Electron cloud meeting #69, 14/8/2019 (indico)

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Update on LHC beam screen analysis (V. Petit)

V. Petit presented the analysis of the beams screens extracted from the low-load dipole C21R6 and the high-load dipole B31L2ß:

- As much as possible, a similar procedure was followed for the two magnets (venting, opening of the PIMs, beam-screen extraction and storage, analysis), to allow for relevant comparisons between them.
- Slices were cut at different positions along the magnets.
- The performed tests include SEY measurement, XPS (surface chemistry), and conditioning with electrons at 250 eV, all performed at room temperature.
- Analysis of the **C21L6** beams screens (showing low heat load during operation) :
    - **SEY measurements:** the SEY was found to be rather uniform as a function of the azimuthal position in the beams screen, for all slices and for the two apertures. Some outliers are measured close to the cuts which are attributed to a contamination that took place during the sample manipulation.
    - **XPS measurements:** it is typical of a copper sample exposed to air. Carbon 1s has atomic concentration in the order of 20%, Cu is found mainly in Cu_2O form. Apart from the few outlies mentioned before, the samples are rather uniform.
    - These results were found for samples located inside the dipolar magnetic field. Samples taken outside the magnetic field are similar, with the exception of some places where a larger amount of hydroxide has formed (this is a consequence of exposure to humidity, it might as well have formed during manipulations after extraction).
    - **Conditioning:** the SEY of the samples before conditioning is lower compared to a beam screen never installed in the LHC, used as reference. After conditioning a SEY smaller than 1.1 is reached both for the C31L6 sample and for the reference one. The dose required to achieve full conditioning is similar. The main effects observed during conditioning are: total reduction of $CuO/Cu(OH)_2$, carbon graphitization, bump at 288.5 eV disappears.
- Analysis of the **B31L2** beams screens (showing high heat load during operation):
    - **SEY measurements:** contrary to the C21R6 case, the samples taken from the magnetic field regions are not azimuthally homogeneous. The flat parts (top and bottom of the chamber) tend to have larger SEY. This feature is not observed on the samples taken outside the magnetic field. This could be a result of the

    different energy spectrum of the electrons at different locations (which are particularly strong in the presence of a dipolar field), as shown by PyECLOUD simulations briefly presented by Gianni.
  - **XPS measurements:** the amount of carbon is extremely low (less than 5% atomic concentration). The most present oxide is the CuO (evident both on the copper peak and on the oxygen peak) which is not expected and is not observed on the C21R6 samples nor on the reference sample never installed in the LHC. On the samples inside the magnetic field this is observed only on the top and bottom part of the screen (where the SEY is found to be higher). It is evident that electron bombardment in the LHC plays a role in the formation of the CuO, as this oxide is found only in the areas where the electron dose is higher and the energy of the impacting electrons is larger. This is confirmed by the fact that in the slice taken outside the magnetic field the CuO is present both on the flat parts and on the sides of the beam screens.
  - **Conditioning**: samples on which CuO show evident alterations in the conditioning curve (measured at room temperature). In particular the conditioning is significantly slower compared to the samples where CuO is not observed (sides of the B31L2 beam screen, C21R6 beam screens, and reference sample never installed in the LHC).
- Next steps of this work will investigate how the CuO has formed, in particular by studying the effect of adsorbed water and the presence of reactive species (ozone, oxygen radicals).
- The formation of CuO requires the presence of oxygen in some form (e.g. O_2, H_2O):
  - From the XPS measurement we know that the thickness is at least 2-3 nm. It would be interesting to assess how much oxygen is required?
  - It would be important to analyze the exact sequence of events (temperature of the sectors when the venting took place). In general the LS1 warm-up and cool-down phases for all sectors should be analyzed.
  - It would be useful to know the concentration of oxygen as function of the depth.
- Samples taken at the position of the brass sliding rings do not show any difference with respect to the others.

Implementation of cross-species ionization in PyECLOUD (L. Mether)

Lotta presented the newly-implemented cross-ionization module for multi-species simulations in PyECLOUD:

- It was shown in e-cloud meeting #67 that cross-ionization can be relevant given the kinetic energy distribution of the electrons in the chamber.
- The equations used to model the cross-ionization process are illustrated.
- The cross-species ionization is implemented in the form of a python class, which:

  - Holds the necessary information on the user defined cross-species ionization processes.
  - Handles the generation of particles through cross-species ionization.
  - Can handle multiple projectiles and any number of ionization processes per projectile.
  - The generating function is called once per time step during build-up simulations.
- Cross-species ionization is activated by adding in the simulation_parameters input file a dictionary that describes the desired ionization processes. The cross-section is provided in the form of a table.
- The cross-species ionization module also contains a self-test routine, which runs by default at the beginning of a simulation, and saves a file for every process.
- Some preliminary results show that above a certain density the cross-ionization contributes significantly both to the electron and the ion density in the chamber.
- In some cases, a “suspicious behavior” is observed in the gap between bunch trains. Investigations are ongoing to assess whether this is physical of there is a an issue with the code.
- With the cross-species ionization, the cloud densities can increase by several orders of magnitude over a single or just a few bunch passages
  - Although PyECLOUD has good macroparticle size management for electron multipacting, the routines are not perfectly adapted to this case
  - Normally the macroparticle number is checked for, and adjusted if needed, at the end of each bunch passage
  - Asynchronous macroparticle regeneration has already been implemented, where their number is checked and adjusted if needed, at every time step.