CERN, 20 June 2023

Marco Pezzetti on behalf of the IC section

https://indico.cern.ch/event/1272575/

Cryogenic Instrumentation Scheme, System Tests and Commissioning

CERN
TE department
CRG group
TE-CRG-Instrumentation and Control Section
Juan Casas-Cubillos, Czeslaw Fluder, Bert Ivens, Marco Pezzetti , Antonio Tovar, Nikolaos Trikoupis, Douglas Valencon, Nicolas Vauthier
20 June 2023

Outline

- Introduction & strategy applied
- Cryogenic instrumentation scheme
- ROADMAP for Instrumentation & radtol Electronic
- Data base & control system (String & P1-P5)
- Radiation test & cold pressure sensor
- Electrical crosstalk studies (cold powering)
- Commissioning
- Conclusion

As an introduction…

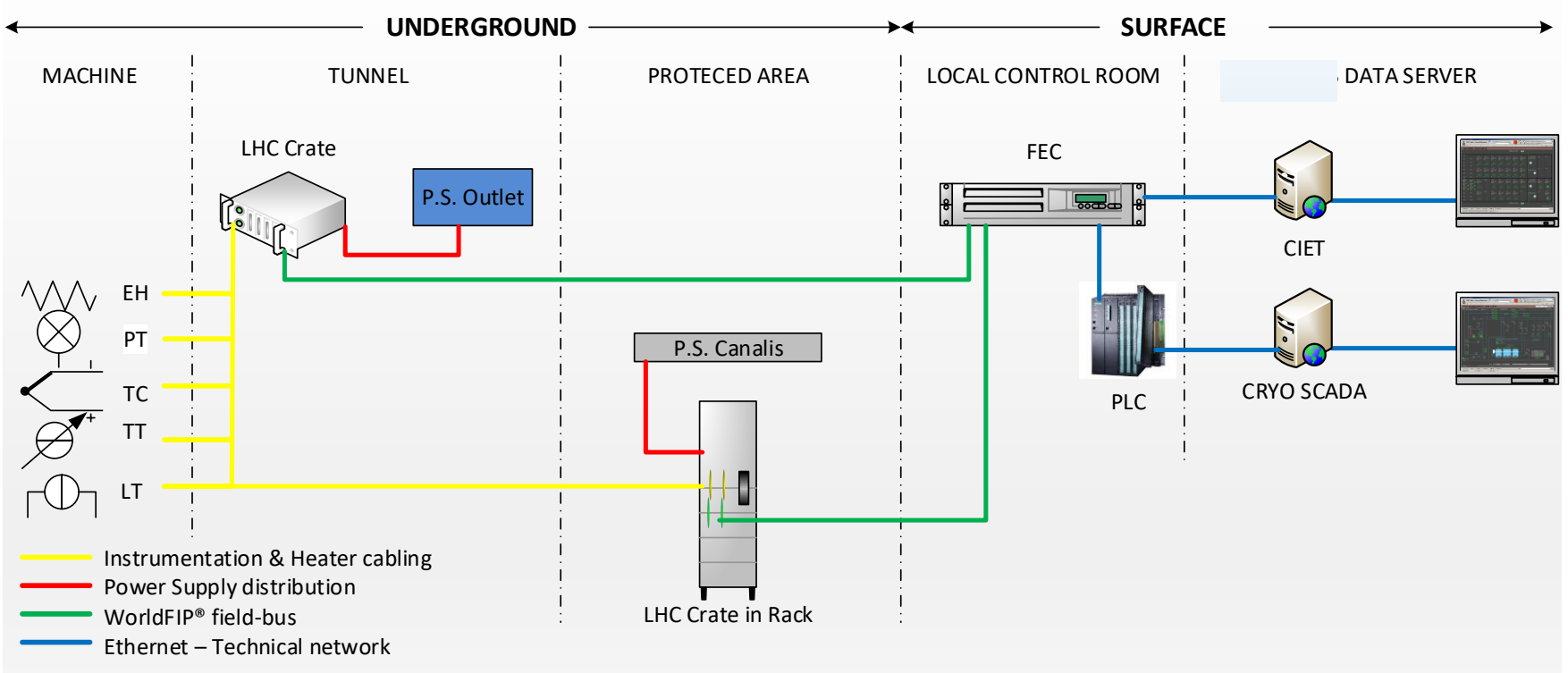
Magnet

QRL

DFB

RF Cavity

LHC Cryogenic Instrumentation Architecture

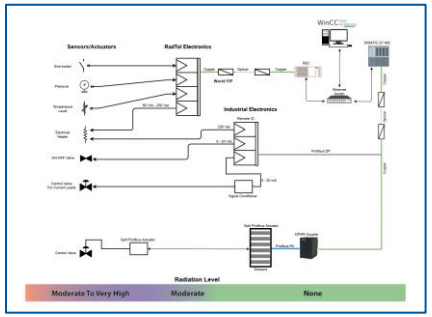


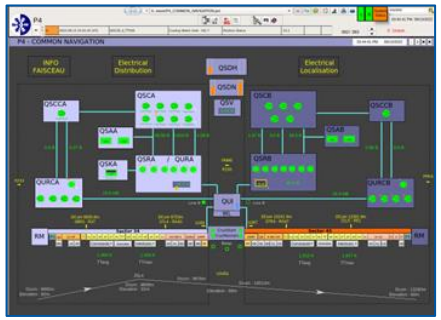
2021-Sept / new CRG-IC section with corresponding mandate:

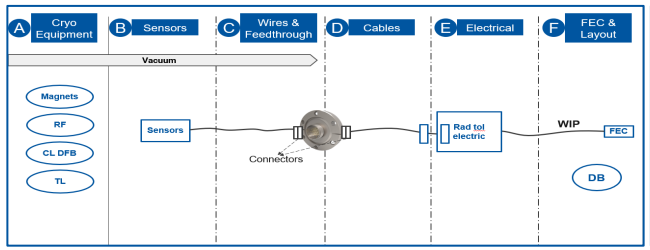
Consulting, Delivery & Installation Support over CERN Cryogenic Instrumentation with associated Sensors, Cabling, Electronics, Control, Calibration & Metrology.

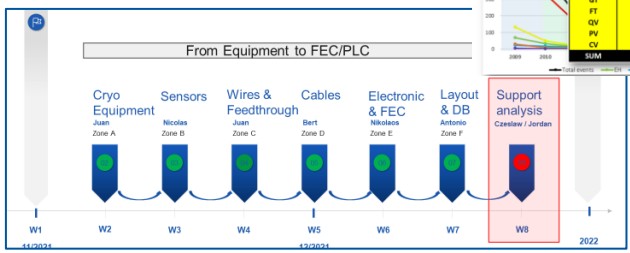
Cryogenic instrumentation strategy…

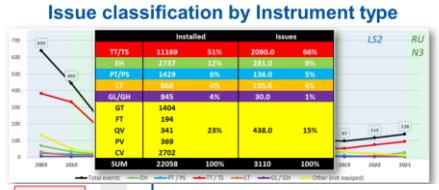
Based on LHC Architecture, Operation & Support History over the 10 past years ⇨REX campaign











⇨ **Review/Define/Share "State of the Art" of Cryo Instrumentation**

⇨ **Ensure/Optimize LHC Spare Procurement**

for HL-LHC:

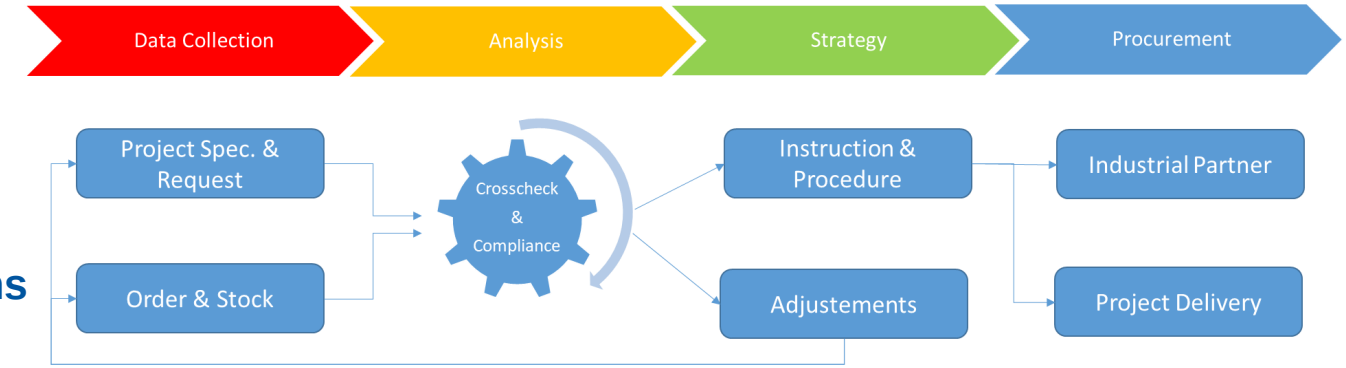
⇨ **Cabling Minimization Strategy (DIC-DIR)**

