CRYOGENICS – strategy, unavailability root causes and limitations

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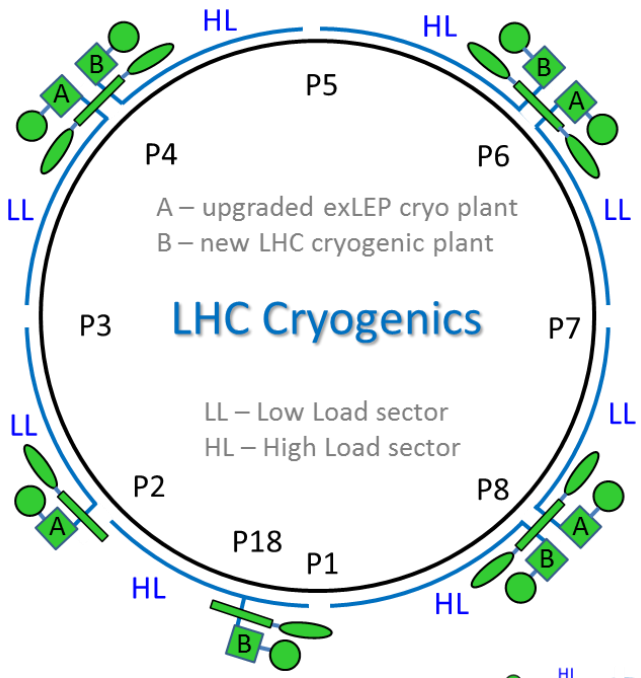
Krzysztof Brodzinski
on behalf of the cryogenic team

With contribution from: S. Claudet, D. Delikaris, L. Delprat, G. Ferlin and E. Rogez

Outlook

- Introduction – strategy and cryogenic hardware configuration for Run2
  - Optimization activities on the beginning of 2016
- Cryogenics availability – statistics
  - Main unavailability root causes
  - Statistics for main rotating machines
  - Helium consumption
- Projection in the future
  - EYETS main activities
  - Proposal of operational scenario in 2017 and limitations
- Conclusions

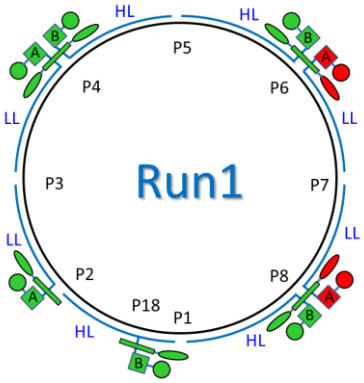
Introduction – strategy

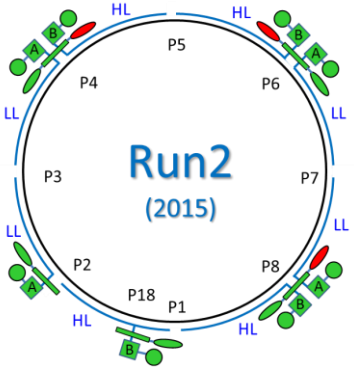


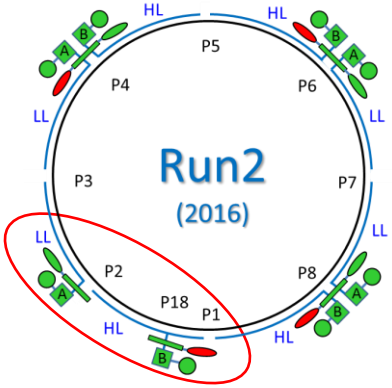
Cooling capacity of A and B are designed to cover nominal LHC operation with equal margins on LL and HL sectors.
BUT:

1. w/o dynamic load B has more capacity margin than A -> easier recoveries,
2. B is more powerful for operation because of its design.

Thanks to build-in interplant connections some special configurations were possible during Run1 and Run2 for problems mitigation, lower power consumption or optimize for availability and helium losses.

