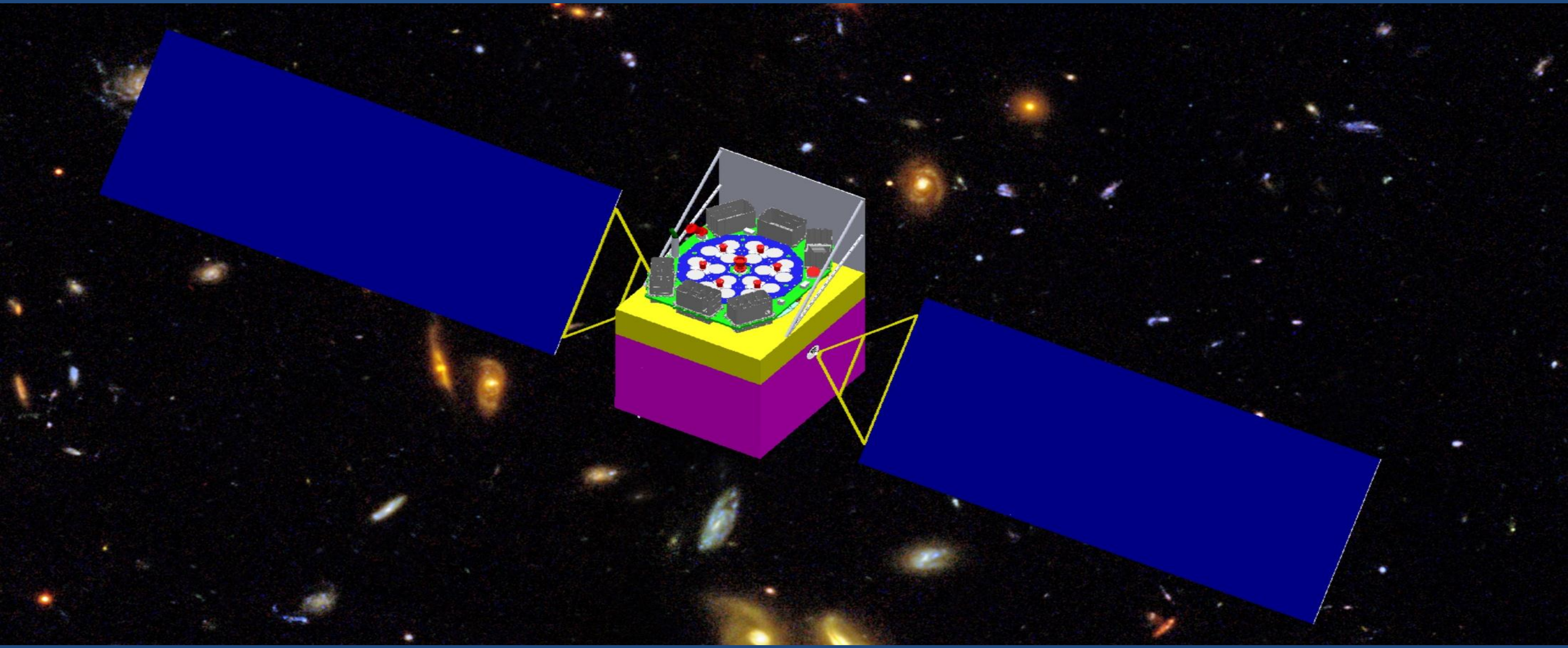
Production of HXMT calibration Files

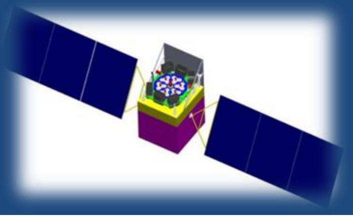


8th IACHEC meeting

LI Xiao-bo

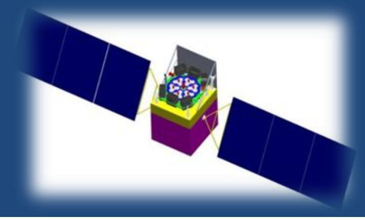
Institute of High Energy Physics, CAS

Outline

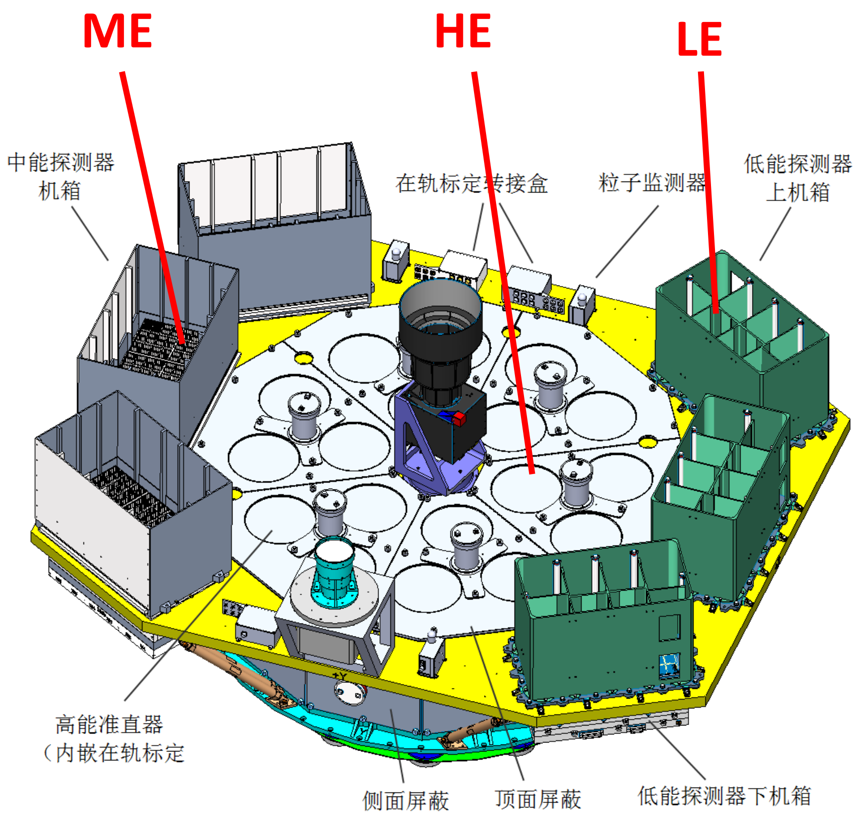


1. **Hard X-ray Modulation Telescope(HXMT)**
2. **Flow of calibration data files**
3. **Calibration parameters for energy response matrix**
   - Energy scale
   - Energy resolution
   - Efficiency
4. **Monte carlo simulation based on Geant4**
5. **Performance of HXMT detectors in electronics test**
6. **Summary**

