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ILC, LHC and FCC MAPS Designs at RAL

Jens Dopke on behalf of RAL PPD/TD folks

Many Thanks to Tony Price for input and material

RAL CMOS Designs

- A bit of history
- OverMOS
  - The Saga
  - Overmos 1A
  - What about OverMOS 2?
- DECAL
  - Where we currently are
- Outlook

Generics

- Long RAL involvement with TowerJAZZ (From when they were still Tower and JAZZ)
  - Developed the Deep P-Well with them, allowing isolation of full CMOS designs in active sensors
- Ran through a great many designs for Particle Physics:
  - TPAC
  - FORTIS
  - CHERWELL ½
  - OverMOS

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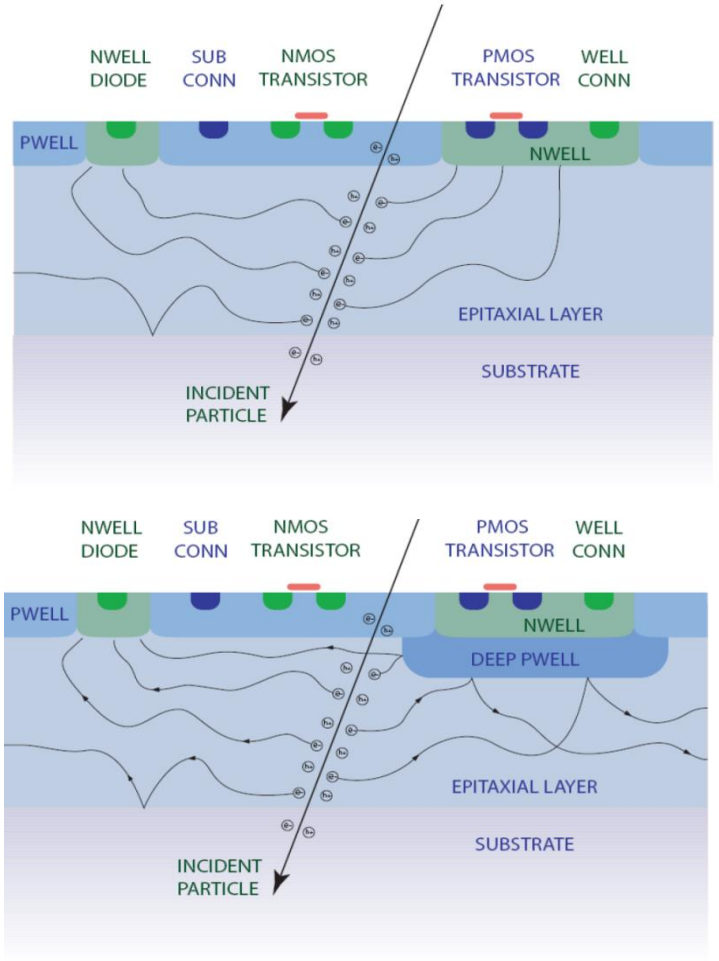
TPAC

- CMOS Sensor aiming at digital calorimetry
  - 50x50 pixels, 168x168 matrix
  - Charge is collected via diffusion
- Delivered designs based on different substrates and process features
  - Proving Deep-Pwells to vastly increase detector performance by reducing charge leakage into non-collecting Nwells



