



# Status of US AUP Contribution

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 HL-LHC AUP Project Manager

12<sup>th</sup> HL-LHC Collaboration Meeting  
 Uppsala, Sweden September 2022

 A poster for the 12th HL-LHC Collaboration Meeting. The top text reads "HIGH LUMINOSITY LHC" in white on a black background. Below that, "12<sup>th</sup> HL-LHC Collaboration Meeting" is written in large yellow and white font, followed by "UPPSALA - Sweden" and "19 - 22 September 2022". The poster features a large image of a golden HL-LHC detector component against a green background. Below the image, there is text describing the meeting's location, objectives, and contact information. At the bottom, there are logos for CERN, FNAL, and Uppsala University, along with a list of organizing committee members and their roles.
 

**CERN - Organizing Committee**

|                     |                       |                     |                                |
|---------------------|-----------------------|---------------------|--------------------------------|
| Oliver Brüning      | Project Leader        | Tord Ekelof         | Chairman                       |
| Markus Ziefleuth    | Deputy Project Leader | Richard Benner      | Head of Physics Department     |
| Cláire Woods        | Project Office        | Maja Öwngård        | Head of FRES Department        |
| Isere Garcia Oliver | Project Office        | Ricco Sarriago Kern | Technical Leader (LHF project) |

**Uppsala - Organizing Committee**

For more details and registration: [cdcc.meehlorn.ch](http://cdcc.meehlorn.ch)  
[www.hilumi.web.cern.ch](http://www.hilumi.web.cern.ch)

Logos: CERN, HiLumi, UPPSALA UNIVERSITY, FNAL.



# Outline

- Introduction
- Project Overview
- Overview of AUP Status
- Summary

# US Contribution to HL-LHC

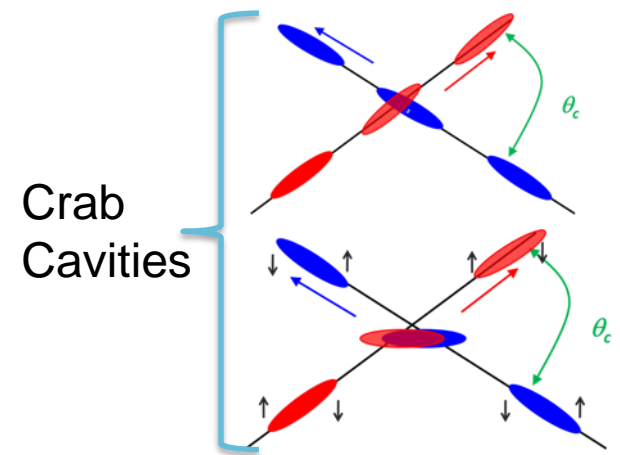


From HL-LHC Project Leader  
O. Bruning - CERN

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<sup>-1</sup> to 3000/4000 fb<sup>-1</sup>
- 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, coordinating efforts from US Labs (FNAL, BNL, LBNL with contributions from ANL, SLAC, JLAB, ODU & FSU)

