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Measurements of 3D Detectors

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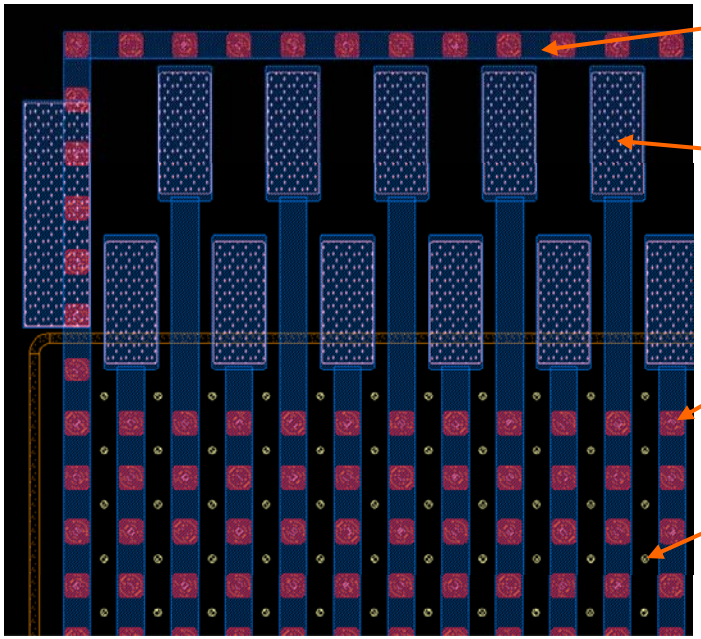
3D Devices

Devices include: Pads, strips, pixels detectors, test structures

Typical device layout –
Strip detector, 80µm pitch

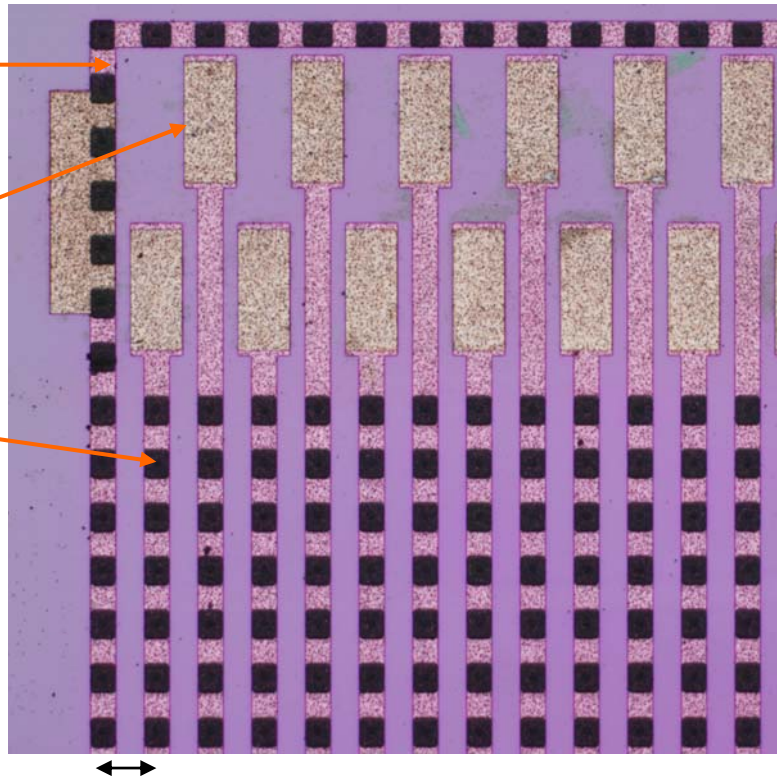


3D guard ring

Bond pads

Collecting electrodes

Bias electrodes (back surface)



80µm

•See Guilio's talk for full details

Wafers

Two 4” wafers produced

one used for the electrical tests

other for bumpbonding

Pixel:

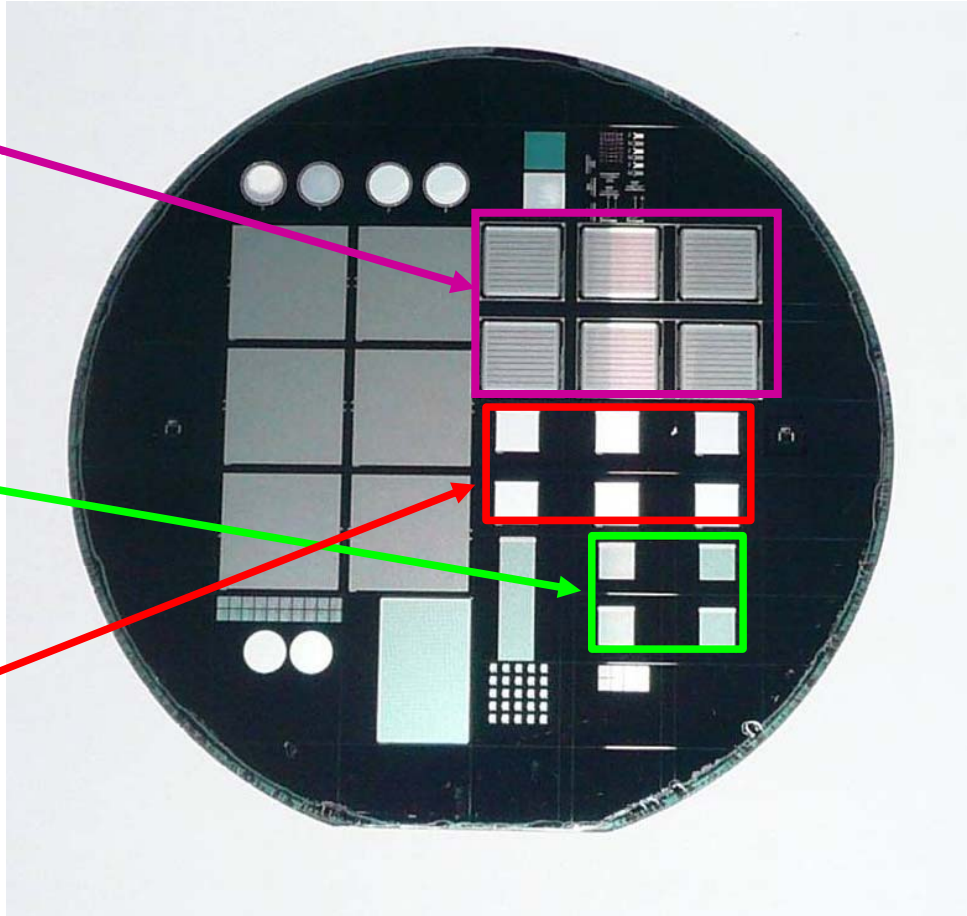
- **6 Medipix2**
- **6 ATLAS pixels**
- **1 Pilatus**

Strips:

- **4 short strips**
- **1 long strip**

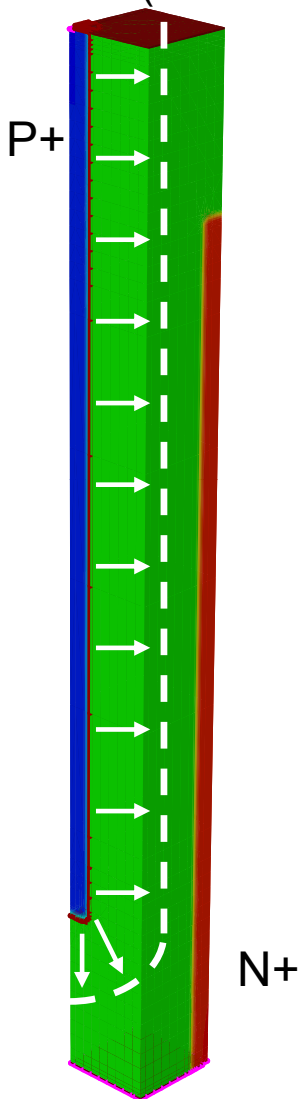
-Other:

- **6 pad diodes**
- **Test structures**



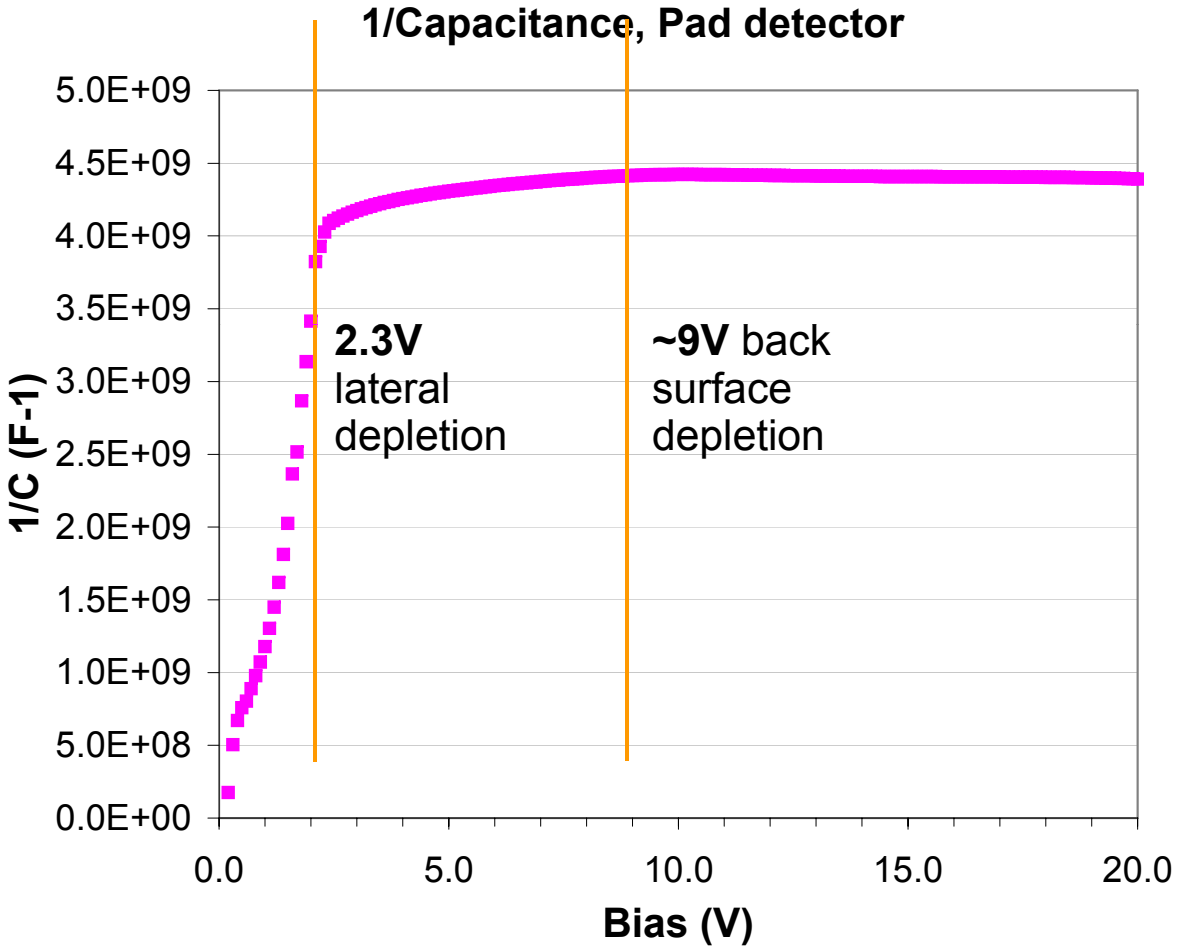
Pre-Irradiation Pads CV

Lateral depletion around column (~2V in sim.)



Depletion to back surface from tip of column (~8V in sim.)

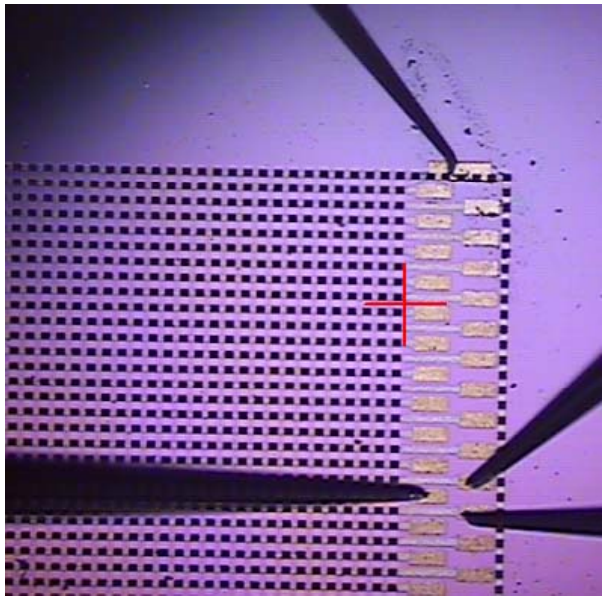
- Pad detector – 90 * 90 columns, 55µm pitch

