

# International Review of the Crab Cavity Performance for HL-LHC Close-out Executive Summary

## HL-LHC CC Review Panel

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*<https://indico.cern.ch/event/590988/overview>*

# Review Mandate and Charge

- The review committee is invited to assess the progress made since the last reviews,
  - **the soundness of the design and technical choices**,
  - **the readiness of the various components and of the procurement plan** (including QA/QC) and test plan.
- The committee is invited to comment on
  - **the status of the integration in the SPS** and first integration **plan in the HL-LHC**.
- A detailed resources analysis is beyond the scope of the review, however comments on the credibility of the plan, also with respect to the allocated resources, are welcome.
- The project is a joint venture between CERN and the US DOE laboratories and universities federated under the US-LARP program (now transforming into a construction project called HL-LHC AUP). The AUP contribution is assumed to be, at present, the full production of dressed RFD cavities.
- The committee is invited to **comment on**
  - **the level of integration of the teams, on the collaboration interface** and on measures that could be pursued to take advantage of the work distribution.

# This review covers the technical design, the performance and readiness of the Crab Cavity System for SPS and HL-LHC.

- **Crab Cavities requirements and final design status**, including cold mass with its interfaces (cryostats, electrical, hydraulic, mechanical, vacuum) and integration issues.
- **The cold mass and integration for the HL-LHC** will be assessed at the level of preliminary design stage, while the **cold mass and integration for the SPS** test will be assessed at the level of technical design;
- **Results of prototype** cavities and He vessel assemblies;
- **Status of production** tooling, finalization of its design and procurement;
- **Components procurement**, status and plans;
- **Test plan, QA/QC**, and safety aspects;
- **Strategy for dressed cavities and cryo-assemblies** construction and/or procurement and overall schedule (assuming the US contribution for RFD dressed cavities);
- **Collaboration level** among various teams in CERN and Europe and in the USA

# Review Report

The **review** covers the **technical design**, the **performance** and **readiness** of the Crab Cavity System for the **SPS** and the **HL-LHC**.

The **review report** is to be composed as follows:

- **Executive Summary** (→ Close-out)
- **Individual findings, comments, and recommendations** (→ Report)
  - **Technical Design and Manufacturing:**
  - **Performance Results and Evolution for HL-LHC:**
  - **Readiness and Preparation for SPS and HL-LHC:**
  - **Collaboration**

# Executive Summary

The Committee is very impressed with the progress with the international joint effort to develop HL-LHC Crab Cavity (CC) technologies and to prepare for the SPS test to be realized by the end of Run-2 (in 2018 before LS2).

We congratulate the excellent CC prototype performances that have reached the design voltage with significant margin and with quality factors acceptable in terms of active load.

## Comments:

- We recognize that both cavity designs (DQW and RFD) are mature, as demonstrated with initial Proof-of-Principle (PoP) prototypes and later with evolved prototypes for the SPS/LHC installation.
- We concur with the plan to keep the CC development with two complementary designs, and agree with the concept of the CM design allowing common interfaces to HPRF and Cryogenics system. The approach meets complementary requirements for horizontal and vertical crabbing in two interaction regions at the HL-LHC.

## Comments (continued, 1):

- The DQW cavity fabrication at CERN and testing results are impressive . The in-house cavity fabrication by the CERN team is strongly encouraged. The transfer of knowledge to the vendor for production will also be a significant effort.
- The RFD design and prototype results are further impressive. The LARP development has been successful. The U.S. Accelerator Upgrade Project (AUP) scope is defined and a sound conceptual design exists. The AUP is in a good position to seek CD-1 approval through the expected CD-1 review in 2017.
- We note that the cryomodule (CM) design/engineering work has been much advanced with high-quality cooperation between CERN and UK.
- We understand that the strategic plan on the Pressure Equipment Directive (PED) is well developed for this project stage.
- We recognize that the team is working very hard on cavity fabrication and testing, RF ancillary production, and CM and cryogenics preparation for the SM18 and SPS test.

## Comments (continued, 2):

- We understand that the SPS validation test represents a very important milestone, to be realized before the LS2. On the other hand, the schedule is very tight with nearly no time margin. The strong leadership with the team-management should be critically important.
- We appreciate the attention paid to simulate, test, and qualify higher-order-mode behavior in each different CC design.
- We believe it is worthwhile to pursue improved cavity assembly/installation processes and tooling to eliminate/minimize performance degradation between vertical test and cryomodule (CM) installation.
- We encourage to consider whether the quality control checks at each step of the cavity fabrication and assembly into the CM are adequate, to prevent problems that are difficult to repair later in the process.
- We strongly support the bunker CM test at SM18, planned with associated cryogenics qualification and integrated RF system checks to be done before the SPS test. The coordination effort and team work are impressive – people acknowledge and accept the challenge.

