Medipix 2: Processing and measurements of GaAs pixel detectors

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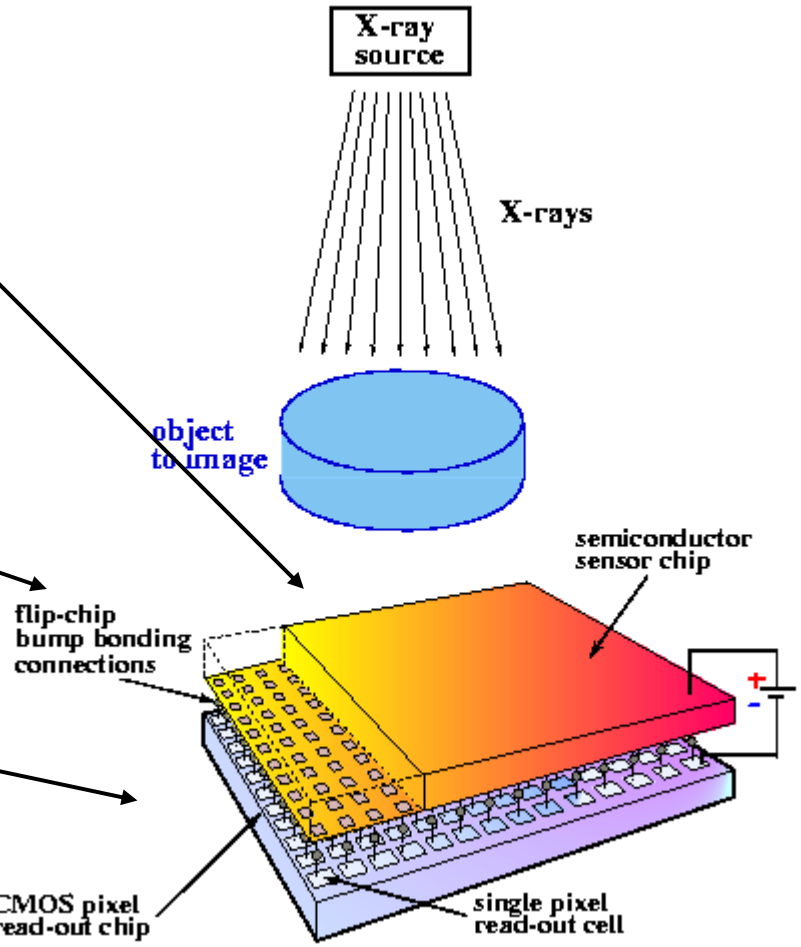
Outline

- Processing of pixel detectors
- GaAs – for detector applications (revival)
- Measurements with GaAs Medipix assemblies
- Comparison with Silicon assembly
- Summary and outlook

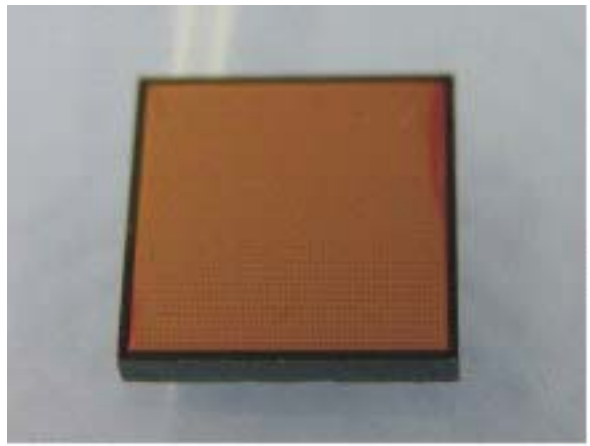
Medipix Activities Freiburg

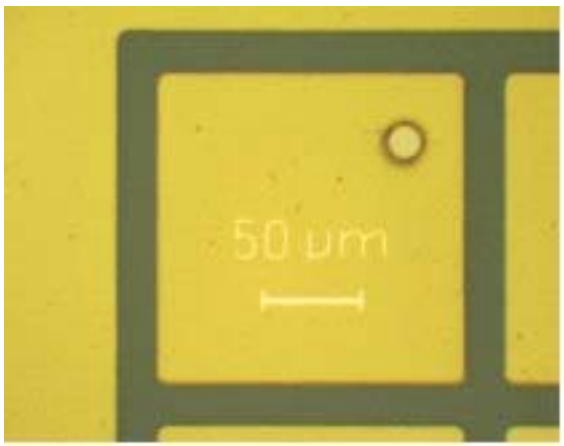
- Development and characterization of detector material: GaAs, CdZnTe
- Processing of pixel detectors: Flip-chip bonding
- Evaluation of detector assemblies: X- and Gamma-rays, …

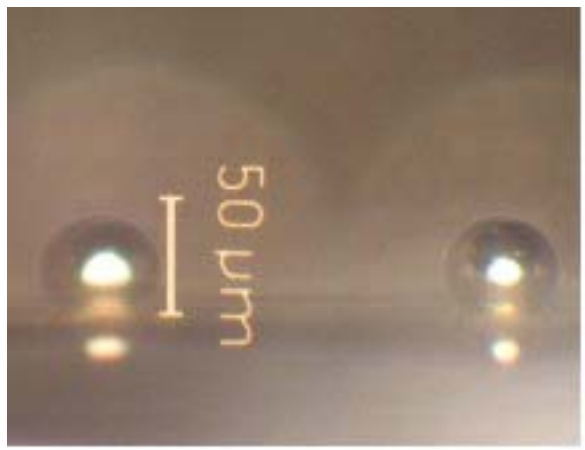


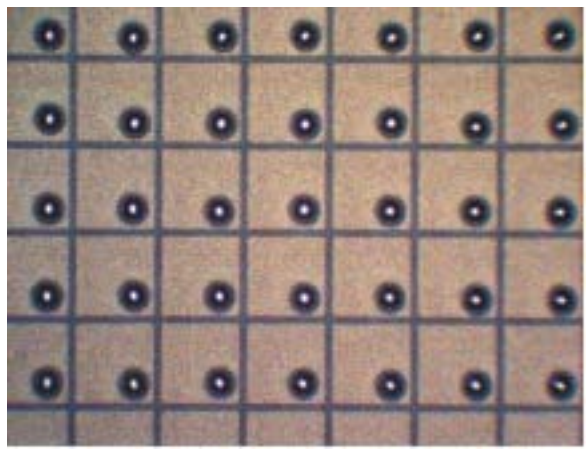
Processing of pixel detectors (FMF)

- pixels sizes down to 55 µm (pixel Medipix2)
- 4000 - 65.000 pixels
- Low temperature processing (< 200 °C)
- Polymere passivation (BCB)
- Low force Flip-Chip-Bonding
- Processing of single detectors or wafers

