Minutes of 46th Collimation Upgrade Specification Meeting

Participants: C. Adorisio (CA), R. Alemany (RA), G. Arduini (GA) (chairman), A. Bertarelli (AB), O. Bruening (OB), R. Bruce (RB), F. Carra (FC), F. Cerutti (FCe), A. Dallocchio (AD), R. De Maria (RdM) (scientific secretary), I. Efthymiopoulos (IE), L. S. Esposito (LE), P. Fessia (PF), M. Fiascaris (MF), L. Gentini (LG), M. Giovannozzi (MG), J. Guardia (JG), V. Kain (VK), A. Lechner (AL), E. Metral (EM), D. Mirarchi (DM), S. Montesano (SM), Y. Papaphilippou (YP), T. Pieloni (TP), S. Redaelli (SR) (chairman), B. Salvachua (BS), F. Sanchez Galan (FS), G. Steele (GS), E. Todesco (ET), J. Uythoven (JU), G. Valentino (GV) (scientific secretary).
Remote: B. Auchmann (BA), H. Garcia (HG), M. Kitzmantel (MK), R. Kwee (RK), T. Markiewicz (TM), A. Ryazanov (AR), N. Sammut (NS), A. Wolski (AW), A. Valishev (AV).

Indico event here.

1 Actions

- SR and EM to verify that the settings and position of the collimators to make sure that these are compatible with stability criteria
- FCe, LE for a WP2 meeting immediately preceding the Hi-Lumi Annual Meeting
- AV and TP to organize a beam beam meeting to compare the results obtained with Lifetrack and Sixtrack for HL-LHCv1.0 without and with field errors (as provided by MG). The parameters of each simulation should be clearly spelled out to allow the comparison.

2 General information (G. Arduini)

The minutes of the previous meeting have been approved with comments from MG and EM. Discussions on the dynamic aperture targets with and without beam-beam effects and a protocol for HL-LHCV1.0 studies are taking place and being followed up by MG and TP in view of the upcoming KEK meeting. EM is following up the action on the overall cooling capacity with S. Claudet. GA thanked the contributors for Chapter 2 of the preliminary design report, which has been sent to the editorial board.

SR announced that A. Marsili finished his fellow contract and left the team at the end of February. A. Marsili is kindly acknowledged for work as scientific secretary of the ColUSM and for his work in the collimation team. SR introduced M. Fiascari who joined the team on Oct. 1st. Maria will work on the design of the FCC collimation system and has accepted to act as scientific secretary of the ColUSM.

3 Status and plans of collimation tests at HiRadMat (A. Bertarelli)

Slides are available here.

3.1 Summary of the presentation

AB presented the plans for the HRMT-23 and MultiMat collimation experiments in HiRadMat Run II, with the aim of testing new materials for the increased HL-LHC intensities. In 2012, HRMT-09 (full TCT collimator) and HRMT-14 (jaw material samples) were very successful experiments that allowed confirming the simulations and deriving operational limits for the presently installed hardware. However, there were several intrinsic limitations and the already extensive instrumentation could be improved further.

The planned tests will ideally exploit the full LIU-SPS beam (228 bunches) on collimators of the latest generation, such as the HL-LHC secondary collimator (TCSPM), the BBLRC wire equipped collimator (TCTW) and the SLAC rotatable collimator. SR clarified that the repetition of the 2004/2006 tests on carbon-carbon collimators is to validate the new collimators with embedded BPMs which are currently installed in the LHC. This design was also not tested against the updated HL-LHC beam parameters. Samples of novel and advanced materials for collimators with little-known constitutive equations under highly bright beams will be also tested (MultiMat experiment).

HRMT-23 aims at testing LIU-SPS beams (440 GeV, 288 b, 25 ns, 2.3×10^{11} ppb) on jaws for HL-LHC collimators. It is currently scheduled to take place in spring 2015. The scope is also to identify damage thresholds. Three fully assembled jaws (TCSPM with Molybdenum-Carbide inserts, TCSPM with Copper-Diamond inserts, and the Phase I TCSP with BPM buttons) will be placed in a specially built tank. It is foreseen to use the TCSP jaw from the spare collimator built for Run II but which had a high outgassing rate. AB commented that this will only be confirmed once the new compliant TCSP spares will become available. The beam size could be reduced to compensate for the smaller energy density. YP added that 2.3×10^{11} ppb will come after LS2, before one could expect no more that 1.6×10^{11} if scrubbing is successful, also small emittance could be obtained with BCMS beams. AB recalled that it was proposed to reduce the beam size by optics changes in the line in order to achieve with the present beams the LIU conditions. The LIU timeline does not fit the required timeline to decide on new collimator production.. GA mentioned that fixed target beam could be extracted with a longer bunch train (about half of the 23 μs limitation of the kicker). AB commented that lengthening the time of deposition could result in other phenomena.

