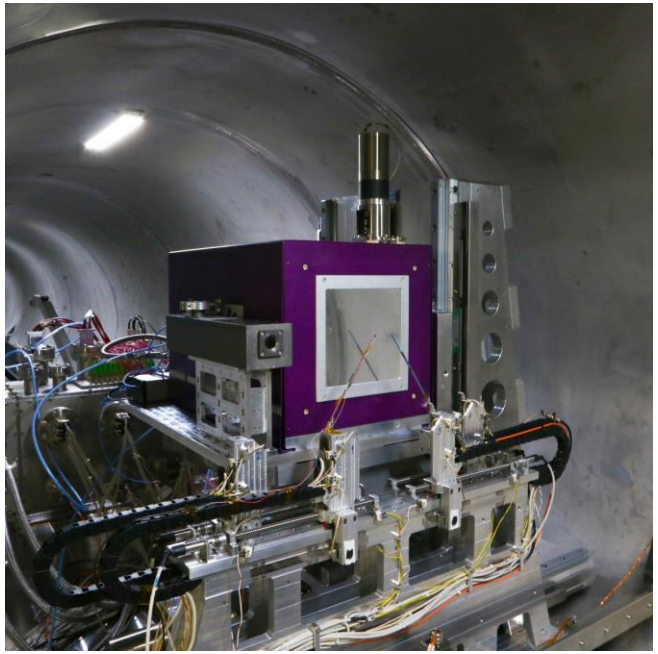
2D Detectors at SIRIUS

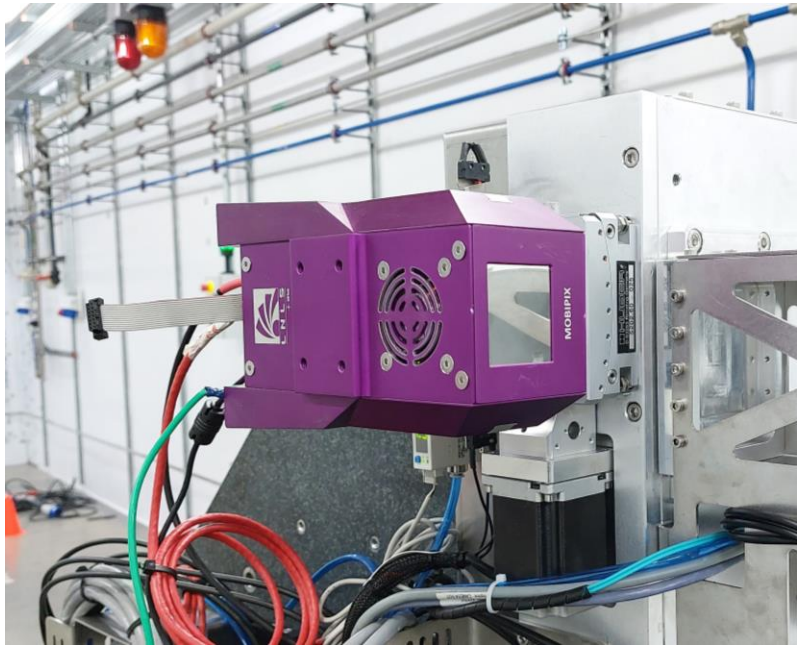
LImA Satellite Meeting @ NOBUGS 2024
Fast 2D detector DAQ at different facilities

LNLS Brazilian Synchrotron Light Laboratory
CNPEM Brazilian Center for Research in Energy and Materials
MINISTRY OF SCIENCE TECHNOLOGY AND INNOVATION
BRAZILIAN GOVERNMENT BRASIL UNITING AND REBUILDING

Current state

- Two main detectors, using Medipix3RX: PIMEGA and Mobipix
- Software stack: EPICS AreaDetector and custom DAQ





