Adventures of an EPICS Developer: Navigating Across International Control Systems

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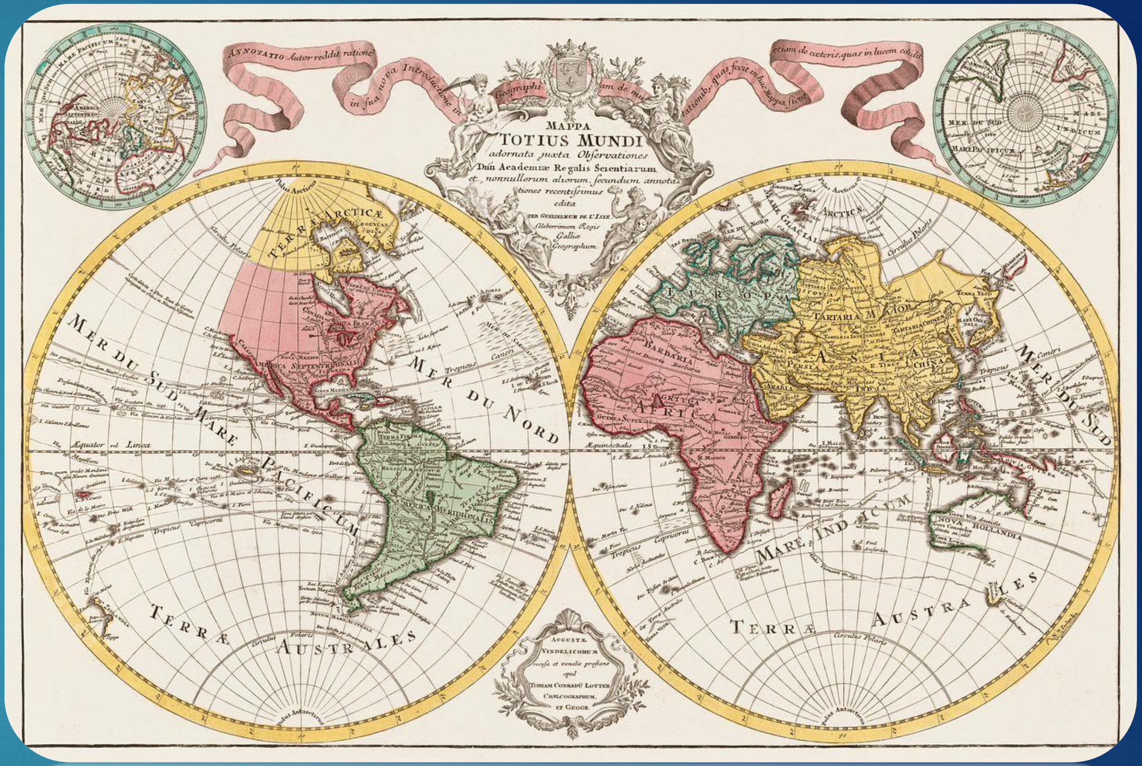
What is a Control System?

Contents

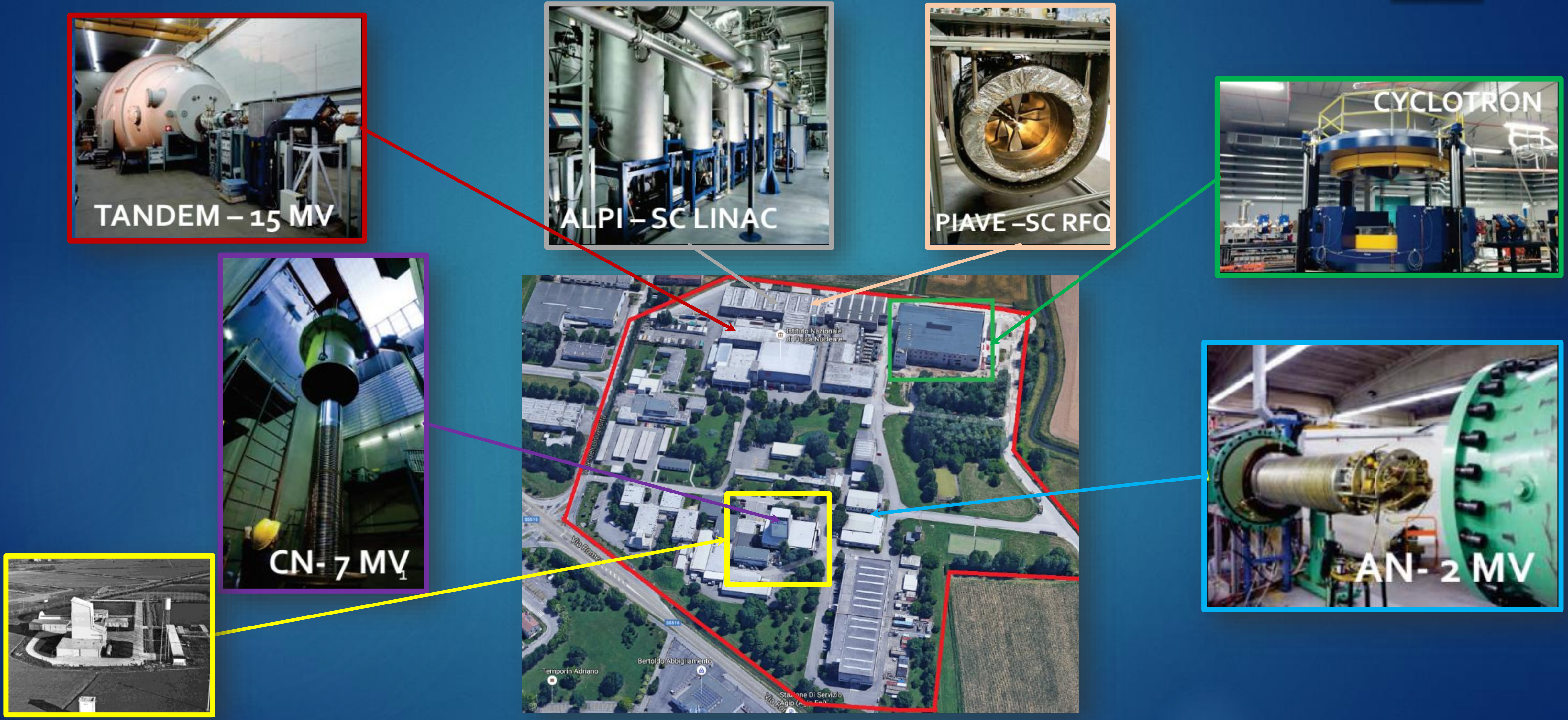
- LNL Facilities and SPES Project (Italy)
- IFMIF Project (Japan)
- ESS Project (Sweden)



