LHC e-cloud simulations Meeting – Draft Minutes

Date: 1 October 2012
Meeting Room: 6-2-008

Attendees: Chandra Bhat (CB), Octavio Domínguez (OD), Giovanni Iadarola (GI), Humberto Maury (HM) and Frank Zimmermann (FZ).

Excused: Gianluigi Arduini (GA), Elias Metral (EM) and Giovanni Rumolo (GR)

Agenda

1. Minutes and actions from the last meeting
2. Plan for scrubbing run: **Gianluigi Arduini, Giovanni Iadarola, Octavio Dominguez, et al**
3. Heat-load simulation update: **Humberto Maury**
4. PS e-cloud simulations - Experiment and latest simulations: **Chandra Bhat**
5. LHC & HL-LHC e-cloud simulations, including ECLOUD-PyECLOUD comparison: **Chandra Bhat**
6. AOB

Outstanding actions from the last meeting

Actions from the last meeting on 10 August:

- **e-cloud simulations, including for a long train w/o gap, of central density, line density and heat load, would be redone with the full version of PyECLOUD and ECLOUD** (**ACTION HM**) – This had been done but would not be presented today; results of convergence study would be presented instead.

- Repeat the simulations of **multipacting thresholds at 25-ns spacing as a function of chamber radius using both ECLOUD and the complete version of PyECLOUD** (**ACTION HM**) – Also this had been done, but would not be presented in this meeting.

- Redo the same simulation as shown with a smaller time step between bunches to see whether in this case a plateau after the passage of the bunch is also observed in ECLOUD (OD) – This had been successfully done after the previous meeting.

- Look at x-y snapshot after the passage of the first bunches (OD) – This had become obsolete.

- Turn off space charge in both codes and simulate build up for a few bunches (OD) – This had also become obsolete.

- Run a **comparison for** field-free region and for **gas ionization** [ACTION] (CB). The results for a field-free region would be shown today.
- Run a comparison for a very low value of the SEY (CB) – This would be shown today.
- Compare photoelectron rate for zero dipole field in order to see that the difference in ECLOUD is not caused by electrons that do not contribute to the further build-up because they are bent back into the wall due to the strong magnetic field (HM) – **Humberto Maury** reported that **for zero field** he obtained the **expected value for the primary electrons** in both codes. The missing electrons in ECLOUD were related to the magnetic field.
- Repeat the **simulation with a very short bunch**, in order to launch all PEs in one step (HM) – still pending
- **Recompute the heat load prediction for LHC and HL-LHC with 25 ns bunch spacing using PyECLOUD** (HM) – Results would be shown today.

Plan for scrubbing run

Giovanni Iadarola presented the plan for the scrubbing run. First he recalled the s**crubbing history of last year**. The arcs were conditioned up to a SEY of 1.52. On 10 July, during the injection test with 25 ns, a slight increase in SEY was observed. The information about this deterioration of the SEY did not come only from heat load. It has been confirmed by a degraded beam lifetime. However, a fast recovery was observed (as expected from past experiments).

Next **GI** summarized the **aims of the scrubbing run**: collect additional SEY data as a function of dose, information for benchmarking, testing scenarios for optimization of the bunch filling pattern and beam parameters, reducing the SEY in the arcs, studies of UFOs and instabilities, etc.

Some considerations about the **choice of the intensity** were exposed. Above N_b=8e10 ppb scrubbing dose (e- energies above 50 eV) decreases, while heat load still increases (at N_b=1.3e11 ppb the dose is just a 10% lower whereas heat load is around 20% higher). Nevertheless, lower intensities yield more instabilities due to higher central density. Then, the e-cloud stripe distribution in a dipole magnet for different bunch intensities was illustrated. The higher the intensity, the further apart are the stripes. So the **idea is to inject nominal intensity (N_b=1.2-1.3e11 ppb) and use the natural intensity decrease to scrub all regions of the beam pipe.**

