Electron cloud meeting #31, 13/07/2015

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Matters arising (G. Rumolo)

- Last meeting took place in June and we mainly summarized the LHC experience and raised few points. The goal of today's meeting is to keep following up on LHC progress and on any open points. Next meeting, scheduled on 2 September (draft agenda), will be fully devoted to the development of the simulation tools, progress and achievements. The speakers are available to present.
- One question still pending is the warming up of few cells per sector (not to affect the global cryogenic capacity, impact to be assessed) up to no more than 80 K (inlet temperature, while on the outlet it would b around 60). Preliminary results from the VSC lab measurements of scrubbing at different temperatures do not show any evident difference between scrubbing at 6 and 80 K, as in both cases scrubbing saturates at an SEY value of 1.35, and even shows a tendency to again deteriorate towards 1.4. However, the lab measurements are made on a cold sample in a warm environment, so it would be interesting to check what happens in the machine with its vacuum composition and the fully cold environment (and pulsed electron bombardment). Therefore, there is a general agreement that it is worth doing this experiment anyway and check the possible effect of temperature on the efficiency and evolution of beam induced scrubbing. The cells were selected by BE/ABP, TE/CRG and TE/VSC together after a few iterations identifying those that would meet certain general criteria, in particular: relatively high heat load, selected cells have a 'twin' cell remaining at low temperature, 60 A current lead on the colder side of the cooling circuit, pressure gauge available close the cell. The detailed list is again provided here below. Since it would be advisable not to make this change while we are running LHC with more than 2000 bunches, the idea would be to apply it during the intensity ramp up after the next MD block, foreseen between 26 and 30 or 31 July. The formal authorization to proceed will be asked at the next LMC during the talk on the scrubbing progress.

S12	13R1_947
	13L2_947
	27L2_947
S23	13R2_947
	13L3_947
	31R2_947

	33R2_947
S34	13R3_947
	13L4_947
S45	13R4_947
	15L5_947
S56	13R5_947
	13L6_947
	33R5_947
S67	13R6_947
	17L7_947
S78	13R7_947
	13L8_947
	25L8_947
S81	13R8_947
	13L1_947
	31R8_947

2016 observations (G. Iadarola)

- Slides are available here.
- Looking at the heat load evolution from the beginning of the intensity ramp up in 2016, it is very hard to spot a scrubbing trend, especiallyis we also take into account the fill-to-fill intensity fluctuations, the voluntary parameter/filling pattern changes, like the switch from trains of 72b to trains of 2x 48b or the adiabatic decrease of the target bunch length at collision, some re-calibrations of the heat load measurements.
- The total power loss obtained adding all the heat loads in the cold regions has been compared with the total power loss adding up all the bunch-by-bunch power losses measured with the stable phase shift. The agreement is within 10% at injection and beginning of the stable beams, but it then tends to diverge and the difference increases for long storage times. This is due to the fact that the stable phase shift is measured with respect to the stable phase of the first 12 bunches, which are not colliding and lose at a much lower rate than all the other bunches when in collision. Therefore, by assuming that reference and comparing with the second train of 12 bunches, which collide instead, we find that we consistently underestimate by ~3 W/bunch the losses attributed to the different bunches. If we apply this correction, the agreement between the two measurements improves also in the later phases of the fills.
- The pattern of the losses in collision, as shown by M. Hostettler, exhibits a clear electron cloud shape once the losses due to burn-off are removed. This is seen equally in Beam 1 and 2 and shows a pattern very similar to the stable phase shift. The ‘build up time’ appears to be different because while the energy loss is dominated by the electron cloud in the stripes of the dipoles, the losses should be dominated by the central density, which is likely to have a different build up pattern.

- Looking at the heat load versus beam intensity, it is clear that, while the curves of the good sectors change concavity for low intensities (suggesting a 'switch-off' of the electron cloud), those of the bad sectors keep decreasing linearly. Fill-to-fill intensity fluctuations for fills with the same controlled longitudinal blow-up in the ramp are found to be correlated with differences in bunch length. If there is bunch flattening, the behavior is also different (and it can be misleading to rely on the numbers provided by the BQM, which quotes an rms value rescaled from the measured FWHM)
- The heat load during the energy ramp seems to increase by a fixed delta for all sectors (~50 W/hc), the absolute spread between sectors remains unchanged between injection and top energy. This value is about double with respect to what would be expected from synchrotron radiation. Looking at the quads (Q6), it is very hard to spot a clear change on the ramp, most of the heat load already comes from injection. The dipoles exhibit the opposite behavior. There is almost no detectable heat load at injection, but the value becomes ~10 times larger when ramping to 6.5 TeV (with a spread between the dipoles on which we have a direct measurement).
- The total electron dose deposited on the walls of the dipole beam screen can be estimated to be close to 0.09 C/mm^2 in 2016 (it was about half this value in 2015) by assuming a conversion factor heat load to electron flux to the wall of 3 mA/W (found from simulations and equivalent to assuming an average energy of the electrons impacting on the wall of about 333 eV) and an impacting segment on dipoles of about 2 cm in the cross sectional area. From the scrubbing curves in laboratory, this value should have been already sufficient to fully scrub the Cu and we are far into the region of asymptotic SEY reduction.

