

New fabrication run of 3D detectors, np and pn devices

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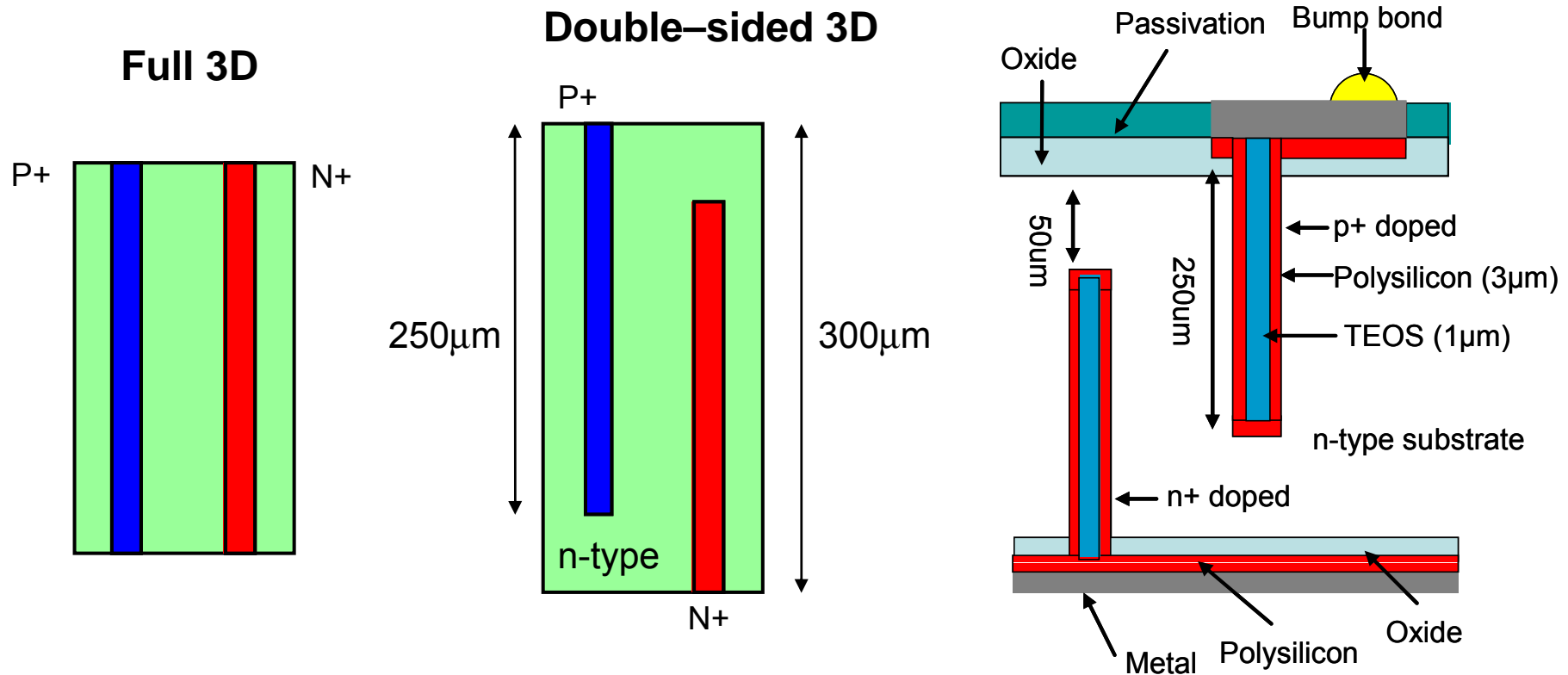
David Pennicard, **Celeste Fleta**, Richard Bates, Chris Parkes, Lars Eklund, Tomasz Szumlak – University of Glasgow

outline

- New fabrication run at CNM
- Measurements at Glasgow on the first fabrication run

Double-sided 3D detectors at CNM

- Detectors fabricated at Centro Nacional de Microelectronica, Barcelona
- Columns are etched from opposite sides of substrate, and don't pass through full thickness
- Column fabrication
 - Reactive ion etching
 - Partial filling with polysilicon then doping



