LHC Beam Operation Committee

Notes from the meeting held on 12th April 2011

1. Some Vacuum Observations with 50 ns beams – V. Baglin (slides)

Good news from the vacuum observations during the scrubbing run. Vacuum activity showed reduction of pressure/beam-current values among many scrubbing run fills. (17 hours of effective scrubbing time in the LHC). Results show a reduction of this quantity which defines the effective cleaning per beam current in the collider of one order of magnitude. The biggest effect of cleaning as expected occurs in the arcs as shown in the measurements of the vacuum pressure/beam-current at the high sensitivity measurement devices (10^{-11} mbar sensitivity) located at the arcs extremity (red squares and blue diamonds).
Another important point is that no contribution to pressure comes from the NEG coated areas as expected since no multipacting occurs in these areas due to the properties of the NEG layer. To check this effect measurements have been taken in the specific areas with and without solenoids on, and no differences have been found proving that no electrons are produced in these prudently coated areas.
While in the ID80 and ID212 warm modules the solenoid cleaning effects showed at the beginning of the scrubbing run a reduction of the pressure (ID80 from 7 10^{-9} mbar to 3 10^{-9} mbar, in ID212 from 9 10^{-9} mbar to 6 10^{-9} mbar). While after 6 hours scrubbing no reduction of the pressure is observed while switching on the solenoids demonstrating the effectiveness of the cleaning.
After 7 hours of scrubbing the LSS1 quadrupoles were still multipacting as shown by a net decrease of the pressure values when switching on the solenoids located left and right of the quadrupoles.
Vincent also showed how well the vacuum pressure rises at the arc extremity correlates with temperature rise from cryogenic measurements in the arcs (example of fill 1683 and fill 1691). The pressure values at warm-cold transitions are one order of magnitude larger than inside the arcs.
At the triplets the pressure levels were always in the 10^{-8} mbar level.
While at the interaction regions they observed 10^{-10} mbar at ATLAS, 10^{-9} mbar at ALICE and CMS and 10^{-8} mbar at LHCb.
A strange behavior has been observed regularly at the Q5L1.B location, maybe the vacuum gauge or a malfunctioning ion pump produces outgassing which could explain the vacuum activity in this area.
Comments:
Concerning the pressure levels at the experiments: J. Wenninger asked if the experiments can deal with the pressure levels reached so far. Vincent said that most of the experiments are NEG coated and with their solenoids switched on the pressure will get even better. Gianluigi

mentioned that to improve now the scrubbing the only way is to either go for 25 ns beams or for longer trains 108 or 144 bunches per train because we have reached now a level of cleaning which will not improve with the present beam configuration.

2. LHC Scrubbing Run April 2011: Cryogenic Observations in the Arcs – G. Arduini on behalf on L. Tavian (slides)

Gianluigi presented the observations collected from the cryogenic group during the scrubbing run.

The scrubbing run has started with the calibration tests of the beam screen temperatures versus energy deposited on the beam screen in some cells selected as reference to measure the heat load (mW/m) due to electron-cloud during the scrubbing runs.

For the 8 fills performed for the scrubbing run the heat load estimated at the reference cells is directly compared to the beam intensities to define the effectiveness of the scrubbing.

The highest heat-load of 70 mW per aperture has been observed on the fill of the 6^{th} April for 50 ns beams with 72 bunches per train and around than 600 bunches per beam. This means that this fill was the most effective for scrubbing however in all cases after the temperature increase there is always a fast recovery. The image current contribution to the heat load follows the beam intensities decay so the modeling used for this contribution to the heat-load is correct. The fills with around 800 bunches (fills number 6 and 7 in his plots) do not show any measurable effect as well as for the fill with 1000 bunches (fill number 8). This means we are now in a steady state, we are not scrubbing any more with the 72 bunches per train. We have reached the limit of cleaning with 72 bunch trains, we have to move to smaller bunch spacing or longer bunch trains.

Comments:

Concerning the Secondary Emission Yield (SEY): L. Evans asked to F. Zimmermann which is the SEY now in these conditions? Frank said it is below 1.7 but still we did not used the maximum number of bunches per train which could still decrease it. But results up to now are extremely encouraging.

3. RF Observations: Stable phase measurements – J. Esteban-Muller (slides)

RF observations of electron cloud are based on the synchronous phase measurements. The measurement principle is based on the fact that the beams interacting with the encountered electron cloud will loose energy that the RF system will compensate for turn after turn. Energy losses relates to the synchrotron phase ϕ_s which in the absence of acceleration follows the relation $\sin\phi_s = W_n/eV$ where W_n is the energy loss per turn and per particle and V the RF voltage amplitude. The method consists in measuring the phase of the RF voltage seen by the center of the bunch, which is determined by measuring the 400MHz component of the bunch using a pick-up. This phase give us an indication of the beam energy losses and therefore of the e-cloud produced. The error phase is an averaged value over the circulating bunches. Then also some single bunch measurements were performed and were presented.

Juan showed as an example the measured phase error as a function of time during the injection of several trains. One can notice the variation of the phase error as soon as a new train is injected after the third train circulating in the accelerator. This is an indication that the e-cloud starts being produced. Then from the fourth train on the shifts in the phase error appear for each train injected. Another example shows the drift of the phase error as a function of time for beam 2, which is a systematic error in measurements. Therefore, all measurements presented were done for beam 1.

Juan presented the results of phase error measurements as a function of beam intensities of the 2010 one week of scrubbing run for the 50 ns and 75 ns beams and for the RF system with voltage of 3.5 MV. The phase error appears as expected higher for the 50 ns than for the 75 ns bunch spacing because smaller spacing between bunches enhances e-cloud production.

