3D production status in CNM and IceMOS

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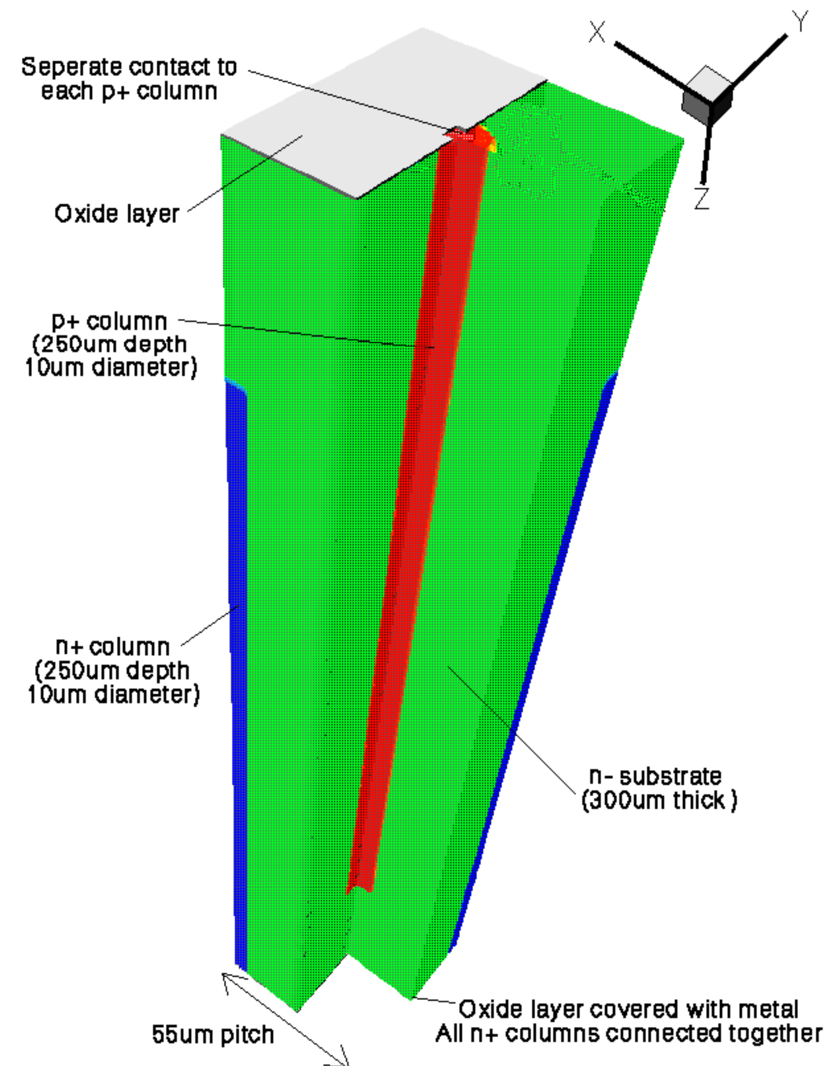
Outline

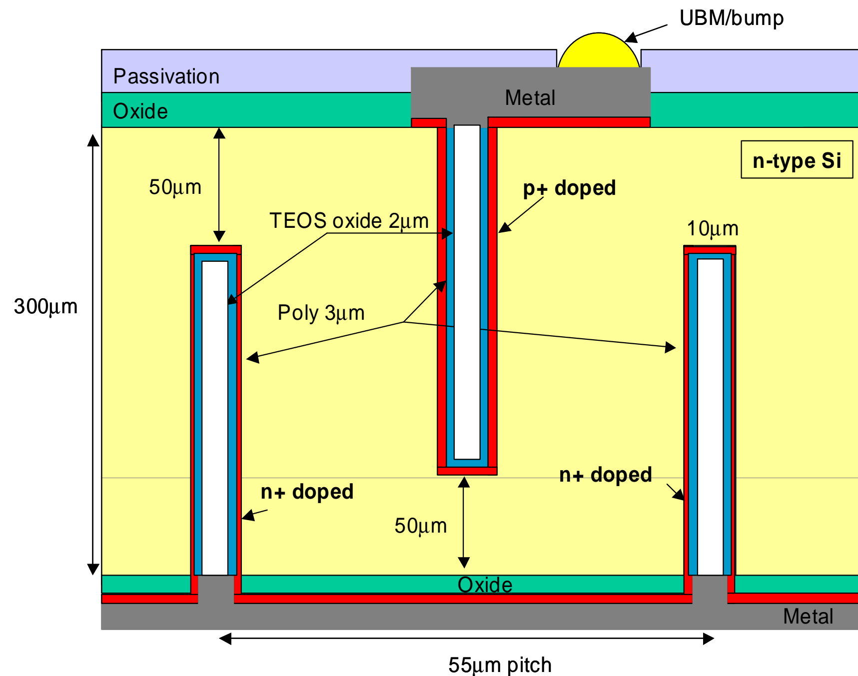
1) Fabrication of Double-sided 3D detector structures at CNM
2) Fabrication of Full 3D detectors in IceMOS
3) Bump bonding