Mask design

Diodes 2D

Medipix2

Test for SEM

MOS

Pilatus

spreading

3x3 matrix

Test structures

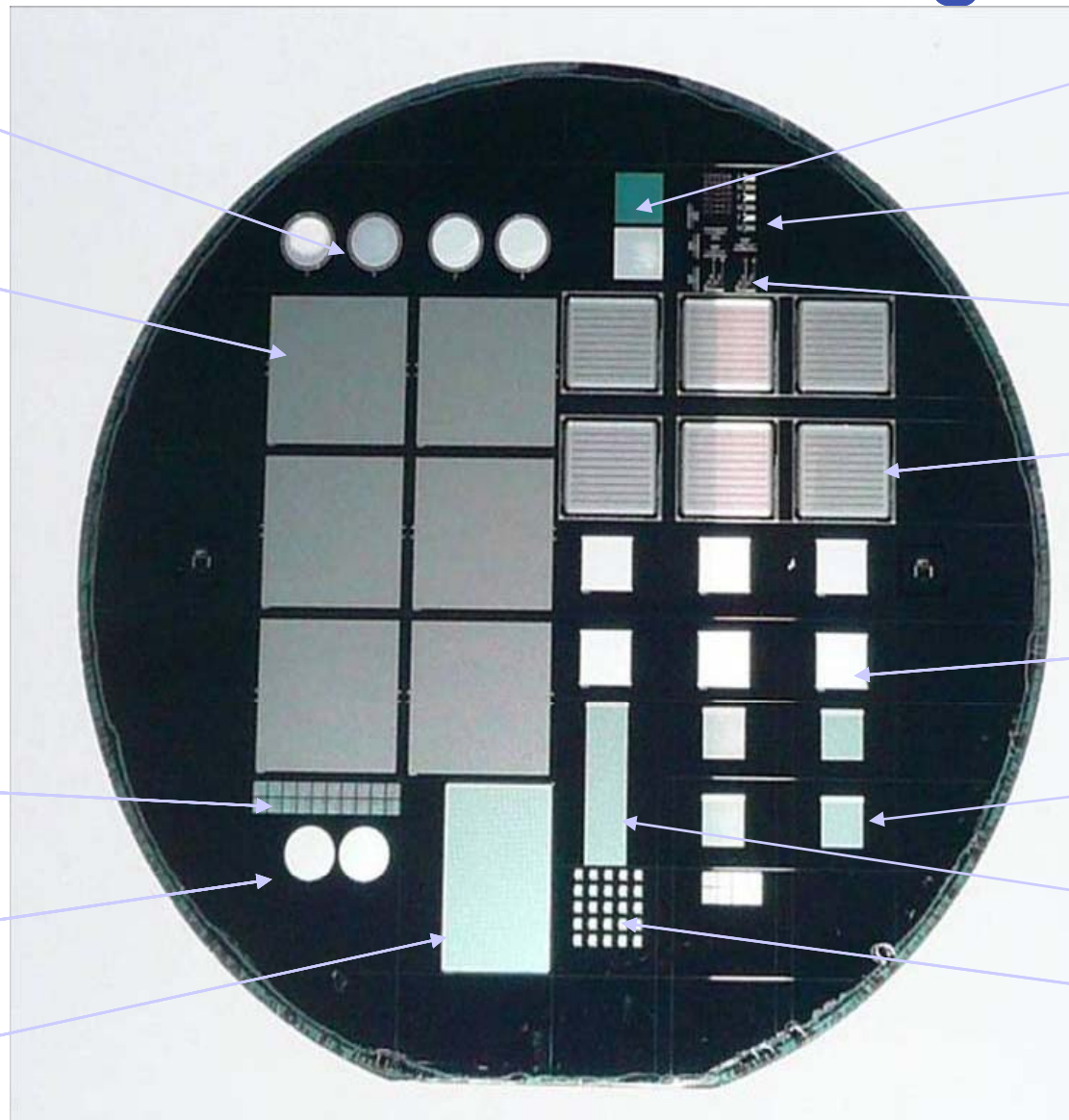
Atlas pixel

3d pads

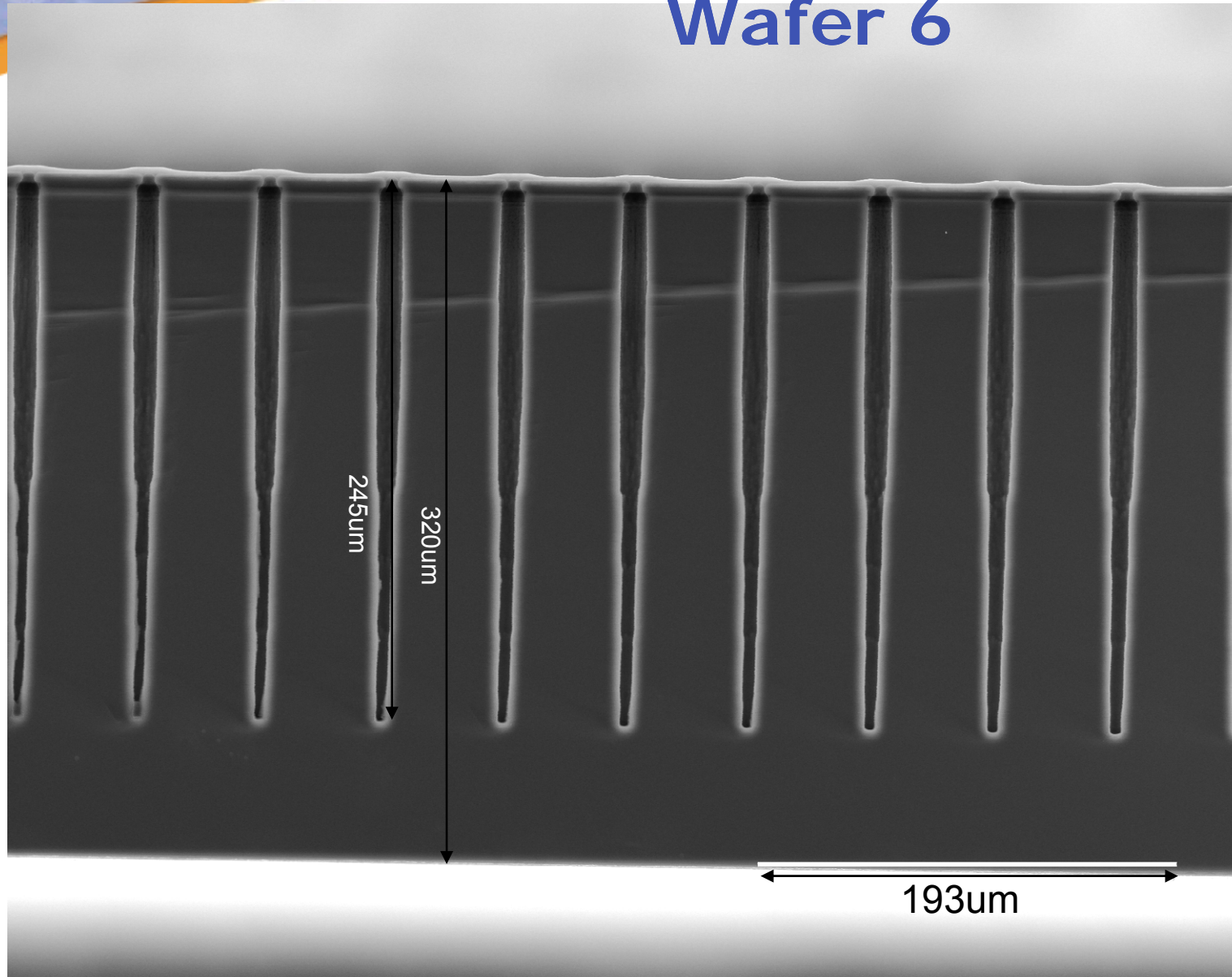
strips

Long strip

10x10 matrix



