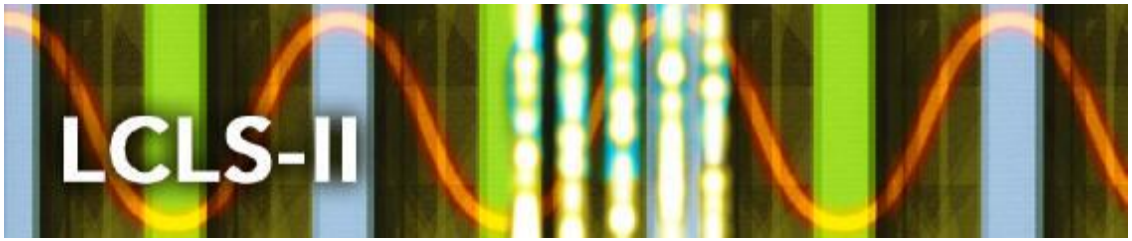


Infrastructure Updates

For LCLS-II Cryomodule Construction

Ed Daly

07-OCT-2014

SLAC NATIONAL ACCELERATOR LABORATORY

BERKELEY LAB
Lawrence Berkeley National Laboratory

Argonne NATIONAL LABORATORY

CORNELL UNIVERSITY FOUNDED A.D. 1865

Fermilab

Jefferson Lab

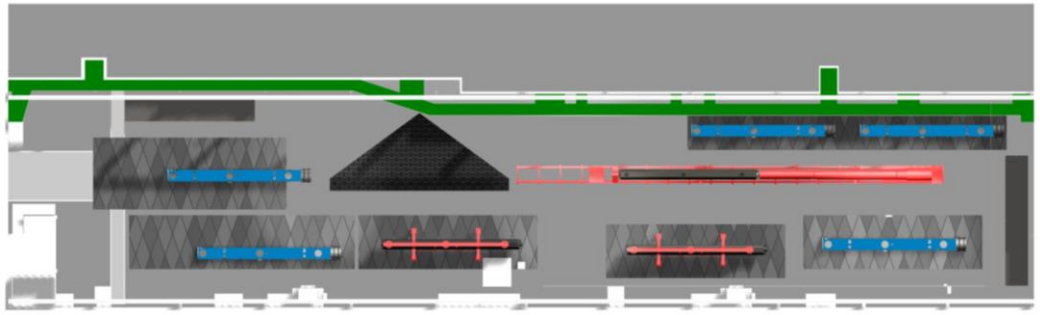
U.S. DEPARTMENT OF ENERGY
Office of Science

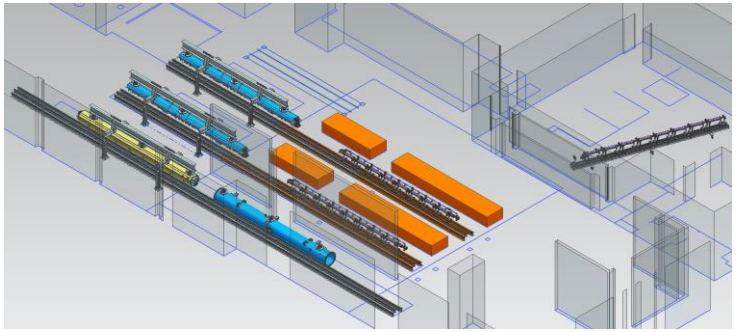
Acknowledgements

- Special Thanks – T. Peterson, T. Arkan, J. Leibfritz, R. Stanek, A. McEwen
- JLab, FNAL and SLAC colleagues
- XFEL Project Teams at DESY & CEA/Saclay

Outline

- Collaboration
- Production Strategy
- CM Production Preparations
  - FNAL & JLab
- Summary





Cryomodule Collaboration

Fermilab is leading the cryomodule design effort

- Extensive experience with TESLA-style CM design and assembly
- Basis: 3-D model & drawings of similar ILC CMs (e.g. Type III+)

Jefferson Lab and Cornell are partners in R&D, design reviews, costing, and production

- Cornell and JLab both have valuable CW CM design experience
- Jefferson Lab sharing half the 1.3 GHz production
  - Recent 12 GeV Upgrade production experience

Argonne Lab is also participating in cryostat design

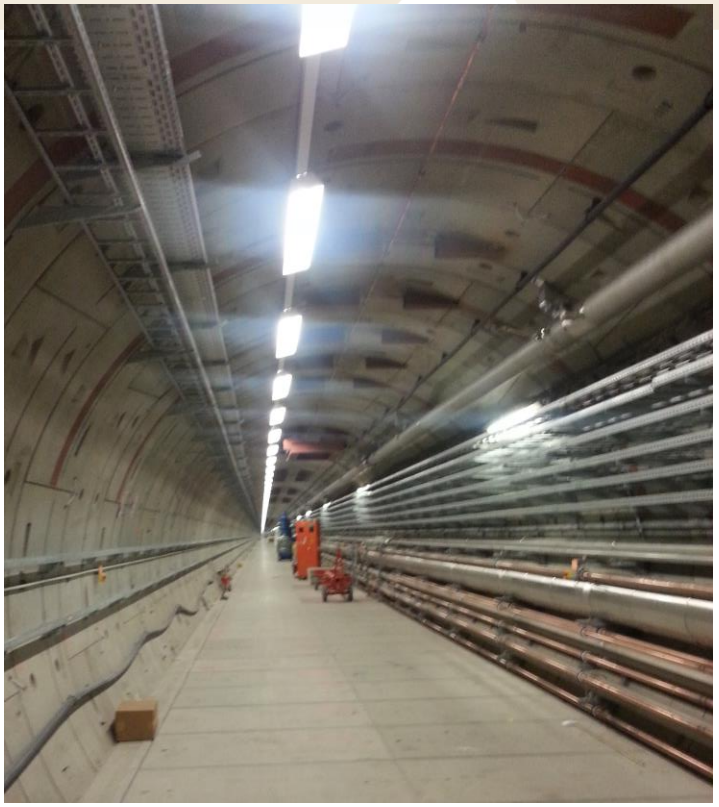
Strategy – One Design, Two Production Lines

- Designs for Prototype and Production CMs (aim to satisfy PR and CM FRS)
- **Identical Prototypes** - utilize as much existing hardware as possible to reduce schedule risk and reduce overall cost while achieving the same performance as the production CMs
- **Identical Production Designs** - utilize as much of the DESY/XFEL design as practically possible to reduce schedule risk and reduce overall cost
  - FNAL produces 16 CMs; JLab produces 17 CMs
- **Identical Parts Received** at Partner Labs
  - Well-developed drawing packages, clear requirements and specifications
  - Concurrent reviews within LCLS-II project
  - Procurement activities – lead technical contacts at Jlab/FNAL/SLAC work together during all phases
- **Identical Tooling Interfaces**
  - Interfaces between CM hardware and tooling are identical
    - Avoid adding custom features to CM
  - Adapt non-CM hardware interfaces to Lab-specific tooling
- **Equivalent Processes yielding Equivalent Performance**
  - Recognize that some tools are different at each lab (e.g. HPR, vertical testing systems, vacuum leak checking equipment, etc.)
  - Monitor key process variables in consistent fashion (e.g. samples to verify etch rates)

Leverage XFEL's Existing CM Experience

XFEL Production - Four cavities per test stand

CM ready for testing (can test 3 CMs at once)



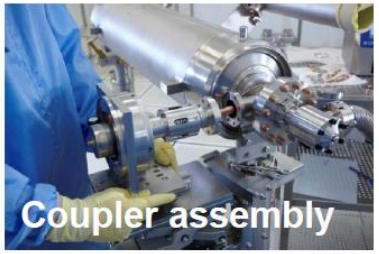
Tunnel construction is underway

Production of CMs is currently ramping up!

Start operations in April 2017, see
http://www.xfel.eu/project/construction_milestones/

Opportunity to Learn from CEA Colleagues

PHASE 3 : PROTOTYPING



Check :

- ✓ Infrastructures
- ✓ Tools
- ✓ Procedures

CEA team trained

Production of CMs is currently ramping up!

XFEL
X-Ray Free-Electron Laser

C. Madec | SRF13-THIOA02 | 26/09/2013 | PAGE 13

Leverage FNAL's ILC-style CM Production Development

Cavity String Assembly

Insertion of Cold Mass into Cryostat Assembly

Cold Mass Assembly

Cryomodule Ready for Transport On-site

Courtesy of T. Arkan, FNAL

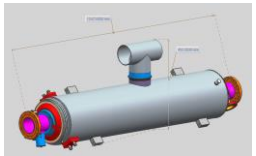
LCLS-II Cavity/Cryomodule Process

A. McEwen

Supplier Partners

Component	FNAL	JLAB	SLAC
Niobium	x		
Cavities		x	
HOM/FP Feed through		x	
Cavity Flanges - VTA Testing		x	
Cavity Flanges - HTB Testing	x	x	
Helium Vessels		x	
FPC- Fundamental Power Couplers			x
Cavity String Bellows		x	
Cavity String Hardware	x		
Magnet	x		
BPM- Beam Position Monitors,	x		
HOM Absorber	x		
Gate Valve		x	
2-Phase Pipe Bellows	x		
End Lever Tuner		x	
Magnetic Shielding	x		
GRHP Sub-assembly Gas Return Header Pipe, Cryostat, Intercept, Thermal Shield, Multi-layer Insulation etc.	x		
Vacuum Vessel	x		
Instrumentation		x	
Interconnect Parts		x	
Shipping Frames / End Caps		x	

X = Lead Laboratory (as of 20Mar2014)



LCLS-II 1.3 GHz Dressed Cavity, Doped and Ready for VTA Testing

JLAB SRF Facility

Receiving in SRF Inventory
- ✓ Mechanical Inspection CMM

Cavity /Helium Vessel Prep. & Test
- ✓ VTA RF Test in liquid Helium @ 2 K

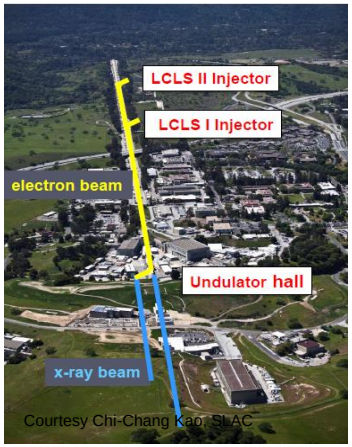
Cavity String Assembly & Leak Test
- ✓ Assemble Cavity String - Class 10 Clean Room

Cryomodule Assembly
- Instrumentation & Wiring
- Tuners, MLI– Multi Layer Insulation,
- Cryogenic Circuits , magnetic shielding, alignment
- Super Insulation Cabling & Shield
- Vacuum Vessel & Final Alignment
- Install Cryogenic Supply Interfaces
- ✓ Horizontal Test Preparation
- ✓ Pressure Test & Leak Check (vacuum)

Cryomodule Test in "Test Cave"
- ✓ Cryomodule integrity @ 2 K
- ✓ Tuners - Range, Hysteresis, & Resolution/ Sensitivity
- ✓ Cavities for Gradient & Dynamic Heat Load Q_o

Cryomodule shipping to SLAC
- ✓ JLAB support for installation of first 3 Cryomodule