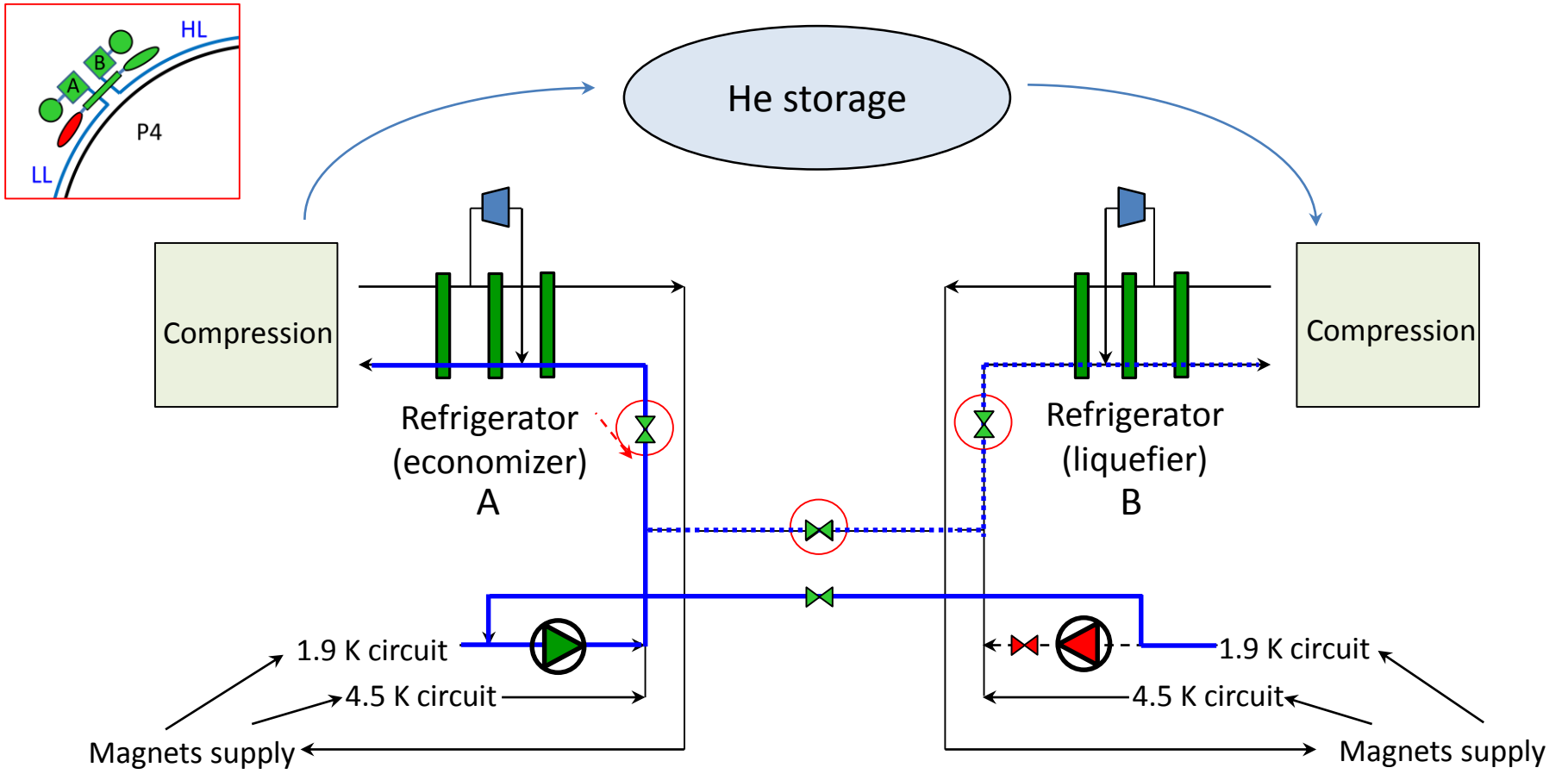






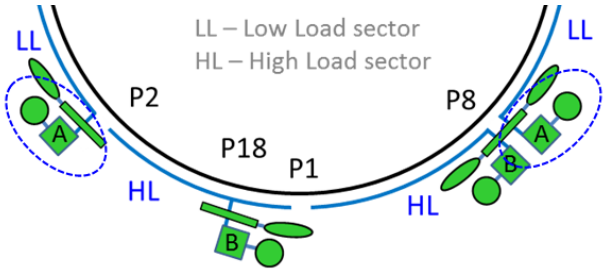
Compressor station
4.5 K refrigerator
Interconnection box
1.8 K pumping unit (cold compressor)

Cryo plants Run2 configuration



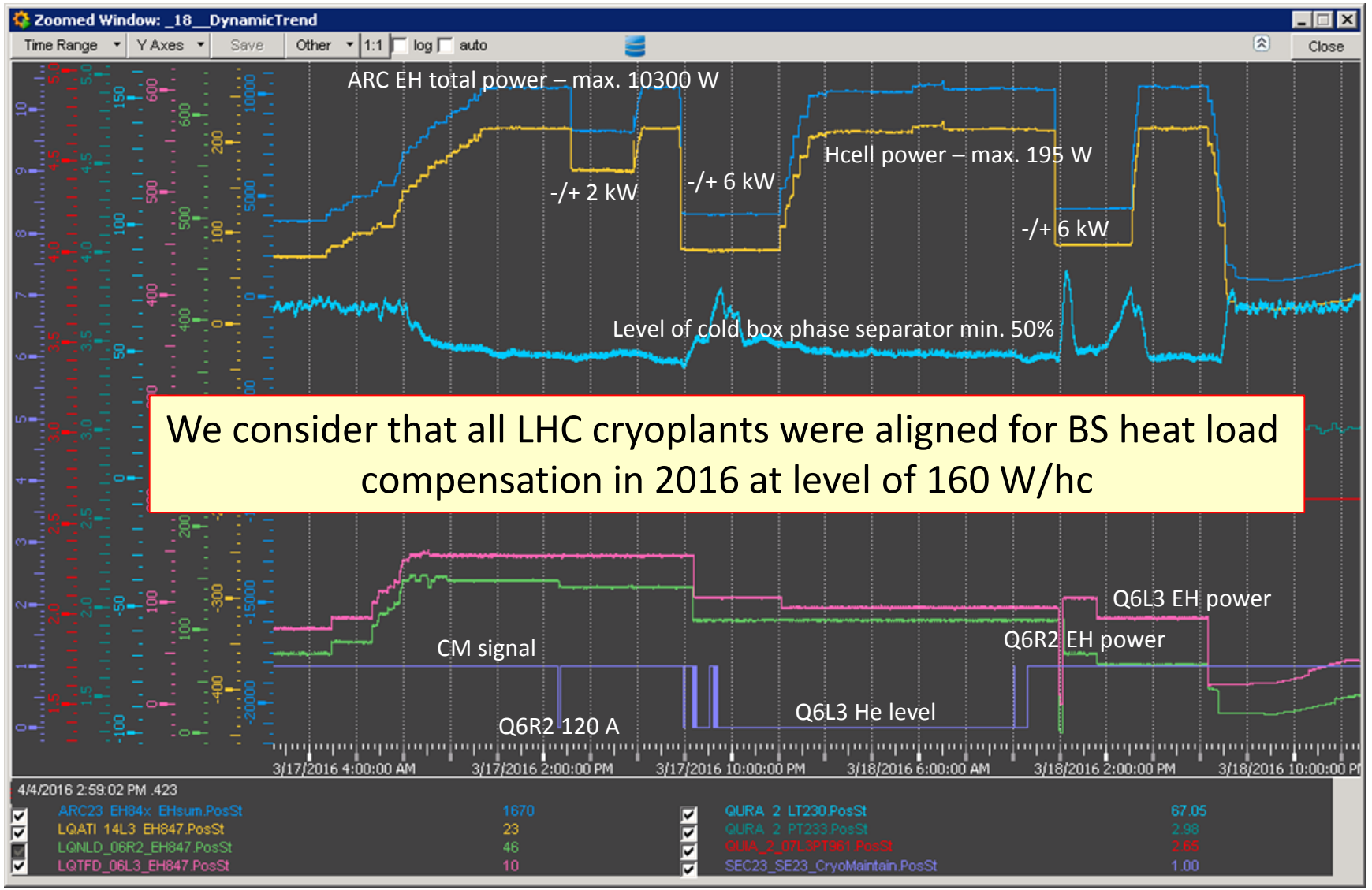
Currently 1.9 K return flow is unbalanced affecting operational stability and performance of the refrigerators. To resolve the issue 3 valves design must be more precise to control the flow –> to be studied and approved –> modifications foreseen for LS2
(such operation was not foreseen originally)

