ELI Beamlines Control System Development

Academia-Industry Matching event
March 15th 2018, Starý Smokovec

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Prague, Czech Republic

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ELI Bemlines

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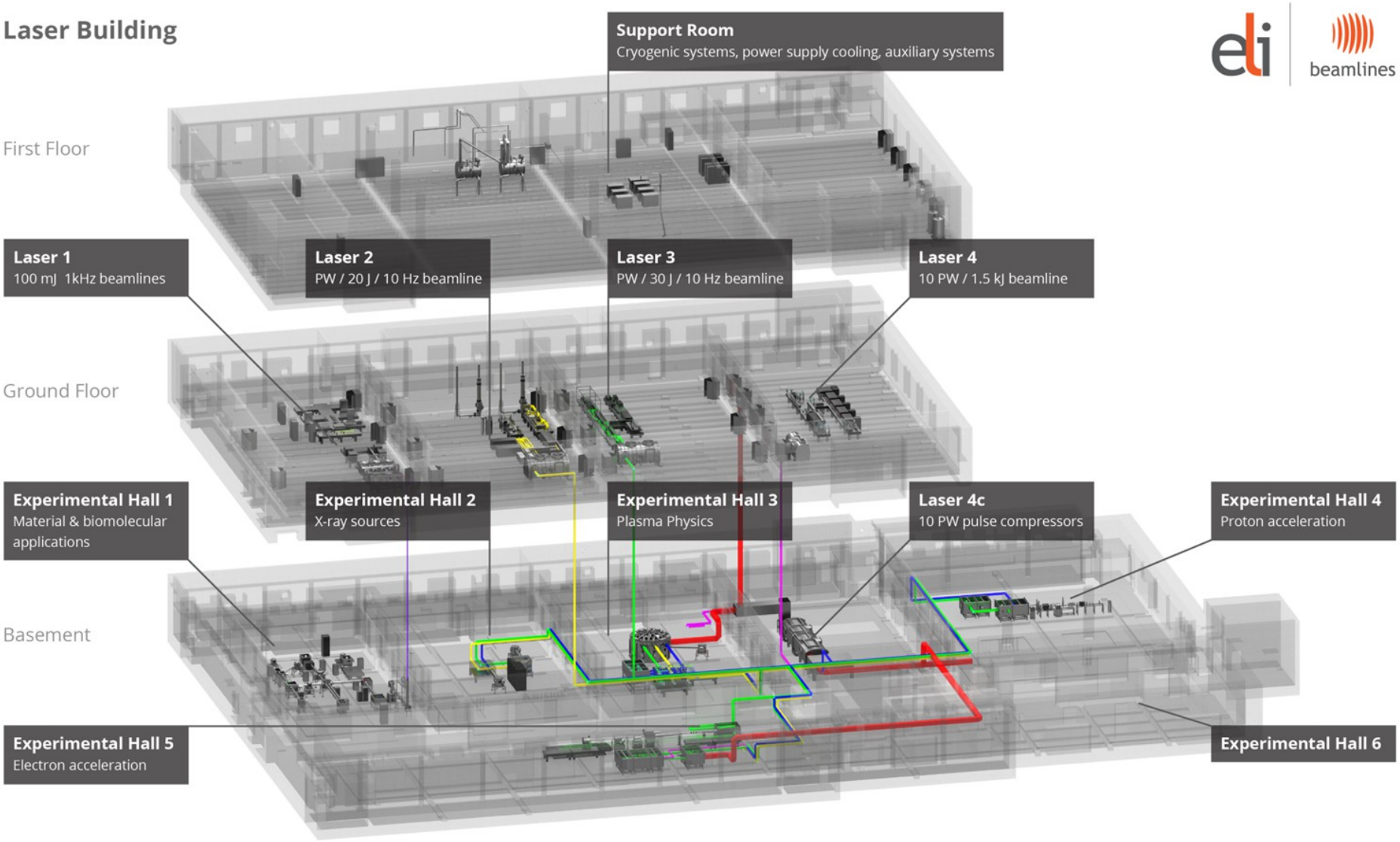


