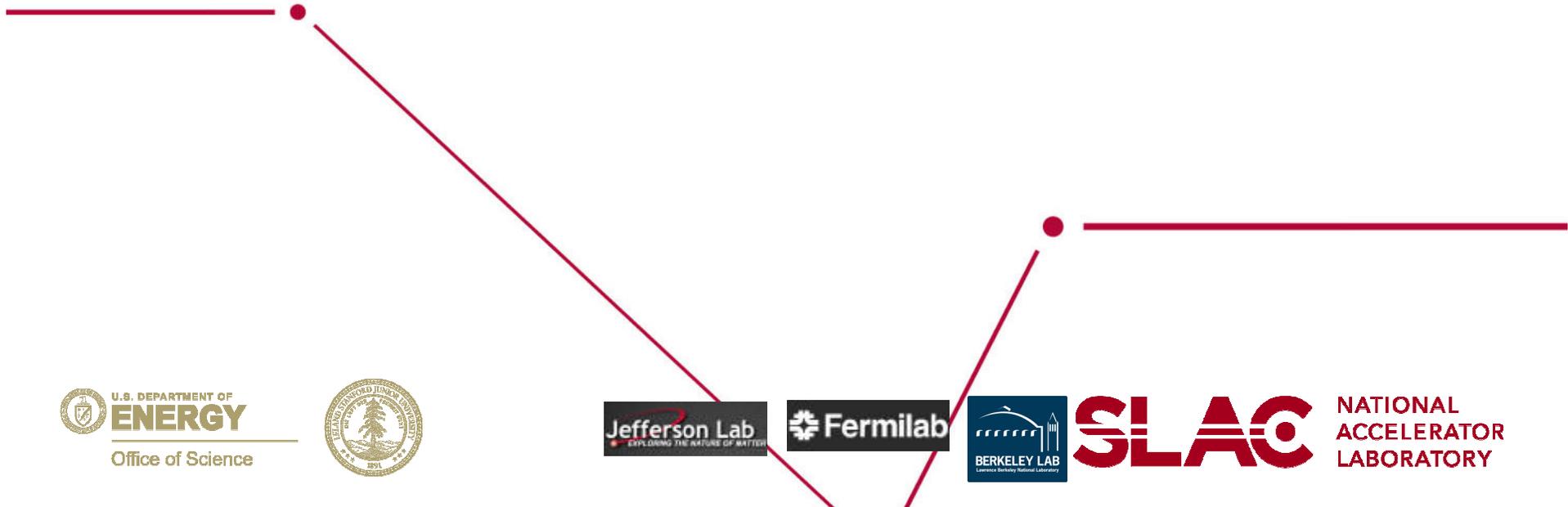


Cryomodule –FNAL

WBS 1.04.05

Camille M. Ginsburg (FNAL)

Deputy STL – Cryomodules / Cryomodule CAM



Outline: FNAL Cryomodule 1.04.05



- LCLS-II cryomodule overview
- FNAL cryomodule work scope
- Cryomodule integration
- Cryomodule schedule



Overview: Cryomodule plan

- Use existing designs to the extent possible to optimize cost and schedule: XFEL/FLASH/TESLA/ILC
 - FNAL has been working with these designs for ~20 years in TTF and ILC context
- FNAL responsible for the CM design
 - In collaboration with JLab&SLAC
- Procurement/fabrication/assembly/test shared FNAL & JLab
 - Provide equivalent products to SLAC
- Cooperation and assistance from DESY/XFEL and CEA Saclay extremely beneficial

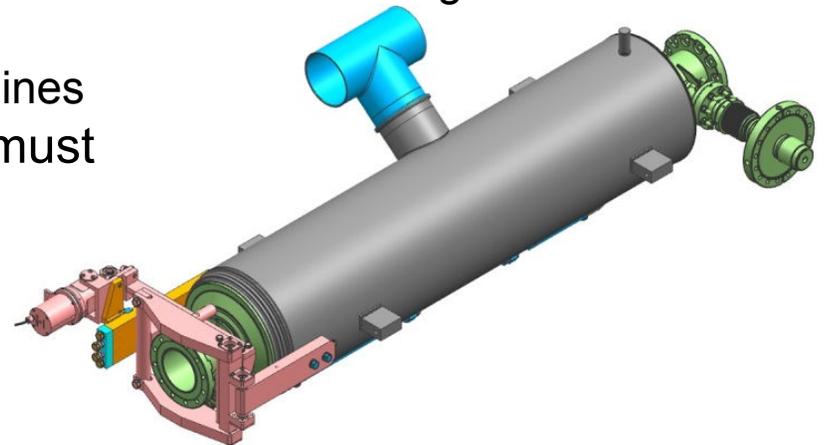
Overview: Cryomodule production model



- 1.3 GHz cryomodules (35)
 - Produce two streams of identical 1.3 GHz production CM at FNAL&JLab
 - Tightly coordinated activity among partner labs
 - Common procedures, common test performance database, common travelers, etc. (within infrastructure limits)
 - Split procurements between the two labs
 - Assemble two prototypes in advance of 33 production cryomodules
 - Prototype designs optimized to use existing components to confirm as many design concepts as possible, on a rapid schedule
 - Design, engineering development, R&D, core staff training, and infrastructure updates are completed with the prototypes
 - Design verification studies of components and concepts performed in a single-cavity cryostat / other dedicated facility as possible
 - Test cryomodules prior to delivery to SLAC, including prototypes
- 3.9 GHz cryomodules (2)
 - Designed, produced and tested at FNAL, following 1.3 GHz for efficiency
- All cavities and cryomodules go in the linac
 - 1st two 1.3 GHz cryomodules (prototypes) work to specification
 - No spare cavities or CM's in baseline; procurement options for one additional CM

