Crab cavity cryogenics – work progress

K. Brodzinski
on behalf of HL-LHC WP4 and WP9 working teams

2021.10.20_HiLumi Annual meeting, CERN, Geneva, Switzerland

Outlook

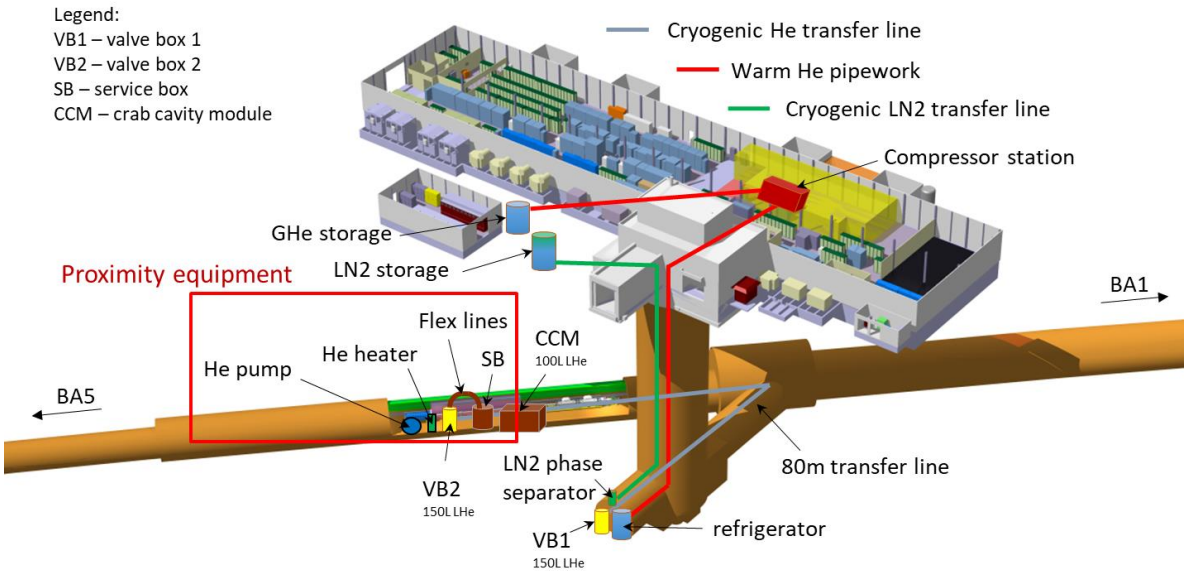
- SPS BA6 test stand
  - Operational feedback from 2021
  - Spares, consolidation and necessary adaptation for RFD
- SM18 M7 preparation update
- Heat load design review
- HL-LHC cryogenic distribution design progress
- RFD design progress
- Conclusions

SPS BA6 test stand

SPS BA6 (LSS6) – underground cryogenic test facility located in SPS (placed on direct LHC beam injector, 450 GeV). It was commissioned in spring 2018 and put in operation for prototype of DQW crab cavity module.

