**197th WP2 Meeting**

**Tuesday 12th Oct. 2021, 10:00 – 12:00**

*Chairs:* Rogelio Tomás

*Speakers:* Ezio Todesco, Rogelio Tomás, Riccardo De Maria

*Participants (zoom):* Xavier Buffat, Joschua Werner Dilly, Ilias Efthymiopoulos, Davide Gamba, Giovanni Iadarola, Nicolas Mounet, Yannis Papaphilippou, Axel Poyet, Thomas Pugnat, Guido Sterbini, Markus Zerlauth

**AGENDA**

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**MEETING ACTIONS**

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<th>Ezio</th>
<th>Report on the outcome of the MCBXF801 field quality measurement.</th>
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<td><strong>Rogelio and Riccardo</strong></td>
<td>Confirm the approval of the proposed MCBXF acceptance criteria in view of the Cost and Schedule Review (already done).</td>
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<td><strong>Riccardo</strong></td>
<td>Distribute IP8 aperture considerations to LHCb (already done)</td>
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**GENERAL INFORMATION (ROGELIO TOMÁS)**

Rogelio reviewed the minutes of the 196th WP2 meeting. No comments were received yet.

The topic of the presentations of the last meeting were recalled and the list of the actions were reviewed.

Sofia and Guido have to check if the ions lifetime can be inferred starting from DA fit and scaling laws (as done by Massimo) or by past measurements. There was a clarification about the adoption of the error corrections in the ion DA studies. As confirmed by Rogelio and Guido (during the meeting) and by Sofia (after the meeting) the corrections were not implemented (as in all similar error DA studies). Rogelio commented that, anyhow, the correction of the errors in the ion DA studies is not a short-term priority. In fact, even without correction (that is in the conservative approach), the DA results seem adequate.

As an outcome of Riccardo’s aperture analysis, Roderik confirmed to the ALICE Collaboration that the aperture of the new ALICE’s beam pipe is fully compliant with the requirements for the ion run. In the last meeting, Roderik summarized that no performance improvements are expected for the light ion run. There is, however, optimism in the potential discovery reach and, eventually, improvement of the machine performance: ALICE 3 is proposing a Letter of Intent and in the Injectors, there is a renovated momentum and interest for light ions.

Rogelio informed the meeting that the Run 4 document is almost finalized. A final check on the completeness of the text and explanations is still needed. The document will be circulated to the co-authors and the HL-LHC management with the aim to distribute it before the HL-LHC Annual Collaboration Meeting.

Yannis informed the meeting about the progress around the beam-beam long range wire compensation project. Oliver Kester (director of Accelerators at TRIUMF) received a positive assessment from ATLAS Canada (an important promoter in the Canadian High Energy community). This endorsement is an important step towards the possible approval of the Canadian in-kind contribution to the project. The present financial envelope (approximately 5 MCHF) could fully cover the construction of the hardware for the BBLR compensation. The approval process for a formal decision is expected at the end of 2022. In order to support it, an internal review at CERN is needed. The Review will cover the beam dynamics relevant aspects, the required budget and propose a planning compatible with the HL-LHC schedule. Yannis mentioned that only if all these three aspects are correctly met/addressed, one can present the proposal to the HL-LHC management. In fact, the aim is to bring added value to the project and not a layer of complications. All additional budget implications for CERN should be addressed. Axel asked if the possible Canadian in-kind contribution will cover the full cost of the wire compensation scheme. Yannis mentioned that this is not clear at the moment (Canadian budgeting includes manpower). Some CERN hardware could be possibly reused but the wire integration will have additional costs (cabling, power supplies, installation...) that are still under scrutiny. Markus commented that the budget reserved by the project to the wire compensation study has been already fully allocated (for the MD and the prototype construction). Markus and Yannis commented that the BBLR wire compensation is an option and is not part of the baseline. Even in the case of an important and ausplicable in-kind contribution, all lines of cost and, explicitly, the CERN cost share need to be fully scrutinized for an eventual final and sound
endorsement. Axel asked if a beam-beam compensation for a single Interaction Region, namely ATLAS’s one, can be envisaged. Yannis answered negatively, commenting that despite the important endorsement of ATLAS Canada (and the, possibly, by the Canadian high energy physics community), the decisional and funding body on this matter is the Canadian Foundation of Innovation. Rogelio asked when the review would take place. Yannis answered that it will take place in May 2022, to have also the first feedback from the Run3 operational experience. Concerning the wire potential, Yannis commented that the demonstrators showed their capabilities already during Run 2. In Run 3, we should focus on the operational aspect of the wire compensation and not, given the inherent limit of the demonstrators, on the performance reach.

