YETS 2022-2023

LHC Beam vacuum activities

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on behalf of TE/VSC/BVO

04.07.2023

Outline

1. LHC vacuum system

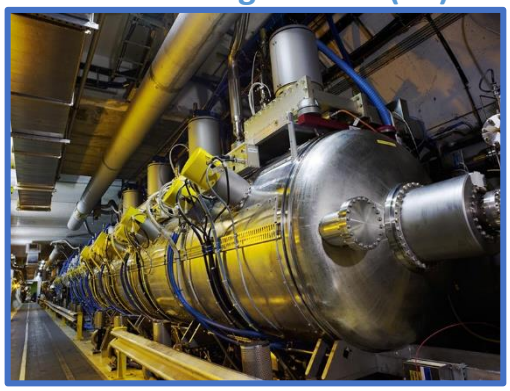
2. YETS Framework

3. Activity overview
   - HL-LHC
   - General activities

4. Summary

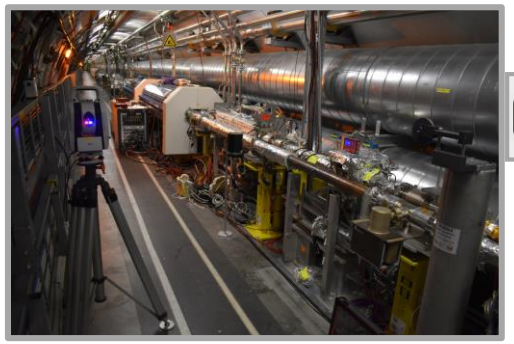
LHC vacuum system

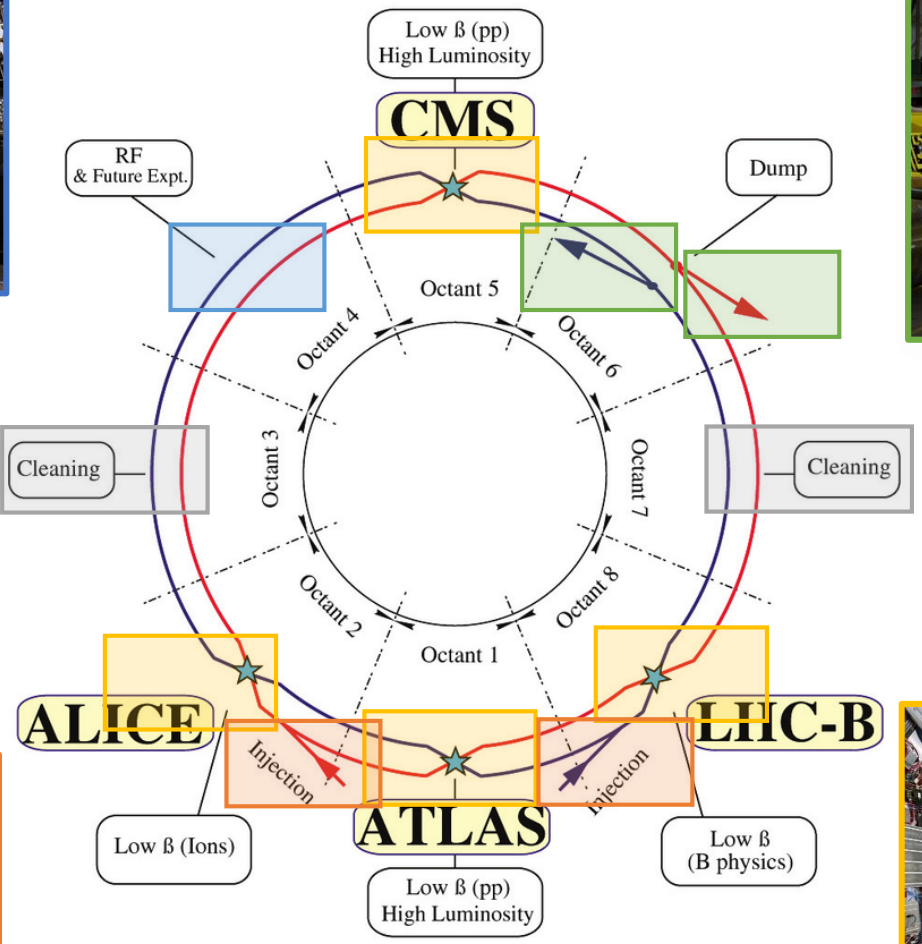
RF accelerating cavities (P4)



2 DUMP lines (P6)

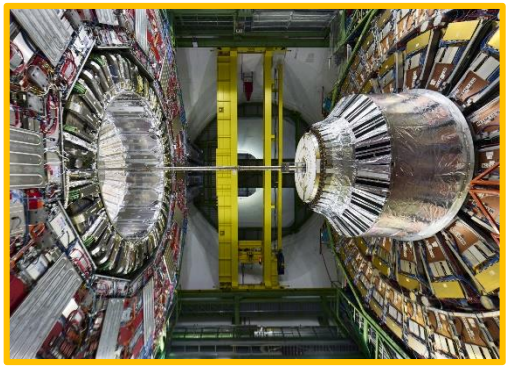
Cleaning insertions (P3, P7)





Transfers lines (TI2, TI8)

4 main experiments



LHC vacuum system

8 Long Straight Sections (~528 m. each)

Room temperature areas:

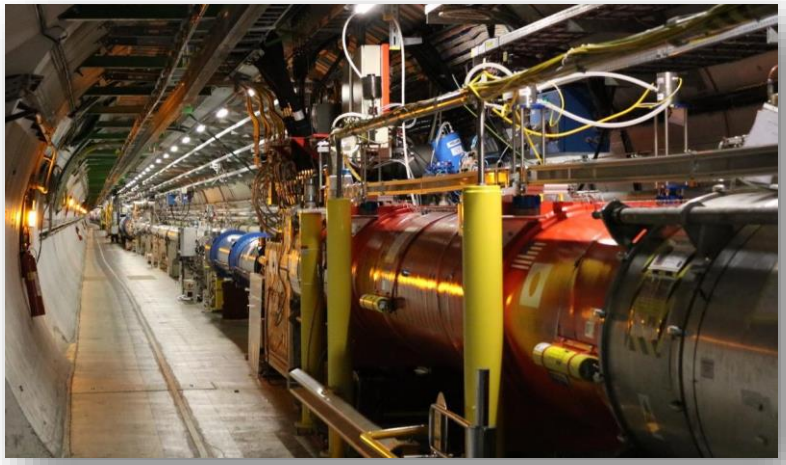
- **5.8 km** of baked system
  - 85% are NEG coated chambers
- Up to **186** vacuum sectors
  - Twin (2 separate beampipes)
  - Combined (common beampipe)

Twin sectors

Combined sectors
(both sides of Experiments)

Cryogenic areas:

- Stand-Alone Magnets (cold bore @4K)
- Inner Triplets (cold bore @1.9K)
- **~1.4** km of cryogenic vacuum pipes
- Up to **82** vacuum sectors

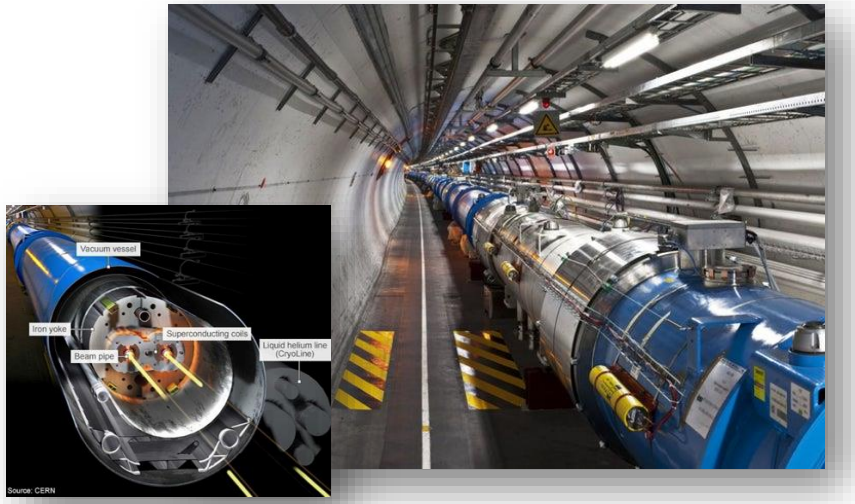


LHC vacuum system

***8 ARCs** (~ 2.8 km each)*

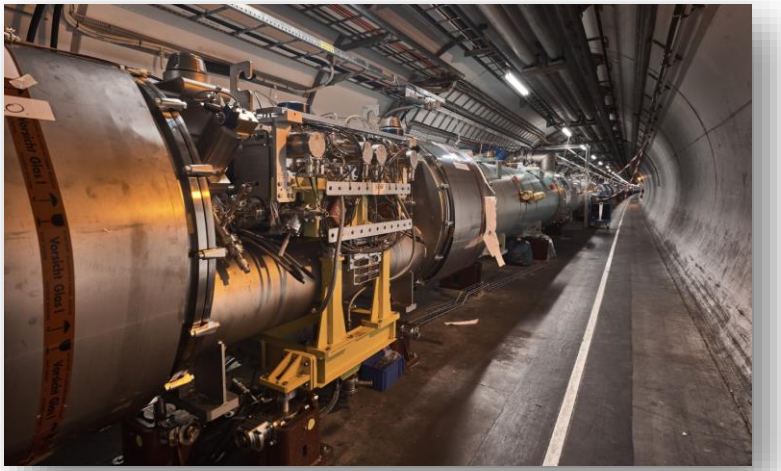
Cryogenic areas:

- Superconducting “bending” magnets
- Cold bore @1.9K, beam screen @5-20K
- **~48 km** of cryogenic vacuum pipes
- Up to **18** vacuum sectors



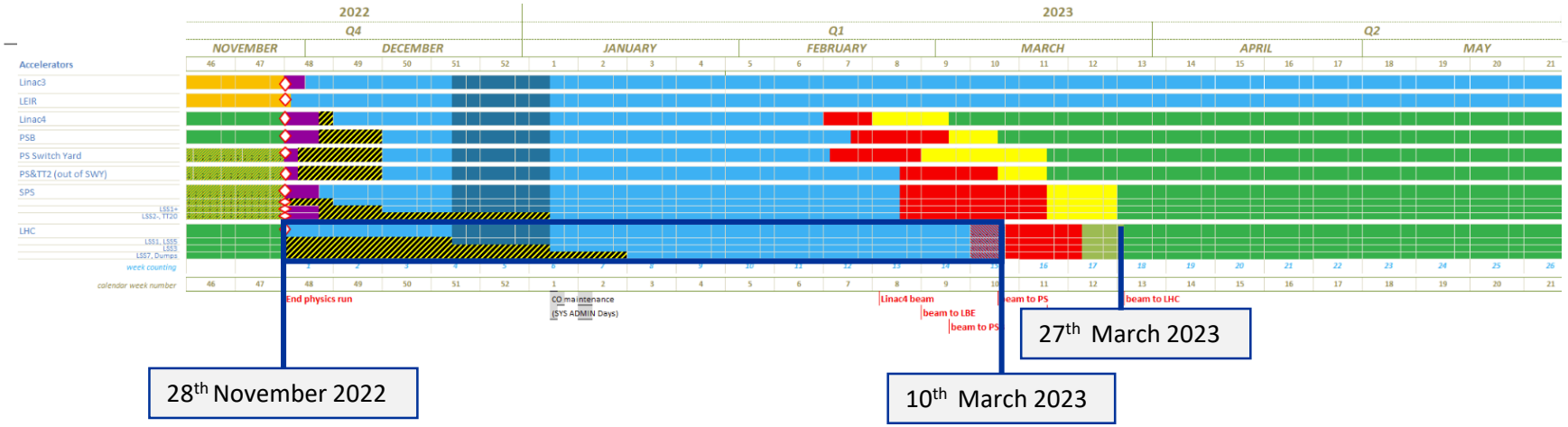
Room temperature areas:

- TCLD collimators
- **2** vacuum sectors



YETS Framework

- YETS (Year End Technical Stop) 2022-2023
- Works from 28th November to 10th March (P7 from 8th January)
- Beam back on 27th March



Maintenance & Operation

- Cryogenics
- Cooling and ventilation
- Vacuum
- Electrical systems
- Survey
- Optics
- …

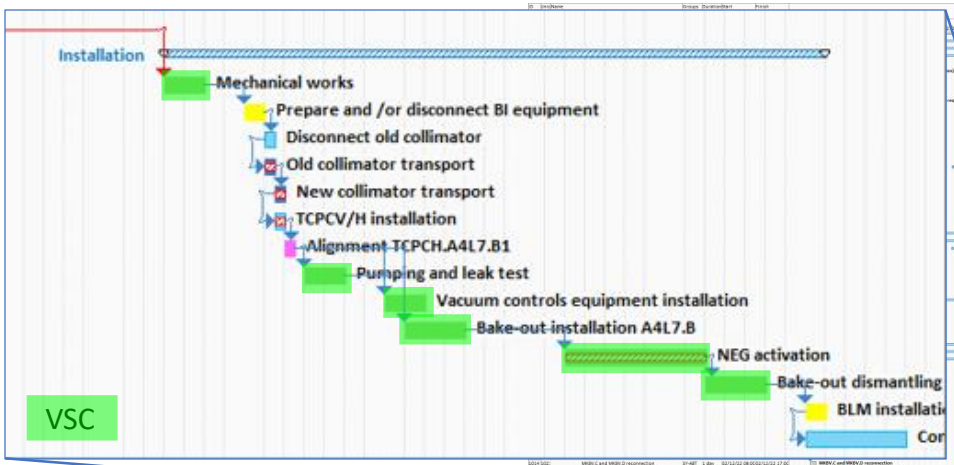
HL-LHC upgrade

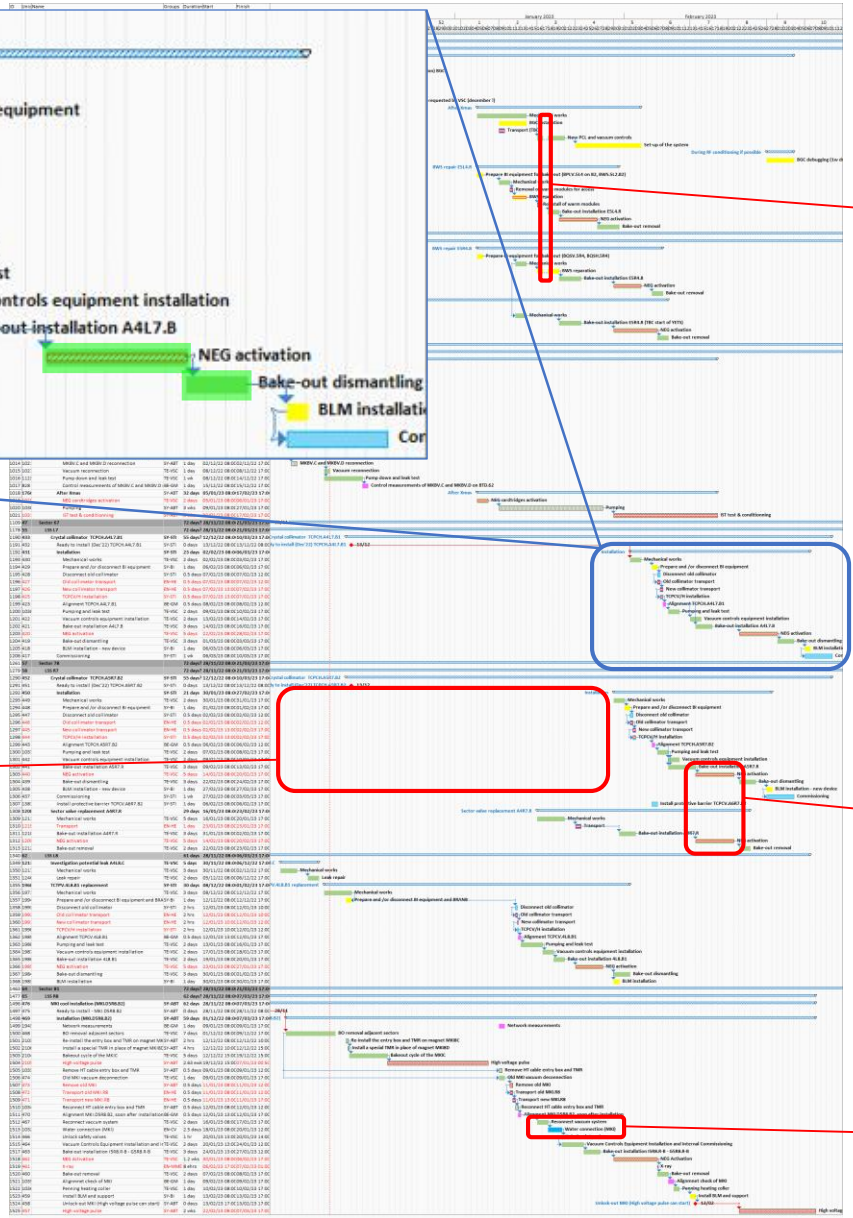
- WP13
- WP5
- WP14
- WP17

Consolidation & other

- Optical fibre
- Telecom cable campaign
- …

YETS Framework: Planning





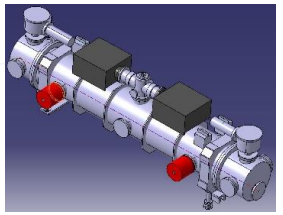
Electrical tests = power cuts

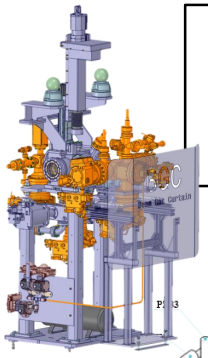
Access constraints

Activities in parallel

Co-activity

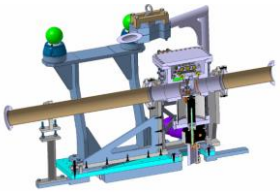
YETS 22-23 activities: Overview



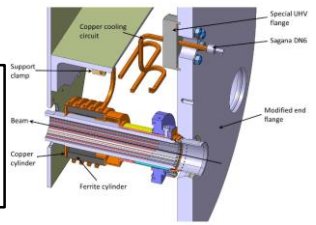


LSS4
- BGC phase II (WP13)
- 2 BWS maintenance
- E5R4.R RF-finger problem suspicion

