

Crystal Growth of detector grade (Cd,Zn)Te Crystals

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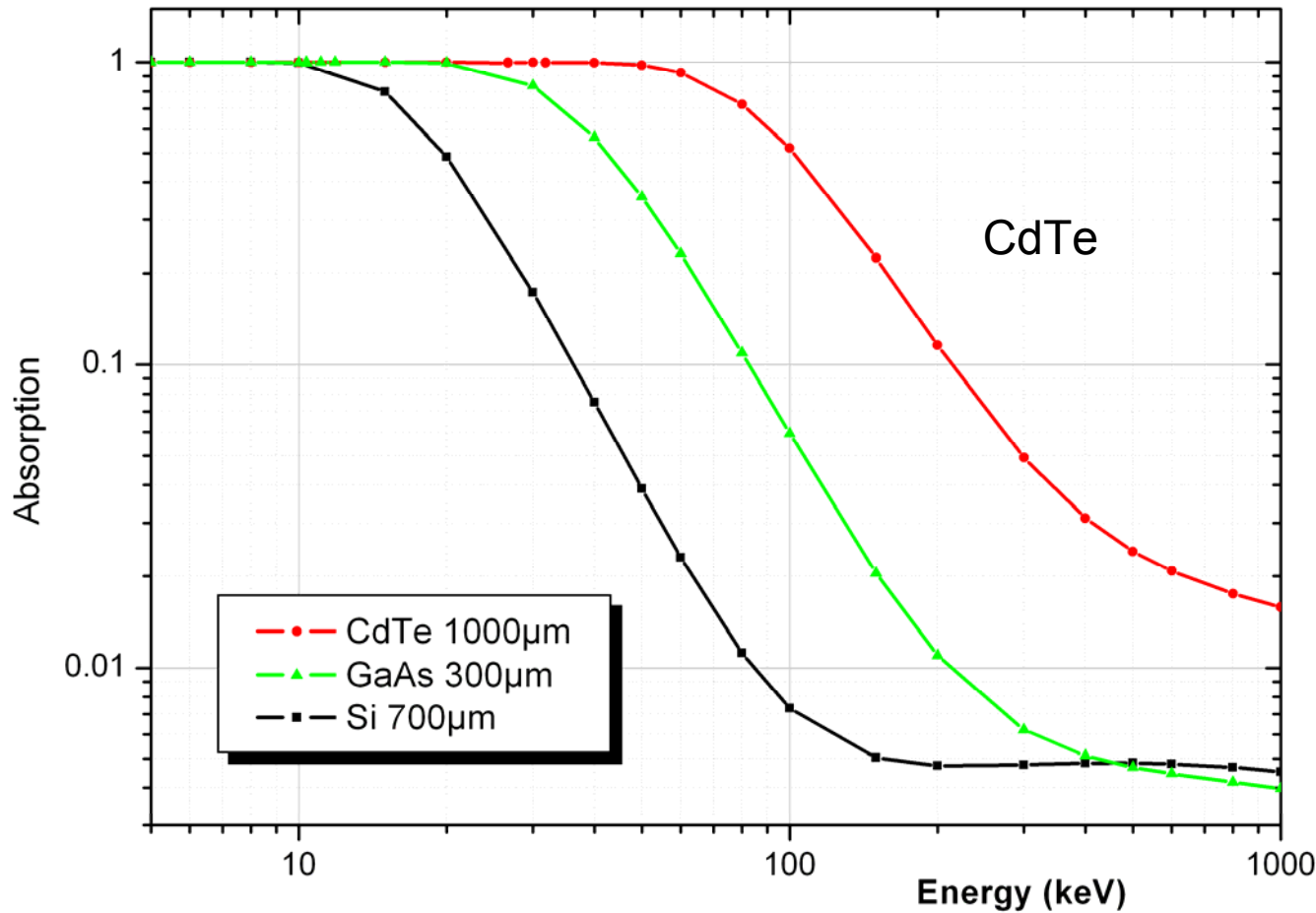
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- Introduction : Detector grade material CdZnTe and CdTe
 - Material Supplier
- Crystal growth of CdZnTe:
 - Growth configuration
 - Growth results
- Material properties
 - Defect analysis: IR microscopy
 - Electrical measurements: CoReMa, I-V
- Detector performance
 - Sensor processing
 - Signal analysis
 - results
- Summary and outlook



Why CdTe / CdZnTe detectors?



absorption

@ 40keV:

Si: 7.5%

GaAs: 55%

CdTe: 100%

@ 60keV:

Si: 2.2%

GaAs: 22%

CdTe: 90%



Full active detector thickness up to several mm possible!

- High absorption
- Working at room temperature
- Low leakage current
- Planar technology (adjusted to CdZnTe)

Material properties:

$E_G = 1.5 \text{ eV}$ $\rho: 10^9 \text{ upto } 10^{11} \text{ } \Omega\text{cm}$, $\mu\tau_e: 10^{-3} - 10^{-4} \text{ cm}^2/\text{V}$

Available wafer size: 2" – 3" (50 - 75 mm) diameter

Thickness of detectors: 1 mm (pixel) up to 15 mm

Drawbacks:

Availability, homogeneity, device technology



- ***Homogeneity on a μm -scale:***
 - material properties (electrical, composition, ...)
 - distribution of defects (Te-inclusions/precipitates, deep levels, ...)
- ***Improvement of energy resolution***
- ***Stable detector performance under high flux radiation***
- ***Improved device-Technology:***
 - Contacts
 - Passivation
 - Interconnections (Flip-chip-bonding)
- ***Reduction of material cost***

Single crystallinity and uniformity are essential keys to succeed.



Supplier	Material	Diameter
Eurorad, France	CdTe, CdZnTe	50 mm
Acrorad, Japan	CdTe	50 – 75 mm
Orbotech, Israel	CdZnTe	40 x 40 mm ²
Yinnel Tech, USA	CdZnTe	50 – 75 mm
Redlen, Canada	CdZnTe	50 mm
eV Products, USA	CdZnTe, CdTe	140 mm

European groups working with CdTe / CdZnTe (selection):

Charles University Prague, LETI CEA, IMEM CNR Parma, Academy of Science Warsaw, Universidad Madrid, University Durham, University Bologna, Polytecnico di Milano, University Surrey

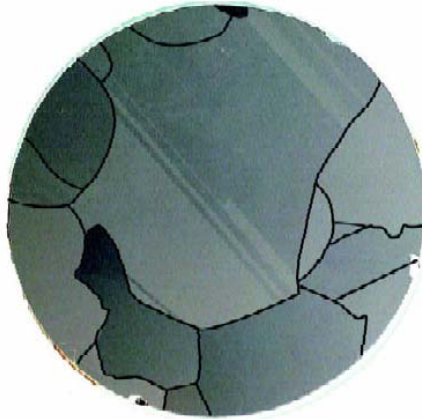


- Growth from the melt (Bridgman Method):
 - Furnace with 4 heaters
 - Synthesis and growth in same cartridge
 - Use of high purity silica ampoule (Heraeus HSQ 800)
 - Growth of 25 mm (0.3 kg) and 75 mm (1.6 kg) diameter
 - Growth of CdTe and $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$
 - Doping with In – 10^{17} 1/cm^3 (0.1 mg - .5 mg)
- Wafer sawing and surface preparation
 - Lapping and etching with Br-Methanol
- Material characterization
- Device fabrication (planar technology):
 - Pixel detectors (Flip-Chip-Bonding)
 - Single detectors

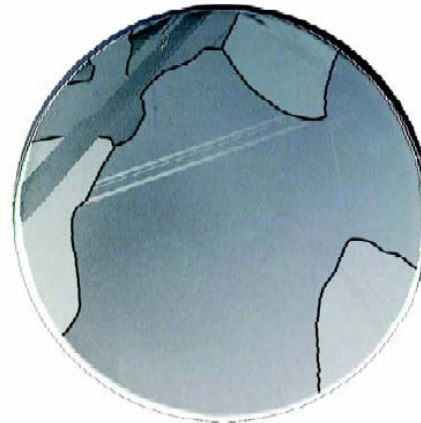
Growth of material and production technology of detectors