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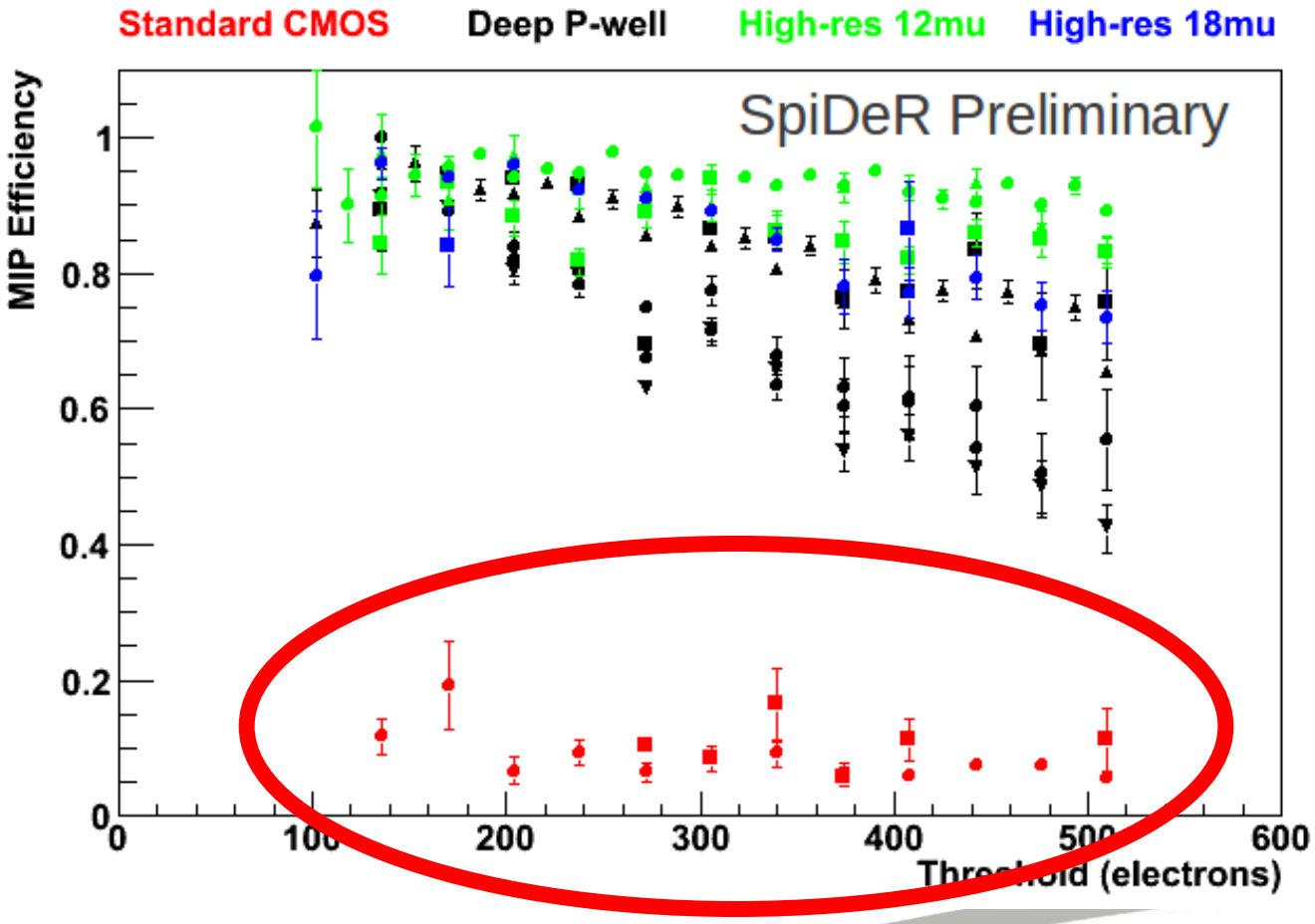
TPAC Performance



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Fortis & Cherwell

- A series of chips implementing different functionality using the INMAPS Deep P-Well:
  - FORTIS: 3T vs. 4T readout, largely reduced noise, S/N ~ 100
  - CHERWELL 1: Calorimetry/Tracking/Vertexing
    - Achieved resolutions of 3.7um with 99.7% hit efficiency
    - S/N of up to >130
  - CHERWELL 2: Prototypes for the Alice ITS upgrade
  - CHERWELL 3: Low power/high speed version with Pixel Masking … never went out
- All of the above eventually drove the OverMOS project
  - Effort on Cherwell was sadly lost over time

