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| * 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)
 | * Findings/List of Action Items – these are items that require formal action and closure in writing for the review to be approved. See Document LCLSII-1.1-QA-0009 for Design Review Requirements and Guidelines
* Concerns – these are comments that require action by the design/engineering team, but a response is not required to approve the review
* Observations – these are general comments and require no response
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| Type of Review: | Preliminary Design Review (PDR) / Final Design Review (FDR) |
| Title of the Review: | LCLS-II Linac Vacuum Conceptual Design Review |
| WBS: | 1.04.05.05.03 - 3.9 GHz Engineering & Design1.04.05.12 - 3.9 GHz Cryomodule Procurement and Fabrication |
| Presented By: | FNAL Design Team (agenda includes presenters)  |
| Report Prepared By: | Edward Daly, JLAB for Reviewers |
| Reviewers / Lab : | E Daly / JLAB (chair), Elmar Vogel / DESY, Paolo Pierini / INFN-DESY, Jacek Sekutowicz / DESY-SLAC, Cho Ng / SLAC | Date: | Review Date: 20 NOV 2015Report Date: 18 DEC 2015 |
| Distribution: | C. Ginsburg, G. Wu and Design Team / FNAL, M. Ross, G. Hays, L. Plummer, D. Marsh / SLAC |

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| Attachments: | [ ]  Review Slides [ ]  Design Checklist [ ]  Calculations [ ]  Other |

| Purpose and Goal of the Review |
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| The review committee is charged to evaluate the preliminary design of the LCLS-II 3.9 GHz CM to assess six areas - technical scope, design management, cost & schedule, ES&H, responses from previous reviews and overall readiness. Concurrently the review committee is charged to evaluate the final design of the LCLS-II 3.9 GHz Dressed Cavity to assess these same six areas - technical scope, design management, cost & schedule, ES&H, responses from previous reviews and overall readiness.The PDR charge:The review committee is charged to evaluate the preliminary design readiness of the LCLS-II 3.9 GHz Cryomodule to assess implementation, procurement, fabrication and installation activities maturity. To carry out this charge the review committee should evaluate the design readiness by responding to the following questions:**Technical Scope**Are all specifications, requirements, performance and interface documents identified, reviewed, and at the level of maturity commensurate with a PDR.Is the design sufficiently mature and technically sound so as to meet the performance specifications? In particular:* 1. Is the HOM, coupler heating, and the CM heat load understood? Qualified yes - see recommendations.
	2. Have the chimney sizes, etc. have been increased appropriately to accommodate the larger average heat load? Qualified yes - see recommendations.
	3. Do the changes made to the cavity geometry increase either the HOM power generated or the multipacting activity? Qualified no - see recommendations.
	4. Are the materials used in the design sufficiently rad hard? Yes.
	5. Is the 1.3 GHz CM beam line absorber effective? Yes.
	6. Have installation issues been identified and addressed? Qualified yes - see recommendations.
	7. Have all the major interfaces been identified and incorporated into the design? Yes.
	8. Are the design differences with earlier-generation cryomodules identified clearly? Yes.
	9. Are strategies for further analysis or testing identified? Qualified yes - see recommendations.

**Design Management**1. Is the design team organized and staffed to successfully complete the project? Yes.
2. Have all of the major risks been identified? Yes.
	1. Are procurements appropriately identified and being planned/prepared? Qualified yes - see recommendations.
	2. Is the development of associated drawing packages sufficiently mature? Qualified yes - see recommendations.

**Cost and Schedule**1. Is the current preliminary cost and schedule reasonable to achieve the planned scope? Qualified yes – see recommendations.

**ES&H**1. Have all related ES&H aspects been identified, and planned to be properly addressed? Yes.

**Miscellaneous**1. Have all the previous design review action items/comments been addressed? Yes.
2. Are there any other issues that have been identified that need to be addressed? No.

