Towards high-resolution X-ray Spectral imaging

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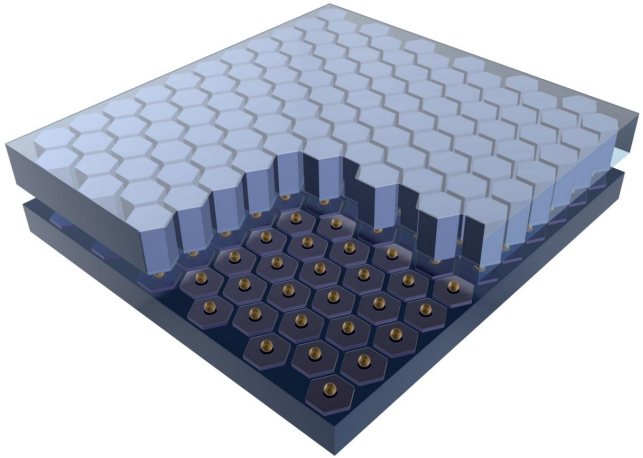
High resolution Imager for X-rays



We plan to develop a new class of **large area , hybrid pixel detectors** with fast, event-driven analog read-out and single-photon sensitivity for high resolution **X-ray spectral imaging of celestial sources** through satellite observations and for **X-ray diffraction (XRD)**, fluorescence and microtomography of industrial, chemical and biological samples.

!Single Photon Position, Energy and Time in one shot!

-) ~10 μm spatial resolution
-) ~300eV energy resolution (FWHM at 8 keV)
-) 50u pixels with high speed and low noise (≤ 30e- ENC) Analog readout
-) Active Area (>2cm^2)

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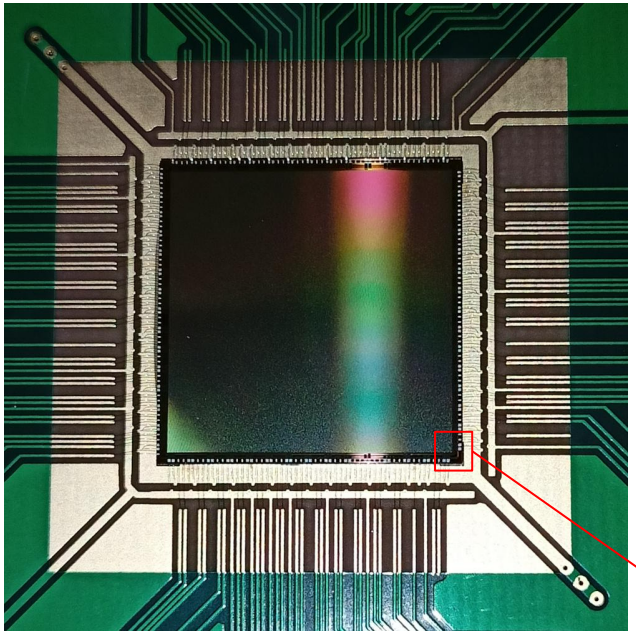
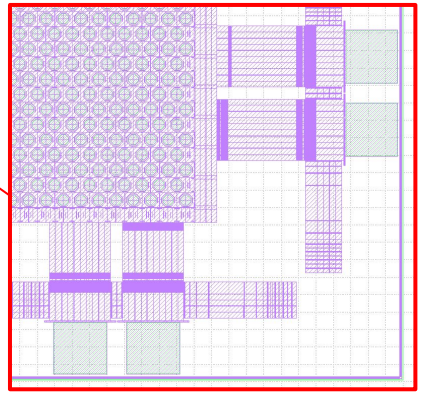
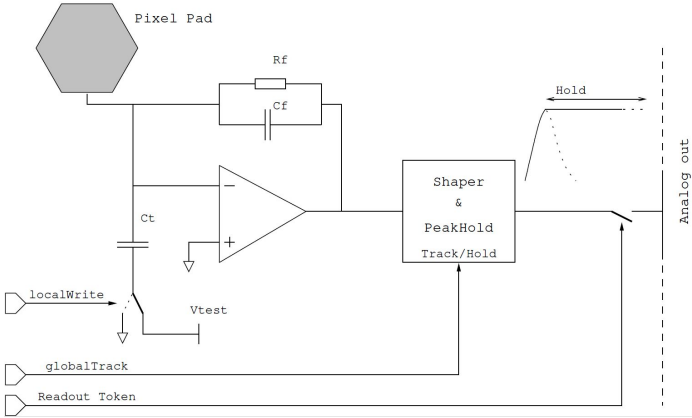
Readout ASIC



