Calibration of eXTP-SFA Focusing Mirror Effective Area Using Continuous Spectrum

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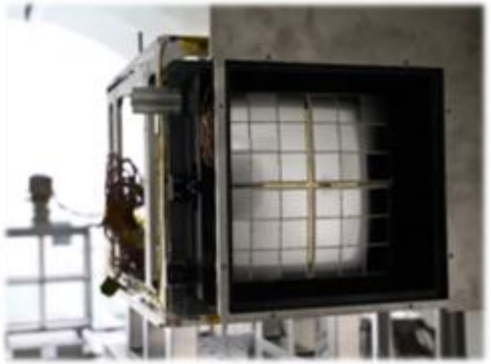
Motivation

X-ray telescopes

FoV

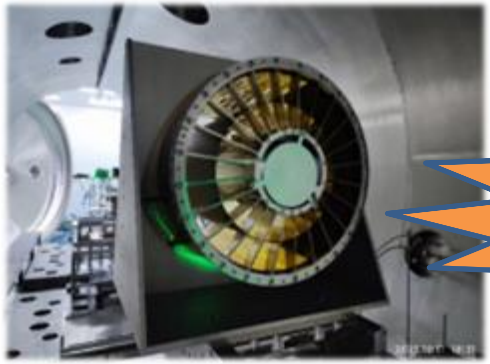


EP-WXT

HPD

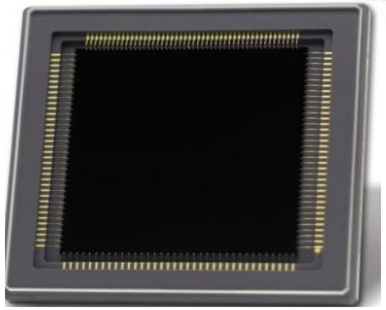
EP-FXT

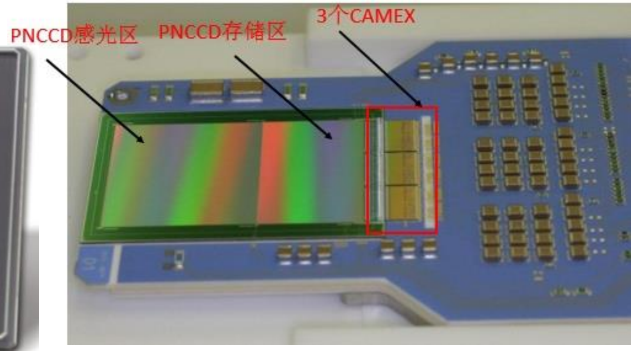
Large Effective Area

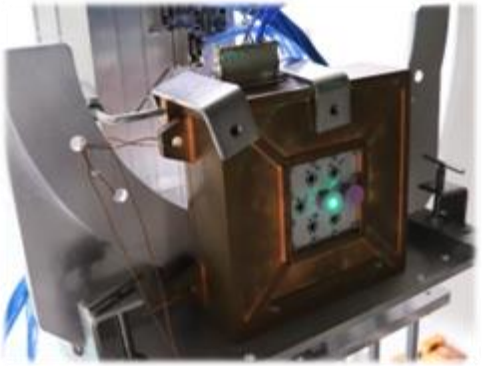


eXTP-SFA

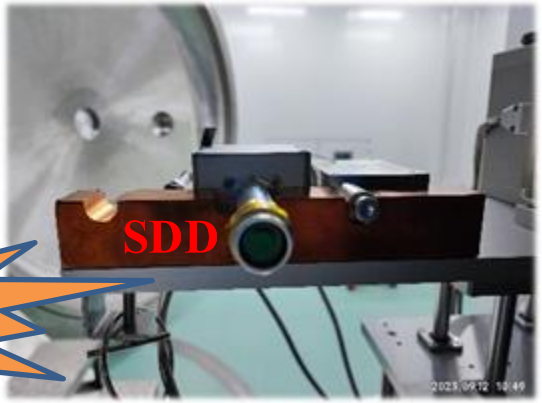
sCMOS(GSENSE400BSI)







To improve testing efficiency



New challenge!
New method?

