Minutes of 111th Collimation Upgrade Specification Meeting

Participants: O. Aberle (OA), C. Accettura (CA), A. Bertarelli (AB), E. Belli (EB) (scientific secretary), R. Bruce (RB), F. Carra (FC), M. Calviani (MC), M. d’Andrea (MdA), A. Fomin (AF), J. Guardia Valenzuela (JGV), G. Iadarola (GI), I. Lamas (IL), A. Lechner (AL), A. Mereghetti (AM), D. Mirarchi (DM), J. Molson (JM), S. Redaelli (SR) (chairman).

1 E-cloud studies for collimators (G. Iadarola) [slides]

1.1 Summary of the presentation

GI presented e-cloud studies for collimators. PyECLOUD simulations were performed for different bunch intensities by assuming the rectangular structure of secondary collimators and by scanning the Secondary Electron Yield (SEY) and the half-gap size. These studies showed that, independently of the SEY of the jaw material, up to 1 cm half-gap no e-cloud formation is expected because the gap is so small that electrons start to oscillate around the beam, without multipacting. However, multipacting can occur if the collimator is in parking position (this would be the case of a standard beam pipe) and in this case one has to check the electron current for SEY values around 1.3-1.4, corresponding to the material that has been characterized by the TE-VSC team. Simulations also showed that the electron current decreases for decreasing bunch intensity.

• SR asked if these studies should be repeated for TCTs, since they have larger gaps compared to the IR7 collimators. GI replied that these studies will be done also considering a more realistic beam, with the right $\beta$-functions and gap values.

Action: RB will send the gap values for the different TCTs and TCLs in IR1/5 and GI will check if there is need for further detailed simulations.

• SR asked if there is a specific feedback from the e-cloud team on the validation of the new MoGr material (without or with Mo coating). GI replied that these values of SEY are very similar to the current values in the arcs so they can be tolerated for km, but of course it would be better to insert collimators where the $\beta$-function is smaller, since it plays a role in multipacting.

2 Update on mechanical design for crystal collimators (I. Lamas) [slides]

2.1 Summary of the presentation

IL presented an update on mechanical design for crystal collimators. LHC configuration includes 4 crystals, 2 installed in 2013 (V1) and 2 installed in 2017-2018 (V2). V1 was produced by CINEL and included all the elements listed in slides 4-7. The problem with this version was the temperature limitation of optic fiber feedthrough for interferometric heads which was making the device un-bakeable.

In V2 the optic fiber feedthroughs were validated through UHV tests and the device became bakeable but the difference of thermal expansion during the bakeout between the StainlessSteel stage and the ceramic stacked piezo was too high and during bakeout the...
piezo contacts were lost. For this reason, a new system including an elastic component between the wedge and the piezo was developed in V2 to ensure the preloading of the piezo at room temperature.

V3 presents several improvements with respect to V2 listed in slide 13: the most important one is the out-of-the-tank adjustment system for optic heads to avoid the loss of optic head signal. In this version, the clearance between crystal and auxiliary pipe was increased for safety reasons, as well as the robustness of the crystal holder (possibly made of Ti for thermal stability) and the integrability (crystals can be installed independently).

From a mechanical analysis, the optimal value for the preload resulted to be 70 N while a buckling analysis of the blades showed non-buckling phenomenon for the range of [-10,10] mrad.

A modal analysis was also performed for different crystal configurations to verify the stability of the system, showing that Ti alloy is more stable with the temperature than Al. Moreover, the screws should be free during bakeout and during transport a max deformation of 5.2 mm has been predicted for the supporting plate of the goniometer. Next steps are listed in the last slide.

- SR commented that the temperature limitation of V1 was also coming from the piezo, in particular its Curie temperature was lower than the bakeout temperature and its properties would thus be lost during bakeout. This was fixed by choosing, for V2, another piezo.

- SR asked if the new design, if successfully validated by a prototype, can be considered as final. IL replied that it needs to be validated. MC commented that two prototypes will be needed, one for continuous test bench and another one to be installed in the machine. However, there is no further improvement needed and the design can be considered as final.

- SR asked what is the possibility to maintain the crystals which are not vacuum compliant, i.e. the two ones presently installed on B1. MC replied that this has to be checked with the vacuum team.