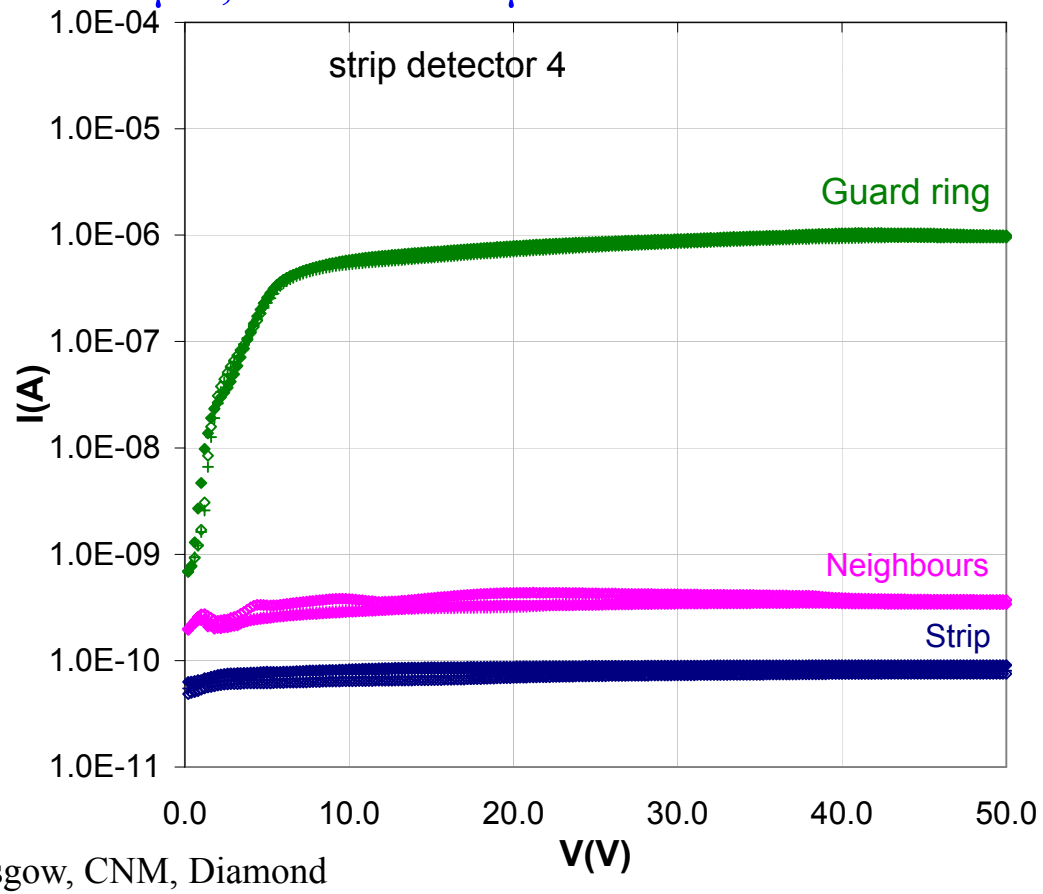


- No breakdown observed, one device 200V

Pre-irradiation Strip IV

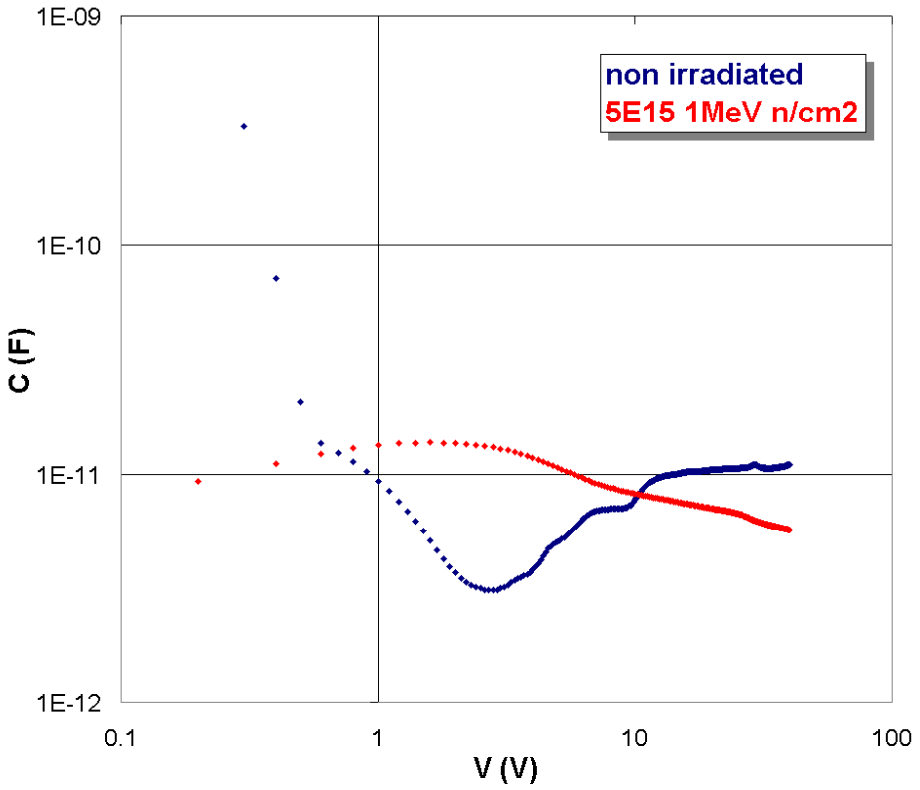
- Measured with 3 strips and guard ring at 0V, backside biased
- Strip currents ~100 pA (T = 21˚C) in all 4 detectors (2 pA/hole)
- Can reliably bias detectors to 50 V (20 times lateral depletion voltage)
- Capacitance to backplane 10 pF/strip
- Guard ring currents vary: highest 20 μA, lowest 0.03 μA at 10V





Irradiated Strip CV

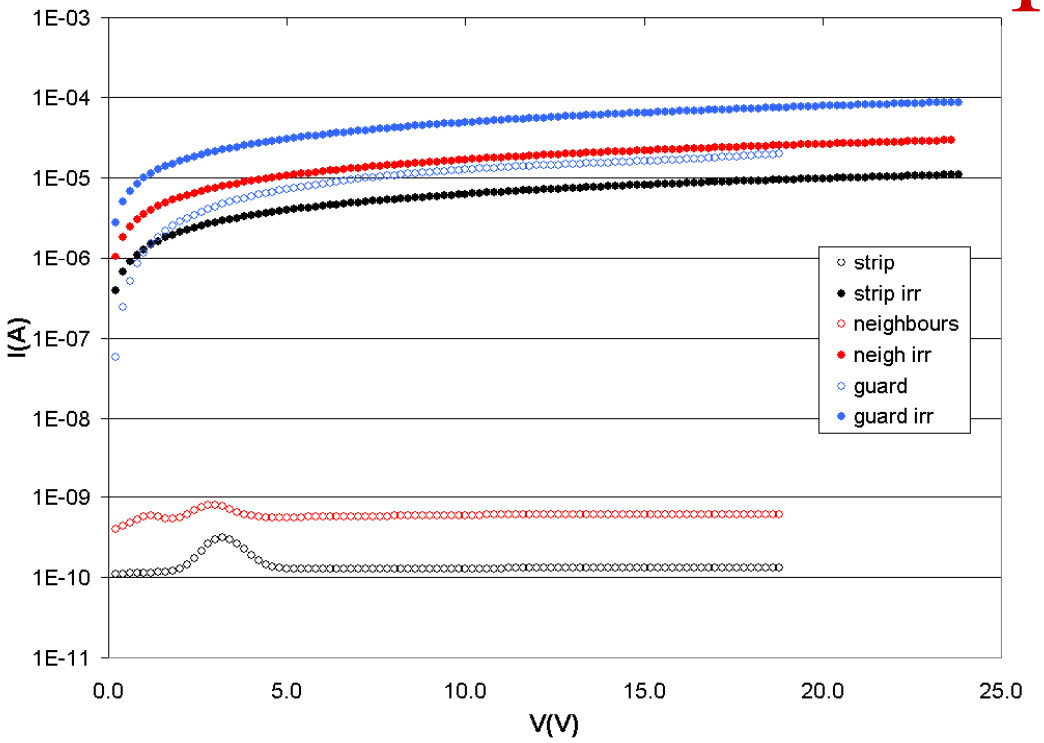
Irradiation and dosimetry: Ljubljana 5×10^{15} n_{eq}/cm^2
Detectors not annealed, kept at -13ºC



C measured between strip and backplane, 21ºC:

- Non-irradiated: C stable after 10 V
- Irradiated:Substrate not fully depleted at 40V

