LHC ecloud simulations Meeting

Date: 21 January 2011
Meeting Room: 354-1-001

Attendees: Chandra Bhat, Elias Metral, Giovanni Rumolo, Kevin Shing Bruce Li, Humberto Maury Cuna, Octavio Dominguez, Tatiana Pieloni, Frank Zimmermann, Gianluigi Arduini, Ubaldo Iriso, Daniel Schulte

Minutes and actions from the previous meeting:
Elias Metral reported that Elena Benedetto had found a threshold if 3e11 m^{-3} in a field-free region. This has to be corrected on pages 1 and 2 of the previous minutes
Kevin Li announced that the threshold in a dipole field at 450 GeV is 7e11 m-3.
Gianluigi Arduini found his old coupled-bunch mathematica notebook. He still has to run it.
Elias Metral commented that the bunch length and transverse emittance of Elena Benedetto and Kevin Li were not the same, so that identical results were not necessarily expected.

Where are the electron-cloud stripes in strong dipoles?
Giovanni Rumolo presented simulations of electron cloud in dipoles of SPS and LHC, looking at the impact of time steps, initial distribution, the number of macro-electrons launched per bunch.
The past SPS measurements with strip monitors were recalled, with data from 2001 and 2010. The data were taken at injection. There were almost always two stripes, unless there is no multipacting (with a NEG chamber). There was no central stripe.
Many recent ECLOUD simulations show only one central stripe. The reason for that was heuristically attributed to the launch of initial electrons via gas ionization inside the beam volume. In 2008 a new feature was included, launching 10% of electrons randomly. This was done to make the stripes visible. This appeared to be able to seed stripes in some parameters ranges, but it did not have the desired effect in other cases.
Questions: is it true that the two stripes collapse into one single central stripe in some parameter range. Where do the 10% of electrons tentatively generated across the chamber come from? Could the stripes seen in the strip monitor also be an artifact? Do numerical paramaters influence ECLOUD simulations in some unexpected manner.
Simulations were run for LHC arcs with “fine” and “coarse” steps. The interbunch-gap time step for the fine run was calculated as 1/10 of cyclotron period (and the bunch time step as 1/10 of the electron oscillation period; this is normally fulfilled when the cyclotron condition is fulfilled). Cyclotron period is 300 ps at SPS injection, and 8.5 ps in LHC at 3.5 TeV.
Generation of primary electrons considered either gas ionization at injection or photo-electron emission at 3.5 TeV.

Frank Zimmermann commented that a photoelectron yield of 0.1 looked high, especially for 3.5 TeV.

Elias Metral commented that stripes appear gas ionization might not be the cause.

Frank Zimmermann asked if the central peak at 3.5 TeV would disappear for slightly lower bunch charge.

Overall charge build-up looks similar for coarse and fine slicing. Daniel Schulte pointed out that at 3.5 TeV is was not known whether the number of stripes is different. It seems that for 450 GeV the difference in the stripes also showed up as a difference in the build up.

Checks were next done for the SPS MBB dipoles. Tracking uses dipole option ibend=18.

Daniel Schulte commented that ibend=18 makes the approximation that the field is locally constant and solves the motion explicitly. The field of the cloud depends on the step. Frank Zimmermann commented that another input parameter controls the number of times the space charge is recalculated. Daniel Schulte pointed out that there is another dependence, namely when the particle moves the field from a different location is taken after each time step.

Giovanni Rumolo remarked that the discrepancy between coarse and fine steps commences when the cloud density becomes significant, which could indicate that it is related to the space charge.

The stripe generation and stripe location depend on the number of steps. Differences get more pronounced for larger SEY value. For larger SEY there are three stripes.

Frank Zimmermann commented that the simulations show three stripes, while the measurements showed two stripes most of the time.

The dependence on the initial distribution was checked, comparing three different cases. Each of the cases has the same difference between fine and coarse as the one shown previously. 0.12 T.

Elias Metral and Frank Zimmermann suggested also running a case with gas ionization inside the beam only, and with 10% across the chamber only.
Cases with coarse steps show a slightly stronger dependence on the initial distribution.
Number of macroelectrons makes no difference.

A table summarizes the simulation parameters that should be assumed – number of slices, number of steps, and bunch length. CPU times become easily prohibitive.

Frank Zimmermann recalled that in 2004/5 there had been nearly perfect agreement in the electron distribution measured and simulated for the SPS. Has something been changed in the code since 2005? (e.g. by Jim Crittenden).

Elias Metral inquired if the R value could matter.

Daniel Schulte commented that with a coarse step the loss of an electron might be noticed too late, resulting in the electron having the wrong energy when it is lost.

Gianluigi Arduini suggested rerunning simulations with the old version of the code.

Frank Zimmermann remarked that the number of grid points was low in the present version of the code.

