Electron cloud meeting #66, 22/02/2019 (indico)

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Investigating the secondary electron energy spectrum in PyECLOUD (E. Wulff)

Eric presented a simulation study investigating the implementation of true secondary emission in PyECLOUD.

- In the usual implementation the energies are drawn from a lognormal distribution cut at 35 eV. The energy of emitted true secondary MPs are independent of their impacting energy.
- This means an impacting macroparticle with energy E_{imp} < 35 eV can give rise to secondaries with E > E_{imp}.
- To investigate whether this has an impact, a different model has been implemented, in which emission energies are still drawn from the same lognormal distribution but the distribution is cut at the impacting energy of the MP if this is smaller than 35 eV.
- The energy conservation can still be broken in single events due to rescaling and splitting of MPs, but this will happen very rarely as the concerned MPs have very low energy (SEY is small in that range).
- To preserve simulation speed, at very low energy the energy distribution is approximated with a linear dependence.
- The implemented model was verified with Monte Carlo tests.
- A set of simulations was launched for the case of a drift section to assess the impact on the simulation results.
- The modification does not introduce any change on the results (e.g. number of electrons and heat loads).

Update on SPS "SEY drum": measurements on copper (V. Petit)

Valentine presented the analysis on the copper sample extracted from the SPS "SEY drum".

- The copper surface was installed in Feb 2018 after two years of measurements on a stainless steel surface. The same portion of the copper surface was exposed to the beam during the entire 2018 run.
- The copper foil was extracted in 2019 and analyzed in the lab.
- Similarly to the case of stainless steel (discussed at the e-cloud meeting on 31 Nov 2018) a slight change of color can be observed on the portion exposed to the beam.
- Interestingly, no mark is observed on the other side inside the beam pipe. Some change in color is observed also on the outside of the beam pipe. This could be an indication that beam induced fields are significant in the cavity structure hosting the drum. Past simulation by C. Zannini seem to support this evidence.

- Differences in SEY are observed also in the longitudinal direction, this also suggests the effect of some RF fields.
- For copper after 1 month in air, the minimum measured is $\delta_{max} \approx 1.55$, i.e. about the same value as measured in-situ. The measured transverse profile is very similar to the one that had been measured for stainless steel.
- Surface chemical analysis reveals a lot of carbon in the exposed area especially on the edge (carbon is not observed on the samples extracted from the LHC).
- Globally less carbon is observed on the copper sample compared to stainless steel (copper substrate still visible), but the copper foil was exposed to the beam for a shorter time.
- As for the stainless steel sample, the copper one exhibits a different background at the edge of the trace. This can be an effect of the carbon thickness or crystallinity.
- Graphitization: For both stainless steel and copper, carbon is more graphitic in the exposed area, but with graphitic carbon we could expect a much lower in-situ yield. Possible presence of hydrogen?
- Surface cleaning: Hydroxide contribution is missing in the irradiated area, and very low in the non-exposed part (effect of desorption under vacuum? effect of heating?)
- In 'center' and 'outside' locations, the O-1s region is a mix between Cu_2O and chemisorbed oxygen (coherent). On the edge (most carbon covered area), we are dominated by chemisorbed oxygen (not explained, but similar to oxygen found on StSt sample at this location).
- As discussed in the past, during Run 3 we could install a high-SEY material in the chamber facing the drum to keep the e-cloud “alive” and measure how low the SEY can be reduced with beam.

Update on spare beam screen observations (V. Petit, slides)

- The analysis of the beam screens on which stains were observed is ongoing.
- Two beam screens were cut for analysis. From a visual inspection the stains look different from each other.
- A sample has been sent to an external company for chemical analysis.
- SEY measurements on the samples “as received” were attempted, but showed that the surface is charging. In these conditions an SEY representative of the machine configuration cannot be measured. At low temperature the conductivity of the insulator is expected to go down.
- A laboratory conditioning experiment was conducted on one of the stains, showing that after electron bombardment the charging effect disappears and a low-SEY is recovered. Normal conditioning is observed outside the stain.
- After conditioning, as the charging effect disappeared, the XPS analysis of the surface could be performed, comparing a region within the stain with a region on the outside.
  - It is confirmed that only copper, oxygen and carbon are observed.

    - Next to the carbon 1s peak another peak is observed that could be CO or carbonate. This is not present outside the stain.
    - A peak compatible with CuO is also observed.
- The next steps will include the analysis of other stains (visually different), air exposure and re-conditioning tests, chemical analysis from external company.

Modelling of a thin insulating layer in PyECLOUD (G. Iadarola)

Gianni presented an investigation on electron multipacting in the presence of an insulating layer on a conducting surface.

- The study is motivated by the observation of "stains" on spare LHC beam screens that seem to be charging.
- Caveat: as we have no quantitative information on the behavior of these spots, it is not possible to make any quantitative estimate. The goal here is instead to try and explore possible mechanisms and behaviors.
- When secondary emission takes place, an insulator charges positively. This has two consequences:
    - An electric effect: the charge on the surface can generate a field in the chamber, potentially changing the dynamics of the cloud;
    - A surface effect: the behavior of the surface, in particular its SEY, changes as a function of the charge state.
- For the electric effect a simple analytical model is developed, which shows that the effect is proportional to the thickness of the insulator. The model is checked against numerical simulations. For realistic values of the insulator thickness, the potential is relatively small. Therefore in first approximation it is neglected.
- Effects on the surface: When an insulator emits electrons its valence band starts being depopulated (formation of holes). This affects the Secondary Electron Yield:
    - When the surface charges, the Secondary Electron Yield tends to 1.0 over a wide range of energies
    - This is a reversible process, the SEY recovers its initial value when the surface discharges
- An insulator module has been included in PyECLOUD. The code keeps track of the accumulated charge and adapts the SEY curve accordingly (the charge Q_{max} for which the SEY of the surface reaches 1.0 is defined by the user). The surface can absorb very low energy electrons, which will tend to discharge it. If the resistivity of the insulator is not infinite there will be a small current to ground. This is also included in the modeling as an additional discharging effect.
- The charging module is built on top of the existing non-uniform SEY module.
- It is activated by selecting switch_model='ECLOUD_nunif_charging'. Surface properties can be defined independently for each segment of the chamber (via the chamber mat files).

- A first set of simulations with relatively small Q_{max} was performed to test the code and investigate different regimes with relatively short simulations:
    - In the absence of any discharging mechanisms (no absorption for low energy electrons, infinite resistivity) the surface charges and the SEY goes down to 1.0;
    - In the presence of discharging mechanisms an equilibrium charge is reached with a corresponding equilibrium SEY.
- A more realistic simulation was performed using a relatively high value for Q_{max} (10^{-10} C/mm^2) and a charge relaxation time of 100 μs. In this case the equilibrium charge is ten times smaller than Q_{max}, therefore the SEY of the surface remains high with a strong impact on the heat load.
- It was suggested during the meeting to check whether the resistive heating in the patch could be significant.