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PSI

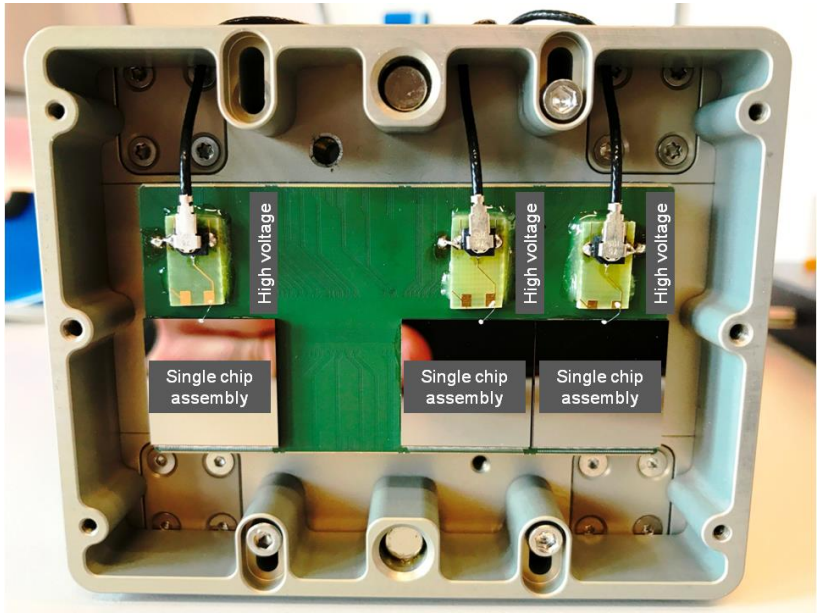
Markus Meyer :: PSD Detectors Group* :: Paul Scherrer Institut

Advancements of high-Z sensor materials evaluated by the low noise, charge-integrating pixel detector JUNGFRAU

21th iWoRiD, Kolympari, 10. July 2019

*** Within Synerjix - Collaboration with ESRF**

JUNGFRAU – charge integrating detector chip



JUNGFRAU	
Pixel size	75 x 75 µm^2
Number of pixels	Single chip: 65k Full module: 0.5M
Noise (r.m.s.)	< 100 e$^-$ ENC (G0) < 55 e$^-$ ENC (HG0)
Dynamic range	< 1·10^4 x 12.4 keV (3 gain stages)
Maximum frame rate	2.4 kHz (cont.) < 1 MHz (burst*) *16 frames

- Using **full module** readout boards and place **three single chip assemblies**

→ **Water-cooling** (typically 15C)
→ **Frame rate: up to 1 kHz**

- **e$^-$ collection** mode

→ **Fixed gain mode (G0|M|L)**
→ **No D**ynamic**G**ain**S**witching (h$^+$ only)
→ **Next iteration** has **native electron collection** (currently evaluated)

presentation outline

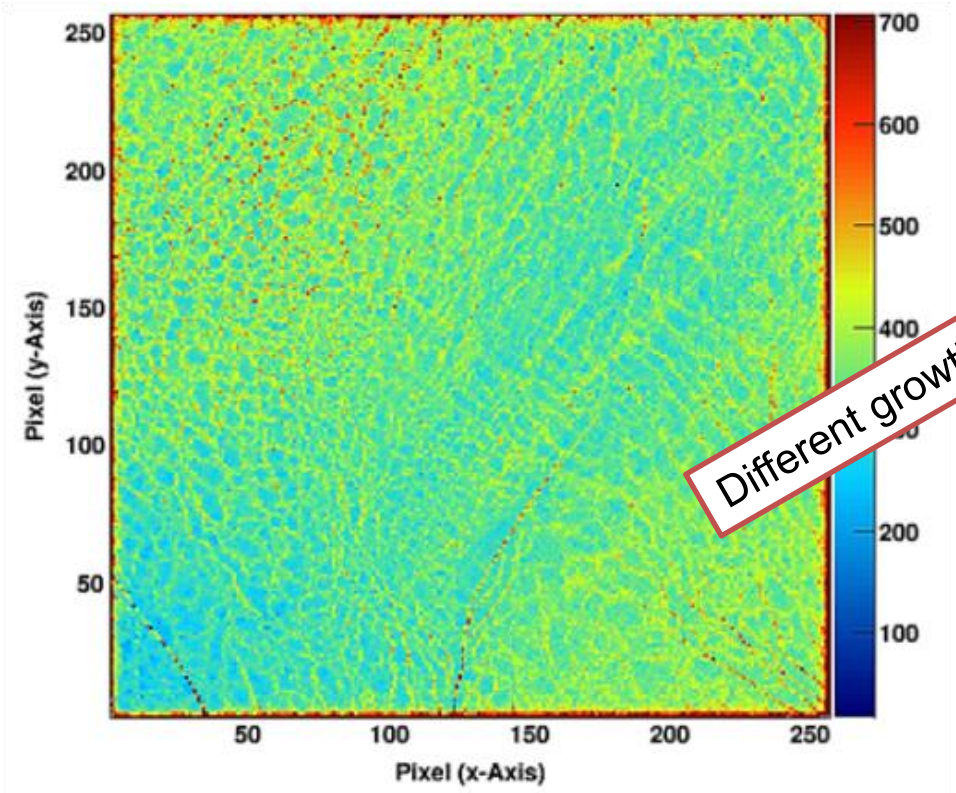
- **Advancements in high-Z material**
- **Pencil beam scan – Experimental**
- **Pencil beam maps**
  - **GaAs:Cr…**
    - **… overview**
    - **… at different energies**
    - **… with higher resolution**
  - **CdTe (ohmic and eSchottky contact)**
- **Conclusion & Outlook**

dark current map of GaAs:Cr sensors

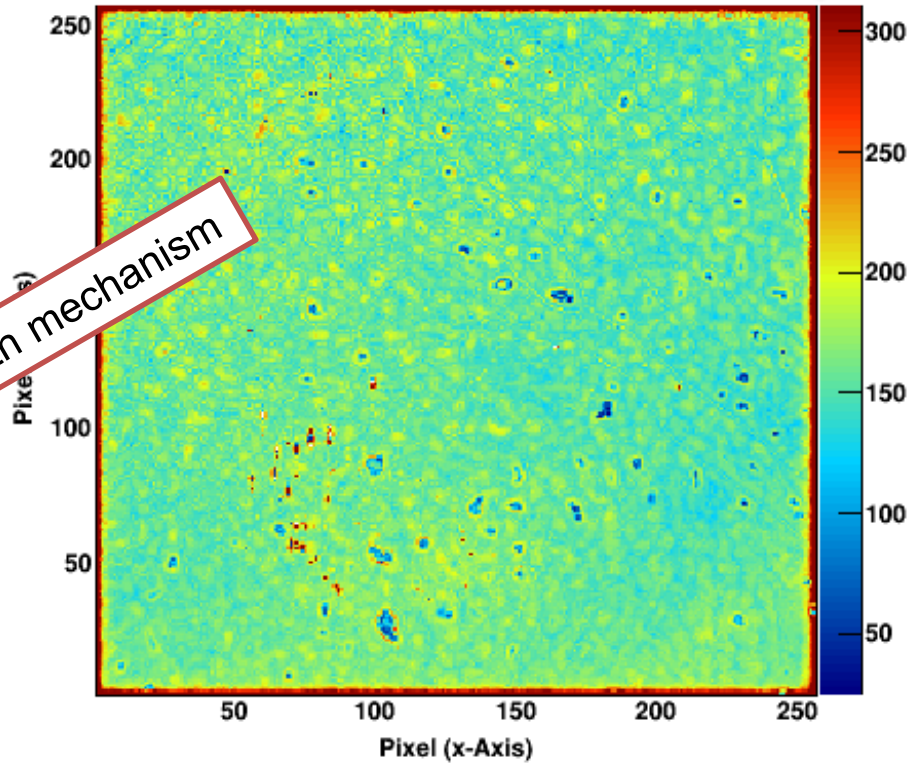
2016 **2017**

T = +15 ºC

Dark current [pA]

