XXXV Cycle

Design of a readout chip for X-ray imaging in hybrid pixel detector

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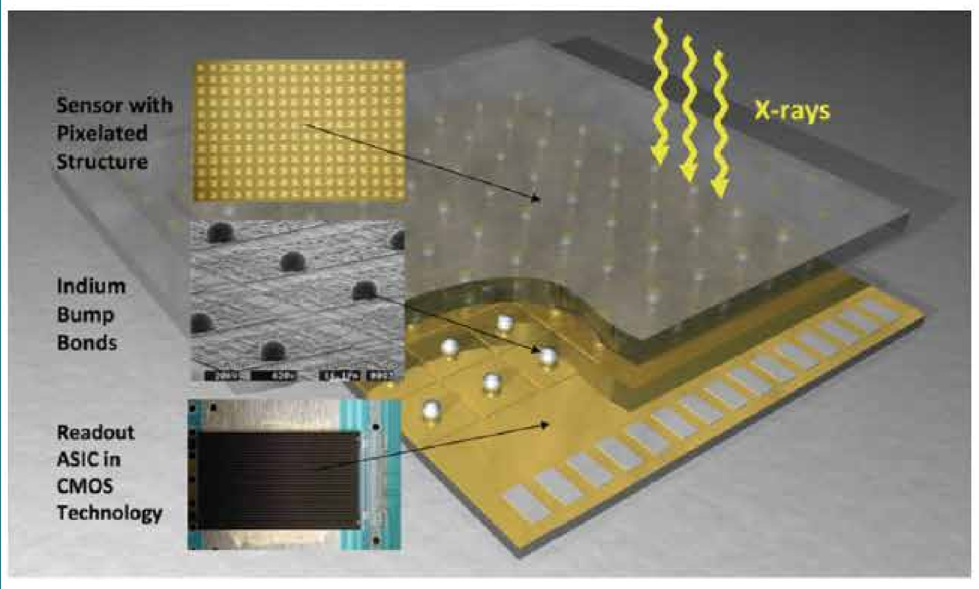
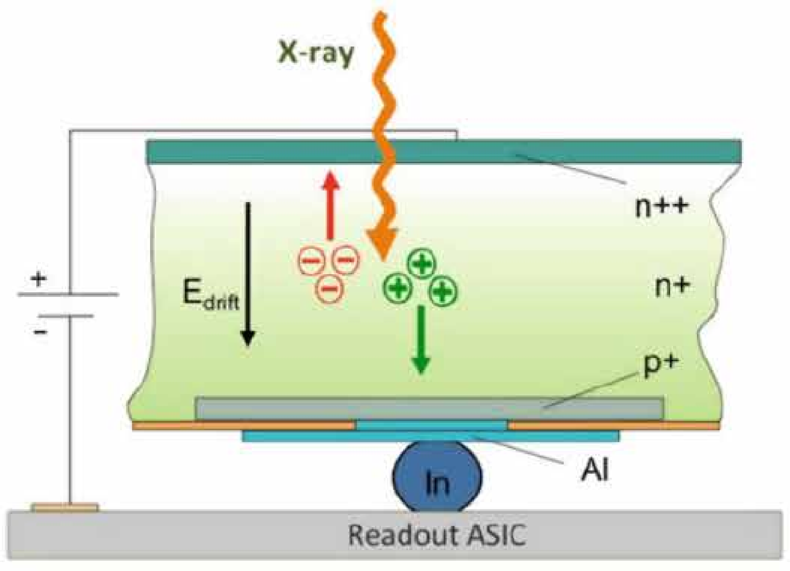
Research context and motivation

