AGIPD

&

PERCIVAL

2 Mega-Pixel Imagers for FELs

Heinz Graafsma, DESY-Hamburg

(Adaptive Gain Integrating Pixel Detector)

a multi-Mega-pixel & multi-Mega-Hz

X-Ray imager the European XFEL

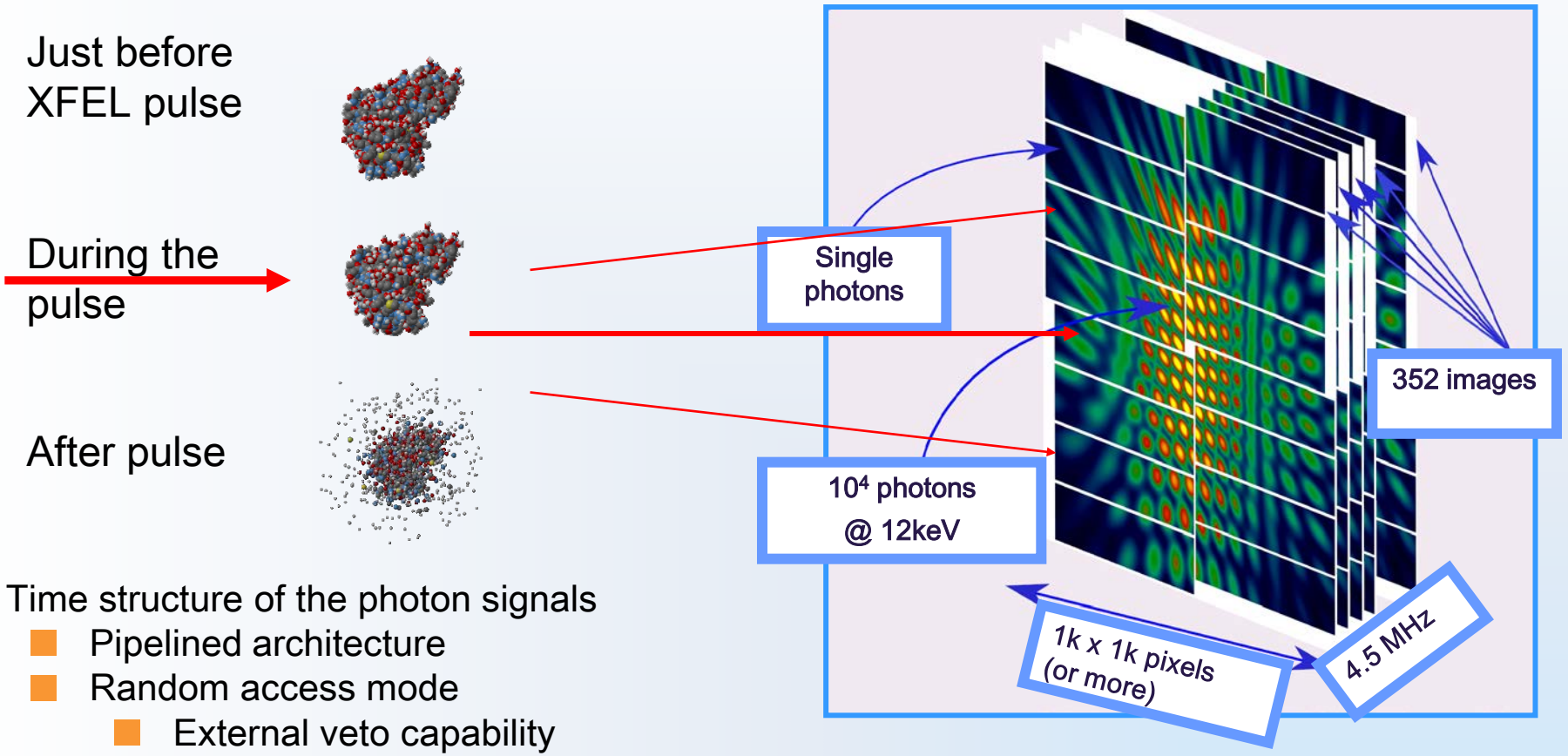
universitätbonn

DESY

PAUL SCHERRER INSTITUT PSI

UHH

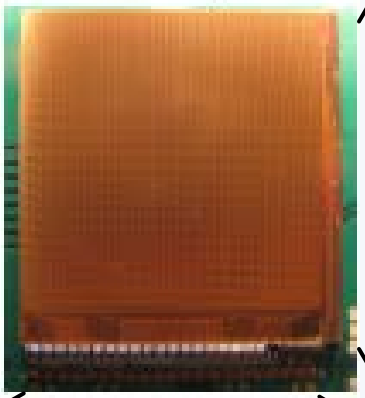
XFEL requirements (2006)

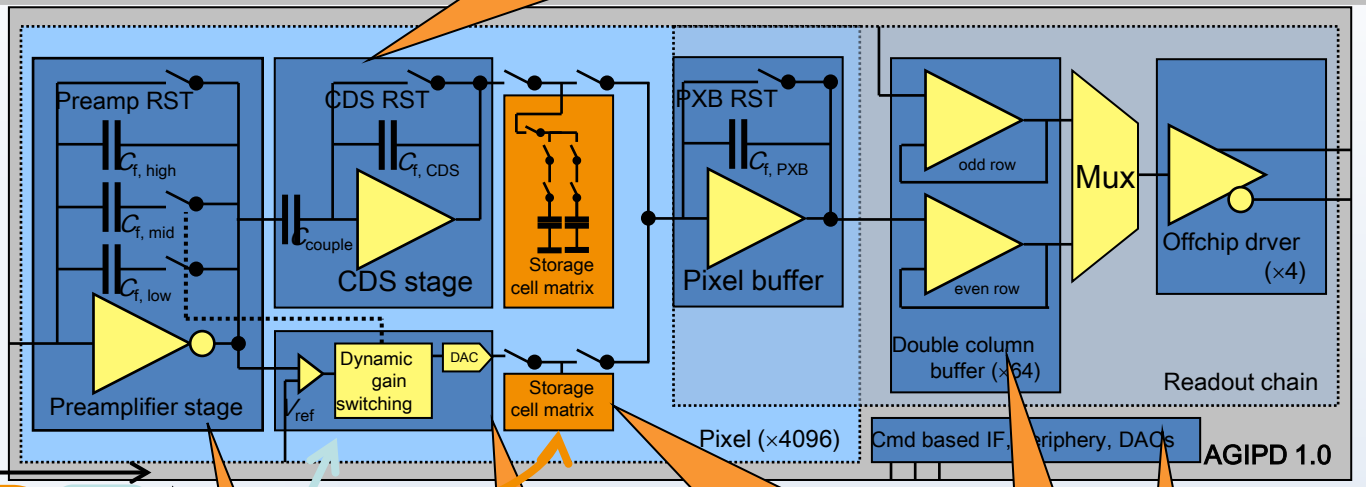


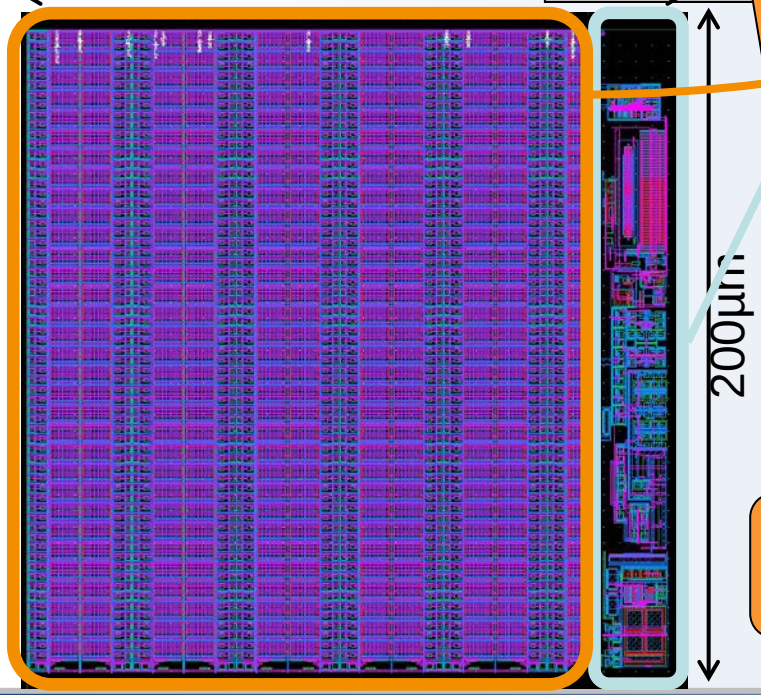
- Time structure of the photon signals
  - Pipelined architecture
  - Random access mode
    - External veto capability
- High radiation dose at small angles: 10^4 photons/(pixel shot)
- over 3 years: 1 GGy @sensor
  - Radiation damage of silicon sensor
  - Radiation damage of underlying electronics (≫10 MGy)
    - Radiation hard design

- 500 µm silicon sensor
- 200 µm square pixels
- Vacuum compatibility
- Detector with central hole

