Actions from this meeting

- If BE-BI agrees, the action on the BPM energy deposition studies can be closed.

1 Temperature increase of collimator BPMs and cables from beam losses (F. Carra) [slides]

Summary of the presentation

During the design phase of TCPPM and TCSPM collimators, focus was given to the loads on the BPM pickups. The simulated geometry was the most loaded collimator, the most exposed MoGr TCSPM which is not going to be replaced as part of the LS2 installations for HL-LHC. Experimental tests were also done to determine the maximum temperature that can be sustained by a pickup. The high temperatures in the in-jaw buttons (up to 700°C in simulations) are given by the dense stainless steel component and the long thermal path to cool it down present in the original design. Actions were taken, reducing the thermal path and switching from stainless steel to Ti. However, simulations showed that the non-conform Ti alloy provided by Solcera did not allow for a sensible temperature reduction (it was specified to use Ti instead of the alloy used by the company). Another issue during production was the fact that the Be pin did not sustain the correct heat treatment and lost its elasticity. For these reasons, the old design was chosen for LS2 production. Simulations for this setup showed maximum temperatures below 400°C. The cable itself was never simulated with FLUKA or ANSYS, so a simplified model was used and temperatures around 50-70°C at the connector were estimated. A third BPM is installed on the TCPPM and TCSPM tank, either upstream or downstream. In this case, assuming perfect contacts and based on the simulations done on the in-jaw BLMs, the maximum temperature is expected to be lower than 50°C in the downstream configuration, and even lower in the upstream configuration, making them basically equivalent.

Discussion

- FCas asked if it would be possible to design a BPM with hollow body. FCar replied that the minimum thickness that could be achieved remains to be seen, but the design could certainly be reviewed and discussed with BE-BI;

- SR asked if the material specifications were given clearly by CERN to Solcera. FCar replied that the exact specifics need to be checked with BE-BI, but EN-MME specifically suggested to use Ti and not an alloy. He also added that the Ti alloy used by Solcera is anyway a robust material, just not very good in terms of thermal conductivity;
• FCas asked if metal is strictly required for the design or if metallized ceramics could be used instead. FCar replied that he agrees with the principle, but the requirements from the functionality point of view need to be checked with BE-BI. AB and SR commented that also the ability of the company to provide such materials needs to be verified; 

• CBC asked about the uncertainty on the temperature calculation. FCar replied that the model is indeed simplified; 

• FCas expressed concern for vacuum leaks due to the heating of the cable caused by beam loads. SR replied that indeed these studies were triggered by past issues with leaks, in order to demonstrate that the heating coming from beam loads is small. FCas mentioned that there are alternative solutions for transmission lines that do not use Si dioxide but just vacuum or air.

2 Technical status and highlights of MoGr production (F. Carra)

Summary of the presentation

FCar started with an overview of the production status for the TCPPMs and TCSPMs. All the primaries have been delivered and validated at CERN, and four of them have been shipped to CINEL. The first six secondaries have been delivered and coated at CERN, while the first five have been validated and the first four have been shipped to CINEL. Batch 14 and onward are produced with the new 93004 graphite powders, which were validated together with Nanoker after reproducibility issues arose with the original 93002 graphite powders. During validation, the new powders showed good properties (same electrical conductivity after coating, better thermomechanical and dimensional stability, worse but tolerable in terms of outgassing in ultra high vacuum). In view of an observed air increase during UHV for some batches, a few actions are being discussed with the vacuum team, including:

- Batch 14 put on hold and wait for more statistics on next batches to re-assess the situation;
- UHV tests for all following batches before and after coating;
- Batch 15 shipped to DTI since it was better pre-coated than batch 14;
- Batch 16 treated to gain a factor 2 in total outgassing, currently under UHV test pre-coating.

In terms of dimensional tolerances, difficulties arose due to the springback of the blocks. Various measures have been put in place to prevent this from happening again, and 93004 powders provide a more stable and easy to machine material. Thanks to the actions implemented, significantly better results in terms of straightness and flatness were observed with secondaries.

