

CONCEPTUAL SPECIFICATION

TARGET SECONDARY COLLIMATOR PICK-UP METALLIC [TCSPM]

Equipment/system description

Second generation secondary collimators (TCSPM, Target Collimator Secondary with Pick-up Metallic) will be built using advanced materials that are conceived to reduce the collimator impedance while maintaining or even improving the jaw robustness against relevant beam failure scenarios. Since the present LHC impedance is dominated by the contribution of the collimators, in particular of the carbon-based primary and secondary collimators in the LHC interaction region IR3 and IR7, the TCSPM upgrade will reduce substantially the total machine impedance.

Layout Versions	LHC sectors concerned	CDD Drawings root names (drawing storage):
V 1.0	IR7 and possibly IR3	LHCTCSPM to be created by S. Chemli

TRACEABILITY

Project Engineer in charge of the equipment tbd	WP Leader in charge of the equipment S. Redaelli	
Committee/Verification Role	Decision	Date
PLC-HLTC/ Performance and technical parameters	Rejected/Accepted	2014-07-01
Configuration-Integration / Configuraton, 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: HL-TC

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 impedance budget is dominated by the contribution of the LHC collimators. For this reason, the present collimation system has been conceived in a way that can be easily upgraded to reduce the impedance [1]: every secondary collimator slot in IR3 (momentum cleaning) and IR7 (betatron cleaning) features a companion slot for the future installation of a low-impedance secondary collimator. A total of 22 slots (IR7) and 8 slots (IR3) are essentially already cabled for a quick installation of new collimators – referred to as TCSM in the present database naming convention – that can either replace the present secondary collimators (TCSG, Target Collimator Secondary Graphite) or be used together with them. Partial preparation of these slots is on-going in LS1.

The importance of minimizing the machine impedance for the HL-LHC has been emphasized in [2, 3, 4] and also in a recent collimation project review [5]. We therefore foresee that, by the time of the full HL-LHC implementation (LS3), a part or all the available TCSM slots might be equipped with advanced collimators using new materials, and possibly coating, to reduce the impedance. Staged installation starting already after LS1 is possible.

Secondary collimators in the betatron cleaning insertion have also a crucial role in the LHC machine protection and might be exposed to large beam losses. Therefore, new material choices and designs must be robust also against beam failure (at least the ones exposed to horizontal losses).

1.2 Benefit or objective for the HL-LHC machine performance

The present baseline for the upgraded secondary collimators relies on a Molybdenum Carbide - Graphite (MoGr) composites coated with pure Mo. This design provides a reduction of 90 % of the individual collimator impedance compared to the present TCSG design made of CFC [6], thanks to a reduction of resistivity by about a factor 100. The option with MoGr and no coating improves the present TCSG resistivity by a factor 5 and is also under consideration.

On the other hand, the new design and materials [7] must be validated for operation. Material properties and the coating options has to be demonstrated. For this purposes, a rich program of validation is in progress, involving:

- tests at HiRadMat, covering material samples as well as full jaw validation;
- mechanical engineering prototyping;
- beam tests at the LHC, planned for 2016 (collimation installation in the 2015 shutdown).

In addition to the impedance improvements, the new TCSPM also features a number of improvements in the mechanical design [7].

1.3 Equipment performance objectives

The secondary collimators are among the most exposed devices in case of regular and irregular beam losses. The new TCSPMs must be compatible with the HL-LHC operation with larger stored beam intensities. For the same scenarios, the foreseen increased bunch intensity by a factor of 2 and smaller emittance are more demanding in terms of high robustness and low impedance.

It is important to stress that the HL-LHC beam parameters pose additional challenges for the collimator survival. The failure scenarios at injection and top energy are presently being reviewed taking into account the operational experience of the LHC Run 1. The results of this review will be used to update the material specifications.

TECHNICAL ANNEXES

2 PRELIMINARY TECHNICAL PARAMETERS

2.1 Assumptions

See the present HL-LHC parameter baseline at [8]. The design is discussed in a recent paper [2]. Key machine parameters that affect the design requirements are, amongst others,

- total intensity and single bunch charge (determining requirements for cleaning and impedance);
- assumed beam lifetime and tail population (cleaning);
- injection and top energy failure scenarios (material robustness);
- total design loss rates.

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
Number of jaws	--	2
Orientation	--	Horiz., vert., skew
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
Stroke across zero	mm	> 5
Angular adjustment	--	Yes
Jaw coating	--	Mo (TBC)
Transverse jaw movement (5 th axis)	mm	+/- 10

2.3 Operational parameters and conditions

Secondary collimators for beam cleaning are needed in all phases of the operation cycle, from injection to collision.