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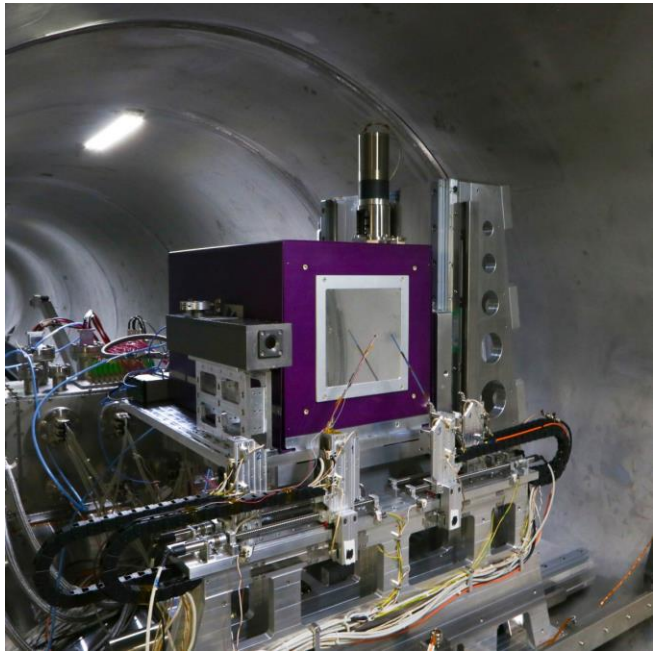
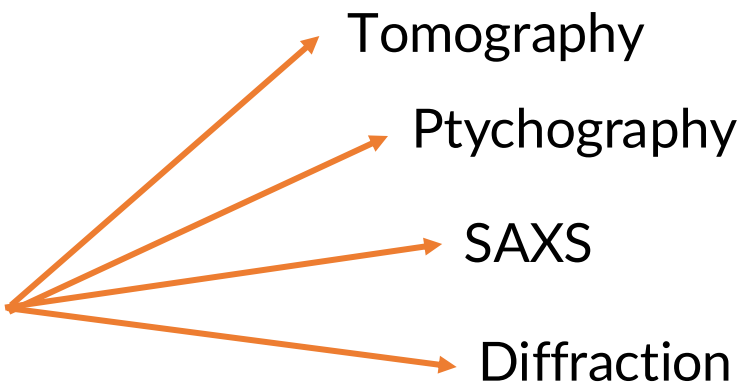
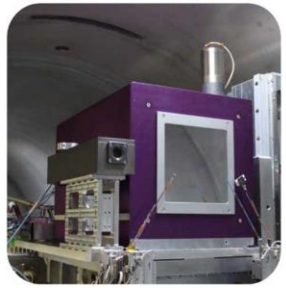
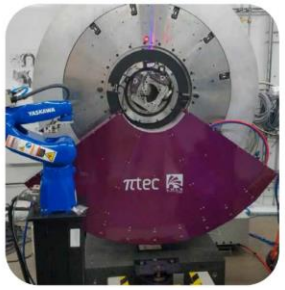




PIMEGA family

	Name	Pixel arrangement	Area	Frame rate	Data rate
	πMƎGA 540D (4x 135D modules)	3106 x 3096 (9.6 MPixels)	170 x 170 [mm^2]	2000 fps @12 bits	Raw: 230.8 Gbits Decoded: 307.7 Gbits
	πMƎGA 135D	1553 x 1548 (2.4 MPixels)	85 x 85 [mm^2]	2000 fps @12 bits	Raw: 57.7 Gbits Decoded: 76.9 Gbits
	πMƎGA 450D	31060 x 256 (7.9 MPixels)	1710 x 14 [mm^2]	1000 fps @12 bits	Raw: 190.8 Gbits Decoded: 254.4 Gbits

Mobipix

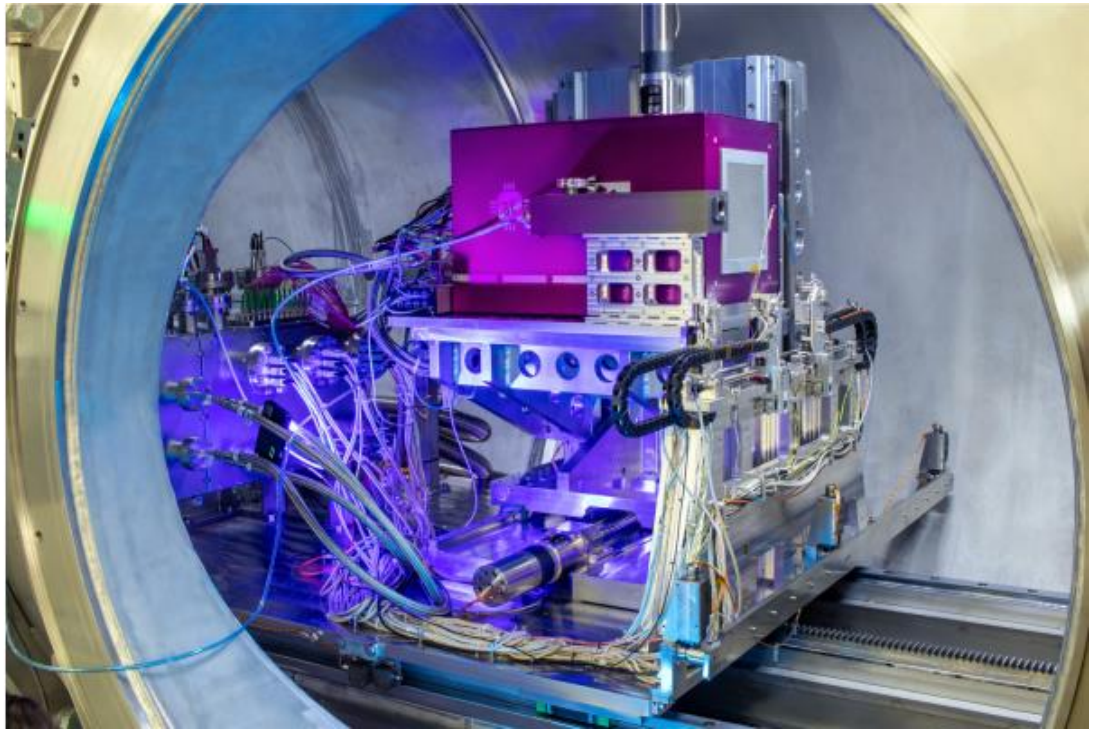
	Name	Pixel arrangement	Area	Frame rate	Data rate
	Mobipix 15D	512 x 512 (0.26 MPixels)	28 x 28 [mm^2]	2000 fps* @12 bits (expected)	Raw: 6.3 Gbits Decoded: 8.4Gbits

