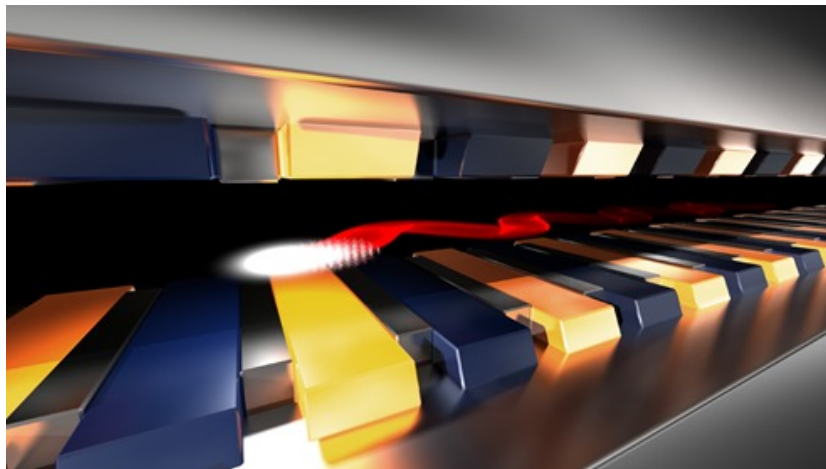# Instrument and Data Systems Control at European XFEL

6th October 2022,

Steve Aplin

Department Head Data at European XFEL

Steve Aplin

2016 **2017** **2018** **2019** **2020** **2021** **2022**

CONSTRUCTION COMMISSIONING EARLY OPERATION

European XFEL

Estimates for procurement related to beamline control systems 2022 - 2027

▉	Control system integration from external vendors and software consultants	250 kEuro / year
▉	PLC System assemblies	150 kEuro / year
▉	PLC System parts	100 kEuro / year
▉	Cabling and connectors	100 kEuro / year
▉	MicroTCA Systems and cards	100 kEuro / year

▉ **Total Estimated Expenditure 700 kEuro / year**
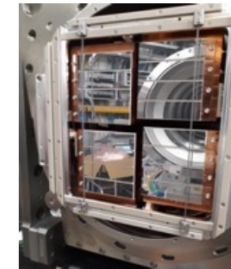
European XFEL

We need more Data ! … be careful what you wish for …

We need more Data ! … be careful what you wish for …

Raw Data Generated at European XFEL Instruments

Detector type	Data/sec
AGIPD 1Mpxl	~7 GB/s
AGIPD 1Mpxl Double images	~14 GB/s
AGIPD 4Mpxl	~30 GB/s *
LPD 1Mpxl	~10 GB/s
DSSC 1Mpxl	~16 GB/s

