Electron cloud meeting #45, 17/07/2017

Participants: E. Belli, P. Dijkstal, G. Iadarola, L. Mether, G. Rumolo, A. Romano, M. Pascale, H.M.Cuna

Electron cloud studies for FCC-ee (Eleonora Belli)

Eleonora presented the main results of her studies on e-cloud for the lepton collider FCC-ee, in particular for the lowest energy case of 45.6 GeV, which is the most critical one from the design point of view because of its high current (1.45 A) and the large number of bunches (70760).

The analytic threshold for the single bunch head tail instability driven by the e-cloud has been estimated for all the energies using an analytical fromula: at 45.6 GeV a density of 0.4e11/m^3 triggers an instability.

Eleonora analyzed the electron cloud build up in both the arcs and interaction region magnets.

In the arcs, the e-cloud formation has been studied in dipoles, quadrupoles and drifts, assuming primary electrons to be generated by photoemission and ionization of hydrogen in the vacuum chamber (with a pressure of 0.75nTorr at 300 K and a cross section of 0.435 Mb), while in the interaction region an initial uniform distribution of 10^9 electrons in the final quadrupoles was considered.

- Simulations in the arcs were run for FCC-ee dipoles, quadrupoles and drifts scanning the photoelectron yield and the photon reflectivity (from 1% to 80%) and assuming trains of 100 bunches with 2.5 ns bunch spacing and 100 ns gap between trains. The heat load and the central electron density were extracted for each element as a function of the Secondary Electron Yield (SEY).
    - Drifts give the highest contribution to the heat load, with a central electron density always above the analytic threshold.
    - The SEY threshold for multipacting in the quadrupoles is about 1.6-1.7, with a central density above the threshold for higher SEY.
    - The heat load in the dipoles is not problematic and from the extracted electron distribution it seems there are no electrons in the central region of the chamber. This is consistent from the simulation point of view (with the assumptions defined in the code and taking into account the generation algorithm for photoelectrons in PyECLOUD) but on the other hand it could be not realistic (because of the particular shape of the vacuum chamber, no photoelectrons are generated in the central part of the pipe). The idea is to implement a new module in the PyECLOUD code to generate photoelectrons per wall segment, allowing for more complex geometries of the beam pipe (as in the case of the winglet chamber for FCC-ee) and a more realistic distribution of photons on different parts of the chamber.
- For the electron cloud build-up studies in the interaction region quadrupoles, the same bunch spacing and filling pattern of the arcs were considered. The SEY multipacting threshold in the IR magnets is about 1.1, which means that a low SEY coating is needed to keep the interaction region e-cloud free. For all the IR quadrupoles, the central density is below the analytic threshold.

Electron cloud studies for FCC-hh and HE-LHC (Lotta Mether)

Lotta presented an overview of the status and future plans for e-cloud studies for the FCC-hh and HE-LHC.

FCC-hh

Build-up studies in arc dipoles, quadrupoles and drifts have been performed considering the main chamber of the (2015 version) of the FCC-hh beam screen with ante-chambers, assuming a copper surface. Both injection (3.3 TeV) and collision (50 TeV) energies have been studied for the beam options under consideration: with equal beam current and a bunch spacing of 25 ns, 12.5 ns and 5 ns respectively. The multipacting thresholds have been determined by build-up simulations seeded with a uniform initial electron distribution. The thresholds in all arc elements are the lowest for the 12.5 ns beam and highest for the 25 ns beam. As in the LHC, the lowest multipacting thresholds occur in the quadrupoles, where an SEY lower than 1.1 is required to suppress e-cloud build-up for all beam options.

The heat load is the highest for the 5 ns beam option, amounting to roughly half of the heat load from the synchrotron radiation. Based on an analytical estimate of the threshold electron density for the single bunch instability, the electron density in the centre of the chamber is in the unstable regime for all beams options when the e-cloud is at, or close to, saturation.

Build-up simulations including photoelectrons show that the amount of photoelectrons has a negligible effect on the heat load, but a significant effect on the central electron density, especially in situations when the e-cloud build-up does not reach saturation. For the 12.5 and 5 ns beams at collision energy the electron density approaches the instability threshold, even below the multipacting threshold, if a few percent of the photons in the synchrotron radiation produce photoelectrons (with the squared cosine distribution) in the main chamber. The vacuum group has estimated that up to 5% of photons could reach the main chamber, implying that for a photoelectron yield above 0.2, beam stability could be at risk. The effect is especially worrying in drifts, where also photoelectrons from the ante-chamber could move into the main chamber.

Simulations of the single bunch instability using PyEC4PyHT have been started, focusing on the 25 ns beam in a dipole at 3.3 TeV, without stabilizing mechanisms. The study identifies a density threshold in the range 1-2.5 × 10^{11}, a factor of 2-3 higher than the analytical estimate. Preliminary results for the 5 ns beam at 3.3 TeV and the 25 ns beam at 50 TeV show a similar scaling w.r.t. the analytical estimate.

In the future, the instability studies will be continued to cover all arc elements, beam options, stabilization mechanism etc. The build-up studies will be done with final designs for the beam chamber, bunch patterns and magnetic fields. To better quantify the effect of the photoelectrons, the option of generating photoelectrons per chamber segment, as discussed by Eleonora, would be useful. For completeness, e-cloud studies in the injectors, especially with the beam variants with shorter bunch spacing, should be considered.

HE-LHC

A study was presented comparing the e-cloud build-up in dipoles for two possible beam screen options: the FCC-hh beam screen with ante-chambers and shielded pumping slots, and a scaled LHC beam screen with a saw-tooth structure on the side and pumping slots in the main chamber. The study considered two different beam configurations: with a beam current similar to the HL-LHC and 25 ns and 5 ns bunch spacing respectively.

The fraction of synchrotron radiation photons absorbed on the top and bottom of the two chambers have been estimated in simulations by G. Guillermo *et al*. For the LHC type beam screen about 0.5% of photons are absorbed on each side respectively, and 0.05%, roughly a factor 10 lower, with the FCC-hh beam screen. In the build-up simulations, the parameters for photoelectron production have been chosen to reflect this difference.

The study shows that the bunch spacing has a much stronger effect on e-cloud build-up than the type of beam screen. The multipacting threshold for the 25 ns beam is around an SEY of 1.45. The heat load is up to a factor 4 higher for the LHC beam screen, reaching values similar to the heat load from synchrotron radiation: 4.6 W/m/beam. For the 5 ns beam, the multipacting threshold is around an SEY of 1, with heat loads around 20 W/m/beam for an SEY of 1.05 for both chambers. If the bunch intensity is halved, the multipacting threshold for the 5 ns beam goes up to around 1.4. For SEYs above 1.1 the central electron density is above the estimated threshold for single bunch instability.

Adjournment

The next meeting will be held on Wednesday, 23/08/2017.

EB & LM, 18/08/2017