Wafer 6

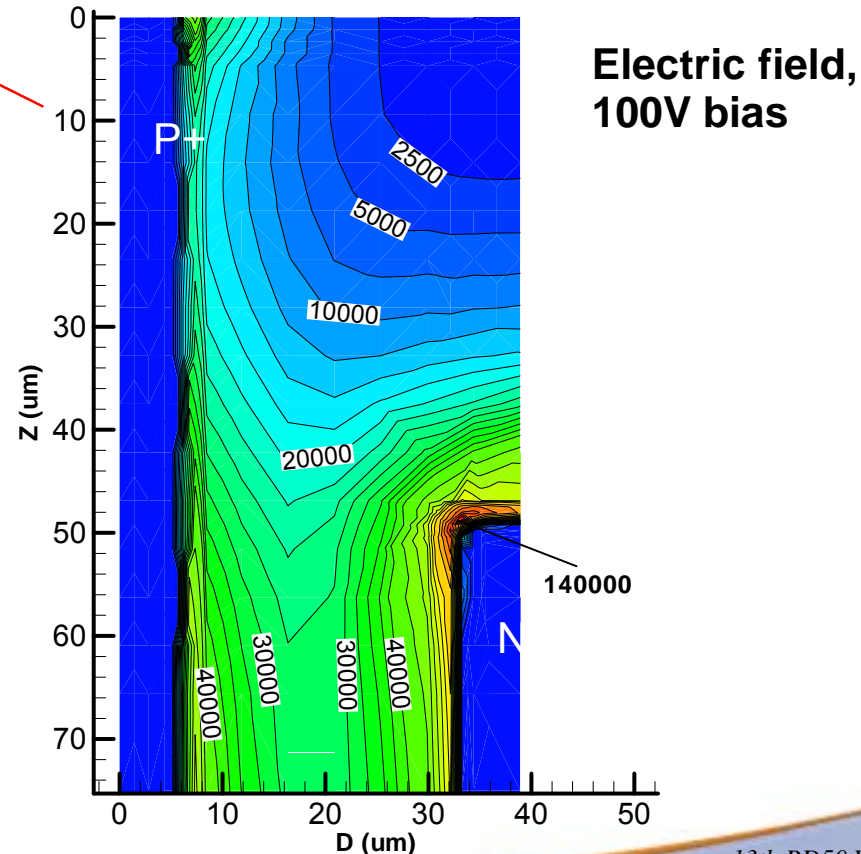
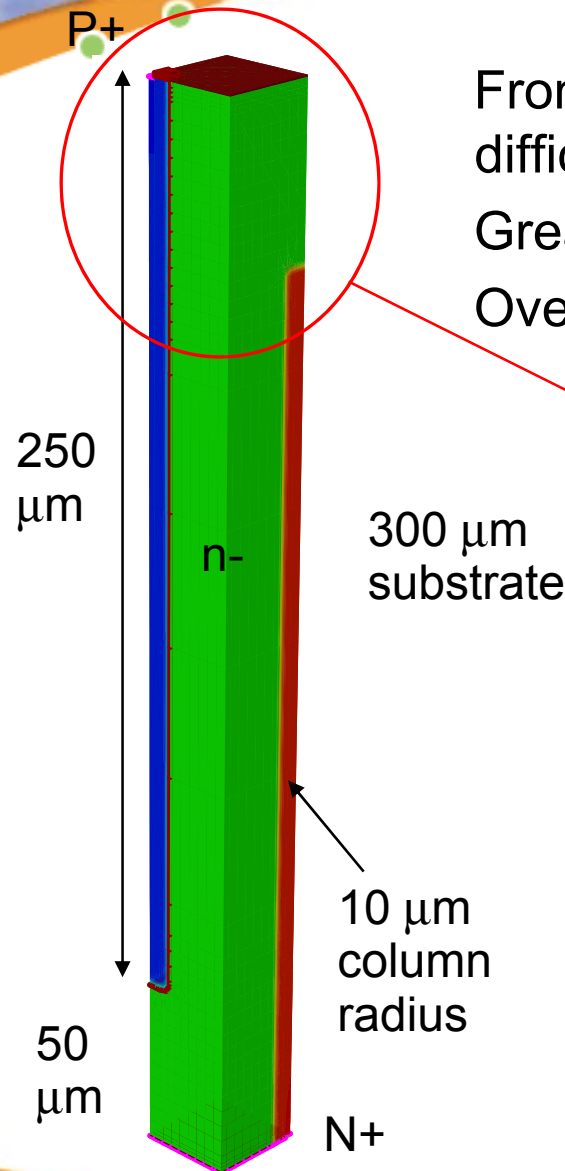


Comparing double-sided to full 3D

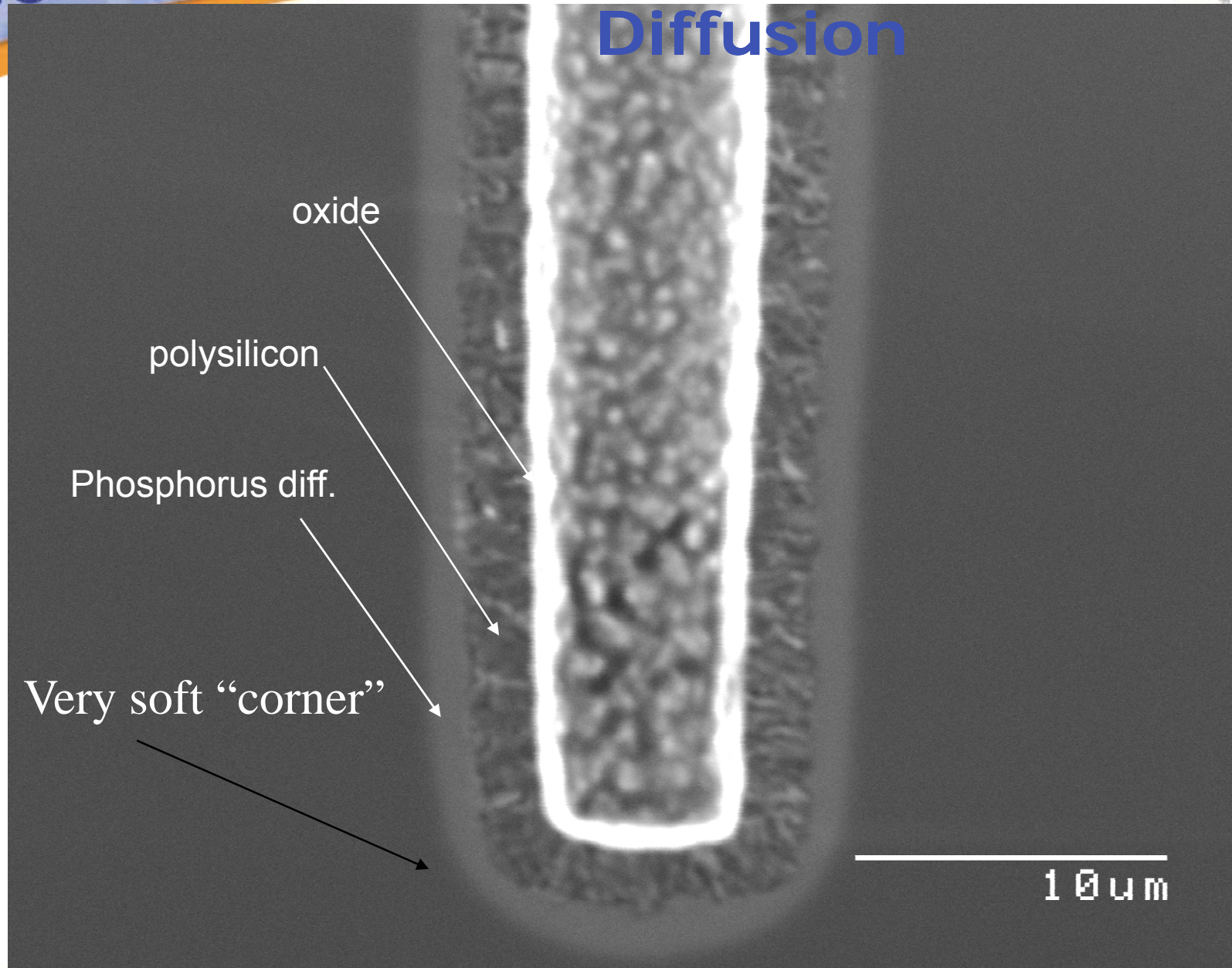
Front and back surfaces have lower field and are more difficult to deplete **X**