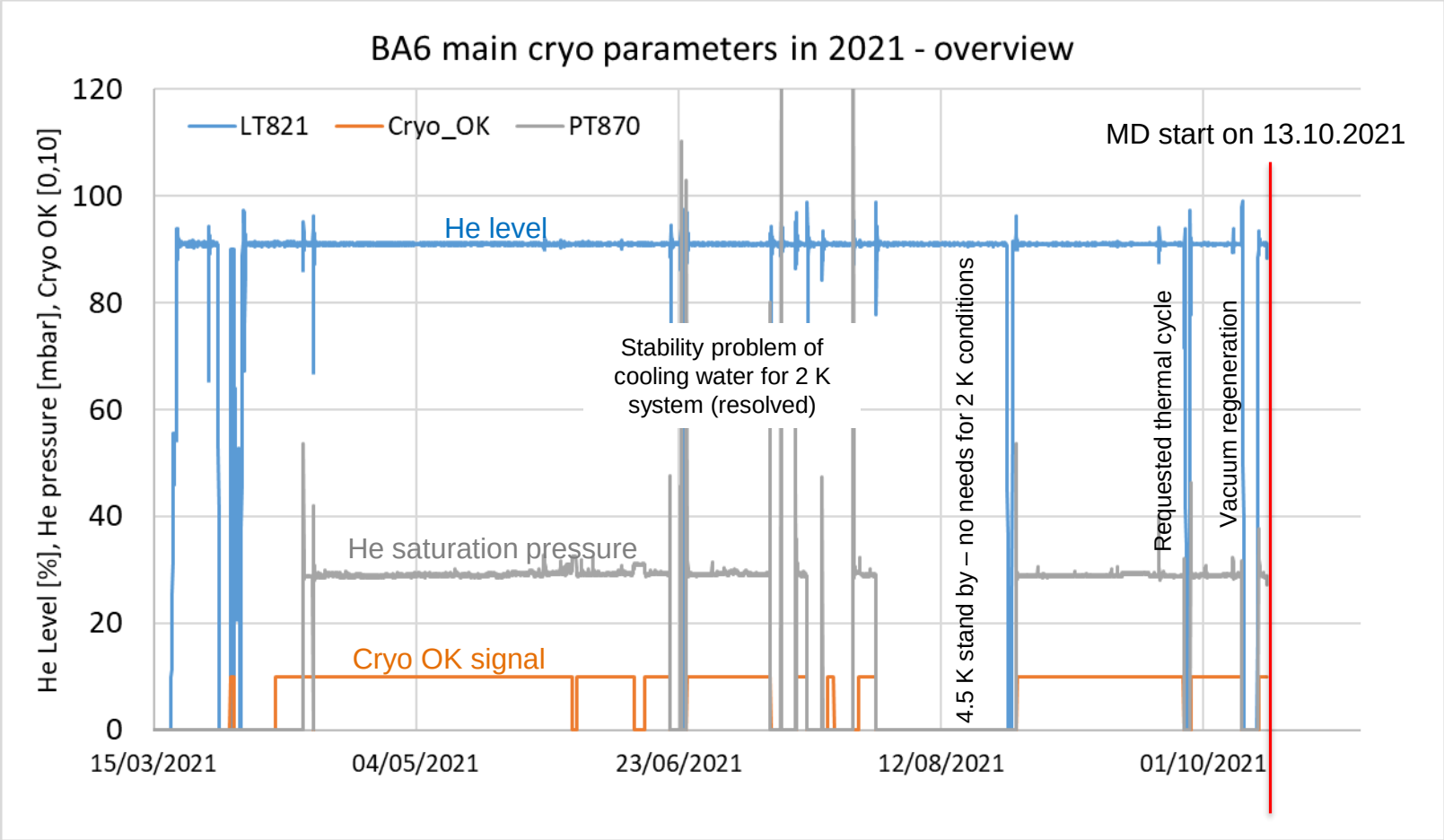
Main parameters:

- Cryoplant with ~750 W at 4.5 K of refrigeration power (or ~7.5 g/s of liquefaction rate)
- 2 K system allows for ~3.5 g/s of He pumping at 30 mbar
- Service box interface with proximity equipment provide connection to ~50 K thermal shield and 2 K or 4.5 K supply circuit (not at the same time).



