PIP-II 650 MHz High Beta Cryomodule Prototype Final Design Review Report

Document number: ED0012338 Rev -

Document Approval

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Revision History

Revision	Date Release	Originator: Role:	Description of Change
-	09 Sep 2020	Ed Daly	Initial Release

Revision control is managed via Fermilab Teamcenter Workflows.

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1. Introduction

The PIP-II Project's superconducting linear accelerator (Linac) will fuel the next generation of intensity frontier experiments at Fermilab. Benefitting from the high efficiencies of superconducting radio-frequency (SRF) technology, the linac shall consist of five types of superconducting cavities and cryomodules. They will accelerate H– ions to 833 MeV for injection into the Booster Complex of Fermilab. Upgrades to the existing Booster, Main Injector, and Recycler Rings will enable them to operate at a 20 Hz repetition rate and provide a 1.2 MW proton beam for the Deep Underground Neutrino Experiment (DUNE) at the Long Baseline Neutrino Facility (LBNF). The superconducting Linac shall operate at harmonic frequencies of 162.5 MHz, 325 MHz, 650 MHz, with energy ranging from 2.1 MeV to 833 MeV. The relativistic β for the H– ions goes from 0.07 to 0.854 over this energy range.

The PIP-II Linac shall consist of one half wave resonator (HWR) cryomodule, two single spoke resonator of type 1 (SSR1) cryomodules, seven single spoke resonator of type 2 (SSR2) cryomodules, nine low beta elliptical cavity (LB650) cryomodules, and four high beta elliptical cavity (HB650) cryomodules. The HB650 cryomodules contain six 5-cell cavities each, with geometric beta of 0.92 and operating at 650 MHz. Due to presence of legacy cavities with geometric beta of 0.90, and due to fabrication and qualification of the beta 0.92 cavities, the prototype HB650 cryomodule may have an exception of having up to three 650 MHz cavities with geometric beta of 0.90. The PIP-II linac is to operate with continuous wave (CW) RF, and a pulsed beam. Having pulsed RF compatibility is encouraged, to lower operations costs. In both regimes cryomodule shall support peak currents of 10 mA chopped with arbitrary patterns to yield an average beam current of 2 mA.

PIP-II is the first US Department of Energy particle accelerator project with significant international in-kind contributions from France, India, Italy, Poland, and the United Kingdom. Due to the complex design of the cryomodules as well as the international partnerships, PIP-II requires a significant design coordination and integration oversight. As part of the oversight strategy, a design review plan specific to PIP-II has been developed. The primary goal of the Project design reviews is to ensure optimized and safe design by identifying potential or actual design problems as early as possible to minimize the cost, schedule, and performance impact.

This review comprises the Final Design Reviews for both the prototype HB650 Cryomodule and the 650 MHz Tuners. These tuners will be used in the HB650 prototype cryomodule and the LB650 pre-production cryomodule. Per the PIP-II Design Review Plan,

- Final Design Reviews (FDRs) are technical and programmatic reviews conducted to give assurance that the completed design achieves all physics, functional, technical, and interface requirements. The technical areas addressed during the review include the design configuration of the selected design; verification planning, requirements, and compliance; operations planning; support equipment; and systems compatibility. In cases of significant complexity, an FDR may be required for advanced prototype procurement (e.g. prototype SRF cavities, cryomodules and ancillary components).

Prototype FDRs enable high-cost prototyping procurements and testing to proceed. Prototype and production FDRs will be identified by indicating which type in the RLS activity names and in the System Design Plans (SDPs).

2. Review Agenda

Location:	Microsoft Teams
Date:	July 29th (Wed.) – 31st (Fri.)
Indico Site: Meeting link: Reviewers:	https://indico.fnal.gov/event/43274/ Join Microsoft Teams Meeting Ed Daly, JLAB (Chair) Camille Ginsburg, JLAB Samuel Miller, FRIB Tom Peterson, SLAC

3. Review Charge Statement & Response from Review Committee

The review committee is charged to evaluate the design and programmatic readiness of the PIP-II 650 MHz high beta prototype cryomodule at final design stage. The review committee is urged to evaluate by responding to the following questions:

1) Technical Scope

a) Are the designs mature and technically sound to satisfy design specifications?
   - Yes, see comments

b) Are the development of CAD and drawing packages sufficiently mature (>90%) for final design stage?

- The CAD packages are mature. The drawing packages are approaching the 90% level; however, it was noted that the strongback and warm magnetic shield drawings have not started.

c) Are items that could affect safety, quality, cost, schedule, or performance mitigated or managed?
   - Yes

d) Are the design, assembly, and testing plan appropriate to validate the prototype cryomodule for performance requirements of the production modules?
   - Yes

e) Are the design and testing plan appropriate to meet transportation requirements?
   - Yes, the simulations in support of transportation are particularly thorough.

