CERN

INFN-LNL, 29 September 2016

By Dr. Marco Pezzetti

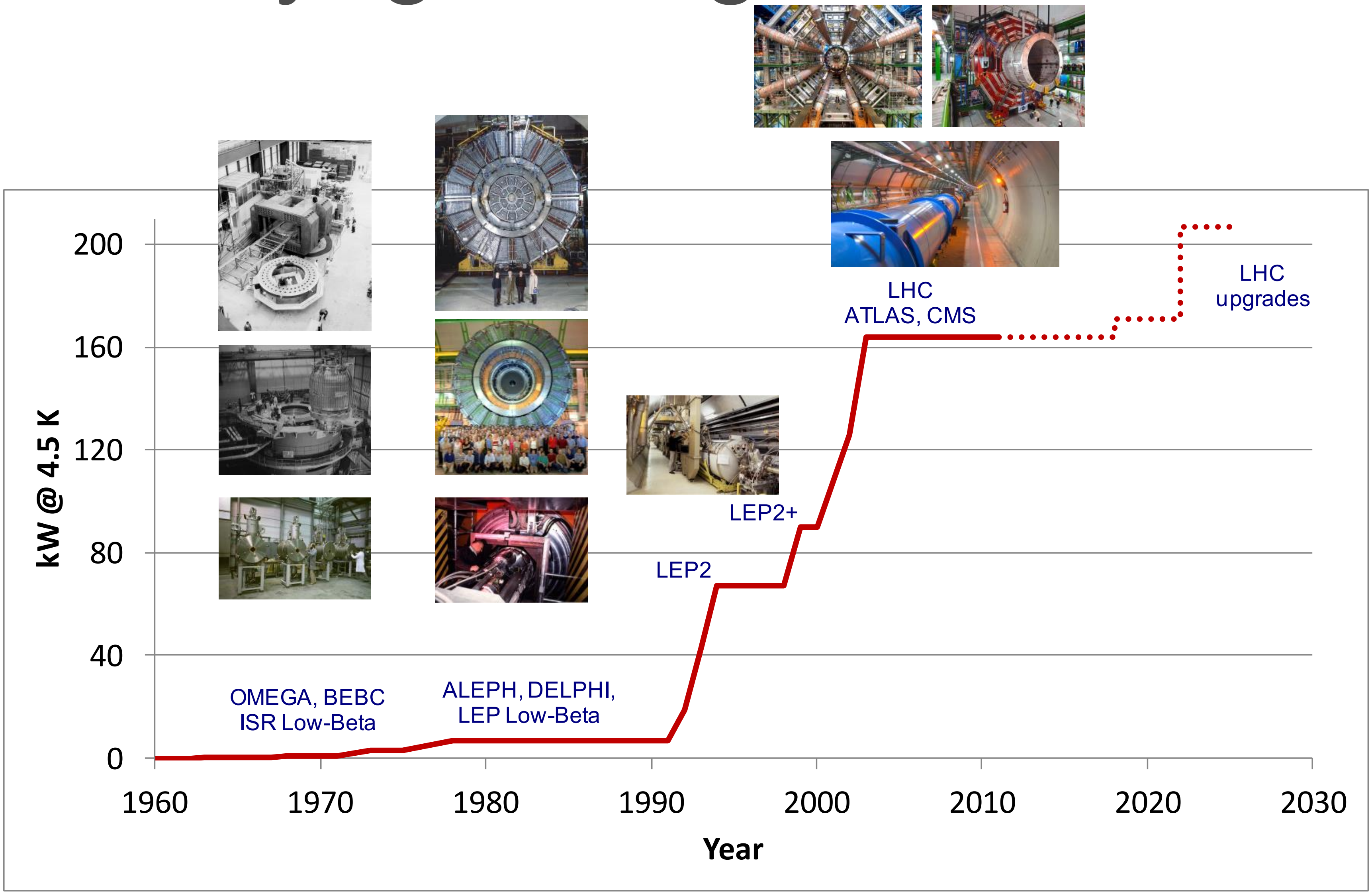
"The control System of the new CERN HI-LUMI SM18 Test Facility infrastructure"

The necessity to upgrade the LHC has given rise to the **High Luminosity LHC upgrade (HL-LHC)** project. The project relies on a number of key innovative technologies, representing exceptional technological challenges, such as cutting-edge 13 Tesla superconducting magnets, very compact and ultra-precise superconducting cavities for beam rotation, and 300-metre-long high-power superconducting links with zero energy dissipation.

The most technically challenging aspects of the LHC upgrade cannot be done by CERN alone and requires a strong collaboration involving external expertise and a global modernization of existing CERN Test Facility infrastructure as in the SM18.

The SM18 hall was originally optimized for the NbTi, LHC magnet testing, but with the (HL-LHC) coming up a major upgrade of the test facility is ongoing.

CERN cryogenic figures



An alignment of interests along time…..

*Europe's top priority should be the **exploitation of the full potential of the LHC**, including the high-luminosity upgrade of the machine and detectors with a view to collecting **ten times more data than in the initial design, by around 2030**. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*

EU Strategy Group on Particle Physics recommended to

*"to propose an ambitious **post-LHC accelerator project at CERN** by the time of the next Strategy update **(NOTE: to take place in 2018)***

...

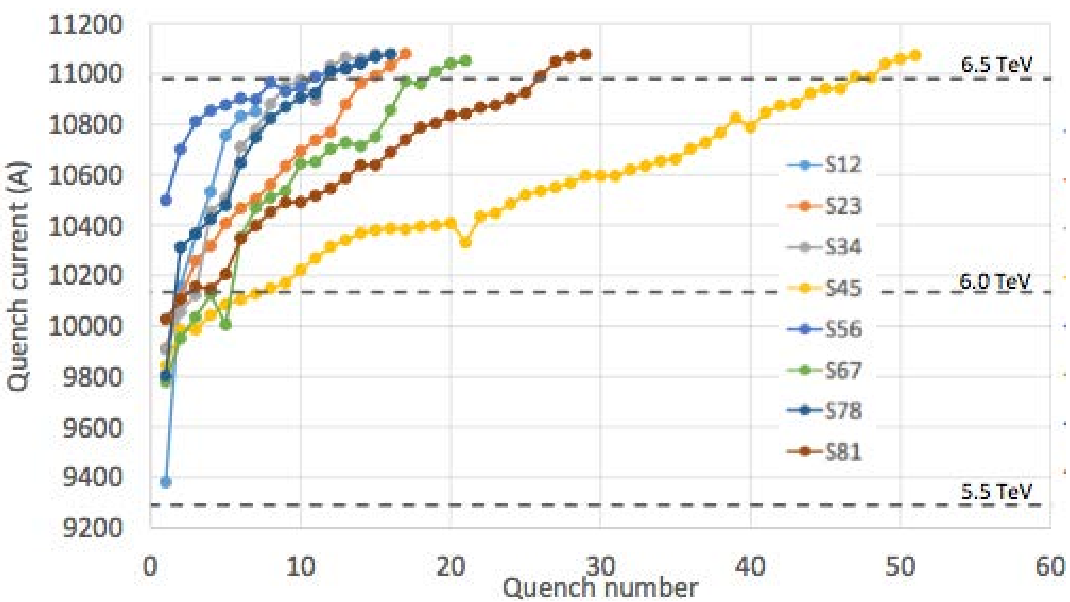
d) CERN should undertake design studies for accelerator projects in a global context,

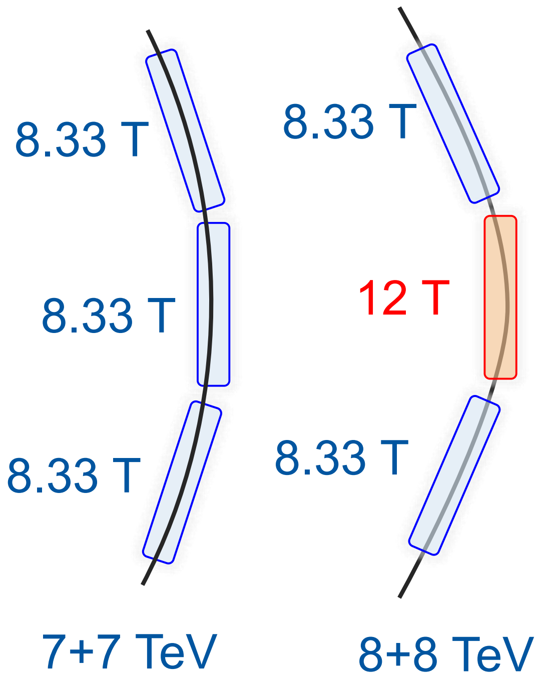
...

LHC to its present limit…..

- Training the machine up to 14 TeV c.o.m.
- (and somewhat beyond, up to 15 TeV c.o.m. at most ?)

- *Partial energy upgrade*, a portion of the magnets may be could be upgraded to increase the energy (building on HL-LHC 11T development program), up to 16 TeV c.o.m. Feasibility and cost effectiveness to be studied





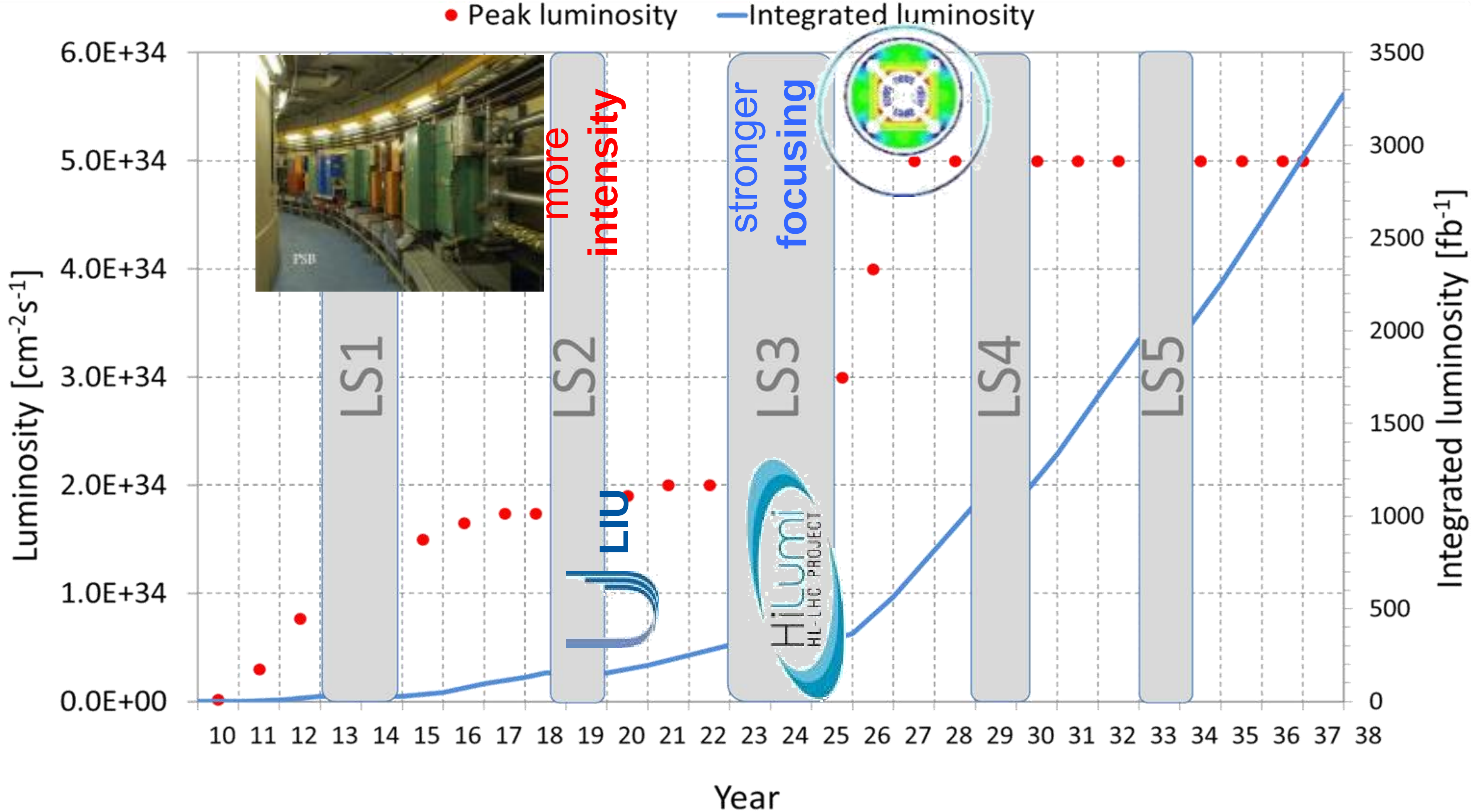
By courtesy of CERN-MP3

Scenarios under study by team led by O. Bruning

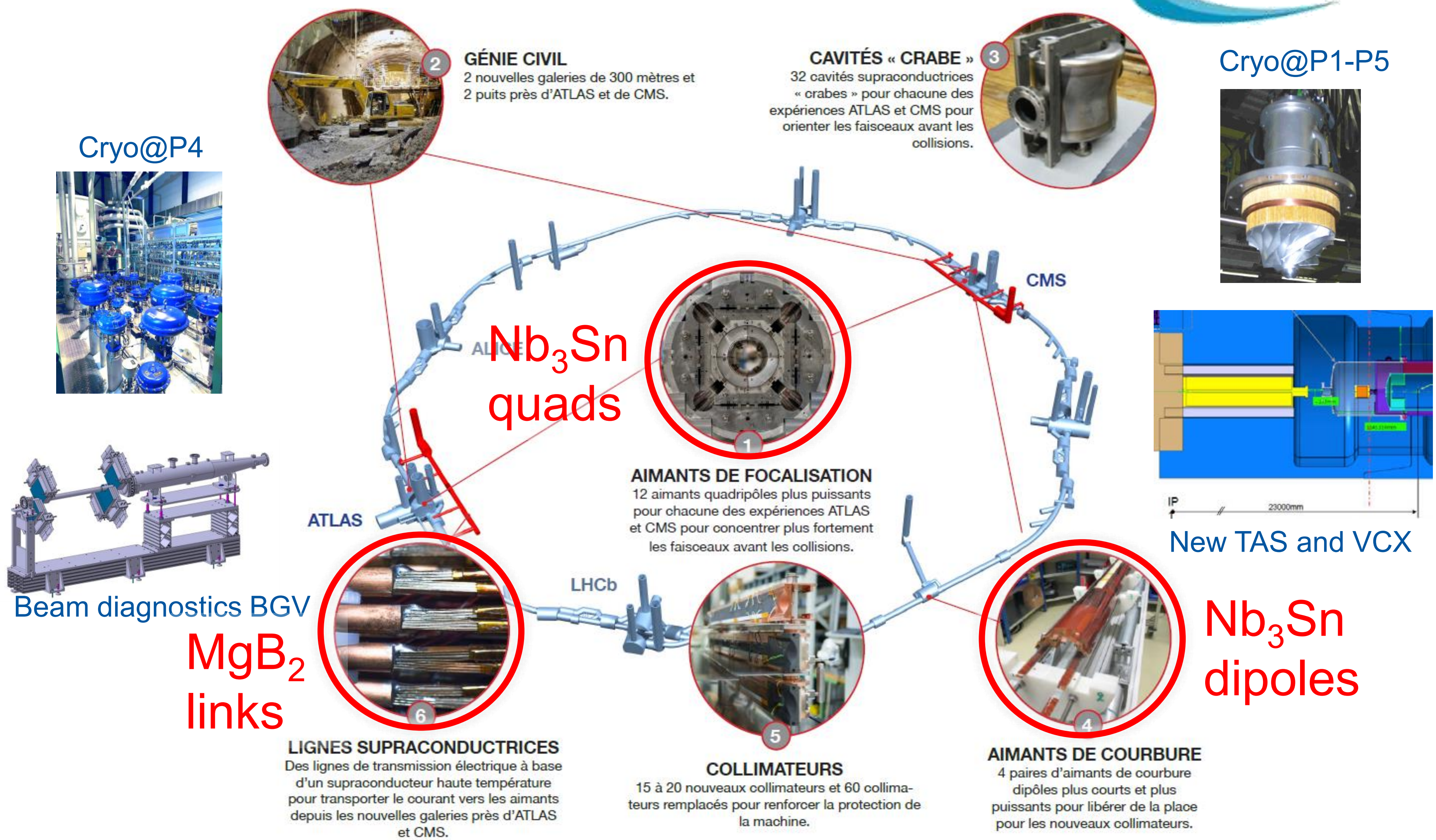
HL-LHC: new light with Nb_3Sn

More data

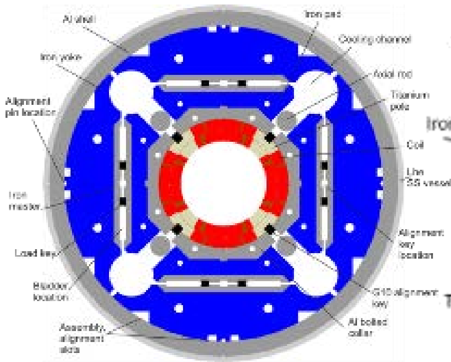
$$\text{Luminosity} = f * N^2 / 4\pi\sigma^2$$



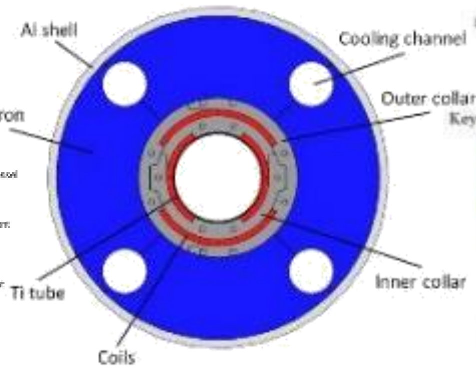
LHC HiLumi project



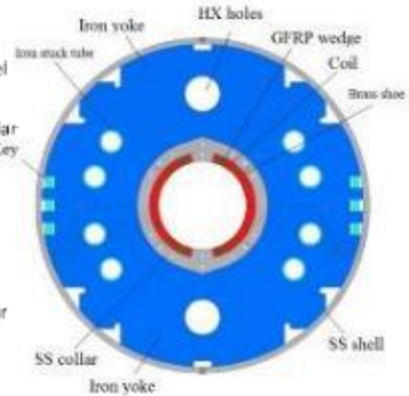
HL-LHC the required magnets



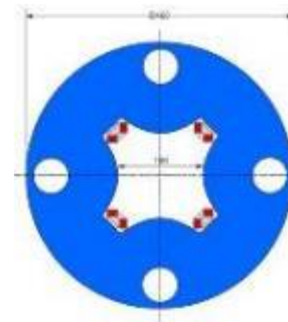
Triplet QXF (LARP and CERN)



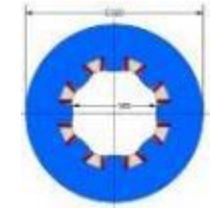
Orbit corrector (CIEMAT)



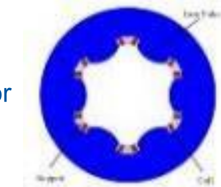
Separation dipole D1 (KEK)



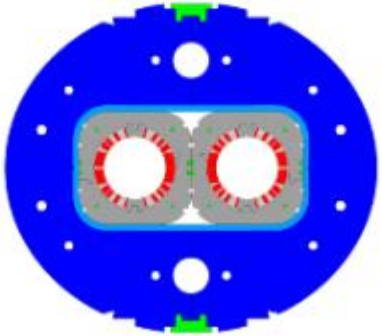
Skew quadrupole corrector (INFN)



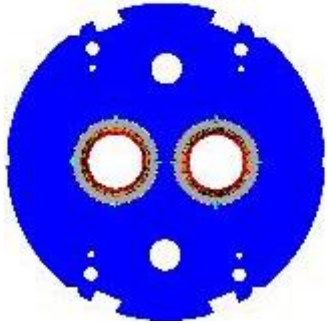
Corrector octupole (INFN)



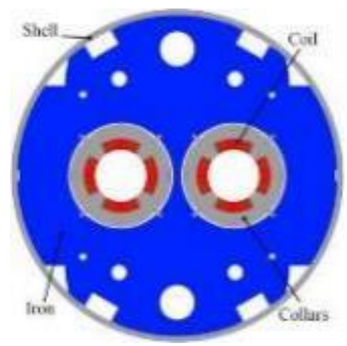
Corrector sextupole (INFN)



Recombination dipole D2 (INFN design)

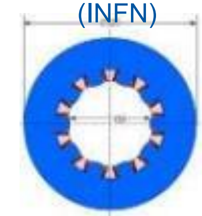


D2-Q4 orbit correctors (CERN)

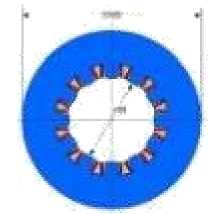


Q4 (CEA)

11 T (CERN)



Corrector decapole (INFN)



Corrector dodecapole (INFN)

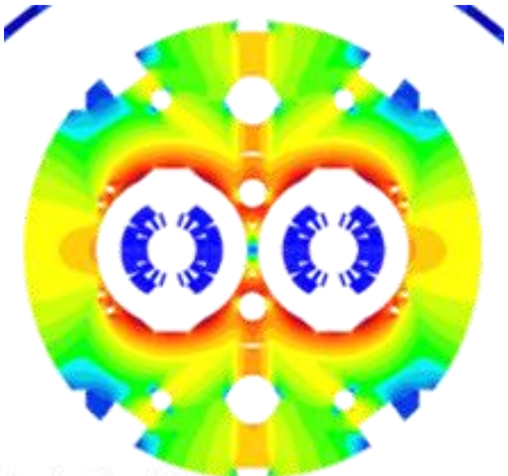
Cross-sections to scale

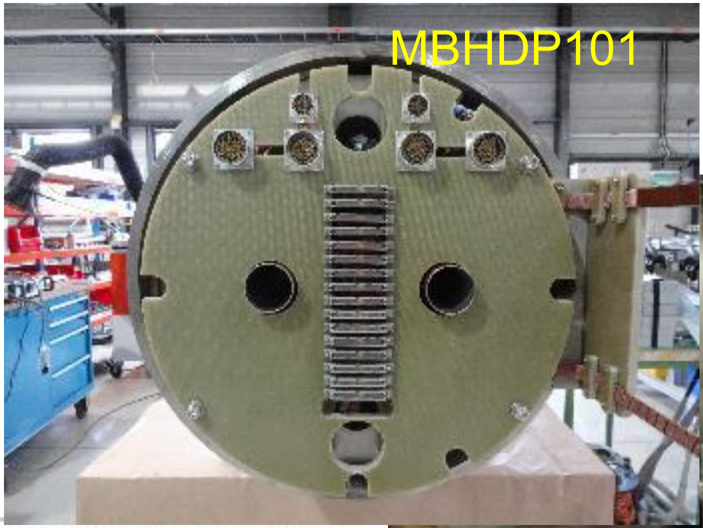
By courtesy of E. Todesco and F. Savary (CERN)

ICHEP2016CHICAGO

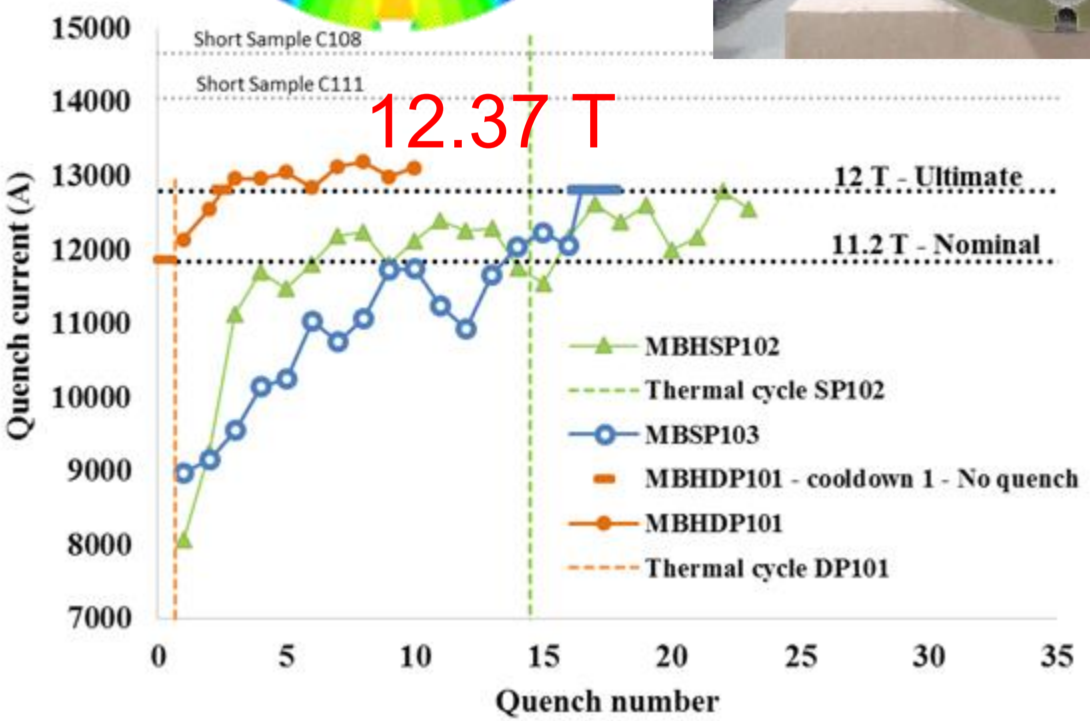
Test of CERN 11T models

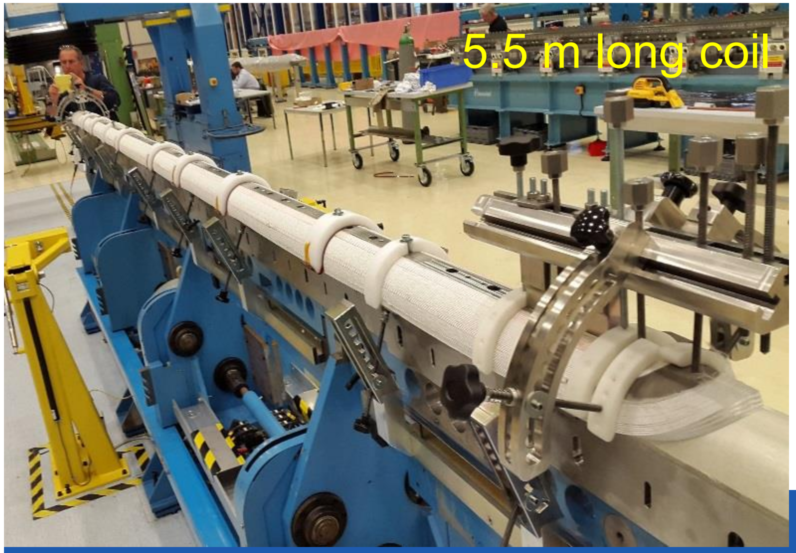
Cos-θ





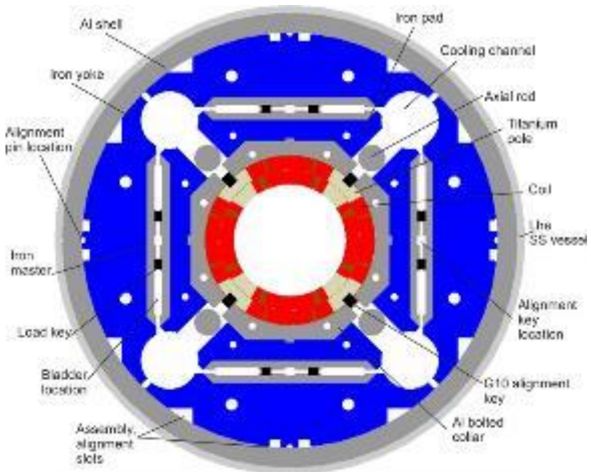
12.37 T

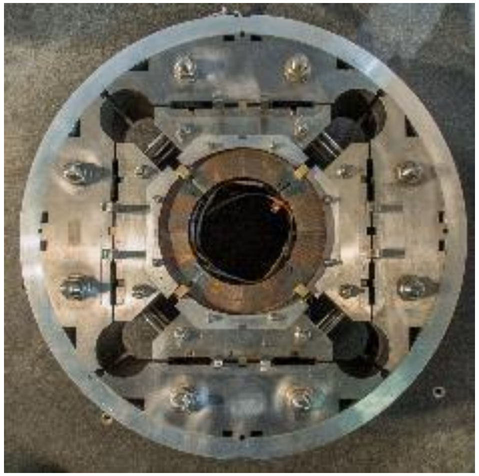




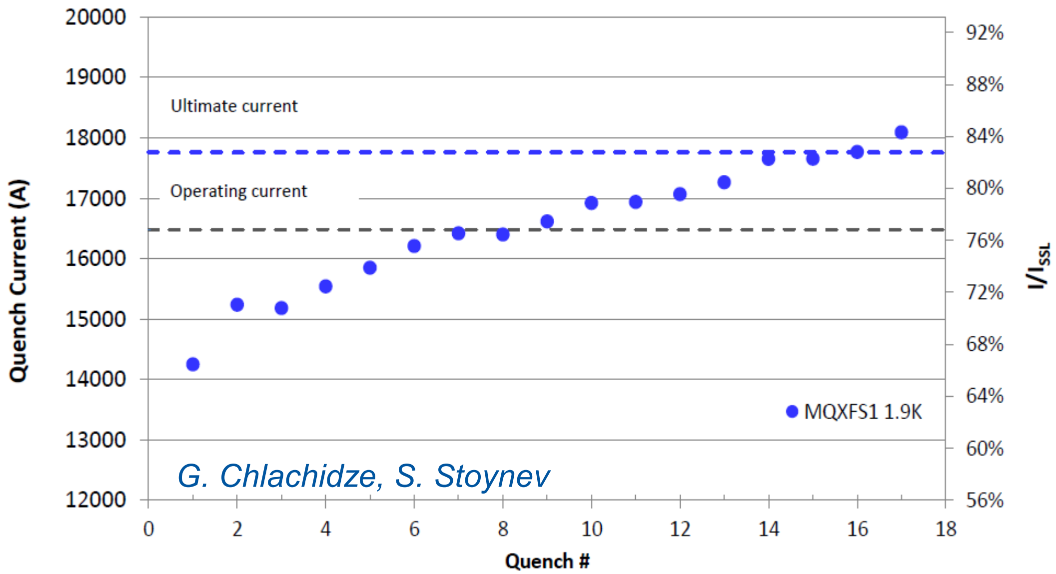
By courtesy of F. Savary (CERN)

Test of MQXFS1 (first model)





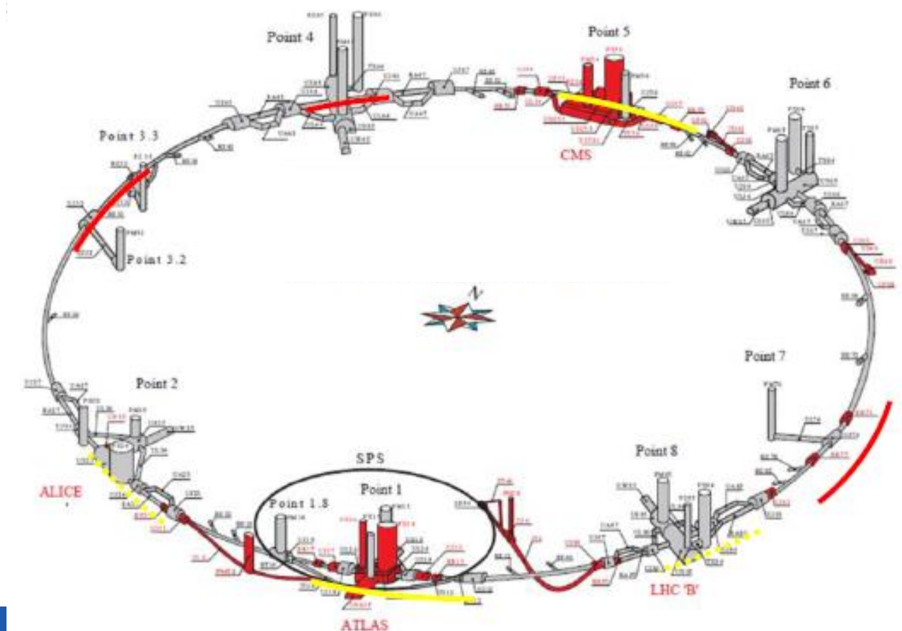
By courtesy of G. Ambrosio (FNAL), P. Ferracin (CERN et al)



The HL-LHC (HiLumi) project Objectives and contents

Determine a hardware configuration and a set of beam parameters that will allow the LHC to reach the following targets:

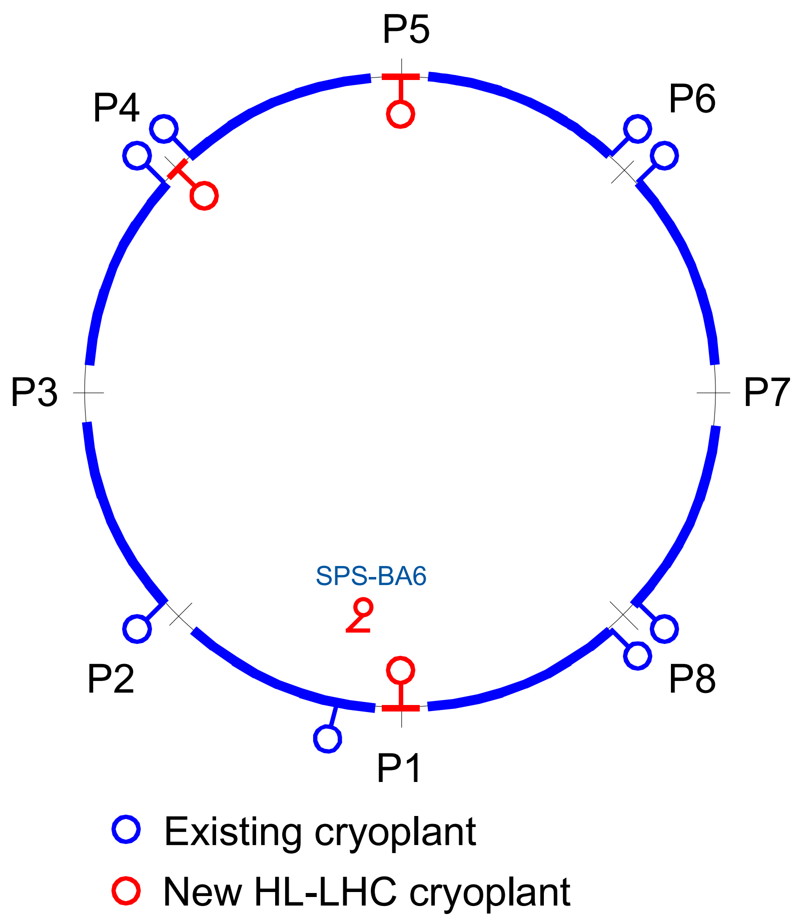
- enable a total integrated luminosity of 3000 fb^{-1}
- enable an integrated luminosity of 250-300 fb^{-1} per year
- design for $\mu \sim 140$ (~ 200) (peak luminosity of 5 (7) $10^{34}\ cm^{-2}\ s^{-1}$)
- design equipment for 'ultimate' performance of 7.5 $10^{34}\ cm^{-2}\ s^{-1}$ and 4000 fb^{-1}



Major intervention on 1.2 km of LHC ring

- New IR-quads using Nb_3Sn superconductor
- New 11 T Nb_3Sn (short) dipoles
- Collimation upgrade
- Cryogenics upgrade
- Crab Cavities
- Cold powering
- Machine protection

