3D Medipix/Timepix testbeam at the Diamond Light Source

Diamond Light Source

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Contents

- Aim of the experiment
- Detectors and light source
- First results
- Future analysis plans

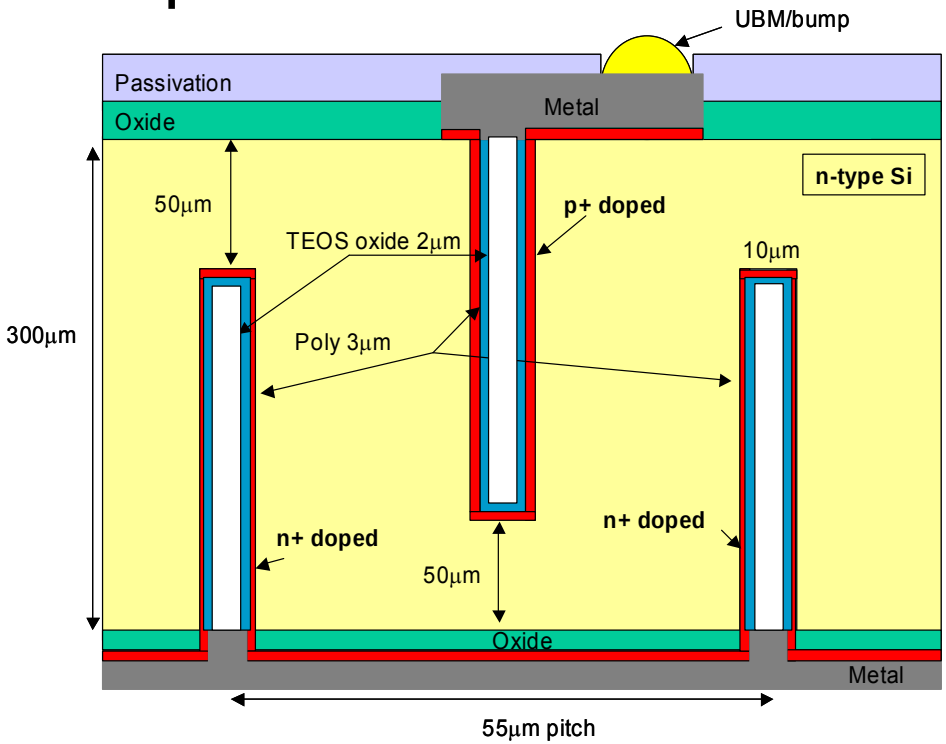
Aim of the experiment

- Study charge sharing inside a unit cell
- Study low efficiency areas inside a unit cell
  - At electrodes and e-field saddle points

- The 3D detector has an electric field that contains the charge inside a unit cell
  - Leads to less charge sharing between pixels
  - Higher signal in hit pixel for mip
  - Better image quality for imaging applications with high energy photons
- 3D detector has physical holes in the substrate
  - Low efficiency and dead regions in the detector
  - Need to understand volume of region and magnitude of efficiency drop