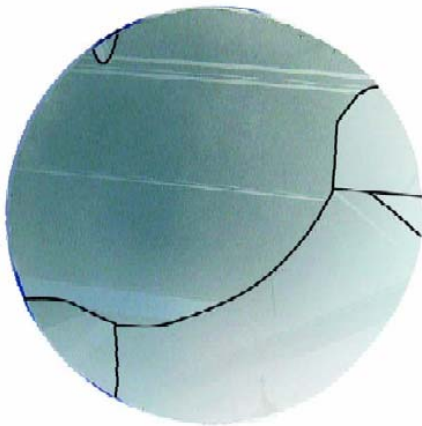
- Single crystal area up to 40 x 40 x 60 mm³



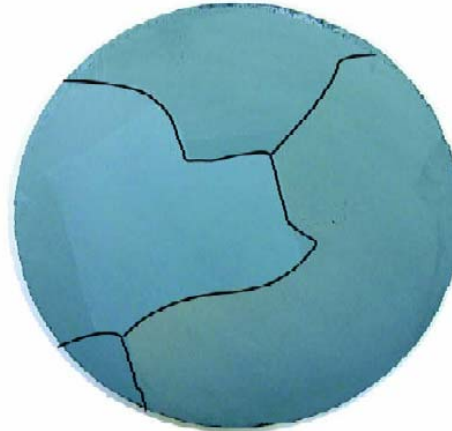
CZT-2000



CZT-2003



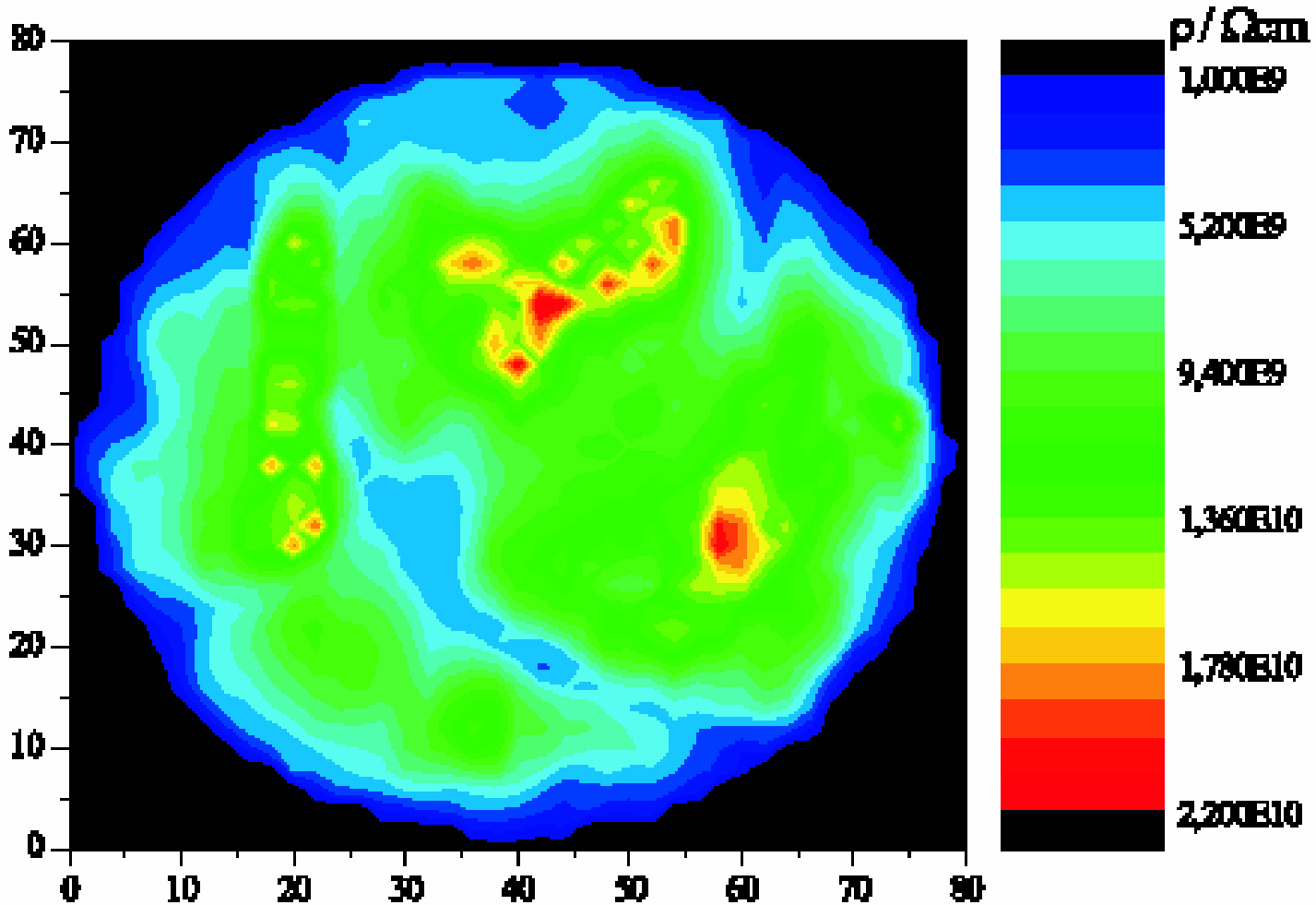
CZT-2005



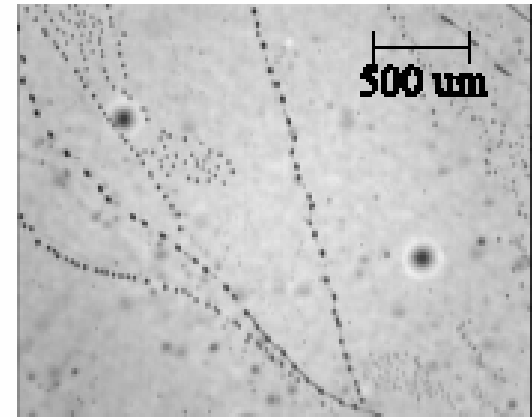
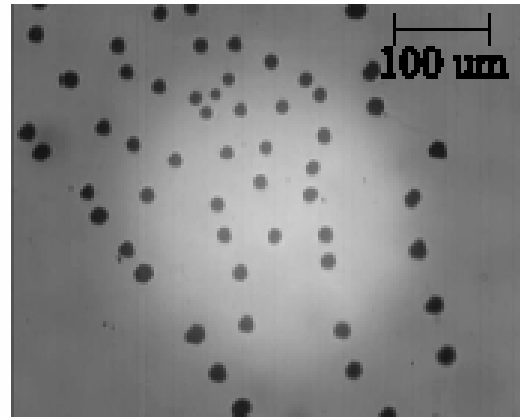
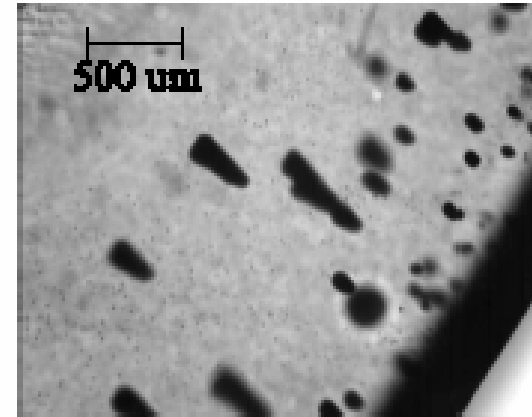
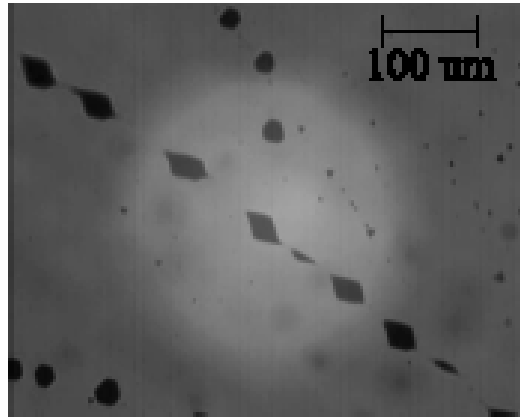
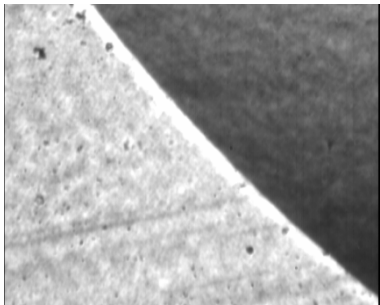
CZT-2006