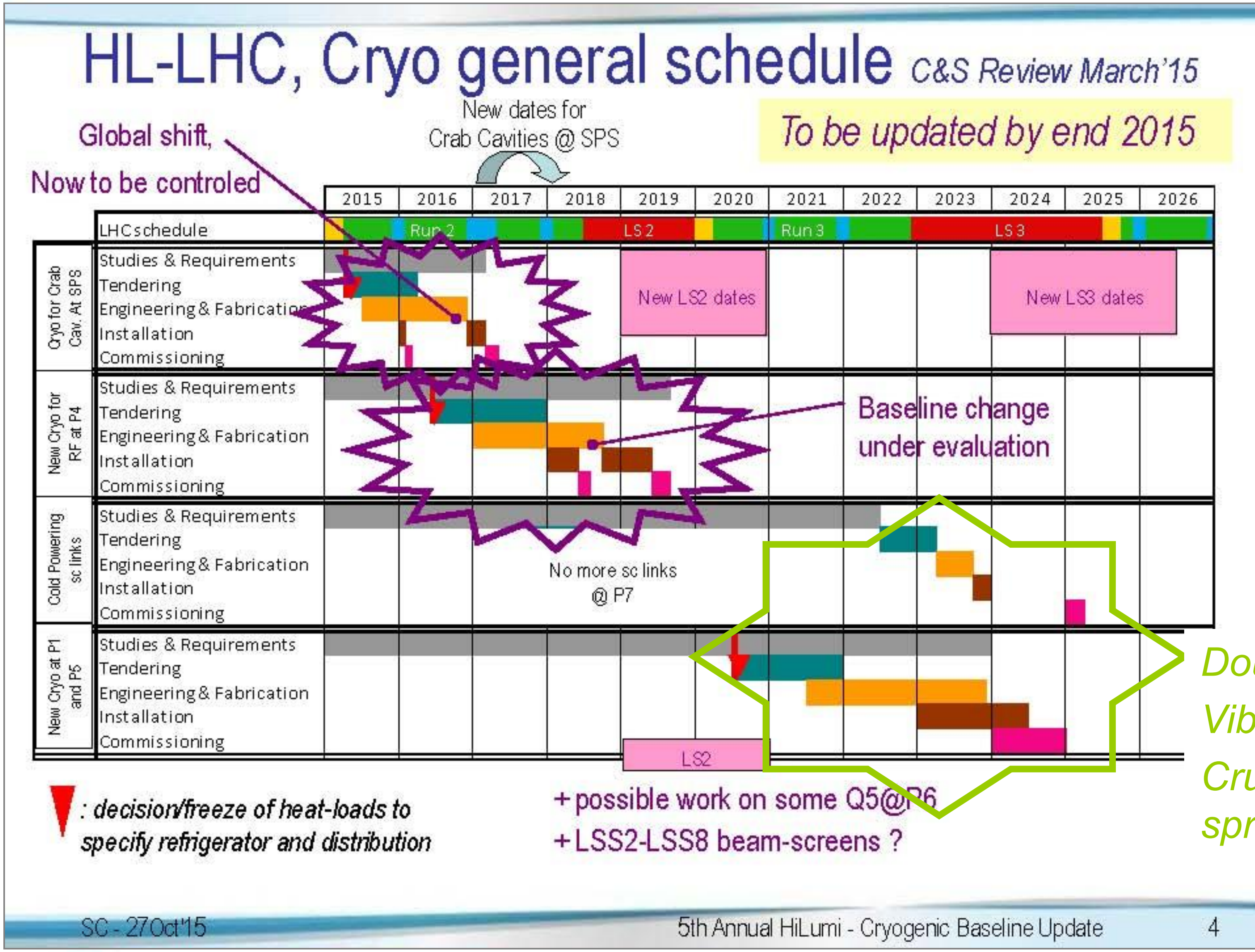
HL-LHC cryogenic upgrade contents



- 2 new cryoplants (~18 kW @ 4.5 K) at P1 and P5 for high-luminosity insertions
- 1 new cryoplant (~4 kW @ 4.5 K) at P4 for SRF cryomodules. (Alternative under study: upgrade of 1 existing LHC cryoplant)
- 11T + Q5@P6 (not reported here)
- SRF test facility with beam at SPS-BA6 primarily for Crab-Cavities

SM18 related activities not reported here

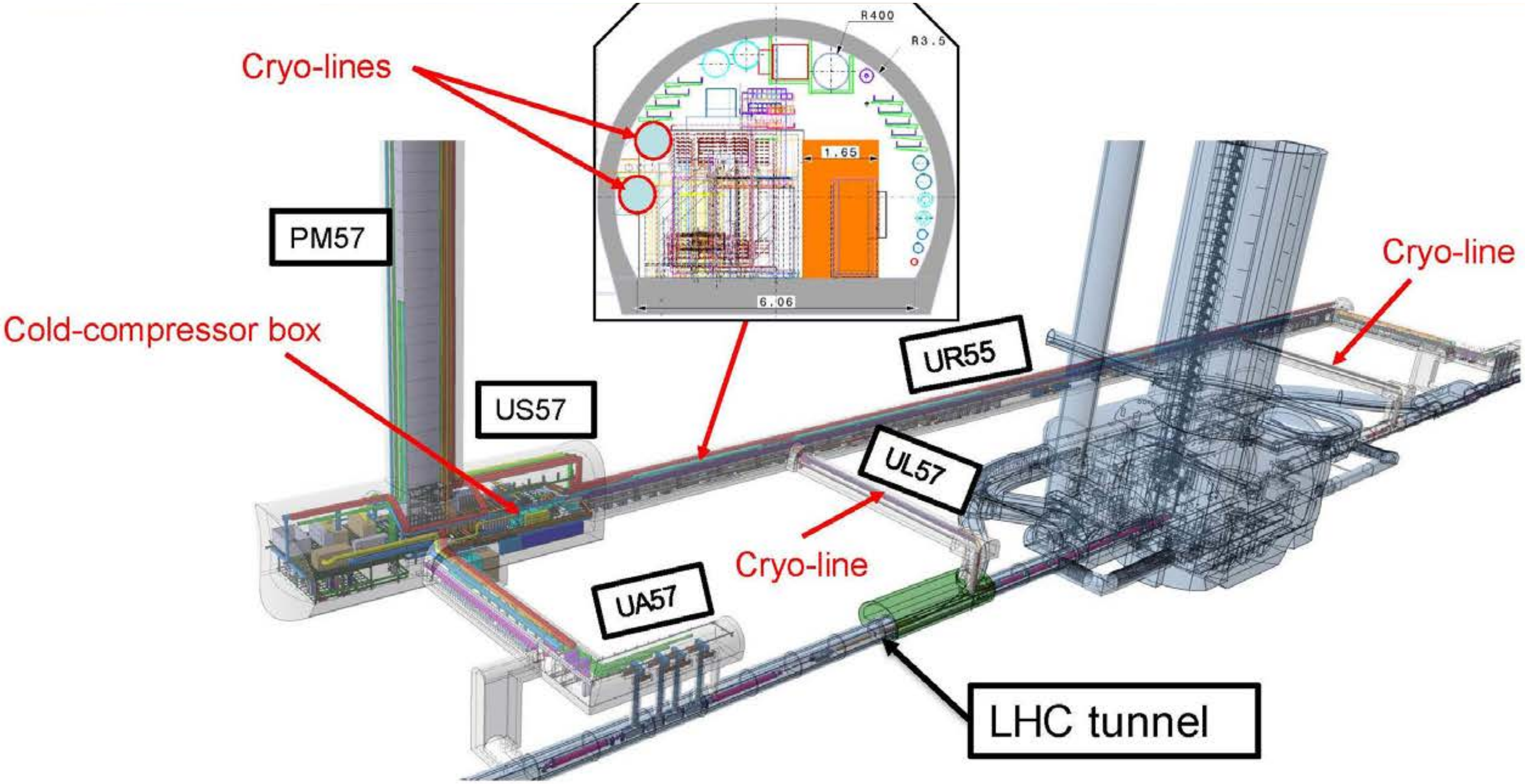
Overall schedule and evolution



Double decker
Vibrations/LS2
Crush program spring'16

The HL-LHC (HiLumi) : P1/P5 cryogenics

HL-LHC 3D integration model



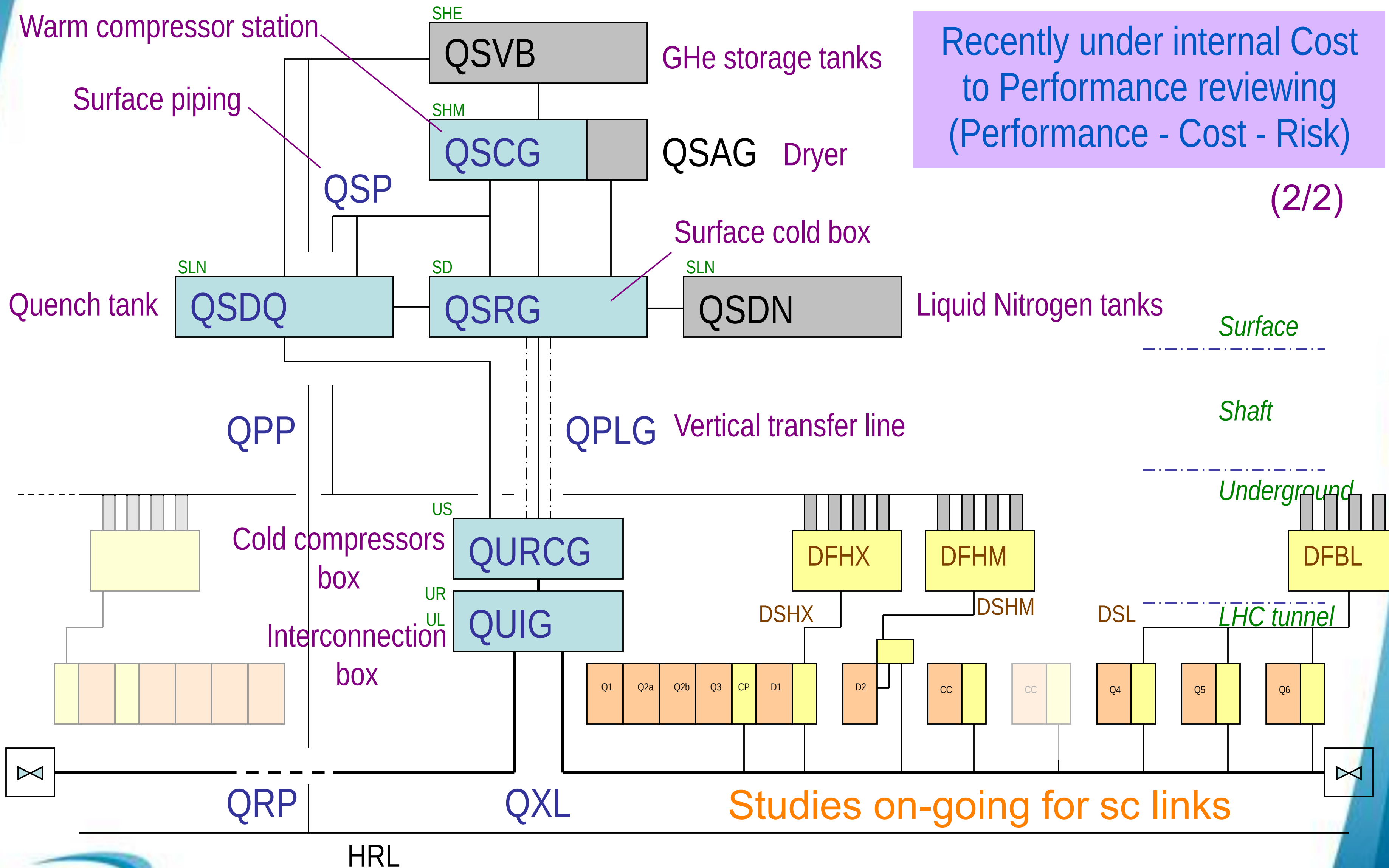
Completely new infrastructure required,
including for Cryogenics!

P1/P5 Cryogenic architecture

18 kW equivalent at 4.5 K, including 3 kW at 1.8 K

Recently under internal Cost to Performance reviewing (Performance - Cost - Risk)

(2/2)



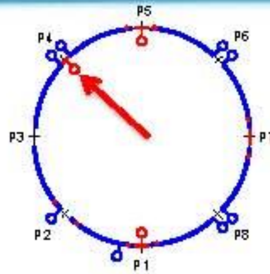
Studies on-going for sc links

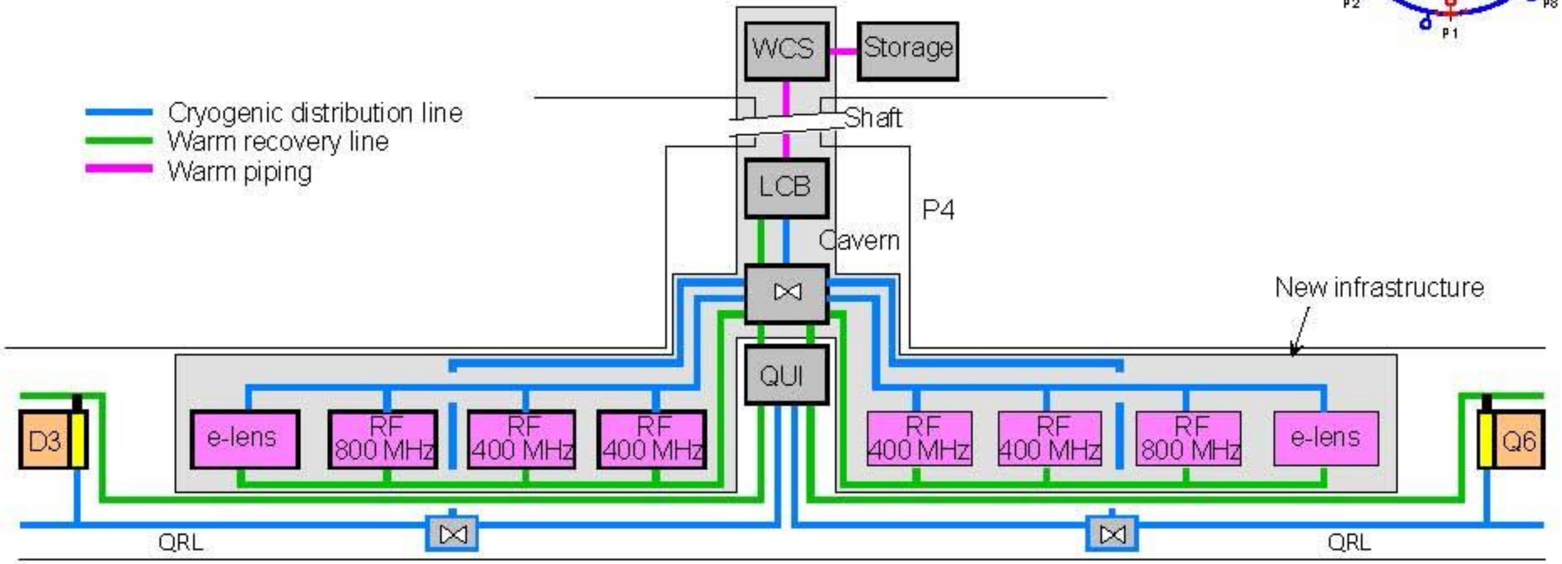
The HL-LHC (HiLumi) : P4 cryogenics

LHC P4 Cryo Baseline

A dedicated refrigerator, valve box and cryolines

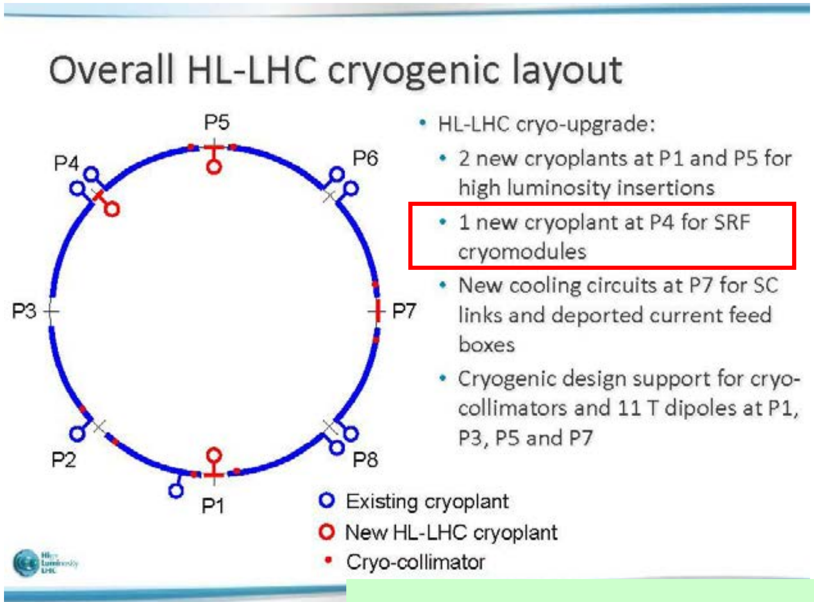
New cryogenic infrastructure at P4





- 1 warm compressor station (WCS) in noise insulated surface building
- 1 lower cold box (LCB) in UX45 cavern
- 1 valve box in UX45 cavern
- 2 main cryogenic distribution lines
- 2 interconnection lines with existing QRL service modules

Baseline so far



Cooling capacity:

- To align P4 on P6 (without RF loads)

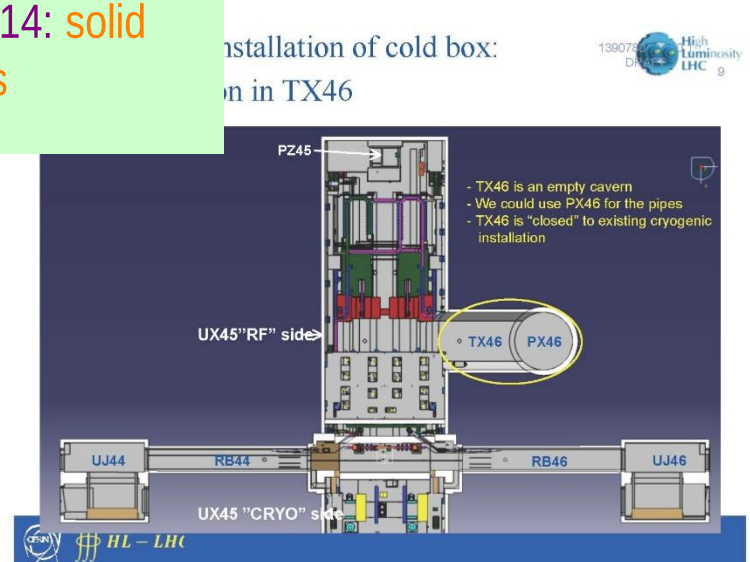
Flexibility:

- For specific RF tuning needs

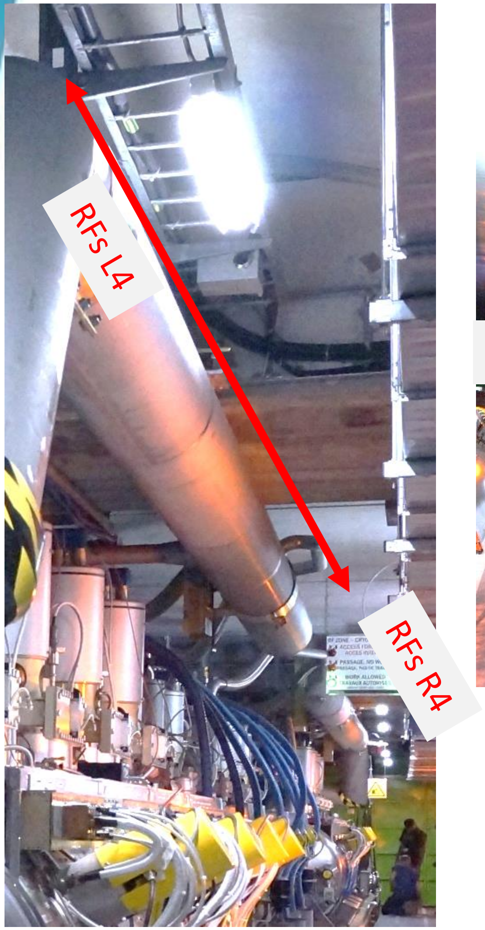
(as part of the tentative to decouple the RF from Magnets following 2008 sector 34 incident, without specific requirement)

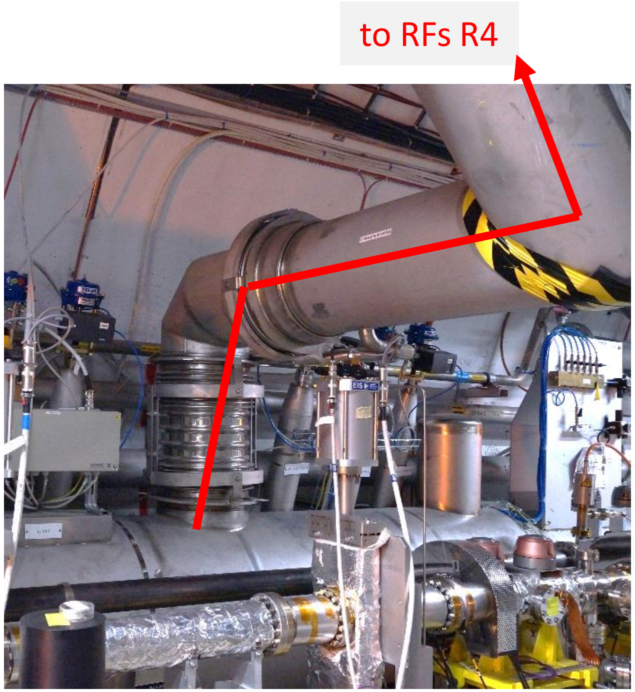
- In view of future "envisaged" sub-systems to be cooled at P4 (e-lens)

Progress 1st semester 2014: solid integration studies



P4-RF distribution line

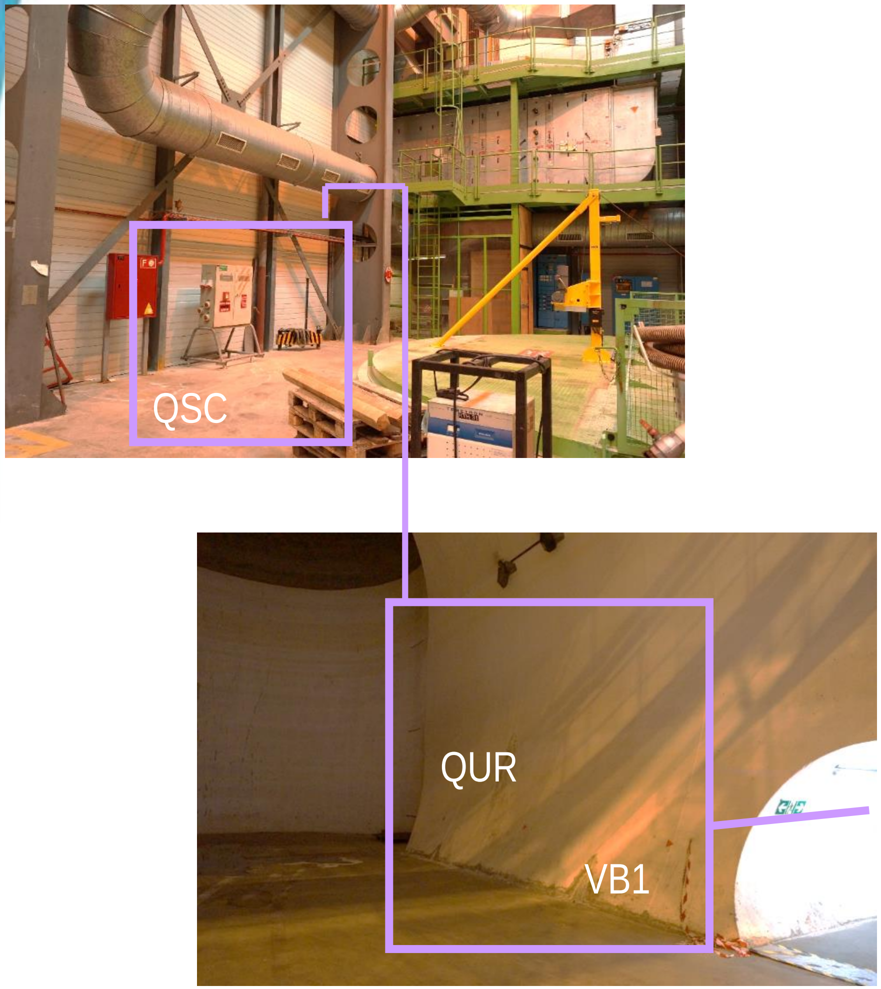




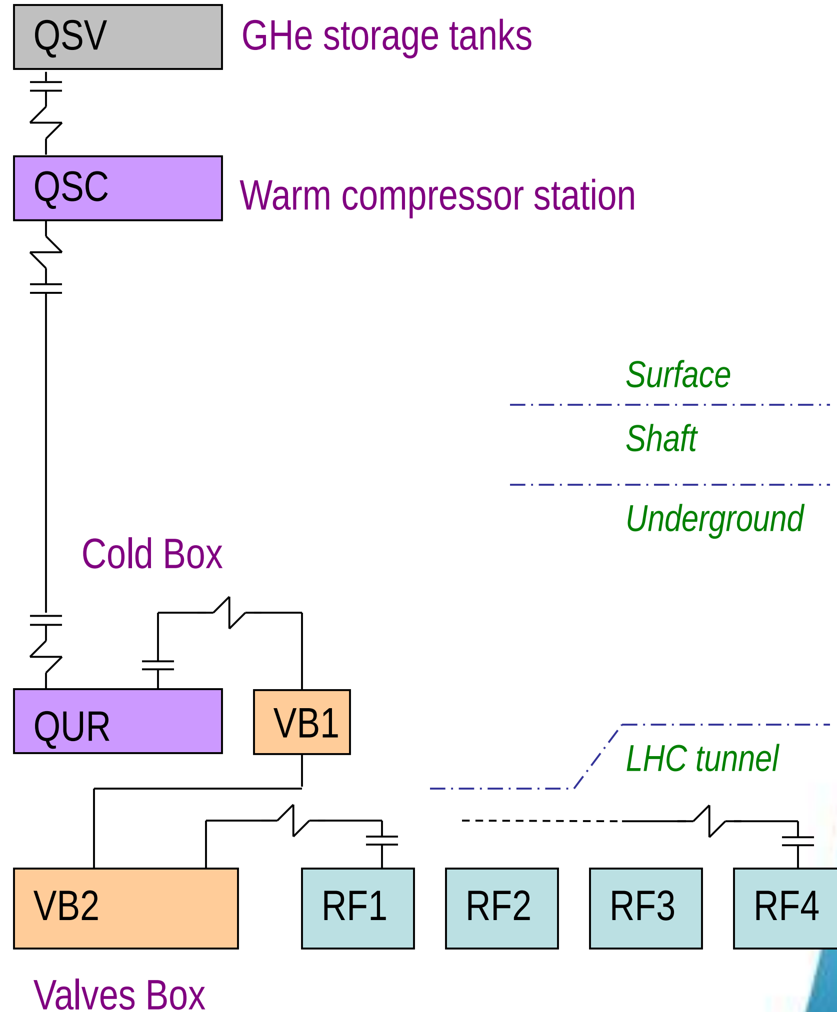
Connection to QRL and distribution along the existing and "future" RF zone (+e-lens!) to be looked at for present baseline and alternative scenario

RF tests refrigeration concept

Simplified infrastructure w.r.t baseline



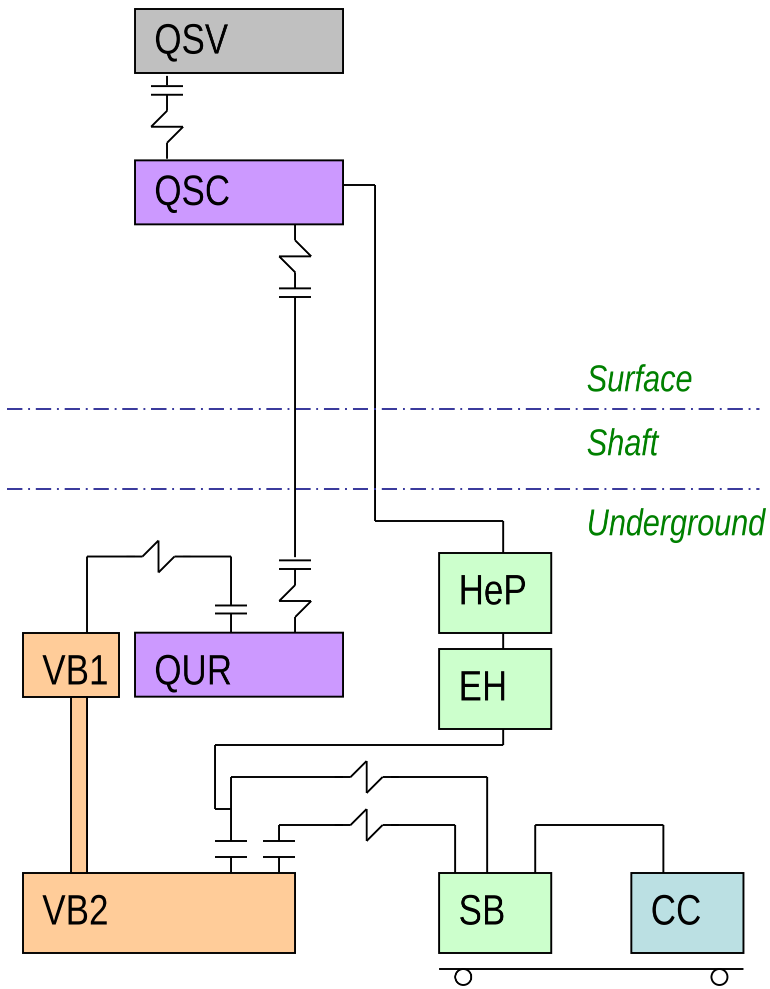
LHC-P4 during Long Shutdowns



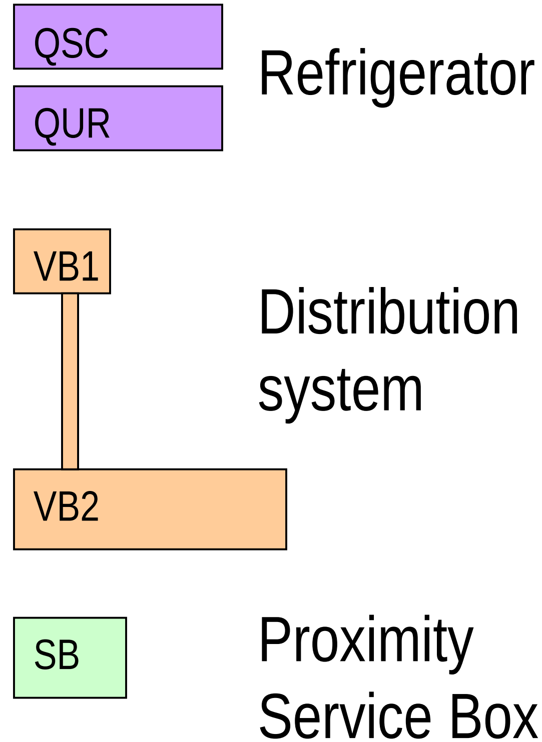
The HL-LHC SPS BA6

SPS RF tests refrigeration concept

SPS-BA6 during beam Runs

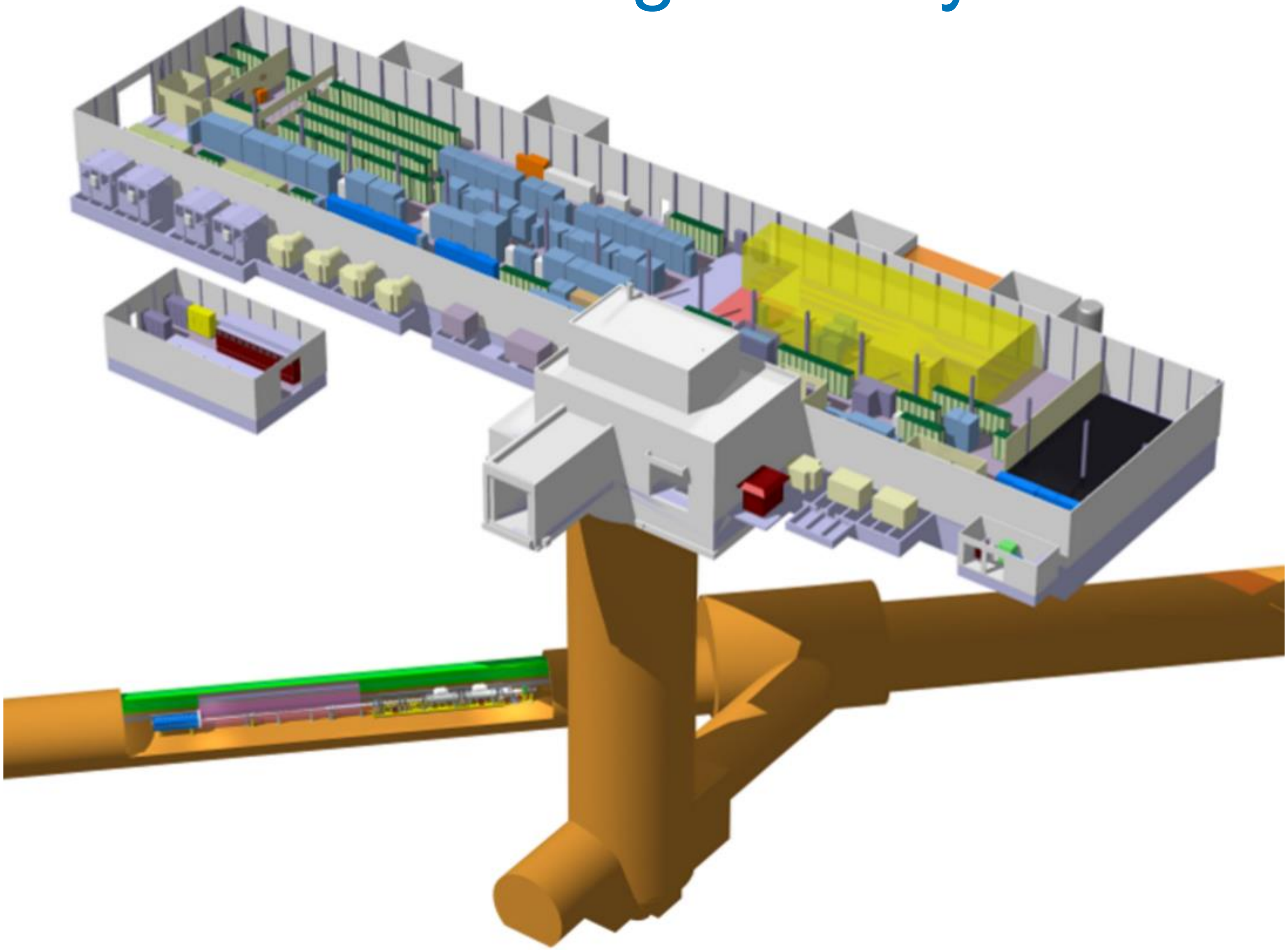


Main Procurement packages



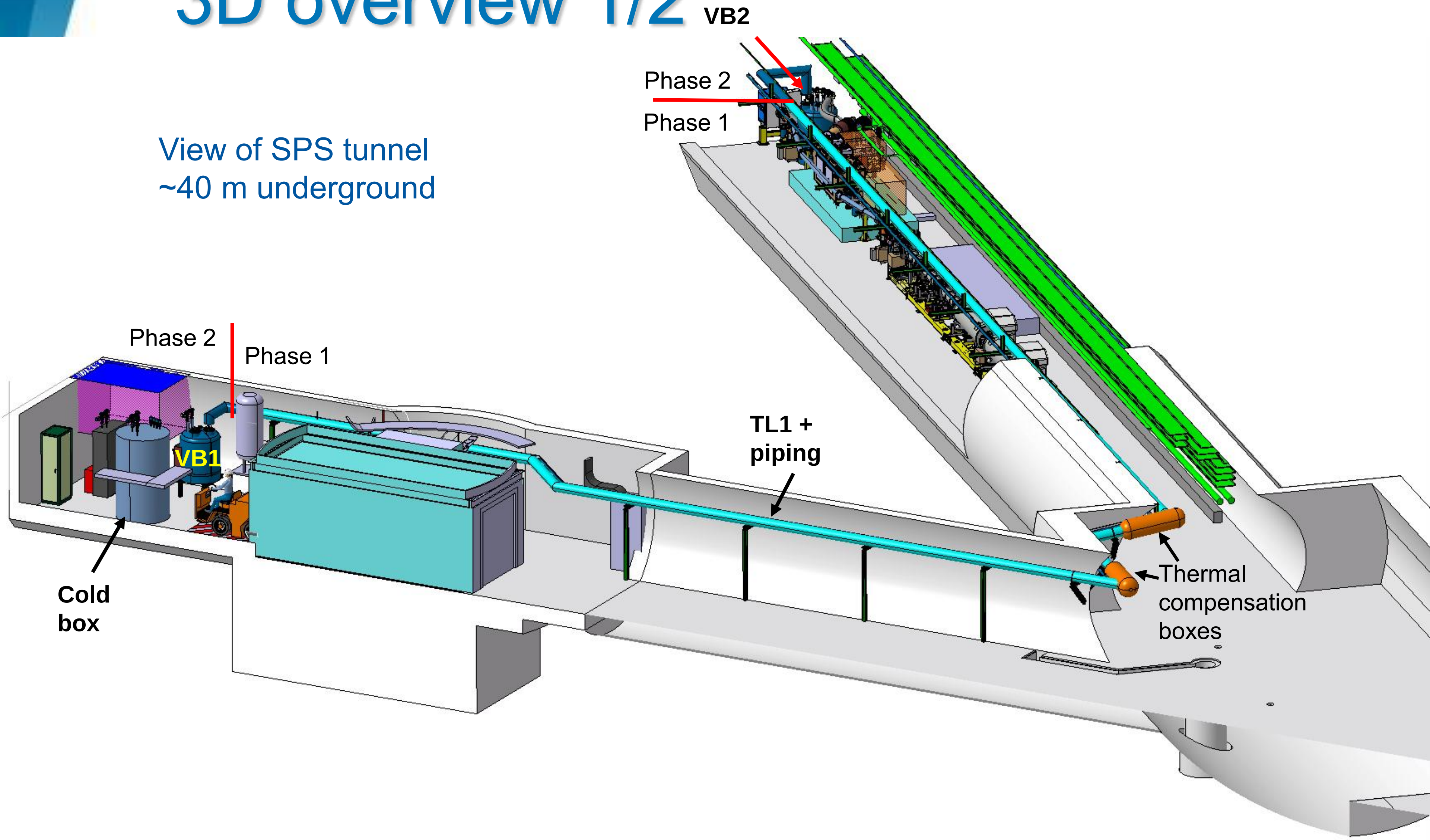
For all: cabling, instrumentation & controls under CERN's scope of work