Greater substrate thickness for given column depth **✓**

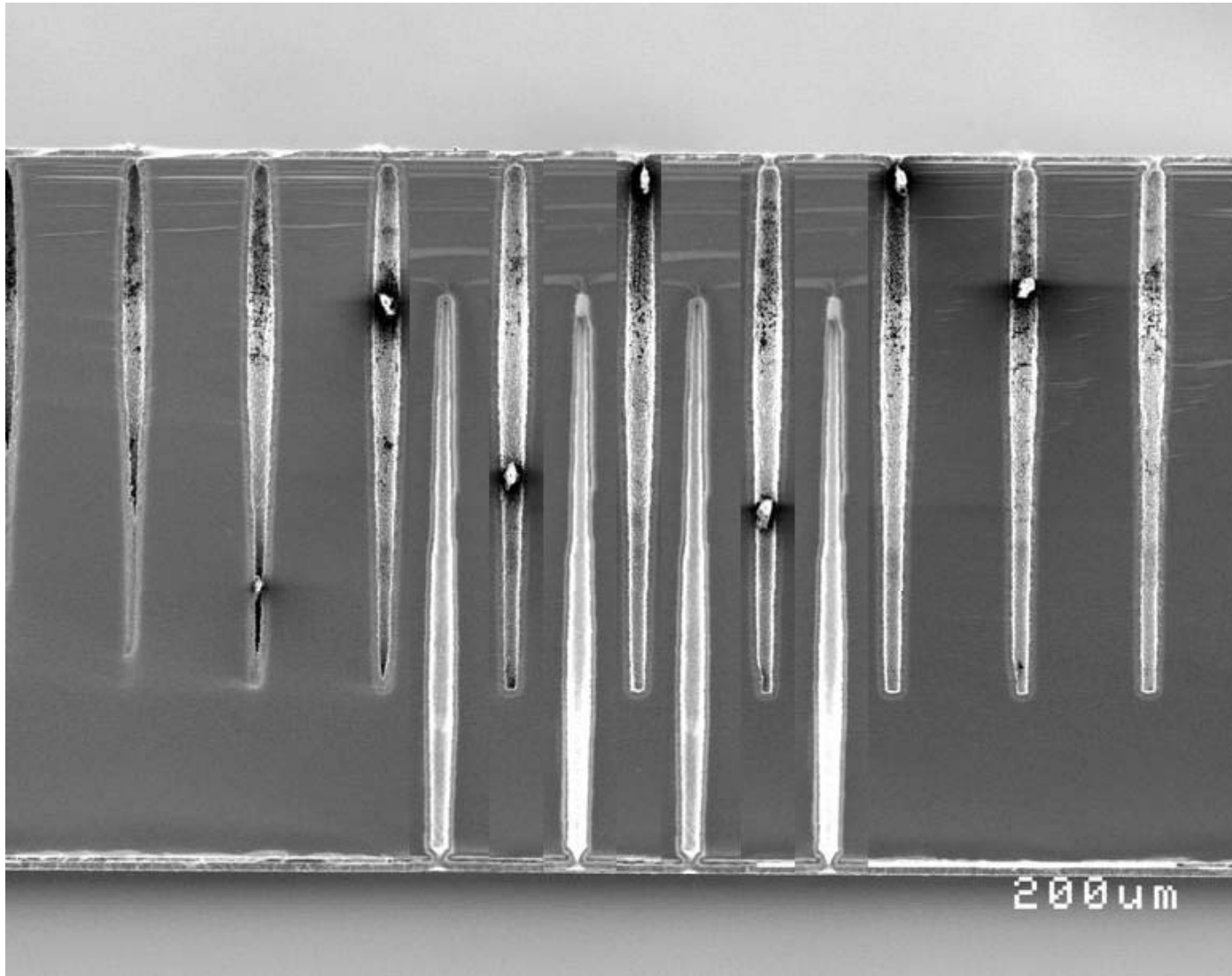
Overall, expect similar radiation tolerance

