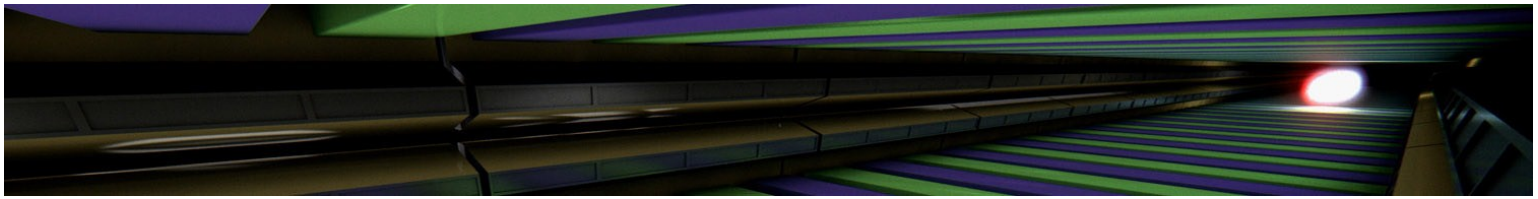
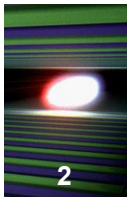


10GbE for data streaming in European XFEL DAQ System

Patrick Gessler (XFEL)

Overview



- The European XFEL Project
- Detectors and photon diagnostics providing data
- Beam time structure drive DAQ and control
- Architecture concept
- Hardware overview
- Processing and streaming
- The big picture
- Conclusion

European XFEL

Der European X-Ray Free Electron Laser

Length	3.4km
Depth of tunnels	6m bis 38m
Costs (Construction, Commission)	> 1 Mrd. Euro
Wave length Photons	0.05nm – 6nm
Users‘ operation	2016

CRISP HELMHOLTZ ASSOCIATION

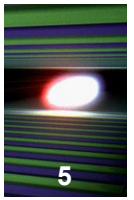
European XFEL

Der European X-Ray Free Electron Laser

CRISP

HELMHOLTZ ASSOCIATION

Detectors and photon diagnostics providing data



Optics (WP73)
- KB mirrors for focusing
- Refractive lens focusing
- Monochromator
- Collimator
- Slits
- Attenuators

Vacuum systems (WP73)
- Turbo pumps
- Ion pumps

Beam diagnostics (WP74)
- Intensity monitors
- Beam positioning monitor
- Photon-electron spectrometers
- K-monochromator and cameras
- Screens and camera

Tunnels contain components listed above

Laser systems (WP78)
- Pump laser and diagnostics

Sample environment (WP79)
- Particle injector
- Cryostat
- Precision stages

Experiment detectors (WP8x)
- e- and ion TOF
- Point detectors (diodes)
- Spectrometers

Experiment 2D detectors (WP75)
- AGIPD
- LPD
- DSSC
- pnCCD

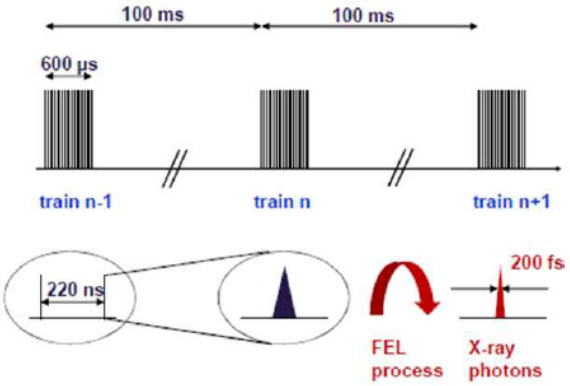
DAQ significant

Experiment hutches contain components above + many of the tunnel instruments

European XFEL

Beam time structure drive DAQ and control

- Readout rate driven by bunch structure
  - 10 Hz train of pulses
  - 4.51 MHz pulses in train
- Data volume driven by detector type and use of data



