LHC e-cloud simulations Meeting – Draft Minutes

Date: 28 November 2011
Meeting Room: 6-2-004

Attendees: Gianluigi Arduini (GA), Chandra Bhat (CB), Octavio Domínguez (OD), Giovanni Iadarola (GI), Humberto Maury (HM), Giulia Lanza (GL), Giovanni Rumolo (GR), and Frank Zimmermann (FZ).

Excused:

Agenda

1. Minutes and actions from the last two meetings
2. Sensitivity studies, heat load benchmarking, heat-load quadrupole oscillations, some pending actions, update on multipacting thresholds for different beam pipe radii, **Humberto Maury**
3. Update on bunch profile studies, **Chandra Bhat**
4. Update on pressure benchmarking, ε_{max} evolution and scrubbing time estimation, **Octavio Dominguez**
5. PyECLOUD, **Giovanni Iadarola**
6. AOB

Minutes and actions of the last two meetings (30 September & 28 October 2011)

Selected actions from before 30 September:

- Include **variable beta function or real Twiss parameters in SPS HT** simulations; inspect simulation snapshots for signatures of coherent motion (KL) – to be followed up by GR
- Report on **experimental e-cloud tests in the SPS** comparing Q26 and Q20 optics (HB?) – GR no difference between Q20 & Q26; still not conclusive ; no head-tail instability in the SPS this year
- **HT simulations with larger initial emittance** to check uniqueness of final emittances; study **sensitivity of final emittance** with respect to other parameters like grid size etc. (reassigned to HTWG, GR)
- **Tune shift of different single bunch modes in HT** (HTWG,GR)
- **Horizontal displacement** of daughter particles – addressed in talk by GI
- **Aperture scan for 25 ns** and for non-round geometry & non-round beam (HM) – to be done
- **Draft note** summarizing e-cloud simulations for the LHC arcs, namely heat load, density (HM) – draft exists

- Study **solenoid resonance effect** (OD) - planned
- Check e- **energy distributions in arcs and straight** sections (OD) - planned
- Complete **note** on vacuum-pressure benchmarking (OD) – in progress
- Understand increase of e- density with **increasing beam size in the PS** (CB, OD); CB will go back to this with the new programme

Actions from the meeting of 30 September:

- Redo plot of **density versus bunch intensity for 50 ns**, e.g. with Gaussian bunches (HM) – on hold
- Look at the **electron energy spectra** (HM) – on hold
- Updated heat-load curves for LHC including for 3.5 TeV (HM) - DONE
- **Review talk by Vincent Baglin** at CERN-GSI e-cloud workshop and possibly contact vacuum group for further information about the change in photoelectron yield (FZ) – check summary of workshop (FZ)
- Do simulation for **ideal flat bunch and compare with a Gaussian profile** (CB,HM) – DONE, results today
- Repeat simulation for **R=0.25** (HM); CB will show a slide
- Initial excitation of **single modes in HEADTAIL** (HTWG, GR) – on hold

Actions from the meeting of 28 October:

- **Bug in ECLOUD:** Repeat simulations at 7 TeV (i.e. B=8.33 T) using gas ionization to see whether it is a problem of the dipole field or whether it is related with photoemission (HM) - NOT DONE yet. Check whether there is a left-right asymmetry in the flux on the wall (HM). Check with PyECLOUD (HM, GI).
- **Quadrupole oscillations:** change #time steps, #macroparticles, and quadrupole option (HM) – Done, will be addressed during the talk. Look at the flux on the wall to see if these oscillations are also present in that case (HM). – TO BE DONE
- **Heat load benchmark at 25 ns spacing:** Study heat load simulations for 25 ns at injection for different values of SEY and R to infer the present surface condition of the arc chamber (HM).
- **25-ns benchmarking study** with 4 different beam configurations (OD) – Done, will be addressed during the talk.

Sensitivity studies, heat load benchmarking, heat-load quadrupole oscillations, some pending actions, update on multipacting thresholds for different beam pipe radii

Humberto Maury presented an update of 4 topics.

