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## International Review of the HL-LHC Collimation System

**Date:** 2019-02-11 to 2019-02-12

**Project/Activity:** WP5

**Attendees:** C. Adorisio, S. Antipov, A. Apollonio, G. Arduini, G. Azzopardi, V. Baglin, C. Bahamonde Castro, E. Belli, A. Bertarelli, G. Bregliozzi, R. Bruce, O. Brüning, X. Buffat, F. Carra, F. Cerutti, P. Chiggiato, M. D'Andrea, R. De Maria, A. Fomin, N. Fuster Martinez, H. Garcia Gavela, H. Garcia Morales, S. Gilardoni, M. Giovannozzi, A. Gorzawski, I. Lamas Garcia, A. Lechner, R. Losito, A. Masi, A. Mereghetti, J. Mestrel, E. Metral, D. Mirarchi, M. Modena, J. Molson, M. Pasquali, D. Perini, Y. Papaphilippou, S. Redaelli, A. Rossi, L. Rossi, B. Salvachua Ferrando, B. Salvant, M. Schaumann, R. Tomas Garcia, A. Verweij, A. Waetz, D. Wollmann, M. Zerlauth

**Review Panel:** R. Aßmann (DESY), W. Fischer (BNL), M. Lamont (CERN), M. Seidel (PSI, Chair), A. Sublet (CERN), W. Venturini (CERN).

**Agenda:** [indico page](#)

### **DISCUSSION**

Disclaimer: these minutes report only the content of the discussions.

#### **1. S. Redaelli – Collimation upgrade plans ([Indico](#))**

- **M. Seidel** asks what the tightest settings of primary collimators are. **S. Redaelli** replies that, while in 2018 the tightest settings were  $5\sigma$ , in the case of HL-LHC the tightest settings would be  $\sim 6\sigma$ , hence more relaxed. Moreover, the retraction between secondary and primary collimators envisaged for HL-LHC is larger than that achieved in 2018. The motivation of this choice is that presently the minimum gap of the TCDQ dump protection device (not under the responsibility of work package 5, WP5) has a minimum allowed gap for protection reasons. In the present baseline this constraint ultimately limits the  $\beta^*$  reach.
- **W. Fischer** asks if the review panel should make recommendations on the number of dispersion suppressor (DS) collimators (TCLDs). **S. Redaelli** replies affirmatively.
- **R. Aßmann** wonders if the collimation specifications (specs) have been updated in view of HL-LHC or new ones have been formulated, e.g. for estimates of total doses in the insertion region (IR) 7. **S. Redaelli** replies that this is indeed the case; in fact, the scenarios are the same as those used for the LHC collimation system (e.g. 0.2 h lifetime for quench assessment) but taking into account the new beam parameters planned for HL-LHC. **S. Redaelli** also reminds that crystals are presently considered only for ions. **O. Brüning** underlines that crystal collimation is a funded R&D program but its implementation is not yet in the baseline. Radiation aspects are addressed by **F. Cerutti** for IR1/5 but there is no dedicated presentation on the IR7. **S. Redaelli** comments that new passive protection is being added in IR7 in the scope of the Consolidation project and **A. Lechner** comments that the present estimates of equipment lifetime are within limits for the luminosity goal of HL-LHC.
- **W. Venturini** asks if there has been any update with respect to the HL-LHC technical design report for WP5 circulated by **S. Redaelli** before the review. **S. Redaelli** replies that only the location of the TCLD and the final number of upgraded secondary collimators in IR7 have been changed.
- **L. Rossi** asks if the cleaning action performed by hollow electron lenses (HELs) is in opposition to that of crystals. **S. Redaelli** replies that HELs allow to control the tail population, but cannot mitigate against fast losses from the core like those during instabilities. In these cases, a better cleaning is the only mitigation. **G. Arduini** underlines that HELs enhance the diffusion speed of beam particles, and they are not meant to catch anything.