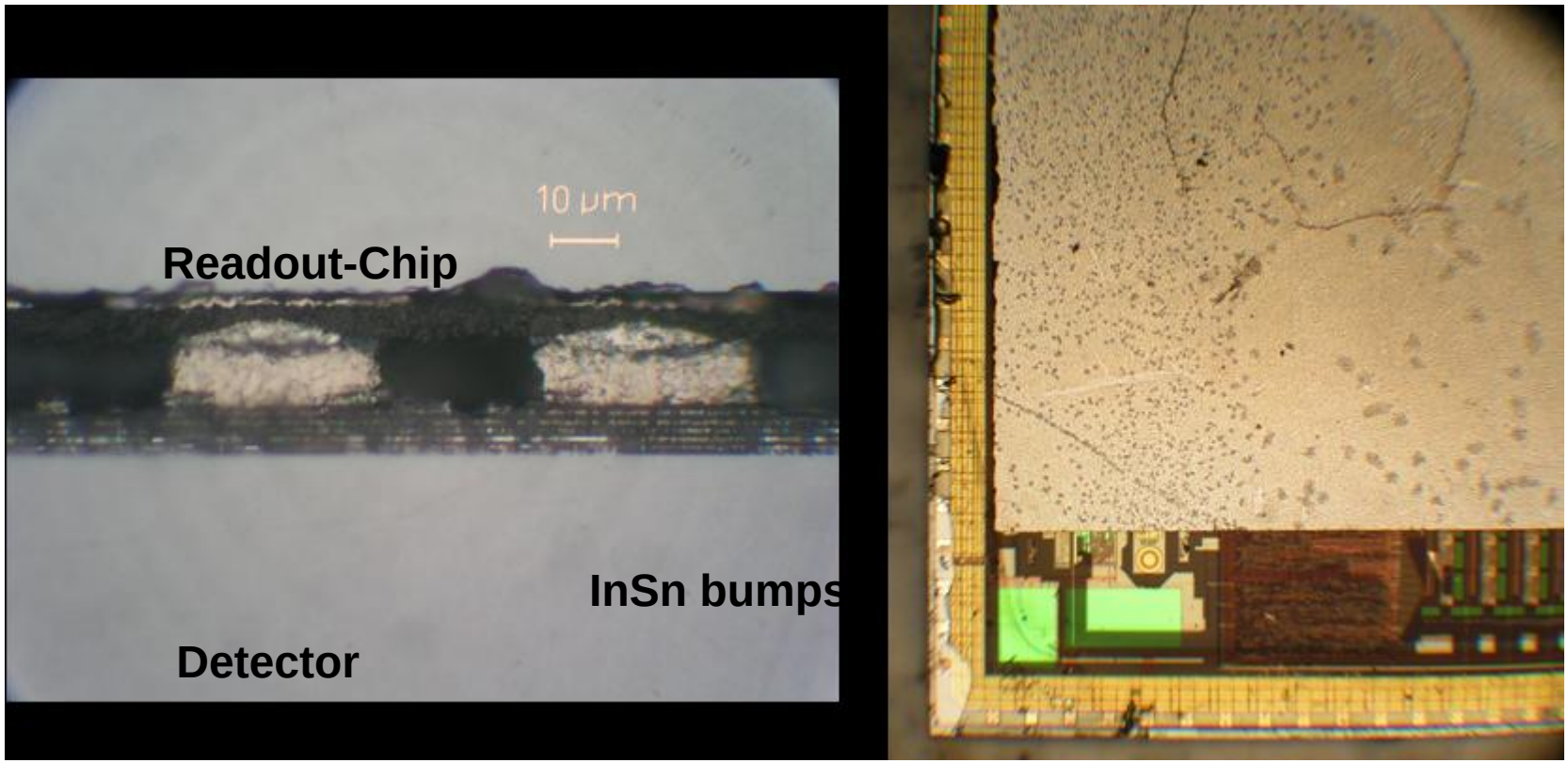




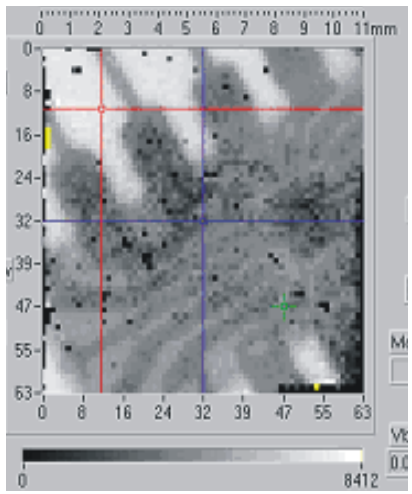


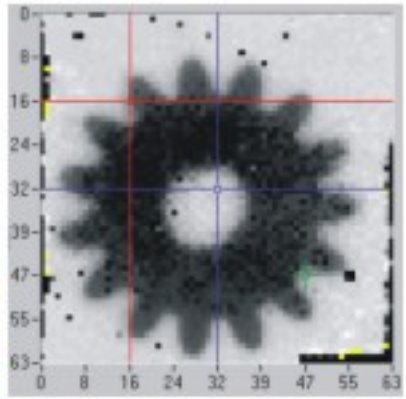


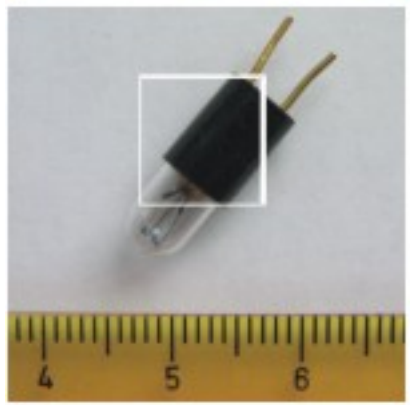
Detector assembly after flip-chip process

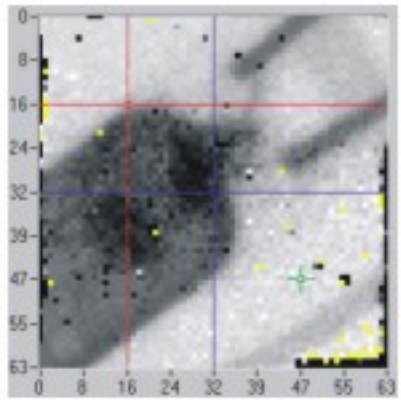


CdTe – pixel detector Medipix1





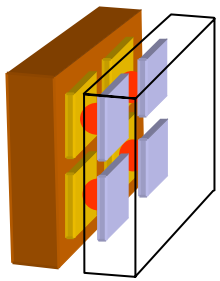




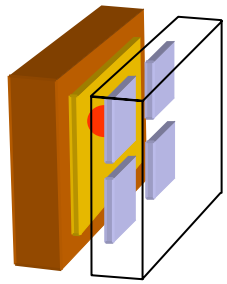
Medipix 2: Processing features

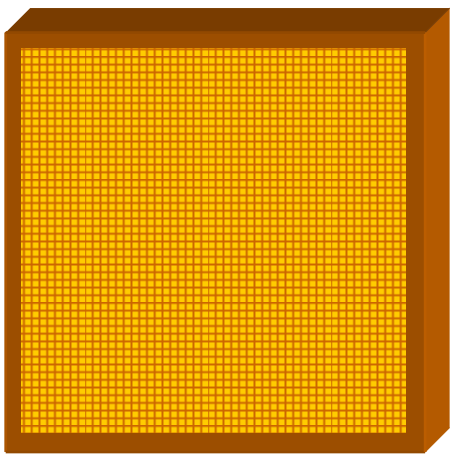
Pixel size on the detector side can be increased
(110x110µm², 165x165µm², ...)
bonding only 1 out of 4 / 9 /... pixels on the MP2 chip

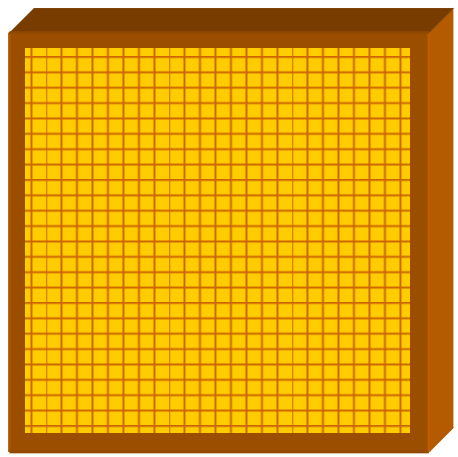
55x55µm²
every MP2
pixel used



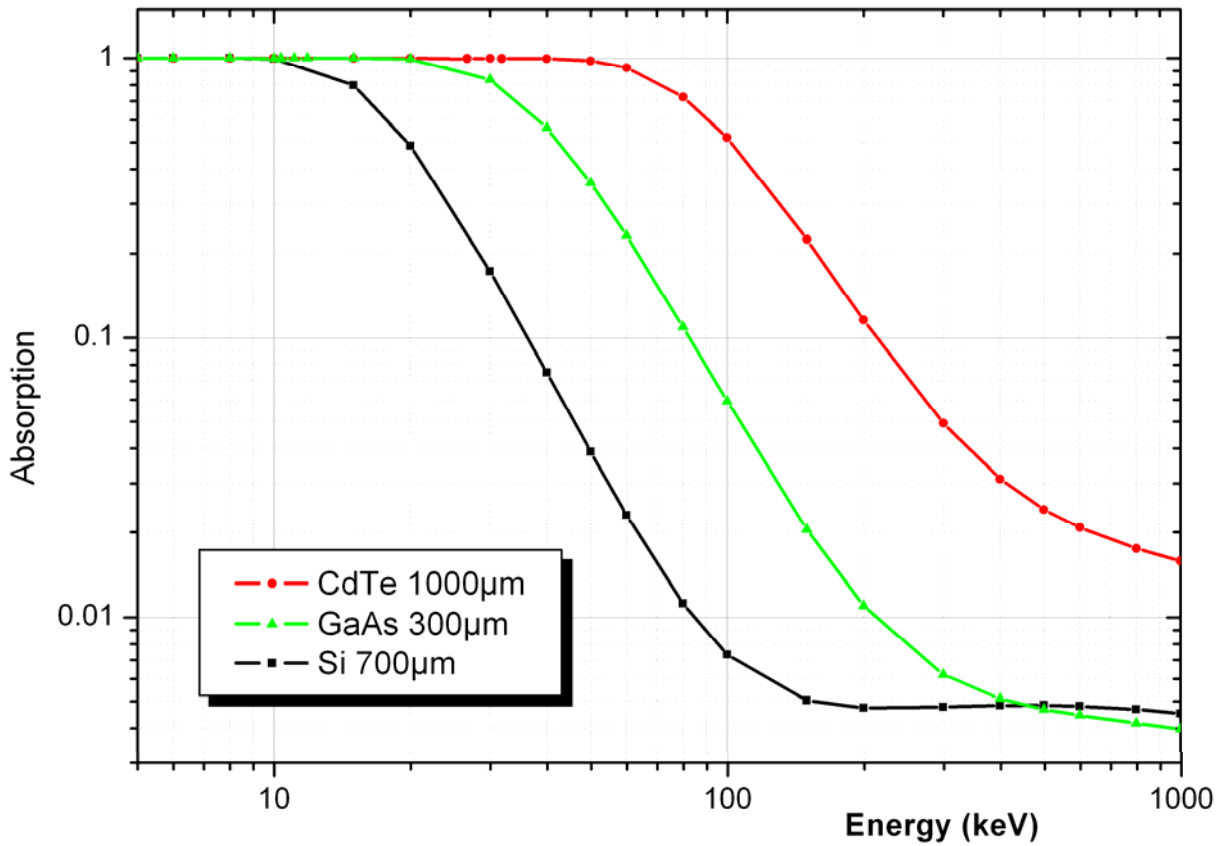
110x110µm²
every 4th MP2
pixel used







GaAs pixel detectors
(LEC material from commercial supplier)



absorption

@ 40keV:

Si: 7.5%

GaAs: 55%

CdTe: 100%

@ 60keV:

Si: 2.2%

GaAs: 22%

CdTe: 90%

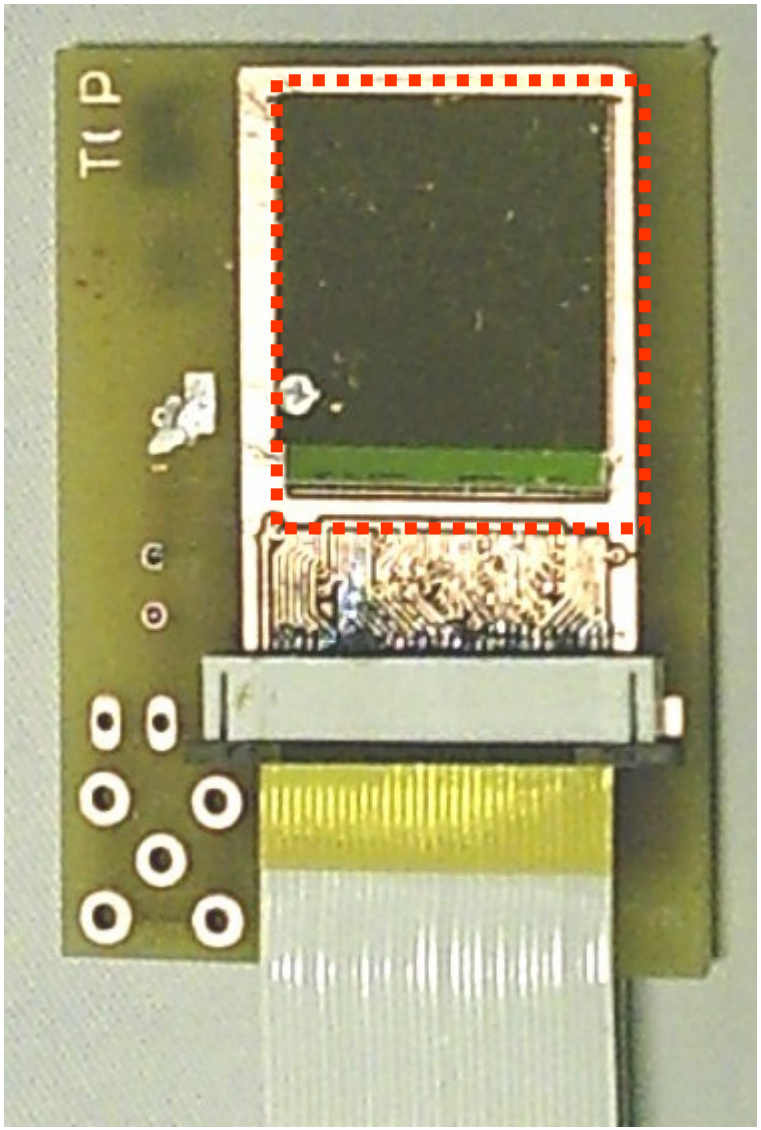
Properties of GaAs radiation detectors

- Semi-insulating material
- Available technology
- Good absorption (< 50 keV)
- Wafer sizes available up to 6 inch
- 55 µm resolution possible (small effect of fluorescence)