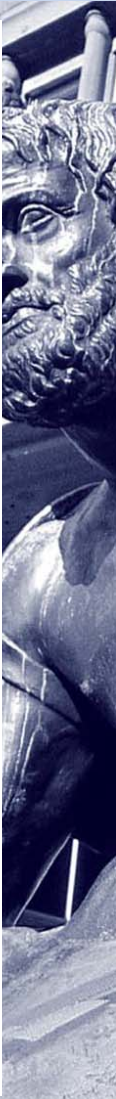
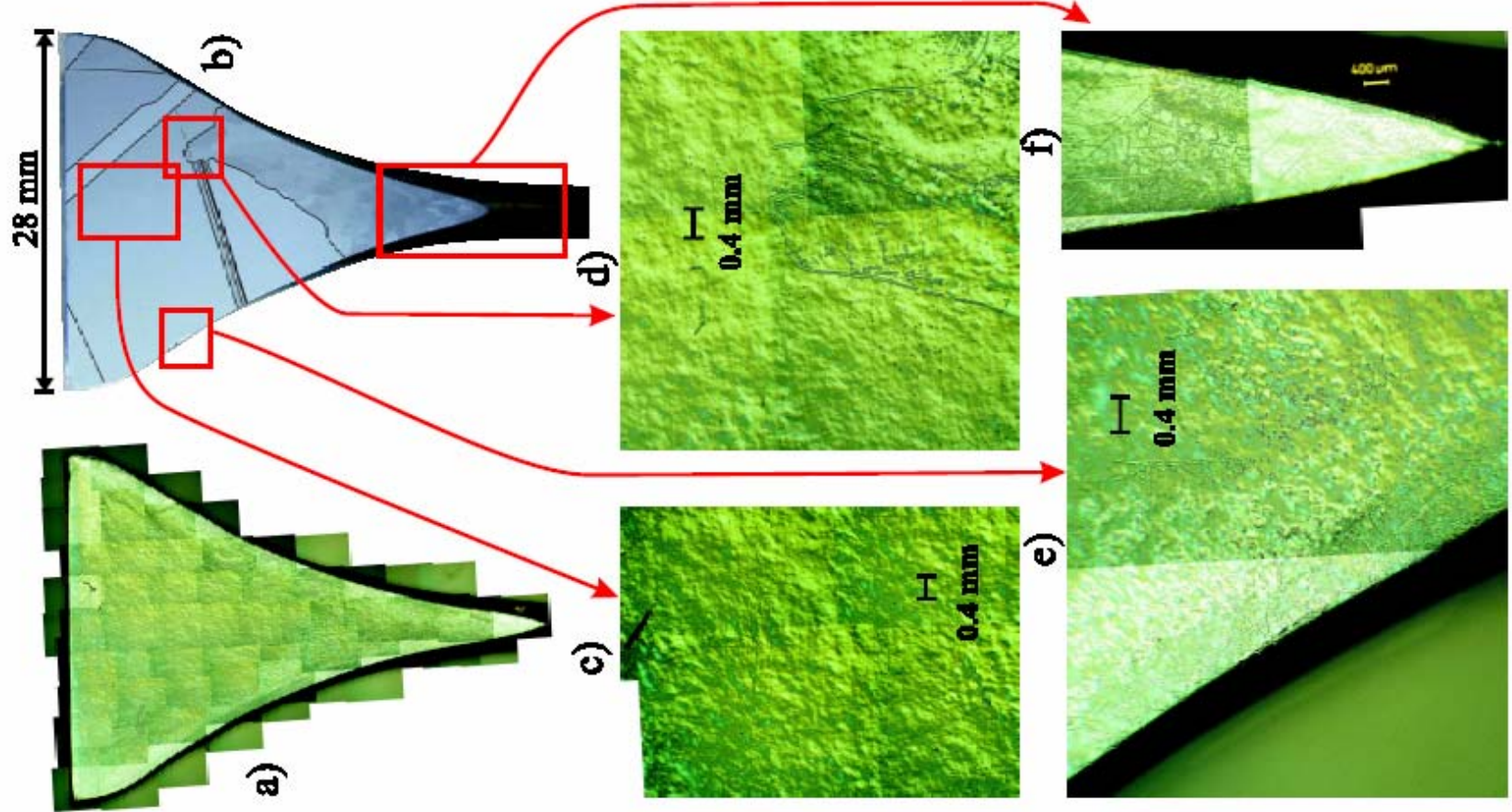
- Resistivity: $0.6 - 2.0 \times 10^{10} \Omega\text{cm}$



- Typical defect: Te-inclusion (size around $20\ \mu\text{m}$)



Analysis of dislocations

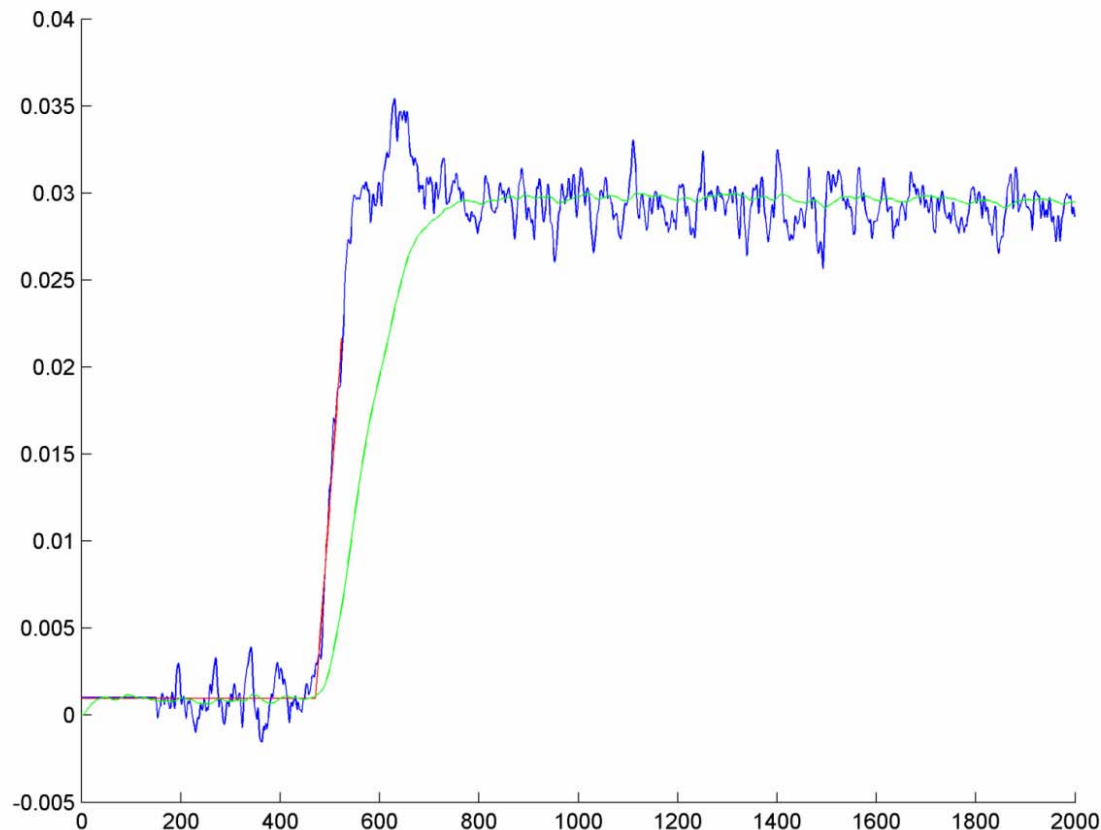


- 3000 – 2×10^4 1/cm² (end of crystal)



Calculation of mobility from detector signal:

$$\left. \frac{dV(t)}{dt} \right|_{t=0} = \alpha = V_0 \frac{U}{d^2} \mu \quad \mu = \frac{\alpha \cdot d^2}{U \cdot V_0}$$





