CONCEPTUAL SPECIFICATION

TCTPM

Equipment/system description

Tertiary collimators are required in all LHC experimental insertions to protect cold magnets with squeezed beams. The HL-LHC baseline in the insertion regions IR1/5 poses new challenges in terms of machine aperture and requires additional tertiary collimator compared to the present LHC layout that features only one pair of horizontal and vertical collimators protecting the triplet magnets. Second generation tertiary collimators (TCTPM, Target Collimator Tertiary Pick-up Metallic) will use advanced materials to improve the robustness against beam losses while maintaining high-absorption, as required for an effective protection of the accelerator components downstream. The TCTPM's are not expected to contribute significantly to the machine impedance, however their design must be conceived taking impedance constraints into account. The new tertiary collimator design will be based on the present TCTP (Target Collimator Tertiary with Pickup) design, in particular they will include in-jaw Beam Position Monitors (BPMs).

Layout Versions	LHC sectors concerned	CDD Drawings root names (drawing storage):
V X.X	IR7 and possibly IR3	TBD

TRACEABILITY

Project Engineer in charge of the equipment	WP Leader in charge of the equipment
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Committee/Verification Role	Decision	Date
PLC-HLTC/ Performance and technical parameters	Rejected/Accepted	20YY-MM-DD
Configuration-Integration / Configuraration, installation and interface parameters	Rejected/Accepted	20YY-MM-DD
TC / Cost and schedule	Rejected/Accepted	20YY-MM-DD
Final decision by PL	Rejected/Accepted/Accepted pending (integration studies, …)	20YY-MM-DD

Distribution: N. Surname (DEP/GRP) *(in alphabetical order) can also include reference to committees*

Rev. No.	***Date***	***Description of Changes*** *(major changes only, minor changes in EDMS)*
X.0	20YY-MM-DD	Description of changes

1 CONCEPTUAL DESCRIPTION

1.1 Scope

The LHC Run 1 operation period has shown that protection of the insertion regions (IRs) is a key asset for the machine performance: the available aperture, to be protected in all operational phases, determines the collimation hierarchy. The present tertiary collimators (TCTP, Target Collimator Tertiary with Pickup) are made of a Tungsten Heavy Alloy (Inermet 180) [1]. They protect effectively the elements downstream but are not robust against high beam losses. Setting margins are added to the collimator hierarchy to minimise the risk of exposure of TCTP to beam losses in case of fast failures. A design with improved robustness would allow reducing these margins and, as a result, pushing further the β^* performance of the LHC, in particular for the HL optics baseline (ATS) that features an unfavourable phase between dump kickers and triplet magnets.

In addition, the HL-LHC updated IR layouts puts additional aperture constraints [2, 3]: up to 4 more tertiary collimators might be required in IR1/5 to protect the Q4 and Q5 quadrupole magnets, in addition to those installed in the present layout (2 TCTP collimators – one horizontal and one vertical – protect the inner triplet). The present baseline under study includes a pair of new collimators in front of the Q5. On-going studies are addressing (1) the need for additional Q4 protection and (2) the need to keep tertiary collimators at the present locations in case additional tertiaries are added upstream.

A new design of tertiary collimators, referred to as TCTPM (Target Collimator Tertiary with Pick-up Metallic), is under study to address the new challenges. This design will be based use novel materials to improve the collimator robustness while ensuring adequate absorption, adequate cleaning and protection of the elements downstream. The TCTPM design and material choice must take impedance constraints under consideration to keep the collimator impedance under control.

Even if less critical because of the larger β^* values, upgraded TCTP's are considered also for IR2/8.

1.2 Benefit or objective for the HL-LHC machine performance

The addition of new tertiary collimators following the updated HL layout is necessary to ensure the same cleaning and protection levels of the present machine and must be planned for LS3.

The experimental experience of beam impacts on collimator material samples at HiRadMat [4, 5] indicates that a Molybdenum-Graphite (MoGr) composite can improve the TCTP robustness by a factor 40-80. Note that the present Inermet design is expected to undergo damage requiring a collimator replacement already if hit by one single LHC nominal bunch of 10^{11} proton at 7 TeV. Other advanced materials are being studied as possible alternatives to further improve the robustness. The HL beam parameters with larger charge and smaller emittance pose additional challenges in terms of beam damage potential.

1.3 Equipment performance objectives

The new tertiary collimators must:

- Ensure adequate cleaning and protection of the IR aperture for the incoming beams, for all the new bottlenecks of the updated HL-LHC layouts;
- Improve the robustness of the present collimators and by ensure adequate levels of robustness for the updated beam HL-LHC parameters (double intensity, half emittance).

