BA6 cryogenic installation & experience, HL-LHC outlook

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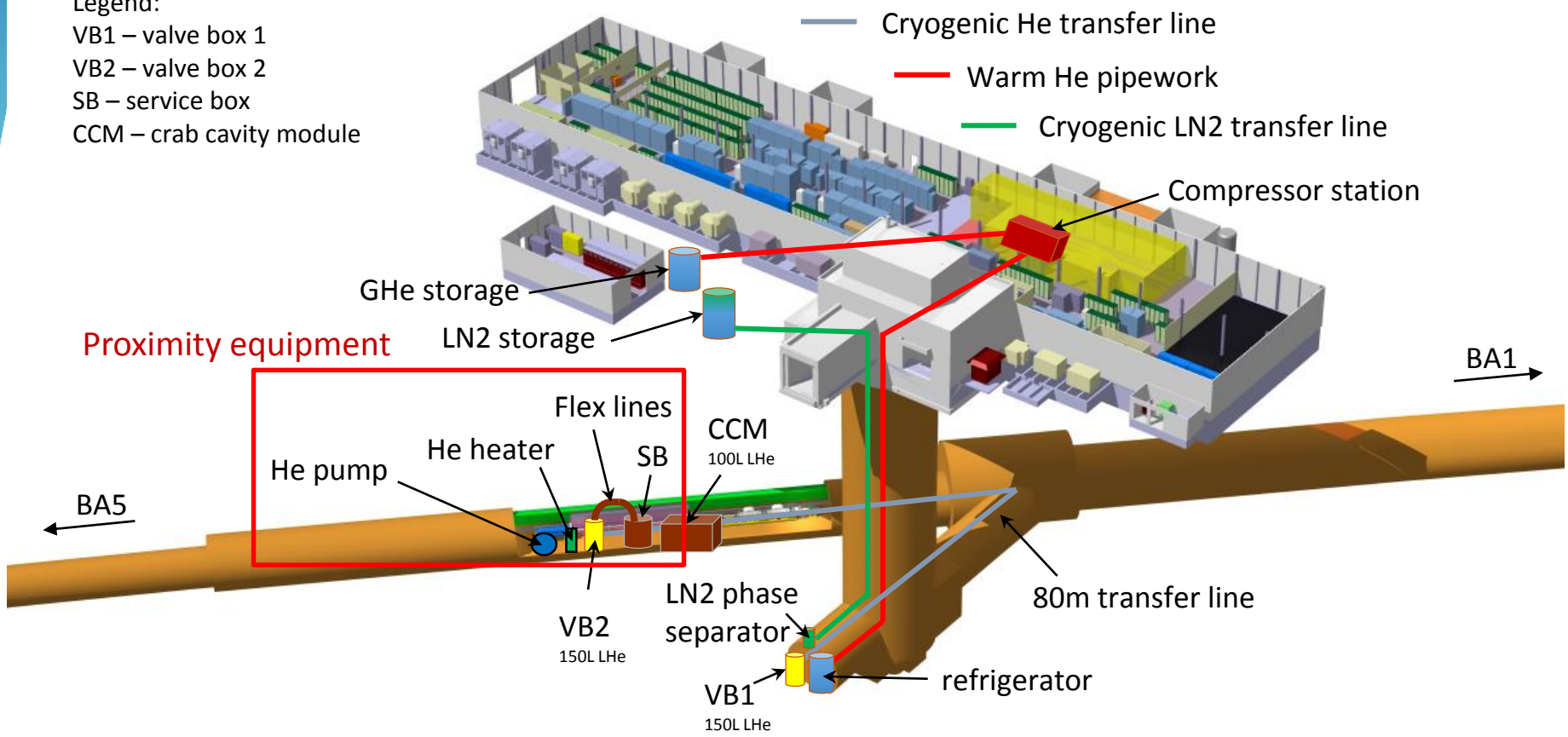
Outlook

- Summary of BA6 operation in 2018
  - Operational experience
  - Heat load estimation
  - Instrumentation failures
  - Outlook on BA6 run until end of 2018 and beyond
  - RFD design aspects
- First PFD for crabs at P1 and P5
- Conclusions

General layout

Legend:
VB1 – valve box 1
VB2 – valve box 2
SB – service box
CCM – crab cavity module