**Overall Readiness**1. Is the design maturity at the level sufficient for preliminary design review approval? Yes for the Cryomodule design.

The FDR charge:The review committee is charged to evaluate the System design readiness of the LCLS-II (System/Device to be reviewed) to approve implementation, procurement, fabrication and installation activities. The dressed cavity is understood to include the niobium and niobium titanium of the bare cavity, as well as the titanium helium vessel with chimney up to and including the SS tee connection to the 2-phase pipe. To carry out this charge, the review committee should evaluate the System Design readiness by responding to the following questions:**Technical Scope**1. Are the designs mature and technically sound to satisfy design specifications? Qualified yes - see recommendations.
2. Is the design likely to meet performance expectations? Qualified yes - see recommendations.
3. Have installation issues been adequately addressed? Qualified yes - see recommendations.
4. Have all the major interfaces been identified and incorporated into the design? Yes.
5. Are all design specifications, requirements, performance, and interface documents reviewed, approved and released? Qualified yes - see recommendations.

**Design Management**1. Is the design team organized and staffed to successfully complete the project? Yes.
2. Have all of the major risks been identified and managed? Yes.
3. Are procurements appropriately planned? Qualified yes - see recommendations.
4. Is the development of associated drawing packages sufficiently mature? Qualified yes - see recommendations.

**Cost and Schedule**1. Is the cost and schedule reasonable to achieve the planned scope? This is a reasonableness assessment by technical experts, not a detailed cost/schedule review. Qualified yes – see recommendations.

**ES&H**1. Are all related ES&H aspects being properly addressed? Yes.

**Miscellaneous**1. Have all the previous design review action items/comments been addressed? Yes.
2. Have lessons learned been addressed? Yes.
3. Are there any other issues that have been identified that need to be addressed? No.

**Overall Readiness**1. Is the design sufficiently mature so as to allow Final Design Review approval? Yes. Action items can be resolved prior to the Procurement Readiness Review.
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| Introduction and Outcome Summary of the Review |
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| For LCLS-II, preliminary designs are defined as having 30 – 50% design maturity. The presentation materials for the 3.9 GHz CM described the design in sufficient detail consistent with this definition found in SLAC-I-060-107-002-00-R001. For LCLS-II, final designs are defined as having 90 – 100% design maturity. The presentation materials for the 3.9 GHz dressed cavity described the design in sufficient detail consistent with this definition found in SLAC-I-060-107-002-00-R001.Substantial technological background exists at FNAL, developed in the last 10 years mainly through ILC and the development and construction of the FLASH 3.9 GHz module. Moreover, the LCLS-II 3.9 GHz systems integrates the recent changes introduced in the EuXFEL 3.9 GHz system and proposes variations (in line with those used for the LCLS-II 1.3 GHz components) to cope with the foreseen CW operation mode. It is pointed out that the 1.3 GHz CM already underwent several design reviews, up to Final Design stage, and that the 3.9 GHz leverages that experience where possible.During the review, a number of issues and concerns were identified and discussed as technical designs were presented. Lessons learned were sufficiently addressed. Hazards were identified and appropriately addressed. In addition, an initial list of failure modes were presented and discussed. Members of the review team provided input and feedback on several design and manufacturing issues.Overall, the review team recommends proceeding to the final design phase for the cryomodule and proceeding with procurement of the niobium materials for cavity production as the cavity design is more that 90% complete. |

| Findings and Action Items |
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| The charge, agenda, presentations and supporting materials can be found at FNAL’s Indico site - <https://indico.fnal.gov/conferenceDisplay.py?confId=10847>.Within the meeting notes are 26 action items that address a variety of technical issues related to the 3.9 GHz CM preliminary design, configuration and layout. A subset of the action items (7 identified with \*) addresses the 3.9 GHz Dressed cavity final design and readiness for procurement.

