Maximum cooling capacity from cryogenics during Run4

(Beam Screen oriented)

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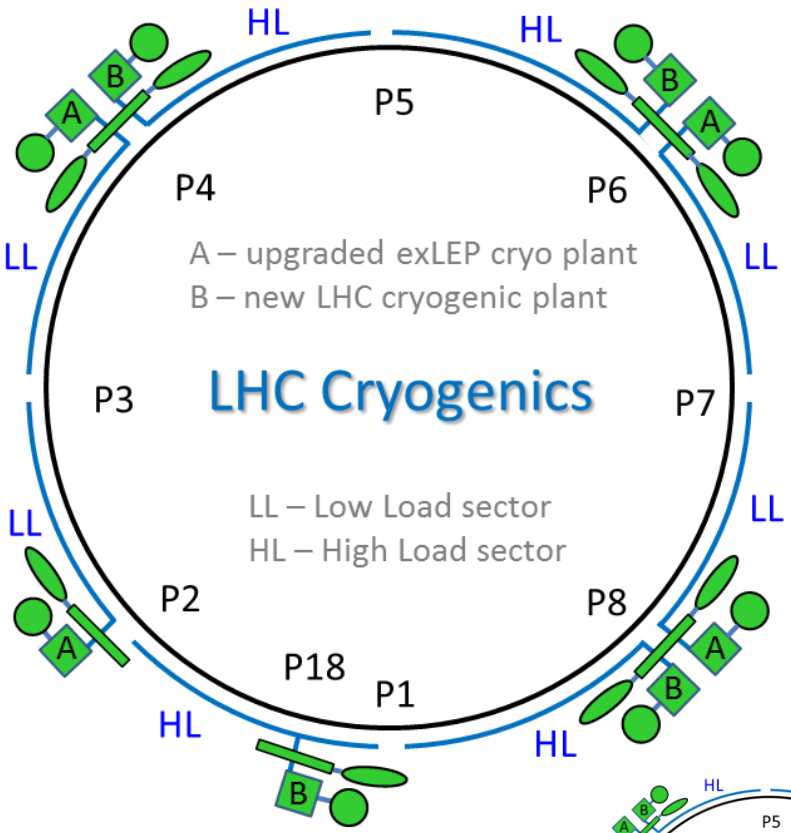
Outlook

- Introduction – LHC cryogenics overview
- Run2 encountered problem for BS cooling
- Applied optimizations
  - Global capacity optimization
  - Optimization on local cooling loops
- Cryogenic capacity for Run3
- HiLumi upgrade and cryogenic capacity for Run4
- Conclusions

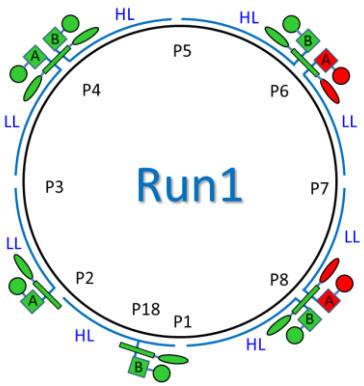
Introduction – LHC cryogenics

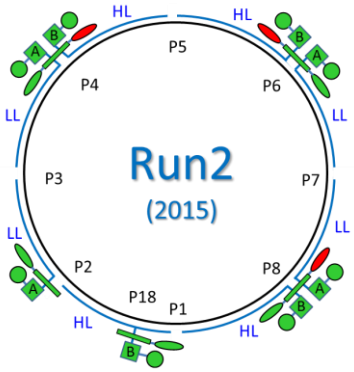


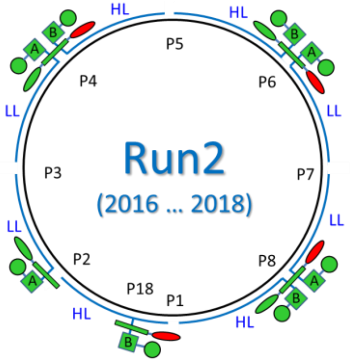
Cooling capacity of A and B are designed to cover nominal LHC operation with equal margins on LL and HL sectors.
BUT:

1. w/o dynamic load B has more capacity margin than A -> easier recoveries,
2. B is more reliable 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 optimization for availability and helium losses.



