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Cadmium Telluride Spectroscopic X-Ray Imaging Detectors

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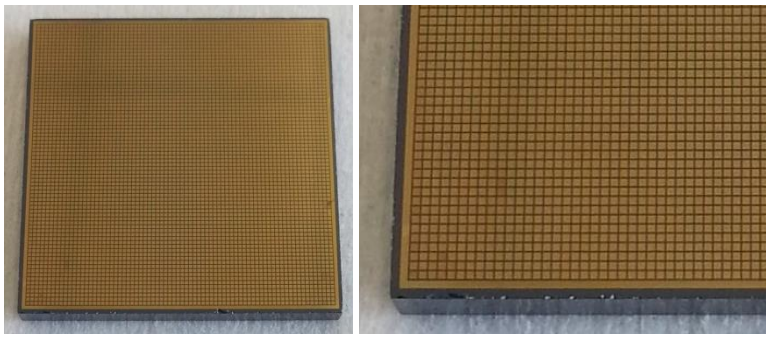
Cadmium Telluride (CdTe)



2.0 cm

- An alternative to Si or HPGe.
- Room temperature operation.
- High X-Ray stopping power (> 20 keV).
- Good electron transport.
- Recent advances in volume and quality.

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HEXITEC – A History

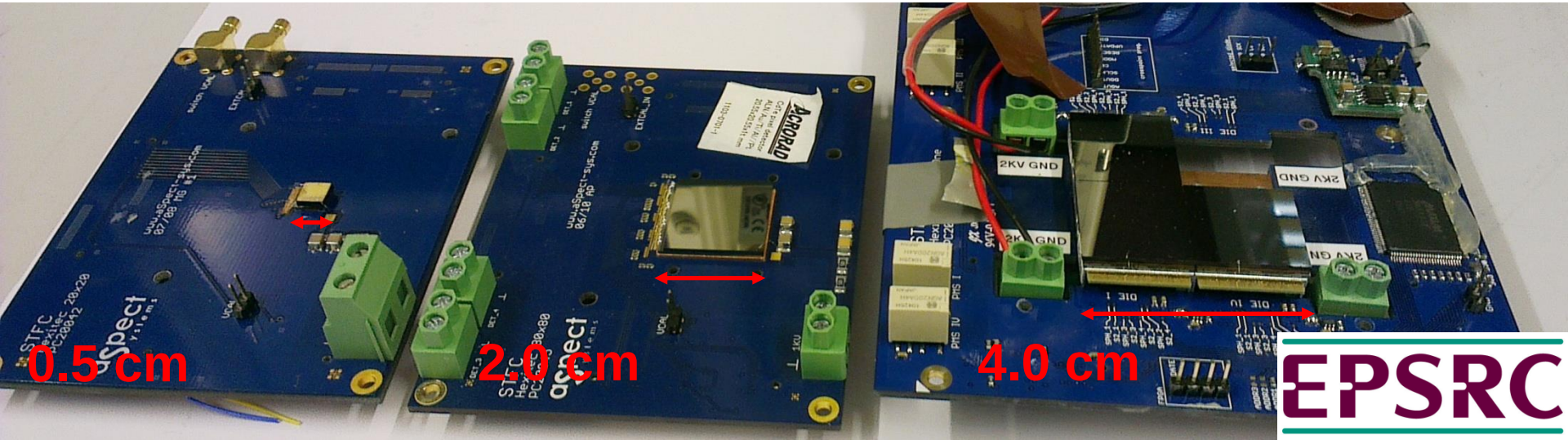
HIGH ENERGY X-RAY IMAGING TECHNOLOGY

- 1G ASIC Fabricated 2008.
- 20*20 250μm Pix = 0.25 cm^2
- CdZnTe $FWHM_{@60\ keV}$ = 1keV

M.D.Wilson et al, NIMA 652, 2011, 158-161

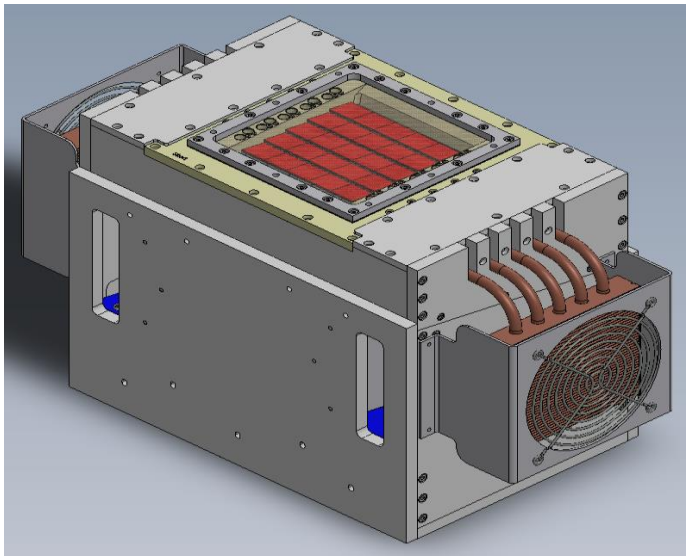
- 2G ASIC Fabricated 2010.
- 80*80 250μm Pix = 4.0 cm^2
- CdTe $FWHM_{@60keV}$ = 0.8 keV

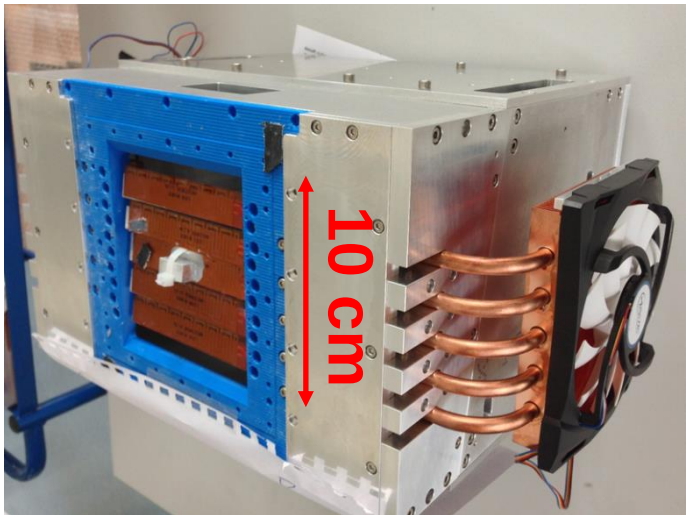
M.C.Veale et al, JINST 7, 2012, C01035



EPSRC

Large Area Detectors

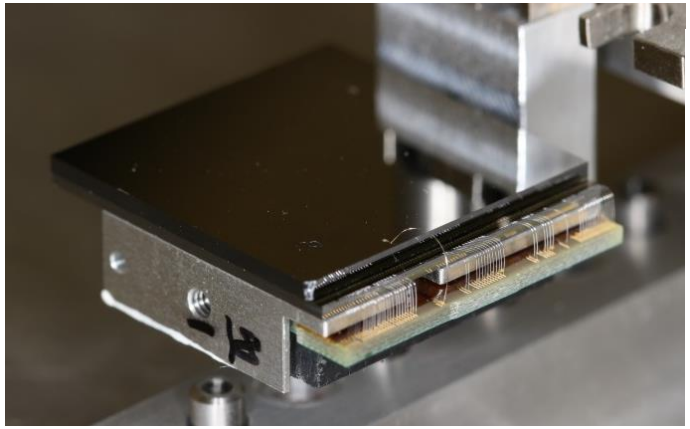


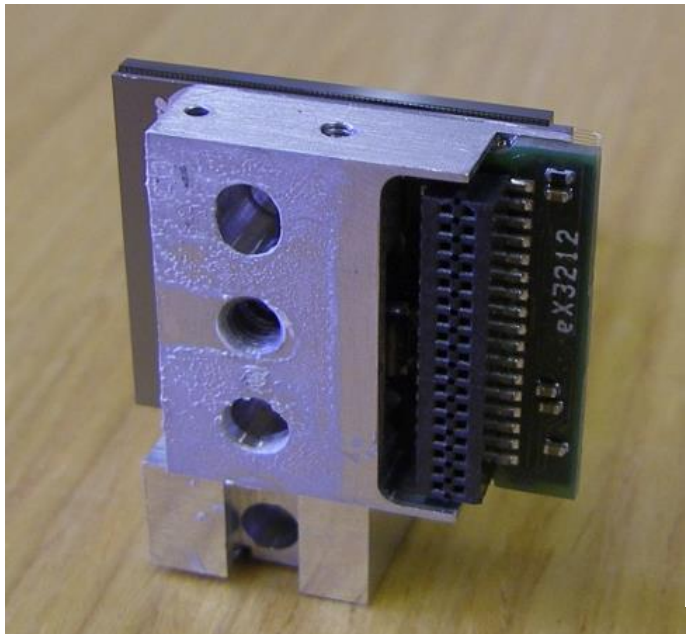


- Large Area Detectors for Imaging Applications.
- Recently developed a 100 cm^2 CdTe camera.
- 25 CdTe modules.
- 5 x 5 array – 3 pixel dead area.
- Each module characterised individually.