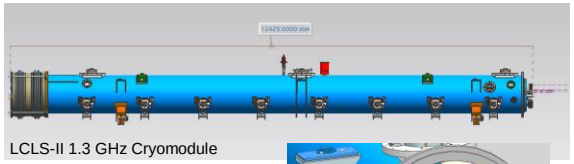
SLAC NATIONAL ACCELERATOR LABORATORY



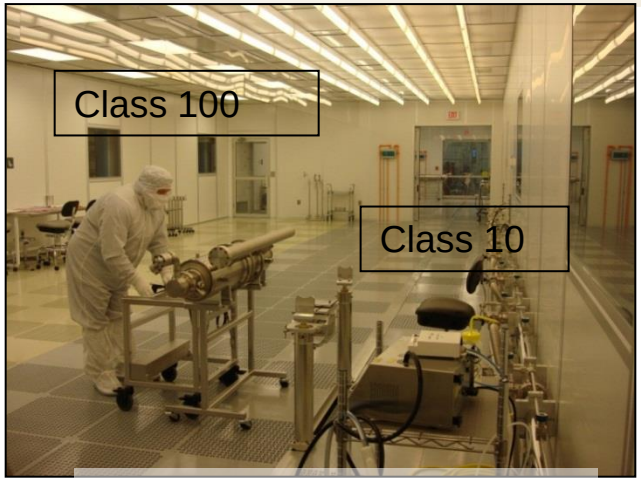
Courtesy Chi-Chang Kao, SLAC

Commissioning at SLAC

Install Cryomodules in Accelerator, cool to 2 K
- ✓ Weld & certify leak tight , pressure test
- ✓ check Controls,
- ✓ Gradient & Dynamic Heat Load - Q_o


LCLS-II 1.3 GHz Cryomodule

FNAL Capabilities and Infrastructure: Cavity String, Cold Mass, Cryomodule Assembly



Cavity String Assembly Clean Room

Cavity String Assembly

Cold Mass Assembly

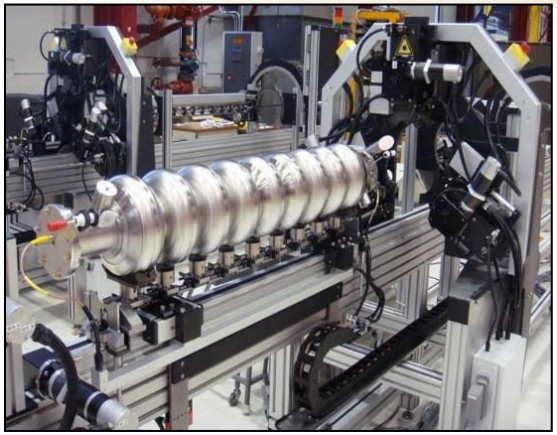
Courtesy of R. Stanek & T. Arkan, FNAL

Cryomodule Transport

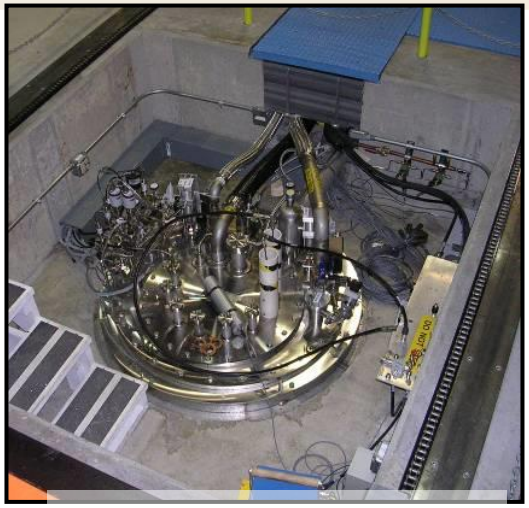
Final Assembly

Final Assembly

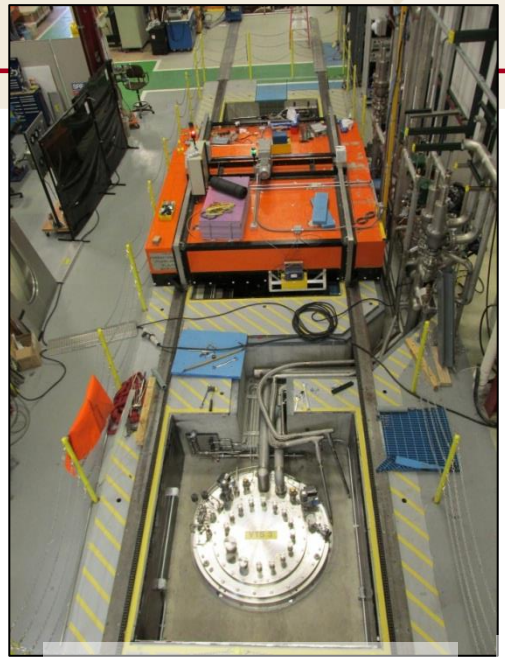
FNAL Capabilities and Infrastructure: Cavity Testing, Tuning



ILC/XFEL Cavity Tuning Machine

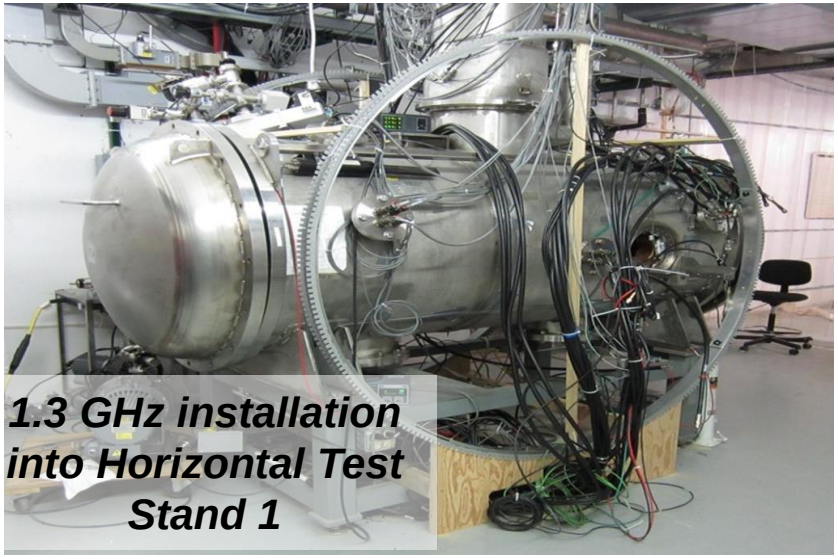


Vertical Test Stand



Vertical Test Stands 1, 2 and 3

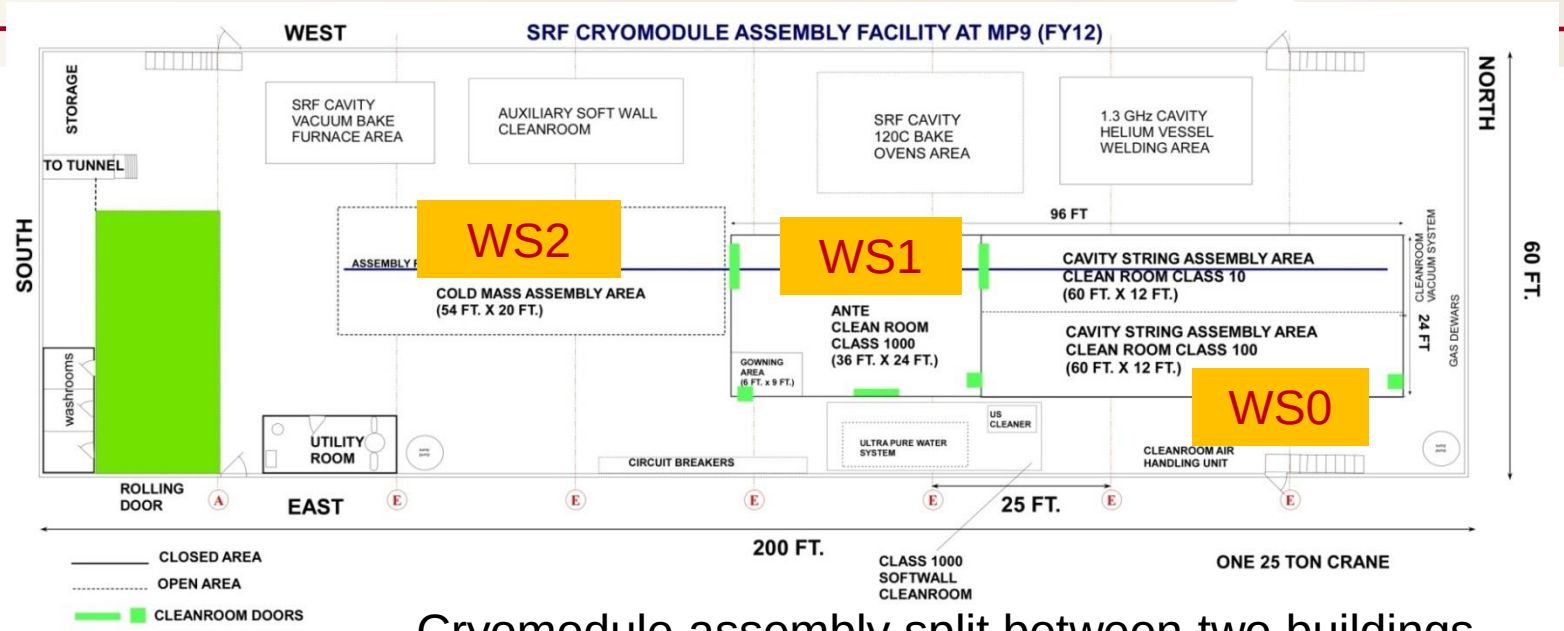
9-cell TESLA-style cavity



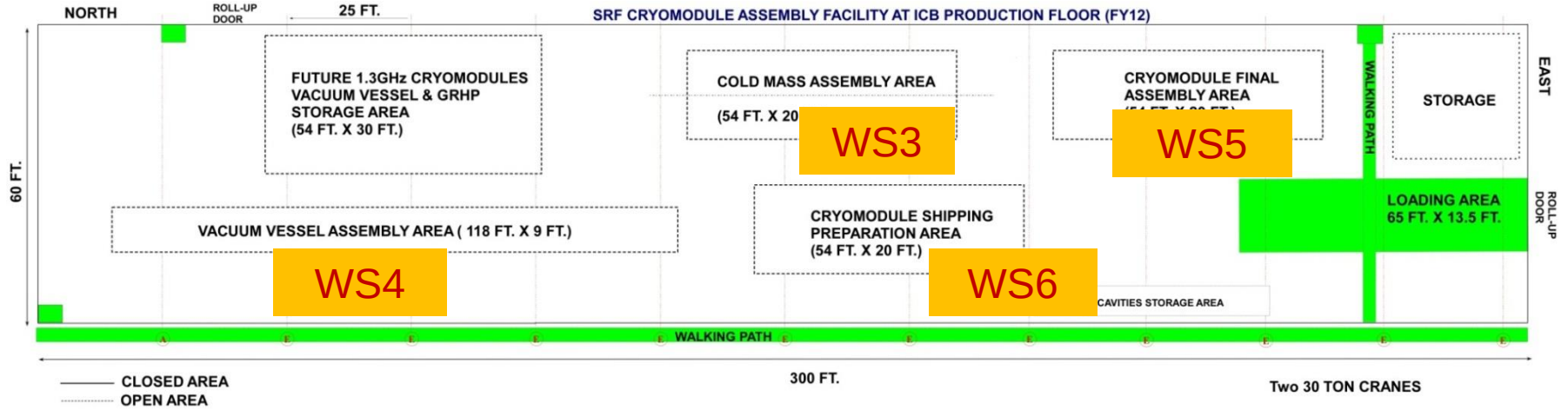
1.3 GHz installation into Horizontal Test Stand 1