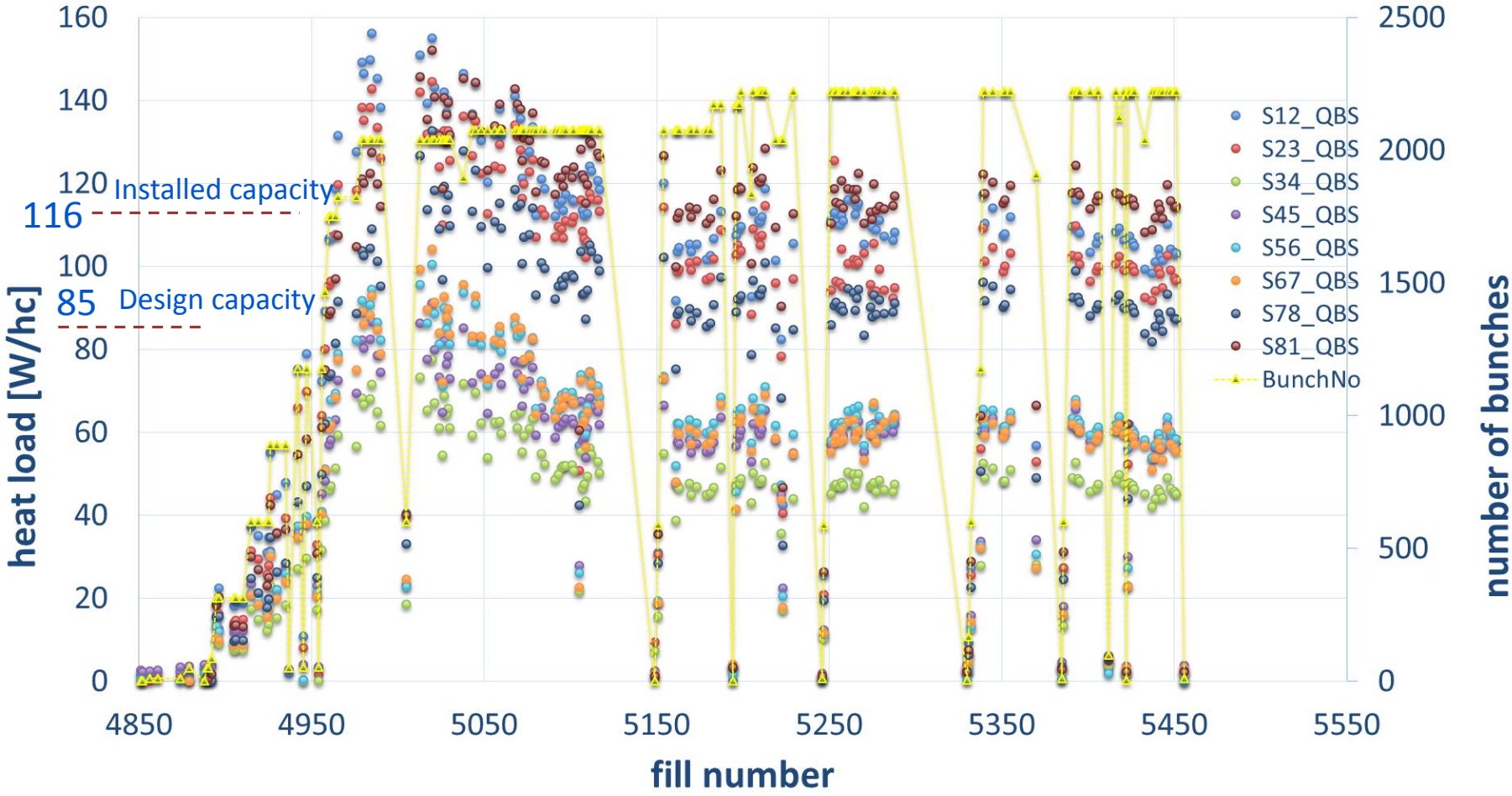




Compressor station
4.5 K refrigerator
Interconnection box
1.8 K pumping unit (cold compressor)

