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Work Package 2:

Real-time Data Processing

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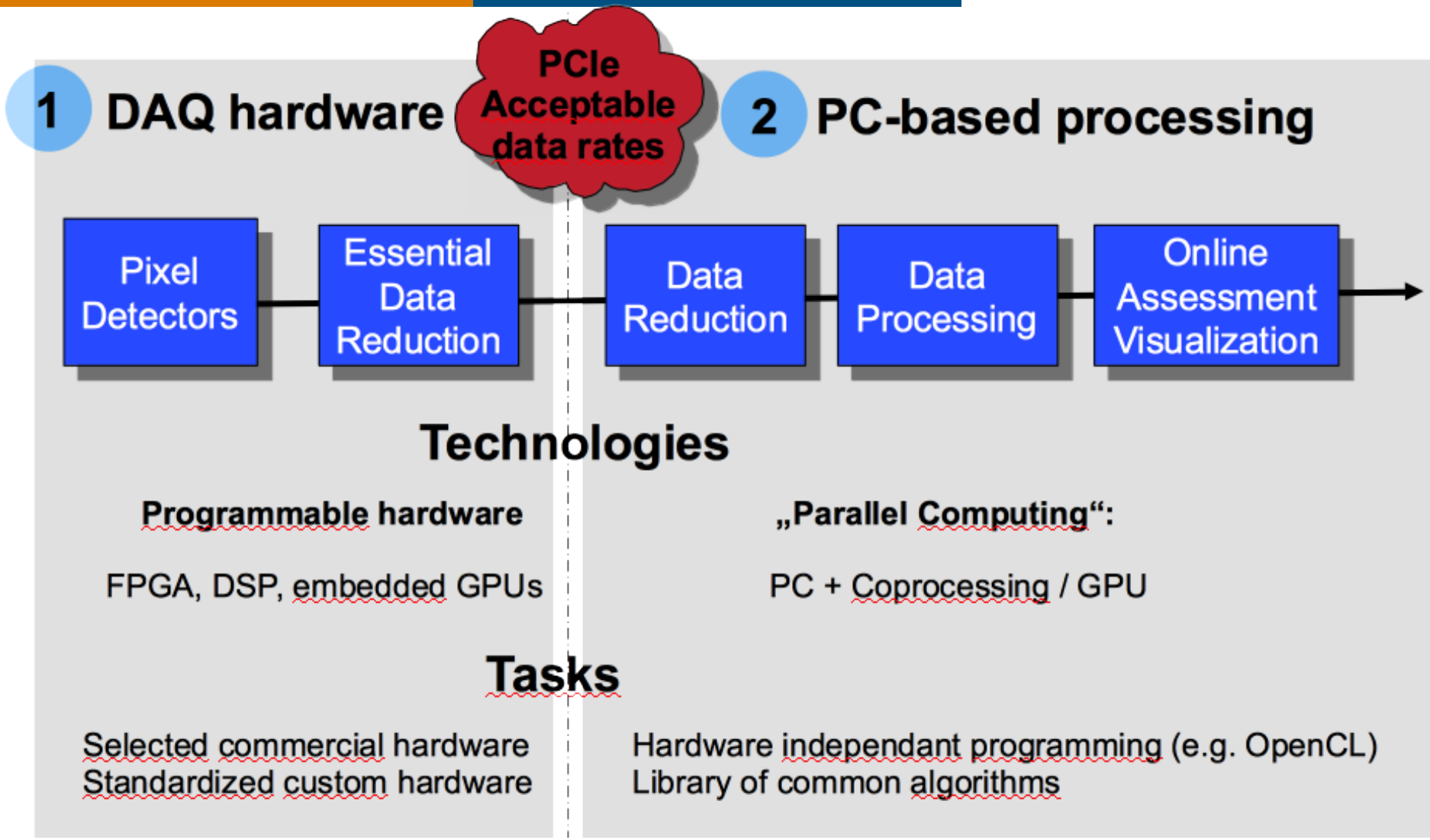
HDRI Spring Meeting 13.-14.4.2015, DESY

DESY JÜLICH FORSCHUNGSZENTRUM GSI HZB Helmholtz Zentrum Berlin HZDR Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung KIT Karlsruher Institut für Technologie

Real-time Data Processing – Concepts in POF2



Real-time Data Processing – Milestones in POF2

- **Data processing with dedicated hardware** ✓
  - programmable hardware platform
- **Real-time data assessment with parallel computing:** ✓
  - Development of computation system based on GPU co-processors
  - ✗ Prototype adoption of a complete PX data flow
  - Implementation of an online tomographic reconstruction
- **General environment for parallel image processing** ✓
  a) Independent from available hardware (OpenCL)
  b) Library of standard algorithms
  c) Easy adaption to new problems

Dedicated Hardware – Selected Results

MTCA.4 (MTCA for Physics)

- RTMs for large channel numbers
- HGF AMC = Multipurpose readout board for several XFEL Machine controls
  - FPGA-based
  - High speed serial links (10G Ethernet)
- Last workshop in Karlsruhe, Dec 14
  - DESY, GSI, FZJ, HZDR, KIT
  - Development of common HGF-AMC Board support package
- Also part of Detector Program (DTS)

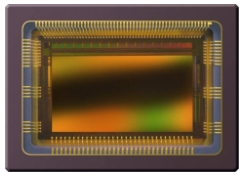
Smart scientific cameras

- **Detectors for high speed imaging**
  - What is commercially available?

Data rates limit camera performance

Scientific sensor developments?

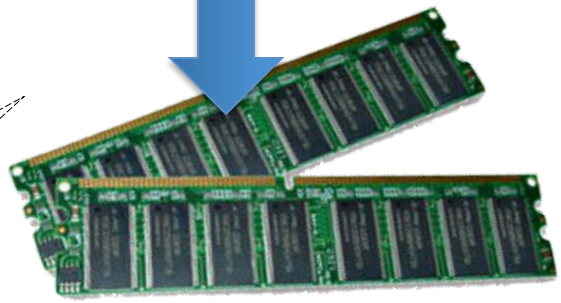
CMOS sensor



pco.dimax 4MP@1300fps
(7500MB/s)

Readout
Camera Link (250 / 850 MB/s)
USB3 (new: 500 MB/s)
GigE Vision (125 MB/s)