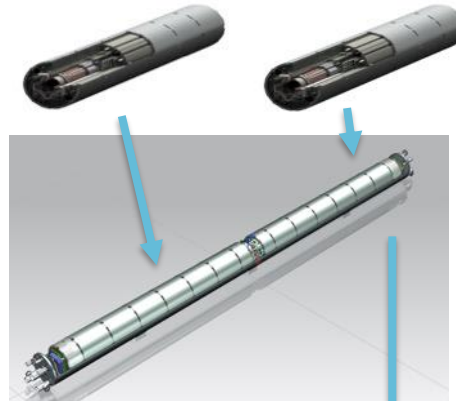


# HL-LHC AUP Deliverable Scope

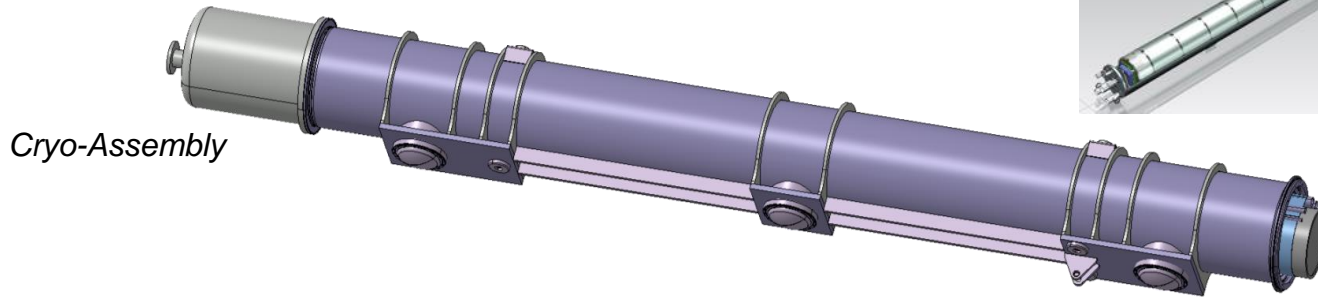
## Technical Details

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

MQXFA  
Magnet



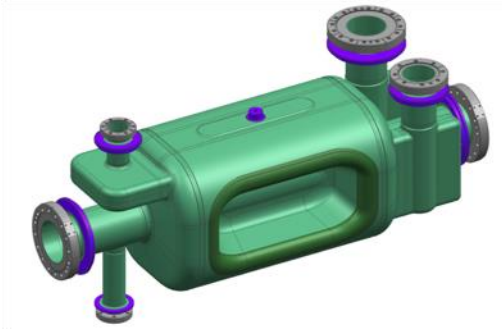
Cold Mass  
Assembly



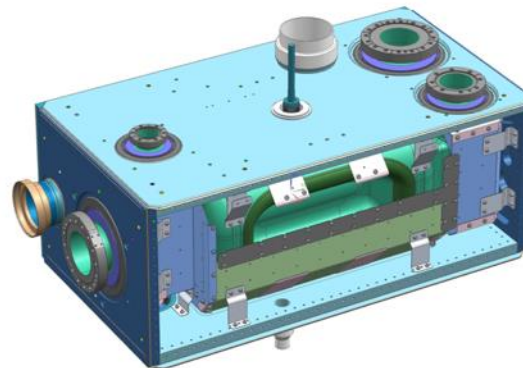
302.2

302.4

- Dressed RFD Cavity  
(10 Dressed Cavities & Ancillaries)



Bare RFD Cavity



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



302.3

RF Ancillaries

# AUP Q1/Q3 and RFD Cavities KPPs

| Parameters  | Threshold Performance   | Objective Performance   |
|---|---|---|
| <b>Inner Triplet Focusing Quadrupoles (Q1 and Q3)</b> | <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>  |
| <b>SRF Crab Cavities</b>                              | <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)

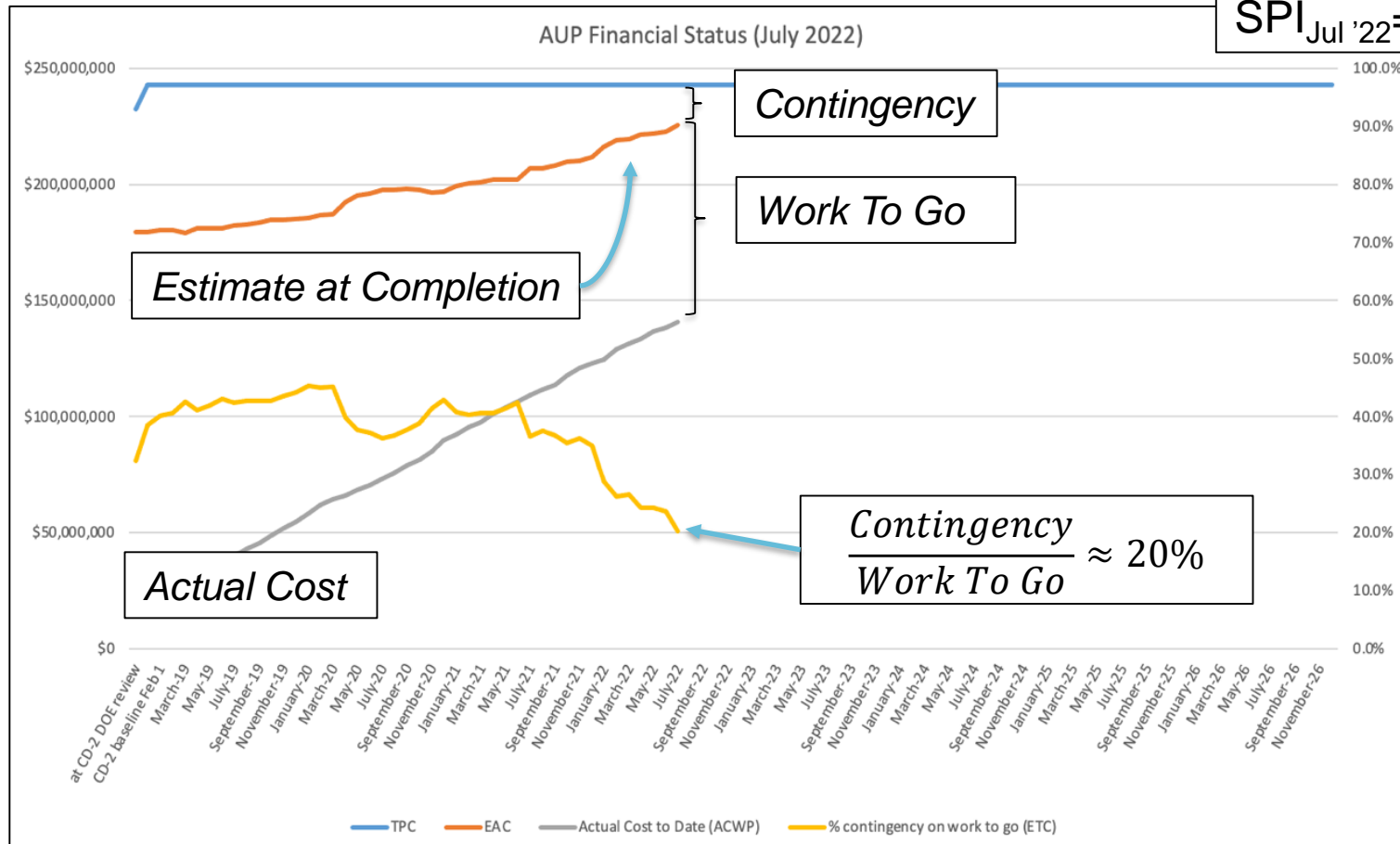
- HL-LHC AUP Project includes Objective KPPs



