LHC e-cloud simulations Meeting – Draft Minutes

Date: 9 May 2011
Meeting Room: 6-2-004

Attendees: Gianluigi Arduini (GA), Hannes Bartosik (HB), Chandra Bhat (CB), Humberto Maury Cuna (HM), Octavio Dominguez (OD), Wolfgang Hofle (WH), Kevin Li (KL), Elias Metral (EM), Tatiana Pieloni (TP), Giovanni Rumolo (GR), Frank Zimmermann (FZ)

Excused:

Agenda

1) Comments on the minutes and actions of the last meeting (28^{th} April 2011)
2) E-cloud feedback and open questions, Wolfgang Hofle
3) Update on arc heat-load simulations (larger δ_{max}-R scan range, higher vacuum pressure), Humberto Maury
4) Revised 2011 benchmarking, linearity check, and solenoid effect, Octavio Dominguez

Minutes and actions of the last meetings (28^{th} April 2011)

Past Actions:

- Horizontal displacement of daughter particles, still pending (potential **ACTION** for Ubaldo Iriso or HM).

- Send LHC parameters to Fatih Yaman, to be done (**ACTION** → FZ)

The rest of the actions have been all done.

e^- cloud feedback and open questions

WH reported on the e-cloud feedback system status in order to prepare a LARP meeting which will take place during the week 16^{th} - 20^{th} May.

First he recalled some aspects of the feedback system studied in 2008. A simple feedback model was used (estimated bandwidth <1 GHz). A pure dipole feedback seems to be not sufficient (it needs a large bandwidth to resolve motion inside the bunch). Some questions were not resolved at that point such as the ***power needed by the system*** and the ***residual blow up*** (incoherent effects).

New results using the WARP code were presented at PAC11 in a paper by R. Secondo (LBNL) et al. For this, a new feedback algorithm has been used. In addition, a 5-tap FIR filter (instead of a 2-tap one used in 2008 computations), which allows to have a realistic feedback with delays, is considered. This filter takes the data from the previous five turns. Simulations with 5000 slices instead of 100 (2008) do not show a big difference. A gain of 0.2 damps completely the coherent motion. Different e-cloud densities have been considered. The results shown referred to the SPS at 26 GeV and an electron density of 1e12 m^{-3}.

Kicks are needed mainly in the head and the tail of the bunch when using a wide-band feedback. These kicks are constantly needed, which is not completely understood yet. The fact of having to kick also the head might be due to the fact that head and tail are coupled. Anyway, if that would be the case, it is still strange that head and tail need the same kick continuously. Perhaps the large excitation in the head and tail is an indication of noise due to the small number of particles in head and tail slices. WH had asked the LARP colleagues to continue the simulation for more than 4000 turns. The kick strength required might depend on the value of an initial static offset from the center of the vacuum chamber introduced in the LARP simulations. The offset results in an asymmetric e-cloud and, thereby, potentially in a “crab-cavity” like closed-orbit distortion varying along the bunch, which the feedback might try to correct. The slices are equally spaced both in WARP and in HEADTAIL codes. In the SPS simulations, several strip line kickers are located around the ring, each providing less than 1 MW, but more than 10 kW, at 26 GeV.

Next, pick-up data from e-cloud and impedance (TMCI) in frequency space were shown. The effects caused by e-cloud are much faster (after ~200 turns vs. ~9000 turns for TMCI).

Some related ongoing activities within the LARP collaboration were presented. There is a proposal for a kicker design taking into account the geometrical constraints from vacuum chamber. A demonstrator hardware (including some amplifiers) in the range of 100 W will be used this year in SPS. The goal is to excite single bunch head-tail oscillations in a controlled way using digital electronics (high speed DACs). Simulations with the WARP code will continue exploring different values of the power, exploring longer time periods as well as different offsets. These simulations have to be compared with other existing codes (HEADTAIL from CERN and CMAD from SLAC), including the present feedback, but it is necessary to find a person to do them. WH mentioned that the candidate for his work recently left SLAC. GA proposed that a person could spend some time at CERN to carry out this work. The conclusion about this point was to inquire inside CERN how to organize the work (**ACTION** → GR, EM) and to inquire at the US LARP meeting about candidate visitors / students to spend two months at CERN (**ACTION** → WH). Furthermore, HEADTAIL would need a few changes / additions: Closed orbit offset, different slicing (FZ proposed to equally populate the slices) and a modified feedback algorithm.

FZ proposed to ask K.Ohmi for cross check (**ACTION** → FZ).

Update on arc heat-load simulations

The results shown use the same parameters as in the last meeting (see previous minutes, 28th April 2011) except for an increased base pressure (from 1 to 32 nTorr) and a widened SEY scan range (up to 2.4).

At 450 GeV the heat load increased by about 1 order of magnitude. A fill factor of 1/10 has been included. The results shown were based on the average heat load over the first two batches. The experiment done during the scrubbing run consisted in up to 1000 bunches at 450 GeV, and 200 bunches at top energy with 1.1 μs between every group of two batches (with 225 ns between the latter). FZ and GA proposed to **perform simulations with a similar filling scheme** (**ACTION** → HM). This would yield a realistic heat-load estimate using more than 2 batches, which may, or may not, be different from the previous one. FZ remarked that at injection the pressure plays an important role.