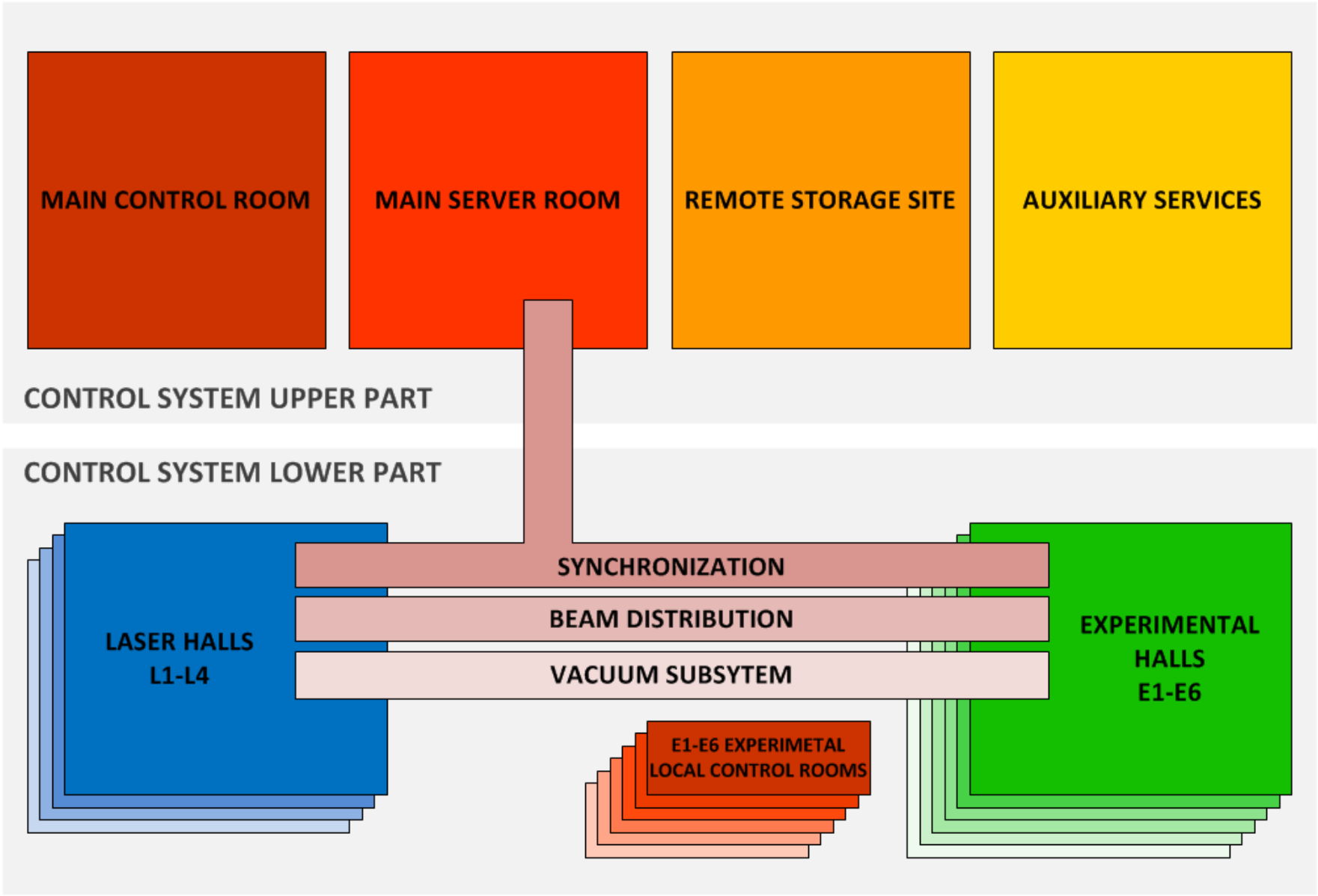
ELI Bemlines

Subsystems and Responsibilities

Basic technologies
- Vacuum system
- Switch-yard control
- Beam alignment
- Beam diagnostics
- Laser interface
- Experiment control

Supplementary technologies
- Control system network
- Timing system/Synchronization
- Data acquisition
- Beam diagnostics
- Machine protection system

CS Structure



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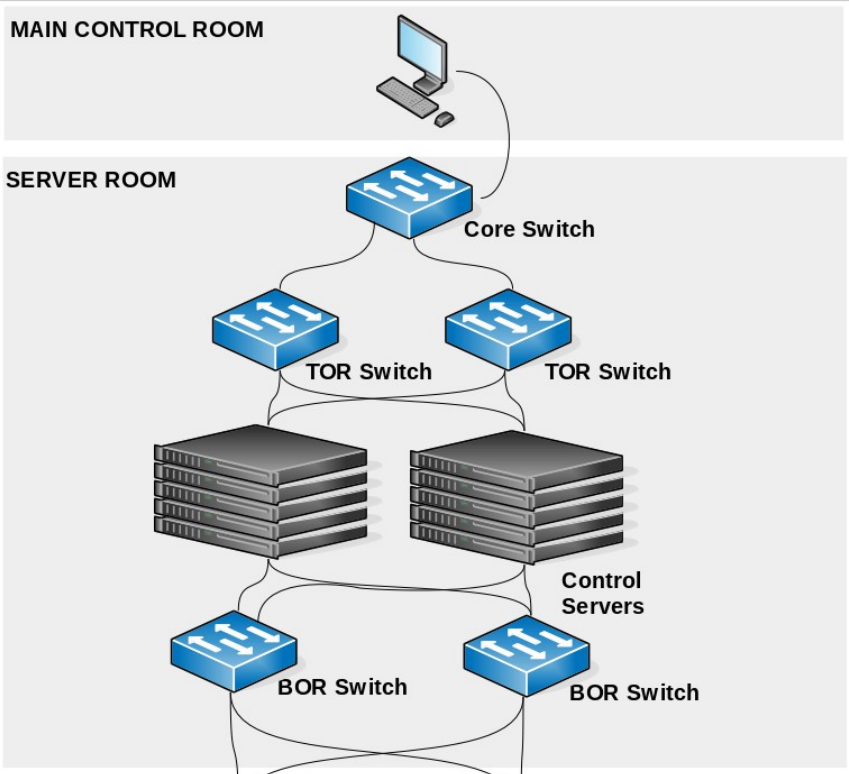
CS Overview

TOP LEVEL



Main Control room

CORE Switch – Cisco Nexus 7700, 10/40Gb/s, 100Gb/s ready

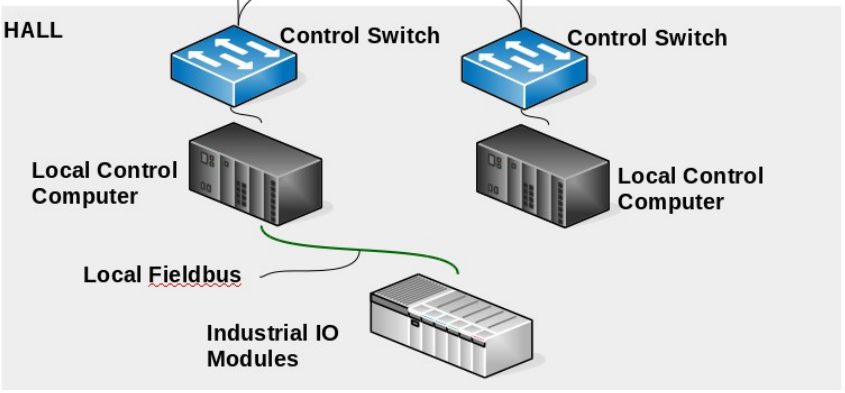
TOR Switch – Cisco Nexus 5672, 10/40Gb/s

Top level control – Server Room

- **Control servers** – Butch of 10 servers
- **Lenovo Systems x3650m5** 2U servers
  - 24 cores
  - 256GB RAM
- **Virtualization** – Private Cloud

