



Status of US AUP Contribution

Giorgio Apollinari – FNAL
HL-LHC AUP Project Manager

14th HL-LHC Collaboration Meeting
 Genova, Italy - October 2024



 The poster for the HL-LHC Collaboration Meeting in Genoa, Italy, is a collage of images. It features a lighthouse at sunset, a group of people standing together, and technical diagrams of particle detectors. The text "HIGH LUMINOSITY LHC" is at the top, and "HL-LHC COLLABORATION MEETING GENOA, ITALY, 7-10 October 2024" is prominently displayed in the center. Below the main text, there is a detailed description of the meeting's purpose and organizers.

Jointly organised by INFN and CERN, the 14th HL-LHC Collaboration Meeting will take place in person in Genoa, Italy from 7th to 10th October 2024. This edition will provide the occasion to showcase the successful production and validation of the first series D2 magnets, produced by ASG in Genoa as an in-kind contribution by INFN (Italy), as well as the completion of production of the MgB₂ wires for the superconducting link by ASG. Based on the traditional programme with plenary and work package parallel sessions, this meeting will serve as a technical update forum for the 8th Cost and Schedule Review, scheduled for 11th to 14th November 2024. The main objectives will be to update all HiLumi collaborators on the advancement of the series production of components for the project, to showcase the status of the IT String test stand installation at CERN, and to update all collaborators on the latest schedule changes.

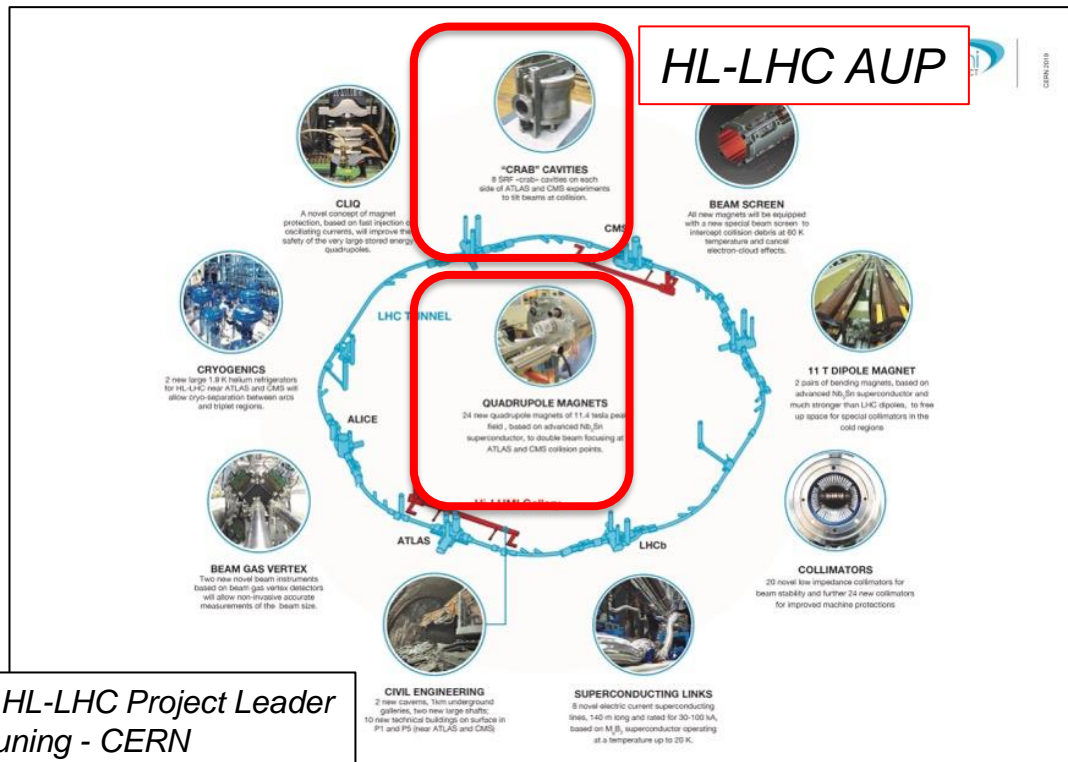
CERN – Organizing Committee	INFN – Local Organizing Committee
Oliver Brüning - Project Leader	Andrea Bersani - Communication Officer
Markus Zerlauth - Deputy Project Leader	Barbara Caffi - MBRD Deputy Technical Coordinator
Cécile Noels - Project Office & Communications	Mirko Corcos - IT Manager
Florence Thompson - Project Office & Communications	Stefania Farison - MBRD Technical Coordinator
	Filippo Levi - Deputy Conference Coordinator
	Alessandra Pampaloni - Conference Coordinator
	Marco Statera - HD Corrector Technical Coordinator

For more details and registration : HL-LHC.Secretariat@cern.ch / hilumilhc.web.cern.ch

Outline

- Introduction
- AUP Project Overview
- AUP Technical and Financial Status
- Summary

US Contribution to HL-LHC

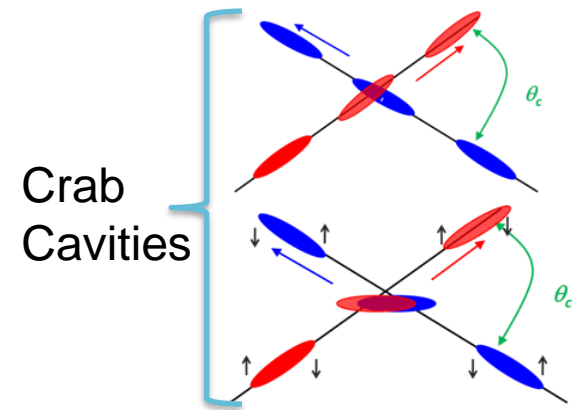


From HL-LHC Project Leader
O. Brüning - CERN

Quad Magnets

$$L = \gamma \frac{f_{rev} n_b N_b^2}{4\pi\epsilon_n\beta^*} R$$

Beam size



- HL-LHC: from 300 fb⁻¹ to 3000/4000 fb⁻¹
- LARP (DOE supported R&D Program) established the necessary technology for the HL-LHC Focusing Magnets and Crab Cavities
- DOE *baselined* HL-LHC AUP Project in 2019 (FNAL, BNL, LBNL with contributions from ANL, SLAC, JLAB, ODU & FSU)
- DOE *re-baseline* AUP in 2023 to absorb COVID impacts on Cost and Schedule