Vertical Cavity Test Facility Control Room

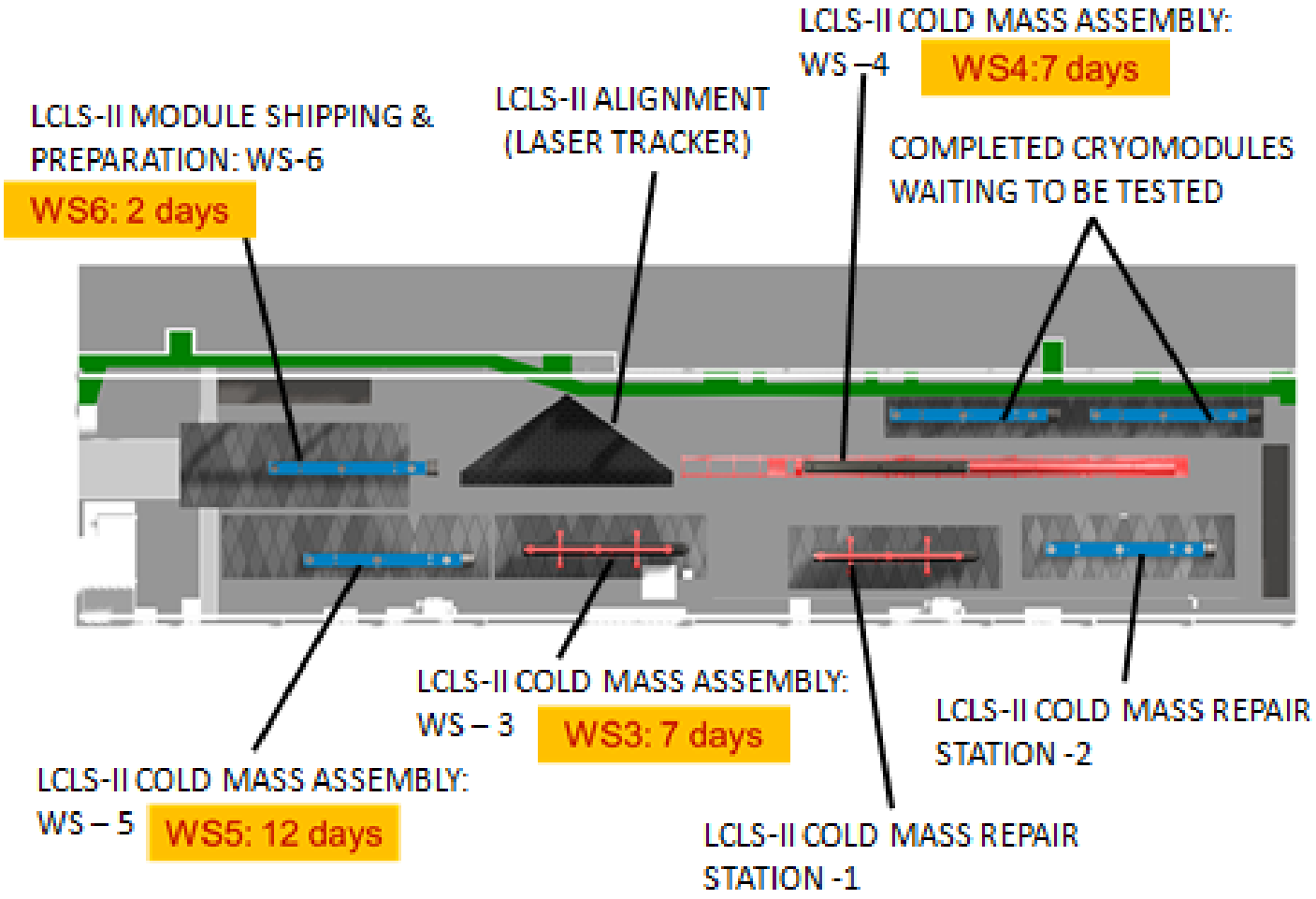
Capabilities and Infrastructure: FNAL 1.3 GHz CM Ass'y



Cryomodule assembly split between two buildings



CAF-ICB during LCLS-II Production



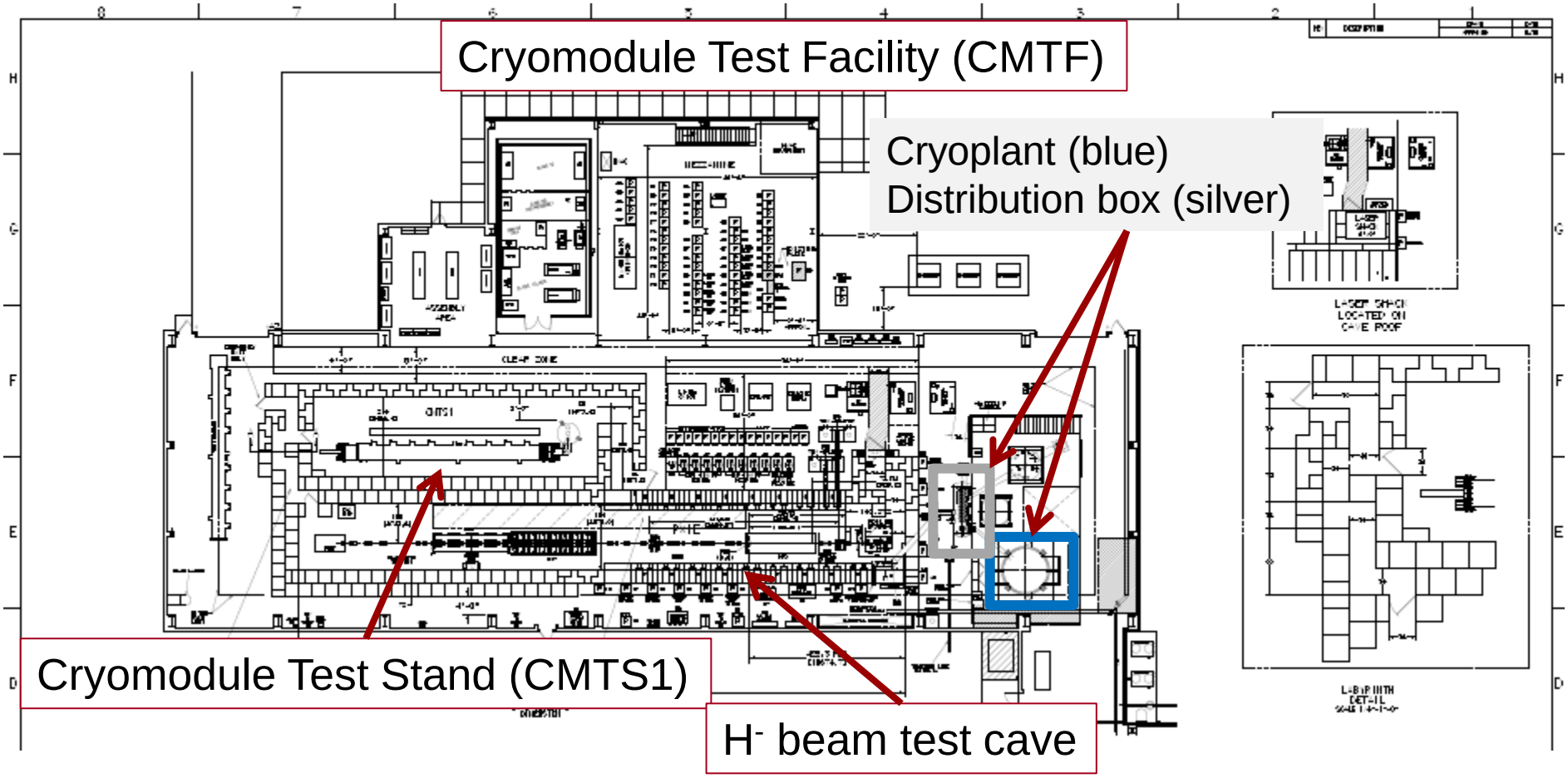
FNAL – Minor Infrastructure Upgrades Ensuring CM Throughput

T. Arkan

- Cleanroom LN2 boiled-off inert gas volume and flow capacity is increased
- Setup new cold end coupler assembly station in MP9 cleanroom (WS0)
- Add a second rail system in MP9 (WS2)
- Duplicate some tooling:
  - Procure one more full set of cleanroom cavity support posts to be used (WS2)
  - Procure one more red spreader bar fixture to be used to transport GRHP assemblies from storage to production floor
- Modify some tooling for LCLS-II cryomodule design
- Additional vacuum and leak check equipment: Vacuum pumps, leak detectors

FNAL – CMTS1 Layout

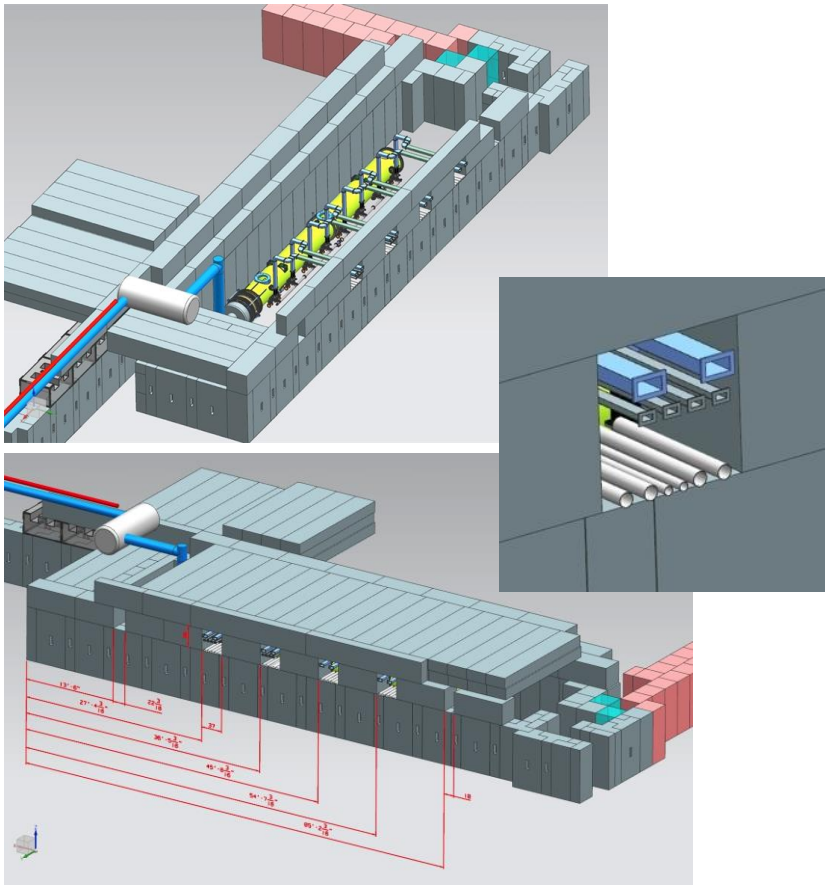
J. Leibfritz



FNAL CMTS1 – Construction on Track

J. Leibfritz

- 3-D model of cave, 1.3 CM, RF WG and cryo distribution is well developed



- 1st two layers (walls, labyrinths and penetrations) are complete
- Next steps – paint blocks and epoxy coat floor, followed by elec. & lighting