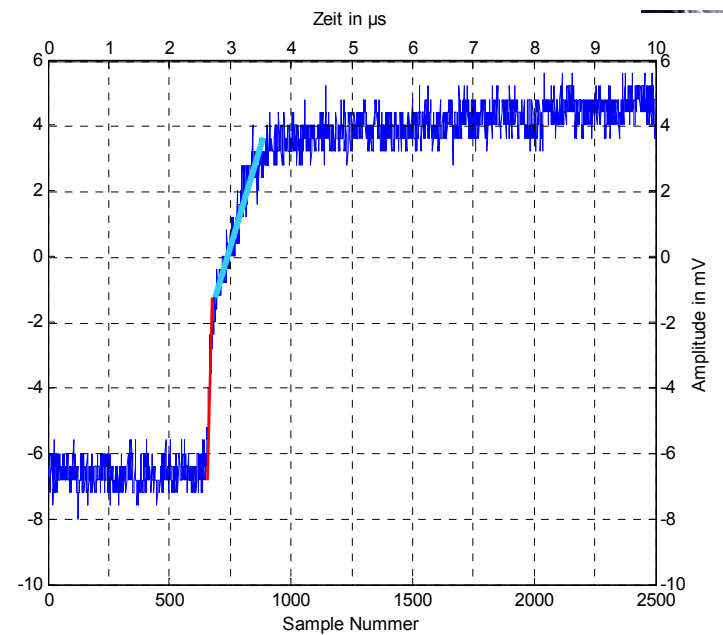
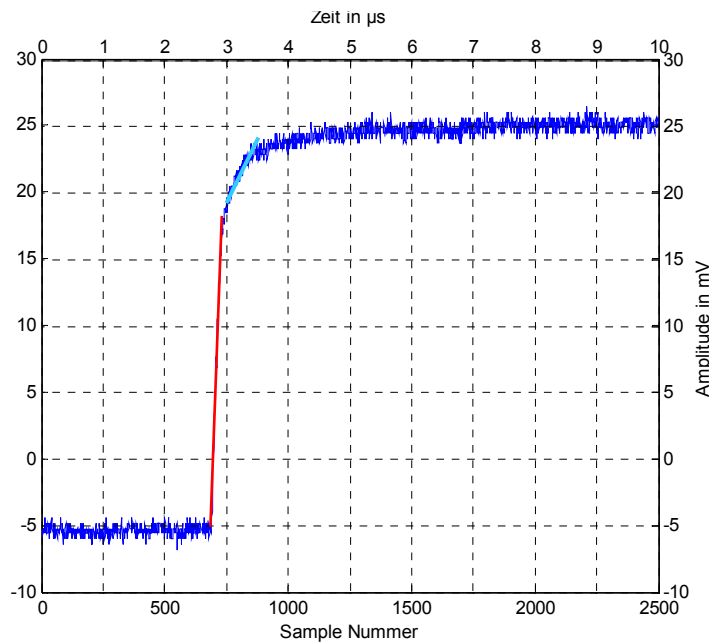
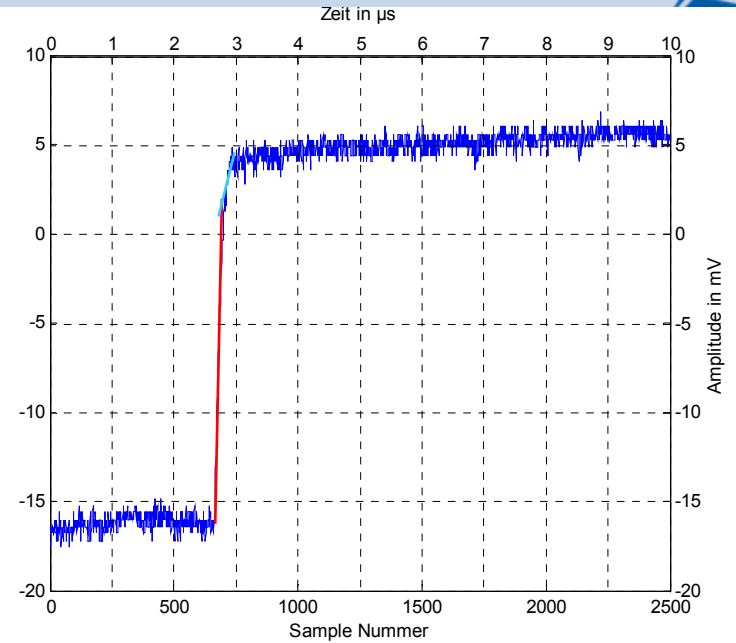
Mobility		Bias								$\mu\tau$	$\mu\tau$	τ	τ
Position		150	300	450	600								
1	mue	980	1136	1118	1024	1065	75	1093	60	2,72E-04	8,E-06	2,6E-07	2,E-08
1	muh	30	30	32	31	31	1	31	1	2,11E-05	3,E-07	6,9E-07	2,E-08
2	mue	959	1055	1079	1023	1029	52	1052	28	2,13E-04	5,E-06	2,1E-07	1,E-08
2	muh	29	32	32	33	32	2	32	1	1,65E-05	2,E-07	5,3E-07	3,E-08
3	mue	937	1010	1059	1033	1010	52	1034	25	1,68E-04	4,E-06	1,7E-07	1,E-08
3	muh	30	33	34	34	33	2	34	1	1,60E-05	3,E-07	4,9E-07	3,E-08
4	mue	1037	1101	1120	1069	1082	37	1097	26	1,86E-04	4,E-06	1,7E-07	1,E-08
4	muh	31	35	36	35	34	2	35	1	1,67E-05	3,E-07	4,9E-07	3,E-08
5	mue	1007	1106	1139	1061	1078	57	1102	39	2,40E-04	6,E-06	2,2E-07	1,E-08
5	muh	30	32	33	32	32	1	32	1	1,88E-05	3,E-07	5,9E-07	2,E-08
6	mue	1036	1129	1148	1081	1099	50	1119	35	2,09E-04	5,E-06	1,9E-07	1,E-08
6	muh	30	33	34	34	33	2	34	1	1,62E-05	2,E-07	5,0E-07	3,E-08
7	mue	1048	1097	1130	1067	1086	36	1098	32	1,91E-04	4,E-06	1,8E-07	1,E-08
7	muh	30	34	33	34	33	2	34	1	1,61E-05	3,E-07	4,9E-07	2,E-08
8	mue	1129	1193	1212	1117	1163	47	1174	50	2,67E-04	9,E-06	2,3E-07	1,E-08
8	muh	31	33	34	34	33	1	34	1	1,78E-05	4,E-07	5,4E-07	2,E-08
9	mue	1078	1134	1165	1082	1115	42	1127	42	2,04E-04	5,E-06	1,8E-07	1,E-08
9	muh	31	34	35	35	34	2	35	1	1,71E-05	4,E-07	5,1E-07	3,E-08

The difference between the Mobility of electrons and holes is a factor of 20!

