# Minutes of 6th Collimation Upgrade Specification Meeting

**Participants:** C. Adorisio (CA), F. Carra (FC), A. Bertarelli (AB), R. Bruce (RB), R. de Maria (RdM), L. Lari (LL), A. Marsili (AM) (scientific secretary), N. Mokhov (NM) (remote), S. Redaelli (SR) (chairman), M. Schaumann (MS), D. Wollmann (DW).

# 1 IR optics for high-luminosity upgrade (R. De Maria)

Slides are available at this link.

## 1.1 Summary of the presentation

RdM introduced optics models for a new 150 T/m triplet for the high-luminosity upgrade. This is not yet the final result as the layouts for the HL-LHC are not yet finalized; but this is the present best guess on working assumptions. The MadX inputs for the presented optics are available in this directory: `/afs/cern.ch/eng/lhc/optics`.

Down to 40 cm $\beta^\star$ , the optics changes is equivalent to the current squeeze, i.e. it is done by using only matching quadrupoles in the IRs. The ATS scheme squeezes further $\beta^\star$ , compensates the chromatic aberrations and changes the $\beta$ functions in the arcs. There are slight differences in the phase advance of the IR with respect to the nominal LHC. From 40 cm $\beta^\star$ to 15 cm, although the quadrupoles in IR1 and IR5 do not vary, the phase advance is slightly perturbed. 15cm (or more optimistically 10cm) is the minimum possible value with the new triplets for round beams to be used with the crab cavities. These optics also exist in a "flat" version, which is optimal if there is no crab cavity available.

The crossing angle was adjusted to get a 12 $\sigma$ beam-beam separation for round beam and slightly more for flat beam at the IP.

The contents of the directory were presented, including the `MadX` tools to create the models, and a specific file for installing crab cavities. SR asked if these new optics change the layout of the machine. RdM answered that it is the case. In addition, the modified aperture models can be found in the `aperture` sub-directory.

The layout changes were presented, as well as the new layout parameters. The $\beta$ function and dispersion at IP5, for the 40 cm and 15 cm $\beta^\star$ were presented. Few magnets are moved compared to the current design, and the consequent aperture changes were presented for different $\beta^\star$ (aperture increase in Q5). The phase advance around IP5 was also presented, for injection energy and collision energy. There is not much difference up to Q6.

The differences between the present crossing scheme and the new one were presented. The main difference is that the orbit bump starts in D2 instead of Q6. The crossing angles generate a dispersion beating (also in the arc). An orbit bump in the arcs around the high-luminosity insertions compensates the dispersion beating.

## 1.2 Discussion

Answering a question by SR, RdM point out that the 15 cm $\beta^\star$ assumes assumes 140 mm available aperture (no shielding) and conservative tolerances for aperture margins. 10 cm $\beta^\star$ assumes more optimistic assumptions on aperture and margins.

SR stated that this presentation was a very nice overview which will be used as input when the group will start simulations. All the needed optics (thin lenses) are already available for SixTrack.

# 2 Choice of materials for phase II collimator tests at HiRadMat (A. Bertarelli)

Slides are available here.

## 2.1 Summary of the presentation

AB presented the status and plans for the research on materials which could be used for the future collimators, and their different advantages and drawbacks. They will be tested with beam at the HiRadMat.

The collimator jaw design was briefly reminded. Each collimator jaw would be made out of 3 sectors, allowing to adjust their flatness and position independently. The current design includes Beam Position Monitors (button pick-ups) which are inserted in the jaws; a copper cooler, and a stainless-steel back-cooler.

A set of 5 *figures of merit* are used to qualify each material: the electrical conductivity, the Steady-state Stability Normalized Index (SSNI), the transient Thermal Shock Normalized Index (TSNI), the atomic number $Z$ and the melting temperature $T_m$. Optimizing these quantities leads to conflicting requirements: for instance, the density of the material usually increases with $Z$, which decreases the robustness.

One of the new materials which match the requirements is the family of Metal Matrix Composites (MMC). They combine the desired properties of metals with the ones of diamond and graphite. The considered materials are: Copper-Diamond (Cu-CD), Molybdenum-Diamond (Mo-CD), Sliver-Diamond (Ag-CD), Molybdenum-Graphite (Mo-Gr). The compared properties of these different material and those of the standard metals (C-C, Mo and Cu) were presented, showing the strong and weak points. For instance, C-C collimators have the best mechanical properties but the worst conductivity.

The main problem of the MMC is the bonding between the metal and the carbon. The diamond tend to degrade and present a graphitisation. The low melting point of some metals (Cu, 1083 ℃; Ag, 840 ℃) is another important issue. Irradiation tests are done or ongoing, to evaluate the degradation of conductivity.

Mo-Gr is a material only considered recently. It has many interesting properties, such as a high melting temperature, a lower density and a good robustness. Its main problems are the mechanical strength, which is being optimized, and a limited surface conductivity, which can be compensated by a pure Mo surface coating. The coating has to be thin enough otherwise the material will behave as pure Mo. Current values are as thin as 10 to 20 $\mu m$. [**Action: Elias**].