2) Management

a) Is the team organized and staffed to successfully complete the project?
   i) Yes, the design team is developed and staffed appropriately to complete the project. As mentioned, diligence in managing the deliverables both at FNAL and from the partners is key to the project success.

b) Have all the recommendations from previous reviews been addressed?
   i) Yes, some of the recommendations from the PDR are yet to be closed. Documentation completion is ongoing.

c) Have all the major risks been identified and managed? Have all lessons learned from previous experiences been incorporated?
   i) Yes, the risk register was presented. In particular, the lessons learned were discussed in the presentations and incorporated into the design.

d) Are appropriate ES&H, QA, and QC steps being implemented?
   i) Yes, ESH, QA, and QC are appropriately developed and implemented.

e) Is the cost and schedule reasonable to achieve the planned scope?
   i) The cost is developed from previous projects, the schedule seems optimistic especially considering the current COVID-19 situation.

f) Are there any COVID-19 impacts and are they being managed appropriately?
   i) Yes, the impacts have been considered and are actively being managed given the uncertainties.

3) Overall Readiness

a) Is the design of the HB650 prototype cryomodule sufficiently mature to allow Final Design Review approval?
   i) Yes, the interfaces should be finalized and the PDR recommendations closed.
b) Is the design of the 650 MHz tuners sufficiently mature to allow Final Design Review approval for use in the HB650 prototype and LB650 pre-production cryomodules?
   i) Yes on HB650. The committee has not sufficiently reviewed the LB650 to give a recommendation.

4. Acronyms

PIP-II	Proton Improvement Plan II Project
HB650	High Beta 650 MHz
LB650	Low Beta 650 MHz
B90	β=0.90 HB650
B92	β=0.92 HB650
PDR	Preliminary Design Review
FDR	Final Design Review
PRR	Procurement Readiness Review
PRD	Physics Requirements Document

5. Relevant Documents

For prototype HB650 Cryomodule

TC#	Description
ED0001322	HB650 Cryomodule FRS

ED0009659	HB650 Cryomodule TRS
ED0003734	Relief valve sizing of the vacuum vessel
ED0006723	SSR1 - SSR2 - HB650 - LB650 CRYOMODULES THERMAL STRAPS
ED0006724	SSR1 - SSR2 - HB650 - LB650 CRYOMODULES COPPER FOIL THERMAL STRAPS
ED0007562	PIP-II HB650 Cryomodule Interface Control Document
ED0008200	Heat loads analysis
ED0009469	Component's weight and Helium volume
ED0009470	Preliminary transport analysis
ED0009719	G11 Support post, Assembly procedure
ED0009813	G11 Support post, MLI Specification
ED0009950	G11 Support post, Design report
ED0010081	Movement during cool down
ED0010433	Master Interface Control Document
ED0011210	2 Phase pipe analysis report
ED0011220	HB650 CM proto PDR review report
ED0011220	HB650 CM proto PDR review response
ED0011225	CM design handbook
ED0011227	PIP-II HB650 CM L3 Internal Interface Control Document
ED0011227	PIP-II HB650 CM L3 Internal Interface Specification Document
ED0011276	Failure Mode Effect Analysis (FMEA)
ED0011810	PIP-II 650 MHz B9A-AES-010 1st STC test report, Oleg
ED0011810	PIP-II 650 MHz B9A-AES-010 1st STC test report, Sasha
ED0012328	HB650 Transportation Requirements Specification
ED0012337	Design and analysis of the thermal shield
ED0012420	Transportation - Design report
EN02594	String lifting tooling
EN03108	Vacuum vessel engineering note
EN03291	Cryomodule lifting tooling
EN04182	Beam line engineering note
F10047288	CAD - Top Assembly
F10127878	Envelope, transverse, PIP II cryomodules
F10088592	CAD - Lifting tooling
F10090094	CAD - Stronback
F10090096	CAD - Stronback + beam line
F10090540	CAD - Beam line
F10101087	P&ID of HB650 Cryomodule
F10105016	CAD - Rail
F10127563	CAD - Dressed cavity 0.92
F10127566	CAD - Dressed cavity 0.9
PIP-II-doc-142	PIP-II Project QA Plan
PIP-II-doc-2964	PIP-II Lessons Learned Procedures
PIP-II-doc-3100	PIP-II Nonconformance Handling Procedure
PIP-II-doc-3283	Tracking in QC plan Tracker
PIP-II-doc-3415	SRF Quality Assurance Plan
PIP-II-doc-4236	High Beta (HB) 650 MHz Cryomodule QC Plan
PIP-II-doc-4369	Low Beta (LB) 650 MHz Cryomodule QC Plan
ED0009629	PIP-II 650 MHz beta=0.90 & 0.92 Jacketed Cavity Prototype FDR Review Report

ED0009629	PIP-II 650 MHz beta=0.90 & 0.92 Jacketed Cavity Prototype FDR Review Response v2
ED0011840	650 coupler proto FDR Review Report v05
ED0011840	650 main coupler proto FDR Review Response