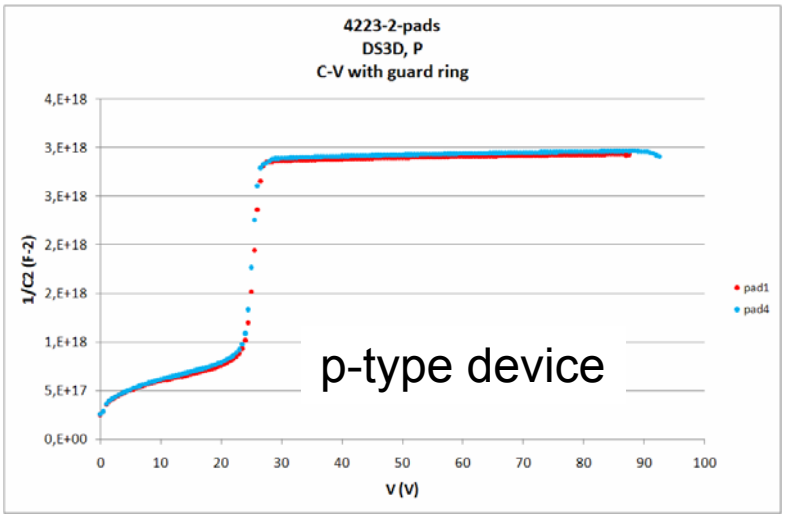
Detectors

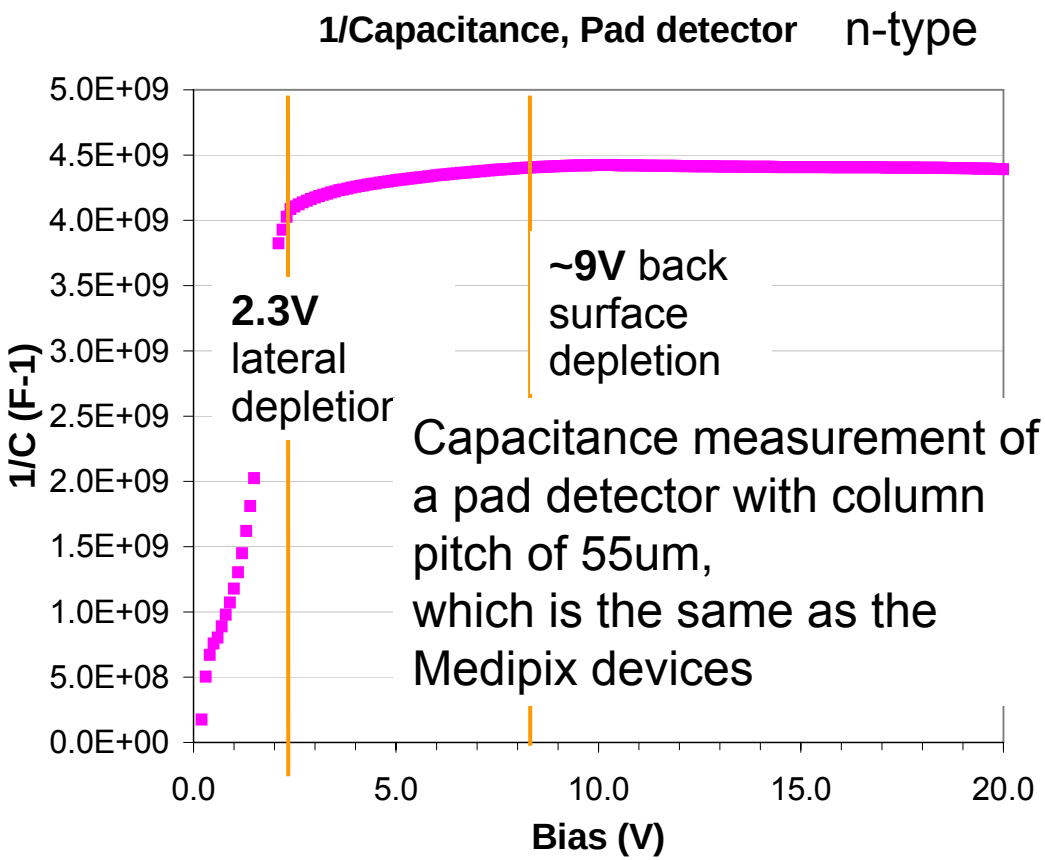
- Double-sided CNM 3D detectors
  - Columns do not pass through full substrate thickness
  - 250µm deep in 285 +/- 15 µm substrate
- Tested both
  - p-bulk and n-readout
  - n-bulk and p-readout



Depletion Characteristics

- Lateral depletion at 2-3V
- Full depletion to back side surface
  - n-type at 9 V
  - p-type 25 V





Electronics

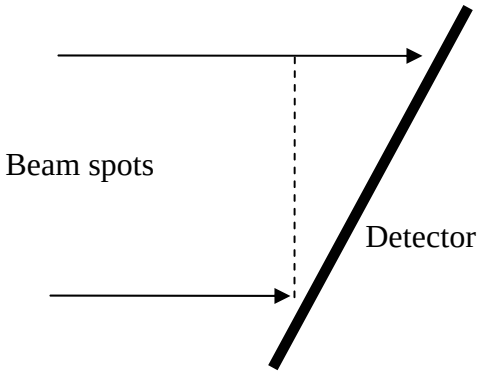
- Medipix and Timepix readout electronics
  - 55 x 55 um square pixels
  - 100ns shaping time
  - Window discriminator per pixel, upper and lower threshold value set
    - Only low threshold used in this experiment
  - Counting device with counter on each pixel
  - Timepix allows time over threshold to be recorded
    - only one photon per frame is recorded in this mode
- Flip chip bonded at VTT (part funded via RD50)
- Medipix USB readout developed by CTU-Prague

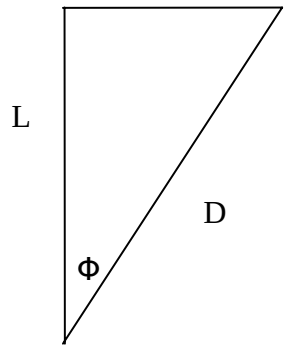
Experimental

- 3rd generation synchrotron Diamond Light Source
- Photon energy = 15 keV
- Beam spot focused to 4.5 x 6.8 um (FWHM). Uncertainty ~ +/-0.2 um. To be confirmed
- Beam scanned over the surface of the Medipix pixel in 2.5 um steps in both x and y
- Scan covered an area of 75 um x 75 um centered on a pixel
  - ¼ pixel scans performed for voltage and threshold scans.
- Number of photons recorded per pixel over the full sensor recorded for each beam position