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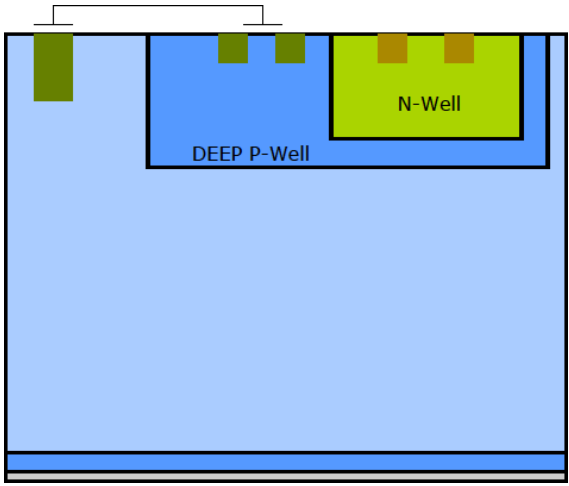
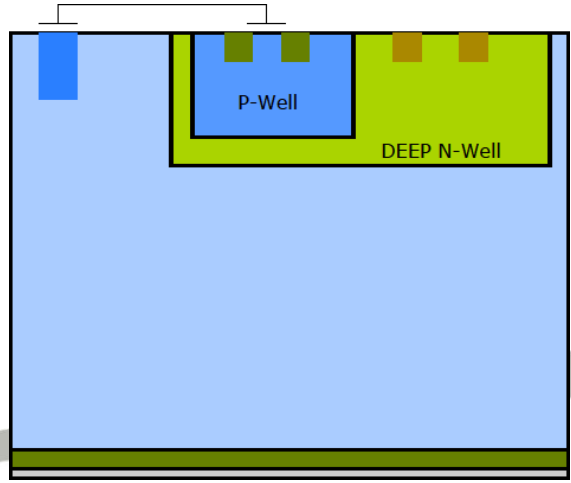
OverMOS – A new hope

- Aim to provide a strip-detector like implementation
  - TowerJAZZ 180nm, with deep P-wells for full CMOS
  - Full depletion of silicon EPI to be achieved through biasing
  - 40x400 pixels, small structures for testing (5x5, where 3x3 can actually be read)
  - Two wafer types, P-on-P and P-on-N (Epi-on-Substrate)
    - P-on-P collects e-, P-on-N collects holes
- Lots of analogue and TCAD simulations done, it all looked good





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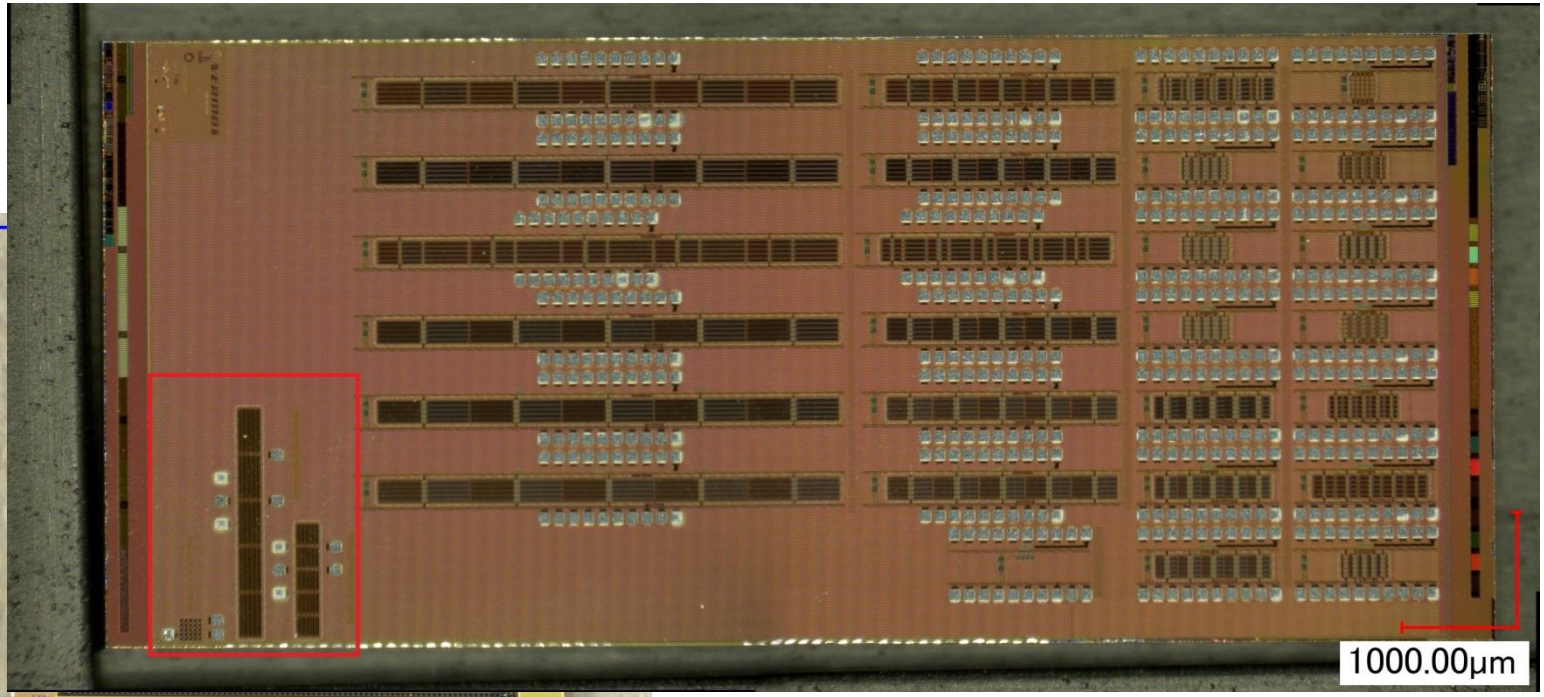