# Financial Situation (Past)

- DOE has disbursed ~172M\$ to the US-AUP Consortium, out of the baselined 242 M\$ (*sans COVID*)

CPI<sub>Jul '22</sub>=1.05  
SPI<sub>Jul '22</sub>=0.96

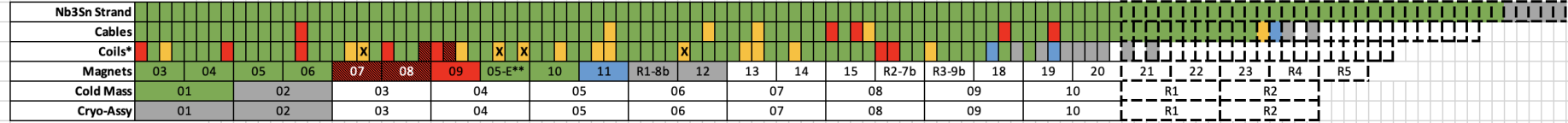


- AUP is beyond the “buoy turn” (~2/3 complete)
- Dangerously low in Contingency

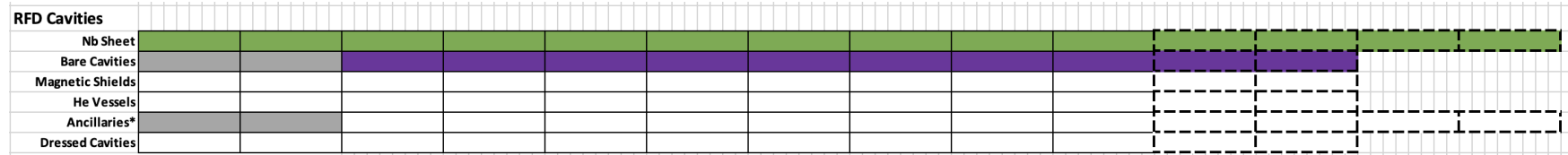
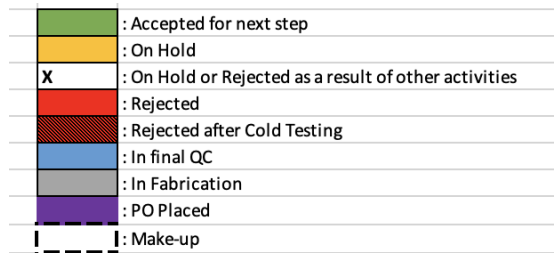
# Production Dashboard

“Basic” deliverables  
80 coils, 20 magnets, etc.

## Q1/Q3 Cryo-Assemblies



\*FNAL/BNL coils in alternating cells  
\*\*Endurance test of previously accepted magnet MQXFA05



\*Include Vertical HOM, Horizontal HOM, and RF pick-up

- Technical Production Details in WPs presentations

# Financial Situation (Past)

|                        | CD-2 Baseline<br>(Feb 2019) | Today<br>(Jul 2022) | Change      |
|------------------------|-----------------------------|---------------------|-------------|
| Management & Shipments | 28M\$                       | 36M\$               | +28%        |
| Magnets                | 97M\$                       | 99M\$               | +2%         |
| RFD Cavities           | 16M\$                       | 21M\$               | +31%        |
| CryoAssemblies         | 38M\$                       | 69M\$               | +81%**      |
| <b>Total</b>           | <b>180 M\$</b>              | <b>226M\$</b>       | <b>+25%</b> |

