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# Update of 3D activity at the University of Glasgow

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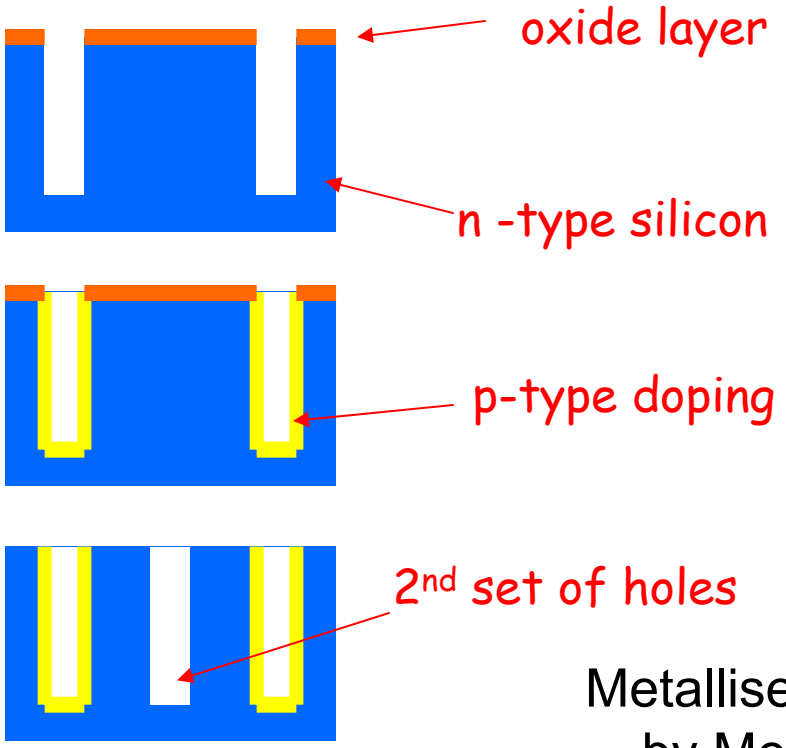
# Contents

- Latest device formation
- Irradiation tests
- Strip and pixel detectors
- Bit of fun: Spectra from GaAs 3D device

# Fabrication




1st set of holes DRIE
or Electro-chemical etching

p-type doping
Boron diffusion
at 1030ºC for 10min

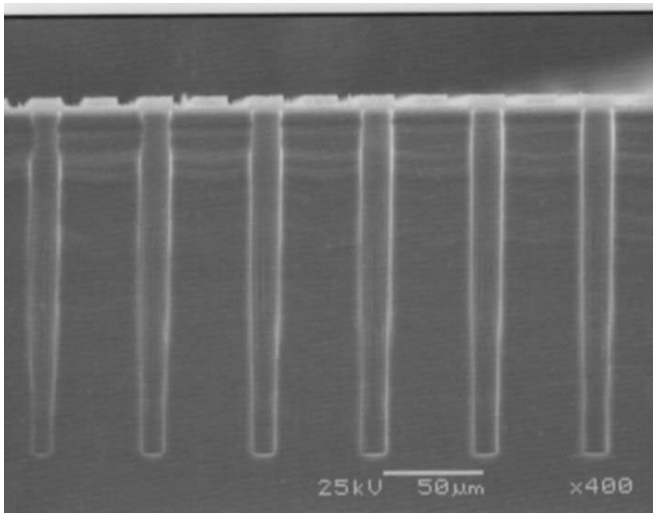
Etch of 2nd set of holes
Metallise, Ru, by atomic layer deposition
by Metorex to form electrical contact

Metallisation of top surface to form device type (pixel, strip)

# Two methods to form pores

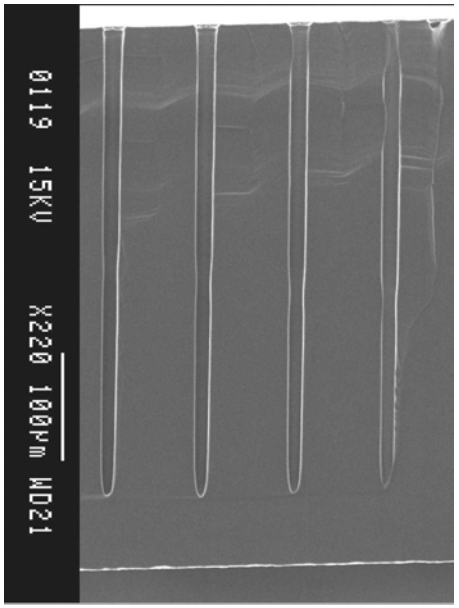
## DRIE

- So far, maximum aspect ratio: 18:1 (depth 183μm)
- Modification to standard equipment to obtain deep narrow parallel walled pores
- In conjunction with STS