Mobipix

	Name	Pixel arrangement	Area	Frame rate	Data rate
	Mobipix 15D	512 x 512 (0.26 MPixels)	28 x 28 [mm^2]	2000 fps* @12 bits (expected)	Raw: 6.3 Gbits Decoded: 8.4Gbits
				200 fps @12 bits (achieved)	Raw: 0.6 Gbits Decoded: 0.8 Gbits

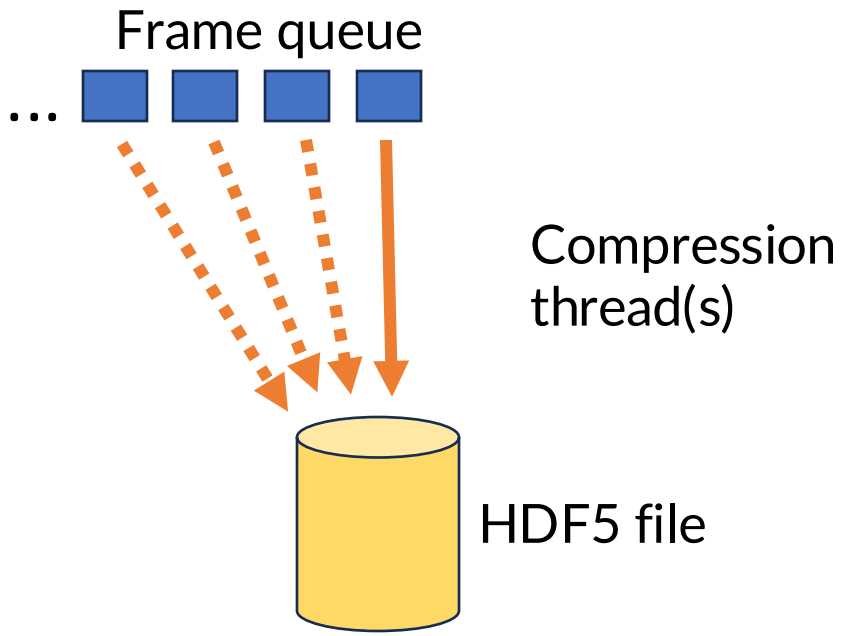
PIMEGA

- **Dedicated server** for DAQ
- RDMA (RoCE v1) over **100Gbps fiber** (4x for 540D)
- Uses custom DAQ software: Pimega Software Suite
- Saves into **Lustre** filesystem



