LHC e-cloud simulations Meeting – Draft Minutes

Date: 07 June 2011
Meeting Room: 6-2-004

Attendees: Chandra Bhat (CB), Alexey Burov (AB), Humberto Maury Cuna (HM), Elias Metral (EM), Frank Zimmermann (FZ)

Excused: Gianluigi Arduini, Octavio Dominguez, Giovanni Rumolo

Agenda

1. Minutes and actions from the previous meeting (16 May 2011), Round table
2. Tune shift from e-cloud / input from Kazuhito Ohmi, presented by Frank Zimmermann
3. Issue of LHC inverted sawtooth chambers, Frank Zimmermann
4. Update on LHC arc simulations, aperture scan, and "missing sawtooth" chambers, Humberto Maury
5. Simulation of SPS e-cloud feedback by Kazuhito Ohmi, presented by Frank Zimmermann
6. PS e-cloud simulations, Chandra Bhat
7. AOB

Minutes and actions of the last meeting (16 May2011)

Past Actions:

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

- FZ reported that Oliver Boine-Frankenheim (GSI) and Fatih Yaman (TUD) had confirmed that the latter would do the energy loss simulations for SPS and LHC; they will send a report of their results within one month.

- FZ reported that Kazuhito Ohmi had performed first wide-band feedback simulations for the SPS electron cloud. Details were presented later in this meeting.

- Concerning someone from LARP or CERN for feedback simulation at CERN, Wolfgang Hofle had informed FZ that the US LARP had successfully compiled the HEADTAIL code. One US LARP student (Ozhan Turgut) should pursue this. Until now Claudio Rivetta (staff) had been working with the code. WH reported that Orzan Turgut could visit CERN twice, in July and in September 2011 (before or after IPAC'2011). SLAC could finance 2 weeks. Ozhan also got an IPAC grant. The US LARP was proceeding with full steam on a practical experiment for the SPS.

- EM confirmed saying that the secondary emission yield in some regions of the LHC could be as large as 3. Paolo Chiggiato had elaborated that all the silver coated RF fingers had an SEY of about 3.

- Several of the actions for HM had been done, namely plots δ_{max}-R space showing contours for typical experimental heat loads (presented later today), investigating the simulated ECLOUD behavior for large SEY and its parameter dependence, such as the number of space-charge calculations, grid size, etc., with first results shown later in this meeting.

- OD had written a draft note summarizing the method and results achieved so far.

- Other **actions** for HM were still outstanding:

- 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].
- Look at the **total number of e^- to check densities** (strange behavior from the 4^{th} batch for a dipole field at injection with SEY=2.4, R=0.4)
- Taking a certain case (e.g. R=0.6 and SEY=2.0), apply variations on simulation parameters (number of steps within the bunch, number of steps within the gap between bunches, number of macro particles, space charge computation steps…) to check the **randomness effect on the level of fluctuations**.
- 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.
- Add horizontal line at 70 mW/m in heat load simulation plots.

- Also for OD a number of **actions** were outstanding:

- 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 laregr-aperture straight sections, in particular their differences, expecting higher-energy electrons in the arcs.
- Complete the **note**.

Tune shift from e-cloud / input from Kazuhito Ohmi

FZ presented an answer from Kazuhito Ohmi to a question on the sign of the tune shift for the 0 mode due to the electron cloud. The answer depended on whether the single bunch tune shift or the coupled bunch modes were being referred to. In general, the **sign of the tune shift depended on the electron distribution inside the beam pipe**. It was positive for an electron cloud concentrated in the beam region or filling the entire chamber. With a cloud concentrated on the horizontally outward side, e.g. photoelectrons constrained by solenoid fields, the tune shift was quadrupole like, negative in the horizontal plane and positive in the vertical. Mixtures and combinations were also possible, resulting in large positive vertical tune shifts and small horizontal tune shifts, close to zero.

Issue of inverted sawtooth chambers

FZ recalled the parameters of the **sawtooth** as well as its measured **effect on the reflectivity and photoelectron yield.** After the 2008 incident, lacking the correct spares, some beam screens had to be installed with inverted orientation. The maximum heat load is expected for both beams in **two optical half cells where beam screens for two dipoles in both apertures are inverted**. In the associated beam-screen cooling loops 2 out of 3 dipole beam screens had the wrong orientation. It is assumed that having an inverted sawtooth is similar as having no sawtooth. The simulation parameters are changed accordingly: (1) the distribution of reflected photons is changed from cos2 p to uniform, (2) the reflectivity is increased from 20 to 80% (pessimistic), and (3) the photoelectron yield is doubled.
First simulations are done for 3.5 TeV and 50 ns spacing. Later simulations will be performed for 25 ns spacing, and also for 7 TeV (where the sawtooth should be more important).

ACTIONS (HM): Simulations of dipole without sawtooth with 50 ns at 3.5 TeV, at 25 ns, and for 25 ns spacing at 7 TeV

Update on LHC arc simulations, aperture scan, and "missing sawtooth" chambers

HM showed the complete updated heat load result for the “real” 50-ns fill pattern with alternatingly 200 ns (in reality 225 ns) and 1.1 microsecond batch spacing, including a **contour plot for the heat load in R-delta space**. The dark blue stripe corresponds to relevant heat-load values between 10 and 70 mW/m. The filling factor is taken into account. Here is a strong correlation between delta and R. The importance of R is likely to change with the bunch spacing.