Cold Box:
- Supply 4.5 K helium into distribution system

Distribution system (VB1, 80 m transfer line, VB2):
- Distribution of helium at required thermodynamic parameters between the CB and PE

Proximity equipment:
- makes direct refrigeration interface to the crab cavity module
- allows for operation of the cavities with superfluid helium at 2 K

2018 run of BA6 cryogenics – overview

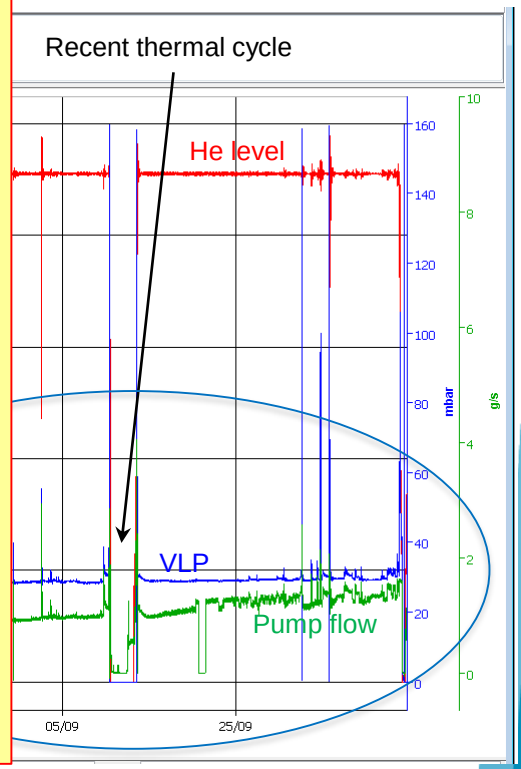
Run at 4.5 K

LN2 impurity problem treated and 2 K comissionning

Run at 2 K

It is important to recognize remarkable operability of entire helium cryogenic system, especially:

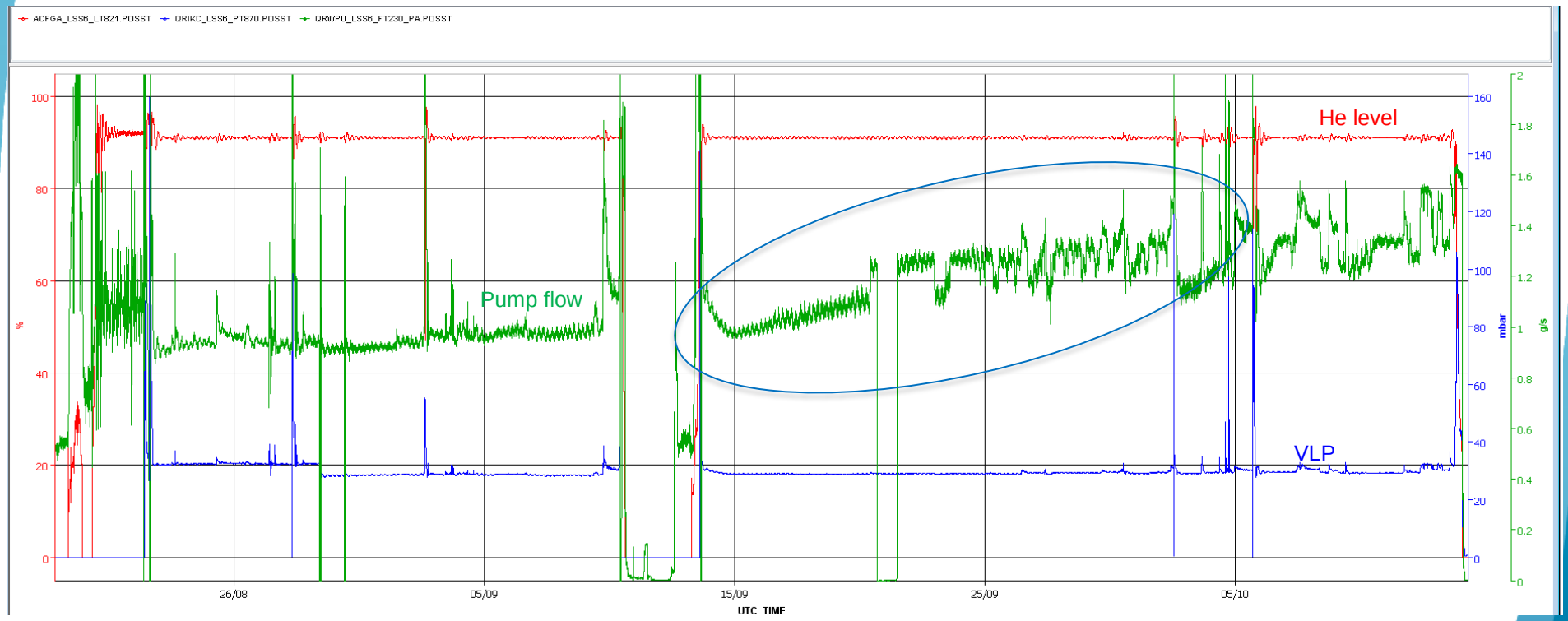
- Reliability of 4.5 K refrigerator with well sized capacity margin (built as mobile solution for other defined applications),
- Stability and thermal performance of the distribution system (VB1, 80 m transfer line and VB2 and innovative solution of multichannel flex lines),
- operational stability of 2 K equipment,
- No impurities present in sub atmospheric part of the system (nearly miracle!) – thanks for work quality of installation team!
- Reliability and flexibility for operational recoveries of 2 K pumps (over 10 years ex-AMS equipment adapted for Crabs)