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## 2. R. Bruce – Overview of present collimation performance ([Indico](#))

- **R. Aßmann** asks why the stored energy in 2017 went down and then was limited in 2018. **R. Bruce** replies that the reason is the problem in 16L2, which is not related to beam tails and related losses.
- **R. Aßmann** asks for more details on protection in the experimental insertion regions for HL-LHC. **R. Bruce** replies that physics debris collimators (TCLs) are mainly for protecting the matching section (MS) against the collision debris; for the inner triplet (IT), the main limitation until the HL-LHC upgrade is the load on its cryogenic system, not curable by the collimation system.
- **R. Aßmann** comments that there were quenches during beam operation. **S. Redaelli** clarifies that these quenches were mainly induced by unidentified falling objects (UFOs), which generate local losses that cannot be addressed by the standard cleaning. There were also other spurious quenches, with none caused by collimation losses. **A. Lechner** specifies that, in case of UFOs, quenches occur locally at the magnet where the UFO takes place.
- **O. Brüning** remarks the impressive reduction of margin between tertiary collimators (TCTs) and the IT achieved in Run II. He wonders if this reduction could be maintained in the HL-LHC era with crab-cavities (CCs). **R. Bruce** replies that there are no obvious reasons why this should not be the case but this aspect should be checked in detail.
- **W. Fischer** asks what is the impact of secondary particles emitted by TCTs in case of an asynchronous beam dump (ABD). **R. Bruce** replies that those particles reach the downstream superconducting magnets and the experimental detectors. Measurements performed by the LHC experimental collaborations at the HiRadMat facility showed that the foreseen levels of radiation can be safely stood by the installed electronics (the estimated values are two orders of magnitude below damage limits).
- **R. Aßmann** asks what would limit tightening further collimators in the HL-LHC era. **R. Bruce** replies that the present bottleneck is the TCDQ, and more pushed settings would have been proposed if this limitation was not there. **S. Redaelli** adds that the HL-LHC success relies on many levelling scenarios; therefore, the overall performance is not strongly dependent on  $\beta^*$ , but he agrees that the known limitations should be removed. For example, tightening the hierarchy could be the only mitigation in case of unforeseen aperture limitations.
- **W. Venturini** asks about the present understanding of beam tail population. **R. Bruce** replies that collimator scans were performed in Run II, showing a high tail population (more detail to be presented by **B. Salvachua**).
- **M. Seidel** asks if there are plans of inspecting collimators in the long shutdown 2 (LS2). **S. Redaelli** replies that during LS1 some collimators were removed and opened, but no sign of damage was found. **S. Gilardoni** comments that detailed inspections can only be done by cutting open collimators and CERN is not equipped to open radioactive devices.

## 3. B. Salvachua – Beam losses, lifetime and operational experience at 6.5 TeV ([Indico](#))

- **R. Aßmann** asks if there is an understanding for the difference between the losses of the two beams. **B. Salvachua** replies that the differences, which can be up to a factor 2, are not understood.
- **W. Fischer** asks if a tail population of 5% beyond  $3.5\sigma$  found in measurements is a figure kept also for HL-LHC. **O. Brüning** underlines that this figure implies 30 MJ of energy stored in beam tails with HL-LHC beam parameters, and failures of CCs with tails so highly populated cannot be neglected. **S. Redaelli** confirms that the extrapolation to the HL-LHC era is very challenging, but the presence of highly-populated tails is consistently observed at the LHC. **M. Lamont** asks if the overpopulated tails develop during the LHC cycle or if they come from the injectors. **B. Salvachua** replies that measurements during



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machine developments with single bunches and end-of-fill tests consistently observed overpopulated tails; however, there are no measurements with full machine at different stages in the cycle, hence there is no final answer.

#### 4. A. Mereghetti – Performance of new designs deployed in Run II and plans for Run III ([Indico](#))

- **A. Mereghetti** shows the peak dose values received by the warm quadrupoles downstream of the primary (TCP) collimator estimated for the HL-LHC era; values are within acceptable levels. **A. Lechner** confirms that those values have been estimated at best with the present understanding of yearly-integrated losses. **F. Cerutti** reminds that dosimeters have been installed at the IR7 warm quadrupoles and results are being analysed.

#### 5. A. Lechner – Cleaning upgrades in the dispersion suppressor ([Indico](#))

- **L. Rossi** asks for confirmation if a main dipole quenched during the 2015 bound-free pair production (BFPP) quench test. **A. Lechner** confirms that the quench at 6.37 Z TeV occurred at a dipole and reminds that the quench level at 7 TeV is expected to be lower by ~20%. **A. Lechner** also points out that machine time was allocated in 2018 to repeat the test, but there was no beam in the injectors during the allocated time; since the test was scheduled immediately before LS2, there was no possibility to re-schedule it.
- **R. Aßmann** asks if the estimation of the losses via simulation is performed by considering an ideal machine only. **A. Lechner** replies that this is the case. However the predicted signal of beam loss monitors (BLMs) is a factor 3 lower than that measured in the DS; this factor is thus taken into account when estimating values of energy deposition for the collimation quench tests (both with protons and ions).
- **M. Seidel** observes that the peak power density of ~50 mW/cm<sup>3</sup> predicted for the HL-LHC takes place in the 11 T dipole upstream of the TCLD collimator; hence, the baseline upgrade is opened to the risks from high loads in the dipole. **A. Bertarelli** and **S. Redaelli** comment that the deployment of Molybdenum-Graphite (MoGr) as jaw material for the TCPs implies a decrease by 10–15% of losses in the 11 T dipole (the simulations were run with TCPs in graphite), but indeed these values are close to the estimated quench limits (see below).