BOR Switch – Cisco Nexus 56128, 10/40Gb/s

LOCAL LEVEL

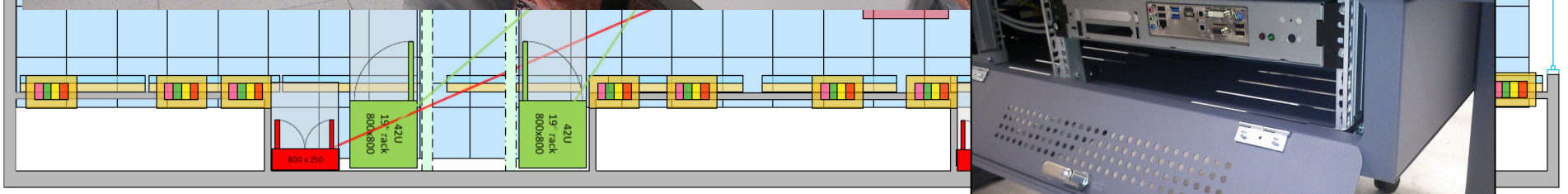


CONTROL Switch – Cisco Catalyst 2960X, 1/10Gb/s

Local level control – Halls&Plant rooms

- **Industrial control**, undemanding applications
- **Advanced control**, challenging applications, with high demands on data rates

CS Top Level



Main Control Room

- 21 Seats
  - 43” Operators monitors
  - 49” Screens on the wall
- Operators computers
  - 8 core Intel CPU
  - Keyboard and Mouse
  - NVIDIA GPU 1050Ti
  - 2x 10Gb/s ethernet (SFP+)
  - on-board

There is not direct access to computer's peripherals, the computer is locked inside the table – safety reason

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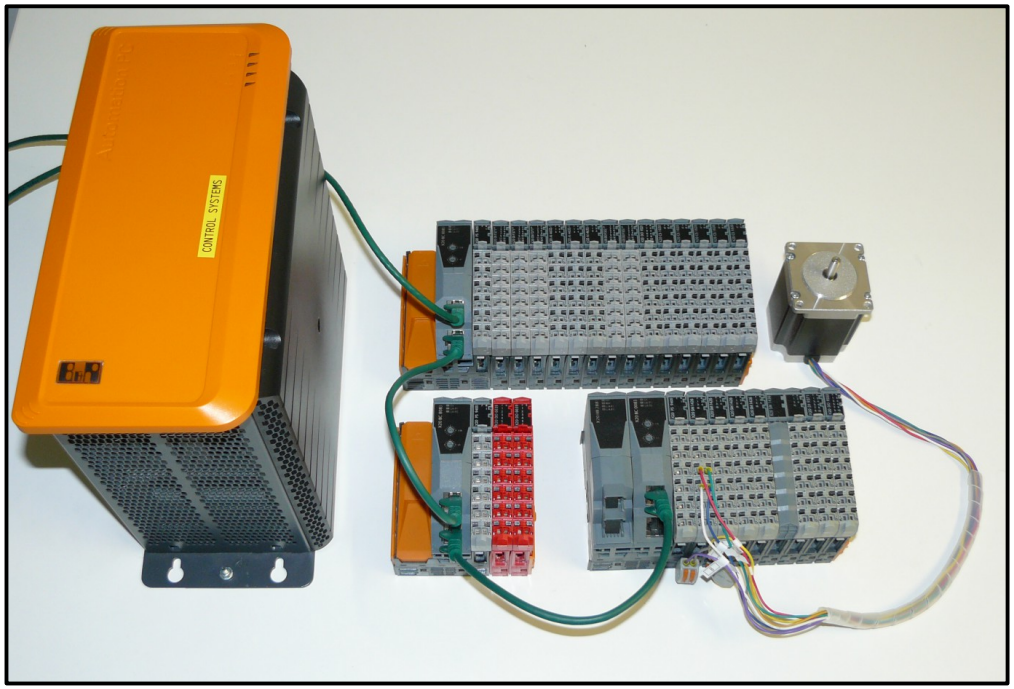
CS Local Control

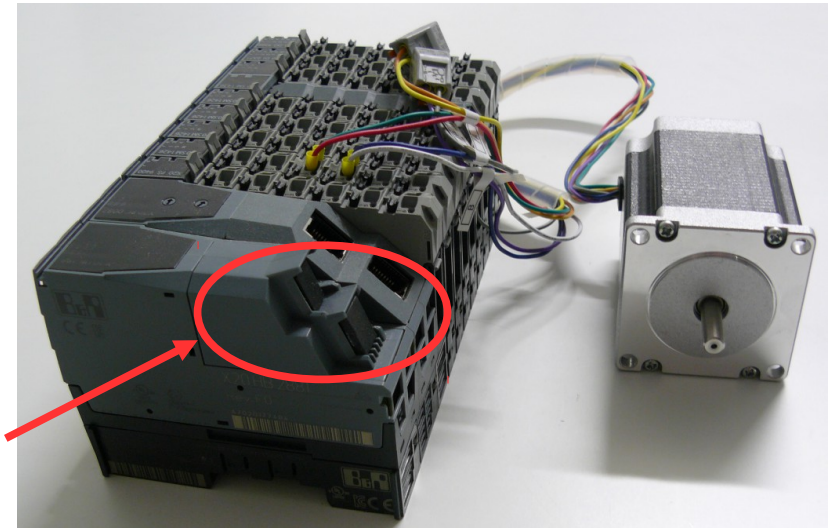
ETHERNET POWERLINK

EtherCAT®



Ethernet based Fieldbus Systems

- Infrastructure based on standard ethernet
- Rich portfolio for Termination & Motion control
- Available with Fiber optics (For galvanic separation and communication on long distances)