Overview: Prototype 1.3 GHz cryomodules

- Purpose of prototypes
 - Test out the design modifications as soon as possible
 - Prove out the JLab infrastructure modifications
 - Develop procedures and travelers, train staff, etc.
- Build two prototype cryomodules, one each at FNAL and JLab
 - Use 16 existing FNAL ILC 9-cell short-short cavities (beam tube lengths)
 - Adapt XFEL-style end-lever tuner to short-shorts, and to permit access through ports
 - Design new helium vessel to accommodate end-lever tuner and larger heat load
 - Titanium to SS transition on chimney and fill lines
- Prototype CM's will go in the beamline and must perform to specification
- Difference of prototype wrt production CM
 - Short-short vs. long-short cavities
 - FNAL-ILC cavities processed at FNAL/JLab/Cornell and dressed at FNAL vs. dressed cavities processed and ready for VT in industry



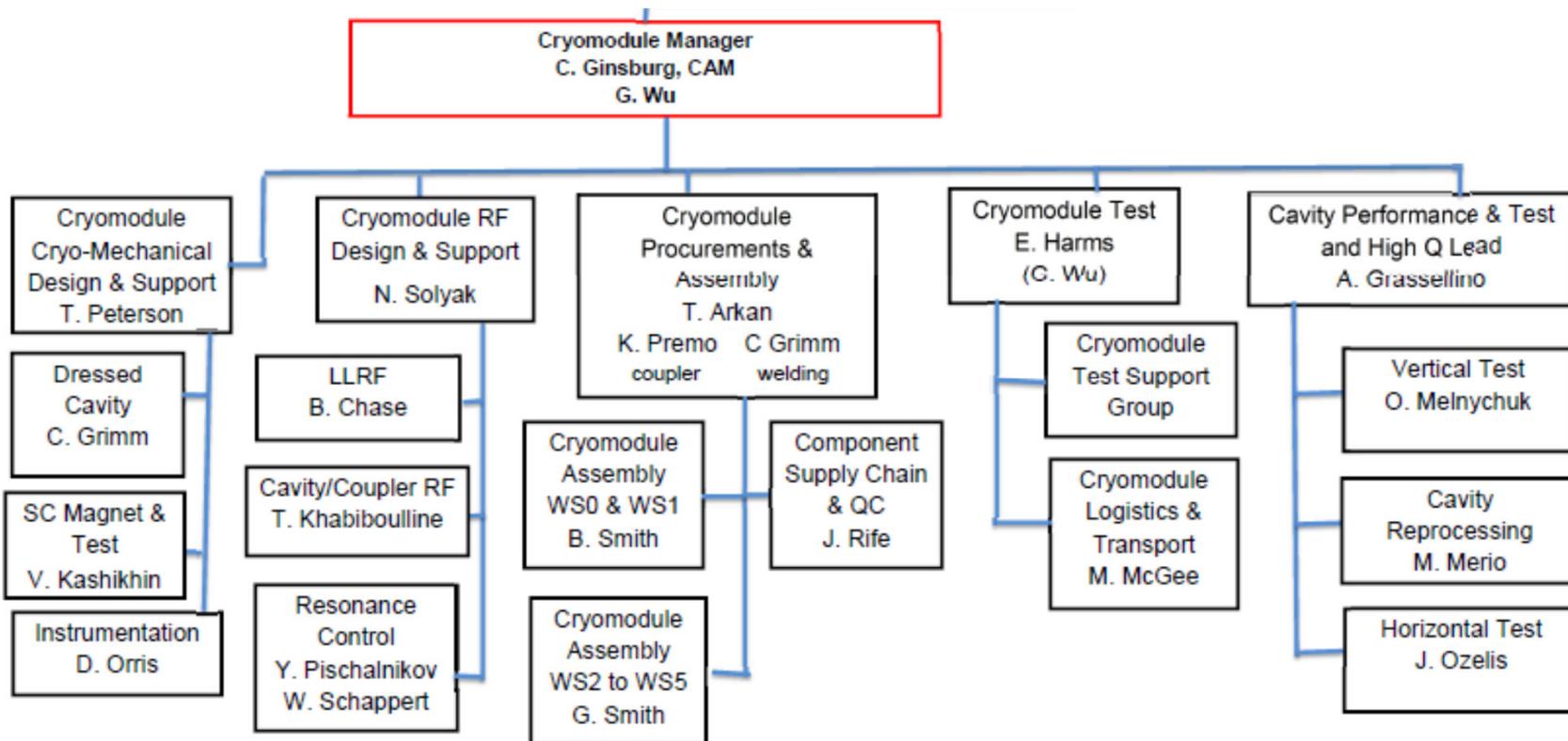


Scope: WBS 1.04.05 contains 11 control accounts

- **PL Management & Integration (1.04.05.01)**
- **Engineering & Design (1.04.05.05)**
- **Prototype Cryomodule (1.04.05.06)**
- **1.3 GHz Cryomodule Procurements (1.04.05.07)**
- **1.3 GHz Cryomodule Cavity Prep/Test (1.04.05.08)**
- **1.3 GHz Cryomodule Cavity String Assembly (1.04.05.09)**
- **1.3 GHz Cryomodule Assembly (1.04.05.10)**
- **1.3 GHz Cryomodule Test (1.04.05.11)**
- **3.9 GHz Cryomodule Procurement and Fabrication (1.04.05.12)**
- **Infrastructure (1.04.05.15)**
- **Installation Support & Shipping (1.04.05.20)**

Scope: Partner Lab Management & Integration

- Oversight and integration of all WBS 1.04.05 related activities
- Overall CM support in areas incl. ES&H, QA/QC, supporting engineering
- CM related travel M&S (including vendor visits)