For 650 Tuner

TC#	Description
ED0001322	650 MHz β=0.92 Cryomodule Functional Requirements Specifications
ED0001830	650 MHz β=0.61 Cryomodule Functional Requirements Specifications
ED0005146	650Mz CAVITY TUNER ENGINEERING SPECIFICATION, B0.9 and B0.92
ED0009658	650 MHz β=0.61 Cryomodule Technical Requirements Specifications
ED0009659	650 MHz β=0.92 Cryomodule Technical Requirements Specifications
ED0011227	PIP-II HB650 Internal Interface Control Document
ED0011227	PIP-II HB650 Internal Interface Specification Document
ED0012009	HB650 B09 Tuner_Installation_Procedure_10_4 (for STC)
ED0012009	HB650 B09 Safety Bracket Removal Procedure_3
ED0012009	HB650 B09 Safety Bracket Installation Procedure_1_v2
ED0012239	Failure Modes and Effects Analysis
ED0012241	Prevention through Design, 650MHZ Tuned
ED0012413	650 Tuner Trust Table
ED0012423	Phytron QC test at FNAL_2 (draft)
ED0012423	Stepper and piezo actuators specs for SSR1-2 cavities (Draft)
F10088673-A	Drawing; ASSEMBLY, LEVER TUNER 650-B92 CAVITY
F10113889	Drawing; ASSEMBLY, LEVER TUNER 650-B90 CAVITY
PIP-II-doc-142	PIP-II Project QA Plan
PIP-II-doc-2964	PIP-II Lessons Learned Procedures
PIP-II-doc-3100	PIP-II Nonconformance Handling Procedure
PIP-II-doc-3283	Tracking in QC plan Tracker
PIP-II-doc-3415	SRF Quality Assurance Plan
PIP-II-doc-4236	High Beta (HB) 650 MHz Cryomodule QC Plan
PIP-II-doc-4369	Low Beta (LB) 650 MHz Cryomodule QC Plan
ED0012683	Lessons learned 650MHz tuner design process

6. Reference Documents

List any relevant reference documents reviewed by the Committee.

1	**Review deliverable documents (CM):** PIP-II-doc-4878
2	**Review deliverable documents (Tuners):** PIP-II-doc-4881
3	
4	

7. Findings

General, factual observations about material presented which require no response. The following also includes notes and comments about discussions during presentations.

Findings

Day 1

1. HB650 CM Prototype FDR and Tuner FDR Introduction - Chandrasekaran
    a. Daly: Since the review in December have there been any updates to the staffing?
    b. Chandrasekaran: Yes, additional staff has been added and some team members have moved up a level. We also had some retirements.
    c. Peterson: It seems like we are validating the prototype that will be built by a completely different crew than who will produce the production modules. Because of this, the communication between FNAL and the other manufacturers will be critical. Drawings will need to be very clear for these communications.
    d. Chandrasekaran: This point is well understood. We have open communication on our prints and cross-train (COVID issues). The documentation understandably will have to be in top form for the communication to work effectively.

2. Tuner introduction and activities at FNAL - Pischalnikov
    a. Daly: On the split ring design, how did you analyze this?
    b. Pischalnikov: We did perform the analysis on this.
    c. Daly: Specifically, how much did the block increase the stiffness?
    d. Pischalnikov: I don't have the number off the top of my head, but we target the same 40KN/mm.

e. Engineering specification, technical requirements specification and functional requirements specification documents are released and approved for both LB and HB tuner designs.
f. Miller: On the split ring design, how do you guarantee the screws don't back out?
g. Pischalnikov: We have encountered this before, wherever possible we use split washer and set screws.
h. Daly: As a follow-up, it looks like your split block is different that was shown in the pictures.
i. Pischalnikov: Yes, they are swapped. There are two setups. The final configuration is the rectangular block.
j. Daly: In your documentation package it looks like several parts that are different reference the same ED number. Review tuner safety bracket installation/removal and tuner installation document numbers.
k. Ginsburg: You stated that you are ready for procurement, are your QA plans in place, particularly for the motor?
l. Pischalnikov: Yes, we have these plans in place.
m. Peterson: Are there any specific differences between the Beta=0.9 & 0.92 and how the tuner attaches?
n. Pischalnikov: This is a modified version of the LCLS-II design and it is consistent between the Beta =0.9 & 0.92.

3. Tuner activities at RRCAT - Jain
    a. Testing has been conducted on an 0.92 cavity.
    b. Daly: How did you settle on the 200 kHz?
    c. Pischalnikov: We are making the assumption that we will have a narrow distribution of cavity frequencies; therefore, we won't need a large range on the tuner.
    d. Daly: If you need to get more range, what do you do?
    e. Pischalnikov: The limitation is not in the tuner, on the 0.9 cavities the piezo stroke may be limited.
    f. Requested copy of PDR report for Tuner if available.
    g. Requested copy of lessons learned documents, either conference paper or presentation from elsewhere.
4. HB650 coupler status - Premo
    a. Interfaces for instrumentation - are they well-defined for the coupler?
    b. Daly: In-vacuum vacuum gauges - who is the vendor?
    c. Premo: Pfeiffer
    d. Plans for on-site visits (kick-off, hold points) need to be updated due to COVID issues.

e. Was the warm waveguide changed after initial high power RF tests? Yes, more testing is planned.
f. Daly: Can the report of the coupler FDR be supplied?
g. Premo: I will get that information.