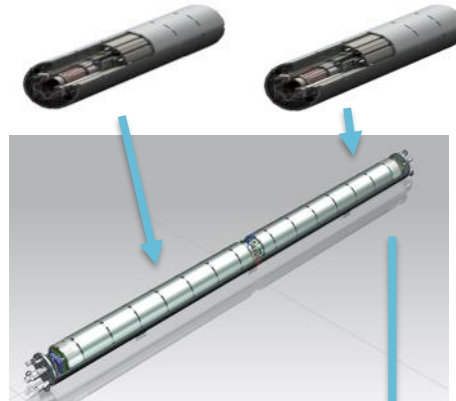


HL-LHC AUP Deliverable Scope

Technical Details

- Q1/Q3 Cryoassembly
(10 CryoAssemblies with 20 Magnets)

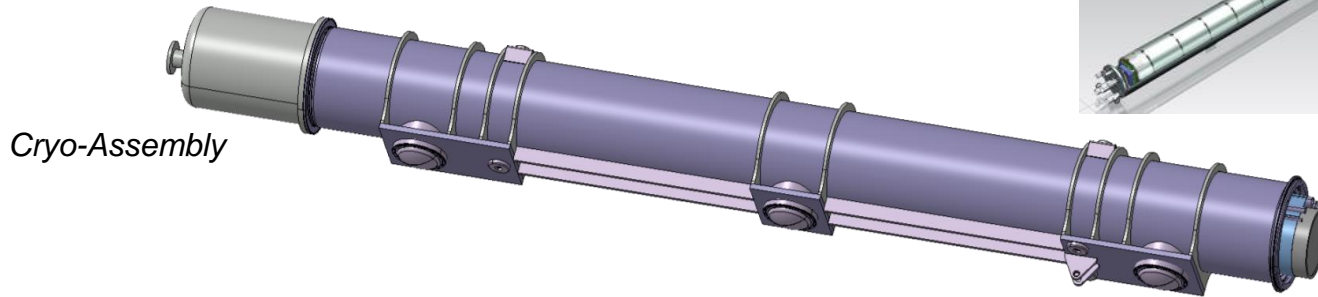
MQXFA
Magnet



Cold Mass
Assembly

302.2

302.4

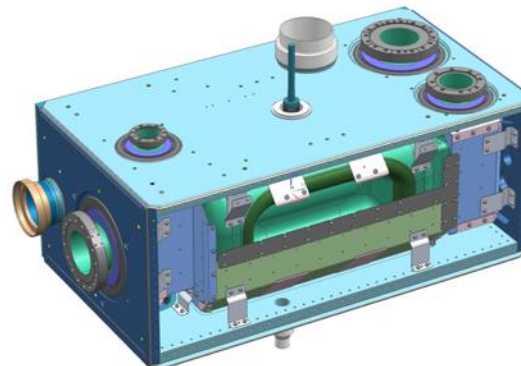


Cryo-Assembly

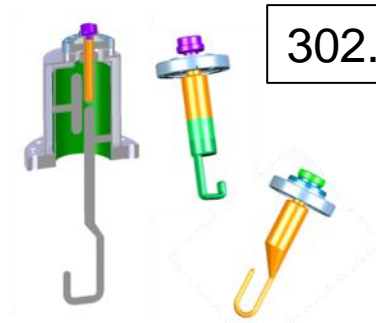
- Dressed RFD Cavity
(10 Dressed Cavities & Ancillaries)



Bare RFD Cavity



Dressed RFD Cavity
(front wall removed to show internal
components)



302.3

High Order Mode
Antennas

AUP Q1/Q3 and RFD Cavities KPPs

Parameters	Threshold Performance	Objective Performance
Inner Triplet Focusing Quadrupoles (Q1 and Q3)	<p>a) 6 Q1/Q3 Cryoassemblies are accepted by CERN after testing at HL-LHC agreed upon Acceptance Criteria for the Cryoassembly. The Cryoassemblies will be assembled from Cold Masses built by HL-LHC AUP and Cryostat kits provided by CERN.</p> <p>b) 3 Q1/Q3 Cold Masses built with magnets tested vertically at HL-LHC agreed-upon Acceptance Criteria</p> <p>c) Complete coils and remaining components for 1 additional Q1/Q3 Cold Mass</p>	<p>4 additional Q1/Q3 Cryoassemblies are accepted by CERN after testing at HL-LHC agreed-upon Acceptance Criteria for the Cryoassembly. The Cryoassembly will be assembled from Cold Masses built by HL-LHC AUP and Cryostat kits provided by CERN</p>
SRF Crab Cavities	<p>a) 8 Radio Frequency Dipoles (RFDs) Dressed cavities for the HL-LHC Crab Cavity System are accepted by CERN after being tested at HL-LHC nominal temperature, nominal frequency, and ultimate cavity voltage. Dressed cavities include HOM couplers, pick-ups, He Vessel and magnetic shields.</p> <p>b) Procurement of components for 2 additional RFD Dressed Cavities</p>	<p>2 additional Radio Frequency Dipoles (RFDs) Dressed cavities for the HL-LHC Crab Cavity System are accepted by CERN after being tested at HL-LHC nominal temperature, nominal frequency, and ultimate cavity voltage. Dressed cavities include HOM couplers, pick-ups, He Vessel and magnetic shields</p>

10 Q1/Q3 Cryoassemblies
(8 Operations + 2 Hot Spares)

10 RFD Dressed Cavities
(8 Operations + 2 Hot Spares)

- HL-LHC AUP Project includes Objective KPPs
- Goals untouched since the Project inception



AUP Project Office Change(s)

- After 26+ years at FNALy, Ruben Carcagno has decided to benefit from the Self-Select Voluntary Separation Program (SSVSP) initiated by Fermilab in early 2024



In name of the whole AUP and HL-LHC teams, we extended to Ruben our most sincere thanks for everything he has done for the HL-LHC Project, wishing him the best in this new phase of life.