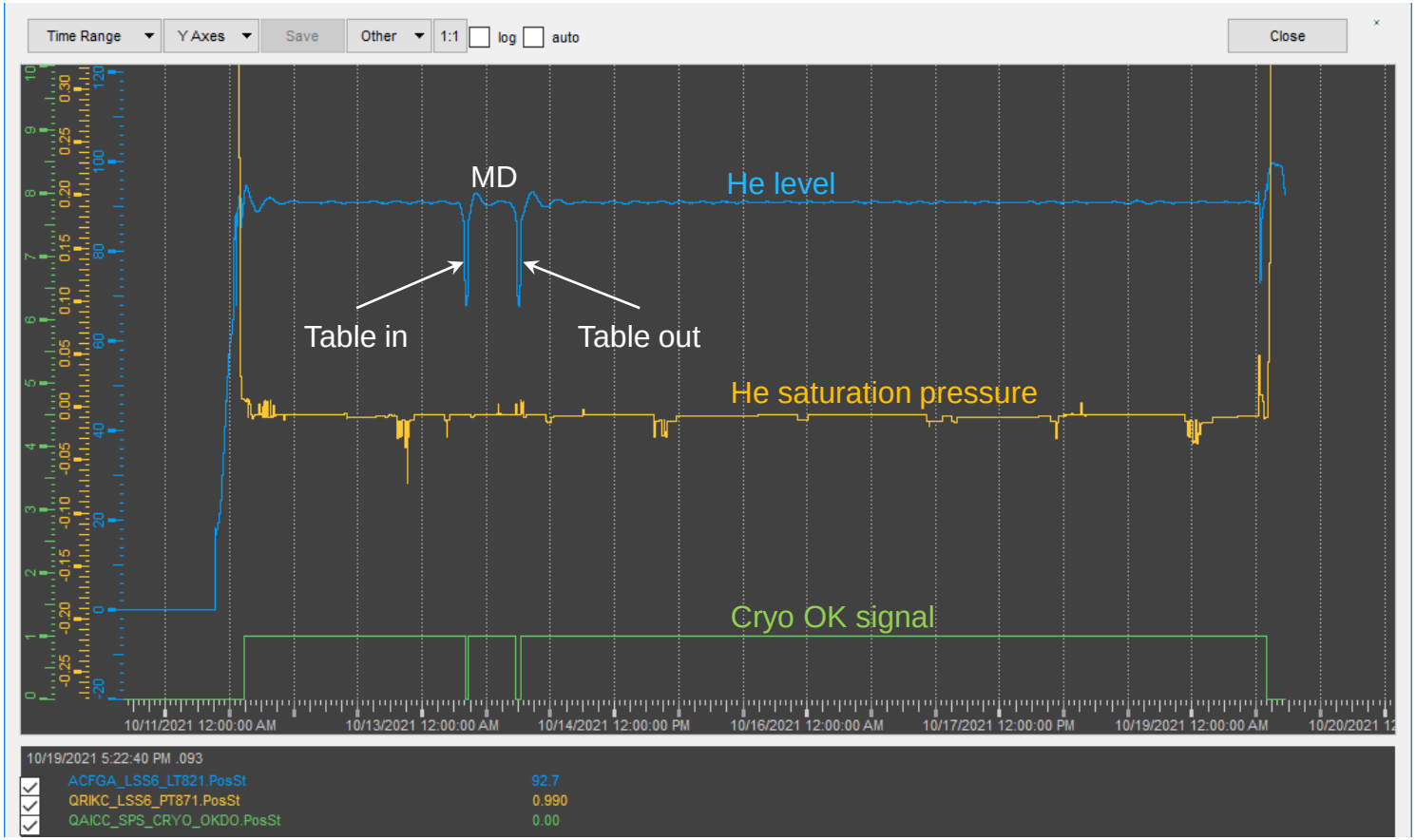
SPS BA6 operation in 2021

Long run done in 2021, some unexpected perturbation from cooling water of 2 K helium pumps experienced, expected stability re-found from September.



SPS BA6 operation in 2021

Cryogenics for MD period and further investigations provided stably.



12.10.2021 — 19.10.2021

SPS BA6 additional comments

Spares:

The adopted strategy for the spares covers two sets of turbines for the cold box (refrigeration and liquefaction modes). No other spares are available as for now. Special attention shall be payed on helium pumps, lost of any of two units might produce long term (several months) unavailability of the system (considering also their integration place behind the SPS beam pipes).

Necessary consolidation:

Done: the LN2 stability was improved thanks to installed additional instrumentation. The VB2 positioning and internal piping were corrected during LS2. Migration to Unicos system for remote control of the refrigerator is ready for implementation.

To be done: Additional oil separation unit (coalescer) is necessary to be installed in TA6 upstream the helium flowmeter to prevent from oil migration and the flowmeter failures during operation (hardware + manpower estimated at ~20 kCHF). The coalescer is recovered from ex-CMS system and can be adopted for SPS needs.

Necessary interface adaptation:

The jumper connection between the Service Box and RFD cryomodule shall be re-designed since it is different from DQW ➔ action MME with KB. The beam screen circuit will not be supplied in SPS but will be tested earlier in SM18 M7.

SM18 – M7 preparation update

Specification with the functional description of the cryogenic requirements for RFD prototype was prepared and sent to mechanical team this summer.

