### HL-LHC IR collimator design: WP5 internal review

**Date of meeting:** 2020-03-04  
**Project/Activity:** WP5

**Participants:** S. Redaelli (BE/ABP), A. Perillo Marcone (EN/STI), F. Cerutti (EN/STI), I. Lamas Garcia (EN/STI), M. Calviani (EN/STI), H. Garcia Gavela (ATS/DO), B. Salvant (BE/ABP), F. Bertinelli (EN/MME), S. Gilardoni (EN/STI), P. Fessia (ATS/DO), A. Mereghetti (BE/ABP), R. Bruce (BE/ABP), V. Baglin (TE/VSC), M. Sabate Gilarte (EN/STI), C. Bertone (EN/HE), A. Bertarelli (EN/MME), L. Gentini (EN/MME), A. Masi (EN/SMM), F. Carra (EN/MME), H. Mainaud Durand (EN/SMM), A. Lechner (EN/STI), E. Rigutto (EN/MME), J. Guardia Valenzuela (EN/MME).

**Excused:** G. Riddone (TE/VSC), P. Chiggiato (TE/VSC), R. Jones (BE/BI), J. Daricou (BE/BI), M. Wendt (BE/BI), N. Biancacci (BE/ABP), G. Arduini (BE/ABP)

**Agenda and presentations ([https://indico.cern.ch/event/892297/](https://indico.cern.ch/event/892297/)):**

1. Introduction to layout and specifications (S. Redaelli)
2. Status of new IR collimator’s design (L. Gentini)
3. Thermo-mechanical calculations (F. Carra)
4. Status of FRAS — specific aspects for collimators (H. Mainaud-Durand)
5. Vacuum aspects of new IR collimation layouts (V. Baglin)
6. Collimator prototyping at CERN — roadmap (F. Carra)
7. Series production roadmap (I. Lamas)

### MINUTES OF MEETING

**Abstract**

The goal of this WP5 IR design review was to assess the status of the HL-LHC IR collimator designs, discuss about possible modifications and agree on a prototyping strategy and timeline to test and validate the innovative features proposed.

Some modifications were proposed and the need to start building the prototypes as soon as possible was stressed. Nevertheless, some room for improvement and areas to be studied in more detail were identified, and this should be addressed before starting the prototype production.

In the meantime, preparatory phases shall be included and some critical components of the assembly shall be built, tested and validated before launching the production of the full prototypes, as the overall design may be affected by any eventual modification of these components.

**Introduction to layout and specifications (S. Redaelli)**

The general layout and specifications of the IR collimators was presented and references to available documentation provided.

V. Baglin asks to share the latest schedule so that everybody works on a common basis. S. Redaelli replied that this had been distributed to all groups following the preparatory meeting to the HL-TCC day. S. Redaelli explains that the schedule for the LS3 production is entirely dependent on feedback from technical teams in Russia, which is still missing. So, we have to work for the moment on a draft established internally before the signature of Russian in-kind agreements.

The qualification of Russian partners – as proposed to the HL-LHC Project Office - includes preparation of samples for e-beam welding and brazing, a complete jaw and then a full collimator. There should be some discussion to review the qualification process for the in-kind partner (M. Calviani, I. Lamas and S. Redaelli.
agree), but for the moment, a milestone for the final validation of the in-kind production lines was indicatively set to the end of 2021, as mentioned in the collaboration agreement.

For the regions other than the beam recombination (designated by the “X” letter), the existing designs should be re-used. However, simplifications of the X design might be considered also for the new collimators in cells 5 and 6 of the matching sections. This design is out of the scope of this review. New fixed masks will also be presented, but they are also not part of the scope of this review.

The current WP5 plan involves the construction at CERN of 2 full prototypes of the IR designs and 2 demonstrators (masks or components of the new IR7 collimator design if needed). S. Redaelli stressed that the IR prototypes must be installable in the machine and serve as spare devices.

Status of new IR collimator’s design (L. Gentini)

L. Gentini presented several aspects of the proposed design and clarified various points raised from questions asked during the presentation.

R. Bruce commented that the given requirements on jaw strokes are compatible also with flat optics. For round optics smaller strokes are needed. It was agreed with WP2 to use the most demanding case as design goal.