## Recommendations:

- Maintain the effort to realize the SPS test before LS2, and start the process for pre-series CC production, in particular, for the DQW.
- Establish a CM assembly plan with adequate tooling and clean procedures to be verified during bunker testing at low power in SM-18 and in prolonged high power testing in the SPS.
- Perform sufficient thermal cycling of the CM components/sub-system before the SM18 test: e.g. cavity with He vessel, HOM couplers, in cases that may be realized in parallel to other work and do not jeopardize the schedule.
- Plan focused performance tests on the pressure sensitivity/stability of the CC/CM at the tests at SM18 and SPS.
- Establish the minimum success criteria at the tests at SM18 and SPS, including alternate solutions in case that the preparation is not completed in time.
- Carefully establish formal agreements (signed documents) on the requirements/specifications, acceptance criteria, and boundary conditions for the HL-LHC Project and, in particular, for the RFD cavities to be fabricated by AUP and delivered to CERN.



# Acknowledgements

- *We would like to thank the HL-LHC CC collaboration and every participant who works so hard to realize the required CC performances, and the SM18 system performance test and the SPS functioning test.*
- *Special thanks for Cecile and Celine for their kindest assistance.*



# Appendix

# Agenda: 3 April, 2017

	Report	Speaker
a.m. 8:15	<b>Closed Session</b>	
8:30	<b>Crab Cavity Project Overview</b> Overview of HL-LHC and Introduction of the review CC inside LARP/AUP Overview of CC for the HL-LHC project Evolution of CC in LARP UK contribution to HL-LHC Crab Cavities and evolution CC engineering overview WP4 QA, QC status and documentation Discussion	<i>Lucio Rossi</i> <i>Giorgio Apollinari</i> <i>Rama Calaga</i> <i>Alessandro Ratti</i> <i>Graeme Burt</i> <i>Ofelia Capatina</i> <i>Isabel Bejar Alonso</i>
	<b>Lunch Break</b>	
p.m. 13:30	<b>SPS CC Test Preparation</b> Cavity/HOM manufacturing at CERN LARP cavity results CERN cavity results SPS-DQW experience (cavity + HOMs) and evolution to LHC SPS-RFD experience (cavity + HOMs) and evolution to LHC Cryomodule & Cryostating Overview Frequency tuning system and p.o.p. tuning results FPC status and HPRF status + coupler mounting (FPC/HOM) CERN-DQW cavity string assembly preparation	<i>Marco Garlasche</i> <i>Hye Kyoung Park</i> <i>Alejandro Castilla Loeza</i> <i>Silvia Verdú Andrés</i> <i>Subashini De Silva</i> <i>Teddy Capelli</i> <i>Kurt Artoos</i> <i>Eric Montesinos</i> <i>Mathieu Therasse</i>
	<b>Closed Session</b>	

# Agenda: 4 April, 2017

	Report	Speaker
a.m.	<b>(Closed Session, TBD)</b>	
8:30	<p><b>SPS CC Test Preparation</b></p> <ul style="list-style-type: none"> <li>Helium Vessel &amp; Cavity Dressing Construction</li> <li>Thermal and magnetic shields</li> <li>SPS cryogenic proximity equipment and SM18 validation</li> <li>Alignment and monitoring</li> <li>SM18 preparation for cryomodule testing</li> </ul> <p><b>LHC CC and <u>Evolution/Production Plan</u></b></p> <ul style="list-style-type: none"> <li>LHC CC integration constraints</li> <li>Pre-series, series strategy and planning</li> <li>US contribution for 10 RFD dressed cavities</li> <li>CERN procurement of DQW dressed cavity</li> <li>UK pre-series with RFD cryomodule</li> </ul>	<p><i>Paula Freijedo Menendez</i>  <i>Niklas John Templeton</i>  <i>Krzysztof Brodzinski</i>  <i>Mateusz Sosin</i>  <i>Alick Macpherson</i></p> <p><i>Paolo Fessia</i>  <i>Ofelia Capatina</i>  <i>Leonardo Ristori</i>  <i>Carlo Zanoni</i>  <i>Thomas Jones</i></p>
	<b>Lunch Break and Visit of RF Facility in SM18</b>	
p.m. 14:00	<p><b>Facility and Infrastructure for SPS Test</b></p> <ul style="list-style-type: none"> <li>SPS Crab Cavity Test Stand: Safety review summary</li> <li>LLRF preparation and RF commissioning for SPS</li> <li>Vacuum considerations for SPS tests and LHC CC</li> <li>Cryogenic considerations for SPS and LHC</li> <li>SPS Test Stand Integration</li> <li>SPS test success criteria,  -- LHC performance aspects and machine protection</li> </ul>	<p><i>Christelle Gaignant</i>  <i>Philippe Baudrenghien</i>  <i>Vincent Baglin</i>  <i>Serge Claudet</i>  <i>Giovanna Vandoni</i>  <i>Oliver Bruning</i></p>
	<b>Closed Session</b>	

# Agenda: 5 April, 2017

	Report	Speaker	
a.m. 8:30	<b>Visit of Main Workshop (for looking at CC fabrication at CERN) (B72, 100)</b>		
	<b>Closed Session, (at B6-2-004)</b> For further Q/A, Discussion, and Preparation for the review report		<i>All</i>
	<b>Lunch Break</b>		
p.m.	<b>Close-out report (B6-2-024)</b>	A. Yamamoto	