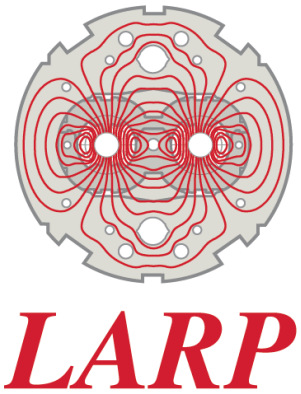


Status of LARP

G. Apollinari, G. Ambrosio, R. Carcagno, FNAL
G. Sabbi, LBNL

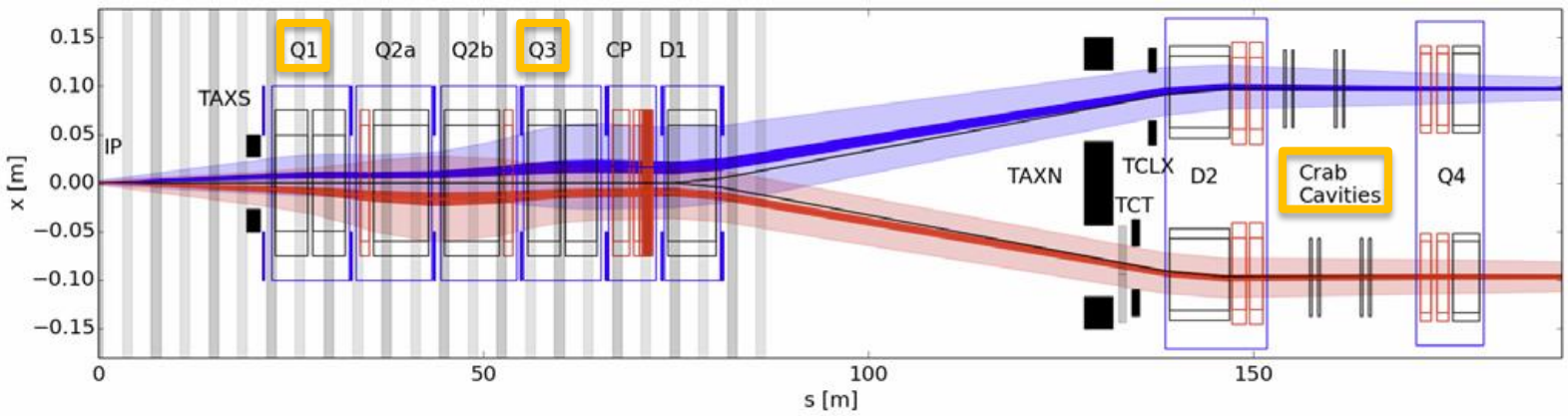
US LHC User Association Annual Meeting 2016
LBNL, November 2-4, 2016

LARP & HL-LHC Accelerator Upgrade Project

- The LHC Accelerator Research Program – LARP – was created to explore advanced technology for future upgrades to the LHC.
  - Started in ~2004 with focus on Nb_3Sn Magnets and Accelerator system Research (CC, Rotatable Collimators, e-lens, WBFS, etc)
  - Run since FY14 with clear Risk Reduction mandate to minimize the technical risk for possible US contributions to HL-LHC.
- DOE plans to contribute to the HL-LHC upgrade through a *Project* called HL-LHC Accelerator Upgrade Project
  - Governed by DOE Order 413.3B which applies to capital assets projects having a Total Project Cost greater than or equal to $50M
- A Properly managed handshaking between LARP and HL-LHC AUP will be a major element of the future success of the US contribution to HL-LHC.

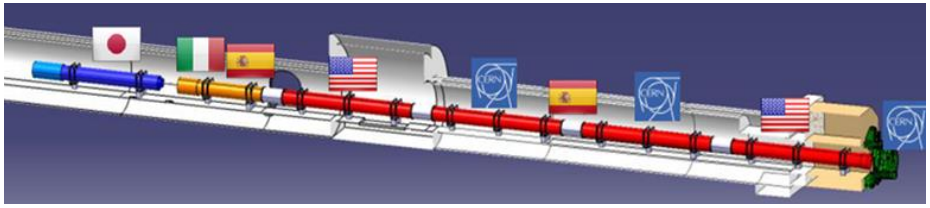
Proposed U.S. contributions to HL-LHC

Insertion Region layout from the IP to Q4



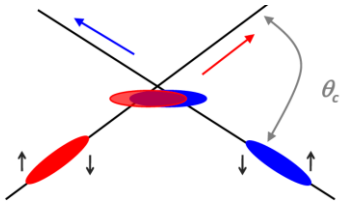
Large Aperture IR Quadrupoles:

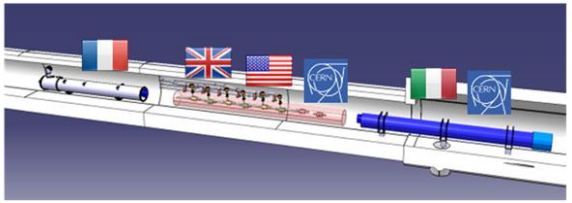
- *From 70 mm MQXA/B to 150 mm MQXF*
- *From NbTi to Nb_3Sn for higher field/gradient*
- *Minimum β^* from 0.55 m to 0.15 m*
- *Compatible with 10x integrated luminosity*