Detector type	Sampling	Data/pulse	Data/train	XFEL/sec
1 Mpxl 2D camera	4.5 MHz	~ 2 MB	~ 1 GB	~ 10 GB
1 channel digitizer	5 GS/s	~ 2 kB	~ 6 MB	~ 60 MB
Low latency feedback	5 GS/s	~ 2 B	~ 4 KB	~ 40 KB
Screen camera	10 Hz	~ 2 MB	~ 2 MB	~ 20 MB

- **Experiment detectors are characterized by large data sizes (PBS)**
  - Need to acquire, long term storage required, offline analysis, multi-user full AAA s/w framework
- **Feedback systems are characterized by low data rates and low send latency (machine+PBS)**
  - Use on-the-fly, no need to store, trigger level with limited analysis, single user
- **Diagnostic devices are characterized by low data sizes (machine+PBS)**
  - Use on-the-fly, possibly short term storage, on-the-fly analysis, single user

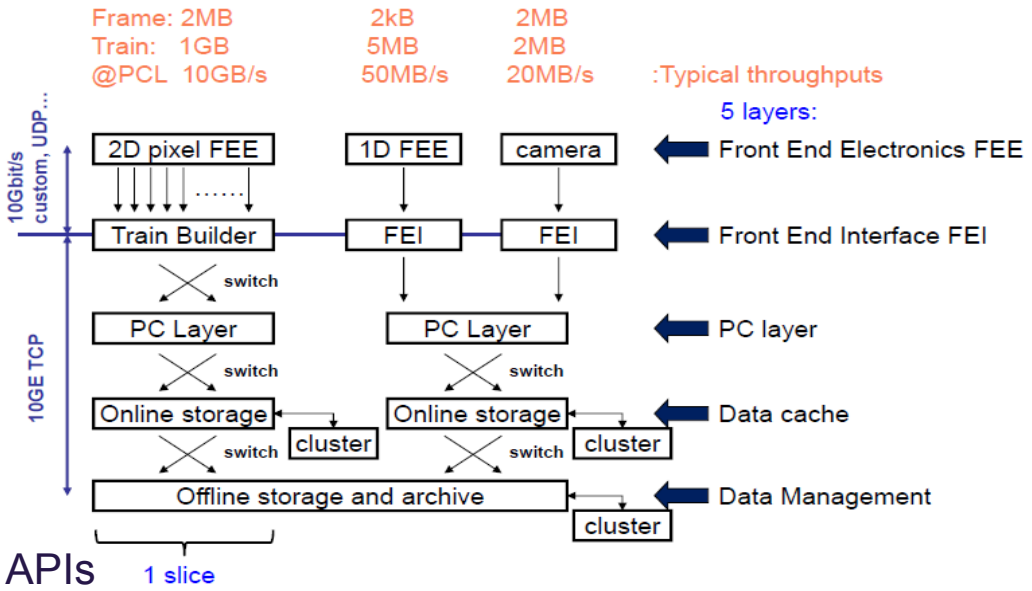
CRISP HELMHOLTZ ASSOCIATION

European XFEL

Architecture concept

Large data volumes, their acquisition, storage and analysis and changing experiment configurations are issues the PBS system architecture is trying to solve

Architecture chosen



- Multiple layers with well defined APIs
  - to allow insertion of new technology layers
- Multiple slices for partitioning and scaling
  - camera sizes will increase and slice replication will be one solution
- Allow full speed write through to online storage, but discourage usage
  - sometimes this capability is needed to understand measurement
- Enforce data reduction and rejection in all layers
  - early data size reductions and data rejection are needed to reduce storage resources

European XFEL

MicroTCA.4 as main platform

- MicroTCA.4 allows
  - High-bandwidth communication between
    - → Boards and CPU via PCIe
    - → Boards via point-to-point connections
  - Synchronization via Timing Receiver
    - → Trigger
    - → Clocks
    - → Machine parameters
    - → Bunch structure
  - Remote control and monitoring
  - Module changes during operation (Hotplu
  - Functional extension via RTMs

Clock & Control RTM
(University Collage London)

DAMC2 – Universal digital AMC
(DESY)

Timing System
(Stockholm University / DESY)

SIS8300 – ADC AMC
(Struck Innovative Systems)

MicroTCA Carrier Hub
(N.A.T.)