Internal Memory
e.g.: 36GB → 5s



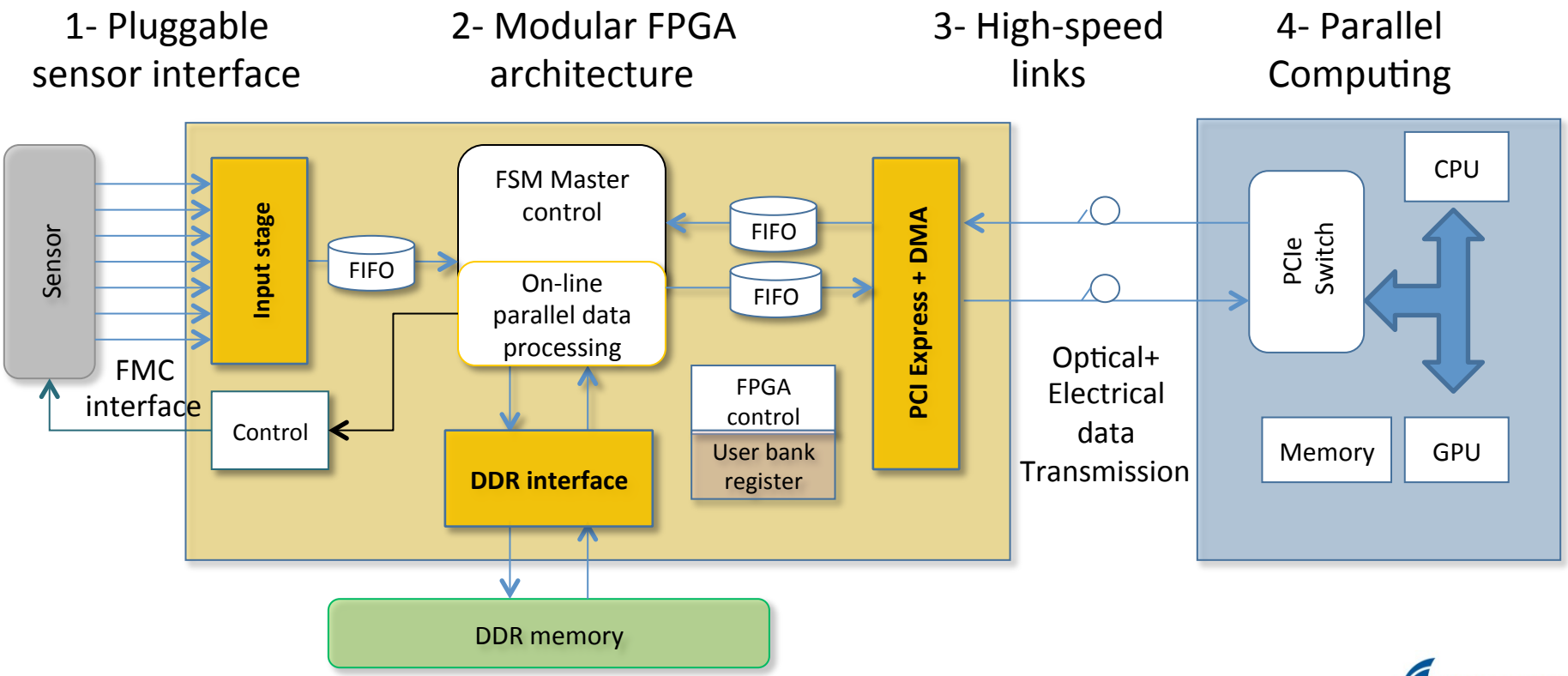
Custom embedded logic is missing

No online data analysis

UFO DAQ Framework

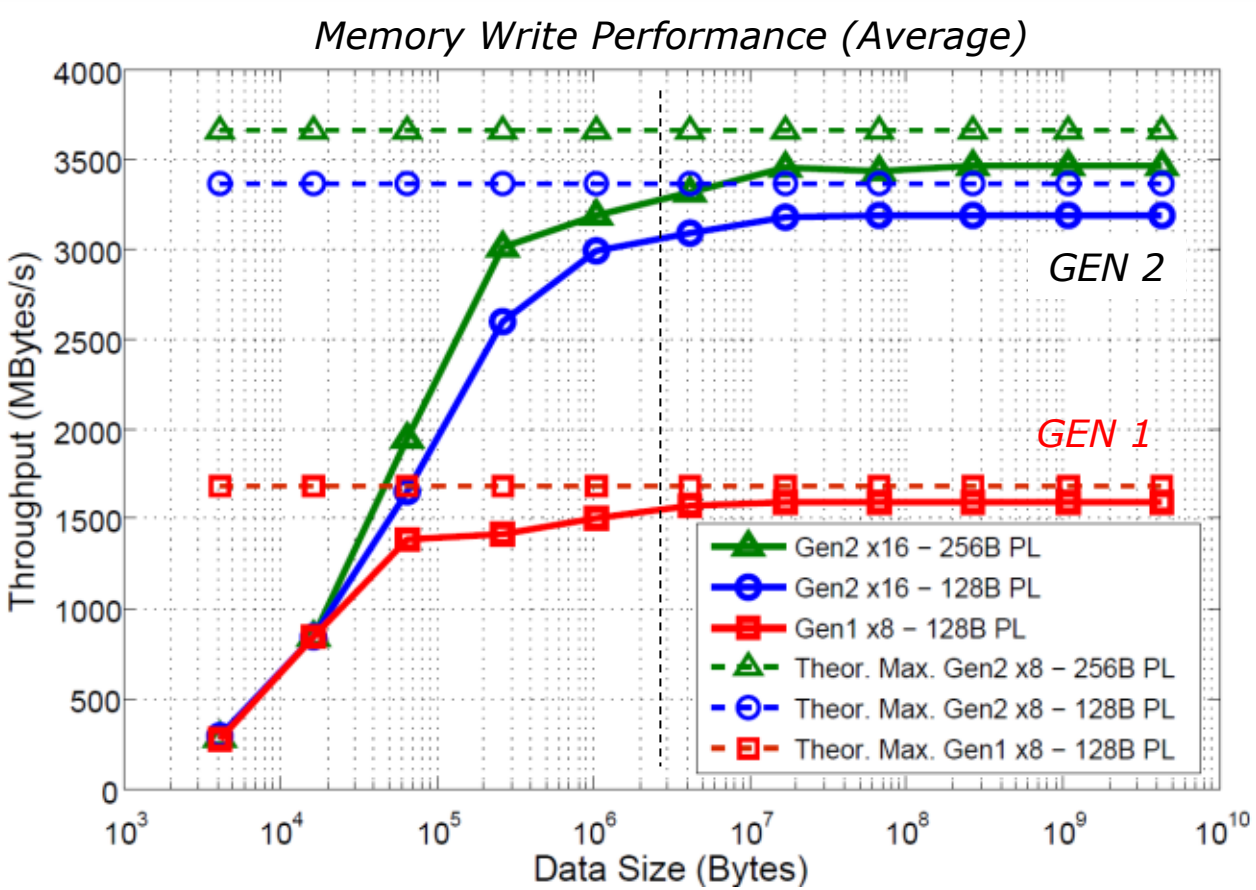
Goal:

- Rapid development of DAQ systems for high-speed sensors



PCIe-DMA Engine – Performance

- Average data throughput of 3.5 GB/s (DMA max data transfer @ 4 GB/s)
- No bit errors observed (tested up to several TB of data exchanged)

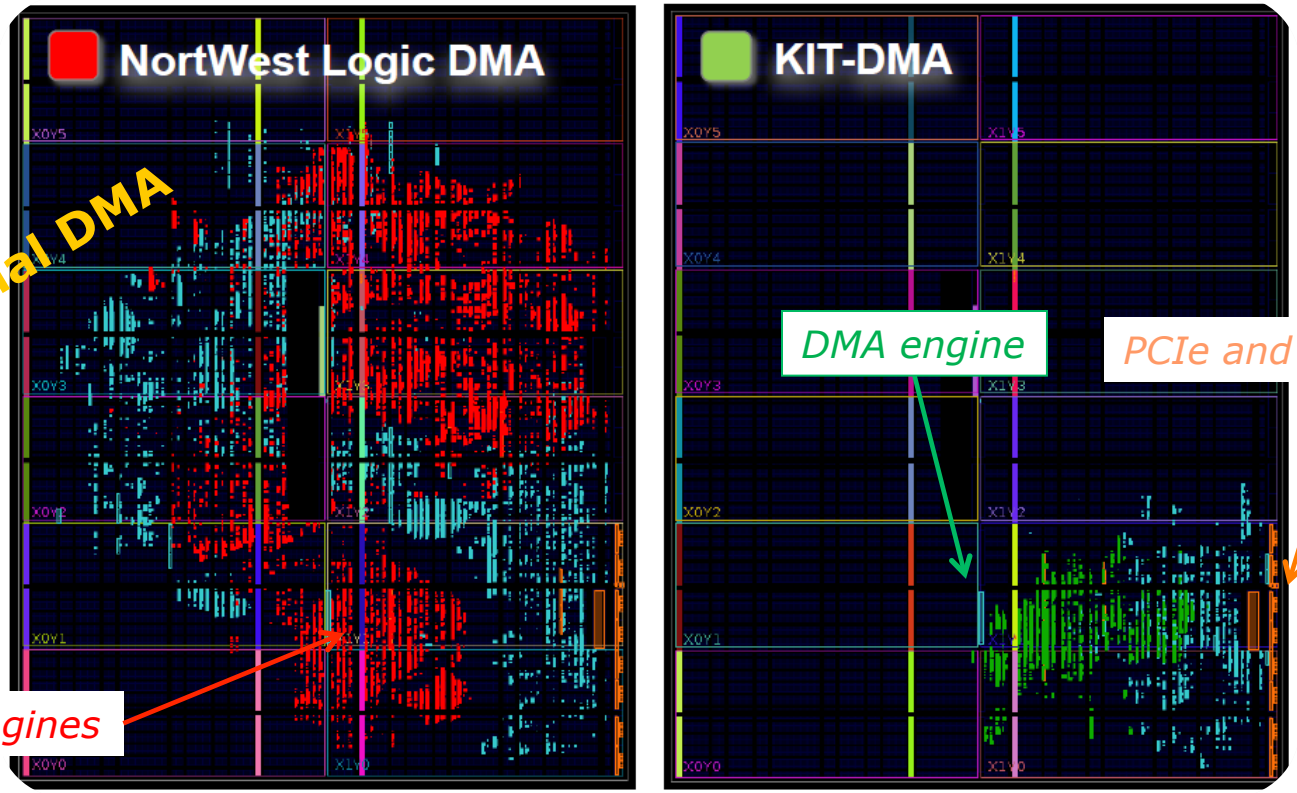


Dash lines theoretical limit

Support for PCIe Gen 3 is in progress

L. Rota et al. IEEE Real *Time Conference 2014*

PCIe-DMA Engine – Floor map