Crab cavities:

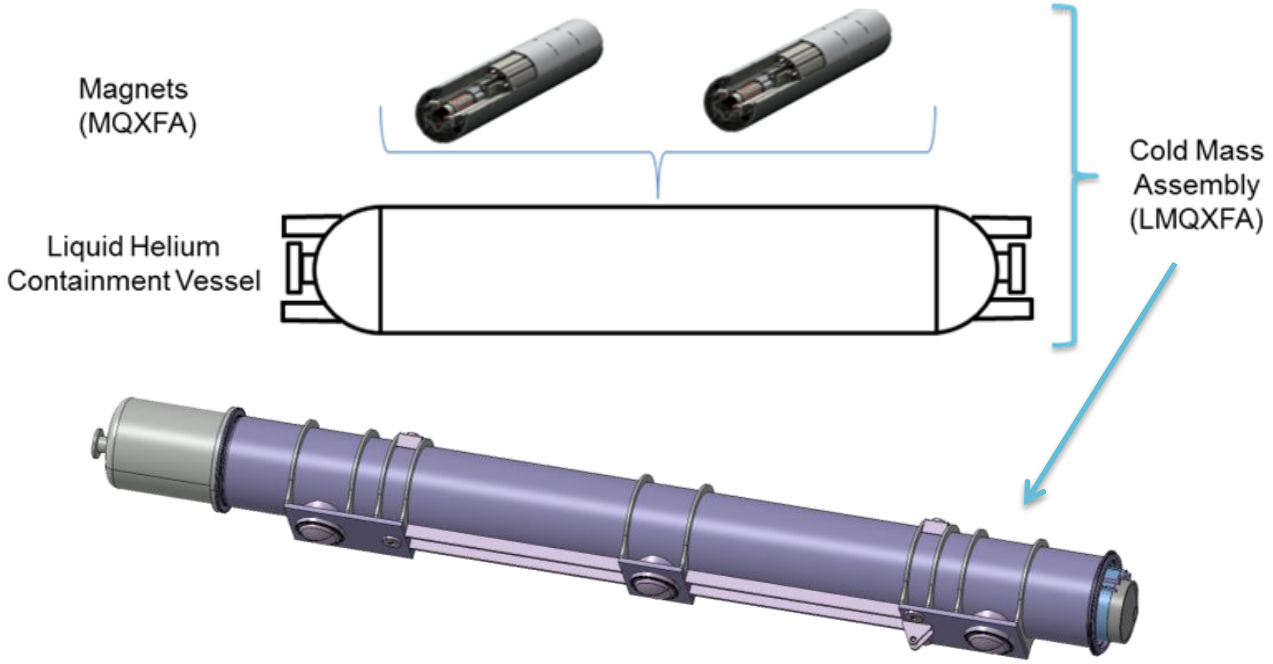
- *Deflect bunch at IP to collide head-on*
- *Restore luminosity loss due to crossing angle*
- *Requires compact superconducting cavities*





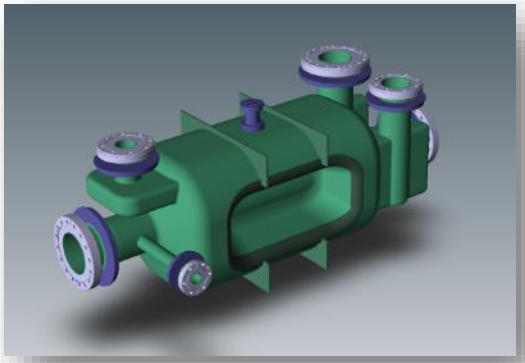
U.S. IR Quadrupoles Scope for HL-LHC

- **Five Q1 and five Q3 Cryostated Magnets**
  - 50% of total IR Quads required (CERN provides Q2s)
  - Includes 1 spare of each (8 for tunnel + 2 spares)
    - Q1 and Q3 cold masses are expected to be ~identical
  - Q1/Q3 magnetic length = 4.2+4.2 m
  - Cryostats from CERN as “assembly kits”



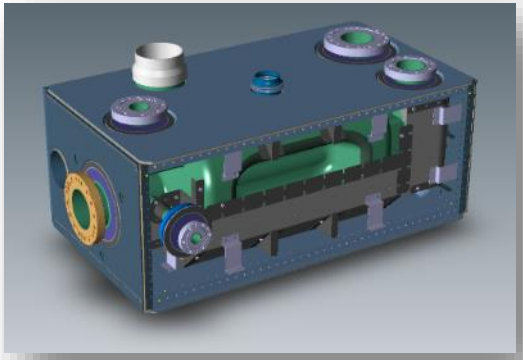
U.S. Crab Cavities Scope for HL-LHC

- **Ten Dressed RFD Crab Cavities**
  - 50% of total required (CERN provides the other 50%)
  - Includes 2 spares (8 for tunnel + 2 spares)
  - Note that the U.S. definition of “dressed” cavity does not include Power Coupler or other elements