Double-sided 3D at CNM

- Double-sided design proposed by CNM
- 4” masks designed by CNM and Glasgow and funded by RD50 common fund
- Aim to fabricate devices at CNM with n- and p-type wafers



Characteristics of the double-sided 3D



- Electrodes etched from opposite sides of the wafer
- Double side processing
- **Short charge collection times** because both carrier types mainly drift horizontally
- **High drift velocity** as the electric field can be increased even after full depletion → **radiation hardness**

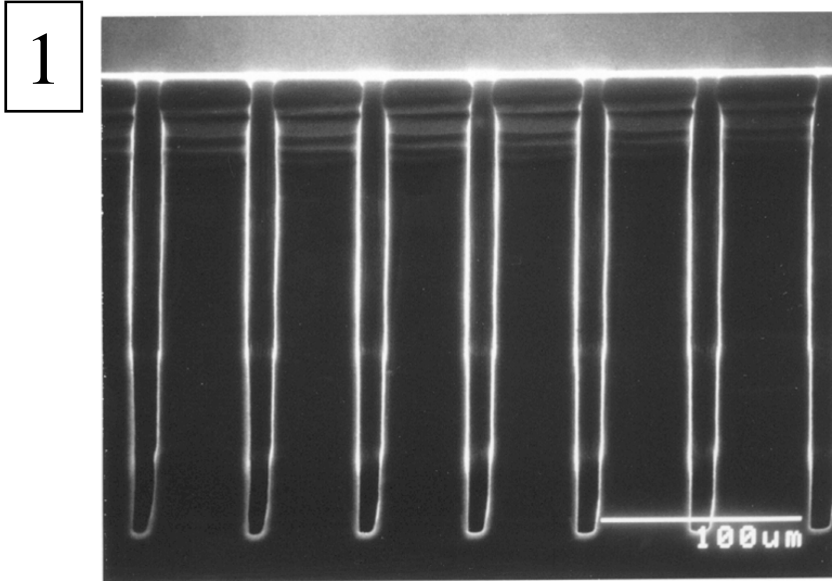
See simulation work in David's talk

The electrodes are partially filled with poly and passivated with TEOS oxide

Fabrication sequence:
1st N^+ holes (etch – poly layer – P doping – TEOS)
2nd P^+ holes (etch – poly layer – B doping – TEOS)

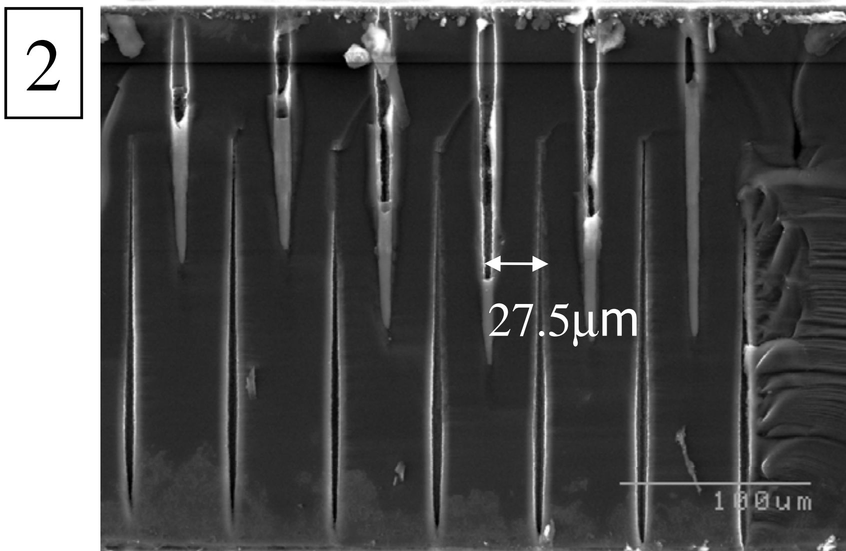
Key steps

1



1. Hole etching
   - 10μm diameter, 250μm deep (a/r 25:1)
   - Al mask
2. Double-side alignment
3. Electrode doping and filling