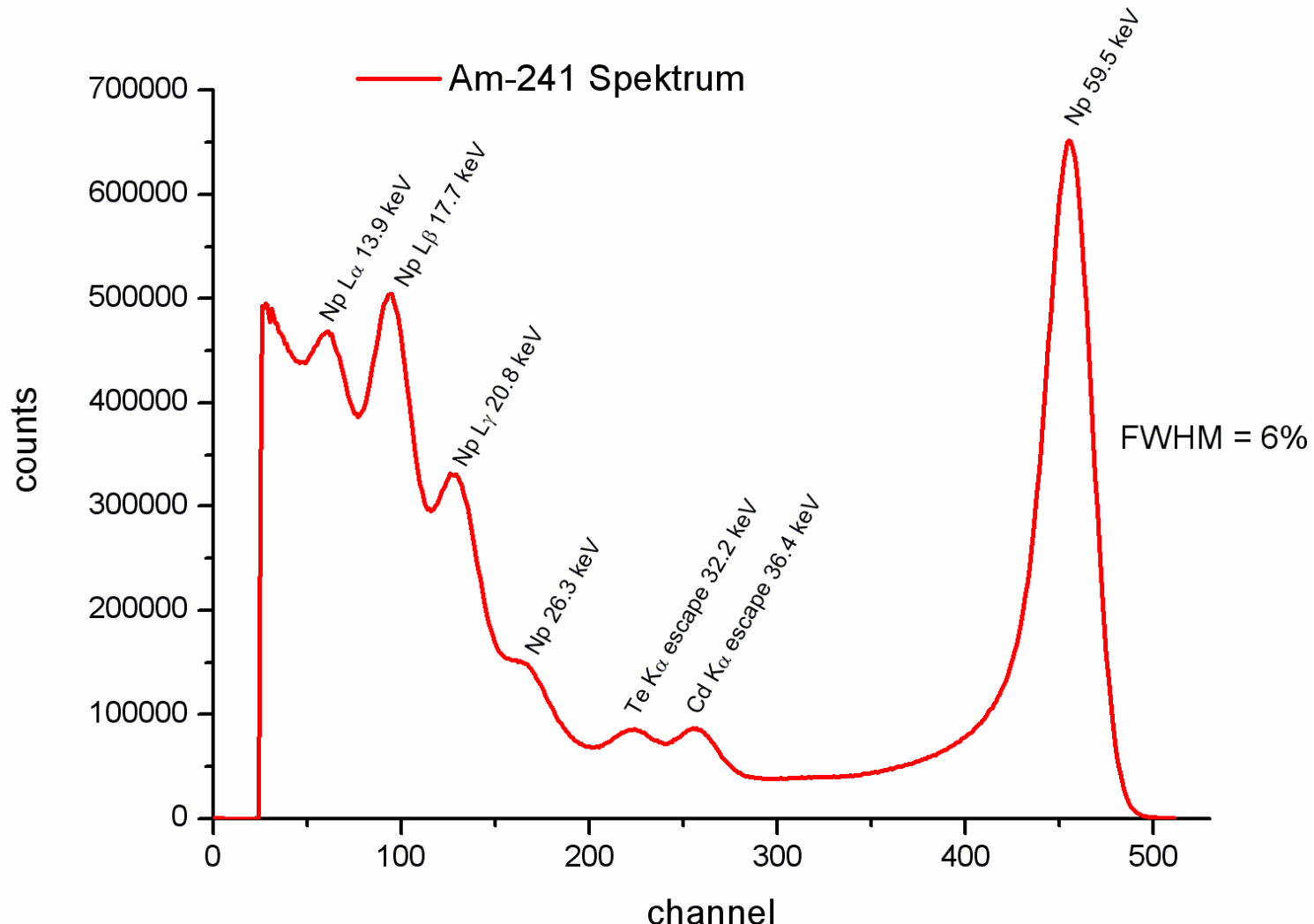


Pulses

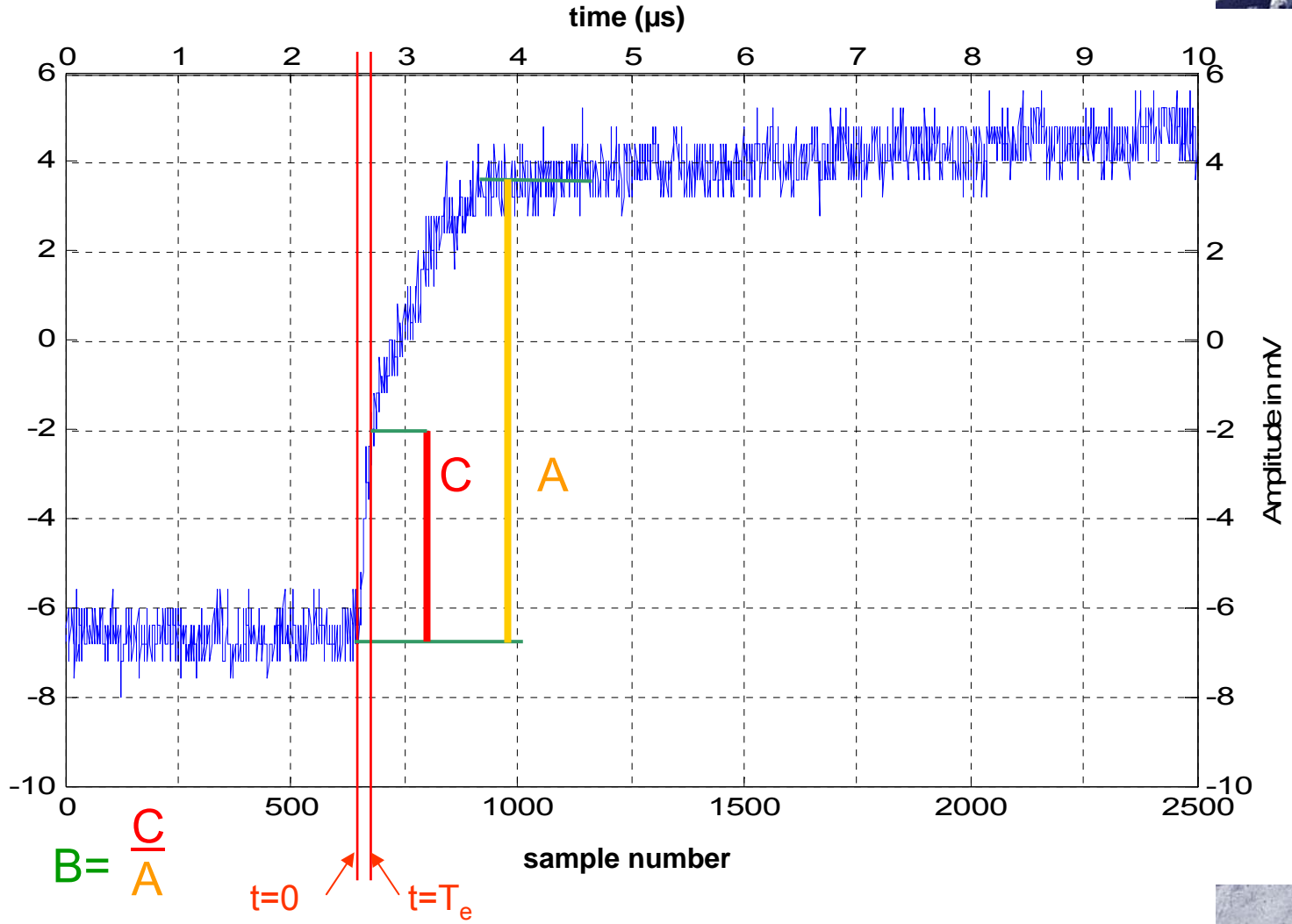
CdZnTe	
Lifetime τ_e (s)	3×10^{-6}
Lifetime τ_h (s)	1×10^{-6}
mobility μ_e (cm ² /Vs)	1000
mobility μ_h (cm ² /Vs)	50

