

Percival: a CMOS Imager for Photon Science

Alessandro Marras

on behalf of the DESY FS-DS group

and of the Percival collaboration



The Percival collaboration & support



The Percivallians:

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Goettlicher, S. Lange, I.
Shevyakov, S. Smoljanin, H.
Hirsemann, Q. Xia, M.
Zimmer, S. Reza

D. Das, N. Guerrini, B. Marsh,
I. Sedgwick, R. Turchetta,

G. Cautero, D. Giuressi, A.
Khromova, R. Menk, L.
Stebel, G. Pinaroli

U. Pedersen, N. Rees, N.
Tartoni, H. Yousef

H. Hyun, K. Kim, S. Rah



Beamline(s) support:

P04 (Petra III):

S. Klump, F. Scholz, J. Seltmann,
J. Viefhaus

Twinmic, Cipo (Elettra):

A. Gianoncelli
N. Zema, S. Rinaldi, D. Catone

I10 (DLS):

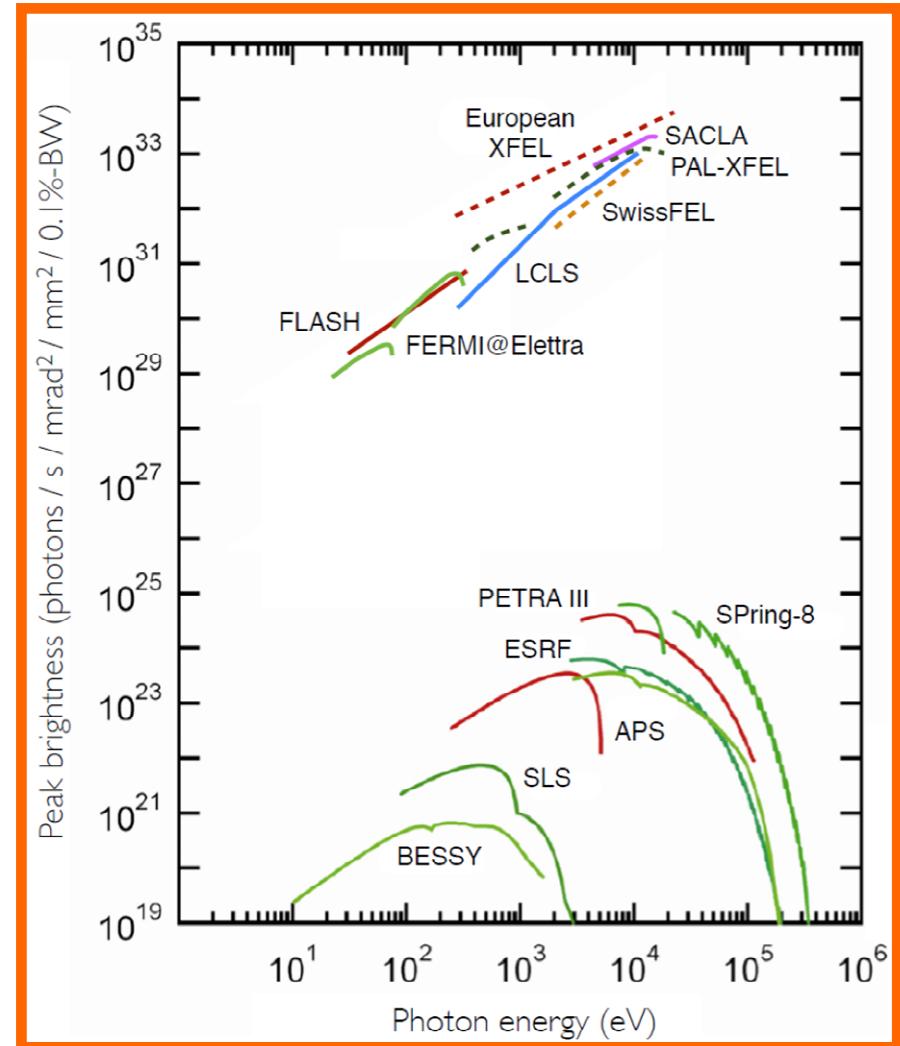
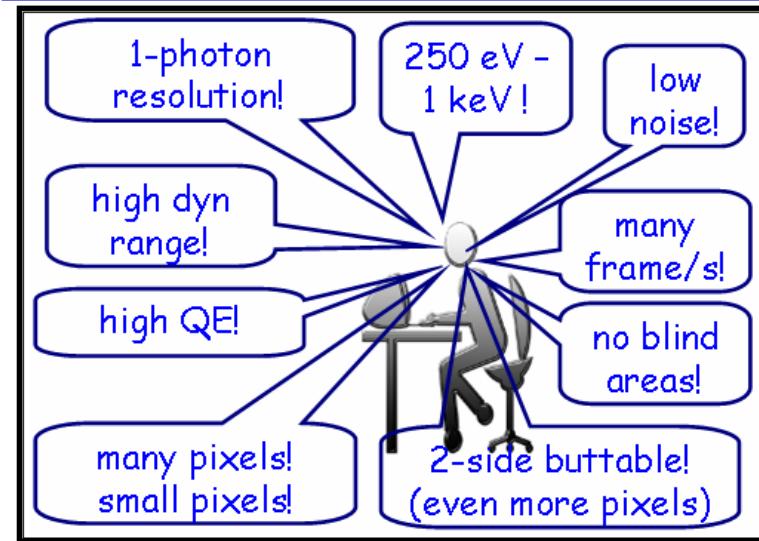
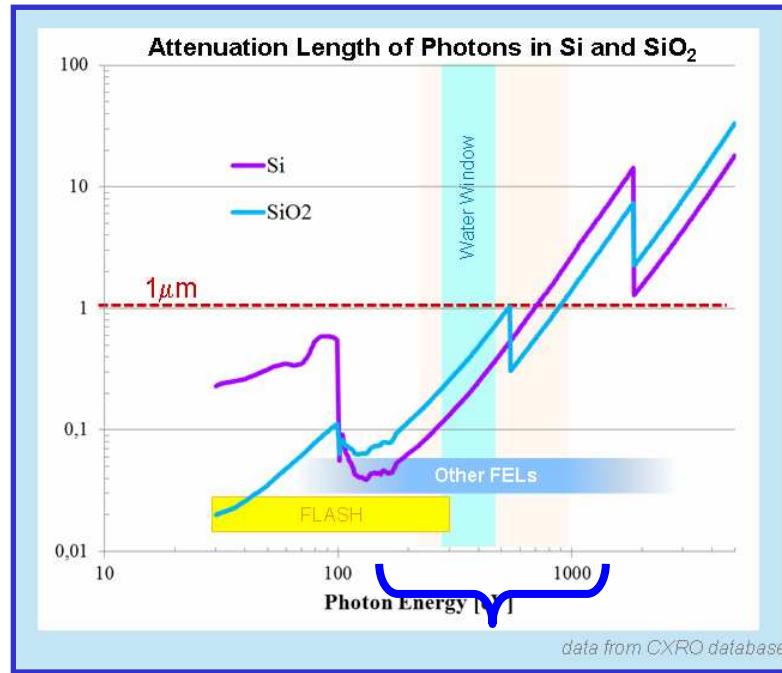
P. Steadman, M. Sussmuth

BL2 (Flash):

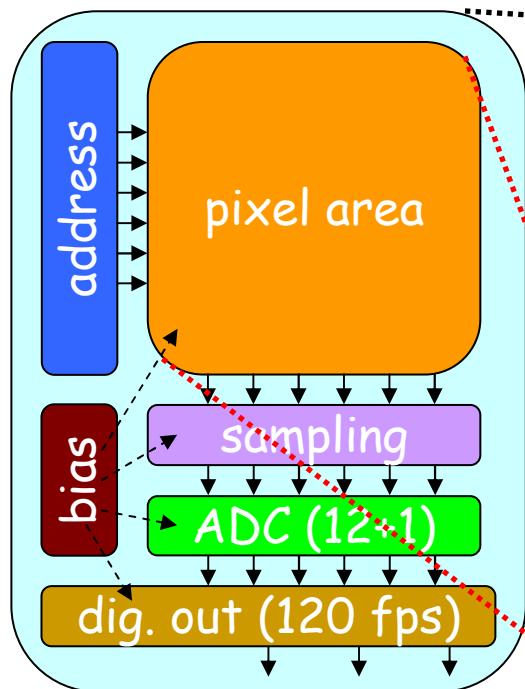
S. Toleikis, S. Duesterer



Motivation



The full PERCIVAL system

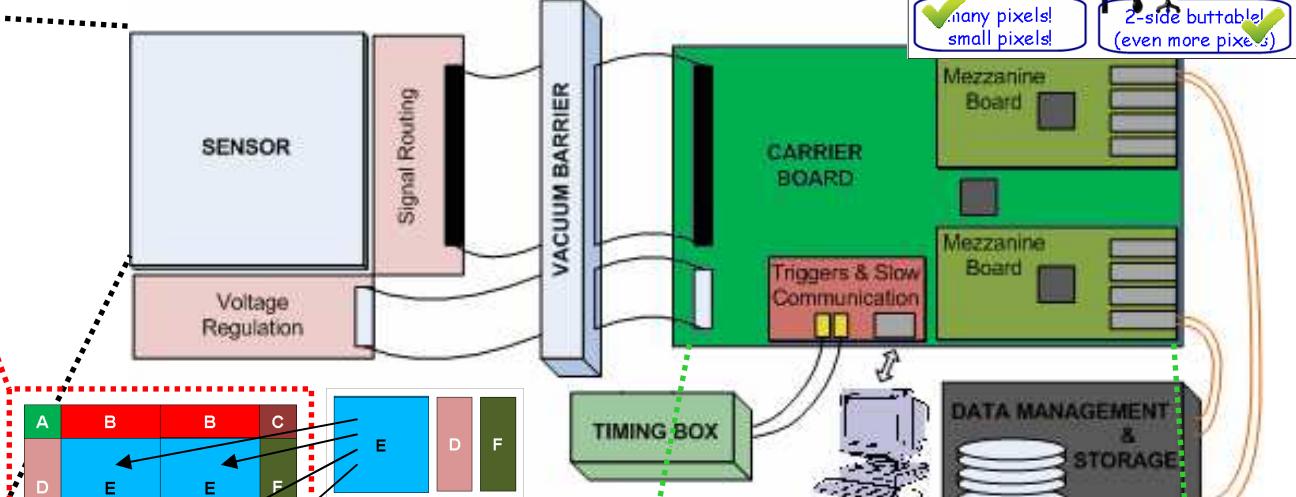


P2M

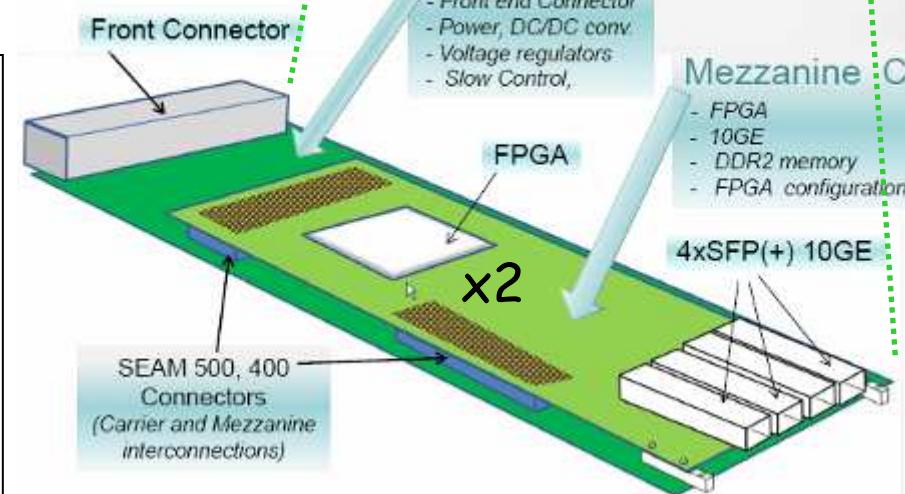
- 2Mpixels
- $\sim 4 \times 4\text{cm}^2$ sensible area
- no gaps or blind areas
- 2-side buttable
- 27 μm pixel pitch
- manuf. ~spring 2016, postproc. ~end of 2016

P13M

- 13Mpixels
- $\sim 10 \times 10\text{cm}^2$
- no gaps
- 2-side butt.
- 27 μm
- later

