LHC Beam Operation Committee

Notes from the meeting held on 31st May 2011

1. Experiment desiderata/wishes – M. Ferro-Luzzi (slides)

Massi highlighted some wishes from the experiments which are divided in three groups:

Going to STABLE BEAMS/OPTIMIZING/LEVELING procedure:

The luminosity limits in ALICE (IP2) and LHCb (IP8) and consequently the need for luminosity leveling for these two experiments are determined by:

ALICE cannot support peak luminosity above 10^{31} Hz/cm^2 for protection problems. A higher luminosity can damage the detector electronics and cause loss of data. With the 50 ns beam a careful choice of the filling schemes guarantees avoiding any accidental error.

LHCb luminosity limit is determined by a better performance of the detectors, it is not a protection issue. The luminosity leveling done for IP8 is an important tool to maximize the physics yield of the experiment combined with a large number of bunches. The physics aim of the LHCb experiment is to achieve the very challenging goal of 1fb^{-1} integrated luminosity by 2011. This will give them the possibility to detect new particles of SUSY theory or eliminate large parameter space.

- In **ADJUST MODE**: Lumi leveling off in LHCb, then **collapse separation** bumps. In LHCb the separation bumps should collapse to a vertical offset to reach luminosity of 1.5×10^{32} cm^{-2}s^{-1} (2-3 σ but should be increased for larger number of bunches)
- In **STABLE BEAM MODE** optimize IP1 and IP5 in both planes to maximize their luminosity, and ALICE to achive the target luminosity then **optimize horizontal** crossing plane for LHCb keeping vertical plane constant. Switch ON LHCb Lumi leveling, VELO closing with initial luminosity. Then lumi leveling ON to target luminosity updated, then increase of luminosity in few minutes.
- **During collisions** LHCb lumi leveling requested when measured luminosity differs by more than 3% from target value.

Filling the LHC:

Massi showed how by reserving all SPS cycles to fill the LHC for physics could reduce the filling time. A rough estimate of the saved time in filling the LHC integrated over the 2011 possible fills for physics shows a gain of possibly 30 hours extra time for LHC physics run. The whole procedure will not affect the CNGS program while there are possible implications on the north area fixed target experiments. The change in filling procedure is also supported by experiment program supervisors if the LHC physics program will gain from this.

SPECIAL REQUESTS:

As first goal the experiments would like to go to a stable configuration with 1380 bunches per beam before the next MD session (29 June- 3 July). But before that they still have four special requests to fulfill which should be done before July technical stop, after the July technical stop till September technical stop all special activities are discouraged.

- ALICE polarity reversal: will allow ALICE to collect the needed data before the technical stop and summer conference.
- Roman Pots set up for TOTEM
- LHCb polarity reversal
- One fill with ALICE fields off (only if no changes in collimators settings are needed).

Comments:

Concerning the lumi leveling procedure for IP8: Jorg commented that collapsing the bumps at a defined separation of 2-3 σ to avoid exceeding the lumi limit at the LHCb experiment is not a procedure they can rely on. The separations at the IPs do not show a good reproducibility from fill to fill, the reason is not yet understood otherwise IP optimizations would not be needed and they would go straight to head-on collisions.

Concerning the filling of the LHC: Jorg commented that in the calculations the beam set-up time is not considered and that we are not yet at the stage of optimizing on SPS cycles. S. Claudet commented that timing is not all, faster injections could bring to worse beam quality.

2. Triplet beam screens: Cryo conditions and last events (principle-settings-bakeout) – S. Claudet (slides)

S. Claudet showed the geometry of the beam screen with the two cooling pipes and the external cold bore which is at 2 K temperature and the schematic of the cooling scheme for the beam screens at the IPs with two control set-points fixed till April 2011 at 15 K at the entrance of the circuit and 20 K at the exit to ensure the temperature stability in case of beam induced heat load. During the April scrubbing run the temperatures of the beam screen exceeded (excursions up to 38 K) the LHC specifications (25 K). To improve the regulation of the temperature of the beams screens the initial beam screen cooling flow has been increased (lower the initial beam screen temperature since excursions are larger and higher initial control valve opening). With these new settings of the beam screen cooling more stable conditions for different beam intensities, have been achieved with a maximum excursion of 25-30 K for 912 and 1092 bunches. The worse cases are observed after injection at the triplets left of point 8 and right of point 2. These have in common that they are downstream of the IP for the injected beam

In the Triplets temperature increases at injection and depends on beam intensities while during the energy ramp there is no dependency but only temperature oscillations.

