Special Joint HiLumi WP2/WP5 Meeting

Tuesday 5th September 2023, 09:30 – 12:00

Chairs: Rogelio Tomas, Stefano Redaelli

Speakers: Colas Droin, Nicolas Mounet, Riccardo De Maria, Marta Sabate Gilarte, Björn Lindström.

Participants (26): Yannis Angelis, Hannes Bartosik, Roderik Bruce, Xavier Buffat, Francesco Cerutti, Riccardo De Maria, Kay Dewhurst, Colas Noe Droin, Lorenzo Giacomel, Massimo Giovannozzi, Pascal Hermes, Giovanni Iadarola, Björn Lindström, Lotta Mether, Nicolas Mounet, Francois-Xavier Nuiry, Yannis Papaphilippou, Konstantinos Paraschou, Thomas Pugnat, Milica Rakic, Stefano Redaelli, Marta Sabate Gilarte, Guido Sterbini, Rogelio Tomas, Frederik Van Der Veken, Carlo Zannini

AGENDA

MEETING ACTIONS

Actions:

1: WP2 to ask cryo experts to present new estimates on the luminosity ramp-up at the start of the fill.

2: Xavier, Nicolas et al., Compute MO stability thresholds also for negative polarities.

3: Nicolas: provide a simplified function for impedance calculations in the matching scripts that includes the geometric impedance.

4: Stefano, Check real limits for collimator power deposition with F. Carra.

5: Nicolas et al., update impedance calculations of new IR7 optics.

(see action list on the WP2 webpage, for the complete list of current actions).

1. General Information (Rogelio Tomas / Stefano Redaelli)

Stefano reported on the recent news from WP5:

- There was a ColUSM last week, with a report by M. Sameed on the progress on electron beam generation and measurement with beam gas curtain in the electron beam test stand. The results are positive and will soon provide a measured beam profile to use in simulations by P. Hermes and M. Rakic. Currently BPMs are being installed for alignment of the electron beam.

Rogelio reported that there is no recent news from WP2 that needs imminent discussion and the minutes of the previous meeting will be discussed at a later point. The goal of this meeting is to review the status and possible options, as well as to define a timeline for the new baseline of Run4.

Nicolas comments that the results of the MO threshold are not yet ready and will be presented at a later point. The presentation Today will focus on the taperings.

Riccardo comments that Lorenzo found a problem with the pre-squeezed beta* in the 2.8 m flat optics that Colas has used for tracking. This has an impact on the long range effect and could affect the results of the DA. Yannis A. has fixed the issue with the optics files. **Rogelio** adds that it indeed might affect the DA, but the results that Colas presents today nevertheless will help guide the next studies.

2. Latest results from DA simulations (Colas Droin)

Colas shows an update on the DA studies for HL-LHC. This is an addendum to the presentation from last week, where the results of an octupolar scan for round optics at 1m beta* were presented. Rogelio asked for a DA study using flat 0.7 / 2.8 m optics and two different emittances (2.3 and 2 µm rad). The results for the flat optics are preliminary, since the betax* and betay* are reversed, however the round results should be solid.

Discussion:

- **Rogelio** notes that flat seems to be a bit worse, pending new results with the corrected optics. There are plenty of ingredients to think of for the next steps.

- **Riccardo** comments that the luminosity changes with the emittance, e.g. for flat optics it goes from 2 to 3.25x10^{34} cm^-2 s^-1 with 2.3 and 2.0 µm respectively. This luminosity is too high for collapsing the beams and perhaps for 2µmrad emittance should relax the beta* a bit, and to repeat these studies. **Rogelio** agrees that a larger beta* might be needed but points out that the results would be better in that case. He adds that flat optics should be addressed first, and that, although there are no concerns, all the points for the round optics should be clarified eventually.

