PAUL SCHERRER INSTITUT

Low-energy x-ray detection with JUNGFRAU

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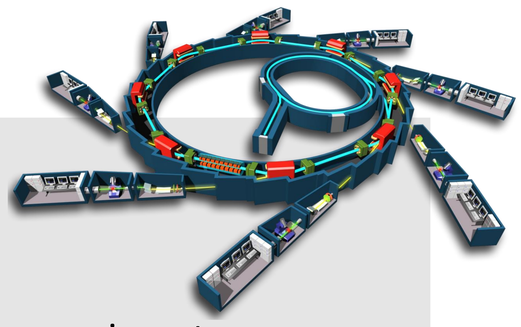
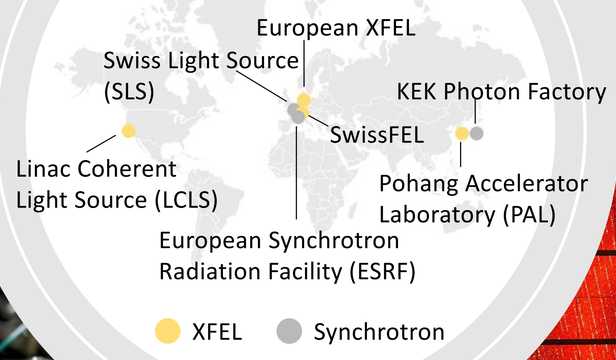


Applications of JUNGFRAU

At free-electron lasers (FEL)

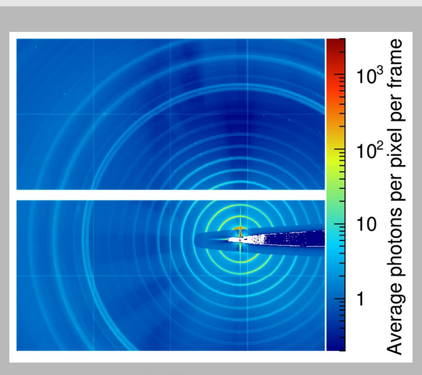
- Original field of application for JUNGFRAU
- Short (fs), intense x-ray pulses
- Observe **ultrafast processes**
- Probe **electronic structure** of materials

Facilities operating JUNGFRAU

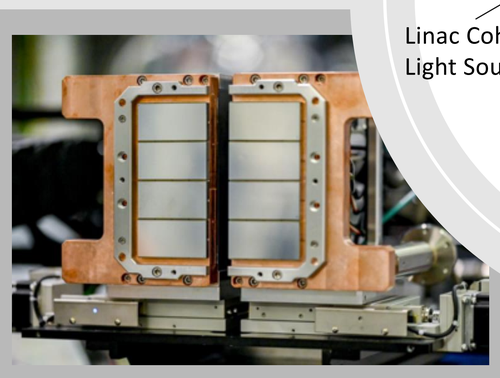


At synchrotrons

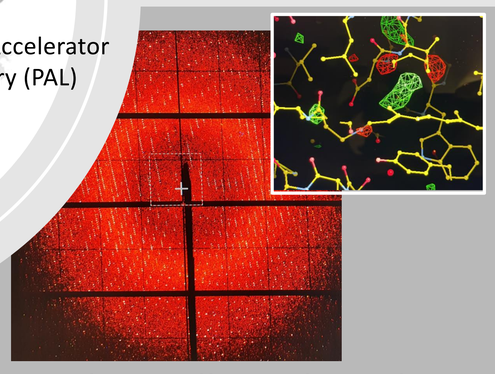
- **Fast, time-resolved** experiments
- Applications, for which **charge sharing** and **pileup** limit the capabilities of photon counting detectors [1]