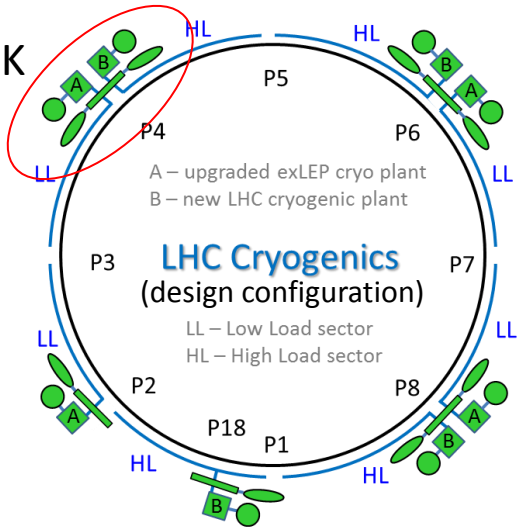
Encountered problem of Run2

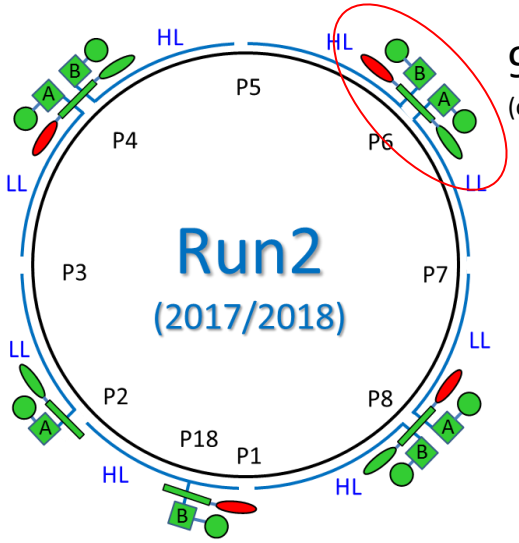
Beam induced heat load on the beam screen circuit – middle of Run2 (2016)



Global capacity optimization

120 g/s @ 1.8 K
(considering Run2 needs)





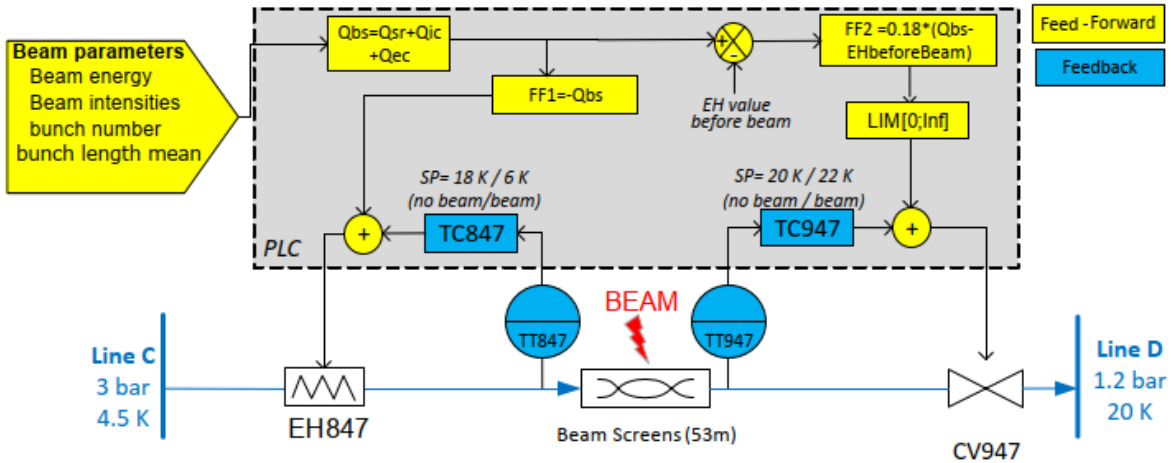
90 g/s @ 1.8 K
(considering Run2 needs)