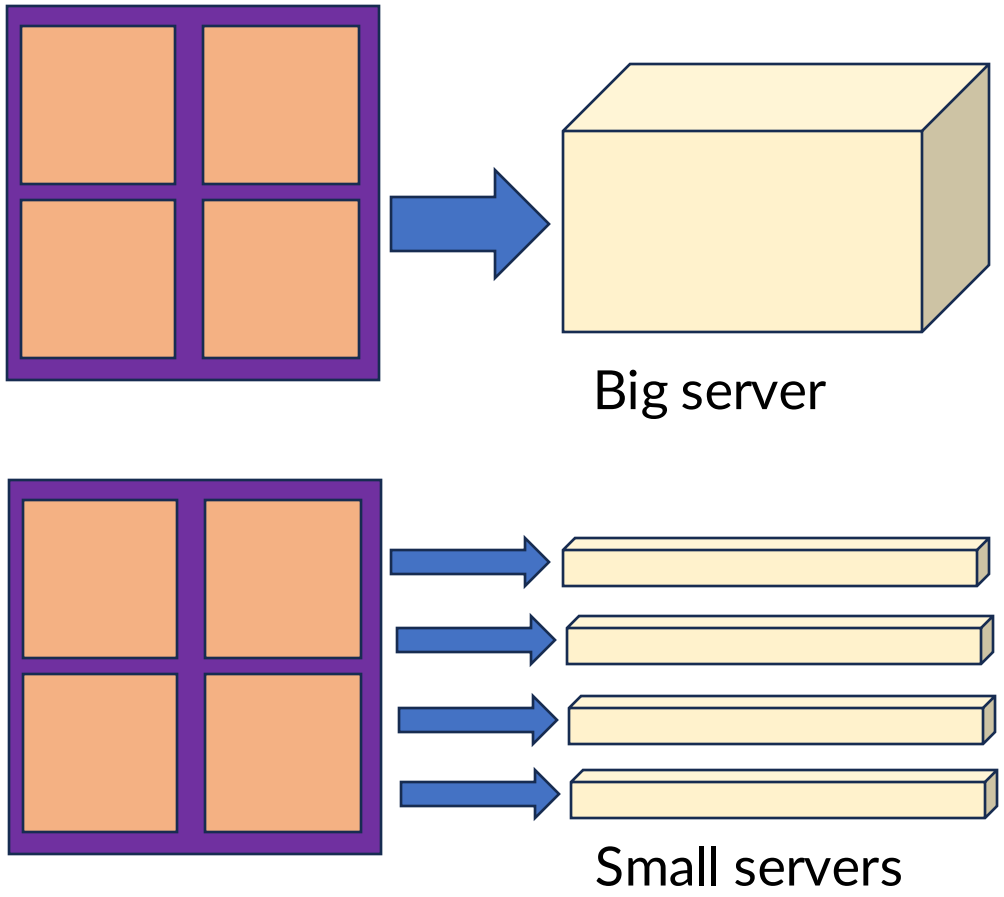
PIMEGA – saving bandwidth

- Saving is limited to ~100fps. **High dead time!**
  - Not necessarily a hardware limitation
  - Data flow is not fully parallelized, doesn't take advantage of multiple threads
  - Compression happens frame by frame, gzip only
  - Adding more threads (⋯▶) would require a complete refactoring



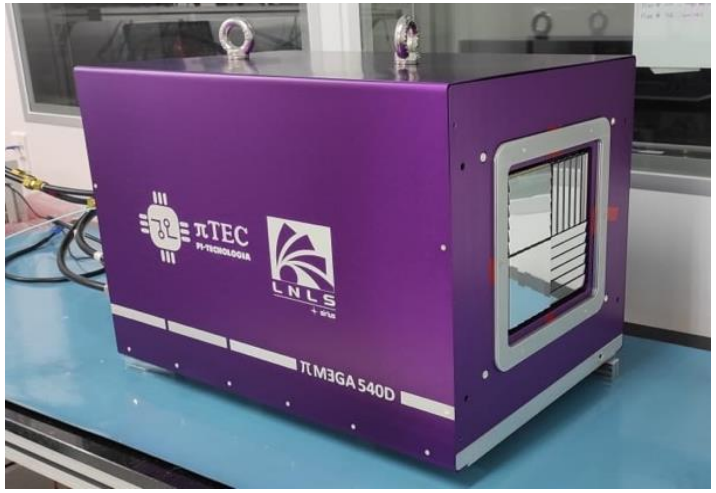
PIMEGA – monolithic application

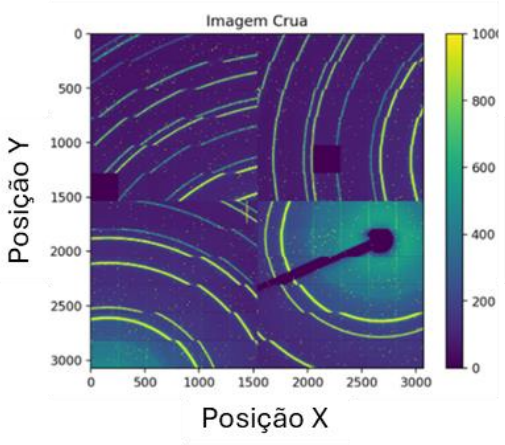
- The 540D detector is essentially made up of 4 135D detectors
  - Requires a powerful server with a lot of IO that can handle the whole load
- Could we have a distributed architecture with 4 servers capable of handling one 135D each?