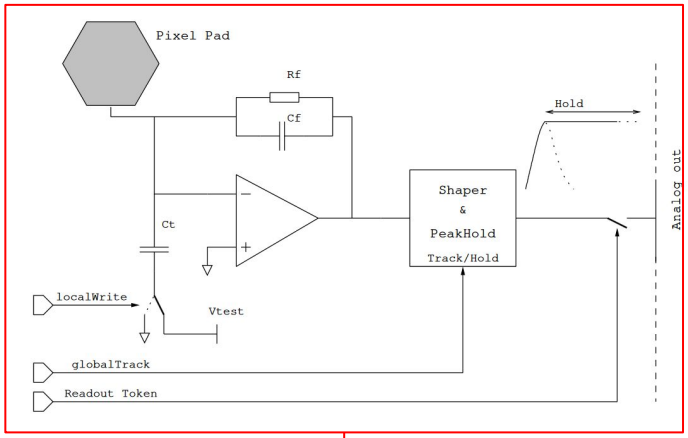
XPOL-III is a readout full custom ASIC developed as part of a GEM based GAS detector for soft X-ray (2-8keV) polarimetry.

- Analog Readout
- CMOS TSMC 0.18u
- **304X352 (107.008) pixels (15.2mm X 15.24mm)**
- **50u pitch (triangular pattern)**
- **Low noise (~30e- ENC)**
- **self triggering**
- adequate rate capability (~10kHz)

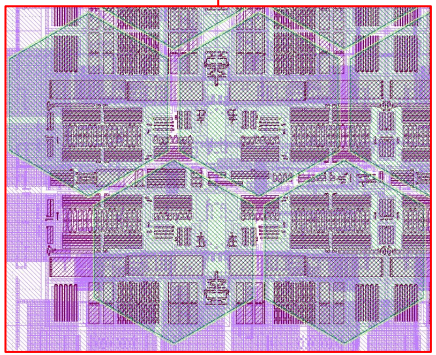




Trigger



X 4



A

In addition to the main signal conditioning chain (CSA + 1us shaper), pixels have a **faster shaper**(O(300ns)). **Every 4 pixels(mini-cluster)**, such faster outputs are summed together and compared versus a global threshold (externally applied) generating a local digital trigger (**mini-cluster trigger**).

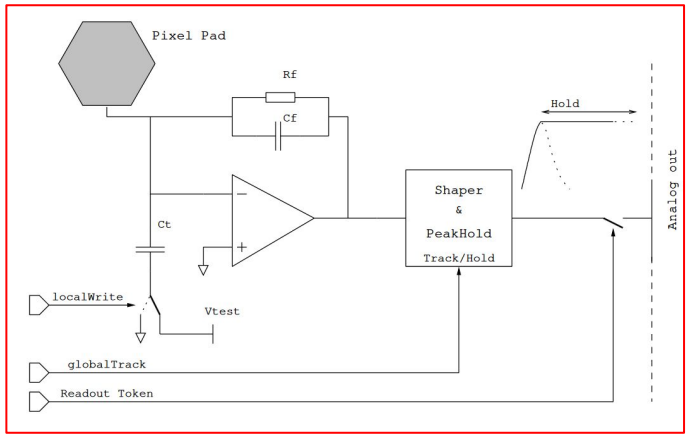
B

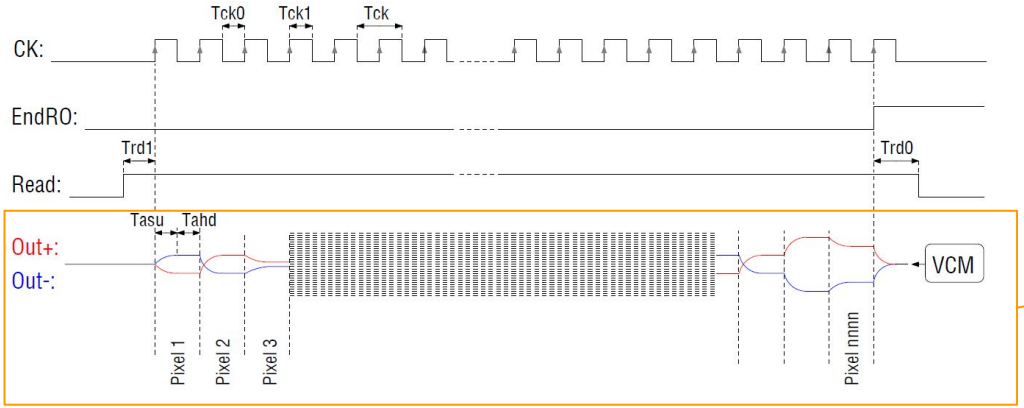
Mini-cluster triggers are **internally or-ed to generate a global (self)trigger signal** (externally routed to the DAQ also) which activates pixels peak detectors.

