Summary of MQXF short model tests, and start of first MQXFA prototype test, for HiLumi LHC IR quads.

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Fermilab

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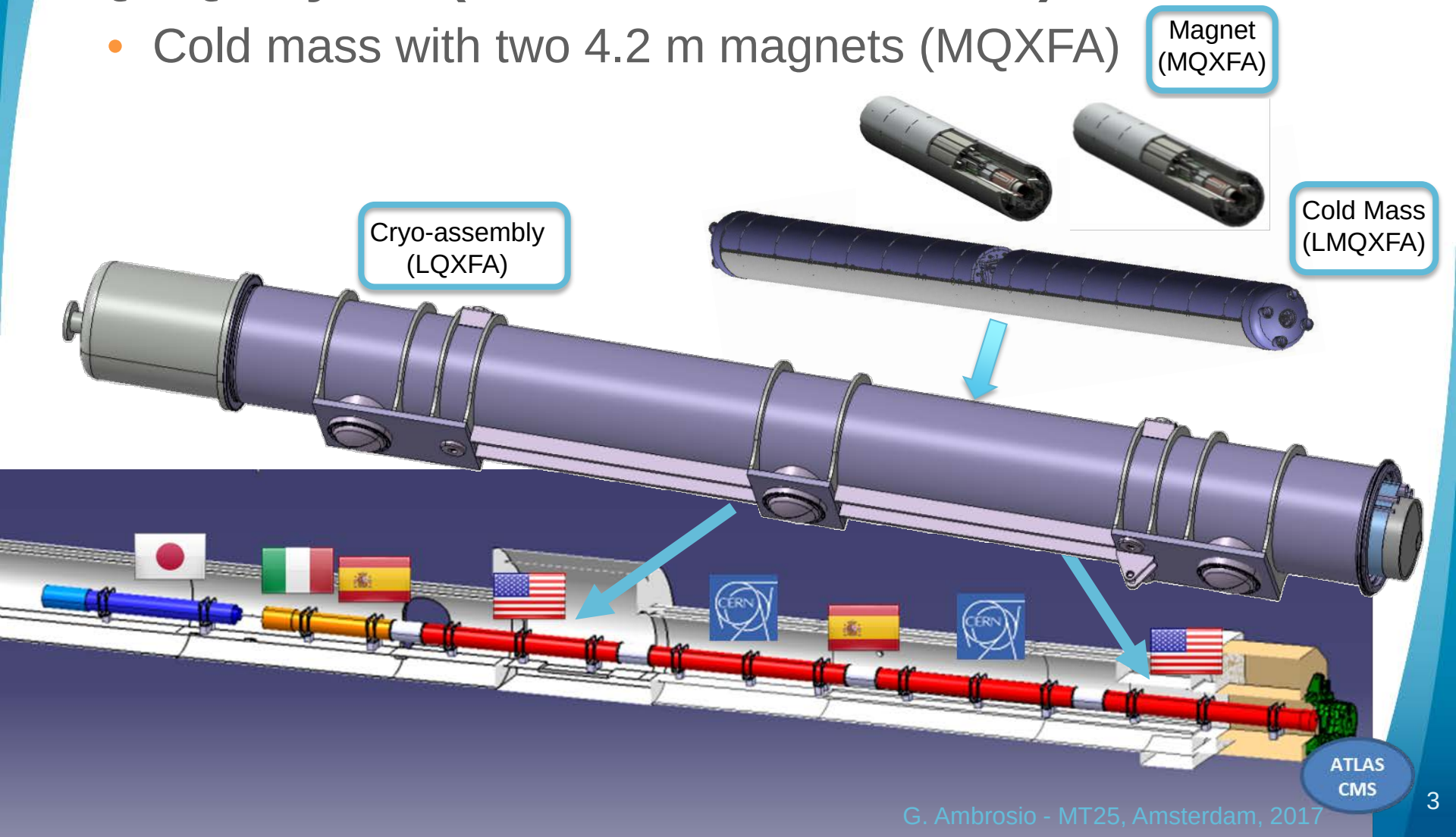
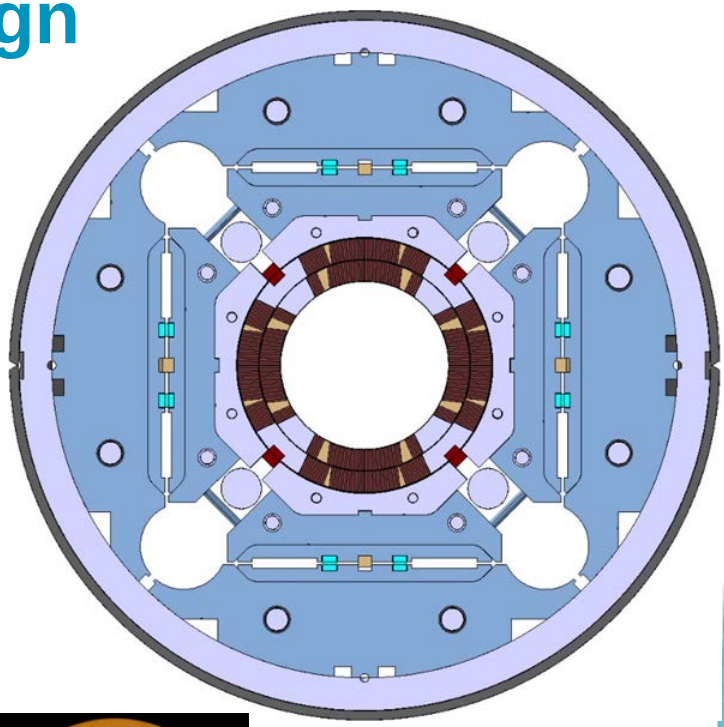
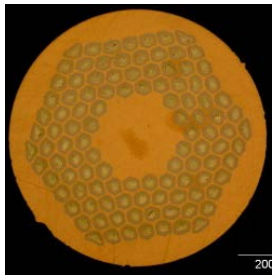
- **Qa/Q2b by CERN**
  - Cold mass with single 7.15 magnet (MQXFB)
- **Q1/Q3 by US (**LARP ➔ HL-LHC AUP**)**
  - Cold mass with two 4.2 m magnets (MQXFA)