⇨ **Standardization Guidelines & Best Practices**

⇨ **Collect WP's Leaders Instrumentation Spec/Request**

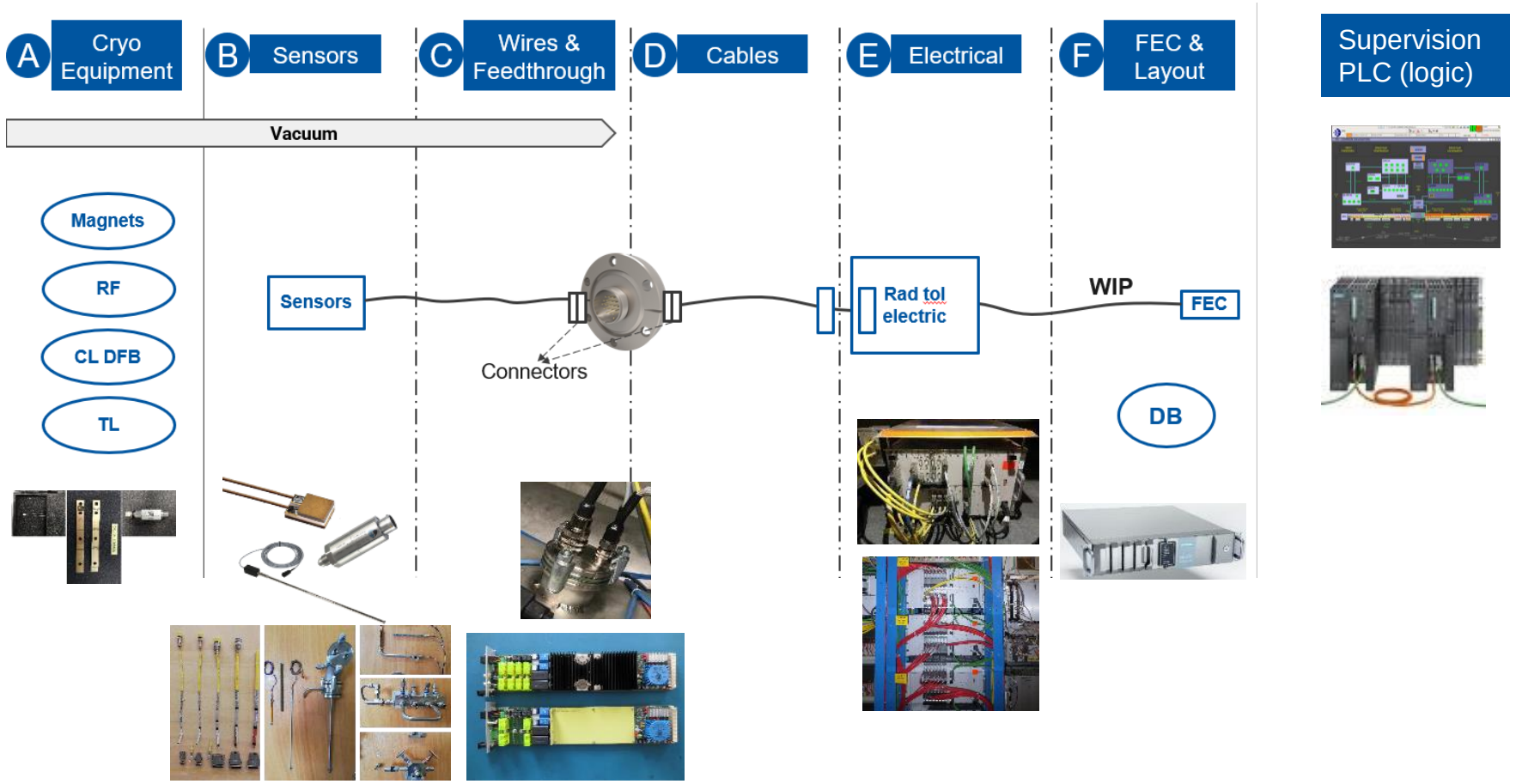
⇨ **Propose Standard/Turnkey Solutions to all Proj.Eng.**

⇨ **Define QA Procedures & Training Qualification Sessions**



- Introduction & strategy applied
- Cryogenic instrumentation scheme
- ROADMAP for Instrumentation & radtol Electronic
- Data base & control system (String & P1-P5)
- Radiation test & cold pressure sensor
- Electrical crosstalk studies (cold powering)
- Commissioning
- Conclusion

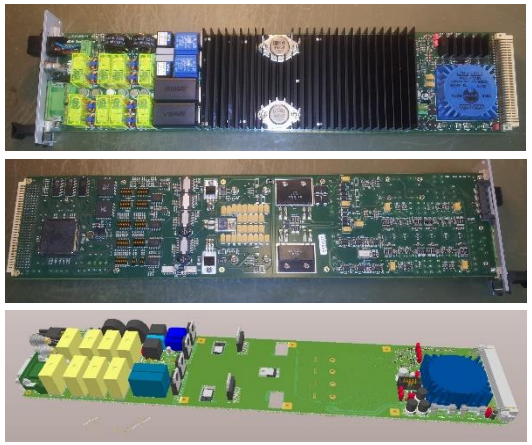
Cryogenic instrumentation scheme



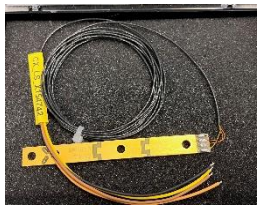
CRG-IC section mandate is to deliver and consult the CERN over cryogenic instrumentation with associated electronics, calibration, metrology, support.

New !! Instrumentation & Electronic laboratories

CERNOX instrument laboratory



Dedicated storage area with INFOR EAM database.



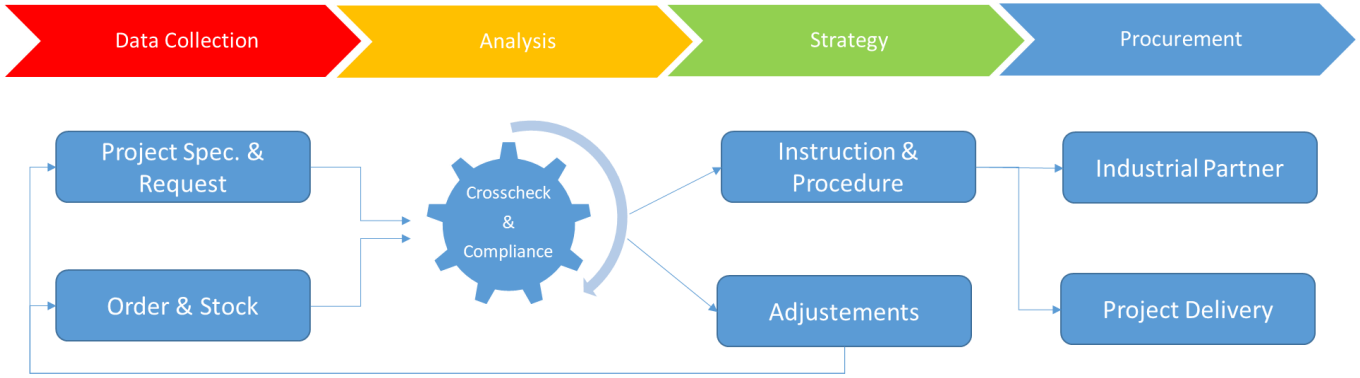
Long block

Short block

CERNOX sensors
assembled and wired on blocks

- Introduction & strategy applied
- Cryogenic instrumentation scheme
- ROADMAP for Instrumentation & radtol Electronic
- Data base & control system (String & P1-P5)
- Radiation test & cold pressure sensor
- Electrical crosstalk studies (cold powering)
- Commissioning
- Conclusion

ROADMAP of the Instrumentation cryogenic for HL-LHC CERN project.



REQUIREMENT	***Iterative process (long!) to require and select the proper instrument***
IDENTIFICATION	
VALIDATION	***Strict criteria, i.e. Leak test, thermal cycle, radiation test and demonstrator***
PROCUREMENT	***IPT criterias***
INSTALLATION	***w.r.t Spec, Tools & Databases technical training for personal qualification. Cable & connectors recommendation***
COMMISSIONING	***w.r.t Spec, Tools technical training for OPERATION***

HL-LHC project cryogenic Instrumentation ROADMAP

HL-LHC WPx
Requirement
{PT- TT –LT – FT- EH}

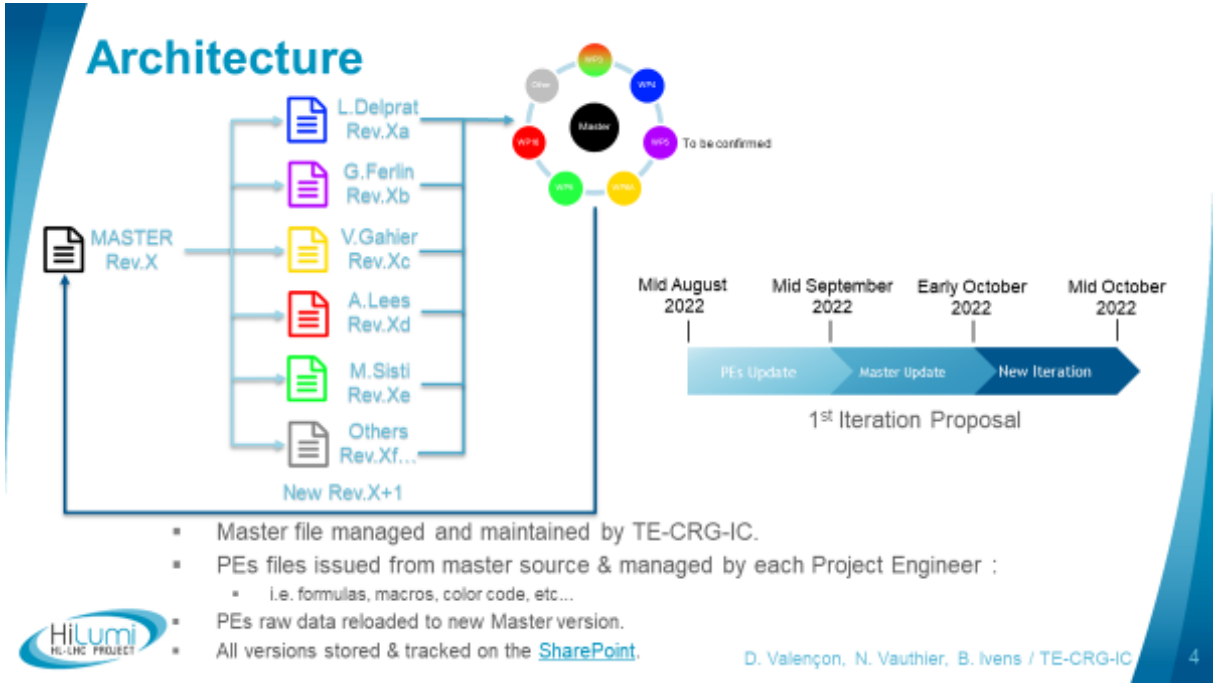
The workflow start with WPx design engineer provides a set of requirements:

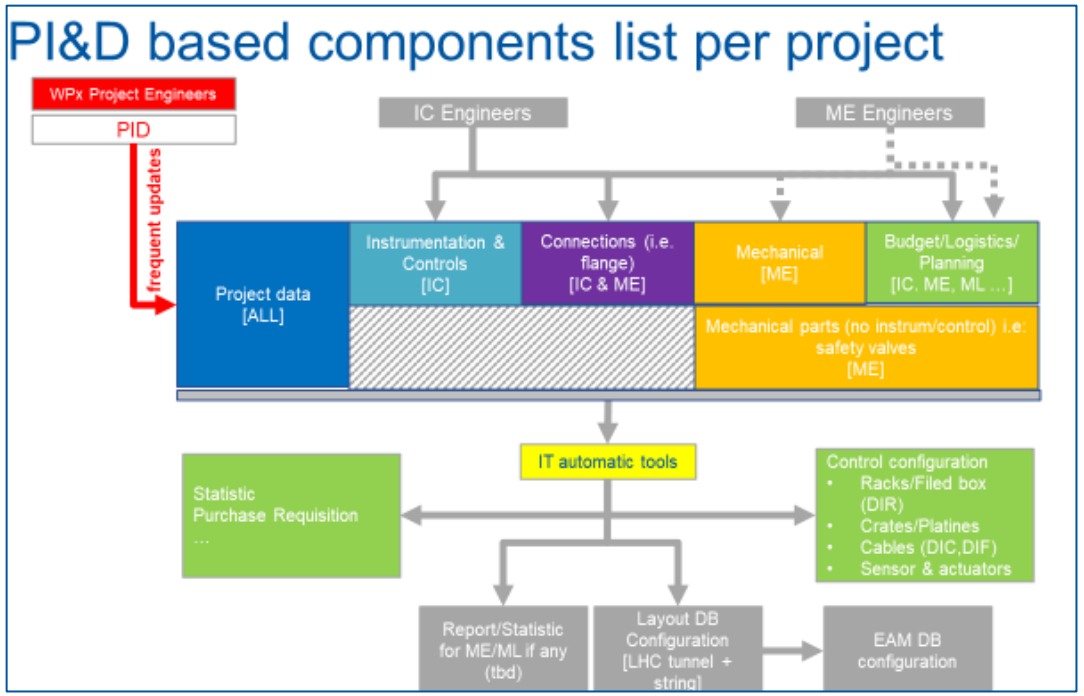
- Quantity including criticality (redundancy)
- Measurement uncertainty
- Environmental conditions

Iterative process (long!) to require and select the proper instrument.

