Rethinking PLCs:

INDUSTRIAL ETHERNET FOR LARGE-SCALE REAL-TIME DISTRIBUTED CONTROL APPLICATIONS

Birgit Plötzeneder

on behalf of the ELI Beamlines CS Team

FZÚ

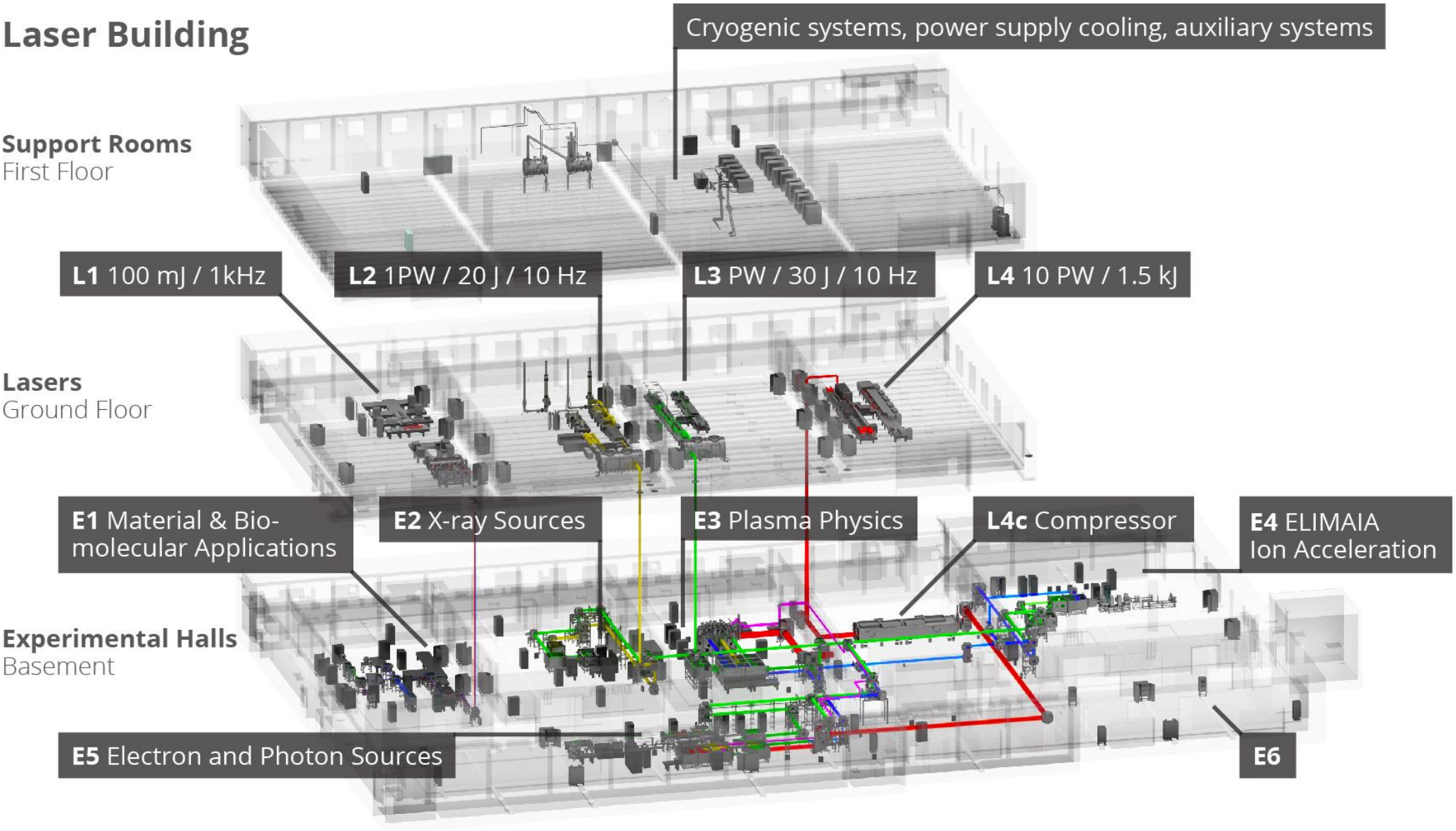
EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

ELI: Distributed laser research infrastructure in Czech Republic, Hungary, Romania

User facilities, just under construction

Scope


Laser Building
Cryogenic systems, power supply cooling, auxiliary systems
Support Rooms
First Floor
L1 100 mJ / 1kHz
L2 1PW / 20 J / 10 Hz
L3 PW / 30 J / 10 Hz
L4 10 PW / 1.5 kJ
Lasers
Ground Floor
E1 Material & Bio-molecular Applications
E2 X-ray Sources
E3 Plasma Physics
L4c Compressor
E4 ELIMAIA Ion Acceleration
Experimental Halls
Basement
E5 Electron and Photon Sources
E6

