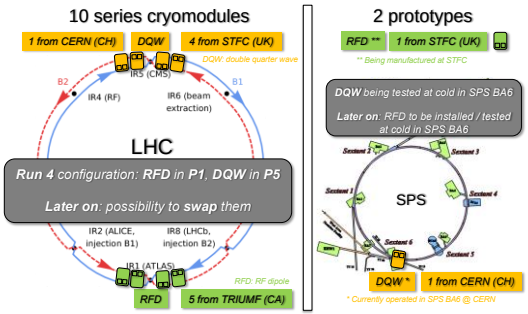
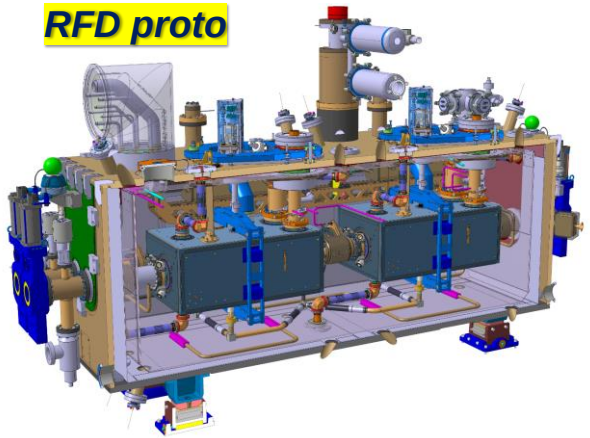
WP4-WP9 Crab Cavities
Experience from RFD proto CM test at CERN SM18 – M7 bunker



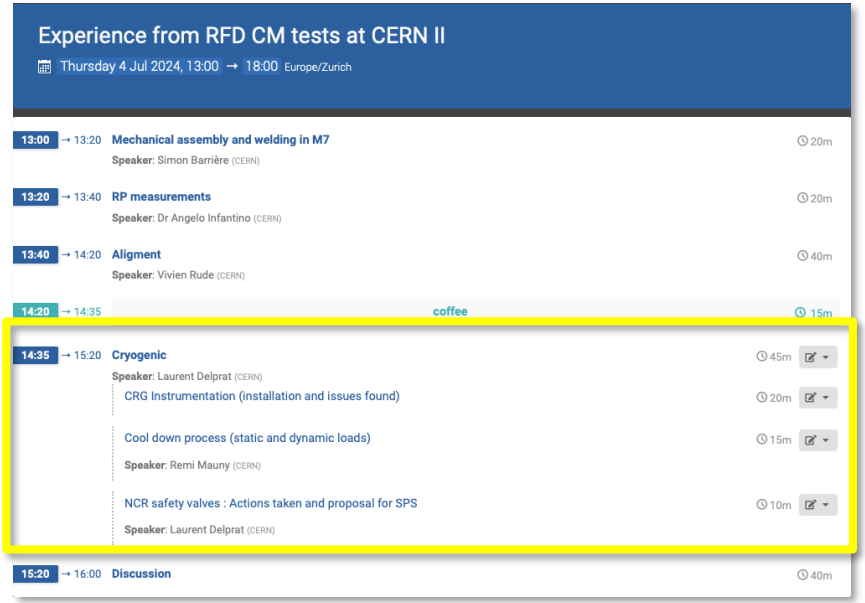


Thursday, July 4th, 2024 - on Indico: 1426215

HL-LHC – Crab Cavities RFD Proto CM test @ CERN – *TE-CRG*

Introduction

- 2023 highlights
- Focus on instrumentation aspects
- Focus on process aspects
- NC relief valve
- Next steps



2023 HIGHLIGHTS

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Dec'22 | **Jan'23** | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | **Jan'24**