European XFEL

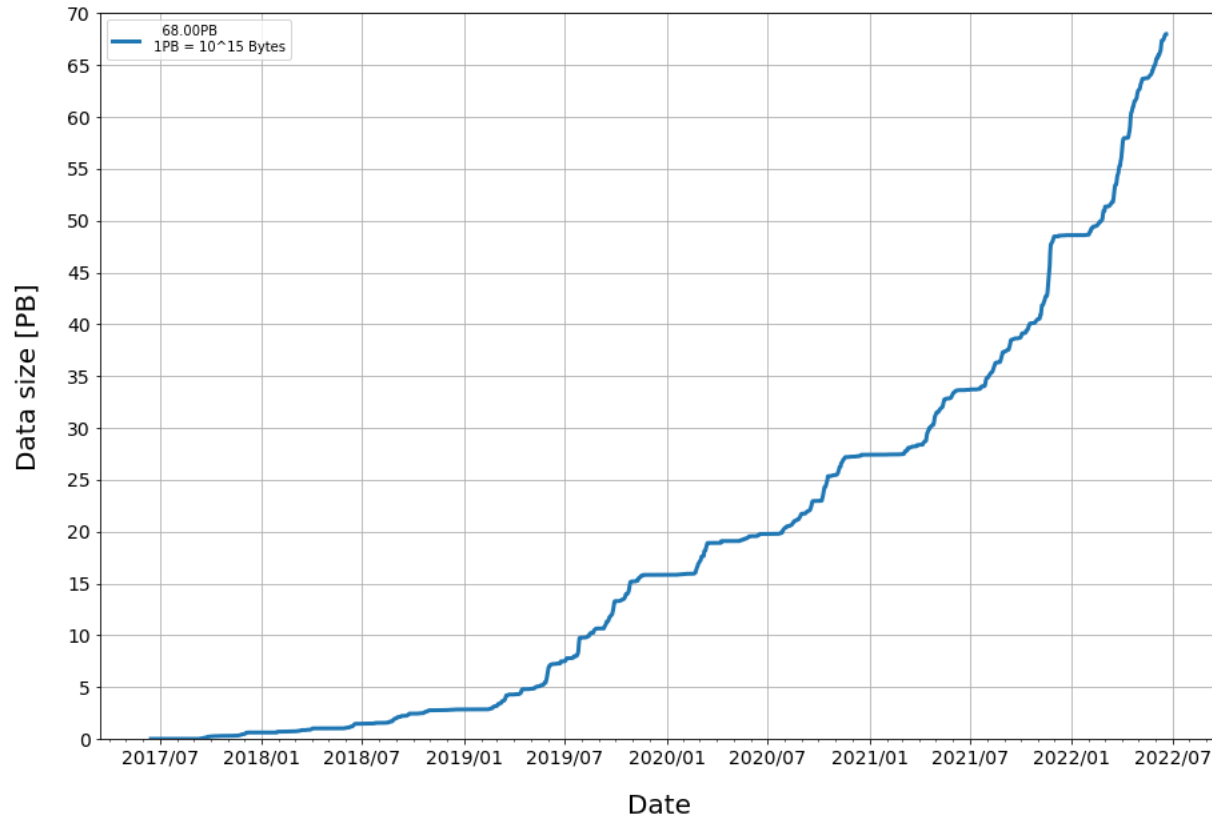**Big Science BuSineSS Forum 2022**

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Raw Data Generated at European XFEL Instruments

68.00PB
1PB = 10^15 Bytes

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The data flow from all four experiments at LHC for Run 2 was anticipated to be about *25 GB/s after* data reduction

- **ALICE: 4 GB/s (Pb-Pb running)**
- **ATLAS: 800 MB/s – 1 GB/s**
- **CMS: 600 MB/s**
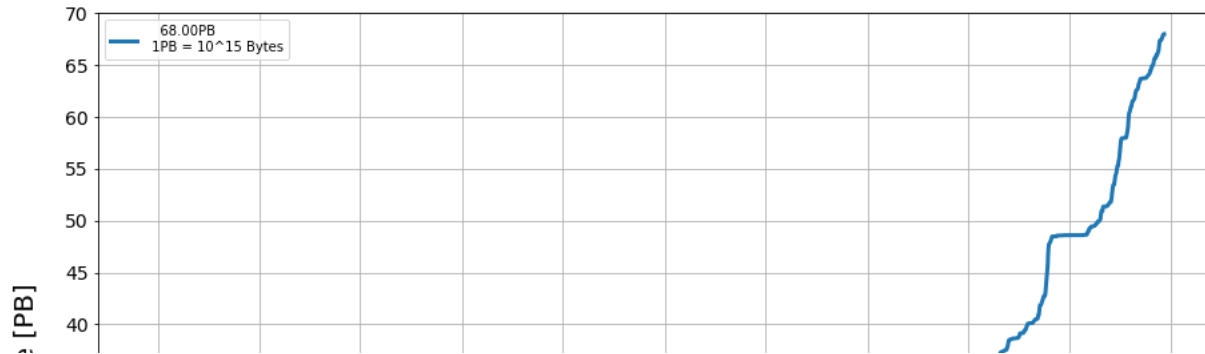- **LHCb: 750 MB/s**

Data reduction in particle physics is built into it's DNA, it is intrinsic to the field's experimental viability.

The experiments are designed from the ground up on data reduction.

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Big Science Business Forum 2022

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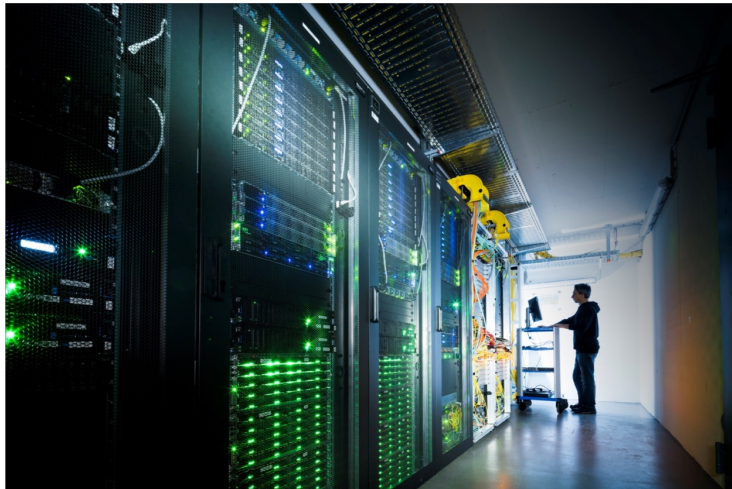- **CMS: 600 MB/s**
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Data reduction in particle physics is built into it's DNA, it is intrinsic to the field's experimental viability.
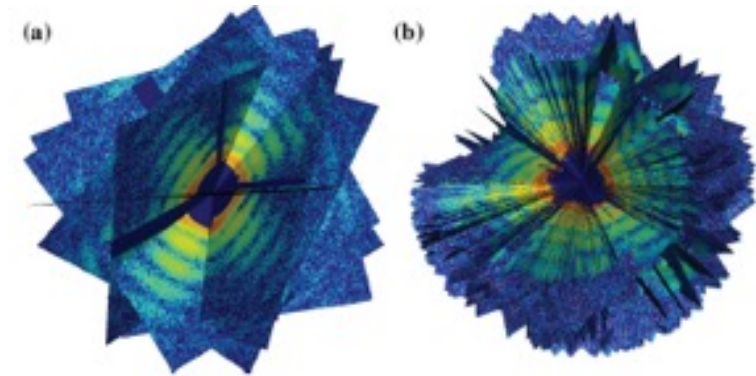
Required Ingest Rate of Data Center
100 GB/s