Seller et al, *Large area CdTe based spectroscopic X-ray imaging detector*, Thurs 9:50 AM

CdTe Detector Modules

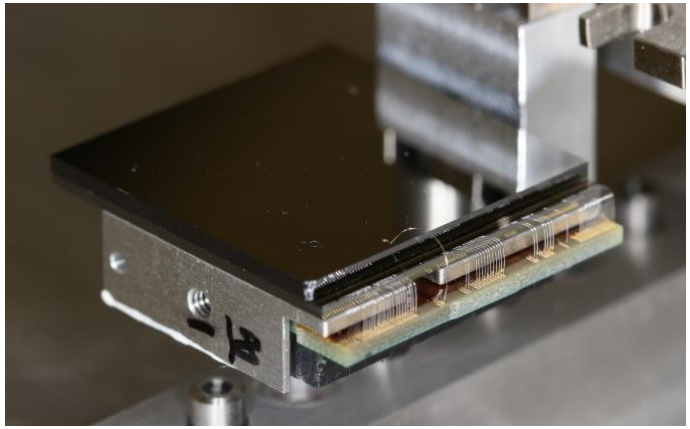


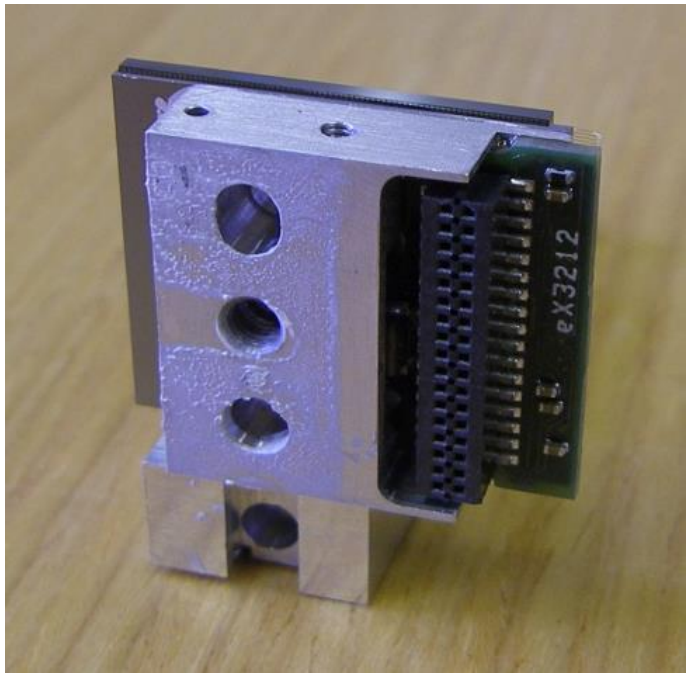


- Acrorad Al-Schottky Anode CdTe.
- 80 x 80 pixels on 250 μm pitch.
- 20.35 mm x 20.45 mm x 1.00 mm.
- Flip-chip-bonded to HEXITEC ASICs.
- Mounted on Al carrier and wedge bonded.
- 3-side-buttable design.

Schneider et al, *Interconnect and bonding techniques for pixelated X-ray and gamma ray detectors*, Weds 3:00 PM

CdTe Detector Testing





- ✓ **High Operating Voltage (>300V)**
- ✓ **Stable Current (σ<2nA)**
- ✓ **Good Bond Yield (>99%)**
- ✓ **90% < 2keV ($FWHM_{@60keV}$)**

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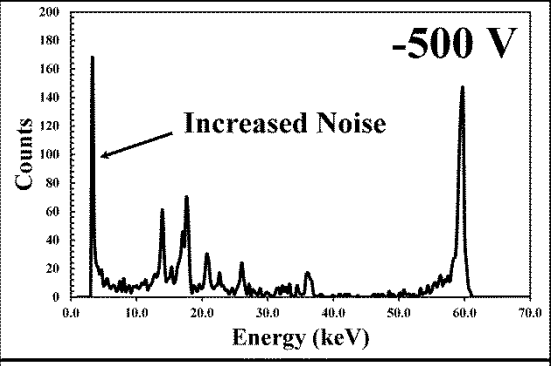

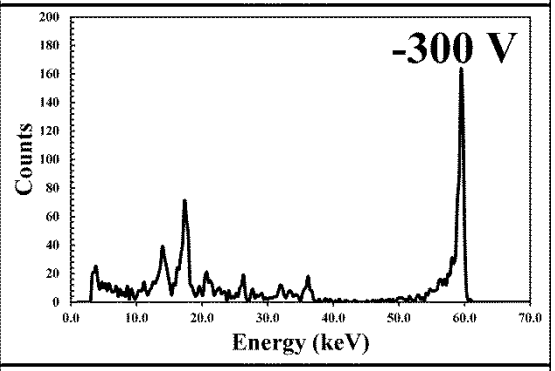

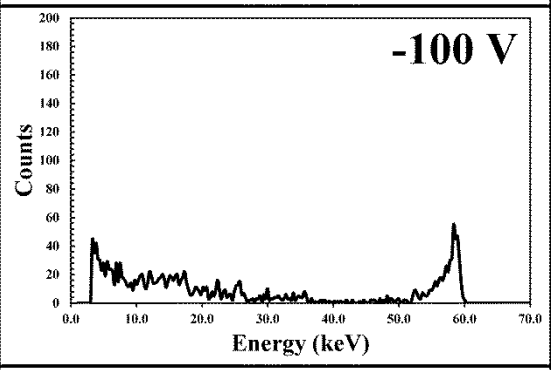

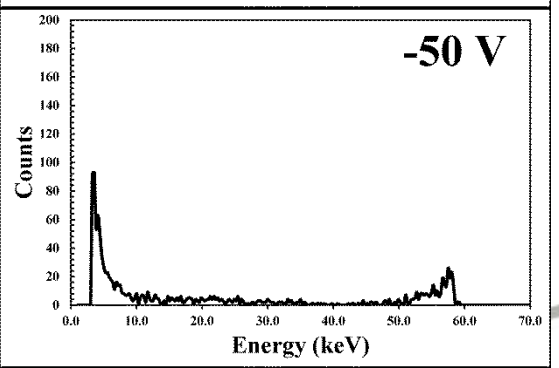

Bias Voltage Effect

- Operating voltage has a large effect on spectroscopic performance.
- Poor spectroscopic performance observed for voltages < 300 V.
- At higher voltages additional noise is observed in the spectra.
- Only detectors where V_{opp} > - 300V are included in the detector.

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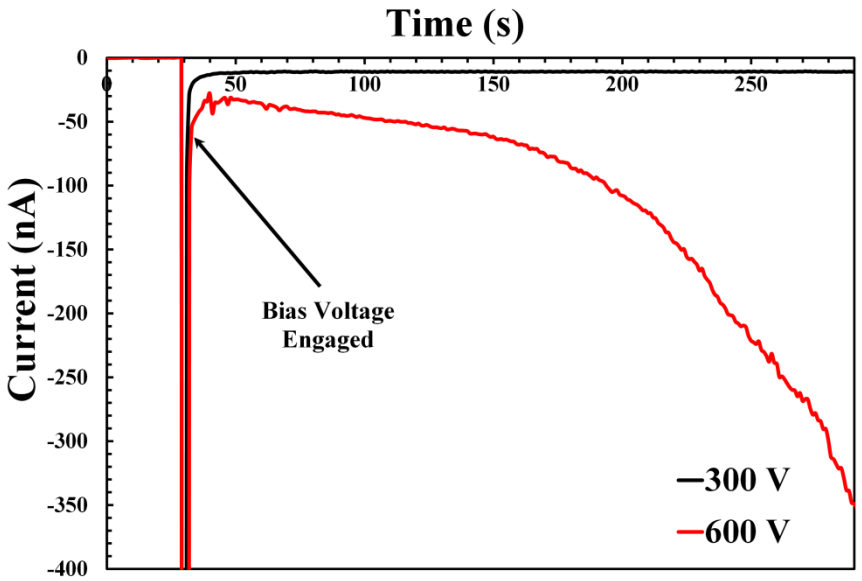
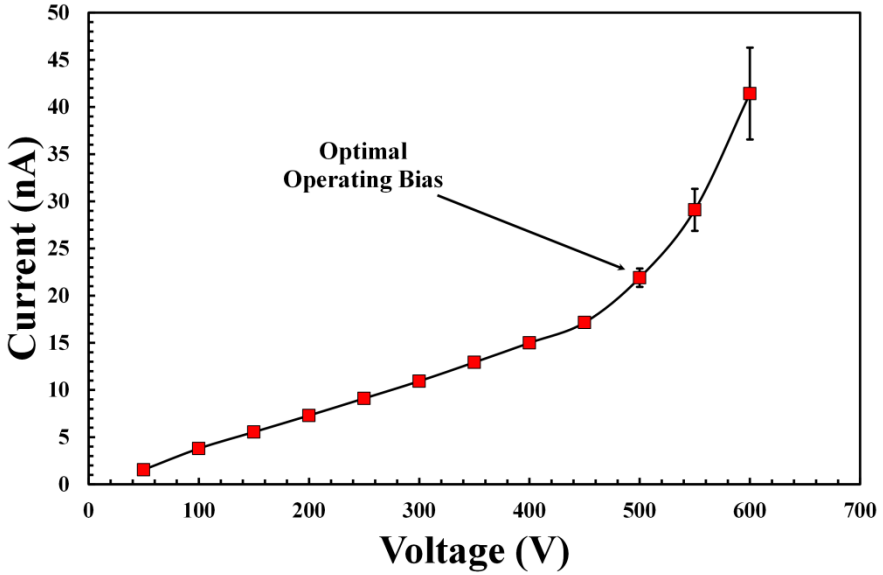
Electrical Characterisation