2



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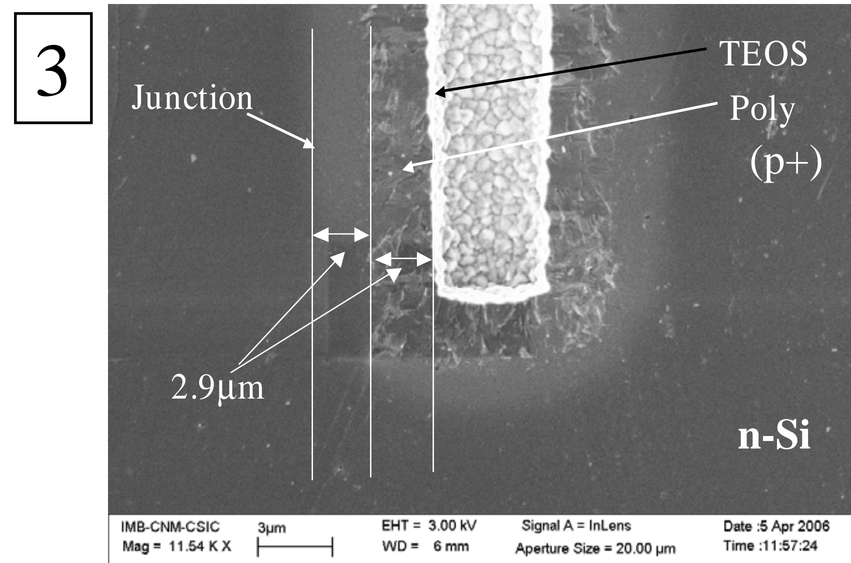
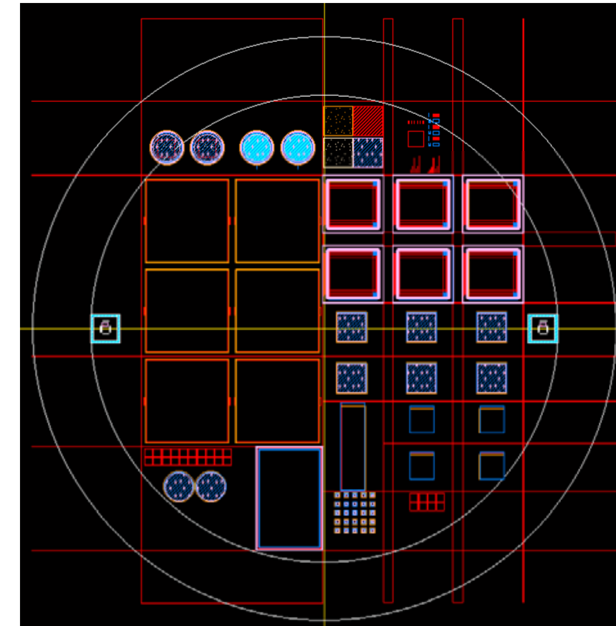
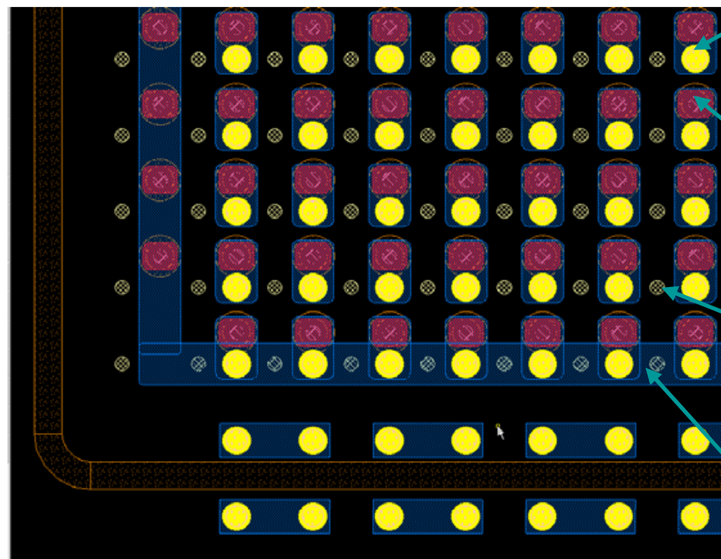


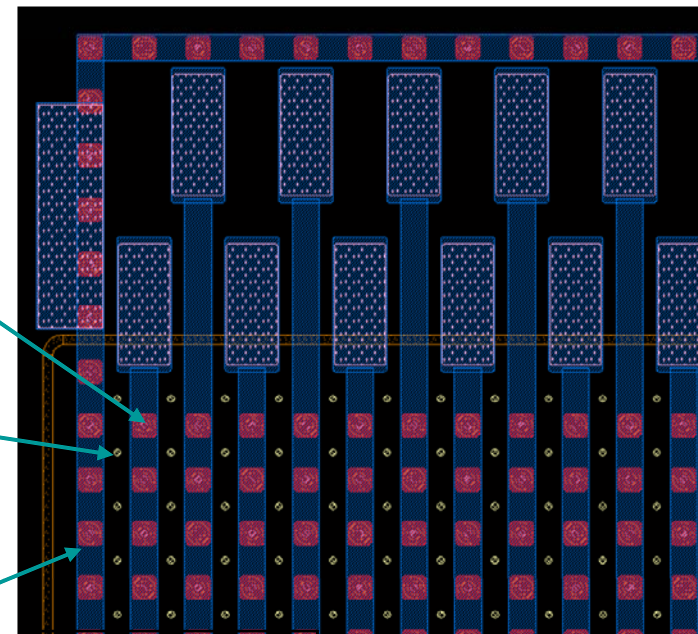
CNM 4″ wafer design

6 Medipix2 pixels	Pitch 55µm, 256x256
6 ATLAS pixels	Pitch 50x400µm, 164x18
1 Pilatus pixel	Pitch 172µm, 97x60
4 short strip	Pitch 80µm, 50x50
1 long strip	Pitch 80µm, 50x180
Pad detectors, test structures	





