Status and Plans of MQXFA Magnets

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8th HL-LHC Collaboration Mtg – October 15 - 18, 2018

Outline

- Prototype magnets:
  - MQXFAP1 test
  - MQXFAP2 test
  - Plans for MQXFAP1b
- Pre-series magnets:
  - MQXFA3 and MQXFA4 Fabrication status
  - Plans for MQXFA3/4 Assembly and Test
  - Design Changes: shims for b6 and length
- Production magnets:
  - Conductor Procurement
  - Preparation for Reviews

Prototype Magnets

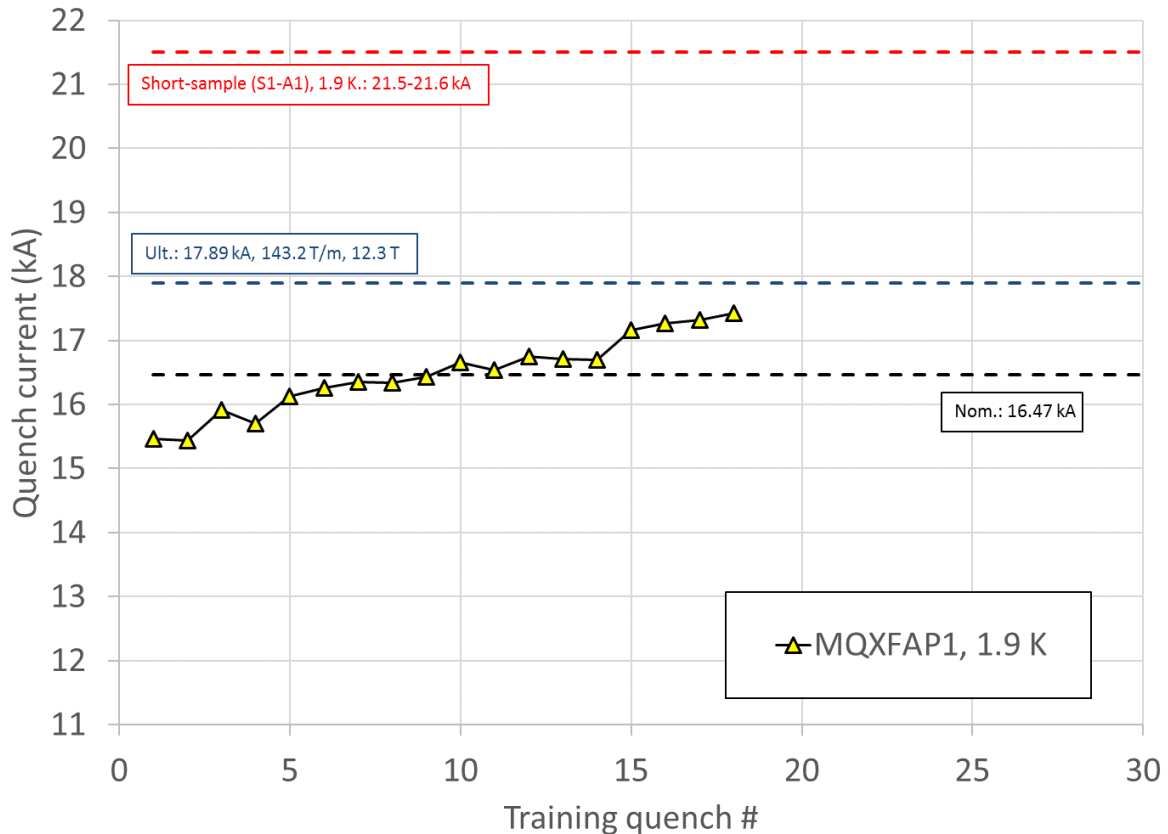
MQXFAP1 Test

- MQXFAP1 features:
  - Coils: 4.0 m, 1st & 2nd generation, several conductors
    - RRP 108/127, 132/169, 144/169
  - Structures: full length

- MQXFAP1 training:
  - 1st quench on Aug 25, 2017
    - Issue with helium recovery line ➔ warm up
  - 2nd and 3rd quench on Nov 13 & 15, 2017
    - Issue still present ➔ warm up
  - 15 training quenches Feb 3-20, 2018
    - Coil-Ground short ➔ test stopped