- \*\*No CryoAssembly prototyping in AUP contributed to imprecise estimates for CM/CA Activities. Also cost increases in Vertical Test
- \*\*Change of Cold Mass FRS requested a redesign of the system. In addition, Q2 Prototypes tested in temporary cryomodules imply “debugging” of Q1/Q2/Q3 CryoAssemblies executed by AUP (*you're welcome !*)



# Rebaseline Process

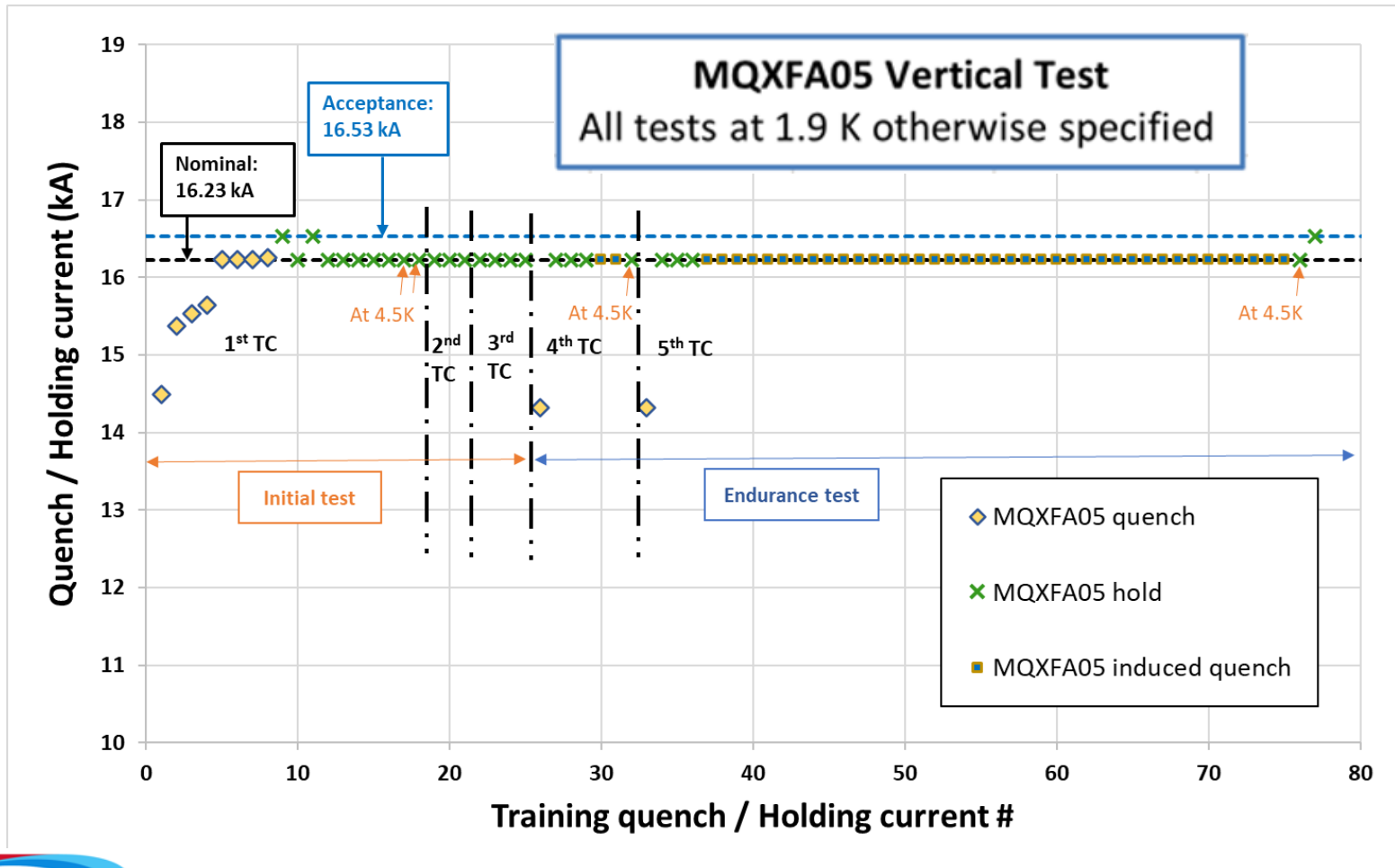
- DOE has acknowledged that the impact of unexpected events such as COVID and Abnormal Cost/Escalations due to geopolitical events are placing AUP in jeopardy of completing its KPPs and is allowing AUP to “*apply for rebaseline*”
- A “Rebaseline Process” has been initiated with funding agency (DOE) with the following goals:
  - *Maintain Objective Deliverables to CERN as approved in 2019 (10 Q1/Q3 CA, 10 Dressed RFD Cavities)*
  - Increase financial support by ~10% (~25M\$ over 242M\$ baselined in 2019) based on rigorous analysis of EUC and (monetization of) Residual Risks
  - Delay of “DOE” Completion date by approximately ~21 months. Delivery dates to be re-negotiated with CERN
  - Rebaseline Reviews:
    - Director Review next week (*thanks to Oliver for participation !*)
    - DOE Review in early December ‘22

