

CMOS MAPS-based digital ECAL

P. Allport¹, S. Benhammadi², R. Bosley¹, J Dopke², S. Flynn¹, N. Guerini², L. Gonella¹, I. Kopsalis¹, K. Nikolopoulos¹, P. Philips², T. Price¹, A. Scott², I. Sedgwick², E. G. Villani², M. Warren³, N. Watson¹, [F. F. Wilson](#)², A. Winter¹, S. Worm¹, Z. Zhang².

1 School of Physics and Astronomy, University of Birmingham, United Kingdom

2. STFC Rutherford Appleton laboratory, Didcot, United Kingdom

3. Department of Physics and Astronomy, University College London, United Kingdom

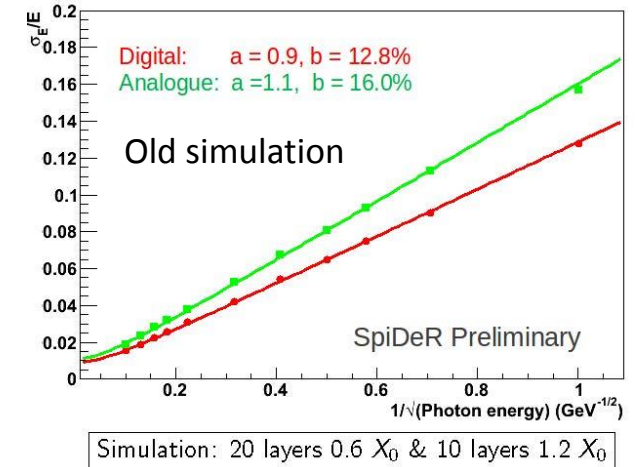
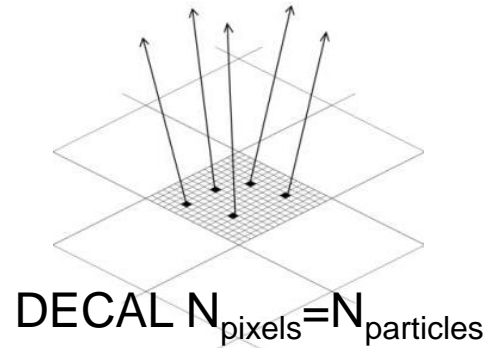
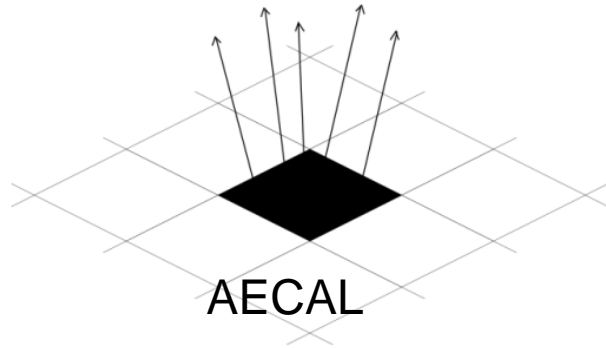
Recent publications [here](#)



- Motivation / Concept
- Does it work?
 - CALICE (see [Roman Poeschi talk](#))
 - EPICAL-2 (see [Fabian Pliquett talk](#))
 - TPAC/DECAL (this talk)
- Prospects/Future

Motivation/Concept

- High granularity offers possibility of using Particle Flow techniques to make best use of all detectors to measure jet energies.



- Compare CMS HGCal cell size (1.1 cm) to CMOS MAPS cell size (50 μm)
- Could lead to a compact calorimeter.
- Reuses development of CMOS Monolithic Active Pixel Sensors (MAPS) for tracking/vertexing:
 - CMOS Industrial cost $\sim \$0.5/\text{cm}^2$ (compared to CMS HGCal cost $\sim \$4/\text{cm}^2$)
 - Radiation hard ($10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$), low power ($< 100 \text{ mW}/\text{cm}^2$ without power pulsing), industrial process, fast (10ns), similar readout to vertexing/tracking (could even be variation of similar sensor), ...