#### 6. E. Skordis – Quench performance and assumptions: simulations and beam tests ([Indico](#))

- **R. Aßmann** asks which collimator settings were used for the proton collimation quench test. **S. Redaelli** and **R. Bruce** reply that the 2015 collimator settings were used, i.e. 5.5 and 8  $\sigma$  for TCPs and secondary collimators (TCSGs), respectively. The tested TCP-TCSG retraction is larger than that of the HL-LHC baseline but it is used as a case-study to benchmark simulations. **F. Cerutti** underlines that it was seen in simulation that the settings of the IR7 shower absorbers (TCLAs) have a relevant impact on the load in the DS.
- **L. Rossi** asks clarifications about the origin of the factor 5 of discrepancy between the predicted and measured BLM signals of the ion collimation quench test. **A. Lechner** replies that this was the result of previous simulations, with a different beam impact parameter; the one presently considered is more pessimistic in terms of losses in the DS, and gives rise to a factor 3 of discrepancy, compatible with what



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is found for protons. **R. Bruce** specifies that the impact parameter currently considered in simulations is  $\sim 1 \mu\text{m}$ ; **R. Aßmann** observes that this value is very large compared to predictions based on halo diffusion, amounting to  $\sim \text{nm}$ . **S. Redaelli** comments that larger impact parameters are obtained in presence of large beam losses, as those achieved in these tests; moreover, the total losses are extremely high in these tests, and the experimental set-up is complex. The quoted “discrepancy factors” should be considered as a very good success.

- **L. Rossi** observes that the peak value of  $25 \text{ mW/cm}^3$  was kept during the proton quench test only for a short time, underlying that the time profile of the loss may explain the missed quench despite of the high load. **S. Redaelli** confirms that this might be an explanation and pointed out that the correct time profiles of losses were well known to the magnet team in the process of estimating the quench limits.
- **R. Aßmann** acknowledges the efforts made in benchmarking simulations against measurements, and he thinks that a factor 3 of underestimation is a good success.
- **R. Aßmann** observes that  $400 \mu\text{rad}$  of tilt angle at the TCP is very large. **W. Venturini** wonders if it is possible to mitigate the misalignment angle. **E. Skordis** confirms that, as expected, simulations show that the local cleaning inefficiency in the IR7 DS is improved by mitigating the misalignment imperfections; he notices that the effects seen on beam 1 (B1) are anyway smaller than those observed on B2, hinting to the fact that either there is no misalignment or it is very small and has no big effect. **A. Mereghetti** reports that an angle of  $\sim 150 \mu\text{rad}$  is seen at the BPM of the horizontal primary collimator of B1; he also reminds that the tests were done with B2 on the same plane; finally, he confirms that once the angles are dealt with by operational functions, the effect from the angle can be mitigated.
- **R. Aßmann** suggests to take into account also other sources of imperfections in the simulations, like the machine aperture. **E. Skordis** replies that, while it is more than possible that such imperfections are there, the underestimation of the BLM signal is equally observed in cell 9 and 11. Since any local machine aperture imperfection should not equally effect both group of losses, a misalignment scenario that affects both cells seem more probable. He also underlines that, while a value of  $400 \mu\text{rad}$  might seem large, for the purpose of the simulation study such a value can be regarded equivalent to a  $200 \mu\text{rad}$  misalignment and a  $60 \mu\text{rad}$  offset of the jaws closer to the beams.