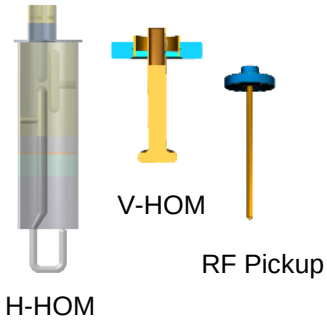
Bare RFD Cavity

Includes:
- Nb Cavity
- Brazed joints to SS flanges
- NbTi Adapter Rings



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

Includes:
- Bare Cavity
- Magnetic Shield
- Helium Tank



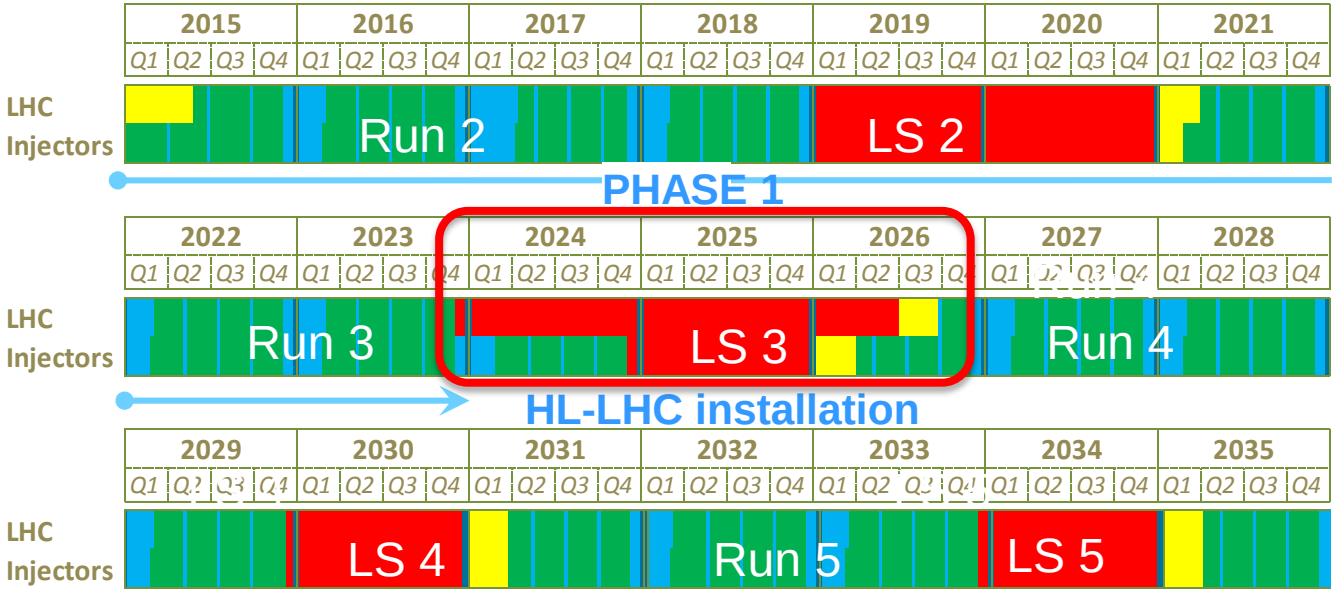
RF Ancillaries

Dressed RFD Cavity

Includes:
- Jacketed Cavity
- RF Ancillaries (H and V HOMs, RF Pick-up)

Schedule

- U.S. Deliverables must support LHC tunnel installation during CERN's "Long Shutdown 3" (LS3) in 2024-2026
- The last U.S. deliverable *for tunnel installation* must be at CERN by the mid of CY2024 at the latest to give enough time for CERN to execute their scope prior to tunnel installation

