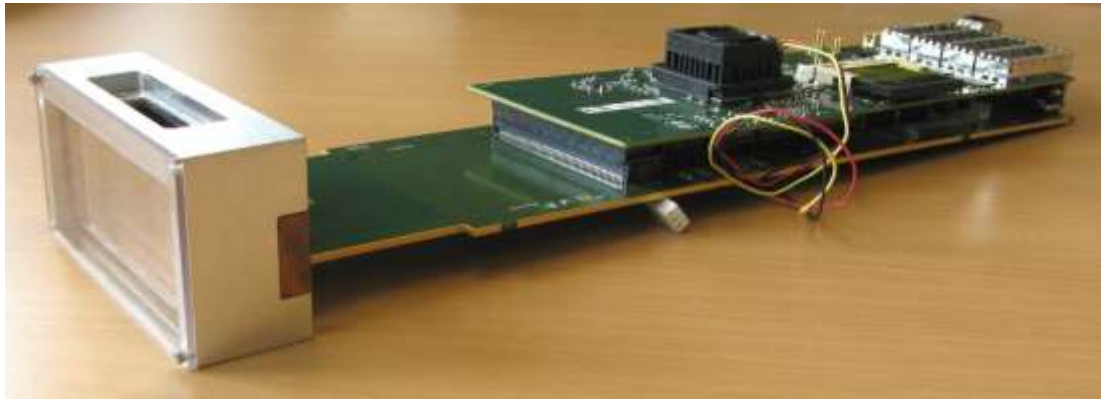
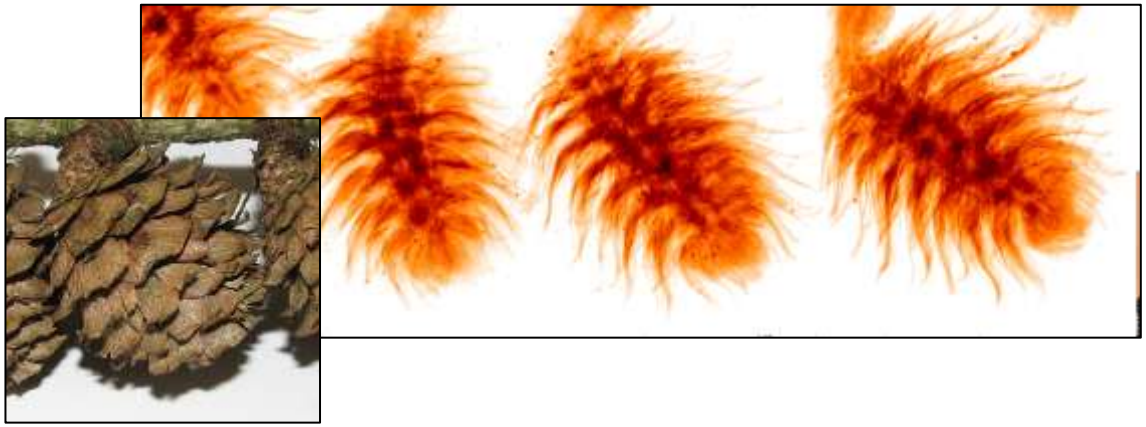
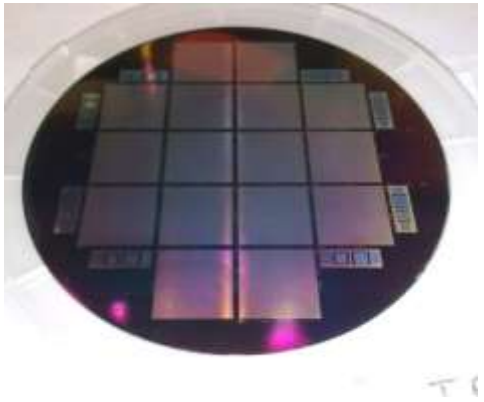
The LAMBDA photon counting pixel detector

Heinz Graafsma, David Pennicard, Sabine Lange, Sergej Smoljanin,
Helmut Hirsemann, - *DESY*
Michael Epple - *Technical University of Munich*
Milan Zuvic, Marie-Odile Lampert - *Canberra France Speciality Detectors*
Thomas Fritzsch, Mario Rothermund – *Fraunhofer IZM*





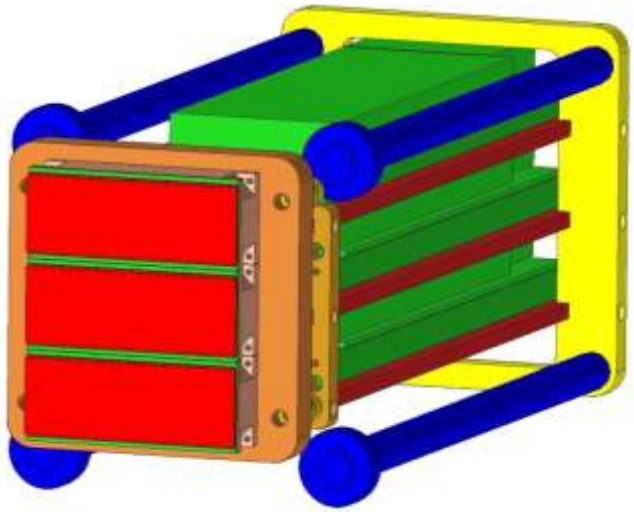


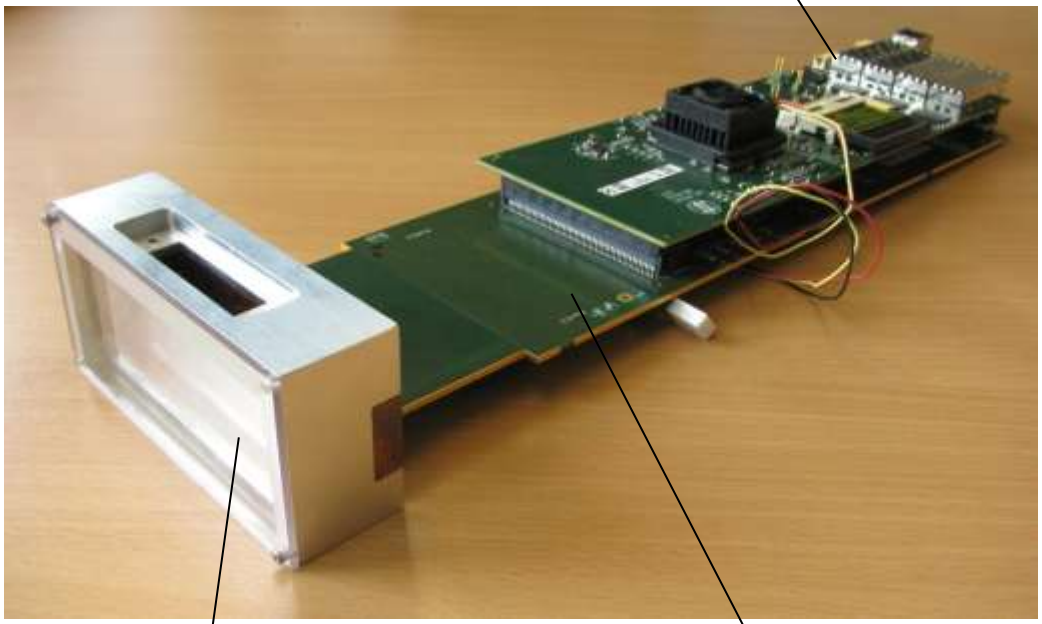
Experiments at PETRA-III

- 6 GeV source with low emittance (1 nmrad)
  - Nanofocusing, high-resolution, coherence…
  - Hard X-rays (>20 keV)
- 14 beamlines
  - 8 in user operation
- 2 extensions under way
  - Replacement for DORIS-III
  - 10 beamlines
  - Higher flux

Large Area Medipix-Based Detector Array

- Photon-counting detector
- Small pixel size (55µm)
- Fast readout (2 kHz+)
- Large, tilable modules (1536 by 512)
- High-Z compatible
  - inc. germanium cooling

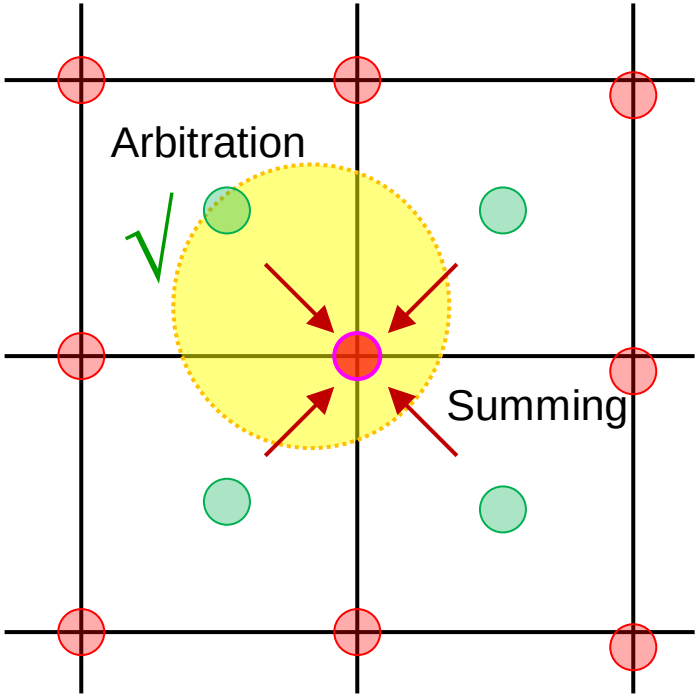




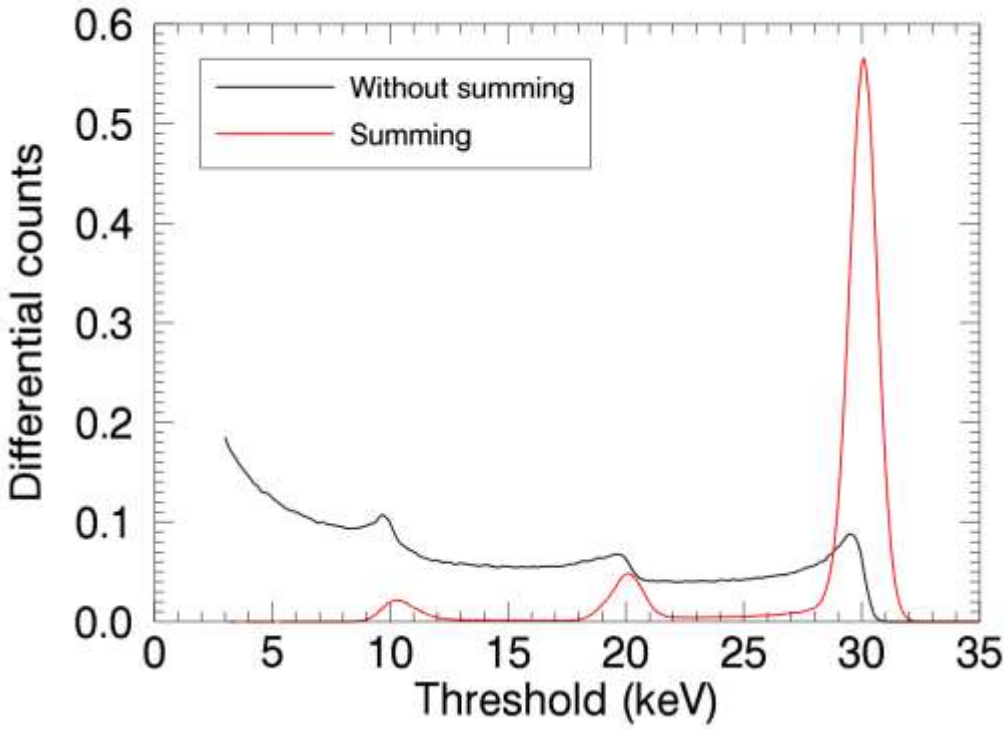
Medipix3 design and high-Z compatibility

- Bipolar input preamp with leakage compensation (followed by shaper)
- Gain selection
- Charge summing (beneficial for thick sensors with fluorescence)

Medipix3 RX charge summing

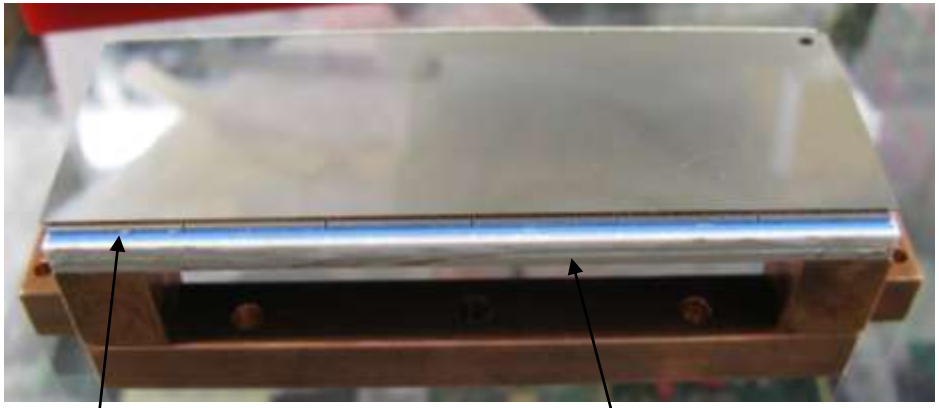


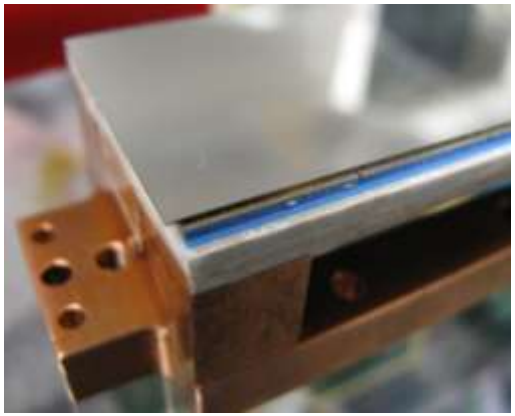
Simulated spectrum - Ge, 100V



Detector head

- 6 by 2 chips (1536 by 512 pixels)
  - Large Si sensor from 5” wafer
    - 300µm Si sensor here
  - 2 x “Hexa” high-Z sensors
- Ceramic circuit board (LTCC)
  - 14 layer board
  - Good match to germanium CTE
  - Cooling through thermal vias
- 500-pin connector on board
  - Full parallel readout (8 LVDS data outputs per chip)
  - ~150 LVDS pairs total





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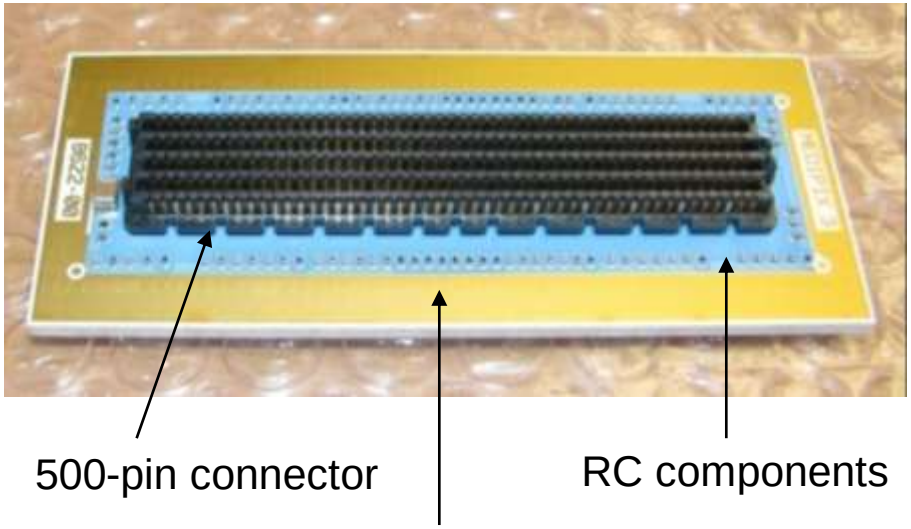
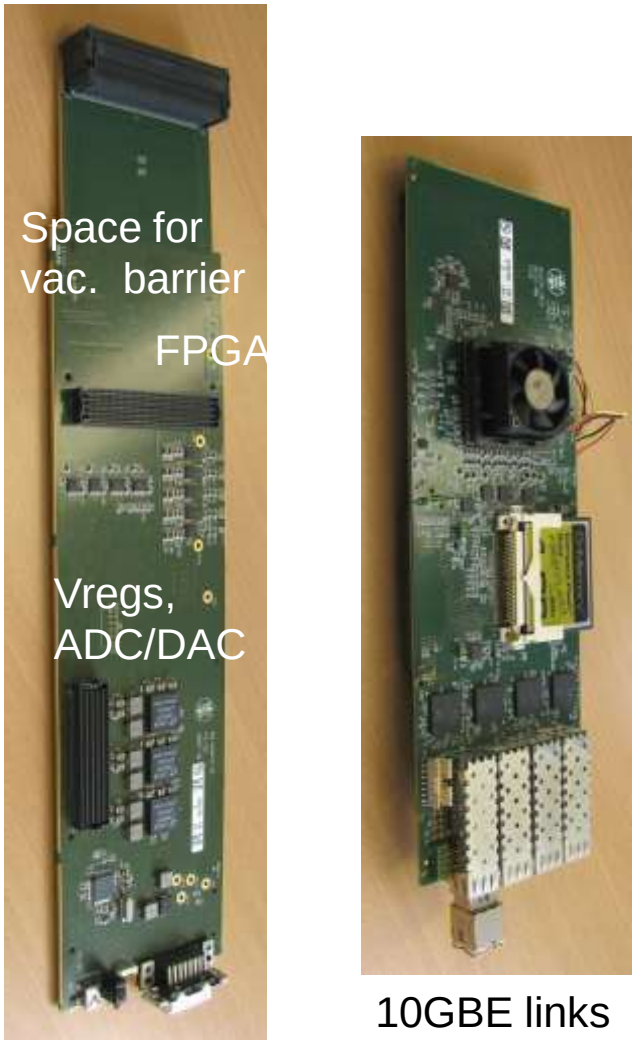


High-speed readout system

- Previously developed prototype system (USB2 readout only)
- High-speed readout with common DESY mezzanine card
  - Virtex-5 FPGA with PowerPC
  - 4 * 10 Gigabit Ethernet links
  - DDR2 RAM (8GB)
- “Signal distribution” board connects to det. head
  - Space for vacuum barrier with germanium detector
- Currently working on high-speed readout firmware



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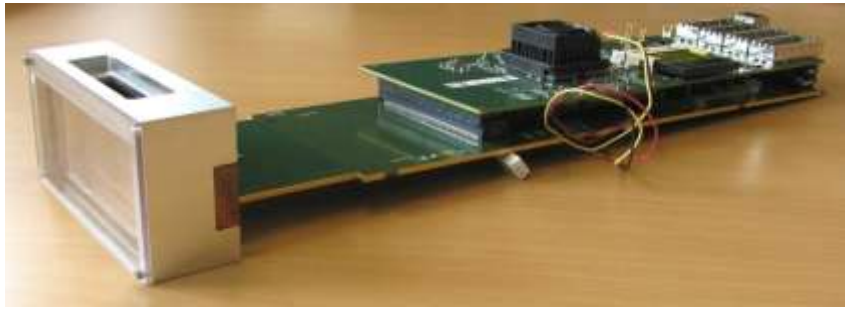
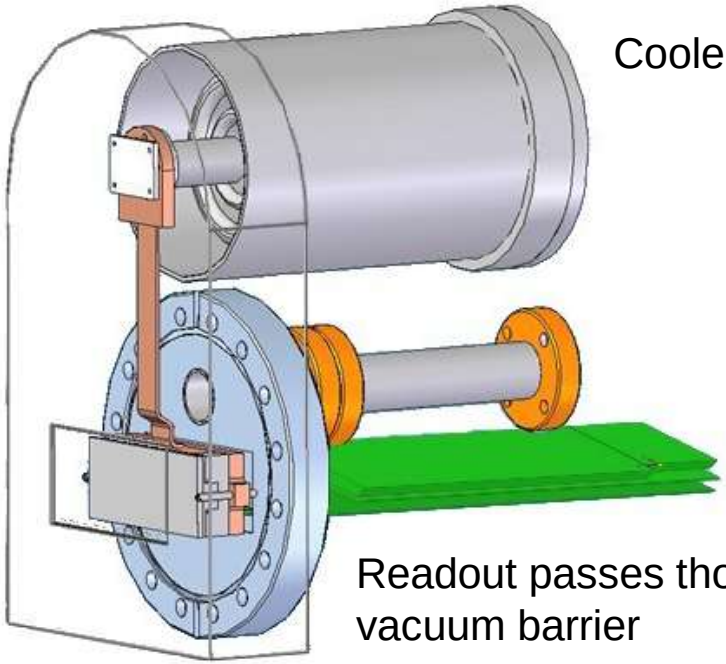
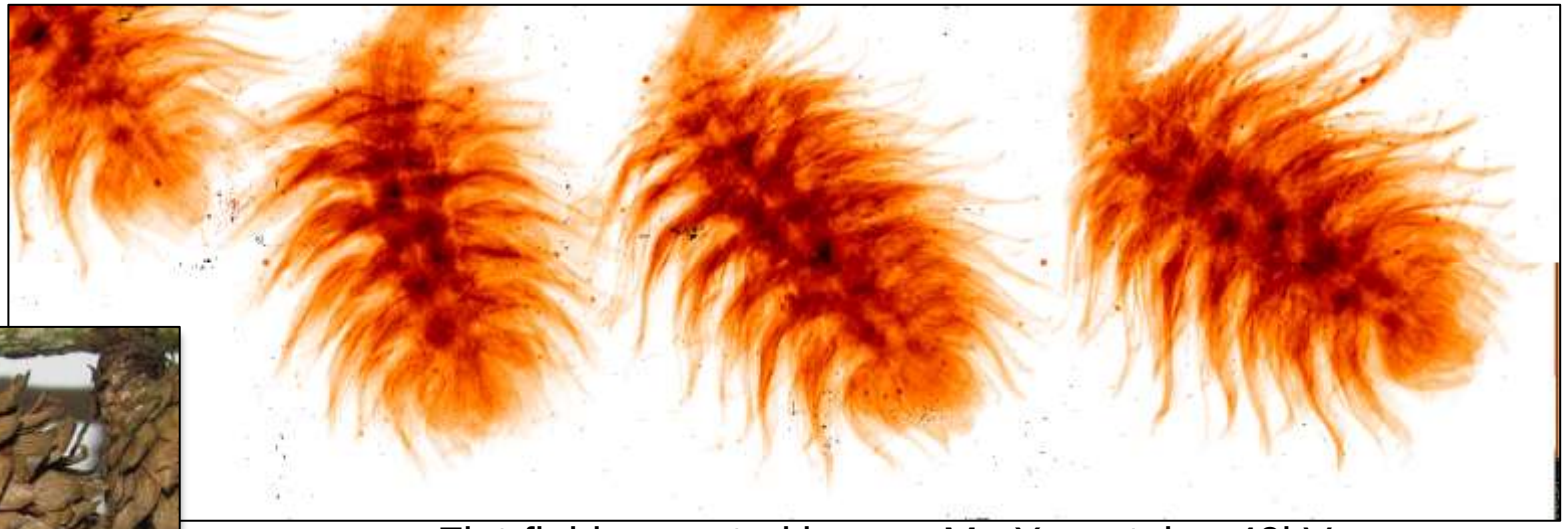




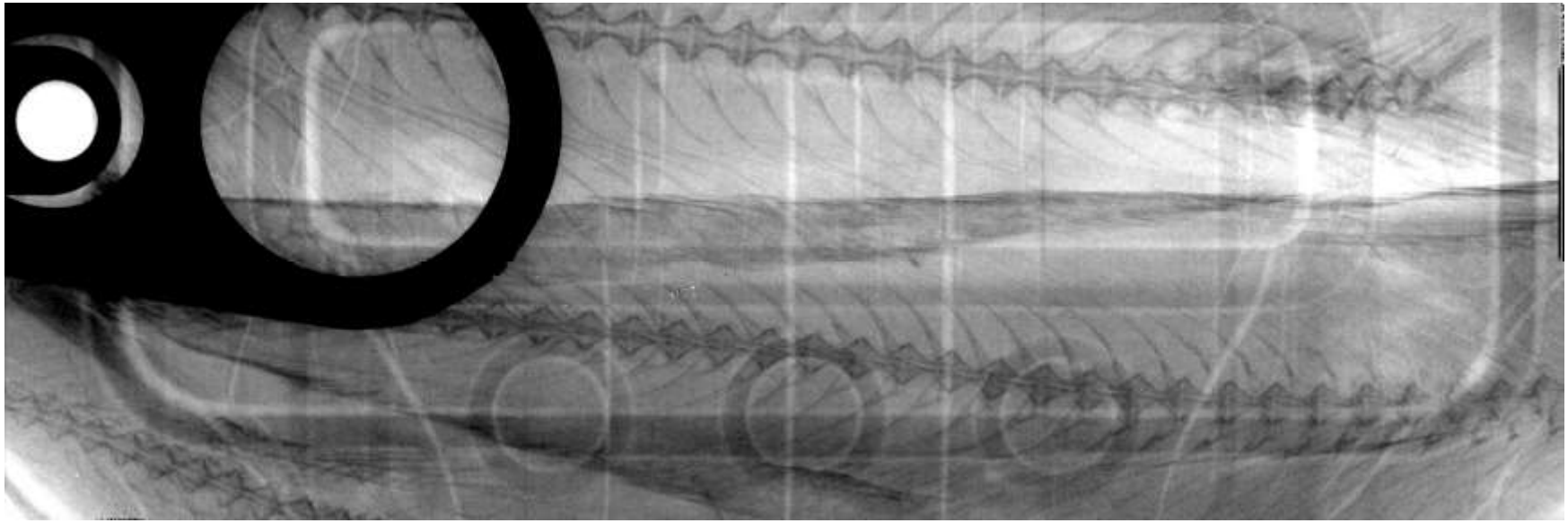
Test results with Si module

- First full Si module assembled (300µm thick sensor from Canberra)
  - Solder bonding at IZM
  - All 12 chips successfully bonded and functional
  - Small no. of bad pixels on chips and bad bumps on test module



Flat-field corrected image, Mo X-ray tube, 40kV

Test results with Si module

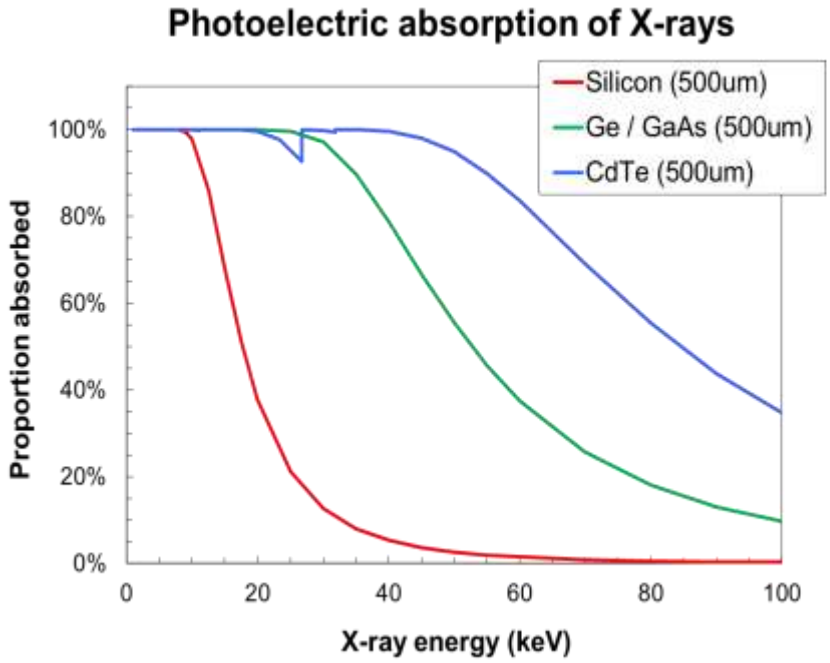


LAMBDA and germanium sensors

- Large Area Medipix-Based Detector Array
  - Flexible photon-counting system based on Medipix3 chip
- High-Z pixel detector development
  - Germanium detector project with Canberra and IZM

High-Z development

- Germanium – Canberra France
  Speciality Detectors, Fraunhofer IZM



Germanium pixel detector

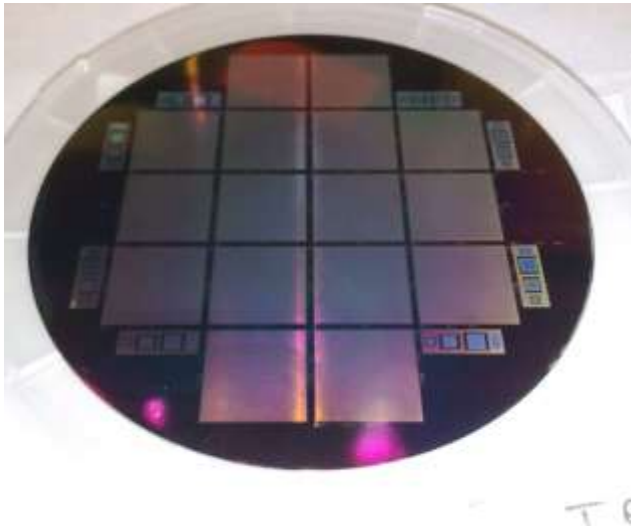
Canberra (Lingolsheim): M Lampert, M Zuvic, J Beau

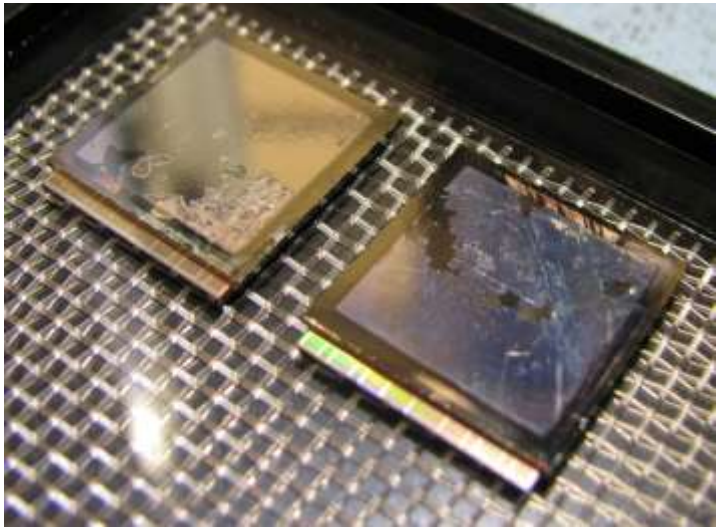
Fraunhofer IZM (Berlin): T Fritzsch, M Rothermund, H Oppermann, O Ehrmann

- High-purity, high uniformity 90 mm Ge wafers available
- Cooled operation needed to reduce leakage current
  - Must avoid saturation & excessive noise in amplifier
  - Est. **-70°C** operation with Medipix3 (55µm)
    - Measured transport and depletion fine at this temperature
- Lambda module designed to be cooled
- *Fine pixellation and bump-bonding had to be developed*

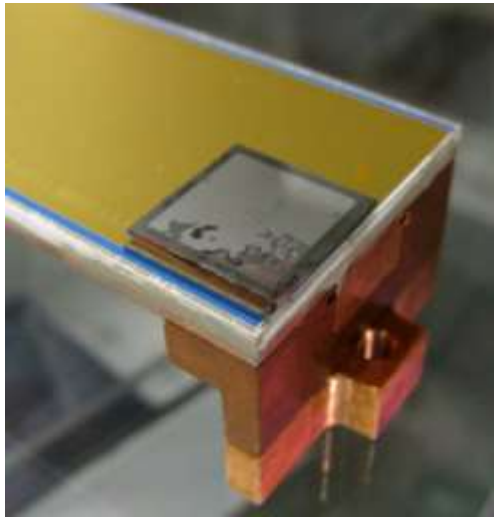
Sensors

- 2 high purity Ge wafers produced by Canberra
  - 16 Medipix3 singles / wafer
- First 2 assemblies bonded
  - Some delamination of back metal

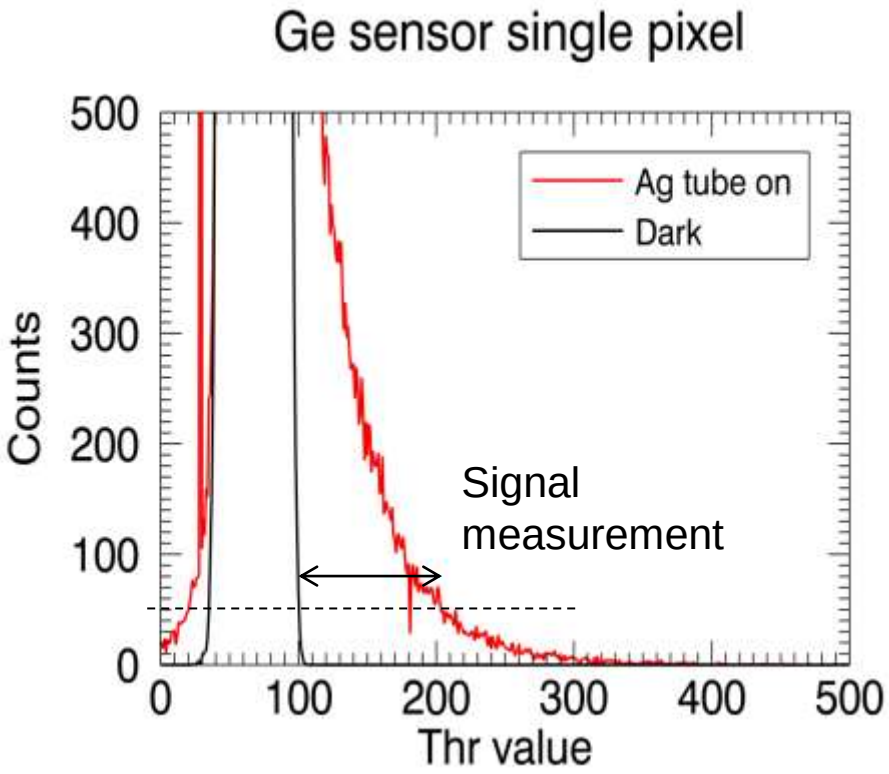


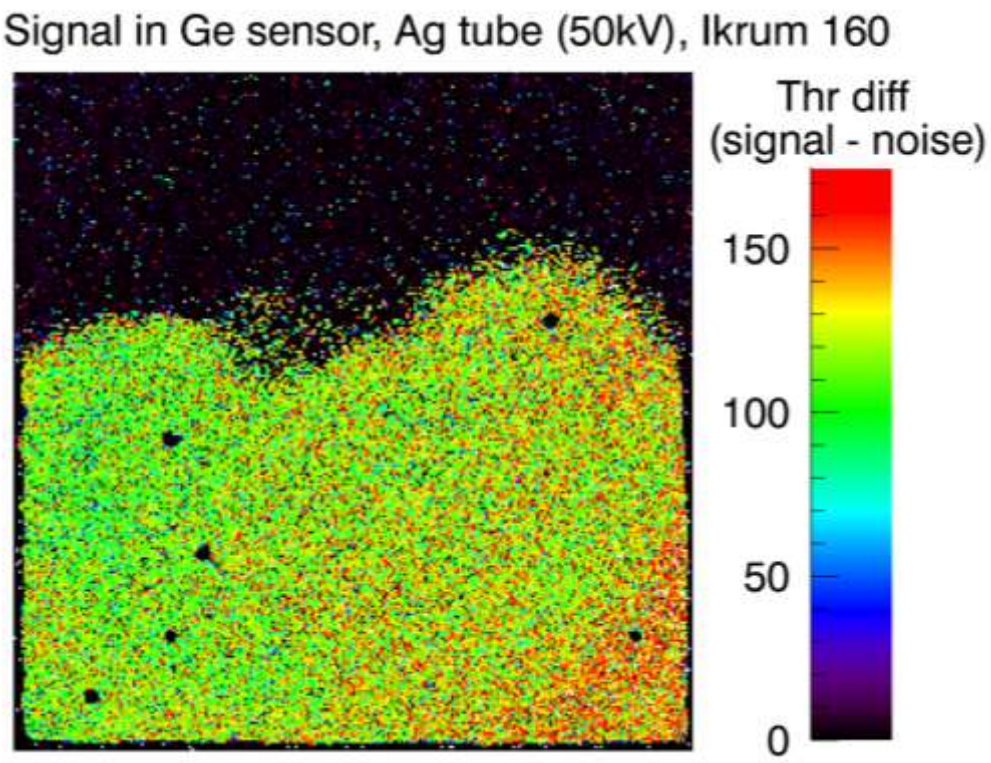


Microscope image of surface



Preliminary test results





Summary

- LAMBDA module fully functional
- High-speed readout (2000 fps) in testing phase
- First X-rays seen with Germanium fine pitch sensor

- Next steps:
  - optimize Germanium handling procedures.
  - Construct Large area Germanium system

LAMBDA and germanium sensors

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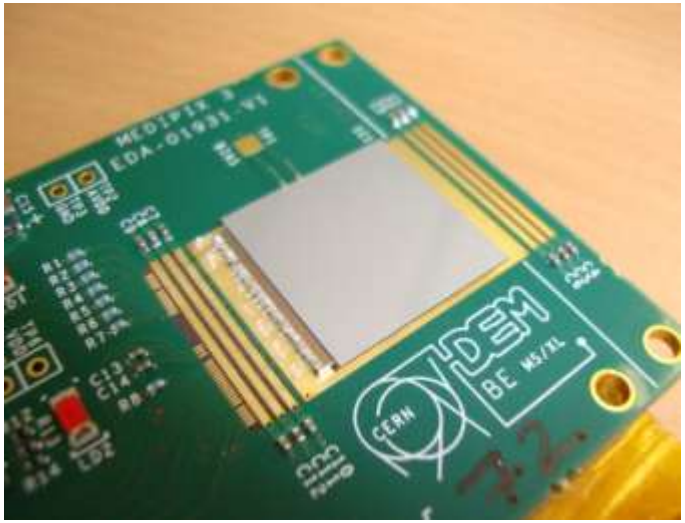
Medipix3 readout chip

- 256 by 256 array of 55µm pixels
- 2 counters / pixel for continuous read-write
  - 2000 fps at 12 bit depth
  - 6 (4) and 1 bit also possible
- Charge summing to compensate charge sharing
- *Medipix3 "RX"*
  - First wafers back last month
  - CRW works
  - Charge summing mode fixed
  - Stability and pixel-to-pixel uniformity as designed