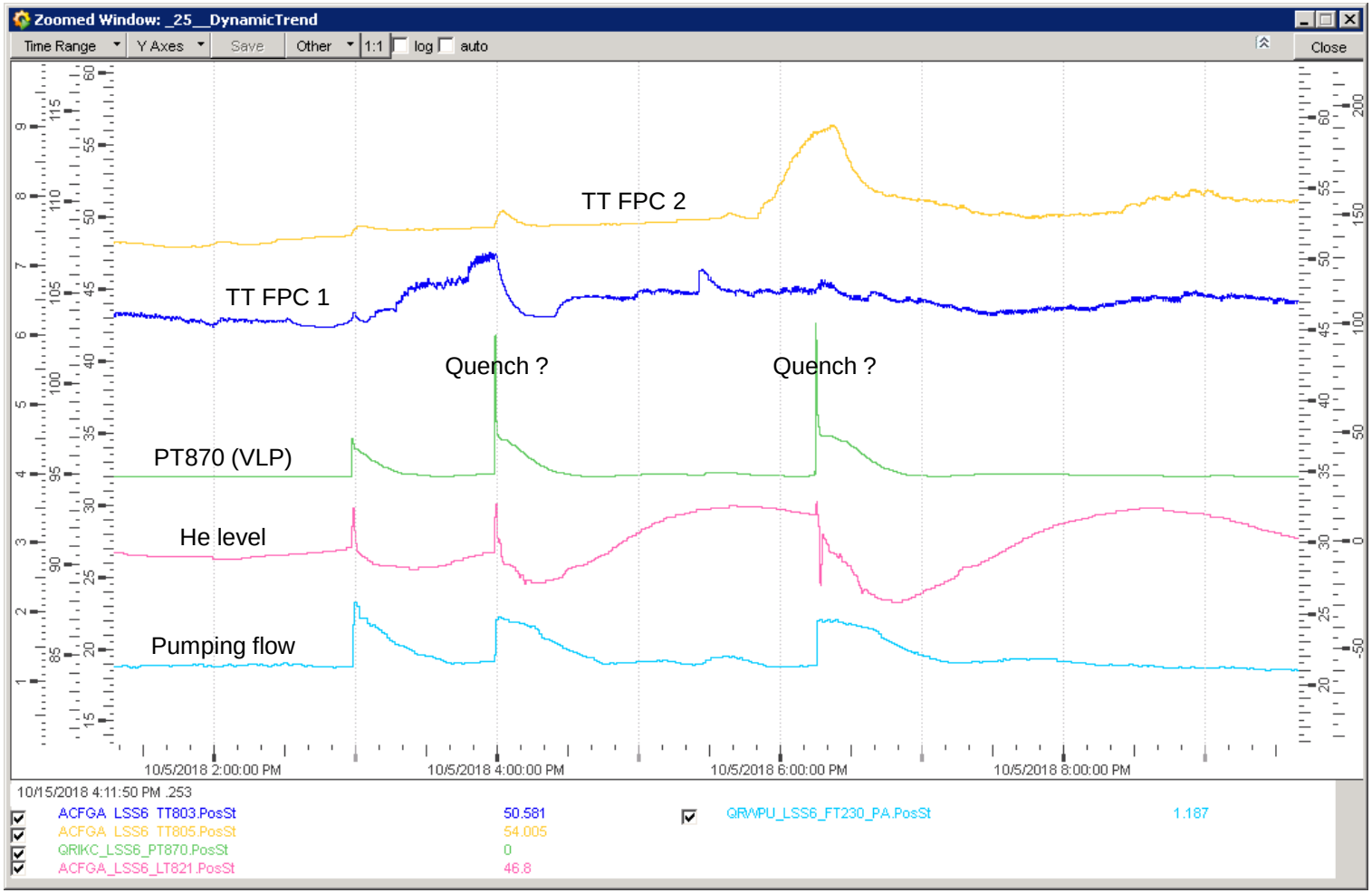
- 3 months of operation at 4.5 K
- 2 months of operation at 2 K (until now)
- Very good availability (after LN2 problems treatment and 2 K comissioning)
- Very good stability of the system (within ~1 mbar at 2 K)