- *Interactions with DOE*
 - Dr. Gianluca Sabbi (LBNL)
 - Long-standing member of AUP LBNL team, previous leader in LARP.
- *Interactions with CERN*
 - Vito Lombardo (FNAL)
 - Risk Manager and CAM in AUP since CD-1



HL-LHC AUP Project Organization



Office of Science
Acquisition Executive

Office of Project Assessment
Director

Office of High Energy Physics
Associate Director
DOE Program Manager

DOE Fermi Site Office
Site Manager
DOE Federal Project Director

Fermi Research Alliance, LLC
M&O Contractor
Director
Chief Technology Officer

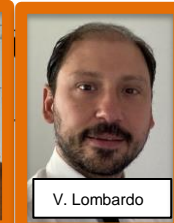
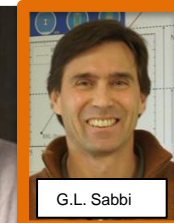
DOE AE: Harriet Kung
OHEP AD: Regina Rameika
DOE Program Manager: A. Hatzikoutelis
DOE FPD: Jerry Kao
FNAL Project Manager: Giorgio Apollinari
Deputy Project Manager: GianLuca Sabbi
Vito Lombardo

CERN HL-LHC Project Office
Project Leader
Deputy Project Leader

US Partner Labs
BNL Representative
LBNL Representative

ES&H Coordinator

US HL-LHC Accelerator Upgrade Project (HL-LHC AUP)
Project Manager
Deputy Project Manager



Project Management
L2 Manager/ Lab Repr.

MQXFA Magnets Fabrication
L2 Manager

RFD Dressed Crab Cavities Fabrication
L2 Manager

Q1/Q3 CryoAssemblies Fabrication
L2 Manager



Progress since last CM on Magnets and CryoAssemblies

- BNL Coil Factory completed Production
 - FNAL Factory maintained at very low production rate for potential coil replacements
- MQXFA07b and MQXFA13b re-assembled and tested
 - MQXFA07 was the first magnet impacted by operations under COVID
 - MQXFA13 was limited (report at last CM), coil replacement
 - ✓ Successfully passed BNL Vertical Test
- MQXFA14b and MQXFA15 assembled and tested
 - ✓ Successfully passed BNL Vertical Test
- MQXFA17 assembled and tested
 - Failed to pass acceptance test at BNL, under coil replacement with *TLS*
- MQXFA18 *TLS* presently under test at BNL
- MQXFA12b *TLS* has been shipped to BNL
- MQXFA16 *TLS* under final preparation at LBNL, soon to be shipped to LBNL

MQXFA Magnets Test History

MQXFA03	VTS Tested OK	LQXFA/B-01	
MQXFA04	VTS Tested OK		
MQXFA05	VTS Tested OK	LQXFA/B-02	
MQXFA06	VTS Tested OK		
MQXFA07	VTS COVID Limitations, coil replaced	MQXFA07b	VTS Tested OK
MQXFA08	VTS COVID Limitations, coil replaced	MQXFA08b	VTS Tested OK
MQXFA09	Assembly NCR (2 coils affected by folded Kapton)	Dismantled	2 coils rejected 2 coils used in 14b and 5, structure used in 11
MQXFA10	VTS Tested OK	LQXFA/B-03	LQXFA/B-04
MQXFA11	VTS Tested OK		
MQXFA12	Assembly NCR (Hipot fail) coils to be replaced	MQXFA12b	TBT ₄ → LQXFA/B-05
MQXFA13	VTS Limitations (end prestress), coil replaced	MQXFA13b	VTS Tested OK
MQXFA14	Assembly NCR (QH hipot fail), coil replaced	MQXFA14b	VTS Tested OK
MQXFA15	VTS Tested OK		

MQXFA Vertical Tests History: TC1 vs. TC2

Magnet	NC found in TC1	NC confirmed in TC2
MQXFA03	0	0
MQXFA04	0	0
MQXFA05	0	0
MQXFA06	0	0
MQXFA07	1	N/A
MQXFA07b	0	0
MQXFA08	1	1
MQXFA08b	0	0
MQXFA10	0	0
MQXFA11	0	0
MQXFA13	1	N/A
MQXFA13b	0	0
MQXFA14b	0	0
MQXFA15	0	0
MQXFA17	1	N/A
TOTAL	4	1
Detection rate	100%	N/A

Magnet Vertical Test Decision

- MQXFA Magnets vertical test is a critical QC step in the execution of the AUP Project
- “Demonstration of stable performance following a thermal cycle” (Memory) was a critical early demonstration at the beginning of the MQXF magnets construction
 - Since the beginning of the AUP projects, all magnets have been tested vertically through 2 Thermal Cycles, and – again – horizontally in the final cryostat through 2 thermal cycle.
- Early in the AUP planning - due to financial constraints - a total of ~5 MQXFA magnets were planned to be inserted in cryostats without a Vertical Test.
 - Experience is indicating that the risk of not testing a magnet vertically has not decreased substantially as production progressed
 - The re-assembly of an LQXFA/B Cryostat was introduced in the AUP Baseline to mitigate risks due to untested magnets

Magnet Vertical Test Decision (cont.)

- Observation that all magnets that failed a vertical test were identified in the 1st Thermal Cycle (TC1) and the vast majority could be repaired.
- Decision: ***Test all remaining MQXFA Magnets vertically through only TC1 and reduce number of magnetic measurements at BNL***
 - Pros:
 - Reduce considerably risks for LQXFA/B, eliminating the necessity to carry forward a cryomodule re-assembly in the baseline schedule
 - Reduces costs and anticipates schedule
 - AUP critical path is *stably* associated with Horizontal Testing
 - Cons:
 - “Memory” establishment delayed from Vertical Test to LQXFA/B Horizontal Test