LSS6 - DUMP BTD62
- Replacement MKBV.B2
- MKBs Pumping upgrade



LSS7
- 2 TCPC crystal collimators (WP5)



LSS8
- MKI cool prototype (WP14)
- A4L8.C Replacement TCTPV.4L8.B1

HL-LHC activities

General activities

VSC-led activity

HL-LHC activities

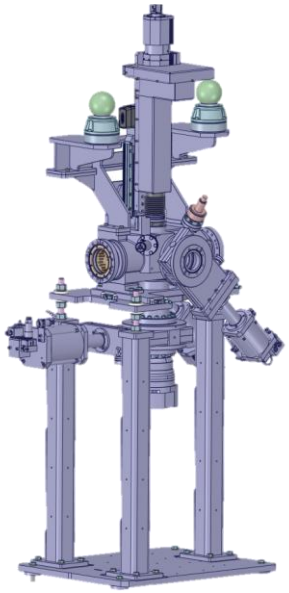
LSS4 | BGC Phase II

BGC (Beam Gas Curtain) phase II installation completed and instrument fully operational for 2023 run

WP13
LHC-BGC-EC-0005

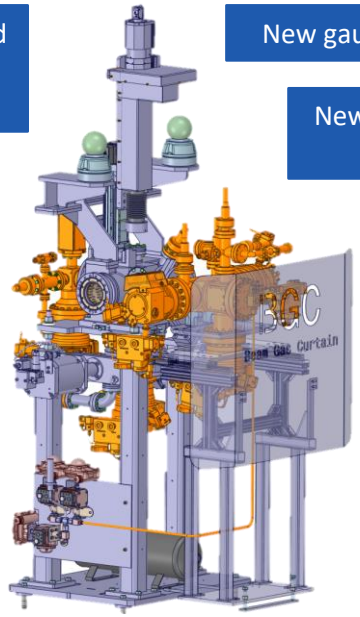
See Cristina's seminar from March 21st

LS2
(phase I)

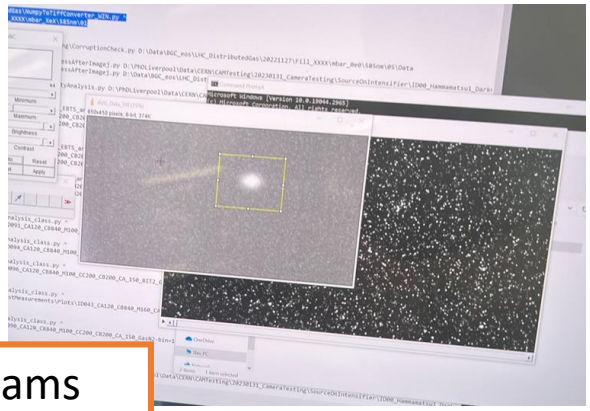


YETS 22-23
(phase II)

- Removal of BGI table and installation of new gas injection system
- Independent compressed air supply (new line)
- 5 turbomolecular pumping groups + 1 dry pump for injection line
- Integration of injection and dump chambers
- New gauges
- New PLC controls + SCADA int.



Beam Gas Curtain: a new instrument for LHC Run 3 - YouTube



First injections done during stable beams

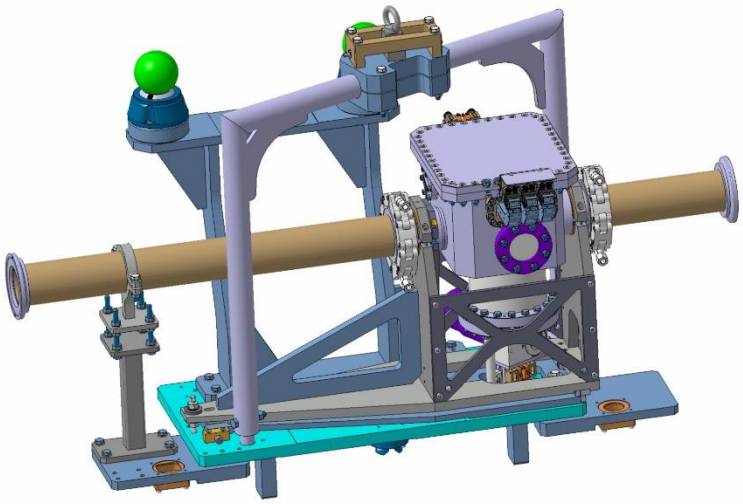
LSS7 | TCPC Crystal collimators

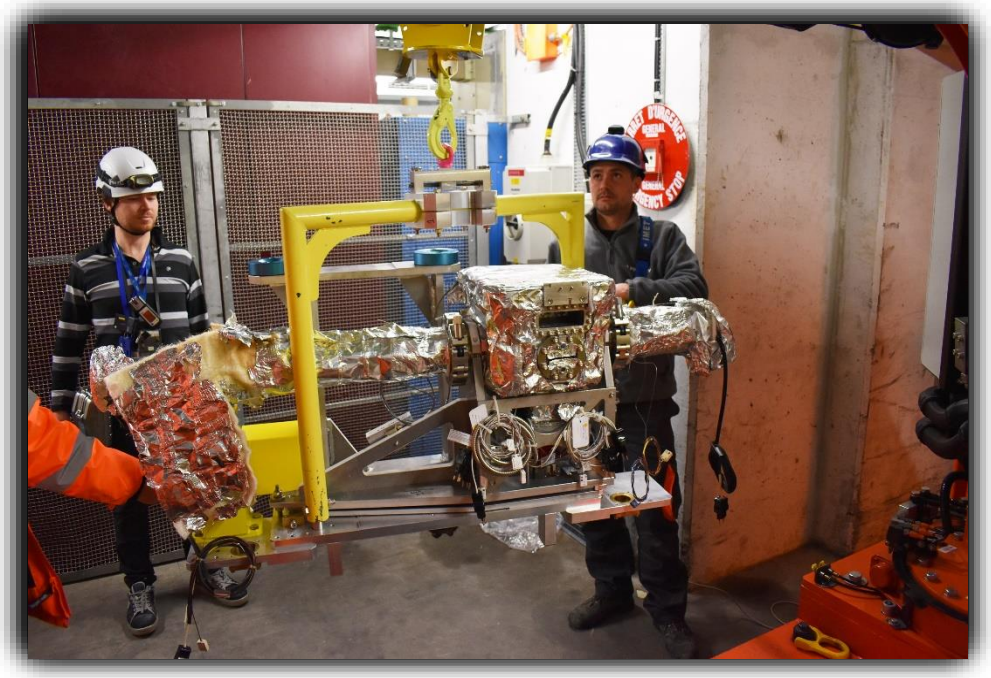
Upgrade of the crystal collimation test stand in IR7

WP5
LHC-TC-EC-0015

- YETS 21-22: Replacement of 2 TCPCV in sectors B5L7.B and B5R7.R
- YETS 22-23: Replacement of 2 TCPCH in sectors A4L7.B and A5R7.R

- Opening of vacuum sector and releasing of collimators from their slot
- Connection of new collimator
- Sector reconditioning: Pump + bake + NEG activation





LSS7 | TCPC Crystal collimators

Last minute removal of TCPCH.A4L7.B1

In March, during OP commissioning tests, the crystal remains **blocked** halfway in **(no beam circulation possible)**

- Prompt action to vent the sector for an inspection (SY/STI)
- Mechanical failure (roller cage jammed). Repair in situ **not** possible
- Crystal collimator removed and slot closed with a vacuum chamber
- Reconditioning of the sector: Pump, re-bake + NEG activation
- Total intervention time: **6 days (very challenging)**