Data Collection

Single and robust **Master template** to collect specification and requirement: TE-CRG SharePoint! DB compatible



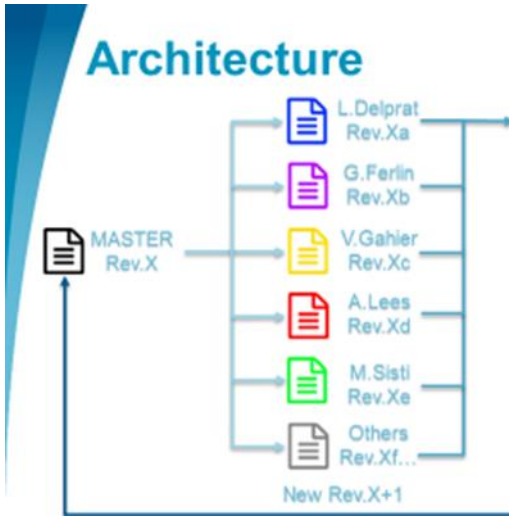


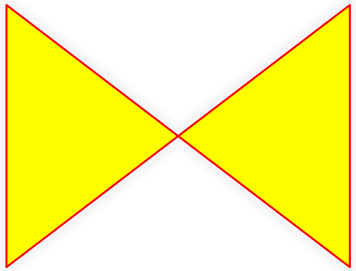
HL-LHC Project Cryogenic Instrumentation ROADMAP

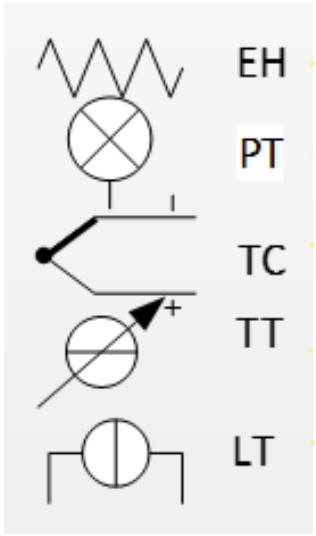
Analysis

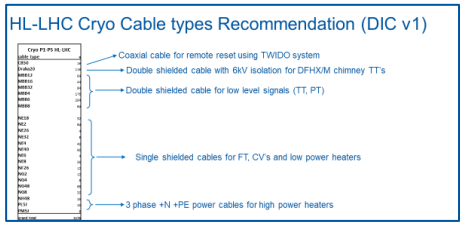
"HL-LHC specification"

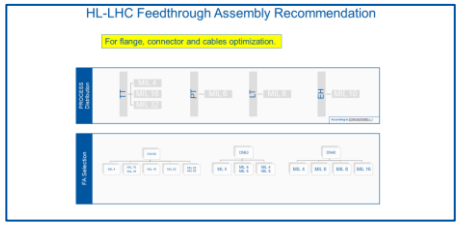
"TE-CRG-IC Instrumentation Standard" EDMS/2899109

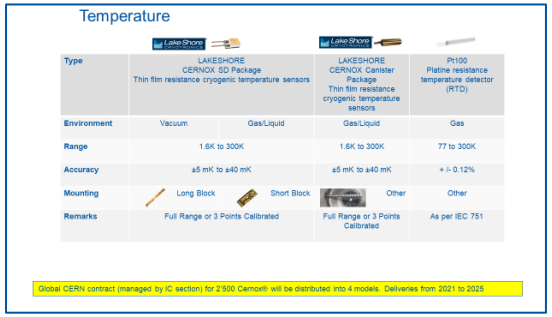


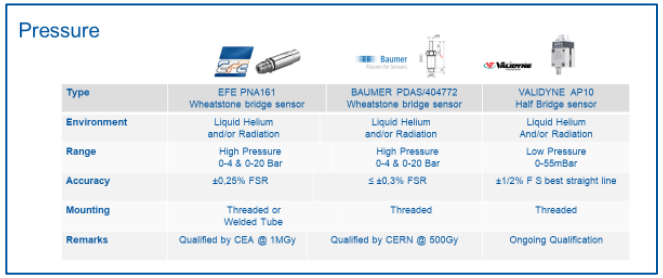


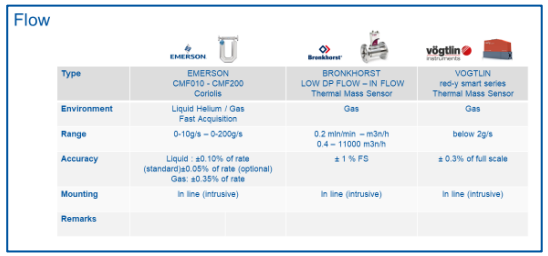


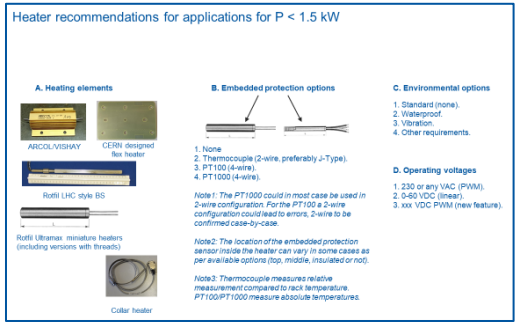












A cryogenic instrument selected must comply a strict criteria protocol such as : Leak Test, Thermal Cycle, Radiation Campaign and Demonstrator.

Strategy for radiation tests on electronics, instruments or material

Radiation affects in a non predictable way the characteristics of sensor. Radiation qualification trough tests were carried to understand effects from heavier and more energetic particles.

Need for radiation test

Path #1

Contact person: Salvatore DANZECA (BE-CEM-EPR)

Option #1: Irradiation at CERN (mix-field)
Performed by CRG or BE-CEM
Website: https://charm.web.cern.ch/
Request link: https://charm.web.cern.ch/content/radiation-test-request-internal-users

Option #2: Irradiation at CERN (Gamma rays)
CERN B772.

Option #3: Irradiation outside CERN (neutrons/protons/gamma)
e.g. PSI or others)
Performed by CRG or BE-CEM

Path #2

Contact person: Federico RAVOTTI (EP-DT-DD)
Website: https://ps-irrad.web.cern.ch/ps-irrad/
Performed by CRG

Path #3

Contact person: Matteo Ferrari (SY-STI-TCD)
Performed by external collaborators
Website: https://ps-irrad.web.cern.ch/ps-irrad/

Path #1: Radiation environment mixed-field (CHARM), protons (PSI), Gamma (B772), …
Electronics/Instruments/Material
Test can be passive (no power) or active (on-power) and can be controlled online.
Doses that can be reached: Typically, 100s of Gy to kGy in few weeks.
Max dose in the range of 100-200 kGy close to target and very long periods.

Path #2: Radiation environment: protons.
Instruments/Material
Very small samples (beam size), high doses can be achieved MGys.
System can be active (on power) and monitored online.

Path #3: Radiation environment (Gamma rays)
Electronics/Instruments/Material
Voluminous objects is possible.

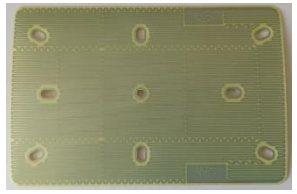
The strategy and type of radiation environment needed depends on the application and needs to be discussed with the TE-CRG responsible (Nikolaos TRIKOUPIS).
Some further info: R2E Annual Meeting 2022: https://indico.cern.ch/event/1116677/

Radiation campaigns

Radiation affects in a non predictable way the characteristics of any sensor. Specific radiation tests were carried to understand effects from heavier and more energetic particles.

Irradiation tests performed at external facility (Expected 1.5 MGy, tested OK up to 5 MGy)

Industrial electrical heater



CERN designed flex heater

Connector bodies

Electrical heaters tested with LN_2 before & after irradiation (>30 thermal cycles, 2 days testing)

Radiation Test: Low 0-60 mbar pressure sensors

Sensors under the test

ABB

Range: 60 mbar
Type: piezoresistive
Passive
Industrial without electronics

ABB in radiation environment:
Tested at CERN in 2018 with conclusion: can be used in high LHC radiation but with limited accuracy
0.6 mbar offset at 10 kGy

Validyne

Range: 55 mbar
Type: inductive
Passive industrial

Validyne in radiation environment:
A US national laboratory used the DP10 pressure sensor to measure pressure build up in vessels containing disposed radioactive materials. The pressure sensor was exposed to radiation over such a long term that it was not designed for recovery or contact by humans.

Test setup

One ABB and two Validyne are measuring pressure in closed and thermally isolated volume. Pressure is controlled by heaters according to ideal gas equation. At 20.40 °C mbar, at 64°C 48 mbar. Temperature is measured inside the volume with Pt1000. Automatic setup reads data once per minute.

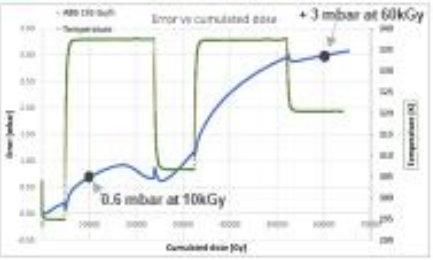
Test at ^{60}Co started on 25th May with goal 100 kGy

Sensors in polystyrene box are placed before cobalt source:
ABB: 192 Gy/h
Validyne1: 145 Gy/h
Validyne2: 231 Gy/h

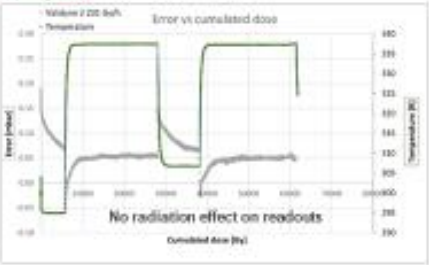
Measuring devices are placed in zone without radiation

Primary results

ABB



Validyne2



PT “cold applications” 0-20 bar installed!