Global capacity optimization – sector 7-8

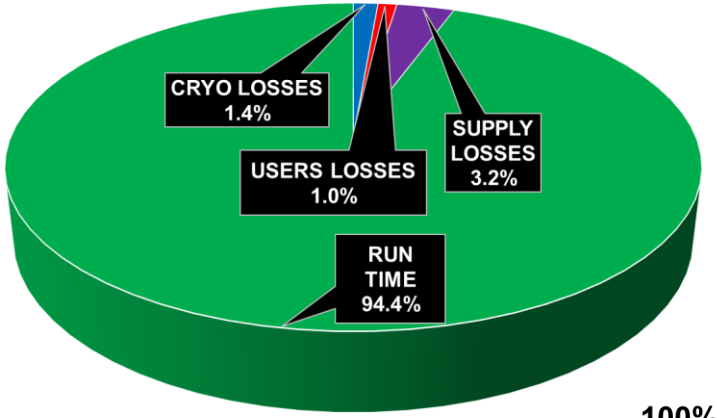


The lowest capacity margin was identified in 2015 at P2 (s2-3) and P8 (s7-8) – both cold boxes were optimized with fine tuning in March 2016.

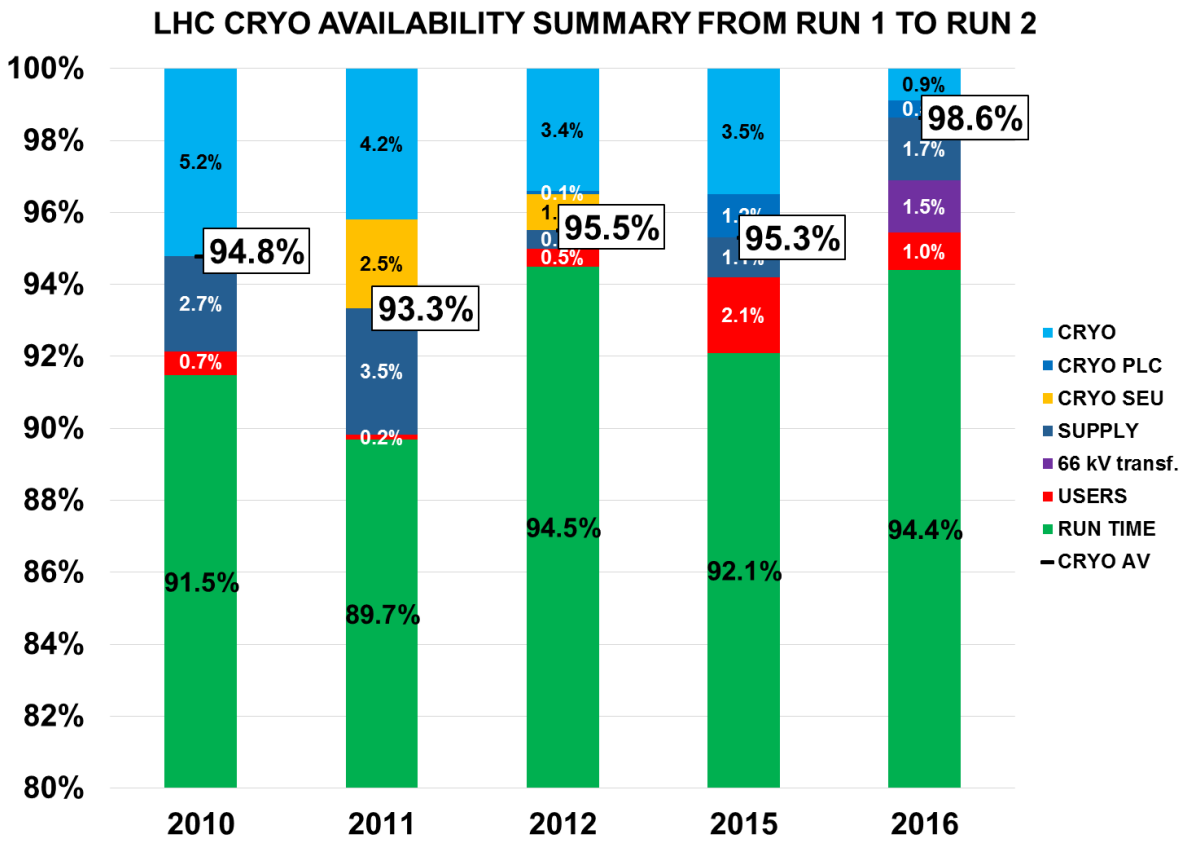
Global capacity optimization – sector 2-3



Availability – Cryo Maintain statistics



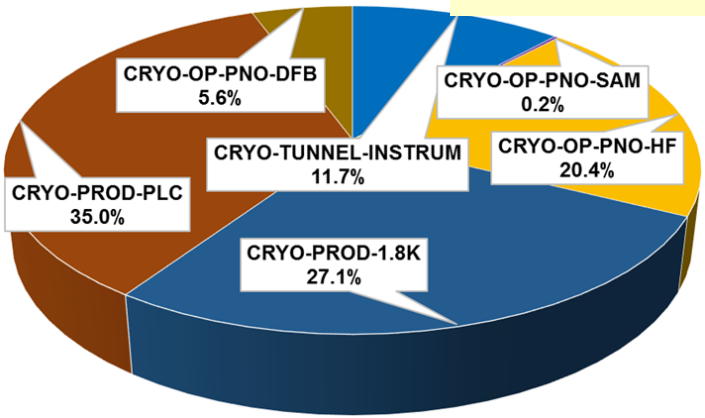
Statistics for Run2 (2016) period
from 25th March to 5th December 2016



