Electron cloud meeting #40, 31/03/2017

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Master proposal presentation: Electron cloud heat load studies for the LHC (Philipp Dijkstal)

Philipp discussed the progress of his Master thesis work.

<u>Heat load recalculation</u>

With the help of TE-CRG and BE-ICS, in particular thanks to B. Bradu, the heat load recalculation for different cryogenic cells was performed. Cells are cooled by helium running through the beam screen cooling pipes and returning to cryoplant. The heat load on the beam screen can be inferred from the measures mass flow and the temperature drop. The valve characterization is very important. The cryogenic team performs test measurements to identify valve constants and other parameters, and in case they are improved after tests the recalculation of the old data is preferred. If the calculation changes, the comparison with the old logged heat load data becomes invalid.

To validate the code, the logged values for a recent fill are compared with the calculated ones with and without the estimating the pressure drop along the circuit. For stand-alone quadrupoles there is barely any difference, since the pressure drop is negligible.

For the arc-cell averages the logged data is slightly different from the one recalculated without the pressure drop. This is because the cells with failing sensors are not ignored in the calculation of the logged data, but are correctly handled in the new module. A small impact of the pressure drop is also visible, especially in the high heat load arcs. This is because of the increased mass flow in the high load cells cells leads to more friction in the cooling pipes.

Offsets on the heat load data (measured in the absence of beam) were studied for the 100 ns fills where no e-cloud effect is expected. After subtracting the offset from the average arc heat load the measurements agree very well with the expectation from impedance and synchrotron radiation. It is still not clear whether this subtraction can be done for the high heat load fills.

The heat load measurements from the MD on the intensity dependence (August 2016) were also analyzed. The error bars used so far represent the offset plus 3% of measured heat load (this value was assessed by the cryogenics team in their calibration tests). Expert support would be needed to estimate errors on single cell measurements.

Data analysis

All the fills from 2015/2016 are ready to be analyzed. To speed up and simplify the data processing a python dictionary with heat loads and measured beam properties was created. This dictionary is intended for the systematic data analysis of many fills, for example it allows fast plotting, for all fills that reached stable beams, of the heat loads at different moments of the cycle, of scrubbing curves etc. also for individual cells.

SEY model parameter scan

The sensitivity of the e-cloud buildup on the secondary electron emission model was studied in simulation, accounting for variation of E_{max} and of the angular dependence δ'max(θ). An additional parameter was added to the exponential in the δ'max(θ) expression and PyECLOUD simulations to observe the impact on the heat loads. It was found that there is no or very little impact of the angular dependence for the simulations of a dipole but the dependence for the quadrupole is very strong. Variations of the spectrum of the secondary electrons were also studied, finding significant changes both for dipoles and quadrupoles.

Proposed future work

Philipp will contribute to the data analysis of the upcoming scrubbing run. He will also work on the improvement of the current simulation model of thearc cells by adding interconnections and higher order magnets. Work on the estimation of photoemission seeding by synchrotron radiation and its inclusion to PyECLOUD simulations is also planned.

Progress update on PhD work: Electron cloud instability studies for the LHC (Annalisa Romano)

Annalisa briefly summarized the different activities carried out during her PhD and presented the main results of her simulation studies on LHC e-cloud driven instabilities.

In 2015, the LHC started routine operation with 25 ns beams. However, the e-cloud remains still a challenge for the machine operation since scrubbing was not sufficient to achieve a full e-cloud suppression. To ensure the beam stability, high chromaticity and octupole settings were needed. Annalisa's simulation studies showed how this, in combination with the e-cloud, can generate a tune spread that can reach the Q_y=.33 resonance. This is consistent with lifetime observations as function of the working point.

In May 2016 instabilities were observed in collisions at 6.5 TeV in most of the fills with trains of 72b. Several bunches blew-up in the vertical plane, as observed on bunch by bunch luminosity and BSRT data. The effect was on the bunches at tails of the trains, which is a typical signature of e-cloud effects. Data analysis showed that most of instabilities occurred for bunch intensities between 0.7e11 and 1.1e11 p/bunch.

At the beginning of June 2016 the vertical chromaticity was increased from 15 to 22 units after going in collision. This allowed for a mitigation of the blow-up, but the instability was still sporadically detected on the bunch-by-bunch luminosity data. Nevertheless, a clear improvement on the number of unstable bunches was observed. At the end of June 2016, after moving to filling patterns with 48 b/train no instability was observed and the vertical chromaticity could be brought down to 15 units. In August 2016 during MD runs with 72 b/train and intensities of 1.1e11, 0.9e11 and 0.7e11 the chromaticity could be reduced to 5 units in stable beams without any sign of instabilities. Scrubbing of the central region of the beam pipe is suspected as a possible reason.

Simulation studies

Understanding of observed instabilities relies on numerical simulations (PyECLOUD-PyHEADTAIL). This is a multi-scale problem in space (the small beam is passing through an e-cloud extending over the whole chamber) and in time (the instability growth times are on a few-second scale whereas electron motion is on a nanosecond scale). Recent work at CERN focused on increasing the performance of simulation tools: a “telescoping” grid was introduced in the Particle-In-Cell solver and parallel computing is exploited through a new parallelization layer (PyPARIS). Typical simulation study use ~400 CPU cores (8-16 cores per job).

To check the potential role played by the e-cloud on the instabilities observed in stable beams, long simulation runs have been carried out with more than 10k turns (~1 s) to approach the timescale of the instabilities observations (~2.5s). Such simulations with realistic machine parameters take 3-4 weeks of computing time on the INFN-CNAF cluster.

An electron density of $5x10^{11}$ p/m^3 in the central region of the dipoles was found to be sufficient to induce a vertical instability (in spite of the high chromaticity and high octupole settings). Increasing Q'_v up to 22 units reduced the emittance growth rate especially at low electron densities. This instability could not be detected over the usual simulation runs of 500-1000 turns.

In the machine, instabilities were observed for bunch intensities below 1e11 ppb. The impact of the beam intensity on the instability threshold was investigated. It was found that for a beam intensity of 0.7e11 ppb the instability threshold is basically unchanged. From PyECLOUD simulations the electron density profiles in the dipoles for different beam intensities were compared and it was found that when the bunch intensity decreases, the central density increases significantly. For bunch intensities below than 1.0e11 ppb, the central density increases rapidly crossing the instability threshold, whereas for bunch intensities larger than 1.0e11 ppb, the estimated electron density is well below the instability threshold. Good agreement is achieved when comparing the simulation results with data from physics fill with observed instabilities (fill 4980): the central density increases over the fill time and crosses the instability threshold when the intensity has dropped to ~0.8e11 p/bunch.

Ongoing studies

Check the impact of the EC in the LHC arcs (dipoles and quadrupoles) both at injection and flattop on the beam stability. Preliminary results were presented:

- *450 GeV vs 6.5 TeV: e-cloud in arc dipoles*
  - At injection both planes are unstable but the horizontal instabilities are much slower.
  - At flat-top thresholds are significantly higher
  - Horizontal instabilities are mode-0 like and they are not observed in the machine because they are damped by the transverse feedback. Vertical instabilities develop for higher frequencies and cannot be dealt by the transverse feedback.
- *450 GeV vs 6.5 TeV: e-cloud in arc quadrupoles*
  - At injection both planes are symmetrically unstable
  - At flat-top no clear instability can be detected

Next steps:

- Improve the understanding of machine settings on the instability threshold (chromaticity, octupoles and transverse feedback are simulating together with the EC).

Adjournment

The next meeting will be on Friday, April 10th, at 16 o'clock.

GS 31/03/2017