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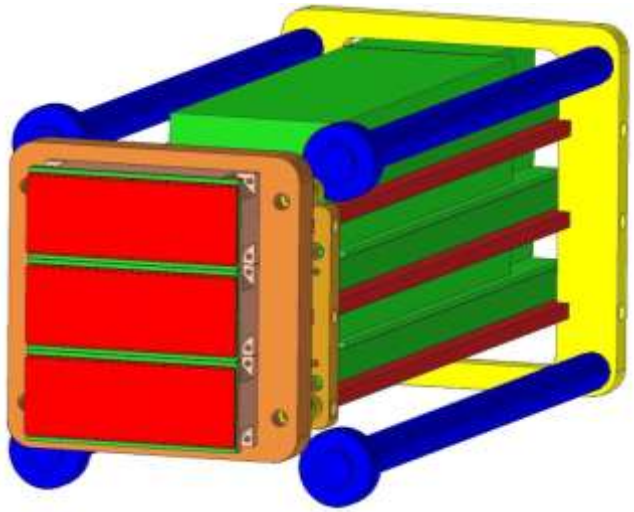

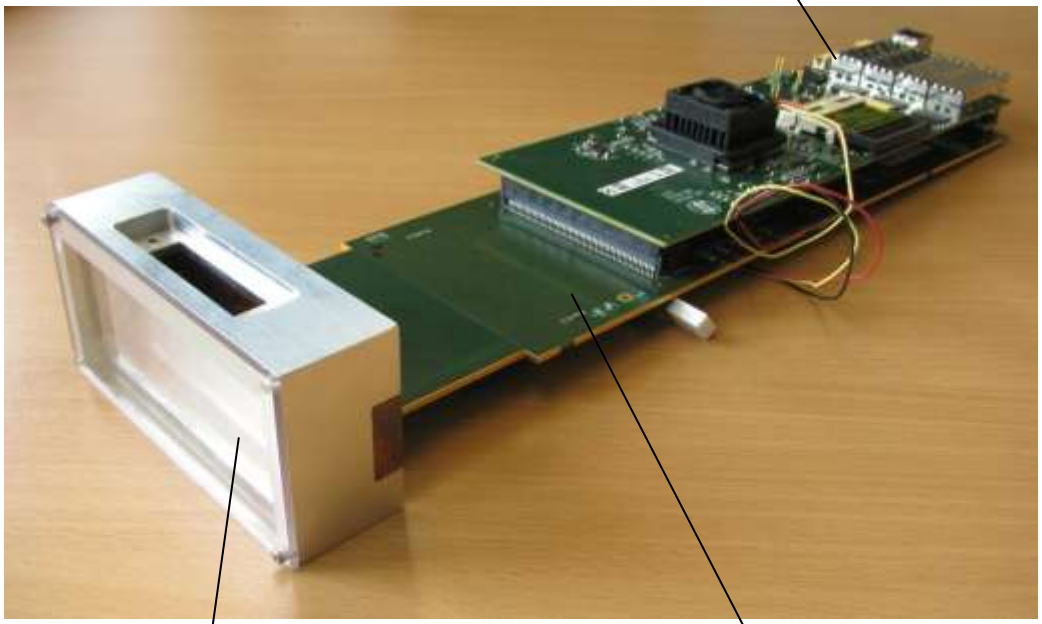

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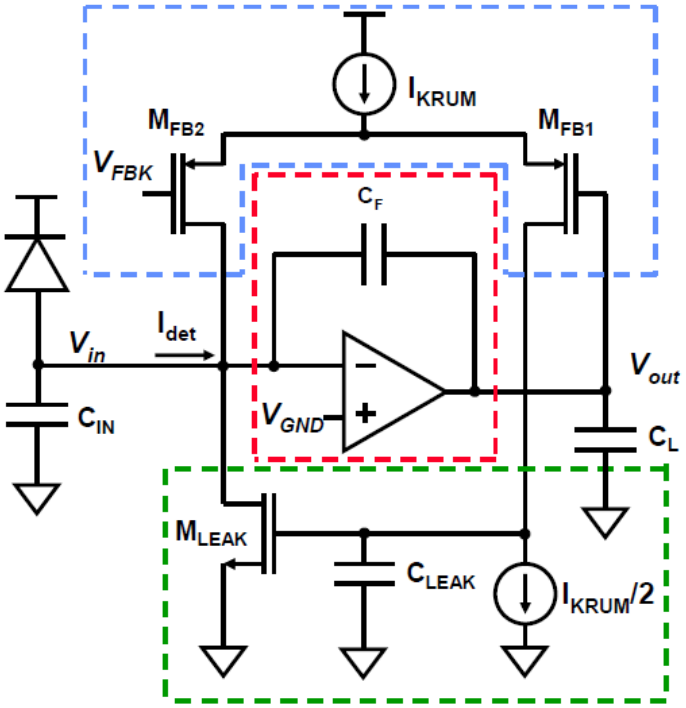


Bipolar discharge circuit

Leakage compensation circuit

Rafael Ballabriga Suñé, CERN Thesis 2010-055

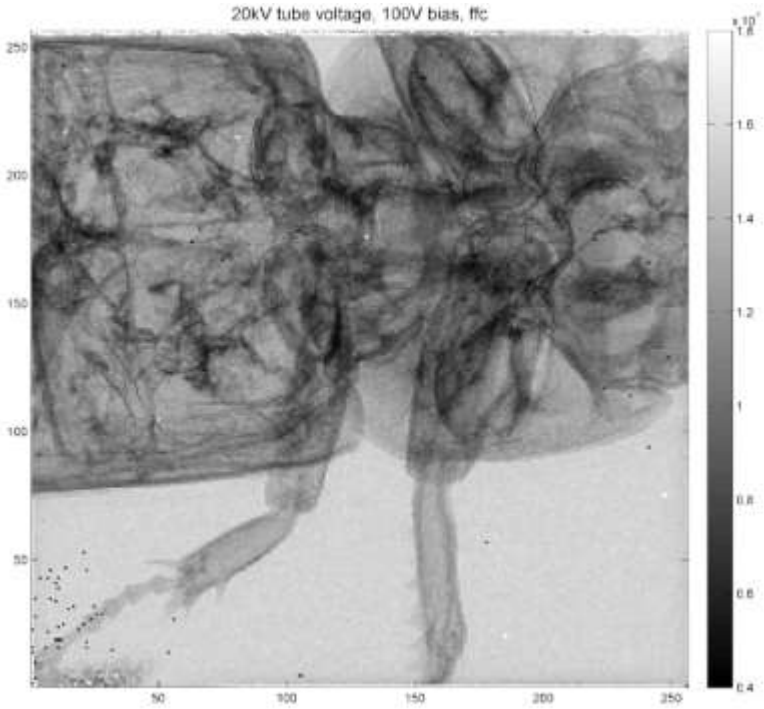
Timepix3

- Currently being developed by Medipix3 collaboration
  - Primarily aimed at particle physics
- Event-by-event readout
  - For each hit get position, time stamp (few ns) and time over threshold
  - Limit of 2 x 10^7 hits / cm^2 / s (average 600 hits / pixel / s)
  - Sufficient for some lower-flux experiments
- Possibilities:
  - XPCS with ~10ns resolution
  - Subpixel resolution of hits (using charge sharing and ToT)
  - Photon energy measurement (but white beam typically high flux)