Medipix2



Strip detector

Processing status

- 1st : p readout columns in an n-type bulk
  - ATLAS pixels won't work (e- readout)
  - Still have Medipix, Pilatus, strips, pads!
  - Status:
    - First run had to be halted due to problems with the TEOS oxide
    - Second run (4 wafers) in process ~ 1 month

- 2nd: n readout columns in a p-type bulk
  - Electrode insulation with p-stops
  - Begin estimate: Sept 2007

Full 3D detectors at Glasgow

- Project Glasgow/Diamond Light Source to develop 3D detectors for X-ray diffraction experiments at the DLS synchrotron

The DLS Synchrotron at Oxfordshire

- **Full 3D** detectors on **n-type Si**
  - Fabrication by **IceMOS Technology Ltd.** (Belfast)
- 3-stages production plan:
  1. Hole etching optimization
  2. Doping optimization
  3. Device production (3 runs)
- Prototype 3D detectors will be integrated and tested with existing r/o electronics
  - Medipix2, Pilatus, Hermes and Beetle readout chips
  - Readout in p-electrodes → hole collection

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First run in progress!
Devices ~ **2 months**

- Prototype 3D detectors will be integrated and tested with existing r/o electronics
  - Medipix2, Pilatus, Hermes and Beetle readout chips
  - Readout in p-electrodes → hole collection

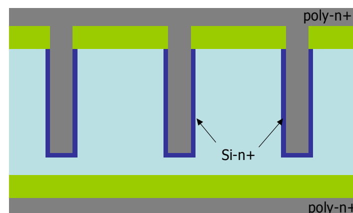
IceMOS process flow

1. n-type Silicon, 500μm

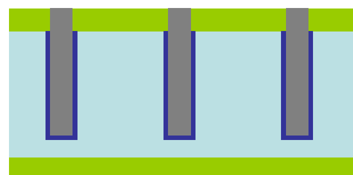
2. Oxidation

3. Hole patterning and ICP etching (~250μm)

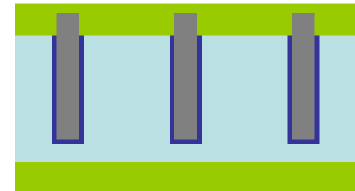
4. Poly filling and doping with P



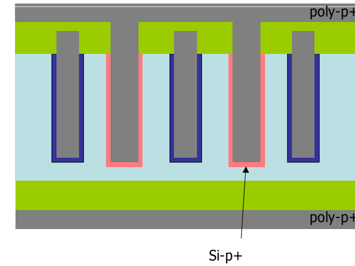
5. Poly planarization front and back



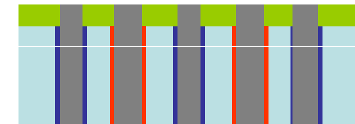
6. Oxidize to protect columns



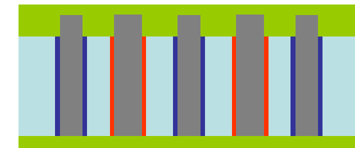
7. P-electrodes



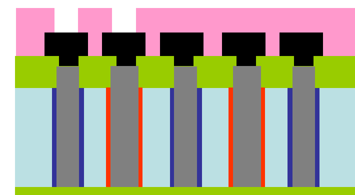
8. Grind/polish to expose electrodes in front and back sides