- **Yannis A.** asks, concerning the cryo, if the beta* can be decreased when there is still high intensity in the machine. **Rogelio** replies that levelling will indeed be done. **Riccardo** adds that we can increase the octupole when we are at collapse, giving us ten minutes to go from 2.5 to 5x10^{34} $cm^{-2}s^{-1}$. He comments further that it will be challenging to choose the right parameters in the beginning of the commissioning. During the intensity ramp up, we will have to step up in beta* for the collapse. In order to gain performance, we should be more aggressive in the beginning and less at the end, however this is contrary to commissioning simplicity. **Yannis P.** asks if we are still limited to these ten minutes due to the cryo system, now that we have the experience from Run3 and how they change configurations. **Rogelio** replies that Riccardo is in contact with the cryo team and they will provide more accurate numbers. **Riccardo** elaborates that these 10 minutes were based on a scaling and reasoning on principles. We should ask for an update, perhaps via the TCC. **Rogelio** and **Yannis P.** agree and add that cryo experts should present in the WP2 meeting such that the different scenarios and assumptions used for their model can be iterated over (**Action**).

- **Yannis P.** asks what pileup scenario is assumed. **Rogelio** comments that the pileup is 130 or 140 depending on the luminosity. **Yannis P.** points out that the experiments are rather interested in the pileup and it would be good to indicate it in the figures. Also, the detectors were reluctant to increase the pile-up beyond, say 140, and that we then should stick to that for the time being. **Rogelio** responds that it is not trivial, because for example with 8b4e we get 140, whereas for the standard beams it is 132.

- **Nicolas** asks if we should aim for a negative octupole polarity at this stage. **Rogelio** replies that the hottest point in terms of DA with negative polarity in the previous baseline scenario was at injection. This is no longer a concern as the new injection optics in 2023 with the phase knob has solved the DA issue with negative polarity. Therefore it would be good to change to negative polarity if we can find a good configuration considering the DA and instabilities throughout the cycle. **Xavier** comments that the octupoles have to be pushed a bit more with negative compared to positive polarity by about a few tens of percent more to compensate for the long range. **Nicolas** adds that the fact that we have Gaussian tails, this should be better in terms of stability diagrams and tune shifts (**Action**: Compute MO stability thresholds also for negative polarity).

3. UPDATE OF IMPEDANCE/INSTABILITIES/MO THRESHOLDS (NICOLAS MOUNET)

Nicolas presents results on the new tapering model for impedance studies that was implemented by Lorenzo. At 1 GHz, the taper resistivity for Cu-coated graphite accounts for 1 % of the full model, which is not negligible. With MoGr tapers, it is a bit higher although not dramatically. Pure graphite tapers are more than one unit of percent worse, which is not acceptable and should be avoided. The coating should be close to 3 µm, with a minimum tolerable thickness of 2 µm.

Discussion:

- **Stefano** comments on slide 4 that we indeed said very strongly that we should not degrade from MoGr overall, and that the tapers should be coated. He wonders if there are any open points regarding the discussion with F.X. Nuiry or actions that should be triggered. **Nicolas** replies that F.X. Nuiry was not present during the presentation last year, although F. Carra and W. Vollenberg seemed to be okay with it. **Stefano** adds that he did not hear of any issues, once it had been established that the coating can be done on the tapered surface. **Nicolas** recalls that this was discussed some time ago. **Stefano** concludes that it should then be taken as a baseline. He further adds that the flat part and the tapering will be a single piece of graphite, according to the last proposal. For the jaw, two blocks of 50 cm each will be used, whereas for the MoGr it was composed of multiple blocks.
- **Rogelio** asks if we are following up the quality assurance with them, and how we can ensure that the coating is above 1 µm. **Stefano** replies that we set a target above the specifications. It is planned to have witness samples in every coated batch for measurements of the resistivity. **Nicolas** confirms this and that we in the contract should add a bit of margin.
- **Rogelio** asks if the resistivity can be measured in the tapered part. **Nicolas** replies that we cannot, but that we can measure the conductivity of the witness samples as well as the thickness of the coating on the tapering.
- **Stefano** asks how we can ensure that the coating is as good on the tilted parts. **Nicolas** replies that we saw a difference in conductivity on the first samples measured by Leonardo where there was a large angle. This was due to the grain size, but ultimately it is linked to the thickness, which we can measure. **Lorenzo** adds that it is important to keep the block stable and that it should not be clamped since this could damage it.
- **Stefano** comments that the tolerance for the coating thickness is quite loose, since there is only a small effect if it is e.g. 3 or 2 µm. **Nicolas** confirms this and points to slide 3 in the presentation.

