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HiLumi LHC

FP7 High Luminosity Large Hadron Collider Design Study

Deliverable Report

Technical Design IR Collimation

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Seventh Framework Programme, Capacities Specific Programme, Research Infrastructures, Collaborative Project, Design Study

DELIVERABLE REPORT

TECHNICAL DESIGN IR COLLIMATION

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Abstract:

The conceptual IR collimation layout for optics V1.0, presented in a previous deliverable report, provided satisfactory cleaning performance but featured longitudinal space conflicts in the region between the TAXN and the D2 magnets in IR1 and IR5. It was then necessary to reiterate the collimator layouts. In this document, the present status of the IR collimation layout is presented and the necessary changes to make all the equipment fit longitudinally are described. The list of remaining studies needed to validate the new layouts is outlined.

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Delivery Slip

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Executive summary

The WP5 teams have worked on detailed integration studies of the conceptual collimation layouts of IR1 and IR5 presented in earlier deliverable documents, in collaboration with the WP8 (Collider-Experiment Interface, which is not part of FP7-HiLumi). We now propose a solution that solves longitudinal conflicts revealed by the integration study for the optics version 1.0. This is being incorporated into the version 1.1. Since IR layouts are still evolving, we could not yet fully validate the new proposed collimation solutions in simulations. Note that also the region around the triplet magnets is still being worked on.

On the other hand, based on previous detailed simulation studies we are confident that the new proposed layout fulfils the required collimation cleaning requirements for HL-LHC.

1. INTRODUCTION

The collimation system installed in the experimental IRs should provide adequate protection for all possible beam loss scenarios. This includes protecting the triplets and matching section magnets from regular and irregular beam losses, both from the incoming beam and the outgoing beam (incoming and outgoing are defined with respect to collision point). In order to achieve the required functionalities with the increased stored beam energy of around 700 MJ and with peak p-p luminosities up to $7.5\text{x}10^{34}\text{cm}^{-2}\text{s}^{-1}$ that is the ultimate value assumed for HL-LHC (while the design value is $5\text{x}10^{34}\text{cm}^{-2}\text{s}^{-1}$), the needed collimators in the experimental IRs have been revised in previous deliverable documents [1]. For the incoming beam, it was proposed to add an additional pair of tertiary collimator (TCT), consisting of one horizontal and one vertical, in cell 5 in both IR1 and IR5. For the outgoing proton beams in IR1 and IR5, the layout for Run II, consisting of three physics debris collimators (TCL4, TCL5, and TCL6) was estimated to be sufficient for proton operation also at HL-LHC, provided they were complemented by up to four fixed masks on the IP side of D2, Q4 and Q5.

Once the conceptual design for the collimation in IR1 and IR5 in Ref. [1] was finalized, a technical implementation work started. It was realized that the foreseen chain of collimation elements in cell 4 (TCTs, TCL4 and fixed mask) did not fit longitudinally between the TAXN and the D2 once all necessary auxiliary elements, such as vacuum bellows, were included. The situation was complicated by the fact that special vacuum bellows, longer than the standard ones, are needed for the TCTs in order to enable movement along the axis perpendicular to the collimation plane. This functionality is necessary to recover a fresh surface to expose to the beam in case of light damage to the TCTs during beam failures and could avoid replacing the whole TCT after asynchronous beam dumps. Furthermore, it was realized in the meantime that the D2 protection was not optimal for all running scenarios [3]. With flat optics, the distribution of collision products surviving the TAXN is similar to what is obtained for round optics, however, the TCL4 in IR5 is placed at a smaller opening in mm, since the normalized setting in units of beam σ is the same, while the optical β-function there decreases. As the TCL jaws have a finite thickness, a larger leakage outside the jaws is observed with flat optics. This leakage is potentially critical for the D2 assembly.

Following these encountered constraints in terms of longitudinal space and D2 protection, it was necessary to make a second iteration of the needed collimation elements, their design and the layout. Based on initial ideas on possible modifications, a massive simulation campaign was launched [3,4], and we are now at the stage where a new layout has been conceived. The new layout is compatible with the longitudinal space constraints and provides also an improved protection of the D2. Section 2 describes the proposed changes for the collimation of the outgoing beam, while Section 3 discusses the required longitudinal space for the TCTs. Section 4 presents the new, improved layout.