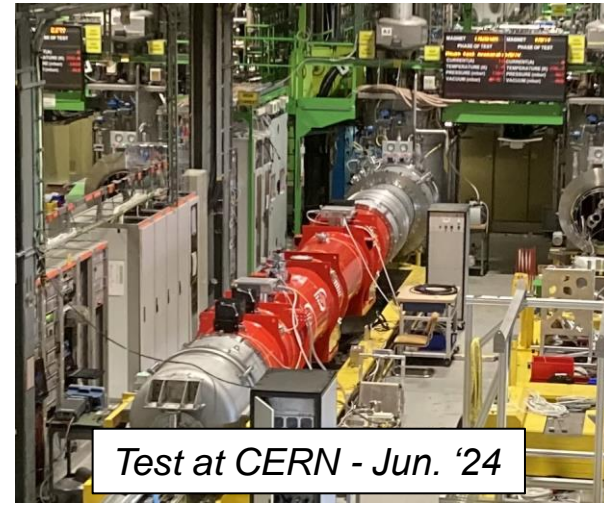
LQXFAB-01 Delivery to CERN



Dr. Harriet Kung Visit and LQXFA/B-01 in final Shipment Preparation – Oct. '23



CERN Arrival - Dec. '23

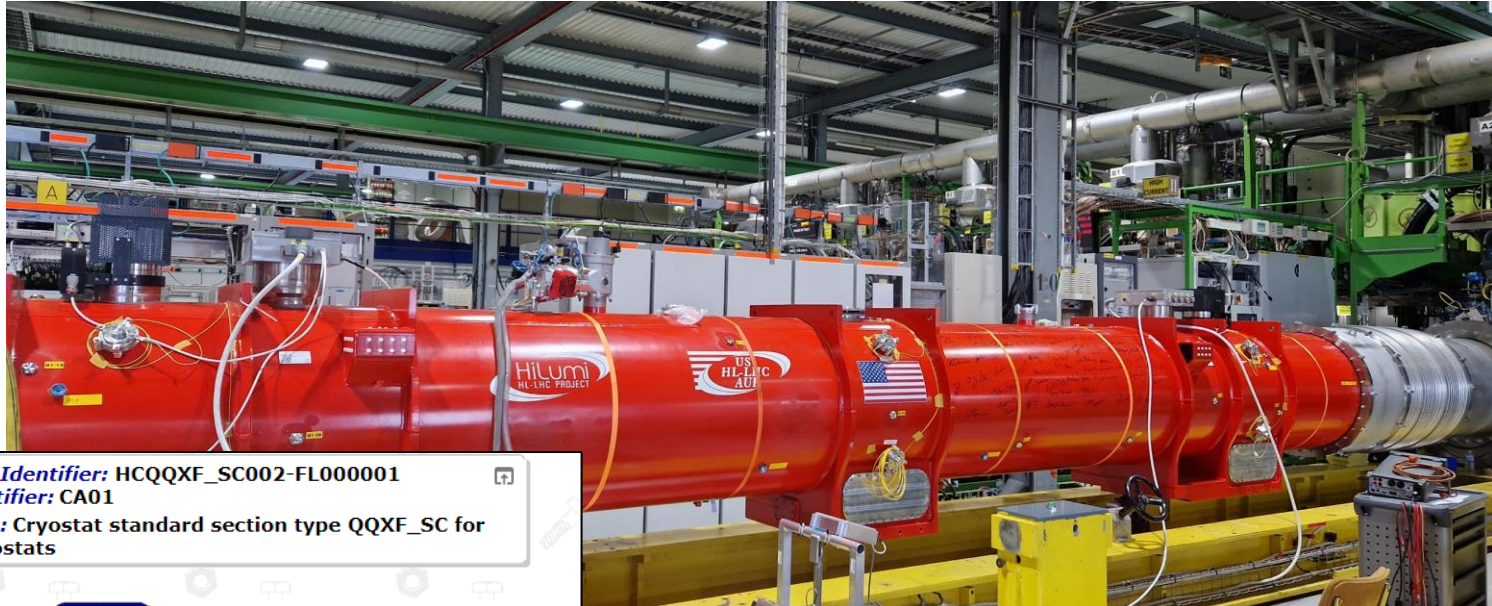


Test at CERN - Jun. '24

- CERN Cryogenic Test of LQXFAB-01 at CERN achieved nominal Current without quenches on June 18th 2024.
- Quench Heaters non-Conformities addressed by delivery of additional/spare elements to CERN (1 MQXFA Magnet, Shell, CM Tool)

LQXFAB-01 Acceptance at CERN

- LQXFAB-01 Accepted at CERN in June 2024 within the framework of AUP-CERN Acceptance Criteria agreements.



Equipment Identifier: HCQXF_SC002-FL000001
Other Identifier: CA01
Description: Cryostat standard section type QQXF_SC for Q1/Q3 cryostats

Main	Made of	Equipment data	Manufacturing	Operation	Non-conformities	Documents	History
Actions: Back to list Edit							
Step Generic Data							
Step ID	320	Other name					
Description	Cryo-assembly acceptance at CERN			Result			
Status	Accepted	Result		Ok			
Completed on	2024-07-02			Open in EAM Light			
Provided by				33644020			
Responsible	Executed by						
Comments							
Acceptance by CERN according to the document US HL-LHC AUP - LQXFA - Acceptance Criteria RECEPTION OF CRYOASSEMBLY AT CERN - EDMS 1868479 v1.2							
LMQXFA01 passed the acceptance tests foreseen in the test plan EDMS 2959525 (see EDM for a summary of the test results for acceptance). The cryo-assembly is accepted for use in the IT String Test, following the agreed path of acceptance between CERN and AUP (see EDMS 2958007), and therefore the cold test can proceed with the 'tests to be carried acceptance', as for the test plan. However, during the final leak tests before cool down in the cryomagnet installed on bench A2, a critical (level 3) non-conformity was identified on mass hydraulic circuit (see EDMS 3124113). Further leak tests are foreseen after warming a test bench leak test. This NCR needs to be resolved before proceeding with the phase 2							