Scope

Python
WhiteRabb
Beckhoff
Xilinx
MTCA
Linux
TANGO
B&R

Laser Building

Cryogenic systems, power supply cooling, auxiliary systems

C++

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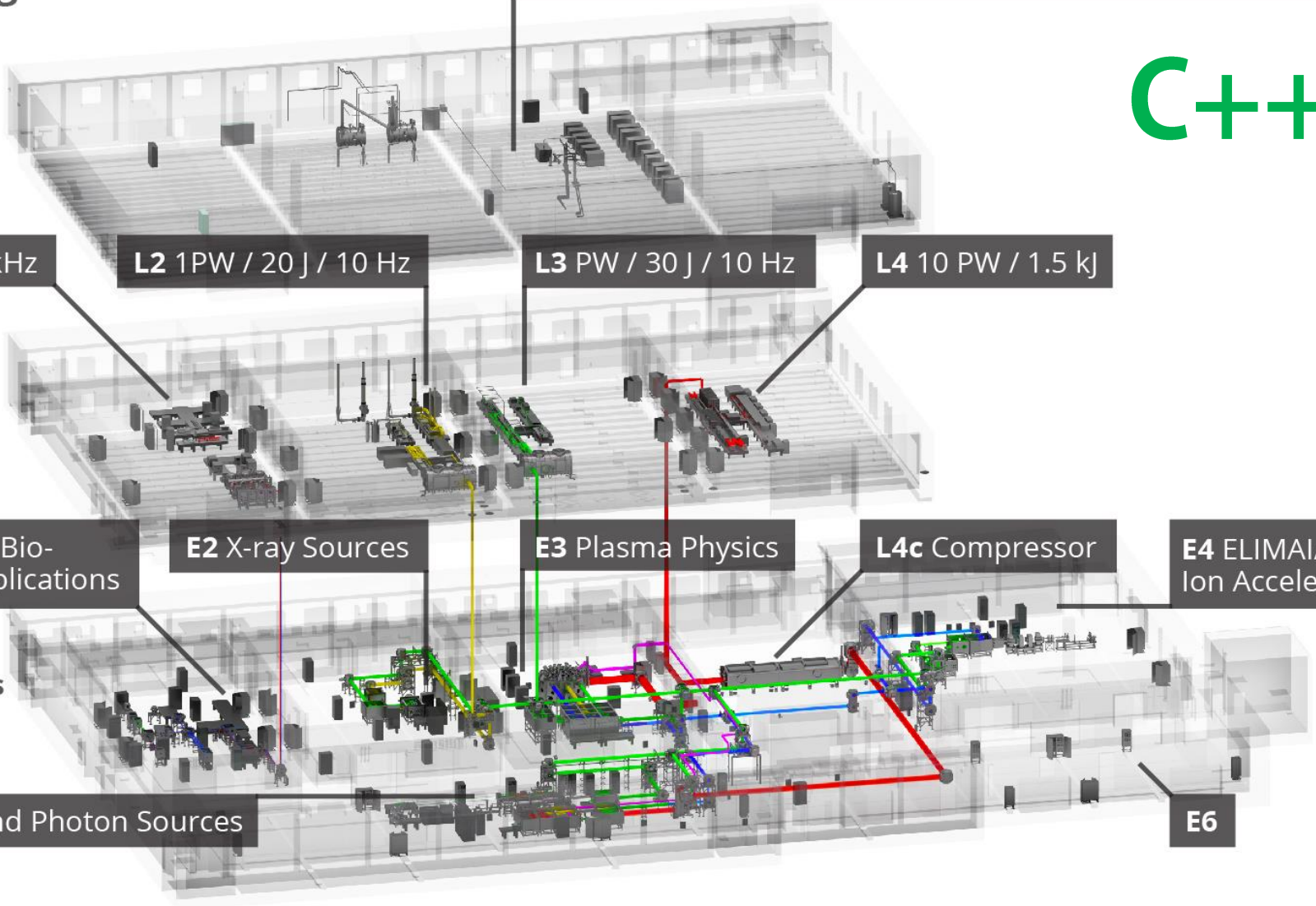