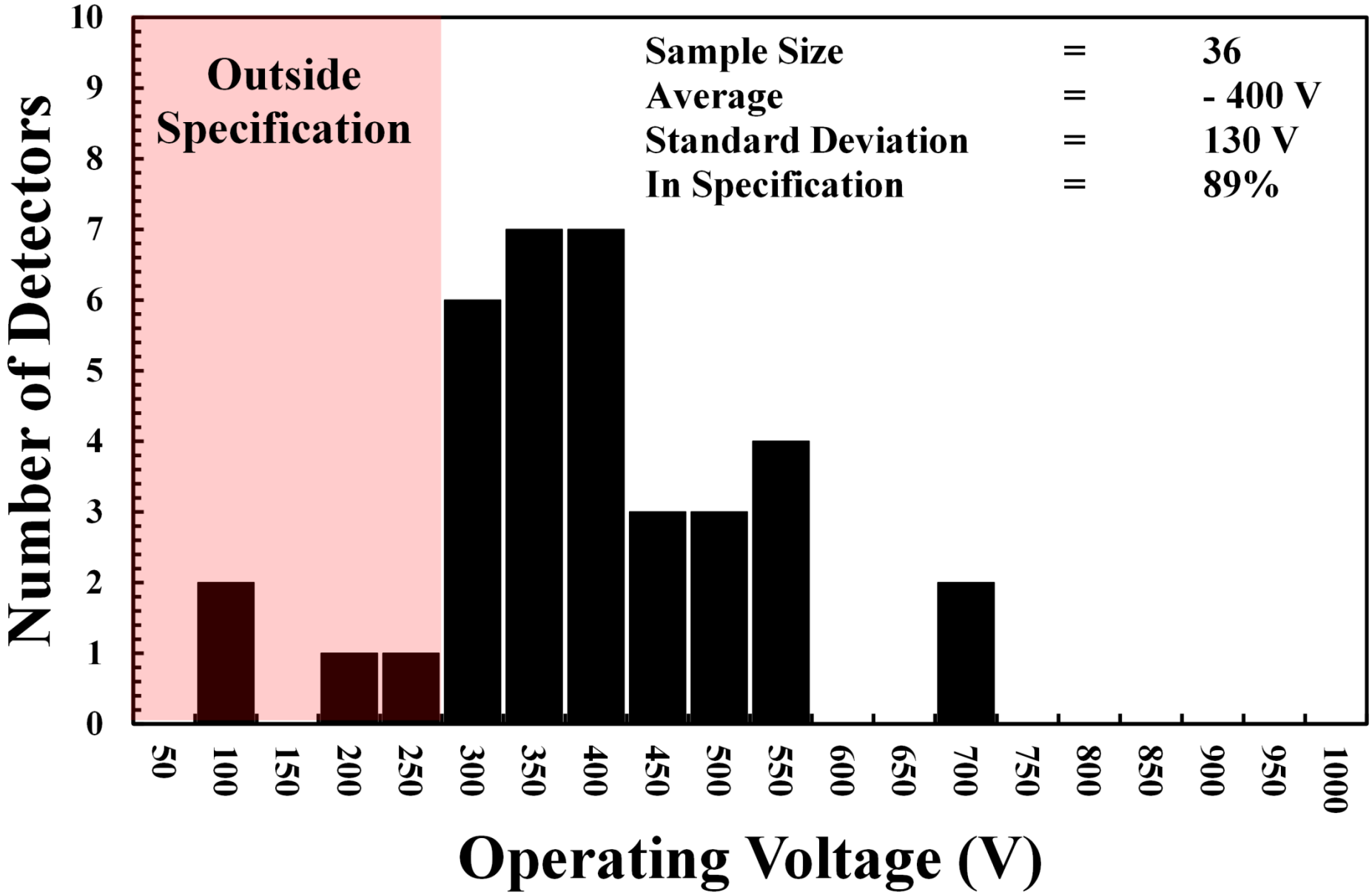


- **Detector temperature held at 20°C.**
- **Keithley 2410 Sourcemeter.**
- **Optimal operating bias defined as:**

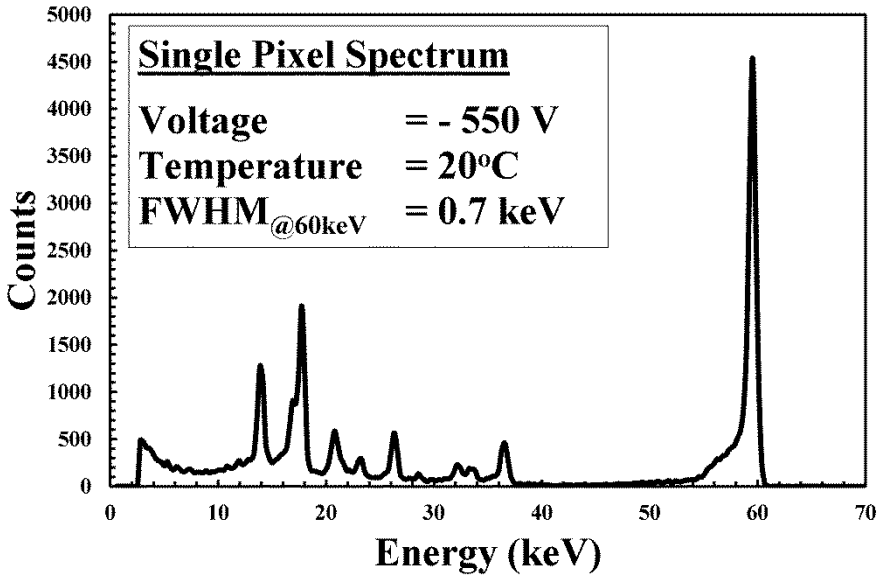
  "the highest voltage achievable for < 2nA of variation over 5 minutes"

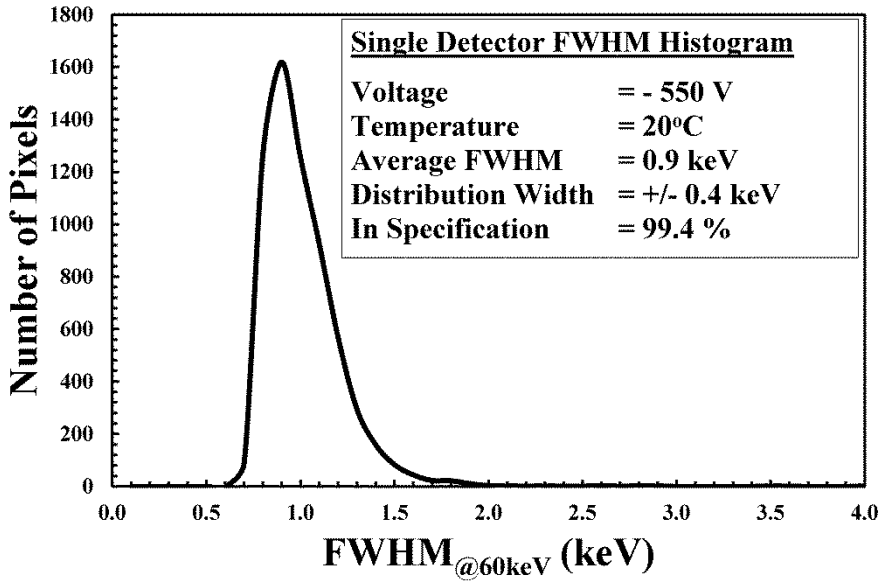
- **Operating bias calculated for each module.**

Operating Voltage



Spectroscopic Performance





- 180 MBq ^{241}Am sealed source.
- γ-rays at 59.5 and 26.0 keV.
- FWHM calculated for all 6,400 pixels at the optimal operating bias.
- Average FWHM ~ 0.9 +/- 0.4 keV.

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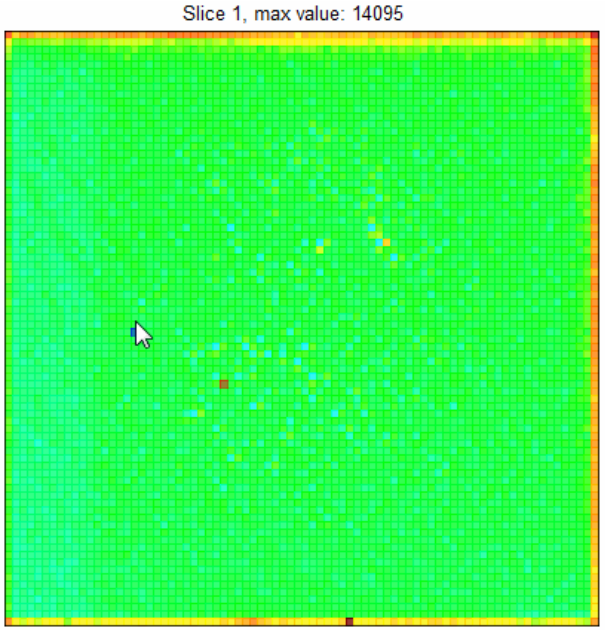
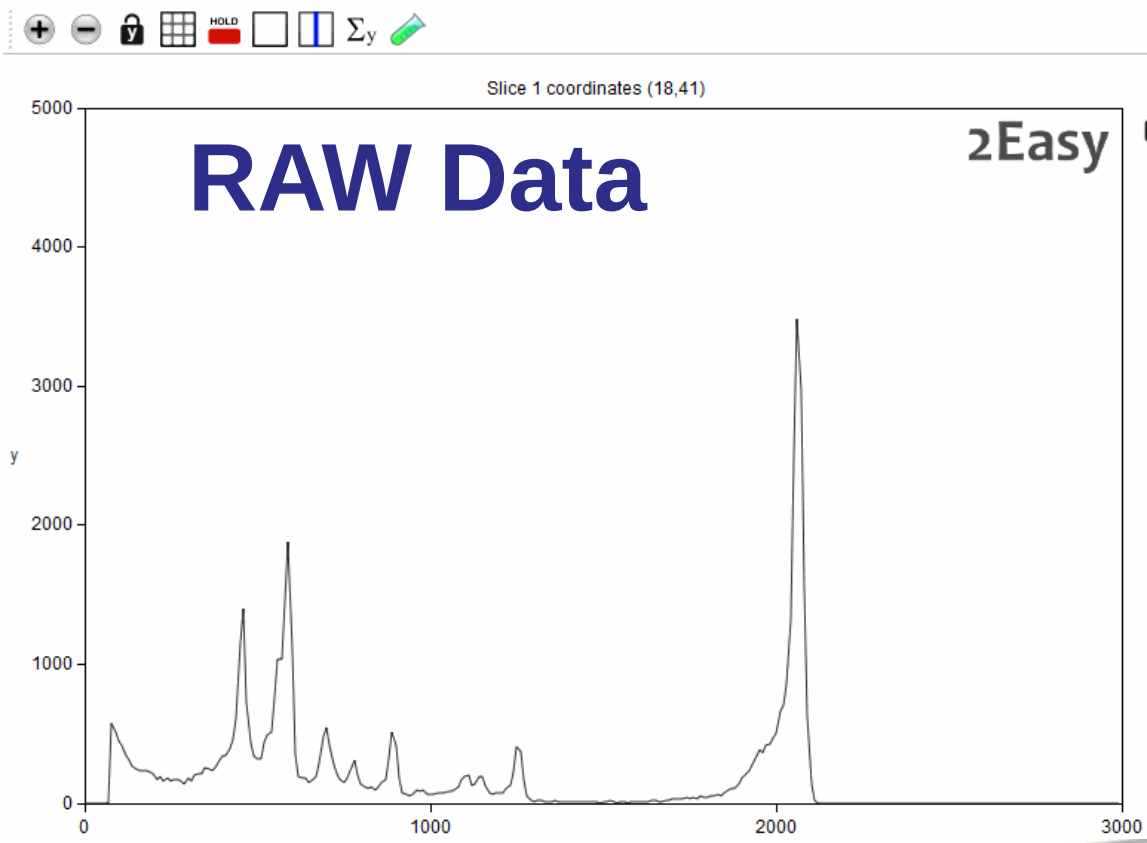
Detector Uniformity



