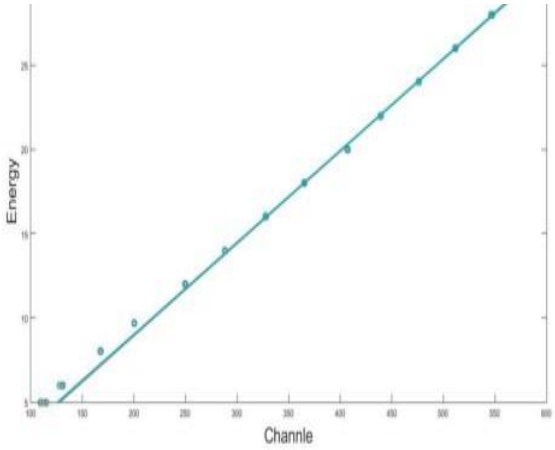
The X-ray source, the monochromator and the vacuum tube is shown in the left, while the test chamber is shown in the right.



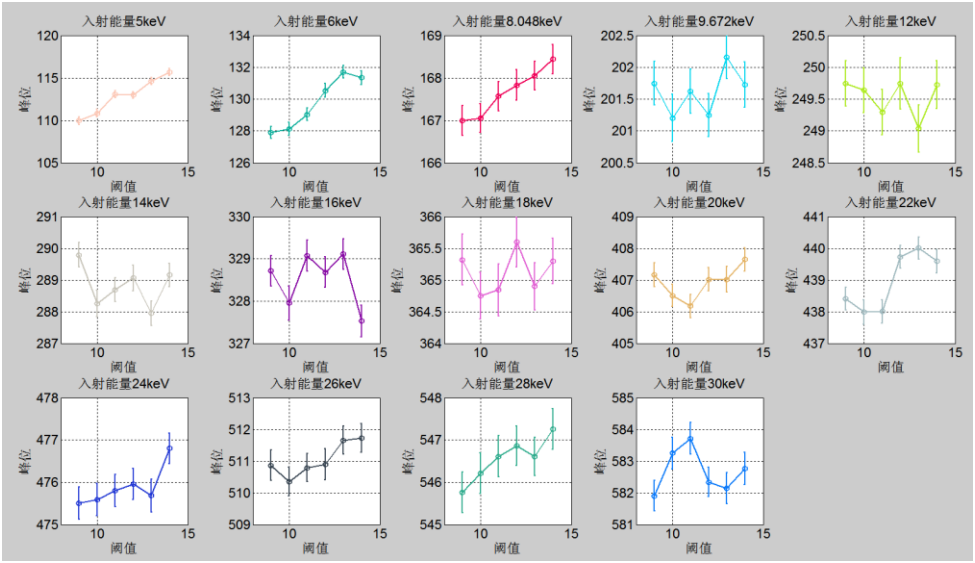


Calibration Results at LXCF-VTHR

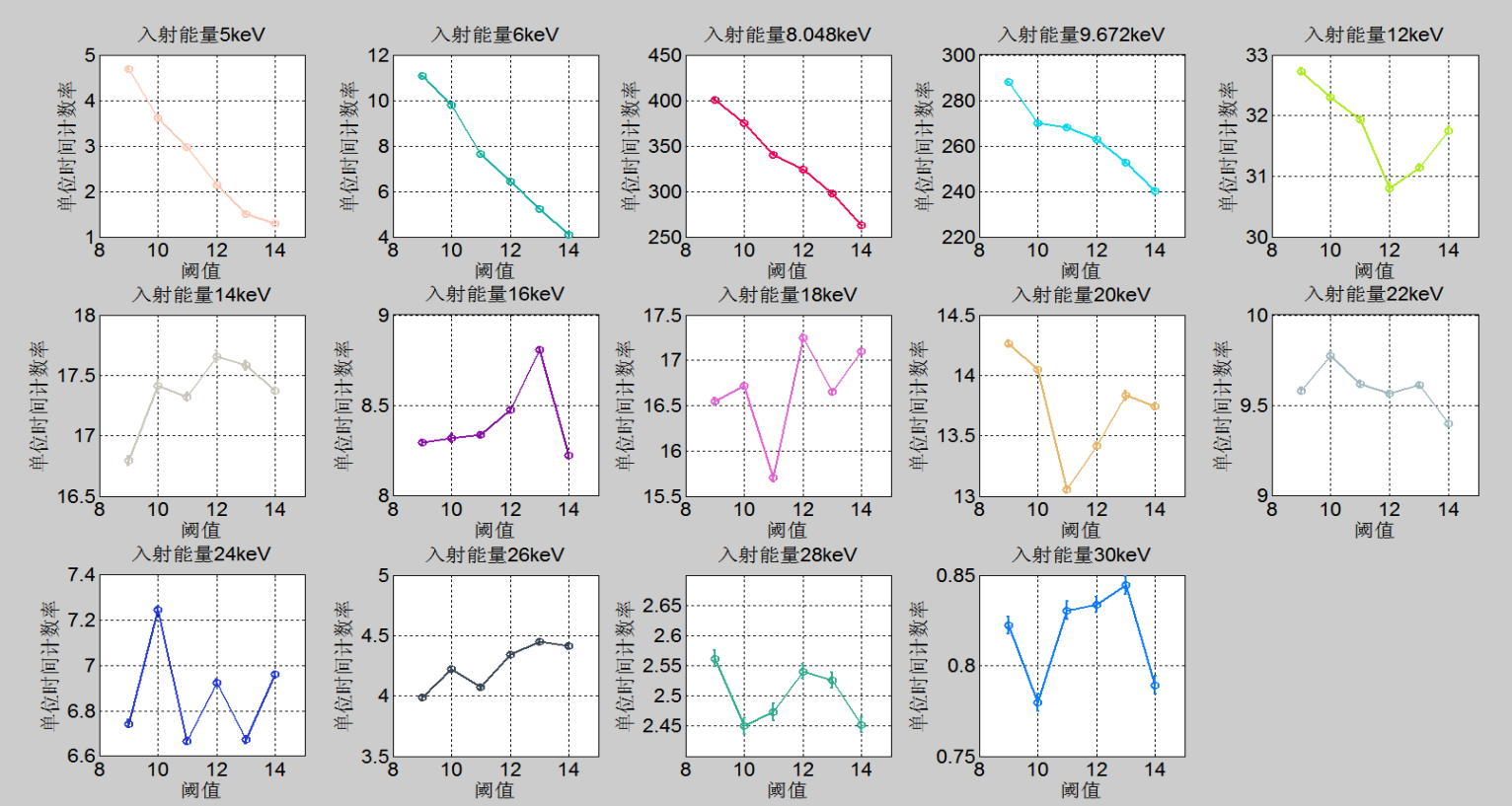




- We tested the monochromatic spectrum of two pixels,while the threshold of the trigger signal （VTHR）was set to 0 to 14, and the incident energy was set 5-30kev at -38.6℃.
- We found that the VTHR has a slight influence on the E-C relationship at 5-10kev.

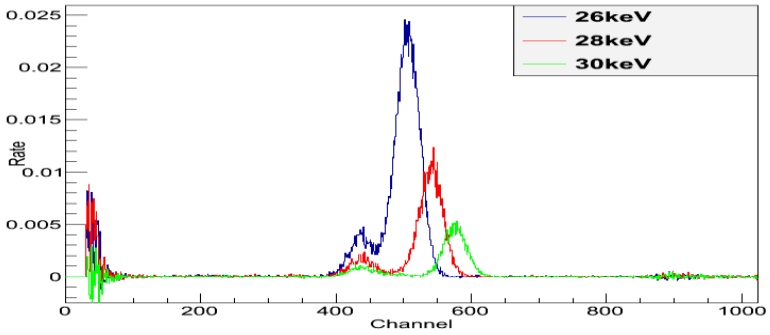


Calibration Results at LXCF-VTHR



- We also found that the VTHR affects the relative detection efficiency of pixels in the 5-10kev band.