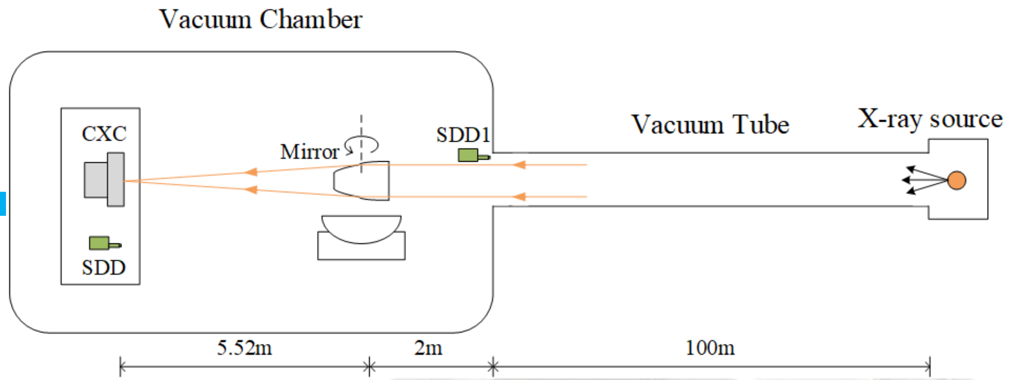
Compared to imaging detectors, SDD has the following advantages:

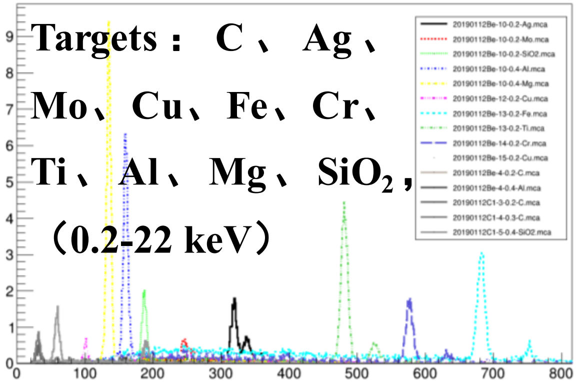
1. Excellent energy resolution of SDD;
2. SDD can withstand higher photon flux conditions;
3. SDD eliminates interference from split events;
4. SDD avoids charge transfer losses between pixels.