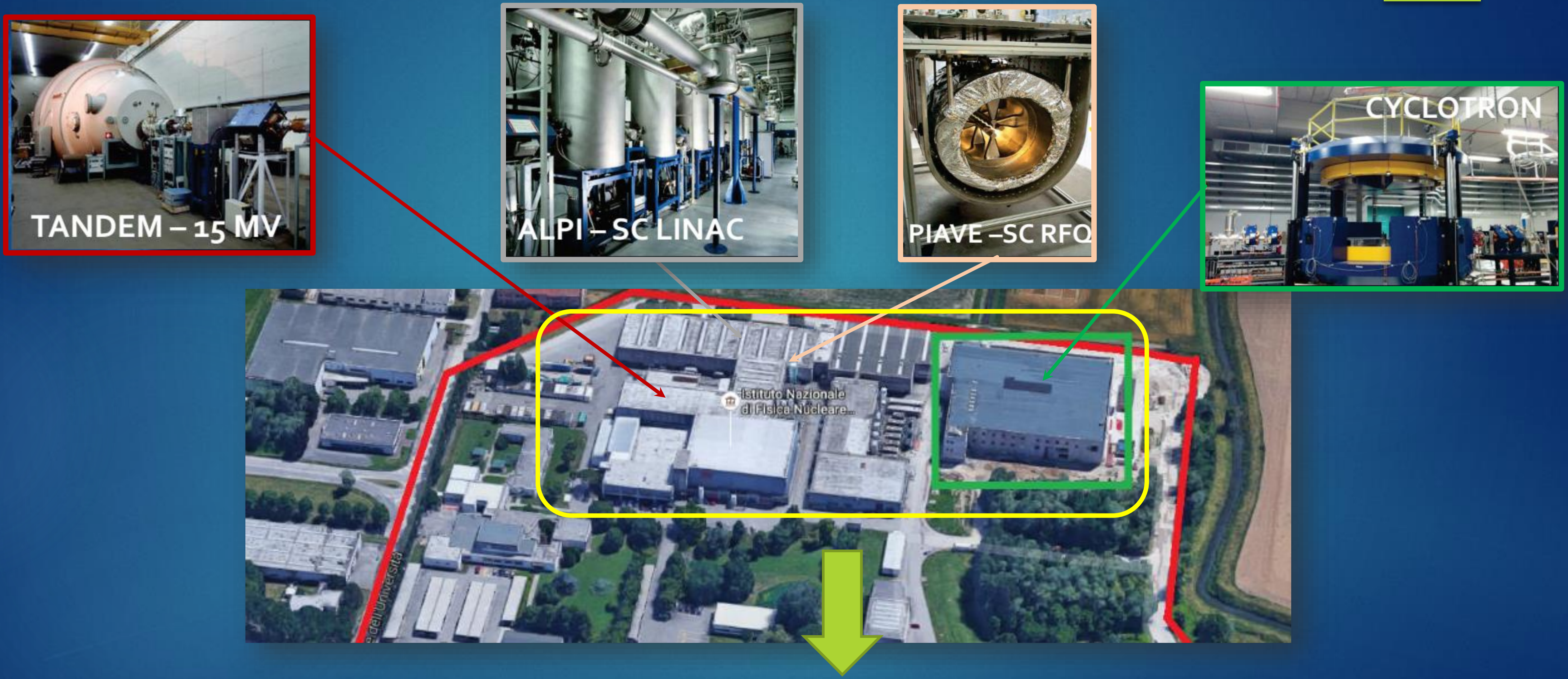
LNL Facilities and SPES Project

ITALY: WHERE EVEN THE TRAFFIC JAMS HAVE STYLE, AND ARGUING WITH YOUR HANDS IS CONSIDERED AN ART FORM

INFN and Legnaro National Labs

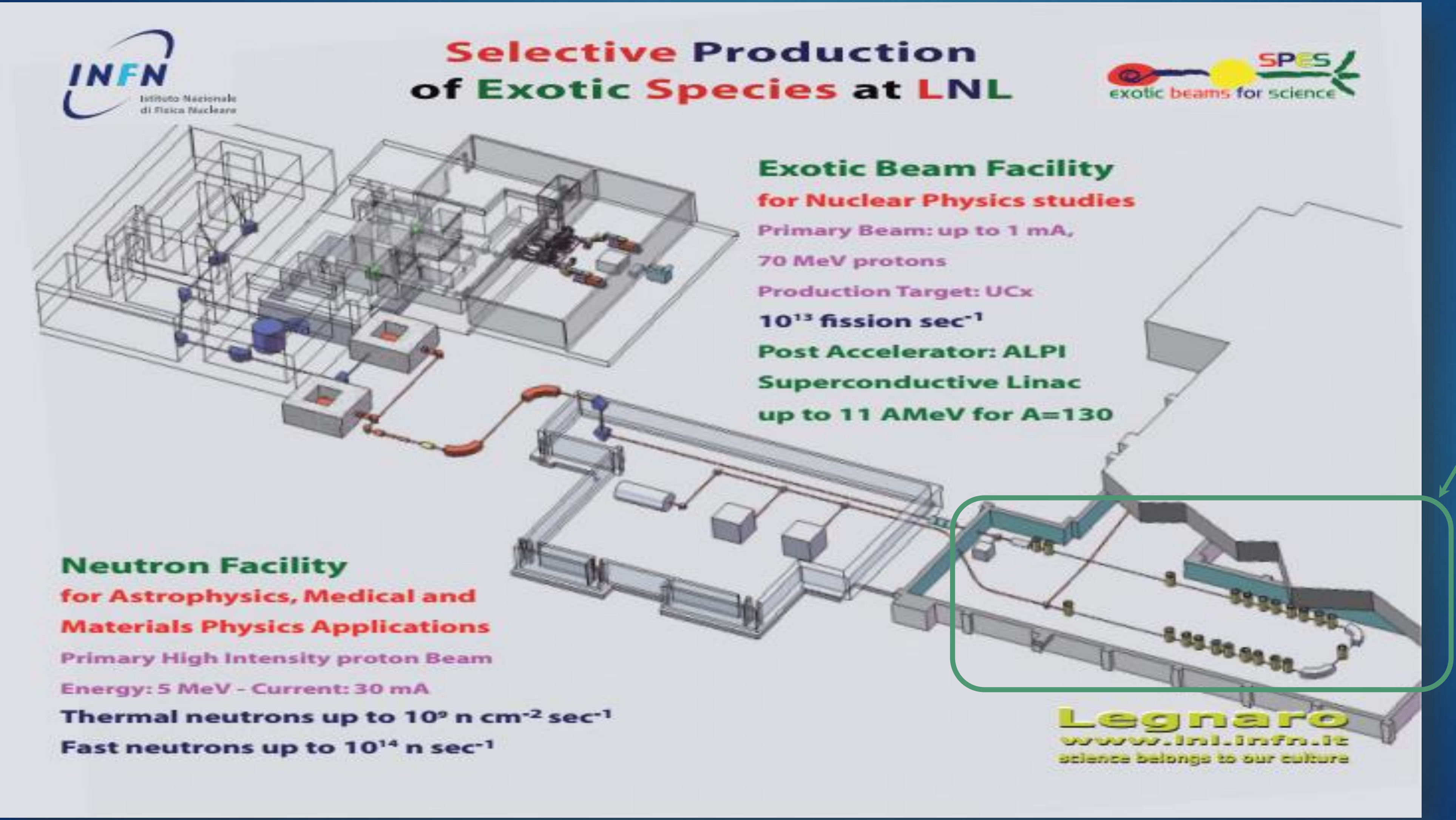


INFN and Legnaro National Labs



SPES Project

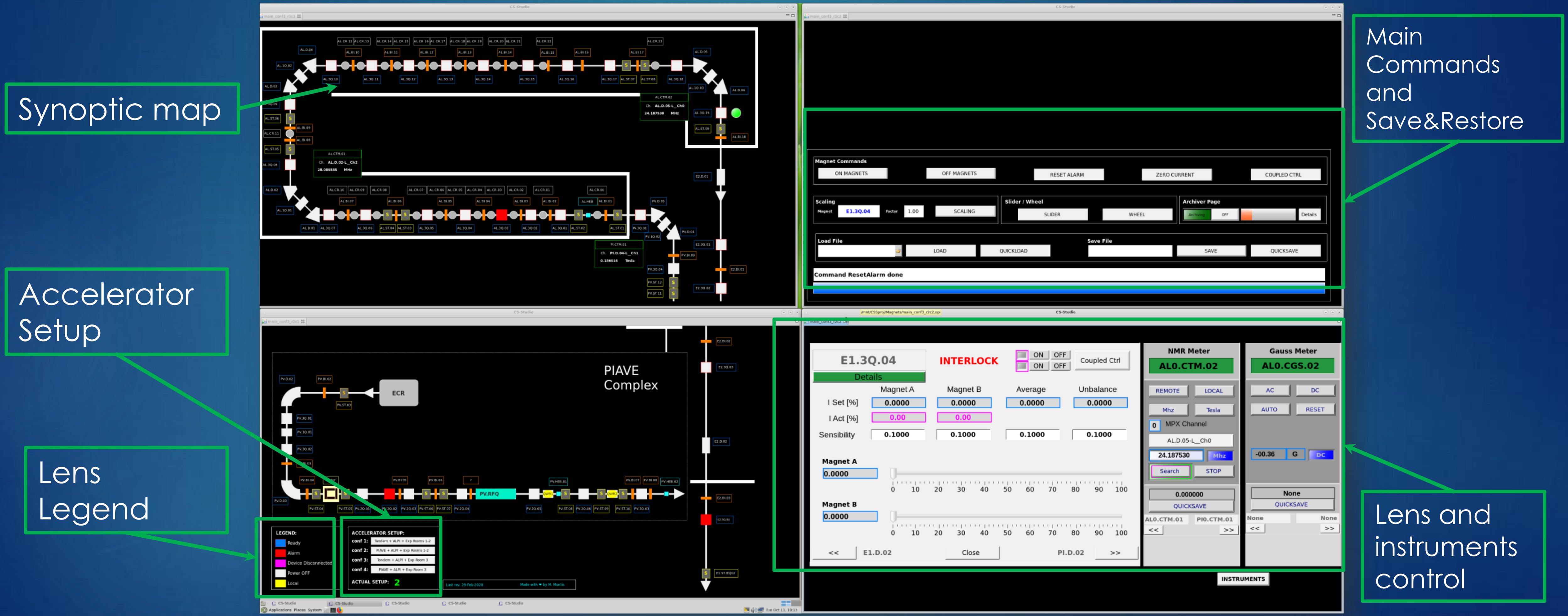
SPES @ Legnaro National Laboratories



Beam Transport Lines for PIAVE-ALPI lines

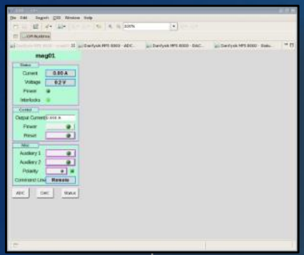
PIAVE-ALPI Beam Transport Lines

Synoptic from Human-Machine Interface

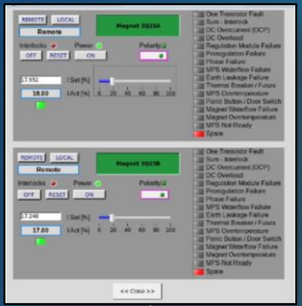


Beam Transport Control System Evolution - GUI

First Prototype

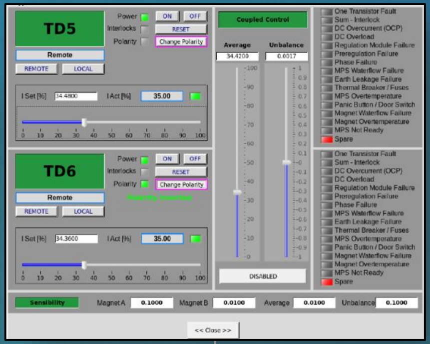


First Magnet GUI

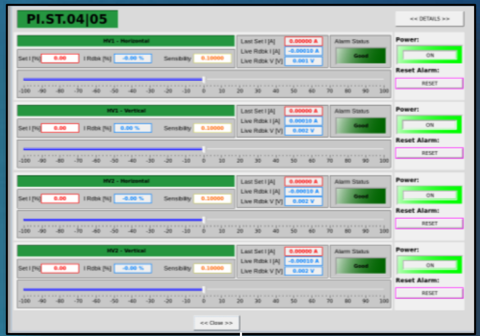


First Steerer GUI

Upgrade Magnet GUI

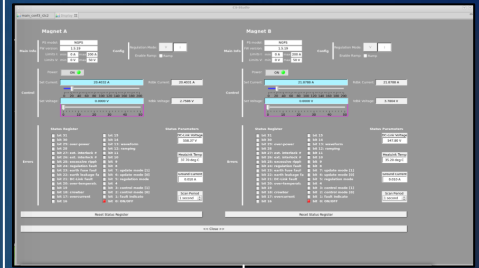


Add new Steerer GUI



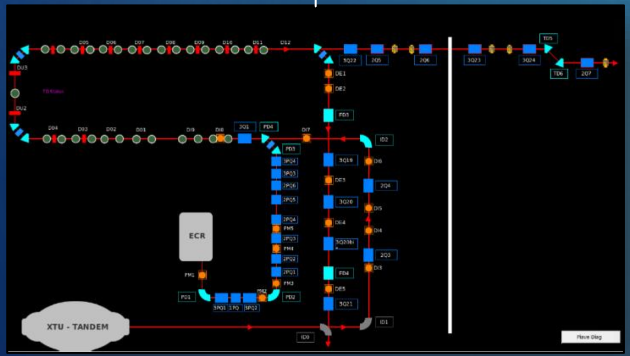
Upgrade Naming Convention

Add new Magnet GUI

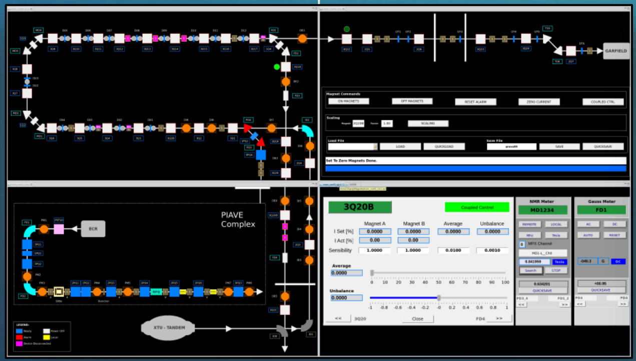


Timeline

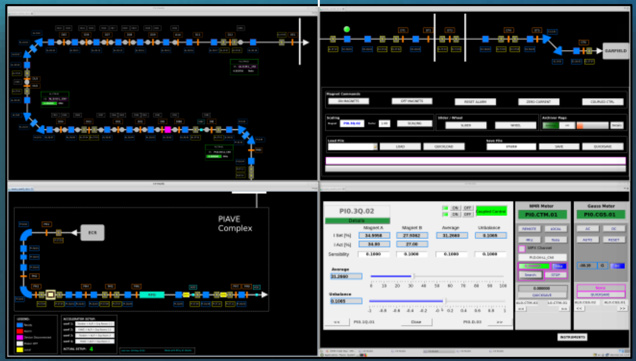
2013 2014 2015 2016 2017 2018 2019 2022



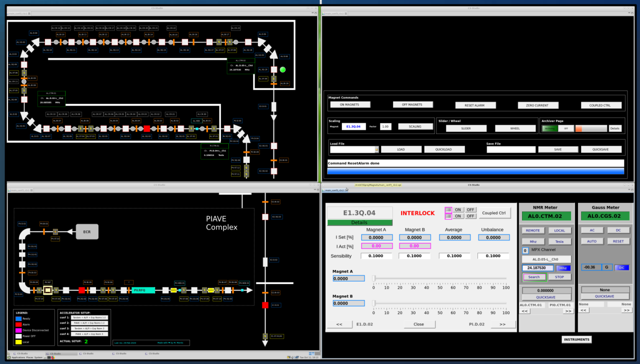
First Synoptic



New Synoptic with 4 monitor



Upgrade Synoptic #1

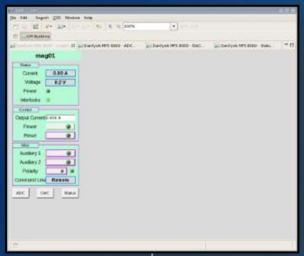


Upgrade Synoptic #2

Beam Transport Control System Evolution - HW

Upgrade Naming Convention

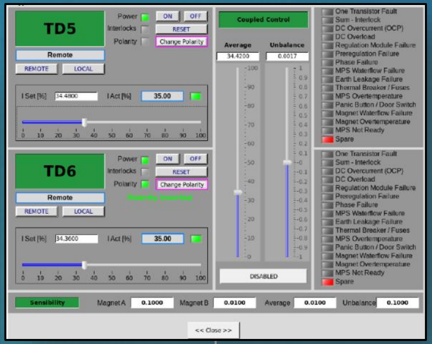
First Prototype



First Magnet GUI

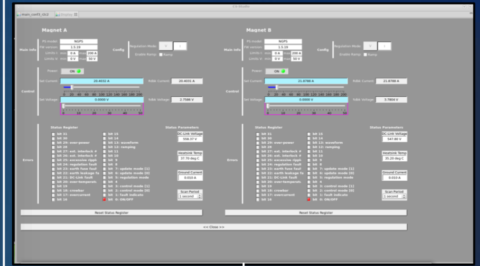
First Steerer GUI

Upgrade Magnet GUI



Add new Steerer GUI

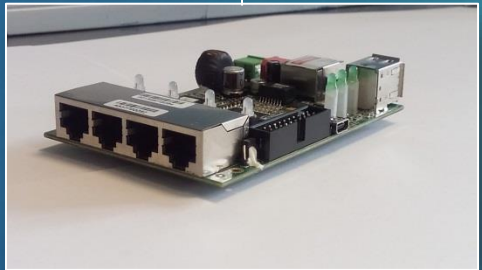
Add new Magnet GUI



Timeline

2013 2014 2015 2016 2017 2018 2019 2022

First Prototype



ARM Based EPICS IOC
In production since **December 2014**

Devices with Ethernet communication

PROXMOX **VM**
(Only for new devices)

Devicemaster (Serial-to-Eth)
in production since **September 2022** (in substitution of INTEL IOC)

Beam Transport Control System Evolution

Timeline

2015

Development of the Beam Transport System on 3rd Room line
+
Online debugging of the polarity reversal system of the dipoles

Modification to the sensitivity adjustment of magnet setpoints
+
Independent management of precision adjustment for each individual magnet's setpoint

Introduction of the management of dipoles and quadrupoles in coupled mode

Rewriting the communication driver for "vintage" Danfysik boards

Introduction of the Save&Restore system based on Cloud
+
Introduction of general commands for system management:

- Save & Load
- QuickSave & QuickLodad
- Alarm Reset
- Zero Current Magnets
- Off Magnets

Extension of the Beam Transport System to cover the entire High Beta region (from MD3 dipole)

Second modification to the sensitivity adjustment of magnet setpoints

Software development:

- NRM
- Gauss Meter

Save&Restore update (addition of Steerer management)
+
Introduction of general commands for system management:

- Fattore di riscalatura

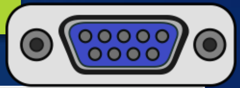
Extension of the Beam Transport System to cover the entire ALPI accelerator

Giant Monitor Supervision

2016

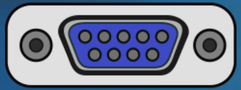
Engineering of the Driver Broker for PIAVE power supplies

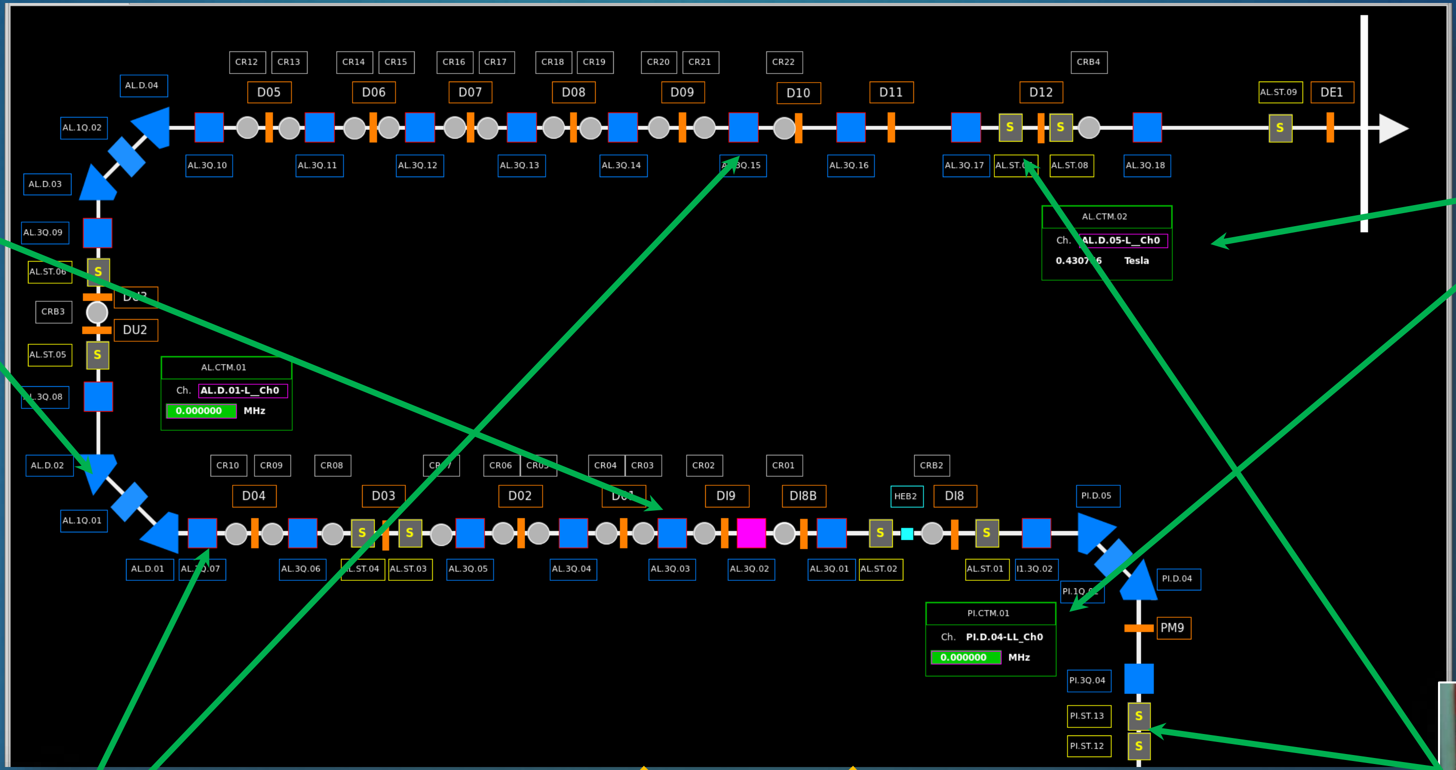
Hardware used in the PIAVE-ALPI lines



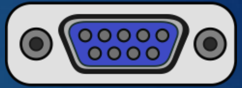
NMR Meter

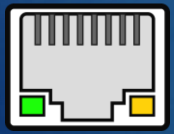
Lens PS





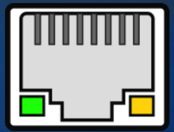
Gauss Meter





Lens PS (+ controller)

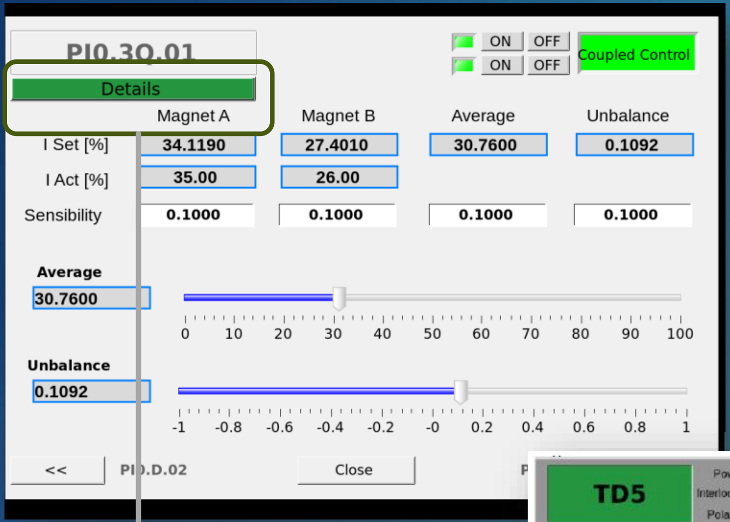
Old Steerer PS

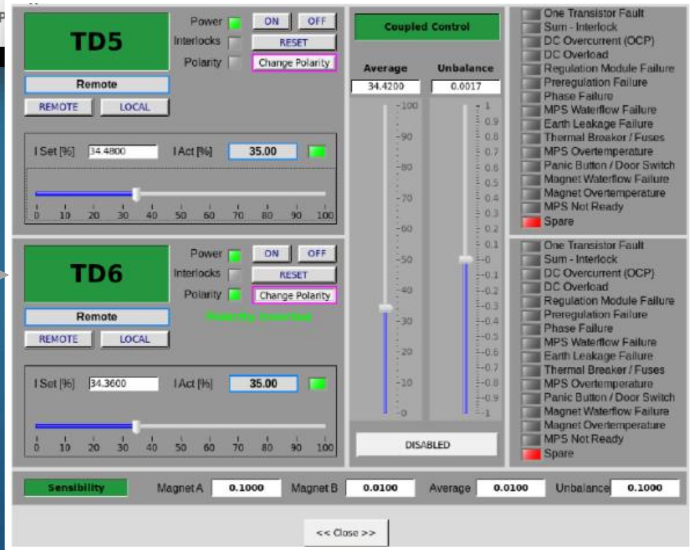


Steerer PS

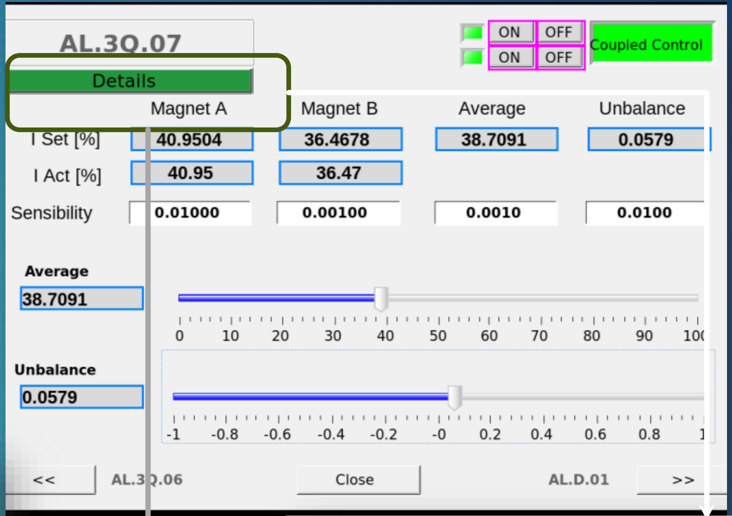
Lens Control

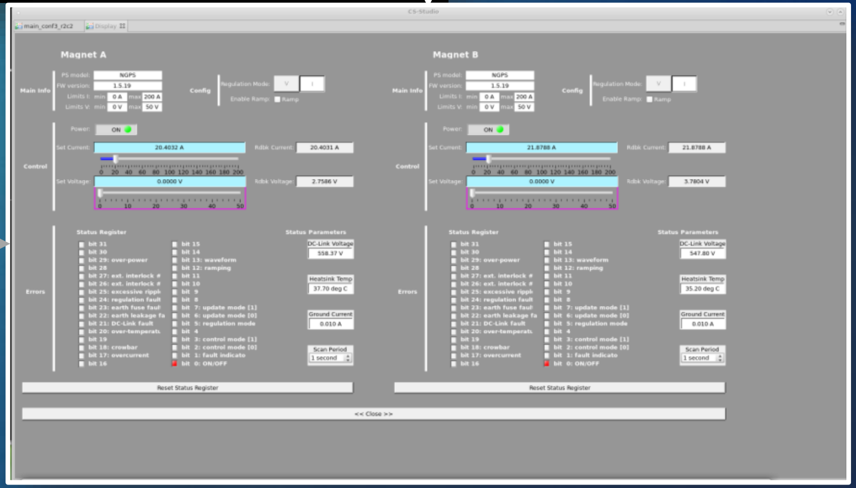
Danfysik Power Supply





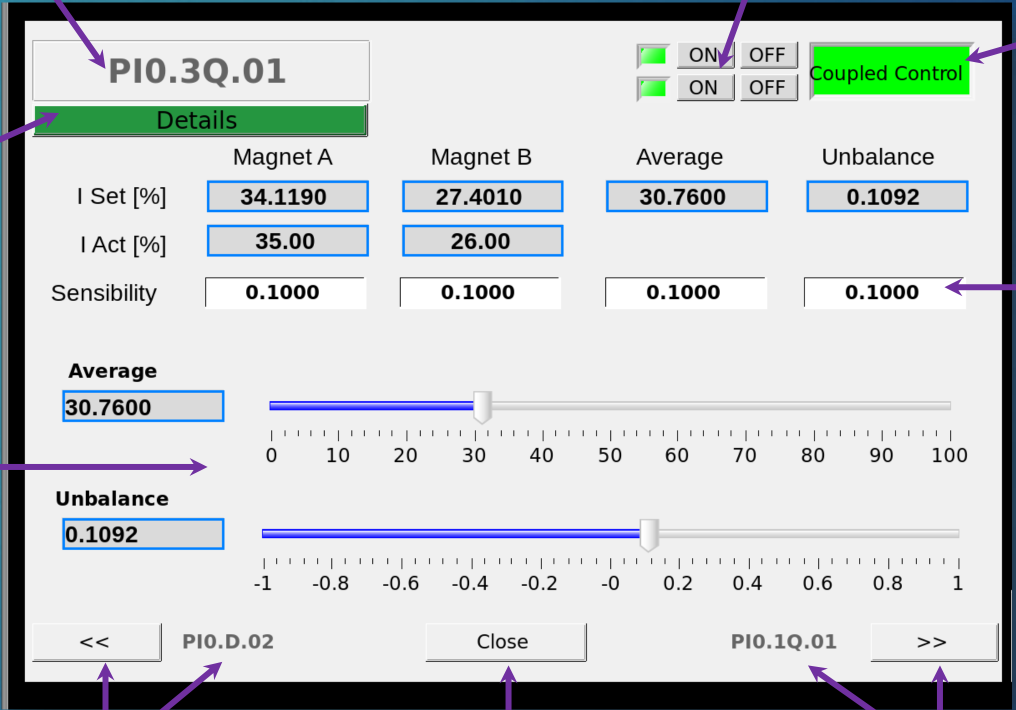
Caenels Power Supply





Lens Control

Features:
- Lens name display
- Coupled control
- Setpoint



Lens Name

Power ON/OFF command

Coupled Control

Lens Details Panel

Slider Sensitivity

Sliders/wheels:
- Average and unbalance
- PS A and PS B

Note:
setpoint and readback in % (not A)

Previous Lens (command + Name)

Close navigation panel

Next Lens (command + Name)

Steerer Control

Steerer Name

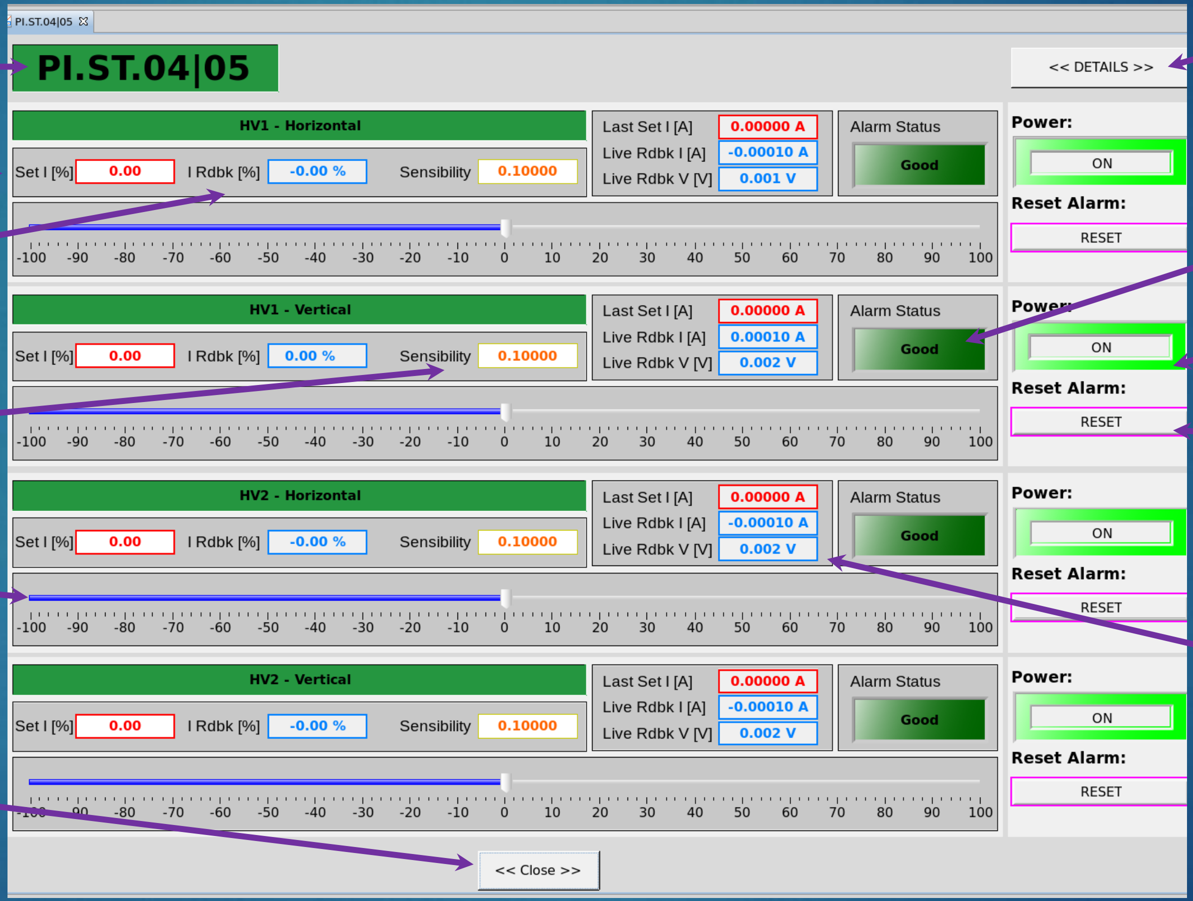
Setpoint value

Readback value
(in percentage)