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Laser Building

Cryogenic systems, power supply cooling, auxiliary systems

Window
C++
Matlab
LabVIEW
EPICS
MRF
Rockwell

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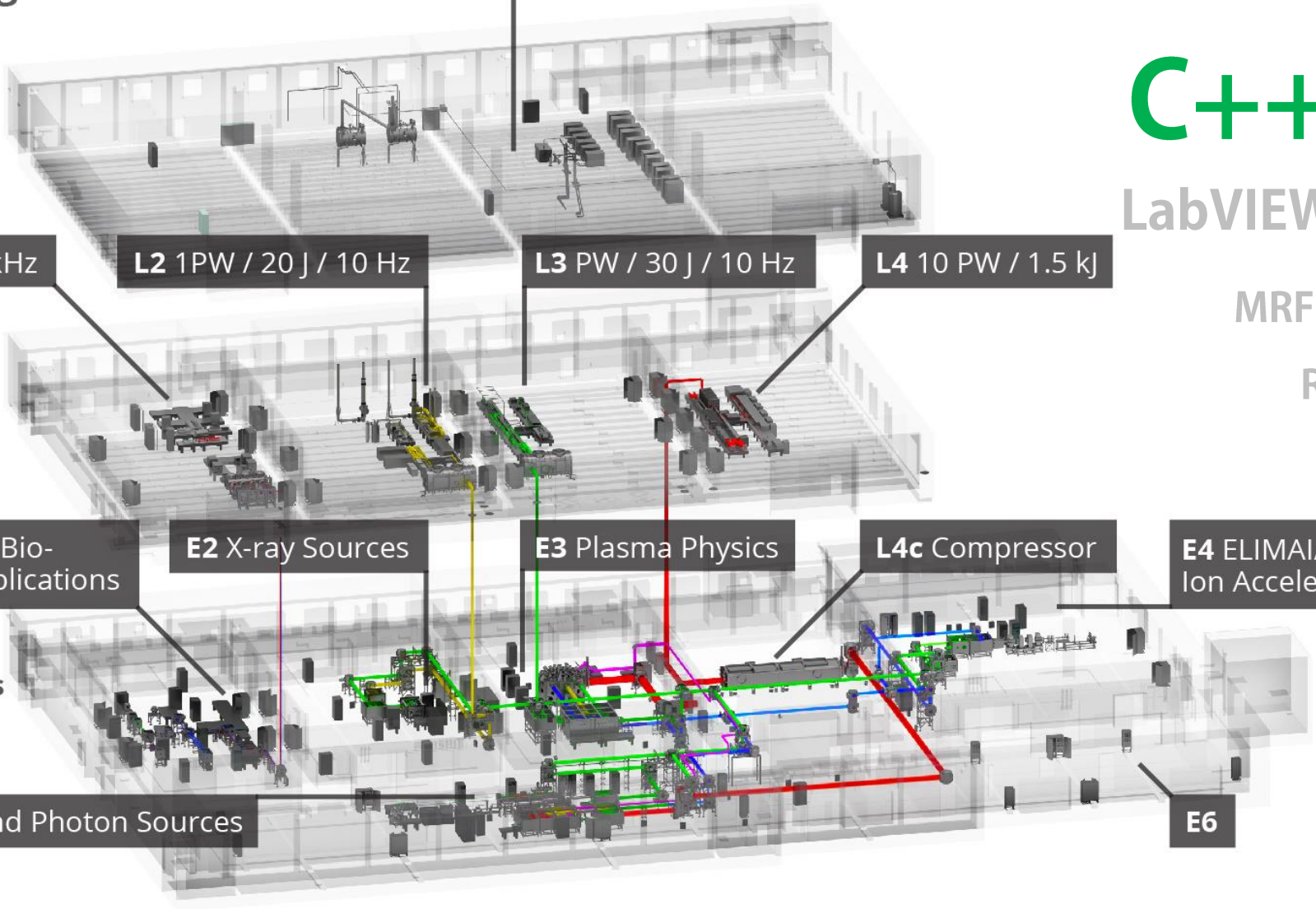