AGIPD ASIC







Correlated double sampling

Analogue RAM for 352 images

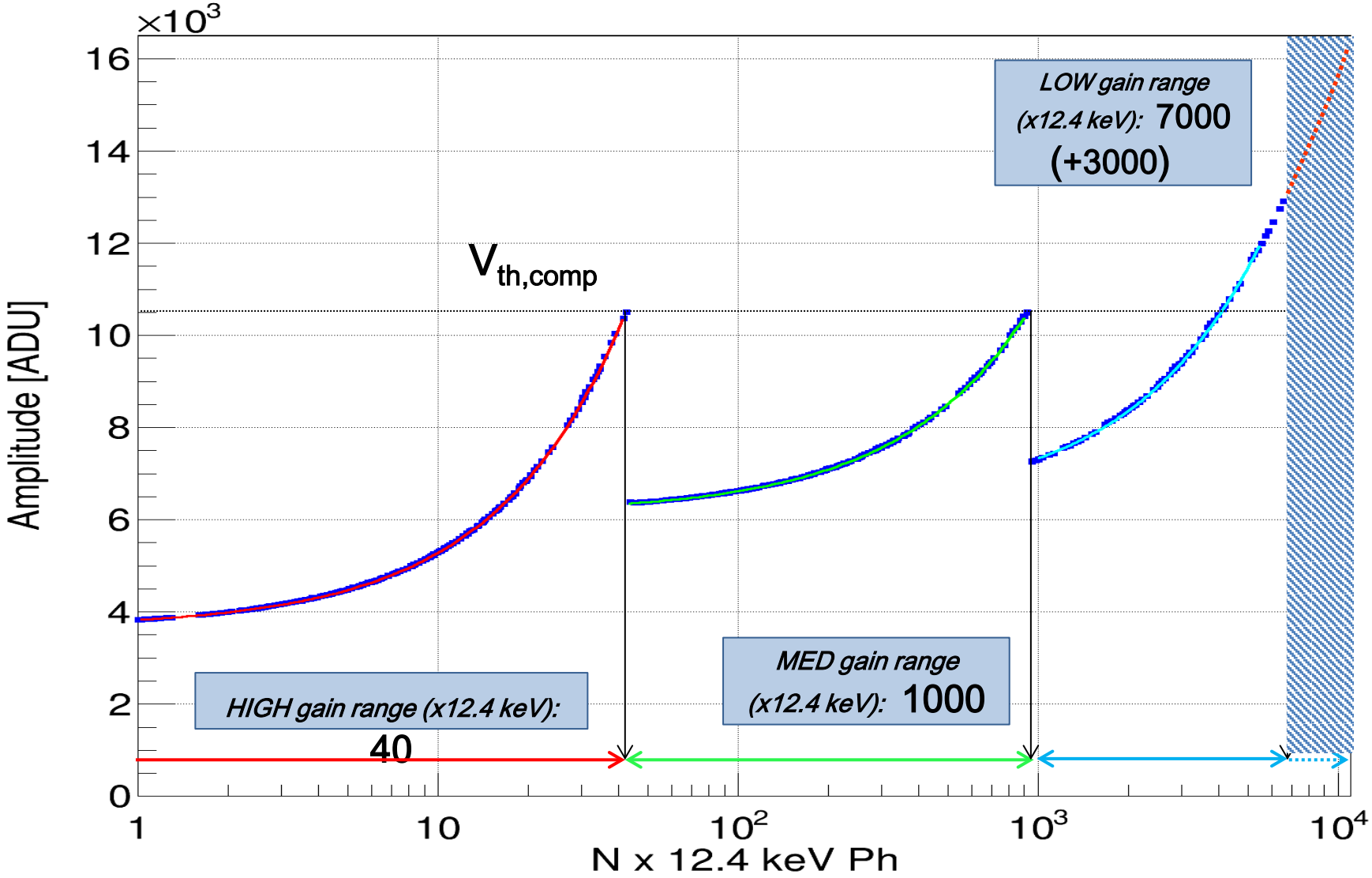
Analogue encoding of gain

Interleaved row Double column readout

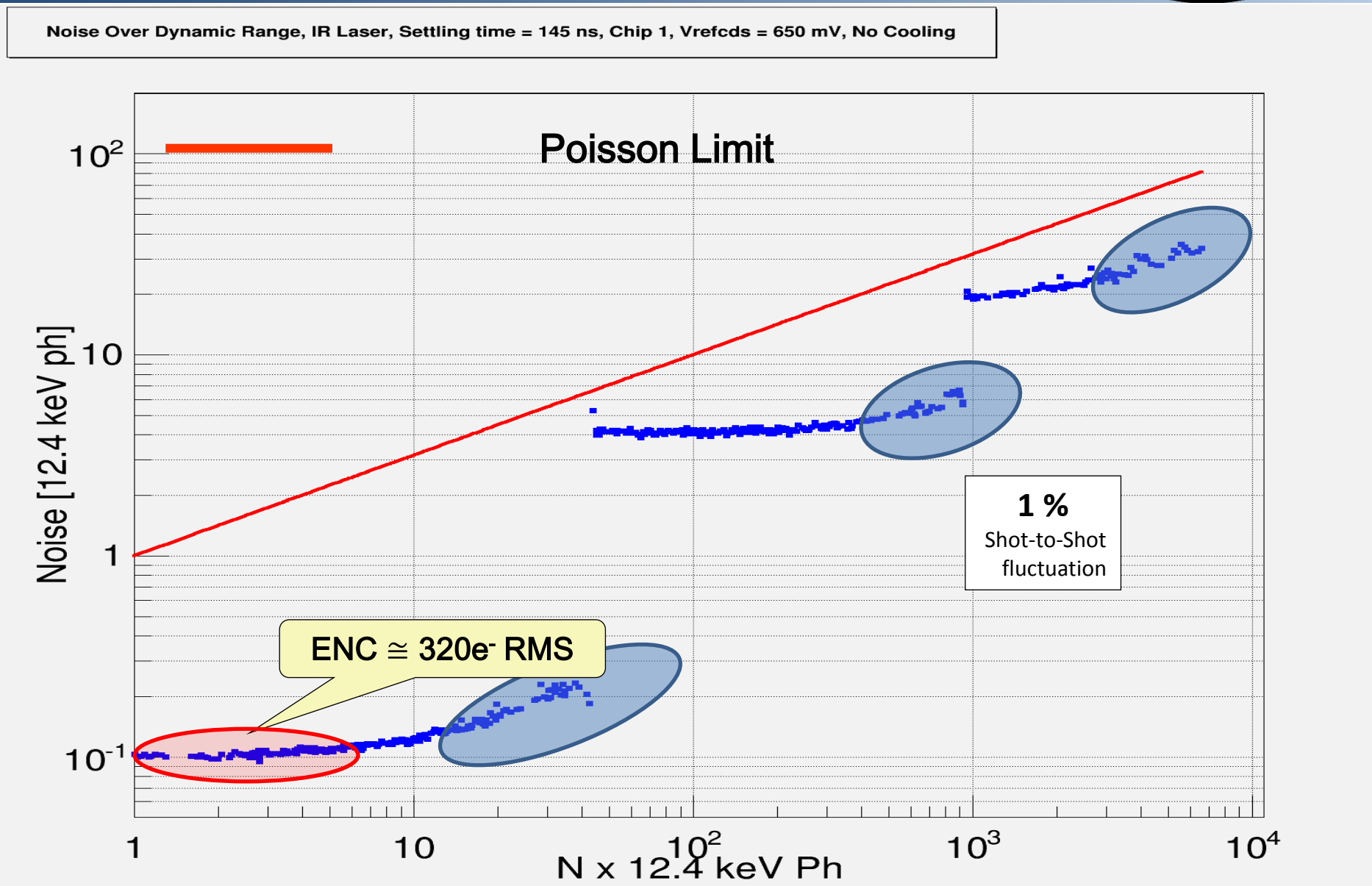
Adaptive gain C_f=60fF, 3pF, 10pF

Command based control via serial IF

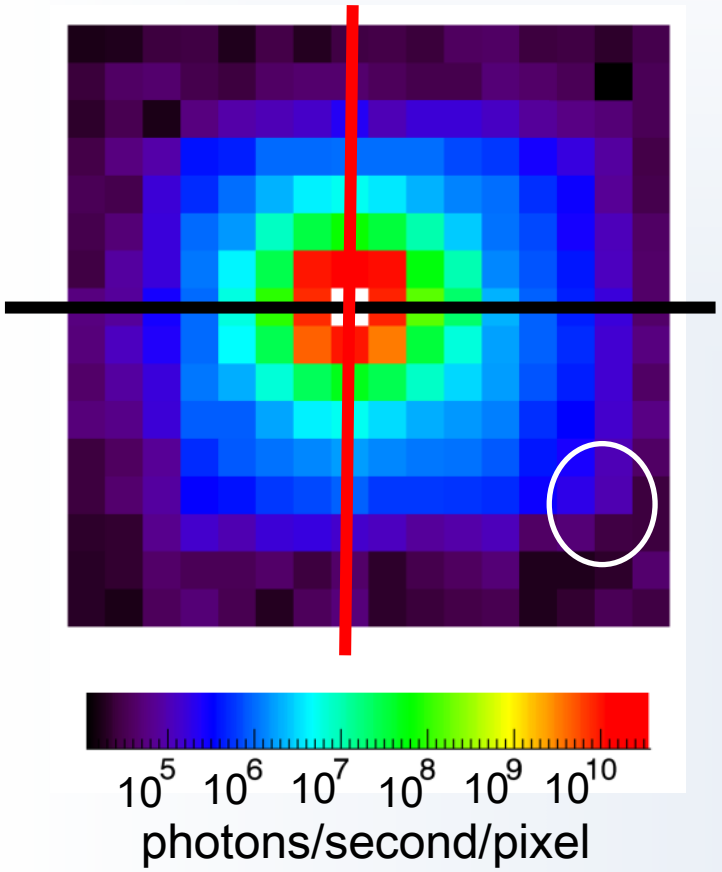
AGIPD1.0
Dynamic Range Scan: IR Pulsed Laser