Quadrupole heat-load oscillations: 2008 heat-load simulations and updated results (varying number of macropaticles and time steps) for an arc half-cell were compared. In the latter one can see funny spikes due to large oscillations in the quadrupole heat load. Heat load for only quadrupoles was also shown with a δ_{max}=1.7. Some bunch intensities show very high values for the heat load. In order to investigate the origin of the oscillations, several simulation parameters have been changed such us the number of time steps, the integration routine (ibend2= 2, 1, 3), and the number of macroparticles. The oscillations continue to appear but show different patterns of minima and maxima. The variation between the different options is up to 25-50%. FZ argues that the oscillations might be an artifact. Varying numerical parameters should lead to a certain convergence, which is not observed.

The heat load dependence on the reflectivity R has been also investigated in the dipole regions for two different bunch intensities. It shows a scatter of order 15% to 30% between R=0.4 and R=0.6 for the two intensities respectively. Funny spikes appear at R=0.5, which by coincidence is the value normally used in all simulations. The variation of the heat load with respect to the number of macroparticles shows a similar behavior although with a different pattern and smaller differences between the lower and higher values (2000 and 4000 macroparticles respectively).

Next, HM showed the results for an average heat load at 25 ns spacing. With R=0.2 and about 1 W/m heat load (as measured with 2 beams) the SEY should have been around 1.8.

An extension of the multipacting threshold versus aperture towards larger beam-pipe radius was done up to 300 mm radius for 50 ns bunch spacing. This had been motivated by an 800-mm diameter chamber in Points 2 and 8. The scan should be still extended up to 400 mm (**ACTION** → HM). The pattern shows some maxima and minima along the beam pipe radius, being sharper between 20 and 150 mm radius. This scan should also be repeated for 25 ns bunch spacing (**ACTION** → HM).

A comparison between the heat load for Gaussian and flat bunches with N_b=4e11 (investigating future high luminosity upgrades) has been carried out. HM originally found that a flat bunch profile gave higher heat load, due to an error in the bunch-length definition. Now, once corrected, there is a good agreement between HM and CB's results. Same behavior is seen for nominal intensity.

Update on bunch profile studies

Chandra Bhat presented the heat load as a function of V2/V1 ratio. A 50-ns bunch spacing looks much better than 25 ns spacing with the same beam current. There is about 30% uncertainty due to errors in photoelectron yield and R.

Update on pressure benchmarking

Octavio Domínguez presented the results of the data analysis from the MD on 25 October 2011, for the experiment with gaps of 4, 3, 2 and 1 microseconds. As usual, ε_{max} was set to 230 eV. Varying ε_{max} from 200 to 260 eV has a clear effect. The best agreement comes with ε_{max} =260 eV, where the three lines cut nicely around R=0.2 and δ_{max}=1.37. In any case the results show that R=[0.2, 0.4] and δ_{max} =[1.3, 1.4]. For another gauge investigated no good results are found. The main reason can be due to much poorer fitting of the surfaces. This fact has to be further investigated (**ACTION**→OD)

This dependence on ε_{max} motivated a revision on this point. Results by C.Yin Vallgren (CYV) and M. Taborelli (MT) were revised. As-received stainless steel has $\varepsilon_{max} \approx$ 280 eV. So it could be interesting to repeat previous simulations with this value (**ACTION**→OD). Nevertheless, the experiments show a variation of ε_{max} during the scrubbing process, which in addition seems to be different if the scrubbing is done in a laboratory with an electron gun or in-situ within the accelerator, i.e. beam induced. In the lab, the variation is small and characterized by a certain increase in the ε_{max} value. On the other hand, the variation looks larger and the ε_{max} values seem to decrease. This fact implies some uncertainty in the ε_{max} value to be used as a parameter for the benchmarking study.

Next, OD calculated the multipacting thresholds at 25 ns bunch spacing for ε_{max} =180, 230 and 280 eV, as 1.2, 1.25 and 1.3, respectively.

