Photon Spectrometry with Dosepix

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On behalf of the Medipix Design Team at CERN
Eurados Workshop
17 October 2016

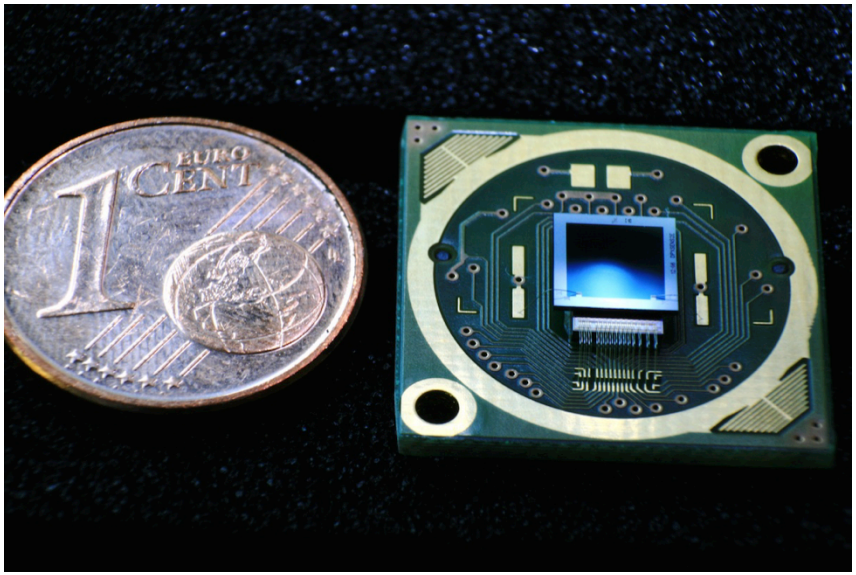
Outline

Hybrid pixel detectors

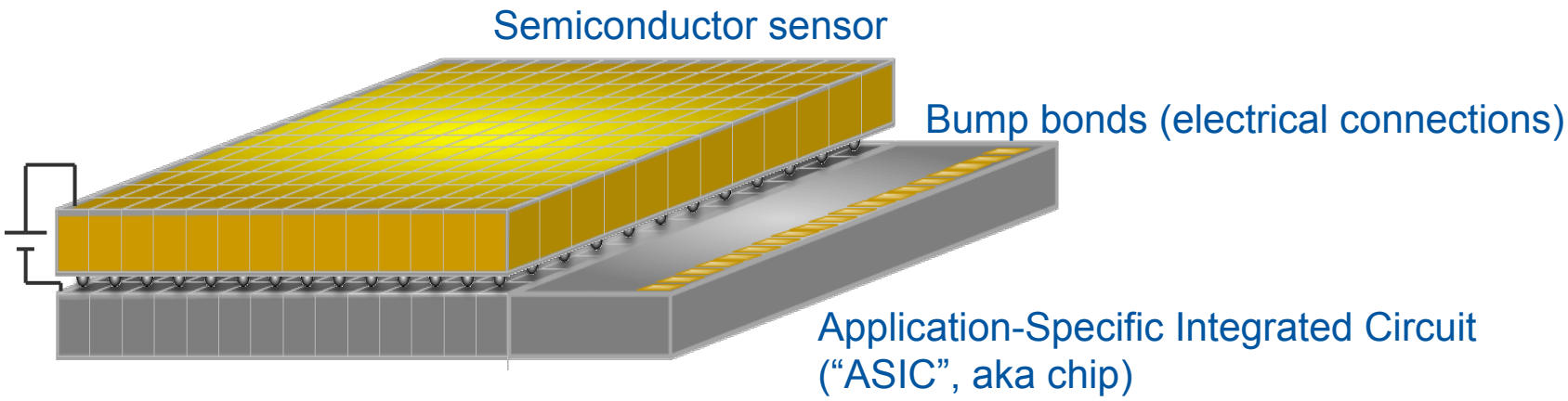
- Single quantum processing
- Medipix

Dosepix

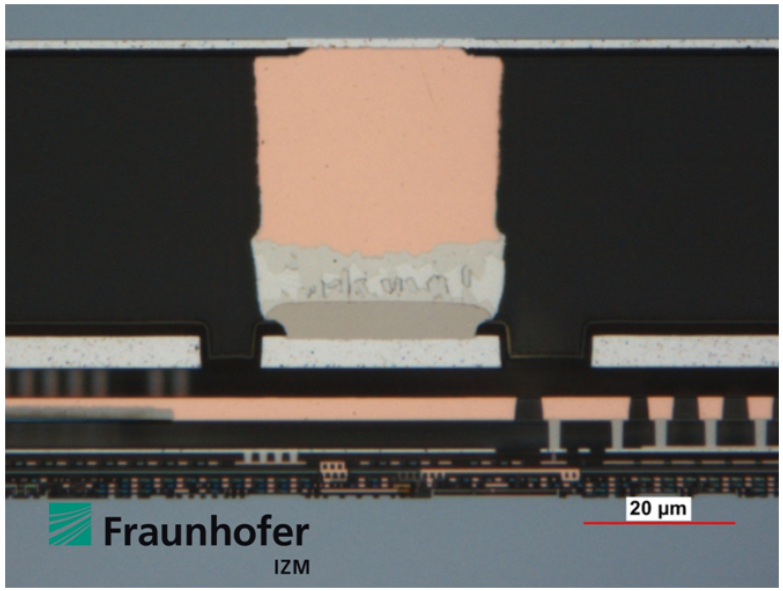
- Count rate
- X-ray spectroscopy
  - Primary beam
  - Scatter radiation



Hybrid Pixel Detectors



Hybrid Pixel Detectors



Silicon sensor

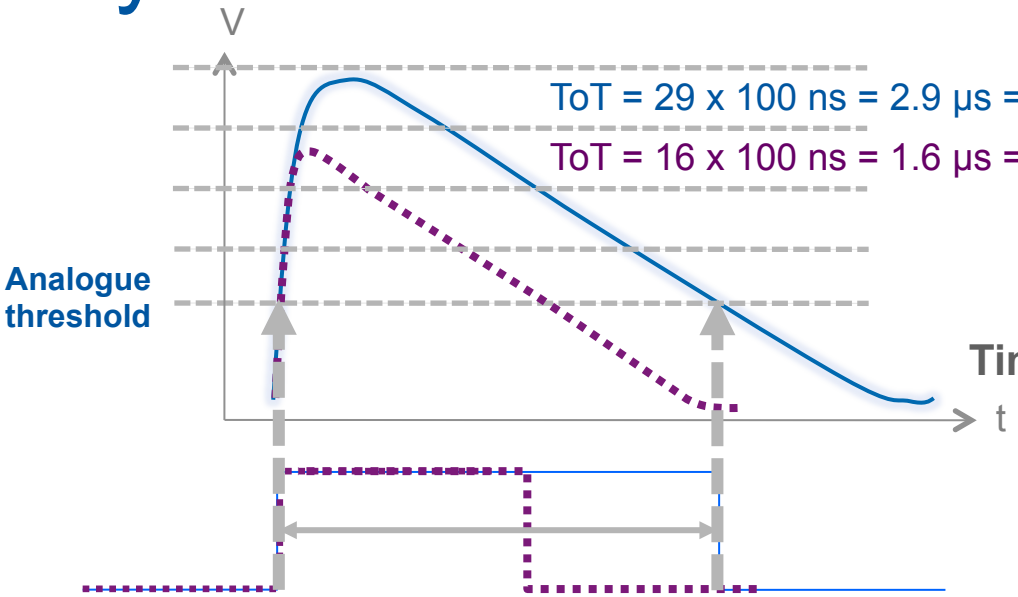
Copper pillar (bump bond)

Transistors and metal connections on the ASIC

Cross-section of the Dosepix detector
Image courtesy of Fraunhofer IZM

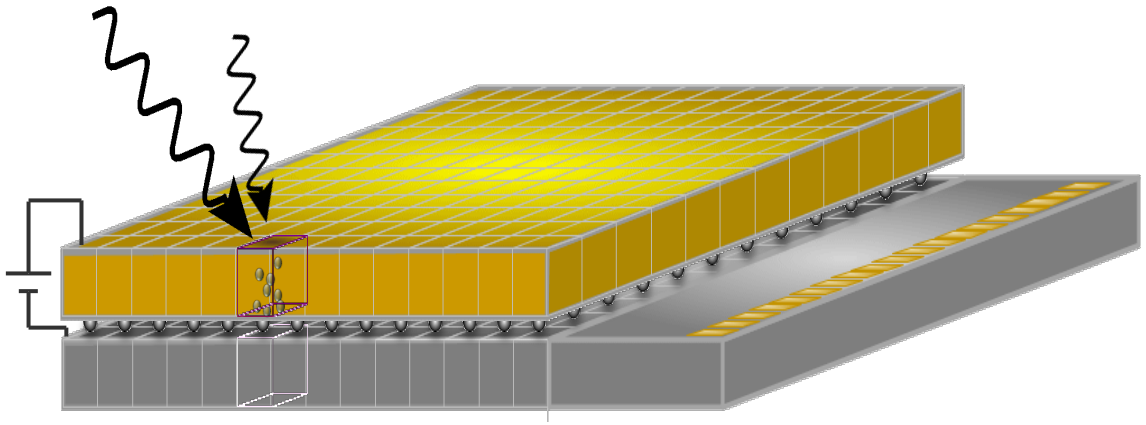
- Appropriate sensor material for application: e.g. Si, GaAs, CdTe
- Optimised electronics for speed, power consumption, functionality, etc.
- 100% fill factor and 100% use of pixel area for circuit implementation
  - Permits single quantum processing