The schedule of the meeting then followed as foreseen.

1. **Update of MCBXF acceptance criteria (Ezio Todesco)**

Ezio presented the proposal for the MCBXF acceptance criteria.

The third nested corrector MCBXFB01 has been tested in July-August 2021. It has been designed and produced in collaboration with the CIEMAT. This magnet design was recently modified to mitigate the observed issues with the magnet retraining when changing the sign of the torque acting on the coils (see EDMS 2612566). The modifications were minor but with an important positive impact. Namely, longer end-spacers were considered.

The test results were presented. Since the very beginning of the test, the improvement was clearly visible. Independent tests showed that:

1. The virgin training process is ten times faster than with the previous design.
2. After changing the torque sign (due to the different polarity of the horizontal and vertical nested correctors), the magnet reached the nominal integrated field of 2.5/2.5 T m in both dipoles with one quench, compared to about 30 in MCBXFBP1 and MCBXFBP2. This second result is a crucial improvement for operation.
3. After the thermal cycle, the magnet reached a nominal integrated field of 2.5/2.5 T m in both dipoles with only two quenches, and was able to operate in all polarity configurations.

The test of MCBXFB01 showed that few quenches occur when the torque is larger than 90% of nominal torque and indeed the torque is the physical phenomena limiting the magnet performance. Given these premises, it was proposed to converge to specifications that satisfy the WP2 requirements, take into account this magnet feature and give some margin and possibility for 7.5 TeV operation. It is therefore proposed to limit the MCBXFB to 2.0 T m in the inner layer and 2.5 T m in the outer layer (and vice versa) and the MCBXFA to 2.5 T m in the inner layer and 4.5 T m in the outer layer (and vice versa).

In such configuration the MCBXFB01 was tested and it successfully reached without quenching 2/2.5 T m and also, for the first time ever, 2.14/2.68 T m (7.5 TeV equivalent operation). This result was repeated for all possible polarities and maximum magnetic field configuration.
The field quality was also shortly presented. At 2.5 T m, the magnet can meet the 20 units range in b3 and a3. This is intrinsic to the magnet design and it is a deterministic contribution. It becomes relevant (larger than 10 units) only above 1.5 T m of integrated field in each dipole. Studies are ongoing on a 2D field model and several measurement data were collected during the MCBXFBO1 test. The analysis is ongoing.

- **Rogelio** thanked the speaker and asked if the cross-configuration can be problematic in terms of field quality. **Ezio** answered that the analysis of the measurement will address this point and the results will be discussed tomorrow (Action: **Ezio**). The field quality is driven by the saturation and being a deterministic effect, it can be corrected. **Rogelio** commented that 20 units can be accepted in view of the FRAS or equivalent deterministic correction. He added that even if possible, this correction adds complexity during operation.

- **Ezio** commented that, concerning the interpolation aspects of the multipolar errors, this is the first time it is attempted. It is not a trivial problem and, probably, it will be addressed by using error functions whose parameters depend on the angle of the excitation of the dipole.

- **Axel** asked if the MCBXFBO1 will be installed in the LHC tunnel. **Ezio** answered that it depends on the approval of this proposal. Most likely it will be installed, while the MCBXFBP2 will be retrofitted (inner coil replacement) and installed. The MCBXFBP1 will be used instead only for the string test.

- **Rogelio** concluded that the proposal is approved pending the confirmation of **Riccardo** concerning the proposed 2/2.5 T m integrated field envelope. **Ezio** observed that the target is to have a clear statement before the technical preparation phase of the Cost and Schedule Review. **Rogelio** informed that the final ok will arrive before next Monday (Action: **Rogelio** and **Riccardo**).