2



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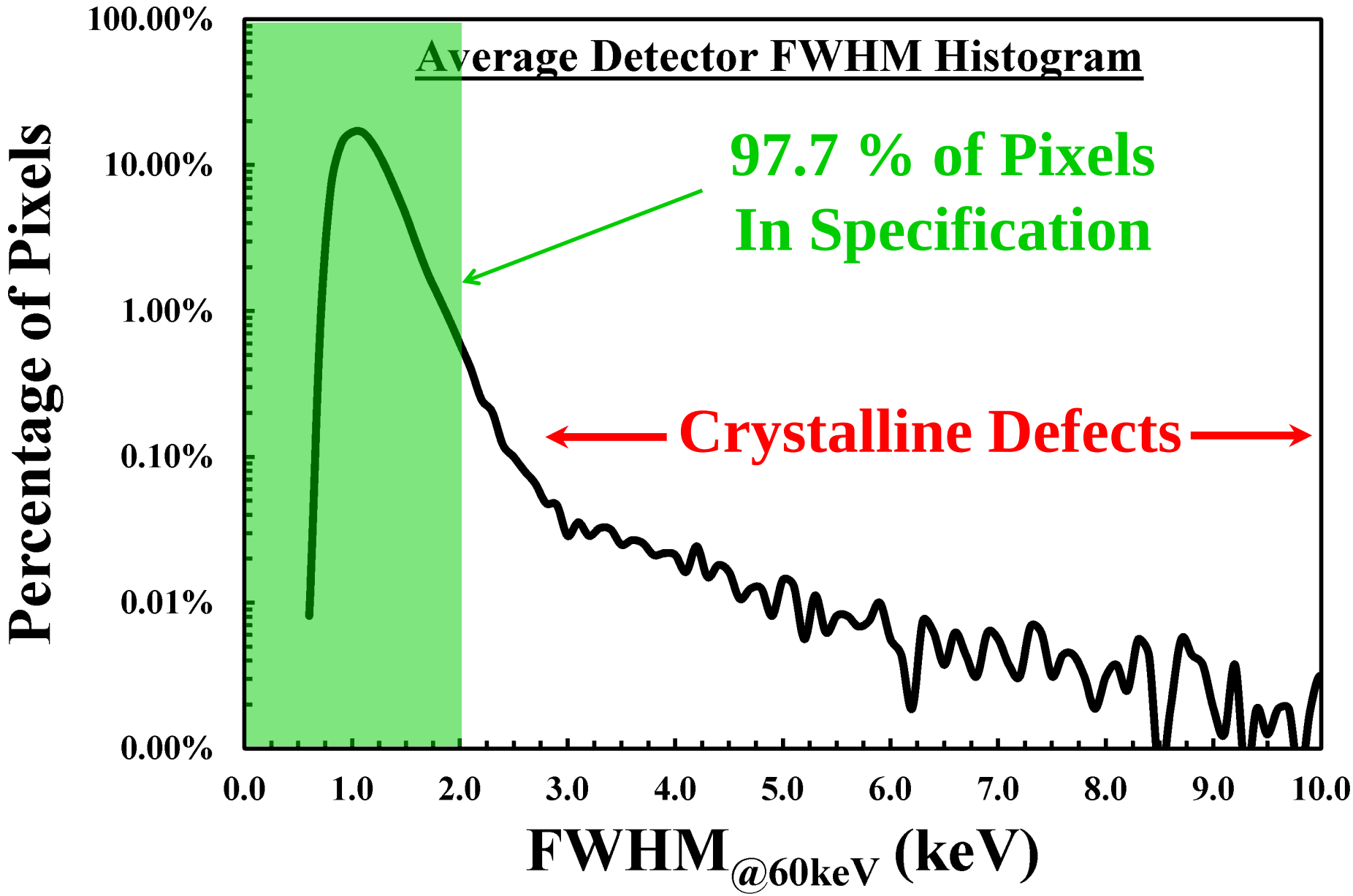
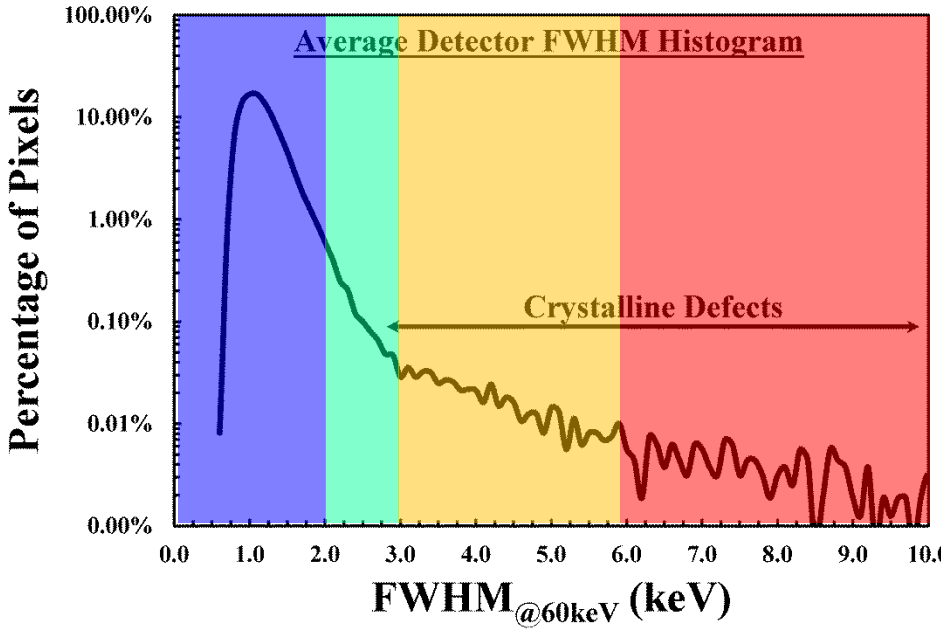
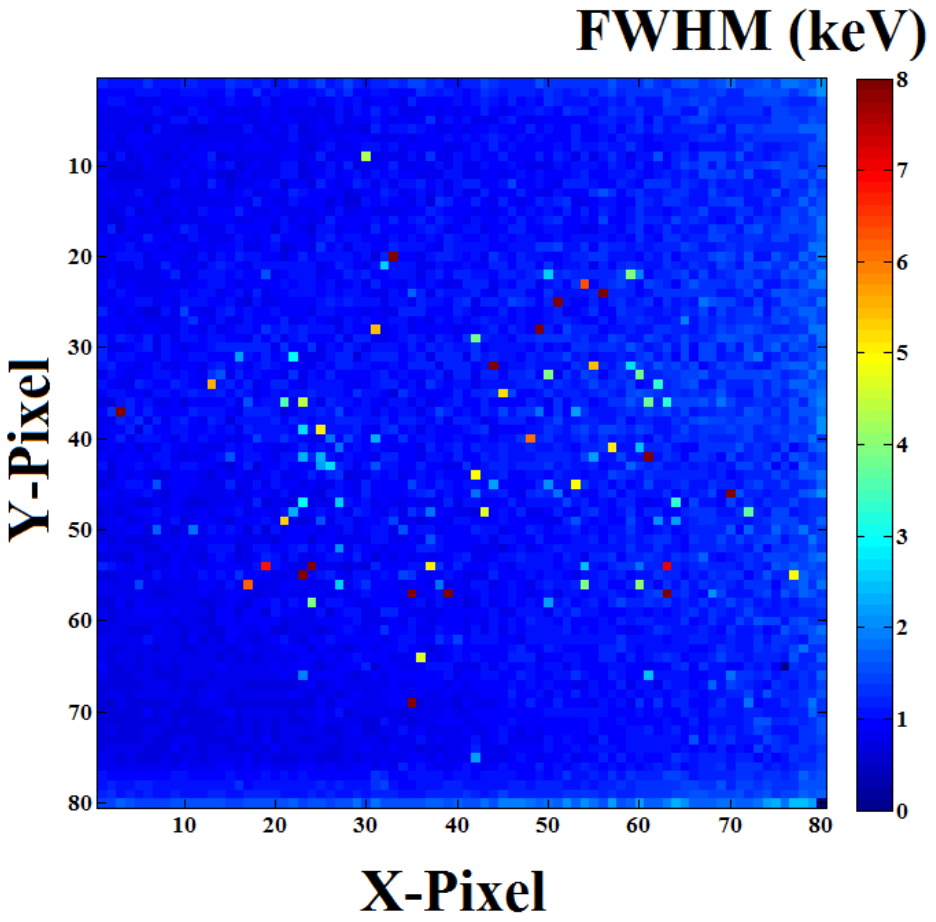
Detector Uniformity