- N.b. results on the coating and measurements were presented in Special Joint HiLumi WP2/WP5 meeting Tuesday 27 Jun 2023

4. UPDATE ON OPTICS / COLLIMATOR GAPS (RICCARDO DE MARIA)

Riccardo presents an update on the baseline for the Run4 optics. The main news from the previous baseline are the removal of the electron lens, addition of the BETS upgrade, impedance concerns, MS10 which allows larger ATS factors and flat optics, new phase constraint from MP, and phase advance optimizations.

Discussion:

- **Nicolas** comments on the tight collimator settings that they might be okay in the first year, but could be problematic for impedance in the second and third year due to the higher intensity. **Riccardo** replies that it is not excluded that we might close the collimator settings during physics fills. **Nicolas** emphasises that in the third and fourth year, we cannot run with tight settings. He adds that we do not know what aperture we will have in the machine, whether or not it is good enough. Also, if the DA is not good enough it will not be possible to go to 7.5 cm. **Rogelio** clarifies that this is for the most pushed optics, not baseline. We should choose a baseline that is compatible with all the parameters, but we should also not lose sight of the performance. As Riccardo mentioned, one could close the collimators between collapse and end of levelling, which opens the door to the most pushed beta. **Riccardo** adds that we should study this in terms of optics so we can profit from it if it becomes viable. The gain in integrated luminosity is between 3% and 4% for normal considerations, but for larger pile-up it can reach up to 6%.
- **Nicolas** asks if the DA results presented by Colas before include the phase advance optimization from point 1 to 5. **Riccardo** replies that they are not yet there, so we could still gain a bit. The phase advance game is tricky, but doable. It is a matter of time and trial and error. As for the people doing simulations, it would be good to invest a bit in speeding up the simulations and to improve the point selections, since we have a large parameter space to investigate.
- **Rogelio** asks what the timeline is for the final optics version. **Riccardo** replies that the IR7 optics should go in with a workable scenario by the end of this month, even if it is not yet optimal. For something that works on paper we should go fast to at least have a baseline. **Rogelio** recalls the point raised by Stefano regarding resources in WP5, and that we should commit to a baseline. **Riccardo** replies that we will need a few iterations. The first iteration could start in one month, including the iteration with Bjorn on the IR7 optics. **Stefano** comments that, concerning the resources, we should ask Oliver if he wants to write a new TDR documenting a new baseline. If we need to produce a document at the same level of detail as for the round optics, it has to go through all the Work Packages, which would require certain resources. **Rogelio** comments that there are several reasons for why the optics are changing, such as the BETS upgrade. **Stefano** responds that they were already in for the round optics, and the MS10 has been discussed for several years as Riccardo presented in the TCC. **Rogelio** replies that we can now go to flat optics at the same time as implementing other changes as there is also the IR7 optics, as well as the machine protection request for a new phase advance constraint from the crab cavities to the TCP. This requires a validation.
- **Francesco** comments that a new optics baseline would imply a rebaseline of all the energy deposition studies. Marta's talk will answer some of the points, but not all of them. All other results provided by WP10 so far are only valid for round optics. **Rogelio** asks if they can evaluate the performance with the new proposed baseline, if Riccardo can provide a new optics within one month. Discussions after the meeting clarified that most of the required studies are already done

as these studies have little dependency on actual optics. **Francesco** replies that Marta will conclude her work for HL by the end of this year, and it would come in a moment of transition which will impact their readiness to react. **Rogelio** emphasises that there is no stress for the timeline and that it can be discussed in a few months, together with Oliver.

