# SUMMARY OF THE COLLIMATION UPGRADE PLANS

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*Abstract*

The LHC collimation system is being implemented in a two-phase approach that was defined in 2004. The phase I has been fully installed in the machine and is presently being commissioned with beam. The system will be completed with the installation of phase II and performance will be upgraded. The completion and upgrade plans are summarized.

## INTRODUCTION

The LHC collimation project was set up by CERN management at the end of 2002 to define and implement a solution for the LHC collimation problem. A phased solution was proposed and approved in 2003. Such a phased approach was required due to the tight time constraints and the requirement to advance cleaning efficiency by 3 orders of magnitude beyond the state-of-the-art. The phase I of LHC collimation was then implemented from 2003 – 2009 during a six-year effort.

The phase I of the collimation system was optimized for robustness while accepting a predicted limitation in intensity reach for both ions and protons. The focus was put on completion of phase I, however, additional efforts and significant resources were invested to prepare the phase II slots already to the maximum (cables, supports, space, vacuum, …).

## EXPERIENCE WITH PHASE I

Before moving ahead with the second and final implementation step for collimation, we wanted to wait for phase I performance to be verified. By now there is very limited beam experience, all with very low beam intensity. However, we can already conclude that the experience with LHC beam has now proven the correct functioning of the phase I collimation system. An example of measured performance with beam in 2009 is shown in Fig. 1. The corresponding simulation result is given in Fig. 2. We note:

1. The measured data can be used to define a cleaning efficiency, as the ratio between the peak loss at collimators and the peak loss at any super-conducting magnet. We find a cleaning efficiency of 99.98% for the presented case (or a maximum leakage of $2\times10^{-4}$ to a super-conducting magnet). This is in excellent agreement with 450 GeV simulations performed in 2006.
2. Measurements were performed in 2009 in different planes and for both beams. Efficiency varies from 99.975% to 99.994% and should be compared to an efficiency of 99.988% that is used for LHC performance predictions.
3. The expected leakage to the super-conducting arcs is already seen at the expected level. Phase II is designed to address this leakage into the super-conducting arcs.

We can therefore conclude that the measured performance is in good agreement with prior simulations and surpasses the HERA cleaning performance by a factor 100. At the same time leakage of losses is seen to the predicted locations, including clear losses in super-conducting magnets. This already proves the validity and potential of the defined collimation path.

The already available results provide us with more confidence concerning the predicted limitation in the required collimation efficiency (5-40% limit for LHC nominal beam intensity).

It was therefore proposed at Chamonix in 2010 to now include completion of LHC collimation into the medium-term plan of CERN.

## PHASE II PROPOSAL

The phase 2 R&D work was accelerating since 2008, supported by additional white paper resources from the CERN member states [2] and EU funds [3]. A solution could be presented in 2009 at an international review for LHC collimation [4]. The proposal is described in detail in [5, 6]. The phase II deliverables are as follows:

1. Improve efficiency by a factor 15-90, both for proton and ion beams. This is achieved by installing additional collimators into the warm regions and special “cryo” collimators into the super-conducting dispersion suppressors.
2. Reduce impedance by a factor 2 without reducing efficiency.
3. Complete IR collimation for luminosity-driven losses, to be ready for nominal and higher luminosity.
4. Address a problem for signal acceptance in the ZDC in IR2.
5. Improve the IR6 protection for the Q4 against showers from the TCDQ dump protection.
6. Allow for automatic collimator setup.
7. Reduce radiation to most accelerator components and increase lifetime of warm magnets in the cleaning insertions.
8. Put in place the prepared handling of radioactive air.
9. Installs the agreed remote handling.

This will enable the LHC to handle nominal and ultimate beam intensities for proton and ion beams. Deciding in 2010 will allow completing the LHC collimation system by 2015.