Single Quantum Processing with Hybrid Pixel Detectors

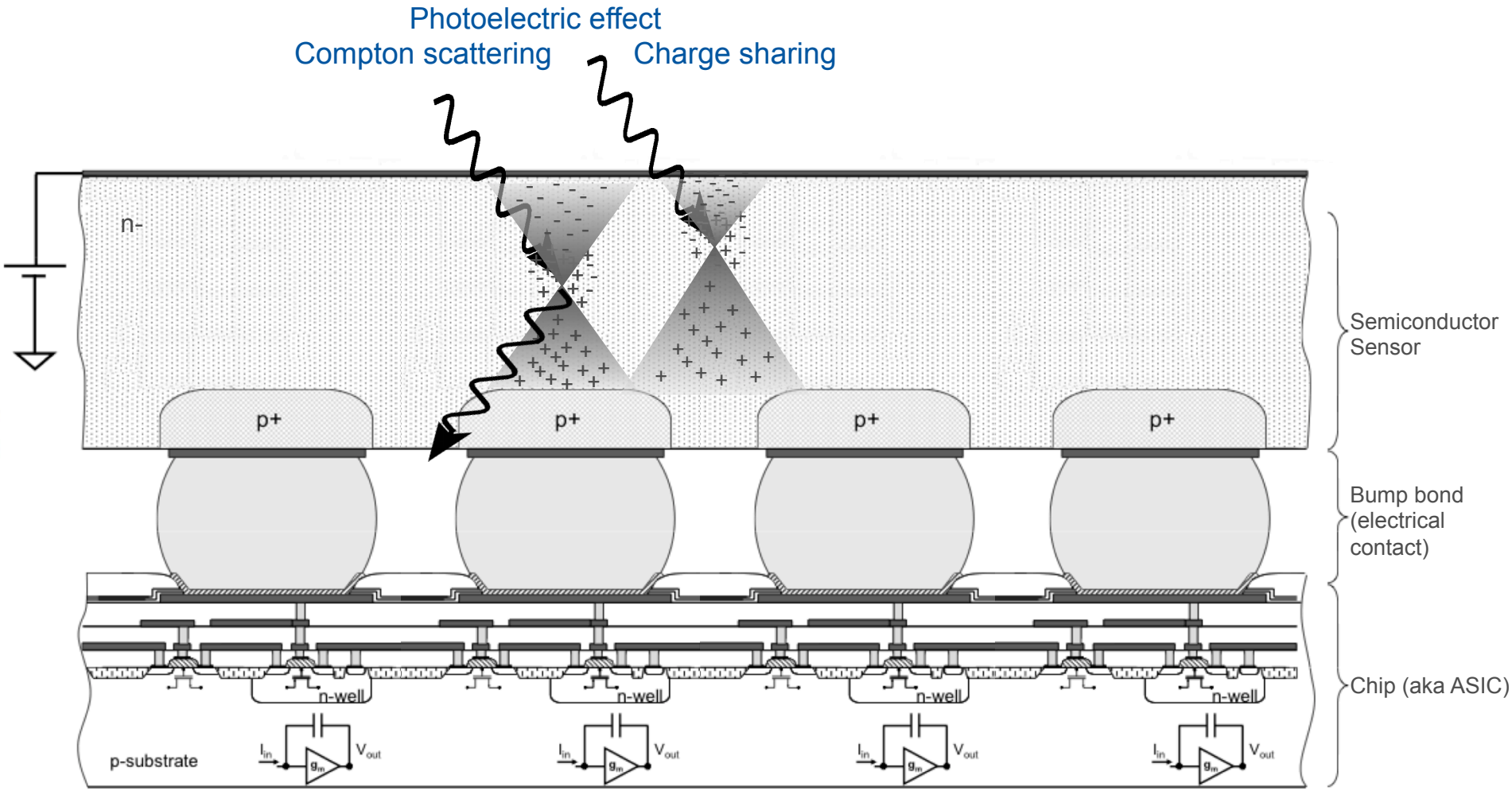


Photon counting E.g. Medipix2, Medipix3

Time over threshold (ToT) E.g. Timepix, (Timepix2), Timepix3, Dosepix



Photon Interaction with Sensor



Dosepix

Main application: dosimetry

Developed by: CERN, U. Erlangen, IBA Dosimetry

ASIC:

- 16x16 pixels=256 parallel spectrometers:
  - 1 global voltage threshold (programmable)
  - 16 energy bin thresholds per pixel (programmable)
  - 12-bit ToT: energy
  - Automatic binning in pixel

Sensor:

- 300 µm Si, segmented into
  - 64 pixels of 55x55 µm^2
  - 192 pixels of 220x220 µm^2

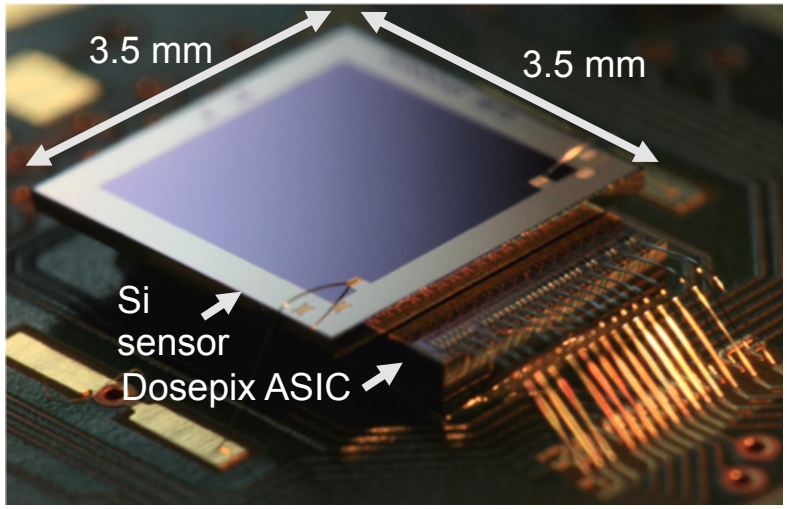
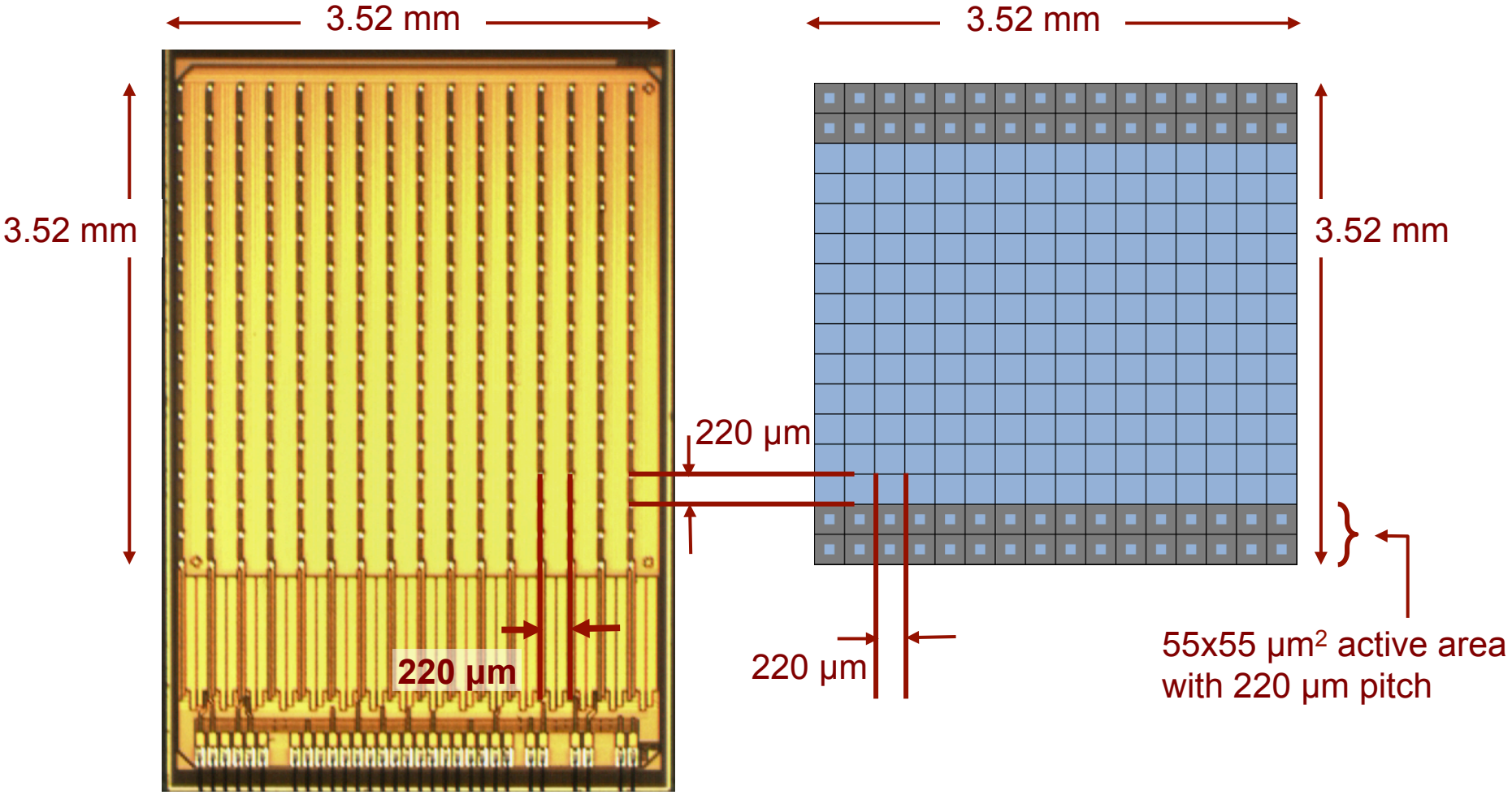