Optical interface

CS Local Control

µTCA Basic Components

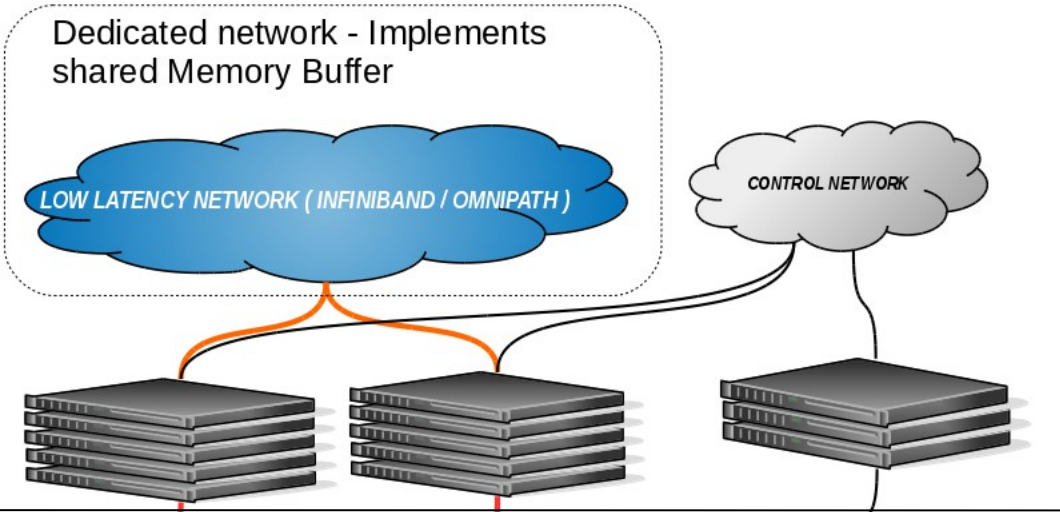
- **Chassis –** part which defines the size of the system
- **Backplane –** flexible architecture, 1Gb ethernet, 8 bidirectional fat-pipes, timing support, AMC-to-AMC and more
- **µTCA (MicroTCA Controller Hub) –** 'defines' the system, including fat-pipe implementation
- **Cooling Unit –** up to two fully controlled redundant units
- **Power Supply –** up to two redundant fully controlled power modules, up to 1kW
- **AMC/RTM Cards –** application cards, more than one computer system can be installed in chassis

Three Levels of µTCA in ELI Beamlines

- **Class A (µTCA.4)** – NATIVE R10-WR – High Demand Control, 12AMC, 12RTM, Redundant MCH, Redundant Power Supply
- **Class B (µTCA.4)** – NATIVE R2-WR – Advanced Control, 6AMC, 4RTM
- **Class C** – NATIVE A1 – 'Standard' local Controller, 6AMC, Mid-Size, Single-Width

DAQ Overview

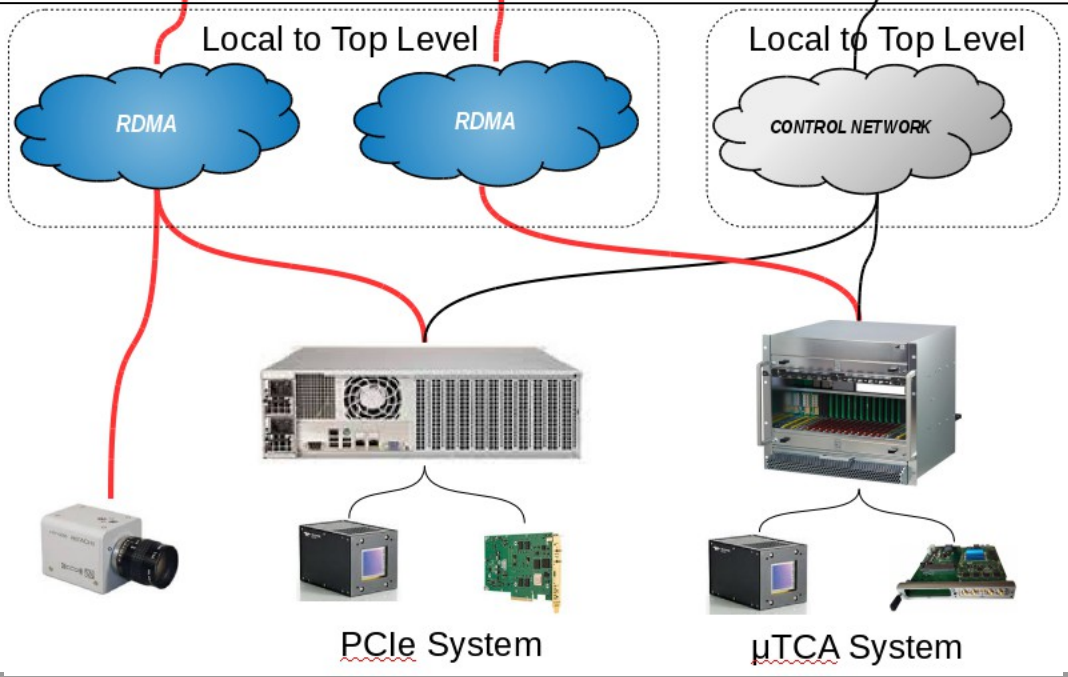
TOP LEVEL



Top Level of DAQ System

- 2x Blade Server
  - 10Gb/s ethernet (mezzanine) each
  - 56Gb/s Infiniband (mezzanine) each
  - 24 cores each Blade
  - 768GB RAM each Blade
  - 4x PCIe slot (2 slots x8, 2 slots x16)