Run 2018 – focus on September

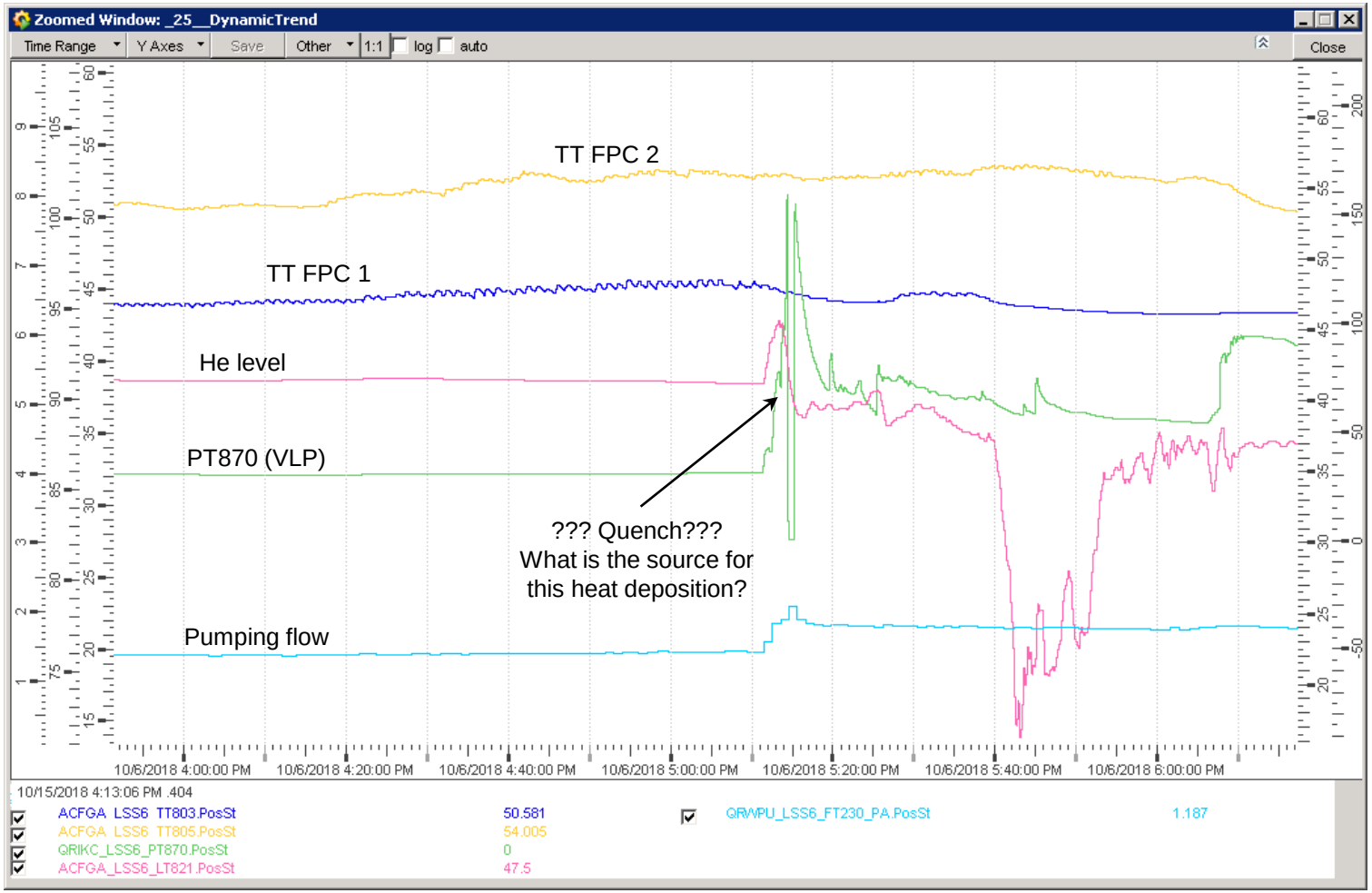
The pumping flow between 15th and 25th September increased from ~0.9 g/s to ~1.3 g/s i.e. static heat load of the module and Service Box increased from ~18 W to 26 W -> no explanation of this phenomenon for now …



