MQXF Status and Plans

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CERN
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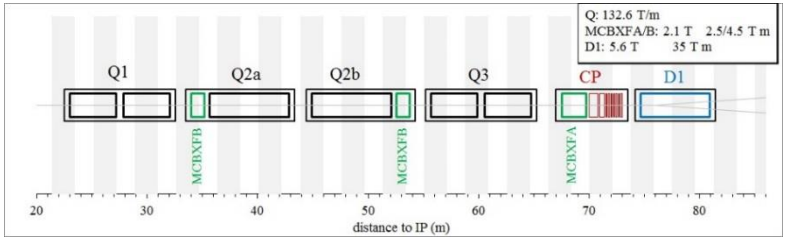
  - T. Salmi

Outline

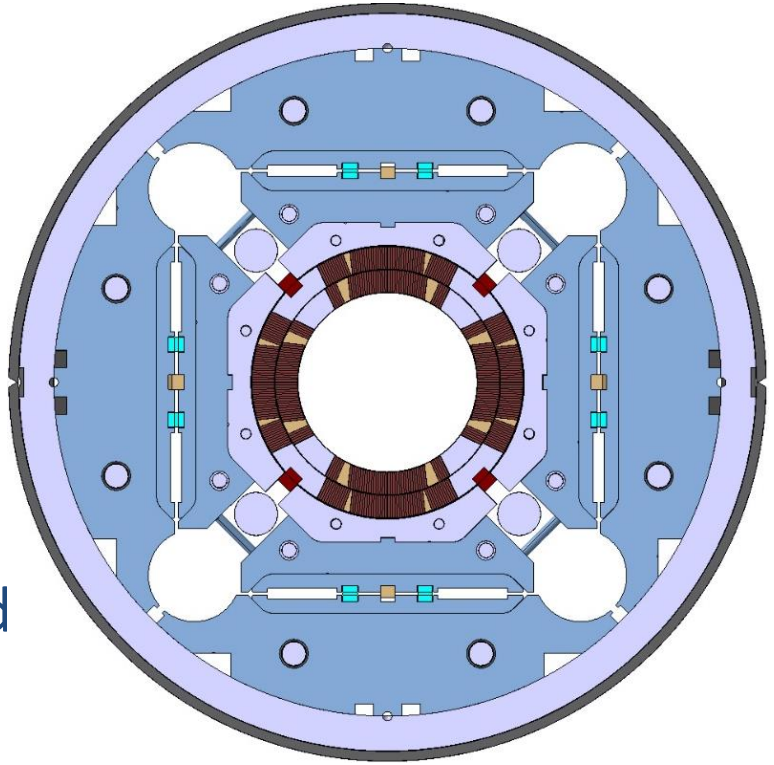
- Overview
- Short model program
- Prototype program
- Series production

Introduction
HiLumi low-β quadrupole

- Target: 132.6 T/m
  - 150 mm coil aperture, 11.4 T B_{peak}



- Q1/Q3 (by US-HiLumi Project)
  - 2 magnets MQXFA with 4.2 m
- Q2a/Q2b (by CERN)
  - 1 magnet MQXFB with 7.15 m
- Different lengths, same design



- Short model phase in progress
  - From 1st to 2nd generation design
- Long prototype fabrication started

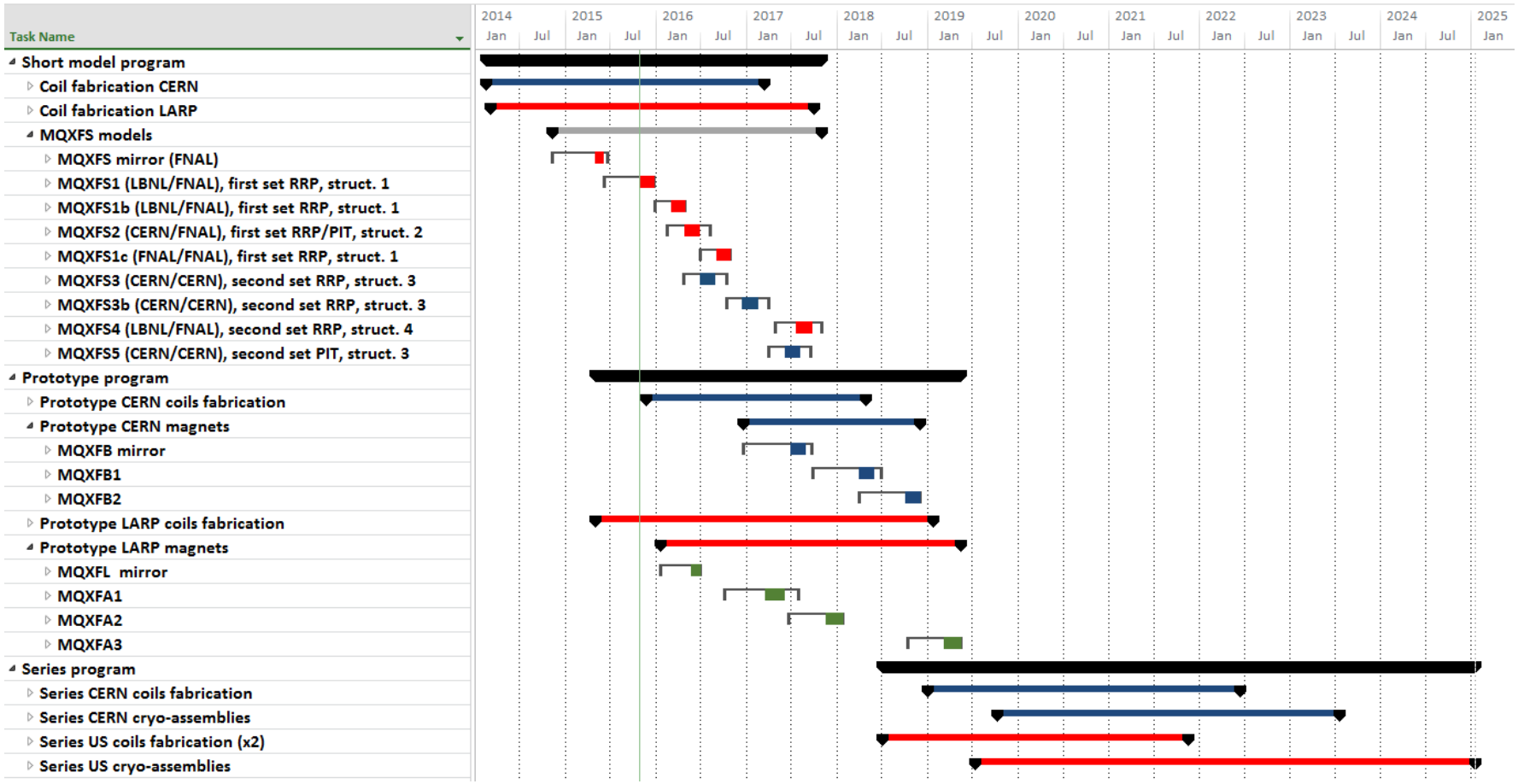
MQXF project schedule overview

- **2014-2017**
- Short model program: *5 CERN-LARP models*
  - First single coil test in May 2015
  - First magnet test in November 2015
    - 2 LARP coils, 2 CERN coils

- **2015-2019**
- Prototype program: *2 (CERN) + 3 (LARP) prototypes*,
  - Coil fabrication starts in 06/2015 (LARP) and 01/2016 (CERN)
  - First single coil test in April/May 2016
  - First magnet test in 03/2017 (LARP) and 03/2018 (CERN)

- **2018-2024**
- Series production: *10 (CERN) + 10 (LARP) cold masses*
  - Coil fabrication starts in 07/2018 (LARP) and 01/2019 (CERN)
  - First magnet test in late 2020