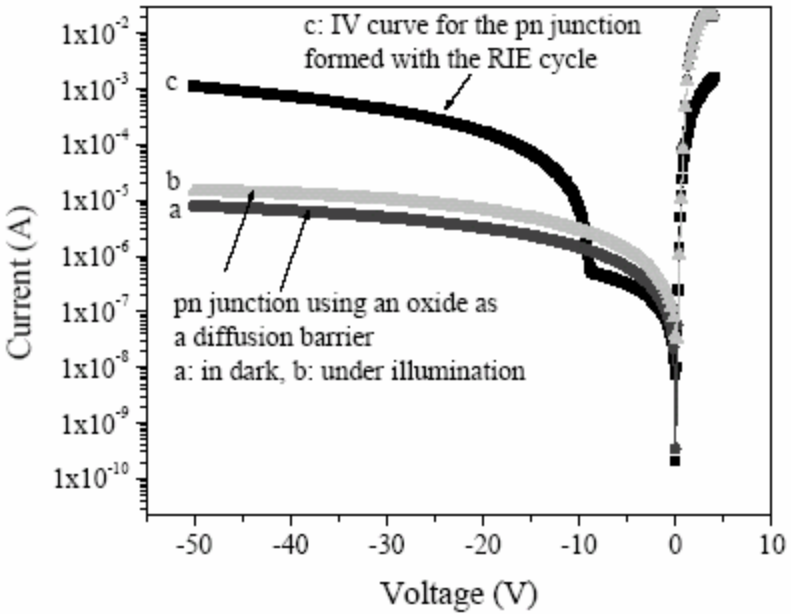

## Electro-chemical etching

- maximum aspect ratio: 30:1 (depth 440 μm, Φ=14 μm)
- 24 hours per wafer
- Cheap



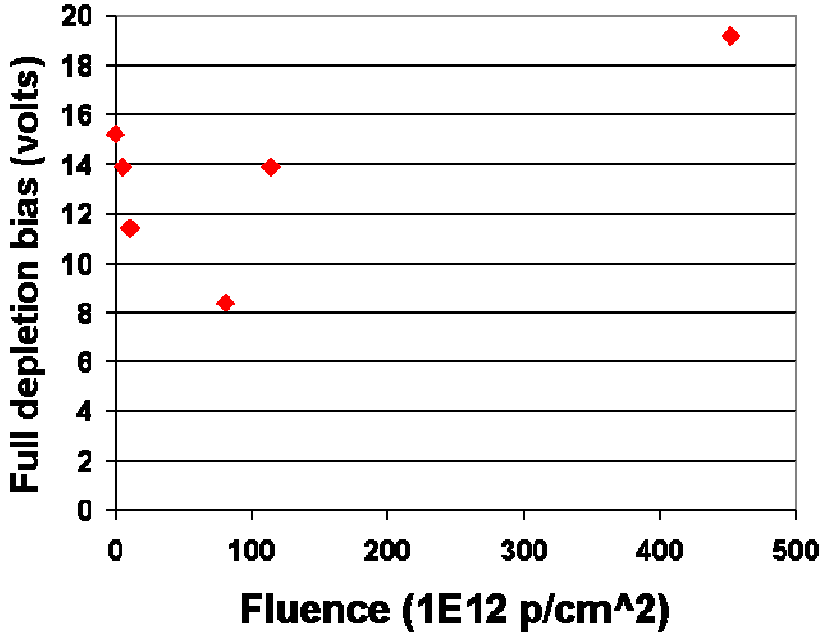
# IV of devices

- Good rectifying np junction formed
- Oxide as diffusing barrier isolates individual cells
- RIE removal of top surface caused increase in current after -10V



