
Report on MQXF cable and design reviews

P. Ferracin

17th HiLumi LHC Extended Steering Committee

15 January, 2015

CERN

Overview

HL-LHC/LARP International Review of

- **The Superconducting Cable for the HL-LHC Inner Triples Quadrupoles (MQXF)**

- CERN, 5-6 November 2014
- <https://indico.cern.ch/event/338963>

- **Committee**

- Chair: Arnaud Devred (ITER IO)
- Herman ten Kate (CERN)
- Akira Yamamoto (CERN & KEK)
- Bruce Strauss (DOE)
- David Larbalestier (NHMFL)

- **The Inner Triples Quadrupoles (MQXF) Design**

- CERN, 10-12 December 2014
- <https://indico.cern.ch/event/355818>

- **Committee**

- Chair: Yamamoto (CERN & KEK)
- Joe Minervini (MIT, Co-Chair)
- Jim Kerby (ANL)
- Shlomo Caspi (LBNL)
- Alexander Zlobin (FNAL)

MQXF Superconducting Cable Review Charges

The HL-LHC Project Leader and the LARP Director call an International Review with the following goals:

1. Are the Functional or Technical Specification for conductor strand and cable adequate to the scope of the MQXF ? Are they sufficiently developed and reasonably finalized ?
2. Does the design of strand and cable meet the specifications in terms of minimum I_c , maximum allowed degradation, minimum RRR, maximum D_{eff} , stability request, cable size, and unit length ?
3. Assess the likelihood of meeting – with adequate margin – the chosen specifications and requirements based on the decade long experience acquired by LARP in cables and magnet construction and the most recent experience in Europe.
4. Is the plan for two types of strand architecture (RRP and PIT) correctly managed inside the program?
5. Is the procurement schedule, with associated QA and test plan, credible and adequate for the prototyping phase (where applicable) and for the construction phase?

MQXF Superconducting Cable Review Structure

Welcome and review charge - IT Amphitheatre (09:00-09:20)

- Presenters: Prof. ROSSI, Lucio; Dr. APOLLINARI, Giorgio

MQXF goals and plans - IT Amphitheatre (09:20-09:50)

- Presenters: Dr. AMBROSIO, Giorgio

MQXF design and conductor requirements - IT Amphitheatre (09:50-10:20)

- Presenters: Dr. FERRACIN, Paolo

Mechanical stability and QXF coil winding - IT Amphitheatre (10:20-10:50)

- Presenters: Dr. FERRACIN, Paolo; Dr. AMBROSIO, Giorgio

Conductor technical specifications - IT Amphitheatre (11:10-11:55)

- Presenters: Dr. BALLARINO, Amalia; Dr. GHOSH, Arup

MQXF RRP-strand for Q1/Q3 - IT Amphitheatre (11:55-12:20)

- Presenters: Dr. GHOSH, Arup

MQXF RRP-strand for Q2 - IT Amphitheatre (12:20-12:45)

- Presenters: Dr. BORDINI, Bernardo

MQXF cable for Q1/Q3 - IT Amphitheatre (14:15-14:45)

- Presenters: Dr. DIETDERICH, Daniel

MQXF cable for Q2 - IT Amphitheatre (14:45-15:15)

- Presenters: Dr. OBERLI, Luc-Rene

PIT strand & cable for Q2 - IT Amphitheatre (15:15-15:40)

- Presenters: Dr. BALLARINO, Amalia

Lessons learnt from CERN experience - IT Amphitheatre (15:40-16:10)

- Presenters: Dr. OBERLI, Luc-Rene

Lessons learnt from LARP experience - IT Amphitheatre (16:30-17:00)

- Presenters: Dr. GHOSH, Arup; Dr. DIETDERICH, Daniel

US-HiLumi conductor procurement - IT Amphitheatre (17:00-17:25)

- Presenters: Dr. GHOSH, Arup

HiLumi conductor procurement - IT Amphitheatre (17:25-17:50)