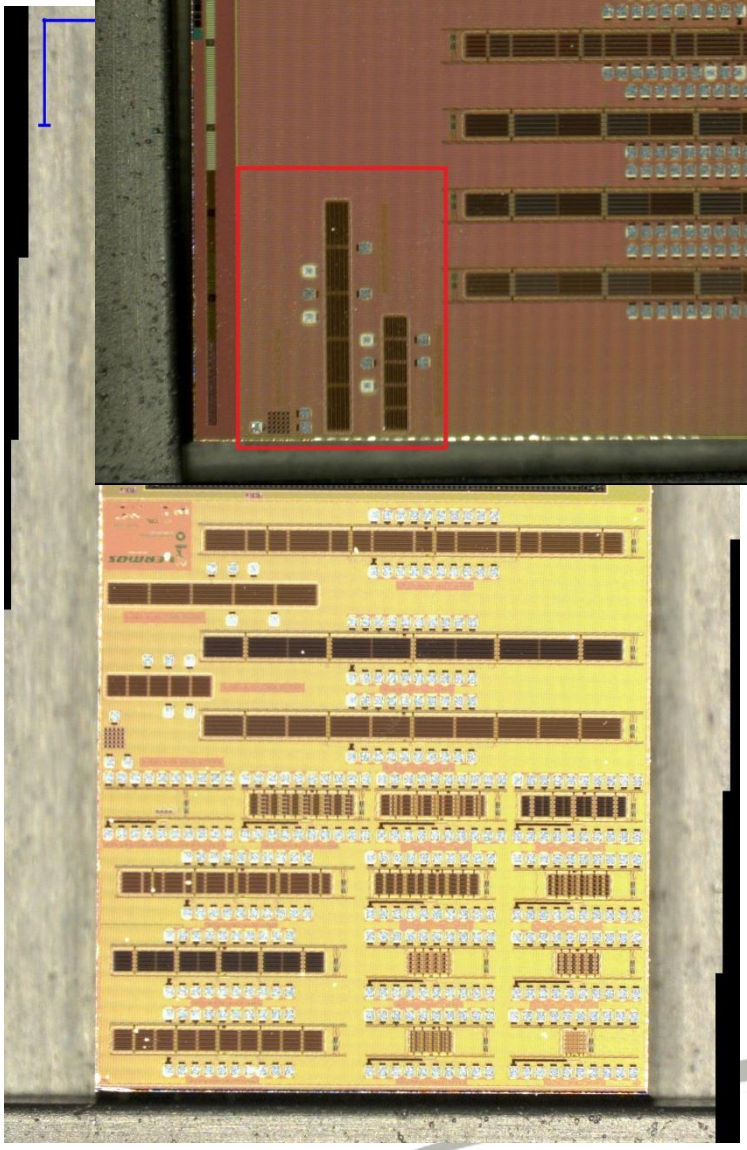

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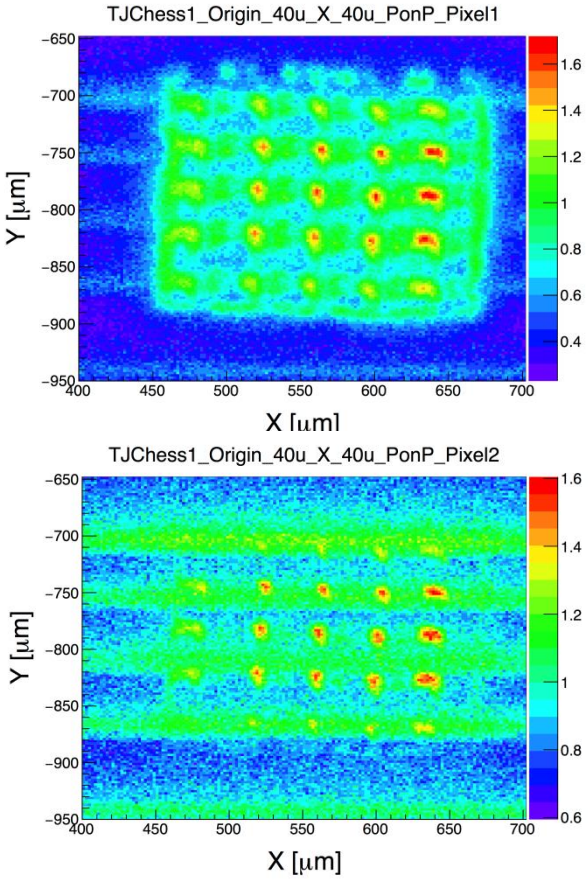
What was tested

- Actives:
  - Charge collection scanned using lasers
    - Uniform charge collection in all pixels
  - Scanned various chip parameters to rectify this
- Passives: IV/CV curves
  - IV revealed source of the biggest problem in full array measurements: **missing p-stop between pixels**