5. HB650 B0.9 and B0.92 cavity status - Eremeev/Puntambekar
    a. Change in cavity layout - will be explained in a later presentation.
6. STC results - Sukhanov
    a. No questions
    b. Comment (Peterson): Slide 10. Quench results in a large pressure rise. I believe the issue is to shut off RF quickly enough with quench to prevent excessive pressure rise.
7. Requirements and Internal interfaces - Roger
    a. Daly: Does the P&ID include the instrumentation on the couplers?
    b. Roger: Yes
    c. ICD and ISD available in Teamcenter
    d. Daly: I am trying to understand the logic of the tuner/FPC interface to the bare cavity
        i. One is done one way and one is done the other.
    e. Concept of identifying interfaces in a table containing an assigned numbering scheme is interesting and may prove useful when coordinating changes during design, procurement and assembly.
8. PDR recommendations, and main changes - Roger
    a. MAWP changed to 2.05 bar (both warm and cold)
    b. Daly: ED is design report correct? EN is engineering note
    c. Roger: Yes
    d. Chandrasekaran: ED is engineering documentation
    e. Miller: What is motivation about switching string arrangement? Is it cavity availability?
    f. Roger/Chandrasekaran: This is actually in line with the PDR and it also allows us to use a single end group design.
    g. Miller: The rest of the interfaces are the same?
    h. Roger: The cryo interfaces to cavities are different.
    i. Peterson: It does not look like the recommendation from the PDR to check stresses in the following failure mode has yet been addressed. Could there be damage with loss of insulating vacuum, due to the strongback cooling at a different rate from the vacuum vessel?
9. Cryomodule assembly process and alignment - Roger

a. Miller: P&ID is preliminary, what is being finalized (Slide 10)? Excel file contains pin-outs and identified flanges
b. Roger: The P&Id should be up to date at this point.
c. Daly: Can we get a copy to review?
d. Chandrasekaran: Yes.
e. Option is available to adjust the individual cavities after installation into the vacuum vessel.
f. Lessons learned from SSR1 assembly use of tooling have been applied to the assembly process for the prototype HB CM.
g. RF Group will determine the electrical axis relative to the end flanges.
h. Daly: The onsite frame is used for SSR1 and the 650, how different are the two modules?
i. Roger: the 650 is 5m longer and 4 tons heavier
j. Holzbauer: We will re-certify the transport frame before using it for the 650. New spring, clearances, etc.
k. Miller: Can you clarify for me the fiducialization process of the electrical center to mechanical center?
l. Roger: RF group measures and fiducializes to beam flanges. The alignment group then picks up this data and carries it forward to the cryomodule. The electrical center is the best fit through the 5 equators; whereas, the mechanical center is the beam port flanges.

10. Vacuum vessel (Mechanical design) - Orlov
    a. Prints are available in Teamcenter; drawings are complete and released.
    b. Vessel engineering note is done. Results are contained in a detailed excel file.
11. Vacuum vessel (Structural analyses) - Chen
    a. Miller: On slide 6, can you please state what the vacuum relief value was?
    b. Chen: 1.5 bar absolute
    c. Miller: Can you point out where on the vessel the relief is located?
    d. Chen: It is on top of the vessel (shows on the model).
12. HBCAM - Zorzetti
    a. Lessons learned from performance on SSR1 and dedicated test bench validate the measurement technique using HBCAM.
    b. Daly: Is the HBCAM intended for the production cryomodules?
    c. Roger: Yes.
13. Thermal Shield - Smith
    a. Drawing released.
    b. Design document released.

14. Cryogenic lines and heat loads - Roger
    a. The number of butt welds in the 2-phase line has been reduced as part of the final design phase.
    b. Miller: On slide 21: QA plan on bi-metals components?
    c. Roger: We do dimensional check.
    d. Miller: Do you do any type of cold shock and leak check?
    e. Roger: We ask that it comes in leak checked on the prints.
    f. Ginsburg: Do you use a certified/reputable vendor on these fittings?
    g. Roger: This is uncertain at this time.
    h. MAWP was halved which reduces the loading on the header during vacuum loss scenarios.
    i. Daly: On Slide 37, what goes on the end of the relief pipe?
    j. Roger: There is a conflat flange that interfaces with cryogenic system
    k. Daly: What does that look like?
    l. Roger: I am not sure what that looks like.
    m. Daly: Is this covered in the interface?
    n. Wu: This is covered in the cryogenic subsystem
    o. Daly: Can you provide this documentation?
    p. Wu: Yes.
    q. In the Master ICD ED00010433, it states "650MHz shall specify helium purge gas and pressure safety requirements for CM devices, and supply appropriately sized relief piping within the CM and external connections to CDS warm helium headers". What calculation demonstrates that the 2K relief piping is sized properly? What size relief is CDS planning to provide for the 2K relief?
15. Pressure drop and valve sizing - Squires
    a. Daly: When are you worried about operating on the low end of the JT valve, during testing or operation?
    b. Squires: During operation.
    c. Peterson: Turn down of linac cryogenics during 2 Kelvin operation will be very limited by cold compressors.
    d. Daly: Are there elements that help balance the load? Like heaters?
    e. Squires: Yes and we looked at that during SSR1 as well.
16. Discussion
    a. Daly: There were a couple of things that we asked for during the day:
        i. FDR reports on cavity and coupler
        ii. P&ID

iii. Cryo interface to relief valve
iv. Recommendations addressed on cavity, coupler, & tuner?

