AGIPD systems for the European XFEL, development and upgrades

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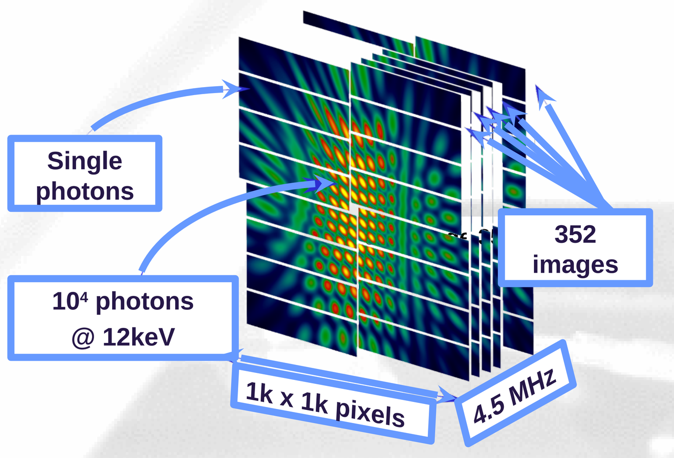
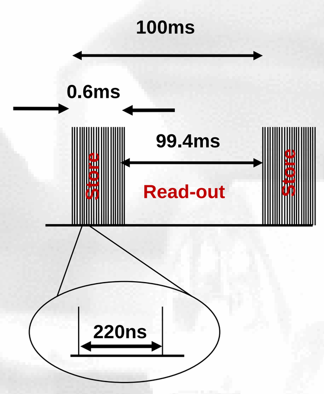
The Adaptive Gain Integrating Pixel Detector

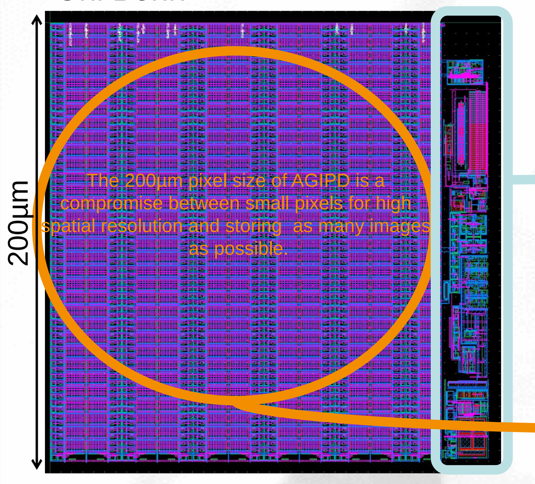
Designed for use at the European XFEL, AGIPD has three key features:

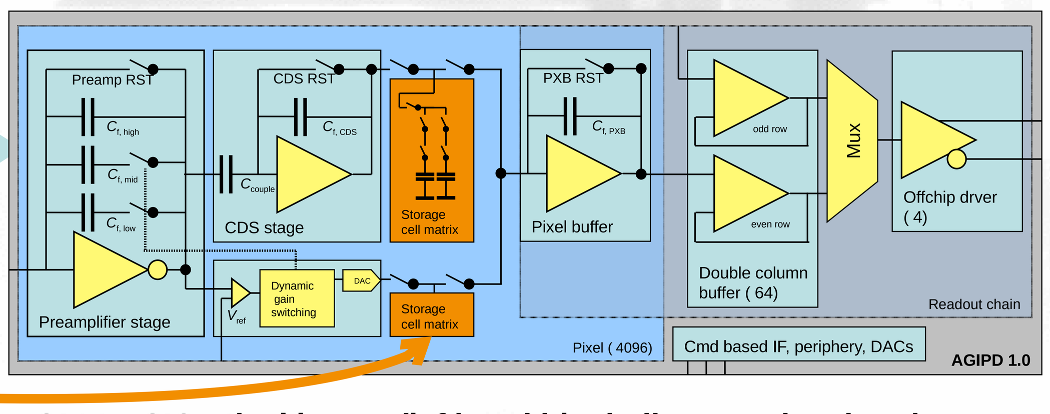
- Single photon sensitivity
- Dynamic range of up to 10^4 photons/pixel/frame.
- 4.5 MHz repetition rate (for 352 images)

Collaboration with PSI, Uni HH and Uni Bonn









AGIPD ASIC: Pixel layout (left) and block diagram showing the analogue readout chain (top)