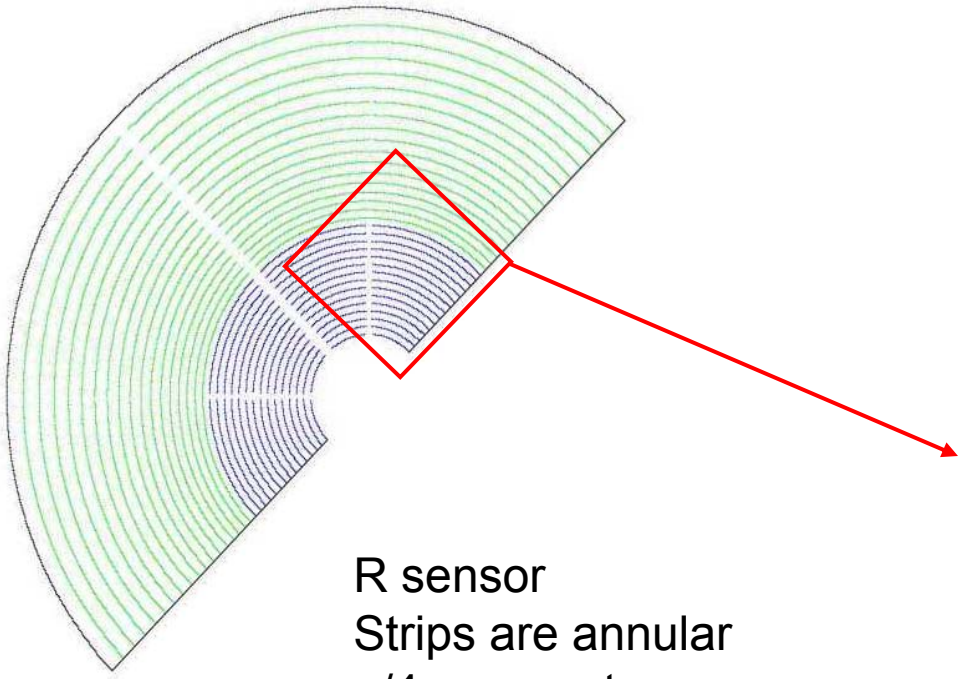
# Proton irradiation

- High res n-type silicon, 85μm pitch, close-packed hexagonal pixels
- Irradiation with 24 GeV/c protons at CERN
- 7 fluences from 5 x $10^{12}$ to 4.5 x $10^{14}$ p /$cm^2$



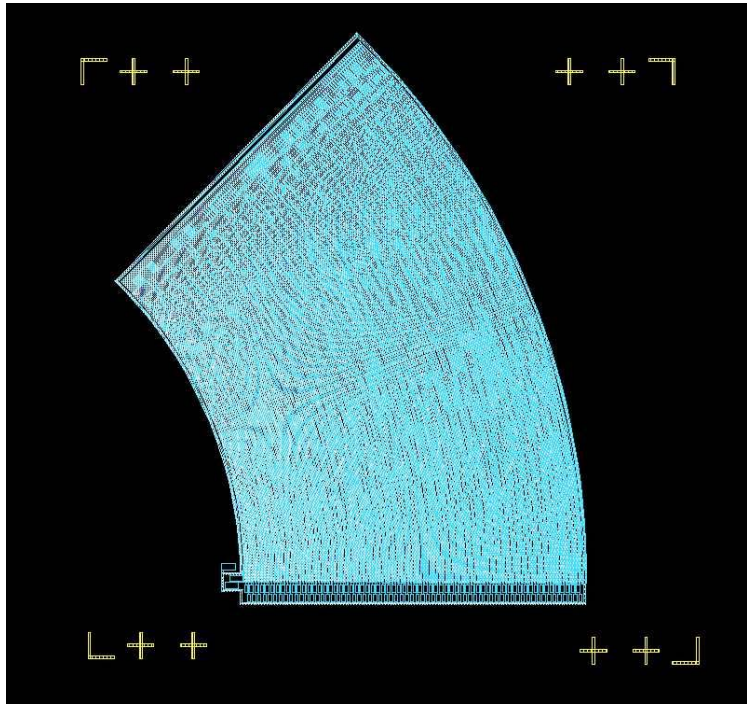

For 4.5 x $10^{14}$ p/$cm^2$
Depletion voltage = 19V
Type inversion observed

# 3D strip detectors : VELO design



R sensor
Strips are annular
$\pi/4$ segments
R = 8mm to R = 42mm
512 strips

3D device
Pitch varies linearly from 45μm at the innermost region to 90μm at strip 128.