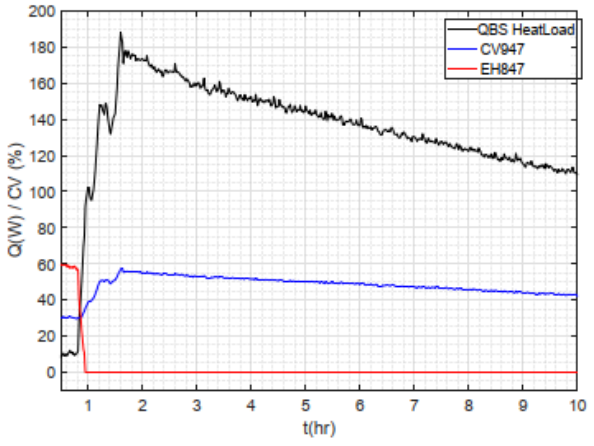
Consideration: 1 W @ 1.8 K isothermal power -> ~5 W @ 4.6-20 K non-isothermal power i.e. with stop of one cold compressor it is possible to spare additional 20 .. 30 W/hc of the capacity for BS cooling.

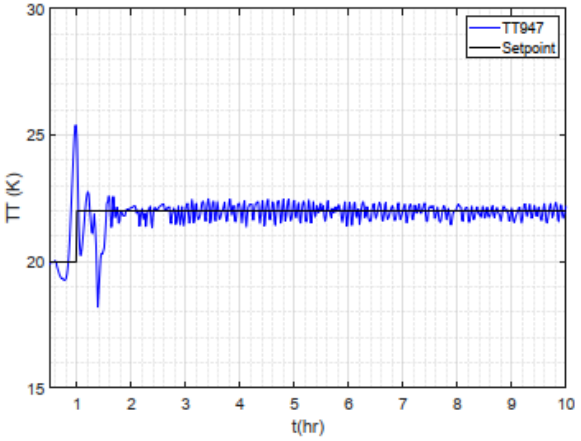
Thanks to such an operation scenario power consumption, helium losses and availability are optimized. The same operation scenario is foreseen for Run3 and could be adapted for standard LHC part for Run4 .

Local capacity optimization

Feed-forward action applied on electrical heater and cooling valve allows for smoothing of the temperature behavior during transient and allows to keep stable operational regime of the cryogenic plant -> minimize the risk of cryogenic condition losses.







B. Bradu

Cryogenic capacity for Run3

- All sectors were measured with long campaign of the tests to confirm available cooling power for BS cooling (reference fill 5979 selected)
- LS2 HiLumi upgrade of LHCA refrigerator at P4 will increase available power for cooling of s34 (Run3)

Cryogenic plant type	AL-B	AL-A	L-A	AL-B	L-B	L-A	AL-A	L-B
LHC sector	S1-2	S2-3	S3-4	S4-5	S5-6	S6-7	S7-8	S8-1
Capacity (design conf.) [W/hc]	180	195	125*	180	240	175	175	230
Configuration Run2 [W/hc]	200	205	145	200	260	195	195	250

*cryo-plant at P4 loaded for RF modules, will be upgraded during LS2, then new measurement required