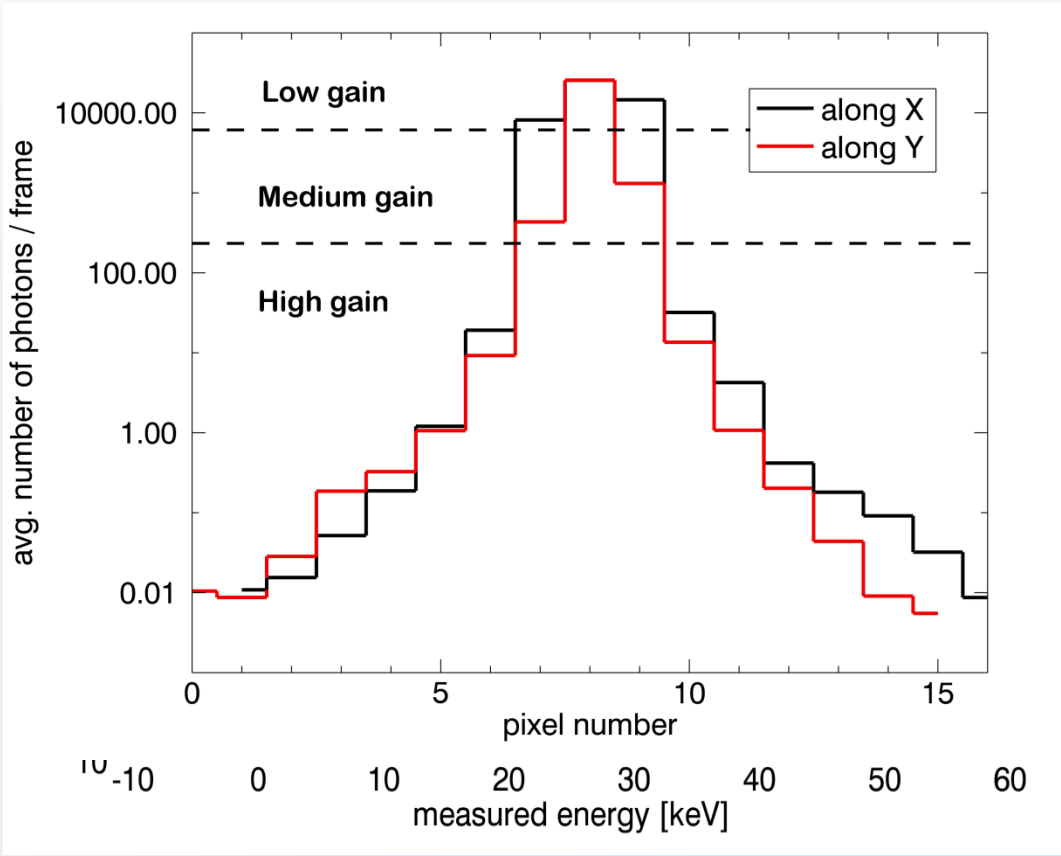


AGIPD1.0
IR Laser: Noise over Dynamic Range



Looking at the direct P10 beam





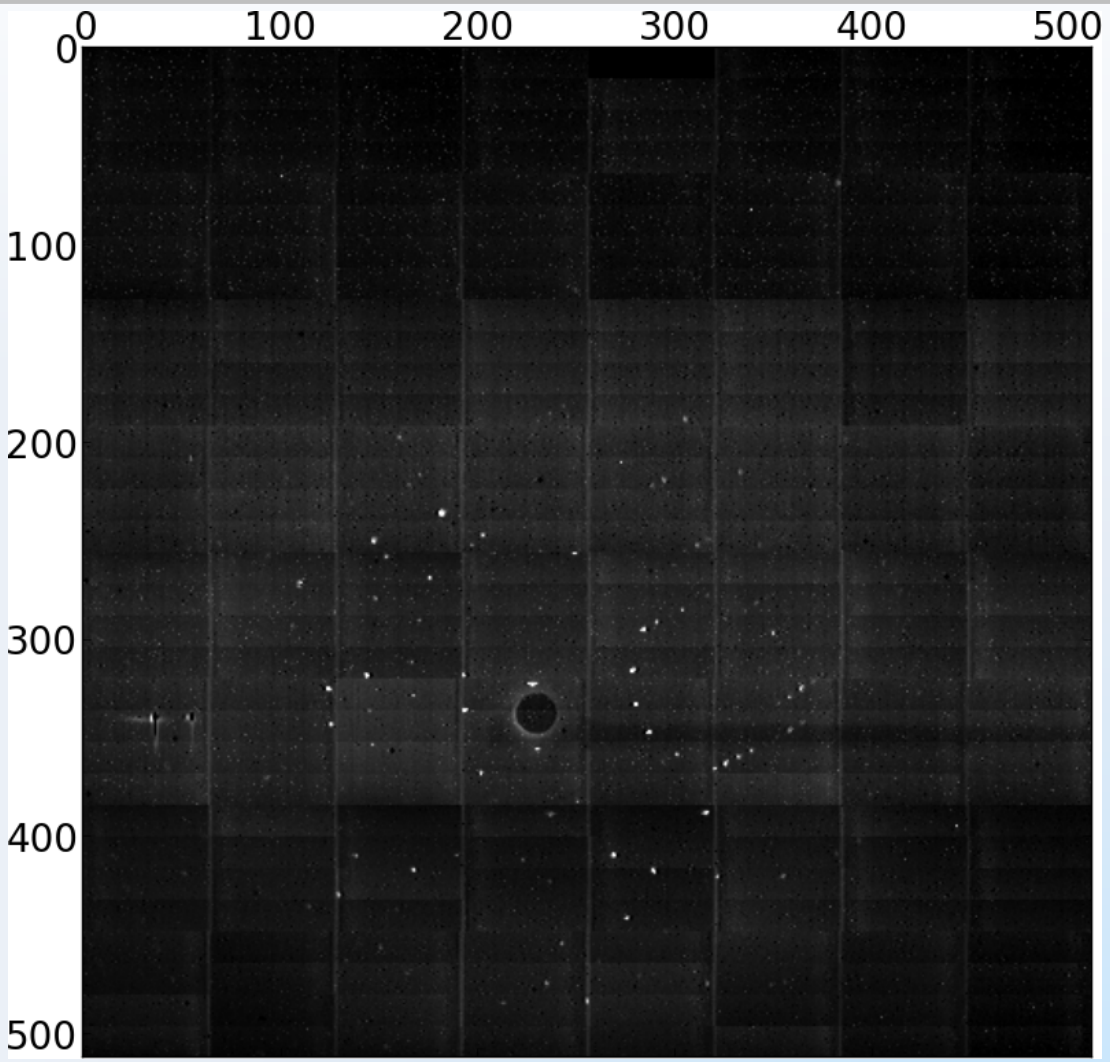
Gain switching experimentally proven

- 10^4 photons / pulse
- Single photon sensitivity
- 4.5 MHz frame rate

Protein crystallography at P10

The experiment:

- Full quadrant
- Lysozyme crystals.
- Bursts of 352 images for each orientation
- E=9.4 keV
- No gain or flat field correction applied yet