- Presenters: Dr. BALLARINO, Amalia

QA/QC plans for Q2 strand - IT Amphitheatre (09:00-09:20)

- Presenters: Dr. BORDINI, Bernardo

QA/QC plans for Q2 cable - IT Amphitheatre (09:20-09:40)

- Presenters: Mr. SCHEUERLEIN, Christian

QA/QC plans for Q1/Q3 conductor - IT Amphitheatre (09:40-10:20)

- Presenters: Dr. PONG, Ian

Summary - IT Amphitheatre (10:35-10:55)

- Presenters: Dr. AMBROSIO, Giorgio; Dr. FERRACIN, Paolo

MQXF Superconducting Cable Review

Outcome and recommendations

- Overall
 - Design goals shall be **conservative**
 - **Critical current requirements are not satisfied**
 - Today we have few % less in J_c in ~20% of the samples
 - Maximize **margin** by all means (length, Cu/non-Cu, ...)
 - Make use of model/prototype phase for tuning specifications (RRR, J_c)
 - Keep **2 strand suppliers**, even though this is additional work

MQXF Superconducting Cable Review

Outcome and recommendations

- Overall
 - RRP
 - Go ahead with **132/169** lower Sn content
 - back up being 108/127
 - PIT
 - Promote a **substantive development program** with BEAS
 - PIT not yet at the level of RRP
 - In the meantime, CERN should go ahead with RRP
 - Fine tuning of the keystone angle a must for PIT cable, and to be considered also for the RRP cable

MQXF Superconducting Cable Review

Outcome and recommendations

- Technical specs?
 - Not complete at this time
- Specifications met by design?
 - Optimistic → **increase margin**
 - J_c and minimum RRR have to be revisited
 - D_{eff} is not critical around 50 μm , so 108/127 can be a backup if needed
- Procurement schedule, QA and test plan
 - Better coordination between US and CERN QA plan and test

MQXF Magnet Design Review Charges

The HL-LHC Project Leader and the LARP Director call an International Review with the following goals:

1. Are the Functional and Technical Specifications for the 3 MQXF magnets (Q1, Q2 and Q3) properly developed and reasonably finalized? Do the 10-year long LARP experience on cables and magnets and the more recent experience in Europe support the chosen specifications?
2. Does the basic design of the MQXF in terms of the magnetic and mechanical structure, quench protection and thermal operative conditions meet the Specifications with sufficient margin? Based on the LARP and European experiences, what is the likelihood of meeting the Specifications?
3. Is the engineering design (including the 3D modeling and the interfacing with other systems) sufficiently developed to assess that there are no show-stoppers in the construction of magnet parts, cold mass assemblies and cryostat, including installation and integration in the machine? Is the magnet and circuit protection adequate?
4. Is the plan for models and prototypes well thought? Is the preliminary construction plan credible?
5. Is the envisaged work share, between CERN and US-LARP the best to maximize the chances of success while minimizing the cost and interfaces?
6. Is there any area or particular field where important technical or managerial risks are under evaluated or ignored?

MQXF Magnet Design Review Structure

Welcome and review charge - 40-S2-A01 (Anderson) (14:00-14:15)

- Presenters: Prof. ROSSI, Lucio; Dr. APOLLINARI, Giorgio

MQXF Requirements and conceptual design - 40-S2-A01 (Anderson) (14:15-14:55)

- Presenters: Dr. TODESCO, Ezio

Feedback from conductor review - 40-S2-A01 (Anderson) (14:55-15:15)

- Presenters: Dr. TODESCO, Ezio

LARP and other programs' experience - 40-S2-A01 (Anderson) (15:15-16:00)

- Presenters: Dr. SABBI, GianLuca

MQXF support structure as extension of LARP experience - 40-S2-A01 (Anderson) (16:30-17:15)

- Presenters: Dr. FELICE, Helene

MQXF overall design - 40-S2-A01 (Anderson) (17:15-18:00)