- **Yannis P.** suggests that an internal discussion should be undertaken with the different Work Packages offline, concerning the new baseline proposal and the required resources.

5. TCL4 GAP EFFECT ON HL ENERGY DEPOSITION STUDIES (MARTA SABARTE GILARTE)

Marta presents a study on energy deposition in IR1 and 5 depending on different TCL4 gaps, in view of the flat optics. An increased gap to 24.7 and 28 mm leads to an increase of the peak dose and power in the D2 by up to a factor of 1.7 and 2.9 respectively with V crossing angle, but that it is just a factor 1.2 and 1.9 wrt to the reference value with H crossing angle. On the contrary, a decrease of the gap down to 11.6 mm, reduces the energy deposition in the magnets, but increases the power load on the inner jaw of the TCL to 277.8 and 304 W. These are about 48 and 70 W above the design specifications (20% and 30%, respectively).

Discussion:

- **Rogelio** asks for clarification on the colours on slide 8, and the margins on the TCL power thresholds. **Marta** replies that they do not know the exact margins but highlighted the values that had increased significantly in red. The reference values that were communicated for the design of the TCLs are shown on the bottom line in the table, "21.1 – ref". The designers considered both the individual power loads of the jaws, and the total of both. As we understand, there is no cooling system for these. **Stefano** interjects that there is cooling, but there is no brazing and there might be a side on the tank where we said that cooling could be avoided. Also the masks are not cooled.
- **Riccardo** comments that the scenario in which the TCL gap is closed is meaningful because it allows for a reduction of the dose to compensate when opening the TCLs for the xing plane switching. He suggests waiting for the next results to see what targeted studies are necessary – if this config is not feasible from a HW point of view, it clearly has consequences.
- **Riccardo** asks if the increase of the radiation by a factor of 2.5 is still within the limit for the D2. **Marta** replies that this increase leads to 12 MGy, which is still below the baseline value of 14. The main issue to deal with now is the power load in the collimator and mask. **Riccardo** comments that the power is only a potential issue if we close the collimators, but they could remain as open as radiation allows. If e.g. a gap of 24 mm with the vertical xing is sustainable, we do not need to close them to reduce the dose when we reverse the polarity. Furthermore, this opening is only needed at the end of squeeze, when the beta* is below 15 cm. **Francesco** clarifies that there is only an issue with power on the jaws when closing them with a horizontal xing angle.
- **Francesco** clarifies that the values that have been presented are what the jaws actually take, and do not constitute a design limit. The reference value for a single jaw is 230 W, with a margin to be defined. He also comments that there are other elements than the jaws in the collimator assemblies where the limits also need to be studied. .

- **Francesco** comments that for the D2 to take up to 50 W, even for short times, may not be trivial. It never took that in the LHC. The cryosystem for D2 should be followed up with WP3 and WP9 (**Action**: Ask Ezio about the actual limitations in D2 - already launched). **Rogelio** comments that it is unlikely for ultimate luminosity to go in any baseline right now, and then we gain 33 % if we go for nominal luminosities. **Francesco** confirms that indeed the presented power depositions should be within design specifications when operating at nominal luminosity .
- **Stefano** asks for a clarification on the plan for when this scenario would potentially be used. **Rogelio** replies that we are currently studying Run4 and that there is more time for Run5 in case there are issues. There are many parameters and Riccardo needs to look at the numbers and see what solutions we can find. None of these numbers are final. **Riccardo** adds that they are good enough to start making other checks. Given these numbers, we should check whether or not the D2 and the collimators can cope. One can also compromise with the crabbing angle.
- **Rogelio** asks why the TCLs cannot be left at the reference values. **Riccardo** replies that they become secondary collimators for beta*<15cm in the parallel separation plane. **Stefano** adds that we cannot have TCLP as secondaries. Then we would need to study the loads from IR7. They are metallic collimators in tungsten, which makes them very fragile. They would also introduce another source of background, and in particular in IR5 we will still have the roman pots.
- **Rogelio** asks if closing the secondaries to provide some margin would be feasible. **Stefano** replies that we have to digest the numbers and see in a separate study. They must stay sufficiently within the transverse hierarchy of IR6 and 7.
- **Riccardo** mentions that for low beta* we want to go as tight as possible, and the beta* reach will probably be defined by the cooling system of D2 and the margins of TCMLB . **Stefano** replies that he can check with F. Carra and F.X. Nuiry to establish the real limits (**Action: Stefano**, Check real limits for collimator power deposition). He stresses that we cannot change the design now, since also the operational spares have been finished. We also need to check the heating for the masks.
- **Rogelio** asks about the MD on closing the collimators during physics fill. **Stefano** replies that an MD request has been submitted, but that there are many options to study and we need to prioritize. Concerning closing the primaries, since they cut into the beam they will produce a lot of losses and it is not sure that it would work. Closing the secondaries during physics would be easier since they do not cut the primary halo, but this implies closing the TCTs and TCDQs as well. It is not excluded but has to be well justified. **Roderik** adds that we need the best cleaning performance, with the best secondary settings, when we have the highest intensity at the start of the fills and SB. We can see if it would be possible to close them further after that. **Stefano** adds further that we do not have large margins on the quenches. He suggests to go through the different options for the evolution of the settings offline with Riccardo and Roderik.

