Using the Medipix2 Detector for Energy Weighting

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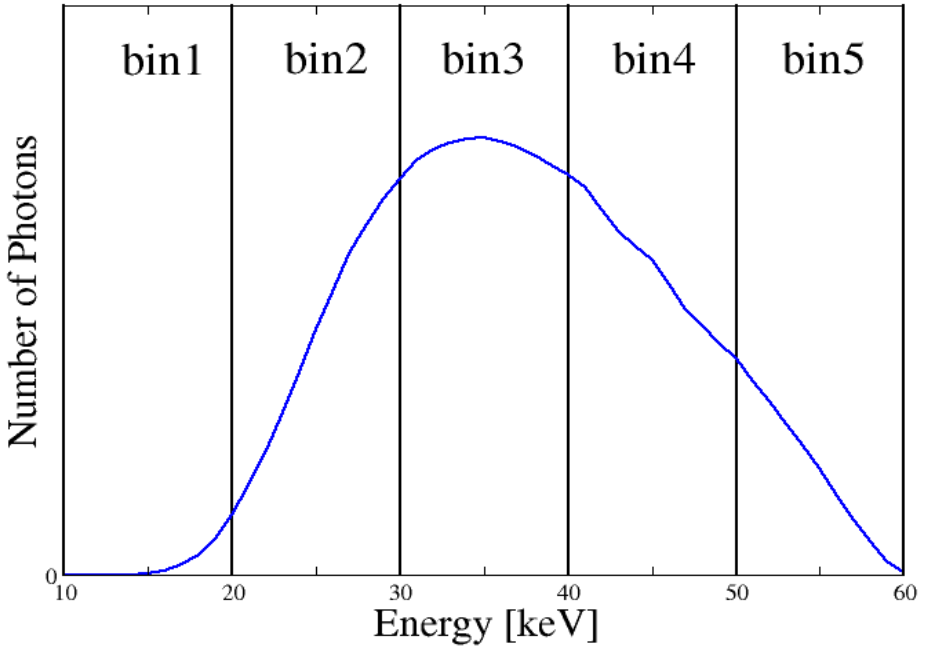
Outline

- Detector Requirements / Medipix2 Properties
- Threshold Masks for Medipix2
- Limitations Caused by Charge Sharing
- Weighting Example : Water / PMMA

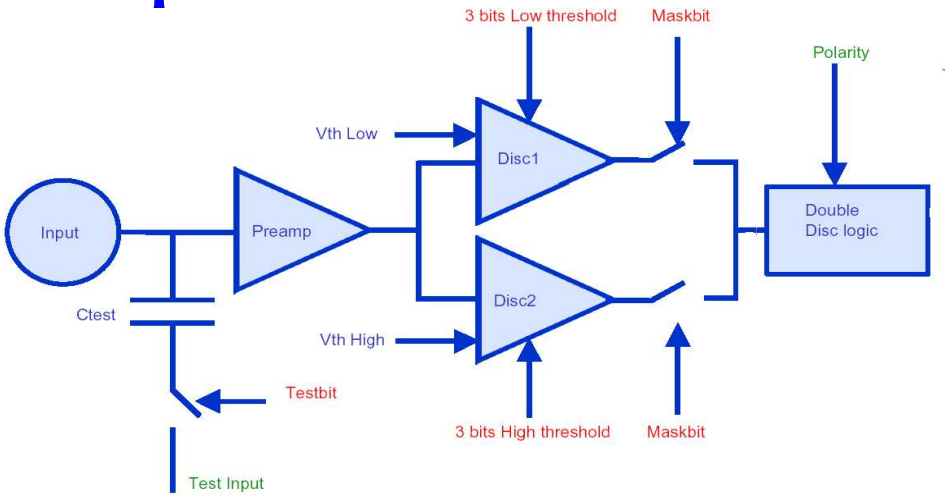
Detector Requirements for Energy Weighting

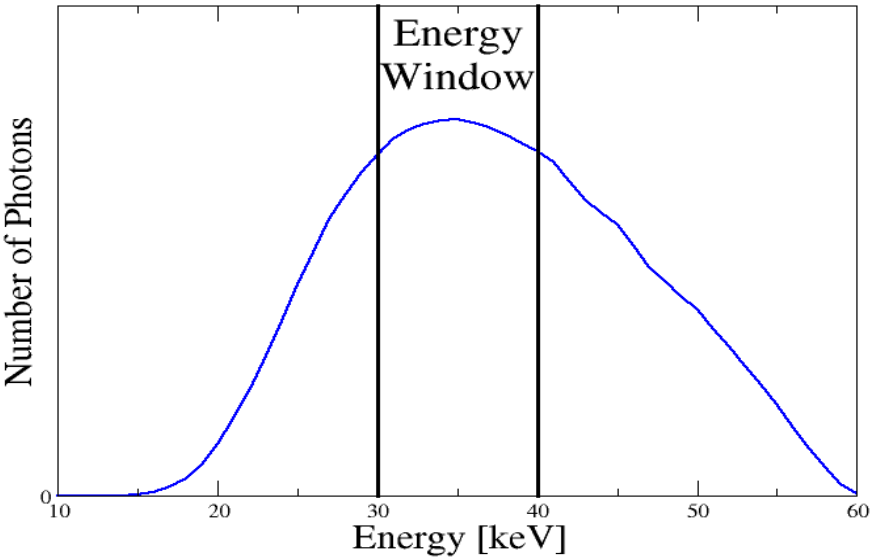
- Determine energy and position of each photon
- Energy resolution: counter for each bin in every pixel
- Pixel logic to increment counter depending on energy of incoming photon



Medipix2 Properties

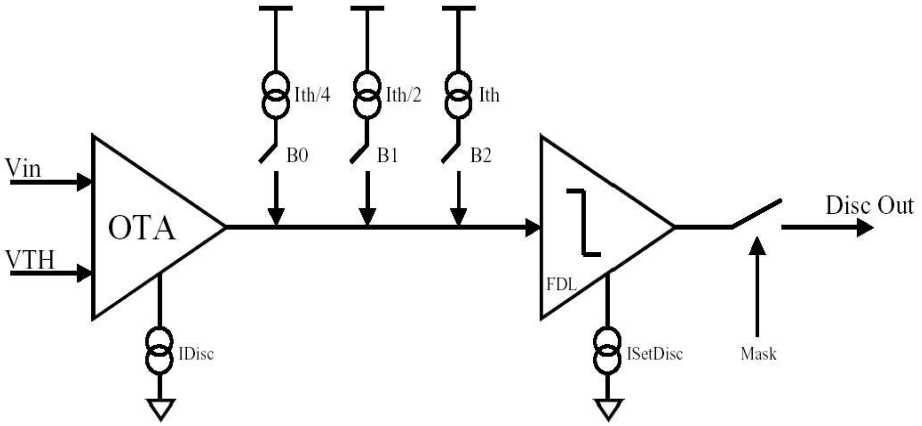
- 2 thresholds (low/high)
- Energy window measurement
- Emulation of Energy Weighting by successive measurements at constant conditions

