CCLRC
Rutherford Appleton Laboratory

Introduction to CMOS Monolithic Active Pixel Sensors (MAPS)

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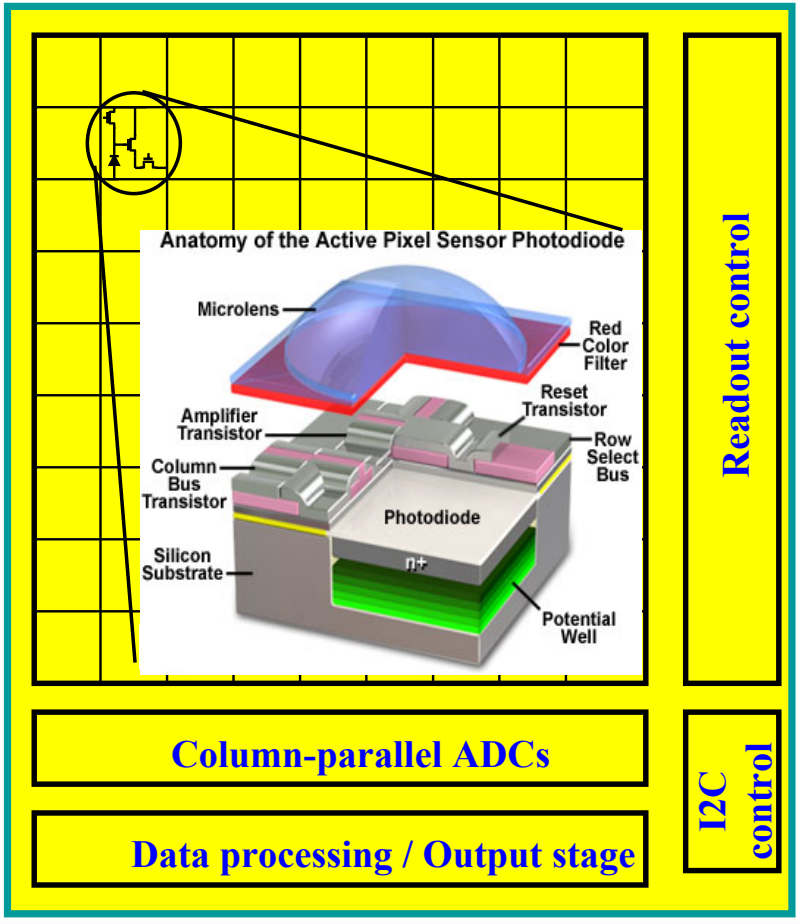
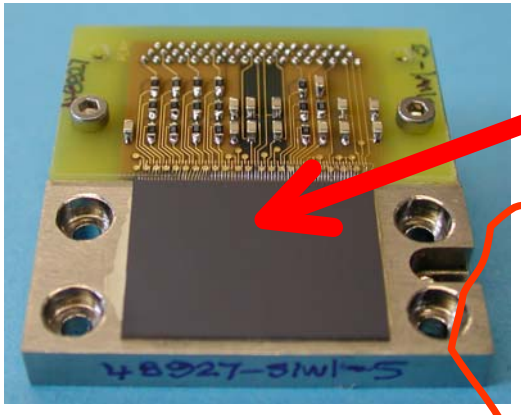
CMOS Monolithic Active Pixel Sensor (MAPS)

(Re)-invented at the beginning of ’90s: JPL, IMEC, …

- **Standard CMOS technology**
- **all-in-one detector-connection-readout = *Monolithic***
- **small size / greater integration**
- **low power consumption**
- **radiation resistance**
- **system-level cost**
- **Increased functionality**
- **increased speed (column- or pixel- parallel processing)**
- **random access (Region-of-Interest ROI readout)**

