Business from technology

Overview on Measured Properties of Edgeless Detectors and their use in High Energy Physics

TIPP 2011 - 2nd International Conference on Technology and Instrumentation in Particle Physics

Juha 13th, Chicago, Illinois

Juha Kalliopuska on behalf of the contributors

VTT Technical Research Centre of Finland

Contributors

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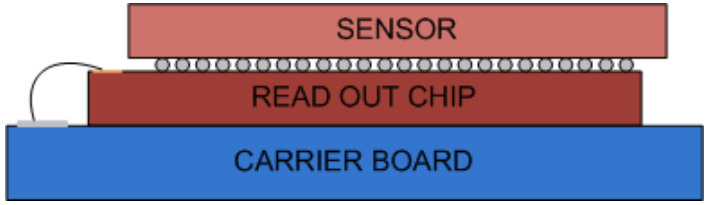
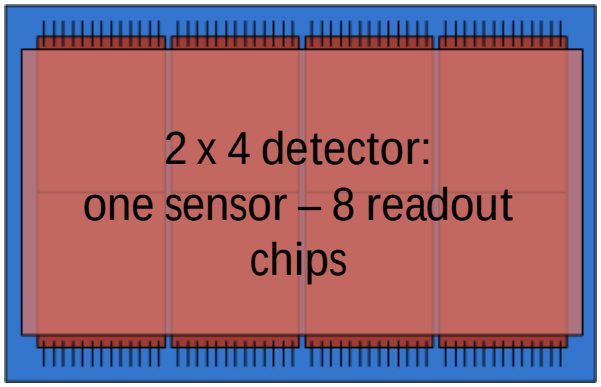
Outline

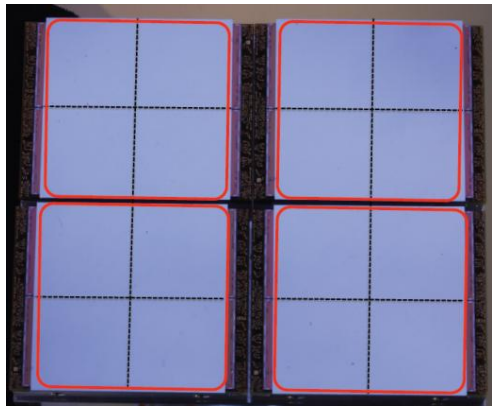
- Large area detector and its components
- Edgeless Si Detector properties
  - IV & CV
  - X-ray response
  - Alpha particle response
  - Tracking capabilities
- Use in high energy physics
- Summary

Large area detector

- Power distribution and data transfer is done via wire bonds to PCB
- Wire bonds cause large dead areas in radiation image – could be minimized by TSVs
- Large-area detector panels minimizing the dead gaps is attractive for imaging and HEP

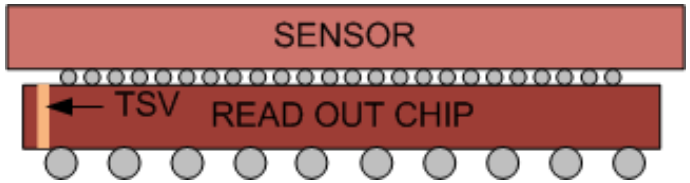


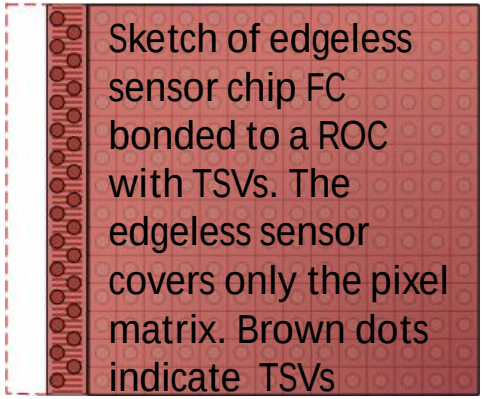


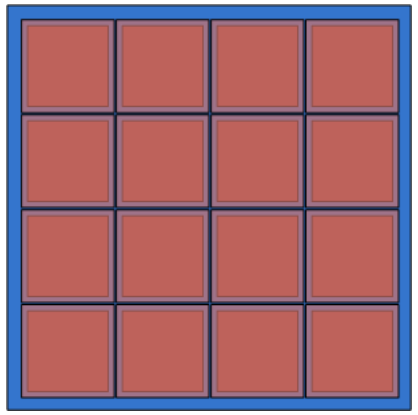


Courtesy of M. Bosma

- Commercial availability of TSV technology is limited and not accessible for small companies
- Large areas build out of pre-tested detectors solve the yield issues related to designs
- Need of fully sensitive sensor volume
- Redistributed ROC periphery







Edgeless detector

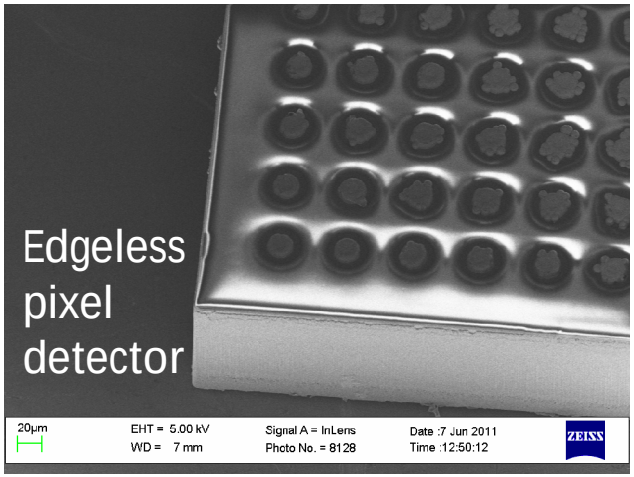
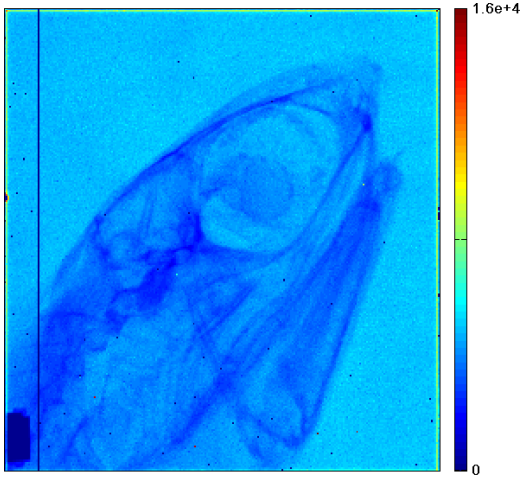
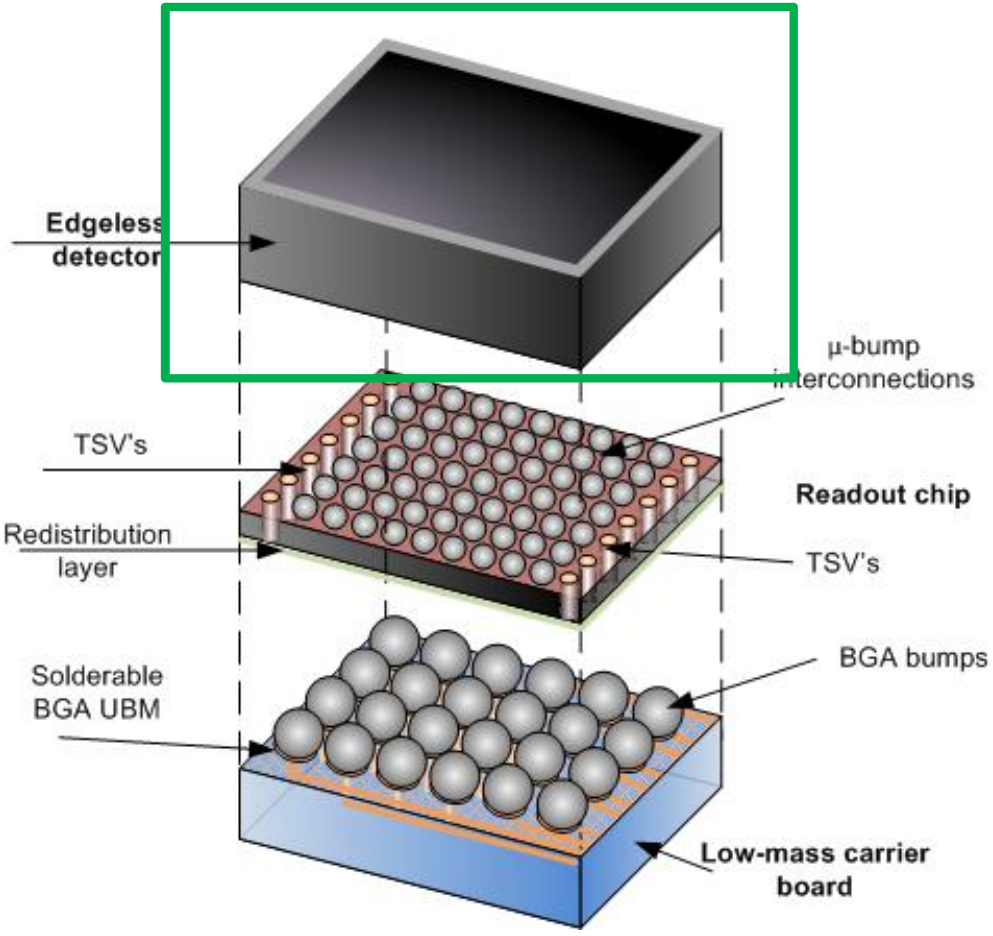


Image of anchovies using VTT's edgeless detector hybridized on Timepix ASIC (Medipix2 collaboration)

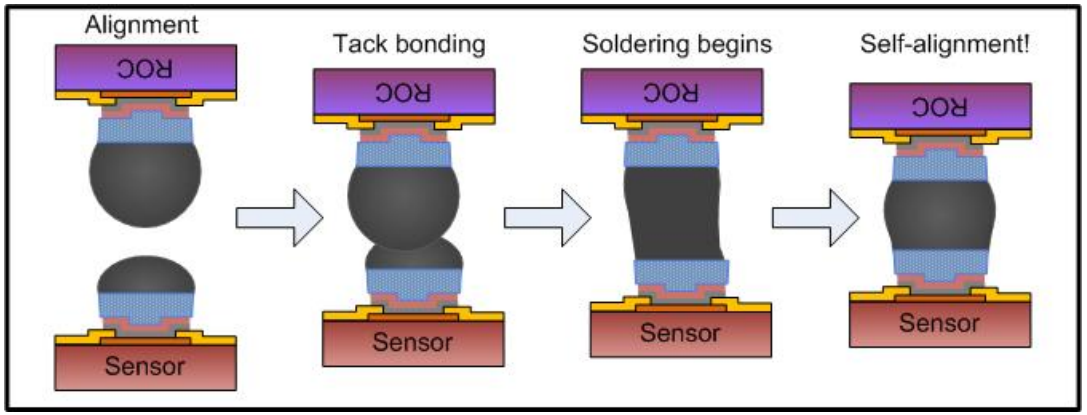


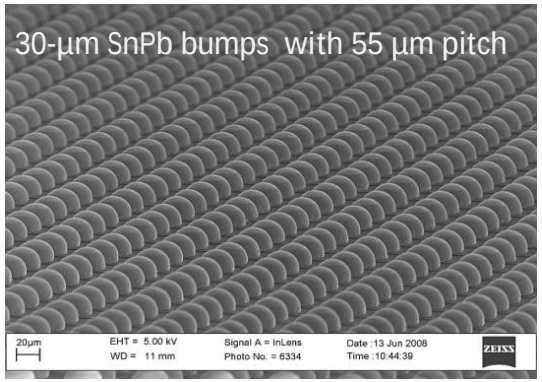
Courtesy of L.Tlustos

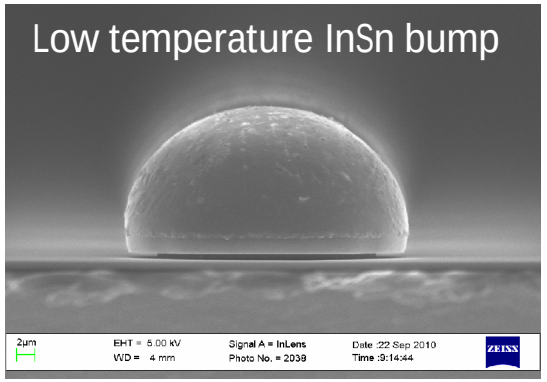


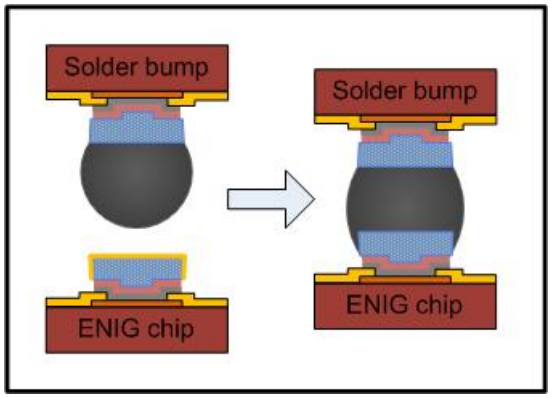
Sketch of a 3D integrated radiation pixel detector