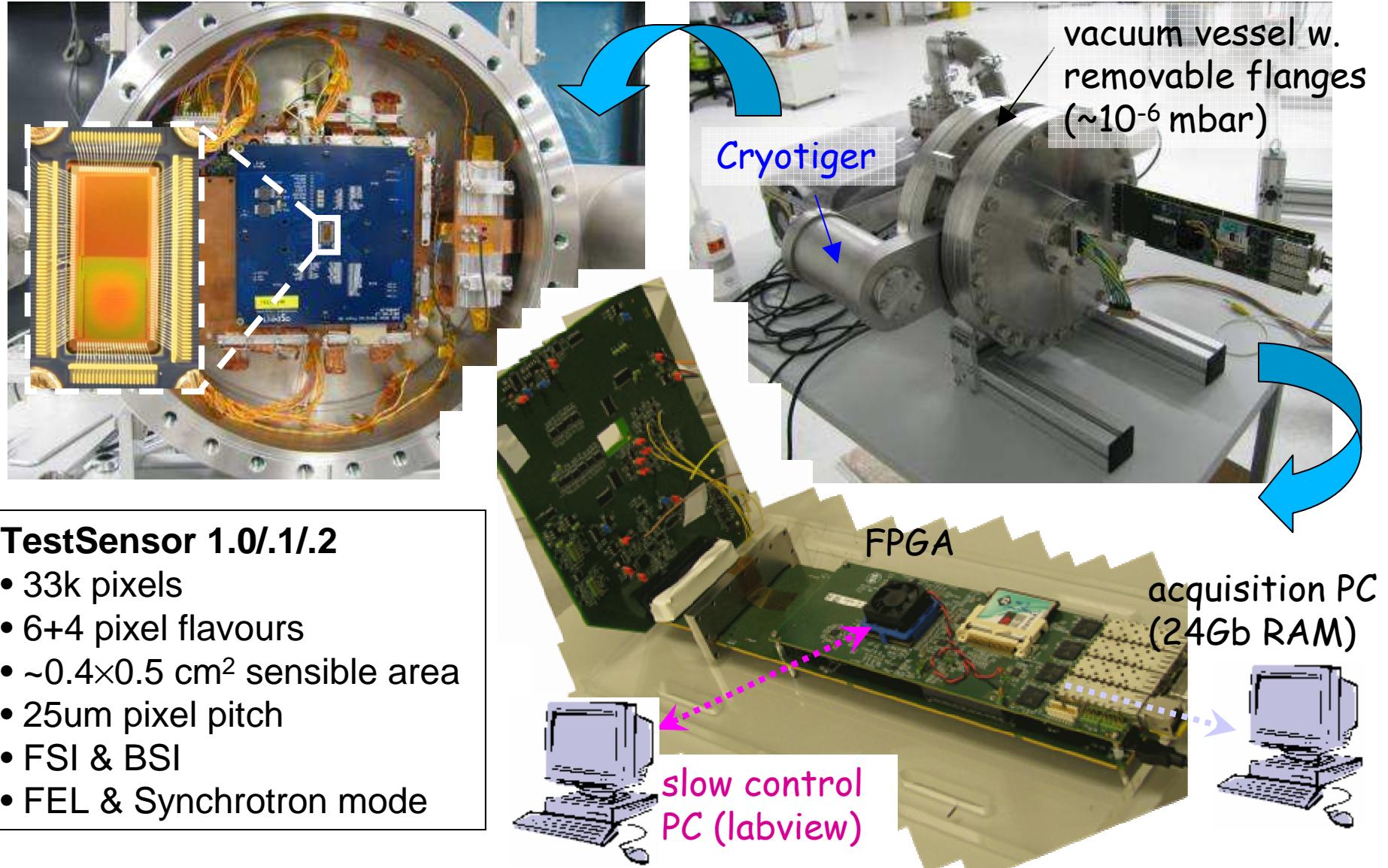


layout stitching

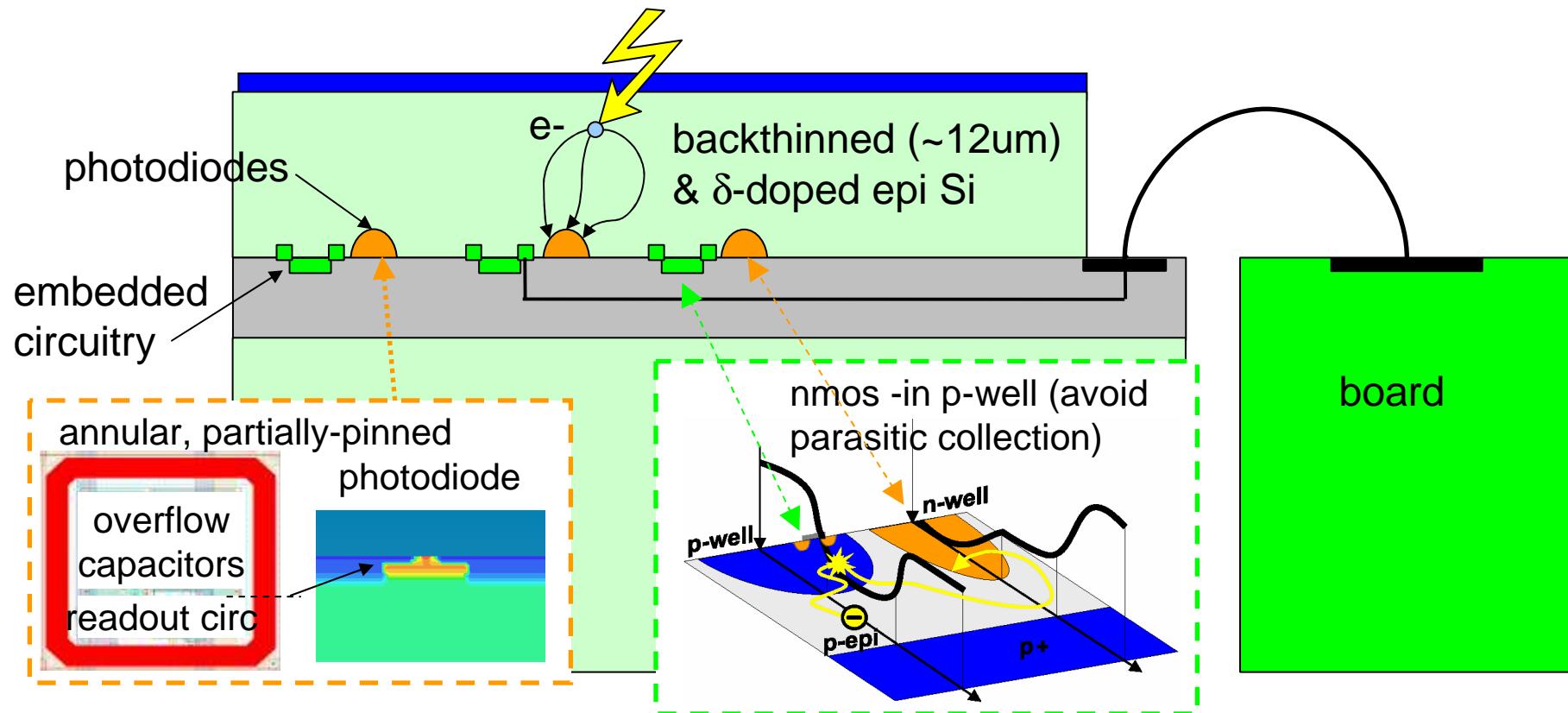


1-photon resolution!
250 eV - 1 keV!
low noise!
high dyn range!
high QE!
many pixels! small pixels!
many frame/s!
no blind areas!
2-side buttable! (even more pixels)

The PERCIVAL prototype



Monolithic Active Pixel Sensor



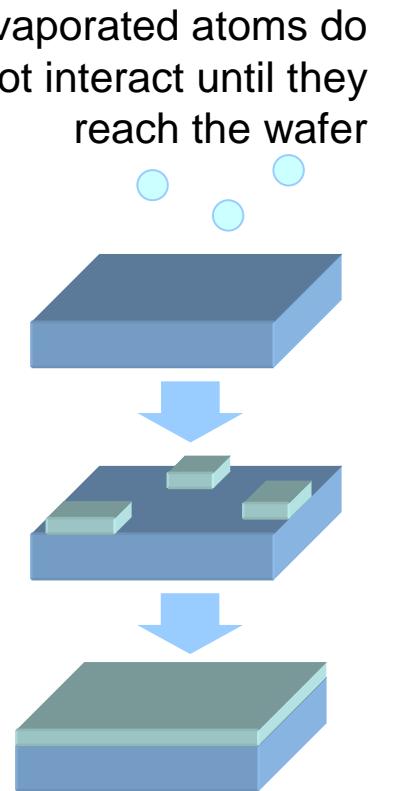
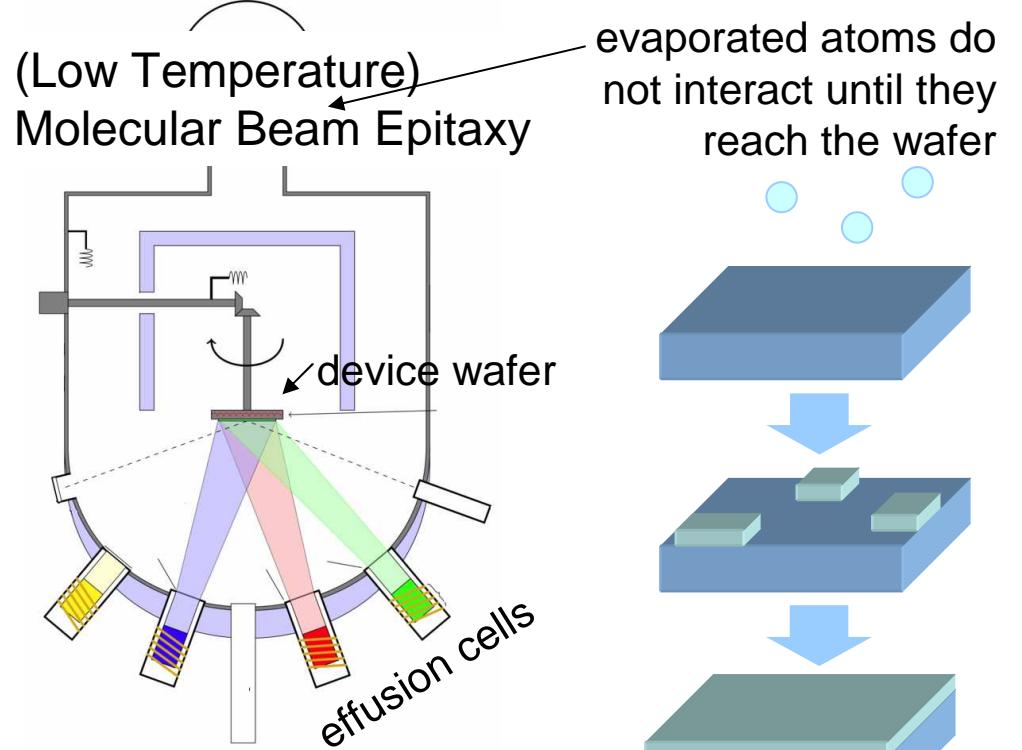
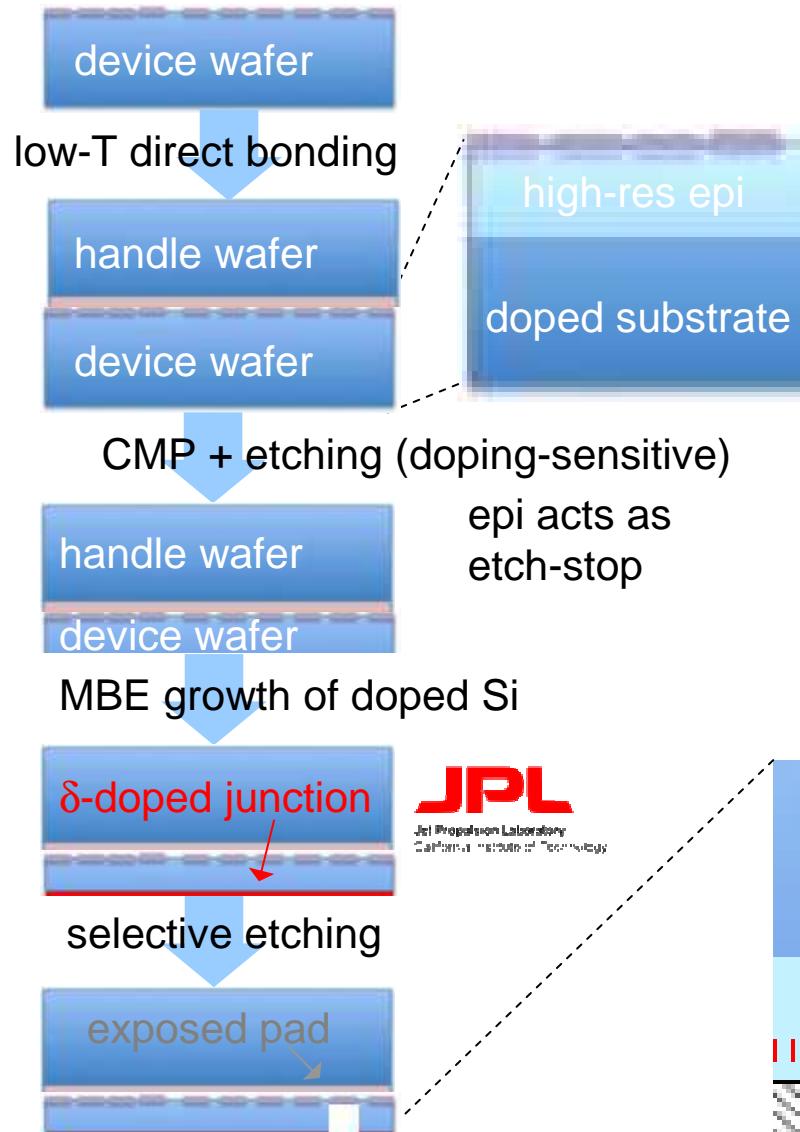
Monolithic: Collecting diodes & readout circuitry share the same substrate