Run 2018 – focus on October 1/2

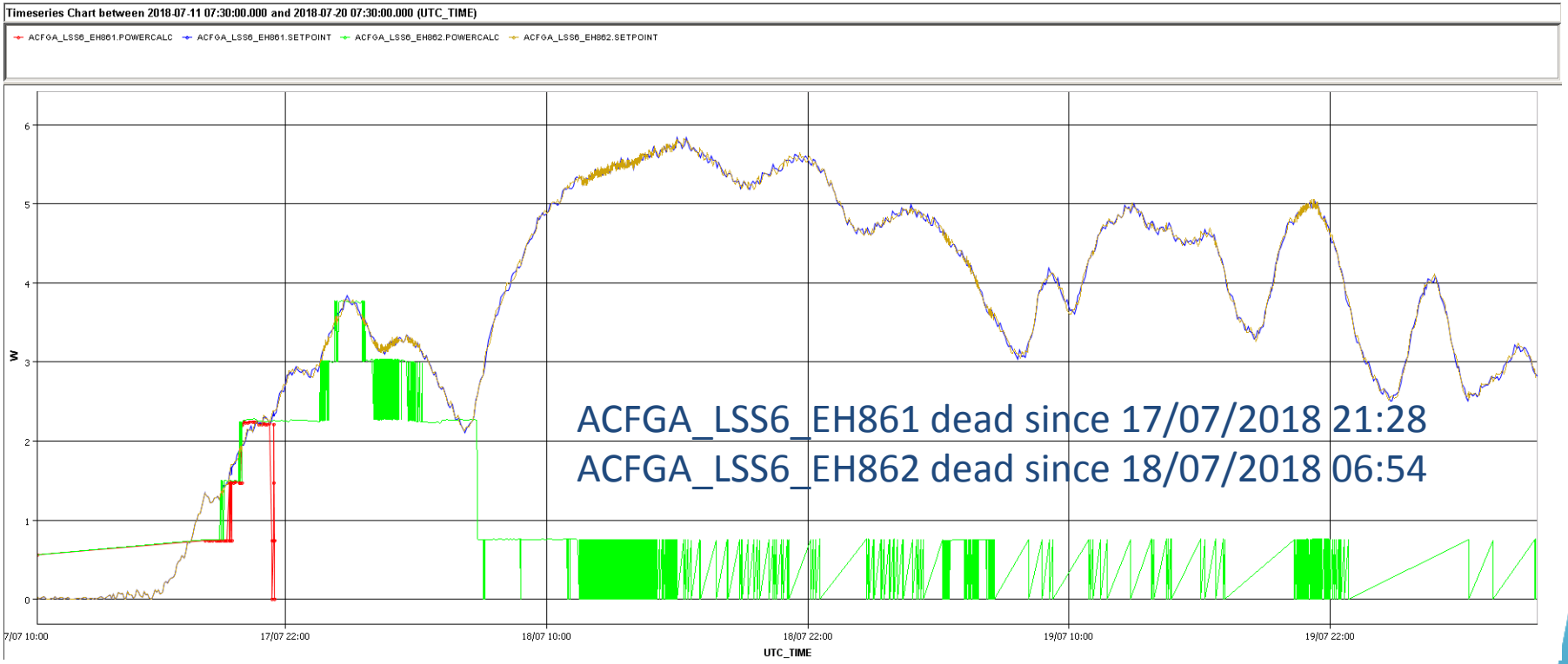


Run 2018 – focus on October 2/2



Major instrumentation failures

We have lost two heaters on the tuner heads. After visual inspection KB + Rama we decided to continue run without any special corrective actions since no condensation/ice was visible on the top of the tuners.



Outlook until end of 2018 and beyond

- Cryogenics for BA6 is foreseen to run at 2 K until end of November
- TS3: endoscopic inspection on Tuners may be performed to investigate for ice presence and potential blockage of Tuner 1
- Number of quenches and safety stops of 2 K pumps shall be minimized – such situation is exploiting the pumps in extreme regimes of operation (no spare pump is available).