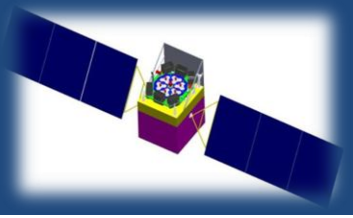
1. HXMT

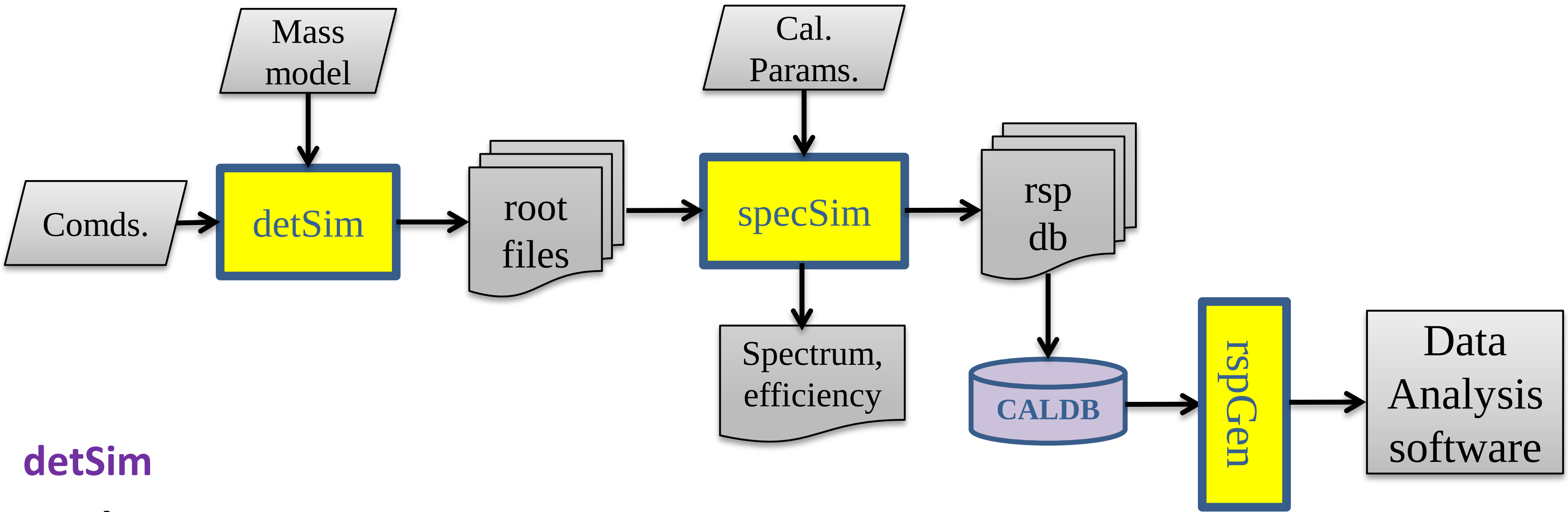


- **Scientific Objectives:**
  - X-ray all sky survey
  - pointing obs. of X-ray source
- **Orbit: circle, 550km**
  - orbital period: ~90mins
  - orbital inclination: 43 degree
- **Instruments:**
  - HE: NaI(Tl)/CsI(Na), 5000cm^2, 20-250keV;
  - ME: Si-Pin, 952cm^2, 5-30keV;
  - LE: CCD, 384cm^2, 1-15keV



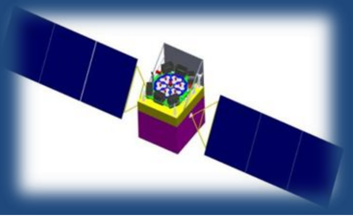
2. Flow of calibration data files





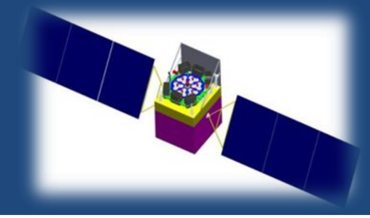
- **detSim**
  - **Inputs:**
    - Mass model of instruments and environment
    - Some commands to configure the simulation
  - **Outputs:**
    - Raw event files(ROOT files)
  - **External dependencies:**
    - GEANT4—toolkit for MC of particle interactions with matter from CERN
    - ROOT– Data analysis package from CERN.

Continue:



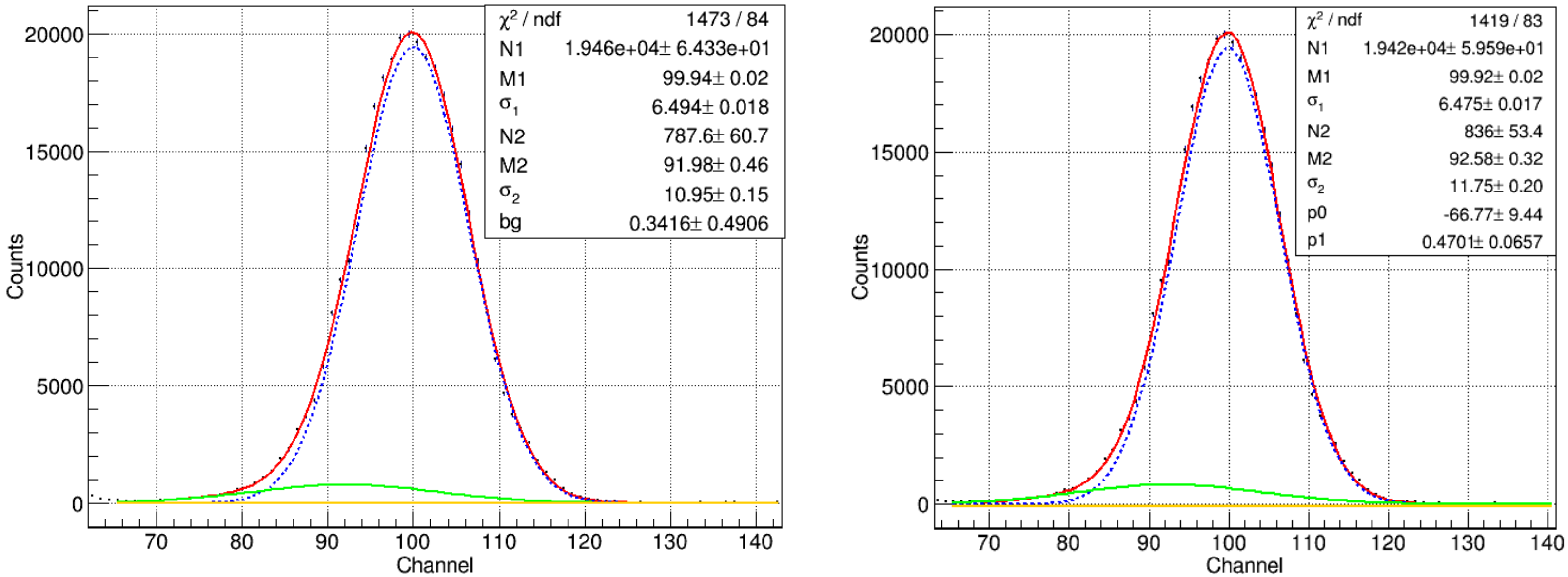
- **specSim**
  - **Inputs:**
    - Raw event root files
    - Calibration parameters from experiment data
  - **Outputs:**
    - Energy response curve and efficiency
    - FITS file, like rmf, arf.
  - **External dependencies:**
    - ROOT– Data analysis package from CERN.
    - CCFITS—FITS data file I/O
- **rspGen**
  - **Inputs:**
    - FITS file from CALDB
    - Some specific FTOOLS developed by HXMT group to generate the RMF of observe ID.
  - **Outputs:**
    - Applicated RMF files
  - **External dependencies:**
    - CCFITS—FITS data file I/O
    - FTOOLS of CALDB related.