CMTS1 Updates

J. Leibfritz

Multi-use CM Test Stand (LCLS II and eventually PIP II)

Cryoplant (new) is fully commissioned

- 500 W at 2K

Design is in progress

- FRS is approved (LCLSII-4.5-FR-0246-R0)
- Builds off the NML and DESY experiences
- Floor layout established
- Cryogenic distribution TL will be out for bid in early September
- LLRF will be based on NML and HTS (CW) systems

Construction has already begun

- Building cave walls
- Ordering parts (chillers, racks, controls…)
- RF power sources will be supplied by SLAC
- Feed Cap and End Cap supplied by BARC (India) – design is complete
  - Production Readiness Review in September 2014

Funding is in place (75% FNAL, 25% LCLS II)

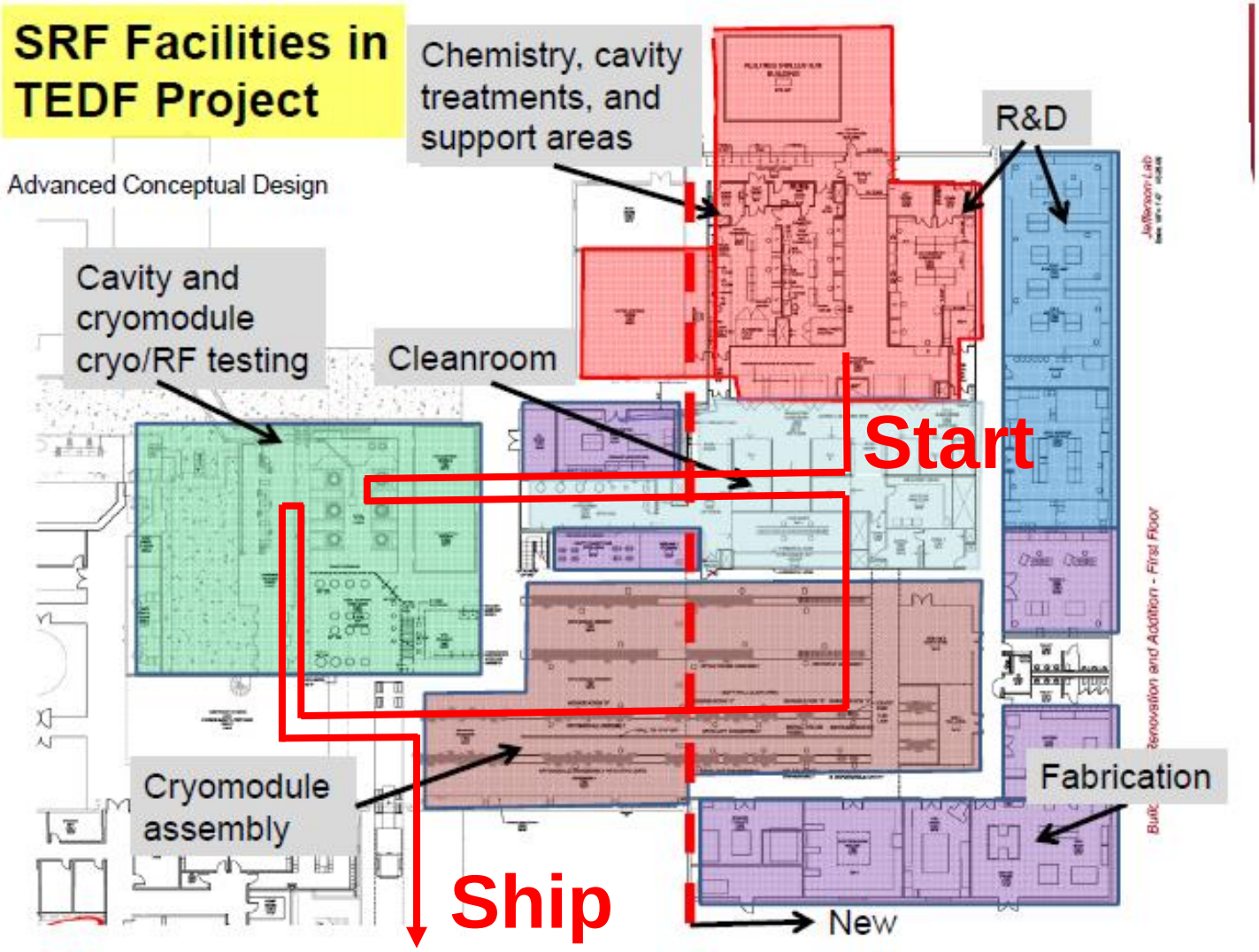
- OHEP is very supportive of this work

Plan to have CMTS1 fully commissioned in October 2015

SRF Facilities at JLab

Located in Annex – Receiving Inspection Inventory

Offsite considered for additional storage



CM Production Preparations at JLab

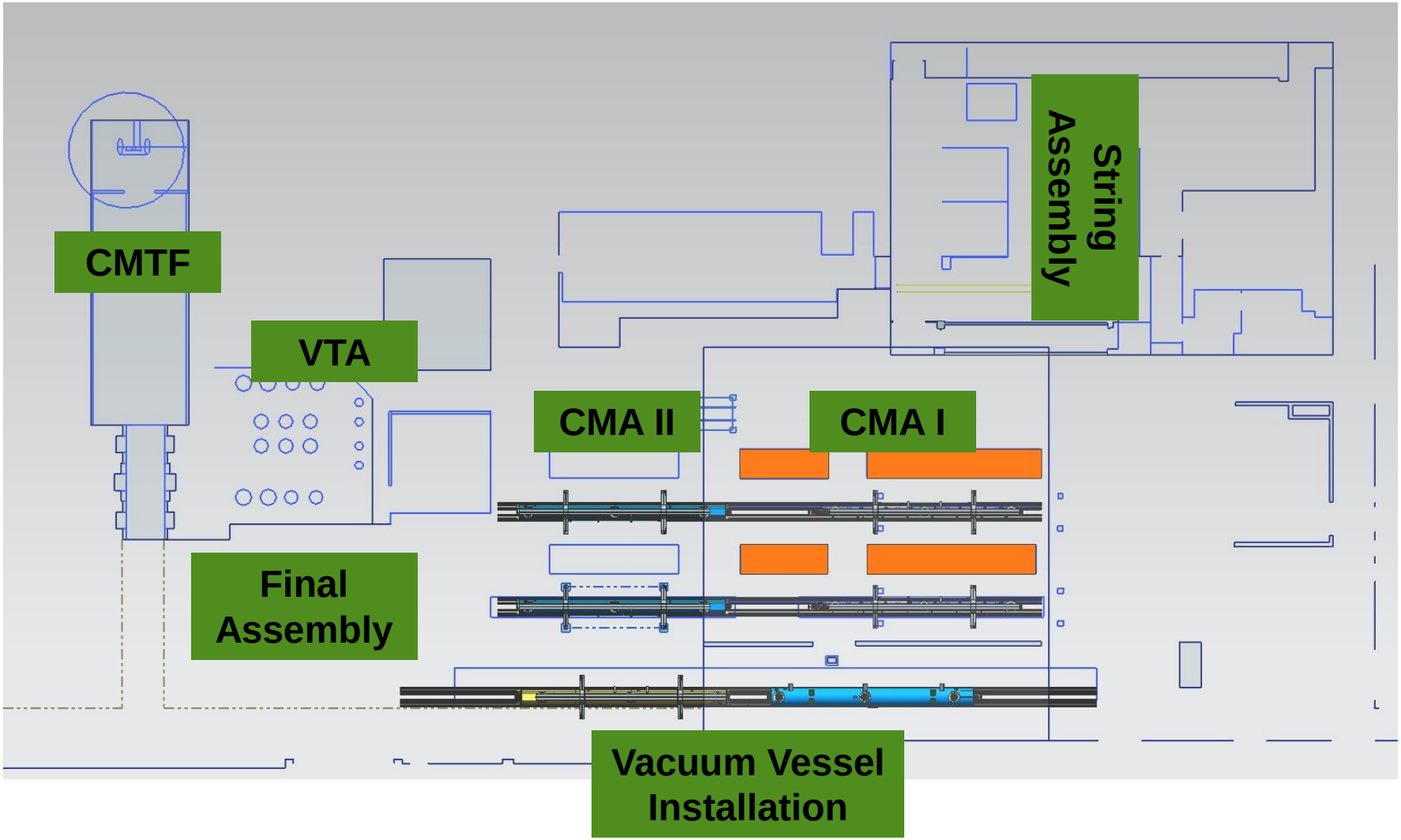
Adapt existing infrastructure and facilities to accommodate LCLS-II components, sub-assemblies, final assembly and testing

Define processes required for component handling, assembly and testing

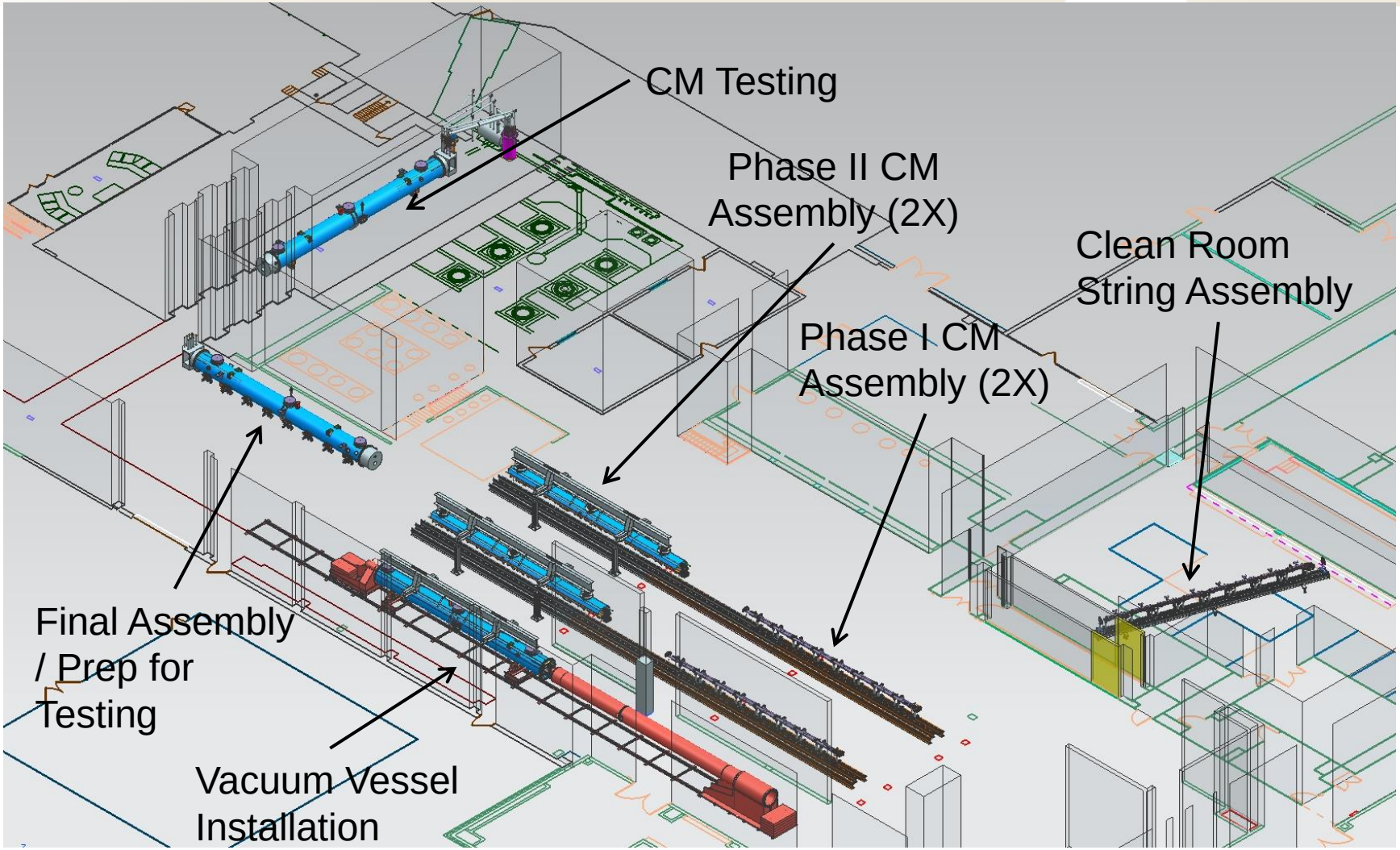
Develop test plans – key activities are cavity qualification from vendors and cryomodule acceptance testing