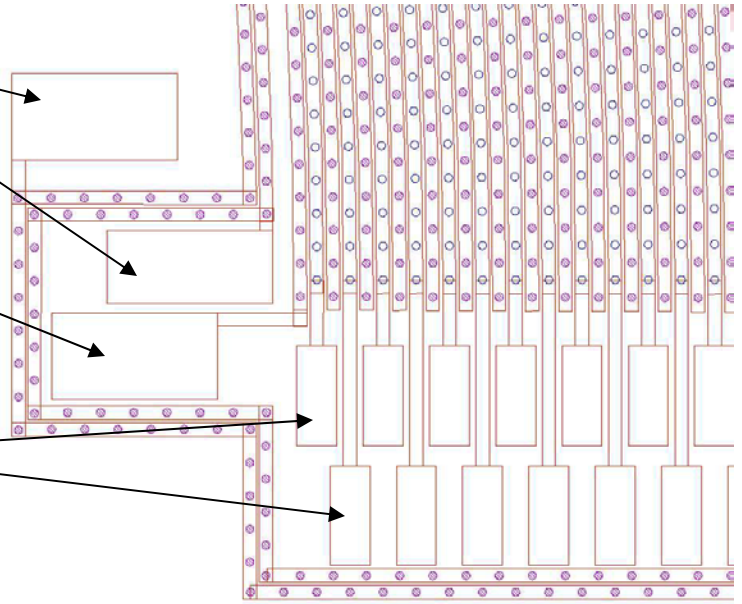
# LHCb VELO

Constant pore spacing of 50μm along the strip.
Pore spacing varies with radius.

Bond pads for guard ring

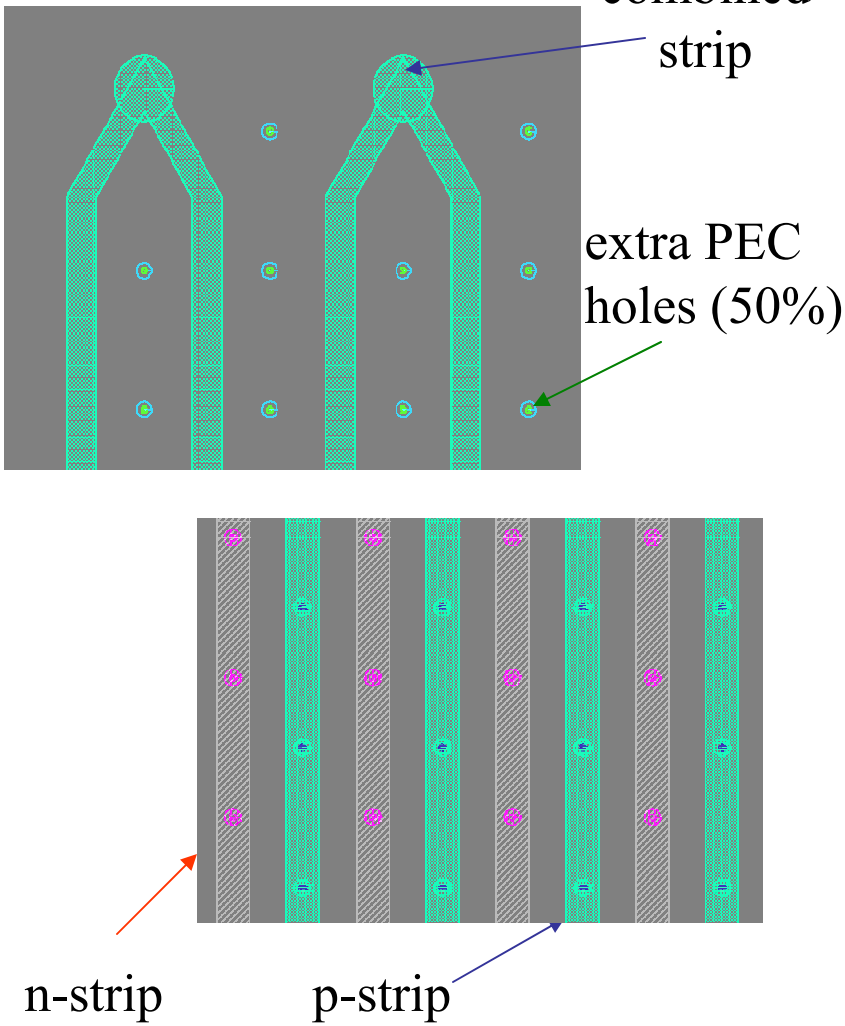
Bond pad for intermediate n-type strips (these are joined at the other end of the strips)

