6th LHC OPERATIONS WORKSHOP, EVIAN2015 SUMMARY OF SESSION 6: 2016 CONFIGURATION AND CHALLENGES

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INTRODUCTION

The sixth session of the 6th LHC Operations Workshop, Evian2015, was dedicated to the presentation of the operational configuration and challenges for 2016. The session included the following five talks:

1) **2016 machine configuration**, by Roderik Bruce;
2) **How to fight collective effects limitations**, by Kevin Li;
3) **Plans for hardware commissioning**, by Mirko Pojer;
4) **Initial commissioning to Stable Beams**, by Belen Salvachua Ferrando;
5) **MD plans**, by Jan Uythoven.

For each presentation of the session, summaries of the discussion that followed the presentations are given.

R. BRUCE: 2016 MACHINE CONFIGURATION

The LHC configuration for 2015 was defined with the main focus on feasibility, robustness and ease of commissioning, with the goal of achieving stable operation at 6.5 TeV with 25 ns beams and low β^*. For 2016 the goal is to increase the performance as much a possible within the limits of machine safety.

MD and operational experience from 2015 showed that in 2016 it should be possible to operate with β^*=40 cm in IP1 and IP5. This requires the use of a tighter collimation hierarchy, an optics with optimized phase advance between the dump kickers (MKDs) and the tertiary collimators (TCTs), and beam-beam separation reduced to 10 sigmas. This is based on the assumption that the machine aperture will not degrade compared to the 2015 measurement with protons (a slightly worse aperture was measured with ions at the end of 2016). More conservative scenarios with β^*=50 cm and β^*=65 cm are are also presented.

Discussion

M. Lamont asked whether the aperture loss measured with ions is now understood. **J.Wenninger** replied that orbit "structures" had developed in the IP and plane where the bottleneck was observed, but from first calculations this cannot explain the full aperture loss. **R. Tomas** commented that also the correction of the waist shift can introduce a small degradation of the aperture.

R. Schmidt recalled that there is an MD proposal to use orbit bumps generated IR6 to simulate trajectories of particles kicked in case of asynchronous dumps. This shall be followed up as an additional method to independently assess the TCT protection.

S. Fartoukh added that chromatic effects will be stronger with smaller β^*, not only on aperture. Perhaps this should be taken into account by tightening the interlock on the RF frequency. He also added that a favorable phase advance between the MKDs and all TCTs will lead to zero phase advance between IP1 and IP5 (bad for off-momentum). **R. De Maria** commented that there is some flexibility, since we do not target exactly zero phase advance.

W. Hofle asked whether the bunch length would be reduced to gain luminosity. **G. Iadarola** commented that in 2015 the bunch length was increased to better cope with heat load from e-cloud at high energy. We could consider reducing the bunch length once we gain sufficient margin on the heat loads. **H. Timko** commented that bunch length should be not too short at the beginning of the fill, to avoid troubles with longitudinal instabilities. With full beams and 25 ns spacing also beam loading is close to the limit.

B. Goddard asked if the stability of the phase advance against optics errors has been assessed. **R. Bruce** replied that he evaluated it for different seeds of optics errors and concluded that it is expected not to exceed a few degrees.

W. Kozanecki asked what is the pile-up expected for 2016. **G. Arduini** replied that it will be in the range of 30-40.

B. Goddard commented that β^*=40 cm gives a quite moderate gain for the added complexity that is required. **R. Bruce** answered that there is not much extra complexity compared to β^*=50 cm. **S. Redaelli** added that the expected gain is of the order of 10-15%. This is not a small contribution.

K. LI: HOW TO FIGHT COLLECTIVE EFFECTS LIMITATIONS

In 2016, beam conditions will be more challenging with respect to collective effects compared to 2015. While running with full 25 ns beams we will continue facing detrimental effects from e-cloud, which make understanding and handling of beam stability significantly more involved. Pushing the optics down to β^*=40 cm will lead to larger impedance due to the tighter collimator settings, stronger beam-beam effects due to the reduced separation, and more pronounced impact from impedance and e-cloud in the triplet regions. Moreover, in case we will operate with high brightness beam variants, the beams will be more sensitive

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to e-cloud effects and the effectiveness of the octupoles will be reduced.

Beam stability relies on good monitoring and control of tunes, chromaticity, coupling and damper kick strength. Important diagnostics for beam instabilities, i.e. the head-tail monitor and the ADT ObsBox, were brought into operation towards the second half of 2015. They should go through further developed and upgrades so that they can be exploited during 2016 for an improved understanding of potential instabilities.

The main recommendations are to complete the intensity ramp-up with nominal beams, and then move to higher brightness. While high chromaticity and octupoles setting might be used to stabilize the beams from injection up to collisions, these settings should routinely be lowered during collision to relax the dynamic aperture limitations which become more stringent due to the head-on collisions. At the same time one will profit from the latter by enhanced Landau damping.

Possible measures and fall-back solutions in case of potential problems with instabilities can be, higher chromaticity, controlled emittance blow-up, longer bunches, collide while squeezing, wideband damper settings. Second order chromaticy could also be explored as an extra source of Landau damping.

Discussion

E. Shaposhnikova asked whether longer bunches should be obtained by lowering the RF voltage or by applying controlled longitudinal blow-up. **K. Li** answered that the blow-up should be preferred, since lowering the voltage would also lower the synchrotron tune, which has a negative impact on the beam stability.

O. Brüning asked if tools are ready to correct non-linear errors of the triplets. **R. Tomás** replied that this is the case and measurements and corrections are planned.

W. Hofle commented that a strong second order chromaticity might have a negative effect on the damping of the injection oscillations, which should be studied in detail.