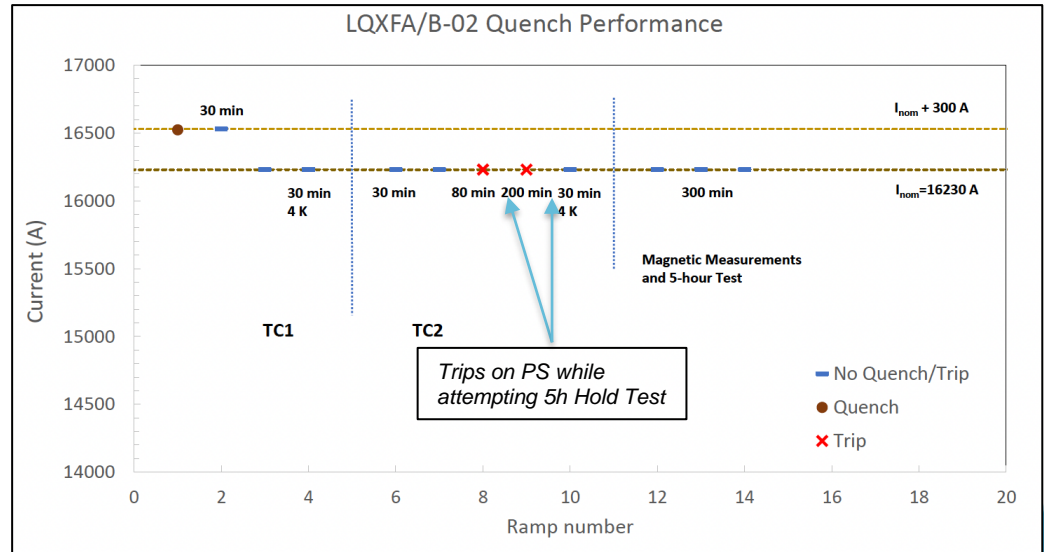
LQXFA01 is accepted after the tests carried out at CERN in the framework of the Acceptance Criteria – Part C (EDMS [1868479](#)) with the following remarks:

- The Cryo-assembly is accepted for installation in the IT String but for the installation in the LHC, the agreed path for acceptance between AUP and CERN is to be completed (See EDMS [2958004](#) and EDMS [2958007](#)).
- During the final leak test prior to cooldown, a leak was detected in the cold mass hydraulic circuit. This nonconformity needs to be investigated and solved prior to starting the phase 2 cryostating.



LQXFAB-02 under Test in IB1- TS4

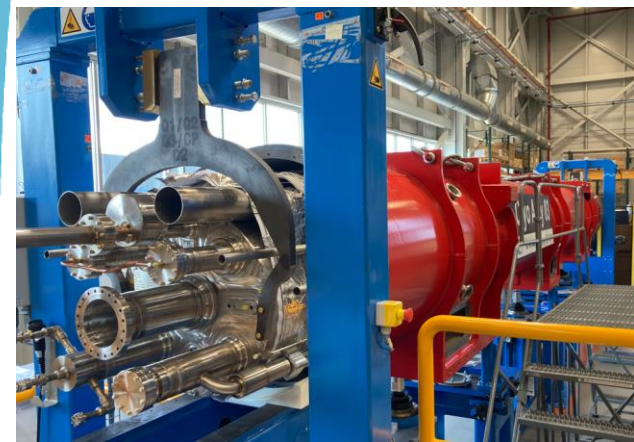
- TS4 underwent massive upgrades to expedite cold test of a cryomodule
 - ~4 months for LQXFAB-01 to Acceptance
 - Still ~3.5 months for LQXFAB-02 from completion of installation to Acceptance (modulo 100k HiPot)
 - Planned for “Pressure & Leak Test” and shipment from FNAL to CERN by Nov. 18th (arrival at CERN by mid-December).



Technical Status

Cold Mass (CM) and Cryo-Assembly (CA)

- CA03 (LQXFAB-03) completed, pending Pressure&Leak test
- CM04 and 05 under Production
- Magnets for CM06 (starting with MQXFA13b) being gathered at FNAL



LQXFAB-03 - Completed



CM04 – Orbital Welding



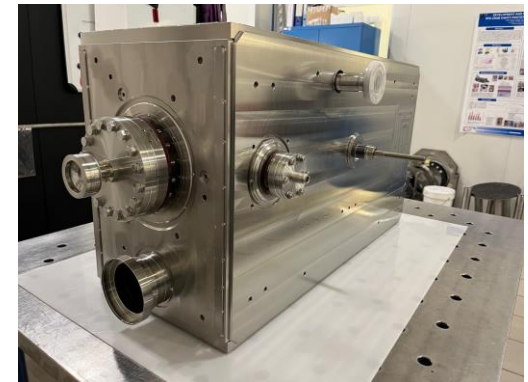
CM05 – Longitudinal Welding

Progress since last CM on RFD Crab Cavities

- Placed order for Production Helium Tanks.
- Completed 2 Pre-series at ZANON.
 - NRFD02 met requirements for Acceptance
 - NRFD01 didn't meet requirements, sent back to ZANON for reprocessing. To be tested at FNAL shortly.
- Documentation under control
- Prototype #2 Cavity (not a deliverable to CERN, but a "trial" delivery to TRIUMF) completed He Vessel installation, at JLAB to be tested.
 - *Prototype #1 at Zanon, not useable after multiple BCP cycles. Instrumental in uncovering and addressing processing issues.*
- JLAB successfully completed design, fabrication & test of pre-series HOMs. Concern on ceramic windows cracking addressed by HOMs production at CERN.