MQXF project schedule overview



Outline

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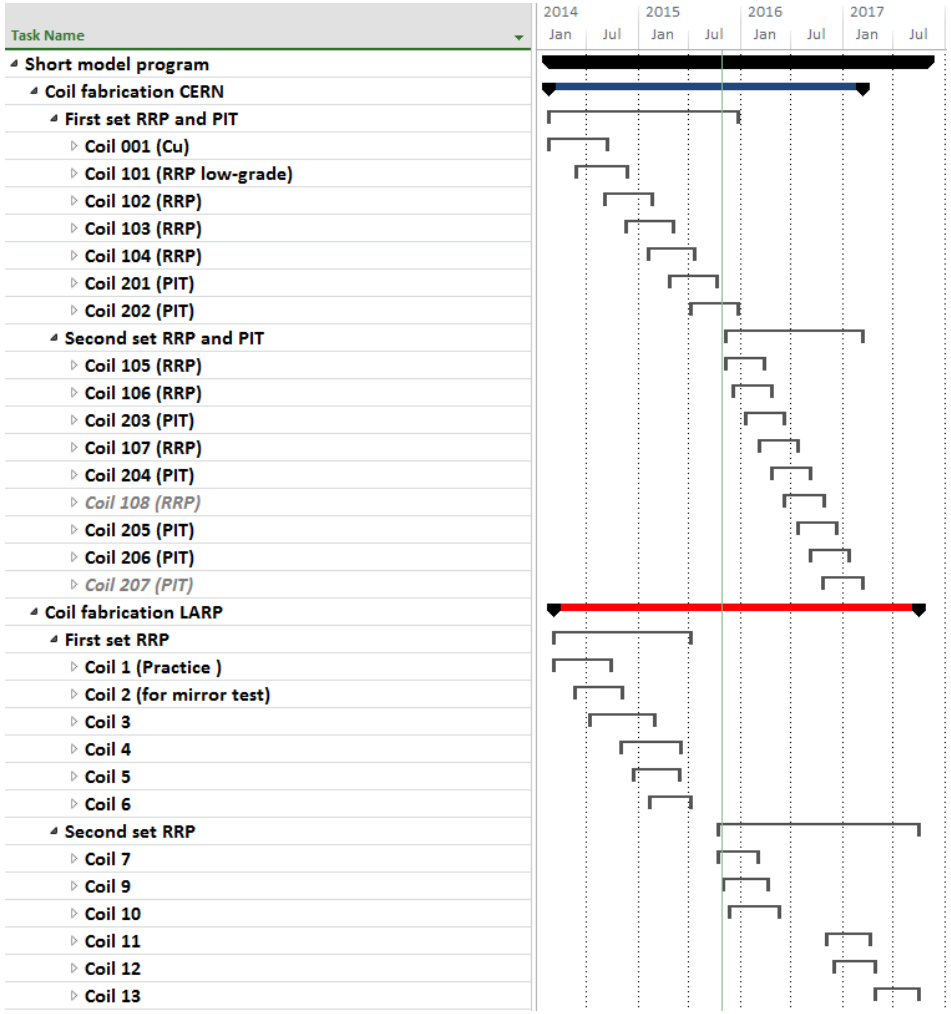
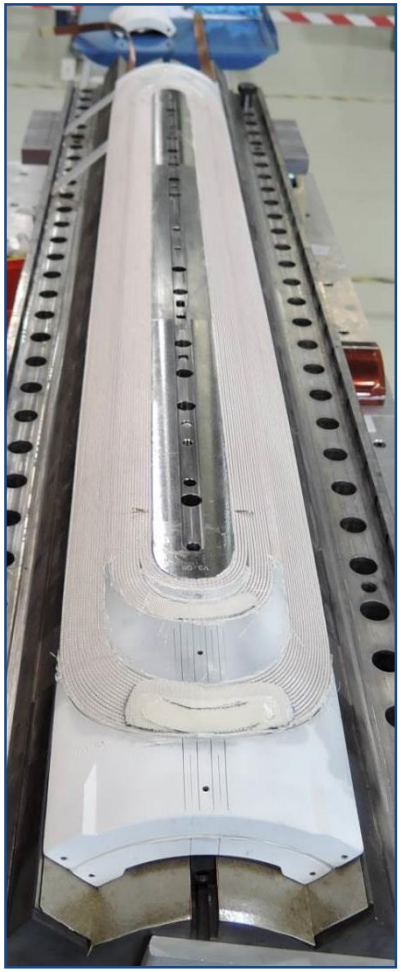
- Prototype program
- Series production

Short model program
First generation coil fabrication



- 13 first generation coils fabricated
  - **001** Cu coil
  - 2 cut coils: **101**, **1**
  - Coil **4** used for tooling improvement
- 9 "good" coils
  - **3**, **5**, **103**, **104** in first test
    - Assembly incident
  - **2**, **6**, **102**, **201**, **202**
    - Splice problem in 102
- 2 models (MQXFS1-2), unless major issues from incident

Short model program
First generation coil fabrication



After winding/curing

After reaction

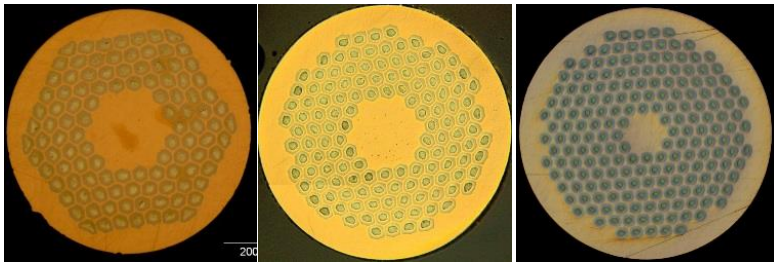
After impregnation

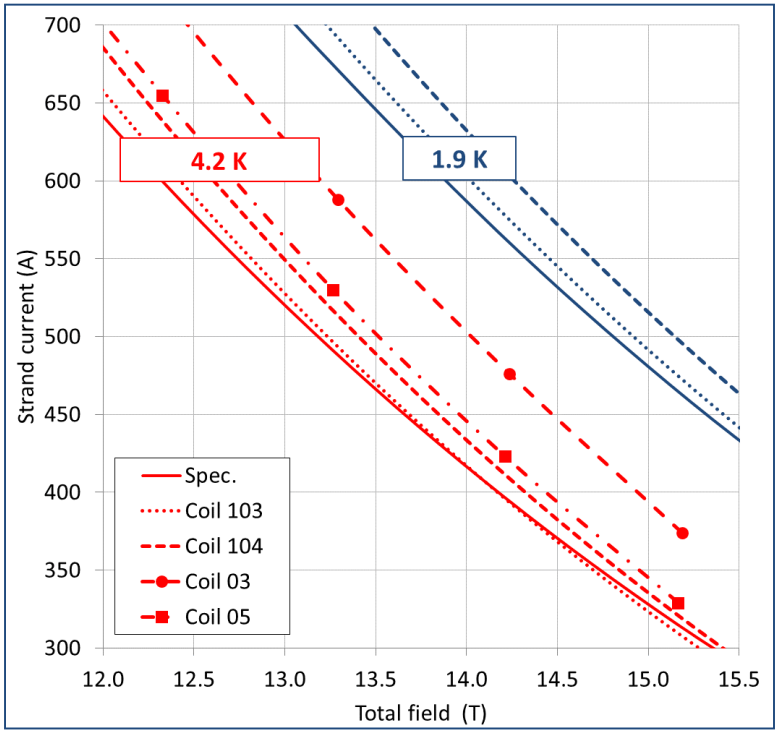
Short model program
Superconducting strand