Alignment

- Align detector perpendicular to beam





$$\cos\Phi = \frac{L}{D}$$

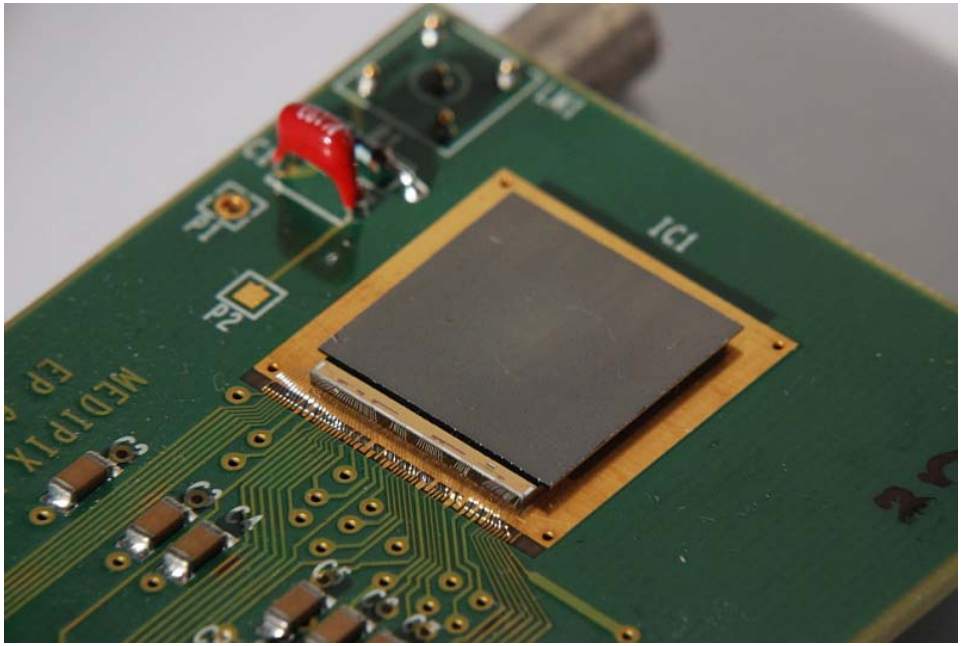
$$\frac{\partial D}{\partial \Phi} = D\tan\Phi$$

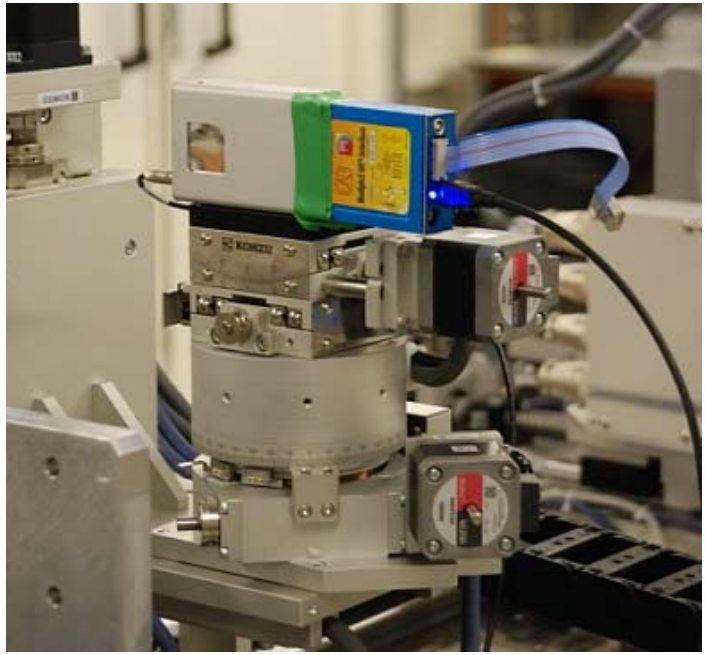
  - Detector mounted in optical stage with 6 d.o.f
  - Move L and measure D as two spots on detector
  - To maximize sensitivity rotated detector by +/-45^{o} and aligned detector
- Automatic trigger of DAQ and scan of stage in x-y

