Characterisation of iLGAD sensors on a JUNGFRAU detector in burst mode operation

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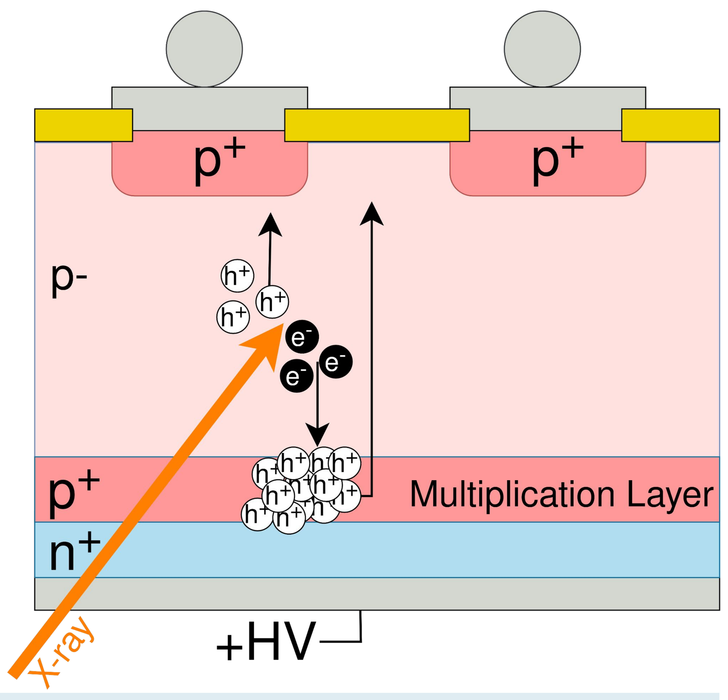
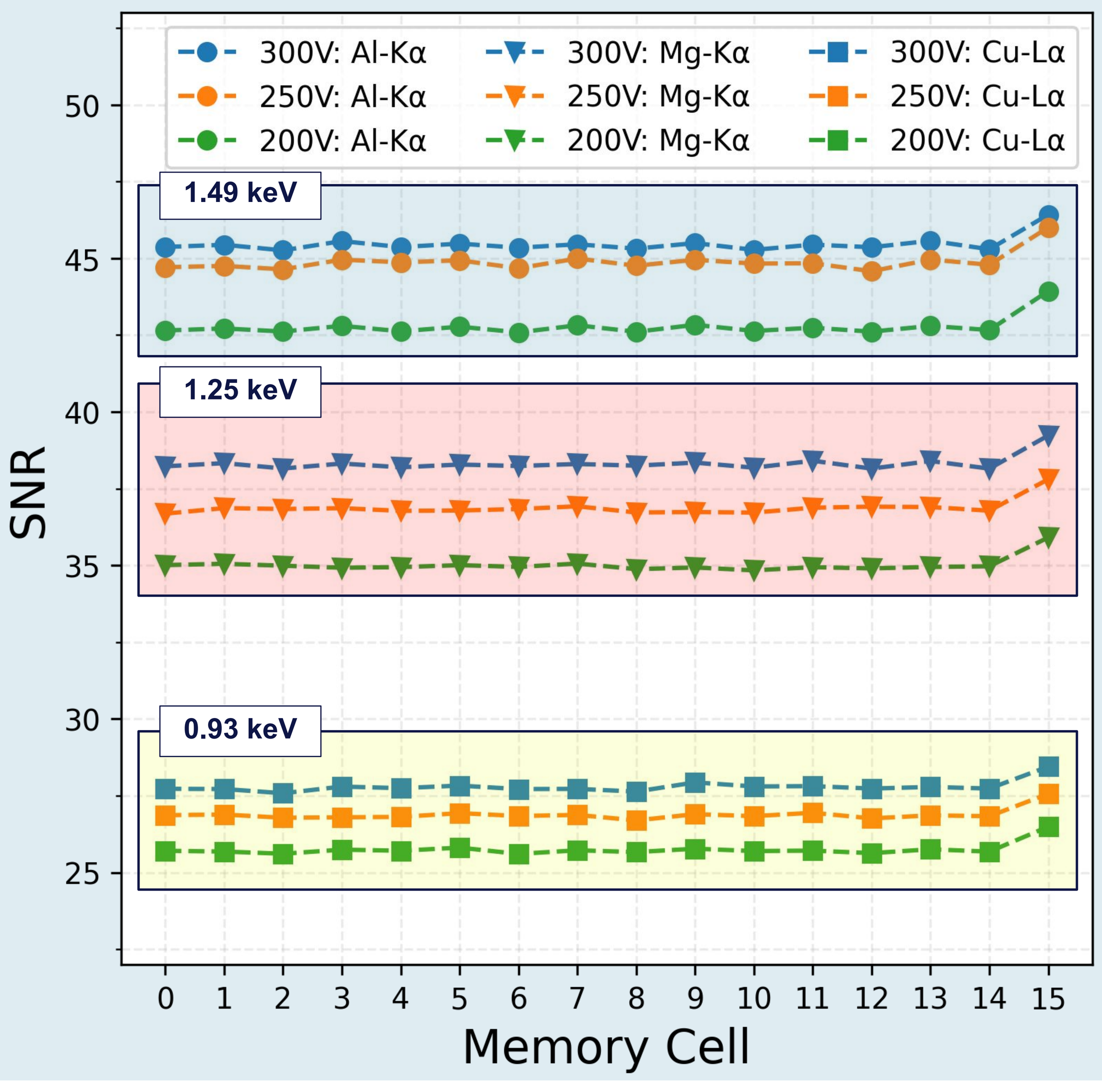
Introduction: Inverse Low-Gain Avalanche Diodes (iLGADs)