SPS BA6 global lay-out

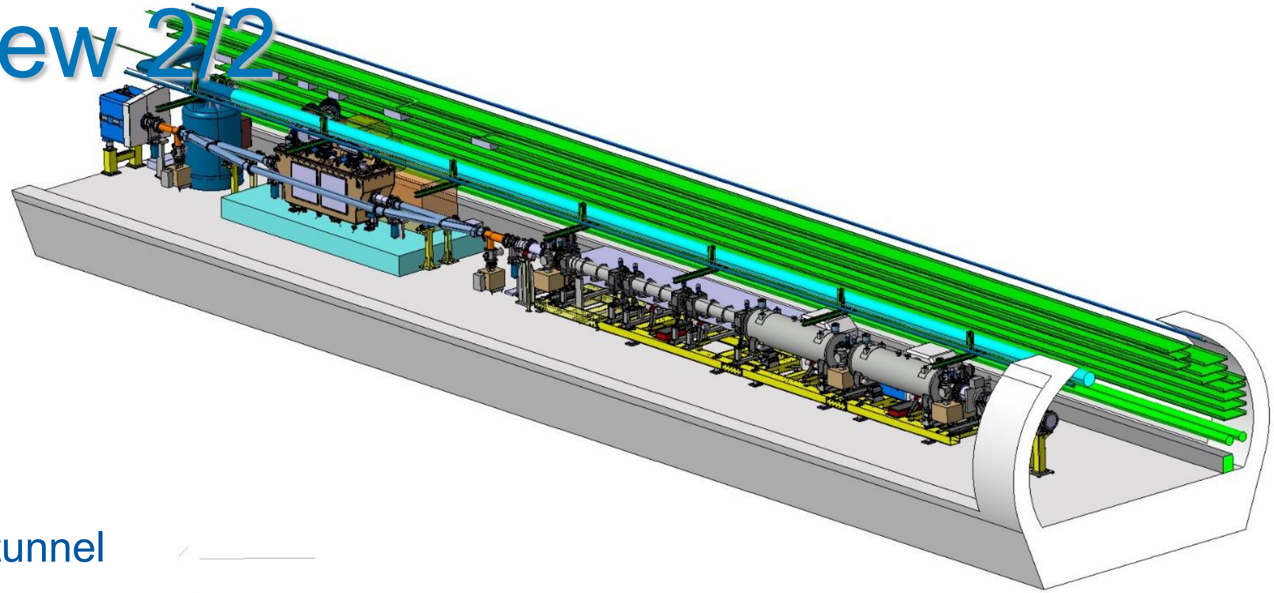


3D overview 1/2

View of SPS tunnel
~40 m underground

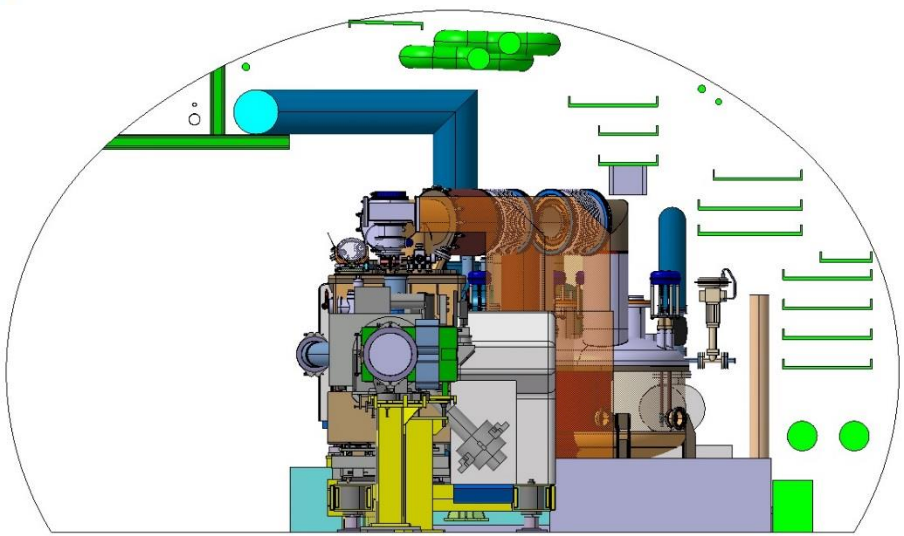


3D overview 2/2

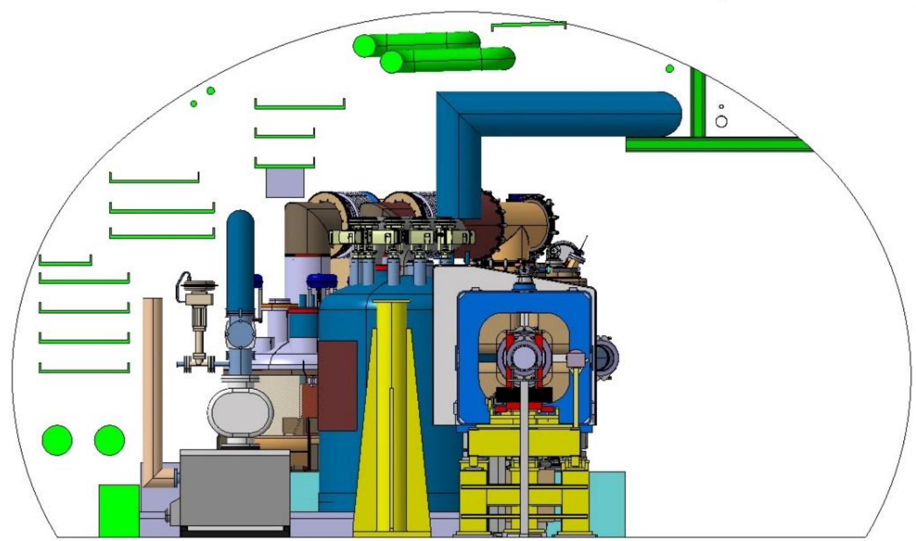


Limited space available

Cross-sectional views of tunnel

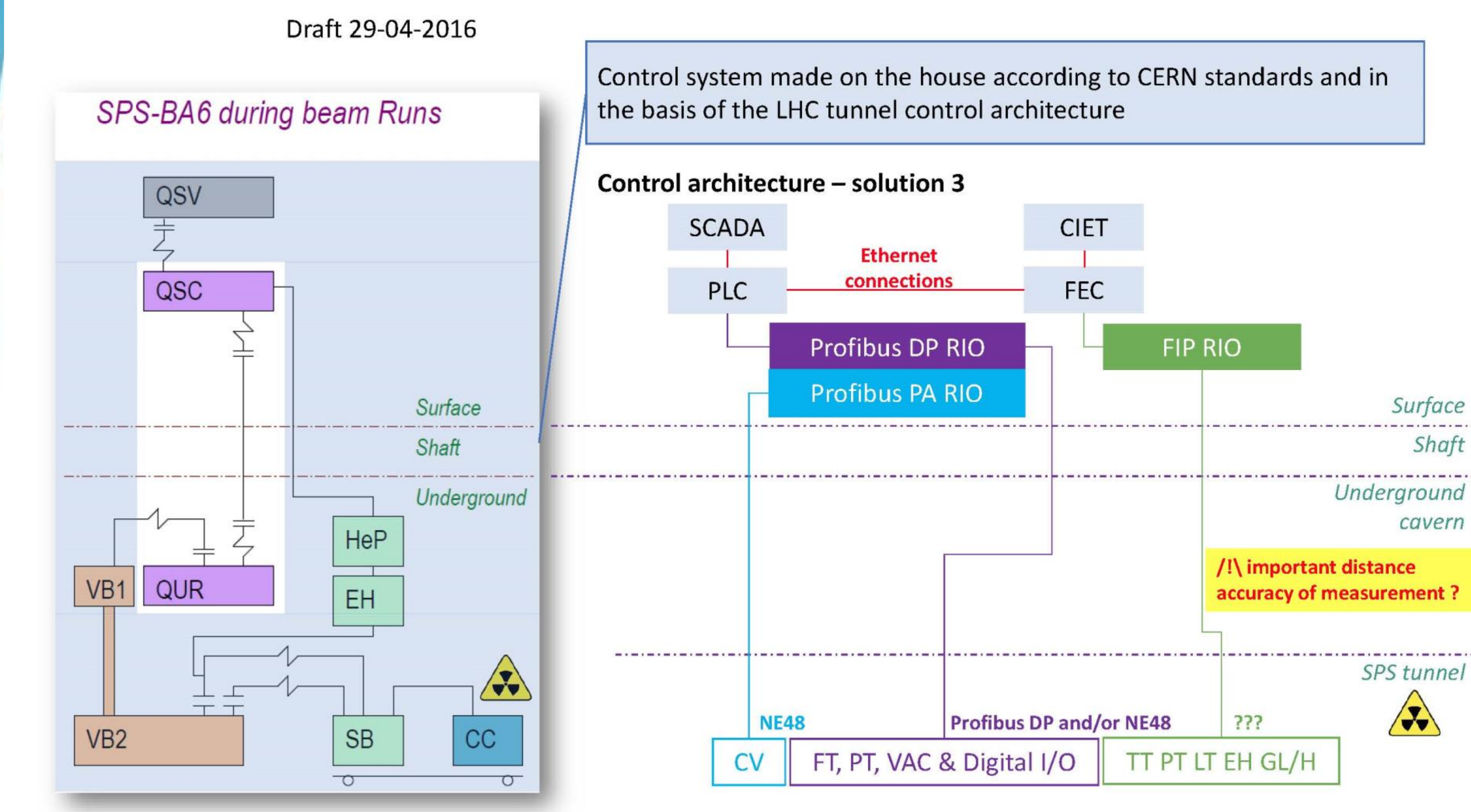


Front side



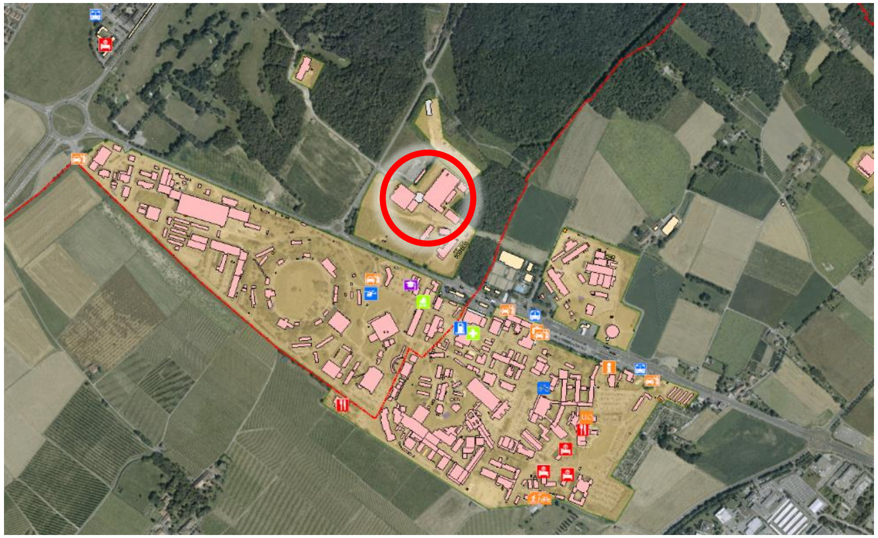
Back side

Baseline for controls architecture



The control System of the new CERN HI-LUMI SM18 Test Facility infrastructure

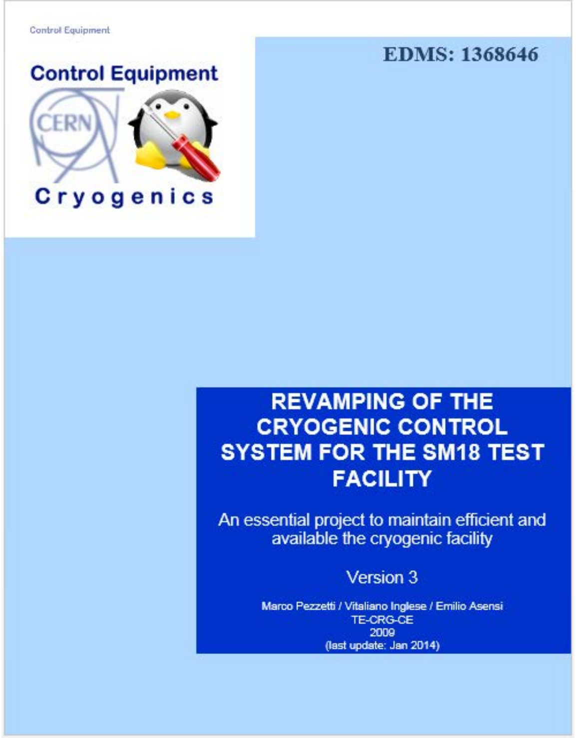
What is SM18 at CERN?



Facility for testing the magnets and instrumentation at very low temperature (lowest being 1.9 K) and up to high currents (20 kA)

M. Pezzetti, V. Inglese, E. Asensi, Revamping of the cryogenic control system for the SM18
test facility, CERN internal note, EDMS id 1368646, January 2014.

In progress since 2009.



Control Equipment

EDMS: 1368646

Control Equipment

Cryogenics

REVAMPING OF THE CRYOGENIC CONTROL SYSTEM FOR THE SM18 TEST FACILITY

An essential project to maintain efficient and available the cryogenic facility

Version 3

Marco Pezzetti / Vitaliano Inglese / Emilio Asensi
TE-CRG-CE
2009
(last update: Jan 2014)

Refurbishment motivations

Viability Problem :

PC supervision 15y old (2 faults during 2014-2015) very **instable and fragile** system

Not in CERN Standards :

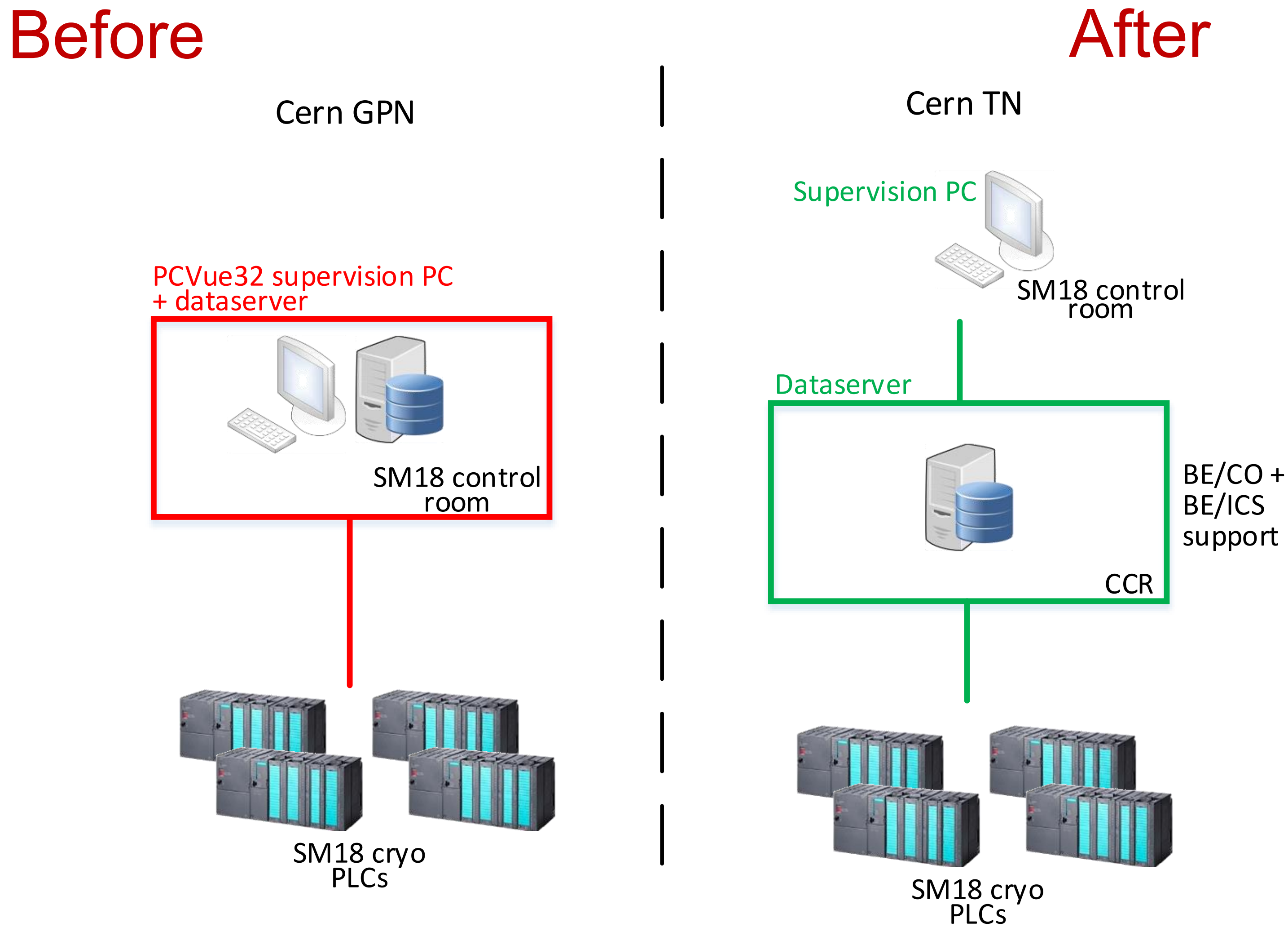
- Non UNICOS program — **Operation issues**
- Obsolete PCVue32 supervision — **Diagnostic issues**
- Supervision not connected to TN — **Security issues**
- Electrical diagrams not up to date — **Support issues**

Evolutions of SM18 :

- **Electrical and software** adaptations to technologies, mechanical changes and new clients over time
- **Priority management system** done for 12 CFBs, we need to take into account the vertical test benches and RF cavities

Refurbishment motivations

supervision architecture

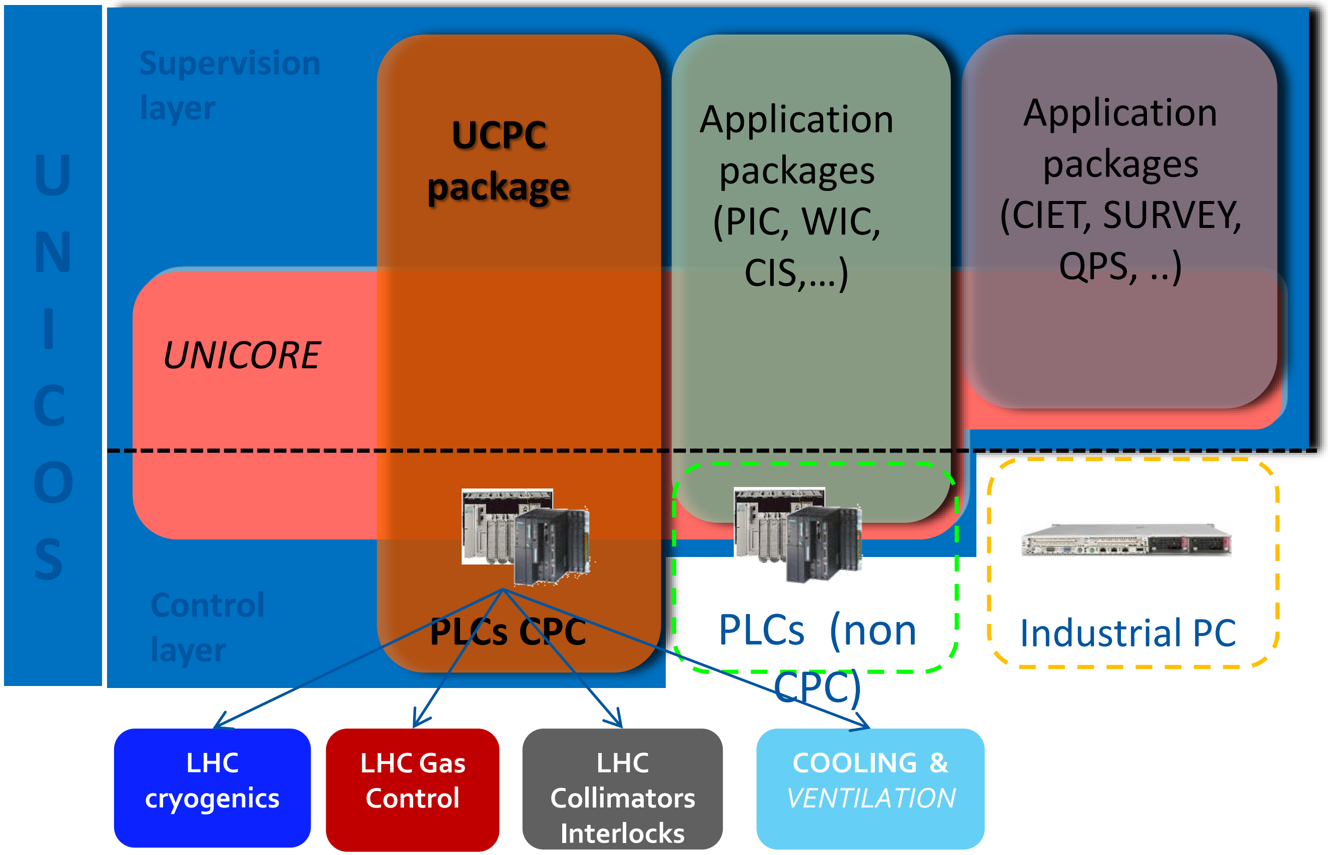


Technical Solution

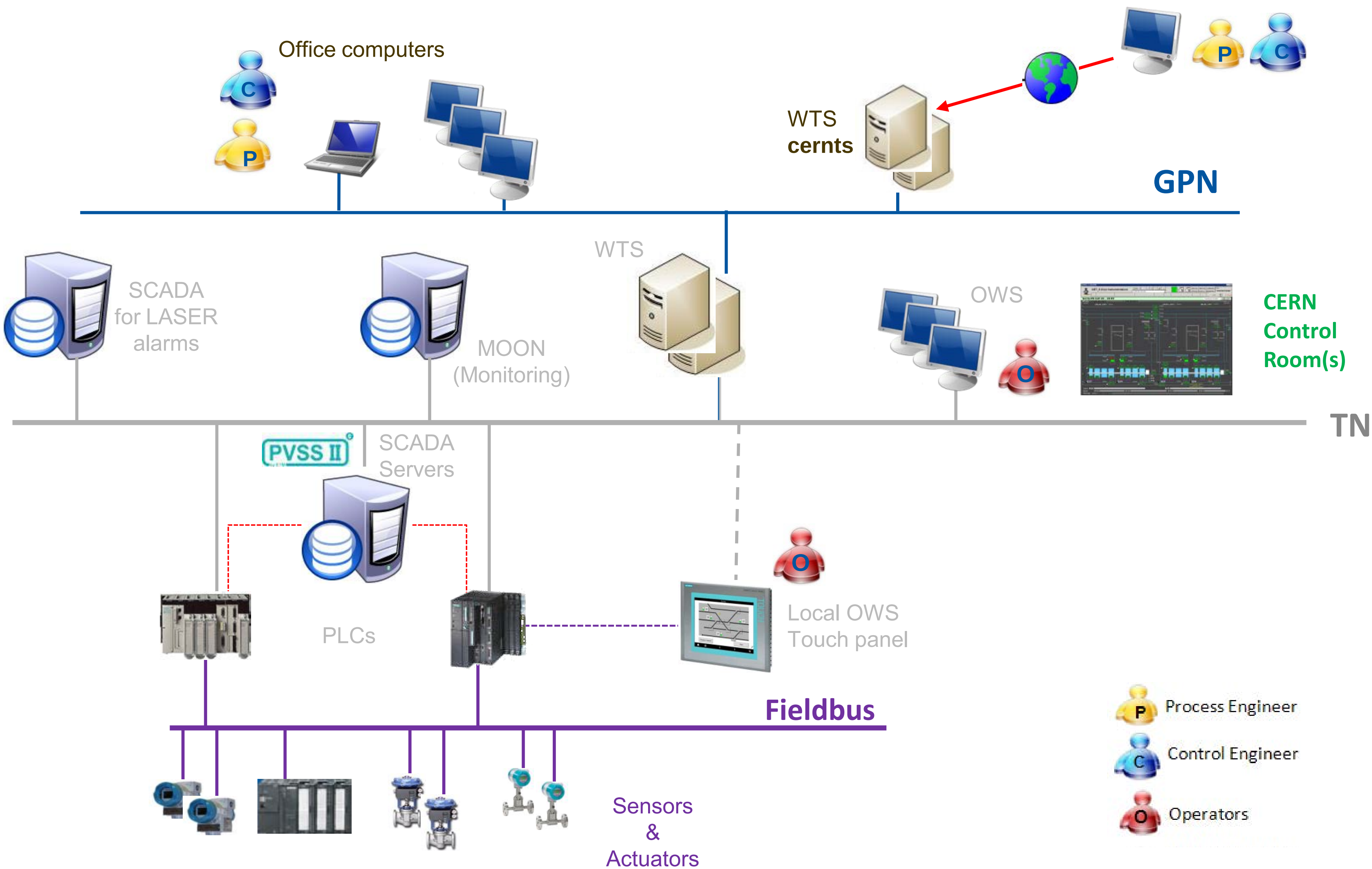
- Use of the CERN industrial control standard

UNICOS is a framework to create control applications

UCPC: A basic package (**Continuous Process Control**) to develop integrated process control applications.



UNICOS basic architecture @ CERN



Development and validation tools

- Automatic Code Generator (UAB)
  - PLC code generation from xml specifications and templates
    - Re-use automatically same control logic on similar processes
  - Supervision generations
    - Automatic addressing and communication between PLC and Supervision
  - Test catalogs
    - I/O test catalog automatically generated
    - Functional test catalog partially generated

- Simulation capabilities
  - "Virtual commissioning" in advance
    - Allow developers to validate control applications offline
    - Allow operators to check that their requirements are understood
  - Simulation solutions are used :
    1. Static simulation of actuators and regulations within PLC
       - Fast to setup but not complete
    2. Process dynamic simulation based on physical models
       - Very complete but difficult to setup

Standardization

- Look and Feel of interfaces
  - UNICOS
- Access Control management
  - Nice account via terminal server + PVSS
  - Generic account on local touch panels
- Archiving of data
  - PVSS for online display
  - LHC Logging for long-term archiving and display in TIMBER
- CCC alarms mechanism
  - Sent via LASER to CCC

Context of SM18 Cryogenic installations

SM18 migration strategy

Initiated by CRG/CE in 2009

The "**CRITICAL**" part -> reestablish normal reliability of the control system itself :

- Valve Box & 25000L LHe dewar (He INFRA)
- RF cavities
- Warm Pumping Unit (WPU)
- Major ethernet network update
- CP & CB Linde 6kW & He Storage

Done!

The "**CONSOLIDATION**" part -> UNICOS standardization :

- Magnets Test Benches (CFBs)
- Cryogenic Test Handling

→ last remaining consolidation

- Anti-cryostats (by BE-ICS)

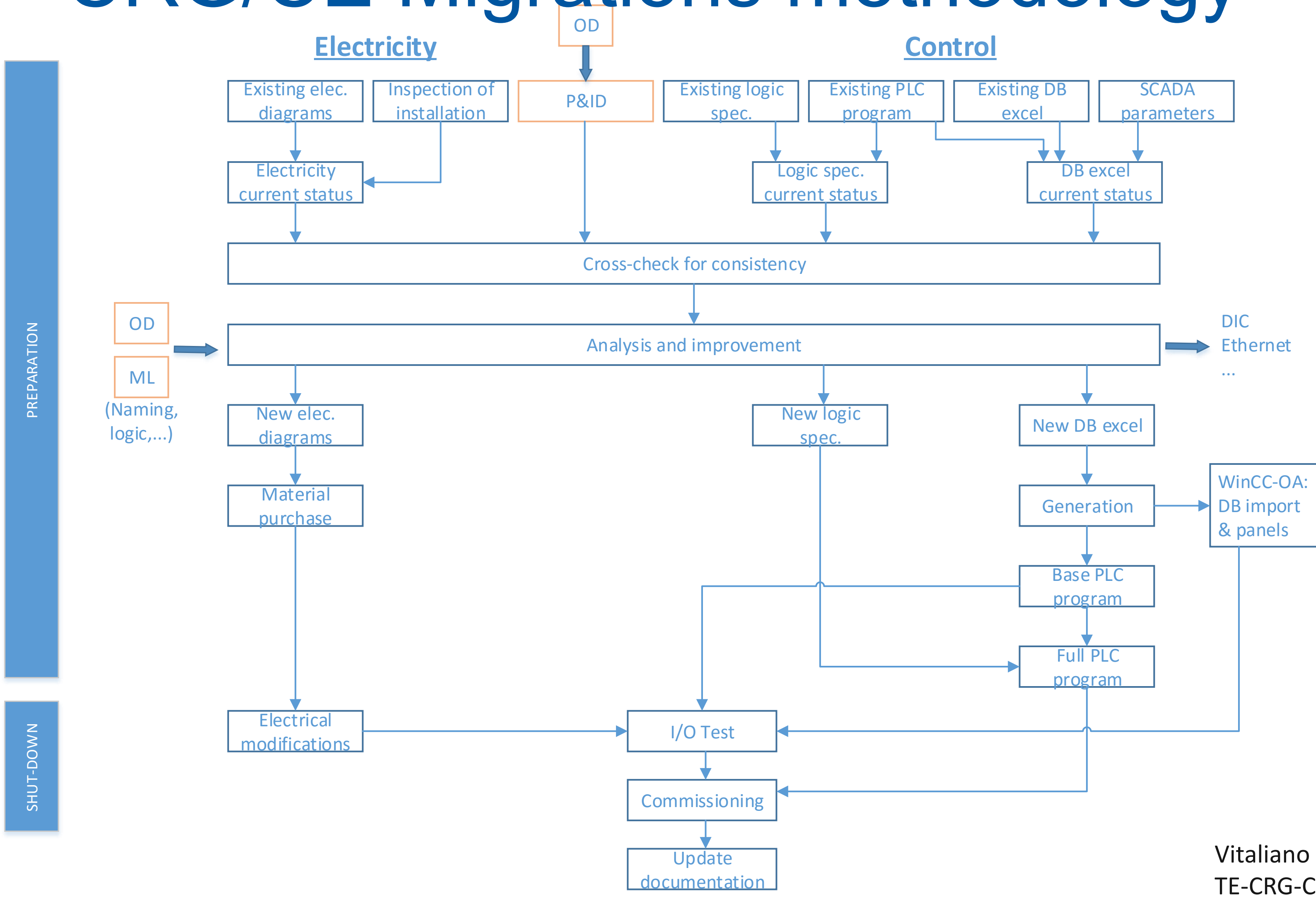
Done!

The "**NEW PROJECTS**" in SM18 test facility.