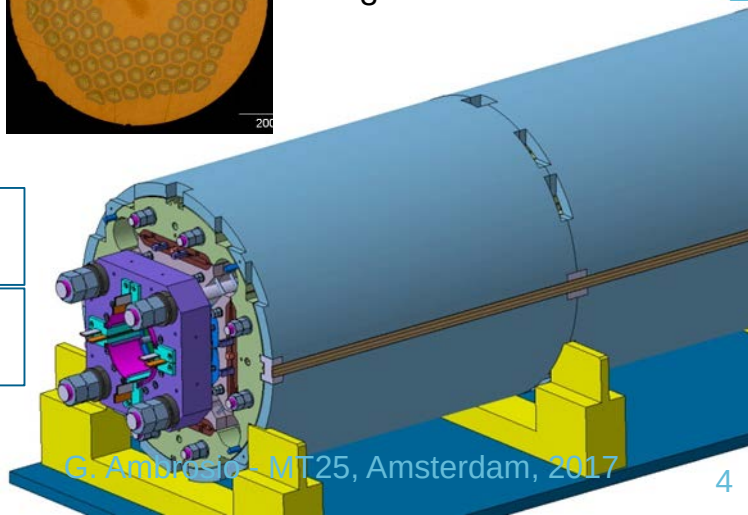
MQXFA(US)/B(CERN) Design

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
Strand diameter	mm	0.85
Strand number		40
Cable width	mm	18.15
Cable mid thickness	mm	1.525
Keystone angle		0.4





