DECTRIS®

detecting the future

PILATUS3 R CdTe HPC detectors for high-energy laboratory applications

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ACA Meeting 2016, General Interest Session, 2016-07-24

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Agenda

1. Hybrid Photon Counting (HPC) Technology
2. PILATUS3 R CdTe detectors
3. Charge density studies with PILATUS3 R CdTe

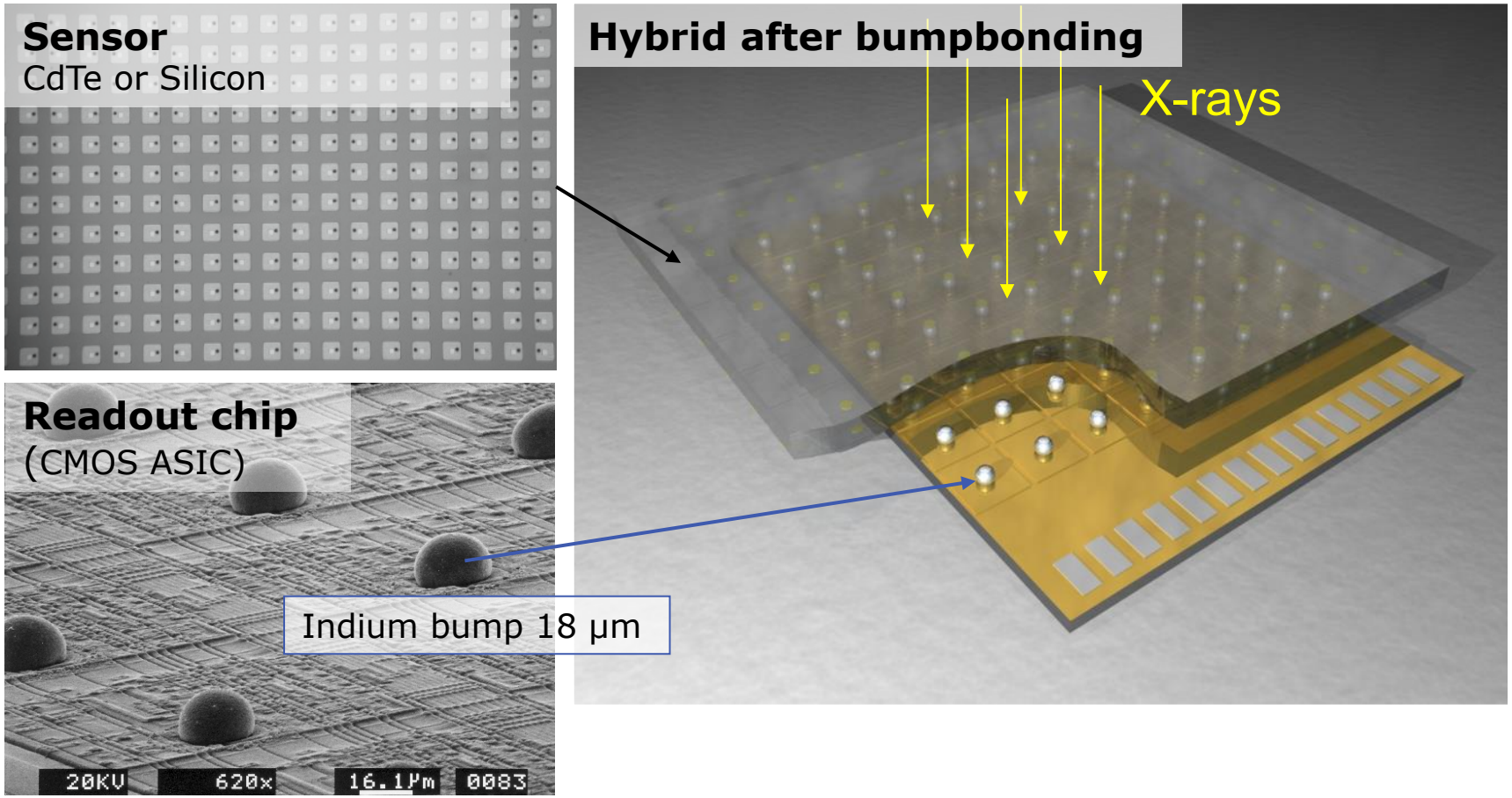
What does HPC mean?