- Cluster G cryostats (3 cryostats + HFM & Cluster D)
- New RF cavities test bench
- FCM/SC-Link
- String 3 (to be confirmed)
- New 35 g/s liquefier

In progress

CRG/CE Migrations methodology



Vitaliano Inglese
TE-CRG-CE

CTH Planning/milestones

Beginning of the project — February 2015

Commissioning of fist CFB

Reverse engineering — October 2015

Interlocks definition — January 2016

9th CFB commissioning

Hardware modifications — April 2016

I/O commissioning

CCL + PL commissioning

CWL commissioning

Shutdown

Last CFB commissioning — July 2016

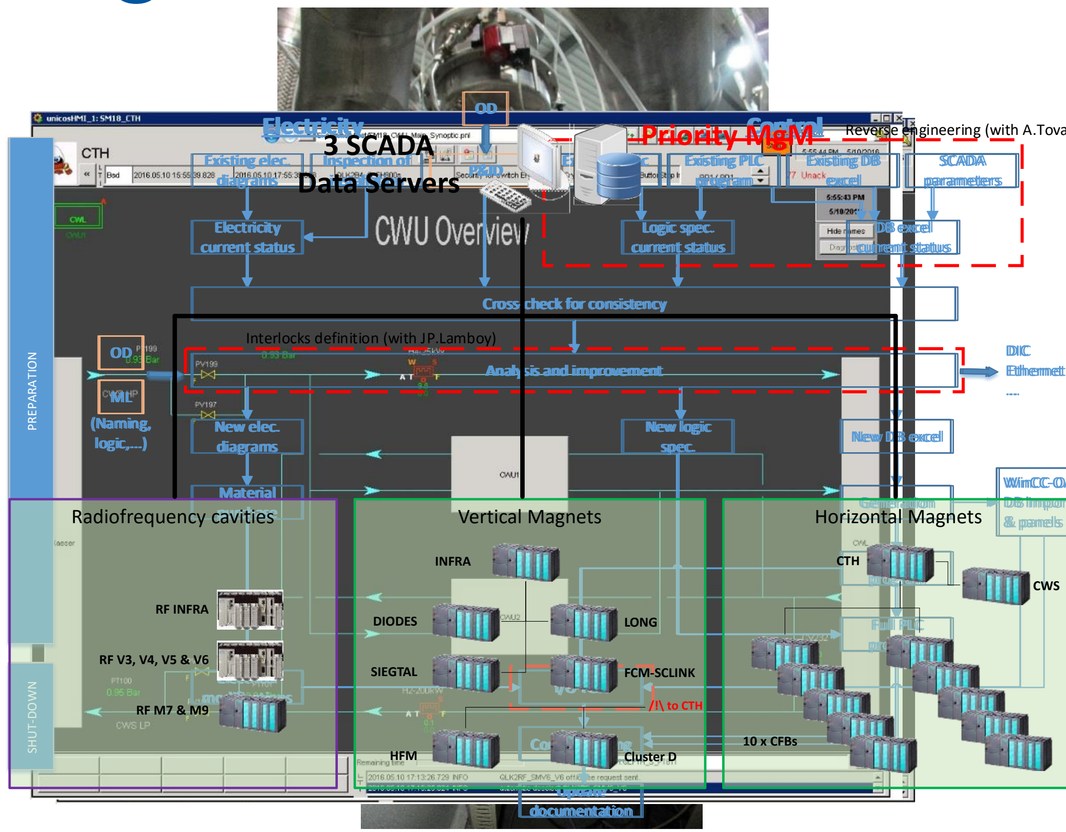
Today

First version of Priority Handling

October 2016

Final version of Priority Handling and KPI

January 2017



CTH and CFBs environment and functions

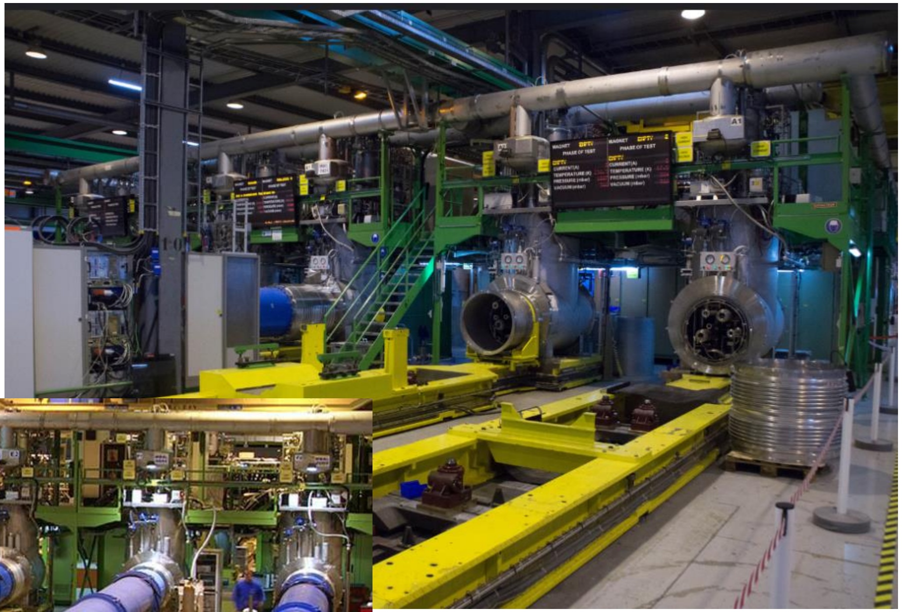
The Cryogenic Feed Box (1/2)

At CERN super conductive magnets have to be tested.

CFB is the interface to connect these magnets to different testing systems.

CFB comprises mainly:

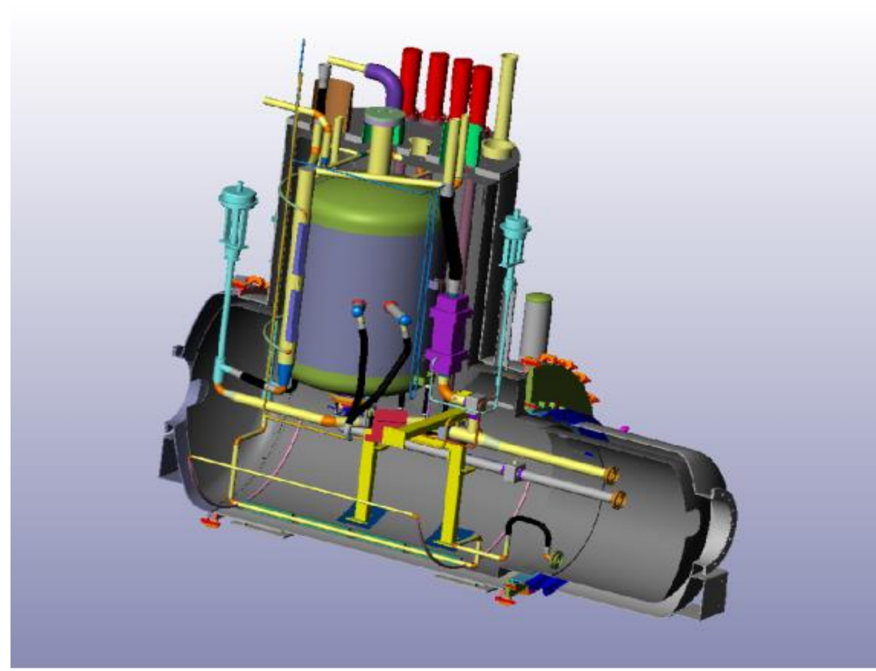
- Helium pipe work
- Helium-cooled
- High current circuits



The Cryogenic Feed Box (2/2)

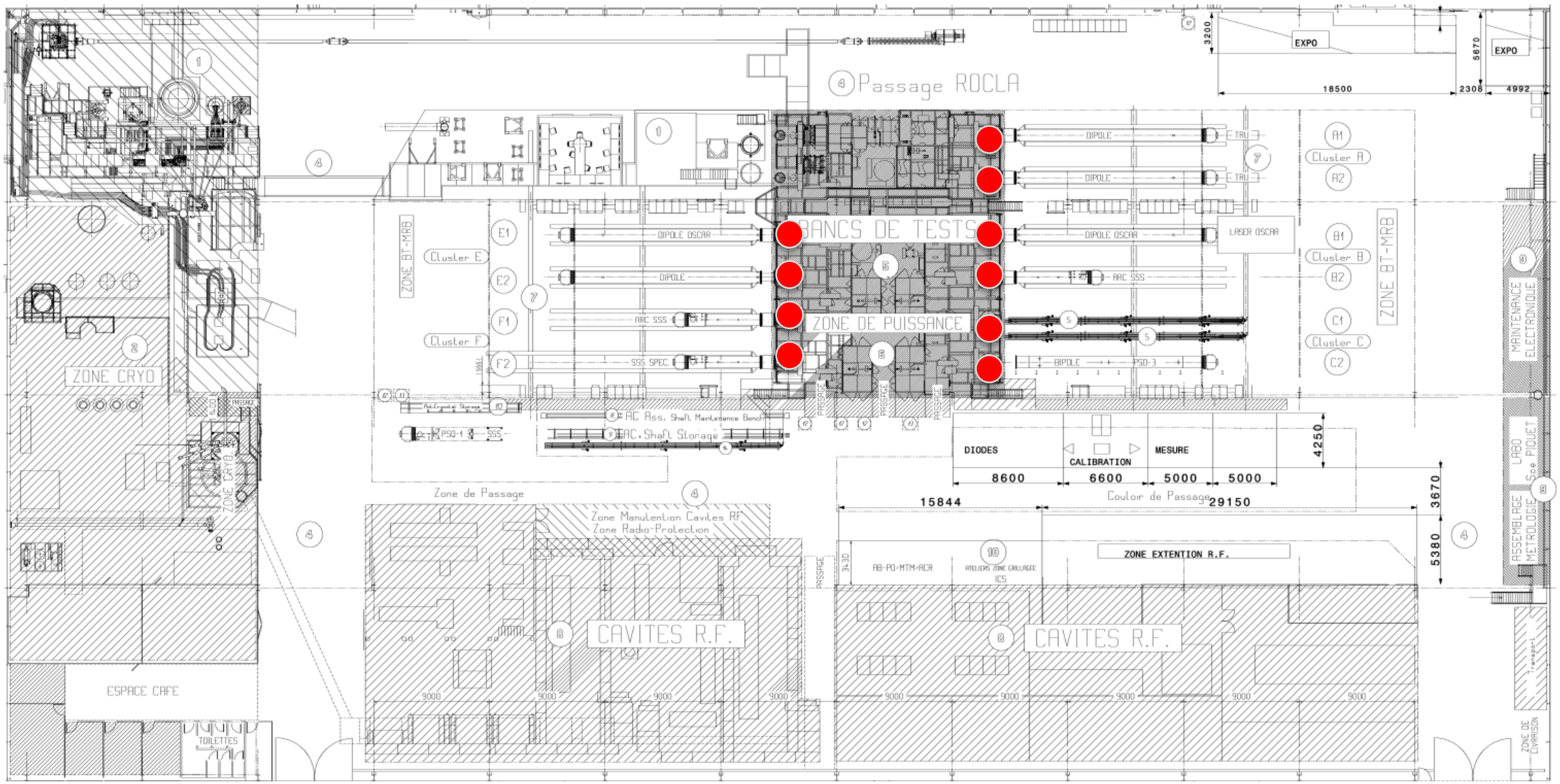
The subassemblies are:

- A vacuum vessel
- A helium vessel
- A gas-liquid heat exchanger
- An actively-cooled thermal shield

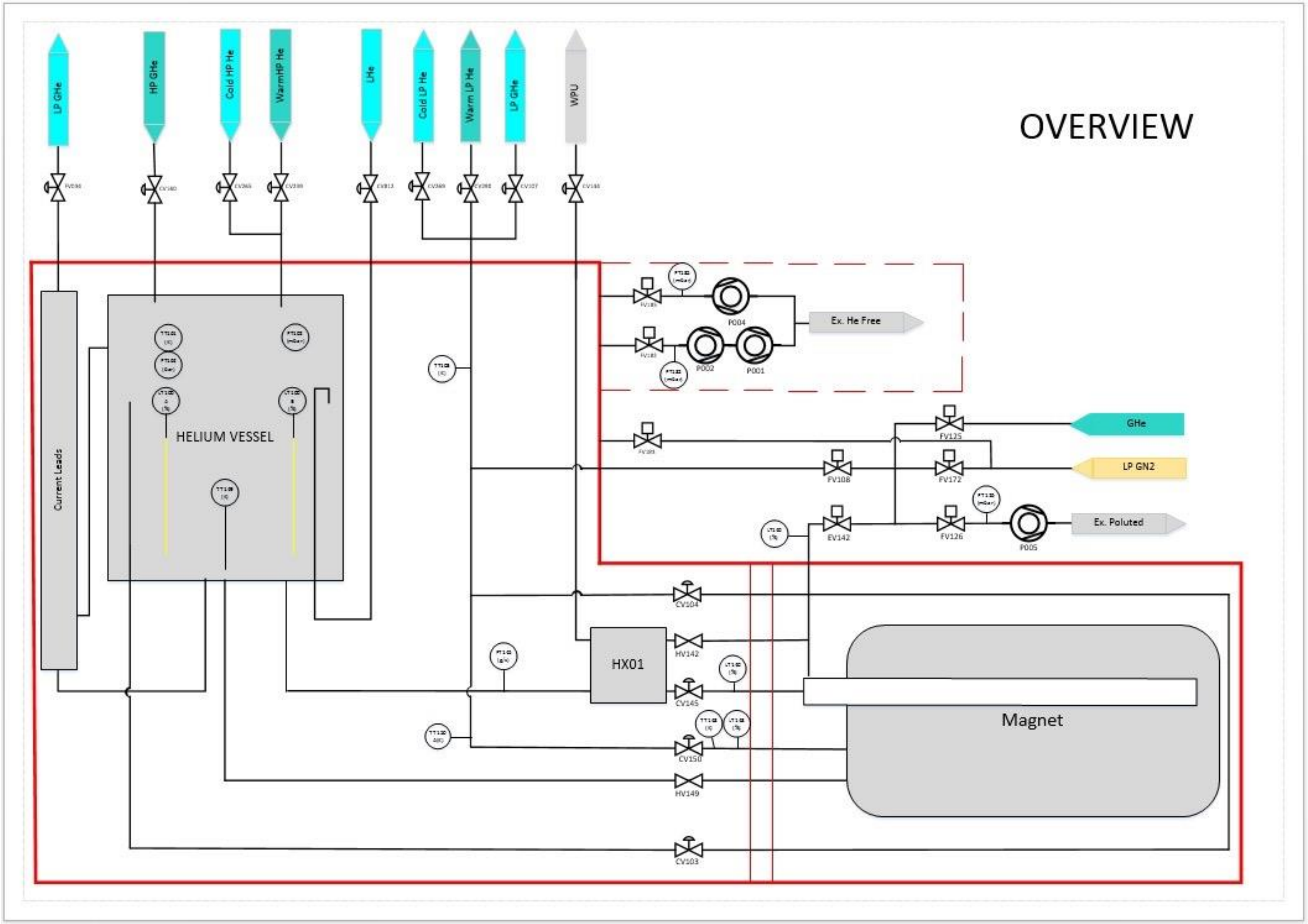


- A set of main current lines
- Internal and external pipe work
- A purge panel
- Instrumentation for remote monitoring and control

Where are located?

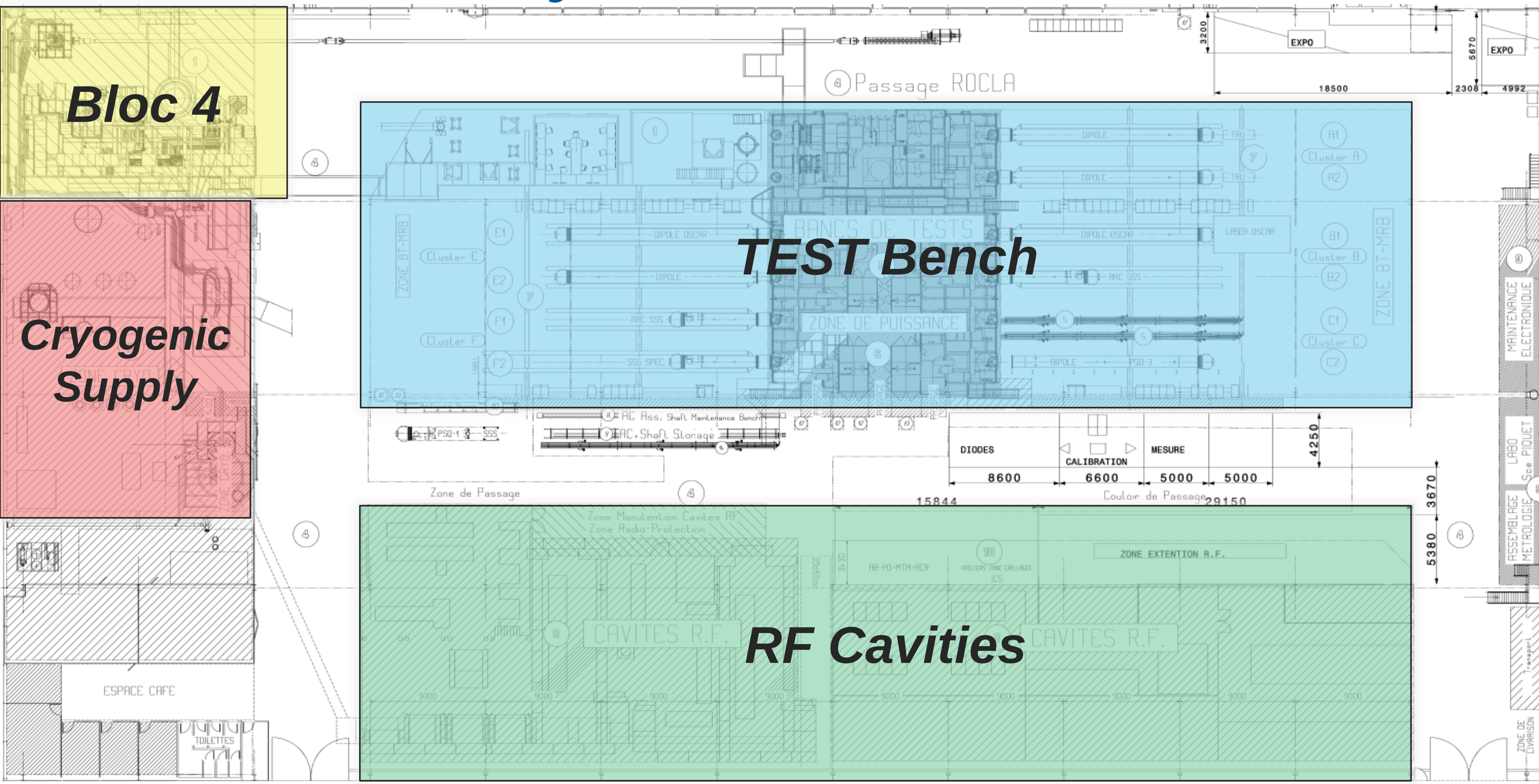


CFB P&ID

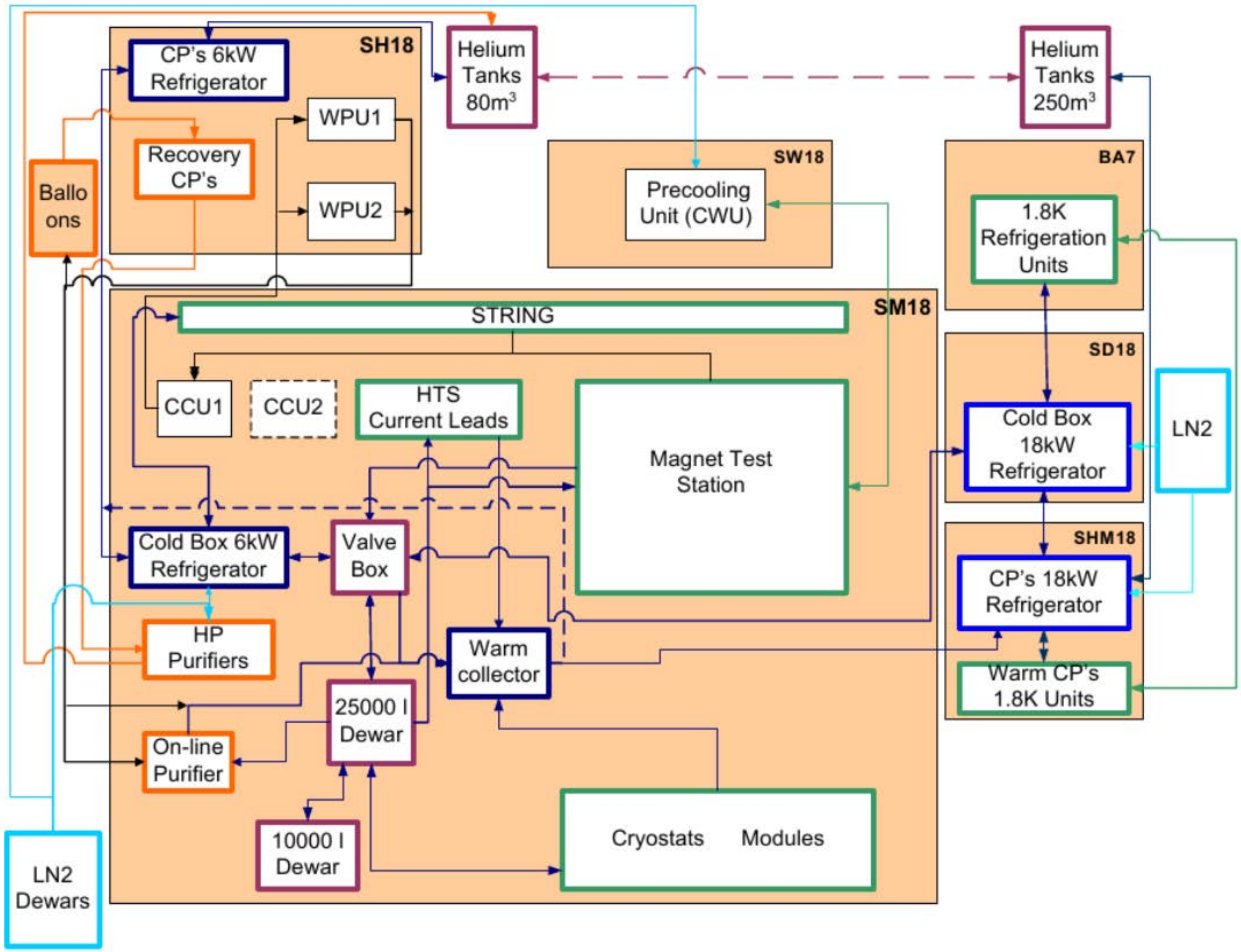


OVERVIEW
LP GHe
HP GHe
Cold HP He
WarmHP He
LHe
Cold LP He
Warm LP He
LP GHe
WPU
HELIUM VESSEL
Current Leads
Ex. He Free
P004
P002
P001
GHe
LP GN2
Ex. Poluted
FV125
FV172
FV108
FV126
EV142
P005
CV104
HV142
HX01
CV145
CV150
HV149
CV103
Magnet

SM18 - Layout

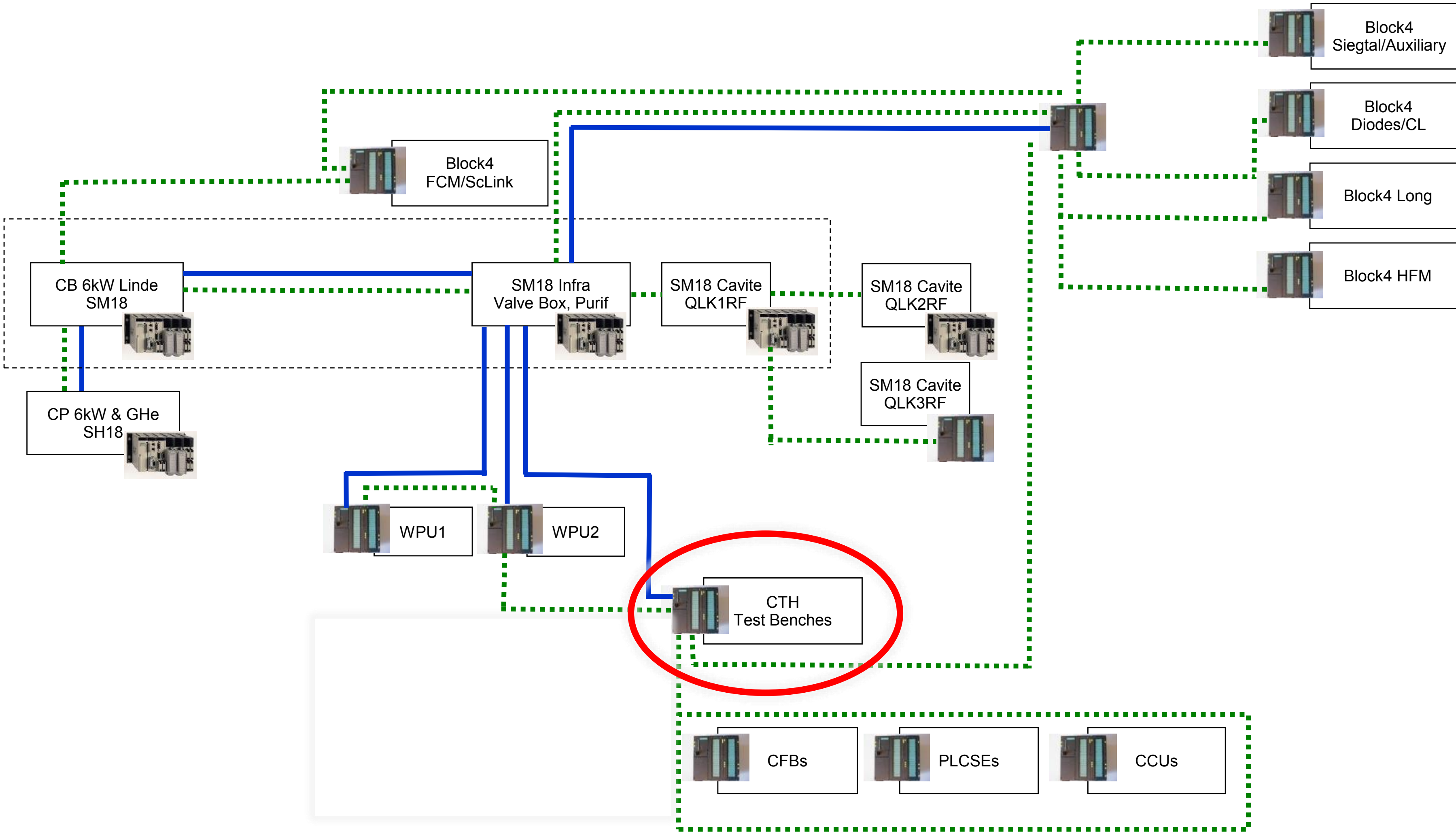

Bloc 4
Cryogenic Supply
TEST Bench
RF Cavities
Passage ROCLA
BANCS DE TESTS
ZONE DE PUISSANCE
CAVITES R.F.
ZONE EXTENTION R.F.
DIODES
CALIBRATION
MESURE
Zone de Passage
Couloir de Passage
ESPACE CAFE
TOILETTES
EXPO
MAINTENANCE ELECTRONIQUE
LABO Sce PIQUET
ASSEMBLAGE METROLOGIE
ZONE DE LIVRAISON

SM18 - Layout

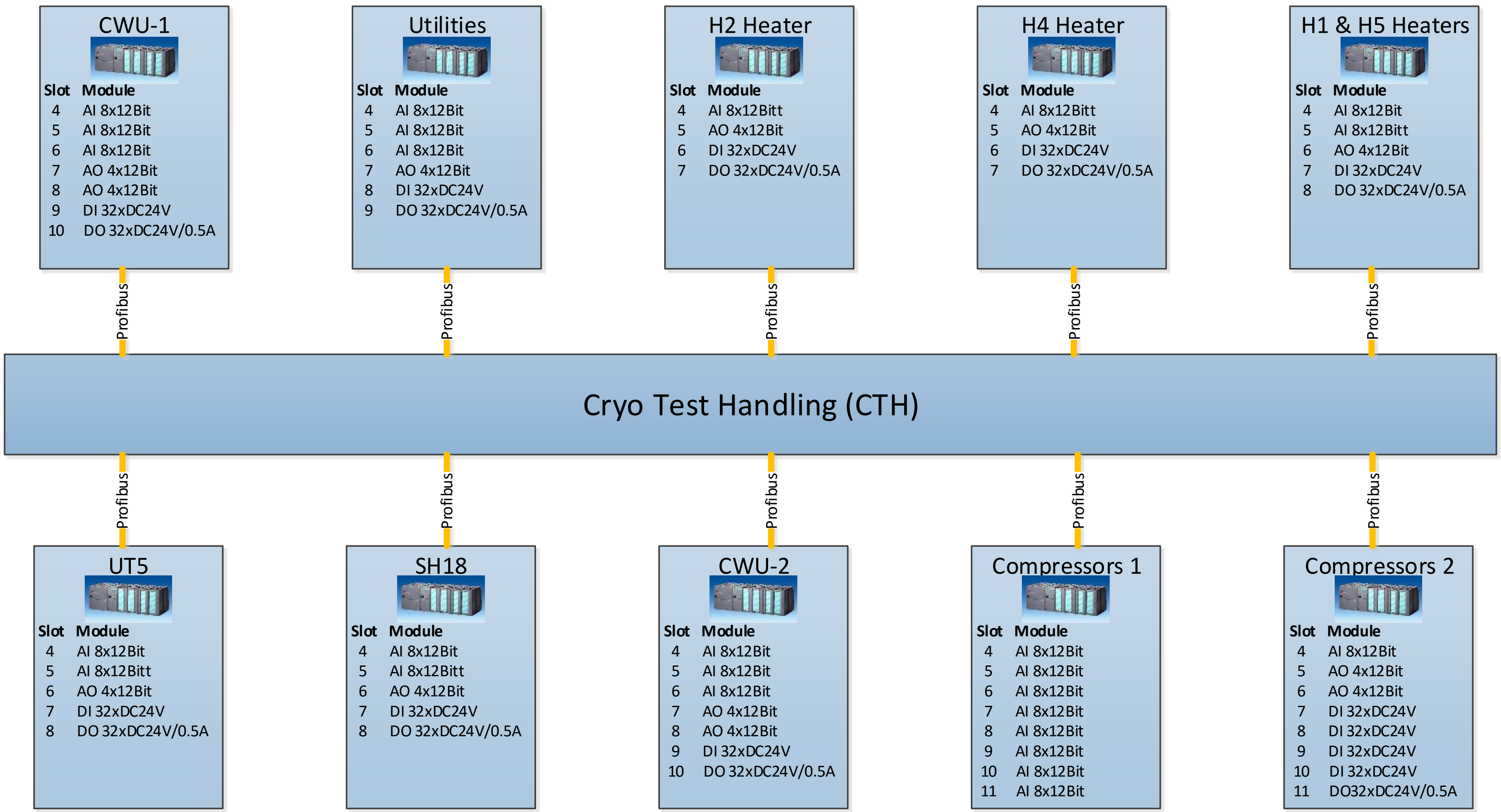


SH18
CP's 6kW Refrigerator
WPU1
Recovery CP's
WPU2
Ballo ons
Helium Tanks 80m³
SW18
Precooling Unit (CWU)
Helium Tanks 250m³
BA7
1.8K Refrigeration Units
SM18
STRING
SD18
CCU1
CCU2
HTS Current Leads
Magnet Test Station
Cold Box 18kW Refrigerator
LN2
Cold Box 6kW Refrigerator
Valve Box
SHM18
CP's 18kW Refrigerator
HP Purifiers
Warm collector
Warm CP's 1.8K Units
25000 l Dewar
On-line Purifier
10000 l Dewar
Cryostats
Modules
LN2 Dewars

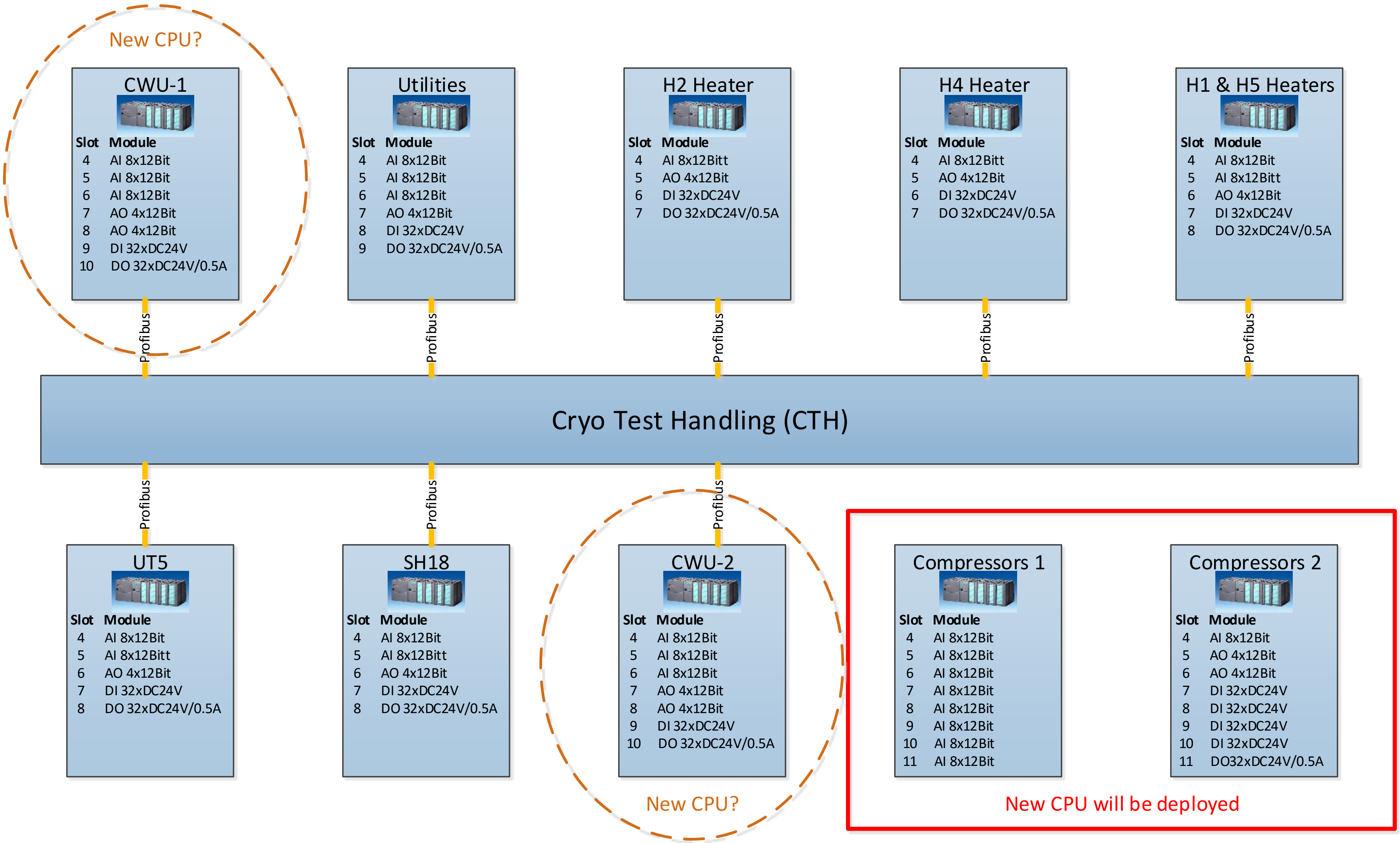
SM18 PLC


Block4
Siegtal/Auxiliary
Block4
Diodes/CL
Block4 Long
Block4 HFM
Block4
FCM/ScLink
CB 6kW Linde
SM18
SM18 Infra
Valve Box, Purif
SM18 Cavite
QLK1RF
SM18 Cavite
QLK2RF
SM18 Cavite
QLK3RF
CP 6kW & GHe
SH18
WPU1
WPU2
CTH
Test Benches
CFBs
PLCSEs
CCUs

