LHC e-cloud simulations Meeting – Draft Minutes

Date: 30 July 2011
Meeting Room: 6-2-008

Attendees: Chandra Bhat (CB), Alexey Burov (AB), Roberto Cimino (RC), Pedro Costa Pinto (PC), Octavio Dominguez (OD), Paul Edwards (PE), Giovanni Iadarola (GI), Miguel Jimenez (MJ), Kevin Li (KL), Humberto Maury (HM), Mounir Mensi (MM), Elias Metral (EM), Giovanni Rumolo (GR), Mauro Taborelli (MT), Yasunori Tanimoto (YT) and Frank Zimmermann (FZ).

Excused:

Agenda

1. Minutes and actions from the previous meeting (27th June 2011). Round table
2. A surface study on the origin of SEY reduction on accelerator walls, **Roberto Cimino**
3. New results on LHC scrubbing-run benchmarking, **Octavio Dominguez**
4. E-cloud simulations for 5-ns spacing, **Giovanni Iadarola**
5. Progress on PS e-cloud simulations, **Chandra Bhat**

Minutes and actions of the last meeting (27th 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 OD 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, complete computation of the **central electron density for 25 and 50 ns spacing** with different values of N_b, SEY and R. Add density points for SEY=1.3 at 25 ns spacing; repeat the density curves for 50 ns bunch spacing

- Complete **sawtooth/no-sawtooth heat-load scans for ultimate bunch intensity** - Priority
- **Aperture scan for a non-round beam** repeat this
- **Aperture scan for 25 ns 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.

- Outstanding **actions** for OD:

- Study the **solenoid "resonance" effect**, e.g. by varying parameters like the bunch length and bunch spacing
- 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** (on going).

- Other outstanding actions:

- Implement **simulations with different feedback bandwidth to ~1.0 GHz** & compute kick strength - how much power? Repeat simulation for new SPS optics (KO, FZ). This would be addressed in the coming month during the visit of Kazuhito Ohmi.
- Set up the latest version of the **ECLOUD on svn –** Done by Giovanni Iadarola. **Post information about the ECLOUD and HEADTAIL svn versions** with additional web-site instructions on how to download the code (GI, GR, FZ). **Regular information** about latest versions of both codes HEADTAIL and ECLOUD **for users** (KL, GR and FZ)
- **Change the number of kicks in HEADTAIL** and **scan the tune** and/or to **model the real SPS lattice** with one e-cloud kick per SPS dipole or placing e-cloud kicks for pairs of MBBs and MBAs (KL, HB). – KL reported that a very high number of kicks was tried, but results did not change. Dominant effect at high density is incoherent effect. Convergence against two discrete slopes. Presentation next time.
- Understand **increase of electron cloud density with increasing beam size in PS** simulations (CB and OD).
- Recheck **saturation level with 16 empty bunch slots** instead of 12 for PS simulations (CB). – now taken into account, presentation today.
- Add John Fox to the mailing list (FZ).

A surface study on the origin of SEY reduction on accelerator walls

Roberto Cimino presented progress on surface studies related to SEY reduction. The presentation first recalled the open problems and motivation for these studies. Some features of KEKB and Super B such us instability thresholds or the presence of antichambers were shown. The activity of the LNF material science laboratory proceeds in collaboration with DAFNE and PETRA3, CERN, RHIC etc. LFN will be soon available to measure SEY reduction of materials. Two SR beam lines are being connected to the experimental system with photon energies in the ranges 60-1000 eV and 35-200 eV, respectively. These beam lines will allow SEY and PEY studies before and after scrubbing and SR conditioning.

Another main line of development is to study, produce and test thin low-SEY films. Carbon photoemission spectrum gets shifted, not reduced, moving from sp3 (a-C) to a sp2 layer (graphite, with a slightly lower binding energy). Temperature can also provoke this graphitization. Once graphite is formed, it becomes stable, regardless of the temperature variation. This shift is not present for other materials such as copper.

Some studies on aluminum have been performed at DAFNE and PETRA III. Measurements with different base pressure yield to different results. So it was decided to clean the surfaces through sputtering before scrubbing the aluminum samples. Once the surface is clean, the SEY should not change, since the energy of electrons is not big enough to modify the atomically clean surface. But during the scrubbing process we add some oxygen and carbon. For the SEY variation the role of oxygen (oxidation) is much more relevant than the effect of carbon. The conclusion is that aluminum is a very reactive material. So aluminum is not suitable for e-cloud sensitive machines and should be avoided unless a proper coating is used.

RHIC has carried out some studies on stainless steel. All the surfaces have been sputtered. It is possible to achieve a δ_{max} = 1.1 and δ_{max} = 1.3 for a cold bore pipe and a warm bore pipe respectively. In the spectra is possible to observe again the shift of the bulk carbon from sp3 to sp2.