In the Arcs the situation is different after the scrubbing run. Now at injection there is only a moderate effect while the most significant contribution to the temperature increase occurs during the energy ramp.

In relation to the temperature increase a vacuum activity has been observed in the triplets due to desorption resulting from the high temperature excursions. A possible solution is to heat the beam screens of the inner triplets to enhance the desorption of hydrogen and favour its migration to the cold bore. Only IP8 inner triplets heaters were upgraded during the last Christmas break to a higher power of up to 100W max (the other IPs have 25 W max power) that means a possible bake temperature of 80 K. The bake-out has been applied at the triplets and examples of the case of IP1 left and IP8 left are shown. For the case of IP1 a very small effect appears which could be due to the limited power of the heater while at IP8 a large effect on the vacuum is observed.

A summary plot of the beam vacuum since the bake-out has been applied shows a reduced activity of the vacuum gauges at the Q1 while some beam induced activity is still present at the D1. Serge also commented that there is a clear relation between the temperature increase and fills where the luminosity is not so good which could lead to local losses.

Comments:

Concerning the arcs behavior: Gianluigi mentioned that two arc cells of the LHC show a an increase of the heat load during the ramp and asked whether it is planned to check their interconnects with a tomography. Serge confirmed that they will be checked at next technical stop.

Concerning the bake-out: Jorg mentioned that the positive effect of the bake-out in point 8 is visible during injection: no problems at injection have been encountered since bake-out.

Concerning the possible cause of heat-load at triplets: Mike asked if this temperature increase could be due to e-cloud and whether this could induce beam instabilities. F. Zimmermann answered that, because of the limited length of the triplets no instability is to be expected.

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3. Pressure variation in the inner triplets during beam operation– G. Bregliozzi (slides)

Giuseppe summarized the vacuum activity observed in relation to the beam screen heat load observations from cryogenics with possible explanation for the out gassing effect. The beam screen is inserted in the magnet cold bore and intercepts the heat load coming from image currents, synchrotron radiation and from e-cloud. The cold bore is at temperature of 1.9 K and provides a cold surface where gases coming released from the beam screens and channeled through the holes are condensed. The beam screen operates at a temperature between 5 and 20 K looking at the saturated vapor pressure versus temperature for different gasses it is important to notice that in this temperature range the vapor pressure of H_2 could be very large while for temperatures above 25 K also the CO vapor pressure becomes significant. AT 1.9 K all saturated vapor pressure are negligible. If the beam screen is covered by a quantity of H_2 or CO exceeding the equilibrium coverage then the presence of the beam will induce temperature oscillations on the beam screen which will induce vacuum transients with increase of pressure and flushing of the H2 and CO to the cold bore.

The gas accumulated in the beam screen can come from the scrubbing run period of April since all the desorbed molecules are then chemisorbed on NEG and physisorbed on the beam screen. To avoid the vacuum transient effect one has to reduce the coverage of gas in the beam screen below the equilibrium coverage. During the technical stop the temperature of the cold bore increased up to 10-15 K while the beam screen temperature was between 15-20 K so part of the hydrogen desorbed from the cold bore condensed on the beam screen.

When the beams are injected the image currents induce a heat-load on the beam screen. The beam screen temperature oscillates and the vacuum pressure spikes can occur depending on the beam screen surface coverage and the temperature of the beam screen. This can lead to possible beam dumps.

A possible remedy is the bake-out by whichwe heat the beam screen and we can flush the excess gases from the beam screen to the cold bore reducing the equilibrium surface and avoiding the vacuum transients. An example of the pressure evolution during the bake-out shows the desorption of H2 and CO while heating and during the cool down the gases were removed from the beam screen to the cold bore.