Sensitivity

Setpoint slider

Close Panel Window



Details Panel

Alarm Status

Power Command

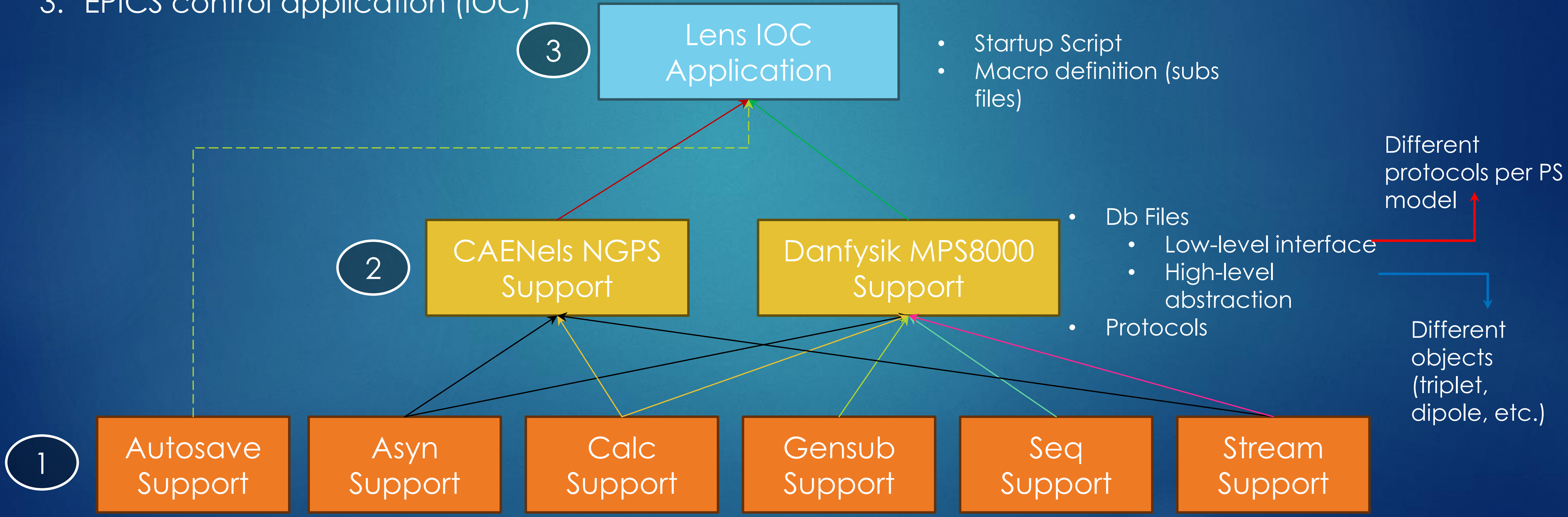
Reset Command

Readback values
(in Ampere/Volt)

Note:
setpoint in **%**
readback in **A**

EPICS Software Structure for Lens Control

Main Groups:
1. EPICS Community Modules
2. LNL Custom Modules
3. EPICS control application (IOC)

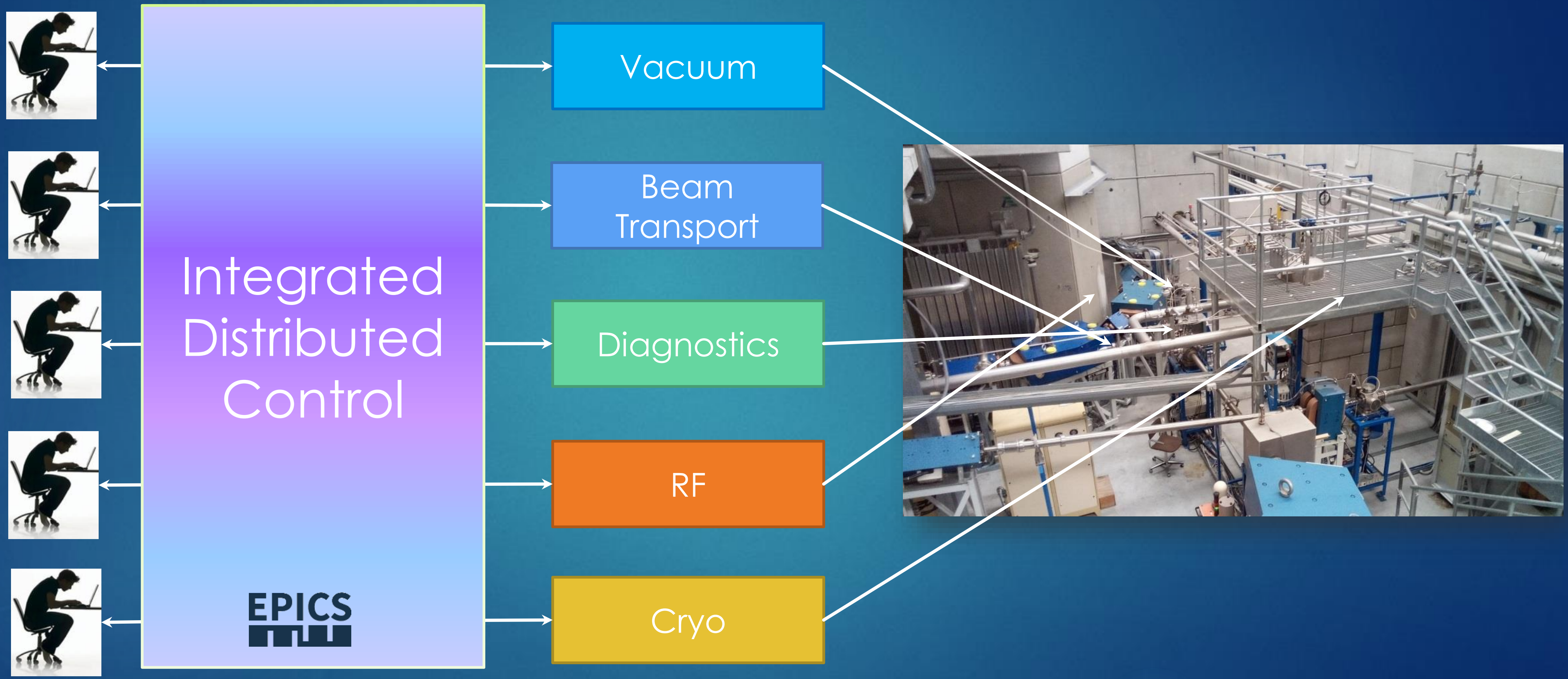


Beam Transport System in Numbers

Parameter	Serial Communication	Ethernet Communication
Number of EPICS IOCs (*)	8 (lens) 1 (NMR) 1 (gauss meters)	11 (lens) 18 (steerers)
Number of Devices	Magnets: 70 NMR: 3 Gauss Meters: 3	Magnets: 11 Steerers: 18
Number of EPICS Variables	~ 5000 PVs	~ 8500 PVs

(*) All the IOCs run in Virtual Machines: PROXMOX Hypervisor + CentOS VMs

The consequences of adopting EPICS



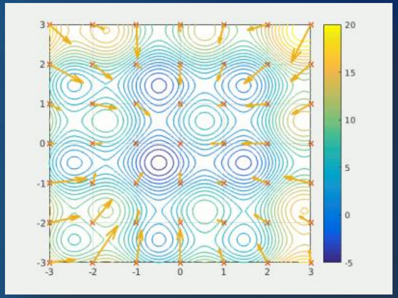
The consequences of adopting EPICS

Accelerator Line Automatic Optimization based on **PSO algorithm** (AI/ML techniques):

PSO problem: $\mathbb{R}^{6} \rightarrow \mathbb{R}\ (middle\ LINAc\ FC)$ and $\mathbb{R}^{10} \rightarrow \mathbb{R}\ (final\ LINAc\ FC)$

Target Element (Faraday Cup)	PSO Execution Time (PSO main params)	Transmission		
		No corrector	Manual Optimization (operators)	Automatic Optimization (PSO)
middle LINAc Faraday Cup	**30 min** pop size: 20 iterations: 10	15%	**41%**	**56.2%**
final LINAc Faraday Cup	**1h** pop size: 30 iterations: 15	1% - 2%	**24.5%**	**35%**

PSO – Particle Swarm Optimization



Pubblication: L. Bellan et al., "**New techniques method for improving the performance of the ALPI Linac**", Journal of Instrumentation, vol. 19, T03005, March 2024. DOI:10.1088/1748-0221/19/03/T03005

The consequences of adopting EPICS

Accelerator Line Automatic Optimization based on **PSO algorithm** (AI/ML techniques):

PSO problem: $\mathbb{R}^{37} \rightarrow \mathbb{R} \quad (middle\ LINAc\ FC)$

Params	Execution Time	Current	
		Manual Optimization	Automatic Optimization
pop size: 25 iterations: -	**45 min**	**43 nA**	**54 nA**
pop size: 25 iterations: 20	**1h 30 min**	**25 - 23 nA**	**29 - 28 nA**
pop size: 25 iterations: 35	**2h 30 min**	**37 - 30 nA**	**60.7 - 49 nA**

Pubblication: L. Bellan et al., "**New techniques method for improving the performance of the ALPI Linac**", Journal of Instrumentation, vol. 19, T03005, March 2024. DOI:10.1088/1748-0221/19/03/T03005

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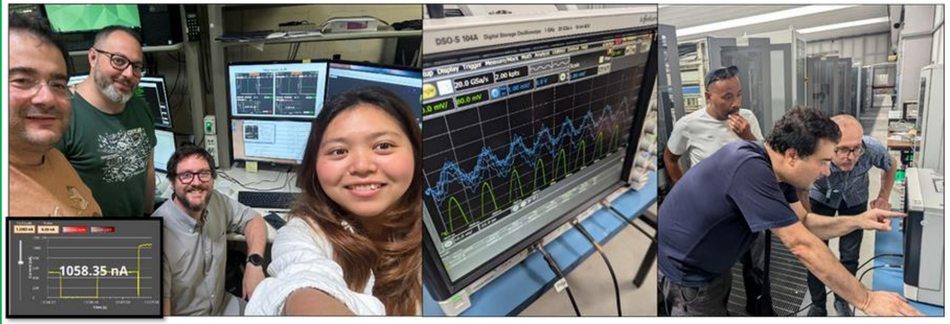


Artificial Intelligence and Machine Learning push PIAVE-ALPI accelerator to record performance in 2024

Automatic tuning with **Bayesian algorithm** and mix with **PSO**

Big Achievement (thanks to EPICS)

Opensource in Control Systems

Where possible, opensource solutions have been adopted in the Control Systems

- **Operative Systems**
- **Control System Framework**
- **Virtualization Hypervisors**
- **Applications and Services for IT architectures**
- **Program Languages and Libraries**

IFMIF Project

JAPAN: WHERE YOU CAN FIND VENDING MACHINES SELLING EVERYTHING FROM SUSHI TO SOCKS, AND TOILETS THAT GREET YOU WITH A SYMPHONY OF SOUNDS

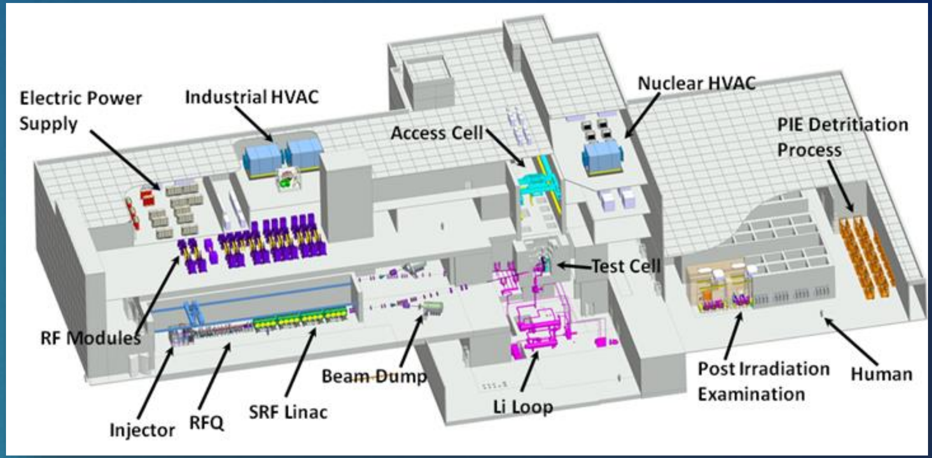
IFMIF Project

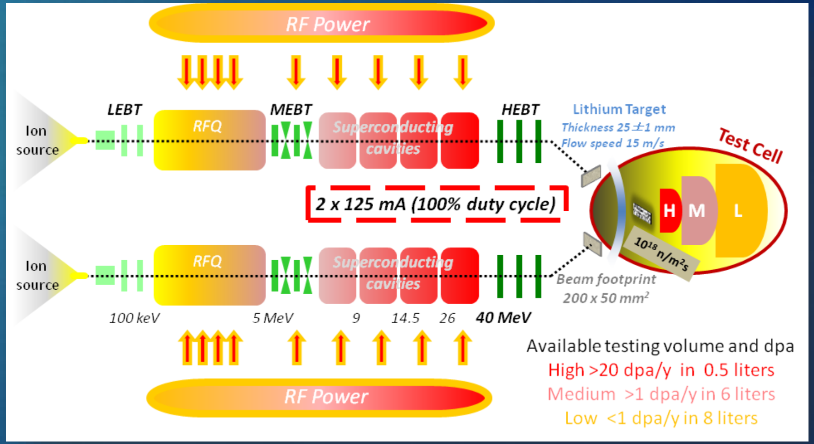
IFMIF (International Fusion Materials Irradiation Facility):

the International Fusion Materials Irradiation Facility, will generate, thanks to two parallel deuteron accelerators, a neutron flux with a broad peak at 14 MeV by Li(d,xn) nuclear reactions that will collide in a liquid Li screen with a footprint of 20 cm x 5 cm.

The energy of the beam (40 MeV) and the current of the parallel accelerators (2 x 125 mA) have been tuned to maximize the neutrons flux to get irradiation conditions comparable to those of a fusion reactor in a volume of 0.5 l that will house around 1000 small specimens.

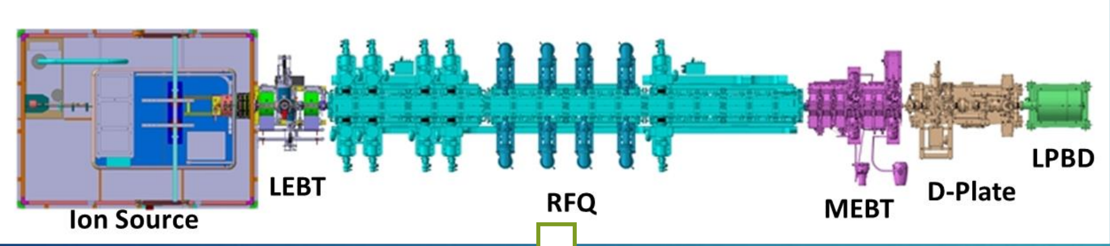
The successful validation of the small specimens' test technique under the Broader Approach Agreement between Japan and EURATOM will allow the full mechanical characterization of suitable materials, and allow the understanding of the degradation that will lead to the design of constituents better tolerant to radiation





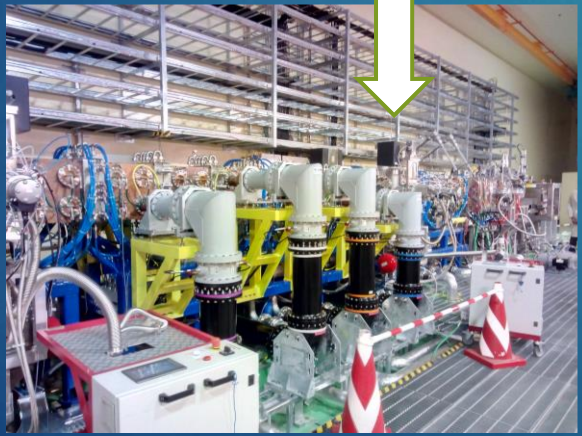
IFMIF–LIPAc Project

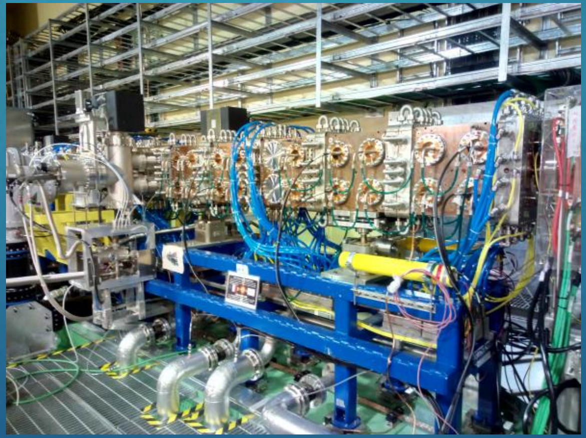
IFMIF-LIPAc: Linear IFMIF Prototype Accelerator



The RFQ will pre-bunch the DC beam from the ion source and will accelerate the beam from 0.1 to **5 MeV** at max **125 mA** current.