The numerical simulations describe the vaporisation and the explosion of the materials, corresponding of the real-case scenario of and accidental impact. The corresponding experimental tests will follow and have never been done before.

Six different materials will be tested: Tungsten, Copper, Molybdenum, Cu-CD, Mo-CD, Mo-Gr. Three types of data acquisition will be used: Laser Doppler Vibrometer, High speed

Camera (30 000 fps) and strain gauges. The main issue is to get enough light for the camera. The design is nearly completed and the manufacturing has started. It would be installed at some point between August and October 2012 for a test in November.

## 2.2 Discussion

SR asked if it possible to gain on robustness. AB answered that lowering cleaning efficiency allows to gain on many other parameters such as robustness. The fact that the new materials are designed on purpose makes them adjustable. SR commented that this could be an option to improve TCT materials in the IRs, e.g. for a better robustness.

NM pointed out that the robustness is very important, and that the radiation hardness is a very sensitive point. The results recently achieved by N. Simos at BNL are interesting but discouraging because the materials seem to be orders of magnitude more sensitive to degradation at cryogenic temperatures than at room temperature. In addition, composed materials are less radiation resistant than simple material. NM asked about the integrated irradiation. LL said that it is $10^{-4}$ DPA per year of nominal beams. AB stressed that the radiation damage aspects are important for us. NM suggested that beam tests could be done for collimator materials at BNL, possibly within the US-LARP program. SR will be at the US-LARP collaboration meeting at the beginning of May and will discuss this option with the colleagues in USA [**Action: SR**].

LL pointed out that there are differences in temperature calculations coming from different codes. The order of magnitude differences in DPA could come from the codes used (Fluka).

# 3 Collimator upgrade scenarios for impedance calculations (S. Redaelli)

SR presented different options for collimator settings in the LHC, in the running periods after the different long shutdowns (LS1, 2, 3). First, a time line presented the different luminosity objectives. The required modifications will be completed during different long shutdowns. After LS1, nominal performance (close to $10^{34}\,\mathrm{cm^{-2}s^{-1}}$ at 7 TeV) will be achieved; after LS2, the luminosity should be doubled; after LS3, the high luminosity LHC (HL-LHC) should be achieved.

SR reviewed the goals for collimator upgrades: to improve the performances — if needed — and manage the replacement of collimators. It represents an opportunity to install newly designed collimators.

LS1 represents the first opportunity to upgrade the system. The installation of a cryogenic collimator was postponed to LS2. The main activity is the replacement of the TCTs in all IRs with an integrated BPM design (?). During LS2, the upgrade could include new materials for TCTs, and collimators in the dispersion suppressors (DS) if the 11 T dipoles are ready. The installation of cryogenic collimators in the DS of IR3 (combined betatron and momentum cleaning), initially foreseen for LS1, has been postponed because the present performances indicate no limitations from magnets quenches after LS1 (cf. ColUSM2, presentations from Chamonix 2012).

The different types of settings: *relaxed, nominal* and *tight*. Tight settings at 4 TeV correspond to the nominal 7 TeV settings in millimeters. All these already good results do not take into account the extra improvement gained from the integrated BPM design. The baseline for max performance reach remains the nominal settings (canonical $6/7\,\sigma$ for TCP/TCSG). Relaxed settings are considered to match the operation conditions (orbit stability, $\beta$ beat)

The settings used in 2012 were presented, insisting on the collision settings. A reminder of all collimator openings was given.

Three consecutive upgrade scenarios were presented. After LS1, only a few changes would be applied (mainly TCTs with integrated BPMs). This would allow achieving nominal settings, with only $1\,\sigma$ difference between the primary and the secondary collimators.

After LS2, the extra collimators in the dispersion suppressor might be installed. One might consider starting to add the metallic collimators (TCSM) with the proper material, if needed for impedance or if if the collimators have to be replaced due to aging. After LS3, several cases are possible. The two first ones would be the same as presented just before, with extra DS collimators around the interaction points. The two other cases correspond to extra DS collimators installed respectively around IR7, and IR7 and 3. It is too early to consider the re-design of the insertion regions.

In conclusion, these slides presented a preliminary starting point for a discussion, and starting conditions for calculations. The benefits from an integrated BPM design are under evaluation. SR commented that the slides will be sent to the impedance team for first feedback and corrections.

### 3.1 Discussion

DW pointed out that the study should show what would be more beneficial in term of machine protection and $\beta^\star$ .

## 4 Next meeting

The next meeting will be held on:
**25th May 2012, 16:00–17:30.**
**Room: 874-1-011 (above CCC).**

**Tentative agenda:**

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| Mikko Karppinen | Present status of the 11 T model program |
| Bernhard Auchmann | Preliminary field quality, thermal aspects and quench margins |