Nb_3Sn Conductor



P. Ferracin et al., "Development of MQXF, the Nb_3Sn Low-β Quadrupole for the HiLumi LHC " IEEE Trans App. Supercond. Vol. 26, no. 4, 4000207

G. Ambrosio et al., "First Test Results of the 150 mm Aperture IR Quadrupole Models for the High Luminosity LHC" NAPAC16, FERMILAB-CONF-16-440-TD

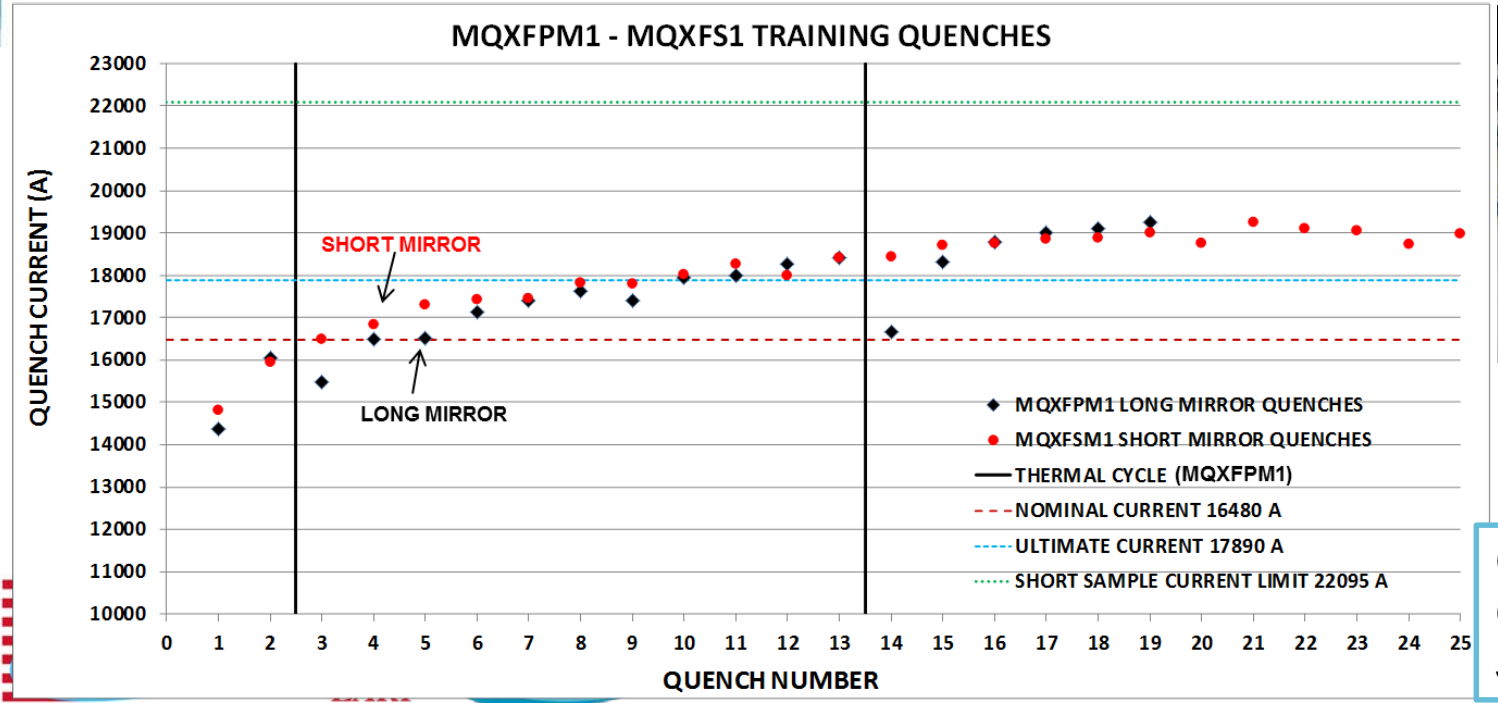
Test Status

- **Single Coils:**
  - Short Coil in Mirror Structure (RRP 108/127)
  - Long Coil in Mirror Structure (RRP 108/127)
- **Short Models:**
  - MQXFS1a/1b/1c (RRP 108/127 and 132/169)
  - MQXFS3a/3b (RRP 108/127 and 132/169)
  - MQXFS5 (PIT 192 w/out bundle barrier)
- **Prototypes:**
  - MQXFA1 - in progress
    - (RRP 108/127, 132/169, 144/169)

