ARC cryogenic capacity in the HL-LHC era

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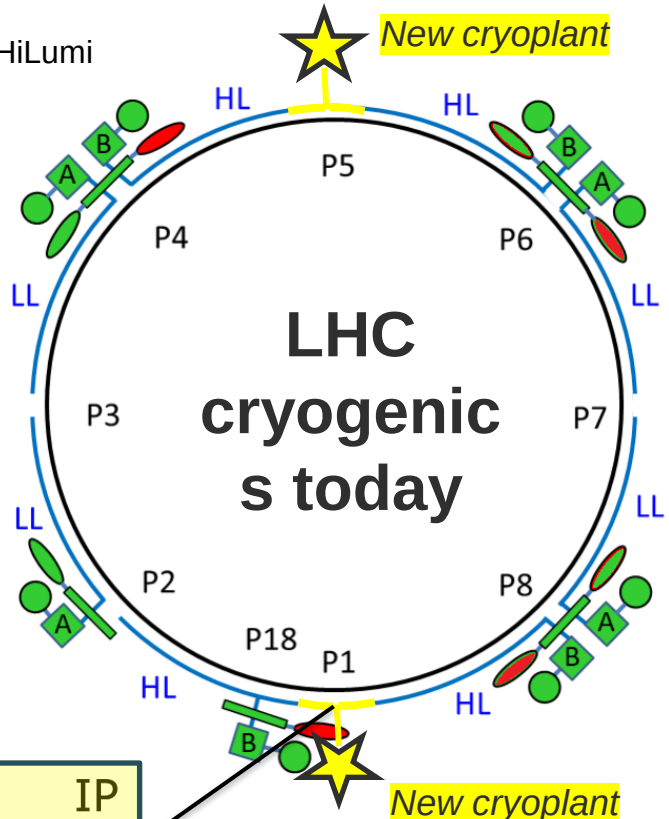
Cryo infrastructures evolutions for HL-LHC (reminder)

- **Non Hilumi sectors (LL) :** S23, S34, S67, S78
  - No changes in cryogenics infrastructures (cryoplants “A”)
  - PS: the cryoplant “A” for S34 was already upgraded during LS2 for HiLumi

- **Hilumi sectors (HL) :** S12, S45, S56, S81
  - Existing cryo infrastructures (cryoplants “B”) remains but…

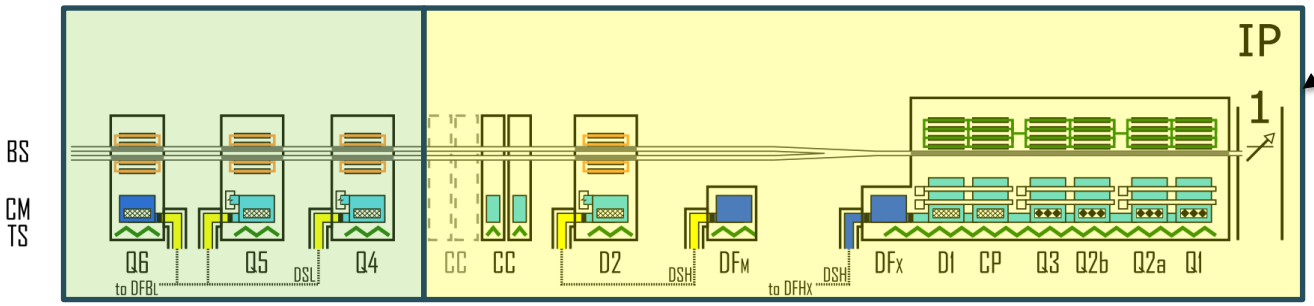
  - The IT + DFBX + D2 + associated QRL removed until Q4
    - ➔ capacity recovery in the existing cryoplants “B” !