Cryo Maintain statistics

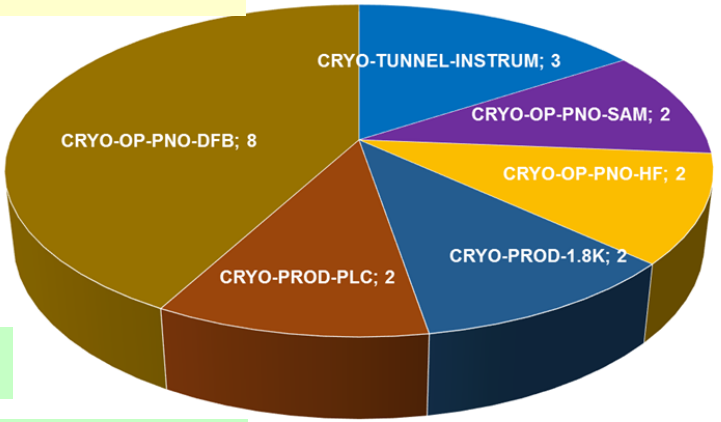
Time affected

2015 Total down time = 273 h 29 min



164 losses

Number of events



19 losses

2016 Total down time = 79 h 25 min

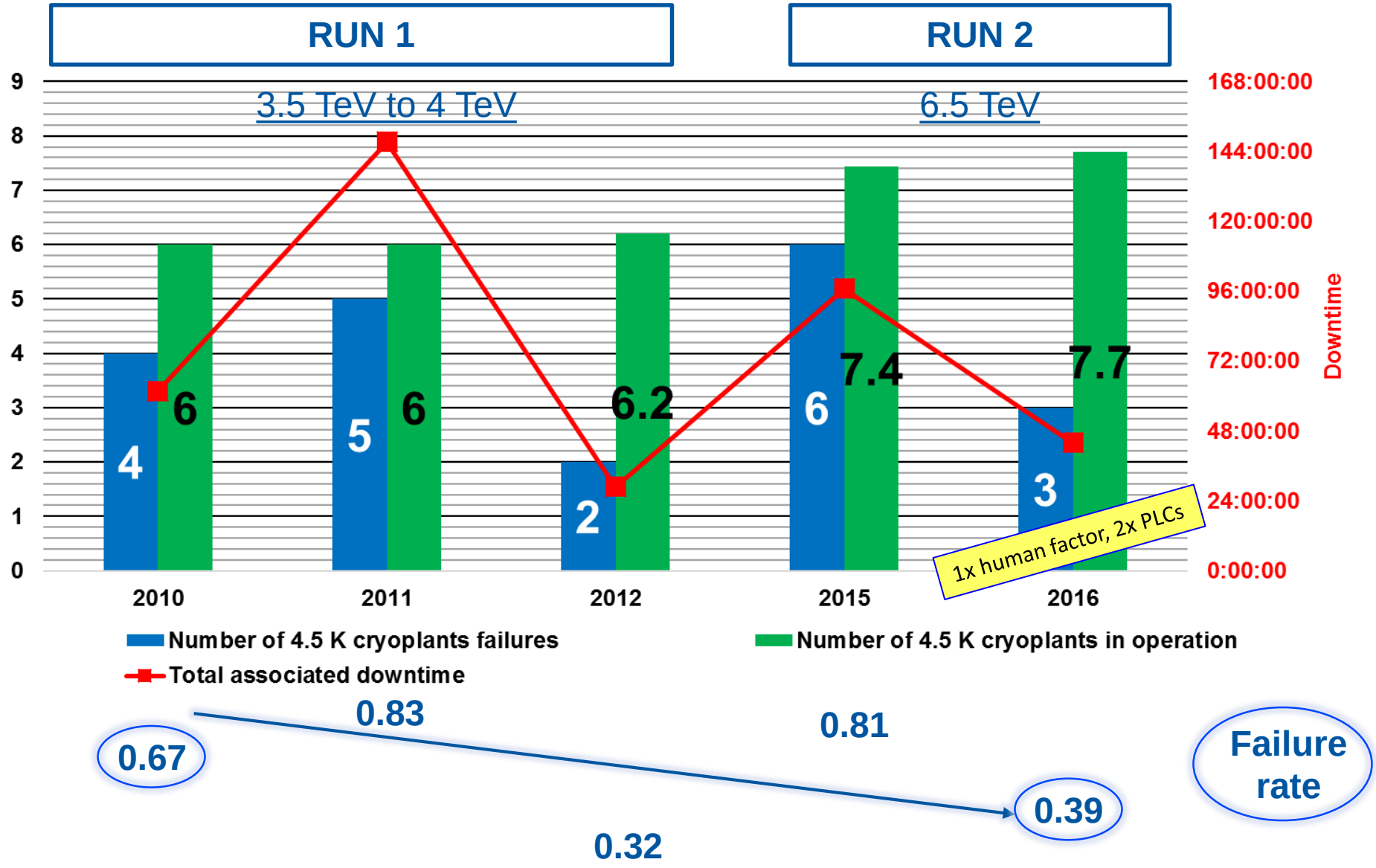
Main improvements (2016 vs 2015) come from:

- good feed-forward tuning for BS control,
- P2 and P8 cold boxes operational optimization for capacity,
- P8 cold box repairs (temporary with varnish applied on AL/SS transition, the transition will be replaced during EYETS),
- DFB level adjustment.