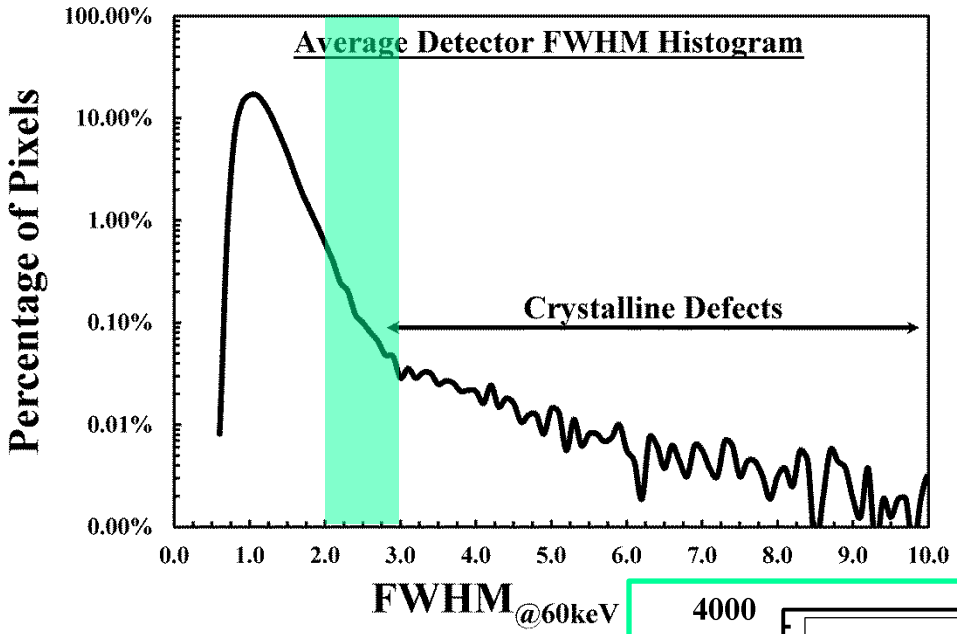


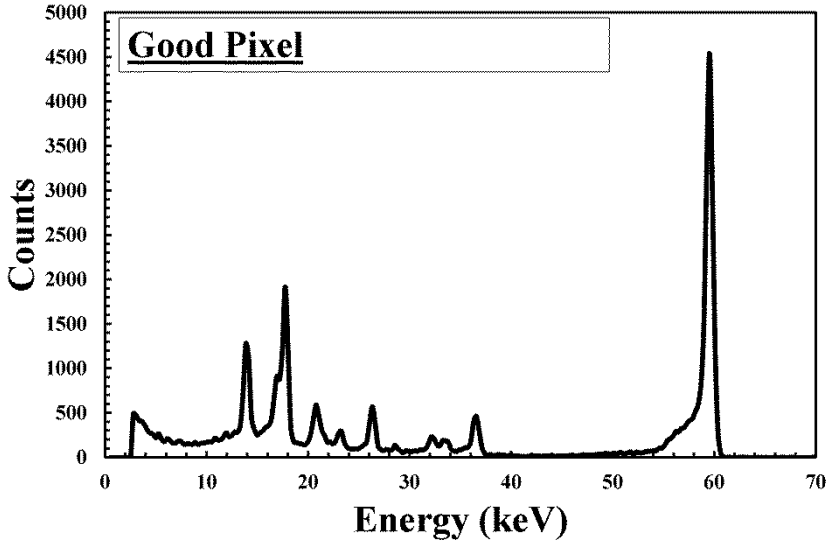
Poor Pixel Performance



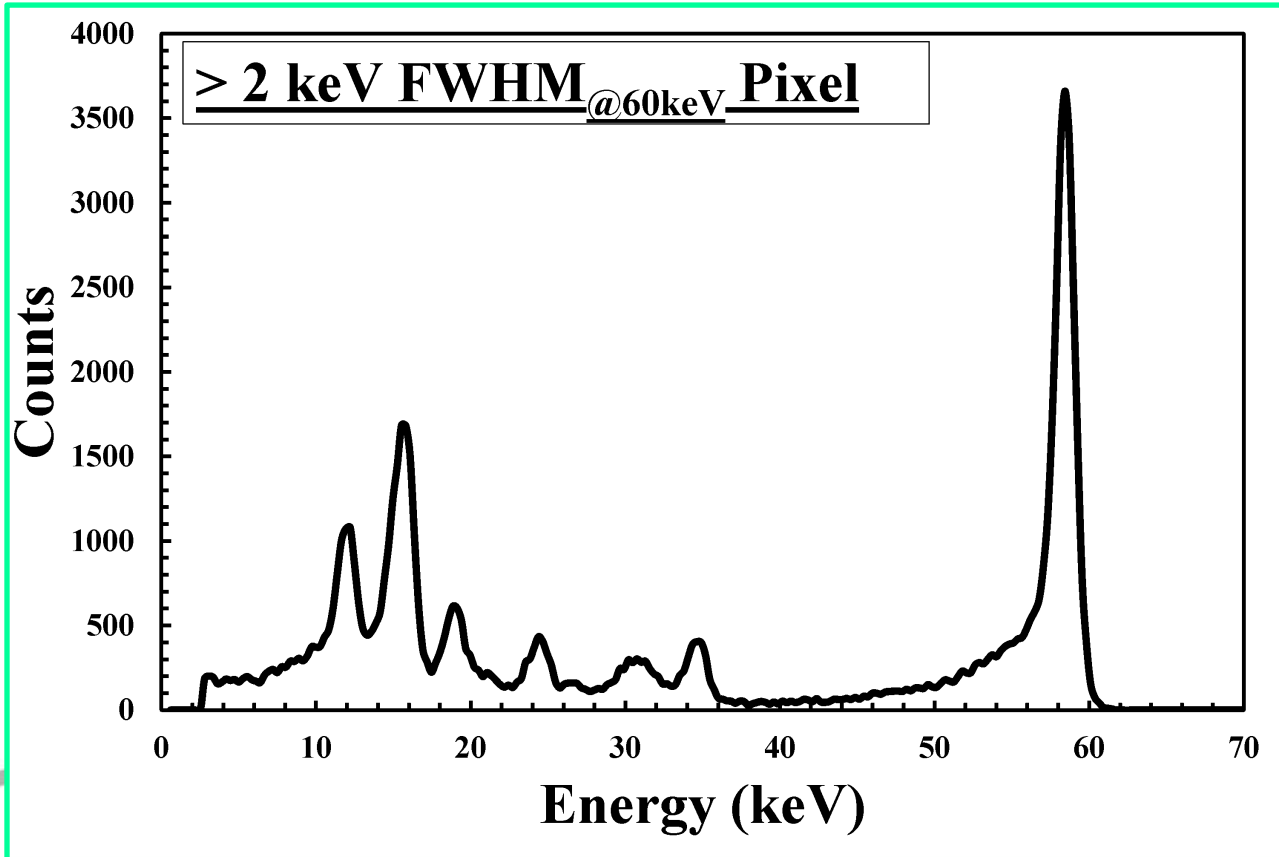
- **Just outside spec:**
  2 – 3 keV
- **Poor pixels:**
  3 – 6 keV
- **Severely degraded pixels:**
  6+ keV