Scope

Python

WhiteRabb

Beckhoff

Xilinx

MTCA

TANGO

B&R

supply cooling, auxiliary systems

Window

C++

Matlab

LabVIEW

EPICS

0 PW / 1.5 kJ

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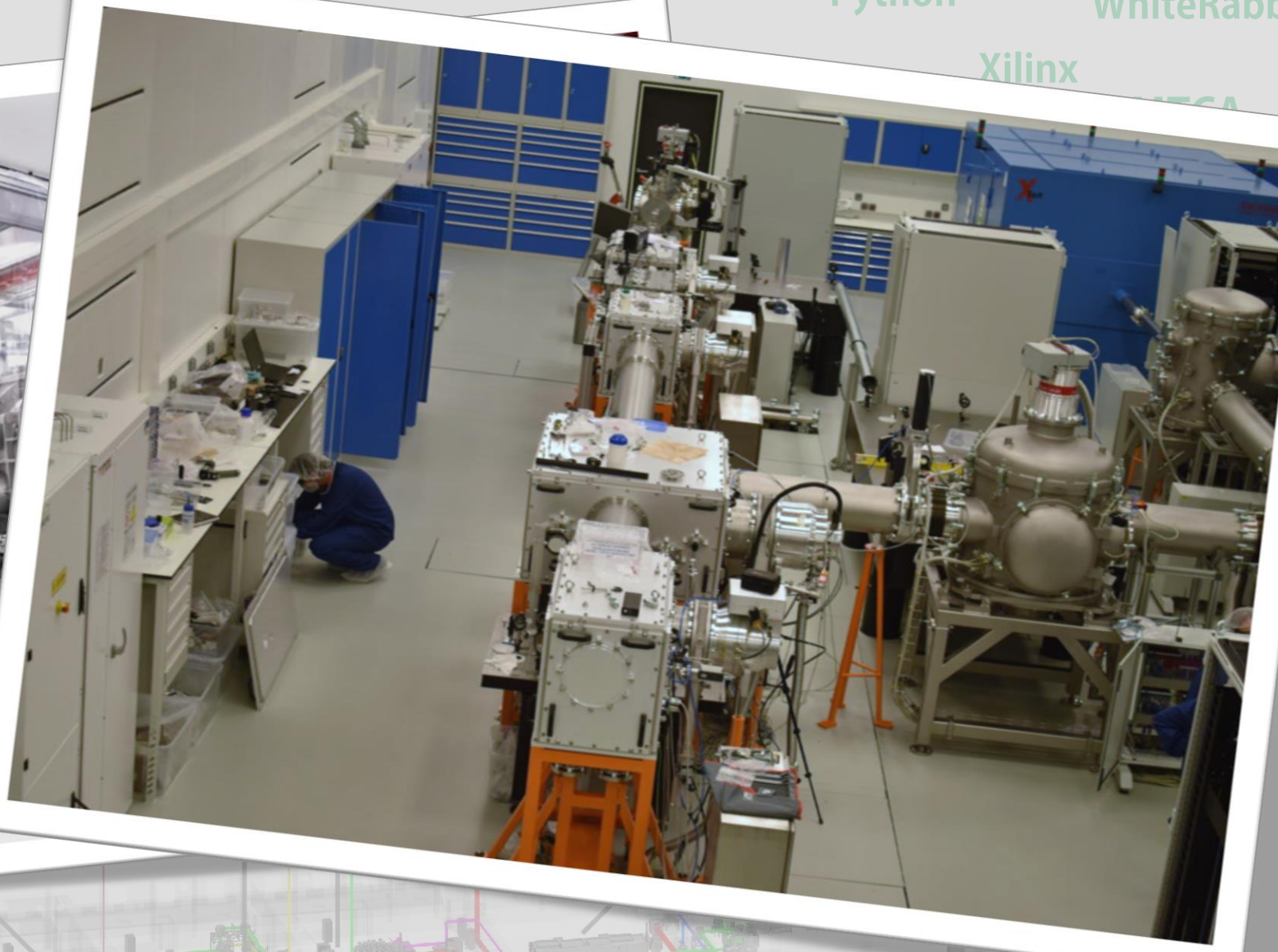
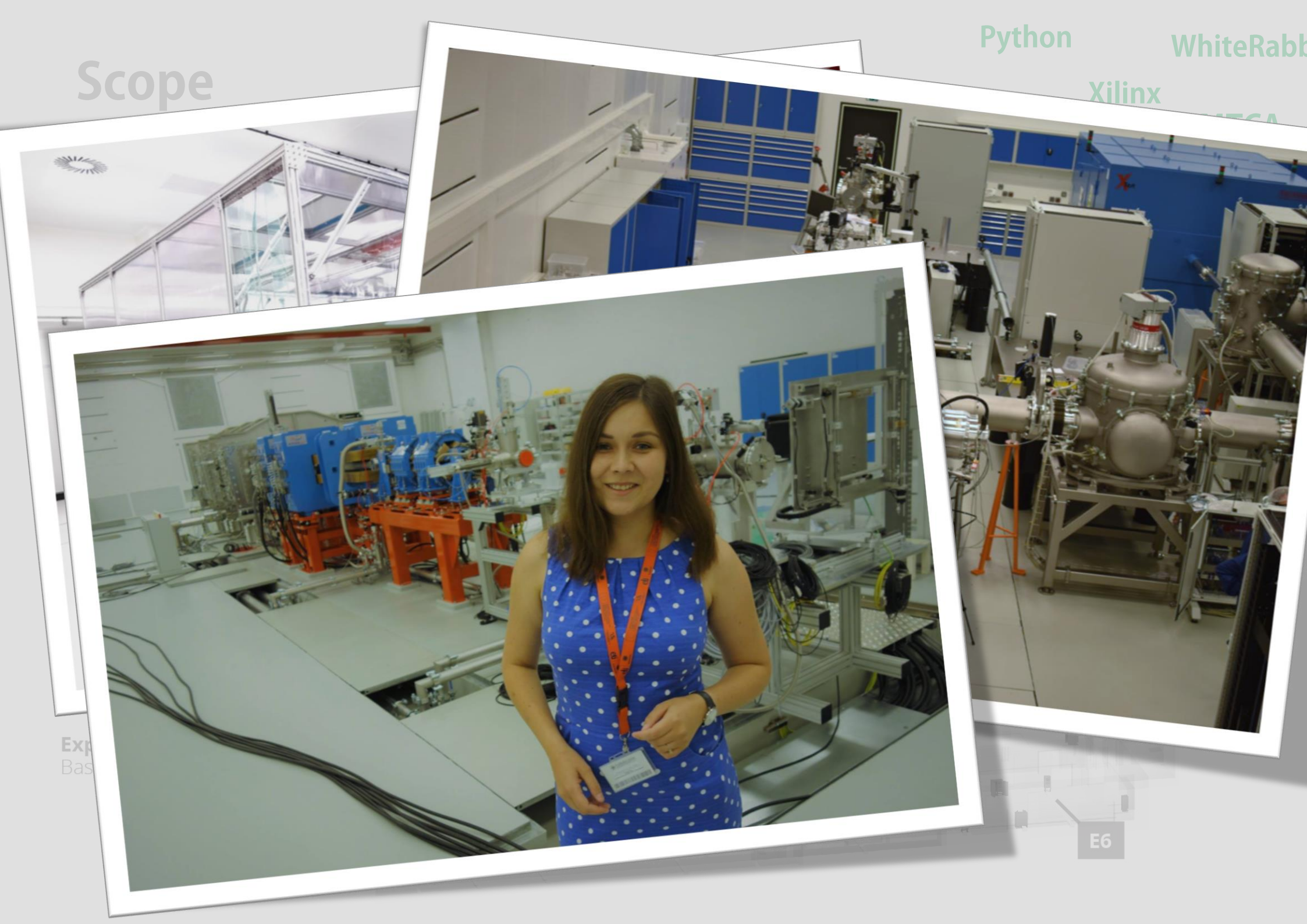


