CERN
CH-1211 Geneva 23
Switzerland

the **Large Hadron Collider** project

LHC Project Document No.

CERN Div./Group or Supplier/Contractor Document No.

AB/XX/XX

EDMS Document No.

Date: 2007-02-16

MPS Commissioning Procedure

THE COMMISSIONING OF THE LHC MACHINE PROTECTION SYSTEM

MPS ASPECTS OF THE COLLIMATION SYSTEM COMMISSIONING

Abstract

This document describes the set of tests which will be carried-out to validate for operation the machine protection aspects of the **LHC collimation system.** The area concerned by these tests extends over 7 out of the 8 long straight sections.

These tests include the Hardware Commissioning, the machine check-out and the tests with beam, to the extent that they are relevant for the machine protection functionality of collimation.

Prepared by :	***Checked by :***	***Approved by :***
Ralph Assmann **Michel Jonker** **Roberto Losito** **Stefano Redaelli** **Thomas Weiler**	**Roger Bailey** **Andy Butterworth** **Bernd Dehning,** **Brennan Goddard,** **Eva Barbara Holzer,** **Verena Kain,** **Mike Lamont,** **Blanca Perea Solano** **Rudiger Schmidt,** **Benjamin Todd,** **Jorg Wenninger,** **Markus Zerlauth**	**Rüdiger Schmidt**

History of Changes

Rev. No.	*Date*	*Pages*	*Description of Changes*
0.1	2007-10-8		First draft for circulation.
0.2	2007-10-10		Comments from S. Redaelli, R. Losito, M. Jonker.

Table of Contents

1. INTRODUCTION 4
2. SCOPE 4
3. PURPOSE 4
4. THE LAYOUT 5
5. TESTS PERFORMED DURING THE HARDWARE COMMISSIONING 5
5.1 INDIVIDUAL VACUUM SYSTEM TESTS 5
6. LINK TO OTHER EQUIPEMENTS 6
6.1 INTERFACES WITH THE BEAM INTERLOCK SYSTEM**ERROR! BOOKMARK NOT DEFINE**
6.2 INTERFACE WITH THE RF SYSTEM 6
7. SYSTEM TESTS DURING THE MACHINE CHECKOUT 8
7.1 CONDITIONS REQUIRED TO PERFORM TESTS 8
7.2 DESCRIPTION OF THE TESTS 8
7.3 STATUS OF THE SYSTEM AFTER THE SYSTEM TESTS 9
8. TESTS WITH BEAM 9
8.1 PILOT OF $1{\cdot}10^{10}$ P^+ AT 450 GEV 9
8.2 43 BUNCHES OF $4{\cdot}10^{10}$ P^+ AT 450 GEV 9
8.3 156 BUNCHES OF $9{\cdot}10^{10}$ P^+ AT 450 GEV 9
8.4 PILOT OF $1{\cdot}10^{10}$ P^+ AT 7 TEV 9
8.5 43 BUNCHES OF $4{\cdot}10^{10}$ P^+ AT 7 TEV 10
8.6 156 BUNCHES OF $9{\cdot}10^{10}$ P^+ AT 7 TEV 10
8.7 936 BUNCHES OF $4{\cdot}10^{10}$ P^+ AT 7 TEV 10
8.8 936 BUNCHES OF $9{\cdot}10^{10}$ P^+ AT 7 TEV 10
8.9 HALF NOMINAL: 2808 BUNCHES OF $5{\cdot}10^{10}$ P^+ AT 7 TEV 10
8.10 NOMINAL: 2808 BUNCHES OF $11{\cdot}10^{10}$ P^+ AT 7 TEV 10
8.11 STAGES DEPENDING ON OPTICS REQUIRING TEST 11
8.12 STAGES DEPENDING ON CROSSING AT IP REQUIRING TEST 11

1. INTRODUCTION

The LHC collimation system has several core functions:

1. Efficient cleaning of the beam halo.
2. Concentration of beam losses and activation at collimators.
3. Passive machine protection.
4. Background control in the experimental detectors.

The system has been designed and optimized for halo cleaning. However, its function of passive protection makes the system a part of the overall machine protection system (MPS) for the LHC. In the MPS it must fulfil its protection functions together with the other protection system such that the machine safety is always ensured. Here, we describe the checks that must be performed in order to guarantee the proper passive protection from collimators.

2. SCOPE

This document describes the procedures and tests for establishing the required passive protection with the LHC collimation system.

Areas concerned: **LSS1, LSS2, LSS3, LSS5, LSS6, LSS7, LSS8, TI2, TI8**.