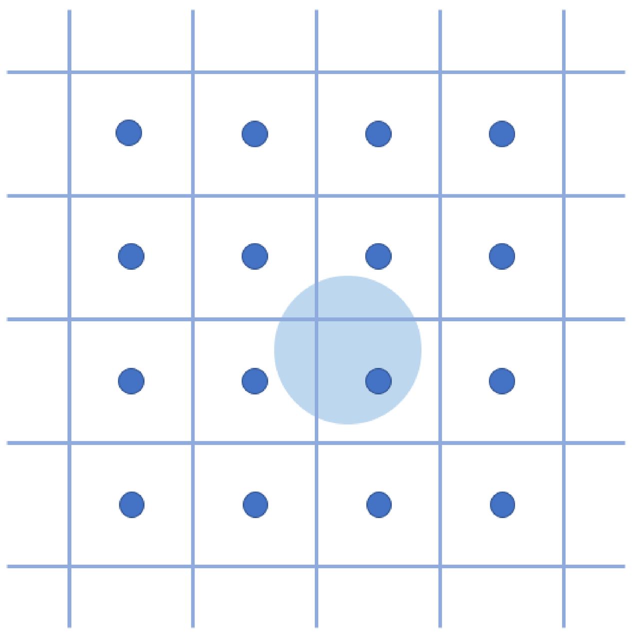
- Hybrid pixel detector is composed of two components, the sensor material and the readout application specific integrated circuit (ASIC), which are connected by bump bonds. The sensor and the readout electronics are processed in different substrate, they can be optimized separately.
- The incoming X-ray photons deposit energies in the sensor and then are directly converted into electron-hole pairs. The carriers are collected by the electrodes and transmitted to the readout chip for processing.
- The hybrid pixel detecor can provide very low noise, excellent contrast-to-noise ratio and very good spatial resolution.
- Applications: High energy physics expriments, synchrotron experiments, X-ray diffraction imaging, spectroscopic X-ray imaging, etc..