Measurements by L. Chen

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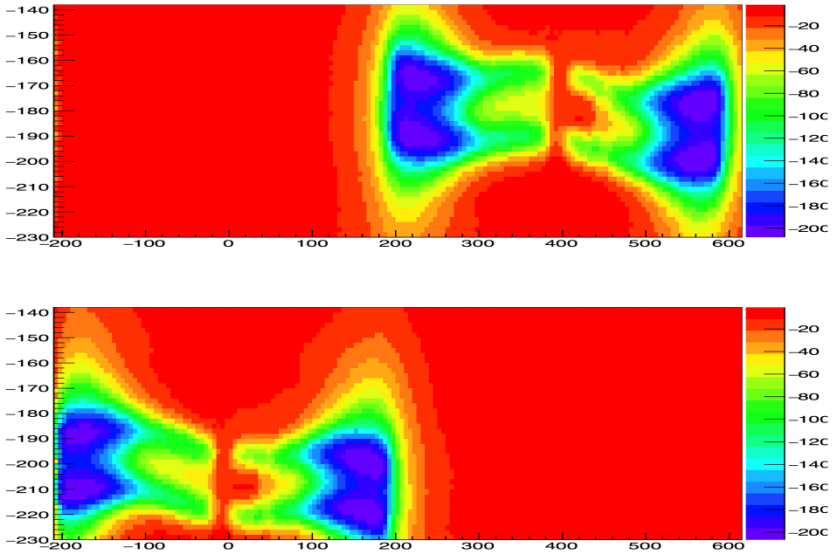
OverMOS 1A – Isolation strikes back

- Added in isolating p-spray between collecting nodes
  - Submitted far fewer structures to be tested
- Lots more TCAD simulations run within PPD
- Shows good first results in Laser scans
- Still to be understood
  - Depletion region growth vs. voltage
  - Charge collection time