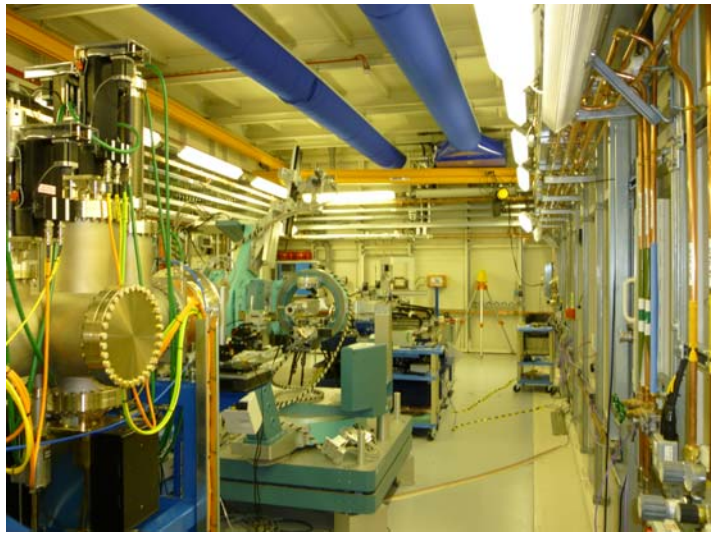
Devices tested

- First device
  - n-bulk p-type readout, 3D, MediPix
  - n-type full depletion at ~ 10V
  - Tested at:
    - 5V
    - 20V
- Second device
  - p-bulk n-type readout, 3D, TimePix (in Medipix mode)
  - p-type full depletion at ~ 30V
  - Tested at:
    - 20V
    - 40V
- Third device
  - n-bulk p-type readout, planar, MediPix
  - Tested at 100V