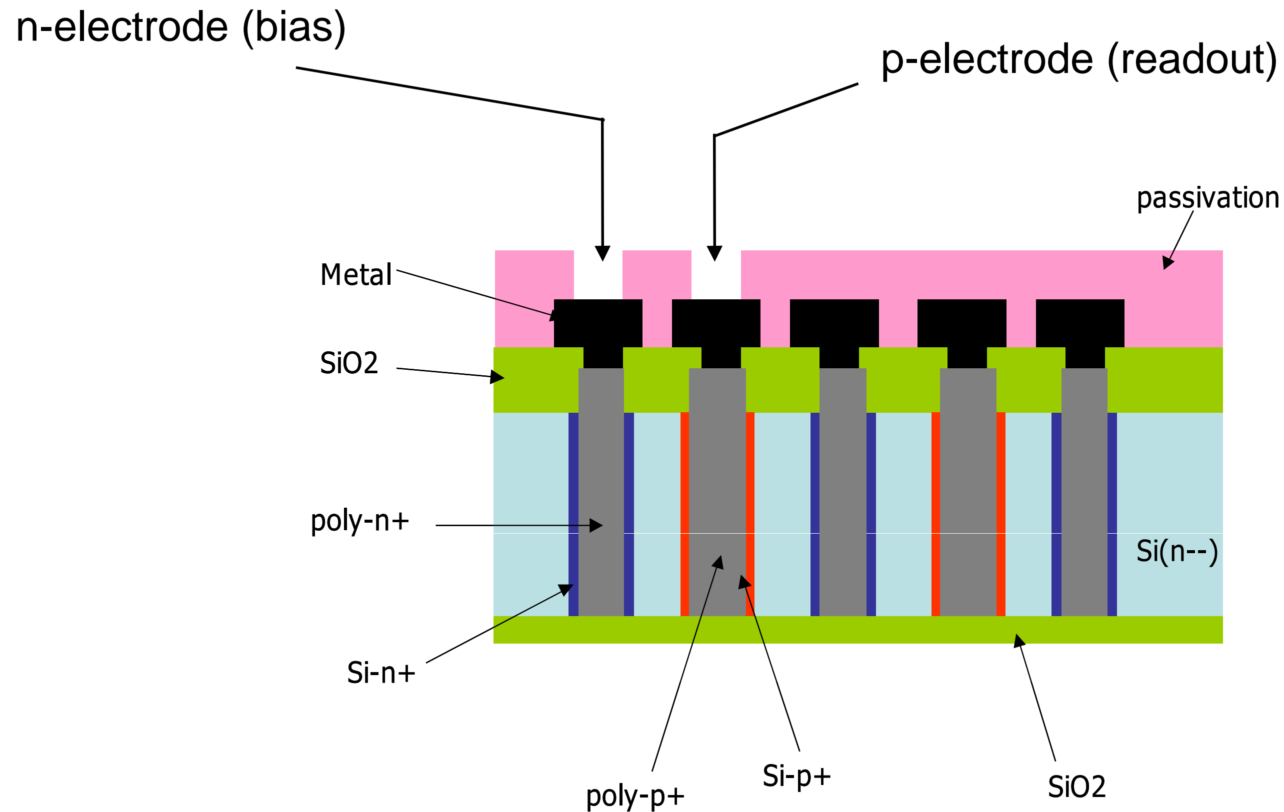
9. Oxidize to protect surfaces



10. Open contacts, metal, passivation



Final device



- **Readout in p-columns** only → no p-stops necessary
- **Bias in n-columns**
- Contacts on the top → need rerouting metal lines that connect all the n+ columns