HiLumi-LHC-CC-Cryo-N-39, EDMS 2647024

Functional description of operation modes for RFD prototype Crab Cavity tests at SM18 and in SPS

1. Introduction

This document gives general functional description of foreseen operation modes related to RFD prototype module of the crab cavity test in SM18 and SPS. These operation modes are:

- Cool down and filling
- Normal operation
- Empting and warm up

The carb cavity cryogenic system is composed of 4 cooling circuits: 2 K normal operation circuit, 4.5 K cool down circuit, 4.5 – 20 K beam screen circuit related to non-crabed beam line) and 60-80 K thermal screen circuit. The corresponding flow diagram of the RFD prototype crab cavity module is presented in Annex 1 and also available via CDD with the following reference: CRNLSQLJ0070.

2. General requirements

The SM18/M7 cryogenic system shall be designed in a way allowing for exchange and conditioning of the crab cavity module without polluting or without necessity for warming up of entire cryogenic distribution system (purge operation and exchange of the crab cavity cryomodule shall be possible only with local warm up of the exchanged module). The isolation of SM18 cryogenic system for CC cryomodule exchange shall be possible using M7 bunker equipment.

It is important to keep in mind that only first DQW prototype was equipped in M7 with related Service Box (now installed and operated in SPS) and all remaining modules starting from first RFD prototype will be directly connected to M7 infrastructure. It means that M7 infrastructure shall provide all required operational functionalities.

The interface drawing for the crab cavity connection is presented in Figure 1.

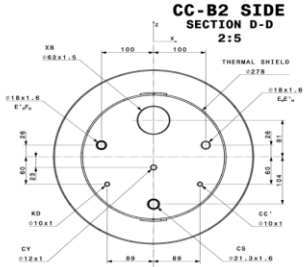
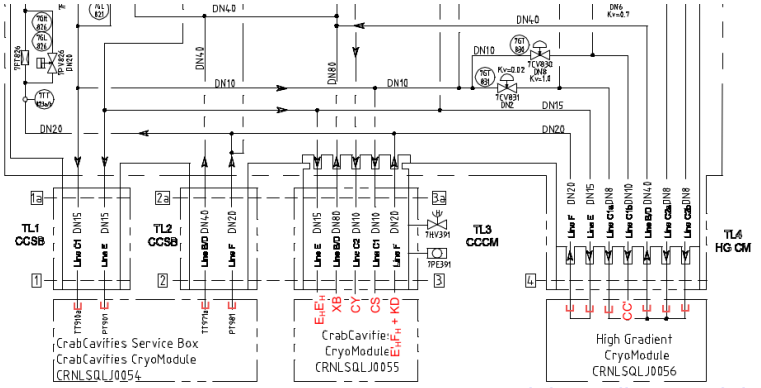


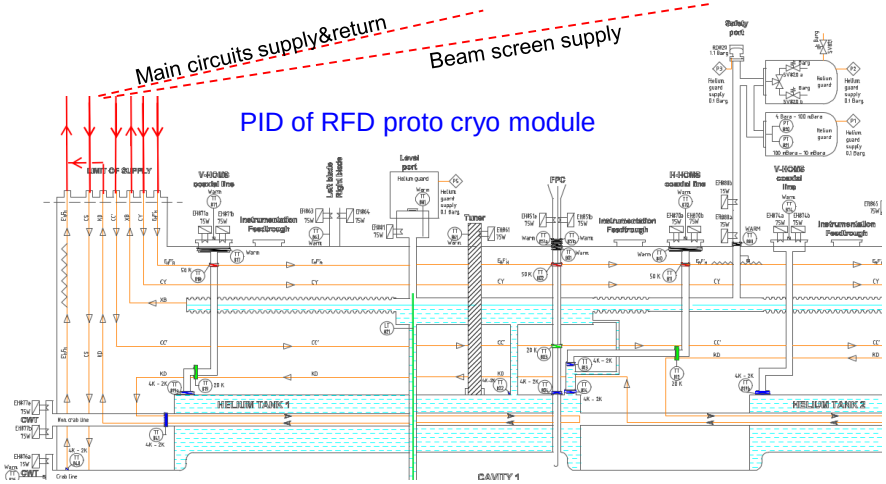
Figure 1 Crab cavity jumper interface – extract from CDD ref. LHCQXL_0020.