Taking these values into account and considering the doses used for scrubbing in the lab from CYV and MT, a rough estimate of scrubbing time has been made. For this, only electrons above 30 eV are considered. There were some doubts about how the estimate dose from SPS scrubbing was deduced, probably from the e-cloud strip detector (to be confirmed, **ACTION**→OD).

It was commented that one cannot have a longer scrubbing time if one starts at a lower value of δ_{max}. The calculation should be done iteratively using differential steps (**ACTION**→OD). OD argued that it was just a rough estimate and that the time should be somewhere between the different values quoted at each δ_{max}.

There is little constraint on reflectivity, but one can infer how δ_{max} varies with ε_{max}.

FZ pointed out that the desorption yield might have varied during the experiment too. Emittance changes as well, but previous studies showed that it did not have much effect on the e-cloud build up. GI pointed out that this depends on the SEY and emittance values, since the effect might be more important close to the threshold. The dependence on the bunch length has not yet been studied.

FZ wondered why the slope of the different lines is so similar. It can be interesting to check in simulations how the slope could be made to vary, e.g. by introducing larger gaps (**ACTION**→OD). OD argued that it would be very useful to do additional measurements with parallel lines (i.e. varying the number of trains with the same batch spacing) for different batch spacings to see if the cut between the parallel lines gets clearer. GA proposed to also repeat the simulations with a more realistic pattern, i.e. with all the batches in the machine instead of simulating in groups of two (**ACTION**→OD).

In order to investigate the different δ_{max} values for the different parts of the machine (HM reported $\delta_{max}\approx 1.8$ in the dipoles) dose rates in arcs and straight sections can be compared, and with this, the resulting scrubbing times (**ACTION**→OD).

Heat loads for different fill patterns might allow determining *R* for the arcs (**ACTION**→ GA, HM, FZ).

PyECLOUD

Giovanni Iadarola presented the PyECLOUD code, including the motivations for the new code, the main changes between ECLOUD and PyECLOUD, the results of some convergence studies and some new features for users.

The main motivation at the beginning was to reorganize ECLOUD in order to develop new features, extract more information about the simulations and facilitate the debugging. But due to the ECLOUD structure and language it was decided to develop a new code since this initial effort could save a lot of time in the future. The chosen language is Python.

Special attention has been devoted to examine and avoid possible ECLOUD limitations like convergence issues or electron distribution in bending magnets (position of stripes, etc.). The new code improves accuracy, efficiency and flexibility.

Next GI revised the main ingredients for electron cloud simulations and the most important improvements: A different management of **macroparticle size and number** (a unique parameter N_{ref} is introduced to deal with all the different processes, which is varied dynamically), a more accurate **back-tracking algorithm** for the impacting electrons (which improves considerably the convergence problems), a more efficient computation of **the electric field generated by the travelling proton beam** (which is pre-calculated on a fine grid), a more general and accurate method for the evaluation of the electron **space-charge field** (which eliminates the convergence problems related to the image-charge approach and also removes the limitation to geometries for which image the charge expansion exists, since it could be calculated offline with commercial software if needed).

A convergence study was also carried out, showing that PyECLOUD offers a better performance than ECLOUD for several examples investigated (linear electron density, heat load, central electron density, total number of scrubbing electrons and horizontal electron distribution). The difference in the computing time for each time step is also very favorable for PyECLOUD.

PyECLOUD allows using measured intensity patterns along a batch among other convenient features for users. Since the computational time is drastically reduced, it's possible to simulate a complete filling pattern with many batches along a ring. It also produces pictures of the electron waves in the different fields.

FZ asked about the tracking algorithm. GI answered that he preserved the original one in ECLOUD by D. Schulte. FZ also asked about the input file. GI answered that 5 input files are needed namely for beam parameters, geometry parameters, model parameters, numerical parameters for simulation and the filling pattern.

It would be convenient to launch an enhanced benchmarking campaign with other users to test different problems that could appear. In this direction, it would be interesting to benchmark pressure rise and heat load with PyECLOUD and compare with ECLOUD result (**ACTION**→ OD, HM).

AOB

The next e-cloud meeting will be announced in due time.

Reported by Octavio Dominguez and Frank Zimmermann