SESSION 3: PERFORMANCE - PART 1

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OPTICS CONTROL IN 2016

Speaker: Tobias Persson

The LHC optics was successfully commissioned down to β^*=0.4 m at 6.5 TeV, beyond the design value of 0.55 m at 7 TeV. In these challenging conditions, it was possible to achieve corrections to β-beating below 1 % at the high luminosity IPs and below 2 % RMS around the ring, marking an unprecedented level of control of linear optics corrections for any high-energy proton collider. These results were made possible by the recent improvements in the measurement of β-functions, namely: the usage of the K-modulation method, the incorporation of the obtained results in local and global corrections, the use of appropriate weights on the different optics parameters, a longer AC-dipole plateau, the N-BPM method, the reduction of the orbit drifts from quadrupole movements. Moreover, a correction of the linear coupling down to the per-mil level was demonstrated in MD using the AC-dipole, achieving the lowest levels ever measured in the LHC. For 2017 it is proposed to correct the effect deriving from the sextupolar errors in the IRs in combination with crossing angles. This should help to further reduce the β-beating.

Discussion

J. Wenninger remarked that the ramp and squeeze allowed to save a significant amount of commissioning time. He then asked whether the stability of the linear coupling in the triplet area is known. **T. Persson** replied that this was relatively stable throughout the year.

NON LINEAR CORRECTIONS

Speaker: Ewen Hamish Maclean

The effect of non linearities in the Insertion Regions (IRs) becomes more and more relevant when decreasing β^*. In particular the amplitude detuning introduced by normal octupole errors in the IRs can significantly perturb the tune spread introduced by the "Landau octupoles" installed in the arcs. This can have a detrimental effect on the performance of beam instrumentation (e.g. linear coupling measurement) and on beam stability.

In 2016 octupolar errors from the IRs could be measured using feed-down and amplitude detuning methods and could be successfully corrected. The positive effects of the correction have been verified through direct observation of octupole resonances and beam-lifetime, also with ATS optics. It is therefore possible to incorporate this correction operationally in 2017.

Sextupole errors in experimental IRs also become a concern at small β^*, as feed-down from these errors can generate significant linear optics perturbations. This is not critical for LHC operation in Run 2 but it will become relevant for HL-LHC. It is therefore important to acquire experience with the correction of this kind of errors.

Chromatic coupling effects can be corrected with negligible commissioning overhead when applying the linear coupling correction. Beam-based compensation of octupole and decapole errors has been applied operationally since the start of Run 2.

Non-linear optics commissioning in 2017 is expected to require two shifts of eight hours.

Discussion

G. Iadarola asked whether it is understood why correction based on magnetic measurements do not work. **E. Maclean** replied that this is most likely due to misalignments.

W. Kozanecki asked whether the mentioned 1-2% imbalance in β^* between ATLAS and CMS is before or after correction. **E. Maclean** answered that this is after correction.

EXPERIENCE WITH THE ATS OPTICS

Speaker: Rogelio Tomas (on behalf of S. Fartoukh)

The 2016 MD program allowed to gain significant experience with ATS (Achromatic Telescopic Squeeze) optics. Optics solutions were developed in order to have a "close to optimal" phase advance between the extraction kickers in Point 6 (MKDs) and the tertiary collimators in Point 1 and Point 5 (TCT). Optics and coupling could be corrected for β^* values as low as 21 cm and the telescopic squeeze could be pushed down to β^*=10 cm with probe beams.

Tests with a few nominal bunches were performed with ATS "pre-squeezed" optics to β^*=40 cm and with a moderately telescopic squeeze to β^*=33 cm. In particular collisions could be established in all experiments and the performance of the collimation settings could be positively assessed. This was an important milestone for the validation of the ATS scheme in view of the HL-LHC upgrade as well as in view of a possible use of the ATS for operation in 2017.

The operational cycle could be further optimized by combining the squeeze down to β^*=90 cm with the energy ramp and reducing the time of the final squeeze at flat-top

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energy to about 4 min. With ATS optics the mass acceptance for the CT-PPS experiment is lower than for the nominal optics. This could be partially mitigated with an optics change operating the Q6 at lower current with a consequent increase of the squeeze time.