TowerJazz 0.18um CMOS techn, over high-resistance thick epi

Coupled to handling wafer, back-thinned, back-illuminated: 100% fill factor

Back surface delta-doped, post-processed: almost no entrance window

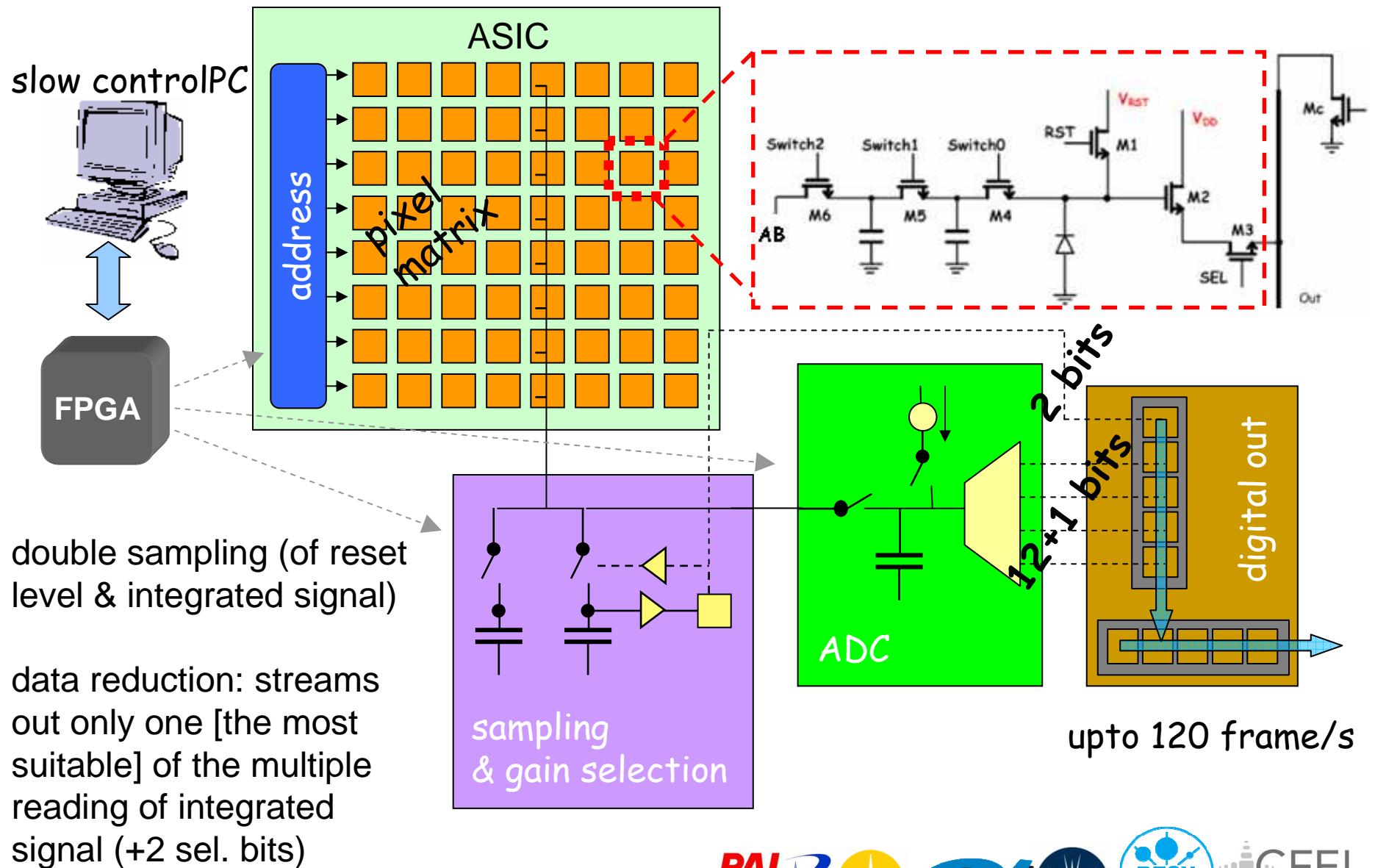
delta-doping of back-surface



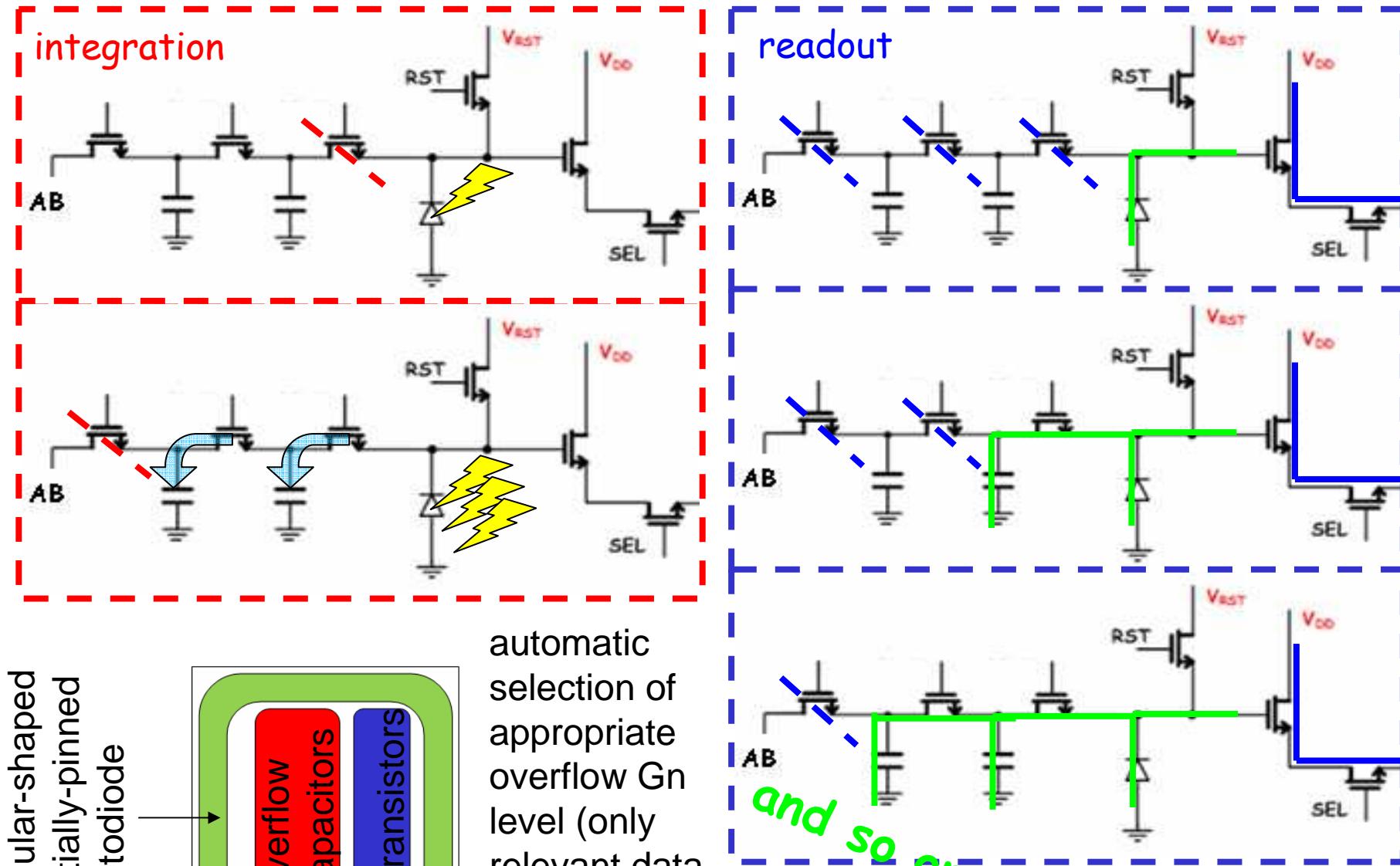
(Nikzad et. al., IEDM14; Hoek et al., KISS Workshop)



The PERCIVAL core



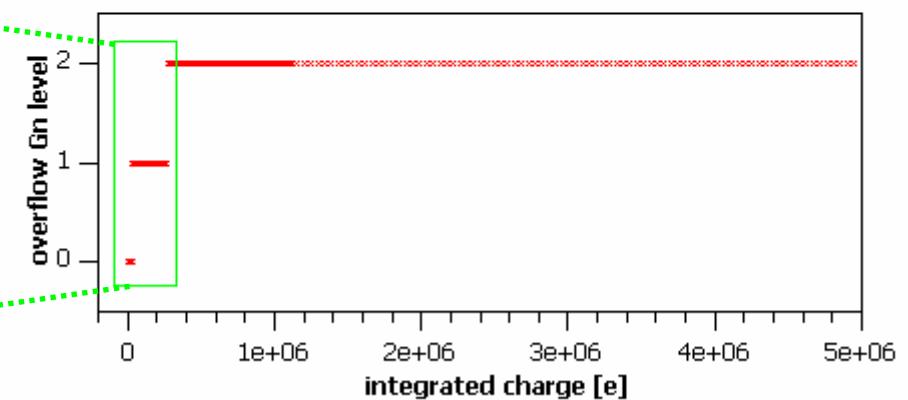
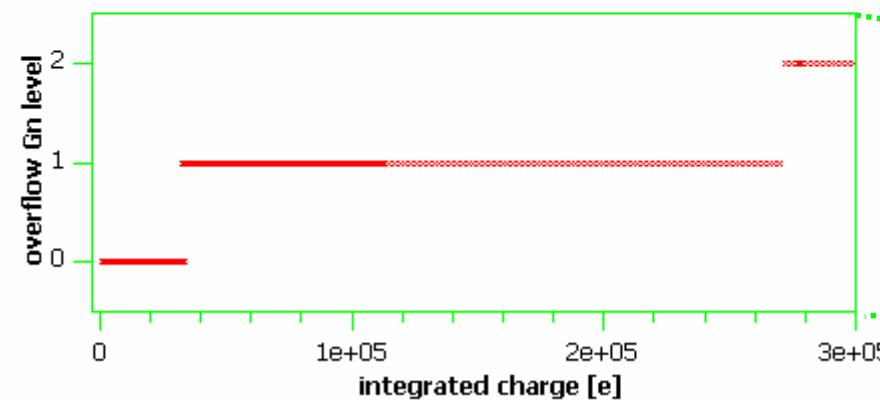
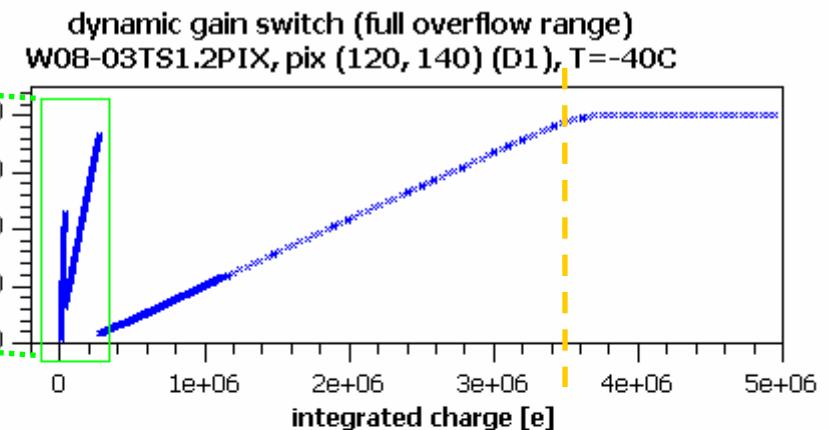
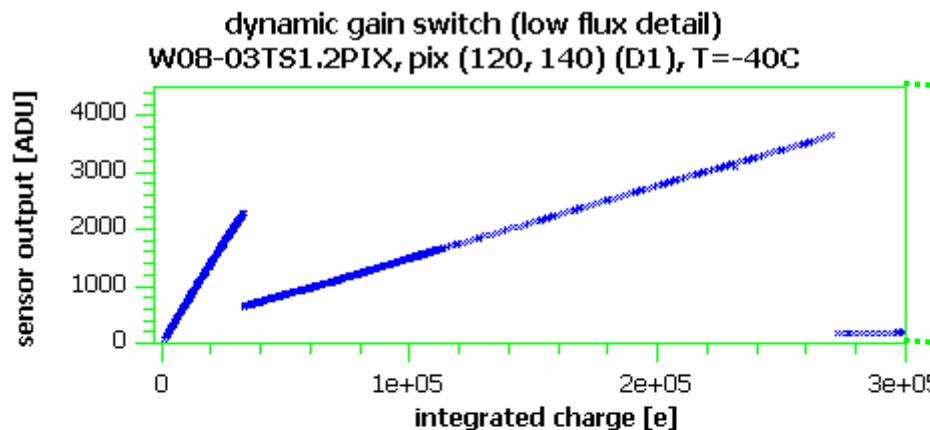
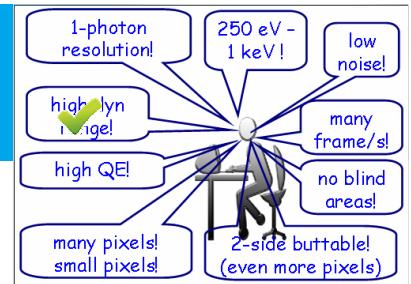
Lateral Overflow



automatic selection of appropriate overflow Gn level (only relevant data streamed out)

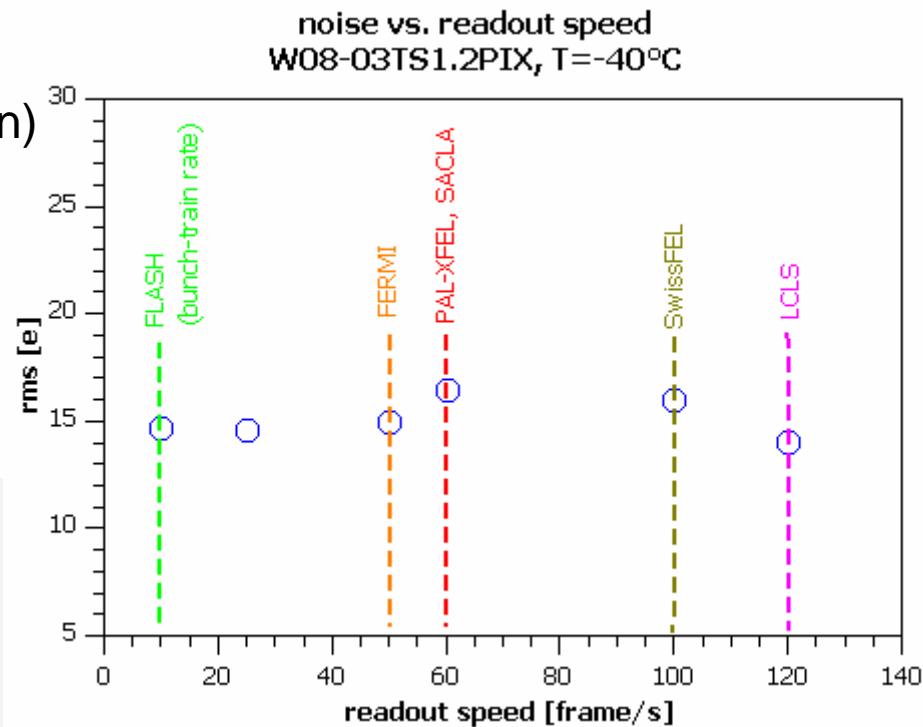
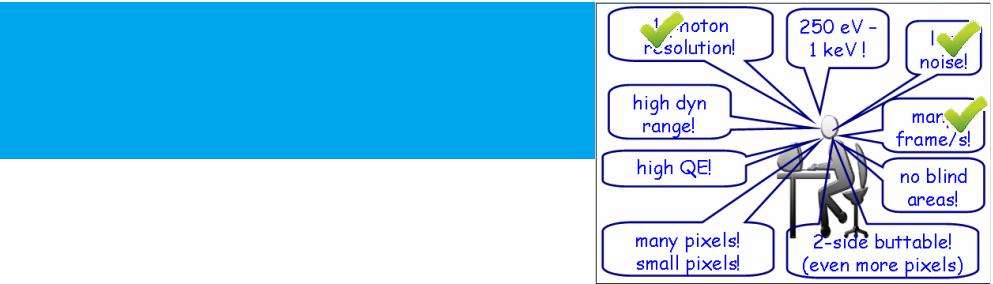
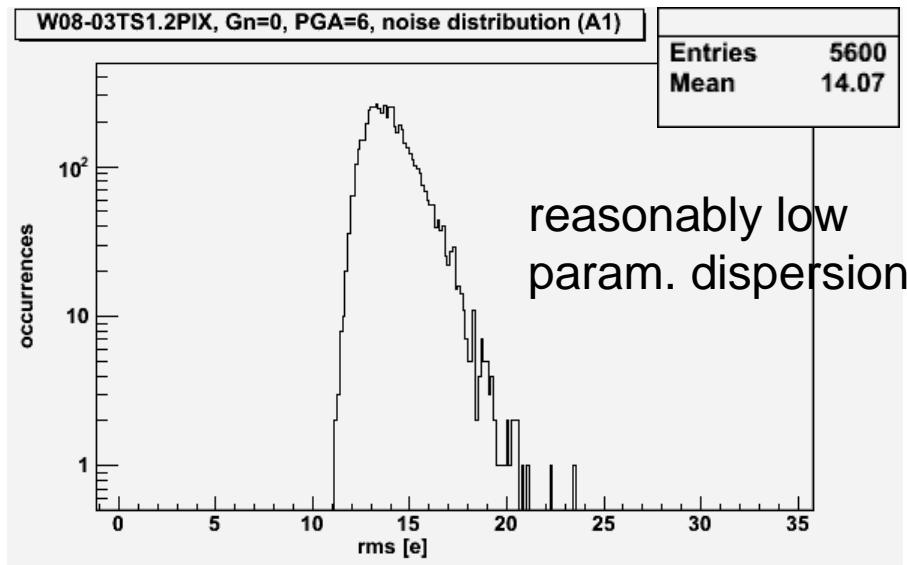
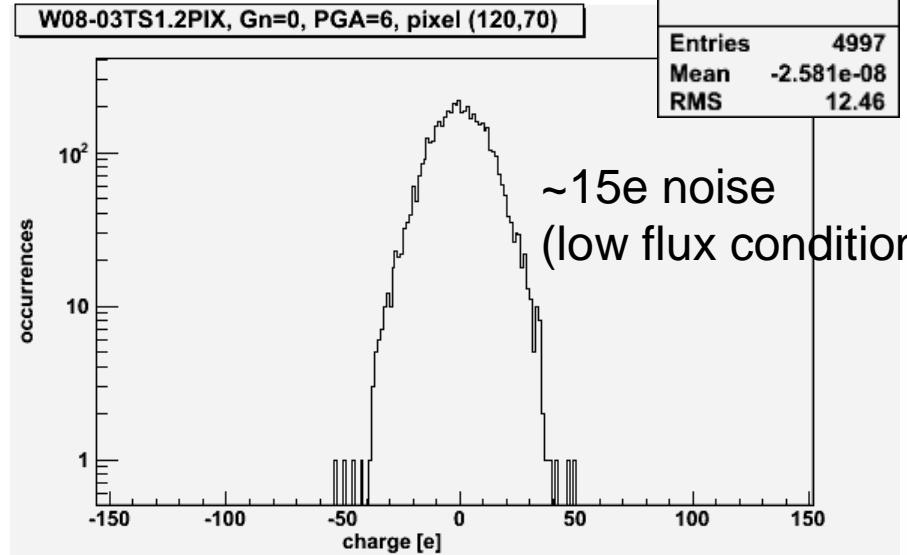
The footer features the logos of four funding agencies: PAL (blue and red stylized letters), OI (yellow starburst logo), DESY (blue circular logo with a grid pattern), and CFEL SCIENCE (blue and grey square logo).