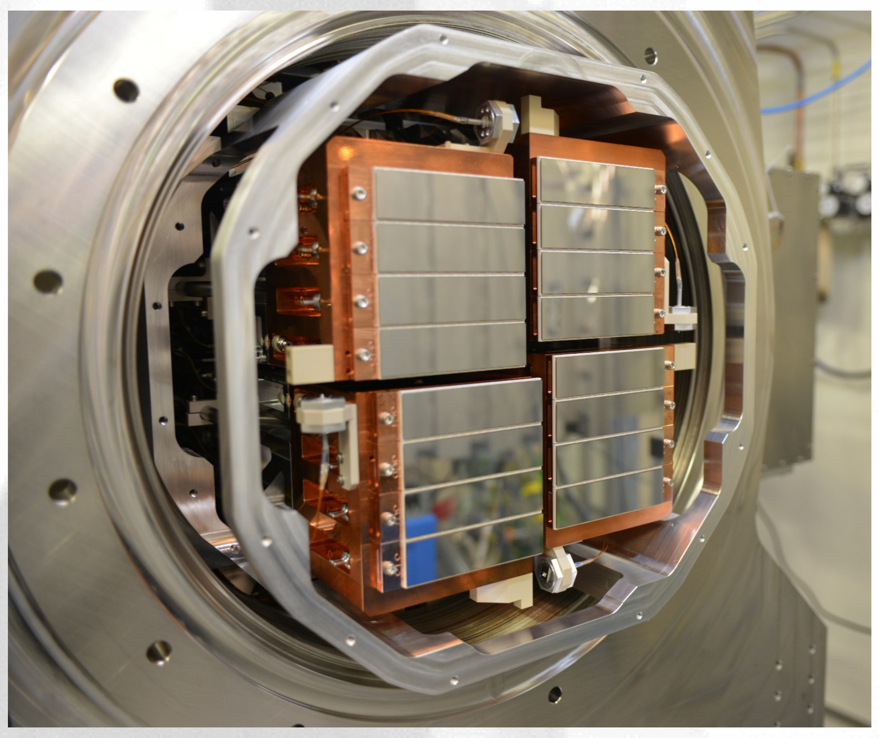
Key Parameters

Operating principle	Charge integrating
Energy range	3 keV-18 keV
Frame rate	> 4.5 MHz (burst)
Memory depth	352 frames
Pixel size	(200 µm)²
Pixel technology	Hybrid Pixel Technology
Total detector size	Variable (modular)
Module size	2.5 10.5 cm², 128 512 pixels
Dynamic range	1 to 10^4 photons/pixel/frame at 12.4 keV
Dynamic gain switching	Yes (3 gains)
Veto/Trigger	Yes (overwriting of frame RAM)
Single Photon sensitivity	Yes (in high gain)

- Preamplifier with adaptive gain by insertion of additional feedback capacitors to lower sensitivity and increase dynamic range once a defined threshold is crossed
- Correlated Double Sampling (CDS) stage to remove reset noise and reduce low frequency noise
- Analogue memory, which can store 352 images
- Read out of stored signals are through the pixel buffer, column buffer and off-chip driver in between the bunch trains (≈25 ms out of 99 ms)

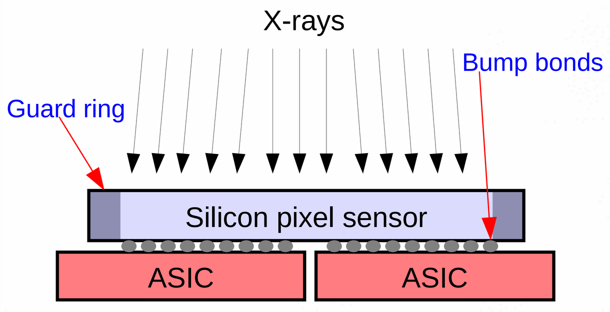
AGIPD 1Mpix systems

- Two 1MPix AGIPD systems operational at European XFEL:
  - SPB/SFX instrument
  - MID instrument

