Outline

• Production workflow
• Lessons learned from pCM
• Current challenges
• Module Assembly Status
• Summary
Supply Chain for Production CMs assembly at Fermilab

- Dressed cavities (RI and Zanon) delivered ready to be tested
- Fundamental power couplers (CPI and RI/Thales) delivered ready to be assembled at WS0 and WS5
- Gate valves (VAT) cleaned to Class 100 standard at the vendor
- BPM cleaned to Class 10 standard at DESY
- BPM electrical feedthroughs (Solcera)
- Copper plated beamline components (fabricated in U.S industrial vendor, plated at SLAC for initial Production CMs, will be plated at Nomura plating in Japan for remainder Production CMs
- Cavity String Assembly Hardware (JT industries) and Seals (Wepek)
- Cold Mass Upper assembly (WXCX, China)
- Cold Mass peripherals from various U.S. vendors
- Split Magnet (Milhous) delivered ready to be tested
- Instrumentation (U.S and International vendors)
- Vacuum Vessel (WXCX, China)
- Vacuum vessel peripherals from various U.S. vendors

Full or batch delivery ➔ Supply Chain Manager working with SOTRs & TD QMD for qualified parts storage in TD inventory system ➔ Parts are kitted & delivered to work stations ➔ Magnetic hygiene QC, clean and use
LCLS-II Production CMs Workflow at Fermilab

1. Receive dressed, ready to be tested in VTS (vertical test stand) cavities from the vendors (Beamline under vacuum)

2. Incoming Inspection at IB4.

3. Test cavities in VTS at IB1

4. Qualified Cavities go to CAF-MP9 cleanroom for cold end coupler assembly (WS0). Non qualified cavities will be re-processed (HPR, light EP etc.) and re-tested.

5. One cavity out of every sixteen will be tested in horizontal test stand (HTS). 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 (WS1)

7. Cold Mass Assembly at CAF-MP9 (WS2)

8. Cold Mass Assembly at CAF-ICB (WS3 & WS4)

9. Final Assembly and QC checks (WS5) and prep for transport to CMTS at CAF-ICB (WS6)

10. Cryomodule Test at CMTS

11. Transport the module back to CAF-ICB (WS6)

12. Prepare and Ship Module to SLAC
CAF-MP9 during LCLS-II Production
CAF-ICB during LCLS-II Production

- Sick CM repair area
- WS4
- WS3
- WS5
- WS6

Diagram with marked areas and labels.
Microphonics issues experienced with pCM at CMTS

- Thermal Acoustic Oscillations (TAO) is believed to be the main culprit
- There are two cryogenic valves on the module: JT (DN6) and cool down (DN10) valves
- Wipers worked for both JT and CD but not 100% - plan is to add additional stem wipers (~4 total) to get temperature ratio under 4 for each segment
- For CM02, we will reverse the plumbing of the inlet and outlet lines to the valves to assess the effect on the AOT
Reduce TAOs (wiper rings helped tremendously)

- TAO occurs during supercritical operation in Line A
- TAO reduces during subcritical operation in Line A
  - Lower flow rates (lower heat load)
  - Ice ball disappears
  - Thermometers added to the warm end of the valve warm up to near room temperature

Rich Stanek
Valve Stem Modifications

Solutions for stem wipers depend on size of valve – DN6 seems to be unique
LCLS-II CM Cryogenic Pipes

Pipe A - 2.2 K supply
Pipe C - 4.5 K supply
Pipe E - 35 K supply
Pipe G - 2 phase He
Pipe B - HGRP
Pipe H - Cool down / warm up
Pipe F - 55 K return
Pipe D - 5.5 K return
Design of Reversed Valves

Cool down valve
Line H
Line A

JT valve
Line A
JT outlet

pCM configuration

CM02 configuration
Modifications on CM2 to reduce vibration

- Support the capillary line from upstream end liquid level probe to cavity#8 as it is done for cavity#1 (done)
- Wrap warm/up-cool down capillary lines with MLI (done)
- Stiffen the support for the JT line by adding some dampening material (done)
- Stiffen the 2-phase invar rods by tying them together with fiberglass strings (done)
- 2-Phase line heater tied to pipe with fiberglass strings (done)
- Full sized tee with tangential injection and baffle for better liquid level management. (only baffle for CM02 due to schedule. Full system us is implemented on CM03)
JT Line Modification for CM03 & beyond

- Replace JT Line Elbow/Weld Socket
- New JT Inlet Design
- Cut Elbow Section From Existing JT Line and Weld JT Line to Reducer Socket. Full sized tee with tangential injection and baffle assembly is Added to 2-Phase Circuit Upstream of Cavity #4

Current Design on pCM and CM02
Cavity #1 & GV connection modification proposal

(Still under analysis)
Cavity #1 & GV connection

Existing GV Support to HGR pipe with Needle bearings

Cavity 1-GV Bellows
GV Sliding Support

Needle Bearing
C-clamps

Connection
GV Sliding Support
to Interconnect. Bar

Tuner Holder
Interconnect
bar

GV Sliding support
Some other challenges

- Copper plated beamline components QC (not standardized acceptance criteria)
- Parts in circulation (PIC): Fabrication of the parts in industry versus CM assembly is not easy to sync. Plus non conformance causes some parts to be kept longer with PIC. Hands-on team busy with assembly get distracted to work on removing PIC from stored parts and return to vendors to eliminate penalty costs. Recommendation: Procure enough PIC (~75%)
- Needed to modify tuner to cavity interface on CM2 due to production cavities not holding same tolerance on Nb/Ti transition ring as pCM (Slide 17)
- Need to stay on top of procurements and component QC even when dealing with experienced vendors
- Retention of the qualified hands-on contract techs was so far not a problem. (though I expect difficulties in the near future) We need to add 2 more cold mass assembly techs and that will complete the initially budgeted CM assembly hands-on manpower resource pool for CAF
Tuner Split Ring Modifications

Split Ring need to be mounted on the cavity between Nb alignment ring and NbTi conical flange close-fitting.