L. Gentini recalled that the IR design does not have the fifth axis, which helps considerably reducing longitudinal constraints. This is possible as the TCTH are planned to be made with CuCD, more robust than Inermet.

Comment after the meeting. If Inermet were to be kept, to be discussed whether the 5th axis feature should be re-implemented in the design.

It was highlighted that the proposed connection system and the interfaces with vacuum components has never been tested. TE/VSC is testing some features and clearly, the collimator prototyping phase for the IR collimators also provides an important opportunity to test all interfaces.

C. Bertone asked whether the guiding shafts and the tool to compress the bellows prevent collision between modules during installation. L. Gentini replied that this cannot be fully avoided as the flanges are larger than the guiding shafts (hence, the collimators could “meet” before the collimator engages the shafts). However, the risk of collisions is significantly low. As design requirement, the operation of the needed VSC connection tool should be compatible with robot intervention. In any case, this feature will be tested in the prototyping phase of the IR collimators.

M. Calviani asks about the expected dose rate. P. Fessia explained that the maximum dose rate was estimated to 1.6 mSv/h @ 40cm (more details can be found in EDMS 2331769).

L. Gentini showed on slide 12 that some designs are different between the three collimators, but for the jaws and the feet, the design is the same, apart from some small adaptations. An effort has been made to minimise variants. S Redaelli commented that we should not label as “new” jaw design types that are already well established (“TCTP”, “TCSPM”, etc.) and argues that in fact only two “new” types of jaws are needed (assuming that the change of material is not a major change for the design).

The proposed design of the jaw positioning mechanism takes into account the beam angles. In the present design, both the jaw’s mechanical stops and the opposing vacuum chamber are tilted. The tank will be installed parallel to the central beam line. The required tilt of the collimator cannot be done at the support level as it would not allow having the same design between the two sides and it would generate stresses on the bellows. SR commented that the proposed design is a bit more difficult to be built, but optimises
the clearance for the machine and the installation procedure. S. Redaelli suggested to double check if with parallel jaws and chambers we have enough aperture margins: this would simplify the design further (Action: S. Redaelli to trigger WP2/S).

A. Perillo Marcone asks if active cooling on the tank is really necessary, considering the low thermal loads on them (few Watts). F. Carra commented that he expects that with no cooling at all, the temperature can rise above 50 °C. S. Redaelli commented that we can then risk to cause a rise of vacuum pressure, which must be avoided close to the experiments. It was agreed that a thorough thermal calculation would be done in order to determine the impact of completely removing the cooling on the tank (Action: F. Carra).

The tank design has been examined with the Main Workshop and the technical teams are convinced that welding is feasible without issues and the overall mechanical design is sound. L. Gentini expects no issues with the welding. A. Bertarelli commented that the construction of the prototype clearly shall be used as an opportunity to confirm this. A. Perillo Marcone asked if the design is similar to that of other collimators. L. Gentini confirms that several features are the same as previous designs, but most of the innovation is found on the remote handling compatibility of the connections and the alignment system, not in the tank.

S. Gilardoni asked if the TDIS tank design could be re-used. This option was ruled out as the design is completely different and does not meet the tight installation constraints in the IR1/S.

Based on previous experience, it was agreed that it would be worth exploring the possibility of making the tank openable, even if it meant allowing for a “clean” cut of a weld, that would minimise risks to pollute the inside of the tank and that would allow for re-welding. S. Redaelli commented that in parallel to the assessment of feasibility, a list of benefits for this feature, which were mentioned during the meeting, should be clearly documented for scenarios with radioactive devices (Action: EN/STI). A. Bertarelli agreed and commented that this option seems more appropriate for IR7.

Independently on whether the tank is openable or not, the welding (or closure by any other means) of a large plate opposite the motors (“lid”) should be done as a last step in the manufacturing process, allowing for the tank to remain open during assembly and tests of jaws. AB recalled that also for the TCLD, the final welding was done at the last minute to keep the collimator open for companies and for various other inspections.

The gasket removal shall be optimised for robot intervention. In the present design, in order to remove the gasket, one collimator has to be removed to make space. (Action: L. Gentini and V. Baglin to assess the feasibility.)

A nipple was added to lubricate the lead screw of the mechanical tables. Detailed analyses on the lead screws in EDMS 2363039).