SDD is more suitable for continuous spectrum effective area measurement

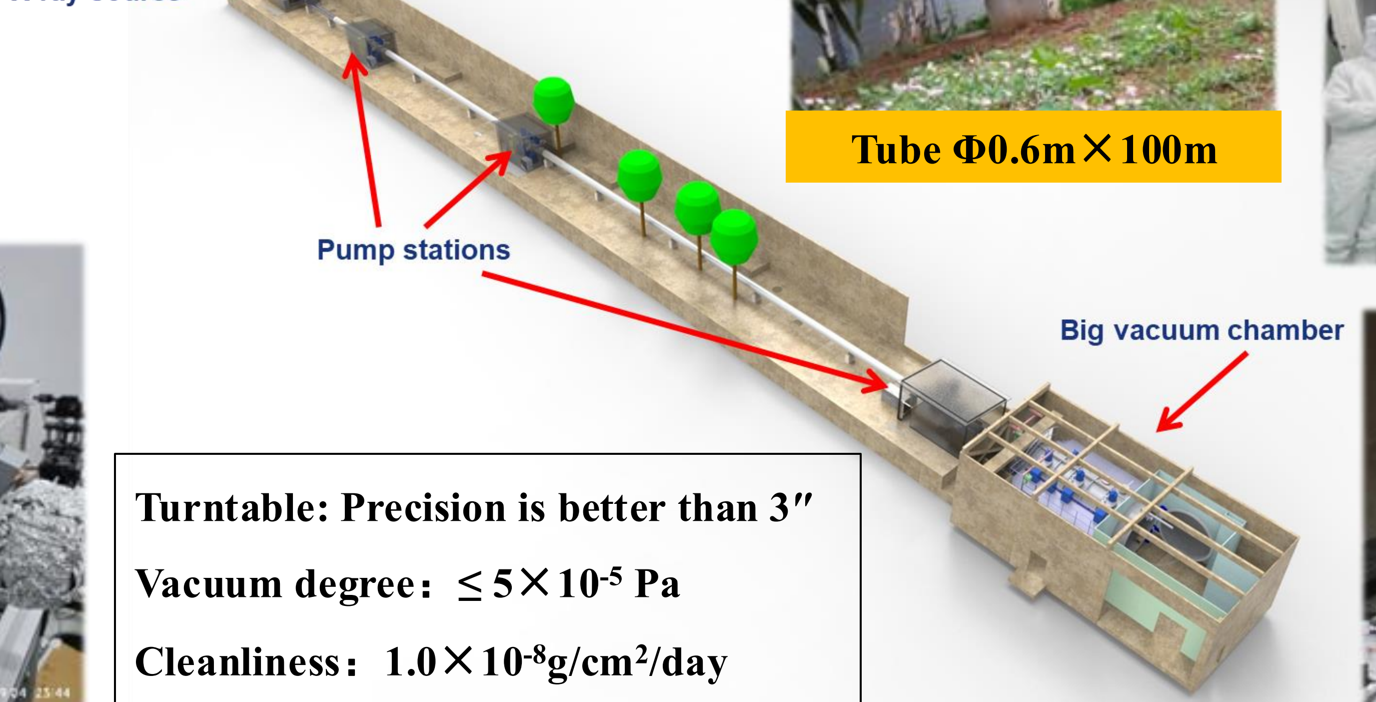
Facility

100m X-ray test Facility





X-ray source



Tube Φ0.6m×100m

Chamber Φ3.4m×8m

Turntable: Precision is better than 3″

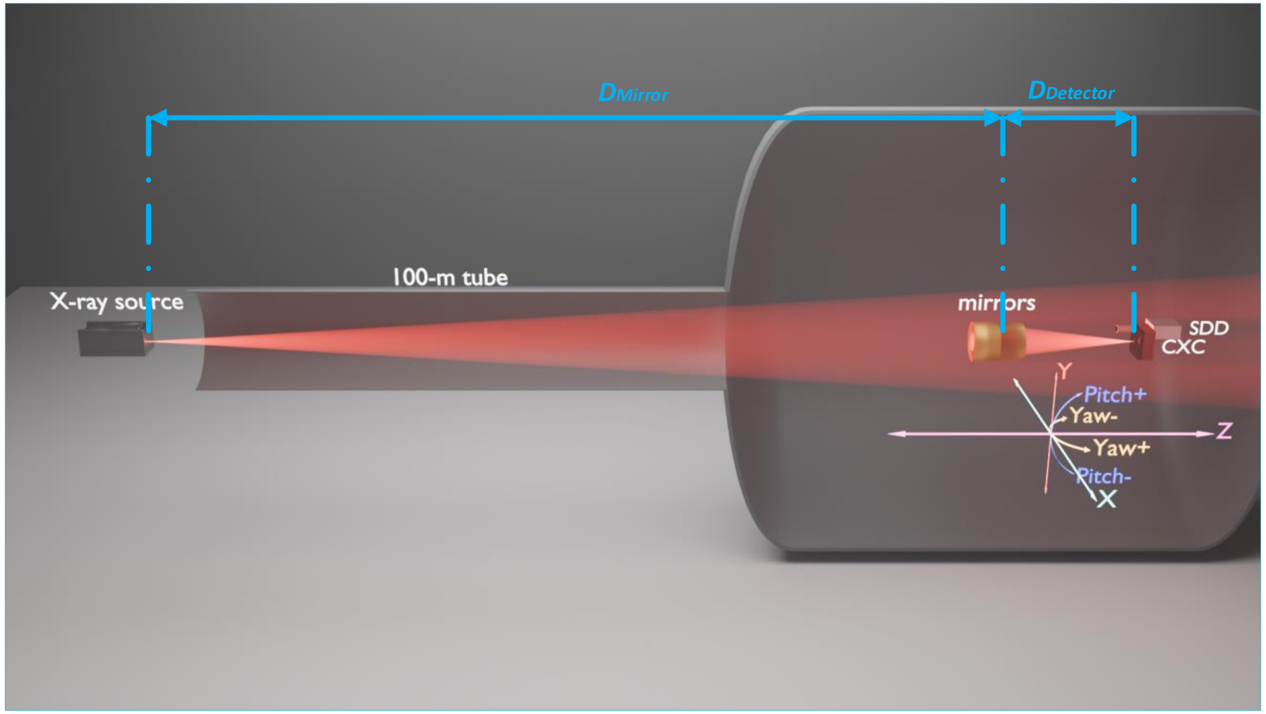
Vacuum degree：≤5×10^{-5} Pa

Cleanliness： 1.0×10^{-8}g/cm^2/day

Detector： SDD、pnCCD

Method

Effective area testing method



$$\mathrm{A}_{eff} = \frac{cts\_mirror}{cts\_flat} \times A_{det} \times G$$

$$G = \left(\frac{d_{source\_mirror}}{d_{source\_mirror} + d_{image}}\right)^2$$

A_{eff}: Effective area of focusing mirror

cts_mirror: Counting rate of detector during focusing

cts_flat: Counting rate of detector during flat field

A_{det}: Effective area of detector

G: Geometric correction factor

$\mathrm{d}_{\mathrm{source\_mirror}}$: Distance from light source to focusing mirror