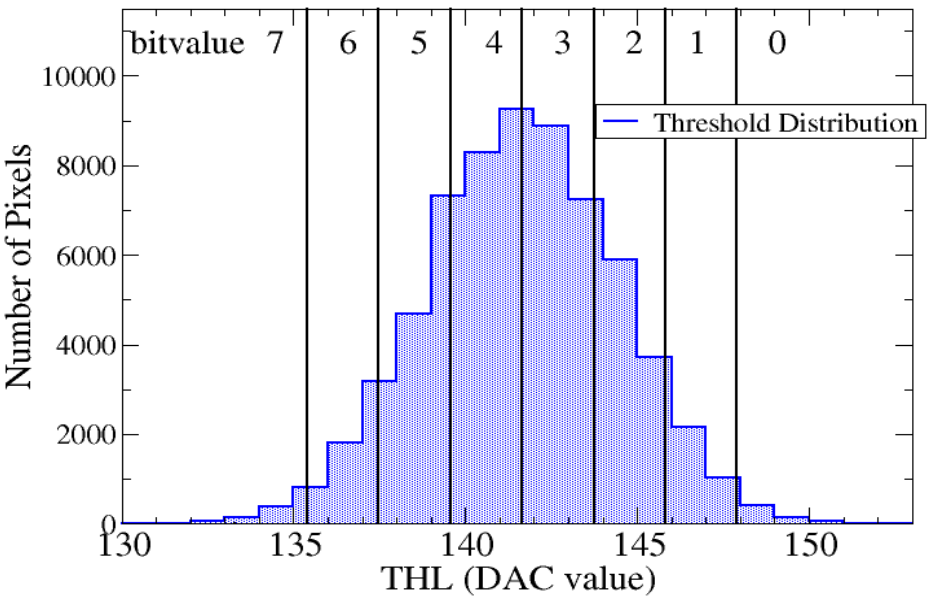




Medipix2 Threshold Masks

- Without equalisation: inhomogenities up to 10 keV
- 3 bit threshold equalisation for both thresholds
- 8 equally spaced correction levels



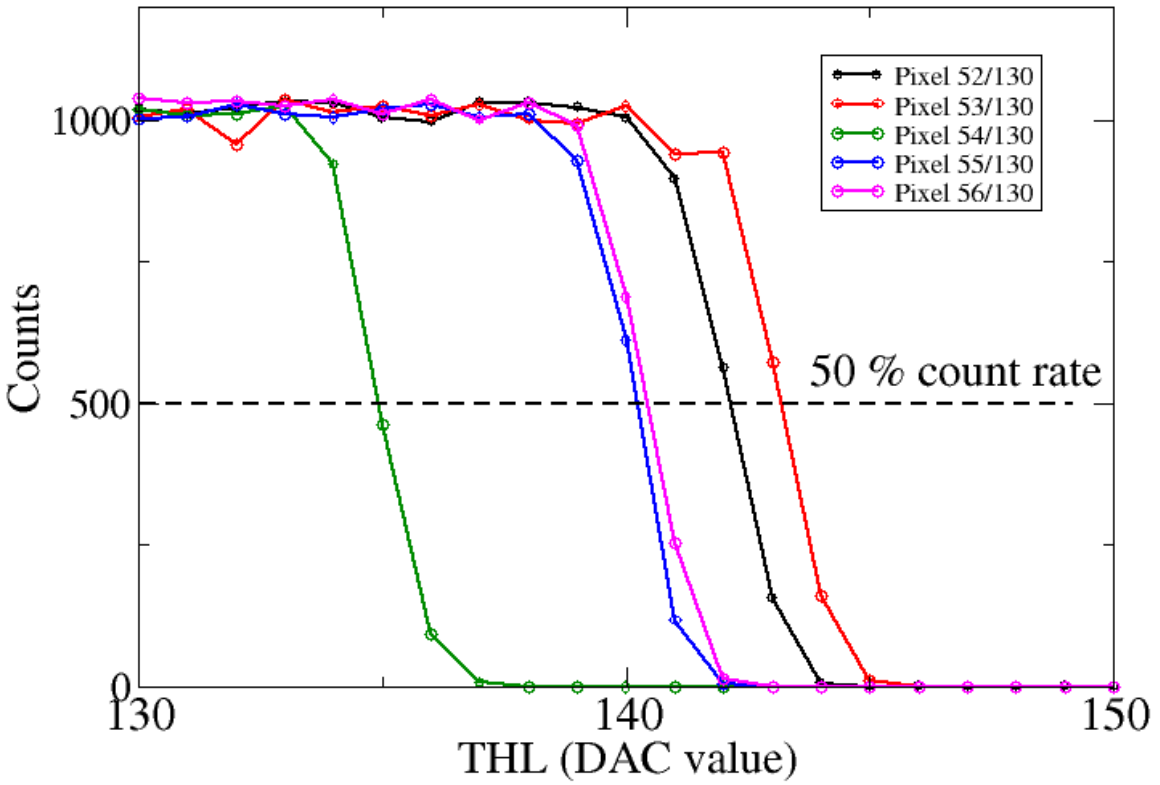


Methods for Mask Generation

- Low Threshold:
  - Noise (Medisoft 4.0)
  - External pulser
  - Monoenergetic source (e.g. Cd-109)
- High Threshold:
  - Copy low threshold mask
  - External pulser
  - (Monoenergetic source)
  - X-ray tube

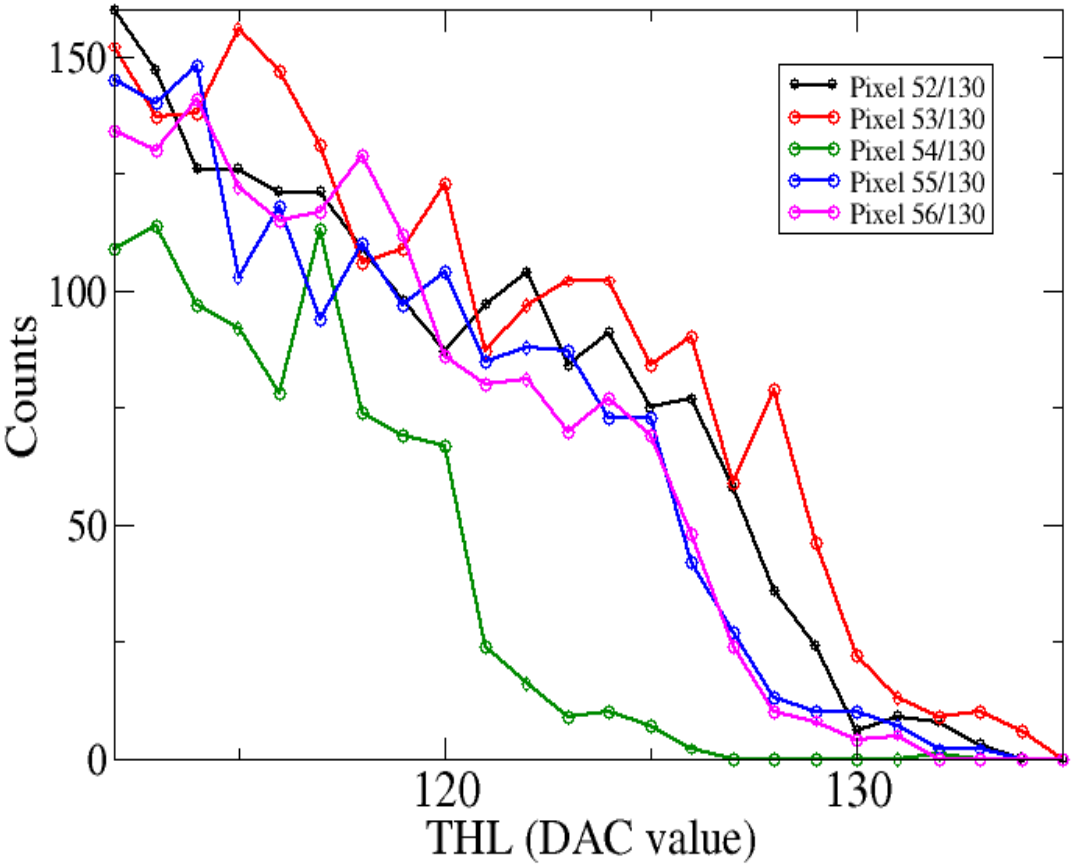
THL: Measurement with Pulser

- External pulser: constant pulse height; simulates monoenergetic source
- Threshold scan (THL DAC)
- Find threshold distribution, calculate bit value