Calibration Results at LXCF: Ag Fluorescence Line

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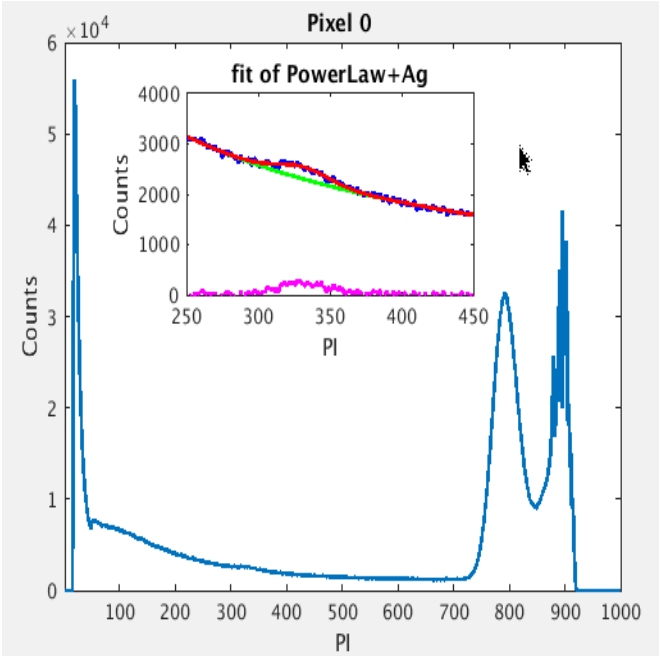
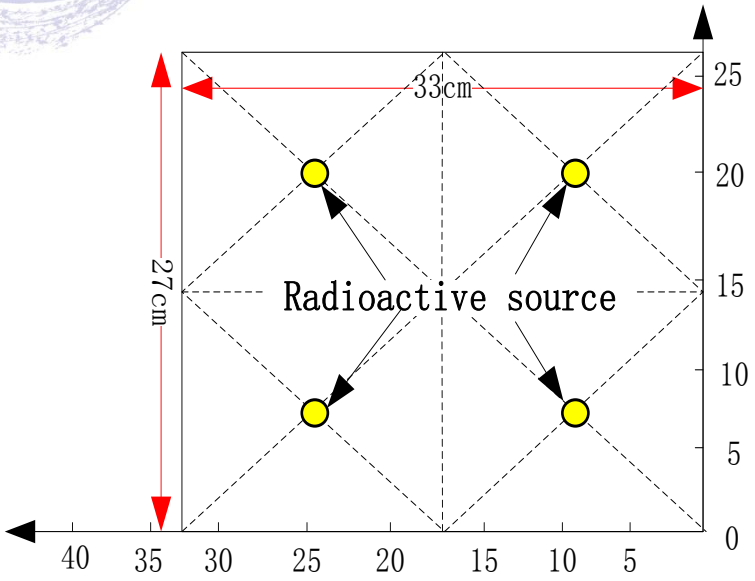
Element 47: Ag      Atomic mass:

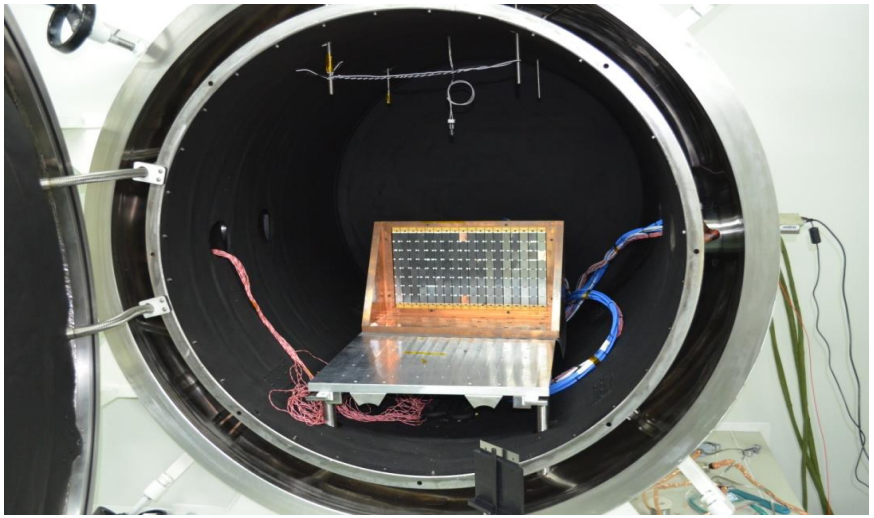
Edge          keV          A
  K         25.5140     0.4859
  L-I        3.8058     3.2578
  L-II       3.5237     3.5186
  L-III      3.3511     3.6998
```

- Si Pin detectors is fixed on the ceramic chip by elargol.
- Through the calibration experiment, we confirmed that when the incident photon energy is greater than 25.5keV, the fluorescence line of silver will be mixed in the Si-PIN energy spectrum.