Readout bond pads
rectifying contacts



# ATLAS SCT

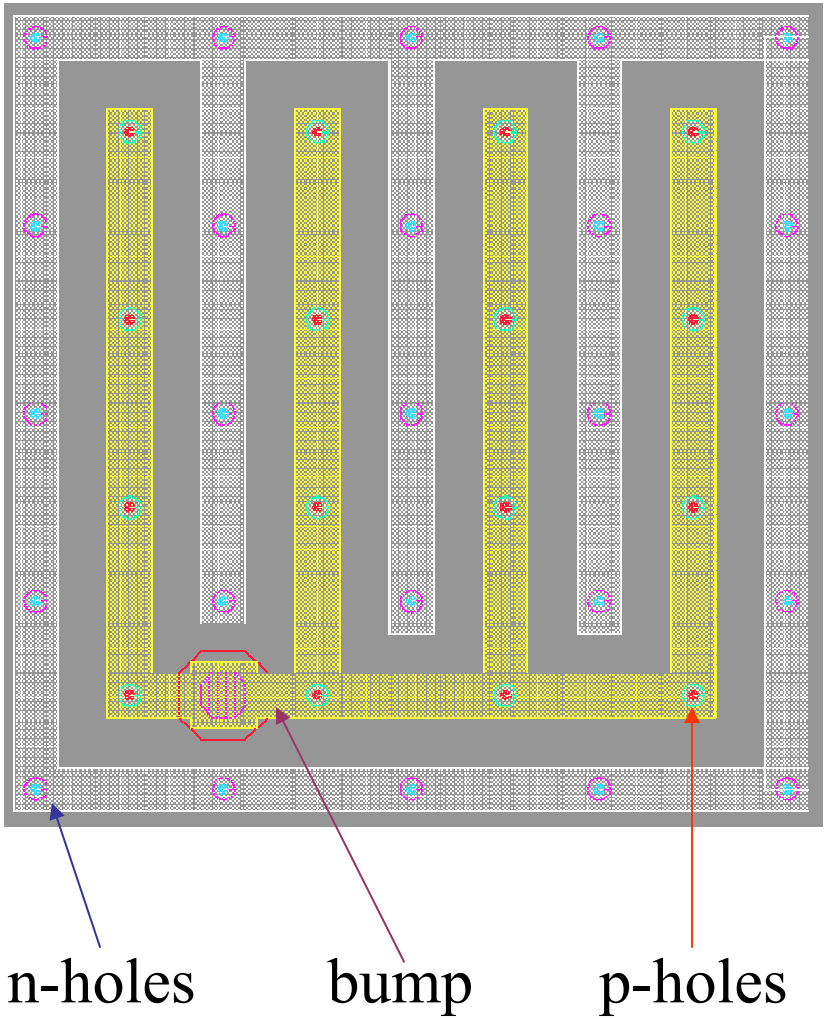
- Baby barrel detector
- 1cm long strips
- Readout strips: 128 + 2 at 80 μm pitch
- Fan-out to bondpads: 85 μm pitch
- Pores: 2 or 5 μm diameter
  42.5 μm pitch n to n
  30 μm pitch n to p



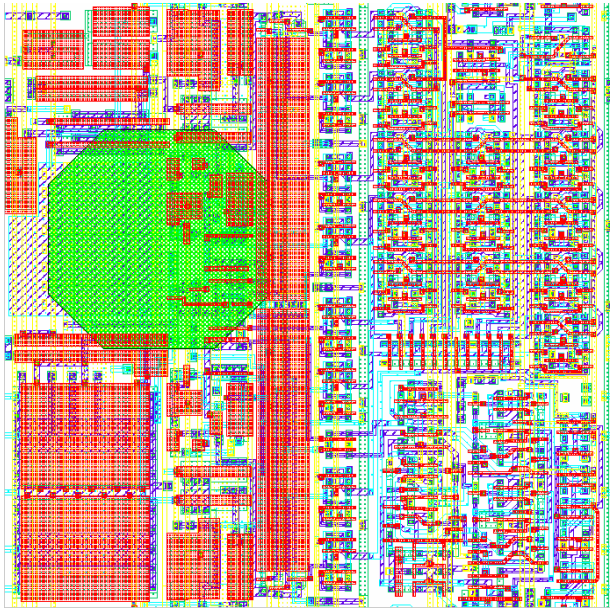
# 3D pixel detector : Medipix1

- Pixels: 64 x 64 array
  170 x 170 μm$^2$
- Strips: 42.5 μm pitch
- Pores: 2 or 5 μm diameter
  42.5 μm pitch (n-n)
  30.0 μm pitch (n-p)