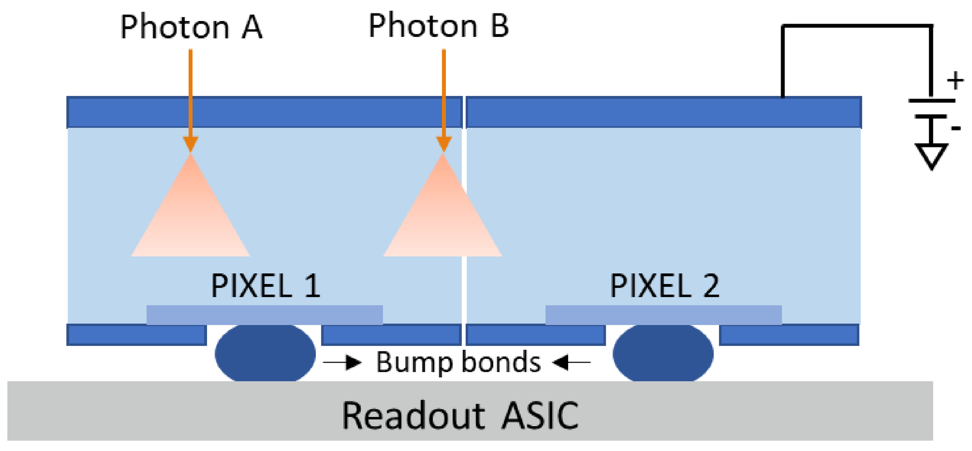




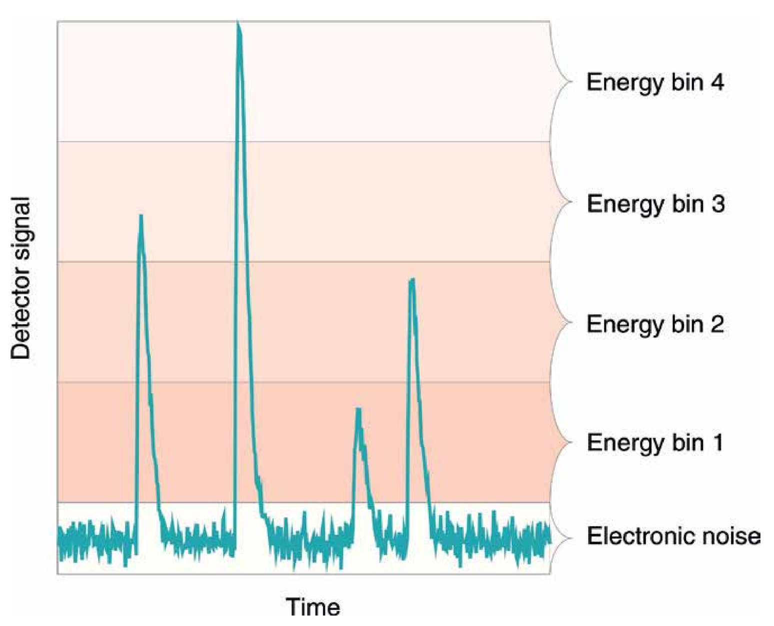
Addressed research questions/problems

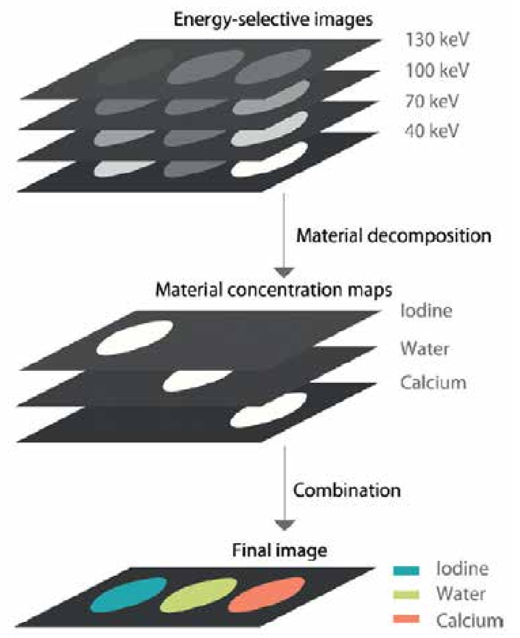
- Charge sharing effect: Under the electric field, during drift, the charge cloud expands due to diffusion effect and electrostatic repulsion. If the pixel size is much smaller than the sensor thickness or the photon absorption takes place close to the pixel boundary, the charge cloud may spread over several pixels. As a result, photon may be ignored or recorded more than once, which would degrade the image quality and energy resolution.





- Multiple energy detection: Measurements with multiple energy bins are required for the material decomposition which can achieve the material identification by the energy dependence of attenuation. One important application of material decomposition is to improve accuracy for measurement of the concentration of a contrast agent and reduce the impact of artifacts in the image.



