QXF Support Structure Design and Development

Helene Felice

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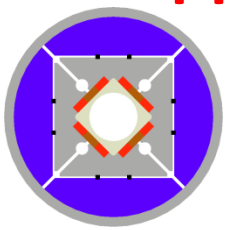
02/17/2014

Outline

- Overview of the support structure development within LARP
  - Magnet History: From Design to assembly
- Support Structure Core Competencies in LARP laboratories
- QXF Support structure Development
  - Plan & Schedule
  - Design Approach: LARP and CERN experiences
    - LARP: Risk Reduction
    - CERN: LHC compatibility
- SQXF Development Status
- LQXF Development Status
- Summary

LARP Support Structure History

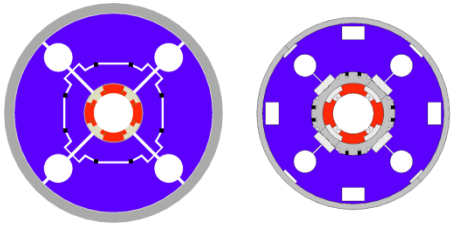
Subscale Quadrupole SQ
0.3 m long
110 mm bore



LBNL Subscale Magnet SM
0.3 m long
No bore

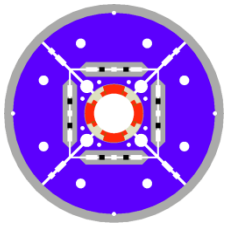


Technology Quadrupole TQS - TQC
1 m long
90 mm bore



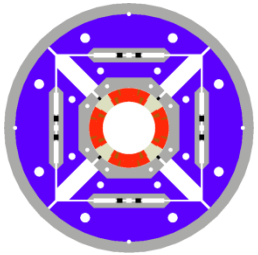
Long Racetrack LRS
3.6 m long
No bore

Long Quadrupole LQS
3.7 m long
90 mm bore



1st assembly: 2009
Last assembly: 2012
Reached 220 T/m

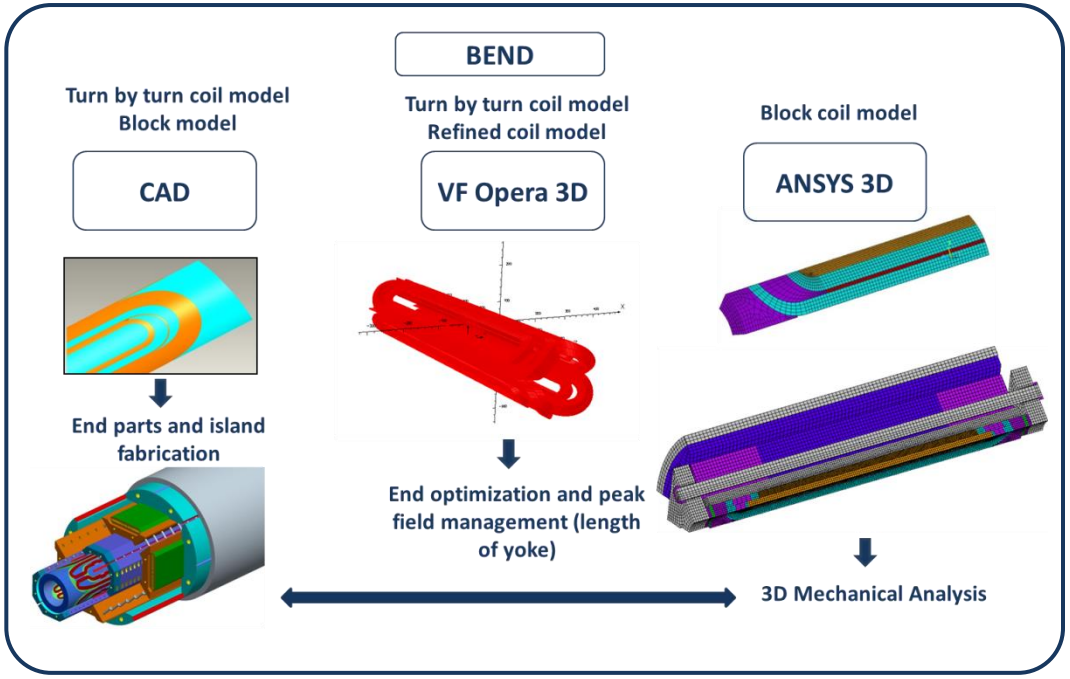
High Field Quadrupole
1 m long
120 mm bore