Inspection of TCPC by SY/STI

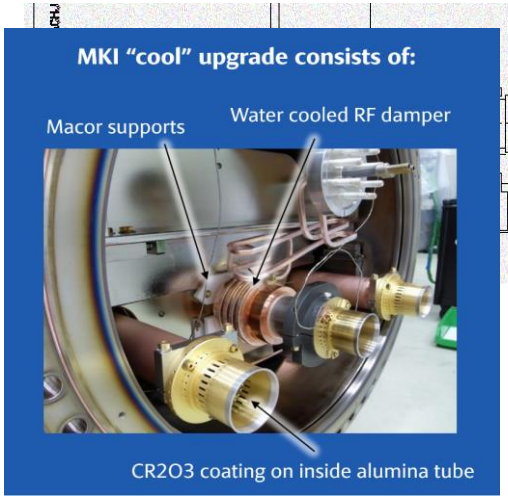
Sector opening (TE/VSC)

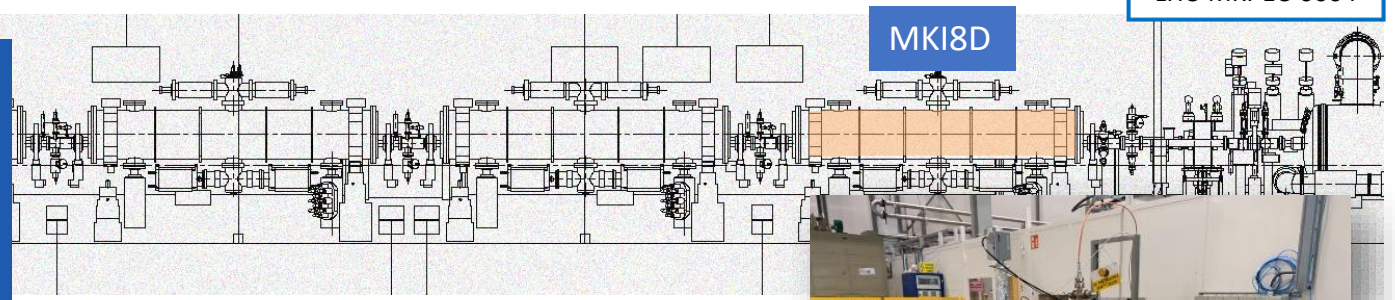
Reinstalled two weeks ago during TS1 – 5 days

LSS8 | MKI cool

First MKI cool prototype installed during YETS 22-23 (1 out of 8)

WP14
LHC-MKI-EC-0004





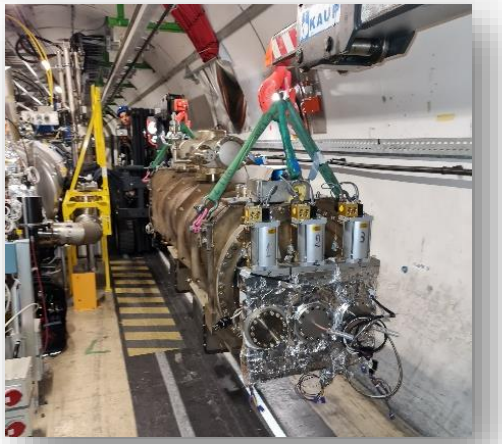
Acceptance test of the MKI cool in Bldg.867

Activities in surface

- Acceptance test of the MKI cool subcomponents
- Acceptance test of the MKI cool tank assembly + bake-out

Activities in tunnel

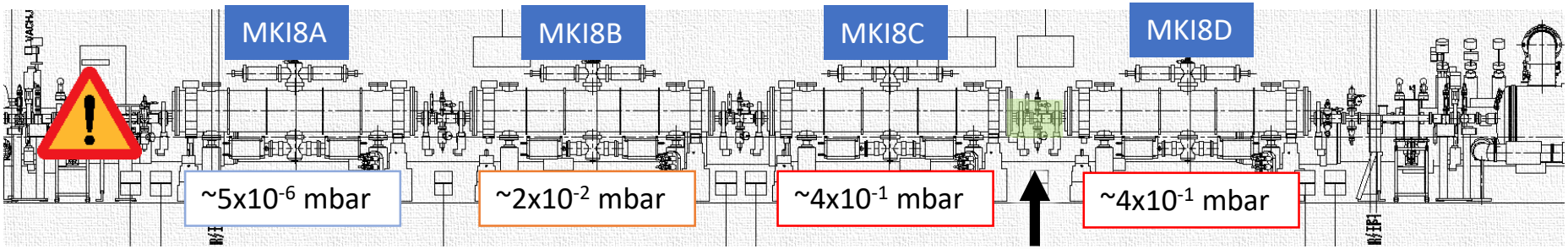
- Adjacent sectors (G5R8 & I5R8)
  - Removal/reinstallation of 4 vacuum assembly modules
  - Reconditioning: Pump + bakeout



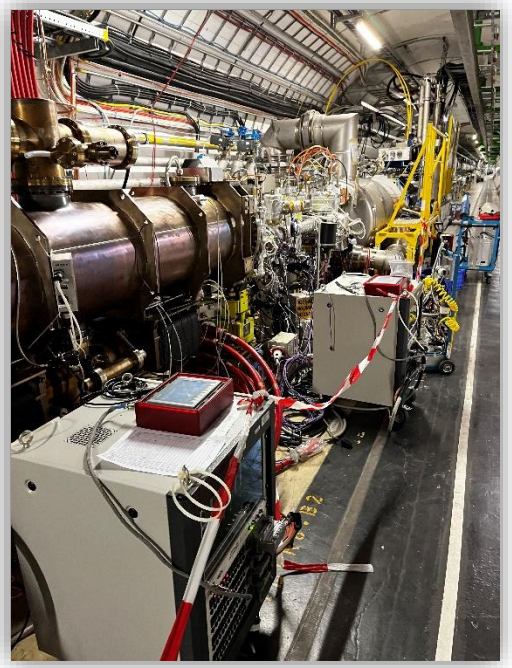
MKI cool transport

LSS8 | MKI cool

Accidental dry **nitrogen inrush** inside all the MKI tanks



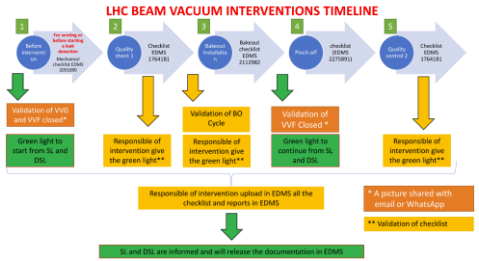
- Pump-down restarted with fast recovery of vacuum
- Bake-out cycle of **MKI8C**
- Reconditioning completed and **nominal pressures recovered** (<1x10^{-11} mbar). No need of additional bake-out in rest of MKIs sectors
- HV test of all MKI performed by SY-ABT. **No issues** identified



Bake-out of MKI8C

Additional safety measures implemented

- ✓ Validation check before interventions
- ✓ Already implemented during YETS 22-23 in other all sectors



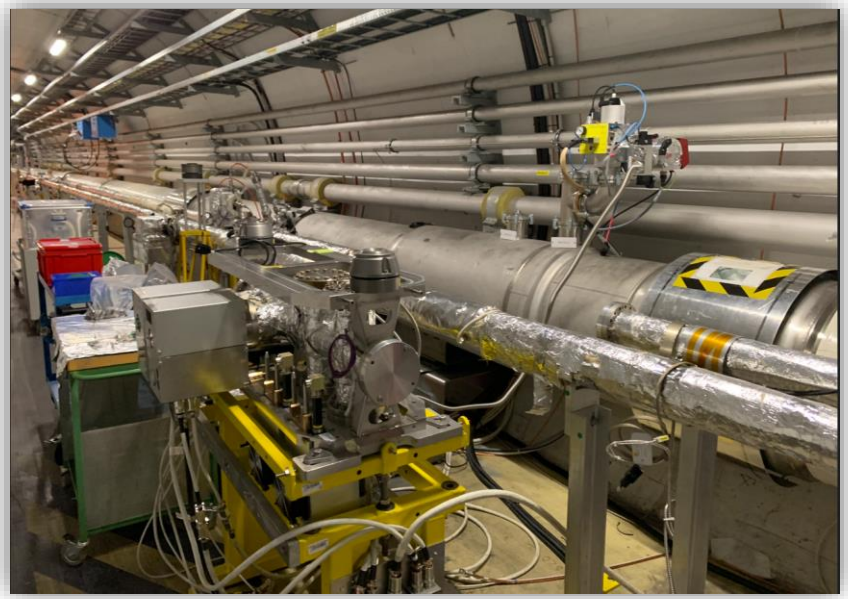
General activities

LSS4 | BWS maintenance

Maintenance of 2 BWS (Beam Wire Scanner) in sectors E5L4.R and E5R4.B

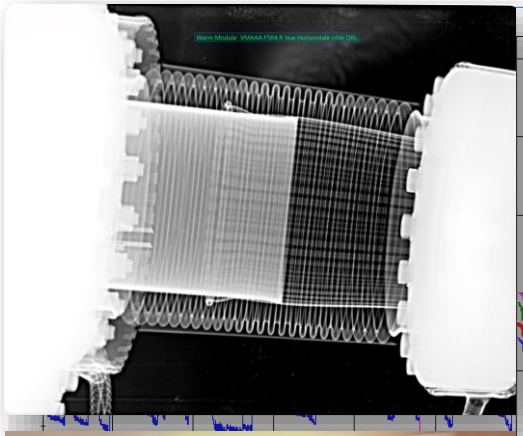
- E5L4.R (outer beam line): additional mechanical intervention requiring **opening and disconnection** of the tank from the beamline
- Intervention by SY-BI : C-wire inspection (exchange) + functional tests
- Vacuum reconditioning: Pump + bake + NEG activation

