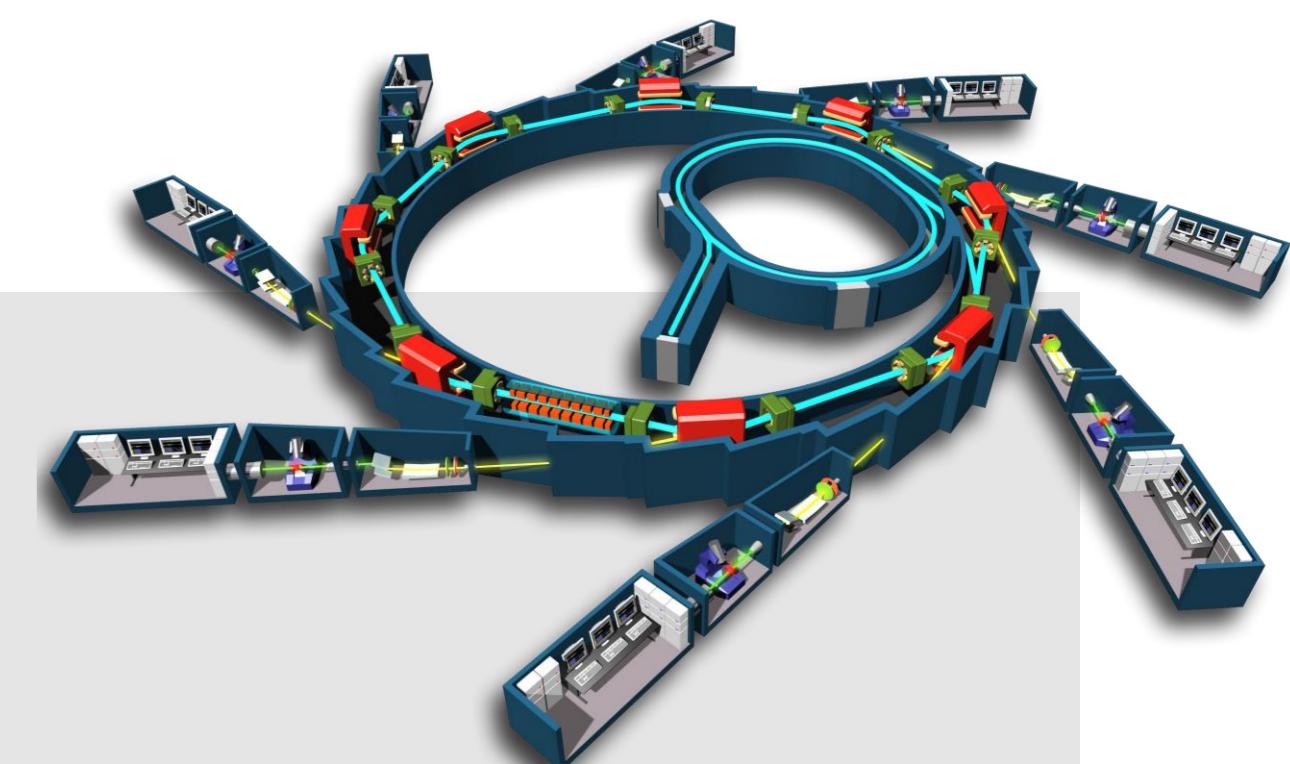


# JUNGFRAU – A hybrid pixel detector for high-performance photon science

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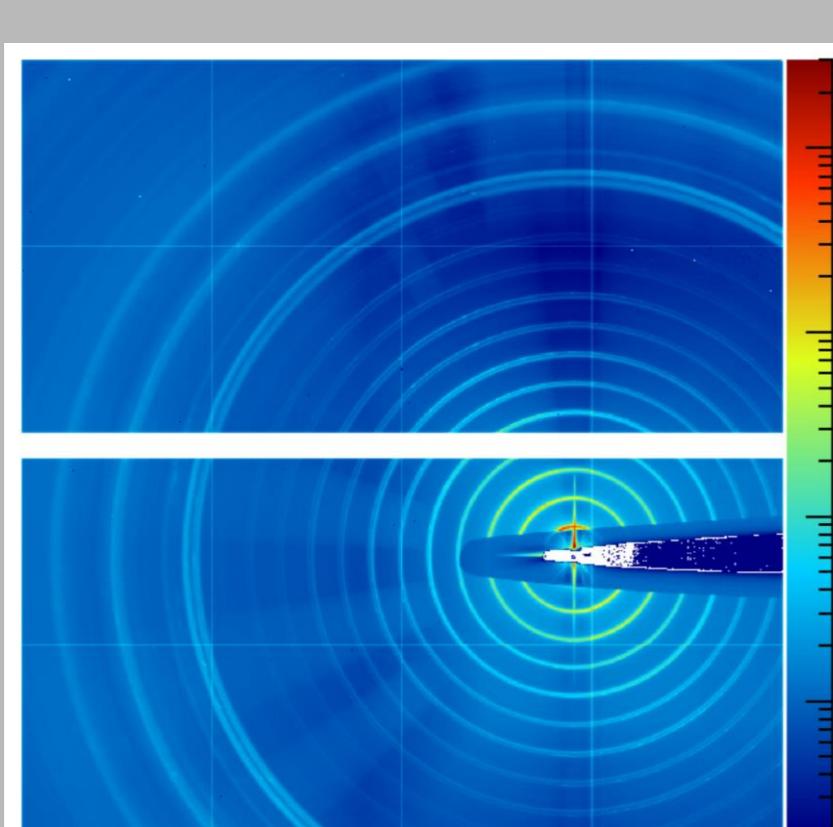
Presented at the 15<sup>th</sup> Pisa Meeting on Advanced Detectors – Edition 