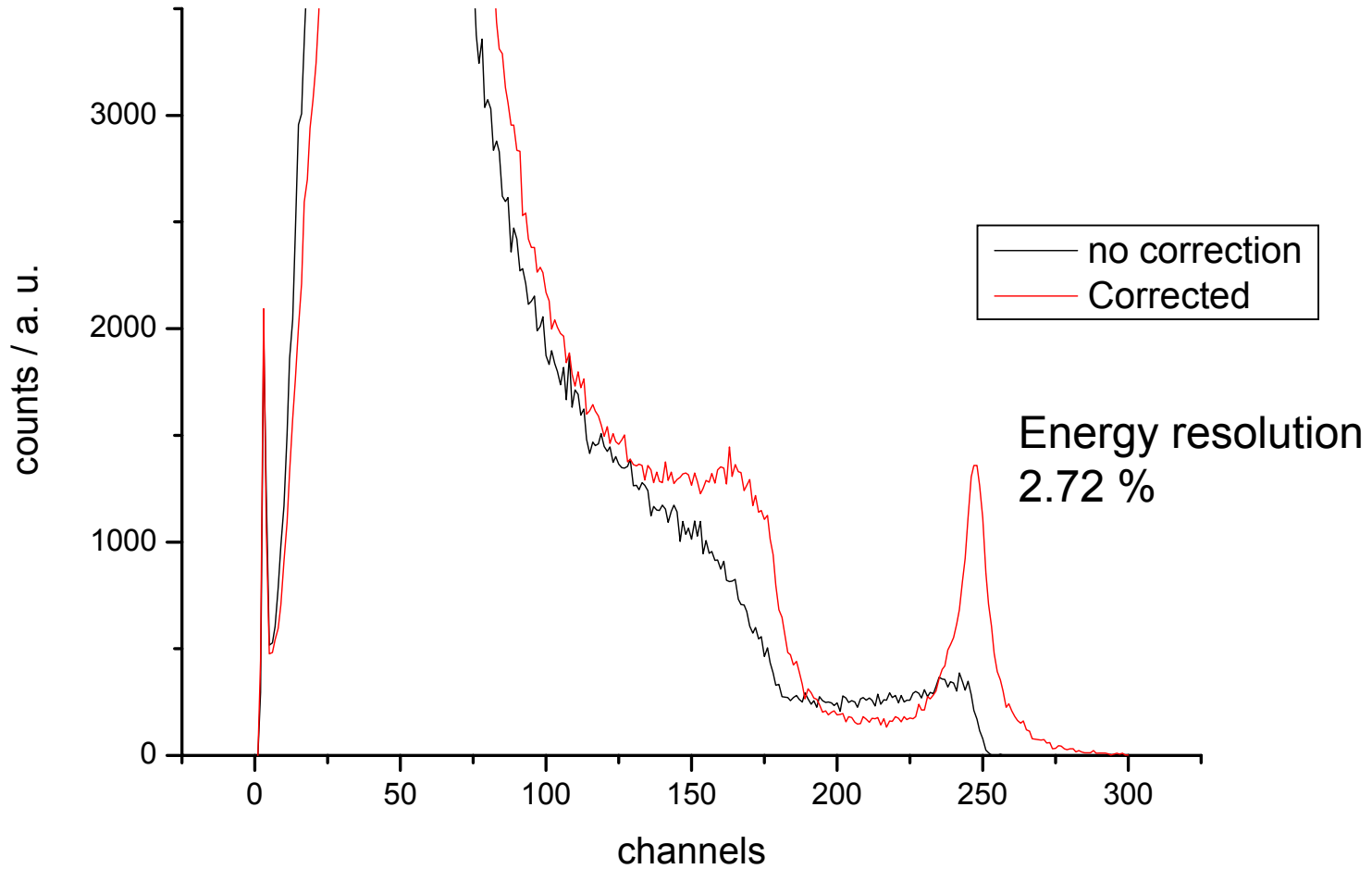


- Planar detector CdZnTe with 1 mm thickness:
 - Au – Au contacts, 250 V bias

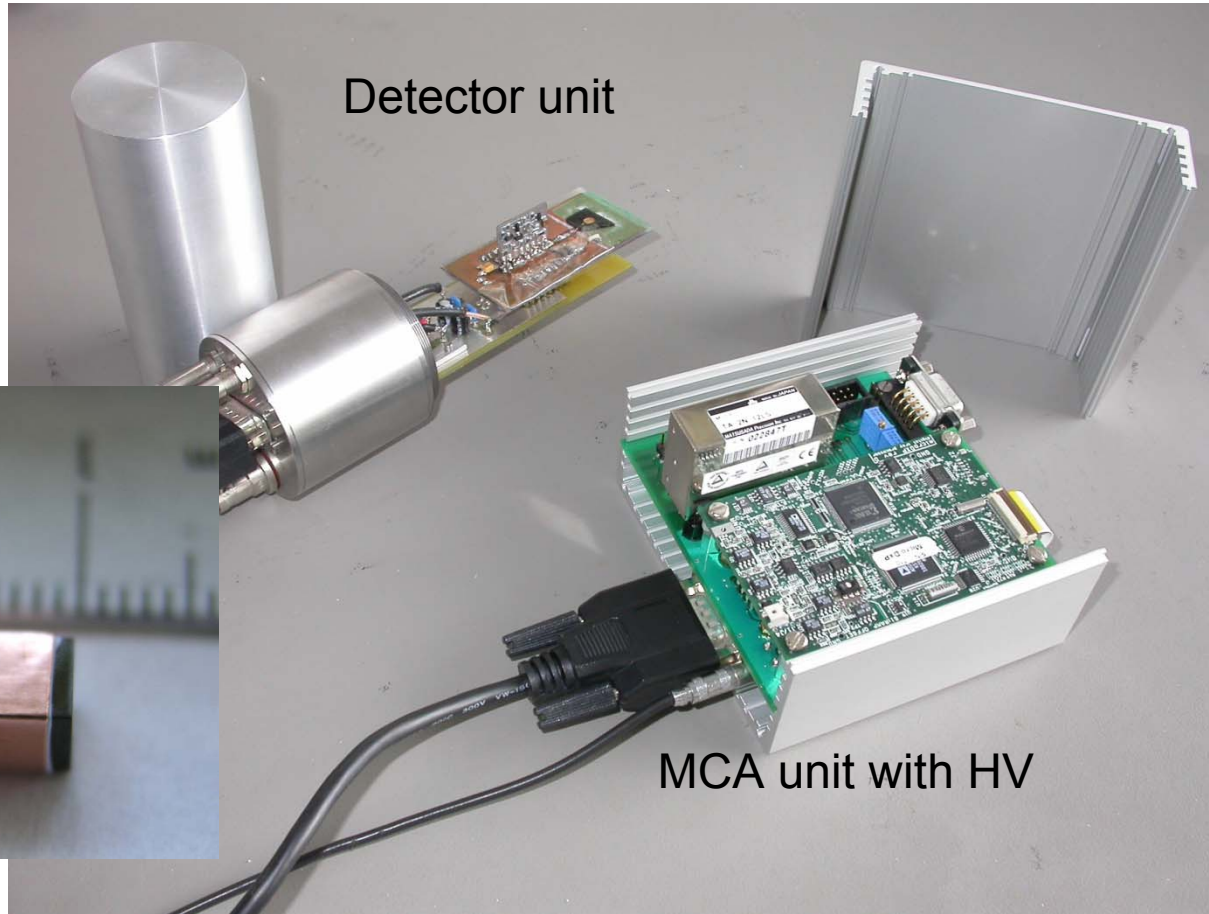


Bi-parametric analysis

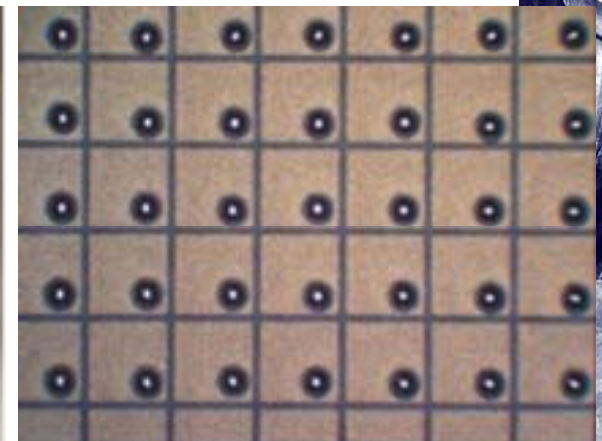
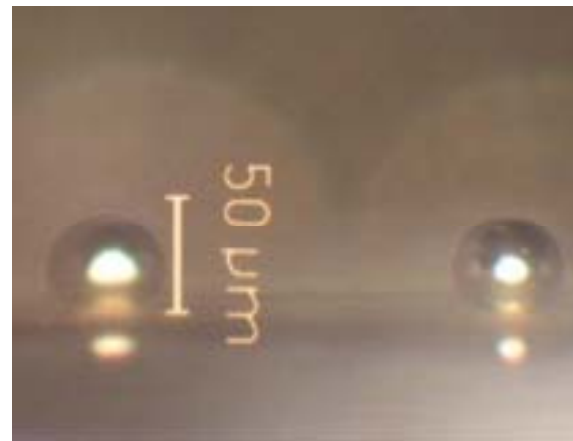
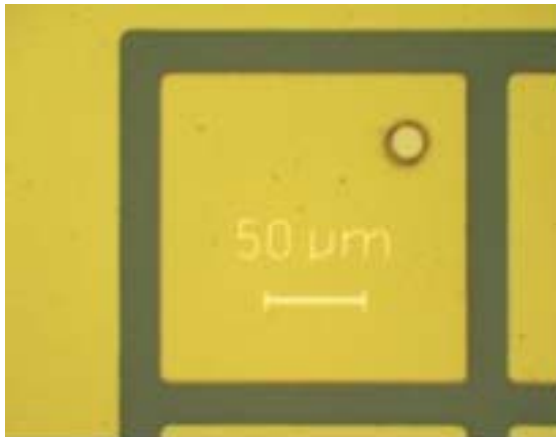
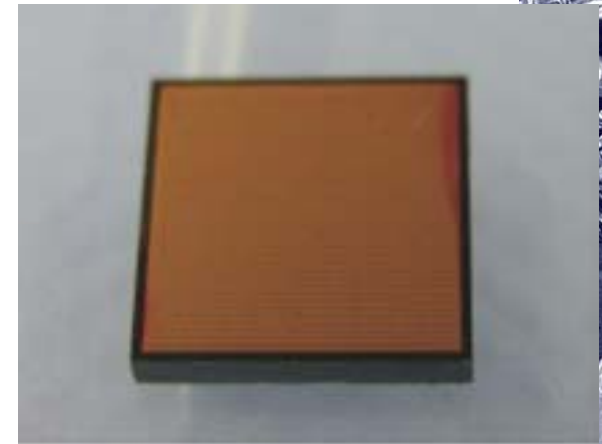




- Detector system for radiation monitoring and isotope identification (cooperation with Bundesamt für Strahlenschutz)