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| **ID** | **Committee Action Items/Recommendations** |
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| **1** | Confirm that the stability specs, 1E-4 and 0.01°, respectively for the amplitude and phase rms, with 130Hz bandwidth are achievable. |
| **2** | Confirm that LLRF and piezo actuator can suppress microphonics below 30Hz (peak). |
| **3** | Determine at what frequencies cavities have mechanical vibrations and how many of the resonances need to be suppressed. If this is difficult to model, consider developing a test plan. |
| **4** | Recommend that the design team performs computer modeling, to determine the tolerable maximum heat leak of cable (static + dynamic) that does not heat the Nb tip above the Tc, and thus does not cause significant increase of the dissipation. |
| **5** | Confirm geometry and materials for the HOM and FP coaxial cables as part of the thermal analysis that finalizes the thermal management scheme. This is done in an effort to ensure that HOM heating is not a performance problem. |
| **6** | Evaluate the possibility of housing 16 cavities in a single cryostat from a technical point of view. This module will be shorter than the 1.3 GHz CM and may provide some cost savings. |
| **7** | The 3.9 GHz module may differ from the 1.3 GHz module for considering seismic and transportation safety. It is recommended to start these design activities soon, especially concerning ES&H aspects for the seismic load, well in advance to include possibly needed corrective actions as part of the final design stage. As part of this effort the acceleration parameters used for the transport of the 1.3 GHz modules should be verified for the case of the 3.9 GHz string support scheme. Confirm the seismic and transportation loads compared with FLASH & XFEL and perform analysis as part of the final design phase. |
| **8\*** | It is proposed to modify the radius of the pullout of the main and HOM couplers. The reviewers recommends that the design team discuss this manufacturing modification, as the pullout radius is rarely a free parameter, with the cavity manufacturer in order to comply with its pullout procedures and with the material properties. |
| **9\*** | The review committee notes that the HOM coupler can top was found hard to tune due to an increase in thickness based on the EuXFEL experience. Several tuning devices had worn out during the operations as an indication of the larger forces needed. Recommend prototyping quickly a further increase in thickness rather than relying on non-linear simulations. This can be part of the cavity fabrication phase. |
| **10** | Plan prototyping activities integrated into the overall schedule for the FPC to confirm that the design changes are acceptable. The design currently proposes changing the ceramic cold window and an increase in copper plating for the warm section or a solid copper design solution. |
| **11** | Consider rapid prototype models to address the feasibility of the assembly operations between the dressed cavity and tuner. There is concern due to the relocation of the tuner ring as compared with XFEL. |
| **12\*** | The welds of the tuner ring are now close to the cavity end used for length adapting to the cavity. The inner surface of the tank and the outer surface of the adapting ring are machined with good tolerances and thus it is needed to ensure that in the fabrication process the machining are performed after the welding, that could lead to local deformation and to out-of-roundness, preventing the sliding of the two pieces. |
| **13\*** | Incorporate comments from reviewers into dressed cavity drawing package and finalize the cavity technical specification. INFN/DESY can provide material drawings for comparison and potential cost savings. |
| **14\*** | Develop and document the frequency recipe for the cavity that includes allowances for chemistry, tuning, vacuum loading and cooldown. Include details and specifications for tuning of HOM cans. |
| **15\*** | Compare the present niobium material list with the previous FLASH and EuXFEL procurements prior to soliciting quotations from vendors. |
| **16** | It is strongly suggested to achieve a quick verification of the beneficial effects of the 120°C bake on the 3.9 GHz cavities, possibly through tests on FLASH or EuXFEL structures, if feasible. |
| **17** | Consider adjusting the overall schedule to build first CM and test prior to building second CM. |
| **18** | Ensure that engineering notes, requirements and analysis are ready for FDR – specifically the Cryomodule Piping Engineering Note, Cryomodule Cavity Engineering Note and the Cryomodule Vacuum Vessel design specification. |
| **19** | Update the heat load estimate engineering note (LCLSII-4.9-EN-0179) prior to the Final Design Review. |
| **20\*** | An agreement needs to be put in place between INFN and FNAL for the cavity licensing agreement. A critical look at the IP licensing agreements is necessary. |
| **21** | The external Q for FPC is almost 3 x 10^7 as compared with 3.6 x 10^6 for XFEL pulsed. Recommend horizontal testing early in order to verify resonance control and operational stability. |
| **22** | Recommend adding tuner access ports in order to address maintenance and reliability concerns. |
| **23** | Perform detailed multi-pacting simulations in order to assess the impact of incremental changes for the proposed cavity design. |
| **24** | Review prototyping plans for the FPC to ensure that the schedule includes appropriate time for these efforts. Include INFN colleagues in the review process. |
| **25** | Verify the required RF transition length between the last cavity and the HOM absorber in order to suppress the radiation power. |
| **26** | The margin for critical heat load through the chimney is not sufficient for 16.5 MV/m and 1.5 x 10^9. The design is constrained such that chimney size is largely fixed. Therefore the design team will rely on baking and magnetic shielding to achieve performance. Recommend developing nitrogen doping as a mitigation strategy. |
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For the CM, it is recommended that these action items be closed as the design team proceeds into the final design phase. For the dressed cavity, it is recommended that these action items be closed prior to the Procurement Readiness Review (PRR). In terms of relative priority, it is expected that dressed cavity issues would take priority over CM design issues. Note that copies of the dressed cavity drawing package were distributed to several reviewers. Comments will be returned by mid-December. The design team should incorporate these comments prior to the PRR. |

