

The study of calibration process for the dual-threshold hybrid pixel array detector of HEPS-BPIX40

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Introduction



Figure 1 High Energy Photon Source (HEPS)

- HEPS (High Energy Photon Source) is the 4th-generation synchrotron radiation source in China.
- Brightness up to: 10^{22} photons/s/mrad²/mm²/0.1% BW
- Emittance superiority: 0.06 nm · rad
- Storage ring energy up to: 6 GeV
- It provides X-rays with energies up to 300 keV

A dual-threshold hybrid pixel detector working in the single photon counting mode was designed for the High Energy Photon Source (HEPS) in China.

The detector module is composed of: Si-PiN Sensor Bump Bonding + Readout ASIC + Electronics.

ASIC Design Specification:

- Pixel Size: 140μm × 140μm
- Pixel Array: 128 × 96
- Counter Rate: 1Mcps/Pixel
- Frame rate: >1kHz

Detector Module Specification:

- Module Array: 576 × 256 (2 × 6ASICs)
- Sensor thickness: 450μm
- PCB type: LTCC
- Energy Threshold: >5keV
- Bad pixel: <0.5‰

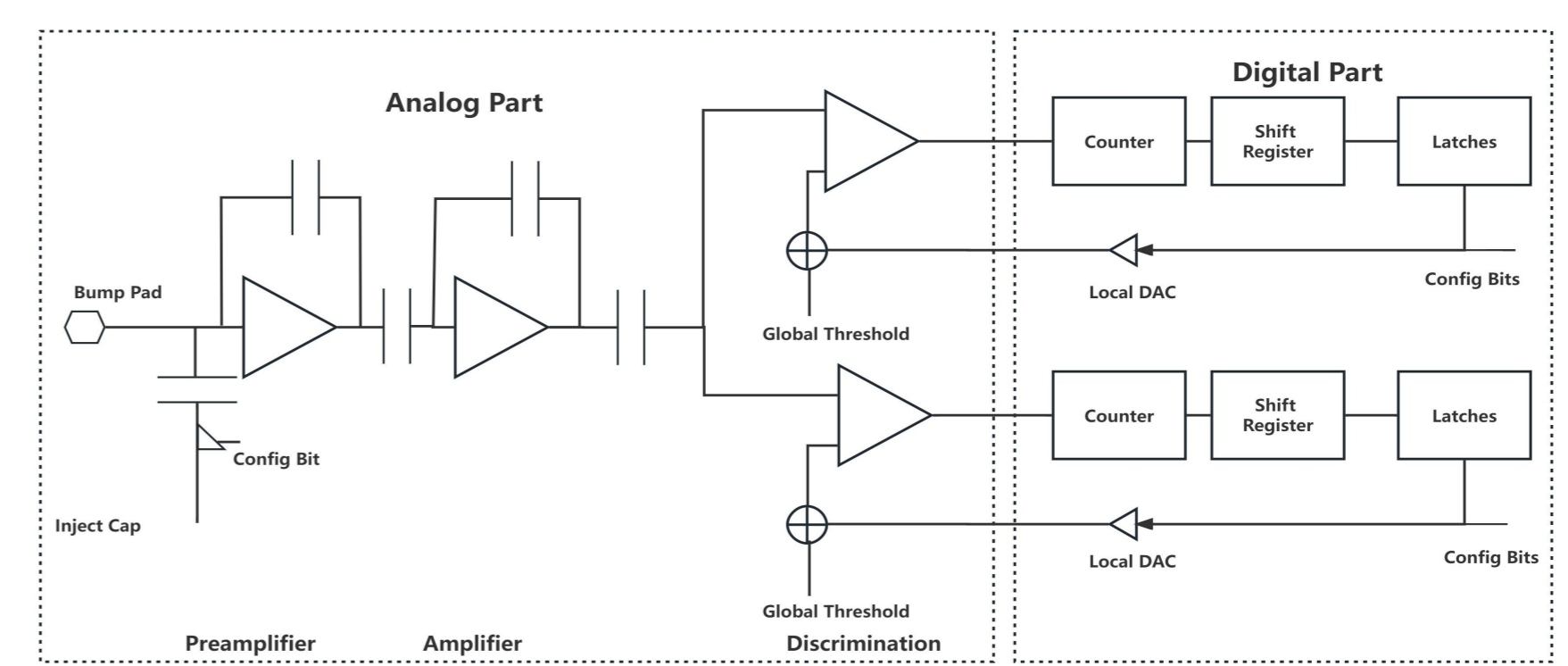


Figure 2 The schematic diagram of single pixel

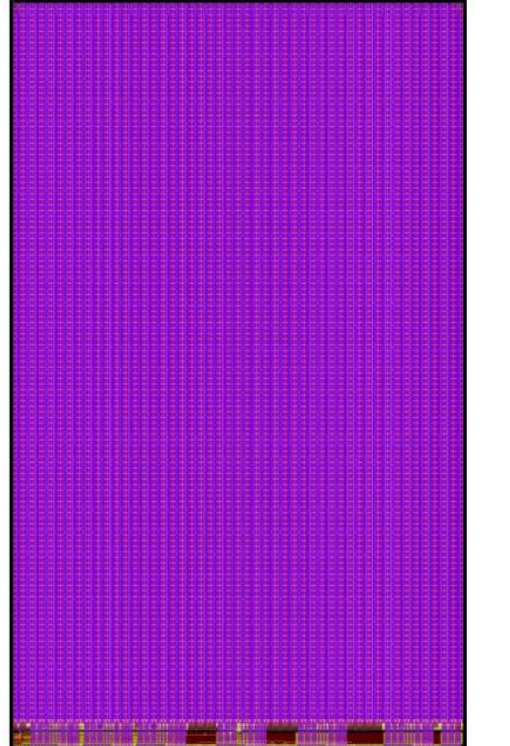


Figure 3 The overall layout of the chip

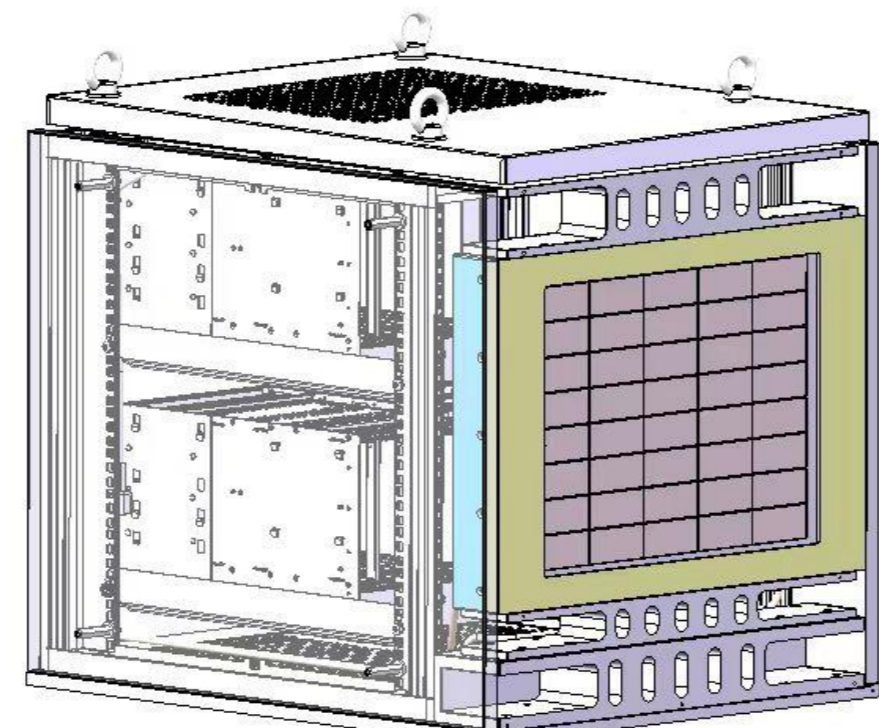


Figure 1 The 6M detector system

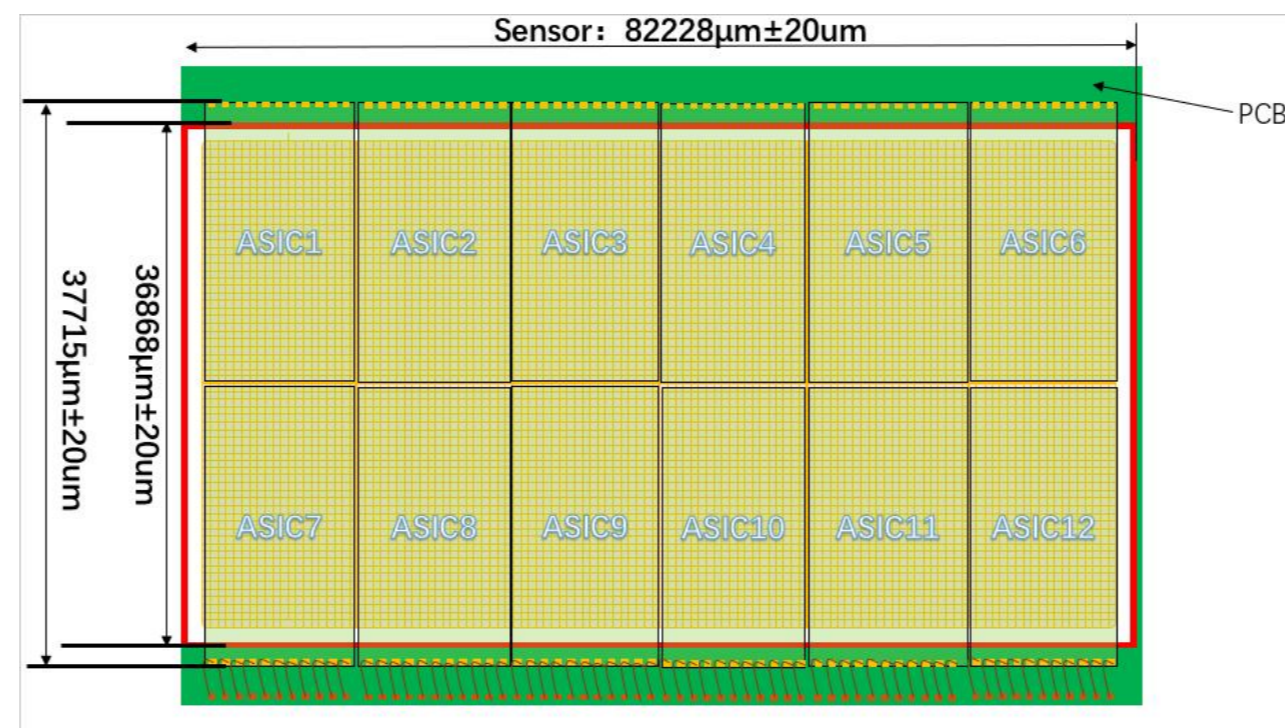


Figure 4 The diagram of module size



Figure 5 The silicon pixel module

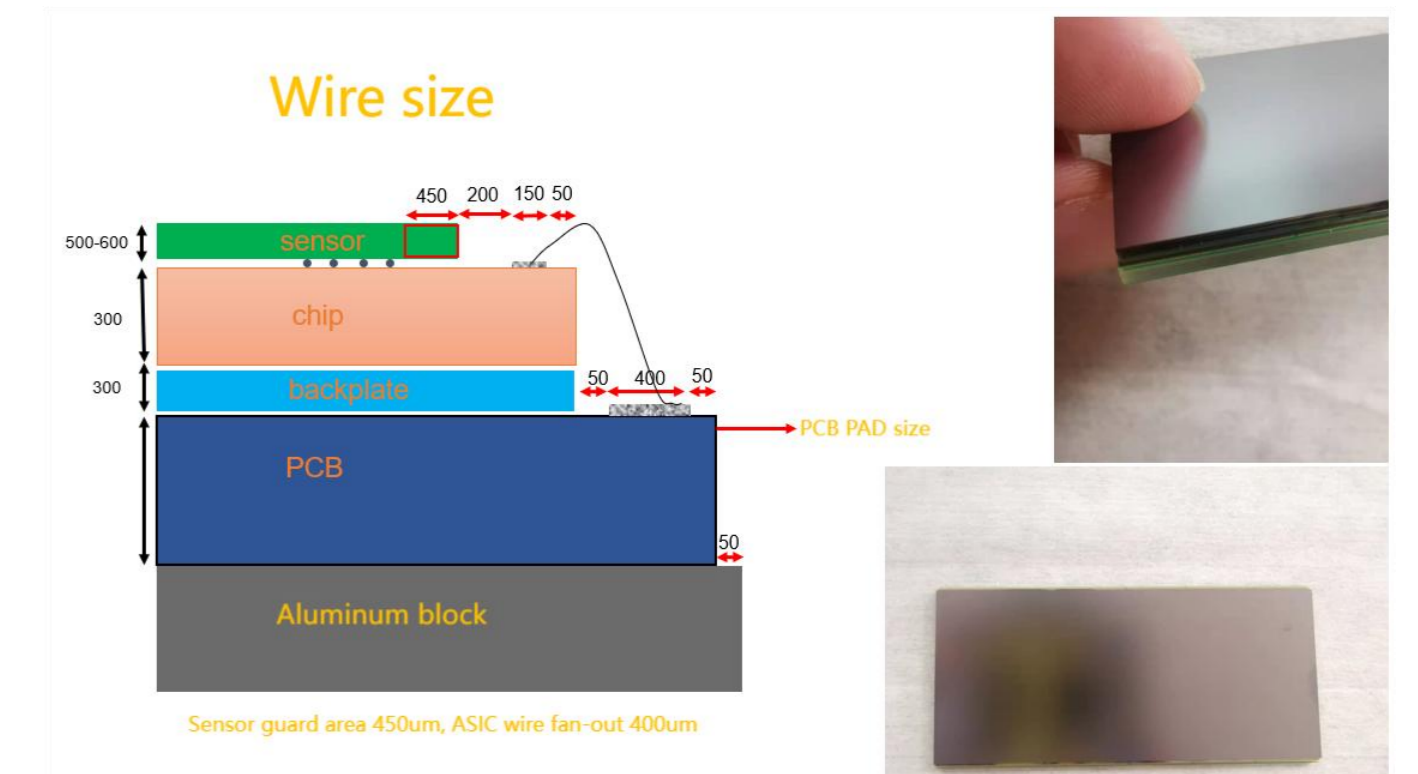


Figure 6 The wiring diagram

Study of the dual-threshold module

Threshold and energy relationship diagram.