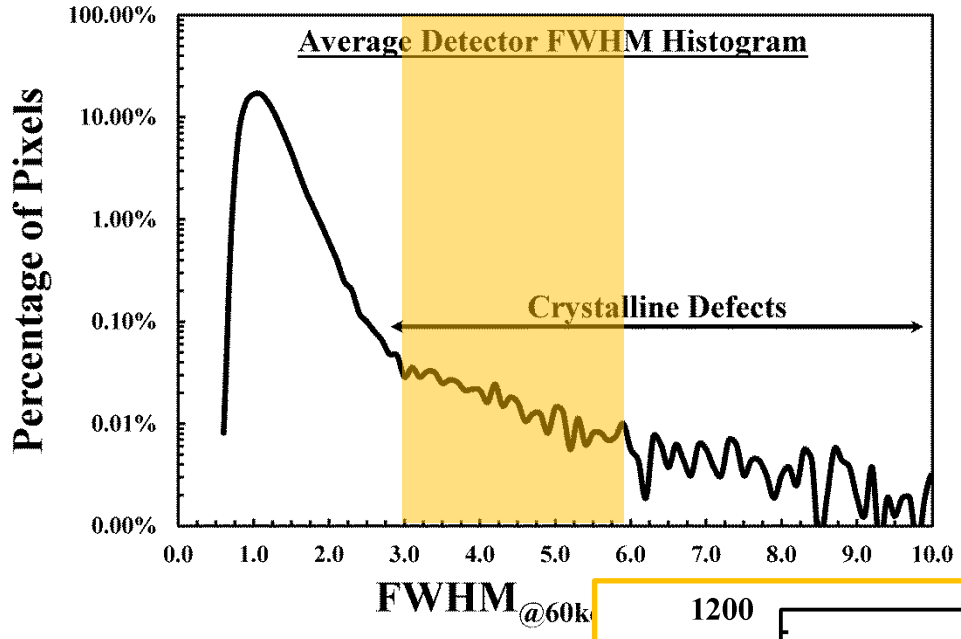


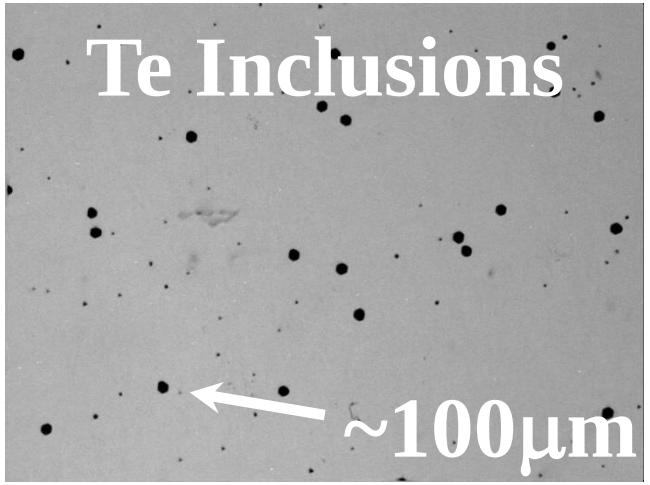


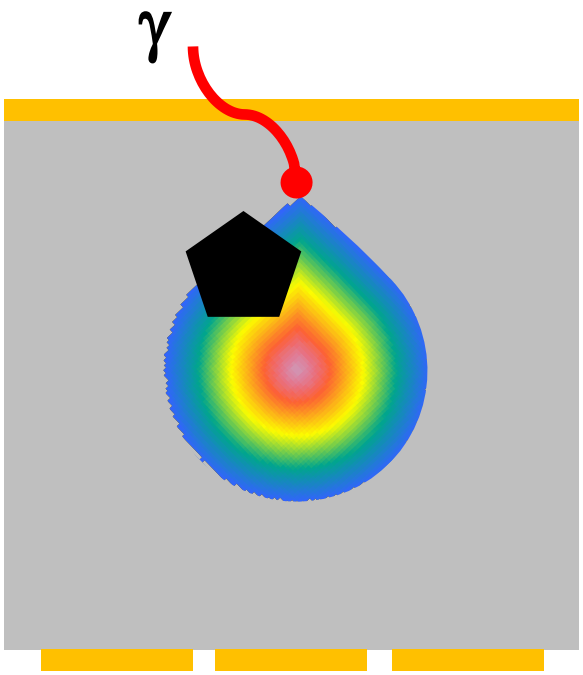


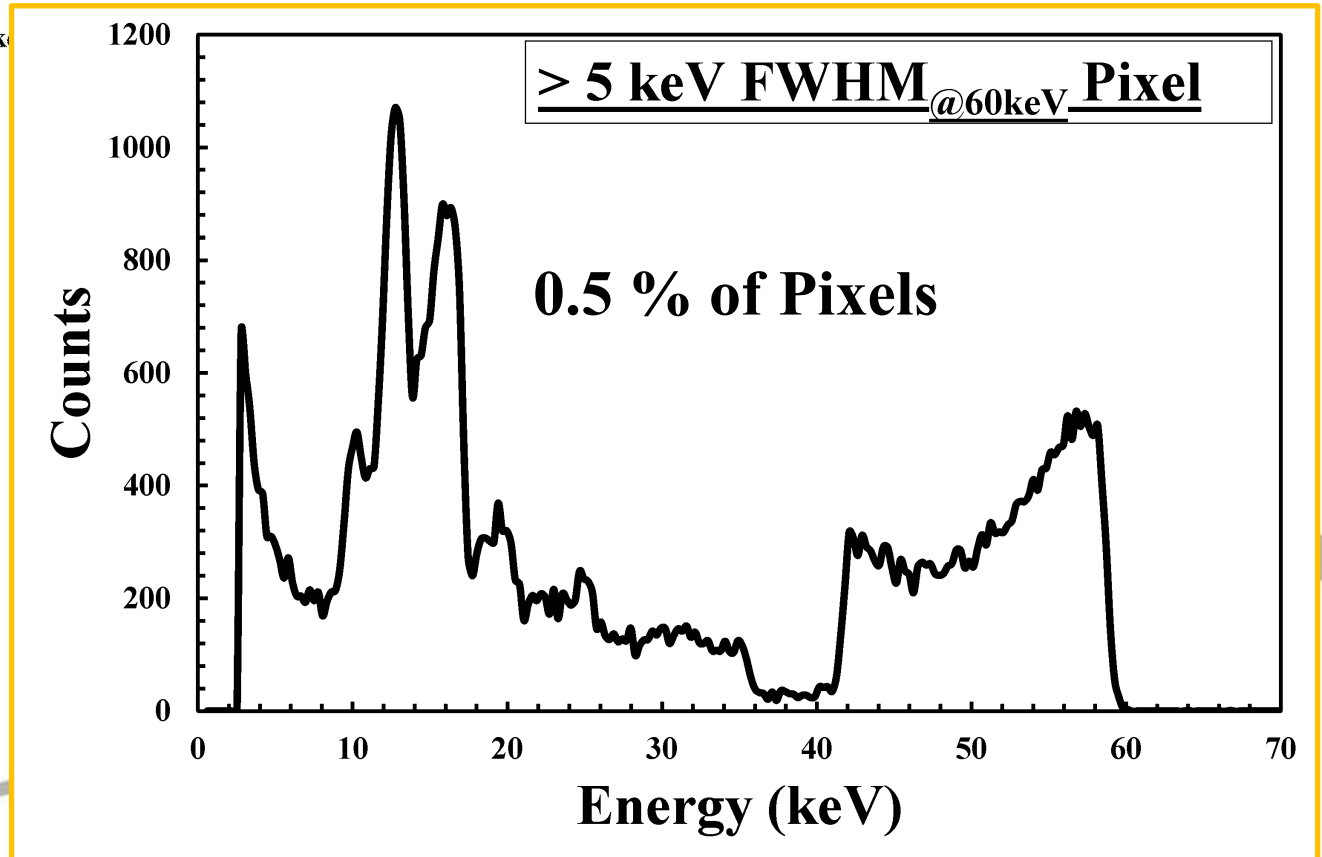
- **Typically located at the detector edge.**
- **Increased leakage current -> noise.**
- **Variations in charge transport properties.**

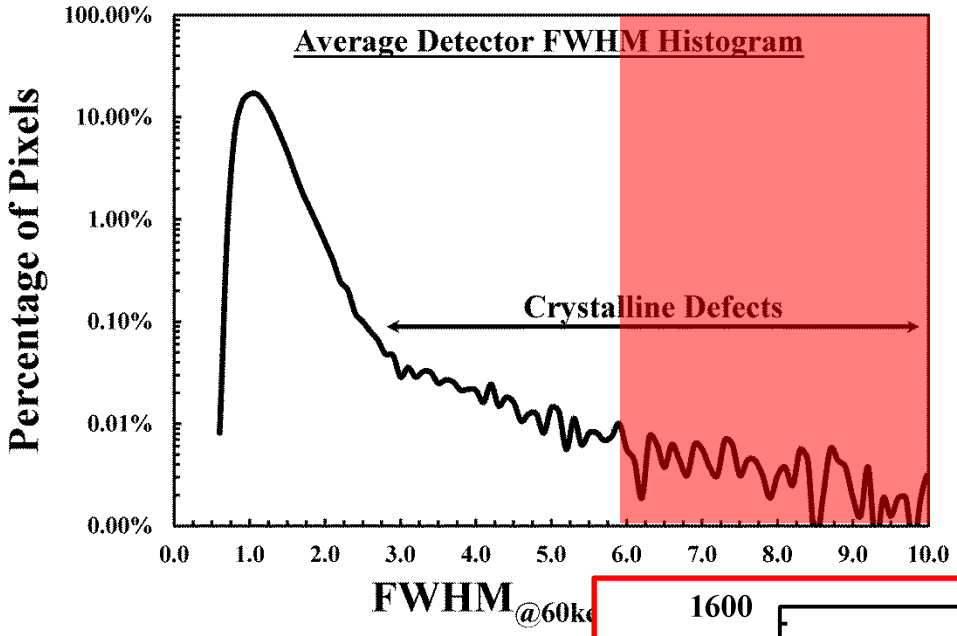


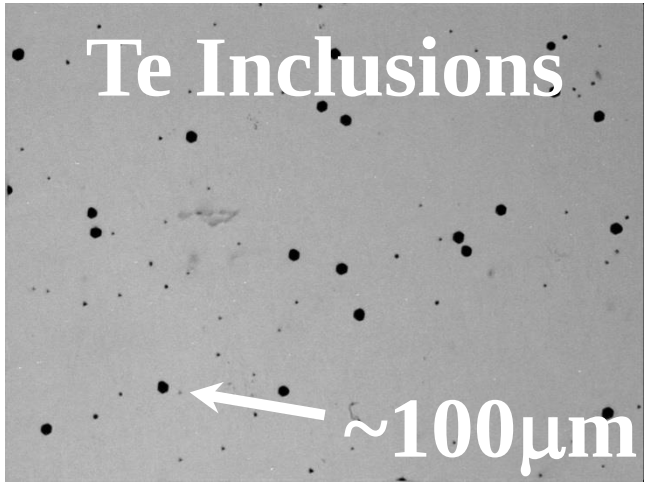

Average Detector FWHM Histogram
Percentage of Pixels
100.00%
10.00%
1.00%
0.10%
0.01%
0.00%
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Crystalline Defects
FWHM@60k