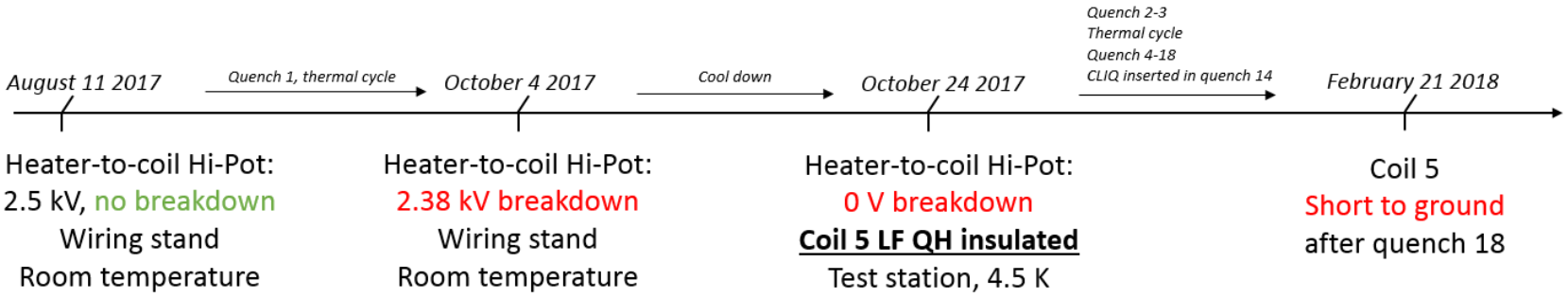
MQXFAP1 Quench History

- Quench protection:
  - Start: IL + OL heaters and dump
  - Q14: added CLIQ
  - Q15: removed IL heaters



MQXFAP1 Short to Ground

- MQXFAP1 test campaign was stopped after quench 18, due to a short to ground in coil 5 outer layer
  - Short to ground occurred where a heater-to-coil short had already been located after quench 1 and thermal cycle

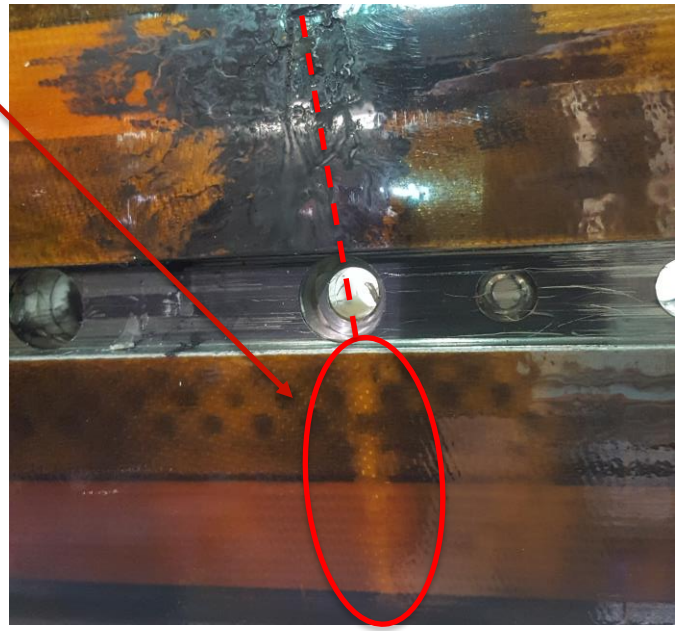


- Multiple shorts heater-to-coil can lead to a short to-ground
  (V. Marinozzi, US-HiLumi-doc-897)
- A study of impact of OL-heater-to-coil insulation failure demonstrated no weakness in the design
  (V. Marinozzi, US-HiLumi-doc-921)

MQXFAP1 Short to Ground: Causes & Prevention

- Short was caused by a series of (now) well-understood events:

- Coil 5 impregnation was poor in the short area:
  - Increased possibility of helium trapped after cold test
  - Insulation brand/vendor no more used after this coil



- Between quench 1 and quench 2, magnet was hi-potted with high voltage (2.5 kV) at room temperature, after helium exposure
  - Coil 5 failed during this hi-pot test
  - Helium at warm is a poor insulator
  - This procedure will not be repeated, according to AUP Electrical Design Criteria

- Hi-pot during training was performed because of rupture of the burst disk and subsequent warm-up
  - Helium relief system was upgraded and demonstrated

➔ The issue was caused by a combination of well-understood events, and each one will be prevented in future tests