- Presenters: Dr. FERRACIN, Paolo

Magnetic design and analysis - 6-R-012 (08:30-09:15)

- Presenters: Dr. IZQUIERDO BERMUDEZ, Susana

Coil design and fabrication - 6-R-012 (09:15-09:45)

- Presenters: Dr. YU, Miao

Mechanical design and analysis - 6-R-012 (09:45-10:30)

- Presenters: Dr. JUCHNO, Mariusz

Quench protection and radiation damage - 6-R-012 (11:00-12:00)

- Presenters: Dr. AMBROSIO, Giorgio

Cooling and thermal analysis - 6-R-012 (12:00-12:30)

- Presenters: Dr. VAN WEELDEREN, Rob

CERN Q2 assembly procedure - 6-R-012 (14:00-14:20)

- Presenters: Dr. PEREZ, Juan Carlos

LARP prototypes assembly toward Q1-Q3 magnets - 6-R-012 (14:20-14:40)

- Presenters: Dr. CHENG, Daniel

Cold mass, cryostat and integration in the LHC - 6-R-012 (14:40-15:10)

- Presenters: Dr. PRIN, Herve

Feedback on MQXFS structure fabrication - 6-R-012 (15:10-15:40)

- Presenters: Dr. MOYRET, Pierre

Readiness of test stations for design validation - 6-R-012 (16:00-16:40)

- Presenters: BAJKO, Marta; AMBROSIO, Giorgio

Short model and prototype plans - 6-R-012 (16:40-17:20)

- Presenters: Dr. AMBROSIO, Giorgio; Dr. FERRACIN, Paolo

MQXF Magnet Design Review

Outcome and recommendations

- Overall
 - Choice of **150 mm** aperture fully supported
 - Scale up of LARP HQ magnet design supported
 - MQXF is the hardest magnet to be accessed (and replaced) and critical proofs of Nb₃Sn – one needs to be conservative
 - Target an operating point of **~75%** on load line (now ~80%)
 - Production magnet should be tested to 105% of nominal
 - Half-length magnet as a **backup option** for Q2
 - More resources on development of test facilities

MQXF Magnet Design Review

Outcome and recommendations

- **Specification** finalized?
 - Not yet, however, the design is converging
 - LARP experience is being well employed
- **Basic design** meet specifications with margin?
 - Likelihood of meeting them is reasonable
- **Engineering design** adequate?
 - Design is sufficiently developed, no show stoppers
 - The procedure of the magnet replacement and safety issues should be well addressed

MQXF Magnet Design Review

Outcome and recommendations

- **Plan** for models and prototypes well thought?
 - Schedule is tight, define contingency plan