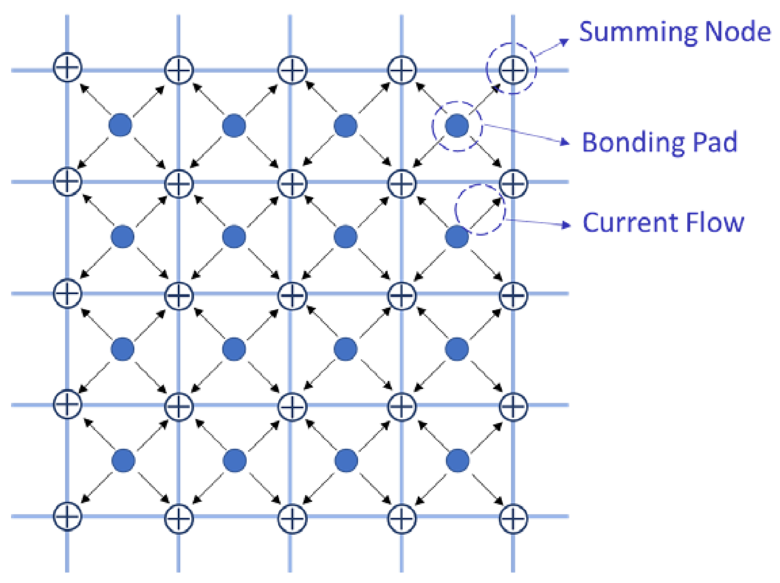


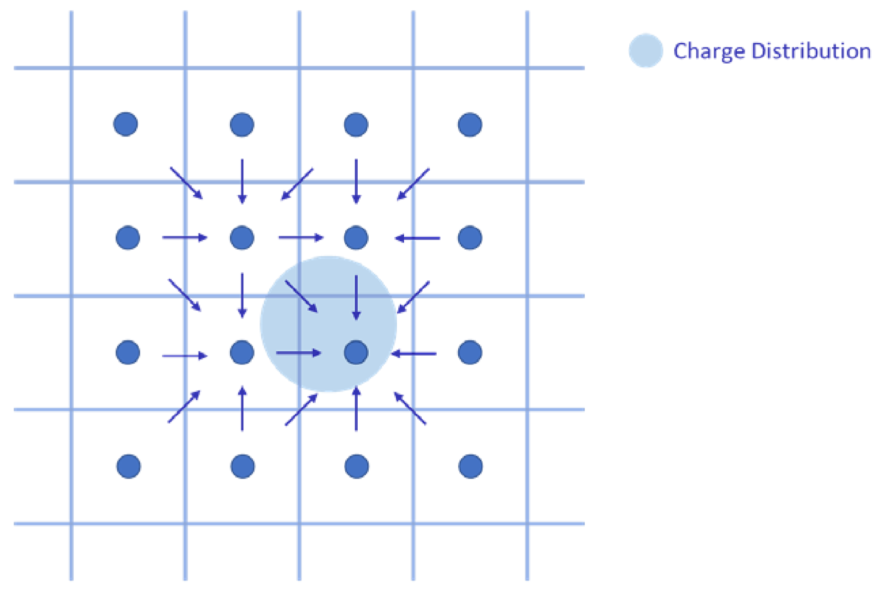
Submitted and published works

- Mian Wang, Zhongwei Bian, Yingjie Wang, Daowu Li, Xiaohui,Li, Jiale Cai, Peilin Wang, Baoyi Wang, Xingzhong Cao , Long Wei, Zhiming Zhang, Peng Kuang, Fuyan Liu, Hongqiang Zhang, Xiaotian Yu, Tianze Chen and Xiangyu Yun, "*A 64-channel high-time resolution digital waveform sampling electronic system based on DRS4 for positron burst annihilation lifetime measurement*", Journal of Instrumentation (Accepted)

Novel contributions

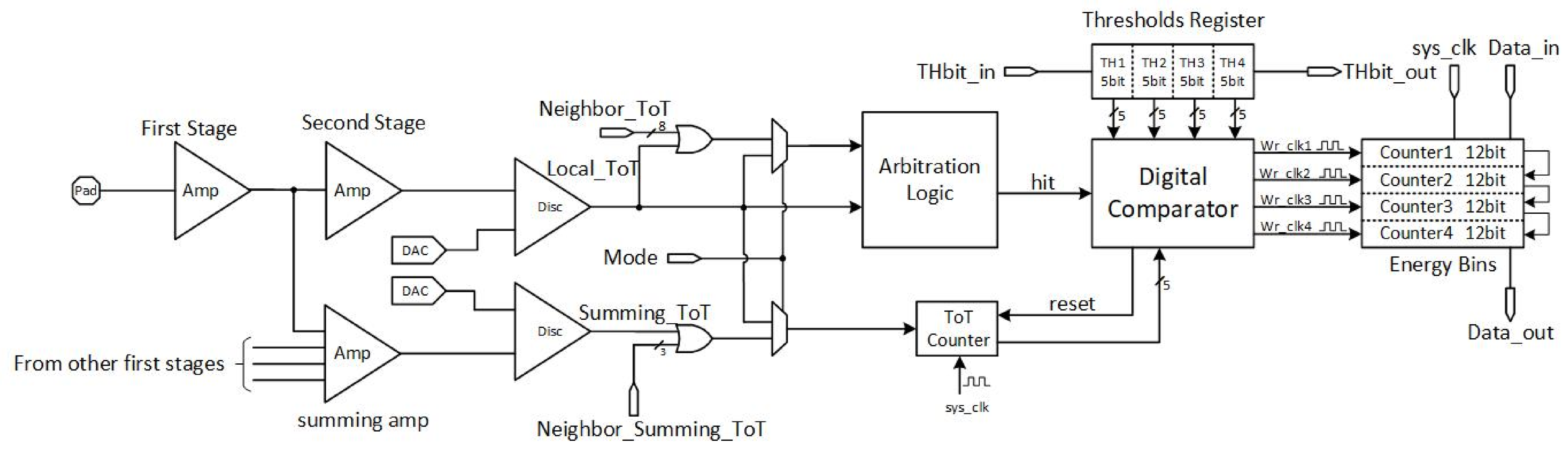
- A summing node is placed at the center of clusters of 4 pixels in order to collect all generated charges and to reconstruct the deposited energies of incoming photons.
- Every pixel is compared with its neighboring pixels and then the whole collected charges from summing node are allocated to the pixel with the largest proportion.