C

A dedicated logic identifies the **vertices of a rectangular area (ROI) enclosing the triggering mini-clusters** (ROT) + a programmable margin and selects them for the readout

Readout

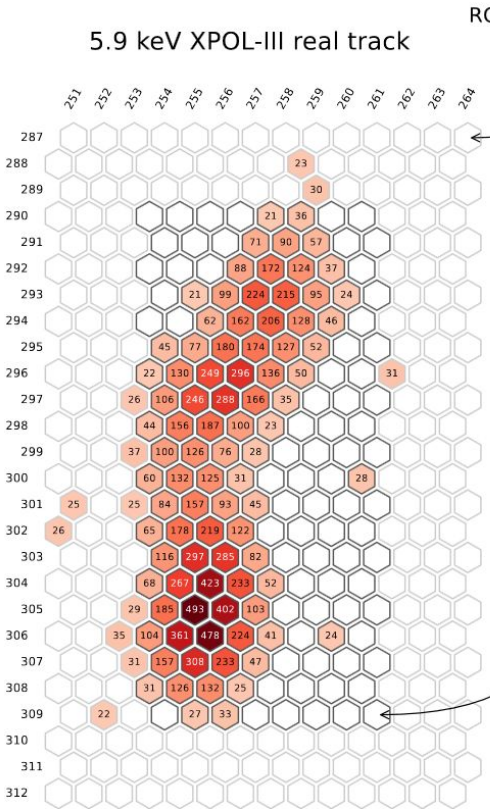




Upon the trigger reception the external DAQ electronics, starts mastering the readout sequence. Which, after the ROI Xmin, Xmax, Ymin, Xmax coordinates have been acquired, consists of a sequential readout of the pixels belonging to the ROI by means of a scan of the pixels peak detectors analog outputs which are serially connected to a differential output buffer at the chip periphery and Analog to Digital (A/D) converted by the DAQ's 14-bits pipeline ADC.

Charge detected by each pixel within the ROI is converted to a differential output voltages to be acquired by the external DAQ electronics

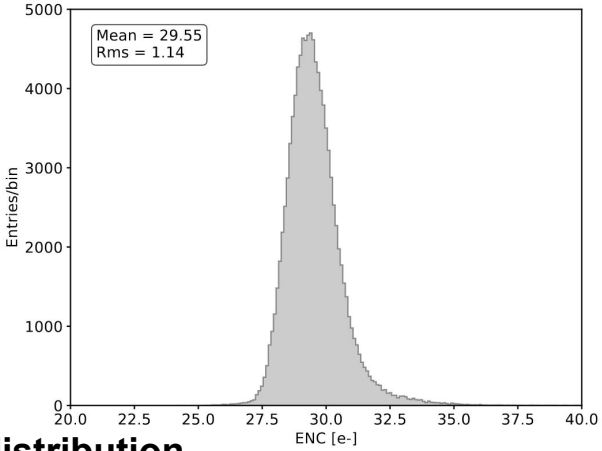
First tests



Example of a real track for a typical 5.9 keV photo-electron as sampled by the readout ASIC in 800 mbar pure DME.