High-performance DSP and FPGA board
(DMCS/DESY)

CRISP HELMHOLTZ ASSOCIATION

European XFEL

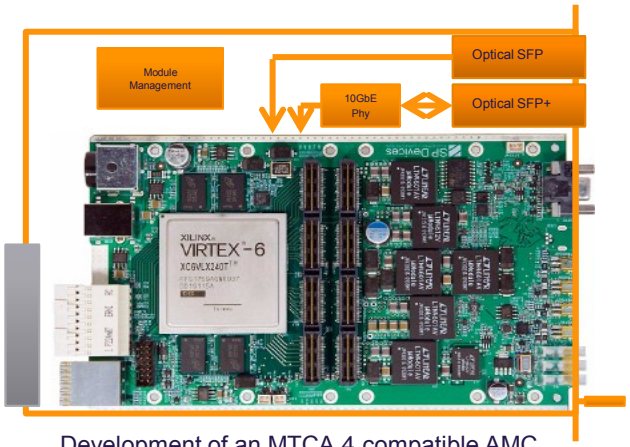
MTCA.4 High-Speed Digitizer developments

- A development with SP Devices Sweden AB just started

Product	Resolution	Maximum Sample Rate	Analog Bandwidth	Channels	On-Board Memory Size	Interface
SDR14	14bit in 14bit out	800 MSPS in 1600 MHz out	500 MHz	2 in 2 out	2 x 500 Mbyte	USB, cPCIe/PXIe, PCIe
ADQ108	8 bit	7 GSPS	2 GHz	1	1024 MS	USB, cPCIe/PXIe, PCIe
ADQ412	12 bit	1.8/3.6 GSPS	2/1.3 GHz	4/2	700 MS	USB, cPCIe/PXIe, PCIe
ADQ1600	14 bit	1.6 GSPS	800 MHz	1	500 MS	USB, cPCIe/PXIe, PCIe
ADQ DSP	-	-	-	-	1 GByte	USB, cPCIe/PXIe, PCIe

- They will design an AMC version of their digitizer family
  - Additional interfaces and MTCA.4 connectivity added
  - Final products expected end of Q4 2012

Existing Products
(PXIe/cPCIe, PCIe, USB)



Development of an MTCA.4 compatible AMC

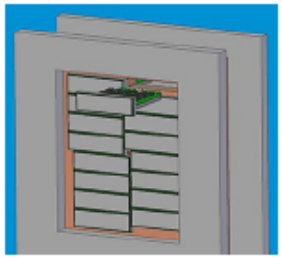
Applications

- Photon Diagnostics
  - XGMD
  - XBPM
  - PES
- Detectors
  - 0D (e.g. APD)
  - 2D (e.g. pnCCD)
- Experiments
  - eTOF, iTOF

European XFEL

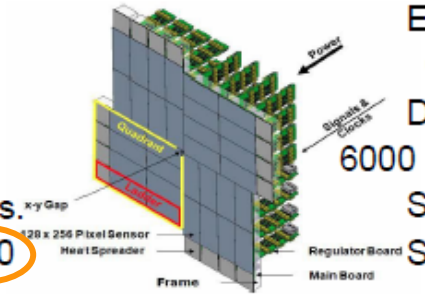
XFEL detectors

AGIPD Adaptive Gain Integrating Pixel Detector (AGIPD)



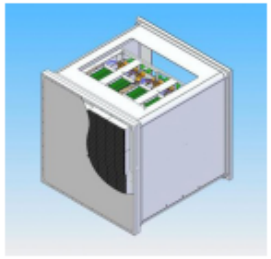
Energy range
3 - 13 keV
Dynamic range
10^4@12 keV
Single Photon Sens.
Storage Cells ≈ 300

DEPFET Sensor with Signal Compression (DSSC)