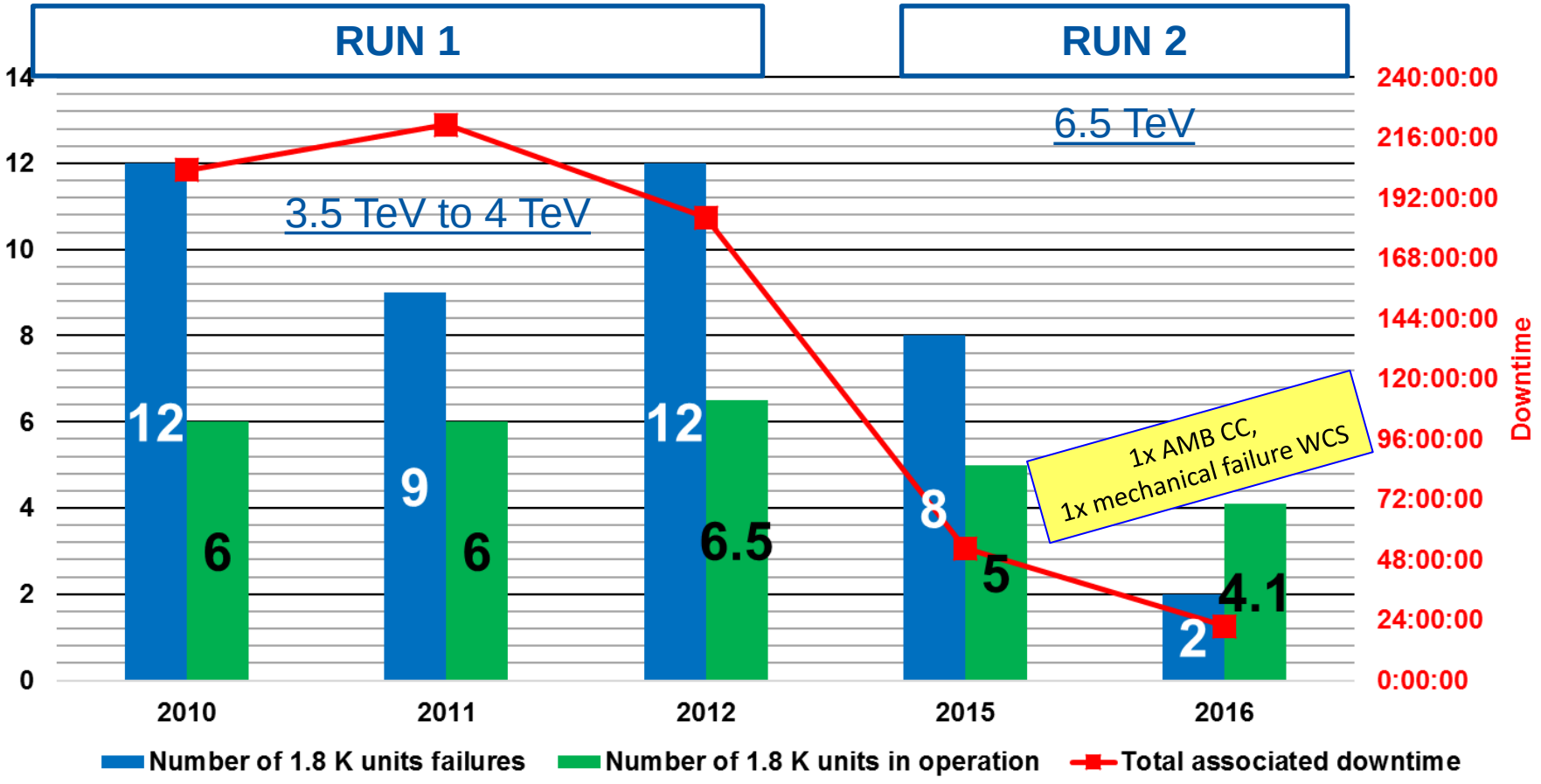
Complementary remarks:

More than 60% of time losses are related to two top contributors (PLC and cryo production plants).
New PLC anti-crash firmware upgraded last YETS 2015/16 did not resolve the failure problems…
New upgrade with PLC Schneider type 580 is planned to start in EYETS – more info from BE-ICS.