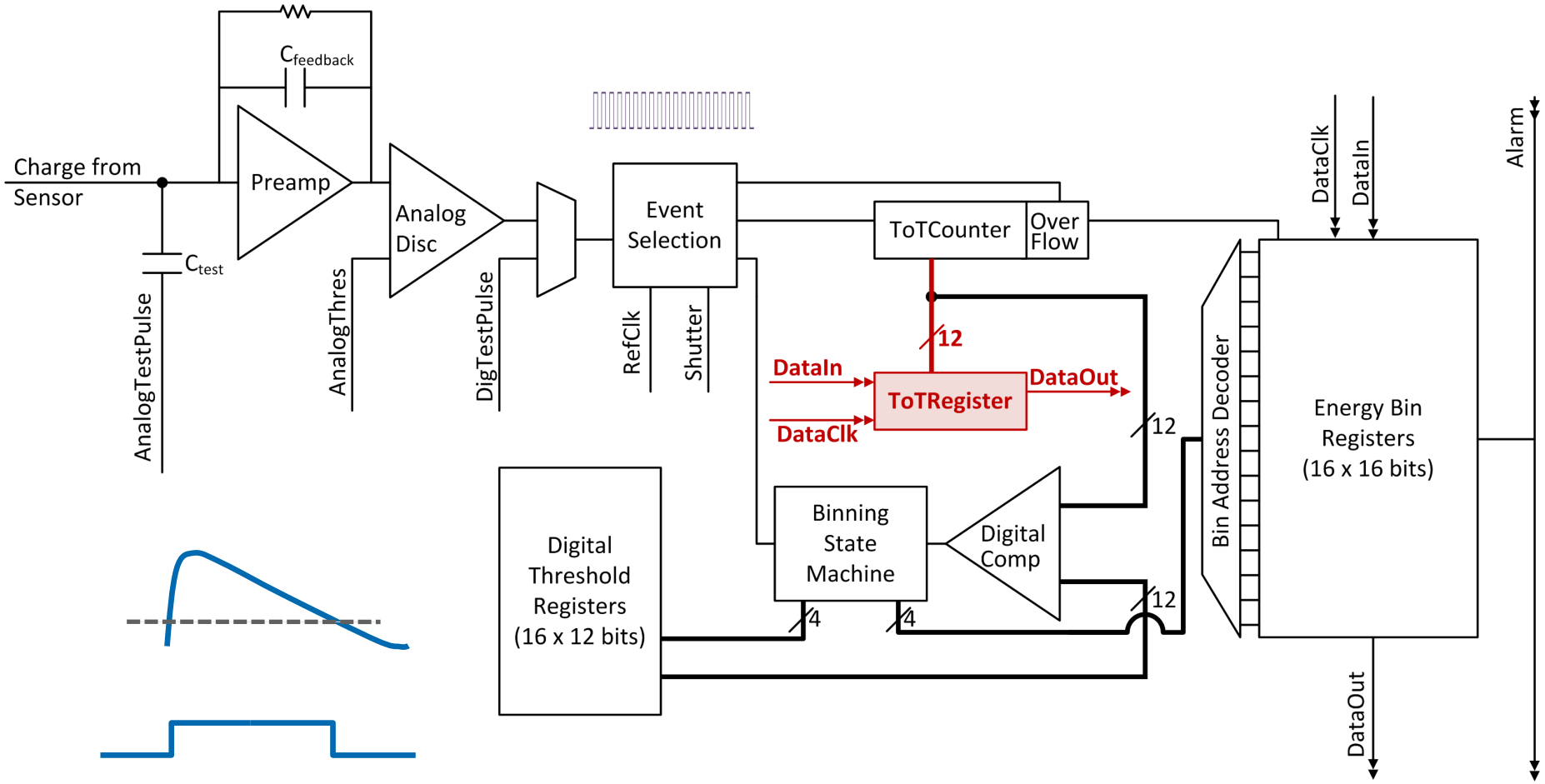
Photo source: T. Gabor

Dosepix ASIC (photo)

Silicon sensor (drawing)