K. Brodzinski, 23.07.2021_v1

First study of the process and feasibility analysis was done. Work is in progress targeting May 2022 for the implementation.

PID of existing cryo valve box in M7

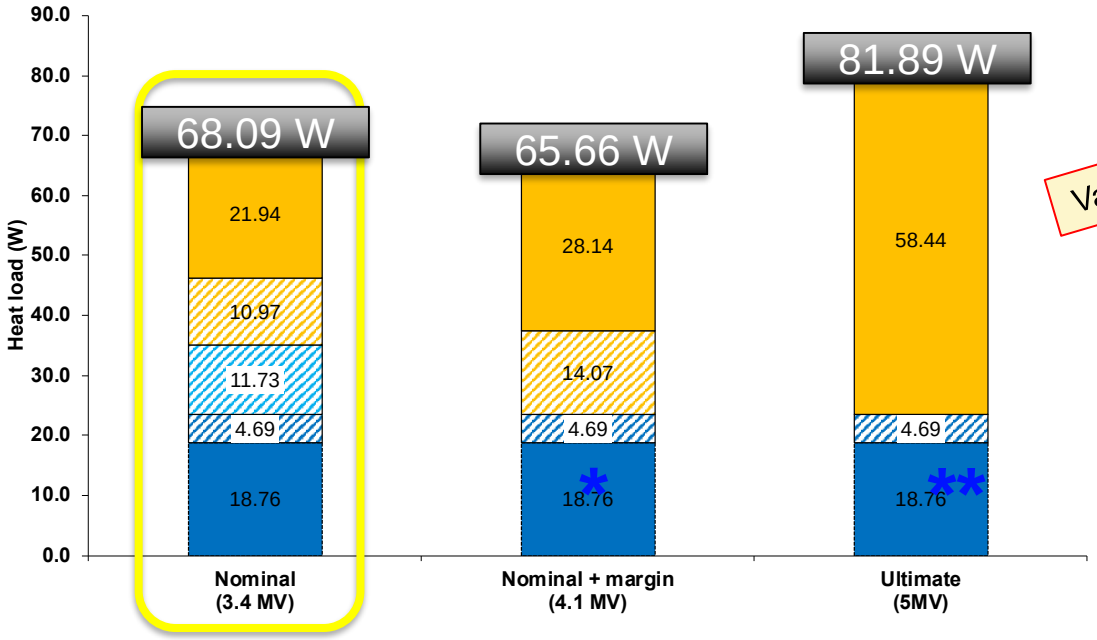




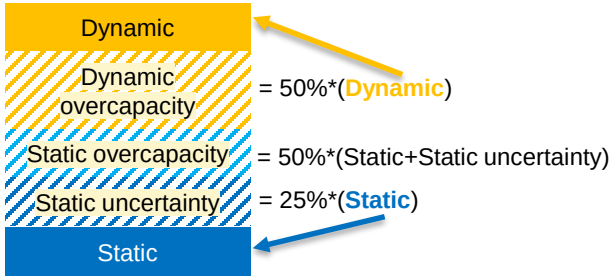
Status: RFD interface drawing is prepared. Engineering study on design of the connection transfer line started.

HiLumi Heat load review 2021 – crabs

HiLumi heat load review held on 27th April 2021. Value of needed cryogenic capacity defined. Cryogenic plant and infrastructure will be designed to cope with ultimate case values. More details on: https://indico.cern.ch/event/1019569/



Values for 1 cryomodule!



** *No overcapacity applied to ultimate case*

	3.4 MV	4.1 MV	5 MV
Comments	**Heat load @ 2 K (W)**		
Dynamic	21.94	28.14	58.44
Dynamic overcapacity	10.97	14.07	-
Static overcapacity	11.73	- *	-
Static uncertainty	4.69	4.69	4.69
Static	18.76	18.76	18.76
TOTAL	**68.09**	**65.66**	**81.89**

