LHC e-cloud simulations Meeting – Draft Minutes

Date: 27 June 2011
Meeting Room: 6-2-004

Attendees: Gianluigi Arduini (GA), Chandra Bhat (CB), Hannes Bartosik (HB), Alexey Burov (AB), Octavio Dominguez (OD), Giovanni Iadarola (GI), Kevin Li (KL), Humberto Maury Cuna (HM), Elias Metral (EM), Giovanni Rumolo (GR), Frank Zimmermann (FZ)

Excused:

Agenda

1. Minutes and actions from the previous meeting (16th June 2011), Round table
2. Fixing an ECLOUD bug for tall beams, **Giovanni Iadarola**
3. Update on SPS e-cloud feedback simulations by Kazuhito Ohmi, **Frank Zimmermann**
4. SPS e-cloud instability scaling with Qs and rho_e - update, **Kevin Li**
5. Update on LHC arc simulations, multipacting threshold and aperture scan, **Humberto Maury**
6. Update on PS e-cloud studies, **Chandra Bhat**

Minutes and actions of the last meeting (16 June 2011)

The minutes and actions from the past meeting were reviewed. A number of actions for HM and OD remained active. Other actions for HM and CB had been completed with results presented in this meeting.

- Outstanding **actions** for HM:
  - Horizontal **displacement of daughter particles**, still pending (potential **ACTION** for Ubaldo Iriso or HM).
  - Simulate **heat load for beam conditions during the 2010 scrubbing run** with 9 x 12 bunches [heat load for this case was 40 mW/m initially].
  - Concerning the question whether at 3.5 TeV 1.1 μs spacing between trains is enough to clear the e- cloud, **remake the plots in a logarithmic scale** to see whether the first batches of each double train are indeed equal, **launch simulations with 2, 4 and 6 batches** to see the **e^- energy distribution after each "double train"** passage, and **look at the losses versus time** (from qlosswh.data file in ECLOUD) with and without energy cut.
  - In addition to heat-load, compute the central electron density for 25 and 50 ns spacing with different values of N_b, SEY and R.
  - Complete **sawtooth/no-sawtooth heat-load scans for ultimate bunch intensity**

- Outstanding **actions** for OD:
  - Study the **solenoid "resonance" effect**, e.g. by varying parameters like the bunch length and bunch spacing
  - **Redo linearity check plots with different initial pressures**, e.g. the pressure before the injection of the next batch, and the initial starting pressure to see the difference.
  - Check the e^- energy distribution in arcs and larger-aperture straight sections, in particular their differences, expecting higher-energy electrons in the arcs.
  - Complete the **note**.

- Other outstanding actions:

  - Implement **FIR filter to reduce bandwidth to ~1.0 GHz** & compute kick strength - how much power? Repeat simulation for new SPS optics (KO,FZ).

Before going to the presentations, a small discussion about the initial seed number of macroparticles took place. AB asked why the number of macroparticles is so important since it depends on the square root of this number (statistical effect). FZ replied that only a small fraction of the primary macroparticles are created at the top or bottom of the beam pipe boundaries, while most are not contributing to the multipacting, so that the effective number of primary macroparticles is much smaller than the total number quoted and the statistical effect is much larger than one would expect from this total number.

Fixing an ECLOUD bug for tall beams ($\sigma_y > \sigma_x$)

In the previous meeting, CB showed that build-up simulation results for (slightly) tall beams ($\sigma_y > \sigma_x$) were not consistent with the results obtained for round and slightly flat beams. **Giovanni Iadarola** (GI) discussed the correct implementation of the kick for a non-round tall beam using the Bassetti-Erskine formula in the ECLOUD code. In the old version of the code, there is a routine that does not compute correctly all the different components of the electric field (free region and image charges from a perfect conducting chamber) when using tall beams. In the case $\sigma_y > \sigma_x$ the Bassetti-Erskine formula cannot be used straightforwardly (a 90º rotation of the x and y axis has to be carried out). In the previous version of the code, rotation of coordinate system had mistakenly been done for both the beam field and the image-charge force , whereas this rotation is only needed for the beam. The rotation of the force from the image charge has been removed and the new results are perfectly consistent with those for flat and round beams.

GI has performed new simulations for different values of the SEY in the SPS with an MBB chamber, where the beam is tall, showing that past simulation results are not exactly reproduced by the corrected code.

The new version of ECLOUD is available in GI's public directory on afs. GA proposed to have a common place to find the latest version of the clode. KL proposed to create a svn for ECLOUD. He will **set up the latest version of the coude on svn** (**ACTION** → KL). It will also be necessary to **post information about the ECLOUD and HEADTAIL svn versions with additional web-site instructions on how to download the code** (**ACTION** → GR and FZ). **Regular information** about latest versions of both codes HEADTAIL and ECLOUD to users will be provided (**ACTION** → KL, GR and FZ)

Update on e-cloud feedback simulations by Kazuhito Ohmi

Frank Zimmermann presented the latest results from Kazuhito Ohmi. A feedback bandwidth of 1 GHz (bandwidth defined as 1/(sample interval)) suppresses the instability significantly. A bandwidth of 3 GHz and even more one of 3 THz can further reduce the residual emittance growth, to basically zero. These simulations have been done using a high number of particles. Increasing the frequency it is possible to reproduce quite accurately the local beam position for short sample intervals along the bunch.