- The right image is the fluorescence line component of the silver in the observation energy spectrum of ME.



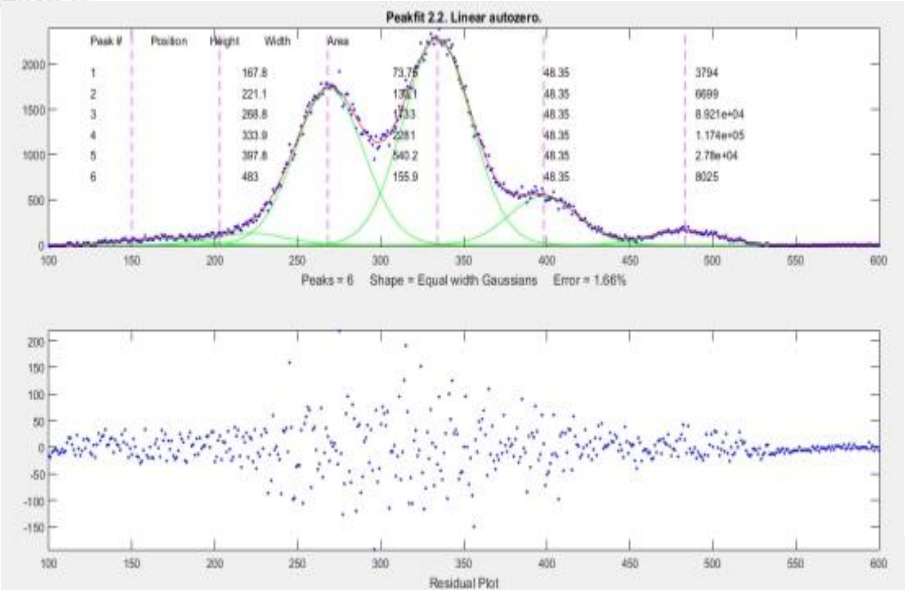
Calibration using ^{241}Am and ^{57}Co

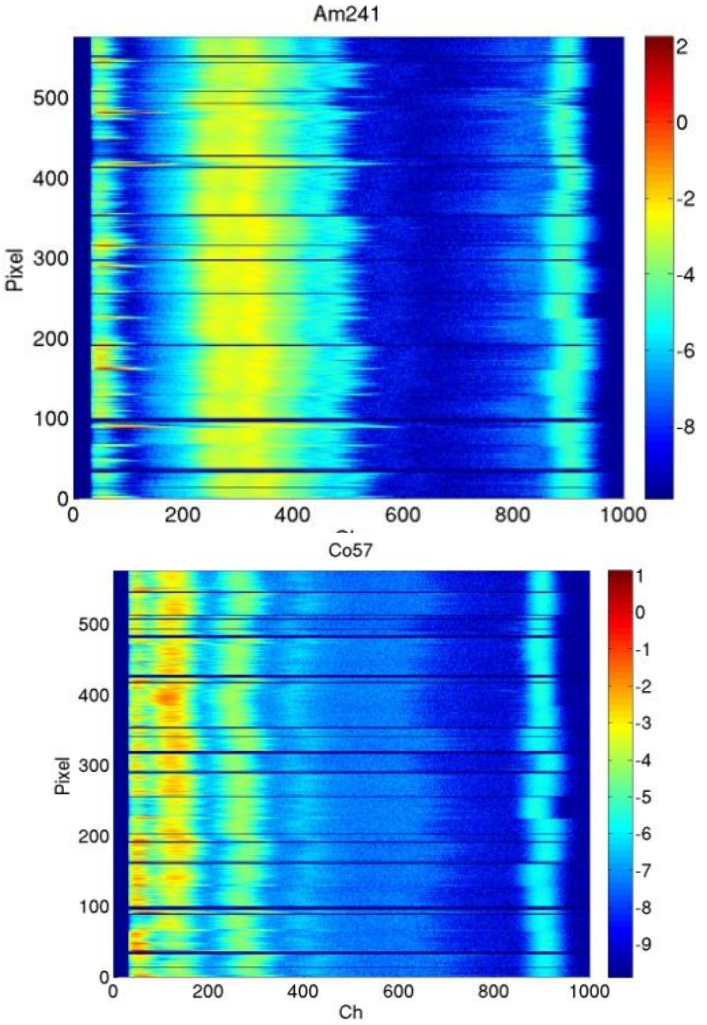




- Two integrated radioactive sources Am-241 and Co-57 were used in the calibration. The left image is the structure of the integrated radioactive source
- The integrated radioactive source is consisted of four single radioactive sources with the activity of 30 μCi each. .
