Electron cloud meeting #65, 22/02/2019 (indico)

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Analysis of the electron motion within the beam (L. Sabato)

Luca presented an update on his study concerning the motion of electrons within the beam.

- For a uniform longitudinal bunch profile, the motion of low amplitude electrons is harmonic in the region where the electric filed can be linearized. The frequency of the oscillation can be written as a function of beam intensity and beam sizes.
- To compare the analytic solution against simulations, the electron pinch is simulated and sufficiently low-amplitude electrons are selected for the comparison.
- In the previous meeting Luca had shown that 500 slices along the bunch are needed to correctly resolve the electron motion.
- For a uniform bunch profile the agreement between analytical solution and simulation results is excellent. Good agreement is found also when introducing a dipolar or a quadrupolar magnetic field.
- When a Gaussian beam profile is considered, the solution found using the average beam particle density describes only qualitatively the electron motion. In particular frequency and amplitude modulation of the electron trajectory are observed.
- Nevertheless, the equation of the harmonic oscillator still locally reproduces the simulated electron trajectory when amplitude, phase and frequency are calculated using the local proton density. An iterative procedure can therefore be used to track the electron. This approach works also in the presence of magnetic fields.
- This study provided a useful crosscheck for the code implementation and shows that also for a Gaussian beam profile and in the presence of applied magnetic fields the simple oscillation formula can be used to estimate local frequencies, which are useful to define the simulation time step.

Low energy electron modelling in PyECLOUD (E. Wulff)

Eric presented a study investigating the modeling of low energy electrons in PyECLOUD.

- In PyECLOUD, secondary electron emission is made of two components: true secondary emission and elastically scattered electrons.
- Physically, these two components behave very differently: electrons undergoing elastic interactions are emitted with the same energy with which they impact. The “true secondary component”, instead, correspond to electrons that are absorbed, but cause the emission of multiple secondary electrons having lower energy than the absorbed one.
- Due to computational limitations we cannot track individual electrons. Instead we use macroparticles (MPs), each representing many electrons. In PyECLOUD, we try as much as possible to rescale the MP size instead of adding or removing electrons. This has implications when generating electron energy and angles.

- In the secondary emission module typically used in PyECLOUD, called “ECLOUD” since it is the same modeling that was used in the ECLOUD code, all macroparticles are rescaled with the total SEY corresponding to their impact energy and angle. In the case of elastic events the energy of the particle is conserved; in the case of true secondary electrons the energy of the emitted MP(s) is generated following a lognormal distribution. The probability of having elastic or true-secondary emission is defined from a perspective of the emitted electrons.
- In the ECLOUD modeling, since we rescale elastically scattered MPs, energy conservation is not respected on single events if $\delta > 1$. Nevertheless averaging over a large number of events, the energy conservation is respected.
- PyECLOUD provides a different secondary emission module called “ACC_LOW” for which these approximations are not made. In this modeling probabilities are defined from the perspective of the impacting electrons and electron generated by elastic events are not rescaled. True secondary particles are still rescaled but using the Secondary Electron Yield per penetrated electron (see slides for exact definition).
- The results of buildup simulations performed with the two modules were compared. As expected, the SEY curves extracted from the simulations are exactly the same. The differences in simulation output on observables like heat load and electron currents are negligible.

Update on multi-species simulations: SMOG2 (K. Poland)

Kyle presented a multi-species simulations study for the SMOG2 experiments.

- The experiment aims at colliding the LHC proton beam with high gas densities.
- The gas cell consists in a circular chamber (1 cm diameter), the gas density will be in the range 10^{18}-1e^{19} molecules/m^{-3}. The coating for the chamber has not been chosen yet, therefore the SEY has been scanned in a wide range.
- Two gas species have been considered: hydrogen atoms and xenon.
- The presence of the ions changes significantly the dynamics of the electrons, which is the main source of energy deposition on the chamber. The heat load increases with the initial gas density and the electron multipacting threshold shifts towards lower SEY. Changes in the electron energy spectrum are also observed.
- These features are more visible for the case of the xenon.
- For more accurate simulations, the gas ionization triggered by the electrons should also be included in the simulations.

Update on LHC arc heat load studies (G. Skripka)

Galina presented an update on the arc heat load studies:

- Previously, experimental data from measurements taken with different beam configurations were used to infer average SEY values for the eight arcs.
- Here, SEY values are inferred at a cell-by-cell level, using data collected with 25 ns beams in 2012 and in 2018. In the high-load sectors (S12, S23, S78 and S81) a degradation between 2012 and 2018 is visible on many cells.
- The heat load expected in each arc using this model for different beam configurations can be compared against experimental data. In particular we focused on data collected with different bunch intensity using trains of 48b (up

to 1.2e11 p/bunch), trains of 12b (up to 1.9e11 p/bunch), 8b+4e (up to 1.5e11 p/bunch).

- The agreement tends to be very good, better than for the estimates made considering constant SEY along each arcs. The sharp drop of the heat loads for high bunch intensity, which had been observed in that case, disappears when considering different SEY in each cell.
- The contribution of the quadrupoles is dominant in the simulation. This seems to contradict the observation from the instrumented cell 31L2.
- The next step is to consider the possibility that a degradation affects only a part of the beam screen length.