International Review of HL-LHC Alignment and Internal Metrology (WP15.4)

26 - 28 August 2019

Review Panel Report

Review Panel Members:

Johannes Prenting (DESY), Jean-Philippe Tock (CERN), Jörg Wenninger (CERN), Horst Friedsam (FNAL) and Georg Gassner (SLAC National Accelerator Laboratory)

General

The International Review of HL-LHC Alignment and Internal Metrology (WP15.4) was held at CERN on 26–28 August 2019.

The Review Panel was requested to assess the alignment solutions foreseen for HL-LHC, with a focus on the internal metrology, the monitoring of inner triplet cold masses and crab cavities inside their cryostat and full remote alignment systems.

The Panel received 30 reports from the collaboration and has recognized the soundness of the proposed solutions individually and as a global system.

The Panel congratulates the collaboration on excellent progress in the alignment and internal Metrology Strategy.

Mandate of the review

The main objective is to review the alignment solutions foreseen for HL-LHC, with a focus on the internal metrology, the monitoring of inner triplet cold masses and crab cavities inside their cryostat and full remote alignment systems.

Scope of the review

- To examine the soundness of the proposed solutions individually and as a global system;
- To verify that all requirements from equipment owners and machine operation are duly covered;
- To check that the interfaces between WP15.4 and the other WPs are clear;
- To check the readiness of the solutions proposed and evaluate the associated risk if any;
- To evaluate the related test plan, acceptance criteria and the overall schedule;
- To examine the procurement strategy, identifying possible risks;
- To put in evidence possible integration issues and safety aspects.

Findings and Comments

F1. Monitoring solutions for the alignment of the HL-LHC Q5-Q5 regions around point 1 (ATLAS) and point 5 (CMS) have been presented both for the assemblies (cryostat) as well as for the internal position of critical element like CCs and CMs of the triplet quadrupoles.

F2. The solutions were developed based on the current LHC triplet experience.

F3. The overall schedule is sound, but will depend on the convergence within 1-2 years of some remaining R&D work. This should be confirmed by a readiness review.

F4. The MT-FSI is a promising solution for the internal alignment of components in particular since the cryo-condensation issues seem to have been solved. The test of the FSI on the CC assembly in the SPS is very promising and provides an excellent real life test of the system.

F5. The WPS will connect (almost) all components on each side of the experiments, with CERN in-house developments to overcome some industry solution limitations.

F6. The motorization system is under development with valuable input from the LHC triplet test stand in B181.

F7. With all components functioning within their specification the overall system should provide accurate remote monitoring as well as powerful alignment capabilities.

F8. The fact that reliable solutions are favoured will help for long term maintenance and availability of the system.

F9. The FRAS will not be a new operation knob as the validation procedures (loss maps etc) after a realignment are quite heavy and time consuming. The FRAS will be used during the beam commissioning phase at the beginning of a run to optimize alignment, orbit corrector strengths and apertures.

F10. The requirements from operation for remote beam-based alignment to optimize corrector strength, adjust the position of the IP and maximize the aperture for beam dynamics have been taken into account.

F11. The required movement margins have been obtained from LHC alignment data collected over the past 10 years with comfortable margins of a factor ~ 2.

F12. The mechanical tolerances on components like bellows for re-alignment have been collected and folded into the design.

F13. Interfaces with other WPs for the design have been taken into account. The fact that jacks for CC, quadrupoles and TAXN are included in several (4) work packages is a potential risk of missing something.

F14. Equipment interfaces to other WPs concern mainly the support jacks, (motorized) equipment platforms, integration of WPS sensors and target on equipment as well as integration into the overall LSS layout.

F15. A procurement strategy has been presented with first deadlines of components to be delivered for the HL-LHC string test.

F16. In-kind contributions take additional time to setup, this needs to be taken into account.

F17. Since the design involves many in house developments, the progress must be followed closely to avoid procurement delays due to design issues and delays. This should be confirmed by a readiness review.