- 0.85 mm strand, 1.2 Cu/SC
- Non-Cu J_c at 4.2 K
  - 2450 A/mm^2 at 12 T
  - 1280 A/mm^2 at 15 T
- Filament $\varnothing \leq 55$ µm

- 3 strands used for short model
  - OST RRP 108/127, 132/169
  - EAS Bruker PIT 192
- RRP meets spec.
  - PIT still 5% less J_c, but only at 12 T

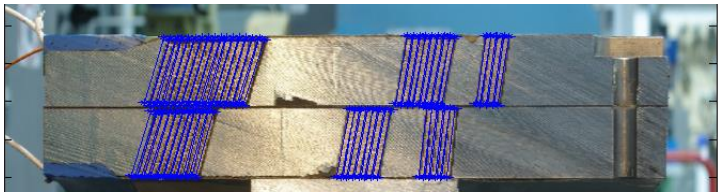
- 108/127 and PIT selected for the long prototypes

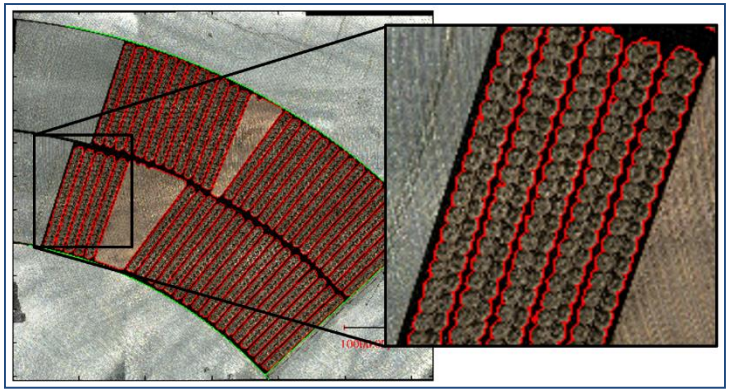


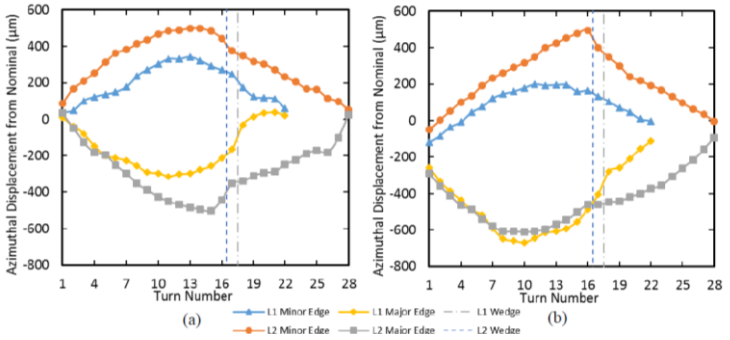


Short model program
First generation coil fabrication

- Good fit of end-spacers
- But, up to 0.5 mm azimuthal and radial shift in straight section
  - Large cavity during reaction
- Smooth fabrication process
- Good electrical performance
- Azimuthal size
  - LARP 50 µm bigger, CERN 50 µm smaller
  - Left-right asymmetry 50-100 µm

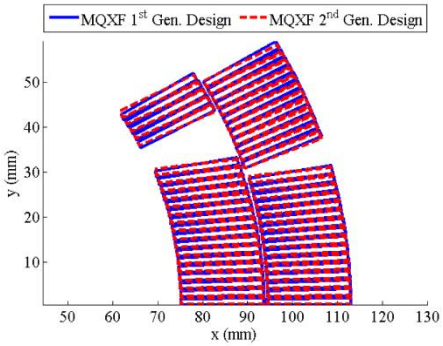


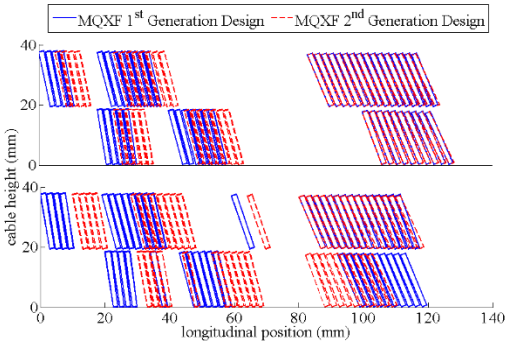




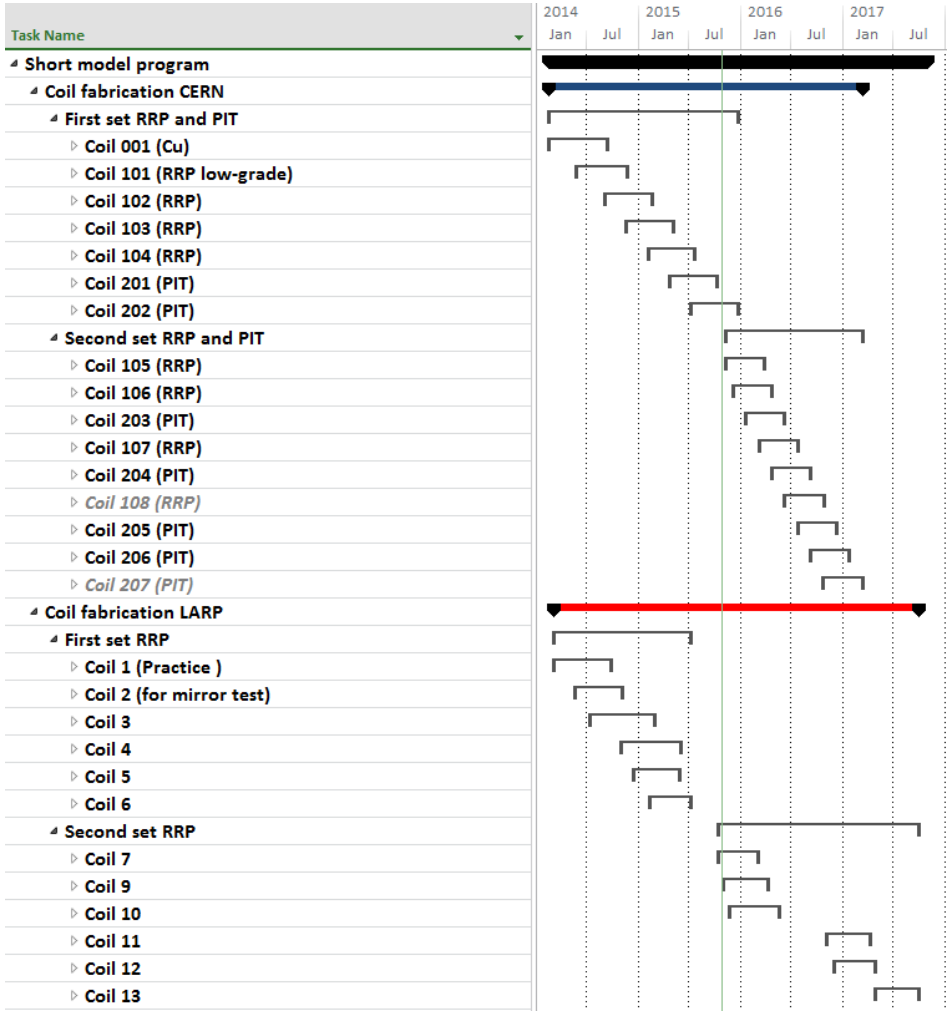
Short model program
2nd generation coil design and fabrication

- New coil design to account for
  - New cable geometry
    - New keystone angle
  - Field quality
    1. Radial cable expansion from 2% to 1%
    2. Insulation thickness from 0.150 to 0.145 mm
    3. Correct the impact of coil mechanical deformation
    4. Optimize harmonics at 123 T/m
       1. mid-value between 90% and 100% of the nominal G
    5. Add S2-glass shims on mid-plane and pole region to control field quality during production,
    6. Compensate for the end effects on the integrated harmonics (in combination with minor changes in the end-spacers' design)
- Review of different insulation layer thickness