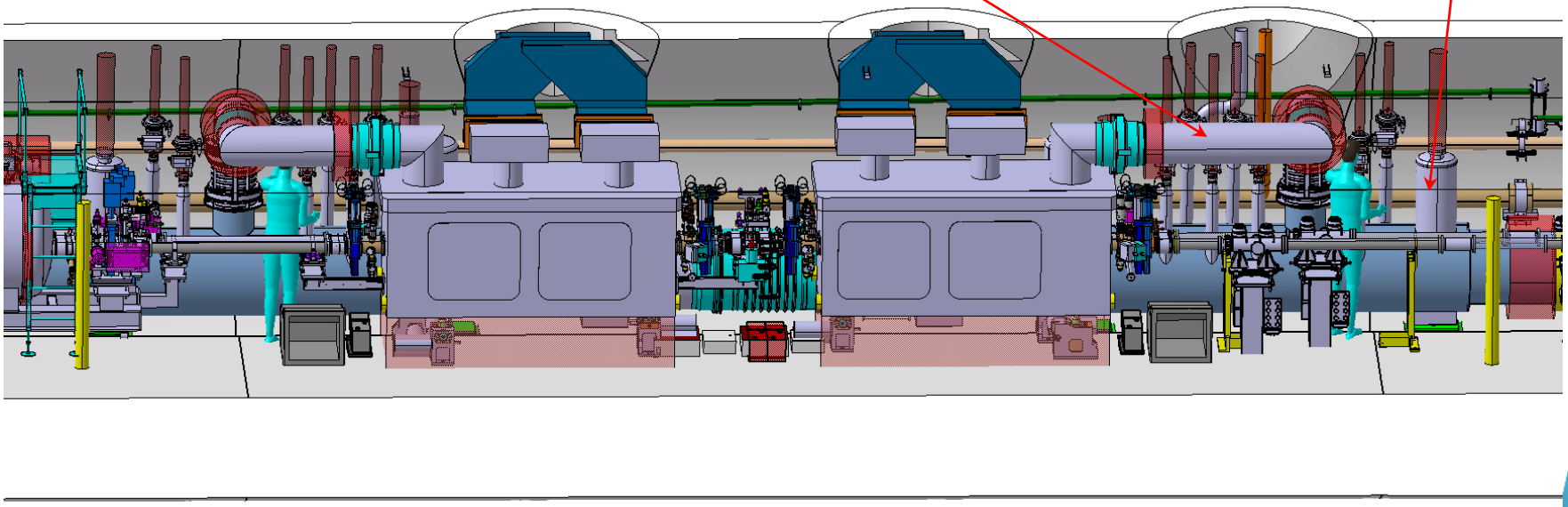
* *Static overcapacity not applied to the 4.1 MV case as already included on RF side for nominal 3.4 MV case*

Supply system for crabs in HL-LHC

HL-LHC – specification of the distribution system is being prepared. Input parameters for design of the system are being defined (including integration) with related ECR for the optics adaptation and for cryomodules position (EDMS 2645150 under approval), including independent warm up of the cryo modules.