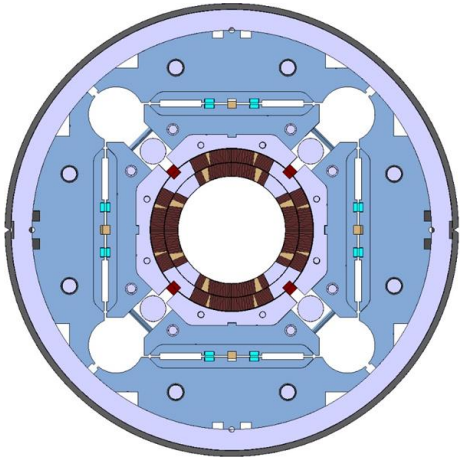


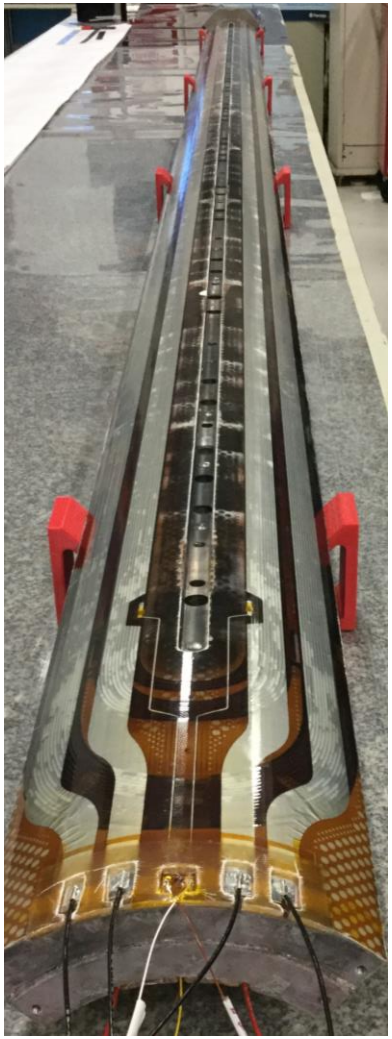
HL-LHC AUP / LARP Handshaking

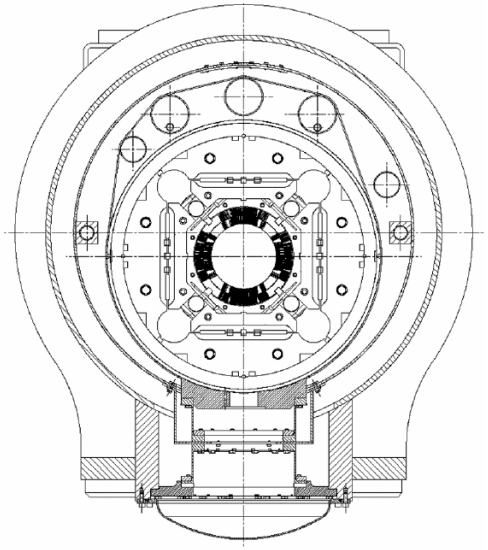
- The US HL-LHC AUP project scope is restricted to series production of US deliverables
  - No R&D, no prototypes
  - Project cost estimate is based on this assumption
- LARP scope is now primarily demonstration and risk reduction for the project, including the specification, design, fabrication, and test of HL-LHC tunnel-ready prototypes
  - LARP activities must demonstrate series production readiness of US deliverables to HL-LHC
  - This assumption needs to be supported by adequate LARP funding in FY18-20 (amounts requested, but no DOE guidance provided yet)

MQXF Quadrupole Parameters and Design

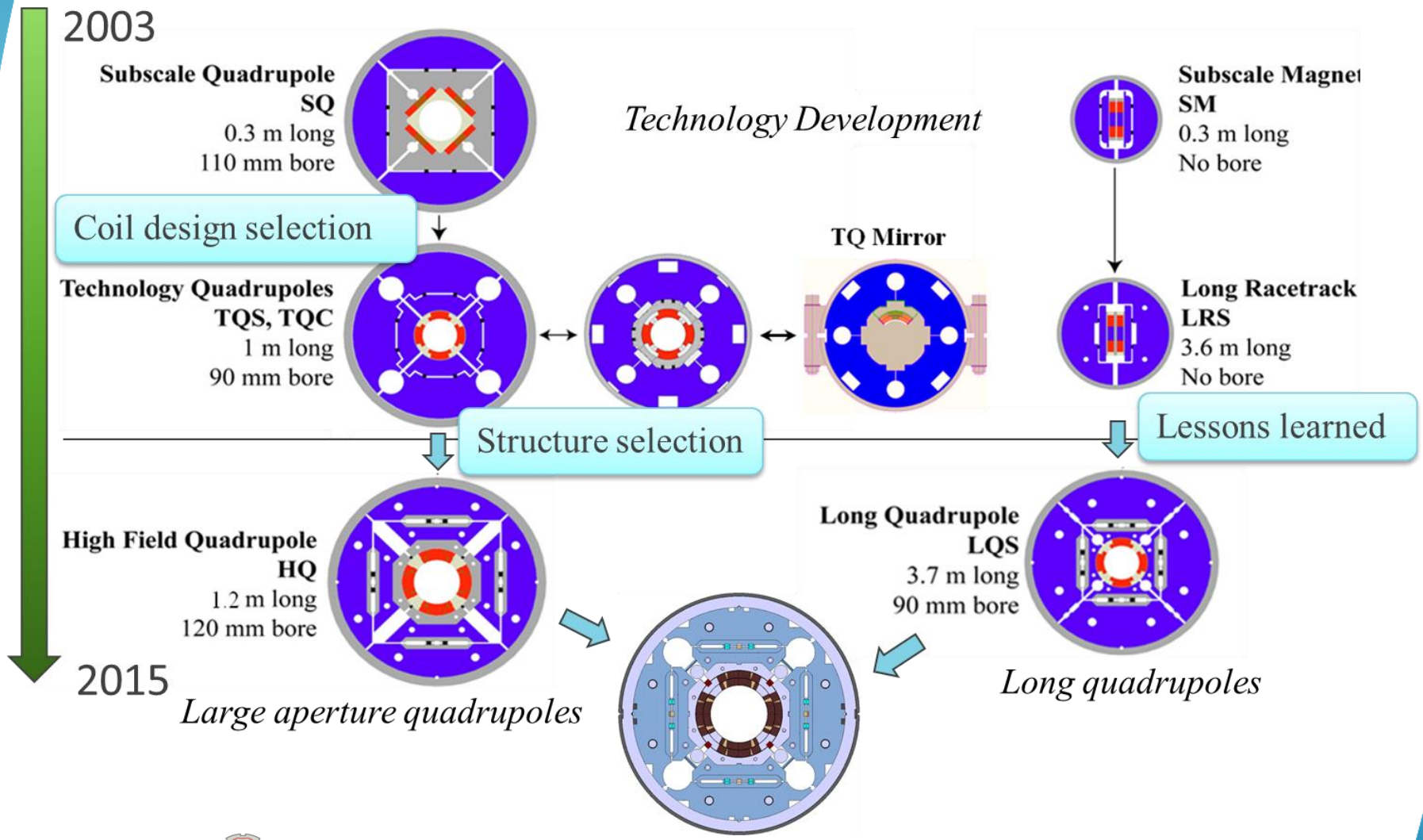
Parameter	Unit	MQXFA/B
Coil aperture	mm	150
Magnetic length	m	4.2/7.15
N. of layers		2
N. of turns Inner-Outer layer		22-28
Operation temperature	K	1.9
Nominal gradient	T/m	132.6
Nominal current	kA	16.5
Peak field at nom. current	T	11.4
Stored energy at nom. curr.	MJ/m	1.2
Diff. inductance	mH/m	8.2