# Progress since last CM on Magnets

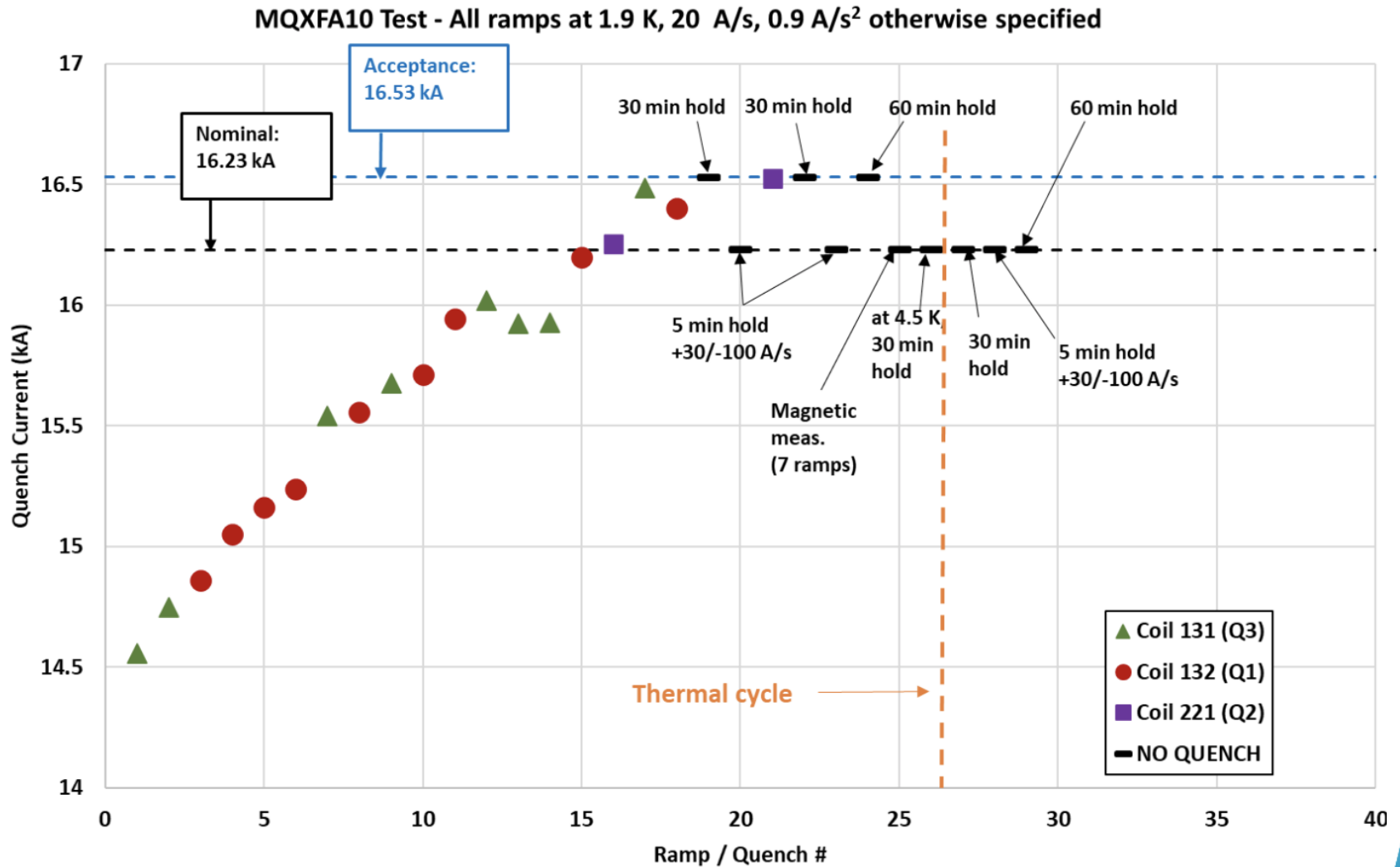
- MQXFA08 did not meet requirements during vertical test. Observed behavior/limitations similar to MQXFA07.
  - Stopped coil/magnet production for ~2-3 months to assess production QA/QC documentation for any major lapse in Quality. None discovered.
  - Autopsy started in earnest in US and, later, in Europe with CERN help. LL on *pole key gaps specifications*, applied from MQXFA10 onward.
- MQXFA09 test prevented by mistake in coil-pack assembly
  - Insulation kapton folded between coils ← Low point of FY22 (~Feb '22)
- To dispel any doubt about resilience of technology (amply demonstrated in the LARP and short model programs), MQXFA05 was subject to an endurance test as specified in the MQXFA FRS.
  - ✓ Successfully passed
- MQXFA10 assembled and tested
  - ✓ Successfully passed BNL Vertical Test
- MQXFA11 assembled and being tested
  - Magnet suffered road accident, but no measurement (electrical, dimensional, visual) performed at FNAL or BNL identified any weakness that would prevent AUP from attempting a cryogenic test.
- MQXFA08b under assembly
  - Limiting coil replaced. Test planned for Dec '22.