Lateral Overflow, dynamic range: test results



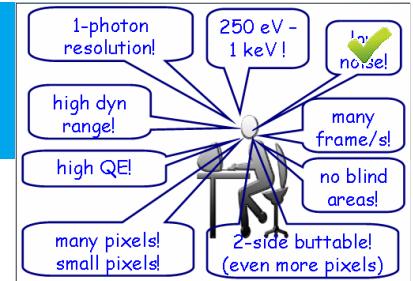
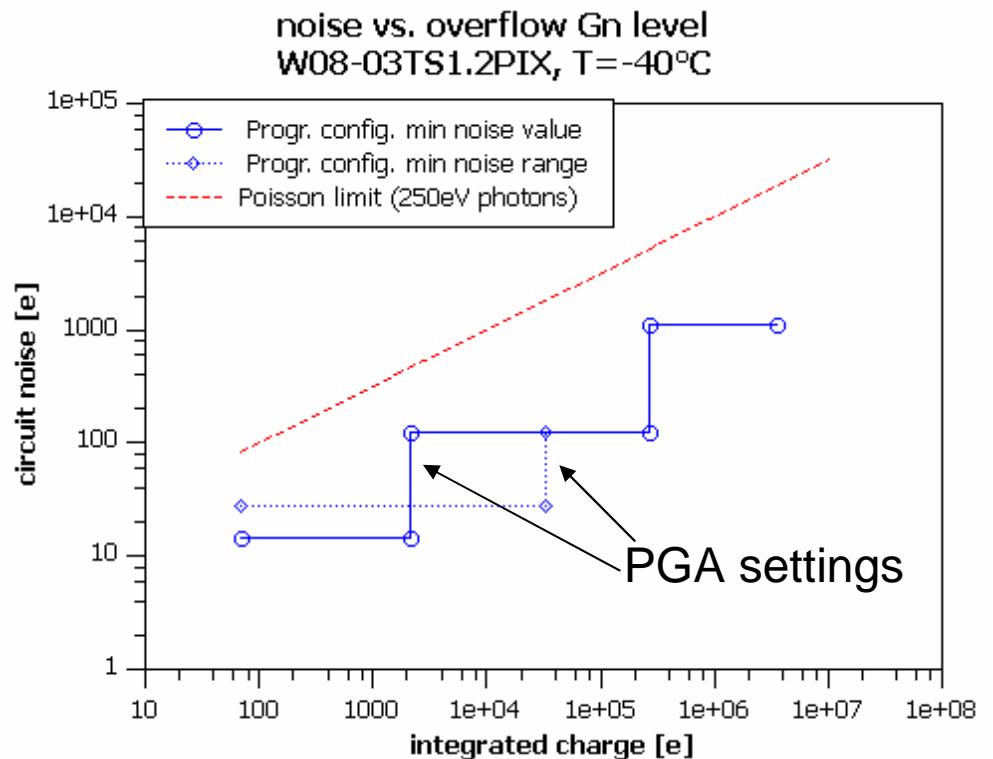
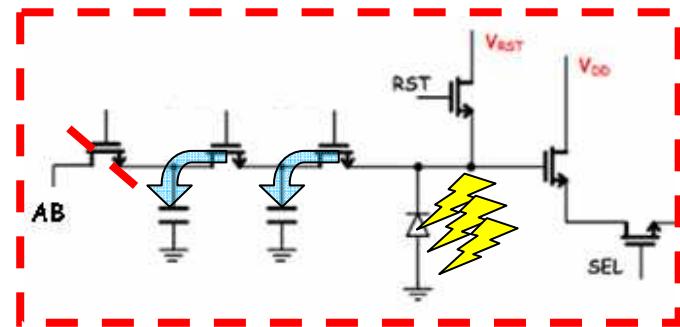
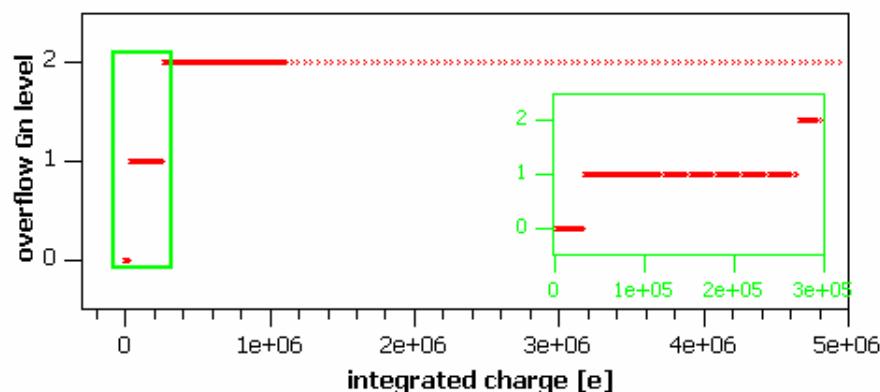
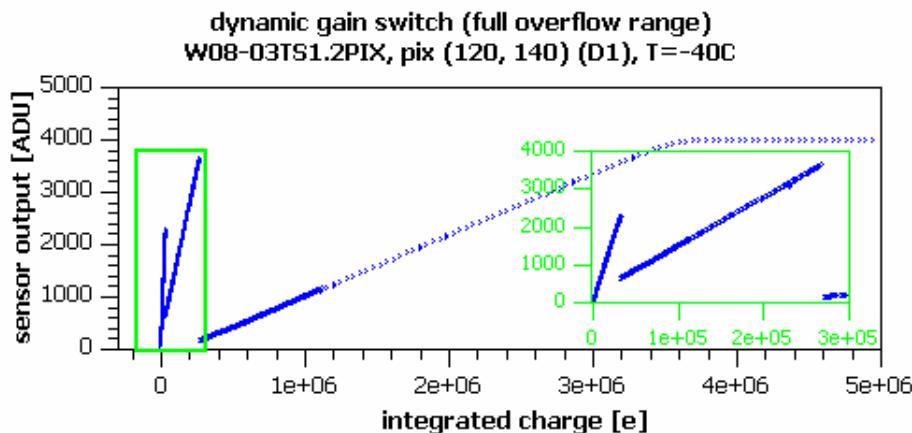
dyn. range: 3.5Me ~ 50k photons @ 250eV

noise: test results



compatible with most FEL frame rates

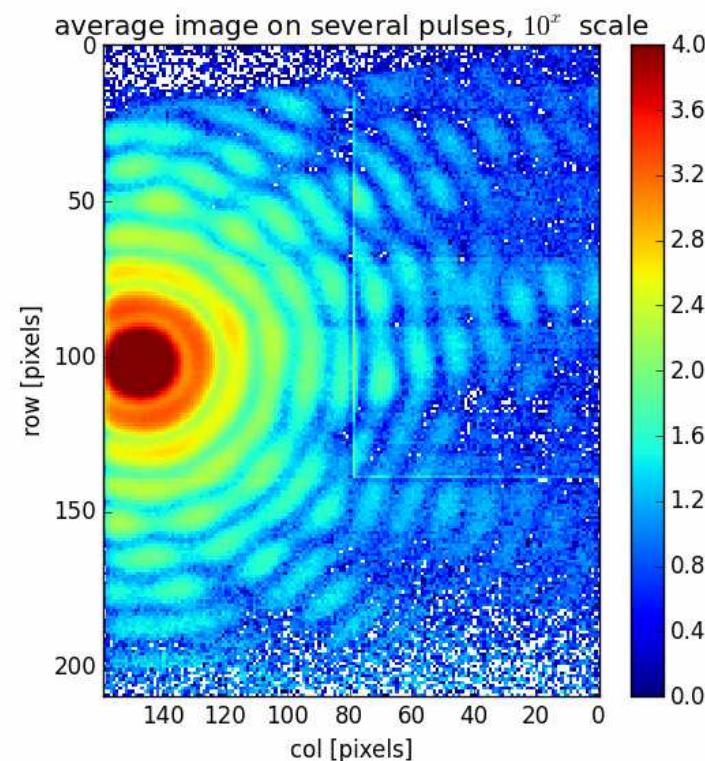
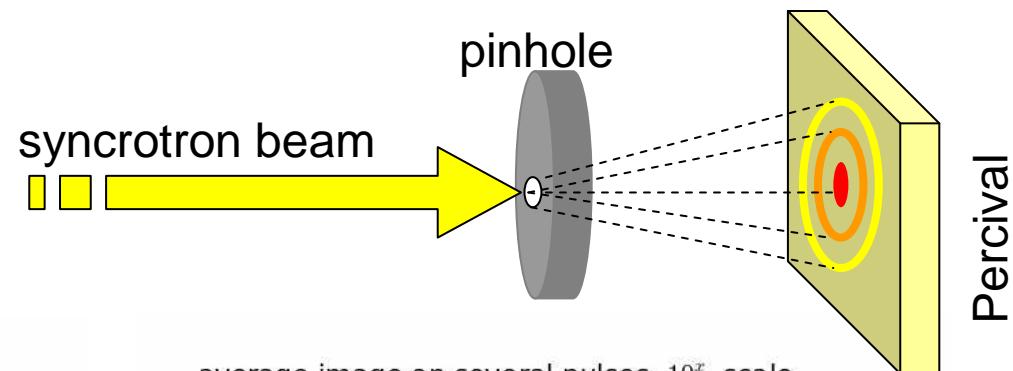
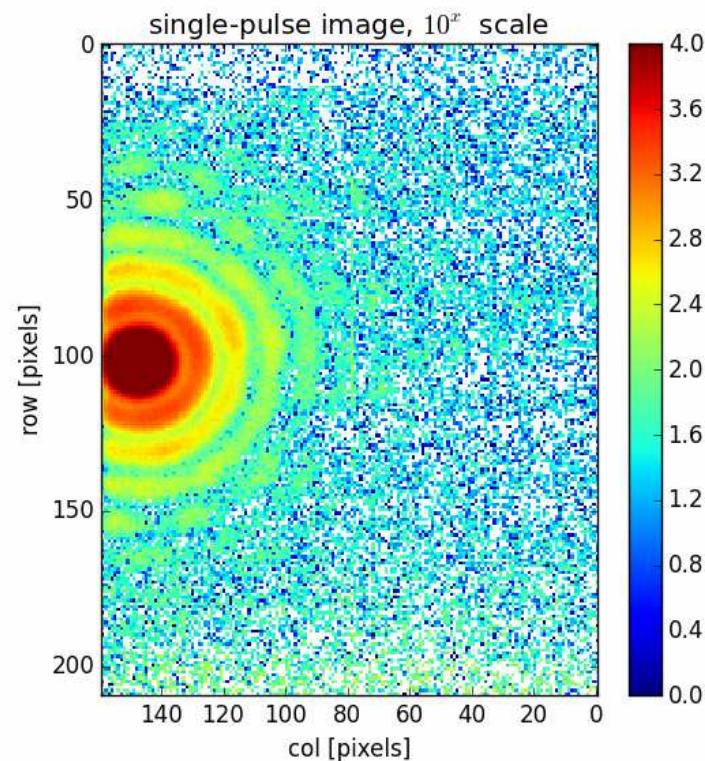
noise: test results