European XFEL

European XFEL

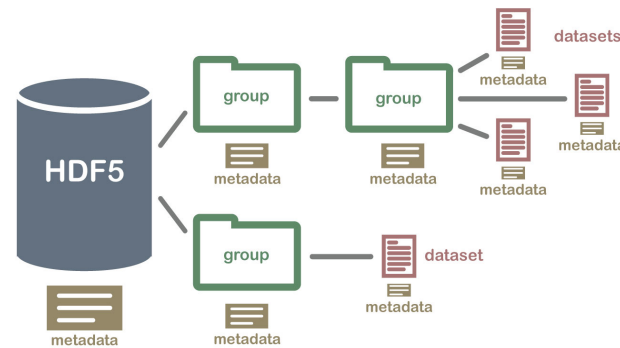# Data Reduction and Compression is the only hope …
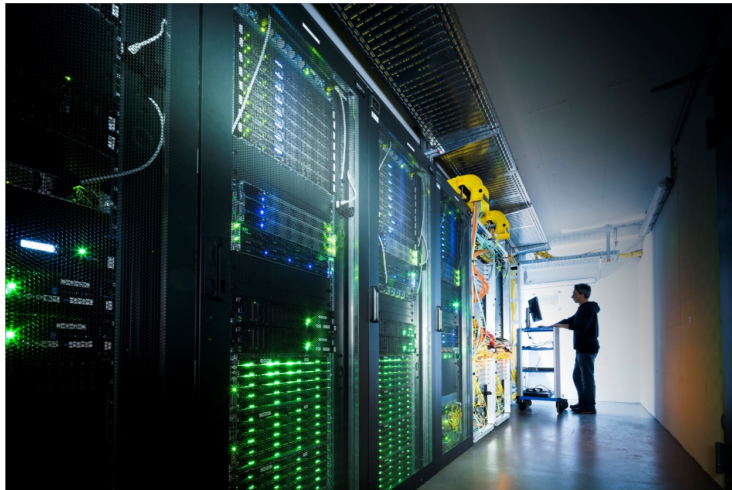
▪ Reduce to Store