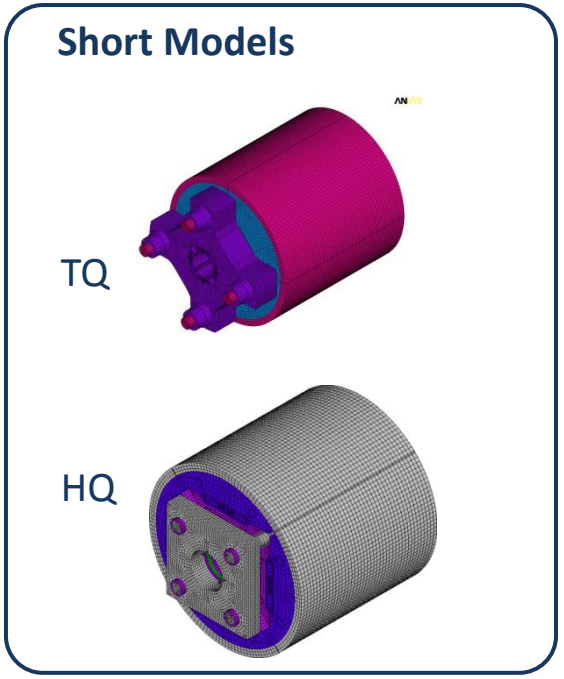


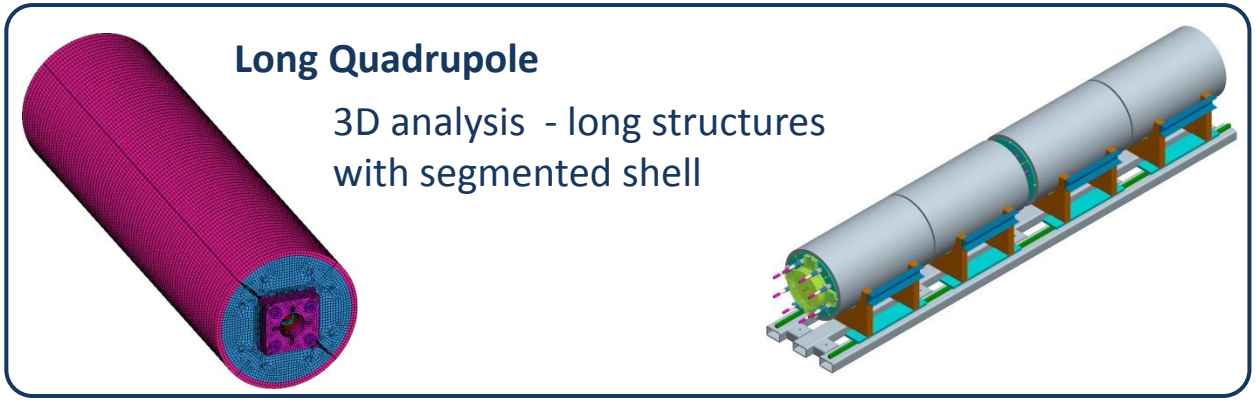
1st assembly: 2010
Most recent: 2013
Reached 184 T/m

Shell based support structure selected as LARP baseline structure

LARP Support Structure Design and Analysis







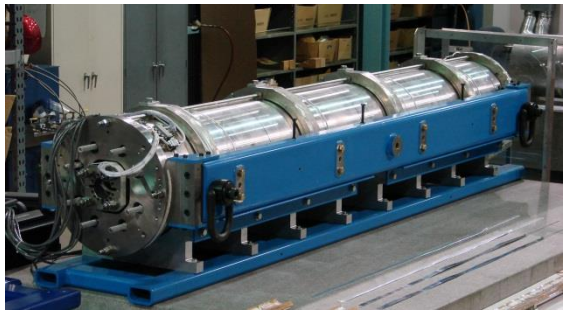
- Analysis capability
  - Magnetic
  - Mechanical
- CAD
- Integrated Design Approach

LARP Support Structure Magnet Assembly Overview

2008 2009 2010 2011 2012 2013 2014

Long Quadrupole LQ

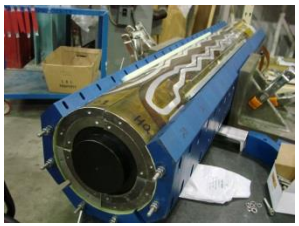
LQS01a and b LQS02 LQS03





End of the TQ program
TQS01a,b,c before 2007
TQS02a,b,c,d before 2007
TQS03a,c,d,e 2007-2008

HQ01a HQ01b - c HQ01d-e HQ02a HQ02b





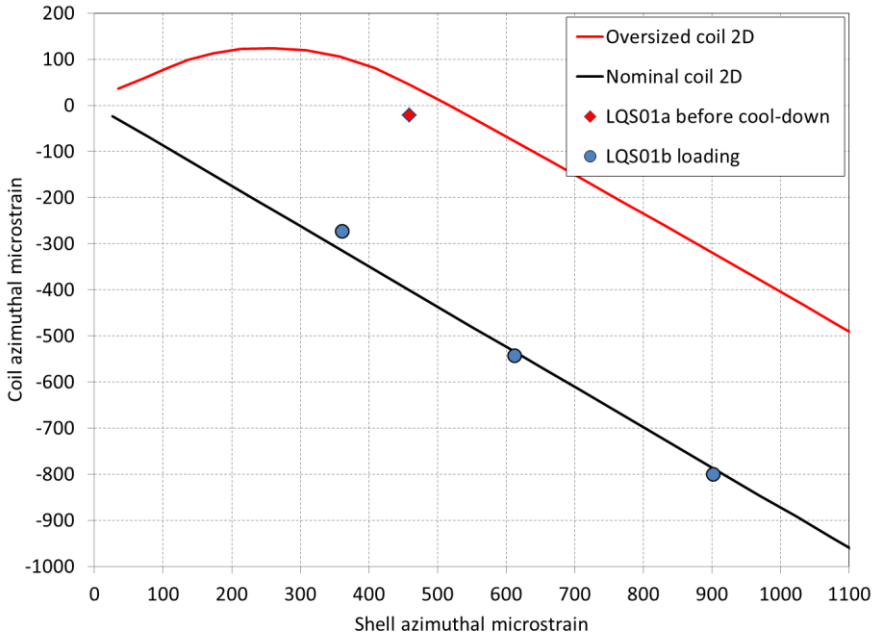


Magnet assembly relying on
Continuous feed-back between
- **Modeling**
- **Strain gauge analysis**

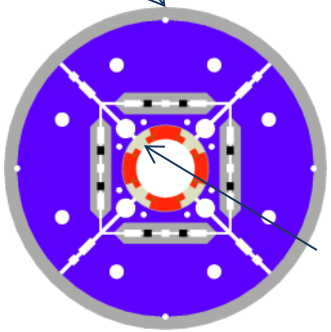
Structure features
- Reversible assembly process
- Adjustable preload

- All LARP magnets but TQC assembled at LBNL
- Integrated approach with modeling and instrumentation correlation