A. Masi asks to verify if the LVDT range is acceptable. It was later discussed that larger stroke would not be a showstopper, but it has to be taken into account in advance as it would require a different calibration approach. A. Masi recalled that with larger strokes, the LVDT precision is also affected.

Given the low power deposited in the jaws, it was questioned whether it is necessary to braze the cooling pipes to the back-stiffener. If brazing were removed from the design, the manufacturing and material selection would be simplified (hence, reducing costs and increasing reliability). A priori, it seems possible to remove brazing with minor modifications of the proposed design. F. Carra recalled that a jaw design without brazing was already used in the past, pending final validation. This would also allow using other materials rather than Glidcop for the jaw (such as CuCrZr, extensively used elsewhere), at a reduced cost.
Comment after the meeting: The TCTP prototype machined by MME was without brazing, and the results in the thermal conductance test bench were good (10.000 W/m2/K). Such values would be acceptable for a standard TCT, and even more for a TCLPX, which has 50% of the load of the TCT.

Action: F. Carra. Re-run the calculations with an TCC of 10.000 W/m2K instead of the “brazing” value used for the TCLPX, just to confirm that a clamped solution is viable.

If the above is confirmed, the design should be adapted to a clamped option (Action: L. Gentini).

The design of the RF fingers and connections is new and has never been tested. This is to be tested during the prototyping phase with high priority. (Action: MME with support from STI).

Comment after the meeting: Cycling tests in 272 will be limited as the building will be phased down by the end of 2020. Therefore, strating new activities shall be avoided unless these can be reasonable executes in a couple of months.

As a general recommendation, A. Perillo Marcone proposes to test some critical sub-components (list to be defined) separately, by means of prototypes of different sub-assemblies/components. The manufacture of the full prototype should only start after all separate components are validated and integrated into the overall design (which could evolve based on observations during prototyping). A. Bertarelli agrees and adds that indeed, some critical tests are planned already. He also commented that several activities can proceed in parallel to the procurement of materials for the prototype.

V. Baglin reminds that the design must take into account the forces generated if a collimator is removed and the rest needs to be put under vacuum, e.g. in the scenario where one collimator is taken out for repair during several days. This is has not been taken into account in the current design. S. Redaelli commented that the specification for this scenario shall be defined well (Action: S. Redaelli/V. Baglin).

C. Bertone reminds that the lifting capacity of the present vehicle planned for collimators is 1 ton and exceeding that will entail major changes. L. Gentini, mentions that the present design is 900 kg, so we must make sure that the weight does not increase further.

Comment after the meeting: Considering recent experience in another project (i.e. the TDIS weight ended up being much higher than originally estimated and then some required modifications increased further the weight), more margin should be created, either by reducing the weight of the device (preferred) or by upgrading the transport equipment to increase its capacity (Action: L. Gentini, EN-HE).

C. Bertone also warned about 3D conflicts during transport. The cross section must remain below the one of a dipole to avoid transport conflicts. It was clarified that some of the components shown in L. Gentini’s presentation are meant to be removed after installation.

Thermo-mechanical calculations (F. Carra)

Different calculations were presented, giving links to find the details about all these simulations.

It was agreed that brazing is not mandatory given the low thermal loads. In this case, CuCrZr (for example) could be used for the back-stiffener instead of Glidcop, resulting in a cost reduction and increasing availability of suppliers.

It was agreed that it would be worth checking the effect of removing the cooling on the tanks. F. Carra commented that probably temperatures between 50 and 100 degrees can be reached but he needs to check with proper simulations. S. Redaelli commented that this action was launched at a HiCoIDEM hoping
for a reduction of costs following the comments from O. Aberle; on the other hand we cannot risk large outgassing from temperature increase close to the experiments (see also above), so this aspect should be studied in more detail (Action: F. Carra).

All stresses seem very low as well as temperature increases due to thermal loads. So, it seems that all components would operate safely.

Status of FRAS — specific aspects for collimators (H. Mainaud)

H. Mainaud Durand presented the different features of the Full Remote Alignment System (FRAS) and the present status.

The weight of collimators is to be updated for FRAS studies, as in the specification document the maximum weight was indicated as 700 kg instead of 900 kg as discussed above. H. Mainaud Durand commented that in any case the limit for the proposed system is 2000 kg.

The wire for WPS sensors is to be blown into a tube. This technique is being validated.