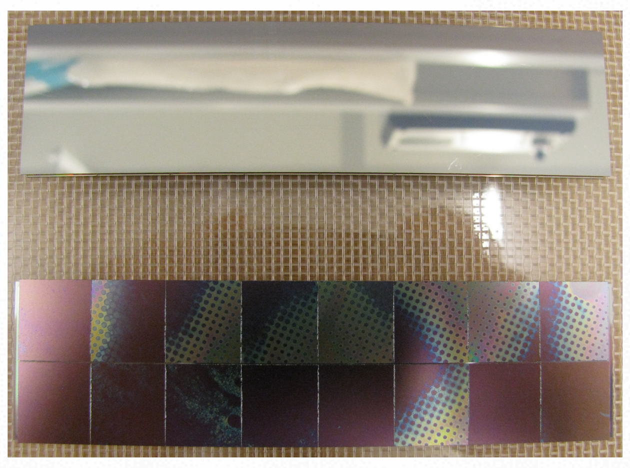


- Operation in vacuum
- 16 modules are mounted on four independently movable quadrants

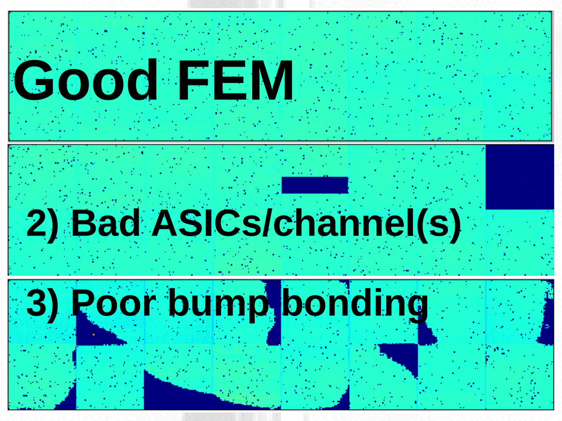
Hybrid probe station and Front-End Module (FEM) Yield improvement