Chandra Bhat asked which *R* value was assumed. **Giovanni Iadarola** replied that always 0.7 was taken. **Octavio Dominguez** added that *epsilon_max was chosen as 330 eV*.
Chandra Bhat commented that **for the PS epsilon_max was almost uniquely determined by the benchmarking.**

Next, the **effect of the different filling schemes** was shown. There is an important difference between 72 and 144 bunches, which will support the scrubbing evolution (from single batches up to trains of 288 bunches if possible) to gain in efficiency.
Scrubbing run requirements (emittance < 3um, solenoids and dipoles should be ON, positive polarity for LHCb, etc.) were next presented as well as some **potential constraints** for a smooth scrubbing run: monitoring of several devices (MKIs, BSRT, collimators), TDI parking position, etc. Especially important could be some **vacuum interlocks at the Point-8 injection kicke**r (MKI.D5R8.B2) and the **performance of the consolidated BSRTs.**

GI continued by showing the different filling schemes for the scrubbing run. Apart from the standard ones, there is a set of schemes starting and ending always with the same group of 4 PS batches, which could bring several advantages (e.g. better comparison between filling schemes…). **Frank Zimmermann** asked if there was **any plan to use the scheme of missing booster bunches** proposed by Octavio Dominguez with the help of e-cloud maps, which would provide almost the same dose while encountering less instabilities. **Giovanni Iadarola** replied there was no such plan.

The **schedule for the scrubbing run** is: Thursday 4 October morning – Injection and transverse damper. Thursday 14:00 to Sunday 12:00 – Go through the filling scheme and accumulate the required dose. Sunday 12:00 to 0:00 – e-cloud studies (chromaticity threshold, emittance blow up, pressure benchmarking). Injection tests for 25 ns were taking place during the meeting.

Frank Zimmermann suggested (re-)**considering the missing booster bunches in case there was a problem maintaining intensity at the tails of the injected batches**. This scheme wasvery similar to filling schemes successfully used at PEP-II.
Chandra Bhat remarked that dropping bunches from the booster might imply some longitudinal adjustments in the PS or SPS.

GI summarized the measurements to be done during the scrubbing run. Chromaticity measurements will take place before starting any high intensity fill. Other beam measurements to be done: transverse emittance (wire scanner, BSRT; also SPS wire scans), **bunch by bunch intensity**, **transverse oscillations** (BBQ, ADT pickup, Headtail monitor, bunch-by-bunch BLM data…), **longitudinal parameters** (bunch length evolution, beam spectra), **electron-cloud measurements** (heat load in arcs, standalone and triplets RF stable phase bunch by bunch, vacuum pressures, BPM electron-flux measurements [VSC]…)

Frank Zimmermann suggested also adding the **BPM system and Schottky monitor** to the list. He inquired about the status of the HEADTAIL monitor

The **plan for 4 TeV measurements** was also presented.

Octavio Dominguez discussed the **filing patterns for pressure benchmarking**. The exact choice of pattern, consisting of single, double or triple batches, depends on the outcome of the scrubbing run. **Frank Zimmermann** suggested also adding a new filling scheme with trains of 4 PS batches, just in case (**ACTION → OD**).

Heat-load simulation update

Humberto Maury reported an update on e-cloud simulations. The main objective was a general **convergence study for both ECLOUD and PyECLOUD** varying several parameters related to the number of macroparticles. Surface parameters and beam parameters for an LHC dipole at 7 TeV were assumed. HM scanned for input parameters yielding the least noisy results.

HM started by discussing the robustness of the **PyECLOUD** results. The first simulations referred to for two trains of 25 ns with **SEY=1.1**.Varying several parameter by 2 orders of magnitude no major differences were found (less than 2%). The **only parameter which generated a considerable change** in peak linear e-cloud density (about 10%) **is the time step** ('Dt' in PyECLOUD). **GI** would like to **check the issue of the time step with HM's input files**.

For **ECLOUD**, considering the same SEY and beam parameters, there is a very good convergence with the number of macroparticles ('npepb') and with the time step between bunches ('nistep'). However, there is a **strong dependence on the time steps inside the bunch** ('nbstep').