Energy range
0.5 - 6 keV (25 keV)
Dynamic range
6000 ph/pix/pulse@1 keV
Single Photon Sens.
Storage Cells ≈ 640

Large Pixel Detector (LPD)



Energy range
5 (1) - 20 keV (25 keV)
Dynamic range
10^5@12 keV
Single Photon Sens.
Storage Cells ≈ 512

Other Detectors

- 0D/1D detectors for high repetition rate applications (e.g. veto, dispersive spectrometers)
- Small areas, low rep. rate, low energy 2D imaging detectors
- Particle detectors (eTOF, iTOF)

Control and DAQ features

- 2D: custom systems (ASICs, capacitive and digital pipelines), acquire limited number of pulses per train; modular design = 16 modules per Mpxl
- 1D: strip detectors
- 0D (diodes…) and Particle detectors: use Fast ADCs or Digitizers

European XFEL

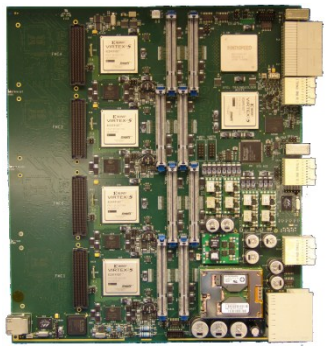
2D detector control, processing and streaming

- Control and synchronization
  - Clock and Control RTM
  - Synchronized with Timing Receiver
  - One RTM controls a 1 Mpixel Detector

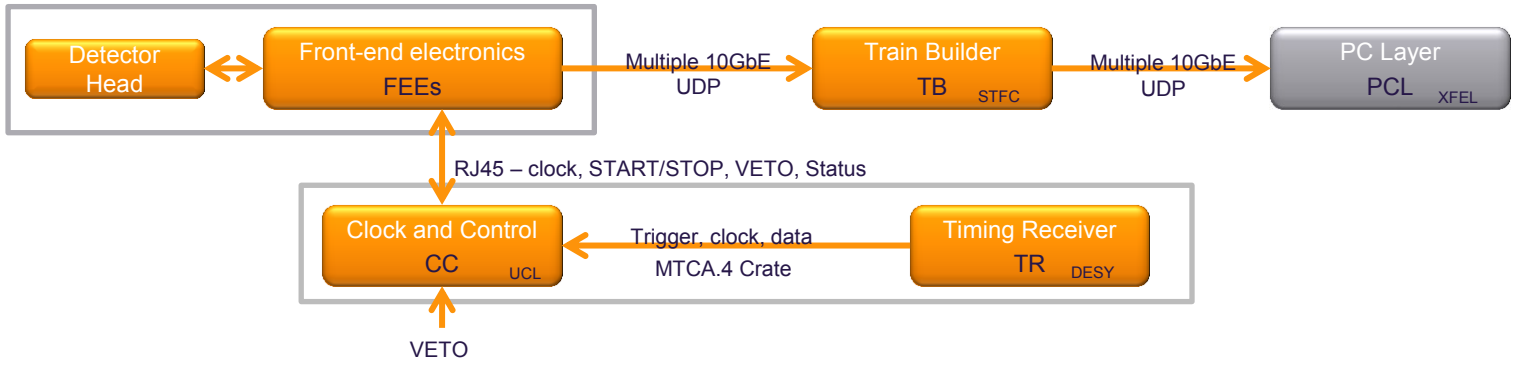
Clock and Control RTM (UCL)

DAMC2 (DESY/FEA)

- Data reorganization and processing in Train Builder
  - Partial frames will be reassembled
  - A complete train put into memory
  - Transmitted via 10GbE to PC Layer
    - → Dual 10GbE FMCs from DESY/FEA



