Hybrid Photon Counting (HPC) detectors
… a journey…

Dubravka Šišak Jung

18th of October 2022

DECTRIS Ltd.
5405 Baden-Dättwil
Switzerland
www.dectris.com

20 years and counting[1]

ELSEVIER

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

Volume 477, Issues 1–3, 21 January 2002, Pages 531-535

A pixel detector for the protein crystallography beamline at the SLS

Ch Brönnimann [a], R Baur [b], E.F Eikenberry [a], P Fischer [c], S Florin [c], R Horisberger [b], M Lindner [c], B Schmitt [a], C Schulze [a]

Show more

+ Add to Mendeley   Share   Cite

https://doi.org/10.1016/S0168-9002(01)01916-7

Get rights and content

[1] Förster, A. *et al*. (2019) Phil.Trans.R.Soc.A377: 20180241. http://dx.doi.org/10.1098/rsta.2018.0241

DECTRIS
detecting the future

Looking back, glancing sideways, detecting the future

1. ***Detector basics***

2. ***Hybrid Photon Counting (HPC) detectors***

3. ***Future challenges***

Detector basics: evolution… and revolution

Roland Horisberger fitting one of the final pieces of the CMS pixel detector at LHC (10 September 2008). (Photo: ETH Zurich / H.R. Bramaz; source ETH Zürich)

1. **Performance**
   - Technical specs: bigger, better, faster
2. **Simplicity of the design**
   - Understanding and controling the processes in the system
   - Fewer sources of errors
3. **Accessibility**
   - Stability, robustness
   - Maintenance
   - Ease of use

DECTRIS detecting the future

Detector basics: architecture & performance parameters

SENSOR

Absorbs the radiation
and converts it to electric charge

READOUT

Translates the electronic signal
into information for the user

Detector properties

TECHNOLOGY I
- Absorption efficiency
- Conversion efficiency
- Spatial resolution

TECHNOLOGY II
- Collection efficiency
- Dynamic range
- Frame rates
- Energy resolution

Performance parameters[1]

Point Spread Function

Stopping power

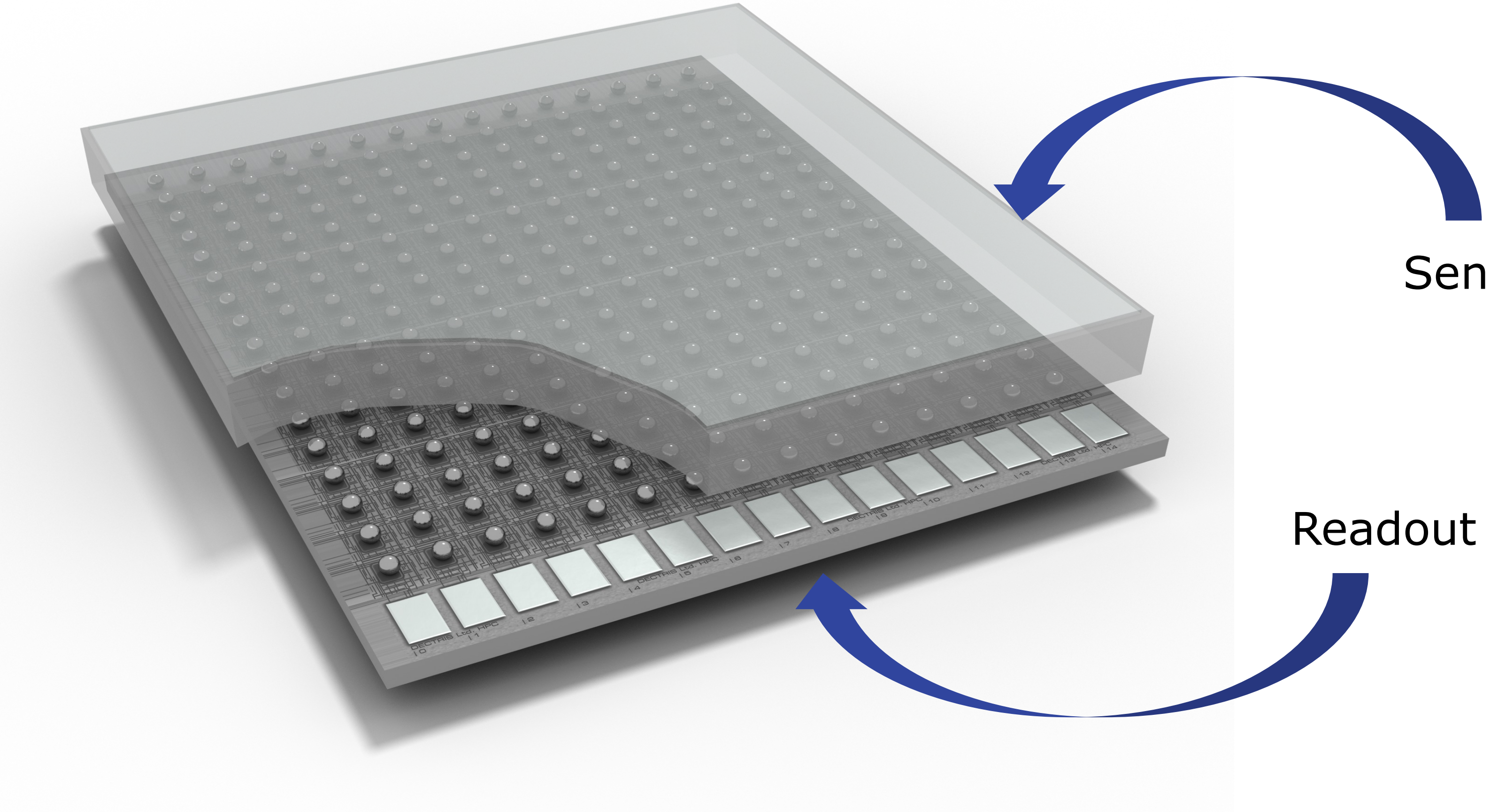
Quantum Efficiency
Detective Quantum Efficiency

Dynamic range

...