Irradiated Strip IV



5×10^{15} n_{eq}/cm^2

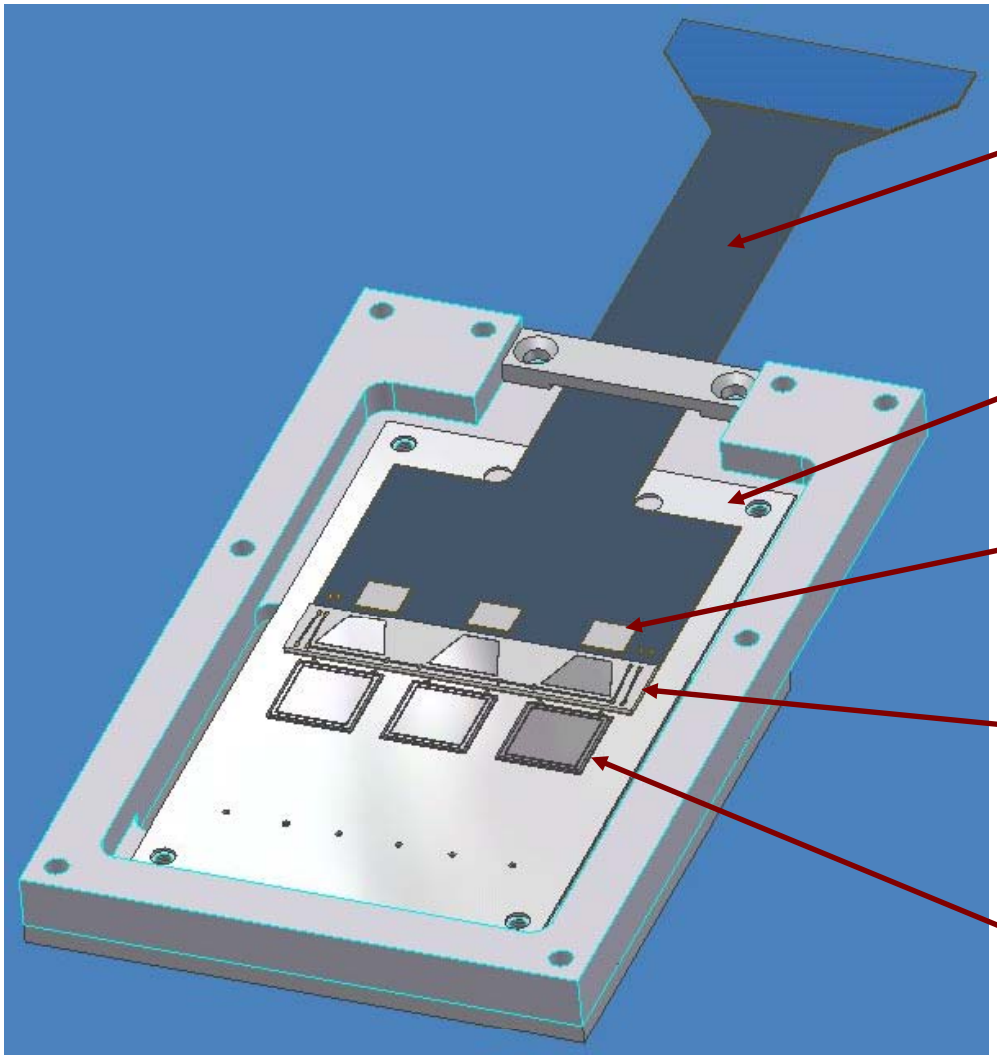
- Same setup as non-irradiated characterisation, 21˚C
- Currents too high to bias to full depletion
- Simulation: V(lat. depletion) = ~50V
  - I(50V) ~ 20 μA/strip at 20˚C
- Reasonable current damage constant, $\alpha \sim 6\times10^{-17}$ A/cm

MIP test setup - LHCb Velo

- Stand-alone setup
- Sr90 source and scintillator / PMT trigger
- Beetle strip readout chip (128 channels)
  - Positive or negative polarity
  - Analogue, 25ns
- Logic only accepts triggers arriving at a specific time relative to the sampling clock
  - Ensures sampling at peak of pulse
  - Allows measurement of front-end pulse shape
- TELL1 readout board reads out up to 4 modules
  - ADC conversion of data
  - Controls Beetle settings, test pulses etc.
- Software decodes and processes data
  - Pedestal subtraction, FIR Filter, linear common-mode subtraction, clustering

(See L. Eklund's talk at the 11th RD50 Workshop)

Modules



Pre-production hybrids from LHCb Inner Tracker

Alumina baseboards (96% Al_2O_3, Coors Tek)

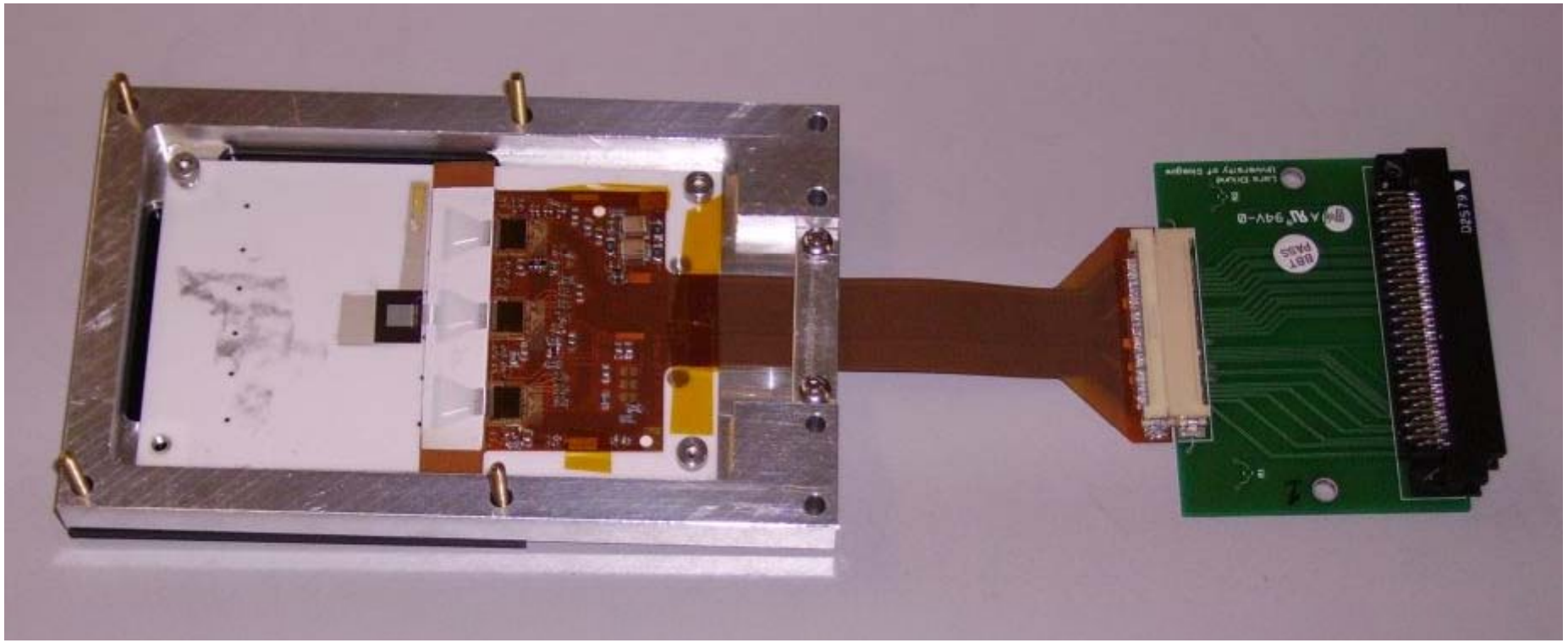
Beetle chips

Pitch Adaptors (produced in Glasgow)