Single Coils in Mirror Structure

Posters by
J. Muratore Po1.01-05
P. Joshi P04.09-12

- Successful test of single short (1.2 m) and long (4.0m) coil in mirror structure
  - Large current & temperature margin
  - Very good memory
- ➔ Coil fabrication (materials & processes) is fine

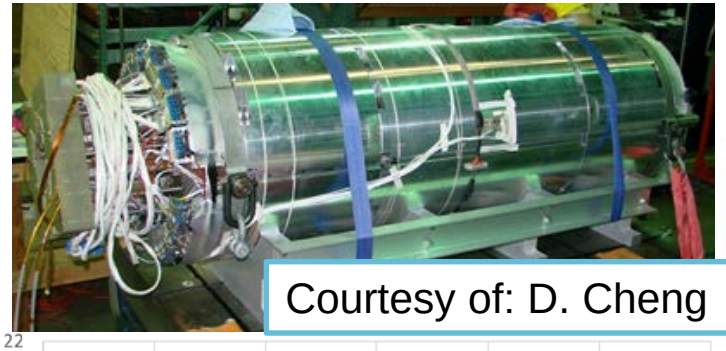


Courtesy of:
G. Chlachidze &
J. Muratore

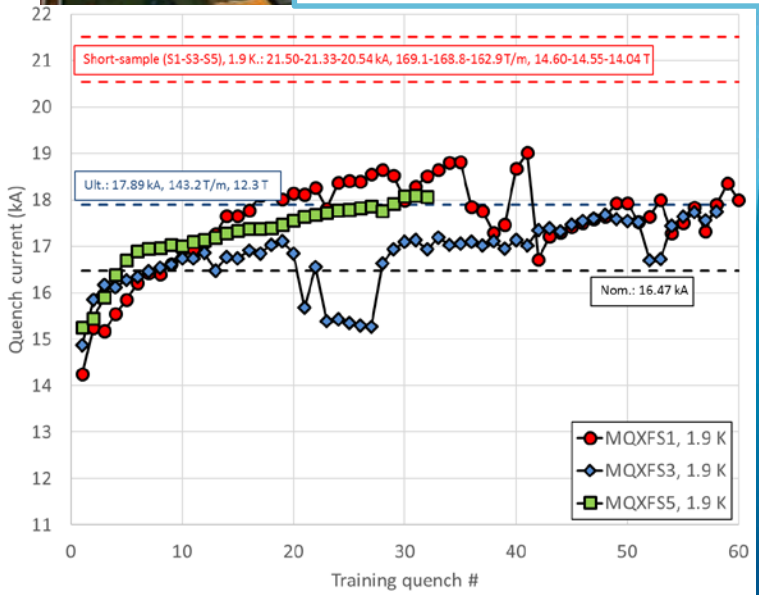
Short Models: Quench History

Talks by S. Stoynev / H. Bajas
Wed-Af-Or23-02 / 03

- MQXFS1a/b/c:
  - Exceeded requirements with large current and temp. margin
  - Very good memory
  - 1c: developed a “weakness”, exceeded ultimate op. current
- MQXFS3a/b:
  - ~Reached ultimate op. current
  - Limiting coil
  - Increased axial pre-stress helped
- MQXFS5:
  - Exceeded ultimate op. current
  - Very good memory
  - Slow training