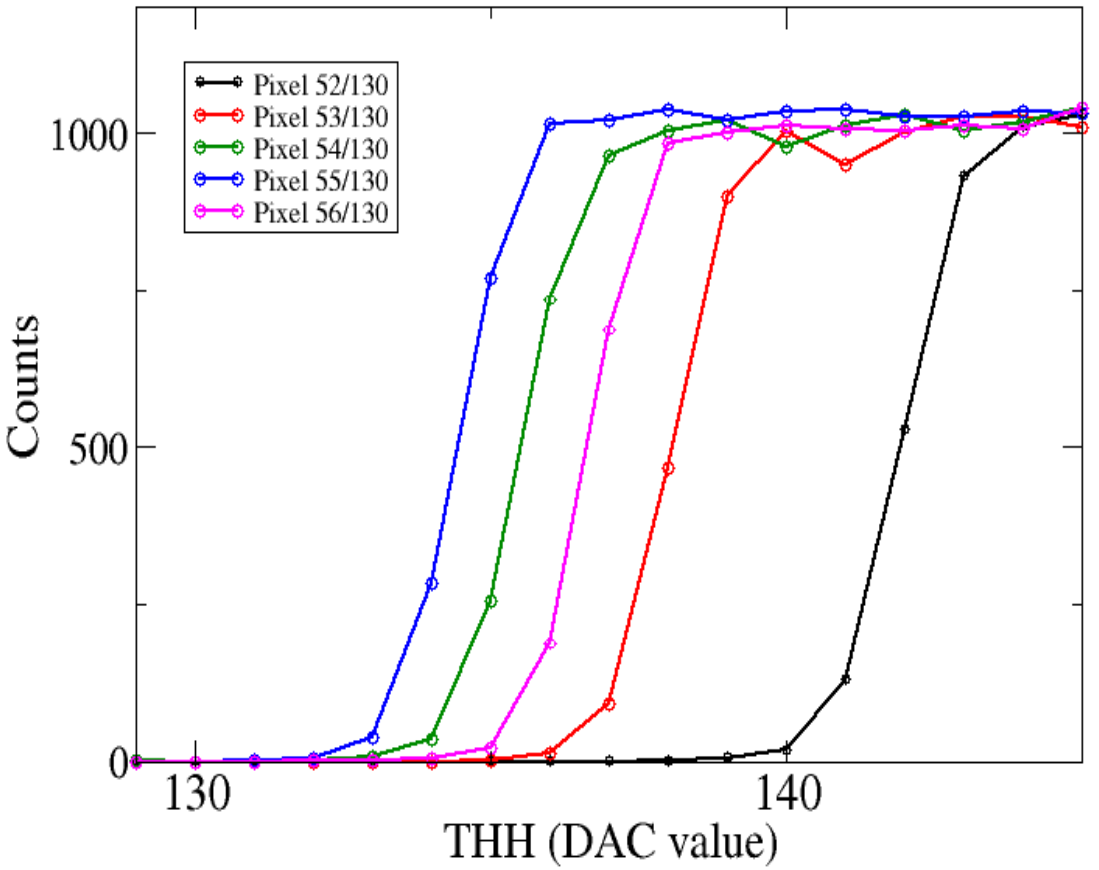
THL: Measurement with Cd Source

- Cd-109 : 22 and 25 keV photons
- Threshold scan (THL DAC)
- Find threshold distribution, calculate bit value
- Charge sharing, low statistics
- Includes sensor layer



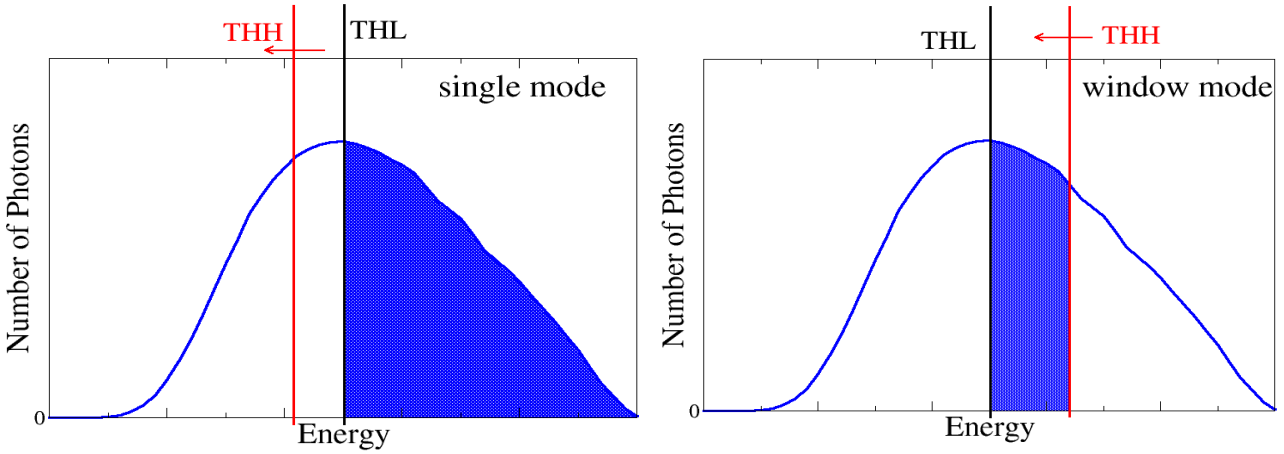
THH: Measurement with Pulser

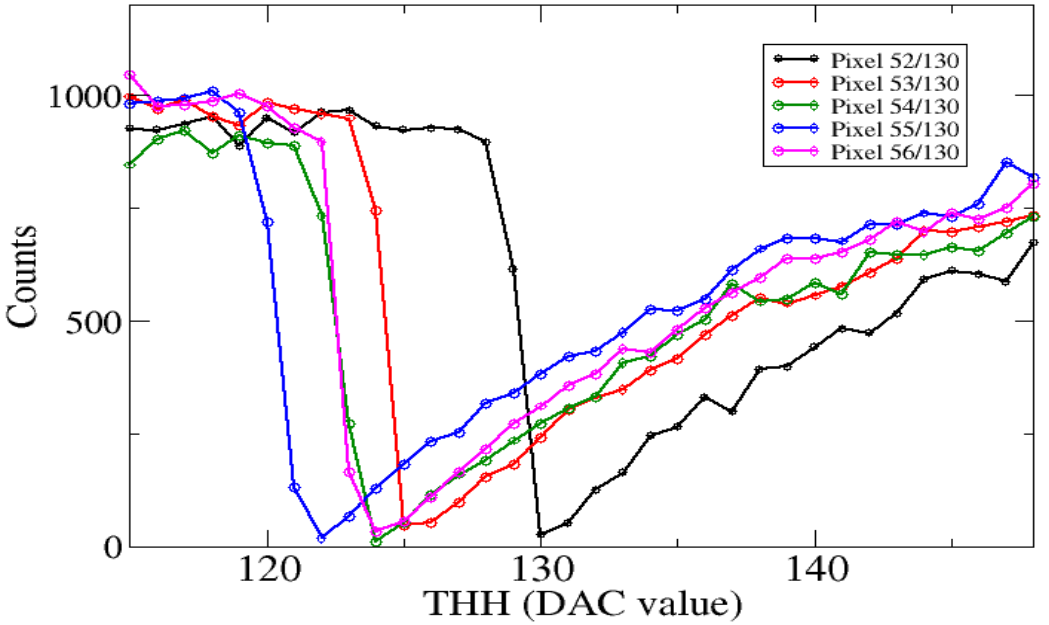
- External pulser: constant pulse height
- Threshold scan (THH DAC)
- THL < THH (energy window mode)
- Find threshold distribution, calculate bit value