Not intended to be in HL-LHC P1/P5, ONLY FOR PRESSURE WAVE STUDIES

EFE model: PNA161

Radiation hard certified to 1MGy

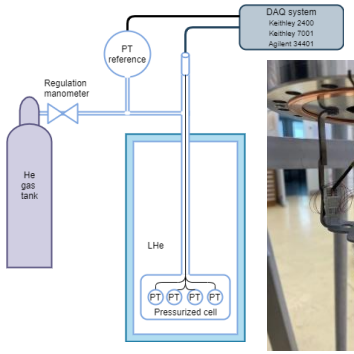
- EFE sensing technology
  - Thin film
    - No oil no o-rings
  - Diaphragm welded on to the pressure port
  - All stainless steel design
- Tested ranges 4 and 20 bar
- Accuracy
  - Linearity and hysteresis : ±0.25% FS
  - Repeatability ±0.02% FS
- Radiation test certificate
- Sensitivity 2 to 5 mV/V
- ~~Operating temperature: -40 to + 125 °C~~
- ~~Compensated temperature range: 0 to + 60 °C~~

Tested at CryoLab in LHe (4K) ✓

Tested with TT/PT IC electronic card ✓

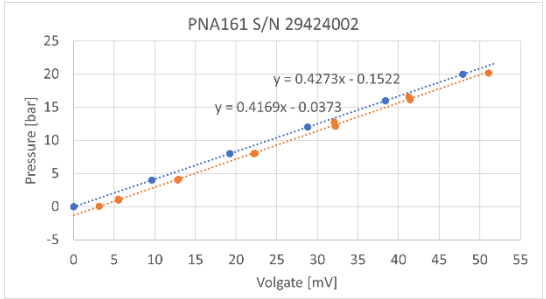
Tests in LHe

PT under the test are pressurized with He from the gas bottle and cooled down to temperature of 4K using a LHe.



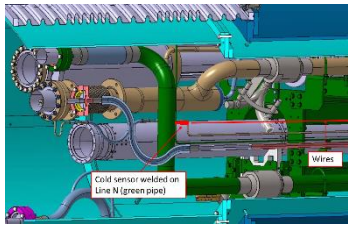
Results example

Input impedance change (warm → cold) up to 8 %
Calibration curve linear (offset 0 to 300 mbar) → as a result sensors must be calibrated at cold individually before installation

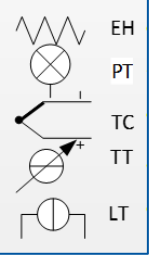


Installation

CFBF1 @SM18
Shuffling Module on N Line
New cable by CRG-IC
05-2023

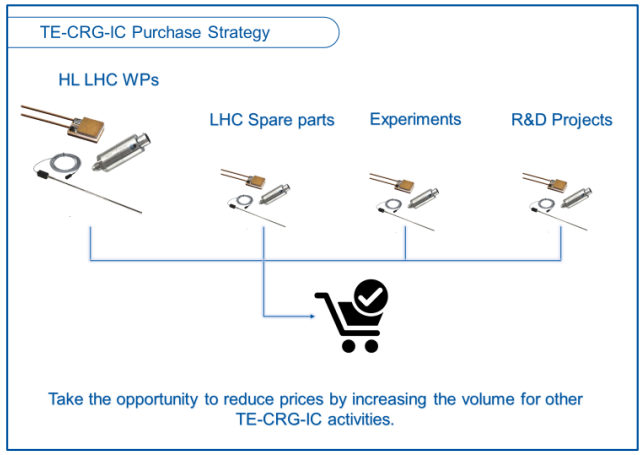


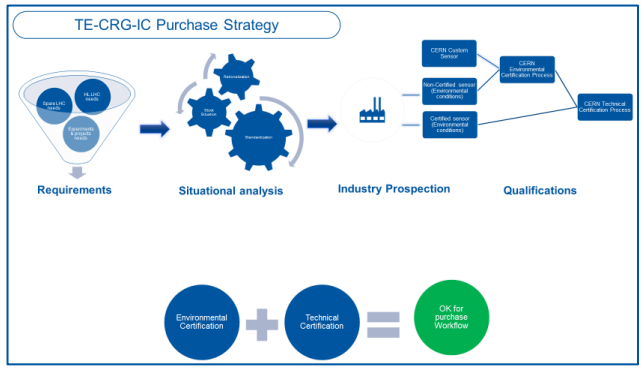
CFBF1 @SM18
Shuffling Module
Mounted on filter on M Line
Existing spare wires of Vtape used
06-2023



HL-LHC project cryogenic Instrumentation ROADMAP

Procurement





TT - Cernox

Type	Qty CC	Cold Powering	HEL	IT	MS	QXL	SUM
Cold finger						52	52
Canister	162		2				164
Long block	66	152	15	92	4	180	509
Short block		148	9	82	8		247
t.b.d	40						40
SUM							1012

TT - Pt100

Type	Qty CC	Cold Powering	HEL	IT	MS	QXL	SUM
Standard	22	396	210	16		144	788
Cold finger		8					8
Collar	3						3
Flex	11						11
t.b.d	310					116	426
SUM							1236

Level gauge

Type	Qty CC	Cold Powering	HEL	IT	MS	QXL	SUM
0-200mm		8					8
0-470mm		8				32	8
t.b.d	22		3		8	12	45
SUM							61

Heaters

Type	Qty CC	Cold Powering	HEL	IT	MS	QXL	SUM
100W	20	32		64	8		124
175W (3 cartridges)	40						40
200W	10						10
250W	300					48	348
500W						12	12
5000W						16	16
15000W		8					8
t.b.d	3		47				50
SUM							608

Absolute pressure sensors

Type	Qty CC	Cold Powering	HEL	IT	MS	QXL	SUM
0-60mBar	20	4					24
0-4 Bar		16		8		32	56
0-20 Bar						84	84
t.b.d	2		3			8	13
SUM							177

Differential pressure sensors

Type	Qty CC	Cold Powering	HEL	IT	MS	QXL	SUM
0-350mBar		8					8
SUM							8

Pressure switch

Type	Qty CC	Cold Powering	HEL	IT	MS	QXL	SUM
t.b.d.						24	8
SUM							8

Feedthroughs

Type	Qty CC	Cold Powering	HEL	IT	MS	QXL	SUM
DN100 1 MIL 16	8			12		8	28
DN100 2 MIL 32	12					8	20
DN100 1 MIL 32 and 1 MIL 4	4						4
DN100 1 MIL 32	8			8		24	40
DN100 1 MIL 4				8		4	12
DN100 1 MIL 3						4	4
DN100 1 MIL 10	8					16	24
DN63 2 MIL 6	8						8
DN63 1 MIL 8		4					4
DN63 1 MIL4 and 1 MIL 8	16						16
DN40 1 MIL 16		4				8	12
DN40 1 MIL 8						12	12
DN40 1 MIL 4						28	28
DN40 1 MIL 6						28	28
TBD		24	16		8	20	68
SUM							308

Connectors MIL-C 26482

Type	Qty CC	Cold Powering	HEL	IT	MS	QXL	SUM
MIL 4	20			8		32	60
MIL 6	16					28	44
MIL 8	16	4				12	32
MIL 10	8					20	28
MIL 16	8	4		12		16	40
MIL 32	36			8		40	84
TBD		24	16		8	20	68
SUM							356

INSTALLATION methodology

CERN : IC Example (proto) plus Technical Protocol TRAINING with documentation and validation.

Industry : Technical Protocol TRAINING with documentation and validation.

HL-LHC radtol electronic “ROADMAP”

Preliminary design Prototyping Needs	Main parts procurement	Design	Prototyping	Radiation tests	Production	Acceptance tests
Needs were estimated as: • 700 -> 850 x TT/PT • 130 -> 150? x EH • 100 x LT • 50 -> 100 x FIP, • 40 -> 60 x Power • 50 -> 100?? x Lateral • 50 x DI/DO • New low-pressure card?	• Long delay parts • Orders of 145 kCHF already placed. • Parts stock in INFOR & B276. • Automated BOM-INFOR.	• TE/CRG	• Managed by BE/CEM.	• Outsourced to BE/CEM @CHARM/PSI (batch validations) • Or by CRG @ CHARM (prototypes)	• Managed by BE/CEM or TE/CRG.	• Electrical tests and testbenches.

	In stock today	Quantity	2021		2022				2023				2024				2025				LS3		
Crate Projects			Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	2026	2027	2028
Crate	0	100		Design	Prototype	Production		Installation													Installation		
Crate transformers	~20	80			Design	Prototype	Production	Installation					Production								Installation		
Crate backpanel	~15	90			Parts procurement			Production					Production					Rad test			Installation		
Lateral cards	0	???				Parts procurement			Design	Prototype	Production		Production								Installation		
TT/PT cards insulated	0	~375	Parts procurement						Design	Prototype	Production	Rad test	Production					Rad test			Installation		
TT/PT cards	0	~375	Parts procurement						Design	Prototype	Production	Rad test	Production					Rad test			Installation		
Low Pressure card	0	???				Parts procurement			Design	Prototype	Production		Production					Rad test			Installation		
LT cards	40	~50+50				Parts procurement				Production			Production					Rad test			Installation		
EH cards	~40	~100	Parts procurement	Design				Prototype				Rad test	Production					Rad test			Installation		
NanoFIP	0	150								Design	Parts procurement	Prototype	Rad test		Production			Rad test			Installation		
DI/DO card	0	???						Design	Parts procurement	Prototype		Rad test	Production					Rad test			Installation		
AI/AO card	0	???						Design	Parts procurement	Prototype		Rad test	Production					Rad test			Installation		
Power cards	44	???				Parts procurement							Production								Installation		

- Introduction & strategy applied
- Cryogenic instrumentation scheme
- ROADMAP for Instrumentation & radtol Electronic
- Data base & control system (String & P1-P5)
- Radiation test & cold pressure sensor
- Electrical crosstalk studies (cold powering)
- Commissioning
- Conclusion

Data integration into the CERN layout database

DB fundamental for Commissioning, support operation and future algorithm ML !

