LHC e-cloud simulations Meeting – Draft Minutes

Date: 15 February 2012
Meeting Room: 6-2-004

Attendees: Hannes Bartosik (HB), Chandra Bhat (CB), Alexey Burov (AB), Octavio Domínguez (OD), Giovanni Iadarola (GI), Humberto Maury (HM), Elias Metral (EM), Vittorio Vaccaro (VV), and Frank Zimmermann (FZ).

Excused: Gianluigi Arduini (GA)

Agenda

1. Minutes and actions from the last meeting
2. Fast scrubbing optimization: e- cloud maps, **Octavio Dominguez**
3. Bunch spacing scan for two different bunch profiles at 7 TeV, **Humberto Maury**
4. PyEcloud simulations for the LHC, **Giovanni Iadarola**
5. AOB

Outstanding actions from the last meetings

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 (reassigned to GI?) – addressed in talk
- **Aperture scan for 25 ns** and for non-round geometry & non-round beam (HM)
- **Draft note** summarizing e-cloud simulations for the LHC arcs, namely heat load, density (HM) – draft exists
- Study **solenoid resonance effect** (OD)
- 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 PyECLOUD.

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
- **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)
- Initial excitation of **single modes in HEADTAIL** (HTWG, GR)

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). 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).

Actions from the meeting of 28 November:

- Extend **multipacting threshold versus aperture towards larger beam-pipe radius** up to 400 mm at **50 ns** and repeat the scan for **25 ns bunch spacing** (HM)
- Investigate **pressure benchmarking problem for another gauge** and whether this is due to an inadequate surface fitting (OD).
- Repeat previous pressure benchmarking simulations with **another value of ε_{max}** (OD).
- Confirm how the **estimated dose from SPS scrubbing** was deduced, e.g. from e-cloud strip detector? (OD).
- **Iterative scrubbing calculation** using differential steps (OD).
- Check how the **benchmarking "slope"** could be made to vary, e.g. by choosing larger gaps (OD).

- Repeat the pressure-benchmarking simulations with a **more realistic pattern**, i.e. with all the batches in the machine instead of simulating in groups of two (OD).
- Compare simulated **dose rates in arcs and straight sections** and with this the resulting scrubbing times (OD) - DONE
- **Benchmark heat loads for different fill patterns to determine *R*** for the arcs (GA, HM, FZ).
- **Benchmark pressure rise with PyECLOUD** & compare with ECLOUD result (OD)
- **Benchmark heat load with PyECLOUD** & compare with ECLOUD result (HM)

Fast scrubbing optimization: e- cloud maps

Octavio Dominguez described the idea of the electron cloud maps. He showed the simulated line density on step *m*+1 versus the density at the previous step *m*. The case considered is for the gauges – warm-warm transition in the LHC, at injection. Simulations were done with PyECLOUD. About 5 simulations of a bunch train passage (saturation must be achieved) followed by a gap (with 5 different bunch intensities) are needed to compute all the map coefficients (four in total). Not only the first empty bunch but also the second empty bunch seems to give rise to a separate map.

For 200 nTorr pressure the map results agreed perfectly with the PyECLOUD simulation. The map for 500 bunches takes miliseconds, compared with a few hours for PyECLOUD, and probably days for ECLOUD. For a given map, the initial pressure (seed electrons) does not affect the behavior after few bunches. Sensitivity of map coefficients with simulation pressure must be further explored (**ACTION** →OD). Maps can also be constructed for the flux on the wall.

AB pointed out that the decaying process of the e-cloud is not a Markovian process (i.e. a process without memory) while the maps treat it like one. This fact could be further investigated.

Typical error of the map result is 5%.

The proposed strategy is to use maps to optimize the scrubbing run by finding the best filling schemes, respecting constraints with regard to vacuum (e-cloud flux limit) and beam stability (density limit). In addition, or alternatively, one can minimize the electron cloud (density) for eventually starting with 25 ns after LS1, without suffering too much beam blow up.

It could be interesting to check the e-cloud at 25 ns in the SPS with the nominal scheme (4x72 bunches) and with an alternative scheme with 5x48 bunches (**ACTION** →OD) [see the reference http://cdsweb.cern.ch/record/1075485/files/project-note-401.pdf provided by EM].