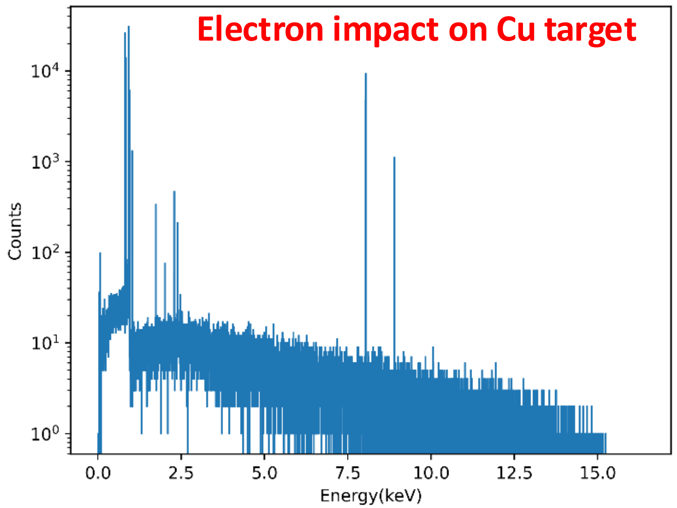
$\mathrm{d}_{\mathrm{image}}$: The distance between the focusing mirror and the detector

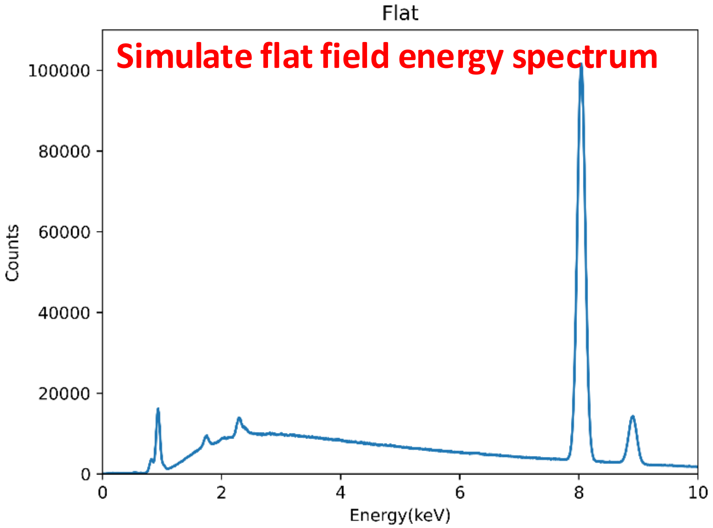
The effective area is calculated based on the counting rates.