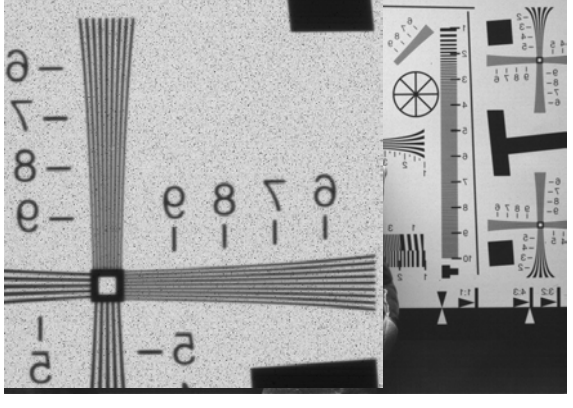


RAL Large area sensors



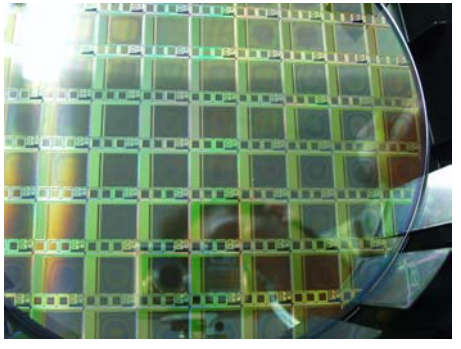
EUVAPS04

12 million pixels
5 μm pitch
Prototype for ESA Solar Orbiter
Backthinned down to epi
ENC = 17 e- rms



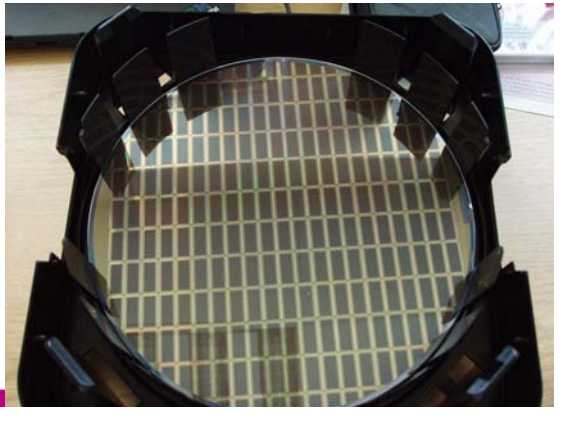
Vanilla/PEAPS

512x512 pixels
25 μm pitch
ENC <~ 25 e- rms (kTC)
Flushed reset
100 fps
12-bit SAR ADC
Region-Of-Interest (ROI) readout: six 6x6 regions @20k fps