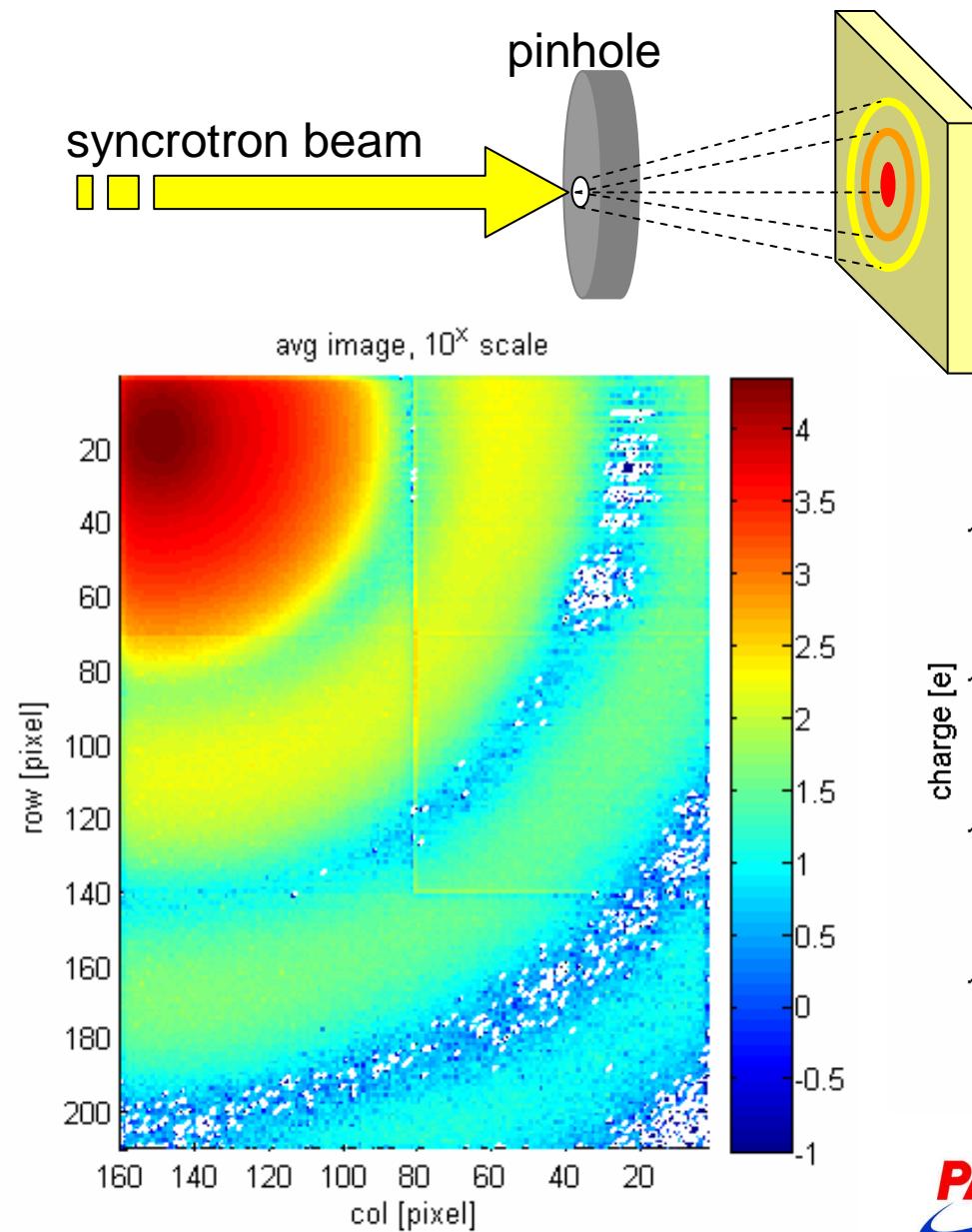
single pulse imaging @ FEL: test results



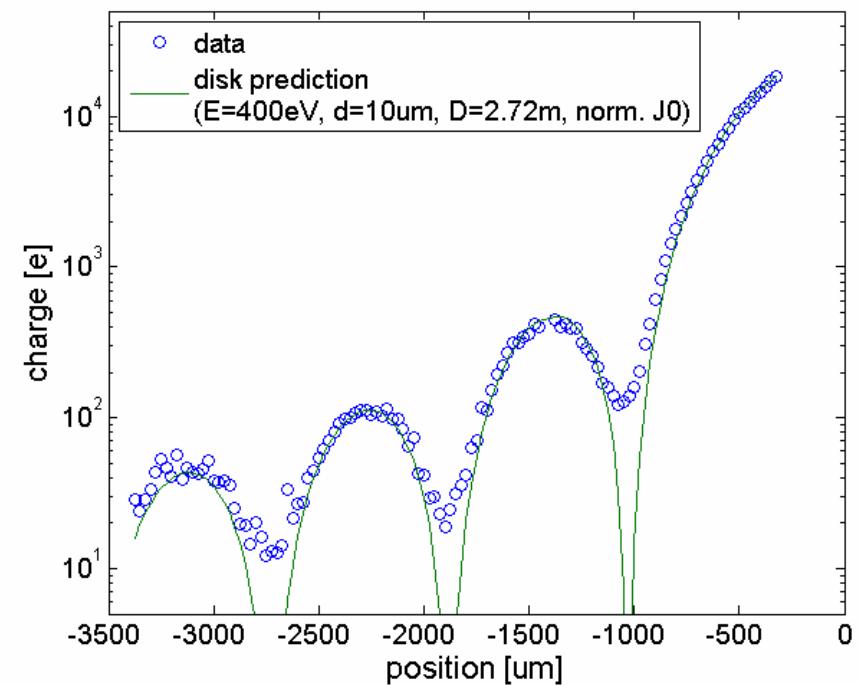
tests at BL2 (Flash)
single-pulse imaging (10Hz)
92eV



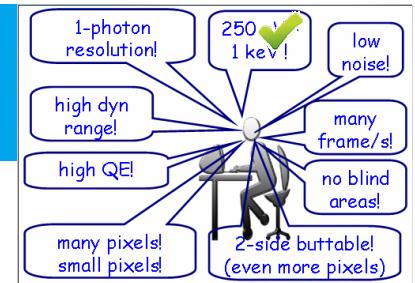
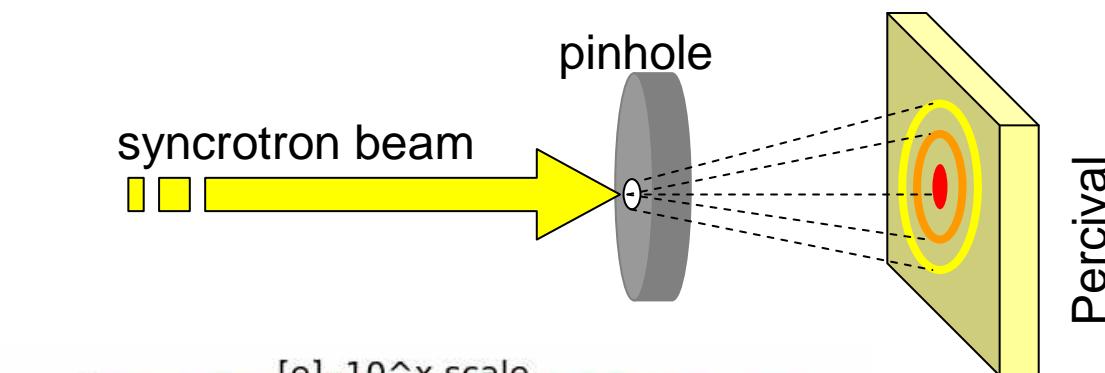
Low-Energy photons: test results



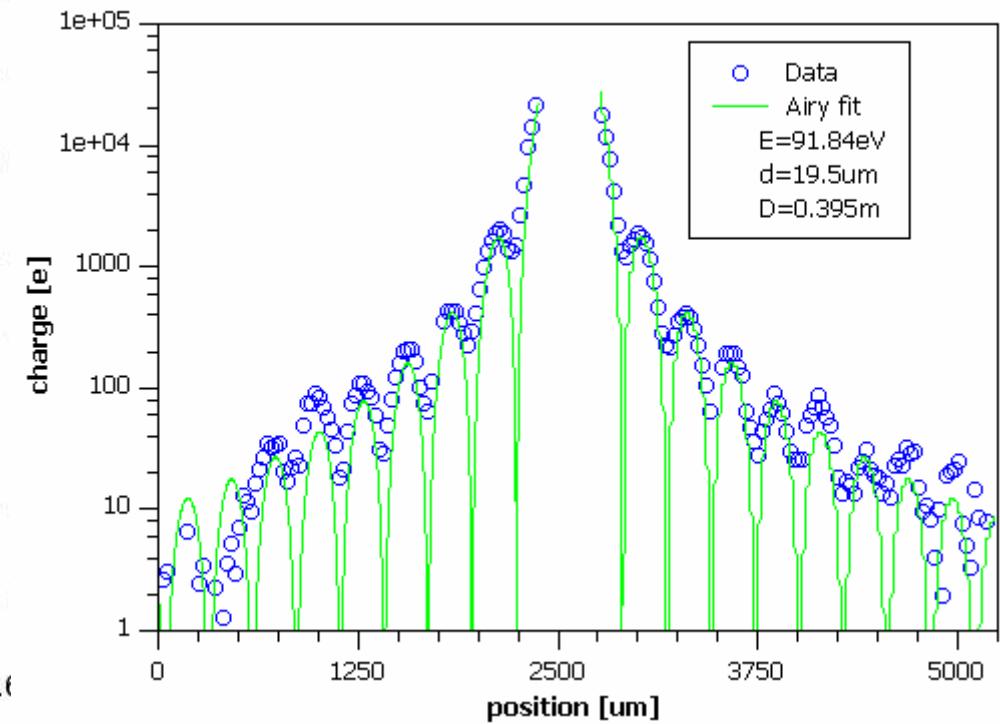
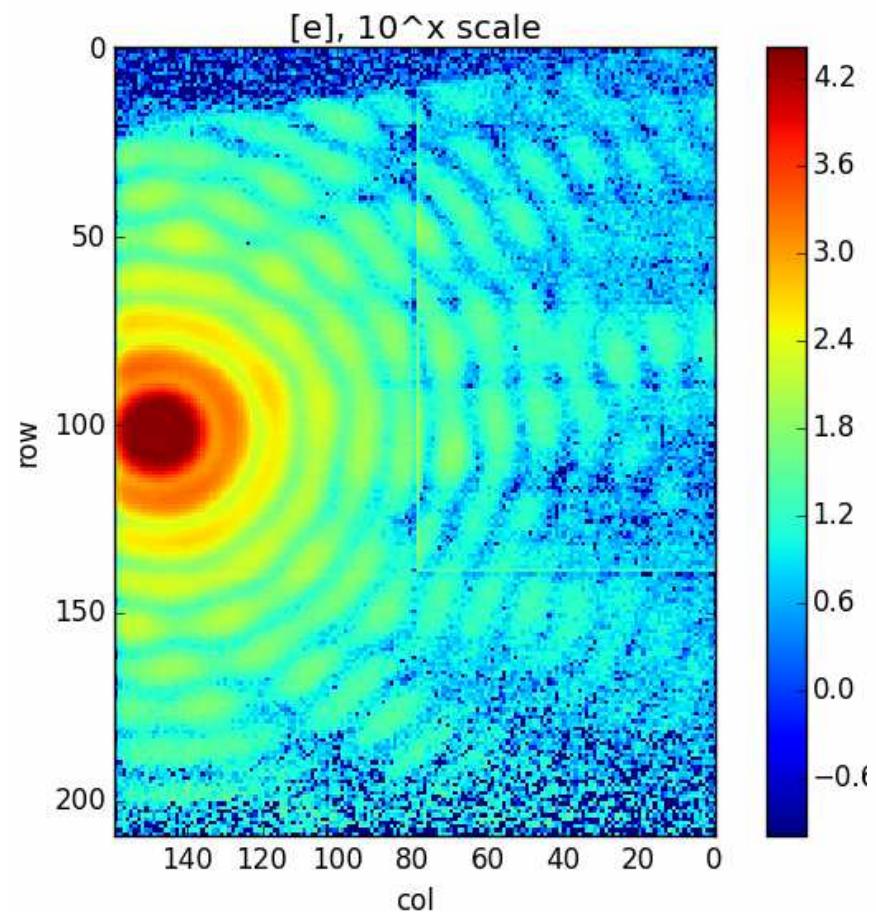
Percival
1-2keV tests at P04 (Petra III)
400eV tests at I10 (DLS)
100-300eV tests at Twinmic,
Cipo (Elettra)



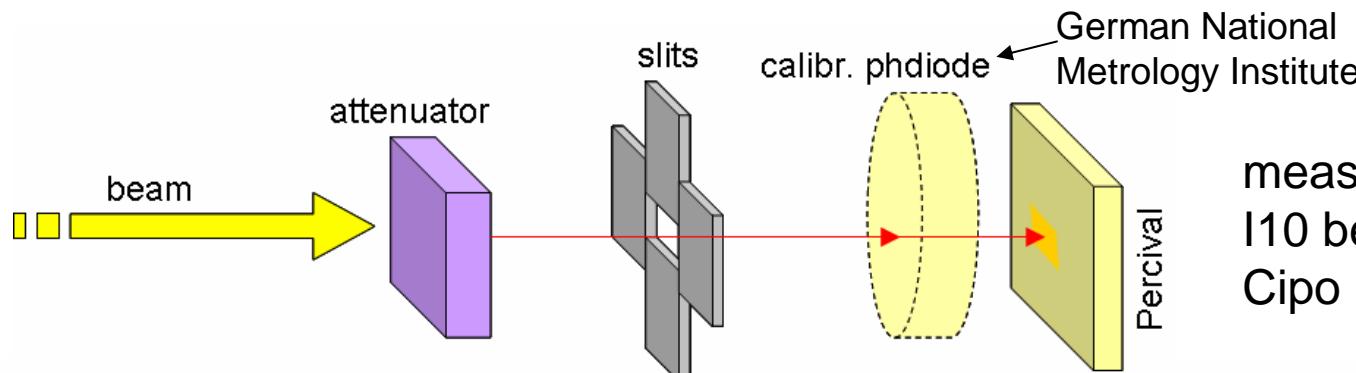
Lower-Energy photons: test results



91.84eV tests at BL2 (Flash)