Same structure of holes as ATLAS SCT
Metal layers differ to realize different detector type



# Medipix 1

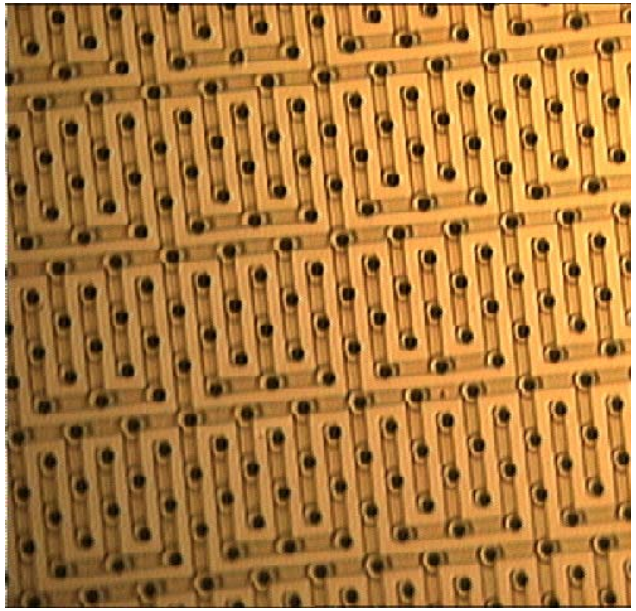


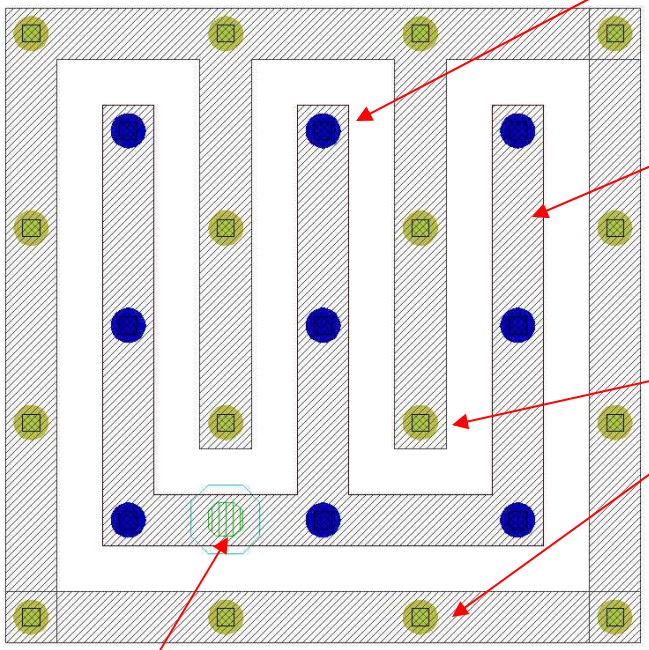
Single photon counting chip
Counter in each pixel
64 x 64 pixels
170 μm pixel pitch

3D detectors
Reduce charged sharing between adjacent pixels particularly useful for photon counting

Planar detectors
Small pixels with thick sensors
Result in charge sharing
Up to 20% for 20keV, 55 μm pixel 300 μm thick detector