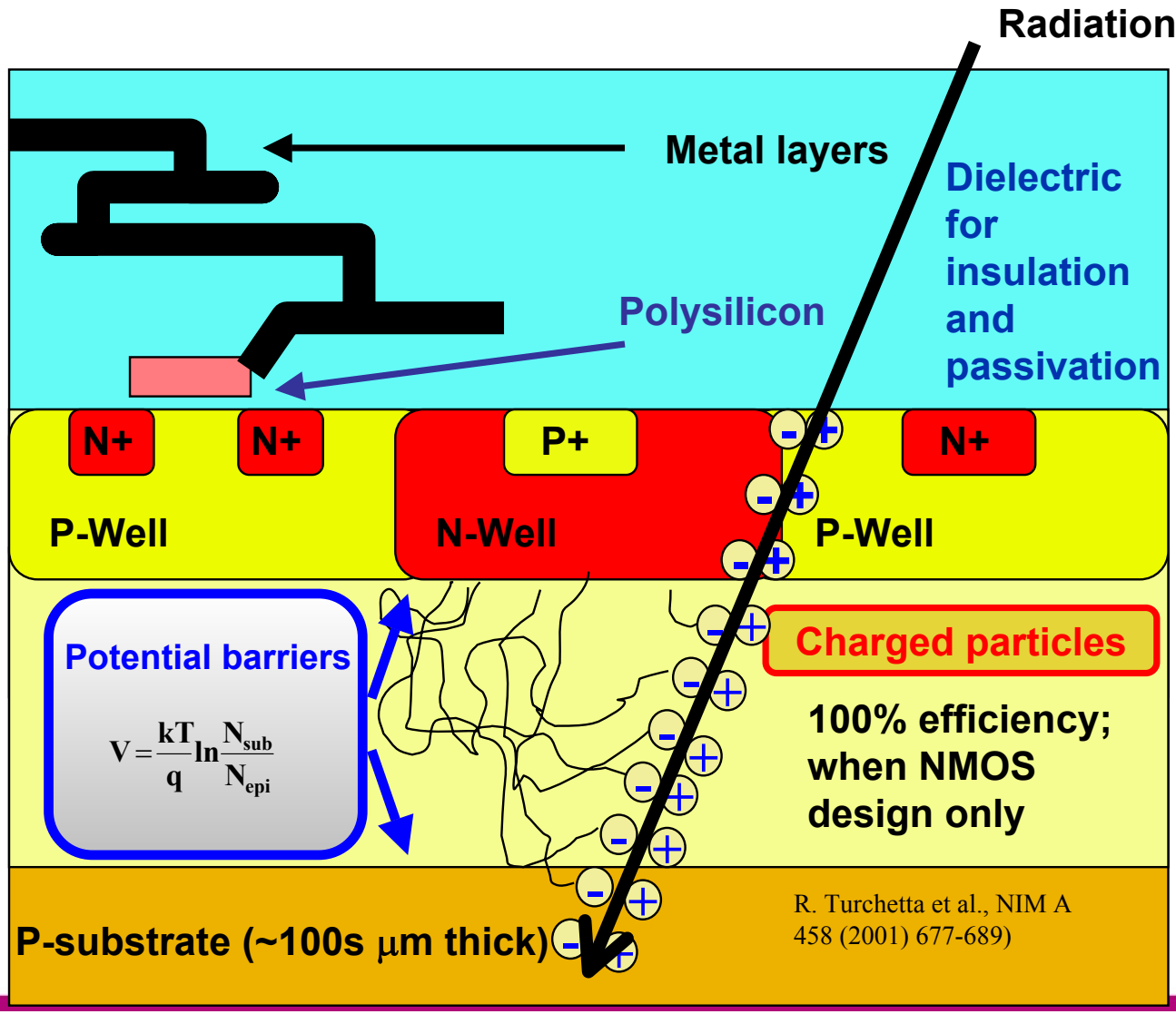


RAL_HEPAPS4

1026x384 pixels
15 μm pitch
ENC <~ 15 e- rms (reset-less)
5 MHz line rate
Rad-hard: > Mrad