Discussion

• CBC asked some clarification on the priorities for the various collimators. FCar and SR replied that the list follows the same priorities given to I. Lamas Garcia for impedance, with the last primary in between the secondaries;

• FCas proposed the idea to make BPM buttons out of carbon. FCar replied that in principle it could work, but it is a matter of convenience for the production;
• FCas asked if hot isostatic pressing can be applied to graphite powders. AB replied that it is possible during processing but it was not done in this case because current is required to heat the powder up, making it a unidirectional process;

• SR pointed out that the first four primary collimators were approved by the vacuum team.

3 Resistivity measurements on coated collimator materials (N. Biancacci) 

Summary of the presentation

NB started with an introduction on the various strategies that are being explored in order to reduce the effect of collimator impedance in view of HL-LHC. A prototype TCSPM in Mo-coated MoGr was installed and tested in the LHC. Higher than expected resistivity was measured and micrometric clusters were observed on the surface, triggering a dedicated investigation campaign. Mo-coating on MoGr was produced using two different techniques, Direct Current Magnetron Sputtering (DCMS) and High Power Impulse Magnetron Sputtering (HIPIMS), and as a comparison graphite samples were also Mo-coated with the same techniques. Resistivity measurements were carried out using three different methods: DC, Eddy-current (<2 MHz) and H011 cavity (16.5 GHz). The results confirm lower resistivity for HIPIMS Mo coating on MoGr, but also show systematically lower results for DC compared to the other methods. Additional analysis to observe microstructures on the surface of the samples was triggered by the fact that HIPIMS results were better than DCMS for MoGr and not as good as expected on graphite. The worse performance of DCMS with respect to HIPIMS could be related to the lower current transmission between grain boundaries. When performed on graphite, the coating shows higher resistivity, likely related to the large voids not present on MoGr. Further activities currently ongoing include a detailed surface roughness characterization of graphite substrate, analysis of Cu coating on graphite and general follow up of batch production samples.

Discussion

• CA pointed out that the lower resistivity measured in DC could be related to the higher temperature reached during the coating is just a hypothesis. AB asked if this means that this situation is not really representative of the real case. CA agreed at least for graphite, and the differences for MoGr can be explained by statistical variations;

• SR thanked the team involved for the comprehensive set of tests and for the follow up of the production (see next talk). The understanding was significantly improved and the focus should now shift to understanding the effect of radiation on Mo coating. Investigations will continue on the worse performance of Mo coating on graphite than on MoGr, but with lower priority.

4 Procedure and status of impedance validation for series production (A. Kurtulus) 

Summary of the presentation

AK showed the results of the probe/loop impedance measurements performed on three primary low impedance collimators. It was decided not to perform wire measurements in order to avoid
the risk of contamination of the low impedance material. All the measured modes were carefully checked for the three collimators to make sure that they were weakly coupled. The resonant frequencies and the unloaded Q were calculated from measurements. Four main modes were observed: \(\sim 0.41\) GHz, \(\sim 0.52\) GHz, \(\sim 0.6\) GHz and \(\sim 0.73\) GHz respectively. However, it is not possible to get information on the shunt impedance, which is required to conclude on the installation. For this reason, simulations were also performed for the TCPPM with a simplified model. First results were observed to be in agreement with measurements, and the shunt impedance values are low. These results were cross-checked using past wire measurements performed on the TCSPM collimator, which has a similar structure to the TCPPM. Given the absence of unexpected large modes in the measurements, the three collimators can be considered acceptable for installation in the LHC. Impedance measurements will continue on the new collimators, along with additional simulations and checks.

**Discussion**

- AB asked what is the limit that has been considered to determine if the shunt impedance is acceptable. NB replied that worrisome values are of the order of k\(\Omega\) for the longitudinal shunt impedance.