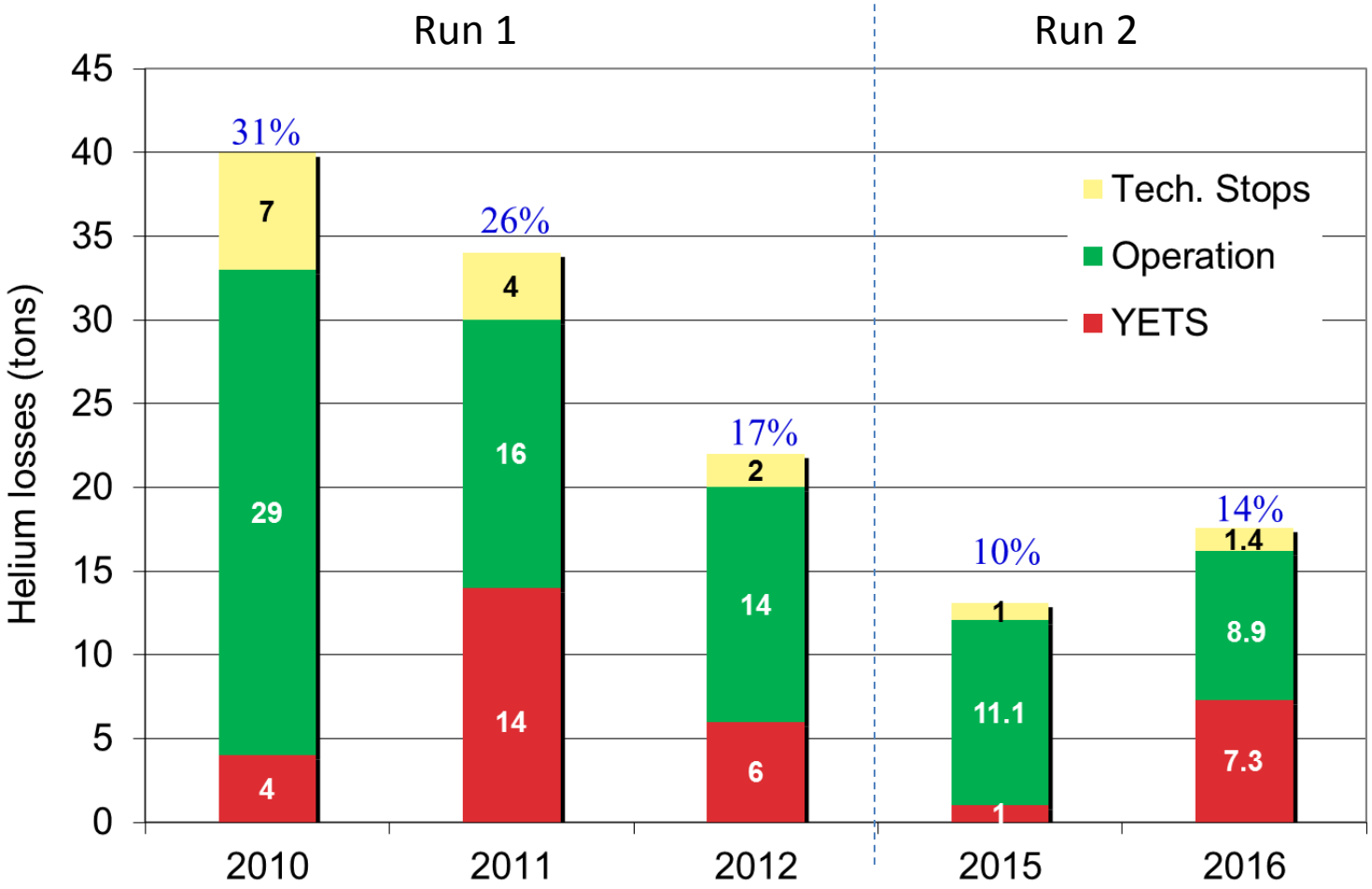
4.5 K refrigerators – cryo causes



1.8 K pumping units – cryo causes

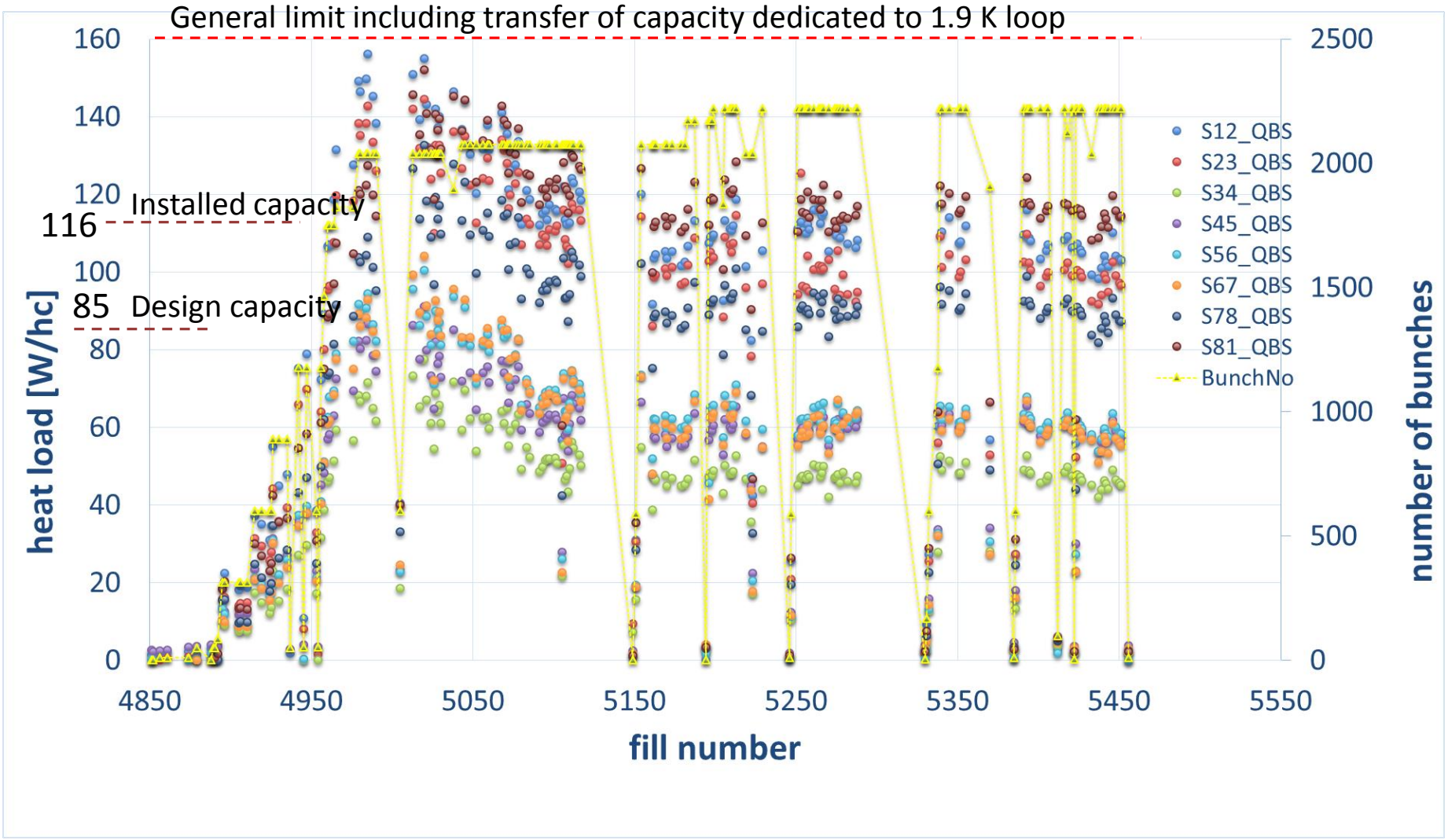


Helium consumption and losses



Progressive reduction of operational losses was obtained thanks to regular leak search. Increase of losses during technical stops/YETS – transients, purges, leak investigation and incidents.