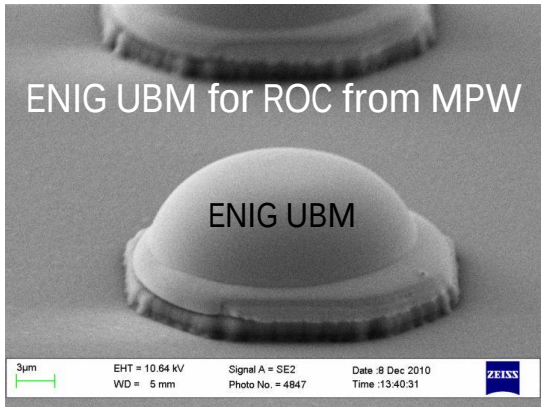
Solder microbumps

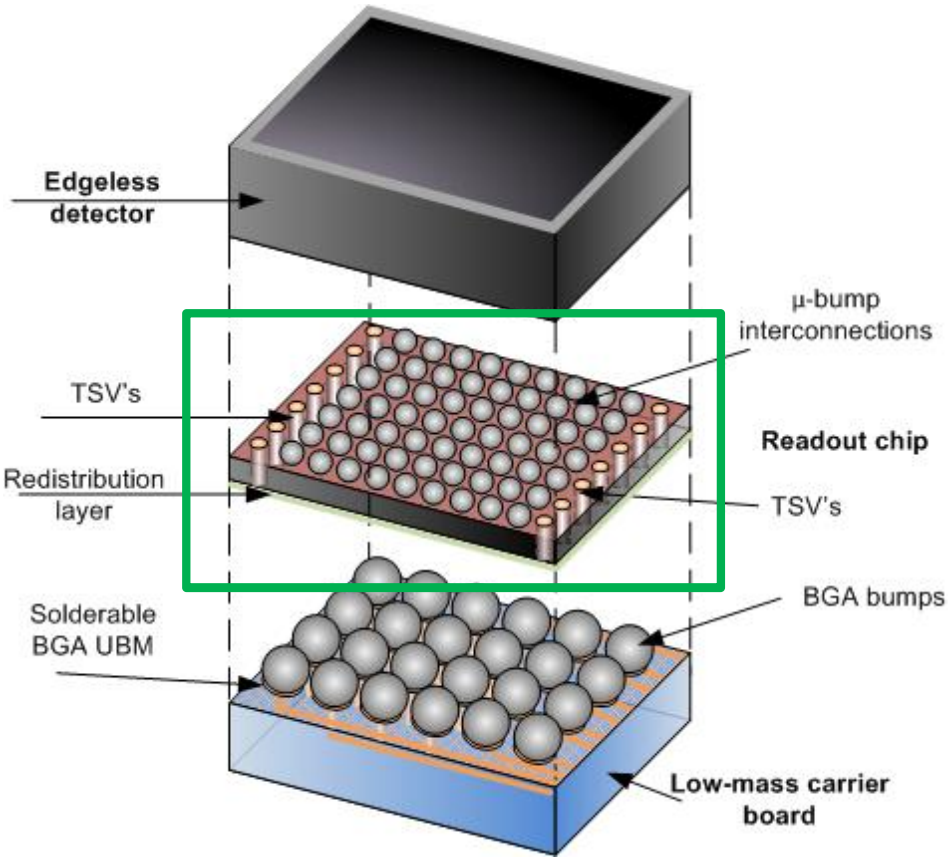








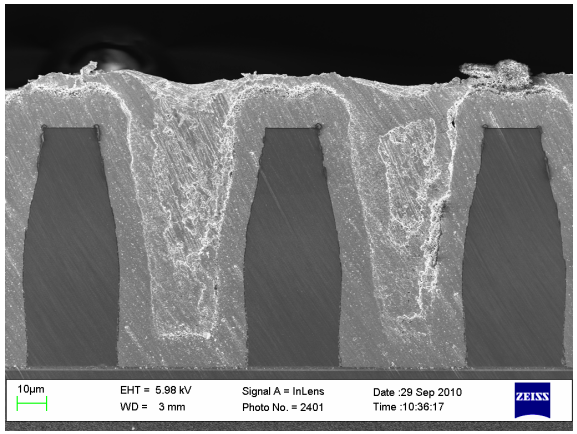




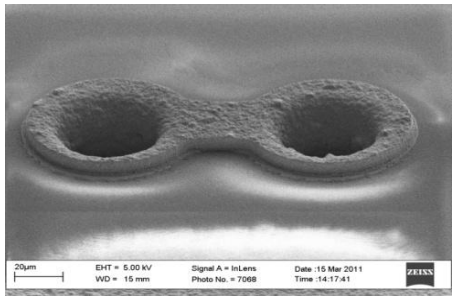
Sketch of a 3D integrated radiation pixel detector

Through Silicon Via

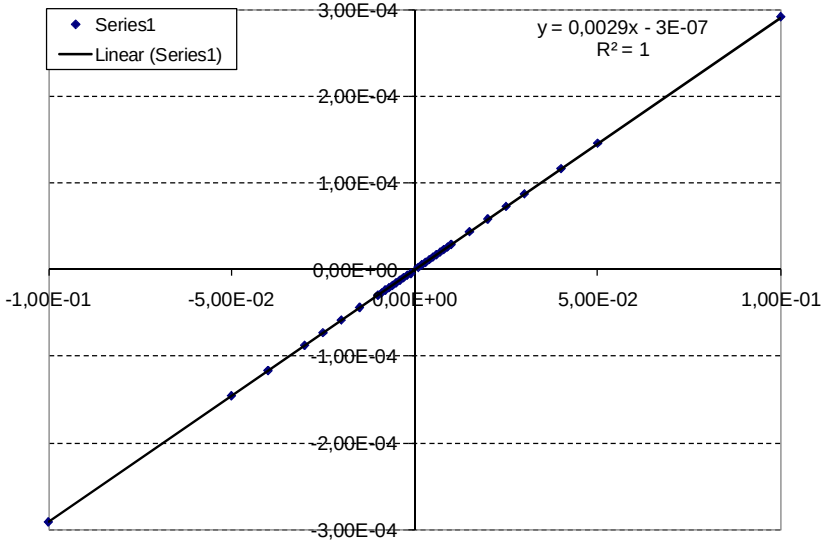
- TSV cross section

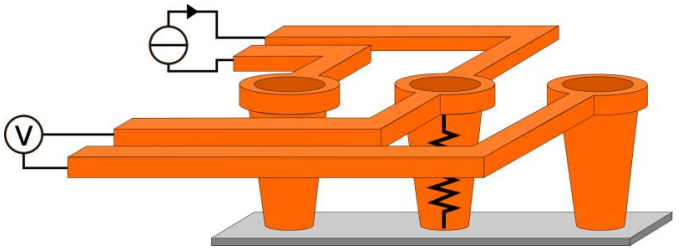


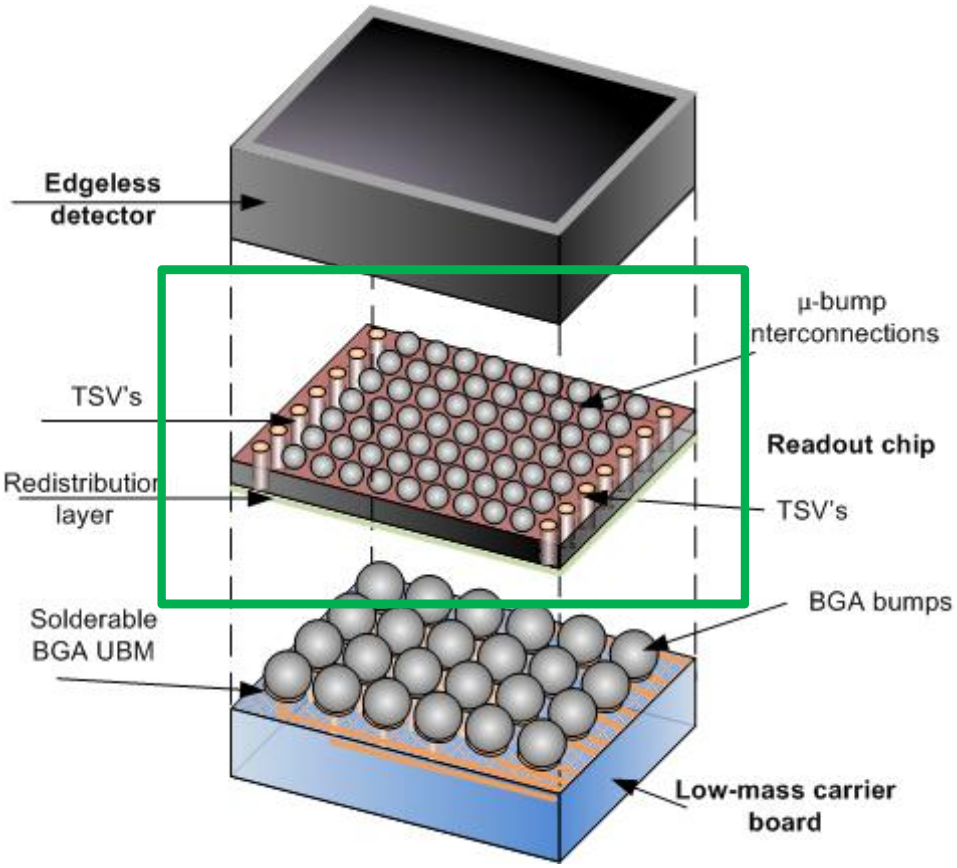
Redistribution metal



- Tapered TSVs with Cu liner
- VTT's demonstrators on 6" wafers, ~30 mΩ via resistance



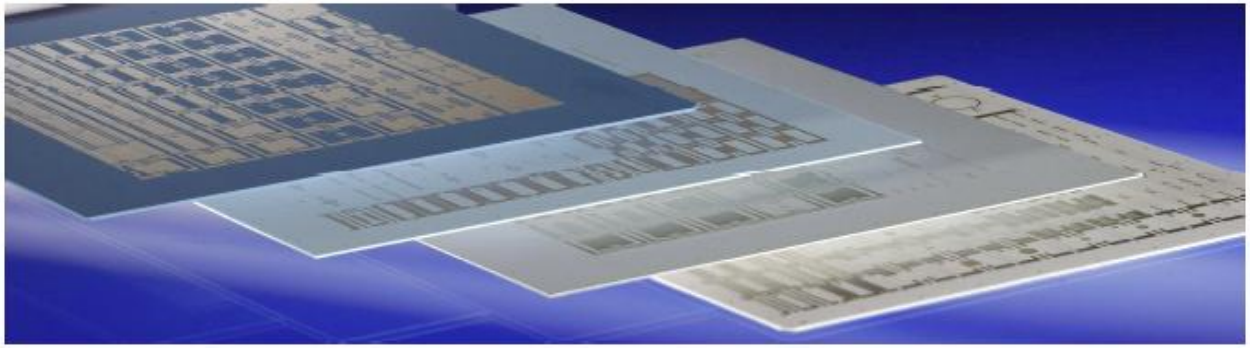


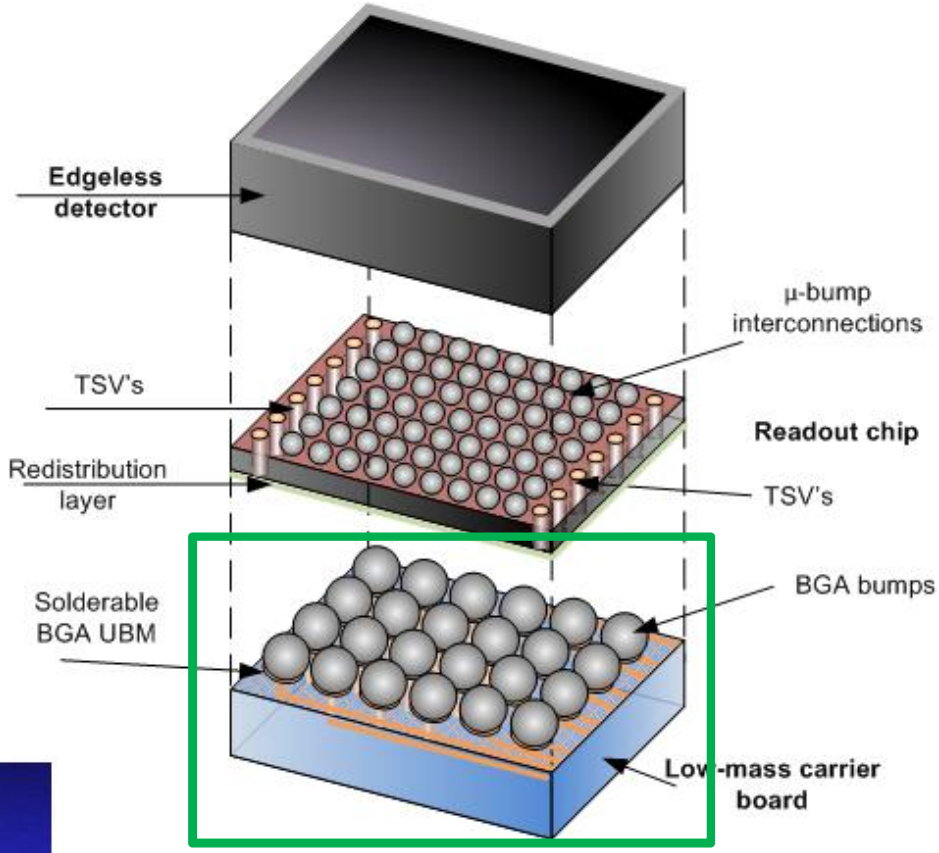


Sketch of a 3D integrated radiation pixel detector

Carrier boards & BGA joints

- BGA joints
  - Standard BGA balls – for medical imaging
  - Plastic core BGA balls to be studied for HEP applications
- Printed circuit board
  - Low mass carriers needed for HEP applications
  - VTT has the LTCC expertise and a production line at its Oulu facility