Day 2

1. Day 2 Opening - Chandrasekaran
    a. Skipped for Executive session
2. Strongback - Mechanical - Lacroix
    a. Miller: On slide 4, is there a stress relief/anneal operation prior to final machining?
    b. Lacroix: Yes, that would be the intent.
    c. Miller: Will this be captured on the FNAL prints?
    d. Lacroix: Yes.
    e. Miller: On Slide 32, are the prints released?
    f. Lacroix: Not for the moment, we need a translation between the CAD packages. FNAL has the STEP files.
    g. Daly: Who is procuring the strongback?
    h. Lacroix: FNAL.
    i. Lacroix/Chandrasekaran: A company is France is translating the files.
    j. Daly: So FNAL has to produce the prints at some point? (The presentation had a check mark next the print package mature item)
    k. Lacroix: Correct.
    l. Miller: Any subsequent revision control is handled by FNAL?
    m. Lacroix: Yes, CEA will remain as a technical collaborator.
    n. Peterson: Does the 0.9 vs 0.92 have any design effect on the strongback?
    o. Lacroix: They use the same design.
3. Strongback - Thermal - Cubizolles
    a. Daly: On slide 8, it is better to install the mu-metal between the strongback and the thermal shield. Is this what has been implemented?
    b. Cubizolles: Yes.
    c. Daly: Has the equilibrium temperature been considered for the mu-metal shield.
    d. Roger: We haven't looked into that effect.
4. Cavity Cool Down - Nigam
    a. Peterson: What does the cooldown sequence look like? Reason for question: Nitin Nigam's presentation looking at support arms relative to cavity lugs. I wondered if cooling the thermal

shields first or helium vessel first matters in terms of any interferences, excessive temporary gaps, or stresses on the support structure.

b. Roger: Cooldown thermal shield then the 5K line.

5. Discussion
    a. The committee is interested in understanding how the beamline vacuum system will be relieved. MC's draft EN 04182 refers to a P&ID (P&ID of cryomodule - ED0004129, different from what was provided) and a 6 psi relief (FNAL design F09000444). This is not shown on the P&ID provided.
    b. Roger: The beamline relief is part of the inter-cryomodule beamline component.
    c. Daly: Is this part of the interface?
    d. Wu: Tentatively, this is the vacuum system.
    e. Daly: Is this in the master interface document?
    f. Wu: No yet, it is a work in progress.
    g. Request a talk on preparations for cold testing at FNAL. In particular, what processes exist for approving that the system is ready for testing - pressure safety, RF power, etc.?
    h. Chandrasekaran: Yes, we can show that.
    i. How many partners require CAD package translation and how much time does this represent for the translation?
    j. Roger: On the cryomodule no, but the strongback tooling package from CEA we will need to translate.
    k. Daly: Do you have those details worked out yet?
    l. Roger: Not yet.
6. Rail design, Lifting tooling and strongback supports - Poloubotko
    a. Daly: On Slide 8, it looks like the features to align the rail are on the end of the beam and below. Does that work to align the rail on the top?
    b. Poloubotko: There are multiple points of adjustment.
    c. Daly: How does the alignment work with this set of features?
    d. Poloubotko: Alignment Group has reviewed and has no concerns aligning it.
    e. Daly:: The 144 inch rail is outside of the cleanroom?
    f. Poloubotko: There are 11 rails in total, 3 of which are outside of the cleanroom.
    g. Ginsburg: The material that you are using, are they the same as the other rail system?
    h. Poloubotko: Yes.
    i. Miller: On Slide 25, you display strongback tooling. As part of a previous conversation, it was identified that CEA needs to design additional tooling. What tooling is this?

j. Poloubotko: Yes, this for end assembly and installation. I just identified the main tooling.