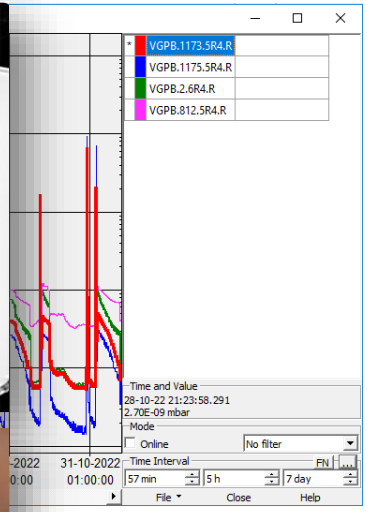
E5R4.B (inner beam pipe)



E5L4.R (outer beam pipe)

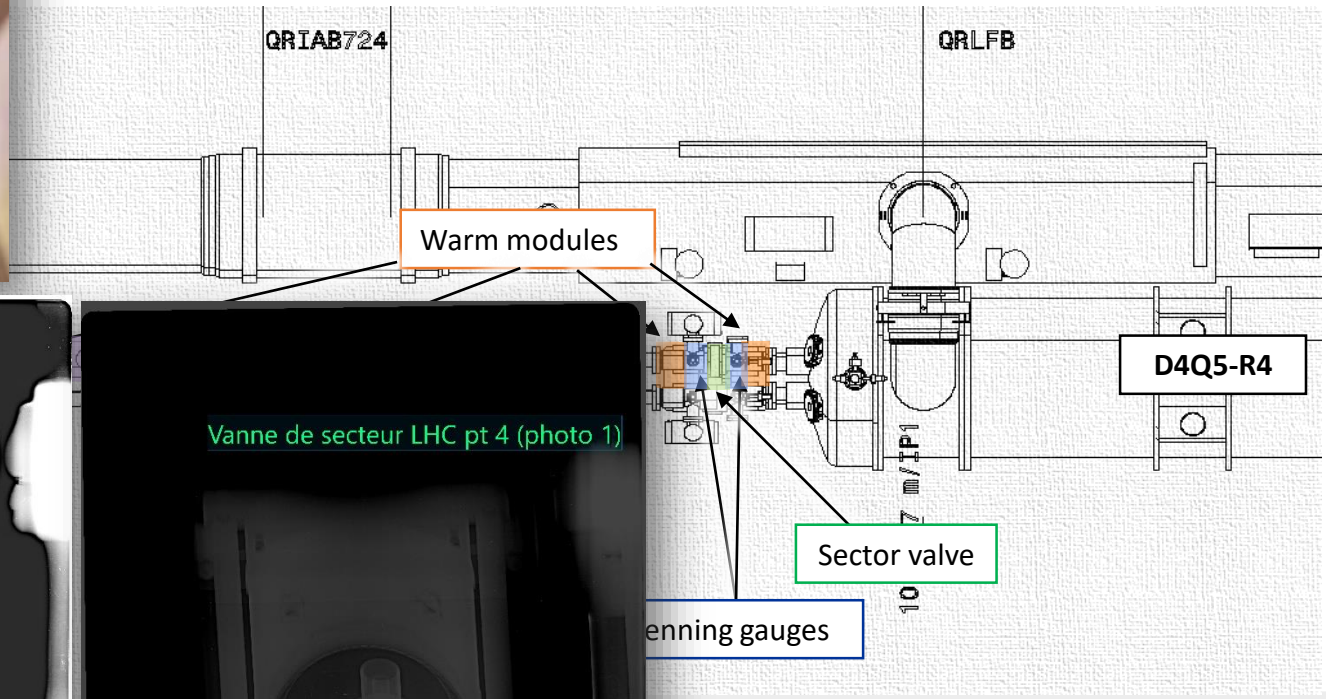
LSS4 | E5R4.R RF-finger problem suspicion





Pressure spikes up to 10^{-6} mbar detected during beam operation in two adjacent penning gauges

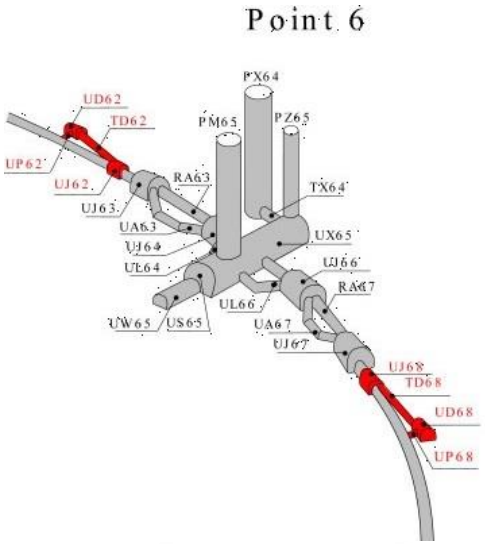
- Objective during YETS: Discard any aperture restriction (ULO, RF-finger damaged, etc.)
  - X-ray (EN-MME) on 4 warm modules ✓
  - Opening of the sector for visual inspection of BQS (Schottky Monitor) and adjacent vacuum chambers ✓
  - Additional X-ray (EN-MME) on sector valve ✓



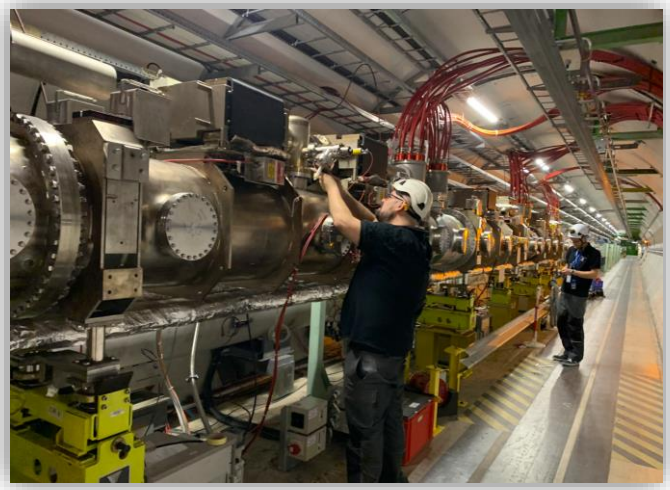
LSS6 DUMP | MKB exchange

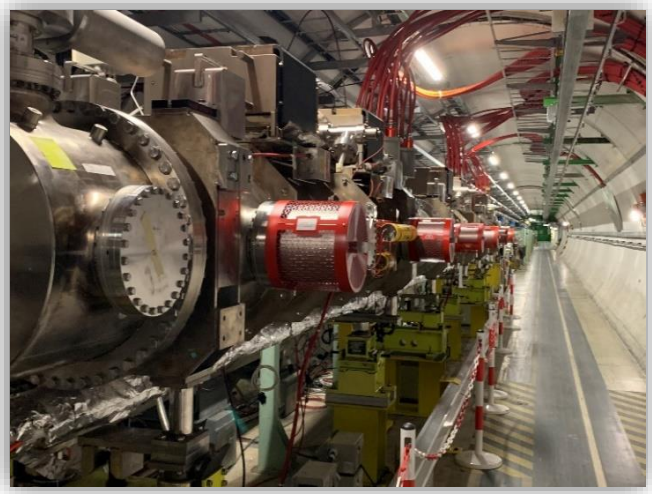
Replacement of the MKBV (C+D) in BTD62 due to an electrical flashover during operation

- New tank upgraded with 2 modifications:
  - New interconnection end cap **plasma screens** with aC coating (SY-ABT)
  - Additional pumping: 2 **NEG cartridges** per tank (TE-VSC)
- Also implemented in all other 5 tanks in BTD62
- BTD68 upgrade planned for EYETS 23-24