RFD proto

SM18 M7 bunker preparation for commissioning @ cold

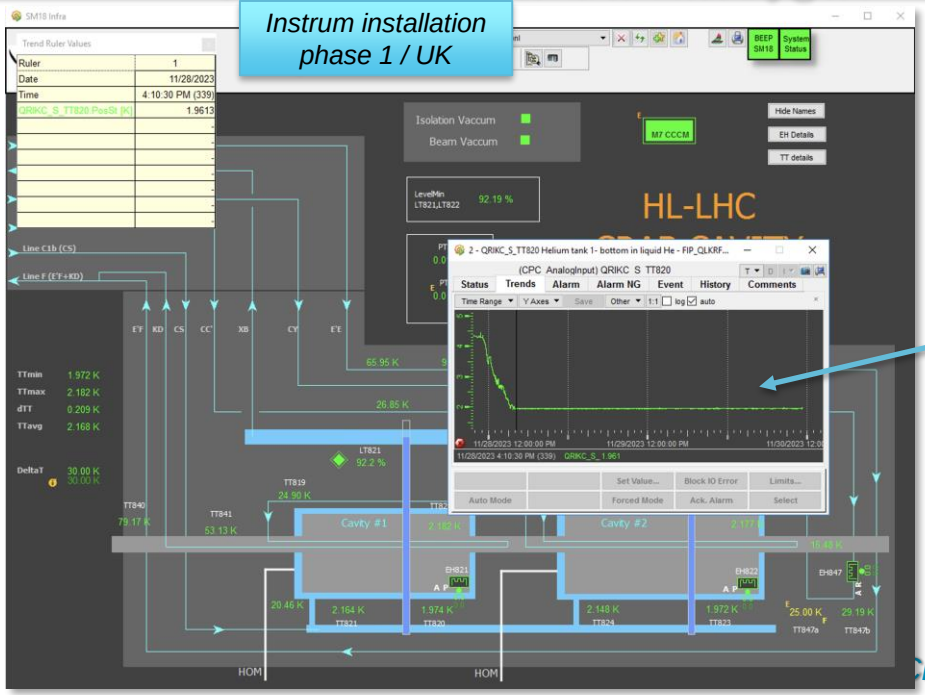
Instrum installation phase 1 / UK

RFD proto delivered @ CERN

Installation, SVs NCR treatment, commissioning

4.5 K *24.11.2023*

2 K *28.11.2023*



INSTRUMENTATION

(feedback CRG-IC/ T. Feniet / N. Vauthier)

Instrumentation aspects (1/2)

- Organization
  - Instrumentation shipping to optimize: the cryomodule builder should receive only the instrumentation he will install => clarification of the installation responsibilities (+ at which phase)

- Instrumentation mounting, training on site
  - Very positive and productive, to be re-conducted – CRG-IC, in charge, should have 1 direct contact with the cryomodule builder (no intermediate with EN-MME, to facilitate the communication), ideally the people in charge of the instrum installation on site
  - Need for CRG-IC to know the profile of the people in charge on site, to better prepare their training & qualification

- Installation on site by STFC
  - Quality assurance
    - cables labels were removed by STFC without CERN approval
    - Pinning strategy not 100% respected by STFC
    - Some TTs were not installed by STFC => had to be done by CERN once delivered
  - Tuners: is there a need for sockets on TT/EH 861/62, to allow their dismounting without removing the sensors?

- 3D integration model & drawings
  - To be included in the model:
    - the sensor wire + its bending radius, the feedthroughs + the connectors, the cabling routing inside & outside the vacuum vessel, the electrical connecting box
  - Quality assurance: actual drilling diameter for the orifices of the Acim Jouanin cartridges was not always consistent with the drawings

Instrumentation aspects (2/2)

- Necessary pending reviews
  - After cold tests: are all the flange heaters necessary? => check their operation (if any), room for simplification
  - Operation: TT847a not operational, to be checked with IC
  - P&ID:
    - TAGs update (TT819a/b to be replaced by 1TT819/2TT819)
    - Add thermocouples on the EH821 & 822 foil heaters (TT827 & 828)
    - Include all existing and physically installed EH on the P&ID (FPC)
    - EH876/877/878/879 (flexible band heaters): they are all equipped with 2 heaters and 2 PT100 => update P&ID accordingly
    - RFD series cryomodules: TT842 to be removed, TT814 & 816 to be added
    - Safety port: import the DQW drawing into the RFD P&ID (1 flange for the chimney, 1 flange for the burst disc)

- FTEs for M7 operation
  - Reception + installation + commissioning: 2 FTEs for 2 weeks, continuous
  - Dismounting: 2 FTEs for 3 days, continuous

- Cryomodules reception at CERN
  - Schedule already available?
  - Quid storage conditions (for the instrum) after M7 dismounting and before LHC installation? Storage duration and conditions (where)?

CRYO PROCESS
(feedback CRG-ML / R. mauny)

Cryo process aspects – intro & overview

- **2 main documents used to write the logic specification** :
  - *«Functionnal description of operation modes»* [HiLumi-LHC-CC-Cryo-N-39; EDMS 2647024]
  - Engineering specification HL-LHC CC : cryomodules for crab cavities [LHC-ACF_A-ES-0001; EDMS 2043014]

- **3 main phases for cool down :**
  1. Cool down from 300 K to 130 K: with controlled inlet temperature ; dTmax = 50 K.
  2. Cool down from 130 K to 4.5 K: by direct LHe injection into CCCM ; no limitation with dTmax below TTmax = 130 K; cooldown as fast as possible (AFAP).