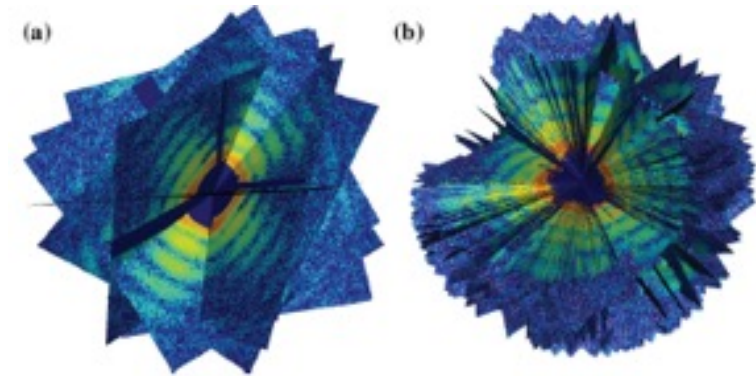## ▪ Reduce to Process

▪ Reduce to Transport

Data Reduction and Compression is the only hope …

Reduce to Store

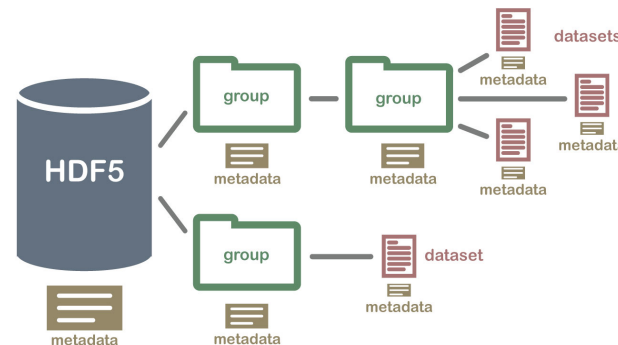**Reduce to Process**

Reduce to Transport
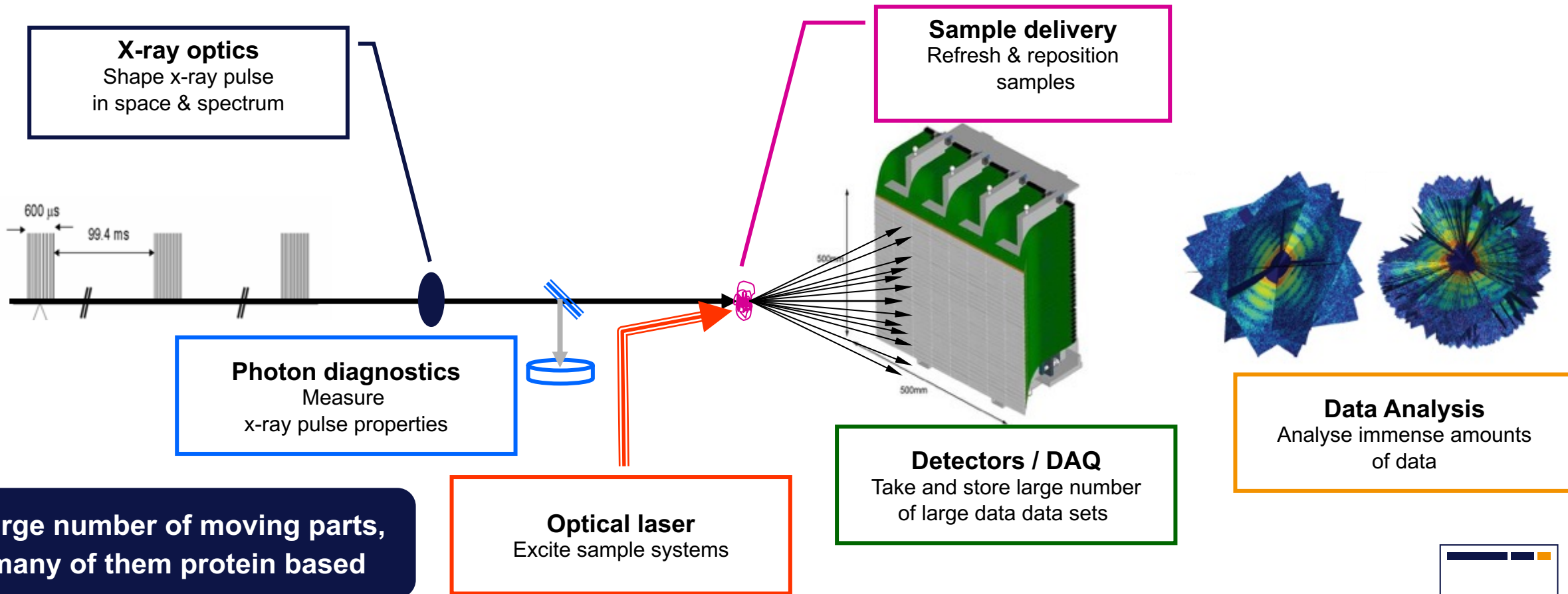
Energy price increase means the Storage : I/O : CPU balance will need to be rethough
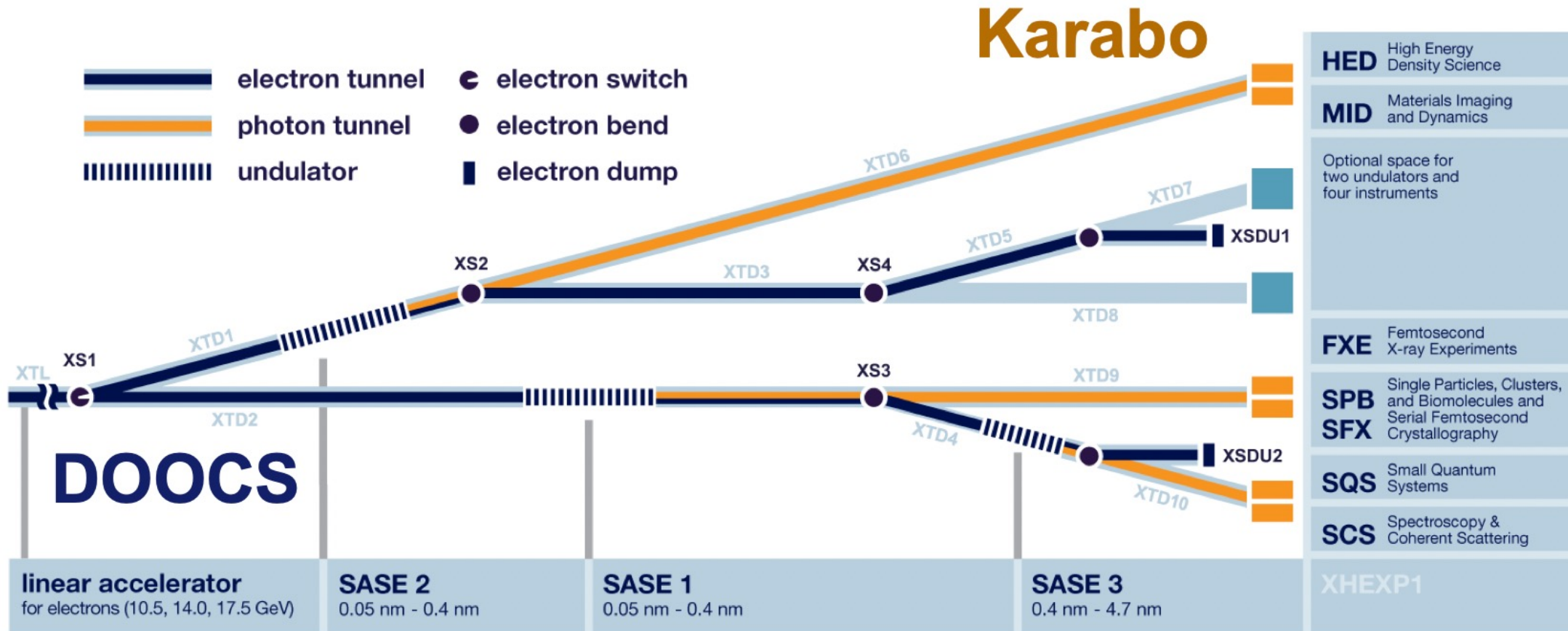
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Big Science Business Forum 2022

