LCLS-II 3.9GHz Cryomodule Preliminary Design Review / Cavity Final Design Review
Friday, November 20, 2015
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Recommendation No. 1 ***Status: Closed***

Date Closed: April 2018

Owner	C. Ginsburg
Recommendation	Confirm that the stability specs, 1E-4 and 0.01°, respectively for the amplitude and phase rms, with 130Hz bandwidth are achievable.
Project Response	Design verification of two fully integrated dressed cavities is foreseen. This entails cold testing at the Horizontal Test Stand. A full suite of tests needs to be developed and this will be included in the test plan. Design verification performed with 3HRI03 at HTS and ended in April 2018. 29.Jan.2019: The HTS test was inadequate to confirm the stability specs, which shall be done in CMTS testing.

Recommendation No. 2 ***Status: Closed***

Date Closed: April 2018

Owner	C. Ginsburg
Recommendation	Confirm that LLRF and piezo actuator can suppress microphonics below 30Hz (peak).
Project Response	Design verification of two fully integrated dressed cavities is foreseen. This entails cold testing at the Horizontal Test Stand. A full suite of tests needs to be developed and this will be included in the test plan. Design verification performed with 3HRI03 at HTS, ended in April 2018. 29.Jan.2019: The HTS test was inadequate to confirm the microphonics specs, which shall be done in CMTS testing.

Recommendation No. 3 ***Status: Closed***

Date Closed: February 2017

Owner	C. Ginsburg
Recommendation	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.
Project Response	Modeling is complete (Khabiboulline, Solyak, et al). The most critical modes were simulated in a fully assembled model as a function of stiffening of frequency tuner. It was found that the longitudinal modes are those that mostly affect cavity detuning. The lowest mechanical mode has a frequency of ~500Hz with sensitivity of ~750Hz/micron. Analysis of these results and cross-comparison with a 1.3GHz cavity, both simulations and measurements, shows that the effect of microphonics for a 3.9GHz cavity is small and there is no need for suppression of mechanical resonances. The

	results of these mechanical simulations and analysis (including Lorentz force detuning, pressure sensitivity, vibration modes) are summarized in LCLS-II Technical Note LCLSII-TN-16-03, *FEA analysis of the LCLS-II 3.9GHz cavity assembly*. Design verification of two fully integrated dressed cavities is foreseen. This entails cold testing at the Horizontal Test Stand. A full suite of tests needs to be developed and this will be included in the test plan. DV complete April 2018.

Recommendation No. 4 ***Status: Closed***

Date Closed: March 2017

Owner	C. Ginsburg
Recommendation	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.
Project Response	Simulations are complete and Technical Note LCLSII-TN-16-05, *Resonant Excitation of High Order Modes in the 3.9 GHz Cavity of LCLS-II Linac*, has been written and submitted summarizing the findings.

Recommendation No. 5 ***Status: Closed***

Date Closed: March 2017

Owner	C. Ginsburg
Recommendation	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.
Project Response	Simulations are complete and Technical Note LCLSII-TN-16-05, *Resonant Excitation of High Order Modes in the 3.9 GHz Cavity of LCLS-II Linac*, has been written and submitted summarizing the findings.

Recommendation No. 6 ***Status: Closed***

Date Closed: November 2015

Owner	C. Ginsburg
Recommendation	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.
Project Response	This option was considered early on, but given the directive by project management to follow the EuXFEL design as closely as possible (8-cavity cryomodule) and guidance to plan for a 3rd cryomodule of 8 cavities as well this option is removed from consideration.

Recommendation No. 7 ***Status: Closed***

Date Closed: April 2017

Owner	C. Ginsburg
Recommendation	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.
Project Response	Agreed. We are working on 3.9 GHz cryomodule design and will include seismic and transportation loading analyses specifically for the 3.9 GHz cryomodule. This will be completed prior to the 3.9 GHz cryomodule FDR. Note LCLSII-4.5-EN-0968-R0 written, submitted, and approved.

