LHC e-cloud simulations Meeting – Draft Minutes

Date: 16 June 2011
Meeting Room: 6-2-004

Attendees: Chandra Bhat (CB), Hannes Bartosik (HB), Alexey Burov (AB), Giovanni Iadarola (GI), Michael Mattes (MM), Humberto Maury Cuna (HM), Eden Sorolla (ES), Frank Zimmermann (FZ)

Excused: Gianluigi Arduini, Octavio Dominguez, Giovanni Rumolo, Elias Metral (EM),

Agenda

1. Minutes and actions from the previous meeting (06 June 2011), Round table
2. SNF Project "Modelling microwave-electron interaction in the LHC" - intermediate results, Eden Sorolla / EPFL/LEMA
3. SPS e-cloud instability with old and new optics - first results, Kevin Li
4. Update on LHC arc simulations, aperture scan, parameter scan, and "missing sawtooth" chambers, Humberto Maury
5. Update on PS e-cloud studies, Chandra Bhat

Minutes and actions of the last meeting (16 May2011)

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.
  - Compute the central electron density for 25 and 50 ns spacing with different vaues if Nb, SEY and R, in addition to heat load.

- 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 laregr-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).

SNF Project "Modelling microwave-electron interaction in the LHC" - intermediate results

Eden Sorolla discussed the framework of this project as a SNF project, and the pertinent experience in electromagnetic modeling available at EPFL/LEMA. The first part of the development was to calculate the **electromagnetic field in a general wave guide**. The exciting current could be given by the electron cloud. The Green function depends on the wave guide geometry. The index n refers to waveguide mode. An arbitrary case should take into account all the modes, but normally there is fast convergence, and in practice the sum is truncated. Analytical expressions for the modes in a rectangular wave guide were presented.
For the LHC arc-chamber wave guide no analytical modes are available. The implemented method to calculate these modes is called **BI-RME (boundary integral – resonance mode expansion)**. It uses the **modes of the rectangular wave guide as basis set to develop solutions for the beam pipe**. For example, fives modes of rectangular wave guides can be used to represent the first real mode.

Frank Zimmermann mentioned as motivations for this development the goals to simulate and understand the microwave diagnostics for electron cloud, the magnetron effect and the possible suppression of electron cloud build up using high-power microwaves.
Alexey Burov commented that the problem might be mainly quasistatic.
Frank Zimmermann quoted the cyclotron frequency in the LHC dipoles as varying from 15 to 230 GHz between injection and 7 TeV. The traversal time across the chamber was 5 ns (~200 MHz).

Some results were presented such as the electromagnetic fields in the beam pipe. A singularity in the Green function evaluation, in some cases still evident close to the wall, can be, and has already been, avoided in the algorithm.

More exotic examples presented were an "eight pipe" and a "bone pipe". The base functions used always referred to the rectangular wave guide.
A trial **simulation for one electron** was shown, including its position & speed. The beam pipe had been larger in this case, and the frequency of the excited mode was 200 MHz. The spectrum of radiation emitted from the electron contained harmonics and sub-harmonics. For the chamber dimensions considered the 200 MHz wave would propagate along the wave guide.

Frank Zimmermann commented that, since the electron motion was strongly perturbed, it would be nice to know the power of the RF wave.

Next steps would be (1) to combine BI-RME method to calculate the modes of the waveguides in LHC with the e-cloud code (BI-RME calculates in less than a second the fields for the LHC beam pipe in 10000 positions), and (2) to implement the calculation of the radiated power spectrum of the electrons accelerated by the proton beam (and/or alternatively by an external RF field) using the history of the electron provided by ECLOUD.

Alexey Burov suggested that a comparison with a Poisson solver might be of interest.

Electron cloud instability with low gammat t optics in sPS

Kevin Li described the framework of this study and the results so far. A low gamma_t meant a high slippage factor, which was acting stabilizing for conventional instabilities. The situation for two-stream instability (e-cloud) did not appear to be straightforward. First results from HEADTAIL simulation studies were shown.
Parameters for the nominal and the low gamma_t optics were listed. The gamma_t had been reduced from 22.8 (nominal) to 18.0, with a corresponding change in the slippage factor eta from -0.00062 to -0.00178. At the same time the integer tune changed by 6 units. In the first study the e-cloud was confined to the straight sections (no dipole field). The number of e-cloud kicks per turn was set to 48. The density of electron cloud was varied. In the simulations the emphasis was placed on the **change in synchrotron tune**. The RF voltage was varied instead of the slippage factor. For intermediate electron cloud density ($3x10^{11}$ m^{-3}) higher RF voltage suppressed the instability and emittance growth, while for larger electron density (10^{12} m^{-3}) the opposite dependence was seen. It was suggested that the high density case did not reflect a coherent instability, but a strong incoherent effect.