# 1st Medipix design



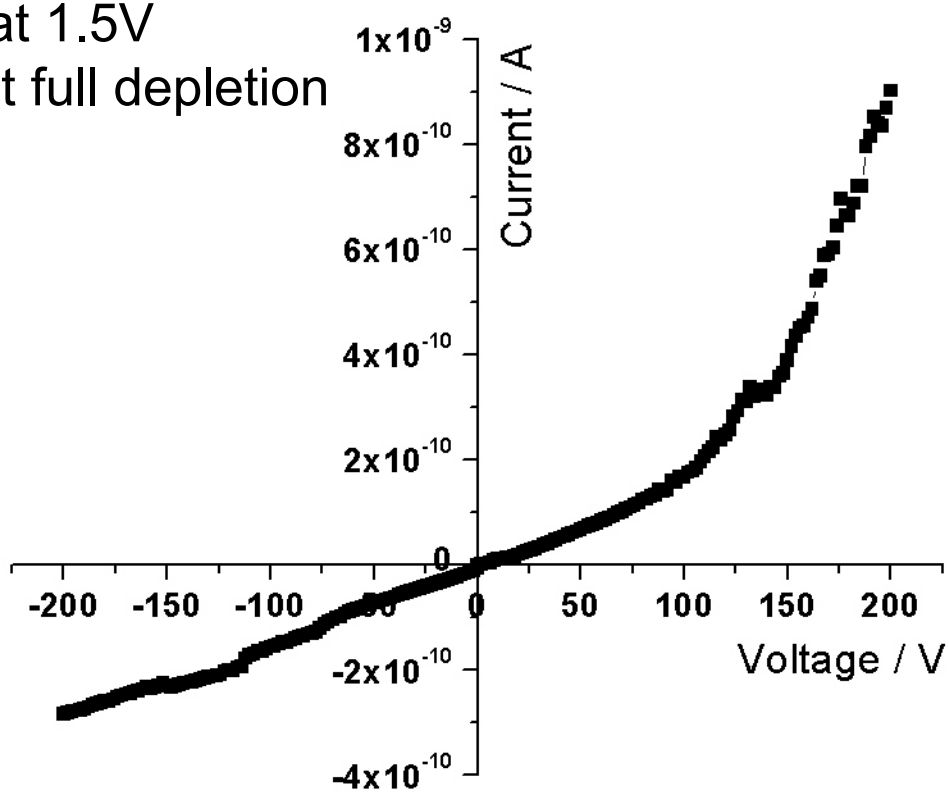



pore diameter : 10μm
width of metal strips : 15 μm
pitch : 57 μm
cell pitch : 170 μm

position of "bump" consistent with Medipix1 chip

# IV of single pixel

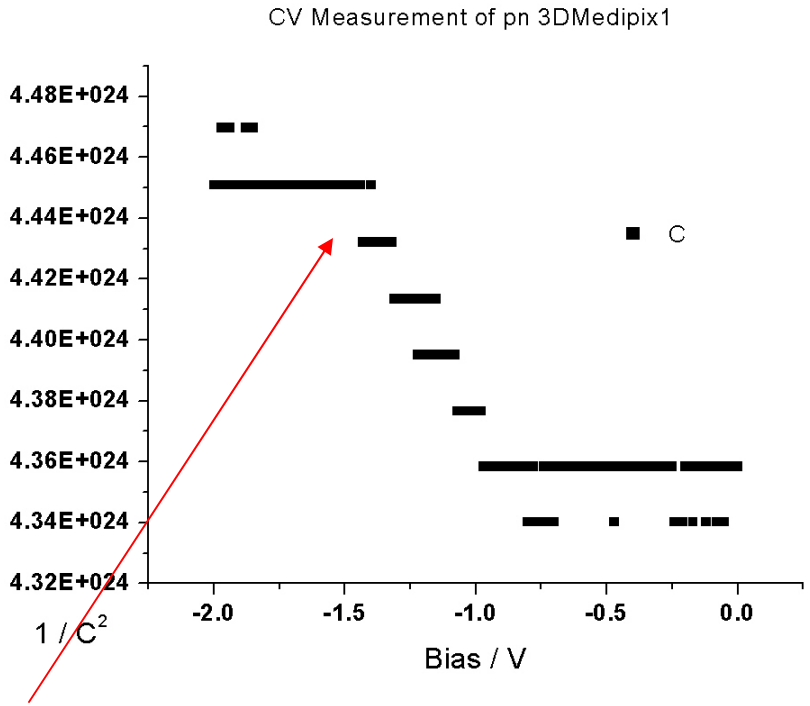
Full depletion at 1.5V
Current ~ pA at full depletion