Glasgow 4″ wafer design

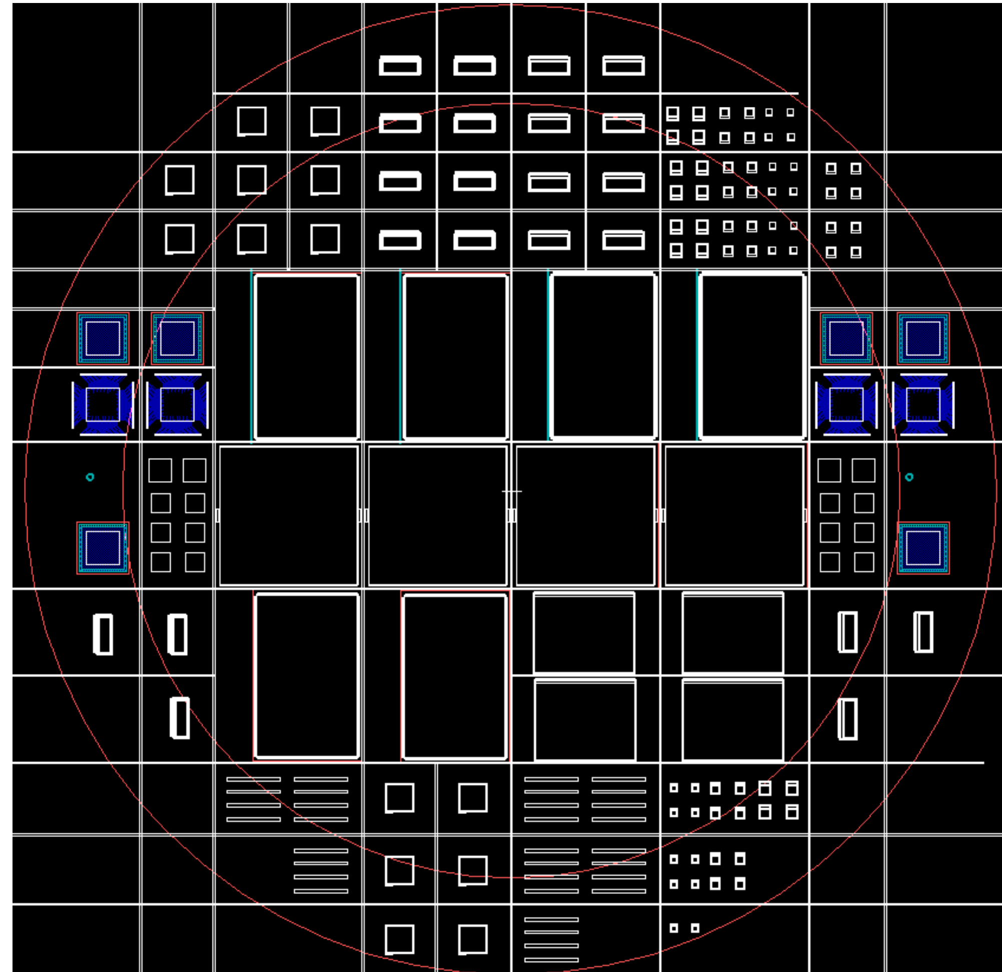
Pixel detectors

- 4 Medipix2
  - Pitch 55 µm, 256x256
- 6 Pilatus
  - Pitch 172 µm, 97x60
  - 1, 4 or 9 cells/pixel

Strip detectors

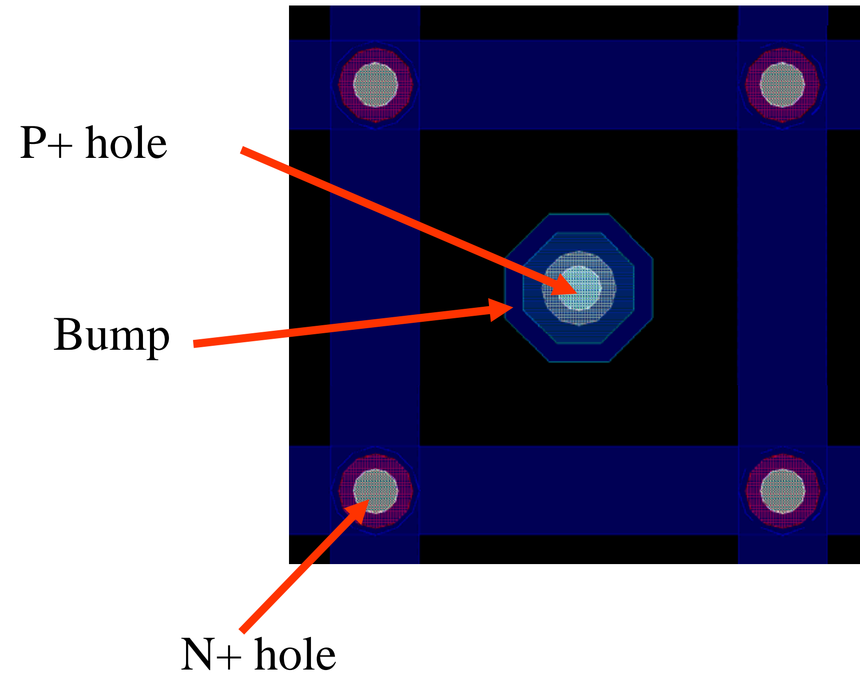
- 4 large (“Beetle”) strips
  - Pitch 80 µm, 128x100
- 22 small (“Hermes”) strips
  - Pitch 125 µm, 32x10
  - Square or hexagonal cell