| Concerns |
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| In this section, concerns identified by the review team are given. In some cases, the concerns are formulated as questions provided by review team members. In all cases the comments and questions here are intended to provide background in order to clarify recommendations.The review team could not find in any presentation an analysis of the mechanical vibrations of the 3.9GHz cavities. The VS stability, both amplitude and phase, for FLASH cavities was demonstrated with Qload of ~1E6, which is 25 times lower than we plan for LCLSII. Are the stability specs, 1E-4 and 0.01°, respectively for the amplitude and phase rms, with 130Hz bandwidth achievable? Can LLRF and piezo actuator suppress microphonics below 30Hz (peak)? Do we know at what frequencies cavities have mechanical vibrations and how many of the resonances need to be suppressed? If this is difficult to model, would it make sense to recommend measuring this? Maybe such a test was already done?Is the 9µW dissipation on the antenna tip? If yes, the design team should perform computer modeling, to determine what is the tolerable maximum heat leak of cable (static + dynamic) which does not heat the Nb tip above the Tc, and thus does not cause significant increase of the dissipation.There will be thermal intercepts on the cable outer conductor but not on the inner conductor. Will the cable inner conductor be made of copper?There will be a sapphire window in the feedthrough, but even though, part of the heat will go to the tip. Is this a problem when the tip is above Tc and dissipation is significantly higher?The design review team proposes to list pros and cons to house all 16 cavities in one vacuum vessel, one cryomodule. Is there any technical, RF-type or mechanical reason not to house all 16 cavities in one cryomodule? It will be still shorter than the standard 1.3 GHz cryomodule and might afford some cost savings.Experience with the FLASH/EuXFEL design and the CW operation of LCLS-II suggests at least two main modifications of the cavity RF design:1. The shift to higher frequencies of the lowest dipole mode trapped in the coupler end group by reducing the beam pipe diameter from 40 to 38 mm, and
2. The overheating of the HOM antennas is mitigated by reducing its penetration in the beam pipe and increasing the length of the bump facing the demountable antenna.