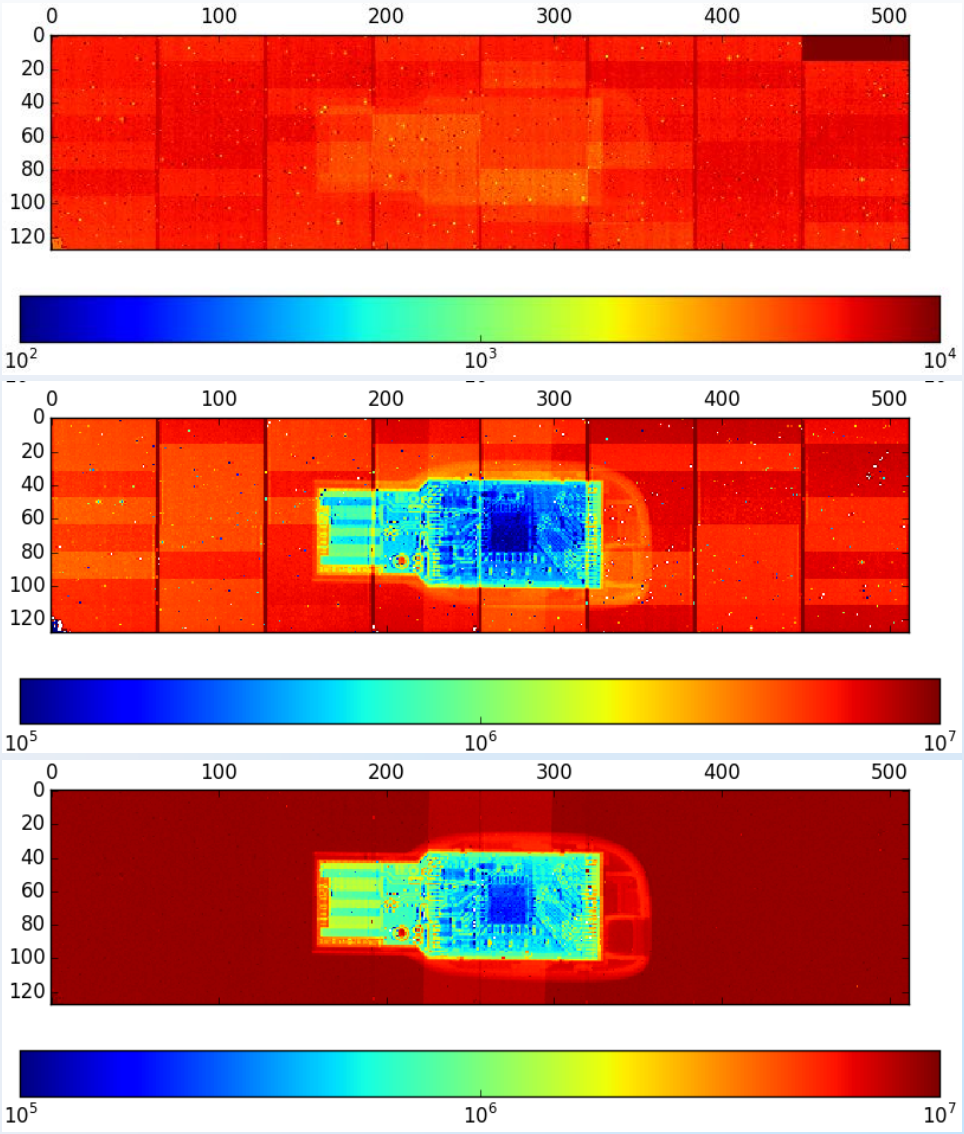
P10 – PETRA III

Calibration is key

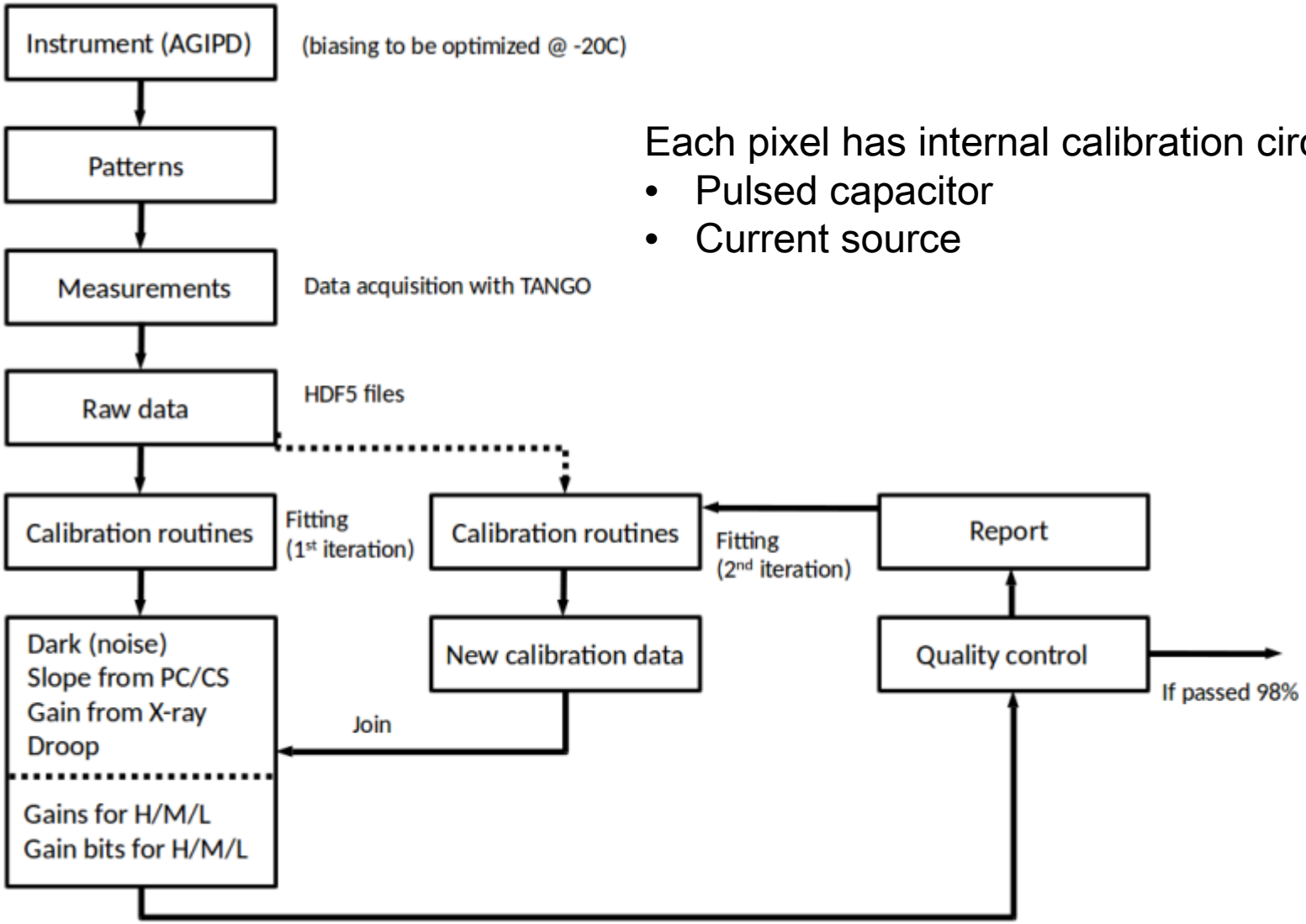
- Mean of 30000 frames
- 50µs integration time per frame

- After dark field correction

- After flat field correction



Calibration Framework

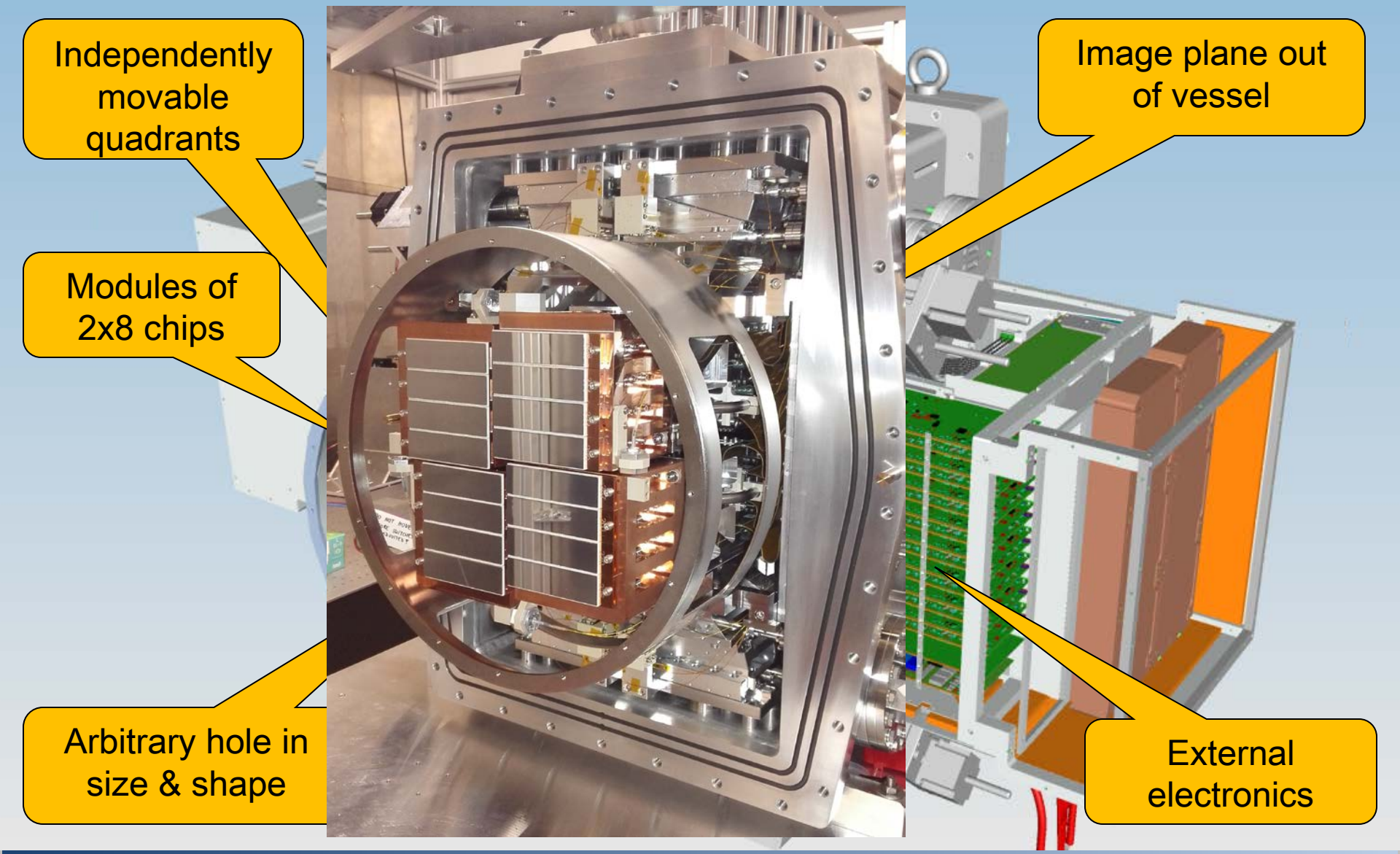


Each pixel has internal calibration circuitry:

- Pulsed capacitor
- Current source

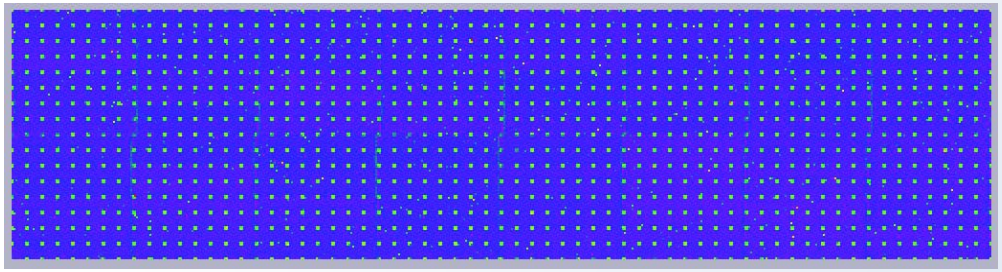
AGIPD 1Mpix Systems

(SPB and MID Beamlines at European XFEL)