Pad detectors, test structures

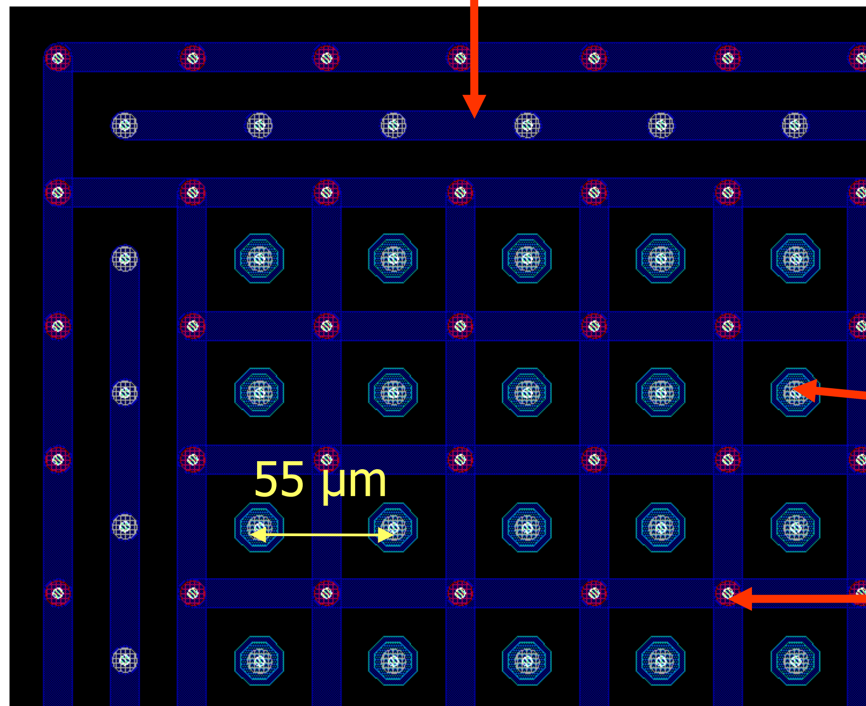


Medipix2

- Pitch 55 µm
- 256x256 pixels
- Medipix2 chip collects electrons and holes



3D guard ring of p+ holes



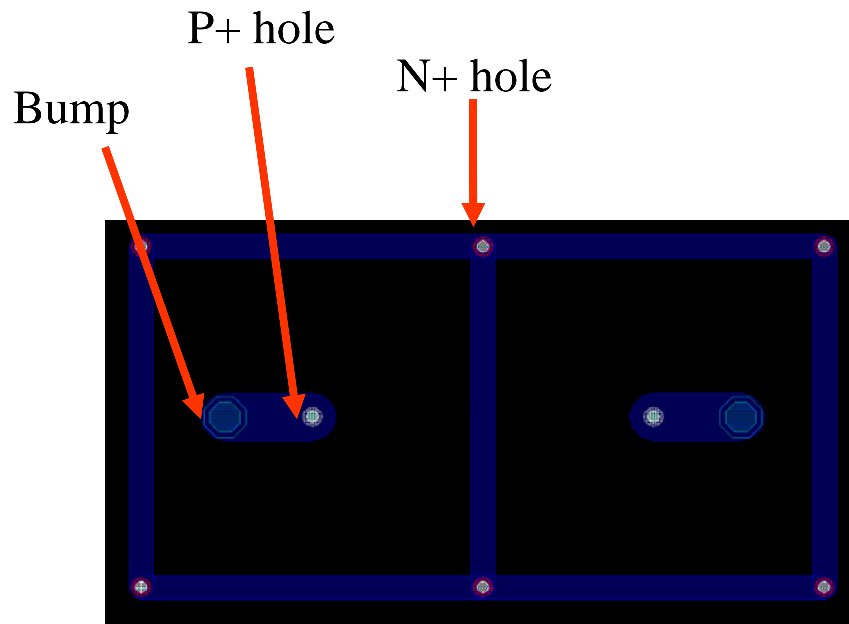
Readout in p+ holes

N+ holes shorted together and biased via a wirebond pad (not shown)

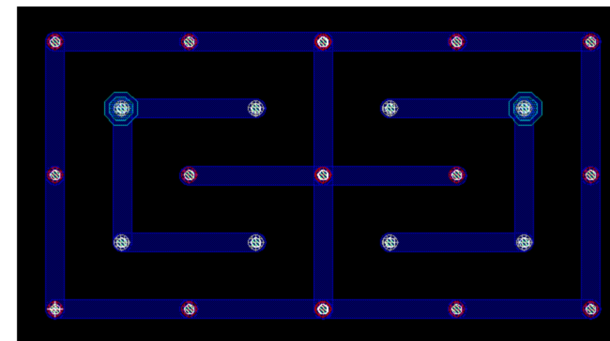
Pilatus

- Photon counting chip designed by PSI for synchrotron applications
- Hole collection
- Pitch 172 µm, 60x97 pixels
- 3D detector: 1, 4 or 9 cells per pixel
  - Hole distance: 172, 86 or 57.3 µm

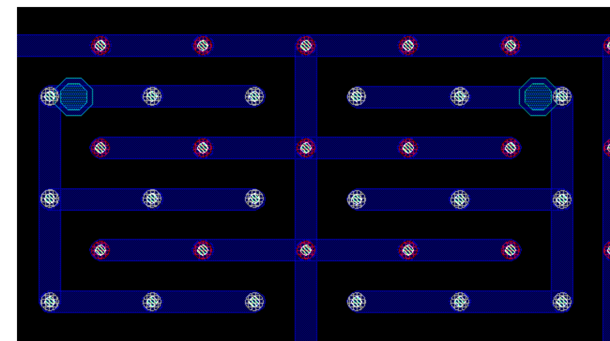
(1 cell = 1 central p-hole surrounded by 4 n-holes)