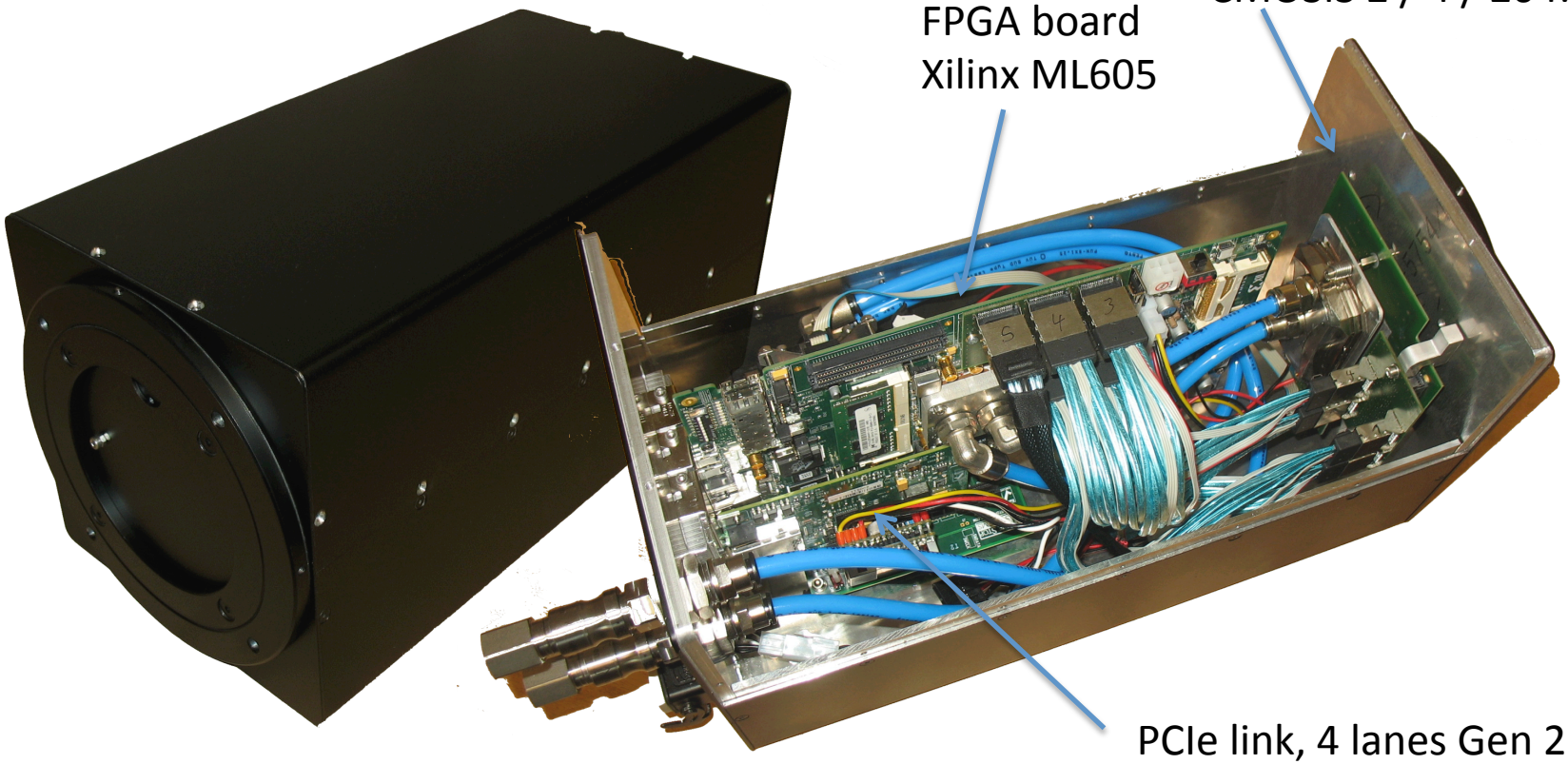
Same logic functions

FPGA: Virtex 6 –> XC6VLX240–2 FF1759

Application 1: Smart phase contrast camera

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

- **Goals:**
  - Automatic grating control
  - Online reconstruction (with GPU)



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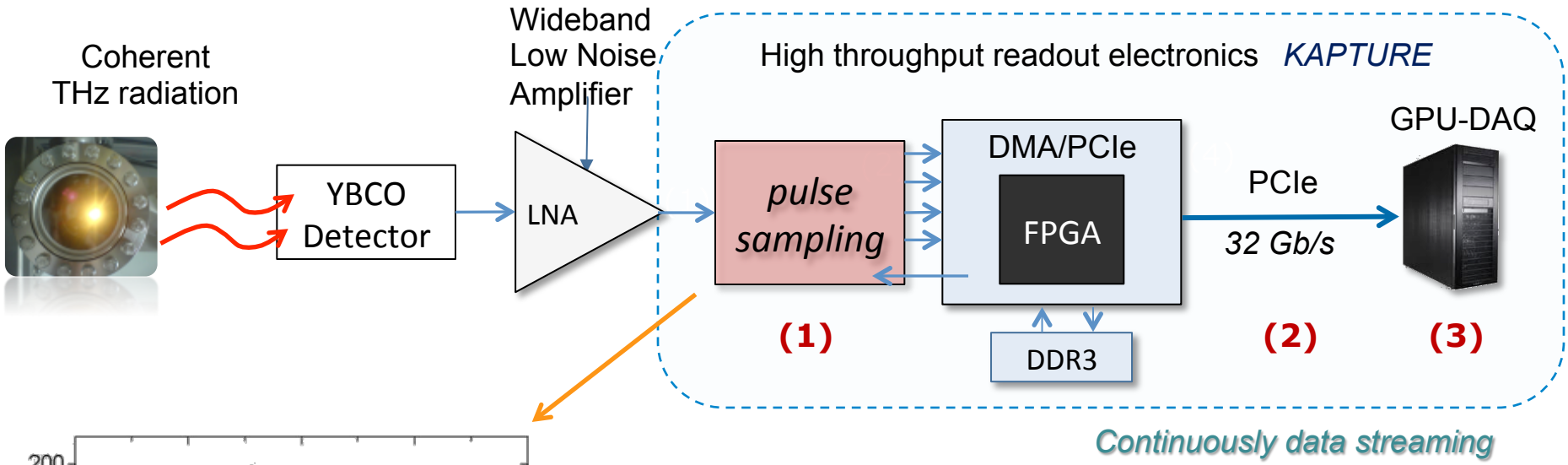
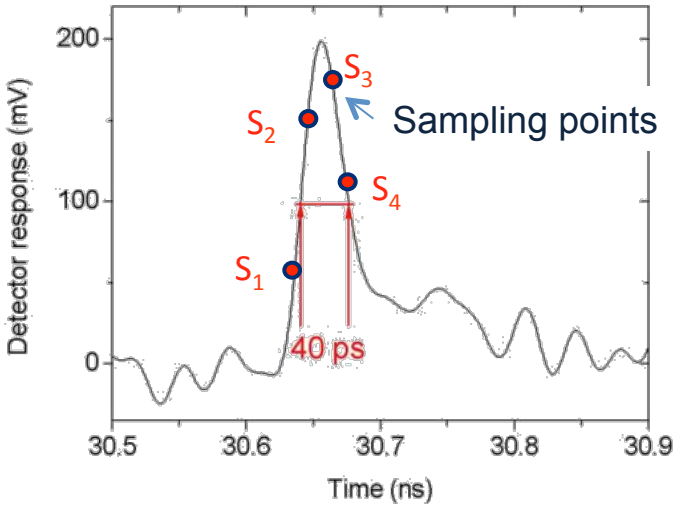
Application 2: Picosecond Pulse Sampling