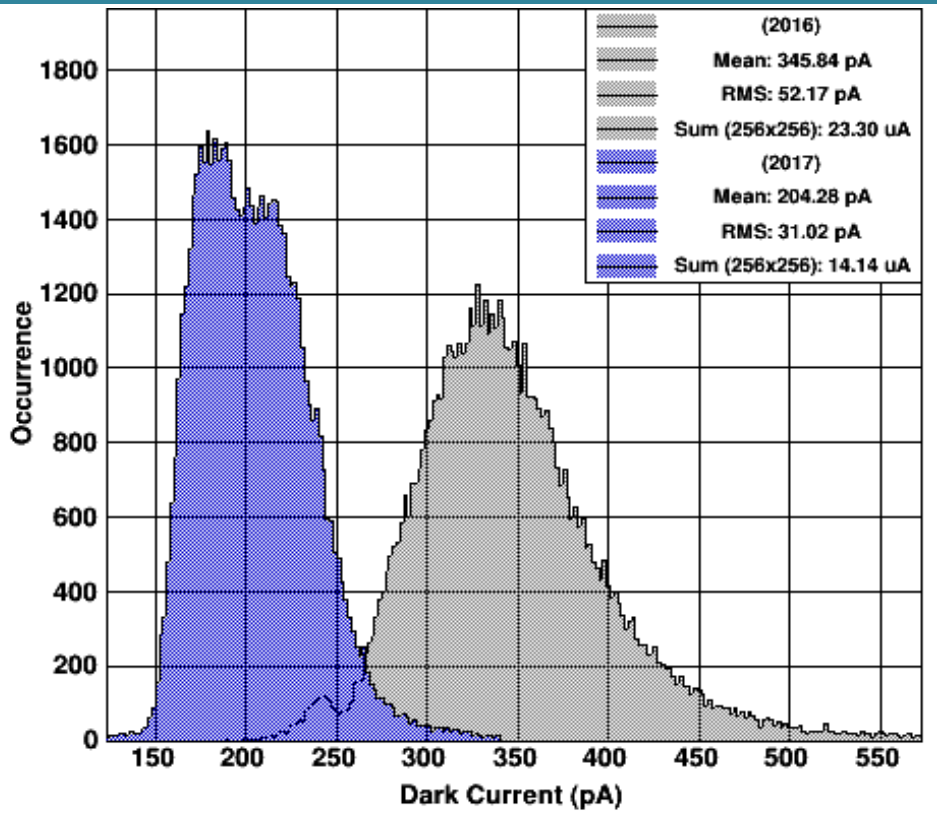


Different growth mechanism



dark current comparison of GaAs:Cr sensors

Comparison: GaAs (2016) vs. GaAs (2017)



GaAs from year	Mean current per pixel	RMS of distribution	Current thru bulk
2016	346 pA	52 pA	23.3 µA
2017	204 pA	31 pA	14.1 µA

Charge-integrating pixel detector:

Direct measurement of (**dark/leakage/signal) current** through **each pixel** possible

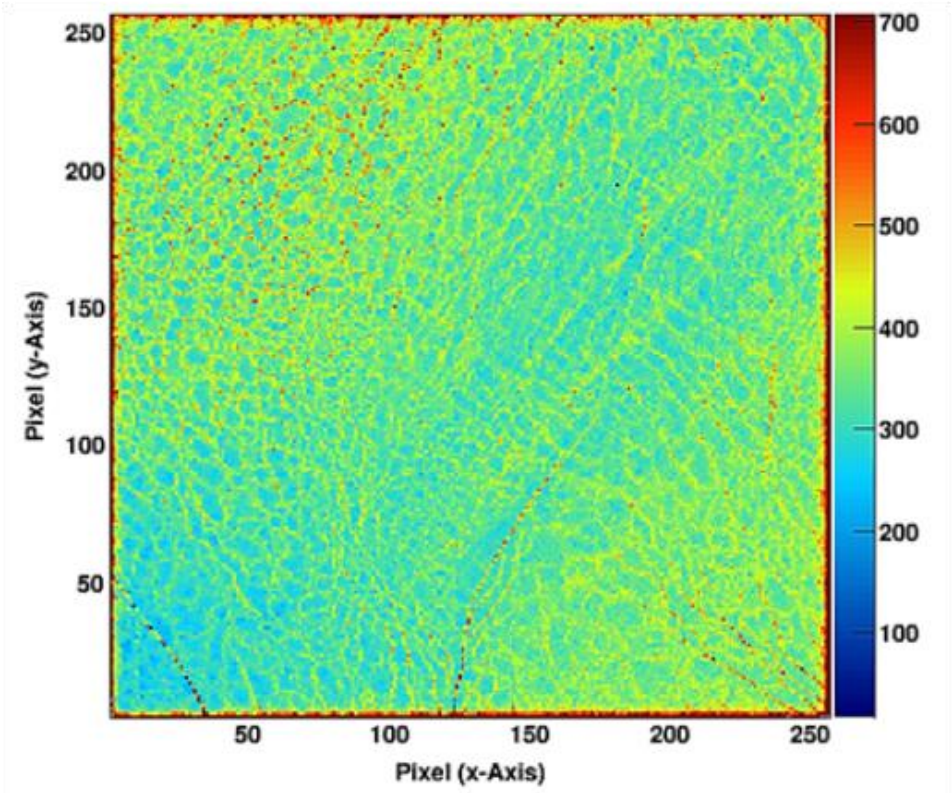
Dynamic range limited by **dark current**