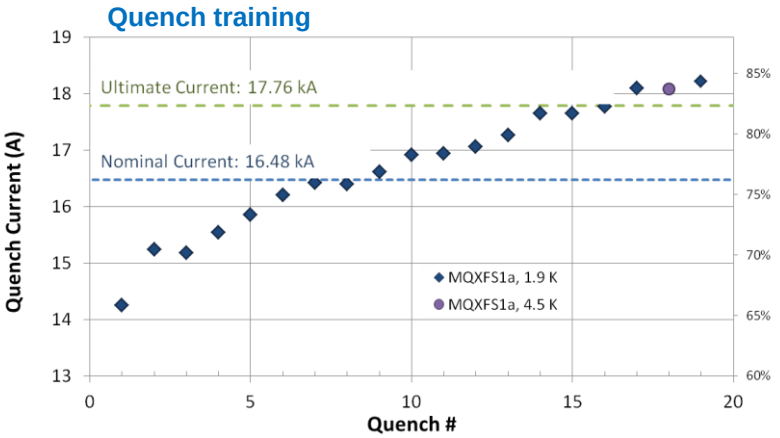
MQXF is based on LARP Nb_3Sn Development

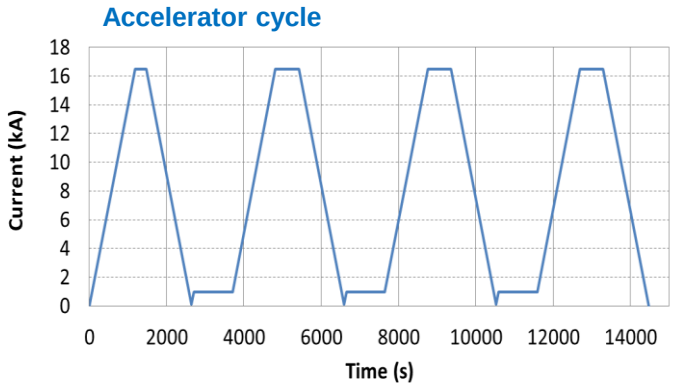


MQXFS1 Short Model Test Results

Demonstrated quench performance well above LHC requirements:

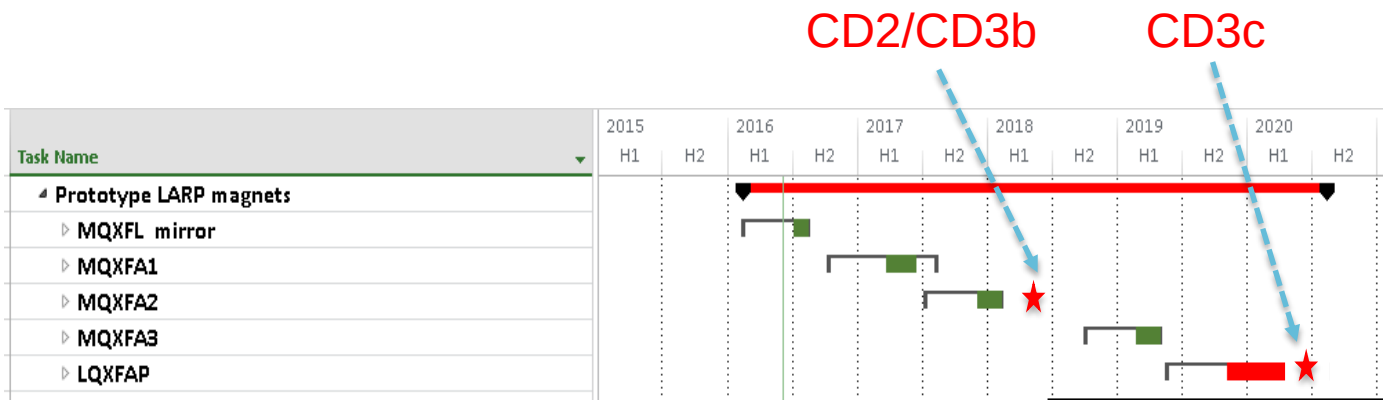
- Surpassed I.nom after 8 quenches and I.ult after 16 quenches
  - Highest quench: 18.1 kA, 145 T/m, B_{max} 12.5 T, 84.2% of SSL
- Retained the highest quench level at 4.5 K, achieving 92.6% of short sample limit
- First quench after thermal cycle was at maximum level achieved during first TC
- Several accelerator cycles including pre-cycle and 2-3 ramps to I.nom or I.ult were performed during both TC1 and TC2
- Capability of maintain I.nom and I.ult over an extended period of time was demonstrated in both thermal cycles
- Additional short model tests are currently underway at FNAL and CERN



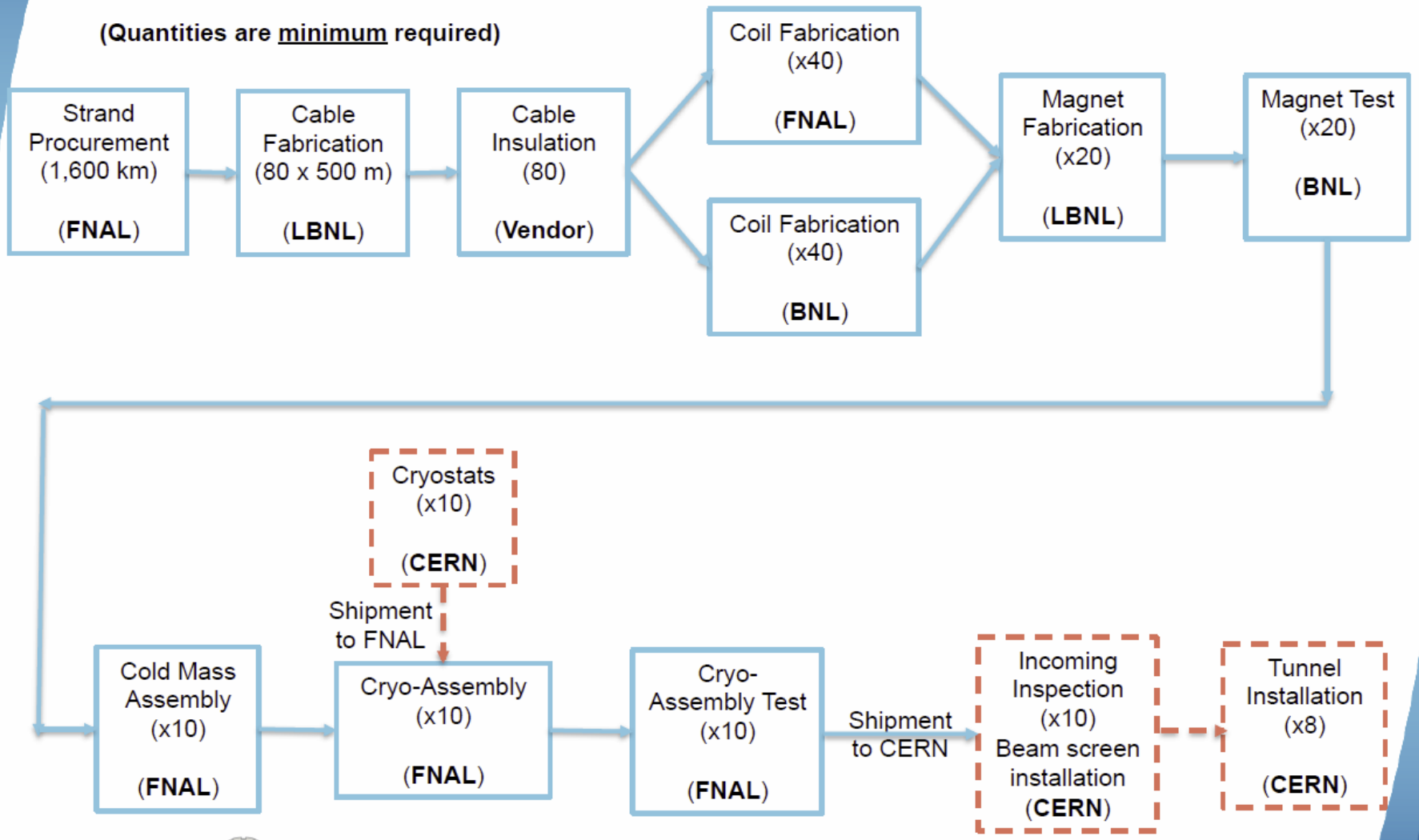


MQXF Long Prototypes

- 4m coil in mirror magnet is under test
- First prototype magnet test in spring 2017
  - 4 m coils: one 1st gen + three 2nd gen coils
- Second prototype magnet test in 2017-2018
  - 4.2 m coils: all 2nd gen coils (first tunnel ready MQXF)
- Third prototype magnet test in early 2019
  - 4.2 m coils, 1st structure with thin laminations
- First prototype cold mass test in early 2020