Experimental Halls
Basement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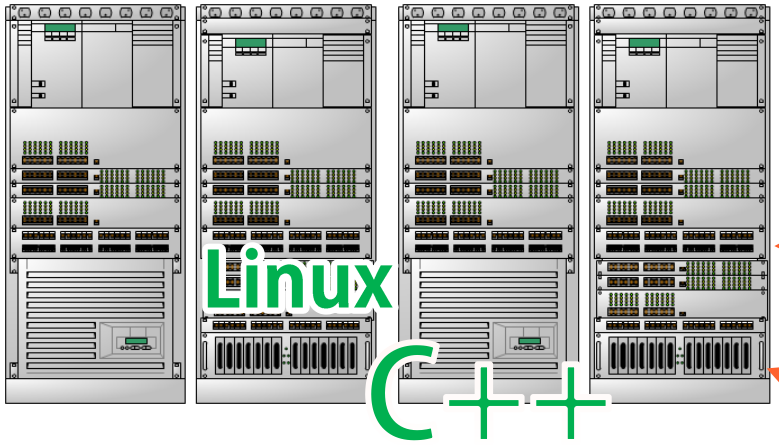
Default architecture

High Level CS



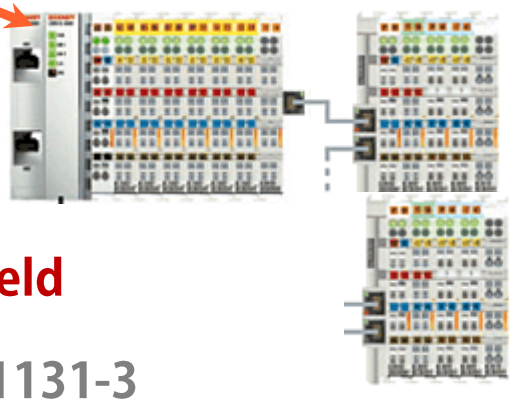
TANGO

Languages like C++, Python,..
Classical servers, often virtualized OS
Middlewares like EPICS, TANGO..
SCADA

OPC

Custom: TCP/IP, libraries,....

- Common Bus (Profibus etc)
- Hardwired



PLCs in the field

Often: IEC 61131-3
Proprietary software
Small, isolated control nodes (CPU + some modules, small industrial Ethernet networks)
Slow process control

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Default architecture

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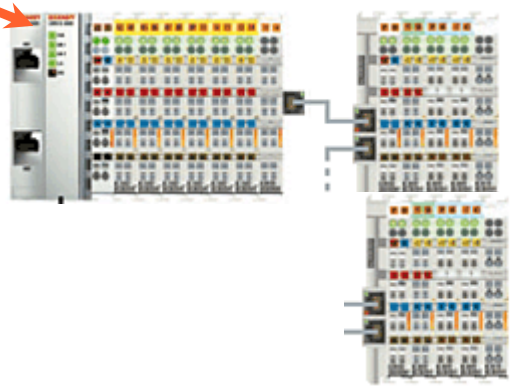

We like that PLCs are **cheap**, **reliable**, **modular** and **fault-tolerant** "hard" **real time** control solutions, even in challenging environments.

But:

- Not a lot of CS engineers can do C++, LabVIEW and PLC. **Multiple skillsets** have to be developed, SD environments maintained.
- **Interfaces are costly** (manpower) and often **awkward**.

=> PLCs are often almost standalone local control units with a thin connection to the main CS.