THH: Measurement with X-Ray Tube

- Use X-ray tube
- Mask for THL, constant DAC value
- Threshold scan for THH
- Find transition between single mode / energy window mode, calculate bit value

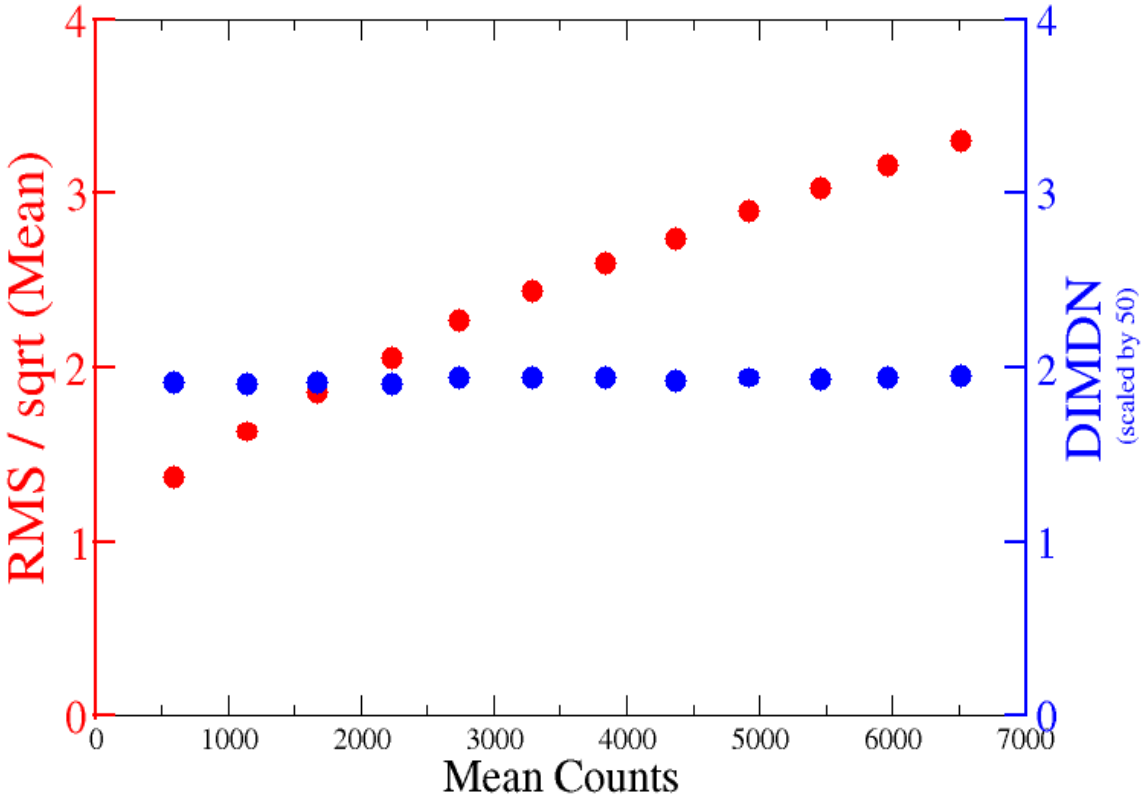




Comparison of Mask Quality

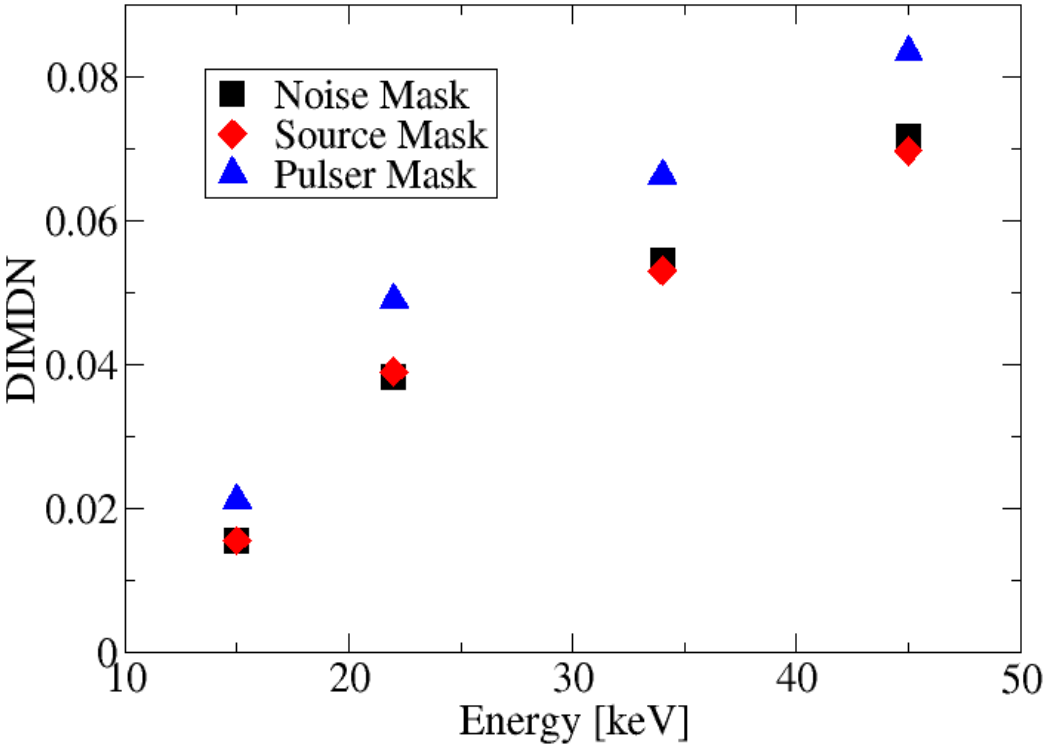
- Load mask on chip and make flatfield images with x-ray tube
- Calculate Mean, RMS
- Dose independent measure for detector noise:

$$DIMDN = \sqrt{\frac{(RMS * RMS - Mean)}{Mean * Mean}}$$



Comparison of Mask Quality

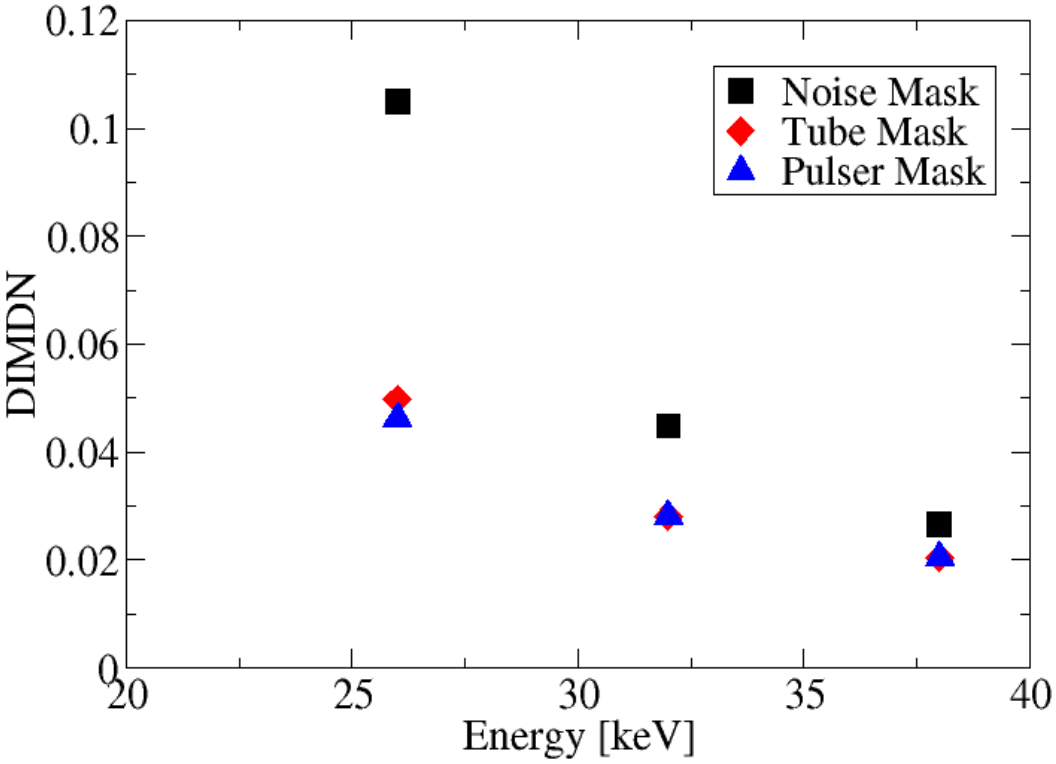
- Low threshold mask:
- Source mask slightly better than noise mask
- Problems with pulser mask