Charge Collection Efficiency: test results

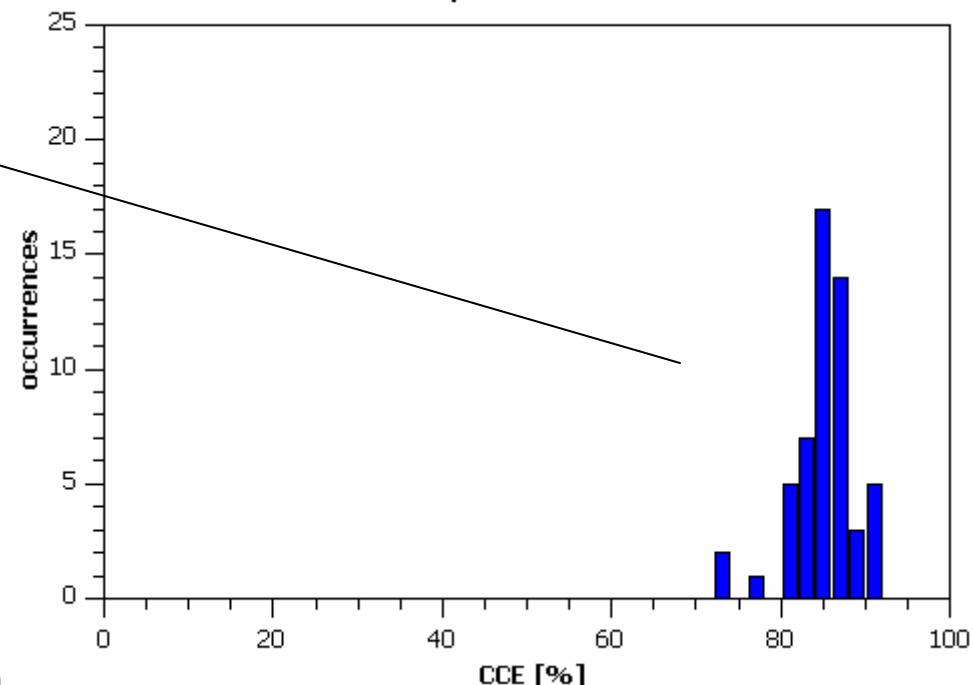
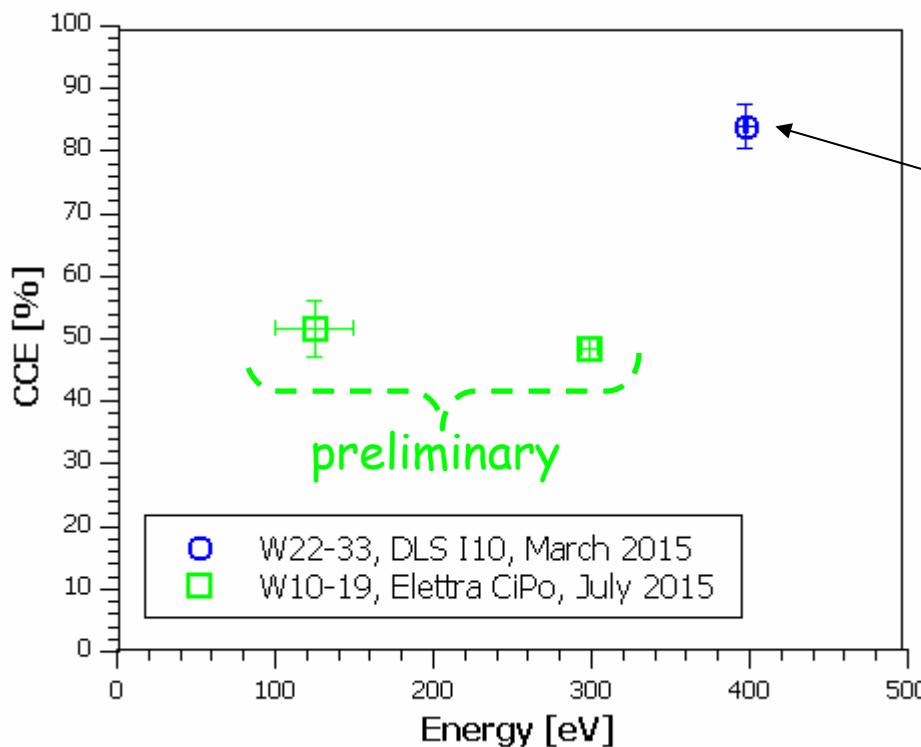


promising

- 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 buttatable (even more pixels)

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

DLS-I10, March 2015



Summary



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

(Pixelated 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 92eV-2KeV
- ✓ measured CCE (125-400eV)

P2M

- ✓ 2M pixels
- ✓ ~4×4cm² sensible area
- ✓ no gaps or blind
- ✓ 2-side buttable
- ✓ 27um pixel pitch
- ✓ manuf. ~spring 2016,
postproc. ~end of 2016

P13M

- ✓ 13M pixels
- ✓ ~10×10cm² sensible area

Summary

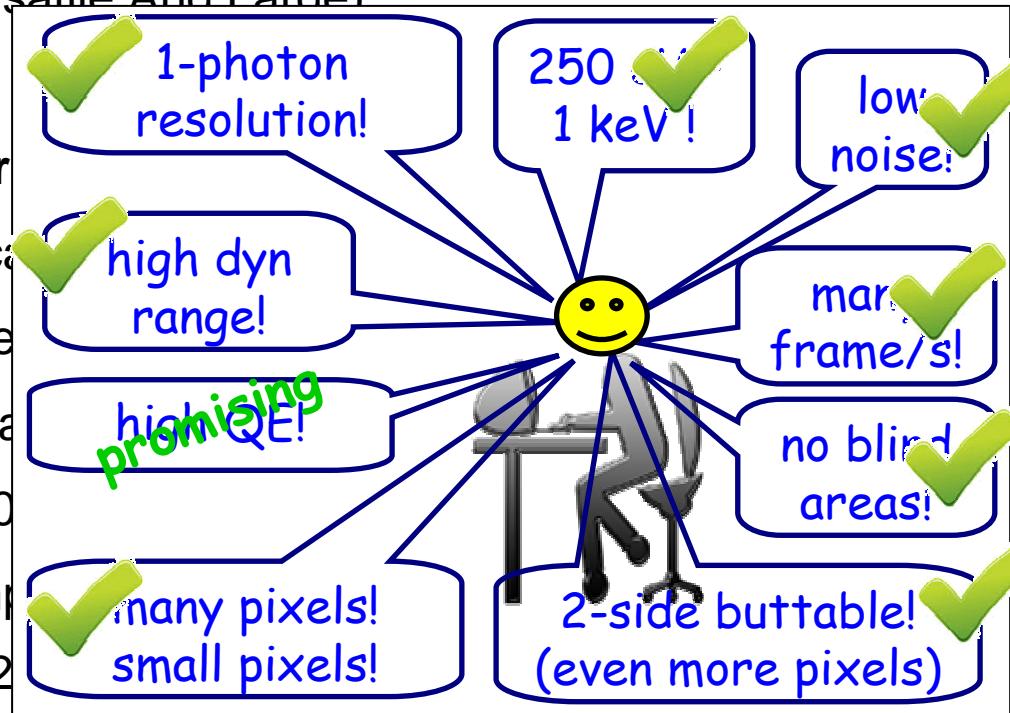


P.E.R.C.I.V.A.L.

(Pixelated Energy-Resolving Cmos
Imager Versatile And Large)

tests on preprod

- ✓ Dynamic range
- ✓ low noise
- ✓ high dynamic range
- ✓ up to 120 frames/s
- ✓ compact
- ✓ tested 12 modules
- ✓ measured CCE (125-400eV)



P2M

✓ 1408×1484 pixels

sible area
nd
e
tch
g 2016,
end of 2016

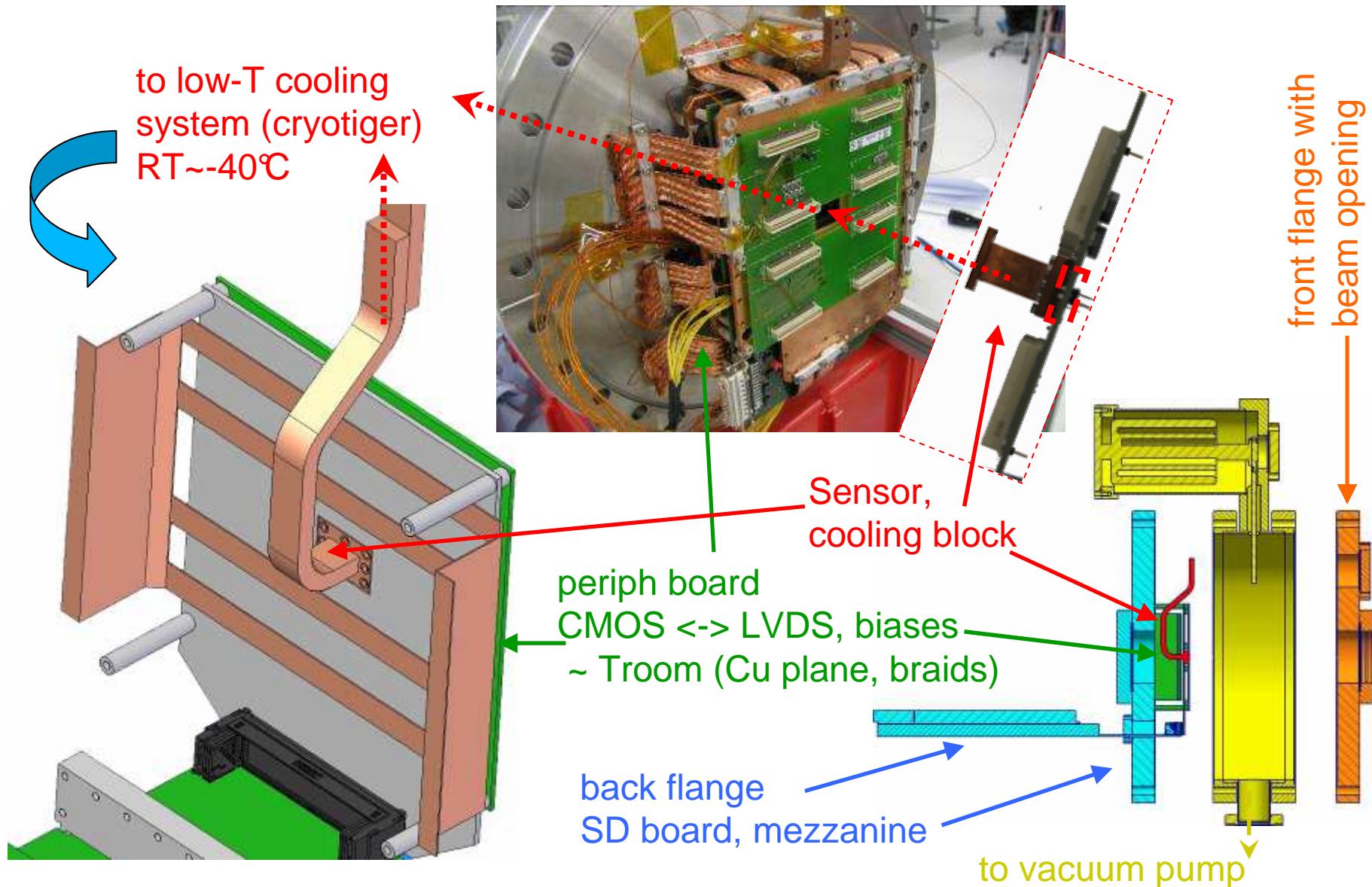
✓ ~ $10 \times 10 \text{ cm}^2$ sensible area



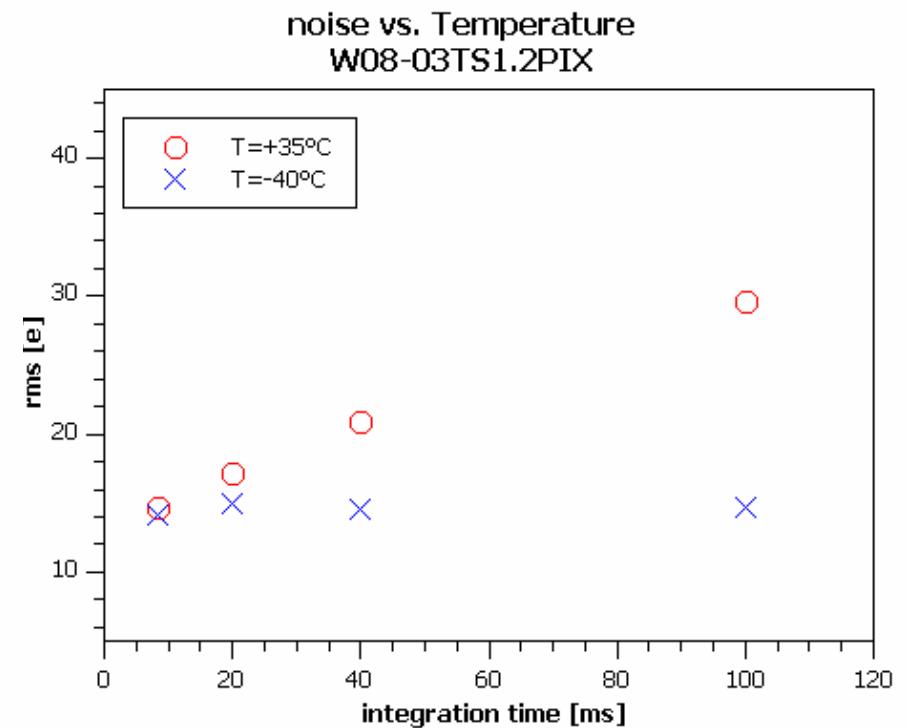
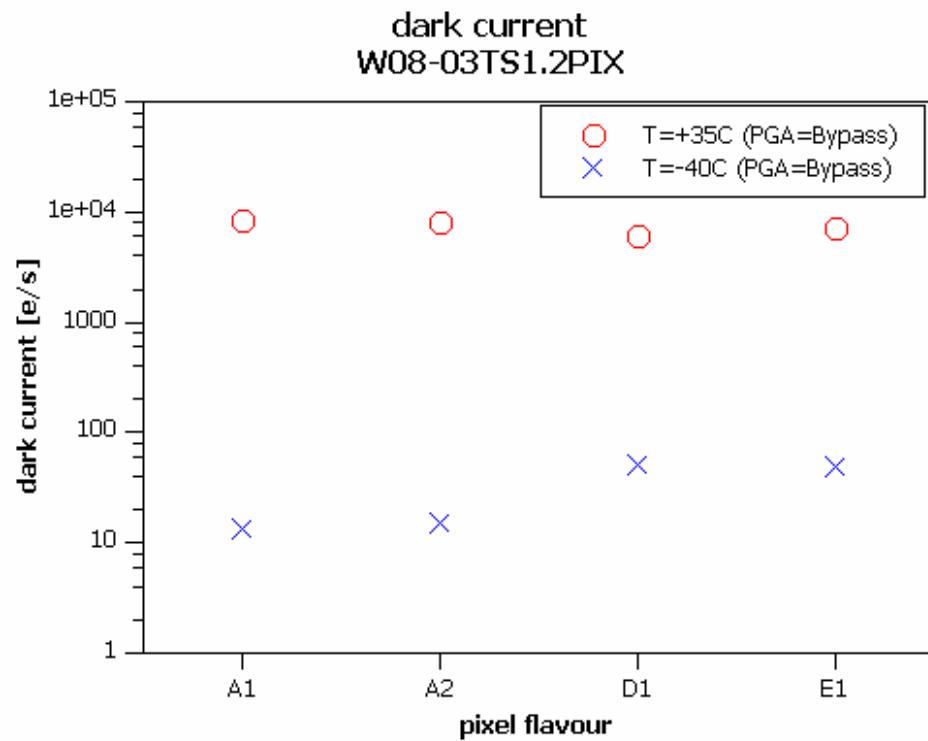
backup