Solution of e-motion in a dipole field:
Daniel Schulte presented the explicit solution of the equation of motion implemented in ECLOUD (ibend=18 option) on the white board.
The parameters "a" and "omega" are assumed to be constant. As long as e-motion stays within a grid cell, the approximation should be OK (provided the field in the original cell does not change).
Daniel Schulte commented that there could be an inaccuracy for an elliptical chamber, since the phase information is lost, which might affect the angle of incidence and yield. For cross-checks simulations could be done with a rectangular or round chamber.

Gianluigi Arduini suggested looking at the trajectory of individual electrons for the coarse and fine time step (***Action: Giovanni Rumolo***)

Elias Metral suggested extracting information from the width of the stripes.

Daniel Schulte pointed out the importance of the uniformity and time dependence of the SEY, which could also affect the structure of the observed stripes.

Frank Zimmermann commented that in the past there had been good agreement between simulations and measurements assuming gas ionization inside the beam only. Daniel Schulte remembered that many of these comparisons had been done for very low field of order 100 G.

Daniel Schulte recommended taking a look at the backtracking of lost electrons, and how this is handled.

Gianluigi Arduini suggested repeating simulations for the lower field of 100 G as in 2005, to see if a good agreement can still be achieved.

Several questions:

- In simulations do not see the two stripes, but see only one or three.
- Argument for launching 10% of e- outside the beam
- Understand reason for dependence number of steps

In 2004 we had a good agreement.

Giovanni Rumolo highlighted that the LHC simulations showed the stripes at injection had a different location than stripes at top energy.

Daniel Schulte suggested checking the dependence on the fraction distributed across the chamber, e.g. by reducing the weight of those macroparticles distributed randomly.

Gianluigi Arduini suggested repeating the 2004 measurements under the same conditions.

IR3 simulation update

Octavio Dominguez presented recent simulation results. He performed scans of Nb and nb.
Measured factor of pressure increase between 1.1e1 and 0.8e11 is about 15. With simulation parameters the factor is 3 with SEY=2.1, R=0.5, and less than three for SEY=2.3, R=0.3.
Next different numbers of bunches were considered.
Measured factor 25 between 36 and 24 bunches compared with 68 in simulation, for R=0.5, SEY=2.4
Both studies indicate that a lower SEY would give better agreement.

e- densities at 50 ns spacing

Humberto Maury presented results of LHC simulations with 50 ns spacing, and 225 ns between trains. Simulations were performed with the standard input file.
Two different definitions of central density sometimes give results that differ by a factor of two.
At 450 GeV, we need to go to SEY=2.0 or below to achieve a central density below 1e11 m^-3, at R=0.5. For an arc drift one needs SEY below 2.5 or 2.6.
At 3.5 TeV in a dipole we need to reach SEY=1.9. In a field-free region one should stay below 2.2, R=0.5.

There was some concern that the density values from 1-mm and from the central grid-cell calculations (with 2 mm cell size) often differed substantially.

Goal for Chamonix should be SEY=1.8.

Frank Zimmermann suggested that to go below SEY=1.8 one could consider scrubbing with 25-ns spacing.

Electron-cloud simulations with 75-ns bunch spacing

Ubaldo Iriso reported simulation results for LHC with 75-ns spacing, for dipoles and field-free region. Goal is to find surface parameters that will give a central density below 1e11 m^-3.
Simulation parameters were 24 bunches per batch, 25 ns spacing, and 4 batches. The bunch length is 11.8 cm, and the transverse beam size 1 mm, corresponding to LHC injection energy.
No electron-cloud activity is seen up to SEY=2.7 with R=0.7.

Frank Zimmermann suggested that the multipacting might occur in a different part of the IR chamber and/or in a dipole field.

Elias Metral quoted a bunch intensity of 1.3e11.

For the arc dipole simulation with 75 ns spacing there is a build up for SEY=2.5 and 2.7.

Densities shown are instantaneous values, including during the bunch passage.

Gianluigi Arduini suggested increasing the initial pressure by a factor 100 and 1000 as a short-cut to find out the long-term behavior (***ACTION Ubaldo Iriso***).

Frank Zimmermann pointed out that the LHC design hydrogen density in the cold arcs is 1e15 m^-3, corresponding to the density expected for 32 ntorr at room temperature. Therefore, in the ECLOUD input the pressure value should be raised to 10 or 30 ntorr.

AOB

Elias Metral reported that the resolution limit from cryogenics of 5 mW/m. With an electron energy of 100 eV, with 400 bunches the resolution limit is 2e11 m^-3. With 1000 bunches, the cryogenic resolution limit is a factor 4 lower than the stability limit.

Tasks/Actions

Reproduce old SPS data in simulations (Octavio Dominguez)
Try to fit IR3 measured data of pressure rise for different train spacings (Octavio Dominguez)
Change IR3 geometry and add weak magnetic field (Ubaldo Iriso)
For the LHC arc increase the pressure by a factor 100 and 1000 (Ubaldo Iriso)
Increase number of grid points by factor 2; check e- trajectories with coarse and fine steps (Giovanni Rumolo)
Repeat simulations for an increased number of interbunch steps (Humberto Maury)

The next meeting will now truly be held after the Chamonix workshop.

Reported by Frank Zimmermann