Sketch of a 3D integrated radiation pixel detector

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- Edgeless Si Detector properties
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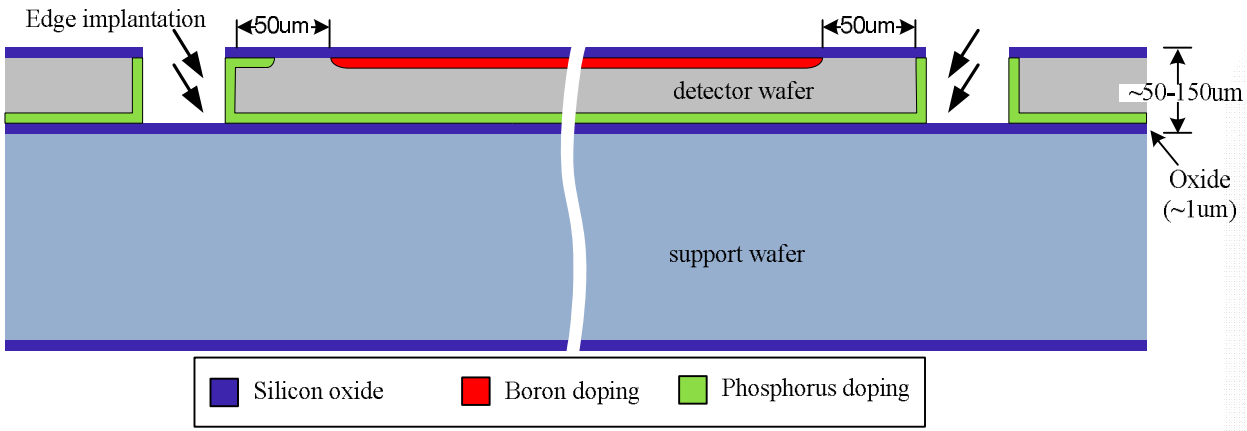
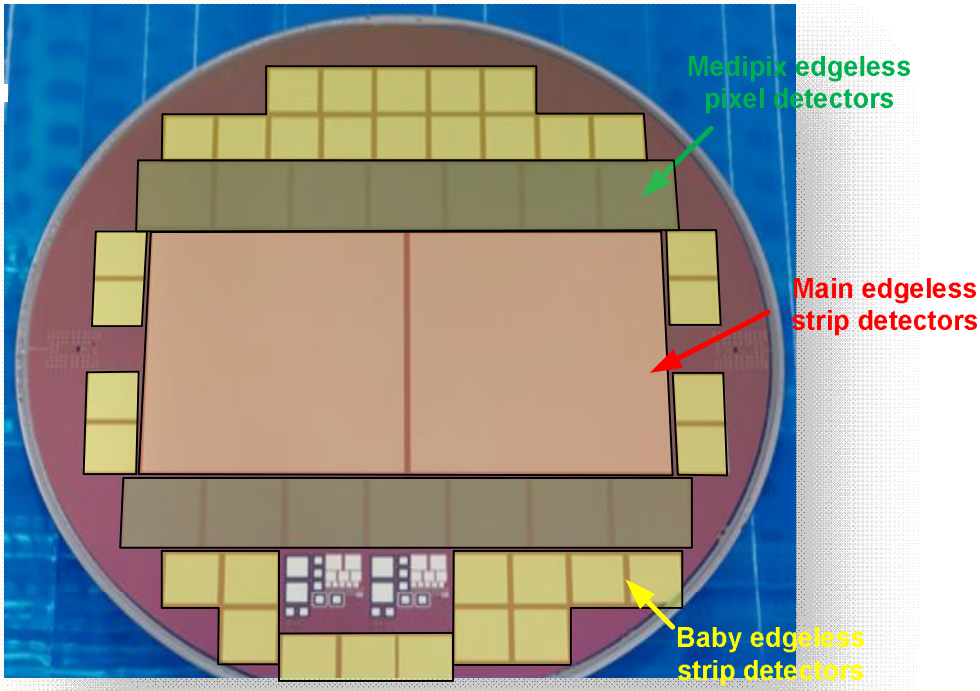
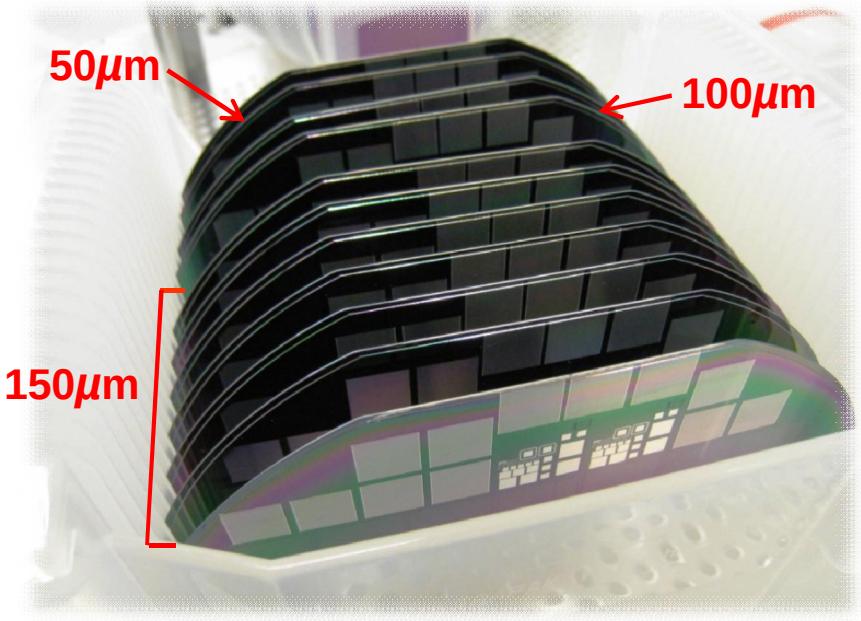
Wafer Layout and Detector Structures

- Various detector designs on 6 inch wafer



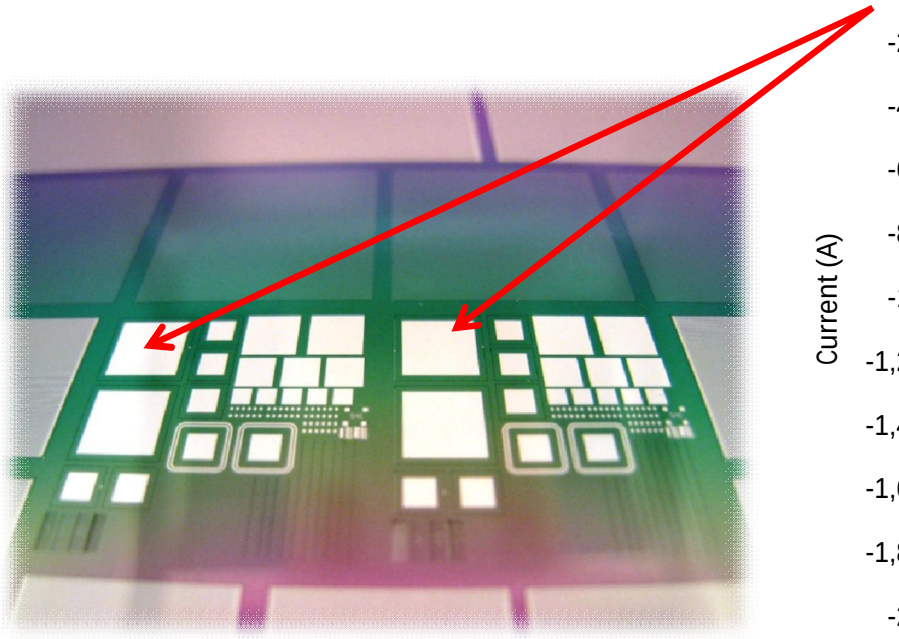


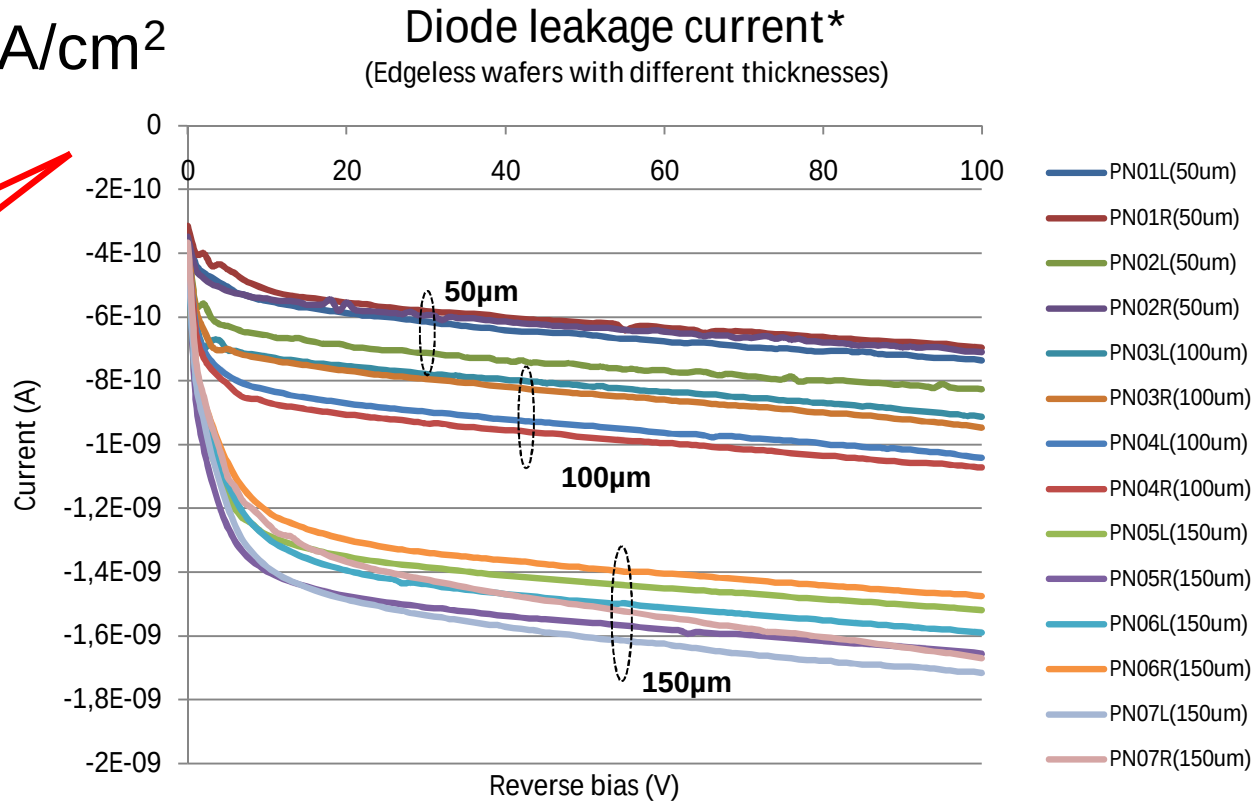


- P-on-n wafers with thicknesses
  - *50µm, 100µm and 150µm*
- Edge implantation

Diode Leakage Current

- Thin wafers with different thickness 50 *μm*, 100 *μm* and 150 *μm*
- Distance from edge to diffusion: 50 *μm*
- Leakage current of 3 - 8 nA/cm²