Strong development over the last 5 years:

- Reduction of defect concentration (EL2)

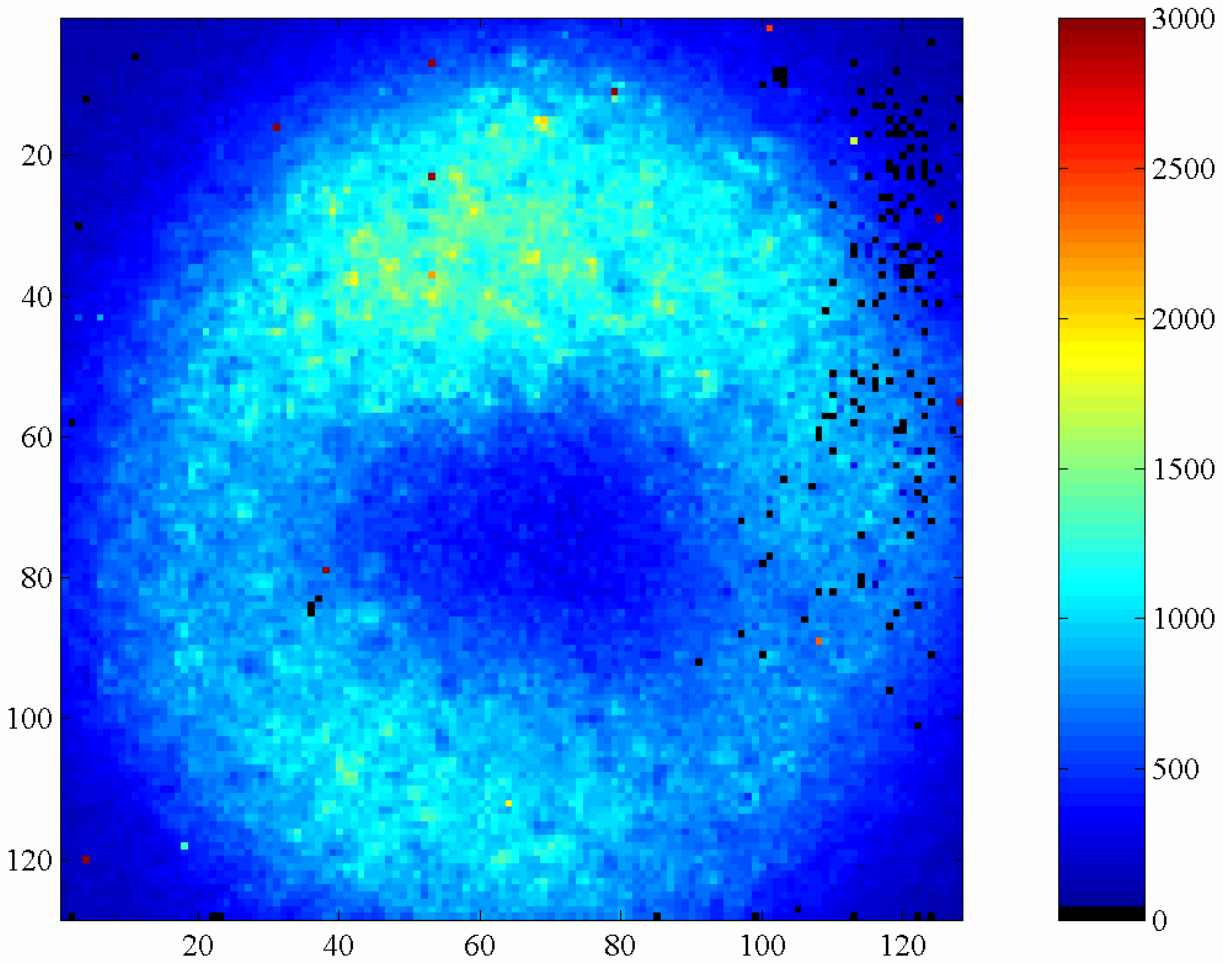
Performance is depending on bulk properties