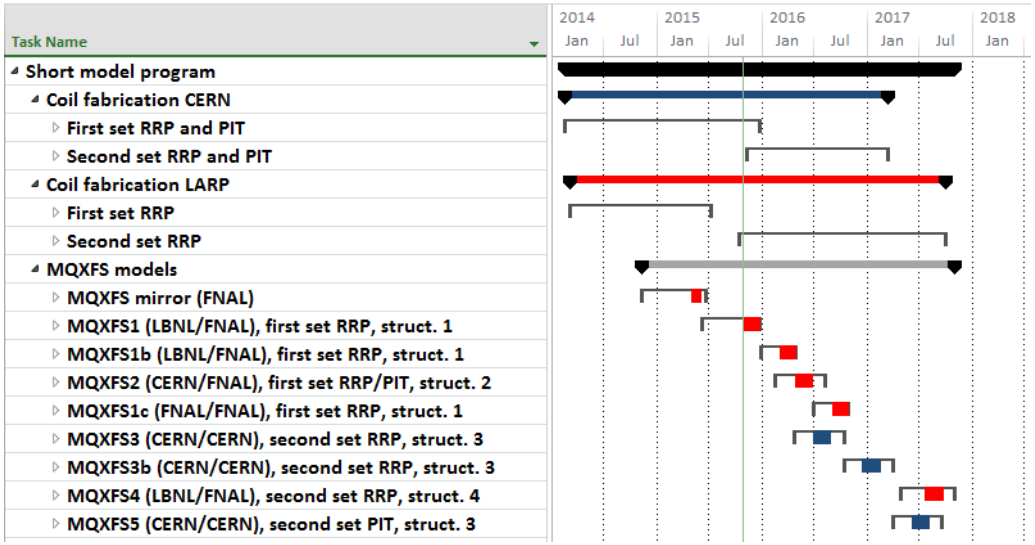


Short model program
Second generation coil fabrication



- 15 2nd generation coils to be fabricated
  - RRP: **4**+**6**=10
  - PIT: **5**
- Fabrication just/almost started
  - About 7-8 months after new cable geometry fixed
- 3 models
  - MQXFS3-4-5

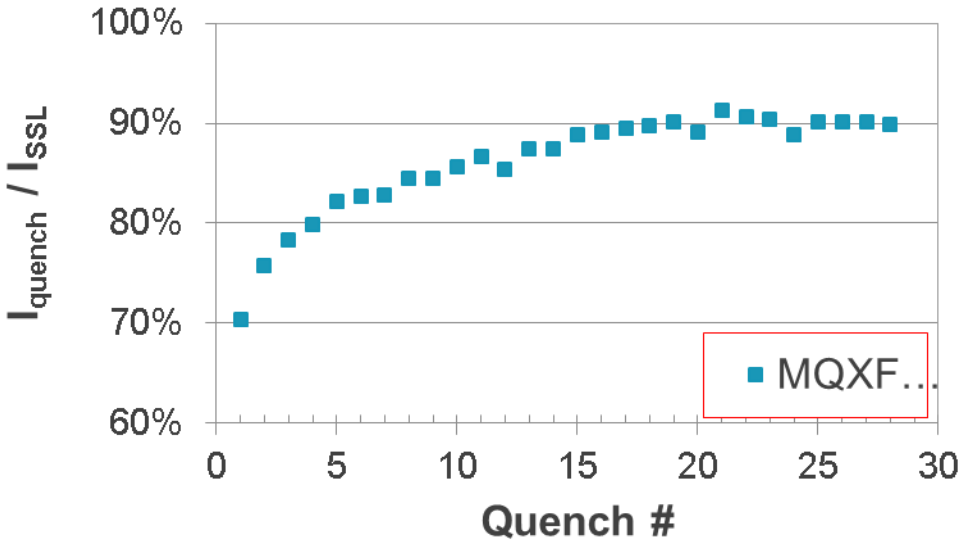
Short model program
Assemblies and tests



- Single coil test done in 05/15
- MQXFS1, assembly test, (LBNL/FNAL): test of I gen. coils
- MQXFS1b (LBNL/FNAL): Increase of pre-load
- MQXFS2 (CERN/FNAL): test additional I generation coils + PIT
- MQXFS1c (FNAL/FNAL): Lhe vessel
- MQXFS3 (CERN/CERN): test second generation RRP and laminated structure
- MQXFS3b (CERN/CERN): change pre-load or coils
- MQXFS4 (LBNL/FNAL): test second generation RRP (reproducibility)
- MQXFS5 (CERN/CERN): test second generation PIT

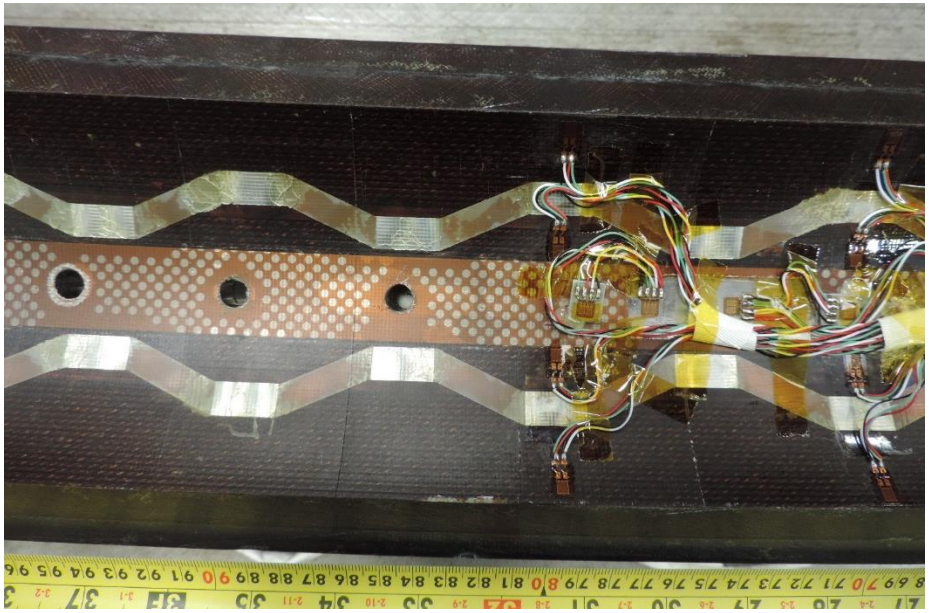
Short model program
Single coil test

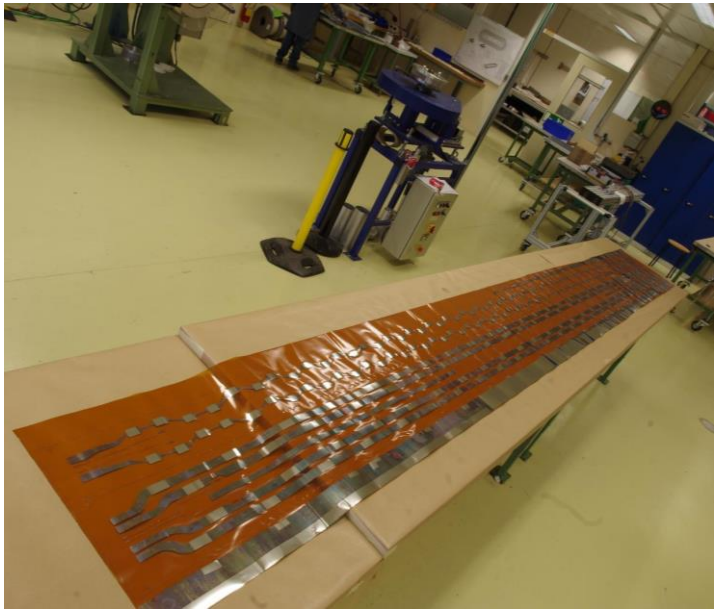
- First short coil tested in mirror
  - 91% of current limits