Physical interpretations of the coefficients exist for the linear and quadratic term. The linear term for field free regions was explained by U. Iriso in his PhD dissertation, while T. Demma et al. explained this linear coefficient in the case of a strong dipole (IPAC'11) as well as the quadratic term (PRST-AB).

Bunch spacing scan for two different bunch profiles at 7 TeV

Humberto Maury presented the heat load results for Gaussian (7.55 cm rms length) and flat (11.8 cm rms length) bunches with varying bunch spacings and four different bunch intensities (including nominal and twice nominal), plus two different values for δ_{max}, a low value (δ_{max} =1.1) and a high value (δ_{max} =1.7), which could be considered as boundaries. Both field free regions and dipoles are explored. The filling pattern used was 72b+8e.

The qualitative behavior for both profiles looks very similar, although the heat load is about 20% higher in the case of Gaussian bunches (maybe due to the smaller length). A plot with a direct comparison will be added to the presentation. The evolution with respect to the bunch spacing is smoother in the case of δ_{max} =1.1. For the larger SEY the heat load dependence is exponential of the inverse bunch spacing.

ACTION: Repeat simulation for flat bunch at the same rms length of 7.55 cm (HM).

CB remarked that he had done a similar study with a consistent result, but also not for constant rms bunch length.

The dependence of electron cloud build up on the bunch length was discussed. A criterion had been derived by Scott Berg in 1997.

CB mentioned that a change in the LHC arc heat load had been observed in 2011.

ACTION: Presentation of measured bunch-length effect on arc heat load (CB)

PyEcloud simulations for the LHC

Giovanni Iadarola presented the results of PyCLOUD simulations for the benchmarking of 25 ns tests in the LHC. A historical review was given of the 25-ns tests in the LHC. There was a total of 5 MDs with 25 ns. Some MD movies were shown. There were large losses at the end of all trains and always a few bunches with constant high intensity at the train heads.

The losses appeared to be incoherent, always accompanied by bunch shortening.

HB suggested performing ORBIT-PTC simulations including electron cloud.

ACTION: Develop HEADTAIL-PTC or HEADTAIL-MAD-X simulation (HT working group)

Examples were shown of the drop in intensity as well as **bunch-length shrinkage** observed along the trains.

EM commented that for the beam-beam interaction similar effects like bunch-length shrinking could happen and should be studied and suggested that it could be interesting to develop a general approach including beam-beam, e-cloud, PTC,…

FZ remarked that the FBCT numbers may be sensitive to the bunch length (the latter was measured by the BQM). EM suggested that the definition of the BQM values should be verified. AB stated that the length reduction is not very sensitive to the losses (losses are bigger than length reduction). CB said that is difficult from the measurements to state a clear dependence between bunch length and losses.

Assumptions of PyECLOUD benchmarking included **R=0.7** (because a lower value would give a too high value of δ_{max} at the start of the first 25-ns run), which is considered to be the same for both beams and uniform in the chamber under study. Gaussian profiles are always assumed.

ACTION: Explore if R=0.5 would really be inconsistent with a “reasonable” value of δ_{max} (GI)

The history of **δ_{max} evolution from benchmarking** was presented for both beams. At the last MD the δ_{max} should have been 1.52. Thresholds shown were for a bunch intensity of 1.15e11 at 25 ns spacing.

The **principle of estimating the bunch energy loss** was explained. Simulations results agreed well with measurements from the RF group. There is a discrepancy in the build-up phase. Possible explanations were given. About 1e9/m uncaptured beam gives perfect agreement for individual later batches. The cryogenics heat load measurement is about a factor two lower than the ones inferred from the synchronous phase shift.

EM reported a similar factor two of discrepancy for the TDI phase shift measurements.

FZ suggested that the RF transient after the abort gap could affect the synchronous phase of the first bunch trains. This transient could be inferred from phase-shift measurements at bunch intensities below e-cloud threshold or from 50-ns measurements, or be predicted by a model, e.g. from Joachim Tuckmantel.

The additionally needed **scrubbing time** was estimated from the experience so far. The typical electron energy inferred from the scrubbing evolution so far is about 20 eV. Relative time increase can be estimated with some confidence and is insensitive to the assumed electron energy.

AOB

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

Reported by Octavio Dominguez and Frank Zimmermann