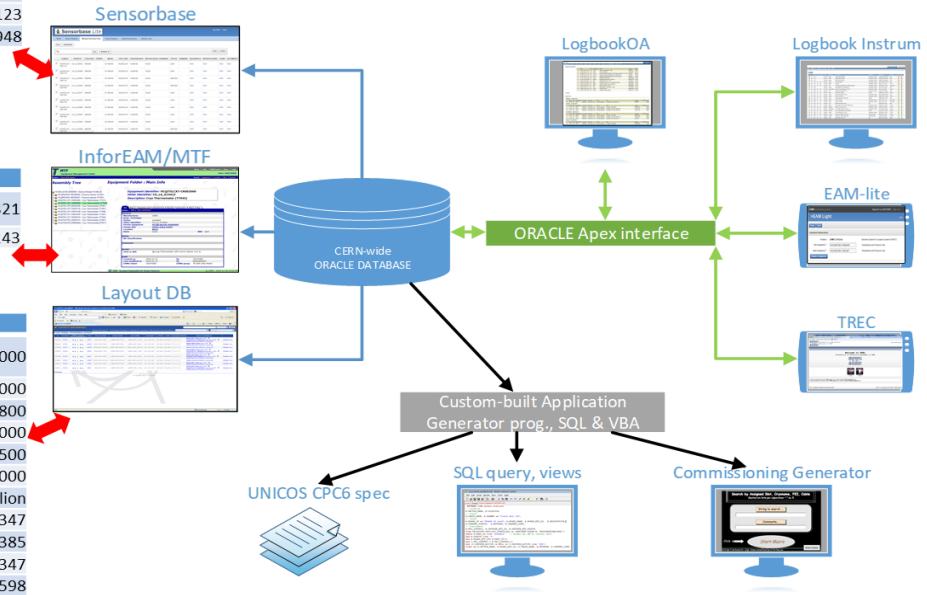
Single, Consistent & Reliable source of information to ensure:

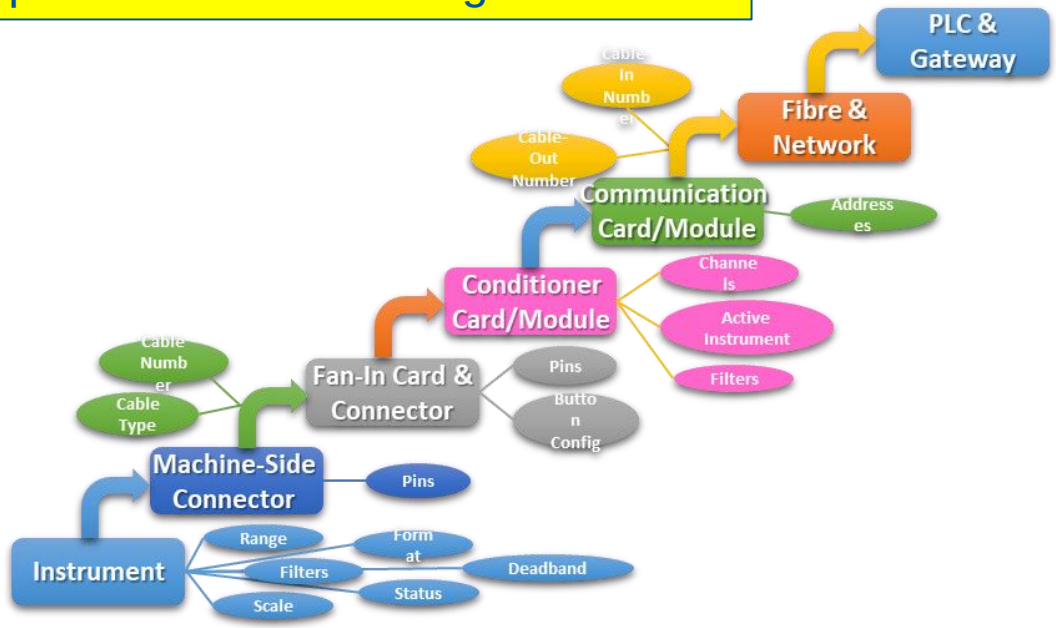
- Identification & HL-LHC standard Naming convention
- Functional positions and hierarchies for all registered equipment
- Connexion & properties of instrumentation channels
- Traceability & Links between other data repositories

TYPE	QTY
Instruments	17'993
Models	126
Measurements points	709'427
Fits	17'123
Interpolation	10'948
…	

TYPE	QTY
Cryo Equipment	128'321
Cryo Equipment Models	243
…	

TYPE	QTY
Equipped Instrumentation Channels	32'000
Spare Channels	6'000
Virtual Channels	2'800
Systems	28'000
Cables	9'500
Pairs of pins	92'000
Properties	1.25 million
Racks	347
Crates, Platine, Fieldboxes	1'385
Electronic modules	13'347
Assets	29'598
…	

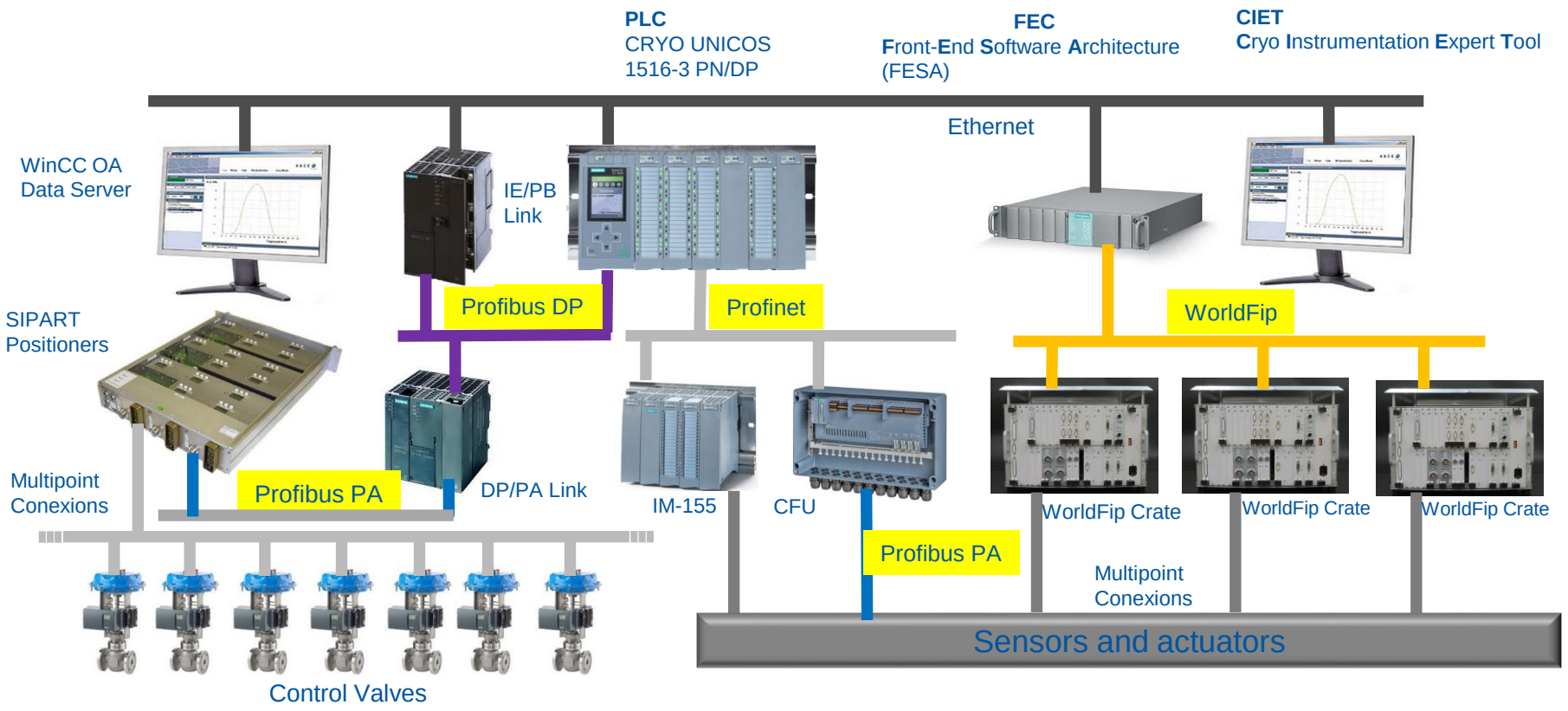




Tools to ensure:

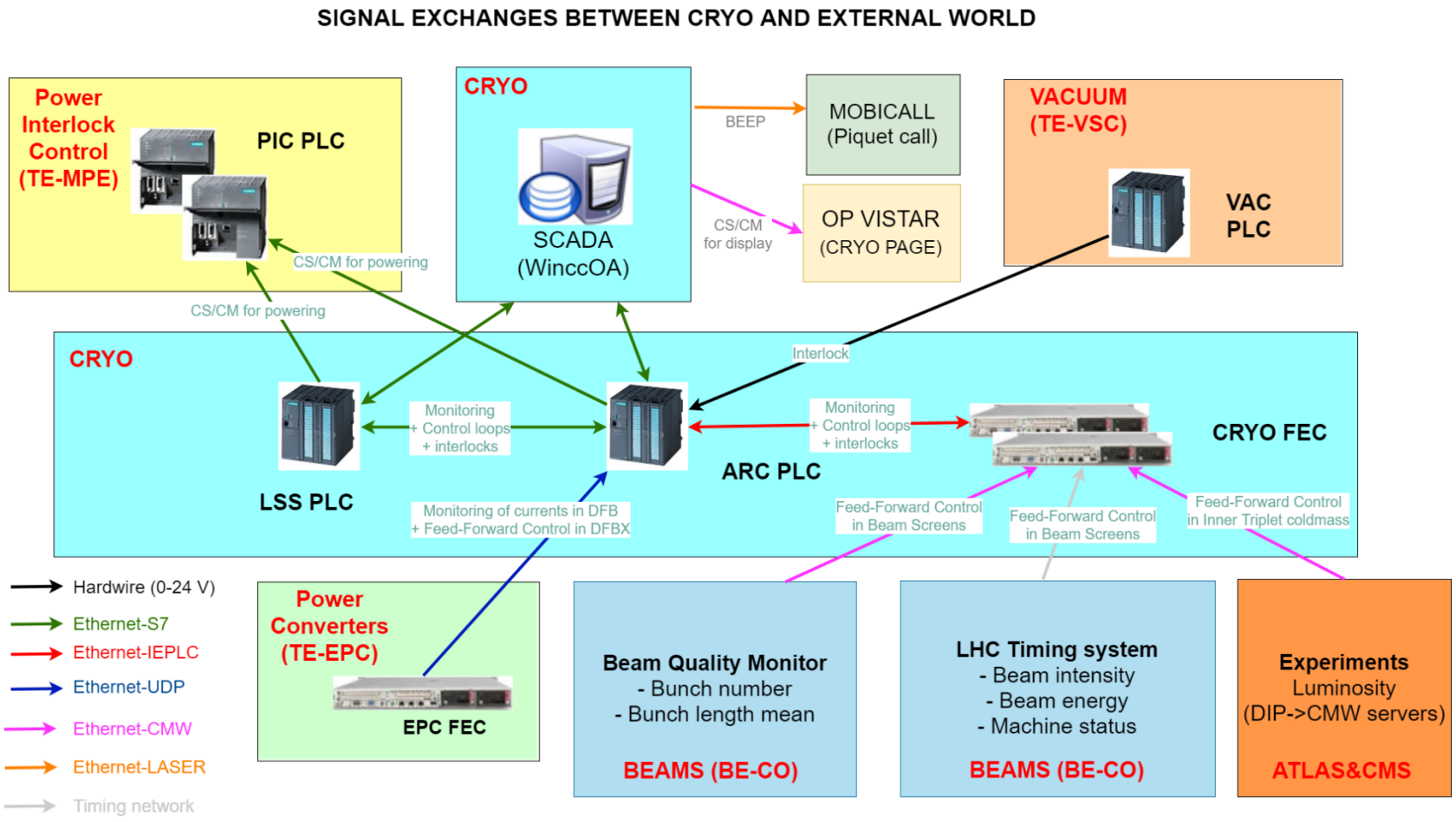
- Installation, Cabling and Commissioning of channel
- Design & Configuration of Cryo Control System
- Custom-built applications for maintenance/diagnostic