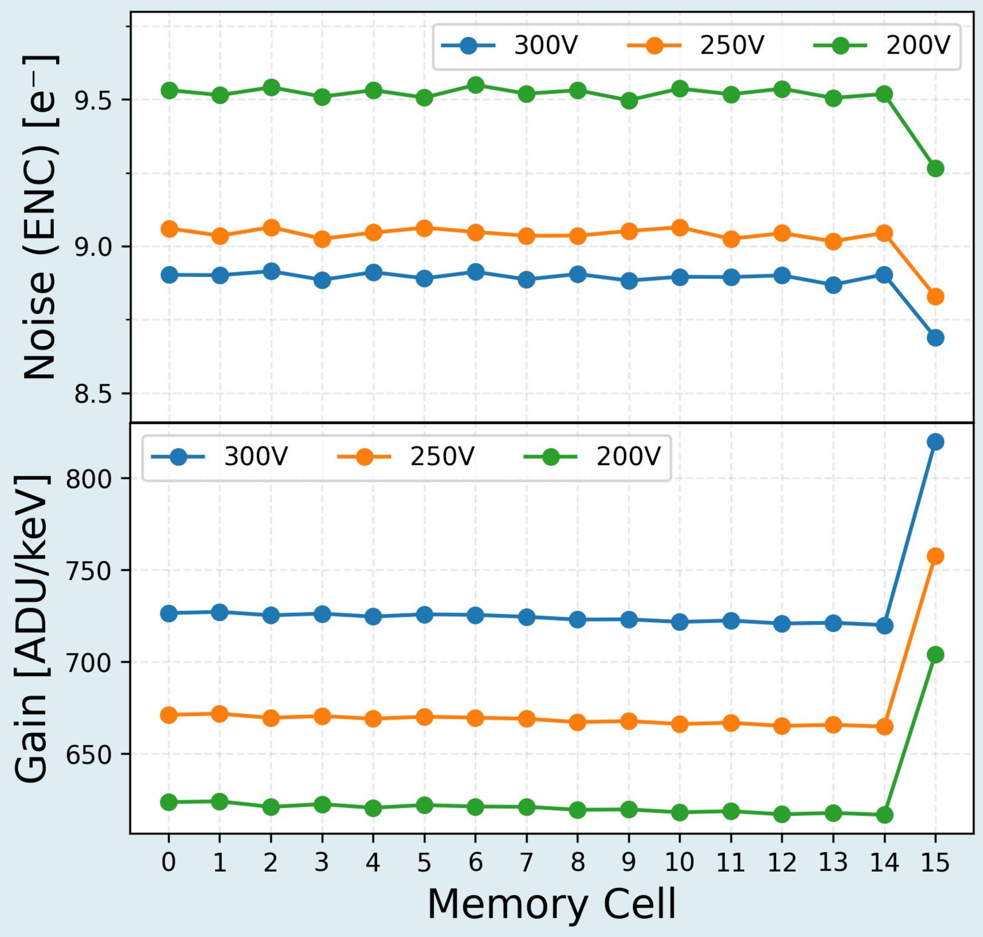
- A challenge of **soft X-ray** detection is the small number of primary electron-hole pairs generated in the sensor, leading to low SNR.
- To overcome this, **iLGAD** sensors [1] have been investigated on a **JUNGFRAU** detector [2], developed by Paul Scherrer Institute (PSI).
- In iLGADs, electrons drift to a multiplication layer with a high local electric field where **avalanche charge multiplication** occurs.
- With JUNGFRAU 1.0, **16 images** can be acquired in **burst** at a rate >100kHz, allowing to exploit the high repetition rate of the Heisenberg Resonant Inelastic X-ray Scattering (**hRIXS**) spectrometer at EuXFEL, which additionally requires low noise and high spatial resolution.