Scope: Engineering & Design CM & compo design

1.3 GHz final

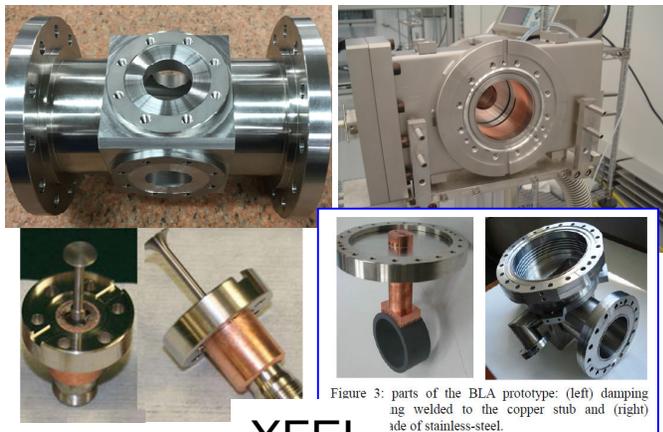
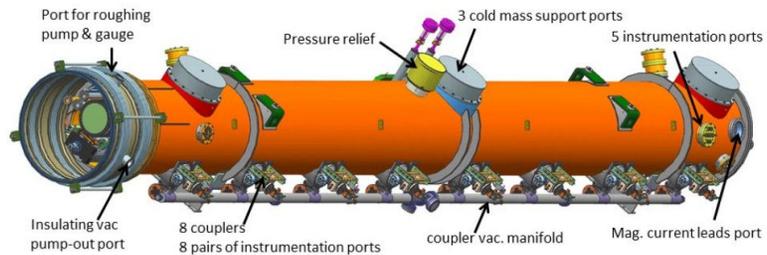
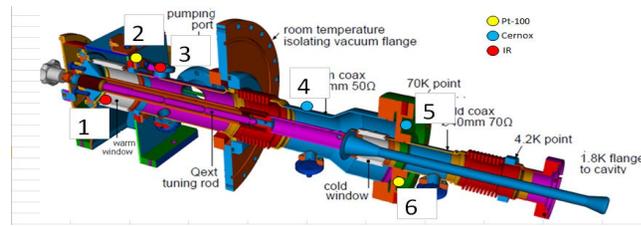
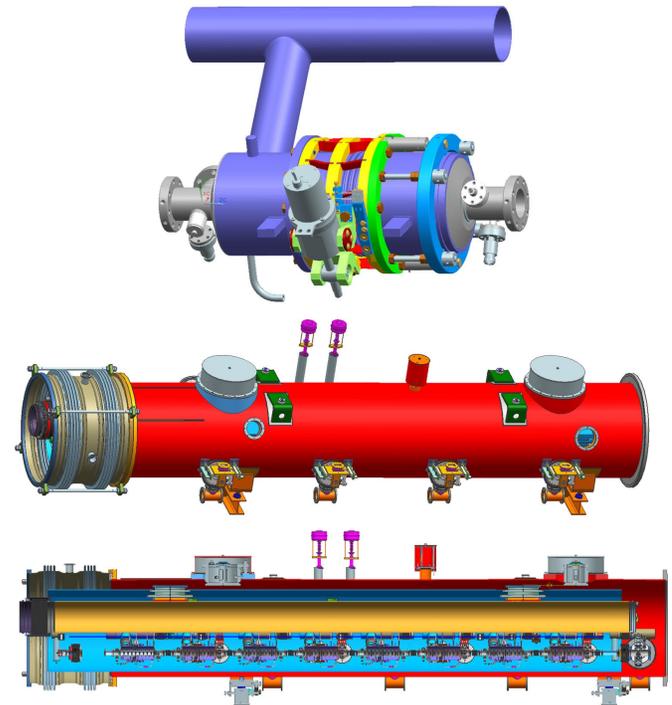


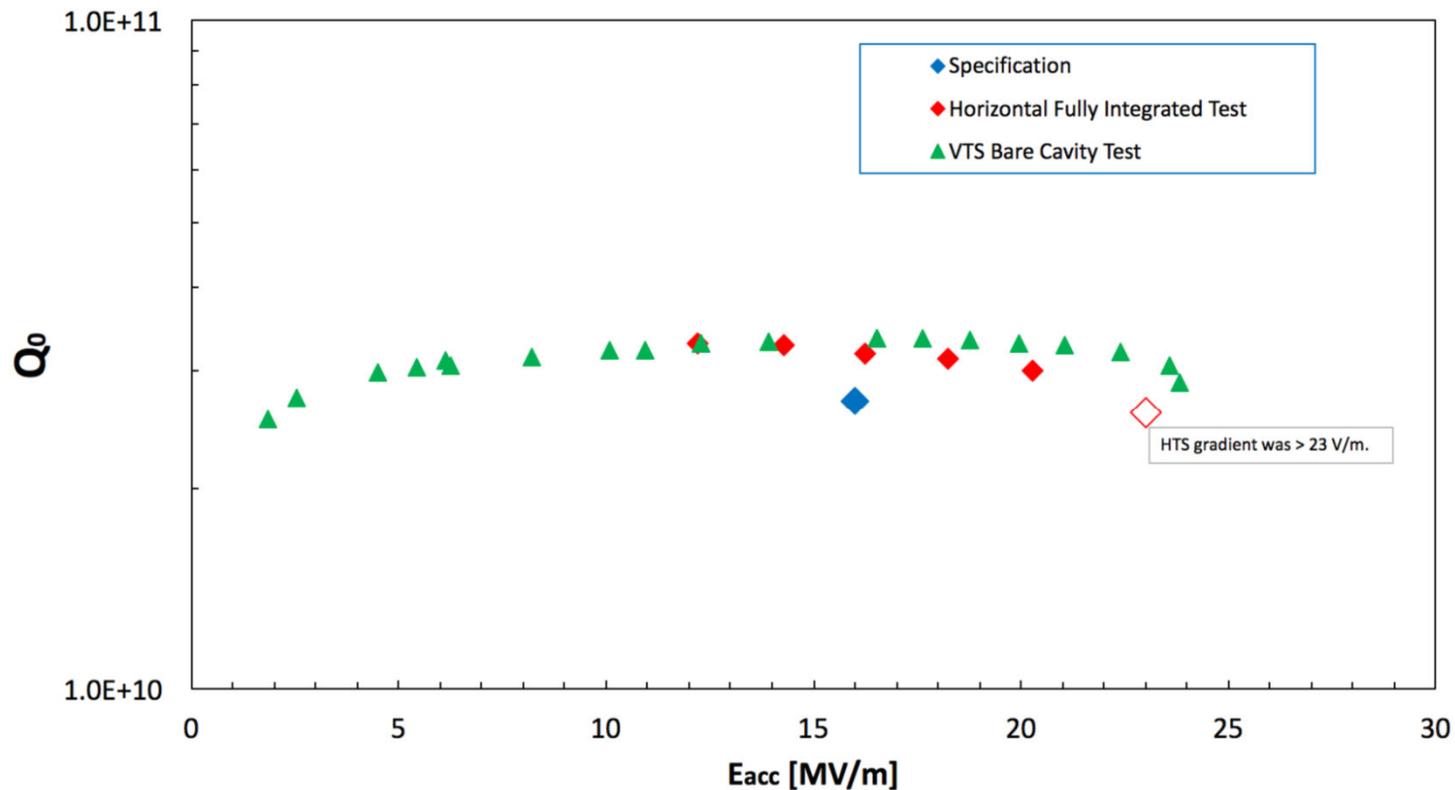
Figure 3: parts of the BLA prototype: (left) damping ring welded to the copper stub and (right) side of stainless-steel.