7. String Assembly - Orlov
    a. Daly: On the warm to cold beam pipe, outside of the endcap, would you have room to put a burst disc.
    b. Wu: Are you proposing a solution to the burst disc? We would prefer not to do this.
    c. Daly: Right now you do not have a solution to vent the beamline, so I would prefer to talk about it.
    d. Orlov/Roger: It does not look like there is room.
    e. Daly: In Roger's talk it was indicated that the end group was released but the assembly was not.
    f. Orlov/Roger: We cannot release the assembly because we need to finalize the strongback drawings.
    g. Peterson: Do you plan to use plated bellows?
    h. Orlov: No
8. String Tooling & Procedure, Traveler - Orlov
    a. Tooling drawing and assembly travelers are in progress.
    b. Ginsburg: Where will the purging area in the cleanroom be?
    c. Orlov: We are using the area on the side of the assembly area.
    d. Ginsburg: Where is the cavity assembled to the support structure?
    e. Orlov: I don't have an answer.
    f. Wu: We have updated the procedure since LCLS-II and eliminated a workstation.
    g. Are you using a backtech cart in class 10 cleanroom?
    h. Wu: Yes
    i. Ginsburg: For the prototype cryomodule, you have to receive the cavities in the order you need to install them?
    j. Wu: Yes
9. Endcap tooling - Cubizolles
    a. No questions
10. Discussion
    a. Executive session
11. Magnetic shields, design, simulation, and hygiene - Xie
    a. Ginsburg: Where do the procedures of magnetic properties end? Does it include stands?
    b. Chandrasekaran: This has been communicated to the assembly floor as it pertains to the stand
    c. Ginsburg: Is this specification driven?
    d. Chandrasekaran: The interface control determines what needs to be reviewed in this regard.

e. Ginsburg: But what document drives this? Is it Xie specification?
f. Xie: We could include this in our engineering handbook.
g. Xie: We will try to expand scope to include tooling. It's not there yet.
h. Daly: What is the status of the procedure?
i. Xie: It is in a preliminary state.
j. Daly: I thought for LCLS-II we had rules for distance from the beamline, is that done here?
k. Xie: Not for this module, Genfa did this previously.
l. Chandrasekaran: It is different for our larger cavities.
m. Daly: What is it?
n. Chandrasekaran: I believe that it is 3 or 4 inches from the equators.
o. Daly: When do you expect this specification to be completed, will it affect procurement?
p. Xie: It will not affect procurement and it will be done soon.
q. Still in the process of releasing the global magnetic shield.

12. Instrumentation installation, procedure, experience - Squires, Lewis
    a. Daly: Can you tell us some of the lessons learned for LCLSII, SSR1, etc.?
    b. Lewis: There were many lessons learned (submitted in documents). We had some issues shipping instrumentation to FNAL and JLAB. This resulted in delays on paying vendors.
    c. Daly: If you have a document, please send it along.
    d. Lewis: Sure
    e. Daly: Are there changes planned between the prototype and production?
    f. Squires: It has already been identified - the items that change. Several sensors inside will be eliminated and external sensors will be reduced as well. There is a plan that is being executed.
13. CM Assembly process experience - Grimm
    a. Daly: Just to clarify, two coldmasses outside the cleanroom would be for different projects, correct? Space exists for adapting to changes in the production plans in MP9 and ICB.
    b. Grimm: Yes.
14. Experience_and_Lessons_Learned - Roger
    a. Several good examples of improvements/lessons learned have been implemented.
    b. Daly: What is the name of the software that contains the lessons learned?
    c. Grimm: I-track, it's a sharepoint application.
15. QA, QC, ESH - Furuta
    a. Ginsburg: What do you do with the risk registry? How does it guide the project?
    b. Chandrasekaran: We use it to create the required contingency.
    c. Miller: At what level is the disposition decided on NCRs?

d. Furuta: Engineer in this case can be escalated if needed.
e. Daly: If it is escalated, to whom does it go?
f. Furuta: To the subsystem lead.
g. Miller: Who authors the incoming inspection (acceptance criteria) of the subsystems?
h. Furuta: Yes.
i. Daly: Is the table on Slide 9 released and it is the same between the prototype and production?
j. Furuta: We need to finalize whether the prototype and production will be different.
k. Peterson: QA requirements for production will be informed by prototype QA experiences during procurement and assembly.

16. Discussion:
    a. Ginsburg: How does the procurement process guarantee that the engineering handbook has been followed?
    b. Roger: This is a book of best practice and partner labs should look at it was well.
    c. Miller: How do you ensure the tenants of the handbook have been applied?
    d. Wu: We would certainly do this at the production readiness review.
17. HB650 Testing CM Testing Plan - Wu (Part of Discussion)
    a. Ginsburg: We received the recommendations from the cavity review that the 0.9 cavities did not get the weld documents.
    b. Wu: Will need the director's approval for an exceptional pressure vessel.
    c. Daly: Did the ORC go smoothly for the HWR?
    d. Wu: That entire cryomodule had the same situation we need to get the director exemption.
    e. Daly: What type of technical information is needed to get the exemption?
    f. Chandrasekaran: The cavity design and the simulation. You need to show that the cavity meets the requirements for the ASME Code. You then are allowed to jacket the cavity and pressure test the cavity. Once complete then the exemption is sought.
    g. Daly: Is the pressure test warm?
    h. Chandrasekaran: Yes
    i. It is noted that there are no plans for microphonics studies in the presentation. Previous experience and lessons learned indicate that this should be in the plan.

