"DFM Detailed Design Review" Report

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This document reports the outcome of the *"DFM Detailed Design Review" (DDR)* held on **18 January 2022** (DFM Detailed Design Review (January 18, 2022) · Indico (cern.ch))

The Report is structured in:

- *Introduction*
- *Findings and comments*
- *Summary of Comments & Recommendations*

Introduction

The Review Scope, Mandate and Program were defined, by TE-MSC in agreement with HL-LHC Project, as following:

Scope: Review the detailed design of the DFM.

Mandate of the Review Committee:

1) Review the functional, technical and interfaces requirements and confirm their completeness in terms of cryogenic, mechanical and electrical aspects;
2) Review the engineering design wrt cryogenic and operational aspects and wrt mechanical and electrical aspects, including interfaces;
3) Review the integration and installation plan in the LHC machine and the compatibility of the DFM location and integration wrt the tunnel environment and interfaces with the other systems;
4) Check the conformity of the safety requirements for both cryogenic and electrical aspects and compatibility of safety equipment with tunnel environment;
5) Review plan and schedule for DFM production;
6) Review strategy and plan for QA and QC, as well as plan for intermediate and final acceptance tests.

Review Committee: M. Modena (chair), M. Bednarek, K. Brodzinski, G. Favre, D. Tommasini

Presentations:

-	*Welcome*	*M. Modena*
-	*DFM in WP6a*	*A. Ballarino*
-	*DFM functional & technical requirements*	*Y. Leclercq*
-	*Follow-up from CDR*	*P. Cruikshank*
-	*Cryogenic flow scheme & cooldown*	*V. Gahier*
-	*DFM transport & Integration*	*G. Aparicio Cantalapiedra*
-	*Engineering detailed design - Cryostat design*	*F. Di Ciocchis, Y. Leclercq*
-	*Engineering detailed design - Interfaces, Assembly, Installation & Maintenance*	*Paul Schneider, R. Betemps*
-	*Cables splices & Instrumentation*	*J. Fleiter*
-	*Safety equipment & safety aspects in the LHC tunnel*	*N. Grada*
-	*DFM supply via UK2 Collaboration*	*P. Cruikshank*
-	*DFM acceptance criteria & QA plan*	*Y. Leclercq*

Acknowledgement

The Review Panel would like to thank the Speakers for the provided presentations clear, concise and complete.

Main Findings and Comments:

This Detailed Design Review takes place about 2.5 years after the Conceptual Design Review (*21 June 2019*). In this long times between the 2 reviews, the DFM design has evolved mainly from cryogenic and mechanical point of view.

The baseline for the procurement (In-kind contribution via the UK2 Collaboration) was reminded, also underlining how the procurement will take advantage from the procurement of the DFX pre-series via the UK1 Collaboration that is successfully on-going.

It was also reminded how the DFM is not an equipment needed for the HL String program in SM18, but how the 1st unit (prototype and future spare) will be needed in order to perform the Reception tests of the 5 DSHM (SCLinks: 4 operative units + 1 spare). The procurement planning (that shows comfortable margins) was illustrated. Up to now, is not planned a validation test for the DFM prototype. The reasons for that were explained and discussed (*see final comment*)

The maturity of the design was illustrated by the different talks covering the main design manufacturing and operation details. The main changes with respect to the Conceptual Design are within the electrical connection (D2-DFM Interlink, mainly on the D2 side) and in the interconnections with the QRL (new design of the jumper and He vaporization module).

The cryogenic design includes a LHe buffer in order to safely withstand 10 min operation without cryogenic supply (for safe ramp-down of the SC circuits). The design and operation pressure of the 3 main elements of the cold powering system (DFHM – DSHM – DFM) is now fully harmonized as well as the safety devices and the set of their triggering in case of problems.

The mechanical design includes few big flanges, around the main electrical splices, that will be clamped and not welded also in the final configuration (LHC installation). This would permit an easier intervention in case of EXCEPTIONAL Maintenance on the SC cables and leads splices. It is envisaged

the fabrication and use of mock-ups in order to develop the eventual reparation procedures and tooling. This seems a very positive approach that the Review Panel fully support.

The DFM will be installed in a specular (not symmetric) layout respect to the IP (at R and L of IP1 and 5). This imply that not all the components will be identically assembled in the R and L configuration.

The DFM will interface the D2 magnet that will be part of the elements operated with the FRAS system. It is important that the alignment ranges and tolerances (for installation and FRAS operation) are fully coherent between the two equipment.

Despite the DFM equipment will be nominally identical (but specular) in the LHC installation points, differences will be present as concerning the supports and fixation to the Tunnel vault that has to permit and guarantee a sound but complex manipulations of the DFM during the interconnection with DSHM and then D2. Up to now, only the supporting system for the 5R location was finalized and communicated to WP15-Integration.