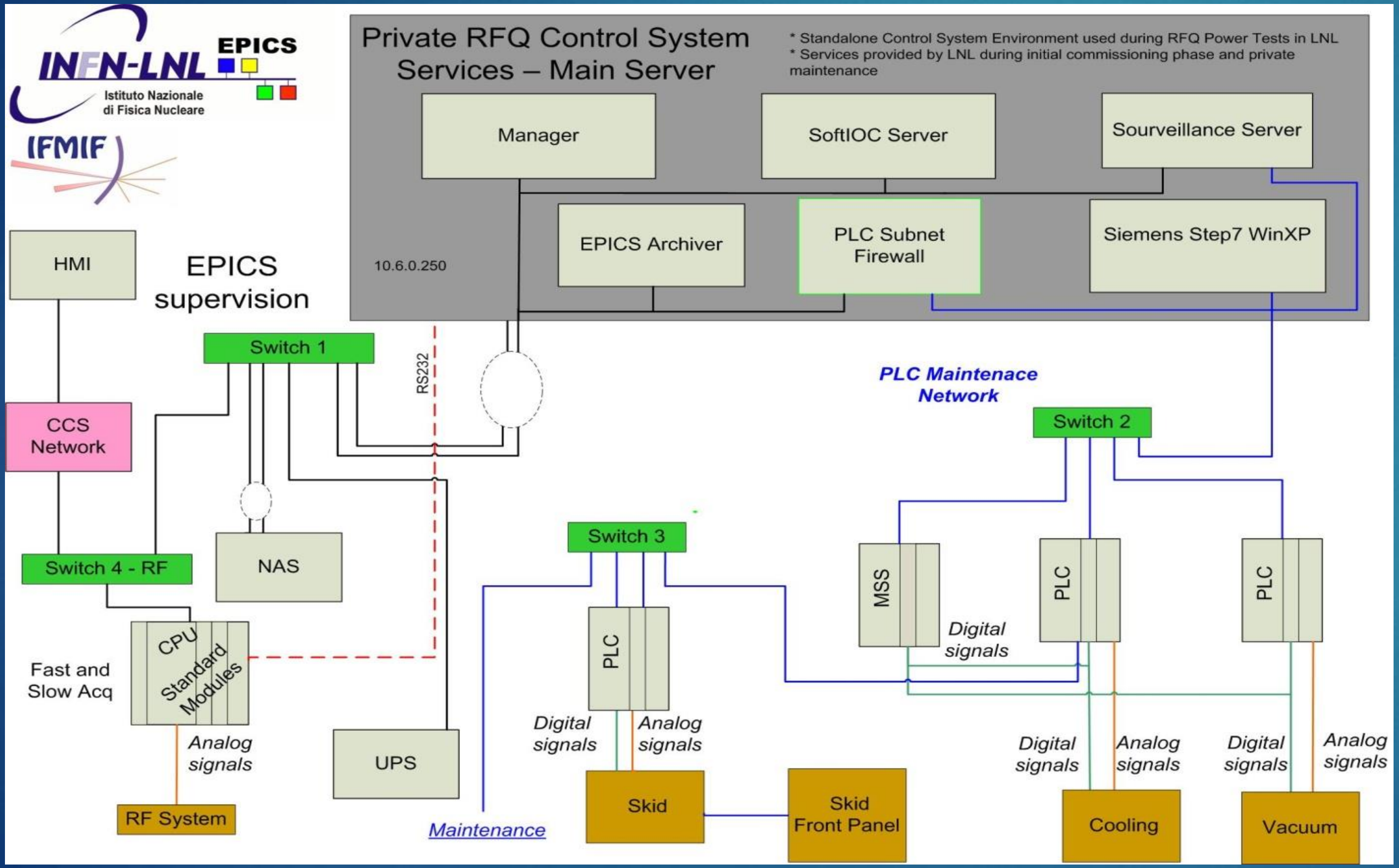
→ RFQ Apparatus is the Italian contribution to the IFMIF-LIPAc project (control included)





IFMIF RFQ LCS Architecture

LCS: Local Control System



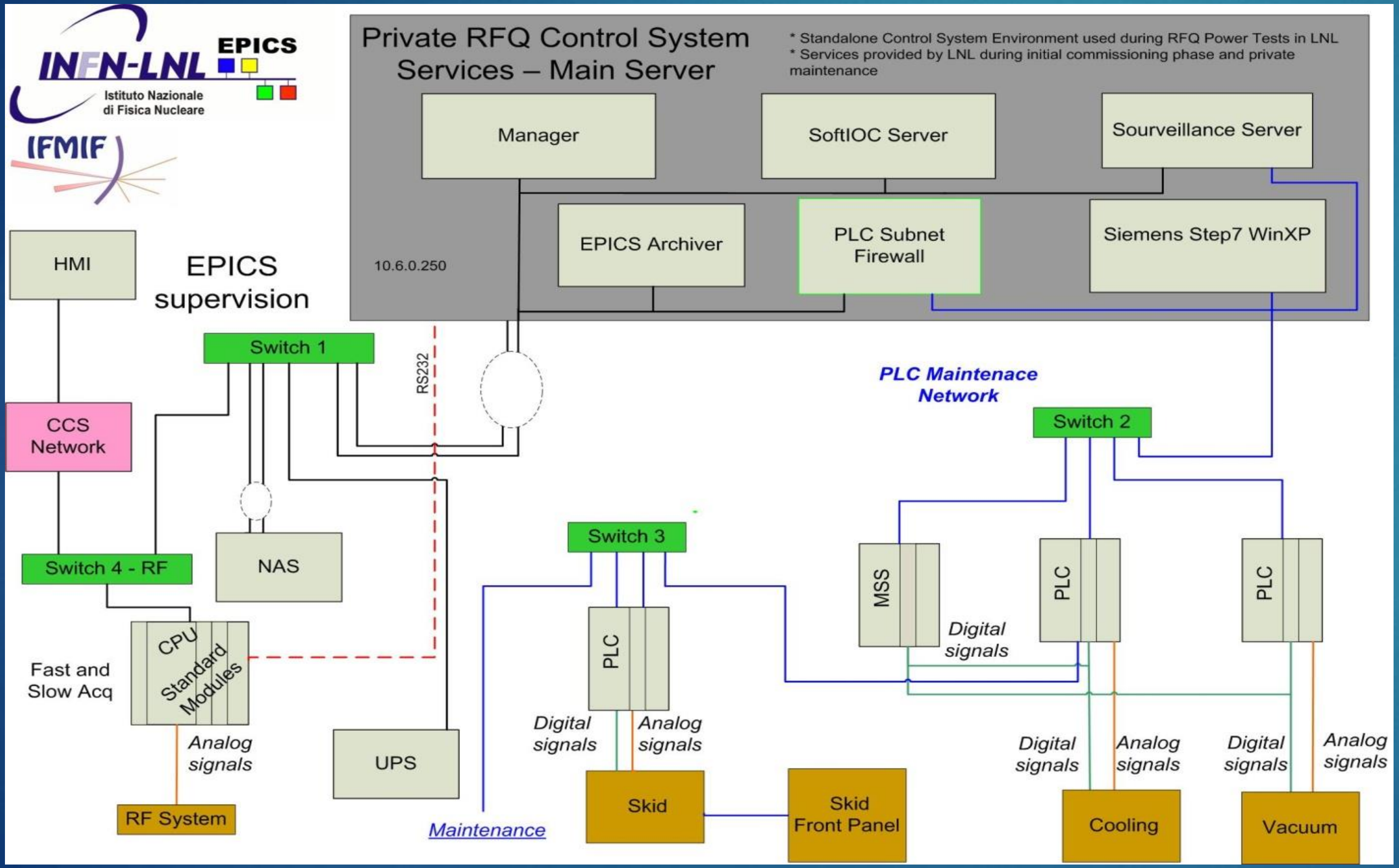
Preliminary design started in **2011**

Cutting-edge technologies in that period:

- Virtualization (Qemu, KVM)
- VME systems for fast acquisition
- PLCs for safety and slow safe systems
- Cobbler / Koan for automatic provisioning
- Nagios for network hosts surveillance

IFMIF RFQ LCS Architecture

LCS: Local Control System

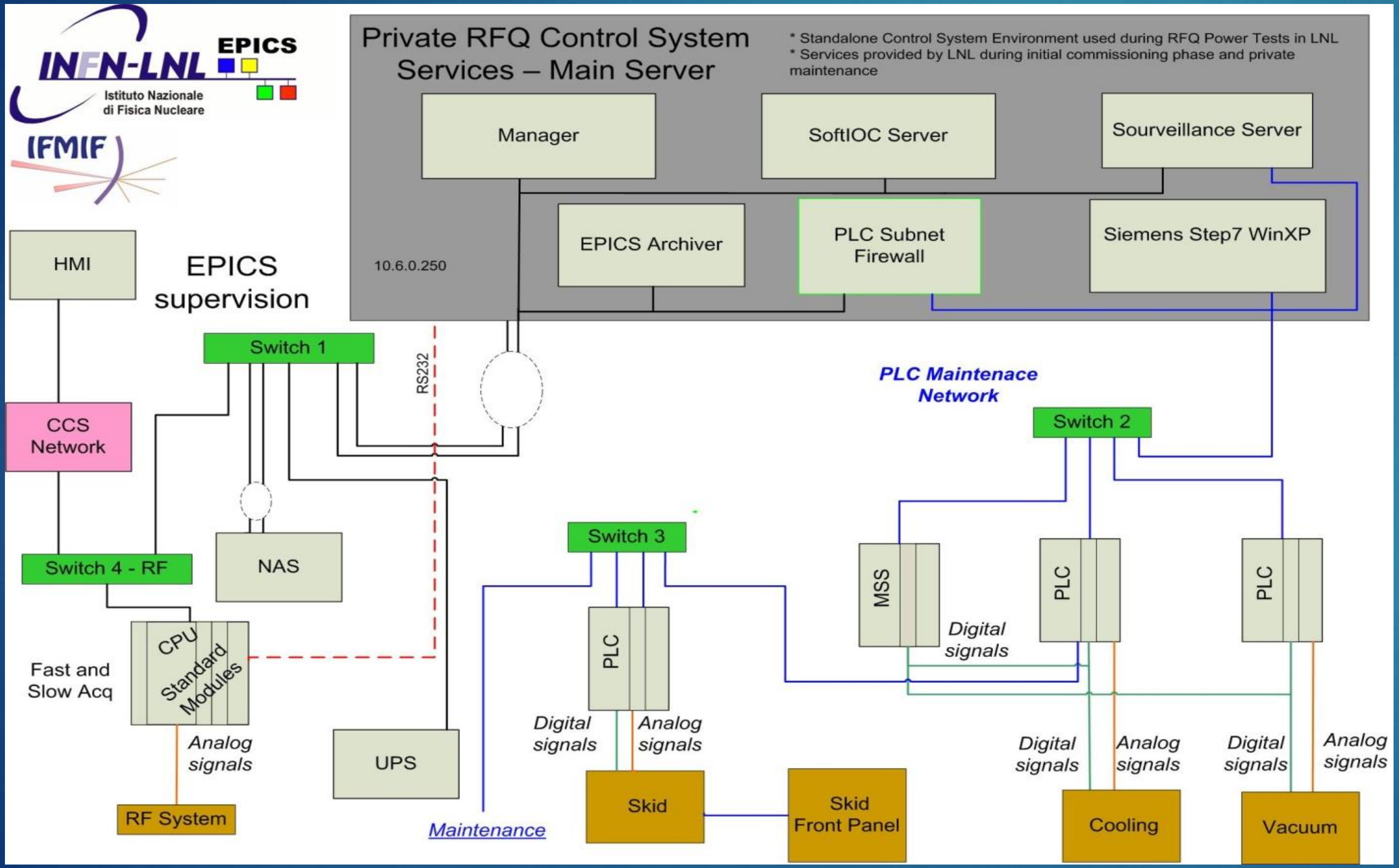


Characteristics of this design:

- Defined to be a **standalone control system** and **interfaceable with Central Control System** (CCS)
- **3-Layer** architecture
- PLC network as a subnet to the EPICS network Managed via Firewall
- Software:
  - EPICS V3 framework (CA)
  - CSS framework
  - S7-PLC software
  - KVM hypervisor (Virtualization)
- Virtualize as much as possible to optimize space, costs and maintenance

IFMIF RFQ LCS Architecture

LCS: Local Control System



- **Control Loop:**

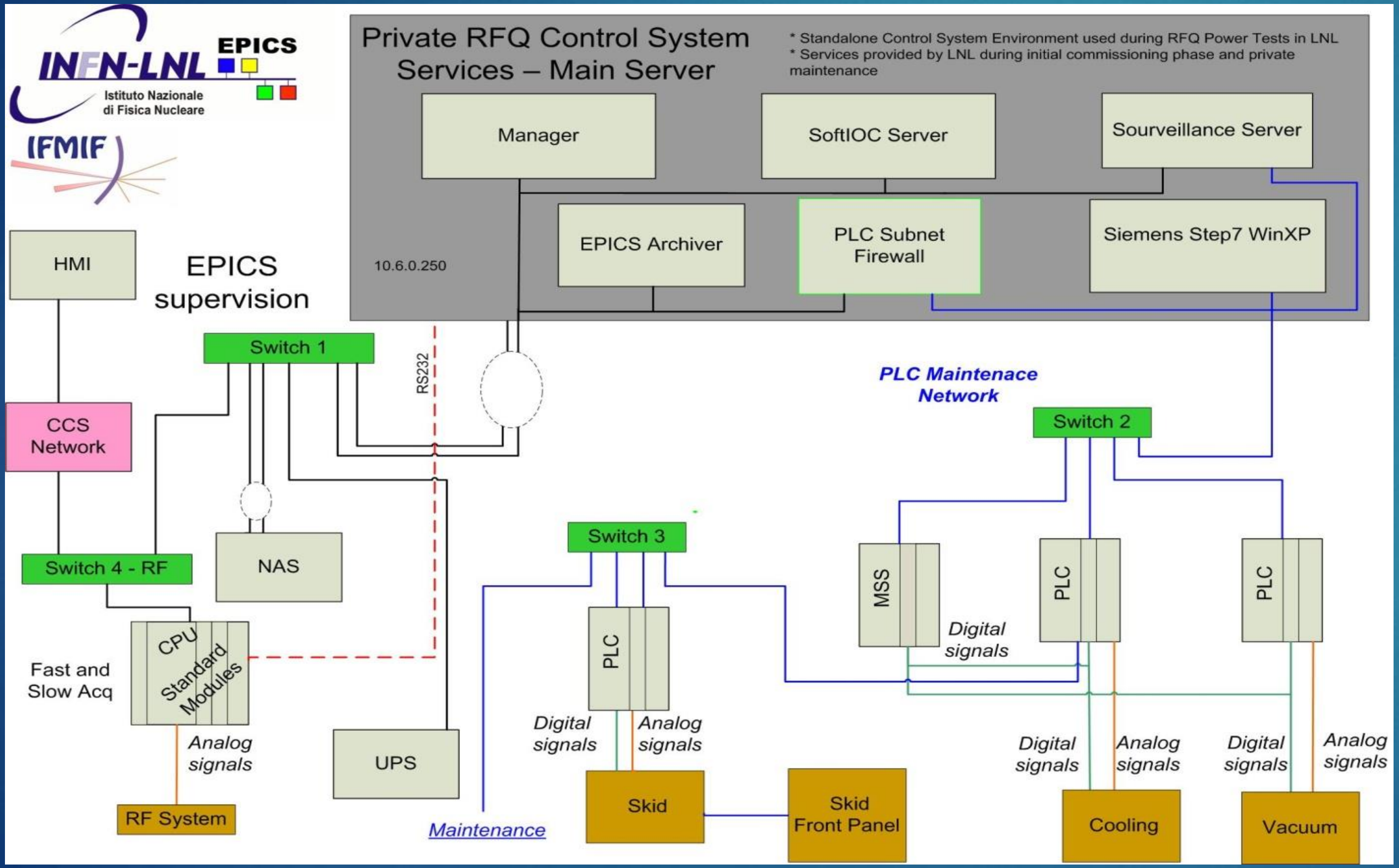
Closed loop between RF and Cooling Systems to minimize frequency detuning into the cavity

- **Logics and Algorithms distributed between PLC and EPICS**

- **Functional Subsystems – HW:**
  - Vacuum: PLC
  - Cooling: PLC
  - RF acquisition: VME
  - RF analysis: general purpose PC (VM)

IFMIF RFQ LCS Architecture

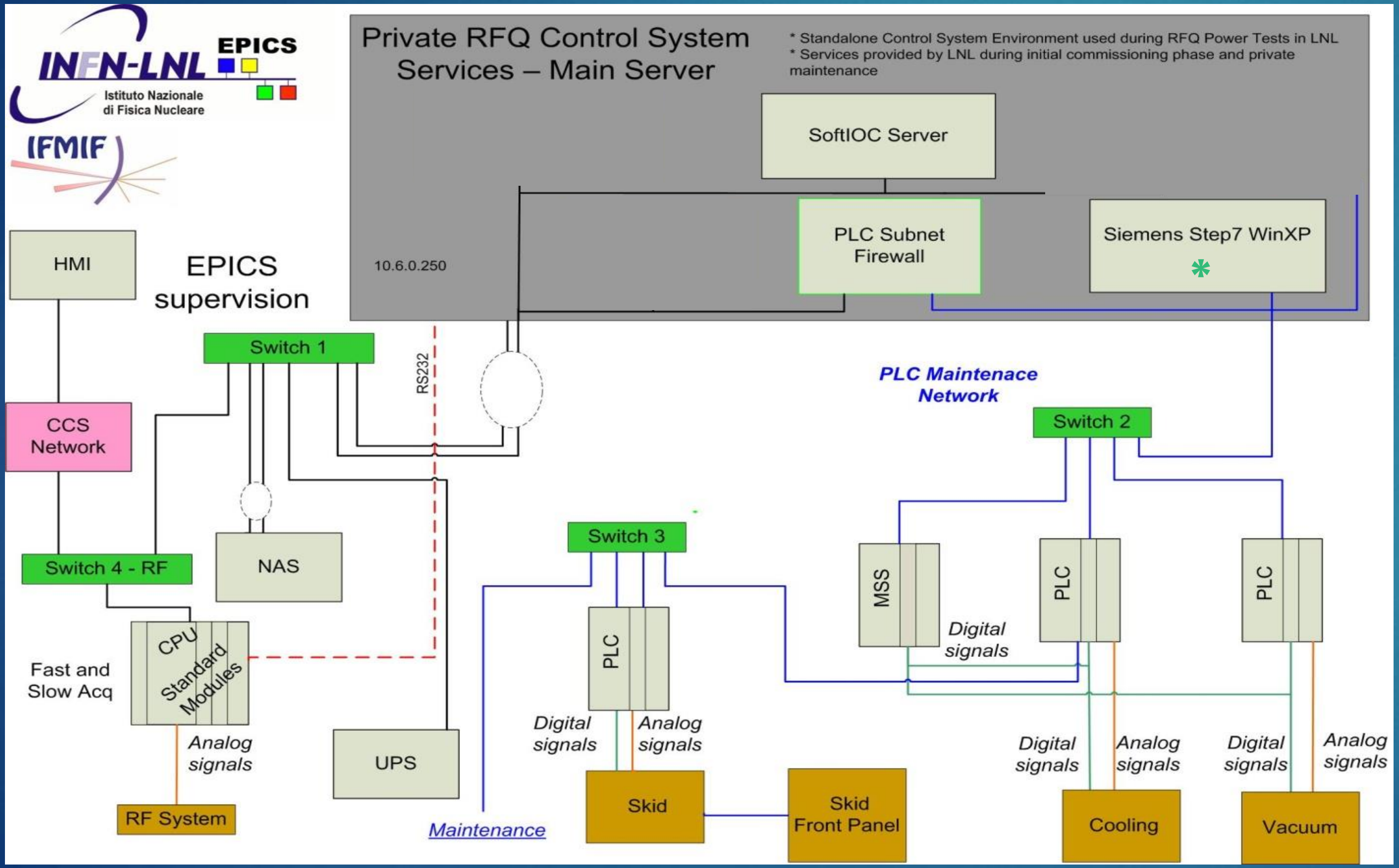
LCS: Local Control System



Control System Architecture **validated** during RFQ power tests performed at LNL in 2014:

- Tested a subset of the entire RFQ, also in terms of number of signals
- Provided additional controls for system not directly provided by RFQ LCS but required for the tests
  - RF System
- Validate design and change technologies and solutions if required (*surface temperature story*)

IFMIF RFQ LCS Architecture – Final Ver.

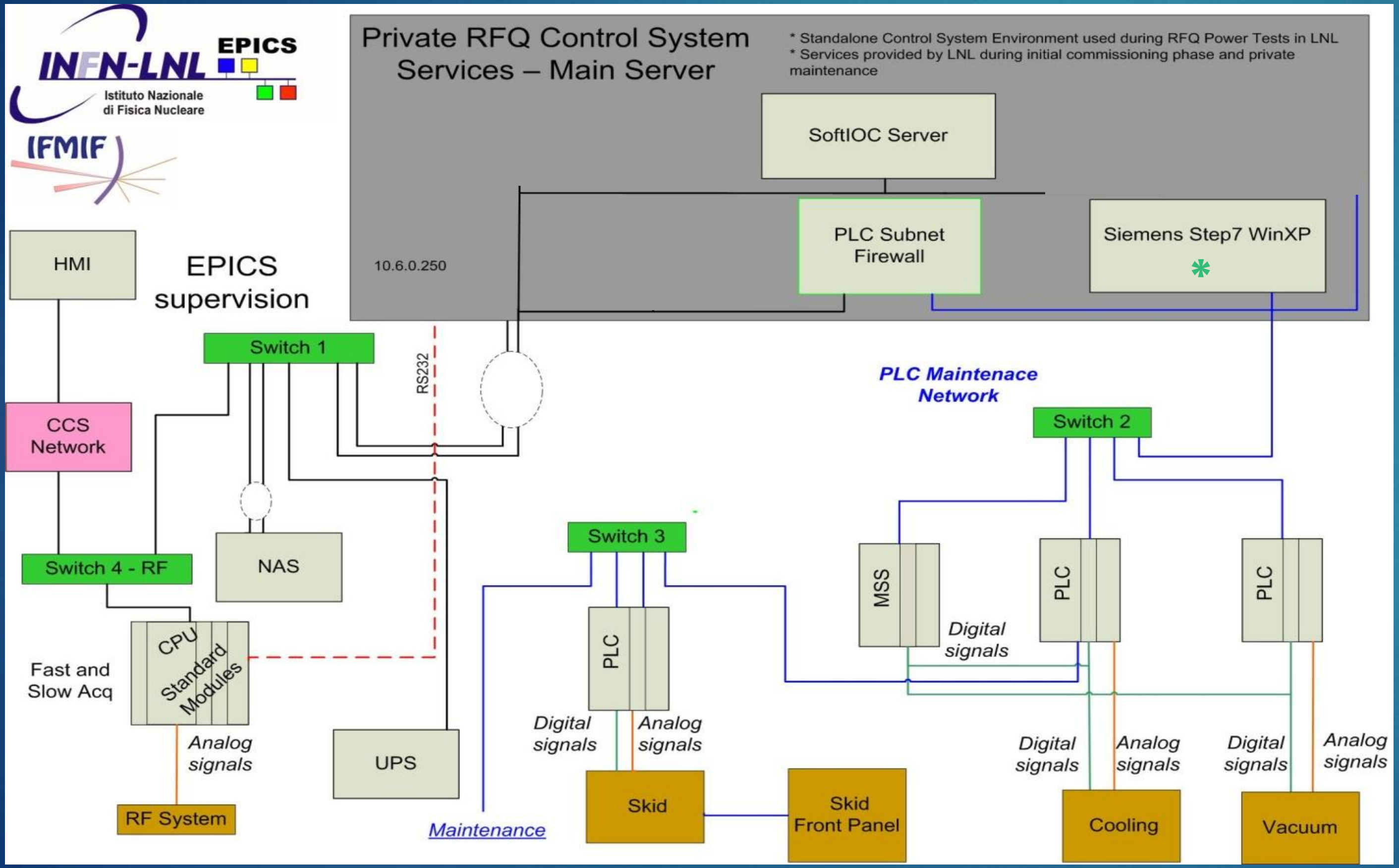


LCS started Installation in Japan in **July 2016**

- All the network services were used during first stage of commissioning, then they were substituted by the ones provided by Central Control
- At EPICS level, commissioning went smoothly and fast because:
  - Basic guidelines to follow
  - Simple EPICS architecture adopted
  - Central Control System under implementation in parallel

*** Used only for maintenance**

IFMIF RFQ LCS Architecture – Final Ver.