Improving dark current properties over the years

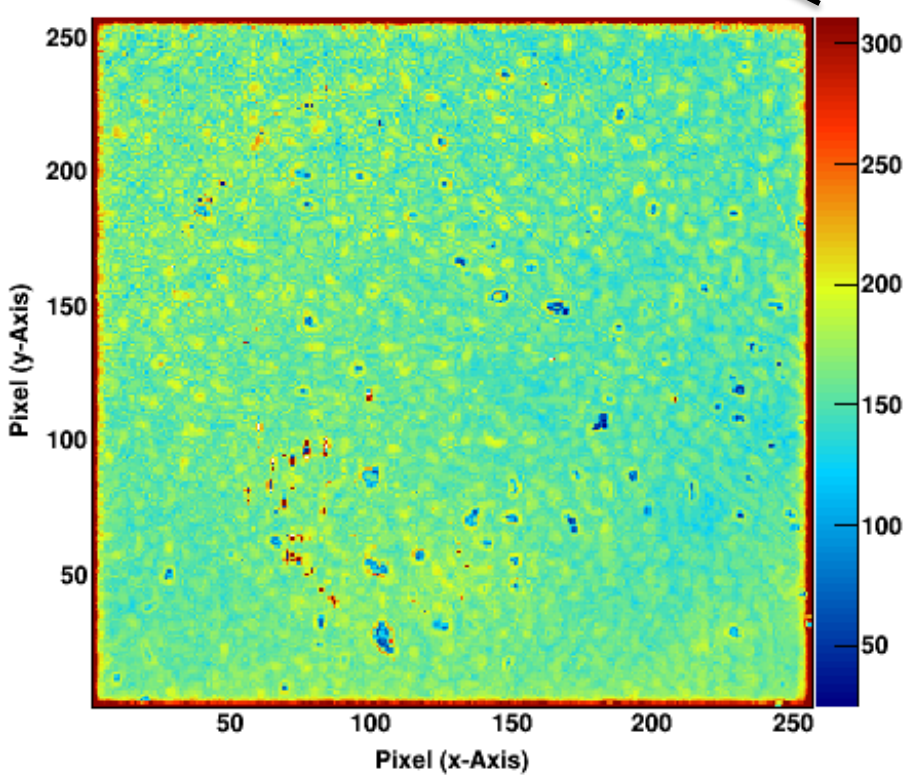
dark current map of GaAs:Cr sensors

2016 | **2017**

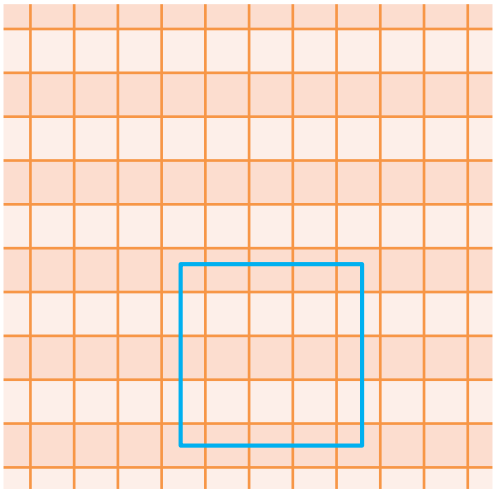
T = +15 ºC



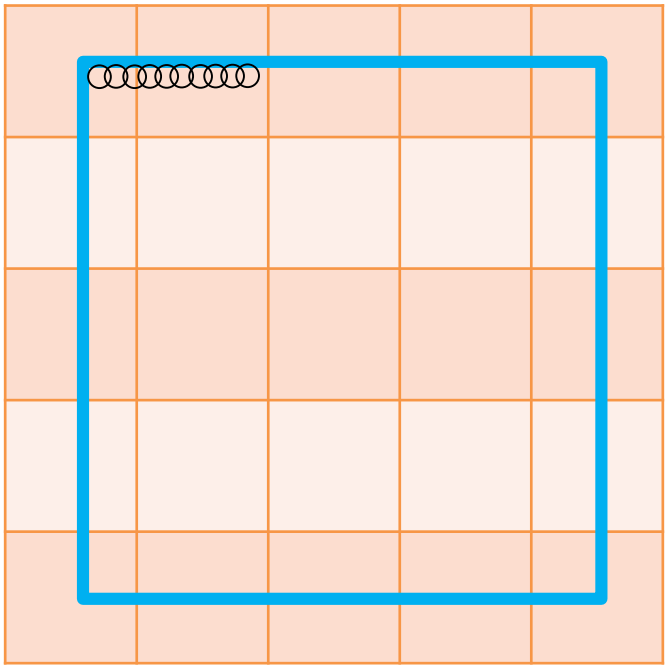
Dark current [pA]



pencil beam scan - experimental



75µm

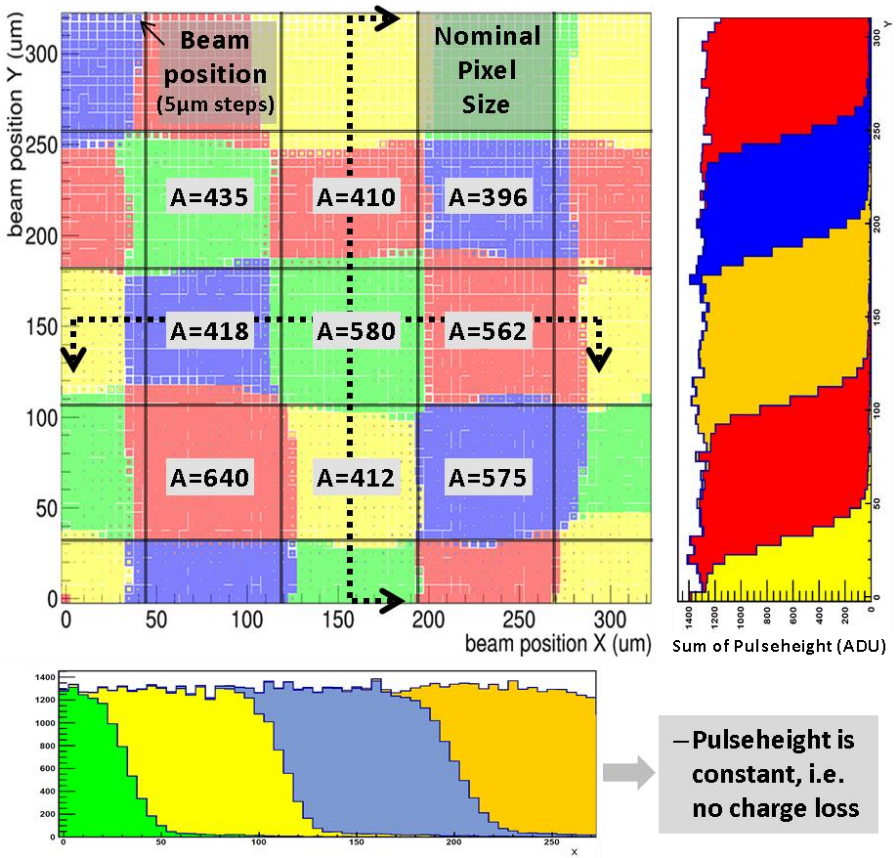


Aim:
determine effective pixel size

Pitch:	5 µm
Spot size:	< 4 µm
	(<10 µm for 30 keV)
Position precision:	< 1 µm

first results - iWoRiD 2018

GaAs Sensor (2016): Pencil Beam Scan (20 keV) @ ESRF

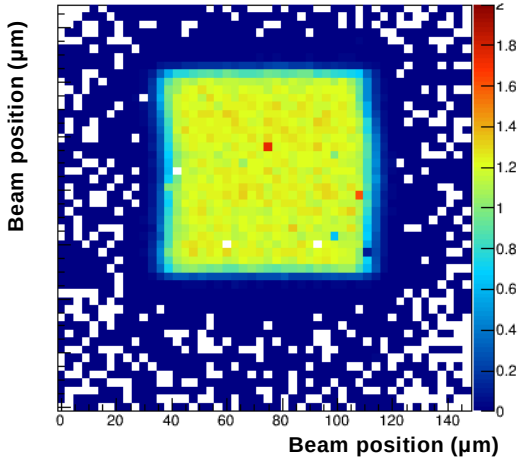


Effective pixel size varies **drastically between pixels (c**ross checked with Si pixels)

Flatfield correctable (not seen with counters)
… however flat field correction is only hiding this effect

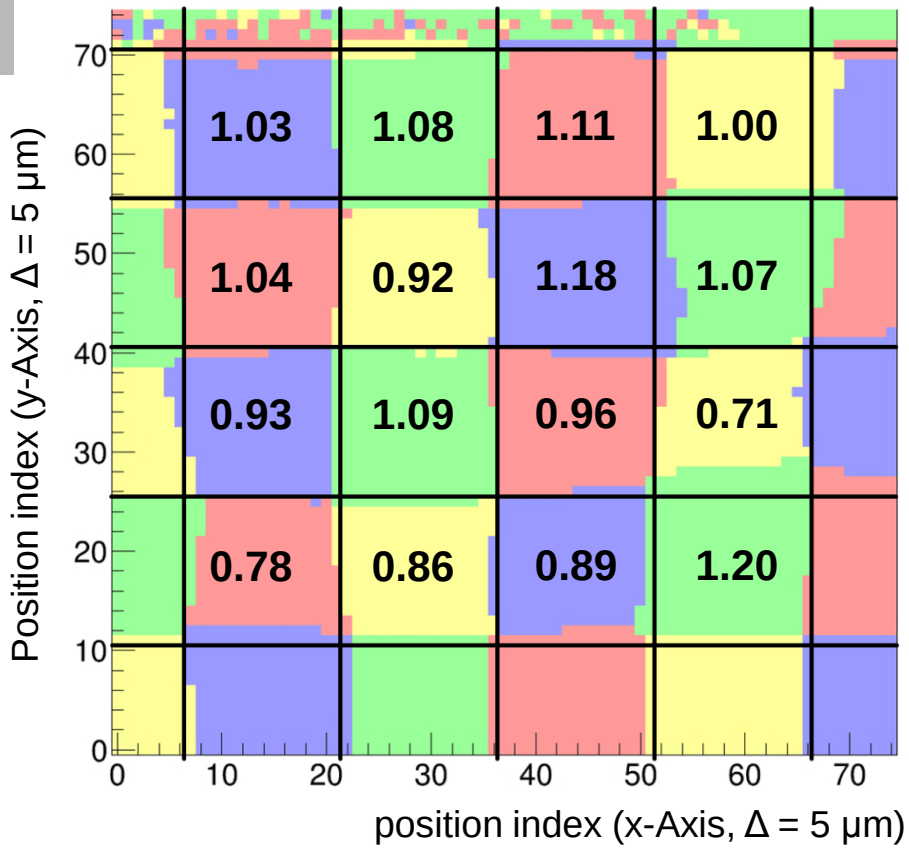
→ **Severe implications** for **interpolation technique** (Clusterwise interpolation matrix)

