Minutes of the 83rd WP2 Meeting held on 17/01/2017

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How to simplify HL-LHC Circuits (R. De Maria)

The presentation covers orbit control in IP1 and 5, need of MS10 and current in Q5 in IR6.

Currently most of the correctors in IP1 are operated at a fraction of their design strength, shared between the generation of the crossing and the orbit correction. The latter is more important in IP5, but still not critical.

The new layout of the orbit correctors in HL-LHC is shown. In this case we demand more strength as, in addition to crossing and orbit correction, we need to provide knobs to offset the beam at the crab cavities and at the IP. We still want to have margins for non-conformities.

A plot shows the margin of the LHC correctors for the HL-LHC case, most of the correctors do not have so much margin. Paolo Fessia asks if there is some budget for the Totem bump, Riccardo replies that in the HL-LHC Totem is not foreseen. Gianluigi asks if we are designing assuming a 2 sigma distribution of errors, Riccardo replies that we do.

Riccardo presents a list of possible simplifications, including their drawbacks.
In particular the reduction of budget for misalignment is related to the possibility of conducting frequent (typically once a year) realignments. Paolo Fessia points out that in case manual intervention is required, there are radiation concerns: in particular we need to wait for cooling times. For this reason a remote alignment system has been foreseen, but the possibility of alignment needs to be assessed taking into account the LHC experience and if the tolerance for alignment are limited than we should also review the need for remote alignment systems. Gianluigi adds that availability requires to avoid frequent realignments, he also points out that if correctors are connected in series a non-conformity on one of them has implications on all the correctors in series and therefore it has a larger impact. It would be important to estimate the cost/complexity saved for each of the proposed options, including their impact on availability and integrated luminosity. Massimo concludes that the WP2 requirements are in terms of Tm and speed, many technical solutions can be accepted but the HW Work Packages need to assess the impact on availability and on cost/complexity so that a decision can be taken based on cost/benefits comparison.

MS10 is required to compensate for geometric aberrations. Without the sextupole in Q10 one has a clear reduction of DA (>1 σ without beam-beam). With beam-beam a clear reduction of the acceptable working point area is clearly visible. Another option consists in removing MS14, however the defocussing sextupole MS14 is required for strength constraints. Removing only the focussing MS14 is not very helpful. One can also try a different optics solution with a different vertical phase advance and the removal of the focussing sextupole MS14. This solution is being studied and looks promising but might require the replacement of weak MQTLs in LSS6. Another option to avoid the installation of MS10 with both MS14f/d disconnected is to increase β^* by 10% at the end of the presqueeze but this would finally limit the β^* reach. Massimo points out that the possibility of bypassing magnets should be checked with hardware experts. Riccardo continues reporting the fact that the installation of the sextupole in Q10 can be complicated by the interconnections. Massimo asks if we can accept the DA reduction. Yannis replies that we target a DA of 6 sigma because the simulations do not include octupoles, errors, pacman… therefore it is not safe to cut on that.

IR6 is a difficult insertion due to the limited number of magnets and the constraints coming from the generation of ATS. There, Q5L is particularly stressed (above or very close to the limits for all the optics considered), in addition some matching constraints have been relaxed a bit (dispersion, phase advance). Q5R is as well stressed in many cases as it is used to control the beta function. Gianluigi stressed that the MKD-TCT phase is very important to gain in protected aperture and on β^* reach and for that reason some flexibility needs to be maintained.

Update on non-conformities and their evolution. Potential limitations for HL-LHC (e.g. MCBY, MQTL, RCS, MCBX, etc) (M. Giovannozzi)

There are two classes of non-conformities: the ones limiting the beam energy and the ones related to the beam dynamics (limits to magnets or circuits). Some of them appeared in the production stage, others during the commissioning, the incident and up to LS1. The possibility to fix non-conformities depends on the availability of spares and, more important, time for the intervention. The flexibility of the LHC design allows to cope with many non-conformities. Massimo shows a diagram summarising all the elements that can be affected by non-conformities in the arc cell.

Apart from the main dipoles, the separating dipole D3.L4 shows a slow training currently limiting the energy at 6.9 TeV, but we believe that more training can solve the issue. Other non-conformities have been found but they are not expected to limit the machine performance.

Some MQTLI (long trim quadrupoles) turned out to be weaker already during the production phase, but there was no possibility to produce more. As mitigation measure, they were installed in IR3, 6 and 7. Up to now there have been no issues, but as IR6 is now used to generate the ATS wave, we may need more strength there. Some other MQTLI showed a reduced operational current, but it is not fully clear if this is a sign of degradation.

A summary table shows the currently implemented workarounds to cope with non-conformities.

During Run1 and LS1 some additional non-conformities appeared, generally not limiting performances. Riccardo asks about the reduced beta/increased crossing in LHCb. Massimo answers that there are correctors that are not conform and limit the maximum external crossing angle in LHCb to about 500 μrad.

Relevant non-conformities are found in the Landau octupoles circuits which are going to be fixed in LS2. RCS.A78B2 has been recently condemned, this may affect the HL-LHC optics.