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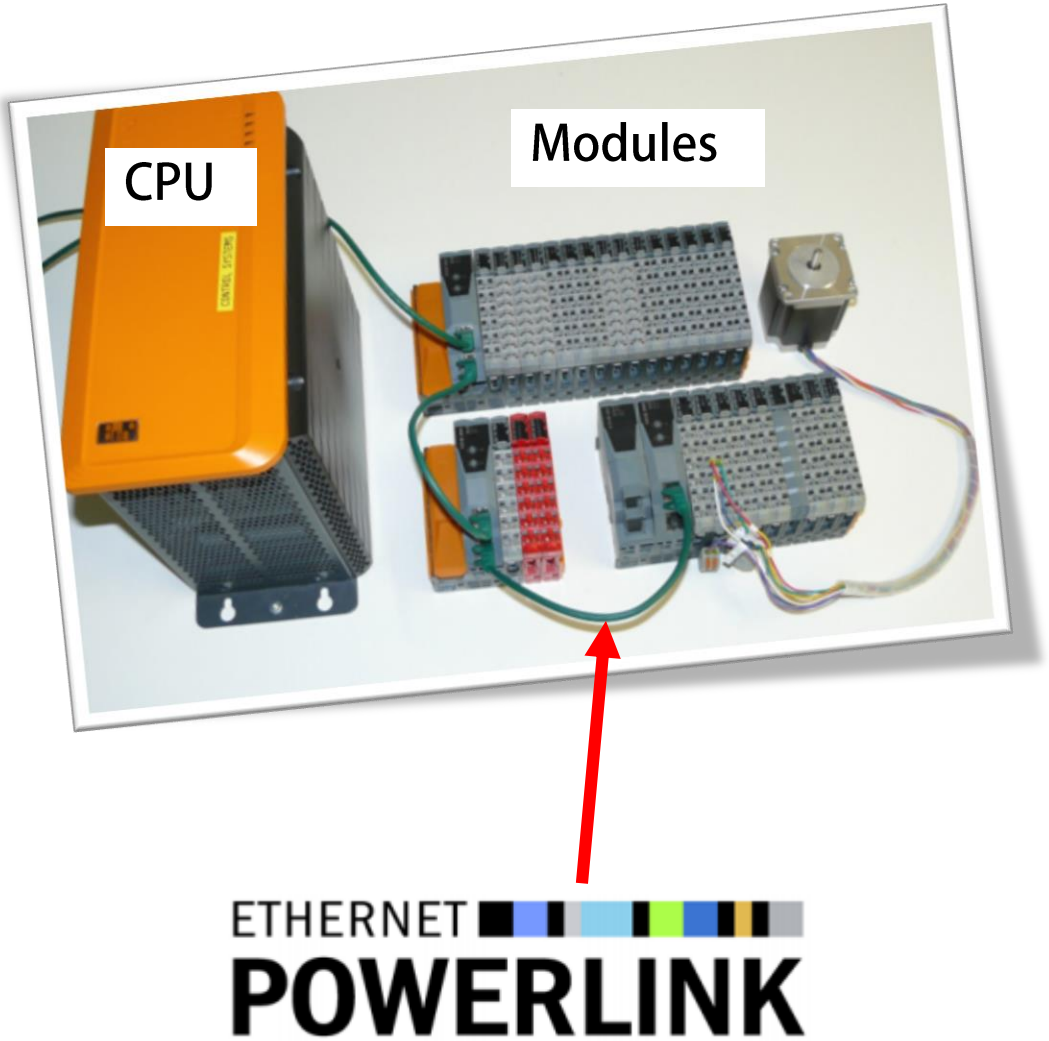
Let's try a more native approach.



1) Start with a PLC with an open industrial Ethernet protocol

Multiple vendors opened their stacks because they want to extend their ecosystem and encourage companies to create new modules.

We like Beckhoff (EtherCAT) and B&R (Powerlink)

2) Kick out the CPU, write an alternative master for instead, and distribute the stack over the entire facility network.

3) Profit.