Si Sensor: Pencil Beam Scan



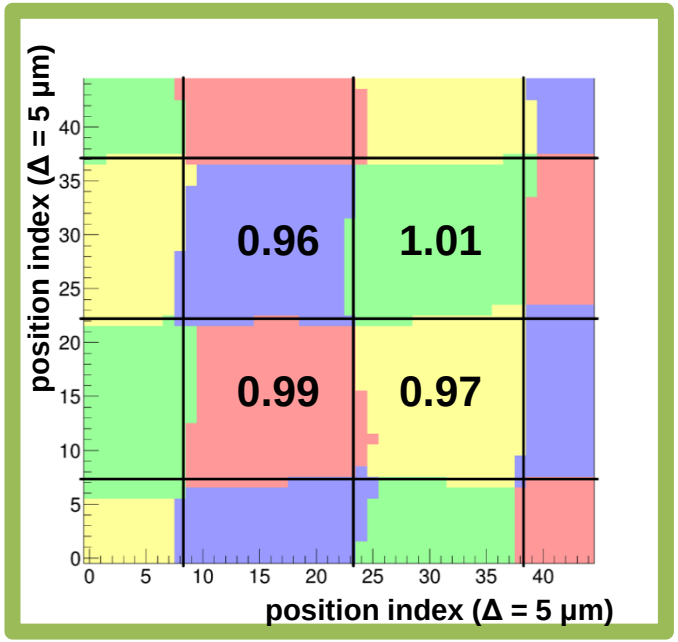
is pixel size variation reproducible?

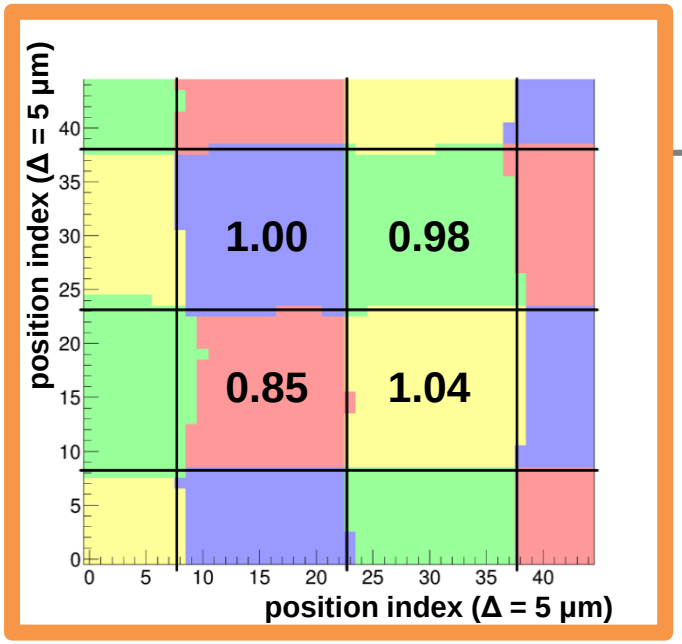
GaAs Sensor (2016): Pencil Beam Scan (20 keV) @ ESRF