  - 2 new cryoplants at P1/P5 will be installed
    - Will manage the future IT+CP+D1+DFX+DFM+D2+CC
      (not discussed in this presentation)



Remain attached to existing cryoplants “B”

Handled by new cryoplants

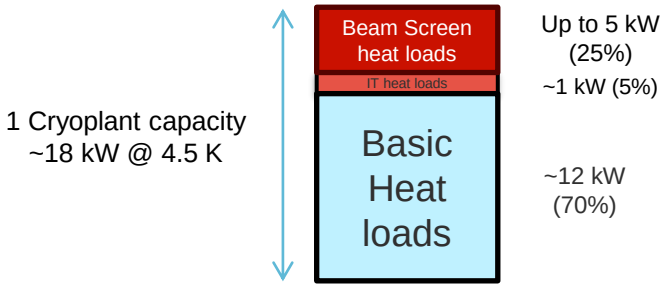


Consequences for the ARC cryo capacities

- LHC cryoplants are supplying many devices in parallel at different temperatures
  - Thermal shields between 50 K and 75 K
  - Main superconducting magnets at 1.9 K (ARC dipoles/quadrupoles)
  - Stand Alone superconducting magnets at 4.5 K (D3, Q4, Q5, Q6)
  - RF cavities at 4.5 K (at P4 only)
  - DFB at 4.5 K with their current leads and superconducting links

No changes expected for HL-LHC

  - Inner Triplet (IT) at 1.9 K around experiments (dynamic heat loads, depending on luminosity)
  - Beam Screens (BS) between 4.5 K and 20 K (dynamic heat loads, depending on beams – sync rad + impedance + ecloud)



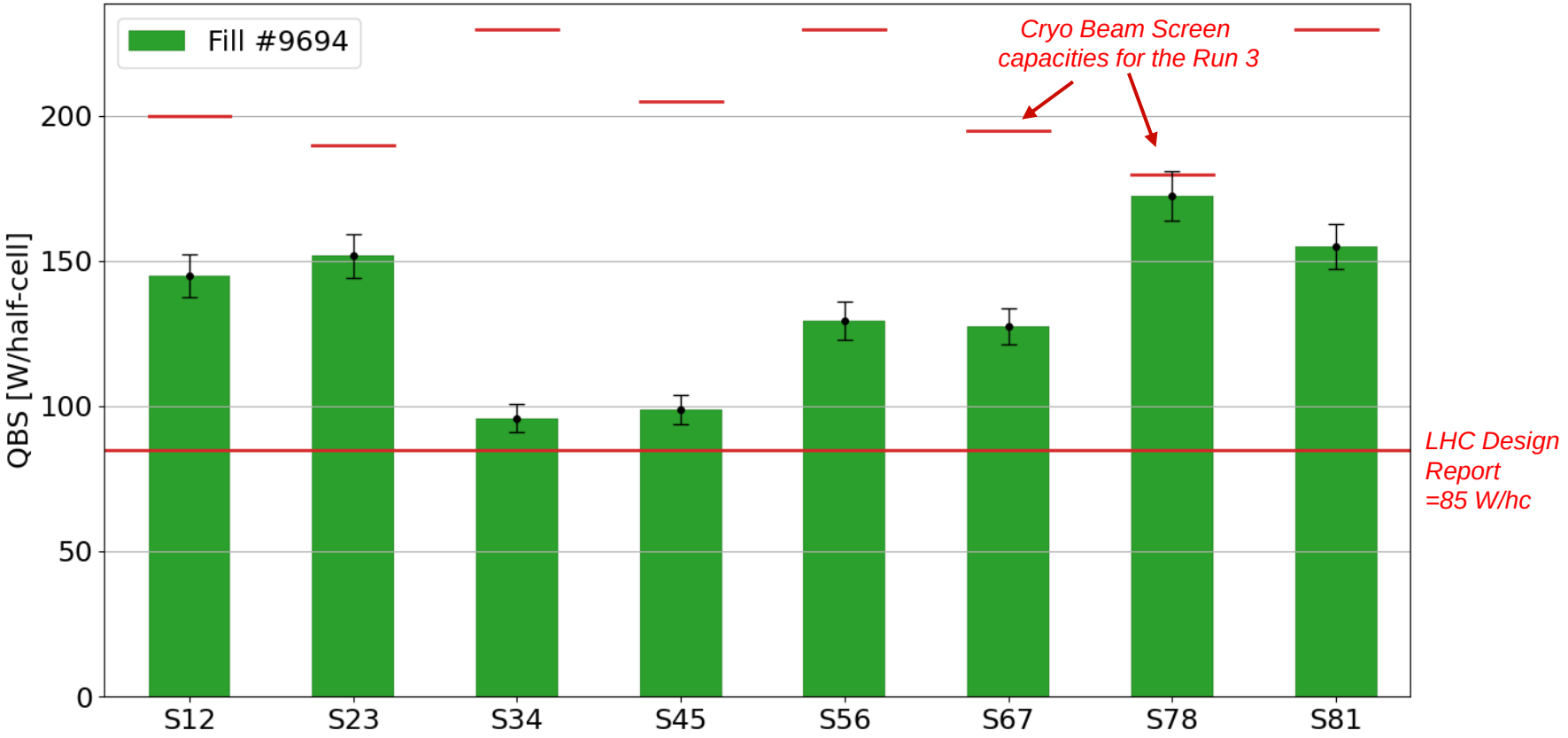
- Changes for HL-LHC:

Expected changes in HL-LHC	Helium massflow	Q @ 1.9 K [per sector]	BS Capa 4.5 K - 20 K [per ARC]	BS Capa 4.5 K - 20 K [per half-cell of 53m]	Concerned sectors
Removal of IT/D1 at P1 & P5 in LS3	-12 g/s	-280 W	+1.3 kW	+25 W/hc	S12, S81, S45, S56

- The available ARC beam screen cryogenic capacities will slightly increase in HL sectors !

Where are we today (2024) ?

- *Beam Screen cryogenic heat load averages in each ARC measured during fill #9694*
  - *31st May 2024 with 2352 bunches @ 1.62e11 ppb (3x36b scheme)*
- *Cryogenics is running at its ultimate limit in S78*
  - *BS heat loads are in average more than twice higher than expected*

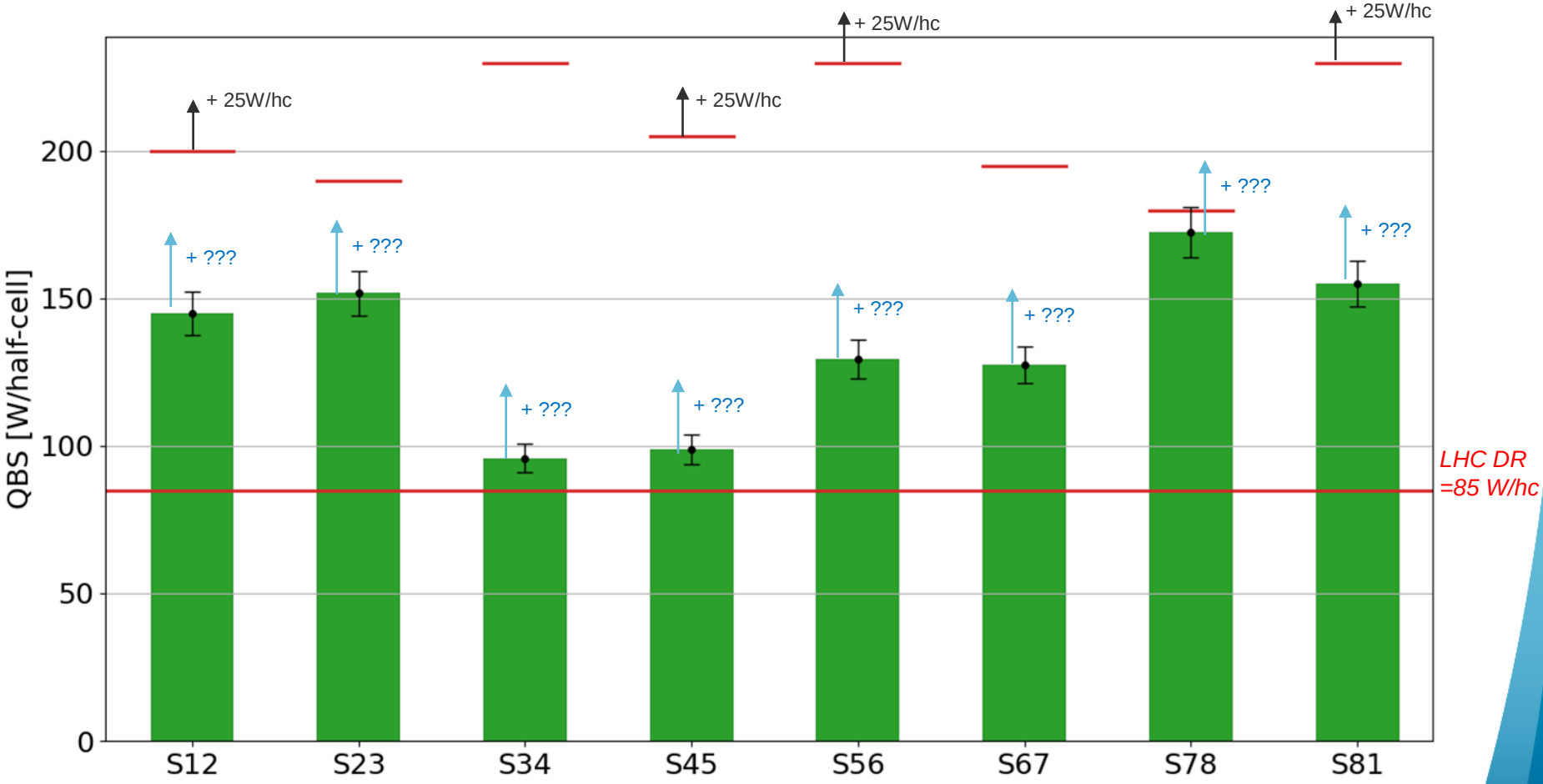


PS: All LHC cryoplants are slightly different and have different capacities & loads (RF, SAM, DFB, triplets, etc.)

What will happen after LS3 ?

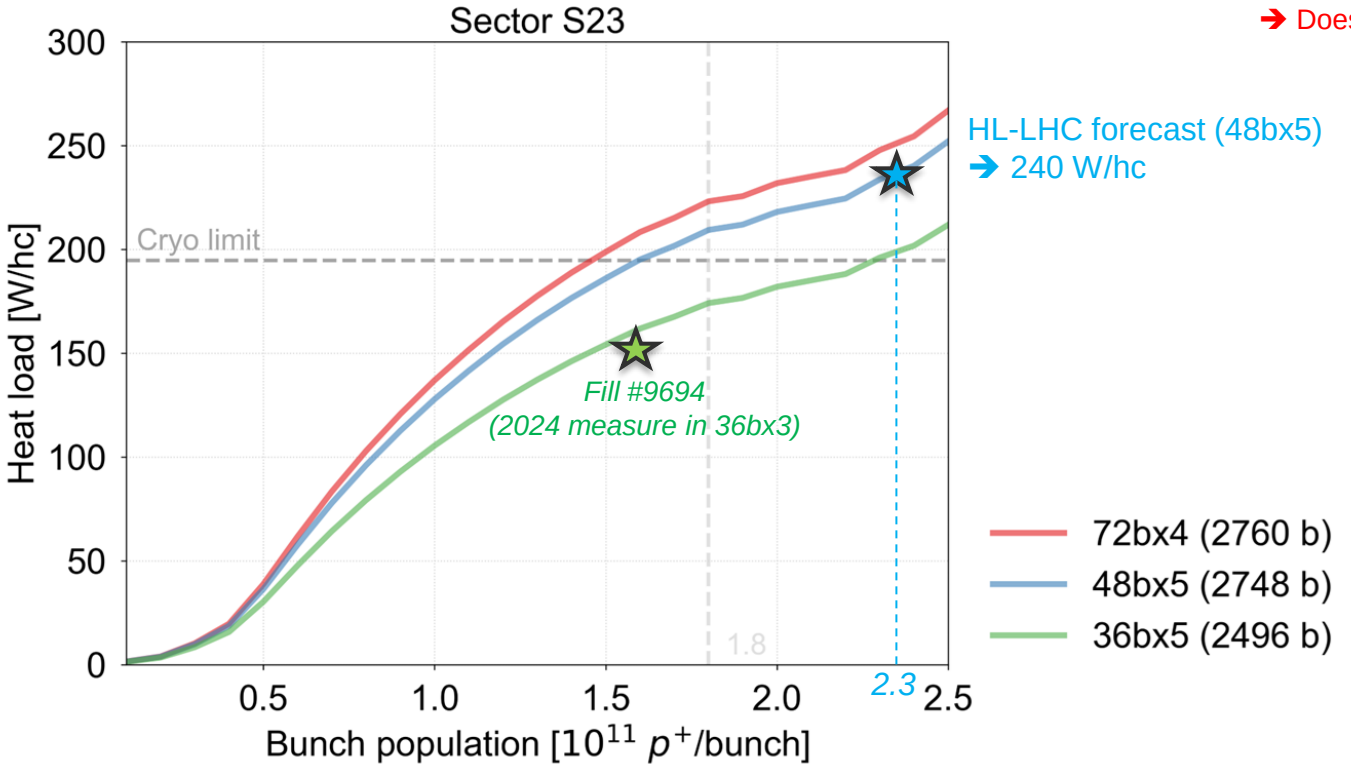
➔ARC Beam screen capacities will increase in HL sectors by +25 W/hc (IT/D1 removal)