HM presented the “funny” plot from the previous meeting, which had referred to R=0.6 and SEY=2.0. The associated action had been to redo the **calculation by changing some**

parameters like the number of steps. Unfortunately in the new simulations R had been set to 0.9 and not to 0.6, by mistake, and the new plots, for which the parameter scans were done, do not look funny. Parameters were the number of time steps between bunches (increased from 2500 to 5000), the number of macroparticles (from 500 to 2000), the number of space-charge calculations between bunch passages (from 10 to 100), and the number of steps inside the bunch (from 150 to 200). For the case considered the **simulation result was rather insensitive to all of these parameter changes**.

ACTION: redo the check for R=0.9 "funny plot" (HM)

A plot showed initial results for the **variation of the multipacting threshold with aperture**. The plot needs to be updated by running simulations for larger and smaller SEY values. The **dependence of the heat load on aperture** for different SEY values was also shown, indicating a maximum for a chamber radius of 45 mm.

Responding to a comment of AB, FZ pointed out the dependence of the SEY threshold on aperture had been studied for 25 ns and 12.5 ns bunch spacing a long time ago, with fairly good agreement between analytical calculations and simulations. The simulations revealed multiple minima at larger radii, which correspond to more complex electron dynamics (multiple kicks for the same electrons, not included in the analytical model); see LHC Project Note 201 (1999).

AB suggested doing simulations for other gaps between batches.

SPS feedback simulation by K. Ohmi

FZ presented electron-cloud simulation results for the SPS at injection from Kazuhito Ohmi. without feedback the instability threshold in a field-free region was found for an electron density between 1 and 2e11/m^3, in good agreement with a simple analytical estimate. The electron oscillation frequency is between 300 and 400 MHz. In a dipole field only the vertical instability appeared. For a larger electron density of 1e12/m^3 the incoherent effect was dominant. This probably is an artifact of the simulation (single e- beam interaction point). Next results were shown including a dipole-motion feedback or a wideband feedback (22 GHz, 40 slices per bunch). The former feedback cannot suppress the emittance growth, but leads to mismatch oscillations. The **wideband feedback suppressed the instability for 2 and 5e11/m^3 is the gain is larger than 0.05 (20 turns).**

EM asked **if the damper can damp mode 0 properly if the chromaticity is not 0**. The answer may need further investigations. In Ohmi san's simulation the chromaticity was zero.

WH commented that the bandwidth of the assumed feedback was much too wide, and unnecessarily so. It would be **more realistic to use a feedback model similar to the one considered by US LARP**.

EM pointed out that the **change of SPS threshold for e-cloud instability with new optics** was an important question, being studied by Kevin Li. The result was to be presented in HDWG.
FZ remarked that Kazuhito Ohmi could also do the simulation for the new optics.

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

ACTION: Presentation by Kevin Li on e-cloud instability for new and old SPS optics.

PS e-cloud simulations

CB reported the status and plan of the PS e-cloud studies. He recalled the motivation for the simulations. The **PS double harmonic RF system can be operated in bunch shortening or bunch lengthening mode** and the resulting changes of the electron-cloud build up should be investigated. The key idea was to simulate and benchmark the observed-cloud effects.
During a 2007 PS MD strong e-cloud signals were observed after the quadrupole splitting (PRST-AB 11, 094401 (2008)). The variation of bunch length in the PS 40 ms before extraction has been obtained from an ESME simulations.
An attempt to reproduce FZ's simulations from 2007, using the latest ECLOUD version 3.3(b), from 3 September 2009, was successful. There were very few differences in the simulation results from 2007 and now. However, the **option for ionization** was different. In 2007 the option 1 was used, CB used option 2. Perhaps (only) in option number 2 some 10% of the ionization electrons are launched uniformly spread across the chamber and not inside the beam (to be checked), or the number of primary electrons is not the same, due to different assumptions on pressure or cross section.
An investigation had been done on the **ionization cross section**, with information from Sergio Calatroni. Using an analytical formula the average cross section at 26 GeV is 1.08 Mbarn assuming a gas composition equal to the one of air. The cross section has a minimum around 1 GeV.

ACTION: Check **actual gas composition**. Plot **ionization cross section versus proton energy** from 1 GeV to 2 TeV (CB)

Choosing the correct **number of macroelectrons** is important. An unphysical "crossing" of lines for different SEY values could be shown to be related to the limited number of macroparticles. Launching 500 macroparticles per bunch is not enough. Many other studies were done (changing

bunch length, seed, ionization cross section, SEY, reflectivity). The simulated electron cloud build up was shown for different bunch lengths.
In summary, an **experiment is proposed/being conducted in the PS** to study the e-cloud effects to study the e-cloud density as a function of bunch profile, bunch spacing and bunch intensity
ECLOUD simulations are being conducted to reproduce the observed e-cloud buildup in the PS, where a systematic approach is adopted to establish minimized statistical effects, and realistic set of physical parameters for the simulation. PS baseline e-cloud data were already taken from 1 to 6 June. The next experiment would be on Wednesday 8 June.

WH commented that at the moment there was no problem with e-cloud in the PS, but in the future problems could come back with higher intensity and smaller transverse emittances. The **dependence on the transverse emittance** should be investigated.

ACTION: PS e-cloud simulations for different transverse emittances (CB)

AOB

EM announced that the Working groups would be presented in the ICE meeting, the electron cloud WG already the next morning, 8 June. Announcement of next meetings should be posted on the respective working group web sites. All WG meetings are open to all ICE members.

The next e-cloud meeting will be held on 16 June. The preliminary draft agenda includes a report from e-cloud developments in Lausanne, and possibly a review of the impact of the new SPS optics on the single-bunch electron-cloud instability.

Reported by Frank Zimmermann