# CV for single pixel

Capacitance of 500fF at full depletion
Note 3D pixel is self guarded

Planar diode = 10fF
Calculated Coaxial approx = 800fF

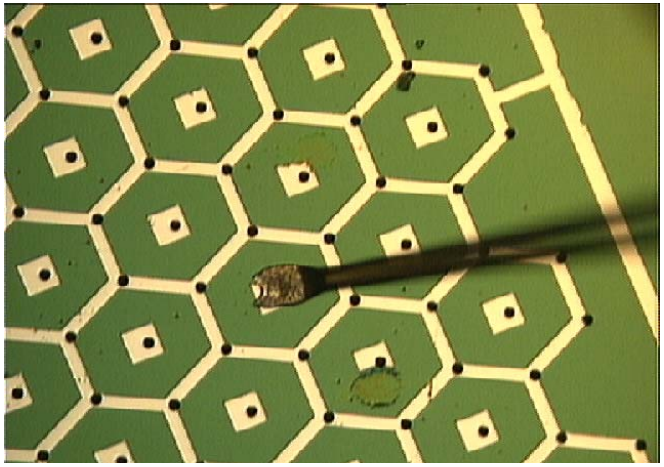


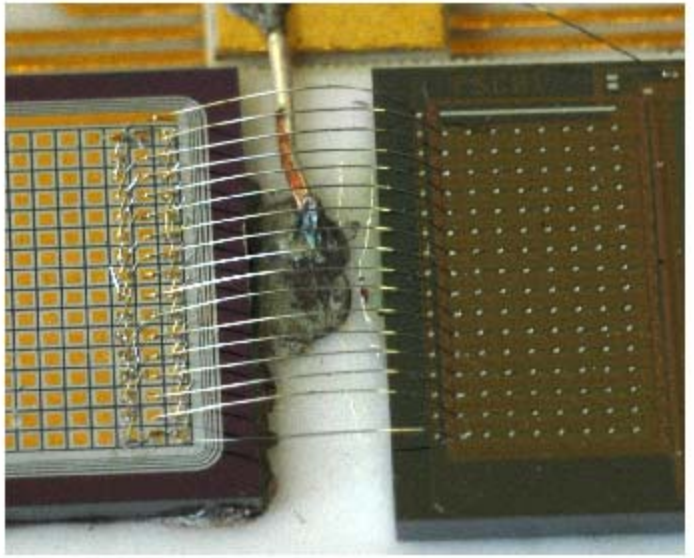

From this data expect
6cm strip ~ 70pF (~ 12pF/cm)
Typical strip detector ~ 1pF/cm

Full depletion ~1.5V

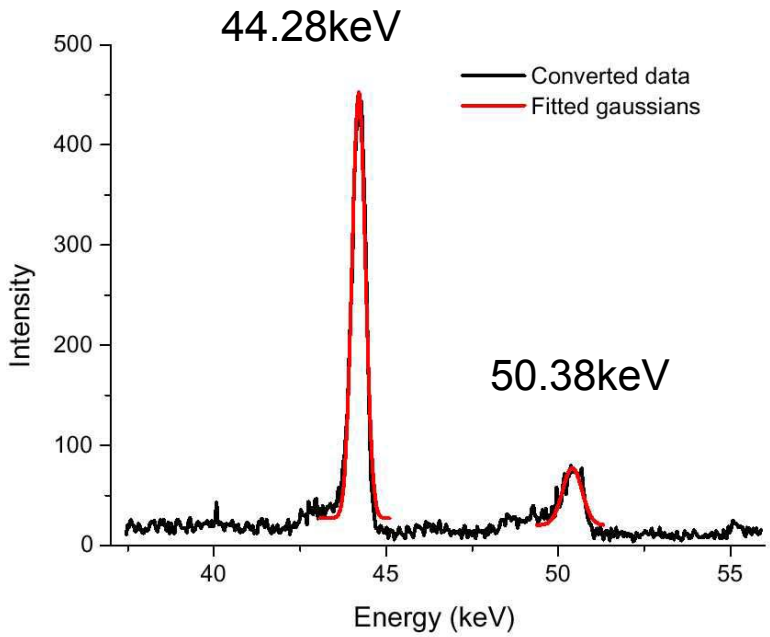
# 3D GaAs diode

- r/o Dash-E : RAL photon counting spectroscopic pixel detector
- SI U-LEC GaAs 500 μm thick
- 170 μm pitch 3D hexagonal pixel
- Laser drilled holes, $\Phi$ = 10 μm
- Metal Schottky contacts
- Wire bonded NOT bump bonded
- Full depletion at 4V, operated at 10V
- Current = 5nA at 20C, operated at -30C, 10 pA





# Results for Terbium $K_\alpha$ and $K_\beta$




CCE 100%
FWHM = 467 eV = 1.06%
$\sigma$ = 199 eV
Large noise due to wire bond
$\sigma_{\text{electronics}}$ = 137 eV

Fano factor calculated = 0.112
Theoretical value = 0.1
Assume $\varepsilon$ = 4.2 eV

| | |
|---|---|
| 2D silicon (300µm) bump bonded (20C) | 1.32 % |
| 2D silicon (300µm) wire bonded (20C) | 2.21 % |
| 3D GaAs (500µm) wire bonded (-30C) | 1.06% |