Short model program
Single coil test

- Good results from perforated trace



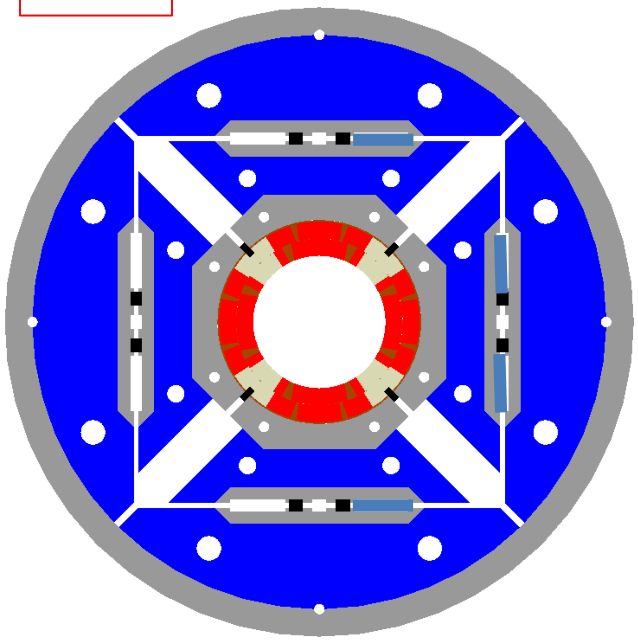


- 1st perforated long trace delivered to CERN today

Short model program
Feed-back from HQ tests

- Excellent training performance
- Magnetic shimming
  - Excellent agreement computations/meas.
  - Not enough to correct HQ non-allowed harmonics
    - More compacted coil in MQXF II generation (see before)
- Additional "transparent" corrective option: increase of cable insulation thickness

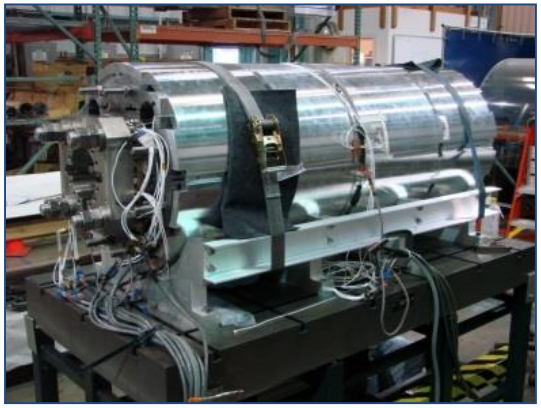
HQ03

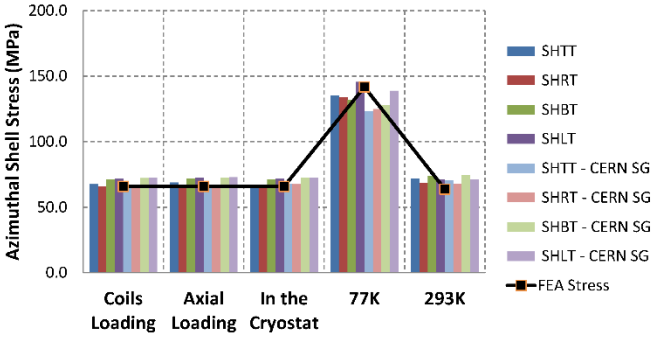


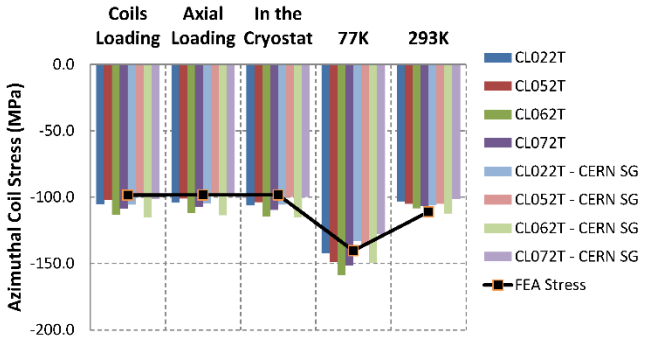
	Calc.	Meas.
Δb_3	2.49	2.74
Δb_5	0.28	0.31

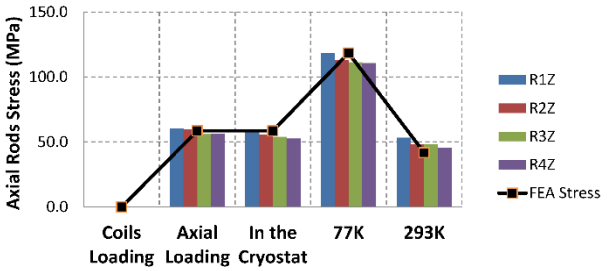
Short model program
Support structures

- Two identical structures assembled and pre-loaded with aluminium coils at LBNL and CERN
- Components instrumented with strain gauges
  - Very good agreement
- Two additional pad/yoke with think laminations to be delivered in 02/16
- Total of ~4 short structure available
  - And 2 teams trained for assembly