Sensors

3D Detector Measurements: Glasgow, CNM, Diamond

3D detector module

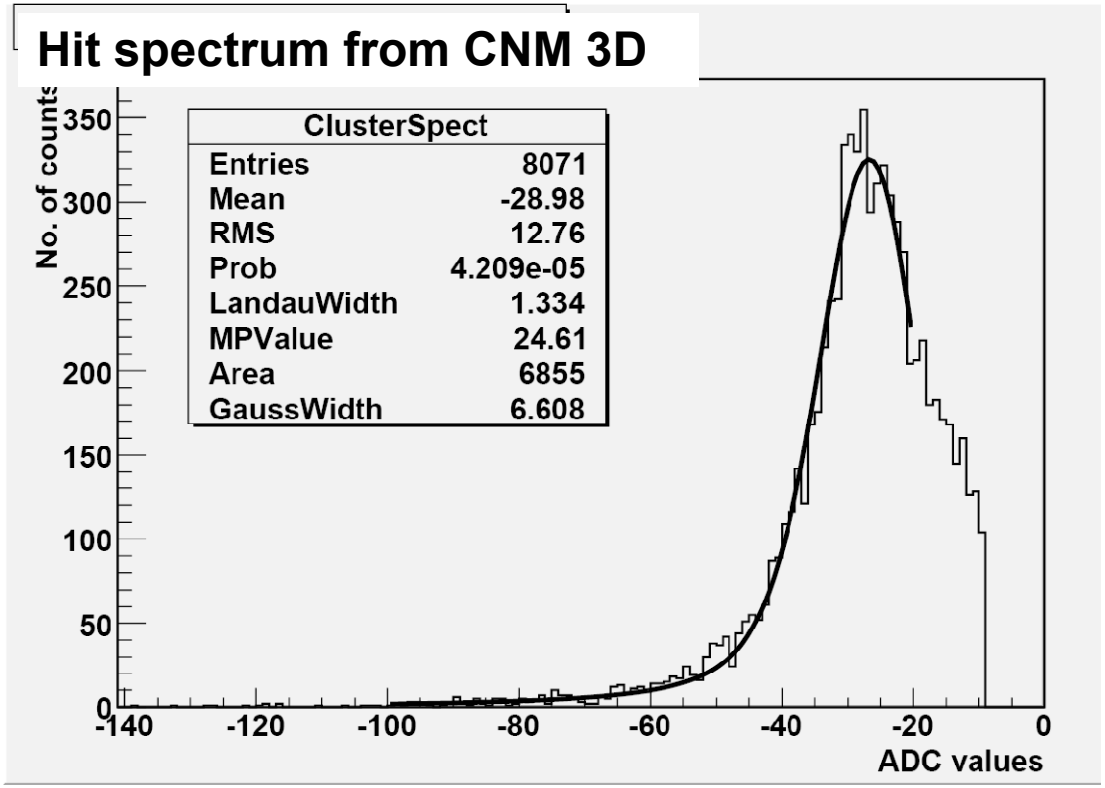


- Strip detectors DC coupled
- Unirradiated (I=100 pA) direct to FE chip
- Irradiated AC coupling needed ➔RC filter
  - No irrad. MIP results today

3D Detector Measurements: Glasgow, CNM, Diamond

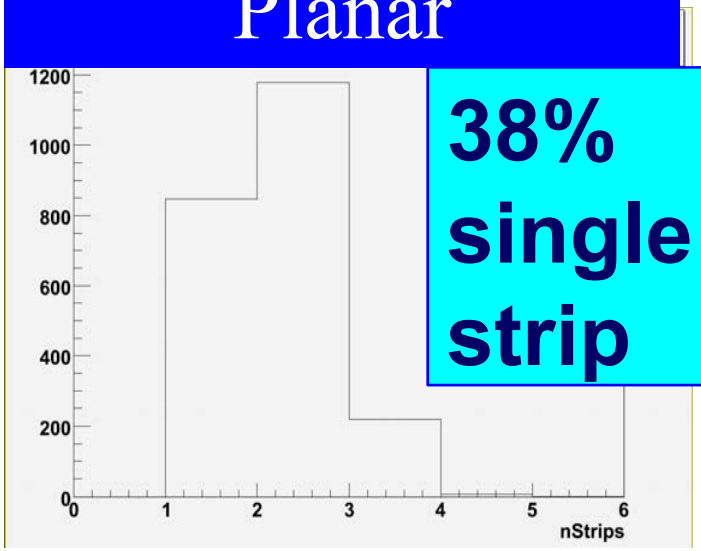
Non-irradiated Strip MIP

- Fitted with Landau convoluted with Gaussian
- More low-amplitude hits seen than expected from Landau
  - Possibly due to particles passing through columns?
- Most probable value
  - 24.6 ADC counts
- Typical noise
  - 1.75 ADC counts
- Signal/noise
  - 15:1