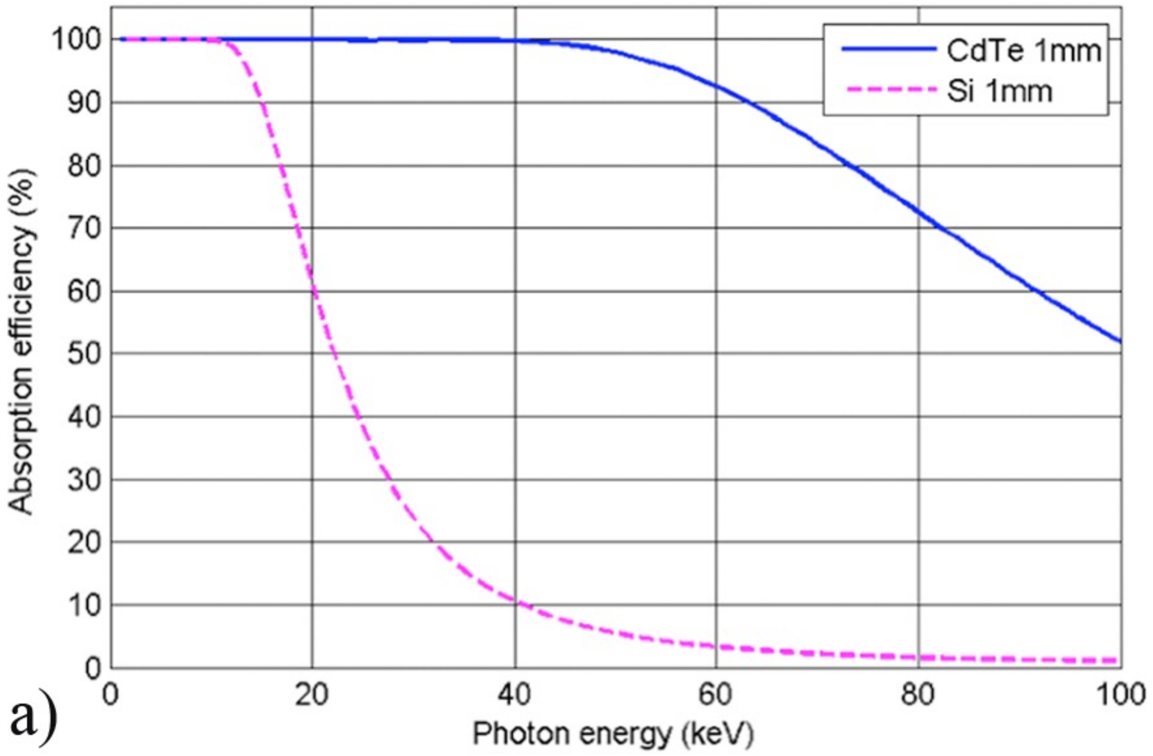
[1] Donath, T. *et al*. (2022) *in submission*

Hybrid design[1] (a very simple design)

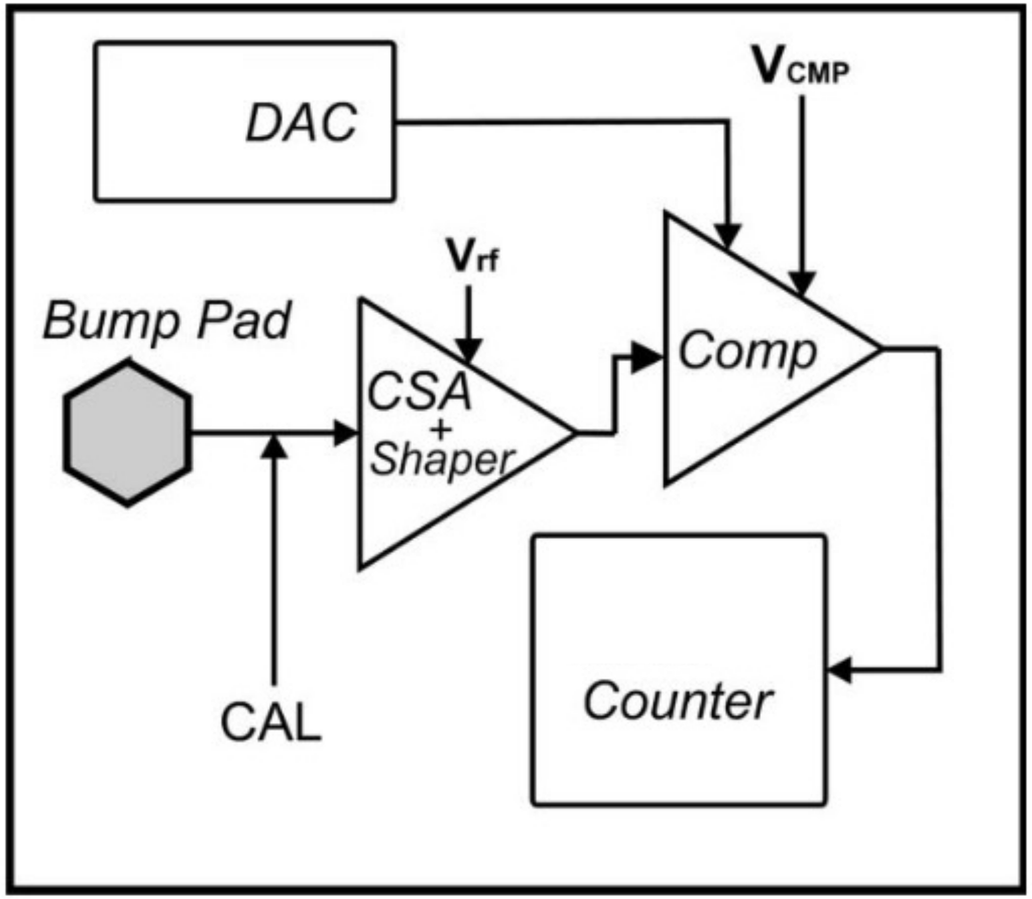


[1] Brönnimann, C, Trüb, P. (2018) *Synchrotron Light Sources and Free-electron Lasers*. pp. 995–1027