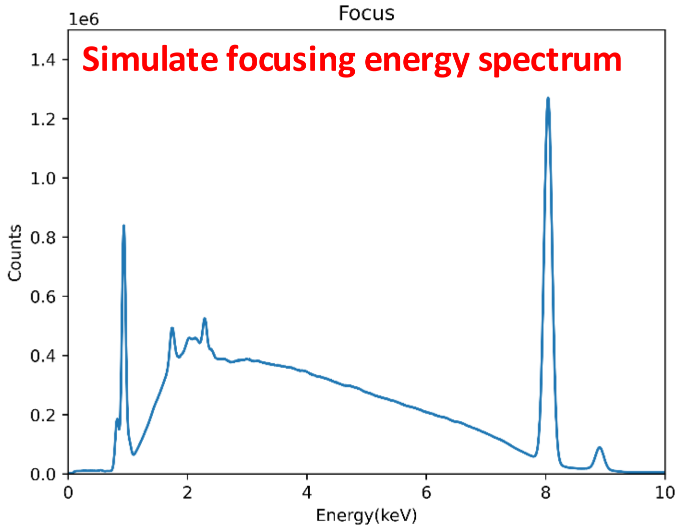
Simulation

1. Simulation of electron bombardment using Geant4 produces the primary continuous spectrum；

2. Energy spectrum detected using the MC simulation detector；

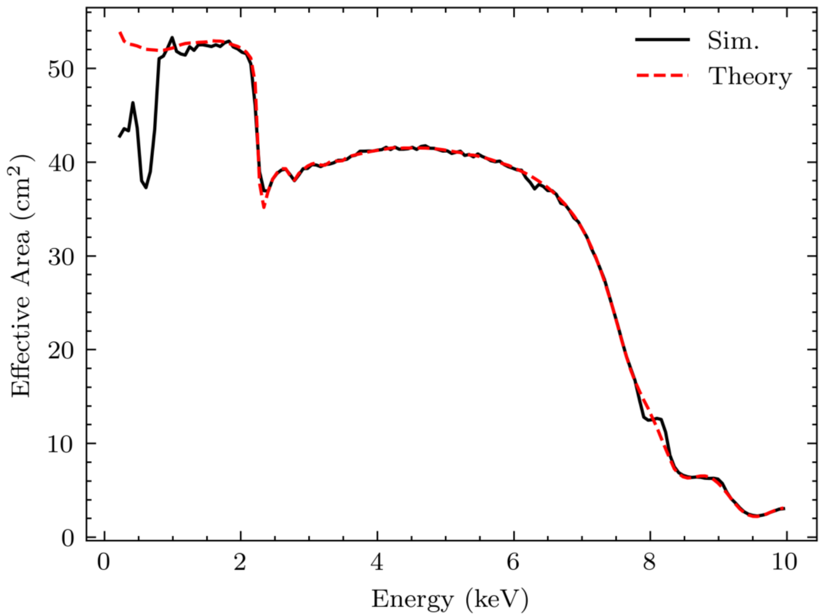






Simulated effective area

- The effective area curve has a certain structure near the target characteristic energy.

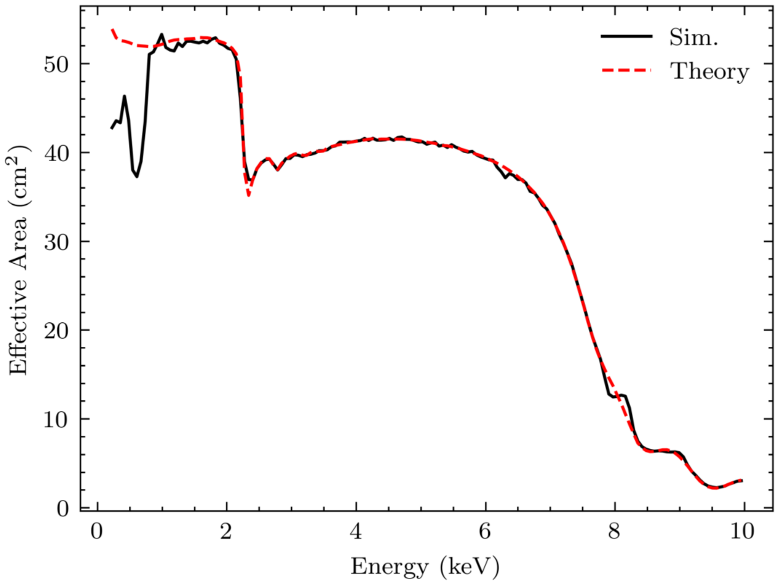


We need to find effective methods for continuous spectrum resolution!

Method

We have improved the calibration method for X-ray focusing mirrors, with key advantages demonstrated in three aspects:

1. **Enhanced Efficiency**: By testing the absorption edge at 2.2 keV characteristic of gold, this method reduces the calibration cycle from weeks to hours.
2. **Extended Energy Range**: Continuous effective area curves have been measured across the entire 10 keV energy range.
3. **Improved Precision**: The focusing mirror is moved only once during the entire procedure, avoiding repeated adjustments for each energy point and thereby enhancing measurement precision.