High-Z development

- Germanium – Canberra France Speciality Detectors, Fraunhofer IZM
- Gallium Arsenide – Galapad project – FMF (Freiburg), KIT (Karlsruhe), JINR (Dubna), RID Ltd. (Tomsk)

GaAs bonded to Timepix (25keV)



Thanks to Simon Procz, Alex Fauler and Michael Fiederle (FMF / University of Freiburg)

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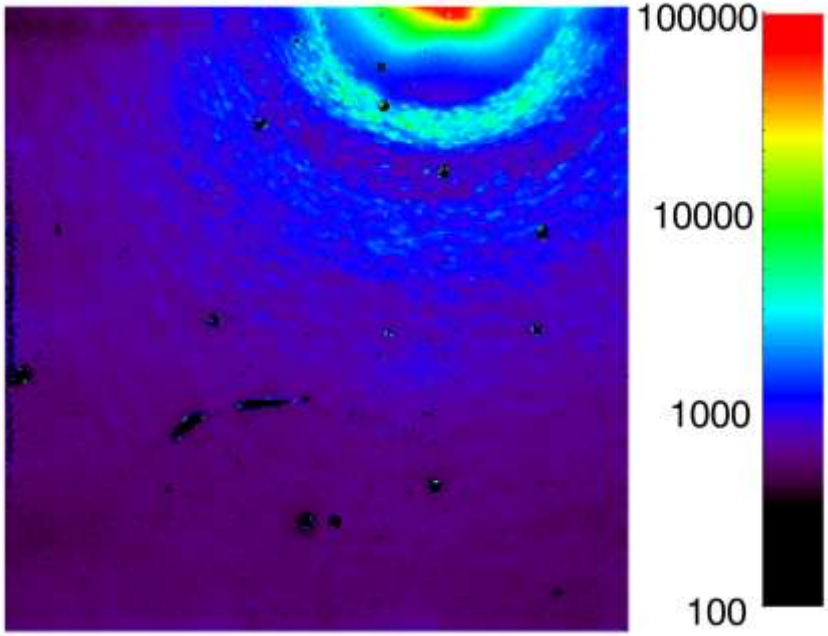
- Gallium Arsenide – Galapad project – FMF (Freiburg), KIT (Karlsruhe), JINR (Dubna), RID Ltd. (Tomsk)
- Cadmium telluride – HiZPAD collaboration, sensors from FMF/XIE (Freiburg)

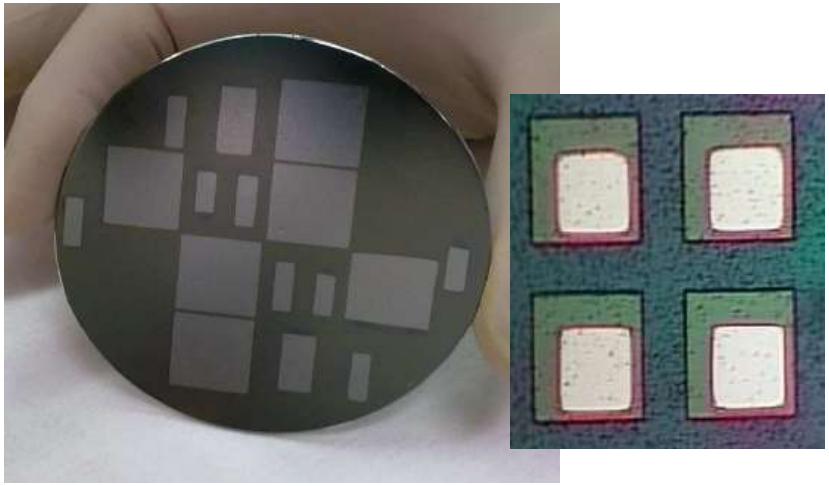
CdTe bonded to Timepix

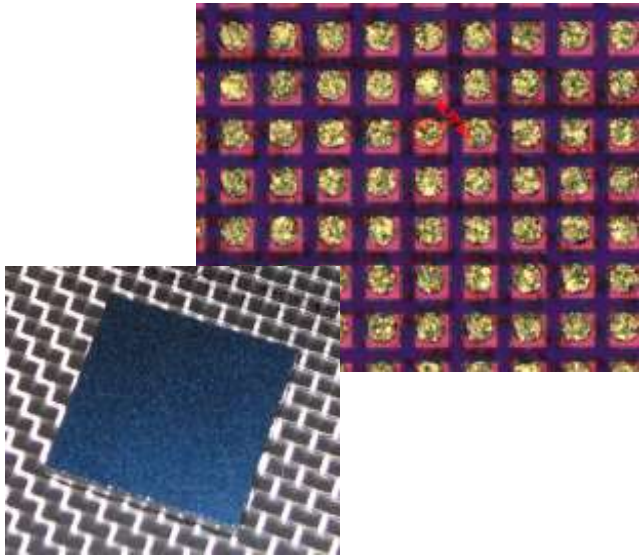


Scattering from $LiMnPO_4$
at DORIS BW5 (100keV)

Sensor production and bump bonding

- Detector structure (Canberra)
  - Modification of existing strip detector technology
  - 55µm pixels, 700 µm thick
  - Electron readout
- Indium bump bonding (IZM)
  - Sensor and ROC bonded at < 100C temp
  - During cooling, ductility of In compensates for mismatch in contraction
  - Process and temperature optimised using Ge diodes
  - Bond height and flip-chip optimised with mechanical dummies





Preliminary test results

- Tested in vacuum chamber with Cryotiger cooler
  - Need to improve isolation – currently can get down to -70ºC)
- Guard ring current high – tested at 50V (~2.5mA current)
  - No breakdown, but reaches source limit
- Not yet equalised
  - Medipix 3.0 has large dispersion!
  - Look at single pixel spectra
- Mini Ag-target X-ray tube used (50kV)