Employ SRF QA Tools used for 12 GeV 100 MV CW cryomodules (aka C100) production and SNS production

JLab CM Assembly Area Work Flow



JLab Proposed Layout for LCLS-II CM Production



JLab Infrastructure, Tooling & Facilities

Vertical Testing of Bare/Dressed Cavities

- Capacity - 4 cavities per week
- Planned rate – 2 cavities per week

Cavity String, Cold Mass and CM Assembly Tools

- Capacity – 2 CM per month
- Planned rate – 1 CM per month

Horizontal Testing Bench – supports Qo R&D and production efforts

- Capacity – 1 test per month
- Planned rate - ~ 1 cavity per CM during production

Cryomodule Testing Facility (CMTF)

- Capacity & planned rate – 1 CM per ~ 6 weeks

JLab Vertical Test Area / Horizontal Test Bench

VTA

- Up to four test stands available for production acceptance testing capable of testing one cavity at a time
- Utilize same cavity hardware (test flanges, feedthroughs, etc.) provided by project to cavity suppliers
- Small modifications required to existing supports
- Ensure low magnetic field environment (“magnetic hygiene”)

HTB

- Plan to conduct five tests during production effort to provide feedback on cavity assembly process or for production development activities
- Modifications to top hat for XFEL-style FPC and small modifications to existing supports

JLab Facilities Improvements: Assembly Tools

Functional requirements for tooling are well-defined

- JLab tooling FRS (LCLSII-4.6-FR-0282) is in review/approval process

Main Cavity Tools

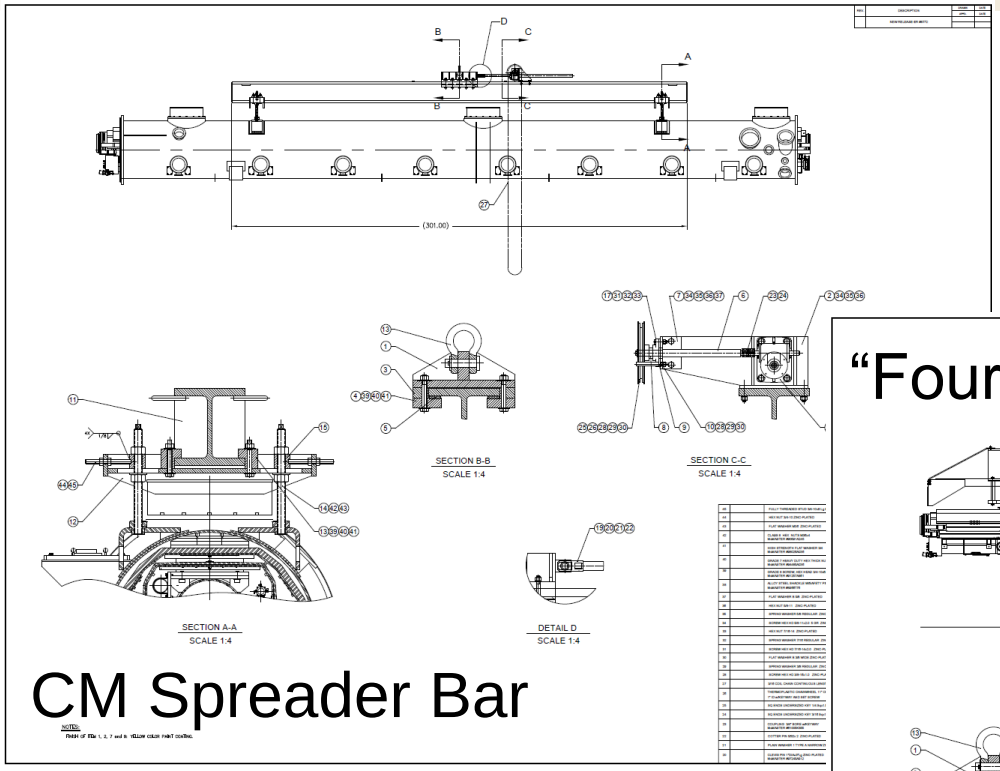
- Clean room tooling* - small fixtures for coupler installation, flange alignment, VTA testing hardware
- Cavity Handling Cages*
- Cavity Processing Tool Improvements (e.g. HPR, Heat Treatment Furnace, Horizontal EP)
- Two sets of carriages for cavity string
- Cavity Handling and Storage Equipment

Main Cold Mass and Cryomodule Assembly Tools

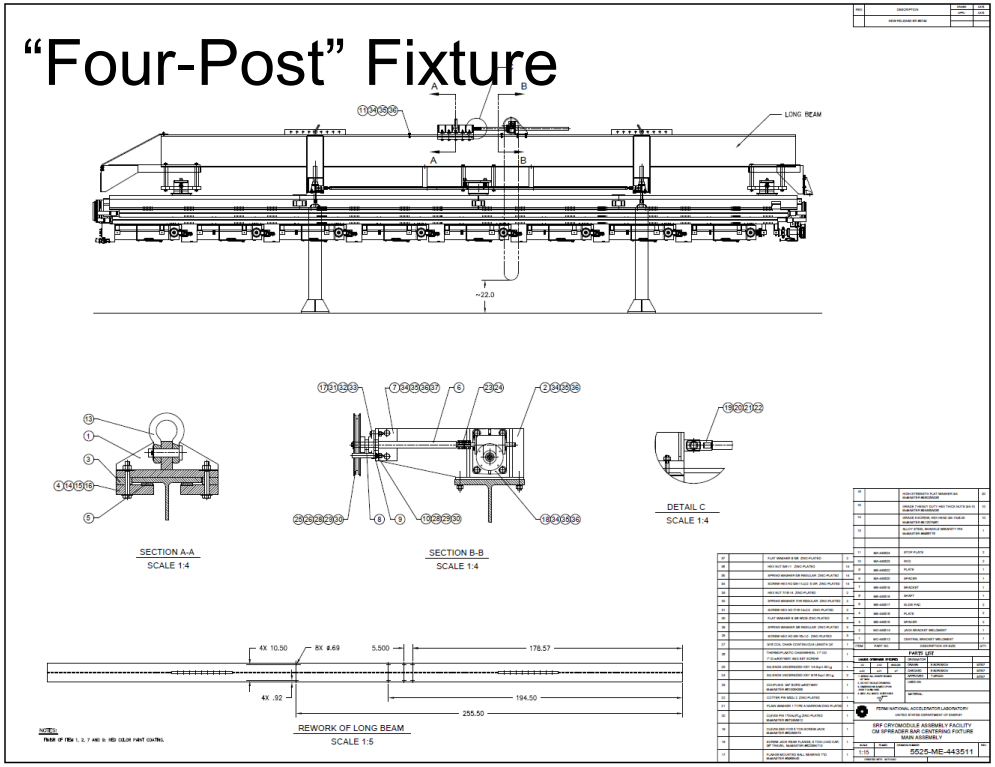
- Cold Mass Spreader Bar* - Supports / Positions Cold Mass for cavity string attachment
- Cold Mass Installation into Vacuum Tank
- Vacuum Tank Supports
- Spreader Bar* - Lifts Cryomodule
- Shipping Frame & End Caps*

*Design exists, purchase copies

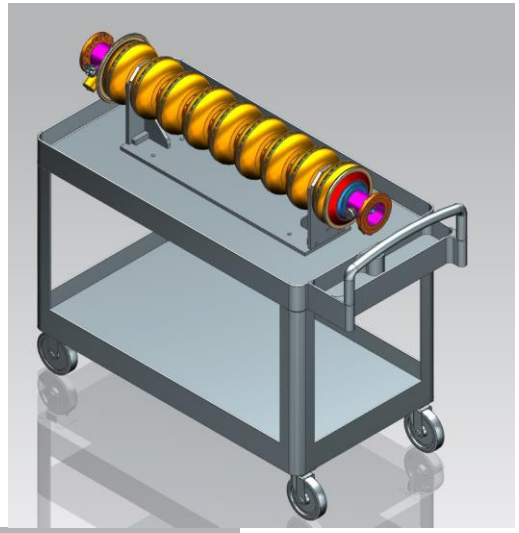
Utilizing Existing DESY/FNAL Designs As-Is