6. UPDATES ON IR7 DESIGN (BJÖRN LINDSTRÖM)

Björn presents an update on the redesign of the IR7 optics. There are two candidate optics, the same that will be tested in the MD later this year, and a new version with a further improvement on the cleaning performance by up to a factor of two. As for the impedance, the vertical component is however only improved negligibly over the reference case, whereas the MD optics gives a 10 % improvement. The new version also requires the limit in one of the magnets, Q9L7.B1, to be increased from 200 to 300 A.

Discussion:

- **Rogelio** asks why the vertical impedance is not improved more. **Bjorn** replies that the large increase of vertical beta function in the horizontal collimators appears to counteract the improvement due to the increased gap. However the simplified equation provided by Nicolas still indicates that both candidate optics should have a similar reduction in the vertical plane. We are currently investigating this issue with Lorenzo.
- **Nicolas** asks if the new TCS coating is taken into account in the matching. **Stefano** replies that this should not play a significant role.
- **Nicolas** mentions that the cubic dependence is only valid for resistive wall, but not for the geometric impedance. A simplified function that takes this part into account could be used, with different weights in the matching. (**ACTION: Nicolas** provide a function for matching)
- **Roderik** wonders if the change of material could impact the final results of the optimization. **Stefano** replies that the differences are likely small.
- **Roderik** comments that R. Cai is studying the improved optics for ion cleaning as well.
- **Rogelio** comments that it is also very good that the cleaning efficiency can be improved, and asks for clarification on the new phase request from TCP to TCT. **Bjorn** replies that this is not a strict requirement since it is not clear how much background the experiments can tolerate. With HLLHCV1.5 optics we saw a large increase of the TCT losses with relaxed settings in IP1 and proposed some possibilities for mitigations. For now it is however not clear if mitigations are required. Nevertheless, the machine protection phase requirement from crab cavities to TCP appears to automatically give us a good phase to the TCTs. **Stefano** adds that we saw an increased leakage due to the change of secondary material to graphite (compared to MoGr), leading to an increase of the TCT losses by up to 55 %.

  Note added after the meeting: Bjorn, Lorenzo and Nicolas looked at the reason for the small improvement of the impedance in the vertical plane. The cause is a large increase of bety in the TCLAs, which counteracts the improvements gained in the other collimators. The TCLAs were previously not being taken into account when designing the optics, since their effect was deemed to be small. The optics have been adjusted to mitigate this, while retaining the same cleaning performance. The impedance calculations are pending but should be ready soon (**Action: Nicolas et al.,** update impedance calculations of new IR7 optics).

7. AoB

The next WP2 meeting will be

No AoB

Reported by Björn Lindström