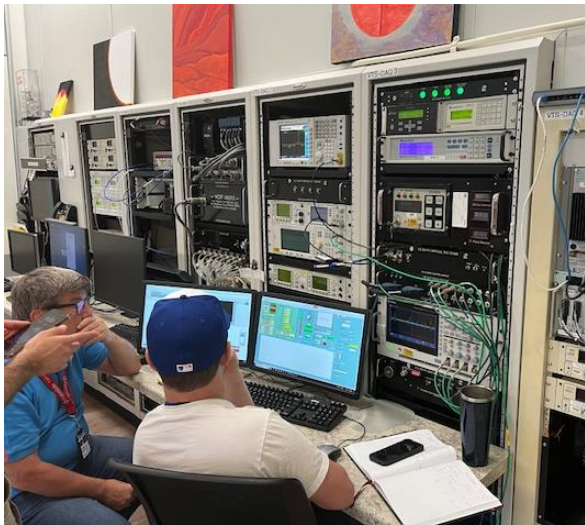
Completed Pre-Series



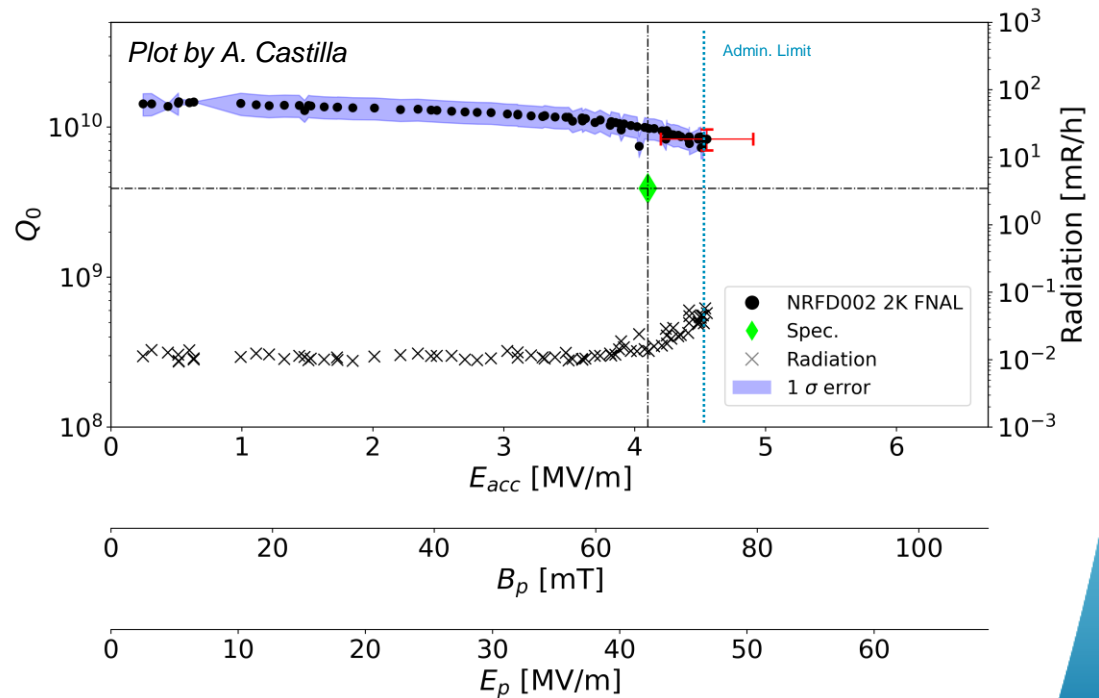
Completed Prototype Helium Tank

Pre-Series #2 (NRFD02) Test Results

- Performed 3 tests in total, always exceeding acceptance requirements, but with radiation onset (indicative of contamination). Onset level continued to improve after successive high-pressure rinses by JLAB.
- Final test shows no radiation up to acceptance level.
- Low field Q_0 is high: Chemistry by Zanon is successful.
- Radiation onset is at high field: HPR and clean assembly by Jlab is successful.

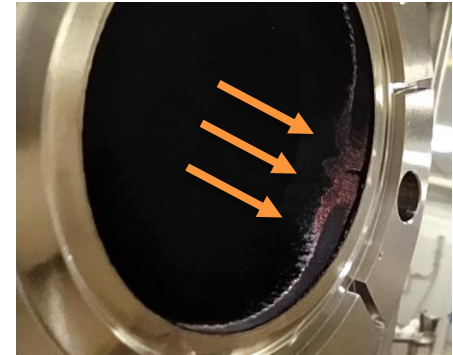


8/26/24: FNAL VTS Control Room

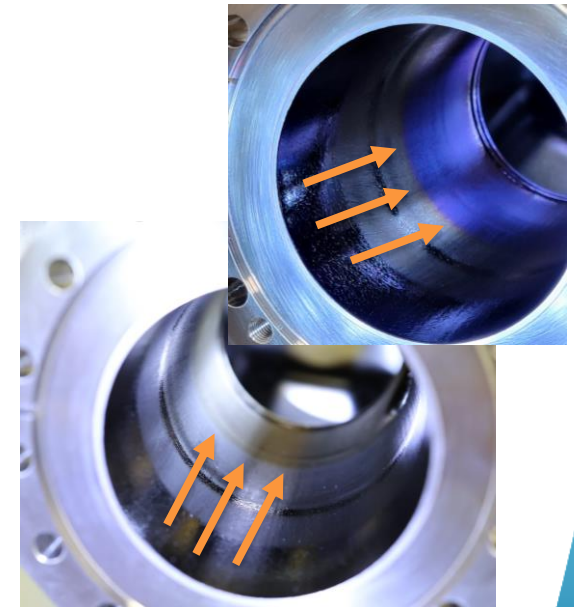


BCP & HPR Issues at Zanon

- **BCP:** Following the investigation for the uneven removal on prototype #1, the chemistry process was improved and tested with successful results.
- **HPR:** Both pre-series cavities are showing localized discoloration. Suspecting excessive and localized HPR pressure. JLAB performed HPR tests which resulted negative.
- Meetings between JLAB and Zanon are facilitating knowledge transfer. We are also planning visits of JLAB representatives in the next months.



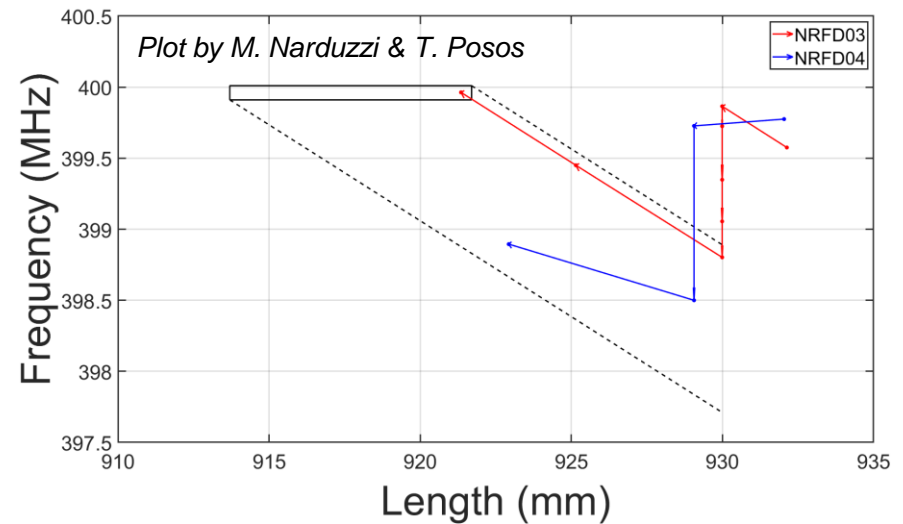
Prototype #1 after 3+ BCP cycles



Pre-Series #1 and #2 with internal discoloration

302.03 - Other Updates

- First two series NRFD03 & NRFD04 are undergoing trim-tune operations (see plot and pictures).
- Non-performing NRFD01 has undergone light BCP at Zanon and is in transit to FNAL for test later this month.
- JLAB test facility shut-down is extended to December due to a safety stop which affected all maintenance and repair activities.