Maturing Systems　7 PB in 7 days 17th Nov. to 23rd Nov.

Controls – Hardware and Software

X-ray optics
Shape x-ray pulse
in space & spectrum

Sample delivery
Refresh & reposition
samples

Photon diagnostics
Measure
x-ray pulse properties

Optical laser
Excite sample systems

Detectors / DAQ
Take and store large number
of large data data sets

Data Analysis
Analyse immense amounts
of data

Large number of moving parts, many of them protein based

European XFEL

IT Infrastructure

European **XFEL**

Beamlines and experimental stations

**Big Science Business Forum 2022**

Karabo SCADA System

■ Karabo is the main control system for the photon tunnels and instruments of the European XFEL

   ■ Broker-based, event-driven architecture

   ■ TCP connections for large data

   ■ GUI with integrated panel/scene builder

   ■ Python & C++ APIs

   ■ Functionality added as self-descriptive plugins, so called devices

■ Karabo has matured in 4 years of operation

   ■ 20k devices, 2M properties

   ■ Routinely handles data rates of 20GB/s
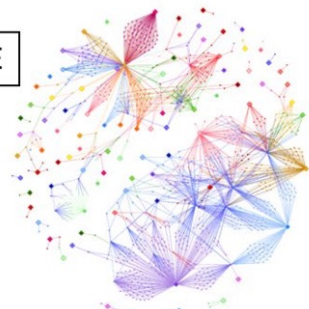
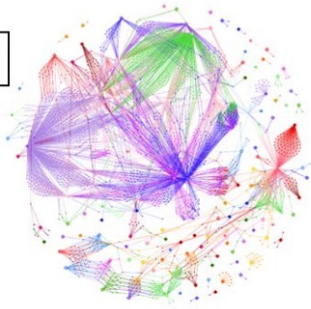   ■ **Soon: public release, MPL2.0 license**
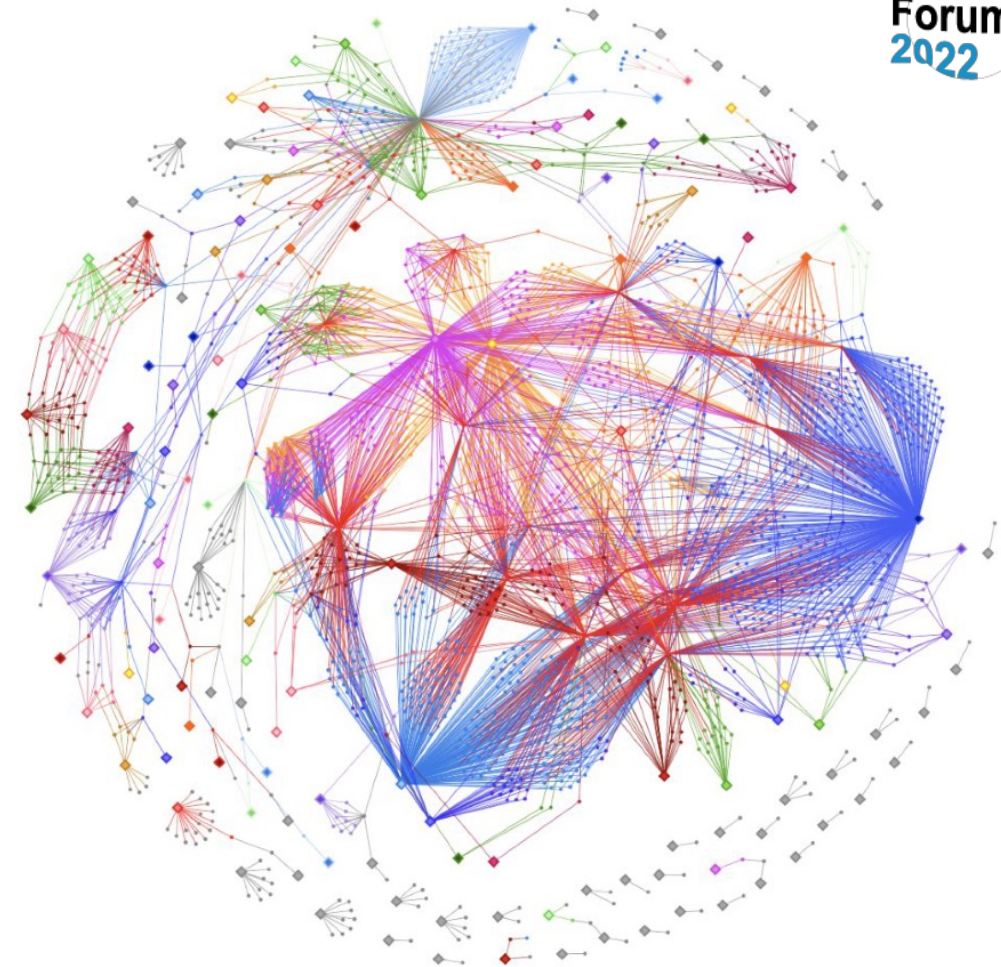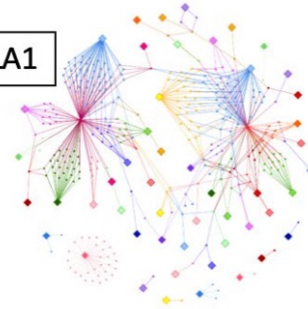

The MID instrument in Karabo

European XFEL

Karabo Eco System
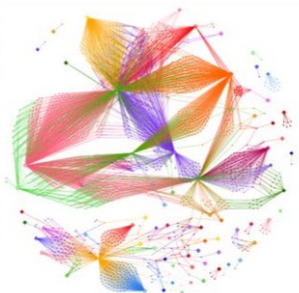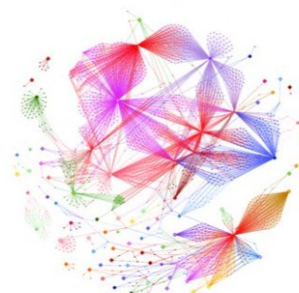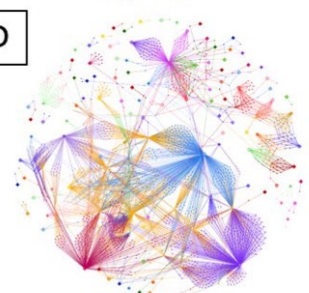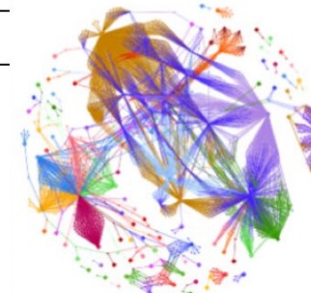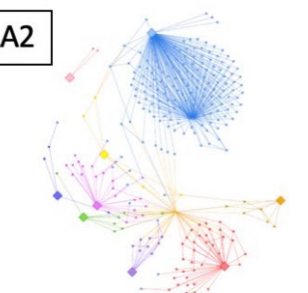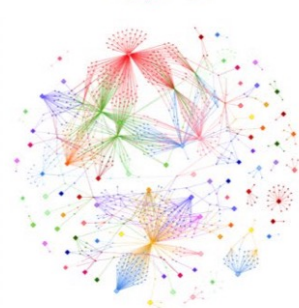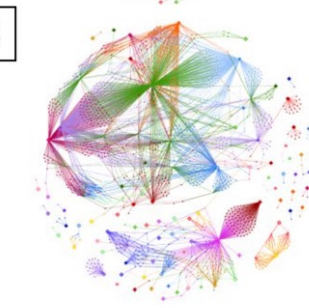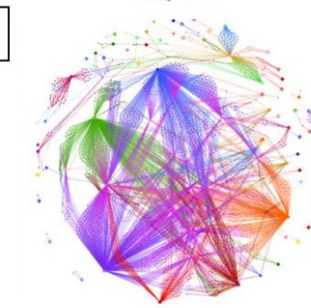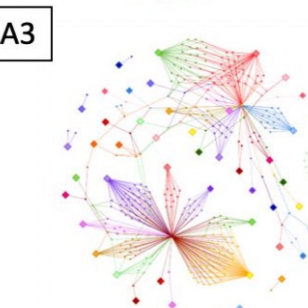
topic	# properties	# devices
LA1	26914.0	257.0
LA2	28103.0	250.0
LA3	32013.0	298.0
SA1	192656.0	1588.0
SA2	274426.0	2260.0
SA3	233216.0	1886.0
FXE	121905.0	905.0
HED	268688.0	1892.0
MID	258094.0	1789.0
SCS	205557.0	1444.0
SPB	267424.0	1872.0
SQS	306817.0	1954.0

