Particam: Ultra-high Resolution Sensors

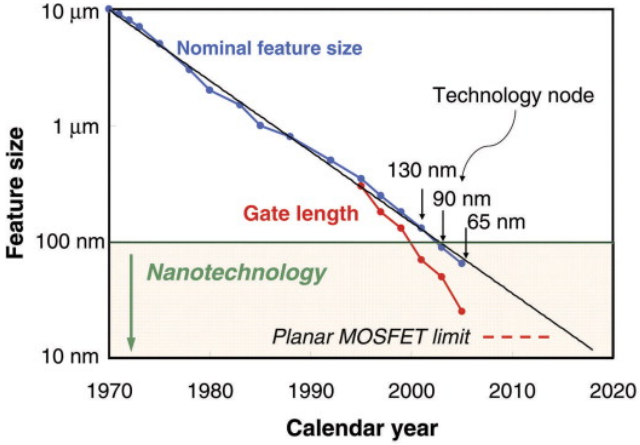
Jan Hammerich[1]
G. Casse [1,2], E. Ejopu[1], M. Gottardi[3], N. Massari[3], L. Parmesan[3]

[1]University of Liverpool, [2]SBAI Universita' la Sapienza (Rome), [3]Fondazione Bruno Kessler (FBK)

R&D Meeting

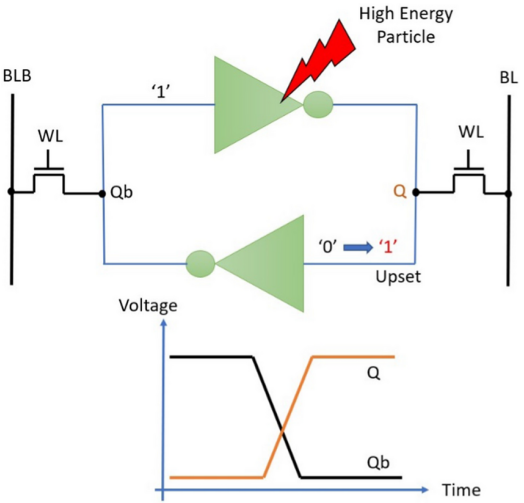
Motivation

- Adoption of smaller feature sizes for particle physics has slowed down over the last years
- Design becomes much more expensive and complex
- Limitations due to bump bonds and transistor size for analogue circuits
- Need a new concept for further miniaturisation to go below $\mathcal{O}(10\,\mu\text{m} \times 10\,\mu\text{m})$ pixel pitch



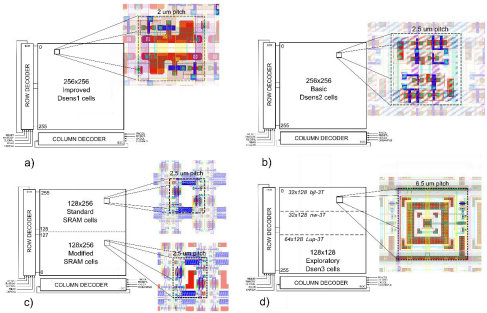
Concept

- Enter the Single Event Upset (SEU)!
- Ionising radiation can flip the content of memory cells
- Normally bad because it can break the configuration of the ASIC
- Much effort is spent minimising the rate and effects of SEUs
- What if we can harness the lightning?

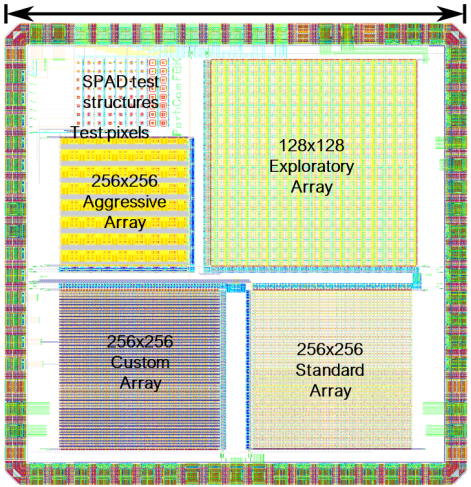


Particam1

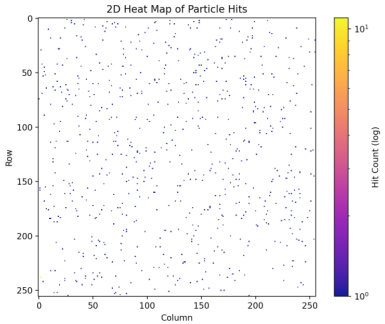
- Generic R&D project
- Demonstrator in UMC 65nm node designed by FBK
- Many different RAM cell designs
- Pixel pitch from 2 µm to 6.5 µm