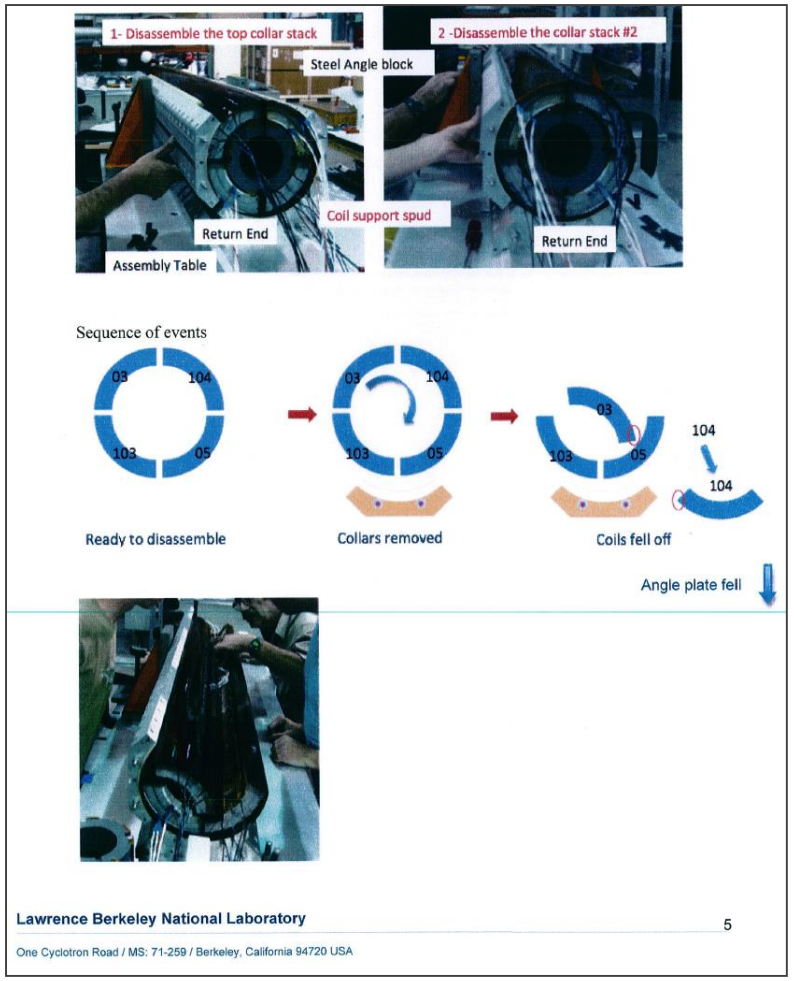


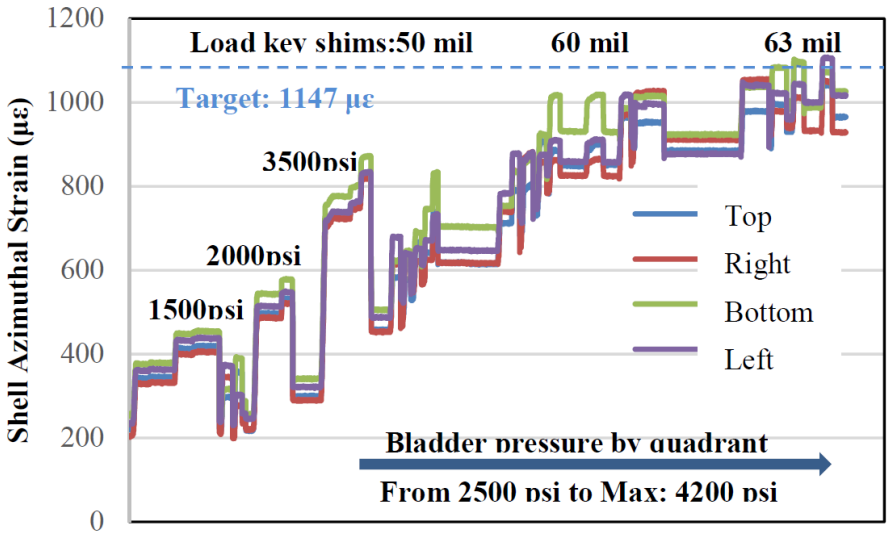






Short model program
Incident and final assembly





Short model program
MQXFS Assembly test

- Cool-down starts on Monday

Outline

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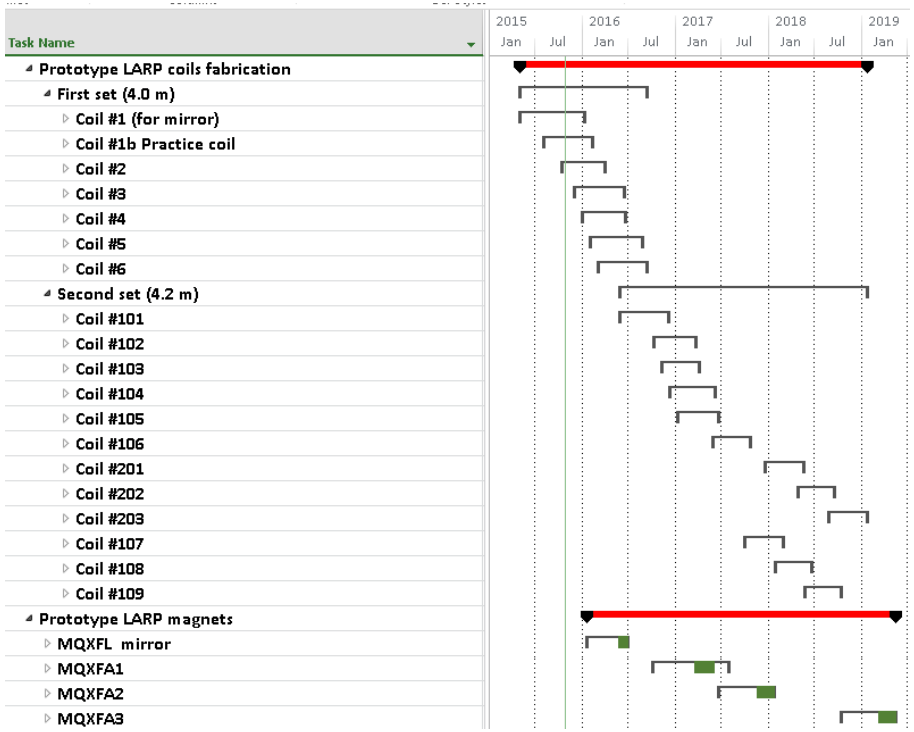
- Prototype program
- Series production

Prototype program
LARP

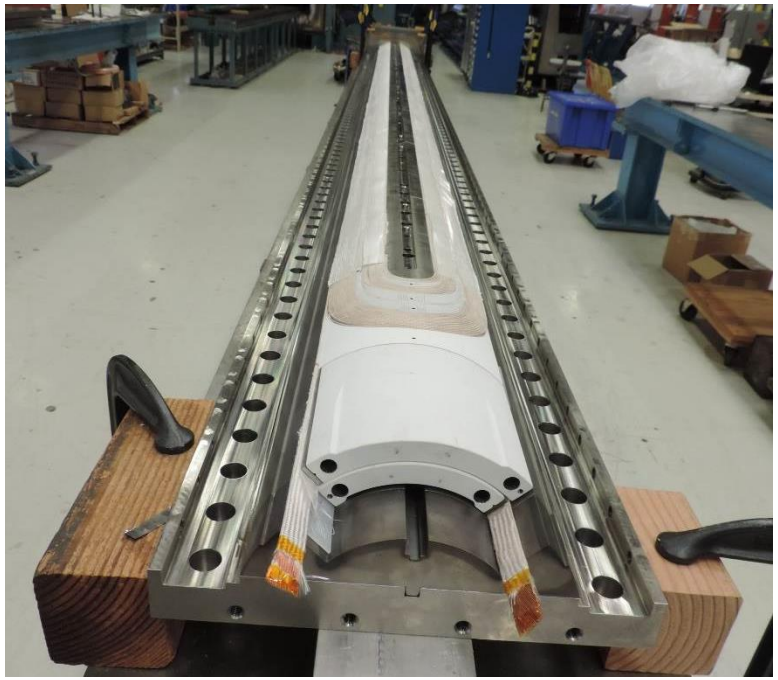


- 19 coils to be fabricated
  - 7 of 4 m
  - 12 of 4.2 m
- Fabrication started in 06/15
- Single coil test in 04-05/16

- 3 prototypes
  - MQXFA1-2: demos for US-HiLumi by 2017
  - MQXFSA3: value engineering for US-HiLumi
    - MQXFA2+A3: prototype cold mass

Prototype program
LARP

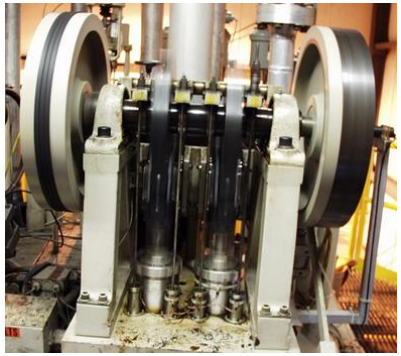
- 2 coils reacted
- 1 coil wound and cured
- 1st long coil with 2nd gen design ready to be wound after feedback from 1st short coil
- Procurement of first long structure in