3. Calibration parameters

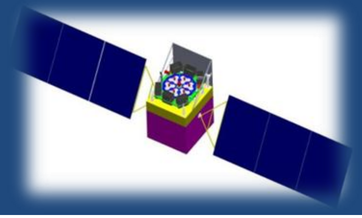


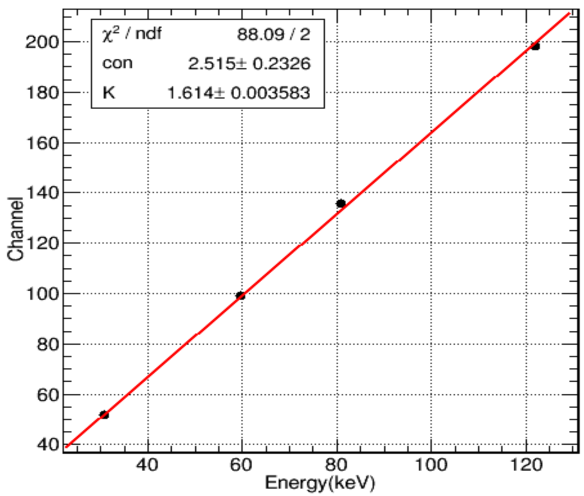
- Energy scale and resolution can be gained through radioactive sources and X beam experiments on ground.

^{241}Am@ HE



- 59.5 keV full energy peak fit:
- The mean and sigma of full energy peak are influenced by the fit range and fit function which we used to describe the background.
- We change the different fit conditions ten more times and get the value and error of full energy peak and its sigma.



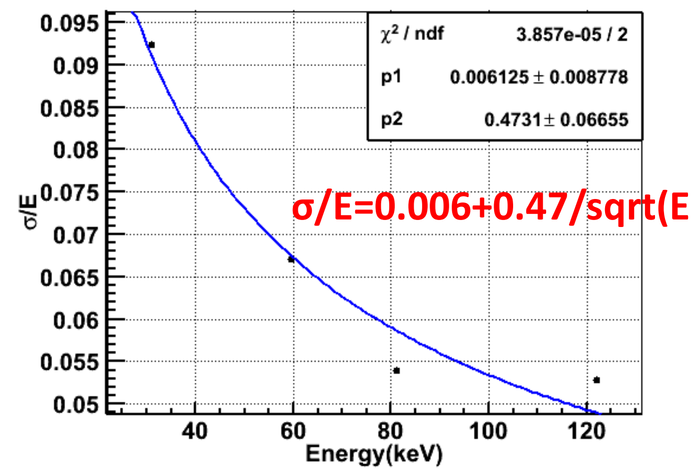


C=2.515*E+1.614

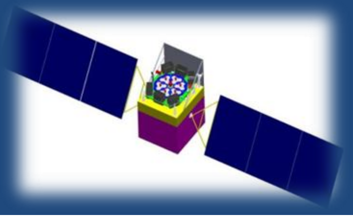
NIM A675(2012)78-83

Fitted FWHM function	Literature		$\bar{R}^2$	
	Detector	References	NaI	$LaBr_3$
$\mathrm{FWHM}(E)=a+bE$	Ge	[3,21]	0.98011	0.99301
$\mathrm{FWHM}(E)=a+b\sqrt{E}$	Ge	[3]	0.99534	0.99904
$\mathrm{FWHM}(E)=a\cdot E^b$	NaI	[15]	0.99310	0.99884
$\mathrm{FWHM}(E)=a+b\sqrt{E+cE^2}$	NaI, $LaCl_3$	[16-18]	0.99581	0.99900
$\mathrm{FWHM}(E)=a\sqrt{E}+bE$	NaI, $LaBr_3$	[3,19]	0.99138	0.99873
$\mathrm{FWHM}(E)=a\sqrt{E}$	NaI	[20]	0.98729	0.99850
$\mathrm{FWHM}(E)=\sqrt{a+bE}$	NaI, Ge	[3,21]	0.97922	0.99923
$\mathrm{FWHM}(E)=\sqrt{a+bE+cE^2}$	Ge	[3,21]	0.91769	0.99917
$\mathrm{FWHM}(E)=a+bE+cE^2$	NaI, $LaBr_3$	[22]	0.99713	0.99979
$\mathrm{FWHM}(E)=a+b\sqrt{E+c}$	NaI, $LaBr_3$	This study	0.99492	0.99922
$\mathrm{FWHM}(E)=a+bE+cE^2+d\sqrt{E}$	NaI, $LaBr_3$	This study	0.99699	0.99980
$\mathrm{FWHM}(E)=a+bE+c\sqrt{E}$	NaI, $LaBr_3$	This study	0.99550	0.99904
$\mathrm{FWHM}(E)=aE+bE^2$	NaI, $LaBr_3$	This study	0.99695	0.98146

- Fit function for the energy-channel relation:
  - C=K*E+con, nonlinear etc.
- The error of energy scale and resolution can be derived through the error propagation .



Efficiency calibration



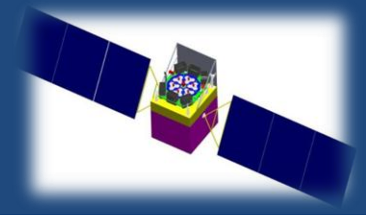
- One method is to use calibrated radioactive sources
  - The reference activities were provided in a calibration certificate by the supplier of the radioactive sources.
  - The activity at the day of measurements were calculated by taking into account the time elapsed since the calibration reference day.

$$\varepsilon(E) = \frac{N}{A * t * p(E) * T(E) * exp - (\mu_{air} * d_{air}) * \Omega/4\pi}$$

  - N is the detected events, A is the activity of the source, T(E) is the transition probability of entrance window, p(E) is branch ratio.
  - For HE, N must meet the energy cut(20—250 keV) and pulse width cut to get NaI-like events. For ME and LE, N should meet the energy cut.
  - Error of efficiency can be estimated.

$$\delta\varepsilon_{exp} = \varepsilon_{exp}\sqrt{(\frac{\delta N}{N})^2 + (\frac{\delta A}{A})^2 + (\frac{\delta p}{p})^2}$$