- Minimum Detection Energy is about 4.02 keV
- 1keV corresponds to about 2.1 LDAC LSB

Three Gains.

- Noise energy and Threshold energy

	Gain0	Gain1	Gain2
Noise energy(keV)	0.23	0.46	0.78
Threshold energy(keV)	3.57	5.53	7.37



Figure 7 The single module diagram

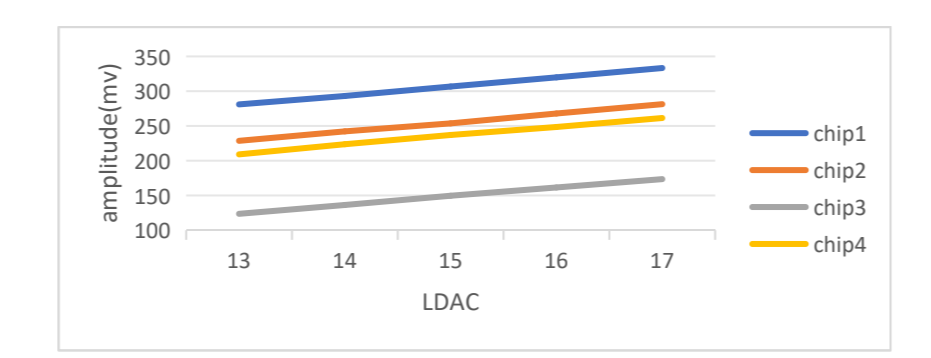


Figure 8 The relationship of the LDAC and amplitude

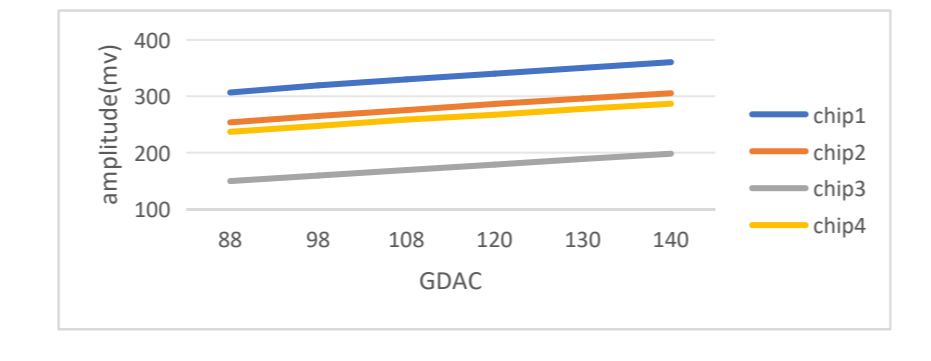


Figure 9 The relationship of the GDAC and amplitude