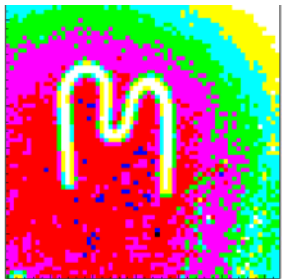
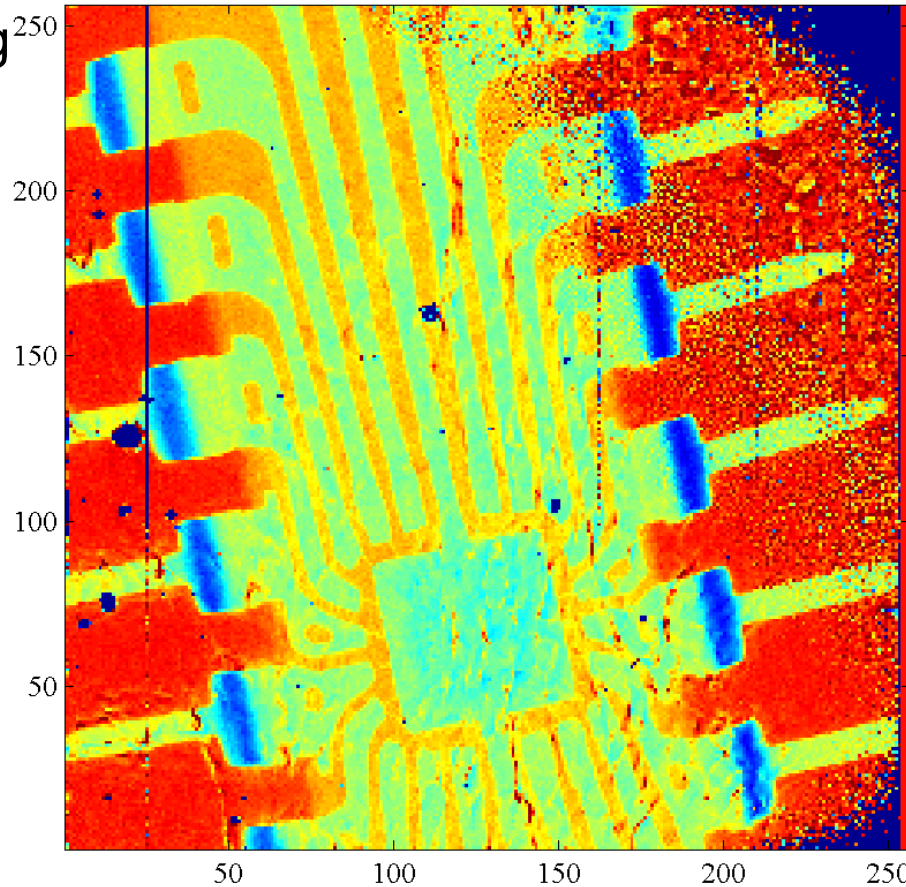


- pixels sizes down to $55 \mu\text{m}$
- 4000 - 65.000 pixels
- Low temperature processing ($< 150 \text{ }^\circ\text{C}$)
- Polymere passivation (BCB)
- Low force Flip-Chip-Bonding
- Processing of single detectors

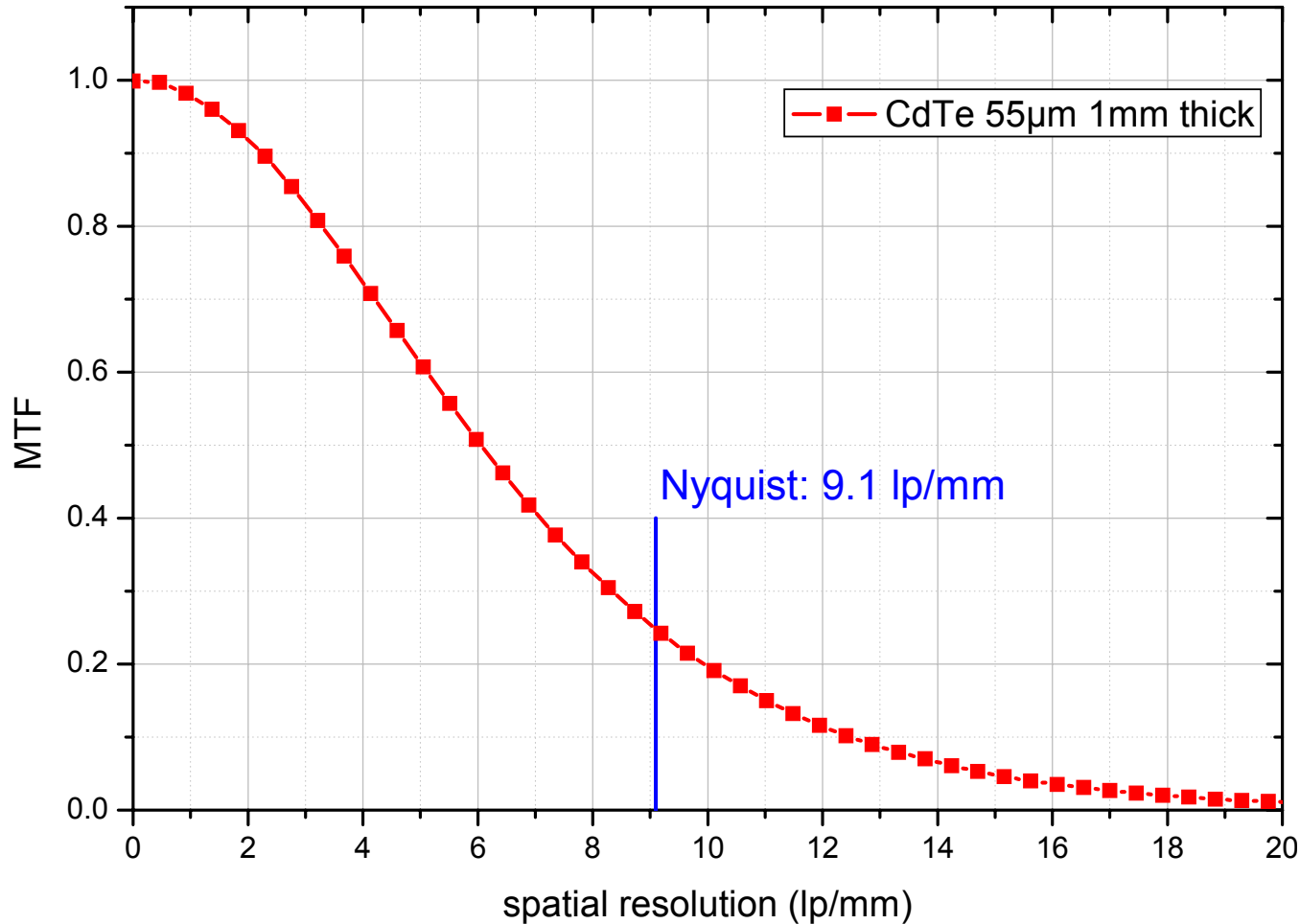


- Detector made in Freiburg²⁵⁰
 - Growth of CdZnTe
 - Detector processing
 - Flip-Chip Bonding
- CdZnTe detector with Pt – Au contacts

TTL-chip 100V e- collection sum of 40 images, ff corrected



MTF determination (edge method)