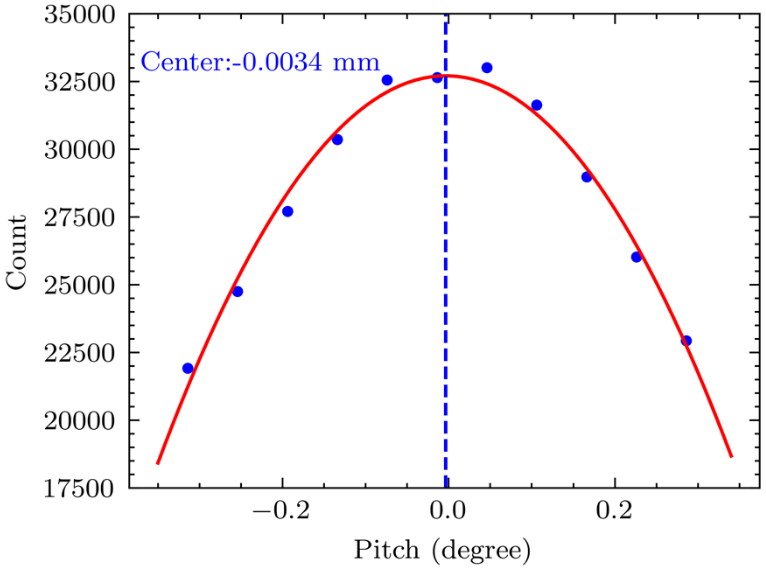


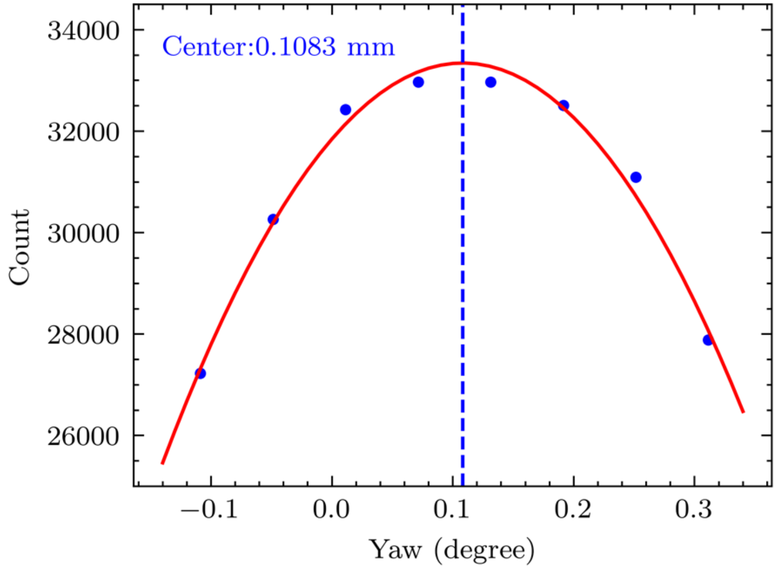
There are still problems to be solved.

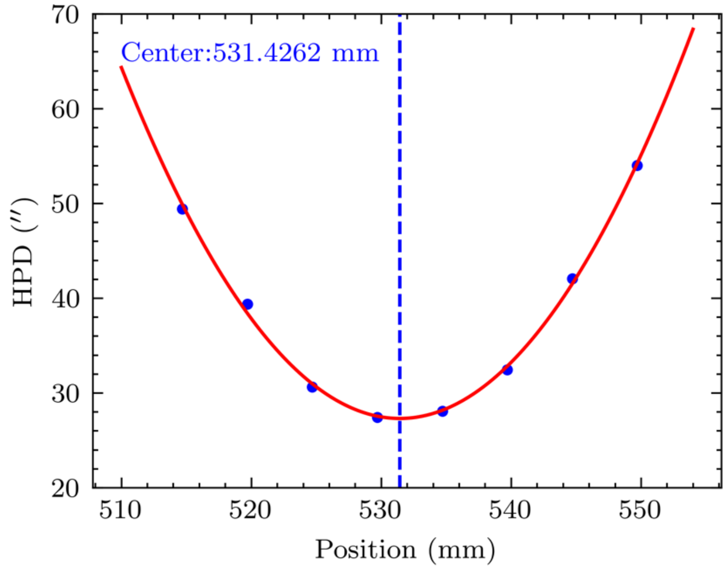
The spectral broadening of the SDD can affect the shape of the continuous spectrum. Additionally, escape peaks from high-energy photons may be recorded as low-energy photons. It is also important to determine whether the SDD's energy response remains consistent across varying photon flux intensities.