Questions were raised on the **definition and implementation of the bandwidth** (factor 2?, use of a second, different type of slicing?), the **behavior between 100 MHz and 1 GHz** (GA proposed to do additional studies with a bandwidth around 500 MHz), the **choice of feedback gain**, **consistency of results for 1, 3 GHz and 3 THz** (FZ pointed out that in some cases 3 GHz looks as good as 3 THz, in others not). AB wondered if one should see **stochastic cooling effect**. (**ACTIONS** → KO). After the meeting KO pointed out that indeed a stochastic cooling effect is seen in some of the simulation results shown when the electron density is 2e11 m^{-3} or lower.

Update on SPS e-cloud instability scaling with Qs and ρ_e

Kevin Li presented HEADTAIL simulation results for the old and new SPS optics which showed the expected behavior that the new "Q20" optics suppresses the electron cloud instability for electron densities below 6e11 m^{-3}. Still puzzling is the enhanced incoherent emittance growth for higher densities.

FZ pointed out that KO observed a similar phenomenon at high electron density and attributed this to an artificial incoherent emittance growth (e.g. due to the small number of kicks). **KL** and **HB** replied that the number of kicks was increased from 10 to 200 (in a field free region) and no change was seen. So it is not clear whether it is an "artifact". More precisely they observed "two

sets of slopes" (one for 10, 20 and 50 kicks and other for the rest of numbers of kicks considered) around which the simulation results cluster. This could be indicative of a resonance effect. That happens only in the vertical plane. In the horizontal plane the slopes for all cases are approximately the same, but the behavior is non-monotonic.

It is suggested to **change the number of kicks** so as to include **odd or prime numbers**, and to **scan the tune and try other working points,** or to **model the real SPS lattice** with one e-cloud kick per SPS dipole (e.g. using the TAILHEAD version of HEADTAIL?) – GA suggested placing e-cloud kicks for pairs of MBBs and MBAs. (**ACTIONS** → KL, HB)

Update on LHC arc simulations, multipacting threshold and aperture scan

Humberto Maury showed the simulated **multipacting threshold as a function of the arc chamber radius for 50-ns bunch spacing** with the same parameters as in the previous meetings (round beams are considered). The scan was extended from 20 to 100 mm. The threshold is lowest between 45 and 65 mm radius, where a plateau can be observed. After 65 mm radius, the threshold starts to rise till 85 mm, where a new plateau is observed until 100 mm. AB pointed out that this is a strange behavior since for infinite radius the threshold should become infinite. GR and FZ suggested that there could be higher order minima e.g. due to resonances or to double or triple kicks. CB wondered if the results would change when **considering a non-round beam** (**ACTION** →HM). It would be interesting to repeat this **aperture scan for 25 ns spacing and include a curve in the same picture** (**ACTION** →HM).

Next, HM showed **multipacting thresholds as a function of *R* for three different bunch spacings in the LHC arcs at 3.5 TeV**. A strong dependence on the bunch spacing and a slight decrease in the SEY threshold with increasing *R* is observed, as expected.

Finally, HM presented the **central electron cloud density at 7 TeV from 2008 simulations for 25 ns spacing**. The density is high for secondary emission yields above 1.4. The central density decreases for large bunch intensities, in contrast to the heat load, which is always larger for higher intensities. HM pointed out that the results shown may give an approximation to the real situation, but the simulations should be repeated with improved parameter choices, e.g. with a larger number of macroparticles.

Three **ACTIONS** have been assigned to HM:

- Add density points for SEY=1.3 at 25 ns spacing
- Repeat the density curves for 50 ns bunch spacing
- Write a draft note summarizing results of LHC simulations for heat load and density in the LHC arcs, including sawtooth, starting from a comparison with measurements.

Update on PS e-cloud studies

Chandra Bhat presented new results. First, he showed a reproduction of F. Rieke &W. Prepejchal (PRA6(1972), p1507) measurements with good agreement. The **ionization cross section increases from about 1 MBarn at PS ejection energy to 2 Mbarn for LHC at 7 TeV**. He argued that, although pressures in the range of a few torr are quoted for the parameter values shown, the effect of the pressure on the cross section is not important for the low pressure (in the order of nTorrs) in accelerators, and that one can assume the "thin-target" parameter values quoted.

Next, CB showed results of PS e-cloud simulations searching for saturation at $\sigma_x > \sigma_y$ and $\sigma_x = \sigma_y$. In both cases, for a beam with σ_x = 1.75 μm and $\sigma_y \approx$ 1.5 μm as well as for one with $\sigma_x = \sigma_y$ =1.75 mm,there is an indication that saturation is reached at the end of the 6th turn. The plan is to take the saturated electron density as starting point for future studies. Strikingly, in both cases the highest value of the beam transverse size gives the highest density. The increase of electron cloud density with increasing beam size looks contrary to previous results for the LHC (or SPS), especially ones close to the threshold (see 14-12-2010 meeting presentation by OD). This fact has to be further investigated (**ACTION** →CB and OD). Anyway, it was shown that the change is big, about an order of magnitude.

GR pointed out that 16 empty bunch slots are assumed in these simulations, while in reality there are 12. **The saturation level will need to be rechecked** (**ACTION** →CB).

AOB

FZ mentioned that recent **proposals for enhanced scrubbing including slip scrubbing, 5 ns, 10 or 15 ns spacing, and having a debunched beam component** could be investigated through simulations.

The next e-cloud meeting will be held on 28 July.

Reported by Octavio Dominguez and Frank Zimmermann