3.9 GHz preliminary



Scope: Engineering & Design: CM design verification

Perform design verification tests of cryomodule subcomponents: HOM's, coupler, magnetic shielding, tuner

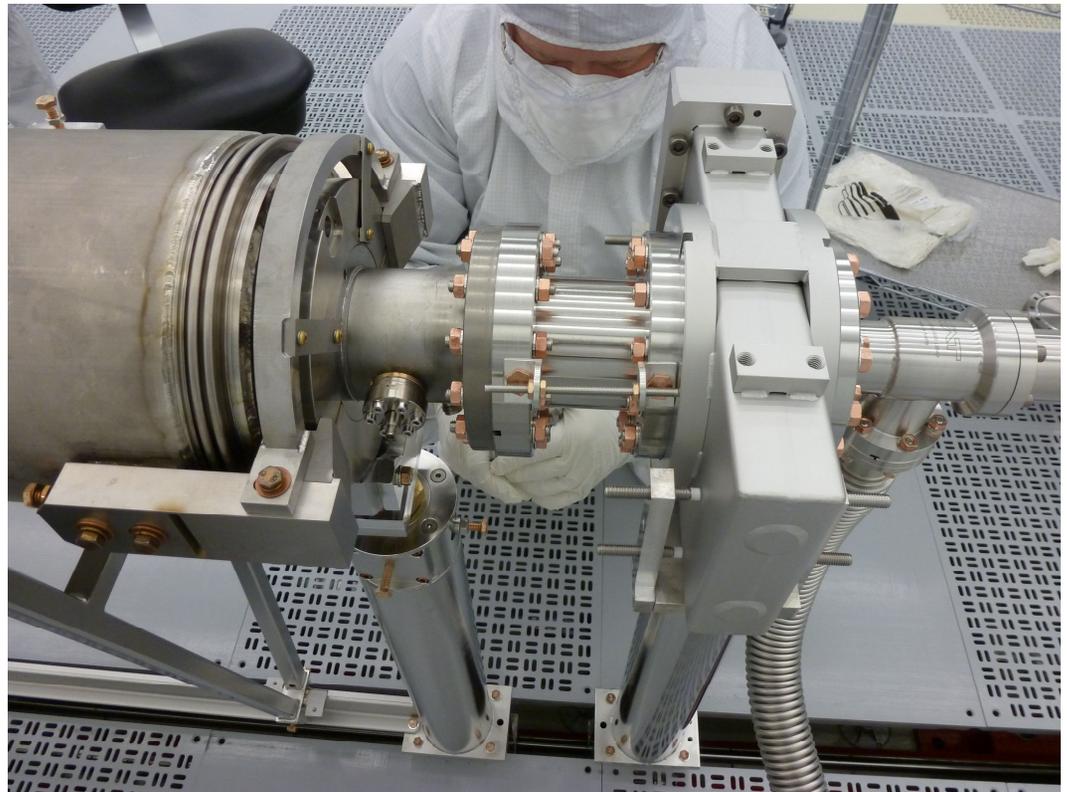


Fully integrated test of TB9AES021:

No degradation from bare to horizontal dressed test with right cooldown procedure, HOMs and high power coupler thermal strapping, and magnetic shielding

Scope: Prototype Cryomodule

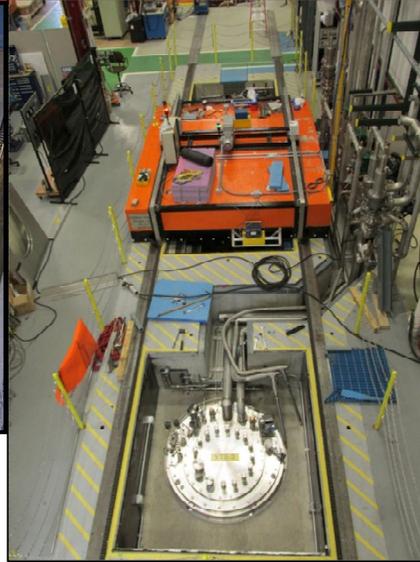
- ✓ Procure materials for prototype CM
- ✓ Surface process and test bare cavities, dress cavities
- ✓ Vertical tests
- CM assembly – in progress
- CM test