The corresponding results with both codes were then shown for **SEY=1.5**. **In ECLOUD there is significant multipacting** and fluctuations appear at large SEY. These fluctuations are reduced increasing the number of macroparticles. **For PyECLOUD no multipacting appears** with a SEY=1.5 and the density is a factor 10 lower than for ECLOUD. **GI** suggested checking whether the number of primary electrons is the same. **HM** replied that the primary electrons in PyECLOUD and ECLOUD are the same for a field-free region, but there appeared to be differences in a dipole field (**ACTION → GI**: **Check Humberto Maury's PyECLOUD simulation for SEY=1.5**).

Heat-load comparison studies for **25-ns spacing** were presented next. The **heat-load ratio ECLOYD/PyECLOUD for different SEY values** (which ideally should be one) shows **large differences at low bunch population**. Here ECLOUD gives lower values at low SEY. In general for increasing SEY (up to 1.6) the ration increases, but at large bunch population it decreases again for the largest SEY or 1.7.

FZ commented that **for the lowest SEY and lowest bunch charge the ECLOUD heat load is 20% lower, which might be consistent with the observation that ECLOUD appeared to have less primary photoelectrons in a dipole field.**

PS e-cloud simulations - Experiment and latest simulations

Chandra Bhat presented an update of PS e-cloud studies. These experiments at the PS have been done in order to study the **e-cloud dependence on the bunch profile**. The final goal is to make extrapolations to the LHC and the HL-LHC. Available bunch profiles and the PS e-cloud measurements were types of longitudinal profiles were considered, as obtained by operating the

higher harmonic cavity in Bunch Shortening Mode (BSM), or Bunch Lengthening Mode (BLM), and by a standard Single Harmonic RF system (SH), respectively.

A continuous change of measured line density as a function of the instantaneous longitudinal bunch profile has been observed during the measurements. Intensity and profile of each bunch are used as input for the simulations. There is a relatively **good agreement between the simulated electron-cloud evolution and the observed e-cloud build up**. Looking at the accumulated electrons at extraction, the **experimental data show a factor 2.7 between BSM50 and BLM50 and ~2.3 between SH and BLM50**.

Replying to a question by **Frank Zimmermann**, **Chandra Bhat** remarked that he had **changed the gas pressure by 50%, without getting a better agreement**.

Comparison between experimental data and the simulations sets a tight range on the surface parameters: Epsilon_max=287 eV+/-3%, delta_max=1.57 +/-1% and R=0.55 (+/-3%). In addition, BLM50 mode gives rise to a factor 2 smaller e-cloud growth.

LHC&HL-LHC e-cloud simulations, with ECLOUD-PyECLOUD comparison

Chandra Bhat next discussed a **comparison of ECLOUD and PyECLOUD for the LHC and HL-LHC**, checking whether there would be any improvement using BSM or BLM modes.

SEY values used in the simulations were 1.1 and 1.5, and R was set to 0.2 and 0.25. For those values and using a Gaussian longitudinal profile, **heat load agrees within 5% between the two codes in the arcs**, but **PyECLOUD gives 35% higher heat load in the drift sections** – to be further investigated (**ACTION CB**). **FZ** commented that a discrepancy in a dipole field would have been more easily understood and could have been attributed to the apparent difference in the number of primary photoelectrons.

However, **very different behaviour**s (especially regarding the build up phase) **of ECLOUD and PyECLOUD were shown for the LHC arcs**. **Results of PyECLOUD and ECLOUD** (on slide 9) **seemed to be swapped** compared with the results of HM, with **ECLOUD now showing a faster build up, saturating earlier and at a lower level** (**ACTION: CB and HM**).

Next, parameters for the **HL-LHC with 25 and 50 ns were shown. There is a good agreement between ECLOUD and PyECLOUD heat loads**. The **effect of BLM and BSM is small (+-/10%). BSM is not going to help EC growth in the LHC. However, foreseen second harmonic Landau cavity will not pose any additional EC related problem in the LHC/HL-LHC.**

AOB

The next meeting will be announced in due time.

Reported by Octavio Dominguez and Frank Zimmermann