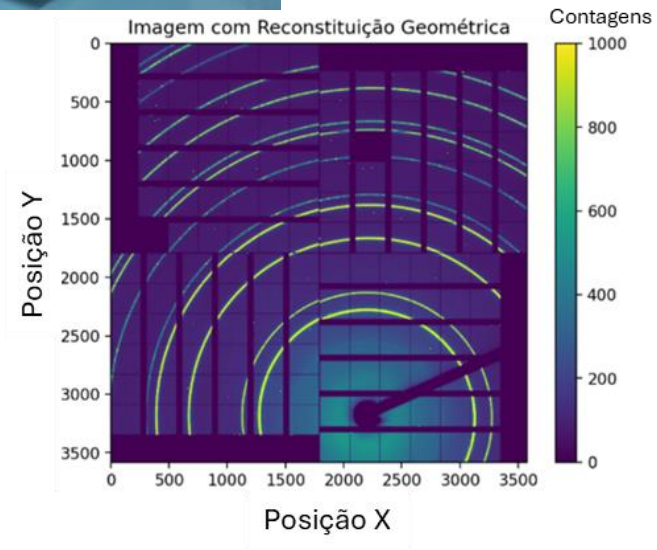


PIMEGA – geometric restoration

- The ASICs can be laid out in **complex geometries**.
  - We need to recover the image on the detector's face
  - Do it for **saved data** or only **visualization**?
  - **GPU acceleration** for restoration?
  - Use up **bandwidth and storage space** to save raw frames and restored frames, since the process is lossy?
  - Integrate with existing HPC to launch restoration jobs?