LCS started Installation in Japan in **July 2016**

RFQ LCS SAT (Site Acceptance Test) performed in **December 2017.**

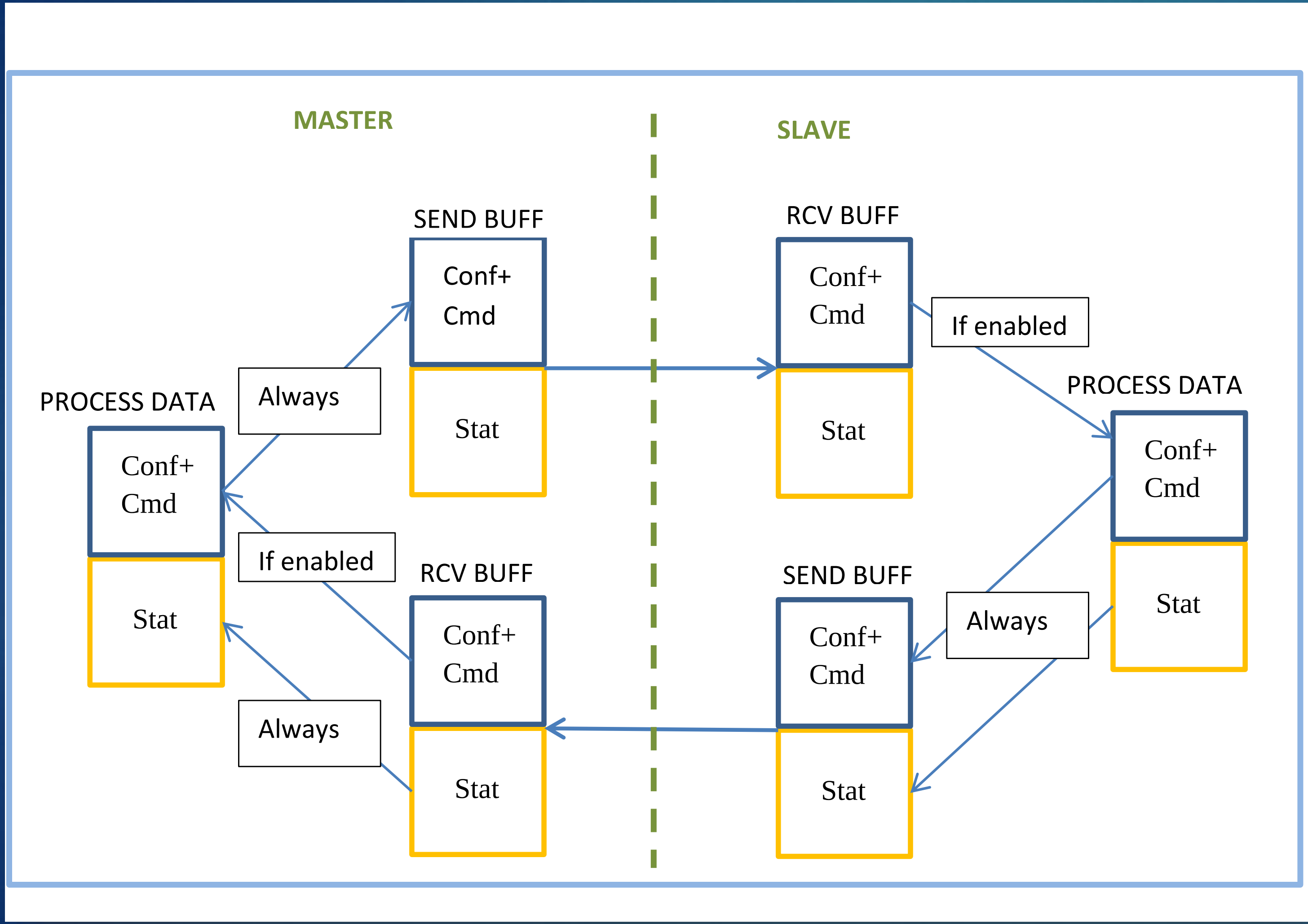
Tests included:

- Documentation (Manuals, Reports, etc.)
- Applications functionality and compliance with Guidelines (EPICS code and PLC code)
- Integration with central tools
- HW and SW interfaces with other LCSs , MPS, PPS and Central Control

IFMIF RFQ LCS in Numbers

Number of	Power Test	Final Stage
IOCs	6	4
EPICS DBs	17	37
EPICS Variables (PVs)	1153	~8000
Channels Archived	970	~1600
GUI panels	15	14

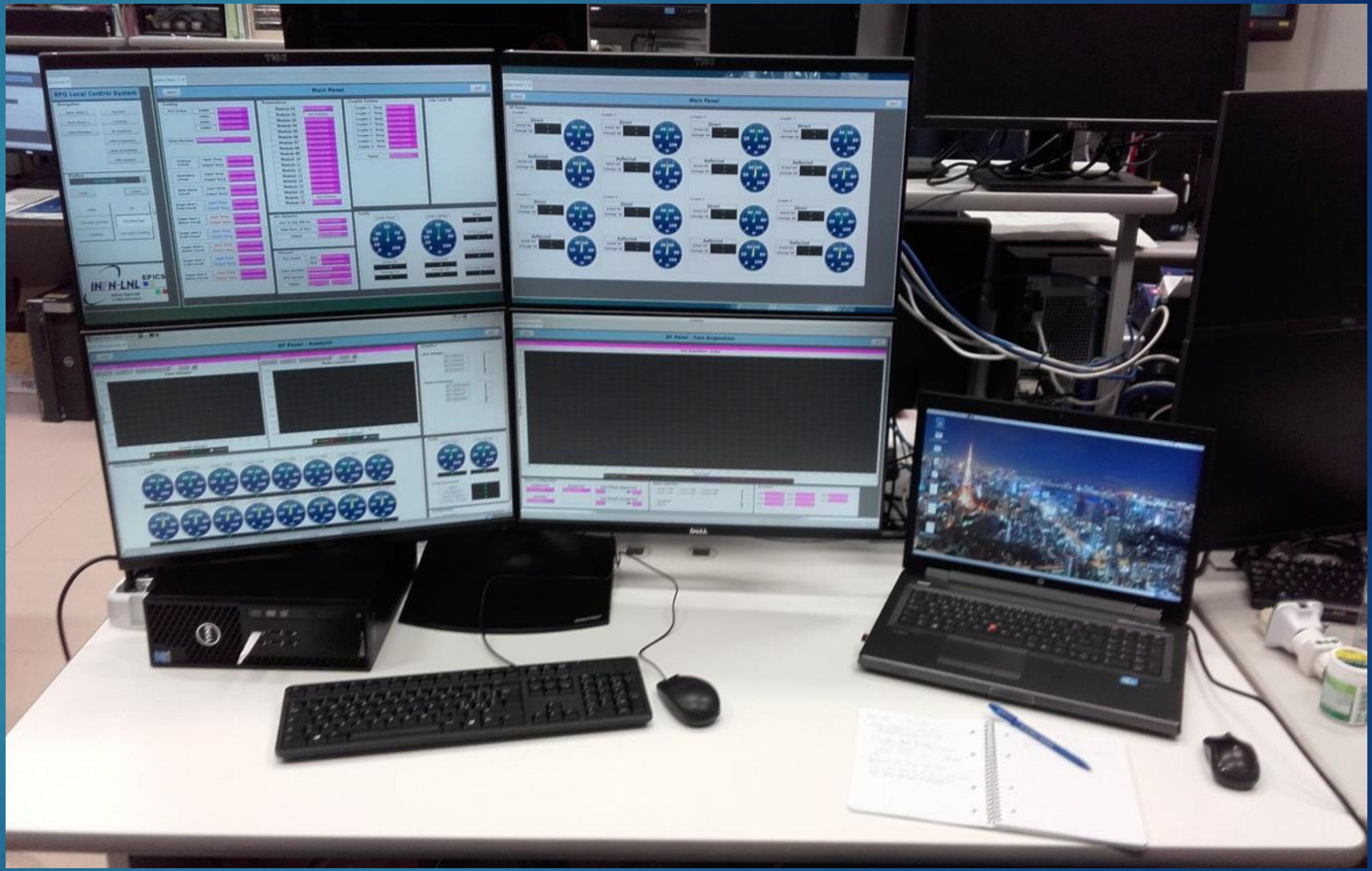
EPICS – PLC Synchronization



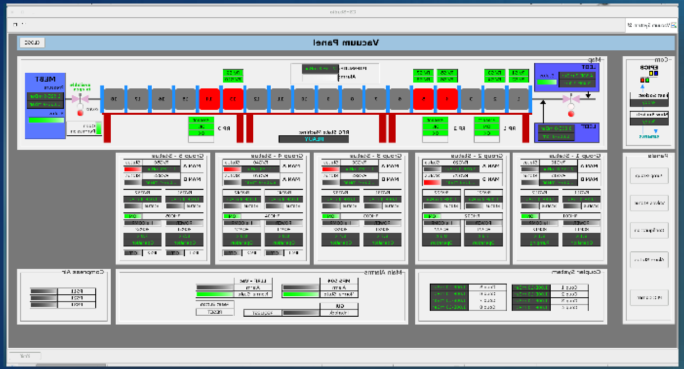
- EPICS – PLC interface:
  - **OPC Server** (first solution)
  - **s7plc EPICS driver** (actual solution)
- S7plc driver
  - is based on send receive over TCP/IP
  - Input and output buffers for data exchange between PLC memory and EPICS IOC
- Dedicated logic to orchestrate data update when PLC transit from local to remote mode

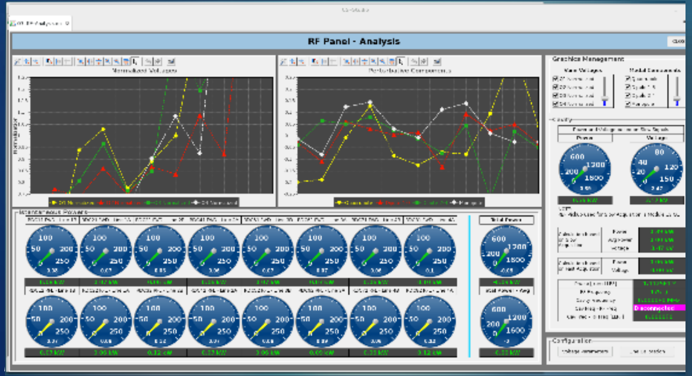
IFMIF RFQ LCS HMI

Profile name	Panels
Main	Navigation Main RFQ 1 Main RFQ 2
Vacuum_pumps	Navigation Main RFQ 1 Main RFQ 2 Vacuum (principal panel) Vacuum pumps
Cooling	Navigation Main RFQ 1 Main RFQ 2 Cooling (principal panel) Skid
RF	Navigation Main RFQ 1 Main RFQ 2 RF analysis (principal panel)
Oscilloscope	Navigation Main RFQ 1 Main RFQ 2 RF analysis (principal panel) Fast acquisition
Vacuum + Cooling	Navigation Main RFQ 1 Main RFQ 2 Vacuum (principal panel) Cooling (principal panel)



IFMIF RFQ LCS HMI



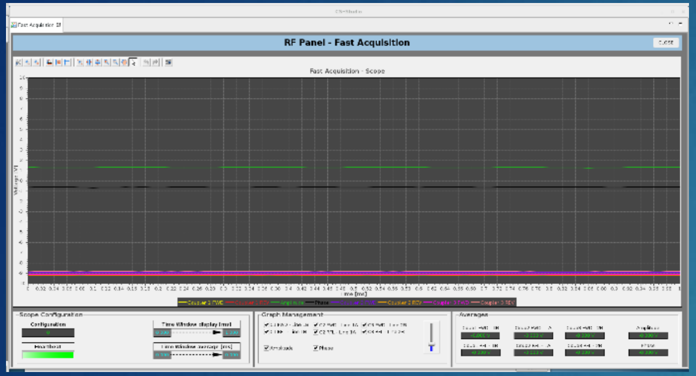


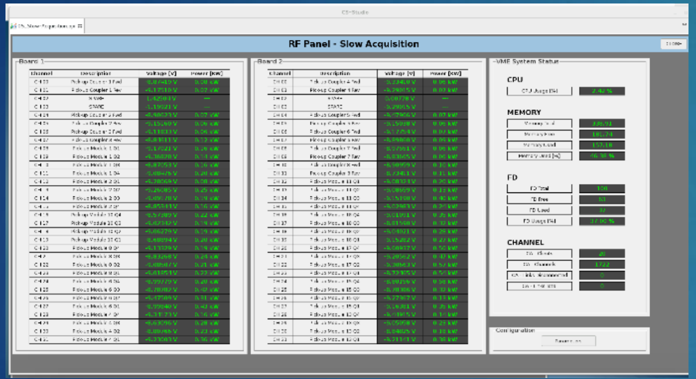
Vacuum:
- Siemens PLC S7-300
- SIMATIC Step7 programming
- Low-level logic implemented in the PLC code
- EPICS V3 interface for remote control + LOC/REM sync

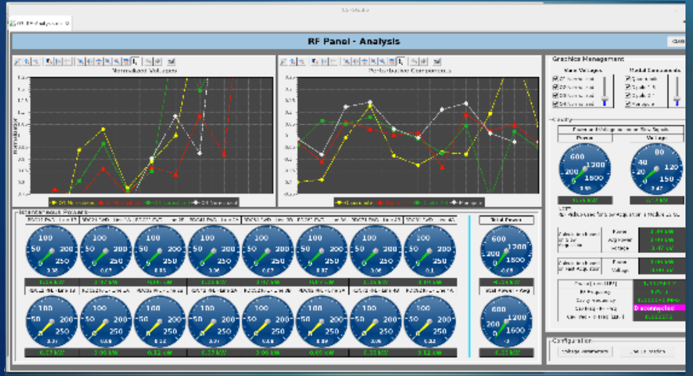
Cooling:
- Siemens PLC S7-300
- SIMATIC Step7 programming
- High-level logic + Low-level logic implemented in the PLC code
- EPICS V3 interface for remote control + LOC/REM sync

RF Analysis:
- EPICS V3 softIOC (pure software application)
- Input: RF pickup signals (fast & slow acquisition)
- Algorithms (high-level logic) based on state machines (SNL / sequencer)
- GUI graphs provided by EPICS PVs

IFMIF RFQ LCS HMI



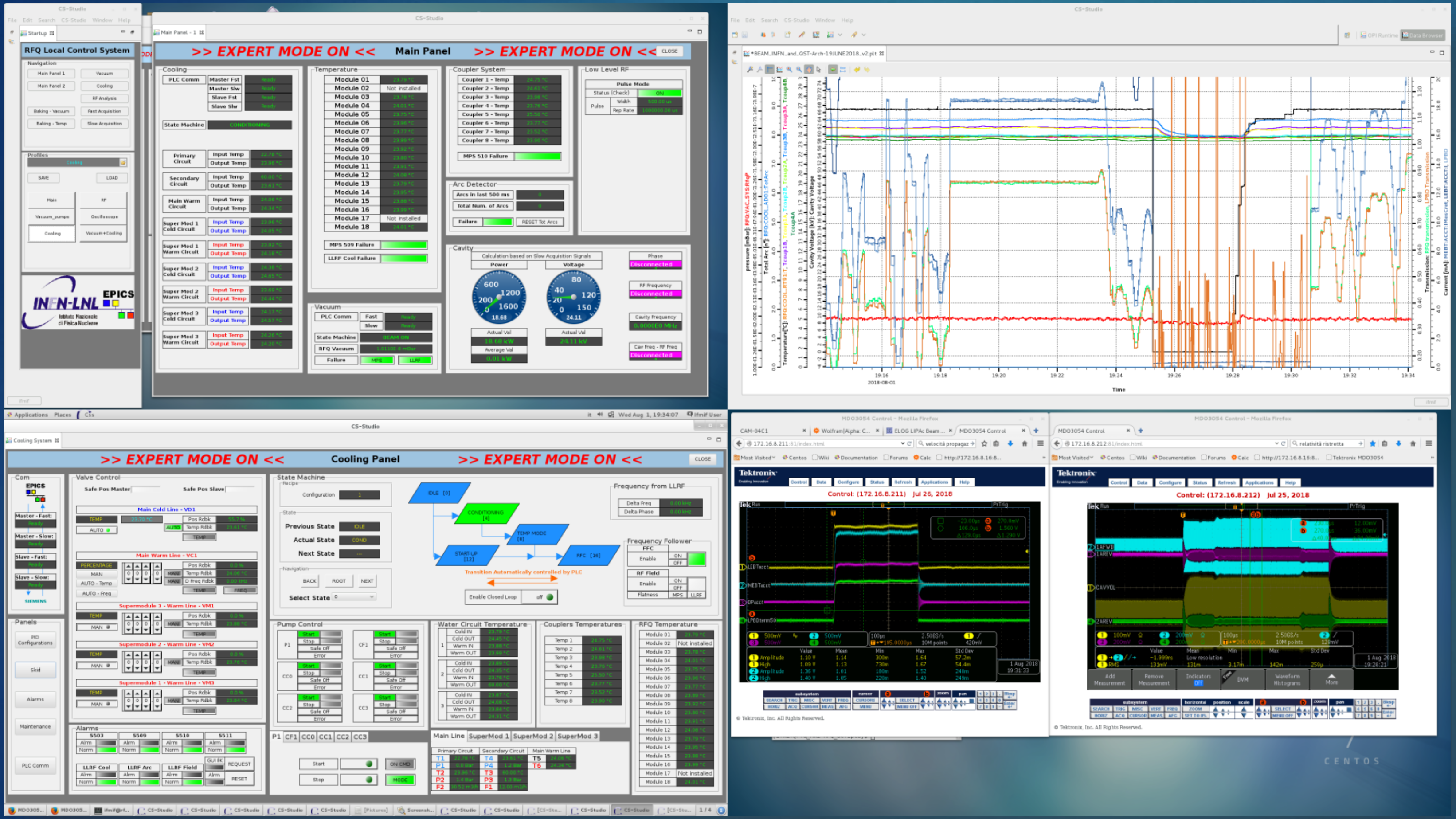


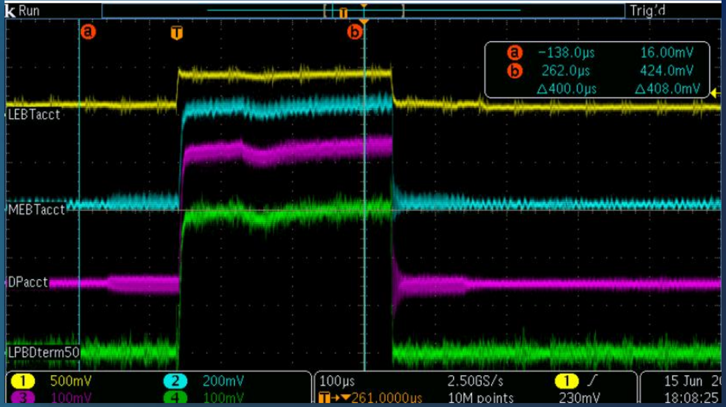


<u>Fast and Slow Acquisition</u>:
- VME system (ICV150, ICV108 acq. boards) + VxWorks RT OS
- EPICS V3 IOC embedded in system + custom driver for acquisition boards
- No high-level and low-level logic