Hybrid design: Sensor



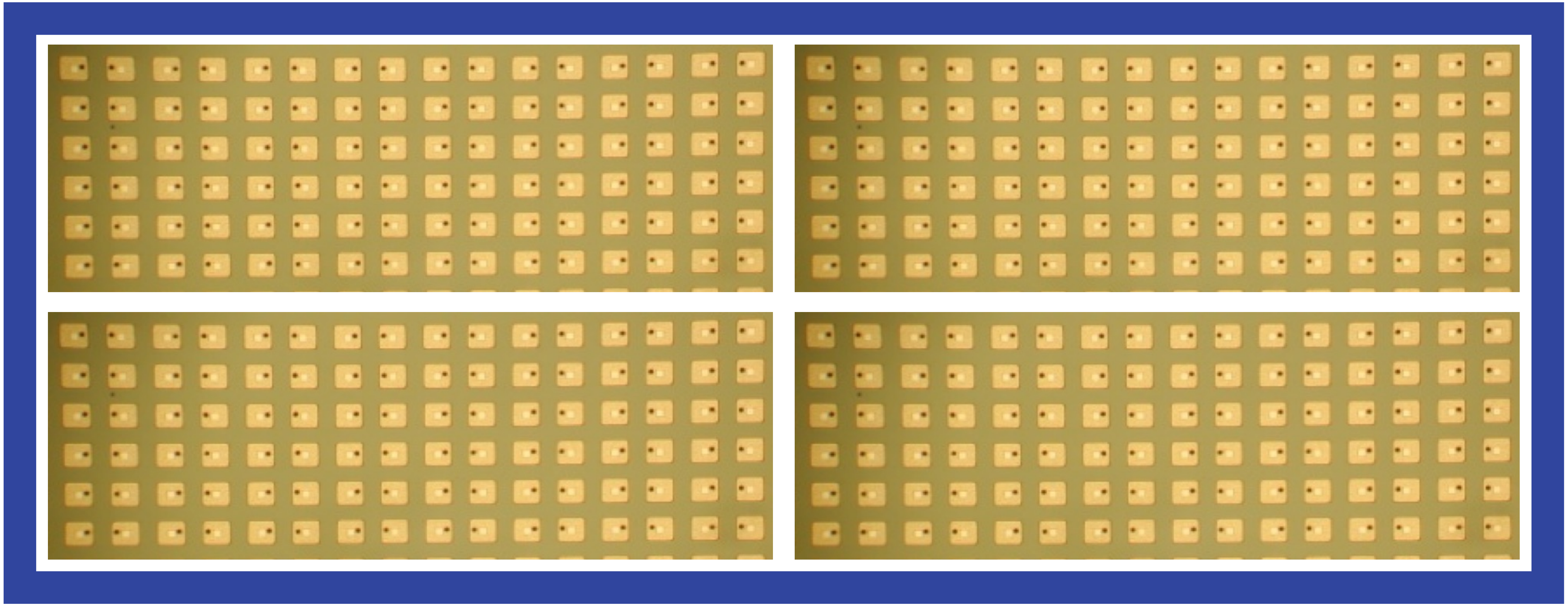
Hybrid design: Readout



Simplified scheme of a readout chip.