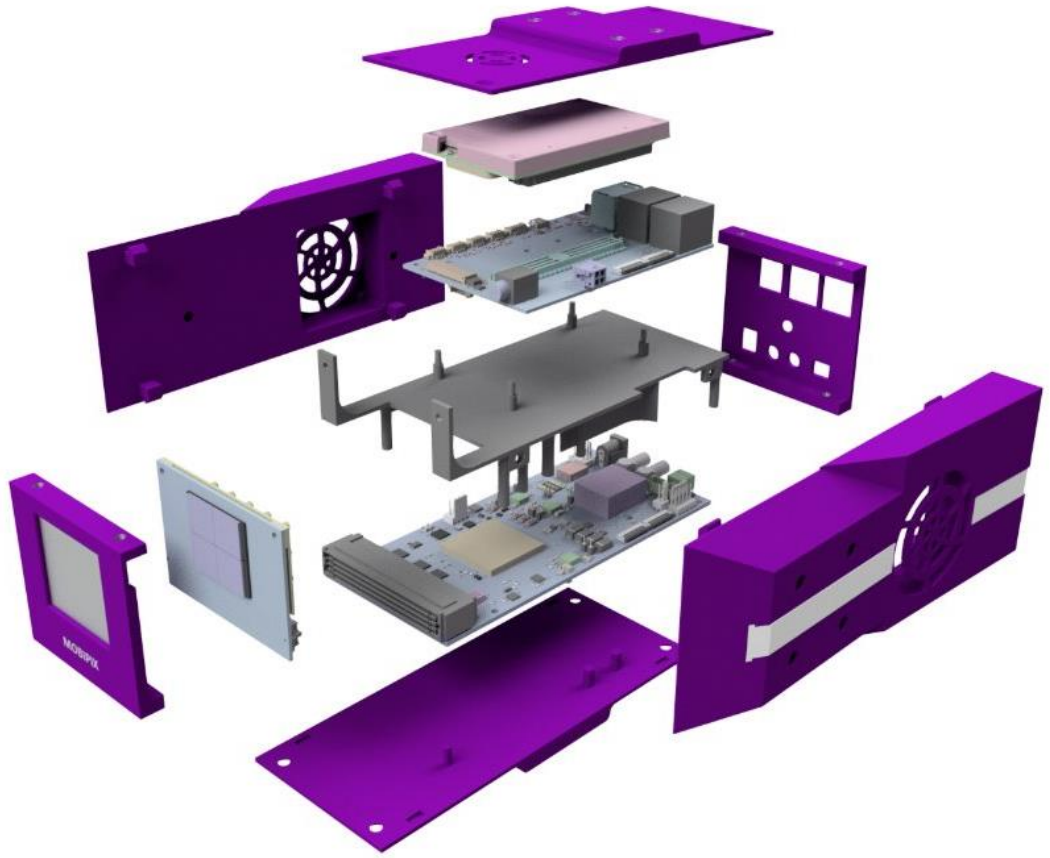




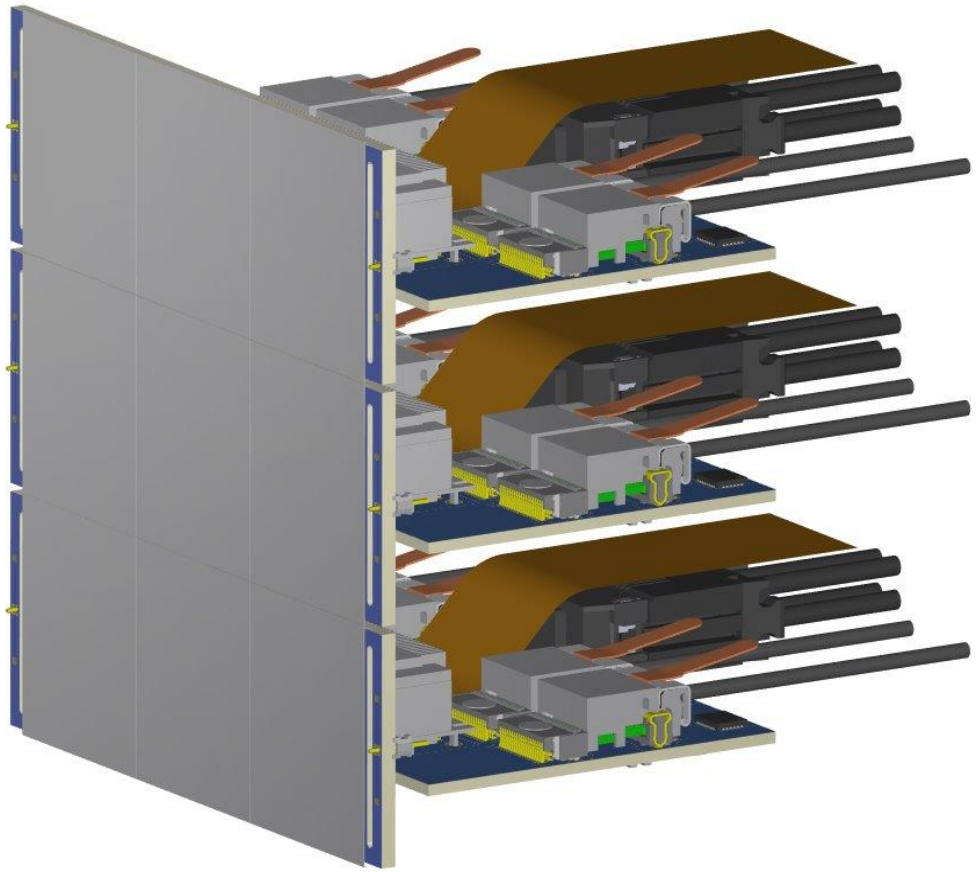


Mobipix 15D

- Embedded CPU inside detector: Jetson Nano TX1 **(discontinued)**
- 2 CSI interfaces
- Uses **AreaDetector IOC** reading frames from Video4Linux
- Saves into **NFS filesystem (very slow)** or local SSD
- **Highest lossless rate achieved: 200 fps**