The time evolution of non-conformities does not appear to be critical, but, at present time, the strategy of limiting the current of the circuits just above their operational settings does not allow to monitor the evolution of their performance and whether they can still be operated to their nominal values.

The sensitivity to missing circuits requires to devise failure scenarios and find a mitigation strategy monitoring a figure of merit as the loss of DA. In case one spool piece circuit is missing the strategy is to share the correction among other circuits. For the MCS in LHC this does not cause a visible impact on DA even for the ATS optics where two classes of arcs (the four arcs participating to the telescopic squeeze and the others) exist..

For LHC non-conformities are not limiting, mitigation measures are in place, some non-conformities will be fixed in LS2. For the HL-LHC more studies are needed to understand which non-conformities require repairing actions. Gianluigi points out that the RSD/F limiting acceleration may cause issues for the combined ramp and squeeze. Paolo points out the need to identify the requirements in terms of budget and allocated resources, in particular in view of the HL-LHC. Rogelio mentioned that the MCS missing circuit should be put in the category of "requiring action".

Sensitivity of integrated luminosity for beam parameter change (Y. Papaphilippou)

Yannis presents the simulation setup: HL-LHC round optics V1.2, 2 crab cavities, 3 units of chroma, octupoles off. The target DA is 6 sigma as we want to keep margin in this somewhat optimistic simulation scenario.

The Beta*-Crossing angle scan shows that there is some margin in DA to reduce the crossing at the beginning of the levelling at 5e34 Hz/cm^2. The required separation would be about 19 sigmas. It is also possible to vary the crossing angle for the ultimate luminosity of 7.5e34 Hz/cm^2. The margin increases with the reduced intensity: by reducing the crossing angle one can reduce pile-up density and energy deposition. The DA studies show that at the end of levelling one can reach down to 9.3 sigma separation, still being at 5e34 Hz/cm^2. From the study it appears that crossing angle could be reduced to no less than 20 sigmas at the beginning of the fill and to 10 sigmas at the end of the fill.

Another possibility is to level with separation. The considered scenario keeps beta* fixed at 20cm. We do not observe a strong dependency of DA on separation: the DA is dominated by crossing angle. For this value of beta* the DA is a bit marginal for the initial intensity, requiring large crossing angles that have implications for the required corrector strength and larger aperture.

Gianluigi comments that the levelling with separation could be kept as a backup as β^* levelling comes with additional advantages or better: levelling by separation could also be used for the fine levelling of the luminosity while the evolution of the β^* is pre-programmed taking into account the expected beam intensity and emittance evolution.

Yannis moves on presenting the experience from 2016: the levelling with separation was already demonstrated. The crossing angle levelling was already proposed and demonstrated in simulation. Some losses appears in the first 2h of the fill, but the situation soon becomes burn-off dominated. Gianluigi noted that it is crucial to determine the origin of the lower lifetime at the beginning of the fill and its correlation with the beam parameters. It is also important to understand how this correlates with the expected DA as this would help in defining the requirements on DA in the presence of beam-beam. **Action: Yannis.**

From the model including IBS, radiation and elastic scattering, one would expect to damp the emittance in the vertical plane, while the horizontal is more or less preserved. However, this is not observed in the data and the vertical emittance is increasing. A summary plot shows the extra emittances blow-up after five hours for the two planes, the blow-up is mostly affecting the vertical plane and it is up to 25% larger than that expected.

Gianluigi asks if the blow up takes place early in the fill or if it is continuous. Fanouria replies that this is being investigated.

The loss of integrated luminosity comes both from extra losses and emittance blow-up, with the latter being constant over the year, and the former showing signatures of the changes to the machine (BCMS switch and crossing reduction).

Gianluigi wonders the impact of this unknown phenomena on the luminosity lifetime, compared to the burn-off lifetime, with respect to the integrated luminosity. Yannis replies that this is a work in progress.

Gianluigi asks about eventual performance losses assuming a 10% larger emittance or 10% lower bunch charge. What happens with BCMS, especially with the schemes that allow very high number of bunches. Gianni reminds that the filling schemes recently proposed give a lower number of collisions in IP8.

Yannis proceeds showing some tune scans. The positive octupoles eats up a lot of DA, while zero and negative octupoles helps to recover space for the footprint. As found for the LHC, the LHCb polarity has an effect which we can, at least partially, recover with tune adjustments.

Gianluigi suggests to try with separated LHCb @ 2e33 Hz/cm^2. Massimo asks if the fact of keeping the external crossing angle constant plays a role and if in case one could change whenever there is a polarity switch Yannis replies that this would mitigate the difference and that should be put on the table but it might imply larger external crossing angles and therefore fixing the nonconformities. Gianluigi noted that it would be important to have simulations for different crossing angles and a given luminosity (2e33 Hz/cm^2) for the start of levelling to verify the potential impact of an increased crossing angle. **Action: Yannis**. Gianluigi and Rogelio pointed out that brightness in 2016 was significantly lower than for HL-LHC and that extrapolations to HL-LHC might not be straightforward.

Reported by Dario, Gianluigi, Riccardo and Rogelio.