- LS2 main consolidations:
  - Leak repairs between cold box and VB1,
  - Position of VB2 and flexible lines to be corrected,
  - Installation of additional circuit for independent warm up of the cryomodule thermal screen circuit,
  - Correction of piping to allow cool down and 4.5 K operation without using of 2 K pumps bypass and avoid complete warm up of circulating gas (significant energy savings and elegancy in operation)

Cryogenics for RFD module

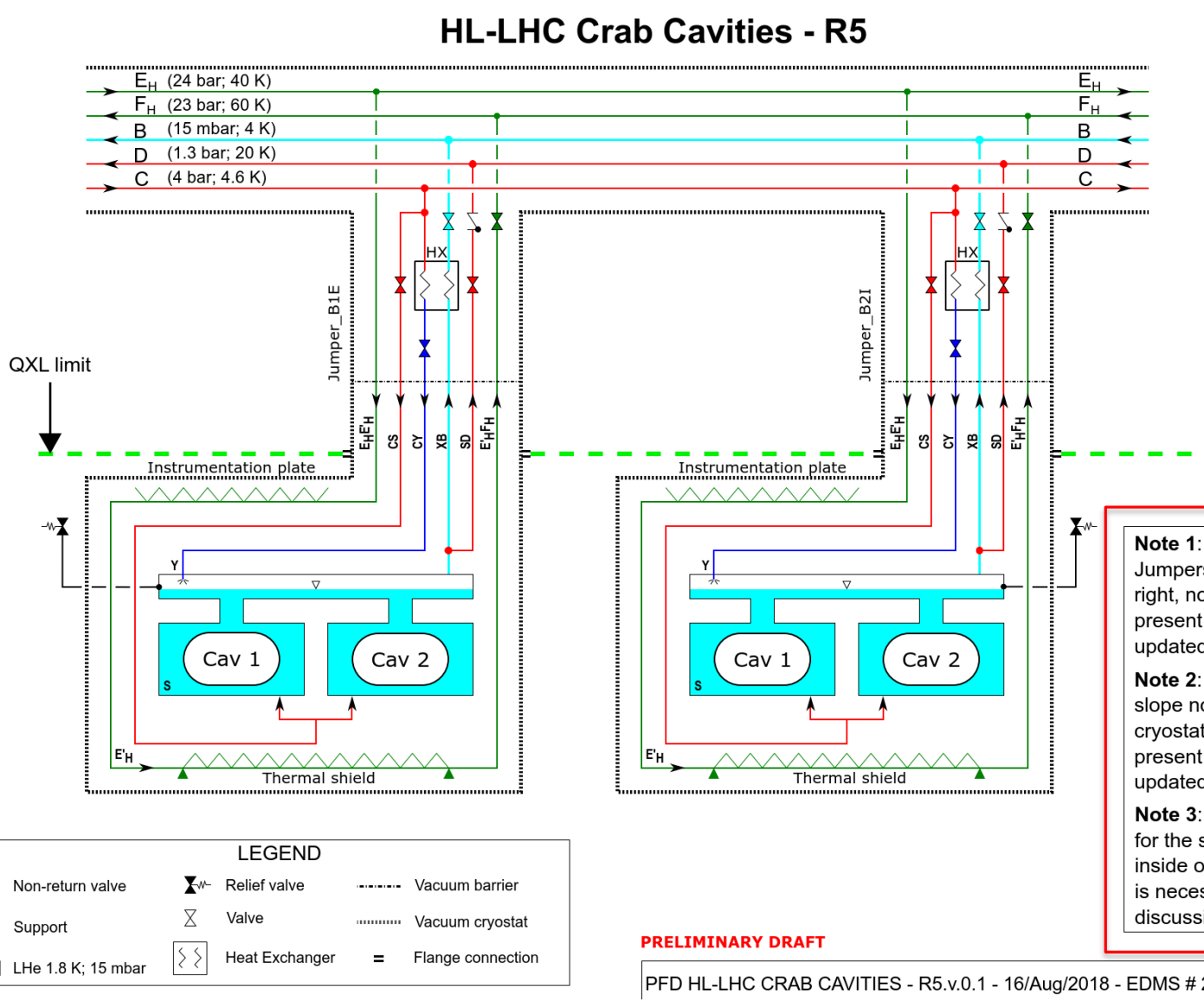
- RFD cryomodule will have one circuit more than DQW – beam screen for "second" beam pipe (operation at 4.5 – 20 K)