Example of Integrated Approach between Magnet modeling and SG analysis

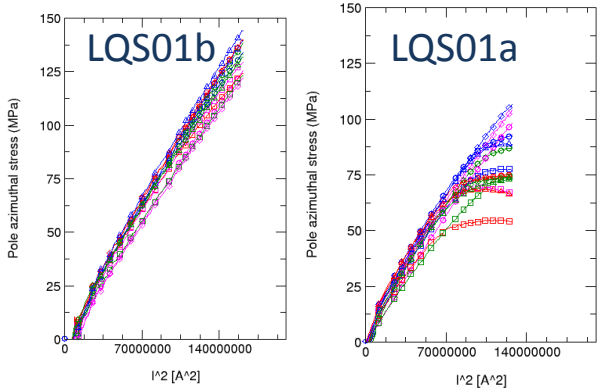


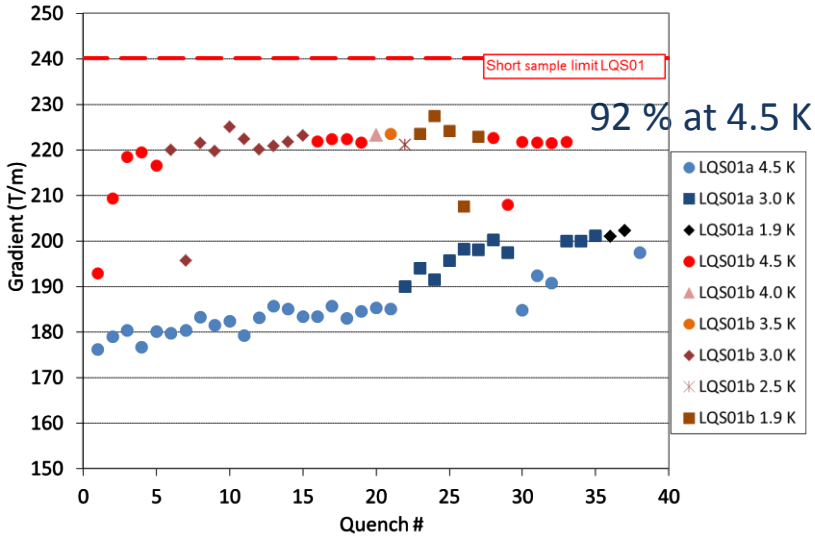
shell Strain Gauge



coil Strain Gauge

Accommodating coil size variability: technical readiness toward production





Support Structure Core competencies

- Item 1: Design (LBNL)
  - Magnetic and Mechanical
- Item 2: Mechanical Instrumentation (LBNL)
  - Strain gauges
- Item 3: Assembly (LBNL)
  - Constant feedback with modeling
- Item 4: Mechanical Performance Analysis (LBNL)
  - Strain gauges analysis, Impact of preload on training
- Item 5: Integration (BNL) => LHe containment

⇒ Support structure core competencies clearly identified

⇒ FY14 focuses on first Items 1 to 3

⇒ Item 5 pending project deliverable identification

QXF Support Structure Development Plan

Short QXF (SQXF)

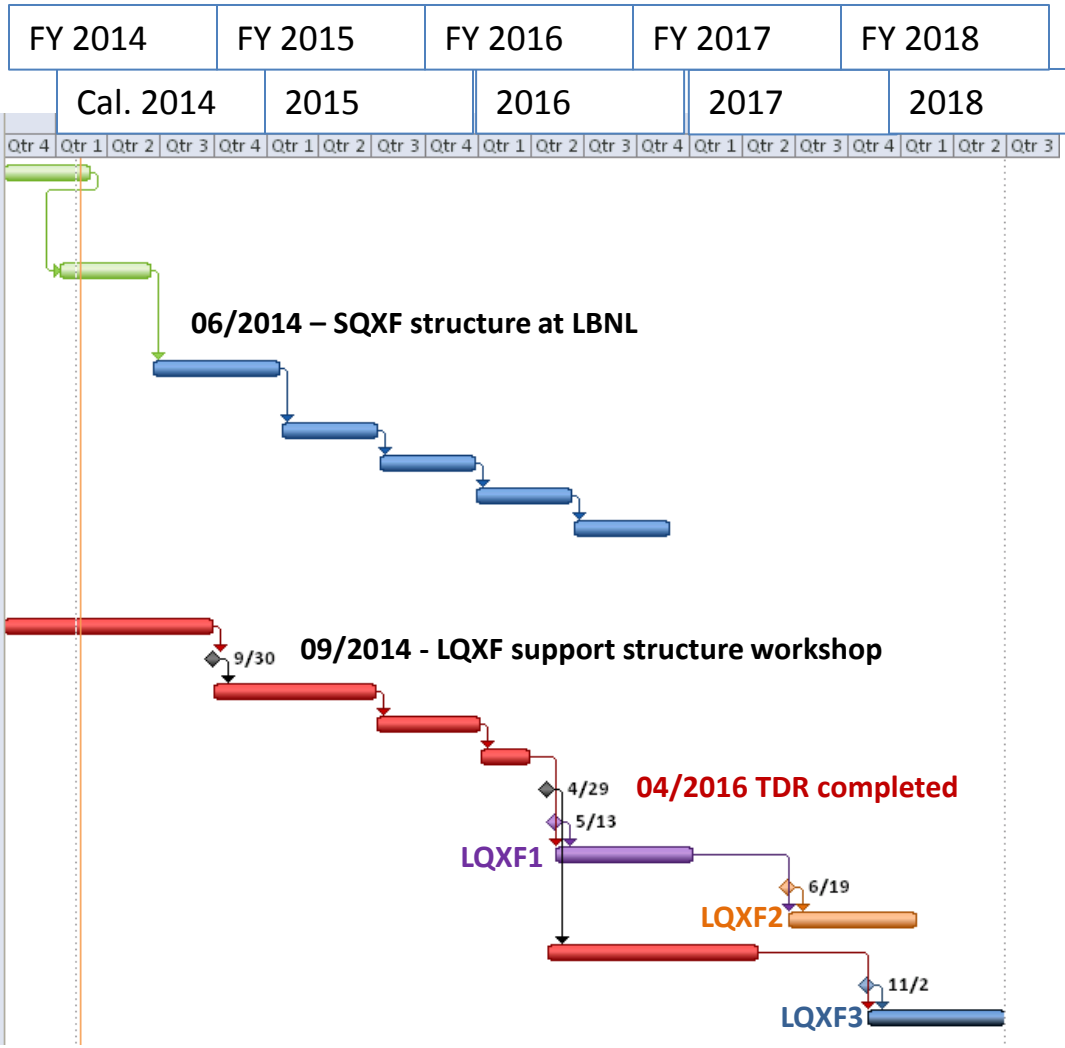
- 2013 to 2017
- Design CERN/LARP
- 2 Structures procured by CERN
  - 1 for CERN: instrumented and assembled at CERN
  - 1 for LARP: instrumented and assembled at LBNL
- 2 short LARP models with preload iterations

Long Prototype (LQXF)

- 2014 to 2018
- Design LARP/CERN
  - LQXF will be a long version of SQXF
- 2 structures procured by LARP
  - Instrumented and Assembled at LBNL
- 3 long models