2.4 Technical and Installation services required

30 TCSM slots are available in the machine for quick installation of the new collimators. Slots are already equipped with supports and services, including cabling. Only the cables from the cable trays on the tunnel wall and the collimator support need to be pulled. Some slots are being prepared during LS1 as part of the system consolidation.

Note however that the present TCSM slot cabling does not include cables for the new BPM pick-ups, which have been added to the design after the initial preparation of the TCSM slots. This must be foreseen.

If it is proven that the present Carbon-based secondary collimators will not be needed anymore in the HL-LHC era (e.g. if the TCSPM material choice is compatible with the updated failure scenarios at injection), the presently occupied TCSG slots might be freed. The removal of the highly radioactive TCSG's after the LHC Run 1 and Run 2 operation could be advantageous in terms of doses to personnel for future tunnel interventions.

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. All the componets must reliably work in a high radiation environment to minimize the machine downtime.

2.7 Radiation resistance

All collimator components are optimized for operation in high radiation environments. This is an important constraint for the collimators in IR7 that will be exposed to the highest doses in the machine.

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

An appropriate spare policy will be established when the total number of installed units will be known. Indicatively, at this stage we assumed 10-20 % of the installed units.

3 PRELIMINARY CONFIGURATION AND INSTALLATION CONSTRAINTS

3.1 Longitudinal range

The TCSM slots are already part of the present layout.

3.2 Volume

Standard collimator design, as the TCSG presently installed. See [7] for recent design considerations. In TZ76 and in UJ32, space must be allocated for the control racks for collimator controls and BPM acquisitions.

3.3 Installation/Dismantling

Slots already available. Replacement chambers presently installed will have to be removed. Potentially, also some of the present secondary collimators TCSG's might have to be removed.

4 PRELIMINARY INTERFACE PARAMETERS

4.1 Interfaces with equipment

Standard as present collimators (plus BPM buttons).

4.2 Electrical interfaces

No changes for any magnet powering system.

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 secondary collimators, which will lead to a complete design validation for LHC operation, are:

- Successful prototyping and beam test in the LHC starting in 2015.
- Successful validation at HiRadMat of material samples and full collimator jaw [9, 10, 11].
- Validation from irradiation tests with proton and ion beams (on-going tests in collaboration with Kurchatov, GSI within EuCARD², and BLN within US-LARP and HiLumi).
- Successful validation of the coating option, if proved necessary.

Note that several of the milestones above are also part of the validation of new tertiary collimator design [12].

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

If proved beneficial for the operation of the LHC before LS3, the funding of the production of low-impedance collimators shall be discussed with the Consolidation project.

Table 4: Tentative schedule for 2 production batches.

Phase	2014	2015	2016	2017	2018	2019	2020	2021	2022
Funct. Spec. prototype									
Eng. Spec. prototype									
Prototyping and beam tests									
Iteration on design									
Production batch 1									
Installation – Commissioning									
Production batch 2									

5.3 Schedule and cost dependencies

Cost sharing with Consolidation 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] HiLumi WP2 milestone document M29, “Initial estimate of machine impedance”, <https://cds.cern.ch/record/1644770/files/CERN-ACC-2014-0005.pdf>
- [4] HiLumi WP2 milestone document M31, “Preliminary estimates of beam-beam effect”, <http://cds.cern.ch/record/1709432/files/CERN-ACC-2014-0066.pdf>
- [5] Recommendation of 2013 Collimation Project review panel, <https://indico.cern.ch/event/251588/>
- [6] N. Mounet, “Transverse impedance in the HL-LHC era”, presentation at the 3rd HiLumi Annual meeting, Daresbury, UK (2013), <https://indico.cern.ch/event/257368/>
- [7] 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>
- [8] HL-LHC Parameter & Layout Committee page, <https://espace.cern.ch/HiLumi/PLC/default.aspx>
- [9] A. Bertarelli *et al.*, presentation at the HiRadMat scientific board meeting of March 14th, 2014, <https://indico.cern.ch/event/303890/>
- [10] A. Bertarelli, “An Overview of HiRadMat Tests on Collimators Materials”, ATS seminar, <http://indico.cern.ch/event/240782/>
- [11] 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).
- [12] HL Conceptual Functional Specification, TCTPM, <https://edms.cern.ch/document/1393893>

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 / Configuration, 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