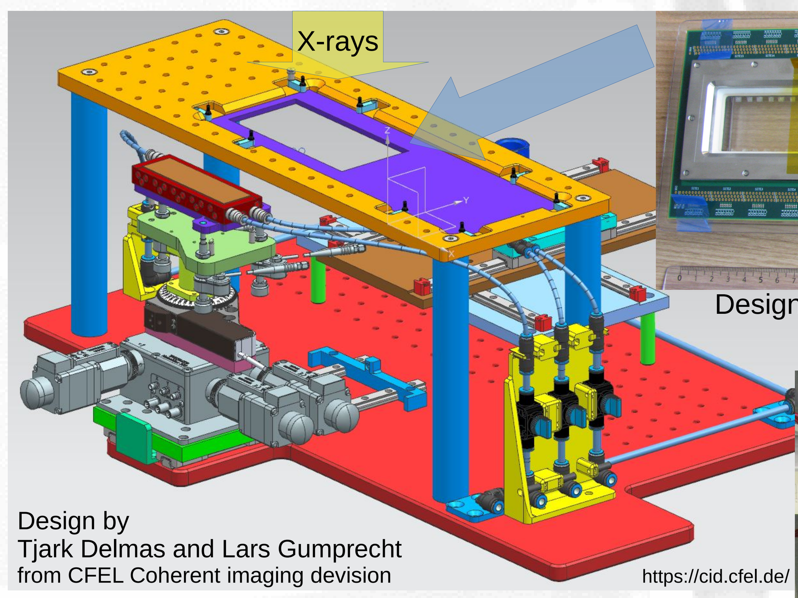


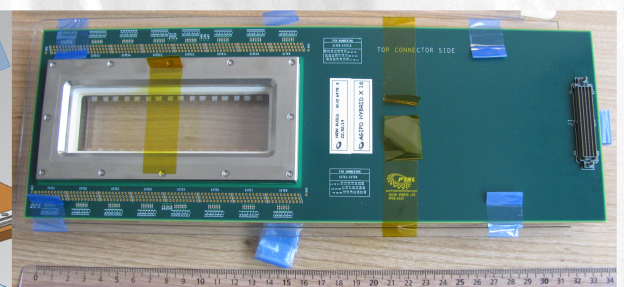
Sensor side



ASIC side

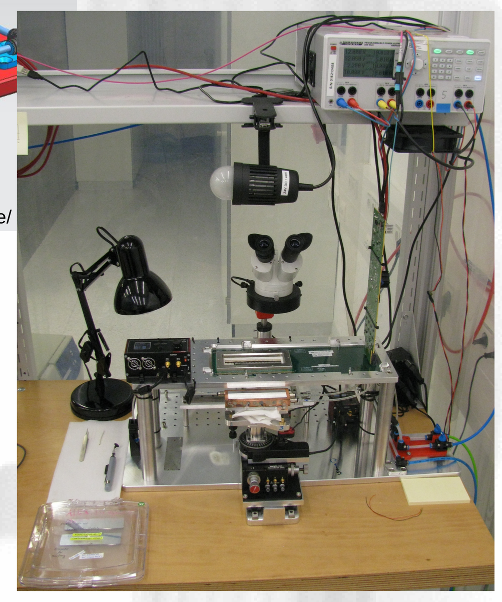






Design by http://www.probetestsolutions.com/

Design by Tjark Delmas and Lars Gumprecht from CFEL Coherent imaging devision https://cid.cfel.de/



FEM Initial Yield and its killers:

44/85=**52%**

Screen
1) Low breakdown voltage = 5/41
2) Bad ASIC/channel(s) = 11/41
3) Poor bump bonding = **15**/41

Improve
4) Too high dark current = 11/41
+ 1 FEM with AUX power problem

The common yield is a product of the yields from every error source $Yc = Y_{1\text{-}3} * Y_4$, and the current yield due to the ASIC, sensor and bonding issues is $Y_{1\text{-}3} = 0.76$: $0.52 = 0.76 * Y_4$, the yield due to the poor thermal connection was so far $Y_4 = 0.68$.

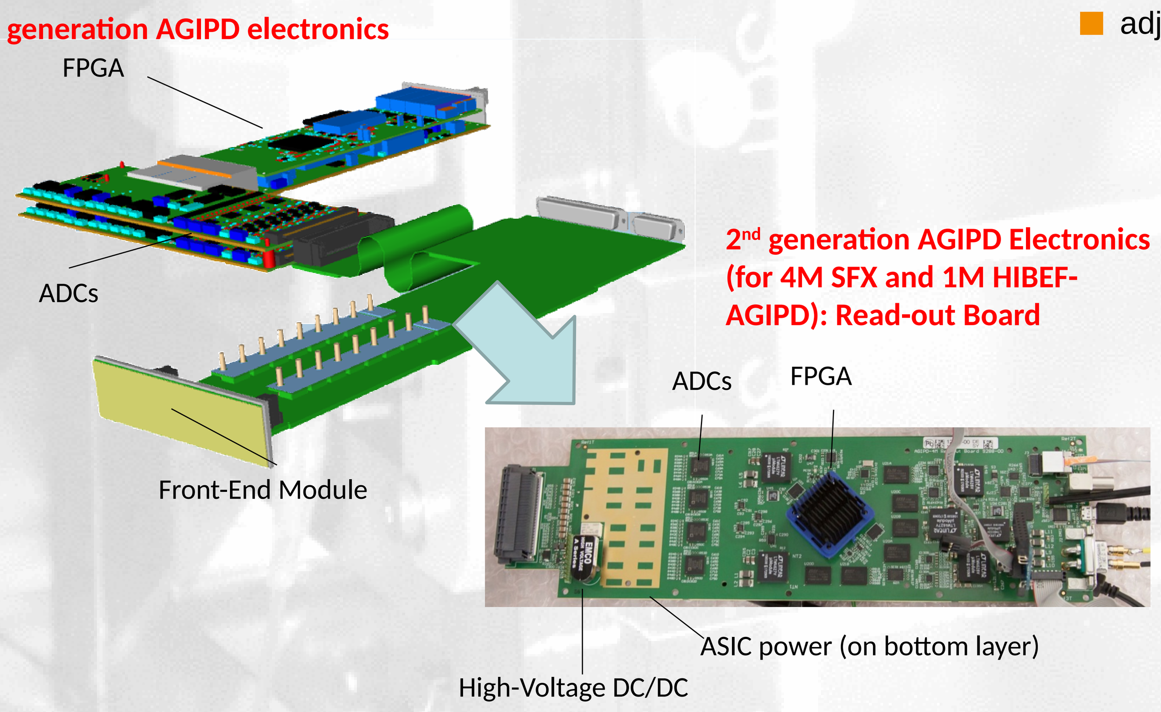
The process of probing sets our $Y_{1\text{-}3}$(after probing) to 1 meaning only the good hybrids go into production of FEMs and thus results in our minimum yield $Yc = 1 * Y_4 = 0.68$ (30% relative improvement) which is a good starting point. Taking into account actions taken for the improvement of the thermal conductivity within the FEM we expect the minimum yield to raise **to at least 0.8.**