The testbeam in photos



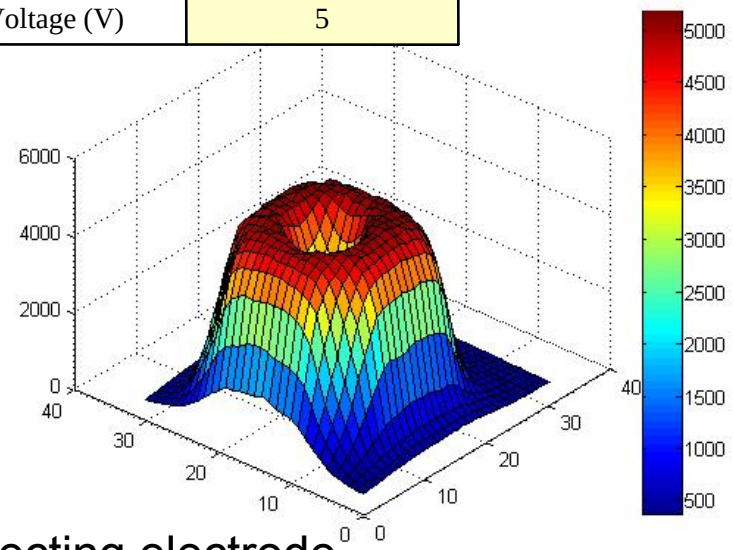




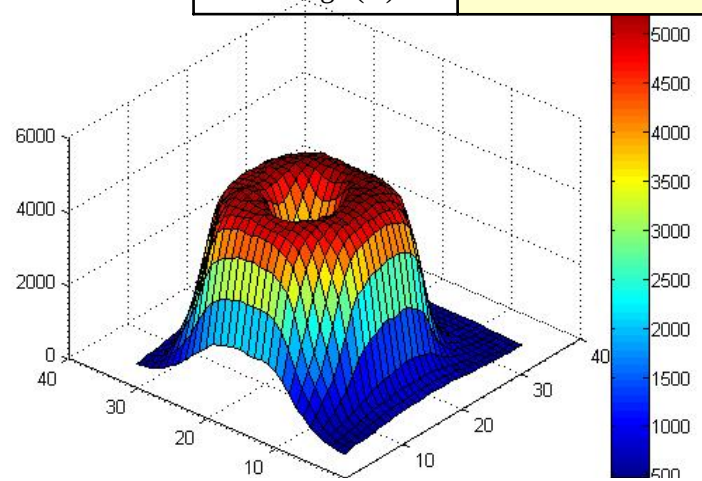
Response function of a pixel

J03-W0026 MXR3D n-bulk

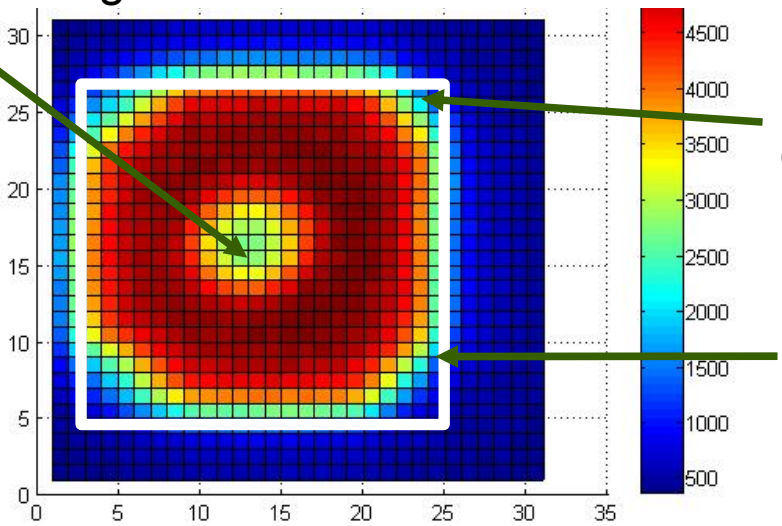
THL	345 (50%)
Voltage (V)	5



THL	345 (50%)
Voltage (V)	20

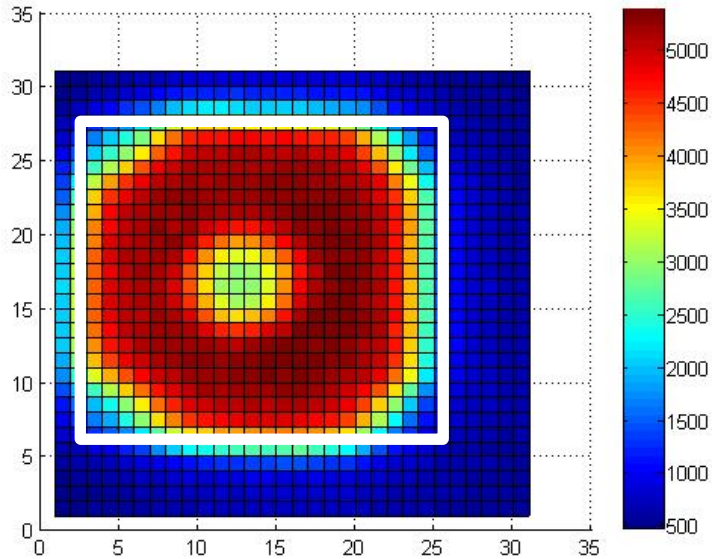


collecting electrode



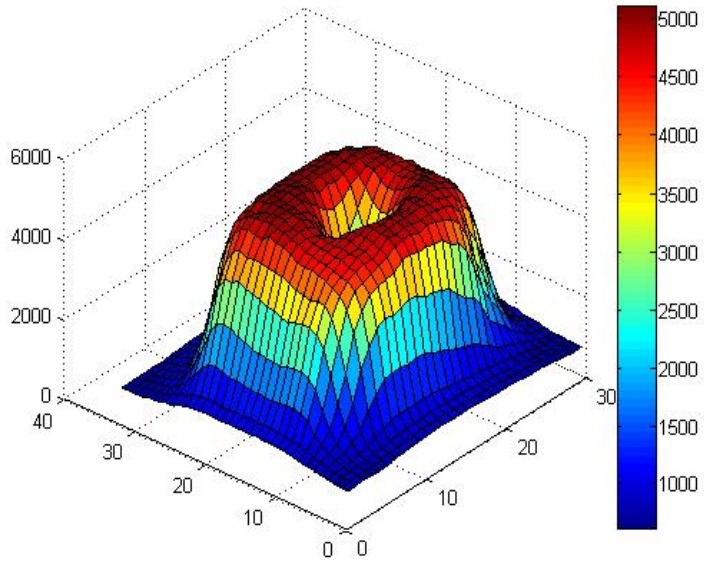
bias electrode

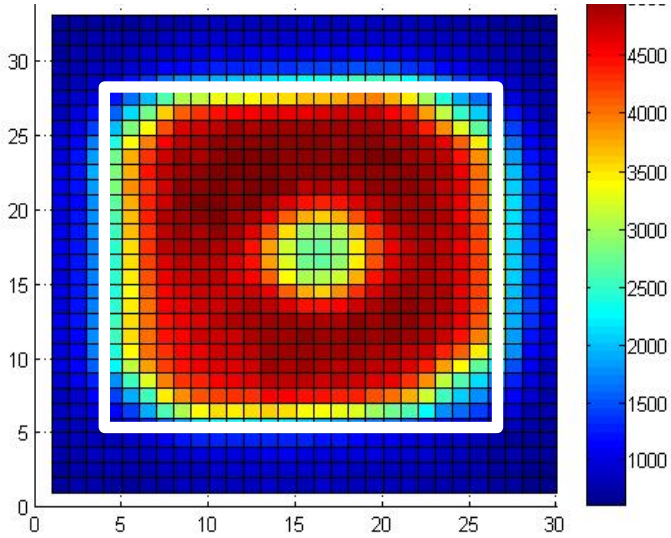
Pixel area 55x55 um^2



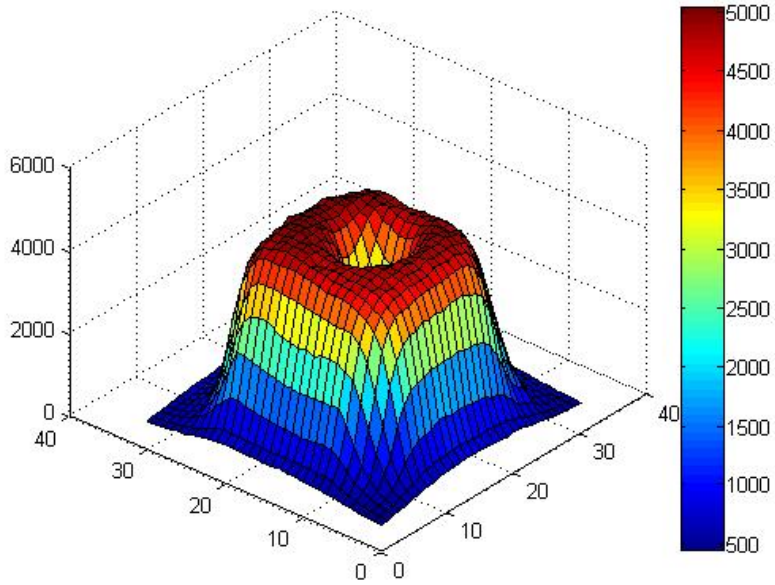
F09-W0015 TPX3D p-bulk

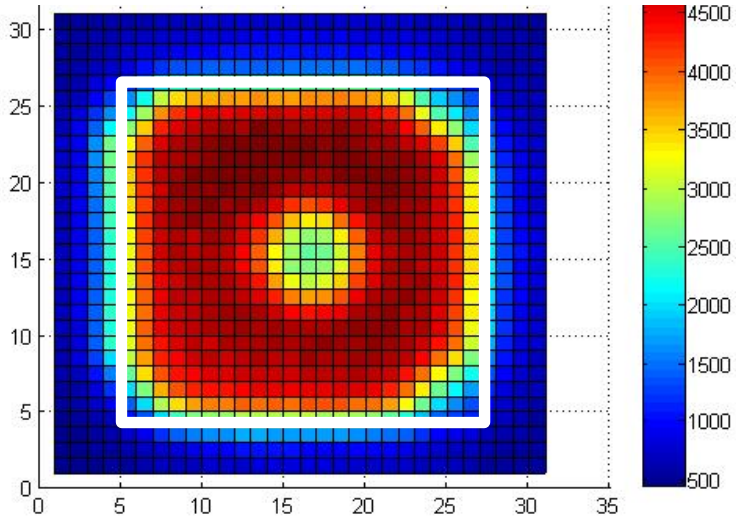
THL	440 (50%)
Voltage (V)	-20





THL	440 (50%)
Voltage (V)	-40

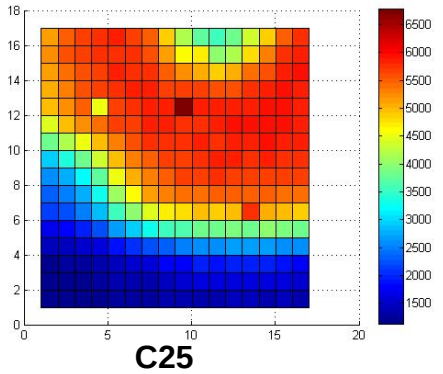


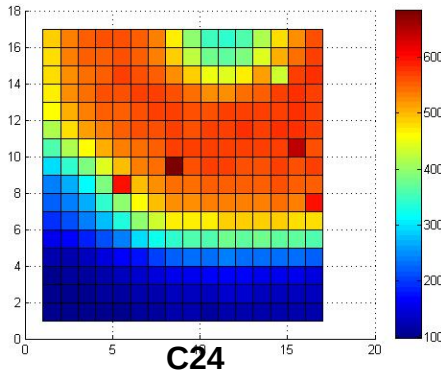


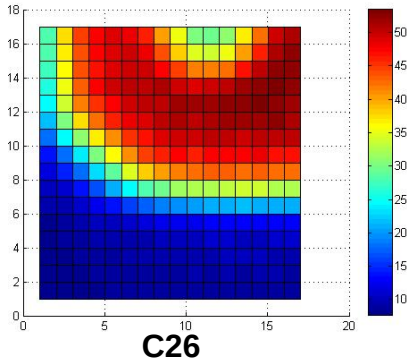
Threshold investigated

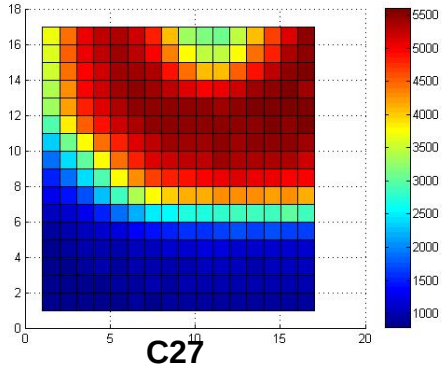