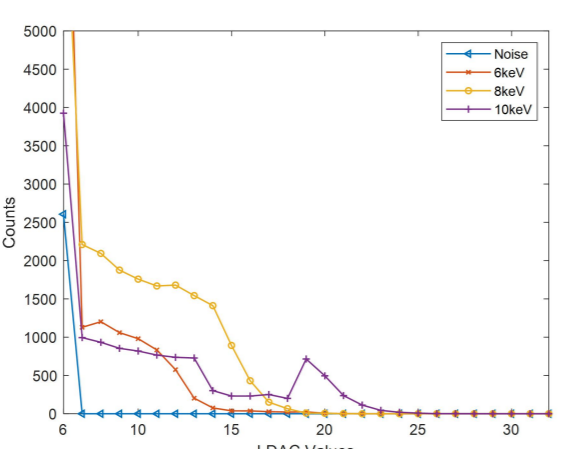


Figure 10 The threshold scans of a pixel for different X-ray energies

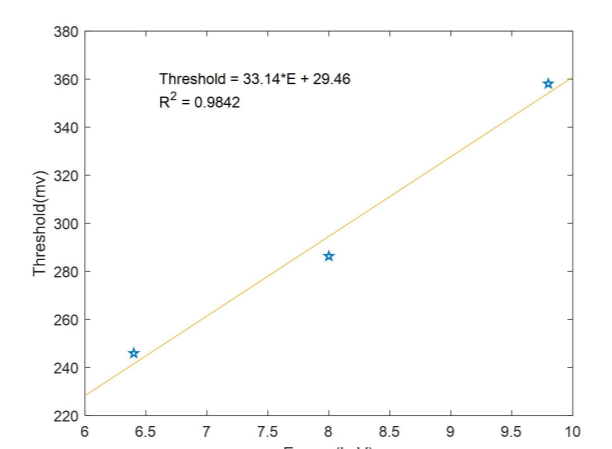


Figure 11 The relationship of the energy and threshold

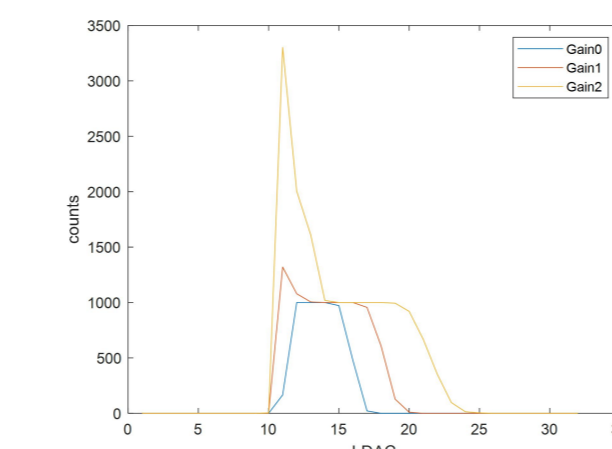


Figure 12 S-curve scanned at different gains

Calibration and Chip Architecture

Calibration process

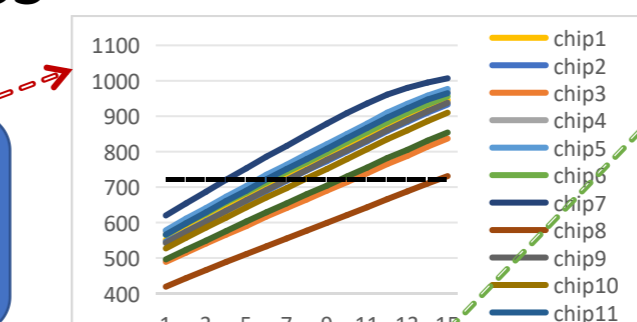
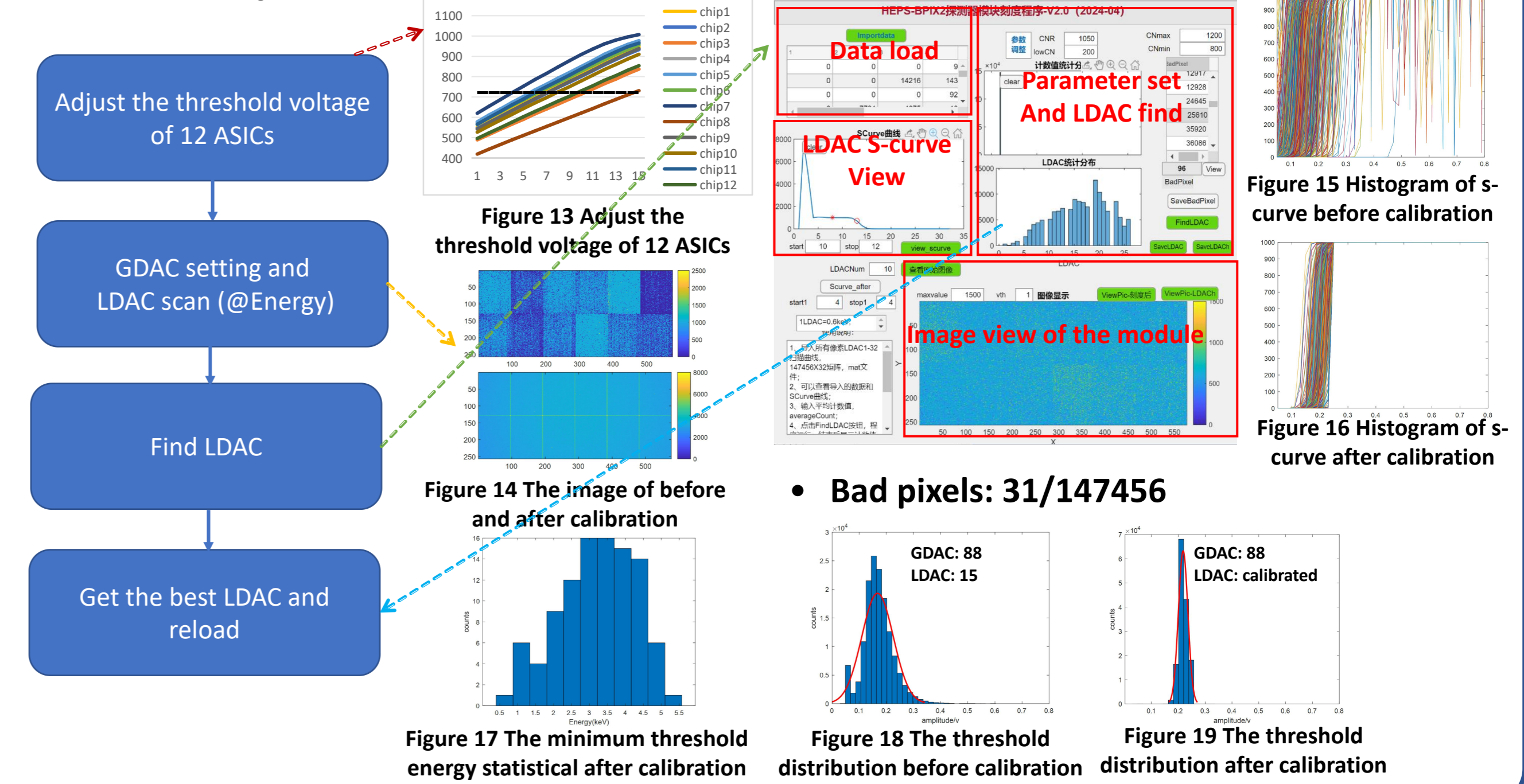