2022, \*[viktoria.hinger@psi.ch](mailto:viktoria.hinger@psi.ch)



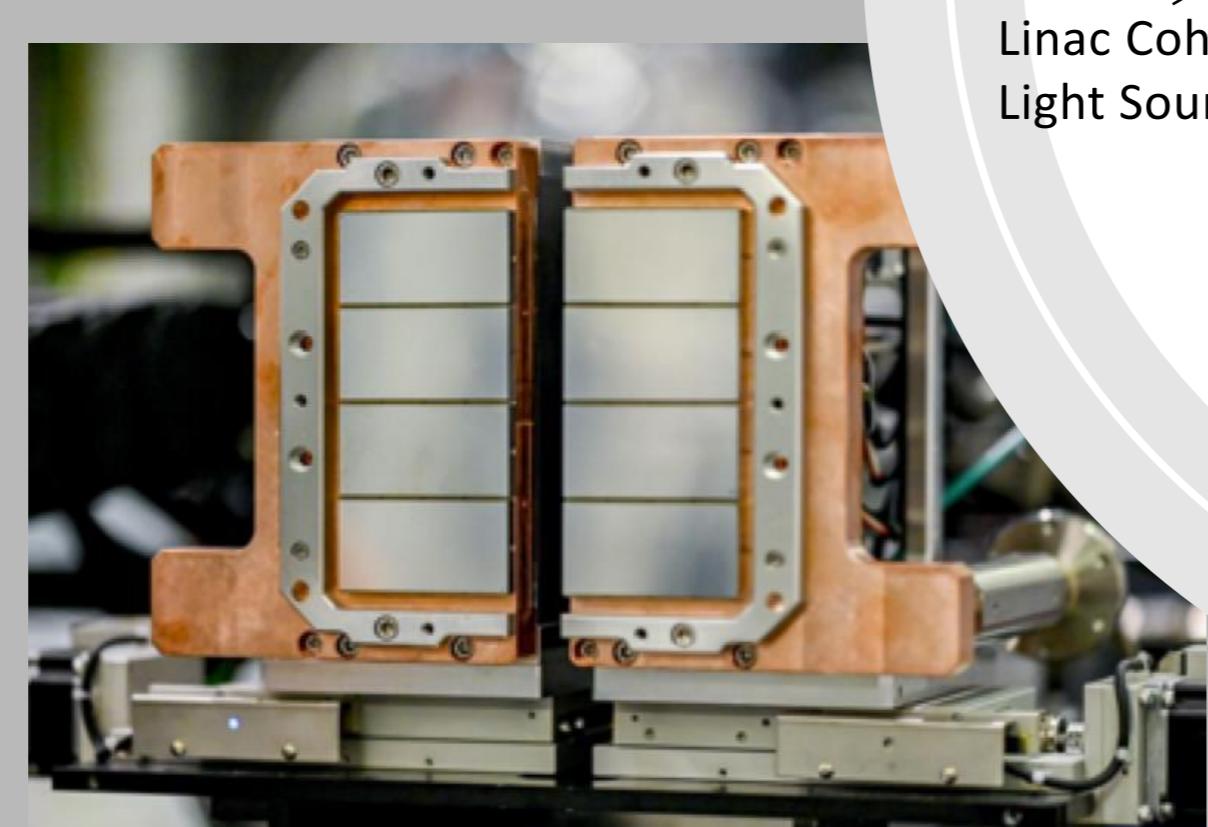
## Applications of JUNGFRAU

### At free-electron lasers (FEL)

- Original field of application for JUNGFRAU
- Short (fs), intense x-ray pulses
- Observe ultrafast processes
- Probe electronic structure of materials