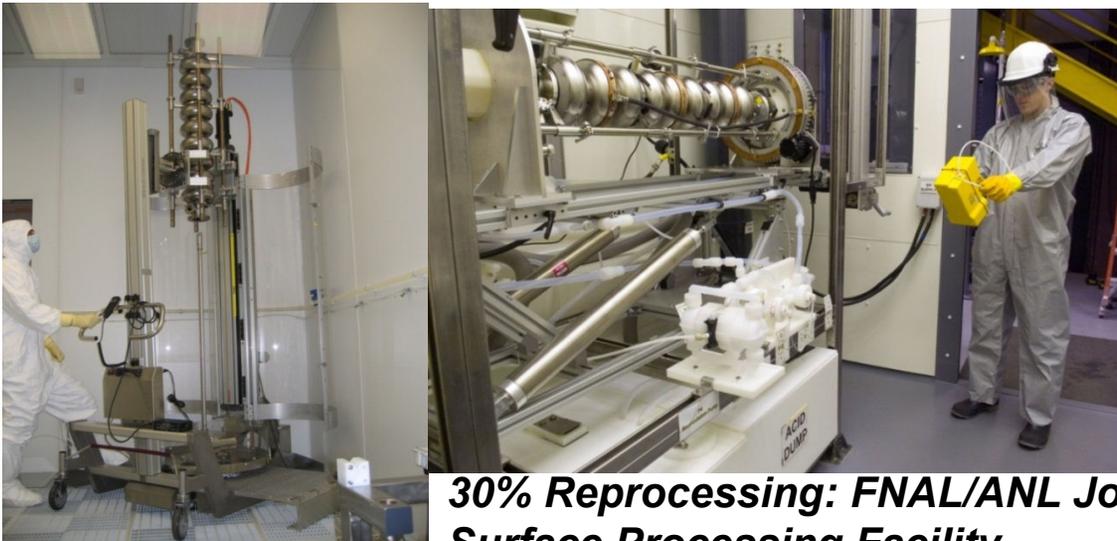
Scope: Cavity Preparation and Test (XFEL model)



**100% cavity qualification:
Vertical Test Stands**



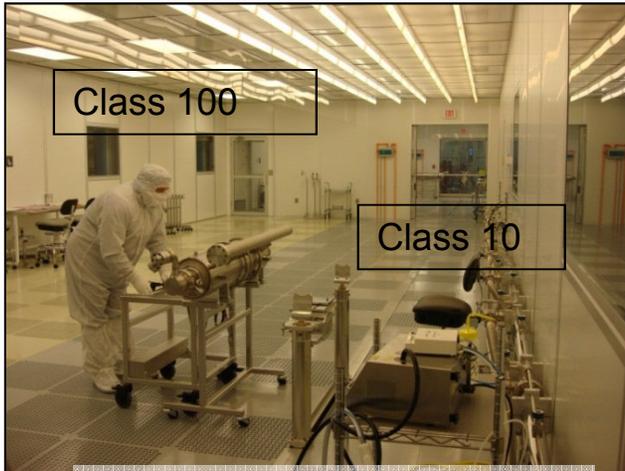
**1/16: Horizontal
(Dressed) Cavity
Test Stand 1**



**30% Reprocessing: FNAL/ANL Joint
Surface Processing Facility**

NRI visit 16.Nov.2015

Scope: CM string and cold mass assembly



**Cavity String Assembly
Clean Room**



Cavity String Assembly



Cold Mass Assembly



Cryomodule Transport
NRI visit 16.Nov.2015

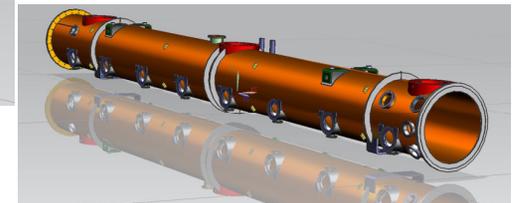
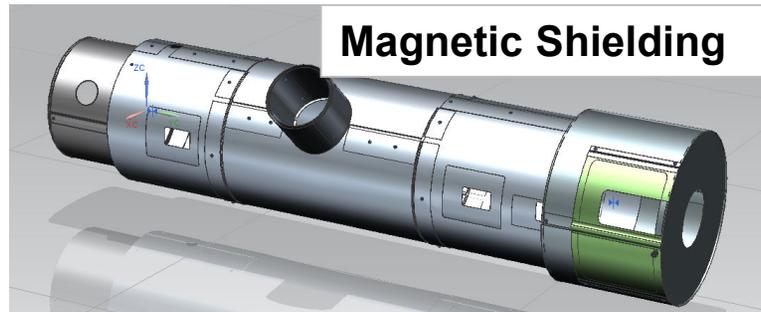
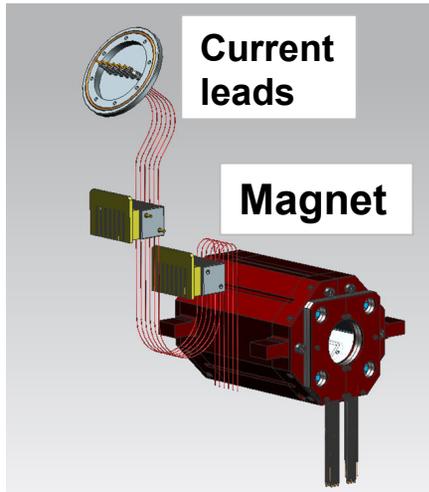


Final Assembly



Final Assembly

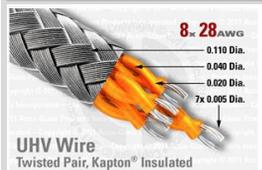
Scope: 1.3 GHz Procurements



1.3 GHz Vacuum Vessels



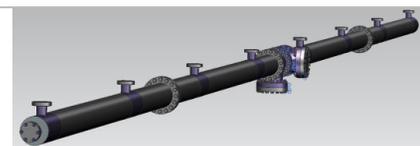
Instrumentation (examples)



