**1-DAY REVIEW   
on the understanding of the LHC performance limitations during Run I**

**WHEN?: MID September => Ideally during the week from 23/09 to 27/09**

Aims of the review are to

1) Summarize with **systematic data analysis** the observations performed in 2012

2) Compare with existing models integrating impedance, beam-beam, e-cloud in the presence of damper, octupoles, chromaticity. Realistic sets of machine parameters should be used for the comparison

The evolution of the following observables (fill-by-fill) should be presented:

* Timing of the instability
* Growth time
* Main unstable lines
* Which bunches/number of bunches becoming unstable
* Which bunches/number of bunches blowing-up
* Intensity distribution and average intensity at the time of the instability
* Tune at the moment of the instability
* Chromaticity at the time of the instability (reconstructed from trims starting from measured data)
* Octupole settings at the moment of the instability
* Bunch length distribution and average bunch length at the time of the instability
* BSRT beam size distribution and average beam size at the moment of the instability
* Emittance at injection
* Separation (in the separation and crossing planes) at the moment of the instability
* RF voltage at the moment of the instability

List of different subjects to be discussed:

**1) Understanding of the instabilities with the old polarity of the octupoles**

* Evolution of the machine (tune, chromaticity, damper gain, octupole strength, separation, crossing angle, noise, intensity, filling schemes, emittances) parameters during the whole period.
* Systematic review of the observations (instabilities during squeeze, going in collision, when levelling in IP1/5, snowflakes). The beam parameters should be reconstructed from measurements and trims.
* At which separation did the instabilities occur? Is this related to beam-beam?
* Which bunches were getting unstable?
* What is the effect of a separation in the crossing plane in terms of stability?
* Understanding of the instability during or at the end of the squeeze? When was it? Was it reproducible?
* Understanding of the instability when going into collision?
* Understanding of the snowflake instability?
* Understanding of the instability when levelling in IP1/5 by separation?
* Effect of the crossing angle in ALICE/LHCb on beam stability? Would have it helped to increase the crossing angle in terms of beam stability?
* Did we see a change after technical stop at the end of June? Were the instabilities occurring more often after that technical stop?
* Did we see instabilities with a smaller number of bunches (e.g. during the ramp-up)?
* Were the instabilities related to a lack of chromaticity control? Did we have negative chromaticity?

**2) Results of the cogging (2-beam impedance) MD**

* Observations and interpretation of the data.
* Machine and beam parameters (chromaticity, damper gain, octupole strength, separation, crossing angle, noise, intensity, filling schemes, emittances) during the whole period.
* Is e-cloud involved? Can we get some information on the RF stable phase evolution and heat load in the triplets during the cogging MD (28/11 06:00-16:00). Did we see any evolution?
* What can we conclude from this experiment? Do we have 2-beam impedance issues?

**3) What did we learn from the other MDs?**

* Observation and interpretation of the data.
* Did/could we learn something from the studies scanning the octupoles’ current to find the intensity threshold? What else can we do?
* Which other studies could have been done to improve our knowledge of the machine?

**4) Understanding of the instabilities with the new polarity of the octupoles**

* Evolution of the machine (tune, chromaticity, damper gain, octupole strength, separation, crossing angle, noise, intensity, filling schemes, emittances) parameters during the whole period.
* Effects of the change of collision process: IP1/5 in collision and then LHCb.
* Systematic review of the observations (instabilities during the squeeze, did we observe anything during levelling, when separating in IP1/5? What was the scanned parameter space and results (bunch intensity, octupoles, chromaticity, tune split, damper settings – gain and bandwidth). At which beta \* the instabilities occurred? How reproducibly as a function of the parameters above?
* Why the instability was mainly horizontal and on both beams before the change of the octupoles polarity whereas it was mainly on B1V with the positive polarity (is it confirmed?)?
* Effect of the tune split (and its sign)? Which bunches were getting unstable as a function of the tune split?
* Effect of the RF voltage?
* Can we explain the end-of-squeeze instability with electron cloud effects? Why the beam should be unstable only for a given density of electrons and stable as soon as we change by +/- 10%? (is it confirmed?) Is the pattern of the instability (bunches that were getting unstable) compatible with electron induced instability? Can we simulate what could happen in the common areas?
* Did we see instabilities with a smaller number of bunches (e.g. during the ramp-up)?
* Effect of flat damper gain, bandwidth. Any?
* Did we see blow-up during the squeeze also with small number of bunches? Can this be explained by e-cloud?
* Did we see snowflake instabilities with IP8 private bunches anymore?
* Did we see instabilities when separating IP1 and 5 anymore?

**5) Stability diagrams and tune shifts with impedance/beam-beam/electron cloud in the triplets/damper/octupoles and chromaticity** **for different families of bunches**

* Evolution of the stability diagram/tune shifts from flat-top through the squeeze and in collision taking into account realistic machine (including realistic separations) and beam parameters. Include orbits, tunes, Q’ and Q” changes due to pacman effects.
* Approximations when really needed in the models should be spelled out.
* How good is the impedance (and related instabilities) model? It is now often said that the impedance is within a factor ~ 2 at top energy and a factor ~ 3 at injection. What does this mean? For which chromaticities (frequencies)? Can we understand these factors ~ 2 and ~ 3?
* What if our impedance model is wrong by a factor 2?
* How good is the Landau damping model?
* What about the other (than octupoles) external nonlinearities during the squeeze?
* What are the orbits, tunes, Q’ and Q” of all the bunches in the train? Can the differences explain the instabilities?

**6) Electron cloud effects**

* Heat load: contributions from impedance and electron cloud? How they compare to RF stable phase measurements?
* Do we understand the heat load in the stand-alone magnets and the triplets? Heat load in the triplets is much larger than estimated (factor 6.5). E-cloud in the common regions? What is the effect of the tighter spacing? Can we see any sign of scrubbing in the heat load evolution in the stand-alone magnets or triplets?
* Do we understand the levelling of the extrapolated SEY and heat load in the arcs? Can this be due to the main quadrupoles? Can we learn something from the behaviour of the stand alones?
* Do we understand the behaviour in the ramp and the comparison flat-top/flat-bottom?
* Do we need additional (e-cloud or other) instrumentation? Measurements in 2015?
* Is the 5+20 ns scheme tested in the SPS of interest in the LHC?

**7) Understanding of the instability at injection**

* Do we understand it?
* Is it correlated with the blow-up that we observe at low energy?
* Characteristics of the instability with 50 and 25 ns?
* Why could we not damp it with the transverse damper?
* Why did we need this amount of Landau octupoles?
* Was it the effect of chromaticity? Electron cloud? Space charge?
* Can it be a potential worry for the future operation (post LS1 and HL-LHC)? Is it a potential source of blow-up at injection?

**8) Experiments required in 2015** **and next steps**

* What are the possible experiments that could allow us to disentangle different effects, prove/confute a given explanation?

**9) Discussion session and conclusions**