S/L QXF Support Structure Overall Schedule

Task Name	Duration	Start	Finish
Engineering Design and drawings	109 days	Tue 10/1/13	Fri 2/28/14
CERN			
SQXF structure procurement	23 wks	Mon 1/6/14	Fri 6/13/14
LARP short models			
SQXFD (includes instrum, assembly , test, disassembly)	32 wks	Mon 6/16/14	Fri 1/23/15
SQXF1 - LARP	24 wks	Mon 1/26/15	Fri 7/10/15
SQXF1b	24 wks	Mon 7/13/15	Fri 12/25/15
SQXF3	24 wks	Mon 12/28/15	Fri 6/10/16
SQXF3b	24 wks	Mon 6/13/16	Fri 11/25/16
LARP long prototype			
Design and analysis	52 wks	Tue 10/1/13	Mon 9/29/14
Long Structure worshop	0 days	Tue 9/30/14	Tue 9/30/14
Drawings+Procurement	40 wks	Tue 9/30/14	Mon 7/6/15
Inspection/Instrum/Pre-assembly	26 wks	Tue 7/7/15	Mon 1/4/16
LQXFD	12 wks	Tue 1/5/16	Mon 3/28/16
TDR completed	0 days	Fri 4/29/16	Fri 4/29/16
4 New coils	0 days	Fri 5/13/16	Fri 5/13/16
LQXF1 (assembly-test-disassembly)	34 wks	Fri 5/13/16	Thu 1/5/17
4 New coils	0 days	Mon 6/19/17	Mon 6/19/17
LQXF2 (assembly-test-disassembly)	32 wks	Mon 6/19/17	Fri 1/26/18
Final Structure procurement	13 mons	Fri 4/29/16	Thu 4/27/17
4 New coils	0 days	Thu 11/2/17	Thu 11/2/17
LQXF3	34 wks	Thu 11/2/17	Wed 6/27/18



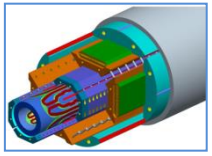
QXF Support Structure Design Approach

- Risk reduction
  - Based on LARP experience
    - Cross-section
      - Shell-based support structure
      - scale –up from HQ to S/LQXF:
        - » Conservative cross-section design
    - Axial choices
      - Shell segmentation
      - Axial loading
- LHC Compatibility
  - Based on CERN experience
    - Specific Features for accelerator integration
      - LHe vessel
      - Heat exchanger accommodation
    - Space allocation in the tunnel
      - Cold mass outer diameter
      - Cold mass length

⇒ LHC compatibility addressed in SQXF and LQXF

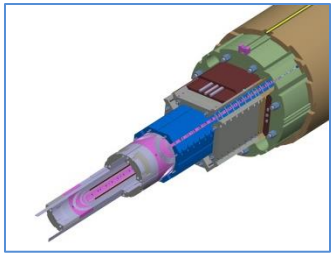
LARP experience
From HQ to QXF– Components

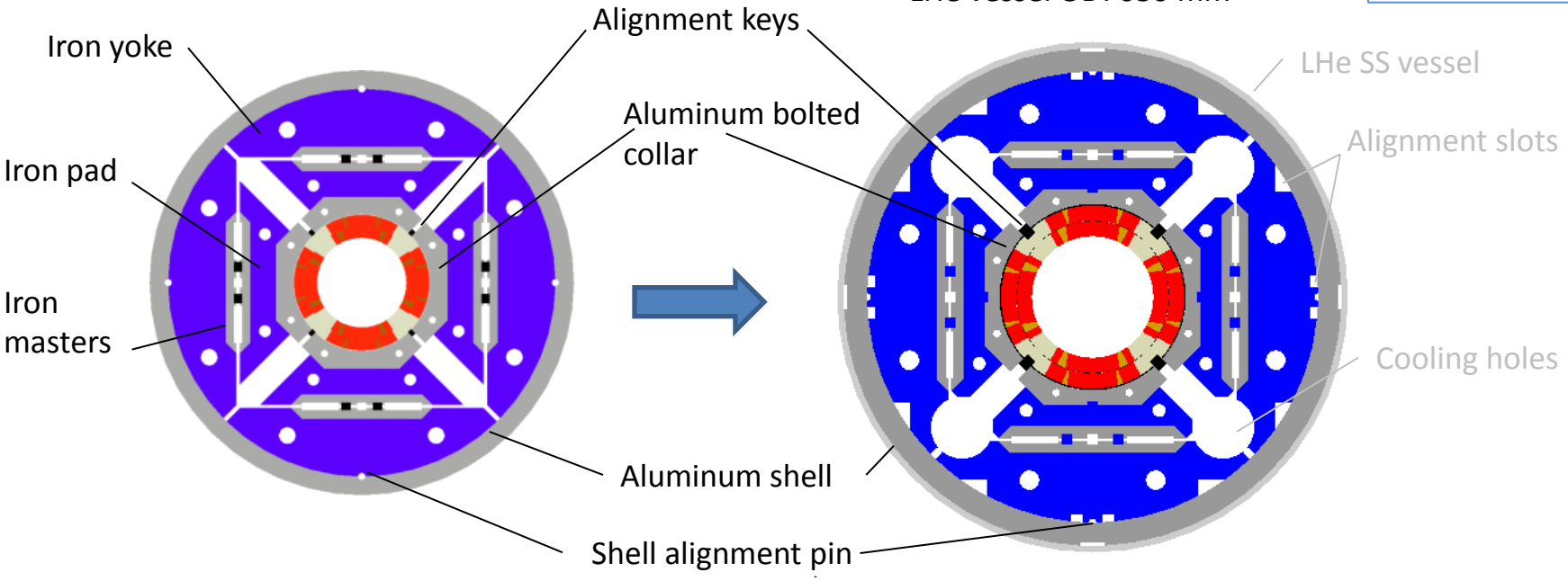
- Shell based support structure:
  - scale-up of the HQ cross-section
  - Re-optimization of the component size
- Largely completed – mainly driven by CERN: regular LARP/CERN meetings



HQ
Alu shell OD: 570 mm
Alu shell thickness: 25 mm

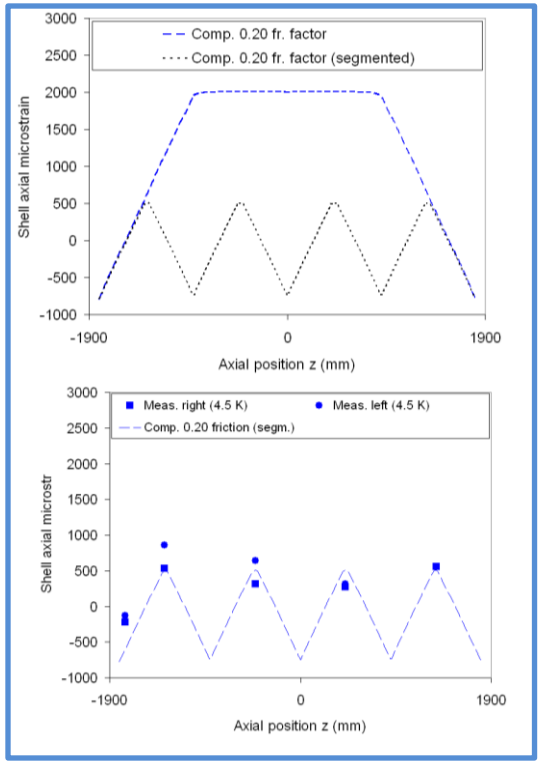
QXF
Alu shell OD: 614 mm
Alu shell thickness: 29 mm
LHe vessel OD: 630 mm