LOCAL LEVEL

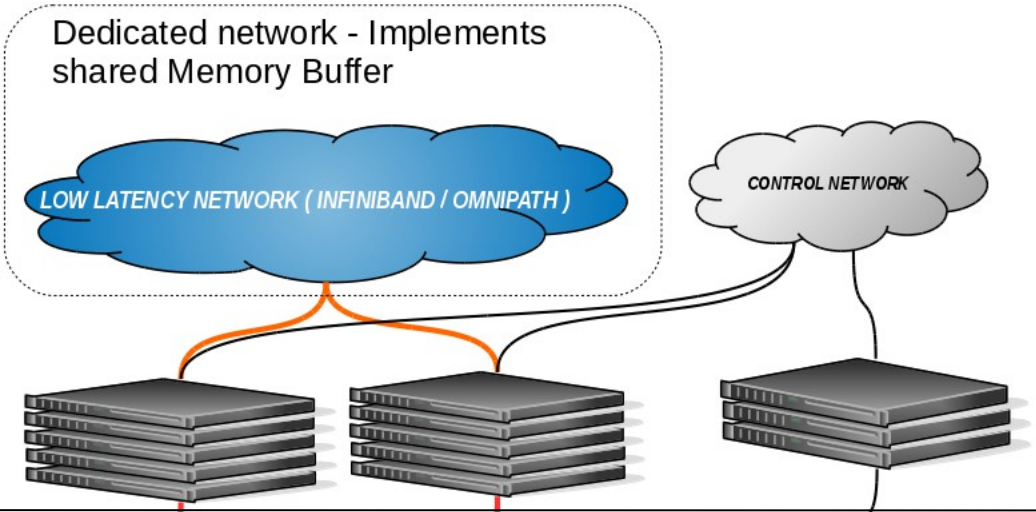


Local Level of DAQ System

- Local PCIe Server
  - 4x 10Gb/s ethernet with RDMA
  - 24 cores
  - 128GB RAM each
  - 10x PCIe slots x8
- µTCA.4
  - 12x AMC, 12x RTM
  - 4x 10Gb ethernet to RDMA
  - MCH-PHYS-80 PCIe on Fat-Pipes, PCIe connection with PCIe local server through optical fibers

DAQ Overview

TOP LEVEL



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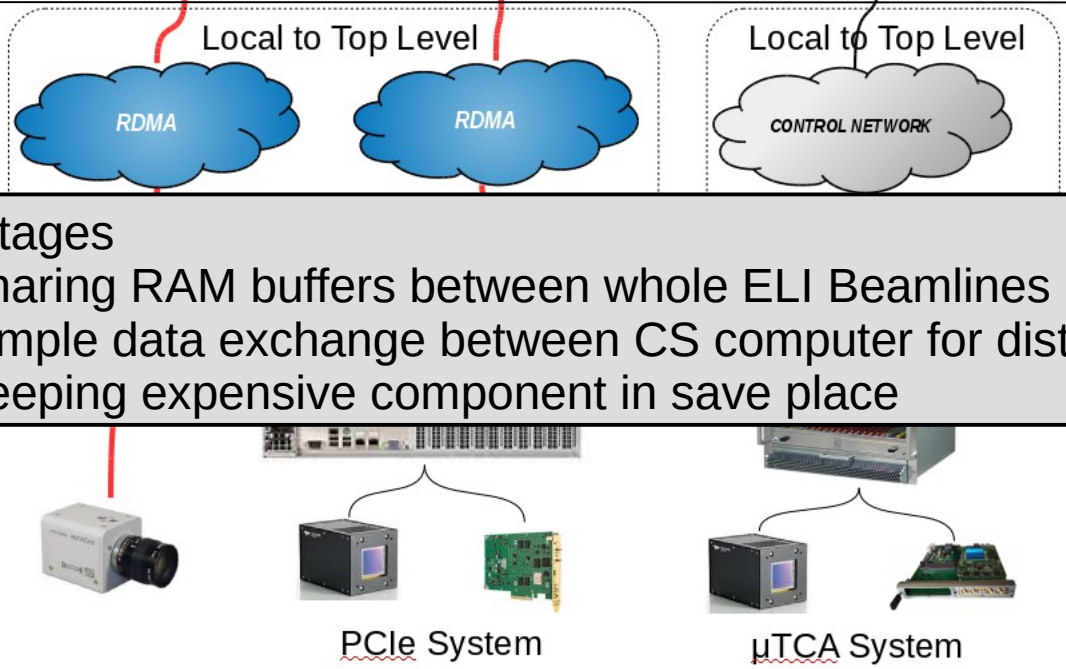


Local Level of DAQ System

- Local PCIe Server
  - 4x 10Gb/s ethernet with RDMA
  - 24 cores

Advantages

- Sharing RAM buffers between whole ELI Beamlines building
- Simple data exchange between CS computer for distributed control
- Keeping expensive component in save place

- 4x 10Gb ethernet to RDMA
- MCH-PHYS-80 PCIe on Fat-Pipes, PCIe connection with PCIe local server through optical fibers

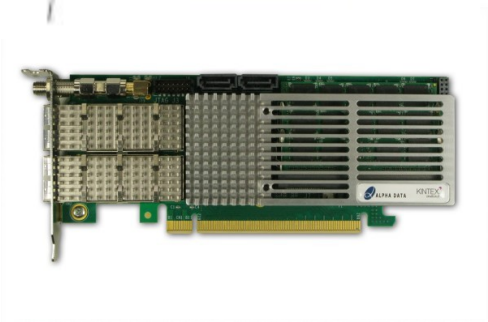
DAQ Top Level

Blade Server With PCIe Slots

Infiniband and Ethernet Switches are integrated inside the chassis.

+

NIC – Our 'standard'
- 2x 10GBASE-X
- RDMA Support



FPGA XCKU060
- 2x QSFP
- SDAccell support
- CAPI support
- 8GB DDR RAM

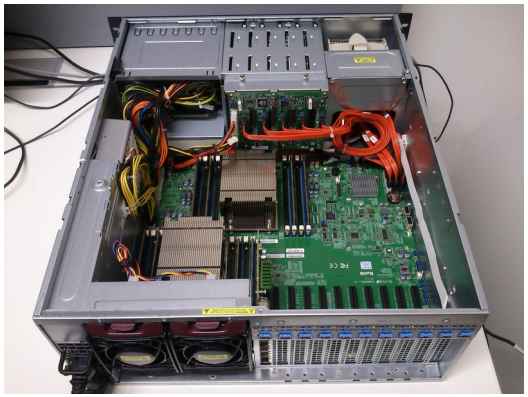
FPGA+NIC
- 1X QSFP (4xSFP+)
- Connect-X NIC Offload chip
- RDMA Support
- XCKU060
- 2GB DDR RAM