Studies on TiN are of big interest for Super-B. S.Bini in collaboration with LFN managed to produce goldish TiN, which is the desired uncontaminated state. A value for δ_{max} = 1.0 is reached after conditioning, as found for KEKB too. It is necessary to apply a dose two orders of magnitude bigger to go from 1.2 to 1.0. MJ pointed out that it would be then necessary a 100 times longer scrubbing time in an accelerator, or maybe more since the efficiency of scrubbing decreases with time. Again, the phenomenon of graphitization (shift from sp3 to sp2) is observed when looking at the spectra. So this seems to be the case for many substrates (with the exception of aluminium).

Next, the importance of the electron impinging energy in the scrubbing process was adressed.The results look very interesting result. Scrubbing at 10 eV gives a minimum SEY of 1.4, while 500 eV gives 1.1. So the potentiality of scrubbing a surface does not only depend on the dose, but also on the spectrum. XPS spectra deliver consistent results, i.e. an incomplete transformation from sp3 to sp2 for the case of the bombardment with energy of 10 eV. The main consequence on the LHC commissioning is that the scrubbing starts to be more efficient for electron energies greater than 30 eV.

There is alternatives ways to make a graphitized surface. CERN uses magneto-sputtering to grow a thick (1-10 micron) film. Then the samples are annealed. It is possible to achieve a $\delta_{max} = 0.95$. MJ pointed out that annealing at 660 °C means that it can only be done on stainless steel (with high impedance). The shape of the SEY vs. Energy curve at low electron energies is also important. It could be more suitable to achieve slightly larger values of δ_{max} with a more convenient behavior at low energies. Results are promising and under study in terms of stability versus time, adhesion etc. INFN line of work concentrates on producing very thin "graphene" like coatings on metal surfaces. In this study layers of about 100 Angstrom have been used but LFN is trying to push towards lower thickness. Thin layers can be much more easily reached with gas desorption. The spectra show that the better the graphite layer the lower we grow the SEY.

AB asked about conductivity of grapheme compared with metals, since it is important for the impedance. RC answered that graphene is a good and robust conductor, and it grows only in a very thin (single) layer.

Other accurate studies are necessary to optimize growth parameters, to test the performance of materials in terms of stability in time, adhesion, cost effectiveness, etc. RC finished saying that the results are encouraging and suggest that this could be the right research direction.

After the presentation there was time for questions. GR asked why the effect of scrubbing disappears as soon as air enters in contact with the surface if the grapheme is stable. RC answered that the surface reacts always. Even small layers of hydrogen can change considerably the work function of the surface. EM asked then what happens if we scrub again this surface. RC answered that the second scrubbing is always faster since you clean the hydrogen layers and make grow new graphene islands in addition to the ones existing from the previous scrubbing process.

PC pointed out that CERN thickness is below 1 micron. A 30-nm coating works, being 400 nm the standard, although both have the same effect. The first layers of the material have to be clean. It is in necessary in addition to grow the first layers for cleaning of the electrode.

Another good diagnostics tool is Raman spectroscopy. MT said that the correlation between Raman and SEY is almost zero. RC replied that this is for thick material, because Raman method is sensitive to the bulk. In any case, financing of Raman spectroscopy in the context of Super-B is not guaranteed.

Gas deposition has been proposed too, but it faces Italian security rules. An approach based on electrons will be tried. Another possibility could be based on laser. PC tried a plasma approach, which was limited by the presence of hydrogen.

MT asked where the carbon comes from. RC replied that the answer is not clear yet. There is a paper by Suetsugu and Katoh in which vacuum pressure from residual gas and grain boundaries are explored as possible sources, but the study was not conclusive. RC argued that bombarding a surface with Auger electrons might develop some carbon, so maybe the carbon could come also from the electron bombardment.

The following discussion address the possibility of "mini grooves" appearing due to rough surfaces.
PC pointed out that goldish color of the TiN might not the best guide for low SEY. Normally dark surfaces work better.

FZ highlighted that benchmarking of measurements against simulations indicates that the low energy electron reflectivity is smaller than 1.0m, and more like 0.2-0.3 RC conceded that the laboratory measurement of this parameter is difficult. A finite energy spread of the laboratory electron beam also needs to be taken into account when interpreting the data.

FZ asked about the new clearing electrodes installed in DAFNE; MJ stressed that clearing electrodes are the only means against photoelectrons. RC commented that photons also scrub, reducing the photoelectron yield by a factor 2.