Optical axis alignment

Step1: Align the focusing mirror with CCD



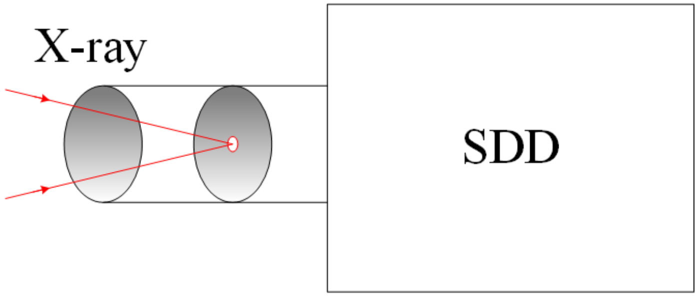




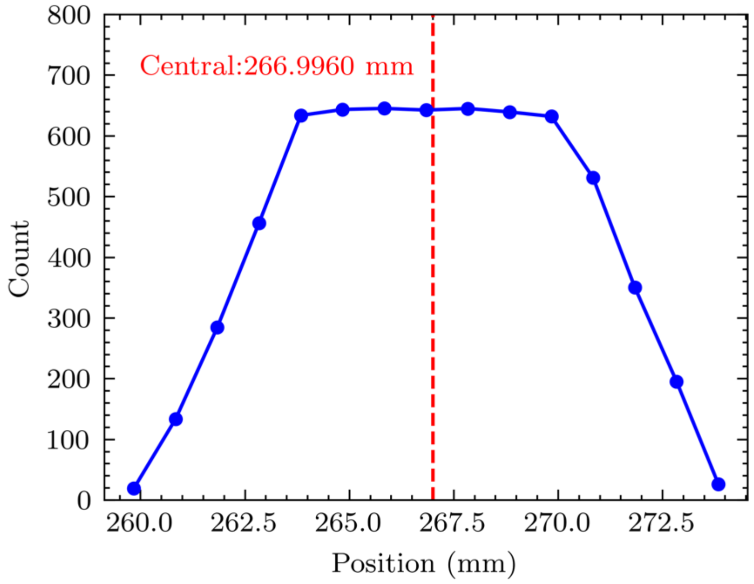
The maximum photon counting rate is at the positive axis position, and the minimum HPD is at the focal position

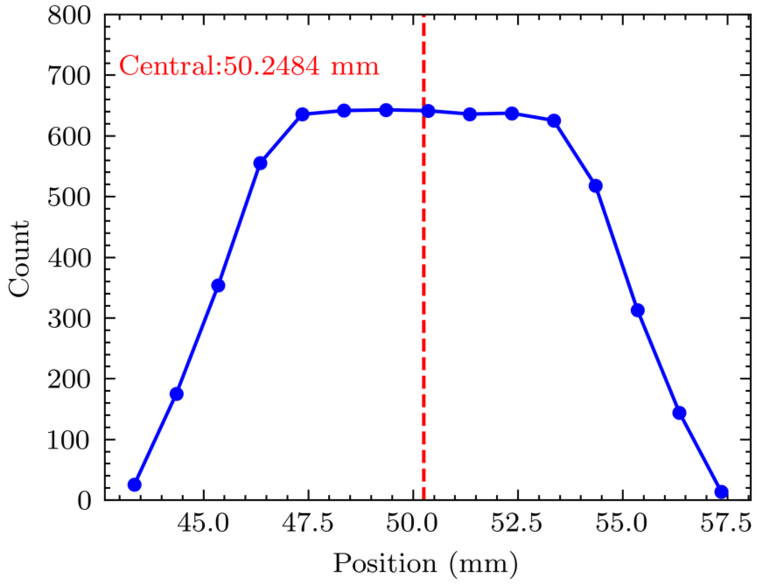
Scanning of SDD position

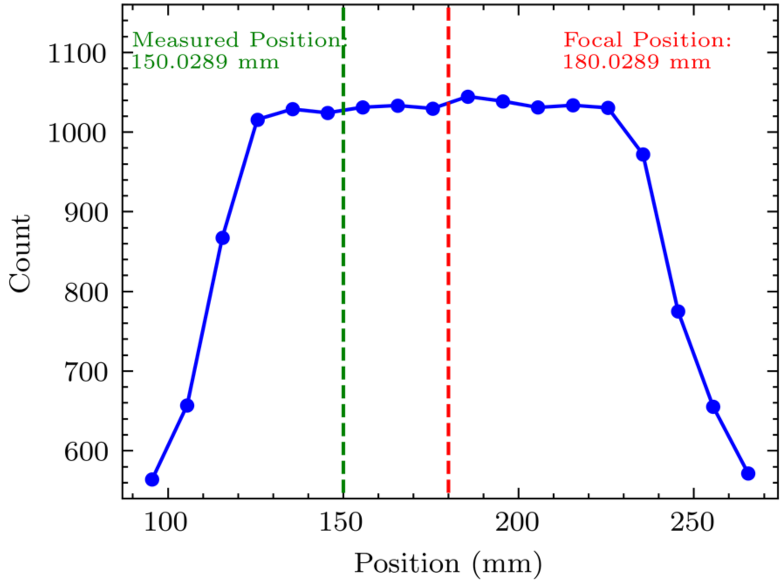
Step2: SDD Position alignment



Collect photons more comprehensively and evenly!