~3.7 e-/ADC count

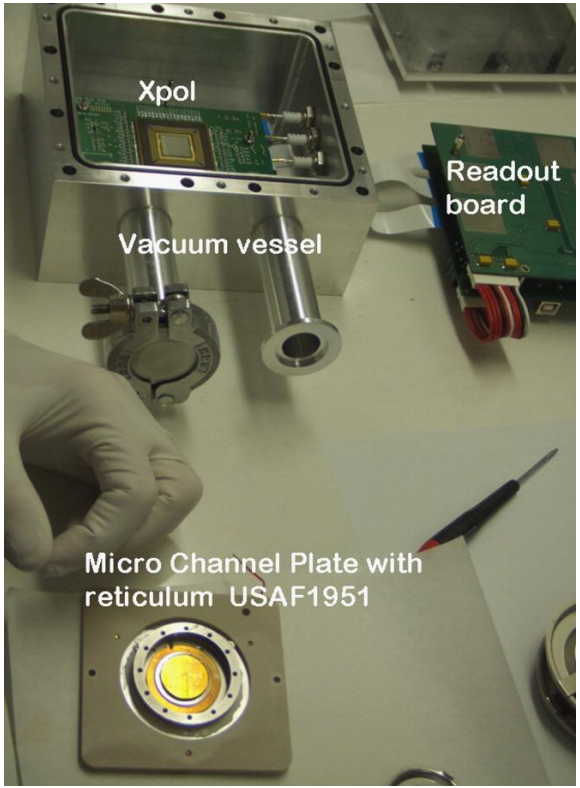
30 e- rms ENC!



!Single Photon Position, Energy and Time in one shot!

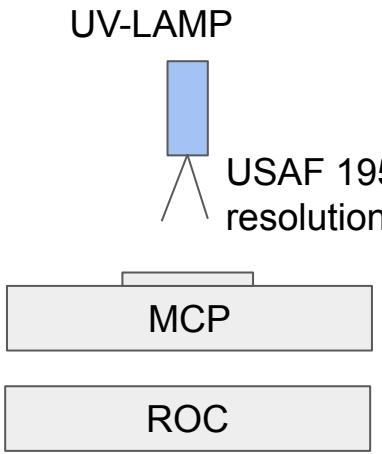
uniform effective trigger threshold distribution (150 e- global threshold)

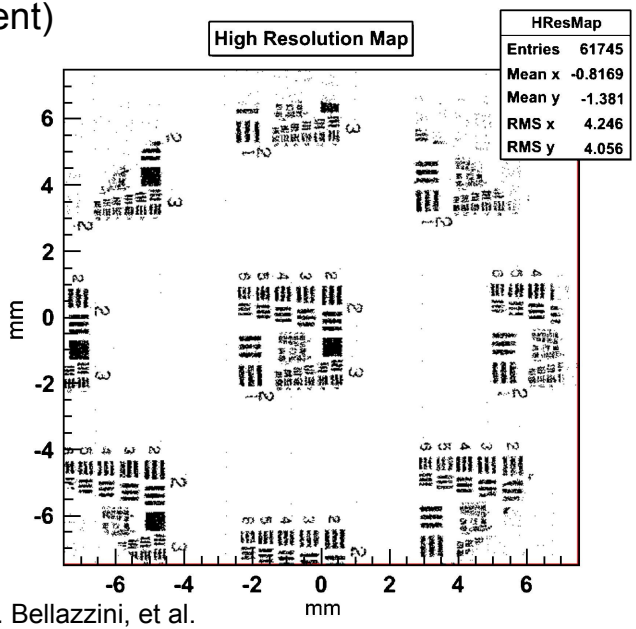
Imaging Capabilities



Sub-pixel resolution Imaging Experiment

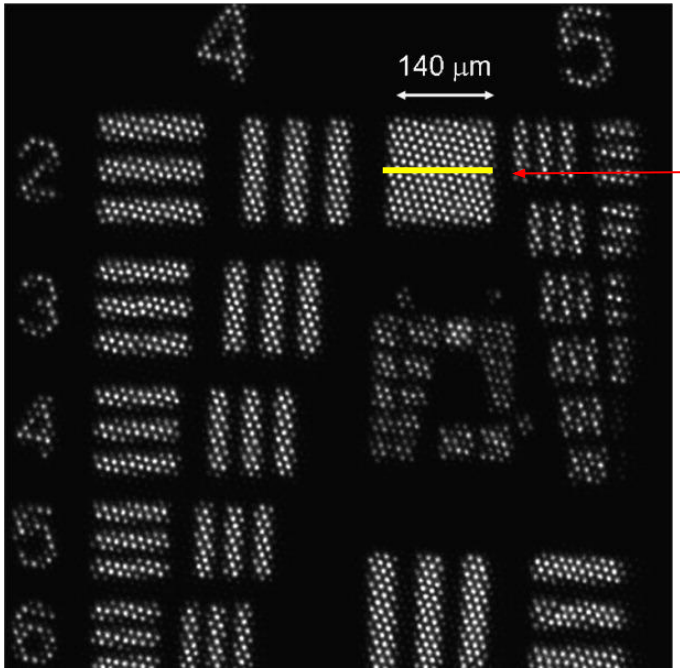
10u pores MCP coupled to our readout ASIC
(50u pixel in hexagonal arrangement)

