# Conceptual Design Review of a Phase II Collimation System for LHC

Report of the Review Committee

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The committee thanks the collimation project leader, Dr. Assmann, for the opportunity to review the plans for collimation at LHC. The committee also thanks the speakers for the effort that went into their presentations. A few committee members also greatly enjoyed a tour of the collimator installation in region 7.

The charge to the committee asked for a very broad assessment of the approach adopted for LHC collimation. This was not really feasible within the constraints of a one day review, with limited time for committee discussion. Instead the committee chose to focus on the next most urgent decisions: whether to proceed with the dispersion suppression collimators and with the HighRadMat test facility. Beyond that, the committee listed a number of areas that appeared to warrant further attention or clarification.

## 1. General comments:

Clearly, collimation for the LHC is a very complex problem which interacts with many other subsystems of the collider. The collimation system is of fundamental importance for successful LHC operation, both from the point of view of operability and technical safety. The collimation team is to be commended for the enormous progress made in the last few years. In addition to completing installation of the Phase 1 system, there has been substantial analysis of the different aspects of the collimation scheme. There has been a systematic and well structured approach to dealing with a diverse set of issues. The committee strongly endorses the staged approach which has been adopted for the overall upgrade of the collimation system. Practical experience from operating the phase-I system with beam will be invaluable to inform future choices and priorities.

## 2. Dispersion Suppressor Collimators (work package A):

The projected radiation and heat load deposited in the cold mass of the dispersion suppressor region appears in simulation to be a serious problem which will likely limit the maximum LHC operating current. The proposed solution of rearranging that region to make room for collimators is clearly a major project, but seems an appropriate solution. The committee also agrees that the components to be installed are sufficiently routine that R&D prototypes are not likely required. Given that the affected components will become increasingly activated (and radiation damaged) with LHC beam operation, it is advisable to proceed with this upgrade as soon as feasible.

The committee recommends that the group proceeds immediately to a conceptual design for this upgrade, and then to a detailed engineering design, assuming no show stoppers are encountered. This will allow the LHC management to make a final decision on whether to proceed with the upgrade, once there is some operational experience with the present system. It may also be possible to begin some preparatory work during the next long shutdown. The committee recommends that the warm solution should be pursued first, given the relative simplicity.

It was noted that a similar modification could ameliorate the known problems with collimation for ion beams. This also requires more design work before a decision, and this should proceed as well.

Some additional comments or concerns related to this upgrade:

- The present overall collimator system was optimized for cleaning efficiency, without particular consideration of losses in the dispersion suppressor. The question was raised whether a different configuration of primary collimators could minimize the semi-elastic interactions that wind up in the cold part of the machine without compromising overall efficiency. We recommend simulations to explore alternative configurations, such as thin metal primaries, before committing to the cold region upgrade.
- We recommend exploring whether fixed collimators could be used, as this would greatly simplify the technical solution.
- As part of the design, it is important to clarify whether flexibility of the beam optics in the dispersion suppressor section is compromised by the planned modifications.
- For ions, the collimators require two jaws, whereas only one jaw is needed for protons. This must be included in the design, especially if IP1 and IP5 must also be compatible with high luminosity with heavy ions.
- We recommend additional study of expected activation in IR7 as it may significantly impact later installation of these collimators.

**3. HIGH RADiation MATerials Test Facility:**

The committee endorses the importance of a test facility to verify the operation of the Phase-II secondary collimators before choosing an implementation solution. Such a facility could also support a wide range of materials tests and damage experiments. However, the material presented did not really detail the experiments to be performed or the diagnostics foreseen. These should be part of the proposal as well as an explanation of the unique features such a facility would offer compared with existing facilities.

## 4. Advanced Collimator Designs

For pragmatic reasons the committee used the limited discussion time to comment primarily on the proposed steps which need to be pursued most urgently. However, this fact should not be interpreted as an attempt to de-emphasize the efforts that were presented in context with the more advanced work packages B/C/D.

The development of a technical solution that could accommodate the full LHC beam intensity, and possibly even upgraded LHC parameters, clearly requires a broader R&D effort that includes also less conventional technical solutions. The approach to perform such R&D work in the form of collaborations with other experienced and accelerator oriented laboratories is strongly endorsed by the committee.