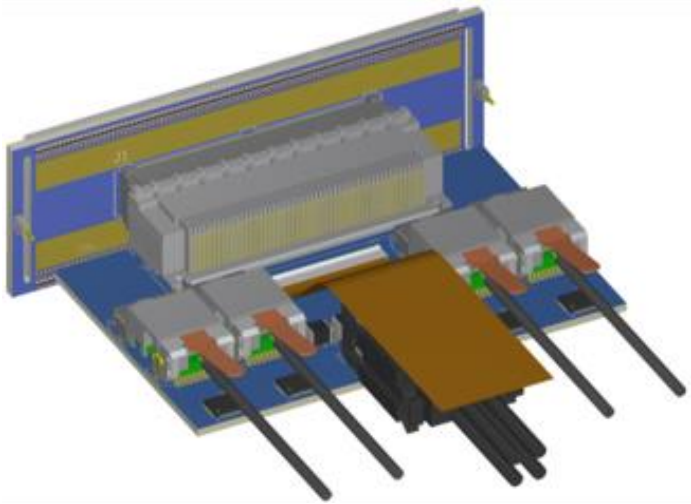


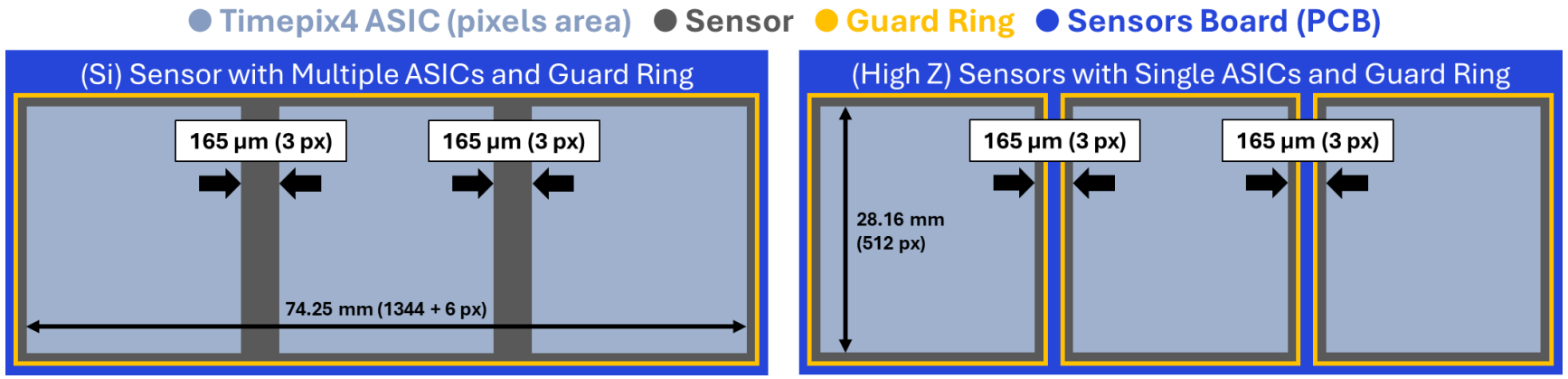
Future challenges – TUPI (TPX4)



TUPI module

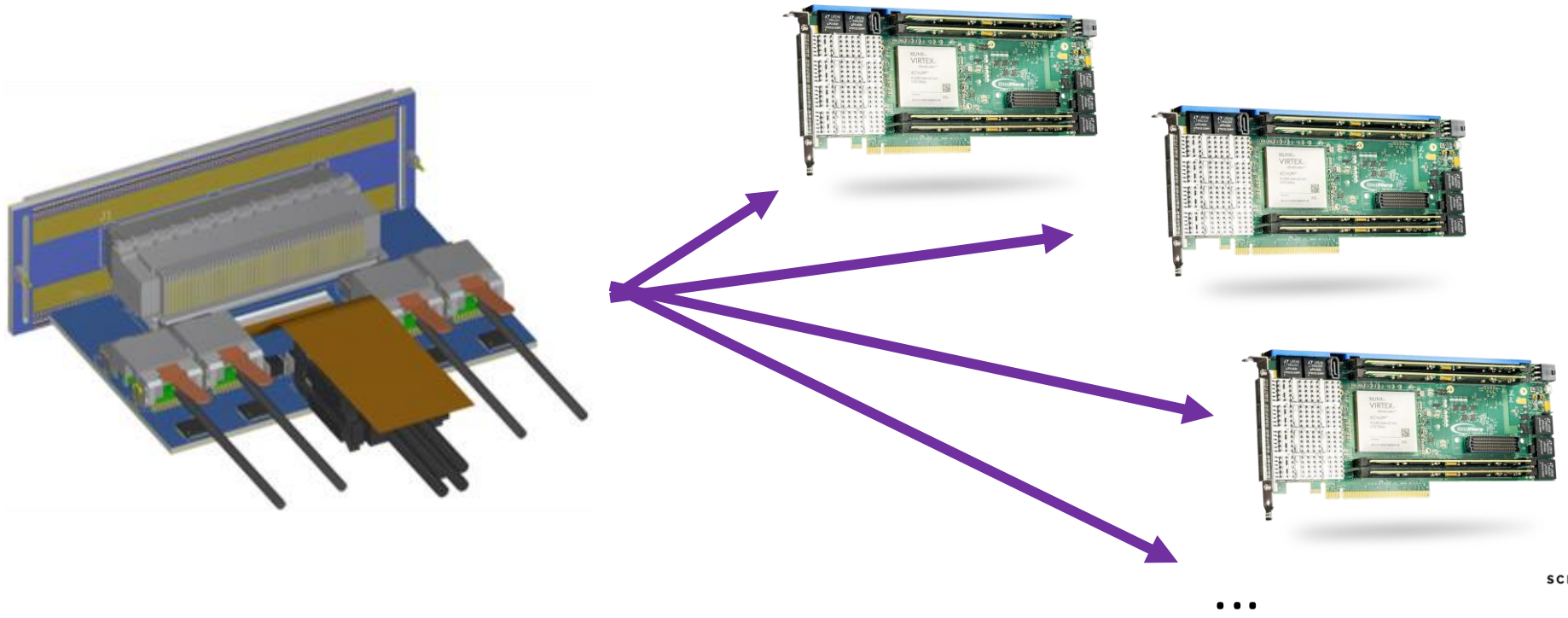
- Timepix4 ASIC (frame-based mode)
  - 512 x 448 pixels
  - 6.94 cm2
  - Up to **44000 fps**
  - Max data rate: **160 Gbps** (16x 10Gbps)
- Each module will have **3 ASICs**!