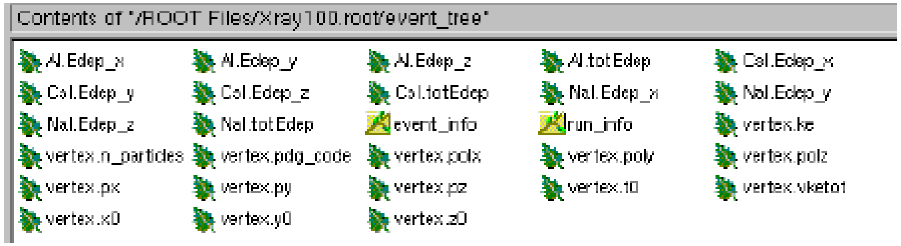
4. MC simulation based on G4



- Parameters for MC tuning:

Exp. environ ement	Incid-ent source	Resolu tion curve	Mass model	Phyical process model

- Output hit information of MC:



Incident Generator — *All kinds of incident particles*

↓

Geant4 Mass Model, Physical process model

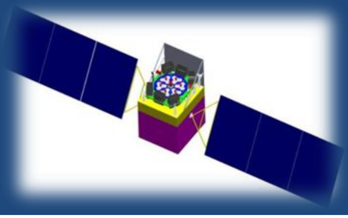
↓

Hit information
Deposit energy
Deposit position

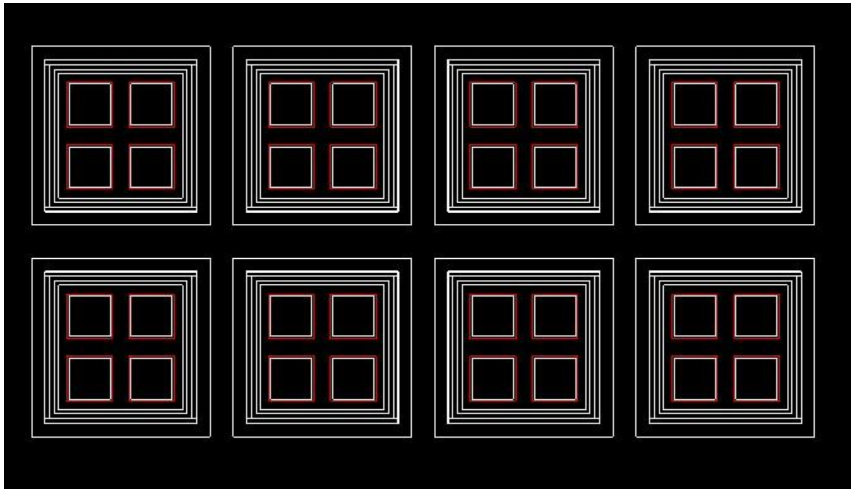
↓ ← Energy resolution and scale

Digitization
ADC spectrum
Pulse width spectrum

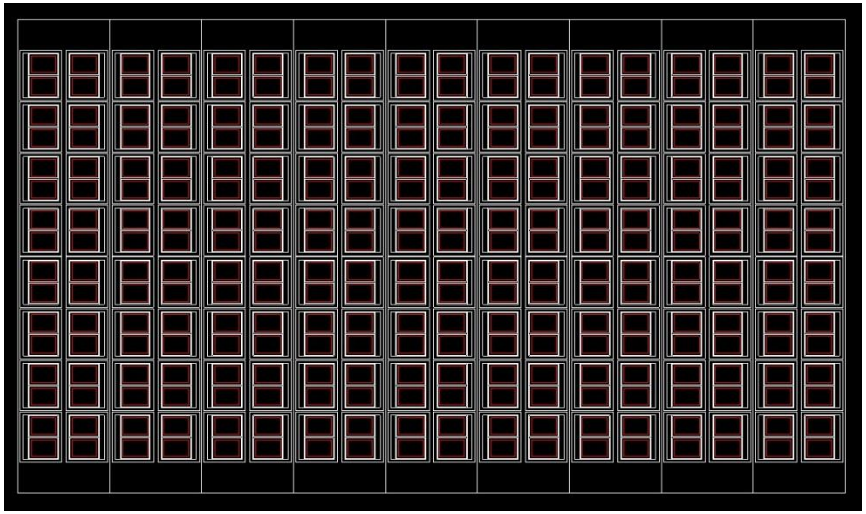
Visualization of HXMT detectors



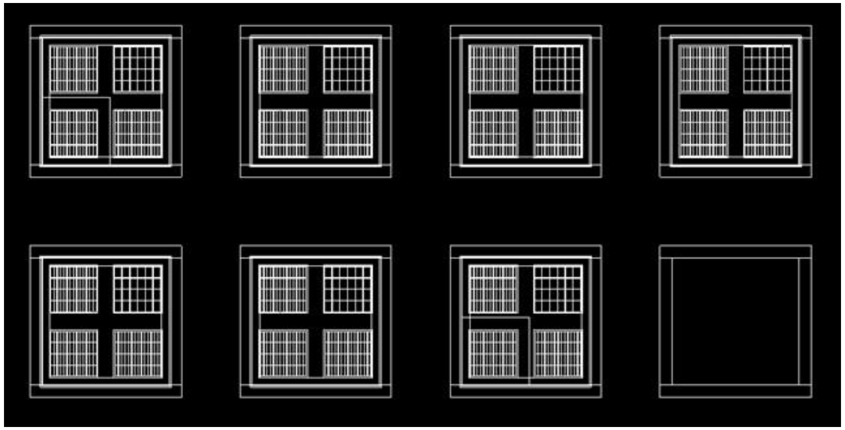
SCD detectors of LE in one box:



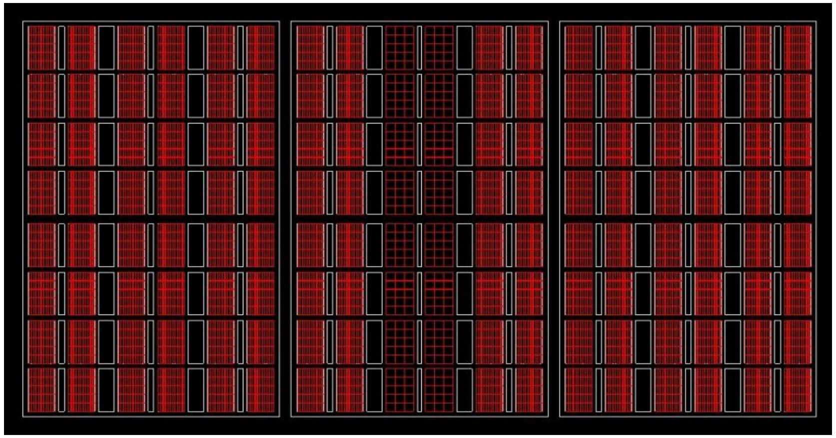
Si-Pin detectors of ME in one box:



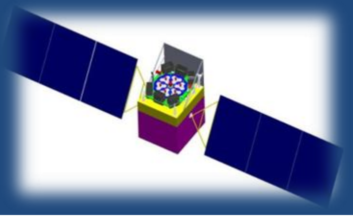
Collimators of LE:



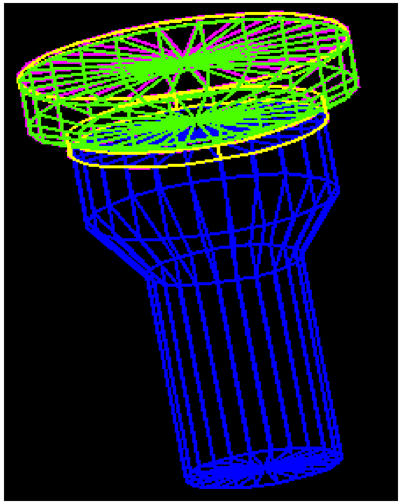
Collimators of ME:



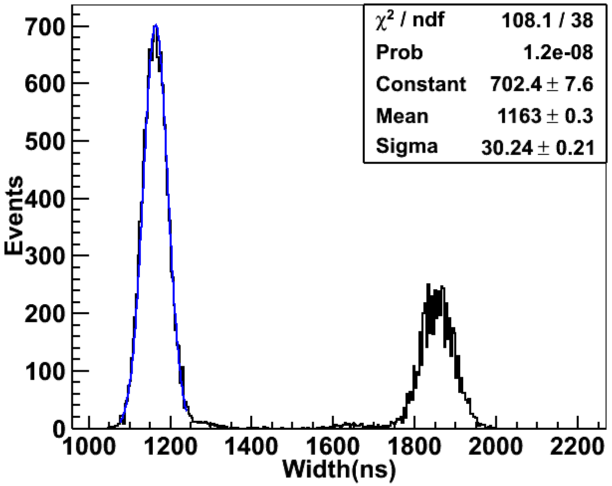
MC Spectrum of HE detector



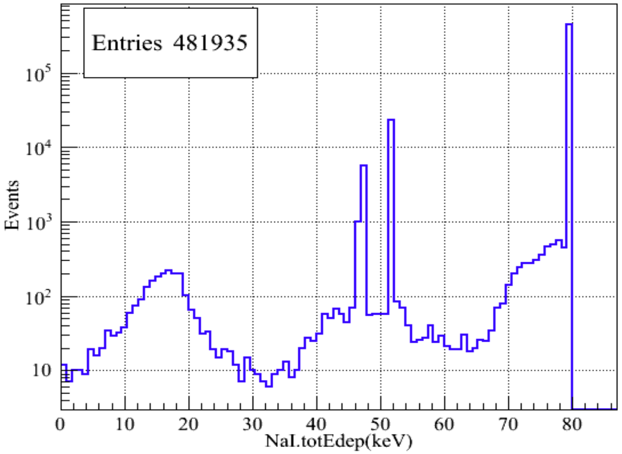
HE detector visualization:



Pulse width spectrum:

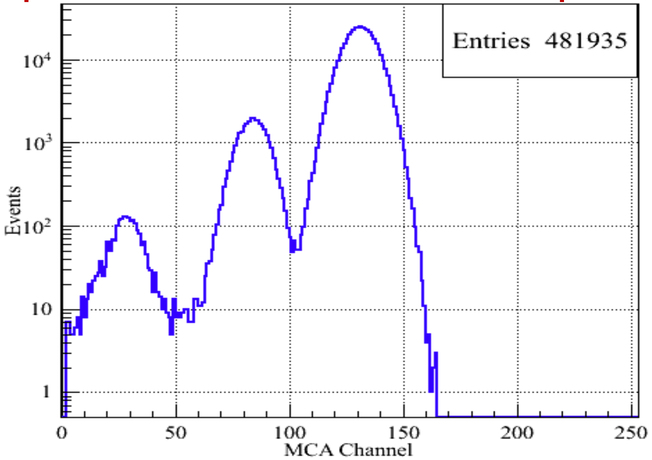


detSim—raw physical spectrum

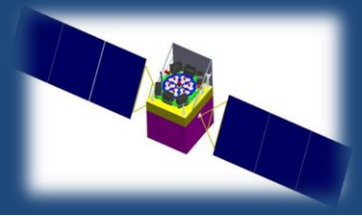


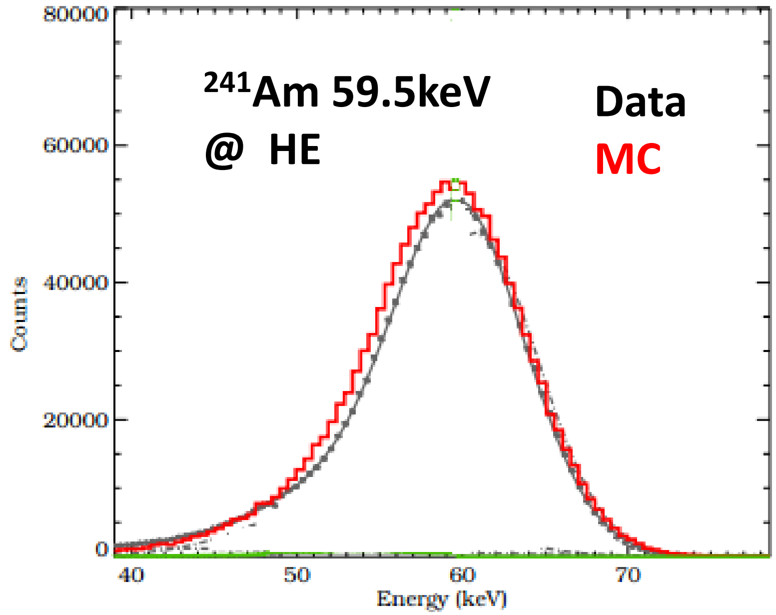
Energy scale and resolution

specSim—instrument-like spectrum



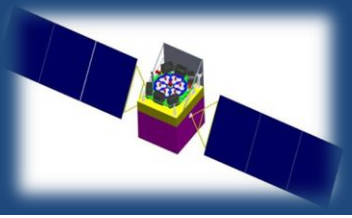
MC energy spectrum vs Data



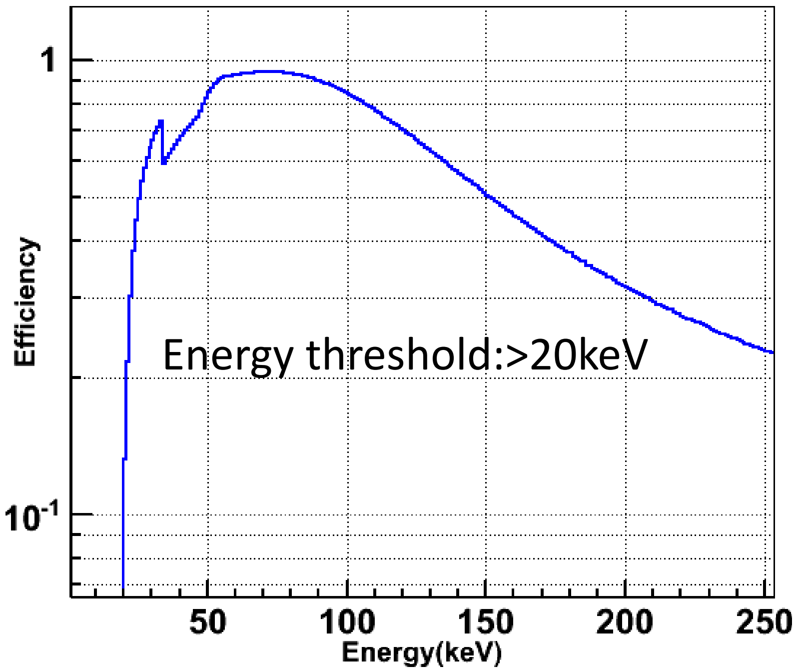


- The difference between MC spectrum and data decides the precision of the energy response.
- Experience to tune the MC parameters to reduce the difference .
- How big system error will be produced if we have several percent difference between the MC spectrum and data?