Comments:

Concerning the bake-out: Gianluigi asked if it is planned to bake-out all the inner triplets. Giuseppe answered yes, the procedure should be applied to all IPs but one has to upgrade the heaters to reach a sufficient temperature for bake-out the CO.

4. Possible impact of longitudinal oscillations on transverse plane – W. Hofle (slides)

Recently it has been observed that transients at injection and longitudinal oscillations are damped after several minutes. Transverse blow-up of some bunches has been observed intermittently. Wolfgang explained that longitudinal oscillations and non linear chromaticity could lead some bunches to experience negative chromaticity during part of the longitudinal oscillation. The longitudinal dipolar oscillations observed at injection had phase oscillation amplitude of +/– 10 degrees, which corresponds to a momentum excursion of +/– 0.76×10^{-4}. This is a small effect but could bring part of the bunch in regions of non-constant Q' moving from positive to negative chromaticity which can cause then emittance growth. Nevertheless the calculations should be repeated and based on more recent measurements of the non-linear chromaticity. **Action: a measurement of the non-linear chromaticity should be repeated.**

Comments:

Concerning the fills cases: Jorg asked if the offset measured on fill 1802 and 1803 means that the beam had different orbits at injection? Gianluigi mentioned one should check if there is any correlation between bunch transverse blow-up during some fills and longitudinal oscillations. A fixed display of the phase evolution would be helpful. Wolfgang explained he looked only at first bunch of the train, which is not maybe representative of the batch. They are working on the fixed display of the phase evolution of the bunches but some work is still needed. Support from OP is required for creating the fixed display.

Concerning the bunch blow-up: L. Evans commented that maybe we the LHC is operating at too low chromaticity? Jorg answered now the chromaticity is measured at the beginning of the injection and then the FIDEL trims are used to keep track of the evolution. Lyn mentioned there could be some relation to the time at flat bottom due to persistent currents evolution on b3. Jorg mentioned FIDEL dynamic correction are applied every second the longer we stay at injection the better the control on the chromaticity. Ezio reminded that magnetic measurements of magnets are planned in SM18 to update all FIDEL modeling coefficients to the actual LHC operational scenarios. Gianluigi reminded that a reduction of the luminosity and of its lifetime is characteristic of the fills where transverse blow-up is observed in some bunches.

5. Frequency characteristics of damper versus growth rates 450 GeV – part 1 - W. Hofle (slides)

N. Mounet simulated the LHC filled with uniform 50 ns bunch spacing at injection energy and results show that the rise time for unstable coupled bunch modes versus the mode frequency is very flat but reduces for very high frequencies. This means that the transverse damper gain should change depending on the frequency of the mode to be damped. The transverse damper gain has a reduced gain for higher frequencies 30% less at 1 MHz than at 3 kHz. Comparing the transverse damper gain versus frequency it is proved that at injection energy the instability can be damped since there is sufficient damper gain available to damp all coupled bunch dipolar modes in the large frequency range because of the reduced rise time of the instability for higher frequencies. At top energy the rise time is flatter and therefore requires the damper gain higher at higher frequency, the case at 3.5 TeV has to be investigated. Furthermore for uneven filling patterns the rise-time of higher frequency terms might increase with respect to that of low frequency ones.

6. Non-Linear Chromaticity Model versus measurements—F. Schmidt (slides)

F. Schmidt presented the model expectation for the non-linear chromaticity in the LHC and compared the model calculations with the measurements available, which are those, made in 2010 by S. Redaelli and

G. Arduini. The model takes into account all the errors and uses 60 seeds for the evaluation. Discrepancies exist between the measurements and the model.

Comments:

Concerning model: E. Todesco commented that one should be careful trusting the optic model results since the non linear chromaticity is very sensitive to the octupoles strengths and in the LHC the octupoles spool pieces are powered with tenth of Ampere, regime in which the hysteresis contribution to the field is dominating. The field produced by the octupoles can be anything so it is not evident to model Q" and Q''' if octupole strengths are unknown.