LCLS-II Cryomodules Production & PIP-II Prototype Cryomodules

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Introduction

- 2 partners labs are collaborating with SLAC for the LCLS-II project:
  - **Fermilab:**
    - Assemble 1 prototype 1.3 GHz CW module (May – October 2015)
    - Assemble 16 production 1.3GHz CW modules (mid FY16 - FY18)
    - Assemble 2 3.9GHz CW modules (early FY19)
  - **JLAB:**
    - Assemble 1 prototype 1.3 GHz CW module
    - Assemble 17 production 1.3GHz CW modules

- **Total:**
  - 35 Cryomodules (1.3GHz CW)
  - 2 Cryomodules (3.9GHz CW)
LCLS-II Prototype Module Assembly

- Use existing ILC R&D 1.3GHz cavities:
  - Process and test bare cavities (MP9, SCSPF, CPL, IB1)
  - Helium vessel welding to the cavity (CAF-MP9)
  - Test some dressed cavities in HTS and some in VTS post helium vessel welding
  - Cavity String Assembly (CAF-MP9)
  - Cold Mass Assembly Phase-I (CAF-MP9)
  - Cold Mass Assembly Phase II, III (CAF-ICB)
  - Cryomodule test (CMTF)
1. Received dressed, ready to be tested in vertical test stand (VTS) cavities from the vendors (Beamline under vacuum)
2. Visual Incoming Inspection at IB4
3. Install, leak check and test the cavities in VTS at IB1
4. Qualified Cavities go to CAF-MP9 cleanroom for cold end coupler assembly. Non qualified cavities will be HPR'ed and re-tested.
5. Some Cavities are then outfitted with tuner and magnetic shielding outside of the cleanroom at MP9 and then go to HTS at MDB for horizontal test. Other cavities still stay in the cleanroom and ready to be assembled into a cavity string.
6. 8 qualified cavities, Magnet Spool Tube, BPM, Gate Valves, Interconnecting Bellows: Cavity String Assembly at CAF-MP9 Cleanroom
7. Cold Mass Assembly Phase-I at CAF-MP9
8. Cold Mass Assembly Phase II, III and prep for transport to CMTF at CAF-ICB
9. Cryomodule Test at CMTF
10. Prepare and Ship Module to SLAC
CAF-MP9 during LCLS-II Production

- WS2: 7 days
- WS1: 12 days
- WS0: 5 days
LCLS-II Modules Assembly Model

- **Prototype (Module #1)**
  - Start on May 2015
  - Complete on October 2015

- **Production Modules #2 through #4 (in series, ramp-up)**
  - Start on March/April 2016
  - Complete on May 2017

- **Production Modules #5 through #13 (2 modules in parallel, peak rate (1 module per 5 weeks)**
  - Start on May 2017
  - Complete on February 2018

- **Production Modules #14 through #16 (in series, ramp-down)**
  - Start on February 2018
  - Complete on October 2018

- **3.9GHz Modules #1 and #2 (in series)**
  - Start on August 2018
  - Complete on March 2019
CAF Mechanical Tech Workforce for LCLS-II

- **Cleanroom Techs (Total of 6 are needed)**
  - **Current:**
    - 3 cleanroom techs, fully trained and experienced
  - **Goal:**
    - Hire 3 new contract mechanical techs and train them

- **Cold Mass Techs (Total of 8 are needed)**
  - **Current:**
    - 2 cold mas techs, fully trained and experienced
  - **Goal:**
    - Hire 6 new contract mechanical techs and train them
• PIP-II R&D prototype cryomodules SSR1, HB650MHz need to be assembled in FY16 and FY17 respectively.
  - Cryomodule Assembly Facility (CAF) infrastructure will be fully occupied with LCLS-II modules production.
  - We need to setup a module assembly infrastructure to assemble PIP-II prototype cryomodules.
  - Once the LCLS-II cryomodules production is completed, CAF infrastructure will be updated and used for PIP-II production modules assembly.
- Qualified hands-on manpower resources shortage is not trivial to solve. Cryomodule Fabrication Group and other support groups which work directly hands-on for the assembly of the cryomodules are understaffed.

- Current plan is to hire contract techs for LCLS-II project (risky approach taking into account long learning/training curve and past experience with the contract help high turnover)

- The same assembly team which will work on LCLS-II modules is needed for PIP-II prototype modules assembly but they will be fully occupied from mid FY15 to mid FY19 with LCLS-II production.

- We would like to hire more contract techs (~6 techs) in FY15 so that they can be trained during LCLS-II cryomodules assembly and eventually do the hands-on prototype modules assembly for PIP-II at HAB and/or other infrastructure that will be setup.