Sensor Characterization

- A prototype with 2x2 ASICs was characterized with **PulXar**: a pulsed X-ray system based on an electron gun and multiple targets producing X-rays with a timing structure similar to EuXFEL.

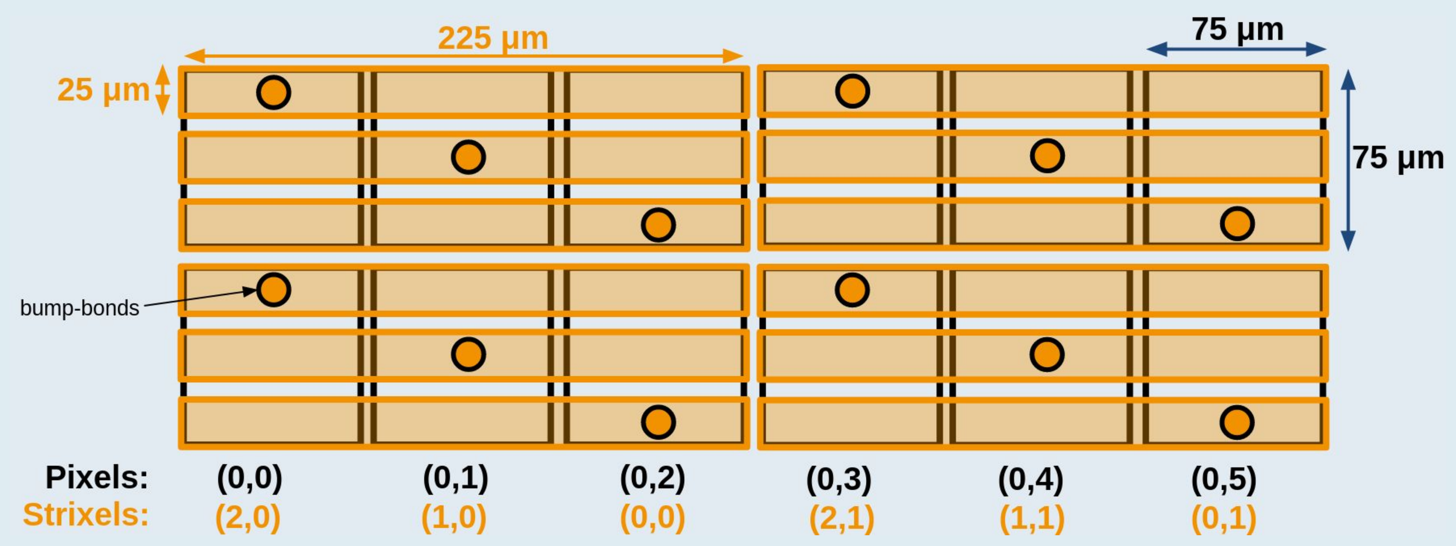




- Measurements were conducted with an exposure time of 5 μs and cooling at -25°C.
- Behaviour is uniform across the 16 memory cells, except for cell 15 (first to be read out) due to its higher capacitance by design.
- Best performance for HV=300V, with average noise **ENC = 8.9±1.1 e⁻** across all pixels and cells, and **SNR ~45 for 1.5 keV** photons.