<u>RF Analysis</u>:
- EPICS V3 softIOC (pure software application)
- Input: RF pickup signals (fast & slow acquisition)
- Algorithms (high-level logic) based on state machines (SNL / sequencer)
- GUI graphs provided by EPICS PVs

IFMIF RFQ LCS in Action





First proton beam injected into the RFQ on 13 June 2018

ESS Project

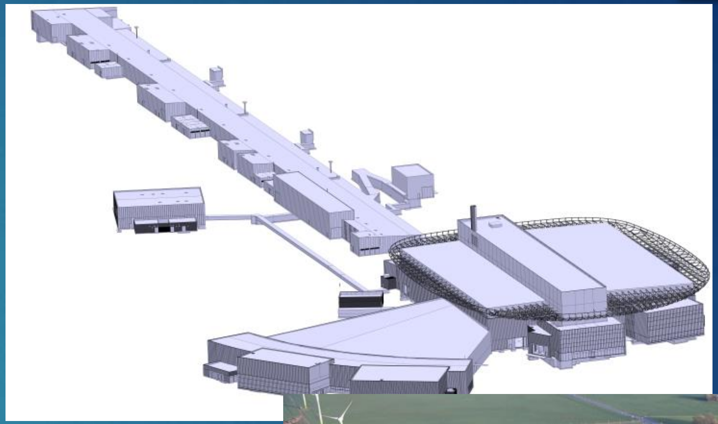
SWEDEN: WHERE MEATBALLS ARE A GOURMET DISH, AND THE ANSWER TO EVERYTHING IS OFTEN JUST A QUICK SAUNA SESSION AWAY

ESS Project

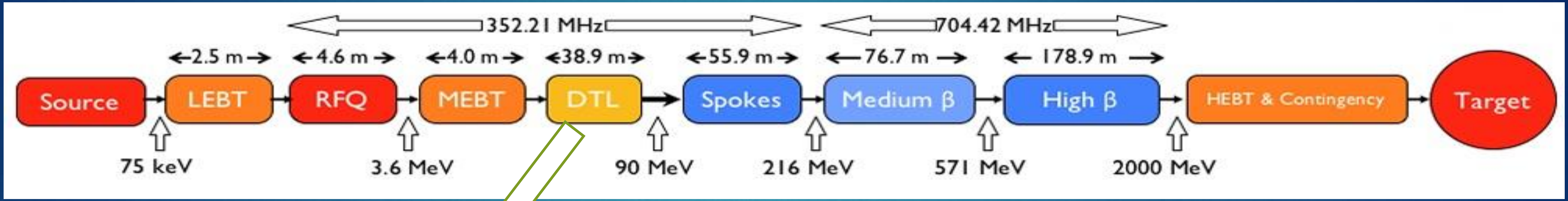
ESS (European Spallation Source):

The European Spallation Source is a multi-disciplinary research facility based on what will be the world's most powerful pulsed neutron source. It is currently under construction in Lund, Sweden.

ESS is the world's most powerful next-generation neutron source, and will enable scientists to see and understand basic atomic structures and forces at length and time scales unachievable at other neutron sources



ESS Project – Drift Tube Linac



The DTL is designed to operate at 352.21 MHz, with a duty cycle of 4% (2.86 ms pulse length,14 Hz repetition period).

Permanent magnet quadrupoles (PMQs) are used as focusing elements on a lattice scheme that is, with half of the drift tubes left empty, leaving space for steerers and beam diagnostics.

The DTL apparatus is composed of 5 macro modules called tanks

→ DTL Apparatus one of the INFN contribution to the ESS project (control included)

DTL Control System Architecture

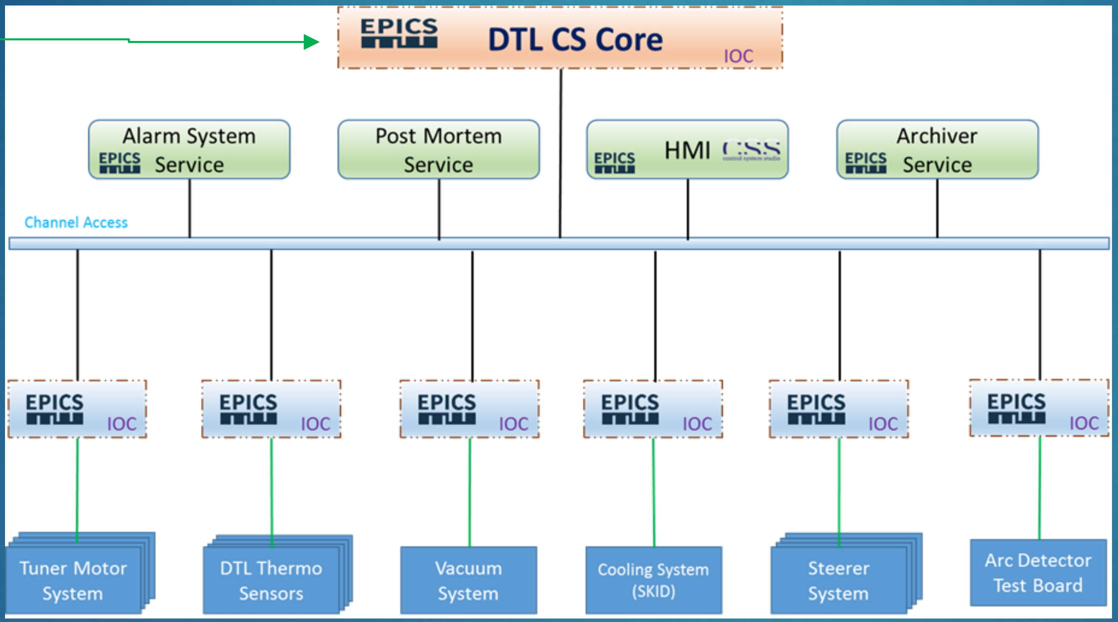
DTL Control System: 3-Layer Architecture

Considerable part of the Control Logic Layer

Services

Control Logic

Functional Sub-Systems (field)

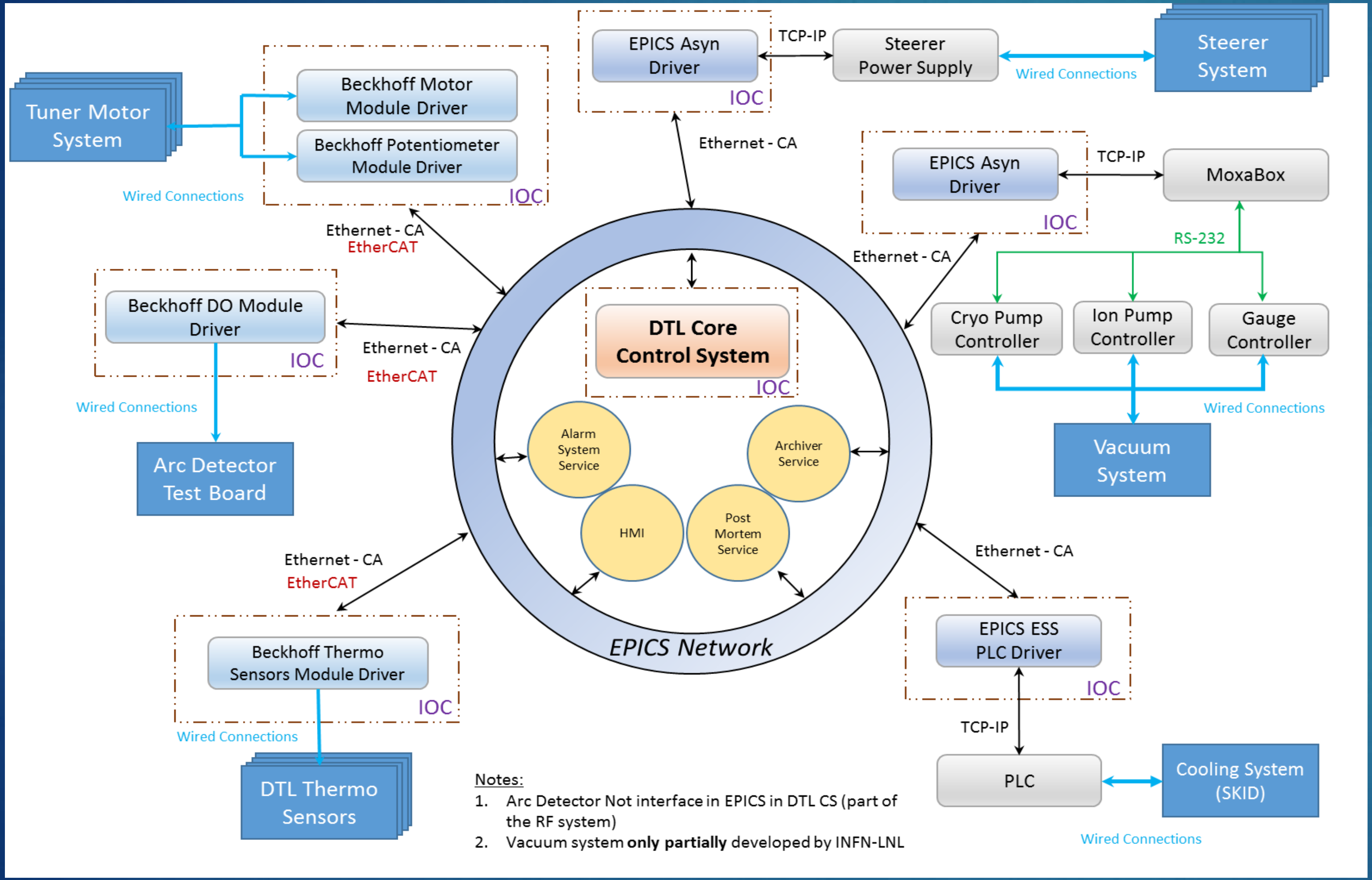


DTL Control System Design and implementation considered the possibility to be a standalone control system for the installation stage

Covid period slowed down the implementation time and, in parallel, ESS infrastructure provided the entire high-level services

DTL Architecture simplified a lot in the final stage

DTL Control System - Technologies



Sub - System	Technology (SW – HW - Protocol)
Thermos Sensors	• EPICS integration and supervision • Beckhoff hardware • EtherCAT protocol
Tuners Motor System	• EPICS integration and supervision • Beckhoff hardware • EtherCAT protocol
Vacuum	• EPICS integration and supervision • Hardware provided by ESS • Serial / TCP-IP communication
SKID	• EPICS integration and supervision • Hardware provided by tender with PLC Siemens S7-1500 (low level I/O)
Steerer System	• EPICS integration and supervision • Hardware provided by tender • TCP-IP protocol communication
Arc Detector	• Hardware system based on AFT Microwave • Custom electronic board for Arc testing

E3 – ESS EPICS Environment

ESS' EPICS Environment (e3) is a design concept and a toolkit intended to

1. facilitate development by abstracting away some of the low-level complexities intrinsic to large EPICS implementations (primarily dependency management)

2. allow for more manageable quality control of released modules as well as IOCs

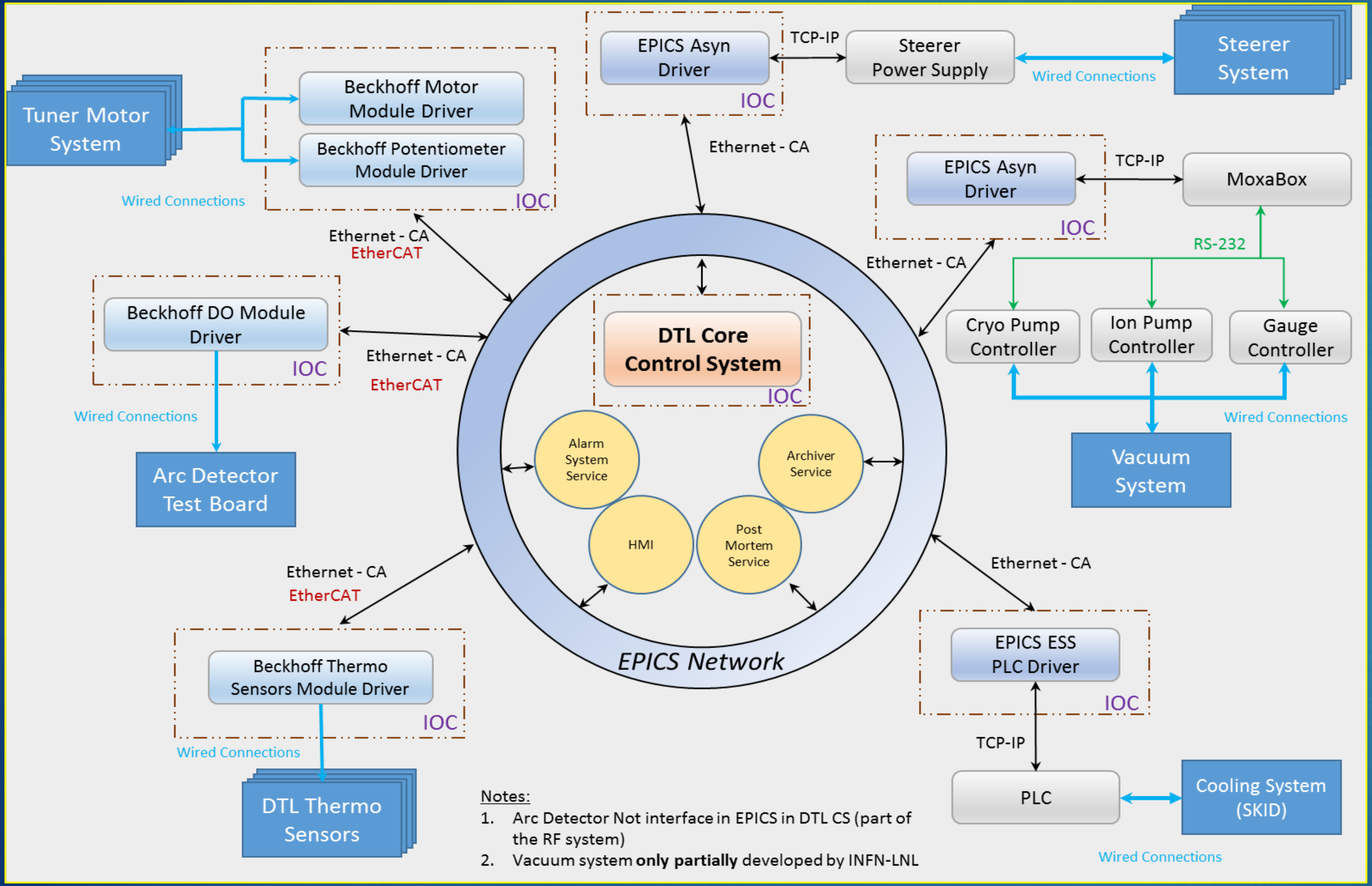
It allows for **easily building EPICS modules directly from source and automagically resolves module dependencies** and allows for site-specific modifications to EPICS modules without needing to directly modify source trees

E3 – ESS EPICS Environment

E3's impact on the development and implementation of the DTL control system has been significant.

- New way to realize EPICS modules, IOCs, etc.
- E3 already provided all the principal EPICS modules
  - Only few devices had required dedicated development
- Key point was **the E3 documentation** and **ESS ICS support**
- Due to the fact E3 evolved though time, the DTL CS implementation had to be updated several times
- Collaboration and teamwork played a crucial role during commissioning stage

ESS DTL LCS



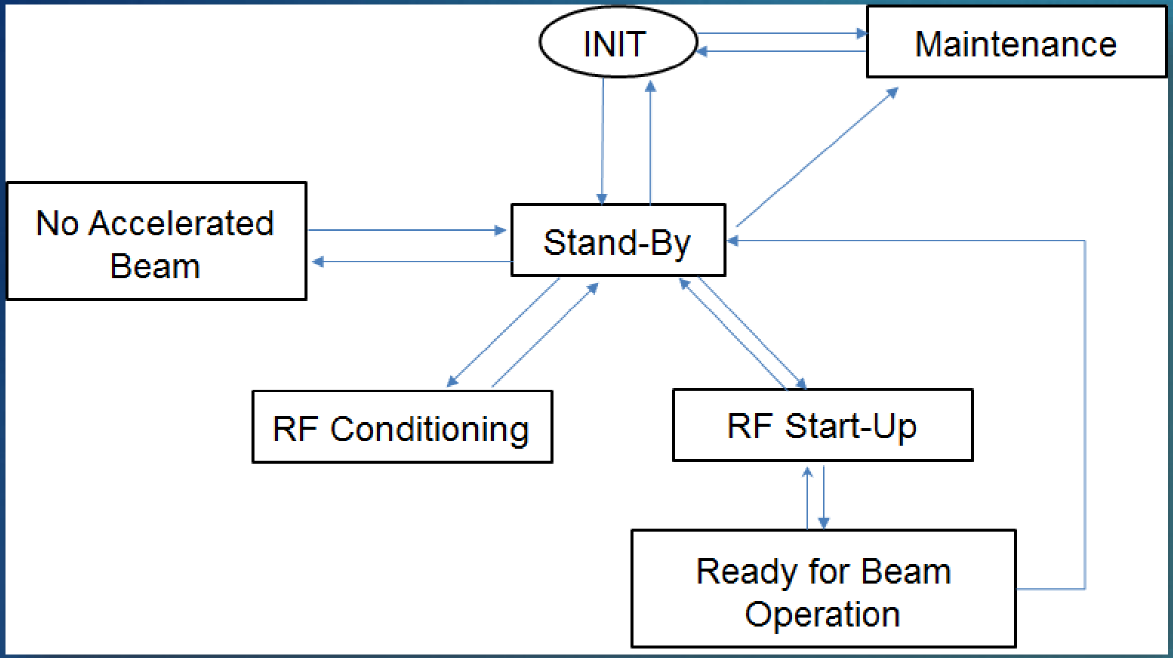
- **Control Loop:**

Closed loop between RF and Mobile Tuner Systems to minimize frequency detuning into the cavity

- **Principal Logic and Algorithms implemented in EPICS** (minor logic done at PLC level for SKID)

- Defined dedicated EPICS state machines to orchestrate the entire apparatus

DTL High-Level Logic & Orchestration



1 Orchestration State machine / DTL Tank

The DTL apparatus will be used to perform two main operations:

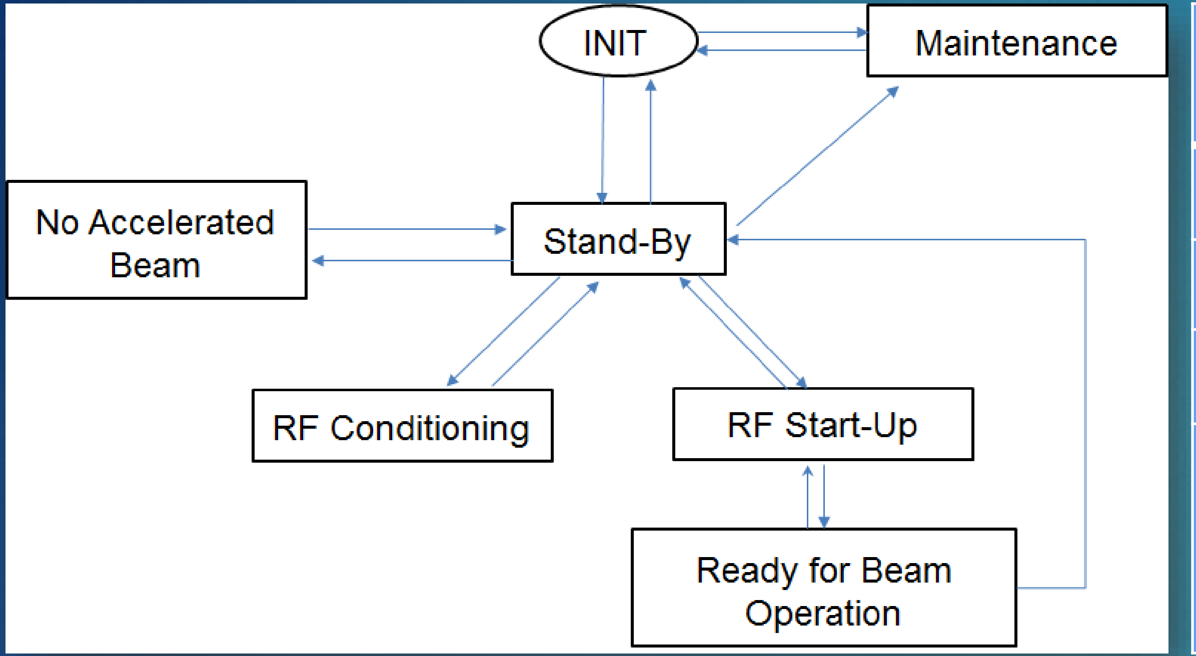
- RF Conditioning
- Beam Operation

Additional Status:

- No Accelerated Beam
- Maintenance

NOTE:
DTL is composed by 5 independent tanks

DTL High-Level Logic & Orchestration



	RF Conditioning	RF Start-up	Ready for Beam Operation	No Accelerated Beam
Cooling	$t_0 \pm \Delta t$ [°C]	$t_1 \pm \Delta t$ [°C]	$t_1 \pm \Delta t$ [°C]	$t_2 \pm \Delta t$ [°C]
Vacuum	P_0 [mBar]	P_1 [mBar]	P_2 [mBar]	P_2 [mBar]
DTL Temperature	T_{0_max} [°C]	T_{1_max} [°C]	T_{1_max} [°C]	T_{1_max} [°C]
RF System	ff mode [-]	ff mode [-]	fixed frequency [-]	
			Δf_1 [kHz] Δf_2 [kHz]	

1 Orchestration State machine / DTL Tank

Main Parameters used to orchestrate the DTL tank

NOTE: State machine and parameters were **defined and identified with the accelerator physics**

(….aka the client)

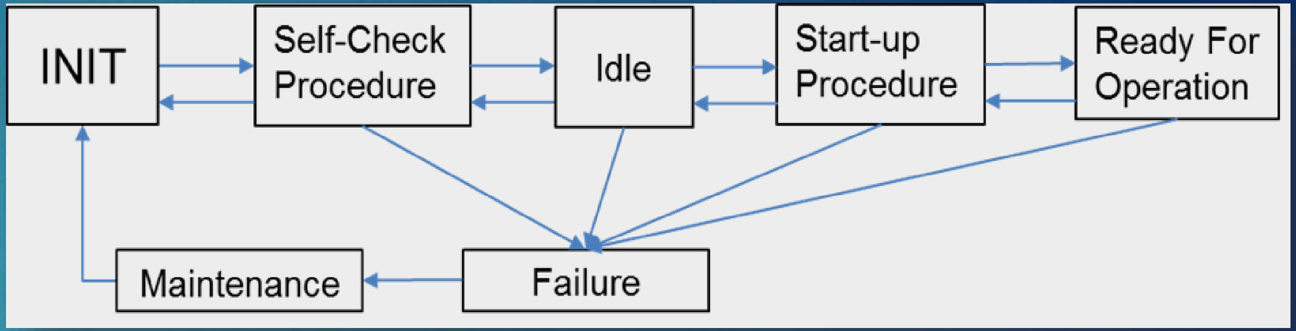
DTL Functional Systema Status

It's important to evaluate every single functional system status:

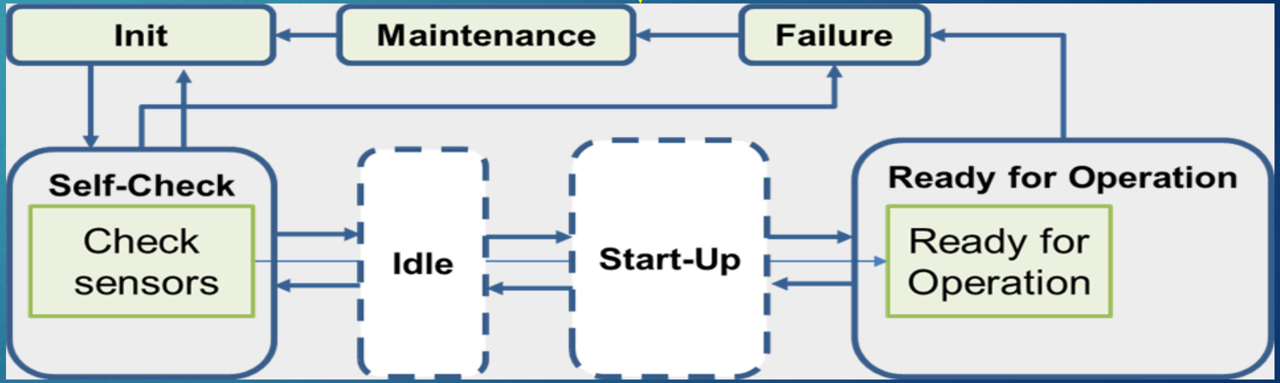
- Cooling
- Steering
- Tuner Motion
- Temperatures

Standardized the state machine model adopted for this activity

Implementation was customized for each single functional system



1 Functional Sub-System State machine / DTL Tank



Functional Sub-System State machine implementation for temperature system

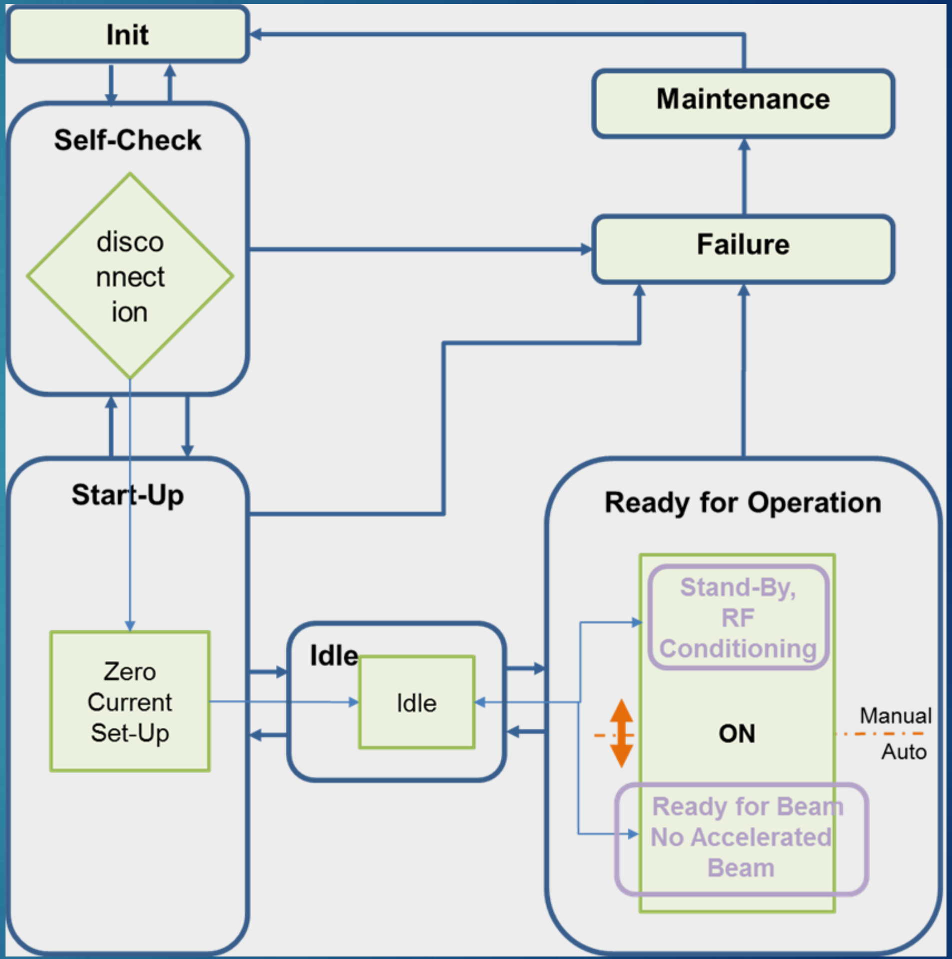
DTL Functional Systema Status

It's important to evaluate every single functional system status:

- Cooling
- Steering
- Tuner Motion
- Temperatures

Standardized the state machine model adopted for this activity.

Implementation was customized for each single functional system

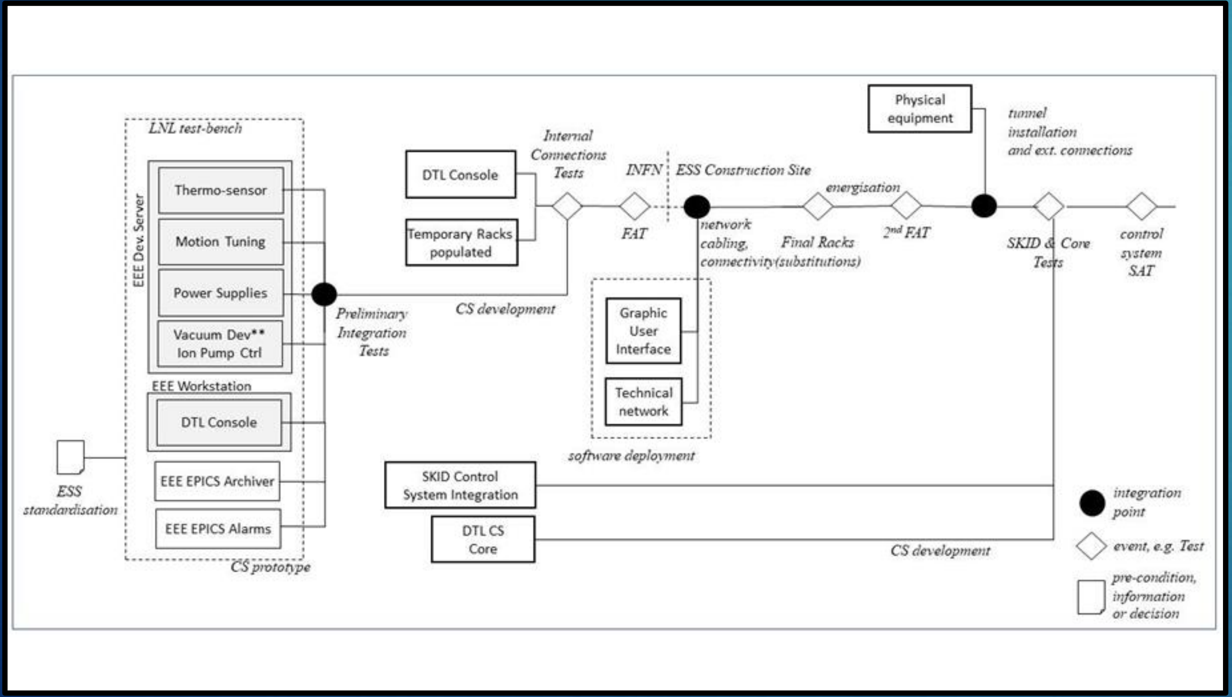


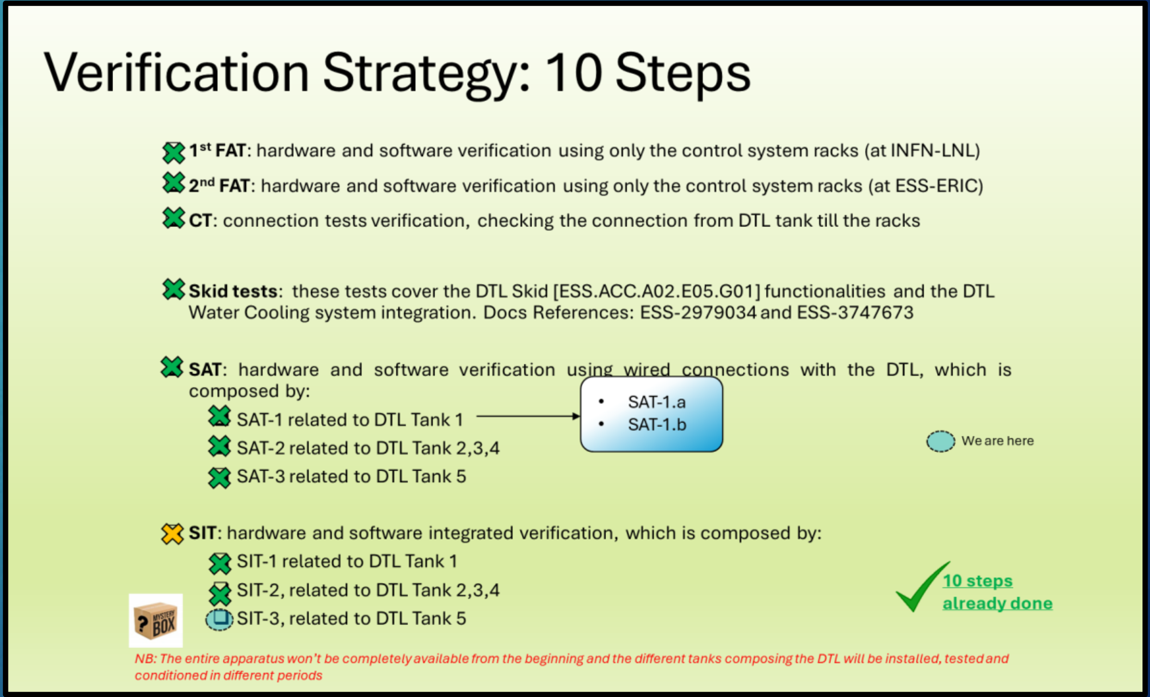
Functional Sub-System State machine implementation for steering system

Commissioning stage

A complex architecture (not only in terms of control system architecture) requires:

- Good plan
- Useful verification stages





Commissioning stage

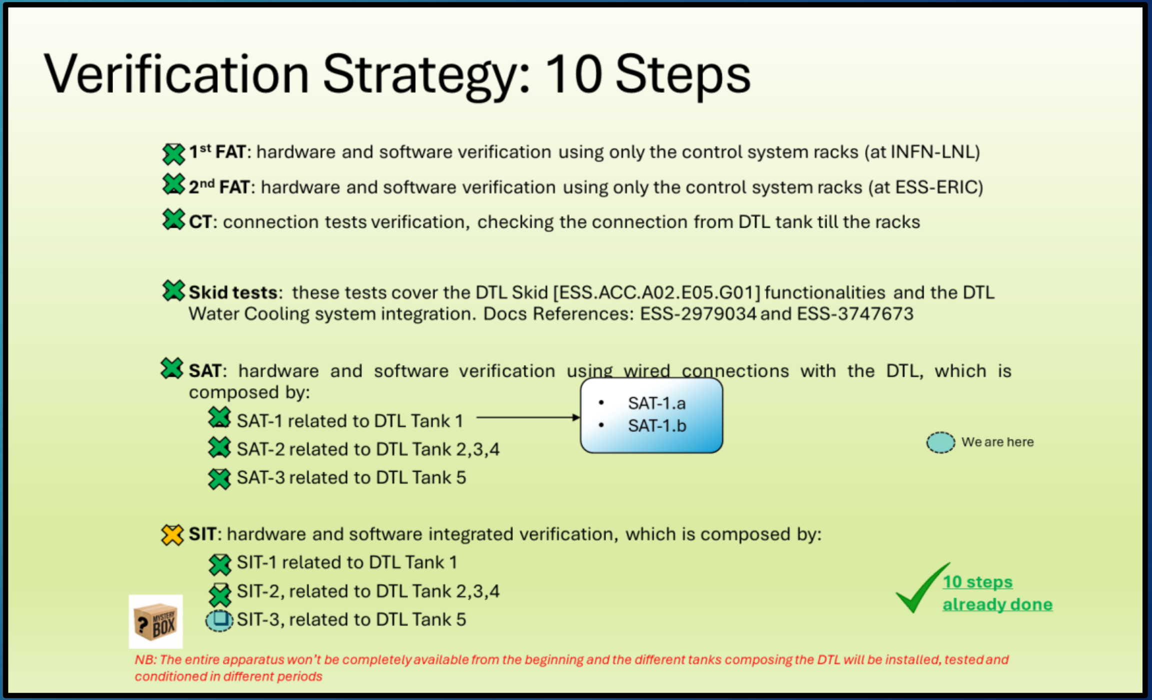
A complex architecture (not only in terms of control system architecture) requires:

- Good plan
- Useful verification stages

Compared to the RFQ commissioning, this activity required more time and effort

- First FAT in January 2020 @LNL
- Second FAT in May 2021 @ESS
- First SAT (SAT1) between January and March 2022
- First SIT (SIT1) in March 2022
- Last SAT (SAT3) in March 2024
- Last SIT is ongoing

COVID-19



NOTE: no power test performed at LNL

Commissioning stage

A complex architecture (not only in terms of control system architecture) requires:

- Good plan
- Useful verification stages

Compared to the RFQ commissioning, this activity required more time and effort

- First FAT in January 2020 @LNL
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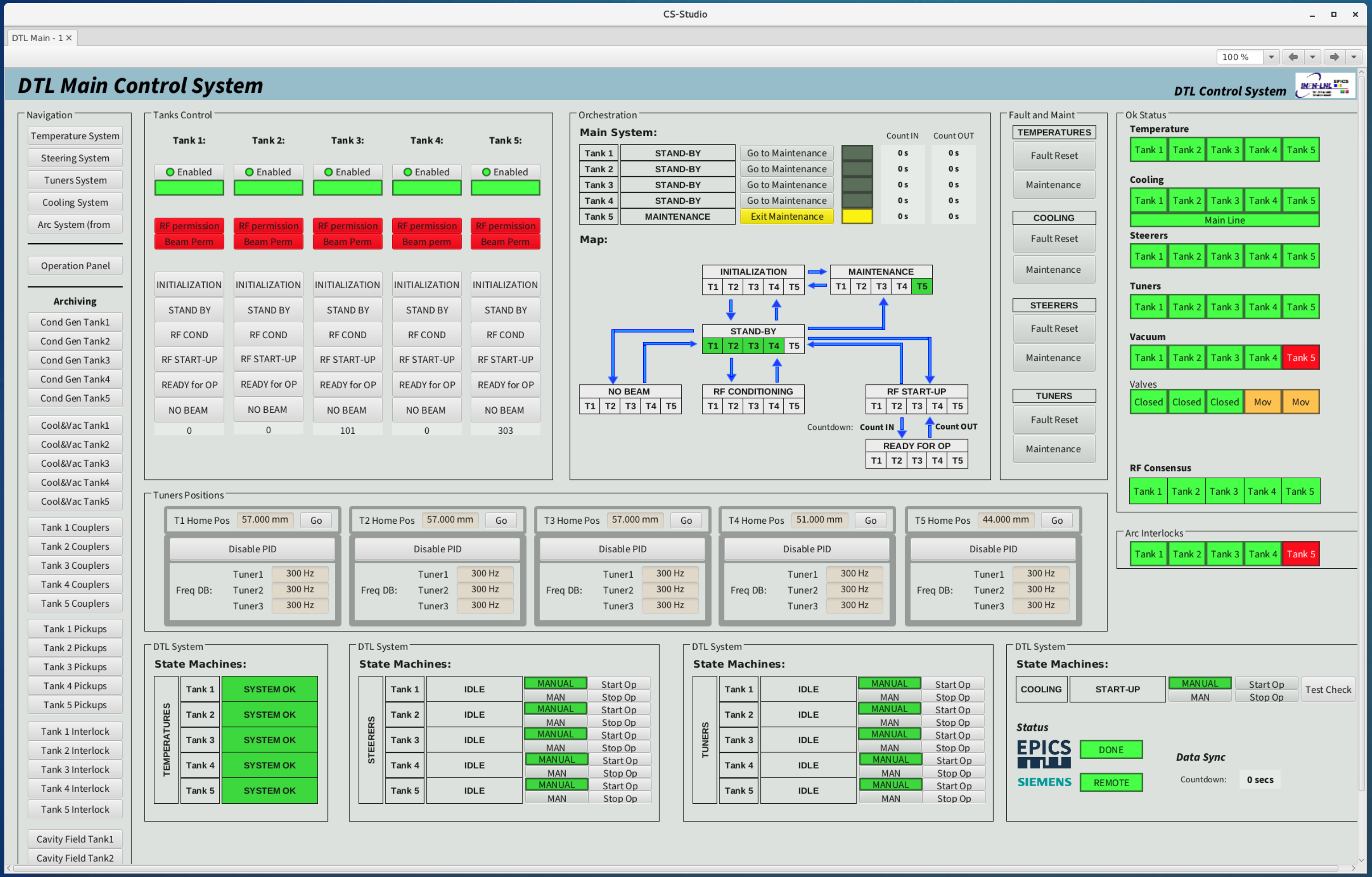
- First SAT (SAT1) between January and March 2022
- First SIT (SIT1) in March 2022
- Last SAT (SAT3) in March 2024
- Last SIT is ongoing