1 cell/pixel



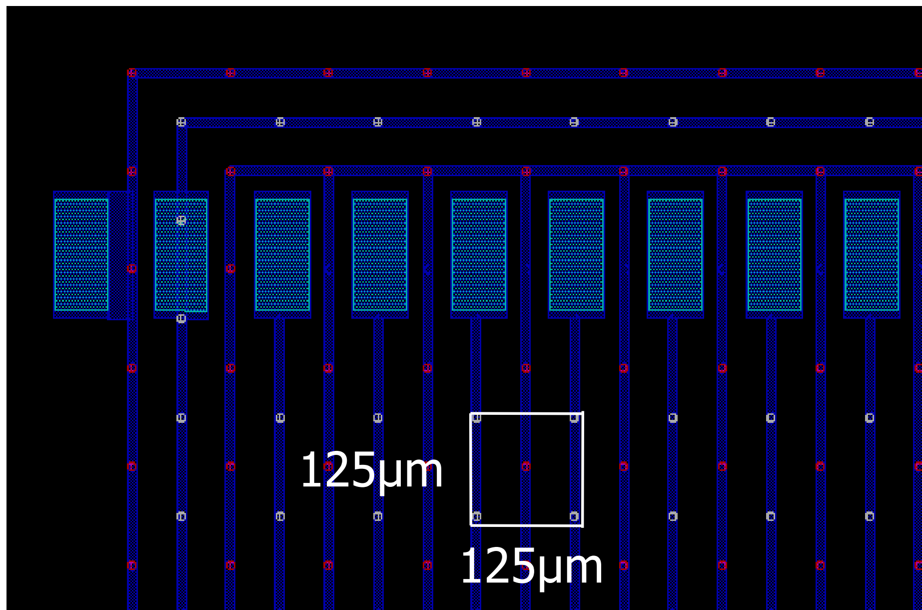
4 cells/pixel



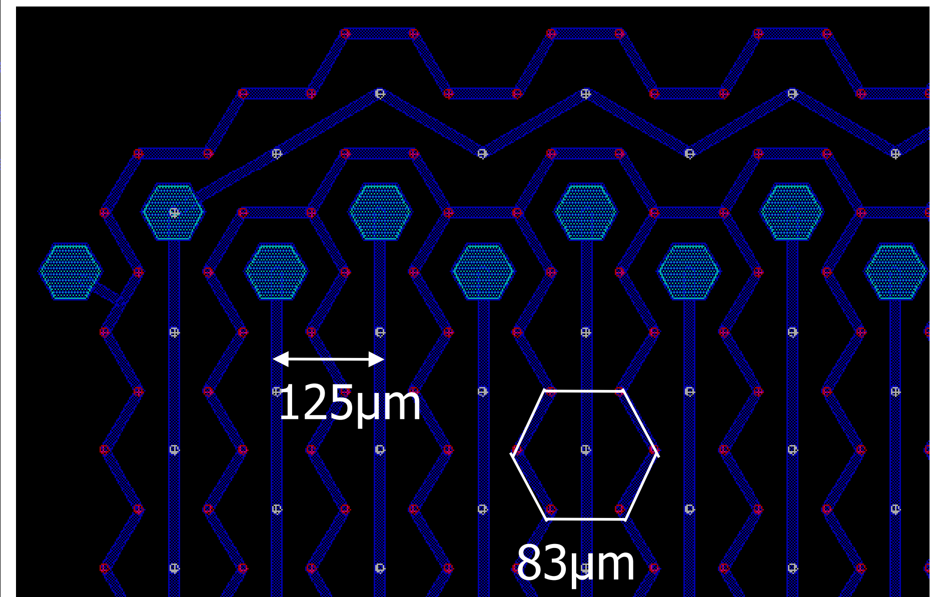
9 cells/pixel

Strip detectors

- Large strip detectors
  - Designed for the LHCb (Beetle) r/o chip
  - 128 strips, pitch 80 µm, 100 columns/strip, DC coupled
- Small strip detectors
  - Hermes r/o chip (BNL, spectroscopy)
  - 32 strips, pitch 125 µm, 10 columns/strip, DC coupled
  - Square and hexagonal designs



Small 3D (sq)



Small 3D (hex)

Bump bonding

- Key aspect for pixel detectors
- Indium bump bonding technology available at Freiburg
  - Yield studies with CNM bump test structure currently being carried out
- Quote from commercial vendor for Medipix for first CNM 3D wafers
  - RD50 funding requested
- Other institutes developing bump bonding processes (*future* runs)
  - Diamond/RAL: In
  - CNM: Sn/Ag electroplating

Summary

- Overview of 3D processing at CNM (Barcelona) and Glasgow
- CNM
  - Double-sided 3D detector structure
  - n- and p-type wafers
    - n-type almost finished (~1 month)
    - p-type also projected
- Glasgow
  - Fabrication at IceMOS Tech.
  - Full 3D detectors
  - n-type Si
  - First devices expected in August
  - Considering design modifications for next runs: active edges, n readout