L.Chen, reading out different Pixels on OverMOS 1.1

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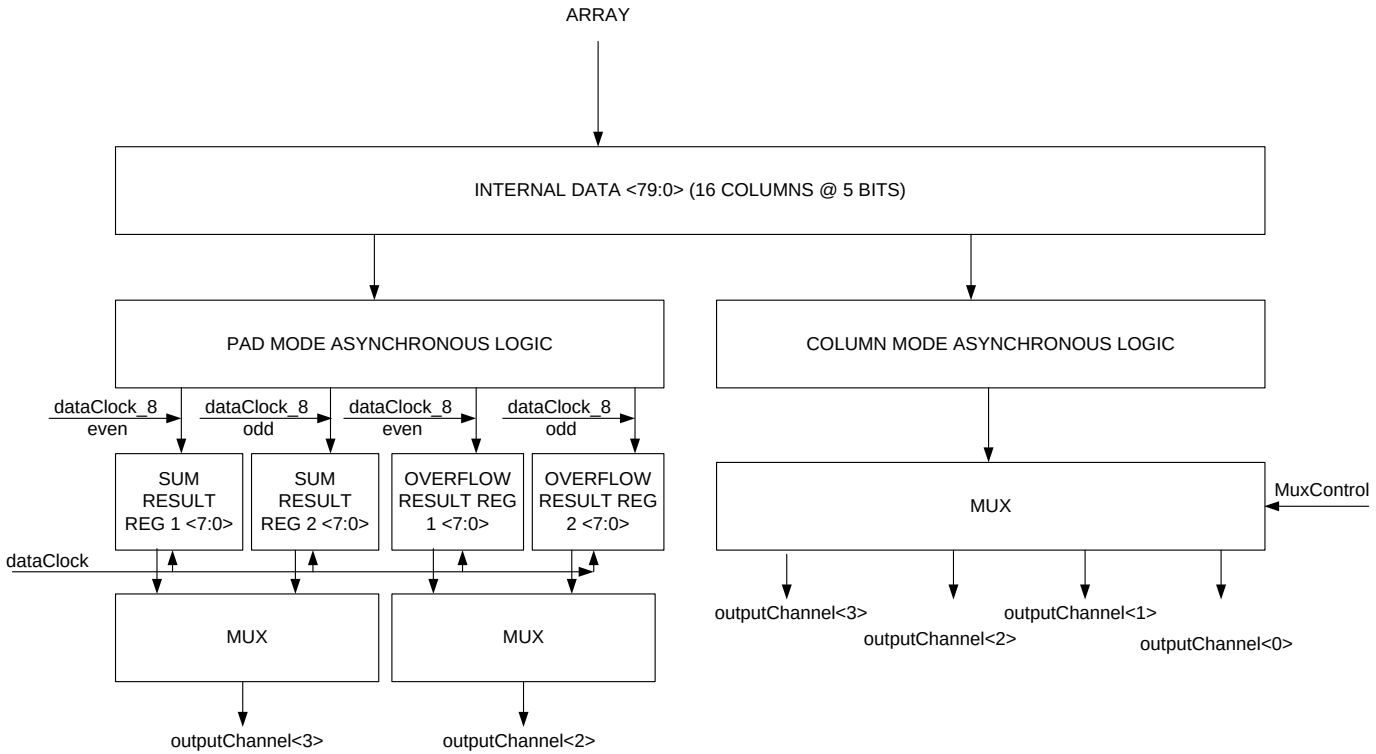
OverMOS 2

- High Resisitivity (epitaxial) CMOS strip-like sensors did not pass the threshold soon enough and were therefore not yet submitted as a large structure
- Primarily for cost and timing reasons
- New projects allow re-utilising the effort though…

DECAL

- Aiming towards the FCC calorimeter community (Follow up from TPAC)
  - Lots of rad hardness eventually
  - Needs cheap silicon
  - Would be good to work with uniform cell size for measuring energy deposits – epitaxial silicon helpful
- Chips primary goal is to count a total sum of hits across a matrix
  - With intermediate sums required, the chip allows to operate in a “strip” mode -> Return of the OverMOS (2)

Block Diagram



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Current Status

- DECAL submitted in May (MPW, 5x5mm^2)
  - Expecting return by end of August++
- Lots of lessons learned from OverMOS went into DECAL:
  - P-type substrate choice
  - AC coupled pixels for biasing
- Currently writing up chip documentation
- DAQ in preparation

TCAD for OverMOS/Decal

- One lesson learned from OverMOS is that we (the physicists) need to invest more time into understanding structures before submission
  - Reviews don't quite cut it when things get complex, needs involvement over a longer period of time
- After OverMOS 1, RAL PPD spent quite a bit of time on setting up TCAD simulations around OverMOS, to understand the charge sharing behaviour as well as its limitations in terms of depletion
- Started looking into other processes as well
  - Trying to support where we can, e.g. by granting departmental visitors access to our infrastructure or running simulation for/with them