Beamline Interconnect Parts



GHRP Sub-Assemblies



1.3 GHz Coupler Pump Lines

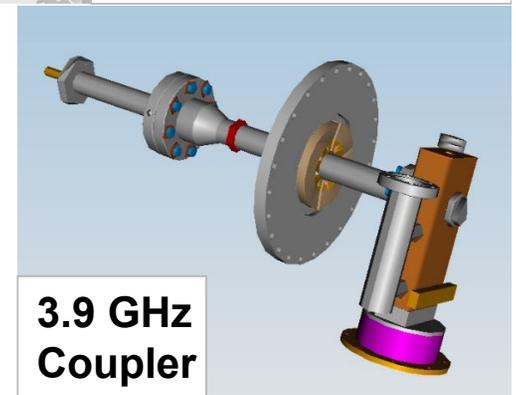
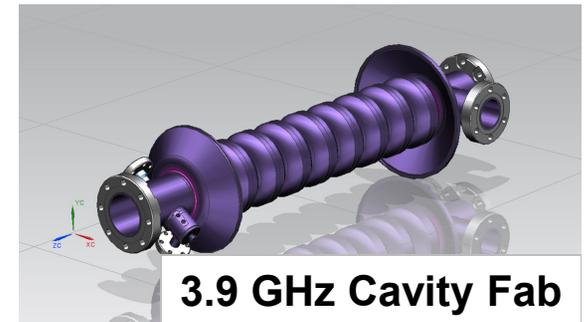
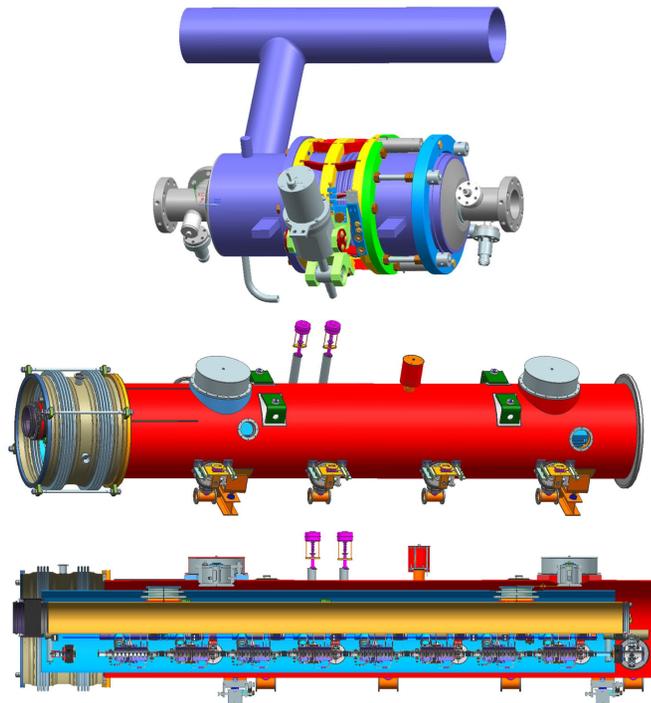


Cavity String Hardware



Scope: 3.9 GHz Cryomodule

- Procurements
- Surface processing
- Cavity qualification test
- CM assembly
- CM test





Scope: CM test

- *Prototype 1.3 GHz CM test will be rigorous: a complete checkout*
 - Performance limitations of individual cavities & complete module
 - Duration 4 months
 - Prototype cryomodule will have more diagnostic instrumentation
- New test stand CMTS1
 - Commissioning will be necessary, to be completed in advance as much as possible
- *Production 1.3 GHz – will begin rigorous and assess as program proceeds*
 - Time constraint: Available test period start-to-finish 6 weeks
 - Nominally 3-week test period
- Critical that CM test program is equivalent JLab<->FNAL
- Both 3.9 GHz cryomodules will be tested, after 1.3 GHz
- Workshop with int'l participation Oct.29-30 to advance test plans

Scope: CM infrastructure

- Design, procure, install, and commission additional infrastructure required to produce and test the 1.3 GHz and 3.9 GHz cryomodules at rates consistent with the project schedule
 - Includes infrastructure for VTS, HTS, Assembly and CMTS1
- CMTS1 is the largest part
 - Infrastructure design developed from other Fermilab SRF Test facilities, e.g., FAST
 - CMTS1 installation is progressing well; all major components are in-house, except SSA's
 - Planned completion of CMTS1 infrastructure is late 2015
 - Commissioning of all subsystems to be completed before receipt of pCM (early 2016)