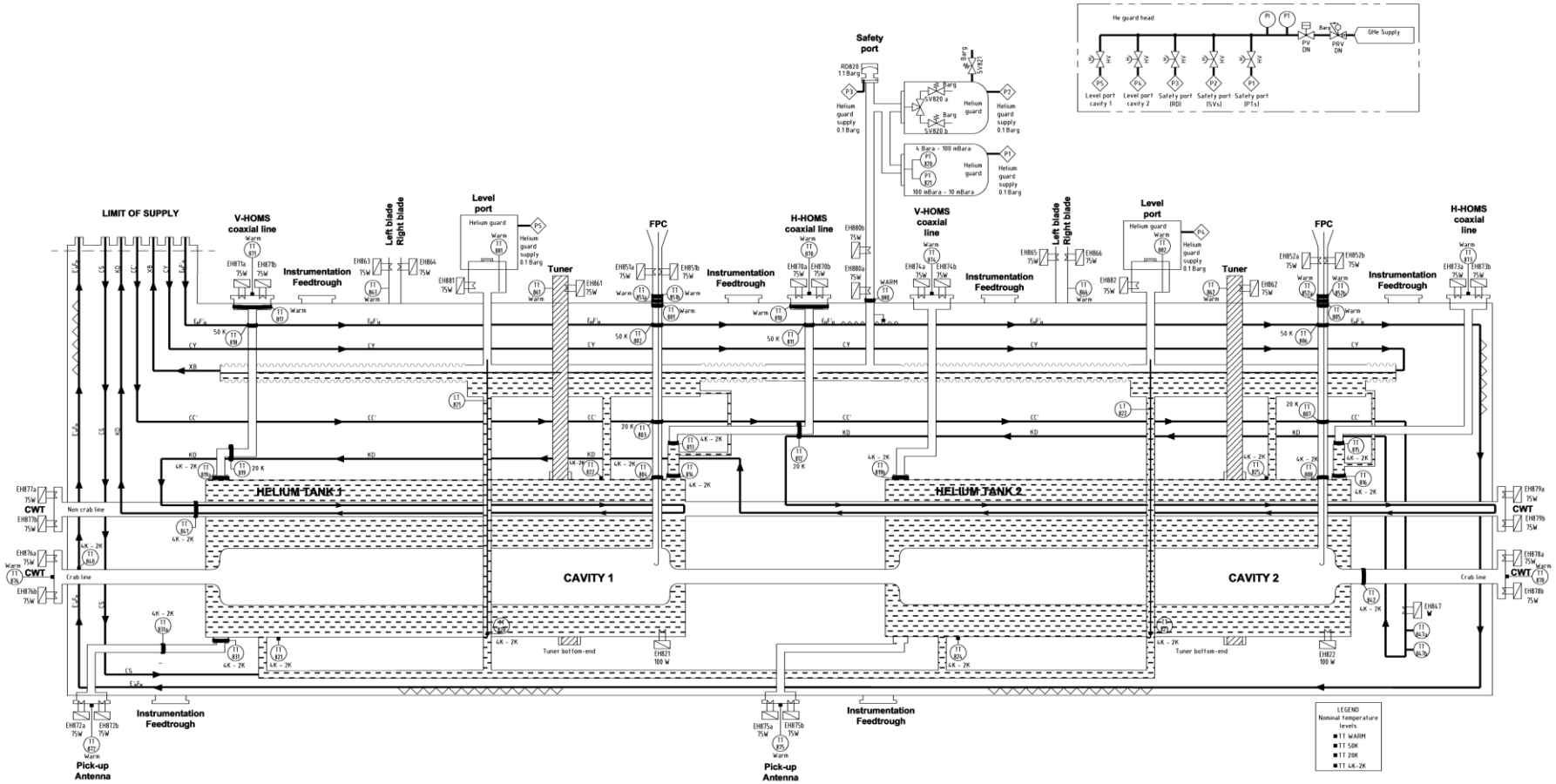
Jumper connection between the Service Module and the CC cryomodule, housing cryogenic supply and return lines.

Warm up heater



RFD proto design progress – PID

The PID of the RFD prototype is ready, validated and transmitted to all partners.
Reference EDMS/CDD: *CRNLSQLJ0070*



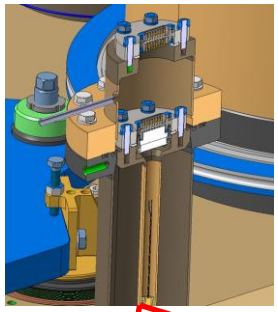
RFD couplers instrumentation

Between March and April 2021 three FPCs (two standard + one spare) were equipped with 6 EHs and 2 TTs (PT100) by CRG instrumentation team.
The work was done onsite at CERN in 864-1-D002 in RF workshop.
Then all FPCs were sent for further assembly process by RF team.

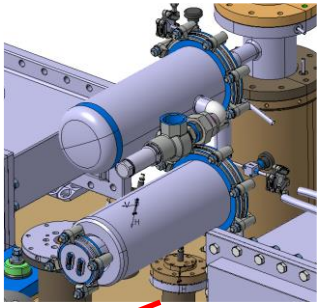
RFD proto – instrumentation

Definition of the feedthroughs is done. There are 5 types of feedthroughs integrated on the cryomodule. All feedthroughs were marked for identification as per quality insurance plan.