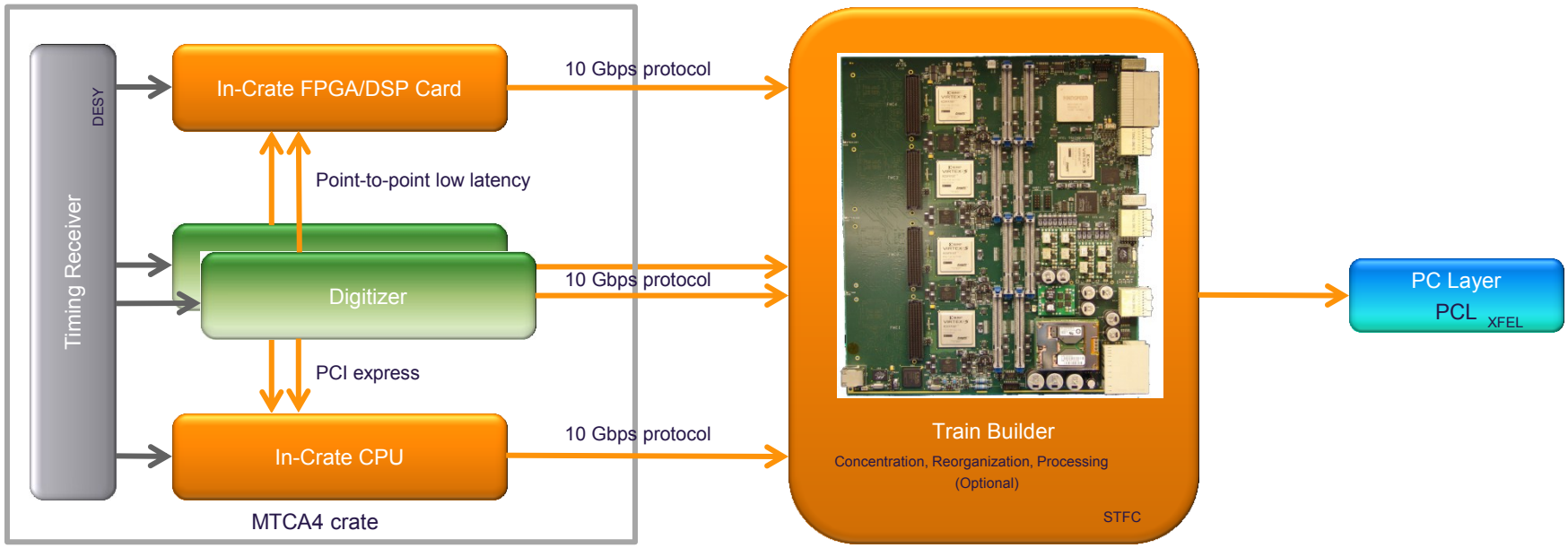
Train Builder ATCA Board (STFC)



CRISP HELMHOLTZ ASSOCIATION

European XFEL

Data processing and transmission concept



- In-crate processing
  - In FPGAs of Digitizer
  - In local CPU
  - In a DSP/FPGA Board
- Processing of multiple sources
  - Processing in FPGAs
  - Multiple Boards
  - Communication between all FPGAs
  - DDR and QDR Memory
- PC Layer
  - Software
  - CPUs
  - GPUs