Pixel Block Diagram

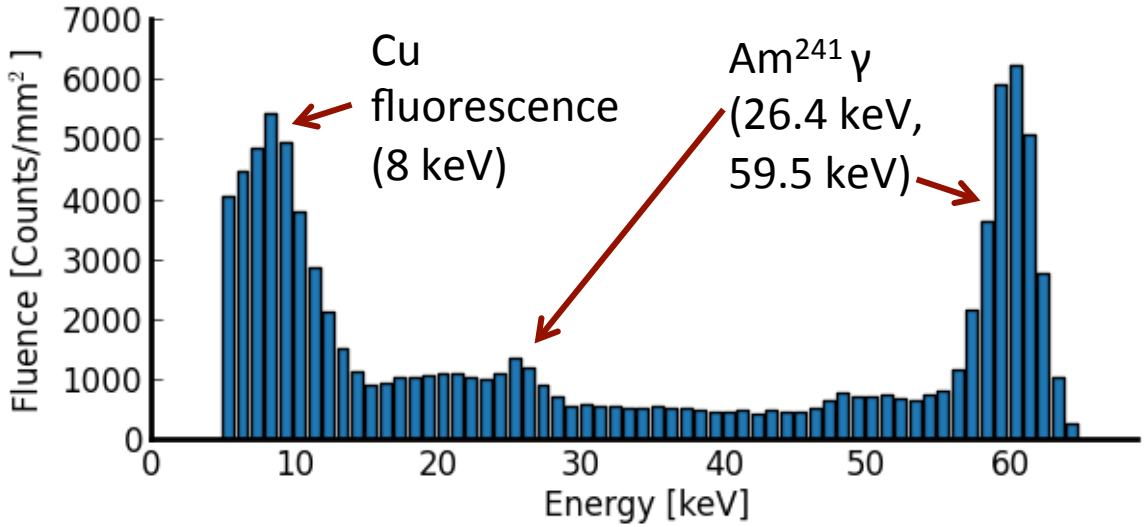


W. Wong, PhD Thesis, 2012

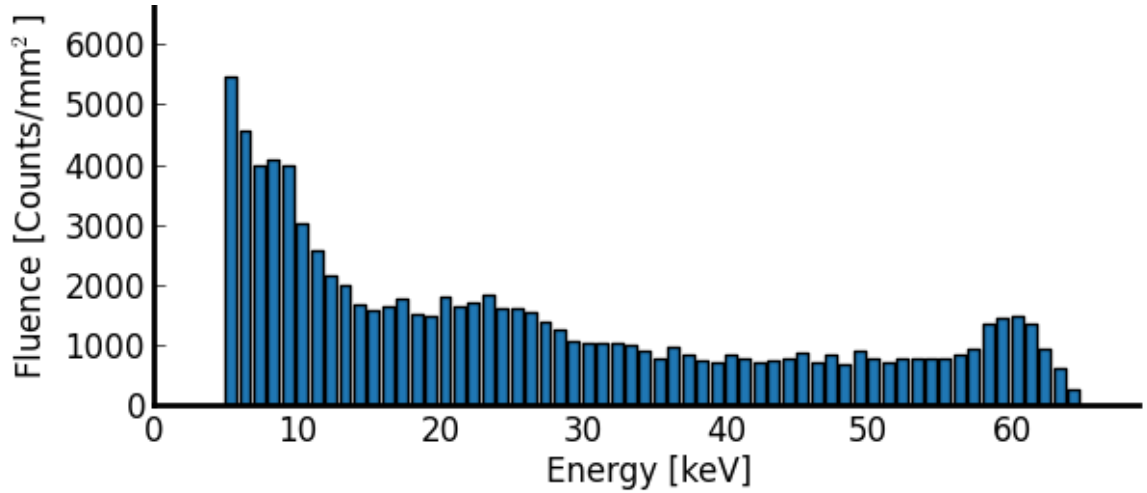
Spectral Response

Spectrum of gamma emissions from an Am^{241} source, filtered to block alphas

220 µm Pixels



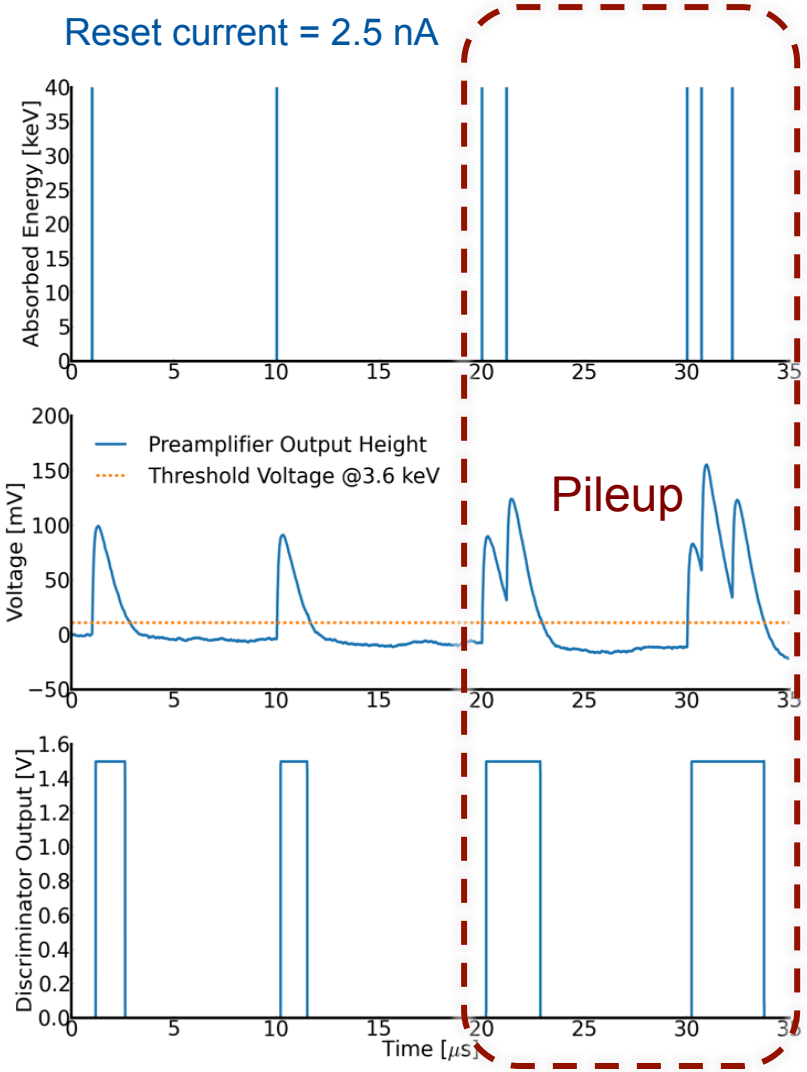
55 µm Pixels



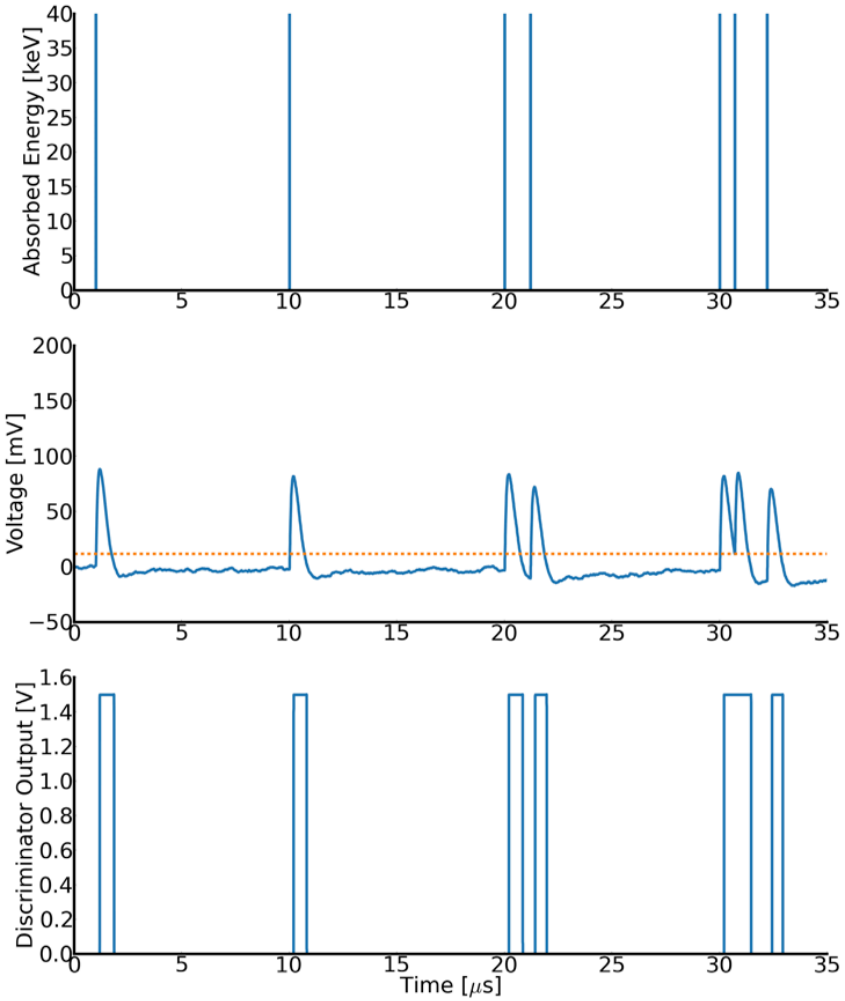
60 bins programmed from 5 – 64 keV (1 keV per bin)

Pileup

Reset current = 2.5 nA



Reset current = 7.4 nA



Characterised Response

Reset Current	Minimum Threshold	Energy Resolution, FWHM (220 µm pixels)			Maximum Linear Count Rate (220 µm pixels)	
		@ 8.5 keV	@ 20 keV	@ 40 keV	@ 30 keV	@ 40 keV
2.6 nA	3.54 keV	1.43 keV (16.8%)	2.81 keV (14%)	3.18 keV (8%)	1.69 Mcounts/s/mm^2	1.67* Mcounts/s/mm^2
7.4 nA	4.27 keV	2.17 keV (25.5%)	2.91 keV (14.5%)	3.79 keV (9.5%)	4.11 Mcounts/s/mm^2	3.57 Mcounts/s/mm^2

*Note: Pileup starts well below the maximum linear count rate (at approx. 10^5 counts/s/mm^2) and will distort spectrum measurements.

E. Frojdh et al., NIMA 2015

Power Consumption = 15 mW to process 10^5 counts/s/mm^2 under nominal chip settings