While the layout changes for HL will only take place in LS3, a staged replacement of the present TCTP's could be envisaged to improve robustness, starting already before LS2 (collimator replacements possibile in short Christmas stops).

TECHNICAL ANNEXES

2 PRELIMINARY TECHNICAL PARAMETERS

2.1 Assumptions

Key machine parameters that affect the design requirements are, amonsgt others, (1) machine aperture in the IR's; (2) IR layout baseline; (3) total intensity and single bunch charge; (4) energy failure scenarios.

2.2 Equipment Technical parameters

Table 1: Equipment parameters

Characteristics	Units	Value
Jaw active length	mm	1000
Jaw material	--	MoGr (TBD)
Flange-to-flange distance	mm	1480 (to be reviewed)
Number of jaws	--	2
Orientation	--	Horiz., vert.
Number of motors per jaw	--	2
Number of BPMs per jaw	--	2
RF damping	--	Fingers
Cooling of the jaw	--	Yes
Cooling of the vacuum tank	--	Yes
Minimum gap	mm	< 1
Maximum gap	mm	> 60 (to be reviewed)
Stroke across zero	mm	> 5
Angular adjustment	--	Yes
Jaw coating	--	No
Transverse jaw movement (5^{th} axis)	mm	+/- 10 mm (at least)

Note that a full validation of the new material, including the compatibility of UHV, is on-going and needs to be completed in time for the final material choice. Different materials are comparatively being addressed [6]. When available, information will be provided to the vacuum team to design the pumping system accordingly.

2.3 Operational parameters and conditions

Tertiary collimators for beam halo cleaning and triplet protection are used in all phases of the operation cycle, from injection to collision. They reach their tighter (normalized) settings at the end of the squeeze process when the machine aperture bottlenecks are located into IR1/IR5.

2.4 Technical and Installation services required

For the full HL implementation in LS3, new collimator slots with complete services must be foreseen, following the change of magnet positions. The cabling of the two already installed TCTP's might be re-used.

On the other hand, earlier upgrades of the system are considered: the replacement of the present TCTP's is possible with a minor intervention by re-using the existing infrastructures (minimum stop duration: 3-5 weeks, driven by bakeout constraints).

Table 2: Technical services

Domain	Requirement
Electricity & Power	YES
Cooling & Ventilation	Active cooling for the jaws (demineralized water)
Cryogenics	--
Control and alarms	YES
Vacuum	YES. The vacuum team recommends the use of Conflat gaskets.
Instrumentation	YES

Table 3: Installation services

Domain	Requirement
Civil Engineering	NO
Handling	YES – special transport
Alignment	YES

2.5 P & I Diagrams

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2.6 Reliability, availability, maintainability

Same standards as the other collimators.

2.7 Radiation resistance

All collimator components are optimized for operation in high radiation environments. This is an important constraint for the collimators in the experimental regions. Total doses on the TCTPM's will be dominated by the radiation due to high-luminosity interactions.

The selection of construction materials will take activation properties into account. The design is optimized to allow for fast repair, maintenance and replacement, depending on expected residual dose rate levels. The design also considers dismantling, radioactive waste conditioning and disposal properties at the end of the lifetime of the component.

2.8 List of units to be installed and spares policy

- The total number of new devices is not fixed yet. The maximum number of collimator per beam is 6 per IR, the present baseline assuming only 4 (one H/V pair downstream of the D2 and one pair in front of the Q5, for the incoming beam). Note that the TCTP's of the LHC or TCTP spares might be re-used for the cases in which the present Inermet robustness is considered adequate (e.g. for vertical collimators not exposed to the asynchronous dump failure).
- An appropriate spare policy will be established when the total number of installed units is known. Indicatively, we assumed 10-20 % of the installed units.

3 PRELIMINARY CONFIGURATION AND INSTALLATION CONSTRAINTS

3.1 Longitudinal range

The longitudinal positions of the present baseline under study are given in [3]. As general guidelines:

- the TCTPM should be located as close as possible to the element that they protect;

- for the inner triplet, TCTPM should be located as close as possible to the D2 magnet to maximize the beam-beam interdistance.

3.2 Volume

Standard collimator design, as the presently installed collimators, should be assumed.

It is important to recall that the collimator integration in the region between TAN and D2 magnets (present TCTP's location) must be studies properly, taking into account the constraints coming from the reduced separation between the two beam pipes. Therefore, new layout/design of the collimator tank must be studies.