- **<u>Design weakness is excluded</u>**

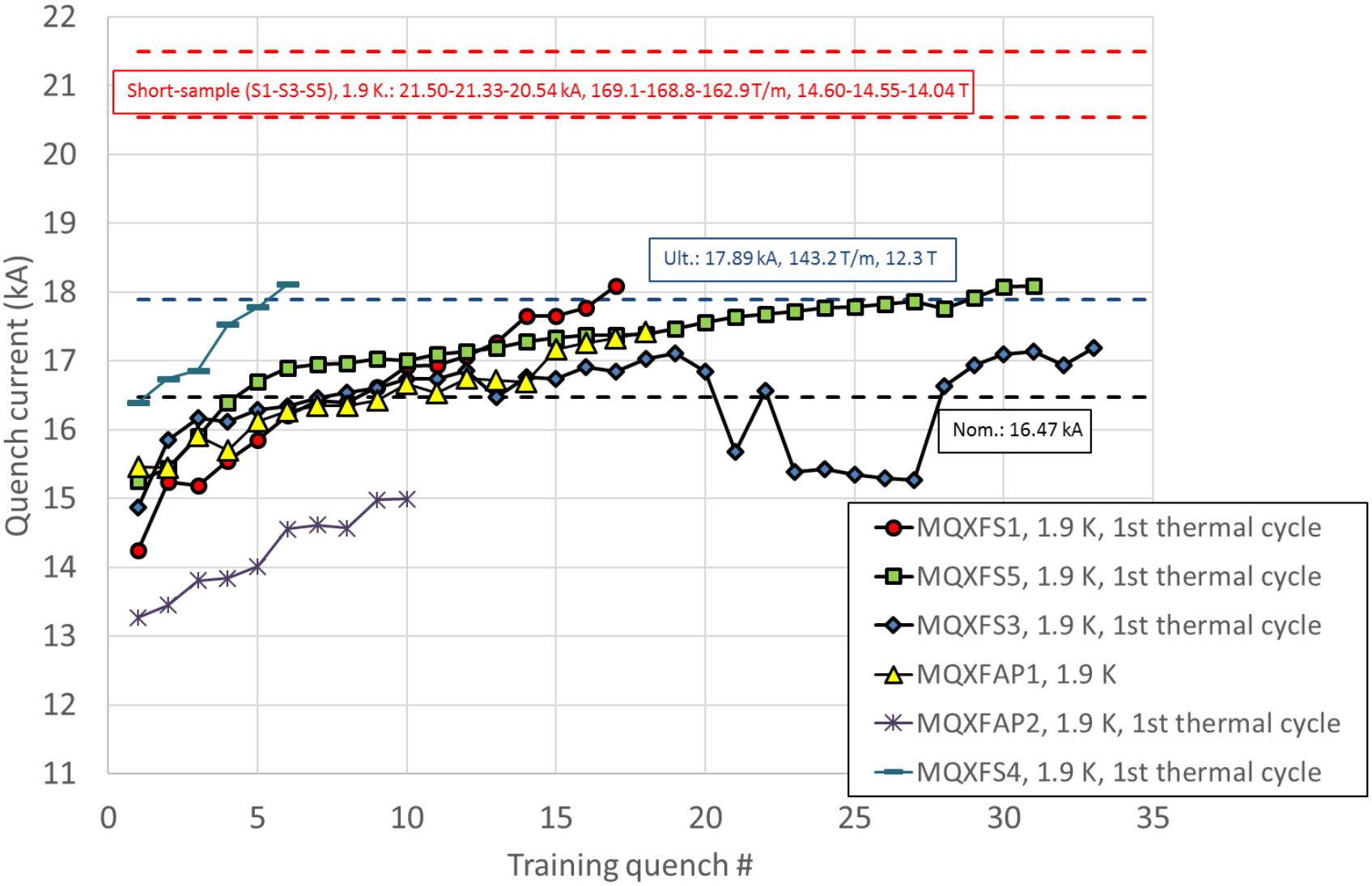
MQXFAP2 (prototype) – MQXFA3 (Pre-series)

Feature	MQXFAP2	MQXFA03
Final coil length (4.2 m magnetic length)	YES	YES
Coil midplane shims meet requirements*	NO	YES
Polyimide free inner coil surface	18%	YES
Holes on coil poles (hole per pole part)	7/8	8/8
Wires according to CERN specs	NO	YES
Solution for IL QH “bubbles”	NO	YES
Provision for coil bumpers	NO	YES
Strain gauges interference w CB integration	YES	NO
Fabricated according to MIPS**	NO	YES

*Approved list of MQXFA materials
**Cable fabrication and Coil at FNAL fabrication: MIPs approved
Coil at BNL fabrication: MIP under approval

MQXFAP2 Quench History

- See presentation by J. Muratore



MQXFAP2 Question

- Why did MQXFAP2 training start so lower than all other MQXF magnets?