RQR Measurement Setup

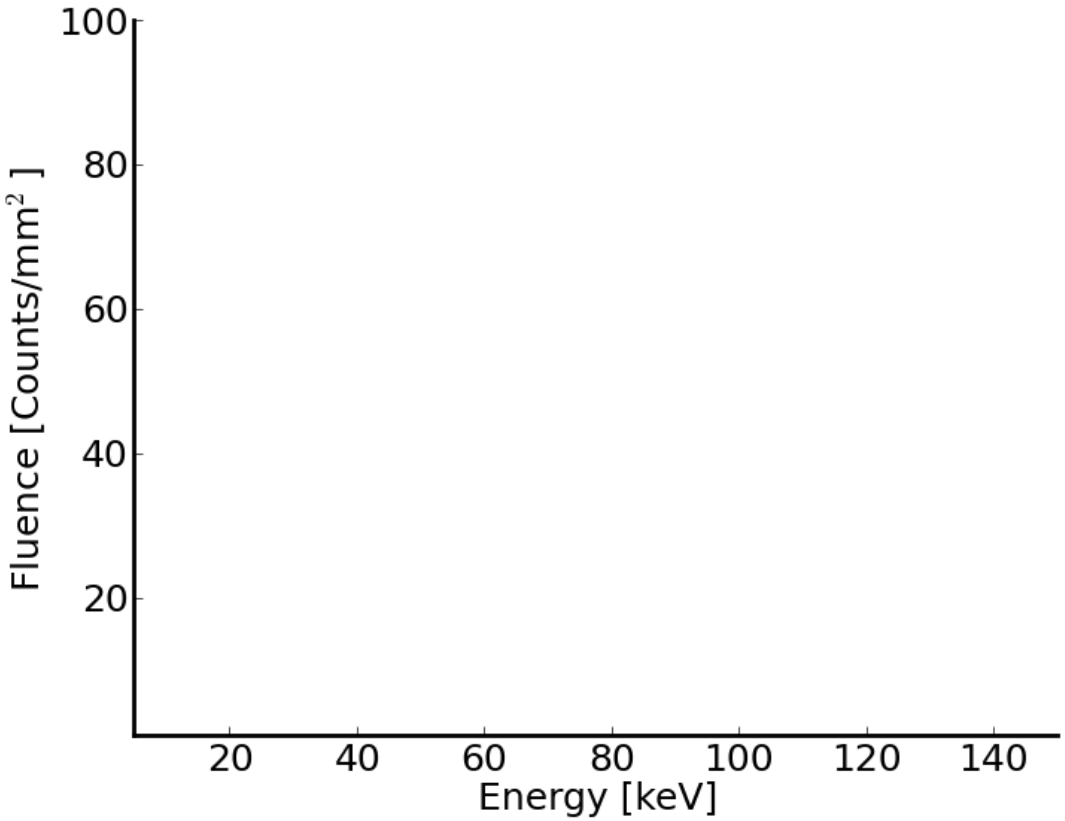
Toshiba KXO-80G X-ray generator with a tungsten anode

Dosepix location, perpendicular to and centred on the beam

RX Toshiba KX0-80G at Institute for Radiation Physics, University Hospital of Vaud

Background Measurement

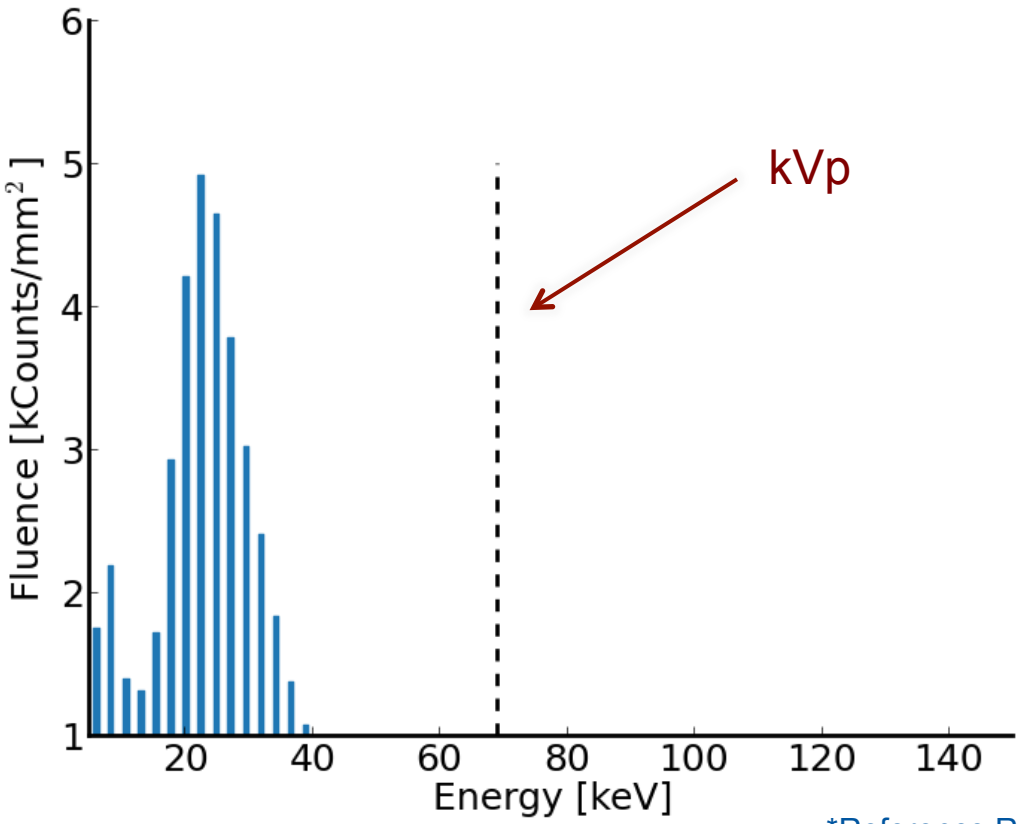
No beam, no hits (“noise free”)