GaAs 1x1 assembly processed and bonded at FMF

Detector bias at 270V I = 50µA

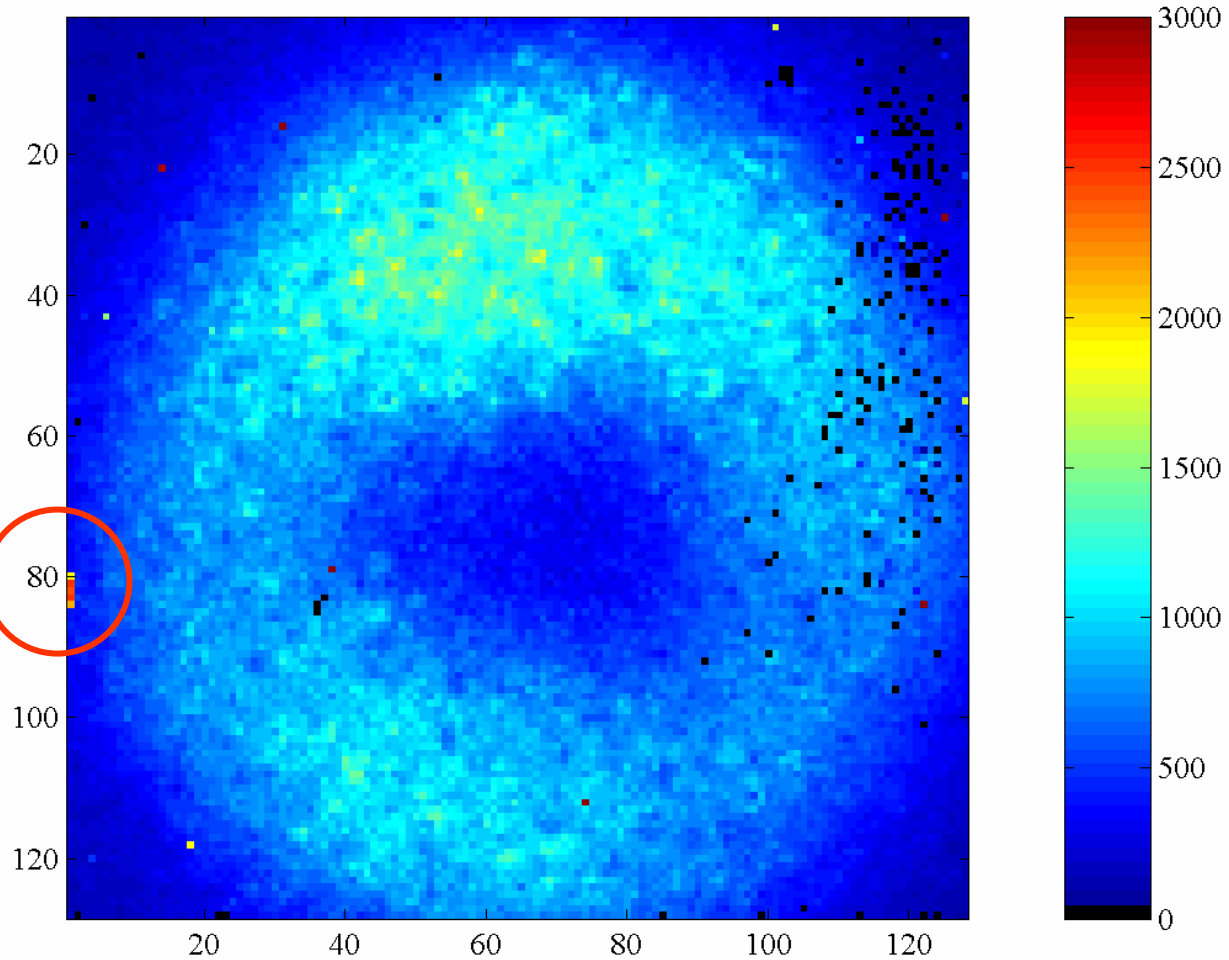
Am-source



Detector bias at 275V I = 400µA

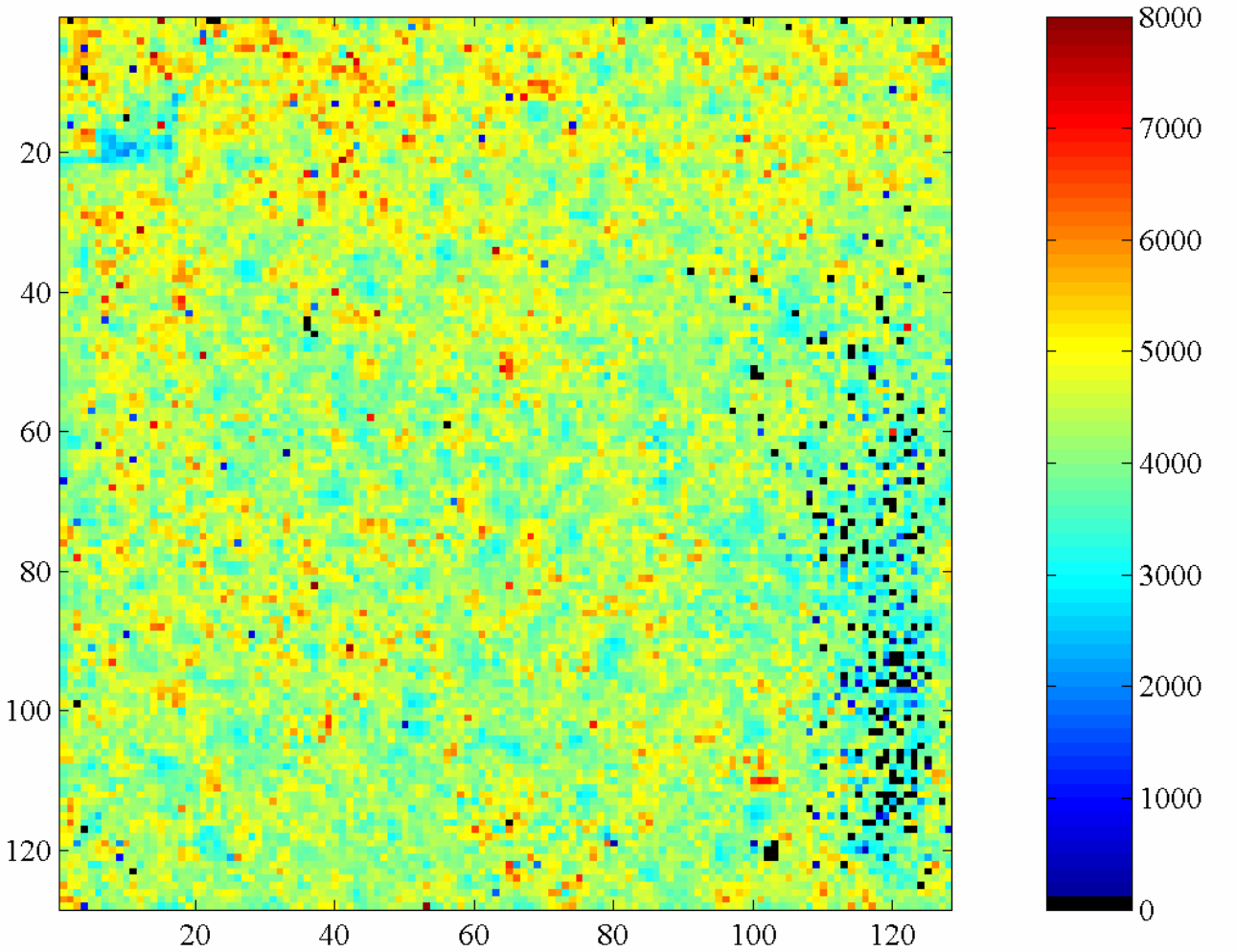
Am-source

High leakage current



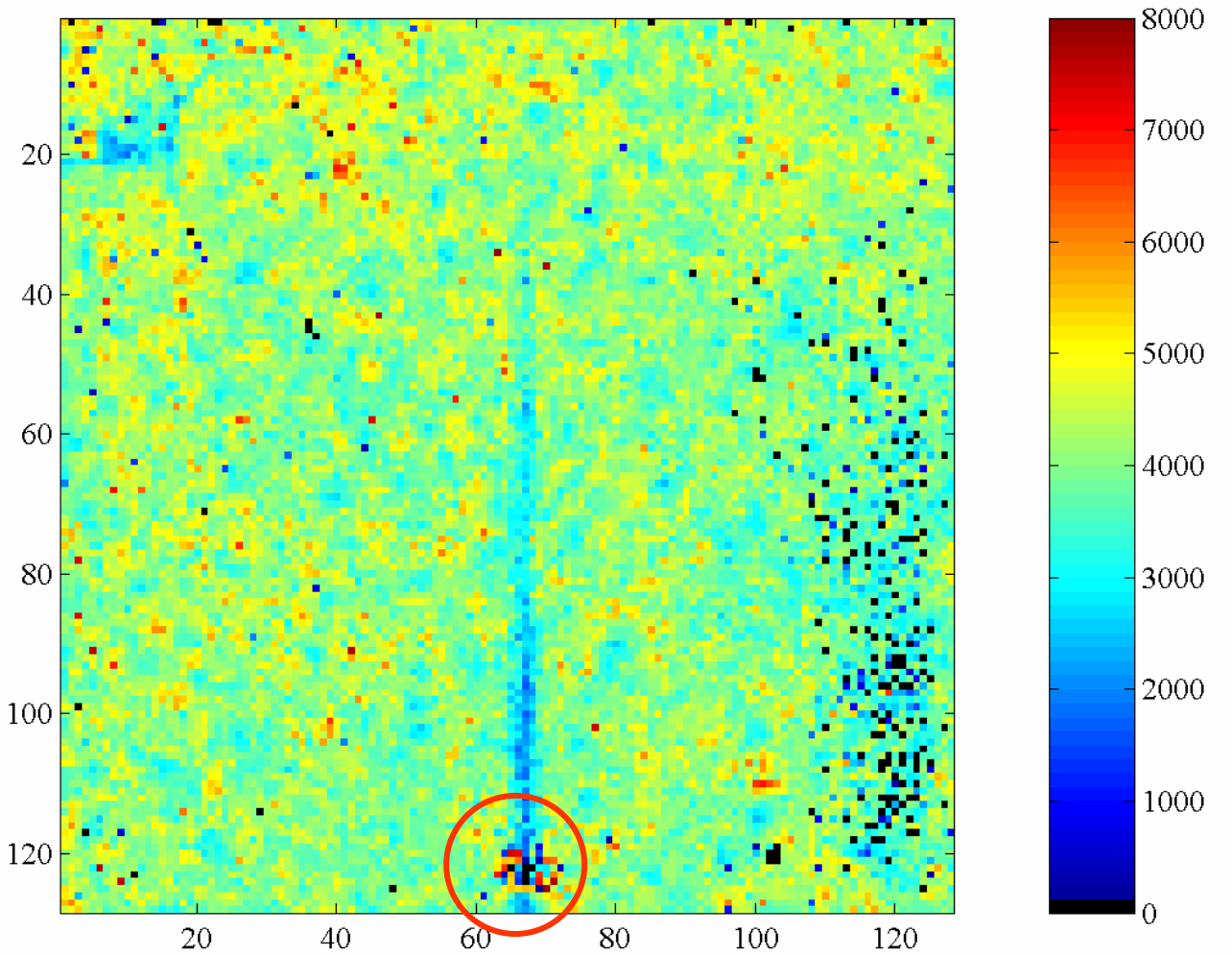
Detector bias at 275V I = 50µA

x-ray tube