DAQ Local Level

PCIe System

PCIe Local Server

- 24 core
- 128GB RAM
- 10x PCIe x8



NIC AOC-STG-b4S

- 4x 10GBASE-X
- RDMA support

FMC Carrier

Kintex UltraScale XCKU085

- Acquisition and local processing
- VITA 57.4 compatible with 57.1
- 16GB DDR RAM
- 1x SFP+

µTCA.4 System

µTCA.4 Chassis

- 12 AMC
- 12 RTM
- WR Support
- MCH-PHYS-80
- PCIe interconnection

FMC Carrier

Artix/Kintex XC7A200, XC7K325

- Acquisition and local processing

Compatible RTM

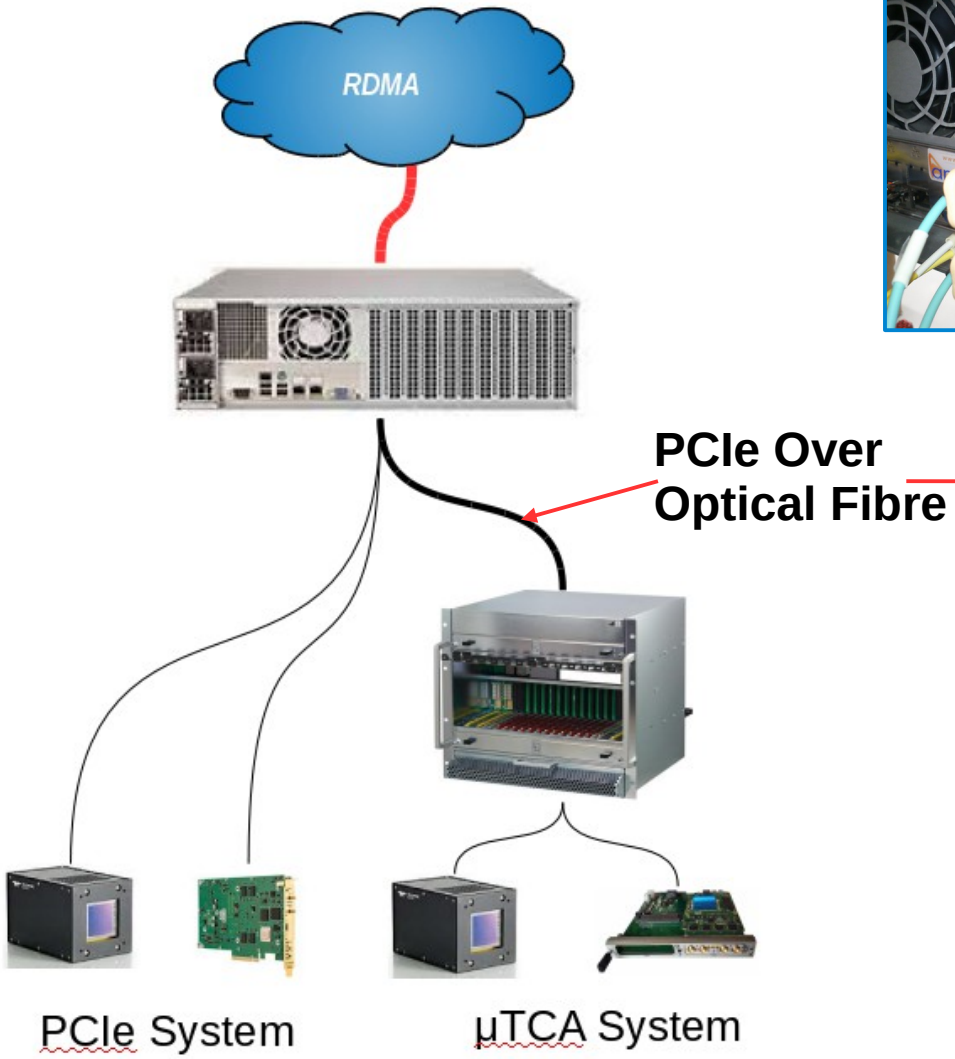
Module

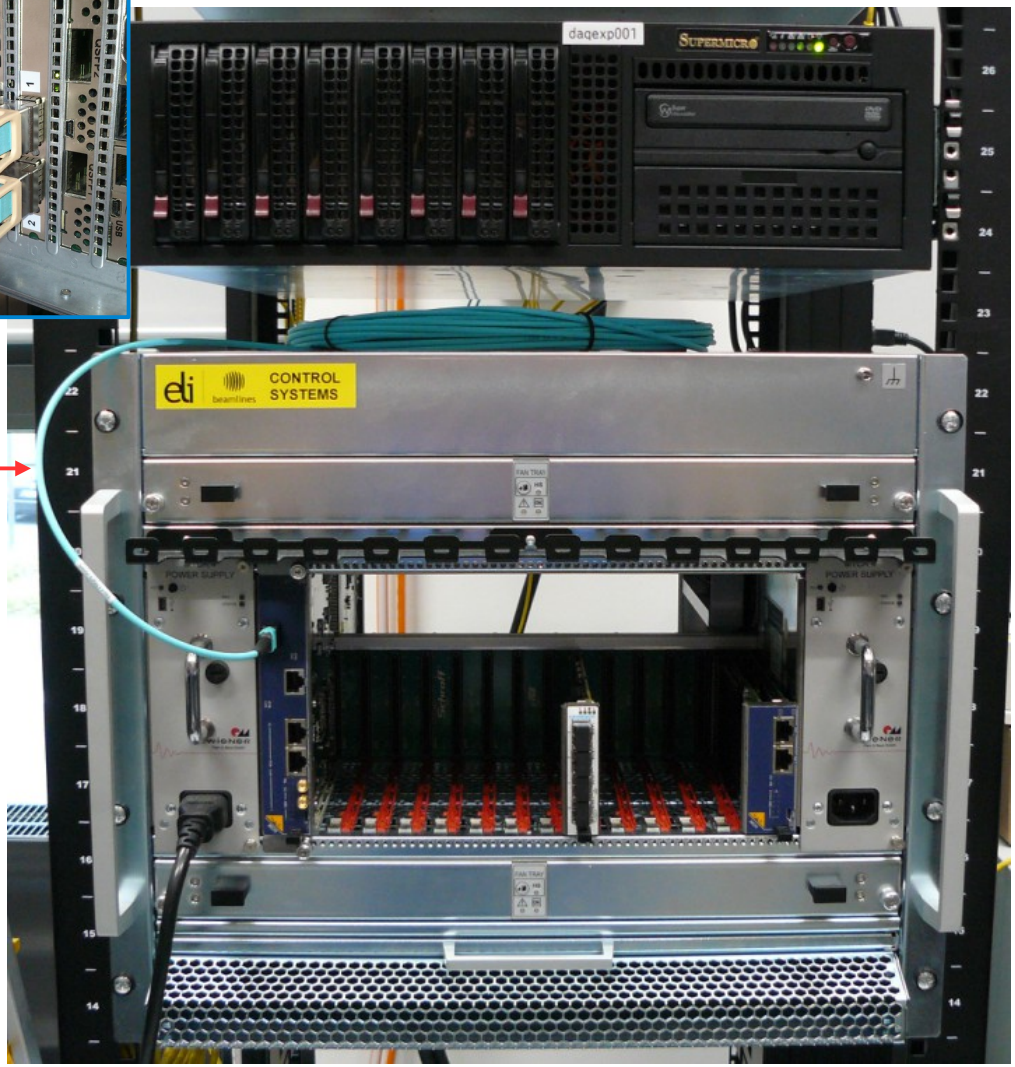
- 8x SFP+

NIC Vadatech AMC211

- 2x 10GBASE-X

DAQ Local Setup

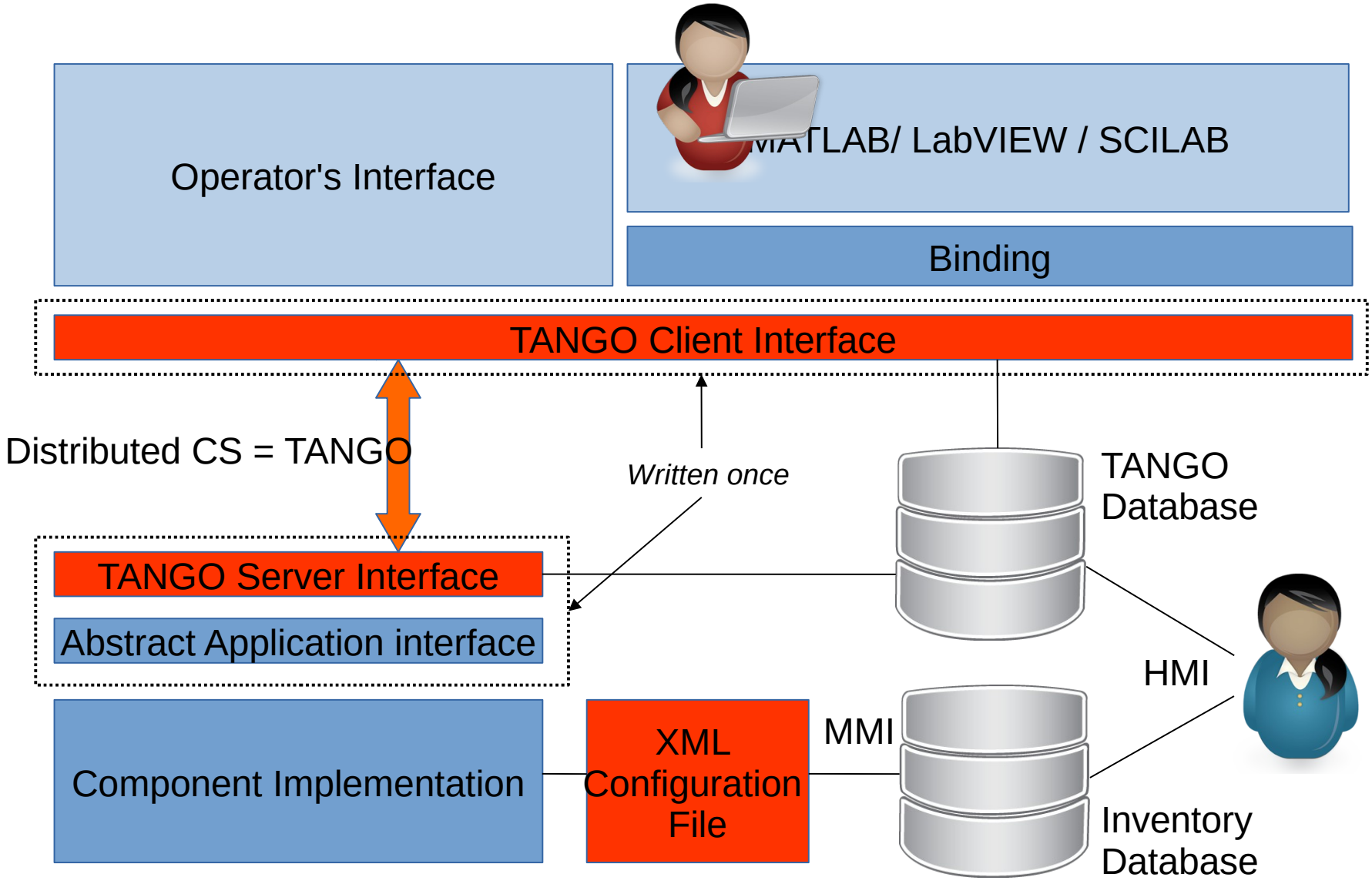




CS & DAQ Installations

CS & DAQ Installations

CS Software



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CS Software

HMI (GUI)