Beam screen – heat load in 2016



*The graph shows raw value of the heat load seen by cryogenics.

EYETS main activities

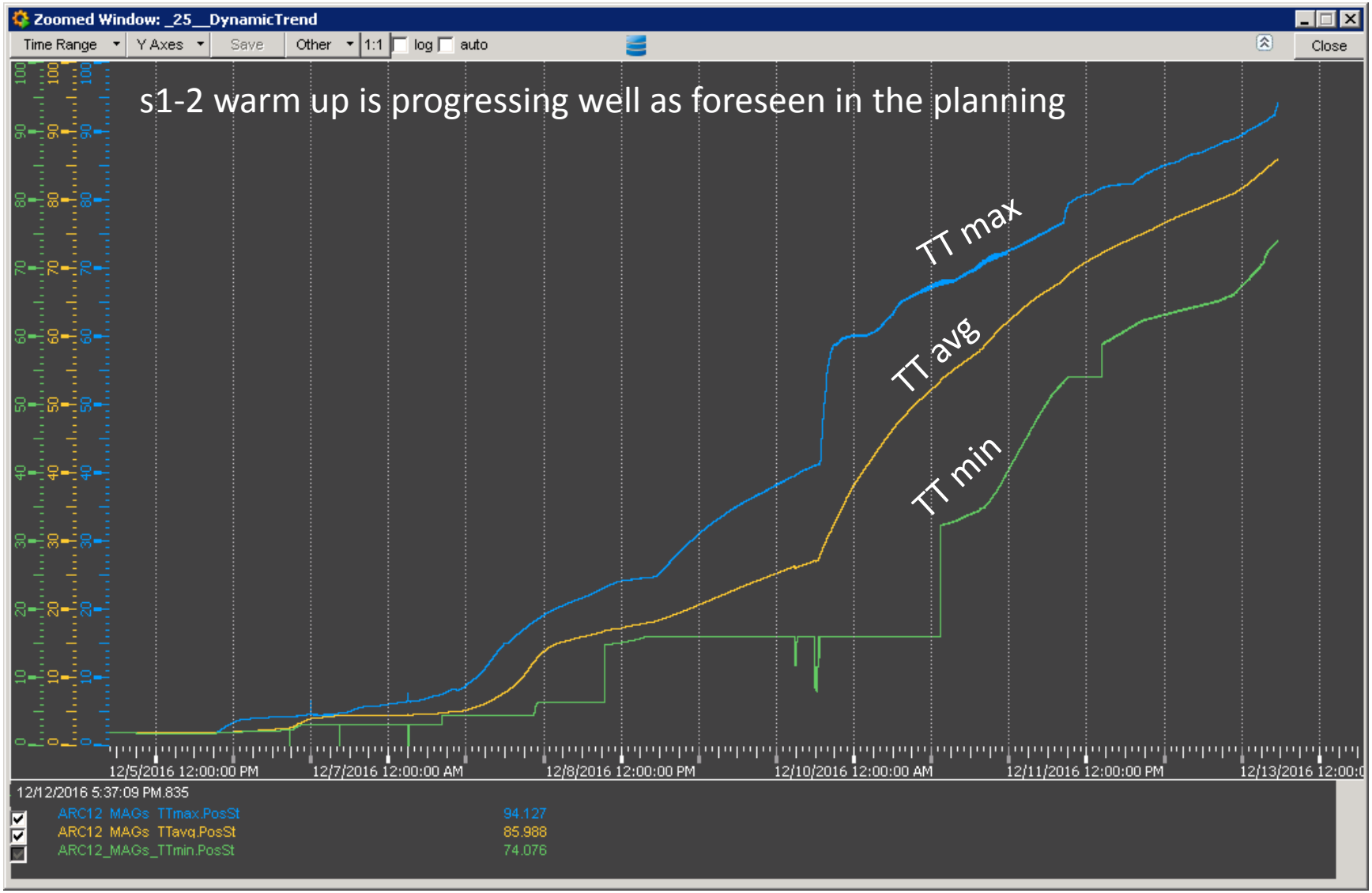
Preparation and conditioning:

- P18 s1-2 – to be completely warmed up for 31L2 dipole replacement
- All other sectors* – to be emptied from LHe and conditioned with GHe at ~30 K
    - *S3-4 and 4-5 – training quench by 15th December then empting

Main repairs and consolidations:

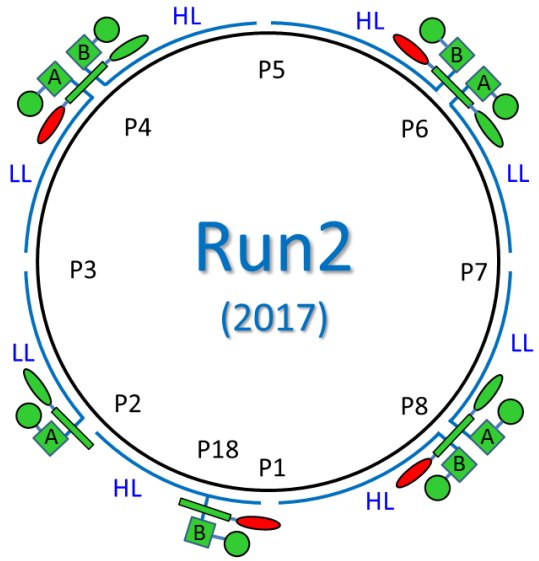
- P8 QSRB cold box leak repairs – AL/SS transition to be replaced
- P4 and P6 QSCAs: installation of additional oil filtering coalescers
- PLCs: upgrade to new Schneider type 580 on 50 % of equipment (by EN-ICS)
- Replacement of active charcoal in 14 adsorbers – standard activity
- Installation of first prototypes of RFL valves (high failure rate – TUs availability)
- Updates of software and multiple other maintenance and repairs activities