- The responses of detectors to the X-ray emission of Am-241 (with emission lines at 13.9 keV , 17.8 keV , 21.6 keV , and 26.3 keV) and Co-57 (with an emission line at 14.4 keV) were measured at different temperatures (-31℃~-0℃).

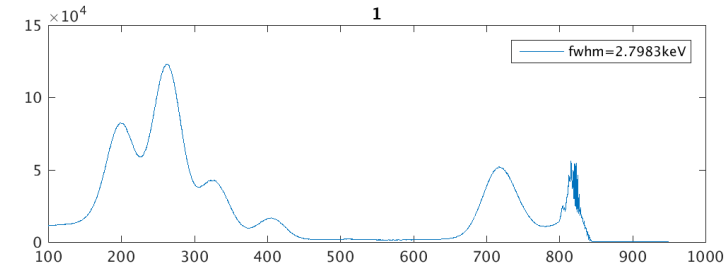
Calibration using ^{241}Am and ^{57}Co

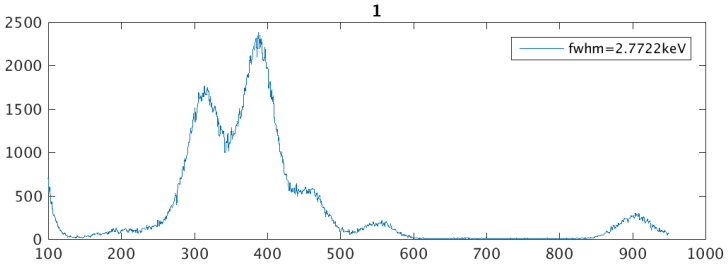




- The left image is the energy spectra of ^{241}Am measured by one pixel(-25℃).
- The right image is the energy spectra of Am-241 and Co-57 measured by the 576 pixels in one MED (-25℃)

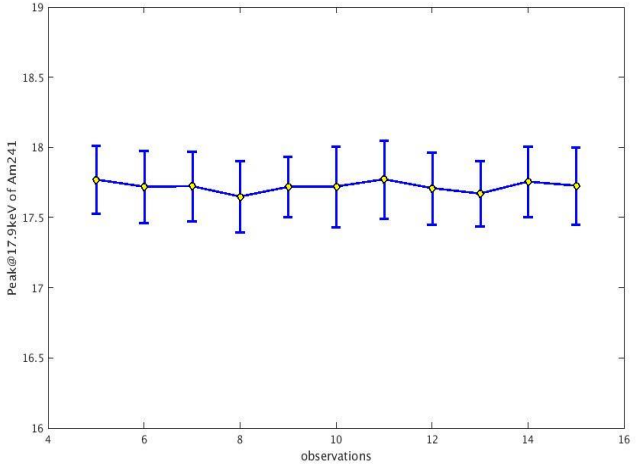
Calibration using ^{241}Am and ^{57}Co



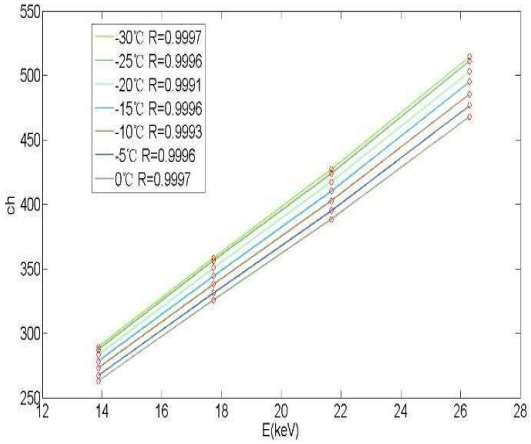


- By comparing the peak position of the 17.9keV branch in the spectra of 61 blank sky observations, we confirm that the EC is almost same as on ground.

- The 24 pixels carried ^{241}Am in orbit can be used to estimate the change of FWHM in orbit. FWHM is almost same with ground.