First System Testing

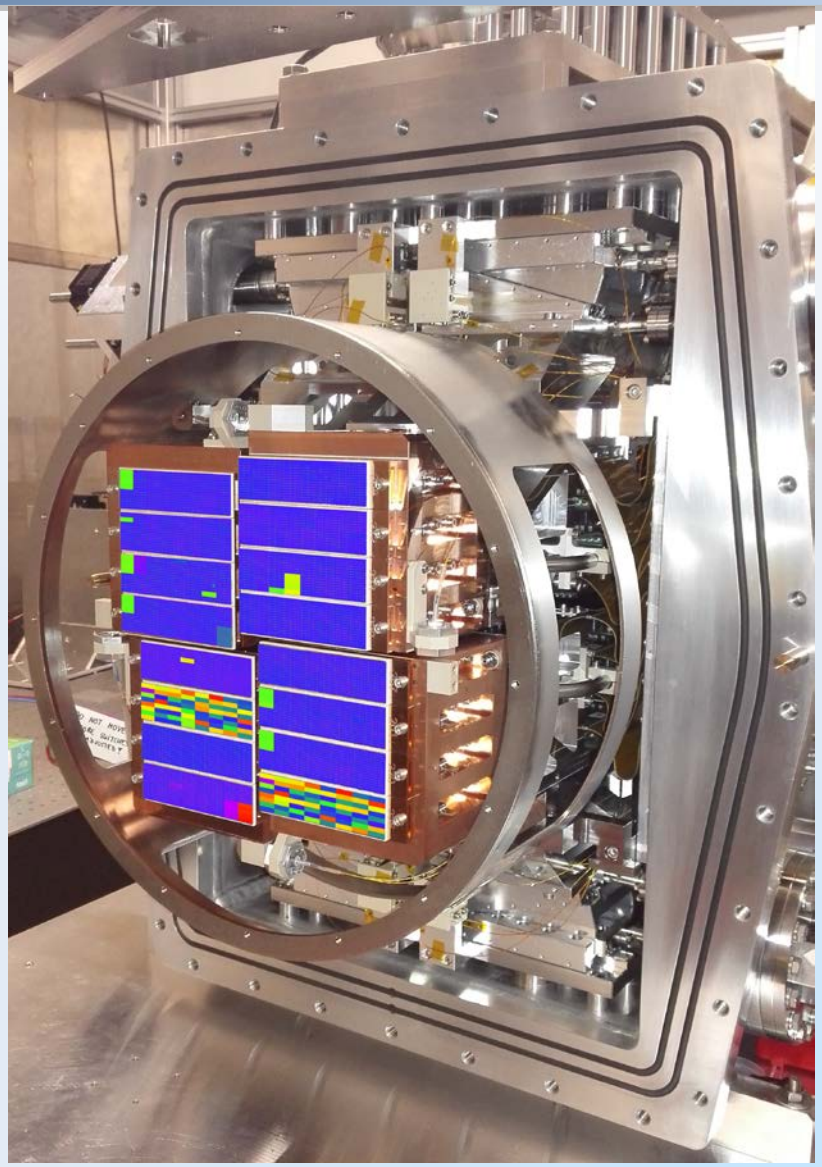
Using internal calibration circuitry:
- record a test pattern
- read out detector



- Two modules have a short
- 5 modules have top left ASIC disabled

==> System has been opened this week

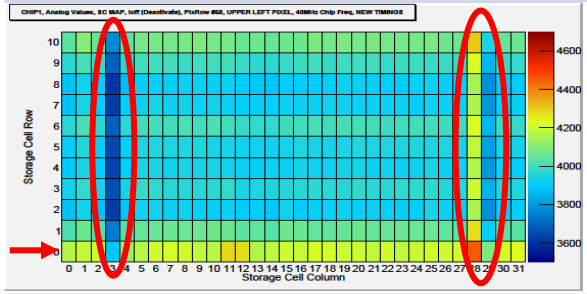
Please note:
modules were build with
untested AGIPD 1.0 chips

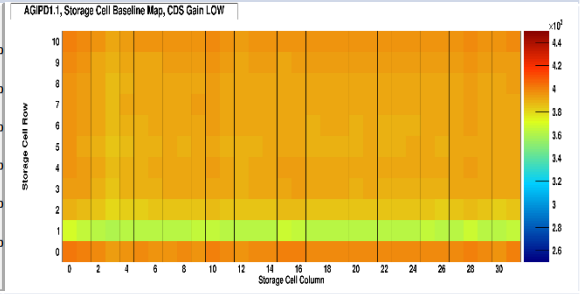


Second version of chip: AGIPD1.1

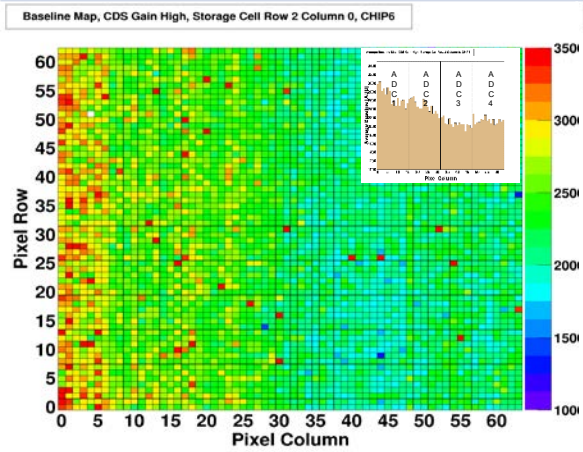
AGIPD 1.0	AGIPD 1.1

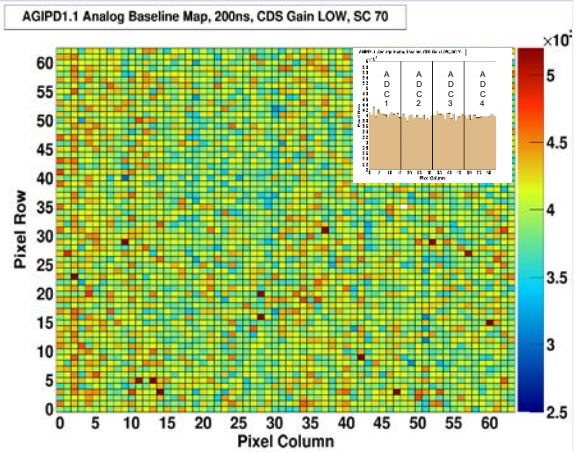
Memory Map (Baseline)



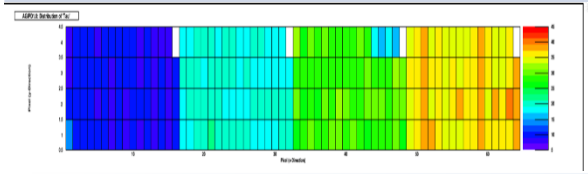


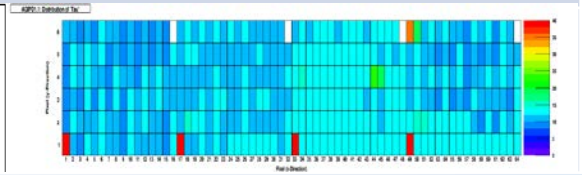
Pixel Map (Baseline)





Output Speed (Rise Time)