Modified split ring with set screws.
Cryomodule Prep & Transport to CMTS

pCM transport from CMTS to CAF-ICB
CM02 & CM03 & pCM at CAF-ICB

CM02 at WS5, CM03 at WS3

pCM
CM02 status at WS5

- Magnet current leads soldering completed
- Warm end couplers & waveguides assembly complete
- Cryogenics valves are welded & leak checked (reverse plumbing)
- Pressure test phase-1 completed
- Estimated completion date of CM02 at WS5: March 31, 2017
• Alignment work is under progress
• No assembly work can be done while alignment is being done
CM04 Cavity String at WS1

- 8 cavities in the cleanroom
- 8 cavities assembled with cold end FPC
Upstream end gate valve is assembled with the spool and Cav#1
As of 3/20/2017, string assembly is completed. Backfill the string and roll out to WS2 today 3/21/2017
Summary

• pCM was assembled and tested at Fermilab. Cavity performance is good. Microphonics issues are being worked on.

• CM02, first production CM is currently at WS5, shall be completed by the end of March 2017

• CM03, second production CM currently at WS3

• CM04, third production CM. String assembly is completed at WS1 and will be rolled out to WS2 today.

• Starting from CM05, we want to exercise the peak rate production throughput. 1 CM fully assembled every 4~5 weeks
Backup slides
Magnetic Hygiene Quality Control for every part, hardware, fixtures, tools that will be used in the cleanroom for assembly prior cleaning

Assembly hardware:
- Wash in the ultrasonic bath
- Dry under Class100 hood
- Move into the Class 1000 ante clean room
- Blow clean with ionized nitrogen while monitoring the particle count in the sluice area (Class 100)
- Transport into the Class 10 assembly area

Electro-polished, rolled thread 316L stainless steel studs; silicon bronze nuts
Cold End Coupler Assembly (WS0)

- Leak check, RGA the dressed qualified cavity (received with beamline under vacuum)
- Assemble pump/backfill/purge flex hose to the cavity
- Backfill the cavity
- Leak check the coupler pair in the processing stand as delivered
- Backfill
- Remove a cold end coupler from the stand
- Assemble cold end coupler to the cavity using particle free flange assembly (PFFA) procedures
- Pump down, leak check, RGA
- Backfill
String Assembly-I (WS1)

- Align 8 cavities for string assembly
- Gate Valve (GV1) to Cavity #1
  Assembly:
  - Check the particle free cleanliness of the GV and clean as needed
  - Sub-assembly of the GV peripherals
  - Installation to the support post and vacuum hose assembly
  - Alignment to the cavity beam line flange
  - Assemble the gate valve to the cavity
Cavity to Cavity Assembly with the interconnect bellows:

• Assemble flex 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
String Assembly-III (WS1)

- BPM+Magnet Spool Tube+GV2 assembly and leak check
  BPM/Magnet package subassembly to the 8 cavity string
- Pump down fully assembled cavity string, bag the bellows, leak check. Backfill
- Roll out of the cleanroom to WS2
Cold Mass Assembly Phase-I at CAF-MP9 (WS2)

Tasks outside of the clean room before the string was lifted off the cleanroom posts to Cold Mass Upper assembly:

- Split Magnet installation
- 2-phase circuit pipes cutting to length & peripherals welding with orbital cutting and welding machines
- Instrumentation (sensors, heaters etc.) installation
- Cavity magnetic shields installation
- Cavity helium vessel insulation installation
- Cavity helium vessel lugs to needle bearings and housings installation
- GHRP to 2-phase pipe welding
- Cool down line to cavity helium vessels welding
- Various leak checks of the helium circuit
- Various electrical checks
- Various RF checks & HOM notch frequency tuning
Cold Mass Transport

• After the cavity string was picked up off the rail and partially assembled to cold mass upper, the cold mass assembly was transported to CAF-ICB (~2 km from CAF-MP9)

• There are a written procedure and a job hazard analysis

• A lead engineer supervises this transport. Accelerometers and geophones are used to collect data during the transport
Cold Mass Assembly Phase-II at CAF-ICB (WS3)

Assembly Tasks: (Phase-II)

- *Align cavities axial position in Z (laser tracker)*
- Magnet and current leads thermal intercepts installation
- *Align cavity string to cold mass (laser tracker)*
- Remove helium vessel safety brackets & Assemble end lever tuner system
- Complete thermal intercepts assembly (HOM connectors, tuner motor etc.)
- RF cables installation
- Complete the end caps magnetic shielding assembly
- Complete the harnessing of the instrumentation wires & RF cables
- Thermal intercepts installation for RF cables
- Electrical & RF Checks
Assembly tasks: (Phase-II cont.)
- Install and weld lower 50K aluminum shields
- 30 layers of MLI as pre-made blankets
- Electrical & RF checks
- Slide vacuum vessel onto the cold mass
- Assemble cold mass supports
- Align cold mass to the vacuum vessel and transfer to external fiducials (laser tracker)
Final Assembly Phase-III (WS5)

- Weld JT/Cooldown valves
- Leak check
- X-ray
- Pressure tests
- Install warm part of the fundamental power couplers and leak check
- Install FPC waveguides and tuner motors
- Route & terminate instrumentations wires and RF cables to the feedthrough flanges
- Install coupler pumping lines, pumps & leak check, leave under vacuum
- Leak check beamline vacuum, leave under vacuum
- *Pump down and leak check insulating vacuum*