INTRODUCTION FOR THIS (2nd) REVIEW ON LPL (LHC PERFORMANCE LIMITATIONS) => DURING RUN II (2015-2016)

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◆ Follow-up of (1st) review on LPL during run I

◆ Limitations due to transverse collective effects only

◆ Aims are to:
  ▪ 1) Summarize the observations performed in 2015 and 2016
  ▪ 2) Compare to existing models integrating impedance, beam-beam, e-cloud in the presence of transverse damper, octupoles, chromaticity, linear coupling, etc.
  ▪ 3) Review the 2012 results
Transverse instabilities are a concern based on the experience of the LHC run I (with 50 ns) and beginning of run II (with 25 ns)

- 3.5 TeV in 2010 and 2011
- 4 TeV in 2012
- 6.5 TeV in 2015 and 2016
- Some instabilities observed & cured
- Some instabilities observed & Not cured
- Some instabilities observed & cured
- Some instabilities observed & cured
- Some instabilities observed & cured
- Some instabilities observed & cured

Nominal cycle 2011

Elias Métral, Internal review on LPL during run II (2015-2016), CERN, 29/11/2016
2 (main) questions since 2012 => Why do we need (at high energy) to use

- High chromaticities (~ +15 units or even more sometimes)?
- ~ Max current in the Landau octupoles (max = 550 A), i.e. much more (factor ~ 5) than predicted from impedance only?

Another important question for HL-LHC => Can the instability at injection be a problem as high values of chromaticities and Landau octupoles current are also used there?

Several possible mechanisms have been identified and will be discussed today

- Important progress made since last review on all of them
- A new mechanism has also been included: linear coupling
Some info from last review

beams. All the observed instabilities could be cured except the instability at the end of the squeeze which was still present at the end of the run and which represents therefore a potential worry for future operation at higher energy, higher beam intensity and high beam brightness.

At the end of last year, the “clear” observations for the instability at the end of the squeeze were the following:
1) It is observed only with 2 beams.
2) It is observed only for β* smaller than a few m.
3) It affects only a few bunches at the very end of bunch trains.
4) Increasing the octupoles current helps.
5) Increasing the chromaticities helps.
6) It is very reproducible and mostly in the vertical plane of Beam1.
7) Once in collision, no instability is observed anymore.

Summary of single-beam instabilities

In summary, several features observed are similar to the ones observed with the instability at the end of the squeeze (see later: tails of batches more critical; hockey sticks).
AGENDA

1) Impedance model and single-beam instabilities (N. Biancacci)
   - How good is the transverse impedance model?
   - Could it explain some of the 2012 instabilities or do we need other mechanisms?
   - Was it an issue to run with very small chromaticities (sometimes negative) during the first part of the year?
   - Can we explain the instabilities observed in 2016 with few bunches for the high beta run?
   - Can we explain the 2016 beam stability of bunches of ~ 1.9E11 p/b within ~ 1.5 μm?
   - Do we have some margin?
   - Remaining questions to be answered / studies to be performed?
AGENDA

2) E-cloud effects in the 2012 instabilities (G. Iadarola)

- Can the 3-beam instability explain the End-Of-Squeeze Instability (EOSI) of 2012 or do we need other mechanisms?
- What could have been the e-cloud effects in 2012?
- Remaining questions to be answered / studies to be performed?
3) Beam-Beam effects in the 2012 instabilities (X. Buffat)

- Can the interplay between Landau octupoles and Beam-Beam Long Range explain the EOSI of 2012 or do we need other mechanisms?
- Can it explain some observed instabilities during the squeeze or in adjust in 2012?
- What are the beam stability predictions for run II with both signs of the Landau octupoles?
- Is the beam predicted to be stable for any parallel offset for both signs of the Landau octupoles (with the ADT on/off)?
- Remaining questions to be answered / studies to be performed?
AGENDA

4) Possible deformation of the stability diagram in 2012 (C. Tambasco)
   ▪ Can a deformation of the stability diagram explain the EOSI of 2012 or do we need other mechanisms?
   ▪ Can it explain other instabilities?
   ▪ Remaining questions to be answered / studies to be performed?
AGENDA

5) Prediction of the destabilising effect of linear coupling (L. Carver)

- A new mechanism has to be taken into account: linear coupling
- Could it explain the 2012 EOSI or do we need other mechanisms?
- How good should be the coupling to be able to accelerate bunches of ~ 1.9E11 p/b within ~ 1.5 μm in 2016?
- Could it explain some past instabilities with few bunches for the high beta run?
- Could it explain some instabilities at injection when the tunes were too close (e.g. after the change of the working point and in the absence of correction of the Laslett tune shifts)?
- Remaining questions to be answered / studies to be performed?
AGENDA

6) Linear coupling in 2012, 2015 and 2016 (T. Persson)

- What was the linear coupling strength (Cminus) along the LHC cycle during 2012?
- What was it in 2015 and 2016?
- Was it stable? Did it change in 2012 e.g. after the 1st Technical Stop?
- What can change it?
- Remaining questions to be answered / studies to be performed?
AGENDA

7) Instabilities at injection and start of ramp (K. Li)

- Can we explain the 2012, 2015 and 2016 injection instabilities / machine settings?
- Do we have some margin?
- Could it be a problem for HL-LHC?
- Remaining questions to be answered / studies to be performed?
AGENDA

8) Instabilities at end of ramp and flat-top (L. Carver)

- Did we observe some instabilities during run II?
- Can we explain them?
- Do we have some margin?
- Remaining questions to be answered / studies to be performed?
AGENDA

9) Instabilities during and at the end of the betatron squeeze (M. Schenk)

- Did we observe some instabilities during run II?
- Can we explain them?
- Why does the beam seem much more stable (in dedicated studies) than predicted at 40 cm in 2016? Comparison with 2015 at 80 cm
- Effect of Q" and other nonlinearities on beam stability?
- Do we have some margin?
- Remaining questions to be answered / studies to be performed?
AGENDA

10) Instabilities in adjust (X. Buffat)

- Did we observe some instabilities during run II?
- Can we explain them?
- Was the TOTEM bump an issue for the beam stability?
- Do we have some margin?
- Remaining questions to be answered / studies to be performed?
AGENDA

11) Instabilities in stable beam (A. Romano)

- In 2016 we observed for some time a "pop corn instability" in stable beam
- Can we explain it?
- Do we have some margin?
- Could it be a problem for HL-LHC?
- Remaining questions to be answered / studies to be performed?