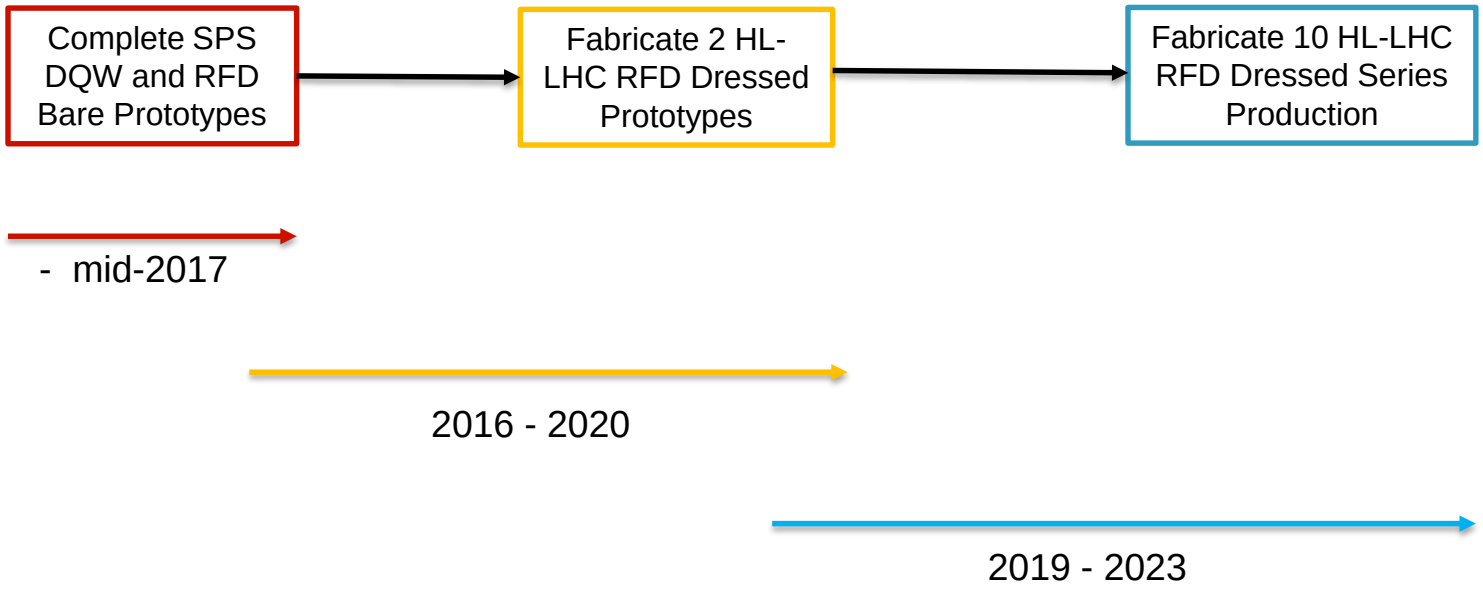
Q1, Q3 Manufacturing Flow Plan



U.S. Roadmap to HL-LHC Cavities

Roadmap:

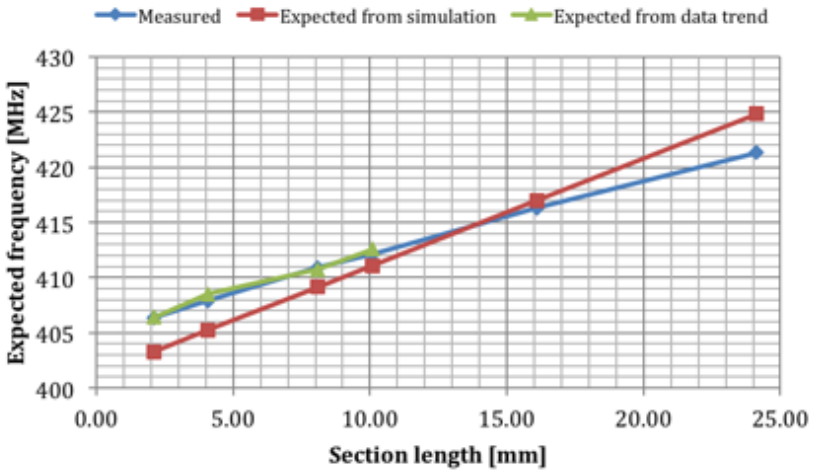
1. Complete the SPS DQW and RFD Bare Prototypes
2. Fabricate 2 HL-LHC RFD Dressed Prototypes
3. Fabricate 10 HL-LHC Dressed RFD Series



