Electron cloud meeting #41, 10/04/2017

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Arising matters (G. Iadarola)

Surface measurements on the dipole chamber that was exchanged in S12 were recently presented at the LMC and we asked the surface team to present their results also here.

SEY measurement of the arc 1-2 removed magnet beam screen (V. Petit)

The B1 chamber of magnet A31L2 recently extracted from the LHC was analyzed in terms of the surface conditioning. Three samples were studied: a part of the main dipole beam screen, the pumping slot shield and a slice of the transition tube to the following quadrupole. It should be kept in mind that the beam screen was warmed up and exposed to air before the measurements.

For each sample the SEY curve was measured in several points. An electron gun with varying energy (down to 100 eV) was used for primary electrons, and the SEY was measured with an accuracy of 0.05. Since the dose received during a measurement is very low it does not affect the conditioning of the sample.

Also the conditioning behavior and the surface chemical composition were studied. A 250 eV electron gun was used to condition the surface, and the evolution of the maximum of the SEY curve vs irradiation dose was measured. The energy of the bombarding electrons was kept fixed, but data on the effect of the energy is available in literature.

For the chemical characterization X-ray photoelectron spectroscopy (XPS) was applied. It is based on irradiation of the surface with photons and measurements of the energy of emitted photoelectrons to determine their binding energy.

Transition tube:

The transition tube is made of copper, but the surface treatment is different from the dipole beam screen: it is first cleaned with a detergent and then treated with Cr. The maximum SEY depending on azimuthal position was measured; no angular dependence was found and the measured maximum SEY was around 2.0. For comparison, after full conditioning in the lab and subsequent exposure to air for 3 weeks, an SEY around 1.6 was measured.

Dipole beam screen:

The maximum SEY depending on azimuthal position was measured for sample areas at four different positions along the magnet (some lying outside of the magnetic field region). Different SEYs, in the range 1.6-1.8, were measured at the different sample areas. For each area, a lower SEY was measured at the location

of the sawtooth structure, whereas no significant difference could be observed between the top and bottom and the welding side, opposite to the sawtooth. For comparison, a maximum SEY around 1.95 was measured on a beam screen that was never installed in the machine. The result gives the impression that the (direct) SR photons might have conditioned the surface on the sawtooth side, but it is unclear why that would not also have occurred in the drift tube.

The conditioning was studied for two extracted samples, as well as the sample that was never installed. In all cases the maximum SEY reached a value around 1.05, however the dose needed to reach 1.35 (the threshold for e-cloud in a dipole) was larger for the never installed beam screen, which started off at a higher SEY (1.9 vs 1.7). After conditioning and subsequent air exposure for 9 days, the never-installed sample was measured at 1.55.

Comparing spectra obtained with XPS for the never-installed sample, before and after conditioning, to the extracted beam screen it can be seen that the LHC sample corresponds to an intermediate case with respect to the amount of $Cu(OH)_2$ on the surface.

Pumping slot shield:

On the pumping slot shield dark traces corresponding to the shape and spacing of the pumping slots can be seen. On the dark traces a lower SEY (1.8-1.85) was measured, compared to the remaining surface with SEY around 2.0. The latter case is comparable to a "cleaned" sample, while a sample that was cleaned, deconditioned and then exposed to air for 1 week shows an SEY around 1.87.

Looking at the XPS spectra, the dark regions have a lower $Cu(OH)_2$ peak; a sign of conditioning.

Possible future studies for both teams

- The period of air exposure was not the same in all the presented measurements (3 weeks, 9 days, 1 week). The effect of the air exposure time on the amount of deconditioning will be studied in the future.
- It was agreed that attempts would be made to measure also the low energy part of the SEY curve. The results could then be used to check and update the SEY model used in PyECLOUD.
- Valentine will also study the B2 beam screen and another transition tube.
- Literature on conditioning due to photon bombardment will be looked up.
- The electron dose as a function of the azimuth angle could be estimated with PyECLOUD simulations using photoelectron seeding. In addition, dedicated simulation studies could be set up to estimate the extent of the region in the sawtooth area where photoelectrons cannot be accelerated because they hit the wall (due to the Larmor radius) and are reabsorbed.