- This approach will solve the mechanical techs need but the support groups staff shortage will still have a negative impact for the assembly schedule of PIP-II prototype modules. We should plan accordingly to hire additional staff for the support groups (electrical, material handling, quality assurance, alignment etc.)
A softwall cleanroom will be setup at HAB. (RFP is out, M&S ~$450,000):

- This cleanroom is large enough to assemble PIP prototype modules cavity strings
- This cleanroom needs to be setup with auxiliary support infrastructure such as cryogenic gas dewars, related piping/manifolds. Particle free UHV pumping carts, related piping/manifolds etc.
- In order to perform the cavity string assembly in this cleanroom, we need to tool up. We will use JLAB style carts on wheels which accommodate the cavity support fixtures in the cleanroom during assembly.
- If we can perform the cold mass and final cryomodule assembly at HAB, this will be the most practical, less risky and most economical approach.
- ~ $310,000 M&S is needed
Proposed Assembly Workflow:
1. 8 cavities, 4 solenoids: Assemble in the HAB cleanroom using JLAB style cart/rail system and new tooling to support each component on the rails. New tooling to align and assemble the interconnecting bellows between the components.
2. Take the cavity string out of cleanroom by transferring to a new cart
3. Assemble cavity string on the cold mass support platform
4. Complete & Align the cold mass assembly
5. Insert the cold mass into the vacuum vessel
6. Assemble warm end of the couplers

Preferably at HAB
LCLS-II & PIP-II combined staffing

Cleanroom Techs:
6 for LCLS-I
3 for PIP-II

Cold Mass Assembly Techs:
8 for LCLS-II
3 for PIP-II

PIP-II techs will work on LCLS-II prototype module and early production modules assembly for training before they work on PIP prototype modules assembly.
Summary

- Cryomodule Assembly Facility (CAF) will be fully occupied with LCLS-II modules assembly between FY15Q3 ~FY19Q1
- Cryomodule Fabrication Group will increase the mechanical technicians pool with contract help in order to keep up with the LCLS-II production throughput
- HAB east end production floor is a good candidate to setup the infrastructure needed to assemble PIP-II prototype cryomodules. A softwall cleanroom for HAB procurement is underway. (RFP was sent out on 7/2/2014)
- The hands-on technicians group will be fully occupied with the LCLS-II work and will not be able to work on PIP-II prototype modules. Not a trivial problem to solve, learning curve is long (~1 year for cleanroom, ~6 months for cold mass) for SRF technicians. Hiring extra contract techs (~6) and have them trained during LCLS-II prototype and early production modules assembly is a good plan. Eventually, they will be responsible for PIP-II modules assembly.
- Support groups understaffing problem is still a major concern for LCLS-II and will also a negative effect on PIP-II prototype modules assembly schedule.
- After the design and R&D phases are completed for LCLS-II, we would like to have a projectized group for the LCLS-II Production Modules assembly and if this model work, the same shall be applied to the PIP-II Production Modules assembly.
Backup Slides
Parts / Fixture / Hardware Cleanroom Preparation

Continuous work

• Assembly hardware:
  – Wash in the ultrasonic bath
  – Blow clean with ionized nitrogen under the Class 10 hood
  – Bag and transport in the Class 1000 ante clean room
  – Blow clean with ionized nitrogen while monitoring the particulates count in the sluice area
  – Transport into the Class 10 assembly

Electro-polished, rolled thread stainless steel studs; silicon bronze nuts
Cold End Coupler Assembly (WS0)

- Leak check the dressed qualified cavity (received beamline under vacuum)
- Backfill the cavity
- Leak check the coupler pair in the processing stand as delivered from SLAC
- Backfill the processing stand
- Remove a cold end coupler from the stand
- Assemble cold end coupler to the cavity using PFFA
- Pump down, leak check, RGA
- **Total duration: 5 days**
- 2 cleanroom techs, 0.5 day per 1 cavity/coupler
- 2 cavities/couplers assembly per day, 4 days to complete 8 cavities + 1 day for extra QA
String Assembly-I (WS1)

**Align 8 cavities for string assembly:** 1 day

- Gate Valve (GV1) to Cavity Assembly: 1 day
  - Sub-assembly of the right angle valve
  - Installation to the support post and vacuum hose assembly
  - Leak check
  - Alignment to the cavity beam line flange
  - Particulate free flange assembly (PFFA) procedures
  - Assemble the gate valve to the cavity
  - Leak Check
String Assembly-II (WS1)

1 day per interconnecting bellows, total = 7 x 1 = 7 days

- Cavity to Cavity Assembly with the interconnect bellows:
  - Assemble vacuum hose to the cavity. Pump down and Leak check. Backfill
  - Align the interconnect bellows to the cavity field probe end beampipe flange
  - Assemble with PFFA
  - Align the bellows to the cavity coupler end beampipe flange
  - Assemble with PFFA
  - Leak Check after 4 and 8 cavities are assembled.
String Assembly III (WS1)

- Magnet+BPM+GV2 assembly and leak check (1 day)
- Magnet subassembly to the 8 cavity string (1 day)
- Pump down, bag the bellows, leak check. Backfill (1 day)

- **Total duration: 12 days**
  - 4 techs direct hands-on assembly
  - 2 techs cleaning parts/hardware
  - All 6 cleanroom techs fully qualified to do hands-on assembly
Cold Mass Assembly at CAF-MP9 (WS2)