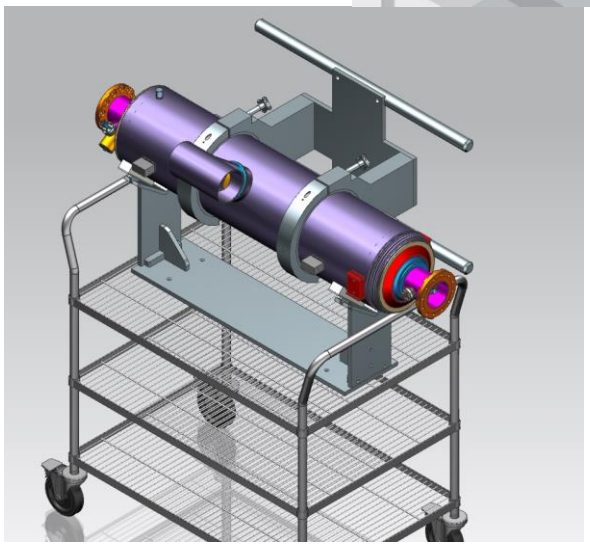


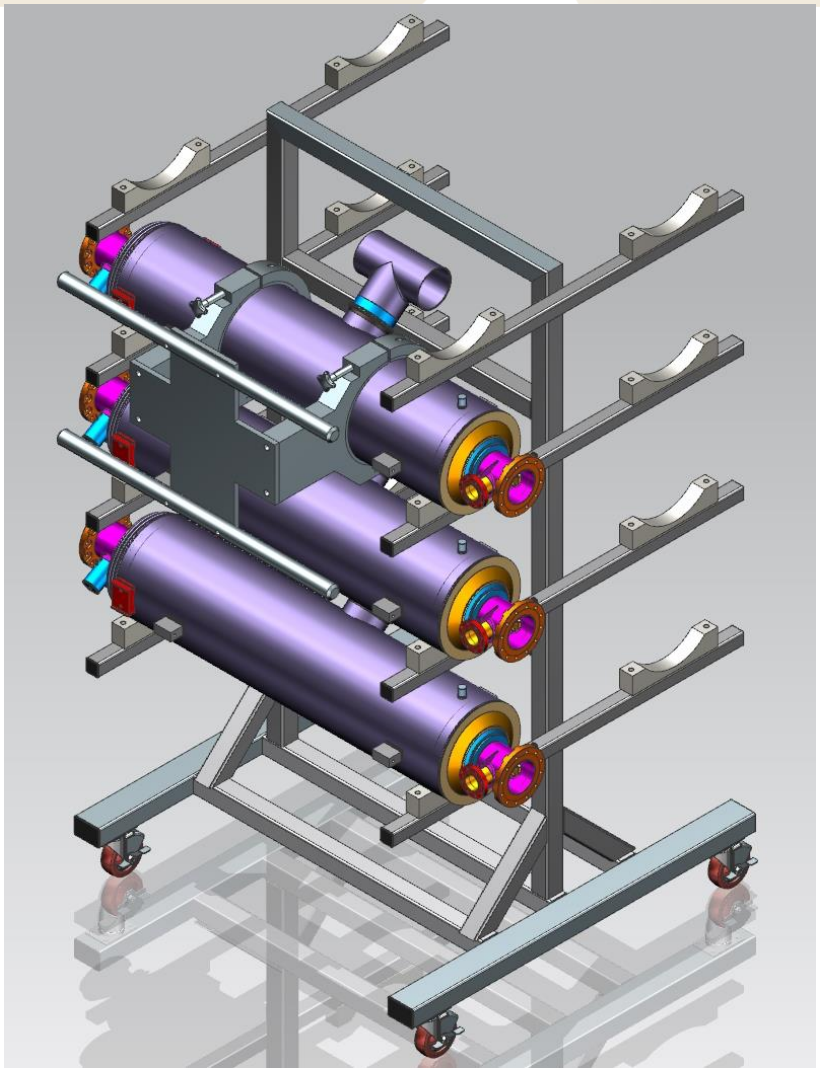
CM Spreader Bar



JLab Cavity Handling and Storage Tooling

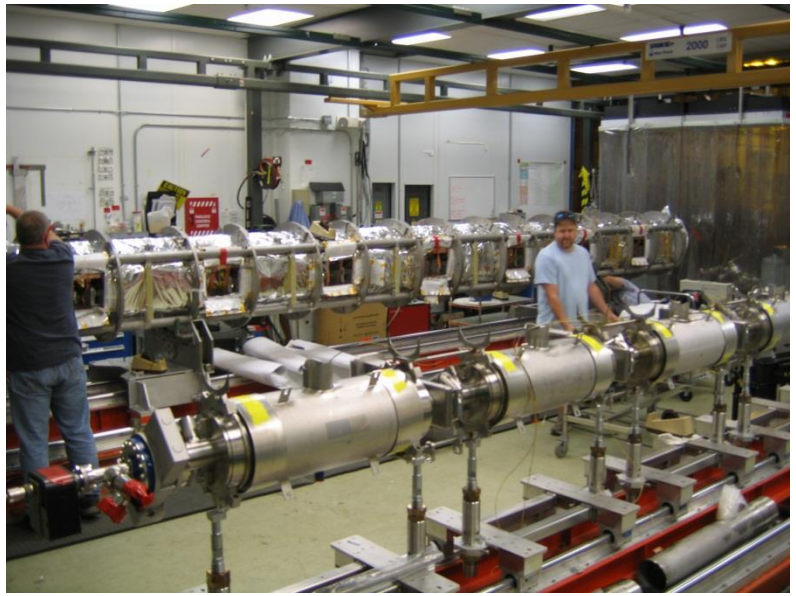




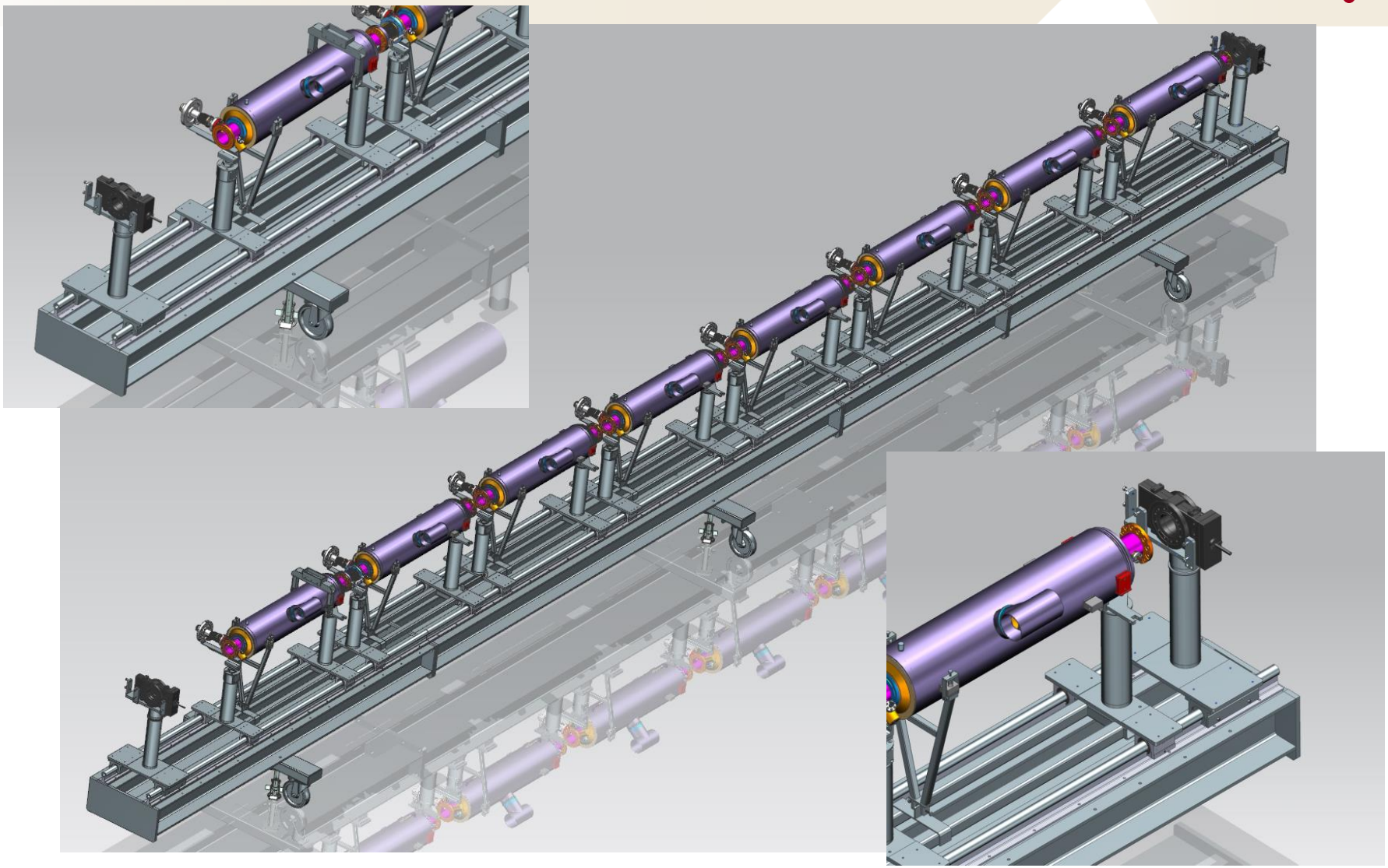


JLab Cavity String Assembly in Clean Room

- “Lollipop” supports for each cavity
- TBD for SC magnet and bpm
- Use mobile rail system rather than rail-in-floor used at DESY, CEA/Saclay and FNAL
- Transfer to CM assembly rails for cold mass assembly

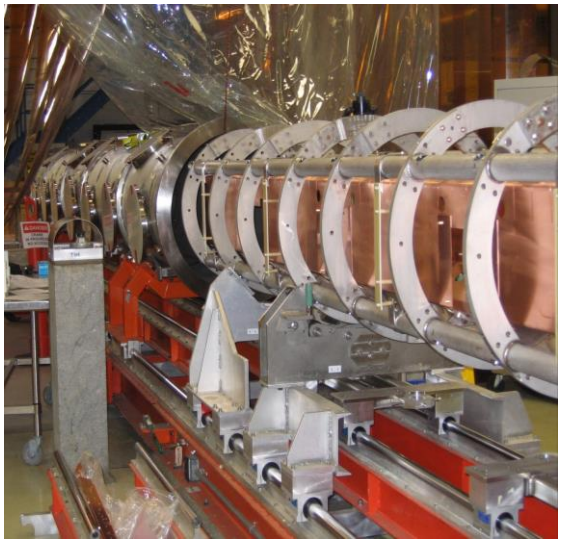


LCLS-II Cavity String on JLab-style Rails

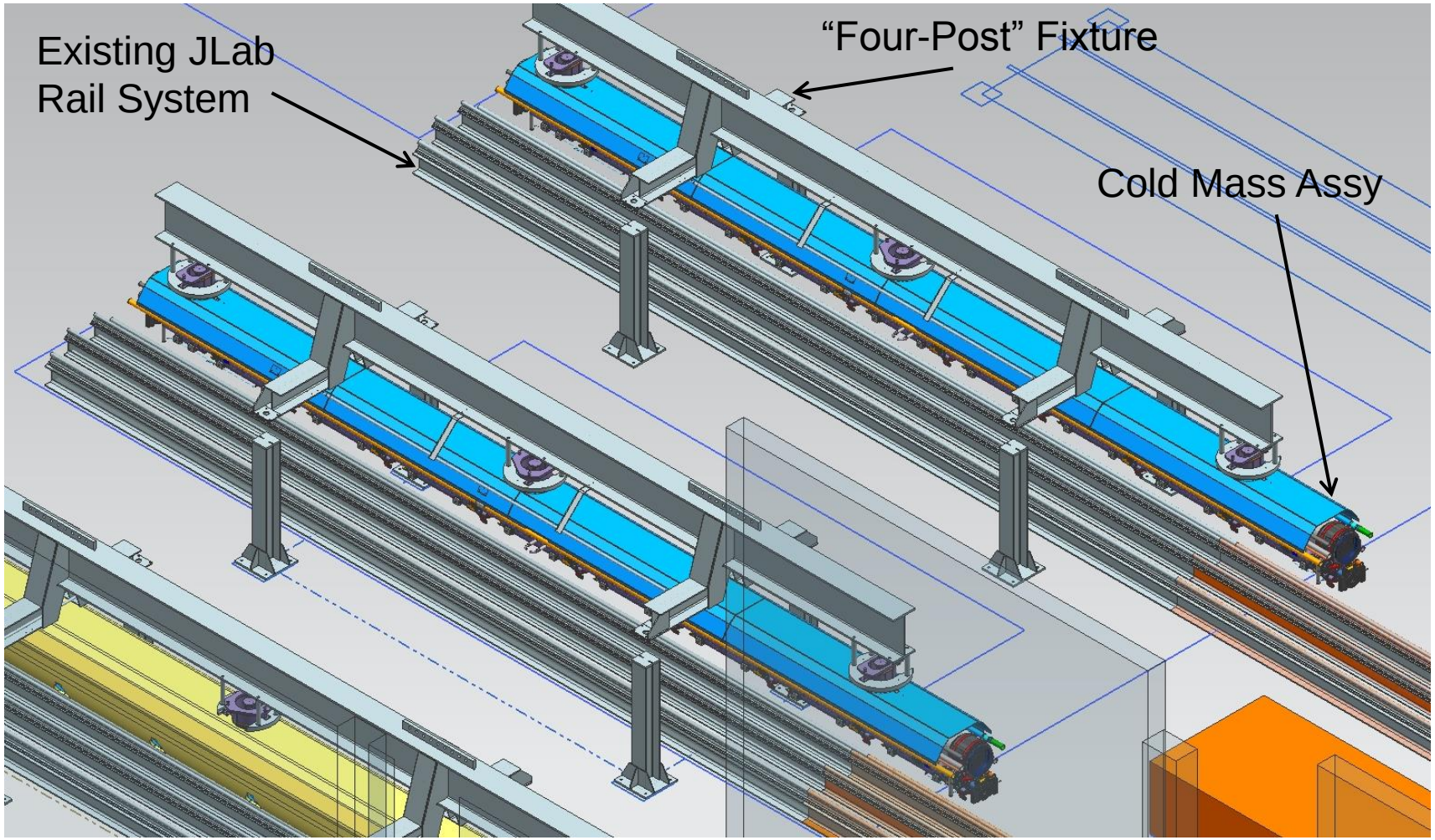


JLab Cold Mass / VV Assembly

- “Lollipop” supports for each cavity
- TBD for SC magnet and BPM
- Two-rail system to transfer cavity string onto GHRP
- Considering use of two-rail system to transfer cold mass into vacuum vessel
- Crane access in high-bay for shipping