As an additional method to deal with the first issue it is proposed to modify the radius of the pullout of the main and HOM couplers. The Committee, however, suggests not to rely on this manufacturing modification, as the pullout radius is rarely a free parameter, but is typically discussed with the cavity manufacturer in order to comply with its pullout procedures and with the material properties.The methods proposed in 1 and 2, without changing the complete RF design of the cavity (the RF cells are kept identical to the old designs), seem to offer the perspective to simplify the HOM tuning procedures and avoid the possibility that the spurious dipole mode falls to close to the operating mode (happened in one EuXFEL prototype which was subject to more than twice the nominal material removal, with the result of compromising its operation at the operating mode).Concerning the HOM cans, an increase of the “hat” thickness t is proposed. One FLASH cavity (t=1 mm) was broken. In EuXFEL (t=1.15 mm) a leak was developed in the area after BCP (but no mechanical action). The use of 1.3 mm, supported by FEM analysis, is proposed. However, the Committee notes that already with the EuXFEL increase the rather tiny notches were found hard to tune, and several tuning devices wear out during the operations, as an indication of the larger forces needed. Prototyping quickly a further increase would be more practical rather than relying on non-linear simulations.A HOM statistical analysis of the sensitivity of the geometry with the modifications proposed in 1 and 2 above with respect to the old RF design suggest no different in the spread of structure resonant losses.The modifications proposed for the coupler (besides the obvious change of the inner antenna length to adapt to the changed beam pipe radius and beam structure) are more substantial:1. Different ceramic window for the cold part
2. Increased copper plating of the inner conductor of the warm section or reduction of the convolution and use of solid copper

Both changes indeed require intense coupler prototyping indicating a conceptual state at this point. The possible reduction of the number of convolutions needs also to be checked with the necessary requirement for the assembly operation. Surely the coupler need to compensate the vertical motion of the cold mass between installation and cold state and also allow the projected geometric tolerances of the cavity flange plane at the module warm flange position.The technical documentation of the design changes was shown. The current dressed cavity design include the RF modifications and the provisions for larger two phase pipe and chimney plus the shift of the tuner ring to one of the cavity extremities, to allow for piezo insertion. The drawing package and the bimetallic joint qualification were shown. The material shown satisfies the FDR preparation level, even if some of the documentation (pressure vessel note) is not yet completed.One possible concern related to the shift of the tuner ring to the end of the cavity is that it is not straightforward to assess the clearance for all assembly operations during (and after) the transferring of the string to the cold mass. In these phases access with hands and tools needs to be granted for several operations (completion of the magnetic shield assembly, cavity alignment and loading of the roller bearings, finalization of the tuner assembly, etc.). Some of these operations turned out to be complex on the XFEL string and appear more challenging in this configuration, where the support is placed across the tuner. Rapid prototype models could address the feasibility of the assembly operations.A second concern is that the welds of the tuner ring are now close to the cavity end used for length adapting to the cavity. The inner surface of the tank and the outer surface of the adapting ring are machined with good tolerances and thus it is needed to ensure that in the fabrication process the machining are performed after the welding, that could lead to local deformation and to out-of-roundness, preventing the sliding of the two pieces.The design team should check carefully procedures for the connection of the GHRP assembly to the cavity string, as the blade tuner is across the supports and accessibility is needed in this region.What has not been presented in this or other presentations is the full strategy for the frequency preparation of the cavities during and after integration, which includes the tuning range capabilities and any requirement for limiting the maximum coarse tuner range to avoid the onset of plasticity at the cavity irises. Due to the high sensitivity to frequency, the relatively low allowance for deformations (it is mentioned the EuXFEL case where the compliance to the MAWP condition of 4 bar imposes a limit of a 0.3 mm coarse range) and the many uncertainties in the frequency response of the cavities during their preparation (e.g. spread of etching coefficients and frequency sensitivities to chemistry), such a strategy is needed to reach correctly the operating conditions within the allowed limits.The niobium procurement intends to follow consolidated material specifications used in the community and was deemed reasonable. As a minor comment, the proposed material procurement, which has not been discussed in detail with potential vendors, appears to be not the most efficient in terms of procurement time and costs. As the material procurement follows after the large quantities ordered for the 1.3 GHz cavities, the use, when possible, of the same stock sizes (e.g. sheets for half cells) could prove efficient towards the schedule. The use of extruded pipes (vs. formed and welded tubes) for such a small cavity production could prove to be poorly effective costwise and timewise. Parts like the NbTi end dishes could be formed by thin sheets as for the FLASH and EuXFEL cavities, avoiding long precision machining on large pieces. It is suggested to compare the present list with the previous FLASH and EuXFEL procurements, in order to agree with material manufacturers a cost and time effective procurement.While the performances shown by the EuXFEL cavities seem at the border of the LCLSII Q-performance requirements, preliminary tests and extrapolation of the large 1.3 GHz experience suggest that a standard BCP followed by a 120°C bake could provide the correct operational margins with minimal modifications to the cavity fabrication and treatment procedure. 120°C bake could also relax the allowed remnant magnetic field in the CM. It is strongly suggested to achieve a quick verification of the beneficial effects of the 120°C bake on the 3.9 GHz cavities, possibly through tests on FLASH or EuXFEL structures, if feasible.An overview of the cost and schedule was presented but not included in the Indico site materials. A detailed schedule was provided which was comprehensive and detailed. Some salient points are captured here:* The overall design approach is to utilize as much pre-existing work product as possible from previous FLASH and XFEL experience.
* Schedule starts FY2016 and finishes end of FY2018
* Staff for 1.3 GHz CM design has transitioned to 3.9 GHz CM design as of FY2016 start
* Cost includes design, procurement, assembly and test
* Fully loaded costs provided for two CMs delivered to SLAC
* Direct costs for CM parts were provided and are reasonable
* Comprehensive LLP list shown
* Cavity and helium vessel procurements are split in current plan – may combine if advantageous
* Risks addressed and are principally copies of 1.3 GHz CM risks
* Four horizontal tests for cavities going into the first CM
* Procuring two spare cavities (18 total)
* Past reviews are listed; 3.9 GHz CM FDR planned for August 2016