Higher Level Motion Control in Karabo

- Generally, two types of integration:
  - Hardware integration through Beckhoff PLCs ➜ Control system interfaces through tcp protocol to in-house developed PLC firmware
  - Direct integration in Karabo ➜ Control system uses vendor-protocols and/or drivers
  - In both cases Karabo provides the operator (and often also commissioning/configuration) interface

- Additionally, Karabo control system provides
  - High-level procedures and virtual/software motors/axes
  - Scanning functionality
  - Sync functionality to other components

European XFEL

**Big Science
BuSiNess
Forum
2022**
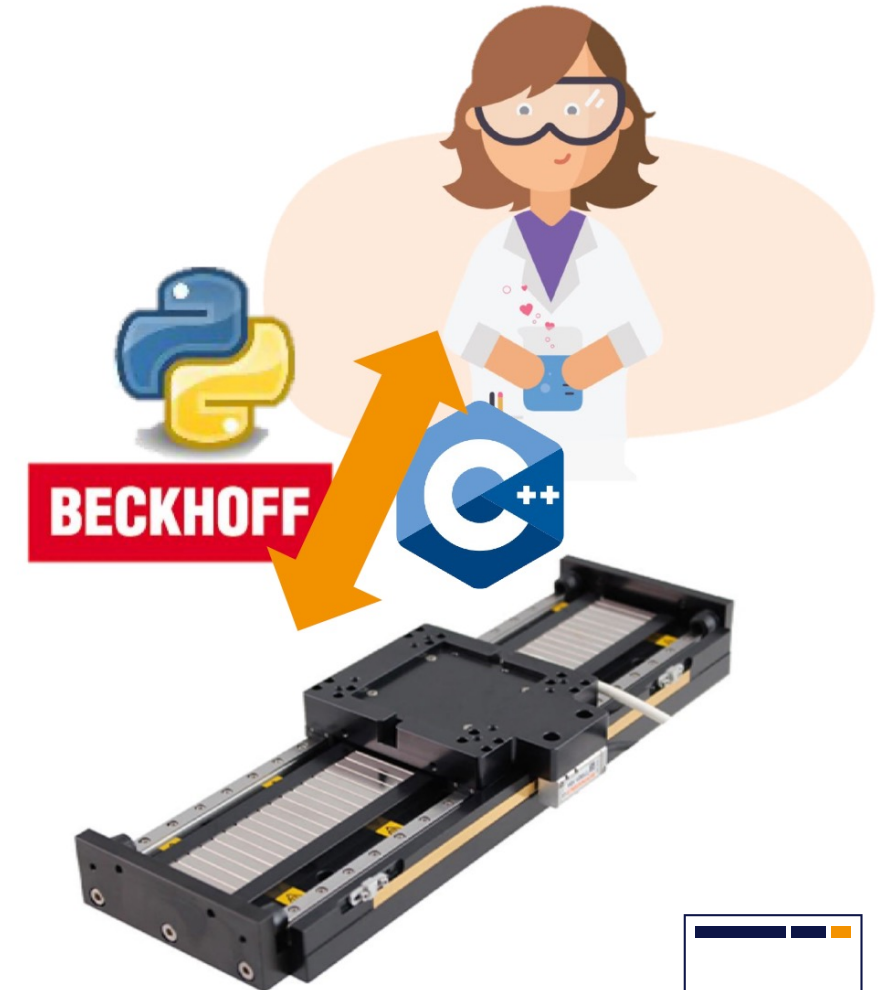
Integration via Beckhoff: Karabo (mainly) provides the Interface