LCLS-II Cold Mass with FNAL Tooling above JLab-style Rails (Phase II Assembly)



JLab Facilities Improvements : Testing in CMTF

Draft FRS for CMTF in Progress (LCLSII-4.6-FR-0285); Similar to FNAL CMTS1 FRS

- Ability to run 8 cavities simultaneously

End Cans (2 sets to support CM production rate)

- Engineering Specification JL0012682S in Review/Approval Process
- Connects CM to CTF valve box via u-tubes
- Interfaces for valves, LL and diodes to monitor and control helium flow/inventory
- Provides reliefs for primary circuit, shield circuit and insulating vacuum space

HPRF

- Receive 1.3 GHz 3.8 kW Solid-State Amplifiers (SSAs)
- Procure Circulators
- Modify Waveguide and Interlocks
- Run line power to SSA/Circulators
- Provide controls in CMTF Control Room

LLRF

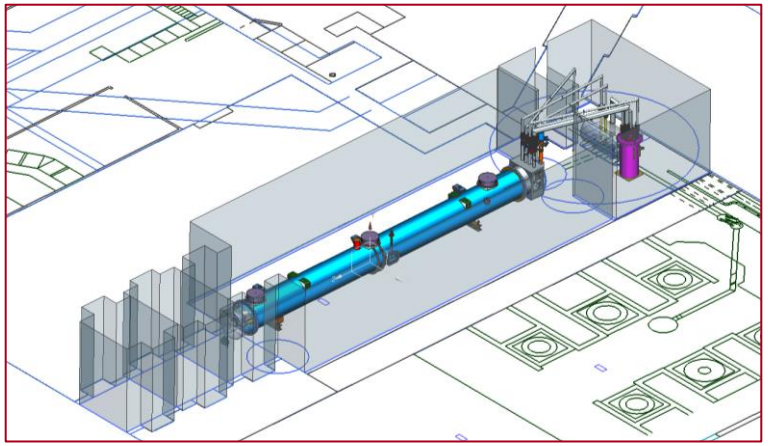
- RF Instrumentation (arc detectors, IR sensors, etc.)
- Provide digital controls in CMTF Control Room
- Software development

Cryogenic Test Facility (CTF)

- Improve return side piping to reduce overall pressure drop from CMTF
- Ensure recovery system (pumping, compression) provides base pressure of 0.031 atm (23 torr) in the CM helium bath
- Improve/replace aging instrumentation such as arc cells, flow meters and temperature sensors

JLab CMTF

- HPRF system suitable for individual cavity testing or 8 cavities in short duration steady state
- TBD system for testing SC magnet – need PS & leads info
- Magnetic shielding encloses testing volume reducing external fields to less than 50 mG
- Cryogenic capacity for testing up to 8 cavities in CW mode
- End Caps – specific for LCLS-II CM testing
  - Interface to CM piping and existing junction box using u-tubes



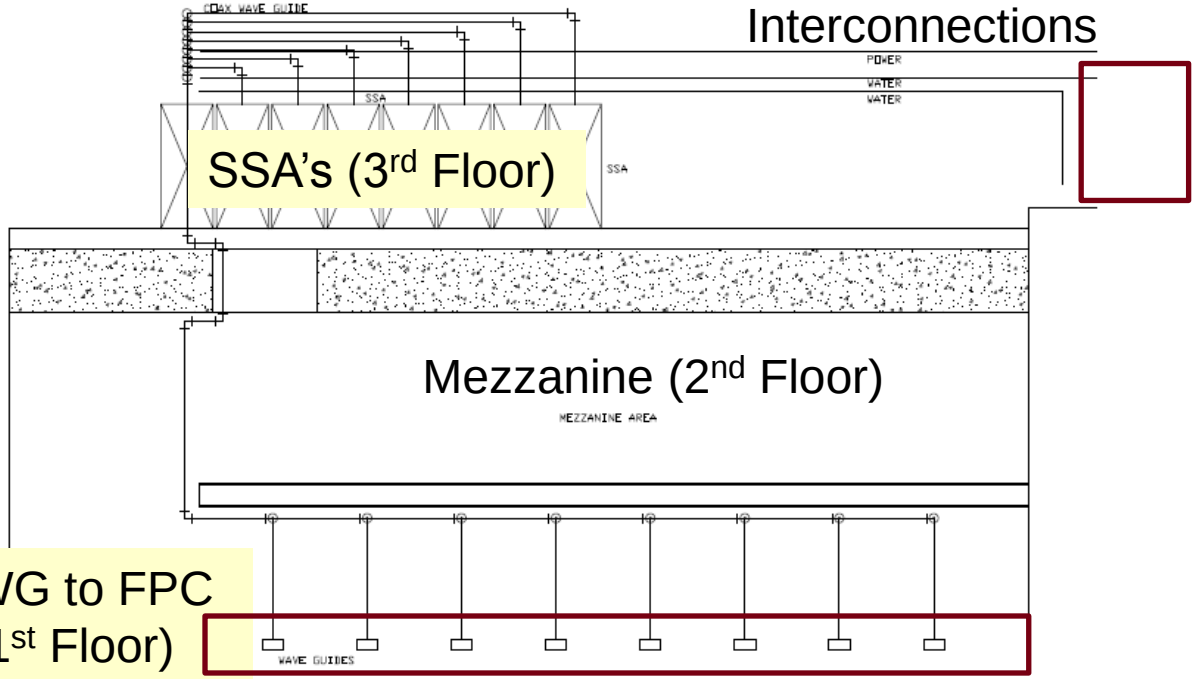
JLab CMTF - Evaluating Layout for HPRF and WG Routing

SSA Location

WG routed thru mezzanine

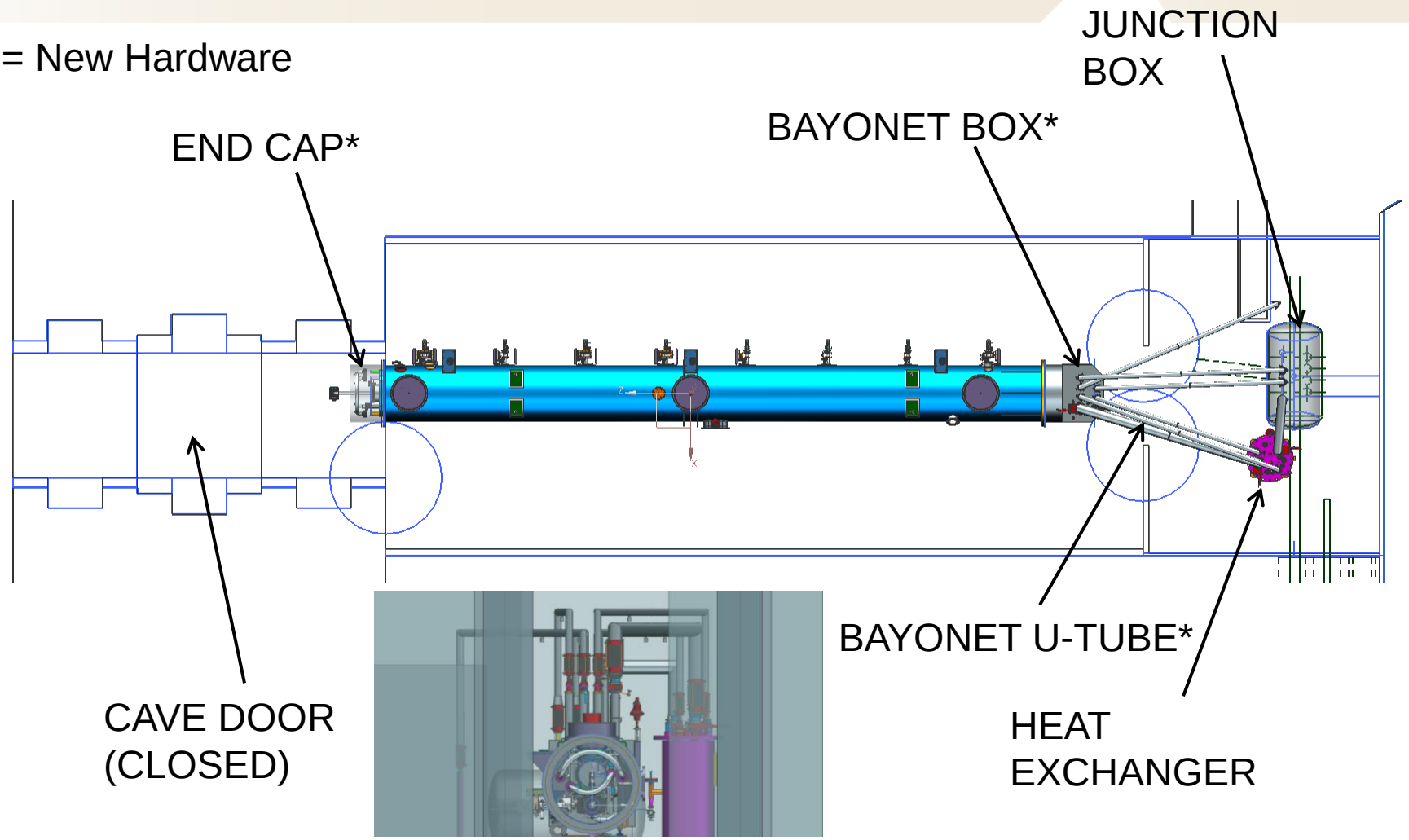
Approach is to site HPRF on third floor, route into cave through mezzanine and connect to CM on ground floor