The multi-material (MultiMat) experiment is based on HRMT-14, and was initially proposed in October 2013. It would allow up to 12 target stations, each hosting a different material sample. AB proposed to join forces and share costs between the different teams (BE/ABP, EN/MME, EN/STI, TE/ABT) with common interests in the experiment. The current status is that the beam time request proposal has been submitted to the HiRadMat scientific committee, and the experiment is expected to take place in early 2016. JU asked why it is scheduled so late. AB replied that most of the resources are currently concentrated on HRMT-23. PF commented that the request for resources should also take into account the increase in magnet production, for which several efforts will be required. SR commented

that one of the goals of HRMT-23 is to confirm the TCSPM design before installation in the LHC in the 2015-16 Christmas stop. The jaw experiments are more urgent than the tests on new material samples.

4 Robustness of a TCDI-like collimator to beam impacts (A. Lechner)

Slides are available here.

4.1 Summary of the presentation

The request for a TCDI test in HiRadMat comes in the context of the upgrade of the SPS-LHC transfer lines and the LHC Injection protection devices for HL-LHC. The installation of the new TCDIs of an upgrade TDI (TDIS) is foreseen in LS2 as part of the LIU and HL-LHC (WP14) project, and hence the materials need to be ordered by end of 2015. This experiment is being submitted to the HRM scientific board for approval.

In order to achieve HL-LHC type beam impact conditions, a customized HiRadMat optics setup is proposed. These high energy densities were never achieved before in HiRadMat. The TCDI jaws will be placed in a custom-made tank, with instrumentation for online monitoring and post-irradiation analysis. The spare TCDIs cannot be used, and hence existing components need to be reused to make the experiment as cheap as possible.

SR asked why the same TCDI as presently installed will be used in the HiRadMat test, when it is already known that the future TCDI length will be longer. Will the proposed tests be conclusive for the final design? AL replied that the peak energy density will be achieved after only a few cm but indeed the details of energy profiles will be different. The test as proposed should be sufficient to address the material response. VK commented that this is a valid point however there will be no time to prepare a prototype with the final design.

5 Energy deposition studies for physics debris (L. S. Esposito)

Slides are available here.

5.1 Summary of the presentation

LE presented new results on the energy deposition studies for physics debris with the updated HL-LHC layout in the TAXN-D2 region. The objective of the study is to understand the role of the mask in front of the D2. As presented in the preliminary design report, the TCL4 settings (10 σ vs 20 σ) were found to reduce the peak power in the D2 by a factor 2. For the Q4, adding the mask had a larger effect than the TCL4 settings (factor 2 reduction).

The models were updated following the new layout. Two options were considered. In the first option, the length of the separated beam pipes is decreased from 3.7 m to 3.5 m, and the beam separation is increased from 148 mm to 149 mm on the IP side and 158.6 mm to 159 mm on the non-IP side. The aperture radius is increased from 38 mm to 40 mm, and

the TCL/TCLMA distance from the D2 is increased by about 50/20 cm. SR asked if this distance could be reduced. PF replied that a full study has not been carried out, but there is not enough margin acting on the warm part. RM added that the possibility of a cold mask has been excluded but it is not clear why BPMs can have cold W inserts in the vacuum, while W masks cannot be placed just in front of the D2 coils in the cryostat. The second option consists in removing the TCLMA and move the TCL towards the D2 by 90 cm. This option would leave room for a redistribution of space for the collimators that presently do not fit in the area.

The changes from version 1.0 and 1.1 resulted in larger power deposited in the 1.1 version due to the increase of the aperture of the TAN and the restriction of the aperture of the orbit correctors. Making a comparison with the simulation results using the previous layout with no mask, LE found an increase in the peak power of the D2 and the first corrector with the second option. Adding the mask has the effect of reducing the peak power profile by a factor 2, but this is limited to the first part of the D2. The mask protects especially the inner side. ET mentioned that the limit should be able to cope with 25 MGy at 3000 fb^{-1}. In terms of power density, 4 mW/cm^3 can be sustained. SR asked what the quench limit is. ET replied that it is 12 mW/cm^3. SR noted that the latest results of quench test analysis that followed the quench tests with beams are not considered for updating the limit of superconducting magnets (latest estimates indicated quench limits up to $\sim$50 mW/cm^3).

The energy deposition on the TCL is not centered due to the direction of the crossing angle. RM asked whether the protective effect is reduced if the length of the TAN is reduced. LE replied that roughly 98% of the power is deposited within the first 3 m.

GA asked whether the position and number of collimators has been passed to the impedance team. Stefano replied that this is being verified. Action: SR and EM to verify that the settings and position of the collimators to make sure that these are compatible with stability criteria

The length of the TAN could be possibly reduced from 3.5 m to 3 m as 98% of the energy is deposited in the first 3 m of the absorber. In the present design the TAN is made of copper a further reduction in length could be obtained by including Tungsten. SR suggested that in this case, one should reduce the TAN on the non-IP side in order to free longitudinal space for the collimators (provided that the intra-beam distance is sufficient to avoid integration conflicts with the other beam pipe).