SM18 SQXL cryogenic Control Architecture



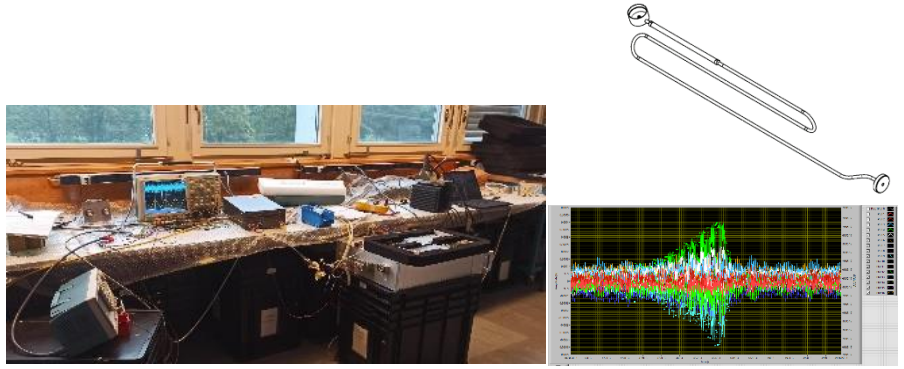
LHC & HL-LHC cryo communication

Interlocking methods and communication with other systems

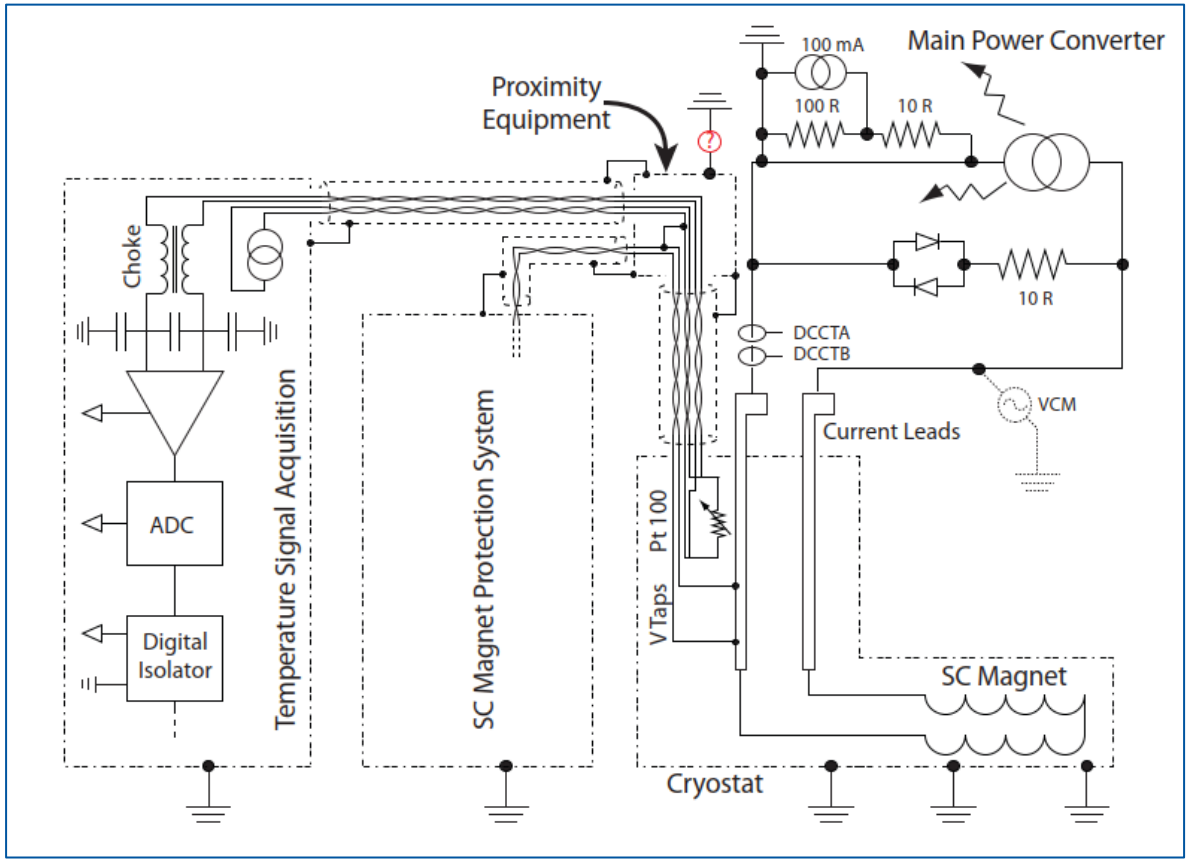


- Introduction & strategy applied
- Cryogenic instrumentation scheme
- ROADMAP for Instrumentation & radtol Electronic
- Data base & control system (String & P1-P5)
- Radiation test & cold pressure sensor
- Electrical crosstalk studies (cold powering)
- Commissioning
- Conclusion

Crosstalk studies



Cross-talk measurements inside IFS tubes (3403 mm). Impact of EH PWM mode on Voltage-taps



Interference/susceptibility of TE-CRG HV TT cards

Working within EMC forum.

Need for EMI tests in the LHC communicated in the 1st EMC forum (Chair Daniel Valuch).

Report from M. Bastos EDMS 2738038 -> (CRG LINK here https://edms.cern.ch/document/2862719).

EMI generation of TE-CRG EH cards to QPS

Crosstalk studies performed in LAB36 and SM18

Report of TE-MPE at https://wikis.cern.ch/display/MPEEP/Cryo+heater+measurements

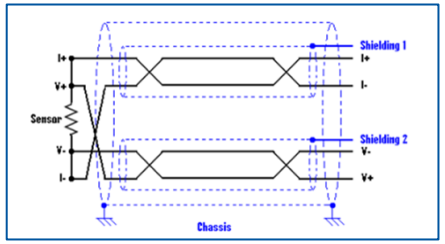
Pending report of TE-CRG for LAB36/SM18.

Preliminary recommendation for HL-LHC: Use 100 VAC/50Hz stepdown transformer .

- Introduction & strategy applied
- Cryogenic instrumentation scheme
- ROADMAP for Instrumentation & radtol Electronic
- Data base & control system (String & P1-P5)
- Radiation test & cold pressure sensor
- Electrical crosstalk studies (cold powering)
- Commissioning
- Conclusion

Commissioning phases “step by step”

The commission procedure/methodology is a 20 years validated protocol tested in LHC
And also, in other various project such as :HIE-ISOLDE, SM18, BA6-SPS….



Sensors	Qty	Type
Lhe Level Gauge	528	Superconducting Wire
Pressure Sensor	694	Strain Bridge
Pressure Sensor	8	Profibus PA
Thermometers	9564	in total
	3300	Pt 100
	5400	Cernox™
	336	Pt 100
	528	Pt 100 & Type-J thermocouple
GH/GL/PS Signals	1152	Mechanical Switch
Actuators	**Qty**	**Type**
Control Valves	1436	Profibus PA
Control Valves	1184	Analogue
ON-OFF Valves	374	Pneumatic
Quench Valves	342	Pneumatic
Electrical Heater	2462	Electrical resistor
Electronics	**Qty**	**Type**
Crate	853	Mechanical Assembly
Power Source Card	1184	COTS based Design
Temperature - Pressure Card	4502	
Sc Level Crad	413	
Digital In Card	317	
FIP comm. card	1266	

QUANTITATIVE AND QUALITATIF RESULTS

Instrumentation Availability

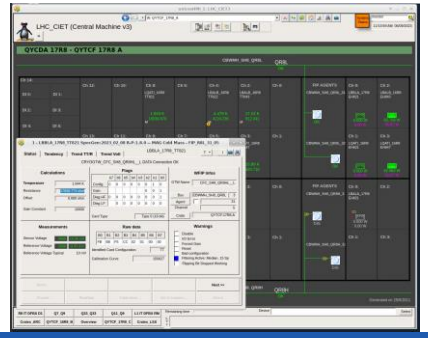
The first operation confirms that the instruments are installed and operational.

Then, the second operation in front of electronic crate includes 3 main set-ups:

- checking the consistency of the data with respect to the LHC layout database,
- simulation of the instrument using a programmable resistor to set a value and compare it with the reading output to validate the data acquisition system,
- final global testing including instruments, electronic card and communication to validate the complete instrumentation chain.

Cryogenic Instrumentation Performance

Field Validation Tools



	Installed	Operational		Degraded		Damaged	
Superconducting Magnets	204	193	94.6%	3	1.5%	8	3.9%
Cryogenic Distribution Line	254	253	99.6%	1	0.4%	0	0.0%
Line N and C' thermometers	108	108	100.0%	0	0.0%	0	0.0%
Electrical Distribution Feedboxes	59	59	100.0%	0	0.0%	0	0.0%
Inner Triplet Assemblies	37	37	100.0%	0	0.0%	0	0.0%
Total	**662**	**650**	**98.2%**	4	0.6%	**8**	1.2%

Conclusion

The LHC cryogenic system with his 16 years of operation have shown impressive results of availability (more than 99%), precision and robustness.

The LHC based HL-LHC cryogenics (CERN-UNICOS) process control associated with custom radtol electronic for his cryogenic instrumentation **solution** is a large complex inter-departmental project with a matrix responsibilities.