J03-W0026 MXR3D n-bulk

Code	25	24	26	27
THL	368 (25%)	368 (25%)	323 (75%)	323 (75%)
V	5	20	5	20


C25

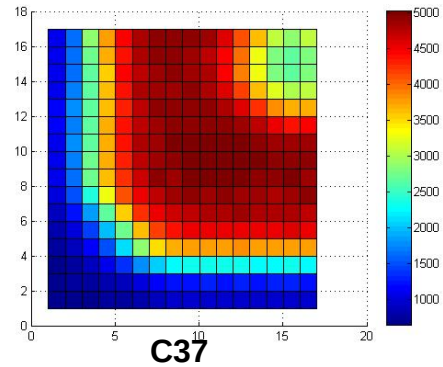

C24

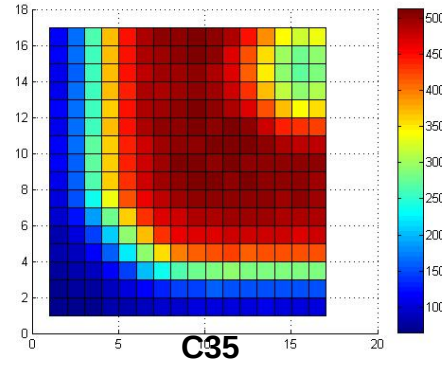

C26

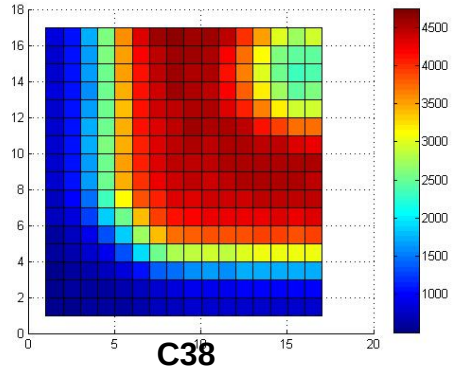

C27

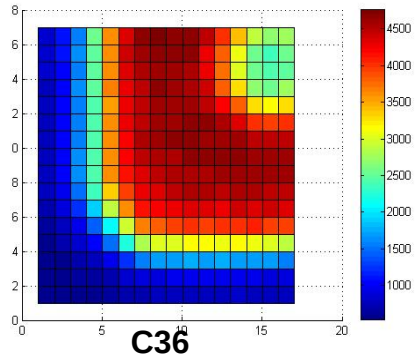
F09-W0015 TPX3D p-bulk

Code	37	35	38	36
THL	407 (25%)	407 (25%)	472 (75%)	472 (75%)
V	-20	-40	-20	-40


C37


C35

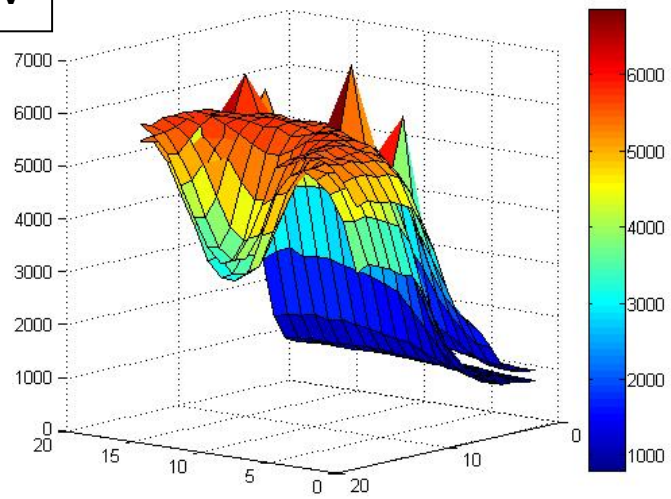

C38


C36

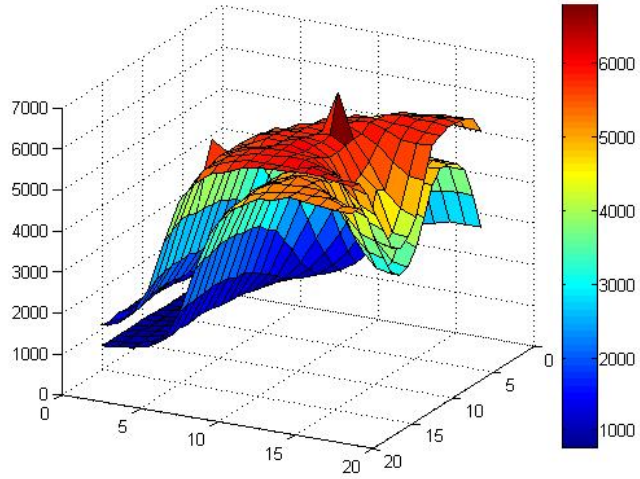
High V

J03-W0026 MXR3D n-bulk

Low V

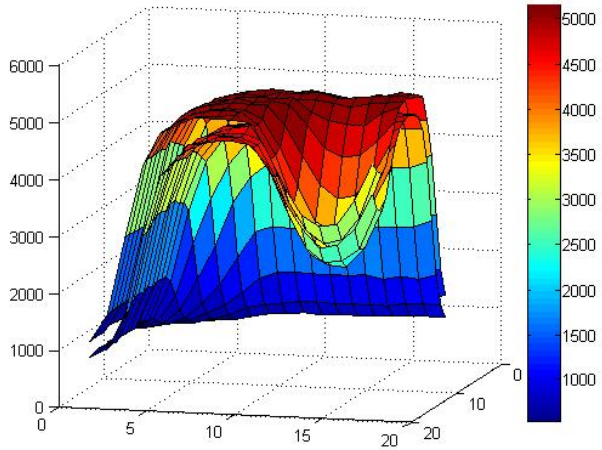


C24 versus C27

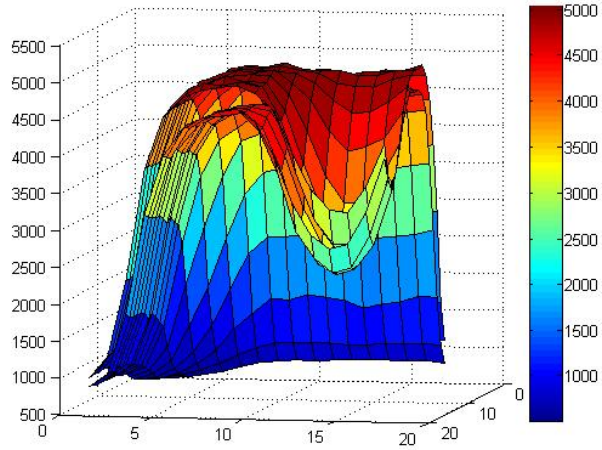


C25 versus C26

F09-W0015 TPX3D p-bulk



C35 versus C36



C37 versus C38

Further work

- Analysis just started
- Detailed analysis to come