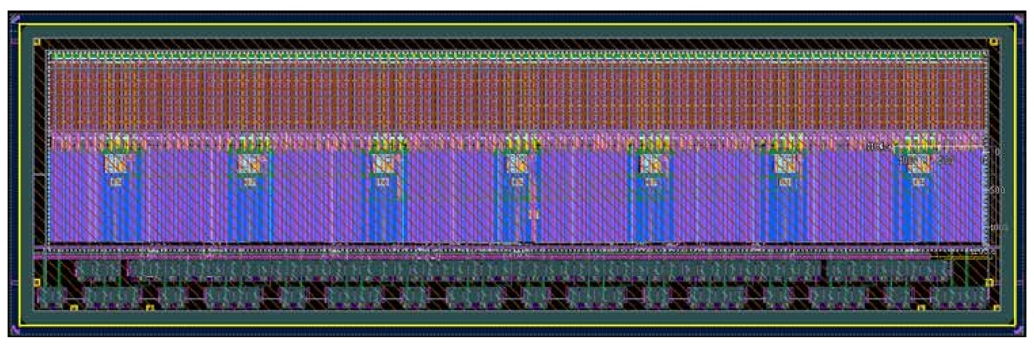
Adopted methodologies

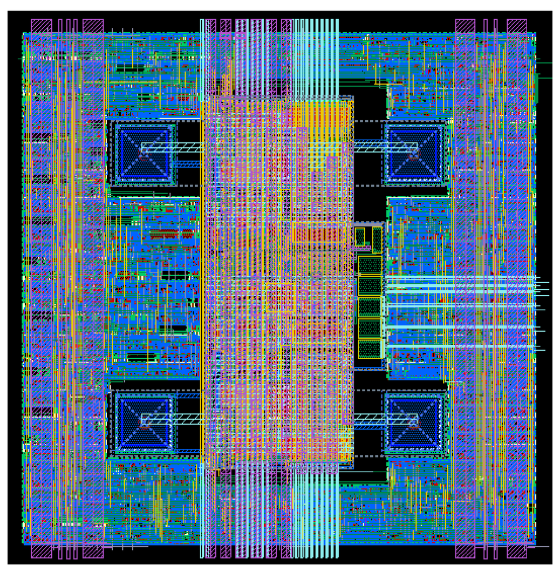
- CMOS 110nm, 6 metals technology was used.
- X-ray energy range:10 ~ 100 keV .
- Shaping time: ~ 100 ns.
- Counting rate: ~ 10^7 cps/mm^2
- Arbitration logic: compares local ToT with 8 neighbor ToTs to decide if local pixel has the largest proportion of the generated charges .
- Digital comparator: assigns a hit to the appropriate energy bin.
- Thresholds registers: define the upper and lower limits of 4 energy bins.
- Energy bins: record the numbers of incident X-ray photons based on their energies.



Future work

- The layout has been submitted to the foundry in July 2022, and the manufactured die will be received in December 2022. The future work will mainly focus on the preparation for the chip test.
- In the next run of submission, we may upgrade the chip with more pixels, more complicated logic to realize more functions.





List of attended classes

- 1NDLRV – Lingua italiana I livello (17/02/2022, 3 credits)
- 01QRGRV – Microelectronics for radiation detection I (waiting for the exam, 5 credits)

Politecnico di Torino

PhD program in

Electrical, Electronics and Communications Engineering