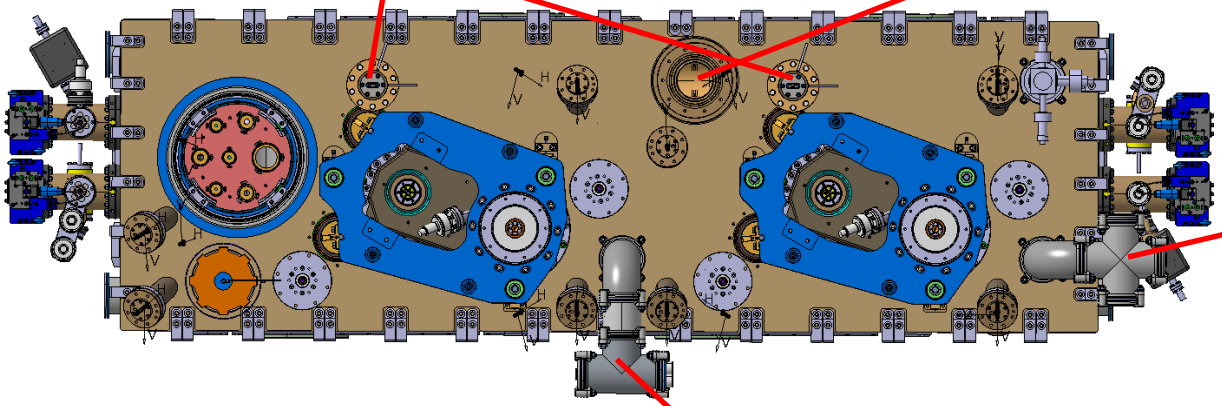
LTs+TTs

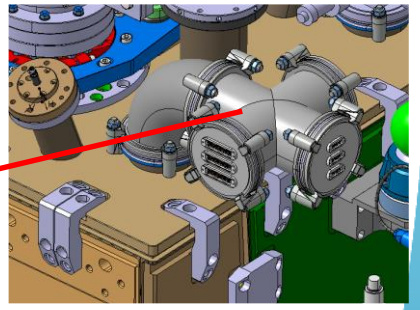


PTs

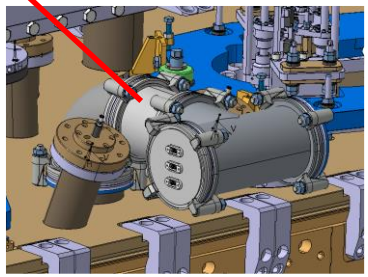


TTs





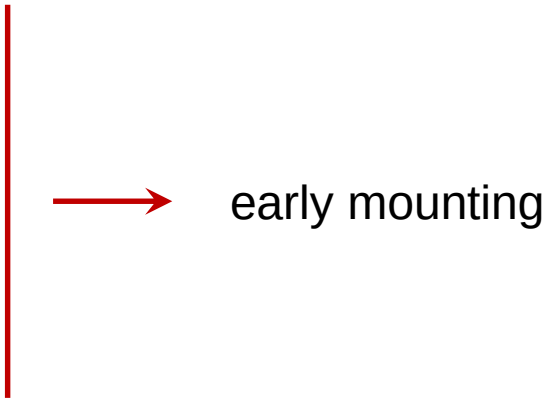
EHs



RFD proto – instrumentation

Status of order:

- The following equipment is received at CERN and ready for distribution:
  - Rupture discs
  - Safety valves
  - Helium bath heaters
  - Beam screen heater
  - Level Transducers
  - Pressure Transducers
  - Cernox TT transducers
  - Feedthroughs



- The following equipment is ordered *(expected by end of 2021)*:
  - External heaters to avoid condensation outside the cryomodule
  - External TTs (PT100) as regulation or protection of the heaters

- To be ordered *(expected by end of 2021):*
  - Feedthrough connectors

Conclusions

- There are several fronts which are under development:
  - Preparation of SM18 M7 bunker
  - Upgrade of SPS BA6 oil separation and adaptation of the interface for RFD prototype
  - Design of RFD prototype with (hydraulics is done, instrumentation being finalized)
- Exploitation of BA6 with tested DQW module is under full control, MD done providing stable conditions,
- Progress in design of RFD prototype in collaboration with MME goes very well
- HL-LHC distribution system design is progressing with first integration models (and with heat load review this summer as an important milestone),
- Instrumentation well advanced, related input files for the assembly of the module shall be completed very soon.

HiLumi
HL-LHC PROJECT

Thank you for your attention!
Questions?

CERN

Great thanks to all people involved in HiLumi adventure!