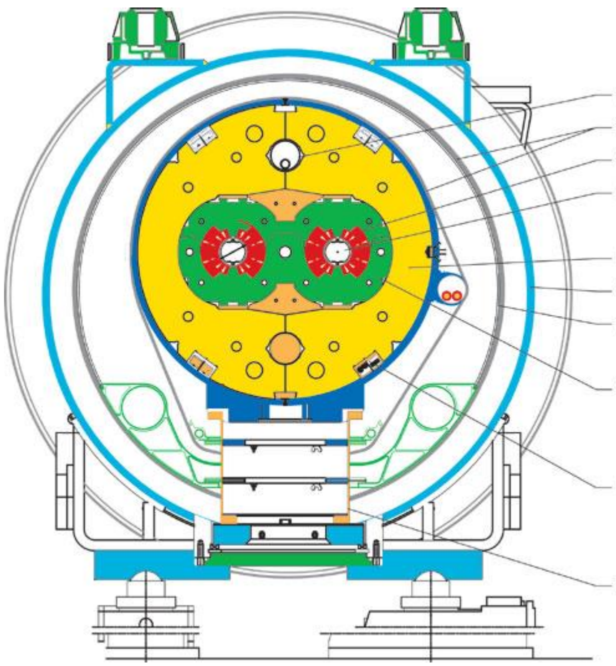
Structure of CTH overview



Structure of CTH overview

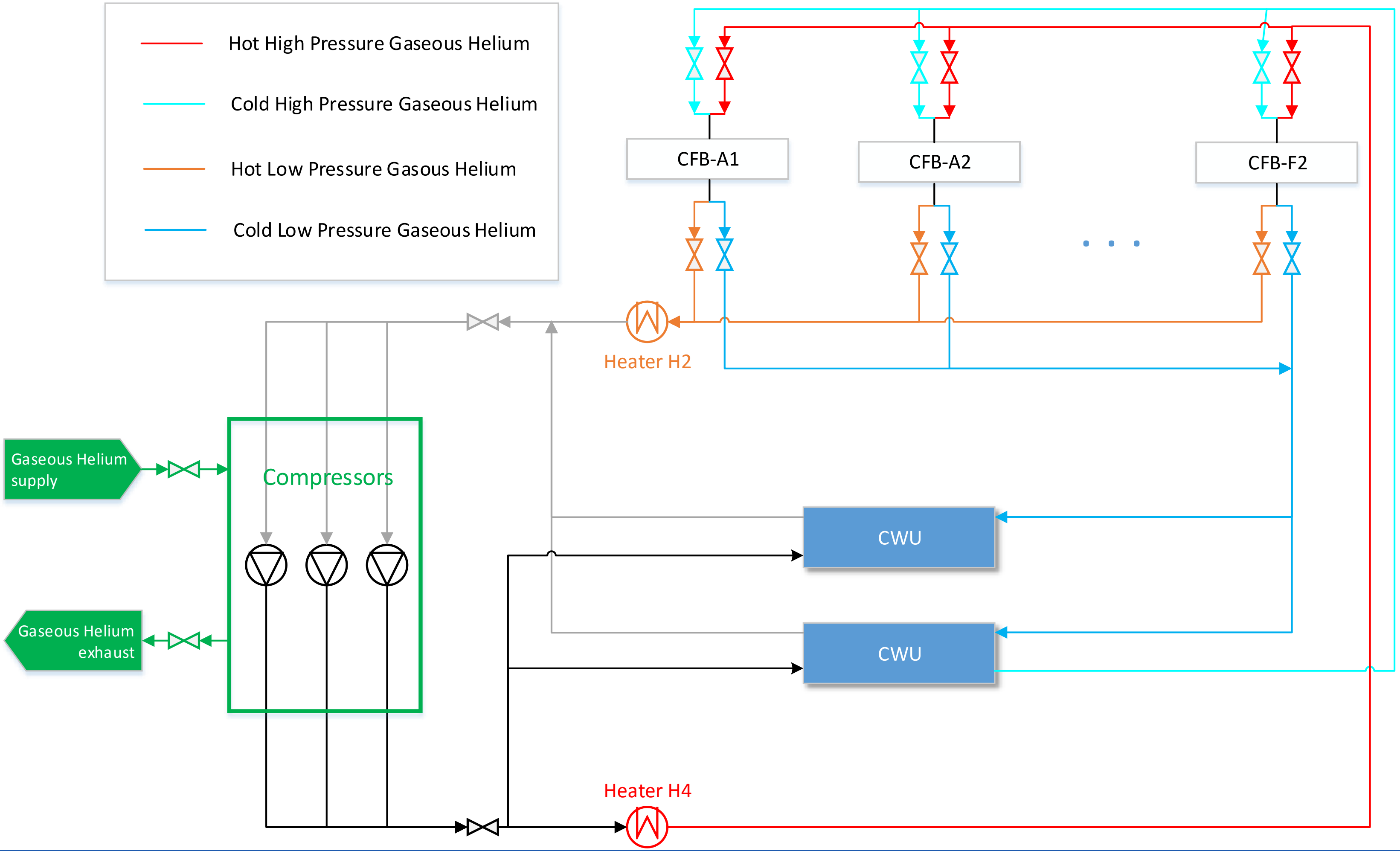


Cryogenic Process

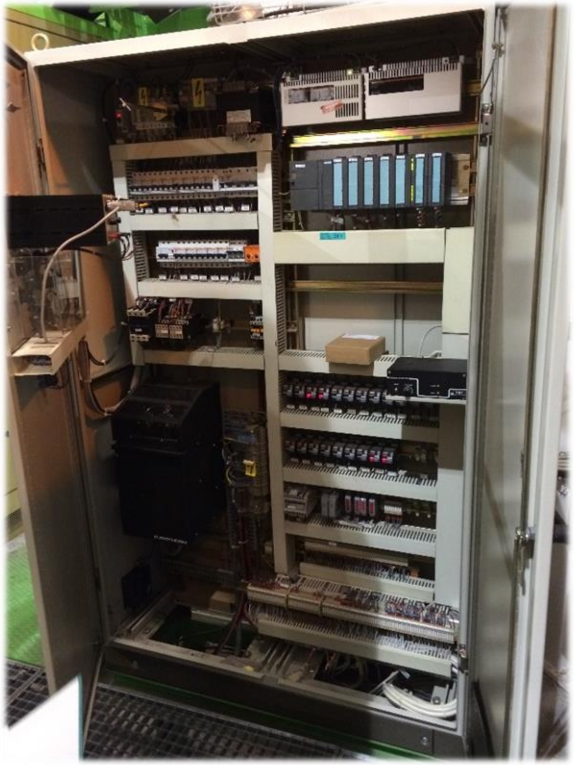


300K -> 80K	→	Gaseous Helium
80K -> 4.5K	→	Liquid Helium
4.5K -> 1.9K	→	Helium Depressurization

