LCLS-II 1.3 GHz Cryomodule

Production Readiness Review

Introduction

A Production Readiness Review (PRR) of the LCLS-II 1.3 GHz Cryomodule was held on 13-14 September 2016 at Fermilab. The agenda and charge are appended to this report. The review committee consisted of: Ian Evans (SLAC), Ralf Eichhorn (Cornell), Hitoshi Hayano (KEK), Axel Matheisen (DESY), Olivier Napoly (CEA, Chair)

1. General Remarks

- The committee thanks the organizers of the review and commends the speakers for the quality of the material presented and of the discussions ensuing the many questions asked to them.
- The scope of the Review encompasses WBS chapters 1.04.05.08/1.04.05.09/1.04.05.10/1.04.05.11, from '1.3 GHz Cryomodule Cavity Prep/Test' to '1.3 GHz Cryomodule Test'.
- The labs are ready to go for production but one key element is still missing, namely the results of the pCMs tests at FNAL and at JLab. The conclusions (comments and recommendations) of this Review are therefore contingent to the successful realization of these tests, and to the compliance of the measured performance of the cryomodules.

2. Comments

- A new « cryomodule equivalence principle » is formulated, replacing the previous « cryomodule identical assembly » paradigm, to take into account the different experiences gained on cryomodule production at FNAL and JLab.
- Different approaches have been gradually implemented for important aspects of the project: part storage, module assembly procedures, control procedures, QA/QC and work flow integrated in the production travelers. This may result in difficulties in communicating lessons learnt and optimizing synergies between FNAL and JLab.
- FNAL manpower allocation is accurately mapped onto the assembly schedule (Oct.16-Apr.18).
- JLab manpower is allocated from their pool of experienced technicians and engineers. This can lead to conflict with other ongoing activities at JLab.
- Design review recommendations have been incorporated.
- Lessons learned from prototype assembly have been incorporated in design and improvements were made. The committee commends the design team.
- Significant delay occurred in pCM assembly.
- Handling of non-conformities took extensive time.
- Learning curve is anticipated.
- Loading of workstations at FNAL was un-uniform. Loading of workstations at JLab was not shown.
- The pCM assembly at JLab is not finished and details of assembly were not completely provided.
- Integrated Safety Management (ISM) and the flow down of ESH requirements is incorporated via Institutional Programs as evidenced by review of supporting documents and FNAL staff interviews.
- Early in Cryomodule Design the need arose to ensure that Fermilab policies also satisfy the requirements of partner DOE Labs. SLAC reviewed the respective Institutional ESH and QA programs to identify gaps which have since been filled.

- Dedicated ESH Support Staff help ensure Project compliance to program ESH/WPC requirements.
- Interviews with FNAL Production Facility staff demonstrated knowledge of the Traveler & QA processes and their ability to make changes. They have incorporated the FNAL Work Planning and Hazard Analysis process, which is key to hazard identification and mitigation. The overview provided of the JLab Work Center Operational Safety Procedures suggests a comparable process.
- The Production Facility (MP9) and Assembly Area at FNAL were clean and tidy, it was obvious staff took pride in what they are doing. The facilities at JLab could not be visited by the committee members so far.
- Both Facility Assembly Travelers looked sufficiently detailed to capture the status of Cryomodule configuration, issues and changes.
- A previous review identified the need to have a unified and consistent Lessons Learned program in place that allowed communication between partner labs (TJNAF, FNAL and SLAC) in a timely manner. The recommendation was addressed by having LL's be part of the Quality Control process and documented via the Deviation Request Form. It does not appear to be implemented.
- Notable Practices at FNAL
    - String Assembly Readiness reviews (30 min max) where the three elements of a readiness review (people, procedures and hardware) are addressed in a brief meeting is a very positive communication tool
- pCM Assembly presentation had lots of photos as do assembly plans/procedures, field staff were in agreement that these are always helpful. Keep up that aspect.
- For QA/QC each lab makes use of a well know and well established software, supported by experienced software engineers.
- Even if software systems for QA/QC are different, documents exchange transfer protocols for documents are established and tested.
- At both laboratories QA/QC documents are well established and complete. Also the team members are experienced in using the QC/QA documentation and the software in use at their lab.
- Lessons learned from prototype assembly have been incorporated in the QA/QC documents.
- Electronic accessibility to the documents on all FNAL Workstations is excellent.
- Exchange of QA/QC documents with JLab production is verified.
- Revision and update of travelers is completed during pCM assembly at FNAL, while at JLab this procedure is ongoing for the assemblies outside of the cleanroom.
- FNAL and JLab seem to be well prepared for the production phase, the implementation is successful.
- CM assembly procedures in use at JLab and FNAL differ for each other. The workflow at FNAL is close to the sequences used for E-XFEL. The sequences applied at JLab are based on the long time experiences of JLab.
- QA/QC of cavities is well defined and straightforward but might conflict with the 30% retreatment rate for cavities planned so far.
- The number of parts in circulation for RF couplers is not enough to fit CM production schedule.
- A specification is required in visual inspection, especially on inner Cu plating of RF couplers.
- Continuous attention is required on the consequences of no couplers RF process.
- The rate of non-conforming first articles, e.g. cavities with field emission and RF couplers not sufficiently clean for CM02, is much higher than expected and would presumably not be compatible with the schedule and resources foreseen for cryomodule production.
- Production throughput (5 weeks) includes margin with respect to the peak rate production target (PTLD).