2nd Generation AGIPD for the European XFEL

New Megapixel AGIPD Detectors

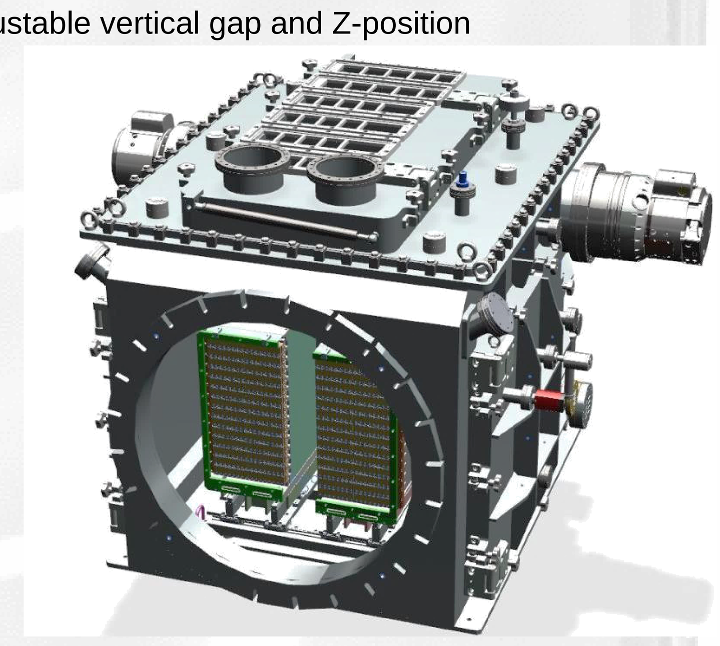
- SFX User Consortium, SPB/SFX instrument: AGIPD4Mpix
- HIBEF User Consortium, HED instrument: AGIPD1Mpix, Initially with Si-sensors, later with HighZ sensors (GaAs/CdTe/CdZnTe for higher photon energies)
- Assembly & Commissioning of both systems in Q3+4 2022

Read-out electronics



AGIPD 4M Mechanics

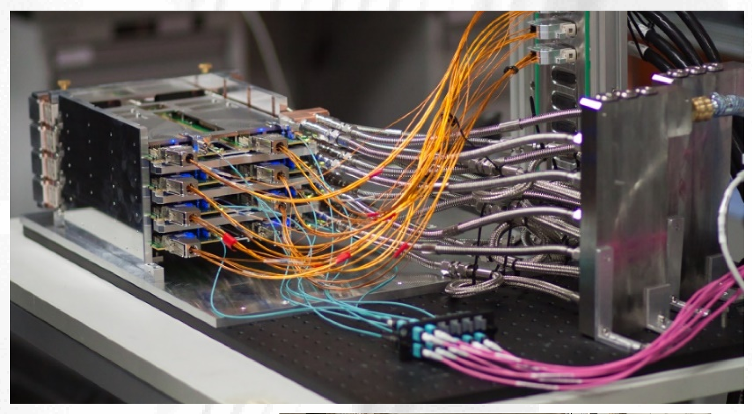
- In-vacuum cooling system of frontend-modules and readout board
- In-vacuum longitudinal motion to vary sample-detector-distance
- AGIPD1M for HIBEF
  - 2 x 8 FEMs
  - fixed horizontal gap
- AGIPD4M for SFX
  - 4 x 14 FEMs divided into 2 halves
  - adjustable vertical gap and Z-position



AGIPD4M for SFX UC

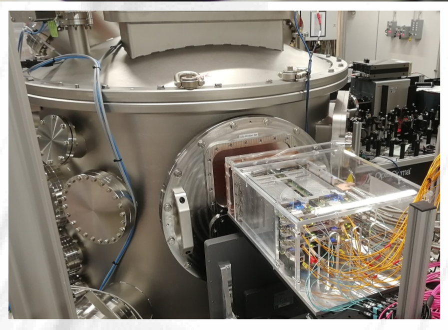
„AGIPD Mini-Half“ – 2nd Generation Prototype