Irradiation of components is planned to be carried out by Fraunhofer Institute (Germany) but needs further discussion with EN/STI. M. Calviani thinks it may be possible to do it at n_TOF during 2021.

Lubricants to be changed by more adapted ones to radioactive environments. Support to be given by EN/STI. M. Calviani reported that the best radiation resistant grease known today is produced in Japan. P. Fessia suggested to explore the possibility of asking for an in-kind contribution from Japan. To be discussed offline (M. Calviani agrees) – even if EN/STI is exploring the potential of another European supplier.

It would be desirable to have a whole set-up in the prototype to test the entire assembly of the ‘X’ region, also with robots. So, the FRAS team supports strongly a prompt preparation of IR collimator prototypes. S. Redaelli asked when this could be available. F. Carra commented that we cannot have 2 prototypes much before mid 2021. H. Mainaud Durand commented that this fits the present plan for validation of the system. For testing the FRAS, a full collimator of the final design is not necessary as the basic functionality can be tested with a standard collimator. Previous intermediate steps would be included in the prototyping/testing plans.

EN/SMM would be ready as of end of 2020.

Vacuum aspects of new IR collimation layouts (V. Baglin)

It was noted that it would be difficult to make a small sector around the collimators due to lack of space to add a valve. For HL-LHC, the vacuum sectors are significantly larger than in the present IRs.

For the two-in-one designs, V. Baglin proposes to add NEG coating on the pipe of the non-collimated beam, including a heating means to activate it. This would add significant additional pumping speed as well as being effective against multi-pacting (Action: L. Gentini).

Carbon coating would be good for multi-pacting but the extra pumping given by NEG is really useful (even if it is not fully activated).

In the design, a 20 mm thick jacket is proposed, but there is only 3 mm clearance between the vacuum chamber and TCTPXV. A solution needs to be found (Action: L. Gentini).

As a general comment, P. Fessia suggested that one could profit from the delayed installation (following the new LS3 schedule) to setup a full mockup of the IR region. S. Redaelli supported this approach and
recalled that the installation tests for the TCLD with the mockup cryo bypass proved the utility of such investments (recalling that the TCLD installation proceeded very smoothly). As an action, S. Redaelli will follow up this proposal for an “X region string” with the project management, together with P. Fessia.

Collimator prototyping at CERN – roadmap (F. Carra)

The prototyping strategy was presented. The proposal from EN/MME is to build 1 TCLPX and one TCTPXH.

F. Carra proposed to have a step-wise approach.

F. Bertinelli warns about potential conflicts with the Main Workshop workload if work does not start in the next few months, so a decision must be taken on when to start manufacturing the prototype. However, he also clarified that in any case EN/MME subcontracts some of the parts when necessary.

S. Redaelli recalled that we need to address the procurement of CuCD for the horizontal TCT prototype (Action: S. Redaelli/F. Carra).

M. Calviani states that the assembly and testing of these prototypes shall be done at the EN/STI workshop in b. 927, which will have a dedicated area for collimator assembly and testing.

Series production roadmap (I. Lamas)

In the general schedule, there should be a milestone (e.g. at the end of 2021) to confirm the technical compliance of samples and prototypes from Russia (Action: I. Lamas Garcia with the support of B. De Girolamo). This imposes constraints on the time available to validate the production in Russia. In absence of a clear plan from Russia, I. Lamas Garcia believes that realistically there is not much time to setup the production and we should therefore proceed with a high pace.

F. Bertinelli proposes to strongly involve the Russian partners from the beginning of the prototyping phase while prototypes are being built at CERN. He reminds that BINP is a very prestigious and competent institute and we should not put in question their capability to built collimators, and rather work with them to prepare well the in-kind production. S. Redaelli replied that the plan to invite Russian colleagues whilst building the prototypes at CERN was already identified and shall be iterated when technical contacts are established.

F. Bertinelli pointed out that the qualification as indicated by I. Lamas Garcia seems too long and production too fast. I. Lamas Garcia argues that this is based on experience and is realistic.

A. Bertarelli insists that given the schedule, the full prototype should be produced as soon as possible.

It was agreed that all the comments will be considered and discussed in a further meeting (to be organised in the next few weeks) to conclude on the way forward.
Documents:

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Distribution List: Participants and excused.