U.S. SPS Prototypes

- Two bare RFD SPS Prototypes and two bare DQW SPS Prototypes under construction mainly by Niowave/Jlab/ODU/BNL and near completion
- Providing valuable experience and “lessons learned” for the production of HL-LHC DQW and RFD cavities at both CERN and the U.S.
- Final prototypes for installation in SPS will be fabricated by CERN

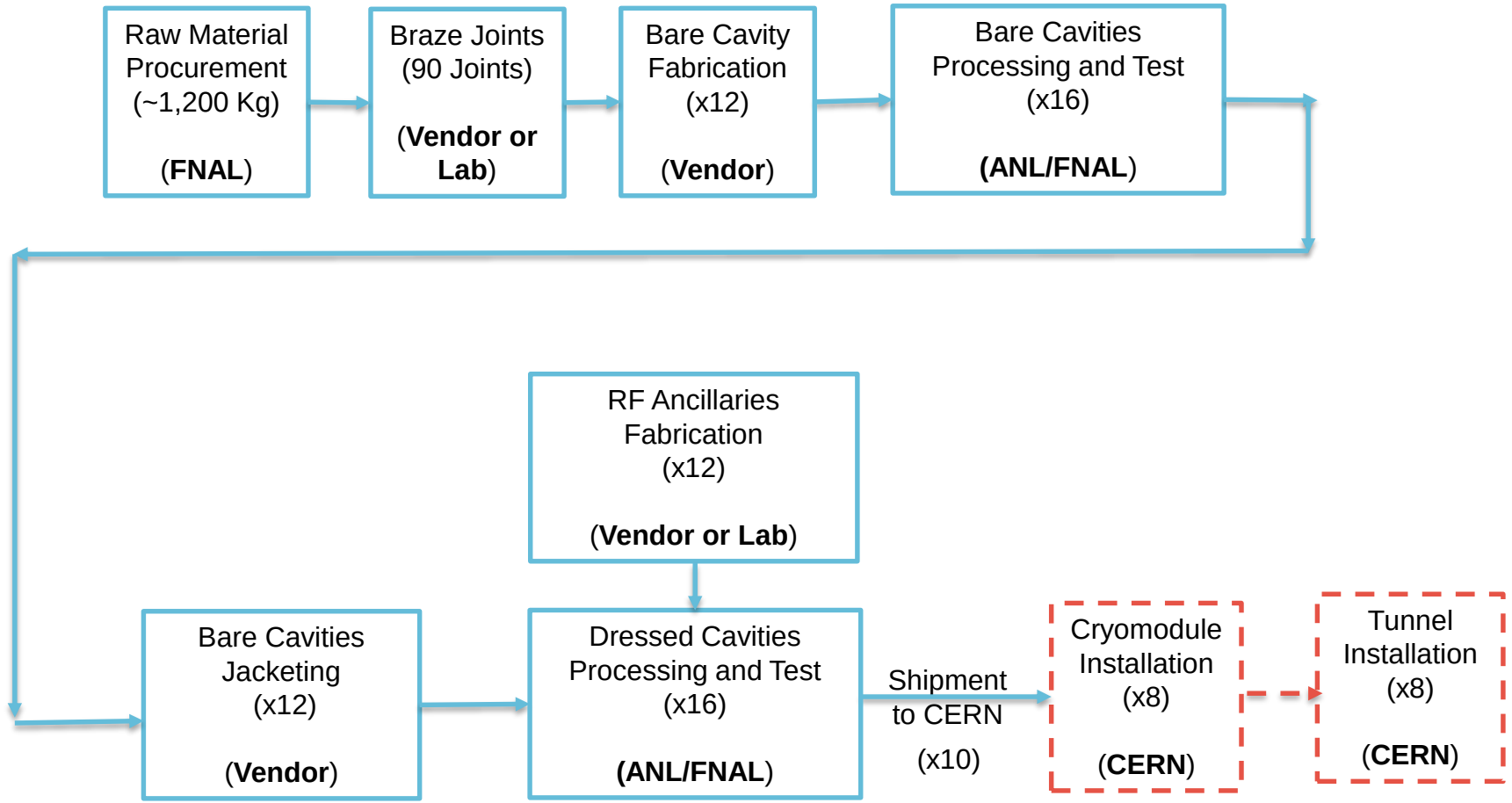
DQW Cavity



DQW Cavity

RFD Cavity

RFD Production Manufacturing Flow Plan



Summary

- Progress being made on several fronts for full approval of HL-LHC AUP in US
  - Coordinated approach between CERN and US on technical and organizational activities for HL-LHC
  - HL-LHC AUP preliminary integrated schedule satisfy DOE funding profile and CERN delivery dates requirements
  - Excellent results from initial prototypes confirm the main design choices and performance targets
- Current priorities:
  - Ensure proper HL-LHC AUP/LARP handshaking on magnets and crab cavities in FY18-20.
  - Improve project funding profile to allow creation of schedule float
  - Development and formal approval of functional requirements and interface specifications for Q1/Q3 and RFDs cavities