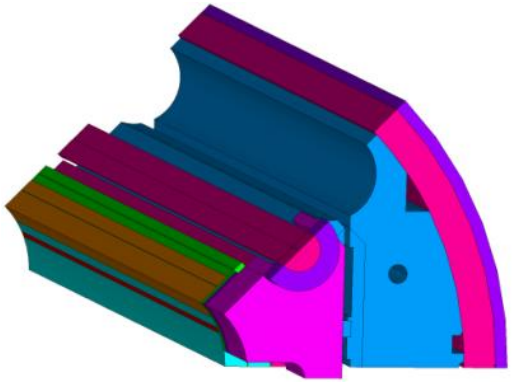


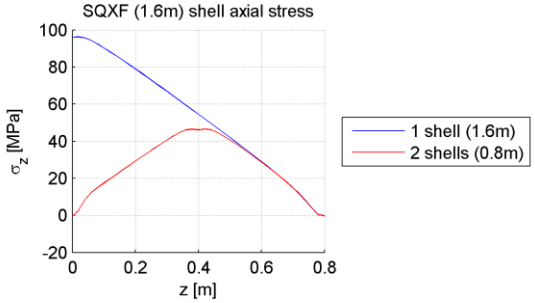
LARP Experience
From LQ to QXF– Shell segmentation

- LR and LQ experience showed the need to segment the shell to prevent slippage
  - During cool-down, shell shrinks more than yoke
  - Friction limits the shell contraction
  - During excitation, slippage may occur



- Decision made on SQXF: 2 segments

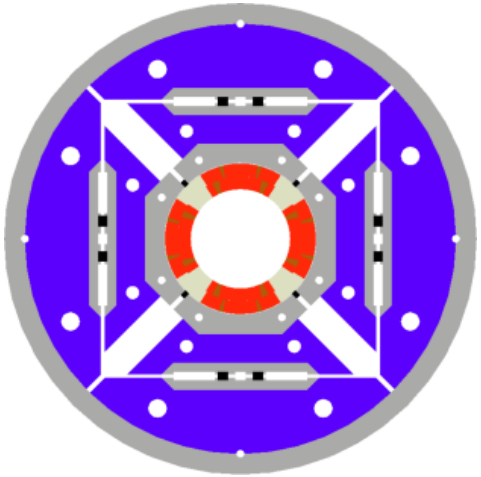




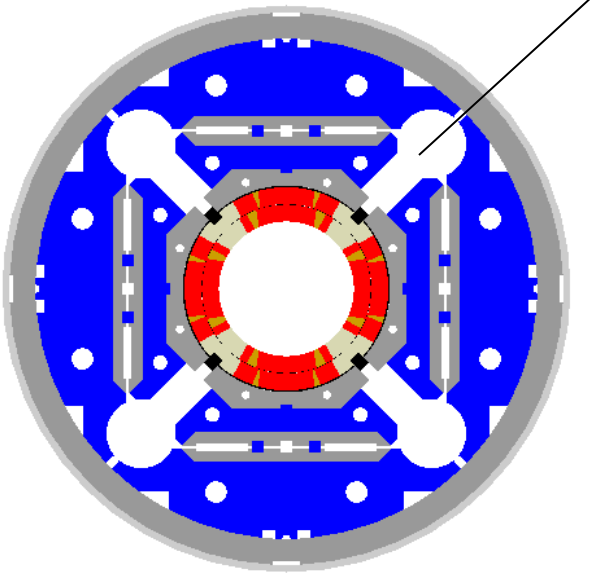
- Decision to be made by 09/2014 (structure workshop) for the LQXF

LHC Compatibility
Heat Exchanger

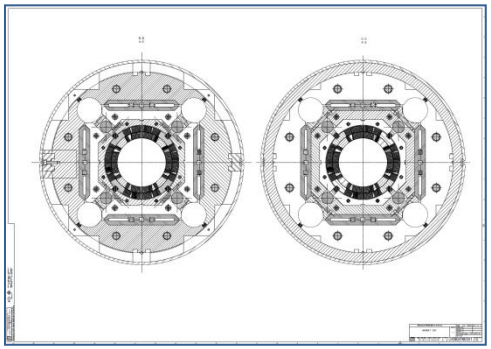
HQ



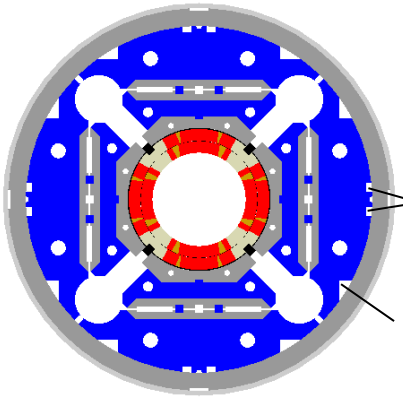
QXF

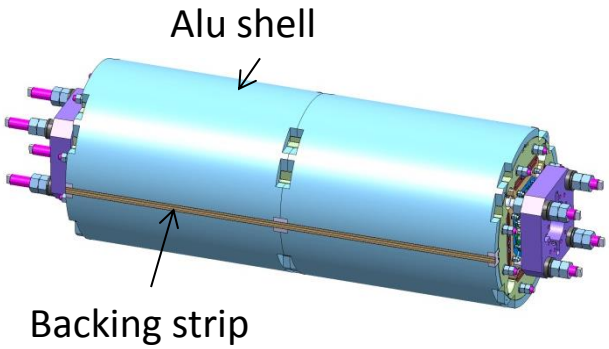


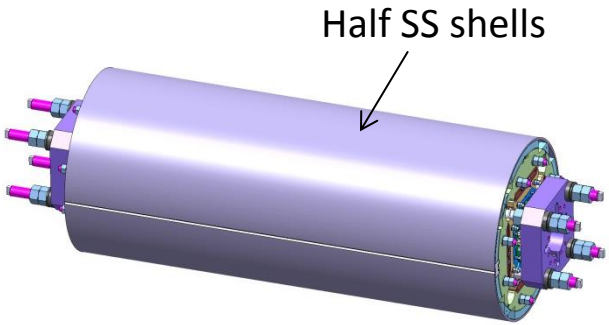
- Heat exchanger OD tube: 77 mm
  - Yoke and pads accommodate cooling holes
  - Continuous feedback from CERN
  - Decision on final size must be made by TDR