➔ARC beam screen heat loads will increase due to the HL-LHC beams (depending on filling schemes and intensities)



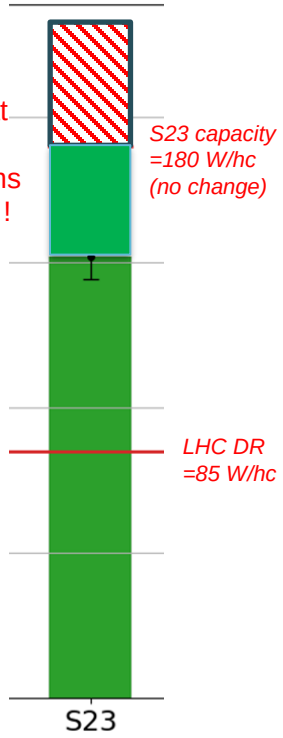
HL-LHC beam screen heat load forecast

- E-cloud simulations done by BE-ABP and presented in Chamonix 2023 by Lotta Mether
  - Assuming no BS treatment and no more beam screen surface degradation during LS3 (optimistic scenario)



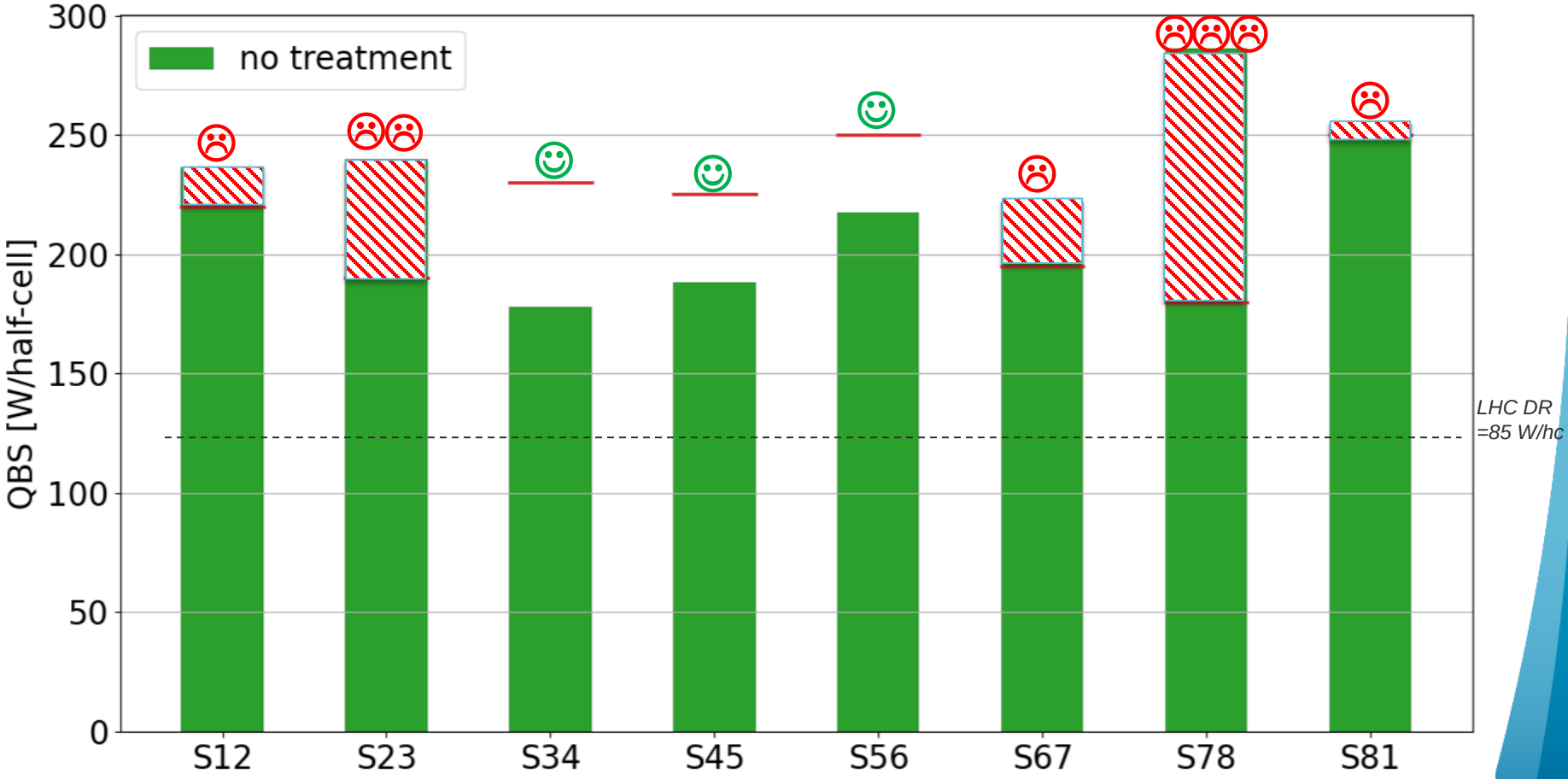
HL-LHC forecast (48bx5)
➔ 240 W/hc

Additional ARC beam screen heat load expected with HL-LHC beams
➔ Does not work !