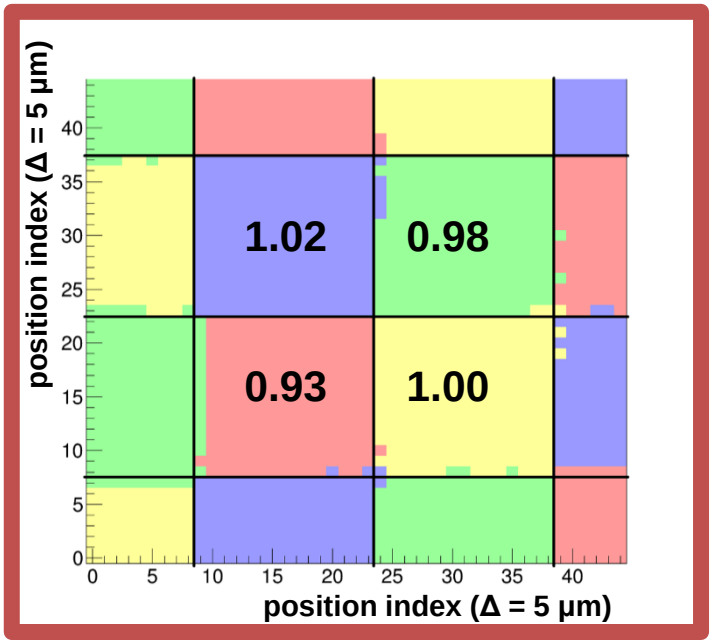


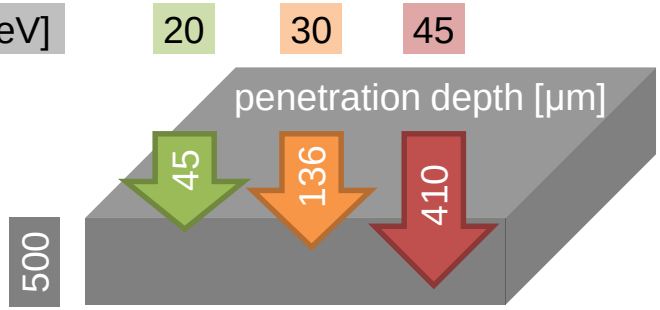
E_{Phot} dependency

GaAs Sensor (2017): Pencil Beam Scan @ ESRF





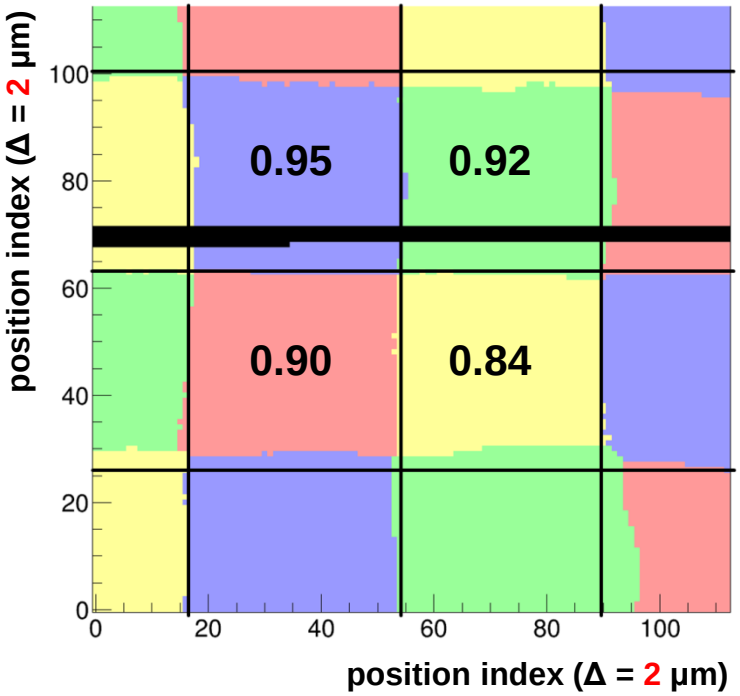




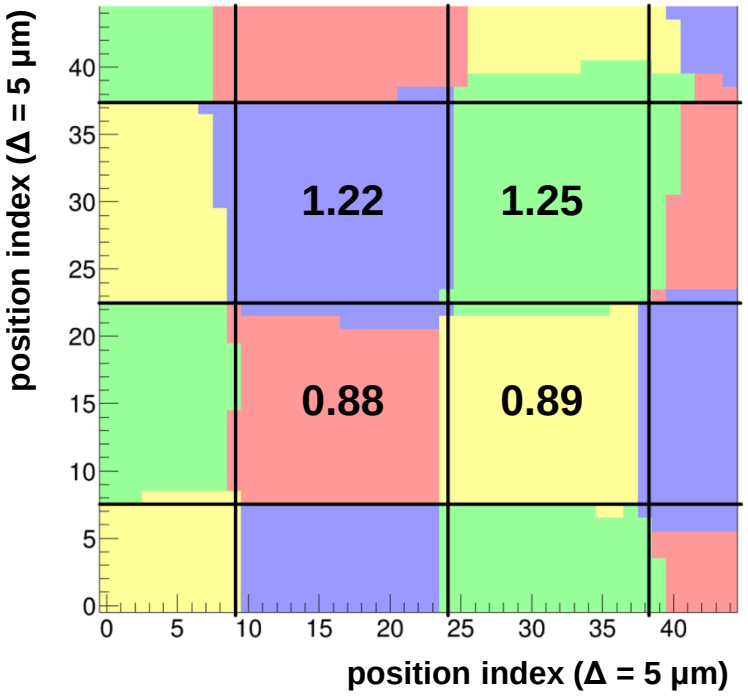
higher resolution

GaAs Sensor (2016): Pencil Beam Scan @ ESRF

45 keV – 2 µm pitch – 07/2017

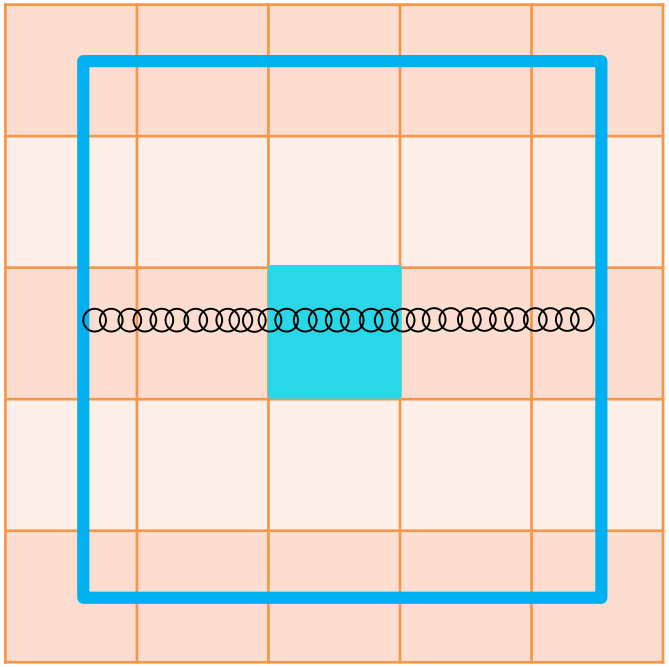


20 keV – 5 µm pitch – 04/2018



CdTe – ohmic contact

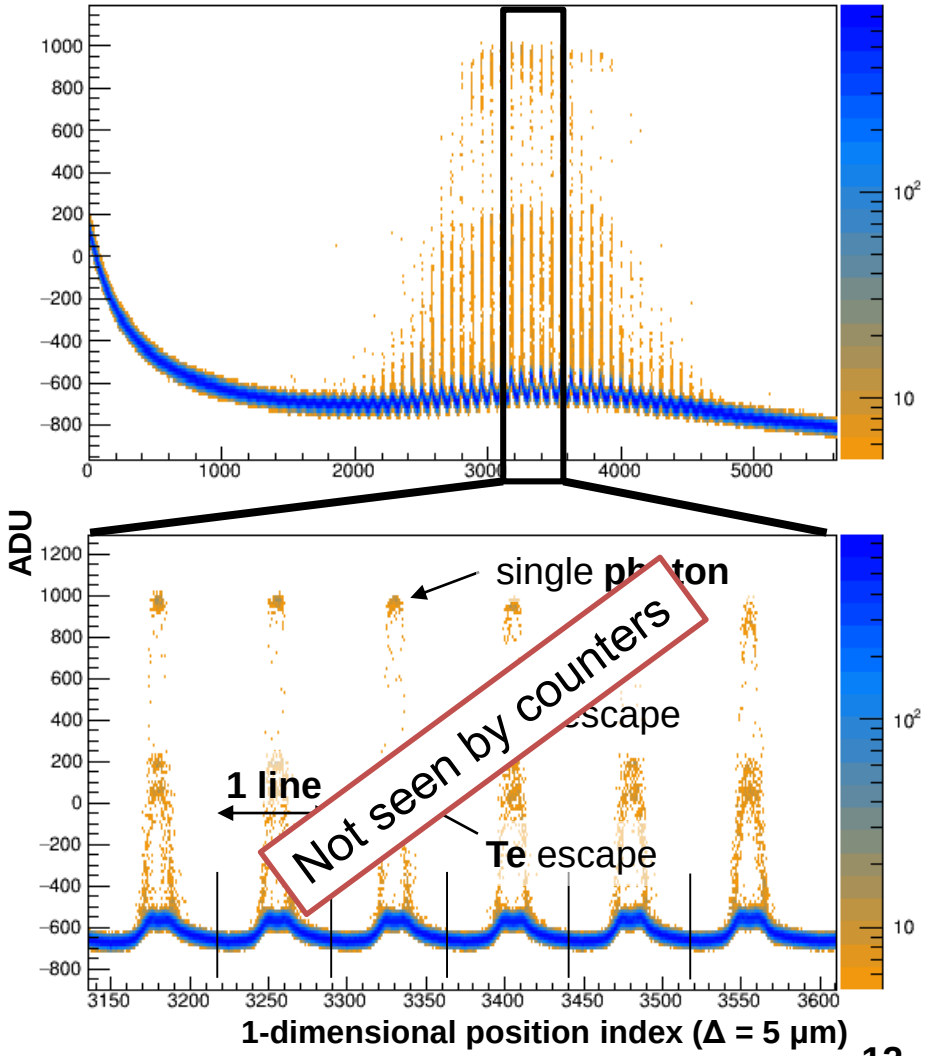
CdTe Ohmic: Pencil Beam Scan (45 keV) @ ESRF



Note:

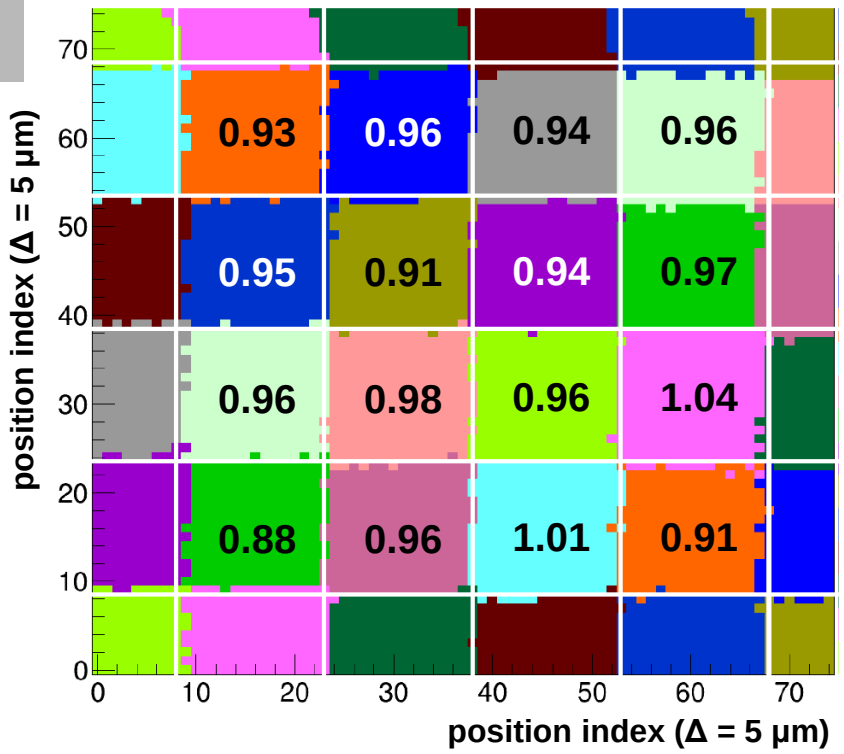
Penetration depth @45keV:	120 µm
Sensor thickness:	750 µm