Warm up curve of sector 1–2



Run2 (2017) scenario and limitations

For 2017 run we plan to apply the same configuration as in 2016



Generated heat load with dynamics as during 2016 can be fully compensated by the cryogenic system. However the below comments are to be considered:

1. The limit to compensate for thermal load on BS circuit is 160 W/hc.
2. During 2016 ITs 1.9 K cold mass suffered from not optimized dynamics of the cryogenics during collisions → special feed forward logic was developed, tested and applied for 2017 operation – no problems expected if heat load below 250 W/IT.
3. Scaling exercise: (~200 W/IT during run of 2016 at 6.5 TeV and L_{peak} =1.5e34 → L_{peak} could raise max to 1.75e34 to produce ~250 W/IT – value confirmed by test during TS2

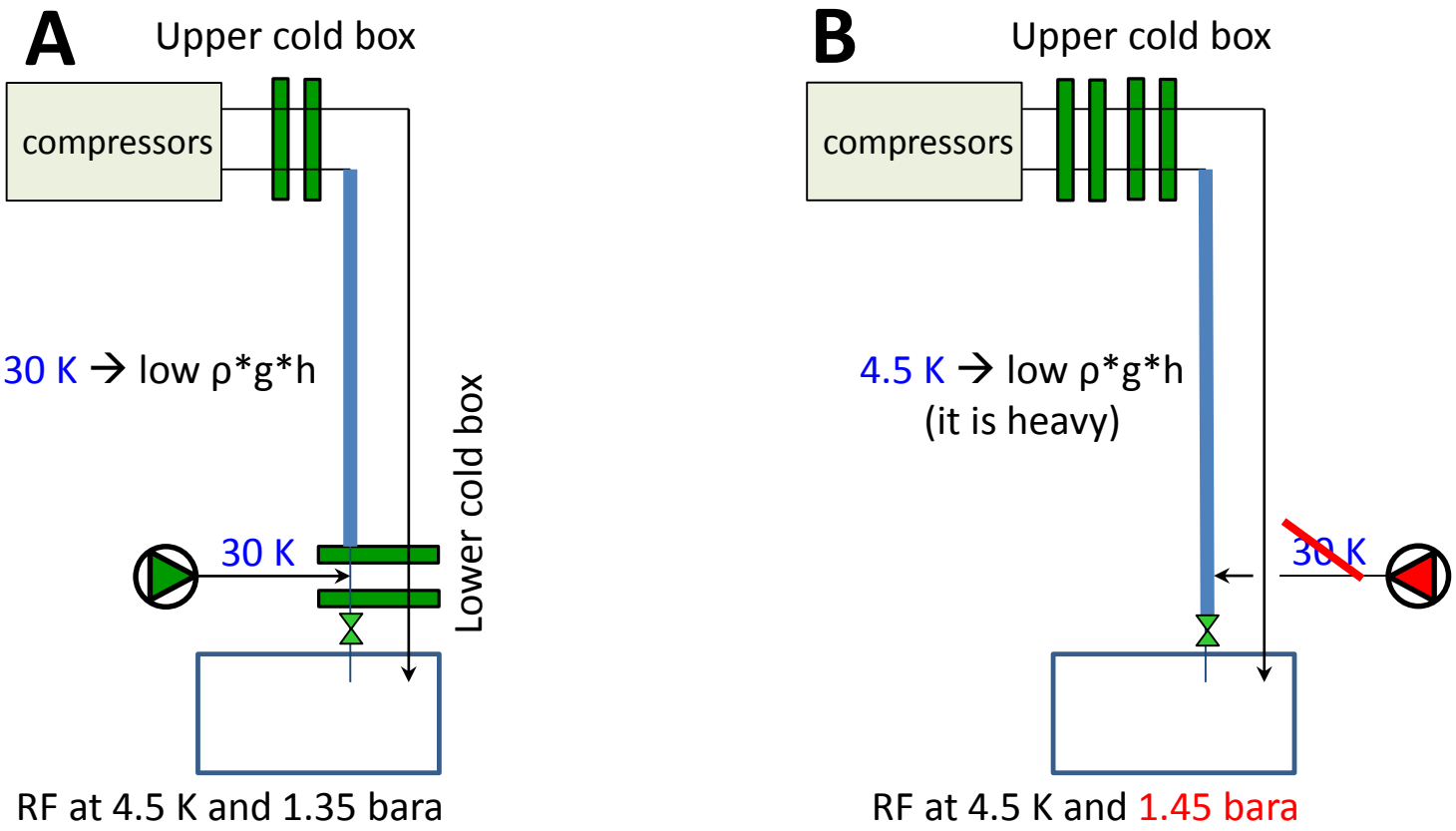
Conclusions

- Cryogenic Run2 (2016) was a success with CM availability at 98.6 % (94.4 % including utilities and users losses affecting cryogenics).
- New configuration was applied and validated for P18/P2 cryo plants.
- Feed forward logic and main cold boxes optimization at P2 and P8 leaded to smooth operation of BS loops, however e-cloud thermal effect stayed above design values (average 1.5*design values for 4 sectors).

- Run2 (2017): referring to lesson learned in 2015 and 2016, cryogenics guaranties at least the same level of capacity as delivered until now. Correct dealing with any higher heat load is possible up to 160 W/hc for BS and 240 W/IT (max L_{peak} =1.75e34 s^{-1} *cm^{-2}).
- Injection of trains with 288 bunches will be next challenge which will require tuning of dynamic response of the cryogenics during injection and ramp.

Thank you for your attention!
Questions ?

Back up – P4 specificity



It is better to boost plant A but it results in high pressure in cavity on side B. With boost of plant B all cavities can run at the same pressure but special equilibrium of capacities by thermal screen circuit must be put in place to mitigate unbalance between two cryoplants A and B (only possible in Linde plants – at P4 and P6) → recommended scenario for P4, no strong preference for P6.