60 bins
programmed from
5 – 150 keV

Primary Beam Spectrum
RQR-5*, 10 mA @ 2s

1 “frame” of data in the 220 µm pixels

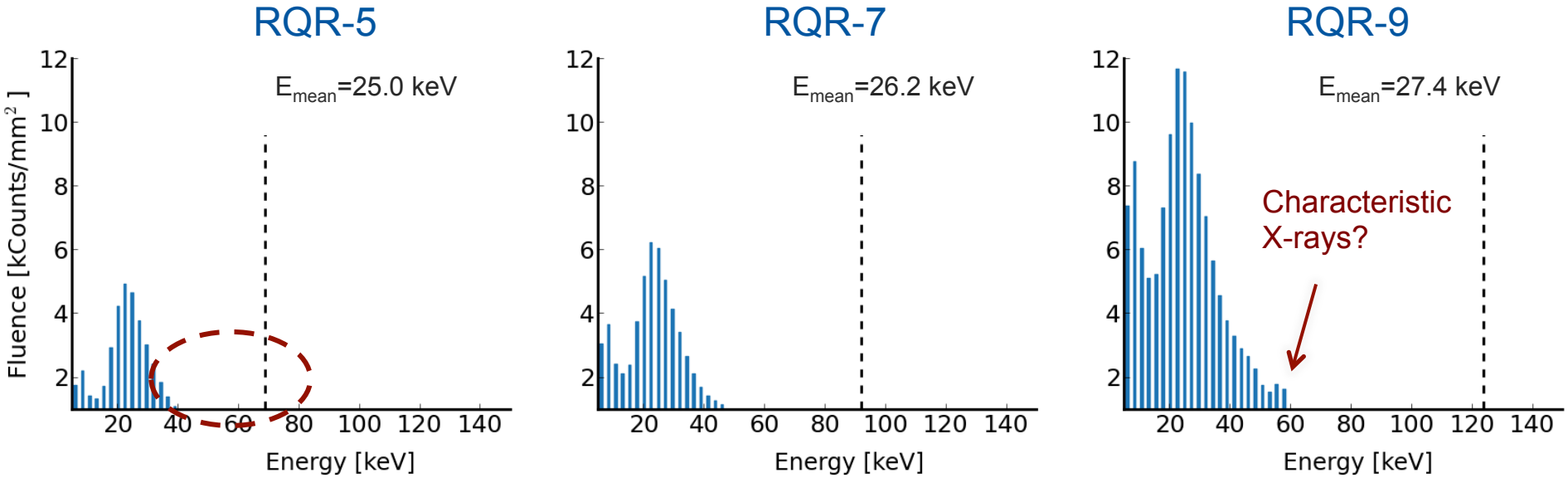


60 bins
programmed from
5 – 150 keV

*Reference Radiation Qualities, IEC 61267

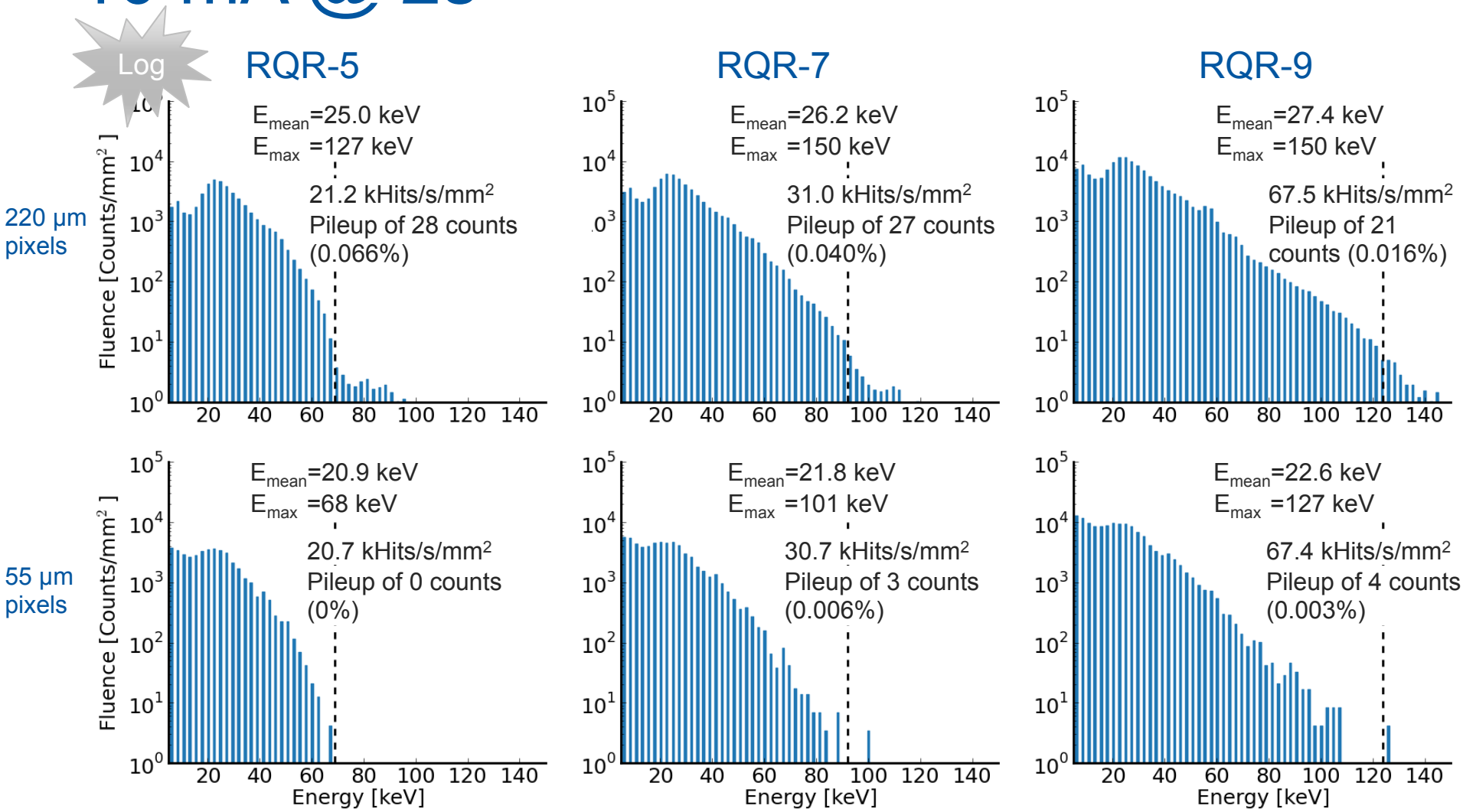
Primary Beam Spectra
10 mA @ 2s

1 “frame” of data in the 220 μm pixels

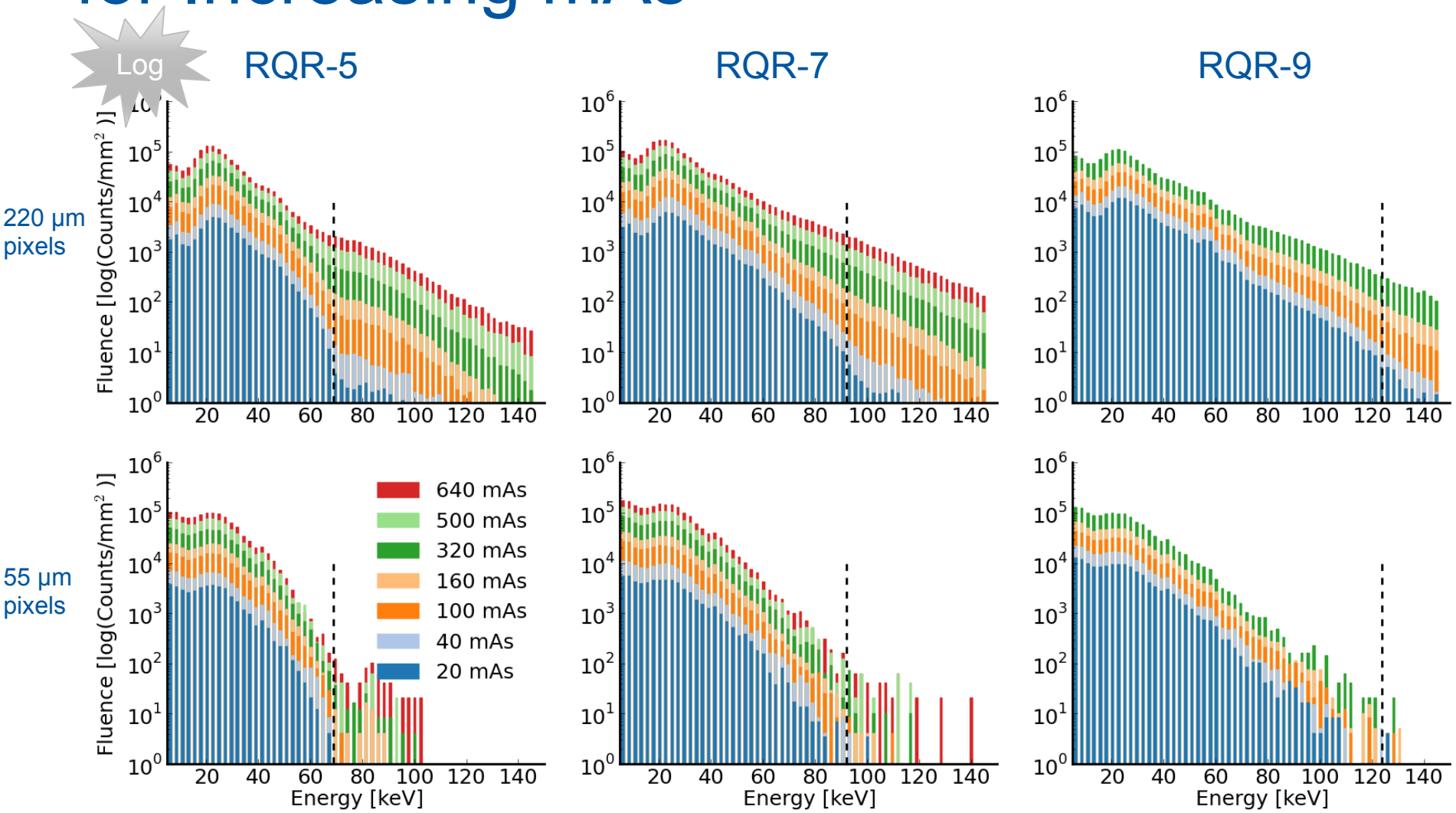


Primary Beam Spectra
10 mA @ 2s

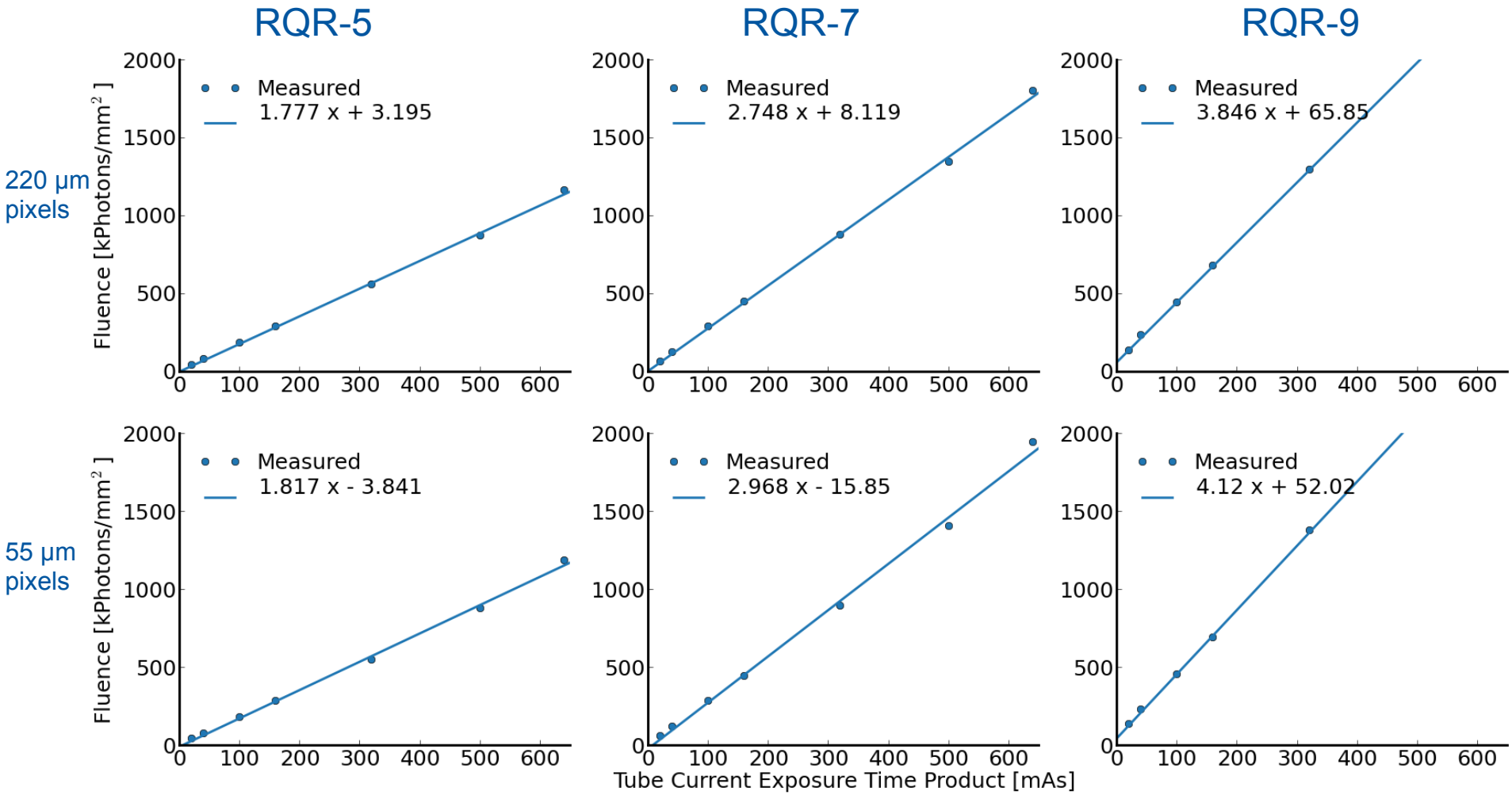
Log



Primary Beam Spectra for Increasing mAs



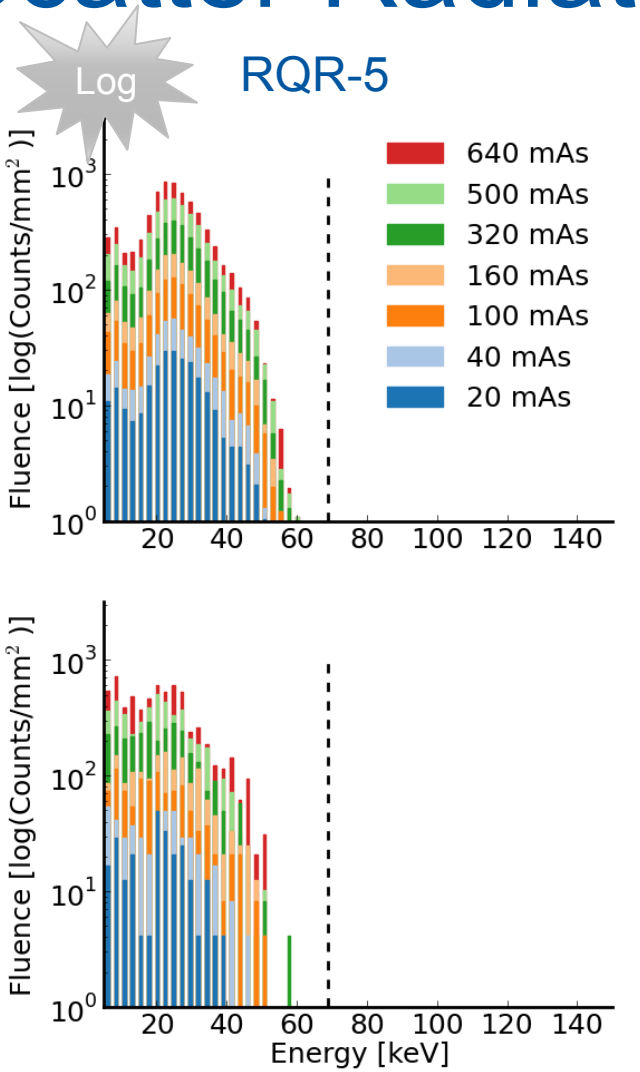
Primary Beam Fluence for Increasing mAs