Recommendation No. 8 ***Status: Closed***

Date Closed: 15 February 2016

Owner	C. Ginsburg
Recommendation	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.
Project Response	Modification of radius of pullout of the main and HOM couplers was one of the options considered. Simulations show that this option does not provide enough frequency shift and it was rejected. In the final design the beam pipe diameter is reduced (by 2mm) to provide the required frequency shift for parasitic modes. Pullout radii have been changed slightly and this has been reviewed and discussed with manufacturer during the procurement process.

Recommendation No. 9 ***Status: Closed***

Planned Date Closed: March 2017

Owner	C. Ginsburg
Recommendation	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.
Project Response	Agreed. Will follow suggestion during fabrication phase and will fabricate a new tuning tool if necessary.

Recommendation No. 10 ***Status: Closed***

Date Closed: 21 November 2016

Owner	C. Ginsburg
Recommendation	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.
Project Response	Agreed. Three existing 3.9 GHz FPC's have been modified by the original vendor in order to prototype the foreseen design changes. A scope of work and schedule has been agreed on. Related activities to allow protoype testing are in progress.

Recommendation No. 11 ***Status: Closed***

Date Closed: 28 March 2016

Owner	C. Ginsburg
Recommendation	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.
Project Response	Agreed. A dressed cavity model has been fabricated and is in hand as is a 3-D model of a bare cavity.

Recommendation No. 12 ***Status: Closed***

Date Closed: 1 February 2016

Owner	C. Ginsburg
Recommendation	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.
Project Response	Agreed. Final machining of helium vessel and tuner adapter ring are to be done after welding.

Recommendation No. 13 ***Status: Closed***

Date Closed: 15 March 2016

Owner	C. Ginsburg
Recommendation	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.
Project Response	Agreed, this is in progress. This final set of cavity specifications are included in the procurement package which is now being prepared.

Recommendation No. 14 ***Status: Closed***

Date Closed: April 2018

Owner	C. Ginsburg
Recommendation	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.
Project Response	A plan for estimated frequencies at each significant step of cavity fabrication, processing, and testing is being developed based on experiences with the ACC39 cavities and the documented frequencies for them per Timergali Khabiboulline. Steps which may introduce uncertainty have been identified. Documenting actual frequencies will be done at each predetermined fabrication and processing steps as soon as prototypes are available as well as on production cavities.

Recommendation No. 15 ***Status: Closed***

Date Closed: November 2015

Owner	C. Ginsburg
Recommendation	Compare the present niobium material list with the previous FLASH and EuXFEL procurements prior to soliciting quotations from vendors.
Project Response	This has been done.

Recommendation No. 16 ***Status: Closed***

Date Closed: April 2018

Owner	C. Ginsburg
Recommendation	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.
Project Response	Agreed. Discussion is in progress to arrange for 'borrowing' such cavities and all agree in principle to this. Details as to what cavities to 'borrow' are being worked out. Benefit of 120 deg-C bake verified during Design Verification tests on three prototype cavities at VTS

Recommendation No. 17 ***Status: Closed***

Date Closed: March 2016

Owner	G. Hays
Recommendation	Consider adjusting the overall schedule to build first CM and test prior to building second CM.
Project Response	There are challenges in scheduling this given that the same assembly and testing infrastructures are employed for both 1.3 and 3.9 GHz CM's at Fermilab. Risks to the overall project schedule are considered to outweigh potential benefits at this time.

Recommendation No. 18 ***Status: Closed***

Date Closed: March 2017

Owner	C. Ginsburg
Recommendation	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.
Project Response	Agree. Update 29.Jan.2019: Cryomodule piping engineering note (EN02315), Cavity engineering note (EN02359), Vacuum vessel engineering note (EN02263), Cryomodule vacuum vessel design specification information is contained within the engineering note.

Recommendation No. 19 ***Status: Closed***

Date Closed: March 23, 2016

Owner	C. Ginsburg
Recommendation	Update the heat load estimate engineering note (LCLSII-4.9-EN-0179) prior to the Final Design Review.
Project Response	Agree. This is an ongoing activity with updates occurring every few months as needed. LCLSII-4.9-EN-0179-R2, including updated 3.9 GHz cryomodule heat load, was released in March 2016.

