DECTRIS®

detecting the future

MYTHEN PILATUS EIGER

First PILATUS3-CdTe detector: calibration and performance

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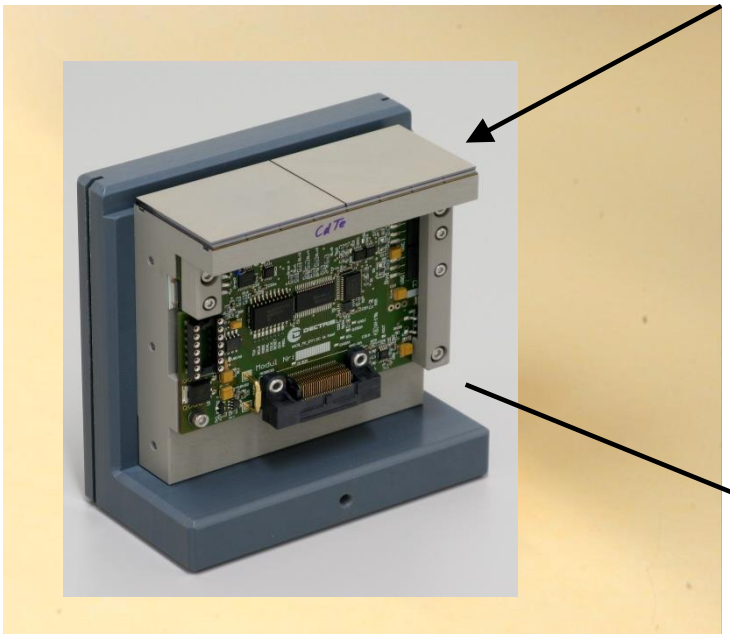
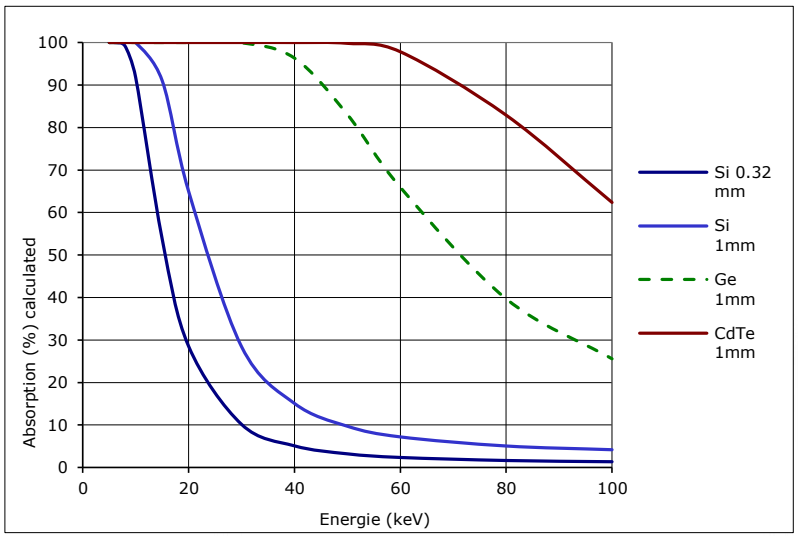
R&D: PILATUS3-CdTe

Extend our product range to higher energy applications



CdTe hybrid assembly



Module active area: 83.8×33.6 mm^2

487×195 pixels = (~100k pixels)

Pixel pitch 172 μm

Agenda

1. PILATUS3 CdTe detector description
2. Comparison of operating conditions
   - CdTe network of Lines
   - Polarization
3. Characterization and Calibration
   - Quantum Efficiency
   - Energy Resolution
   - Point Spread Function
4. Summary

PILATUS3 ASIC & CdTe

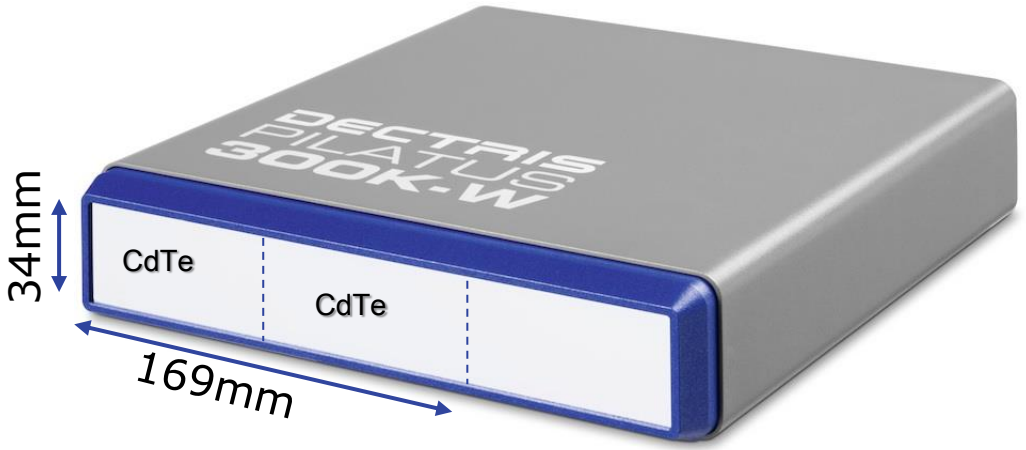
1. CdTe sensor

- ***CdTe from Acrorad available in a size of 42x34 mm → half module***
- ***1 mm thickness***
- ***172 µm pixel pitch***
- ***Ohmic contacts and e^- collection mode***

2. PILATUS 3 ASIC

- ***Instant Retrigger Capability***
- ***compatible with e^- collection***
- ***extended energy range for high energy***