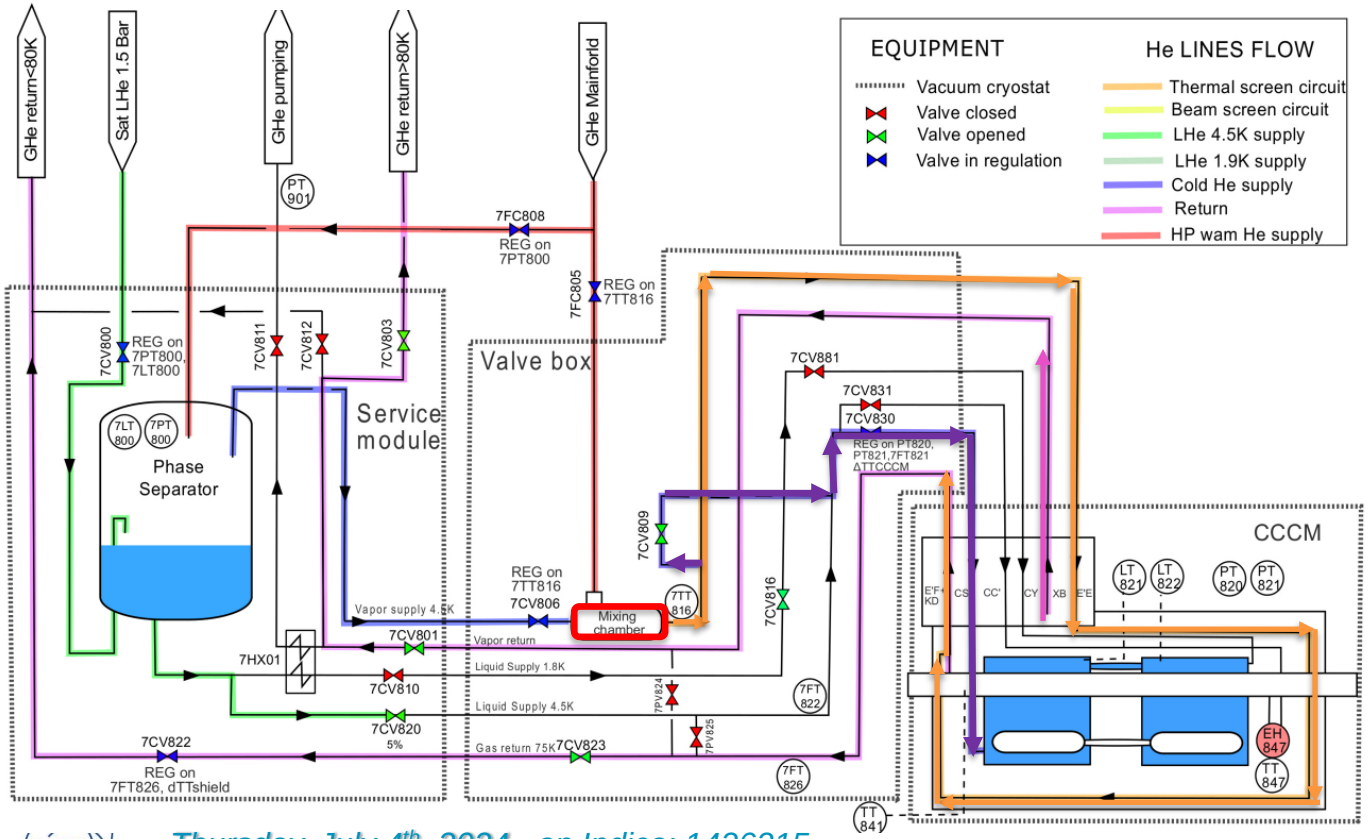
  During these 2 phases, specific attention needed to CCCM pressure (< 1.5 bar)

  3. Pumping phase from 4.5 K to 2 K: beam screen (BS) circuit put in service, then pumping.

- **1st RFD proto operation : 21 Nov. – 10 Dec 2023 (Logbook event 117205)**
- **2nd RFD proto operation : 11 April – 14 June 2024 (Logbook event 119101)**