European XFEL

The big picture – DAQ and control part 1

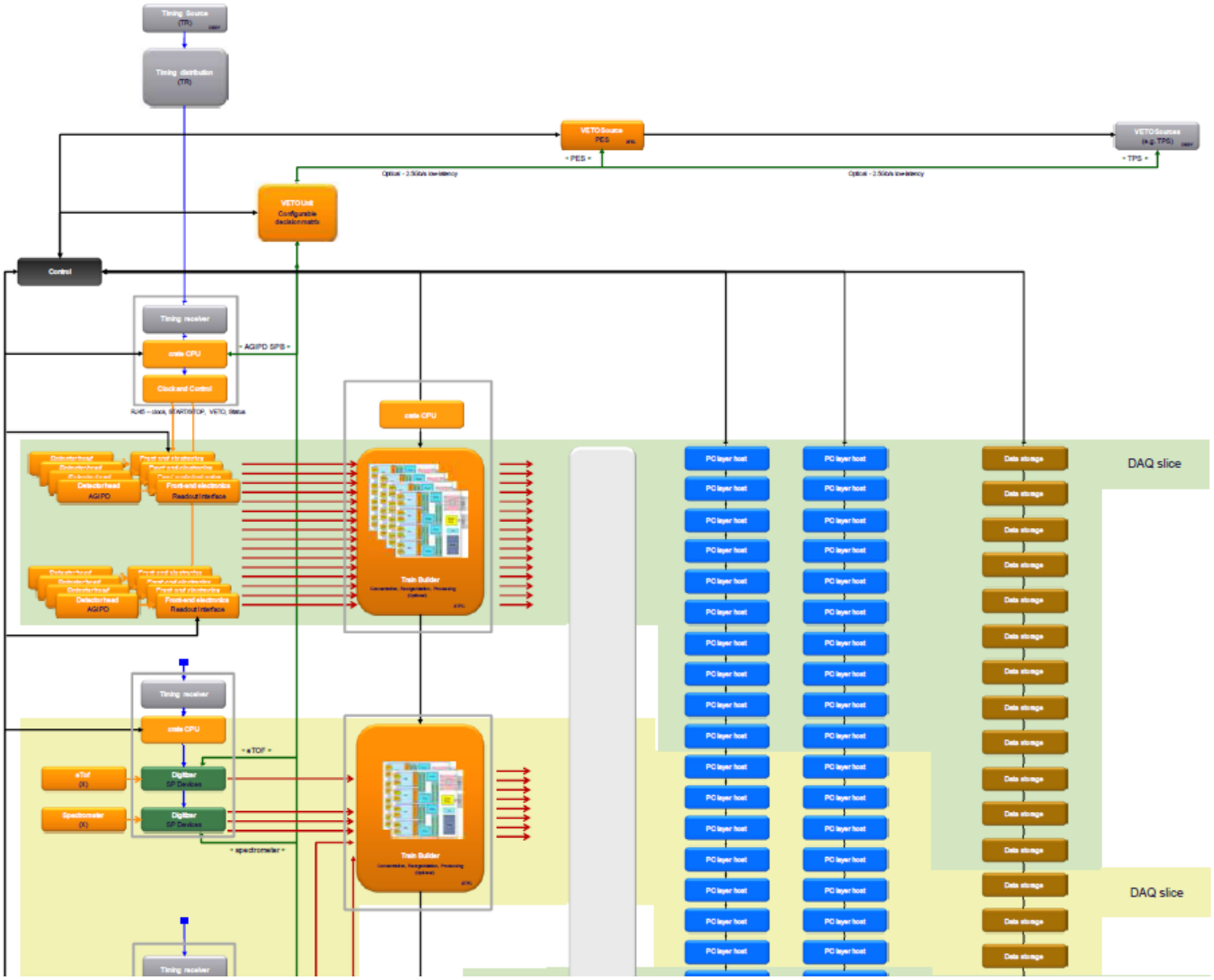
Timing synchronization
- Two DAQ timing fibres per expt.

VETO signal providers
- beamline photon diagnostics
- e-machine diagnostics
- target diagnostics