Day 3

1. Day 3 opening - Chandrasekaran
2. Transportation Plan - Holzbauer, Roger

a. PIP-II HB-650 Cryomodule Transportation Design Report Document Number: ED0012420 is incomplete.
b. FDR for Transportation planned for early September 2020.
c. Lessons learned from previous transportation experience are applied.
d. PIP-II HB650 Cryomodule Transportation Specification, Document number: ED0012328, was released as draft in December 2019.
e. Miller: At what level is transportation involved in design reviews?
f. Holzbauer: The engineers have it ingrained in their culture (for LCLS-II), but formal design reviews have not taken place
g. Miller: Has anything been added in the design handbook as it pertains to transportation?
h. Holzbauer: I have been charged to add this, it has not been added yet. A panel will be formed at FNAL to review transportation concerns.
i. Peterson: Have you settled on air transport?
j. Holzbauer: We are settled on air. The advantages are numerous over sea transportation. Notably the offloading tends to be significantly better for air transport.
k. Peterson: How do you intend to gain access inside the cryomodule to add these components for transportation?
l. Roger: Yes, through the transportation port.

3. Transport frame - Kane
    a. Daly: Slide 9, truck beds tend to be cambered, one of the lessons from LCLS-II was that we had to shim to the truck bed. How are you going to account for that?
    b. Kane: We would need to shim up in the corner.
    c. Daly: You may need to rerun the analysis.
    d. Kane: Yes, we will do that before the FDR.
    e. Daly: On Slide, 14 you derived a set of specifications, where do they come from?
    f. Kane: Road & Air.
    g. Daly: On Slide 15, how did you derive the loading values?
    h. Holzbauer: The cryomodule was designed to these specifications and the frame reduces the values to these numbers.
    i. Daly: Are there provisions for mounting instrumentation and power supply on the frame?
    j. Kane: Yes.
    k. Daly: And these are written into the specifications?
    l. Holzbauer: Yes, they have been in since the first draft.
4. Transportation analysis - Helsper, Cheban
    a. Daly: Slide 9, it looks like the fill line was missing on the bottom?
    b. Cheban: Yes there is a bottom fill line.

c. Daly: Are one of the cavity lugs fixed and the other allow sliding?
d. Cheban: Correct.
e. Cheban: During transportation, all four lugs are locked.
f. Daly: So why would alignment change during transportation?
g. Helsper: It is possible for one side to come apart at a time, with no bolt support from one direction.
h. Peterson: I note, the cavity cooldown considered the lighter block for the cooldown. This should be consistent with the vibrational analysis.
i. Daly: On slide 42, you looked at that valve and decided that you were above 10 Hz and it was ok?
j. Cheban: Correct.
k. Daly: On Slide 39, you remove the spider once onsite?
l. Cheban: Correct
m. Daly: Would you exceed the specification with transportation onsite?
n. Cheban: We will not approach with 1.5g while transporting onsite.
o. Daly: Is the specification different?
p. Holzbauer: No, but we will make the distinction.

5. Discussion
   a. Relief discussion
   b. Daly: Is the current relief coded?
   c. Dalesandro: Yes.
   d. Daly: With the lower MAWP, will the relief still a reclosable relief still be used?
   e. Dalesandro: It is uncertain at this point, but we have to look at the change.
   f. Daly: It sounds like the interface between the cryomodule and the cryogenics is still developing.
   g. Dalesandro: Correct.
   h. Daly: Is the ICD defined, or is the interface defined?
   i. Dalesandro: The ICD defines that there is an interface, the ISD does not yet give the specification.
6. Schedule and Cost - Chandrasekaran
   a. Ginsburg: A comment, I think you can take credit for all of the transport simulation in the risk register.
   b. Ginsburg: Where are the cavities going to be jacketed?

c. Chandrasekaran: We will jacket as many cavities as possible before the system is moved. We will coordinate with the move to finish the work.
d. Ginsburg: Where do the QC related items for the travelers and kitting go?
e. Chandrasekaran: They are within the procurement WBS. Travelers are within the design.
f. Ginsburg: So they are estimated now?
g. Chandrasekaran: Yes.
h. Ginsburg: Do you have a dedicated procurement person that works full time on this?
i. Chandrasekaran: PIP-II has a dedicated procurement manager, for the 650 MHz we will have a dedicated buyer.
j. Ginsburg: I would advise working with the procurement group early to devise the procurement strategy.
k. Ginsburg: Who is responsible for transportation frame drawings?
l. Chandrasekaran: We will be using SFTFC drawings, we will contact them for any changes.
m. Daly: You told me the 4 month of delays due to Covid, are the efficiency loss been recognized?
n. Chandrasekaran: We have only done the linear shift at this point, we have not yet incorporated any efficiencies at this point.
o. Daly: Slide 19, you had duration for procurements, have they been checked against LCLSII and SSR1.
p. Chandrasekaran: Yes, on average they are right on, but here as some procurements that will take longer.
q. Daly: Is it correct, that the cold testing in phase is a gate?
r. Chandrasekaran: Yes.
s. Daly: It looks like there is some overlap.
t. Chandrasekaran: There is some minimum acceptance, to fulfill the gate. There is extended testing that is still planned.
u. Daly: Is there any concern that there are performance hits during local road testing?
v. Chandrasekaran: We use the road test to confirm the frame and then perform warm tests (leak testing, sensor, etc).
w. Daly: How many horizontal tests do you have planned?
x. Chandrasekaran: We have not completely thought that out yet.