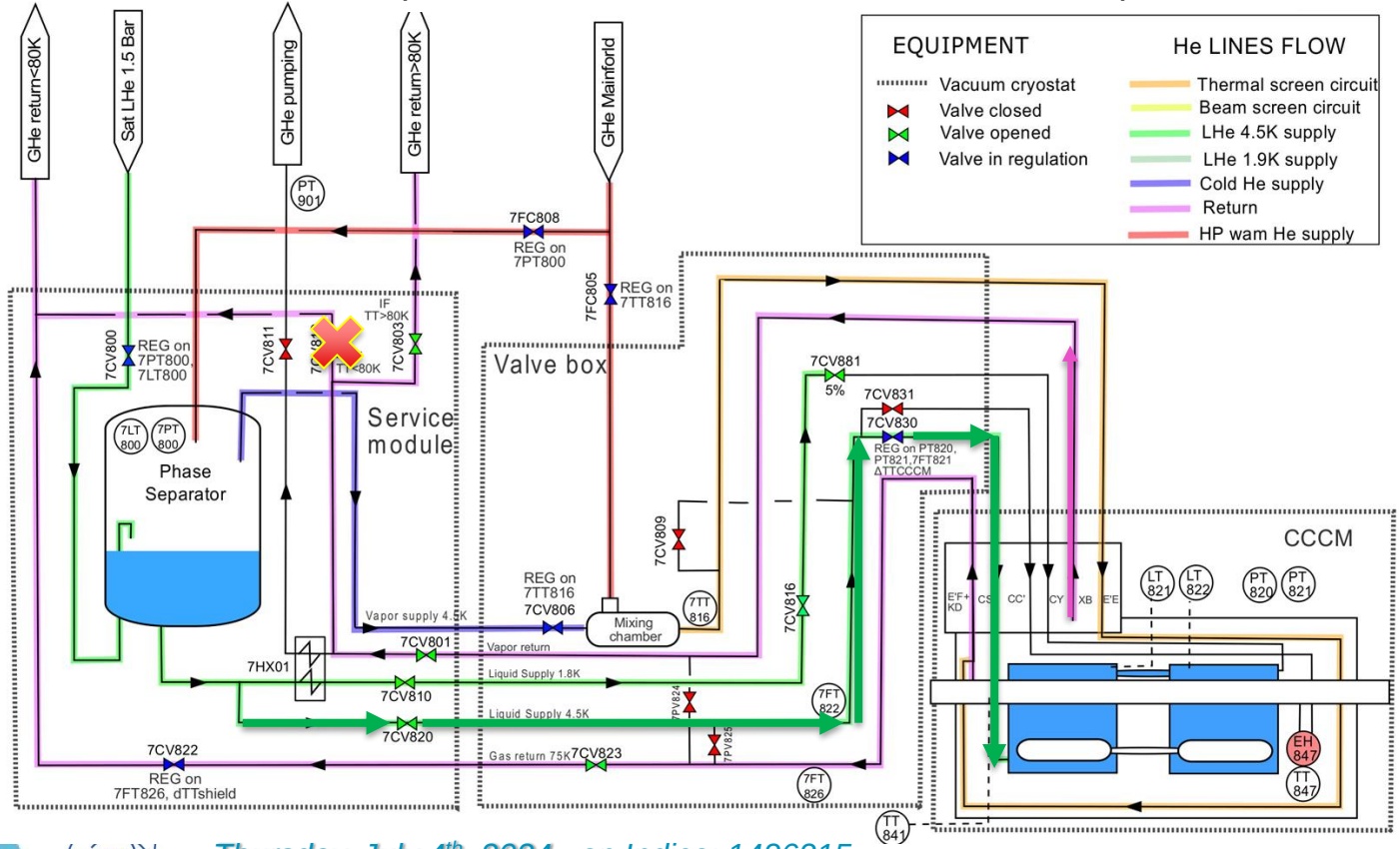
Cryo process aspects – PFD1- CD 300K-130K – dTmax 50K