- Exploration in progress:
  - Pre-stress, pole-key gap, coil-collar interface appear within range of previous magnets
  - Quench Antenna *"may be showing all quenches starting close to return end" (Work in progress)*
  - All voltage taps in Inner Layer Return End lost

MQXFAP1b Plans

- Completed spare coil (coil P06)
  - Previous spare was coil tested in long mirror, but it developed coil-heater shorts after cold test
- Assembly to start in a few weeks
- Test planned to start in February 2019

Pre-series Magnets

Cabling and Insulation

- We have made 26 (successful) + 1 (quarantined) QXFA cables to-date.
  - Quarantined because of crossover ~1 m past minimum length
- All cables except the quarantined cable have been braided.
- Minor insulation rub-off issues on 9 cables
  - the issue has been identified (vibration during shipment) and resolved by adding protection between cable and spool flange.
- Two shipments mishandled by the carrier.
  - Accelerometers are now used on all shipments.
- LBNL RRR system commissioned. Kinks are measured systematically. Trend agrees well with B-OST QC: 15% rolled strand is a good indicator.
- Cost and schedule performance on EVMS are excellent.
- AUP Conductor Quality Plan on EDMS “under approval”

Coil Name	Wind Start	Impregnation Complete	Duration, calendar days	DRs	
QXFP01		At BNL			
QXFP02		At BNL			
QXFP03	Jan 4, 2016	Jul 8, 2016	186	7	OK
QXFP04		At BNL			
QXFP05	May 10, 2016	Oct 10, 2016	153	11	OK
QXFP06	Jun 13, 2018	Oct 3, 2018	112	12	OK
QXFA101	July 20, 2016	Apr17, 2017	271	18	Quarantined electric
QXFA102		At BNL			
QXFA103	damaged				Rejected
QXFA104	Jan 31, 2017	Jul 10, 2017	160	10	OK
QXFA105		At BNL			
QXFA106	May 25, 2017	Oct 16, 2017	144	13	OK
QXFA107	Aug 8, 2017	Feb 14, 2018	190	11	Quarantined electric
QXFA108	Dec 6, 2017	May 7, 2018	152	11	Quarantined electric
QXFA109	Feb 5, 2018	Jun 25, 2018	140	11	OK
QXFA110	Apr 23, 2018	Aug 15, 2018	114	9	
QXFA111	Jul 5, 2018				
QXFA112	Aug 22, 2018				
QXFA113	Oct 11, 2018				

Talk: "Electrical QC to coil parts" by V. Marinozzi; Wed 16:30

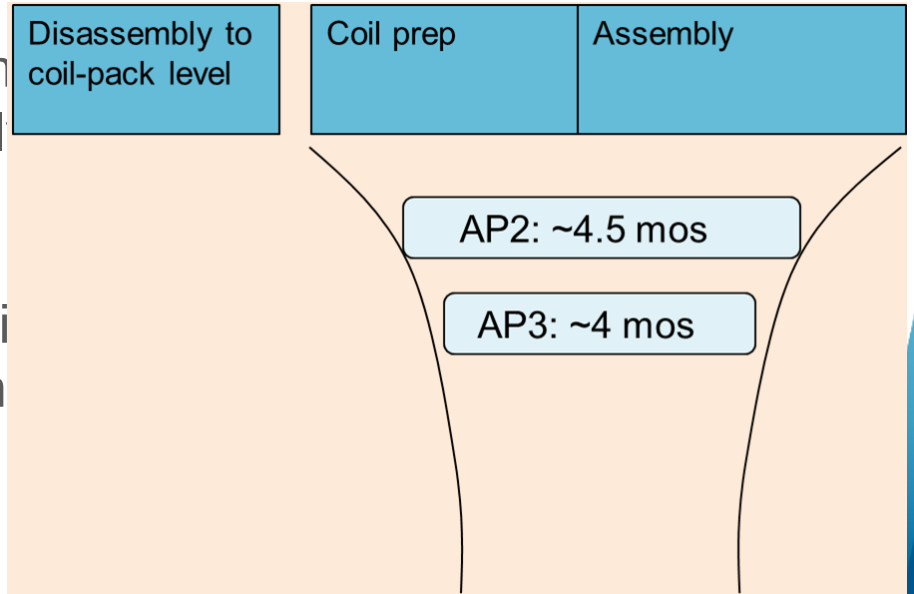
Coil Fabrication at BNL

- QXF coils reacted and impregnated at BNL:
  - QXFP01, QXFP02, QXFP04 (4 meter).
  - QXFA102, QXFA105 (4.2 meter).
  - All coils have been used in magnets.
    - (Mirror, MQXFAP1 & MQXFAP2).
  - DRs:
    - QXFP01 – short coil to pole (electrical issue of some FNAL/CERN coils)
    - QXFP04 – small area with chipped epoxy.
    - QXFA105 – chipped ceramic coating on saddle tip.