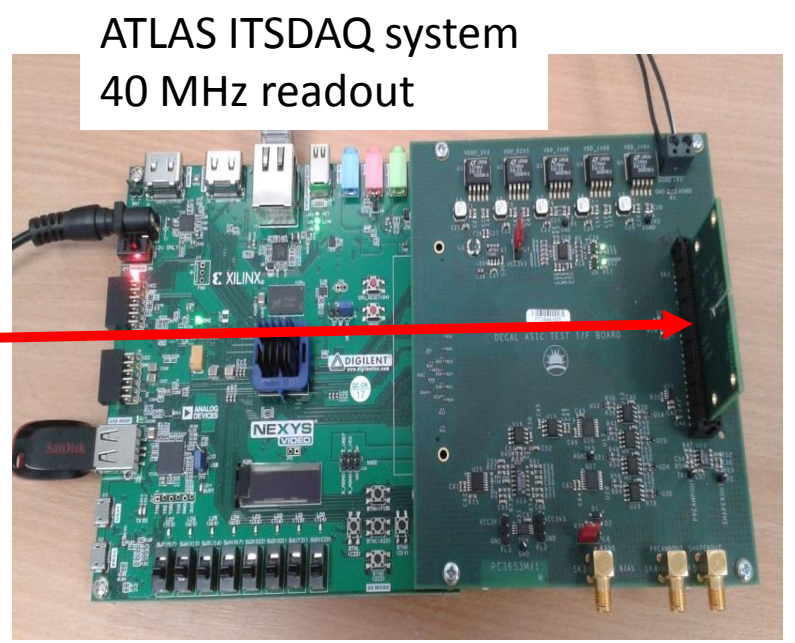
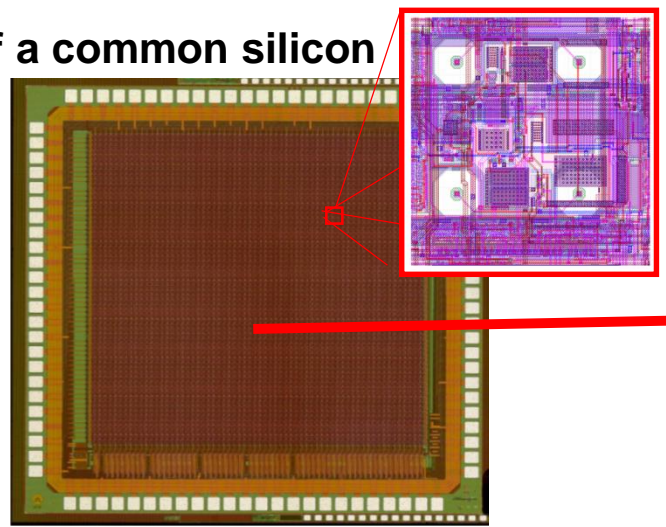
DECAL MAPS Sensor: Single Pad (4mm×4mm Array) Prototype

Concept in FCC-hh context of a common silicon development for:

- Outer tracking
- Pre-shower
- EM calorimeter

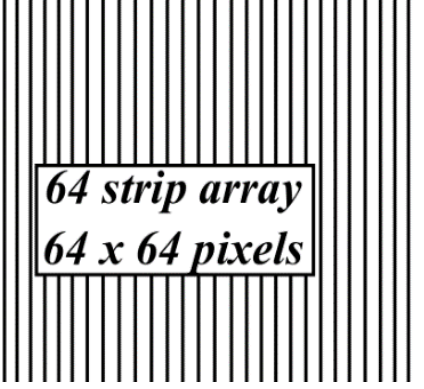
Reconfigurable sensor as:

- 4mm×50µm strips
- 4mm×5mm pad



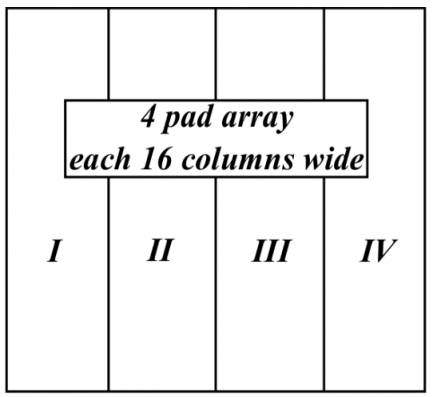
Prototype as proof of concept (180nm TowerJazz CMOS*)