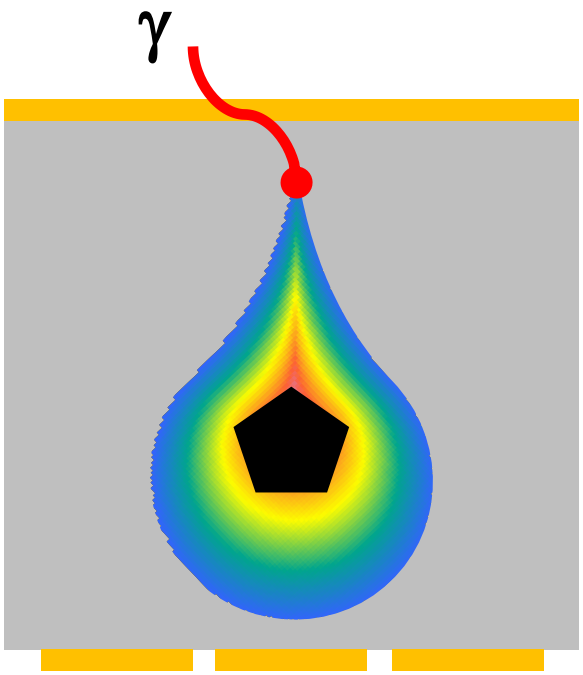

Te Inclusions
~100μm

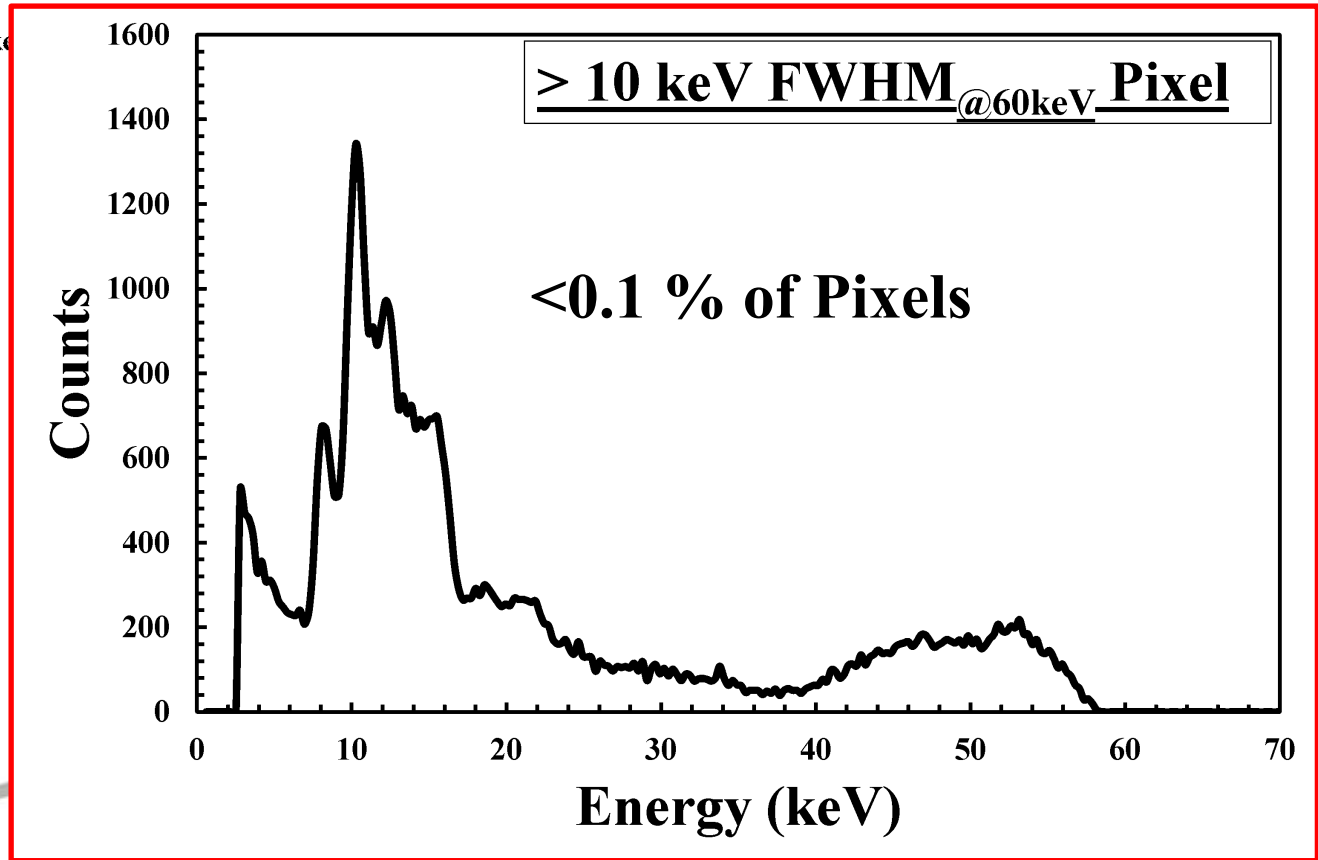

γ


> 5 keV FWHM@60keV Pixel
0.5 % of Pixels
Counts
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
Energy (keV)

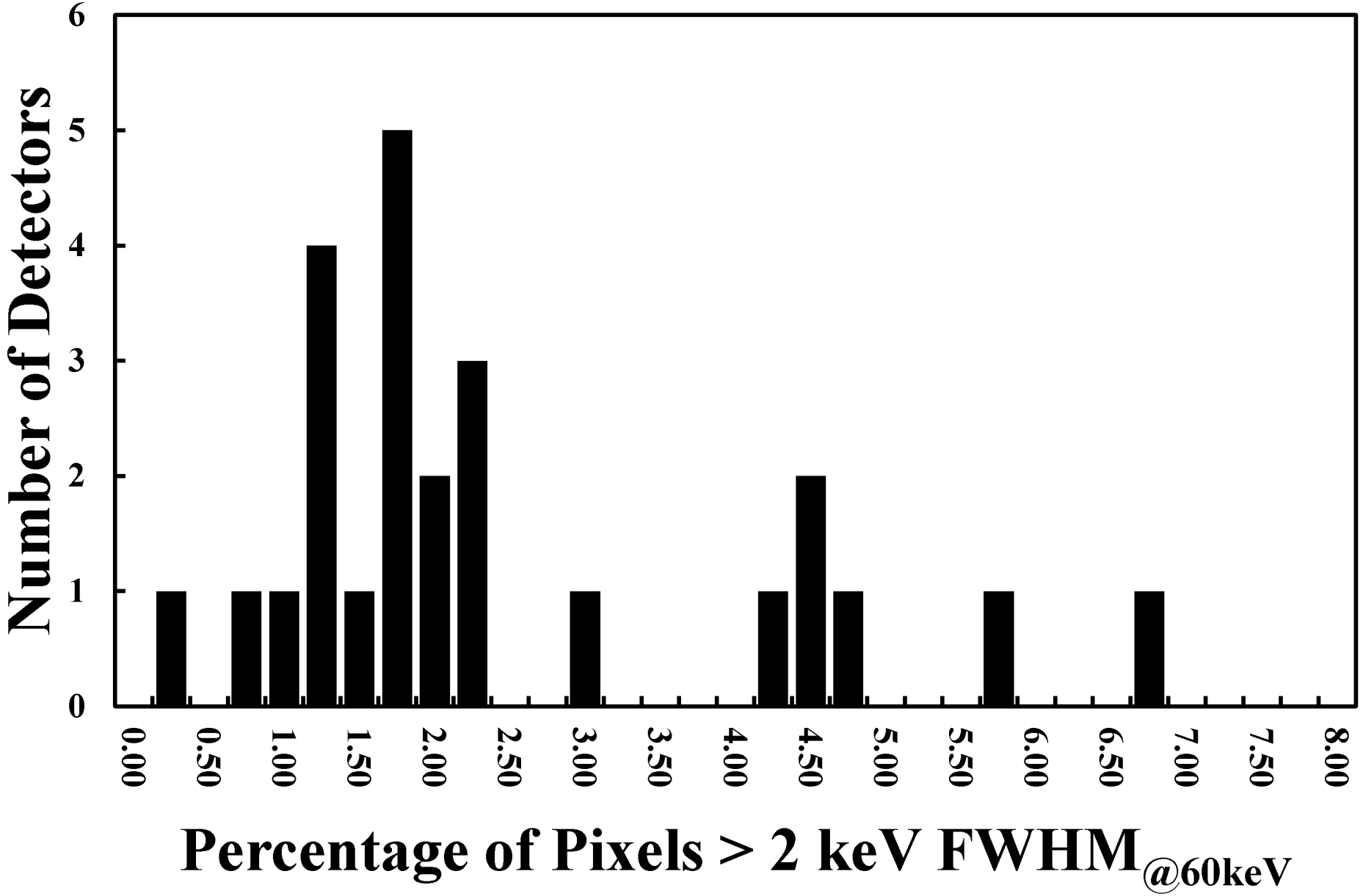

Average Detector FWHM Histogram
Percentage of Pixels
100.00%
10.00%
1.00%
0.10%
0.01%
0.00%
Crystalline Defects
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
FWHM@60ke


