

CONCEPTUAL SPECIFICATION

TECG FOR CRYSTAL COLLIMATION AT THE LHC

WP5

Equipment/system description

Crystal collimation of hadron beams is considered as a possible way to improve the collimation cleaning at the LHC, for proton and ion beams. In order to demonstrate the feasibility of this concept, a crystal collimation experiment has been setup for beam tests in LHC Run 2. The initial installation performed in IR7 during LS1 consists of 2 goniometers (TECG devices) mounting crystals for horizontal and vertical collimation tests. Existing collimators are used to intercept the channelled beam in a layout that has been designed to achieve a better cleaning performance than the present collimation. Infrastructures have been prepared to potentially extend the crystal setup by adding additional diagnostics.

Layout Versions	LHC sectors concerned	CDD Drawings root names (drawing storage):
V 1.1	IR7	TECG

TRACEABILITY

Project Engineer in charge of the equipment A. Masi (?)	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 / Configuration, 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

Crystal collimation of hadron beams is considered as a possible way to improve the collimation cleaning at the LHC, for proton and ion beams. In order to demonstrate the feasibility of this concept, a crystal collimation experiment has been setup for beam tests in LHC Run 2. The initial installation performed in IR7 during LS1 consists of 2 goniometers (TECG devices) mounting crystals for horizontal and vertical collimation tests. Existing collimators are used to intercept the channelled beam in a layout that has been designed to achieve a better cleaning performance than the present collimation. Infrastructures have been prepared to potentially extend the crystal setup by adding additional diagnostics.

Note that for high-intensity proton operation, the LHC collimation system must withstand beam losses equivalent to up to 1 MW and above. The present system could achieve this already at 4 TeV [3]. This aspect is a crucial one for the feasibility of LHC crystal collimation of proton beams. Such an aspect is not addressed in the scope of the present R&D for beam tests that are designed, in this first phase, for low-intensity beam tests only.

1.2 Benefit or objective for the HL-LHC machine performance

The present scope of MD studies does not provide immediate benefits for the performance. This is an R&D program aimed at demonstrating the feasibility of crystal collimation for the LHC. Note that crystals are installed on one beam only (beam 1).

Potential benefits of the crystal collimation concept for the LHC are:

- Reduce the losses in the dispersion suppressors in IR7 due to reduced impact of single diffractive losses compared to the present primary collimators;
- Achieve collimation cleaning comparable to or better than the present system with a reduced number of collimators;
- Reduce collimator impedance thanks to the usage of less secondary collimators, at larger gaps;
- Significantly improve the betatron cleaning of ion beams.

1.3 Equipment performance objectives

The installation of the test devices should ensure the main goals of MD studies:

- Adequate angular precision and stability to demonstrate channelling at injection and top energy;
- Crystal properties must be adequate to demonstrate the expected improvement of collimation cleaning at injection and top energy compared to the present collimation.
- Function-driven position and angle control to demonstrate collimation cleaning in dynamics machine phases like ramp and squeeze.

Clearly, the controls implementation must be designed to respect the LHC standards in terms of machine protection to ensure that crystals are only used for the scope of low-intensity beam tests.

The installation plan included services for additional instrumentation [4]. The need for this will be assessed and reviewed during 2015.

The installed goniometers are designed to have no impact on the high intensity operation of the LHC. This is achieved thanks to a shifting mechanism that takes the goniometers out of beam, offering a replacement chamber transparent to the circulating beam, outside of controlled MD times.

TECHNICAL ANNEXES

2 PRELIMINARY TECHNICAL PARAMETERS

2.1 Assumptions

The collimation crystal experiment is designed for low-intensity beam test at injection and top energy. The maximum total intensity at injection will be about 10^{12} protons. At top energy, details of safe conditions at 6.5 TeV are being worked out within the machine protection teams for the operation in 2015. Present figures indicate about 2×10^{11} p as a possible upper limit [4].

The operational range of the crystal should allow to set the crystal at the same gaps at the same aperture in beam size units as the primary collimators, for a comparison of the cleaning performance achieved with the standard system. This corresponds to half gaps of down to 1 mm

2.2 Equipment Technical parameters

The technical parameters are described in detail in a recent engineering change request document [5]. See also discussion at the LMC [6]. No further technical details are presented here.

2.3 Operational parameters and conditions

The goniometer devices are not optimized for high-intensity proton operation in HUV environment. They should not be exposed to high intensity beams until enough operational experience is accumulated with this hardware. The scope of initial collimation tests with crystals is anyway limited to safe beam intensities.