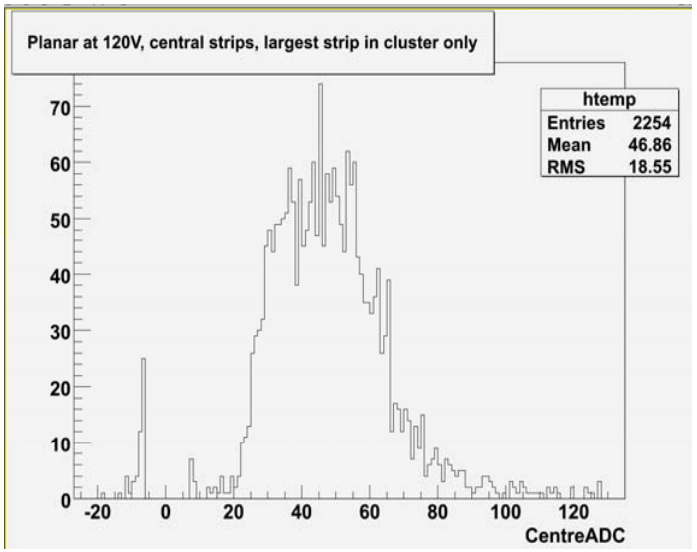


Cluster Size: Planar vs 3D

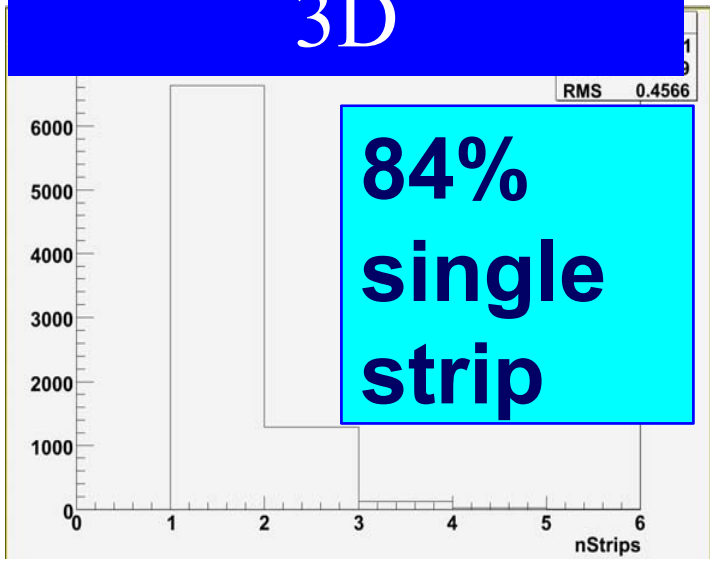
Planar



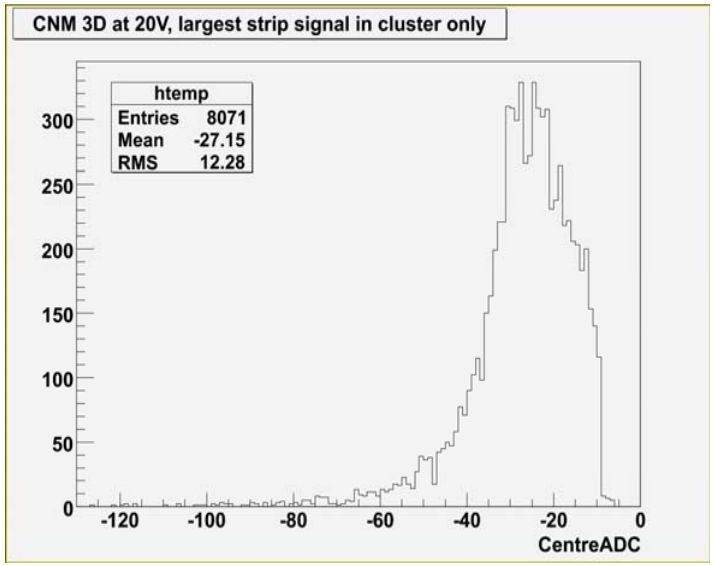
38% single strip



3D



84% single strip



- Careful study as sensitive to data processing (cluster thresholds, FIR filter)

3D Pixel Medipix2

- 3 Medipix3D (+ 1 planar) bump bonded at VTT
- USB Interface for Medipix (CTU, Prague)
- Tested with X-ray source Glasgow, Diamond

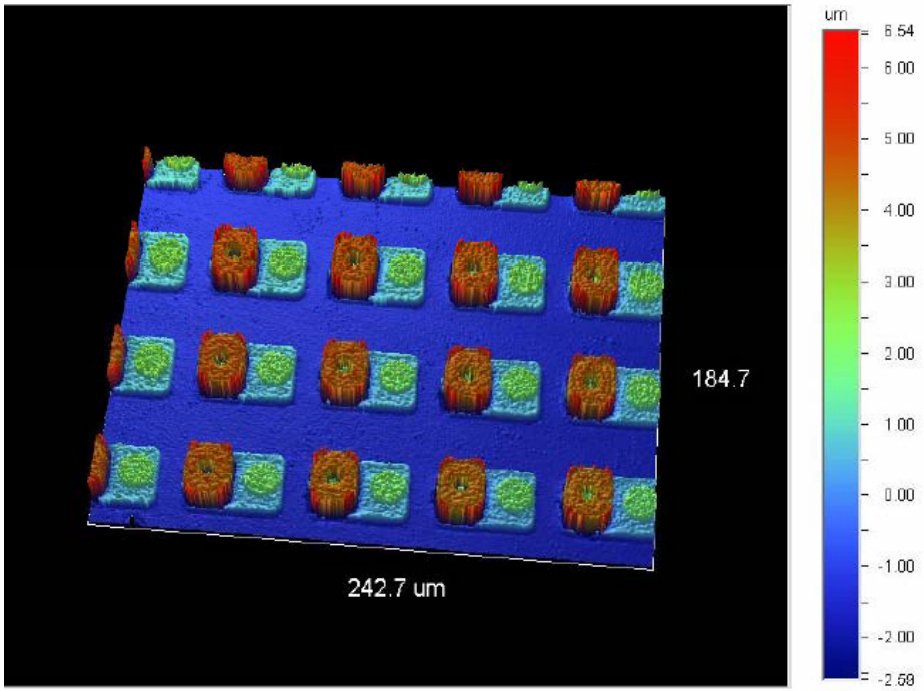
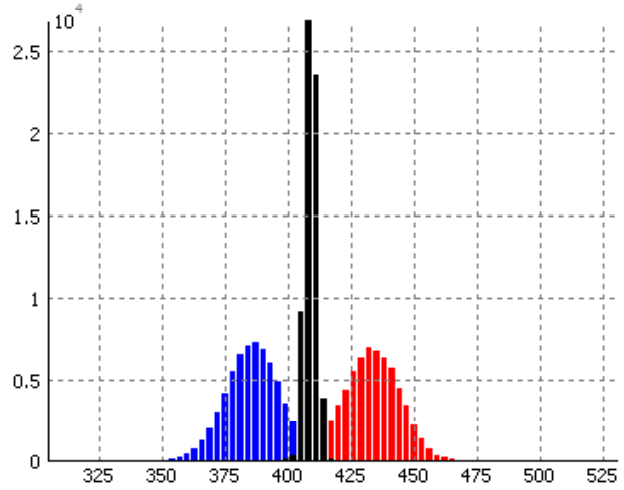


Image: VTT Finland

MediPix

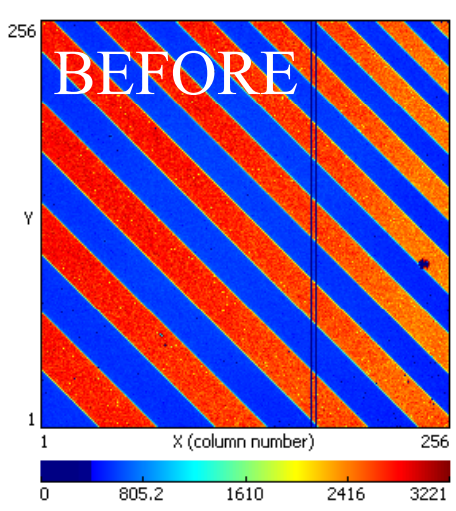
- 2nd grade sensors – two dead columns
- Unbonded pixels at the edge of two devices