■ EEE group implements most functions in firmware on
Beckhoff PLCs, so-called "soft devices"

　■ Logic & state machine
　■ Parameters

■ Two generic flavours:

　■ MC2: uses Beckhoff motion library
　■ SimpleMotor: deprecated custom-made

■ PLC and Karabo interact via custom TCP protocol

■ PLC provides self-description of functionality

　■ Karabo Beckhoff package render this as interface
　■ Adds state protection
　■ Possibly some higher level functions
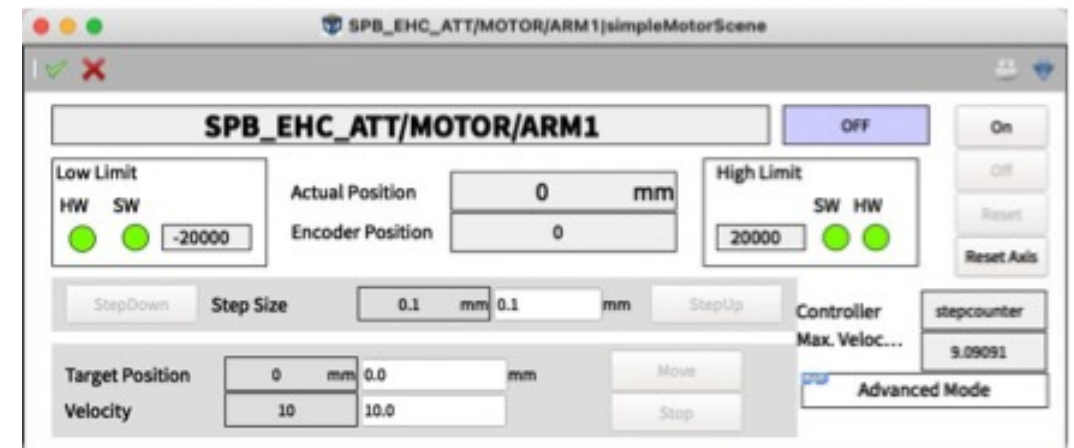
Generic operator interface for an MC2 motor

European XFEL

FPGA based online calibration and hit-finding project by Maxeler

- The Development phase will officially end soon
  - Calibration and Peak finding hardware algorithms have been implemented in the platform
  - Validation and integration of the platform in XFEL is ongoing

- Contribution from multiple XFEL colleagues
  - Control, Data Analysis, Detector, ITDM and SPB
  - Amount of time/expertise needed was underestimated

- Goal is to have the platform up and running in SPB as soon as validation is concluded
  - Press release or possible article in a Conference will follow

European XFEL

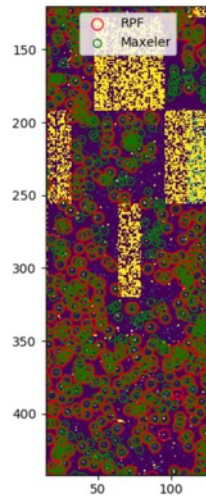# FPGA based online calibration and hit-finding project by Maxeler

Start of project

Installation of platform in Laboratory

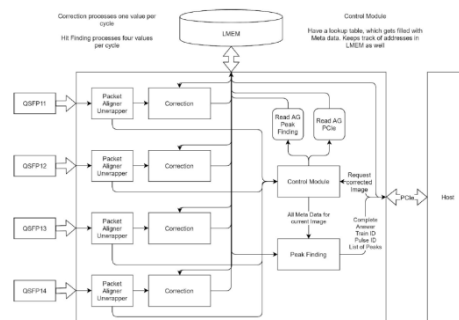**A**GIPD Reference Data

Initial Maxeler Software models

Deliverable 1

Validation of Maxeler SW results

Data handling in the Maxeler platform
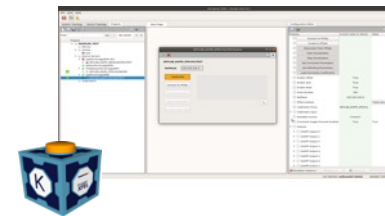
Software library interface

Deliverable 2

FPGA implementation of Software models

Decoding of XTDF/TTP data protocol

Extra development for calibration algorithm

Deliverable 3

Validation of Maxeler XTDF/TTP decoding

Extra extra development for calibration algorithm

Karabo Interface to the Platform

Deliverable 4

Validation of entire data flow in laboratory

Installation and Validation of platform in SPB

End of project

We are here now!

- Karabo device for communication with Calibration database
- Validation of Hardware Calibration

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