- QXF coil winding and curing at BNL:
  - Installation and commissioning of winding and curing tooling complete.
  - One practice coil wound and cured.
  - Winding and curing of 1st pre-series has been completed, coil is being prepared for reaction.

MQXFA Structure Procurements and Assembly

- **MQXFAP1a**
  - ~ 12(!) mos. procurement lead time for some components (FY16-FY17)
  - ~ 7 mos. assembly effort, which included MQXFA1M (mechanical model assembly & disassembly)
- **MQXFAP2**
  - ~ 6 mos. procurement lead time (min. for shells)
  - ~ 6 mos. assembly effort, which included MQXFAP1 disassembly (1.5 mos.), magnetic measurements and alignment survey
- **MQXFAP1b**
  - Replacement coil is being sh
  - Expecting ~ 3 mos. Assembl subassembly activities)
- **MQXFA-03**
  - ~ 6 mos. procurement lead ti
  - ~ Expecting ~ 4 mos. assem



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Plans for MQXFA3 and MQXFA4

- MQXFA3
  - assembly start: February 2019
  - Test start: May/June 2019
- MQXFA4
  - assembly start: April/May 2019
  - Test start: ~September 2019

Design Changes – b6

- Modification of coil-pole and coil-midplane shims to fix b6
  - To be implemented starting from coils for MQXFA5
  - Schedule risk:
    - If a coil for MQXFA4 fails after fabrication of coils with b6 adjustment has started
      - Option 1: we make another coil with present design ➔ 3 month delay
      - Option 2: we use a coil with new design ➔ some un-allowed harmonics (computation in progress)

Design Changes – Structure Length

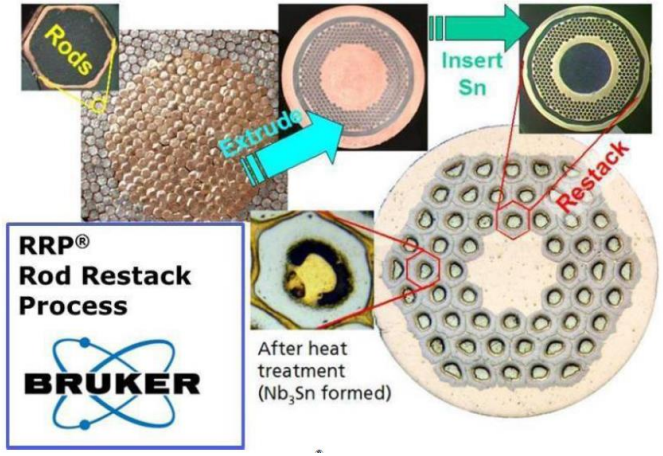
- Review of expansion loop in LMQXFA is in the plans
- Based on review outcome MQXFA structure length may be shortened.
- Options:
  - Splice connection box (pizza box) closer to end plate
  - End plate closer to yoke

Production Magnets

Note: AUP achieved **CD-3a for production strand procurement**
AUP needs **CD-3b to start production magnet fabrication & test**

Status of AUP Nb_3Sn wire procurement

- AUP wire production order for **FY18**
  - **300 km (15 ULs)** – placed. Despite delays in placing the order, all wires are **on schedule** to be received by the end of the calendar year with no impact in schedule. All raw materials procured, All sub-element completed.
  - **580 km (29 ULs)** – option to be exercised in Oct 2018. Projected to be delivered by the end of CY19.
  - Additional **100km (5 ULs)** placed through LBNL. On track to be delivered by April 2019