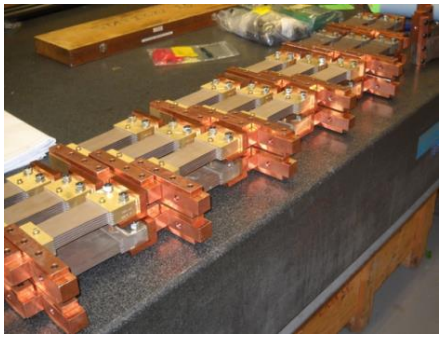


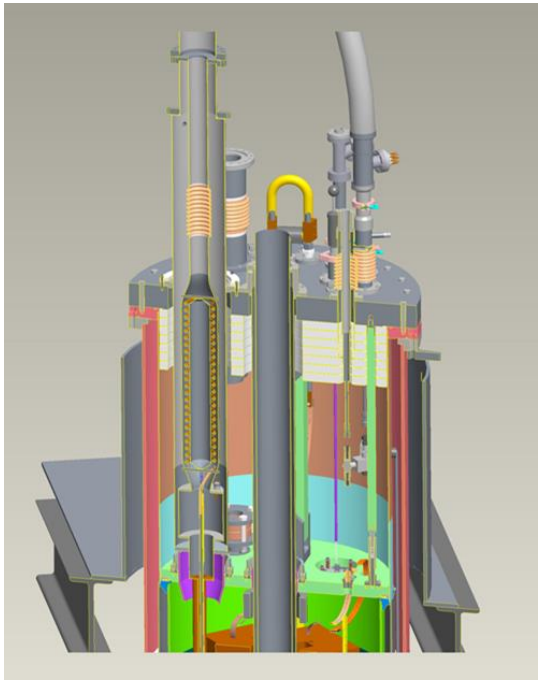
LARP Prototype program
Upgrade of BNL Test Facility in progress

- Cryogenic facility
- Power supply
- Test dewar

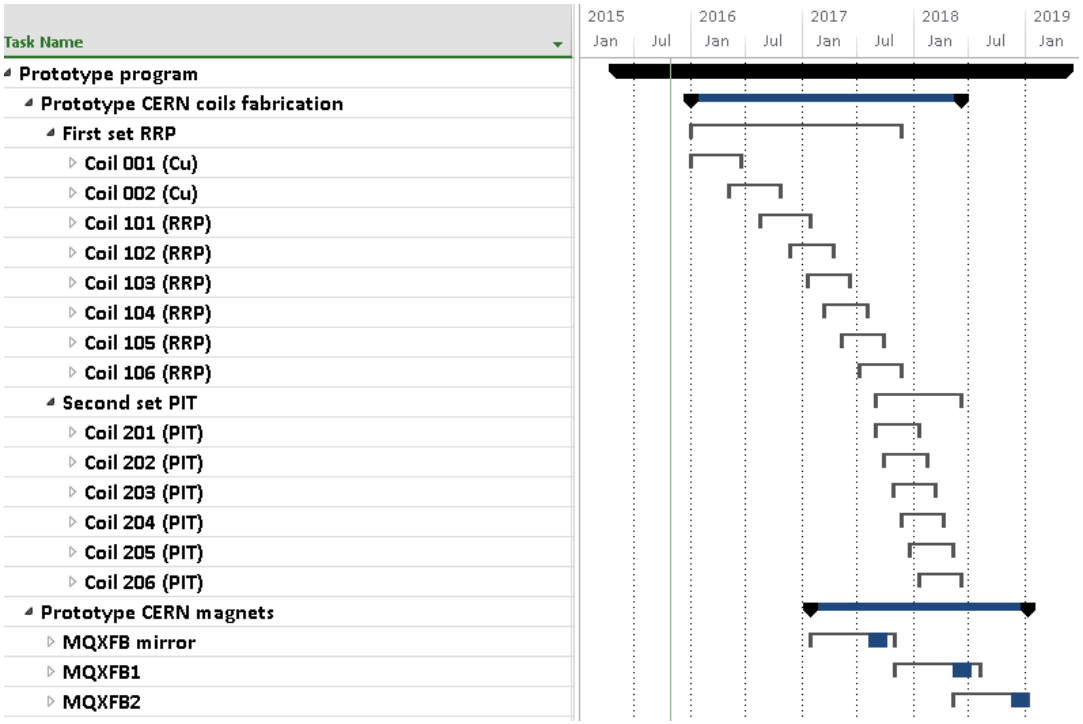
To be commissioned in April 2016







Prototype program
CERN



- 14 coils to be fabricated
  - Cu: **2**
  - RRP: **6**
  - PIT: **6**
- From 01/16 to 06/18

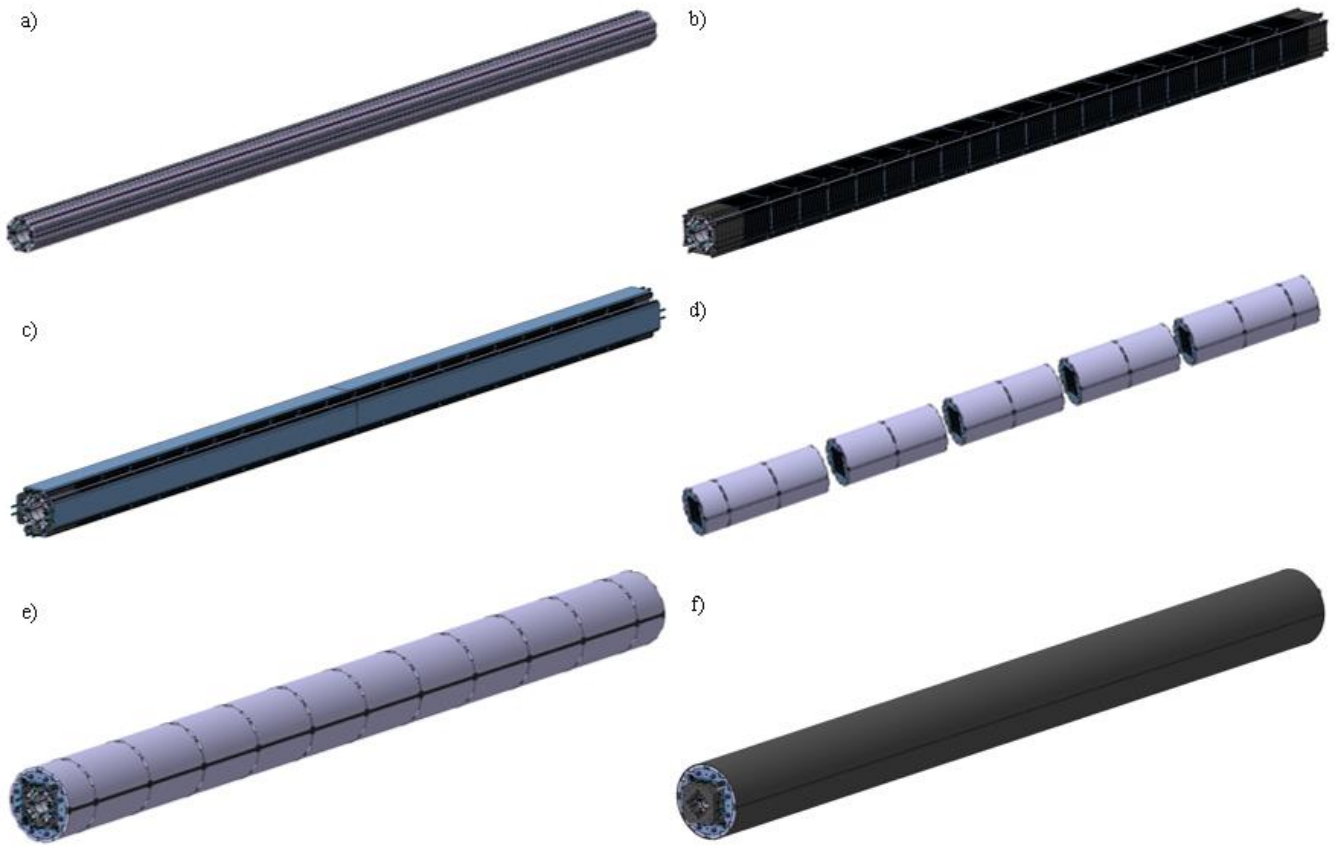
- Single coil test?
- 2 prototypes by the end of 2018
  - One with RRP coils, one with PIT coils