- Transportation between WS2 and WS3 at FNAL (string through the weather) may be troublesome.
- Maintenance/calibration/certification of infrastructure, tooling and instruments are in place.
- Supply chain management is in place.
- JLab production differs from FNAL in many respects (additional HPR after testing, warm coupler assembly while string under vacuum, no nitrogen purge, etc…)
- Cool-down performance of conduction-cooled magnet in FNAL pCM was not reported.
- The plan of tuner-piezo performance test in FNAL pCM was not reported.
- The preparation of JLAB pCM-testing is on-going: the plan of experiment is mentioned for cavity and BPM, but not for the magnet.
- Cryogenics capacity is limited for different reasons at FNAL (project demands, LCLSII cavity re-testing) and at JLab (available cooling power and cooling rate) for cryomodule tests, with a potential impact on the rate and validity of the cryomodule RF tests.

3. Recommendations (**BOLD** indicates must be complete before proceeding with assembly of production module)

3.1 Keep CM02 cavity string in the clean room until the test of the pCM cryomodule is completed, independently at both laboratories.

3.2 Design and manage communication 'bridges' between the two teams in order to increase harmonisation and synergy for the best profit of the project as a whole.

3.3 Foresee some flexibility/contigency in the manpower allocation to allow for schedule shift, for whatever reason.

3.4 Continue analyzing prototype assembly issues and continue implementing lessons learned

3.5 Regarding design, keep processes and personal assignments alive in case there are unexpected findings after testing the prototypes (pCM's) or on the second article assembly (CM02's)

3.6 Complete the design of support stand to meet the seismic requirements.

3.7 Define how lessons learned will be documented and communicated, ensure everyone is aware of process and uses it.

3.8 Consider using the 30 min Readiness Review (the purpose is to ensure that drawings, travelers, parts, and tooling are all in place) for all discreet assembly work; and propagating to JLAB activities.

3.9 Perform a review to ensure that implementation of travelers/procedures is well understood by technicians.

3.10 Allot resources to analyze data of conforming parts to detect trends that might become non-conforming.

3.11 Exchange and synchronize QC inspection documents, especially NCR, between partner labs on regular basis for tracking quality of incoming parts.

3.12 Establish a scenario for cavity retreatment like E-XFEL did.

3.13 Specify handling of coupler shipping case during shuttle transport from and to vendors (cleanliness, integrity).

3.14 Continue monitoring RF performance of the couplers during module testing and cavity horizontal testing.

3.15 Consider means to reduce WS1+WS2 PLTD at FNAL using E-XFEL experience, to further increase the contingency in the production throughput.

3.16 Add the quality control of infrastructure/tooling/instruments to the traveler systems.

3.17 Continue implementing pure N2 flushing gas distribution in the clean room at JLab to mitigate the risk of field emission, pending on the pCM and CM02 test results.

3.18 Check the magnet temperature vs. time, and perform magnet excitation test.

3.19 Check the LLRF control stability including with piezo-tuner in the loop.

3.20 Regarding the issue of field emission of cavities, analyse the cavity surface by sampling the residuals with adhesive carbon tape and SEM observation.

3.21 Consider involving both labs experienced personnel in a review of the industrial process of cavity fabrication.

3.22 Consider a ramp up and recovery scenario, including infrastructure capacity and increased QC, how to stay in schedule if major problems appear, e.g. high rate of incoming non-conformities.

3.23 Assess the cryogenics plants capacity in terms availability, cooling power and cooling rate.

4. Committee Responses to the Charge

1. Technical Scope and Schedule (FNAL and JLab):

- Is the scope of work defined properly? **YES**
- Is the schedule reasonable to achieve the defined scope? **YES**
- Are there opportunities for schedule advancement or schedule recovery in cases of cryomodule rework or repairs? **YES, contingent to findings from module tests and cavity tests**
- Are the prototype test-results, as available, consistent with initial acceptance criteria? **N.A., prototype test-results are not available**

2. Cryomodule Assembly Team (FNAL and JLab):

- Have all key project team members been identified? **YES**
- Have roles and responsibilities been clearly defined? **YES**
- Is the staffing level suitable to support the production plan? **YES**