IE asked whether a study on the dependence of the shielding efficiency as a function of the TAN longitudinal position has been done. FC replied that this has been done in the past (a movement of 4 m in the direction of D2 has been considered, with the corresponding change in aperture and separation between the two apertures and no significant change has been observed - see WP2 Task Leader Meeting presentation on 29/9/2013 - slides)

In conclusion the mask in from of D2 reduces the peak power deposited in D2 by a factor 2 and in particular is effective to protect the central part of the D2 between the two beam apertures. On the other hand, the doses without mask are within the assumed specs for the nominal settings with no error.

SR noted that from the distribution of the energy deposited in the TCL4 it seemed that part of the radiation could escape behind the TCL4 jaws and optimization of the thickness of the jaw and opening of the jaw located between the two beam apertures could reduce further the effect of the mask.

The following next steps are identified in preparation of the KEK Hi-Lumi Annual Meeting:

- Study the impact of larger TCL jaws and possible optimization of the inner (between the beam apertures) jaw position.
- Determine the impact of the mask for this optimized configuration.
- Study the sensitivity to the crossing angle for the nominal optics for the optimized configuration (TCL with constant opening in beam sigmas)
- Study the dependence of the energy deposition as a function of the different alternative optics solutions (having different crossing angles) with constant TCL opening in beam sigmas.
- Consider an optimized design of the TAN including Tungsten.
- Action: FCe, LE for a WP2 meeting immediately preceding the Hi-Lumi Annual Meeting.

6 Update on HL-LHC studies on triplet aperture (H. Garcia)

Slides are available here.

6.1 Summary of the presentation

HG presented SixTrack simulation results to assess the cleaning losses at the IR aperture bottlenecks without the TCTs in place. A triplet aperture scan was performed in 2-4 mm steps for IR1 and IR5. A perfect machine was considered.

From the history of the particles that hit the magnets in the interaction regions, HG concluded that most of them hit a primary collimator only once, and a few hit a second primary collimator. A very small percentage of particles also hit a secondary collimator before hitting the triplet. Following the aperture scan, the IR1 downstream and IR5 upstream regions were found to be severely impacted.

The next steps will be to clarify the local inefficiency, assess the machine protection aspects, consider the impact of different error sources and determine whether TCTs in only cell 5 are sufficient for HL-LHC. Gianluigi asked if the scan plots could highlight the points that correspond to the present HL-LHC aperture layout. SR remarked that it is not as straightforward since the imperfection cannot easily implemented in the models and one should take as reference the aperture as calculated by the MAD aperture model with the present margins. RM asked what is the required inefficiency for the HL-LHC and SR remarked that it is not clear and rather one could use the present simulated LHC inefficiency as a target. GA reminded that the main goal is to determine what are the required collimator settings (compatible with impedance) that is required to protect the magnets with the presently know apertures.

7 Follow-up on beam-beam studies (A. Valishev)

Slides are available here.

7.1 Summary of the presentation

Following-up on questions raised in previous meetings and in the last WP2 Task Leaders meeting by Stephane AV presented the result of the simulations DA with beam-beam for a full virtual luminosity case with multipole errors. A study shows that the DA drops from 5.5 σ to 4.4 σ when multipole errors are added. The 10th and 13th order resonances are driven by long range beam-beam. The multipole errors couple with difference resonances and lead to resonance overlap. With energy errors synchro-betatron resonances are dominating. This occurs if no slicing in IP8 is applied, with 7 slices in IR8 no significant difference is observed in dynamic aperture by introducing magnetic errors. The effect of head-on beam-beam is significantly reduced. GA noted that the analysis of the effect of the field errors should be conducted with realistic levelling scenarios both with SIXTRACK and LIFETRACK. This should be discussed in detail in a beam-beam meeting. Action: Sasha and Tatiana to organize a beam beam meeting to compare the results obtained with Lifetrack and Sixtrack for HL-LHCv1.0 without and with field errors (as provided by Massimo). The parameters of each simulation should be clearly spelled out to allow the comparison.

8 Updates from Task Leaders (WP task leaders)

- Task 2.2: Nothing to report
- Task 2.3: Nothing to report
- Task 2.4: A follow-up on beam induce heating occurred for the new Alice beam pipe and other experiments for impedance sources. Next week the interplay between beam-beam and impedance will be discussed.
- Task 2.5: AV and YP had a Skype meeting to discuss the programme for the long-range beam-beam compensation studies.

The next WP task leaders meeting will take place on Friday 10th October 2014, TP is expected to present PACMAN effects and ET is going to give an update on the magnet field quality.