PHASED APPROACH TO THE LHC INSERTION UPGRADE AND MAGNET CHALLENGES

R. Ostojic, CERN, Geneva, Switzerland

Abstract

The LHC is on its way for operation with beam in 2008. The first goal of CERN and the LHC community is to ensure that the collider is operated efficiently, gradually reaching its maximal performance. In parallel, discussions have started and there is already a wealth of ideas on the possible directions for upgrading the LHC insertions. In this talk, we illustrate some of the constraints limiting the upgrade scenarios, and argue that a phased approach with several intermediate targets is necessary. In the first phase, the known bottleneck in the low-β triplets needs to be removed in the perspective of the physics run of 2013. This phase relies on the mature Nb-Ti superconducting magnet technology, where improvements for a small scale production are still possible.

PHASING OF THE UPGRADE

The LHC, the largest and most complex endeavour in the history of high-energy physics, is almost complete. By the end of 2007, the collider will be fully installed and individual system tests completed. The machine sectors are being progressively cooled down and commissioned.

The LHC construction effort has been enormous and has taken up all of CERN's material and human resources and has required considerable international participation. In parallel, the HEP and accelerator communities have been investigating possible routes towards increasing the reach of this unique scientific instrument. There is a wealth of ideas how to upgrade the LHC systems, mostly in the high-luminosity (ATLAS and CMS) insertions. The strategy, as given in the strategy statement of the CERN Council [1], is clear: to maximize the physics return, any upgrade of the LHC insertions in the first period of running has to comply with the operations schedule and existing infrastructure. On the other hand, LHC relies on the injector chain and its reliability. These accelerators, in particular the venerable PS, must have priority in maintenance and upgrade. These boundary conditions lead to a phased approach to the upgrade of the LHC luminosity.

Within the long list of LHC systems, there are certain major constraints which have to be taken into account when discussing the scope and timing of the luminosity upgrade. One of the major ones concerns the available cooling power of the cryogenic system in the two interaction points. As discussed by L. Tavian in LUMI-06 [2], the cooling capacity of the refrigerators was defined on the basis of extensive evaluation of the heat loads, and made to match the "ultimate" beam parameters [3]. It is clear that any increase of cooling requirements, in particular those related to the increase of luminosity beyond 2 10^{34} $cm^{-2}s^{-1}$ will need dedicated cryogenic plants serving the inner triplets around CMS and ATLAS. Their installation will in turn most likely require some level of civil engineering in the underground areas. This type of insertion upgrade is best done at the time when the two experiments will also require longer shutdowns to perform their own extensive modifications.

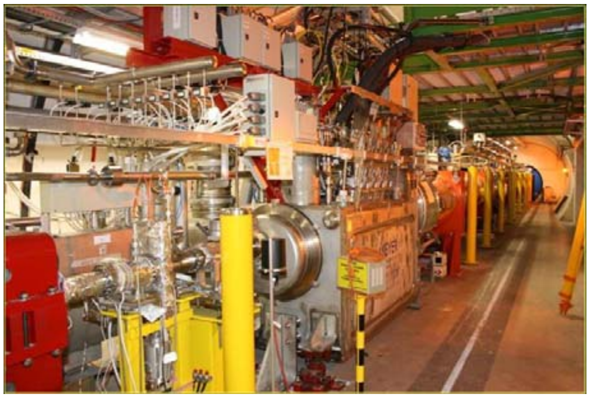

Figure 1: The low-β triplet in the ATLAS insertion.

Figure 2: A view from the low-β triplet towards CMS.

Another example of the general constraints is related to the LHC tunnel. The general access and transport of magnets to and from Points 1 (ATLAS) and 5 (CMS), illustrated in Figs.1-3, are such that long hauls over several kilometres alongside the chain of magnets and other equipment are unavoidable. Although care had been taken during tunnel studies to enable transport of magnets at any time, the LHC tunnel is a tight place and transport of equipment is a delicate affair that requires careful planning, even more so since some parts of the arcs may have to be warmed up for exchanging magnets. The replacement of the triplets in the high luminosity insertions may therefore require more time than just a typical annual shutdown of the machine.

Figure 3: Transport of magnets in the LHC tunnel.

These examples, as well as the urgency in renovating the LHC injector chain, lead to a situation where for technical and cost reasons the upgrade of equipment in the LHC insertions will be naturally phased over a longer period of time and will contain intermediate targets. The first to be handled are several bottlenecks that are known to limit the luminosity reach (collimation system, triplet aperture). They should be removed as soon as practically possible.

In this context CERN has started work recently on the "Phase I" upgrade, which concerns ATLAS and CMS experimental insertions. The goal of the upgrade is to enable focusing of the beams to a $\beta^*=0.25$ m and reliable operation of the LHC at 2 10^{34} $cm^{-2}s^{-1}$ on the horizon of the physics run in 2013. The upgrade concerns mainly the low-β triplets, but does not foresee any modifications of the interfaces with the two experiments, which remain at their present location (19 m from the IP). The low-β quadrupoles will feature a wider aperture than the present ones, and will continue to use the technology of Nb-Ti Rutherford cables cooled at 1.9 K developed for the LHC dipoles. The D1 separation dipole, as well as any other element in the beam line will be adapted to the triplet aperture. However, the present cooling capacity of the cryogenic system and other infrastructure elements remain unchanged.

MAGNET CHALLENGES

Although the Nb-Ti technology has reached full maturity with the magnet developments for the LHC, the envisaged "Phase I" upgrade is not without concerns, related in particular to the relatively aggressive planning which requires a string test of the full inner triplet by 2012. An important aspect of this effort is the need to finalize the choice of the main parameters of the low-β quadrupoles on the basis of current knowledge of optics, while having a very limited feedback from the LHC operation. On the magnet side, a number of design features of Nb-Ti magnets could still be improved for a small scale production, in particular the cable insulation, allowing improved operational margins at ultimate LHC luminosity. In the same spirit, the thermal optimization of the coil and of the collaring and yoking structures, as well as the coupling to the heat exchanger, could be improved to allow more efficient use of the available cooling power at 1.9 K. Similarly, the shielding of the triplets, both within and outside the magnets, should be revised and improved if possible, such that the thermal loads at higher temperature levels are proportionally increased to alleviate the power extracted at the 1.9 K level.

The main effort of the intermediate upgrade will focus on the low-β quadrupoles themselves. Nevertheless, the performance targets are such that modifications in auxiliary equipment servicing the triplets, as well as in other sections of the insertions, will be necessary. For all the equipment, cost-effective solutions need to be found and external collaborations developed.

CONCLUSIONS

Due to the imperative of efficiently running the LHC, and also for a number of technical and cost reasons, the upgrade of equipment in the LHC insertions will be phased over a longer period of time and will contain intermediate targets. The "Phase I" upgrade is focused on removing known bottlenecks and enabling reliable operation of the machine at its "ultimate" parameters on the horizon of the physics run in 2013. This intermediate upgrade must be compatible with the foreseen operations schedule and the existing infrastructure. The shortest route for providing new low-β quadrupoles in this time frame is to use the existing technology of Nb-Ti cables cooled at 1.9 K, where several improvements are still possible.

Achieving optimal operation of the LHC in medium-term requires extensive modifications in the injector chain. The "Phase II" upgrade needs to be synchronised with the completion of new injectors, and with substantial improvements in the cryogenic infrastructure in the ATLAS and CMS insertions.

REFERENCES

[1] The European strategy for particle physics, CERN/2685.
[2] L. Tavian, LUMI-06, Valencia, Oct 2006.
[3] LHC Design Report, CERN-2004-003.