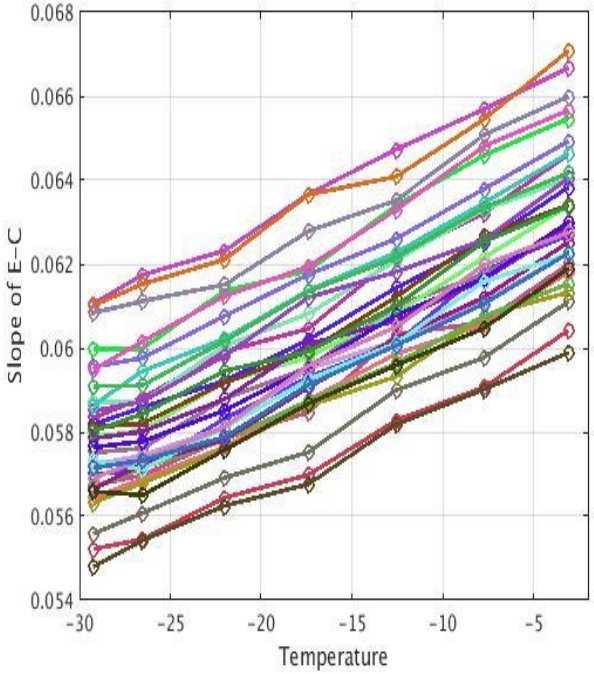


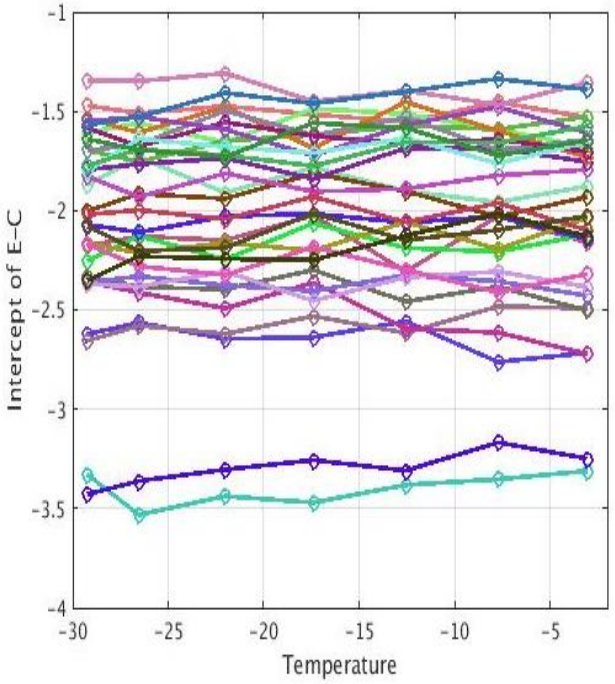
Calibration using ^{241}Am and ^{57}Co



The E-C relations of one Si-PIN pixel at temperatures from -30℃ to 0℃ with a step of 5℃ (from up to the bottom)

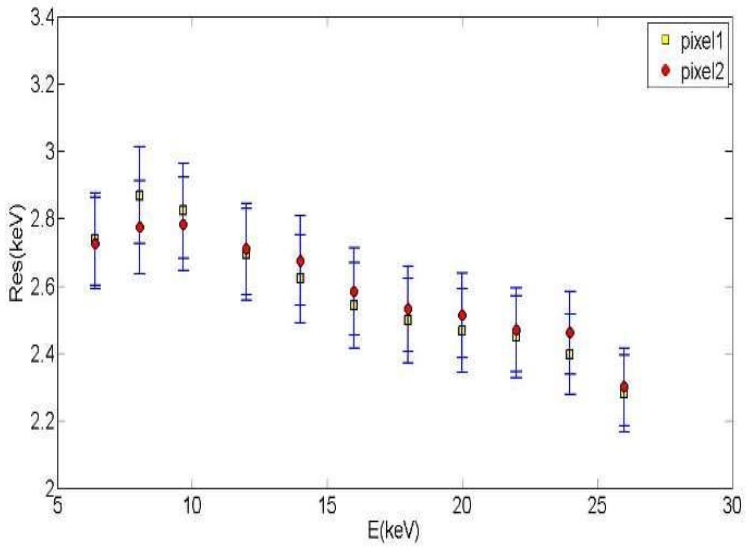
The values of the slope of the E-C relations of the 32 Si-PIN channels in one ASIC at different temperatures

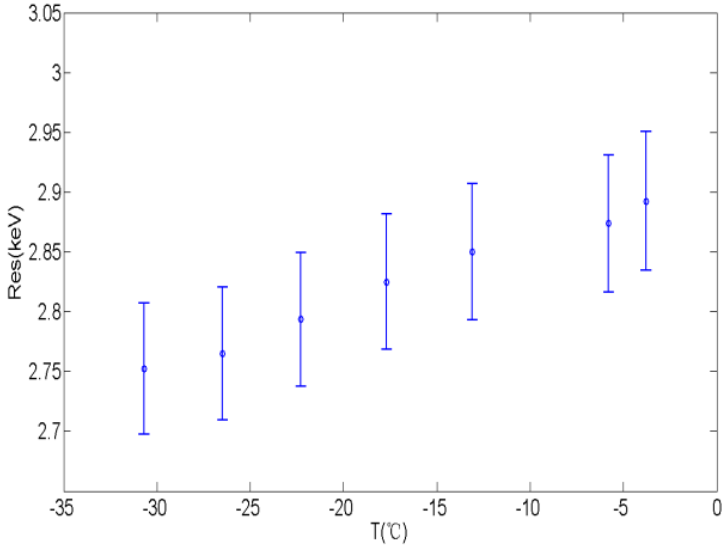




The values of the intercept of the E-C relations of 32 Si-PIN channels in one ASIC at different temperatures.

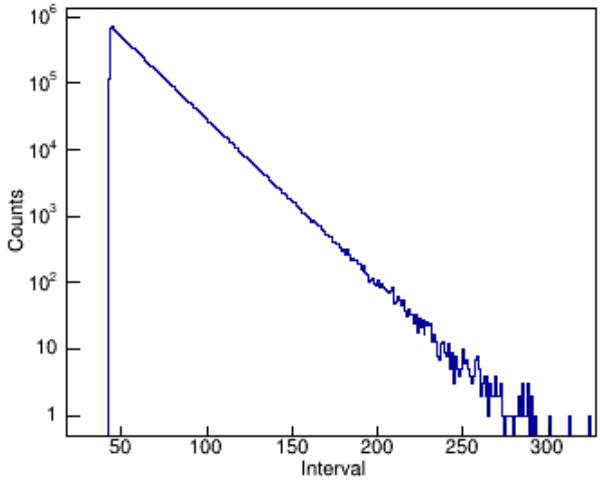
Calibration using ^{241}Am and ^{57}Co





- The energy resolution of ME is mainly determined by the noise of the detector and readout electronics. Compared with the effect of the electronics noise.
- With the performance of the ASIC, which will be with the smaller uncertainty when the input signal becomes larger, the energy resolution (FWHM) is better with the incoming energy increased
- Since the leakage current of Si-PIN detectors decreases at lower temperatures, the energy resolution also decreases at lower temperatures

Calibration using ^{241}Am and ^{57}Co



- The time interval spectrum of an MED obtained in thermal vacuum test. The horizontal axis is in units of 6 μs (-20℃).

- The dead time (TD) of ME is a combination of ADC dead time (TADC) and readout dead time (TRD). If n pieces of ASICs (out of the 6 ASICs in one unit that are controlled by an FPGA) are triggered in the same FPGA sampling period (16μs), they will be considered as triggered simultaneously. The dead time is TD= TADC + n × TRD now. The typical value for TADC and TRD is 162.1μs and 93.7μs respectively. The on orbit count rate of ME is usually very low and thus only one ASIC will be triggered in most cases. As a result, the time interval spectrum is a standard negative exponential curv The x-axis is in units of 6 μs, i.e., the precision of the time code. In case of single ASIC trigger, the dead time is about 42 or 43 time code units, corresponding to 252~258 μs.

Summary

ME contains 1728 channels of Si-PIN detectors covering 5-30 keV and its total detection area is 952 cm^2.

The energy resolution is about 2.96 keV in the whole energy range of 5-30 keV and the dead time is about 255 μs.

The response functions of the detectors at different temperatures and different VTHR have been calibrated for the 1728 pixels with radioactive sources and monochromatic energy X-ray beams.

The energy resolution improves when the working temperature decreases by 0.5‰ per degree and at the same time the slope of the E-C relations decreases by 0.2‰ per degree.