  - Symmetry of images, pixel centres, count normalisation
  - Deconvolve pixel response from beam profile
  - Understand efficiencies
    - Function of voltage and position
    - Saddle point investigation
  - Charge sharing as a function of beam spot position from pixel edge
- Compare to planar device

Additional Information

Code	22			23			24			25			26			27		
J03-W0026 MXR3D n-bulk	1st exp (156,120)*			2nd exp (156,120)			3rd exp (156,120)			4th exp (156,120)			5th exp (156,120)			6th exp (156,120)		
THL	345 (50%)			345 (50%)			368 (25%)			368 (25%)			323 (75%)			323 (75%)		
Voltage (V)	5			20			20			5			5			20		
Max Event (i,j)	5169.6	11	15	5368.2	12	18	6846.6	9	8	6772.6	12	9	5353.8	12	14	5610.8	12	15
Min Event (i,j)	368.8	31	1	477.4	1	1	983.6	1	2	1133	1	1	771.8	1	1	796.6	1	1
CentralEl (i,j)	2735.4	16	12	2924.2	17	12	3362.0	17	11	3530.6	17	11	2884.8	17	11	3086	17	10
Reduced matrix	(10:23,7:20)			(10:23,7:20)			(10:17,6:16)			(11:17,5:17)			(11:17,5:17)			(11:17,5:17)		

Code	31			34			35			36			37			38		
F09-W0015 TPX3D p-bulk,	1st exp (158,135)			2nd exp (158,135)			3rd exp (158,135)			4th exp (158,135)			5th exp (158,135)			6th exp (158,135)		
THL	440 (50%)			440 (50%)			407 (25%)			472 (75%)			407 (25%)			472 (75%)		
Voltage (V)	-20			-40			-40			-40			-20			-20		
Max Event (i,j)	5099.8	22	12	5017.2	21	13	5132.6	10	10	4772.2	17	9	5029.0	10	9	4751.2	17	10
Min Event (i,j)	615.2	33	30	450.4	1	1	650.4	1	1	535.4	1	1	649.8	1	1	501	1	1
CentralEl (i,j)	2702.4	17	16	2577.6	15	16	2732	14	15	2389	15	15	2648.4	15	15	2348.2	14	15
Reduced matrix	(11:23,9:23)			(10:20,10:23)			(8:17,9:17)			(8:17,8:17)			(8:17,8:17)			(8:17,8:17)		