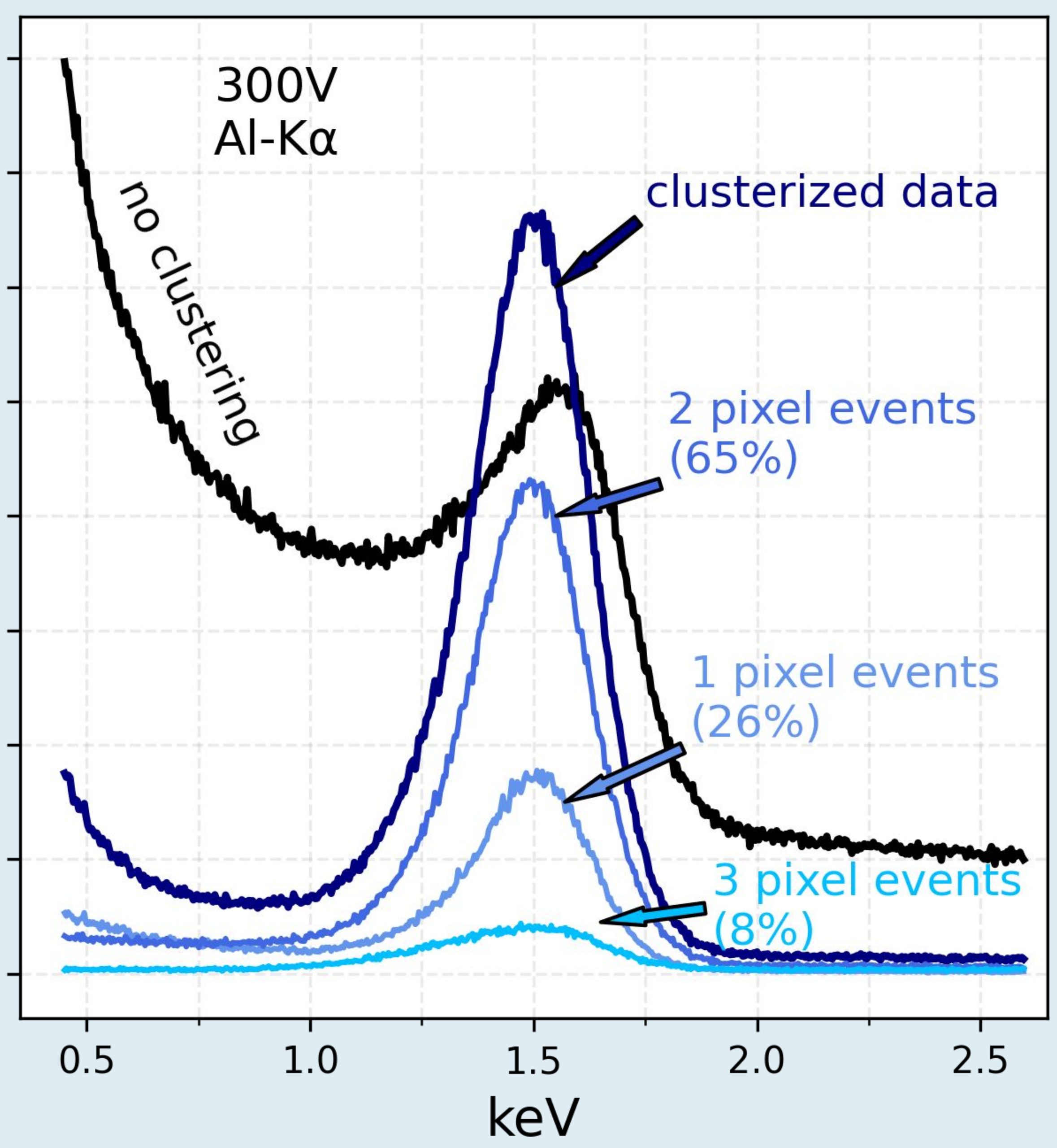
Sensor Geometry

- Sensor features horizontal "strixels" (25x225 μm²) for **increased spatial resolution** in one of the dimensions.
- ASICs are those of standard JUNGFRAU detectors, with square 75x75 μm² pixels.
- The different bump-bond layout requires **pixel remapping** to accurately reconstruct the pixel order in the acquired images.