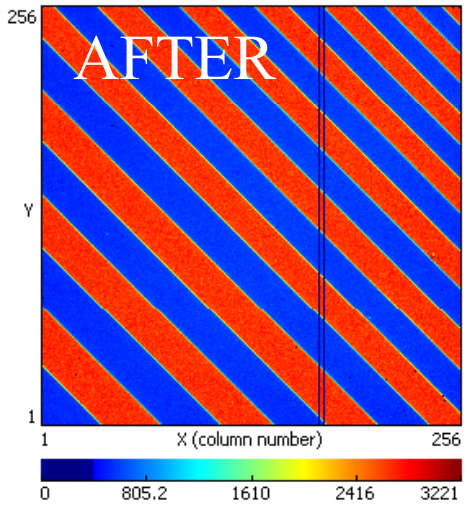
Threshold Correction of each pixel



Noise Distribution
Low Threshold All
High Threshold All
Individual Correction

Flat Field Correction

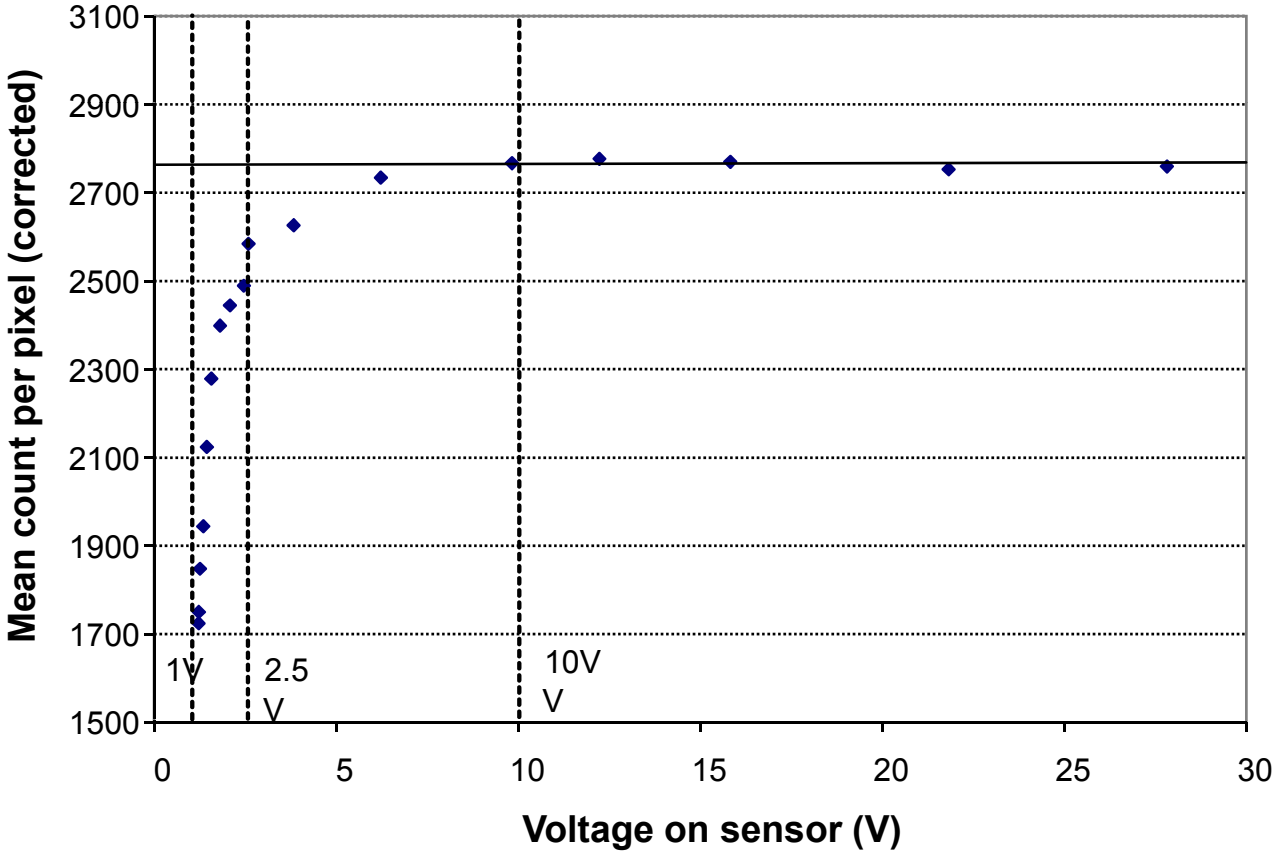




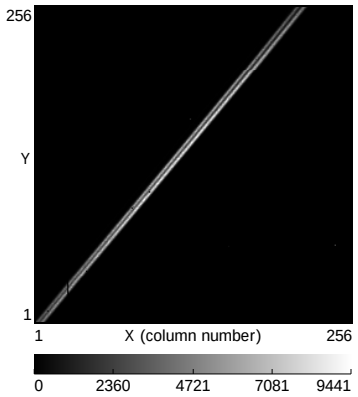
Pixel Count Rate versus Voltage

- Confirm IV,CV result for pad, strip devices

3D - Bias scan with X-ray tube

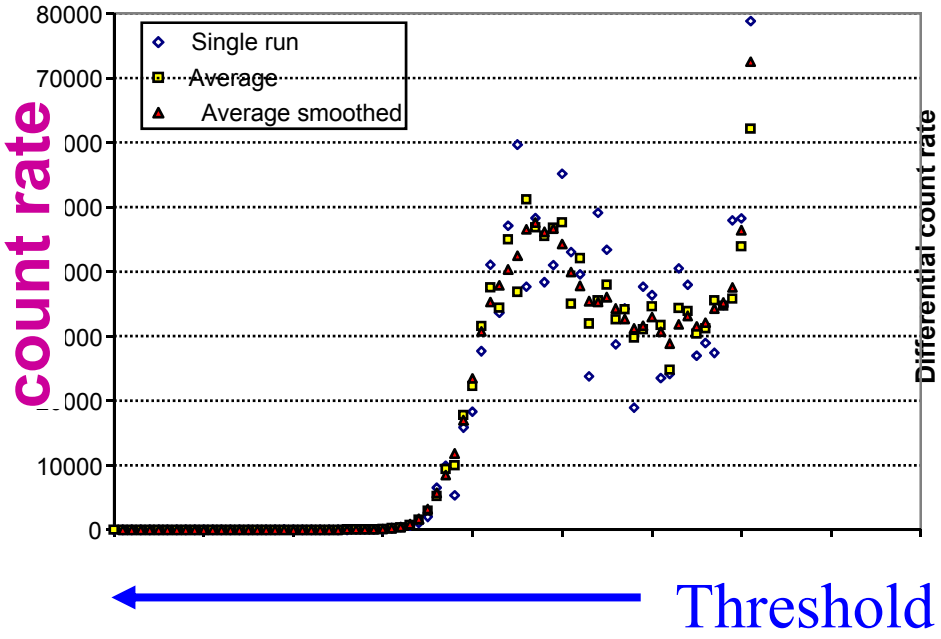


Monochromatic X-ray

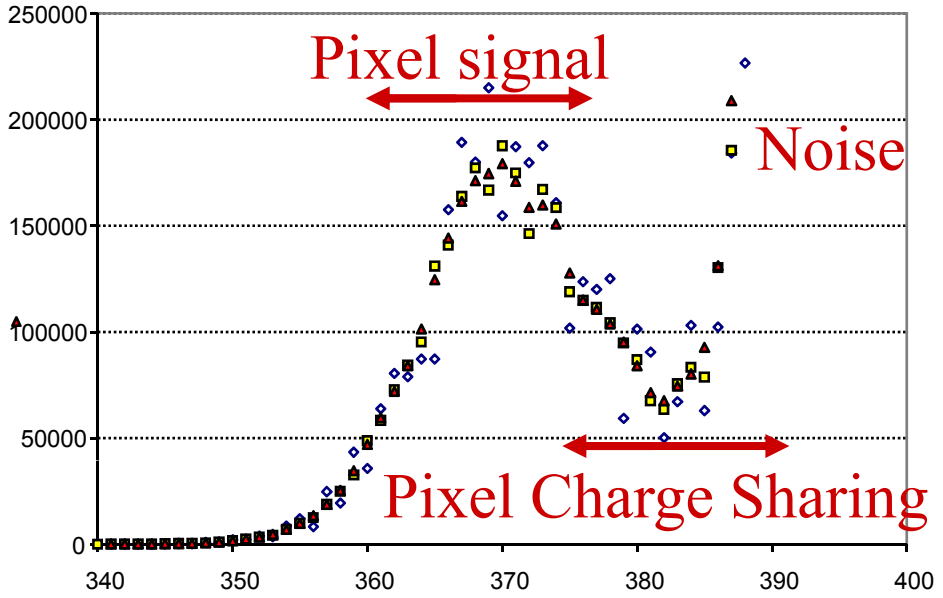


- 8 keV X-ray
- Planar Medipix/ 3D Medipix
- Compatible Signal
- Reduced Charge-sharing