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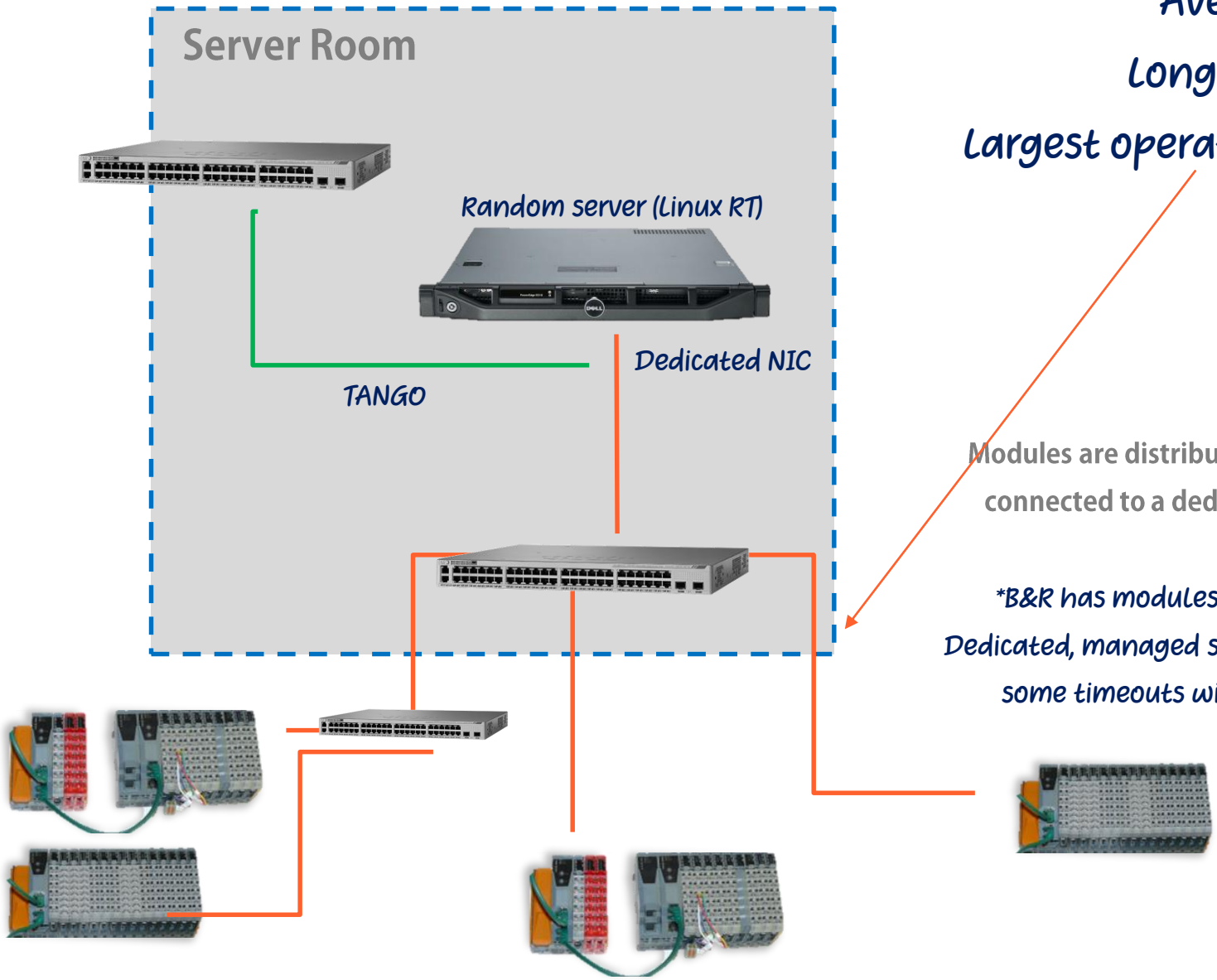
How this looks in real life



Average span: 250m

Longest distance: 450m

Largest operational system: 40 sub-units

Modules are distributed over entire facility, connected to a dedicated fibre network*

*B&R has modules with LC connectors!
Dedicated, managed switches are best. We had some timeouts with cheap hardware.

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How this looks in real life

Fieldbus-API

PowerLink

EtherCAT

Purpose: Control the bus
Abstraction of stacks provided by Beckhoff + B&R

CS-IO

Motor

DIO

AIO

Communication

...

Purpose: Implement typical modules

TANGO-Servers

LabVIEW Integration

Purpose: Integrate Into the facility

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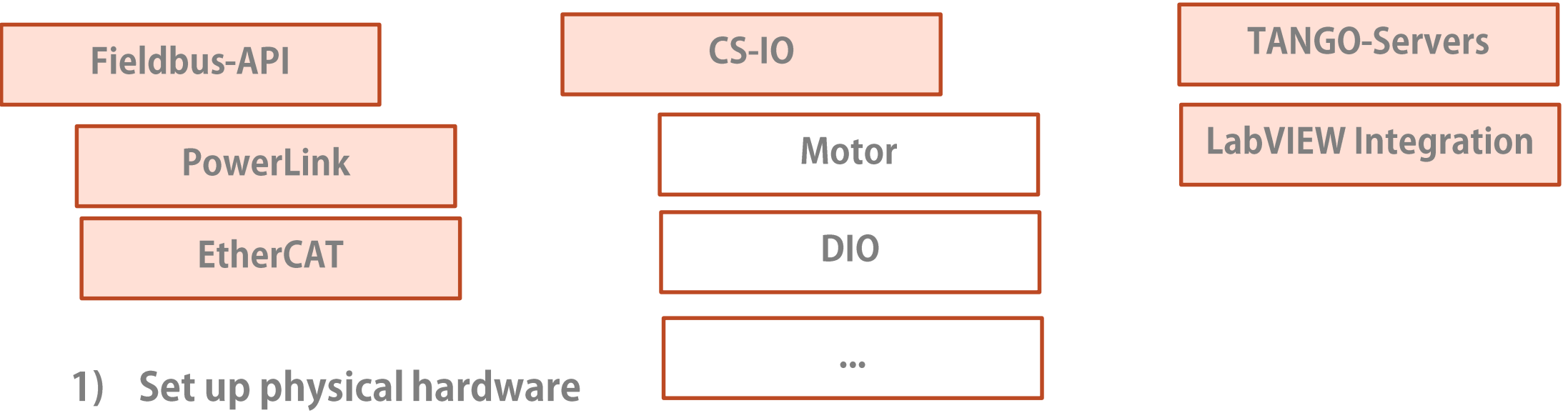
How this looks in real life



1) Set up physical hardware

2) Configure topology + registers with Automation Studio/System Manager

3) Fieldbus-API: Start (via TANGO Server)
starts physical modules in the background