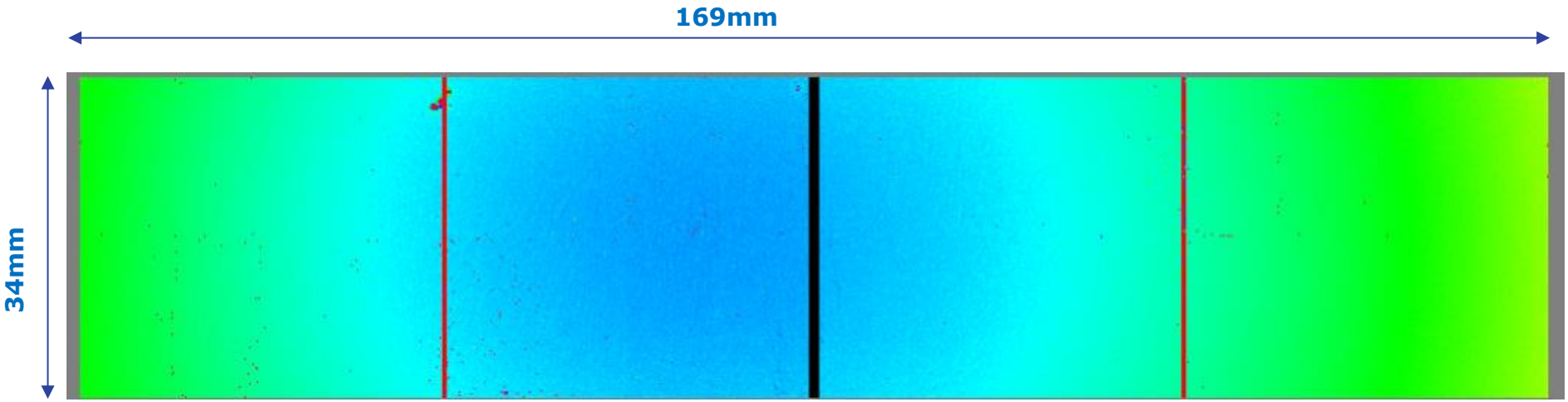
Test setup



First multimodule PILATUS3 CdTe detector

Detector calibrated @ different gains from 8keV - 80keV

Dead pixels = 8‰
Hot pixels(>1.5mean) = 6‰



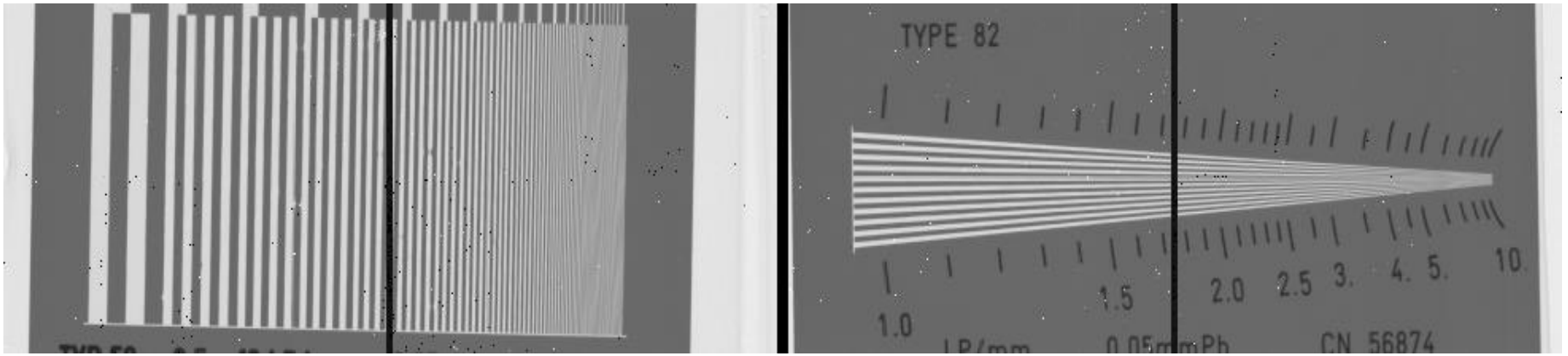
Flat Field on the PILATUS3 CdTe with homogeneous fluorescence beam Sn sample

Trimmed and FF corrected
Mean ~ 20000 counts
Exposure time = 10s
Mean ~ 2000 cps
Sigma ~ 1.5%

First multimodule PILATUS3 CdTe

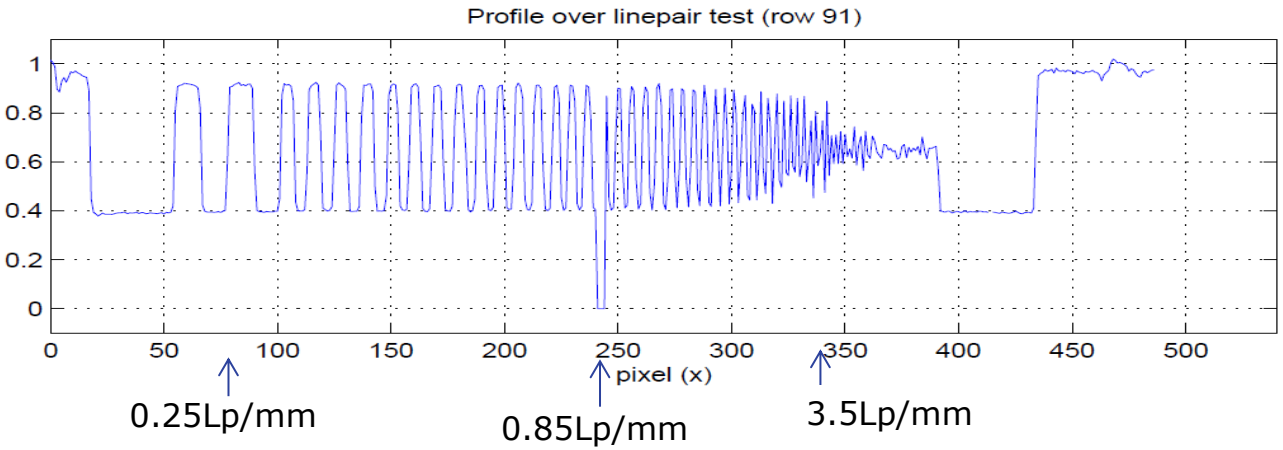
Tests1: 0.05 Pb,
Lp/mm: 0.25…6

Test2: 0.05 Pb,
Lp/mm: 1…10



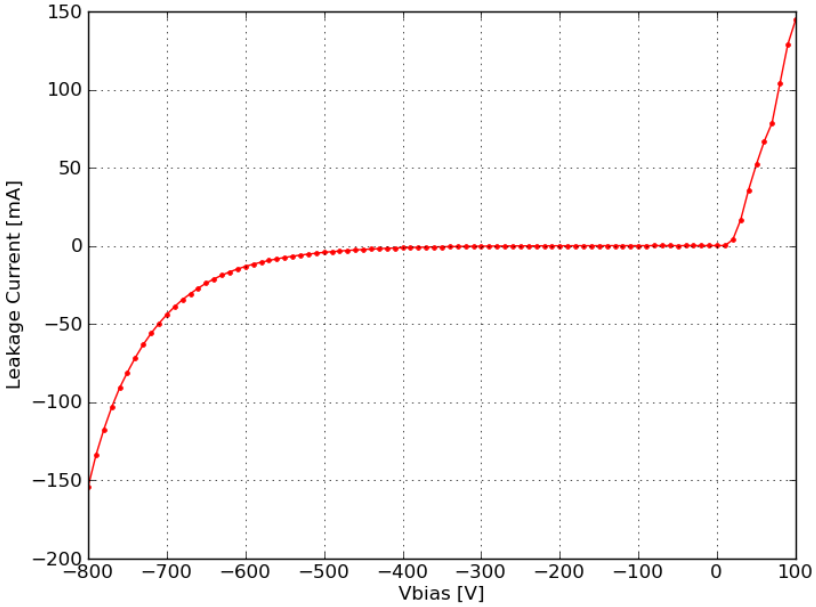
X-ray images of line pair test with PILATUS3 CdTe with homogeneous illumination from X-ray tube, tungsten target at 60 kVp and 3 mm aluminum filter.