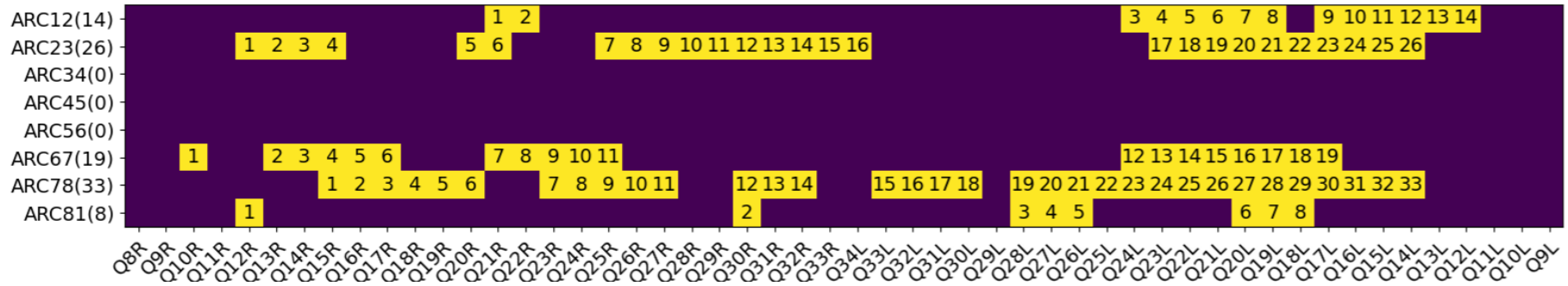


The same exercise was achieved for each sector

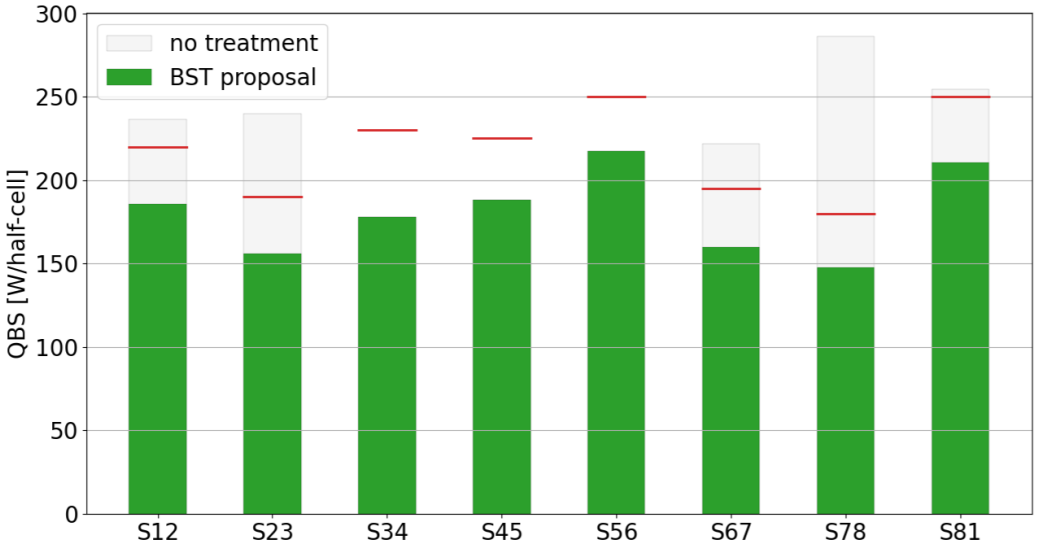
➔ Impossible to operate HL-LHC with the forecast beams due to the extra heat loads generated by the e-clouds



Proposed solution: Beam Screen Treatment (BST)



- Deposit a thin Amorphous Carbon over the BS surface to reduce the e-clouds heat loads (in situ)
- Project managed by TE-VSC (G. Rosaz)
- Objective is to treat 100 half-cells (2 x 5.3 km) of beam screens during the LS3
- Sector margins after treatment if no more degradation: [34,34,52,37,33,35,32,40] W/hc
- ~15% margin in all sectors is mandatory due to the uncertainly on the treatment efficiency and on potential further BS surface degradations during LS3



Conclusion

- LHC cryogenics infrastructures will remain the same for the ARC cooling in the HL-LHC era
  - The cryogenic BS capacities for the ARC will slightly increase after LS3 in the HL sectors (~ +10%) due to the removal of the IT+D1 around P1 & P5 from the existing cryoplants

- Nevertheless, the HL-LHC beams will induce up to +150% of heat loads on beam screens due to the e-clouds ➔ not manageable by cryo, 5/8 sectors will be above the ultimate limits !

- Solutions consists in “treating” 2x5 km of beam screens during LS3 to reduce the e-clouds (carbon coating)
  - BST project under study/preparation by TE-VSC, already included in LS3 planning
  - This solution would allow to restore enough cryo margin in all ARC for HL-LHC beams

- Reducing the e-cloud heat loads handled by the existing LHC cryogenic infrastructures is essential to operate the HL-LHC properly, this is not an option.