- Work outside of the clean room before the string was lifted off the rail to the cold mass support: (Phase-I)
  - Transport the cavity string to the adjacent rail (0.5 day)
  - 2-phase helium pipes & bellows welding (1 day)
  - Cavity magnetic shields installation (0.5 day)
  - Tuner installation (0.5 day)
  - Cavity insulation installation (0.25 day)
  - Temperature sensors instrumentation and RF cables installation (1 day)
  - Cavity helium vessel lugs needle bearings and housings installation (1 day)
  - Various leak checks / pressure tests of the helium circuit (2 days)
  - Various electrical and RF checks (0.25 day)
  - **Total duration : 7 days**
    - 4 mechanical techs for 7 days
    - 2 electrical techs for 1.25 days
    - 1 welder for 1 day
After the cavity string is picked up off the rail and partially assembled to the cold mass support, the cold mass assembly is transported to the Vacuum Vessel Assembly Area at CAF-ICB (~5km from CAF-MP9).

(1~1.5 days, 4 mechanical techs)
Cold Mass Assembly at CAF-ICB (WS3)

Assembly Tasks: (Phase-II)

- Put the cold mass on the 4 support spreader bar fixture (0.25 day)
- Assemble Magnet (0.5 day)
- Align cavity string to GRHP to 0.1 mm (laser tracker) (2.5 days)
- Complete the interconnect magnetic shielding assembly (1 day)
- Complete the coupler heat shields intercepts assembly (0.25 day)
- Complete cooling straps assembly to the cavities HOM (0.25 day)
- Complete the harnessing of the instrumentation wires & RF cables (0.5 day)
- Various electrical checks (0.25 day)
- Weld the magnet current leads to the magnet instrumentation box (0.25 day)
- Various leak checks of the helium circuit (1 day)

**Total duration: 7 days**

- 4 mechanical techs for 7 days
- 2 electrical techs for 1 day
- 3 alignment techs for 2.5 days
- 1 welder for 0.25 day
Assembly on Big Bertha at CAF-ICB (WS4)

• Assembly tasks: (Phase-II)
  – Install and weld 80K shields (1 day)
  – Lay and wrap 30 layers of MLI (1 day)
  – Trim insulations around main couplers, magnet and cold mass support posts (1 day)
  – Electrical checks (0.5 day)
  – Slide vacuum vessel onto the cold mass (0.25 day)
  – Align cold mass to the vacuum vessel (laser tracker) (2 days)
  – Weld magnet flanges (0.25 day)
  – Various leak checks (1 day)

  – **Total duration : 7 days**
    • 4 mechanical techs for 7 days
    • 2 electrical techs for 0.5 day
    • 3 alignment techs for 2 days
    • 1 welder for 1.25 day
Final Assembly Phase-III (WS5)

- Install warm part of the main power couplers (6 days)
- Route & terminate instrumentations wires and RF cables to the feedthrough flanges (2.5 days)
- Install coupler pumping lines & leak check (1 day)
- Pump down and leak check insulating vacuum (2.5 days)

- **Total duration : 12 days**
  - 4 mechanical (semi cleanroom) techs for 8.5 days
  - 4 electrical techs for 2.5 day
Cryomodule Transport Preparation (WS6)

- Transport completed Cryomodule from CAF-ICB to the CMTF: 2 days
- Shipping preparation to SLAC: 2 days
Cleanroom Group

- Work Week 1: @WS0 total duration needed = 5 days
  - Cold end couplers to qualified cavities assembly – 5 days
- Work Week 2: @WS1 total duration needed = 12 days
  - Cavity string assembly – 5 days
- Work Week 3: @WS1
  - Continue cavity string assembly – 5 days
- Work Week 4: @WS1
  - Complete cavity string assembly – 2 days
  - Cleanroom group cleans hardware/components for next assembly – 3 days
- Work Week 5: @WS0
  - Cold end couplers to qualified cavities assembly (next module) – 5 days
Assembly Workflow Schedule -II

Cold Mass Group

- Work Week 4: @WS2 total duration needed = 7 days
  - Cold Mass Assembly Phase-I - 3 days
- Work Week 5: @WS2
  - Complete Cavity Mass Assembly Phase-I - 4 days
  - Transport cold mass from MP9 to ICB – 1day
- Work Week 6: @WS3 total duration needed = 7 days
  - Cold Mass Assembly Phase-II – 5 days
- Work Week 7: @WS3 & @WS4 total duration needed = 7 days
  - Continue Cold Mass Assembly Phase-II – 5 days
- Work Week 8: @WS4
  - Complete Cold Mass Assembly Phase-II – 4 days
- Work Week 9: @WS5 total duration needed = 12 days
  - Cryomodule Assembly Phase-III - 5 days
- Work Week 10: @WS5
  - Continue Cryomodule Assembly Phase-III – 5 days
- Work Week 11: @WS5 & WS6
  - Complete Cryomodule Assembly Phase-III - 2 days
  - Transport Cryomodule to CMTF – 2 days

Next Cavity String comes out of the cleanroom

Next Module delivered to CMTF on week 16