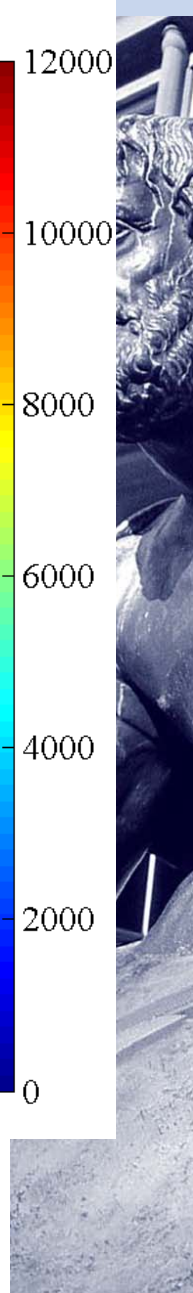
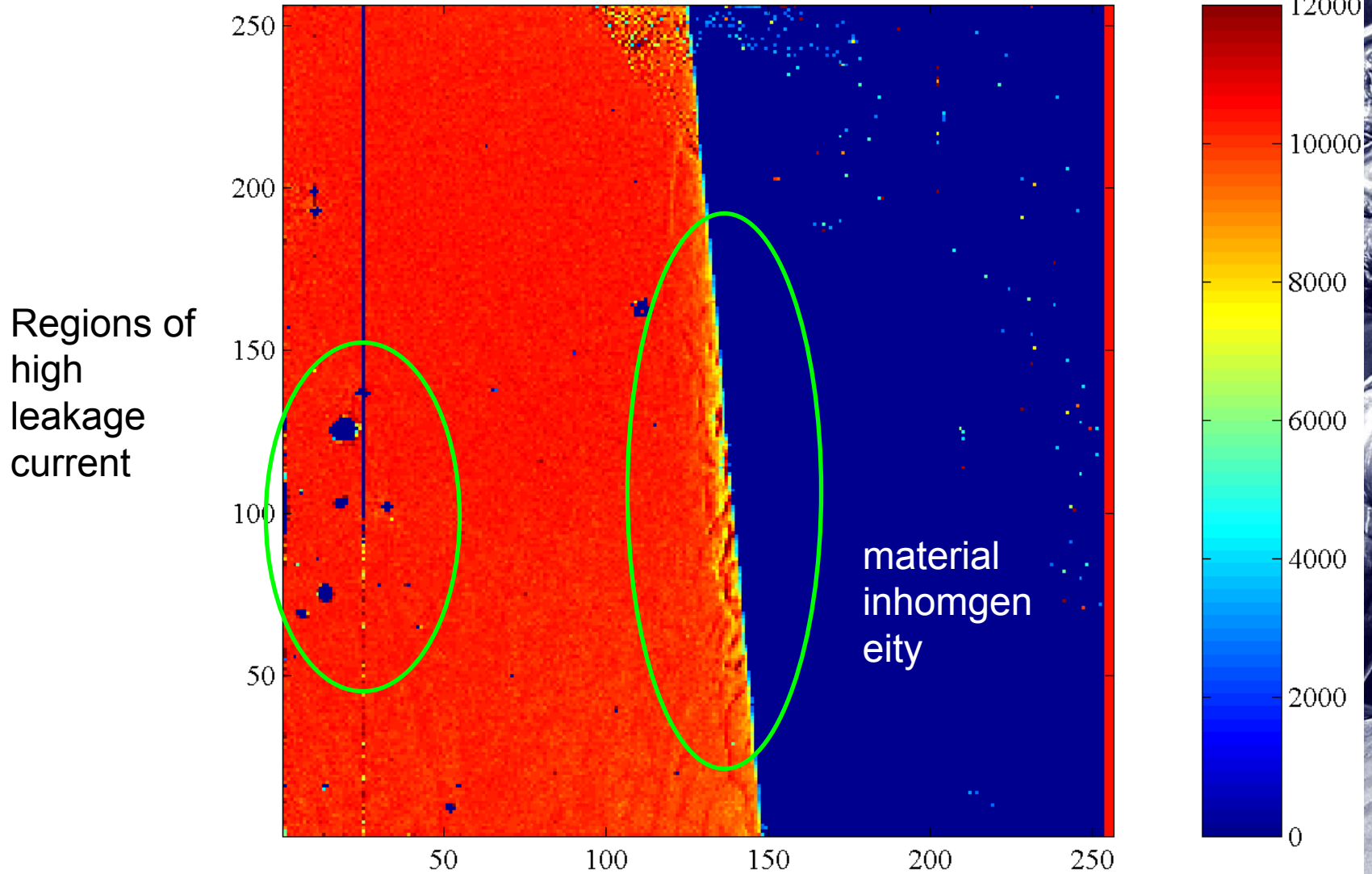


MTF not as good as expected.

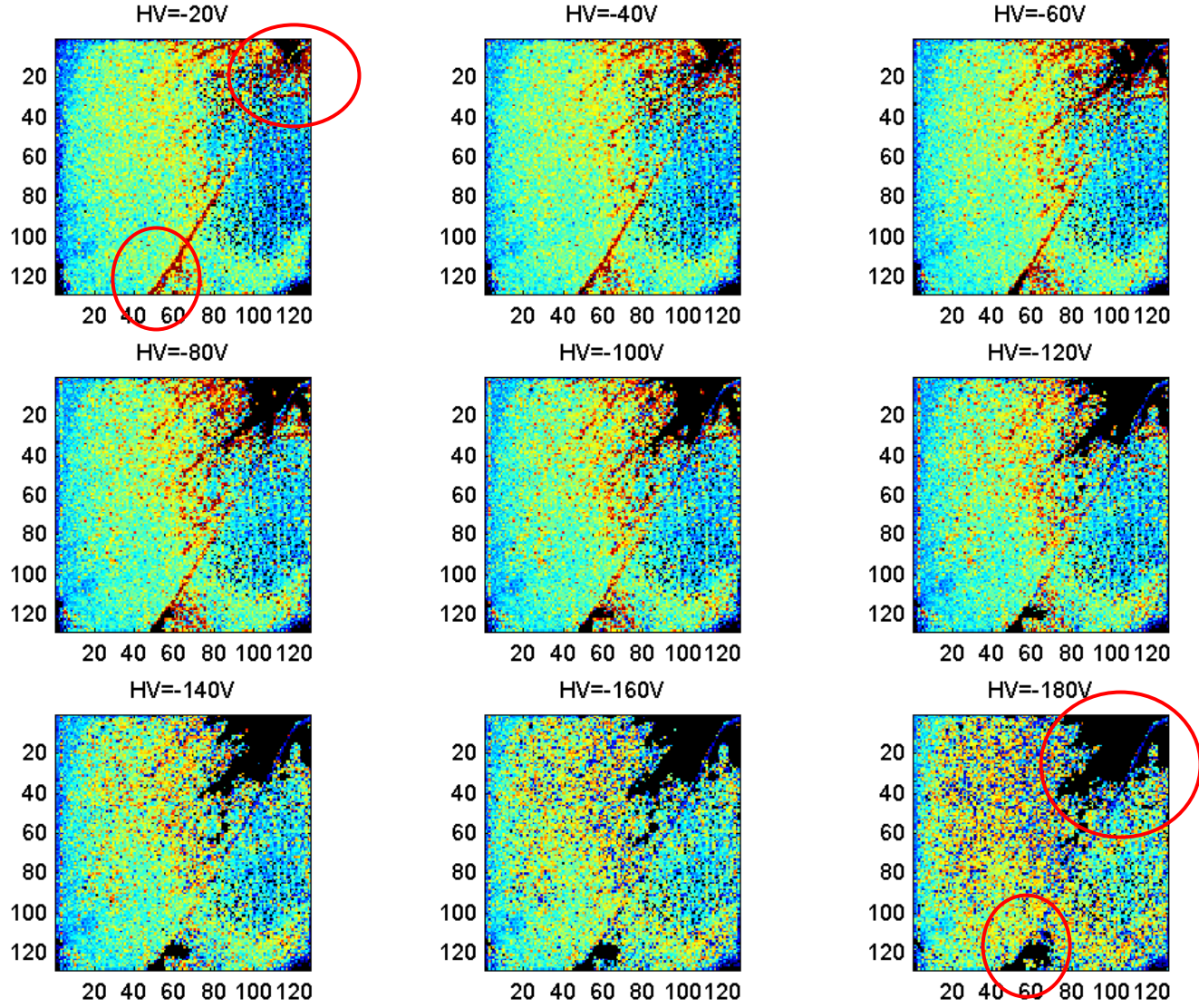
Reasons:

- Thickness of detector 1mm → larger charge diffusion
- bias voltage too low (due to some regions of high leakage current)

MTF-Pb-edge 100V e- collection sum of 40 images



FMF CdZnTe (e- collection) normalized



- Growth of 75 mm crystals with 40x40x60 mm³ single crystals
- (Cd,Zn)Te:In:
 - High resistivity material
 - Detector performance (without corrections):
 - FWHM:
 - 5.3 % @122 keV and 6.0 % @ 59.5 keV
 - Peak-to-Valley: 1:5
- With correction by signal-analysis:
 - FWHM: 2,72 % @ 622 keV
- Technology for pixel detectors Medipix 2 with 55 μm pixels:
 - CdTe
 - CdZnTe
 - GaAs

Acknowledge: European Space Agency
Bundesamt f. Strahlenschutz





European Detector Group

Website:

www.rtsd.eu

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Abstract Submission Deadline: May 9, 2008

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