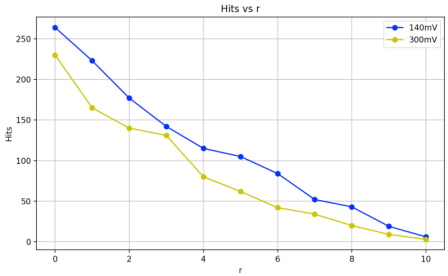


≈ 2.1mm!



Particam1 Alphas



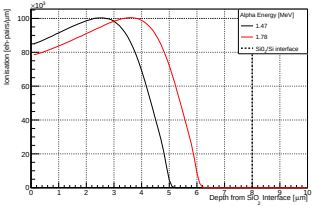


- Particam1 has minimal depletion $\rightarrow$ almost no charge collection
- Some arrays can detect alphas with a 10% efficiency
- Had help from the CTL and the nuclear structure group and got a new strong alpha source
- Idea: Cover Particam1 in a neutron converter and detect

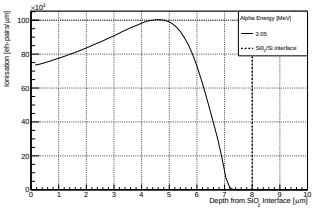
Particam1 Neutrons

- Test Particam1 with converter coating as detector for ultra-cold neutrons with PSI
- Got sensors coated with B10 at PSI and used the neutron source in the CTL
- Couldn't detect anything
- Turns out the alpha from B10 doesn't penetrate deep enough
- Tried again with a Li6 coated device mounted in front of the sensor
- Li6 also doesn't penetrate deep enough

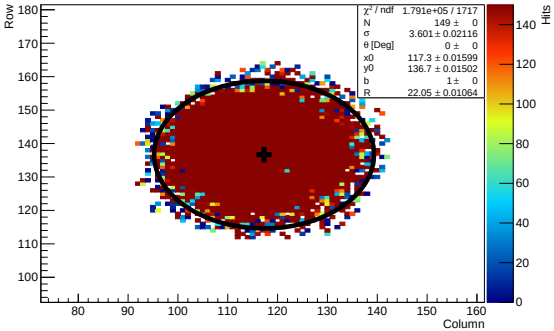
Boron

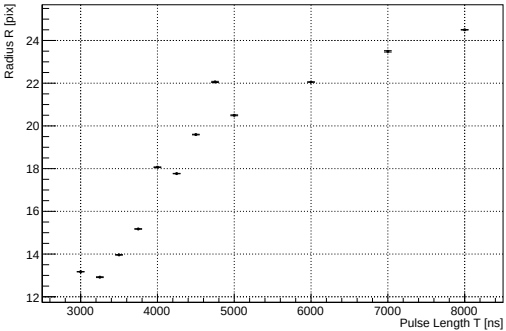


Lithium



Particam1 Laser Measurements

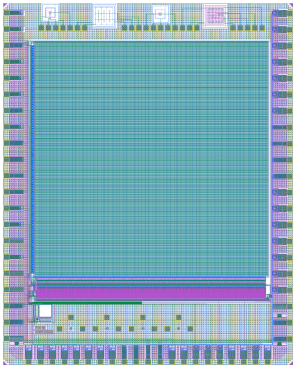


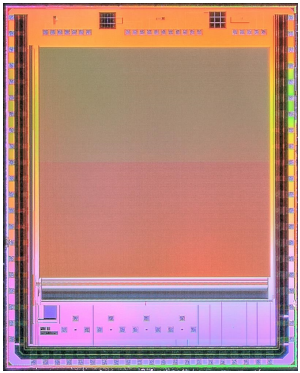


- Particam1 responds to laser beams
- Collaborated with the atom interferometry group to measure the energy dependence
- Measured the spot diameter as function of the pulse length
- Currently investigating use as laser alignment tool