Frank Zimmermann suggested checking that changing eta gives the same result as changing the RF voltage, since the effect on the bucket shape would be different. **Alexey Burov** commented that the phase space density should be kept the same in the comparison. **Frank Zimmermann** had also suggested checking whether the slippage is applied between electron-cloud kicks.

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

Humberto Maury presented new results.

He recalled the simulation parameters for 50 ns (LHC dipole at 3.5 TeV; alternating gaps of 200 ns and 1.1 microsecond). To explore the **"funny" case** from previous meetings (R=0.6, SEY=2.0; at the threshold of multipacting), he changed the number of space-charge calculations, the number of time steps inside the bunch, the time steps between bunches, the number of macroparticles (increased from 500 to 2000). As shown at the last meeting, above the multipacting threshold (for R=0.9) there no significant difference between the various cases. Here, changing any parameter affected the result noticeably. The strongest dependence was seen on the **number of macroparticles**.

The **study of multipacting threshold as a function of chamber radius** has been continued for 50 ns spacing. This stidy was done for a field-free region at 3.5 TeV, also for 50-ns spacing. The multipacting decerased from 2,3 at 20 mm chamber radius to 1.2 at 45 mm radius. It remained very flat and low (1.2) for larger radii, at least up to 65 mm.

Simulations with and witouth sawtooth pattern have been performed for 3.5 and 7 TeV, with 25 ns bunch spacing. The difference in the input parameters between the simulations for the two beam energies is the photoelectron yield (reduced by a factor 10 at 3.5 TeV) and the bunch length (7.55 m and 9 cm). Without sawtooth pattern the photoemission yield is taken to be two times higher, there is a different azimuthal distribution of photoelectrons, and also a different reflectivity value of the photons is assumed (as discussed in a previous meeting). There is only a small difference in the heat load at large SEY values (1.5) for nominal intensity at 25 ns. **In the region of low multipacting, below SEY=1.5, missing the sawtooth at 3.5 TeV leads to a local increase in electron heat load by about an order of magnitude, which is roughly equivalent to the effect of increasing the beam energy (in a chamber with sawtooth) from 3.5 TeV to 7 TeV.** A chamber without sawtooth at 7 TeV will experience the highest heat load. **For SEY of 1.5 or above there is little difference between a chamber with and without sawtooth** (except for ultimate intensity, where without the sawtooth chamber about 50% higher heat load is still observed at SEY=1.5).

ACTION: Complete sawtooth heat load scan for ultimate intensity (HB)

Update on PS e-cloud studies

Chandra Bhat presented news on the PS e-cloud studies.
He computed the ionization cross section for different gas species as a function of beam energy using Bethe's formula. The best guess for the ionization cross section at the PS extraction energy was **1 Mbarn** instead of 2 Mbarn previously considered.

Frank Zimmermann pointed out that, on the slide, the cross section was specified for some (high) pressure range. **Chandra Bhat** replied that it should not depend on the pressure.

ACTION: Extend plot to higher energies, up to 16.5 TeV (CB)

The **dependence of PS e-cloud build up on transverse beam size** has been studied, with beam sizes that should correspond to emittances in the range 1 - 5 micron (to be confirmed). The cases sx=sy, sx>sy, and sx<sy have been considered. The **case sx<sy does not seem to work in the code** (no electron cloud evolution; results very different from the other cases).

ACTION: Check sy>sx in ECLOUD code (Giovanni Iadarola)

The **PS e-cloud experiments** are progressing. Baseline data have been taken on MD6 LHC25 with a special RF configuration, including tomoscope data, transverse emittance data, beam intensity, and e-cloud data from PS e-cloud monitors. ESME simulation were done with two RF systems, either enhancing the compression or making a flat beam. The interesting information is contained in the last 5 ms. A transverse bump on last turn moves beam away from e-cloud detector, so that the last turn's data can be ignored. There are about 2.5 synchrotron oscillations within the last 5 ms. Raw data indicate that the **bunch flattening reduces e-cloud build up**. Bunch length oscillations are also visible.
To improve the experiment, in the future one could turn on 80 MHz at 20 kV and not at 0 (by "paraphrasing" two RF cavities).

AOB

The next e-cloud meeting will be held on 27 June.

Reported by Frank Zimmermann