Some Components of Series #3 and #4 ready for trim-tuning

302.03 - RFD Tests and Delivery Dates

ZRI Serial	Bare Cavities delivered to FNAL	Bare Cavities qualified and back at Zanon	ZRI Serial	Jacketed Cavities delivered to JLAB	Dressed Cavities Delivered to TRIUMF	CERN Serial
NRFDP001	6/1/2024	8/1/2024	RFDP001	9/15/2024	1/15/2025	HCACFCA005-UP000001
NRFDP002	8/17/23	9/15/2023	RFDP002	4/16/2024	1/31/2025	HCACFCA005-UP000002
NRFD01	10/7/2024	12/1/2024	RFD01	1/30/2025	3/31/2025	HCACFCA002-UP000001
NRFD02	4/16/2024	9/20/2024	RFD02	11/19/2024	2/15/2025	HCACFCA002-UP000002
NRFD03	11/15/2024	1/14/2025	RFD03	2/28/2025	4/29/2025	HCACFCA002-UP000003
NRFD04	12/6/2024	2/4/2025	RFD04	3/21/2025	5/20/2025	HCACFCA002-UP000004
NRFD05	12/27/2024	2/10/2025	RFD05	3/27/2025	5/26/2025	HCACFCA002-UP000005
NRFD06	1/17/2025	3/3/2025	RFD06	4/17/2025	6/16/2025	HCACFCA002-UP000006
NRFD07	2/4/2025	3/21/2025	RFD07	5/5/2025	7/4/2025	HCACFCA002-UP000007
NRFD08	2/22/2025	4/8/2025	RFD08	5/23/2025	7/22/2025	HCACFCA002-UP000008
NRFD09	3/12/2025	4/26/2025	RFD09	6/10/2025	8/9/2025	HCACFCA002-UP000009
NRFD10	3/26/2025	5/10/2025	RFD10	6/24/2025	8/23/2025	HCACFCA002-UP000010
NRFD11	4/9/2025	5/24/2025	RFD11	7/8/2025	9/6/2025	HCACFCA002-UP000011
NRFD12	4/23/2025	6/7/2025	RFD12	7/22/2025	9/20/2025	HCACFCA002-UP000012

Agreed Late Delivery Dates
Apr-25
Jun-25
Jul-25
Sep-25
Oct-25

- Delays since last update can be attributed to prioritizing quality and shape accuracy, managing NCRs according to QA plan, increased duration of JLAB VTA shut-down.
- Dressed Prototype estimated to arrive at TRIUMF in January 2025.
- Pre-Series cavities estimated to arrive at TRIUMF in Spring 2025.
- Zanon BCP shut-down in October: We expect this will cause an additional delay for the 2 pre-series (still being estimated ~1-3 weeks).

Visual Representation of KPPs Achievements

MQXFA Magnet

Cold Mass Assembly

Cryo-Assembly

MQXFA13b

MQXFA16TSL

MQXFA12bTSL

MQXFA18TSL

MQXFA17bTSL

Threshold

Objective

RFD Bare Cavity

RFD Dressed Cavity

Threshold

Objective

- ✓ Completed, sitting on a shelf or delivered to CERN
- ✓ Under Fabrication
- ✓ Under Test

DOE Independent Project Review

July 2024

- Standard “yearly” review run by DOE
 - Thanks for help provided by HiLumi Project Office
- Positive outcome

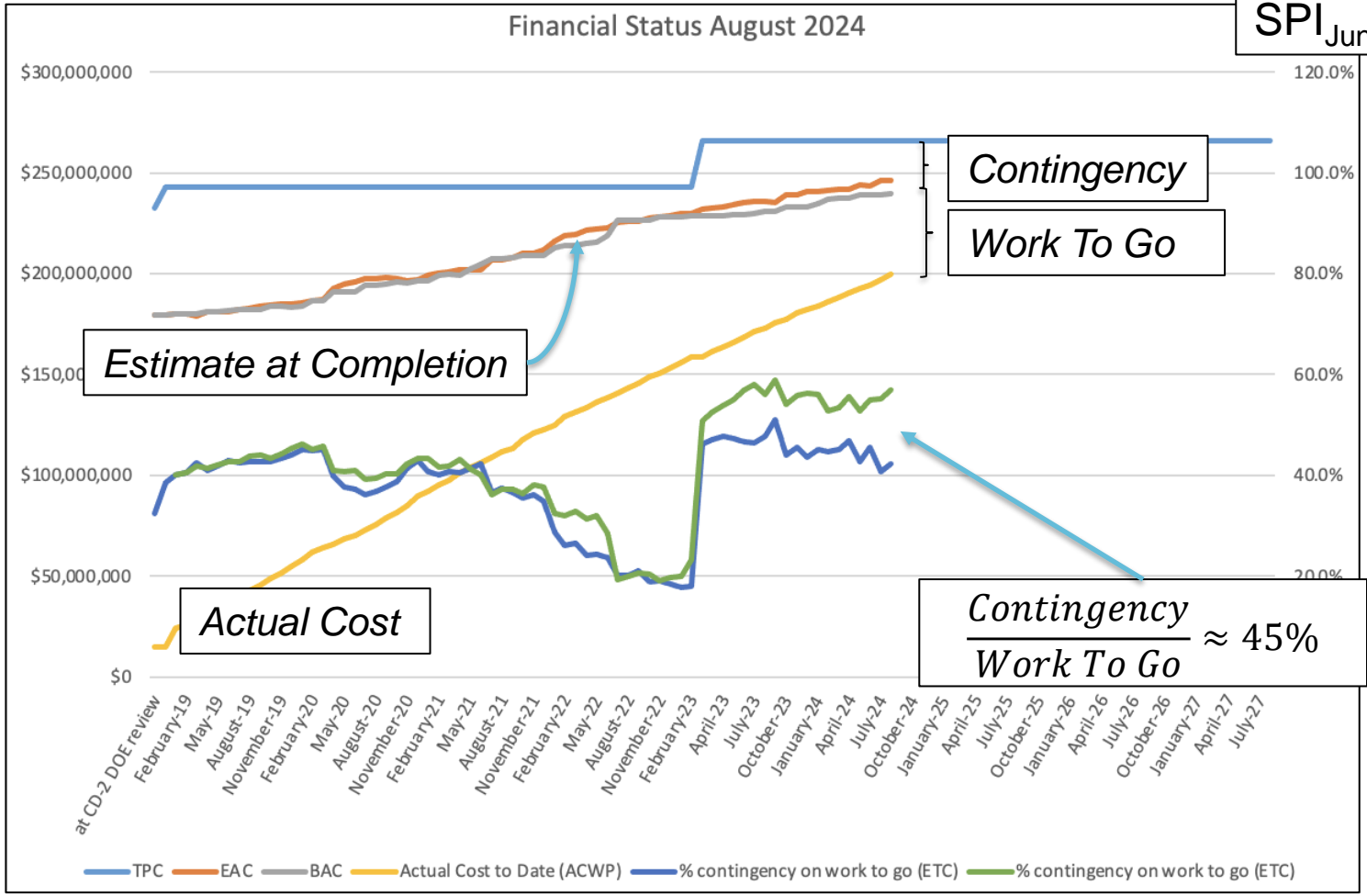
Overall, the project is on track to complete within TPC and CD-4 date. It is fully funded and has sufficient schedule and cost contingencies. The Cost and Schedule Performance Indices (CPI/SPI) are .99 and .99, which is relatively stable. There is aligned production with CERN’s delivery/need by dates.