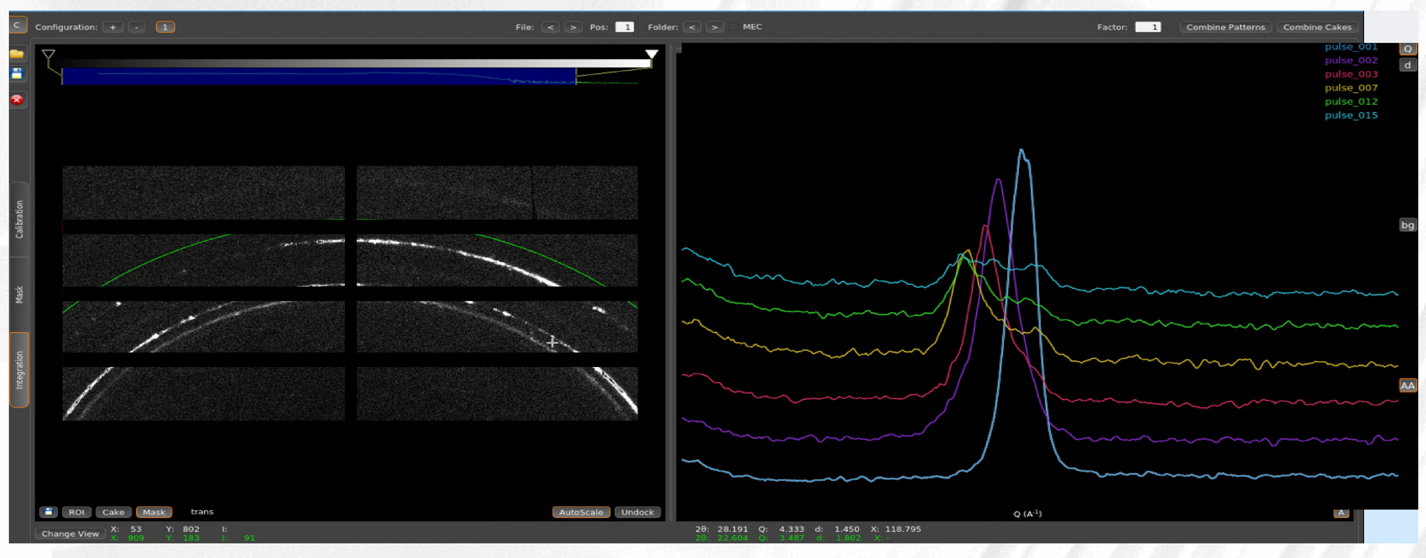
- Integrate small system into XFEL's controls, timing and DAQ system -> feedback to AGIPD firmware
- Commission and characterize 2nd Gen AGIPD system with XFEL
- Characterize AGIPD1.2 with XFEL
- Provide first MHz-diffraction capability for HED/HIBEF until delivery of final system



AGIPD Mini-Half System, HED/HIBEF

- 8 Readout Boards, 8 front-end modules = 500kpix
- 4x AGIPD1.1, 4x AGIPD 1.2 FEMs
- 1 Receiver Board – without interlock functionality, link to EuXFEL Clock&Control
- Operated in air, water cooled