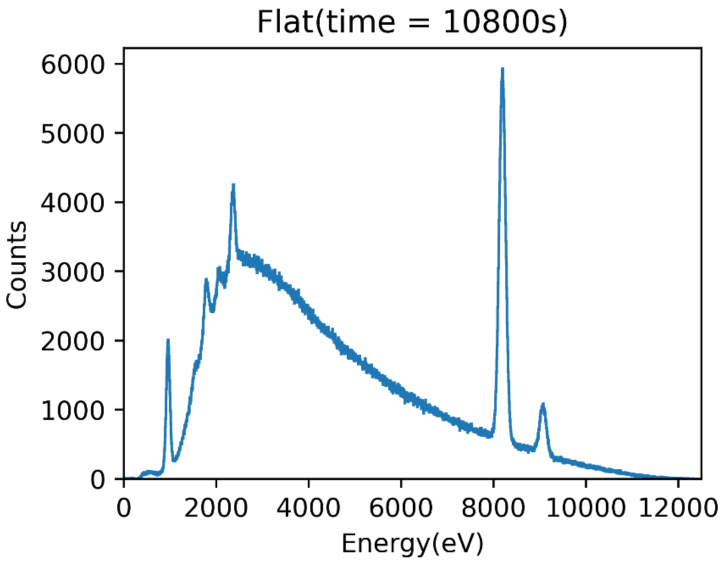


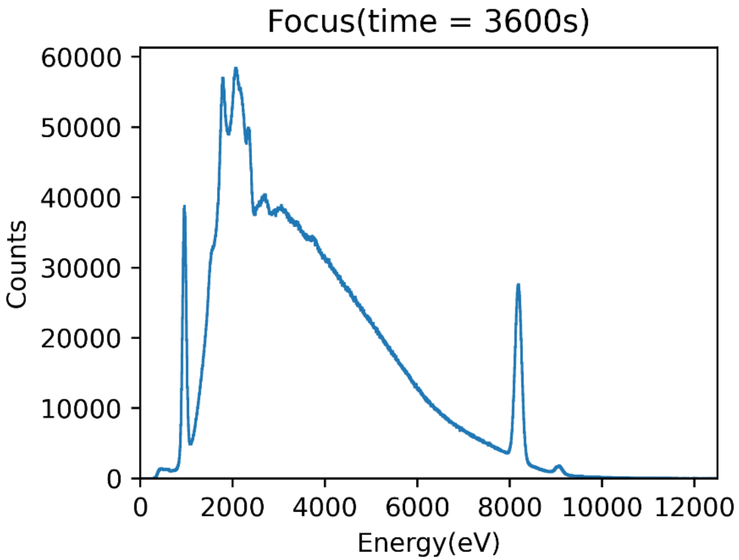




We moved the SDD in three directions to determine the central position and ensure full photon collection

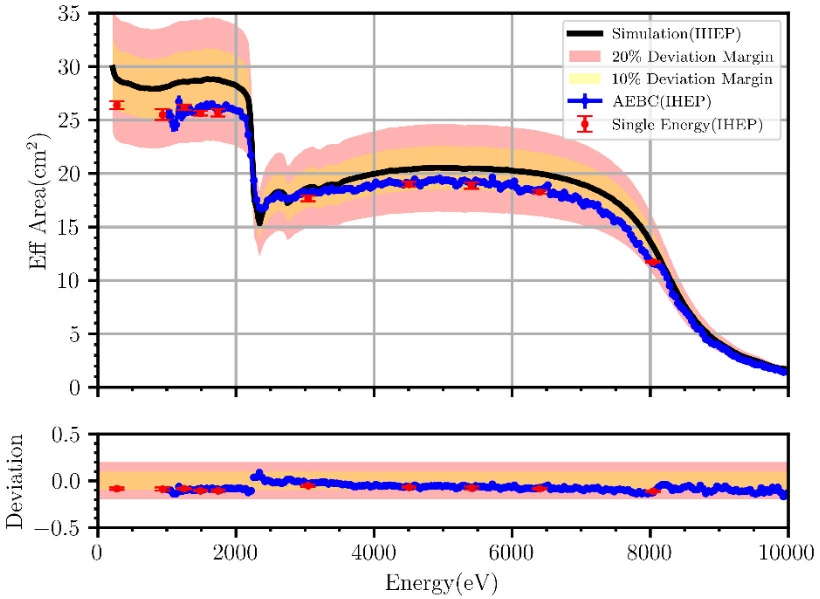
Effective area test





Effective area test

- The effective area curve is obtained by directly dividing the focused energy spectrum by the flat-field energy spectrum.



The consistency with single energy point testing is better than 3%!

Due to the detector's response characteristics, the energy spectrum around the characteristic peaks and escape peaks needs to be analyzed.

Next step

1. Accurately calibrate the energy response of the SDD to reduce its effect on the broadening of the continuous spectrum.

2. Reduce the interference of escape peaks from high-energy photons in low-energy photon measurements within the continuous spectrum.

3. Correct for variations in the SDD's energy response under conditions of high photon flux.

Thanks for your suggestions