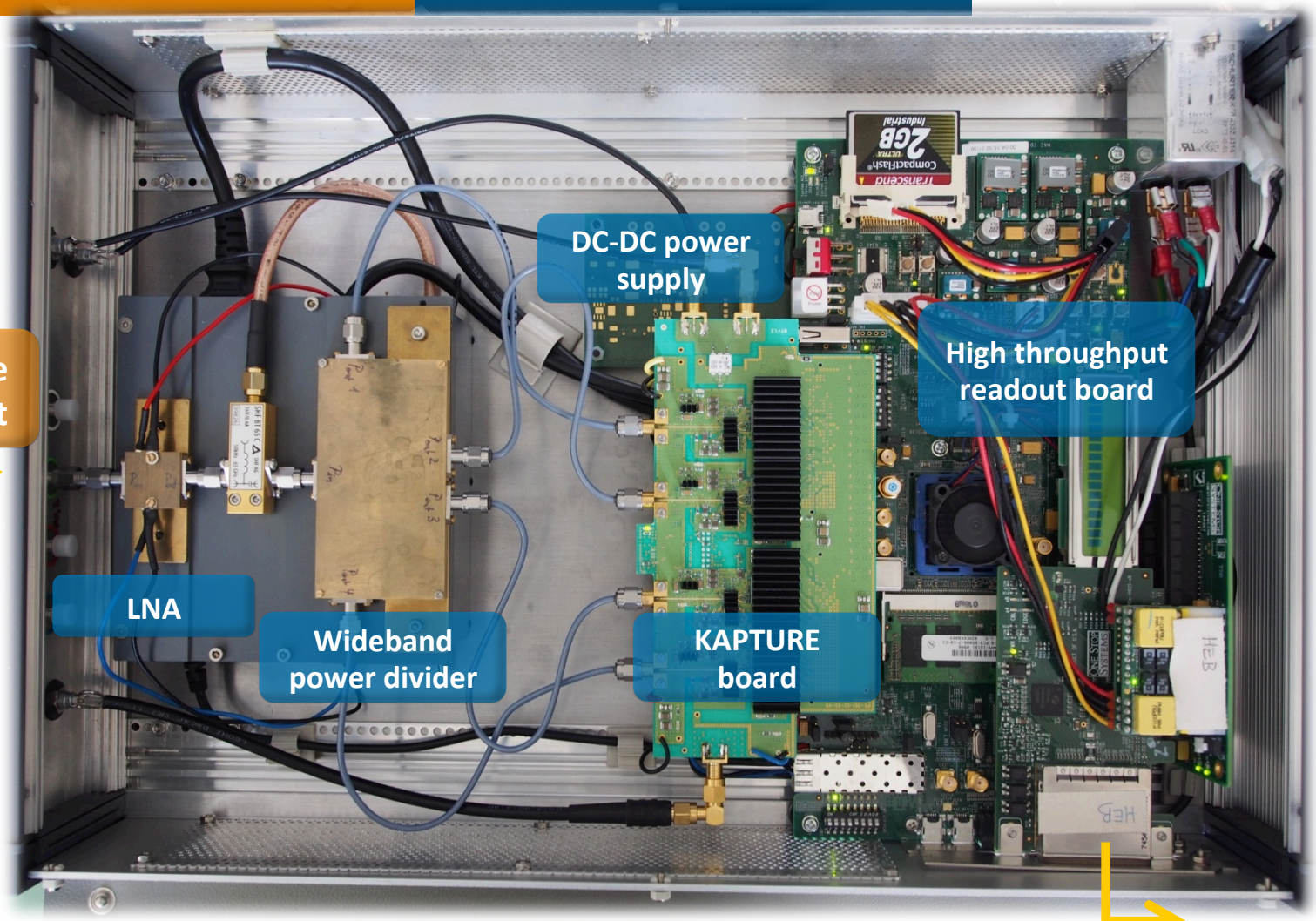
Pulse repetition rate 500 MHz
Data rate 3 GB/s

1. Sampling: each pulse sampled with 4 samples by **KAPTURE** system , minimum sampling time of 3 ps.

2. Data transfer: digital samples transferred to high-end GPU (Graphics Processing Units) by a PCIe-DMA architecture

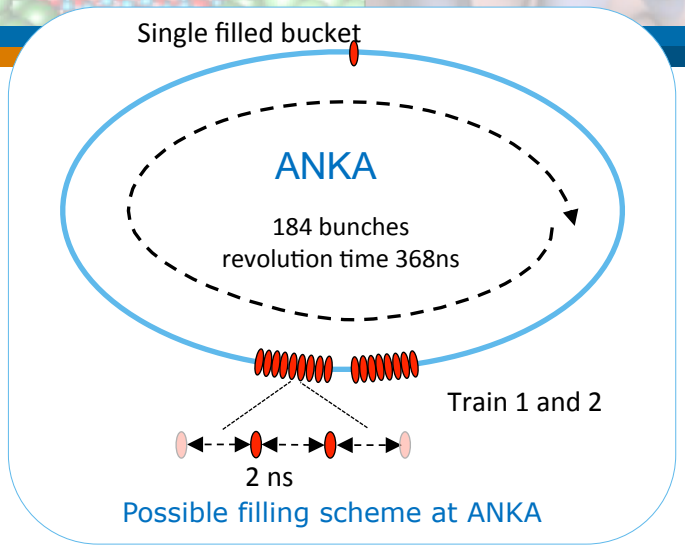
3. Real-time GPU data elaboration: pulses reconstruct, amplitude and peaking time respectively with "mV" "picosecond" accuracy are evaluated