3 PIE status of HRMT-35 (I. Lamas) [slides]

3.1 Summary of the presentation

IL presented the status of post irradiation examination (PIE) done on graphite blocks irradiated during HiRadMat-35. Given the uncertainty on TDI Cu-coating behaviour under impact conditions, other different coated absorbing materials were tested, with Mo and Cu coatings, considering three different impacts (deep, grazing and tilted) in order to reproduce the worst case scenario. Numerical pre-irradiation studies showed that for the Mo jaw the temperature is always lower than the melting point while for the Cu-coating there is a partial melting in the range of the stripe width between 580 µm and 700 µm and the max length and width of the melting region is found at 300 µrad tilted impact at 0 σy.

A dynamic test has also been performed to check the homogeneity of the materials (no crack inside) and the surface was evaluated by optical microscopy, confirming that Cu-coating is melting while Mo-coating is not (with some spallation damage), as predicted by simulations.

SEM analysis showed a homogeneous coating deposition on graphite for both Cu and Mo and a measured thickness in agreement with the theoretical one (2.5 µm).
SEM analysis was also performed for Cu-coated blocks only, on the damage area, confirming Cu melting with consequent open spaces and blisters, probably due to the outgassing of the substrate, and showing a melting thickness of about 615\(\mu\)m, in good agreement with simulation results. The same analysis on Mo blocks confirmed no melting of Mo, but the coating seems to detach as in spalling damage, with a width of damage stripe as predicted by simulations.

Further PIE studies will be tomography to analyze the damage also in the substrate, adhesion tests and RF impedance measurements.

- SR asked if in these tests the substrate is always graphite. IL replied that it is the case.
- AB asked if any projection has been observed in the tank and, if yes, what material. IL replied that dust of Cu was found.
- SR asked the timeline foreseen to work on these materials. IL replied that now the blocks are at 1\(\mu\)Sv so they can be cut.
- SR asked if a scaling can be applied to define a safe intensity at 7 TeV because at top energy only a very small amount of beam (probably in the worst case one bunch) has grazing impact on secondary collimators.

Action for AL, AB, IL, ideally to have a feeling before the February review.

4 Summary of recent UHV tests on MoGr (C. Accettura)

4.1 Summary of the presentation

CA summarized the results of vacuum tests on Molybdenum-Graphite performed during the 2nd half of 2018 (after fixing the production cycle that led to not compliant blocks of the batch 1, which was rejected and not payed to the company.).

Batches 2 and 3 are both compliant in terms of total outgassing that is below the acceptance limit of the jaws while in terms of internal leak (i.e. estimation of the total air content in the material) batch 2 was above the limit, probably because it was exposed to air after Ne venting. In any case, this effect can be mitigated with the installation of NEG cartridges, whenever necessary. From RGA spectra, it was observed that the \(H_2\) content of the samples is almost equal to the \(H_2\) content of the reference test bench. Therefore, acceptance criteria based on a normalization to \(H_2\) are not appropriate and one has to consider the absolute value. For the same reason, simulations were performed to check the influence of \(CH_4\) on the beam lifetime, pointing out that a significant methane outgassing has negligible effect on the beam lifetime.

For batch 4, the power cut in December 2018 caused some problems during the vacuum firing by increasing the pressure up to \(10^{-2}\) mbar (while the max acceptable value is \(10^{-5}\) mbar). Therefore, the vacuum firing for batch 4 was repeated in January (last week) and the report is ongoing.

Regarding the coating outsourcing, DTI coating is the best one compared to CERN and Polytechnic, not only in terms of vacuum performance but also for electrical resistivity and adhesion. In particular, after 6h of thermal treatment at 400\(\degree\)C the outgassing rate, the internal leak and the \(CH_4\) content were back to the values of the uncoated sample. The coating was also validated in terms of adhesion by performing a baking in ”bad vacuum”, showing no degradation of the coating adherence.
SR asked why the $CH_4$ issue became apparent in the production and was overlooked in the qualification process of the company. AB replied that in those tests performed on a single block the scaling between $H_2$ and other species led to wrong conclusions because $H_2$ was not coming from the block but from the tank.

AB commented that baking cycles with artificially bad vacuum conditions were performed because there was a concern about the presence of gas causing degradation of the coating adhesion. CA replied that indeed by exposing the coating to a low level vacuum, it could absorb gas, in particular $H_2$ that makes it brittle and $O$ with a consequent oxide formation. SR commented that it would be important to explain at the review the motivation behind all these tests, pointing out all the initial concerns and the feedback from vacuum.