The DFM instrumentation was finalized with sound redundancies for all the critical signals. The IFS and other instrumentation flanges are LHC standards or common with the HL magnets (IFS "L-type"). The references (EDMS docs) for all the electrical circuitry parameters, protection and splices manufacturing were provided.

A "schematic assembly phases summary" for the DFM was shown. The assembly details were developed also with the support of colleagues from the Main Workshop (the welds and welding procedures will remain critical for such devices). A preferred scenario and schematic for installation of DSHM, DFM, D2 (but also for TAXN and collimators presence/interference) was presented as well as the schematic of all the manipulation to be done for the final overall installation and interconnection of the system.

QA and QC aspects were presented. Some documentation (including the ITP and ElQA tests) are still under completion or revision. Participation of ElQA Team in the definition of tests and test levels will be a plus. Since a PRR (Production Readiness Review) is anyway planned to be hold in Q2 2022, that will be the occasion to fully check the completeness and consistency of all technical and contractual documentation.

Summary of Comments & Recommendations:

Referring to the six **Review Mandate specifications**, the Review Panel main conclusions and recommendations are here presented:

1) ***"Review the functional, technical and interfaces requirements and confirm their completeness in terms of cryogenic, mechanical and electrical aspects":***

The Functional Specification (doc. is now released) is clear and contains all the expected interfaces. Technical Specification is actually under Engineering Check.

2) ***"Review the engineering design wrt cryogenic and operational aspects and wrt mechanical and electrical aspects, including interfaces":***

The DFM design seems complete and correctly addressing all the different aspects: mechanical, electrical, cryogenic and vacuum operation. The electrical interconnection with D2 was finalized and the cryogenic design modified. The cryogenic design takes advantage of the experience matured with the DEMO program. It seems that alignment ranges and tolerances wrt the D2 (FRAS) ranges are not fully checked/validated.

→ ***RECOMMENDATION N.1:*** *Check and validate with Survey team the coherency of the alignment ranges and tolerances of the DFM respect to the D2 in their full FRAS operation ranges.*

3) *"Review the integration and installation plan in the LHC machine and the compatibility of the DFM location and integration wrt the tunnel environment and interfaces with the other systems:*

The assembly phases of each individual DFM and installation, including the interconnection with the DSHM, QXL and D2 are "mainly unilaterally" defined. The interaction with other equipment installation procedures has to be detected. The supporting system, that is a crucial element, is today finalized only for the 5R location.

→ ***RECOMMENDATION N.2****: The integration and installation study has to be completed for the four installation sites. Information (3D models of the supporting systems) has to be provided soon to WP15-Integration in order to check and validate the integrability of the DFM at all sites.*
→ ***RECOMMENDATION N.3:*** *The installation sequence and the possible interference with other equipment installation has to be fully checked for all the installation sites (work to be done under the coordination of WP15-Integration).*

4) *"Check the conformity of the safety requirements for both cryogenic and electrical aspects and compatibility of safety equipment with tunnel environment":*

A complete safety study of the full system (DFHM – DSHM – DFM) was performed by WP6a and HL Safety Officers. The analysis seems complete as well as the design and positioning of all the safety elements and their triggering (actuation sequence) in case of problems, this in order to minimize risks for Personnel and equipment.

→ ***RECOMMENDATION N.4****: Check that the full safety analysis done for the DFM system and solution/setting chosen are also coherent with the approach taken in the DFX system design (aspect studied some years ago)*

5) *"Review plan and schedule for DFM production":*

The production plan is finalized and shows a comfortable margin. This plan will be an Addendum of the UK2 Collaboration Agreement that is not yet signed (signature *expected for mid-February 2022*).

6) *"Review strategy and plan for QA and QC, as well as plan for intermediate and final acceptance tests":*

The manufacturing and QA/QC documentation is under finalization. It is defined following the HL Quality Plan. The PED documentation is under preparation with all concerned parts (CERN, SOTON, CERN-HSE, and later the chosen Notification Body).

→ ***RECOMMENDATION N.5:*** *WP6a envisages a synergy with CERN ElQA Team to develop and to detail a set of electrical tests that will be part of the procurement ITP and of the final installation ITP. The Review Panel strongly support this proposal.*

→ ***RECOMMENDATION N.6****: The technical and QA/QC documentation plan seems completed and under releasing. It will be a task for the future PRR to check the completion and coherency of all the documentation. Being the welds and welding procedures critical for such devices, it will be good to have a review of the welds configurations details, defects acceptances criteria and related quality control plan together with EN-MME colleagues (if not yet done).*

→ ***RECOMMENDATION N.7:*** *It was widely discussed the aspect of a missing Prototype Validation Test. This seems justified by the cryogenic operations now very similar to the one of the DEMO project that was widely tested, and by the fact that the DFM prototype will be anyway utilized to make the Reception tests of the series DSHM.*
Nevertheless, the Review Panel encourages to study/propose possible validation tests also at the light of the available time presents in the general procurement plan. Such tests could in fact bring operational experience that will short the global system commissioning needed at the end of LS3.