Any proprietary requirements or IP that are included in this design? INFN was the lead lab for this work from FNAL/FLASH design. INFN is willing to share data on recent cavity testing results.The margin for critical heat load through the chimney is not sufficient for 16.5 MV/m and 1.5 x 10^9. The design is constrained such that chimney size is largely fixed. Therefore the design team will rely on baking and magnetic shielding to achieve performance. Doping could be considered as a mitigation strategy.FPC proposed modifications are possibly not consistent with the current schedule – these should be vetted with INFN colleagues. The details are:* Shorter antenna (QL~2.5e7 vs. 1.5e6)
* Increase thickness of copper plating in inner conductor from 30 microns to 150 microns
* Reduce length of 2 inner bellows in inner conductor from 20 convolutions to 10-15 convolutions.
* Increase thickness of ceramics in cold window to move parasitic mode away.

Customizing the length of the FPC antenna is done as a last step in order to reduce cost. This is viewed as risky but has been done in the past on other projects.How long is the required RF transition length between the last cavity and the HOM absorber to suppress the radiation power?Proposed prototyping efforts are not in the current P6 schedule; some design verification will be required for the FPC.Detailed multi-pacting simulations have not been done for these incremental changes but are planned.Very detailed mechanical comparison between XFEL and LCLS was presented. Closing the loop with manufacturing drawings from the vendor to capture the latest design is needed.The project team is considering the trade-off between make vs buy for the cavities. The pressure vessel engineering note will be approved by SLAC prior to contract award. Cavity specification may need to be completed prior to contract depending on procurement strategy.Bi-metallic transitions are different from 3.9 GHz but have been analyzed.What is the status of the frequency recipe for the 3.9 cavity? This should be updated based on XFEL experience.Two HTS tests are planned which will be used to verify the tuner performance. A total of four are planned. The procurement for required components needed in advance of HTS tests is a schedule challenge.For design, a large amount of documentation has been leveraged from 1.3 GHz CM design work.The primary design issues highlighted are: * Tuner (modification to add piezos to existing blade tuner design)
* RF Power Input Coupler for CW operation
* Cavity dynamic heat – larger diameter 2-phase chimney
* Reduce trapped modes – minor change to ends, but not cavity
* Support structure is still under development and includes the supports for the BPM and gate valves.
* No magnet.
* BPM alignment requirements are absolute and obviously not relative to a magnet. The design can consider a reduced requirement if necessary.