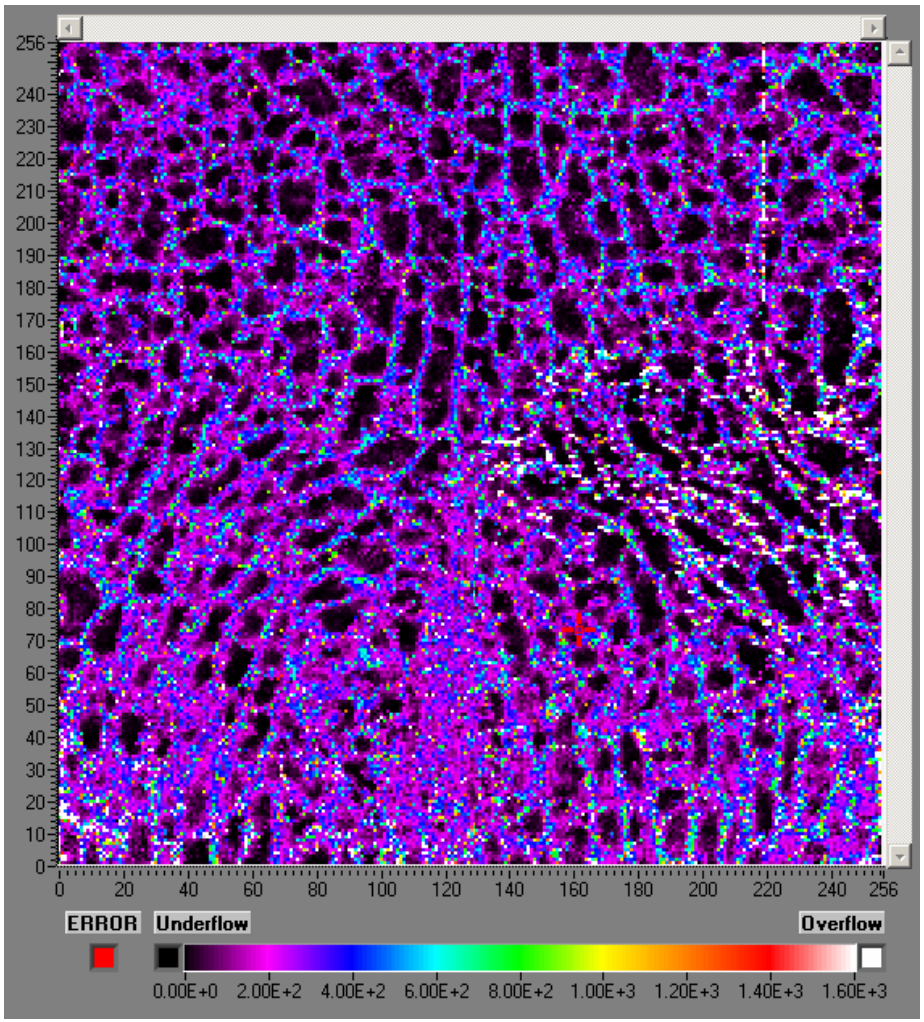


Detector bias at 280V I = 300µA

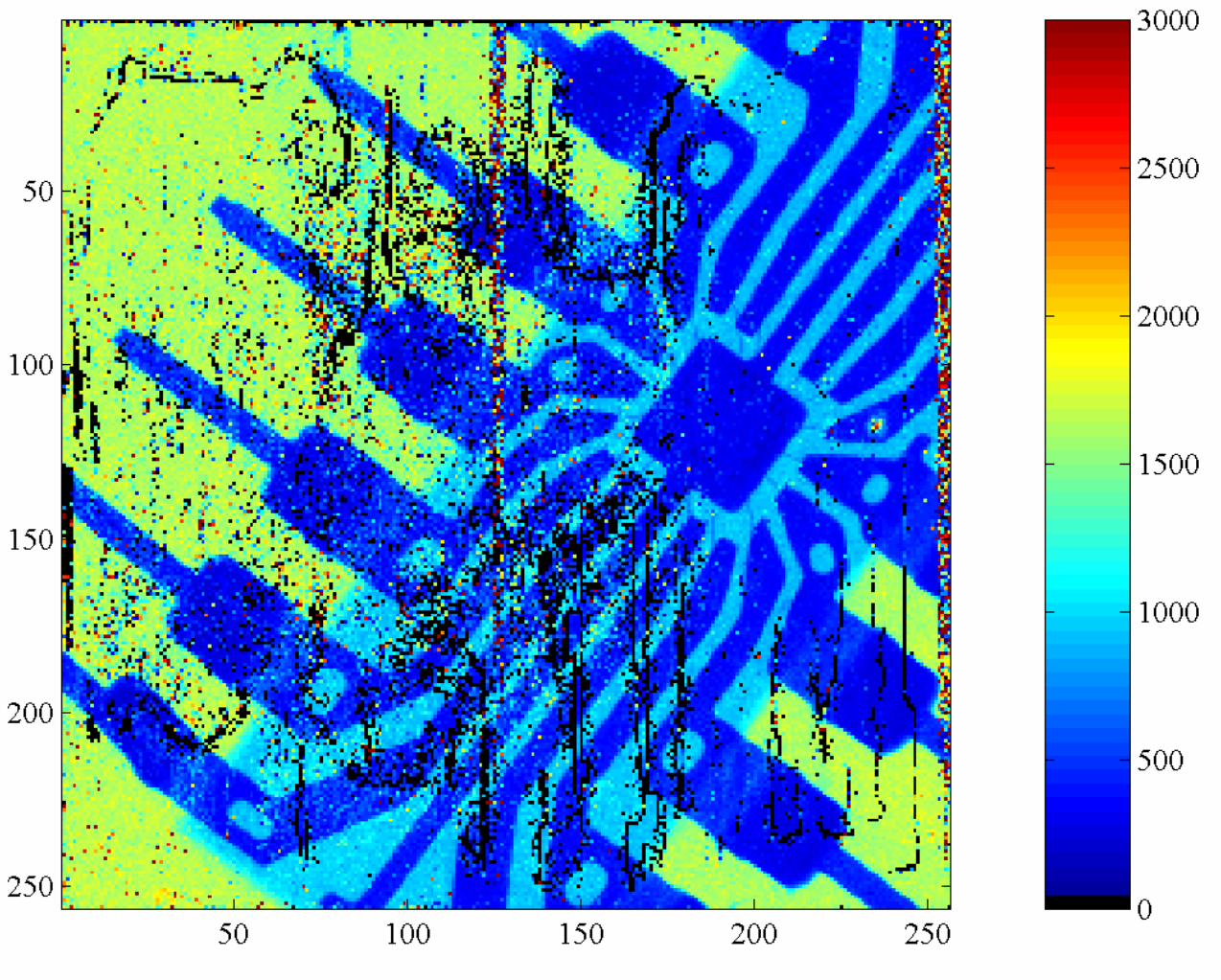
x-ray tube



Cell structure at low bias

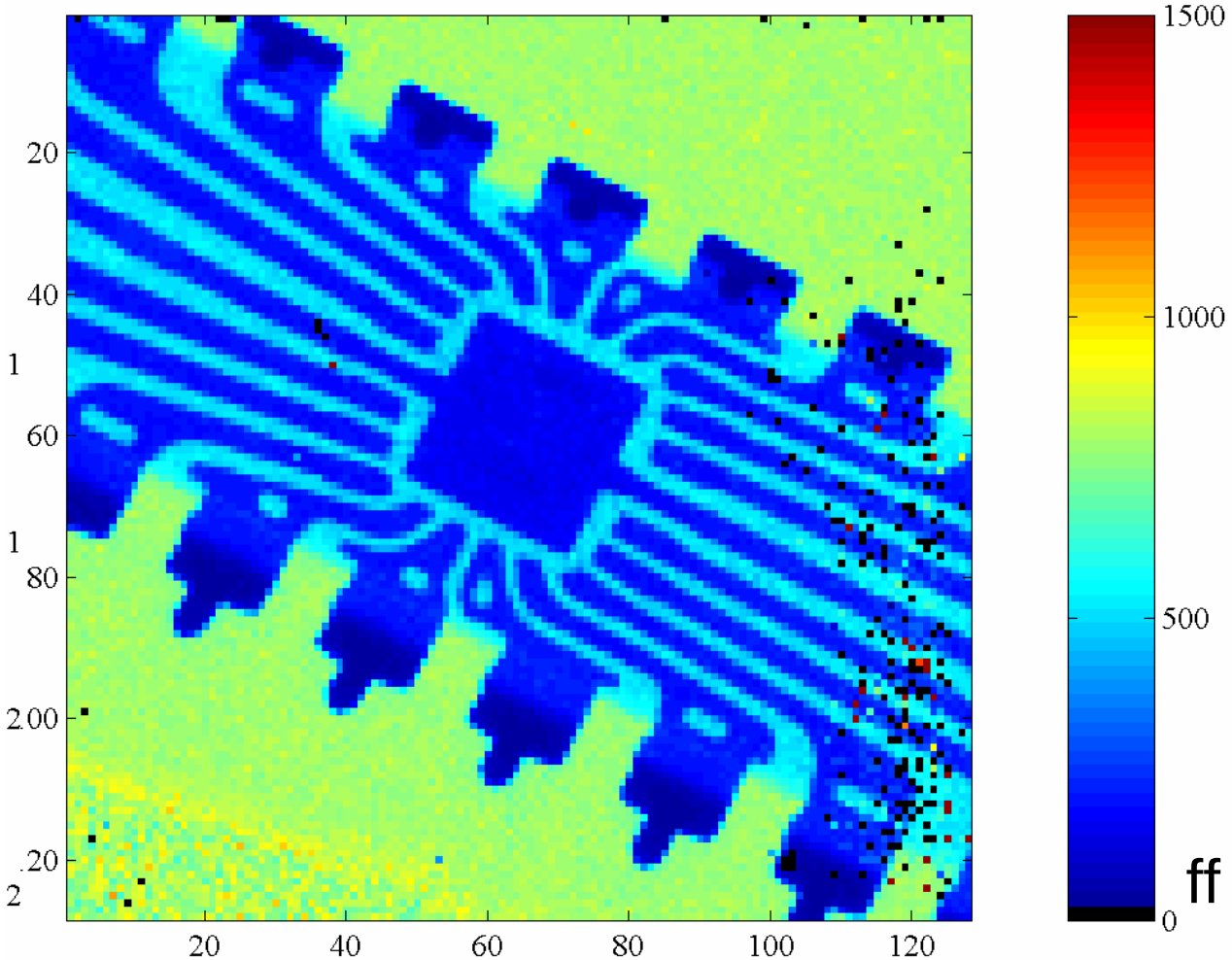


GaAs 55x55µm² detector



ff corrected

GaAs 110x110µm² detector



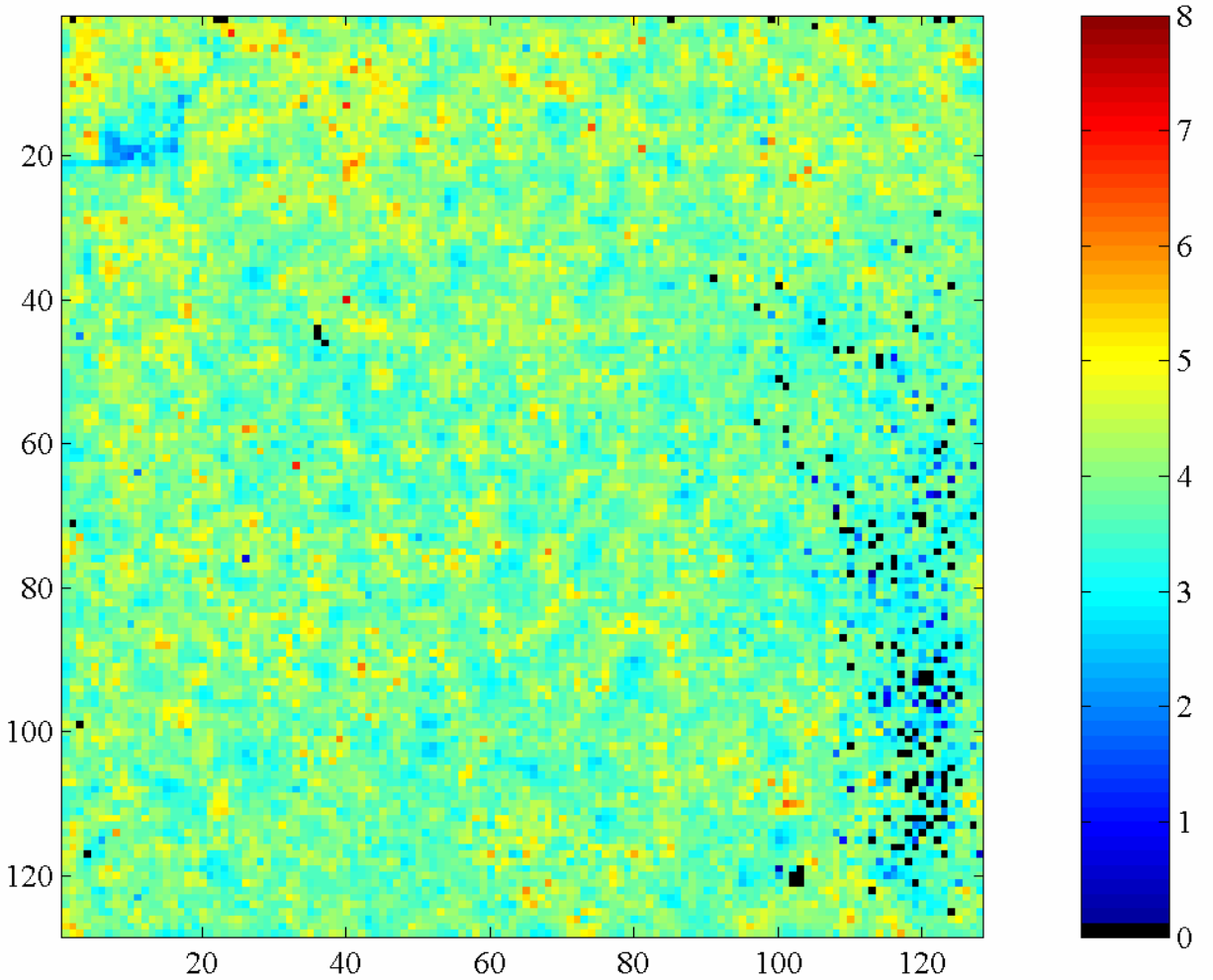
ff corrected

dose: 90µGy (W 60kV 7mA 1.5mm Al 30ms)