ACTION: organize ECLOUD2012 or 2013 workshop in Italy (Roberto Cimino)

New results on LHC scrubbing-run benchmarking

Octavio Dominguez presented an update on simulations for LHC measurements on 6th April, 10th-12th April, and 19th May.

On the 6th April (first night of the scrubbing run) two experiments took place, one showing the dependence on the batch spacing and a second one checking the linearity of the electron cloud effects. Updated results were shown followed by a discussion on the effect of vacuum pressure and which initial baseline pressure to take. There was an agreement in taking $\Delta P_i/\Delta P_2$ (see presentation) as the value for the simulated flux ratio for the first experiment, while $(P_i-P_0)/(P_1-$

P_0), being P_0 the base pressure before the injection of any batch, for the second. Next, some plots showing the quality of 3rd order fits were shown. Usually ϕ_2 has the largest value of χ^2 (i.e. the worst fit). Another plot showed the results for a 5th order fitting. Despite some differences in the shape of the curves, the solution continue being in the same area. The results for another gauge explored (VGPB.2.5L3.B) were similar.
The same procedure has been applied to the data taken during the 10th – 11th April. Up to 14 double trains with the structure [36b + 225 ns + 36b + 4.85 μs] were injected, having a total of 1020 bunches in the machine. The results show parallel lines, although a clear displacement towards a lower value of the SEY seems to appear.

The results for the 19th May, when up to 12 triple trains with the structure [36b + 225 ns + 36b + 225 ns + 36b + 925 ns] were injected (1308 bunches in the machine), show again parallel lines. OD considered these results quite surprising and studied a larger range in R (up to 1.0) and different values for ε_{max} (200 eV, 225 eV, 235 eV, 260 eV), always with the same behavior (the different values for ε_{max} just shift the lines upwards or downwards for bigger and smaller values respectively). FZ pointed out that these are indeed good results: Since R reports on the memory effect of the e-cloud, and since the double (or triple) batches are injected at the same time, some information is lost. If that's true, all the lines should converge to one, which appear to be the case for large number of batches injected, where in addition pressure measurements are more reliable (due to a longer time of the measurement, saturation pressure is reached). It would be necessary to carry out an additional measurement with different batch spacings to get an intersection, which would yield to the solution for the SEY and R values. Anyway, if we consider the lines with a higher number of batches for both experiments as the most reliable, it is seen again in May a displacement towards lower SEY values from the previous results (April).

MJ remarked the big importance of the variation in bunch intensities. This effect can be more dramatic even than the inaccuracy of the pressure gauges.

Finally, OD investigated the importance on the ECLOUD input pressure. It appears to be clear that the simulations have to be done always with the equilibrium pressure as input.

ECLOUD repository on svn

Giovanni Iadarola showed the ECLOUD svn repository and how to use it. Different modified version (presenting new features) can be added allowing having different branches.

E-cloud simulations for 5-ns

Giovanni Iadarola discussed different SPS scrubbing scenarios using 25 and 5 ns bunch spacing, the former using nominal beam parameters and the latter using an intensity of $7 \cdot 10^{10}$ ppb. For the case of 25 ns 4 trains of 72 bunches (separated by 225 ns) would be injected, while for the case of 5 ns basically the entire machine would be filled in.

The e-cloud build up has been simulated for the MBB bending magnets at injection energy. Assuming a SEY of 1.4 or 1.5 the scenario with 5 ns would be more efficient from $N_b = 2.5 \cdot 10^{10}$ ppb. The main reason is that with 5 ns the saturation is constantly reached, while for 25 ns the clearing gap makes "losing" some time with the build up for every turn. EM pointed out that the intensity looks too high.

Another possibility is to use a 5ns train at nominal intensity having a length of 2.1μm (about 10% SPS length). A rough calculation suggests that this solution is more efficient with respect to the nominal 25ns beam by a factor 7.5, already including build up time and the filling factor.
FZ commented that the location being scrubbed could be different depending on the intensity. This needs to be checked (**ACTION** → GI).

Progress on PS e-cloud simulations

Chandra Bhat presented new results from the PS data from the 8th June 2011 in BLM mode. Simulations of electron cloud during bunch splitting process have been carried out using standard charge distributions in ECLOUD. CB has made some changes in ECLOUD that can handle non-standard charge distributions and non-standard filling patterns. Test with irregular filling patterns and different charge distributions (Gaussian, triangular, uniform and trapezoidal) were shown. The agreement with experimental data seems to be OK.

There was a discussion on the length relation between Gaussian and other distribution. The relation used was 4 $\mathrm{sqrt}(3) \cdot \sigma$, which was taken as the length for other profiles.

AOB

The next e-cloud meeting will be held on 9 August from 10:00.

Reported by Octavio Dominguez and Frank Zimmermann