The review team advises the design team to consider the trade-off between tuner access ports and design verification / performance testing for the tuner. The 1.3 GHz modules have tuner access ports.Updated heat loads results in 165 W per CM dynamic + static.Two vacuum pumps instead of one on the coupler pumping lines.The cryostat components such as vacuum vessel, GHRP assembly, and magnetic shields are at a conceptual level. Out of these components, the design team should consider which components to develop first in order to manage schedule concerns. |

| Observations |
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| All the 3.9 GHz module preparation activities start after the 1.3 GHz completion. As a mitigation for possible delays during the 3.9 GHz assembly, it was stated part of the 1.3 GHz CM production assembly activities could be shifted from FNAL to JLAB.Provisions of two spares having two different cavity versions (left and right) effectively reduces to having a single spare for each type. This is the same strategy used at EuXFEL (8 needed, 10 procured), just it is worth to point it out clearly for risk management, in case a higher redundancy per critical item need to be enforced according to project rules.The full FNAL ES&H Manual has been followed for the module design, and the procedure scrutinized by SLAC. The pressure vessel approach is similar to what has been followed by EuXFEL, i.e. treating the 3.9 GHz as pressure vessels devices (even if outside the ASME scope), using consolidated and documented FNAL procedures. Most of the pressure system analysis documents of the 3.9 GHz components follow closely those already issued for the 1.3 GHz components, half of them have already been approved by the SLAC Pressure System Program Manager and the remaining half is soon to be submitted. There are no doubts that the 3.9 GHz module will be able to pass the same review easily, in view of the many similarities and the much smaller dimensions of the 2K circuit.Also, concerning Electrical, ODH and generic What-If analysis, the 3.9 GHz components share the same characteristics of the 1.3 GHz ones.The 3.9 GHz module may differ from the 1.3 GHz module for what concern seismic (and transport!) safety. While it is certainly true that the cavity mass is considerably less, due to the reduced dimensions of the cavities and the alternating coupler concept for the string, the 3.9 GHz module uses the same string support concept of the EuXFEL design, with much lower longitudinal stiffness. The EuXFEL design was not checked for seismic safety, or for long road transport. It is suggested to start these activities soon, especially concerning ES&H aspects for the Seismic load, well in advance to include possibly needed corrective actions early in the design stage.It is stressed the fact that LCLS-II is a third generation design, building on the FLASH and EuXFEL, implementing specific provisions to adapt the concept to the CW operation.Among these changes the most important ones are * the increased handling of RF loads at the cavity (larger 2phase He pipe and chimney and modifications to the cavity end groups)
* the increased handling of resistive losses in the coupler (several design variants)
* introduction of active frequency stabilization capabilities (piezo in tuner)