In particular we would like to mention the SLAC design of a rotatable collimator. These can rotate a new fresh surface to face the beam after an occurrence of beam induced damage. This allows them to use copper which has better conductance and a higher density. The technical design presented seems to be worked out thoroughly in many aspects such as thermal analysis, tolerances, manufacturing techniques and also experimental testing. Unfortunately the idea of integrated BPM s was not an initial design requirement, and SLAC is only now exploring ways of implementing button or cavity BPMs into their design. Also it is not completely clear how a severe beam impact will be detected, i.e. how a conclusive decision is made that the collimator has to be rotated by another increment. This also applies to the primary collimators and to other secondary collimator designs.

Another potentially very beneficial proposal consists in the application of a hollow electron beam that effectively functions as a beam scraper for the LHC proton beam. This hollow e-beam scraper might be an excellent solution to relax the sensitivity of the collimator loss rates with respect to small beam jitter, as it was observed at HERA or the TEVATRON. The committee recommends to further develop this idea and to investigate carefully the potential threats this system presents to the overall LHC beam quality. For example the p-beam will receive a net kick if the hollow e-beam is not uniformly distributed, and in combination with time dependent variations this can lead to emittance blowup of the p-beam core.

Other comments related to advanced collimators:

- For the collimators which can survive a few hits, the specification on minimum number of hits to be survived was not given. This should probably be specified in early 2010, after some operational experience. The rotatable collimators can accommodate 20 hits, the linear ones 5. The simplest adequate solution is clearly desirable.
- Some of the studies presented included imperfections (beam optics, collimator alignment etc.). Studies of the advanced secondary collimator scheme should also be done with these errors.
- We think the integrated BPM`s are an excellent idea, but there were concerns about their operational performance. The impact of showers and thermal effects on these BPMs should be studied. Another concern was mechanical play in the moving devices or backlash when changing direction. The possibility of rapid

testing of the concept in the SPS was mentioned in the presentations and this is strongly supported also by the committee.

**5. Additional comments or concerns (no particular order):**

- Data from the Kurchatov Institute was presented showing the variation of relevant material properties, such as electrical and thermal conductivity, with radiation dose. The expected radiation damage of LHC collimators should be brought in relation to the Kurchatov measurements. We think it important to clarify the time scale of possible performance degradation of the presently installed graphite collimators.
- The committee noted a possible weak point in detection of damage at the primary collimators. The concern was that one would observe degradation of cleaning efficiency but not know the origin. Temperature measurements alone may not be conclusive. The LHC operation with the phase I collimation system should be used to study methods for damage detection and to connect (offline) optical inspections of the collimator surfaces with observations gained during operation, as the planned archiving of microphone signals.
- It was suggested to study implementation of a thin scattering tip at the edge of the primary collimators to increase the local diffusion rate of particles beyond this amplitude. The faster diffusion should result in larger impact parameters and might help especially with the collimation of heavy ions.
- From HERA experience, spikes of loss rate are potentially very important and can be a dominant operational limitation. In particular, dust falling into the beam can cause extreme bursts of losses; e.g. from vertically movable Roman pots.
- Given the importance of controlling loss spikes, the committee felt that relying only on the hollow e-beam scraper R&D was risky (see comments above). The committee recommends that alternative schemes for creating a halo-free margin should also be explored.
- In particular, the team could consider and study the virtue of controlled halo cleaning by small local beam orbit motion at the main collimator to prevent halo from accumulating between spikes. Period and duration of the orbit approach to the main collimator would need to be optimized in order to compromise between minimizing the probability for the spike coinciding with the orbit bump and minimizing the enhanced rate during cleaning. This method was used in HERA successfully when running with a detrimental spike. While trying to find the source of a spike, the machine was kept running. This went on for about 6 weeks.
- With ion beams, it is difficult to capture primary scattered ions with a large energy deviation at the secondary collimators. The team could consider optimizing the dispersion at the main collimator (by detuning the dispersion suppressor). This would create a correlated betatron amplitude and phase associated with dp/p which could help improving the capture of these ions.

- The experiments requested clarification on what technical forum will be created to study interference between collimators and forward detectors in the experimental insertions. For example, an optimization of the TCL settings which takes into account both machine and physics constraints should be carried out and followed up in the identified forum.
- Lastly, experimental tests using the SPS etc. are encouraged whenever possible.