S. Redaelli commented that in case of issues with instabilities, slightly lower bunch intensity could also be considered as a mitigation measure.

V. Kain commented that a controlled increase of the transverse emittance in the injectors is in principle possible, but the exact mode has still to be defined and implemented.

G. Kotzian commented that the kicker strength is mainly relevant for injection oscillation damping. For instability control, it is also important to focus on the early detection of the instability onset.

M. POJER: PLANS FOR HARDWARE COMMISSIONING

The machine will restart after the 2015 YETS (year-end technical stop) and the scope of the hardware commissioning includes some 7000 commissioning tests for the power converters, in addition to the standard commissioning without beam of the other accelerator systems. This is critical as 12 days are presently allocated in the schedules (as a reference, it was recalled that the commissioning time allocate in 2012 was 4 weeks). It was recalled that the machine will be closed on March 4^{th} and after that accesses will be controlled tightly.

The scope of the machine checkout was recalled, emphasizing that all the systems should be ready to inject and ramp low intensity beams at startup. Some details of the key test per main systems were recalled. It was pointed out that the RF will require significant time for conditioning and that they changed to FESA3 so dedicated software checks should be planned.

Discussion

S. Redaelli commented that it is planned to install in IP1 new Roman pots for the AFP experiment. Their commissioning should also be planned before starting beam operation.

B. SALVACHUA FERRANDO: INITIAL COMMISSIONING TO STABLE BEAMS

In 2016 only four weeks are allocated for re-commissioning with beam until the first stable beams with a few bunches. During this period the main systems (injection, dump, RF, collimation, instrumentation) will have to be setup and qualified, the optics will have to be measured and corrected, and the machine aperture will have to be measured in order to assess the final β^* reach. A review of the beam commissioning requirements for each key accelerator system was presented, with indicative time estimates.

Following the first stable beams with a few bunches, a 4-days scrubbing run will take place. After that, the intensity ramp-up in physics will take place. The ramp-up strategy will be similar to 2015 except that it will be done with trains of 288 bunches. Before reaching about 500 bunches, 20 h of stable beams in at least three different fills will be required at each intensity step. Thereafter we could envisage to continue with "mini" intensity steps (e.g. one train of 288 bunches per step) as was done in the last part of the 2015 run.

Discussion

P. Collier asked whether it would be more efficient to use short trains in the first intensity ramp-up and to focus on using the 288b. injections only later. **G. Rumolo** answered that the 288 b. trains can significantly enhance the scrubbing efficiency and will be therefore used during the dedicated scrubbing run. For the same reason longer trains should be preferred also during the physics intensity ramp-up, at least before limitations from e-cloud are encountered.

M. Wendt asked whether the use of doublet beams is envisaged for the beginning of the run. **G. Iadarola** an-

swered that doublets should be tested only later in the year, after accumulating enough scrubbing dose with the standard 25 ns beams.

E. Métral added that the linear coupling should be kept under control, since this could have an important impact on beam stability.

B.Goddard asked what measurements should performed to take a final decision on the value of β^* and what is the overhead to step back. **S. Redaelli** answered that detailed commissioning plan has to be established. However, the overhead can be made very small – no more than a few shifts – if the decision is taken early enough in the initial commissioning.

B. Goddard asked whether the combined ramp-and-squeeze is assumed as baseline for 2016 and whether this is compatible with the collide-and-squeeze, in case this is needed for beam stability. **J.Wenninger** answered that no particular problems are expected to use ramp-and-squeze. **S. Redaelli** added that there is no major overhead expected on the commissioning time. **G. Arduini** answered that β^* would be 3 m at the end of the ramp while the collide-and-squeeze would be needed only for smaller values of β^*. Therefore the two procedures should be completely compatible. **M. Lamont** added that, from the 2015 experience, there is no indication that the collide-and-squeeze is needed.

W. Kozanecki recalled that Van der Meer scans are also planned for 2016. It will be important to schedule them early enough, ideally close to the first fills at low luminosity and certainly before the summer conference.

J. UYTHOVEN: MD PLANS

The MD program in 2015 was successful, with very good machine availability. More than half of the MD time was dedicated to validate solutions for the 2016 run, while about 18% of the time was dedicated to tests directly related to 2015 operation (ideally this should be less). The new MD webtool was effective to collect the MD request and to manage the MD schedule, and the rMPP approval procedure worked smoothly.

Aspects where efficiency could be improved were identified, like the need of checking key equipment before the actual MD. The importance having proper documentation through MD notes was stressed. In 2016 the focus will move to performance improvement for the long term, with a substantial time devoted to the deployment of the ATS optics.

Discussion

P. Collier commented that a list of possible tests and measurements should be available, in case luminosity production is interrupted due to problems.

E. Bravin commented that, even without writing the MD notes, a significant amount of information on the MDs is available (e.g. LSWG presentations). This puts in question the statement that the MDs are lacking documentation if the MD notes are not prepared. The MD users are asked already a significant amount of documentation in the MD preparatory phases.

G. Arduini asked what is the situation with respect to β^* leveling. **J. Wenninger** answered that the concept is proved, but operational experience is still missing. Some information on orbit stability can be obtained from data collected parasitically in 2016.

J. Jowett commented that ion collision time in 2016 will be tight. So one should evaluate the possibility to anticipate ion MD and make them part of the standard allocated MD time if possible.

S. Redaelli commented that End-of-Fill tests can be very effective for many studies. **R. Schmidt** agreed, but added that strict machine protection procedures should be enforced, since the stored beam energy at the end of physics fills is typically still very large.

T. Pieloni asked whether small tune changes can be applied on different physics fills to study the effect on lifetime. **J. Uythoven** answered that this is possible but a detailed request should be prepared.