Electrical and Water Interconnections



JLab CMTF Conceptual Layout

* = New Hardware

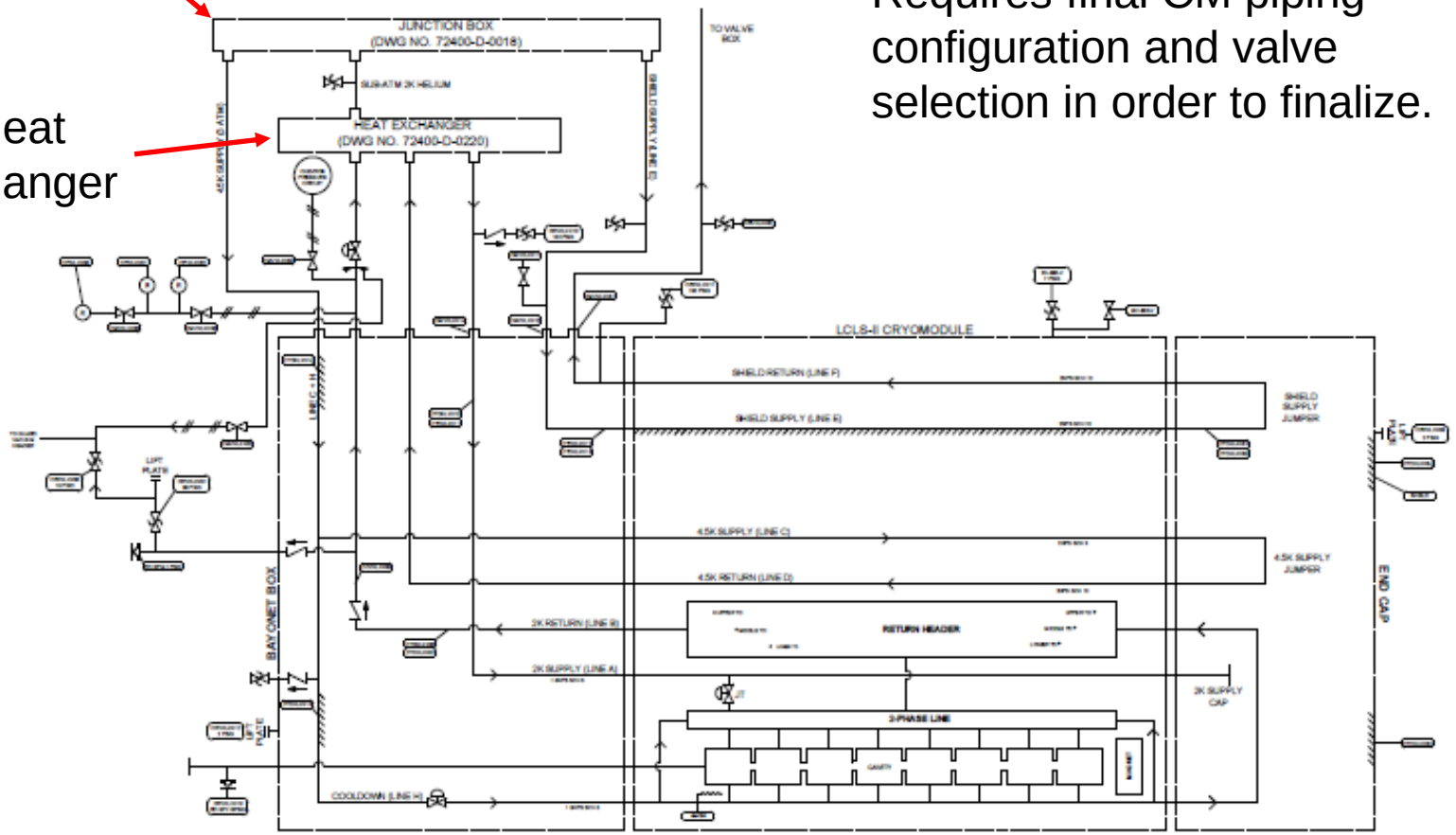


End view of CM with bayonets connecting JB, HX and BB

CMTF Process & Instrument Diagram in Progress

Junction Box

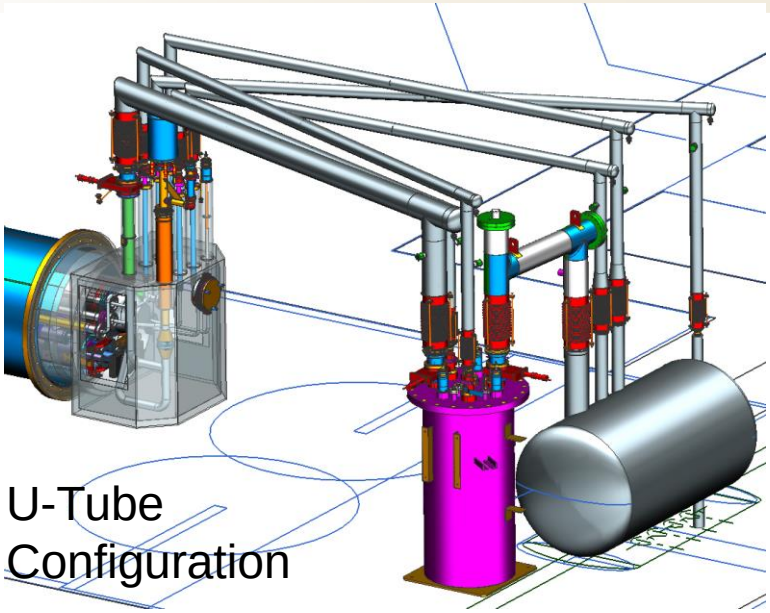
2K Heat Exchanger



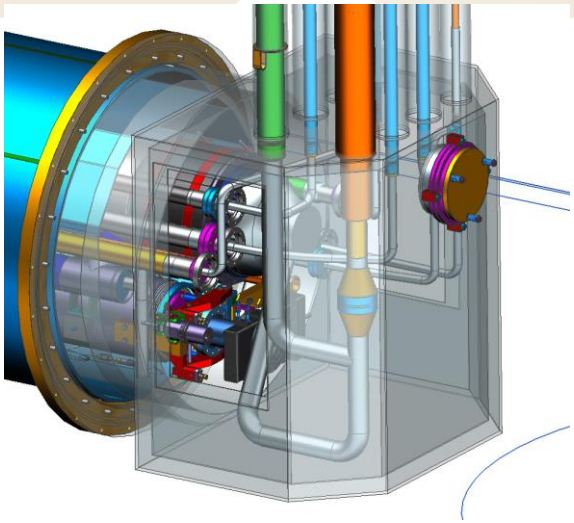
Requires final CM piping configuration and valve selection in order to finalize.

Bayonet Box LCLS-II CM End Cap

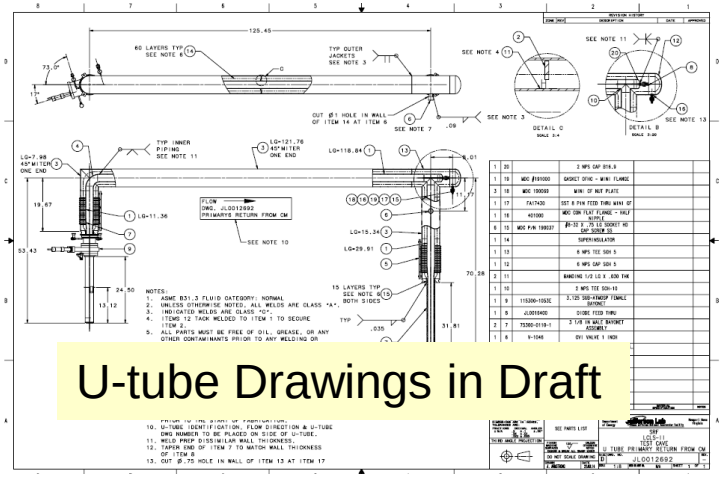
JLab CMTF End Can – Preliminary Design



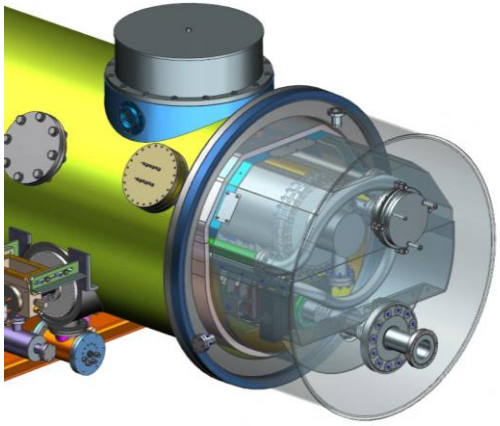
U-Tube Configuration



BAYONET BOX 3D Model



U-tube Drawings in Draft



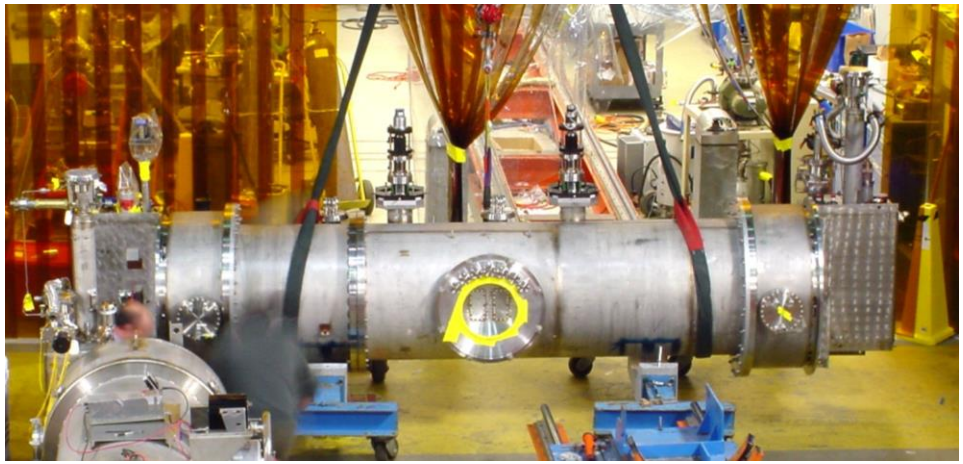
END CAP 3D Model

JLab HTB modified for LCLS-II Testing

- Horizontal testing capability for one dressed 9-cell cavity with tuner with inner magnetic shield
- RF power via coax cable or FPC
- Cryogenic supply – evaluating CEBAF and LCLS-II End Caps
- Magnetic Environment
  - Magnetically shielded test cave < 50 mG
  - Outer mag shield just inside vacuum tank

Modifications

- Tophat area to accept coax or FPC and instrumentation
- Include LL standpipe for LL control
- Design flex lines to connect internal piping to end caps



Six Month Look Ahead

- Cryomodule Design - Continue collaboration with SLAC, FNAL and XFEL colleagues on cryomodule production planning
- R&D - Support ramp-up of cavity testing for high Qo and the prototype cryomodule activities
- Infrastructure Design
  - Complete designs for JLab-specific assembly tooling and fixtures
  - Complete designs for End Cans (FNAL & JLab)
  - Complete designs for upgrading CMTF controls, instrumentation and RF hardware (FNAL & JLab)
- Procurements
  - Start procurements for cavity and cryomodule assembly tooling and fixtures (FNAL & JLab)
  - Start end can procurements (JLab)
  - Start procurement of CMTF LLRF and HPRF components (FNAL & JLab)

Summary

- Strong collaboration with XFEL on Infrastructure Development

- Goal for production of CMs at JLab/FNAL is “identical design, identical parts, equivalent processes to yield equivalent performance”
  - Infrastructure development supports this goal

- Overall Plan for Cryomodule Design & Production
  - R&D / Design Modifications Complete FY14/15
  - Infrastructure / Tooling FY14/15
  - Prototype CMs (2 units) FY15/16
  - Start of Production 1.3 GHz CMs (33 units) FY16
    - Rates of 1 CM per 6 – 8 weeks in current plans
  - Start of Installation at SLAC FY17