Trimmed
FF corrected

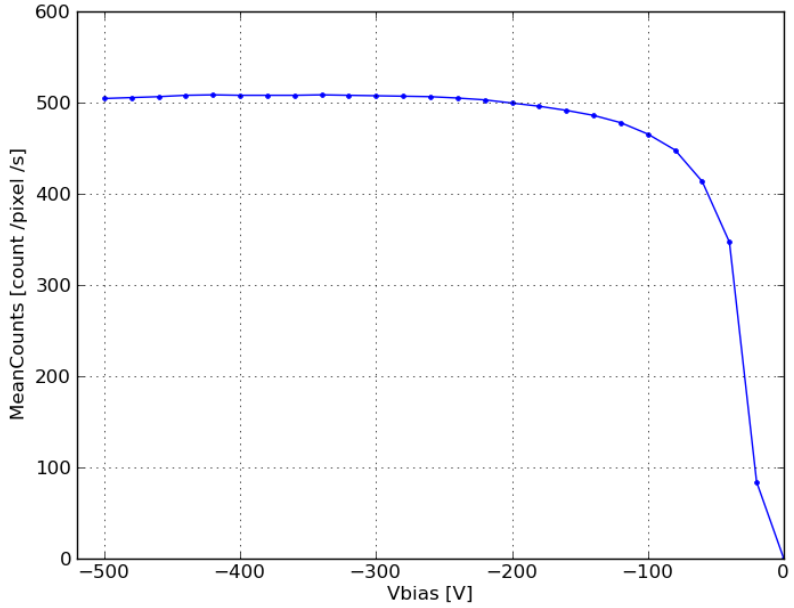


CdTe Bias characteristics

Half Sensor, 1 mm thickness



IV characteristics

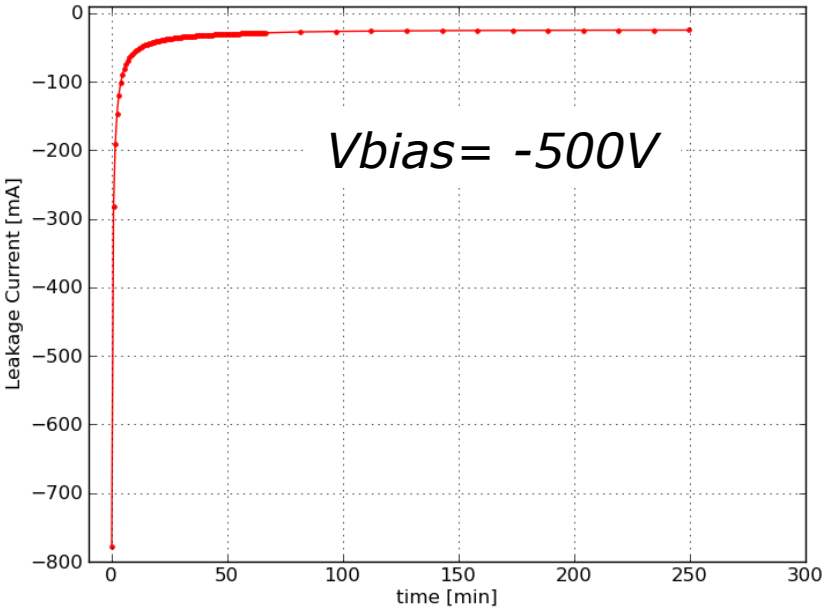


Mean number of counts vs bias, fluorescence sample Sn

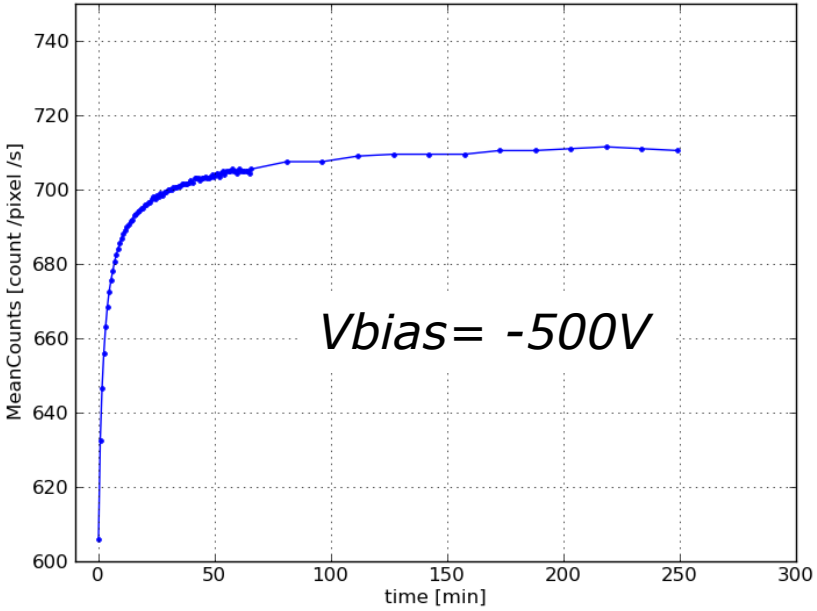
Sufficient charge collection at Vbias < -200V

CdTe Time characteristics

Half Sensor, 1 mm thickness



Leakage current vs time



Mean number of counts vs time, fluorescence sample Sn

Leakage current:
-780 µA after Bias on
-50µA after 10min
-24µA after 4h

Mean Number of Counts:
is @ 2% of the final value after 10min
is @ 1% of the final value after 30min