Strip mode

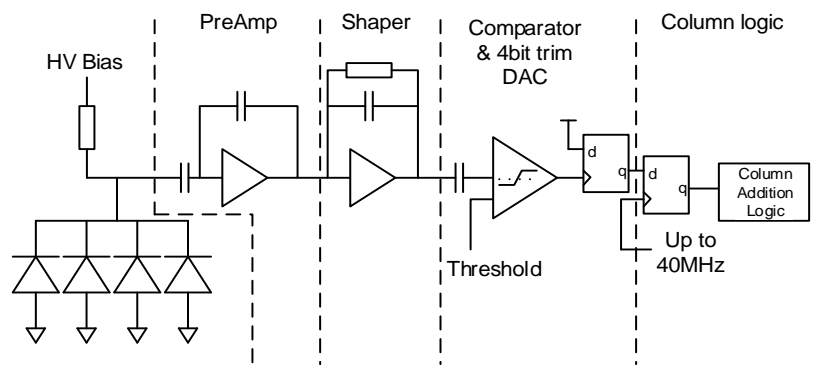


Information on up to 3 hits per column gives data rate 5.12Gb/s

Pad mode

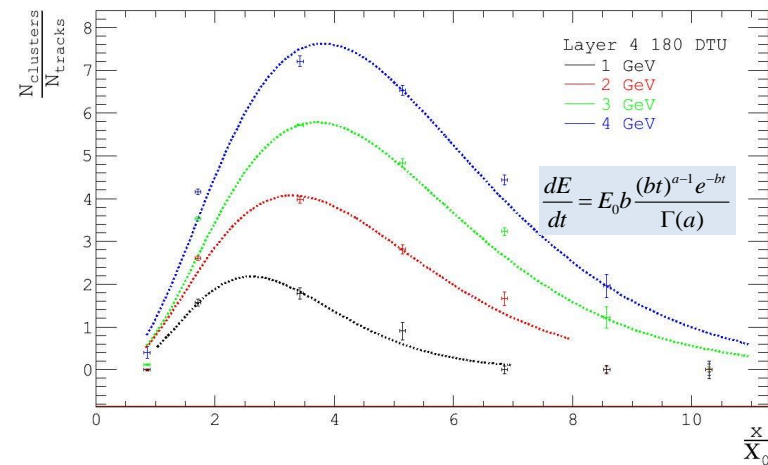


Information on up to 15 hits per column giving 240 hits per pad gives data rate of 2.56Gb/s

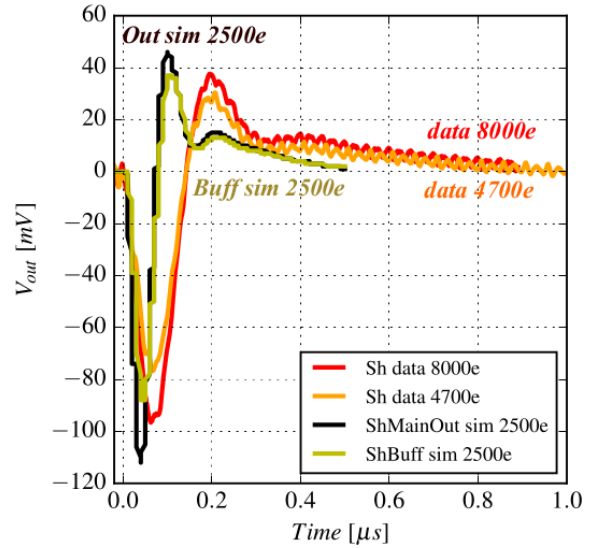
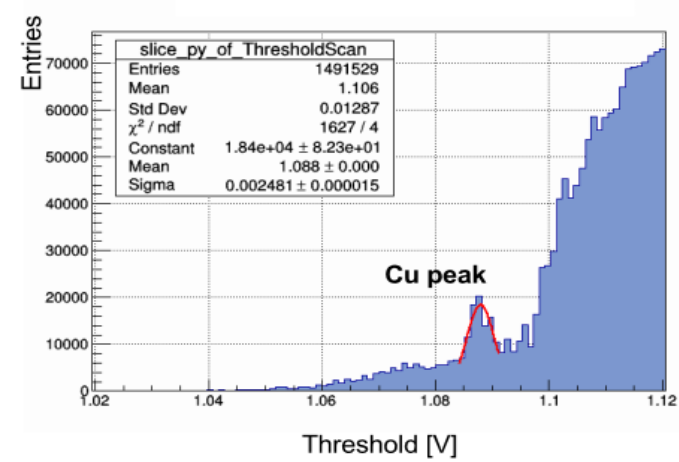


Specification	Unit	Value
Pixel Pitch	um	55
Resolution	pix	64 x 64
Frame Rate	MHz	40
Input Referred Noise	e- rms	80
Max hits/col (pad mode)	hits	15
Max hits/col (strip mode)	hits	3

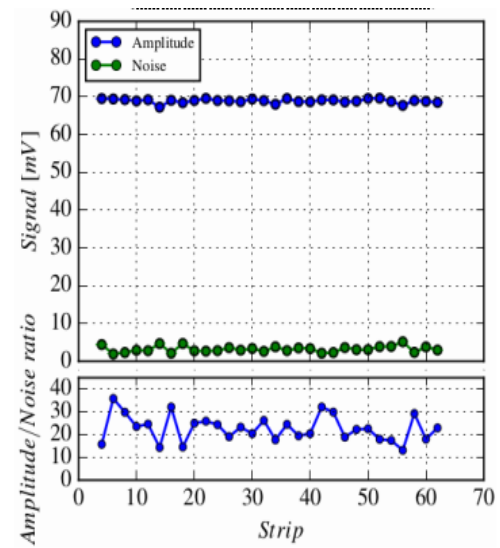
Initial Results in 2020/2021



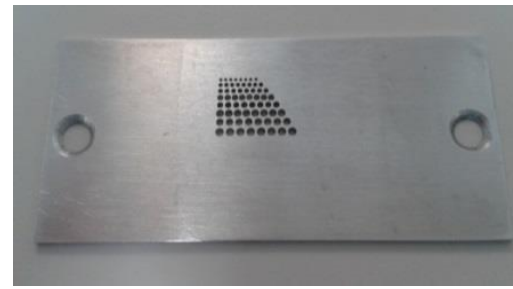
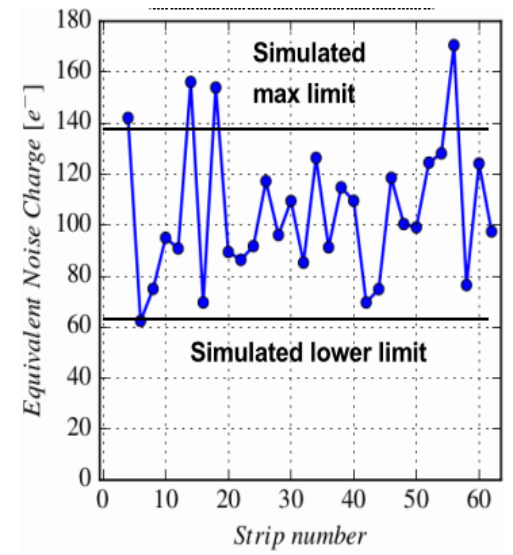
Old results from DECAL precursor TPAC: slower and not radiation hard.



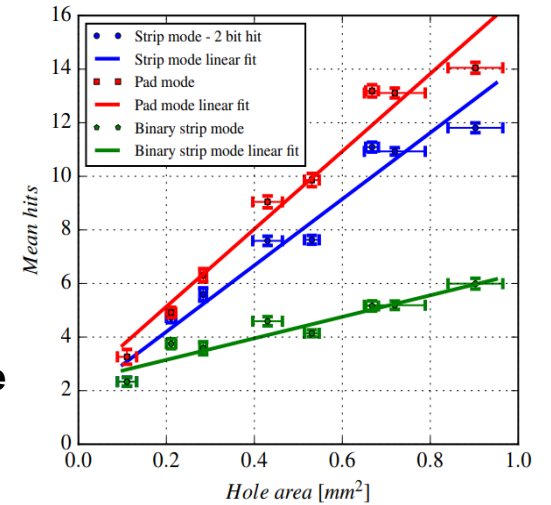
Some delay in measured response time with respect to FE simulation (but expect ~10ns signal collection)



Expected signal: $8050\text{eV} / 3.6\text{eV} = 2236e$
 Signal/Noise ≈ 22 Noise $\approx 100e$ (goal $\sim 80e$)



Check pad and strip mode response to different area light spots



Future

- The digital Calorimeter concept using CMOS MAPS has been shown to work by a number of groups.
- A small number of groups of various sizes are continuing R&D work for specific detectors (e.g. ALICE) and general future collider concepts (LC/FCCee/FCChh/CEPC/...).
- DECAL sensor continues to be tested as a sensor for digital calorimetry and outer tracking.
 - Pad, strip and binary readout working.
 - Adequate noise achieved.
 - Fast charge collection demonstrated.
 - Investigating radiation-hard processes and change to charge collection layout.

- [A Reconfigurable CMOS Sensor for Tracking, Pre-Shower and Digital Electromagnetic Calorimetry](#), Hiroshima Symposium, P. Allport et al, NIM A 978 (2020) 164459
- [Towards a Reconfigurable CMOS Sensor suitable for Outer Tracking, Pre-shower and Digital EM Calorimetry at Future Facilities](#), CERN EP seminar, P. Allport et al.
- [SiW ECAL Studies for FCC-hh and Their Implications for FCC-ee](#), 3rd FCC Physics and Experiments Workshop, P. Allport et al.
- [A Reconfigurable CMOS Sensor for Tracking, Pre-Shower and Digital Electromagnetic Calorimetry Application of Semiconductor Tracking Detectors](#), HSTD20, P. Allport et al.