Flatfield acquisition (W 60kV, 1.5mm Al)

without correction, only th.adj.mask is activated

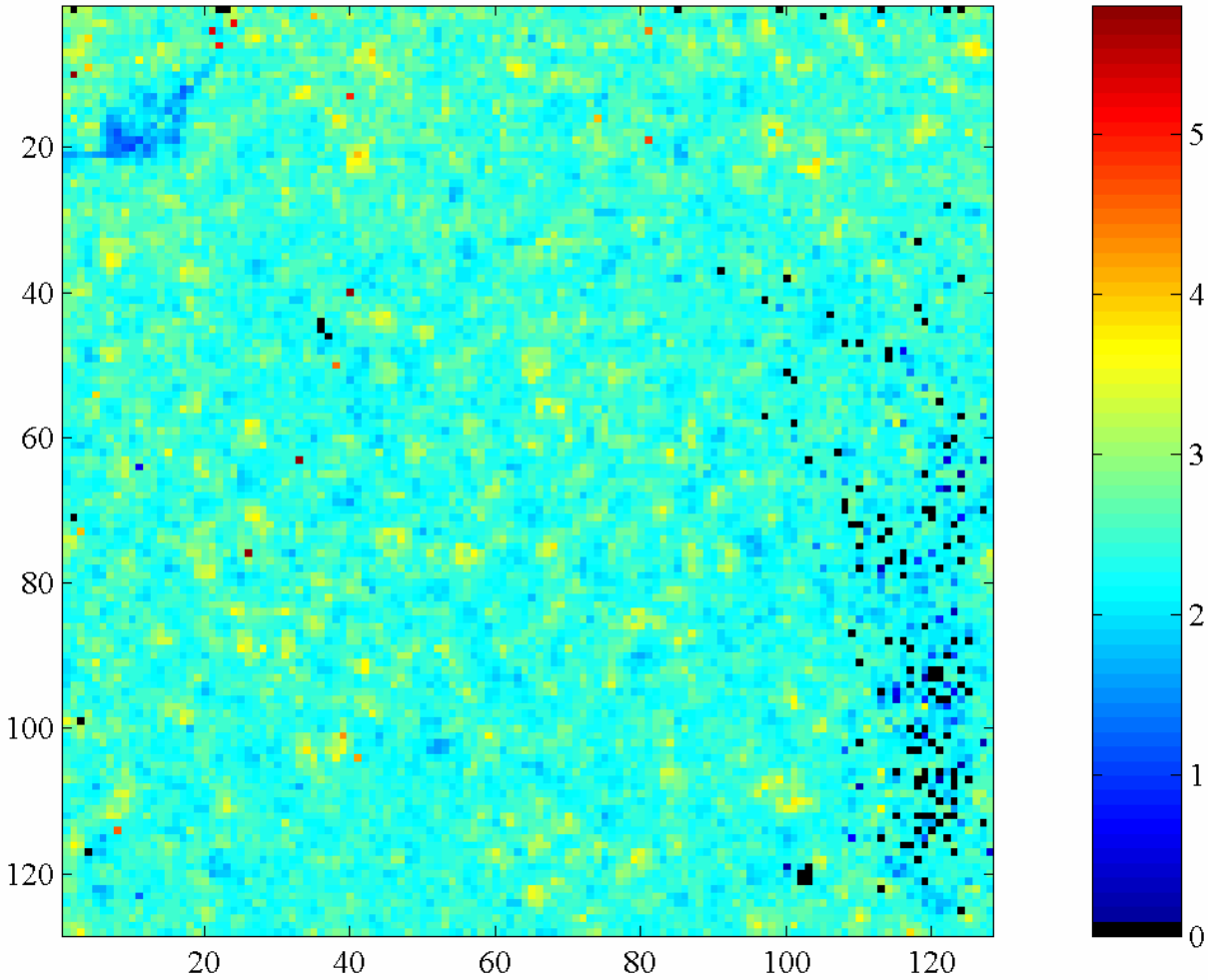
270V



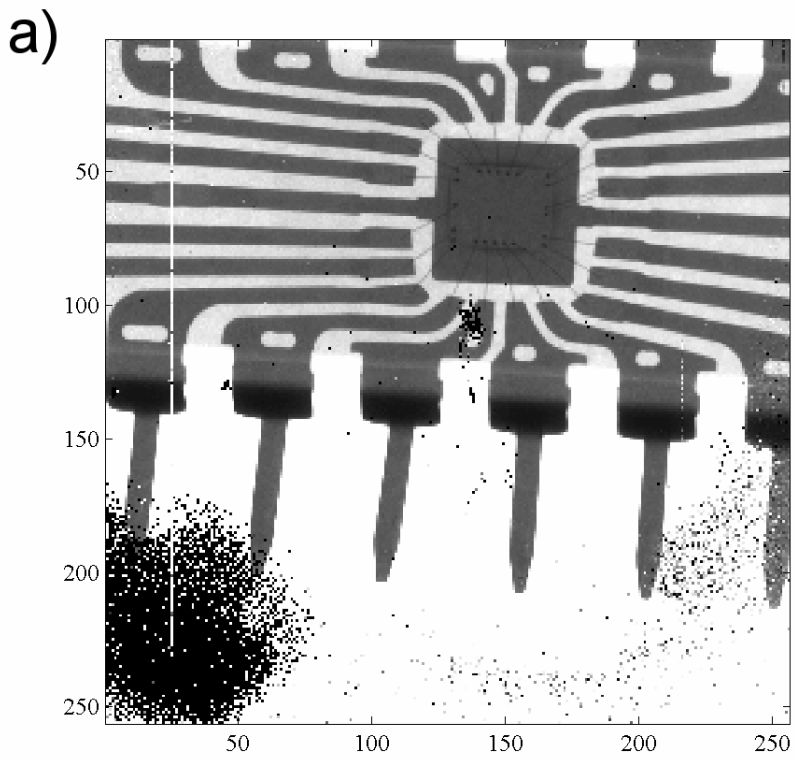
Flatfield acquisition (W 60kV, 1.5mm Al)