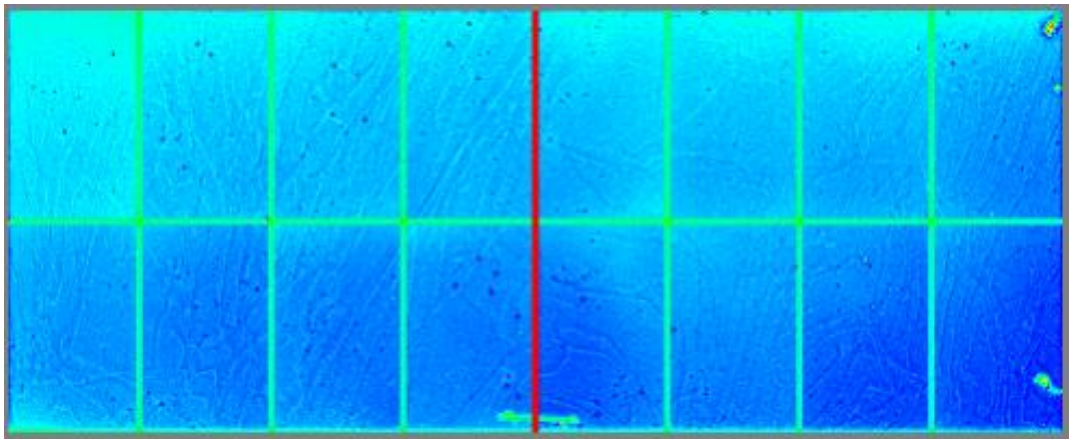
Time Stability and Polarization

1. *measurements:*
   - ***PTB Laboratory at BAM Line at BESSYII***
   - ***Xray tube W target 60 kVp, 3 mm aluminium filter***
2. *network of lines with time and irradiation*
3. *polarization of the sensor at high fluxes*
   - ***Less polarization at higher bias voltage***

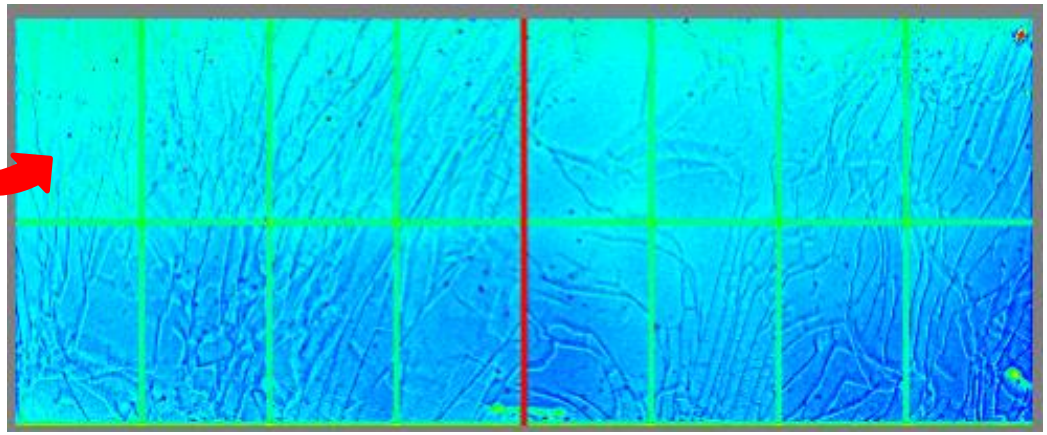
Network of Lines

- *Single module, 100K CdTe*
- *Vbias = -500V*
- *Trimmed*
- *Not flat field corrected*
- *High gain, Eth = 10000eV*
- *Xray tube tungsten target at 60kVp and 3mm Al filter*
- *flux* ***1.8 Mcounts/pixel s***
- ***61 Mcounts/mm² s***