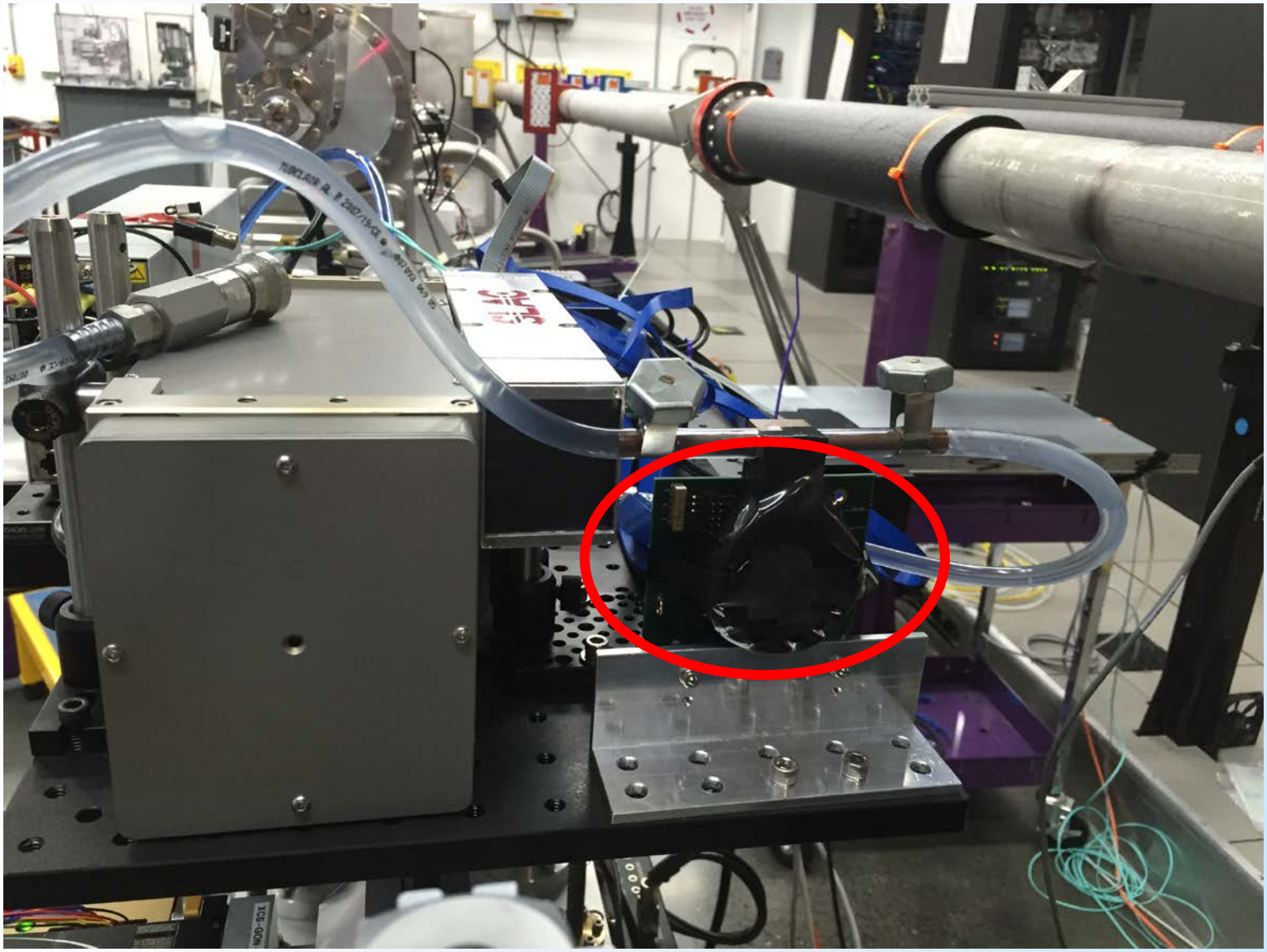




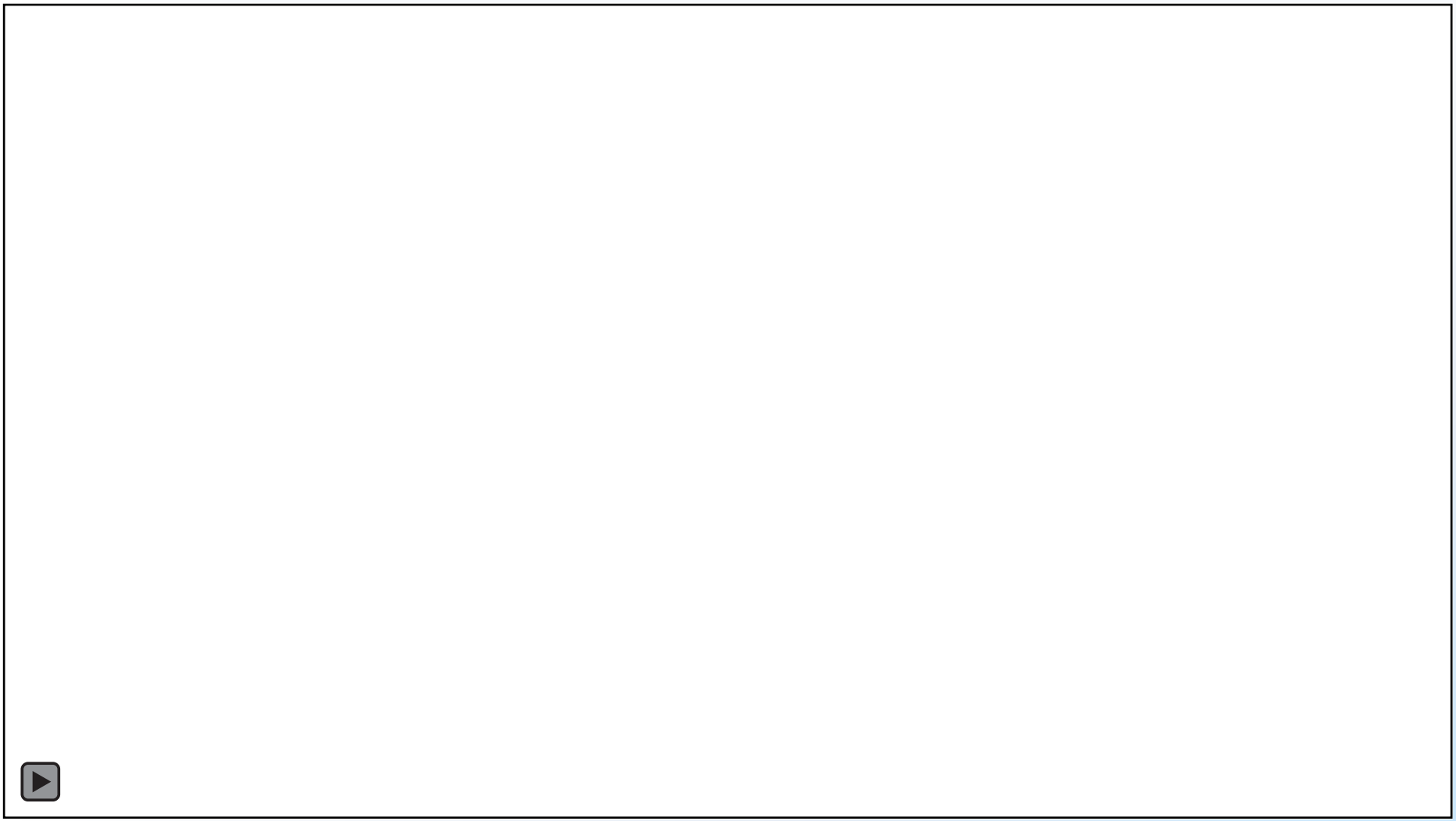
Back from foundry end of February 2016

- New calibration circuits
  - Better range & granularity
- Different encoding & readout of gain signals
  - Easier discrimination
  - No level adjustment for readout
- Improved routing inside the pixel
  - Lower crosstalk
  - Homogeneous pedestal map
  - No interference with calibration circuit
- Improved power distribution
  - Lower gain dispersion
  - Better pedestal homogeneity
  - Shorter (CDS) settling times
- Reworked readout lines
  - Lower capacitance & resistance
  - Higher readout speed
  - Lower speed dispersion between analogue ports
- Individual buffering of off-chip driver reference voltage
  - Eliminates ‘Ghosting’ crosstalk
- On-chip filter caps
  - Improved stability
- New Power-up reset
- Stronger buffers for MUX clock and token
- ……