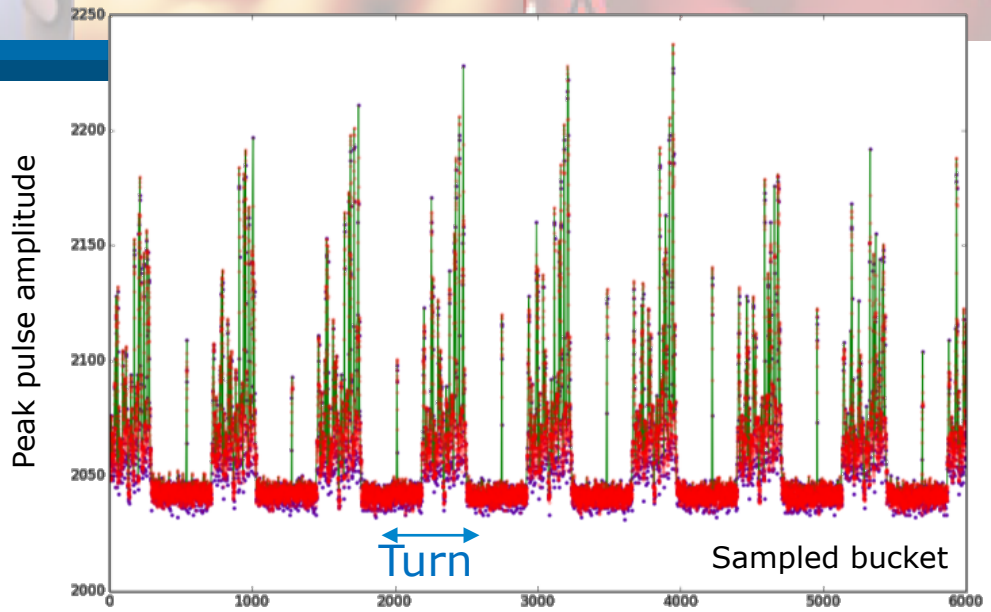
KAPTURE System



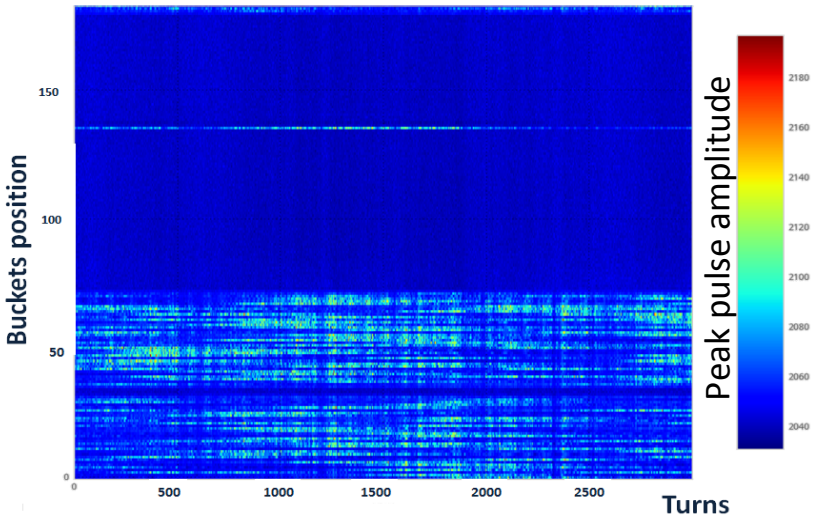
KAPTURE Measurements

1399650235.855.out

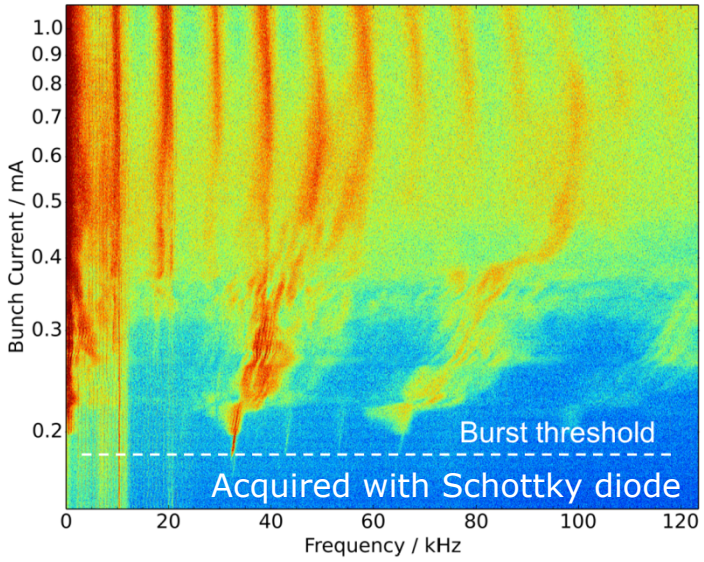




CSR fluctuation in time domain
with YBCO detector



CSR frequency behaviour vs. different bunch current



General environment for parallel image processing

How to support code development for GPUs?

Requirements:

- Processes data streams (usually 1 to 4 dimensional floating point data)
- Detect and use all hardware resources

Developer:

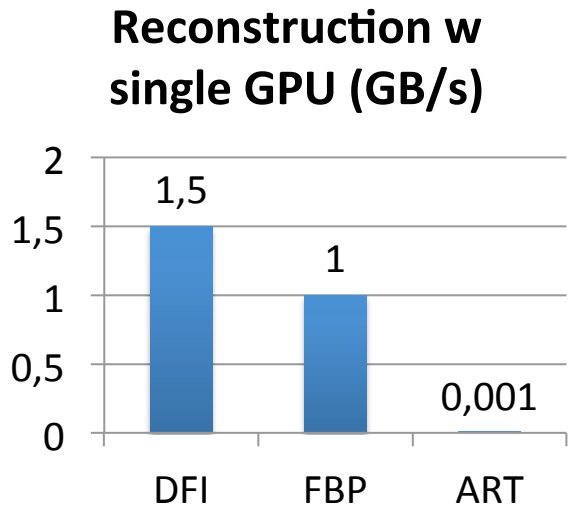
- Hides parallelization and concurrency details
- Management of memory transfers
- Multiple implementations (e.g. for CPU + GPU)
- Automatic scheduling

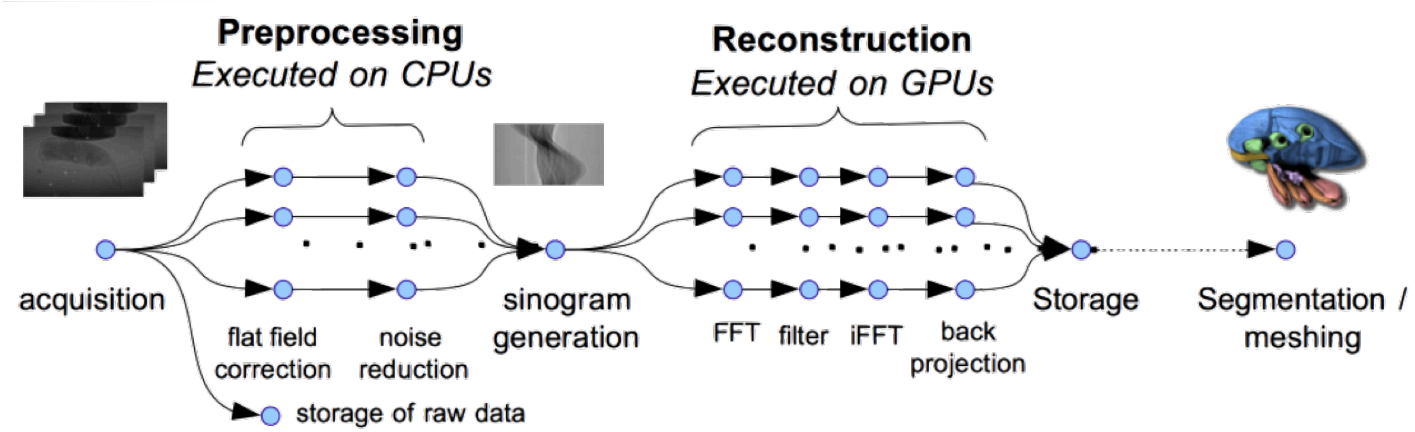
User:

- Simple end-user interface
  - GUI + Scripting
- Modular algorithm design

UFO Parallel Processing Framework

- Free and open-source
- Supports OpenCL parallel hardware
- Hardware-specific optimizations
- Fast pipelined architecture
- Scheduling across multiple devices and nodes
- Introspection interface to Python and other scripting languages
- Integrated with Tango control system





Used at:
- ANKA
- ESRF
- PETRA 3
- HZDR

HDRI in POF3 (2015-2019)

POF3 proposal

*"Common to all large-scale facilities is […] how to cope with the **huge amounts of data** […] in terms of **real-time analysis**, evaluation, storage and archiving. To meet this challenges […] **MML continues** […] **HDRI** […]."*