First Image after HV reset, 15min wait without flux

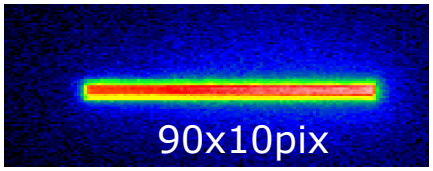


… after 42h @ 1.8Mcps

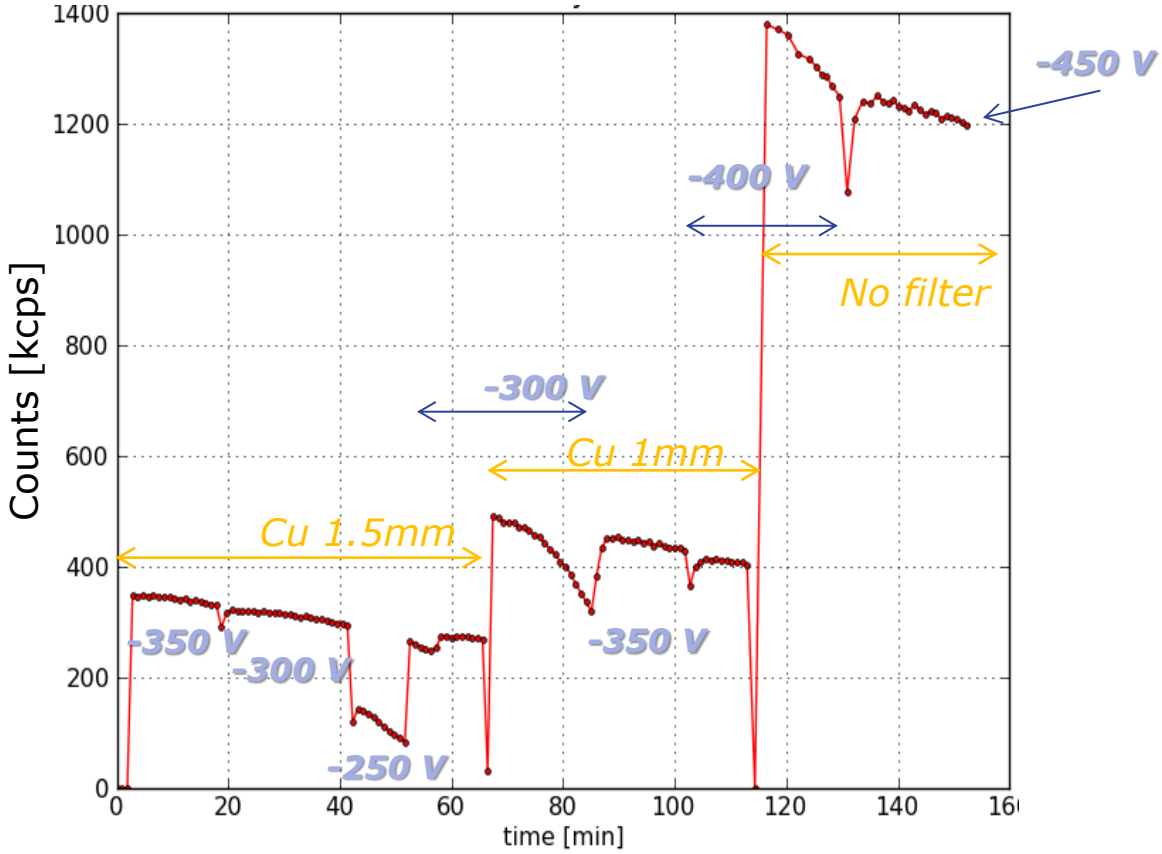


development of the line structure in time under continuous flux

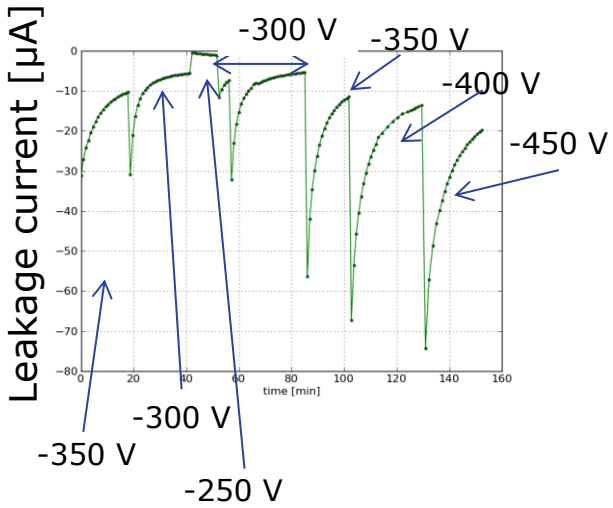
Mean count stability @ BAM line (May 2013)



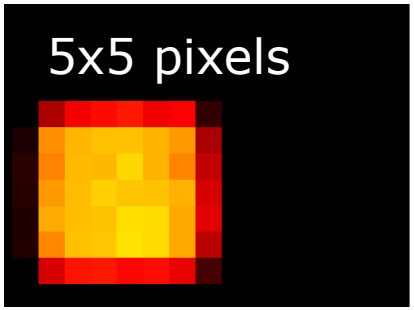
Irradiated area



- *Half Module, CdTe*
- *Vbias = **-250 …– 450 V***
- *Not Trimmed*
- *Retrigger ON*
- *Beam Energy = 60 keV*
- *flux changed with Cu filter of different thickness*



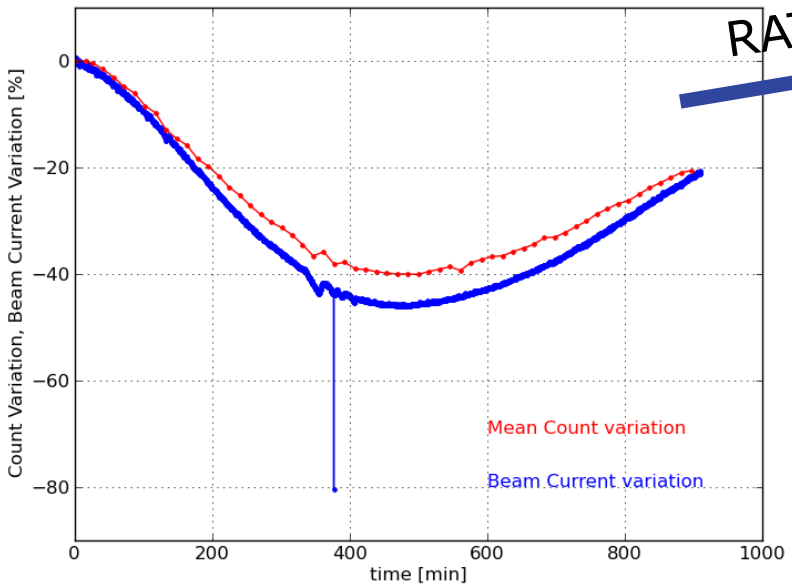
Mean count stability @ BAM line (May 2014)



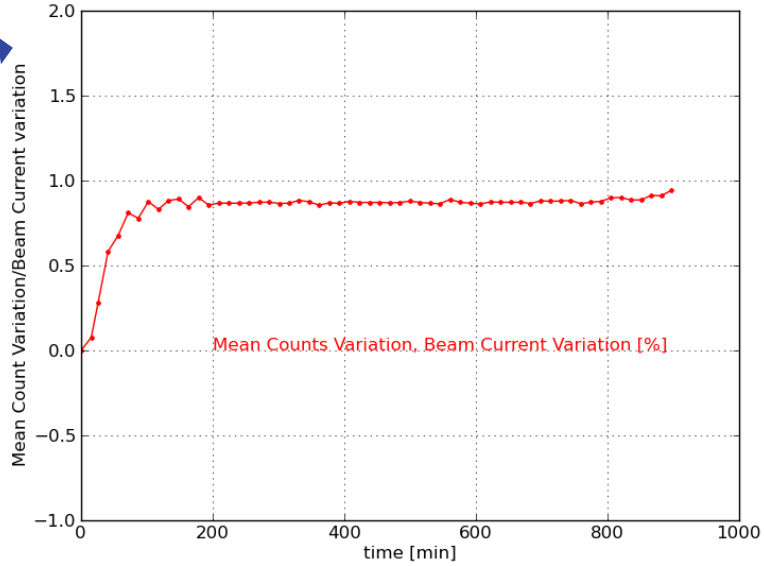
Irradiated area

- *CdTe*
- *Vbias = **-500 V***
- *Trimmed*
- *Retrigger ON*
- *Beam Energy = 33 keV*
- *Night irradiation @ constant flux*

flux ~2.5 10^6 counts /pixel s
~ 8.5 10^7 counts/mm² s



RATIO



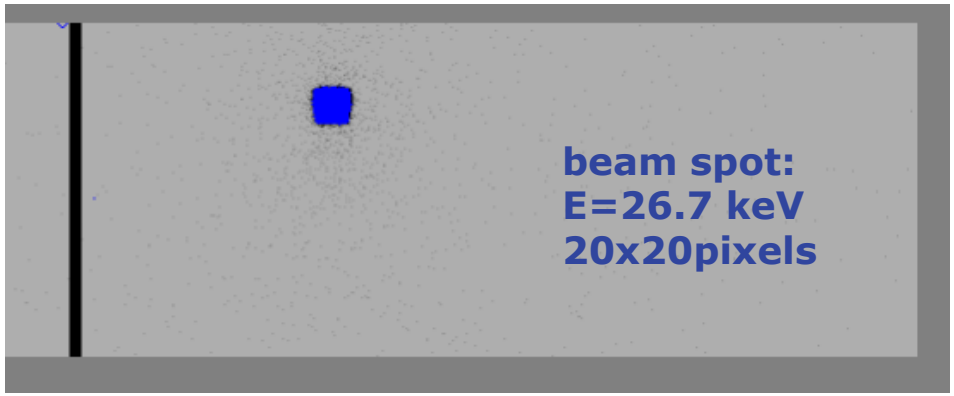
Detector characterization @ BAM line

1. Synchrotron Beam:

- ***Low flux to avoid pulse pileup maximum 50kHz***
- ***Measurements at different energies, below and above the K edges: Cd (26.7 keV) and Te (31.8 keV)***