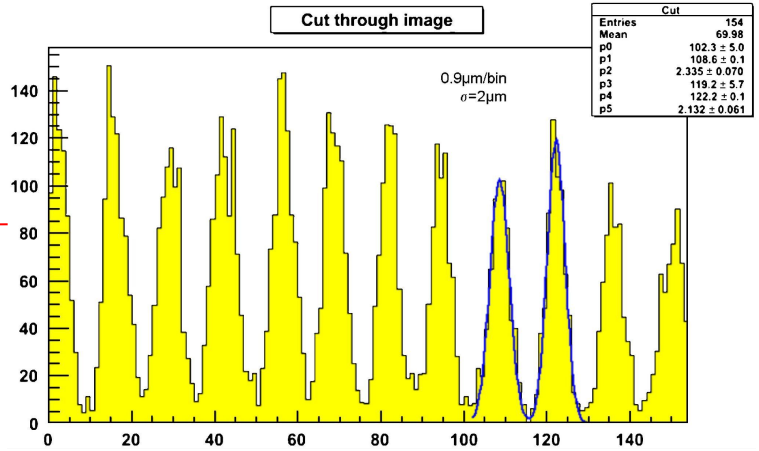




"Single photon imaging at ultra-high resolution" R. Bellazzini, et al.
https://www.sciencedirect.com/science/article/pii/S0168900208004178

Imaging Capabilities



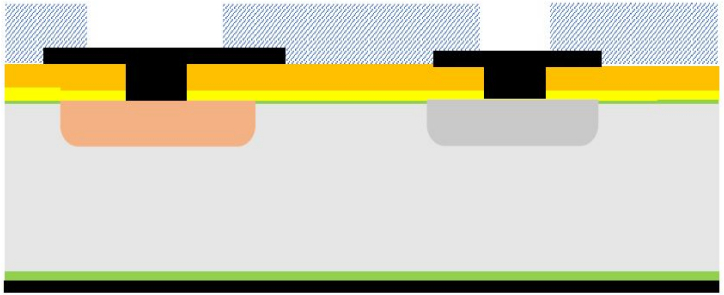


MCP pores 10u aperture / 12u pitch are clearly resolved

Charge converter device is limiting the resolution, readout intrinsic resolution is much lower thanks to the centroid reconstruction

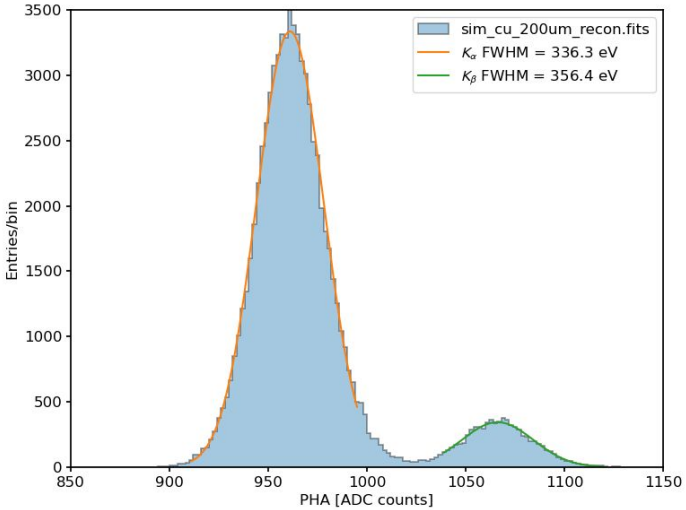
Next Steps

Sensor design and development



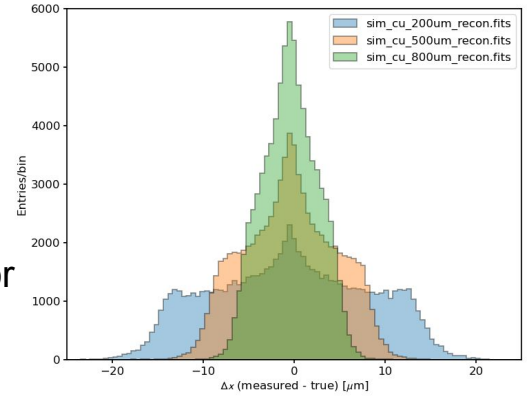
XPOL-III Si Sensor
300u thick 50um pitch

MC Simulations in Si detector



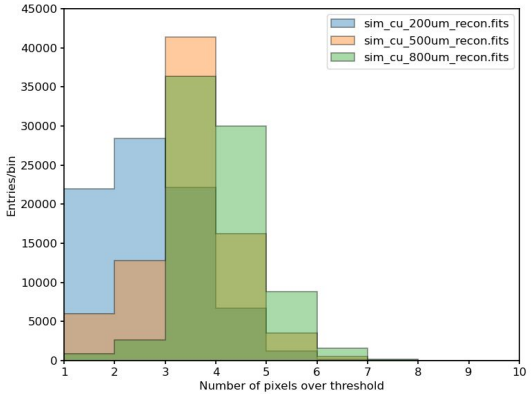
8.028keV Cu-Kα2
8.049keV Cu-Kα1
8.905keV Cu-Kβ1,3

!50u pixels!



Charge barycenter error distribution

Pulse Height distribution shows a clear separation between Cu K-alfa and K-beta lines



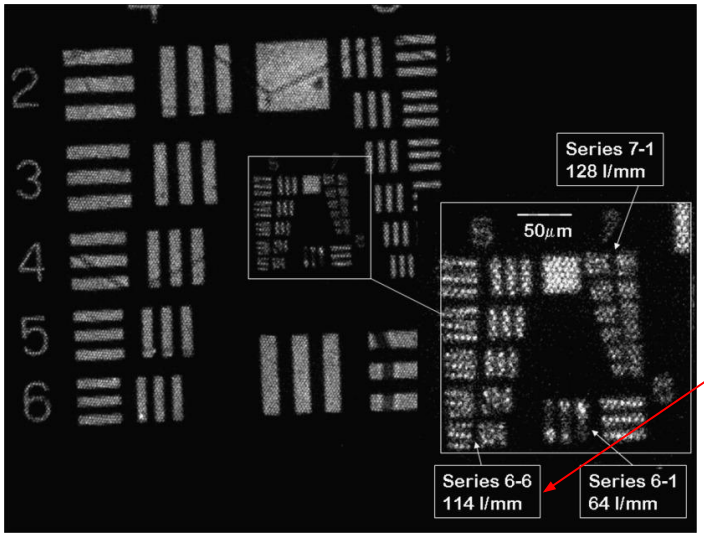
Cluster size distribution

Conclusions

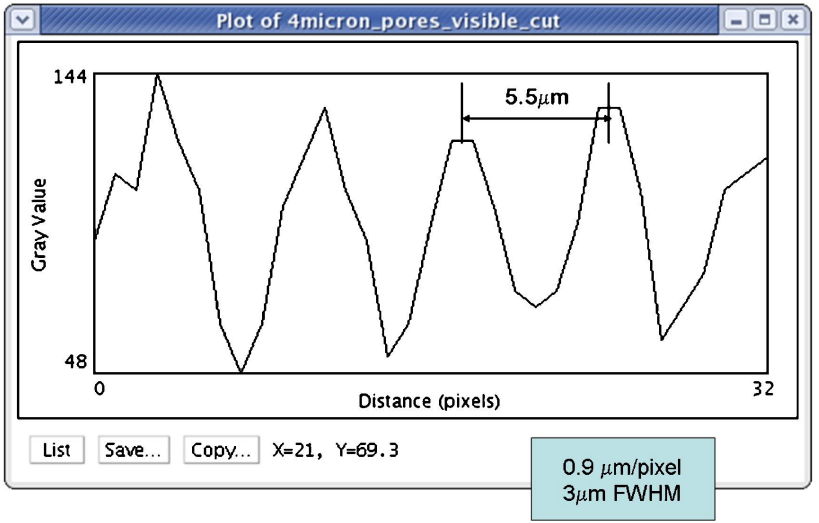
A new approach, based on single photon detection and full analog readout for hybrid pixel sensors is paving the way towards high spectral, positional and timing resolution X-ray imaging.

Preliminary experiments and simulations have been conducted and demonstrate its feasibility.

Imaging Capabilities



MCP 4u aperture pores



114 lp/mm Series 6-6 image profile

spatial resolution still limited by the MCP