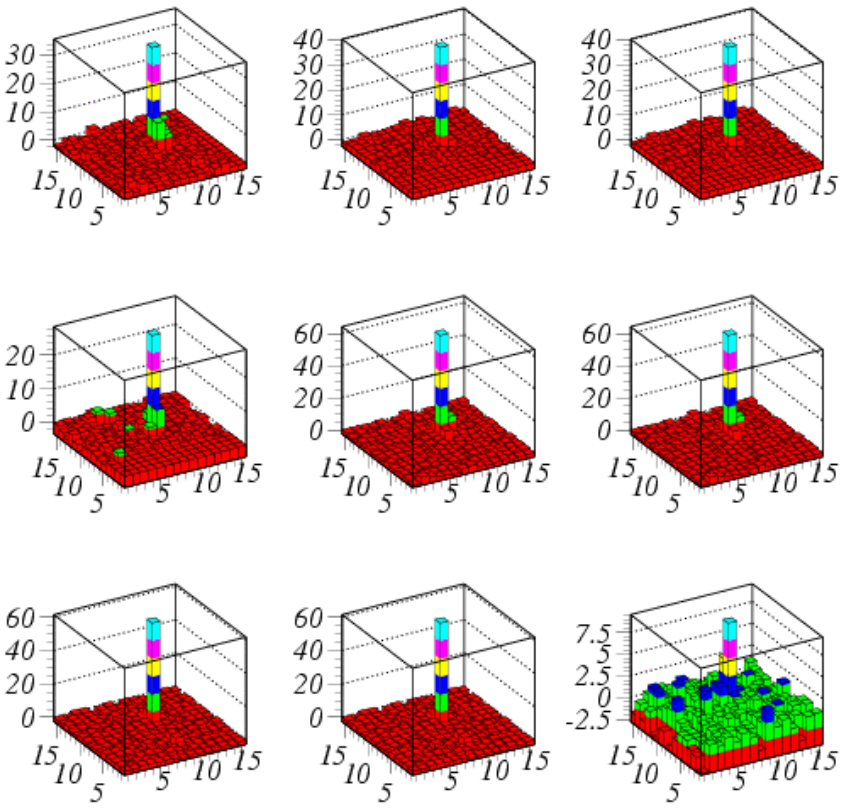
MAPS for charged particle detection



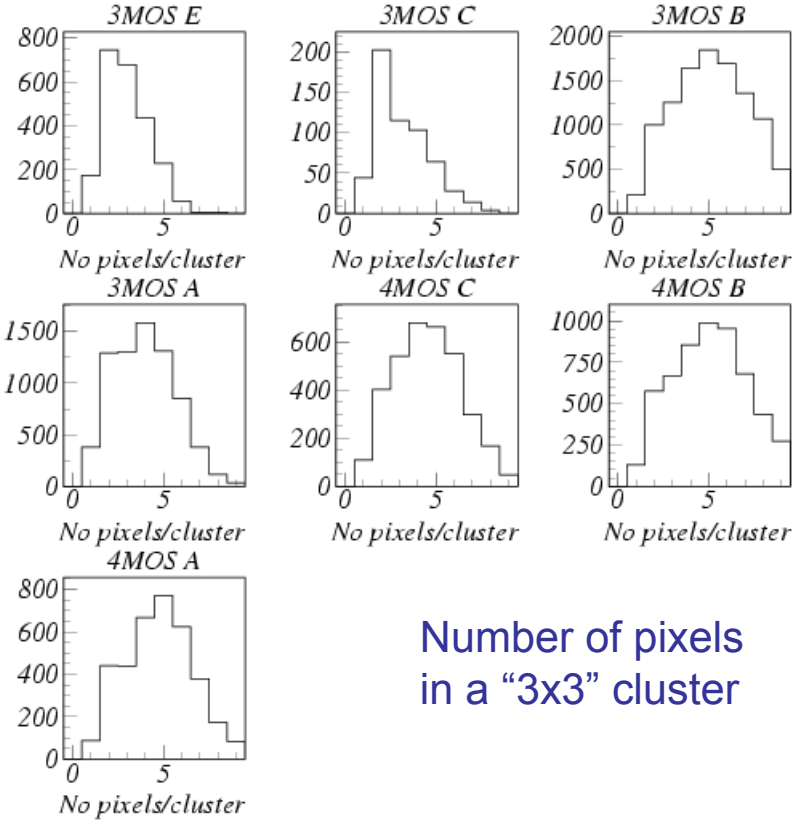
Signal from individual particles

Beta source (Ru106) test results. Sensors HEPAPS2.

Cluster in S/N

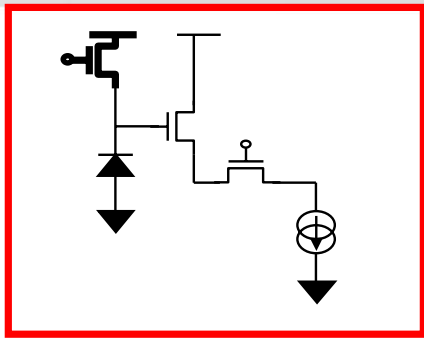


Signal spread



Number of pixels in a “3x3” cluster

3T pixel



Baseline (minimum) design.

Low noise detection of MIPs first demonstrated in 2001.