Review: Strengthening of this initiative is of fundamental importance

New work package structure

1. **Standard Data Format and Offline Data Processing Frameworks**
2. **Fast Online Data Processing Frameworks**
   - Scalable Parallel Computing
   - Configurable Data Acquisition Systems
   - Online Data Processing Frameworks
3. **Scientific Computing**

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WP2: Fast Online Data Processing Frameworks

Milestones:

- **Standard platforms for online monitoring**
  - High-performance acquisition and computing hardware
  - Fast control system for computationally intensive applications
- **Applications based on DAQ hardware and computing platforms**

- **Near-time analysis frameworks**
  - Early data quality checks
  - Based on DPDAK, DAWN and UFO-Framework
- **Application of real-time data processing + data quality checks**

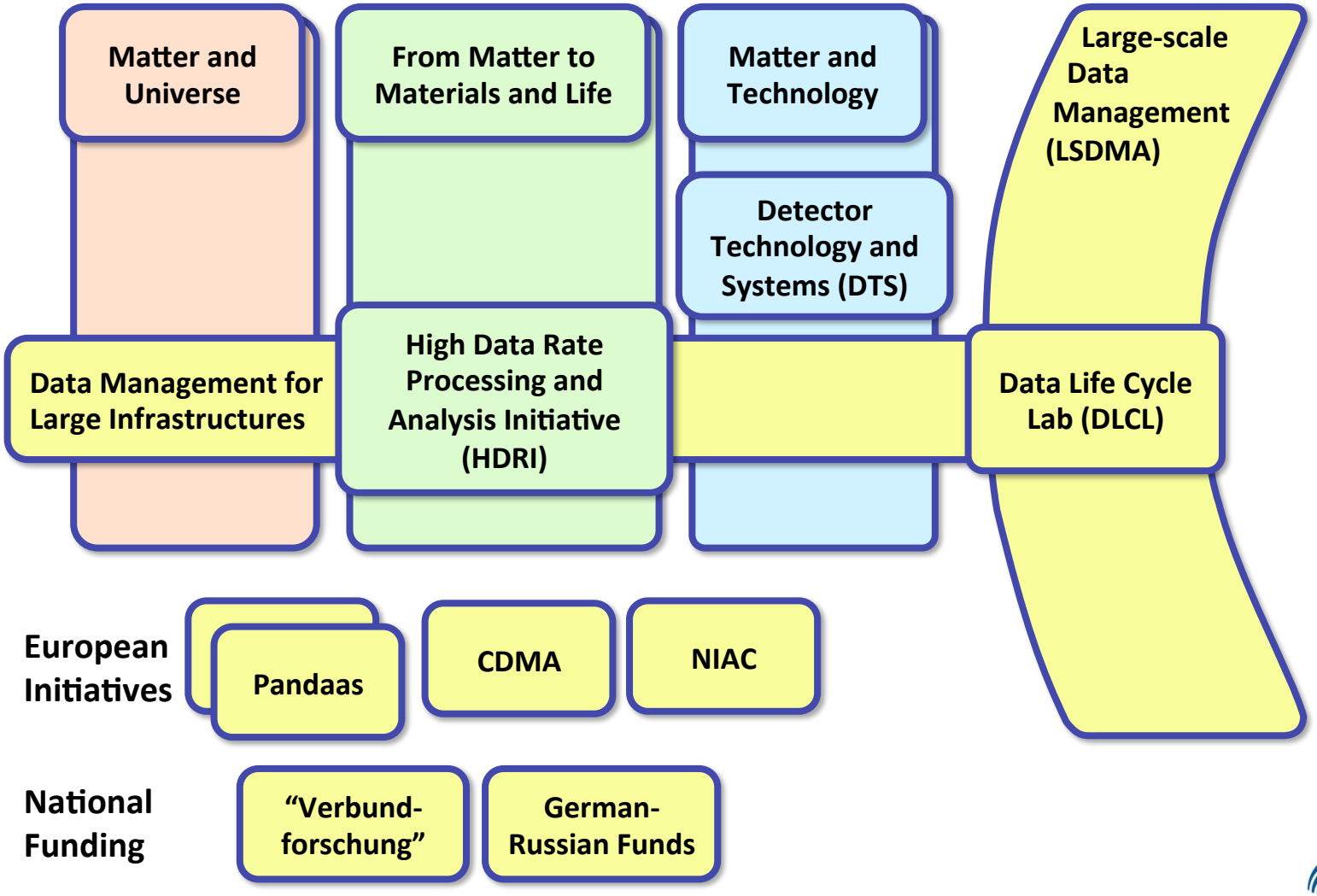
- **Web portals for data access and remote computing**
  - Integration of online tools