# MQXFA05 Endurance Test

- Successfully Completed on 5/27/2022
  - Completion of test made possible by delivery of GHe from FNAL to BNL.



# MQXFA10 Test Completed Successfully



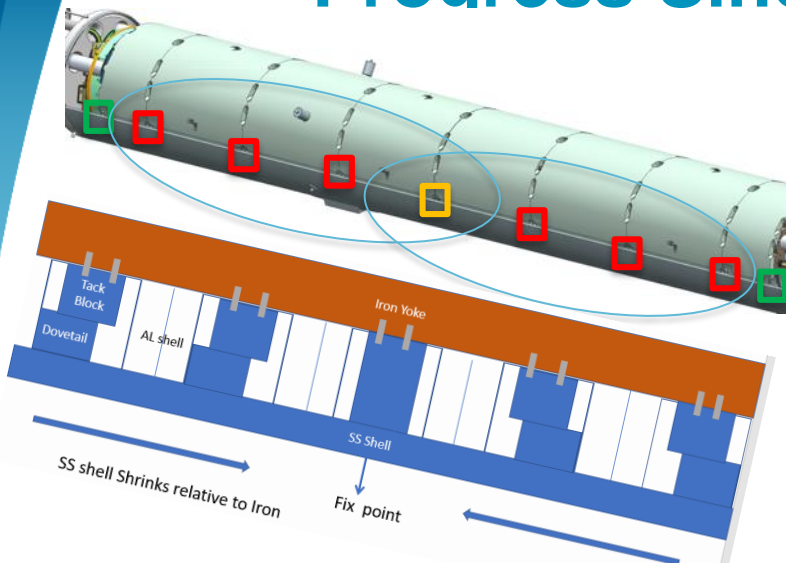
# MQXFA11 truck incident

- The truck transporting the MQXFA11 magnet from LBNL to BNL was rear ended by another truck on 7/20/22.
- The main hit took place on the right back corner. During the incident the truck rear axle disengaged as displayed below.
- The magnet was moved to FNAL on 7/28/22. Upon arrival a visual inspection was performed followed by electrical checkout, metrology survey, analysis of the fiber optic sensors and accelerometer data analysis
  - max shock: 6 or 10 g vertical (depending on the device in the same accelerometer unit)
- All tests and analyses are OK. Magnet is at BNL undergoing Vertical Test



# Progress Since Last CM on CM/CA

T. Vouris in WP3



- 302.4.02 Cold Mass Assembly Fabrication
  - CM-01 requirement modification from "Pressure Wave"
    - Design modification has been addressed
    - Weld completed per ASME. Pressure Vessel notes approved. *Pressure and Leak tested*
  - Q2 bus bar production about to start



Dummy cold mass is inserted

Truck with the Cryostat kit #2

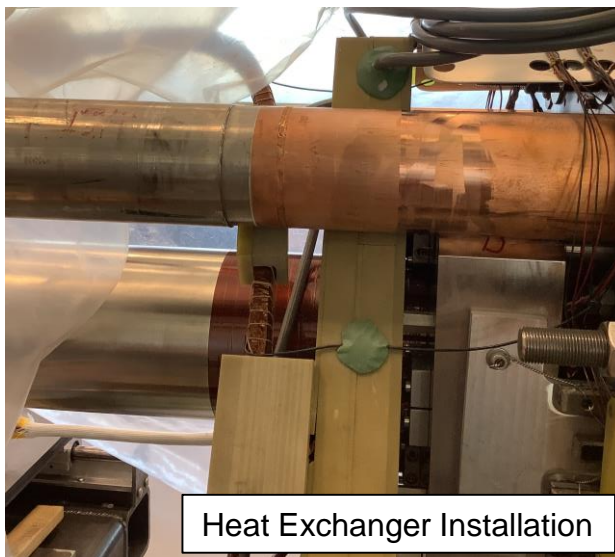
Quench Line modification



- 302.4.03 Cryo-Assemblies Fabrication
  - Dummy Cold mass insertion performed
  - Visit by CERN expert (M. Struik) facilitated first real Cold Mass insertion (*thanks !*). IFS visit next.
  - Several kits in house or in transit.
- 302.4.04 Cryo-assemblies Horizontal Test
  - Ready to accept CA01 !