Global view of the process

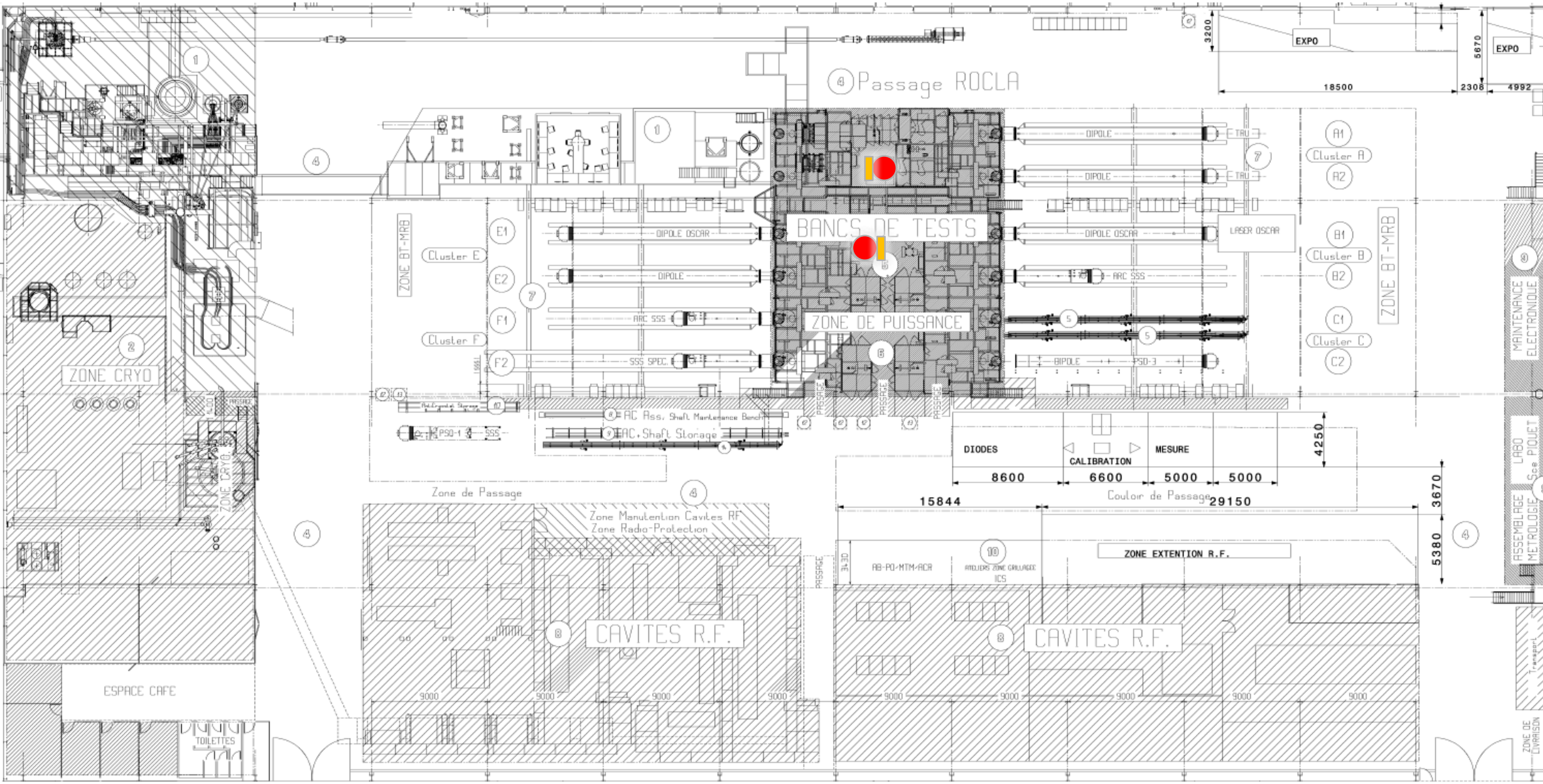


CWUs : Revamping of Cooling and Warming Units

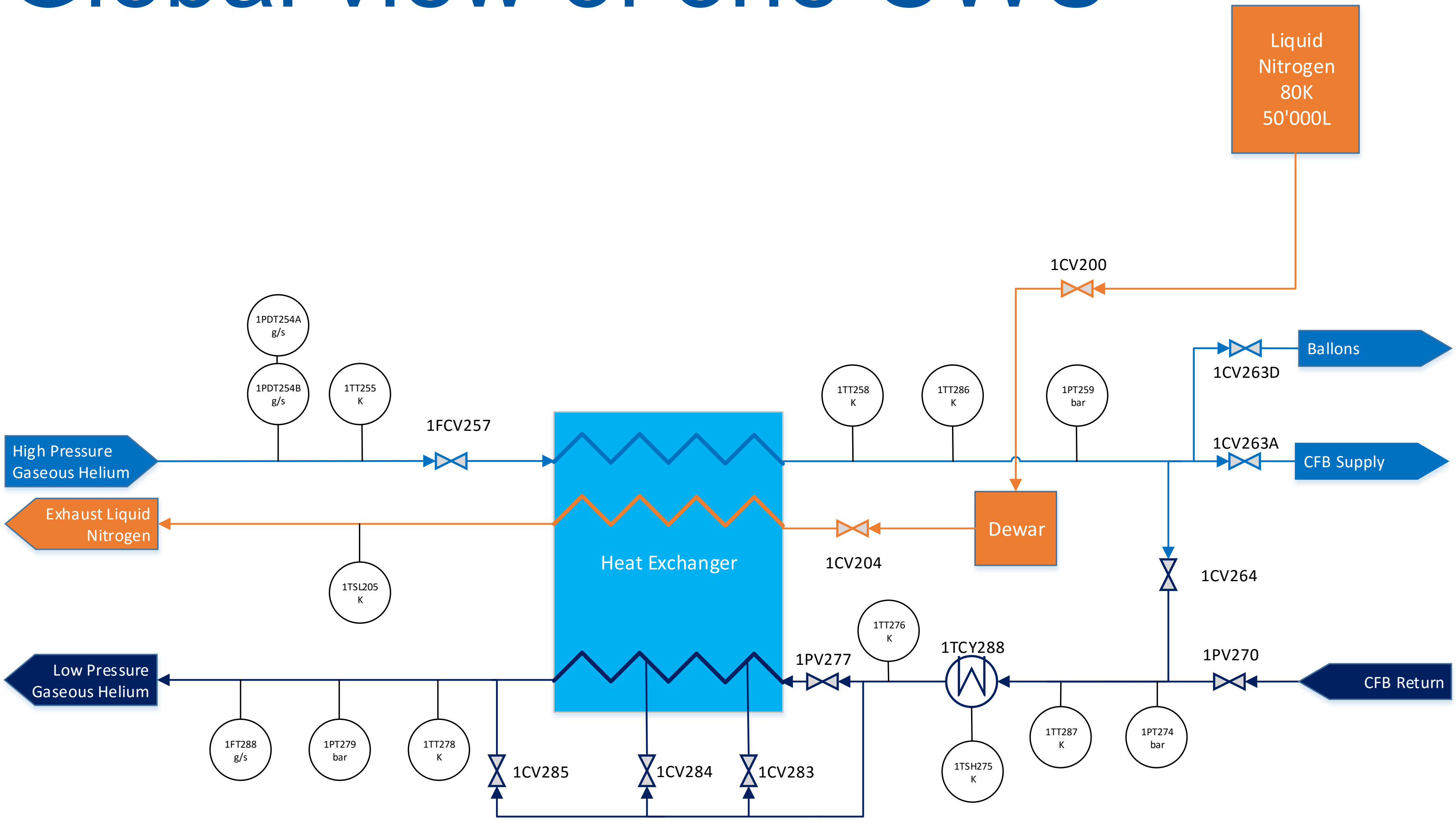


300K -> 80K

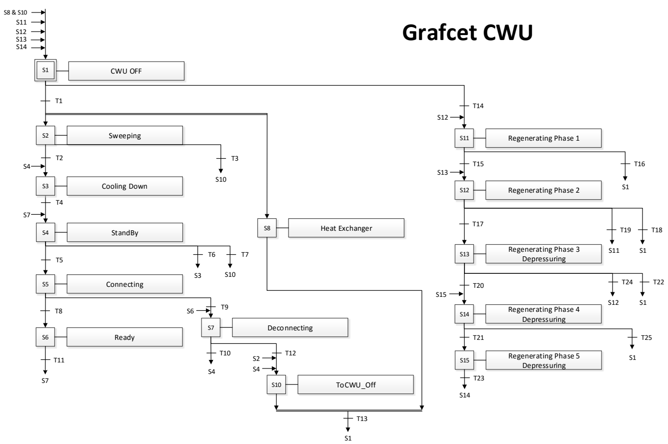
CWUs Localisation



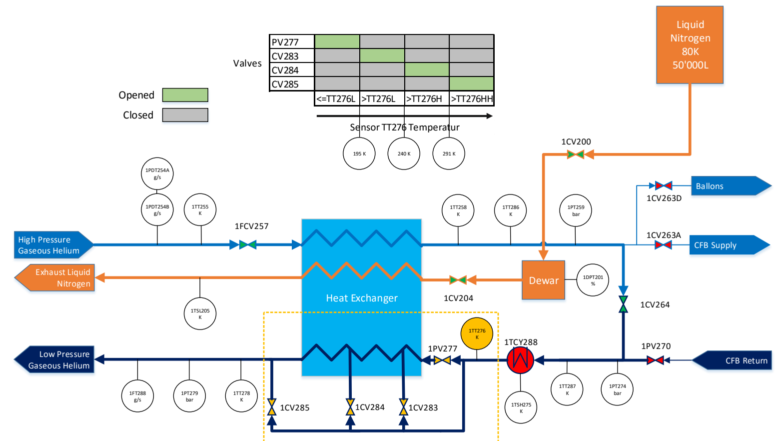
Global view of one CWU



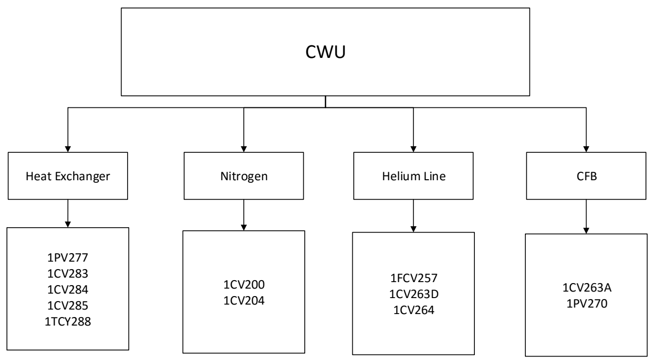
What is done



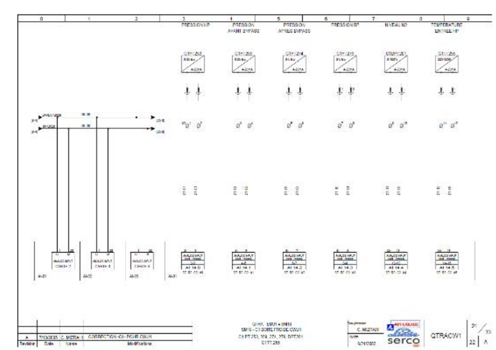
Temporal General Grafcet



Schematic PID process
For each Step



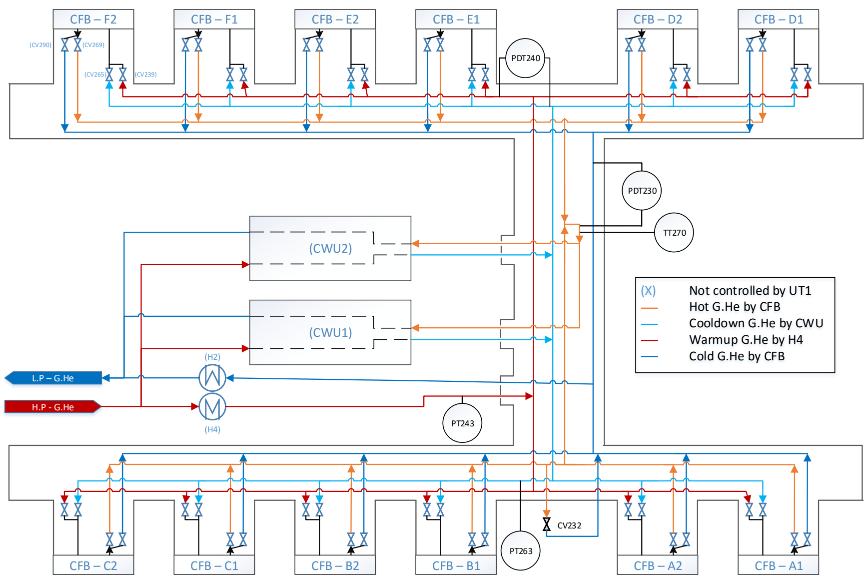
Temporal PCO Structure

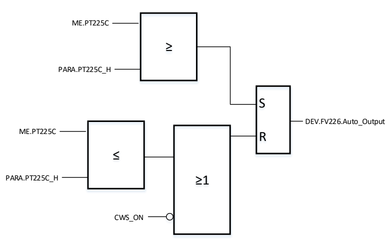


Check Electrical Installation

300K -> 80K

UT1 : Revamping of Cooling and Warming Line

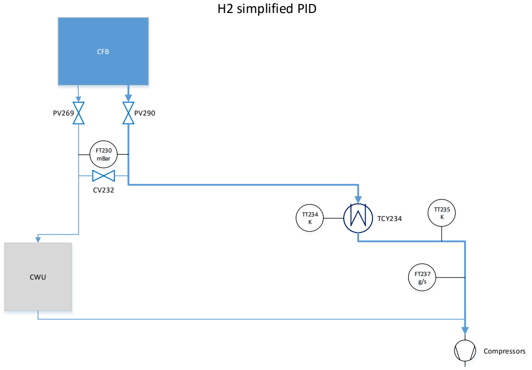


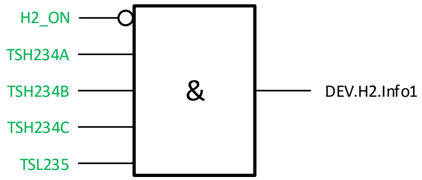


- Simplified PID
- Logical Specification
- Check Electrical Installation

Revamping of heaters in CWL

H2 simplified PID

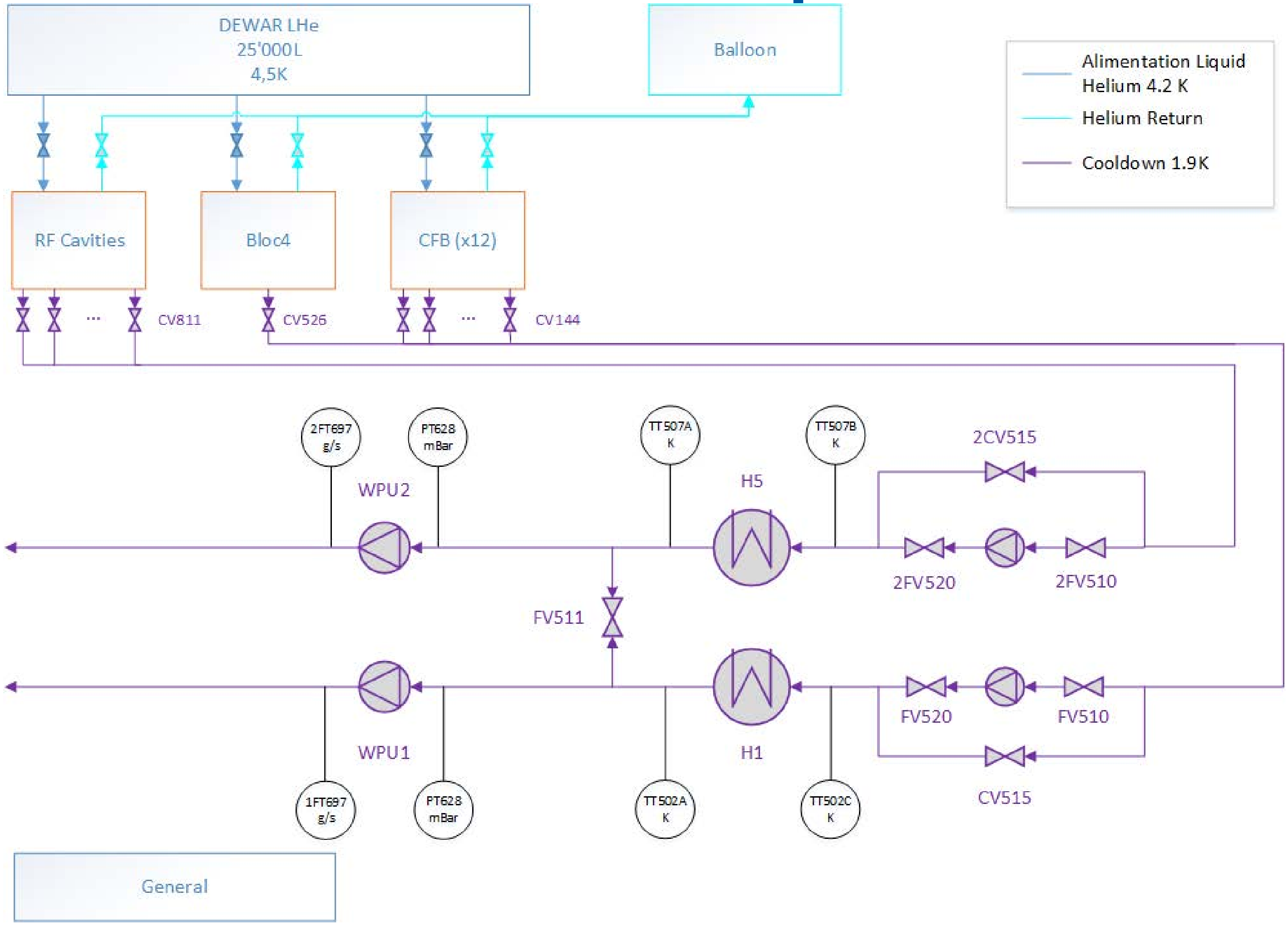


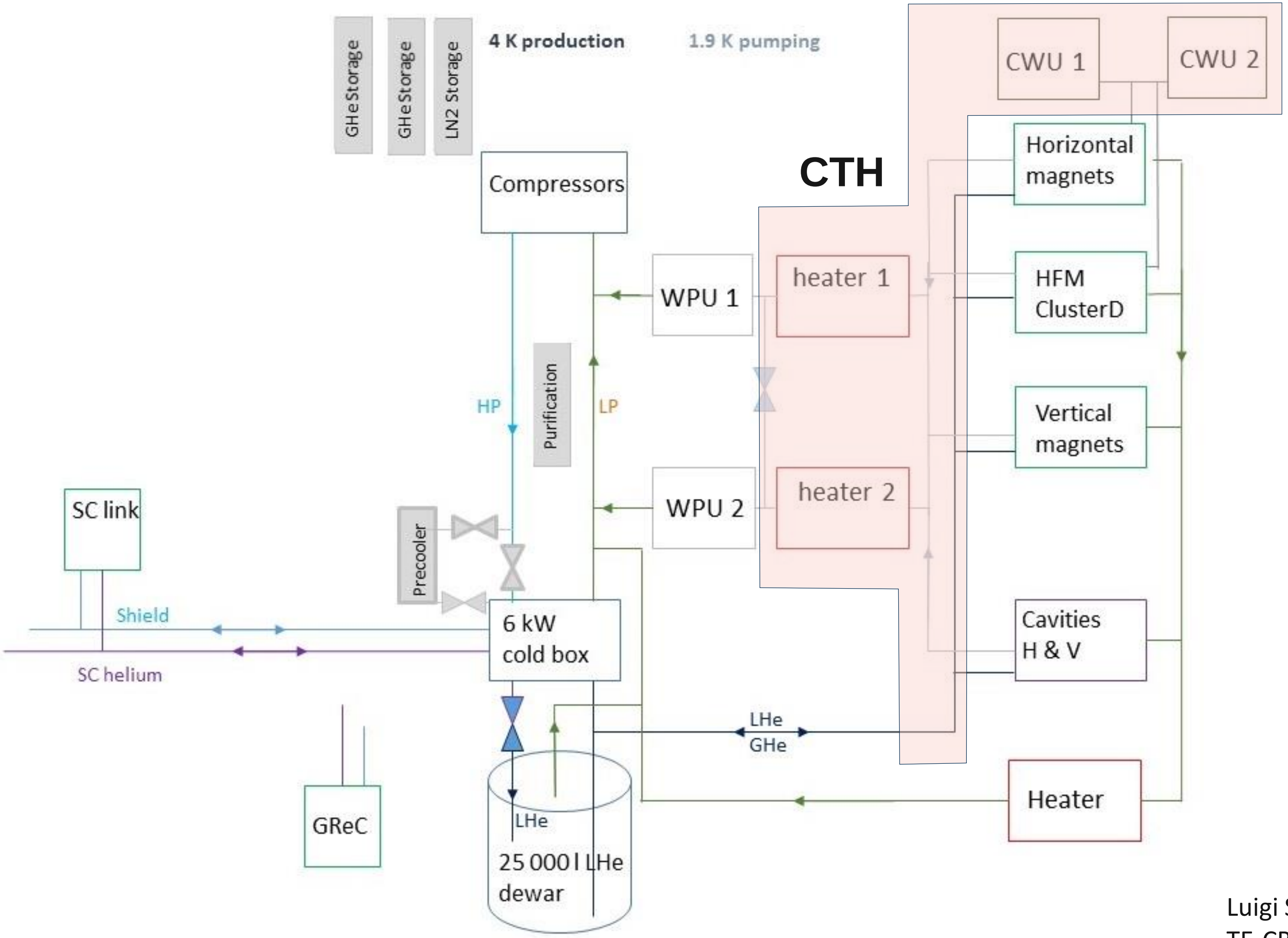


- Simplified PID
- Logical Specification
- Check Electrical Installation

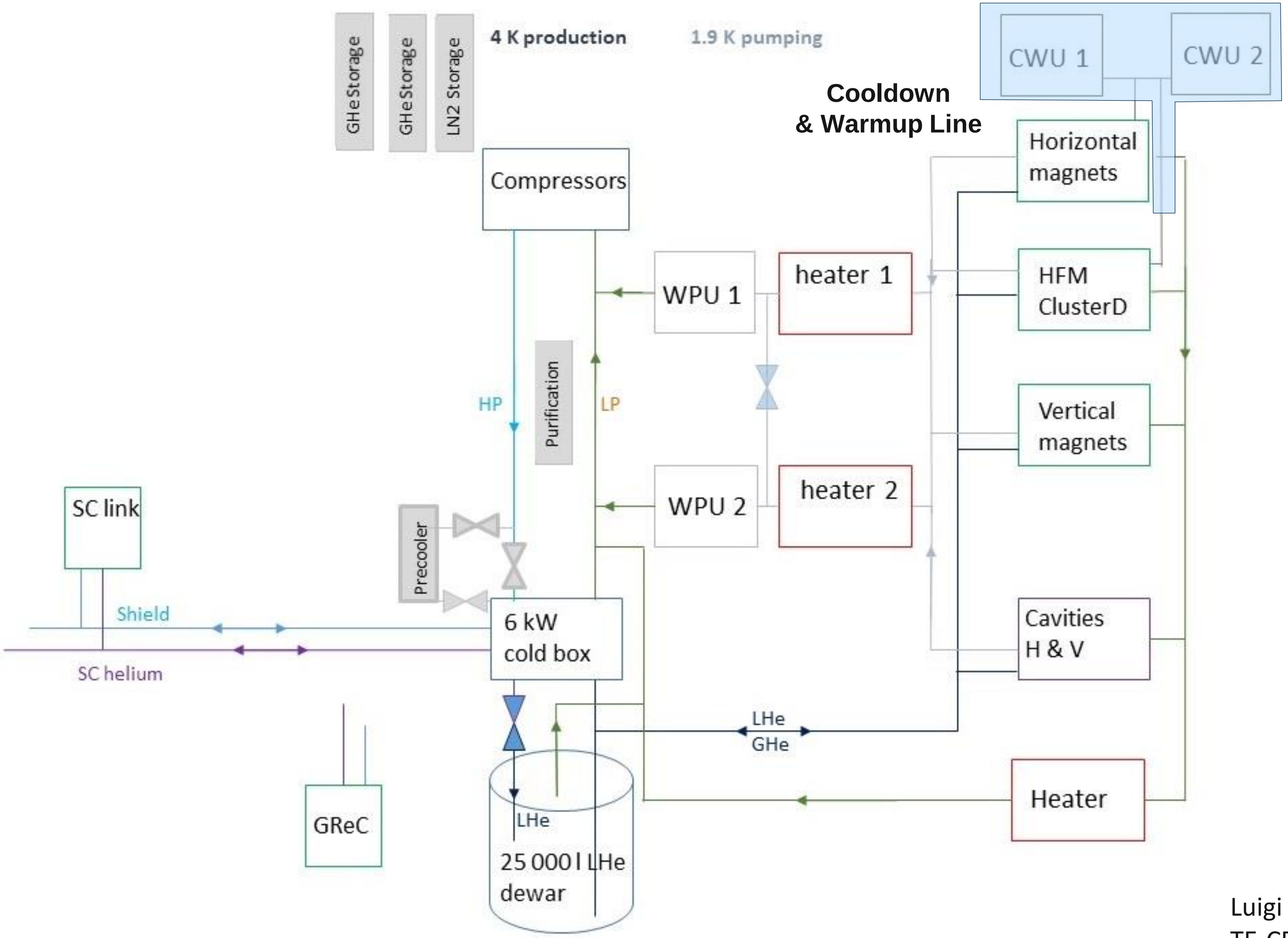
Second and third Cooling

Global view of the process

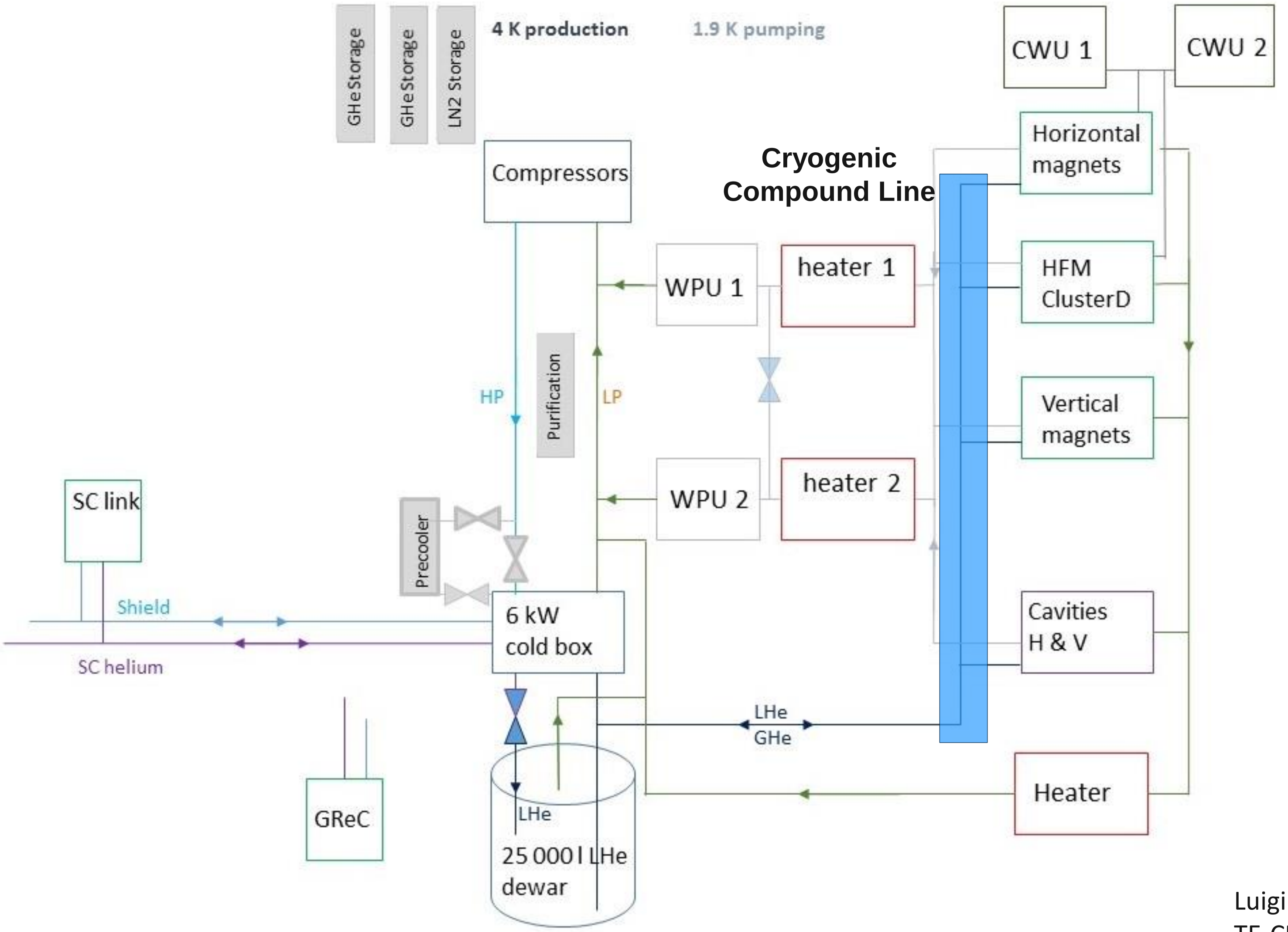




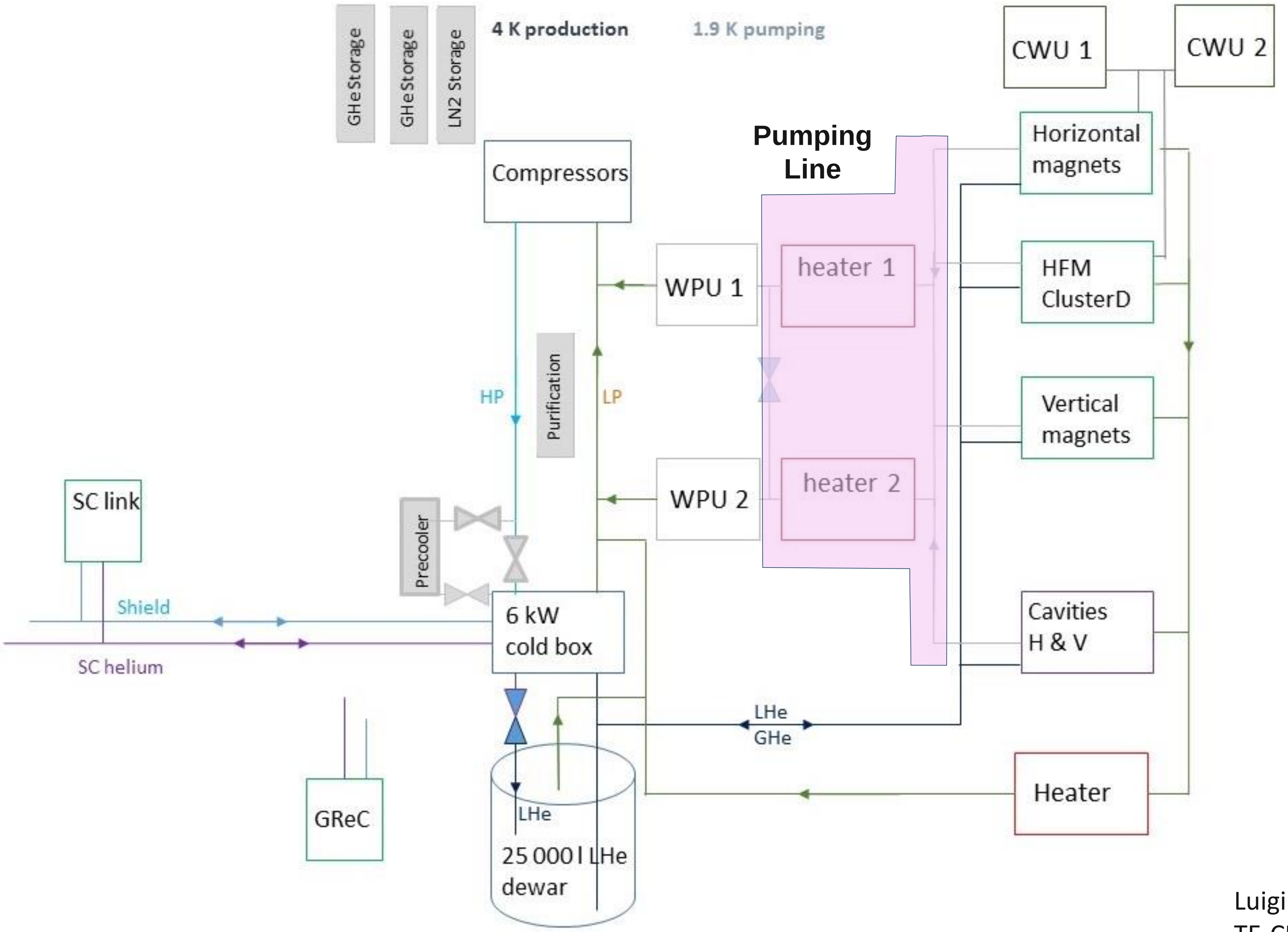
Luigi Serio
TE-CRG



Luigi Serio
TE-CRG



Luigi Serio
TE-CRG

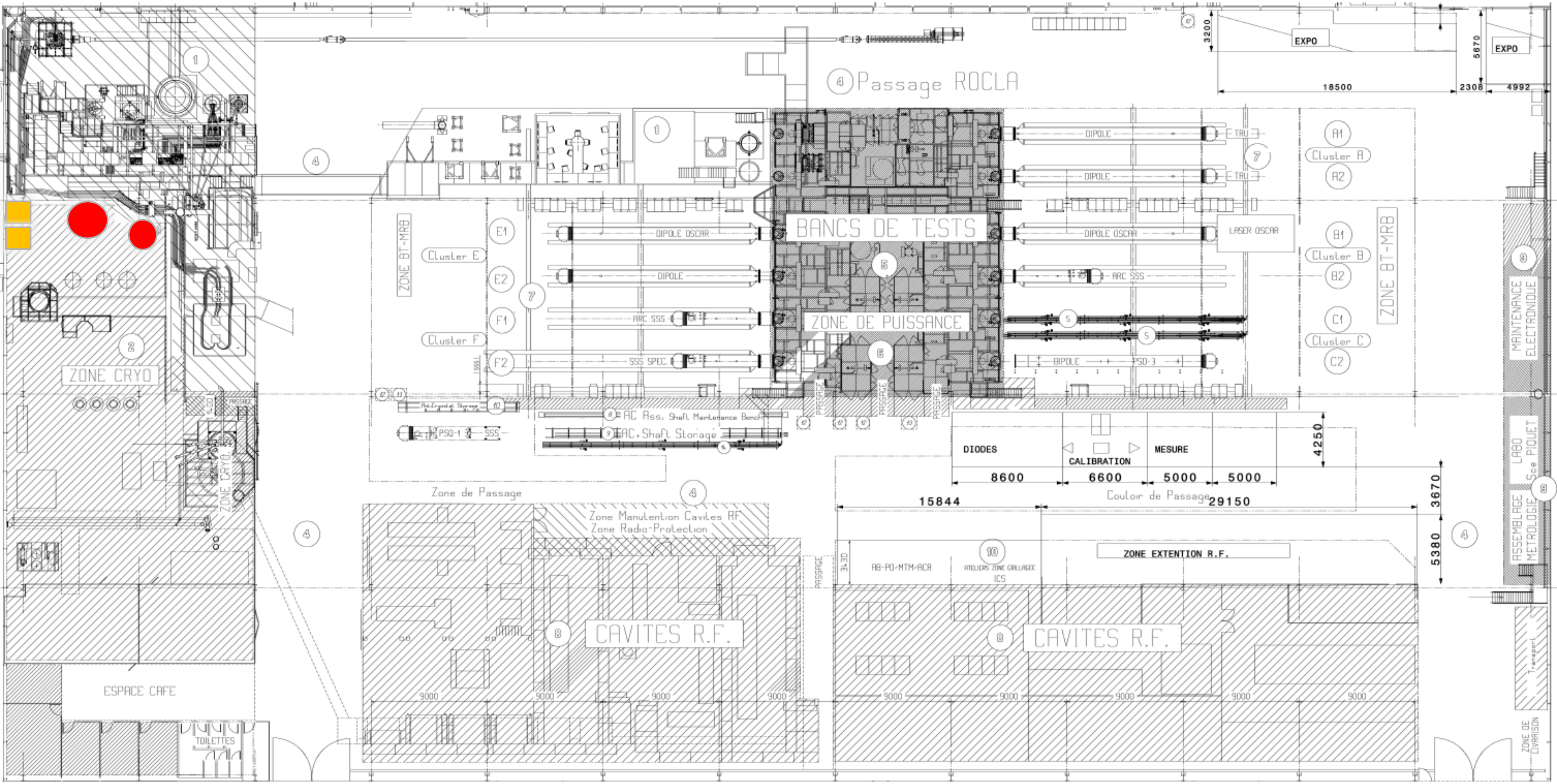


Luigi Serio
TE-CRG

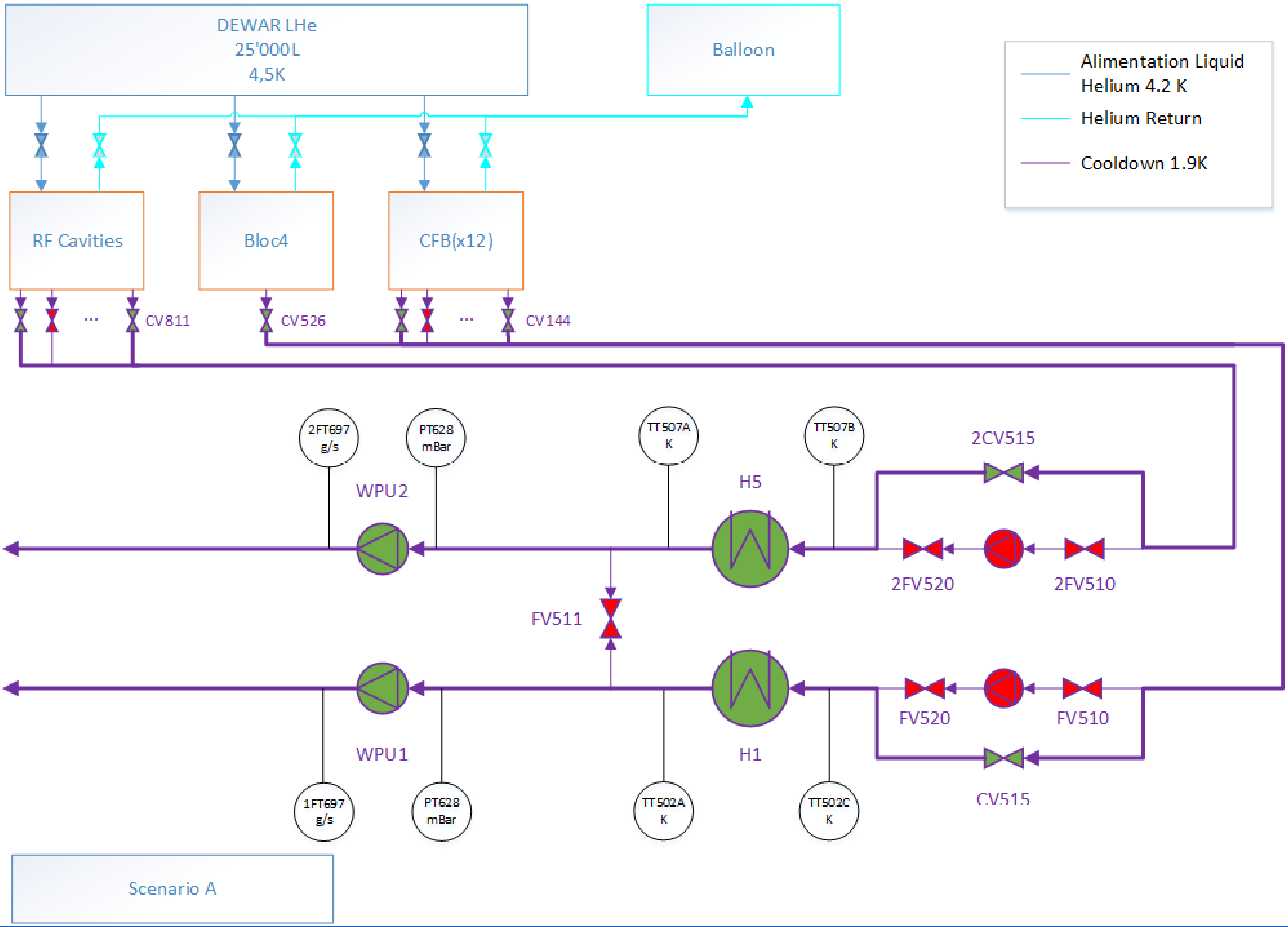
H1 & H5 : Revamping of Heaters in 1.9K Pumping Facility

4.5K -> 1.9K

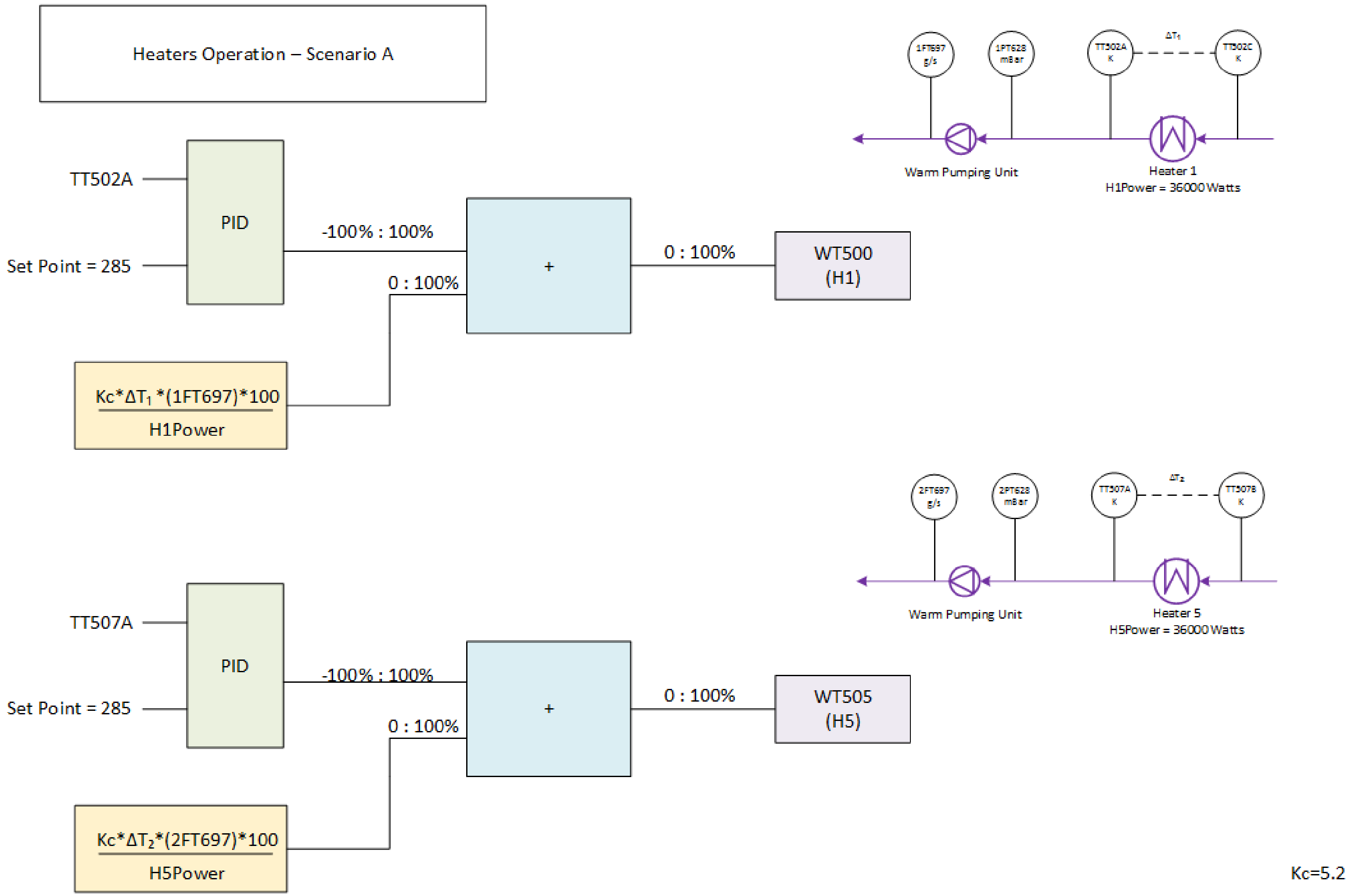
H1 & H5 Localisation



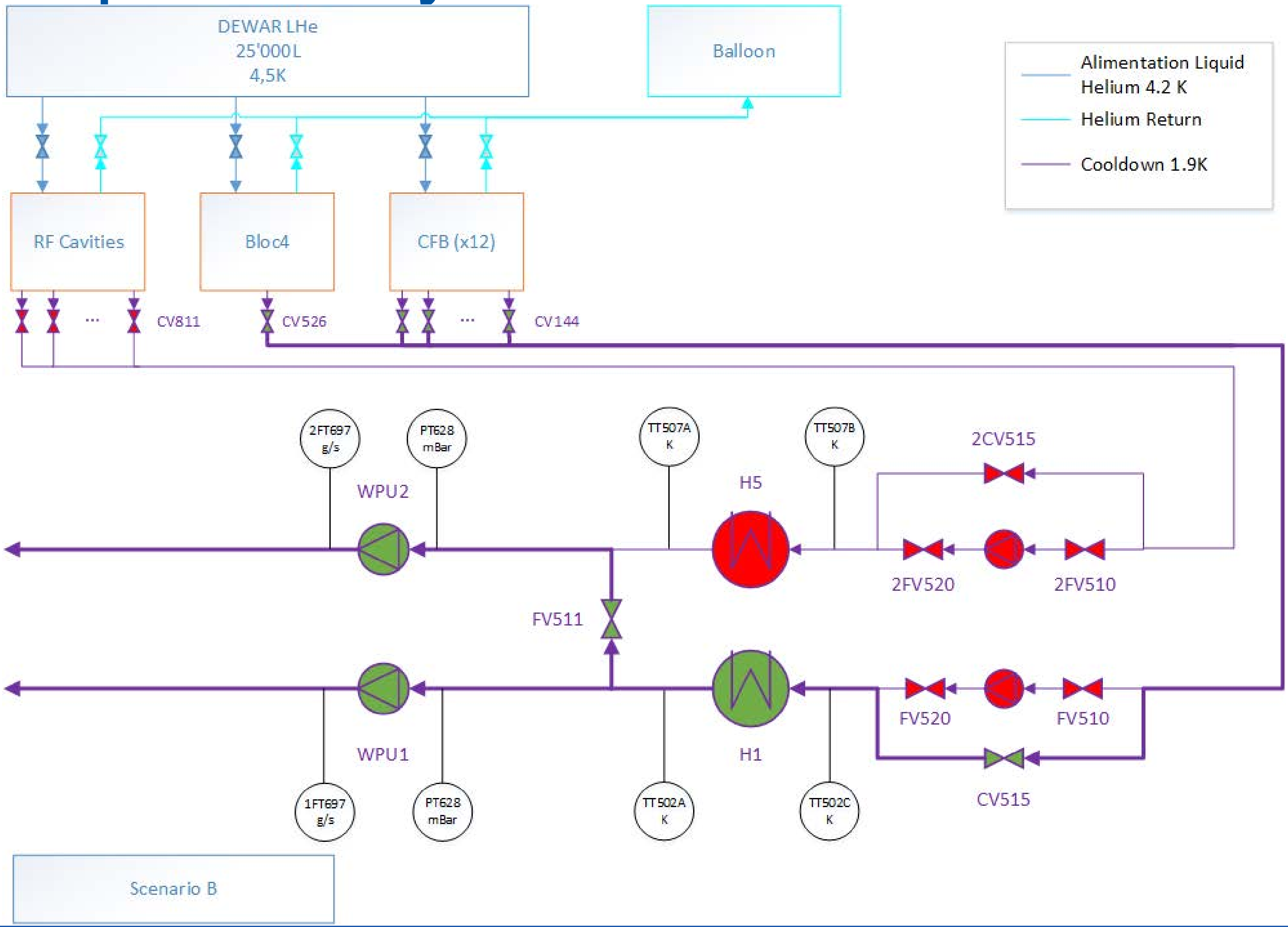
Actual Process



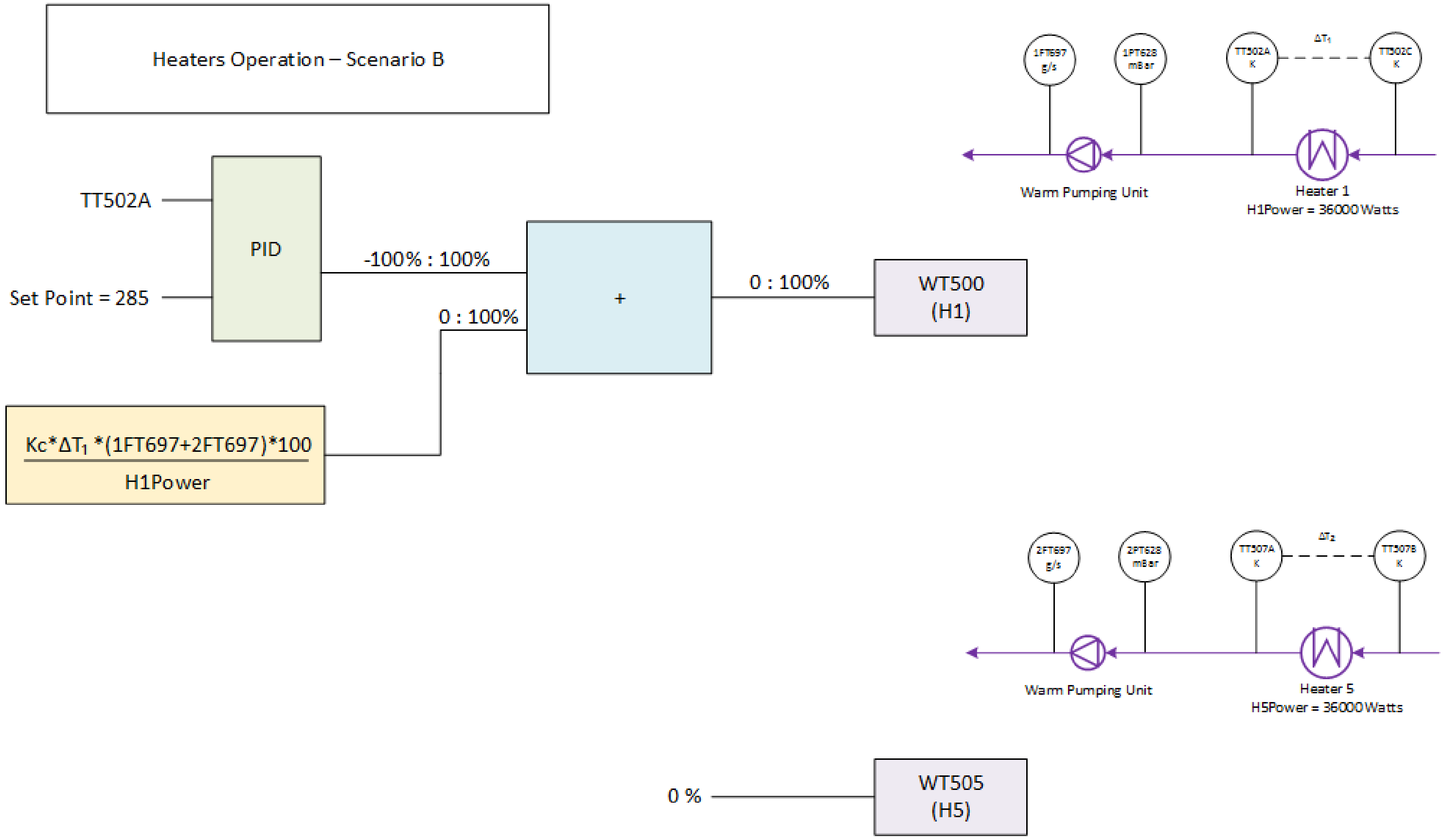
Actual Process



New possibility

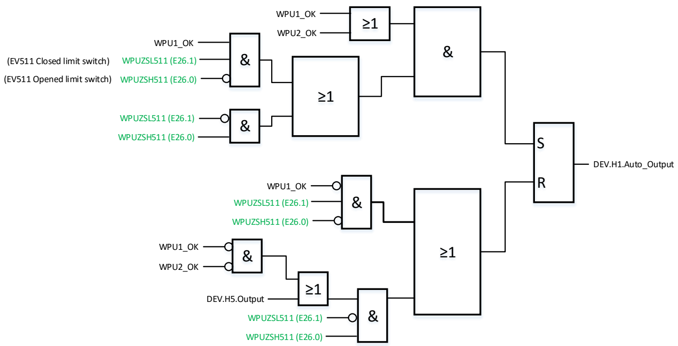


New possibility

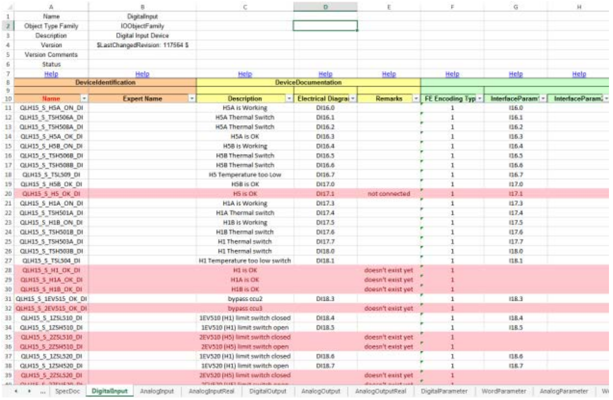


Kc=5.2

What is done



Specs Analysis



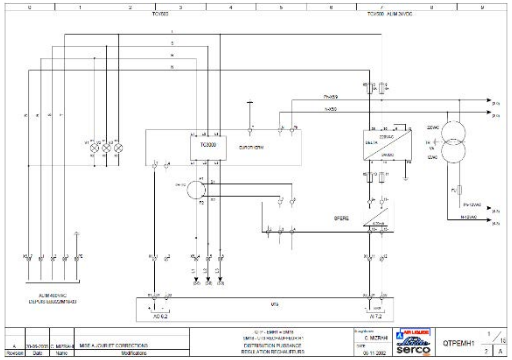
	A	B	C	D	E	F	G	H
1	Name	DigitalInput						
2	Object Type Family	IOObjectFamily						
3	Description	Digital Input Device						
4	Version	$LastChangedRevision: 117564 $						
5	Version Comments							
6	Status							
7	Help	Help	Help	Help	Help	Help	Help	Help
8	DeviceIdentification		DeviceDocumentation					
9								
10	Name	Expert Name	Description	Electrical Diagra	Remarks	FE Encoding Typ	InterfaceParam	InterfaceParam
11	QLH15_S_H5A_ON_DI		H5A is Working	DI16.0		1	I16.0	
12	QLH15_S_TSH506A_DI		H5A Thermal Switch	DI16.1		1	I16.1	
13	QLH15_S_TSH508A_DI		H5A Thermal Switch	DI16.2		1	I16.2	
14	QLH15_S_H5A_OK_DI		H5A is OK	DI16.3		1	I16.3	
15	QLH15_S_H5B_ON_DI		H5B is Working	DI16.4		1	I16.4	
16	QLH15_S_TSH506B_DI		H5B Thermal Switch	DI16.5		1	I16.5	
17	QLH15_S_TSH508B_DI		H5B Thermal Switch	DI16.6		1	I16.6	
18	QLH15_S_TSL509_DI		H5 Temperature too Low	DI16.7		1	I16.7	
19	QLH15_S_H5B_OK_DI		H5B is OK	DI17.0		1	I17.0	
20	QLH15_S_H5_OK_DI		H5 is OK	DI17.1	not connected	1	I17.1	
21	QLH15_S_H1A_ON_DI		H1A is Working	DI17.3		1	I17.3	
22	QLH15_S_TSH501A_DI		H1A Thermal switch	DI17.4		1	I17.4	
23	QLH15_S_H1B_ON_DI		H1B is Working	DI17.5		1	I17.5	
24	QLH15_S_TSH501B_DI		H1B Thermal switch	DI17.6		1	I17.6	
25	QLH15_S_TSH503A_DI		H1 Thermal switch	DI17.7		1	I17.7	
26	QLH15_S_TSH503B_DI		H1 Thermal switch	DI18.0		1	I18.0	
27	QLH15_S_TSL504_DI		H1 Temperature too low switch	DI18.1		1	I18.1	
28	QLH15_S_H1_OK_DI		H1 is OK		doesn't exist yet	1		
29	QLH15_S_H1A_OK_DI		H1A is OK		doesn't exist yet	1		
30	QLH15_S_H1B_OK_DI		H1B is OK		doesn't exist yet	1		
31	QLH15_S_1EV515_OK_DI		bypass ccu2	DI18.3		1	I18.3	
32	QLH15_S_2EV515_OK_DI		bypass ccu3		doesn't exist yet	1		
33	QLH15_S_1ZSL510_DI		1EV510 (H1) limit switch closed	DI18.4		1	I18.4	
34	QLH15_S_1ZSH510_DI		1EV510 (H1) limit switch open	DI18.5		1	I18.5	
35	QLH15_S_2ZSL510_DI		2EV510 (H5) limit switch closed		doesn't exist yet	1		
36	QLH15_S_2ZSH510_DI		2EV510 (H5) limit switch open		doesn't exist yet	1		
37	QLH15_S_1ZSL520_DI		1EV520 (H1) limit switch closed	DI18.6		1	I18.6	
38	QLH15_S_1ZSH520_DI		1EV520 (H1) limit switch open	DI18.7		1	I18.7	
39	QLH15_S_2ZSL520_DI		2EV520 (H5) limit switch closed		doesn't exist yet	1		

SpecDoc | DigitalInput | AnalogInput | AnalogInputReal | DigitalOutput | AnalogOutput | AnalogOutputReal | DigitalParameter | WordParameter | AnalogParameter

Temporal Unicos DataBase

```
(*************************************************************)
(***********************  H1 and H5 Control  ****************)
(*************************************************************)

IF WPU1_OK AND WPU2_OK THEN   // WPU1 AND WPU2 Running

    DEV.FV511.Interlock:= Blocked;
    DEV.FV511.Auto_Output:= Closed;
    IF WPUZSL511 AND NOT WPUZSH511 THEN

        FT697H1:= REAL_TO_DWORD(WPU2_Read.W1PDT697);
        PT628_1:= REAL_TO_DWORD(WPU2_Read.W1PT628);
        DEV.H1.Auto_Output:= ON;
        FT697H5:= REAL_TO_DWORD(WPU2_Read.PDT697);
        PT628_2:= REAL_TO_DWORD(WPU2_Read.PT628);
        DEV.H5.Auto_Output:= ON;
        Uti_Com_DB.Pumping_OK:= (DEV.H1.NFault OR DEV.H5.NFault) AND PSH225B AND Alarms.TT507AL.Rdy AND Alarms.TT502AL.Rdy AND Alarms.PT811L.Rdy;

    END_IF;

ELSIF WPU1_OK AND NOT WPU2_OK THEN  // WPU1 Running

    DEV.FV511.Interlock:= Released;
    IF WPUZSL511 AND NOT WPUZSH511 THEN

        FT697H1:= REAL_TO_DWORD(WPU2_Read.W1PDT697);
        PT628_1:= REAL_TO_DWORD(WPU2_Read.W1PT628);
        DEV.H1.Auto_Output:= ON;
        FT697H5:= REAL_TO_DWORD(0.0);
        PT628_2:= REAL_TO_DWORD(0.0);
        DEV.H5.Auto_Output:= OFF;
        Uti_Com_DB.Pumping_OK:= DEV.H1.NFault AND PSH225B AND Alarms.TT502AL.Rdy AND Alarms.PT811L.Rdy;

    ELSIF NOT WPUZSL511 AND WPUZSH511 THEN

        FT697H1:= REAL_TO_DWORD(0.0);
        PT628_1:= REAL_TO_DWORD(0.0);
        DEV.H1.Auto_Output:= OFF;
        FT697H5:= REAL_TO_DWORD(WPU2_Read.W1PDT697);
        PT628_2:= REAL_TO_DWORD(WPU2_Read.W1PT628);
        DEV.H5.Auto_Output:= ON;
        Uti_Com_DB.Pumping_OK:= DEV.H5.NFault AND PSH225B AND Alarms.TT507AL.Rdy AND Alarms.PT811L.Rdy;

    END_IF;

ELSIF NOT WPU1_OK AND WPU2_OK THEN  // WPU2 Running
```

Testing Program



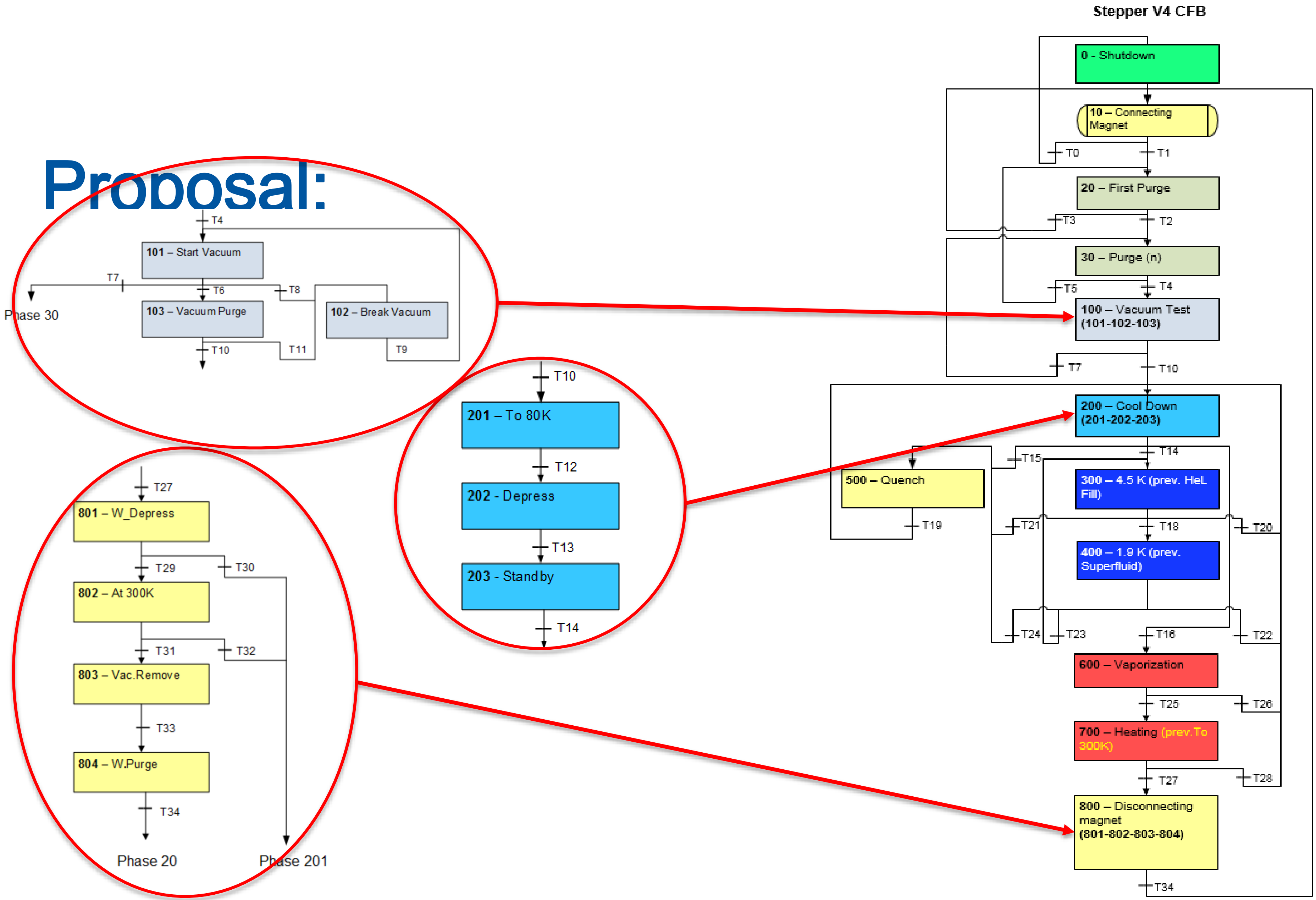
Check Electrical installation

Analysis current program

- The CFB main program is divided into different Phases, which are composed by Steps.
- There are conditions to pass from one Phase to the next one and conditions to pass from one Step to the next one.
- All this conditions are set by Parameters.