Resources

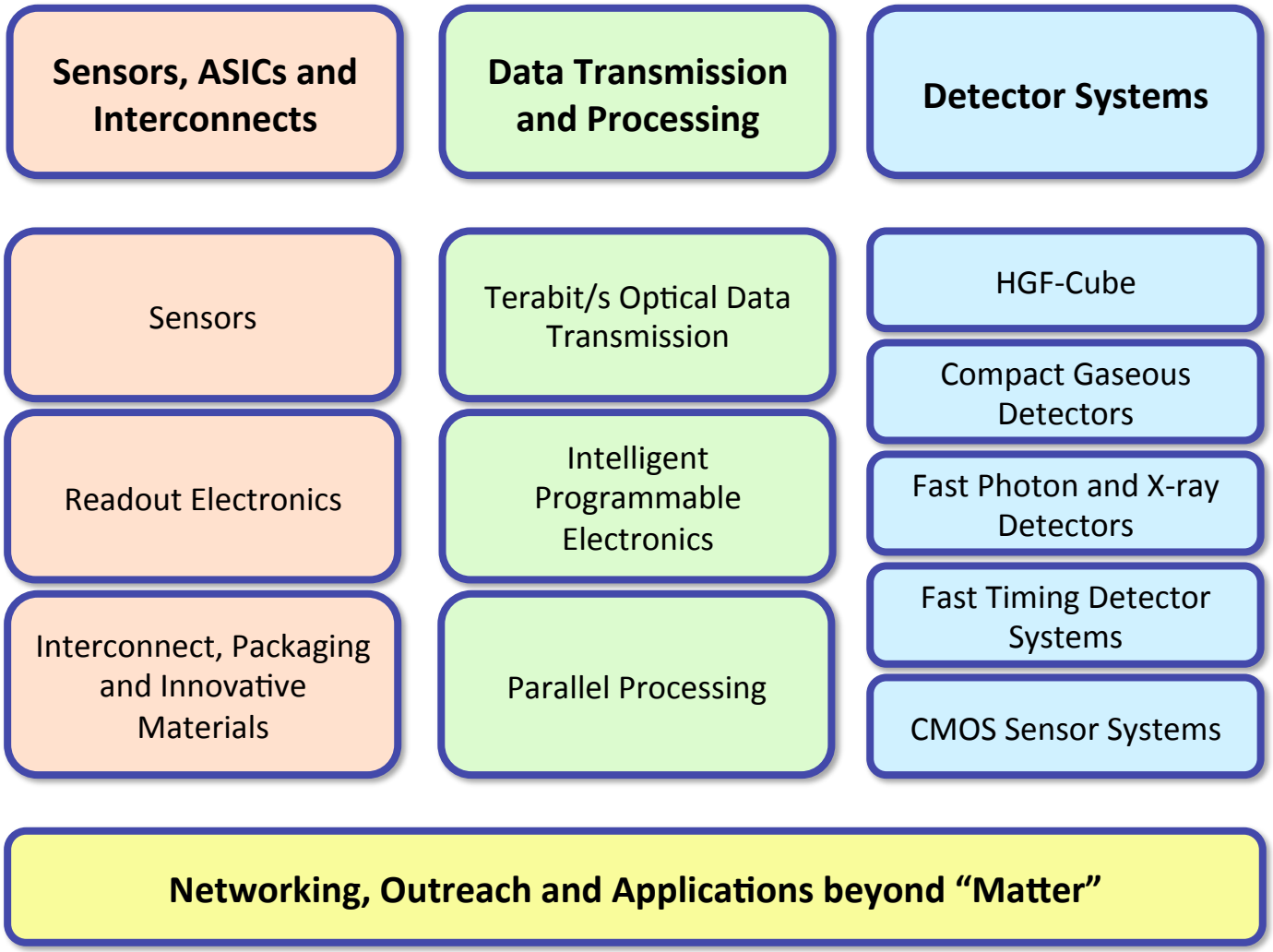
Helmholtz Centre	POF (FTE)	Additional funding (FTE)
DESY	8	1.5
FZJ	1	4
HZB	2	0
HZDR	0.5	0
HZG	1.5	1
GSI	0.5	1
KIT	2	0
Total	**15.5**	**7.5**

Source: POF3, Volume 3

HDRI in the Research Programme "Matter"



Detector Technology and Systems (DTS)



DTS Activities

Selected Milestones:

- **Common technology platform based on Helmholtz AMC**
- **Scalability of CPU/GPU clusters for DAQ systems**
- **Helmholtz-Cube / Lambda**
- **Multi-channel bolometric detector systems**

Highlighted projects (Common fund):

- **Ultrafast 1D line detector for optical and near IR radiation**
  - Caselle, Hiller, Müller, Rota, Weber (KIT), Correa, Dariusz, Gerth, Graafsma, Steffen (DESY)
- **New DAQ-Electronics demonstrator system for X-Ray tomography**
  - Kaever (HZDR), Zimmer (DESY), Balzer (KIT)

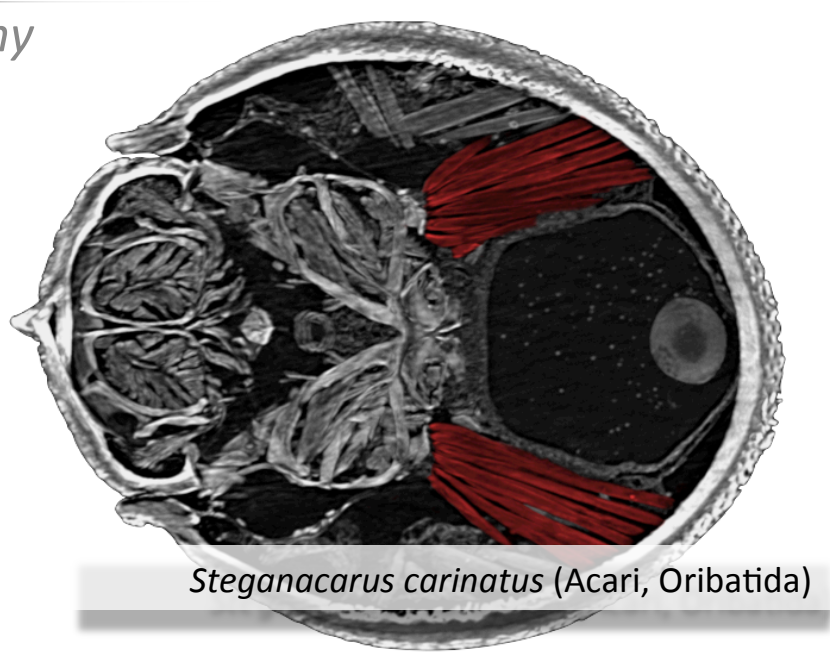
Arthropod Structure revealed by ultra-fast Tomography and Online Reconstruction

Arthropod Structure revealed by ultra-fast Tomography and Online Reconstruction

A new method for ultra-fast X-ray tomography

Science-driven development of

- Management of large datasets
- Cloud-based analysis environment
- Advanced segmentation of 4D X-ray images



Steganacarus carinatus (Acari, Oribatida)

Network for functional morphology and systematics:

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UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

KIT Karlsruhe Institute of Technology

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Virtual Analysis Infrastructure

Cloud technologies enable remote analysis
without data download

4
- Interactive
4D visualization

ASTOR web-portal

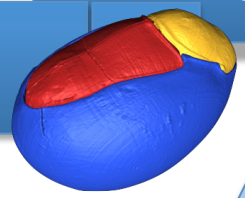
2
- Access via DFN + DSL
- Remote 3D applications

Virtual analysis infrastructure

Long-term archive

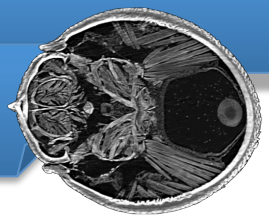
ASTOR processing cache

5



3 - Managing large-scale datasets

ANKA imaging beamline



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Tasks:

1 - Science-driven
2 - Analysis infrastructure
3 - Work flow
4 - Web portal
5 - 4D analysis
e.g. segmentation

Summary

- **HDRI in POF2**
  - Established technology platform of beamline scientists, engineers, computer scientists, IT departments, …
  - Introduced parallel computing (w GPUs)
  - Common hardware platforms are exisiting

- **HDRI in POF3**
  - Technologies (cont.)
  - New focus: Data access + analysis of “big data”
  - Resume:
    - “The task are not getting smaller”
    - More resources required
    - Search collaboration with DTS, LSDMA, Universities, …
    - HDRI should be link between beamline scientists and technology experts