2. **OUTCOME OF THE COST & SCHEDULE REVIEW PREPARATION MEETING**

*(ROGELIO TOMÁS)*

**Rogelio** presented the Outcome of the Cost and Schedule Review (CSR) preparation meeting. Despite the fact that WP2 will not directly present during the Cost and Schedule Review, it was a main player during the preparation meeting.

An overview of the 2021 CSR was given (changes since the last CSR, risk identification and mitigation proposal, and performance analysis). In particular the 2019 CSR recommended to re-evaluate the requirements on HL-LHC components for operation at ultimate intensity and to scrutinize the added technical risks.

In view of that aim, the report on Run 4 operational scenario was prepared and is almost finalized. The document presents and discusses

1. the main HW changes (deferral of the MS10 installation, adoption of the hollow electron lens, partial upgrade of the secondary CFC collimators, cancellation of 11 T in LS2, crystal collimation for ions, increase in the expected CC noise level, addition of the FRAS, main sector dipole power converter upgrade, exchangeability of the CCs between IR1 and IR5),
2. and the main operational changes (collimator gap from 6.7 to 8.5 $\sigma$ at top energy, luminosity limitation at the start of stable beams due to cryogenic control constraint, reduction for IP8 $\beta^*$ from 3 to 1.5 m and choice of positive octupole polarity).

An overview of the Run 5 hardware and operation scenario was given (MS10 is assumed to be installed in LS4 together with the 11 T dipoles, improvement on the $\beta^*$ reach and possibility to explore moderate flat optics, etc.).

An overview of the new technical risks and mitigation was given (noise from CC and HEL, D1/2 field quality, bbb luminosity fluctuation, MQXF gradient slow drifts, Q2 sorting, IR orbit correctors availability, delay in the hardware availability, etc.).

A rich list of achievements, results and reports was presented with particular emphasis on the items that were not considered in the previous baseline and therefore have or will require extra efforts within WP2. A list of the next milestones was shown together with a task plan until 2023. This was complemented by the WP2 budget and manpower plan.

- **Davide** informed that he is finalizing the BPM specification report taking into account the duty cycle figures, as requested by **Michal Krupa**.
- **Ilias** asked some details about the need for CC interchangeability between IR1 and IR5. **Rogelio** explained that this is needed in case of exchange of crossing planes in IR1 and IR5 (the nominal crossing plane is horizontal and vertical in IR1 and IR5, respectively). A crossing plane exchange could be envisaged for two reasons: (1) maximization of the triplet lifetime with a better azimuthal redistribution of the radiation dose and (2) flat optics optimization. **Markus** commented that it is important to keep the CC interchangeability option open.
- **Ilias** asked about the CC spare policy. **Markus** commented that there are spare cavities but he could not recall that the set of spare is sufficient or intended to refurbish a full CC cryo module.

3. **Aperture considerations for potential LHCb VELO upgrade**

   *(Riccardo De Maria)*

**Riccardo** reported about the discussions in view of the LHCb VELO upgrade. This upgrade is investigating the possibility to have a fixed VELO and not, as presently, a moveable one.

The most demanding optics in term of aperture requirement is the injection optics ($\beta^* = 10$ m).

A table with the aperture budget in the horizontal and the vertical planes was presented (for z=80 cm from the IP). The contributions from betatronic envelope, orbit, orbit errors and ground motion were considered. The linear sums of all contributions give a minimal mechanical aperture of 13.8 mm in H-plane and 15.5 mm in V-plane.

The figures and the message are consistent with the one communicated to the ALICE Collaboration.
• Rogelio agreed and approved to distribute the document to the LHCb Collaboration (Action: Riccardo).

4. ROUND TABLE (ROGELIO TOMÁS)

The next WP2 meeting will take place after the HL-LHC Collaboration Meeting foreseen on October 19th-22nd. The invitation and the agenda will be distributed in due time.

Reported by Guido Sterbini