Figure 13 Adjust the threshold voltage of 12 ASICs

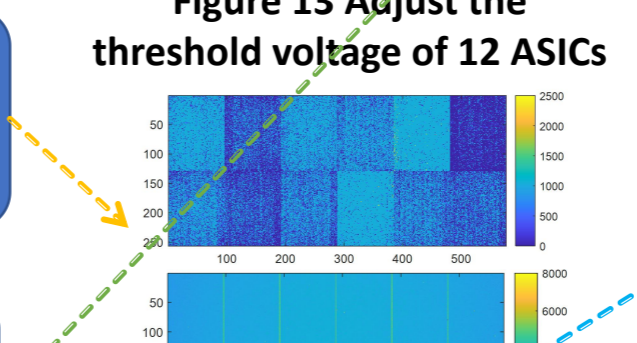


Figure 14 The image of before and after calibration

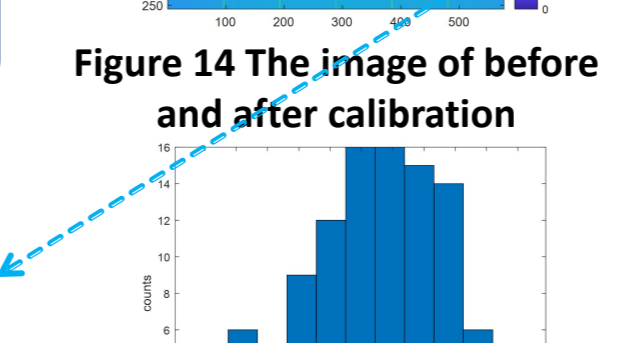


Figure 17 The minimum threshold energy statistical after calibration

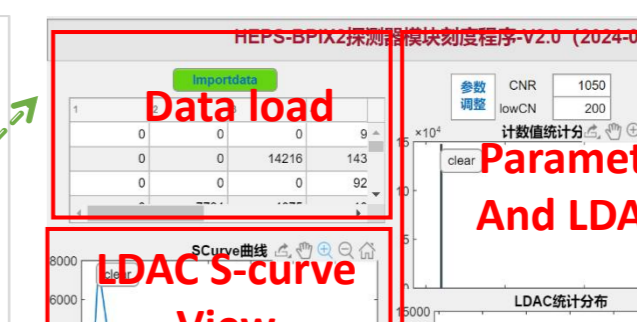


Figure 15 Histogram of s-curve before calibration

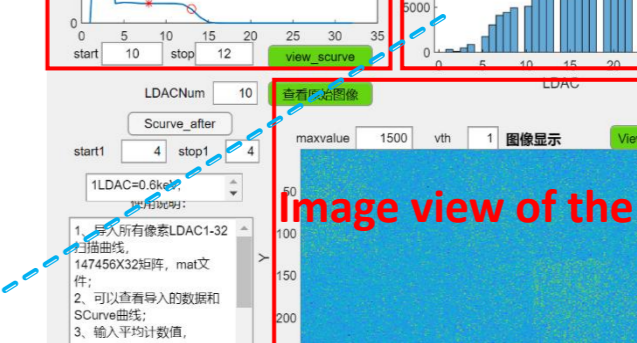


Figure 16 Histogram of s-curve after calibration

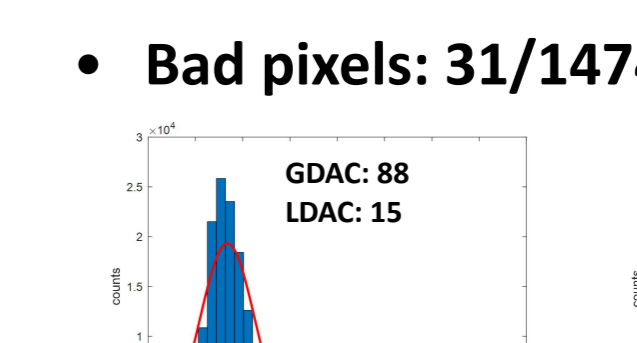