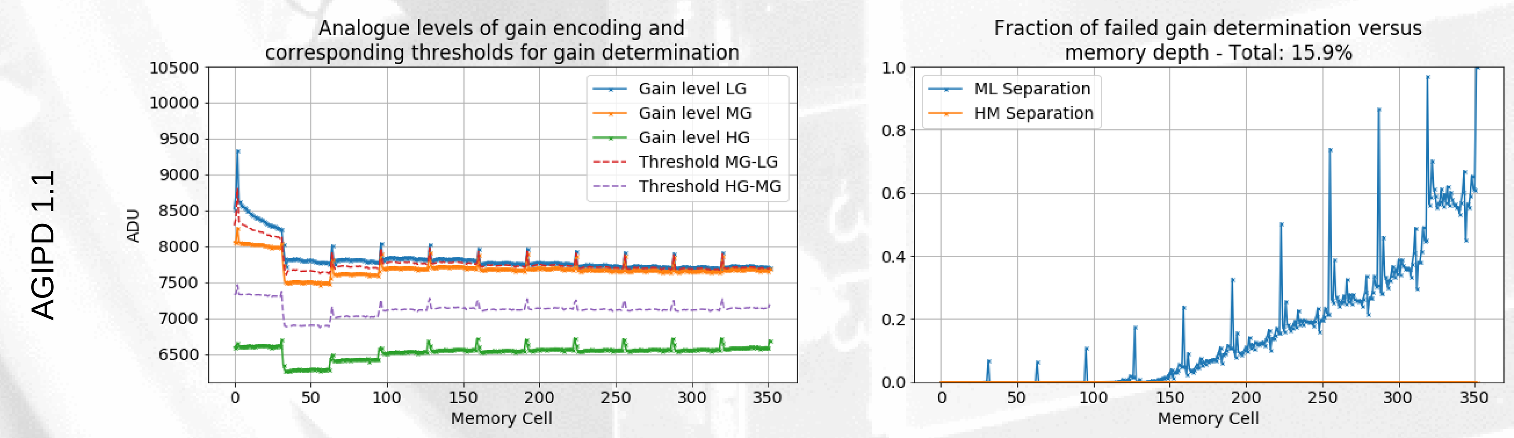


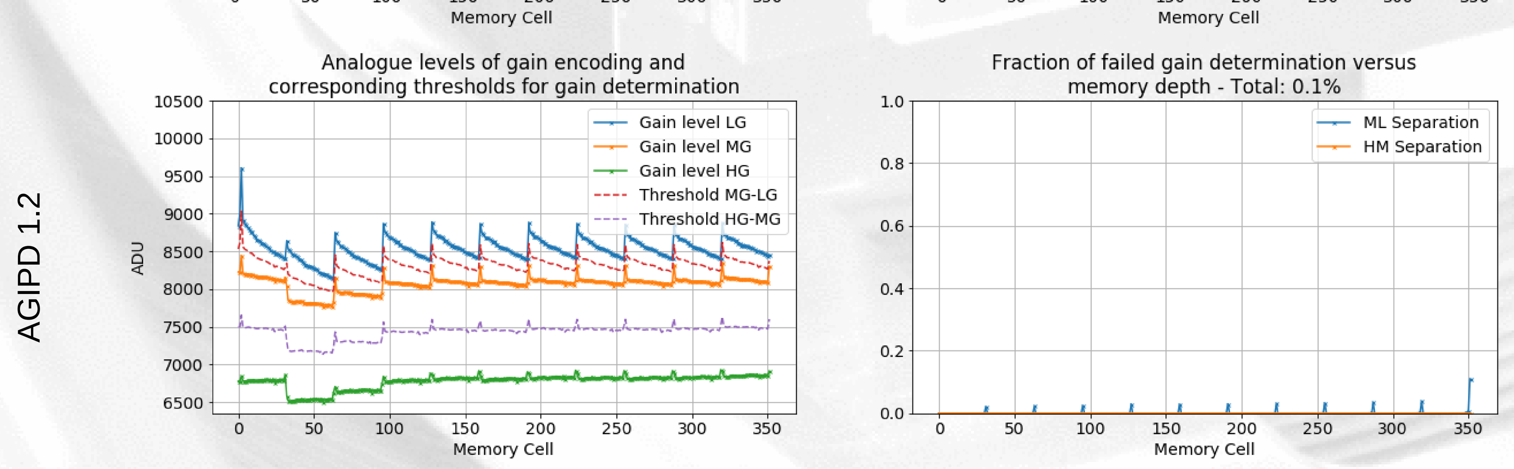


Experiment Nov 2020: Single-train MHz-pulse-resolved diffraction data from X-ray (and laser-) heated Platinum in diamond-anvil cells, intra-train thermal peak shift and melting

AGIPD1.2 ASIC

- New ASIC to improve encoding of 3rd gain stage

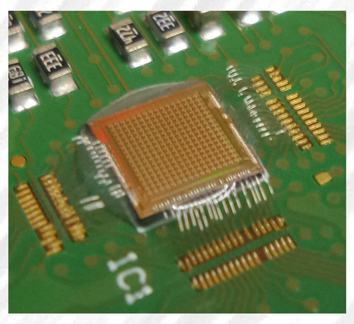




HighZ sensors & ecAGIPD (AGIPD1.3) ASIC

- Higher photon energies (>12keV) require sensor materials different (heavier) than Si for better absorption: HighZ sensors, e.g., GaAs, CdTe, CdZnTe
- HighZ sensors: almost always electrons are the better charge carriers, requires new ASIC as the existing AGIPD1.1 and 1.2 are hole-collecting only
- Electron-collecting AGIPD0.6 MPW test chip (16x16 pixels) is currently tested showing expected functionality and performance
- AGIPD1.3 full ASIC is ready for tape-out

AGIPD0.6



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