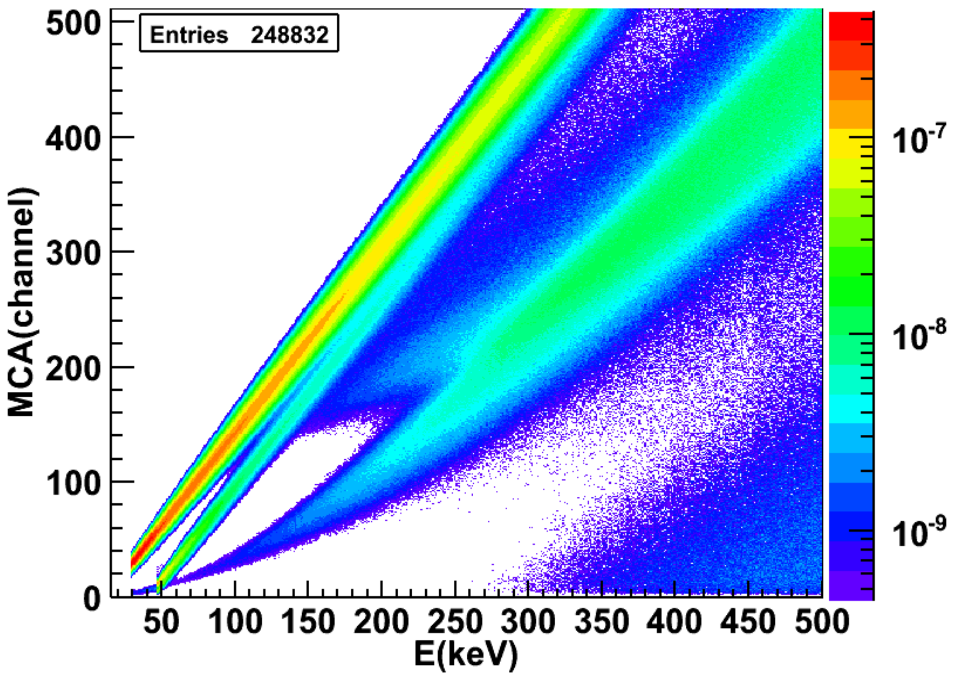
HE Detector response:



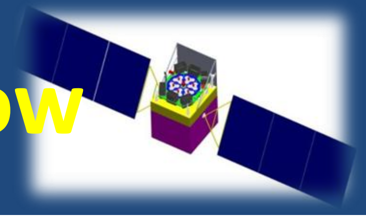
Efficiency:

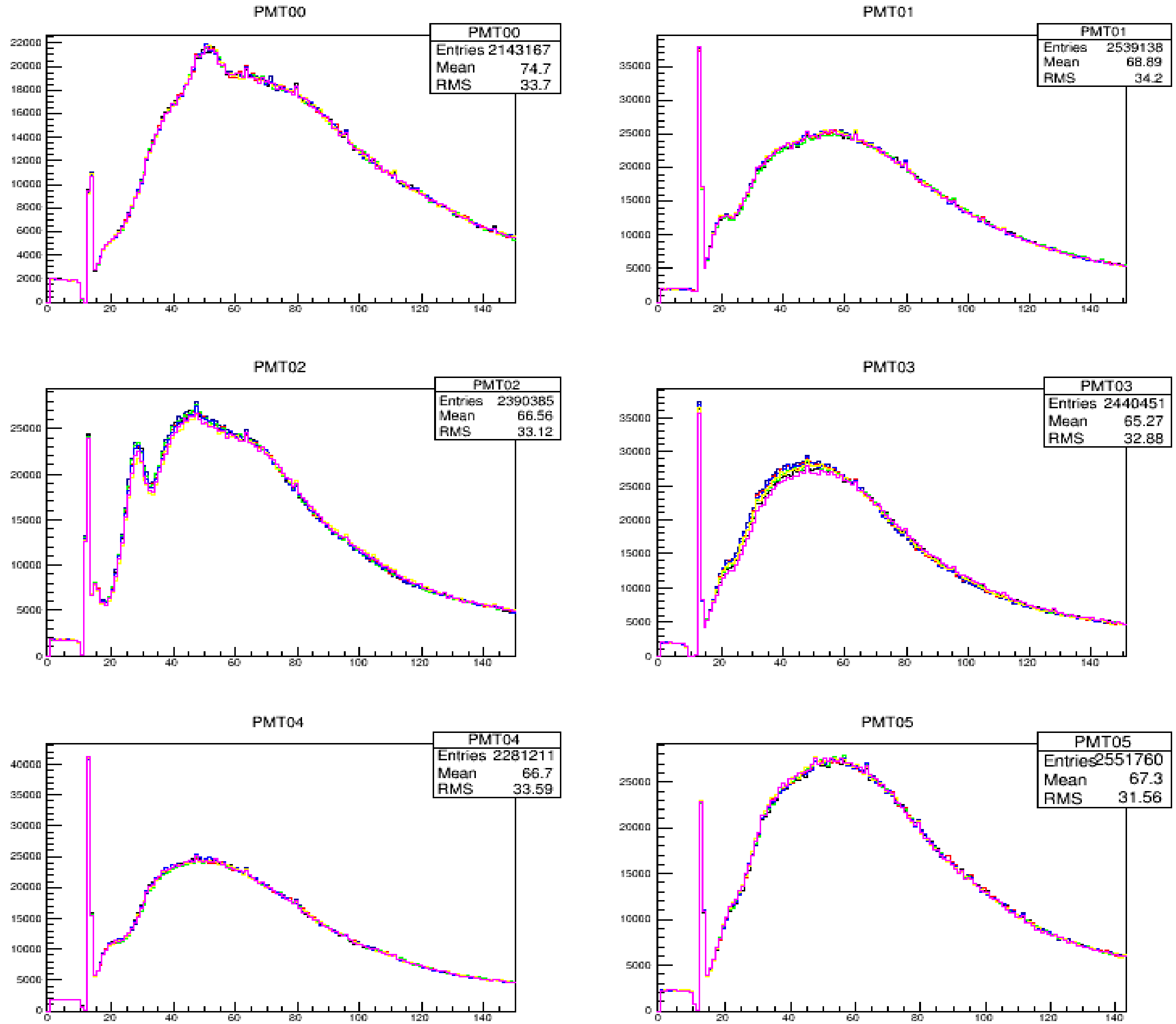


RMF:



5. Performance of HXMT detectors now

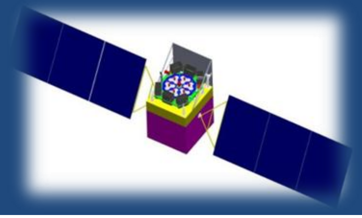


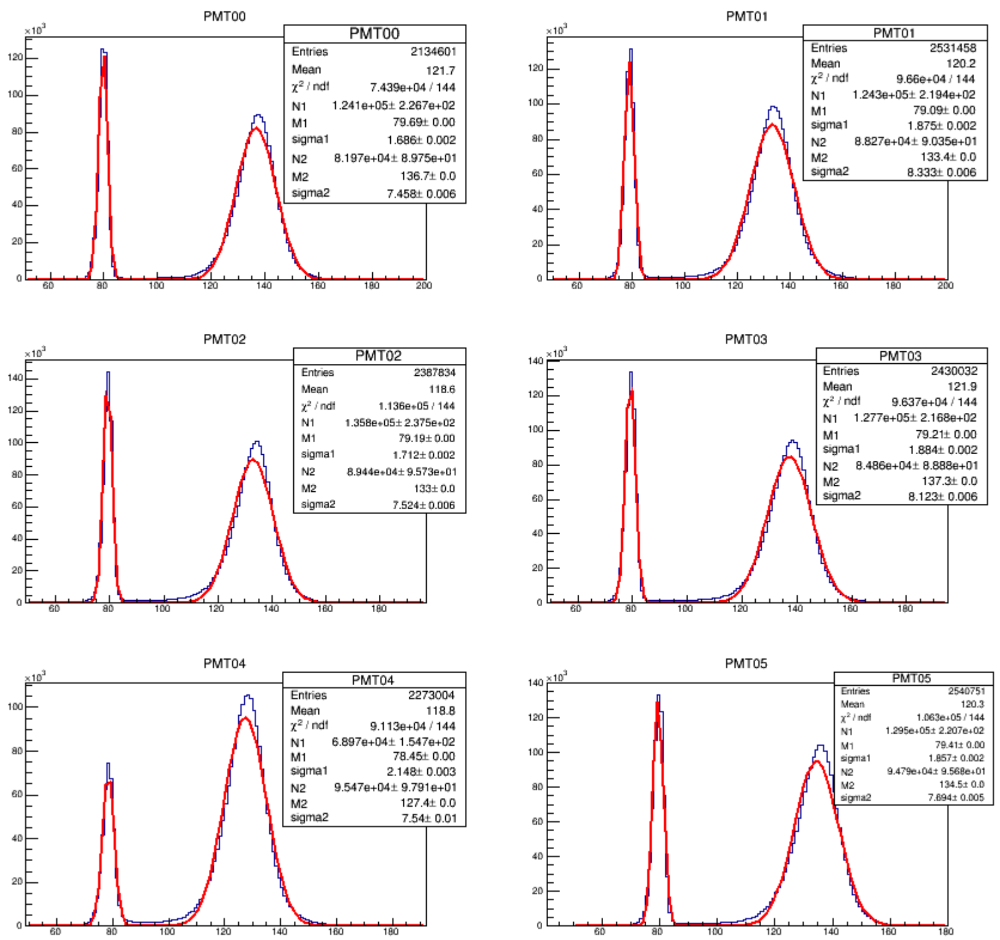


Energy spectrum of 6 detectors in one group.

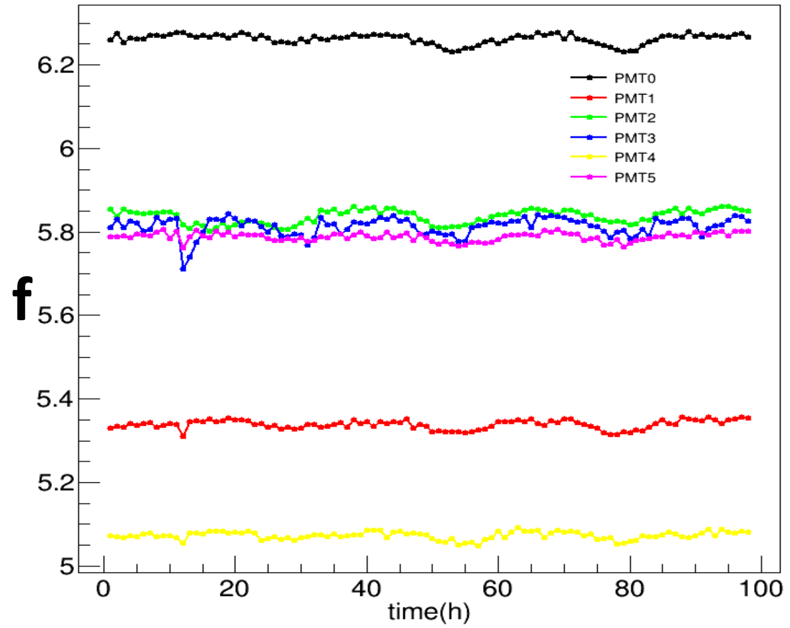
One color represents one hour.