Courtesy of: D. Cheng

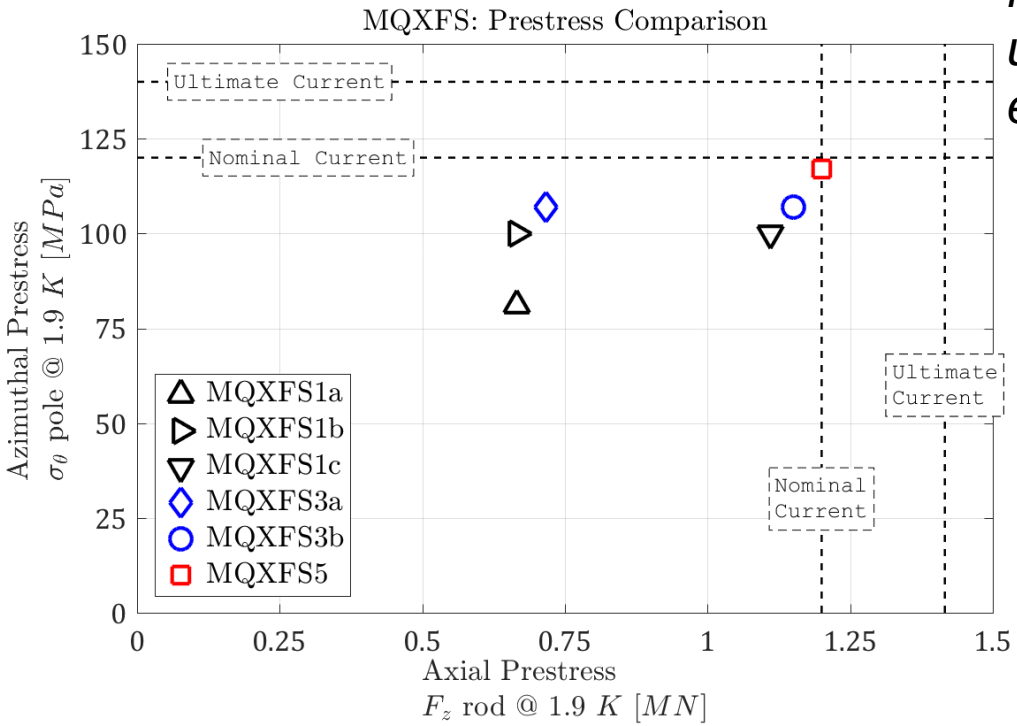


Courtesy of:
P. Ferracin,
G. Chlachidze,
S. Stoynev,
H. Bajas,
M. Bajko

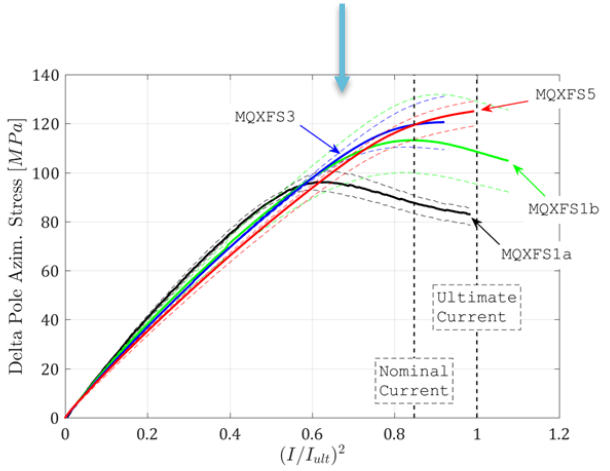
Short Models: Pre-stress

Talk by G. Vallone
Mon-Mo-Or3

- Exploring pre-stress space (azimuthal & axial)
  - Azimuthal up to nominal current looks OK in new magnet
  - Axial up to nominal current looks OK in new magnet
  - Mixed results when increasing axial pre-load in tested magnets



Note: azimuthal values recalibrated using coil-pole "detachment" during energization (max – 10 Mpa)

