HL-LHC Cold Powering: Are There Viable Options?

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(MgB_2 cable in flexible cryostat cooled by forced flow of GHe at 4.5-17 K)

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(Nb–Ti cable in rigid cryostat cooled by forced flow of supercritical He at 4.5-5.5 K)

- Cu Variant

(string of water-cooled Cu cables and tubes)

- Conclusion

Preparation Status

- Extended version of presentation was given to MCF on 16 January 2018.
- Comments received after the presentation are being integrated.
- Cost comparison is being finalized.
- Thereafter are the main conclusions.

MgB_2 HL-LHC Baseline

- *Viable and innovative option (with a potential for generating technological spin-offs comparable to what the Tevatron did for Nb–Ti or to what LHC did for HTS leads)*

but…

- – proposed design changes offer potential rationalizations/simplifications that need to be assessed;
- – design and development to be completed (by end of 2019);
- – manufacturing and installation plan to be consolidated (by end of 2020);
- – tight QC to be implemented during production, integration and installation.

Nb–Ti Variant

- *Viable back-up option relying on well proven technologies*

but…

– not a straightforward extrapolation from LHC DSL experience;

– operating margin of design presented here is limited and likelihood of a link quench consecutive to an inner triplet magnet quench is high (consequences on machine operation to be assessed);

– performances may be improved by reducing cable losses and/or more efficient cooling (time scale for cable development: ~2 years minimum);

– “rigid” cryostat design and manufacture and cable insertion procedure to be developed and qualified;

– tight QC to be implemented during manufacture and installation.

(Note: if one wants to keep this back-up option available, one needs to assess what to do in terms of design studies and R&D; point of not return: cost and schedule review of 2020.)

Cu Variant

- *Not a viable option at this stage of the project*

because…

- it calls for additional civil engineering at the exits of the vertical shafts into the LHC tunnel (due to the fact that present civil engineering, layout and ancillary equipment have been optimized for a superconducting link option and that if a copper option had been considered from the start, the optimization would have likely led to a different configuration);
- of additional power consumption of ~4 MW (8,000 MW.h/year);
- it calls for redesign (extra capacity) of cooling and ventilation;
- and last but not least, of maintenance issue due to activation in DFBX area of the LHC tunnel (the very reason why some equipment was moved away from the tunnel to the new service gallery).

Preliminary Cost Comparison

Manufacture, Integration, installation and 10-Year Operation Costs for One 100-m-Long IT Side Link (MCHF)			
	MgB_2	Nb-Ti	Cu
sc strands			
Cu			
cabling			
insulation			
cryostat			
insertion			
installation			
sc link Test			
HTS Leads			
HTS Lead Test			
DFX (LHC Tunnel)			
DFH (new gallery)			
Splices			
Cryo (capital + 10 year operation with 6000 hours/year)			
extra electrical power (10 year operation with 2000 hours/year)			
Total			
(1) with shield and no 20 K supply to leads			
(2) with 20 K supply to leads			

Extra Capital Equipment Costs for Total HL-LHC Project (MCHF)			
	MgB_2	Nb-Ti	Cu
Extra Civil Engineering			
Extra Cooling & Ventilation Capacity			
SM18 Infrastructure Upgrade for sc Link Tests			
SM18 Infrastructure Upgrade for HTS Lead Tests			
Total			

- Salient features are
  - Cu variant cost not far from MgB_2 baseline cost (likely higher when including extra civil engineering);
  - Nb–Ti option is % cheaper (main difference comes from sc material and cabling costs).

Recommendation

- MgB_2 option is challenging, but this is the price of innovation, and it is the assessment of the CERN TE-MSC Group management that it can be done

$\Rightarrow$ *mobilize and focus CERN TE-MSC resources on this option.*

- Point of no return for back-up Nb–Ti option: Cost and Schedule Review of 2020.