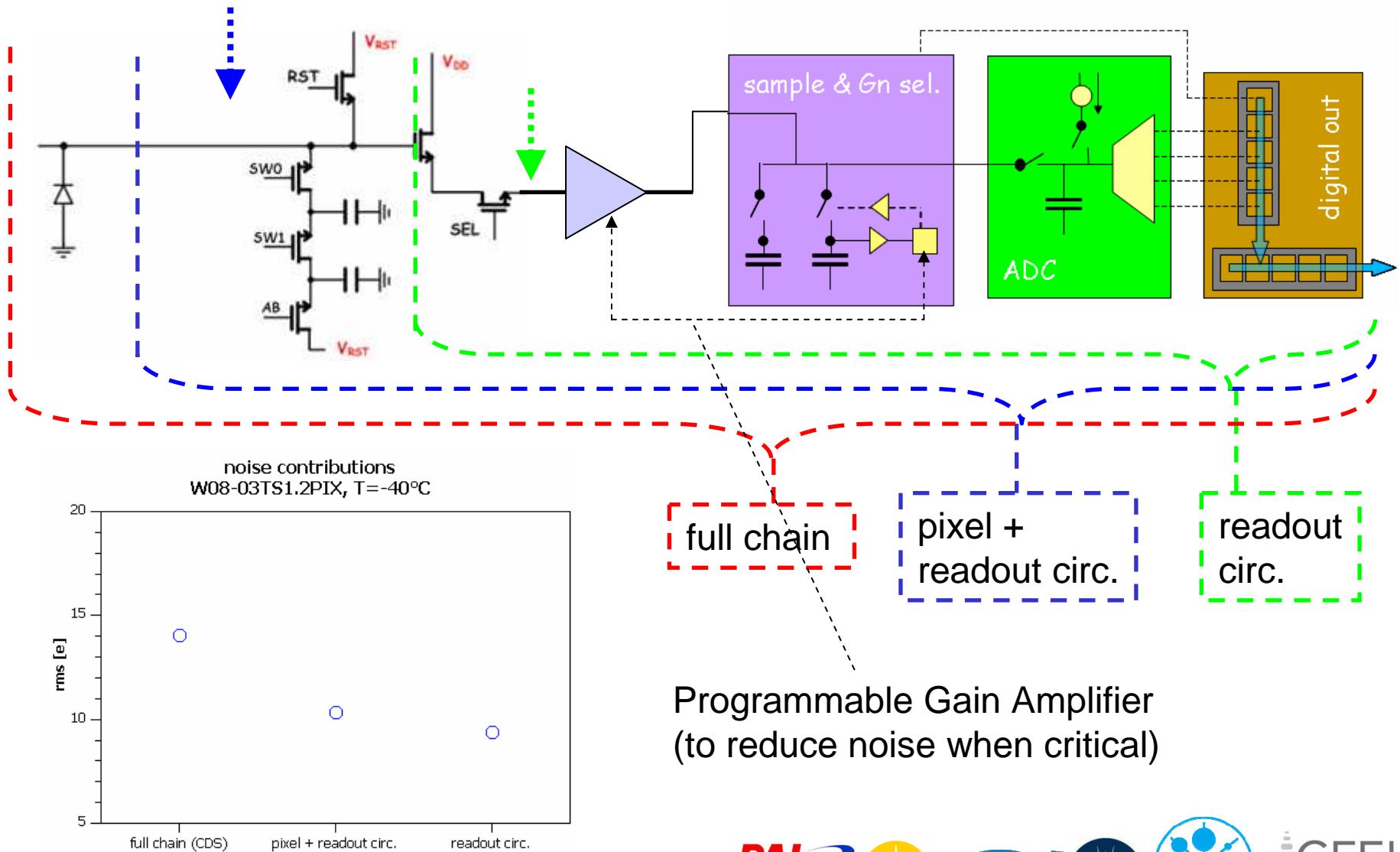
The PERCIVAL prototype



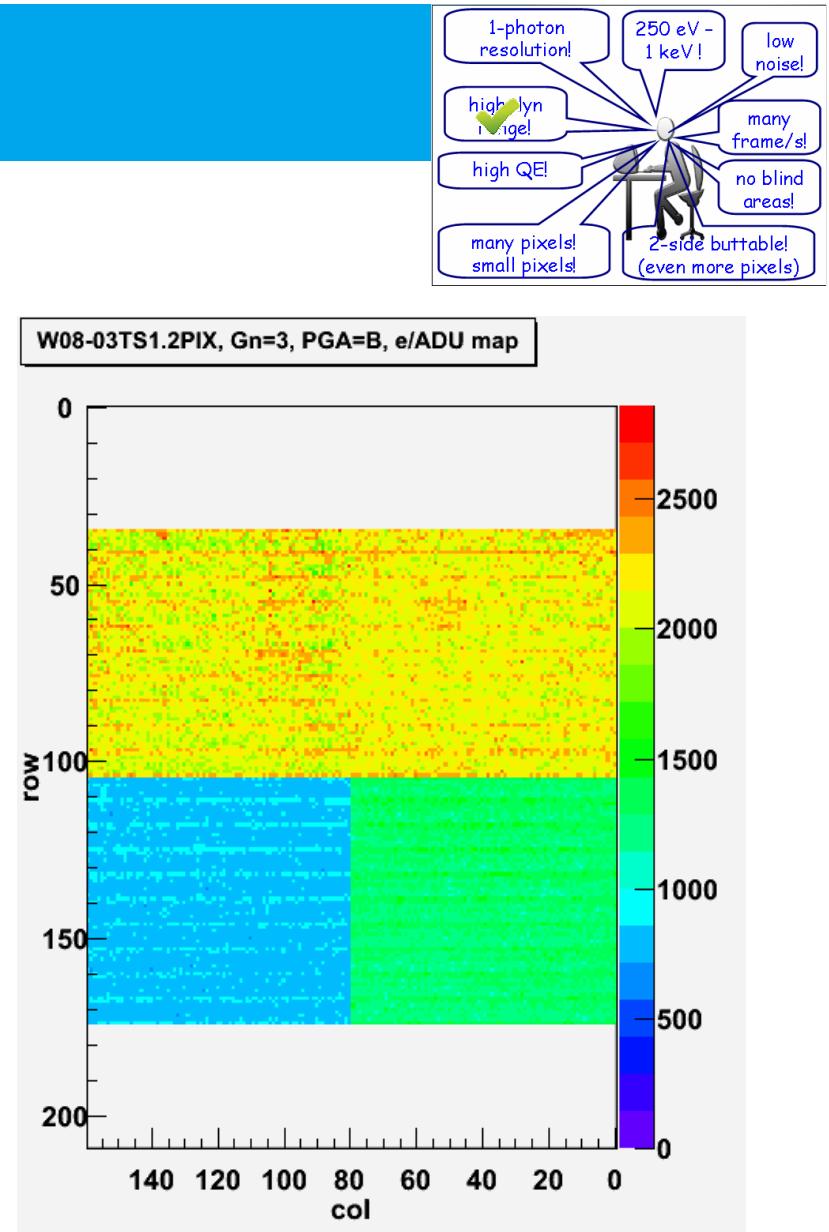
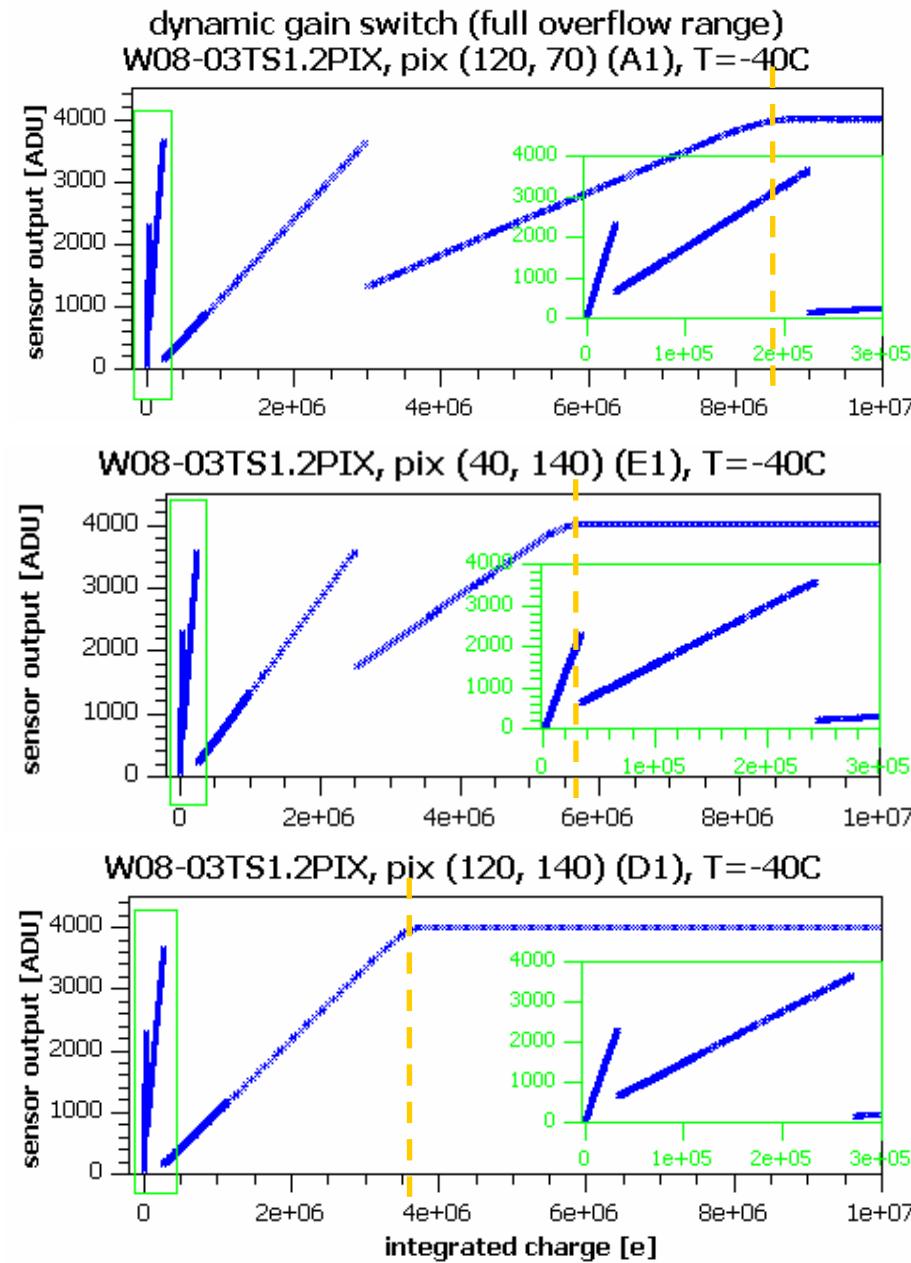
Temperature effects