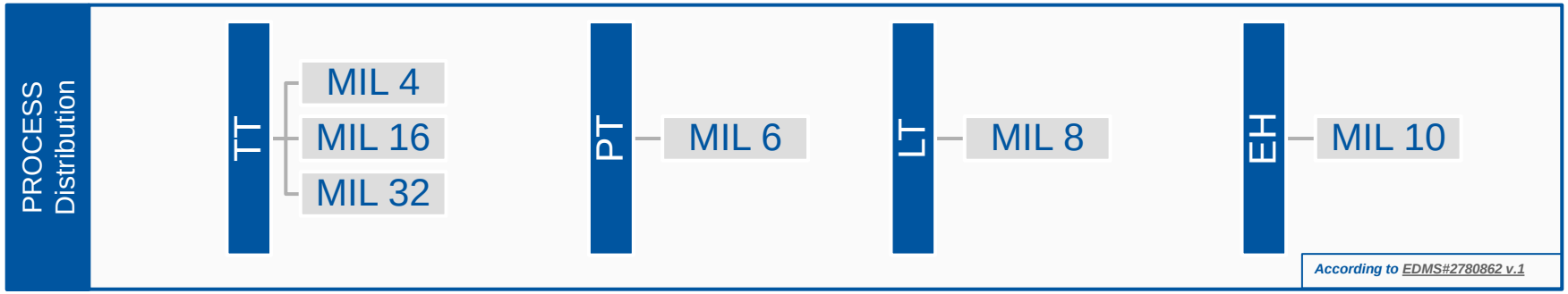
The HL-LHC cryogenic associated with custom radtol electronic for its cryogenic instrumentation being constructed is a mature “state of the art” technology.

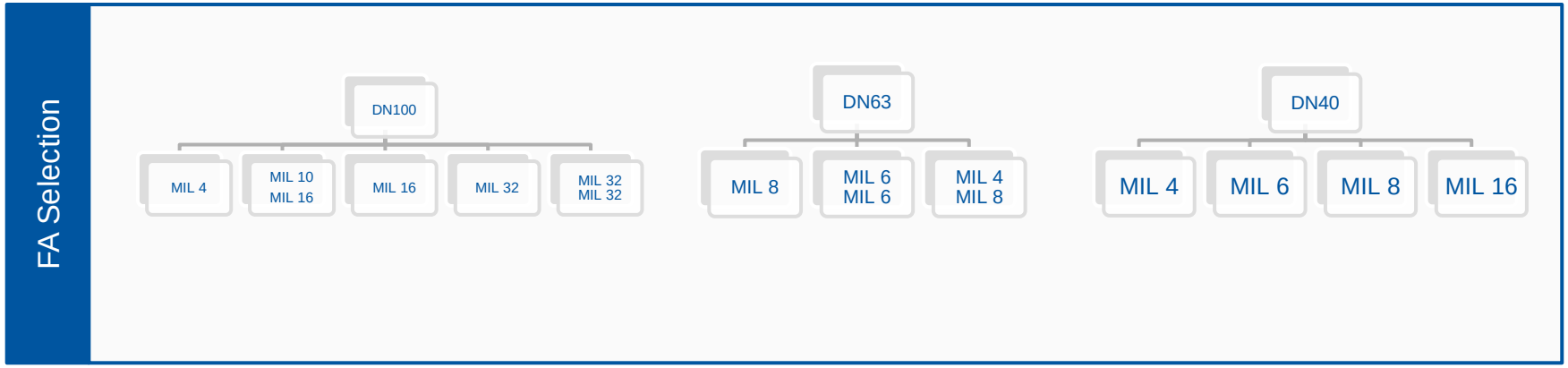
Moreover, a continuous and repetitive evolution w.r.t the LHC cryogenic system is ongoing.

Spare slides

HL-LHC Feedthrough Assembly Recommendation

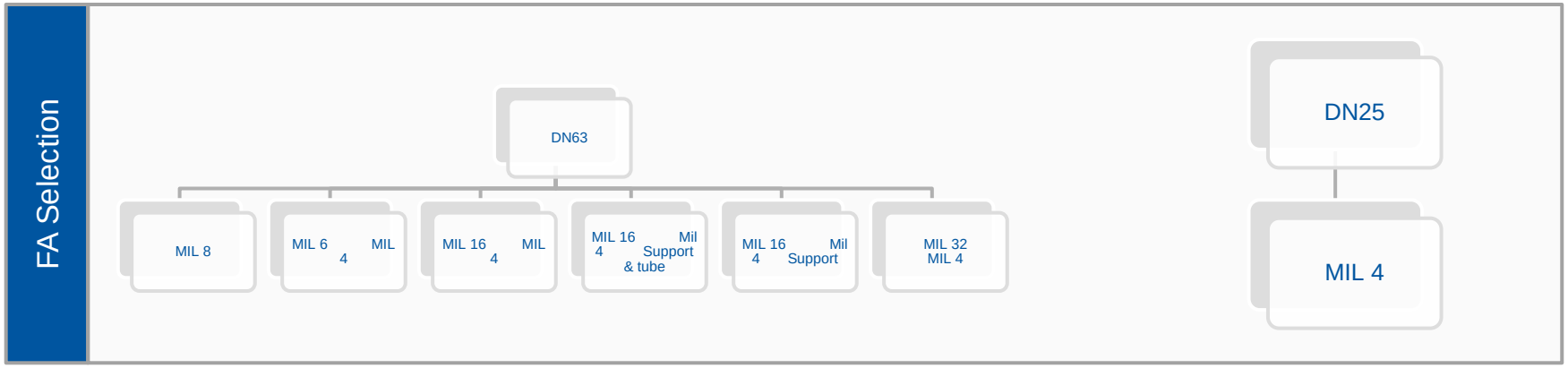
For flange, connector and cables optimization.





LHC Feedthrough Assembly Recommendation

For flange, connector and cables optimization done in LHC.



HL-LHC Cryo Cable types Recommendation (DIC v1)

Cryo P1-P5 HL-LHC	
cable type	#
CB50	16
Draka20	116
MBB12	64
MBB16	44
MBB32	84
MBB4	176
MBB6	204
MBB8	64
NE18	32
NE2	64
NE26	4
NE32	8
NE4	40
NE40	60
NE6	4
NE8	36
NF26	12
NG2	12
NG4	8
NG48	68
NG8	20
NH48	16
PL5J	16
PM5J	8
Grand Total	1176

Coaxial cable for remote reset using TWIDO system

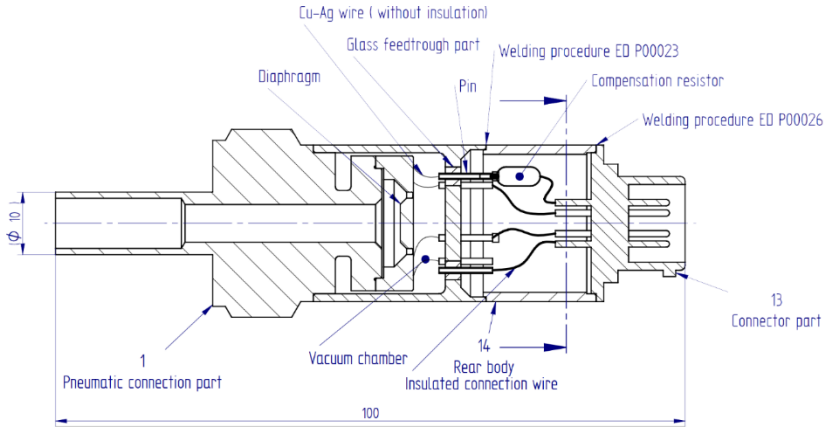
Double shielded cable with 6kV isolation for DFHX/M chimney TT's

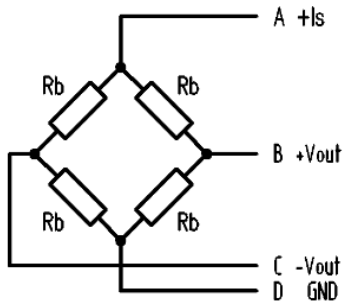
Double shielded cable for low level signals (TT, PT)

Single shielded cables for FT, CV's and low power heaters

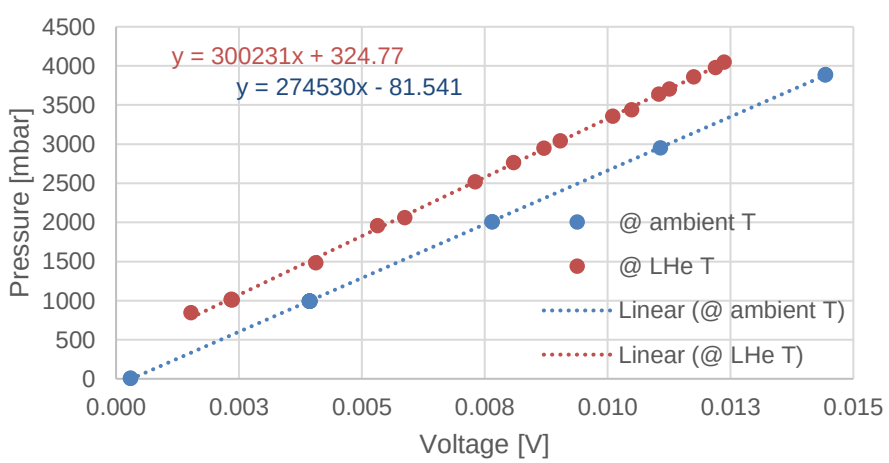
3 phase +N +PE power cables for high power heaters

PT “cold applications” 0-4 bar





TESTED FOR COLD APPLICATION

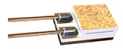
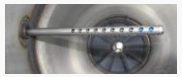


Tests were performed before summer holidays.