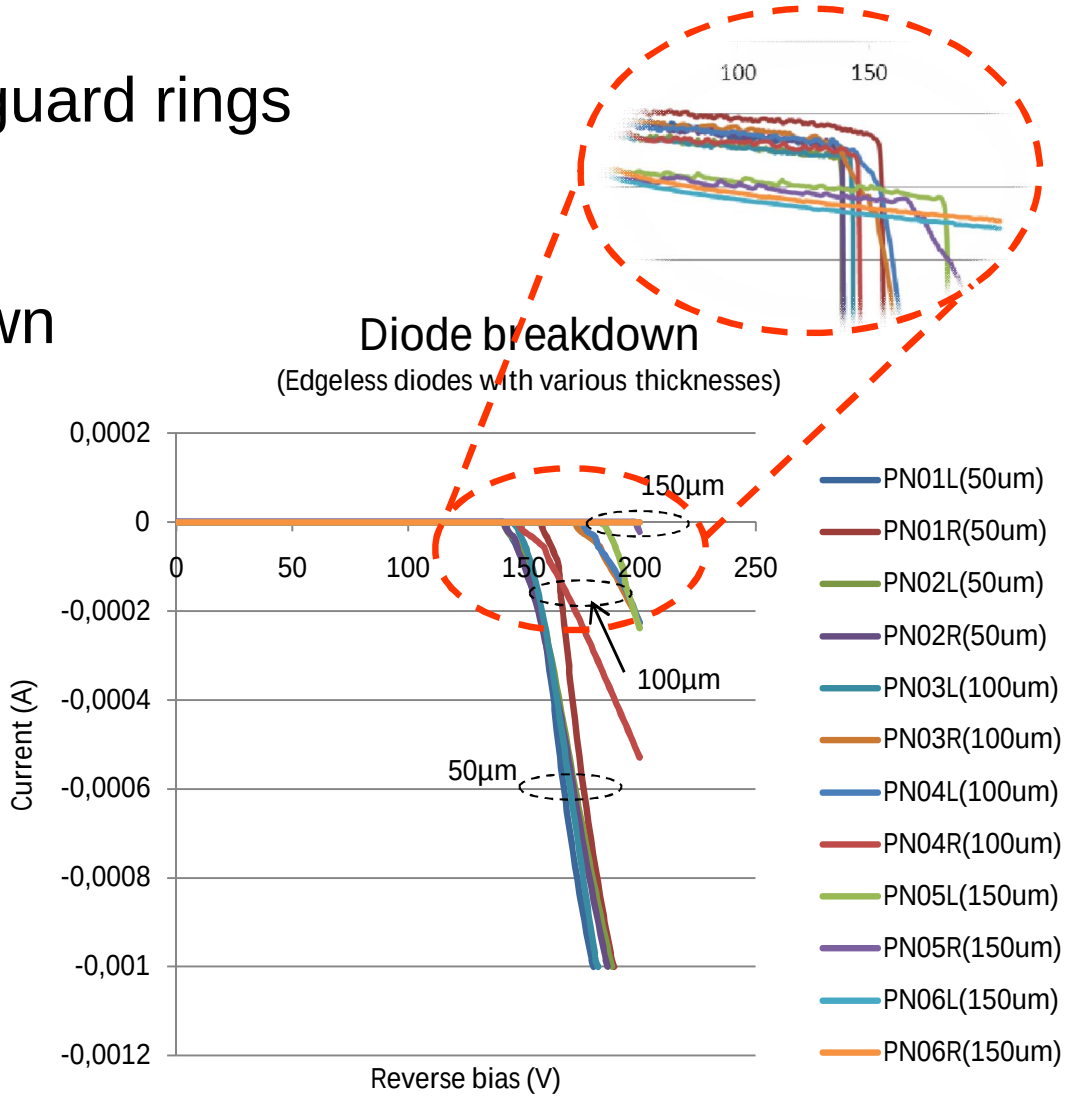




* Diode area: 5 mm x 5 mm

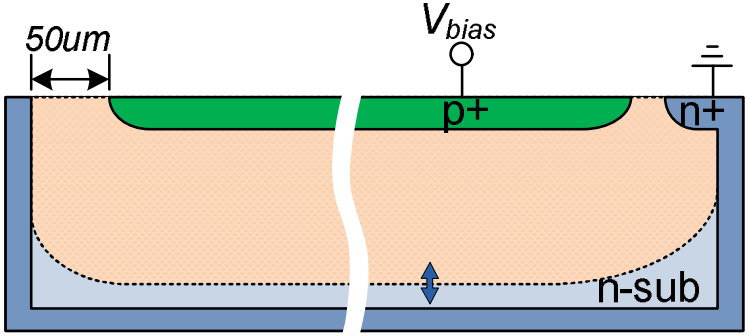
Breakdown

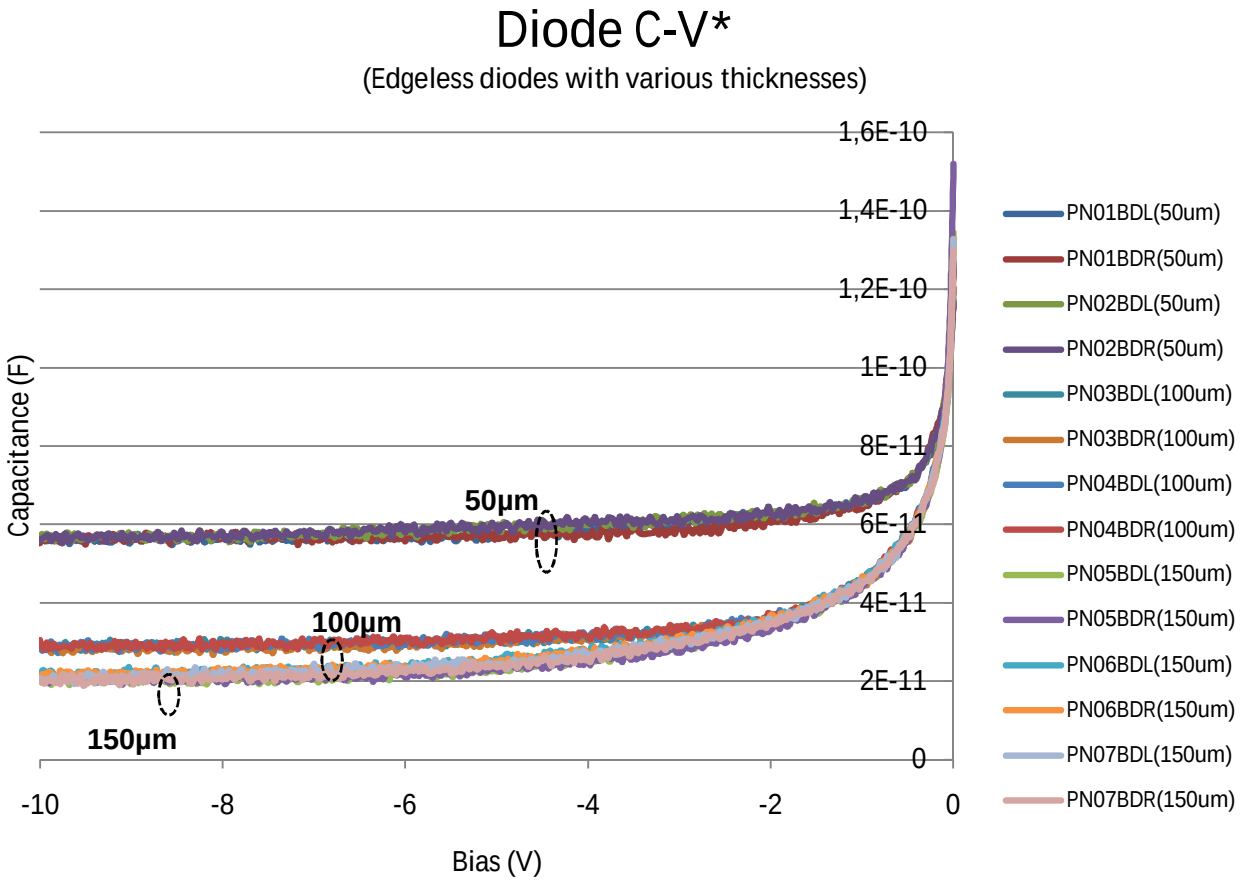
- Sharp breakdown features – no guard rings
- No breakdown below 130 V
- Thicker wafers improve breakdown performance
  - 50 µm: 135 ~ 150 V
  - 100 µm: 140 ~ 170 V
  - 150 µm: 170 ~ >200 V



Diode C-V

- Full depletion voltage of edgeless detectors with different thicknesses
  - 50 µm detector: ~ 4.5 V
  - 100 µm detector: ~ 7 V
  - 150 µm detector: ~ 8.5 V
- Edge distance dependence of capacitance
  - Capacitance of 8 - 22 pF/cm^2
  - Only slight shift when thickness increases from 100µm to 150µm





* 10kHz, diode area: 5 mm x 5 mm

Outline

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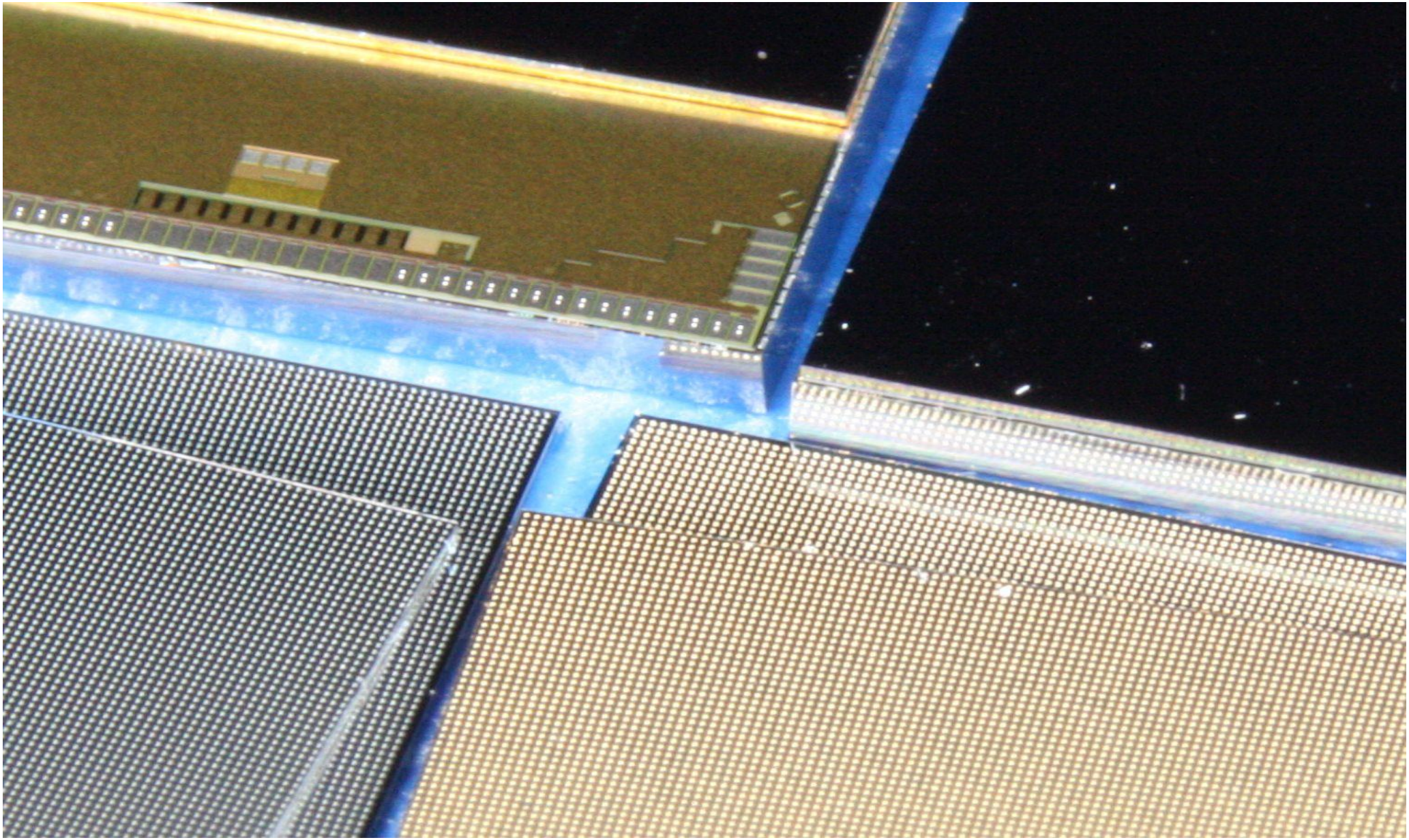
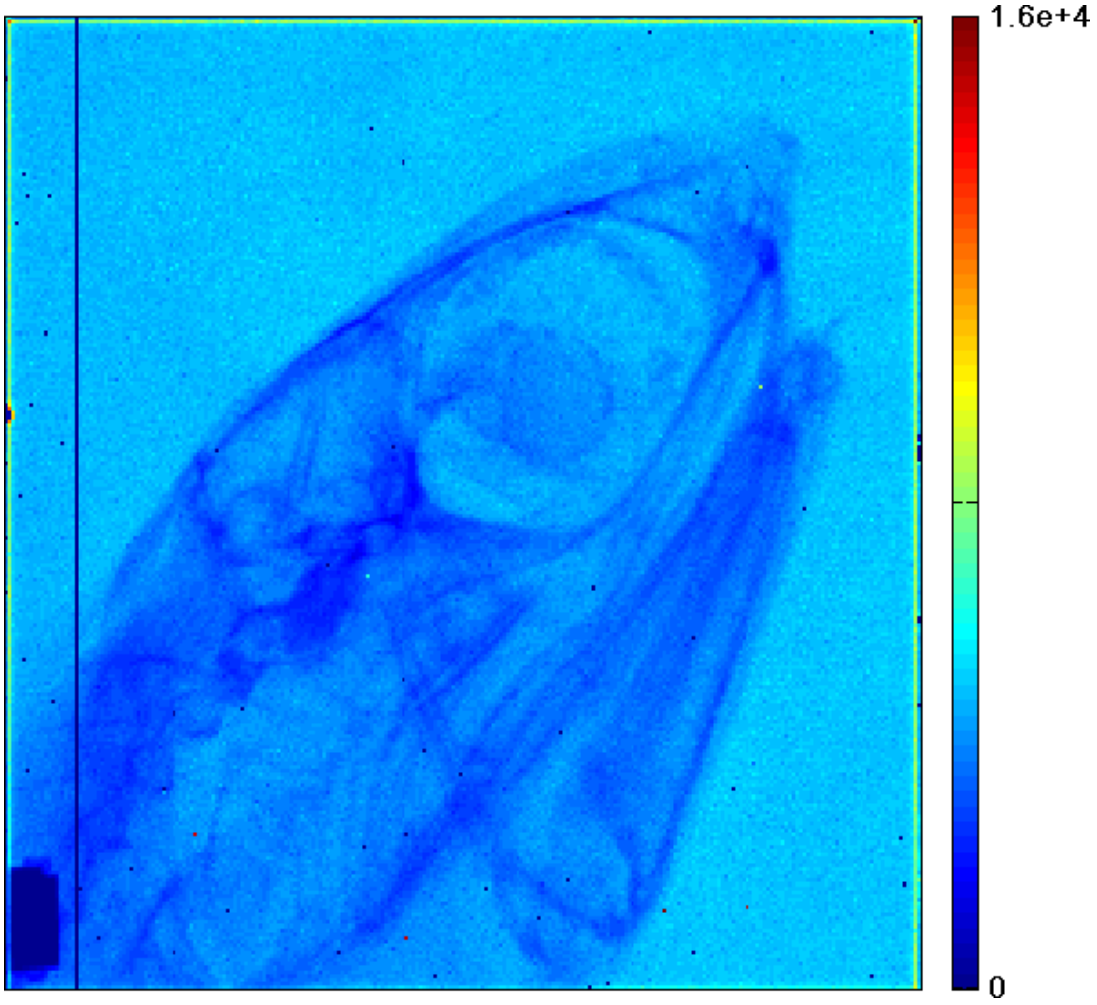
Flip-chip bonding to Medipix2 Readout Chip

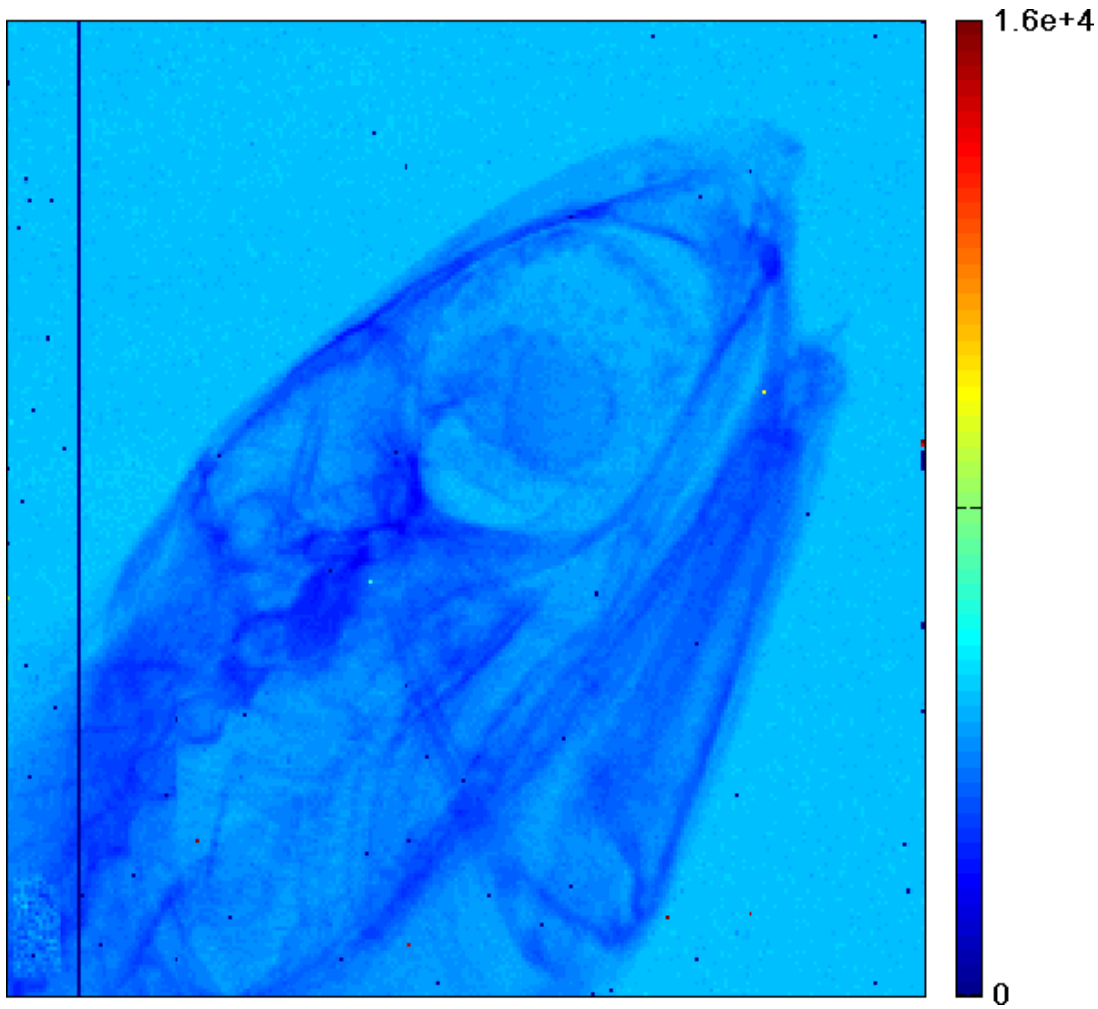


Medipix2 X-ray images with 150 µm detector

No correction

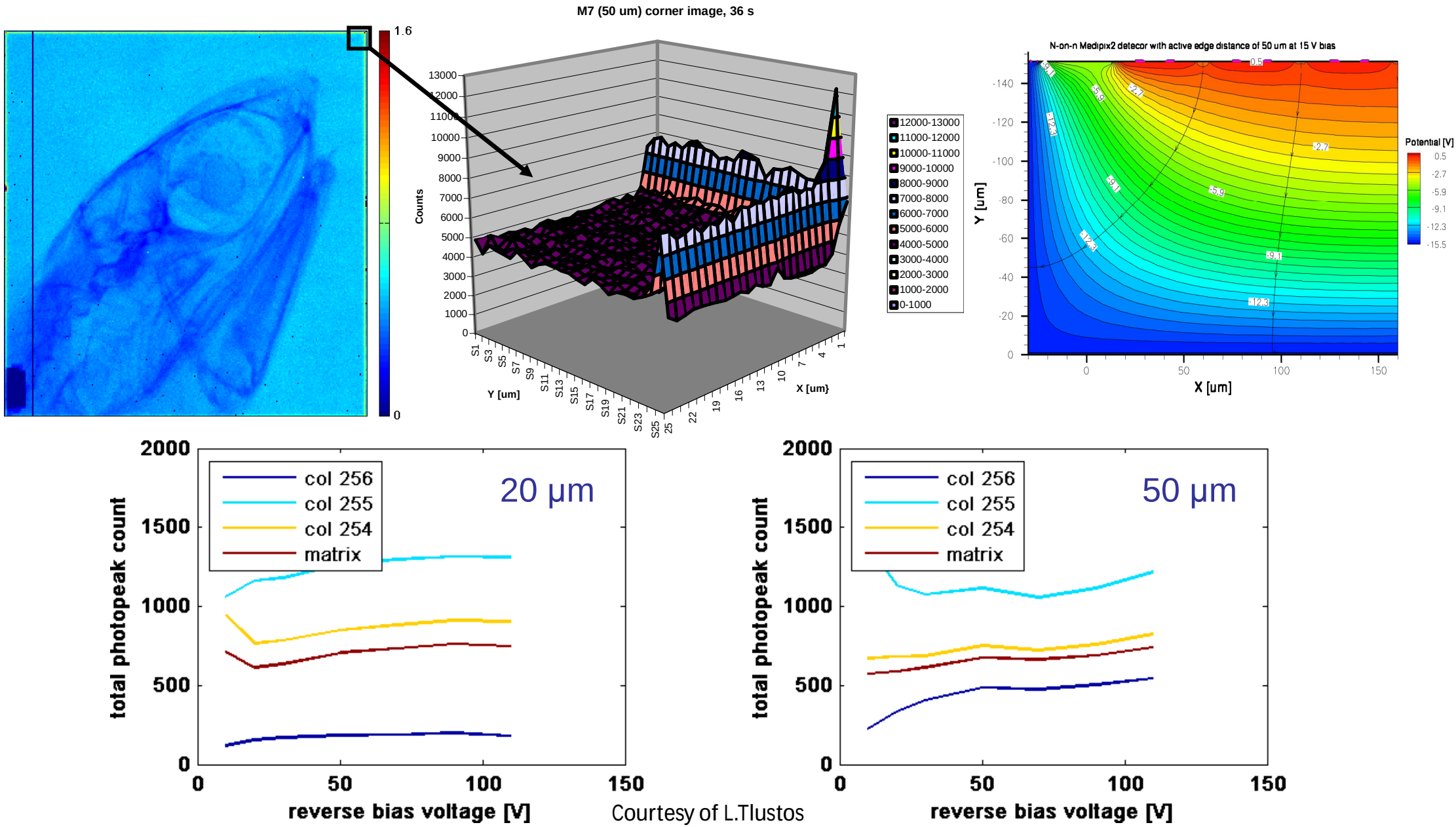


Flat field corrected



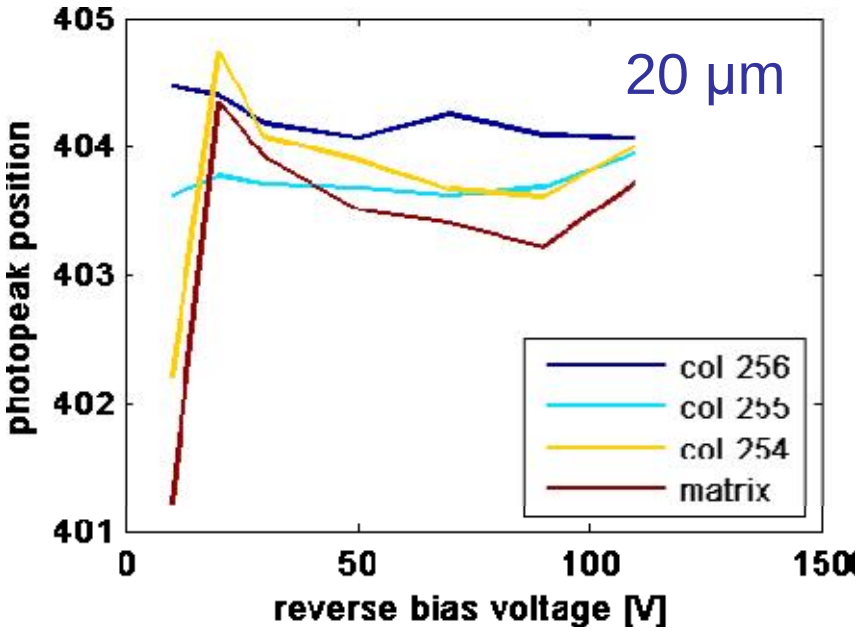
Courtesy of L.Tlustos

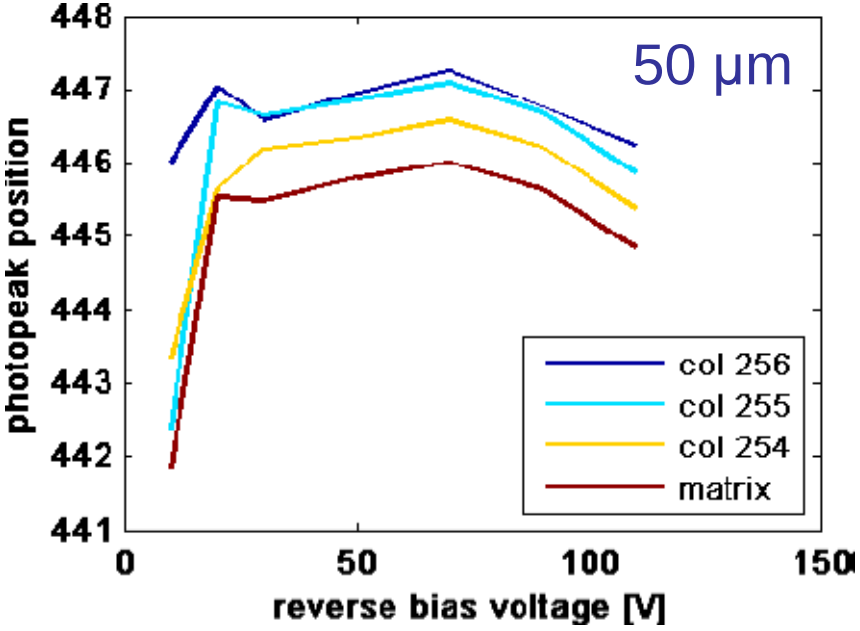
Count rate dependence

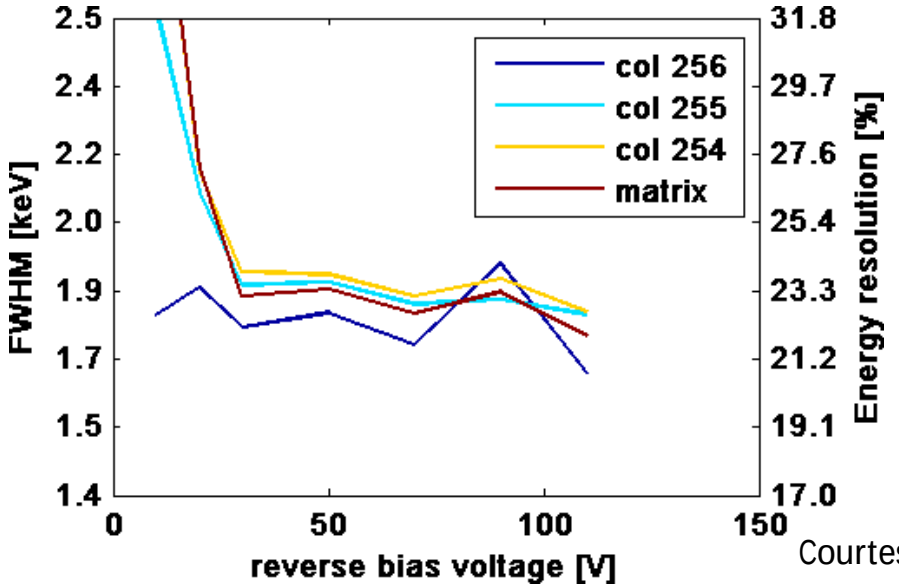


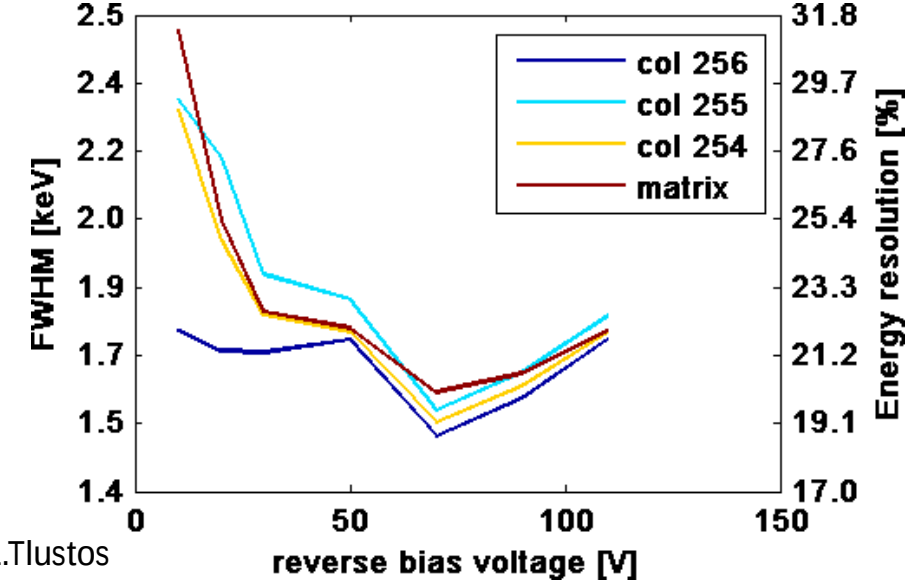
Courtesy of L.Tlustos

Photopeak position and energy resolution at 8 keV









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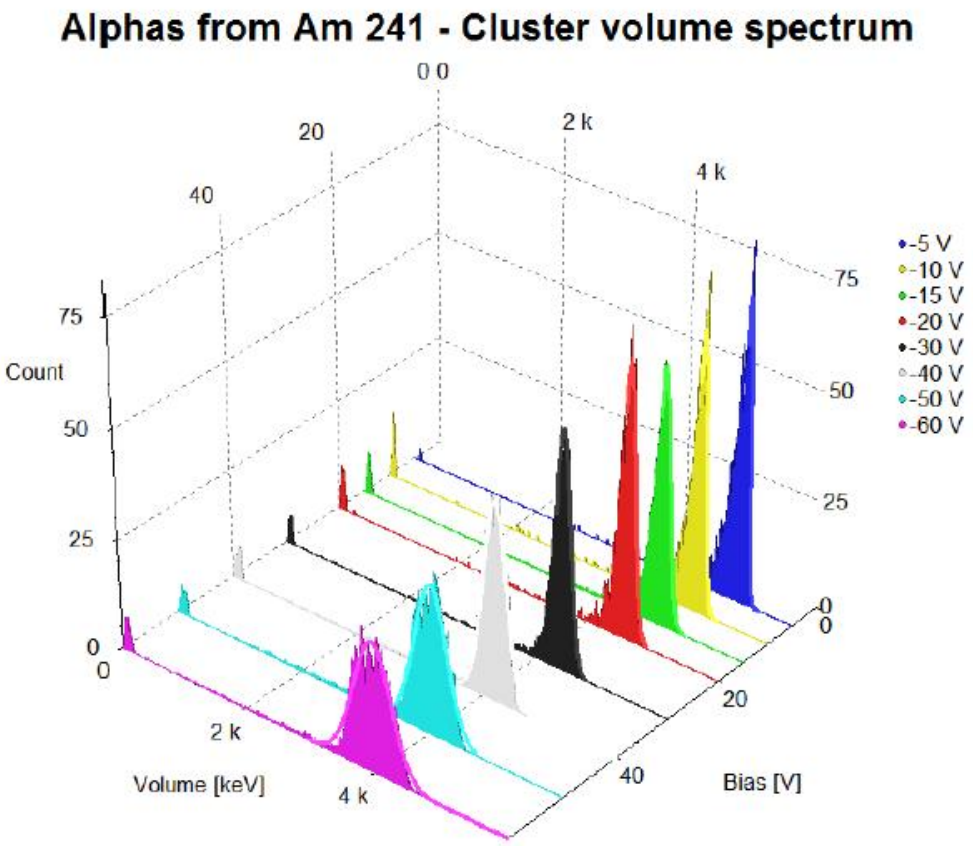
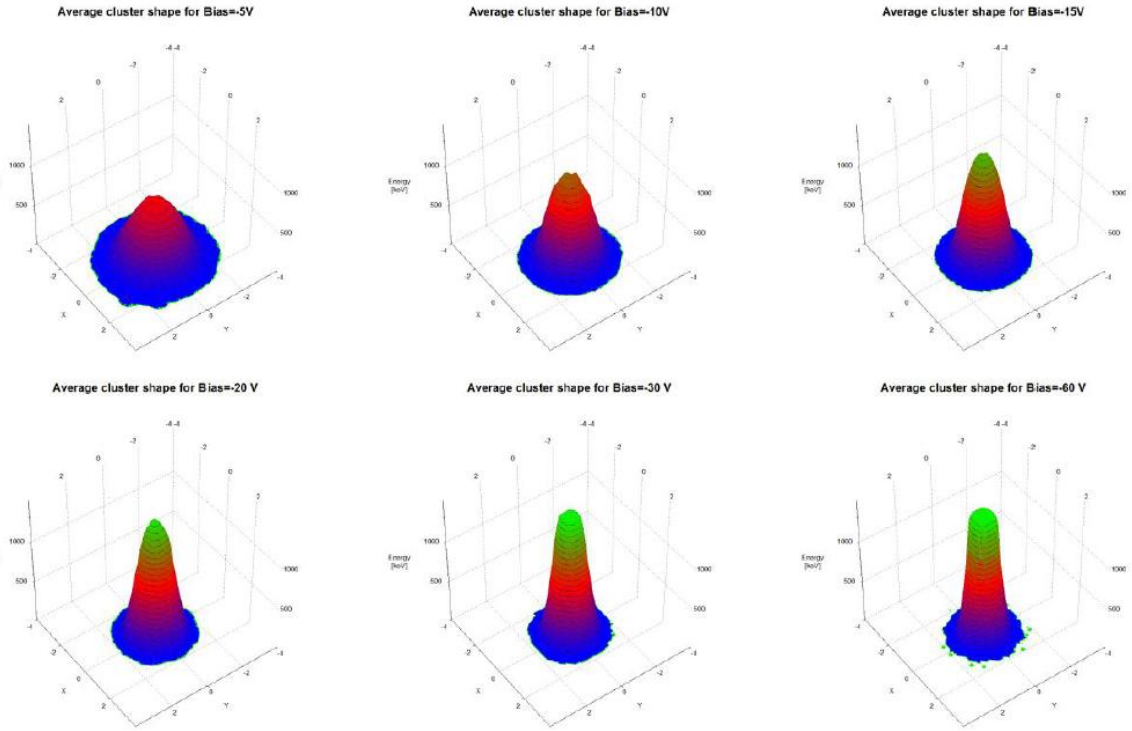
Alpha particle response

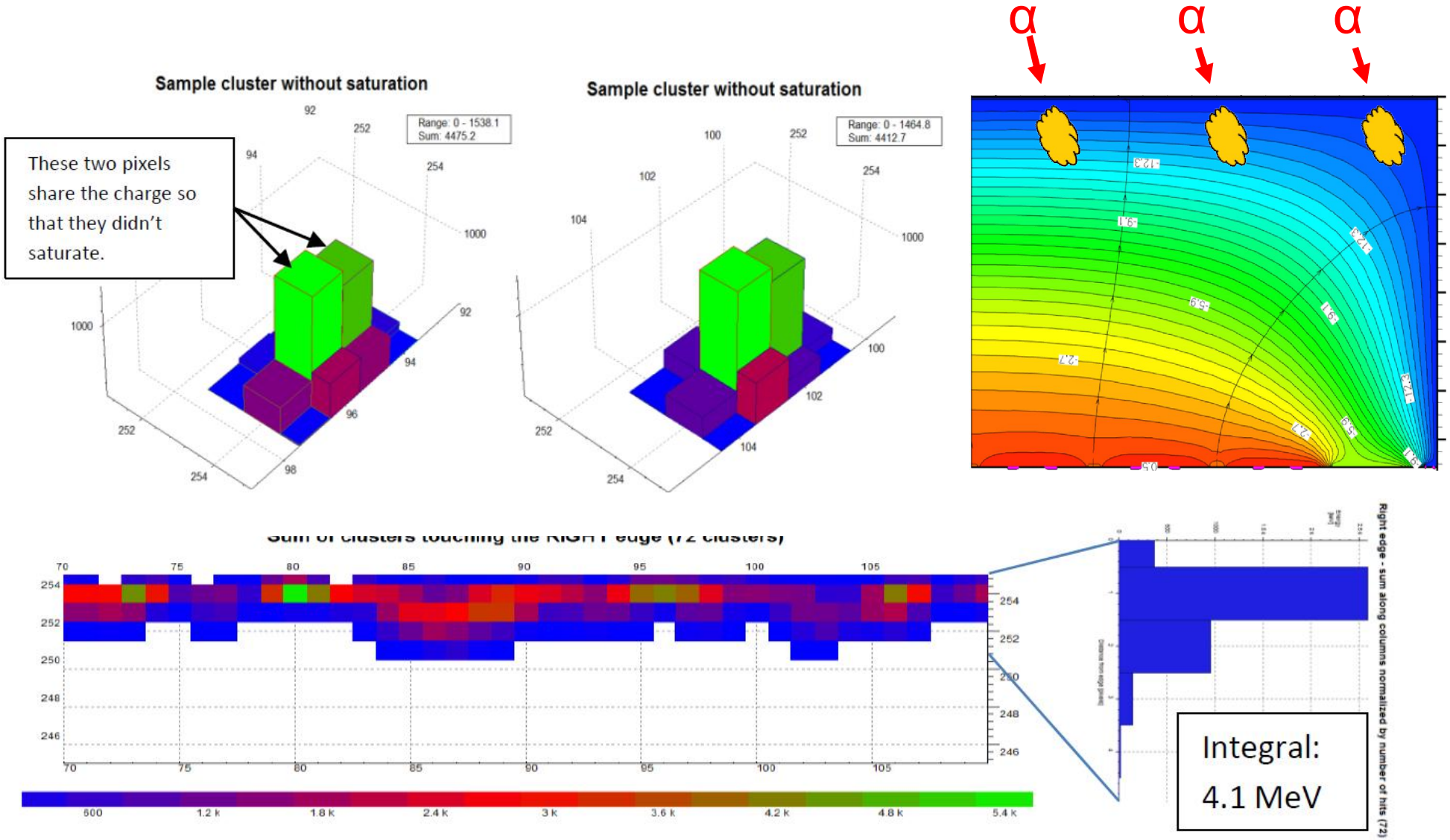
- Detector operated at 15 V reverse bias (full depletion voltage) to minimize the charge losts due to saturation
- Single pixel charge saturation (amplifier) at ~1.5 MeV





Courtesy of J.Jakubek

Alpha response at edge region



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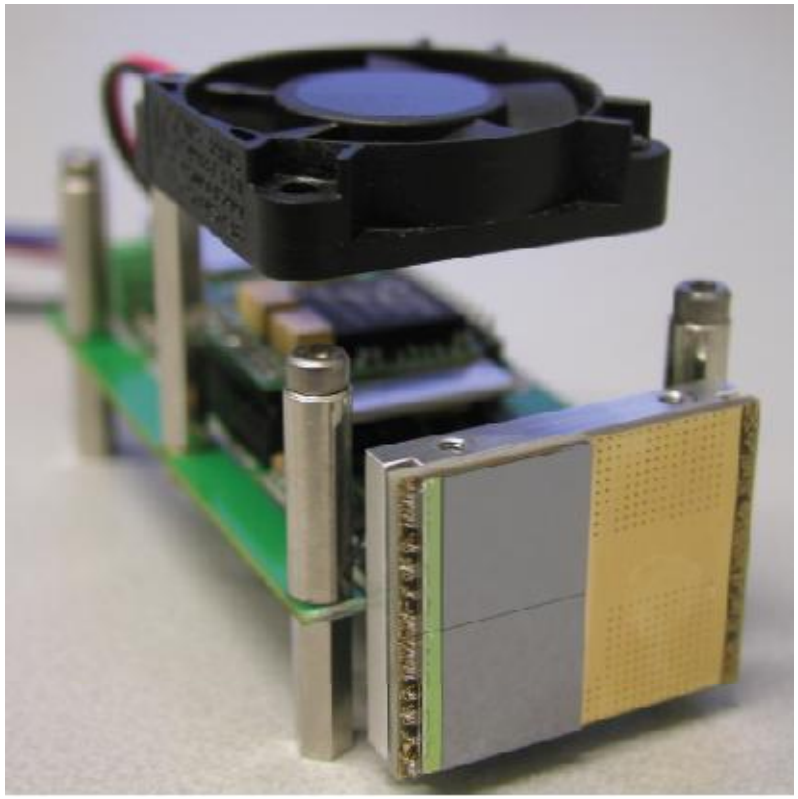
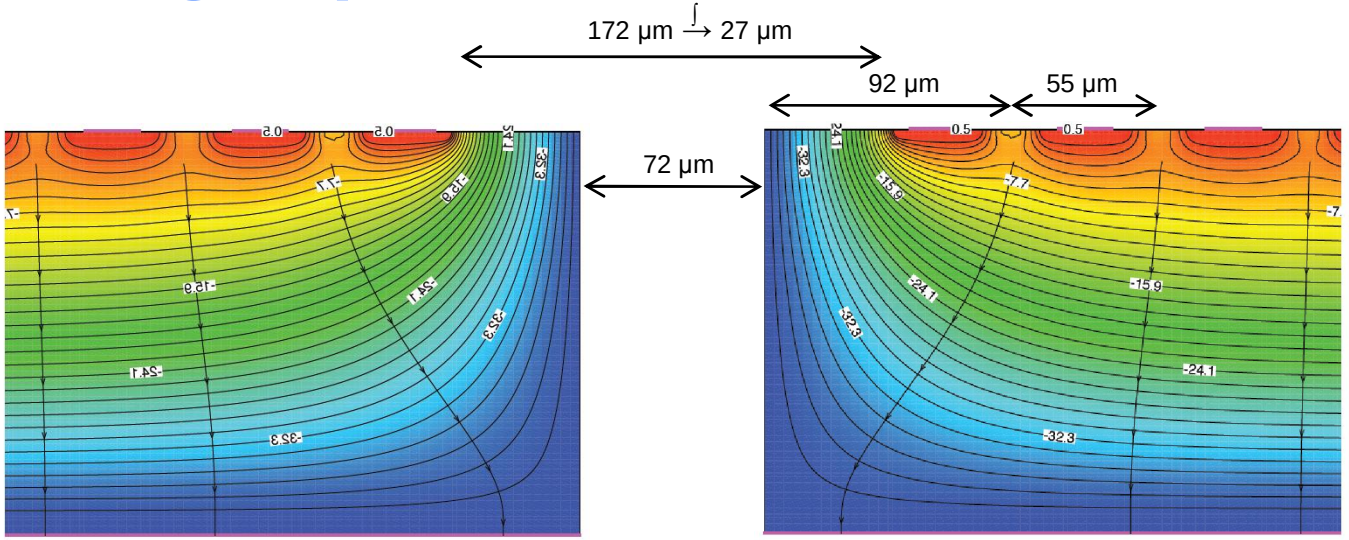
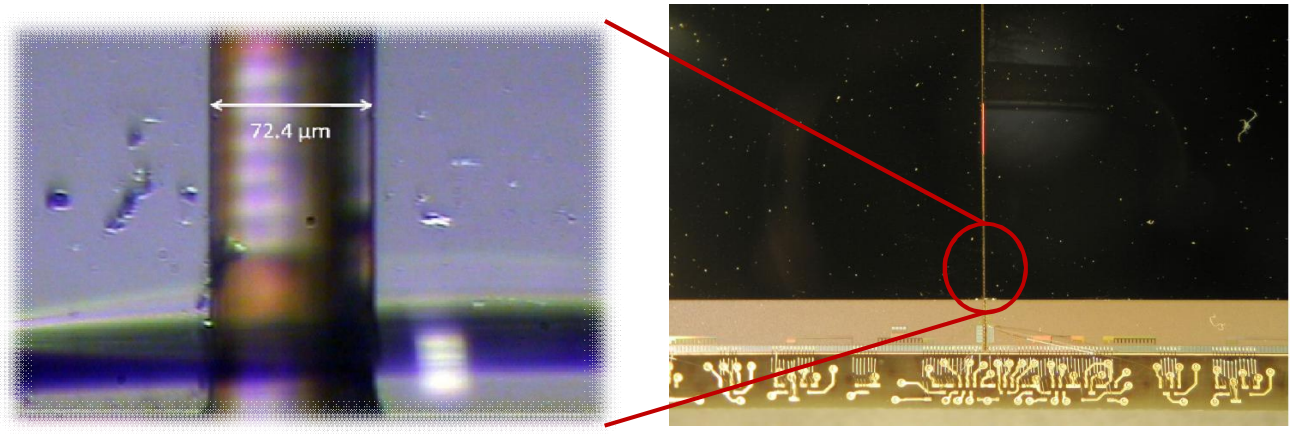
Tracking capabilities



Two edgeless silicon detector on a Timepix ROCs mounted and wire connected to the RELAXD readout board.

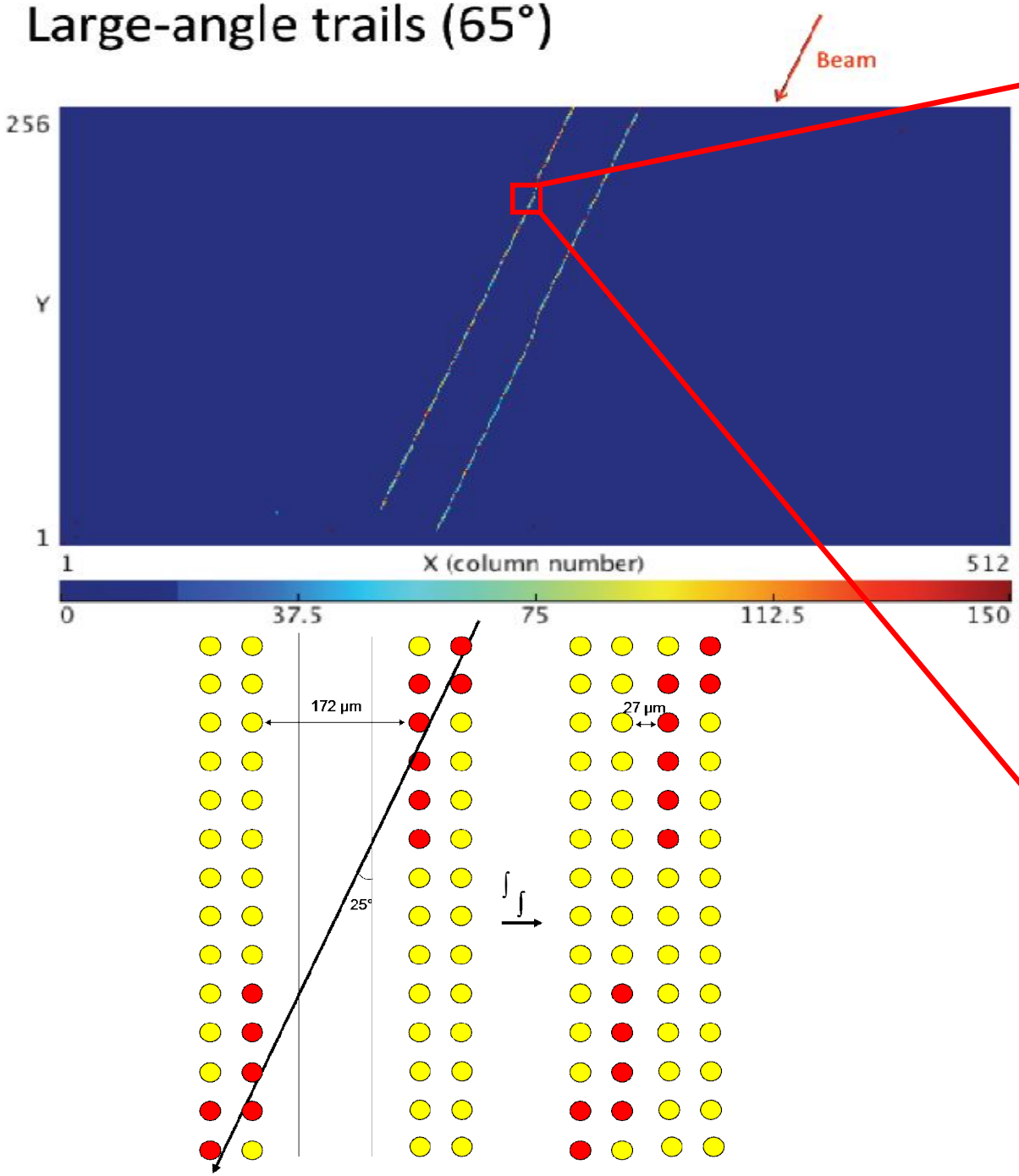


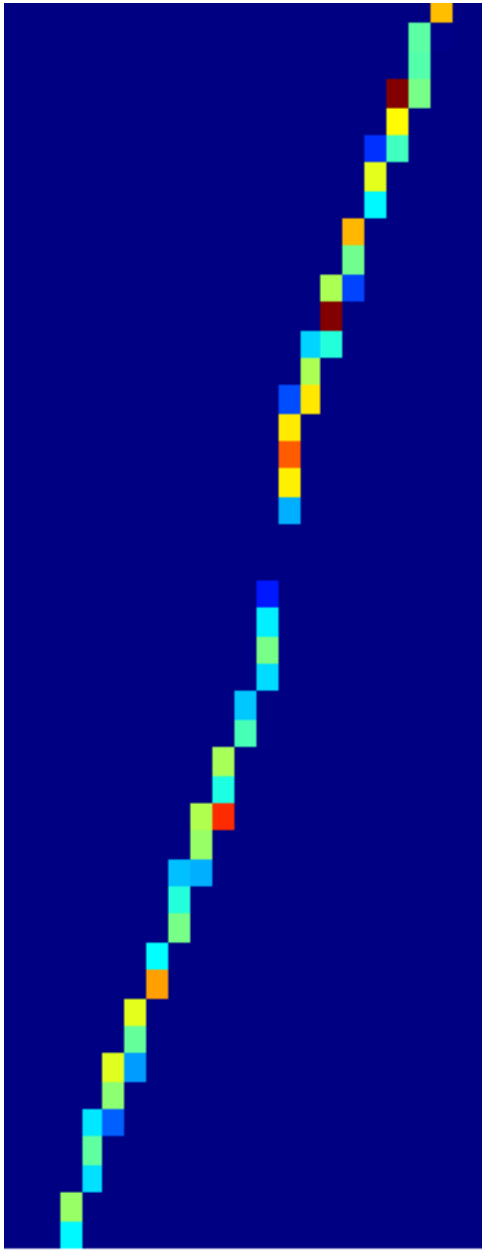
Detectors physical gap is 72 µm and is operated at -40 V reverse bias. The gap is caused because the Timepix ROC has larger area than the edgeless silicon detector that is bonded to it.