## 7. L. Bottura – Quench performance and assumptions: magnets and cryogenics ([Indico](#))

- **O. Brüning** asks if **L. Bottura** can confirm that  $\text{Nb}_3\text{Sn}$  is more heat-tolerant than Nb-Ti. **L. Bottura** replies affirmatively, underlying the factor 2 difference on quench limits. He adds that the quench limit of  $70 \text{ mW/cm}^3$  at 7 TeV is calculated by averaging the power density on the cable cross section, whereas if the radial peak is taken, the quench limit is  $100 \text{ mW/cm}^3$  (lower side of the range inferred from measurements at the SM18).
- **W. Venturini** notices that for losses on intermediate timescales, Nb-Ti is better than  $\text{Nb}_3\text{Sn}$ . **L. Bottura** confirms the observation, but adds that predictions for Nb-Ti in these time scales depend a lot on the assumptions about the heat transfer to the helium bath. **L. Rossi** comments that the actual amount of superfluid helium impregnating the cable matters a lot, which actually varies in the machine, from location to location.



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- **M. Seidel** asks what the uncertainty of the estimations of the quench limit of the 11 T dipole is. **L. Bottura** replies that these estimations are quite solid, as they rely on measurements performed in conditions very well controlled<sup>1</sup>.

## 8. N. Fuster Martinez – Operational experience with ions ([Indico](#))

- **W. Fischer** notices that the design goals of HL-LHC with ions have been almost reached already in Run II; hence, it is very likely that the performance with ions in the HL-LHC era will exceed the design goals. He wonders what will be the next bottleneck. **S. Redaelli** and **G. Arduini** reply that the limiting factor will probably be the performance of the injectors. **W. Fischer** wonders what will limit the luminosity reach in ATLAS and CMS. **O. Brüning** underlines that ALICE, the detector dedicated to data taking with heavy ion beams, should perhaps not run at luminosities lower than that of the other experiments. **J. Jowett** adds that this constrain was applied in the past but no longer since 2018, as ATLAS and CMS got twice as much integrated luminosity as that of ALICE<sup>2</sup>.
- **M. Lamont** asks if the collimator settings used during the ion data taking can be further improved. **R. Bruce** replies that there is not much room for improvement, since the system effectively behaves as a single-stage cleaning system, with fragmented ions leaking out to DS cold magnets. He also adds that there could be room to optimise the dispersion function, but this would entail a relevant dispersion wave. **S. Redaelli** remarks that in the context of the R&D activity of crystals with heavy ion beams, several tighter IR7 collimator settings were tested with ions, with no relevant improvement in performance.

## 9. F. Savary – Status of the 11 T dipole project ([Indico](#))

- **W. Fischer** notices the tight schedule for installation of the 11 T dipoles in IR7. He wonders what happens if the schedule is not respected. **L. Rossi** acknowledges that there is the chance to miss the installation on one beam, but there might also be other reasons for delaying the end of the LS2; in that case, the management may accept to extend the LS2, opening to the possibility of the late installation of the 11 T dipoles. In case of delays, another possible installation window could be the first available extended year end technical stop (EYETS), since the feasibility of exchanging a cold magnet within some months was demonstrated during EYETS2016. **O. Brüning** underlines that the actual LIU beams won't be available for at least the entire first year of Run III. **S. Redaelli** asks if there is a deadline for decision of installation; **F. Savary** replies September 2019.
- **M. Lamont** wonders if every assembly (i.e. 11 T and cryogenic by-pass) will be fully validated on the test bench. **F. Savary** replies negatively; **O. Brüning** adds that the complete assembly cannot be transported to the tunnel in any case and therefore needs to be disassembled before installation in the tunnel. Testing by individual components before installation in the tunnel therefore seems to be sufficient.

## 10. E. Metral – Impedance models, operational experience and expected limitations ([Indico](#))

- **W. Fischer** wonders if all the stripes tested with the prototype of upgraded secondary collimator (TCSPM) are suitable for the impedance upgrade of the IR7 collimators. **E. Metral** and **S. Antipov** remark that already with Mo coating, octupoles will be operated at full current, taking into account the factor 2 of

<sup>1</sup> Offline: **L. Bottura** remarks that, due to the different heat transfer mechanisms in Nb<sub>3</sub>Sn and Nb-Ti coils, magnet experts are relatively more confident in the values of the 11 T dipole than in those of the regular LHC MB.

<sup>2</sup> It should be noted that, in the same year, ATLAS and CMS took data at a peak luminosity 6–7 times that of ALICE.



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discrepancy between the required current predicted by simulations and that operationally needed. **S. Redaelli** adds that Mo-coating behaved well in HiRadMat tests, and hence TiN was definitively dropped from the pool of possible coating materials.