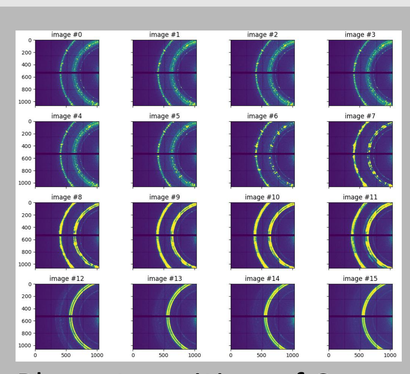
Powder diffraction at LCLS



Four-megapixel JUNGFRAU system at EUXFEL SFX beamline



Serial crystallography with **1 ms time resolution** (visiting MAX IV, Sweden)



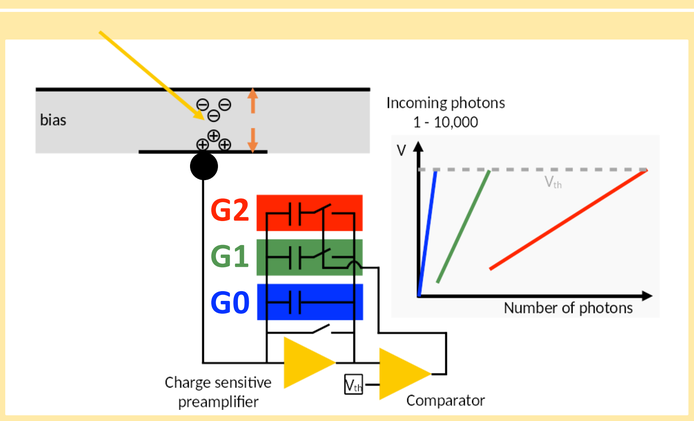
Phase transition of Sn, measured with **7 µs burst mode** at ESRF ID09

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 × 75 µm²)
- Three **dynamically switching** linear gains per pixel
- **Noise below Poisson limit** over full range
- Maximum frame rate 2.2 kHz



JUNGFRAU pixel schematic with dynamic gain switching architecture

JUNGFRAU 1.1

- Newest ASIC version
- Improved **output linearity**
- **Noise** reduced from 52 e^- (version 1.0) to **< 34 e^-** in high gain

Poster by **M. Carulla**

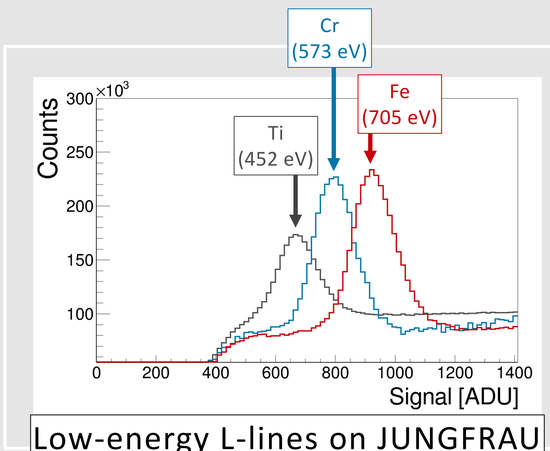
Entering new territory: Soft x-ray detection

Talk by **J. Zhang**

First results are looking strong!

Thin entrance window (TEW)