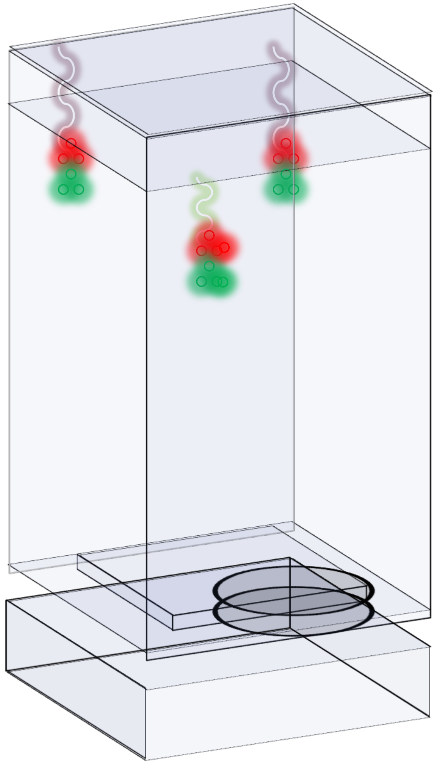
DECTRIS
detecting the future

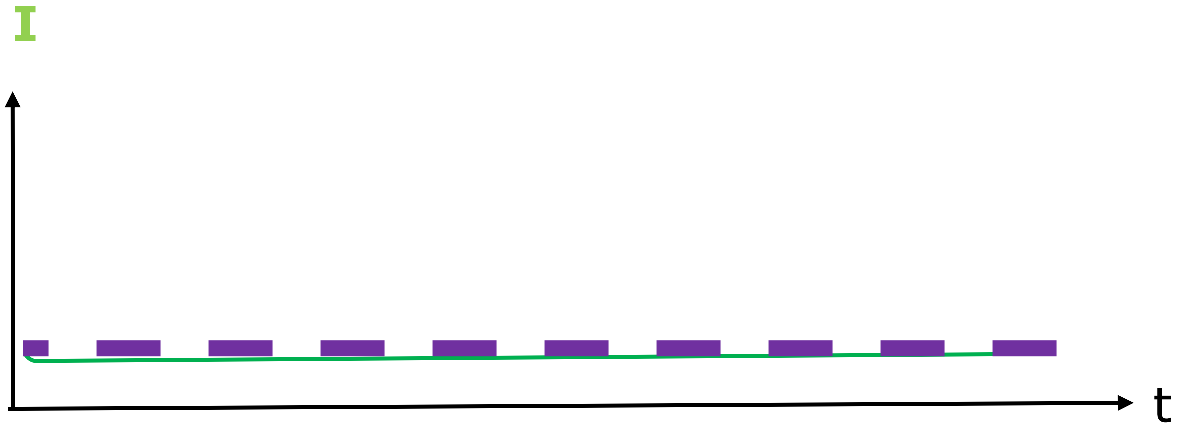
Hybrid design: large-area detectors

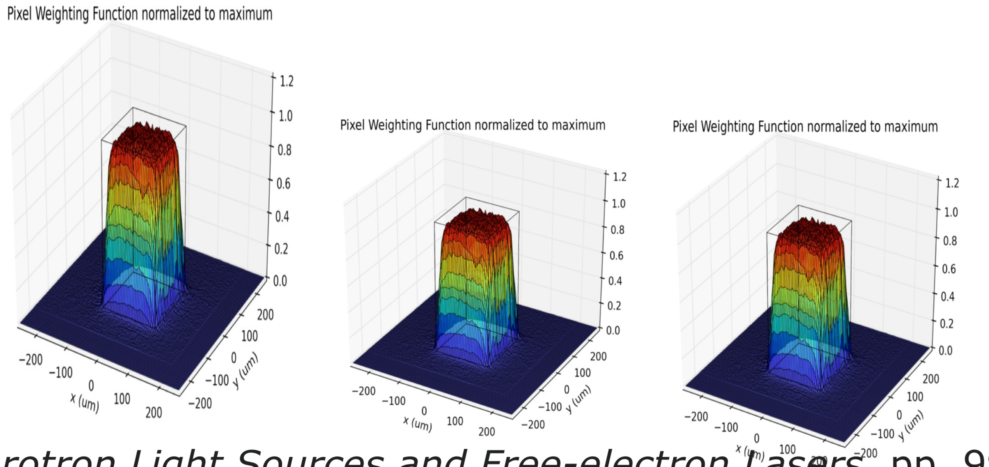


DECTRIS detecting the future

Single photon counting[1] operation

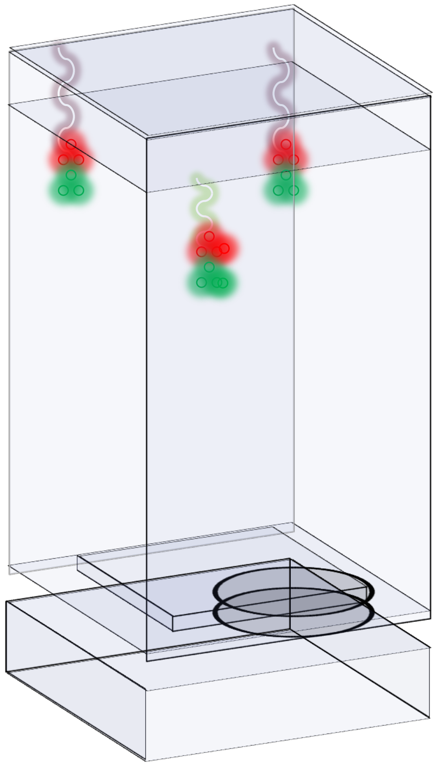


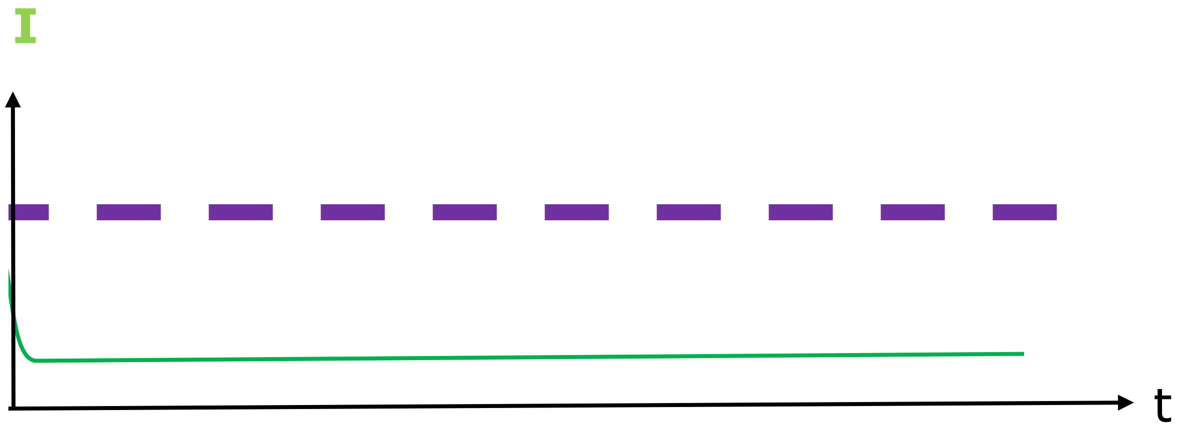


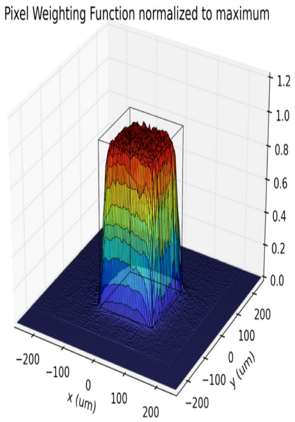


[1] Brönnimann, C, Trüb, P. (2018) *Synchrotron Light Sources and Free-electron Lasers*. pp. 995–1027

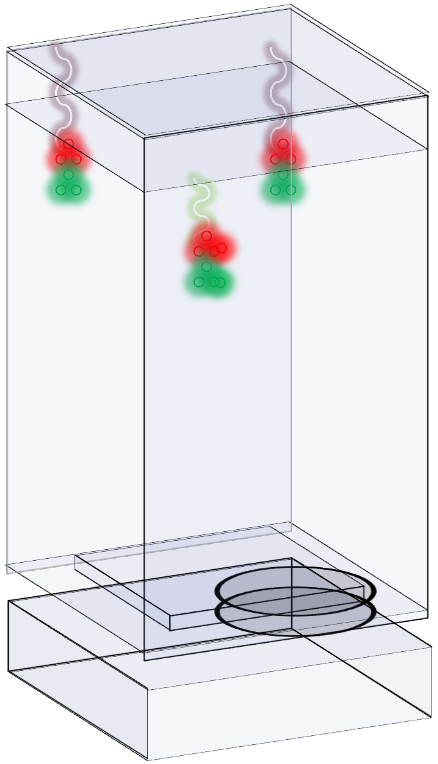
Single photon counting operation: Adjustable energy threshold