Drawing is for Baumer sensors;
EFE refused to send documentation with detailed design (Discussion still in progress), **but design is identical.**

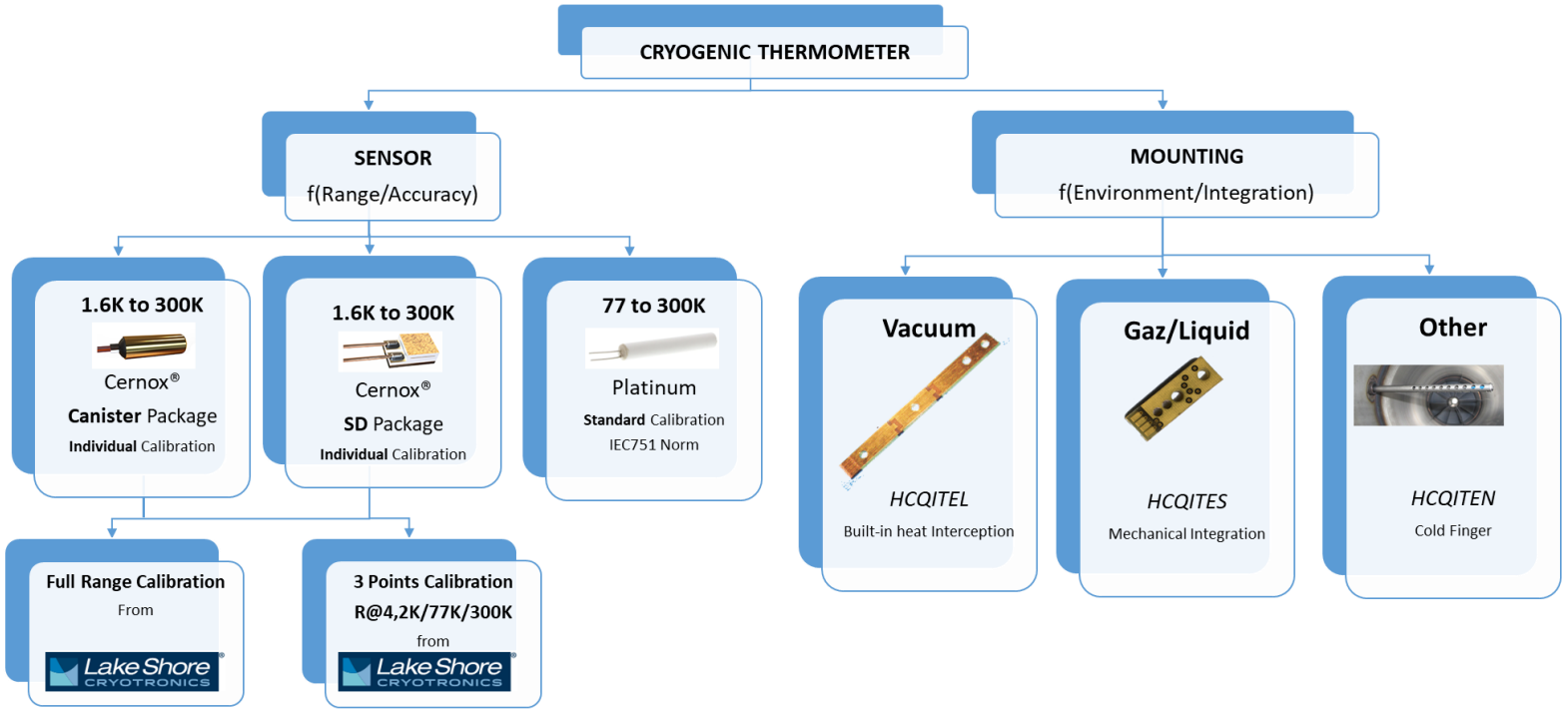
Calibration curves different for ambient and LHe temperatures, **but still linear.**

Temperature

	Lake Shore CRYOTRONICS 		Lake Shore CRYOTRONICS 	
Type	LAKESHORE CERNOX SD Package Thin film resistance cryogenic temperature sensors		LAKESHORE CERNOX Canister Package Thin film resistance cryogenic temperature sensors	Pt100 Platine resistance temperature detector (RTD)
Environment	Vacuum	Gas/Liquid	Gas/Liquid	Gas
Range	1.6K to 300K		1.6K to 300K	77 to 300K
Accuracy	±5 mK to ±40 mK		±5 mK to ±40 mK	+ /- 0.12%
Mounting	 Long Block	 Short Block	 Other	Other
Remarks	Full Range or 3 Points Calibrated		Full Range or 3 Points Calibrated	As per IEC 751

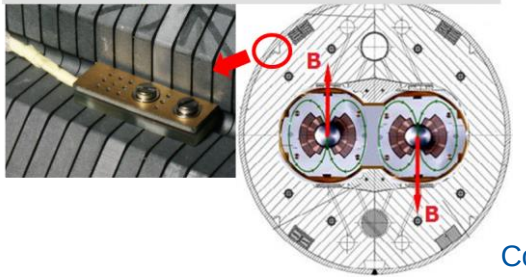
Global CERN contract (managed by IC section) for 2’500 Cernox® will be distributed into 4 models. Deliveries from 2021 to 2025

Temperature

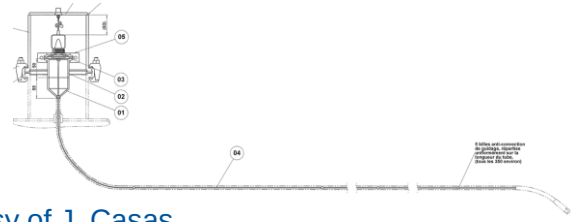


LHC pipeline (vacuum) thermometer

LHC cold mass thermometer.
Mechanical protection for cable and fast flow

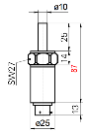


Insertion Thermometer
Example: LHC QURC, wire with alignment balls

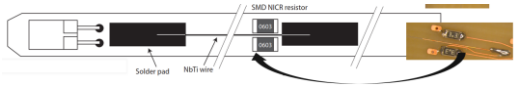


Courtesy of J. Casas

Pressure

			
Type	EFE PNA161 Wheatstone bridge sensor	BAUMER PDAS/404772 Wheatstone bridge sensor	VALIDYNE AP10 Half Bridge sensor
Environment	Liquid Helium and/or Radiation	Liquid Helium and/or Radiation	Liquid Helium And/or Radiation
Range	High Pressure 0-4 & 0-20 Bar	High Pressure 0-4 & 0-20 Bar	Low Pressure 0-55mBar
Accuracy	±0,25% FSR	≤ ±0,3% FSR	±1/2% F S best straight line
Mounting	Threaded or Welded Tube	Threaded	Threaded
Remarks	Qualified by CEA @ 1MGy	Qualified by CERN @ 500Gy	Ongoing Qualification

Level



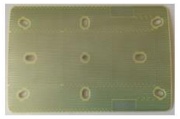
Type	CRYOGENIC LTD Fiberglass/Stainless steel Superconductive level gauge	AMERICAN MAGNETICS Fiberglass/Flexible Superconductive level gauge	CERN Design PCB Superconductive level gauge
Environment	Liquid Helium	Liquid Helium	Liquid Helium
Range	Up to 2m	1” to 36” inches standard up to 80” inches	Theorically not limited
Accuracy	Not specified	Not specified	TBD
Mounting	Tube	Tube	Tube
Remarks	Diam min: 2,1mm	Diam min: 4,7	Diam min: 4mm (TBC)

CRG-IC R&D program

Flow

	EMERSON 	Bronkhorst® 	vögtlin instruments 
Type	EMERSON CMF010 - CMF200 Coriolis	BRONKHORST LOW DP FLOW – IN FLOW Thermal Mass Sensor	VOGTLIN red-y smart series Thermal Mass Sensor
Environment	Liquid Helium / Gas Fast Acquisition	Gas	Gas
Range	0-10g/s – 0-200g/s	0.2 mln/min – m3n/h 0.4 – 11000 m3n/h	below 2g/s
Accuracy	Liquid : ±0.10% of rate (standard)±0.05% of rate (optional) Gas: ±0.35% of rate	± 1 % FS	± 0.3% of full scale
Mounting	In line (intrusive)	In line (intrusive)	In line (intrusive)
Remarks			

Heater

	ARCOL 	ROTFIL CETAL 	ROTFIL acim jouanin 	CERN 
Type	ARCOL HS100 100R F Wirewound resistors	Industrial Multiple Suppliers Cartridge	Industrial Multiple Suppliers Inserted Cartridge	CERN Design Kapton Foil
Environment	Liquid Helium/Gas and/or Radiation	Liquid Helium/Gas and/or Radiation	Gas and/or Radiation	Liquid Helium and/or Radiation
Range	100W	5000 / 15000W	500 / 1000W	100W
Accuracy	-	-	-	-
Mounting	Copper plate 		Hole inserted	Glued
Remarks	PWM controlled		w/ or w/o Thermocouple	w/ Pt100

Radiation Test: Low 0-60 mbar pressure sensors

Sensors under the test

ABB

Range: 60 mbar
Type: piezoresistive
Passive
Industrial without electronics

ABB in radiation environment:
Tested at CERN in 2018 with conclusion: *can be used in high LHC radiation but with limited accuracy*
0.6 mbar offset at 10 kGy

Validyne

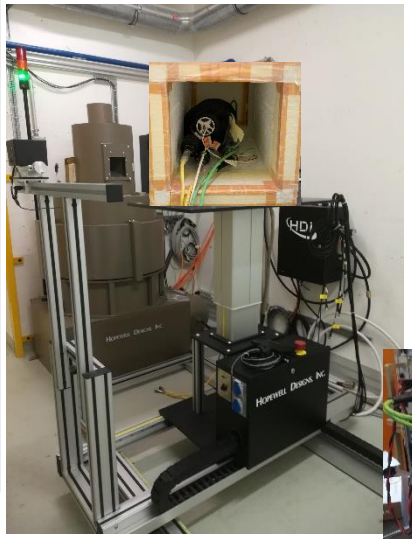
Range: 55 mbar
Type: inductive
Passive industrial

Validyne in radiation environment:
A US national laboratory used the DP10 pressure sensor to measure pressure build up in vessels containing disposed radioactive materials. The pressure sensor was exposed to radiation over such a long term that it was not designed for recovery or contact by humans.

Test setup

One ABB and two Validyne are measuring pressure in closed and thermally isolated volume. Pressure is controlled by heaters according to ideal gas equation. At 20 40 °C mbar, at 64°C 48 mbar. Temperature is measured inside the volume with Pt1000. Automatic setup reads data once per minute.

Test at ^{60}Co started on 25th May with goal 100 kGy

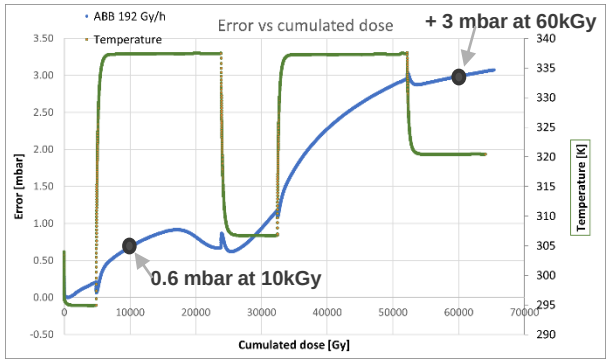


Sensors in polystyrene box are placed before cobalt source:
ABB: 192 Gy/h
Validyne1: 145 Gy/h
Validyne2: 231 Gy/h

Measuring devices are placed in zone without radiation

Primary results

ABB



Validyne2