Particam: A fully digital sensor for sub micron resolution

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Motivation:

Over the past decades the spatial resolution of pixel sensors has only marginally improved. Analogue frontends require larger transistor sizes for optimal performance discouraging miniaturisation and the adoption of smaller process nodes.

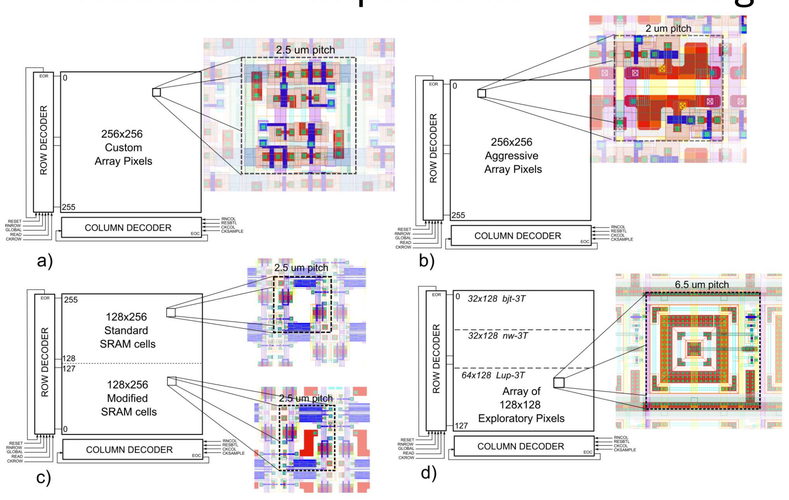
→A new approach is needed to achieve a sub micron spatial resolution

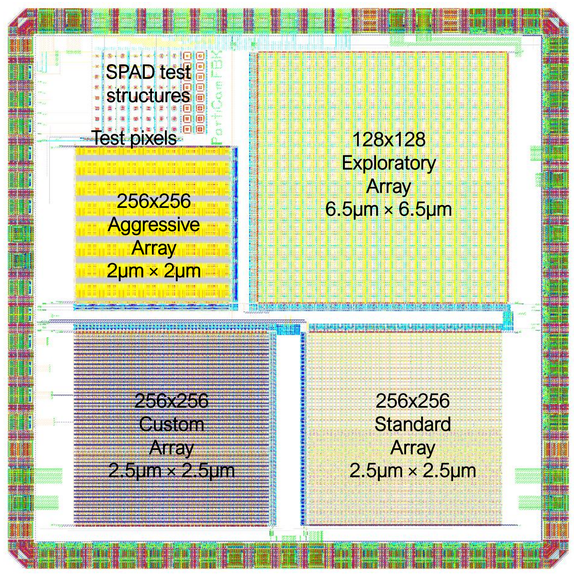
Solution:

Implement the pixel cell as single bit memory cell and harness Single-Event-Upsets (SEU) for particle detection.

Particam1 [1]:

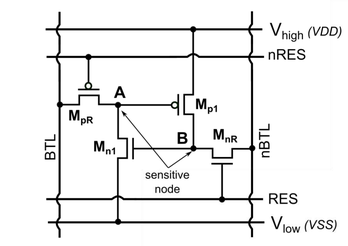
- Implemented in the 65nm UMC node
- 4 matrices with different pixel designs
- Readout via simple address decoding

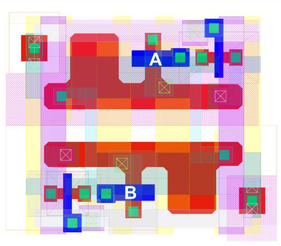


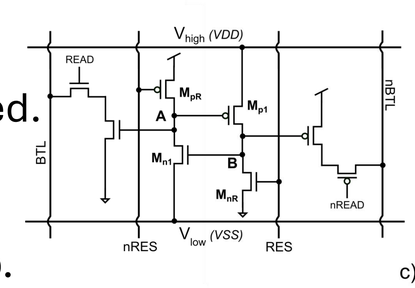


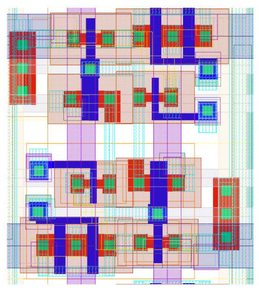
Working Principle:

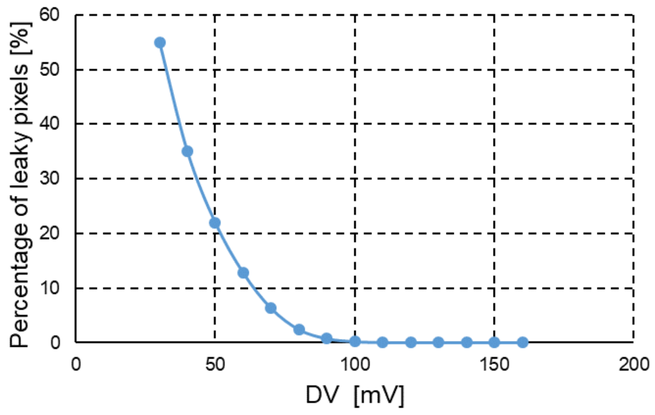
Aggressive (**a**+**b**) and Custom (**c**+**d**) array are implemented as imbalanced flip-flop. Charge induces a flip from 1 to 0 at very low threshold charge C_T compared to the Standard SRAM cell while the opposite flip is strongly suppressed. Transistor leakage current "precharges" the pixel after reset but can also cause the pixel to flip. Increasing DV=VDD-V_{high}=V_{low}-GND reduces leakage at the price of C_T .

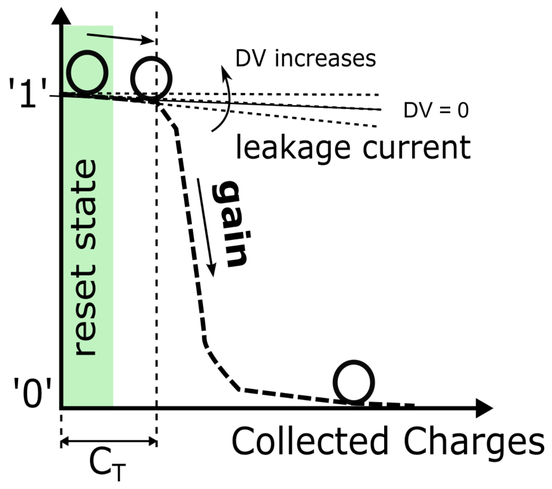


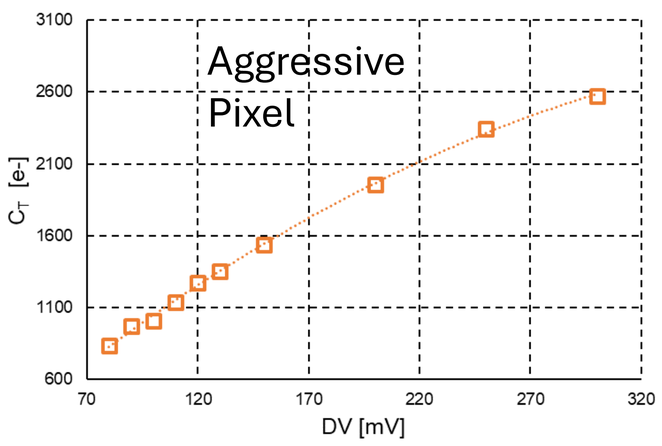


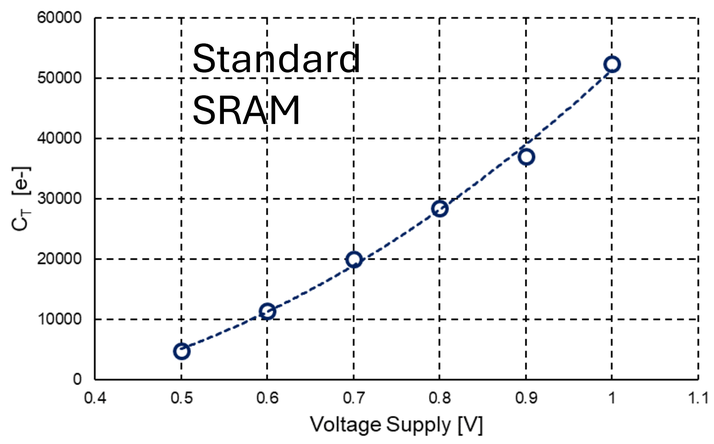






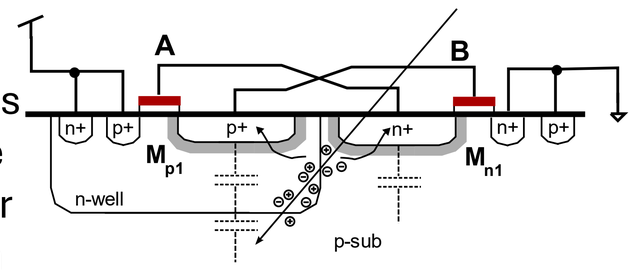


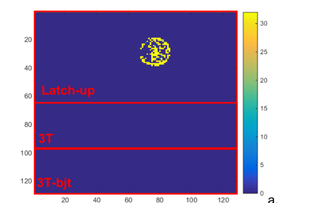


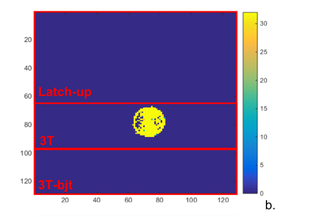


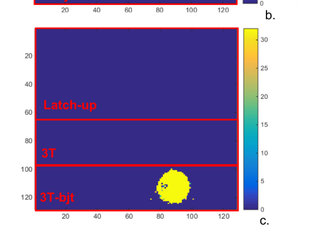
Challenges:

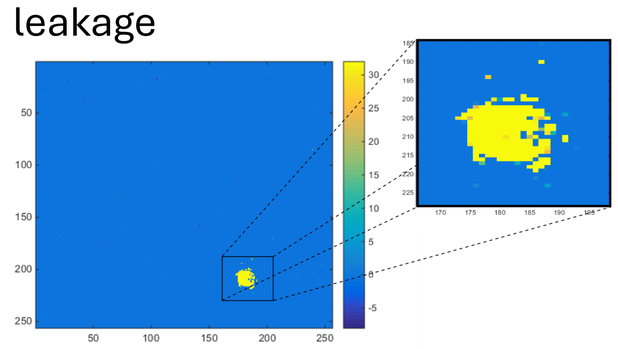
- No deep junctions or large substrate bias result in poor charge collection
- Pixels respond to laser light but only some flavours detect alphas
- Broken address decoders in small pixel matrices
- Periodic resets required due to leakage





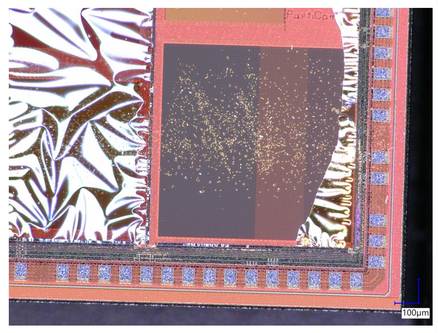






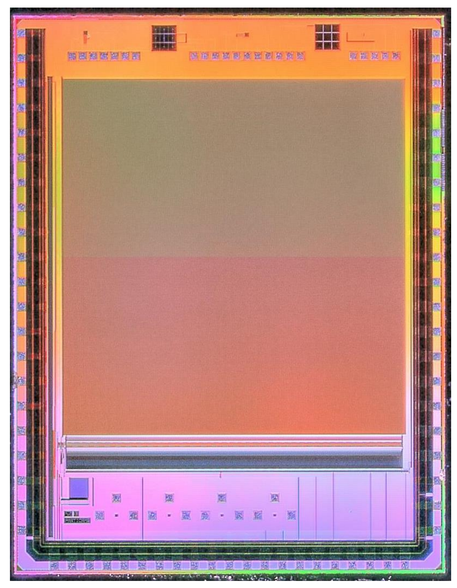
First Application:

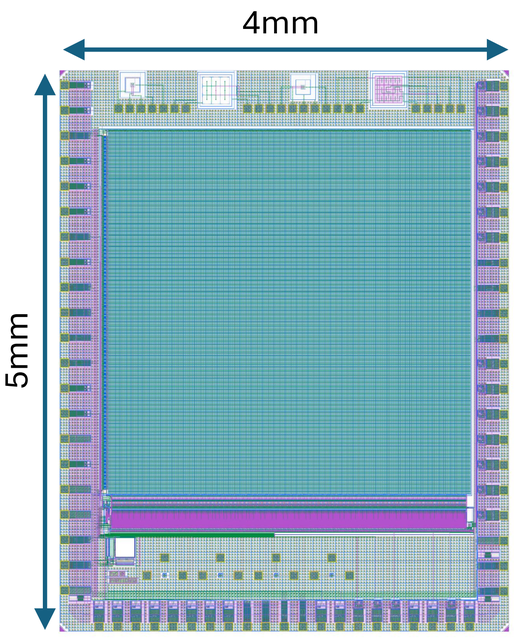
- Coat sensors in boron carbide converter layer for neutron detection at PSI
- First attempt on coating of bare dies unsuccessful
- Coating bonded sensors on carrier in progress



Outlook:

- Particam2, produced in the LFoundry 110nm node, was received recently and is being tested
- Particam2 has a 14µm high resistivity epi-layer and a VBD of ~70V
- Extensive survey of possible process nodes for future designs is ongoing
- Identify possible applications within (linear collider experiments, scattering experiments, testbeam telescope,..) and outside of particle physics (neutron detection, medical physics, imaging,..)





References:
[1] G. Casse et al., "A novel concept for a fully digital particle detector" 2022 JINST 17 P04010

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