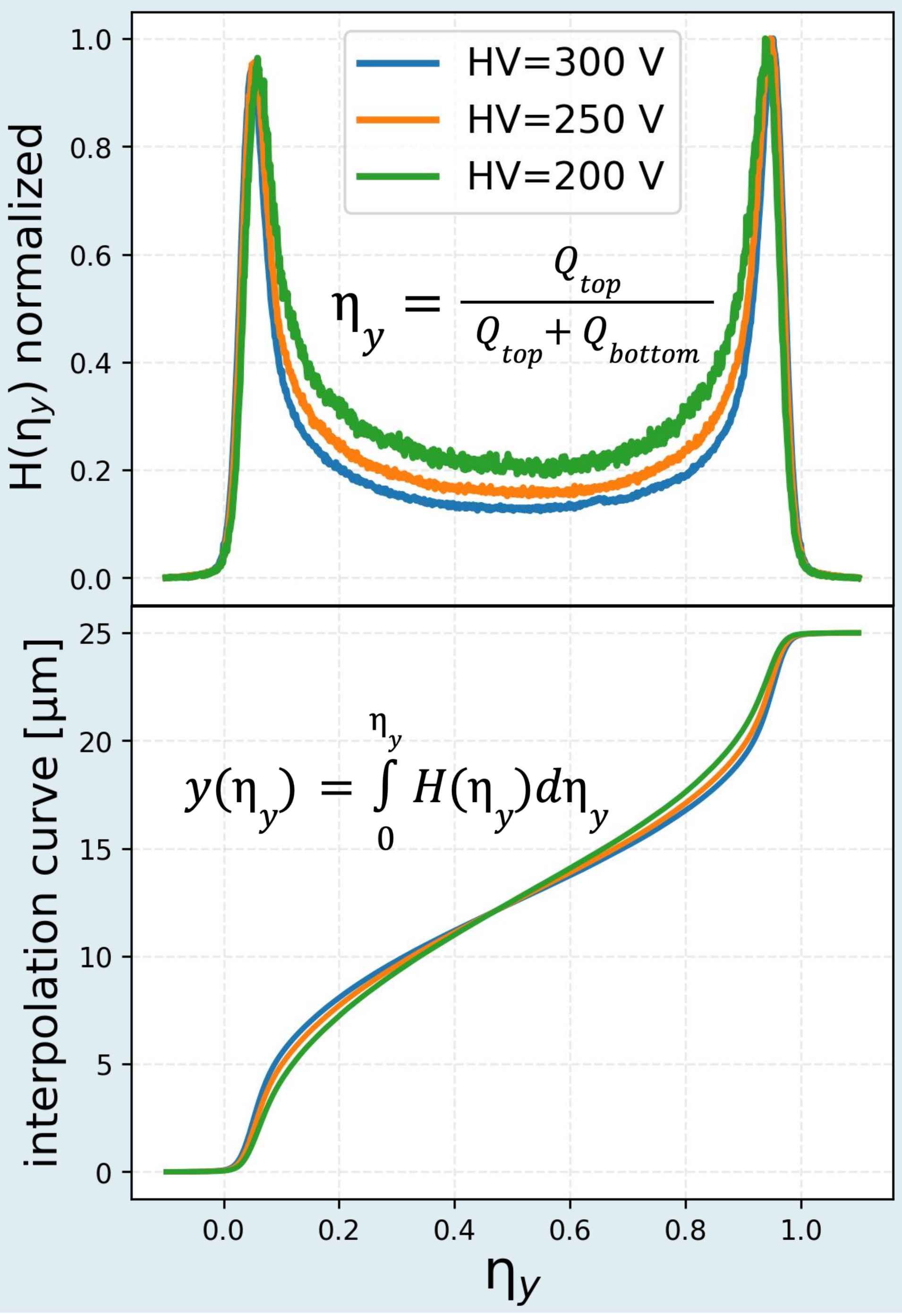


Clustering & Interpolation

- A single photon typically induces signal in multiple pixels across their short dimension.
- Photon hits can be reconstructed by **clustering**:
  - **Charge shared** across a cluster is summed and attributed to the central pixel.
  - **Thresholds** based on pixel noise are applied to determine which pixels belong to a cluster.