Results at 3.5 TeV present more or less the same behavior and the same order of magnitude as at injection. HM remarked that taking the average over 2 batches, the values with SEY=2.1 and SEY=2.2 are very similar. This is not the case when the average over 6 batches is considered.

Next, the central density along the trains was shown to identify the onset of multipacting and to possibly benchmark the simulation results against instability observations. The central density decreases from the 4th batch with a SEY=2.2. This behavior can be due to the size of the grid points, since the central density is taken in the central grid point (1/25 of the pipe size), and the distribution might change in the different batches. It has **to be checked and compared with the total number of electrons** (**ACTION** → HM). GA asked if this behavior had been seen before and FZ wondered if the computation of the space charge in ECLOUD should be done more often.

The thresholds for multipacting have been identified in the arcs for injection and top energy. They go from [2.5, 0.2] to [2.1, 0.6] for injection and from [2.4, 0.2] to [2.0, 0.6] for top energy. FZ commented that the results at top energy would me more reliable since the effect of the (self-consistent) pressure at injection is important and we do not know it.

GA pointed out that the e- density values shown should be big enough to produce strong instabilities. FZ answered that these instabilities could be suppressed by nonzero chromaticity and using the damper. GA remarks that this might not damp all the single bunch instabilities.

Some **ACTIONS** have been suggested:

- Extend the study to larger values of R (HM).
- Make plots in δ_{max}-R space showing contours for typical experimental heat loads (HM).
- Explore another more realistic input pattern (highest priority) also at 3.5 TeV (HM).
- Possible correction of the filling factor for different cases.
- Take the average over 6 batches with the filling pattern considered too far (6 batches spaced by 200 ns) to obtain an upper limit (the average over 2 batches being the lower limit) (HM).
- Investigate the ECLOUD behavior at SEY=2.2 and its parameter dependence (number of space-charge calculations, grid size) (HM).
- Simulate heat load for beam conditions during the 2010 scrubbing run with 9 x 12 bunches.

EM commented that secondary emission yield of some interconnects could be as high as 3 according to Paolo Chiggiato. **To be confirmed** (**ACTION** → EM).

e^-cloud benchmarking update

OD made first a review of the experiments carried out during the first night of the scrubbing run and commented again on the different problems that had been found (see previous minutes, 28th April 2011). The intensity and pressure history during the night was shown. New results for the "variation of the batch spacing" experiment were shown since there had been a mistake last time (24-bunch trains instead of 36). Again, the raw data do not give a clear solution since we would need a 3rd point for verification. Nevertheless, a solution close to the 2010's observations can still be seen. 3rd and 5th order fits have been done showing three solutions with good agreement among both fits.

Next, OD reported on the second experiment of the night consisting in the injection of eight 36-bunch batches with 2 μs batch spacing. All gauges show exponential growth at the beginning followed by saturation and a linear behavior after the 3rd batch. Simulations have been done in order to reproduce this behavior. The experimental pressure for each batch just before the injection of the next batch has been taken as seed pressure in the simulations from 1 to 8 batches. This has been done with 4 possible solutions, the three obtained with the 3rd order fit ([1.86, 0.12], [1.69, 0.91] and [1.70, 0.12]) and the best one from last year's raw data ([1.85, 0.25]). The best agreement between simulations and experimental data comes from the latter for all gauges investigated. FZ proposed to **make additional contour plots with the information from this experiment**. Three (or more) new curves could be obtained taking the pressure ratios with different number of batches close to saturation region (**ACTION** → OD).

The last topic was the effect that solenoids might have on the e^-cloud. At this stage of the work only simulations have been done without any comparison with the experimental results. Vacuum people informed that solenoids have been ON especially in the regions close to the triplets in IP2 and IP8. That is why the location considered was the gauge VGPB.123.4L2.X.PR, which is located close to the inner triplet in IP2. The filling pattern consisted of two 36-bunch batches separated by 2 μs. The best solution for SEY and R found before has been used.

For any field (starting from 5 G) the e-cloud is small. A non monotonic effect can be observed. B=10 G gives the best performance. Around 50 G some “strange” behavior appears. It might be caused by resonances (e.g. with the bunch length), which have to be investigated.

The behavior at B=100 G shows an enhanced trapping of electrons in the central region of the beam pipe.

A **new parameter set (varying pressure, bunch length, bunch spacing, bunch intensity …) has to be investigated** to explore higher pressures and possible resonances (**ACTION** → OD).

TP asked if any asymmetry between beam 1 and beam 2 can be observed. OD answered that due to several reasons only beam 1 has been studied till now. GA pointed out that much less scrubbing had been done for one beam initially, but now the features should be similar for the two beams.

The next meeting may be held on Monday 16th May (note unusual day). Room and time will be communicated in due time.

Reported by Octavio Dominguez and Frank Zimmermann