HPC

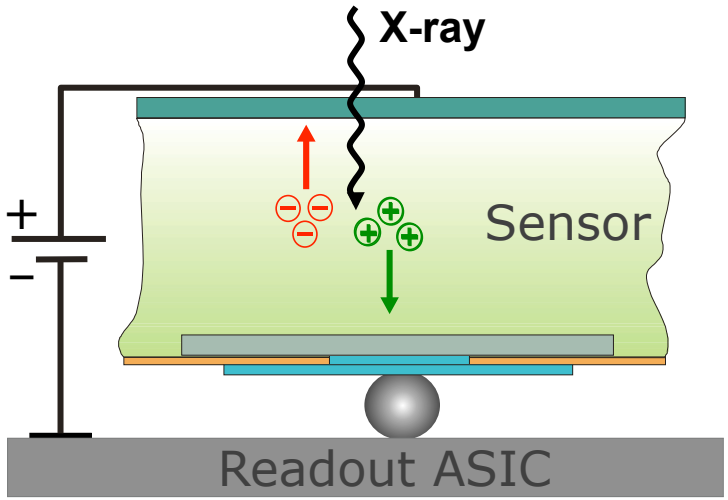
= Hybrid Photon Counting

= hybrid pixel technology + single-photon counting

Hybrid pixel = sensor pixel + readout pixel



Hybrid Photon Counting: direct conversion and photon counting



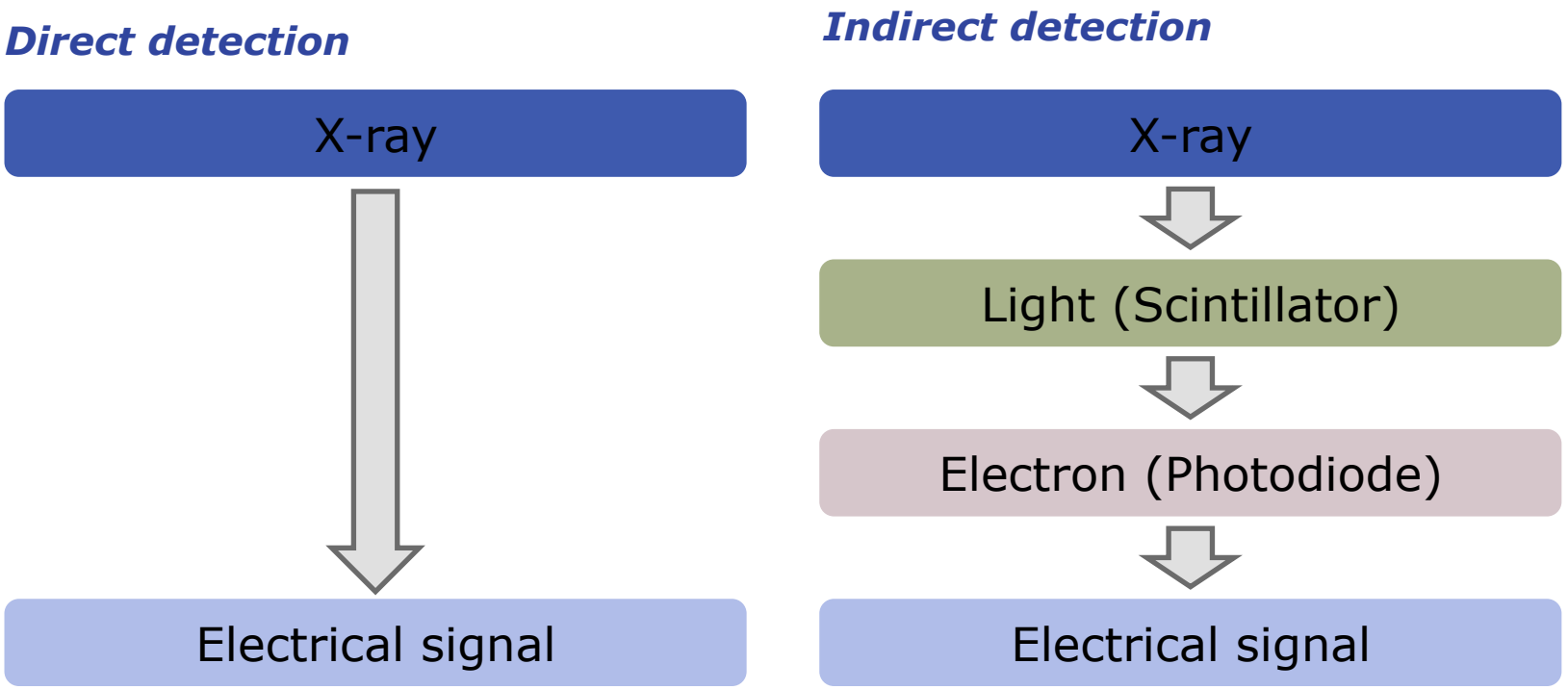
Sensor pixel

- *Absorption of X-ray photons*
- ***Direct conversion** to charge*
- *Charge is captured by electric field*
- *=> **Sharp point spread***

Readout pixel

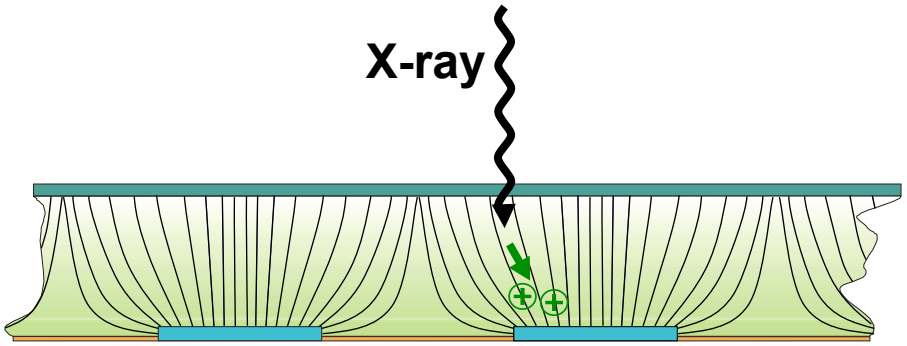
- *Detection of charge*
- *Digital **counting** of absorbed X-ray **photon***
- *=> **No dark signal***
- *=> **No readout noise***
- *=> **No reset noise***
- *=> **Fast readout***
- *=> **Highest dynamic range***

Direct vs. indirect detection



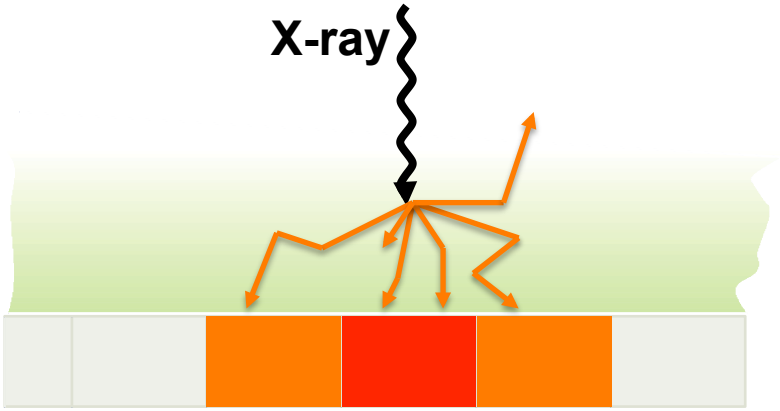
Direct vs. indirect detection

Direct detection



- *X-rays directly converted to charge*
  - *single conversion step **maximizes sensitivity and accuracy***
- *Charge is captured in an electric field, signal spread is minimized => **low point spread function***

Indirect detection

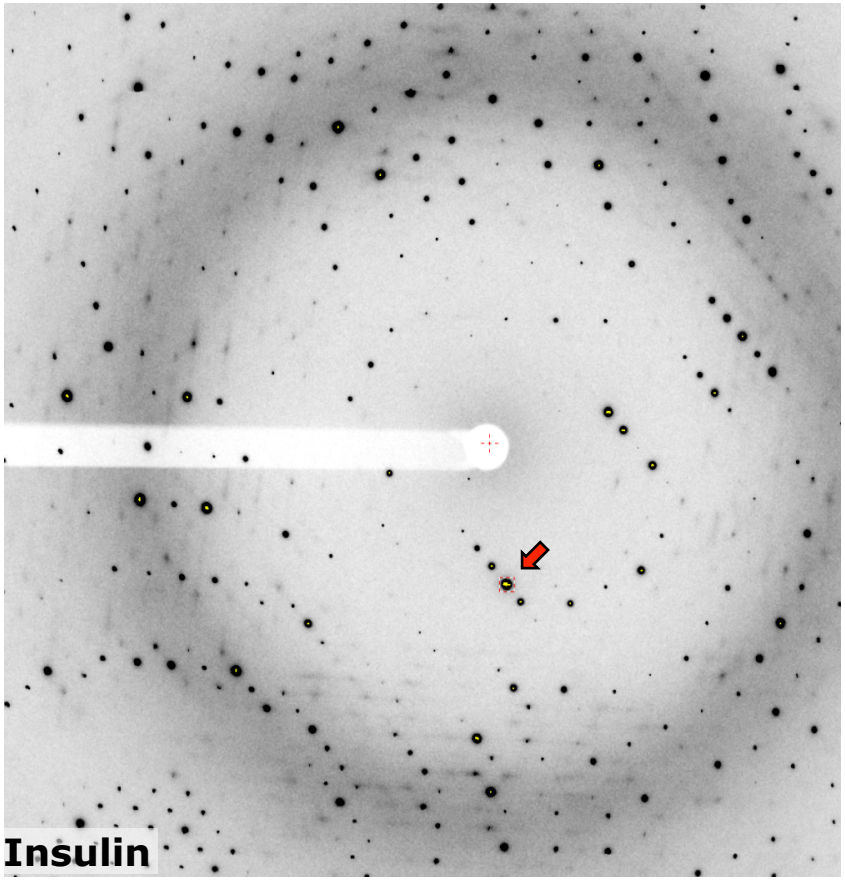


- *X-rays converted to light*
- *Light is scattered in the scintillator*
  - *Signal is spread over several pixels => **large point spread function***
  - *Light is partially lost => **lowers sensitivity***

Dynamic range and point spread

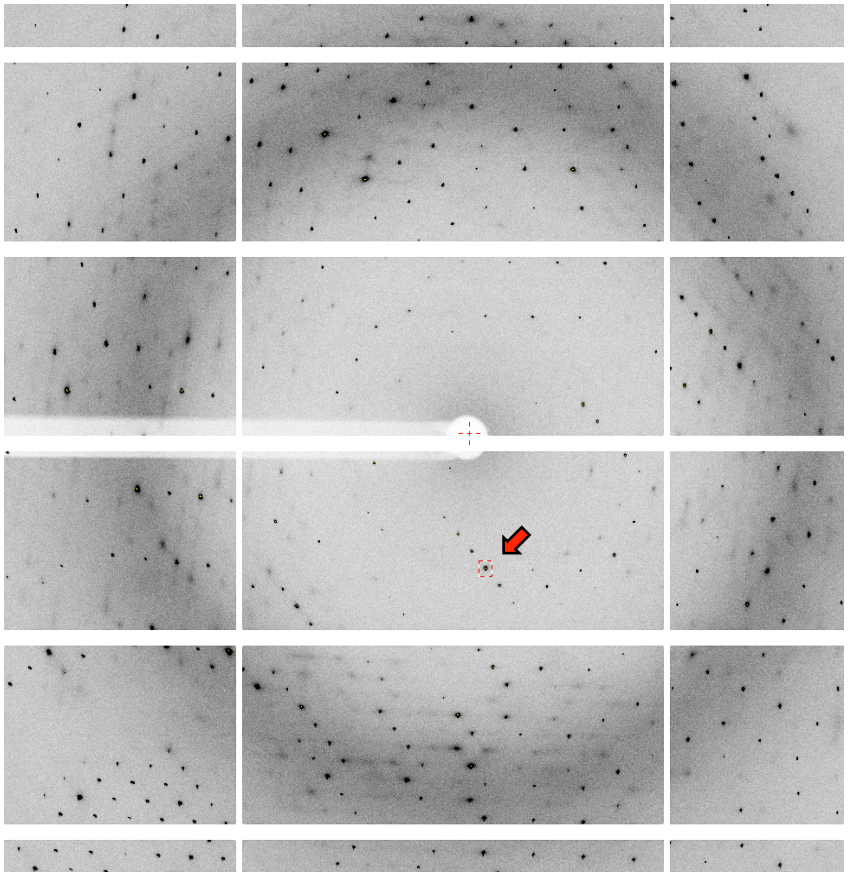
CCD

16 bit (65 535 ADU)



PILATUS

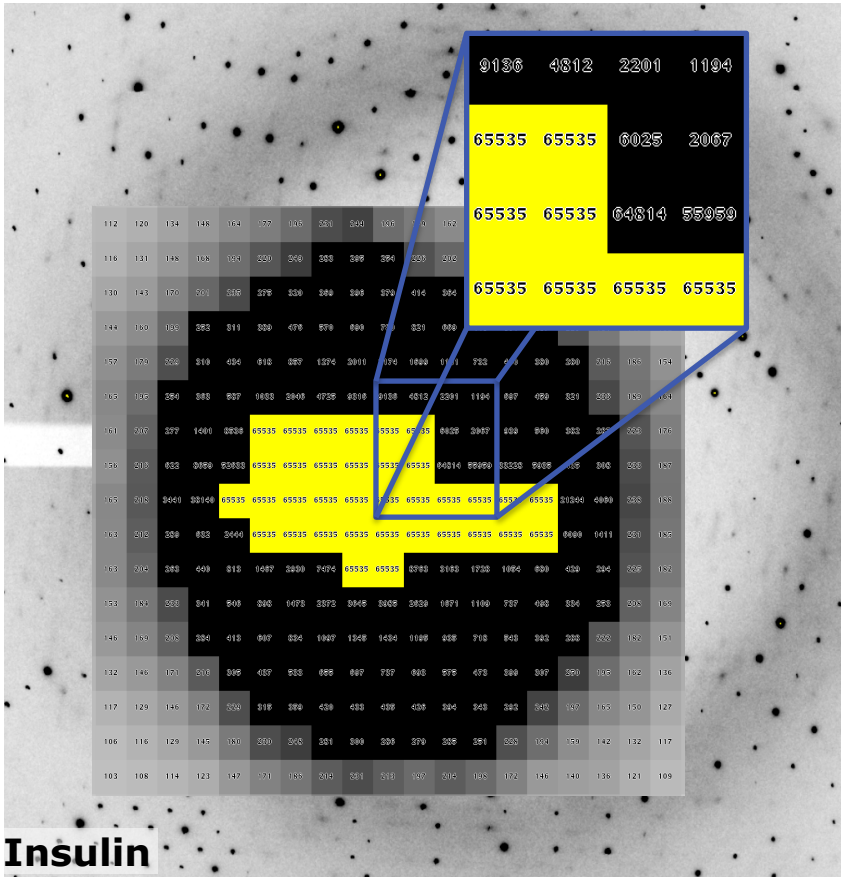
20 bit (1 048 575 counts)



Dynamic range and point spread

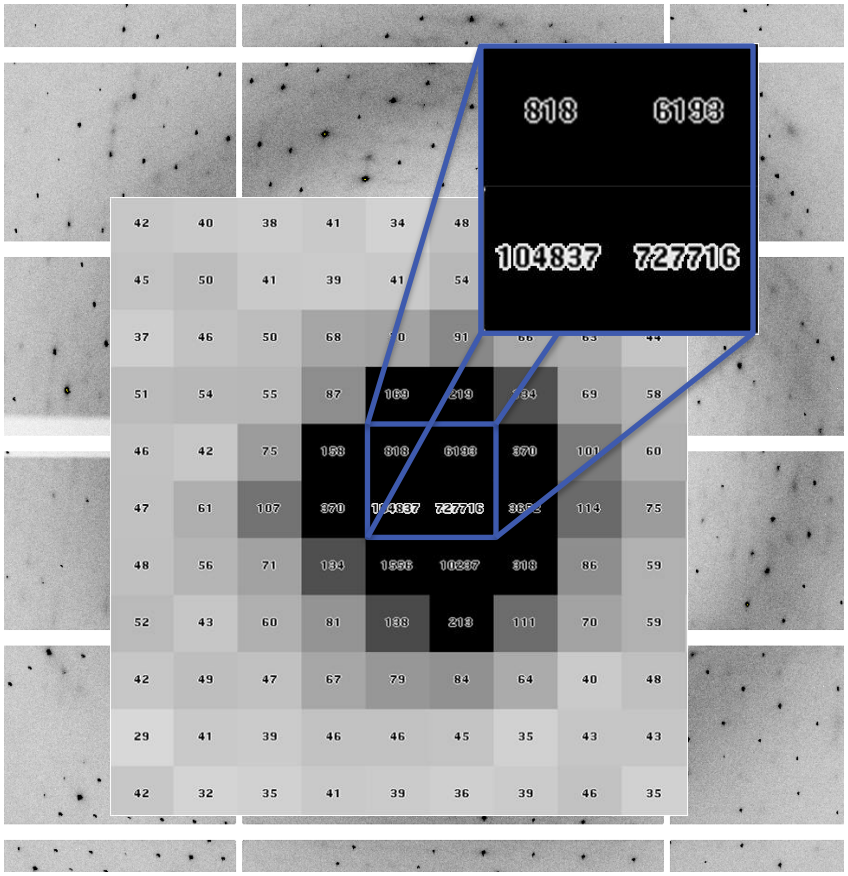
CCD

16 bit (65 535 ADU)

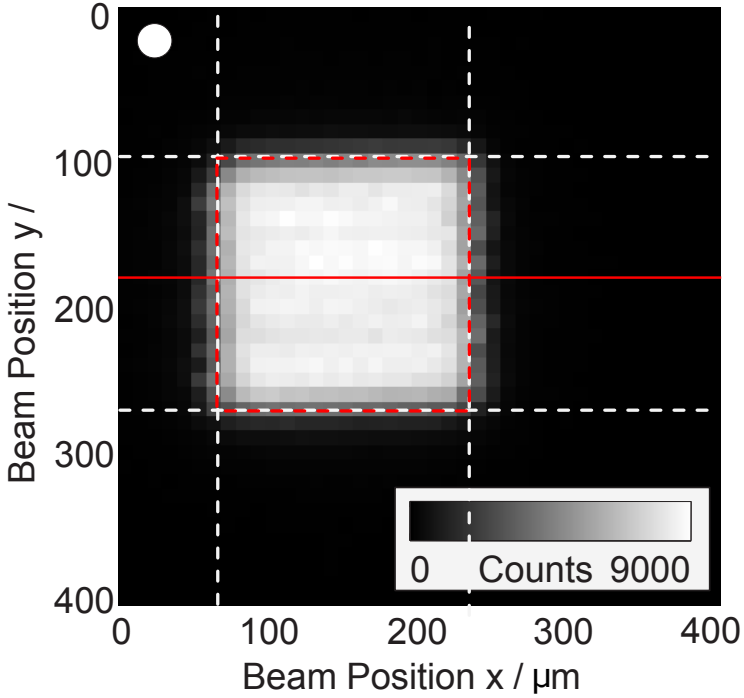


PILATUS

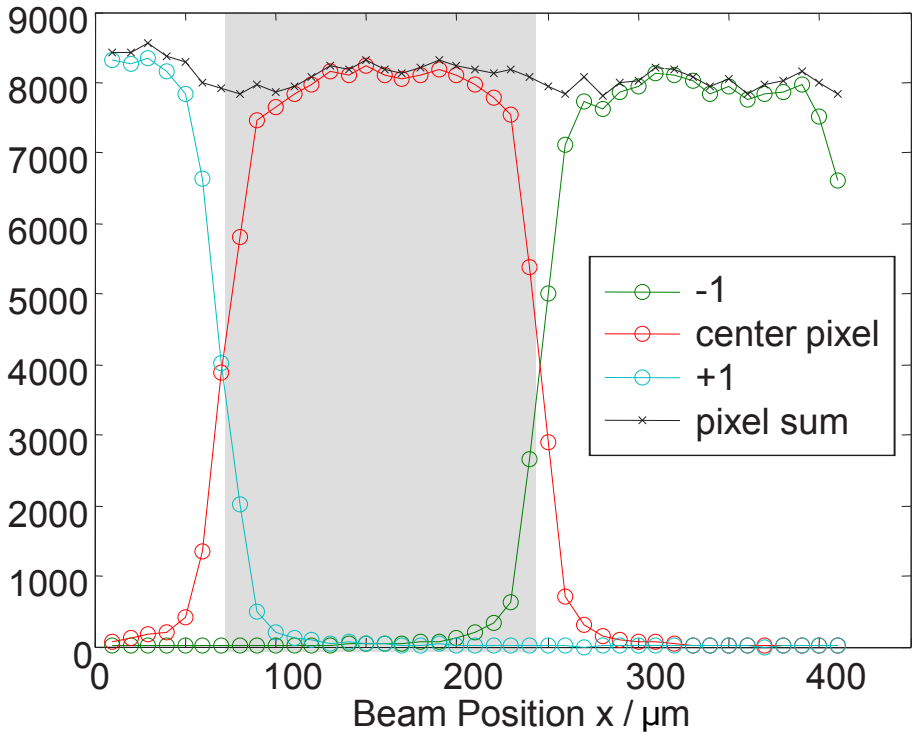
20 bit (1 048 575 counts)



Direct conversion for high spatial resolution

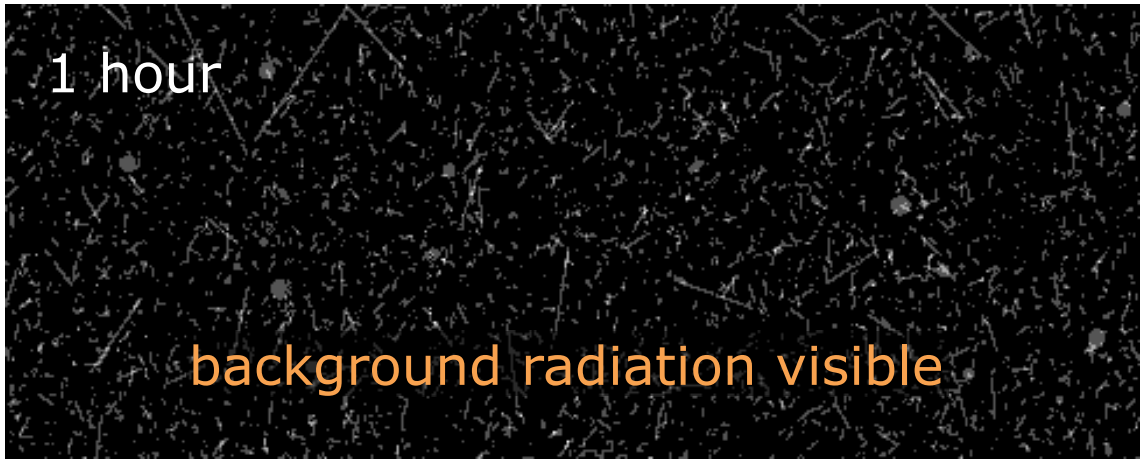


20 µm pencil beam, 10 µm rastering



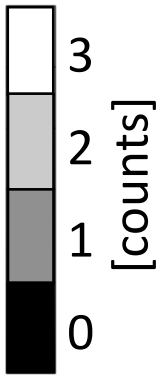
Noise-free detection





Dark images show

- **no readout noise**
- **no detector dark noise**

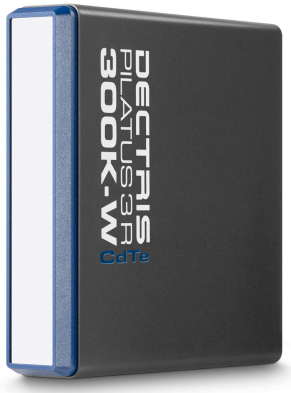


Darkfields from PILATUS 100K detector

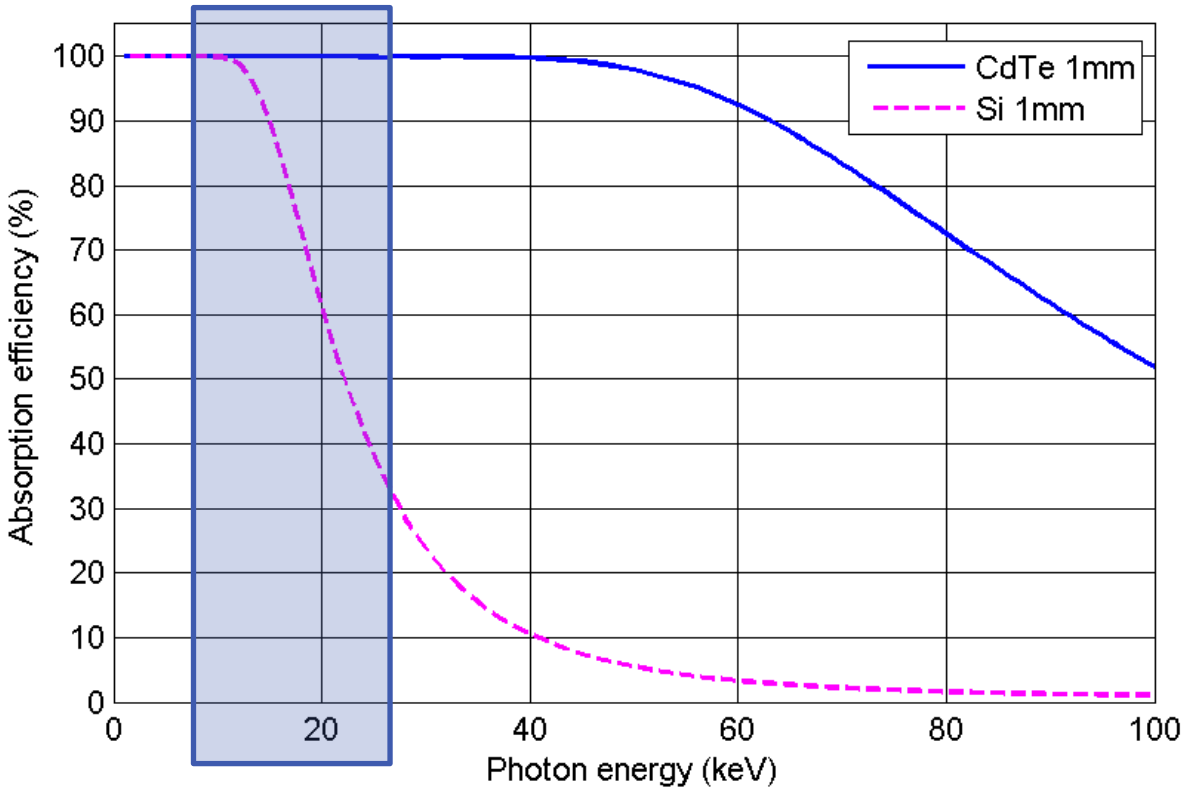
PILATUS3 R CdTe 300K and 300K-W



PILATUS3 R CdTe - key specifications

PILATUS3 R CdTe	300K	300K-W
		
Sensitive Area [mm²]	83.8 x 106.5	253.7 x 33.5
Pixel size [µm]	172	
No. of pixels (hor. x vert.)	487 x 619	1475 x 195
Maximum frame rate	20 Hz	
Read-out time	7 ms	

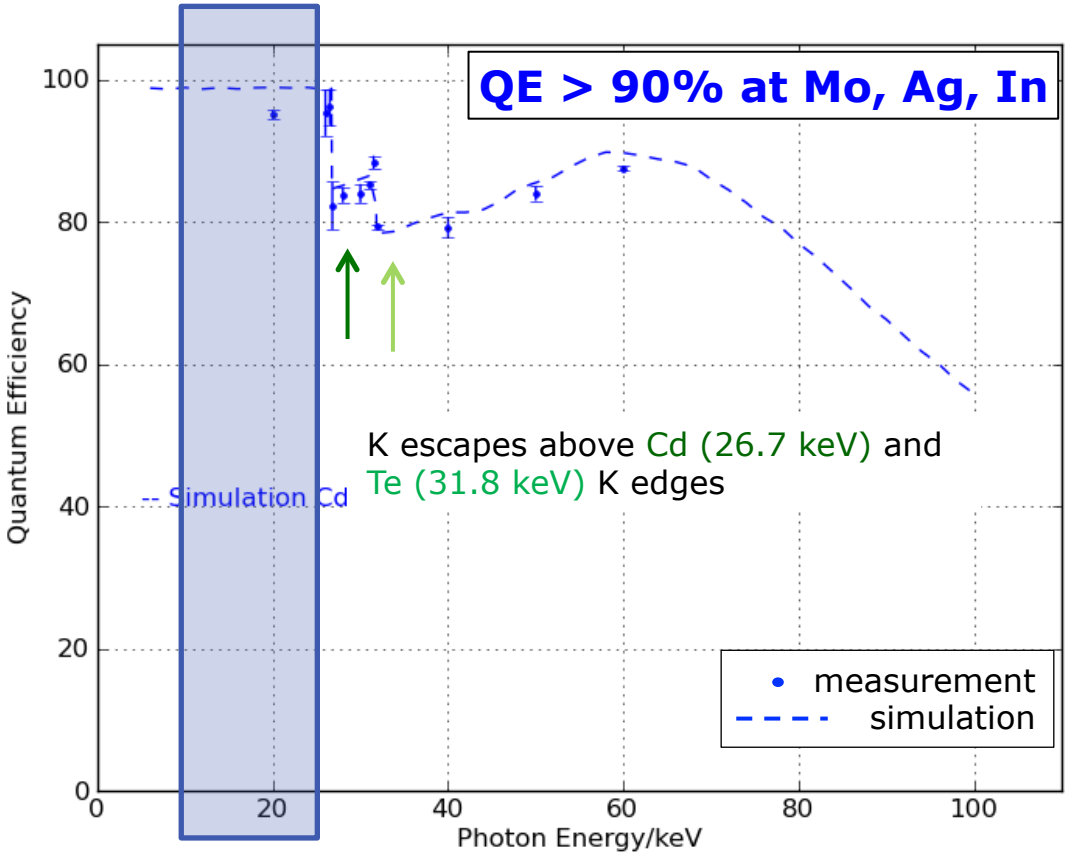
Absorption Efficiency CdTe vs Silicon



Quantum efficiency > 90% for Mo-, Ag- and In-Kα
thanks to

- *high absorption efficiency*
- *direct detection*
- *noise-free single-photon counting*

Quantum Efficiency measured and simulated



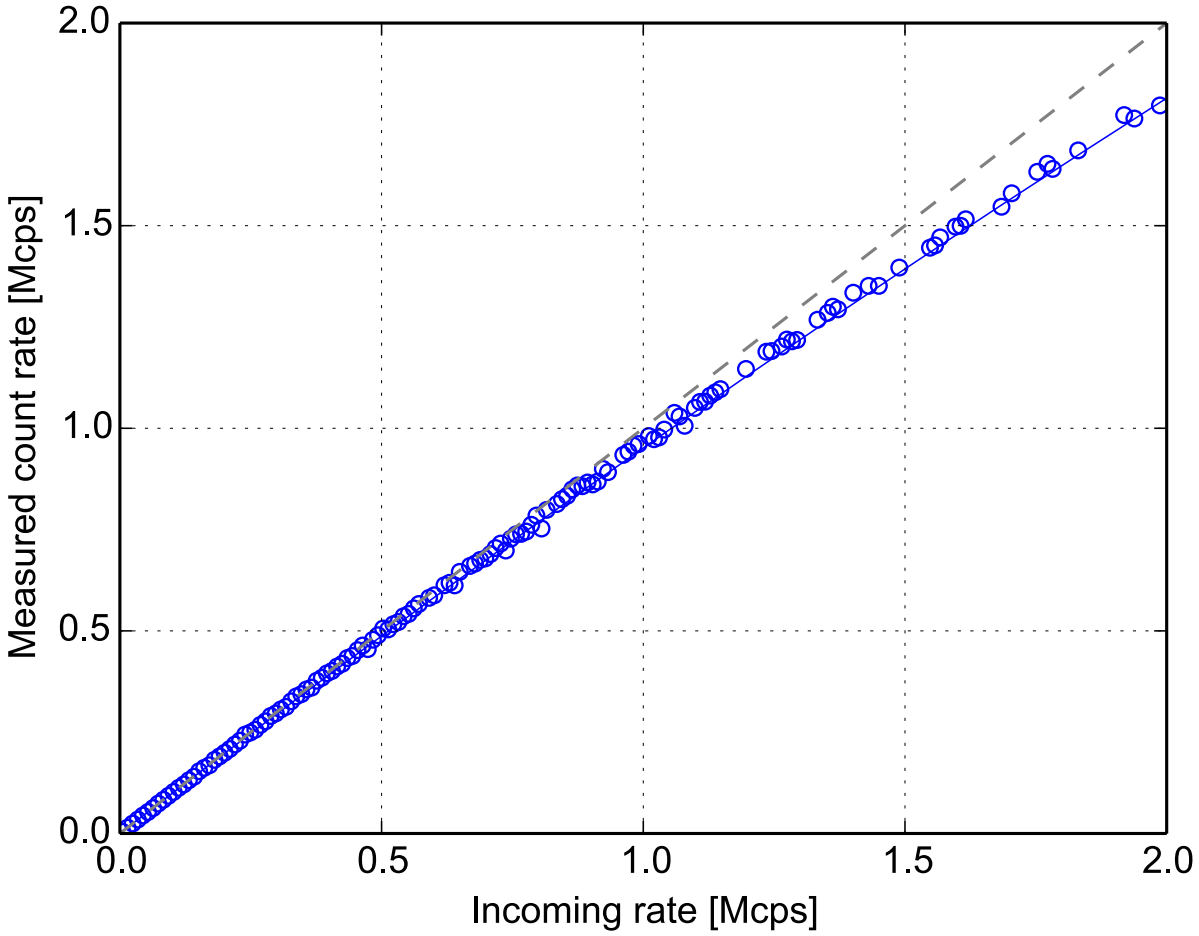
QE measured in cooperation with PTB at BAM beamline at BESSY II

- *photon energy 20 to 60 keV*
- *low flux of max. 50 kcps*
- E_{th} = *50% photon energy*

Simulation using HORUS

scripts provided by D. Pennicard (DESY).
D. Pennicard and H. Graafsma, *JINST* 6, P06007 (2011)

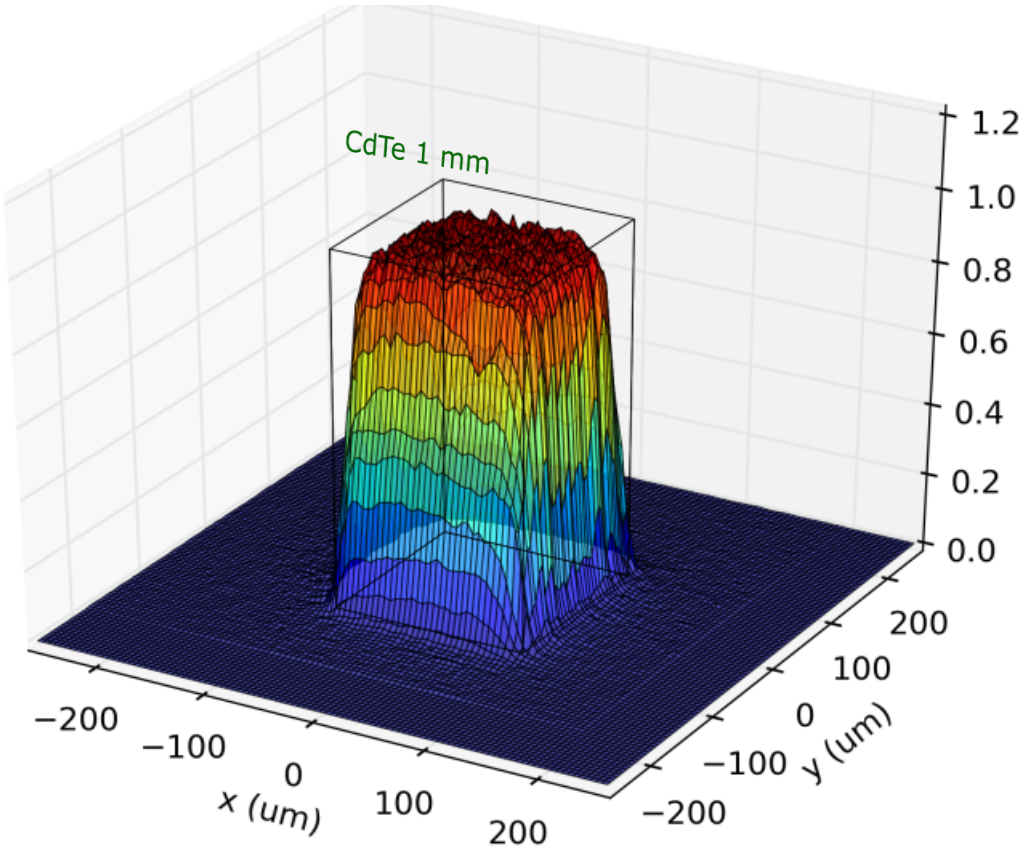
Count rate performance

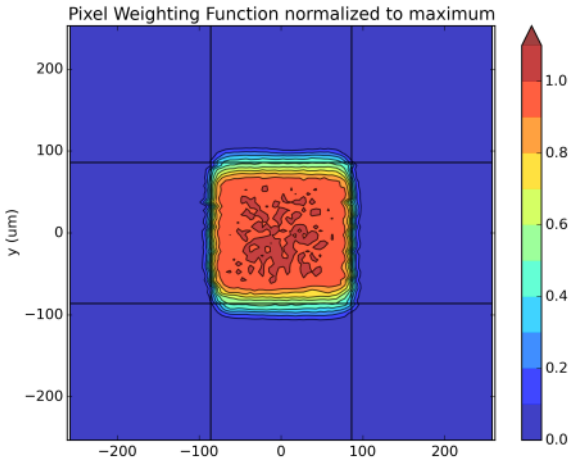


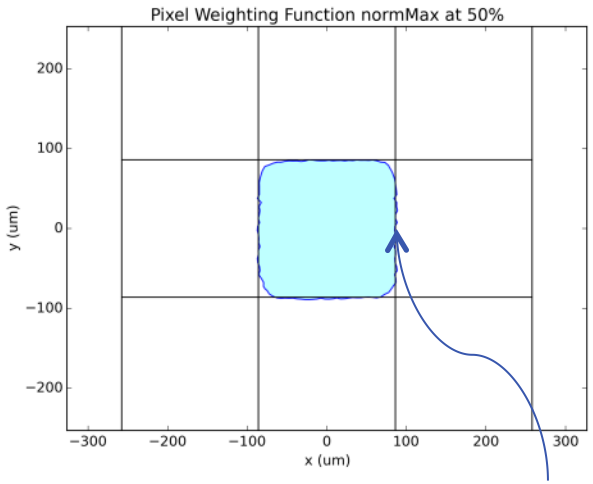
- *Wide linear range for laboratory applications*
- *Simple yet accurate correction*

$$N_{\text{obs}} = N_0 \exp(-N_0 \tau)$$

Spatial Resolution







Pixel response scanned using a 10 µm diameter pinhole.

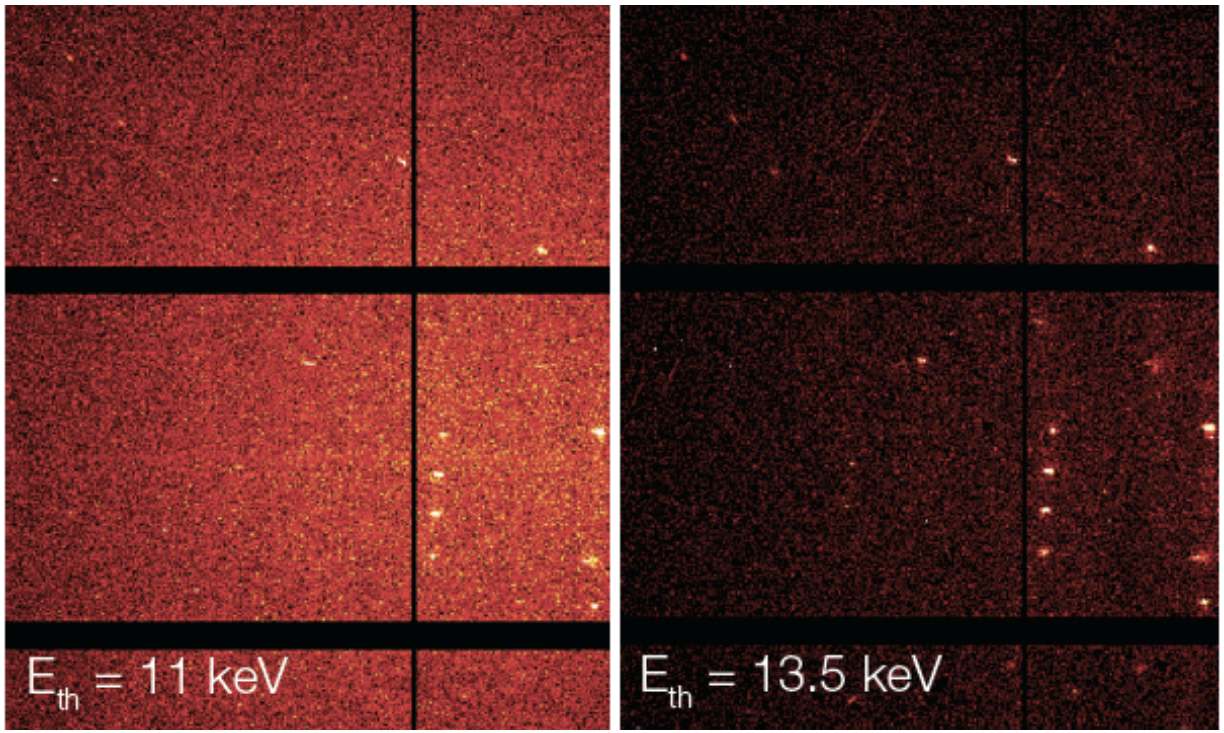
50% countour level matches pixel border

PILATUS3 R CdTe – key advantages

High-energy CdTe sensor + PILATUS3 HPC technology

- *Quantum Efficiency > 90% for Mo-, Ag- and In-Ka*
- *No readout noise, dark noise or reset noise*
- *Sharp point spread function (1 pixel)*
- *High dynamic range: 20 bits (1,048,576 counts)*
- *Fluorescence background suppression*

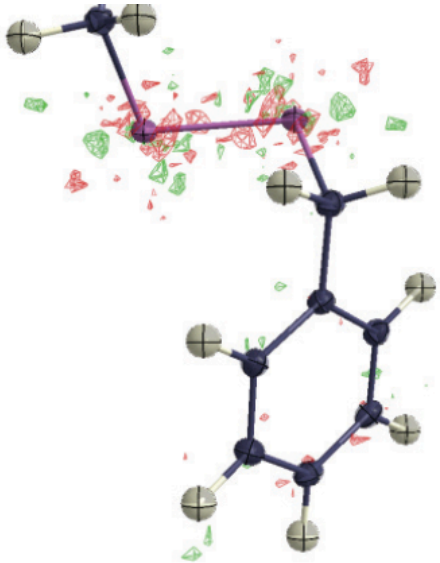
Dibenzyl diselenide Fluorescence suppression



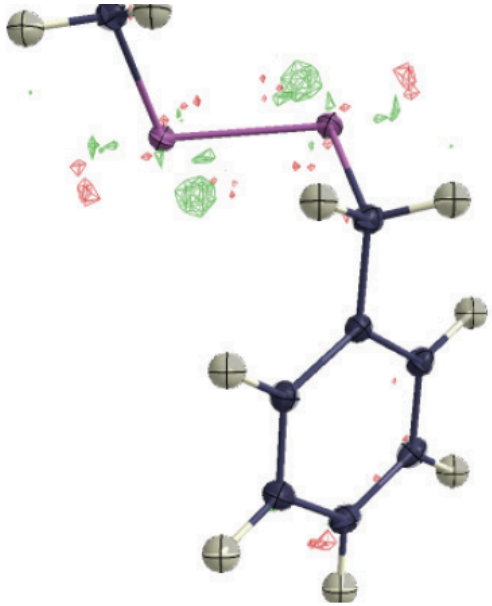
- *Ag source*
- *Se fluorescence between 11.2 and 12.5 keV*
- *Fluorescence background suppression with 13.5 keV threshold energy*

Courtesy of Stalke lab, University Goettingen

Dibenzyl diselenide
Residual density maps



CCD

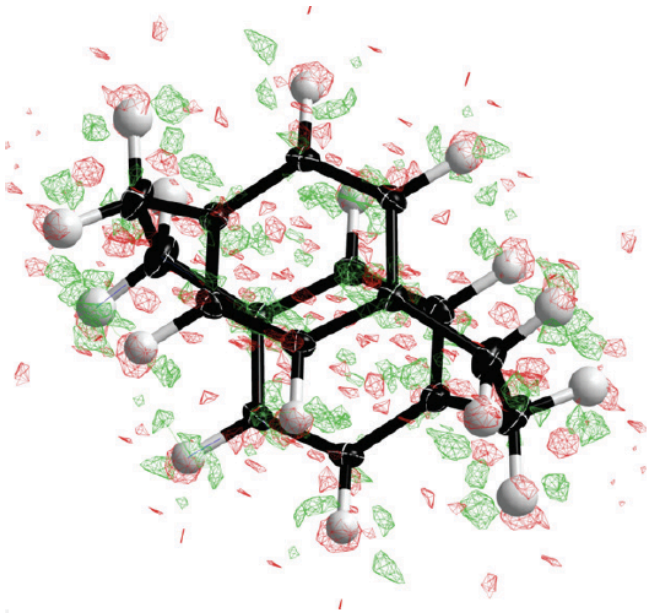


PILATUS3 R CdTe

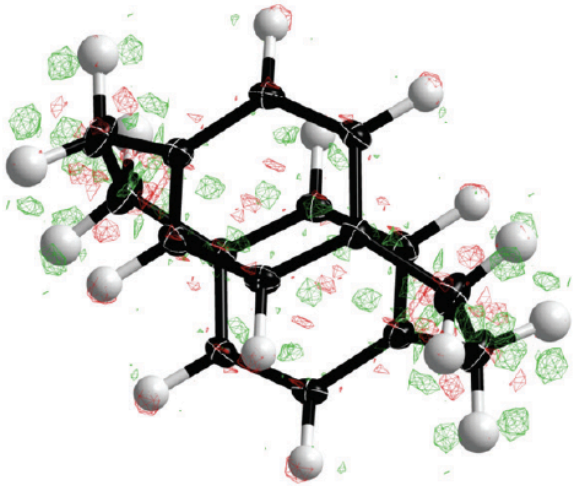
– *isolevels at*
± 0.11 e Å^{-3}

Courtesy of Stalke lab,
University Goettingen

Paracyclophane
Residual density maps



CCD



PILATUS3 R CdTe

– *isolevels at*
± 0.047 e Å^{-3}

Courtesy of Stalke lab,
University Goettingen

Summary

PILATUS3 R CdTe 300K and 300K-W now available for high-energy X-ray applications in the laboratory

Key advantages

- *Quantum Efficiency > 90% for Mo-, Ag- and In-Kα*
- *No readout noise, dark noise or reset noise*
- *Sharp point spread function (1 pixel)*
- *High dynamic range: 20 bits (1,048,576 counts)*
- *Fluorescence background suppression*

Acknowledgements

Stalke lab, University Göttingen

- *Regine Herbst-Irmer*
- *Christian Schürmann*
- *Lennard Krause*
- *Felix Engelhardt*
- *Dietmar Stalke*

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