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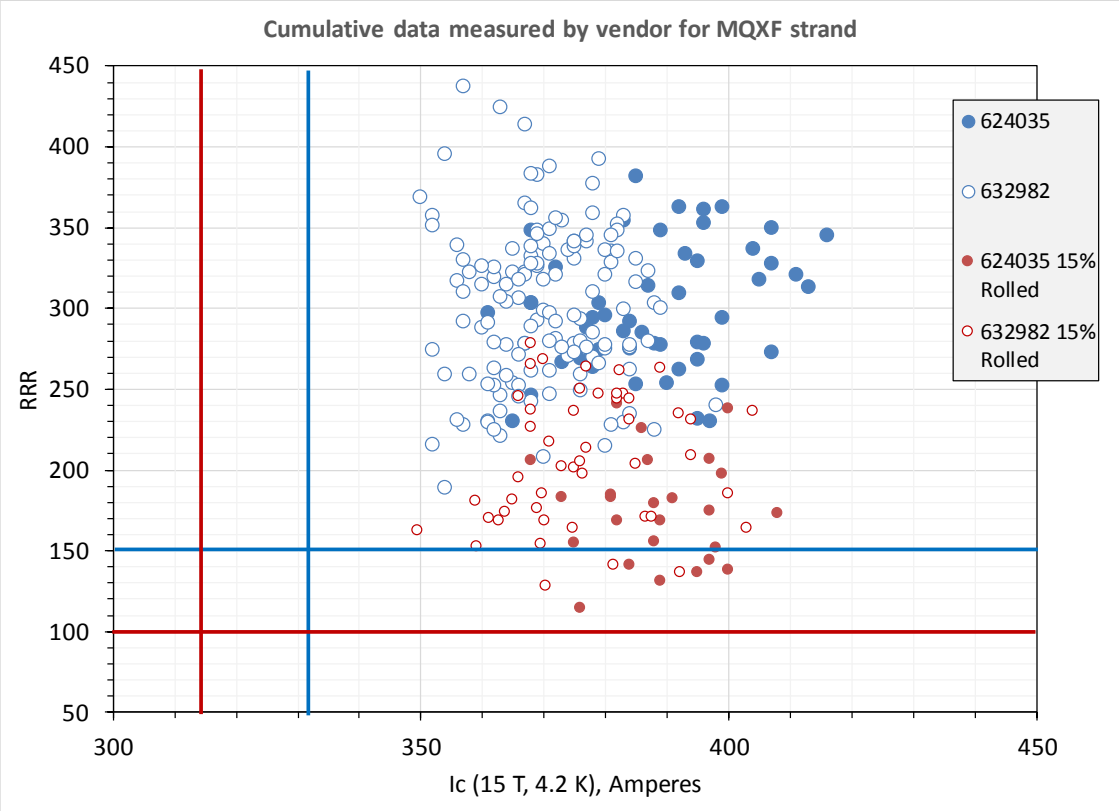
Strand Procured by LARP and Supplier's QC

- 2 LARP competitive procurements **with AUP specification**, resulted in ~3 tons (208 km Aug 2015, 400 km May 2017) of RRP 108/127
  - A change of the heat treatment was approved in 2017 → shift in data



Round
Rolled

symbols
2015 = filled
2017 = open

Preparation for CD-3b Review

- Technical mini-review in November to show that prototypes met all MQXFA requirements
  - We need to complete MQXFAP2 test

- CD-3b Review in Dec 11-13
- We need to complete and approve all documents:
  - MQXFA Acceptance Criteria
  - MQXFA Interface Specifications & Documents
  - MIP for coils at BNL (to be approved)
  - MIP for magnet assembly (to be finalized and approved)
  - Conductor QA/QC Plan

Conclusions

- Prototype magnets:
  - Lessons learned from MQXFAP1, implemented in all coils and tests
  - MQXFAP2 test is in progress
- Pre-series magnets:
  - Fabrication is well advanced:
    - Cables are doing great
    - Coils: we need to finalize QC to coil parts, and monitor production
    - Structures: too early for conclusions
- Production magnets:
  - We have to compete documents for CD-3b review

Extra Slides

Coil Fabrication at FNAL

Coil Name	Wind Start	Impregnation Complete	Duration, calendar days	DRs
QXFP01		BNL		6
QXFP02		BNL		8
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QXFP05	May 10, 2016	Oct 10, 2016	153	11
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QXFA109	Feb 5, 2018	Jun 25, 2018	140	11
QXFA110	Apr 23, 2018	Aug 15, 2018	114	9
QXFA111	Jul 5, 2018			5
QXFA112	Aug 22, 2018			1
QXFA113	Oct 11, 2018			0

QXFP DR's = 50
W&C = 24
React = 2
Impreg = 2

QXFA DR's = 110
W&C = 47
React = 11
Impreg = 39
Elec = 12
Ship = 1