TANGO Interface

COMPONENT API

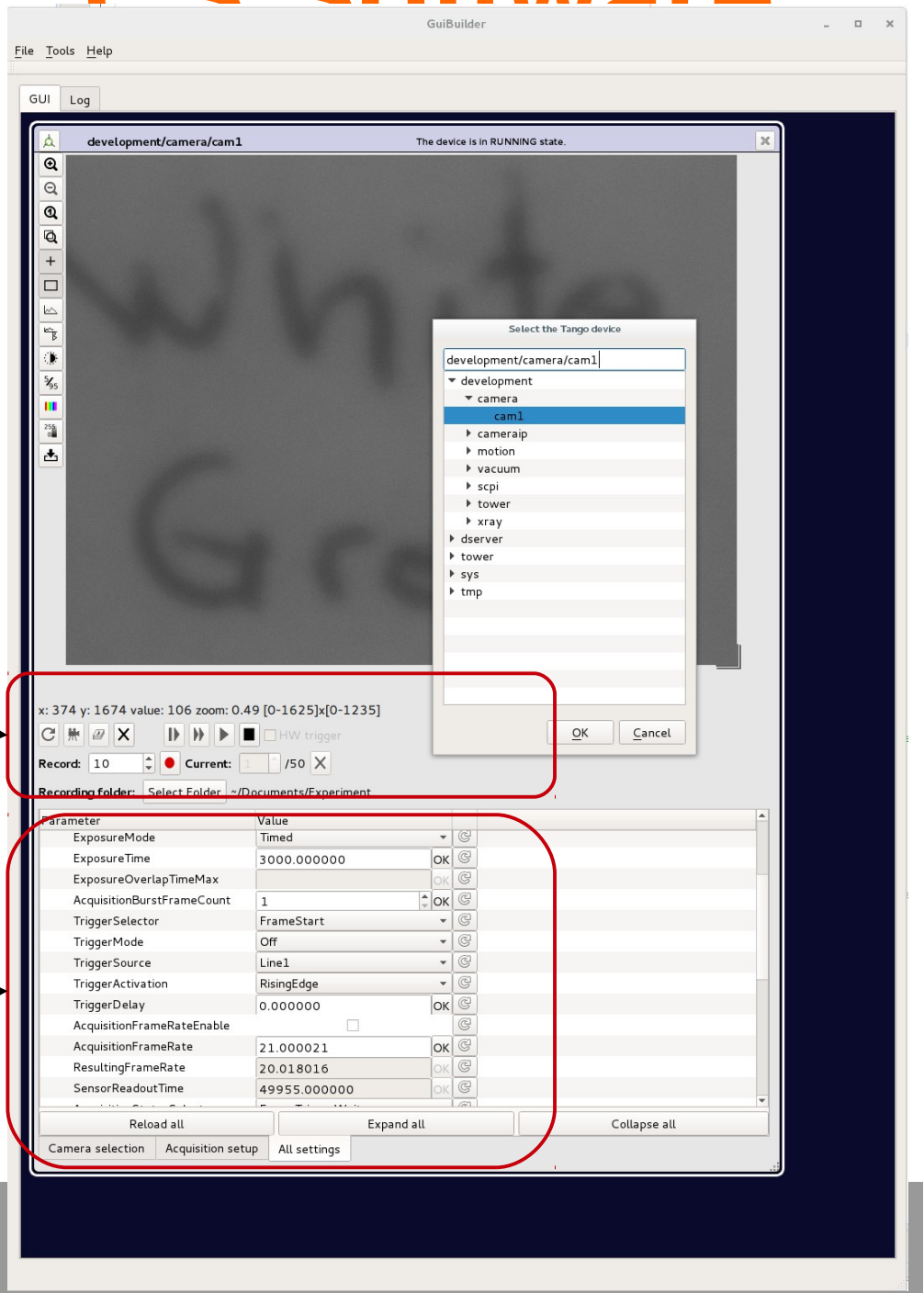
SOFTWARE COMPONENT

XML Configuration

Component API –
Defines Component GUI Interface

Three sources of XML:

- Local file (User def.)
- Inventory DB (Start)
- Data Stream (HMI/GUI)



CS Software

Plugins

- Reuse API
- Component does not have to be even recompiled
- New HW support may be simply into control system

Plugin API

- Extremely simple
- Version support (taken from git tag)

```
template<typename T> class Plugin
{
public:

    Plugin();

    ~Plugin();

    void attach(const std::string path);
    void detach(void);

    T* operator->(void) const throw(csexception::CSRuntimeError);

    uint32_t majorVersion(void);
    uint32_t minorVersion(void);
    uint32_t patchVersion(void);
}
```

CS Software

Industrial System Interface

- Industrial IO Abstract API
- Fieldbus Abstract API

Industrial IO Abstract API

- All standard interfaces are defined
- Digital IN/OUT, Analog IN/OUT, Stepper Drivers, etc

```
class DigitalInput
{
public:

    virtual const bool operator[](const std::size_t idx) const = 0;
    virtual uint32_t size(void) const = 0;
    virtual uint32_t ports(void) const = 0;
    virtual uint32_t getPort(const uint32_t port, bool &isValid) const = 0;
    virtual uint32_t portSize(const uint32_t port) const = 0;
    virtual bool getBit(const uint32_t bit, bool &isValid) const = 0;

…

class AnalogInput
{
public:

    virtual const double getVoltage(const std::size_t idx) const = 0;
    virtual double max(const uin32_t channel) const = 0;
    virtual double min(const uin32_t channe) const = 0;
    virtual uint32_t ports(const uin32_t channe) const = 0;

...
```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CS Software

Industrial System Interface

- Industrial IO Abstract API
- Fieldbus Abstract API

Fieldbus Abstract API

- All necessary functions are supported
- Actually PowerLINK and EtherCAT

```
class csfbus
{
public:

    virtual FbusState initialize(void) = 0;

    virtual FbusState shutdown(void) = 0;

    virtual FbusResponse discover(CSAPISet &apiSet) = 0;

    virtual FbusState start(void) = 0;
```

ICALEPCS 2017: Control System Software Environment in ELI Beamlines
ICALEPCS 2017: Cameras in ELI Beamlines: A Standardized Approach

Thank you for attention!