LCLS-II-HE Design and Milestone Review Report

Type of Review:	Production Readiness Review		
Title of the Review:	LCLS-II-HE Cryo Sys – Cryomodule Production Readiness Review - FNAL		
WBS:	1.02		
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Reviewers / Lab :	Stephane Berry/CEA, Jeremiah Holzbauer/FNAL (chair), Rich Poliak/SLAC, Rich Stanek/FNAL	**Date:**	July 7, 2021
Distribution:	Quality Assurance, Control Account Manager, System Manager, Systems Engineering Manager, Project Manager		

Attachments:	☐ Review Slides ☐ Design Checklist ☐ Calculations ☐ Other_____

Purpose and Goal of the Review

This review will evaluate the readiness of Fermilab's processes, procedures, infrastructure, and staffing to commence production and testing of LCLS-II-HE cryomodules.

Introduction and Outcome Summary of the Review

- The committee strongly commends both the SLAC and FNAL HE teams on their preparation, presentations, and discussions during the review
- The candidness of the team during discussions is applauded
- The committee looks forward to seeing the progress of the HE project at both FNAL and JLab

1) **Are Fermilab's processes and procedures for HE CM assembly adequately developed, documented, and verified?**
   a) **Yes**, the Assembly work-flow was presented, but not much discussion due to maturity of the process. The procedures are in an advanced stage thanks to the LCLS-II experience and checked with the verification Cryomodule (vCM), but work on verification for some details is still needed. For example, implement the helium tank leak check after the Vertical Test Stand (VTS) or detail the retightening process in case of leak discovered on beam line vacuum.
   b) LCLS-II and HE are so similar that idea of having a short list of differences in processes and procedures might have interest for the team.
   c) Workstation for cold coupler assembly has been included in cavity string assembly workstation ("WS0 to WS1").
   d) Assembly of the module while the string is under vacuum is under control, this is the result of partner know-how exchanges and hands-on experience with vCM.
   e) Further verification of the assembly method was satisfactory. The test results of both LCLS-II 3.9GHz and LCLS-II-HE vCM relating to field emission and cleanliness standards are state of the art.
2) **Has Fermilab demonstrated the adequacy of their CM assembly infrastructure for HE CM production?**
   a) **Yes** the project team led an R&D effort which has been successfully completed to develop the new cavity processing protocol and has transferred the technology to industry.
   b) There is no major change in the infrastructure except the construction of a new clean area attached to the existing one dedicated to a competing project.

Introduction and Outcome Summary of the Review

c) In case of schedule conflict (new clean area delayed), big tools like rails and cavity post might be used by the competing project.
d) LCLS-II 3.9GHz string was the first proof of principle "WS0 to WS1", a satisfactory result has been achieved with the change in the vacuum manifold of the cleanroom. The purge update was previously in place for LCLS-II CM. On the contrary, the Mass Flow Controller are a new set-up.
e) LCLS-II-HE vCM was a second verification on this "WS0 to WS1", also demonstrating that the longer hoses were sufficient to accommodate all cavities

3) **Is the Fermilab schedule, supply chain, and staffing plan adequate to meet the CM production timeline?**
   a) **Yes**, considering that the key assumptions that went into building the schedule are met. Namely, that vendors deliver key components on time (particularly the cavities and couplers), the reprocessing rate stays around the ~45% target, and most importantly, the CM assembly staff remain available when LCLS-II HE needs them. This is particularly troublesome since the demand by projects is much higher now than at the time of LCLS-II. Although there is confidence that the number of techs is sufficient, the pace of production and the unknown draw from other projects can have major impact. The critical facility pinch points are the clean room in MP9 (as the second clean room for PIP II becomes fully functional) and the CM test stand in CMTF (since the cryogenic system is shared with PIP2IT).
   b) There should be a more definitive statement as to what sets the required date for delivery of CMs to SLAC since the schedule implies the CMs will sit in storage for a year before installation. The possible tradeoff is delivery on schedule so that the CMs can sit around versus spending extra time with a CM that is having performance issues.
4) **Are Fermilab's processes and procedures for HE CM testing adequately developed, documented, and verified?**
   a) **Yes.** Strong experience from LCLS-II has been extended to cover the additional challenges of the HE Project. The successful testing of the vCM solidifies that the procedures have made the leap from LCLS-II personnel to HE personnel. Strong collaboration with SLAC/LBNL staff has allowed adaption of the new EPICS/LLRF systems. The cross-training of SLAC staff should continue to assist with both eventual commissioning and FNAL testing schedule.
5) **Has Fermilab demonstrated the adequacy of their CM testing infrastructure for HE CM production?**
   a) **Conditional Yes**. While the facility (cryogenic, LLRF, HPRF, instrumentation, controls, etc.) successfully executed the vCM test, it was clear that the high inlet temperature required qualification of the vCM with low gradient on cavity 1 due to the high vapor fraction. This configuration is considered sufficient assuming that CM testing at LERF at JLab (with lower inlet temperature) allows unit testing with all cavities at full gradient.
6) **Are QA/QC, ES&H, and WPC processes defined and implemented for HE CM production?**
   a) **Mostly Yes**, There have been instances of escapes of the incoming QC process to ensure that material specifications are reviewed to prevent incorrect parts making their way into the workflow and in some cases the absence of clear acceptance/rejection criteria included in travelers has also led to missing non conformances.
   b) Given the lessons learned form LCLS-II, there are higher expectations for the LCLS-II HE project, i.e., the bar has been raised. It is assumed that issues identified in the LCLS-II lessons learned will not be repeated and that effort will instead be focused on identifying the next level of possible problems.
   c) LCLS-II HE must guard against complacency in that, given their LCLS-II experience, the staff may feel like they are fully aware of all the risks and have them covered. This is when mistakes can happen.