LHC Compatibility
LHe containment

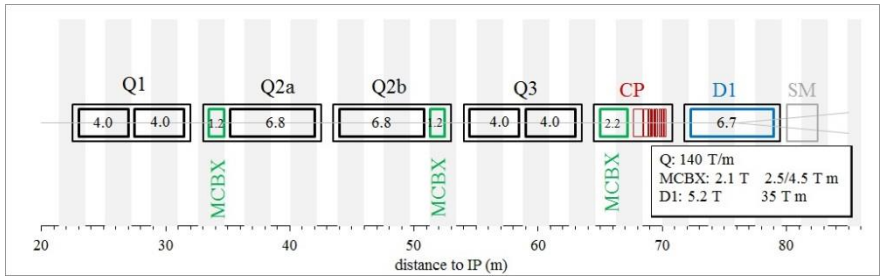






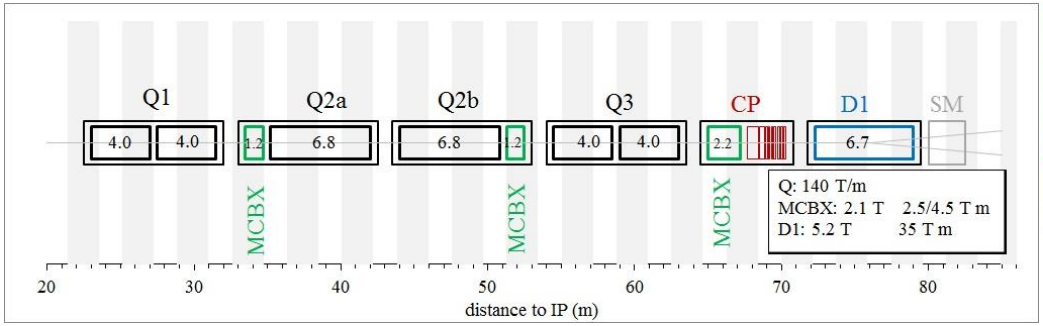
- 2 LHe containment assembly proposals under discussion
  - Welded shell (CERN)
  - Inertia tube (BNL)
- Solution dependent on project deliverable
  - Pending decision
- Some features already implemented in SQXF shell
  - Aluminum shell and Yoke laminations accommodates features for Stainless Steel (SS) shell welding.
    - Welding blocks in yoke screwed in yoke laminations
    - Backing strip Tack welded to welding blocks
    - 1st Half shell Tack welded to backing strip and rotation
    - 2nd half shell placed on top and welded to the first one

- 2 SQXF (#3b and 5) will be assembled in one SS shell toward the end of the SQXF program (CERN)



LHC Compatibility
Longitudinal length constraint

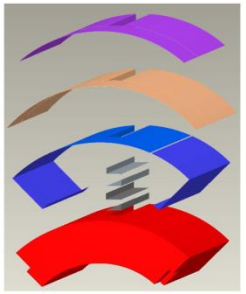
- Connection side
  - 500 mm from end of magnetic length to cold mass end cover
- Non connection side
  - 500 mm from end of magnetic length to beginning on next magnetic length
  - To be shared between 2 QXF in Q1 and Q3
- Addressed in SQXF design
- Final decision to be made before TDR



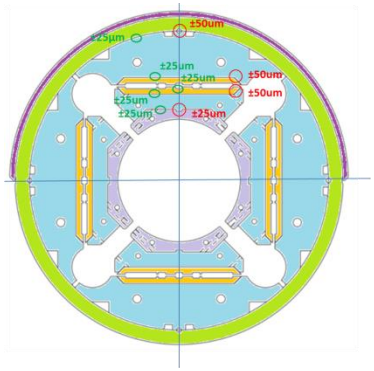


Additional topics

- Work in progress by CERN and LARP
  - Ground plane insulation
    - Ongoing development
    - Meet LHC standards
    - Is compatible with structure assembly tooling



  - Tolerance analysis
    - Impact of parts tolerances
      - on field quality
      - on preload distribution



  - Coil size: measurements using CMM
    - to define appropriate mechanical shimming using experience from recent HQ builds
    - to select coils during assembly for preload homogeneity

QXF Support Structure Development Plan

Short QXF (SQXF)

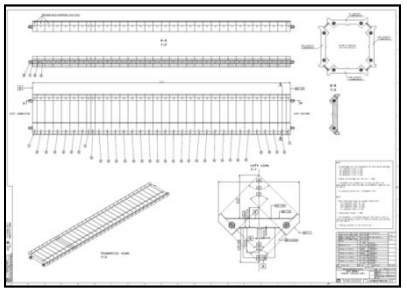
- 2013 to 2017
- Design CERN/LARP
- 1.2 m magnetic length
- 2 Structures procured by CERN
  - 1 for CERN: instrumented and assembled at CERN
  - 1 for LARP: instrumented and assembled at LBNL
- 2 short LARP models with preload iterations

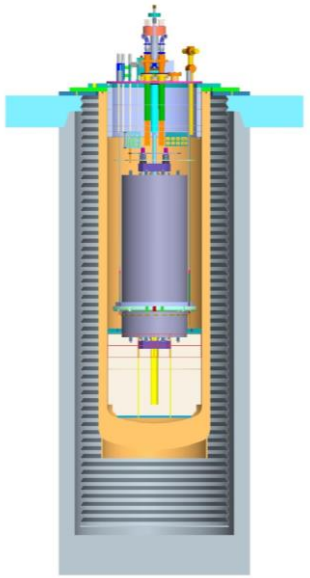
Long Prototype (LQXF)

- 2014 to 2018
- Design LARP/CERN
  - LQXF will be a long version of SQXF
- 4 m magnetic length
- 2 structures procured by LARP
  - Instrumented and Assembled at LBNL
- 3 long models