2. Measurements:

- ***Energy resolution***
- ***Quantum efficiency***
- ***Point Spread Function***



Quantum Efficiency

Measurements performed BAM line:

- *Beam energy in range 20- 60keV*
- *Max flux 50kcps*

Detector:
- *PILATUS3 CdTe detector*
- *1mm thick*
- *Vbias = -500V*
- *Eth = 50% beam energy*

Quantum Efficiency(*):
- Sum of the counts on irradiated pixels/photon fluxes measured with calibrated diodes

Simulation performed with HORUS:

(JINST 6 P06007 2011)

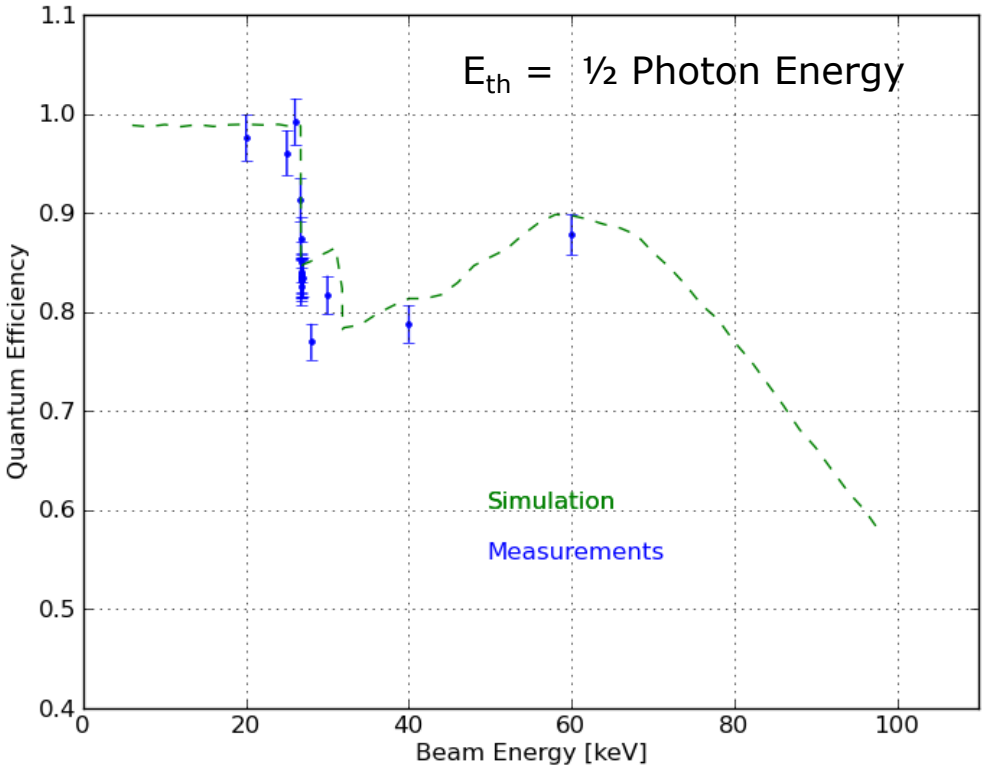
Scripts provided by D. Pennicard (DESY)

Simulation parameters:
- *CdTe 1mm*
- *Thr/E 50%*
- *Pixel size 172µm*
- *Bias voltage -500V*

(*) T.Donath et al., J. Phys.: Conf. Ser. ***425****, 062001 (2013)*

Quantum Efficiency

Element	K edge	$K_{\alpha 1}$	$K_{\alpha 2}$	$K_{\beta 1}$	$K_{\beta 2}$
Cd	26.7	22.98	23.17	26.09	26.64
Te	31.8	27.2	27.47	31.00	31.70



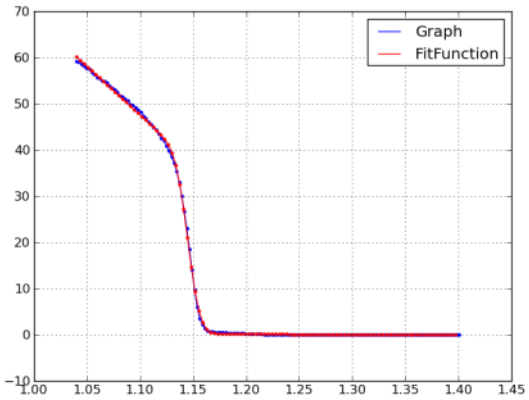
PILATUS3 CdTe
1 mm
Vbias=-500 V:

~100% for E<26.7 keV
~80% for 26.7<E<40keV
due to Cd and Te fluorescence

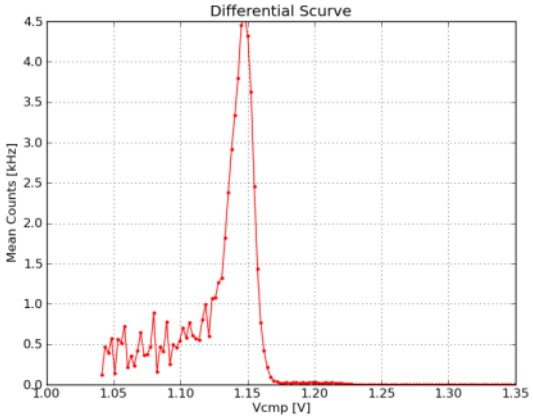
Energy resolution

Beam Energy = 25keV

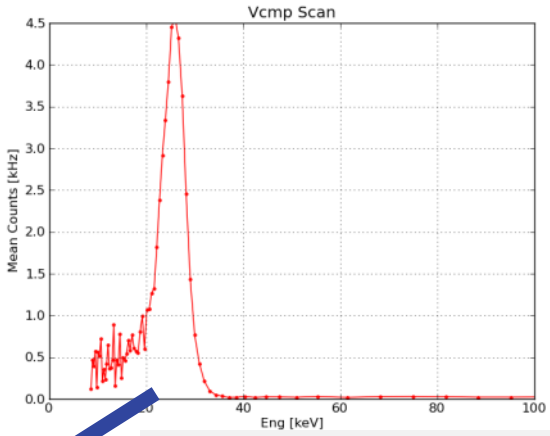
Scurve in threshold



differential

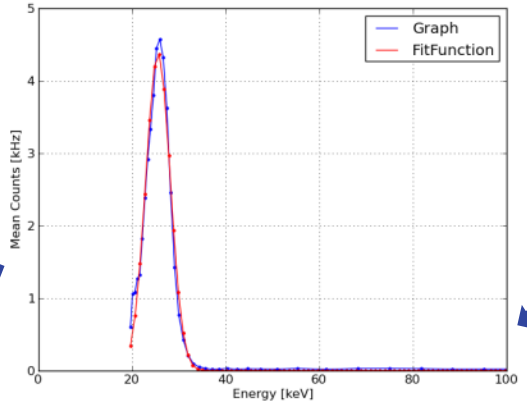


Xaxis rescaled in Energy



Gauss fitting function:

$$ae^{\frac{-(x-mean)^2}{b^2}}$$

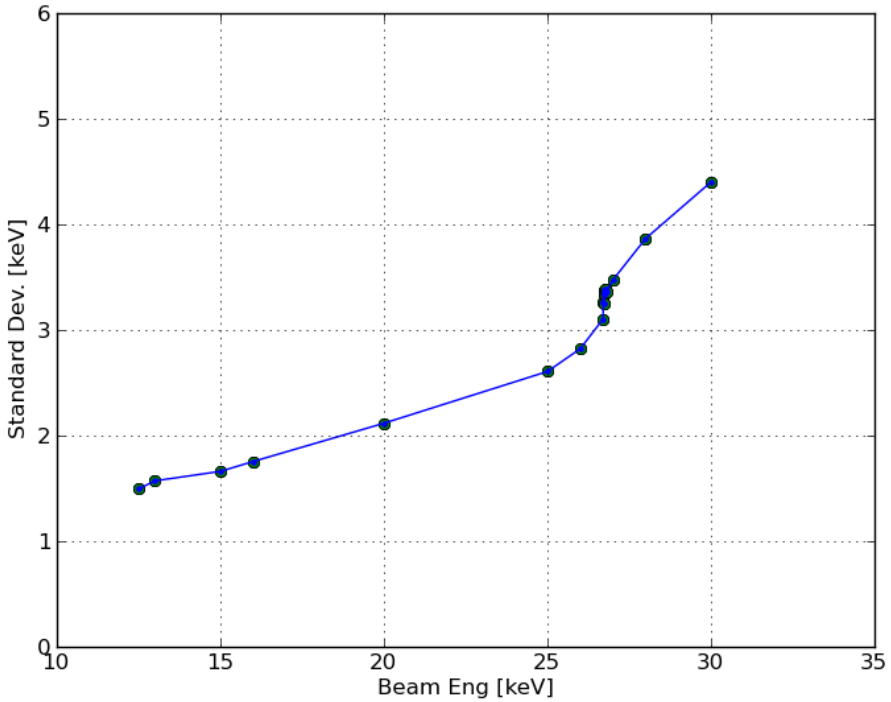


$$StandardDev.\sigma = {}^{b}/_{\sqrt{2}}$$

$$FWHM \sim 2.35 \cdot \sigma$$

Energy resolution

Element	K edge	$K_{\alpha 1}$	$K_{\alpha 2}$	$K_{\beta 1}$	$K_{\beta 2}$
Cd	26.7	22.98	23.17	26.09	26.64
Te	31.8	27.2	27.47	31.00	31.70



PILATUS3 CdTe
1 mm
Vbias=-500 V:

Resolution = 2.1 keV @ 20 keV
FWHM = 4.9 keV @ 20 keV
FWHM/Eng = 25 % @ 20 keV

Resolution get worse above 26 keV

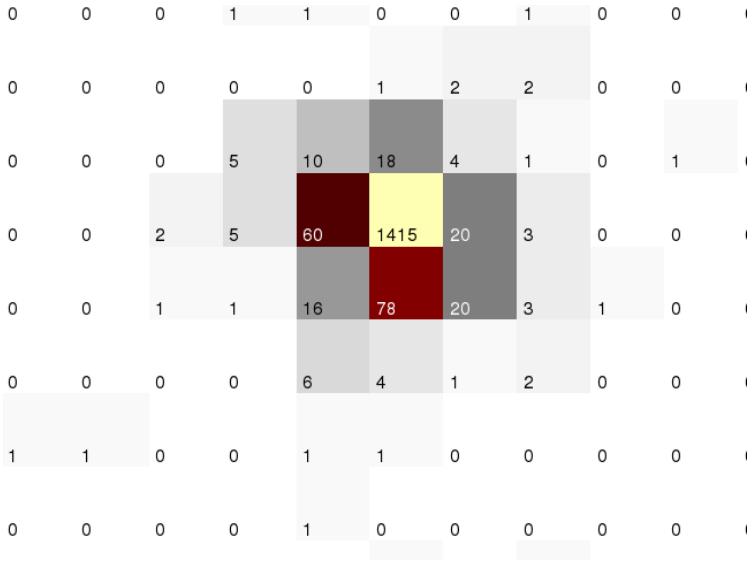
Point Spread Function

Measurements performed at BAM line:

- *Beam energy in range 26- 50keV*
- *Max flux 50kcps*
- *20µm pinhole beam*

Detector:
- *PILATUS3 CdTe detector*
- *1mm thick*
- *Vbias = -500V*
- *Eth = 50% beam energy*
- *Detector moved through the beam scanning an area of 750µm in steps of 20µm (five consecutive pixels)*

Point Spread Function definition(*):
- *Counts detected by a individual pixels as a function of beam position*



Point beam, beam Energy 28 keV, exposure time 0.1s,

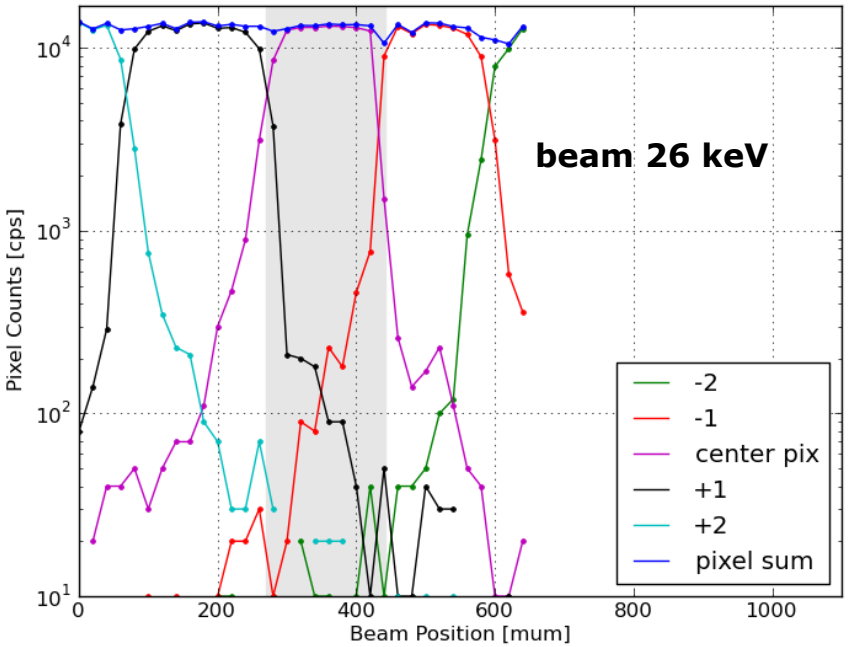
*(*) T.Donath et al., J. Phys.: Conf. Ser. **425**, 062001 (2013)*