MULCOPIM conference: impressions and highlights (P. Dijkstal)

The MULCOPIM conference organized by the European Space Agency (ESA), took place 5-7 April in Noordwijk (NE). It is devoted to MULtipacting, COrona, Passive

Inter Modulation (PIM) relevant for satellites. In spite of the strong synergy with electron cloud activities regarding the multipacting part, for satellite application, the concern lies mainly in avoiding the occurrence of multipacting altogether in high power RF cavities (much less on scrubbing effects). Five sessions were entirely devoted to SEY modelling and measurements with many contributors mainly from Spanish institutes, ONERA (France), Frascati and China. Giovanni and Philipp took part in the conference.

The SEY session talks were covering the topics of coatings, surface modelling, SEY measurement techniques and SEY measurements. See the MULCOPIM workwhop website for agenda.

A lot of on-going work on SEY physics and modelling was presented, e.g. modelling the physics of the secondary electron emission process for both conductors and dielectrics (and mixed structures used for coating), detailed modelling of roughness at different scales, fitting with existing models including the dependence on incidence angle. However, there was no mention of surface conditioning or scrubbing, since the main goal for the space community is to reduce the SEY below 1, in order not to have any multipacting – which would prevent the RF device from working. There was also very little interest in the behaviour of low energy electrons.

Since their interest is mainly in low SEY surfaces, surface geometries are simulated in detail to explain the process of lowering SEY (e.g., D. Wang, J. Smith). The presented talks were on modelling of laser-etched surfaces to assess whether the SEY reduction depends on the change of chemical or geometric properties, modelling of porous surface and machined surfaces.

The SEY of dielectric materials was presented in the talk of M. Belhaj from ONERA. When secondary emission occurs, the dielectric charges up and there are internal and external space charge forces changing the SEY behaviour. In case of mono-energetic electron bombardment, the SEY tends to become 1 for basically all energies of incident electrons. It might be interesting to look for possible implications for our cases of ferrites, ceramic tubes and dielectrics exposed to the beam. In these situations the secondary emission is not a local property but depends on the full geometry of the problem.

Monte-Carlo simulations of SEY were presented with intersting pictures of the events inside the material after an electron impacts the surface.

R. Mata and M. Angelucci showed measurements of the SEY dependence on temperature in their presentations. Experiments were done at Valencia Space Consortium (VSC) for temperatures between -150^{o}C and 150^{o}C. The results are very preliminary and need to be improved due to some technical issues, but the first data suggests lower SEY at lower temperatures.

E. Bronchalo from the University of Elche presented a systematic comparison of SEY models with experimental data for Pt surfaces. The measured energy of secondary electrons does not depend on the energy of the incident electron. The dependence of the SEY on the angle of the incident electrons up to 55 degrees was described. Whereas the exponential coefficient in the SEY expression is fixed

at 0.5 independent of the incident energy in PyECLOUD, this presenter fitted the model with a parameter representing higher angular dependence at higher energies and lower with lower energies. It is planned to repeat the experiments for Cu and steel.

Overall, the conference was a very interesting experience. The next MULCOPIM will be in three years in Valencia. Meanwhile, ECLOUD'18 at Elba island is planned tentatively for 3-6 June, 2018, possibly within the ARIES framework.

AOB: ObsBox measurements from the 288b-injection in 2016 (L. Carver)

In 2016 there was a single injection of 288 bunches in the LHC, during the setup for the scrubbing run. A beam dump was triggered after ~11000 turns due to a strong vertical instability. Lee was asked to check if it was a coupled-bunch instability, which is confirmed by the analysis. In the presented pictures and video it can be seen how the strongest instability develops in the third batch. It starts from the end of the batch as a slow wave and grows faster, developing multiple wave nodes along the batch.

Adjournment

The next meeting will be scheduled in due time.

GS and LM 10/04/2017