7. Procurement Plan - Roger
    a. Daly: Are you saying you are buying the strongback and the vacuum vessel together?
    b. Roger: Yes.
    c. Daly: Has this been done before?

d. Roger: On LCLSII, we had several POs at one vendor.
e. Miller: For suppliers that you would intend to visit onsite, do you have a plan in case the COVID situation would not allow for it?
f. Wu: Where possible we will use our partner labs; otherwise, we will have to rely on the technology.
g. Daly: What is the procurement plan for the tuner?
h. Chandrasekaran: Most components are purchased, less the tuner frame.

8. Discussion
    a. Ginsburg: Does FNAL have contingency plan due to COVID.
    b. Chandrasekaran: Yes

8. Comments

Observations with value judgments, or "soft" recommendations that require action by the design/engineering team, but where a formal written response is not a requirement.

The PIP-II CM Design Handbook is a notable practice that will result in a reference that multiple laboratories in the collaboration can utilize to guide their design choices in order to be consistent with overall needs for PIP-II. An aspect of procurement readiness reviews could be to ensure that procurements are compliant with the handbook. Add a transportation section to the design handbook, and ensure that the magnetic shielding and magnetic components section is adequately detailed to aid in procurement, possibly referencing other documents for substantive detail.

There are many examples of adjustments, modifications and changes to the prototype HB CM based on assembly experience with SSR1. It is clear that the team is applying lessons learned from the SSR1 CM where appropriate.

The cryogenic system makes use of the bi-metallic transition joints. Historically, these components have exhibited leaking, even within rigid quality programs. See recommendation.

Ensure that there is sufficient time for the strongback tooling to be finalized, particularly since it requires translation and print detailing by FNAL.

The procurement schedule for vacuum vessel, thermal shield, strongback and magnetic shielding is aggressive. Both the magnetic shielding and strongback drawings are incomplete and this is likely to impact the

procurement schedule. There may not be enough time in the schedule for the procurement technical leads to prepare technical documentation for procurements and technically evaluate bids, considering several large mechanical fabrication procurements are expected to take place in parallel and the limited number of technical leads.

To optimize procurement efficiency, we endorse the concept of appointing a dedicated buyer in Fermilab Procurement as soon as possible. It would be advantageous to work with that person early in the procurement planning to ensure you are on the same page with respect to procurement strategy.

The cavities must be brought into the cleanroom for string assembly in the order they are to be assembled. This is a constraint different from LCLS-II, for which qualified-cavity availability was already a significant schedule driver, and could impact PIP-II schedule.

Although important fabrication information is not available for the beta=0.90 cavities, because the procurement was a decade ago and the fabrication company is out of business, the project expects to be able to qualify these cavities for pressure safety through the Fermilab SRF safety subcommittee, and has done so for one of the cavities already. The project might check with APS-TD procurement to see whether the old data may be available on a disk, in case that facilitates approval.

Large pieces of carbon steel such as the base of the string assembly rails or the cryomodule test stands can be magnetic. It would be useful to develop a plan for demagnetization, or establish a magnetization spec for procurement to be confirmed in QC, to ensure the magnetic field generated by such components is not so high that it magnetizes other sensitive components such as magnetic shielding.

Lessons learned tracking system employed on SSR1 is a notable practice and should be continued in the future for the prototype HB CM as well as other complex components.

Consider documenting the analysis performed on the strongback in an engineering note.

Quality Assurance plans and requirements for production will be informed by prototype QA experiences during procurement and assembly. Careful records of QA experiences and lessons from prototype fabrication will be important to improve production QA. QA/QC effort has been included appropriately in procurements, design and assembly tasks.

Consider adding microphonics studies to prototype CM testing plans. These would be valuable even if the environmental sources in the test stand are different from those in the tunnel.

The detailed simulations and analysis of the impact of transportation on the cryomodule and its internal components are excellent and provide an important mitigation to transportation risk. We also found the transportation system requirements, such as natural frequencies below 10 Hz on the shipping frame and above 10 Hz within the cryomodule, to be clear and appropriate.

The current approach for shipping includes removable restraints prior to final assembly at FNAL but before movement into the test stand or tunnel. Specifications for on-site handling should be carefully developed.

Interface to CDS needs to be confirmed considering the change in MAWP for the 2K relief circuit.

Design approach and Interface need to be developed and defined for beamline vacuum relief.

9. Recommendations

Items that require formal action and closure in writing prior to receiving approval to move into the next phase of the project, or items that require formal action and closure in writing prior to the next review.

1) Develop a program to fully qualify bi-metallic transition joints.

2) Interfaces to the cryomodule need to be finalized and documented prior to production cryomodule FDR.

3) Previous review recommendations must be closed.

4) Design handbook tenets should be reviewed as a part of procurement and production readiness.