Step 120 : CoolDown 300-130K with mixing chamber

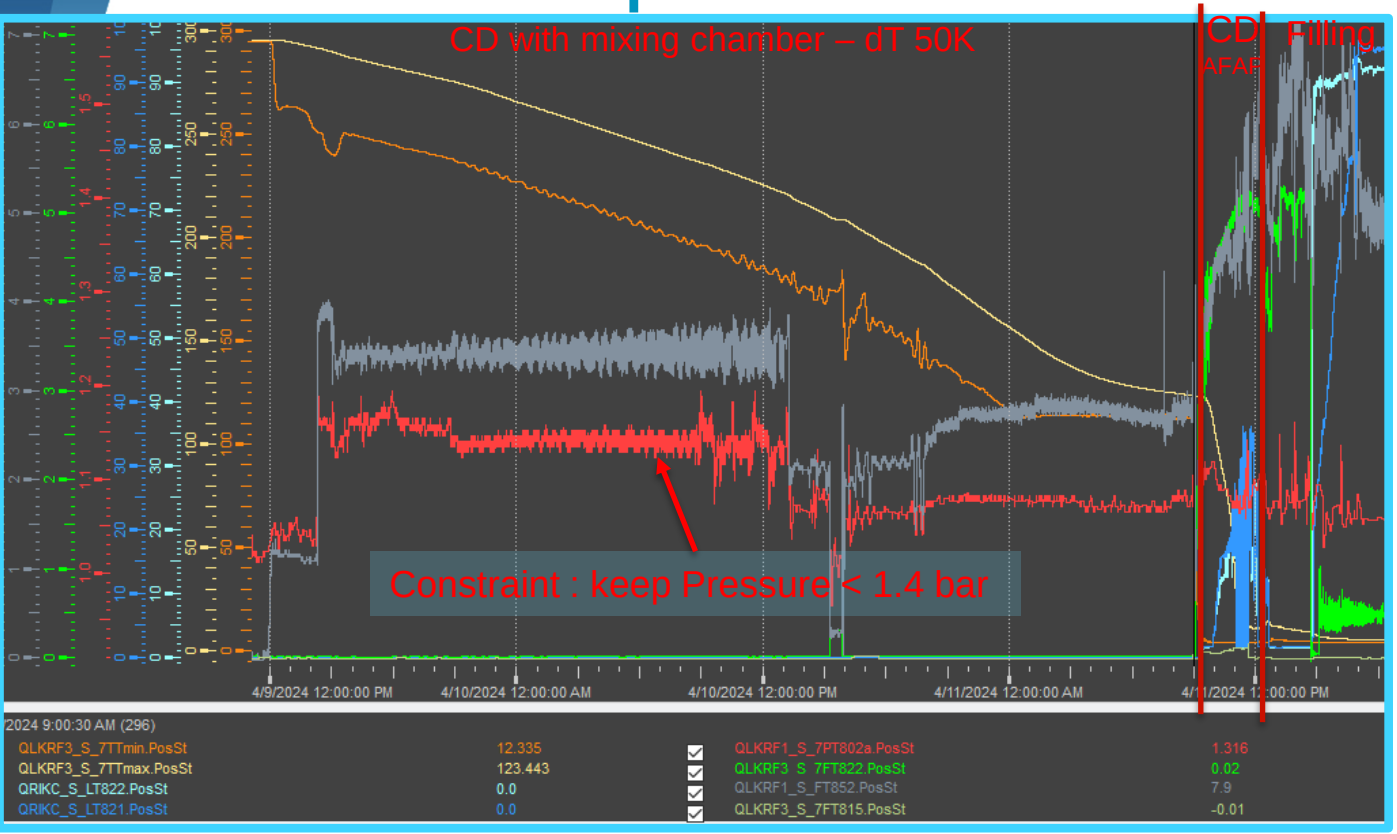


Cryo process aspects – PFD2- CD 130K- 4.5K – AFAP

Step 130 : CoolDown 130 K- 4.5 K - As fast as possible

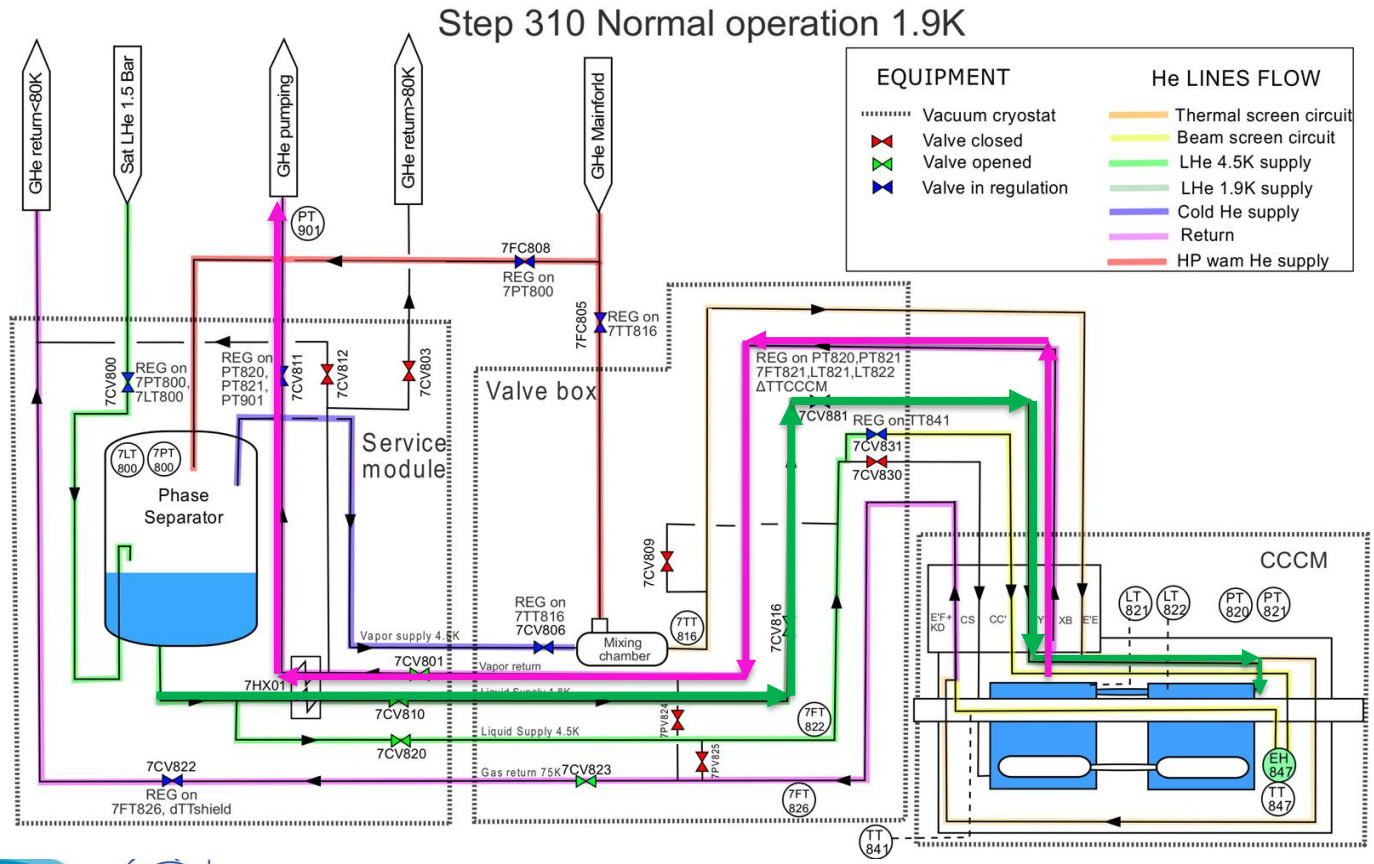


Process aspects – Cool Down 300 K -> 4.5 K

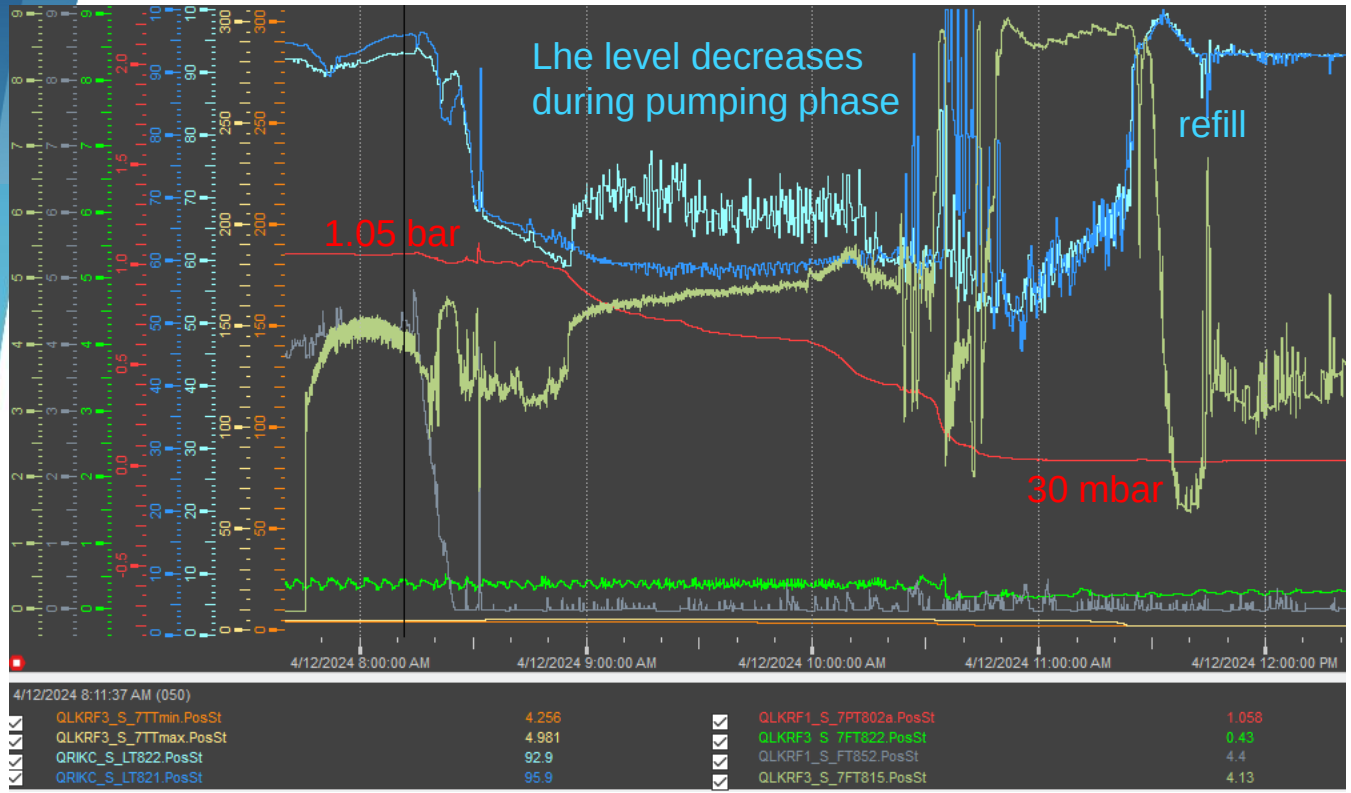


Cool Down time (300 K -> 130 K – *dT 50 K*)	46 h
Cool Down time (130 K -> 4.5 K - *AFAP*)	2 h
Flow during CD in cryomodule	~2.2 – 3 g/s
Flow during CD in TS	~1.3 g/s
Filling	6 h
Flow during filling	~ 5.2 g/s
Flow to maintain cav filled at 4.5 K	~ 4 g/s
Tot. CD time to 4.5 K	54 h

Cryo process aspects – PFD 3 - Nominal operation @ 2 K



Process aspects – Pumping down to 2 K



Pumping time to 30 mbar	2.5 h
Min LHe level during pumping step	60 %
Flow during pumping step	~5 g/s
Refill time at 30 mbar	40 min
Flow during refill step	~8.5 g/s
Total Time for CD 300 K -> Cryo_Ok (without interruption)	**58 h (2.5 days)**