The equipment types concerned include:

1. Collimator-like objects (movable collimator jaws inside the LHC vacuum system): **TCP, TCSG, TCTH, TCTVA, TCTVB, TCLA, TCLP, TCLIA, TCLIB, TCDI**.
2. Absorber-like objects (fixed absorbers outside of LHC vacuum system): **TCAPA, TCAPB, TCAPC**.
3. **To be decided: Roman Pots operated from the collimator control system.**
4. **To be decided: Other collimator-like objects: TDI, TCDD**

It is noted that the set-up for halo cleaning and optimization of cleaning efficiency is not included here.

3. PURPOSE

This document

1. gives a comprehensive list of the components which will be the object of the tests.

2. describes in detail the procedures which will be applied for these tests and their sequence.

Each test has in front one of the following letters, defining at which interval or at which occasion the described test needs to be repeated (in the column labelled Repetition):

N	Not to be repeated
S	To be repeated after every Shutdown
P	Periodical repetition required, like 1 x per month; details to be defined in text
O	To be repeated when LHC optics is changed

X	To be repeated when crossing scheme is changed

This document is meant to be the reference document for the checklist which will be used during the commissioning of the MPS. Results of the tests will be documented in the MTF database.

4. THE LAYOUT

The collimation system is described in the LHC design report, various publications and documented in the web site of the LHC collimation project (http://www.cern.ch/lhc-collimation-project).

5. TESTS PERFORMED DURING THE HARDWARE COMMISSIONING

This part describes the tests which are validated during the equipment's hardware commissioning period and have to be validated also for the machine protection system commissioning.

5.1 INDIVIDUAL COLLIMATOR TEST

Every single collimator will be tested during hardware commissioning.

5.1.1 CONDITIONS REQUIRED TO PERFORM TESTS

- **Installation of collimator.**
- **Installation of cables.**
- **Installation of controls racks in tunnel and on surface.**
- **Timing signals available.**
- **Electrical power, communication systems up, collimator controls applications up, expert applications, access to collimator.**

5.1.2 CONDITIONS DURING THE TESTS

Presence is required at control system racks and at collimator.

5.1.3 DESCRIPTION OF THE TESTS

Details of the tests have been defined in the Hardware Commissioning procedures and reports have been implemented into MTF. It is noted that some sanity checks will be included in operational control procedures at the end of each fill, for example a cycle of the collimator up to switch positions. These are not considered to be part of the commissioning of MP functionality. Here, we summarize the commissioning steps required for the MPS functionality of the collimation system:

	Rep.	Action	Group(s) Responsible
1	S	**Check remote jaw movement with stepping motors.**	AB/ATB
2	S	**Check response of position sensors and remote readout with jaw movements.**	AB/ATB
3	S	**Calibration of position sensors.**	AB/ATB

4	S	**Check response and remote readout of temperature sensors.**	AB/CO
5	S	**Check cooling water flow.**	AB/ATB
6	S	**Check response of switches.**	AB/ATB
7	S	**Check communication and functionality of CSS (collimator supervisory system).**	AB/CO
8	S	**Check communication and functionality of collimator controls application.**	AB/OP

5.1.4 STATUS OF THE SYSTEM AFTER TESTS

The full functionality of the tested collimator will be established at the end of hardware commissioning.

6. LINK TO OTHER EQUIPEMENT

The interfaces listed in this paragraph concern only the ones in relation with the Machine Protection System; it does not describe any procedures to test the interfaces to protect individual equipment.

6.1 SIGNALS BETWEEN COLLIMATION CONTROL SYSTEM AND BEAM INTERLOCK SYSTEM

Signals from the collimation system to the beam interlock system:

- **Interlocks from switch positions.**
- **Interlocks from position sensor readings.**
- **Interlocks from motor and controls status.**
- **Interlocks from temperature sensors.**

Signals from the beam interlock system to the collimation system:

- **Timing signal with MP information (beam energy, squeeze factor, machine state).**

6.2 SIGNALS BETWEEN COLLIMATION CONTROL SYSTEM AND BEAM LOSS MONITORING SYSTEM

There are several links foreseen for operational set-up of LHC collimators. However, in the collimator control system **no interlock will be generated due to BLM measurements**. This is fully handled through the BLM system and is therefore not described here.

6.3 SIGNALS BETWEEN COLLIMATION CONTROL SYSTEM AND OTHER BEAM DIAGNOSTICS

Additional information will be received from the BPM system, the beam current signals, emittance measurements, etc (partly through the database). **None of these will be used to generate hardware interlocks** and are therefore not described here (can be used later for software interlocks).