- **R. Aßmann** underlines that asymmetric settings could be useful to increase the intensity reach. **A. Bertarelli** suggests that shorter secondary collimators can be an alternative. **S. Redaelli** replies that with asymmetric settings there is a gain of 10–15% in octupole current, but cleaning inefficiency should be handled carefully, keeping in mind the exposure of the upstream 11 T dipole to losses.
- **W. Fischer** wonders what are the assumptions on linear coupling for the impedance estimations presented by **E. Metral**. **E. Metral** replies that all estimations are done supposing that linear coupling is corrected below a value specified in [1].
- **W. Venturini** wonders if the limit in octupole current currently considered comes from the hardware or from other considerations. **G. Arduini** replies that it is important to have a good trade off between stability and dynamic aperture. Moreover, it is important to keep in mind the factor 2 quoted by **E. Metral** on required stabilising octupole current. **E. Metral** stresses the fact that such a factor 2 is not a safety margin, but it is due to a source term to beam instability presently seen in measurements and not yet fully understood; the most likely source is noise from the transverse damper and power converters, still under careful investigation.

## 11. **H. Garcia Morales – IR collimation upgrades: incoming beam** ([Indico](#))

- **R. Bruce** underlines that TCT jaws in W would not survive an asynchronous beam dump (ABD) if there is no good phase advance from the dump kickers (MKDs). **M. Lamont** asks what the phase advance between TCTs in cell 6 and 4 is; this is close to zero at small  $\beta^*$ .
- **M. Lamont** wonders if the loss of a single bunch on a TCT was realistically seen in operation. **S. Redaelli** replies that in this accidental case the beam would drill a hole in the jaw, as seen in HiRadMat tests. **R. Bruce** adds that a more likely operational failure case where such a loss could happen is during BLM-based collimator alignments with jaws very close to the beam; otherwise, it is unlikely to hit the TCT with full machine.
- **S. Redaelli** asks if the reviewers can give feedback on the choice of Copper-Diamond (CuCD) as better material to sustain single bunch impacts on the TCTs. On one hand, CuCD is not as good as W in absorbing secondary particle showers that leak to the IT and the detector; on the other hand, a TCT in W would imply that TCTs are devices that can be sacrificed and replaced in case of impact, with consequent machine downtime.

## 12. **F. Cerutti – IR collimation upgrades: outgoing beam** ([Indico](#))

- **O. Brüning** underlines the very good flexibility of the IR collimation design in the experimental IRs, given the relative large aperture of the absorber of neutrals (TAXN). **S. Redaelli** remarks that the present LHC layout with TCL collimators in cell 6 (TCL.6) is quite a luxury, since TCL.6 collimators are actually re-used TCTs. He asks, in case of a forward physics program in the HL-LHC era, what is the tolerance on TCL.5 settings. **F. Cerutti** replies that this aspect should be studied, provided that there are specs about the forward physics program. **O. Brüning** comments that no consistent request has been prepared by the experiments so far.



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- **R. Aßmann** wonders if CCs have been taken into account and how they change the picture. **F. Cerutti** replies that they are present in the FLUKA model, and the radiation levels they undergo have a significant dependence on the preceding vacuum layout. It would be interesting to have reference figures to set acceptable limits. **O. Brüning** adds that such a request has been forwarded to the team in charge of developing CCs for HL-LHC, but no reply has come so far; nevertheless, the presently investigated TAXN aperture reduction should have a beneficial impact on them as well. **S. Redaelli** asks if the CC kick can be taken into account in FLUKA studies. **F. Cerutti** replies affirmatively.

### 13. P. Fessia – Plans and goals for remote alignment and impact on collimator designs ([Indico](#))

- **M. Lamont** wonders what will be taken as fiducial for the remote alignment. **P. Fessia** replies that all the systems will be horizontally aligned against a reference wire, pulled between TAXS and Q5, while the vertical reference will be the Hydraulic Levelling System that will also cover the same sector of the machine. He also adds that the machine protection team (MP) asked to put in place interlock logics. **D. Wollmann** remarks that, when elements are re-aligned, there might be the need to re-validate the machine. **O. Brüning** also adds that procedures on how to carry out the alignment efficiently should be laid down.

### 14. A. Rossi – Review of hollow e-lenses ([Indico](#))

- **M. Lamont** comments that the figure of 5% of total beam intensity contained in beam tails outside 3.5  $\sigma$  is quite high. **B. Salvachua** confirms that this value comes from scraping measurements performed at flat top. **O. Brüning** adds that the origin of this high tail population is not known yet; nevertheless, it is not granted that highly populated tails won't be present in the HL-LHC era, so machine experts should be prepared to deal with them. **S. Redaelli** underlines that measurements were done with small beam emittances, which will be present also in the HL-LHC era.
- **M. Seidel** wonders if there are requirements on the electron beam uniformity. **A. Rossi** replies that work is still on-going, e.g. evaluating with simulations the effect of imperfections in the hardware. **S. Redaelli** adds that it will also be important to define an acceptance criterion on the rotation of the electron beam, which is related to the stability of the electron beam.