AGIPD 1.1 being put to the test

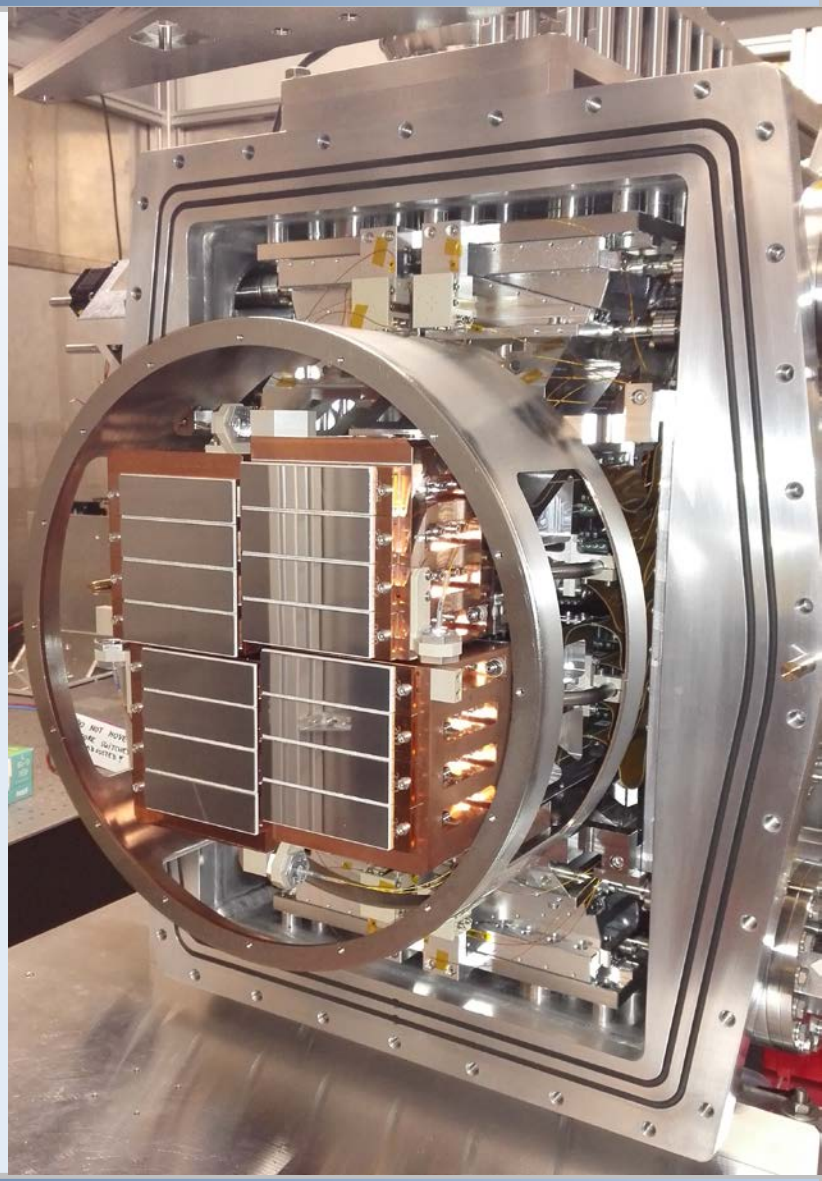


AGIPD 1.1 being put to the test



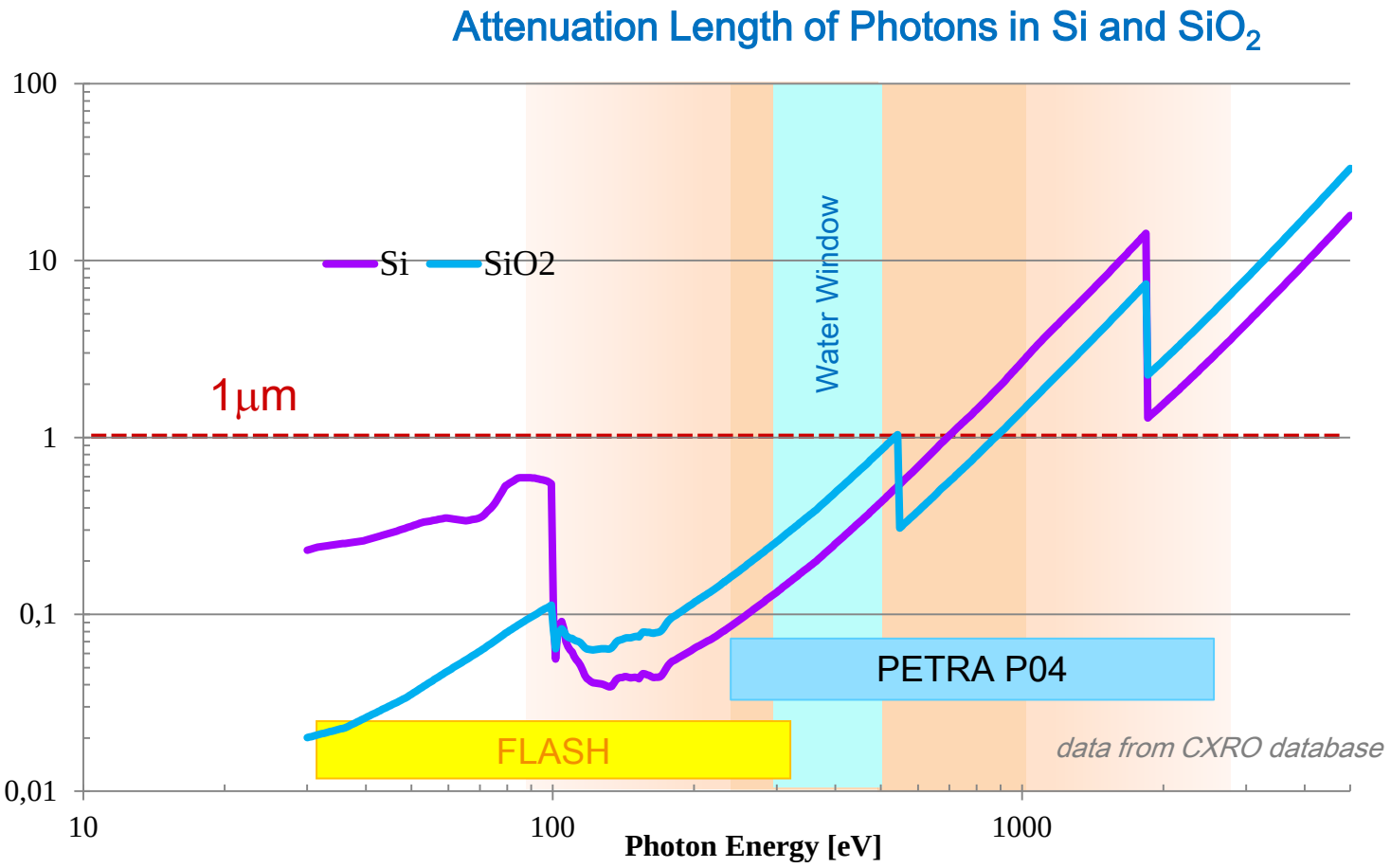
AGIPD Planning

- Handover of 1st 1M-system (SPB) October 2016 (with AGIPD 1.0)
- Replacement of AGIPD 1.0 with AGIPD 1.1 for SPB early 2017 (before first beam)
- Handover second 1M-system (MID) early 2017 (with AGIPD 1.1)
- Development of 4M system for SFX (new layout of electronics) has started (see H. Chapman's talk)



(Pixelated Energy Resolving CMOS Imager, Versatile And Large)

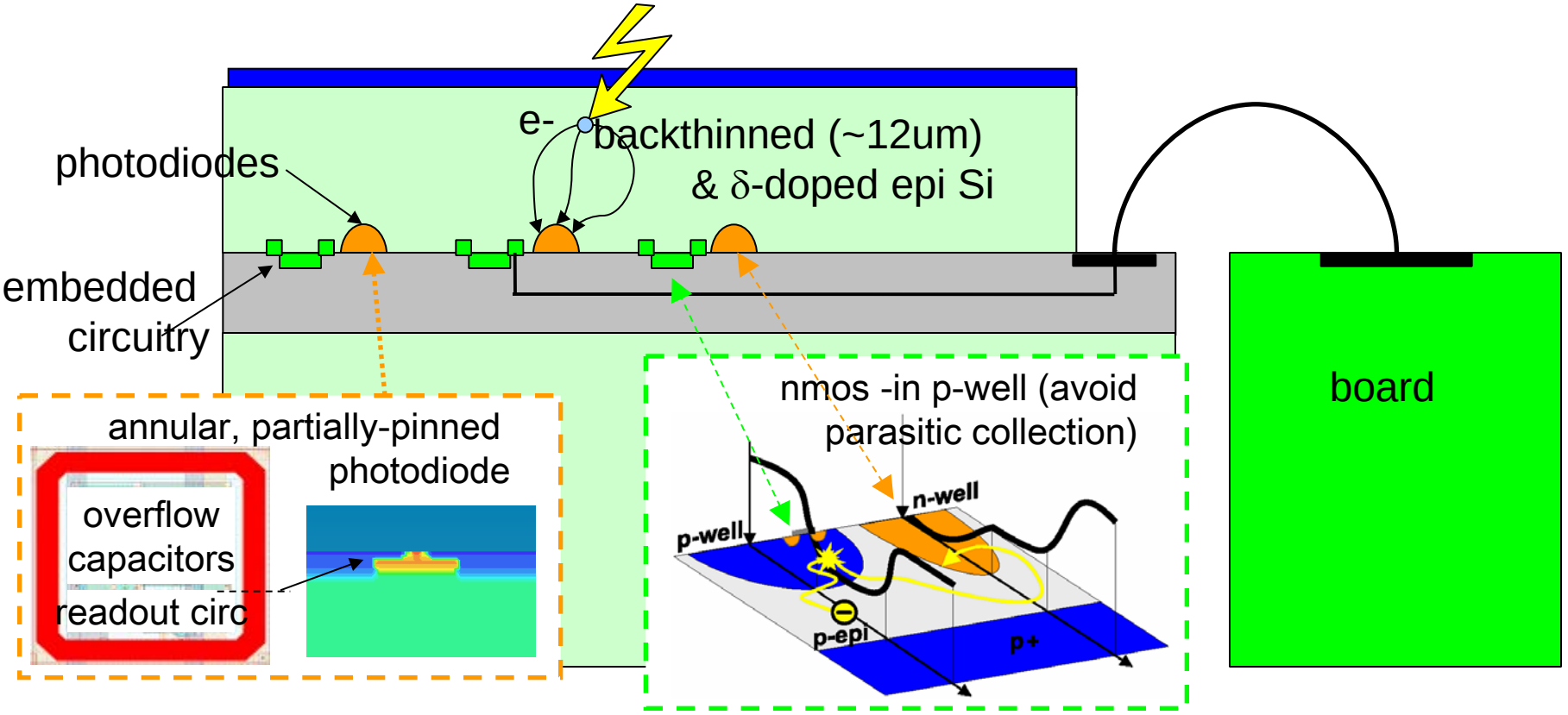
Soft X-ray Challenges – reaching the sensor



At (very) soft X-ray energies, QE is limited by passive window thickness!

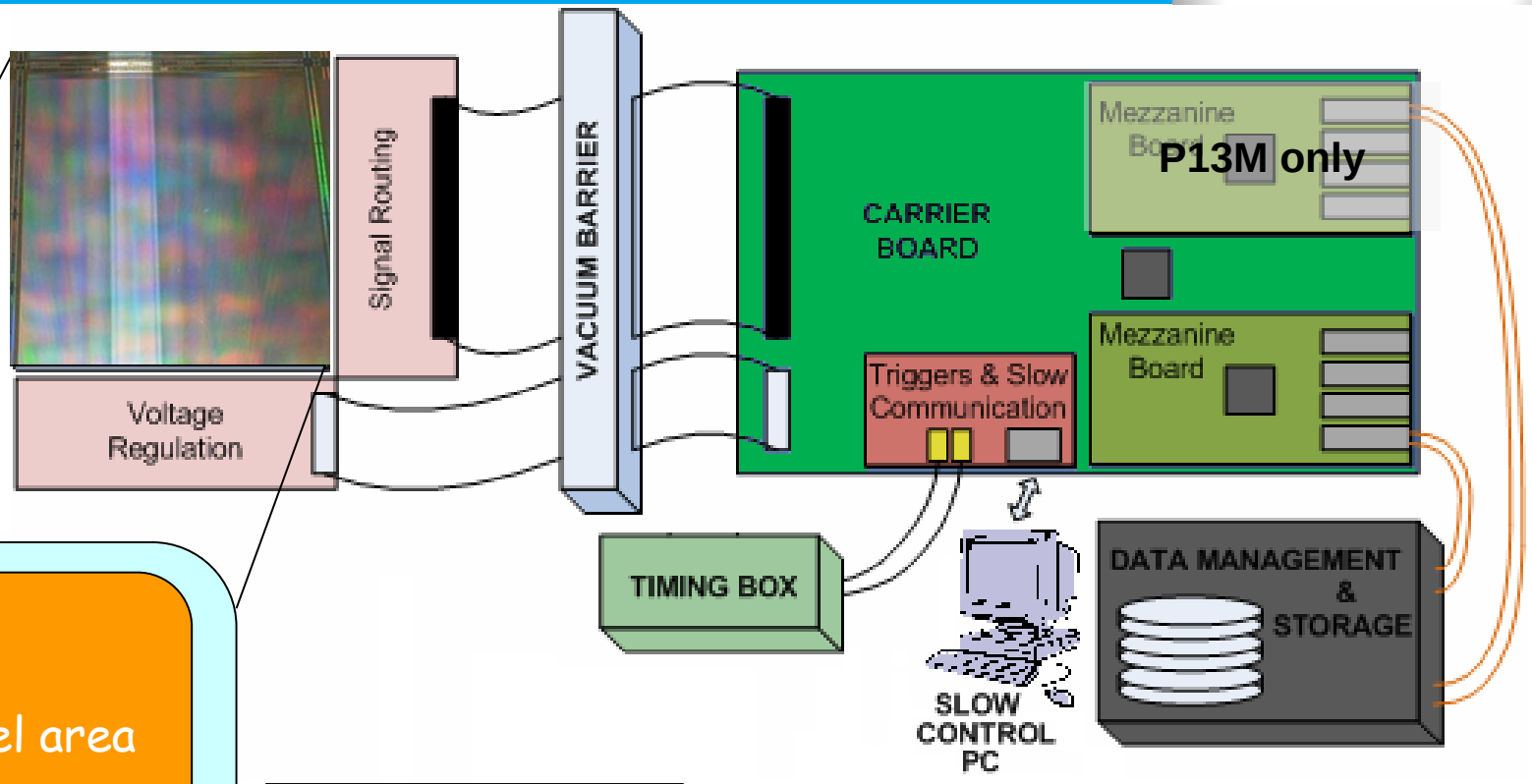
e.g. 50 nm of SiO_2: loss of 25% of 250 eV photons