Comparison of Mask Quality

- High threshold mask:

- Copy low mask not suitable
- Pulser and tube masks ok
- Smallest possible bin size with tube and corresponding low mask: 2-3 keV

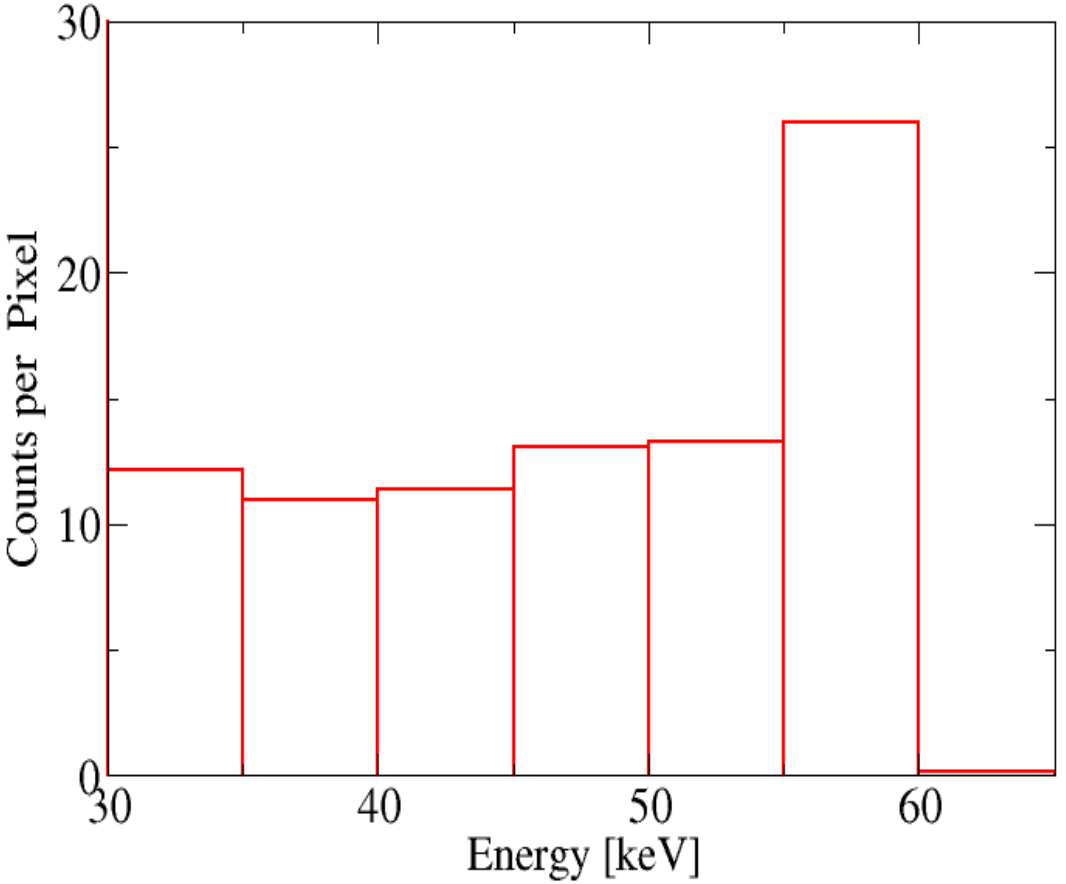


Limitations for Energy Weighting

- Energy information is lost because of detector effects
- Especially: charge sharing
- Consequence: photons are sorted in wrong bins
- Medipix2: pixel size 55 µm * 55 µm
  for 300 µm Si sensor layer : average charge spread compared to pixel size so large, that charge sharing becomes important in majority of cases

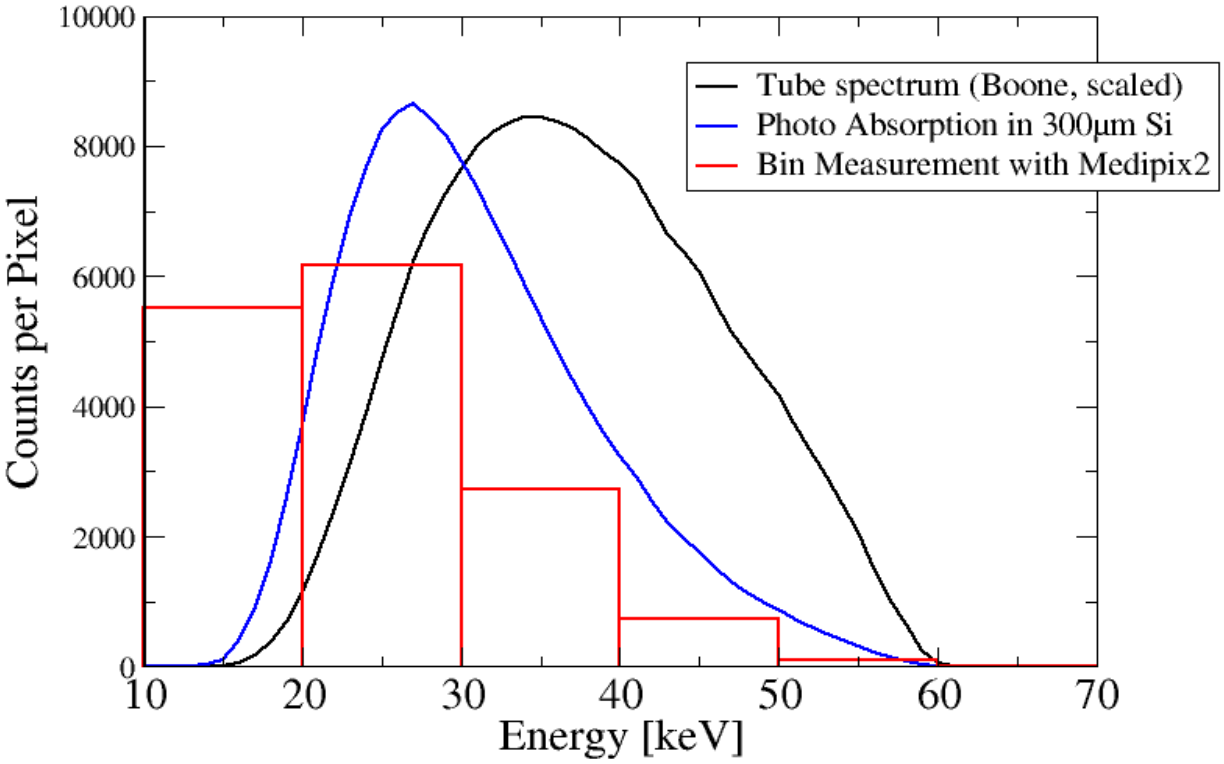
Charge Sharing with Am-Source

- Am-241 monoenergetic source: 59,5 keV
- Ideal detector: only signal in one bin
- Medipix2: most counts in wrong bin
  →Energy Weighting: wrong weighting factor