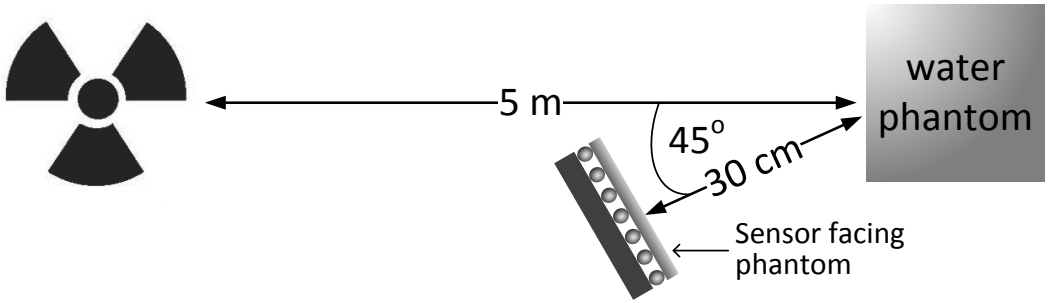


Scatter Radiation Measurements

220 µm Pixels

55 µm Pixels



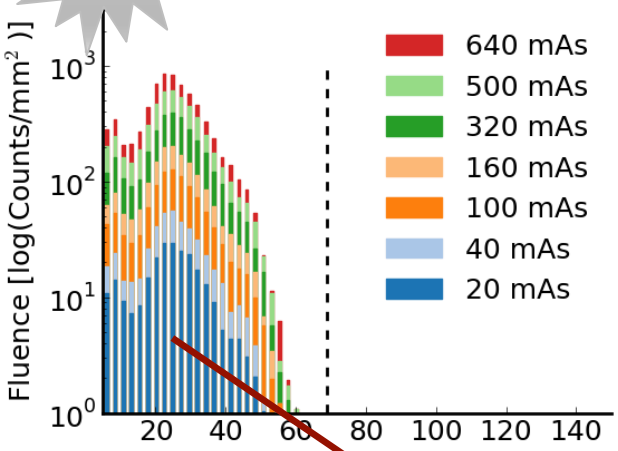


Scatter Radiation Measurements

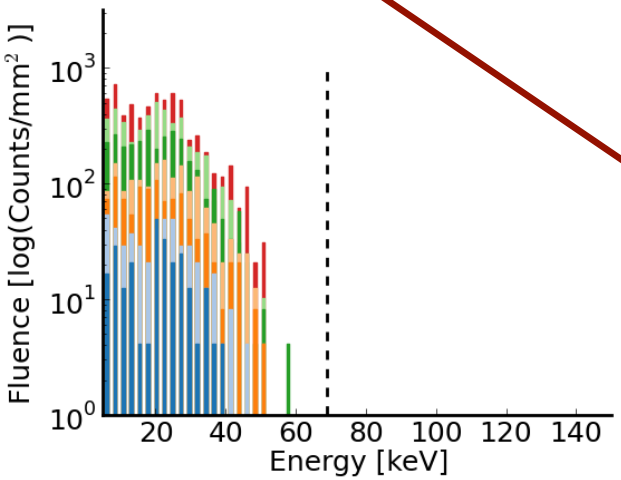
Log

RQR-5

220 µm Pixels



55 µm Pixels

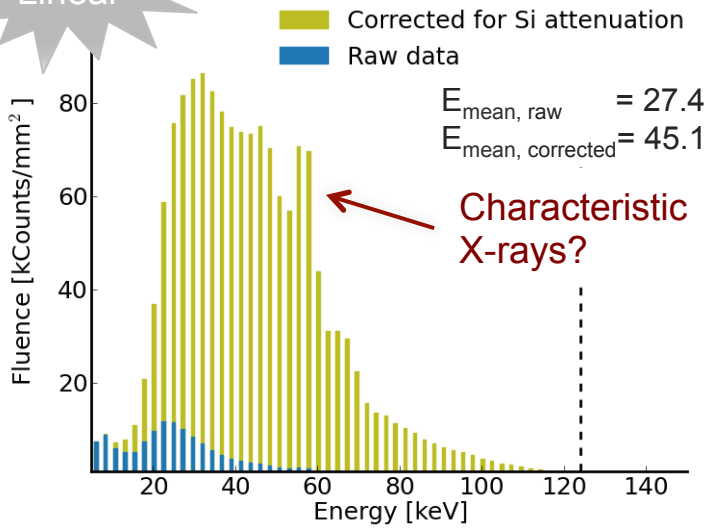


On-going work:

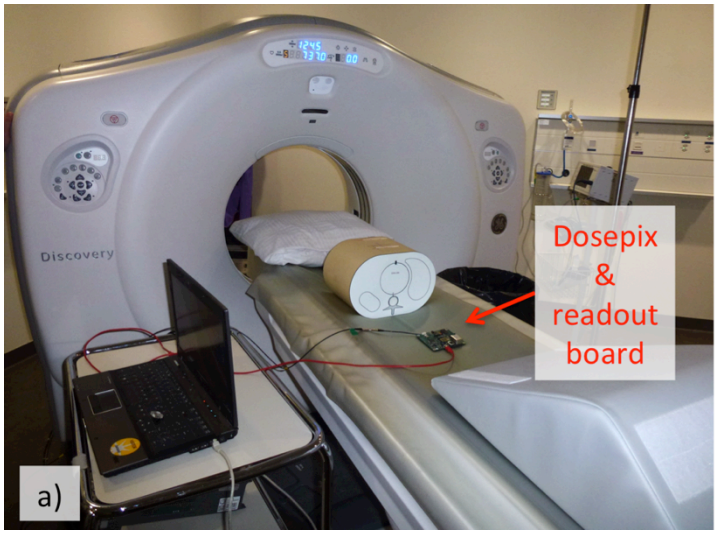
1) Correct for Si absorption efficiency
2) Develop spectrum reconstruction
   - Study impact of charge sharing, Compton Scattering, etc.
3) Calculate air kerma
4) Characterise scatter radiation in CT scan

