AGIPD at the European XFEL
Status and Future Plans

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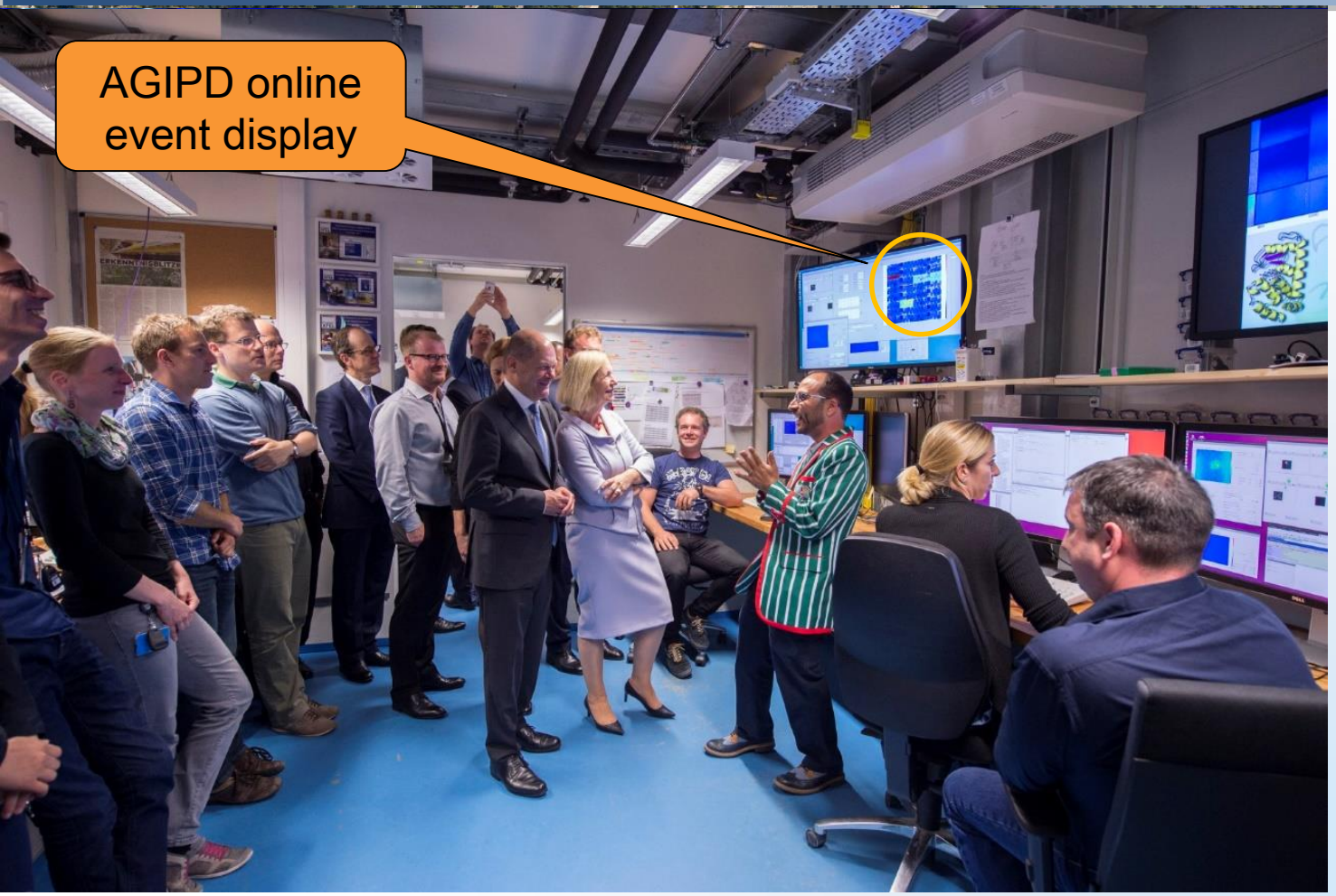
Outline

The AGIPD System	European XFEL Single molecule imaging Requirements
AGIPD 1.1 Readout ASIC	Architecture Dynamic gain switching Performance
AGIPD Detector systems: SPB & MID	Overview First user experiments Results
AGIPD Detector Systems: SFX & HiBEF	Readout boards Optical communications Cooling and mechanics
ecAGIPD for HiBEF	Electron-collecting AGIPD AGIPD06 demonstrator
Conclusion	Summary Outlook

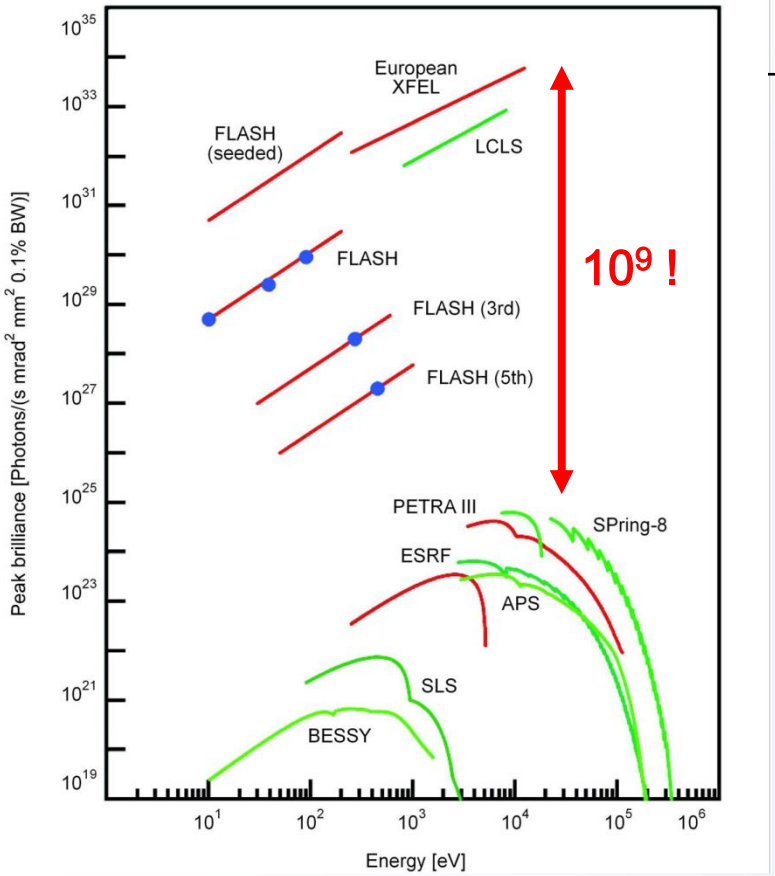
European XFEL
Inaugurated September 1st 2017

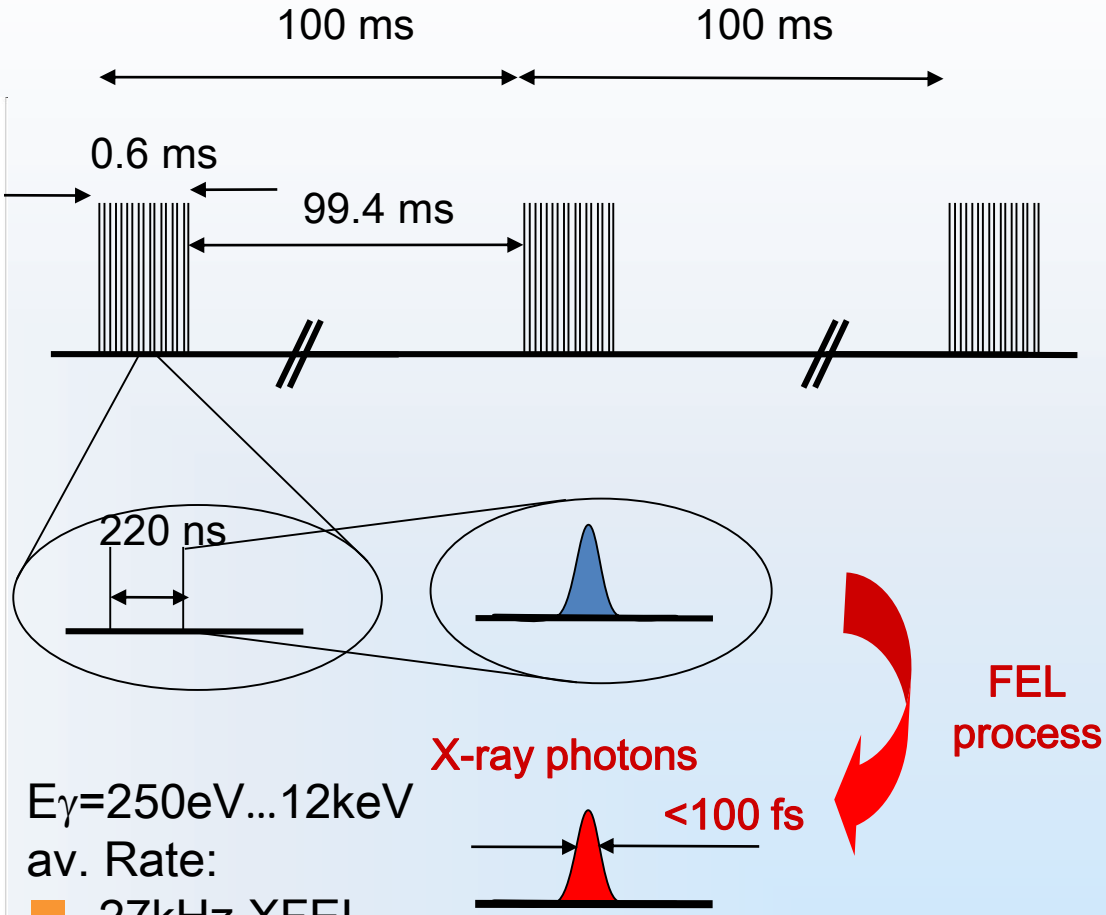


September 1st 2017 the European XFEL was inaugurated by Dr. J. Wanka, the German federal minister for research and education and representatives of the other member states. After cutting the famous red ribbon…..

…she removed a beam attenuator and the diffraction rings of a powder sample, registered by the 1M pixel AGIPD detector at the SPB instrument demonstrated that the most powerful hard X-Ray Free Electron Laser went into user operation.

European XFEL properties



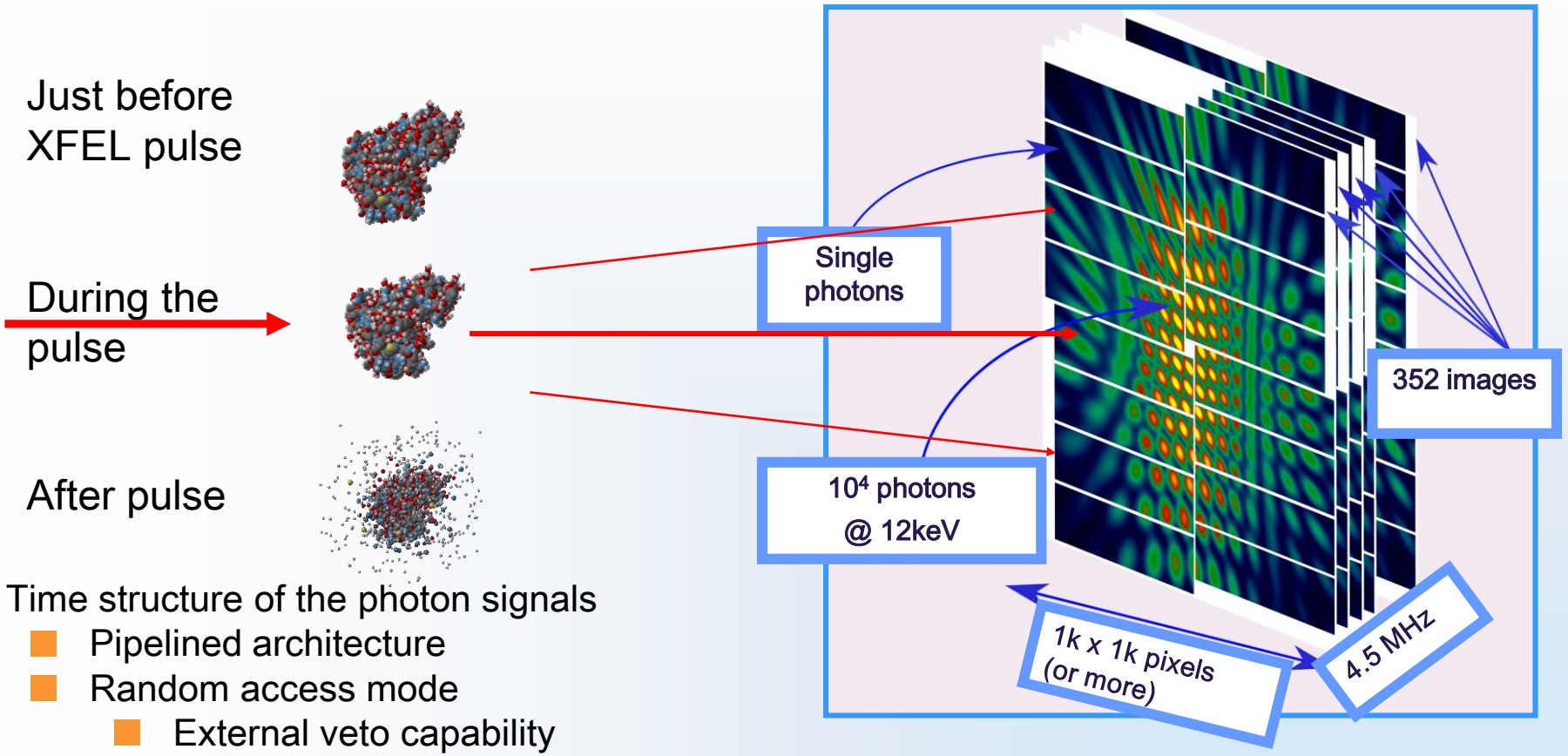


Eγ=250eV...12keV

av. Rate:

- 27kHz XFEL
- 120Hz LCLS
- 60Hz SCSS

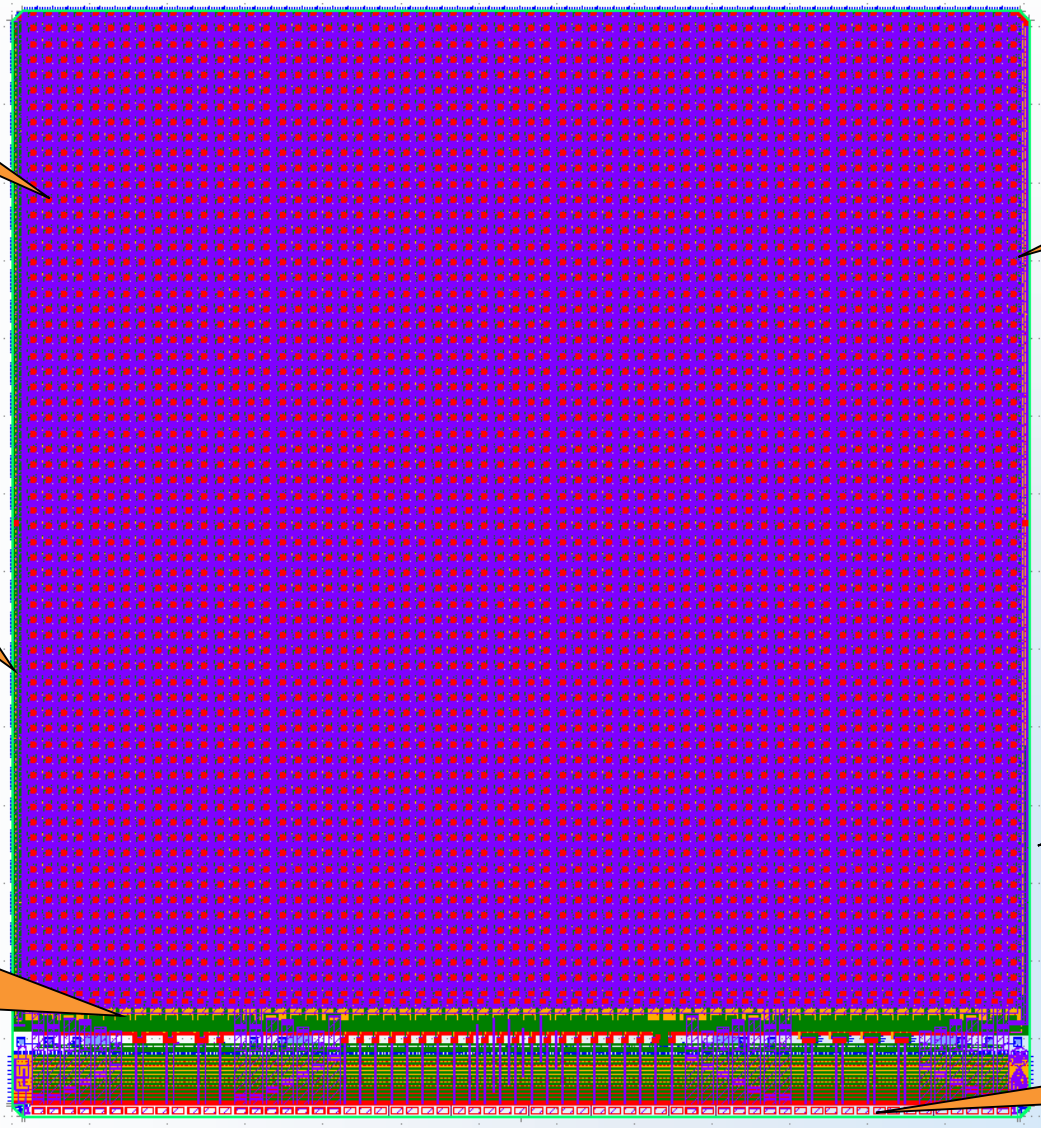
AGIPD Scientific Case: Single Molecule Imaging & SFX



- 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 1.1 ASIC



64 x 64 pixels

IBM/GF 130nm CMOS

200 µm × 200 µm pitch

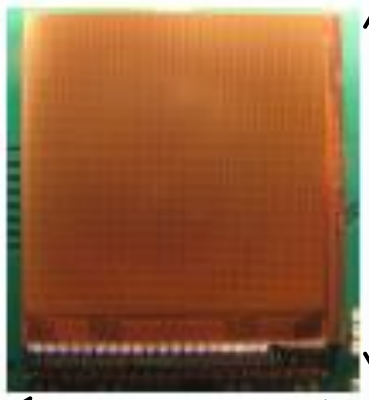
12080 µm × 14210 µm

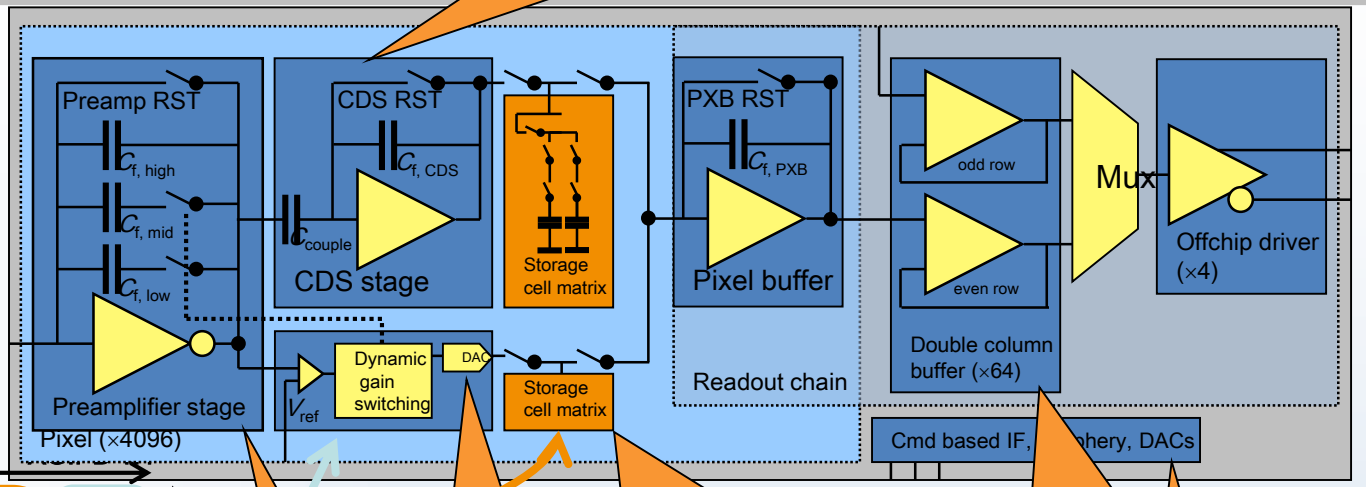
4.5 MHz Frame rate (burst)

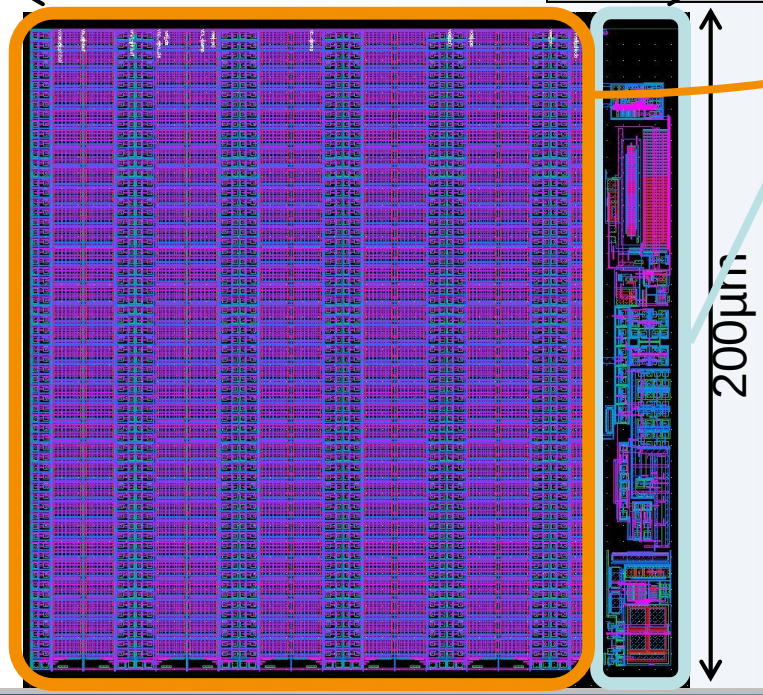
Command based interface

Analog readout

AGIPD 1.1 ASIC







Correlated double sampling

Analogue RAM for 352 images

Interleaved row Double column readout

Analogue encoding of gain

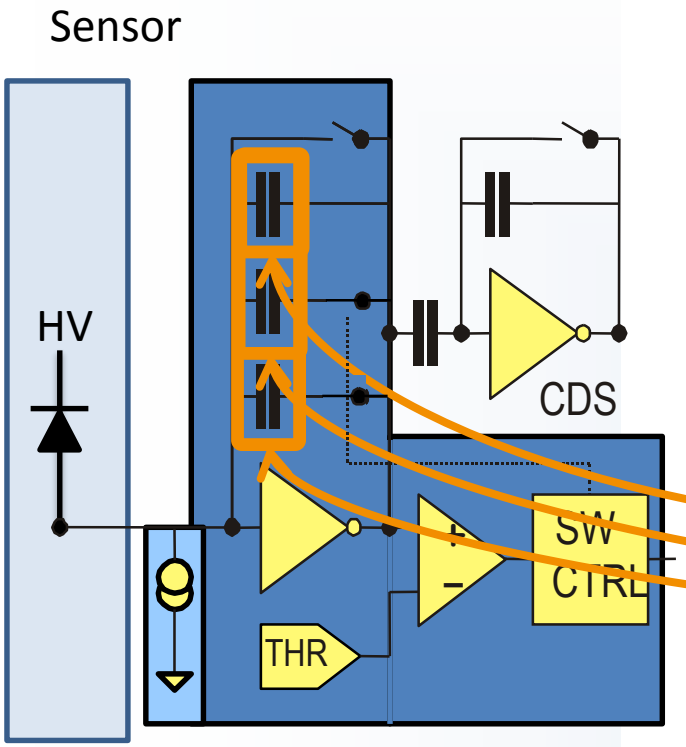
Adaptive gain C_f=60fF, 3pF, 10pF

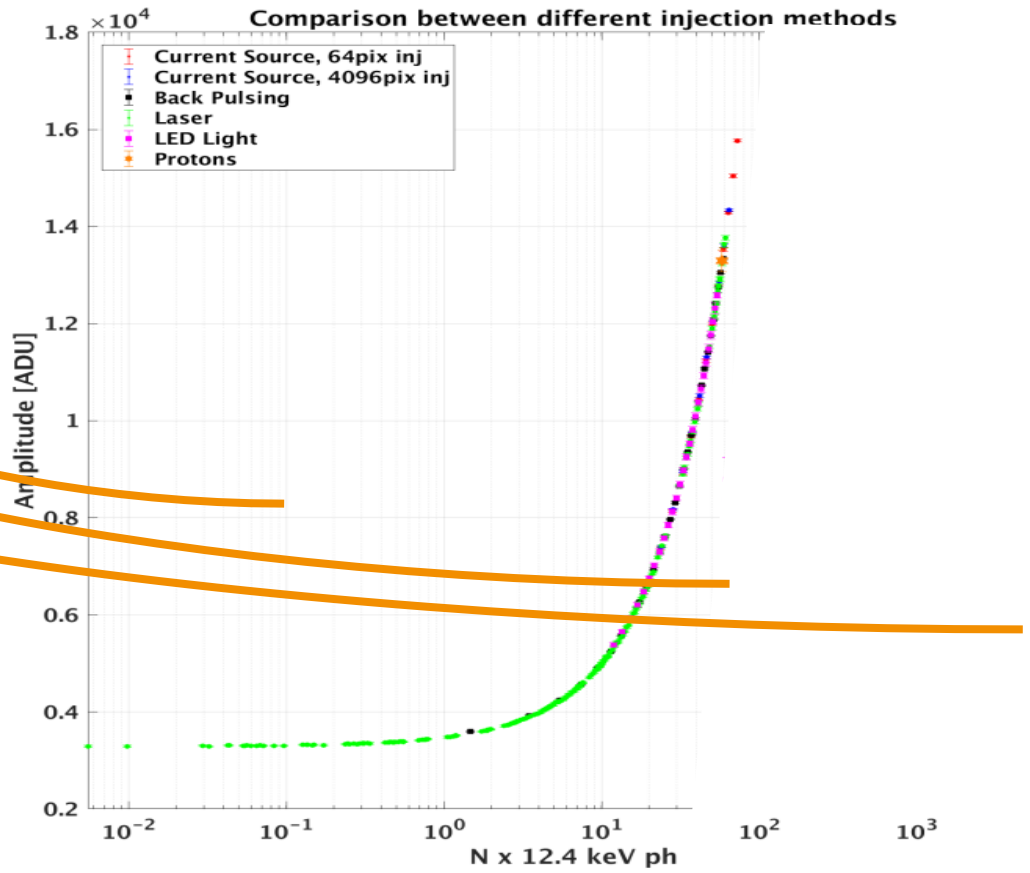
Command based control via serial IF

Remaining Issue:

- Separation between med/low gain signals disappearing with burst length

Adaptive gain switching





Calibration circuitry

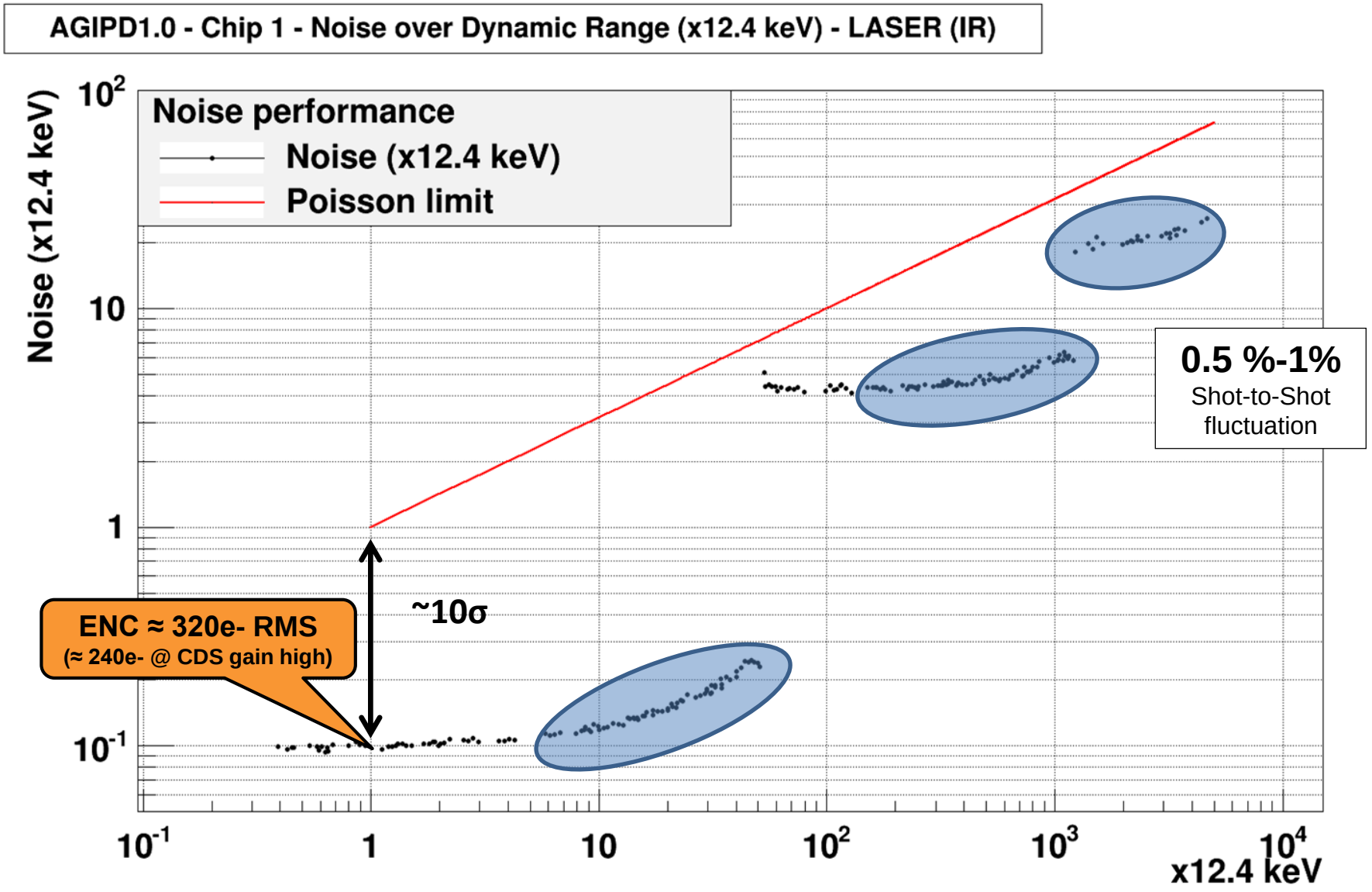
Adaptive gain amplifier

Line spectra covering all 3 gains with (1MeV) Protons@LABEC

High gain: 50-80 Photons with single photon sensitivity.

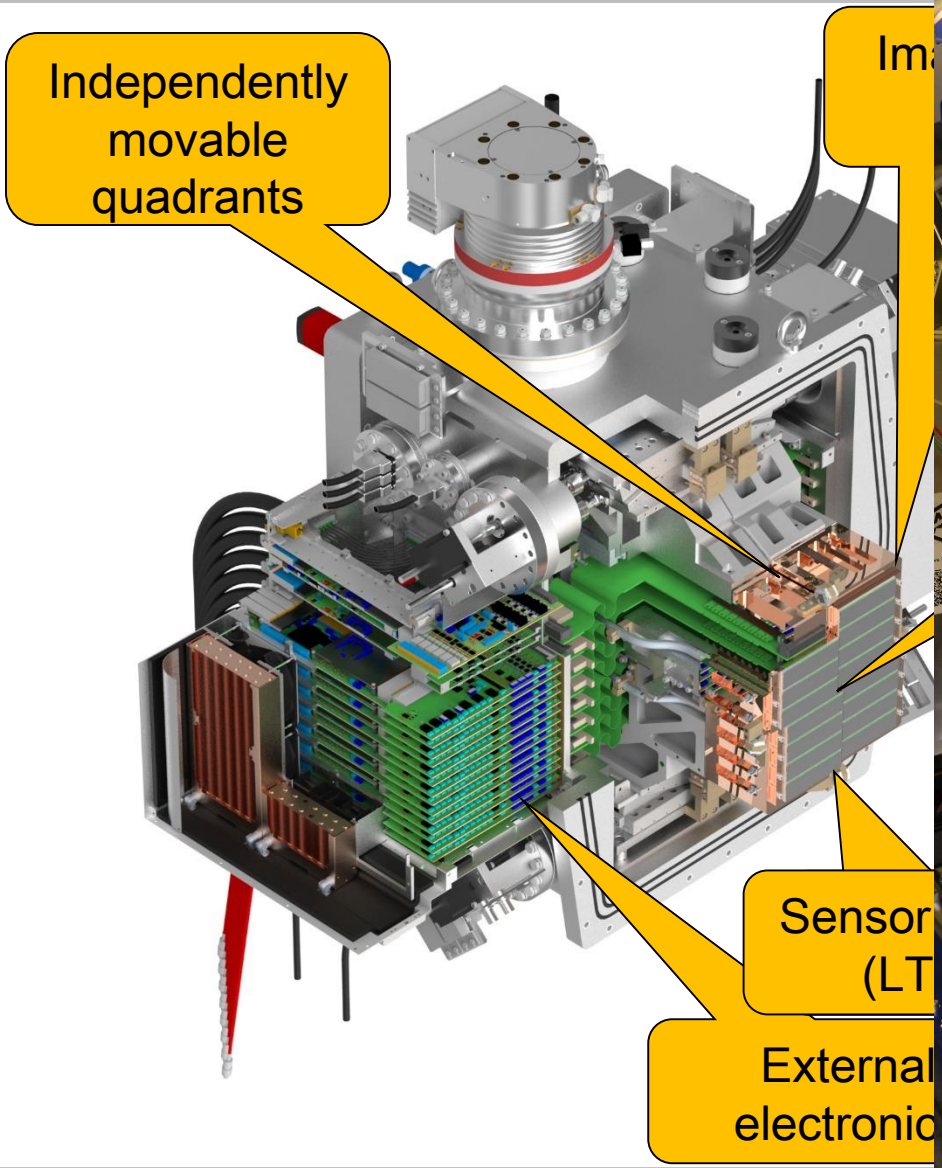
Low gain: 5000 photons with linear gain
+5000 photons with 1% nonlinearity.

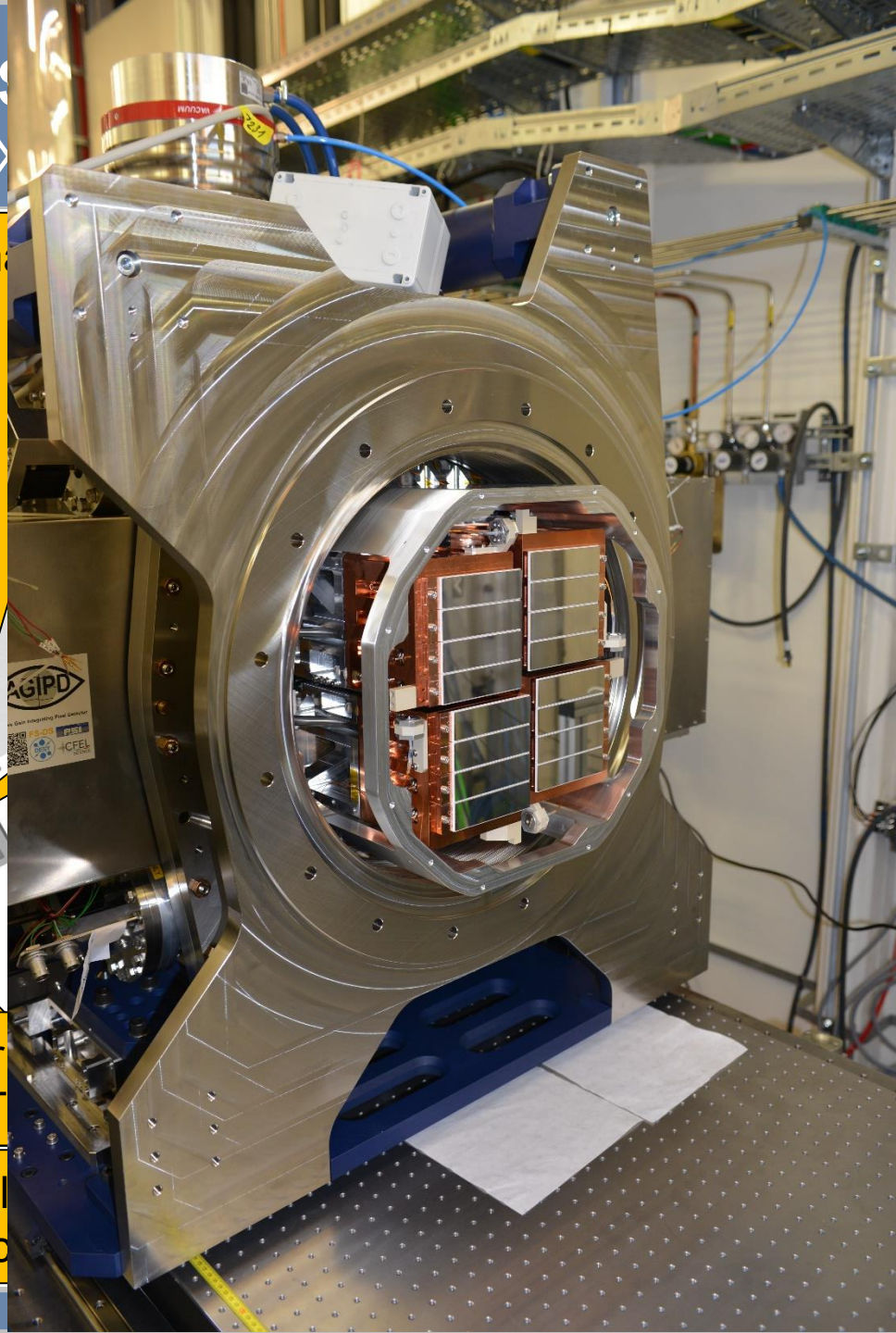
AGIPD Detector noise



AGIPD 1Mpix System

(SPB and MID Beamlines at European X

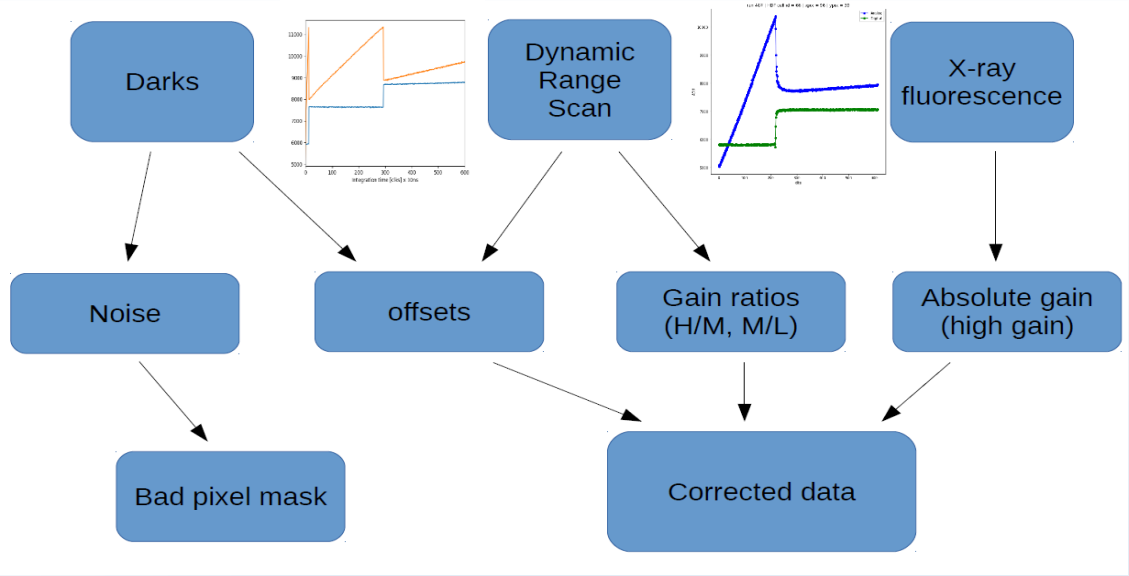


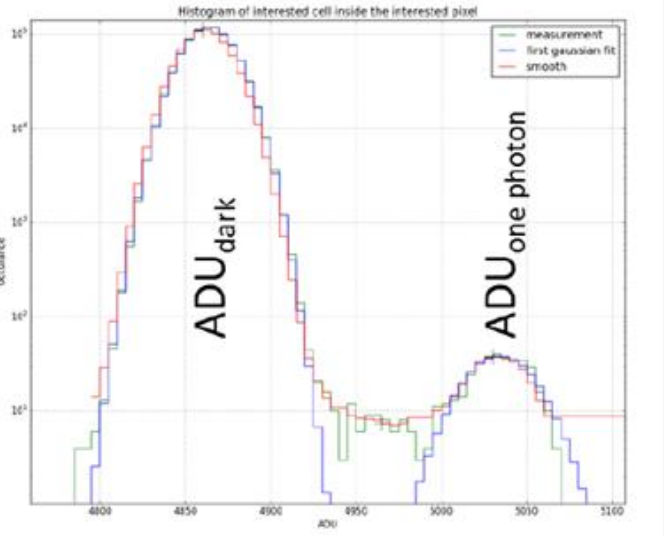


AGIPD 1Mpix Systems:
Calibration

Feed calibration frame work with

- Pulse capacitor dynamic range scans for all memory cells used
- Cu-K_α data at XFEL
- Dark data for High and Medium gain level





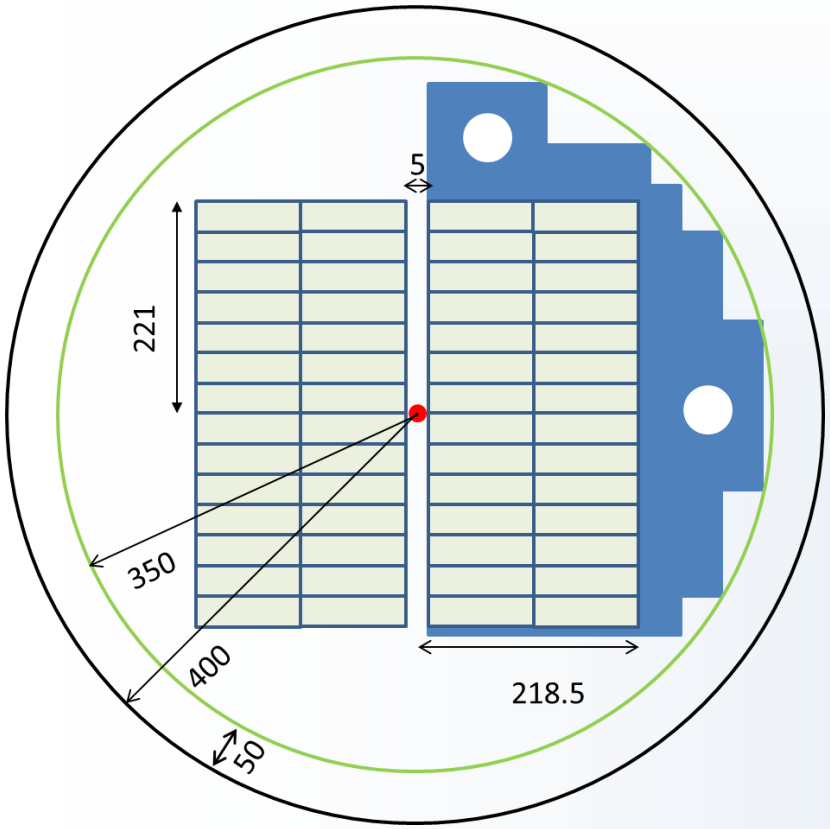
Calibration framework follows a modular concept and allows removing, adding and exchanging building blocks

- Huge number of fits!
- 65,536 pixels
- 352 memory cells
- 3 Gains + 3 Offsets
- ≈138,000,000 fits / module
- 16 Modules → 2.2×10^9 constants
- computation time, fit quality, non-constant fit ranges

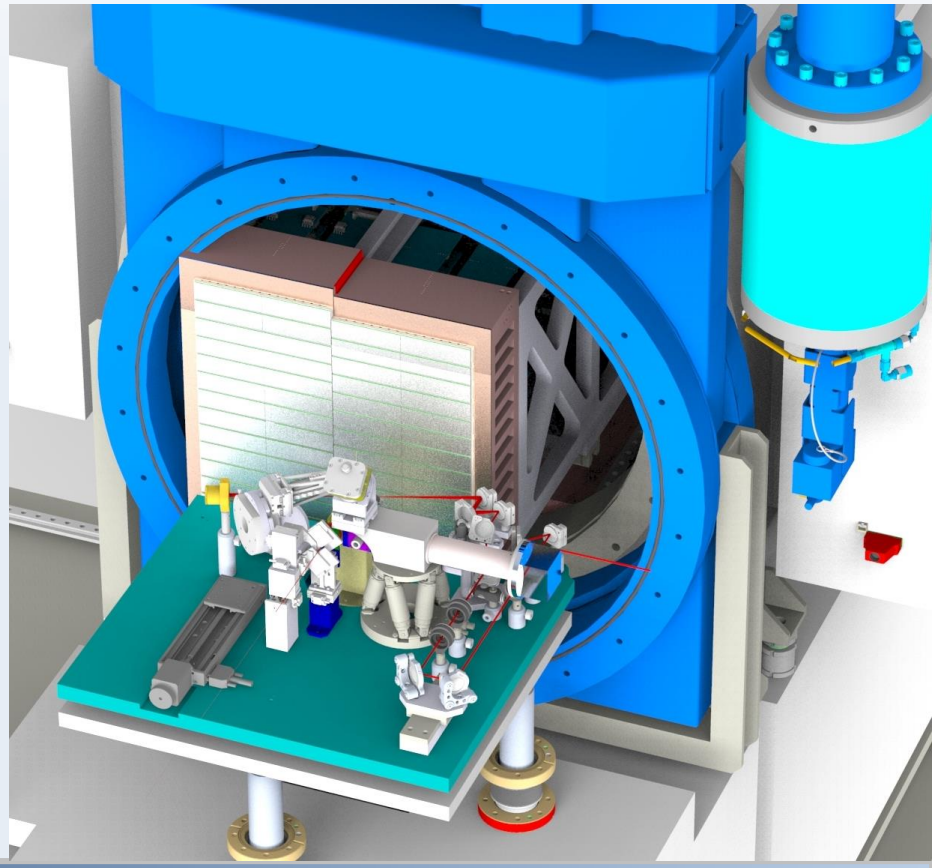
First User Experiment:
XFEL2012 (14th – 19th Sept. 2017)

Sorry, material not to be distributed removed

AGIPD 4M Detector for SFX



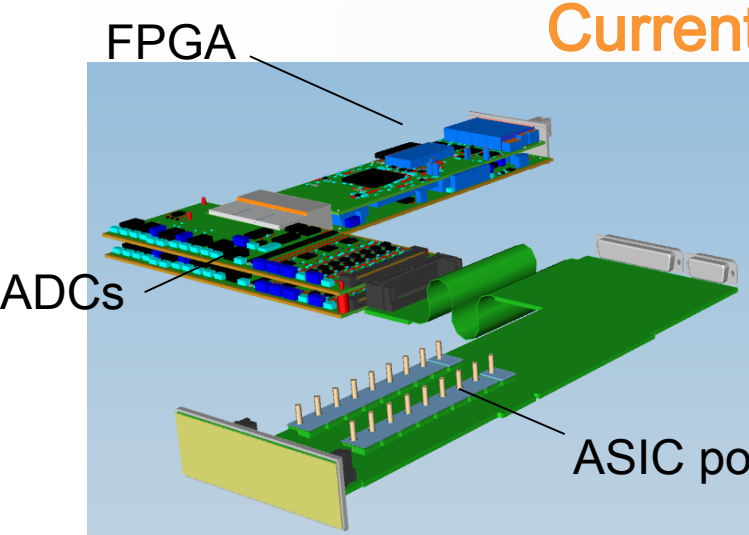
- 4 x 14 Front-End-Modules
- Two wings
  - 2 x 14 FEMs each
  - Individual in-vacuum x-motion



- In-vacuum z-motion into the gate valve (inner diameter 800mm)
- Travel range of 400 mm

AGIPD 4M Detector for SFX

Current readout boards



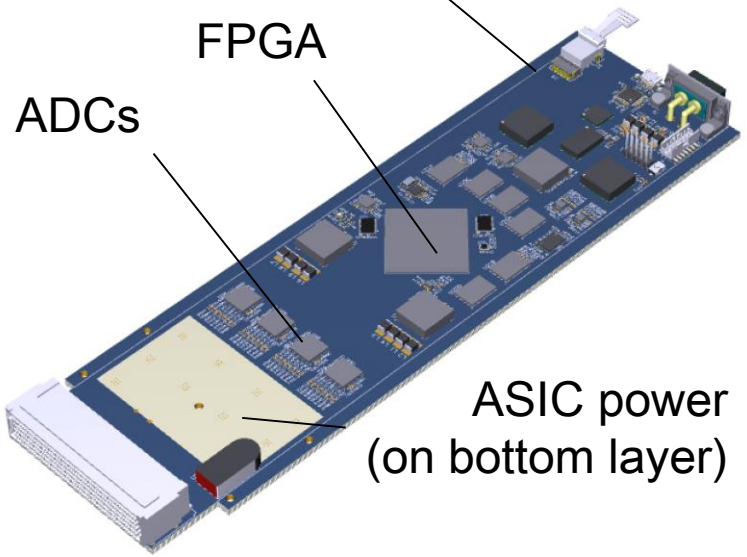
Challenges

- Complete redesign of two boards
  - Readout board in vacuum
  - Receiver board outside vacuum
- Cooling of PCB in vacuum

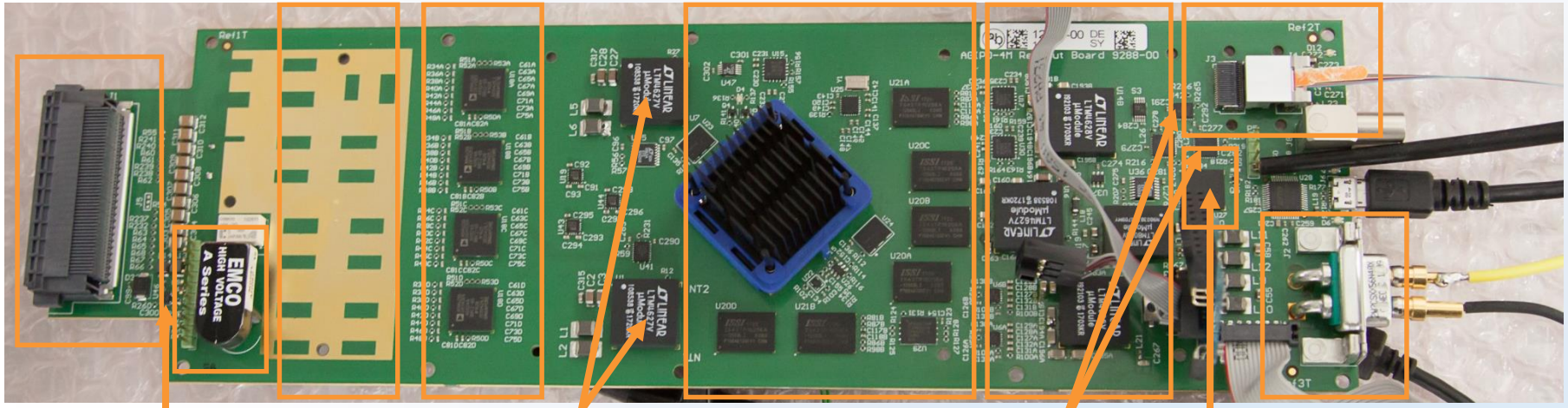
Advantages

- Short analogue signal path
- Local DC/DC -> less power cables
- Control and DAQ completely based on optical data transmission

New readout board

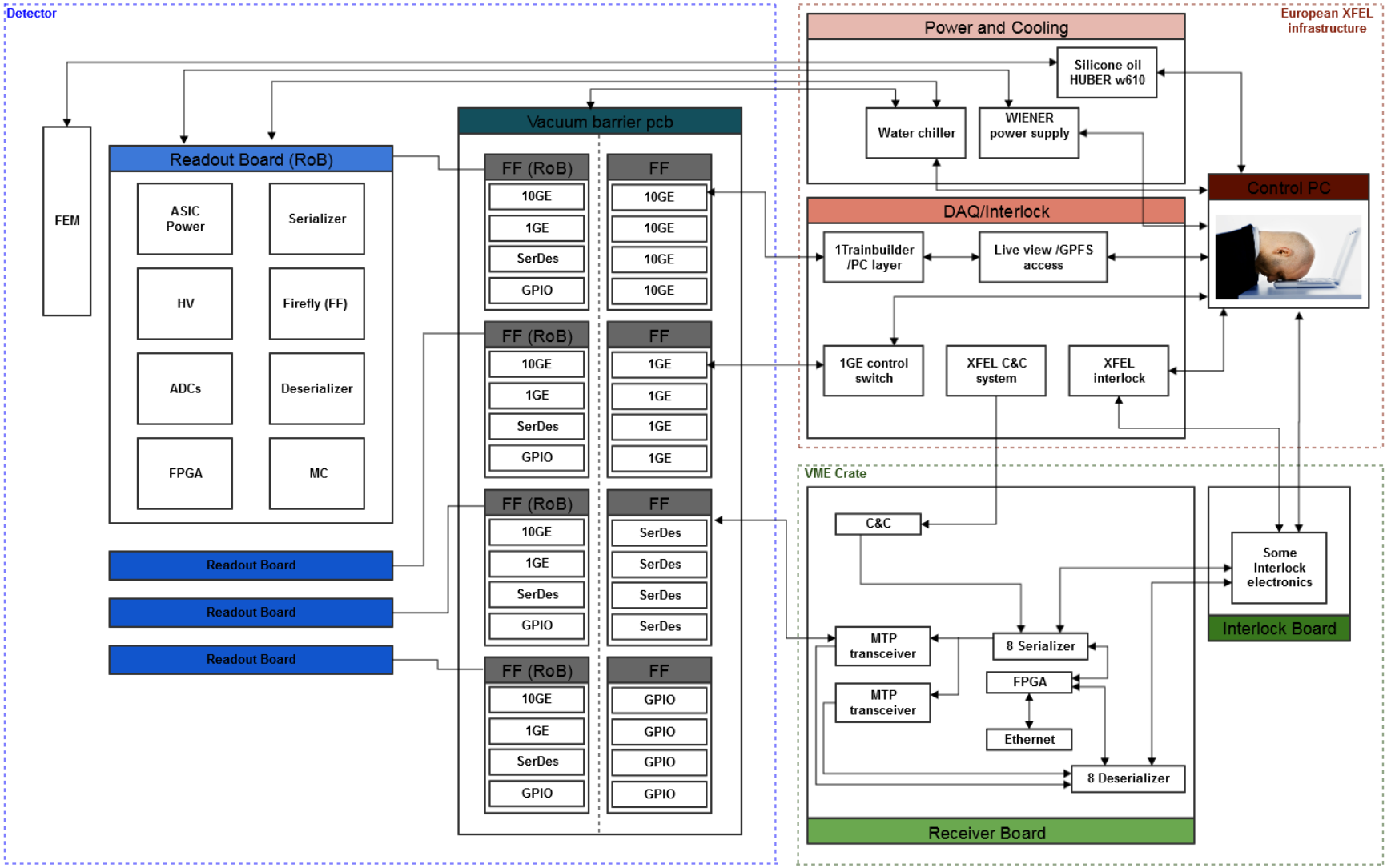


AGIPD 4M Detector for SFX



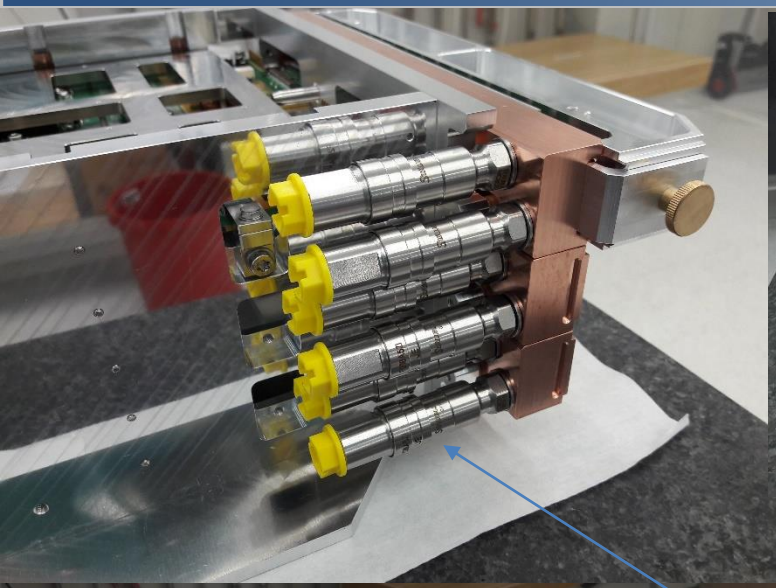
- Two Prototypes arrived
- Successful commissioning without major issues

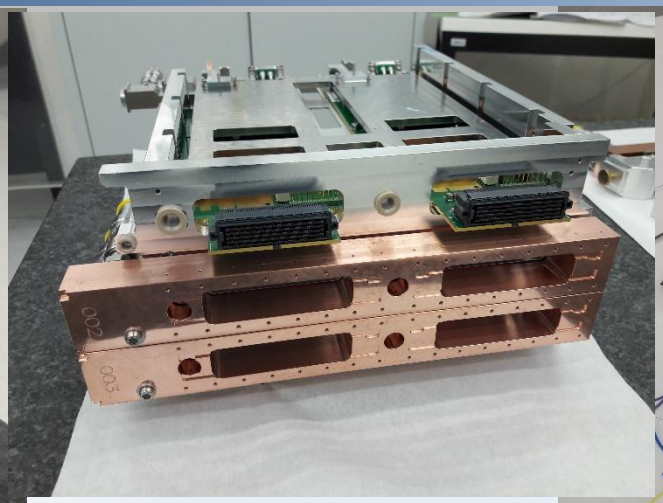
AGIPD 4M Detector for SFX

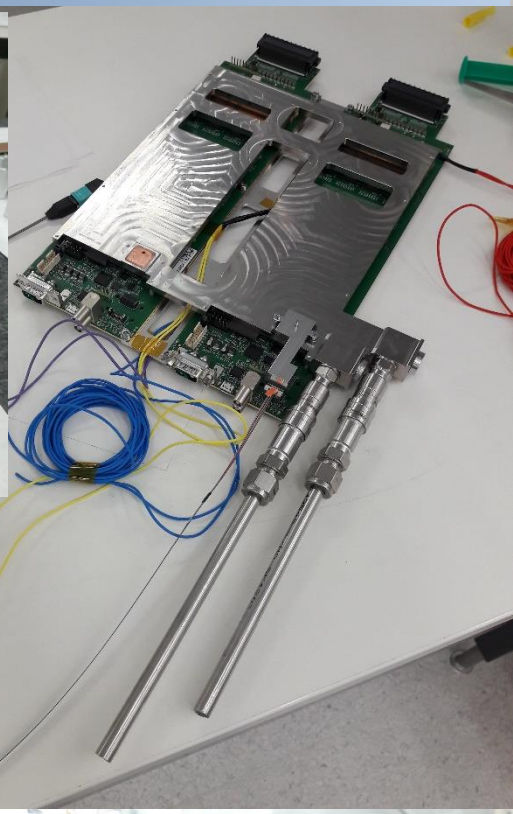


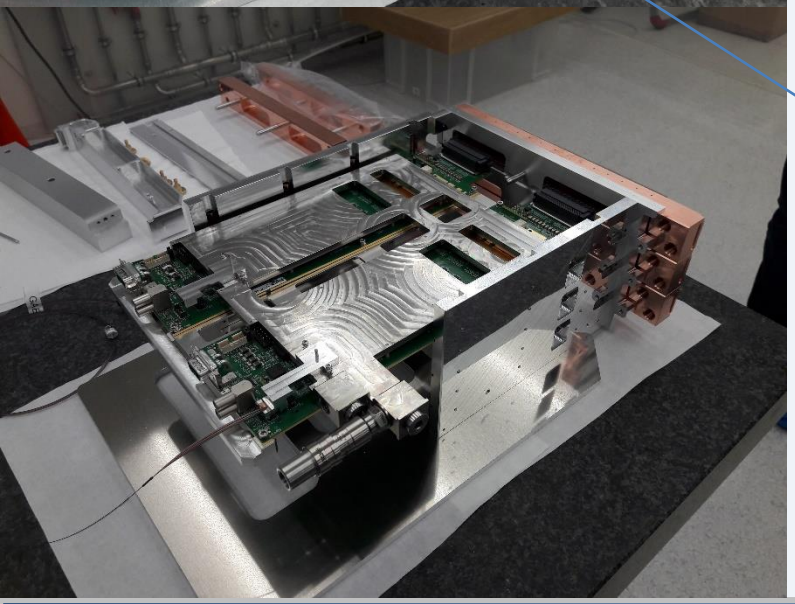
AGIPD 4M Detector for SFX

In-Vacuum Cooling



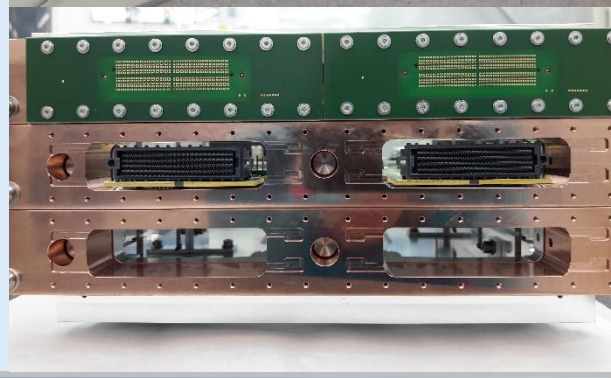




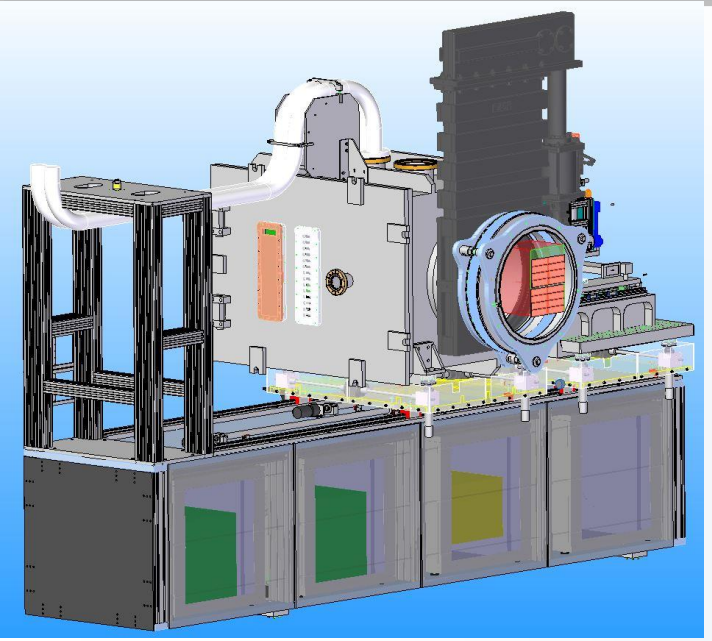


Liquid Cooling of

- Modules
  - Cooling channels in Copper frame
  - Coolant: Silicone oil
- Readout boards
  - Coolant: Water
- In-Vacuum connectors



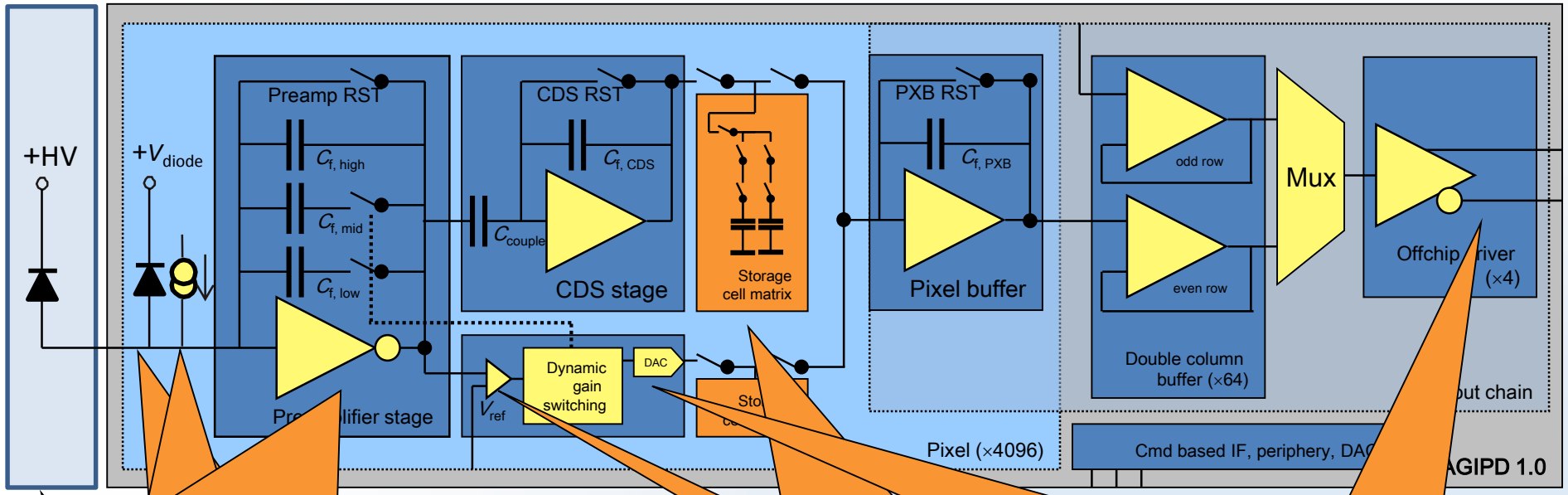
AGIPD 1M Detector for HiBEF
@HED Endstation of European XFEL



The HiBEF (Helmholtz International Beamline for Extreme Fields) experiment @ EuXFEL needs a 1Mpix detector for **E_{ph}≥25keV**

- The existing AGIPD detector collects positive charges (holes)
  - Easier to realise radiation hard sensors
  - Slower – less demanding to handle large charges (circuit wise)
- AGIPD is not suitable for experiments with photons above ~15keV
  - The Silicon sensor gets inefficient ~15keV
- High-Z Semiconductors, esp. GaAs promise efficient sensors for E_{ph}≥25keV
- Composite (III/V) Semiconductors feature relatively short charge carrier lifetimes
- Collection of Electrons (i.e. the fast component) is required

HiBEF:
From AGIPD to ecAGIPD



Swing will be opposite polarity (positive)
Different baseline (low) required

Gain bit encoding should m
signal polarity

Reverse current stimulus required

Signal in memory will be negativ cial)

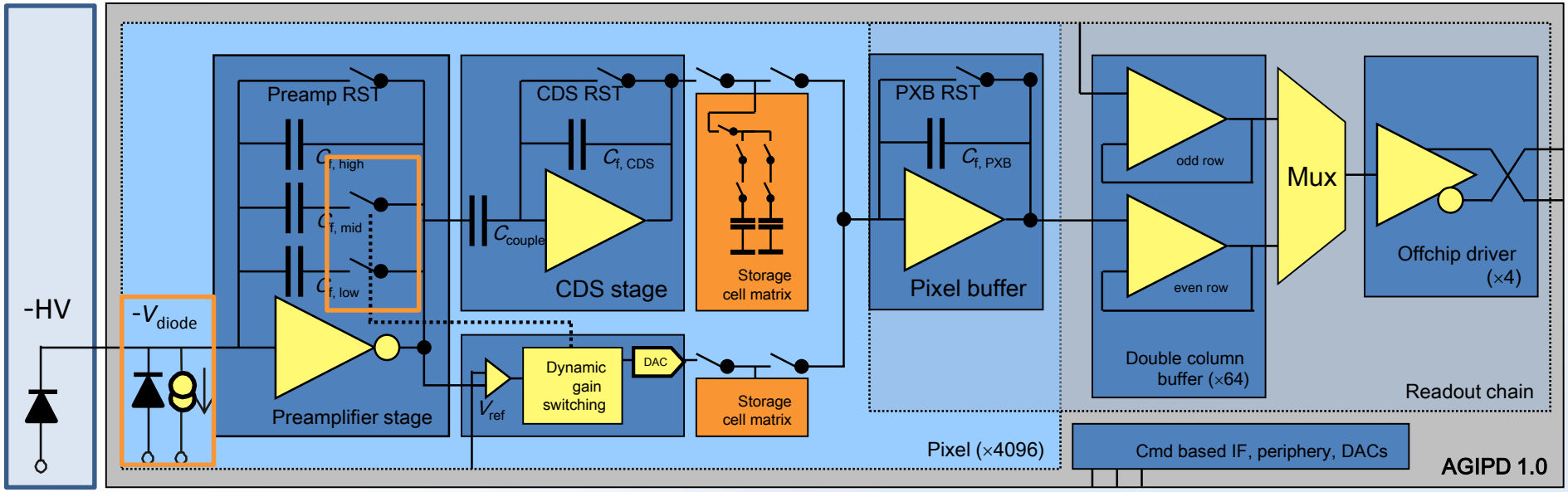
Input needs to be protected against the negative rail

Polarity mus sed

Sensor will produce negative charges

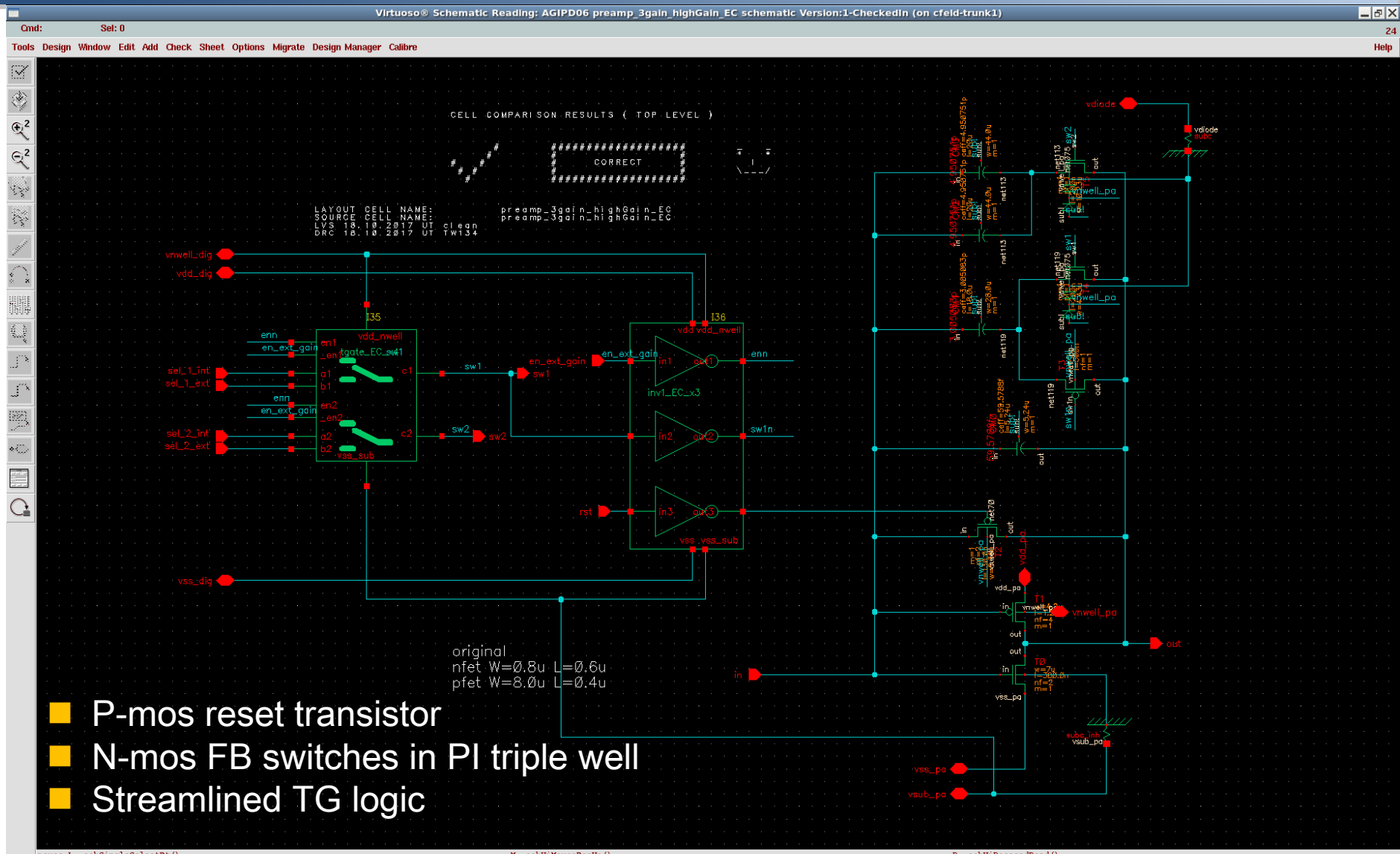
Reverse Polarity – behaves like AGIPD 1.x

ecAGIPD



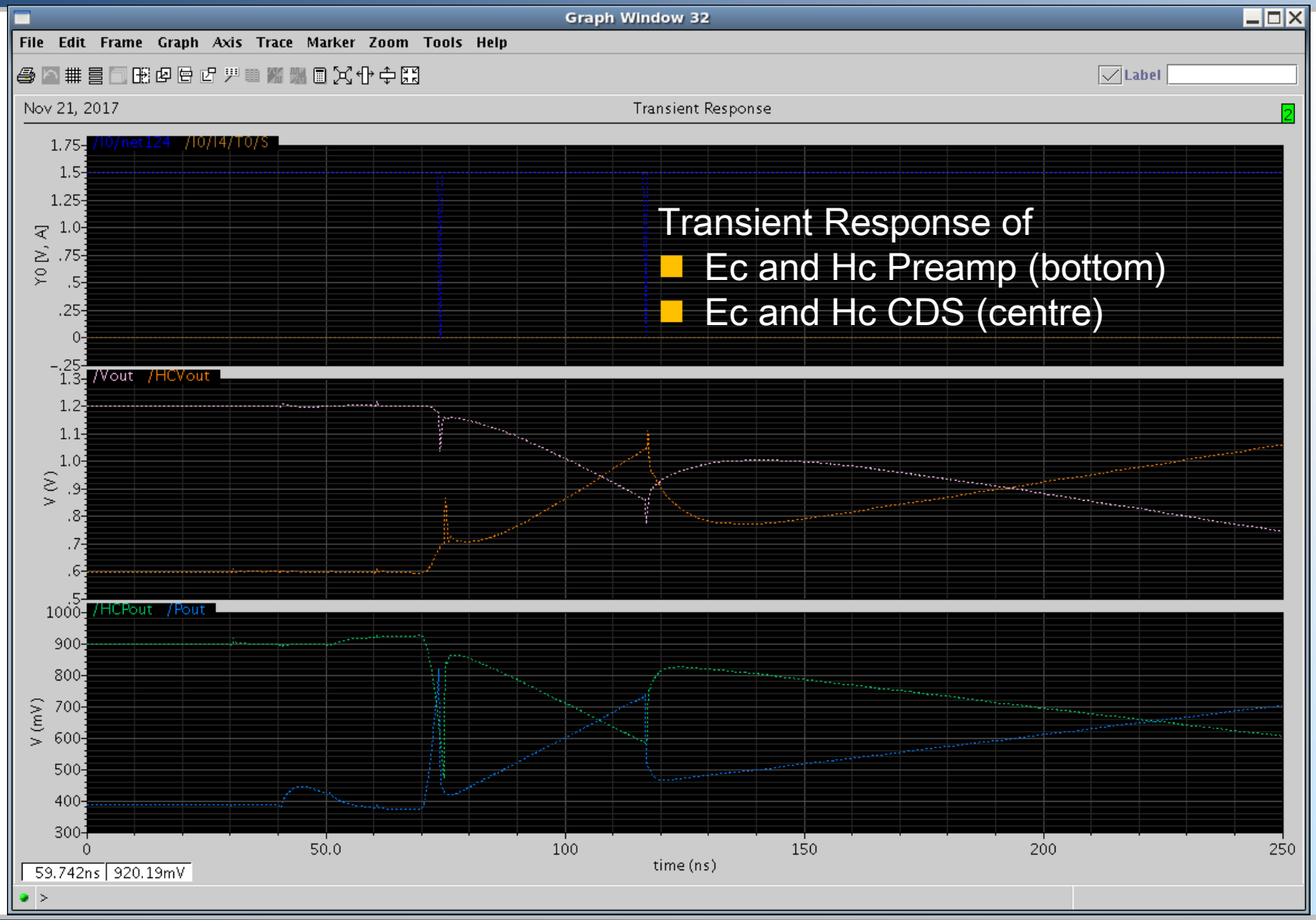
- Triple-well structure at negative (V_{diode}~-1V) voltage containing
  - Input protection diode
  - Current source for test stimulus = current mirror driven by existing source
  - Feedback switches
- Modified Preamp
  - New baseline at ~400mV
- Discriminator of opposite polarity
- Changed gain encoding
  - Hi <-> Lo
- Swapped output pads

ecAGIPD-Preamp

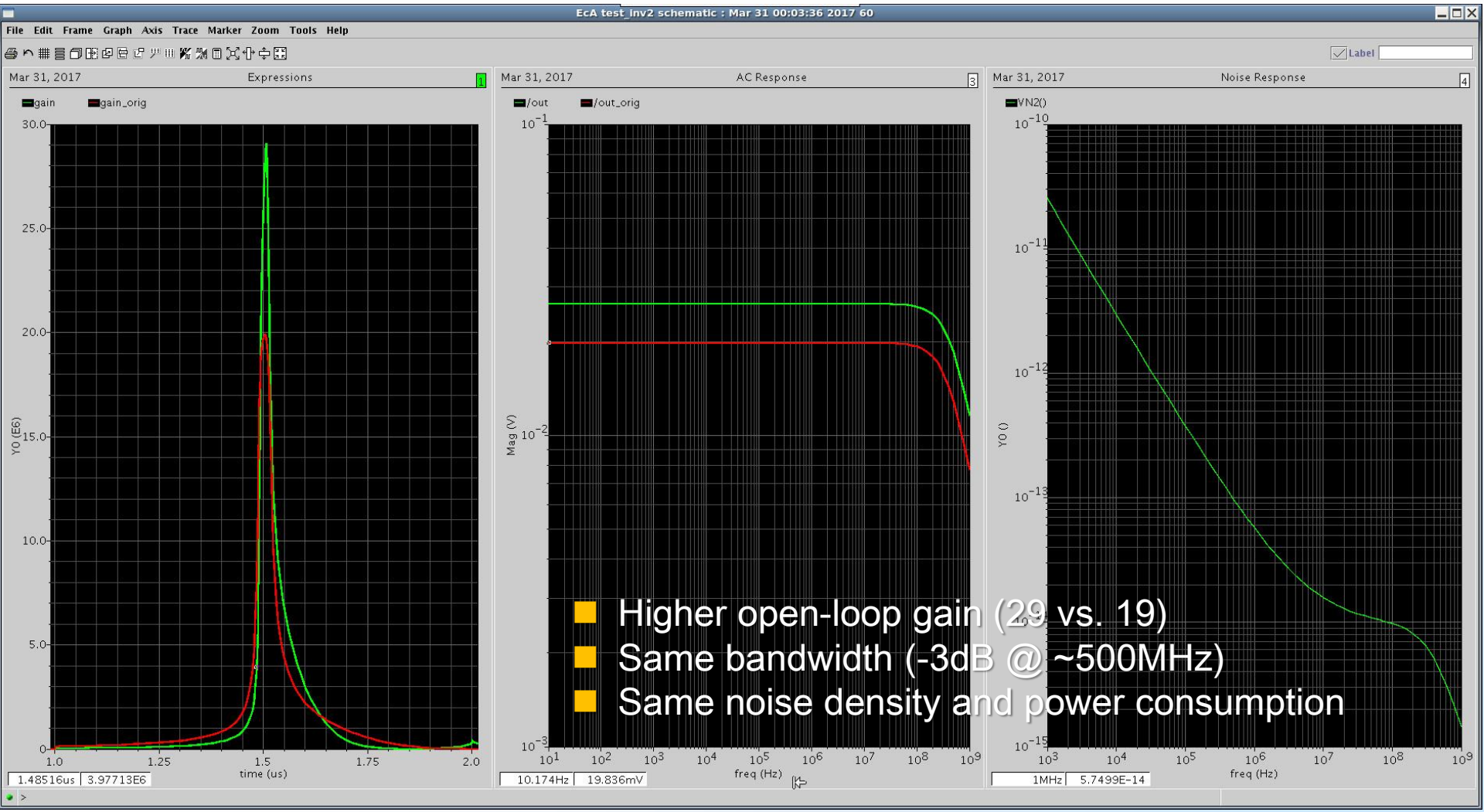


- P-mos reset transistor
- N-mos FB switches in PI triple well
- Streamlined TG logic

ecAGIPD-Preamp

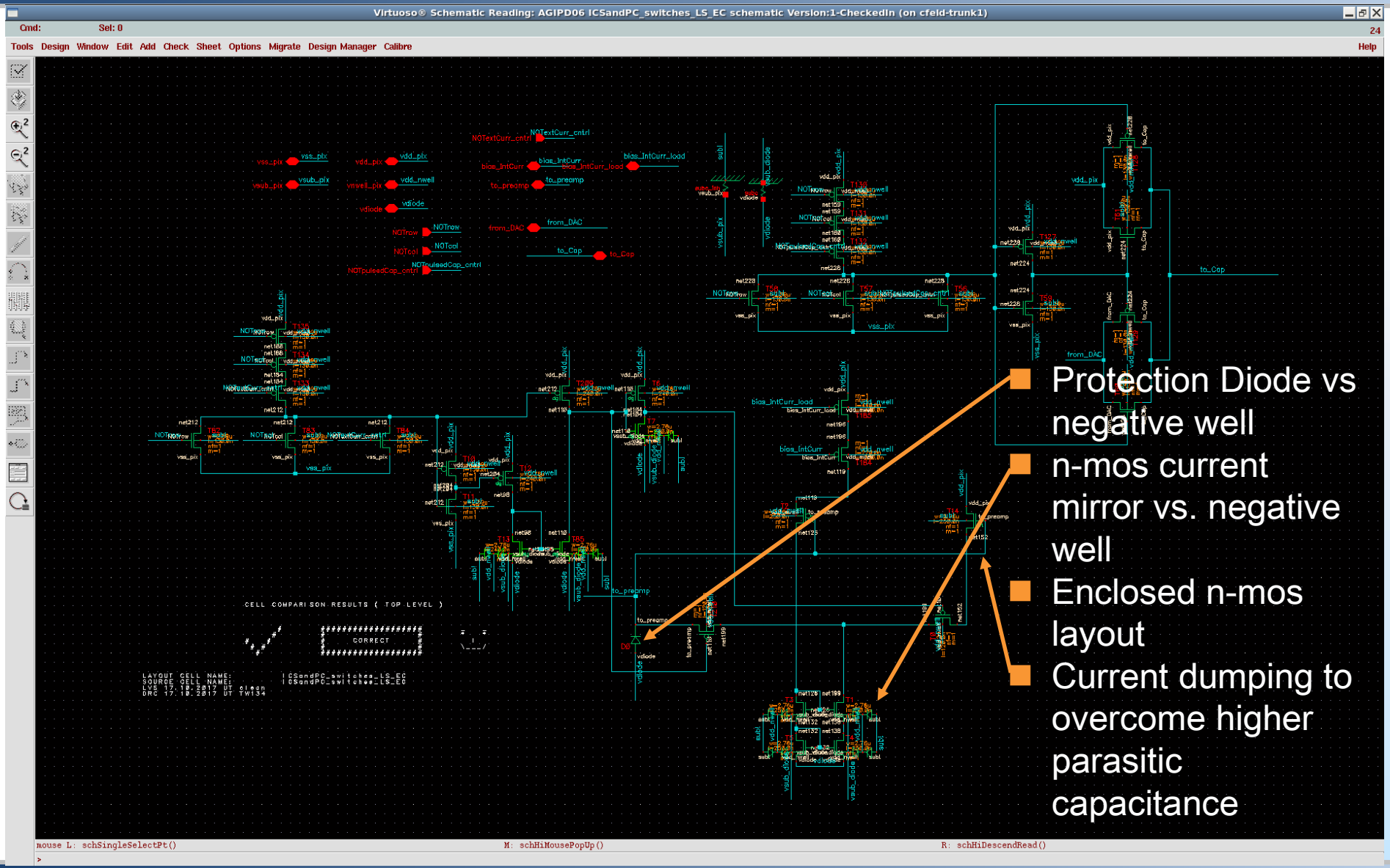


ecAGIPD-Preamp

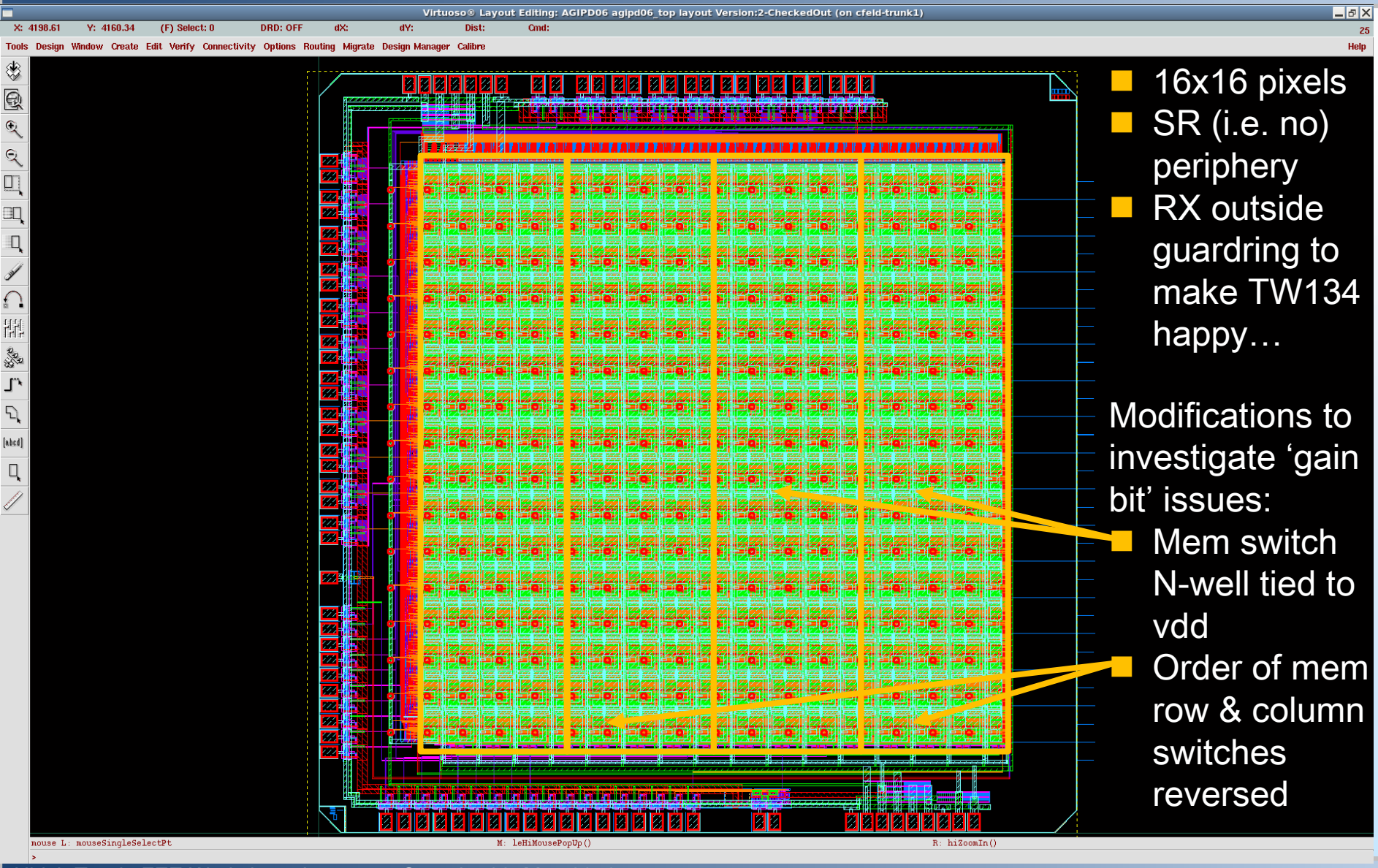


- Higher open-loop gain (29 vs. 19)
- Same bandwidth (-3dB @ ~500MHz)
- Same noise density and power consumption

ecAGIPD-Test Current Source



ecAGIPD: AGIPD06 Prototype



- 16x16 pixels
- SR (i.e. no) periphery
- RX outside guardring to make TW134 happy…

Modifications to investigate ‘gain bit’ issues:

- Mem switch N-well tied to vdd
- Order of mem row & column switches reversed

Beyond AGIPD

European XFEL operation will change in the 2nd half of the 2020s.
Tentatively 2 additional operation modes are foreseen:

- CW operation at 100kHz
- 'Long Pulse' mode with ≤200kHz in 500ms bursts, i.e. 50% duty cycle

On the same time scale the PETRA IV DLLS will become available.

- Intensity will allow to record complete diffraction patterns in ≈10µs

Plans for a possible successor of AGIPD are

- ≥100kHz (CW) imager
- 100 µm × 100 µm Pixels
- Dynamic gain switching
- In-pixel (group) ADC
- (Very) Limited pipeline for burst mode

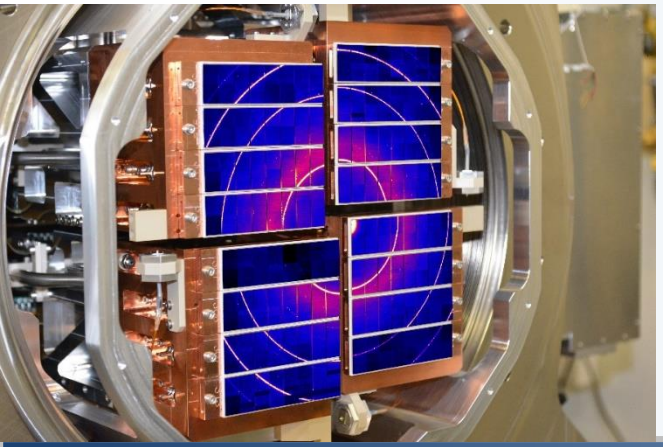
Summary & Outlook

AGIPD 1.1 (SPB/MID)

- System fulfils all requirements, esp. in terms of
  - Noise (<310e / <1.2 keV)
  - Single photon sensitivity
  - Dynamic range (>10^4γ @ 12.4keV)
  - Speed
- 1st 1Mpix system (SPB) in user operation
- 2nd 1Mpix system (MID) is ready for delivery
- Issues with low/med gain discrimination
  - Mask fix under investigation

SFX AGIPD 4M and HiBEF 1M systems

- Commissioning of new readout boards currently ongoing
  - No major issues
- Evaluation of advanced cooling concepts
- Both systems will be delivered with Silicon sensors & AGIPD 1.x ASICs



ecAGIPD for HiBEF

- Will replace Silicon sensors with High-Z ones
- Changes
  - Electron collecting preamp
  - Reversed polarity of discriminator
  - New calibration circuit
  - Use of twin wells
  - Reversed gain encoding levels
- AGIPD06
  - 16x16 ecAGIPD prototype
  - Submitted 13.11.2017
  - Manufacturing @ GF only started end of March (30.03.18)
  - -> Silicon expected in June
  - Also includes modifications to investigate low/med gain discrimination issues
- Missing for an 64x64 EcAGIPD
- Swapping of outputs
- Layout (vDiode, some routing outside the matrix…)

100kHz Imager for CW-XFEL and PETRA IV

- Concept studies
- More specs needed

http://photon-science.desy.de
/research/technical_groups/
detectors/projects/agipd