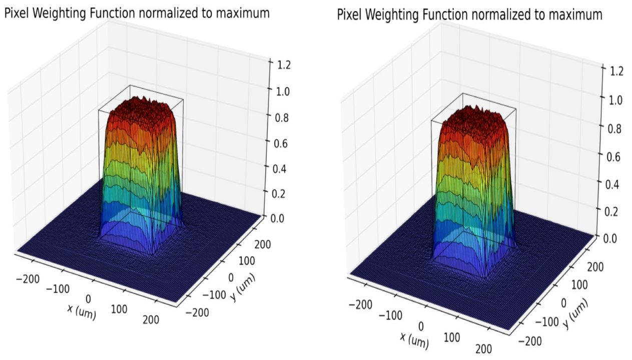






Single photon counting operation: Two energy thresholds





DECTRIS
detecting the future

Hybrid design + single photon counting = Hybrid Photon Counting detectors[1] "A revolution"

[1] Brönnimann, C, Trüb, P. (2018) *Synchrotron Light Sources and Free-electron Lasers*. pp. 995–1027

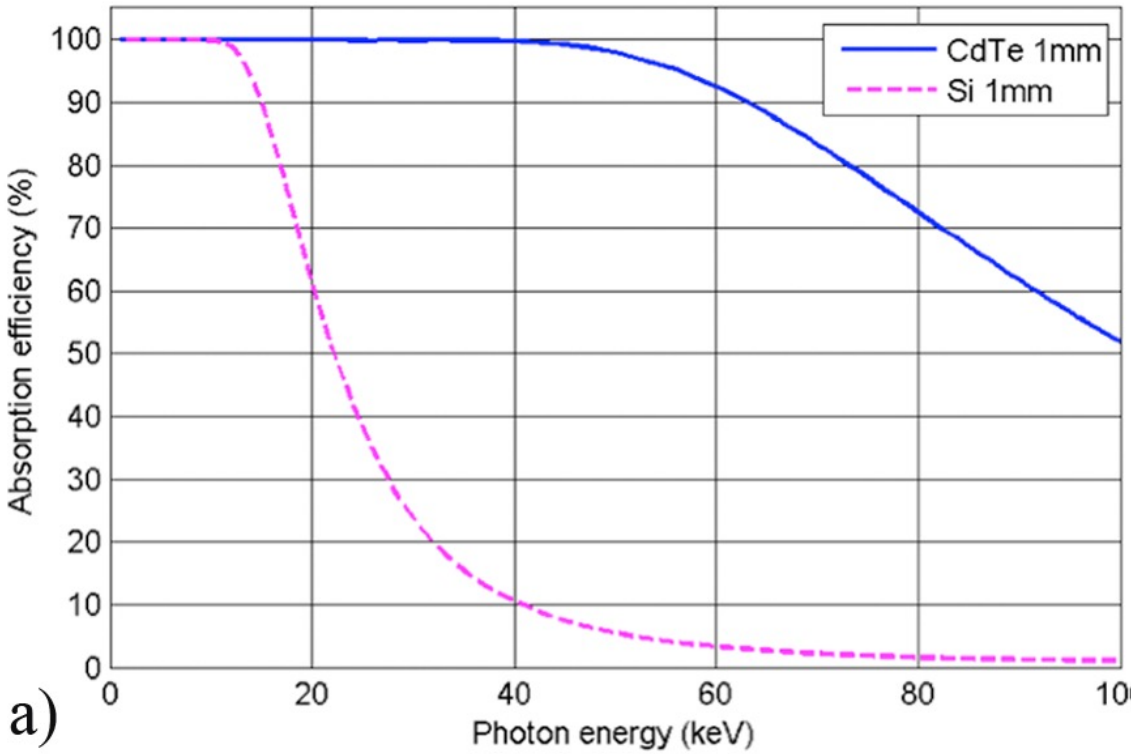
DECTRIS
detecting the future

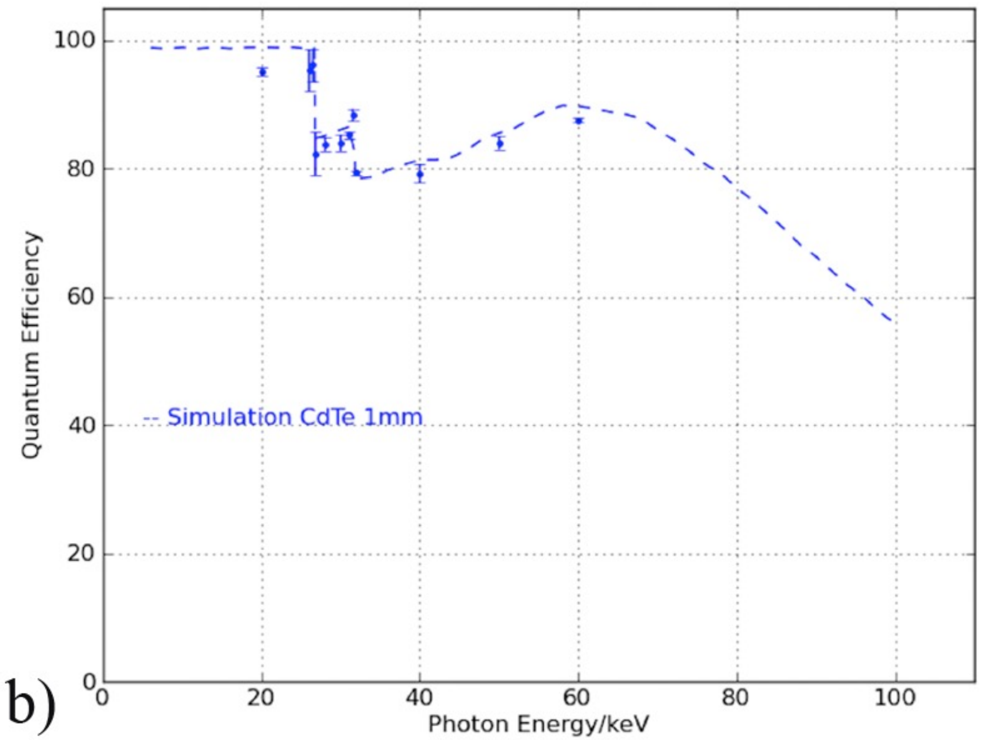
(1) Evolution of HPC detectors: bigger, better, faster

1. **Not all HPC detectors are the same**
   – *Different producers, different technical specs*
2. **If you encounter two detectors with the similar name, they are not necessarily the same**
   – *Different product lines, different specifications*
   – *Different generations of detectors*
3. **Two detectors with the exactly same name can also be different**
   – *Calibrations, firmware (updates)*