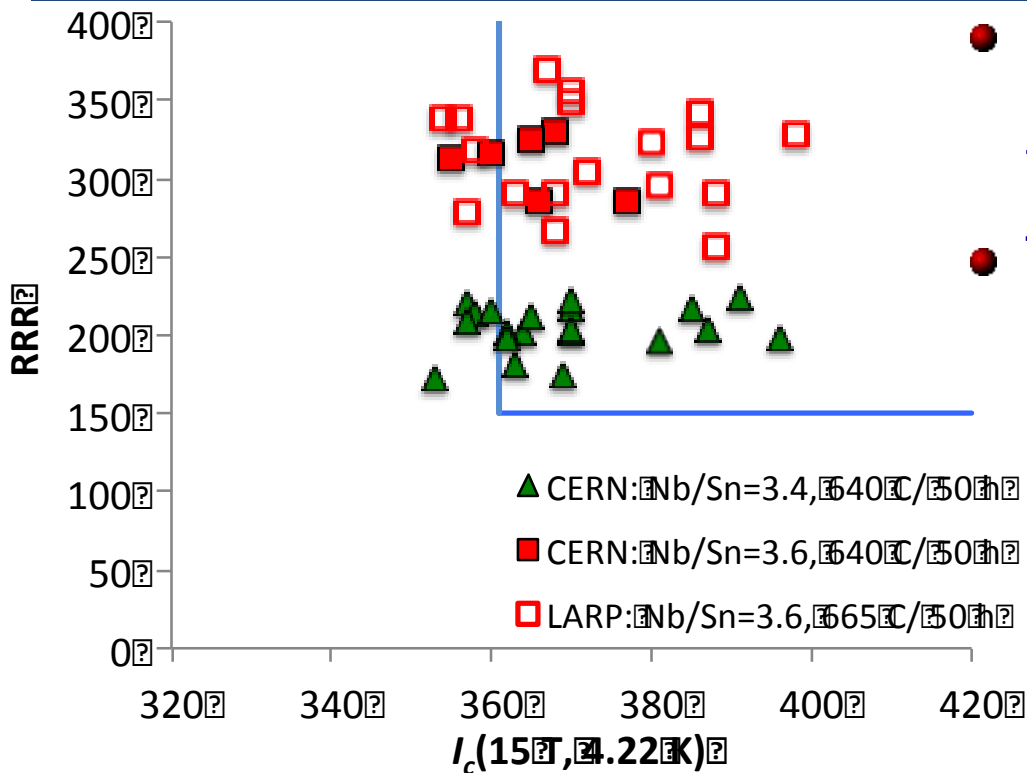
- **Risks** not evaluated?
 - Some technical points need special attention
 - Overall failure mode scenario and safety
 - Magnet operation margin
 - Beam screen design and integration
 - Use of PIT conductor in CERN quadrupoles
 - Inner-layer protection heaters and their effect on coil cooling

...more general comments from both reviews

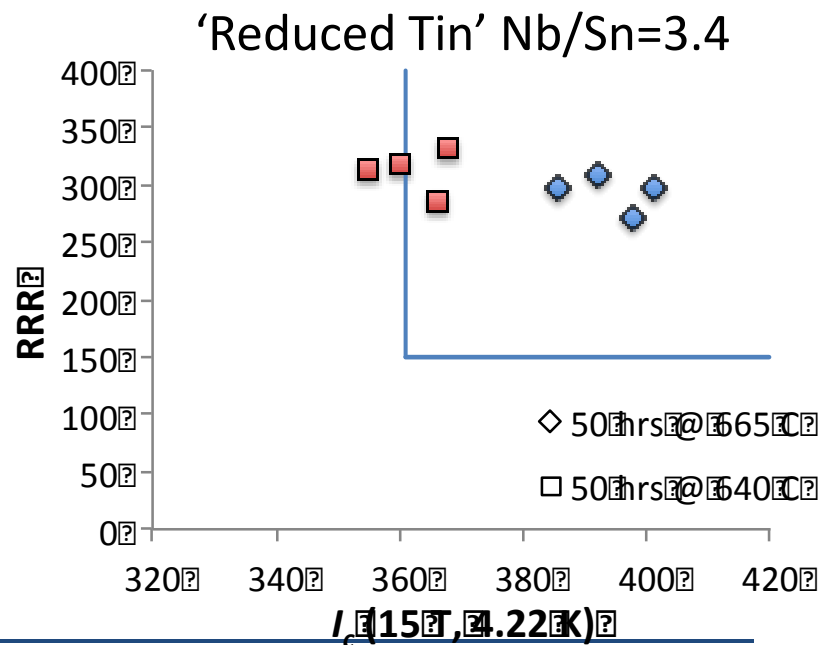
- Critical, important project; **unique opportunity**
- Enthusiastic transatlantic team, bringing a **new generation** of scientists and engineers
- Excellent communication Hi-Lumi - LARP
 - “Work sharing and cooperation are **exemplary**”
- Great recent progress
- Now, from an R&D to construction project

Appendix

The Procured 132/169 RRP wire



- Not all the piece lengths fulfill the specifications (with the used heat treatments)
- The 'reduced tin' wire appears to have a larger potential



- The 'reduced tin' wire seems to have margin for an heat treatment optimization