PSF 26keV vs 28keV

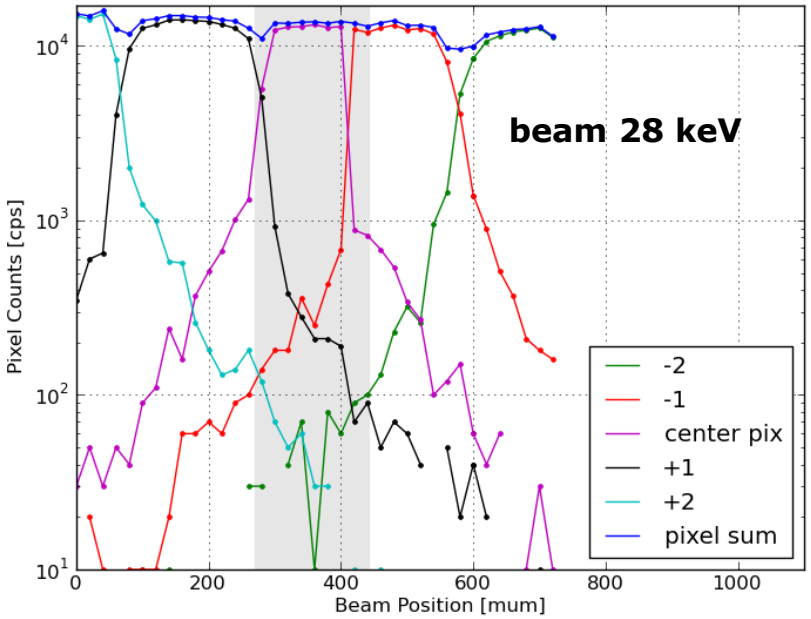
Element	K edge	$K_{\alpha 1}$	$K_{\alpha 2}$	$K_{\beta 1}$	$K_{\beta 2}$
Cd	26.7	22.98	23.17	26.09	26.64
Te	31.8	27.2	27.47	31.00	31.70

PILATUS3 CdTe
1 mm
Vbias=-500 V:

- *26 keV beam: steep fall of the PSF by 3order of magnitude on one pixel distance*
- *28 keV beam: fluorescence photons in the neighbor pixels*



Pixel counts vs beam position, Log Scale



Pixel counts vs beam position, Log Scale

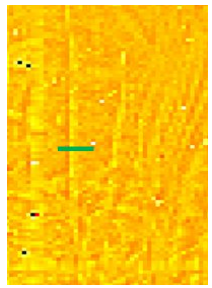
Point Spread Function

PSF measured over a CdTe distortion line:

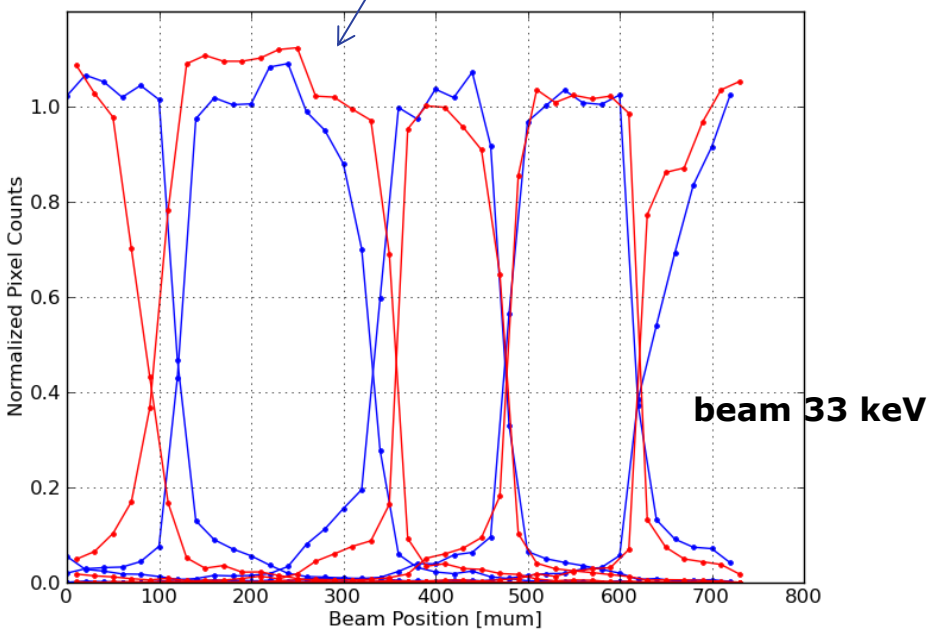
- ***BLUE CURVE:*** *before irradiation*
- ***RED CURVE:*** *after 15 hours of irradiation with Beam 33 keV and flux 2.5Mcps (slide 12)*

PILATUS3 CdTe
1 mm
Vbias=-500 V:

- *Evidence of the line formation with an increase of the width of PSF curve of the pixel with higher counts (yellow color in the image)*



Pixel 341,61 (yellow)



Pixel counts vs beam position

Summary

- ***Demonstrated the first multimodule PILATUS3 CdTe Detector***
- ***Count stability achieved operating at bias voltage -500V***
- ***Characterization of the CdTe 1mm:***
  - ***Quantum efficiency in agreement with simulation***
    - ~100% for E<26.7 keV
    - ~ 80% 26.7<E<50keV
    - 90% @60keV
  - ***Resolution of 2.1 keV @ 20 keV***
  - ***PSF as expected for 172µm pixel and E< 26.7 keV,***
  - ***Fluorescence Cd and Te photons are also measured in the neighbor pixel***
  - ***Widened PSF for a pixel in the CdTe distortion line after irradiation***

Thank you for your attention

Mean count stability
BAM beam line (May 2014)