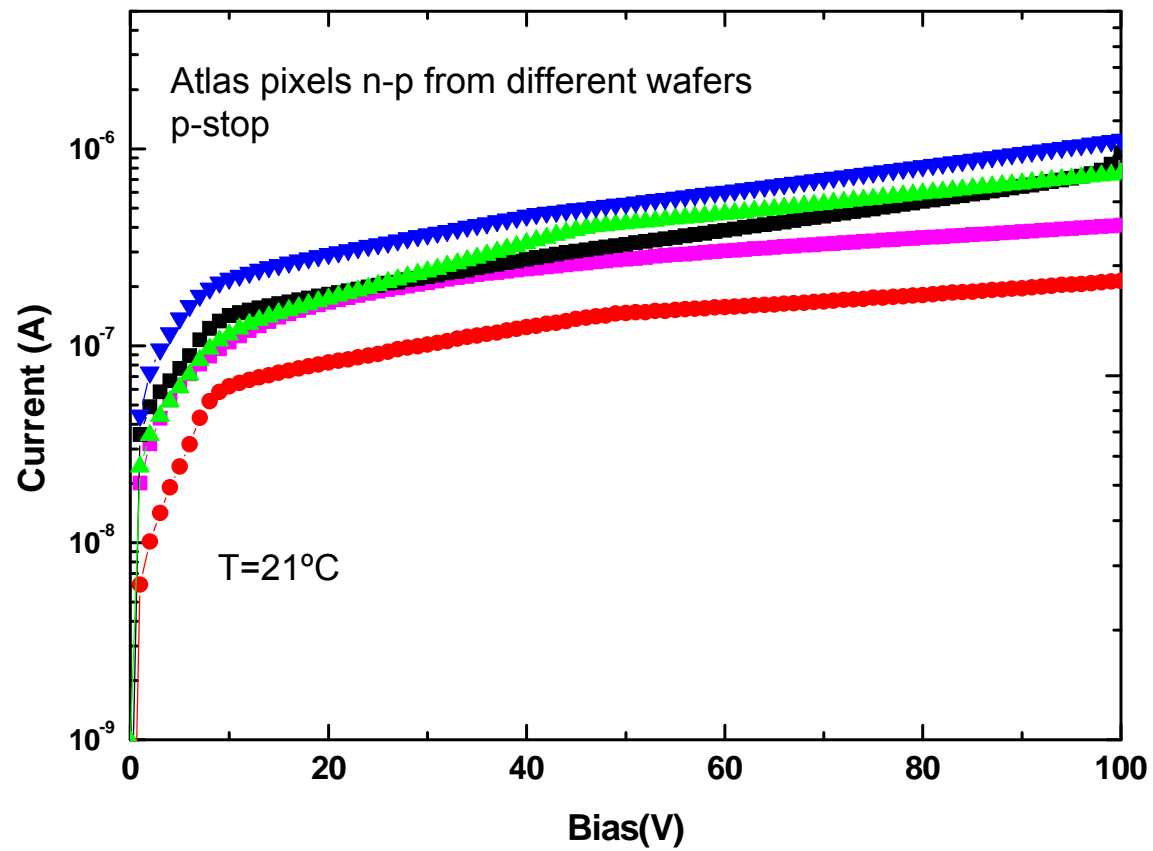


Diffusion

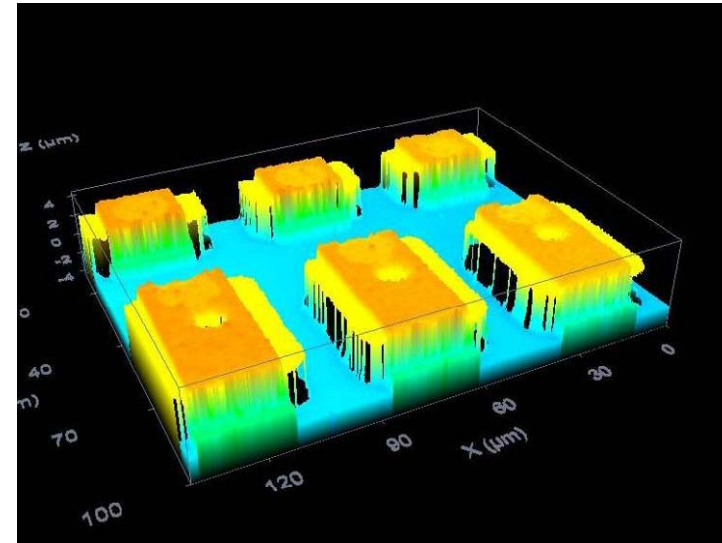
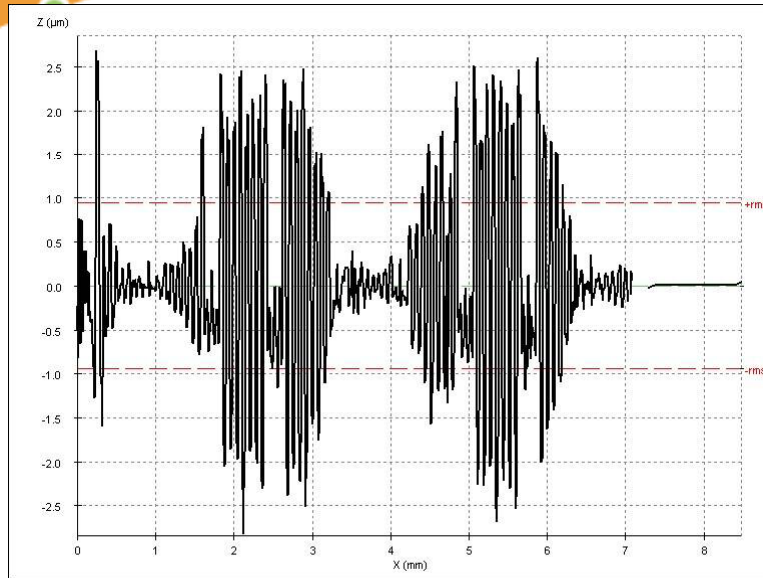


Double side

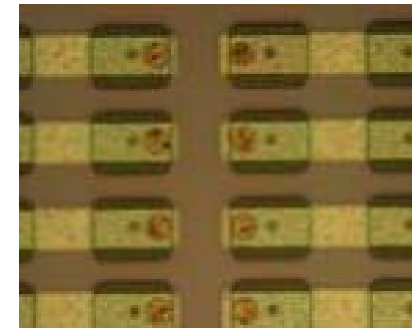




Bump bonding



UBM-Ni/Au

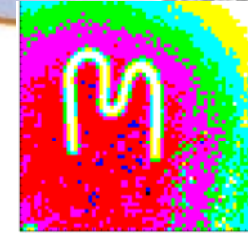


- 2 full wafers sent to Freiburg for In Bump Bonding.
- 10 chips will be sent to VTT for bonding with medipix2 timepix chip
- Glasgow in contact with IZM for bonding with FI3 atlas readout

Measurements at Glasgow

First fabrication run 2007

Medipix2 3D detectors



256 by 256 array of 55 μ m square pixels

Readout chip for X-ray detection

- Each photon hit is compared to a pair of adjustable thresholds

Pixel counts no. of accepted hits during acquisition time

Surface of 3D detector



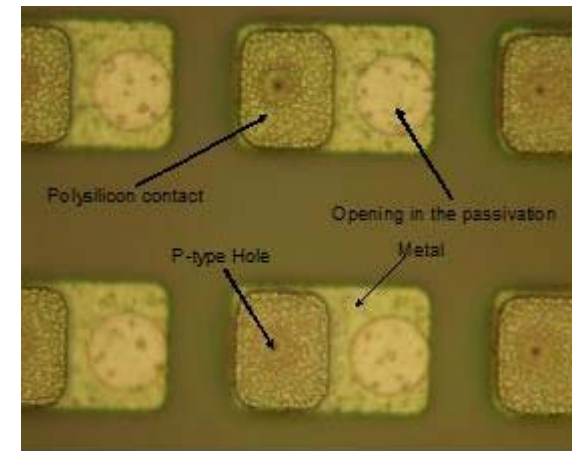
55 μ m
pixels

P-electrodes

N-electrodes on back
(not visible)

3D guard ring

Bump bond pad



Medipix2 3D detectors



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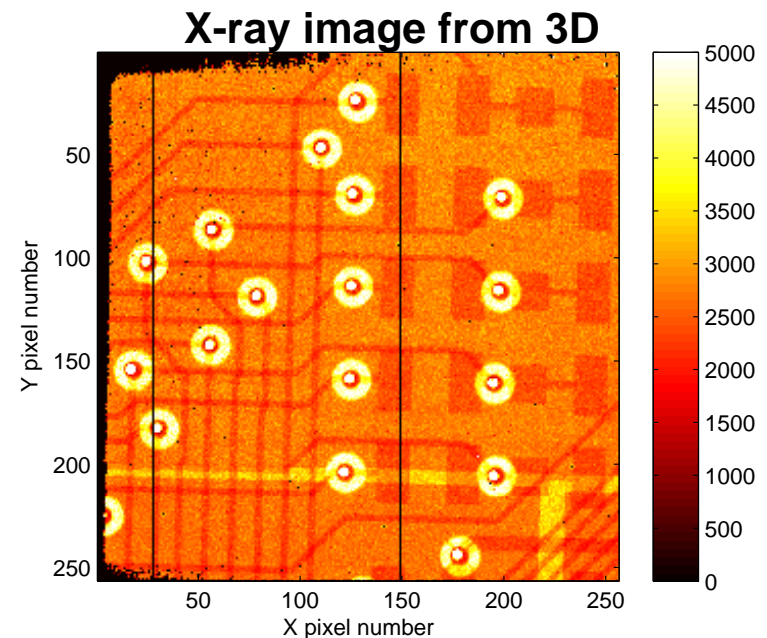
3 detectors bump-bonded to readout chips at VTT

- All 3 detectors work, though 2 show dead pixels along edge
- Possibly due to bending of wafer during poly-Si deposition

Medipix 3D connected to USB readout system (IEAP, Prague)