Te Inclusions
~100μm

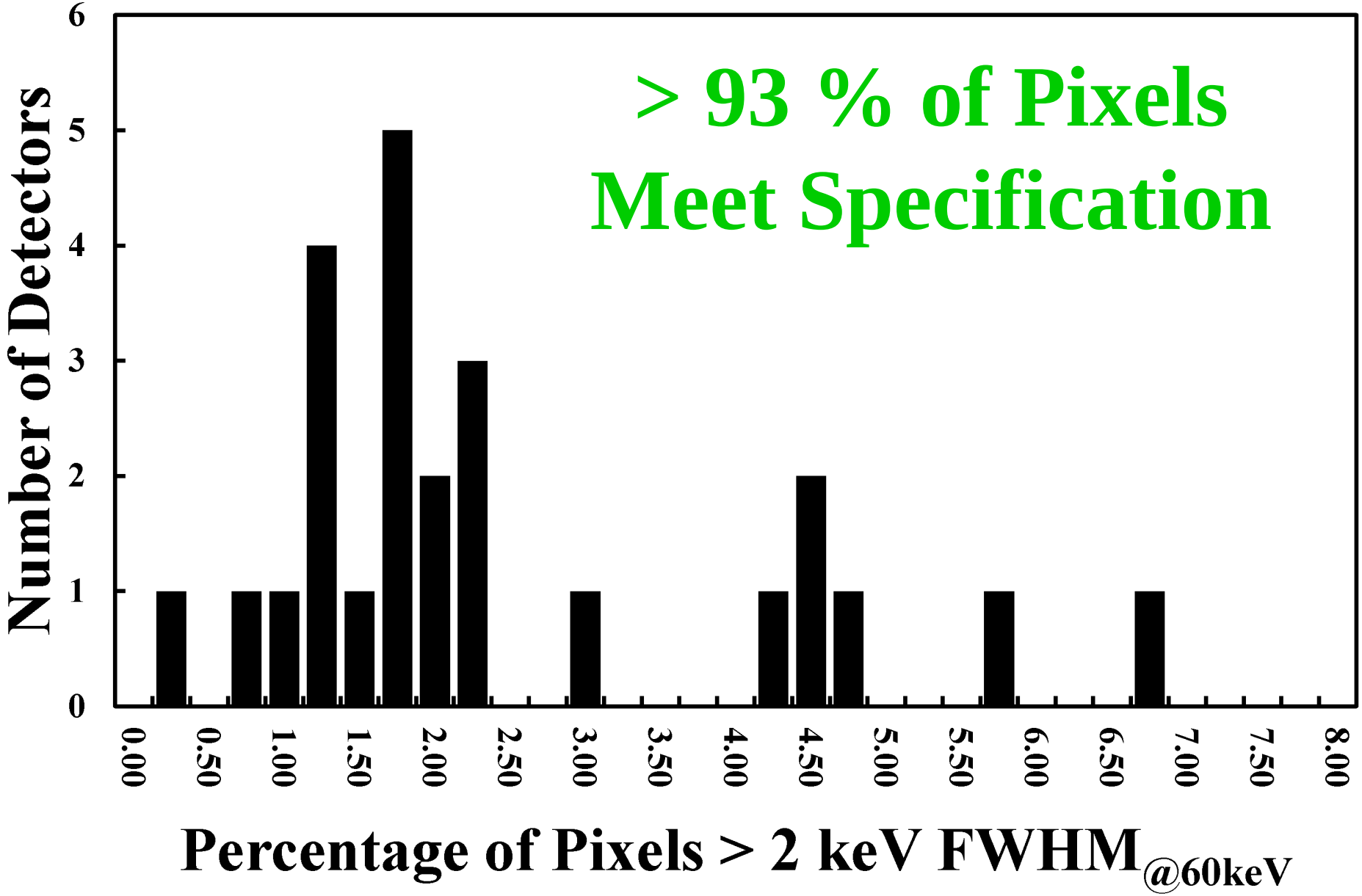

γ


> 10 keV FWHM@60keV Pixel
<0.1 % of Pixels
Counts
1600
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
Energy (keV)

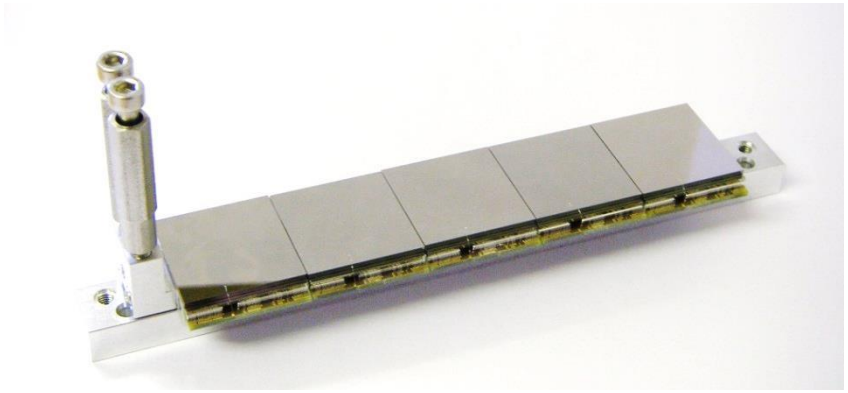
Crystalline Defects



Crystalline Defects

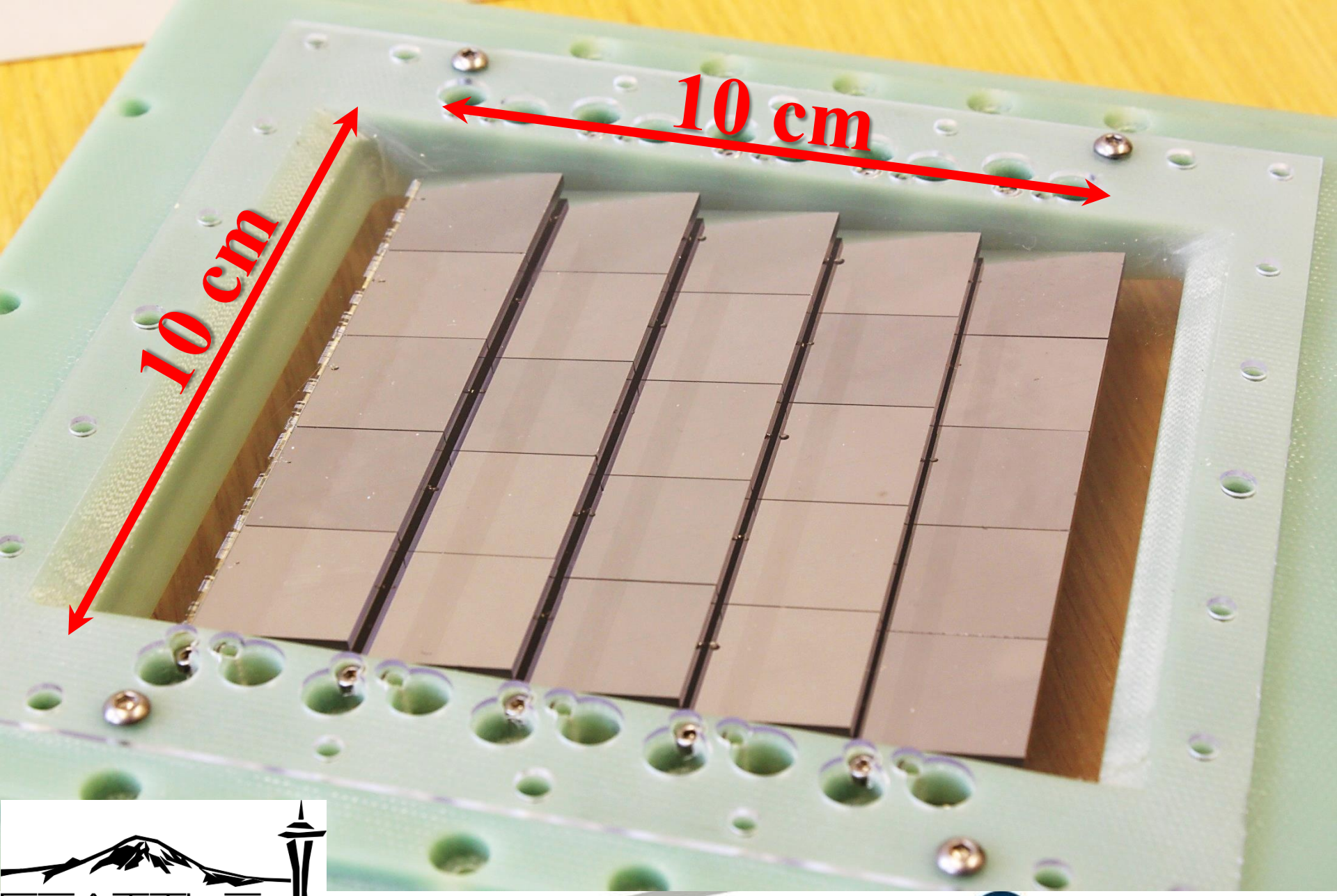


Final System Assembly



- 25 Detectors Assembled.
- “Roof-Tile” Arrangement.
- 160K Pixels.
- Operating Temperature = 20^{o}C.
- Operating Voltage = - 300 V
- > 95 % FWHM$_{@60keV}$ < 2 keV.
- Commissioning Sept ‘14.

Seller et al, *Large area CdTe based spectroscopic X-ray imaging detector*, Thurs 9:50 AM



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For More Information on HEXITEC and it's applications:

Wednesday – Session 10 @ 15:00

Duarte et al, *Influence of edge surface leakage current on the performance of pixelated CdTe radiation detectors.*

Thursday – Session 12 @ 11:40

Scuffham et al, *Imaging of Ra-223 with a small-pixel CdTe detector: potential for improved image quantification for radionuclide dosimetry.*

Thursday – Session 14 @ 17:10

Pani et al, *Dual-energy mammography with a pixellated spectroscopic detector.*