The ATS MD program in 2017/2018 foresees the validation of the flat optics (e.g. 60/15 cm), possibly in synergy with tests on long-range beam-beam compensation using electromagnetic wires. Long-range beam-beam compensation with octupoles and the HL-LHC running scenario with negative octupole polarity will also be studied.

Discussion

M. Deile stressed that the figure of merit used to compare options for CT-PPS should take into account that at least three roman pots need to be used for their measurements.

M. Lamont asked whether the reason for which the expected loss peak in IR8 was not observed is understood. **S. Redaelli** answered that this is not yet understood and could be investigated with further tests in the future. Nevertheless it is good that the model was found to be pessimistic.

M. Lamont asked whether any showstopper has been identified that would prevent the deployment of the ATS optics in 2017. **R. Tomas** answered that the only real concern is the performance for CT-PPS physics. **G. Arduini** underlined that the problem identified in 2015 consisting in an unfavorable MKD-TCT phase advance is now mitigated. **R. Bruce** commented that still the phase advance is more favorable in the nominal optics compared to ATS. **G. Arduini** replied that the ATS satisfies the specifications defined for machine protection. **R. Bruce** stressed that for operation in 2017, the β-beating in the collimation area should be further corrected w.r.t. 2016 MDs.

M. Solfaroli reminded that at the moment we have one missing sextupole spool piece circuit and we need to compensate with those of the other arcs. He asked whether losing a second of these circuits is expected to be an issue. **R. Tomas** replied that detailed studies would be required to have an answer but he does not expect serious issues.

COLLIMATION EXPERIENCE AND PERFORMANCE

Speaker: Daniele Mirarchi

The performance of the LHC collimation system in 2016 was summarized. The system proved to be very reliable and effective, with no magnet quench due to losses from circulating beams and an excellent local cleaning inefficiency steadily at about 10^{-4} at 6.5 TeV. A big effort was put in place to minimize the setup time during commissioning. An optimized procedure was developed to obtain off-momentum loss maps without incurring into beam dumps. A record-time of about five hours was needed to align the entire system. Daniele also gave a brief overview of the setup and performance of the system during the ion run, for which the same short set-up times and steady performance were underlined. Highlights from collimation MD activities, both in view of the the choice of settings for 2017 and of interest for the HL-LHC project, were presented.

Discussion

Referring to one of the MD activities reported in the presentation, **F. Roncarolo** asked whether the losses observed with TCPs set at 4.5 σ indicate that this is an ultimate limit. **D. Mirarchi** and **R. Bruce** replied that the poor lifetime in the MD was observed also before applying the tight collimator settings. Therefore they would like to repeat the test before drawing firm conclusions.

R. Schmidt finally pointed out that the observed losses were comparable to those happening when going in collisions; hence, they would not represent a problem for machine protection.

ANALYSIS OF BEAM LOSSES

Speaker: Stefano Redaelli

S. Redaelli gave an overview of levels of beam losses throughout the year. The performed analysis relies on tools of loss decomposition in the three phase planes and beam lifetime estimations. Lifetimes during Run II were very good, showing a remarkable improvement with respect to performance in 2012. The handling of $\sim$250 MJ beams it the LHC was excellent, running steadily with nominal gaps at primary collimators, regular 25 ns beams, and values of β^* at the high luminosity IPs 30% smaller than the nominal value. A small decrease of the beam lifetime was observed when the crossing angle was reduced.

Discussion

B. Goddard asked whether the same type of analysis could be run on the cycle from injection to collisions. **S. Redaelli** replied that transmission is not in the plots and the analysis should be added. Nevertheless, the ramp was always very clean.

G. Arduini reminded that a better control of beam stability was a key factor to reduce the losses with respect to Run 1.

J. Wenninger also underlined that orbit control in Run 1 was poorer due to temperature fluctuations of the BPM system and less smooth orbit corrections. He also remarked that the point at β^* equal to 1.3 m had problems especially with BCMS beams, but they were cured by coupling corrections.