Since then, with a number of technologies/epi thickness:

AMS 0.6/14, 0.35/∞, 0.35/14, 0.35/20, AMIS (former MIETEC) 0.35/4, IBM 0.25/2, TSMC 0.35/10, 0.25/8, 0.25/∞, UMC 0.18/∞

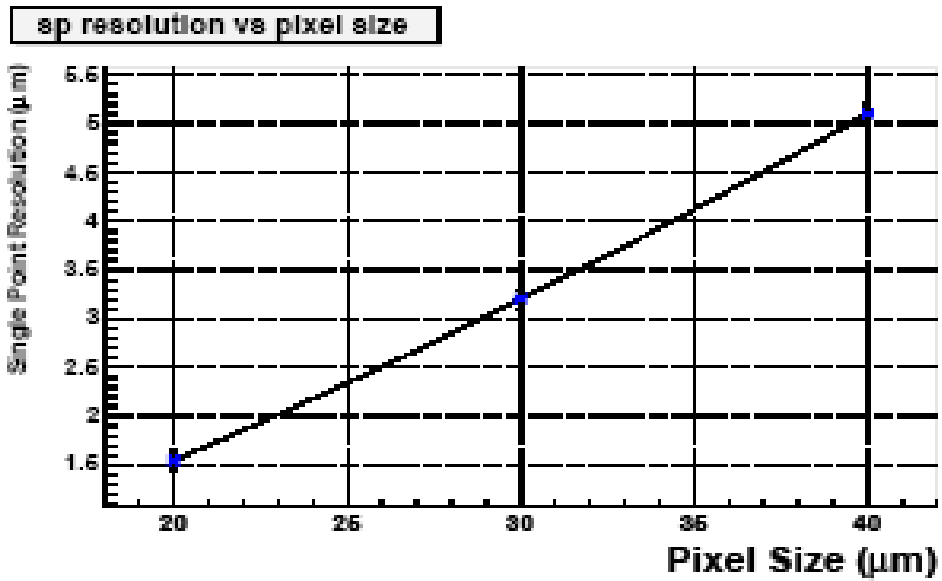
Noise <~ 10 e- rms

Spatial resolution 1.5 μm @ 20 μm pitch, with full analogue readout

Good radiation hardness

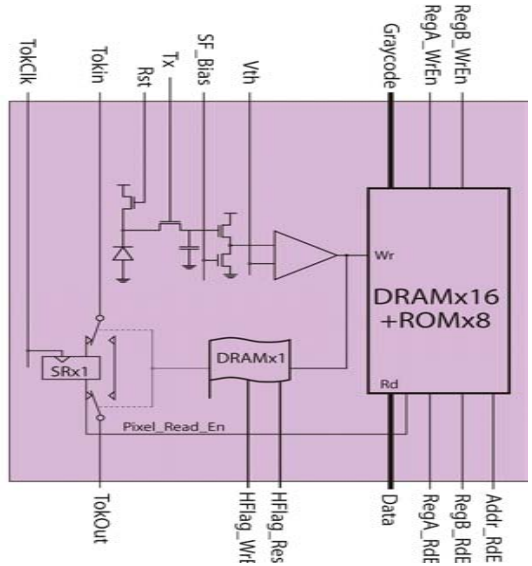
Low power

Speed: rolling shutter can be a limit



In-pixel digitisation

- OPIC (On-Pixel Intelligent CMOS Sensor). Designed by RAL within UK MI3 consortium
- In-pixel ADC (single-slope 8-bit)
- In-pixel TDC
- Data sparsification



Test structure. 3 arrays of 64x72 pixels
@ 30 μm pitch
Fabricated in TSMC 0.25/8
PMOS in pixel → sub-100% efficiency
Starting point for R&D on ILC-ECAL Calice