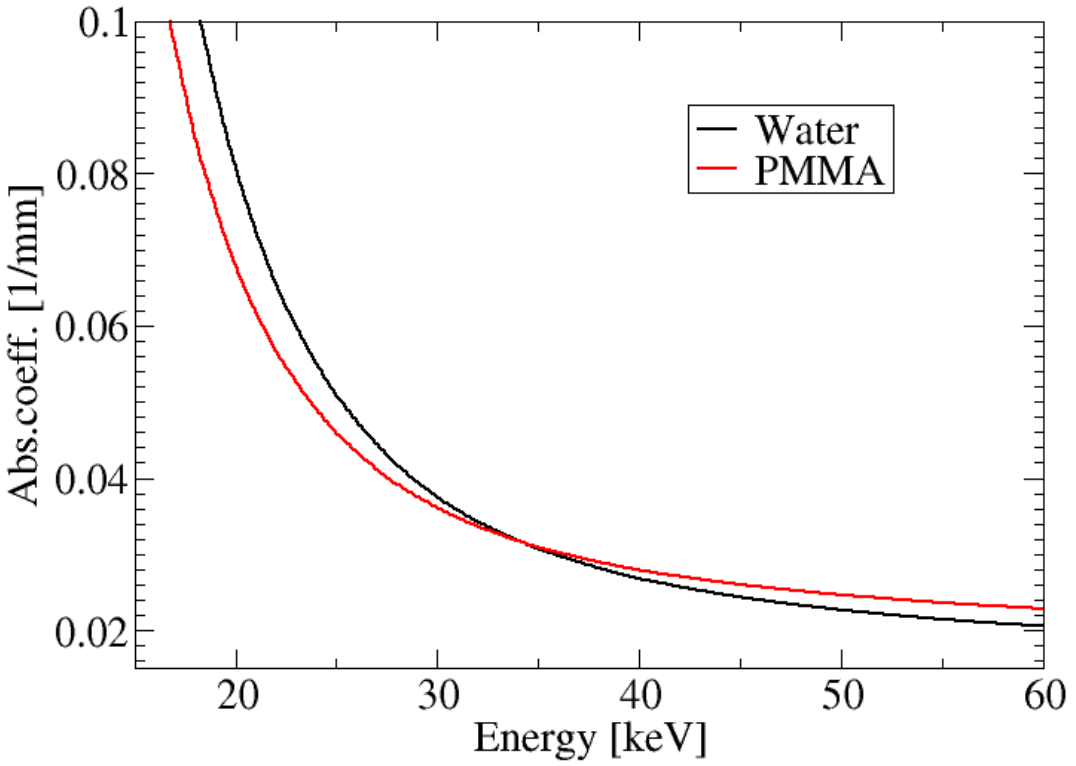
Charge Sharing with Tube Spectrum

- X-ray tube spectrum: 60 kV, 2mm Al filter
- Different absorption for different energies in 300 µm Si
- Charge sharing for all energies
- In lowest bin signal from all photon energies



Weighting Example: Water/PMMA

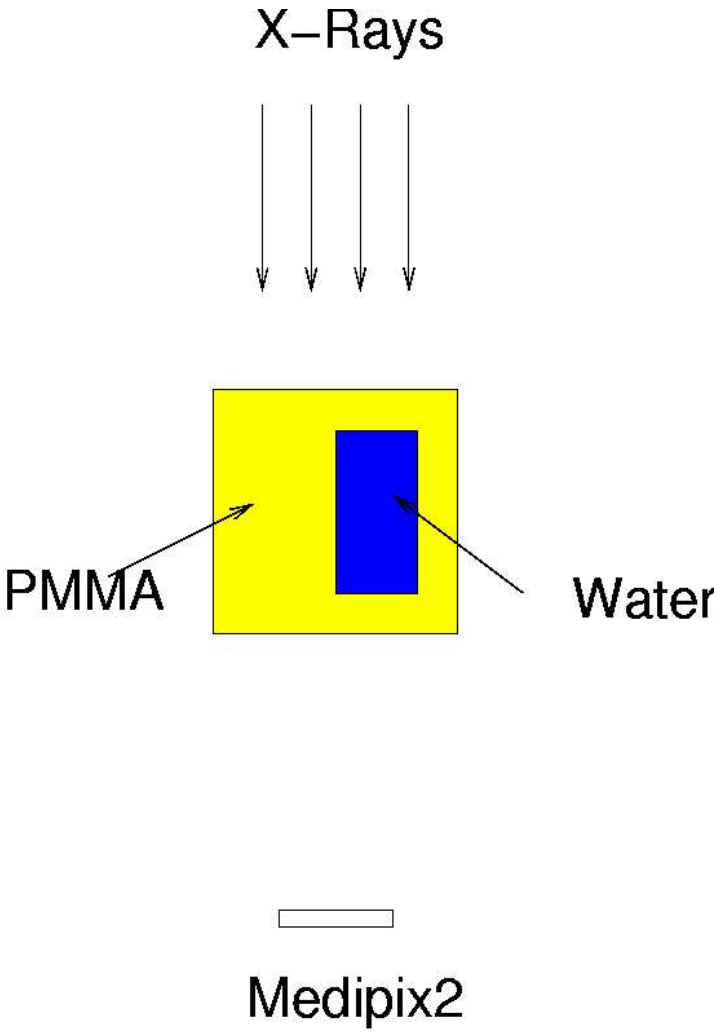
- Intersecting absorption coefficients
- Below intersection: more absorption in water
- Above intersection: more absorption in PMMA
- “Classical” example for Energy Weighting



Weighting Example: Water/PMMA

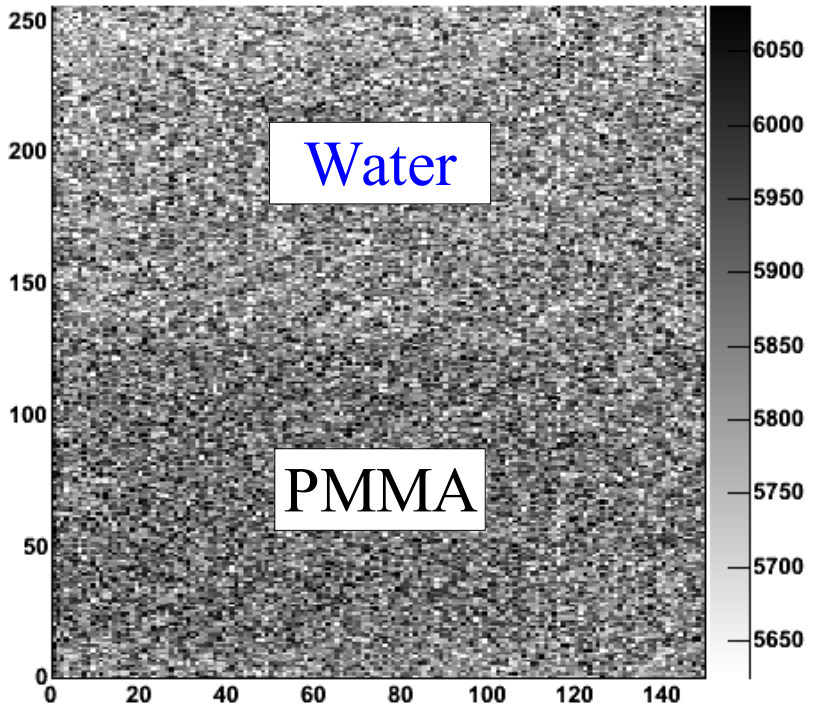
- Imaging Parameters:
- 60 kV tube voltage
  W anode
  2mm Al filtering
- Detector : Medipix2
  300 µm Si, 150 V
- All images flatfield corrected