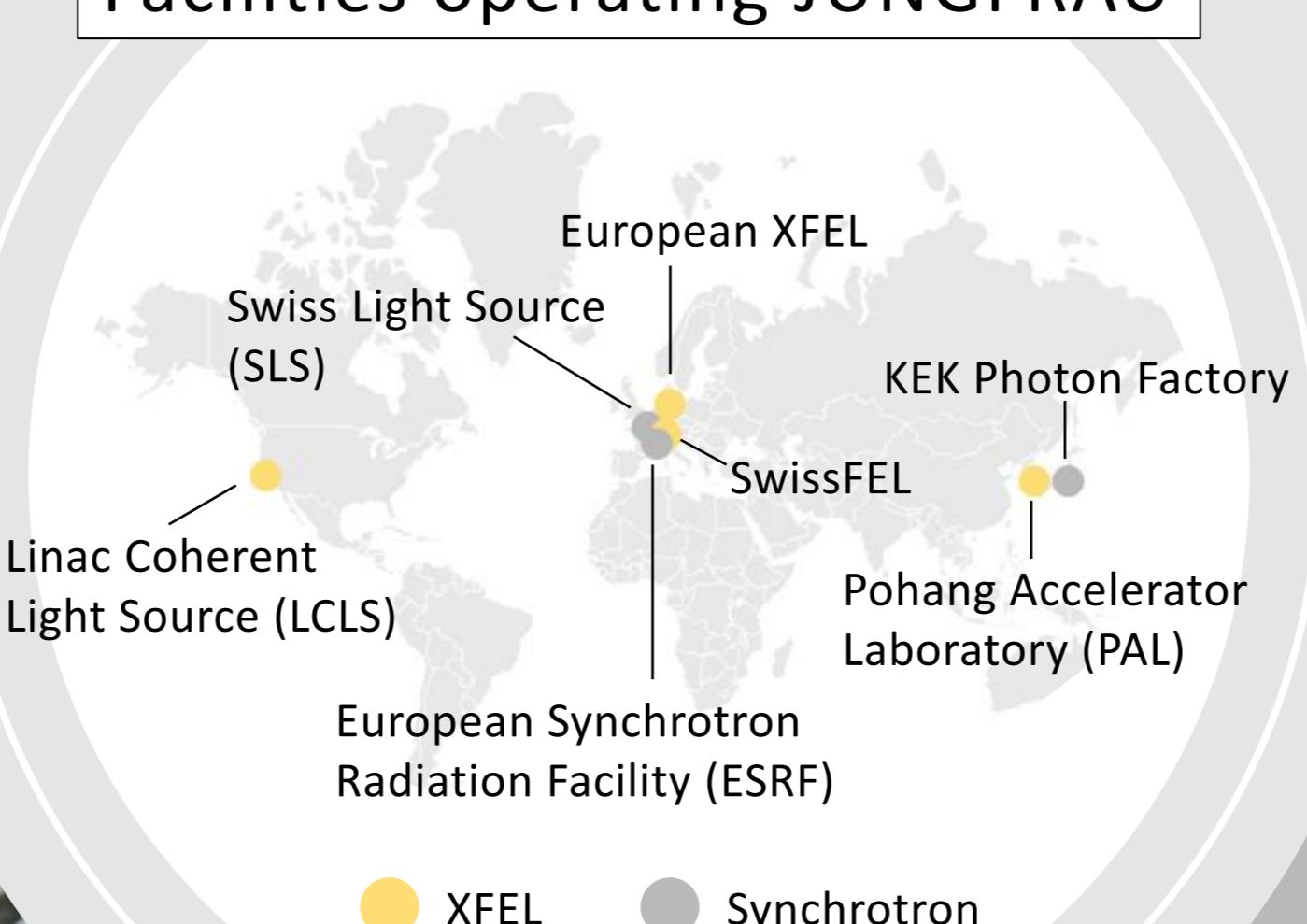


Powder diffraction at LCLS



Four-megapixel JUNGFRAU system at EUXFEL SFX beamline

### Facilities operating JUNGFRAU

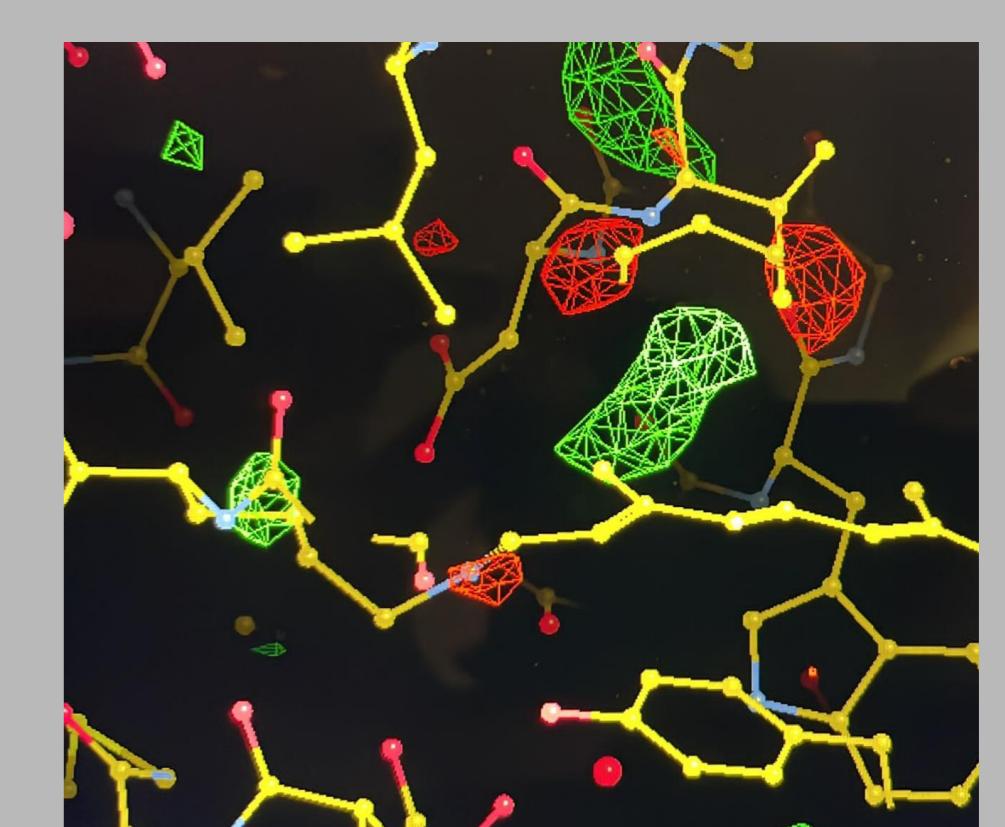


### At synchrotrons

- Fast, time-resolved experiments
- Applications, for which charge sharing and pileup limit the capabilities of photon counting detectors [1]



First synchrotron serial crystallography with 1 ms time resolution (MAX IV, Sweden)