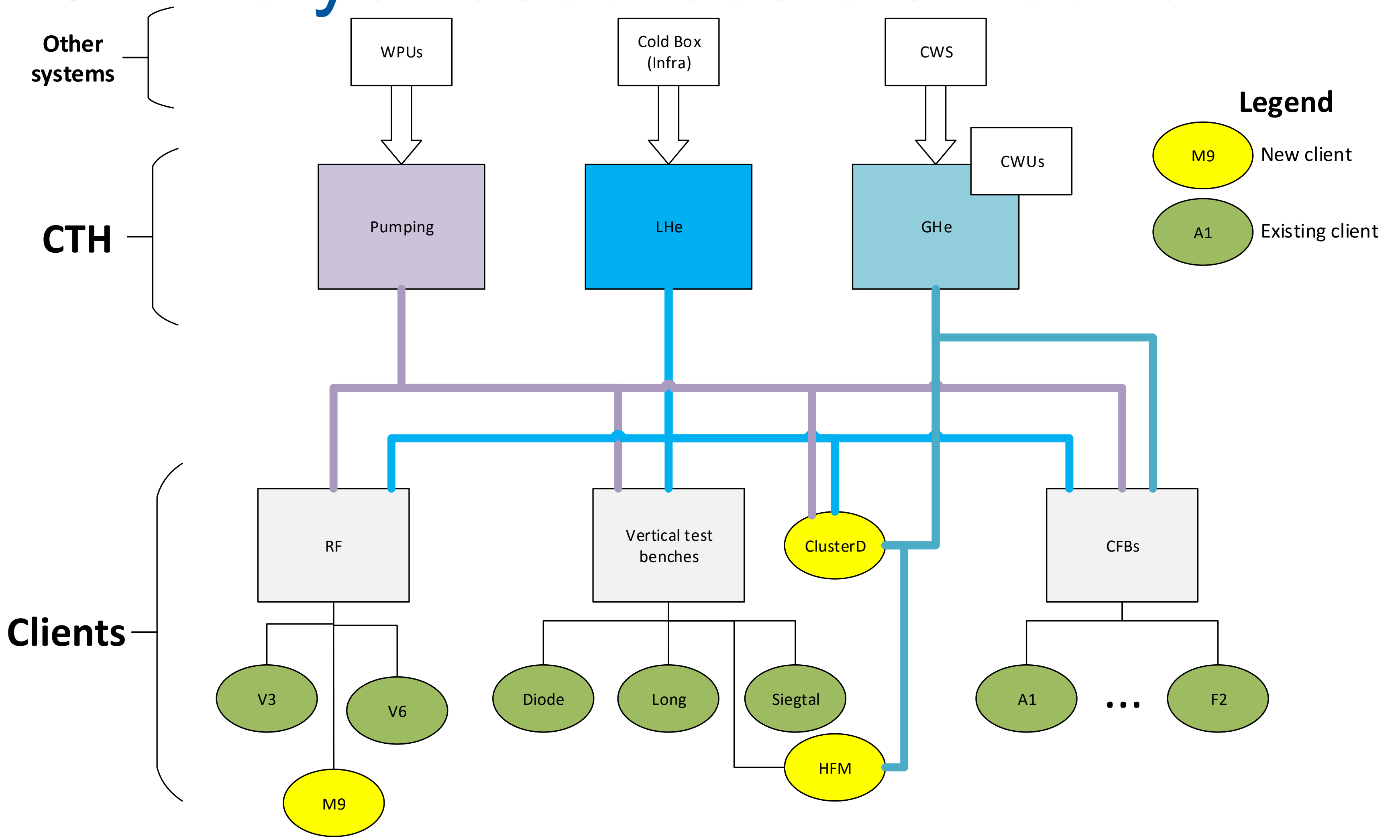
Task: simplify and unify to standard solution

Proposal:



Stepper V4 CFB
0 - Shutdown
10 – Connecting Magnet
T0
T1
20 – First Purge
T3
T2
30 – Purge (n)
T5
T4
100 – Vacuum Test (101-102-103)
T7
T10
200 – Cool Down (201-202-203)
T15
T14
500 – Quench
T19
300 – 4.5 K (prev. HeL Fill)
T21
T18
T20
400 – 1.9 K (prev. Superfluid)
T24
T23
T16
T22
600 – Vaporization
T25
T26
700 – Heating (prev.To 300K)
T27
T28
800 – Disconnecting magnet (801-802-803-804)
T34
T4
101 – Start Vacuum
T7
T6
T8
Phase 30
103 – Vacuum Purge
102 – Break Vacuum
T10
T11
T9
T10
201 – To 80K
T12
202 - Depress
T13
203 - Standby
T14
T27
801 – W_Depress
T29
T30
802 – At 300K
T31
T32
803 – Vac.Remove
T33
804 – W.Purge
T34
Phase 20
Phase 201

CTH cryo resources distribution



CTH main functions

Before

CTH PLC

- Gaseous Helium and Nitrogen handling (CWL, CWU) for precooling to 80K
- Liquid Helium line (CCL) from Dewar (infra) to clients
- Pumping handling (PL, H1, H5)
- Priority MgM for CFBs

CTH main functions

After

CTH PLC

- Gaseous Helium and Nitrogen handling (CWL, CWU) for precooling to 80K

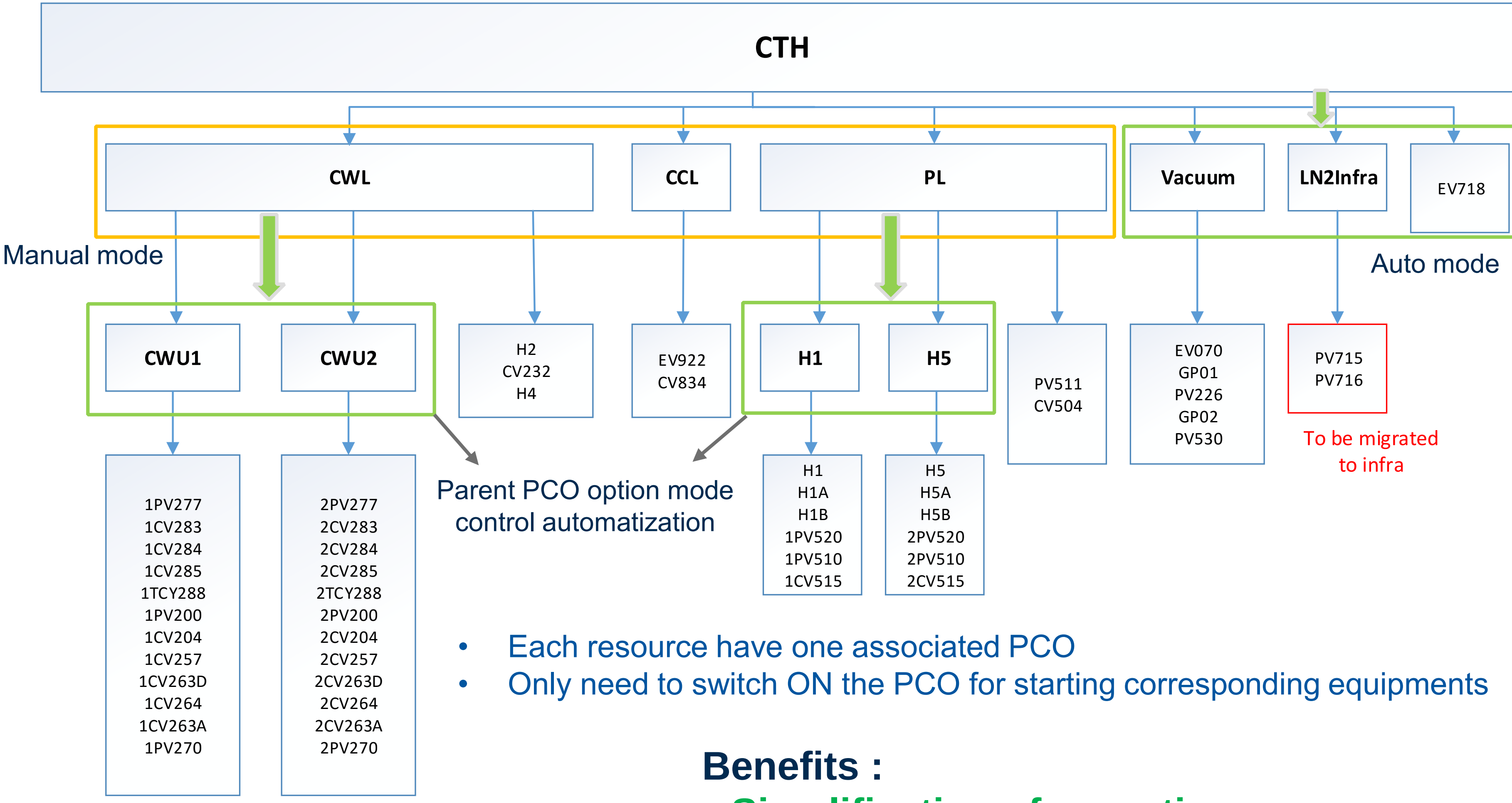
- Liquid Helium line (CCL) from Dewar (infra) to clients

- Pumping handling (PL, H1, H5)

SCADA data server

- Priority MgM for **all SM18 clients** (CFBs, RF cavities & Vertical Test Benches)

PCO Structure



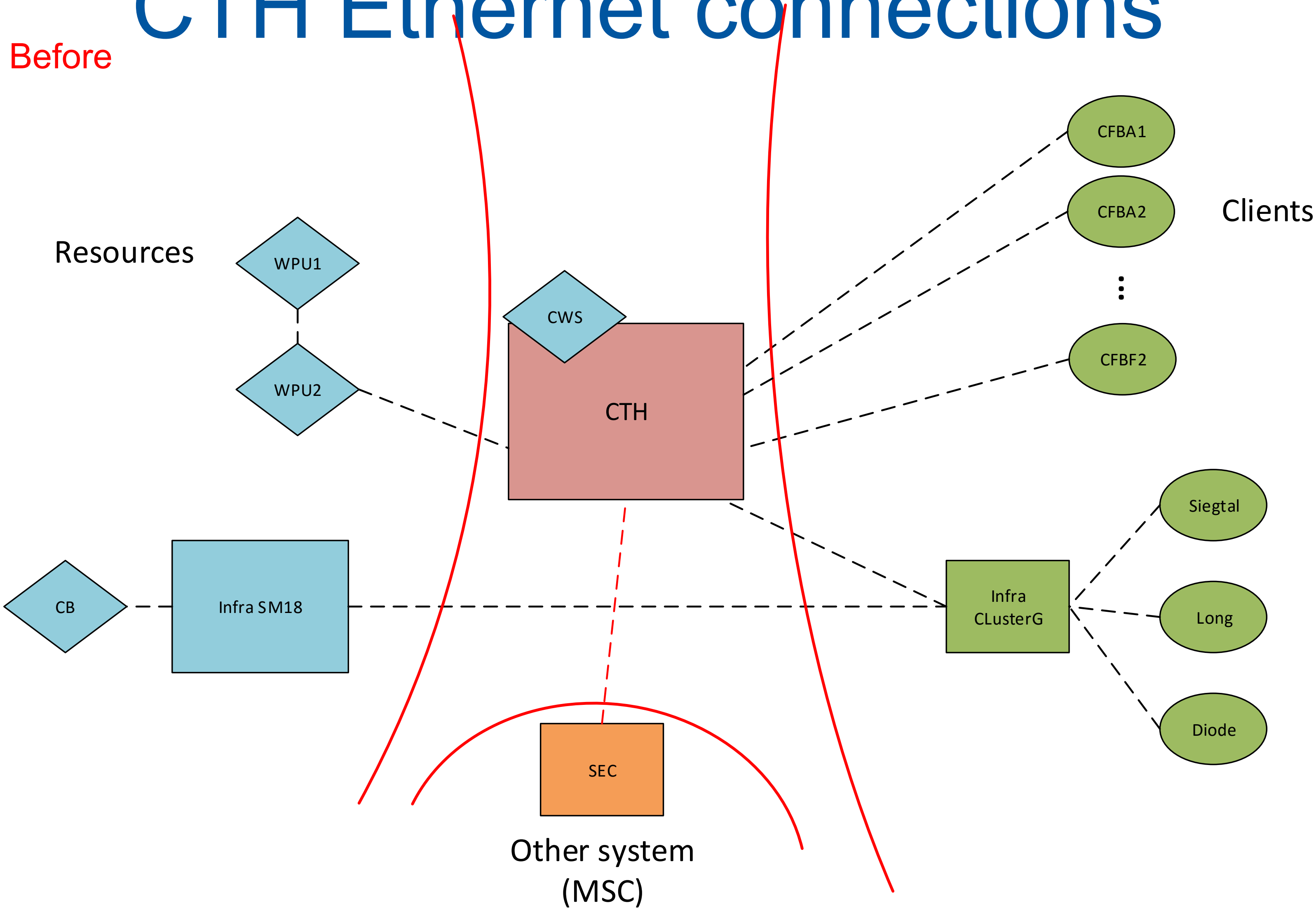
- Each resource have one associated PCO
- Only need to switch ON the PCO for starting corresponding equipments

Benefits :

Simplification of operation

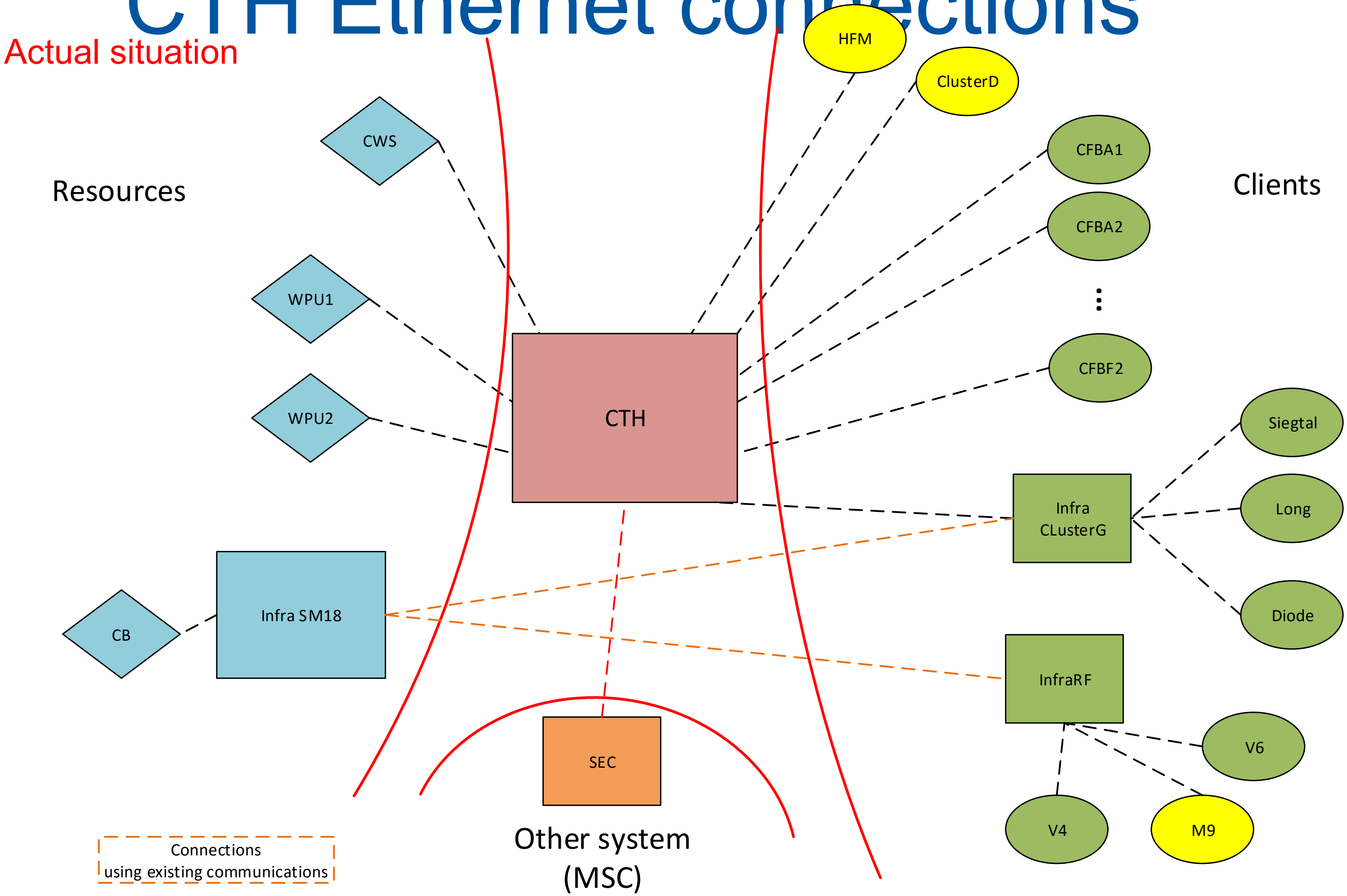
Control hardware modifications

CTH Ethernet connections

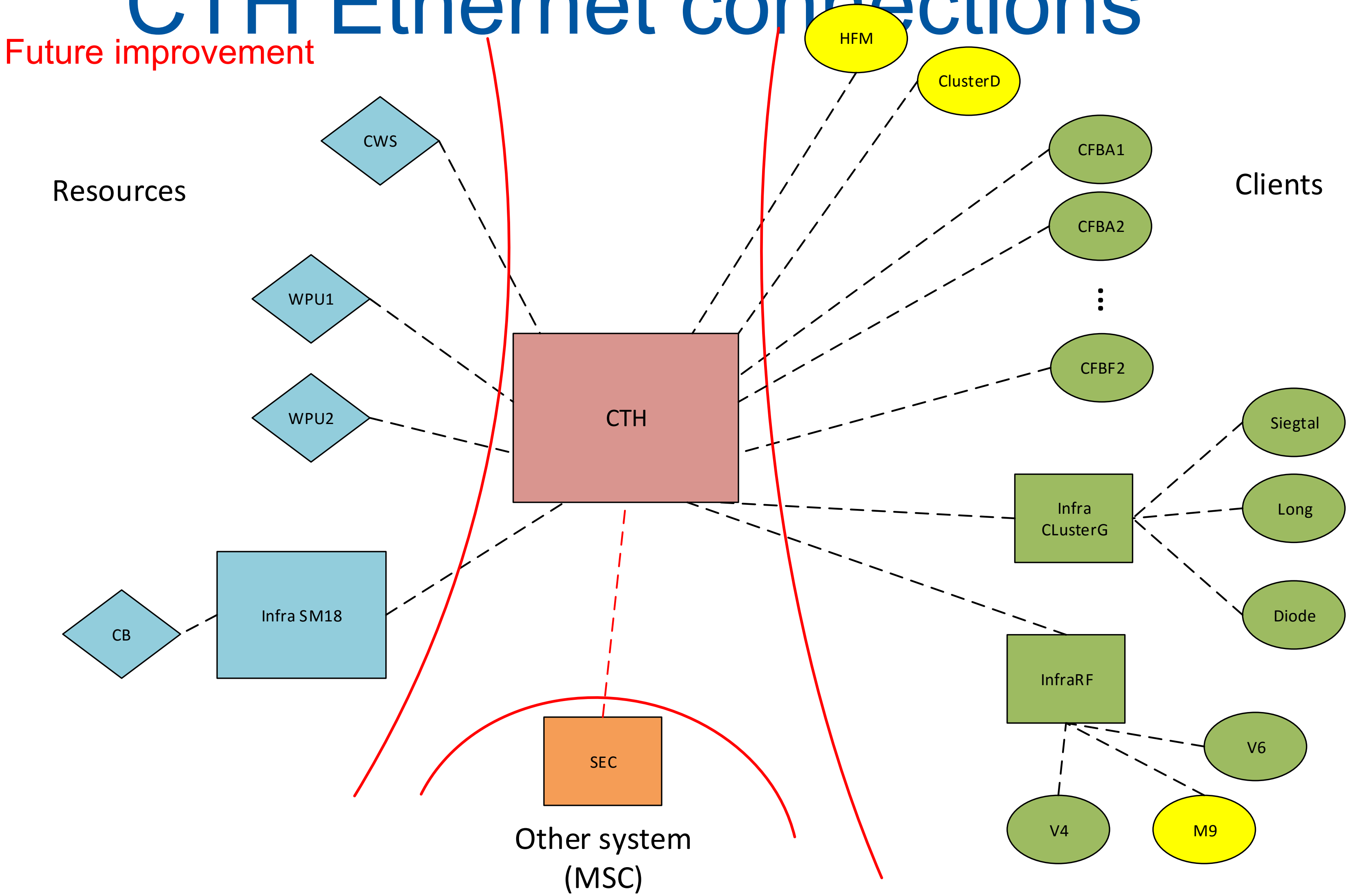


CTH Ethernet connections

Actual situation



CTH Ethernet connections

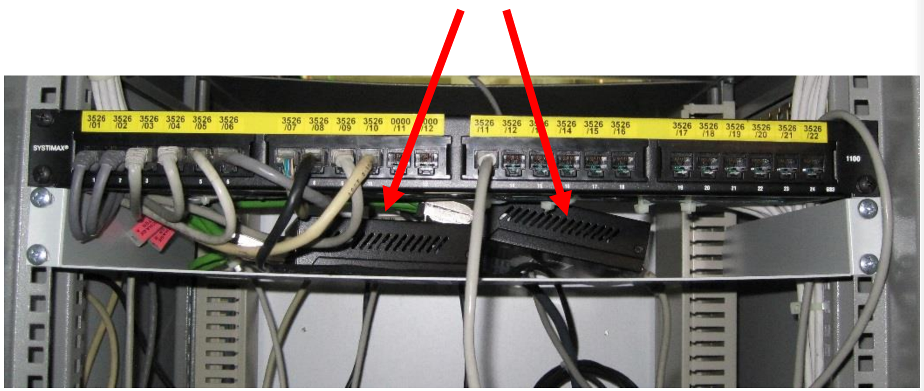


Ethernet network reliability improvement

Before

Situation :

- PLCs connected to two non fixed fan-out



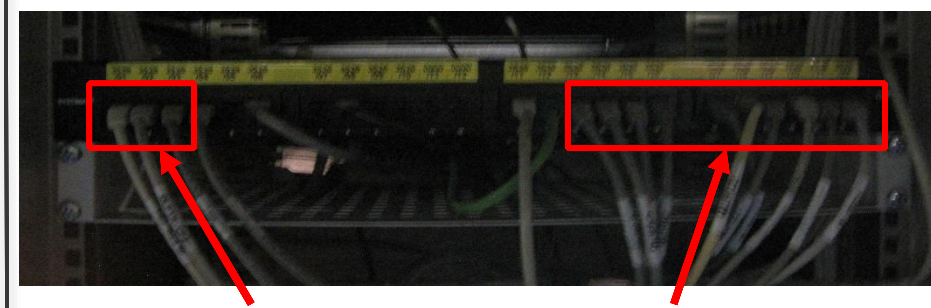
Problems :

- Subject to connection problems if touched
- Additional possible network break-point

After

Situation :

- One dedicated individual outlet per PLC



Benefits :

- **Standard and more robust configuration**

CPU rack

Before

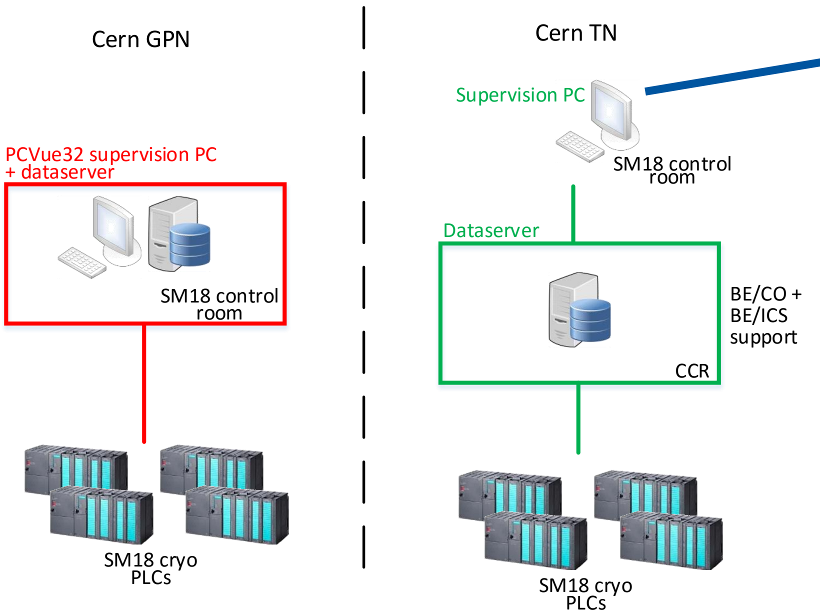
- Siemens S7-414 + CP 443-1 (external Ethernet module) x13 (CTH + 12 CFBs)

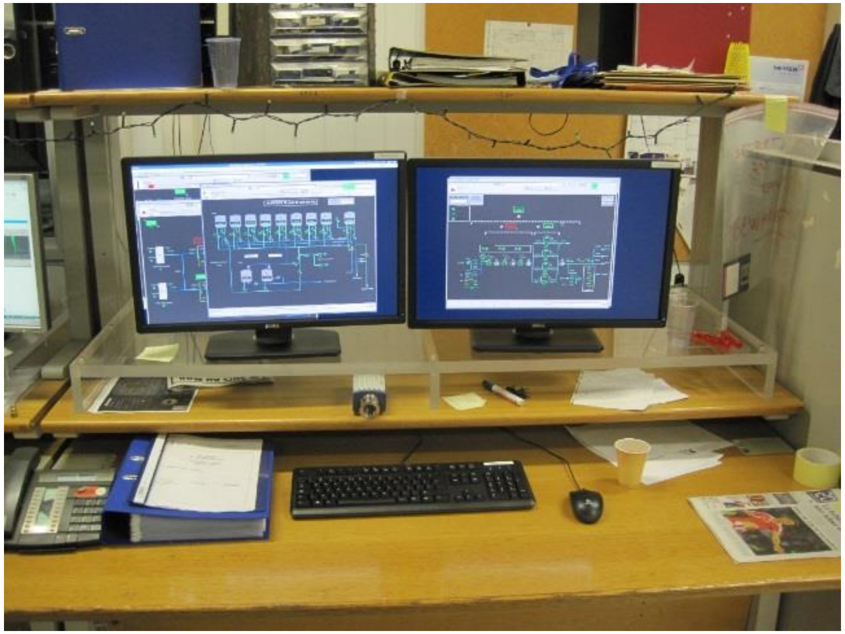
After

- Siemens S7-317-2 PN/DP x11 (10 CFBs + ClusterD)
- S7-317-2 PN/DP + 2 CP 343-1 Advanced (CTH ~20 connections)

New OWS for Control room

4 Linux (LHC standard) OWS in operation
(and maybe more in the new control room)





New OWS

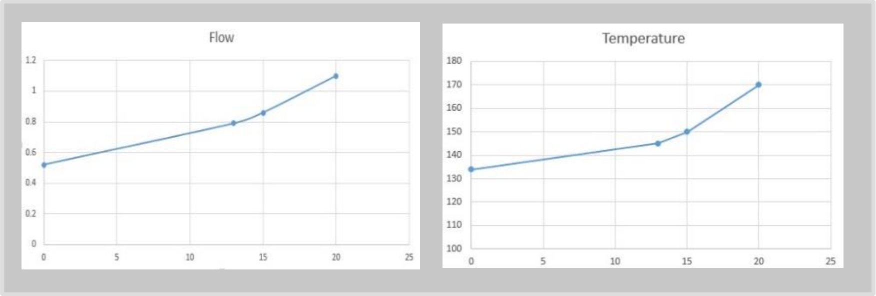
Benefits :

- **Standard supervision system**
- **Security improvement**

CFBs current leads LHe flow valves control depending on current value

Context :

- New HL-LHC Current Leads (up to 20kA)
- Regulation previously done with fixed flow value
  (Enough for 12kA but not for 20kA)
- Choice to use Current value to regulate flow



Regulation study done by Vladislav Benda
(Flow and temperature depending on current in kA)

Hardware modifications :

- Add of new AI card on each bench (x10)
- Current value cabling by MSC

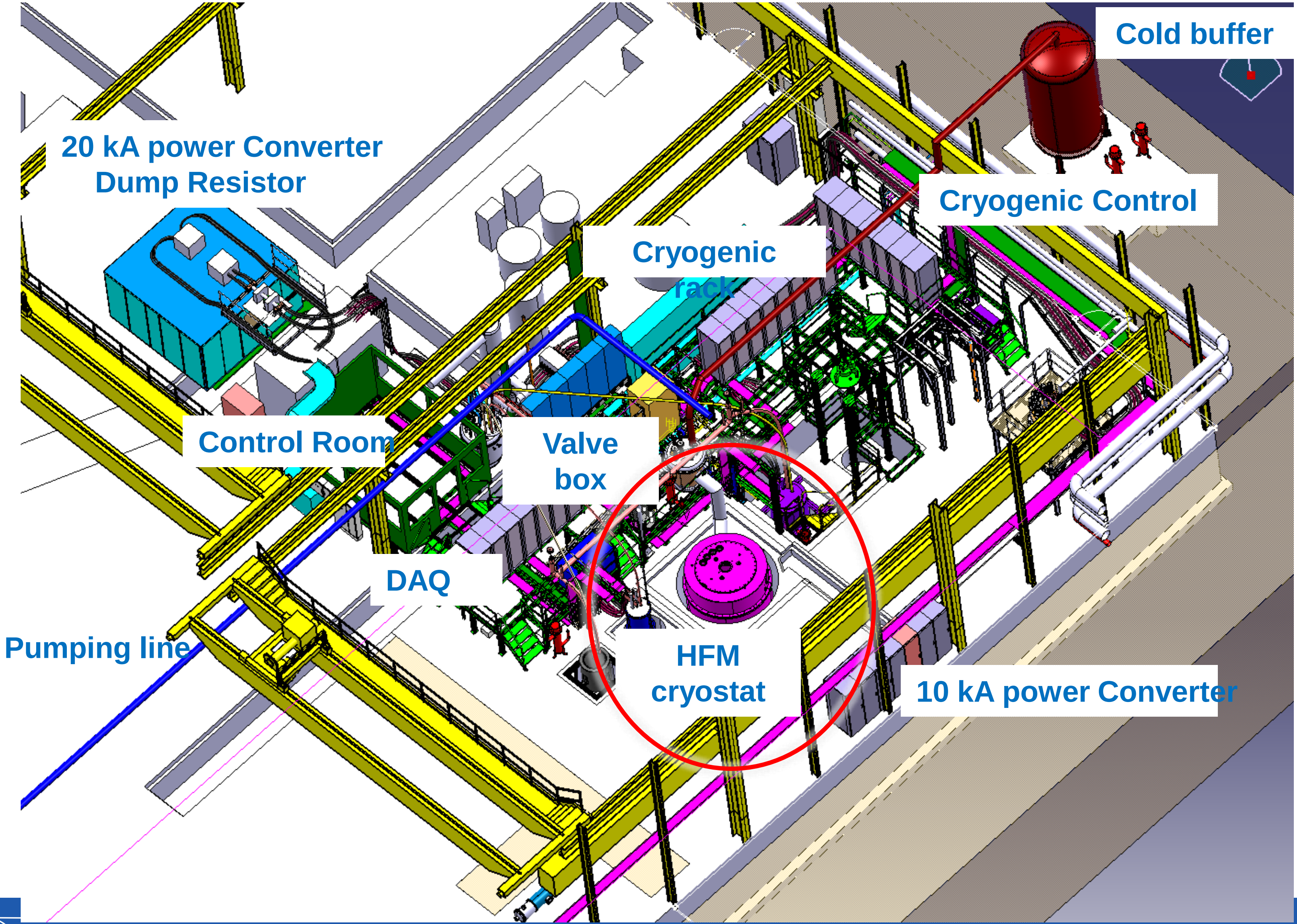
System tested and in production

Benefits :

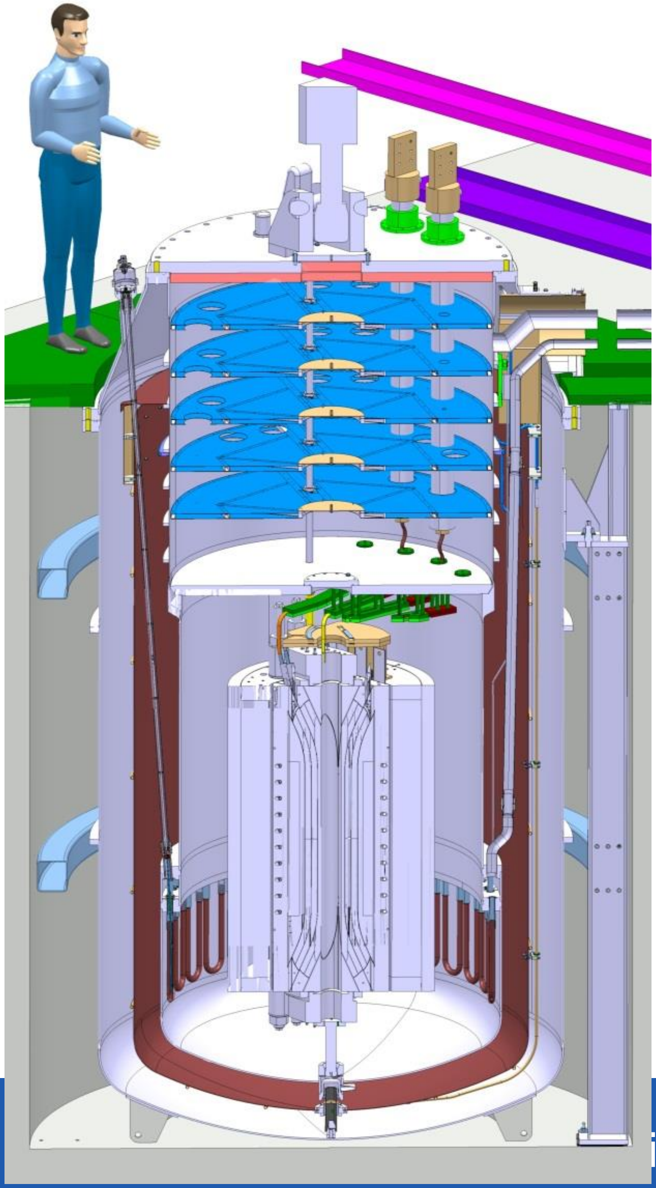
- **Adapted to HL-LHC magnets test**

New test station “HFM” & “Cluster D”

The High Field Magnet test station (CERN, SM18)

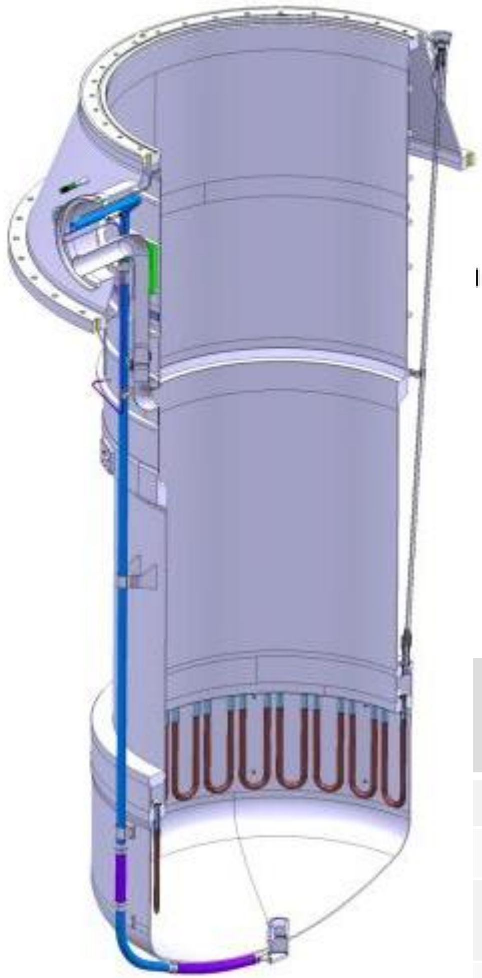


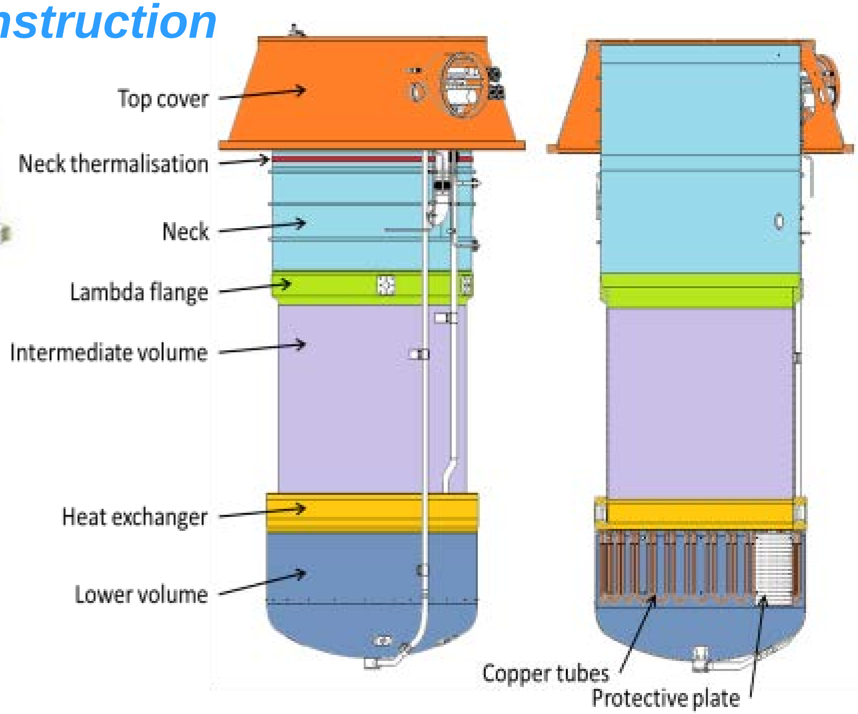
The HFM test cryostat



Helium vessel, main features

Ready to launch construction





Item	Material
Vessel and Pipes	AISI 304 L
Hoses and bellows	AISI 316L/316 LN
Heat exchanger	OFE Copper brazed to AISI 316 LN
Thermal shield	OF Copper