Tests included:

- HW functionality (cabling, labelling, etc.)
- EPICS and PLC SW functionality (for SAT)
- Integration in the production environment
- HW and SW interfaces with other LCS and ESS CS Services (archiver, alarms, version repo, etc.)
- Documentation (manuals, verification reports) ⟶ **Big impact**

ESS DTL LCS HMI



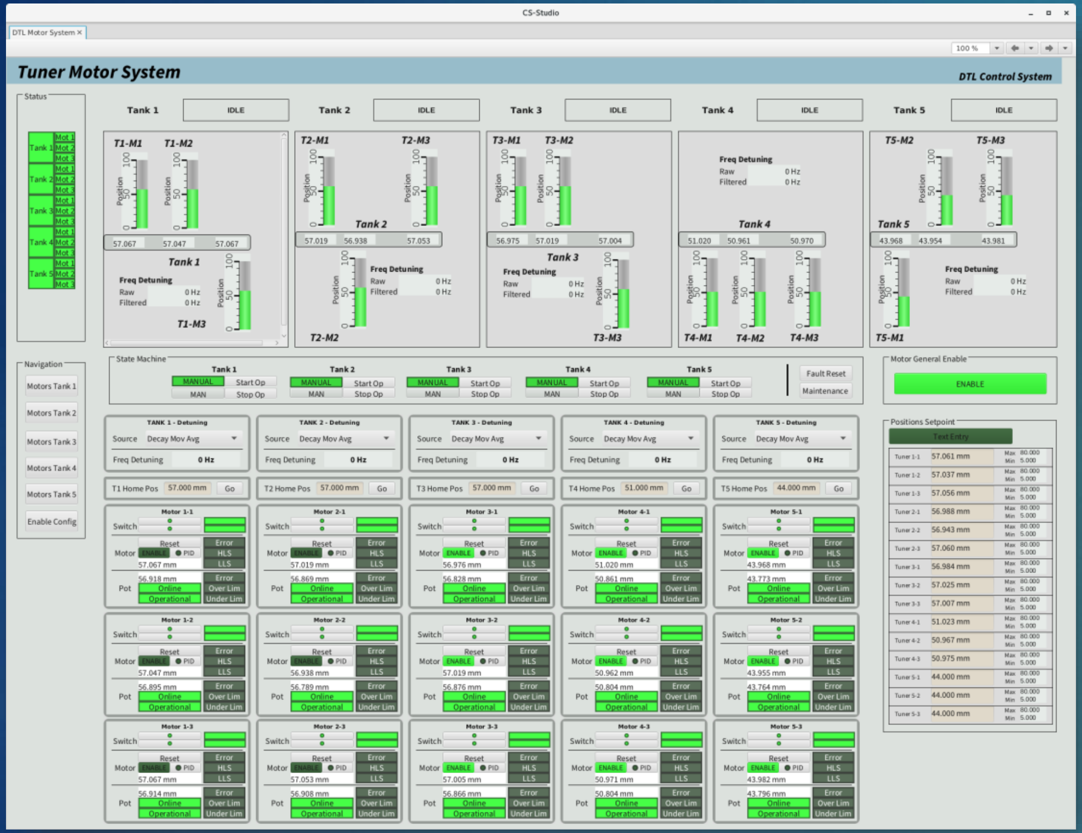
- **DTL Main Panel:**

Contains the main parameters provided by the functional systems used by the DTL

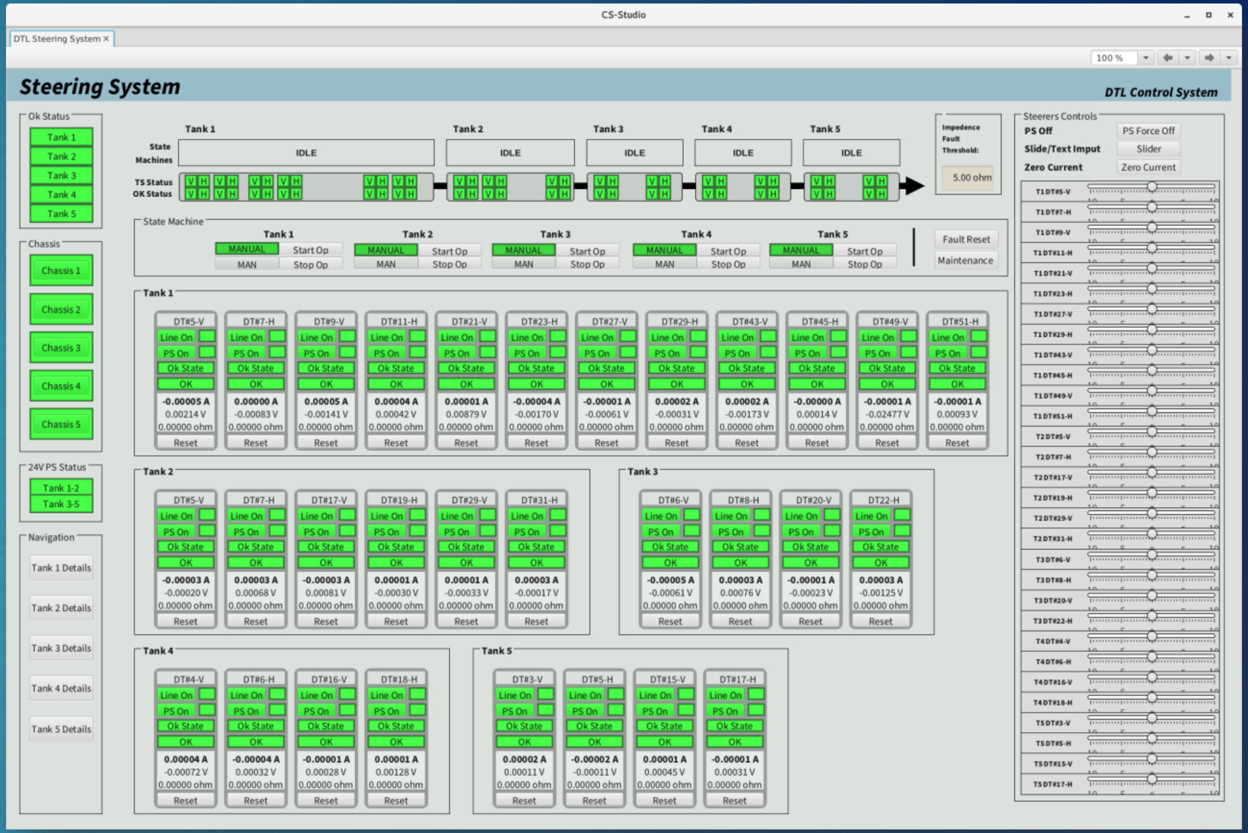
- Temperature
- Tuners
- Steerers
- Cooling (SKID)
- Vacuum
- RF

It also provides the interface to the high-level orchestration

ESS DTL LCS HMI

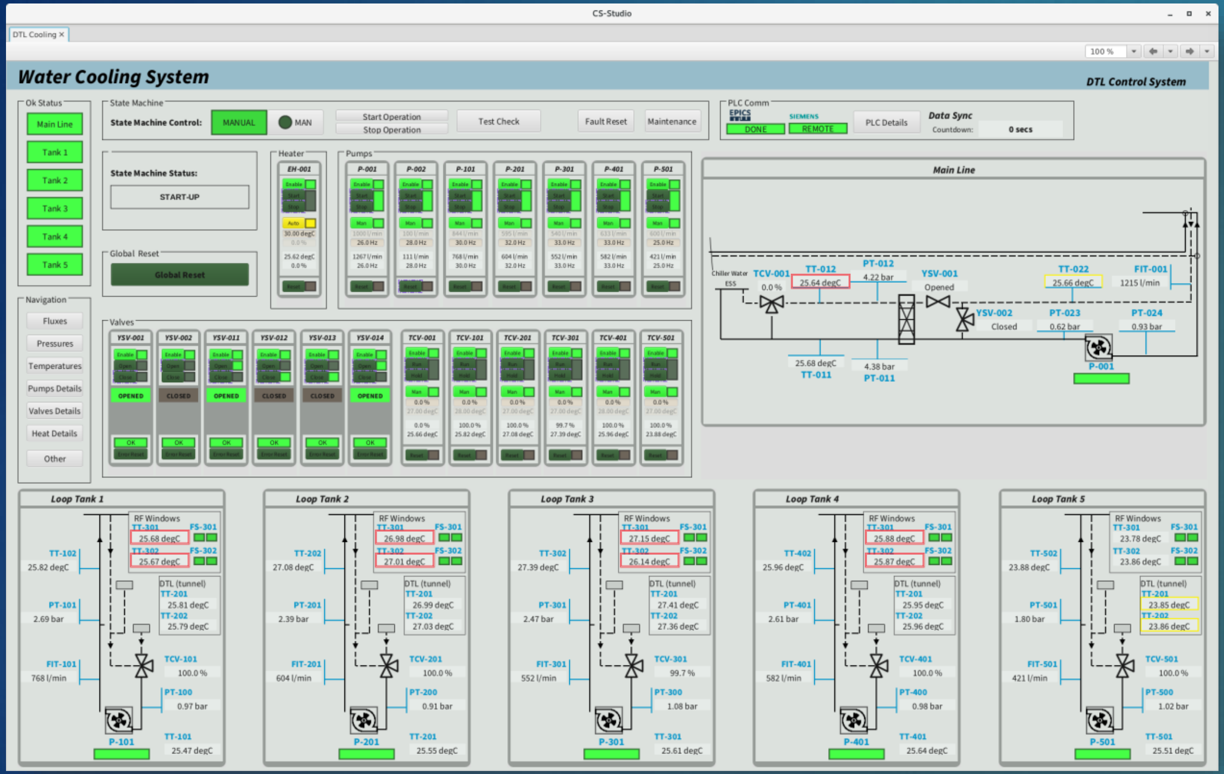


Tuners control panel

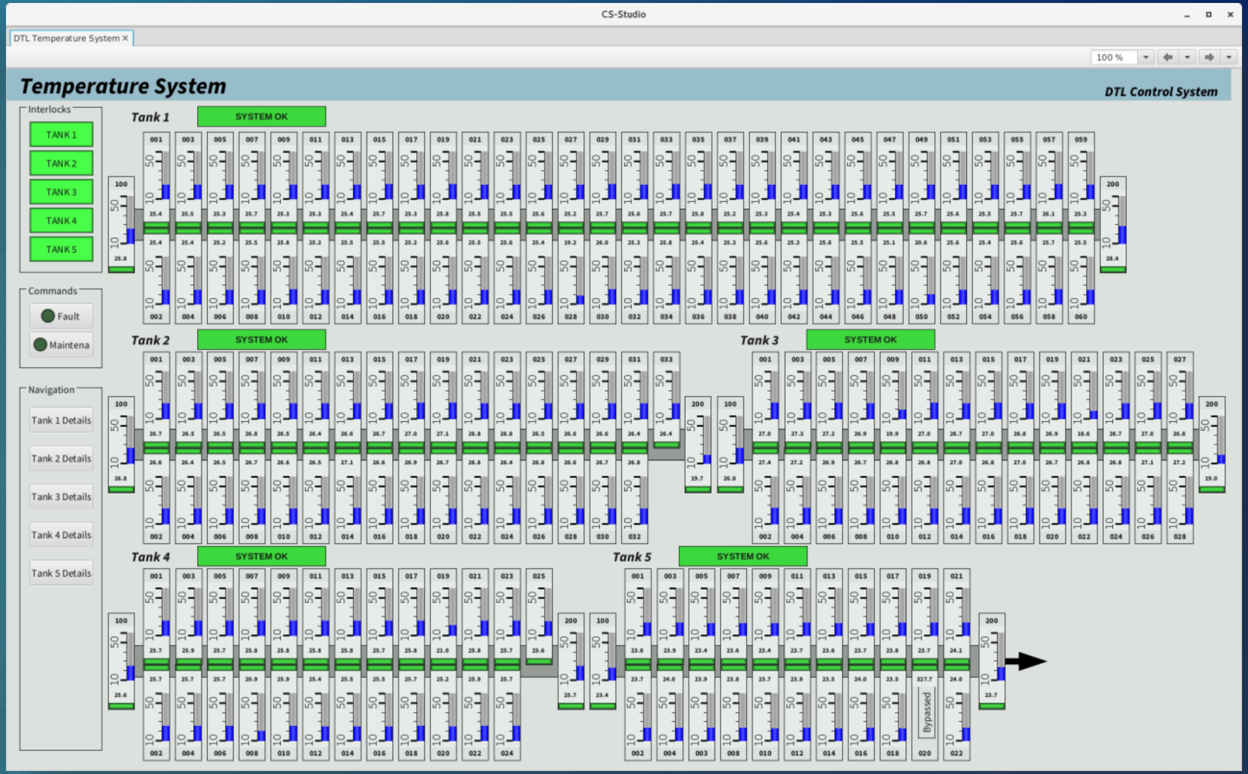


Steering control panel

ESS DTL LCS HMI

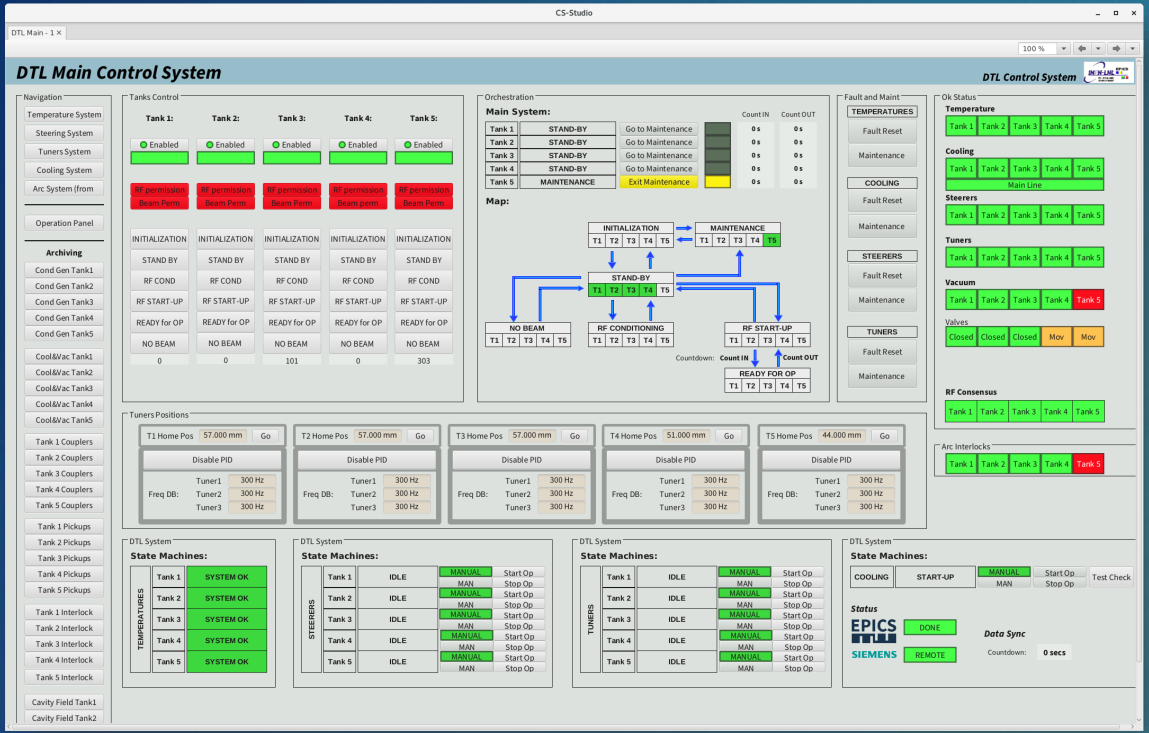


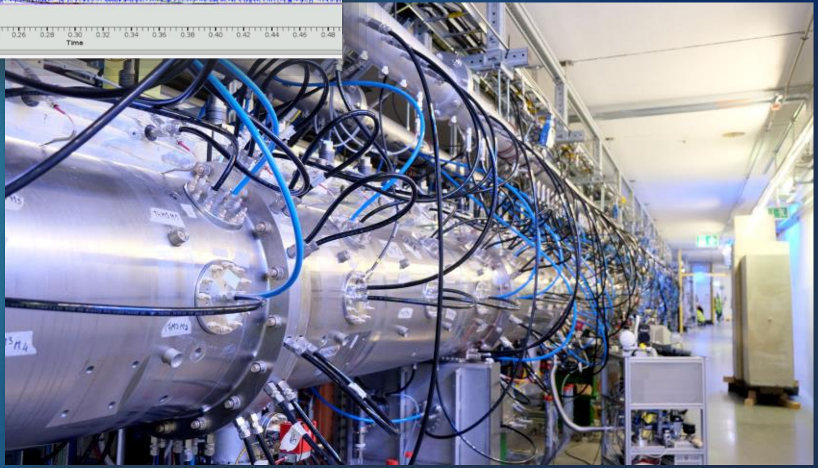
Cooling control panel



Temperatures control panel

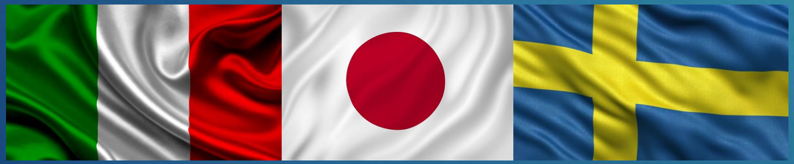
ESS DTL LCS in Action





DTL Conditioning: Tank1 started in 2022 Tanks 2,3,4 in 2023

Lessons Learned



"LESSONS LEARNED" IS JUST A FANCY WAY OF SAYING, "OOPS, LET'S NOT DO THAT AGAIN!"

(Distributed) Lessons Learned

- **Long R&D and software architecture had an enormous (good) impact in maintenance and device extension**
  - New magnetic devices can be integrated in the beam transport system in term of days
  - End users can not distinguish between different devices
  - same GUI → easier learning curve for operators
  - GUIs designed and developed with operators → “happy wife, happy life” rule

- **Maintenance HW and SW**
  - HW: industrial PCs required several maintenances during preparation times
  - HW & SW: removed internal EPICS IOCs in Caenels models → optimized code structure
  - SW: virtualization has decreased downtimes and preparation times
  - SW: great feedback from EPICS Community for code debug and driver exchange → big impact during development

(Distributed) Lessons Learned

- **Usage of opensouce solutions**
  - Good impact in terms of €€ and important support from communities (….considering consolidated communities)
  - Possibility to customize service / application
  - Requires dedicated skills and knowledge to proper configure and maintain systems
  - Dedicated teams are desirable, but difficult to achieve

- **The Choice of the right hardware**
  - New Caenels devices with Eth → introduced virtualization for beam transport system
  - From industrial PCs to Virtual Machines → minimized bottleneck in the HW maintenance

(Distributed) Lessons Learned

- **The Function of Power Test**
  - Possibility to validate control system architectures and technologies involved
  - Possibility to change (in time) solutions if required

- **The Importance of Documentation**
  - Keep track of the activity is a time-consuming activity
    - create and manage documentation could be required to be done in parallel with CS development and implementation
    - Don't underestimate the time required…. Overestimate it!
  - In a project, different documentations are required at different stages and for different scopes
    - Each kind of document requires different tools and services (i.e., wiki, git, etc.)
  - It is possible that documentation is connected to project's milestones and payments

(Distributed) Lessons Learned

- **Adopting EPICS as Control System Framework**
  - The EPICS architecture can be designed and implemented choosing only the tools and applications really required
  - Fantastic framework to define a distributed control system where there is the need of integrate different HW and SW solutions
  - Define a real distributed control system (sort of shared memory)
  - It is open source and supported by a real active community

(Distributed) Lessons Learned

- **Working with EPICS**
  - Require a good control architecture design in order to implement the best solution according to the project requirements
  - Size of the control system
  - Number of functional sub-systems involved and their sizes
  - Additional network services needed
  - Do not sub-estimate the network!

- **The Naming Convention is a critical point: understand your requirements and compare solutions from different laboratories**
  - A bad naming convention can have dramatic consequences in terms of maintenance, control system architecture and downtimes

Thank You for Your Attention