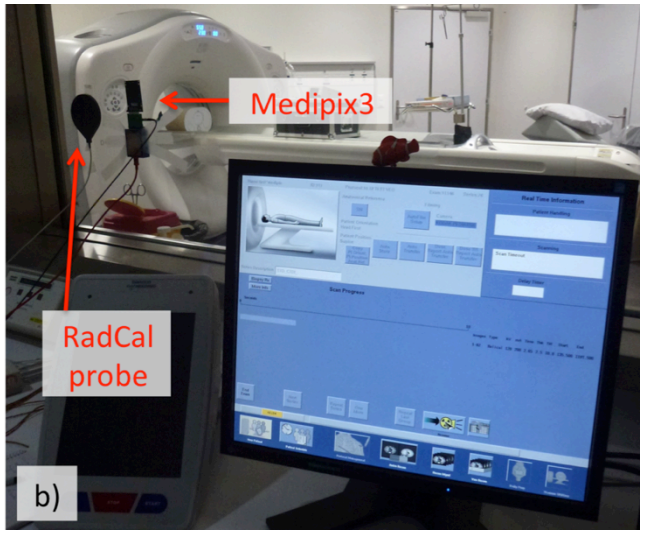
Linear

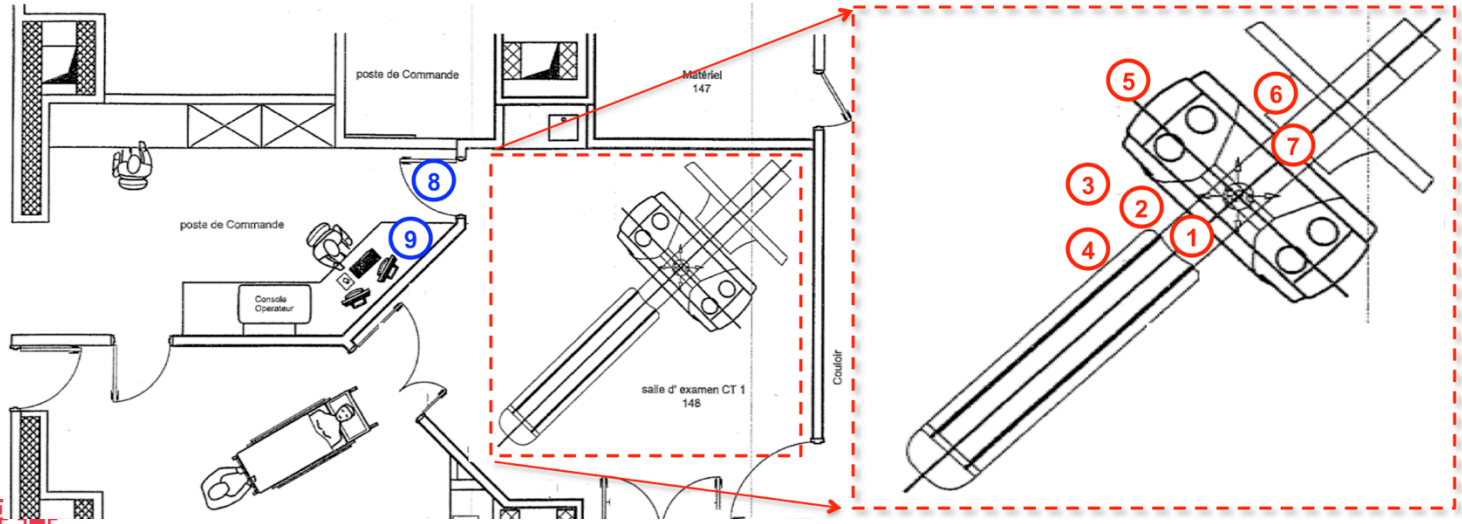
RQR-9 Primary Beam in the 220 µm pixels 20 mAs



Scatter Radiation in CT Scan

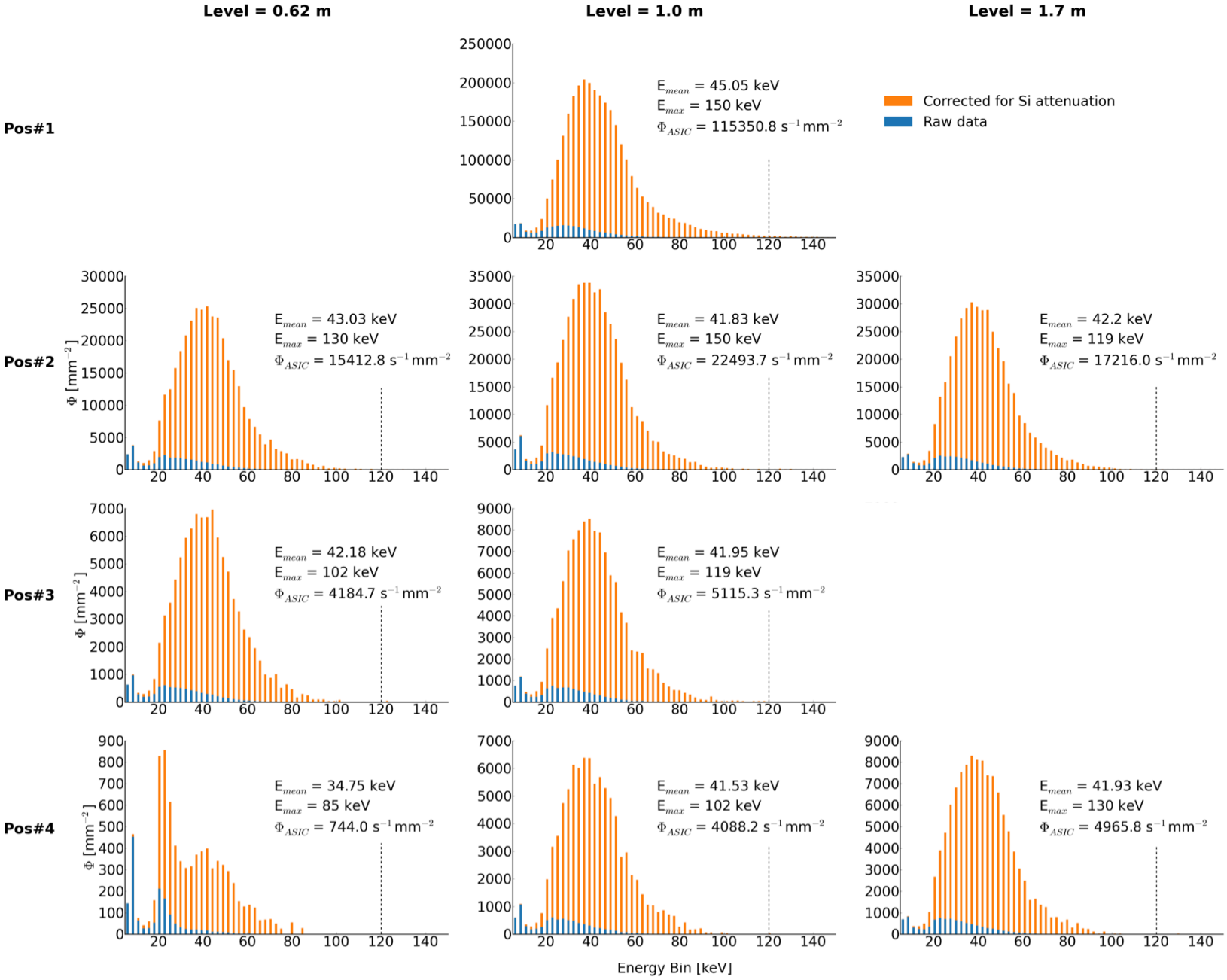






Patient imaging facility, University Hospital of Vaud

Scatter radiation spectra during scan of a QRM anthropomorphic thorax phantom:120 kVp, 200 mA



Summary

- Hybrid pixel detectors permit choice of appropriate sensor material
- Absorbed energy can be measured by:
  - Pulse Height
  - Time over Threshold (ToT)
- Our detectors measure fluence at a given energy
  - Dosimetric endpoints can be calculated offline with energy dependent conversion factors
  - Raw fluence data remains available for future calculations or definitions