The overall requirements (for physics, design, operation, safety, alignment, shipping, cryogenic operation, vacuum, component testing …) are published in several documents. Also in this case it is noted that the acceleration parameters used for the transport of the 1.3 GHz modules should be double checked for the case of the 3.9 GHz string support scheme. All requirements satisfy the PDR level for all components.The LCLS-II 3.9 GHz tuner adopts the mechanics of the EuXFEL tuner (slim design), with the addition of piezo capabilities for microphonics stabilization and use of the same actuators of the 1.3 GHz cavities (therefore integrating the high reliability if these devices demonstrated by the dedicated longevity tests). The piezo casing is derived from the 1.3 GHz work, avoiding shear forces and guaranteeing uniform preload.FNAL following SLAC guidance on Seismic and ODH in particular – results from initial cross-walk and 1.3 GHz CM and Cryoplant/CDS activities have been incorporated.The design team is taking a conservative approach for 3.9 GHz design using ASME BPV. The helium vessel diameter is less than 6” but still treated as a pressure vessel.XFEL followed PED for the 3.9 GHz; LCLS-II follows a similar path via 10CFR851/ASME BPV using FESHM 5031.6 and following a guideline for SRF cavities compiled by a committee.Differences between Fermilab & SLAC pressure systems reviews – FNAL is striving to meet both sets of requirements. Specifications for procurements are written to meet both sets of requirements.Document Document #1. Cryomodule Piping Engineering Note 3.9 TBD (1.3 EN01803)2. Cryomodule Cavity Engineering Note 3.9 TBD (1.3 EN01774)3. Cryomodule Vacuum Vessel 3.9 TBD (1.3 ED0002339)4. LCLS-II CDS Relief System Requirements LCLSII-4.9-EN-03005. LCLS-II CDS Gas Return Pipe Pressure Drop Analysis LCLSII-4.9-EN-02926. LCLS-II CDS HT Shield and LT Intercept ∆P Analysis LCLSII-4.9-EN-0295Above noted docs are referenced as part of the design analysis work.Failure Modes and Effects Analysis considers 1.3 & 3.9 GHz CMs equivalent although there are internal differences.For the tuner, the installed mechanism operates in the opposite direction as compared with INFN solution. Modifications to the tuner include addition of limit switches, safety rod and phytron motor/transmission. The analyzed tuner stiffness is approximately 40 KN/mm. Electrical wiring will include kapton insulation in order to improve radiation resistance. Due to backlash of the transmission, piezo electric actuators have been included in the design.The Qo will be updated to range from 1.0 to 2.0 x 10^9 (as opposed to 1.5 on the low end).The shipping loads as part of the preliminary design are 1.5 g in all three directions.Helium piping is identical in sizing as are reliefs.Couplers alternate on each side of CM. Fixed coupling planned. Three-stub tuners can be used if needed as has been done by INFN for XFEL.Magnetic hygiene procedures for 1.3 GHz CMs will be followed for 3.9 GHz CMs.No magnet planned in this CM, only a BPM.The beam pipe diameter modified slightly to shift trapped mode. Simulations for power removed by HOMs have been performed. Analysis shows Q\_hom < 10^6 for most dangerous modes.Thermal analysis of cable heat loads with heat stations at both 5 and 50 K was presented. The analysis does not include thermal contact resistances at heat stations and could potentially overestimate the performance of the cable. XFEL cables are between 2 and 2.4 meters. LCLS-II cables will be selected during FDR phase and design presented.Ceramic measurements for FPC windows are on-going.The same BPM used for 1.3 GHz CMs is incorporated in the design. No changes are planned.HOM absorber is a one-off customized design.The following specifications will be used for the niobium materials procurement:* Niobium - Technical Specifications, Niobium Material: XFEL/007, Revision C, May 7, 2010.
* Nb55Ti - Technical Specifications, Nb55Ti Alloy: XFEL/008, Revision C, May 7, 2010.

For rod materials, the review team and design team agreed that keeping relative cost in mind is important when procuring rod or bar especially for small quantities. Complex formed parts requiring dies and tooling may be less expensive if machined out of rod or bar in some cases.Conical disks were formed for FNAL FLASH cavities.INFN/DESY can provide material drawings for comparison and potential cost savings.Cavity nominal Qo and gradient are 2 x 10^9 at 16.5 MV/m. Nitrogen doping is not considered.The magnetic field budget is 34 mG allowed at cavity when considering 120 deg. C, only 4 mG allowed without magnetic shielding. The magnetic shielding design is conceptual only – the baseline plan is to include a single layer outside of the helium vessel. |