Requests for Action/Recommendations

1. Ensure Accept/Reject criteria are defined and included in all Incoming QC and Workstation Travelers to ensure that non-conformances/discrepancies are flagged, reviewed and dispositioned. Ensure all rejected/non-conforming parts from LCLS-II inventory are segregated prior to LCLS-II HE production, and that this segregation is carried forward.
2. Formalize the interaction of projects that will draw on FNAL resources in a common schedule (at a summary level) to shows overlaps where resources (people, tooling, and infrastructure) will be in high demand.

Comments

3. The project should consider applying the LCLS-II HE Change Request process for reviewing proposed changes to incoming Inspection/QC procedures, sampling, etc.
4. The potential for deltas for determining Max Usable Gradient between EPICS and ACNET is disconcerting. While this wasn't an issue for LCLS-II Gradient specs it does put into question what the Max Usable Gradients for LCLS-II CMs may be.
5. The CM production schedule doesn't show improvements in duration over the course of the project, the limitation appears to be constraints by CM Testing. FNAL should examine if improvements could be achieved and what the implications to cycle time could be.
6. The project should consider performing a detailed review of the processes and procedures with an eye towards matching up what is done at each lab (FNAL & JLab). This should include major QC steps and lessons learned (VV/UCM QC, cavity He-space leak check, M-mount installation). There should be a common standard of performance between both facilities. A short-term exchange of personnel may be worthwhile.
7. Travelers should be reviewed before production begins to check that they include the specification limits where measurement data is recorded, thus, making it easy to see where things are out of spec. It may be possible to write a script that runs through all the travelers and kicks out the values that are abnormal.
8. Develop a process whereby inventory levels at each of the CM assembly facilities can be easily shared to help eliminate a shortage of parts at either.
9. Procedures are 100% ready but work on verification for some detail is needed. For example, in case of leak discovered on beam line vacuum on WS1 detail the saturated leak measurement, the non-contaminant leak rate threshold and retightening process.
10. Analyze the availability of key individuals and determine if there is adequate backup in case that individual is not available.
11. Determine whether a more formal "release to ship" process is needed at other critical vendors (other than WXCX or RI).
12. Determine whether adequate visual evidence (pictures/movies) is being recorded at critical stages of the component QC and CM assembly.
13. The CM testing schedule for HE requires continuous testing cycles for approximately two years. It is unlikely that this time will not be interrupted due to cryogenic operations issues. Consider building time for routine maintenance of the cryogenic system into the testing schedule to reduce unexpected downtime.
14. Direct cavity production oversight was critical for LCLS-II and will continue to be so for HE. It is recommended that, if COVID-19 continues to impede project staff from visiting the cavity vendor in-person, that a European partner is identified that can send a qualified representative in the project's place.
15. The oversight of the cavity testing by the Cavity Technical Board should be as flexible and responsive as possible to avoid delaying or complicating VTS testing logistics.

Findings

a) LCLS-II HE is iterative on the LCLS-II design. Fermilab is again the CM Designer of Record. A rigorous change control and configuration management system has been in place and working, although errors in this process have been discovered.

b) Fermilab will build 13 production CMs (not counting the vCM). All will be tested at CMTS.

c) The delivery of CMs to SLAC is not driven by their tunnel installation date but rather the desire to have some continuity in the assembly and test sequence.

d) Two cavities in the vCM and a significant number of remediation cavities have been found to have the older length of field probe. The change of field probe length was made during LCLS-II production. This led to lower pickup probe field coupling and higher probe power at field, resulting in potential thermal and phase stability issues in operation. This issue was discovered late in vCM testing. The remediation cavities will be reworked at the vendor and retested at FNAL.

e) Instances of not validating material certifications upon receipt, examples being 316LN and high tensile strength SiBronze, indicate a gap in the QC processes. FNAL will assess this going back and in the future.

f) LCLS-II HE anticipates a relatively high yield for its cavities but has an option to expand the cavity procurement in case additional information indicates a lower than expected yield. This decision is planned such that cavity vendor production would not be interrupted.

▪ The title of the item or system ▪ A description of the item ▪ WBS Number ▪ Type of design review ▪ Date of the review ▪ Names of the presenters ▪ Names, institutions and department of the reviewers ▪ Names of all the attendees (attach sign-in sheet) ▪ Completed Design Checklist (if utilized)	▪ Requests for Action/Recommendations – require action by the design/engineering team and are tracked to closure. Criteria: o Concise sentence starting with an action verb (Consider…, Analyze…, Evaluate…, Compare…, etc.) o Based only on material presented or note if necessary material is missing o Supporting information leading up to a recommendation should exist in the Findings and Comments sections o Only make recommendations that relate to the project taking a different course of action o Group items into a single recommendation when possible ▪ Comments – personal opinion or thoughts of reviewers related to a Finding ▪ Findings – factual restating of important points presented and require no response