Note that the upgrade of the IR collimation systems also involves solutions for local cleaning at the dispersion suppressors, based on 11 T dipoles and “TCLD” collimators [1,2]. This is not subject of this deliverable document, as no changes took place from the latest deliverable document [1]. This document is focused on the changes that affected the region between TAXN and D2.

2. COLLIMATION LAYOUT FOR THE OUTGOING BEAM

In order to improve the D2 protection, and at the same time gain longitudinal space, a proposal was brought forward, in which the 50 cm long fixed mask in front of the D2 is removed, at the same time as the thickness of the jaws of the TCL4 is increased. This would allow the TCL4 to intercept the particles that otherwise go on the outside of the jaws in flat optics.

This proposition has been verified in simulations [3] and the main results are also summarized in the WP5 milestone document [4]. It was found that the thicker TCL4, called TCLX, indeed provides sufficient protection of the D2, also for flat optics, if the material is also changed from copper to tungsten. As a first design sketch, which demonstrates the needed thickness of the jaw, the FLUKA model of the TCLX is shown in Fig. 1, together with the present, thinner TCL design. The simulations in [3] show that the protection is adequate both for damage caused by long-term irradiation, as well as the instant heat load from physics debris that could bring the D2 close to the quench limit.

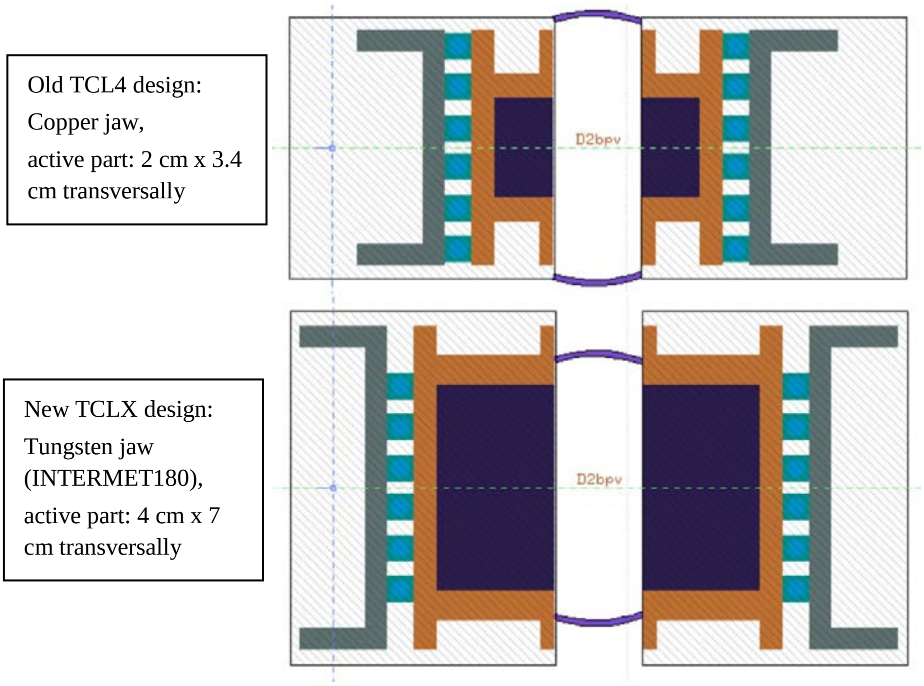

Figure 1: A schematic of the transverse cross section of the TCL design, as implemented in FLUKA (top), together with a first guess on the TCLX design (bottom), including thicker jaws, where the jaw material should be changed from copper to tungsten. Figure from Ref. [3].

Furthermore, longitudinal space could also be gained by reducing the length of the TAXN. The results, discussed in detail in Ref. [3] and summarized in the milestone document [4], indicate that a length reduction of up to 1.5 m could this could be possible, if also here the material is changed to tungsten. The possibility of removing the mask and shortening the TAXN thus provide up to 2 m longitudinal space, which is used in the new proposal for the layout.

3. COLLIMATION LAYOUT FOR THE INCOMING BEAM

Apart from protecting the IR magnets from regular beam losses, the TCTs on the incoming beam should also provide a sufficient shielding in case of accidental losses, for example form asynchronous beam dumps. In this latter case, the TCTs might intercept much larger intensities. As they are made of INERMET (a tungsten alloy) in order to provide optimal stopping power, they are not as robust as the carbon-fiber-composite (CFC) collimators that are positioned closer to the beam. Therefore, the TCTs risk to be damaged during asynchronous beam dumps. If the suffered damage is only minor, the collimator design supports a movement of both jaws perpendicular to the collimation plane, along what is called the 5^{th} axis[1]. This would expose a fresh and untouched jaw surface to the beam and could allow the operation to continue without a lengthy intervention to replace the collimator. It is considered very important to keep the functionality of the 5^{th} axis movement for the TCTs active also for HL-LHC.