Single pixel response



CdTe – ohmic contact

CdTe Ohmic: Pencil Beam Scan (45 keV) @ ESRF



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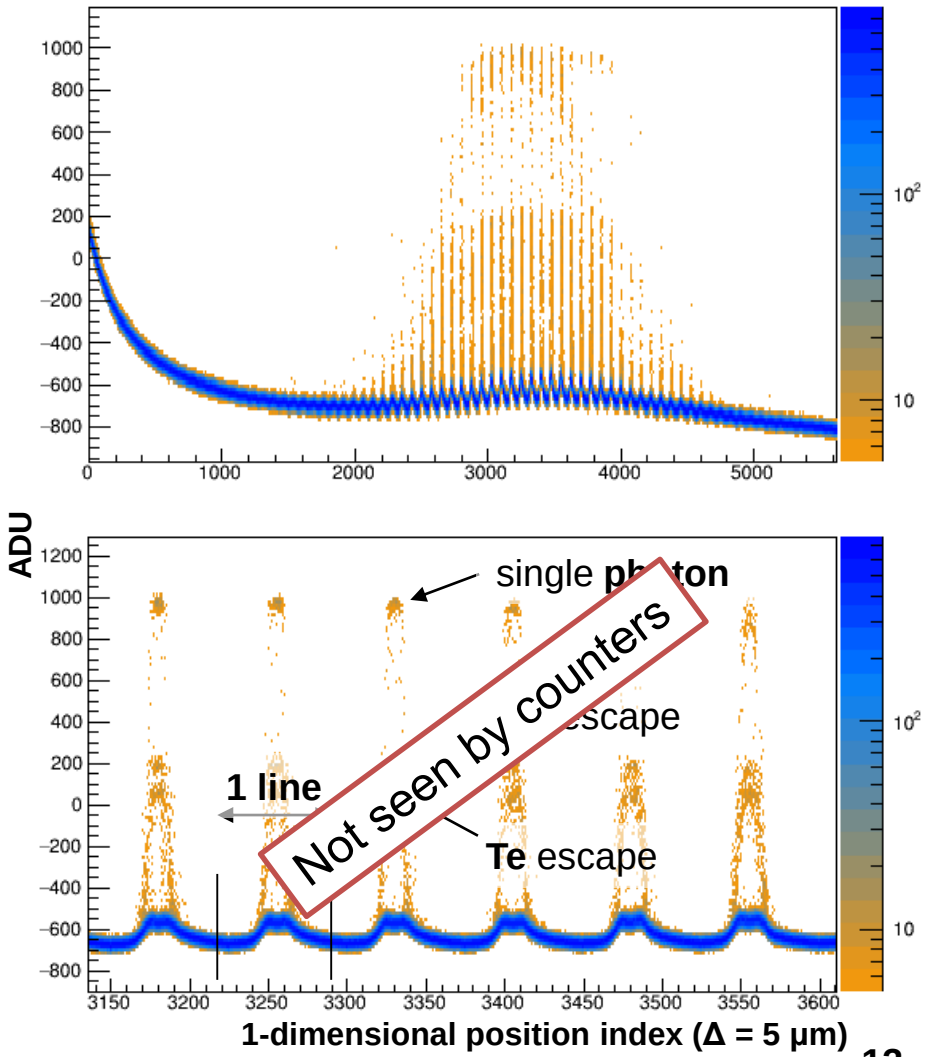
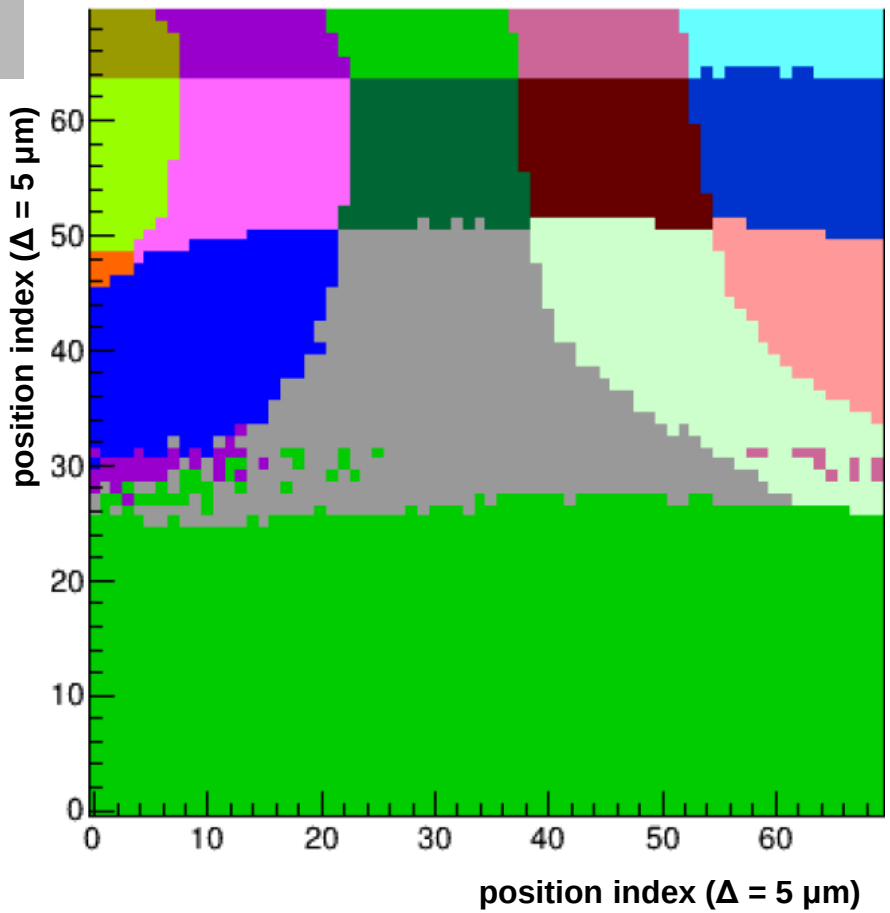
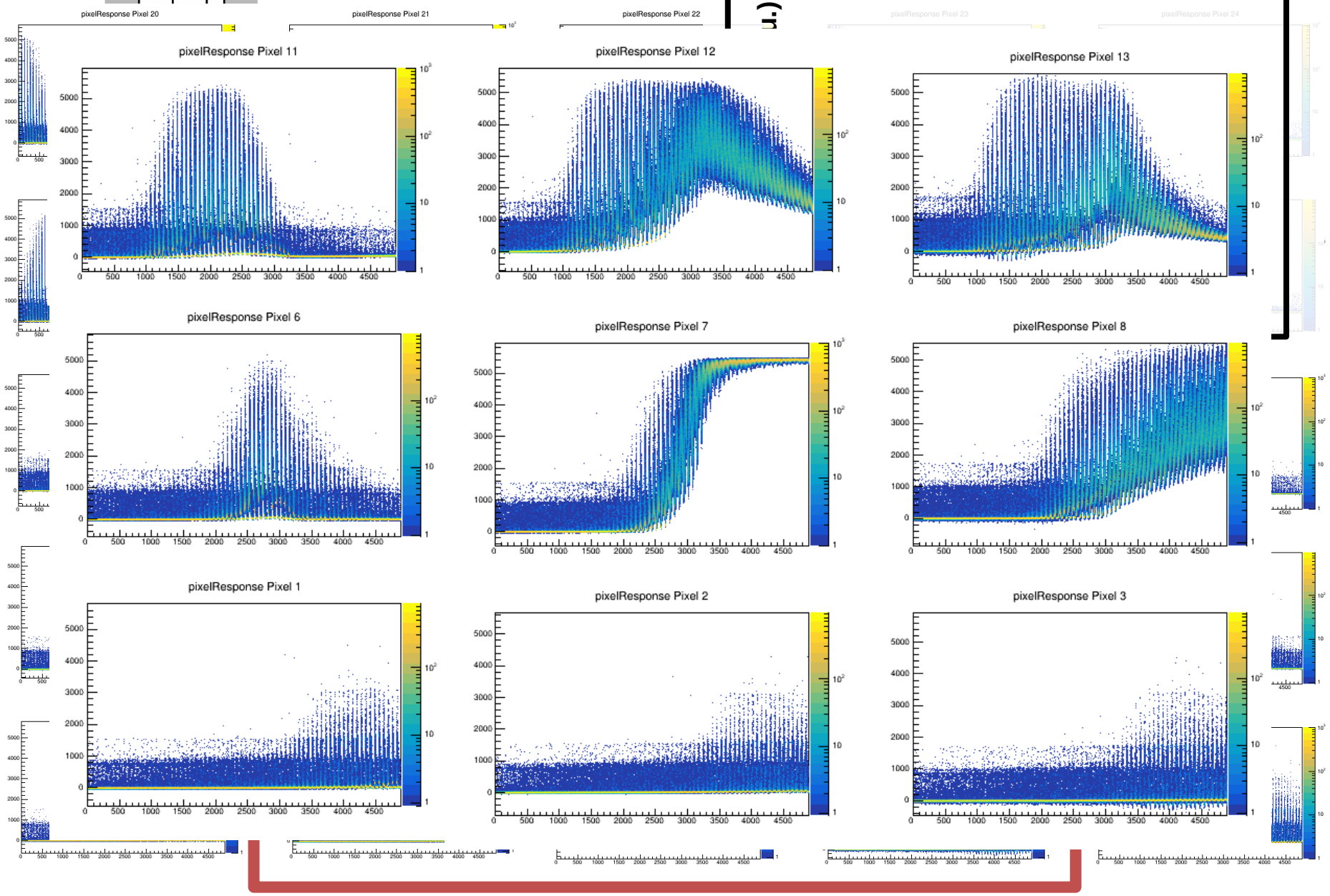


CdTe – eSchottky contact

CdTe eSchottky: Pencil Beam Scan (45 keV) @ ESRF

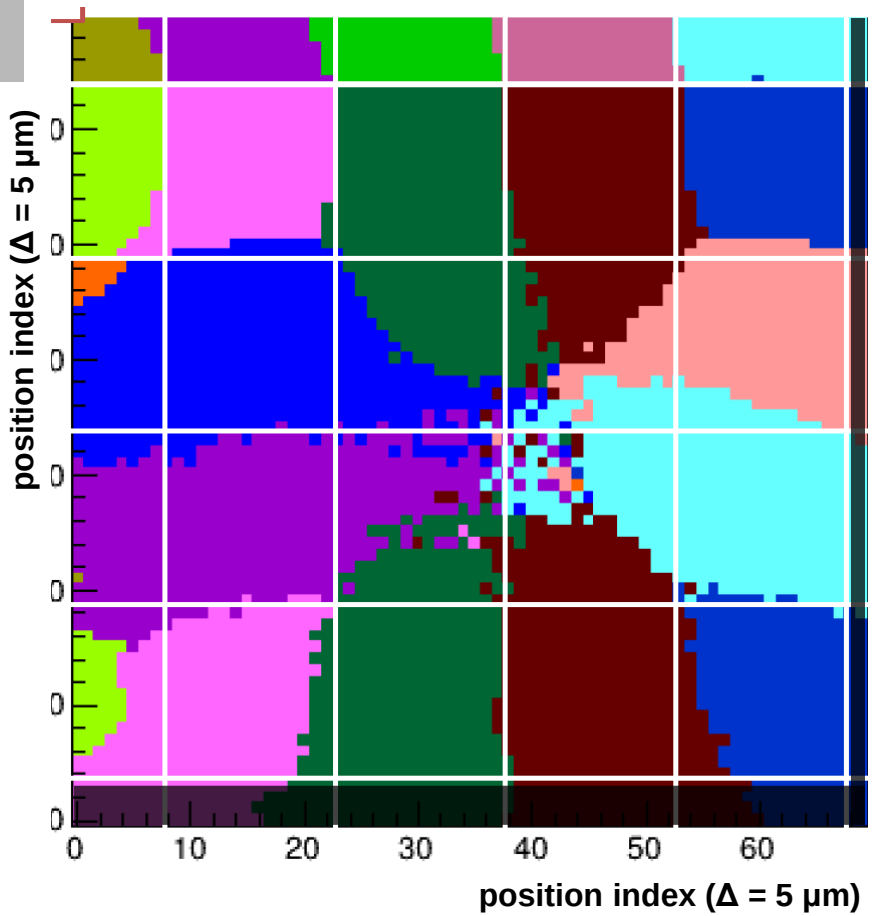


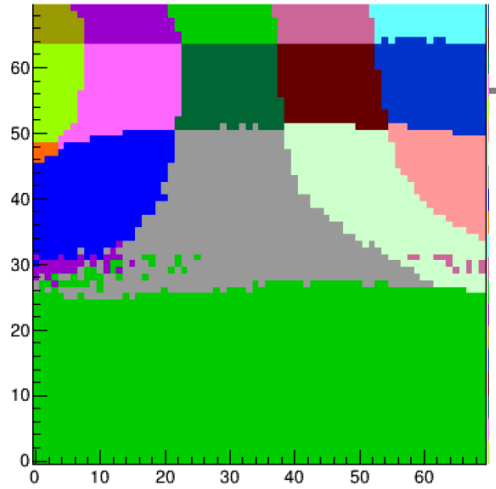
single pixel response



CdTe – eSchottky contact

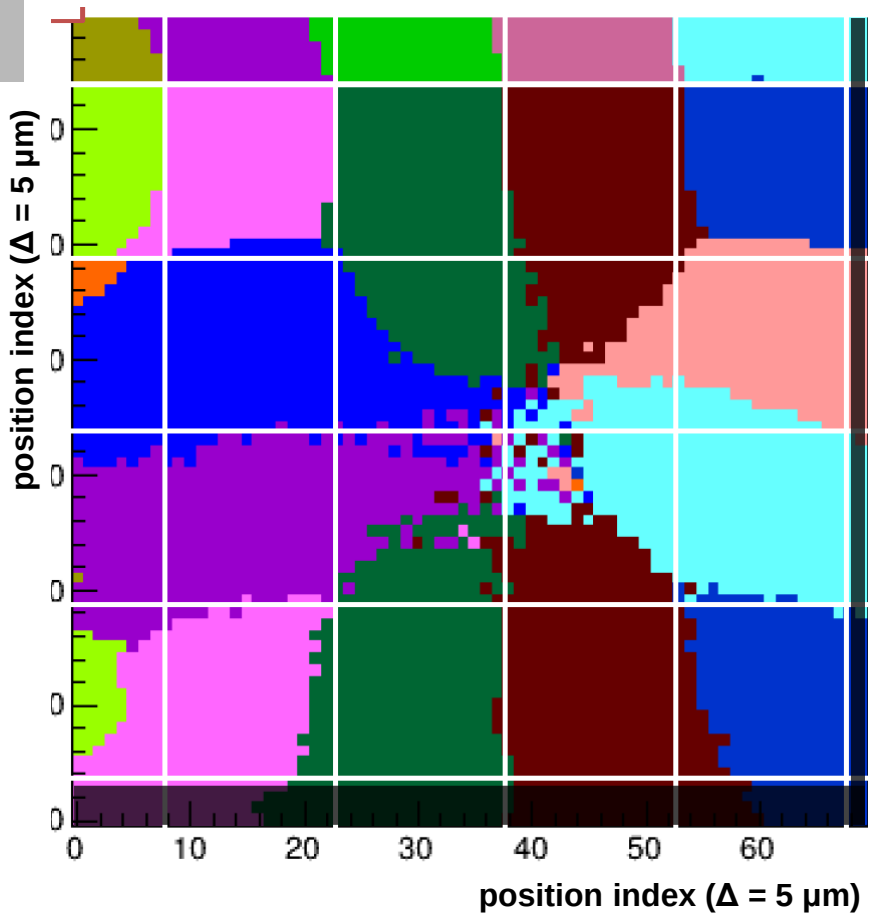
CdTe eSchottky: Pencil Beam Scan (45 keV) @ ESRF



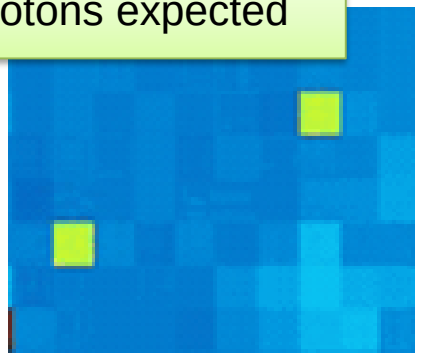


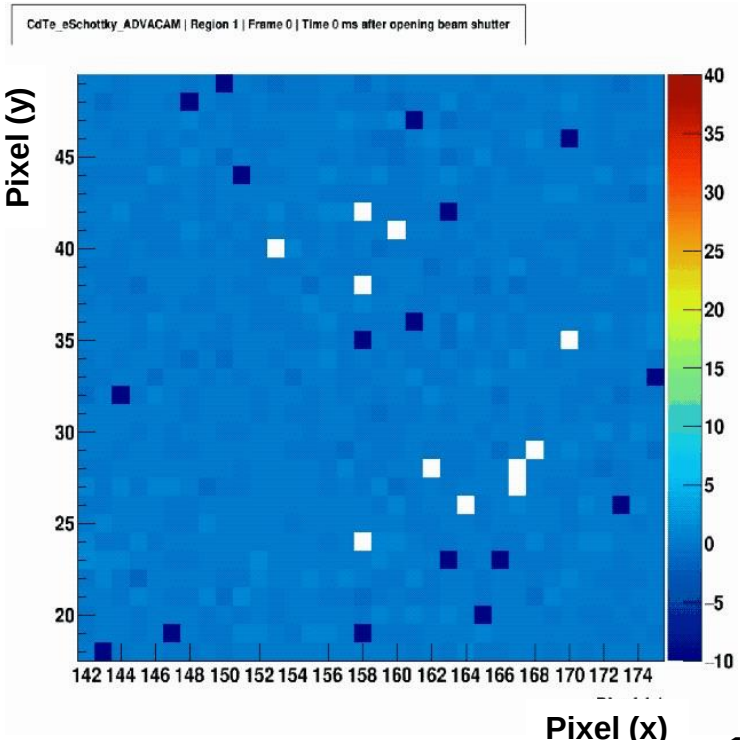
CdTe – eSchottky contact

CdTe eSchottky: Pencil Beam Scan (45 keV) @ ESRF



20 keV photons expected





Conclusion

GaAs:

- Varying pixel size (quite stable over time)
- More defined at higher energies due to higher penetration depth.

CdTe ohmic contact:

- Well defined pixels

CdTe eSchottky contact:

- Repeat measurement aiming at intact ROI
- Understand arc behavior in more detail

Outlook:

- Increase statistic …

… combined with increased vertical and horizontal resolution

Thank you very much for your attention !

- SLS Detector Group - PSI

Anna Bergamaschi, Rebecca Barten, Martin Brückner, Sabina Chiriotti, Roberto Dinapoli, Erik Fröjdh, Dominic Greiffenberg, Carlos Lopez-Cuenca, Markus Meyer, Davide Mezza, Aldo Mozzanica, Sophie Redford, Christian Ruder, Bernd Schmitt, Xintian Shi, Dhanya Thattil,Gemma Tinti, Seraphin Vetter and Jiaguo Zhang

- Synerjix collaboration - ESRF

Paolo Busca, Pablo Fajardo and Marie Ruat

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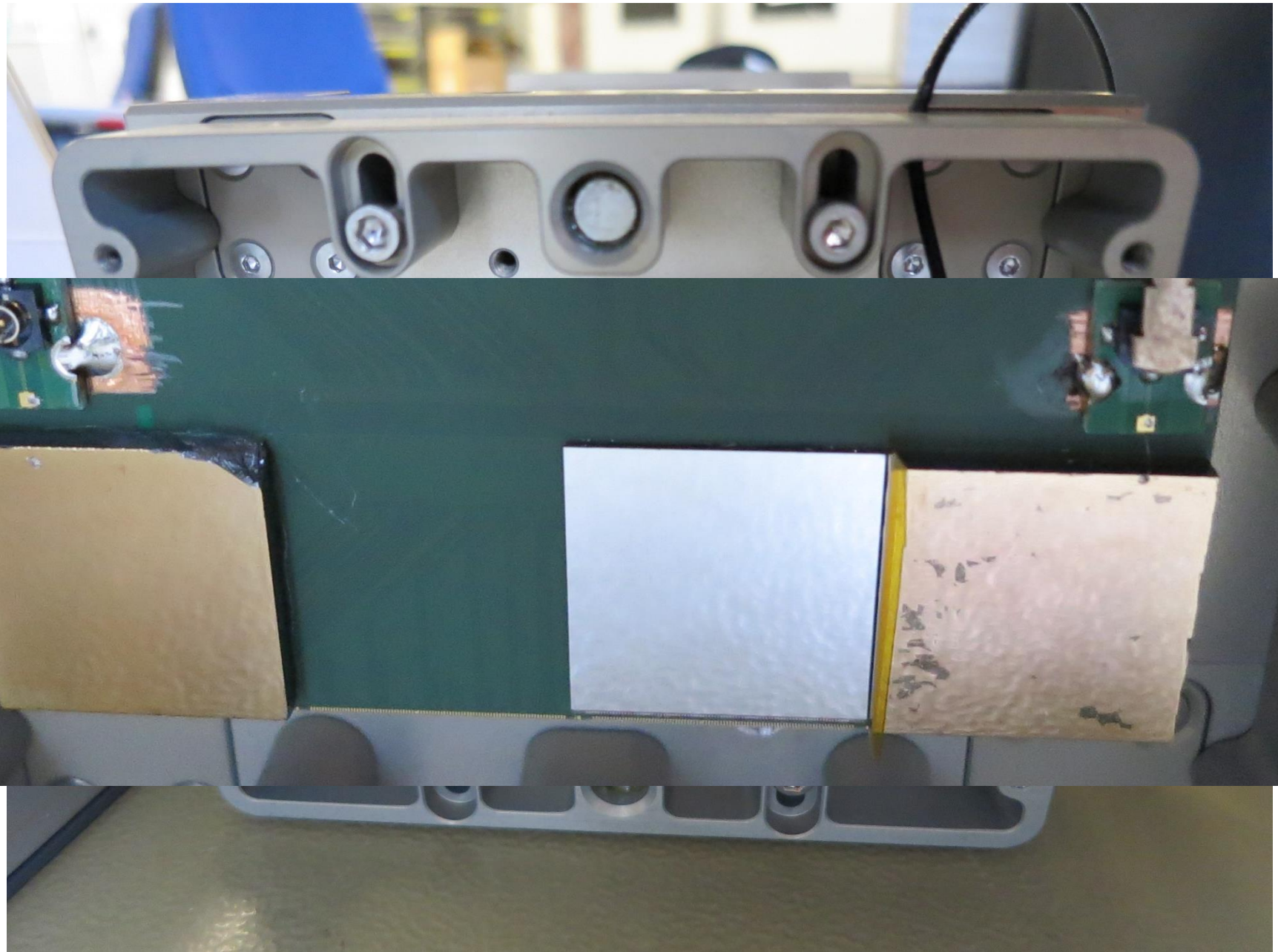
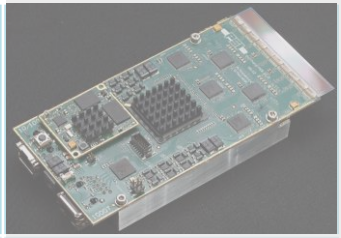


Charge integrating detectors

	GOTTHARD	AGIPD[1]	JUNGFRAU	MÖNCH
				
Technology	IBM 130 nm	IBM 130 nm	UMC 110 nm	UMC 110 nm
Status	Modules available	Modules available	Modules available	(Advanced) Prototyping
Pixel size	50 µm (Strips)	200 x 200 µm^2	**75 x 75 µm^2**	**25 x 25 µm^2**
Maximum system size	Modules (=10 ASICs)	1Mpixel (=16 Modules)	16Mpixel (=32 Modules)	Single Chips (=2x3 cm^2)
Noise (r.m.s.)	<200 e$^-$ ENC	< 322 e$^-$ ENC < 214 e$^-$ ENC (HG)	**< 100 e$^-$ ENC (G0)** **< 55 e$^-$ ENC (HG0)**	**<35 e$^-$ ENC**
Dynamic range	**< 1·10^4 x 12.4 keV (3 gain stages)**	**< 1·10^4 x 12.4 keV (3 gain stages)**	**< 1·10^4 x 12.4 keV (3 gain stages)**	< 500 x 12.4 keV (2 gain stages)
Maximum	40 kHz (cont.)		2.4 kHz (cont.)	**6-8 kHz**

[1] Developed with the University of Bonn (GER), the University of Hamburg (GER) and DESY

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Paper DG