# LMQXFA01 Assembly

- Alignment/Shell Welding of LMQXFA-01



# LMQXF01 Insertion in Cryostat

- August 31, 2022: first insertion of an AUP HL LHC cold mass into a vacuum vessel





# Crab Cavities - Achievements since early 2021

- Completed 2 prototype cavities
- Resolved PRR recommendations and started fabrication of 2 pre-series cavities
- Placed order and started fabrication of 2 Helium tank prototypes
- Placed order for 10 series cavities
- Successful cold tests of 2 Prototypes
- Completion of RF Ancillaries Prototypes
- Failed attempt on 1<sup>st</sup> cold test of RF Ancillaries
- Held PRR for RF Ancillaries

# Status of Pre-Series Cavities at Zanon



End Cap



H-HOM & V-HOM waveguides



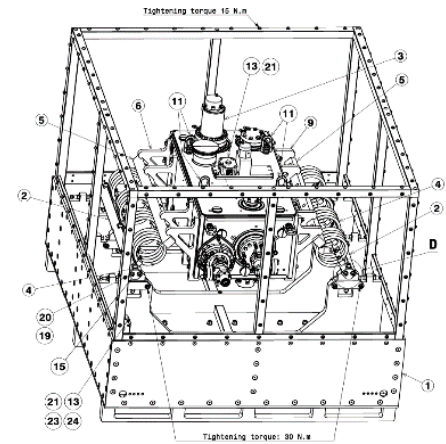
Half Main Body



FPC waveguides

# Q1/Q3 CryoAssemblies and RFD Cavities Transportation

- Completed visit and road-test of shipping frame with dummy load at Emmert (TX). Analysis OK
- Initiating dummy load test shipment to CERN, full analysis to follow.
- Adopting proven CERN shipping frame design for shipping AUP RFD cavities to TRIUMPF
- Frame design was used to successfully transport two CERN RFD cavities to UK (Daresbury Lab) in 2021