- Measuring Setup:



Counting vs Energy Bins

Counting: Small Contrast and SNR

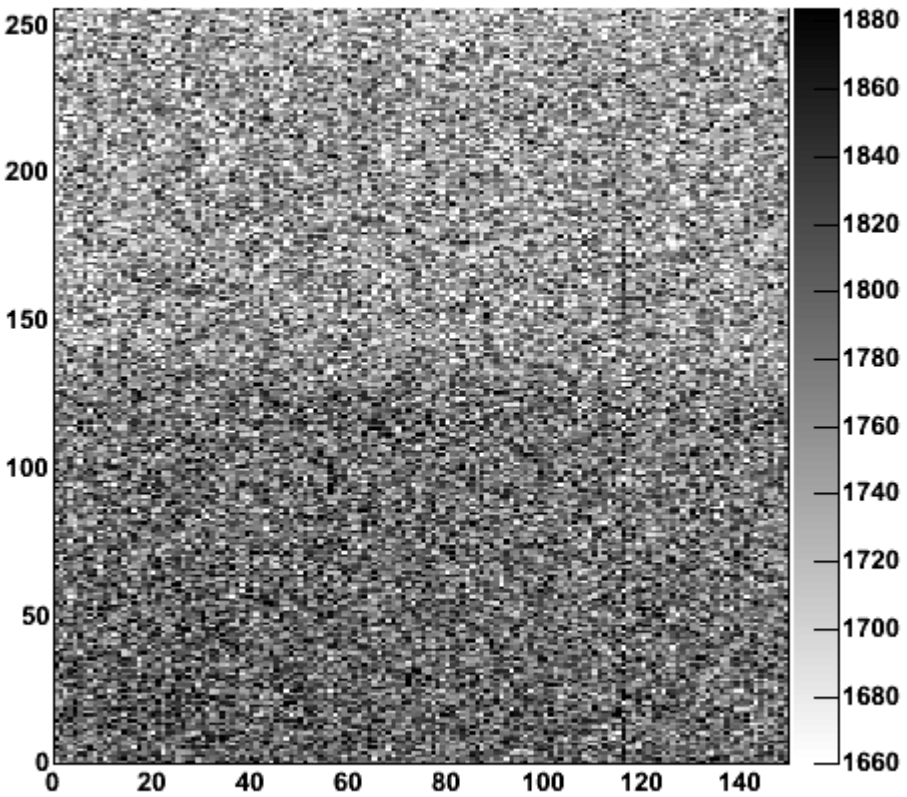


- 5 Energy bins:

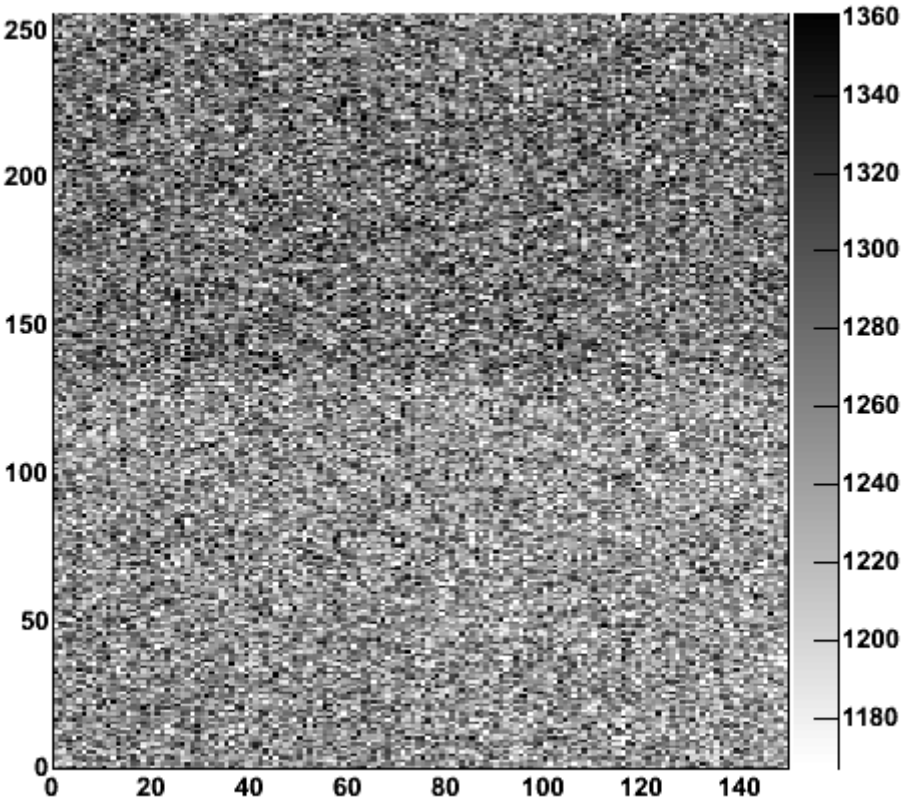
- Bin1: 9 – 16 keV
- Bin2: 16 – 23 keV
- Bin3: 23 – 31 keV
- Bin4: 31 – 45 keV
- Bin5: 45 – 60 keV