Distributed architecture

- Each ASIC has **16 high-speed transceivers** (8 for each half), which will be connected directly to the DAQ board
- This naturally enables a ***partial frame dispatch*** system

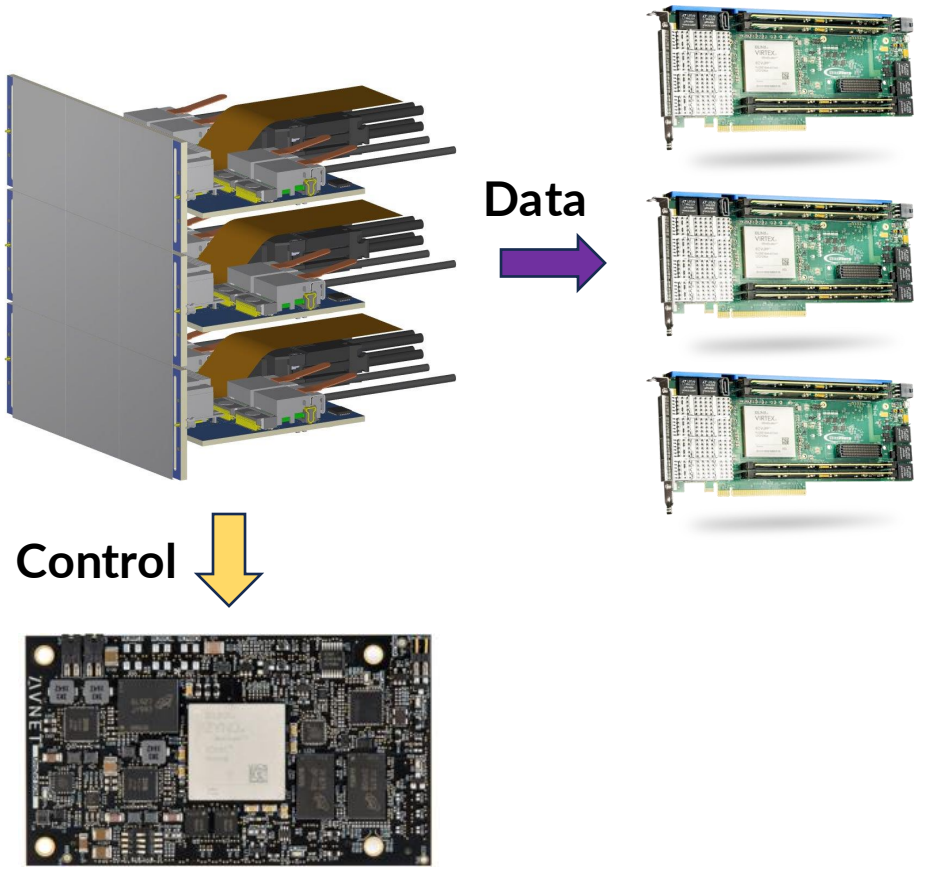


Data-driven mode

- The TPX4 ASIC supports a data-driven mode, where each photon hit generates an event packet with position, Time-of-Arrival and **Time-over-Threshold** information
- There is interest in supporting this mode for multi-energy acquisitions
- Can we **reuse** the DAQ software? How?
  - Use frames as simple memory buffers and store event data in them to be decoded later?

Split control

- The DAQ boards will be connected to some amount of servers running the DAQ software, and they need to be **configured for each acquisition**
- The ASICs will be a connected to a **control board**, whose functionality will be exposed over Ethernet
- How to **guarantee consistent acquisition state between these devices**?



DAQ software choices

LImA2	AreaDetector	Odin
• ***Partial-frame dispatch*** needs to be implemented • Control needs to be **integrated** to **AreaDetector**/EPICS	• **In-house** experience • Distributed archictecture needs to be implemented from scratch. Is it enough to create a **super-process** which controls everything else?	• ***Partial-frame dispatch*** needs to be implemented • ... we haven't looked into Odin as much yet

- We will **keep using AreaDetector** for other devices: GenICam cameras, integration with Pilatus, Vortex detectors. Automatic integration with the control system, aren't as high performance.
- However, for our high performance detector family (i.e. TUPI), we would like to **converge on a single software platform**.
- None of these existing solutions use **Parallel HDF5**. We would like to investigate its usage, either for decreasing the amount of files (no Virtual Datasets) or for performance.

Thank you

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