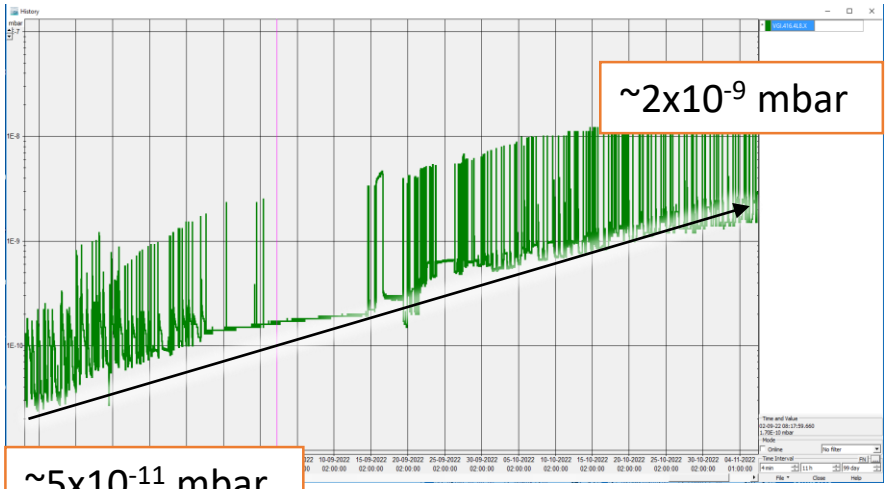
CapaciTorr HV 2100 (ZAO alloy)





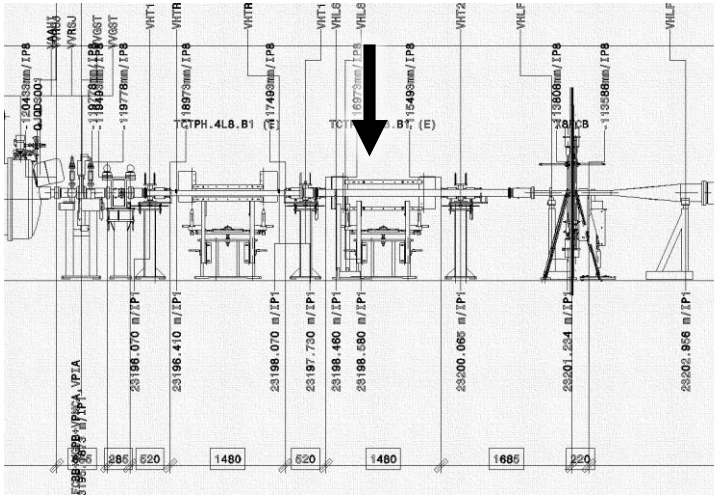
Plasma screen coated

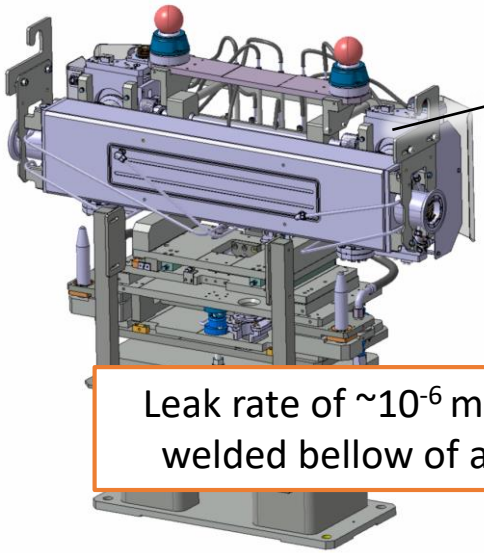
LSS8 | A4L8.C replacement TCTPV

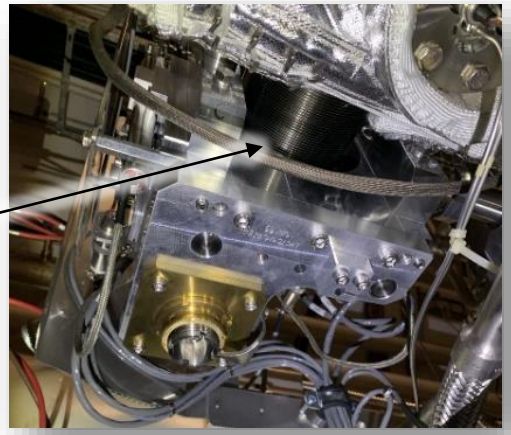


Pressure increase detected in sector A4L8.C over a period of months

- Complex and long vacuum sector (>50 m, recombination area, chambers ID 212 mm)
- Leak confirmed at the beginning of YETS





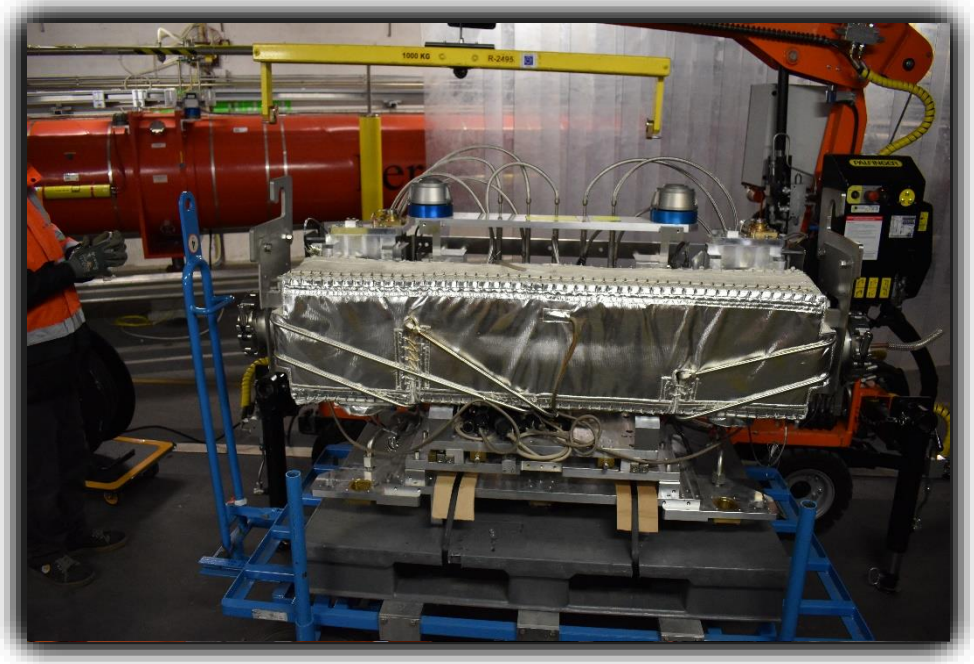


Leak rate of ~10^{-6} mbar.l/s detected on an edge welded bellow of a collimator (TCTPV) motor

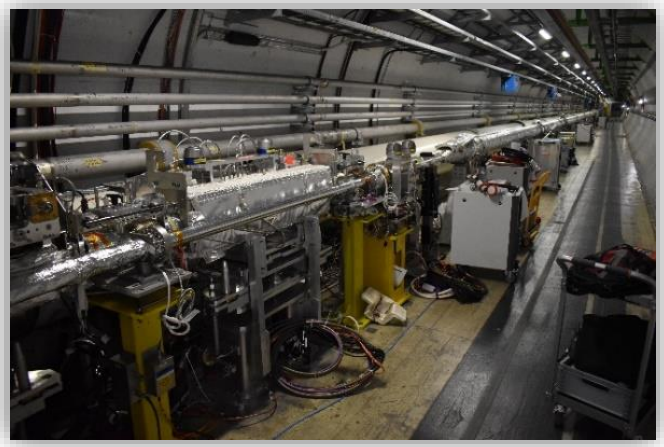
LSS8 | A4L8.C replacement TCTPV

Replacement of TCTPV.4L8.B1 by spare one

- On surface, series of validation done by different groups (including vacuum acceptance test)
- New collimator installed
- Base pressures recovered after bakeout

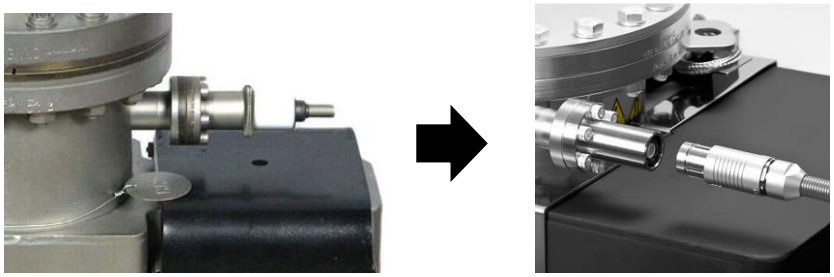


Vacuum acceptance test of spare TCTPV in bldg.867



Consolidation and non-conformities

- 12x old ion pumps (VPI) exchanged by new pumps (VPIAN) with HV Fischer feedthrough