### 15. I. Lamas Garcia – Status of LS2 production and prospect for LS3

- **R. Aßmann** wonders if the jaw flatness is verified after relevant manipulations during the collimator production like rotation. **I. Lamas Garcia** replies that the required tolerance is 40  $\mu\text{m}$ , and it is checked before and after the installation of the jaw in the tank. **S. Redaelli** underlines that the requirements on the collimator jaw flatness are the same as those used to qualify present LHC collimators. **A. Bertarelli** adds that the tolerance on jaw flatness takes into account the installation angle of the collimator. **S. Redaelli** remarks that the acceptance limit on the jaw flatness of present TCTs is 100  $\mu\text{m}$ , thanks to the high values of the optics  $\beta$  function at the location of installation.
- **R. Aßmann** wonders about the lifetime of roll-screws. **I. Lamas Garcia** replies that they have been tested until failure in the workshop in building 272. **A. Bertarelli** adds that the specification of their lifetime is 30'000 cycles. The present test cycles are different from those deployed in the past, since the new tests aim at replicating the slow movement of collimator jaws during the LHC energy ramp. **S. Redaelli** adds



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that brushless motors are another R&D line being currently explored. **F. Carra** reports that other R&D effort is being put on lubricants or even to find solutions without lubricants at all. **S. Gilardoni** adds that there is a contact with a company in Geneva for designs with and without screw lubricant. **S. Redaelli** remarks that Run II was a very quiet running period under this point of view; **I. Lamas Garcia** highlights maintenance as key activity for such a result.

## 16. A. Bertarelli – Performance of new HL collimator designs

### [\(Indico\)](#)

- **R. Aßmann** asks if there is a specific problem with the geometric impedance of collimators. **E. Metral** and **S. Redaelli** reply that there is no specific issue. The design of the upgraded collimator is effective in reducing the resistive wall impedance to the level that the geometric component is now visible (see plots presented).
- **O. Brüning** wonders how realistic the injection failure scenario is. **A. Lechner** replies that, in order to take place, the injected beam should completely miss all the injection protection collimators in LHC (i.e. TDI, TCLIA and TCLIB), which is practically impossible.
- **R. Bruce** underlines that the deformation for 0.2 h beam lifetime is an elastic one, with no permanent effect. **S. Gilardoni** makes the attendees note the different signs of the sagitta with respect to the 1 h beam lifetimes; **A. Bertarelli** confirms the remark, underlining that for the 0.2 h beam lifetime the jaw always moves towards the beam ('+' sign).
- **A. Sublet** asks if there are solutions against the jaw deformation in the case of the 0.2 h beam lifetime. **A. Bertarelli** replies that as mitigation actions the design could be changed. Possibilities include deploying HIPped jaws or jaws with a reduced length; in the latter case, the sagitta would be roughly reduced by a factor 4 assuming the same energy deposition per unit length, since it depends on the square of the length. However, effects on the cleaning performance should be addressed. **A. Lechner** remarks that shorter TCSPM jaws imply higher long-term load on downstream magnets. **R. Aßmann** wonders if there should also be a relevant degradation of the performance; **A. Lechner** comments that proton impacts on the secondary collimators are quite deep, so there should be a minor change in cleaning whereas a more important one on shower development.
- **M. Seidel** asks if a variation in surface conductivity within the production series is expected. **A. Bertarelli** replies that the surface conductivity is verified on every single block with sigma test, an RF eddy current system, which is a commercial instrument. The test is very fast (~1 s) and almost priceless. Variations of the order of 10 % have been seen so far.
- **R. Aßmann** wonders if the performance of the TCSPM collimators in terms of impedance gets degraded by a beam impact like in a failure scenario. **A. Bertarelli** replies that the bulk material has a very good conductivity, hence impedance-wise a scratched surface is not a complete disaster; moreover, the transverse extension of the damage seen in HiRadMat experiments emulating failure scenarios is small, with a limited impact on impedance. **E. Metral** confirms the statement; **S. Gilardoni** adds that a similar conclusion was drawn with tests dedicated to the TDI. **S. Redaelli** comments that in case of a suspect of damage to the coating, the size of the scratch is small and an undamaged surface can be newly exposed to the beam by means of the 5<sup>th</sup> axis functionality; he also underlines that so far there was no need to deploy this functionality.
- **L. Rossi** expresses interest in the option of shorter collimators. **A. Bertarelli** underlines that, in addition to a reduction of the costs, there are several other beneficial effects from a TCSPM design with shorter





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jaws, i.e.: lower overall load on the jaw, smaller bending for the same load, lower contribution to resistive-wall impedance, and reduced outgassing.