3. Design Status (FNAL):

- Are all design specifications, requirements, performance, and interface documents reviewed, approved and released? **YES**
- Are the drawing packages 100% complete and released to permit successful fabrication? **YES, with the exception of cryomodule tunnel supports.**
- Have all previous design review recommendations been addressed and/or closed out? **YES**

4. *ES&H and Work Planning and Control (FNAL and JLab):*

- Is there evidence of work planning and control processes in day-to-day procedures? **YES**
- Have all safety risks been identified and ranked? **YES**
- Is there evidence of appropriate hazard mitigation plans? **YES**

5. *Quality Assurance and Quality Control (FNAL and JLab):*

- Is there a process for configuration management in place, e.g. drawing release status, change approval authorization, red-line process, as-builts, etc? **YES**
- Is the process for incoming component inspections, sub-system check-out, documentation, and responsibilities well planned? **YES**

6. *Production Management (FNAL and JLab):*

- Have all of the major risks been identified and managed? **YES, risks have been identified but risk management still continues**
- Is the supply chain in place and well planned, especially drop-shipments between partner laboratories? **YES**
- Are the processes for qualification, QA, material handling, storage, and risk mitigation adequate for the cavities and fundamental power couplers (FPCs), both of which are high-risk, no guarantee elements? **YES**
- Have lessons learned and traveler documentation from Eu-XFEL, Fermilab CM02, and JLab 12 GeV Upgrade been incorporated into the assembly procedures and component/system check-out planning? **YES**

- Are all travelers and assembly procedures updated and available? **YES**
- Is there an agreed upon plan in place to collect and deliver all relevant inspection, assembly and testing data to SLAC for each cryomodule? **YES**

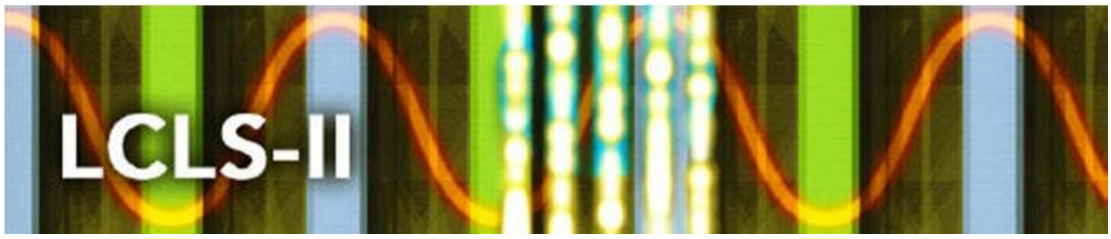
7. Miscellaneous (FNAL and JLab):

- Have all of the major risks been identified and managed? **same as above**
- Are there any other issues that have been identified that need to be addressed? **depends on the outcome of the pCM tests and cavity tests**

8. *Overall Readiness (FNAL and JLab):*

- Are all plans, processes and resources in place to fabricate the LCLS-II cryomodule, so that there is a high likelihood of success to meet the schedule and system performance requirements? **YES, pending action on recommendations and, contingent on the availability of the cavity and module tests stands (e.g. cryogenics)**

Appendix 1 - Charge



LCLS-II Review Committee Charge for:

1.3 GHz Cryomodule

Production Readiness Review

The review committee is charged to evaluate the production readiness of the LCLS-II cryomodule at Fermi National Accelerator Laboratory (FNAL) and Thomas Jefferson National Accelerator Lab (JLab). To carry out this charge, the review committee should evaluate the system readiness by responding to the following questions:

1 Technical Scope and Schedule (FNAL and JLab)
   a. Is the scope of work defined properly?
   b. Is the schedule reasonable to achieve the defined scope?
   c. Are there opportunities for schedule advancement or schedule recovery in cases of cryomodule rework or repairs?
   d. Are the prototype test-results, as available, consistent with initial acceptance criteria?

2 Cryomodule Assembly Team (FNAL and JLab)
   a. Have all key project team members been identified?
   b. Have roles and responsibilities been clearly defined?
   c. Is the staffing level suitable to support the production plan?

3 Design Status (FNAL)
   a. Are all design specifications, requirements, performance, and interface documents reviewed, approved and released?
   b. Are the drawing packages 100% complete and released to permit successful fabrication?
   c. Have all previous design review recommendations been addressed and/or closed out?

4 ES&H and Work Planning and Control (FNAL and JLab)
   a. Is there evidence of work planning and control processes in day-to-day procedures?
   b. Have all safety risks been identified and ranked?
   c. Is there evidence of appropriate hazard mitigation plans?

5 Quality Assurance and Quality Control (FNAL and JLab)
   a. Is there a process for configuration management in place, e.g. drawing release status, change approval authorization, red-line process, as-builts, etc?
   b. Is the process for incoming component inspections, sub-system check-out, documentation, and responsibilities well planned?