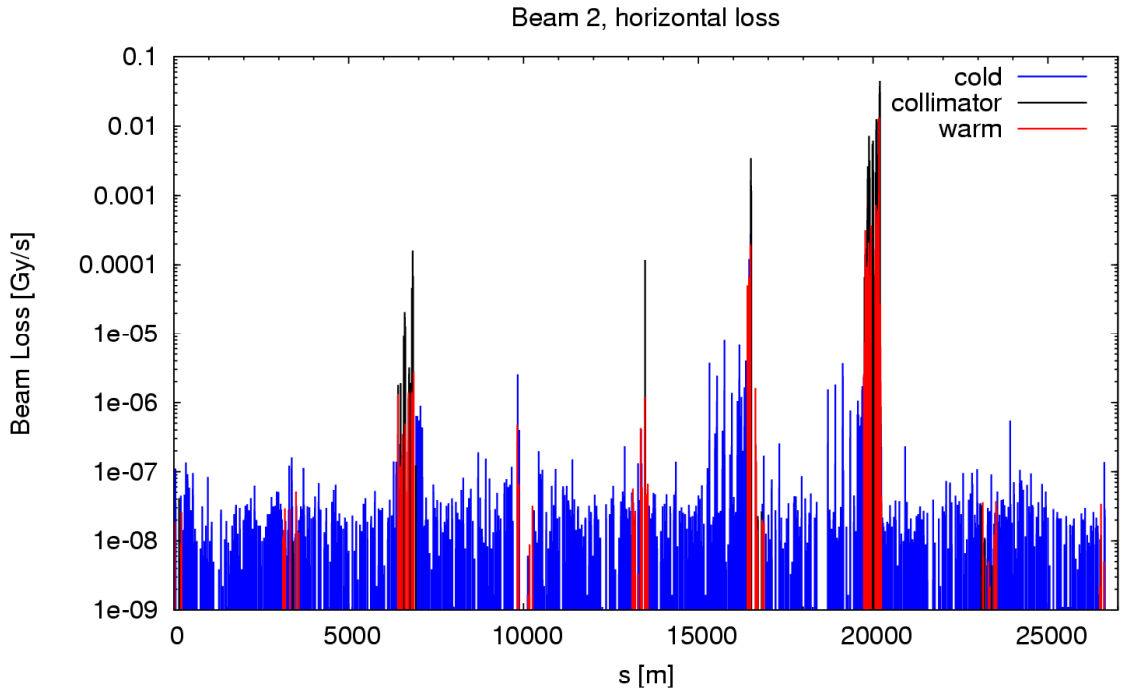


Figure 1: Example of a measured beam loss distribution around the LHC ring at 450 GeV. Horizontal beam losses were generated for beam 2 that goes from right to left. Losses were intercepted at the primary collimators in IR7. Clear losses are seen in the cold regions (blue bars) downstream of the cleaning insertions. Black bars indicate losses in collimators and red bars losses in room-temperature (warm) magnets.

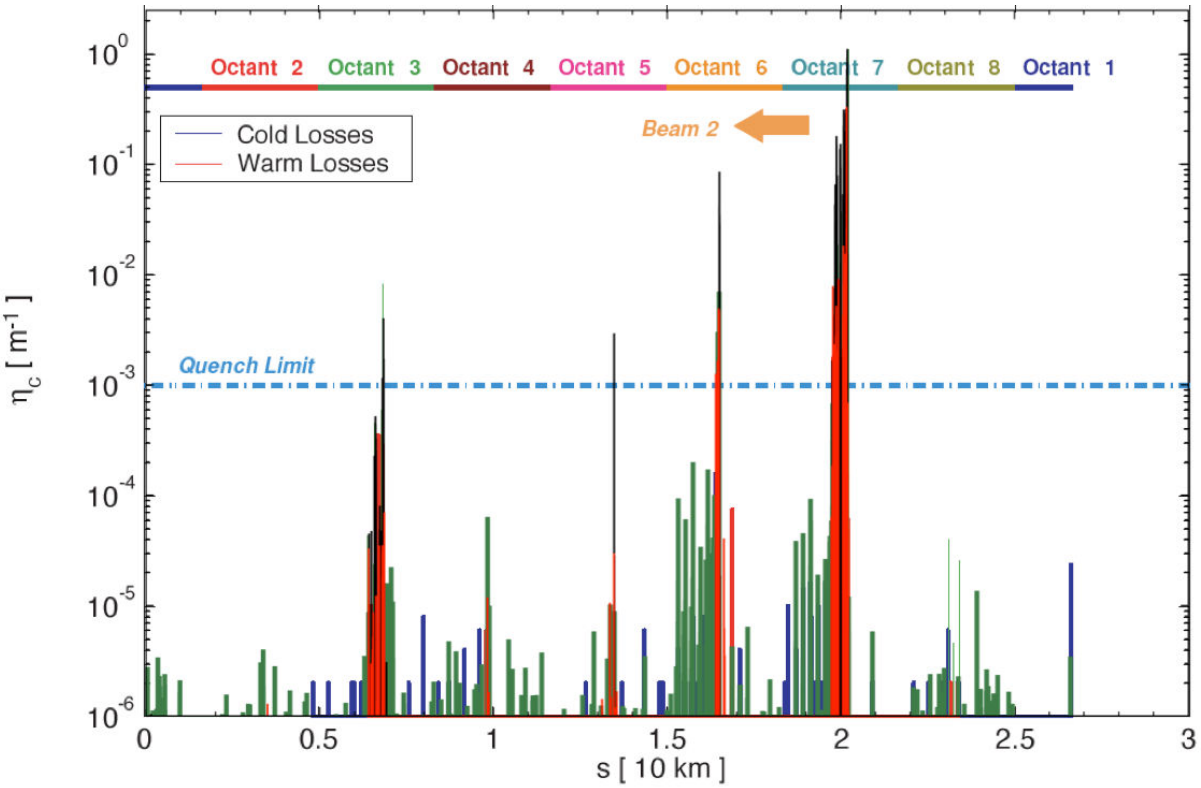


Figure 2: Simulated inefficiency ("beam loss") around the LHC ring for beam 2 losses at 450 GeV and with a worst case design orbit error. From [1].