Pulse width spectrum



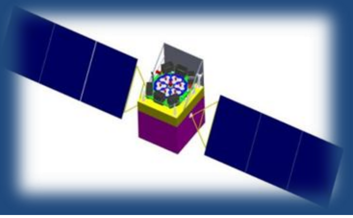


$$f = (M2 - M1)/(\sigma 1 + \sigma 2)$$

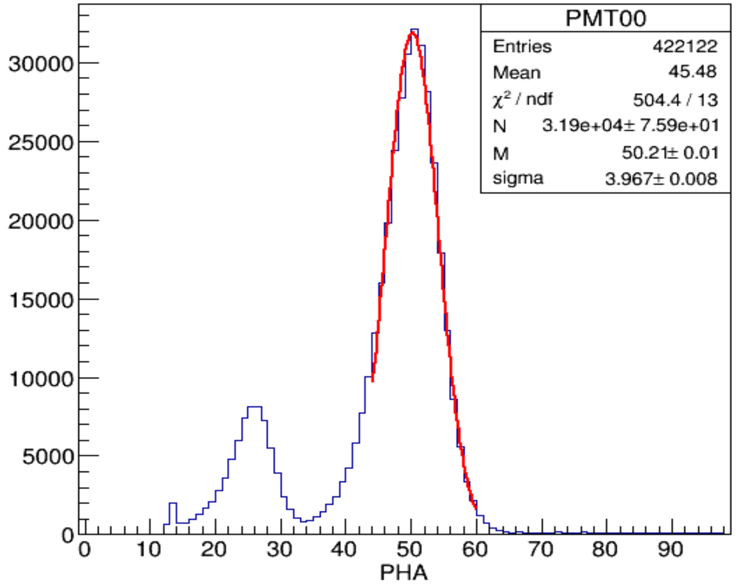


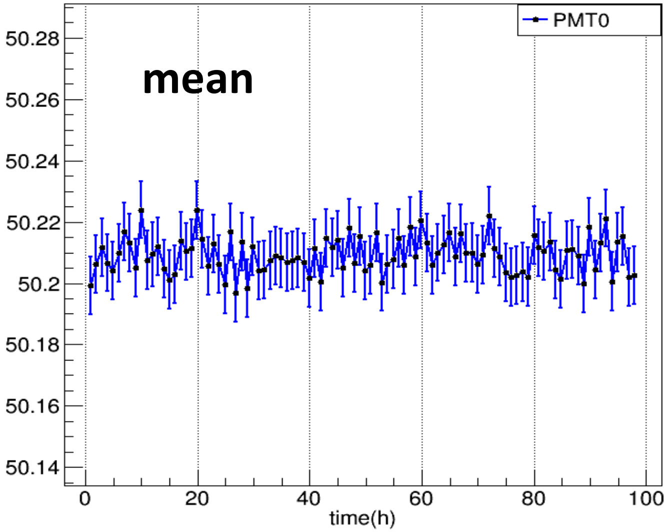
100 hours of test for one group of HE.

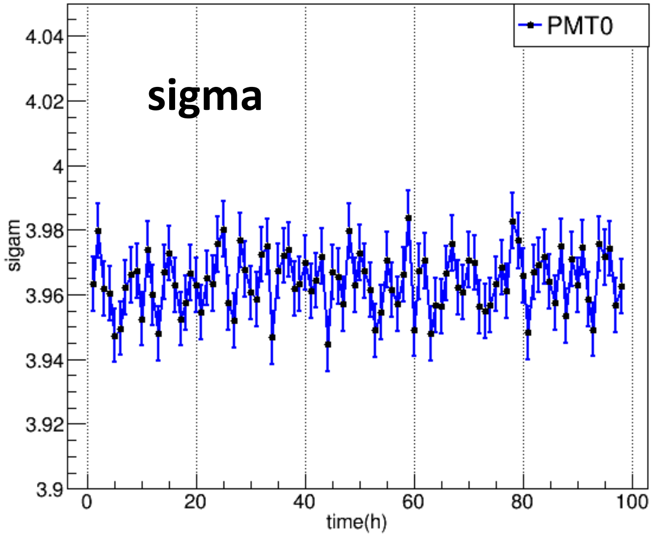
Automatic gain control



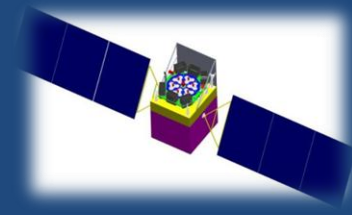
- ^{241}Am source of in-orbit calibration detector was used on one PMT in the 100 hours test.



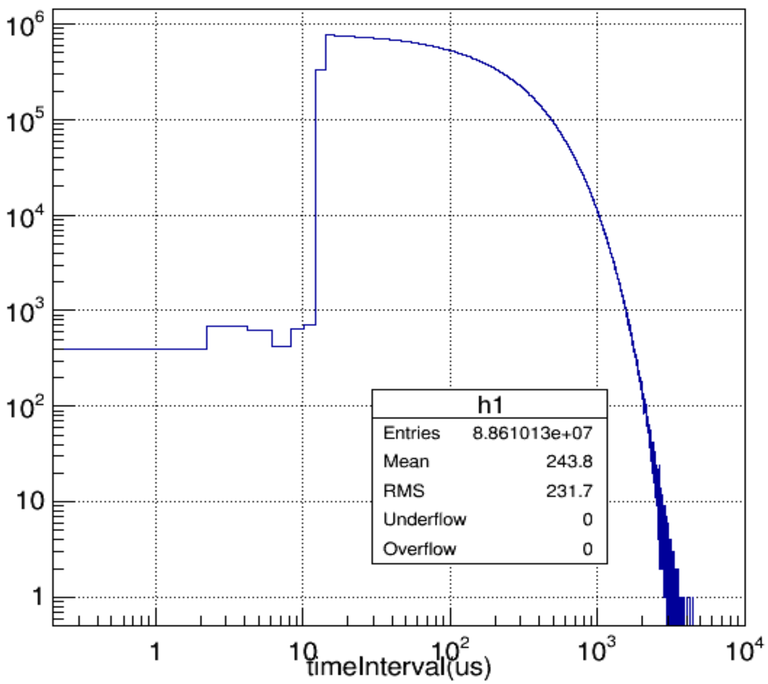




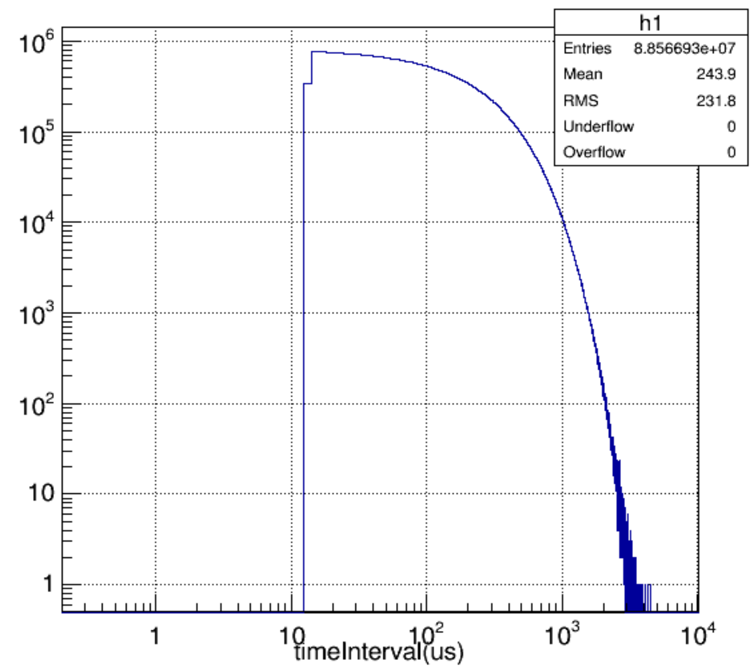
Time interval distribution



- Time Interval distribution of 6 HE detectors in one group.
- Time used to process one signal needs 12us.

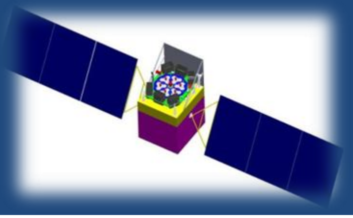


All Events, including GPS second events, physical events and radioactive events.



Physical events or radioactive events

6. Summary



- **Elaborate calibration experiments will be done in IHEP soon.**
- **Detector simulation:**
  - Simulation software ✓
  - Preliminary MC result vs experiment data ✓
  - Long-term work to tune MC parameters
- **Calibration parameters and their accuracy**
  - Energy scale, resolution and efficiency ✓
  - Timing related
- **CALDB**
  - Design the CALDB of HXMT ✓
  - Calibration software for users

Thank you for your attention!