In order not to jeopardize the machine operation, the goniometers are not seen by the beam thanks to a translation mechanism that moves the crystal into beam position only when their operation is allowed. In all other conditions, the goniometer is replaced by a replacement chamber that, impedance and vacuum wise, is equivalent to a standard drift vacuum chamber [5]. Adequate interlocks will be put in place to remove the beam permit if a goniometer moves into the beam. This interlock might be masked with safe beam intensities only: this is the operational scenario foreseen for MDs.

The installation of the goniometers uses cabling, support and services of the present collimation system. The system has been designed with quick plug-in and disconnection features in case the services used will be required for other collimation purposes (replacement of a collimator using TCMS slots, system upgrade, etc.).

2.4 Technical and Installation services required

Table 1: Technical services

Domain	Requirement
Electricity & Power	YES
Cooling & Ventilation	NO
Cryogenics	YES
Control and alarms	YES
Vacuum	YES
Instrumentation	YES

Table 2: Installation services

Domain	Requirement
Civil Engineering	NO
Handling	YES
Alignment	YES

2.5 P & I Diagrams

--

2.6 Reliability, availability, maintainability

Availability for MD purposes. System described here is not foreseen for standard beam operation.

2.7 Radiation resistance

The goniometers are installed in a high radiation environment. An optimized design for quick intervention is mandatory and requested by RP. The policy for dismantling this equipment after the scope of beam tests, or in case the infrastructure used by this hardware is needed for other purposes, must be agreed with RP.

2.8 List of units to be installed and spares policy

- Two devices installed on B1 only for horizontal and vertical tests.
- One goniometer for lab tests.
- One goniometer for SPS beam tests.

Tests at the SPS and in the laboratory are considered integral part of this study as they will minimize the MD time requirements at the LHC.

3 PRELIMINARY CONFIGURATION AND INSTALLATION CONSTRAINTS

3.1 Longitudinal range

Details of the longitudinal positions are discussed in [5].

3.2 Volume

See [4].

3.3 Installation/Dismantling

Adequate policy for dismantling will have to be established in 2015 depending on the IR7 radiation levels.

4 PRELIMINARY INTERFACE PARAMETERS

4.1 Interfaces with equipment

--

4.2 Electrical interfaces

No changes for the powering. See [5]

5 COST & SCHEDULE

5.1 Cost evaluation

The cost of the present installation, as of mid-2014, has been co-funded by

- LHC Collimation Project (AB-0809), from consolidation
- UA9 collaboration
- HL-WP5 (Collimation Project)

Future activities shall be funded on the HL-WP5, code 61064, with participation from the UA9 collaboration.

5.2 Approximated Schedule

The scope of the present installation covers beam tests during the LHC Run 2.

Detailed strategy for the next steps will be established in 2015 after having accumulated enough beam test experience.

Note that the scope of the HL studies for crystal collimation also covers prototype device for lab tests and SPS beam test (the latter co-funded by the UA9 collaboration) that are considered essential to optimize the beam time for LHC MDs.

5.3 Schedule and cost dependencies

--

6 TECHNICAL REFERENCE DOCUMENTS

- [1] W. Scandale *et al.*, "Optimization of the crystal assisted collimation of the SPS beam", Physics Letters B, [Volume 726, Issues 1–3](#), 7 October 2013, Pages 182–186, 10.1016/j.physletb.2013.08.028
- [2] D. Mirarchi *et al.*, "[Final Layout and Expected Cleaning for the First Crystal-assisted Collimation Test at the LHC](#)", IPAC2014, Dresden, GE (2014).
<http://accelconf.web.cern.ch/AccelConf/IPAC2014/papers/mopri110.pdf>
- [3] B. Salvachua *et al.*, "[Handling 1 MW Losses with the LHC Collimation System](#)", IPAC2014, Dresden, GE (2014). <http://accelconf.web.cern.ch/AccelConf/IPAC2014/papers/mopro043.pdf>
- [4] L. Ponce, "Commissioning and Operation of Machine Protection systems", presentation at the LHC Operation Workshop, Evian2014, <https://indico.cern.ch/event/310353/>
- [5] EDMS document 1329235, <https://edms.cern.ch/document/1329235/1.0>
- [6] See discussion at the 174th LMC meeting, Feb. 19th, 2014. <https://espace.cern.ch/lhc-machine-committee/default.aspx>

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