without correction, only th.adj.mask is activated

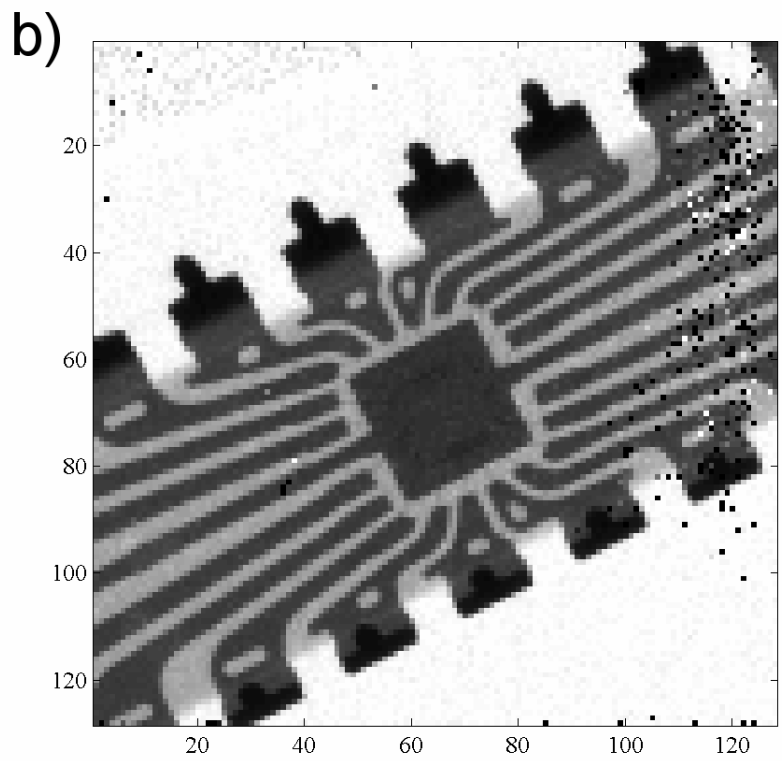
190V



X-ray images of TTL-chips

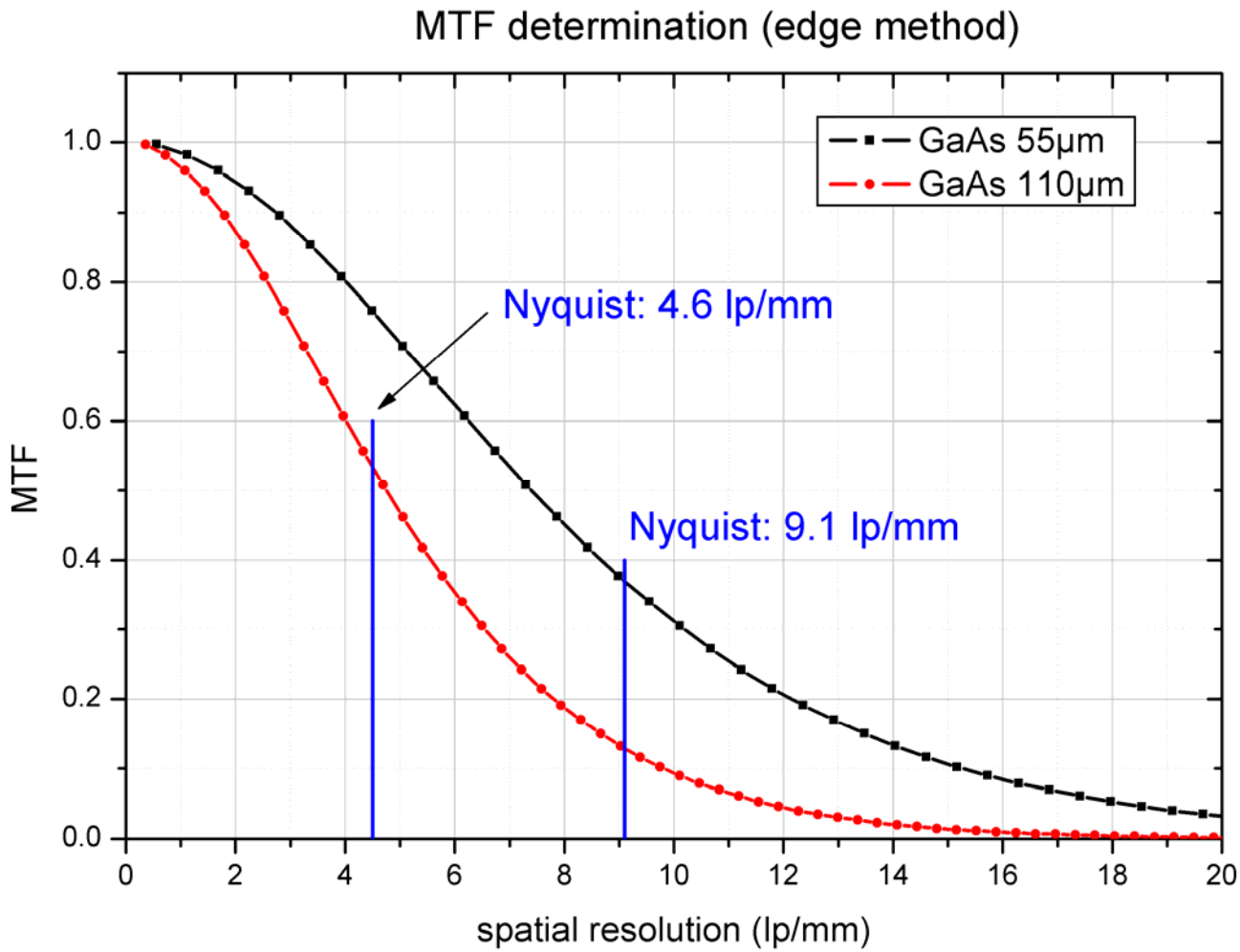


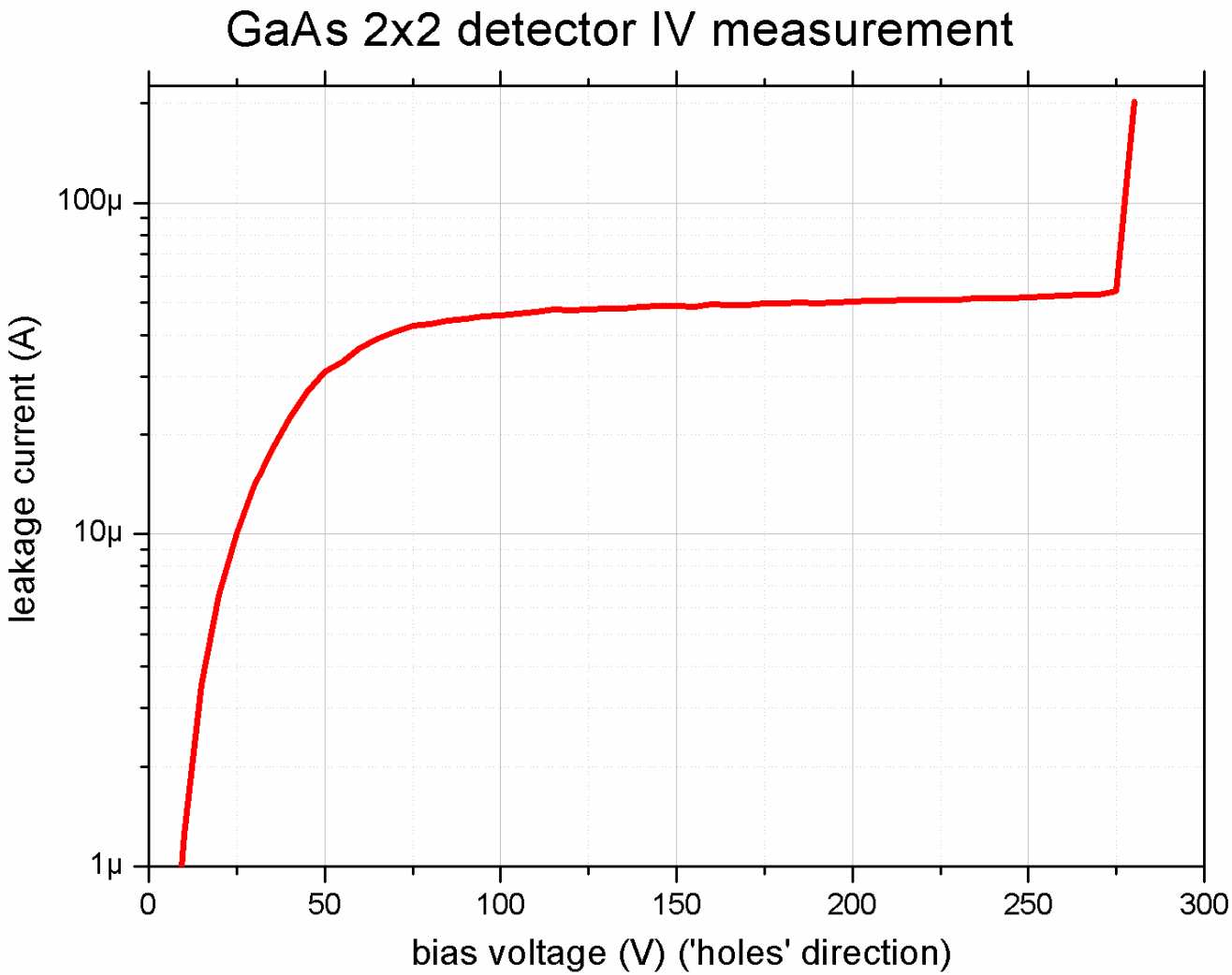
GaAs 55x55µm²

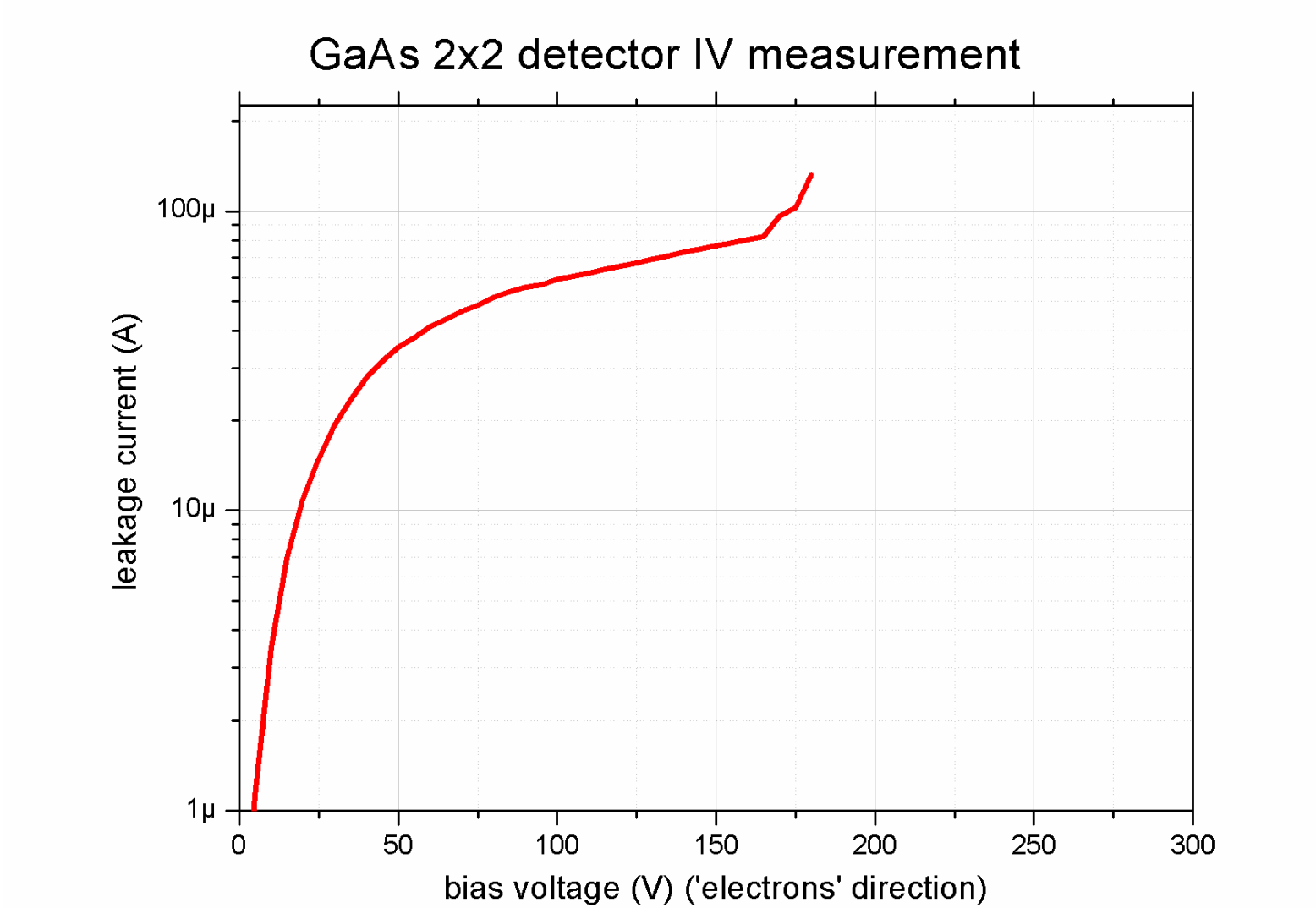


GaAs 110x110µm²

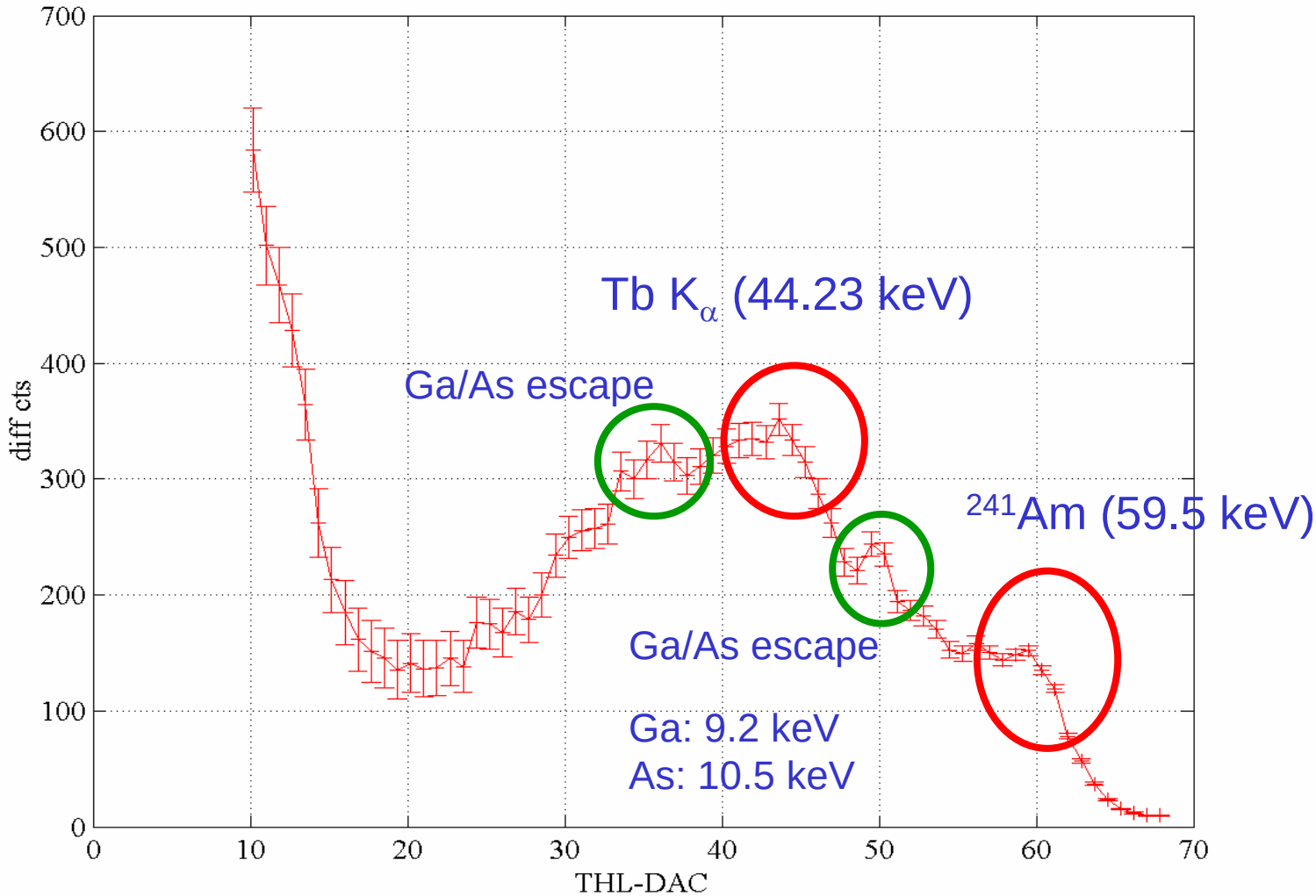
MTF comparison GaAs



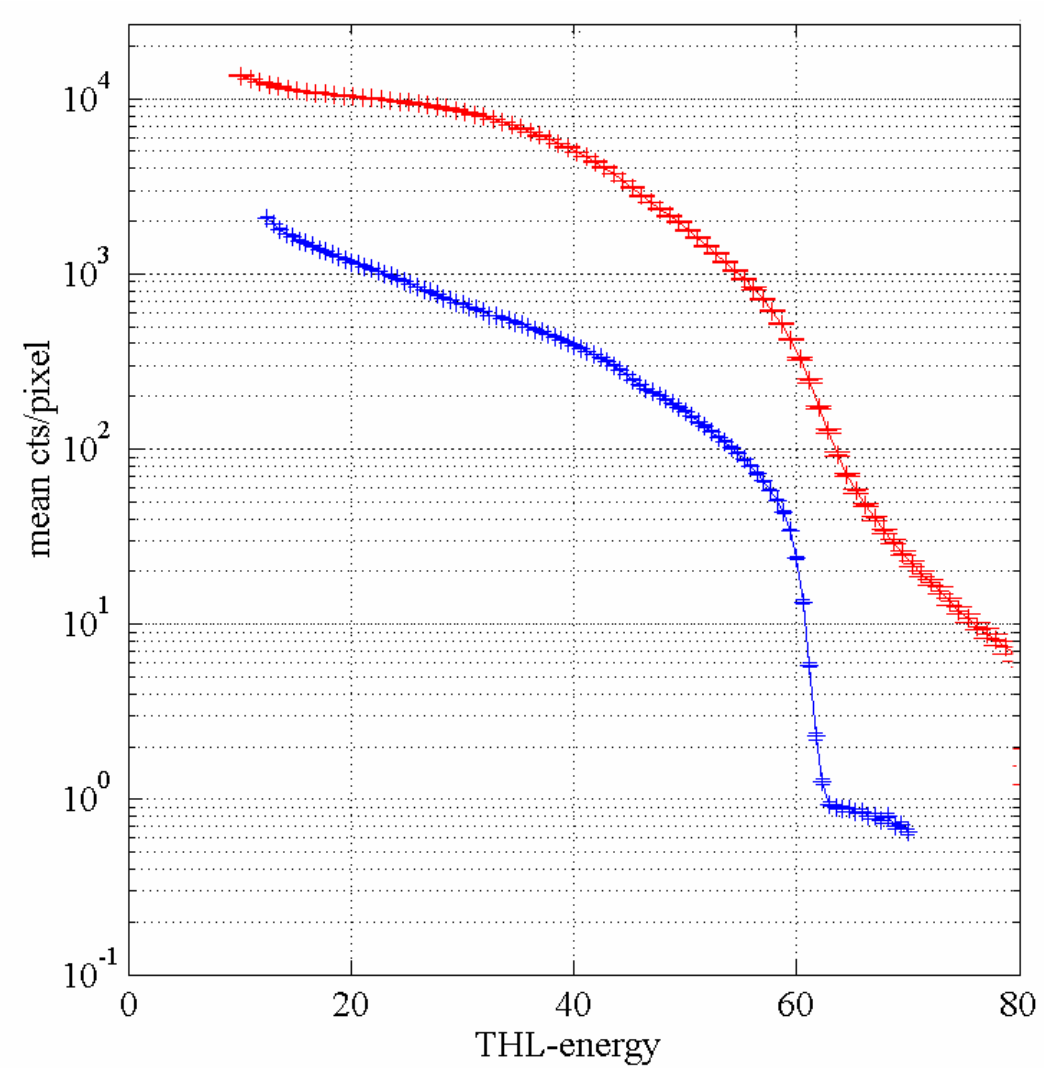

GaAs 2x2 detector IV measurement
leakage current (A)
100µ
10µ
1µ
0
50
100
150
200
250
300
bias voltage (V) ('holes' direction)


GaAs 2x2 detector IV measurement
leakage current (A)
100µ
10µ
1µ
0
50
100
150
200
250
300
bias voltage (V) ('electrons' direction)

Energy calibration for 300µm GaAs assembly



Comparison of integrated counts



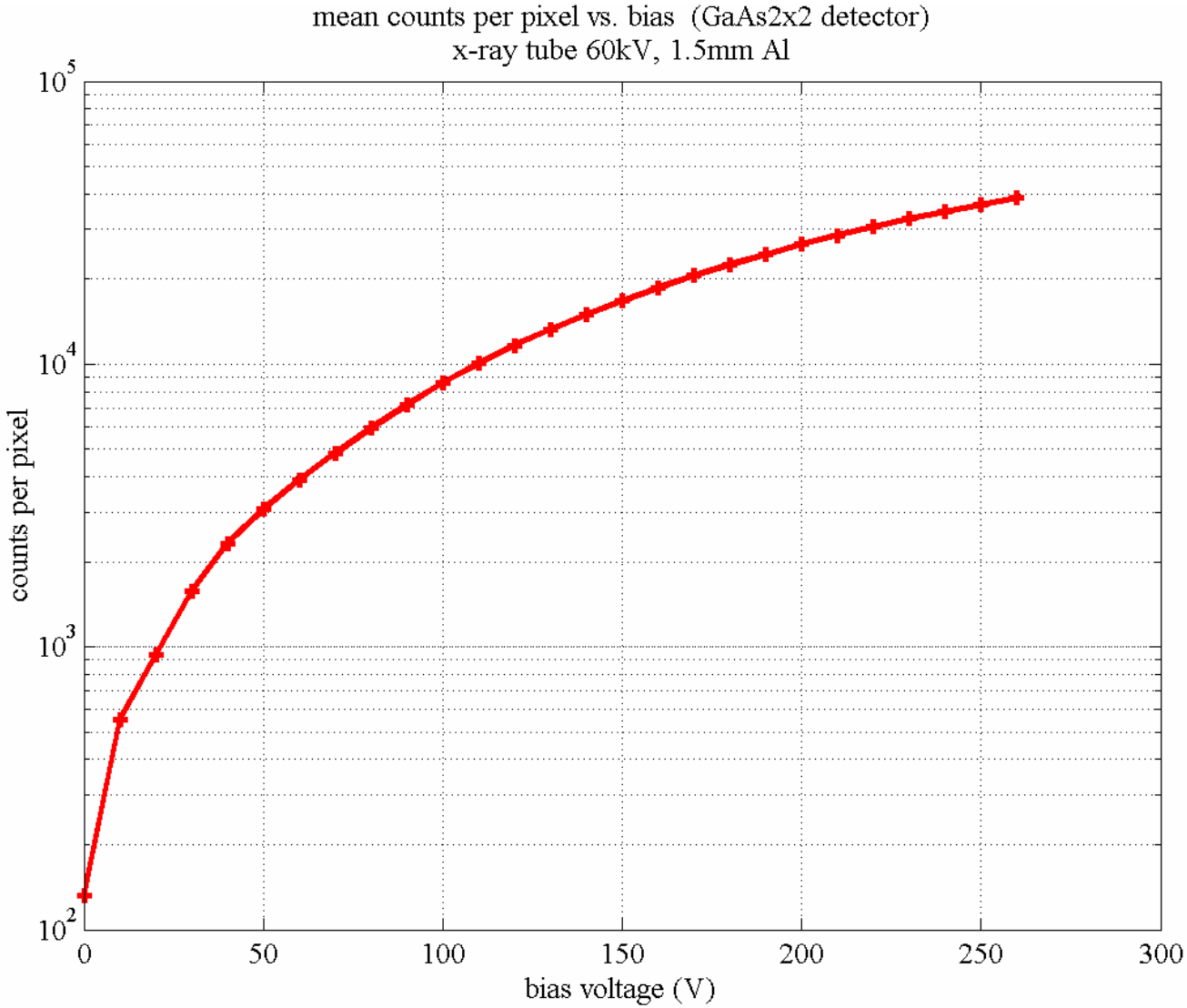
same acqu.time

source:

^{241}Am 59.5keV
Tb K_α 44.2keV

-- : 300µm GaAs

-- : 700µm Si


mean counts per pixel vs. bias (GaAs2x2 detector)
x-ray tube 60kV, 1.5mm Al
counts per pixel
bias voltage (V)
10^5
10^4
10^3
10^2
0
50
100
150
200
250
300

Advantages of „pixel binning“:

- SNR will be increased
- if unused pixels are switched off, THL can be set to lower values
- pitch can be adapted to application + material and/or thickness
- charge sharing can be reduced

Disadvantages:

- one pixel has to compensate 4/9 times higher leakage current
- lower spatial resolution
- counters are „full“ very quickly → more frequent readout

Conclusion

- Flip-chip-process successful for GaAs
- 55µm and 110 µm pixel detectors
- MTF and absorption (for higher E) are at the theoretical limit
- material not fully depleted
  - processing of 250 µm wafers
  - higher bias (HV passivation)

Research on material properties:

- Comparison of LEC and VGF material

- Processing of QUAD

Thanks for your attention!