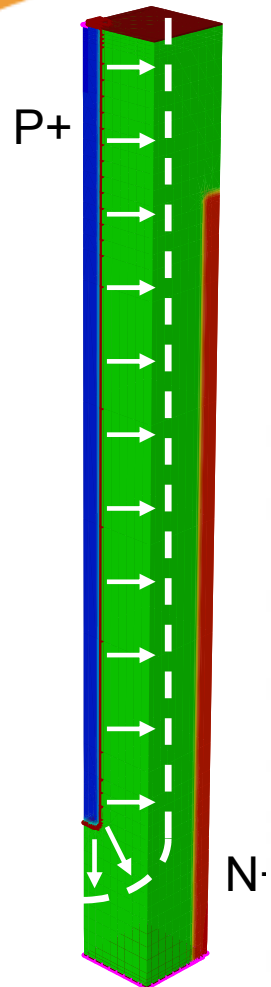
Medipix-3D chip



Depletion of Medipix2 3D

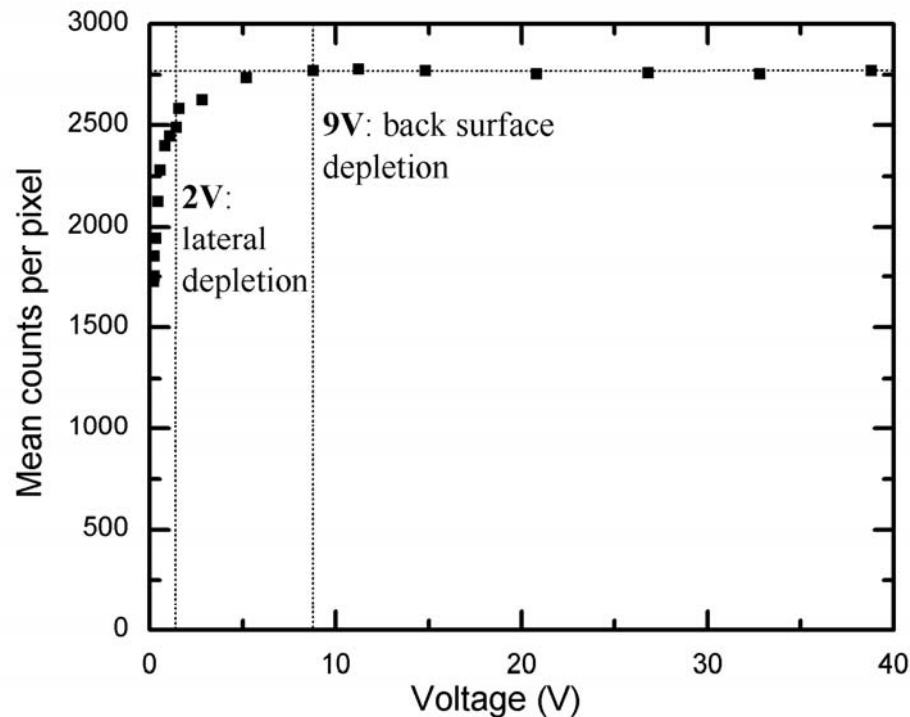
Tested count rate vs bias with 60kV tungsten X-ray tube

- Rapid increase in count rate up to 2V – lateral depletion
- Count saturates around 9V – full depletion
- CVs on test structures follow same pattern



Depletion from
column tip to b

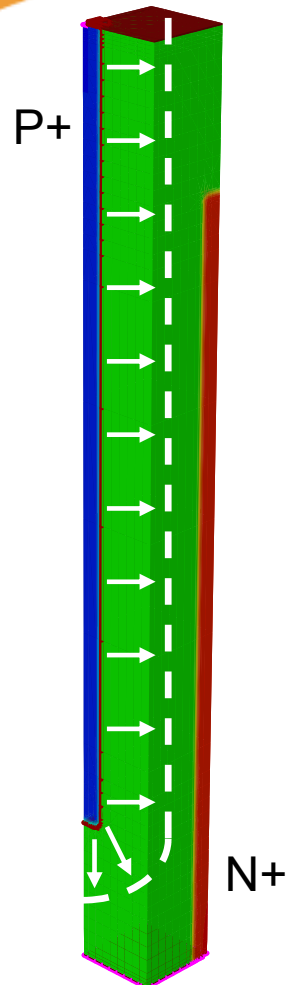
X-ray tube test



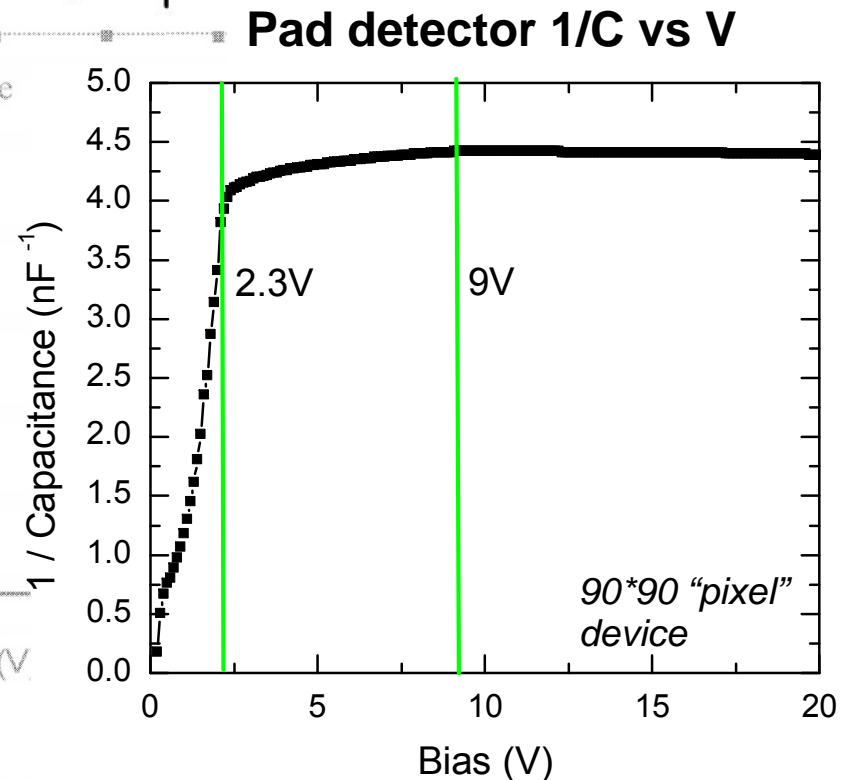
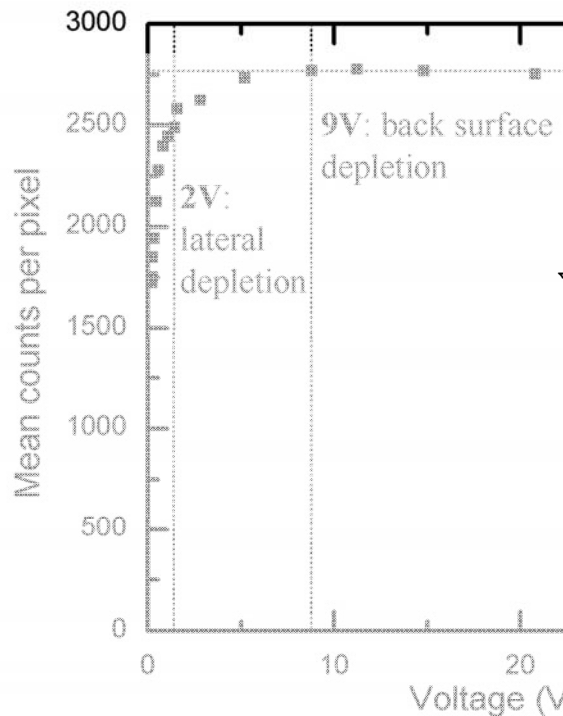
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Depletion from
column tip to back



hard

Spectral response of Medipix2 3D

Spectral response tested with monochromatic X-rays at Diamond

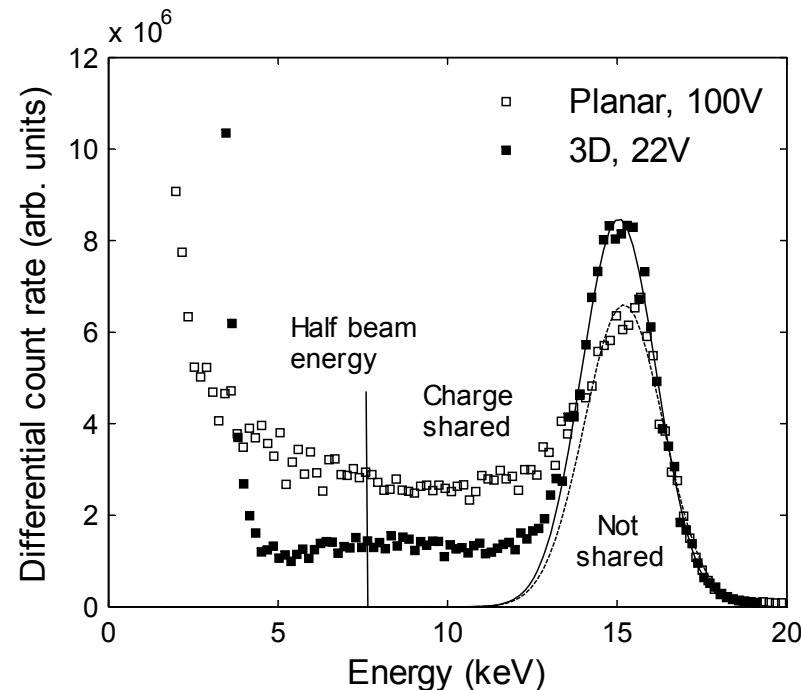
- 300 μ m planar p-in-n detector tested for comparison (100V)

3D detector shows lower charge sharing

- 23% of hits shared on 3D, 40% on planar

Slightly lower count rate on 3D (\sim 15%), most likely due to loss in electrodes

15keV X-ray spectrum



*Thanks to Julien Marchal,
Nicola Tartoni and others at
Diamond*

3D strip detectors

4 detectors

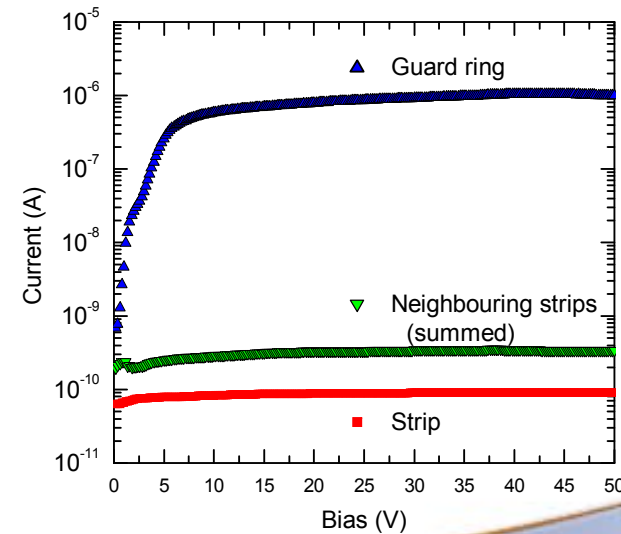
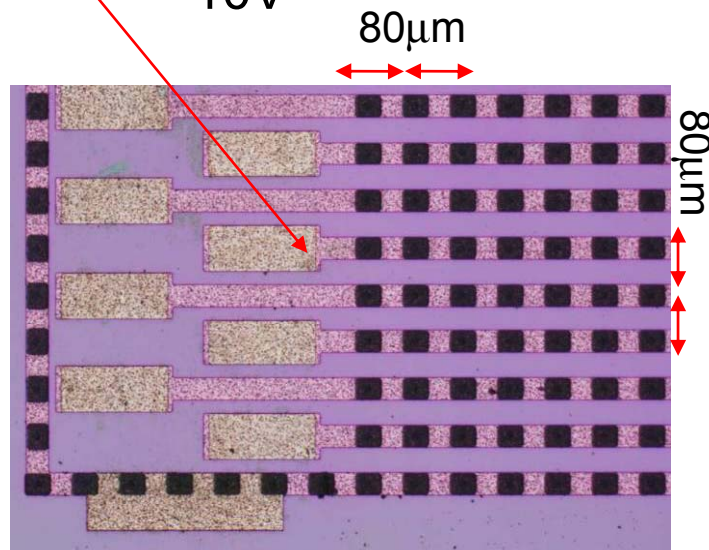
50 p+ readout columns per strip; 4mm length

50 strips

Unirradiated IV:

- $\sim 100\text{pA/strip}$ current in all detectors at 50V and 21°C (2 pA/hole)
- Guard ring current varied: best $0.03\mu\text{A}$ @ 50V, worst $20\mu\text{A}$ @

P+ columns linked
by track 10V



MIP test setup with LHC-speed electronics

Tested with ^{90}Sr beta source

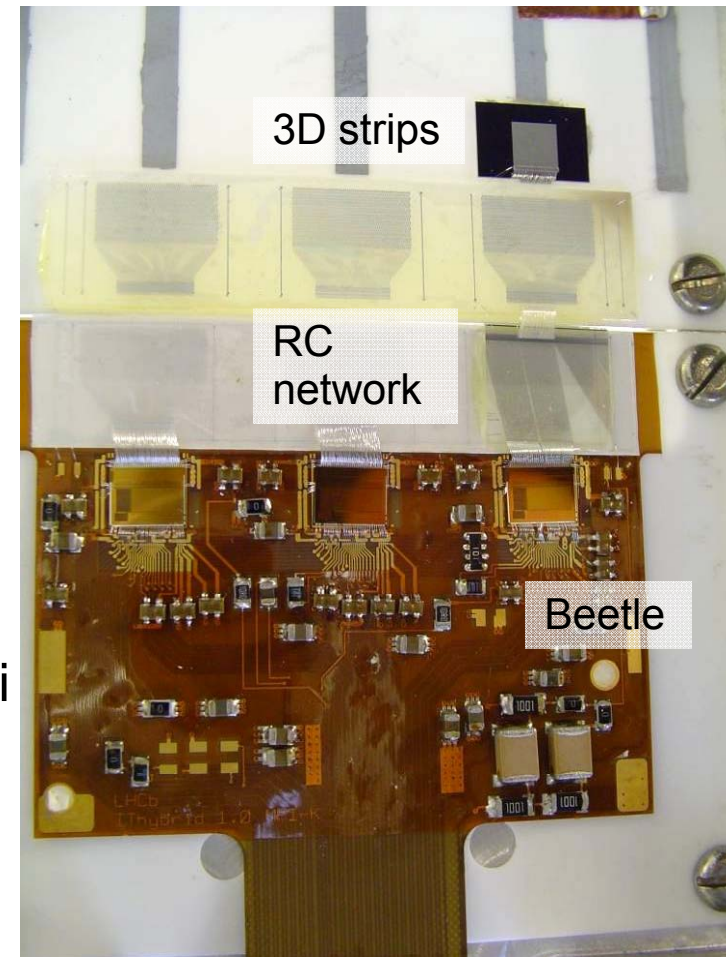
LHCb electronics (Velo, Si tracker)