F18. Integration and interfaces with other local equipment have been presented. Integration layouts are well advanced and close to completion.

F19. The impact of radiation has been considered for the integration and the choice of the components (TBC).

F20. Concepts for personnel as well as beam related safety have been already developed. Safety and beam interlock requirements have been identified.

F21. Safety and equipment protection aspects associated to the remote re-alignment have been considered, in particular the tracking of the position of each equipment relative to its neighbours.

F22. A UAP platform to provide a uniform solution for the support of all equipment is under development, this would not just be beneficial for the project but also for CERN in general. Benefits include less time for personal in high radiation areas, increased speed of alignment and improved ergonomics for workers.

Recommendations

R1. A complete and comprehensive table of requirements and target accuracies / tolerances should be compiled as soon as reasonably possible.

R2. The integration of the support jacks and the motorisation should be followed carefully (crab cavity interferences of jacks).

R3. The polyurethane for the jacks at SPS caused issues, the possible impact on the HL-LHC motorized jacks needs to be looked at. The final 'system owner', responsible for operation and maintenance of the FRA system, should be clearly identified.

R4. The history of the incremental displacements must be kept. This is mandatory for avoiding too large cumulative offsets on bellows.

R5. In-house WPS and HLS developments are important and need to be followed through to mitigate the risk of a single manufacturer (Fogale Nanotech) for these sensors.

R6. With a whole suite of new sensors, a lot of tests and developments are still required. Extra care should be taken to validate the systems before, during and even after installation, built in as many tests and redundancies as reasonable (e.g. include measurements to stable points/surfaces).

R7. As some of the components, like targets, will be installed at other institutes during module assembly (CCs) detailed procedures must be put in place to ensure correct installation. A detailed test procedure should be developed at reception of the components at CERN.

R8. The test plans should continue to address work ergonomics in the tunnel to minimize intervention times and radiation doses to personnel.

R9. The SM18 string test (close to reality) will be an invaluable test ground for the final design, providing some window for last minute improvements. It will reduce time during installation/ commissioning.

R10. In the current scheme, the combination of the different measurements relies on the initial fiducialization. The feedthroughs might move during pump down and cool down. As the access to the feed-through on the wall side will be difficult in the field, possible movements of the feed-throughs need to be studied in advance.

R11. FSI/ laser tracker: effect of scratches or dirt on the glass spheres has to/ will be evaluated.

R12. The experience gained on the crab cavity test in SPS can in a large extent be used for cryomagnets (FSI).

R13. Automated laser tracker measurements are not part of the project. It can be an interesting improvement for the future provided it does not divert resources from the baseline activities.

Responses to the Individual Charges/ Questions:

- To examine the soundness of the proposed solutions individually and as a global system:

Yes, the proposed solutions seem sound individually and as a global system

- To verify that all requirements from equipment owners and machine operation are duly covered:
  Yes (we recommend to issue a list of requirements)

- To check that the interfaces between WP15.4 and the other WPs are clear:
  Yes

- To check the readiness of the solutions proposed and evaluate the associated risk if any:
  Yes, the solutions proposed are well underway to be achieved within the proposed schedule, risks should be mitigated as much as possible by increasing redundancy within the systems and by monitoring its progress (readiness review), see recommendations.

- To evaluate the related test plan, acceptance criteria and the overall schedule:
  Yes, if all the test plans are executed as proposed (string test milestone), special attentions should be given to the man power resources

- To examine the procurement strategy, identifying possible risks:
  Yes, see recommendation on in-kind contributions

- To put in evidence possible integration issues and safety aspects:
  Yes, but the jack interference needs to be looked at as pointed out by the presenters

Acknowledgments

The Review Panel would express sincere thanks to all participants for their outstanding effort for the HL-LHC Alignment and Internal Metrology and for preparing the high-quality reports and intense discussion at this international review held on 26 – 28 August, 2019 at CERN. Special thanks to Ms. Elodie Kurzen for her kind cooperation and assistance in the successful organization of the review.