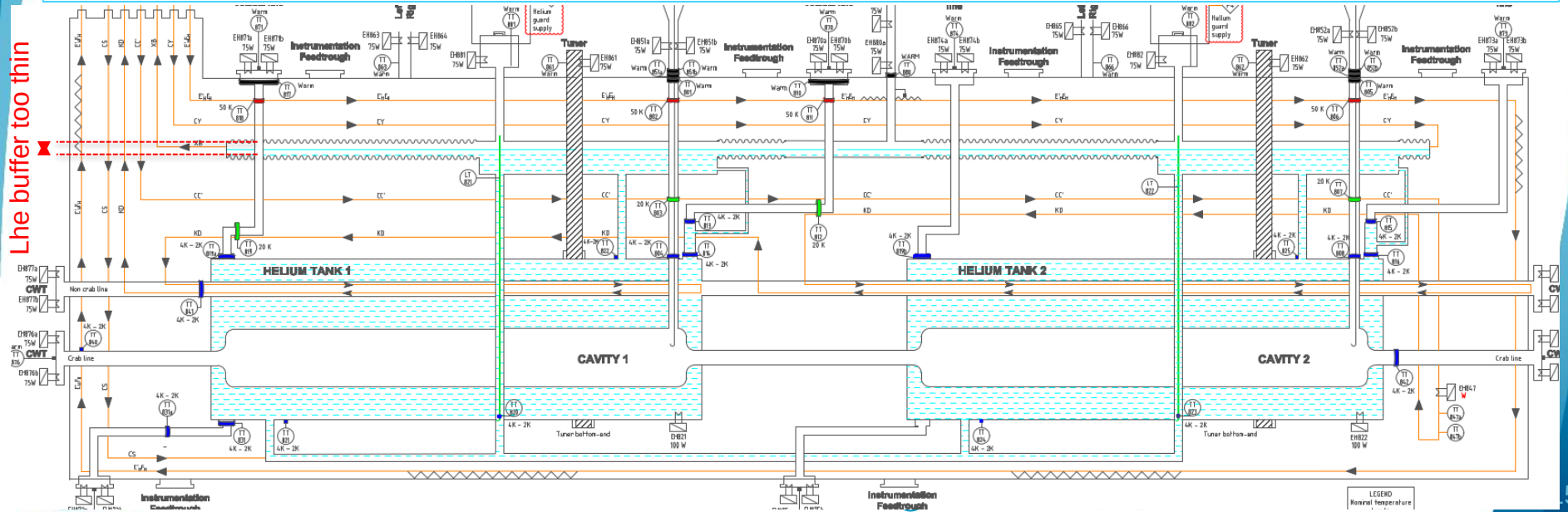
Process aspects – Nominal operation @ 2 K

Flow during nominal operation @ 2 K : 3.5 g/s [Eq. Heat load: 70 W]
Flow through Thermal Screen + Beam screen : 2.4 g/s + 0.3 g/s

<u>Limitation of instabilities during RF conditioning</u> :

- LHe level not easy to maintain with dynamic heat load. It can drop suddenly due to geometrical aspects (chimney)
  - ✓ Setting level controller with reactive PID parameters.
- Adaptation of Cryo_Ok logic to gain margin
  - ✓ Bigger margin with LT threshold (Low level set at 80% instead of 88% before)
  - ✓ Pressure SetPoint lowered from 30 to 20 mbar

Lhe buffer too thin



Process aspects - conclusion

- What went well
  - cooldown & warm-up
- Engaged manpower / resources, time spent for preparation
  - 3 days for cool down; 3 days for warmup
- What could have gone better
  - Bigger LHe buffer on top of the cavities
    => to have more operational margin on liquid helium level regulation

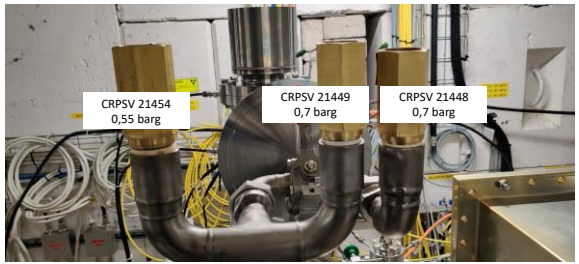
NC RELIEF VALVE

NC relief valve

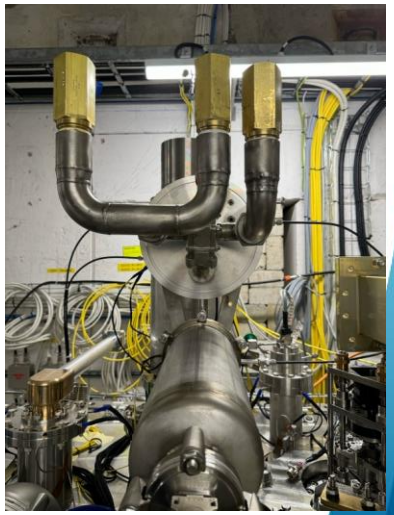
- Valves found leaky on Nov. 10th'24
  - Reference: EDMS document 2998467 v0.1
  - HSE test outcome: all 4 valves leaky between 160 mbarg and 220 mbarg (for a set pressure of 350 mbarg)