All above measurements with input from reference fill in 2017 F5979

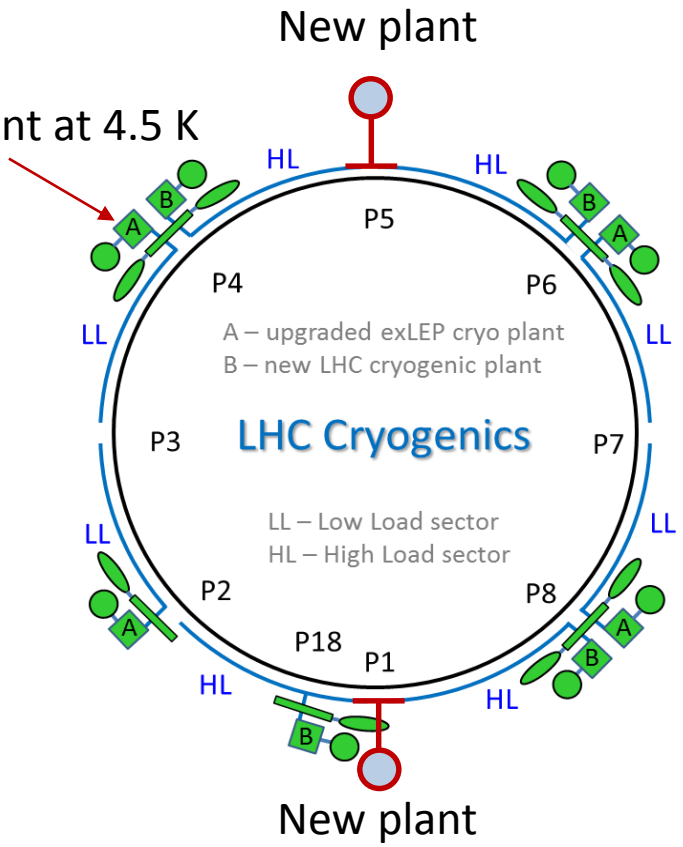
Black – measured value

Grey – recalculated value (contingency of 10 W/hc considered)

- In case of P1 and P5 IT loaded at maximum value at 1.8 K (~ 270 W what corresponds to L=~2 10^{34} Hz/cm^2), the available power for BS cooling in s12, s81, s45 and s56 will decrease by 5 W/hc)

HiLumi cryogenic upgrade

Upgrade by 2 kW equivalent at 4.5 K



New plants will allow to recover capacity provided to IT cold mass cooling i.e. 270 W/IT at 1.9 K => 25 W/hc for BS cooling (concerns sectors: 1-2, 2-3, 4-5 and 5-6). The P4A upgrade should provide more than upgrade of P1/5 (to be measured).

Cryogenic capacity for Run4

- All sectors were measured with long campaign of the tests to confirm available cooling power for BS cooling (reference fill 5979 selected),
- HiLumi upgrade will affect 4+1 sectors (installation of two new cryoplants at P1&P5 and upgrade of one cryoplant at P4),
- The estimated capacities of the cryogenic plants are summarized in table below.

Cryogenic plant type	AL-B	AL-A	L-A	AL-B	L-B	L-A	AL-A	L-B
LHC sector	S1-2	S2-3	S3-4	S4-5	S5-6	S6-7	S7-8	S8-1
Capacity (design conf.) [W/hc]	200	195	>180	200	260	175	175	250
Configuration Run2 [W/hc]	220	205	>200	220	280	195	195	270

Conclusions

- Run2 brought to LHC cryogenics new challenge for BS induced heat load compensation. The required cooling power was beyond expectations and beyong installed capacity allocated for this non-isothermal cooling,

- Thanks to the fact that mainly 1.9 K heat load was lower than estimated and thanks to global and local optimizations, the necessary cooling capacity could be provided,

- The cooling capacities of the cryoplants after HiLumi upgrade will increase for BS in case of 5 sectors, and in case of 3 sectors will remain on the level of 200 W/hc (concerns sectors 2-3, 6-7 and 7-8),

- The presented estimate is based on today experience.

Thank you !