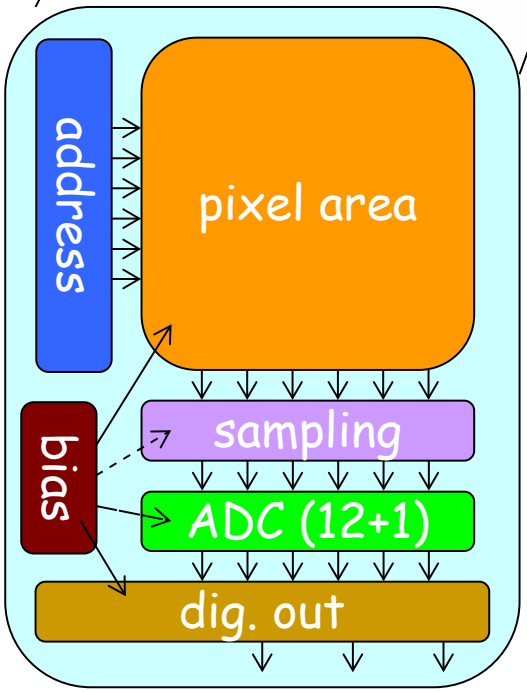
Monolithic Active Pixel Sensor



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

The full PERCIVAL system

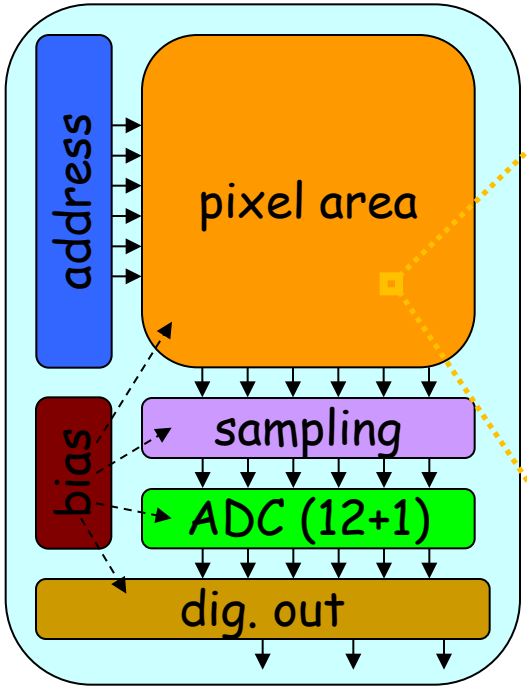


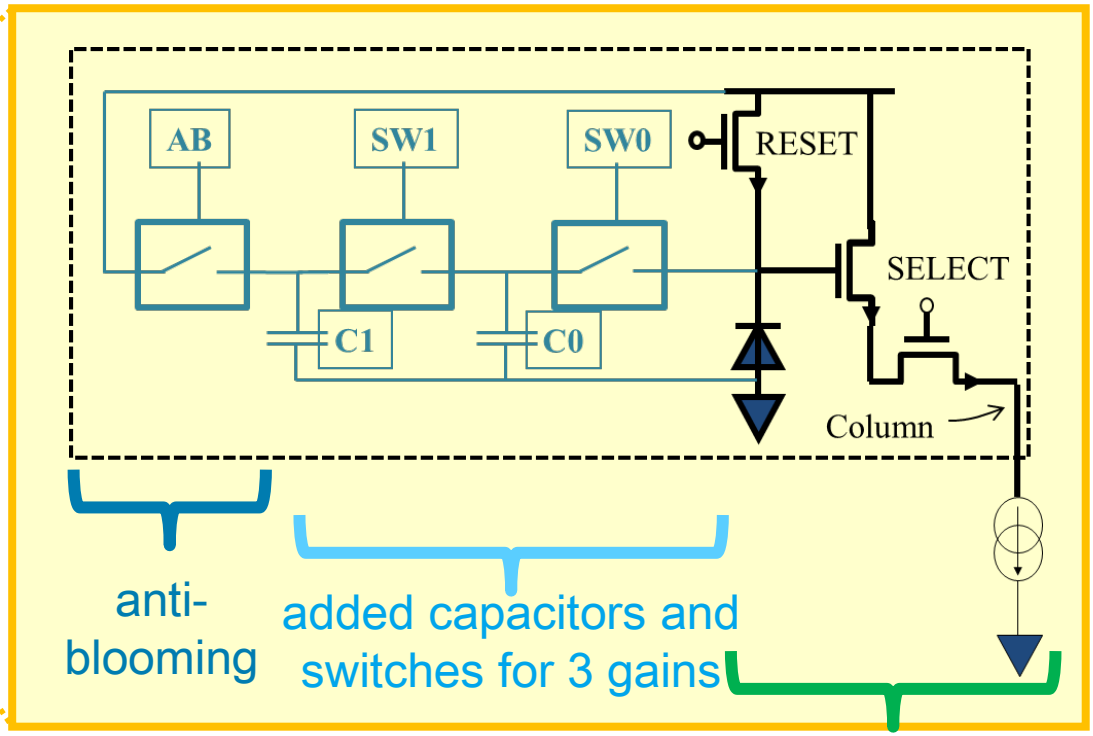


P2M

- 2 Mpixels
- ~4×4cm^2 area
- 2-side buttable
- 27um pixel pitch
- 300 Hz
- available ~2017

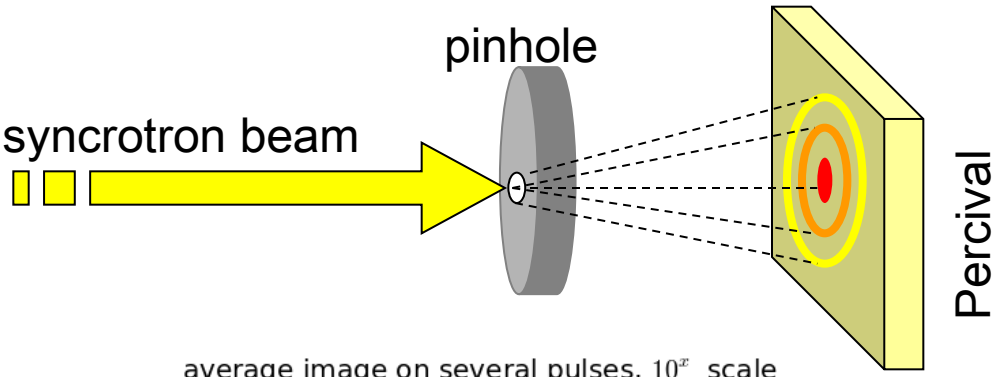
The Percival Sensor

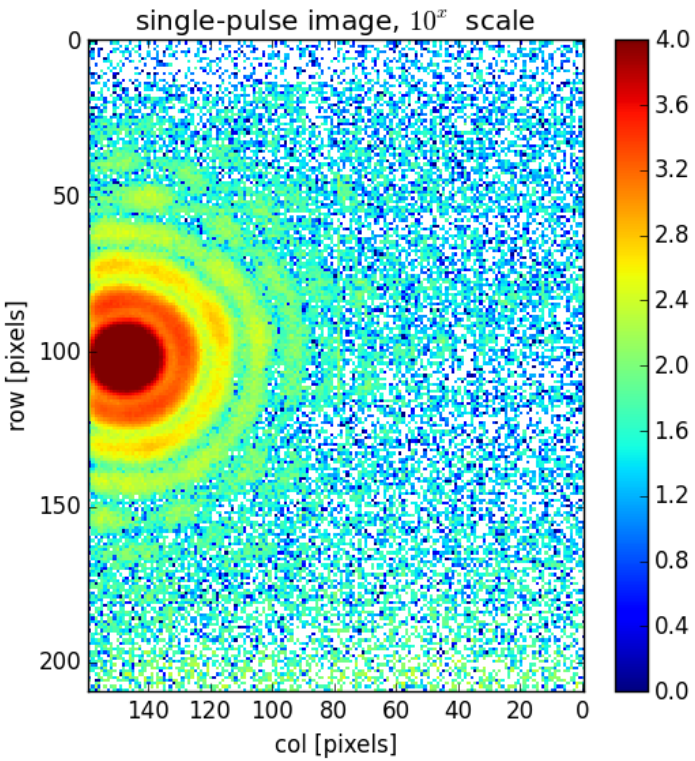


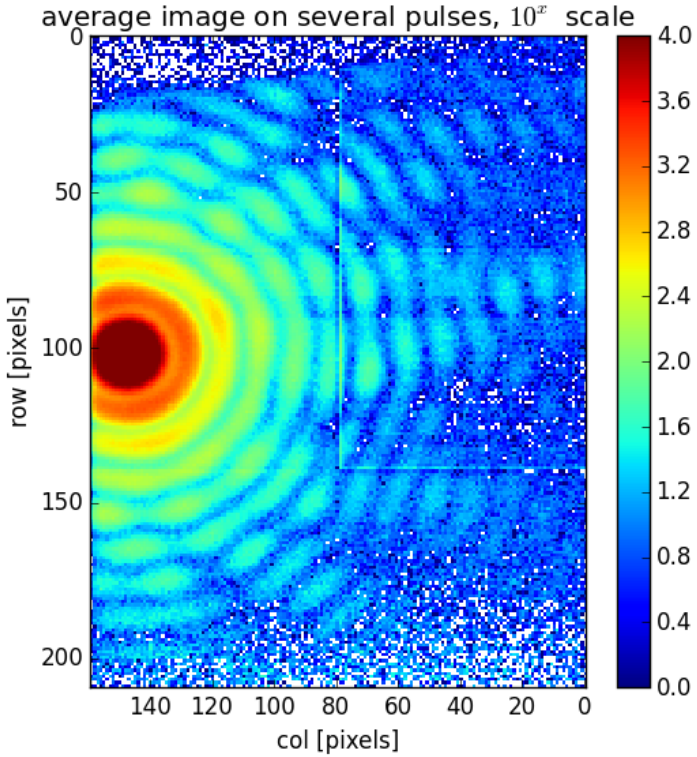


single pulse imaging @ FEL: test results

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







Summary – the short version

PERCIVAL

single photon resolution!

< 100eV …
250eV-1keV
… few keV

low noise!

When?
1st half 2017

high dynamic range!

many frames/s !

high QE!
TBC

No blind areas !

many pixels!
small pixels!

2- side buttable!
(even more pixels)

DESY

Summary

- First AGIPD 1M (SPB) ready for delivery in October 2016
- Replacement with new chips (SPB) before first beam (fully calibrated)
- Second AGIPD 1M (MID) being assembled; delivery early 2017
- AGIPD 4M (SFX) under development

- PERCIVAL proven imaging from 92 eV to 2 keV
- PERCIVAL 2M expected back from foundry October, BSI chips spring 2017