## 17. F. Carra – New materials: status ([Indico](#))

- **L. Rossi** asks if long term damage to the coating has been evaluated. **A. Bertarelli** replies that there are some measurements performed with protons, but the post irradiation examination (PIE) has not started yet. Tests with ions will start at the end of March 2019, and the expected activation will allow for PIE results to be available sooner than with protons. **S. Redaelli** adds that the budget for the PIE of the proton irradiation is allocated, and discussions are on-going between the relevant teams in order to finalise the post-irradiation tests. **S. Gilardoni** specifies that the capsule used at BNL has materials of interest for other projects, for which specific green lights should be collected before proceeding with the PIEs.
- **R. Aßmann** asks why coated graphite was investigated. **F. Carra** replies that coated graphite was considered in the past as alternative plan to coated MoGr in case of unexpected issues; he also underlines that coated CFC was proposed as alternative plan, but later abandoned because of the unsuccessful tests reported also in the presentation. **S. Redaelli** underlines that the solution of coating graphite jaws was studied as an alternative following the vacuum issues with the first samples of MoGr. **R. Aßmann** wonders if the possible change of bulk material of the jaw has been assessed in terms of dose to personnel and activation of air. **C. Adorisio** replies that no assessment on these topics concerning MoGr and CuCD has been done. **F. Carra** underlines that most of the load on secondary collimators goes to the metallic structures, which do not change for different jaw materials.
- **L. Rossi** wonders how many companies have been qualified for CuCD. **F. Carra** replies three; in case of tender, offers from the three of them may be accepted.

## 18. G. Bregliozi – Review of vacuum performance ([Indico](#))

- **R. Aßmann** asks if, during the coating validation test, it was possible to disentangle outgassing through the coating layer from that from the un-coated bulk material. **G. Bregliozi** replies negatively, and he remarks that he does not expect relevant outgassing from the bulk. **W. Venturini** suggests to repeat the test with an un-coated sample and make a comparison.
- **S. Redaelli** reminds that the priority for installation of the TCSPM was to measure the impedance of the various coating stripes to finalise the design for series production; all the issues found with vacuum with the TCSPM prototype should not be mixed with the good present situation during production, achieved thanks to the efforts of the many teams involved.
- **M. Seidel** asks if Mo-coated CFC jaws are compliant with vacuum specs, given the higher porosity of CFC. **G. Bregliozi** replies affirmatively. **W. Venturini** asks if adhesion of Mo to CFC has been checked. **O. Brüning** replies that it should be checked.
- **A. Sublet** asks if the origin of the high content of CH<sub>4</sub> is known. **G. Bregliozi** replies that there are uncertainties, also because the effects of H<sub>2</sub> on CH<sub>4</sub> are not clear. Further investigations are planned.
- **R. Aßmann** wonders if bubble formation in the bulk material has ever been observed and if it could ruin the coating, especially in case of thermal loads (bubble would reach the surface and try to evacuate through the coating layer). **G. Bregliozi** replies that bubble formation was never seen, and he underlines that coating is performed under vacuum, so nothing can be trapped below the coating layer. **F. Carra** and **G. Arduini** also remind that the jaws undergo a thermal treatment at 400°C, which should make this effect visible.



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## 19. A. Masi – Collimator controls upgrade plans ([Indico](#))

- **L. Rossi** wonders why power supplies have a short lifetime. **A. Masi** replies that the lifetime of power supplies is dominated by that of the capacitors in the hardware.
- **A. Masi** underlines that collimators are cycled during technical stops every month or every six months; moreover, the collimator cycles performed during LHC operation are taken into account when evaluating the lifetime of the bearings. He also reminds that the lifetime of motors is dominated by radiation.
- **M. Lamont** wonders if cost of personnel has been included in the in-house solution for the upgrade of the collimation control system. **A. Masi** replies affirmatively; he also reminds that the final cost is comparable to that of the off-the-shelf solution, since raw material accounts for only a third of the total and the rest is taken by man-power.