It is also noted that the collimator jaw stroke might need to be updated compared to the present design (see also Table 1) depending on the final β^* values decided for HL-LHC. Maximum collimator gaps above the present 60 mm value might be required.

3.3 Installation/Dismantling

Dismantling and possible re-location of the present TCTP's infrastructure. Several new slots required.

4 PRELIMINARY INTERFACE PARAMETERS

4.1 Interfaces with equipment

Standard as present collimators.

4.2 Electrical interfaces

No changes for any magnet powering system.

Table 4: Circuits to be generated

New circuit description	Circuit LHC code name (if known)	Approx. current rating (if known)	Approx. voltage rating (if known)

List circuits to be modified/affected by the installation of the new equipment

Table 5: Circuits to be modified/affected

Circuit LHC code name	Action on the circuit

5 COST & SCHEDULE

5.1 Cost evaluation

Cost to be charged on the collimation code 61064.

5.2 Approximated Schedule

The key milestones for the upgrade of tertiary collimators, which will lead to the complete design validation, are:

- Successful HiRadMat beam tests. This is also done in synergy with the tests on the new generation of secondary collimators TCSPM.

- Successful prototyping and beam tests in the LHC starting in 2015 (synergy with advanced material for the new TCSPM [7]). This will prove the compatibility of new materials/design with the LHC operation.
- Validation from irradiation tests with proton and ion beams (on-going tests in collaboration with Kurchatov, GSI within EuCARD^2, and BLN within US-LARP and HiLumi).

Complete the production and installation for the HL implementation will take place in LS3 ("production batch 2"). On the other hand, if proved necessary, replacement/installation of a few to several collimators might take place already before or in LS2 ("production batch 1"). This concerns up to 4 units (all horizontal TCTP's in IR1/5), as required to push the beta* performance in the high luminosity points.

For this scenario, a sharing of cost with the Consolidation project might be envirsaged.

It is noted that, since the installation slots are ready, shorter Christmas shutdowns can be used to install a few units, if needed.

Table 6: Tentative schedule for 2 production batches.

Phase	**2014**		**2015**		**2016**		**2017**		**2018**	**2019**	**2020**	**2021**	**2022**
Func. Spec. prototype	■	■											
Eng. Spec. prototype		■	■	■									
Prototyping and beam tests				■	■								
Iteration on design					■	■	■	■					
Production of some units					■	■	■	■	■				
Installation – Commissioning										■			
Production batch 2													■

5.3 Schedule and cost dependencies

Cost sharing with Consoidation project to be discussed for implementation before LS3.

6 TECHNICAL REFERENCE DOCUMENTS

[1] R. Assmann *et al.*, Collimation chapter of the LHC Design Report, edited by O. Brüning *et al.*, http://ab-div.web.cern.ch/ab-div/Publications/LHC-DesignReport.html

[2] HiLumi WP2 deliverable document D2.1, https://cds.cern.ch/record/1557082/files/CERN-ACC-2013-009.pdf

[3] R. Bruce *et al.*, "IR layout baseline for background studies", presentation at the 29th meeting of the Collimation Upgrade Specification meeting, http://indico.cern.ch/event/274532/

[4] A. Bertarelli, "An Overview of HiRadMat Tests on Collimators Materials", ATS seminar, http://indico.cern.ch/event/240782/

[5] M. Cauchi *et al.*, "High Energy Beam Impact Tests on A LHC Tertiary Collimator at CERN HiRadMat Facility", Phys. Rev. ST Accel. Beams **17**, 021004 (2014).

[6] F. Carra *et al.*, "Mechanical engineering and design of novel collimators for HL-LHC," IPAC2014, Dresden, GE (2014). http://accelconf.web.cern.ch/AccelConf/IPAC2014/papers/mopro116.pdf

[7] HL Conceptual Functional Specification, TCSPM in IR3/7, https://edms.cern.ch/document/1393878

7 APPROVAL PROCESS COMMENTS FOR VERSION X.0 OF THE CONCEPTUAL SPECIFICATION

7.1 PLC-HLTC / Performance and technical parameters Verification

Comments or references to approval notes. In case of rejection detailed reasoning

7.2 Configuration-Integration / Configuraration, installation and interface parameters Verification

Comments or references to approval notes. In case of rejection detailed reasoning

7.3 TC / Cost and schedule Verification

Comments or references to approval notes. In case of rejection detailed reasoning

7.4 Final decision by PL

Comments or references to approval notes. In case of rejection detailed reasoning