- Assumed approach: with lessons learnt on first DQW, we will adapt maximum solutions from first DQW but in the way to make the module compatible for LHC – interfaces and integration. The main differences will concern the following aspects:
  - Jumper interface to be done with standard LHC size,
  - BS circuit to be integrated in the module,
  - 2 K TTs to be installed in the liquid helium (at least 2 sensors),
  - Safety devices to be integrated on the cryomodule (tbc),
  - LTs exchange possible from outside of the cryomodule (tbc).

Additional remarks concerning testing:

- Present SPS Service Box interface was not designed for "LHC compatibility" – adaptation of jumper interface to be designed, in addition w/o major modification there is no possibility to supply BS circuit,
- SM18 M7: similarly to SPS, M7 is not designed to supply BS but required modifications are less invasive than in SPS.

HL-LHC first pfd study



Note 1: position of the Jumpers, left, center, right, not jet defined; present PFD to be updated accordingly.

Note 2: influence of the slope not jet defined; cryostat orientation on present PFD to be updated accordingly.

Note 3: beam screen for the second beam inside of the cryomodule is necessary and under discussion at present.

PRELIMINARY DRAFT

PFD HL-LHC CRAB CAVITIES - R5.v.0.1 - 16/Aug/2018 - EDMS # 2013776 - M.Spitoni

Conclusions

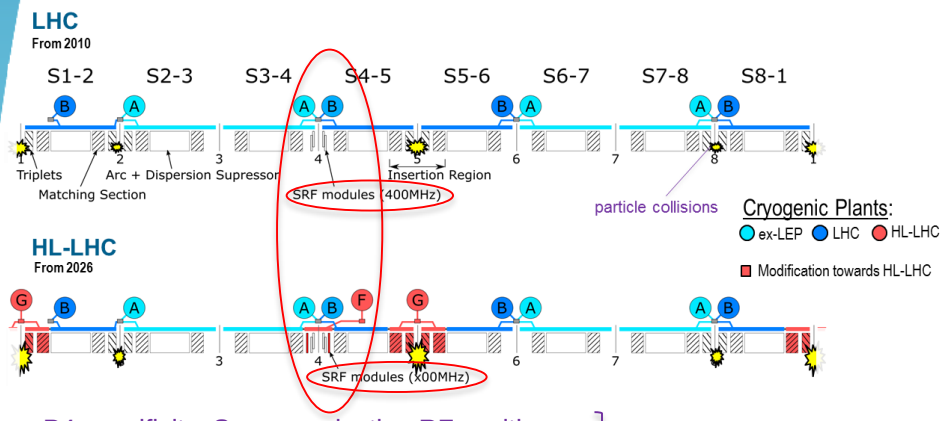
- BA6 cryogenics is running well – reliable 4.5 K refrigerator operation, good performance of the distribution, remarkable stability and flexibility for transients of 2 K pumping system
- Water impurities in LN2 system definitively cleaned in August 2018
- Investigation on Tuner 1 is foreseen during TS3
- More understanding on increased static heat load as well as sources of abrupt thermal loads (related to quenches?) is necessary – action BE/RF +EN/MME +TE/CRG
- RFD cryomodule cryogenics design started EN/MME+TE/CRG
- Testing infrastructure for RFD to be reviewed, adaptation to be clarified
- P1&P5 configuration and interfaces study started.

Thank you for your attention!
Questions?

Great thanks to all people involved in HiLumi adventure!

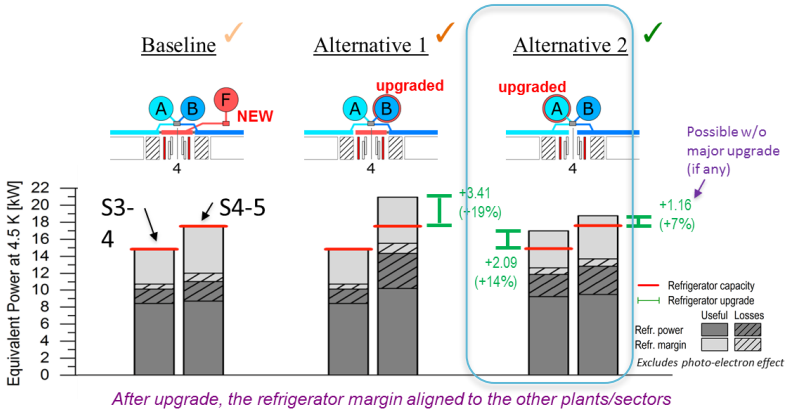
HL-LHC P4 status

LHC configuration vs HL-LHC baseline



P4 specificity: Superconducting RF cavities
HL-LHC: Increase of beam induced heat load
⇒P4: Cryo. bottleneck

CERN and AL + LK studies (based on total useful cooling capacity of +2 kW @ 4.5 K)



After upgrade, the refrigerator margin aligned to the other plants/sectors

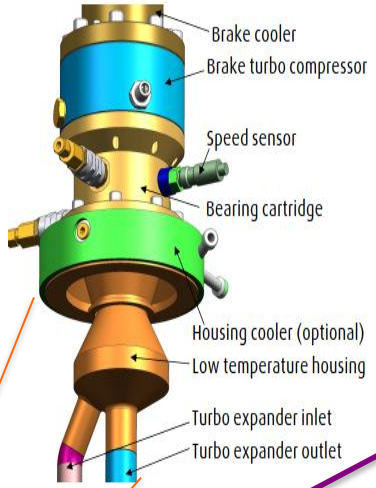
94.R0.00-CETS-0001 - Feasibility Study - Task 1 EDMS # 1753614
Provide process input data for LHCA Upgrade

- P4 capacity upgrade (status and milestones):
  - Tendering documents sent 28Sept'18, feedback expected in 4 weeks (thanks to the 3 technical studies done so far), adjudication foreseen FC_Dec'18
  - On site verification scheduled Feb-Mar'19
  - Turbine housing installation: Q4_2019
  - Test at cold Q2_2020

HL-LHC P4 status

Principle of the capacity upgrade: to replace turbines by new type (more efficient)
This requires exchange of turbine housings & instrumentation

QSRA: 4 Tu



QSRA: 3 Tu (+T9)

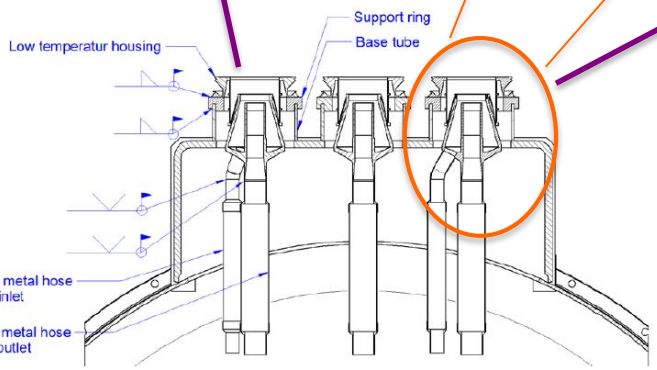


Figure 5: UCB, upgraded, TED45 low temperature housing placement and welding seams