Recommendation No. 20 ***Status: Closed***

Planned Date Closed: March 2017

Owner	G. Hays
Recommendation	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.
Project Response	For LCLS-II 3.9 GHz cryomodules, only Fermilab drawings are used and no additional agreements are required for procurements. INFN and Fermilab have been working together on 3.9 GHz design activities for more than a decade, collaborating on FLASH (DESY), XFEL, and now LCLS-II. Fermilab has greatly benefitted from the collaboration with INFN. INFN has been especially helpful to Fermilab in the development of LCLS-II cryomodule models and drawings, providing all the XFEL drawings we requested, which have been used as an important reference. Significant modifications have been made to the cryomodule design by Fermilab for CW operation. We anticipate that Fermilab drawings and experimental results for CW operation may be used in the future by INFN toward a possible XFEL upgrade to CW operation. Additionally, a use agreement between SLAC and INFN is in progress which addresses INFN involvement with the LCLS-II project. Fermilab strongly supports this agreement as an acknowledgement of the key role INFN has played in development of the Fermilab 3.9 GHz

	LCLS-II cryomodule design, and the agreement has no impact on Fermilab 3.9 GHz cryomodule procurements.

Recommendation No. 21 ***Status: Closed***

Date Closed: April 2018

Owner	C. Ginsburg
Recommendation	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.
Project Response	Agreed. Design verification of fully integrated dressed cavities is foreseen. This entails cold testing at the Horizontal Test Stand. A full suite of tests needs to be developed and this will be included in the test plan. Design verification performed with 3HRI03 at HTS and ended in April 2018.

Recommendation No. 22 ***Status: Closed***

Date Closed: November 2015

Owner	C. Ginsburg
Recommendation	Recommend adding tuner access ports in order to address maintenance and reliability concerns.
Project Response	This has been considered. Given the facts that coupler ports, by necessity, are on both sides of the cryomodule and that the piezo actuators will be inaccessible even if coupler ports were provided leads to rejection of this recommendation. Experience with ACC39 at FLASH suggests the tuners (w/o piezo) are of high reliability. In normal LCLS-II operation 14 of the 16 total cavities will be operated allowing for redundancy.

Recommendation No. 23 ***Status: Closed***

Date Closed: March 2017

Owner	C. Ginsburg
Recommendation	Perform detailed multi-pacting simulations in order to assess the impact of incremental changes for the proposed cavity design.
Project Response	Simulations are complete and findings documented in Technical note LCLSII-TN-16-04, *Redesign of the End Group in the 3.9 GHz LCLS-II cavity*.

Recommendation No. 24 ***Status: Closed***

Date Closed: 1 March 2016

Owner	C. Ginsburg
Recommendation	Review prototyping plans for the FPC to ensure that the schedule includes appropriate time for these efforts. Include INFN colleagues in the review process.

Project Response	INFN (and DESY) colleagues agree with plans and have agreed that XFEL couplers now at Fermilab can be used for baseline cw measurements. Arrangements are in process to transfer ownership of Fermilab-owned 3.9 GHz FPC's to LCLS-II to expedite prototyping.

Recommendation No. 25 ***Status: Closed***

Date Closed: 6 June 2016

Owner	T. Raubenheimer
Recommendation	Verify the required RF transition length between the last cavity and the HOM absorber in order to suppress the radiation power.
Project Response	The work is documented in LCLSII-TN-16-06, *Generation and Absorption of the Untrapped Wakefield Radiation in the 3.9 GHz LCLS-II Cryomodule*.

Recommendation No. 26 ***Status: Closed***

Date Closed: 30 March 2016

Owner	C. Ginsburg
Recommendation	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.
Project Response	Since the review the PDR has been updated with revised nominals for the cavity gradient and Q0. A revised chimney design has been finalized which provides a step diameter increase at the Titanium to Stainless transition. This design permits 36 W of heat transport, a 60% margin relative to the heat resulting from a nominal cavity gradient of 13.4 MV/m, a Q0 of 2.0×10^9, which is 14.3 W per cavity. . A just as, if not more, promising mitigation strategy than nitrogen doping under consideration is 120° C baking. Work on this has already begun, and will be completed prior to the 3.9 GHz cryomodule FDR.