DECTRIS
detecting the future

Sensor matters

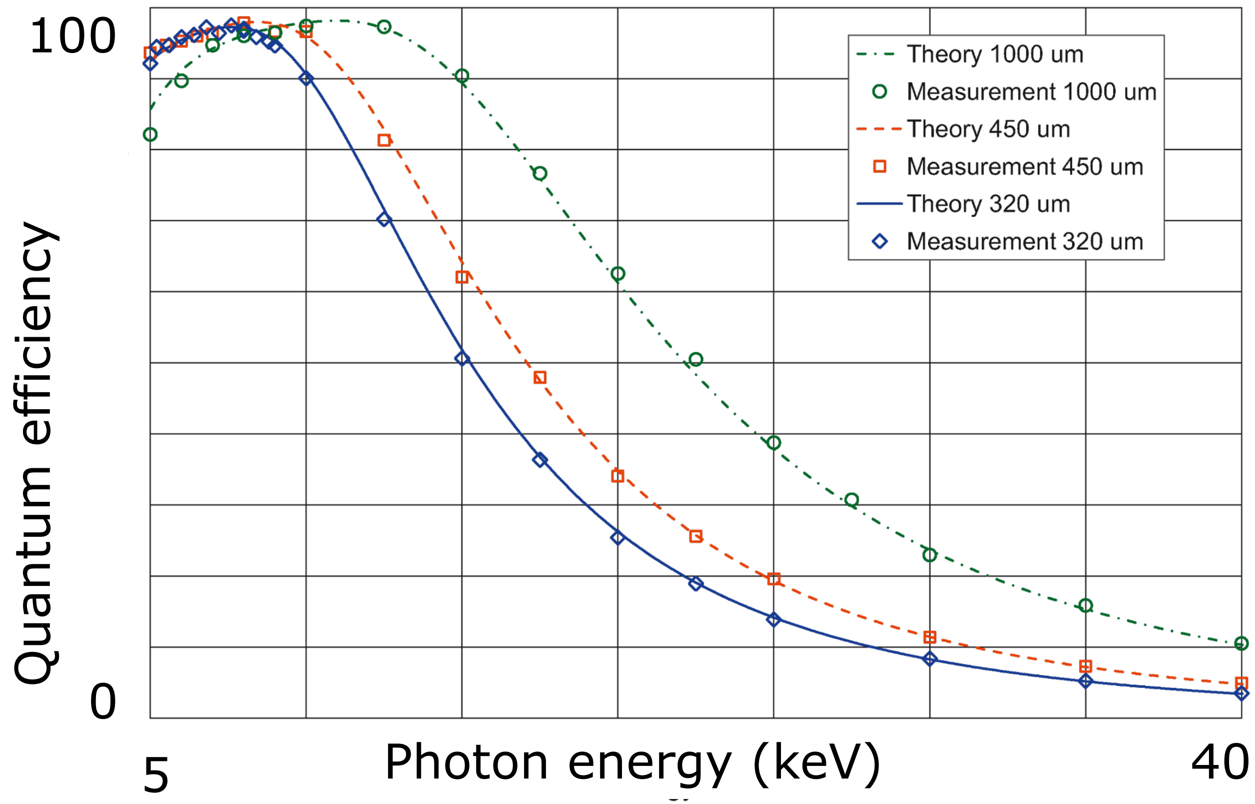




Rather relevant for setting the exposure time correctly.

DECTRIS detecting the future

Sensor thickness and energy range



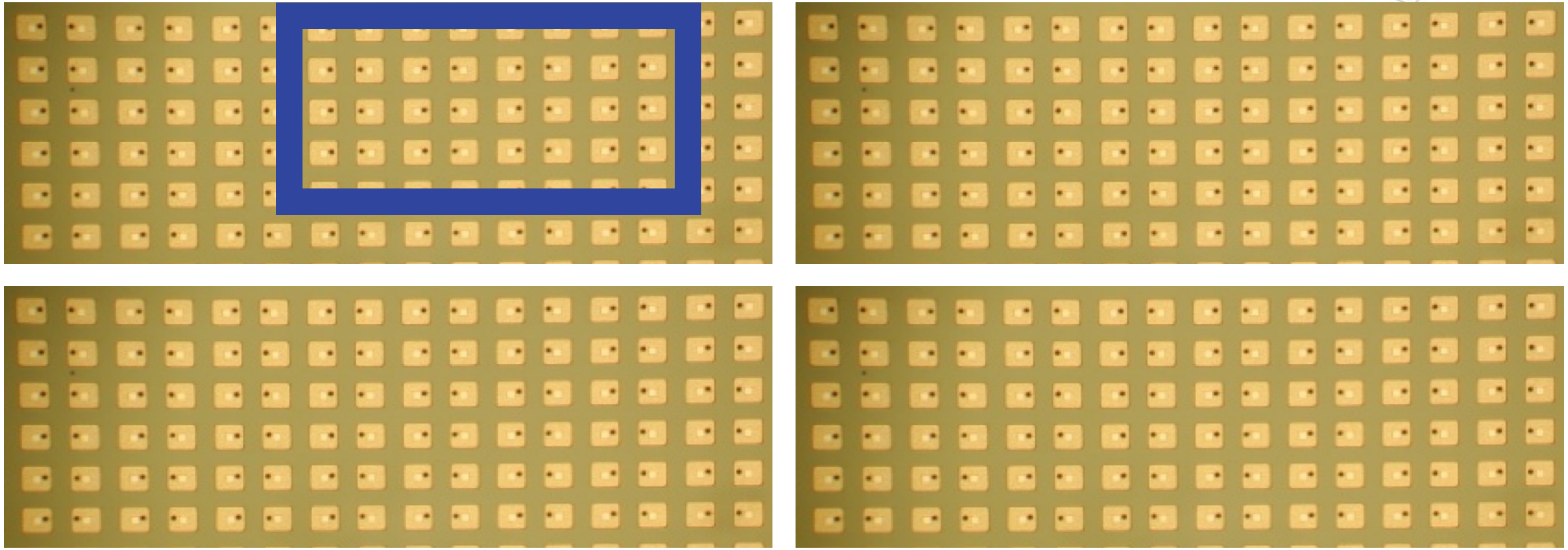
Energy & Threshold ranges	320 µm 4 mm	320 µm 8 mm	450 µm 8 mm	1000 µm 8 mm
Energy range [keV]	4-40	5-40	6.6-40	7.4-40
Threshold energy range [keV]	3.5-20	4.5-20	5.5-20	6-20

Relevant for expectation management.

Example only! Please do not refer to data in the table as general values.

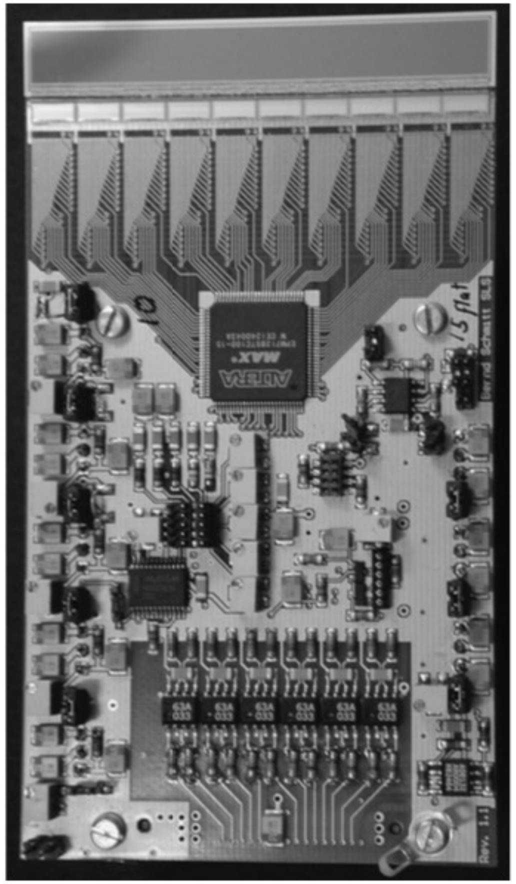
DECTRIS detecting the future

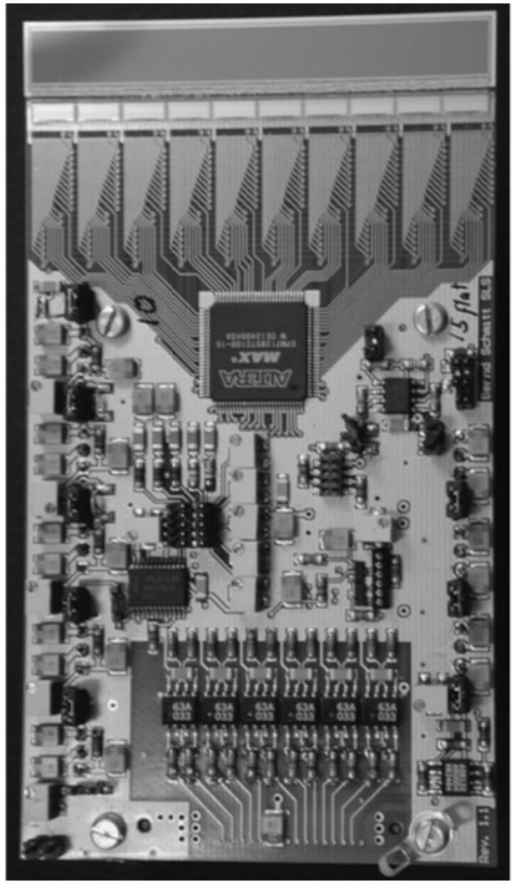
HPC: correlation size-speed

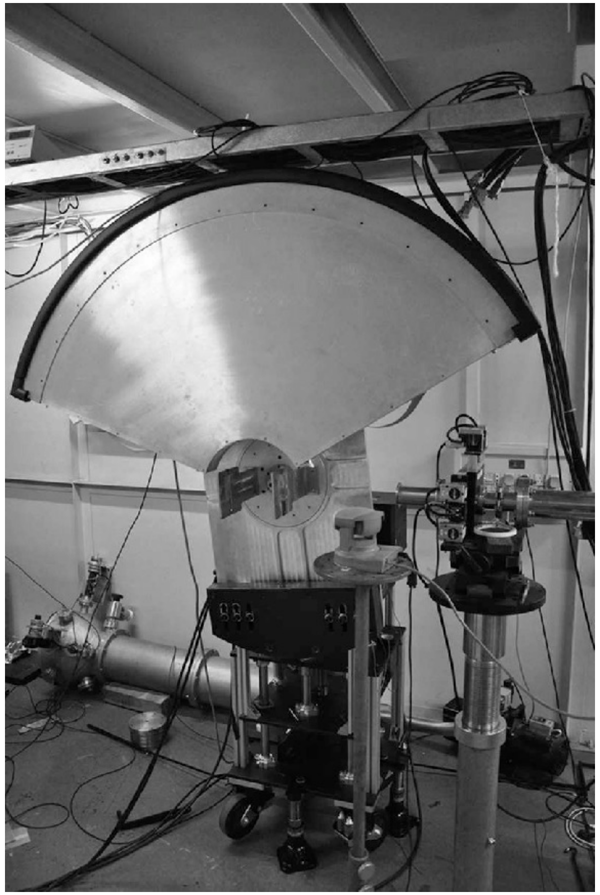


Some implementations are specific to detectors at certain beamlines.

Correlation size-speed-dynamic range



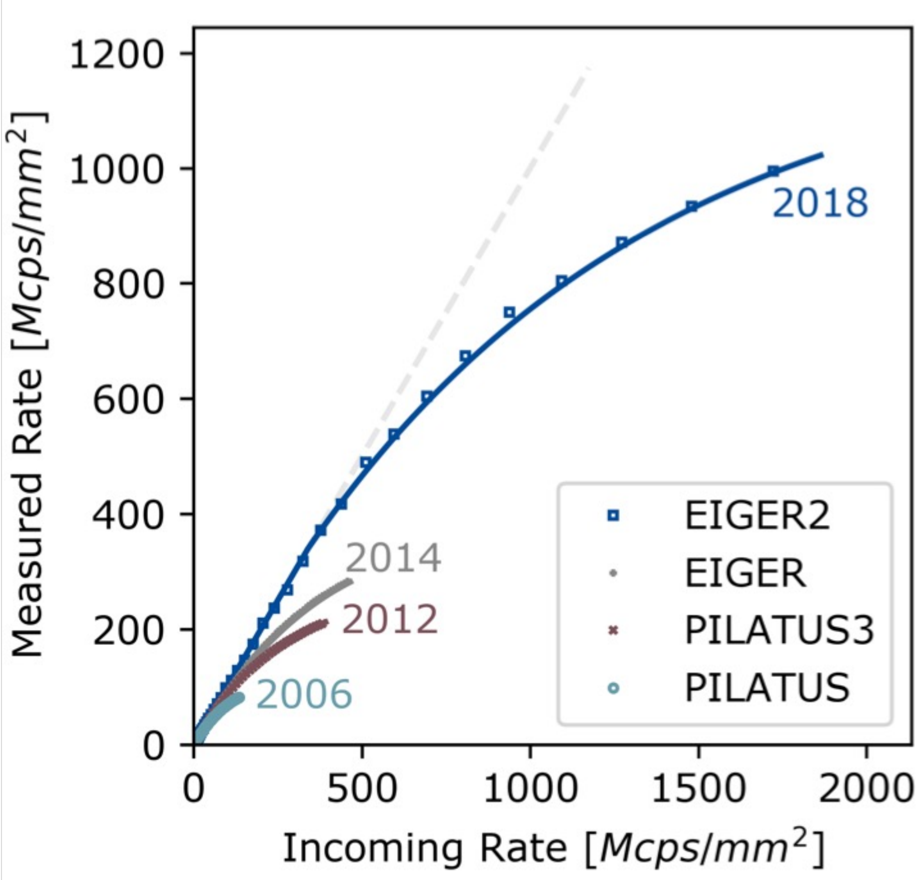




1000 Hz at
24-bit dynamic range

Older detectors might have different correlations between the size and speed.

HPC count rates



[1] Loelliger *et al*. (2013) *IEEE Science Symposium NSS/MIC*, **N6-2**, 610-615.

(2) Doing things with HPC detectors: accessibility and ease of use

Experiments -> trying out things

Measurements -> using a set up procedure

1. ***Some things are implemented for convenience***
2. ***Some things you have to think about :)***

Corrections

1. ***Energy calibrations***
2. ***Geometrical corrections***
3. ***Count rate corrections***

Provided. Stability of correction/calibration files

4. ***Experiment-specific corrections***
   - *Parallax correction*[1]
   - *Geometry corrections*[2,3]
   - *Other*[4]

[1]Pauw, B.R. *et al*. (2018) *J. Appl. Cryst*. **50**, 1800-1811.

[2]Krause, L. *et al.* (2020) *J. Appl. Cryst.* **53(3)** 635-49.

[3]Wright, J. *et al.* (2022) *Crystals* **12**, 255.

[4]Kato, K. *et al.* (2019) *J. Synchrotron Rad.* **26**, 762-773.

(3) Some practical advice

Trust your beamline scientist, but make sure to understand your experiment or measurement.

Use the detector within its specifications.

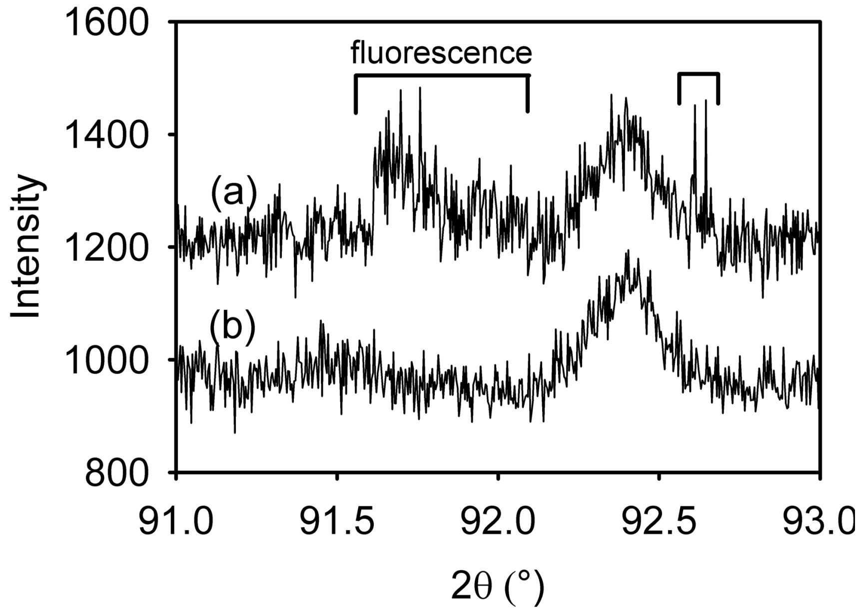
Sensor, counting and statistics

- *Type and thickness of detector sensor vs. chosen X-ray energy*
- *Adjust exposure time accordingly!*
- *For CdTe detectors, exposure times in the range of couple of seconds are usually sufficient (at synchrotron beamlines)*
- *Your data statistics are limited by the number of count collected, as well as by the number of counts used for the flat file*

DECTRIS
detecting the future

Energy threshold

- *Is adjustable and it can used for sample fluorescence suppression*
- *Significant change of the energy threshold might require a custom flatfield file*
- *Energy threshold has a certain resolution -> do not set it too close to the energy of the incoming photons*



(a) Flourescence
(b) Fluorescence suppression

Haverkamp, R.G., Wallwork, K.S. (2009) *J. Synch. Rad.* **16**, 849-856

DECTRIS detecting the future

Unusual data

- ***Check if all necessary corrections were switched on (or have proper values set)***

- ***Some wrong settings can be corrected post-experiment***

Look into the future

(1) Evolution of HPC detectors -> EIGER2 update (Max, Friday)

(2) Data:

What we learned fro macromolecular crystallography

- *Standardisations*
- *High throughput*

Doing the right thing and doing it right

- *Accuracy and reproducibility*

=> Data, meta-data, standards (processes, workflows)

DECTRIS
detecting the future

THANK YOU FOR YOUR ATTENTION

Dubravka.sisak@dectris.com

DECTRIS
detecting the future