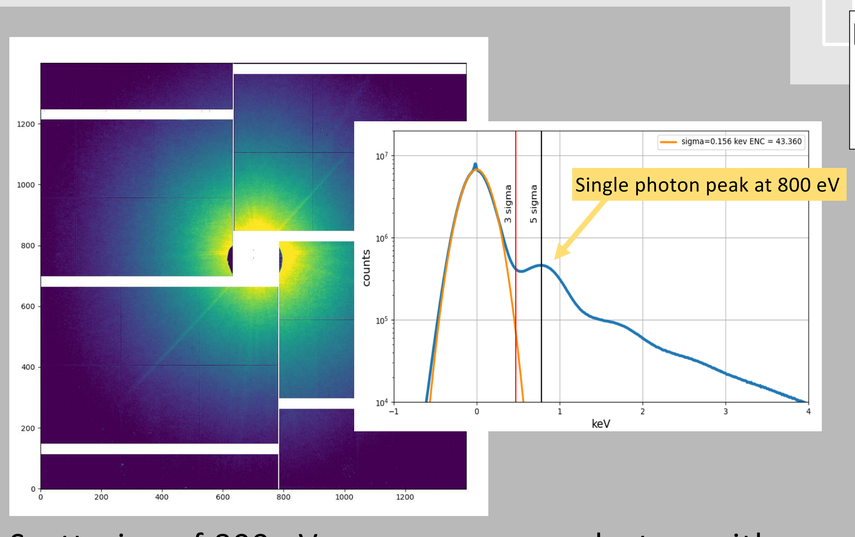
- Improve **quantum efficiency (QE)** at low energies
- First system at **SwissFEL Maloja** using JUNGFRAU 1.1 and TEW sensors
  → Enables **single photon** detection down to **800 eV**



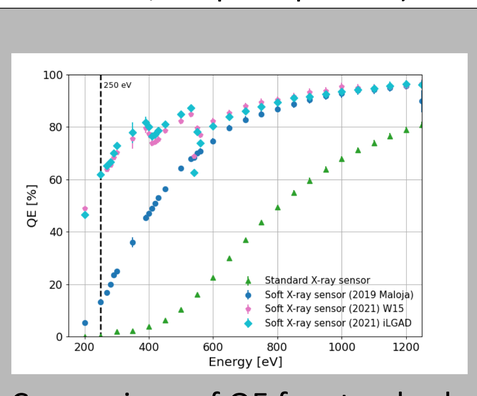
Low-energy L-lines on JUNGFRAU iLGAD in high gain (2×2 clusters, -22°C, 10 µs exposure)

Low gain avalanche diode (LGAD)

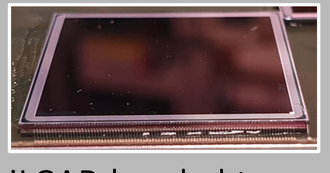
- Sensors with **intrinsic gain ~ 10**
- **Inverse LGAD (iLGAD)** with TEW
  → Cooling required due to leakage current
  → **Noise ~ 5 e^-** (-20°C, 5 µs exposure)
  → Will enable **single photon** detection down to **~ 250 eV**



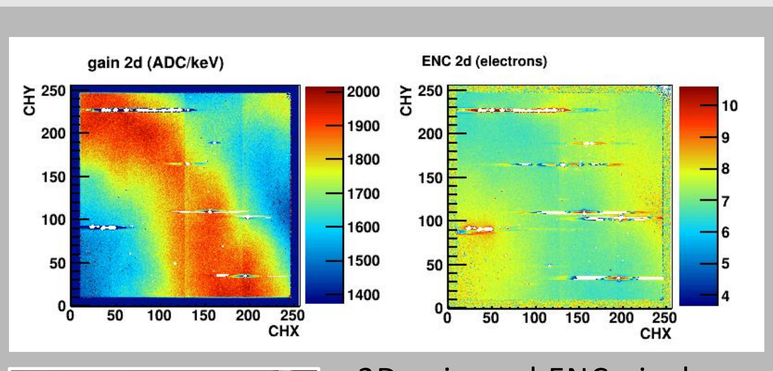
Scattering of 800 eV x-rays on xenon clusters with JUNGFRAU 1.1 and TEW at SwissFEL Maloja [2]



Comparison of QE for standard and TEW/iLGAD sensors



iLGAD bonded to JUNGFRAU 1.1 ASIC



2D gain and ENC pixel map on JUNGFRAU iLGAD (Ti fluorescence at -22°C, exposure 10 µs)

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[1] F. Leonarski *et al. Nat. Methods* **15,** 799–804 (2018)
[2] V. Hinger *et al. J. Instrum.* (forthcoming)