The 5^{th} axis movement requires, however, special vacuum bellows that can bend in order to follow the motion. These special bellows, called VMT, are longer than the standard vacuum bellows: a length of 520 mm is required in the connection between two collimators, and 220 mm are needed at the end of a collimator next to other elements.

Placing the TCLX next to the required vacuum assembly at the D2, assuming that the fixed mask is removed, the TCTs can be fit longitudinally right after. Accounting for the above quoted lengths of the respective bellows, the centre of the vertical TCT would end at 131.46 m upstream of the IP, along the orbit of the incoming beam, and the vertical TCT at 133.46 m. This corresponds to small longitudinal shifts of 13 mm and 367 mm respectively, compared to the previous layout iteration. These shifts should be completely negligible in terms of cleaning and protection performance on the incoming beam.

In cell 5, where a new pair of TCTs is planned to be installed, the layout has been finalized and should not pose any longitudinal integration problems. The drawing is shown in Fig. 2, where also the TCL in cell 5 can be seen. This TCL is already installed and part of the present LHC baseline. With these final longitudinal positions, a design study is going to be launched to address the transverse integration of the different collimators.

[1] The two corners of each of the two collimator jaws can be moved independently, which defines the basic four degrees of freedom of the collimator position. The movement perpendicular to the collimation plane is hence called the 5^{th} axis movement.

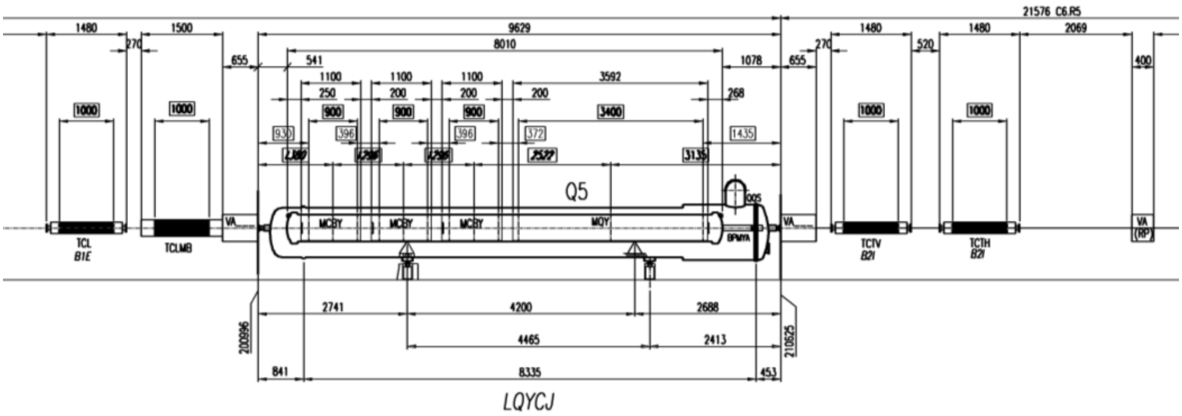

Figure 2: Present solution for the layout in cell 5, where the presently installed TCL, as well as the planned new pair of TCTs, can be seen. Courtesy of P. Fessia et al.

4. IMPROVED COLLIMATION LAYOUT PROPOSITION

Using the longitudinal space that can be freed by removing the fixed mask on the IP side of D2, the VMT bellows for all three collimators – TCTH, TCTV, and TCLX – almost fit in the available space. There are still 106 mm missing. However, since this is a very small fraction of the active TAXN length of 3.5 m, and this length could possibly be reduced without significant loss in protection as discussed above, this is presumed not to be an issue.

Figure 3 summarizes the present layout solution between the TAXN and the D2, in which the TAXN is supposed to be 106 mm shorter, the mask in front of the D2 has been removed, and the VMT bellows have been added to allow the 5th axis movement. It should be noted that, at the time of writing, although there is general consensus for this variation, it has not yet been formally approved by the Parameter and layout committee.