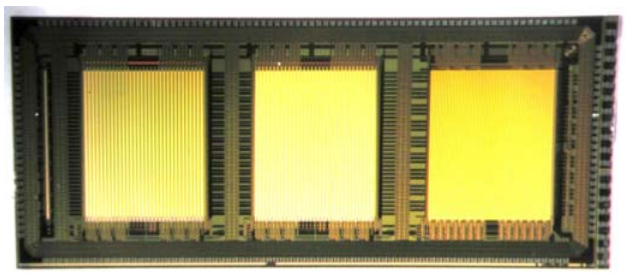
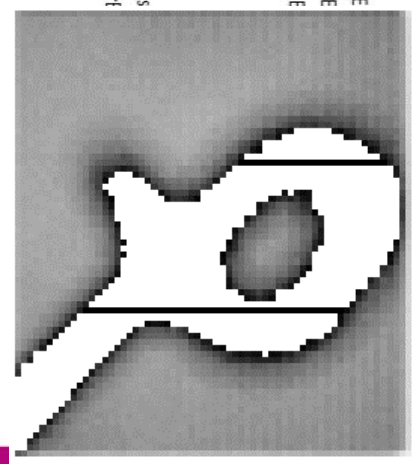
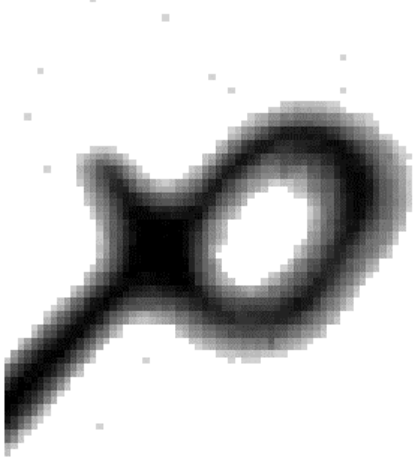


Image obtained with the sensor working in TDC mode with sparse data scan. White pixels are those which didn't cross threshold

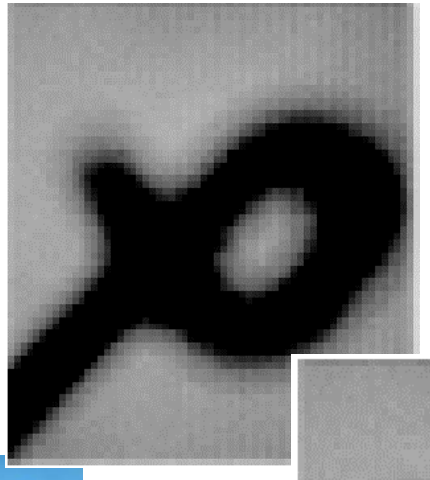


Experimental results

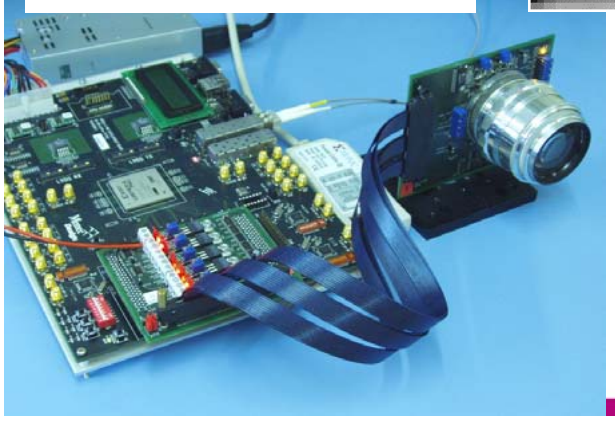
In-pixel ADC

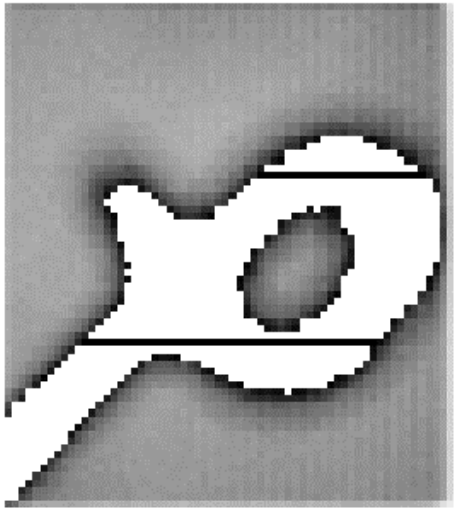


Timing mode capture



In-pixel thresholding





Sparse data
(timing mode)