Observations of 2011 scrubbing run are:

75 ns beams before scrubbing run spread in phase error as a function of beam intensities for the different fills of 22nd March and 4th April. The RF system is now settled at a voltage of 6 MV. Measurements have been taken before the scrubbing run.

75 and 50 ns beams during scrubbing run a summary plot shows the phase error as a function of the beam intensities for the several fills used for the scrubbing run with 75 and 50 ns beams. Important to notice how the phase error decreses while the scrubbing occurs, clear indication that the cleaning is efficient. And that the slop for the 50 ns beams approaches the 75 ns slopes clear indication of the cleaning.

2010-2011 comparisons Juan compared in one plot 2010 and 2011 scrubbing run measurements. Due to different RF settings (RF voltage was 3.5 MV in 2010 and 6 MV in 2011) a scaling factor is applied to 2011 results for direct comparison to 2010. To be noticed that for both cases the 50 ns beams are more effective in scrubbing showing higher phase errors than the 75 ns beams. Better situation than 2010 since phase error smaller than last year achievements.

Another plot of the 50 ns beam slopes as a function of time (fills of scrubbing run) shows clearly a decrease of the phase error during the scrubbing run proving again the effectiveness of the cleaning.

Bunch by bunch Phase error measurements of Fill 1675 show for the full beam a decrease of the phase error to zero at the end of the beam and a reduction of the bunch by bunch spread in time consistent with the fact that synchrotron oscillations are excited at each injection and need a time scale of 10-15 minutes to be damped. Looking at a single batch level one can notice a common path/trend along the trains which can be related to e-cloud. Only a full analysis and comparison to the intensity fluctuations and/or positions will clarify what determines the trend. An analysis of the single bunch synchrotron oscillations of the last 5 bunches of the last circulating batch at different times among 20 minutes shows the oscillation amplitudes decreasing for the last bunches. Unfortunately the measurements were taking only for few turns and a full synchrotron period to define frequencies and phases was not covered. Important to notice the reduction in time of the synchrotron oscillation amplitudes.

4. Some Beam Observations during the LHC 2011 Scrubbing Run –E. Metral (slides)

Elias presented some beam observations during the scrubbing run 2011. He started the presentation highlighting the objective of the scrubbing run: reach a stable situation with at least 1000 bunches in the LHC with a 50 ns bunch spacing. This condition has been achieved on Monday 11th April 2011 with the Fill 1694.

For the beam dynamics observations several instruments have been used to understand the dynamics during the scrubbing process.

BSRT single bunch emittances measurements showed the effect of the e-cloud on the beams emittances showing also a trend along the bunch train as expected since the cloud density changes along the trains reaching after a while the saturation. When the stable condition has been reached no more emittance growth has been measured in the beamswith the BSRT.

Schottkys single bunch tunes: it is expected that the presence of the e-cloud will produce in the proton bunches a coherent tune shift proportional to the cloud density. For the nominal LHC the expected tune shift should be of 0.05 units for a cloud density of 1.2 10^{13} m^{-3} while for a reduced density of 5 10^{11} m^{-3} the tune shift should be of the order of 0.002. Schottkys single bunch measurements of Fill 1674 show a clear trend along the bunch trains with tune shifts of the order of 0.003 leading to a e-cloud density of 7 10^{11} m^{-3} which is in agreement with expectations. The bunch tune shifts appear reasonable in the case of stable batches while when the BSRT measurements show emittance growth the Schottky data are more difficult to interpret and unrealistic shift of 0.1 units appear. Analysis is still on-going to explain the data collected.

Bunch Length: e-cloud can lead to bunch shortening as showed with an example from the scrubbing run where a reduction of the bunch lengths occurs along the different batches of the beams.

FBCT measurements give information on the bunch losses. During the scrubbing it has been observed that last bunches of the trains normally loose more respect to the others showing a clear trend along the trains. Elias also showed the effect of the injection of one batch (the last one) on the whole beam which was observed sometimes during the scrubbing run. The cause of this effect has nothing to do with e-cloud effects but it is related to the beam RF phase module and has been solved by the experts.

ADT measurements: the transverse damper pick-ups give the possibility to measure the single bunch oscillations as a function of time and therefore give information on possible coherent oscillations if any due to e-cloud. Data are still under analysis but some effects have been observed during the scrubbing run, as for example the development of a Christmas tree which means coherent oscillations were developing.

BBQ measurements: the same Christmas tree structure observed with the damper pick-ups was observed also with the BBQ on the 10th April on beam 1. The Christmas tree pattern has been already observed last year as a consequence of the beam losses. Further analysis should define if for any of the oscillating frequency we have an increase in the oscillation amplitude or not. On beam 2 the BBQ showed a strange pattern of multiple peaks five minutes after the injection of the 11th batch of beam 2. This effect is not yet understood. In some cases sidebands are observed on the BBQ for few minutes after injection of a batch but none of the oscillations were growing in amplitude. A possible explanation to such an effect could come from coupling to longitudinal coherent oscillations.

Comments: R. Assman in the morning we have observed losses modulated by synchrotron oscillations after 5 minutes Philippe answered that RF is still looking into this but the fact that they occur after 5 minutes give indication that it is not related to RF.

L. Evans asked Gianluigi how can one decide now which path to take. Gianluigi said that it is needed to test the ramp to see if we have margin with the present scrubbed machine otherwise go for 144 bunches per train to gain more margin. Lyn remembered that integrated luminosity is the goal for 2011 and 75 ns can give an important fraction of it thanks also to the much better quality of beams from injectors after one can think of the 50 ns beams. Gianluigi remembered that with the 75 ns beams we cannot have high intensities as for the 50 ns beams that's why it is such a promising.

We have postponed Massi summary of Beam filling schemes.