4) Fieldbus-API: Discover (via TANGO Server)
returns collection of CS-IO modules (generates dynamic TANGO Attributes)

5) Commands: CSIO.dosomething, FieldBus.sync (in a loop)

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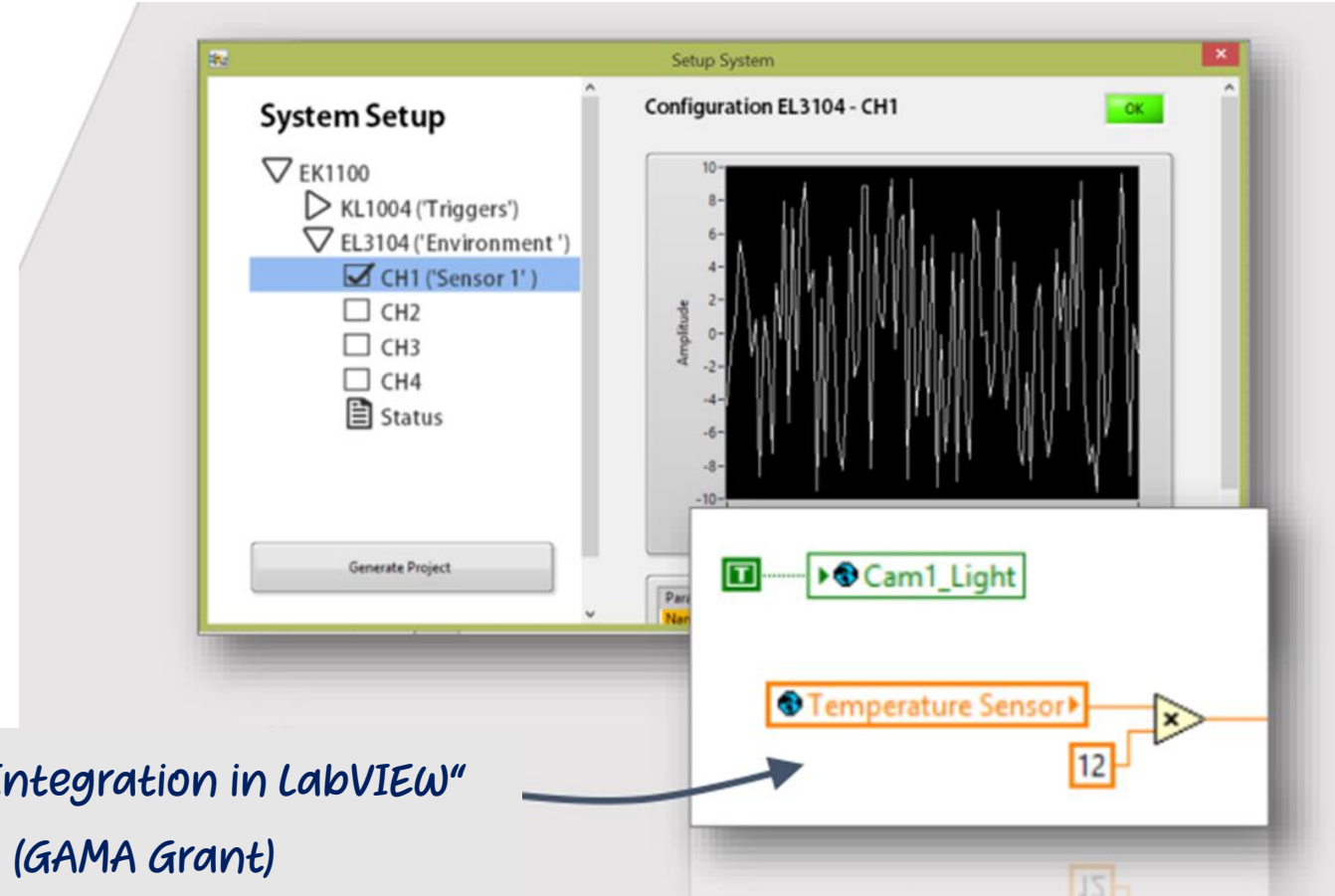
Where are we now

1) Largest setup: Beamline with 40 modules, ca 250m span, 10ms cycle time

2) Laser Interfaces: Vacuum + MSS
- Runs on National Instruments cRIO, ardwired signal exchange
Install a B&R head inside their rack, connect fibre - done.
New signal = just add a module.



„Native Integration in LabVIEW"

(GAMA Grant)

Where do we want to go

This is a large-scale functional prototype, but not quite ready.

1) **We want a TANGO Server for every module instead of dynamic attributes inside of one server.**

2) **We need to rework our top layer abstraction: We have nice generic motor / DIO /.. GUIs and APIs. We haven't yet combined this with the fieldbus API. The end user shouldn't know what they are dealing with..**

3) **Performance: Limitations and performance has to be quantified more accurately.**

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Thanks for the attention!

Our team is hiring!

CS Engineers with C++/Linux

System Admin

...

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