The work program has been optimized after the end of Chamonix. Work will start only in IR3 and will then proceed to IR7 and IR2. This minimizes resources, should allow for first performance gains in 2013 and implements a solution in case of any problems with radiation to electronics in IR7. It is noted that the collimation upgrade program can be stopped or slowed down in case of any problems in IR3 or in case of lower than expected beam losses.

## DELIVERABLES AND MILESTONES

The proposed work plan is matched to the presently planned major shutdowns, in particular the 2012 long shutdown for splice consolidation and the 2014/15 long shutdown for connection of linac4. Any shifts in these shutdowns will affect the deliverables for LHC collimation phase 2. The following deliverables and milestones have been defined:

- **Year 2010:**
  - MTP input to CERN directorate. Approval of construction plan to 2013.
  - Summer: Assessment of feasibility of installing cryo collimators in IR3 in the long shutdown of 2012.
  - Start of cryo design and production for IR3 only. Continue ongoing R&D for phase 2 secondary collimators.
- **Year 2011:**
  - Summer: Review of lessons with LHC beam. Approval of construction plan to 2015.
  - Continuation cryo work and production for IR3 at full speed.
  - SPS and HiRadMat beam tests for phase 2 secondary collimators.
  - Start production of additional collimators: industry, CERN, SLAC.
- **Long shutdown end 2011 to beginning 2013:**
  - Implement cryo modifications and install 4 “cryo-collimators” for both IR3 dispersion suppressors.
  - Implement combined betatron/momentum cleaning in IR3 (install 10 collimators into the IR3 warm region).
- **Year 2013:**
  - The IR3 cryo collimation is operational. Combined betatron/momentum cleaning system is available in IR3.
  - Better collimation efficiency and lower impedance. Should allow for increased p and ion intensity.
  - Losses can be almost fully relocated to IR3 in case of IR7 problems with radiation to electronics.
- **Long shutdown 2014/15:**
  - Install 4 TCLP collimators in IR1 and IR5 (requires removal of TOTEM Roman Pots).
  - Implement **cryo** collimation in IR7 and IR2.
  - Install 30 phase II secondary collimators in IR3 and IR7 (complementing existing phase I collimators).
  - Install 2 hollow e-beam lenses as scrapers.
  - Install 2 new TCT’s in IR2 to solve ZDC acceptance problem.
  - Install 2 tungsten collimators in IR6 (improved cleaning downstream of TCDQ, avoid quenches of Q4).
  - Install the agreed remote handling for the highly radioactive LHC cleaning insertions.
  - Install missing equipment for IR7 air ducts and commission modified ventilation and air conditioning.
- **Year 2015:**
  - The phase II of the LHC collimation system is completed.
  - Intensity reach of the LHC is maximized and should allow ultimate intensity for both proton and ion beams.
  - The operational complexity of the collimation system is significantly reduced.
  - The high luminosity insertions IR1 and IR5 are ready for nominal and higher luminosity.
  - The IR2 insertion is equipped for nominal and higher ion luminosity.
  - The ALICE ZDC has full signal acceptance.
  - The weakness for Q4 in IR6 is removed.
  - LHC is equipped with remote handling for highest beam intensities.

It is noted that the presented work plan is success-oriented, trying to ensure that LHC luminosity can be increased as fast as possible and that collimation solutions are available when needed. The plan has unavoidable technical schedule risks.

## CONCLUSIONS

The plan for completion and performance upgrade of LHC collimation (“phase II”) has been summarized. After the Chamonix meeting the plan has been adjusted to the resource constraints over the next years. Technical details and explanations of the various ingredients of collimation phase II can be found in the references and have not bee repeated here.

## ACKNOWLEDGEMENTS

I thank the full collimation team for their terrific help in getting this system designed, produced, installed and commissioned over the last 7 years.

## REFERENCES

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[3] The EuCARD project at: http://www.cern.ch/eucard

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[5] R. Assmann et al, “Accelerator physics concept for upgraded LHC collimation performance”. PAC09. CERN-ATS-2009-080.

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