- 2x non-conform Penning gauges (VPGB) exchanged

Bake-out

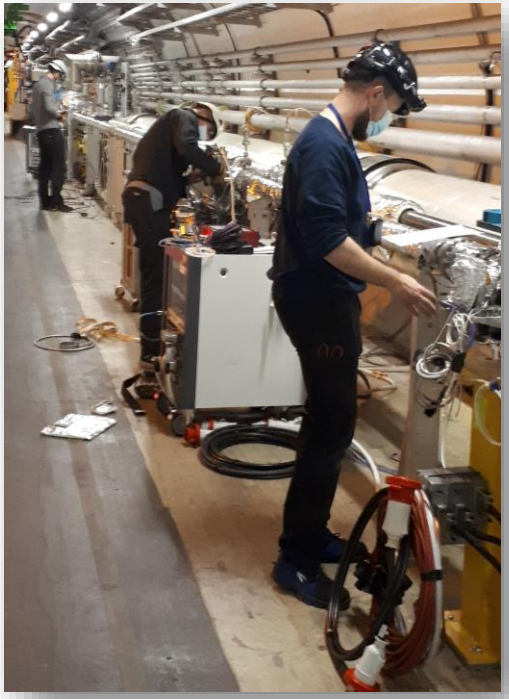
Some numbers:

- LHC Vacuum sectors baked: **9**
- Length of beamlines baked: **182 meters**

But not only…

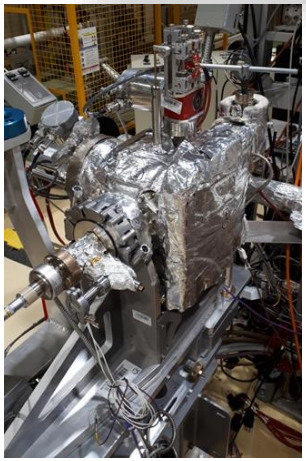
- Injectors Vacuum sectors baked: **3**
- Length of beamlines baked: **45 meters**

➢ Bake-out racks used: **27**



Example of instruments equipped:

- MKI
- Crystal collimators (TCPC)
- Beam Wire Scanners (BWS)
- BRANB
- TCLIA, TCTPV and TCTPH
- AWAKE expansion volume



Crystal collimator

AWAKE expansion volume

Summary

- All activities planned have been performed in time with no impact for the restart of the machine.
- More activities with respect to baseline including last minute interventions (crystal collimator removal) but well-executed.
- Challenging management of the bakeout activities due to implication of the involved team in parallel activities in the Injectors complex.

Thanks to all TE/VSC participants, FSU and AL4030 colleagues!

TE/VSC/BVO

- G.Bregliozzi
- J.Sestak
- J.Finelle
- G.Cattenoz
- K.Owens
- N.Zelko
- K.Henneli
- E.Page
- J.Hansen
- O.Santos
- I.Wevers
- …and more

TE/VSC/ICM

- L.Zygaropoulos
- J.De la Gama
- I.Lobato

FSU

- D.Digonzelli
- C.Moreillon

Industrial support

- P.Caseiro
- P.Ouvrier

Thank you for your attention

Any questions?

Spares

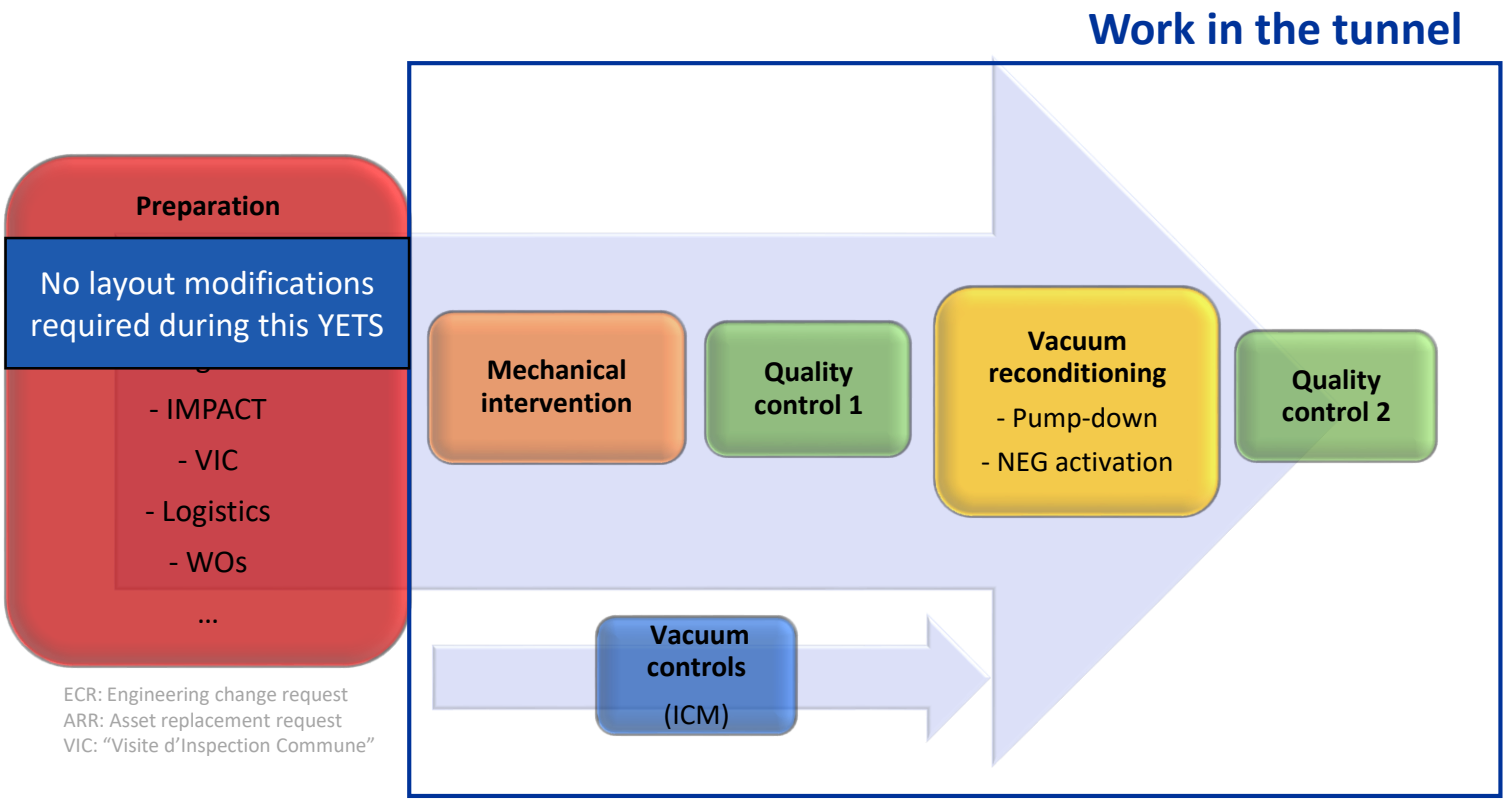
LHC vacuum system

LHC in numbers: Vacuum

Component	Quantity
Vacuum sectors (cryogenic / RT)	88 / 186
Vacuum sectors valves (all LHC)	241
Roughing valves (LSS)	348
Ion pumps (special / 30 / 60 / 350 / 400 l/s)	12 / 625 / 177 / 36 / 35
NEG cartridges (D400 / D2000)	257 / 0
Bayard-Alpert gauge (LSS)	201
Penning gauges (LSS)	571
Pirani gauges (LSS)	331