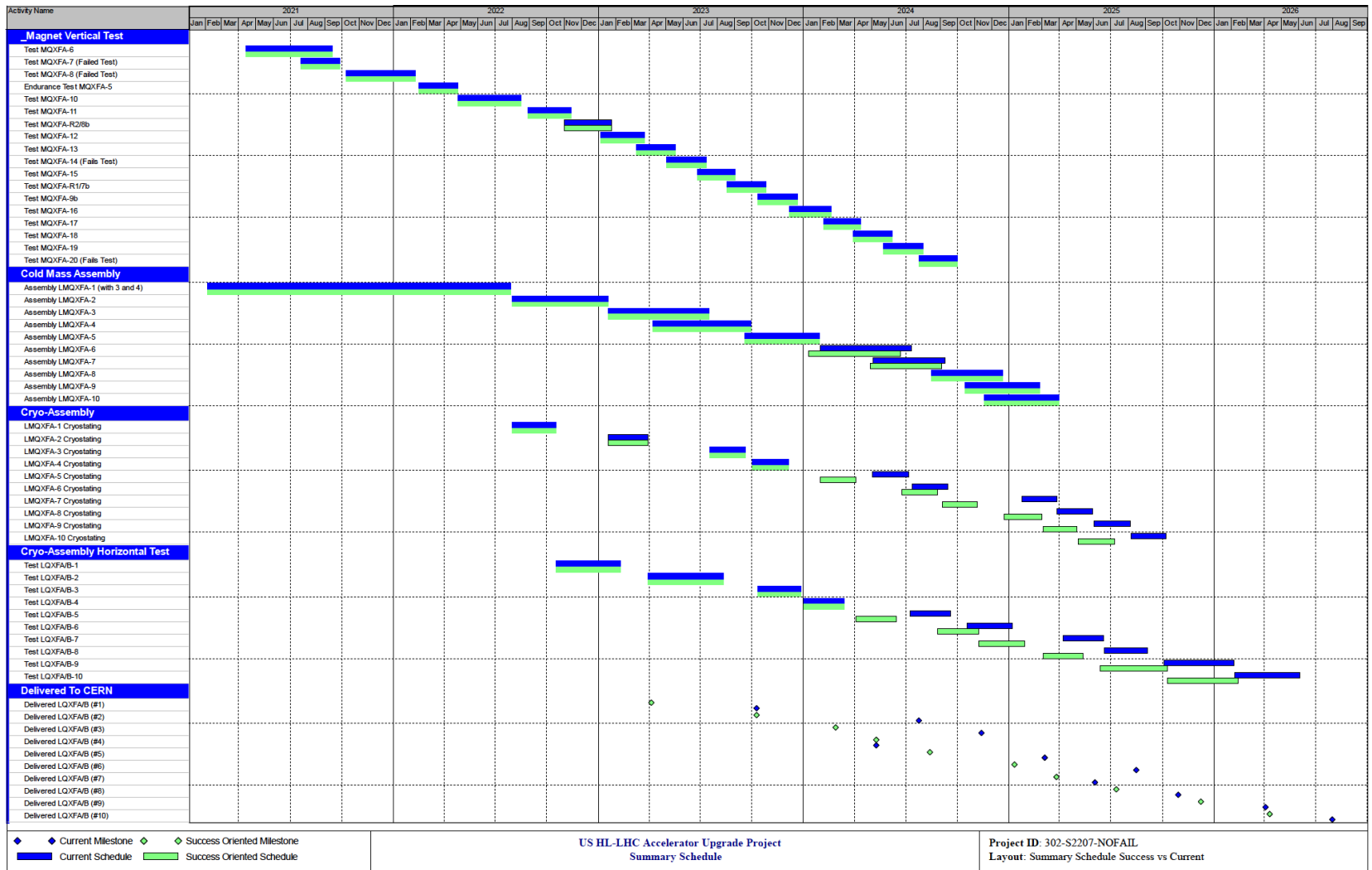
# Delivery Dates to CERN

|                   | (To Be) Agreed Early Delivery Date |  |  |  |  |  | (To Be) Agreed Late Delivery Date |
|-------------------|------------------------------------|--|--|--|--|--|-----------------------------------|
| Q1/Q3 Delivery 01 | Oct-23                             |  |  |  |  |  | Sep-24                            |
| Q1/Q3 Delivery 02 | May-24                             |  |  |  |  |  | Apr-25                            |
| Q1/Q3 Delivery 03 | Jul-24                             |  |  |  |  |  | Jun-25                            |
| Q1/Q3 Delivery 04 | Nov-24                             |  |  |  |  |  | Oct-25                            |
| Q1/Q3 Delivery 05 | Mar-25                             |  |  |  |  |  | Feb-26                            |
| Q1/Q3 Delivery 06 | Jun-25                             |  |  |  |  |  | May-26                            |
| Q1/Q3 Delivery 07 | Aug-25                             |  |  |  |  |  | Jul-26                            |
| Q1/Q3 Delivery 08 | Oct-25                             |  |  |  |  |  | Sep-26                            |
| Q1/Q3 Delivery 09 | Apr-26                             |  |  |  |  |  | Mar-27                            |
| Q1/Q3 Delivery 10 | Jul-26                             |  |  |  |  |  | Jun-27                            |
|                   |                                    |  |  |  |  |  |                                   |
|                   |                                    |  |  |  |  |  |                                   |
|                   | (To Be) Agreed Early Delivery Date |  |  |  |  |  | (To Be) Agreed Late Delivery Date |
| Cavities 01 & 02  | Mar-24                             |  |  |  |  |  | Feb-25                            |
| Cavities 03 & 04  | Jun-24                             |  |  |  |  |  | May-25                            |
| Cavities 05 & 06  | Jul-24                             |  |  |  |  |  | Jun-25                            |
| Cavities 07 & 08  | Sep-24                             |  |  |  |  |  | Aug-25                            |
| Cavities 09 & 10  | Oct-24                             |  |  |  |  |  | Sep-25                            |

*1 cell = 1 month*

- CERN-FNAL MOU Dates to be agreed upon with CERN prior to DOE Rebaseline Review in Dec. '22

# Magnets/CM/CA Activities



# Conclusions

- AUP is ~2/3 complete
- Steady progress on MQXF Construction
  - 5 magnets passed vertical test, 2 more in progress now
- Slow starting on LMQXF and Q1/Q3 construction due to specification changes following MQXFBP1/P2 experience and FRS changes.
  - CA01 in final stages of completion. Horizontal test coming up.
- RFD Crab Cavities series cavities order placed. Pre-production cavities under fabrication.
- AUP will need a *rebaseline* (or *budget infusion*, in CERN jargon) to address COVID/Abnormal Escalation impacts. Planned for late CY2022.