Cave exterior April 2015

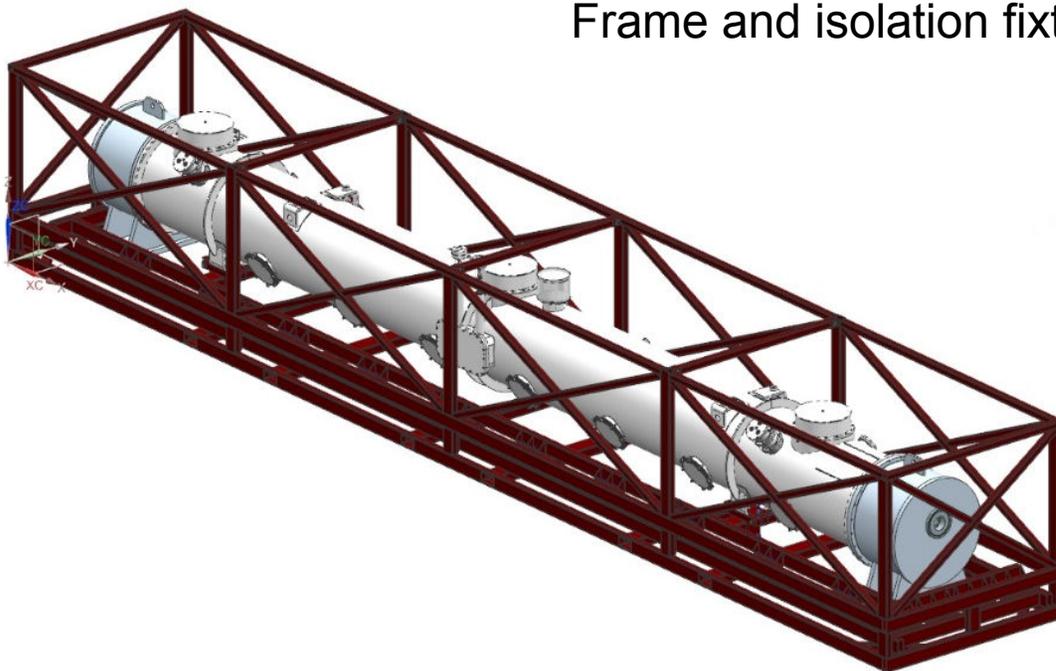


Cave Interior Oct 2015

NRI visit 16.Nov.2015

Scope: Installation support & shipping

- Ship all CM's from FNAL to SLAC including all fixtures and transport costs plus FNAL installation support



Frame and isolation fixture



Integration: LCLS-II 1.3 GHz CM procurement model

- Procurements distributed JLab/FNAL
- Deliveries split between JLab/FNAL
- Documented
LCLSII-4.1-PM-229
- Using JLab SOTR framework
One assigned at each lab
Direct communication

Components	Primary Responsibility		
	FNAL	JLAB	SLAC
Niobium (Prototype) - existing cavities	NA		
Niobium (Production)	X		
Cavities (Prototype) - existing cavities	NA		
Helium Vessels (Prototype)	X		
Cavities w/Helium Vessels Ready for VTS (Production)		X	
Cavity Feedthroughs		X	
Cavity Flanges & Associated Hardware/Seals (VTS and HTS compatible)		X	
Fundamental Power Coupler (FPC)			X
Cavity String Interconnecting Bellows		X	
Cavity String Assembly Hardware and Seals	X		
SC Magnet Assembly	X		
Beam Position Monitor (BPM)	X		
Gate Valves		X	
Beamline Vacuum Monitoring Manifold & Gauge	X		
Two-phase Pipe Bellows	X		
Tuner System tuner, actuator, piezos (Prototype)	X		
Tuner System tuner, actuator, piezos (Production)		X	
Magnetic Shielding	X		
GRHP Sub-assembly	X		
Vacuum Vessel	X		
Coupler Pumping Lines and Pumps (ion+TSP) + vacuum gauges	X		
Instrumentation	X		
Liquid Level Probes and JT Valve	X		
Beamline Interconnect Parts including Aluminum Heat Shields	X		
HOM Absorber		X	
Shipping Frames and End Caps + Shock Log Devices		X	



Integration: LCLS-II CM project integration w/ partners

- Regular teleconferences
 - JLab & SLAC personnel work closely with FNAL for design, procurement, fabrication and test of the 1.3 GHz cryomodules
- Documentation
 - Physics Requirements Documents
 - Functional Requirements Specification
 - Engineering Specification Documents
 - Interface Controls Documents
- Reviews
 - All include safety in the charge
- Safety and quality assurance are incorporated into all procurements and assembly travelers



Integration: QA/QC Summary

- Quality systems are in place at both Labs, and have proven effective in numerous past projects
- SLAC-specific requirements have been incorporated
- Completed QA Cross-Walk exercises in Nov/Dec 2014
 - M. Skonicki (SLAC LCLS-II QA/QC lead) studied processes at both labs to ensure QA/QC systems consistent with and adequate for LCLS-II
- On-going regular QA discussions between JLab and FNAL on project QA.
- Both Labs are using electronic travelers, and will be collecting a common set of parameters
- Designs are controlled through Teamcenter
 - Both SLAC and JLab have access
- Our quality systems are in use now for the prototype cryomodule work

Integration: Parts Procurement, QC, Storage & Inventory Management



- Both labs responsible for incoming QC of split-delivery components, independent of who ordered the component
- Critical dimension checks for parts and sub-assemblies (100%)
- Fundamental power couplers: QC performed at vendor site; receive ready for assembly
- Vacuum vessels (carbon steel) will be demagnetized before use (100%)
- All vacuum parts will be 100% leak checked
- Stainless steel parts and hardware will be checked for remanent magnetization (100%) and demagnetized as needed.
- Hardware with gauge thread etc. mechanical QC (% sampling)
- Responsible SOTR signs off incoming parts or produces NCR
- Accepted parts go to storage, using inventory management tools
- Relevant parts go to the production floor after cleaning/sorting as kits.

Integration: 1.3 GHz Cryomodule External Physical Interfaces (LCLSII-4.5-IC-0372)



- Module support and alignment
- Module interconnections (HGRP, beamline, cryogenic piping, thermal shields, vacuum vessels)
- Coupler and waveguide supports
- Instrumentation connectors
- Pressure relief, tuner access, cryogenic valve ports, lifting features
- Vacuum systems and their requirements (beamline, insulating vacuum, warm coupler)
- Pre-shipment and post-shipment vacuum requirements
- Differences between prototype and production modules
- Document is signed off and released (June 2015)

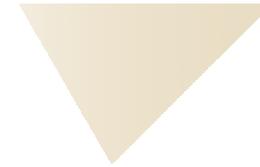
Integration: CM Interconnect/Installation Responsibilities