Courtesy of M.Bosma

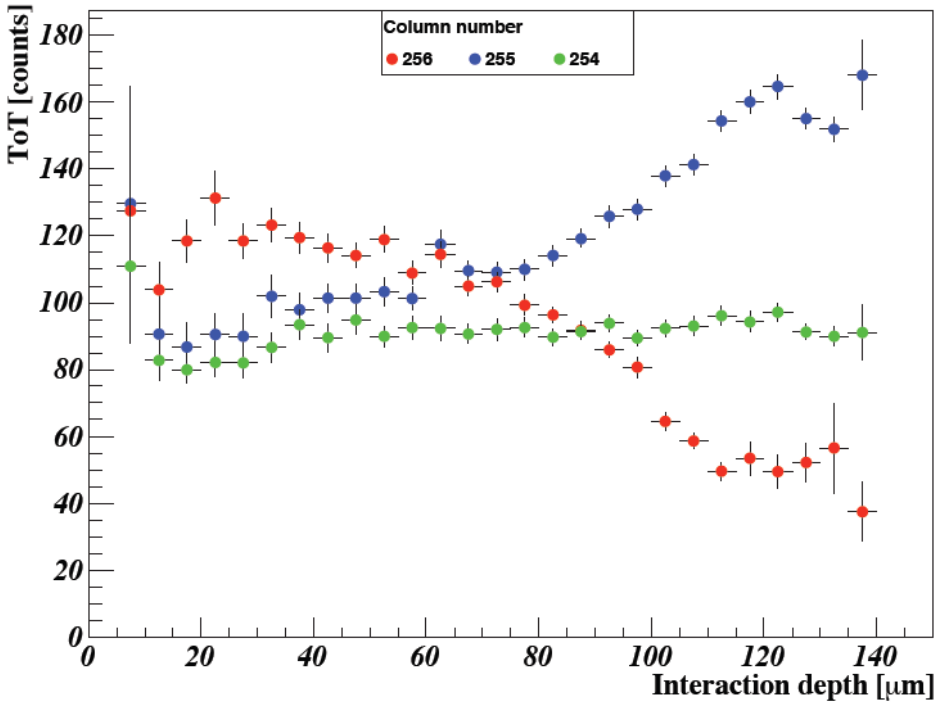
Large-angle trails (65°)



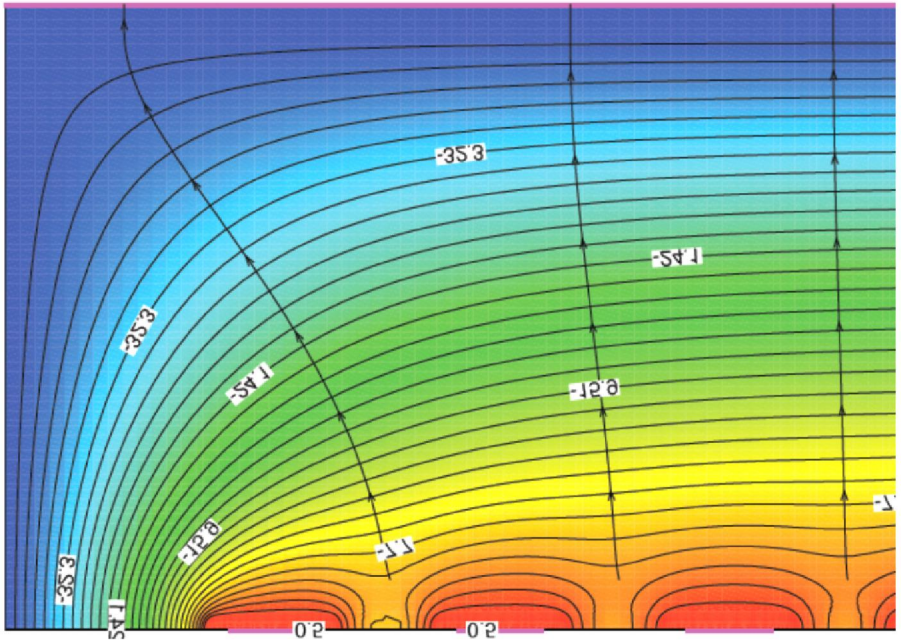


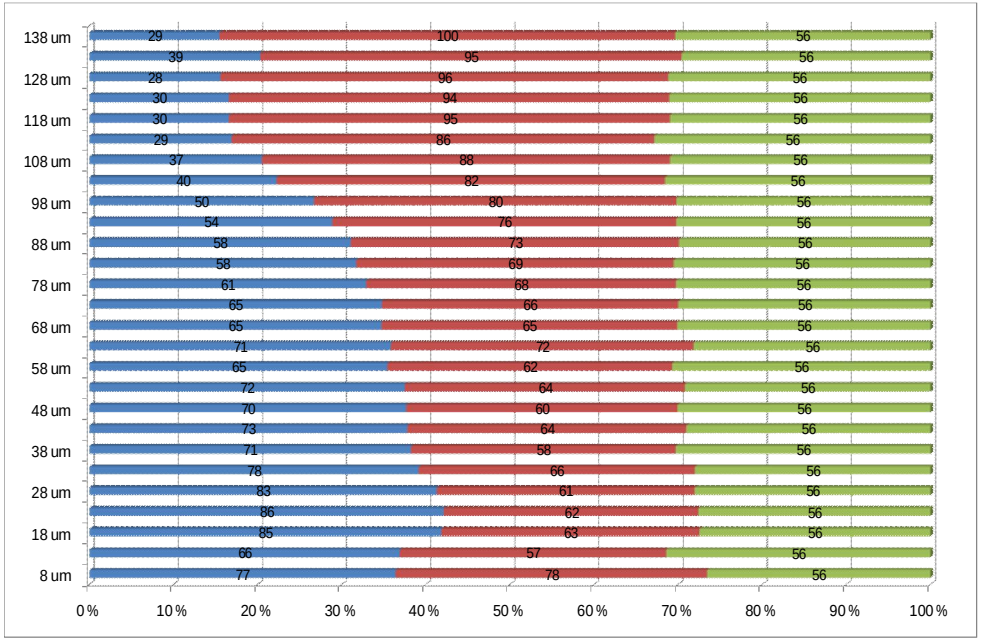
Courtesy of M.Bosma

Depth dependence



Courtesy of M.Bosma





ToT dependence on the interaction depth at -40 V reverse bias.

Average of ToT ~302.5
STDEV of ToT ~9.4
Error bar of depth ~5 μm

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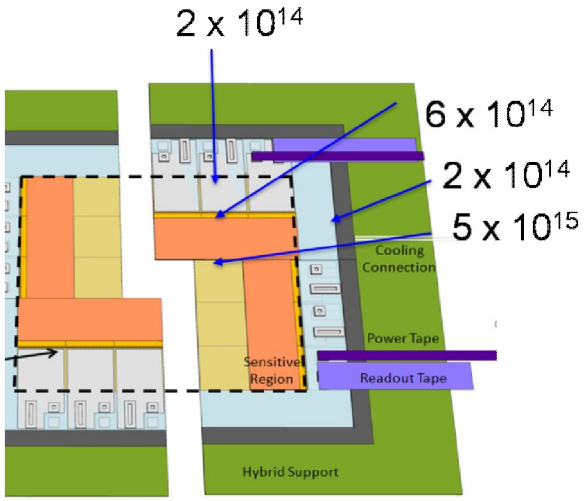
Use in high energy physics

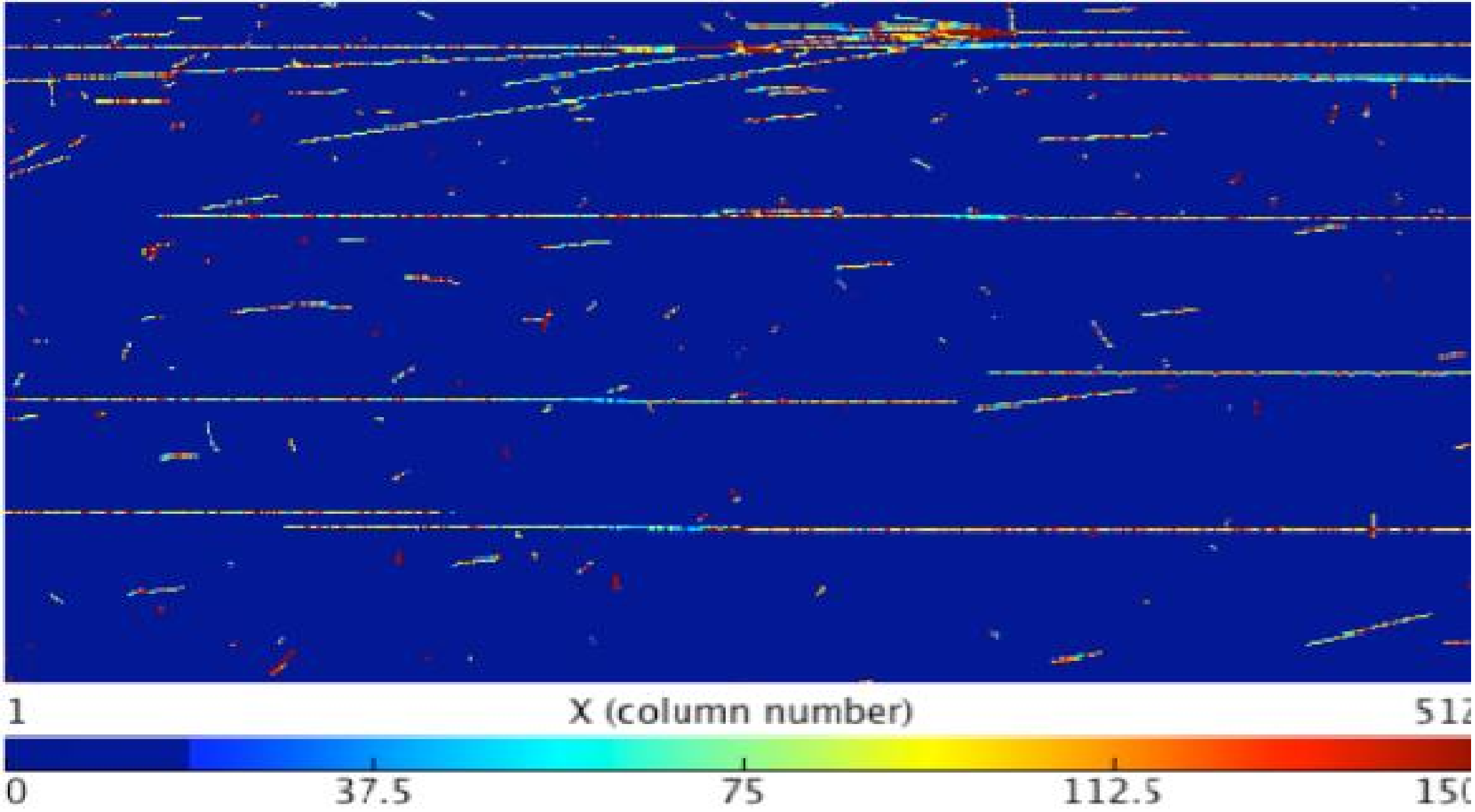
- Seamless tiling of detectors to track particles without loss of information at inner barrel pixels
- Large area coverage at barrel and at front disks
- Close approach to the beam with fully sensitive detector volume at front physics (FP420, Totem, LHCb)
- Construction of the detector from pieces with different properties to correspond to the environment (f.e. LHCb)
  - Thickness – radiation tolerance vs. signal vs. spatial resolution
  - Bias voltage – use high bias only if needed
  - Guard rings – higher operation voltage (unirradiated)
- Radiation hardness of thin edgeless detectors?
  - After irradiation guard rings are irrelevant?



Courtesy of P. Collins

Summary

- Large area hybrid imaging detector requires complicated and expensive integration techniques and edgeless detectors
- VTT's process technology has been shown to provide good properties for thin edgeless detectors for particle tracking and photon detection
- Edgeless detectors suffer from inhomogenius electric field at the edge regions – can be fairly easily corrected
- The complite physical volume of the detector is sensitive to the radiation - full energy information is conserved
- Construction of a tracking detector from smaller pieces in particle physics can turn the limitations of detector's properties to an engineering issue


1
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