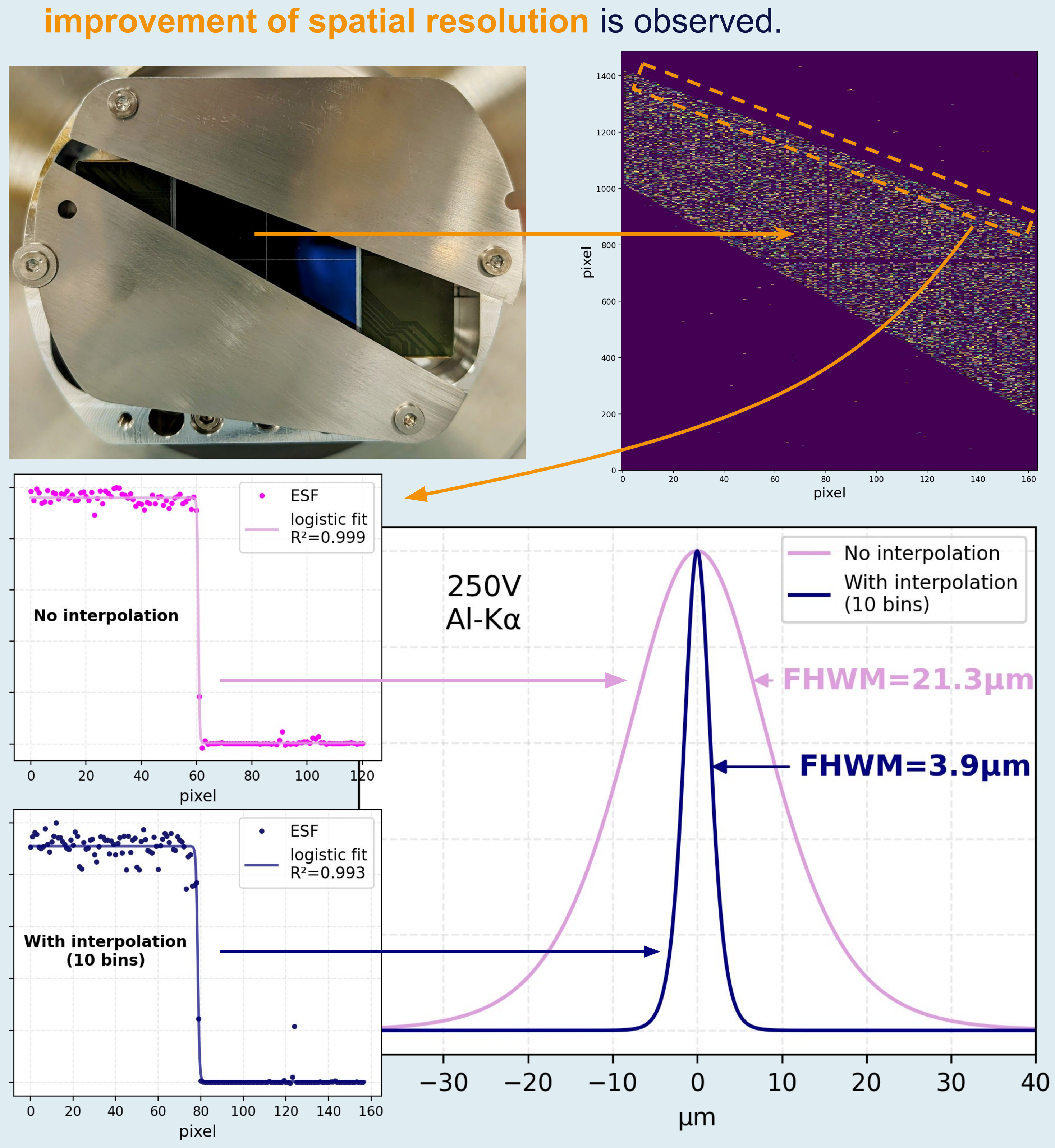


- Charge-sharing information can be exploited for **sub-pixel resolution** through interpolation.
- The **eta-function** quantifies the charge-sharing behaviour across the pixels and is calculated from flat-fields.
- **Lower HV increases charge-sharing**, which improves spatial resolution after interpolation. The compromise between SNR and spatial resolution can be balanced for specific cases.



Sub-pixel resolution

- Knife-edge measurements were done by installing 2 sharp-edged masks, obtained by surface grinding, ~7 mm in front of the sensor.
- The edges are positioned at an angle so that pixels along them have different proportions of light and shadow, covering all possible photon hit positions within pixels.
- The Edge Spread Function (**ESF**) is acquired, and the Point Spread Function (**PSF**) is calculated from its derivative.
- Spatial resolution is calculated from the FWHM of the PSF.
- Employing interpolation with the eta-function method, a significant **improvement of spatial resolution** is observed.



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[1] Hinger, V. *et al.* Frontiers in Physics 12 (2024): 1352134
[2] Sikorski, M. *et al.* Frontiers in Physics 11 (2023): 1303247

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