Images from Energy Bins

Bin 3 23-31 keV



Bin 4 31-45 keV

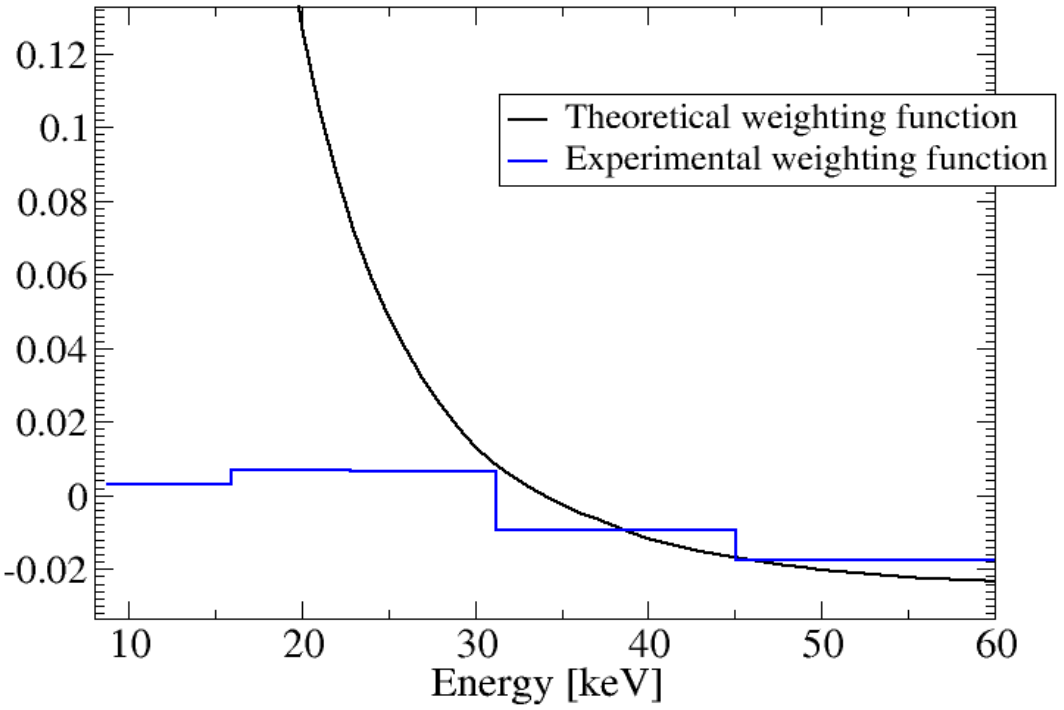


Weighting Function

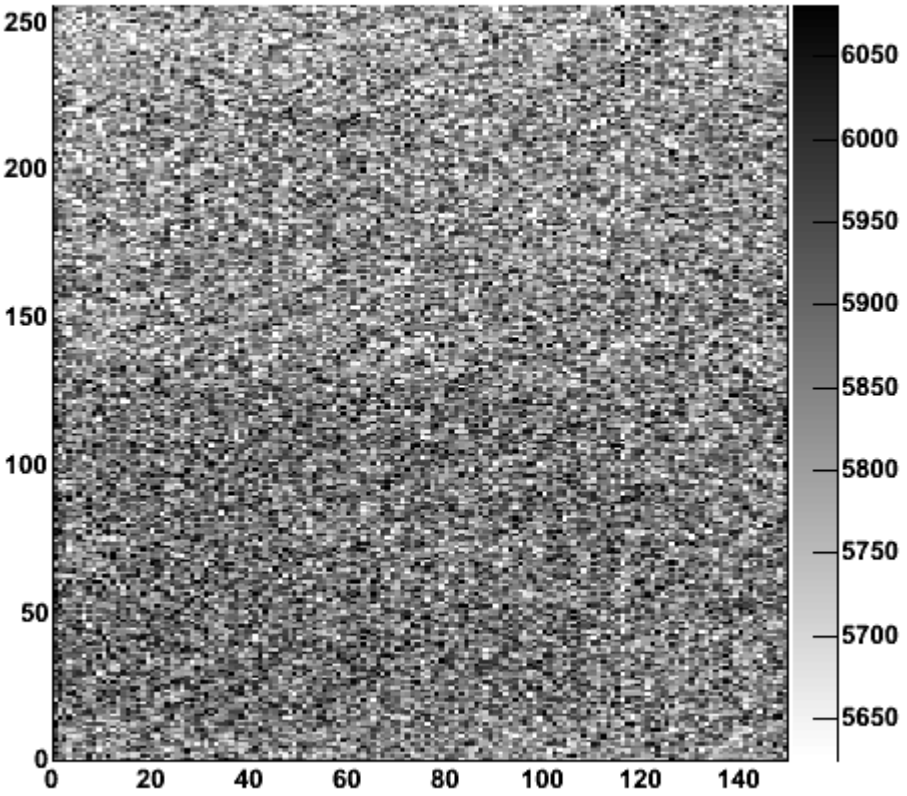
- Weighting function calculated from image:

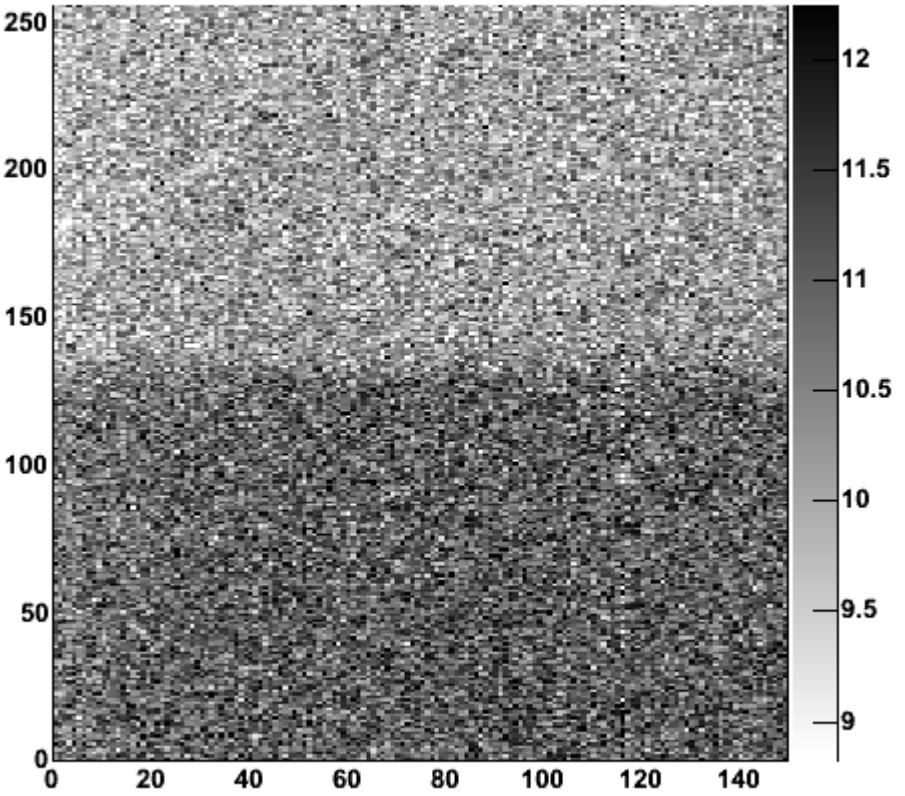
$$w = \frac{(I_1 - I_2)}{(I_1 + I_2)}$$

- Large discrepancies compared to theoretical weighting function (ideal detector)



Comparison:
Counting / Weighting





SNR improvement: > 2.2

Conclusion

- Threshold masks can be optimised
- Energy window measurements with Medipix2 successful
- Energy Weighting is possible and results in SNR improvement
- Charge sharing problem has to be solved

Additional Material

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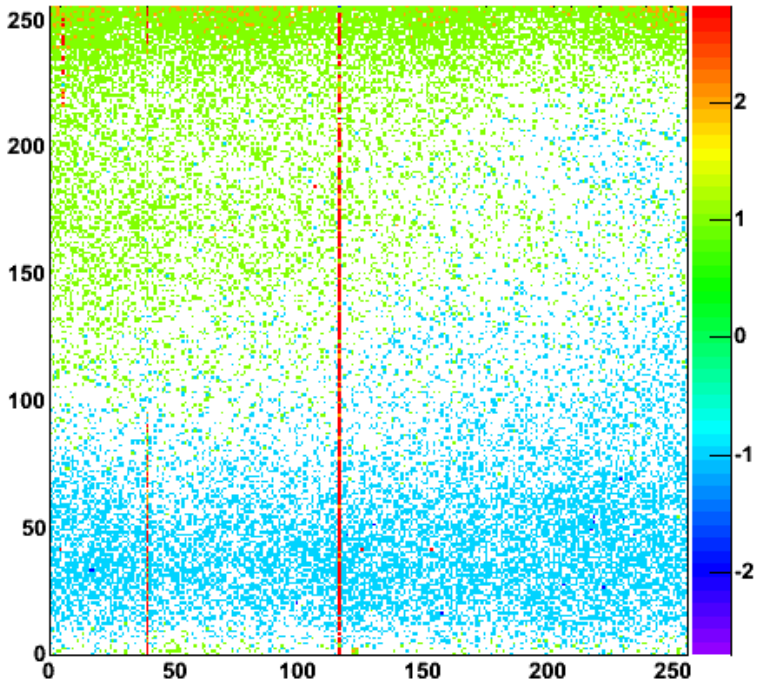
Pulser Mask – Source Mask



Comparison of Mask Quality

- Load mask on chip and make flatfield images with x-ray tube
- Calculate mean, RMS
- Detector noise ∝ mean
- Quantum noise ∝ sqrt(mean)
- Dose independent measure for detector noise:

$$DIMDN = \sqrt{\frac{(RMS * RMS - Mean)}{Mean * Mean}}$$

Same Mask, but varying acquisition time: