Experimental characterization of the PERCIVAL soft X-ray detector

Alessandro Marras,
C.B. Wunderer, M. Bayer, J. Correa, P. Goettlicher, S. Lange, I. Shevyakov, S. Smoljanin, M. Viti, Q. Xia, M. Zimmer, D. Das, N. Guerrini, B. Marsh, I. Sedgwick, R. Turchetta, G. Cautero, D. Giuressi, A. Khromova, R. Menk, L. Stebel, G. Pinaroli, R. Fan, J. Marchal, U. Pedersen, N. Rees, P. Steadman, M. Sussmuth, N. Tartoni, H. Yousef, H. Hyun, K. Kim, S. Rah, S. Reza,
and H. Graafsma

Outline

Percival:

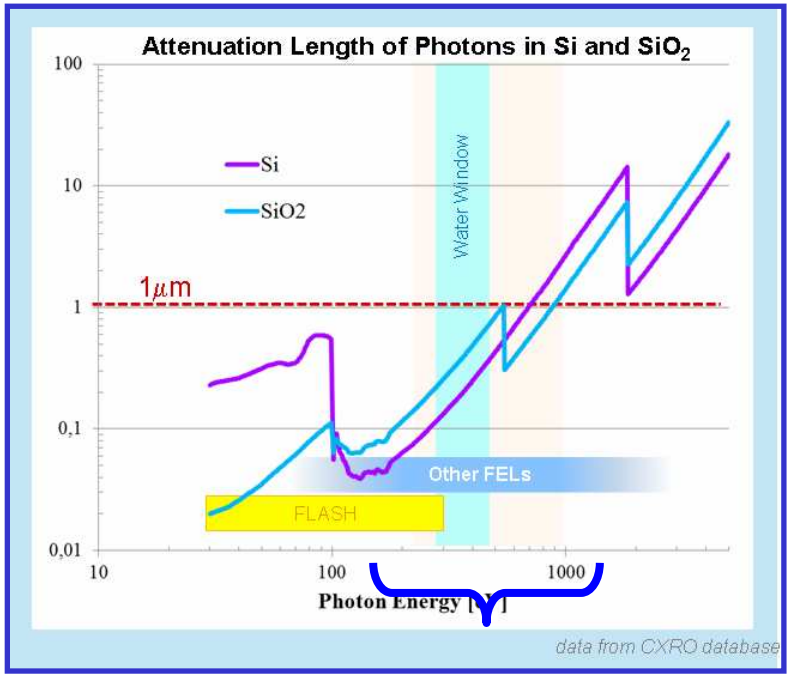
- why do we do it
- how do we do it
- when will it be available
- what's special about it
    - the full system
    - the prototypes
    - lateral overflow

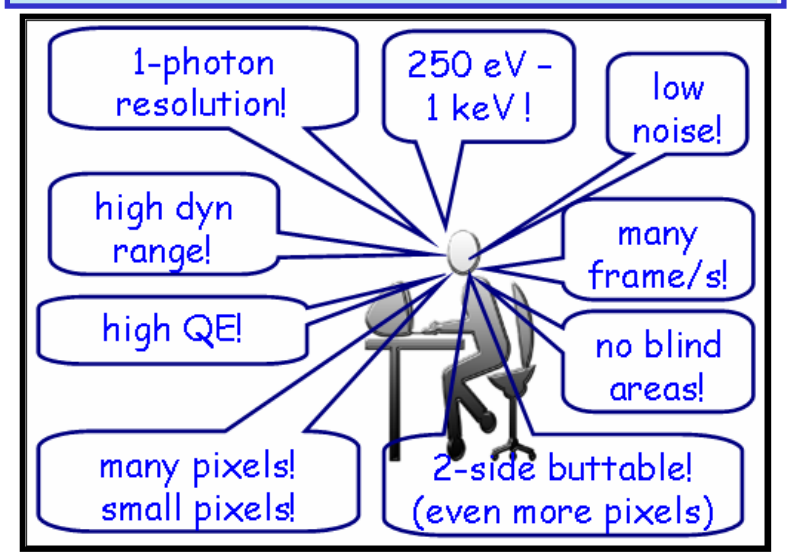
Percival performance

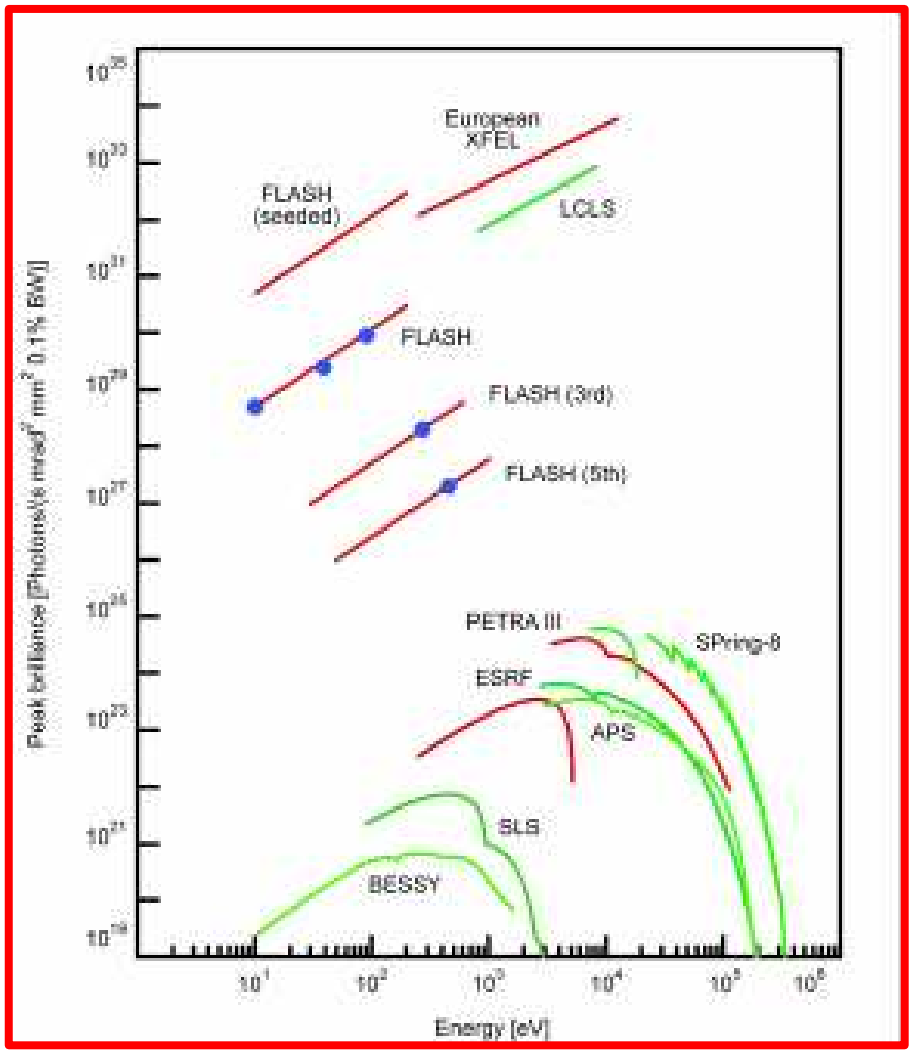
- dynamic range
- noise
- speed
- response to low energy photons
- CCE

- Conclusions

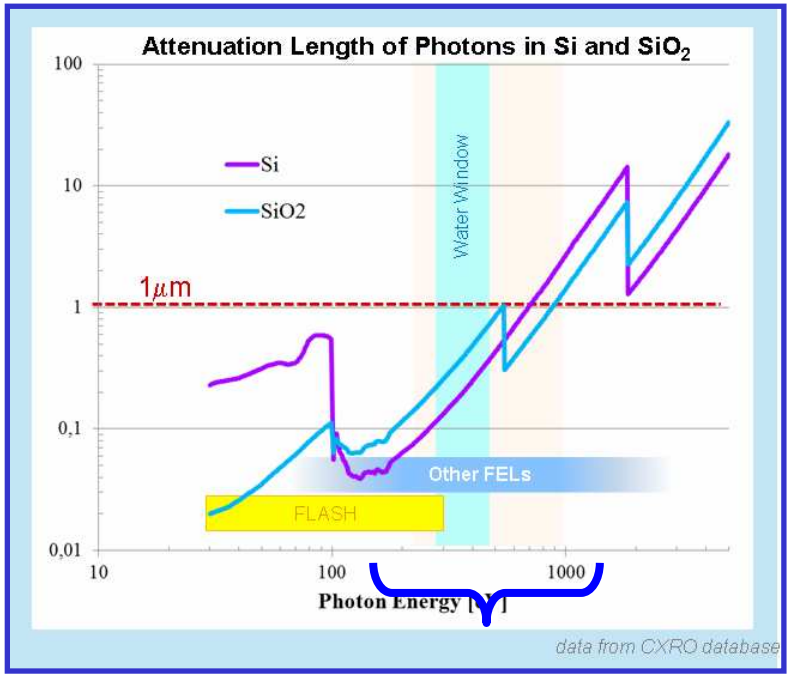
Motivation


Attenuation Length of Photons in Si and SiO2
100
10
1
0,1
0,01
Si
SiO2
1µm
Water Window
Other FELs
FLASH
10
100
1000
Photon Energy [eV]
data from CXRO database


1-photon resolution!
250 eV - 1 keV !
low noise!
high dyn range!
many frame/s!
high QE!
no blind areas!
many pixels! small pixels!
2-side buttable! (even more pixels)


European XFEL
FLASH (seeded)
LCLS
FLASH
FLASH (3rd)
FLASH (5th)
PETRA III
SPring-8
ESRF
APS
SLS
BESSY
Peak brilliance [Photons/s/e mrad² mm² 0.1% BW]
Energy [eV]

Motivation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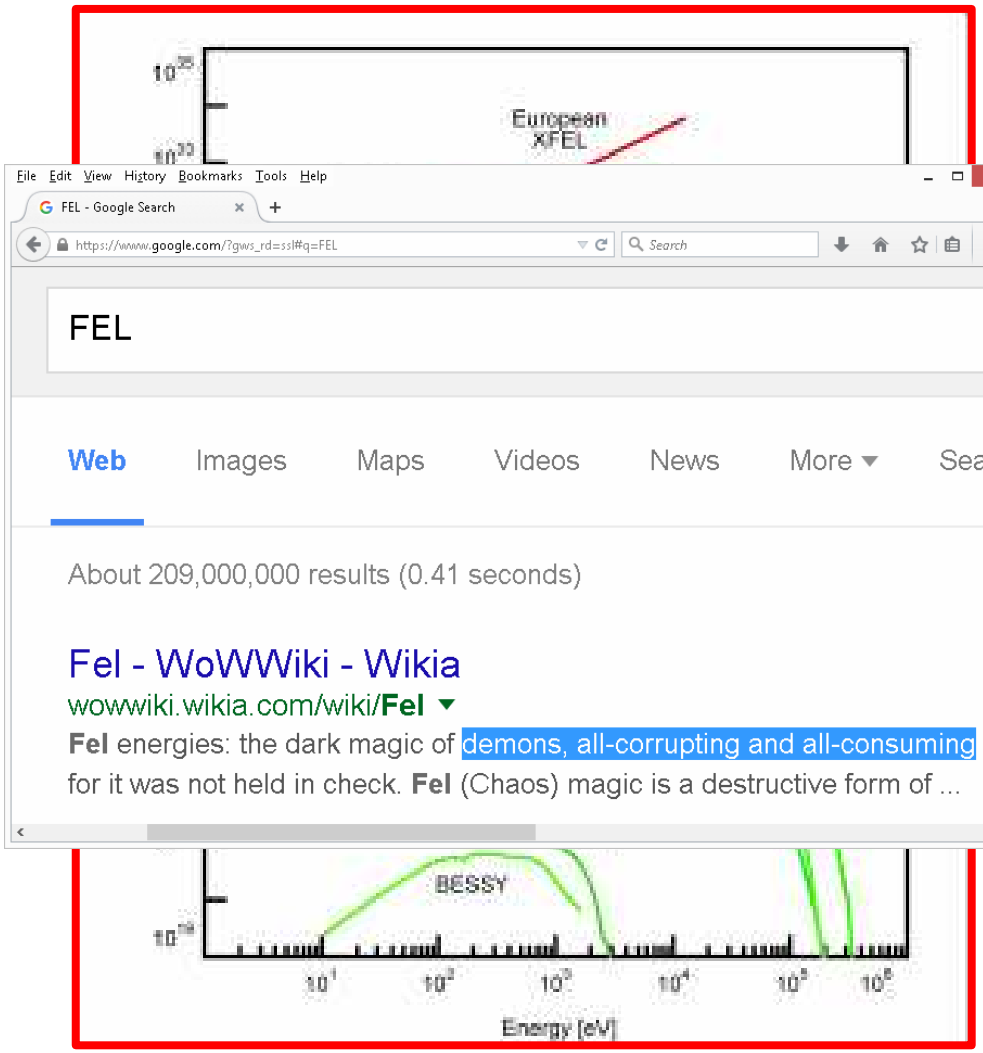
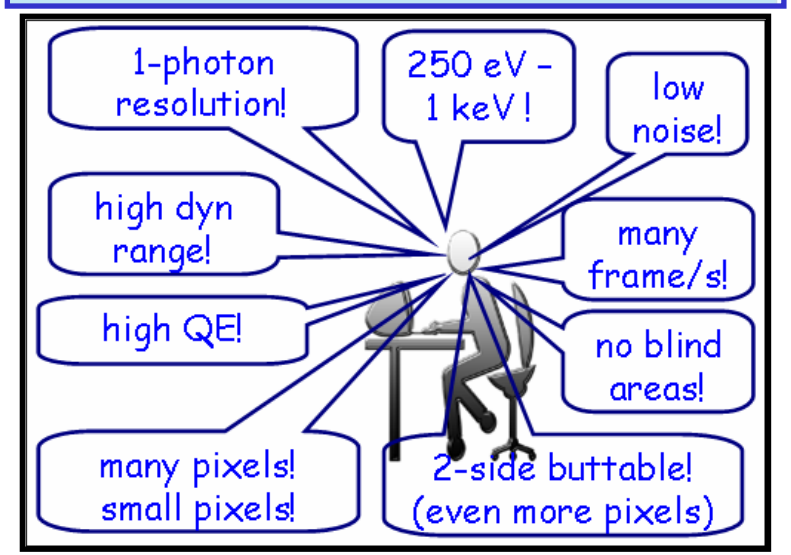