- JLab and FNAL are jointly responsible for procurement of the interconnect parts
- The interconnect kit comprised of these parts is delivered to SLAC
- JLab and FNAL will provide relevant procedures from their laboratories, and advise on related SLAC procedures
- SLAC is responsible for installation in the LCLS-II tunnel
 - DESY/XFEL providing installation guidance
 - JLab and FNAL also provide installation guidance

Cryo Systems to Accelerator Systems ICD LCLSII-2.5-IC-0056

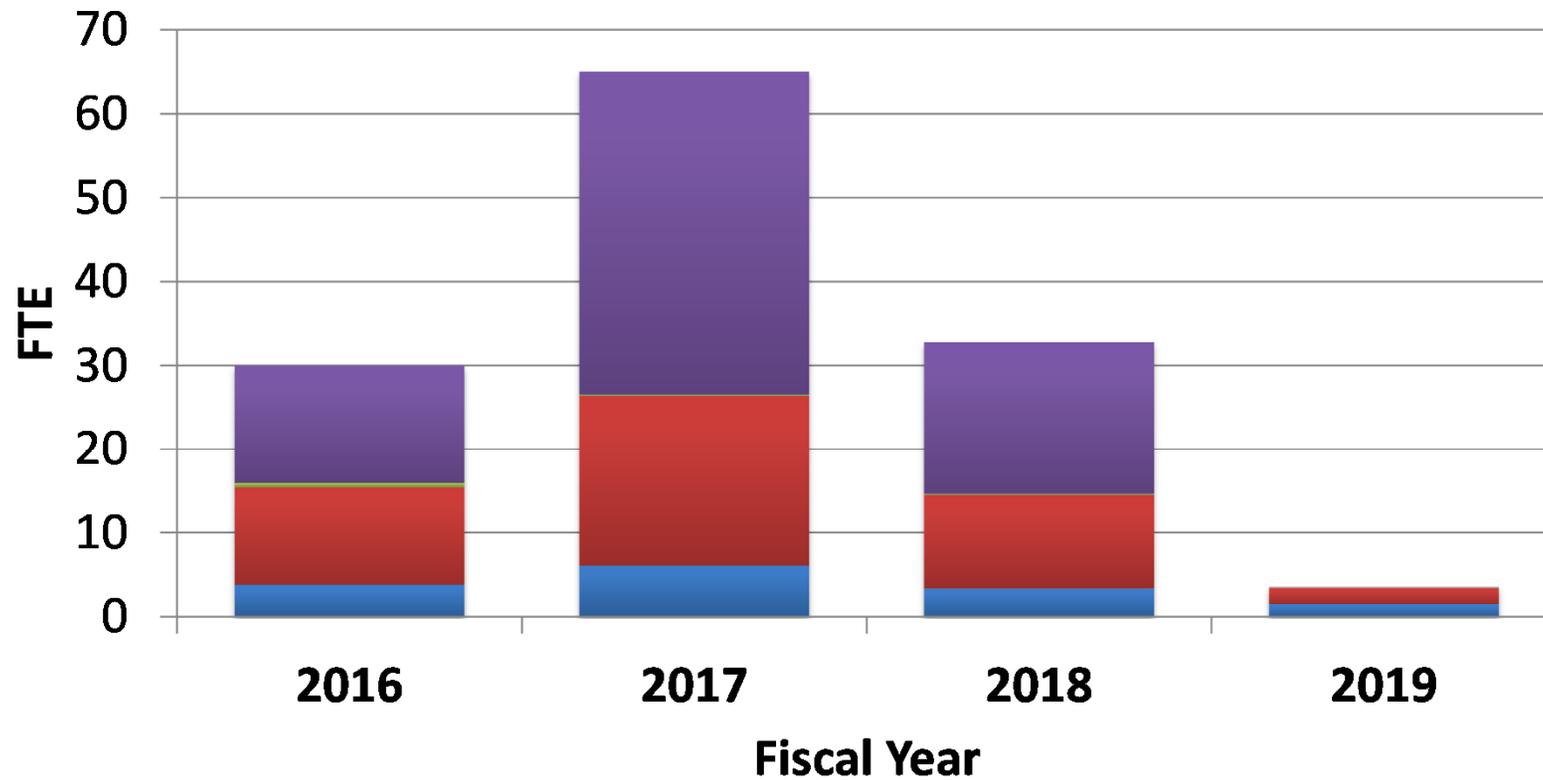
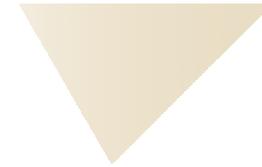
Summary Schedule



1.04 Cryogenics System

Fiscal Year	2013				2014				2015				2016				2017				2018				2019				2020			
Quarter	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4
Cryomodules - FNAL	FNAL - Engineering & Design																															
					FNAL - Prototype 1.3 GHz Cryomodule																											
					Niobium Procurement																											
					FNAL - 1.3 GHz Cryomodule Production Procurement																											
									FNAL - 1.3 GHz Cryomodule Assembly & Test																							
													FNAL - 1.3 GHz Cryomodule Shipping																			
																FNAL - 3.9 GHz Cryomodules																

FNAL Cryomodule 1.04.05 Resource Usage By Fiscal Year



■ 1. Management ■ 2. Engineers ■ 3. Designers ■ 4. Technicians

44 FTE Average Past 2 Months (Aug & Sep 2015)

Conclusions: FNAL Cryomodule 1.04.05



- 1.3 GHz cryomodule
 - Design and design verification are ~complete
 - Most reviews complete
 - Assembly plans mature, prototype CM assembly is ongoing
 - Procurements started
- 3.9 GHz cryomodule
 - Design started
 - Reviews start in November
- Clear interfaces
 - Procurements, including QA/QC
 - Assembly procedures, travelers
 - Test procedures, travelers
 - With final details being worked out as issues arise
- JLab/FNAL/SLAC partnership working well
- Risks, cost and schedule are well understood

Acknowledgements



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