Particam2

- Produced in LFoundry 110nm node, an epi-layer imaging process
- $12.6\,\mu m \times 12.6\,\mu m$ pitch with analogue readout
- Chip designed by FBK, test structures on the top by Liverpool
- Critical processing issue makes the active matrix unusable

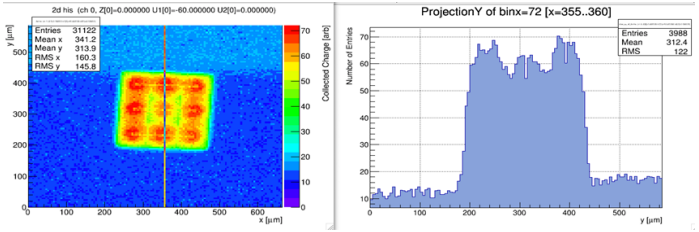




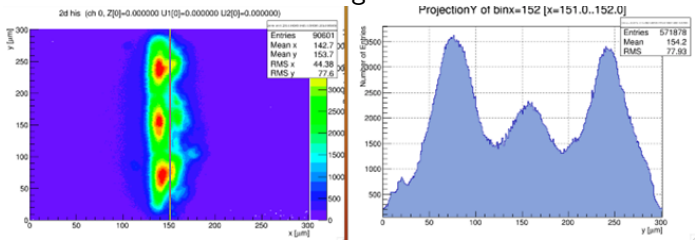
Particam2 TCT

- Test structures could still be used
- TCT setup in Liverpool decommissioned for pEDM
- Managed to get access to the TCT setup in Manchester
- Sensors manufactured on 15 µm high-res epi so depletion is small
- Can resolvea the 1.5 µm metal traces for routing

Top

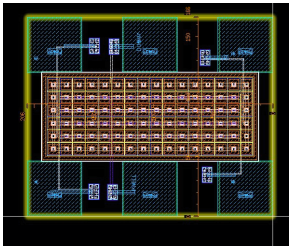


Edge



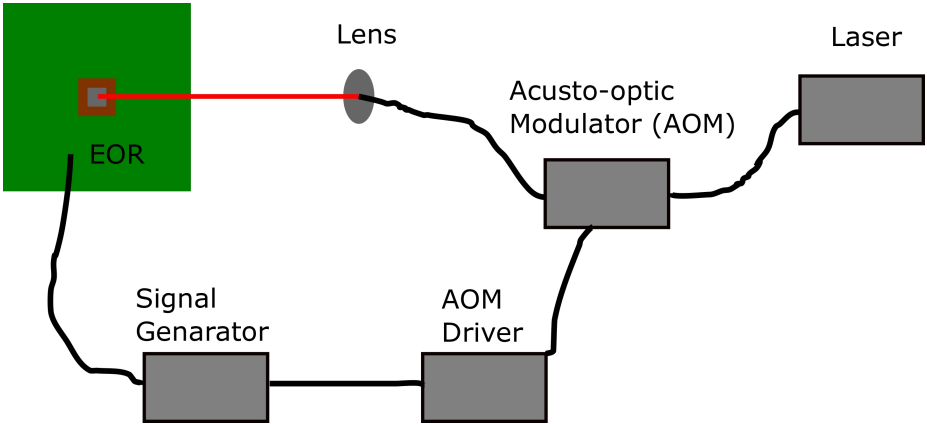
Particam3?

- Evaluating different small process nodes for further submissions:
  - TPSCo 65nm
  - GlobalFoundries FD-SOI: 22nm
- Only got access to the TPSCo 65nm PDK recently and don't have the submission schedule yet
- GF 22nm has 7 MPWs per year, aiming for one in the first half of next year
- Placed a small test structure on a submission from FBK (10.8 µm pitch)