Planar



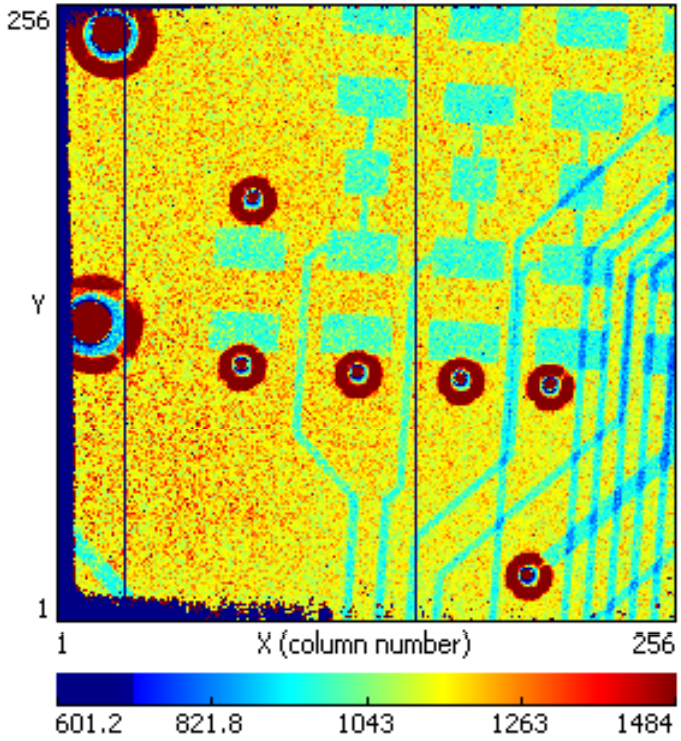
3D



Summary

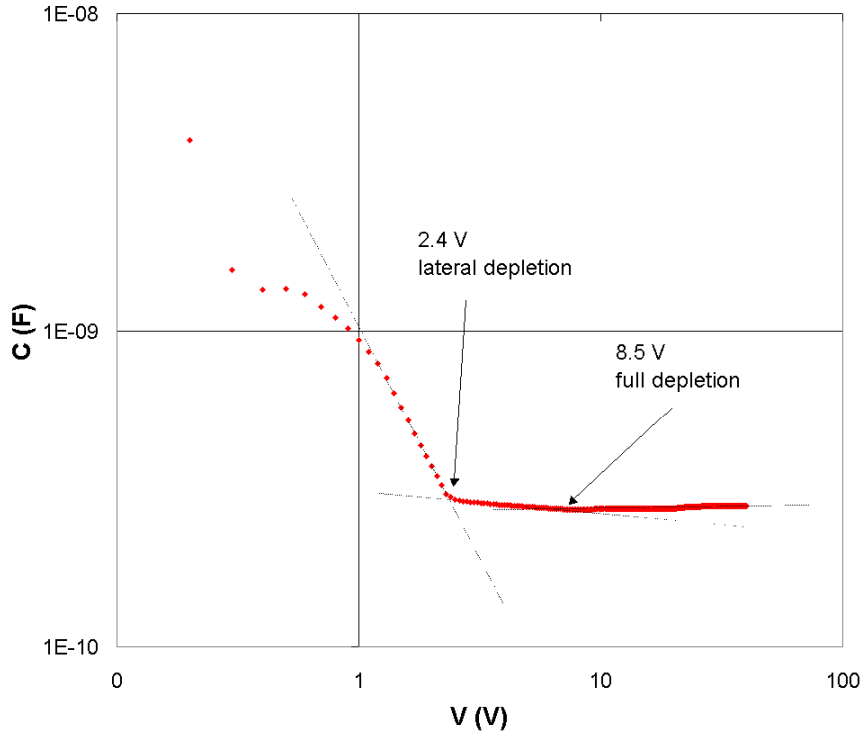
- Pad, Strip & Pixel Detectors Tested
  - Lateral depletion 2.3V
  - Strip MIP show 15:1 Signal:Noise
  - Reduced Charge sharing
- CV,IV after irradiation
  - Depletion expected ~50V
  - To test at low temp
  - To do MIP tests
- Future Work
  - Production CNM, ICEMOS
  - Testbeam at Diamond
  - Testbeam at FNAL
    - (LHCb VELO)

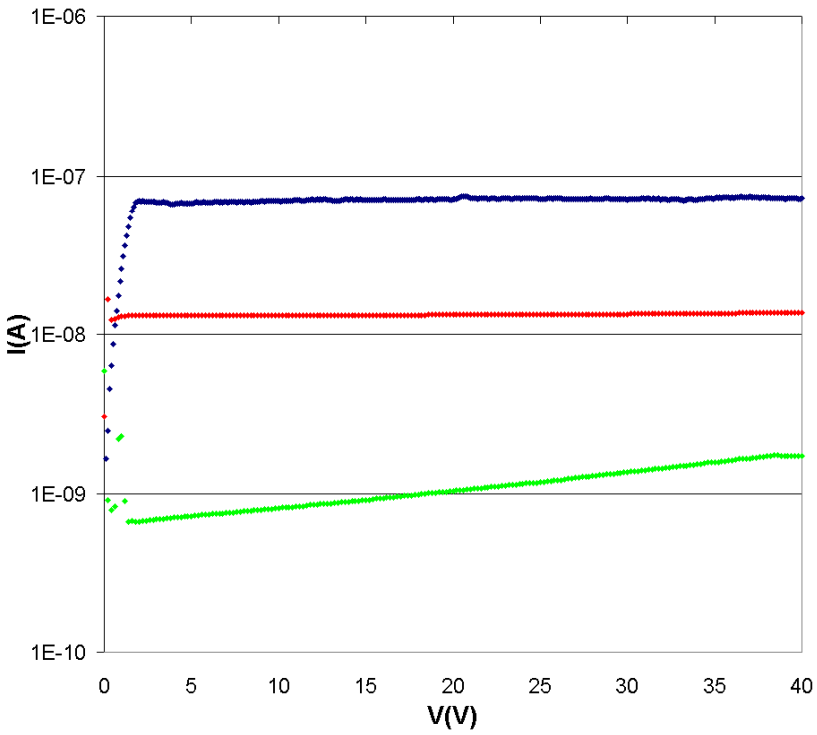
3D Medipix image of a PCB



Backup

Pre-irradiation results in pad detectors





- Guard ring and central diode at 0V, backside biased, T = 21˚C
- Lateral depletion at 2.4 V (pitch 55 μm), full depletion at ~8.5 V
- Current per hole 0.1–10 pA
- Two detectors tested to 40 V, one to 200 V, without signs of breakdown

3D Detector Measurements: Glasgow, CNM, Diamond

Charge collection results CNM3D strip