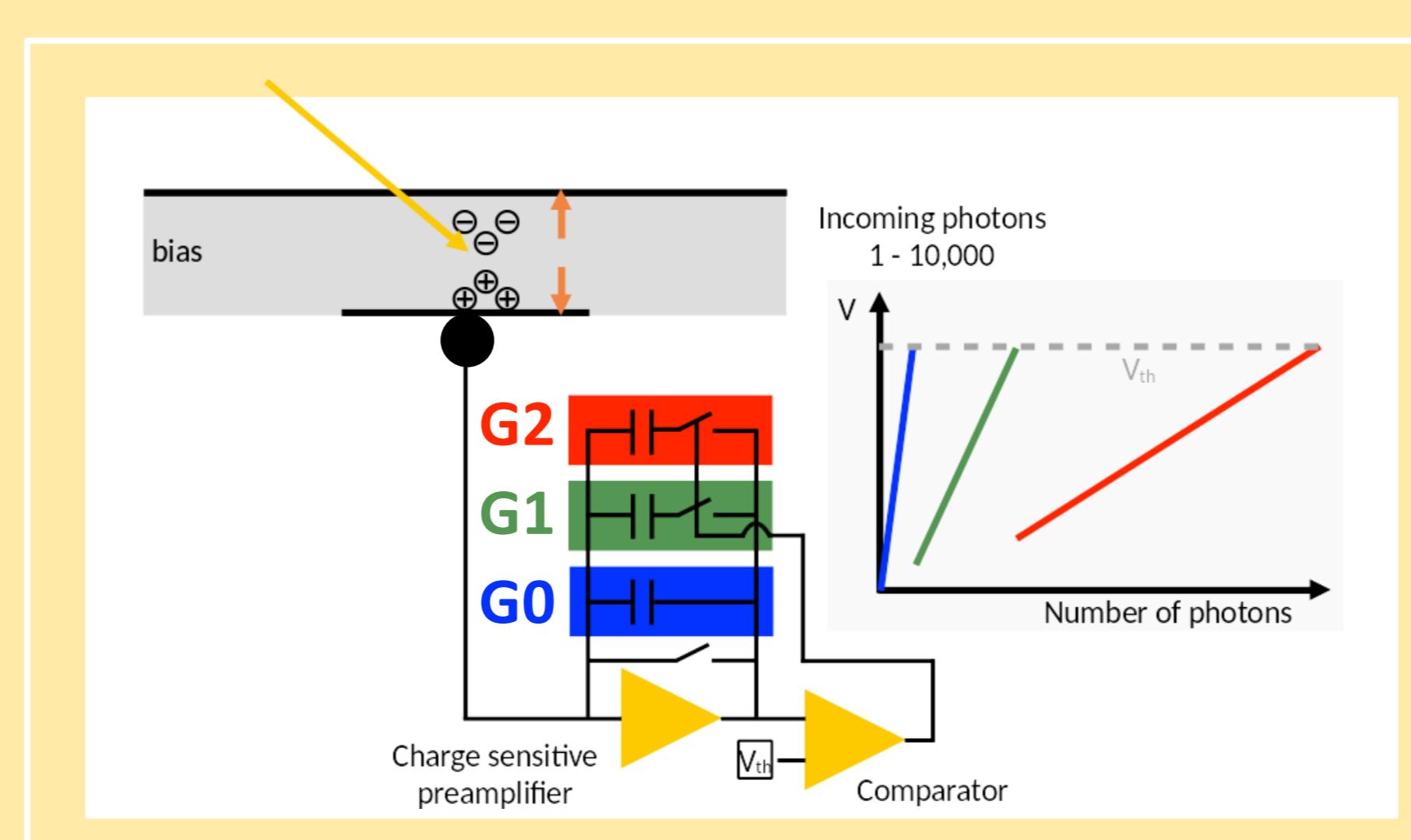


## JUNGFRAU in a nutshell

Sensitive from 1 –  $10^5$  photons from 1.2 keV – 12 keV per pixel per image, no matter when the photons arrive

### How is it possible?

- Charge-integrating hybrid pixel detector ( $75 \times 75 \mu\text{m}^2$ )
- Three dynamically switching linear gains per pixel