Backup

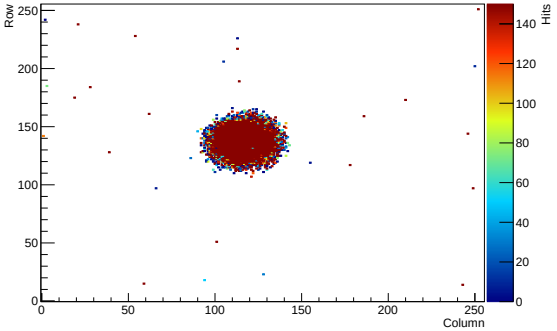
Laser Setup UoL



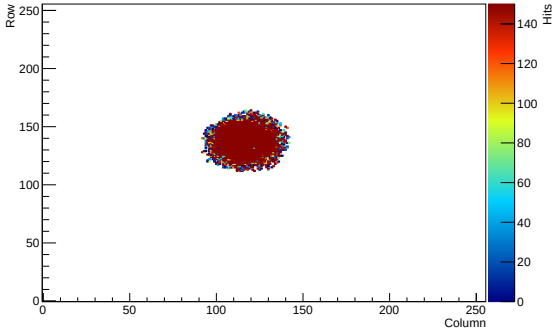
- Colleagues of the atom interferometry group kindly set something up for me
- 780nm (infrared) continuous laser
- Acousto-optic modulator (AOM) gates the laser
- Vary pulse length for more energy

Laser Analysis I

Raw



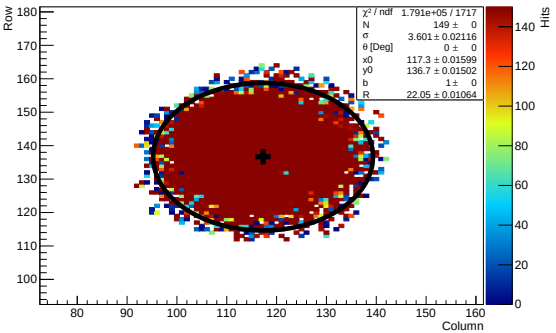
Cleaned



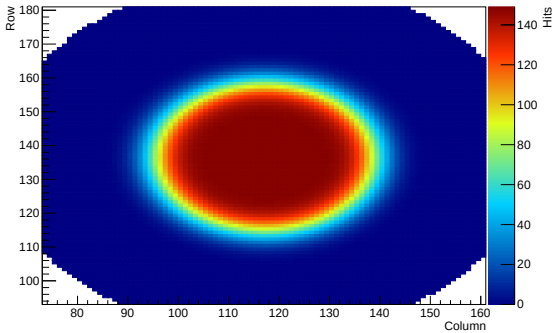
- Remove all pixels that have no neighbour within +-1 with hits to remove noise

Laser Analysis II

Fit results

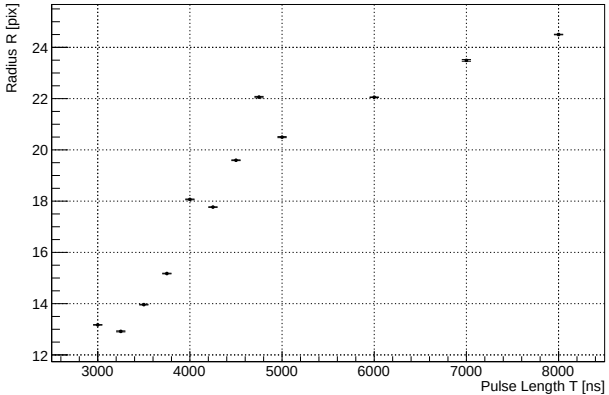


Fit function



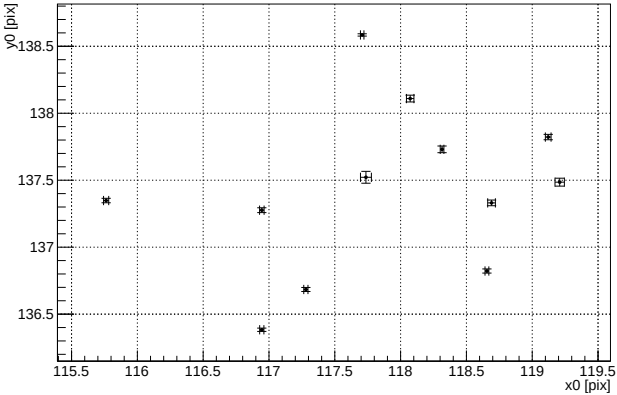
- Fit hit map with circular s-curve (Gaussian error function erf)
- Extract centre points x0/y0, radius R for a given pulse length T
- (implemented generalised rotated ellipse but circle works better)

Laser Radius



- Beam is Gaussian so radius grows slower for longer pulses

Laser Spot Position



- x0 within 4 pixels = 8um!
- y0 within 3 pixels = 6um!