SQXF
FY14 LARP Scope of work

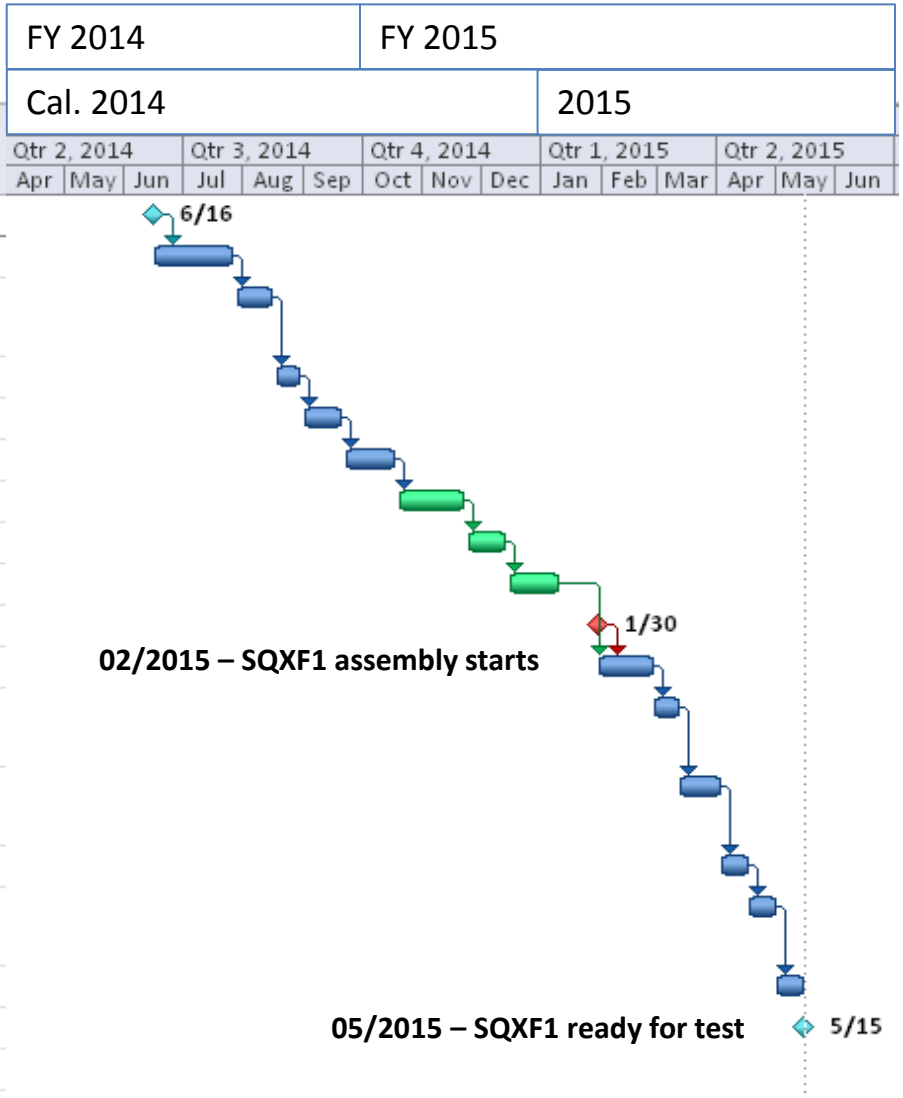
- Finalize support structure design with CERN
- Validate drawings for procurement (by end of Feb/2014)
- *CERN launches procurement*
- Finalize assembly procedure
  - Using LARP experience (LQ)
  - Using CERN production oriented experience
- *Structure QA at CERN*
- Structure and dummy coils arrive at LBNL (June 2014)
  - Structure components and dummy coils QA at LBNL
  - Structure and dummy coils instrumentation
- Assembly of the mechanical model (Sept 2014)
  - With dummy coils
  - Preparation for cold (LN_2) test at LBNL





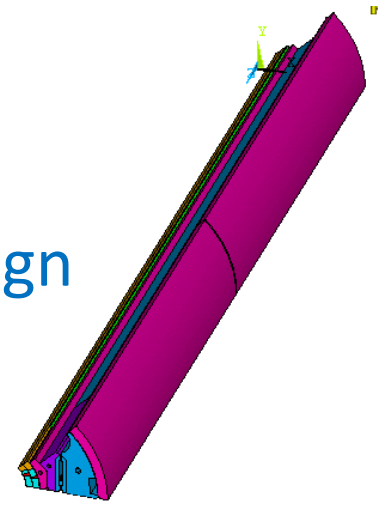
SQXF1 - schedule

Task Name	Duration	Start	Finish
Structure at LBNL	0 days	Mon 6/16/14	Mon 6/16/14
Parts Inspection	1.5 mons	Mon 6/16/14	Fri 7/25/14
Dummy coil instrumentation	3 wks	Mon 7/28/14	Fri 8/15/14
Rods instrumentation	2 wks	Mon 8/18/14	Fri 8/29/14
Shell instrumentation	3 wks	Mon 9/1/14	Fri 9/19/14
Yoke shell sub-assembly	4 wks	Mon 9/22/14	Fri 10/17/14
SQXFD assembly	5 wks	Mon 10/20/14	Fri 11/21/14
SQXFD cold test	3 wks	Mon 11/24/14	Fri 12/12/14
SQXFD disassembly	4 wks	Mon 12/15/14	Fri 1/9/15
4 coils ready	0 days	Fri 1/30/15	Fri 1/30/15
Coil pack assembly	4 wks	Fri 1/30/15	Thu 2/26/15
Coil pack insertion and assembly set up	2 wks	Fri 2/27/15	Thu 3/12/15
Azimuthal and axial loading	3 wks	Fri 3/13/15	Thu 4/2/15
Splice Box	2 wks	Fri 4/3/15	Thu 4/16/15
SQXF1 QA and shipping prep	2 wks	Fri 4/17/15	Thu 4/30/15
SQXF1 shipping	2 wks	Fri 5/1/15	Thu 5/14/15
SQXF1 ready for test	0 mins	Fri 5/15/15	Fri 5/15/15