Item	Tolerances/leak rate
Lambda flange to top flange (ø1600 mm)	Parallelism within 1 mm
Centring pin to top flange	Position within 2 mm
Maximum welds leak rate	1.10^{-10} Pa.m^3/s

Item	Internal diameter [mm]	Length [mm]	Thickness [mm]
Top cover	1610/2300	770	10
Neck	1610	1650	3
Intermediate volume	1500	1655	8
Lower volume + Dished end	1700	890	8
Total length	4320 mm		
Total weight	3350 kg		

Property		Value
Magnet + Support weight		17 tons
Operation pressure	Internal	1 bar (max. 4 bar)
	External	0 bar
Design pressure	Internal	0 bar / 4.5 bar
	External	0 bar /1.5 bar
Nominal temperature	Neck	293 K – 4.2 K
	Helium vessel	1.9 K

SM18: HFM

Cryogenic distribution system:

- 20-Jun : successful pressure test;
- Preparation works for the commissioning (safety devices, vent lines, instrumentation, …)

Commissioning of TF :

- Plan drafted, including check lists;
- Warm tests started beginning of July
- Missing elements (MSC)
  - Insert to be completed
  - Some cables
- Proposals for cold commissioning (~2 months) depending on magnet availability
- Ready for cool down mid July

Mechanical Valve Commissioning Part List HFM TF
v1 CERN/TE-CRG

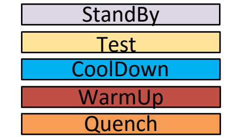
COMMISSIONING - CONTROL VALVES

Date:
Signature

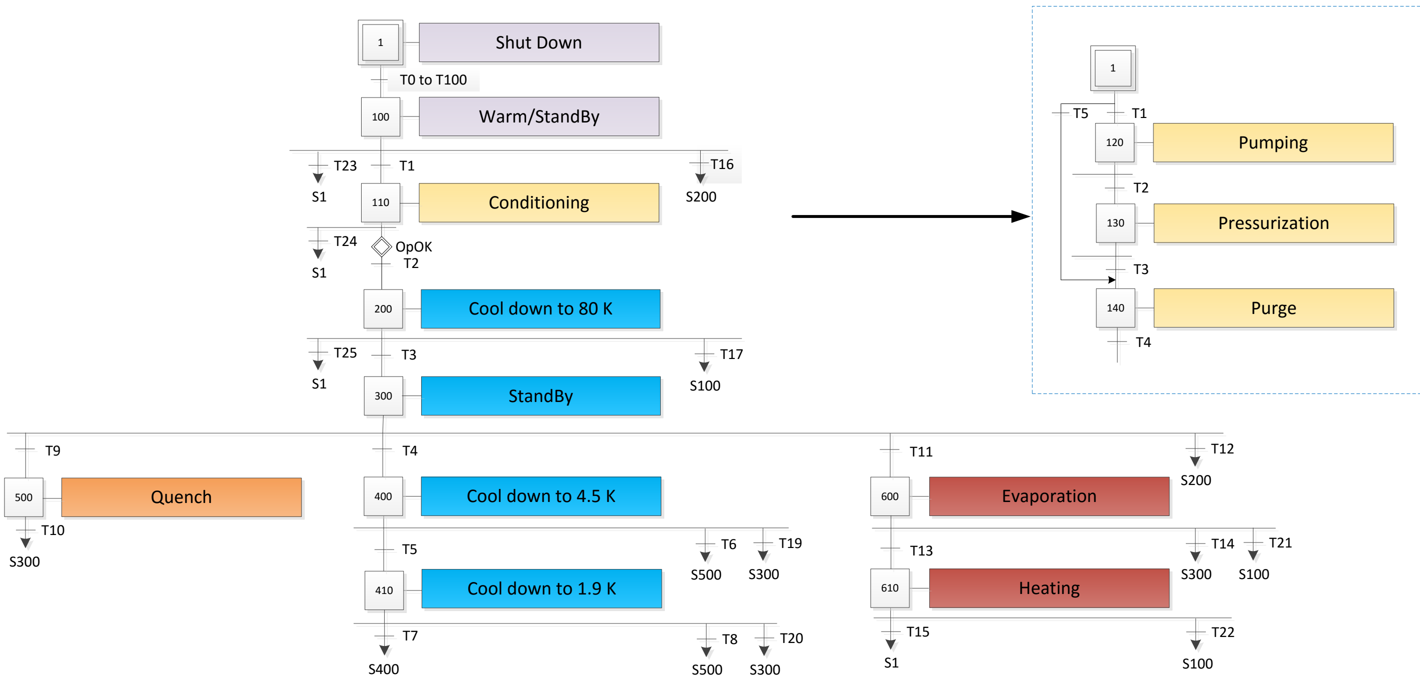
				Characteristics: Specification				Characteristics: General			Compressed Air	Closed		Travel							
Tag	Type	Sub Component	Compressed Air	DN	Kv	PN	Output range	General Description	Supplier	Serial Number	Leak Tightness	Normally Closed	Leak Tightness2	Preload [mm]	Travel [mm]	Feedback 0%	Feedback 50%	Feedback 100%	Smooth Movem	Oscillation/stability 50%	
3CV810	Control Valve	He Rack	3HV810Y	15	3.1	25	bus	GHe outlet for 20 kA current lead	WEKA												
3CV811	Control Valve	He Rack	3HV811Y	15	3.1	25	bus	GHe outlet for 20 kA current lead	WEKA												
3CV812	Control Valve	He Rack	3HV812Y	10	1.4	25	bus	GHe outlet for 10 kA current lead	WEKA												
3CV813	Control Valve	He Rack	3HV813Y	10	1.4	25	bus	GHe outlet for 10 kA current lead	WEKA												
3CV830	Control Valve	He Rack	3HV830Y	40	45	25	bus	Purge	WEKA												
3CV839	Control Valve	He Rack	3HV839Y	10	4.5	25	bus	Pecooling line "He guard"	Flowserve												Sipart by
3CV851	Control Valve	Valve Box	3HV851Y	10	1.4	25	bus	LHe to phase separator	WEKA												
3CV852	Control Valve	Valve Box	3HV852Y	10	2.8	25	bus	LHe filling of lower part of cryostat	WEKA												
3CV853	Control Valve	Valve Box	3HV853Y	6	0.6	25	bus	LHe filling of upper part of cryostat	WEKA												
3CV854	Control Valve	Valve Box	3HV854Y	6	0.15	25	bus	LHe from L/G heat exchanger	WEKA												
3CV855	Control Valve	Valve Box	3HV855Y	50	71	25	bus	1.9 K pumping valve	WEKA												Helium gu
3CV856	Control Valve	Valve Box	3HV856Y	25	10	25	bus	LHe cool down, cold return	WEKA												
3CV857	Control Valve	Valve Box	3HV857Y	15	4	25	bus	Cold GHe outlet after quench	WEKA												
3CV858	Control Valve	Valve Box	3HV858Y	15	1.5	25	bus	Shield, GHe cold outlet	WEKA												
3CV860	Control Valve	Valve Box	3HV860Y	10	0.8	25	bus	Warm GHe from cryostat, neck cooling	WEKA												

Operation, phases

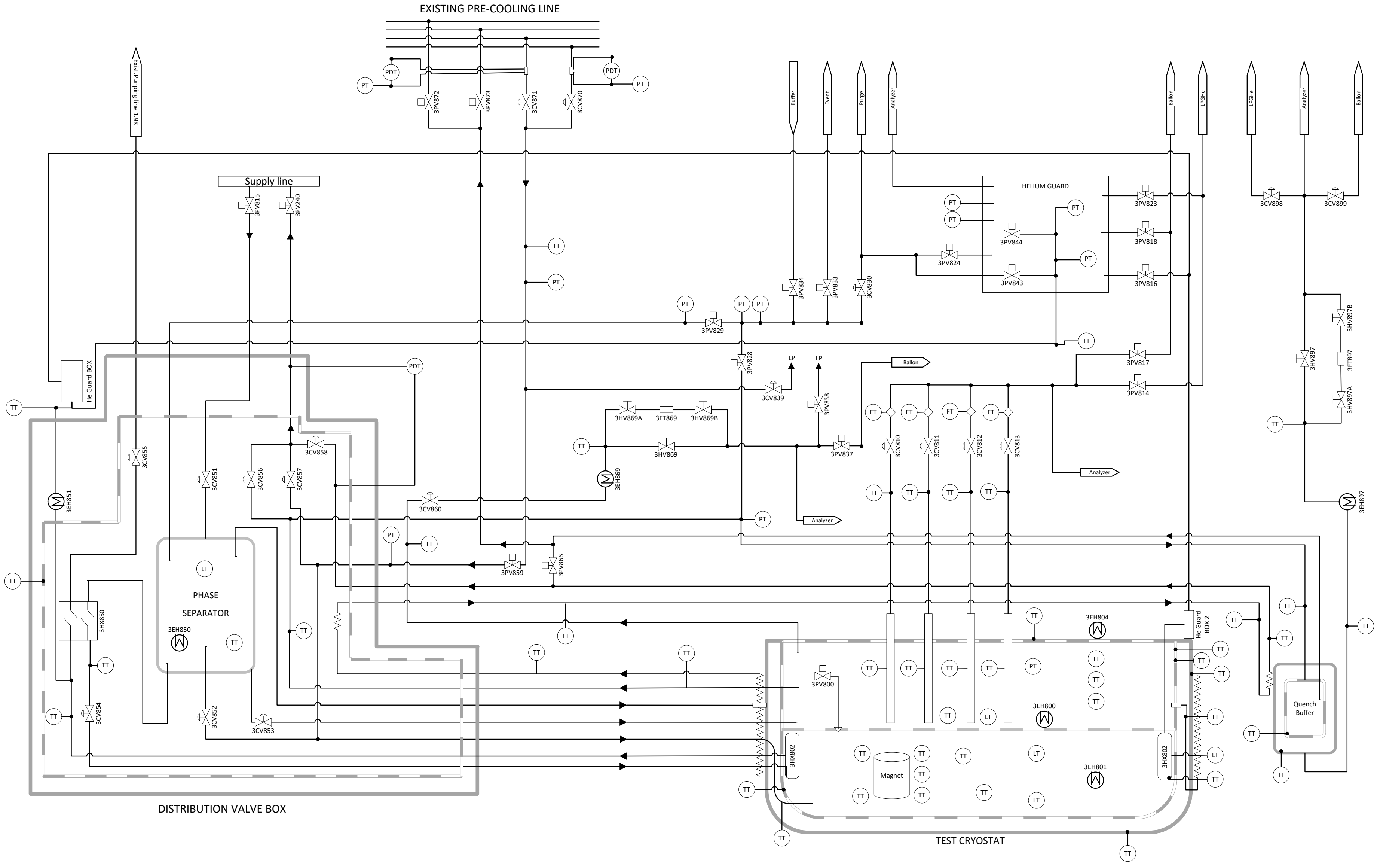
- Magnet cool-down
  - From 300K to 80K
    - Pre-cooling box>pre-cooling line>lower part of cryostat & magnet>upper part of cryostat>quench line>cold buffer>pre-cooling line>pre-cooling box. τ =8h
  - From 80K to 4.5K with LHe
    - Phase separator of the valve box>low part of cryostat & magnet>upper part of cryostat>quench line>cold return of supply line. τ =8h
    - At first to a balloon via CV860 when helium is pure (analyzer) to cold retour by CV856
    - Small part of the flow through the quench buffer via EH897 to the balloon and when pure (analyzer) to LP
  - From 4.5K to 1.9K
    - Standard cooling by pumping. τ =1-1.5 day
- Thermal shield and 1.9K circuit cool down from 300K to nominal temperature
  - Thermal shield: Phase separator of the valve box>thermal shield>warm outlet. Later on to cold return of supply line. τ ~ 2 days
  - 1.9K circuit: Phase separator>gas/liquid heat exchanger>liquid/liquid heat exchanger>1.9K pumping line>EH851>helium guard>balloon or LP; when cold to the 1.9 K pumping line
- Warm-up
  - Main circuit: magnet cryostat, quench buffer. Equivalent to magnet cool down from 300K to 80K, but from 5K to 300K.
  - Thermal shield: HP GHe heated by EH852 to 350K coming in the phase separator, passing all shield circuit and leaving through warm return by CV 859 to EH869 and to LP or to balloon.
  - 1.9K circuit: The same warm GHe from the phase separator>liquid/gas heat exchanger>liquid/liquid heat exchanger>pumping line> cold buffer>EH851 >helium guard to LP or balloon (analyzer)
- Nominal condition
  - Stability
- Quench
  - After quench evaporated helium comes to a quench buffer to reduce a pressure below 4 bar (design pressure)
  - Cold helium gas from the cold buffer can be used to re-cool the magnet after quench: quench buffer>quench line>upper part of the cryostat>lower part of the cryostat by PV800>cold return by CV857
- Other function
  - Safe operation: analysis, safety valves & rupture disks, software
  - Purge
    - Cryostat and a quench buffer by valve PV828, DN40
    - Phase separator, shield circuit and 1.9K circuit by PV829, DN25
  - Analysis of GHe purity by common analyzer of VMTF (ex Block 4)
  - Leak and pressure test
  - Simple dismantling of an insert with a magnet: only 4 warm lines of current leads to be disconnected



Main Stepper

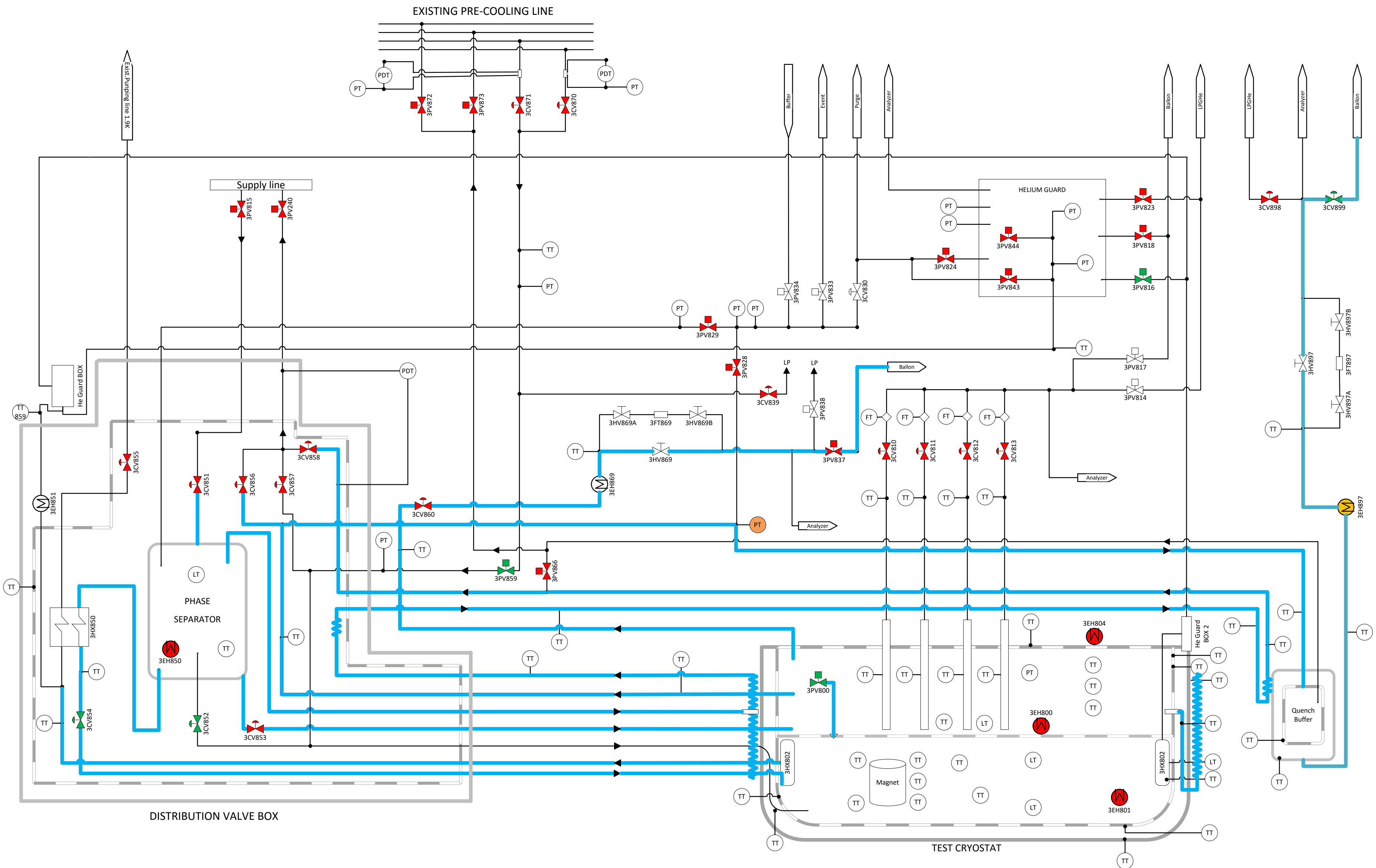


HFM Simplified P&ID



OPEN
CLOSE
OPEN/CLOSE
REGULATION

S-100 SECURE STAND-BY



SM18: Cluster D

Cryogenic distribution system:

- Quench buffer delivered 17-Jun
- Connection by Criotec next week
- He Rack leak tested. Installation at SM18 from next week
- Cryostat not available

Quench buffer provisionally stored close to SM18

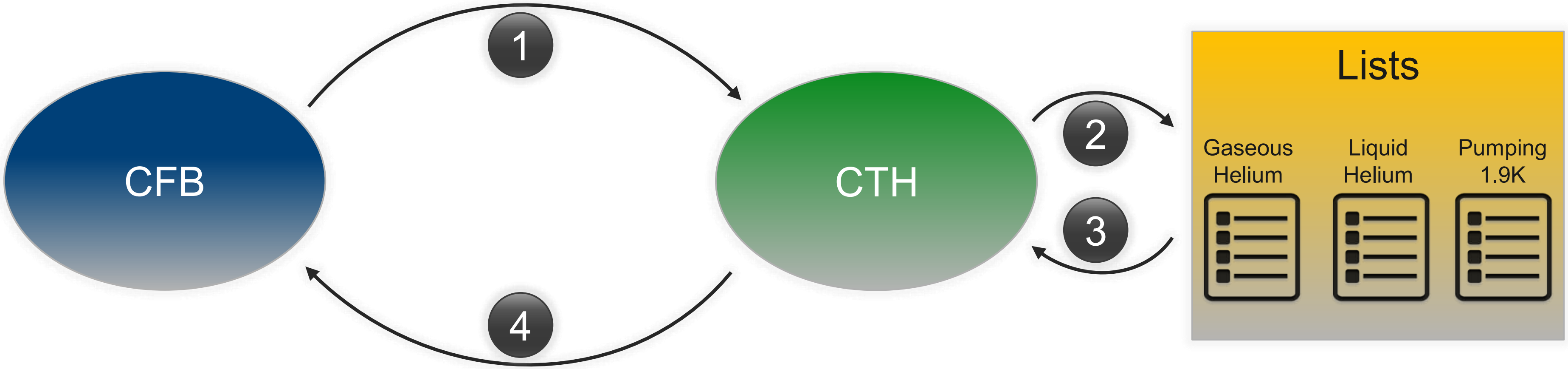
Results and Challenges

- **Human challenges**
  - Common understanding: Effective
    - Cryogenic facility domain.
    - Operation constraints.
    - Use of a framework.
  - Changes in organization: Being effective
    - Subcontracting vs Partnership.
  - Adoption of UNICOS by end users: Effective

- **Method**
  - Specifications: Being effective
    - Adoption of new method and tools
    - Early specifications.
    - Involvement of all actors.
  - Documentation: To be improved
    - Identification of technical document to be updated.
    - Documentation for operators.

CTH handling of CFBs resources

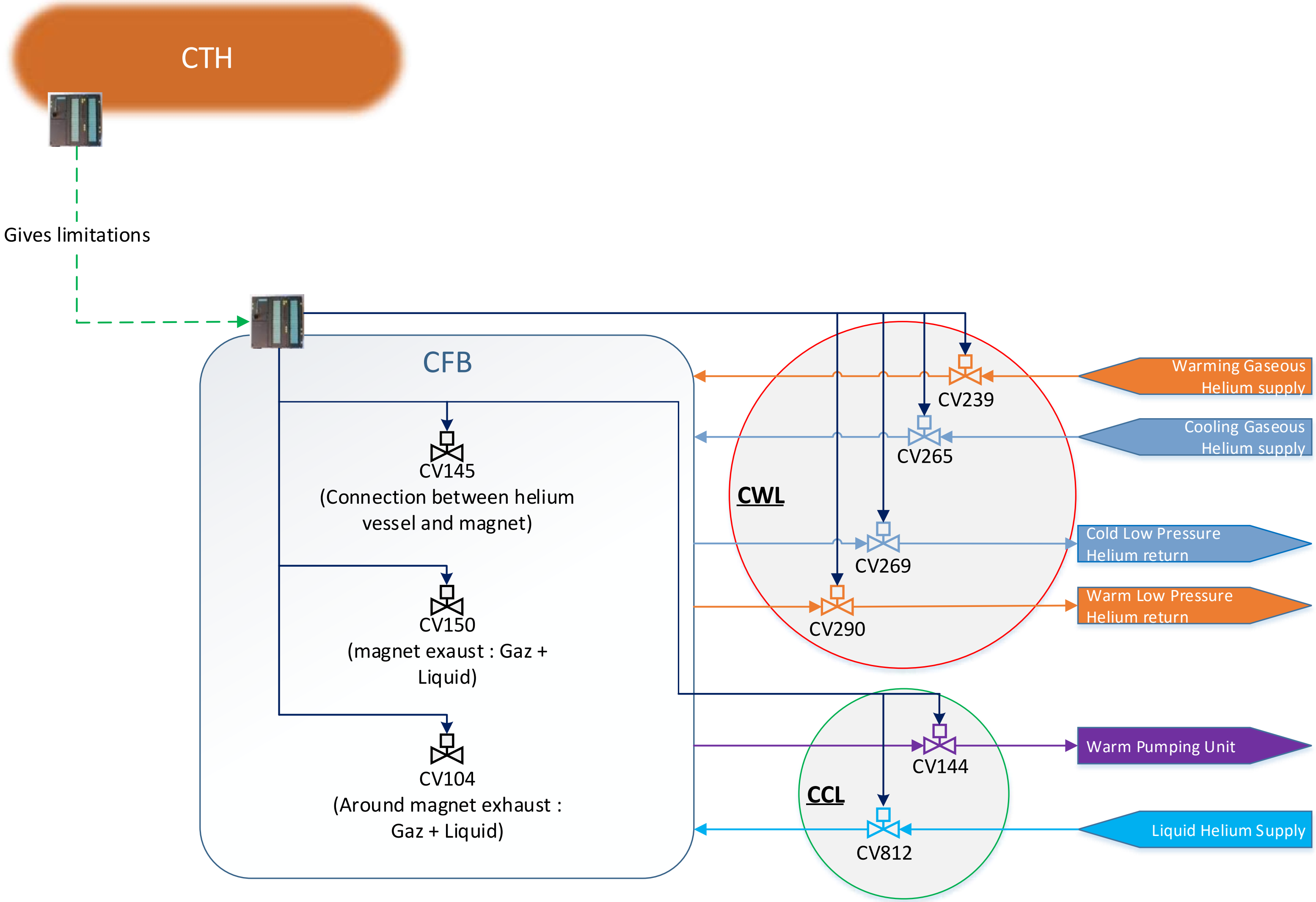
CFB asks resources to CTH



CTH gives limitations
in using resources

CTH manages
priority lists in function of
availability resources

CTH – CFB Limitations



Cryogenic Test Facility Monitoring

- Identification of sensitive variables
  - % opening of supply valves
  - Features of magnet (dipole, quadripole)
    - Mass, dimensions…
  - Available resources

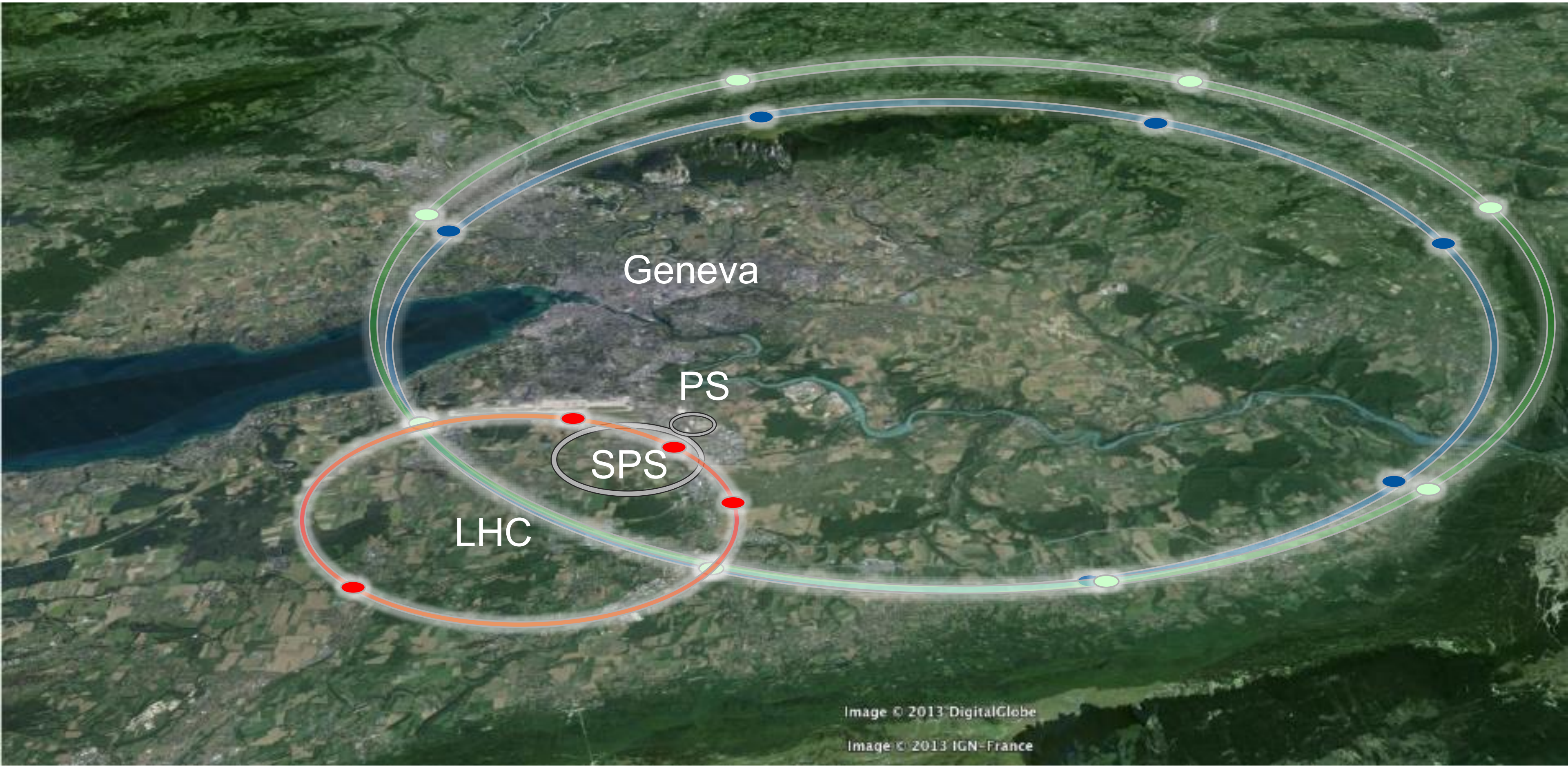
- Building of a model
  - Matlab, EcosimPro

Conclusion

- Ambitious scope and tight planning
  - All involved people are new with limited contracts.
- Results for operation and maintenance
  - Homogeneity on new control systems.
  - Flexible operation.
- Collaboration is effective
  - Technical solutions validated.
  - Method and tools used.
- Improvement identified
  - Documentation, good practices to be systematically applied.

Enlarging the horizon

Ideas beyond the LHC: the FCC's



LHC	HE-LHC	FCC-hh	FCC-hh
27 km, 8.33 T	27 km, **20 T**	80 km, **20 T**	100 km, **16 T**
14 TeV (c.o.m.)	33 TeV (c.o.m.)	100 TeV (c.o.m.)	100 TeV (c.o.m.)
1300 tons NbTi	3000 tons LTS	9000 tons LTS	6000 tons Nb_3Sn
0.3 tons HTS	700 tons HTS	2000 tons HTS	3000 tons Nb-Ti

The HL-LHC (HiLumi) project
From accelerator physics to technology

Accelerator physics

Reduce emittance

Increase bunch population

Reduce beta at collision

Reduce crossing angle

Increase intensity & brightness of injectors: the LIU project

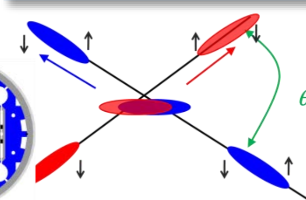
Limit beam-beam effect

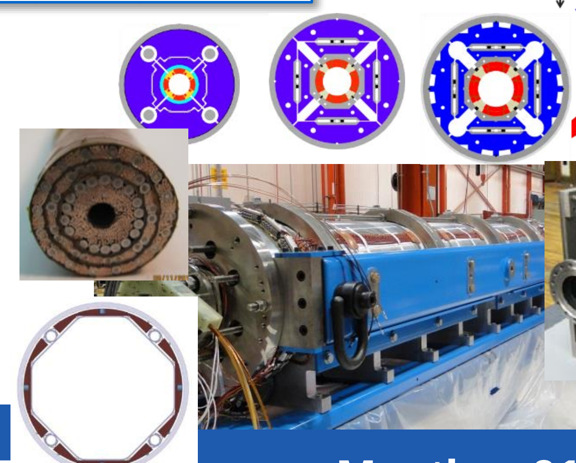
Accelerator technology

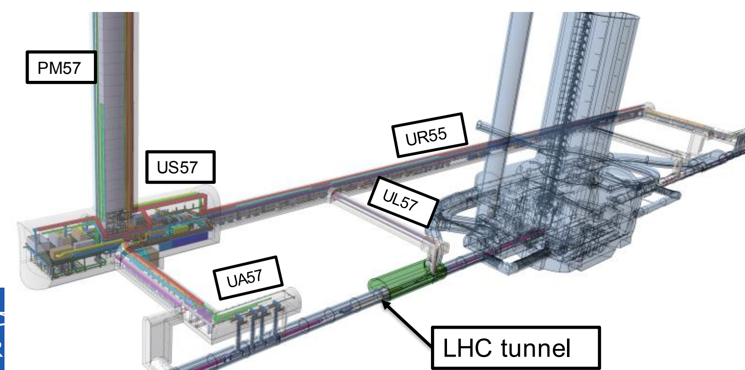
More powerful cryogenics
Improved collimation
Improved machine protection
Stronger R to E → relocation

New low-beta quadrupoles

"Crab" cavities





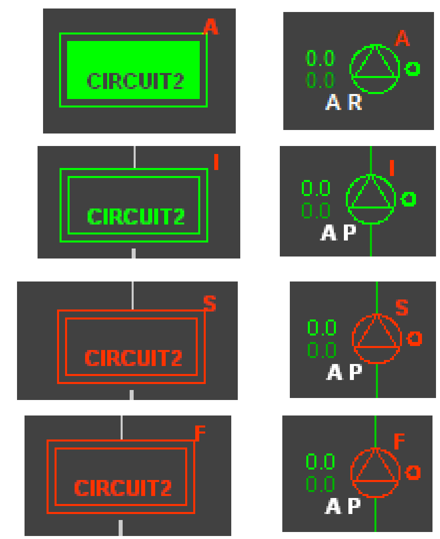


Alarms and Interlocks

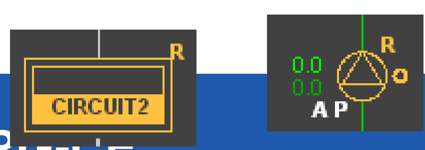
- **Alarm:** Visual information indicating a potential problem (**A**)
  - No interlock on the process

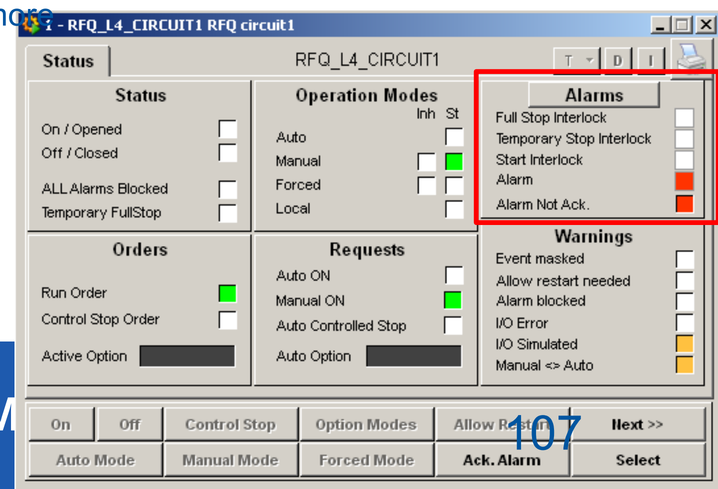
- **Interlock:** Action on the process (in any operation mode)
  - Interlock on PCO: Run Order is reset
  - Interlock on actuator: Go to fail-safe position
  - **Start Interlock (I):**
    - Avoid the starting (stay « Off »)
  - **Temporary Stop Interlock (S):**
    - Go to fail-safe position while the condition is filled
    - Restart automatically if the condition is not filled anymore
    - Acknowledgement (**Ack. Alarm**) stops the blinking
  - **Full Stop Interlock (F)** :
    - Go to fail-safe position while the condition is filled
    - Acknowledgement (**Ack. Alarm**) stops the blinking
    - « **Allow Restart** » allows the restart if the condition is not filled anymore

Active Condition:
Letter **A**, **I**, **S** or **F**



« Allow restart » needed to restart:
Orange letter **R**





Interlock Diagnostic

- From synoptic:
  - Double click on actuator or unit.
    - button « *Alarms* » from the faceplate display all possible FS, TS, SI, AL on this unit or actuator
  - Other solution: right click on the widget and click on « Alarms »