- Few technical (Crab Cavities) and Managerial (Handling of Objective/Threshold KPPs) recommendations
 - To be discussed at the CERN-AUP Steering Meeting

Financial Situation (Past)

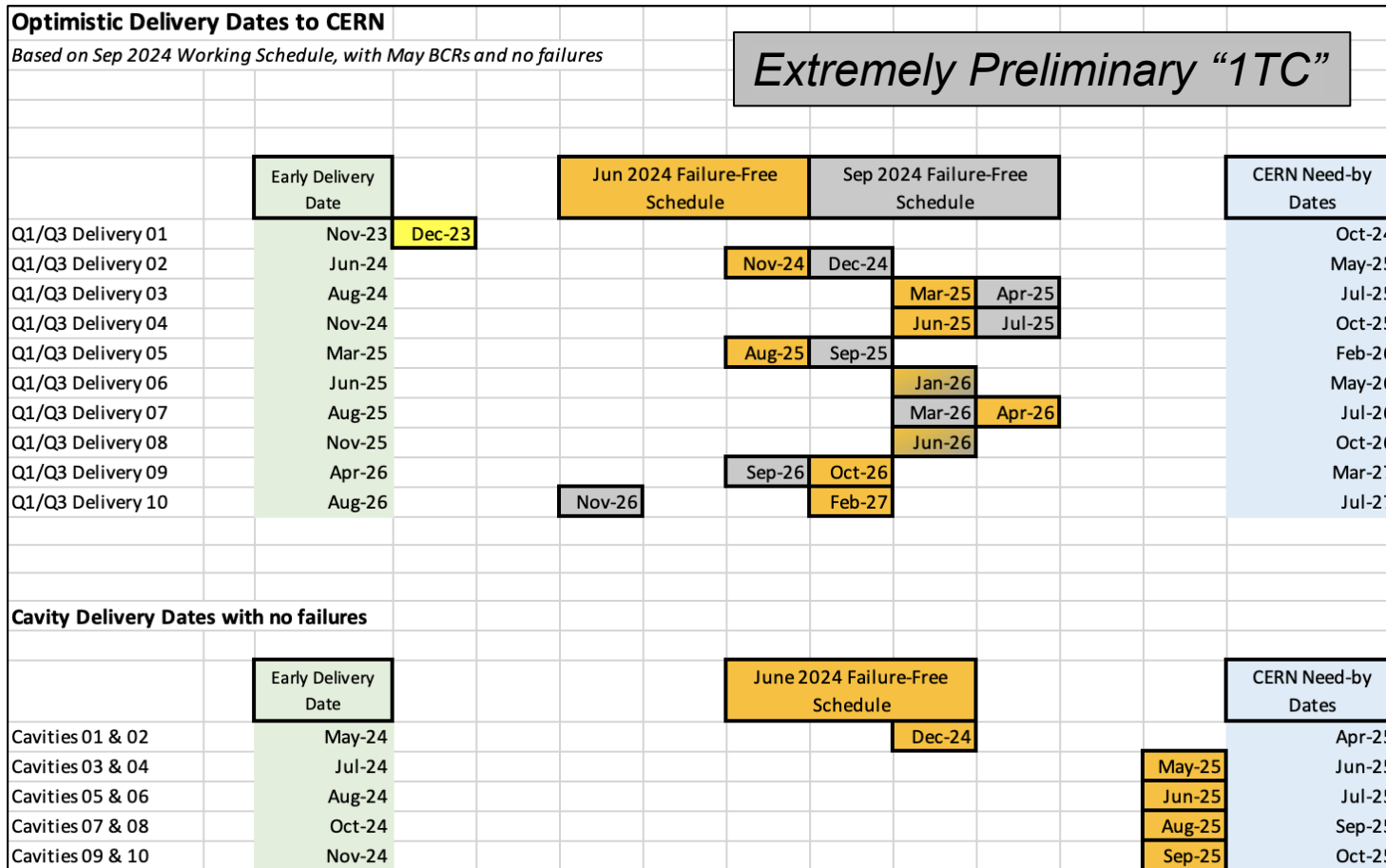
- DOE has disbursed \$266M to the US-AUP (*fully funded*)

CPI_{Aug '24}=0.99
SPI_{Jun '23}=0.99



- AUP is in the “last leg of the race” (~80% complete)

Delivery Dates to CERN (June 2024)



- Success Oriented Schedule provided to CERN WPs as input for upcoming Nov. '24 C&S Review

Conclusions

- AUP is over 80% complete
- Steady progress on MQXFA Construction
 - 11 magnets passed vertical test.
- LQXFAB-01 Accepted by CERN
- LQXFAB-02 under test at FNAL, planned for shipment to for String Test before end of CY.
- LQXFAB-03 Close to completion, awaiting Horizontal Test
- RFD Crab Cavities Series Production Order and He Vessel Production Order placed.
 - Pre-series cavity accepted and moving to He Vessel Assembly.