Prototype program
CERN

- W&R tooling by end of the year
- R&I tooling by early 2016
- Long oven by 04/16

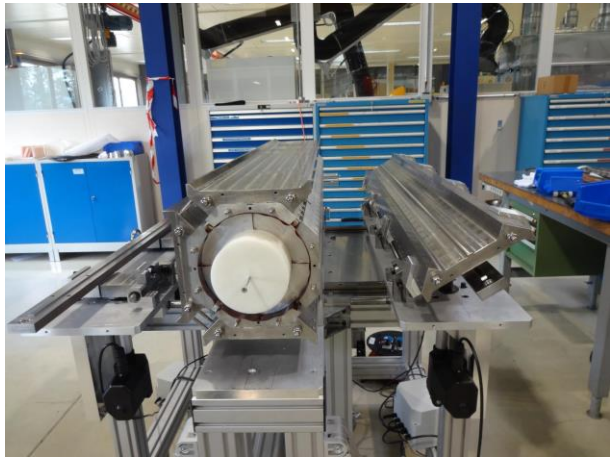
Prototype program
CERN

- Design of MQXFB structure in progress



Prototype program
CERN

- Development of assembly tooling for long laminated structure in progress



Outline

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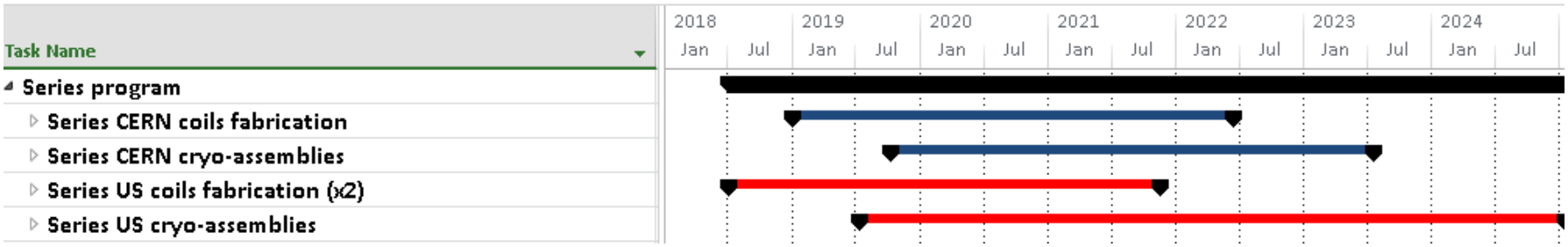
Series production

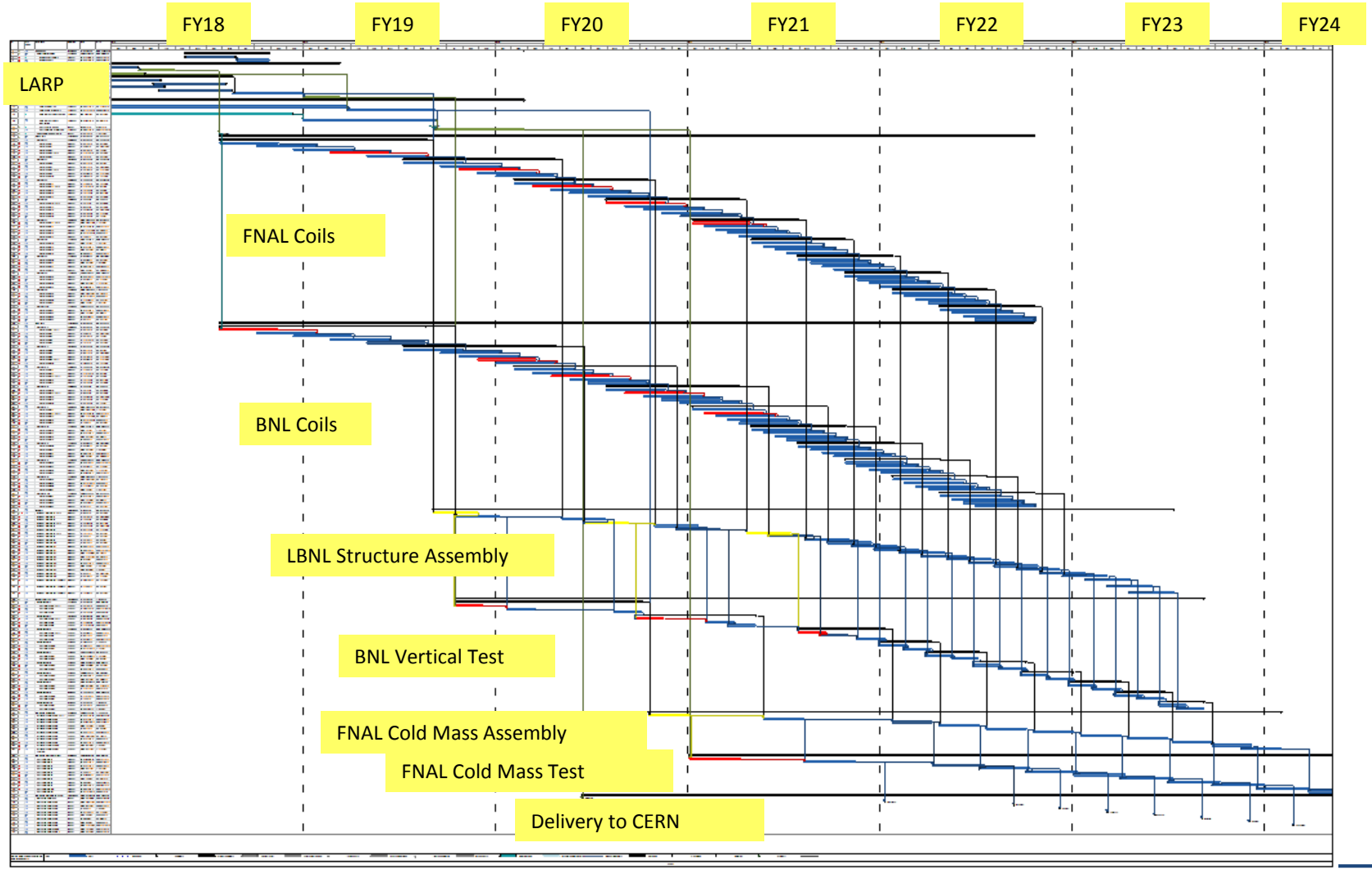
- 10 cold masses each
- CERN
  - 50 coils starting in early 2019 (after II prototype)
  - Last magnet ready by end of 2023
- US-Hilumi
  - 90 coils starting in mid 2018
  - First cold-mass delivered to CERN in 11/21
    - 8th in 11/23
    - Last in mid-24
  - Wrt CERN, additional shipment + cryostating + test



Additional slides

Preliminary Integrated Schedule

- MS Project with logic dependencies



Preliminary LQXF CERN Delivery Dates

Cold Mass	Delivery Date
LMQXFA-1	10/11/21
LMQXFA-2	6/13/22
LMQXFA-3	9/9/22
LMQXFA-4	12/8/22
LMQXFA-5	3/8/23
LMQXFA-6	6/6/23
LMQXFA-7	9/4/23
LMQXFA-8	11/27/23
LMQXFA-9	2/19/24
LMQXFA-10	5/27/24

- US-HiLumi
  Coil Fabrication Starts 4/27/18
- Base project duration 76.2 months (6.3 years)
- New expected LHC tunnel installation in 2025 during LS3
- Last cold mass for tunnel installation (LMQXFA-8) delivered before the end of 2023
- Two spares (LMQXFA-9 and 10) delivered in 2024