Figure 18 The threshold distribution before calibration

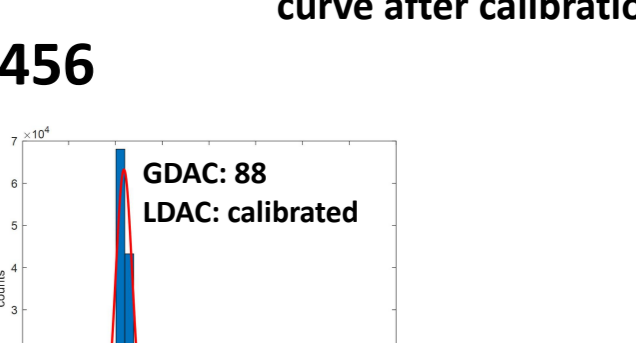


Figure 19 The threshold distribution after calibration

• Bad pixels: 31/147456

Test Results and some image



Figure 20 The module installation diagram

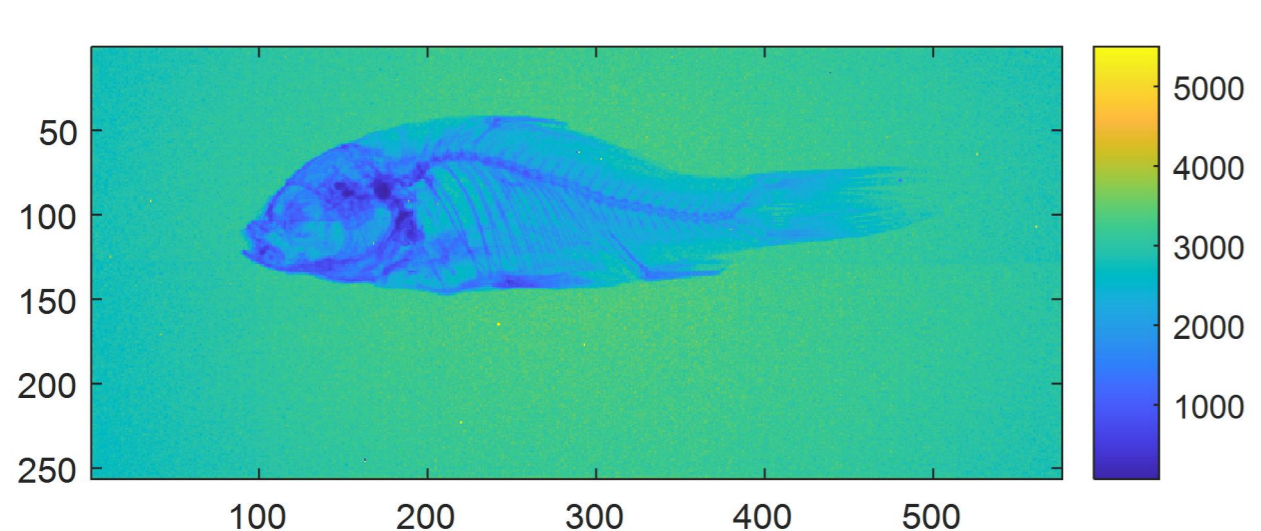


Figure 21 2D dual-threshold small fish imaging under X-ray tube(20keV)

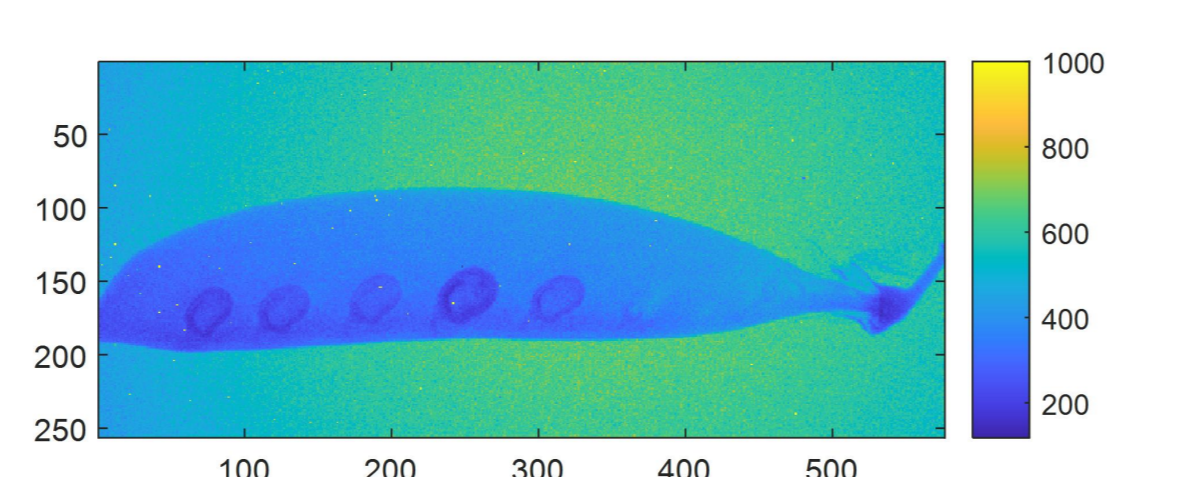


Figure 22 2D dual-threshold pea imaging under X-ray tube(15keV)