Beetle readout chip

- 40MHz readout rate
- Analogue readout

Strip detector was DC coupled

- Added RC network chip to connect irradiated sensor to Beetle
- Thanks to Jaakko Härkönen, Helsinki



Charge collection in irradiated strips

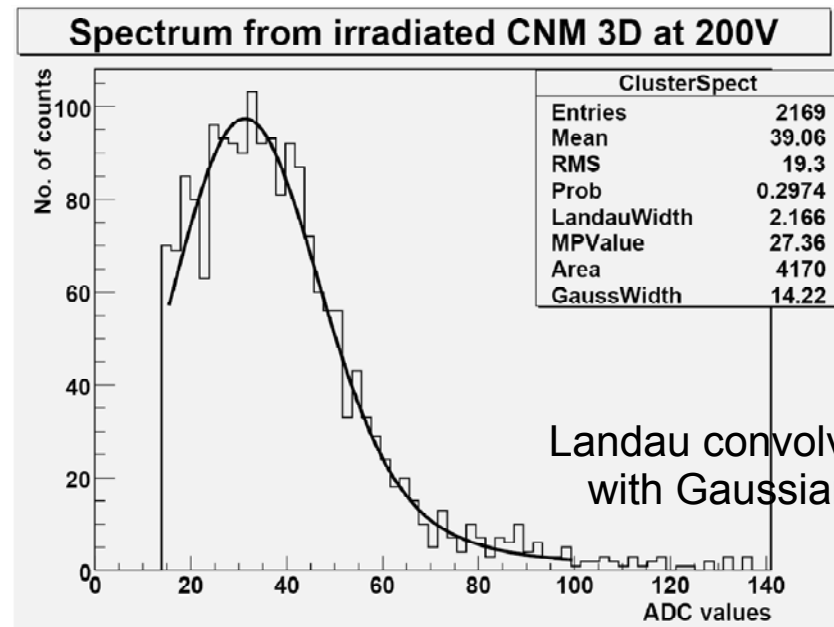
Strip detector irradiated to $5 \cdot 10^{15} n_{eq}/cm^2$ with reactor neutrons at Ljubljana

When cooled, detector could be biased to 200V during tests

- When cooled, some strips suddenly became noisy (even without bias); investigating test setup

System calibrated with undamaged, AC coupled n-in-p planar detector

12,800e signal

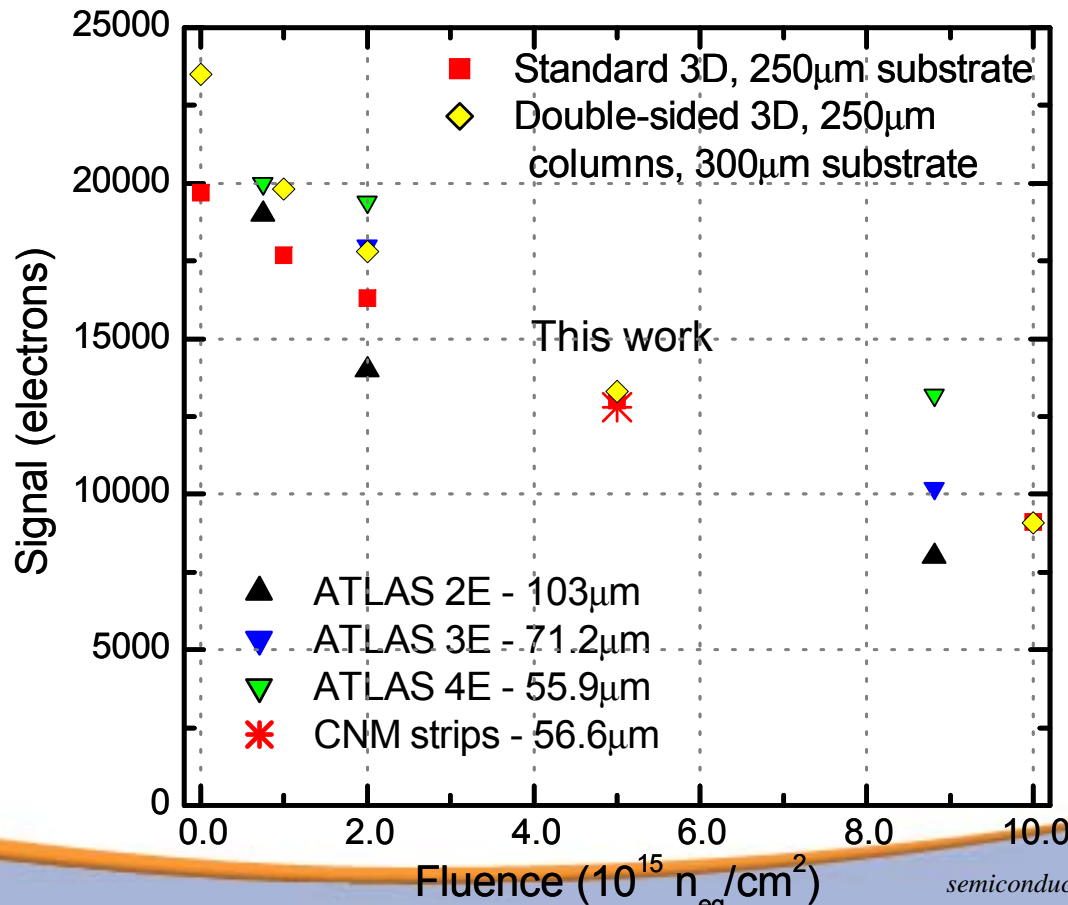


Comparison with other 3D detectors

Signal from Stanford 3D – Cinzia da Via (Manchester) NSS '07

- 250 μm columns in 250 μm p-type substrate, n+ readout
- Electrode spacings (indicated) are compatible with ATLAS pixels

CNM strip results are similar



NB: Need to consider SNR to compare detectors

Conclusions of the second fabrication run

- Fabrication run with 16 wafers (only two were damaged during the process).
- 8 n-p wafers and 6 p-n wafers.
- Different geometries: Atlas pixels, Medipix 2, Pilatus and DC strips.
- P-stop isolation, holes aspect ratio 25:1 (10 μ m diameter, 250 μ m deep).
- Detectors are diced and prepared for bump bonding, UBM deposited on different wafers (no all).
- Double side processing demonstrated to be very reliable and repeatable.
- Tests of the first run of double-sided 3D detectors show:
 - Successful Medipix2 pixels with low V_{dep} and low charge sharing
 - Good readout signal from strips after $5 \cdot 10^{15} n_{eq}/cm^2$ damage