- Noise < 34 e<sup>-</sup> in high gain, and below Poisson limit over full range
- Maximum frame rate 2.2 kHz



### Recent improvements

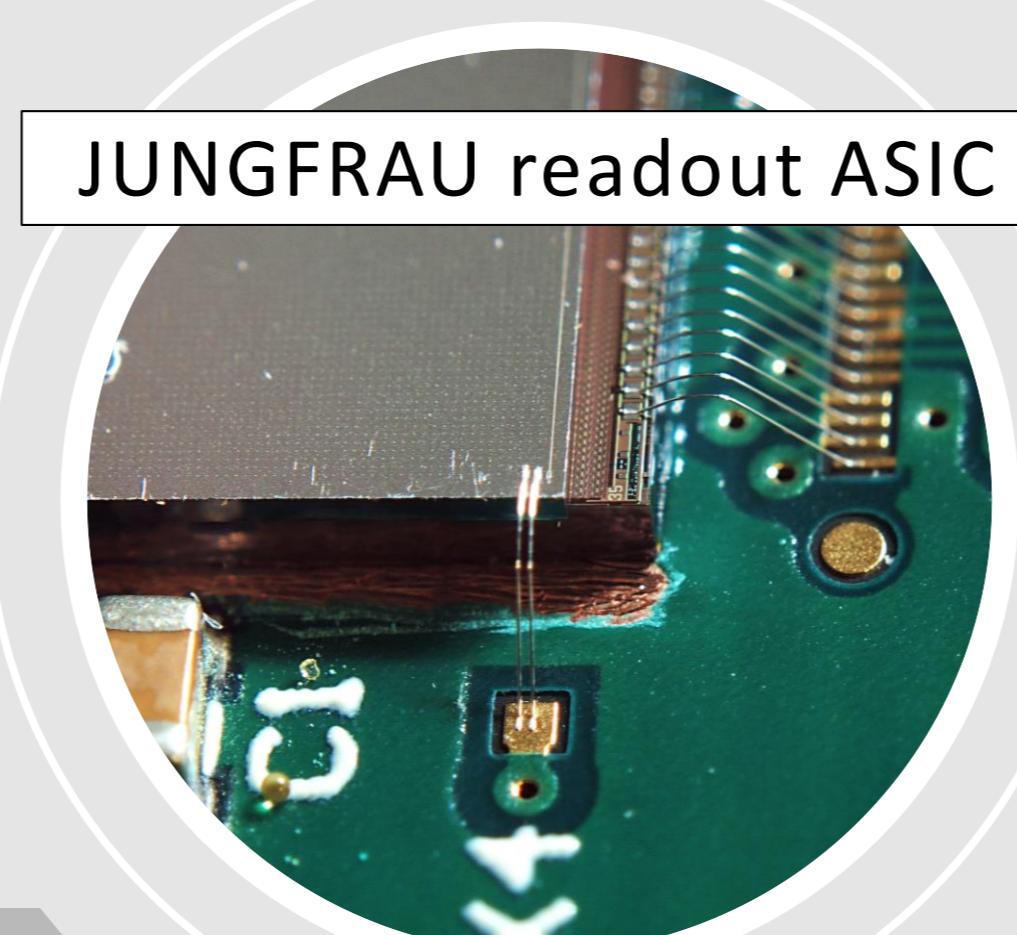
- New ASIC version: **JUNGFRAU 1.1**
  - Improved output linearity
  - Lower noise
- X-ray entrance window**
  - Optimized sensor process
  - Improved quantum efficiency at low x-ray energies

## The journey ahead

Extending the sensitive range of JUNGFRAU toward both ends of the x-ray spectrum

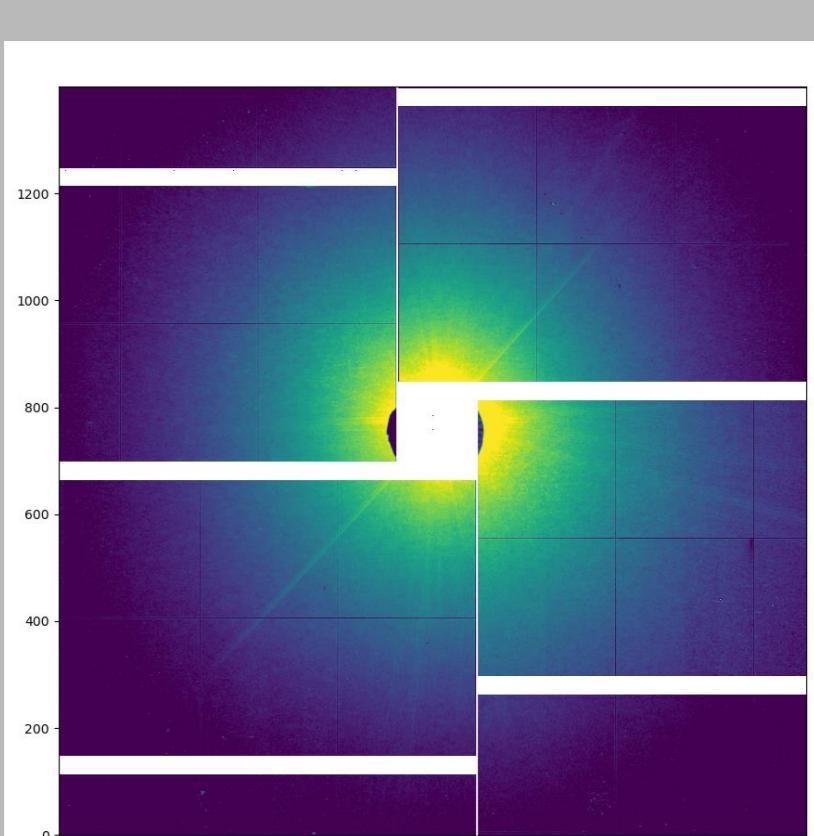
### Soft x-rays: 250 eV – 2 keV

- Sensors with thin entrance window
  - First system installed at SwissFEL Maloja
  - Single photon detection down to 800 eV
- LGAD sensors with intrinsic gain ~ 10
  - Optimized entrance window
  - Inverse LGAD (iLGAD) to improve fill factor

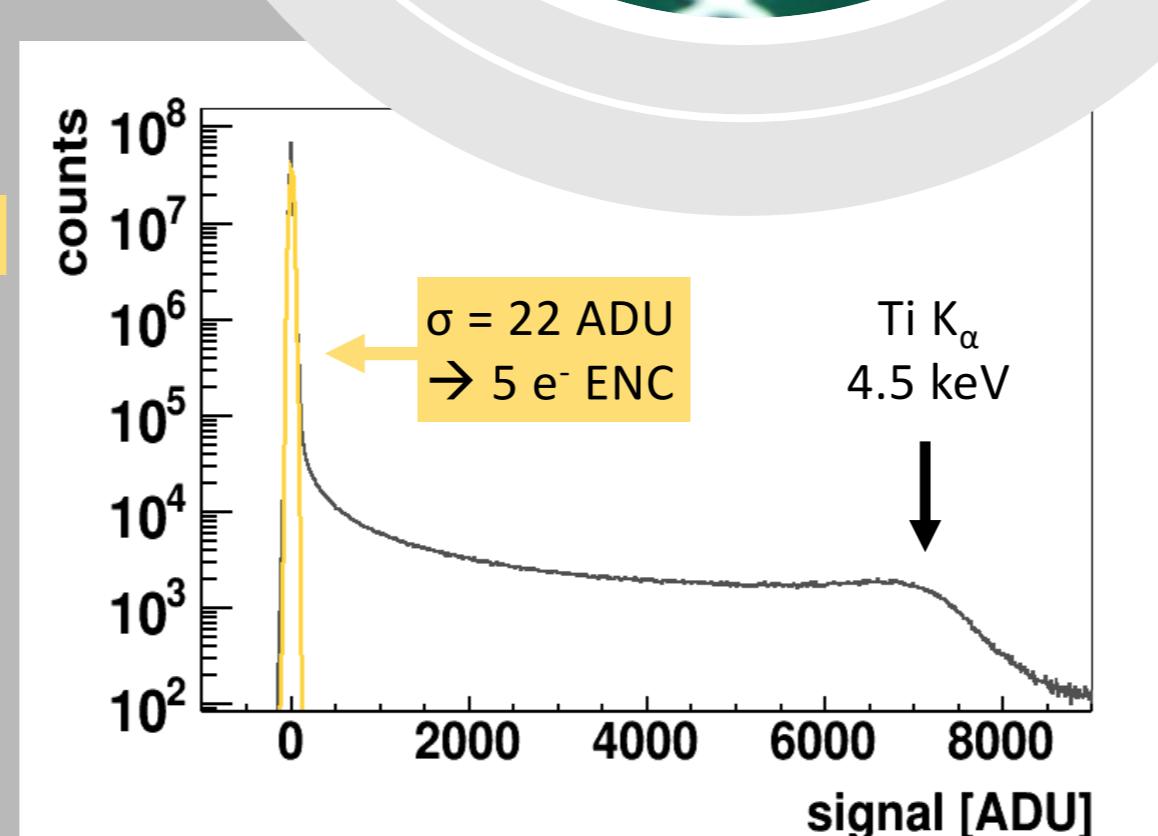


### Hard x-rays: 12 keV – 150 keV

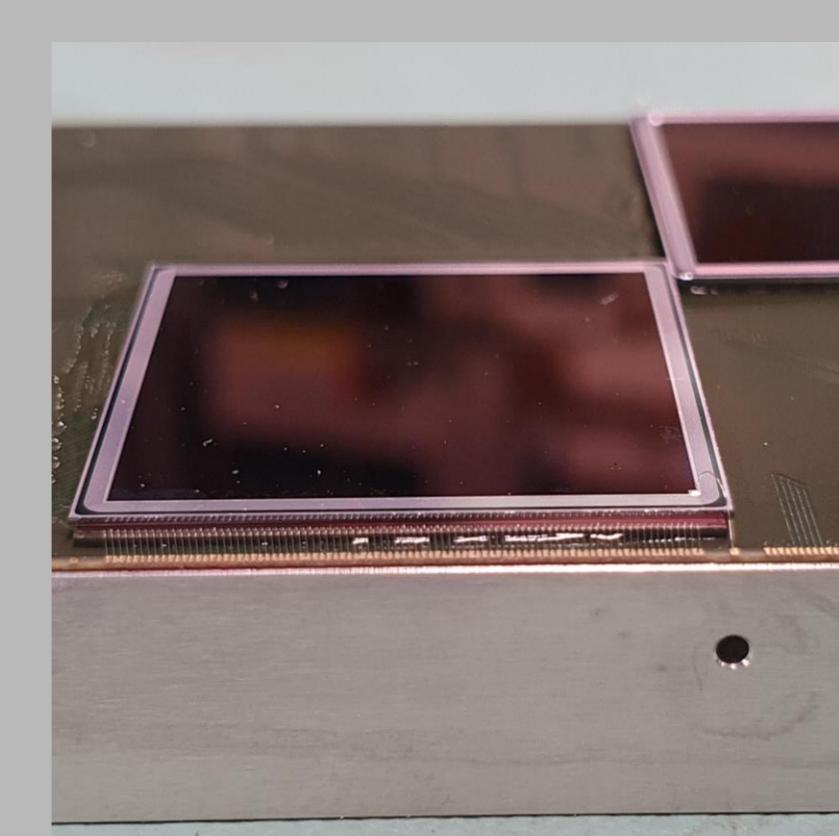
- High-Z sensors
  - Improve quantum efficiency at high x-ray energies
  - GaAs:Cr, CdTe, CdZnTe
  - CdZnTe so far shows best quality
  - However, GaAs is easier to procure



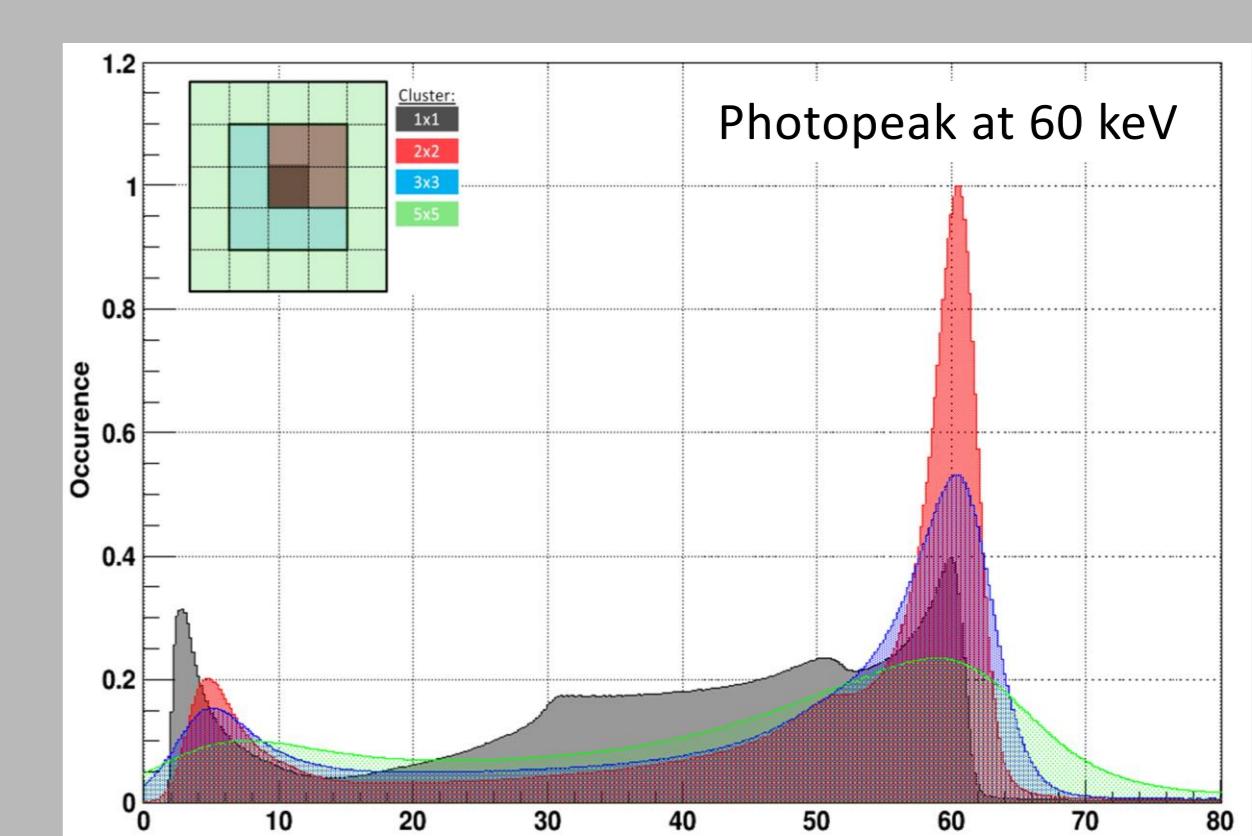
Scattering of 800 eV x-rays on xenon clusters, taken with JUNGFRAU at SwissFEL Maloja [2]



Ti fluorescence on JUNGFRAU iLGAD in high gain at -19.5°C



iLGAD bonded to JUNGFRAU 1.1 ASIC



Energy spectra of 60 keV photons with JUNGFRAU-GaAs assembly [3]



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[1] F. Leonarski *et al.* *Nat. Methods* **15**, 799–804 (2018)

[2] V. Hinger *et al.* *J. Instrum.* (forthcoming)

[3] D. Greiffenberg *et al.* *J. Instrum.* **14** (05), P05020 (2019)