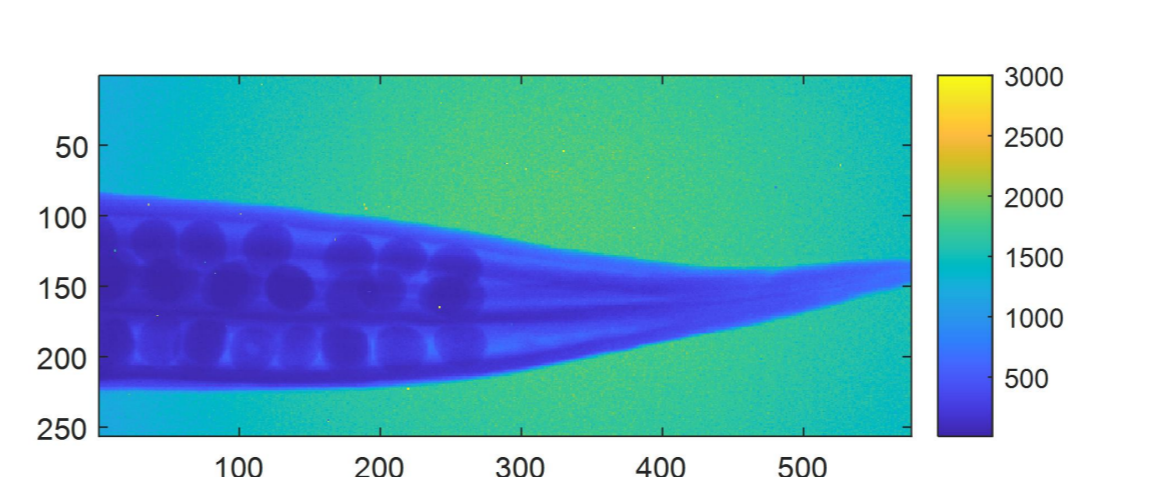


Figure 23 2D dual-threshold gumbo imaging under X-ray tube(15keV)

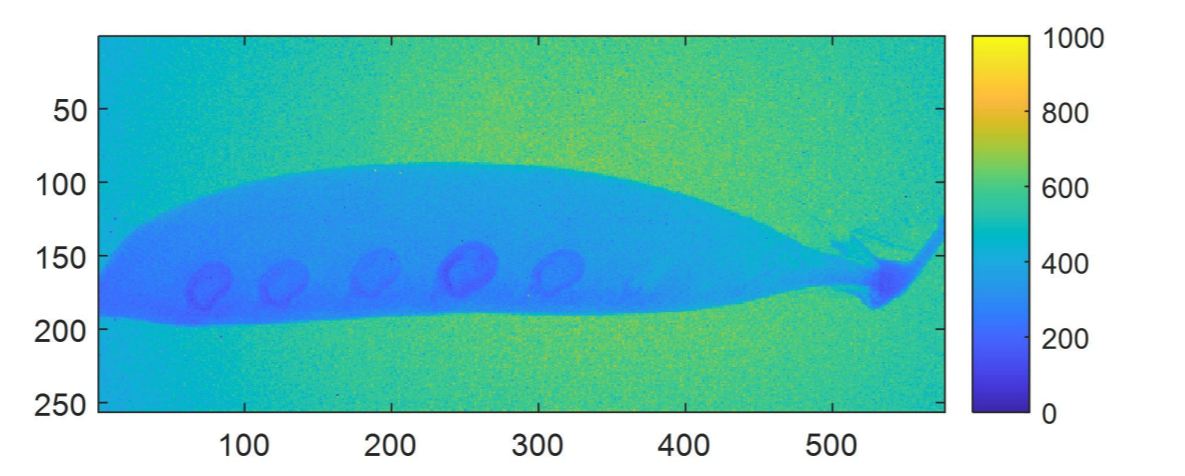


Figure 24 The cosmic ray trail



Figure 25 The 6M prototype electronics system

Verification of imaging with dual-threshold pixel detector.

- small fish image
- pea image
- gumbo image

The whole machine.

- silicon pixel modules: 40
- The complete 6M pixel detector is about to be assembled.

Summary and Outlooks

HEPS-BP40 is a dual-threshold pixel array detector working in the single photon counting mode designed for the HEPS in China. A 6M engineering detector will be constructed in this year for the HEPS-BA Biomacromolecule beam line with the energy of 12.4keV. We will finish the whole detector calibration in the next time and test the 6M detector online.