2015 Commissioning with Beam - Introduction

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Abstract

In motivating the session, the challenges of re-commissioning the LHC in 2015 are introduced.

INTRODUCTION

The LHC has been pulled apart and put back together again. There have been major system consolidation and upgrades including significant control system upgrades at all levels. Besides this a number of innovative suggestions have be proposed to improve operational performance; these will have to be introduced judiciously to avoid compromising initial commissioning.

The good performance of Run 1 performance was based on a number of factors, all of which have to be re-established for Run 2. These factors are listed below.

- Beam from the injectors featuring high intensity with impressively low emittance.
- Beam in the LHC enjoyed, in general, good lifetimes and good transmission through the cycle – despite high bunch population.
- Exploitation – there was efficient passage through all phases of the LHC cycle on a regular, operational basis.
- Understanding - great strides were made in establishing optics, aperture, a robust and accurate magnetic model. Collective effects received a lot of attention and significant progress was made in understanding the interplay of beam-beam, impedance and instability.
- Machine protection unpinned operation with unprecedented beam and magnetic energy.
- System performance was, in general, excellent. Systems included: RF, power converters, collimators, beam dumps, injection, magnets, vacuum, transverse feedback, machine protection, magnets, magnet protection, beam instrumentation, beam based feedbacks, controls, databases, high level software, cryogenics, survey, technical infrastructure, access, radiation protection.
- System availability was also acceptable thanks to a concerted effort by the system teams and a focussed global effort by the R2E project team.
- Problem solving was also necessary. Looking forward to Run 2, known unknowns include: UFOs, electron cloud and beam stability.

The main re-commissioning objectives are:

- Measure and re-establish appropriate beam behaviour in terms of lifetime, beam loss, and stability.
- Measure and establish the key operational limits: aperture; minimum β^*
- Set-up optics, injection, beam dumps, collimation and validate the set-up through all phases of the operational cycle. It is note that the final optics choice still to be made.
- Given the above, establish the nominal cycle with a robust set of operating parameters.
- Commission beam based systems: transverse feedback, RF, injection, beam dump system, beam instrumentation, power converters, orbit and tune feedbacks.
- Commission and test machine protection and re-establish the required, high level of protection.
- Along the way check the understanding of: magnet model; optics; quench levels; UFO rates; stability limits.

CHALLENGES

Operationally the LHC is not a new machine. The teams involved carry forward considerable experience. However they will face familiar and new challenges. Principal among these challenges are the higher operational energy and the move to 25 ns bunch spacing. The latter brings with it significantly worse electron cloud, implying that scrubbing will be one of the main drivers of commissioning in 2015. 2015 challenges are summarized in the tables 1, 2, and 3.

System modifications

It is also important to note that an impressive range of system modifications across the board have taken place during LS1. These have addressed:

- reliability, availability, performance, functionality, and system protection;
- improvements which realize creative thinking based on experience at all levels (hardware, software, controls);
- hardware grades giving increase processing speed and data transfer rates;
- improved analysis tools and diagnostics;
- noise reduction, better stability, and resolution;
- better fault tracking.

These modifications are going to take some shaking out both without and with beam.

Table 1: Challenges of high energy

Issue	Consequences
Higher stored beam energy	Potential for serious damage
Lower tolerance to beam loss, lower quench margins	Premature beam dumps
	Tighter parameter control
More energy dumped in triplets and collimator regions	Beam loss, heat load
Lower intensity set-up beams	Commissioning efficiency
Systems closer to maximum (RF, converters, beam dump)	Premature dumps, asynchronous dumps

Table 2: Challenges of 25 ns operation

Issue	Consequences
Injection of 25 ns beams	Bigger beam size, higher intensity per injection
Electron cloud	Instabilities, emittance growth, desorption, heat-load
UFOs	Premature dumps
Long range beam-beam	Poor lifetime, larger crossing angle

Table 3: Other challenges

Issue	Consequences
Radiation to electronics	Premature dumps
Emittance blow-up (non e-cloud)	Performance
Reset of vacuum system and	All conditioning lost: MKI, TCQQ, TDI
vacuum non-conformities	local heating - out-gassing
Impedance	Beam stability
Reduction in beam size - natural	Beam stability
Reduction in beam size - BCMS	Beam stability, brightness
	- limitations of protection devices
Loss of expertise	Commissioning efficiency

Beam stability

One interesting issue referenced in table 3 is that of beam stability. In 2012 with high bunch population single beam head-tail instabilities were observed at various phases of the operational cycle. There were also signs of an interplay between the two beams at the end of the squeeze and while going into collisions. The standard cure is Laudau octupoles. These provide a amplitude dependent tune shift and thus a betatron frequency spread in the bunch which provides Landau damping. The octupoles have been essential to LHC thus far. As regards Laudau damping the negative de-tuning given by the negative polarity setting is more effective than positive de-tuning. However, in the squeeze at lower β^* there is apparently interference between the tune spread from the octupoles with that from long-range beam-beam and in this case positive detuning is preferred.

Looking forward to 6.5 TeV, betatron amplitudes naturally go down with energy, and there is the possibility of using lower emittances. Both these reduce the effectiveness of the octupoles, suggesting the use of negative polarity. However, the issue in the squeeze might still have to be faced. There are some uncertainties and we will need to establish the limits with beam during commissioning and ramp-up and then make the choice.

CONCLUSIONS

There is a lot to sort out (safely). It is important to reduce the dimension of problem space during initial commissioning wherever possible.