6 Production Management (FNAL and JLab)
   a. Have all of the major risks been identified and managed?
   b. Is the supply chain in place and well planned, especially drop-shipments between partner laboratories?
   c. Are the processes for qualification, QA, material handling, storage, and risk mitigation adequate for the cavities and fundamental power couplers (FPCs), both of which are high-risk, no guarantee elements?
   d. Have lessons learned and traveler documentation from Eu-XFEL, Fermilab CM02, and JLab 12 GeV Upgrade been incorporated into the assembly procedures and component/system check-out planning?
   e. Are all travelers and assembly procedures updated and available?

f. Is there an agreed upon plan in place to collect and deliver all relevant inspection, assembly and testing data to SLAC for each cryomodule?

7 Miscellaneous (FNAL and JLab)

a. Have all of the major risks been identified and managed?
b. Are there any other issues that have been identified that need to be addressed?

8 Overall Readiness (FNAL and JLab)

a. Are all plans, processes and resources in place to fabricate the LCLS-II cryomodule, so that there is a high likelihood of success to meet the schedule and system performance requirements?

Appendix 2: Review Agenda

Tuesday, September 13, 2016

- 08:00 - 08:15 Committee Closed Session *15'*
- 08:15 - 08:20 Introductory Remarks / Safety Briefing *5'*
  Speaker: Richard Stanek (Fermilab)
- 08:20 - 08:50 Cryomodule Project Overview *30'*
  Speakers: Camille Ginsburg (Fermilab), Edward Daly (Thomas Jefferson National Accelerator Facility)
  Material: **Camille's Slides** **Slides**
- 08:50 - 09:20 CM Design Status *30'*
  Speakers: Joshua Kaluzny (Fermilab), Mr. YURIY ORLOV (FERMILAB)
  Material: **Slides**
- 09:20 - 10:20 FNAL pCM Assembly Experience *1h0'*
  Speaker: Tug Arkan (Fermilab)
  Material: **Slides**
- 10:20 - 10:30 Coffee Break
- 10:30 - 11:15 JLab pCM Assembly Status *45'*
  Speaker: Tony Reilly (Jefferson Lab)
  Material: **Slides**
- 11:15 - 12:00 FNAL CM QA/QC *45'*
  Speaker: Jamie Blowers
  Material: **Slides**
- 12:00 - 13:30 Lunch
- 13:30 - 14:00 JLab CM QA/QC *30'*
  Speaker: Johnny Leung (Jefferson Lab)
  Material: **Slides**
- 14:00 - 14:30 JLab CM: Status of travelers/procedures *30'*
  Speaker: Katherine Wilson (Jefferson Lab)
  Material: **Slides**
- 14:30 - 15:00 FNAL Cavities: QA/QC, qualification, work flow *30'*
  Speaker: Alex Melnychuk (Fermilab)
  Material: **Slides**
- 15:00 - 15:30 JLab cavities: QA/QC, qualification, work flow *30'*
  Speaker: Kirk Davis (Jefferson Lab)
  Material: **Slides**
- 15:30 - 15:50 Coffee Break
- 15:50 - 16:10 FNAL couplers: QA/QC, qualification, work flow *20'*
  Speaker: Ken Premo
  Material: **Slides**
- 16:10 - 16:30 JLab couplers: QA/QC, qualification, work flow *20'*

Speaker: Mircea Stirbet (Jefferson Laboratory)

Material: Slides

- 16:30 - 17:00 Discussion *30'*
- 17:00 - 18:00 Committee Closed Session *1h0'*

Wednesday, September 14, 2016

- 08:00 - 09:00 FNAL CM Production Plan *1h0'*

  Speaker: Tug Arkan (Fermilab)

  Material: Slides
- 09:00 - 09:45 JLab CM Production Plan *45'*

  Speaker: Bob Legg (Jefferson Lab)

  Material: Slides Video document
- 09:45 - 10:30 Discussion *45'*
- 10:30 - 10:45 Coffee Break
- 10:45 - 11:30 FNAL pCM Test Results *45'*

  Speakers: Dr. Genfa Wu (FNAL/TD), Elvin Harms (Fermilab)

  Material: Slides
- 11:30 - 12:00 JLab pCM Test Plans *30'*

  Speaker: Mike Drury (JLab)

  Material: Slides
- 12:00 - 13:30 Lunch
- 13:30 - 14:00 Closing Remarks *30'*

  Speakers: Camille Ginsburg (Fermilab), Edward Daly (Thomas Jefferson National Accelerator Facility)

  Material: Slides
- 14:00 - 15:20 Committee Closed Session *1h20'*
- 15:20 - 16:20 Close-out *1h0'*