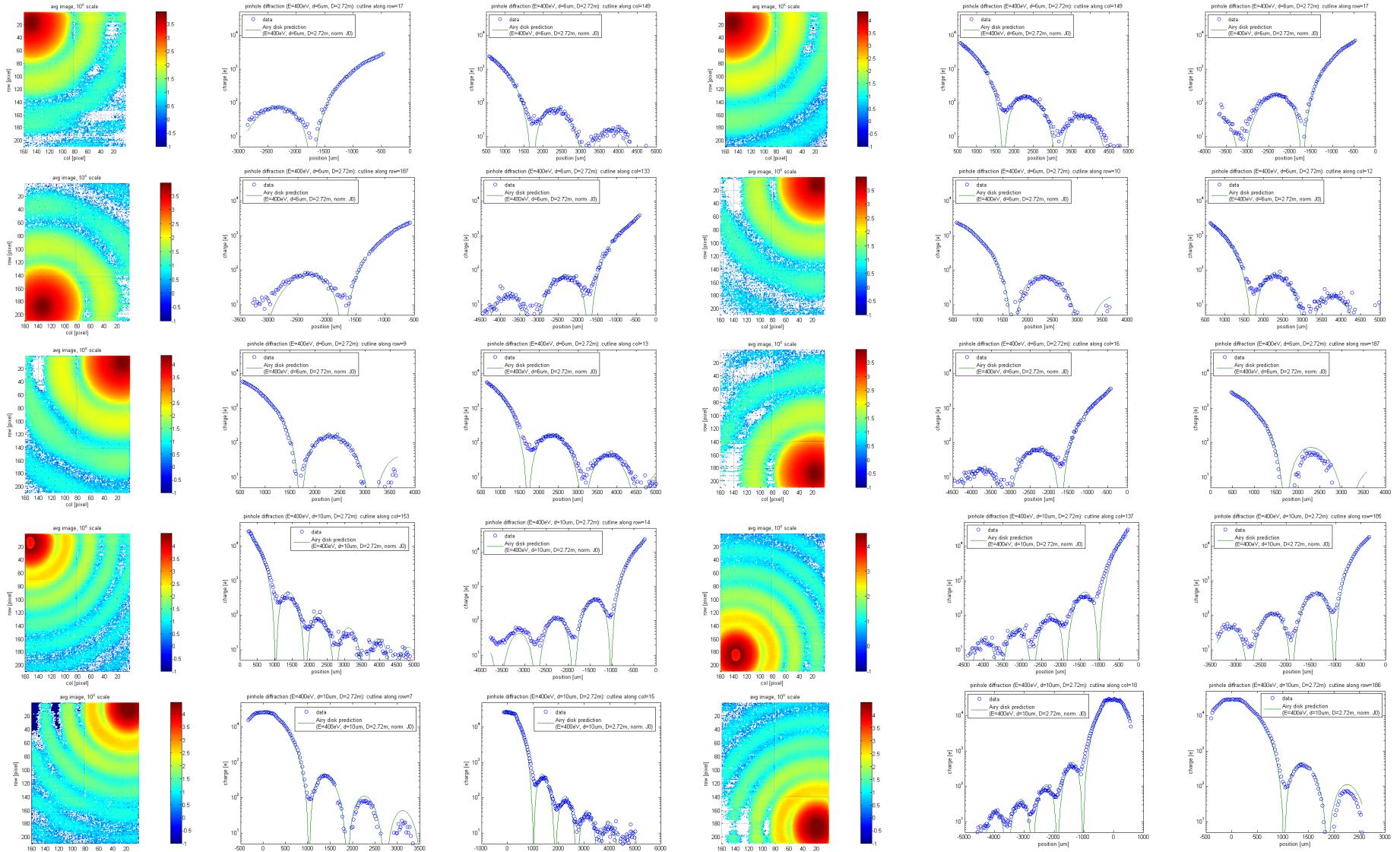
noise analysis



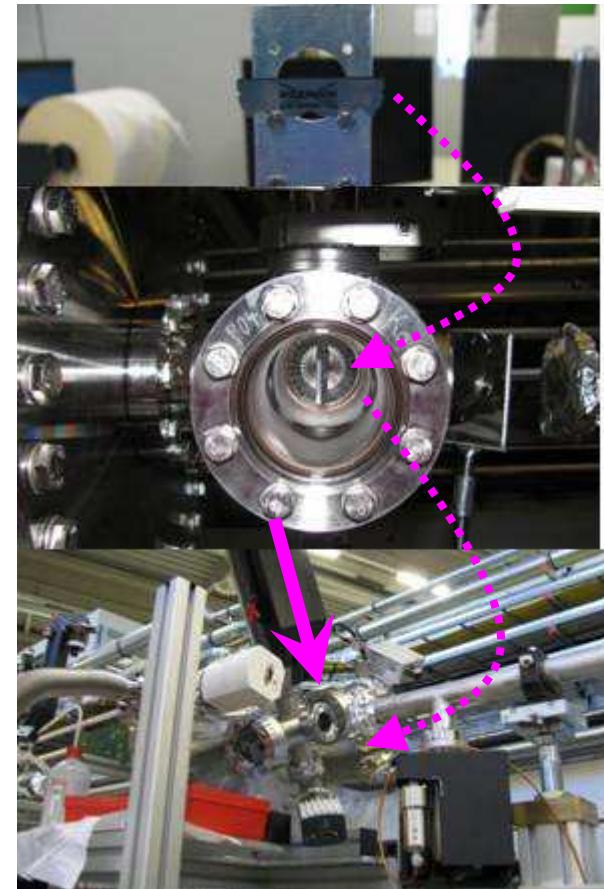
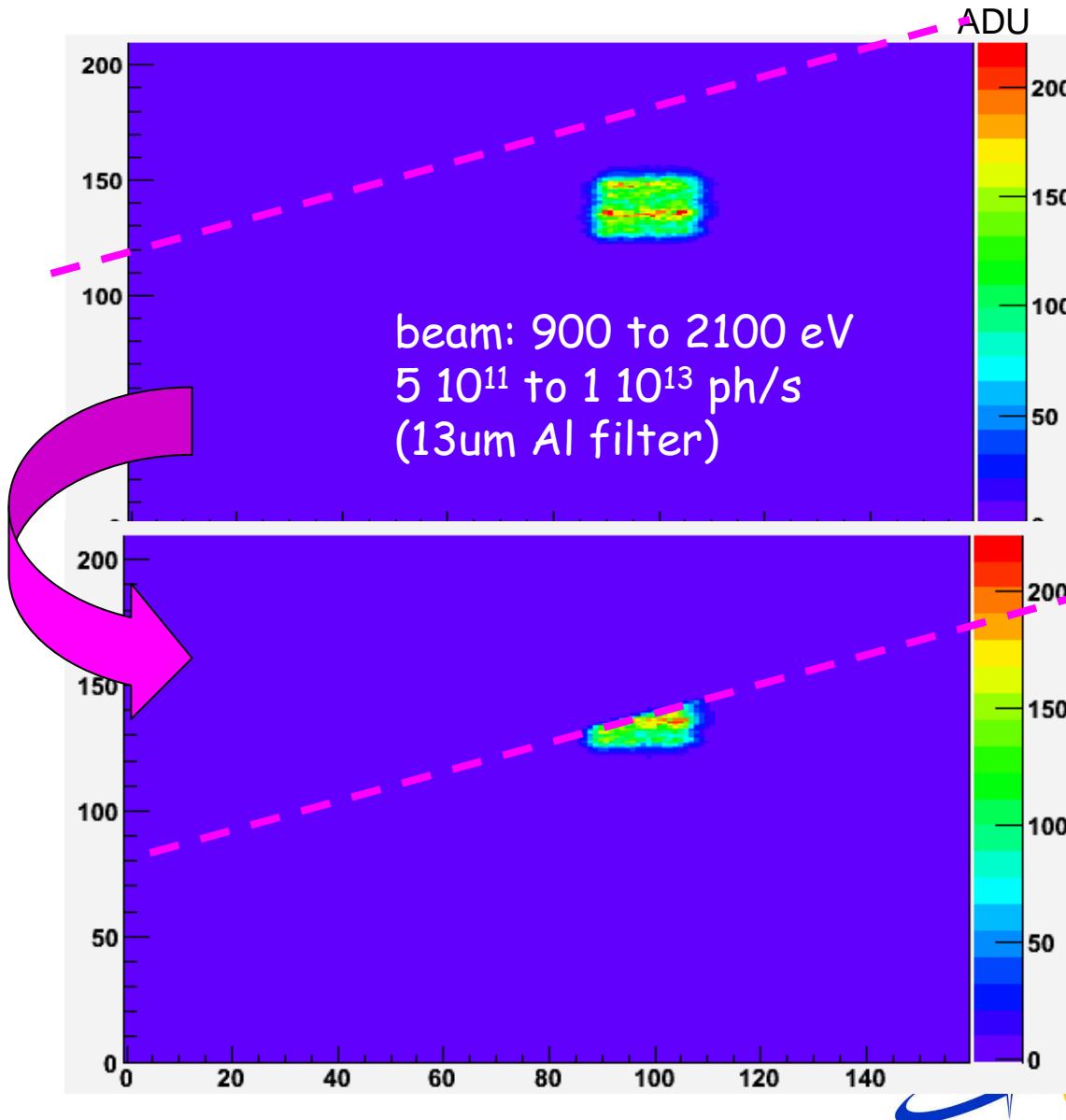
Dynamic range



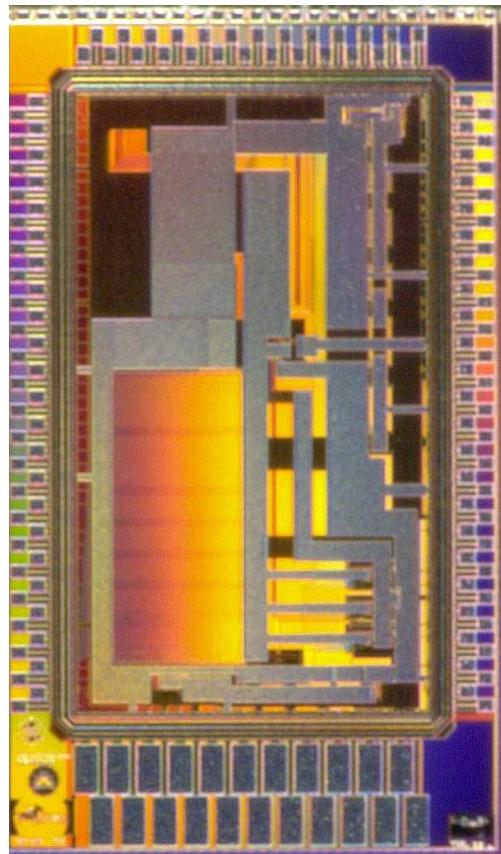
response to low-Energy photons



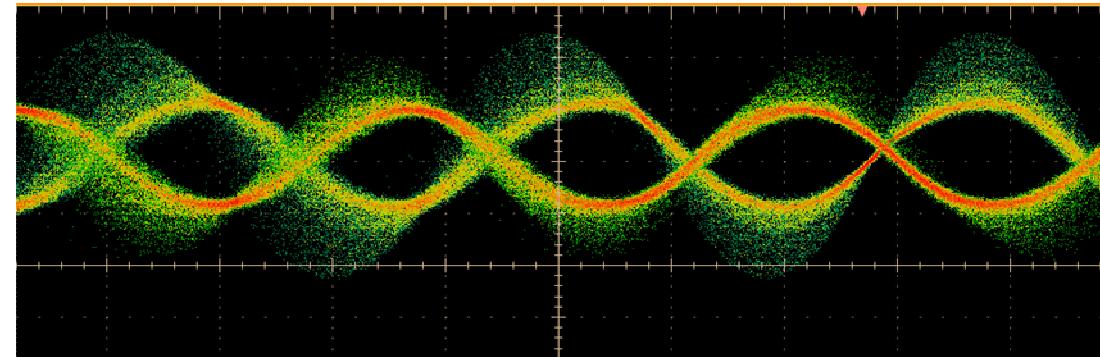
keV-Energy photons: test results



measurements at P04
beamline (Petra III)

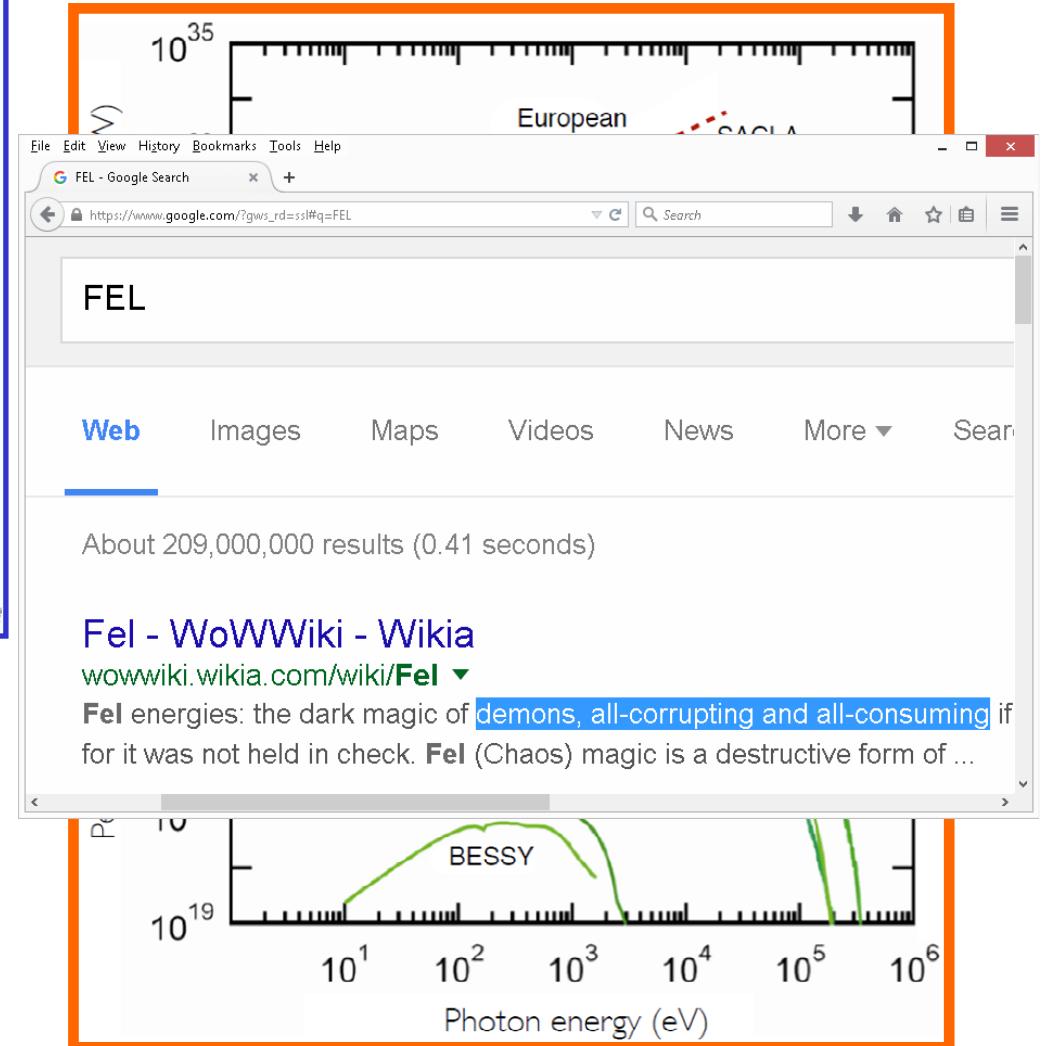
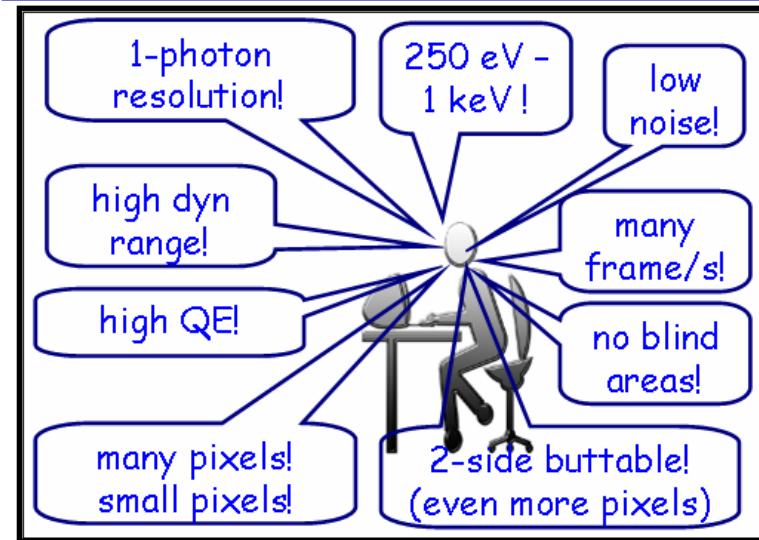
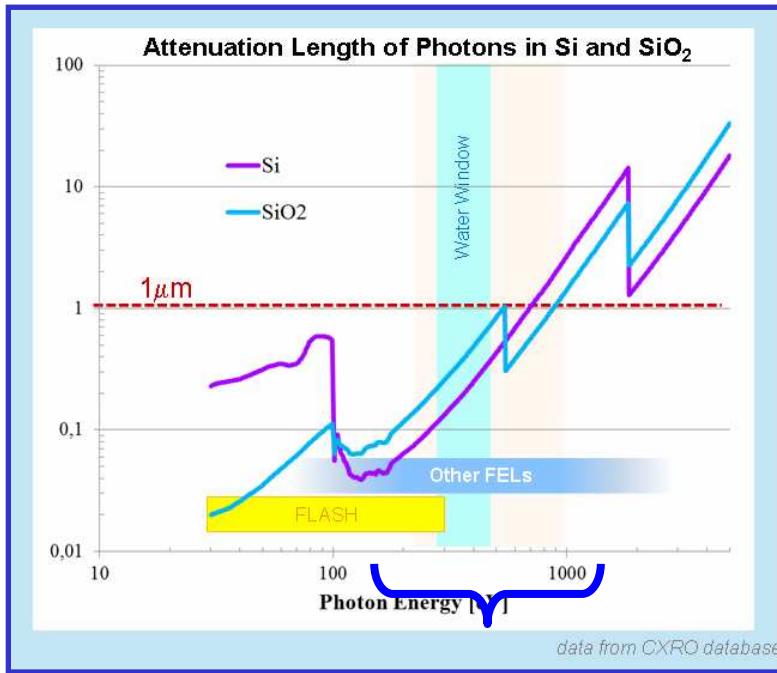


- PLL: Operating up to 400MHz
- LVDS Stages: Operating at 800Mbits/s (limited by DAQ system)



Iain Sedgwick, FEE2014

Motivation



Outline



Percival:

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

Percival performance

- dynamic range
- noise
- speed
- response to low energy photons
- FEL compatibility
- CCE
- Conclusions