LQXF
FY 14 LARP Scope of work

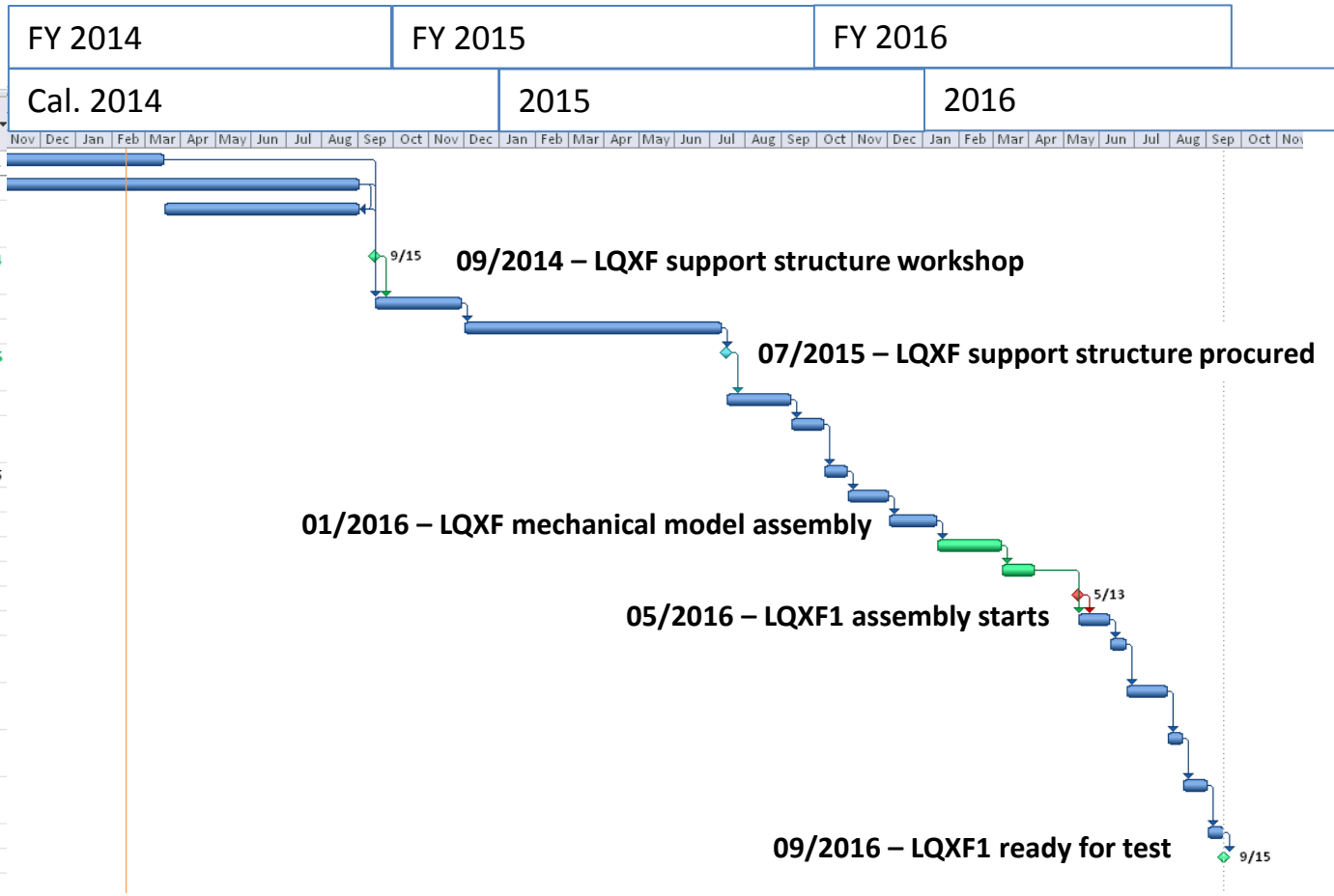
- Finalize support structure analysis
  - Shell segmentation: ongoing
  - Axial preload: ongoing
- Finalize the support structure engineering design
- Finalize Assembly procedure
- Finalize Assembly tooling for long coils
  - Using LARP experience (LQ)
  - Using CERN production oriented experience



- September 2014: LQXF support structure workshop before proceeding to drawings and procurement

LQXF1 detailed schedule

Task Name	Duration	Start	Finish
Coil Assembly tooling	24 wks	Tue 10/1/13	Mon 3/17/14
Long structure analysis	48 wks	Tue 10/1/13	Mon 9/1/14
Long Structure Engineering Design	24 wks	Tue 3/18/14	Mon 9/1/14
LQXF structure design review	0 days	Mon 9/15/14	Mon 9/15/14
Drawings	11 wks	Mon 9/15/14	Fri 11/28/14
Procurement	8 mons	Mon 12/1/14	Fri 7/10/15
Structure components at LBNL	0 days	Wed 7/15/15	Wed 7/15/15
Parts Inspection	2 mons	Wed 7/15/15	Tue 9/8/15
Dummy coil instrumentation	4 wks	Wed 9/9/15	Tue 10/6/15
Rods instrumentation	3 wks	Wed 10/7/15	Tue 10/27/15
Shell instrumentation	5 wks	Wed 10/28/15	Tue 12/1/15
Yoke shell sub-assembly	6 wks	Wed 12/2/15	Tue 1/12/16
LQXFD assembly	8 wks	Wed 1/13/16	Tue 3/8/16
LQXFD disassembly	4 wks	Wed 3/9/16	Tue 4/5/16
4 coils ready	0 days	Fri 5/13/16	Fri 5/13/16
Coil pack assembly	4 wks	Fri 5/13/16	Thu 6/9/16
Coil pack insertion and assembly set up	2 wks	Fri 6/10/16	Thu 6/23/16
Azimuthal and axial loading	5 wks	Fri 6/24/16	Thu 7/28/16
Splice Box / instrumentation	2 wks	Fri 7/29/16	Thu 8/11/16
LQXF1 QA and shipping prep	3 wks	Fri 8/12/16	Thu 9/1/16
LQXF1 shipping	2 wks	Fri 9/2/16	Thu 9/15/16
LQXF1 ready for test	0 mins	Thu 9/15/16	Thu 9/15/16



Summary

- QXF Support Structure development based on strong LARP achievements
- QXF Support Structure compatibility with LHC relying on tight interaction with CERN
- Two main goals in FY14
  - SQXF: short model to be assembled with dummy coils
  - LQXF: complete the long support structure design
- Toward the FY18 milestone
  - the design and development of the QXF structures is an important risk reduction factor toward the use of Nb_3Sn magnets in accelerator magnets