European XFEL
File Edit View History Bookmarks Tools Help
FEL - Google Search
https://www.google.com/?gws_rd=ssl#q=FEL
Search
FEL
Web
Images
Maps
Videos
News
More
About 209,000,000 results (0.41 seconds)
Fel - WoWWiki - Wikia
wowwiki.wikia.com/wiki/Fel
Fel energies: the dark magic of demons, all-corrupting and all-consuming if for it was not held in check. Fel (Chaos) magic is a destructive form of ...
BESSY
Energy [eV]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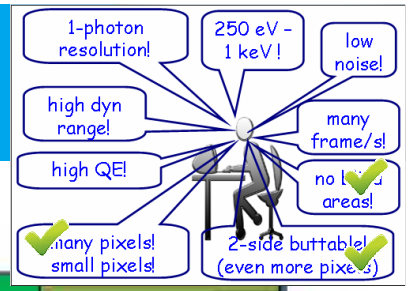
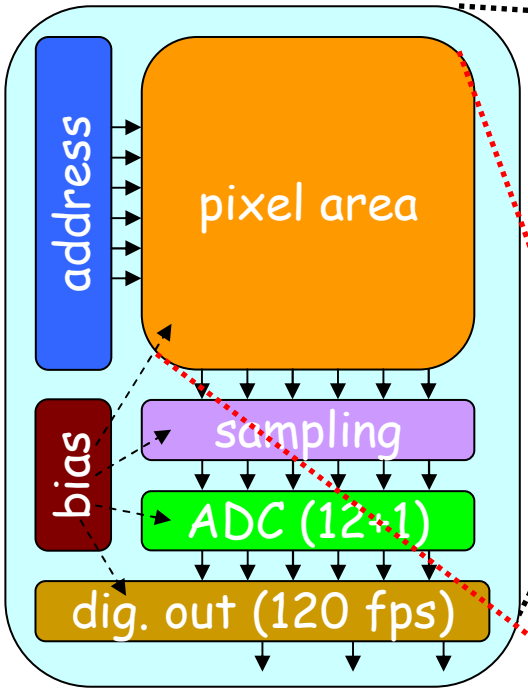
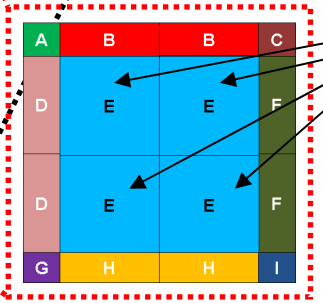
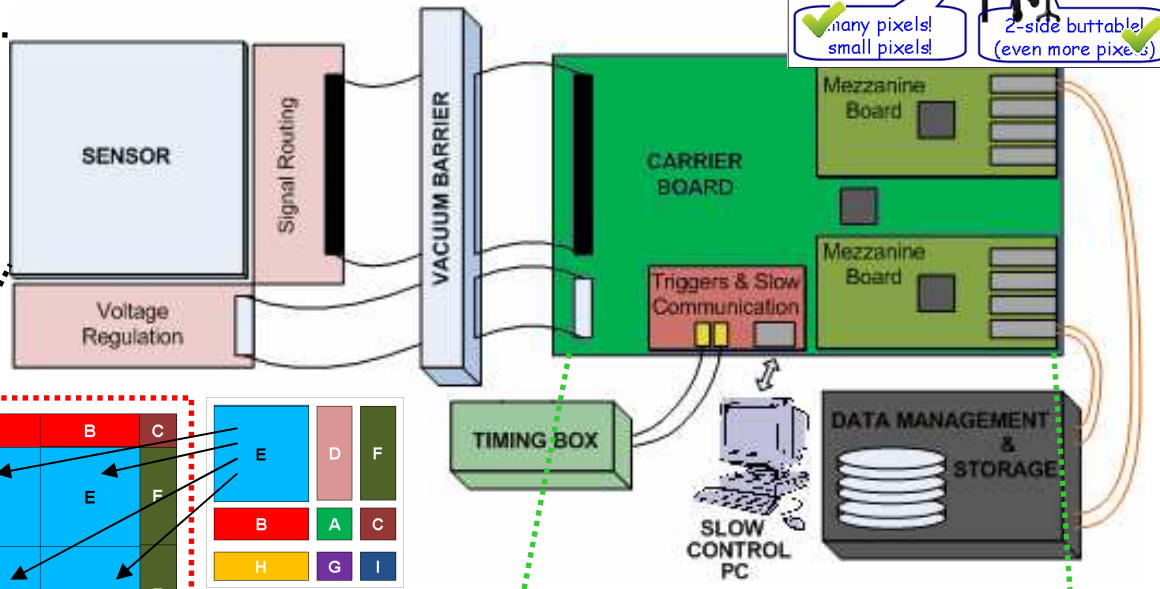
The full PERCIVAL system

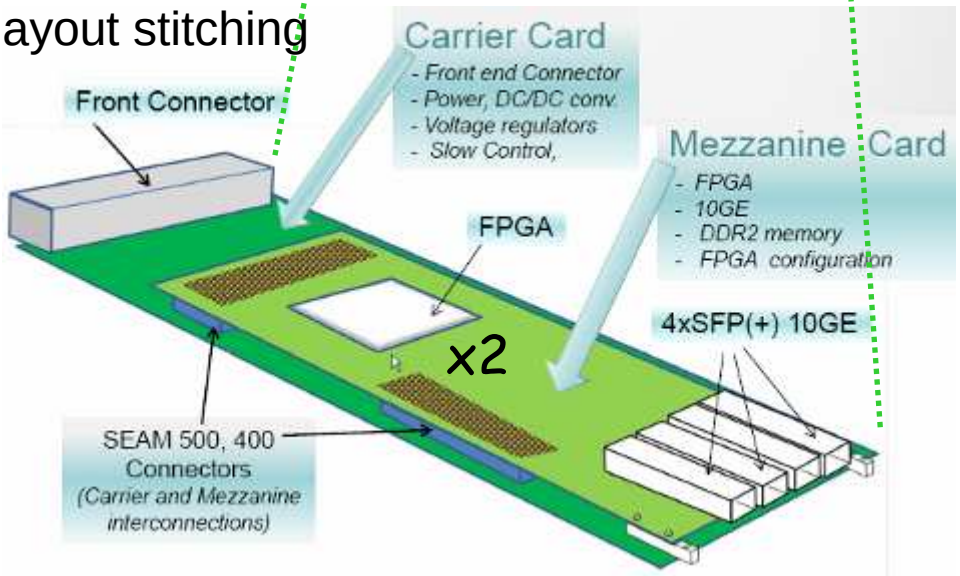






layout stitching

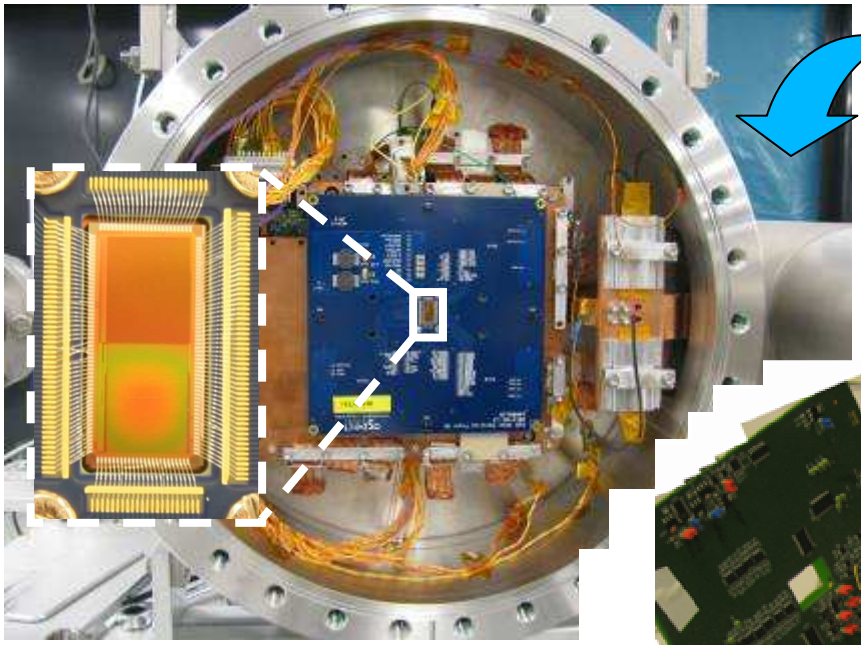


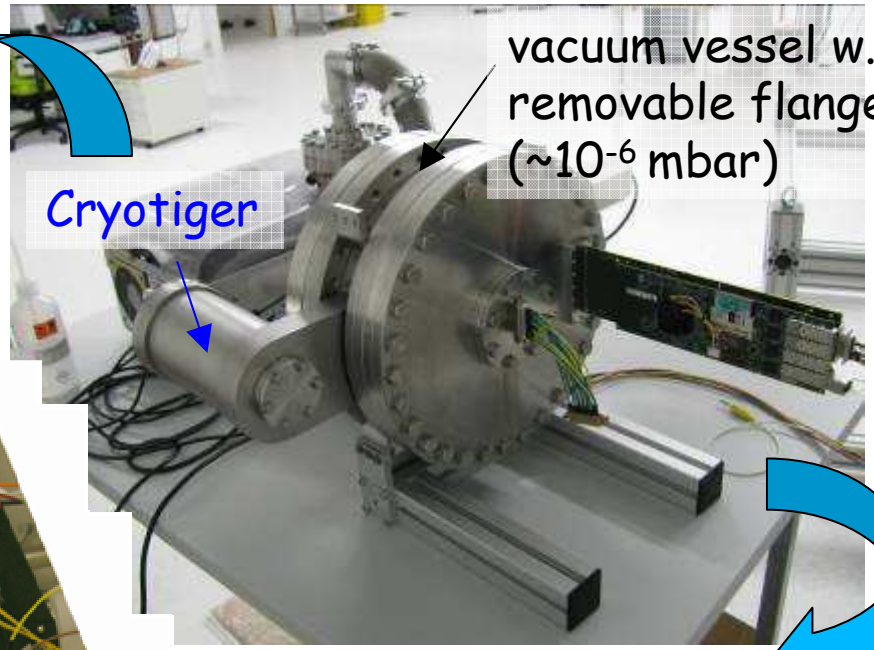


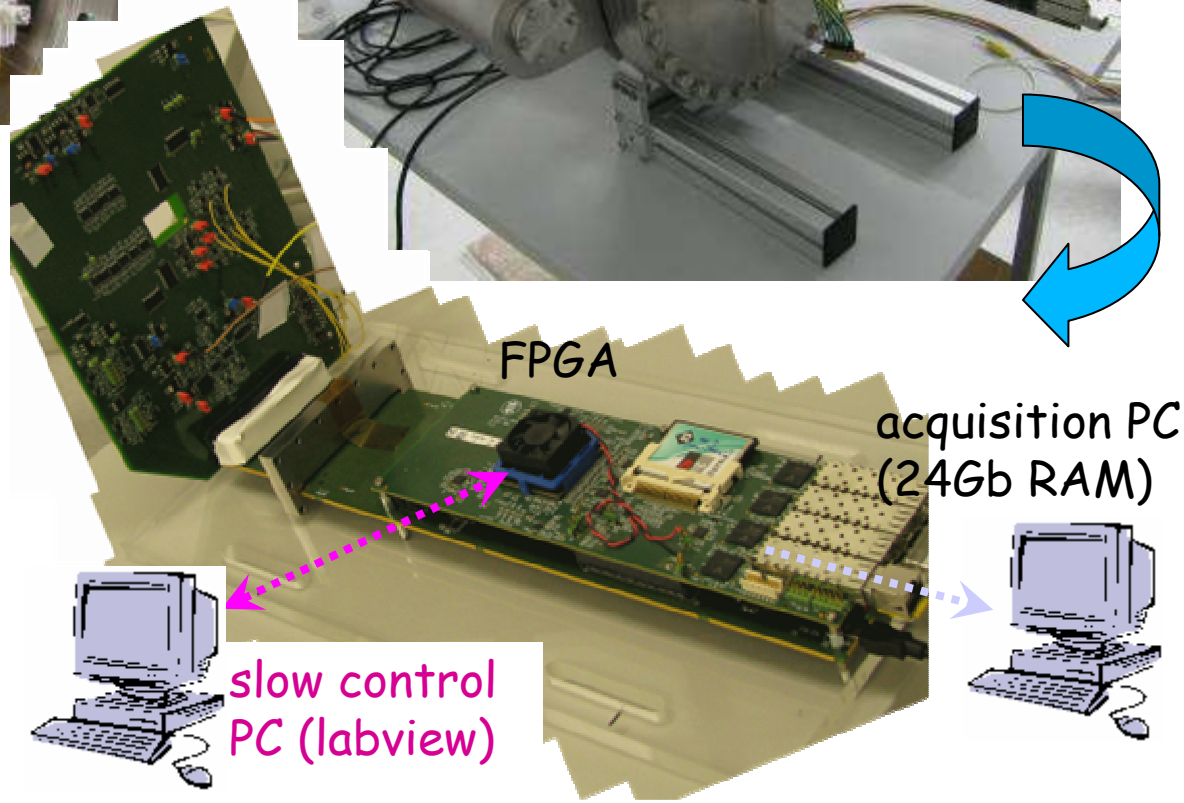
P2M
- 2Mpixels
- ~4×4cm² sensible area
- no gaps or blind areas
- 2-side buttable
- 27um pixel pitch
- manuf. ~spring 2016, available ~2017

P13M
- 13Mpixels
- ~10×10cm²
- no gaps
- 2-side butt.
- 27um
- later

The PERCIVAL prototype



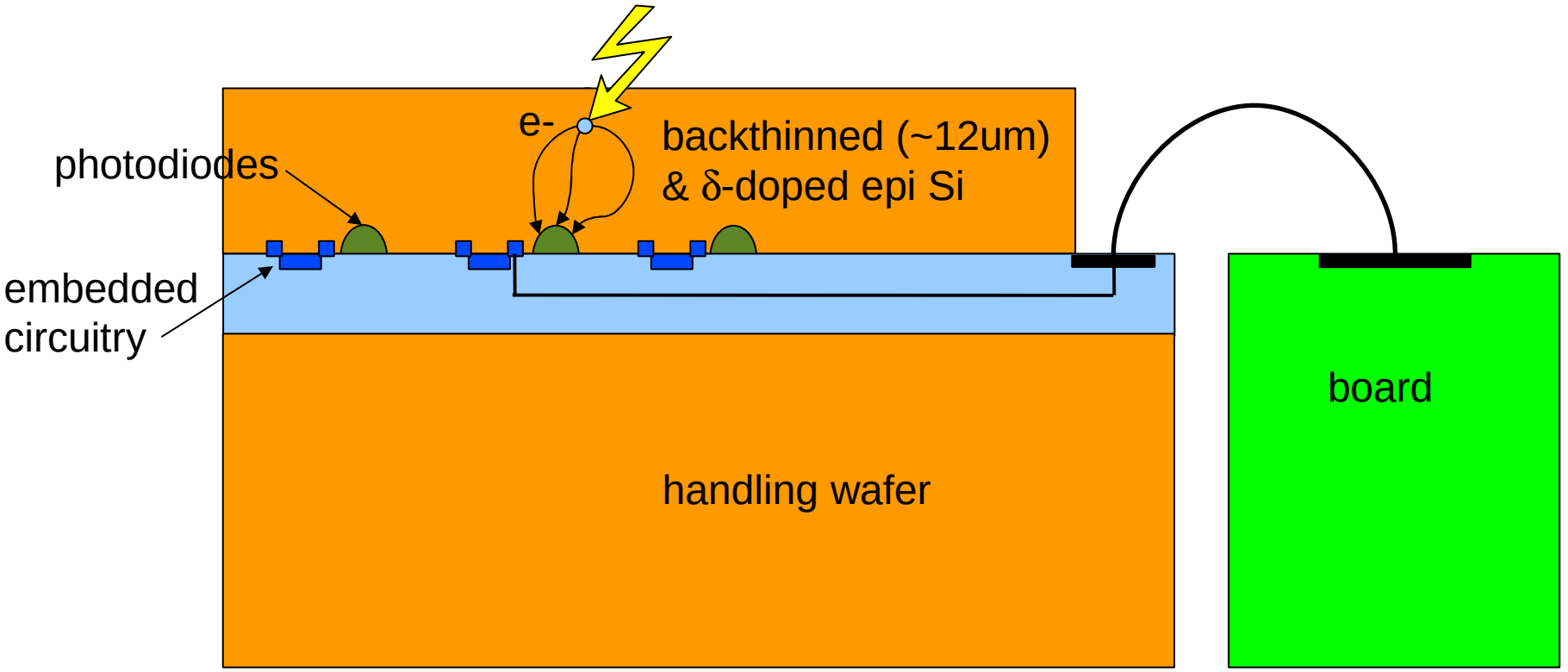




TestSensor 1.0/.1/.2

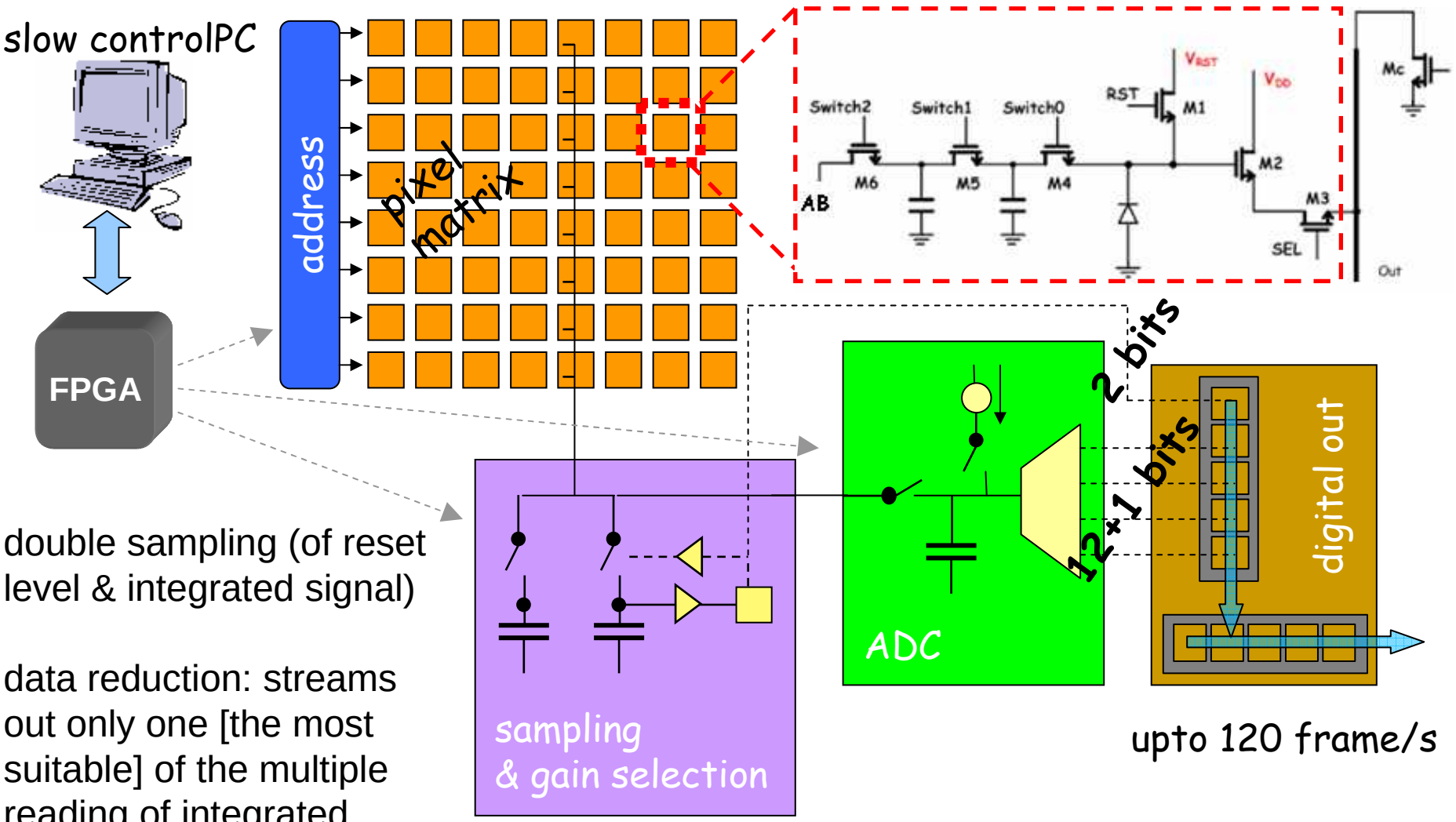
- 33k pixels
- 6+4 pixel flavours
- ~0.4×0.5 cm^2 sensible area
- 25um pixel pitch
- FSI & BSI
- FEL & Synchrotron mode

Monolithic Active Pixel Sensor



Monolithic: Collecting diodes & readout circuitry share the same substrate
Coupled to handling wafer, back-thinned, back-illuminated: 100% fill factor
Back surface delta-doped, post-processed: virtually no entrance window

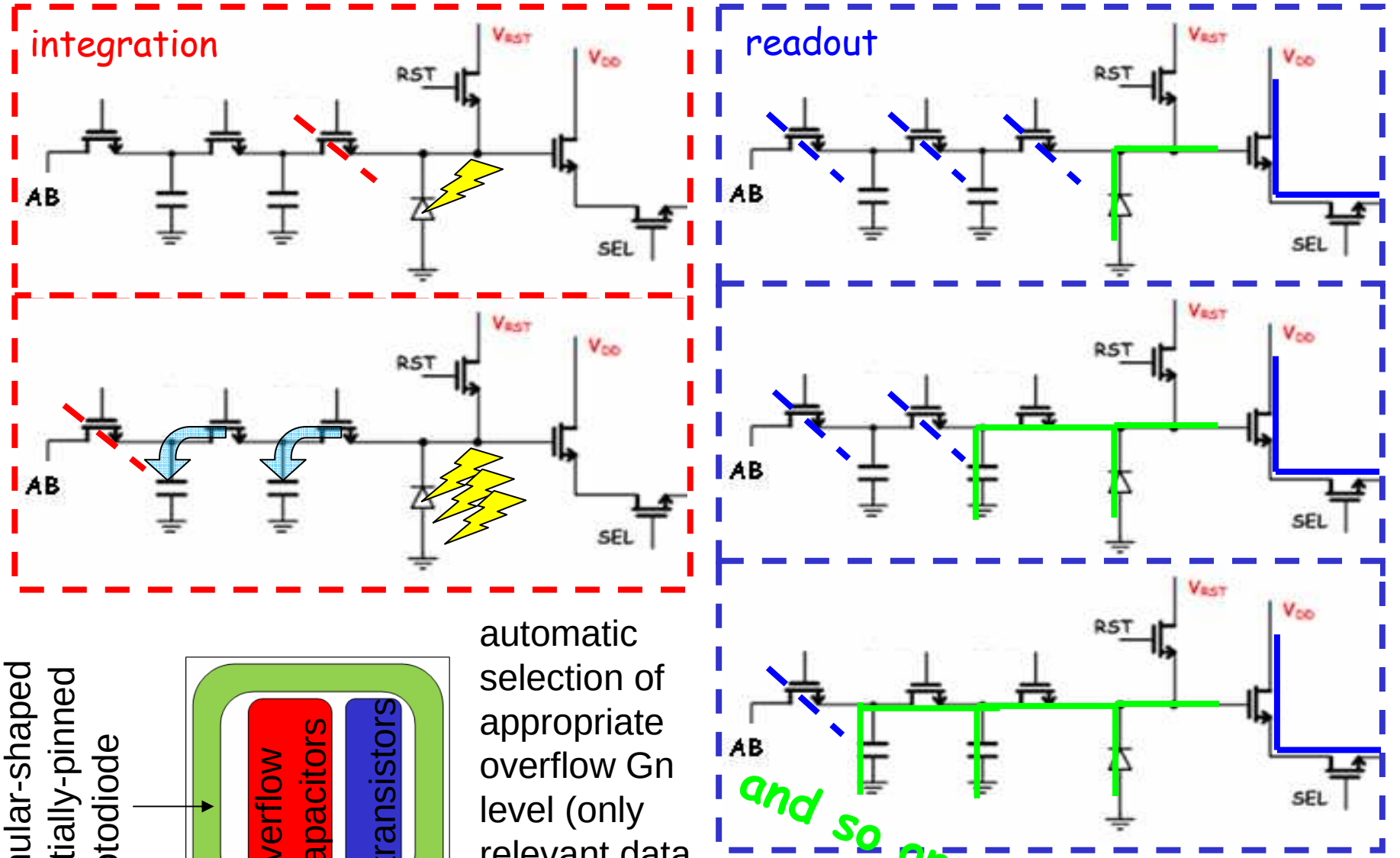
The PERCIVAL core



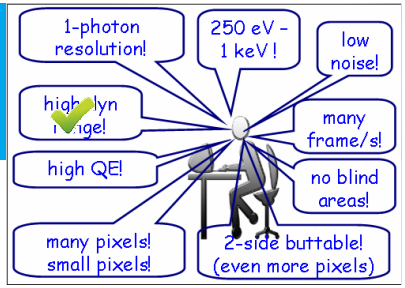
double sampling (of reset level & integrated signal)

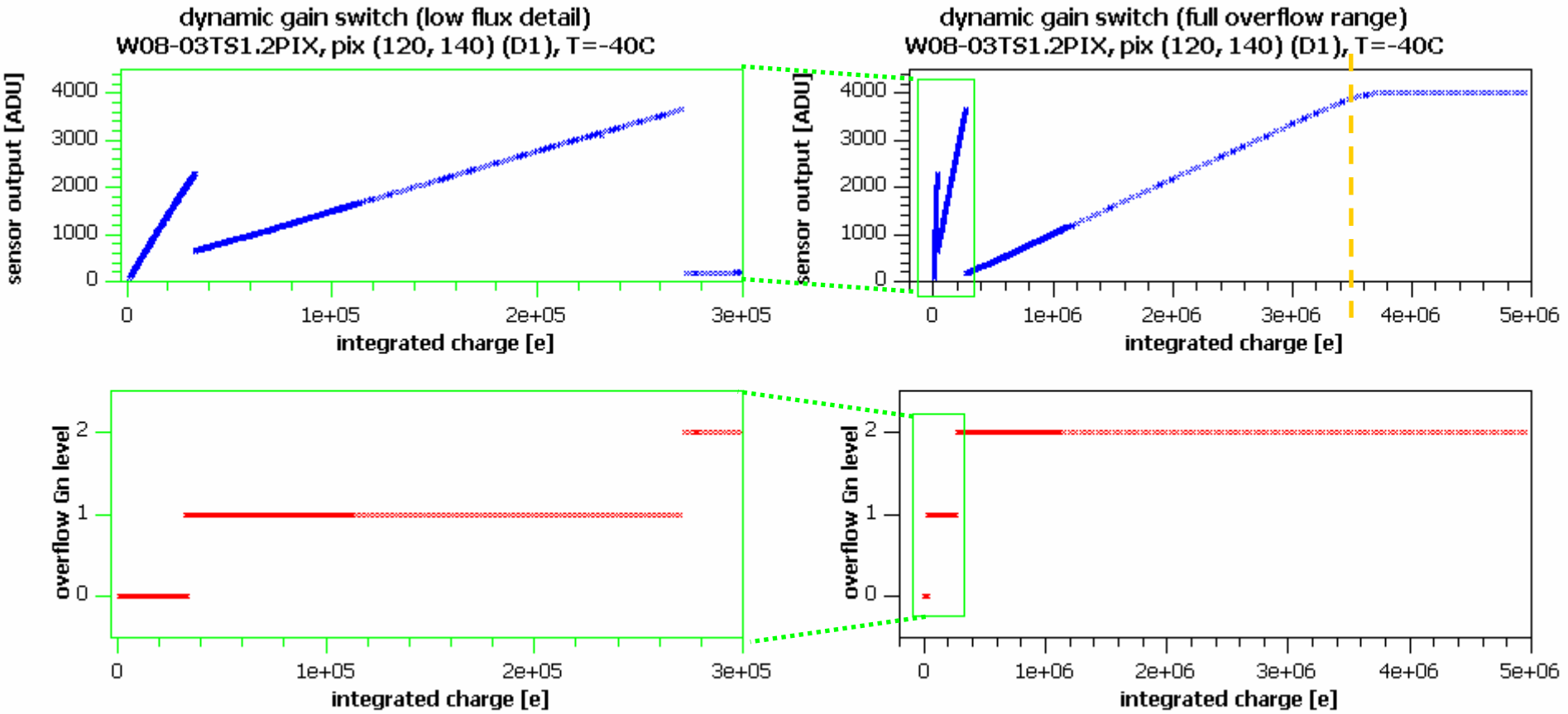
data reduction: streams out only one [the most suitable] of the multiple reading of integrated signal (+2 sel. bits)

Lateral Overflow



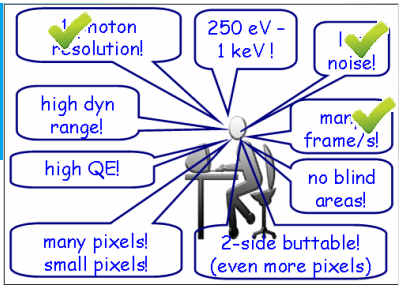
Lateral Overflow, dynamic range: test results

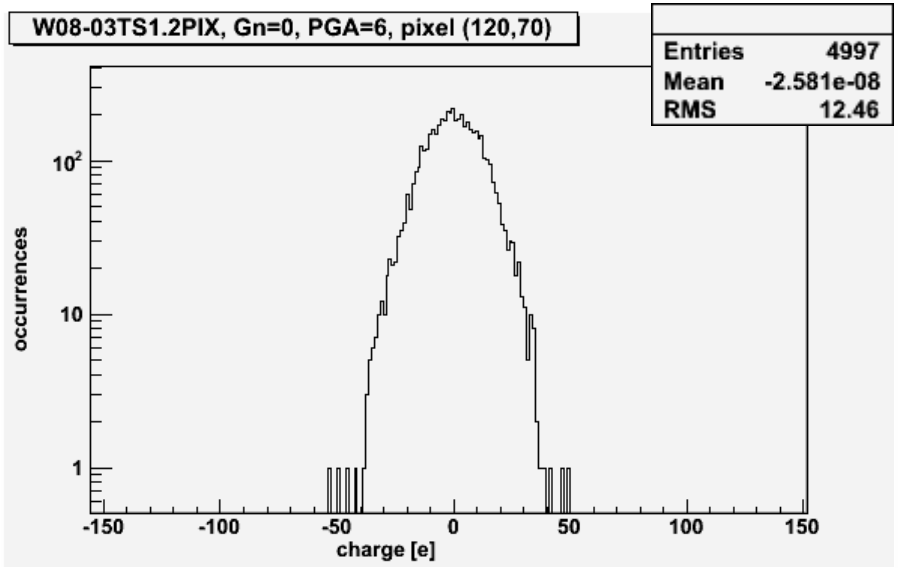


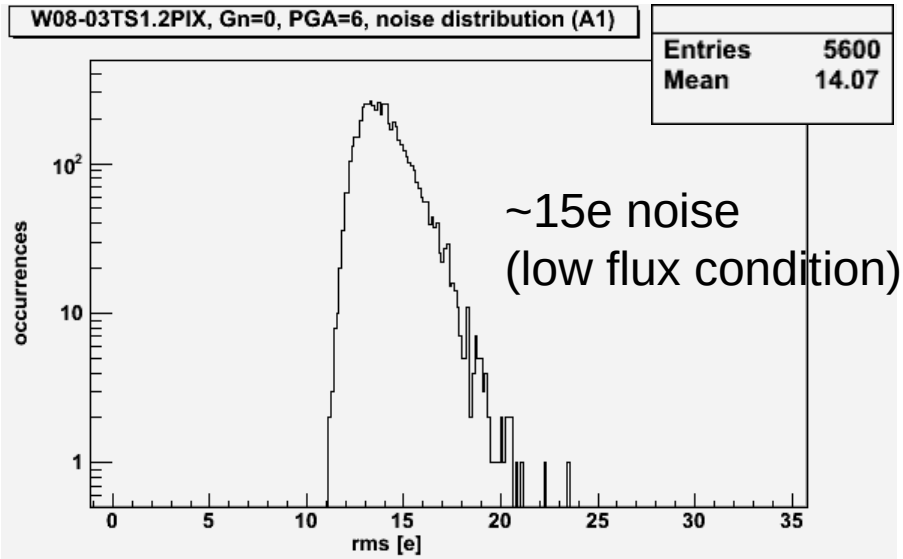


dyn. range: 3.5Me ~ 50k photons @ 250eV

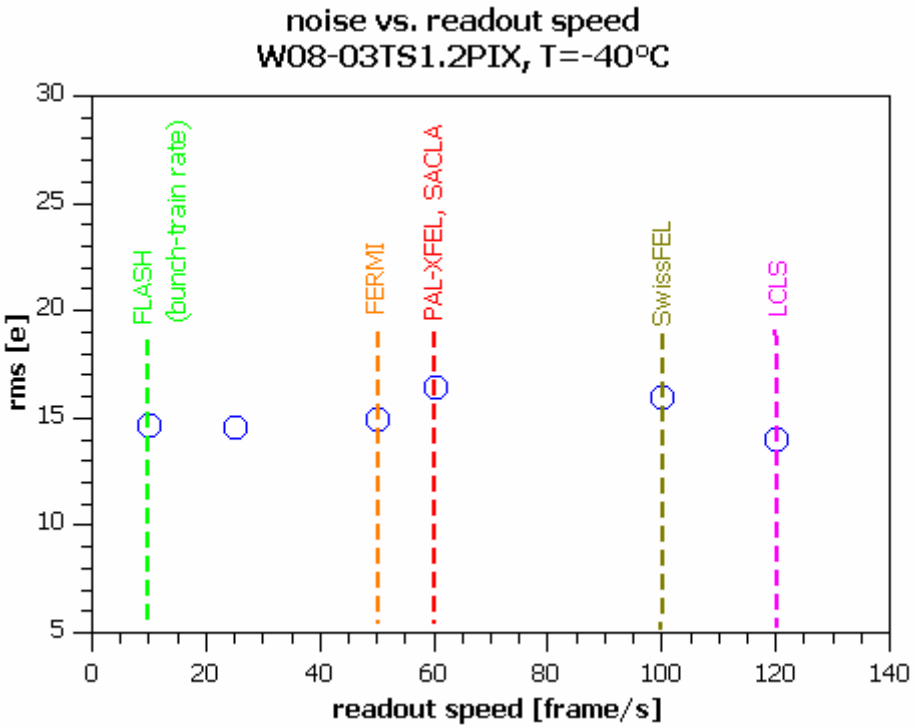
noise: test results





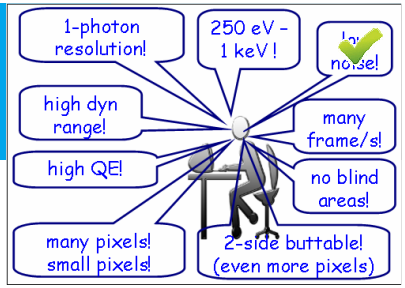


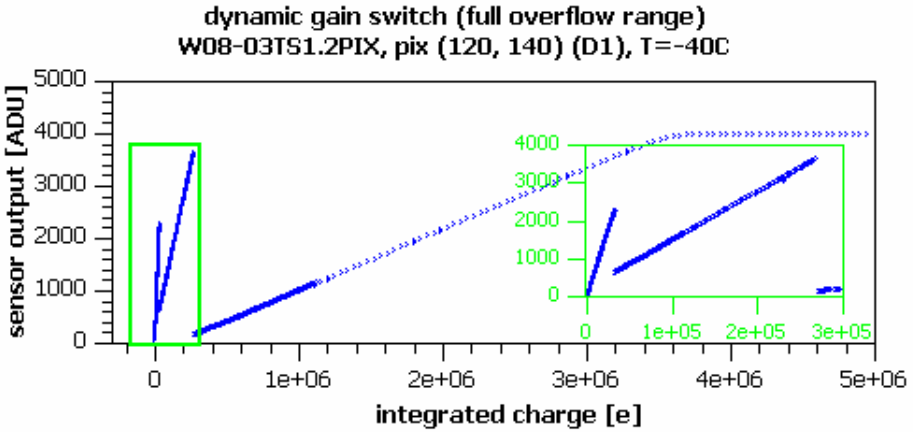
~15e noise
(low flux condition)

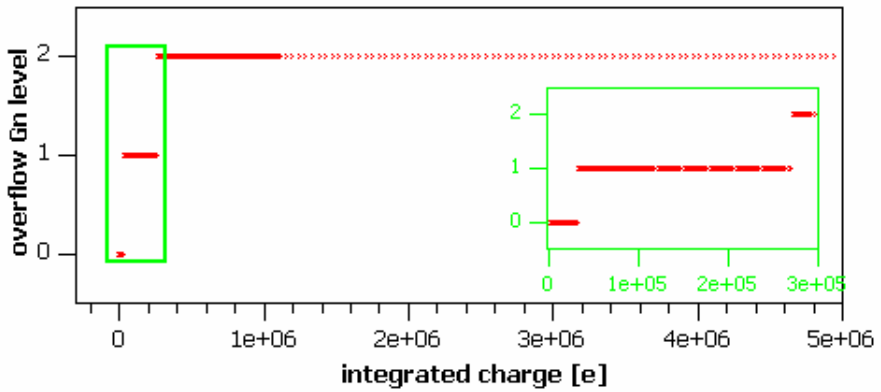


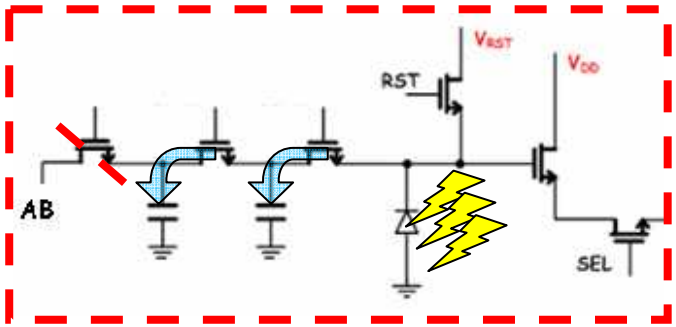
compatible with most FEL frame rates

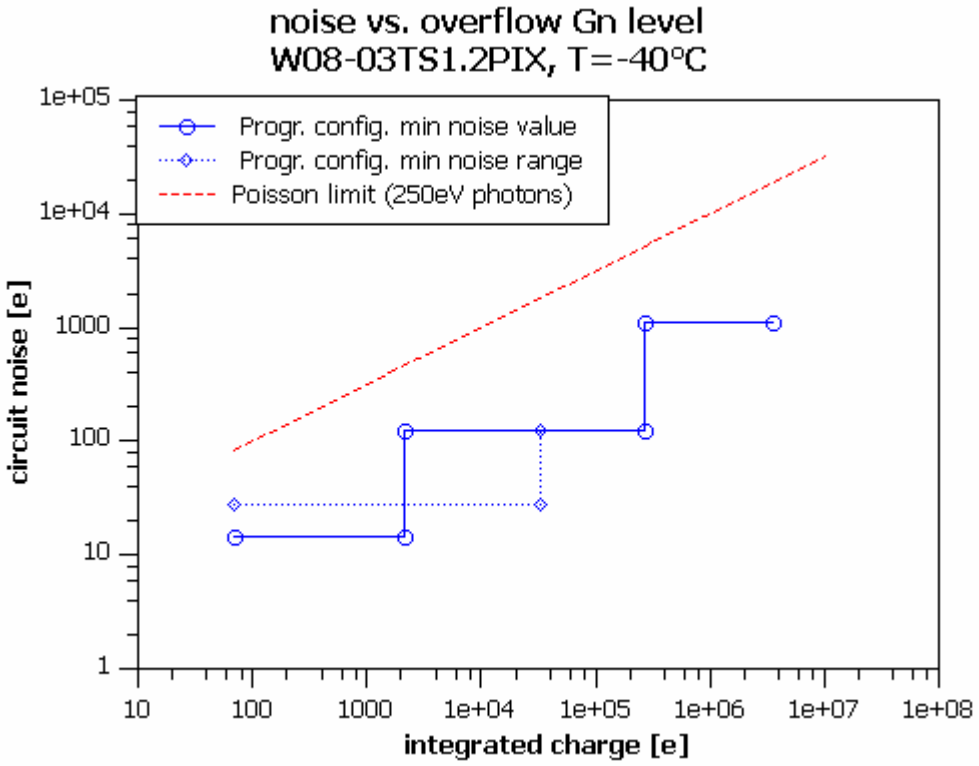
noise: test results



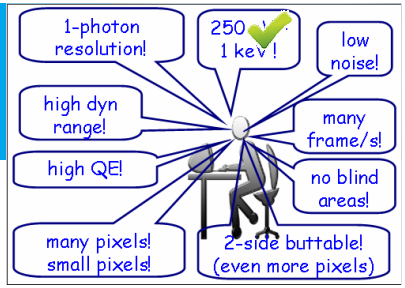


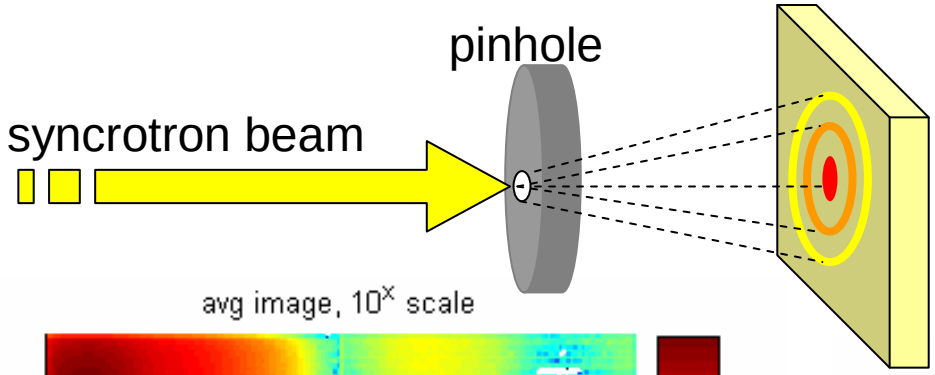






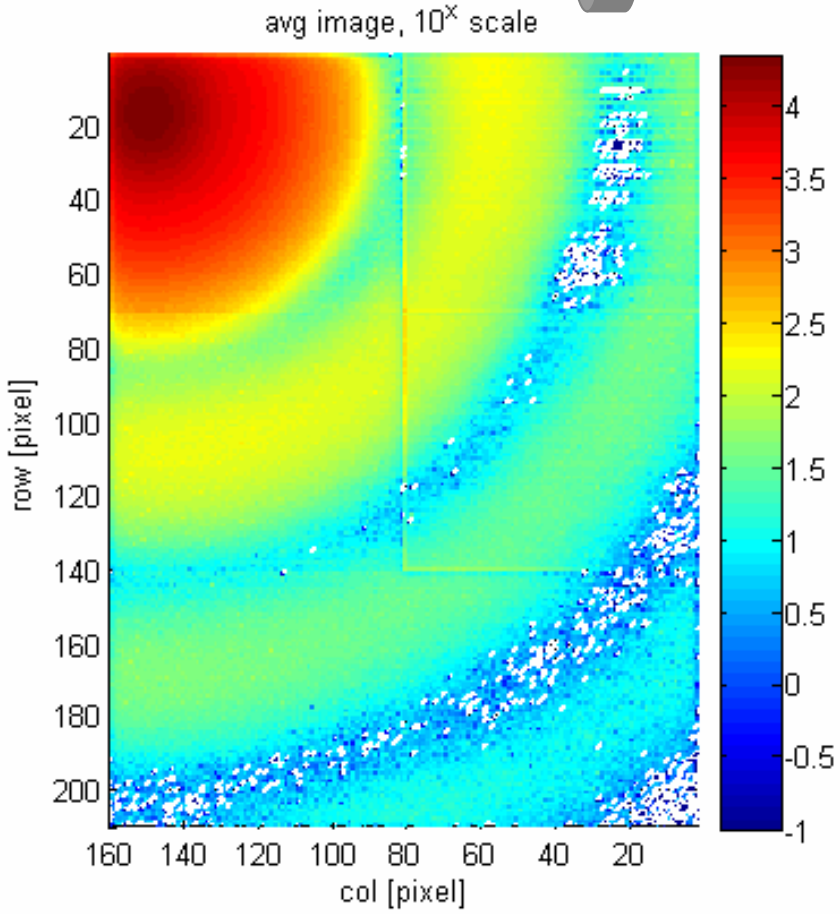
Low-Energy photons : test results

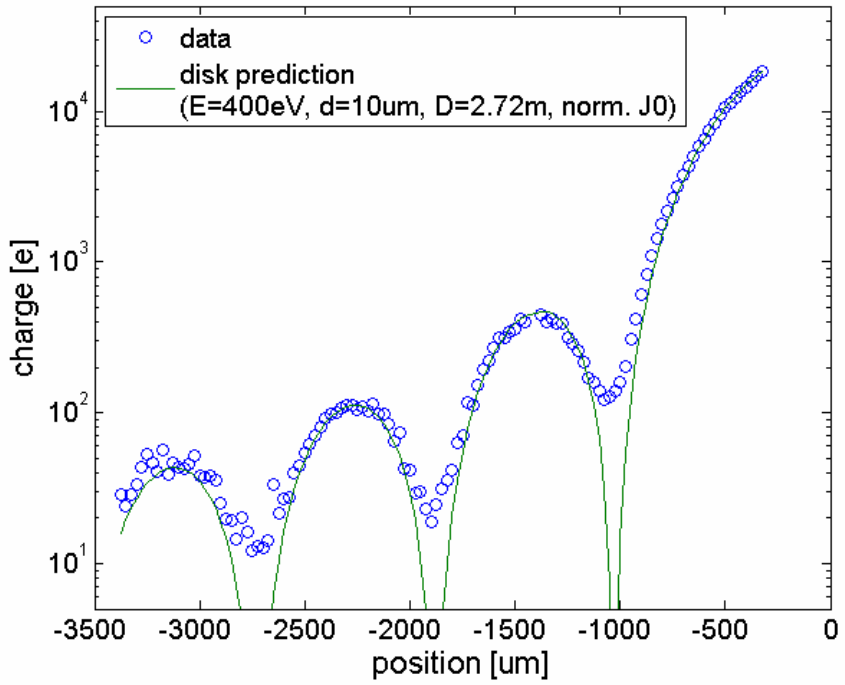




1-2keV tests at P04 (Petra III)

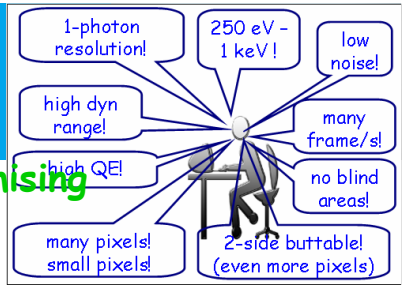
400eV tests at I10 (DLS)



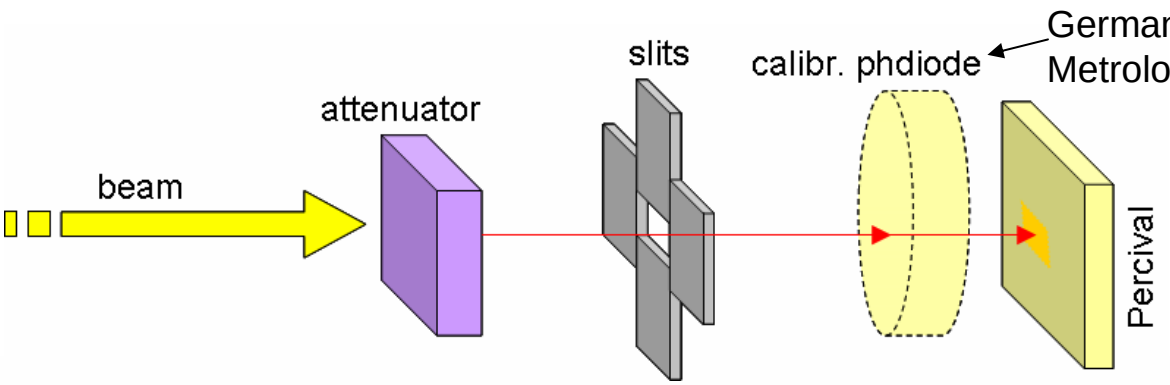


PAL DESY CFEL SCIENCE

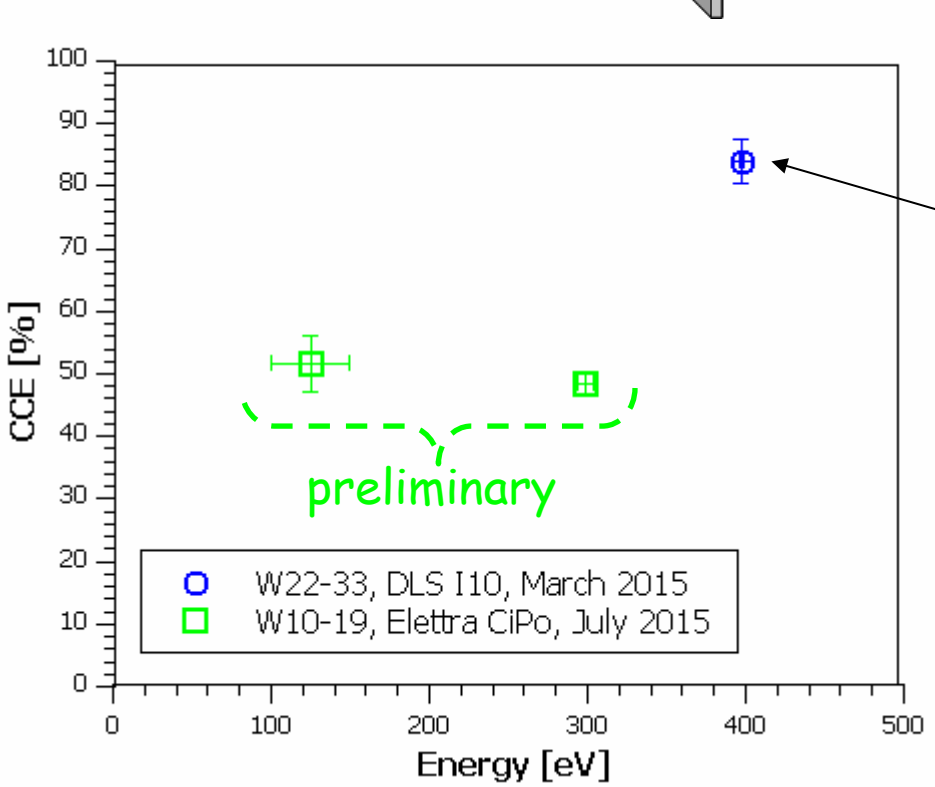
Charge Collection Efficiency: test results

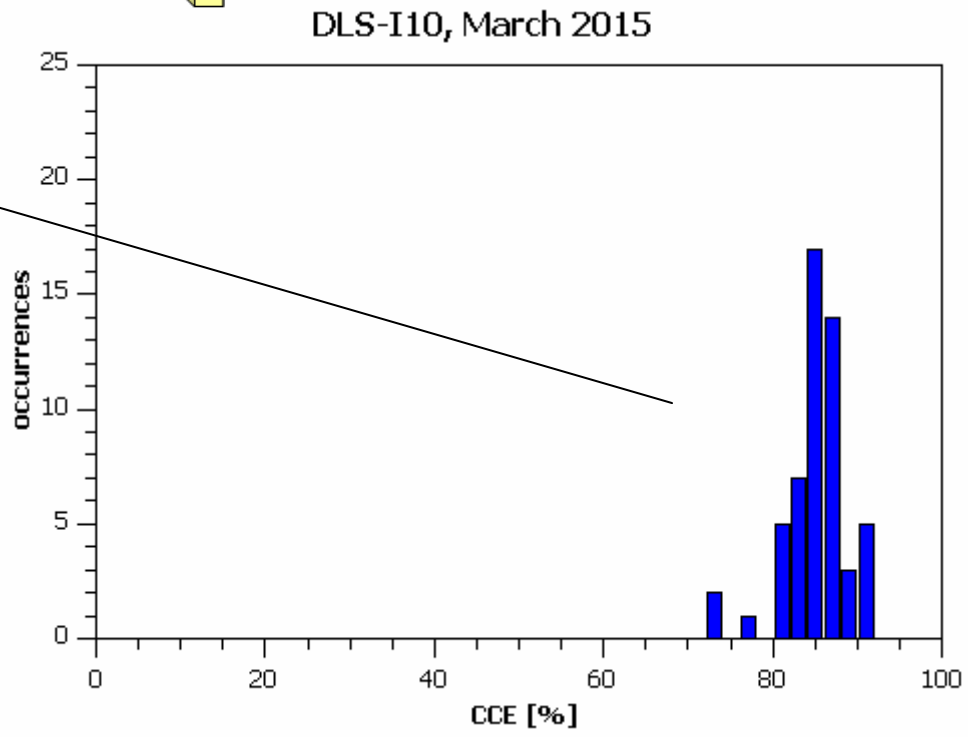


promising



measurement at
I10 beamline (DLS)
Cipo beamline (Elettra)





Summary

P.E.R.C.I.V.A.L.

(Pixellated Energy-Resolving Cmos Imager Versatile And Large)

tests on prototypes

- ✓ Lateral Overflow
- ✓ low noise (~15e)
- ✓ high dynamic range (3.5Me – 50k ph.)
- ✓ up to 120 frame/s
  - ✓ compatible most FEL
- ✓ tested 125eV-2KeV
- ✓ measured CCE (125-400eV)

P2M

- ✓ 2M pixels
- ✓ ~4×4cm^2 sensible area
- ✓ no gaps or blind
- ✓ 2-side buttable
- ✓ 27um pixel pitch
- ✓ manuf. ~spring 2016, available ~2017

P13M

- ✓ 13M pixels
- ✓~10×10cm^2 sensible area

Summary

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(Pixellated Energy-Resolving Cmos Imager Versatile And Large)

tests on pr

✓ Dynamic

✓ low noise

✓ high dyna

✓ up to 120

✓ comp

✓ tested 12

✓ measured CCE (125-400eV)

P2M

✓ 1408×1484 pixels

sible area

nd

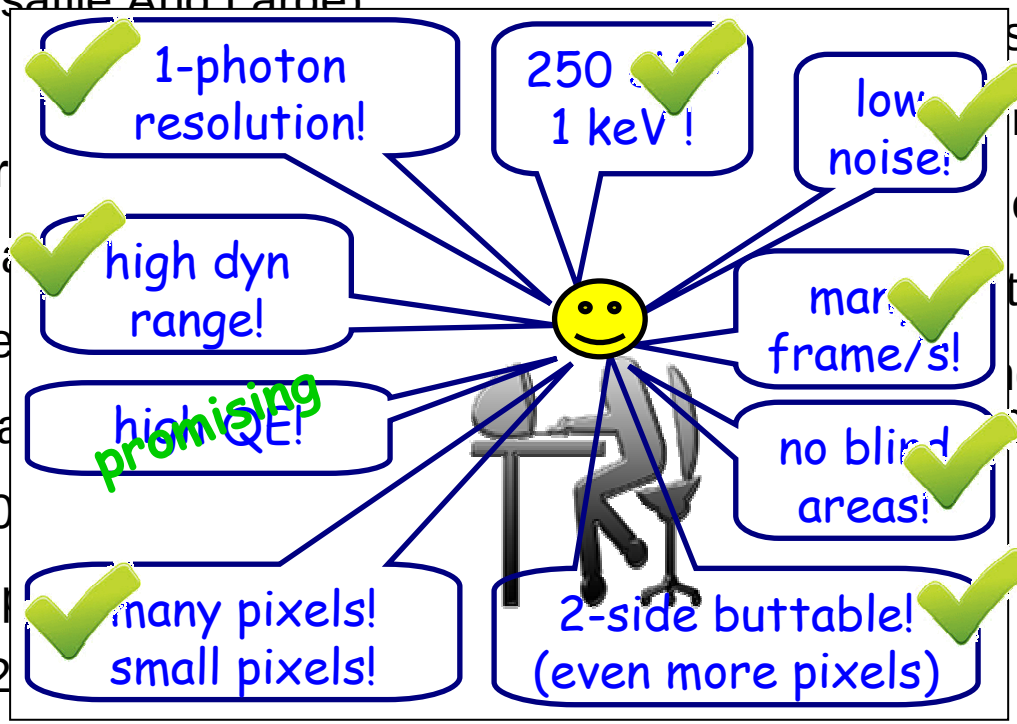
e

tch

g 2016,

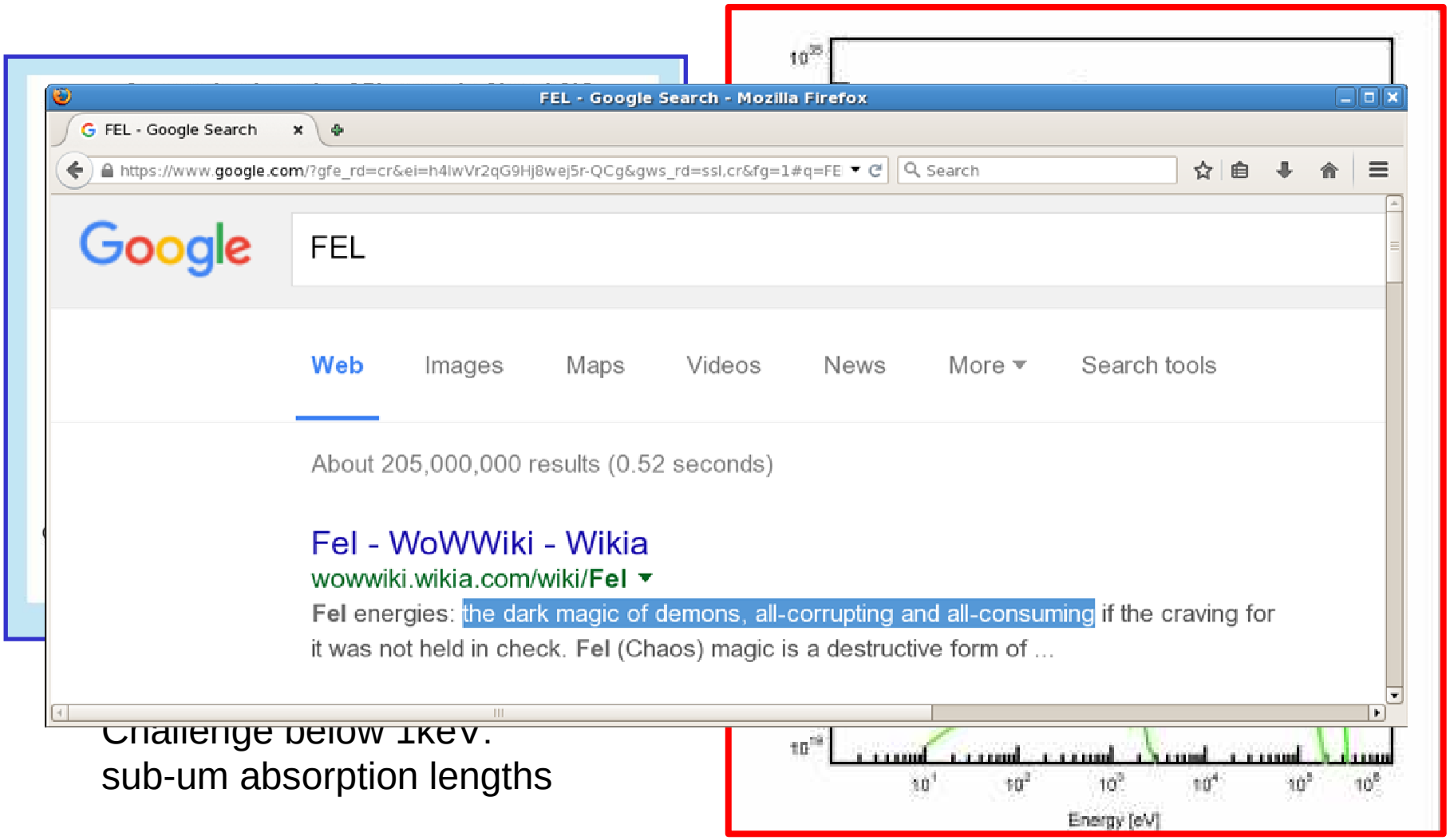
2017

✓~10×10cm² sensible area



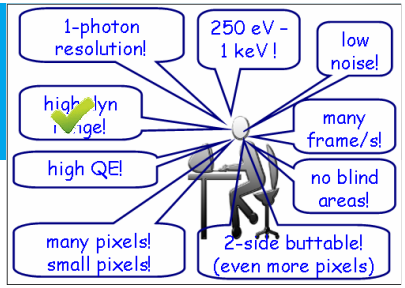
backup

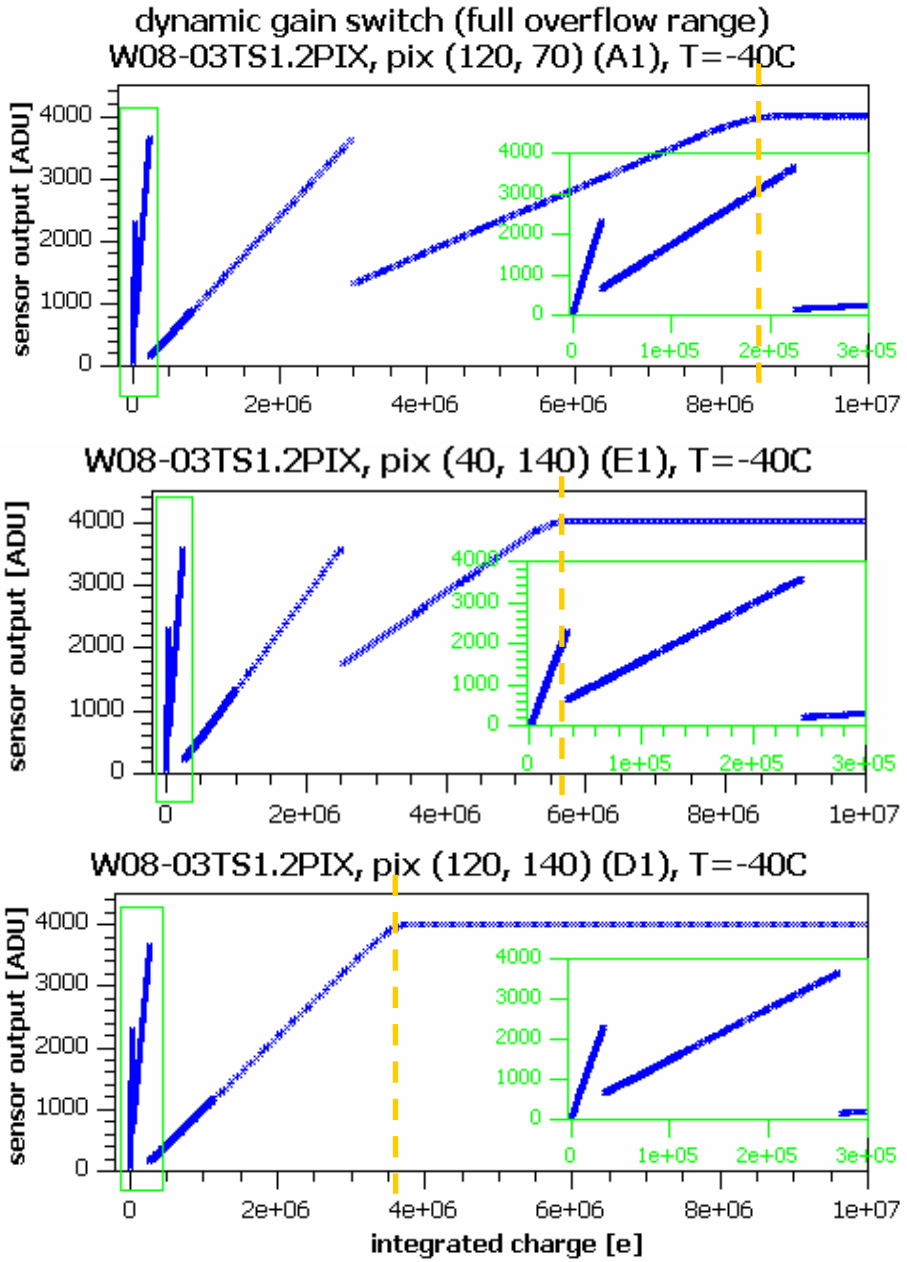
Motivation

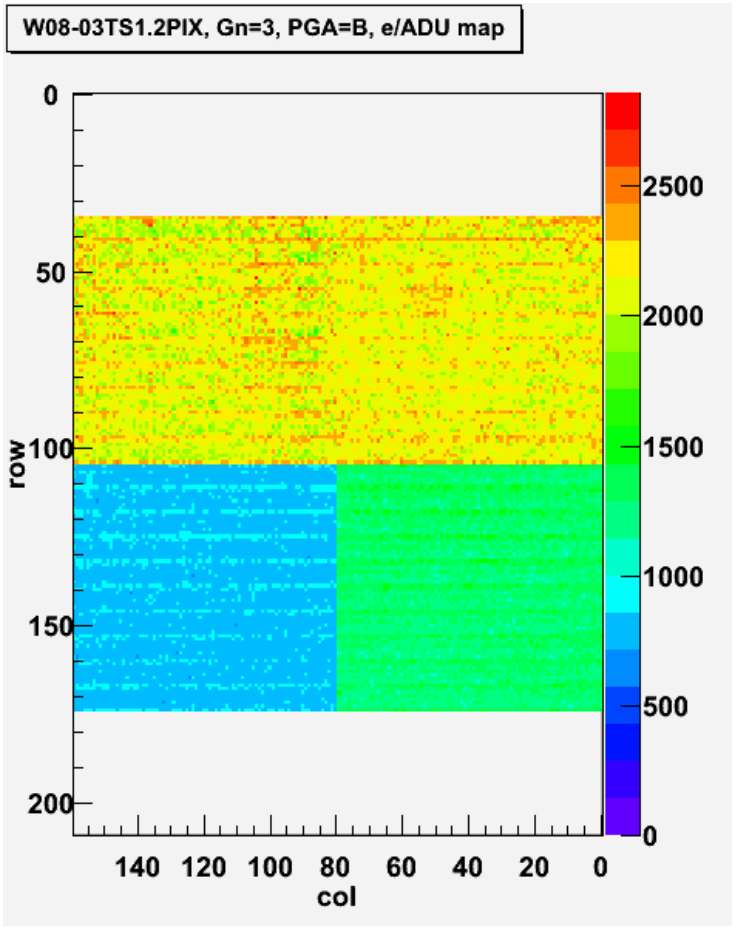


Challenge below 1keV:
sub-um absorption lengths

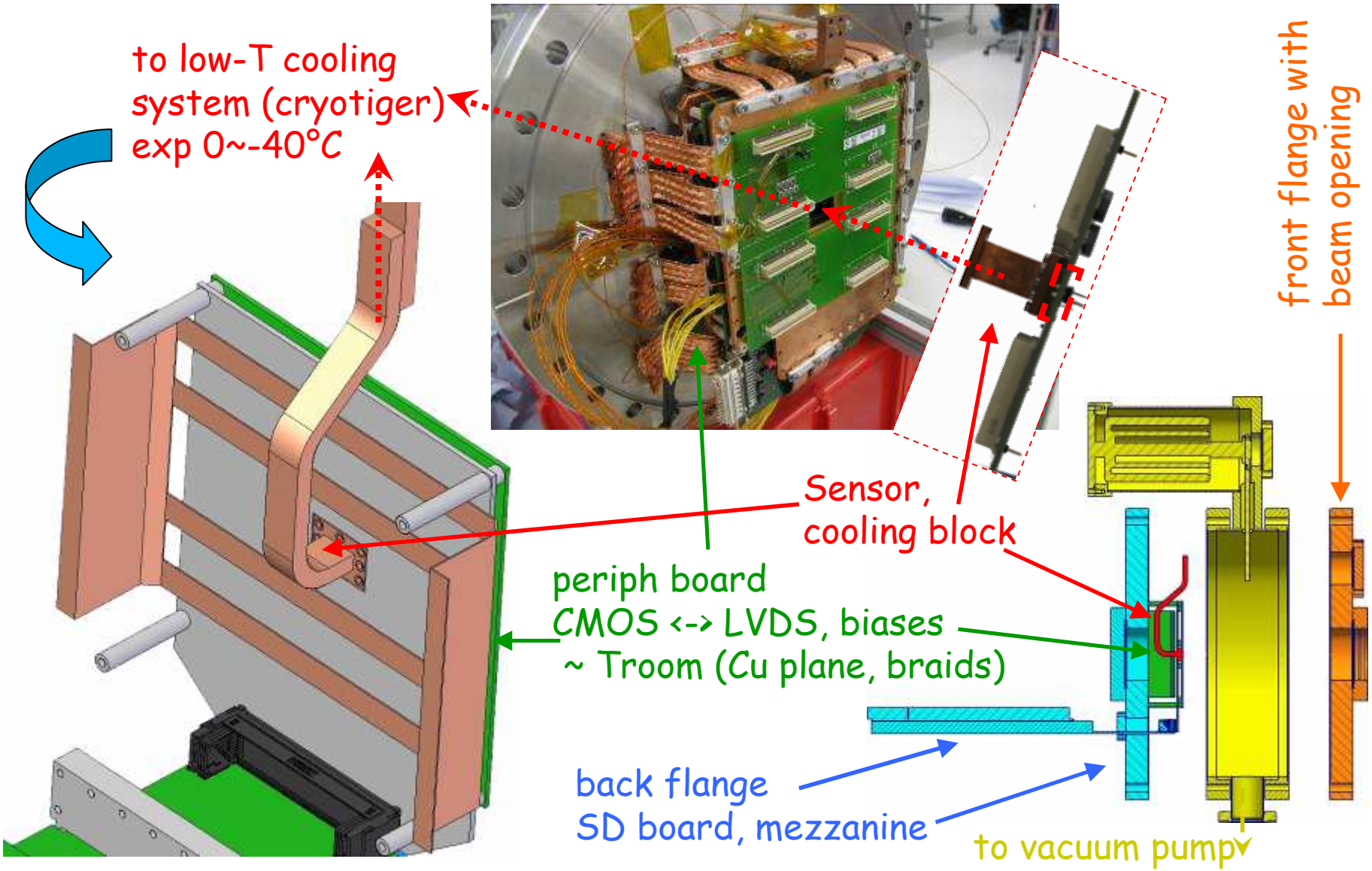
Dynamic range



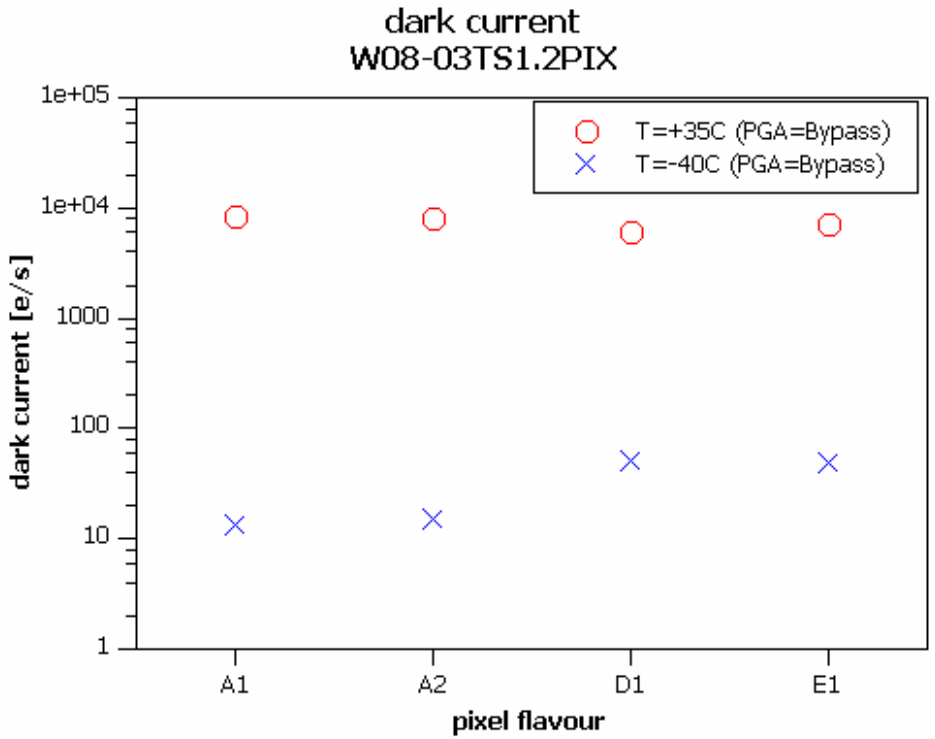


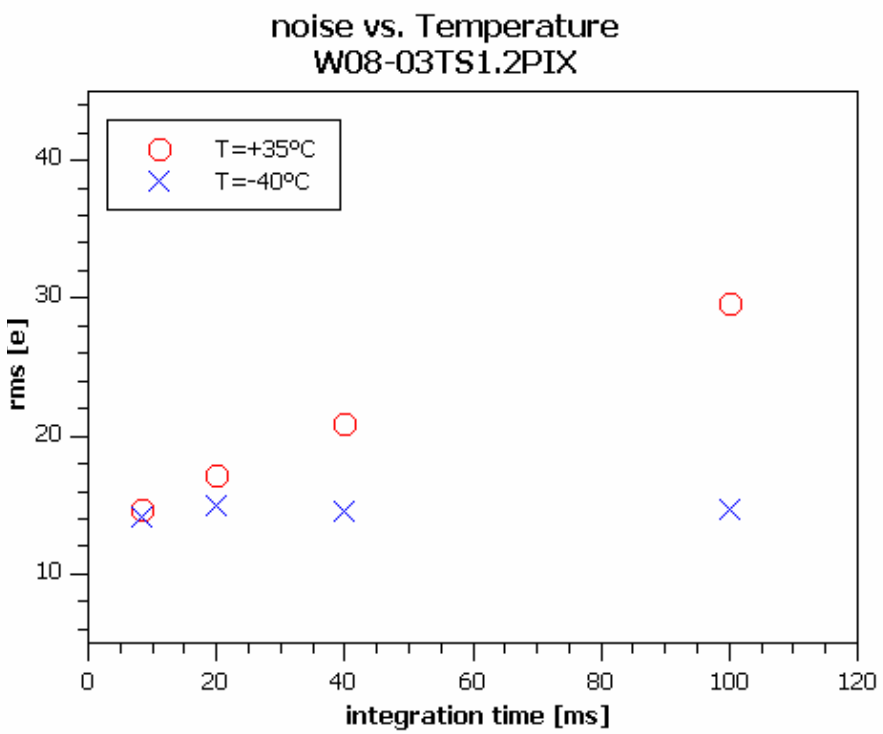


The PERCIVAL prototype

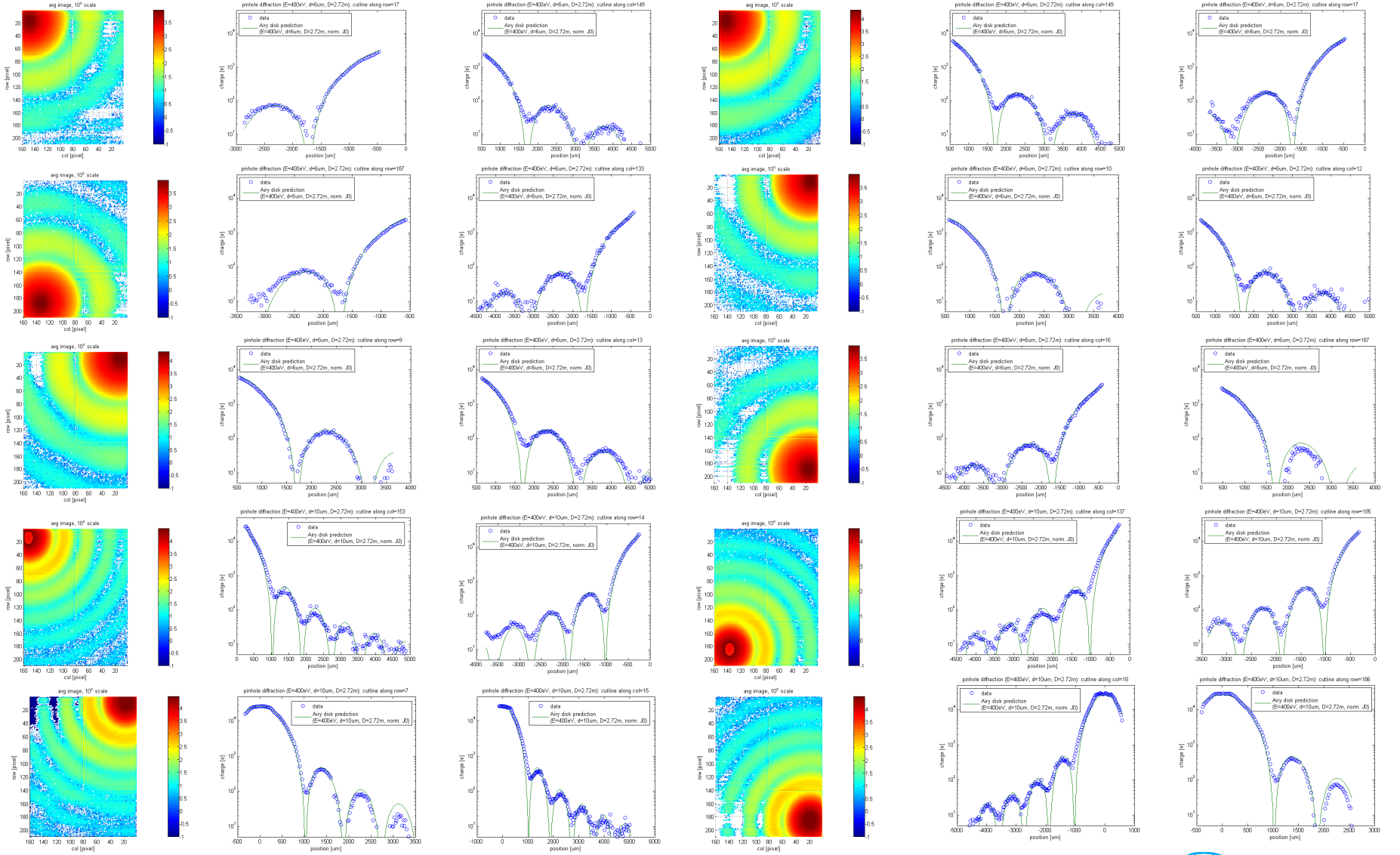


Temperature effects

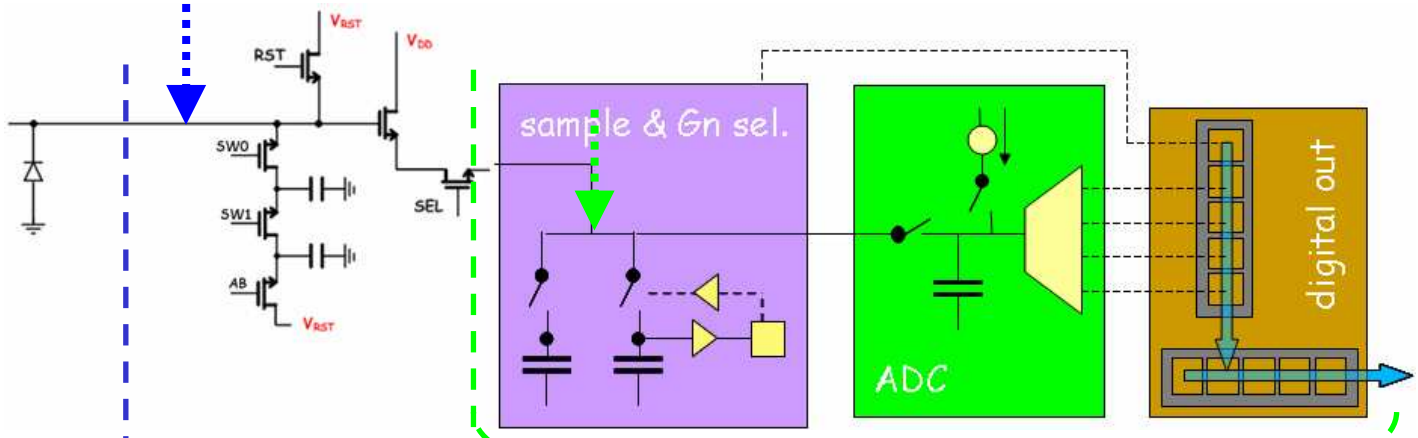


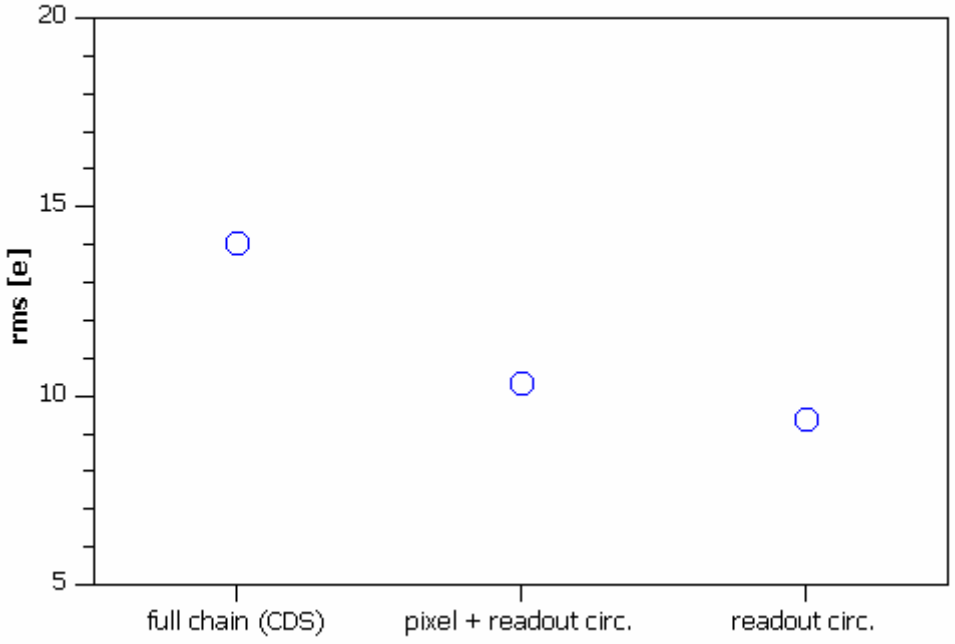


response to low-Energy photons



noise analysis



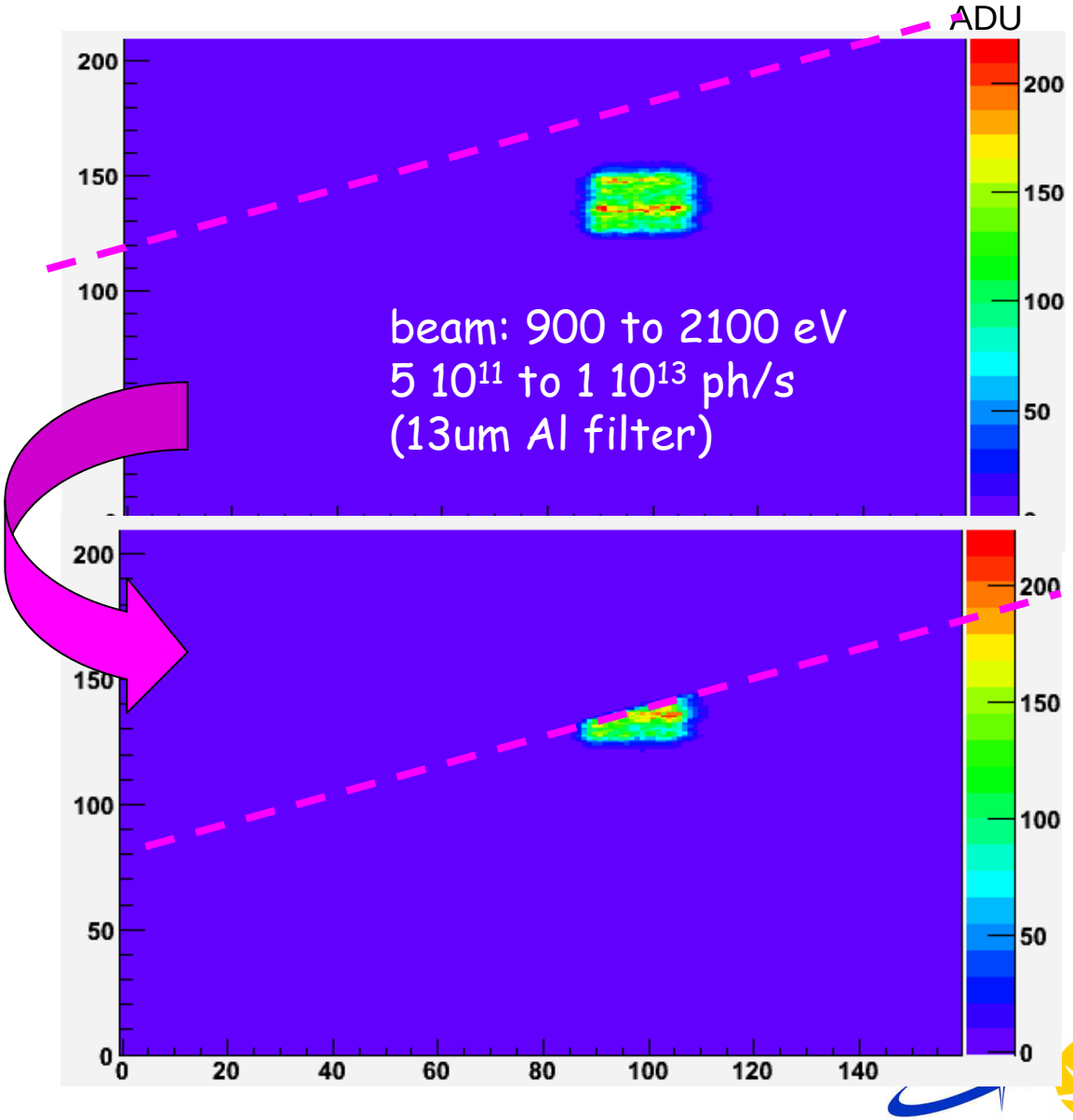


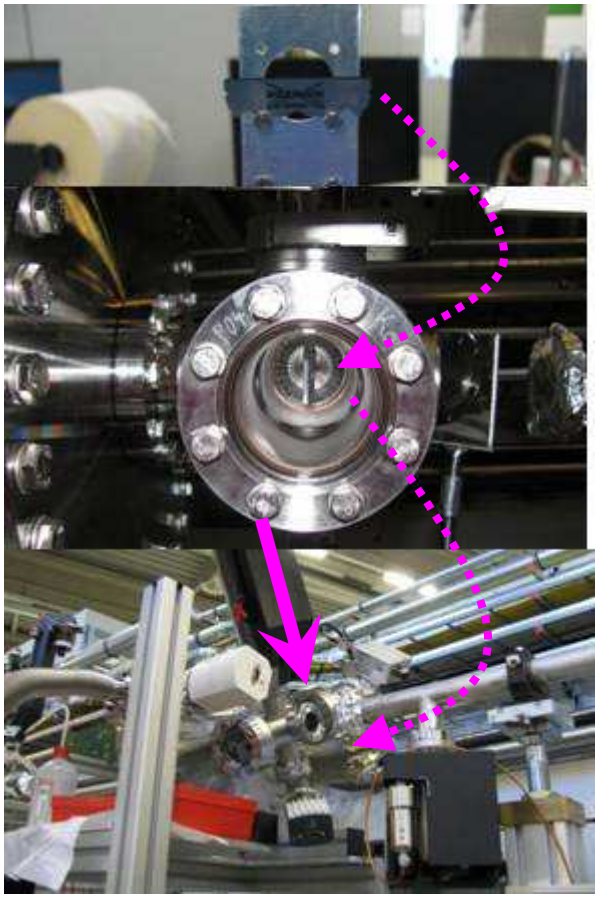
full chain

pixel + readout circ.

readout circ.

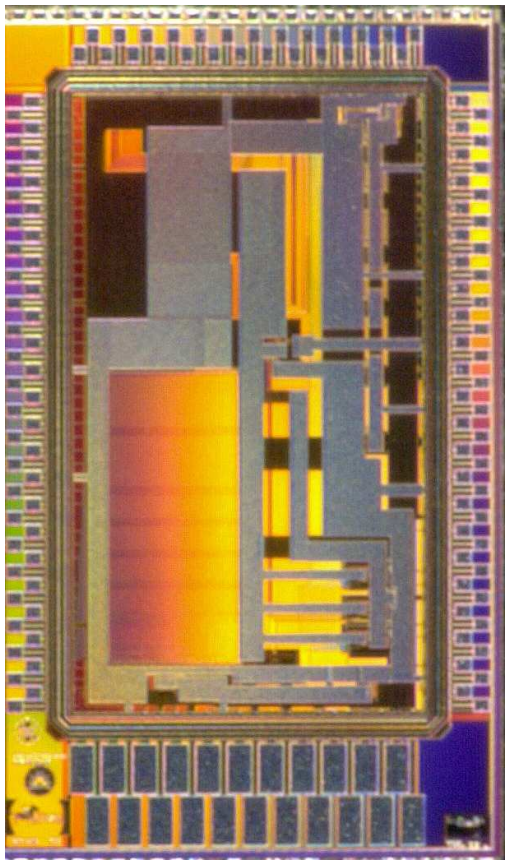
keV-Energy photons: test results





measurements at P04 beamline (Petra III)

TS3 tests



- PLL: Operating up to 400MHz
- LVDS Stages: Operating at 800Mbits/s (limited by DAQ system)