QBS evolution (E. Rogez)

- Slides are available here.
- Since originally it was assumed that the heat load would decrease linearly with bunch intensity to reach eventually 0 for 0 intensity, the calculated decay of the heat load during stable beams (with the beam current decreasing) tended to diverge from the real value, especially for long fills. This was corrected by introducing a threshold of 4e10 p/bunch (for all sectors), at which the heat load vanishes. With this assumption, the theoretical value fits much better the measured one.
- The batch spacing increase from 250 to 300 ns seems to reduce of 1.6% in average the heat load, probably within the accuracy of the measurement (also considering the fluctuations on the beam intensity)
- The effect of changes in bunch length was clearly seen in the heat load behavior.
- The cell-by-cell heat load exhibits the presence of a bump in Sector 23.
- The corrections to the flow equations, which result in a more precise calculation of the heat load (already applied to sectors 12 and 23) were also applied to sectors 78 and 81 during TS1, leading to visibly higher

values. A full sector test was performed only for the most critical sectors (S23 and S78) and it need to be planned for all the other sectors: S12, S34, S45, S56, S67 and S81.

Sector-by-sector beam loss observations (D. Mirarchi)

- Slides are available here.
- The integrated losses from the IC BLMs (1.3 s integration time) were analysed in each sector over the cycle, with closer checks to single cells and dipoles (MB) and quadrupoles (MQ) separately. A set of 12 fills from 13/6 to 10/7 was taken into account: all fills with stable beams lasting for more than 12 hours. The common features are discussed.
- Like in 2015, a change of loss rate is visible at end of ramp in about all sectors, with S12 exhibiting the most significant increase. Besides, in 2016 a change of loss rate is also seen in 'Adjust' only in sectors S12 and S81 (with S81 exhibiting the most significant increase). Separating the readings from MB and MQ, it seems that the latter feature comes from the MQs.
- The cell-by-cell analysis reveals that the largest change of slope in Adjust is seen in C.15.R8 (ULO, where there is also an orbit bump) and a few others. It can also be disentangled whether these losses come from Beam1 or Beam2 (e.g. the losses at the ULO come from Beam2)
- Looking at the overall plots of the integrated losses at selected points along the fills for all the analysed fills, we can see this year that S12 and S81 are still those with most losses (and they are also those with the highest heat loads), but then surprisingly S45 comes third, while this sector is one of the best behaved in terms of heat load. The similarity between the patterns is therefore still present, but less striking than in 2015.
- Parameter studies were made scanning the crossing angle and the electron density in the chamber (by adding a uniform electron distribution with a certain density on top of the one naturally formed by the build up process and concentrated around the main diagonals of the chamber). As expected, the extent of the tune footprint increases with lowering the crossing angle (and we go back to the old large distribution for 0 crossing angle, i.e. when the two beams are on axis). We would need electron densities of the order of 10^{13} m^{-3} at the beam location to have a measurable impact of the electron cloud in the triplets on the general tune footprint (i.e. in the same order of magnitude as the density in the center, which we know is certainly not the case).

Simulation studies of e-cloud in LHC LSS and its effect on dynamic vacuum (J. Sopousek)

- Slides are available here.
- The purpose of this work is to explain the behavior of the dynamic vacuum measured with some selected gauges in the interaction regions of

LHC. The electron cloud is one of the important ingredients to interpret the observed patterns and evolution.

- A certain number of gauges has been considered (between Q5 and Q7). The main features of the observed dynamic pressure behavior are a clear rise during the injection, then in some cases there is a rise also along the ramp (due to synchrotron radiation induced desorption), in one case the pressure drops along the ramp (similarly to the heat load in the inner triplets), and finally a drop in pressure is observed when going in collision (which could be due also to change of orbit in the interaction region or the movement of some collimators)
- To adapt to the different filling patterns in 2015 and 2016, PyECLOUD simulations were run for a specific filling pattern made of a train reaching saturation and a train with gaps of different length. The behavior of the heat load was then parametrized using coefficients inferred by this simulation and these coefficients were applied to reconstruct the evolution for the different filling patterns.
- The SEY thresholds were evaluated for all the chambers without magnetic field. Larger chambers have lower SEY thresholds. It is also very interesting to notice that including photoelectrons as seed electrons significantly lifts up the curves especially in the region around/below the multipacting threshold. With only 5% PEY (as found in the old measurements by V. Baglin) ~5 W/m turn out to be generated by photoelectrons alone in the arc beam screen for an SEY of about 1.4. This could be the mechanism that causes the observed increase of heat load in the different sectors along the ramp? Anyway, a factor 5 more desorption is indeed observed with 25 ns beams with respect to e-cloud-free 100 ns beams (with a similar number of bunches).
- Two regimes can be identified for electrons in quads. Those moving on or close to the main diagonals are mainly trapped around the strong gradient field lines and exhibit a chaotic from one pole to another accumulating and multipacting. Other stripes are also generated in the regions with high magnetic fields and lower gradients far from the center of the chamber, and these are really similar to the stripes forming in dipole fields. Since trapping and stripes depend on the gradient of the magnetic field, larger gradients can lead to a decrease of electron cloud, which is seen in some gauges with the drop of pressure when the ramp takes place.
- Then all the magnets of the interaction were simulated and their SEY evolution was reconstructed in 2015 assuming a measured laboratory scrubbing curve and the measured heat loads. It was found that by assuming a 67x slower conditioning and a time constant of 40 days for deconditioning between fills, the evolution of the heat load in 2015 could be reasonably reconstructed.
- At this point a vacuum simulation of the full interaction region in dynamic regime was run including all the following ingredients: surfaces in Cu and NEG, beam screen inside/outside cold mass, ionization pumps, NEG cartridges, static pressure, synchrotron radiation desorption (this also needs the distribution of the hitting synchrotron radiation calculated with SyncRad3D), desorption from electron cloud. A common desorption

coefficient is assumed (obviously this value also changes during scrubbing)

- The pressure profiles that were produced with this technique show very large values inside the quadrupoles (up to 1e-7 mbar) and match reasonably well the values of dynamic pressure measured from the available gauges in the interaction region of ATLAS.

Adjournment

Next electron cloud meeting will be taking place on 2 September.

GR & GI, 15/07/2016