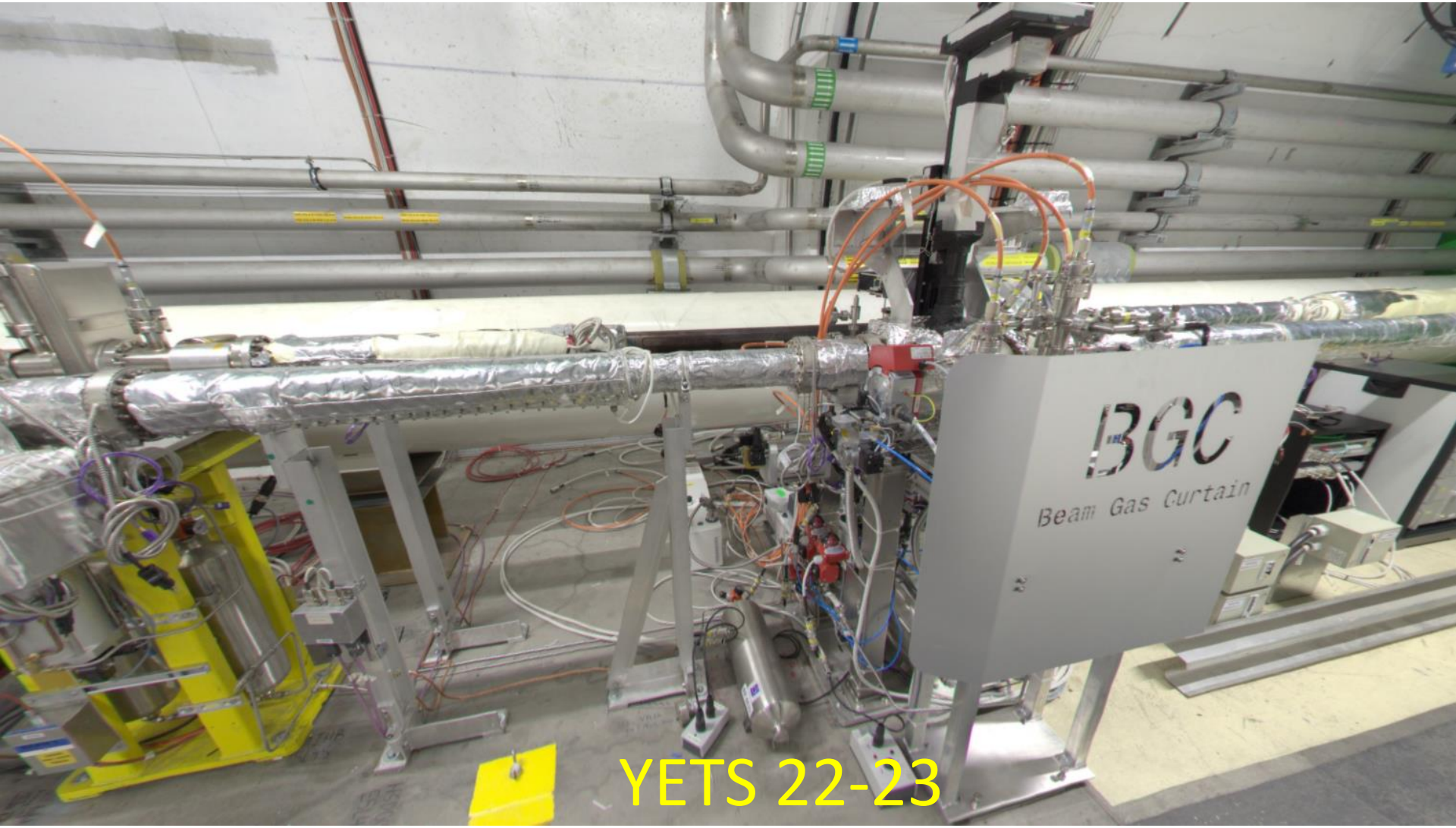
Item in LSS	Length (m)	% wrt total
SAMs & ITs @ cryogenic T	~ 1365	19
LSS @ RT baked	~ 1000	14
LSS @ RT with NEG chambers	~ 4800	67
Total length under vacuum	~ 7200	100
~ 85% of the baked vacuum system is NEG coated		

The way we work

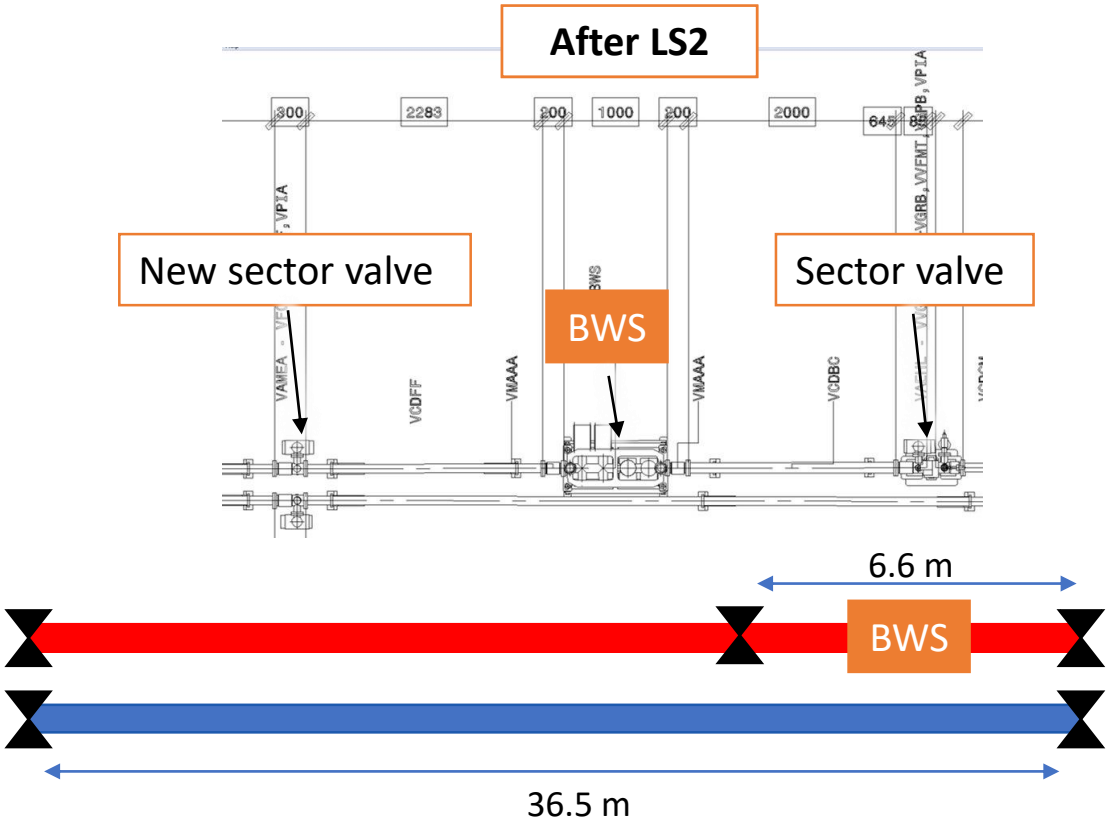


ECR: Engineering change request
ARR: Asset replacement request
VIC: "Visite d'Inspection Commune"

LSS4 | BGC Phase II



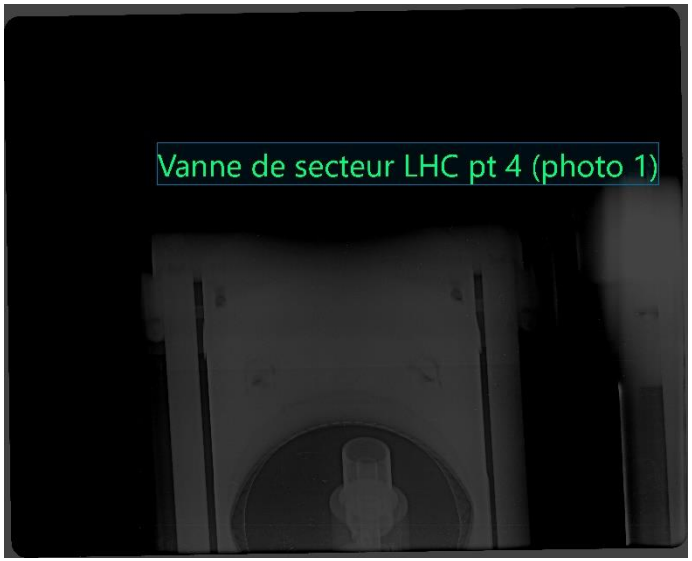
Sectorization during LS2



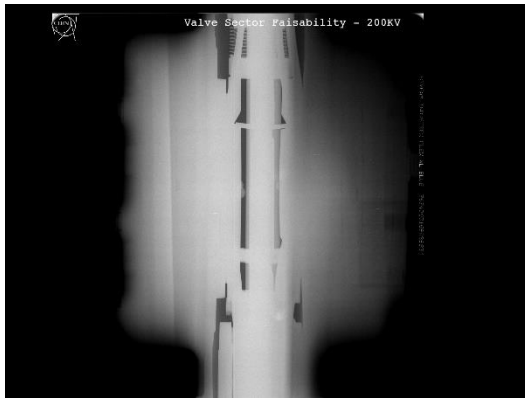
LSS4 | E5R4.R RF-finger problem suspicion

X-ray on sector valve

VVGSH.1174.5R4.R



Feasibility study on random valve (on surface)



LSS4 | E5R4.R RF-finger problem suspicion

X-ray on sector valve

VVGSH.1174.5R4.R