Control
- Ethernet

SPB large area camera
- AGIPD

Other expt. detectors
- eTof
- spectrometer



CRISP HELMHOLTZ ASSOCIATION

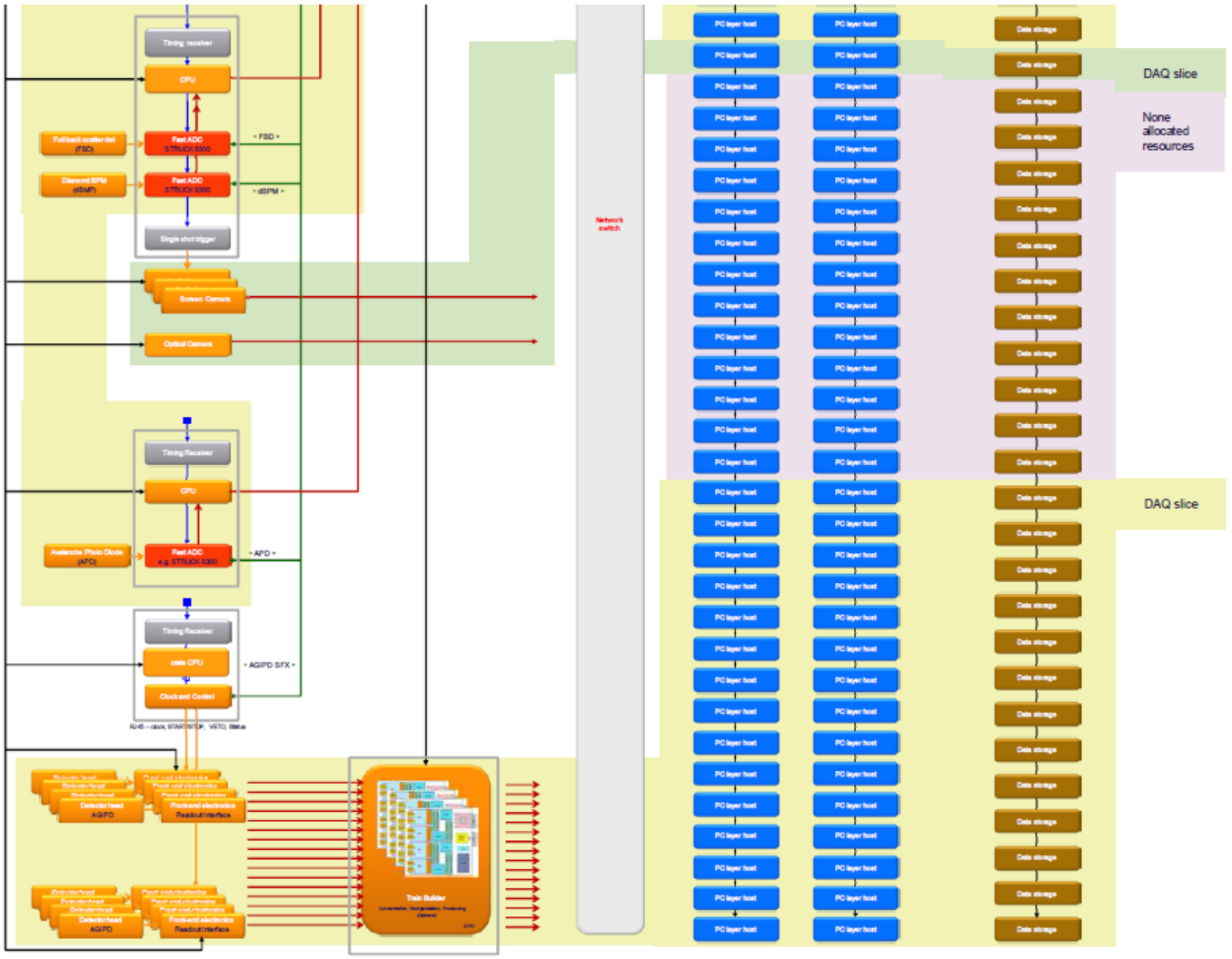
European XFEL

The big picture – DAQ and control part 2

Experiment diagnostics
- BPM position monitors
- FBD foil back-scatter det.
- screen cameras
- optical microscope

Experiment VETO
- flourescence monitor
- …

SFX large area camera
- AGIPD



DAQ layer:

European XFEL

Conclusion

- 10GbE interface rare on standard modules (PC, Digitizer)
  - Manufacturers thinking about adding it
  - Has to be requested in most cases
  - Add-on boards might be needed
- 10GbE provides a standard to stream data to FPGAs and PC
  - FPGA stages could be replaced with PCs for testing
  - COTS hardware available
- Bandwidth is sufficient for current sources but at limit
  - Future detector generations will require more
- Currently only UDP/IP implemented
  - Fine for FPGA → FPGA with no switch
  - TCP/IP via switch and to PC layer required/desired

Thank you for your attention!

Questions?