- Mitigation for M7 operation in 2023-2024
  - Removal of the PRV HeGuard
  - Use of 1 single relief valve (Circle Seal) with set pressure of 700 mbarg

- Retained setup



References of the Circle Seal relief valves used for the RFD prototype cooldown and warmup in M7



NEXT STEPS

Next steps

- Complete the tests of RFD prototype in SM18
- Review the series P&IDs (+ update instrum list)
- Solve every non-conformity
  - CRG side: replace the currently installed pressure relief valve and re-install the associated HeGuard
- Get prepared for SPS BA6 operation of the RFD prototype
  - Installation & Commissioning with cryogenic test facility at SPS BA6

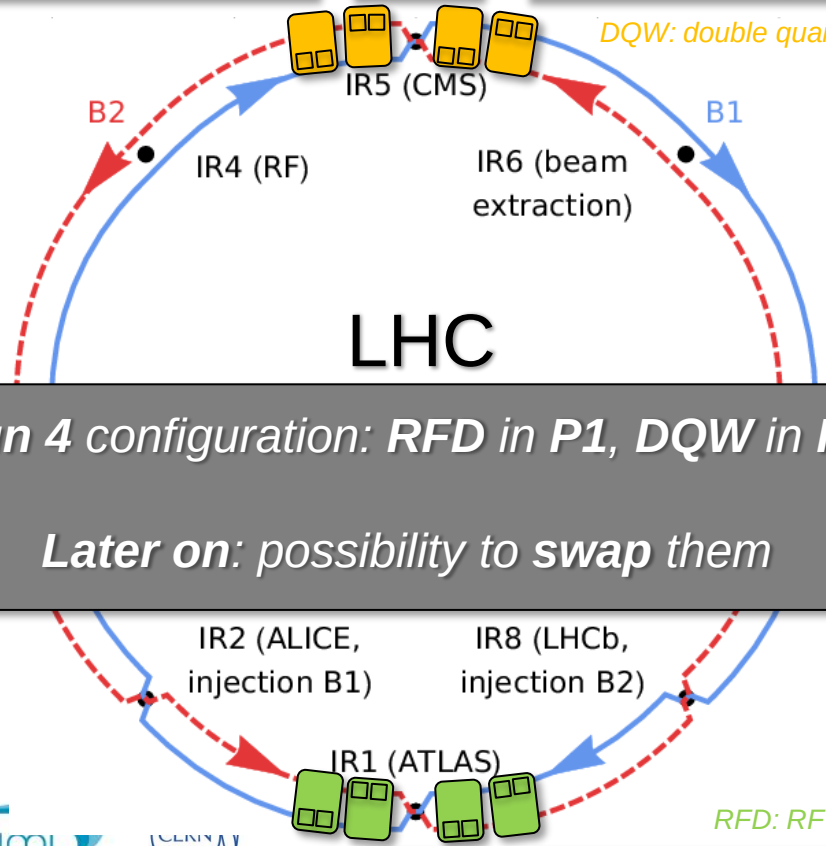
THANK YOU

SPARES

10 series cryomodules

1 from CERN (CH) | *DQW* | *4 from STFC (UK)*

DQW: double quarter wave



Run 4** configuration: **RFD** in **P1**, **DQW** in **P5

***Later on**: possibility to **swap** them*

RFD: RF dipole

RFD | *5 from TRIUMF (CA)*

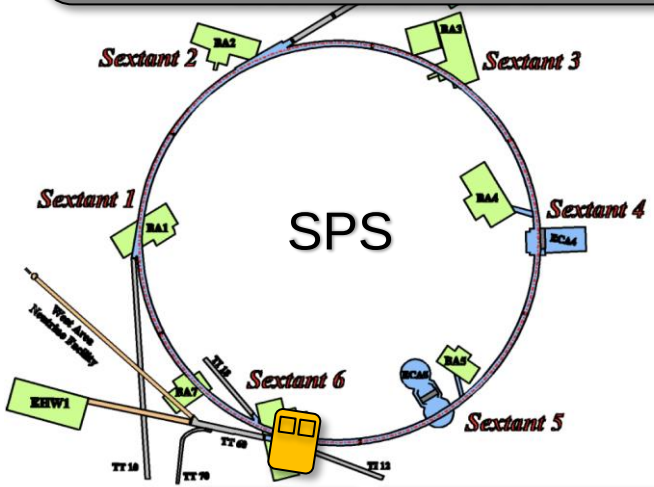
2 prototypes

*RFD *** | *1 from STFC (UK)*

*** Being manufactured at STFC*

***DQW** being tested at cold in SPS BA6*

***Later on**: RFD to be installed / tested at cold in SPS BA6*



*DQW ** | *1 from CERN (CH)*

** Currently operated in SPS BA6 @ CERN*