6.4 SIGNALS FROM COLLIMATION CONTROL SYSTEM TO THE ALARM SYSTEM AND LOGGING

Alarms will be sent if irregular situations are encountered. Presently it is **not foreseen to generate interlocks associated with these alarms**. It is therefore not described here.

Logging will be performed for analysis of losses and collimator settings. **There is no need for safety-critical fast post-mortem data.** Therefore this is not described here.

6.5 INTERFACE WITH THE MCS SYSTEM

The following data exchange is foreseen with the machine critical settings system (here we only include MP relevant data).

6.5.1 HUMAN INPUTS, POSSIBLY INFREQUENTLY UPDATED

Basic protection parameters must be defined via human input, after detailed analysis and agreement among all parties involved:

1. **Dump threshold for jaw temperature.**
2. **Required switch configuration for the collimators in different machine modes (details to be discussed – maybe hold this in the trim database).**
3. **Required collimation gap versus time, energy and squeeze factor (as needed for ensuring passive protection).**

6.5.2 SEMI-AUTOMATIC INPUT FROM THE COLLIMATION SYSTEM TO THE MCS FUNCTIONALITY

Automatic or semi-automatic procedures will provide calibration data that defines the accuracy of sensor readings and jaw positioning. After human approval, this data is entered into the appropriate databases as critical parameters (full MCS functionality is required):

1. **Calibration data for position sensors.**
2. **Results of beam-based calibration of collimators.**

6.5.3 AUTOMATIC MP INPUT FROM MCS FUNCTIONALITY TO THE COLLIMATION CONTROL SYSTEM

The MCS system is used to prepare and store the operational machine protection limits for every fill, based on the human reference input and the collimation calibration data:

1. **Required MP switch status versus machine mode (the implementation of this is still under discussion).**
2. **Required MP collimation gap versus energy and squeeze factor. Initially time-depending MP limit would be useful for avoiding limitations with squeeze factor.**
3. **Sensor calibration data in case of memory loss. The PXI system will be rebooted and load the calibration data during the reboot process.**

The general philosophy is as follows: The limits for every machine mode are distributed to the collimator low-level front-ends. Subsequently they are checked on a regular basis (every few minutes) to prevent data corruption. The safety of the interface with the MCS is of utmost importance as any data corruption will immediately compromise passive protection in the LHC.

7. SYSTEM TESTS DURING THE MACHINE CHECKOUT

After the Individual System Tests, described in the previous sections, have been successfully completed, the integral system should be tested from the CERN Control Centre (CCC), simulating as much as possible future operation with beam.

7.1 CONDITIONS REQUIRED TO PERFORM TESTS

- **Successful completion of the individual tests for collimators.**
- **Successful completion of the tests mentioned in the previous sections.**
- **MCS system available and fully tested.**
- **LHC controls system operational (trim, functions, …).**
- **Logging system available.**
- **Alarm system available.**
- **Timing event distribution available.**
- **Sequencer available.**

7.2 DESCRIPTION OF THE TESTS

The required tests are listed below:

		Action	Group(s) Responsible
1	S	**Test of link with MCS system:** 1. Introduce human inputs (6.5.1). 2. Introduce semi-automatic input from collimation system (6.5.2). 3. Generate MP limits from MCS and transfer into collimation control system (6.5.3).	AB/ABP AB/ATB AB/CO AB/OP
2	S	**Test generation of interlocks while moving jaws in a single collimator:** 1. From switches. 2. From position sensors (MP gap). 3. From controls status (e.g. rack down). 4. With time driven functions. 5. With MP information (energy, squeeze factor).	AB/ABP AB/ATB AB/CO AB/OP
3	S	**Test generation of interlocks while moving collimator families:** 1. From switches. 2. From position sensors (MP gap). 3. From controls status (e.g. rack down). 4. With time driven functions. 5. With MP information (energy, squeeze factor).	AB/ABP AB/ATB AB/CO AB/OP

4 S **Sanity check for link to temperature sensors:**
Generate interlock artificially (no possibility to heat up jaws without connection bake-out equipment).

7.3 STATUS OF THE SYSTEM AFTER THE SYSTEM TESTS

After these tests the **collimation machine protection functionality (defined with collimator gaps, collimator position sensors and MCS data) will be fully established.**

8. TESTS WITH BEAM.

8.1 PILOT OF $1{\cdot}10^{10}$ P^{+} AT 450 GEV

The following steps must be performed:

1. **Check of sensors readings and controls for beam-induced pickup noise.**
2. **Update of MCS input after beam-based calibration of collimators and taking into account the available machine aperture.**

8.2 43 BUNCHES OF $4{\cdot}10^{10}$ P^{+} AT 450 GEV

The following steps must be performed:

1. Check of sensors readings and controls for beam-induced pickup noise.
2. Update of MCS input after beam-based calibration of collimators and taking into account the available machine aperture.
3. **Study and setting of interlock thresholds for jaw temperature.**

8.3 156 BUNCHES OF $9{\cdot}10^{10}$ P^{+} AT 450 GEV

The following steps must be performed:

1. Check of sensors readings and controls for beam-induced pickup noise.
2. Update of MCS input after beam-based calibration of collimators and taking into account the available machine aperture.
3. **Check of interlock thresholds for jaw temperature.**

8.4 PILOT OF $1{\cdot}10^{10}$ P^{+} AT 7 TEV

The following steps must be performed:

1. Check of sensors readings and controls for beam-induced pickup noise.
2. Update of MCS input after beam-based calibration of collimators and taking into account the available machine aperture.
3. **Update of MCS input for collimator settings during the energy ramp.**

8.5 43 BUNCHES OF $4 \cdot 10^{10}$ P^+ AT 7 TEV

The following steps must be performed:

1. Check of sensors readings and controls for beam-induced pickup noise.
2. Update of MCS input after beam-based calibration of collimators and taking into account the available machine aperture.
3. Check of interlock thresholds for jaw temperature.

8.6 156 BUNCHES OF $9 \cdot 10^{10}$ P^+ AT 7 TEV

The following steps must be performed:

1. Check of sensors readings and controls for beam-induced pickup noise.
2. Update of MCS input after beam-based calibration of collimators and taking into account the available machine aperture.
3. Check of interlock thresholds for jaw temperature.

8.7 936 BUNCHES OF $4 \cdot 10^{10}$ P^+ AT 7 TEV

The following steps must be performed:

1. Check of sensors readings and controls for beam-induced pickup noise.
2. **Update of MCS input for higher intensity (cleaning) and taking into account the available machine aperture (impossible to perform beam-based calibration of collimators with this intensity).**
3. Check of interlock thresholds for jaw temperature.

8.8 936 BUNCHES OF $9 \cdot 10^{10}$ P^+ AT 7 TEV

The following steps must be performed:

1. Check of sensors readings and controls for beam-induced pickup noise.
2. Update of MCS input for higher intensity (cleaning) and taking into account the available machine aperture (impossible to perform beam-based calibration of collimators with this intensity).
3. Check of interlock thresholds for jaw temperature.

8.9 HALF NOMINAL: 2808 BUNCHES OF $5 \cdot 10^{10}$ P^+ AT 7 TEV

The following steps must be performed:

1. Check of sensors readings and controls for beam-induced pickup noise.
2. Update of MCS input for higher intensity (cleaning) and taking into account the available machine aperture (impossible to perform beam-based calibration of collimators with this intensity).
3. Check of interlock thresholds for jaw temperature.

8.10 NOMINAL: 2808 BUNCHES OF $11 \cdot 10^{10}$ P^+ AT 7 TEV

The following steps must be performed:

1. Check of sensors readings and controls for beam-induced pickup noise.

2. Update of MCS input for higher intensity (cleaning) and taking into account the available machine aperture (impossible to perform beam-based calibration of collimators with this intensity).
3. Check of interlock thresholds for jaw temperature.

8.11 STAGES DEPENDING ON OPTICS REQUIRING TEST

The following steps must be performed for every significant change in optics:

1. **Beam-based calibration of all collimators (with special emphasis on TCT) for a few nominal bunches.**
2. **Check of sensors readings and controls for beam-induced pickup noise.**
3. **Update of MCS protection gaps for the experimental IR's.**
4. **Update of overall collimator settings for system consistency.**
5. **Check of interlock thresholds for jaw temperature.**

8.12 STAGES DEPENDING ON CROSSING AT IP REQUIRING TEST

The following steps must be performed for every significant change in crossing angle:

1. Beam-based calibration of TCT collimators for a few nominal bunches.
2. Check of sensors readings and controls for beam-induced pickup noise.
3. Update of MCS protection gaps for the experimental IR's.
4. **Possibly update of overall collimator settings is required for system consistency.**
5. Check of interlock thresholds for jaw temperature.