## 20. D. Mirarchi – Crystal collimation for lead ion beams ([Indico](#))

- **M. Seidel** asks what happens when the crystal is oriented in amorphous. **D. Mirarchi** replies that the performance is very similar to that of the standard system. **W. Fischer** asks why crystals cannot replace regular TCPs, with a net benefit on beam impedance. **S. Redaelli** replies that the deployment of crystals mainly target ion beams, for which impedance is less of an issue; he also underlines that, in order to use crystals with protons, an absorber capable of standing 1 MW of primary beam losses should be designed.
- **L. Rossi** wonders if the origin of the 10 Hz oscillations has been identified. **D. Mirarchi** replies negatively, even though a possible kick originating the observed closed orbit distortion has been identified, and the extension of the kick is compatible with magnet oscillations. **L. Rossi** asks if there was any correlation with work by civil engineering for HL-LHC; **O. Brüning** replies that no correlation was found.
- **L. Rossi** asks if four crystals would be sufficient for cleaning purposes. **S. Redaelli** makes the attendees noting that in case of loss scenarios implying an orbit distortion (as in the 10 Hz case) the crystal may be missed.
- **O. Brüning** wonders if there are expectations on the cleaning performance when using HELs and crystals at the same time. **D. Mirarchi** replies that HELs would increase the impact parameter on crystals, improving their efficiency. **S. Redaelli** adds that the interplay between HELs and crystals should be studied in detail.
- **M. Seidel** asks if the lifetime of crystals has ever been evaluated. **D. Mirarchi** replies that several measurements were taken in the H8 experimental facility at CERN, showing that there was no decrease in channelling efficiency after direct beam impacts. Moreover, in Russia they are used for extraction; based on this experience, it was concluded that crystals should be exchanged at the end of each run. **M. Seidel** concludes that there is no practical limitation on the deployment of crystals from damage; **D. Mirarchi** agrees with the statement, and **O. Brüning** remarks that this was also the conclusion drawn during the crystal day right after the 2018 HL-LHC annual meeting.

## 21. Close Out ([Indico](#))

- **O. Brüning** notices that the committee did not make any recommendation on the number of crystals required for operation. **M. Lamont** replies that four should be enough.
- **S. Gilardoni** announces that recently there was a review of the dumping system, but no final decision on the upgrade of the TCDQ device has been taken yet. **S. Redaelli** and **G. Arduini** comment that the possible

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upgraded design should take into account  $\beta^*$  reach and impedance reduction consistently with the project goals.

- **L. Rossi** asks if there are strong arguments against short collimators. **M. Seidel** and **R. Aßmann** reply that the cleaning performance with shorter TCSPMs has not been addressed; moreover, it is not clear how the effective length travelled by beam particles through a bent jaw changes with a shorter collimator and what the consequences in terms of cleaning are.
- **M. Seidel** underlines the relatively little margin between peak energy deposition in the upstream 11 T dipole and the estimated quench limit; nevertheless, he also recognises that moving the entire package back to cell 8 would not allow the machine to be run with ions. **L. Rossi** and **S. Redaelli** agree on the fact that Run III will give the opportunity to assess the limits of the 11 T dipole with circulating beams.
- **S. Redaelli** asks clarifications on the recommendation by the reviewers to substantiate the upgrade of TCT jaws to CuCD. **M. Seidel** replies that there was no strong evidence for the need of an upgrade in TCT jaw material. **S. Redaelli** observes that, leaving the TCT jaws in W, the event of an ABD would entail a stop of the LHC physics data taking of few days; moreover, with CuCD jaws there would be no need for the 5<sup>th</sup> axis functionality at these collimators, which would simplify their design and improve the integration in a region of the LHC already problematic. **O. Brüning** recommends to strengthen the arguments in favour of CuCD. **R. Aßmann** notices that there was effectively no failure in Run I and Run II with direct beam impact on the TCTs; moreover, the fact of having a small and interlocked MKD-TCT phase advance is a good strategy to save money and gain in performance.

### **ACTION**

None

**Documents:** None**Prepared by:** A. Mereghetti, S. Redaelli**Date:** 2019-03-12**Approved by:** O. Brüning**Date:** 2019-03-18**Distribution List:** Standing members of the meeting and participants**References:**

[1] S. Antipov et al., "Update of the HL-LHC Operational Scenarios for Proton Operation", CERN-ACC-NOTE-2018-0002, CERN, Geneva, Switzerland (2018) - <https://cds.cern.ch/record/2301292/files/CERN-ACC-NOTE-2018-0002.pdf>