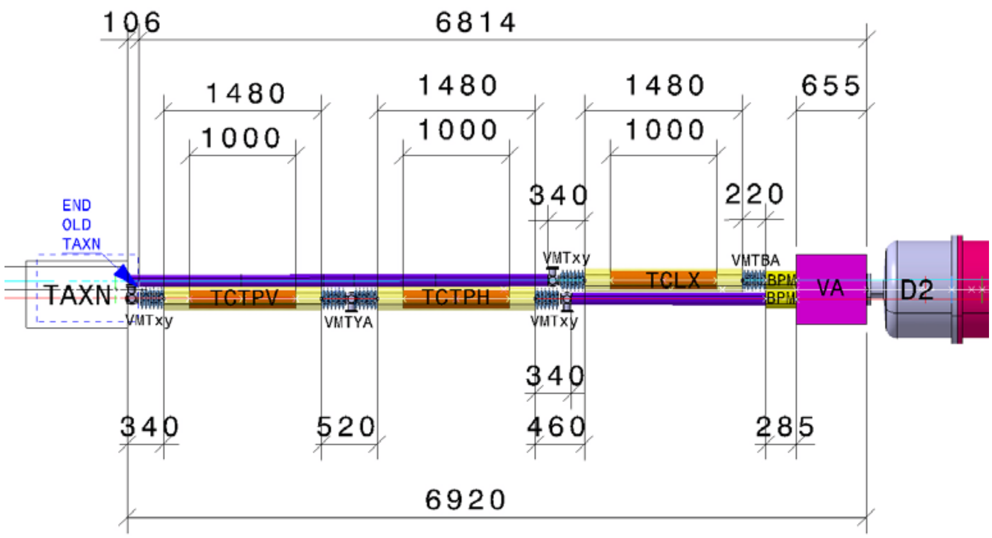

Figure 3: Present solution for the layout between TAXN and D2, where the mask on the IP side of D2 has been removed (all measures in mm). Still, in order to fit the vacuum bellows required for moving the collimators along the 5th axis, the TAXN has to be shortened by 106 mm. Courtesy of B. Vazquez De Prada, P. Fessia et al.

5. CONCLUSION

In conclusion, integration issues were encountered while finalizing the collimation layout in the experimental insertions. In order to fit all equipment longitudinally, the design of the IR collimation had to be revisited. It was found that some space could be freed by removing the fixed mask in front of the D2 and instead making the jaws of the TCL4 thicker and made of tungsten. A detailed mechanical design for this new collimator, which has been named TCLX, has still to be worked out, as well as its transverse integration.

With the new proposed solution, the two TCTs, as well as the TCLX, the BPM and all required vacuum assemblies fit between the TAXN and the D2, if the TAXN is shortened by 106 mm from a total length of 3.5 m. Although this has not yet been officially approved, it should not cause issues in terms of protection.

In addition, simulations show that the protection of the D2, Q4, and Q5 is adequate with the new proposed collimation solution. The protection of the D2 is even improved with the new solution, in particular for flat optics, where the old solution with the thinner TCL4 jaws allowed some particles, not intercepted by the mask, to leak through the TCL4 on the outside of the jaws.

For the incoming beam, the new layout implies longitudinal shifts of the TCT positions by less than 40 cm. This should be completely negligible for the performance. Nevertheless, it is planned to repeat simulations with the final baseline in the whole LHC ring, once it has been fully approved.

The layout in cell 5, which has also been presented, poses no longitudinal integration issues. Future work will be focused on the design of new collimators and on the verification that the proposed longitudinal layout does not pose issues for the transverse integration of collimators in this region.

6. REFERENCES

[1] WP5 deliverable document D5.5, http://hilumilhc.web.cern.ch/science/deliverables

[2] 42nd meeting of the Collimation Upgrade Specification working group, held on August 1st, 2014. http://indico.cern.ch/event/333525/

[3] Esposito, L.S. and Cerutti F. (2014), “Energy deposition for HL-LHC v1.1: TAN/D2/Q4”, Presentation at the 4th Joint HiLumi LHC-LARP Annual Meeting, Tsukuba Japan, 2014.

[4] WP5 Milestone report MS52, CERN-ACC-2015-0041.

7. ANNEX: GLOSSARY

Acronym	Definition
DS	Dispersion Suppressor
IR	Interaction Region
IP	Interaction Point
LS1, LS2, LS3	Long-shutdown1, 2, 3
TCLD	Target Collimator Long for Dispersion suppressor
TCT	Target Collimator Tertiary