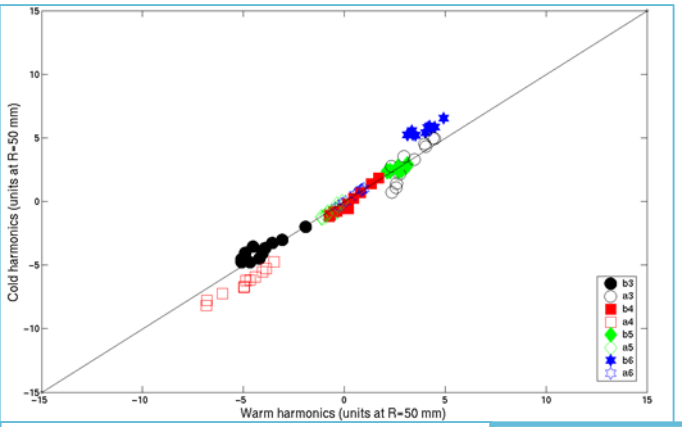


Courtesy of: G. Vallone & P. Ferracin

Short Models: Field Quality

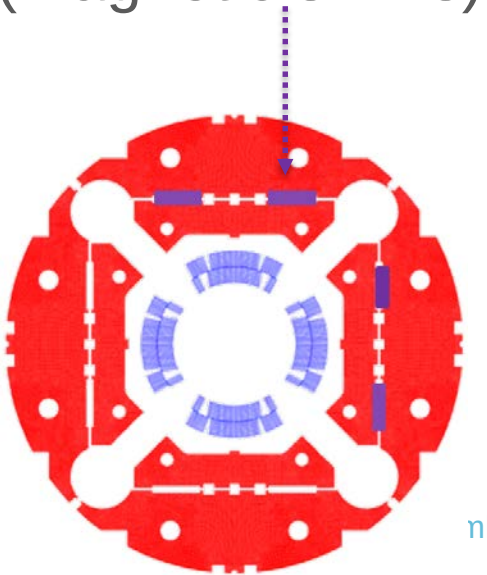
Talk by S. Izquierdo Bermudez
Wed-Af-Or23-04

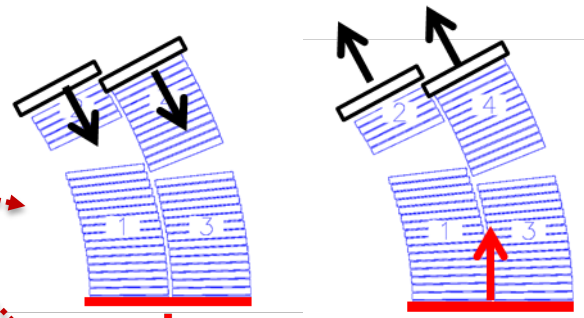
- Some MQXFS1/3/5 harmonics were above target
  - MQXFS1 focused on uniform stress
  - MQXFS3/5 assembly focused on Field Quality
- Solution: shimming
  - During coil fabrication (S2-glass)
  - During coils-pads assembly (Polyimide)
  - After magnet assembly (Magnetic shims)

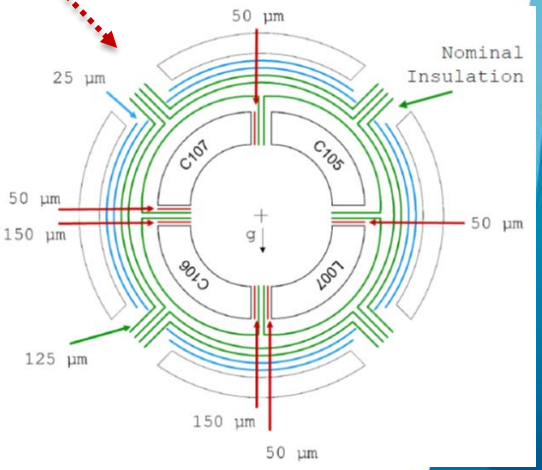


Warm-Cold Harmonics correlation in MQXFS1

Courtesy of: J. DiMarco







Quench Protection

Talk by E. Ravaioli
Wed-Af-Or24-01

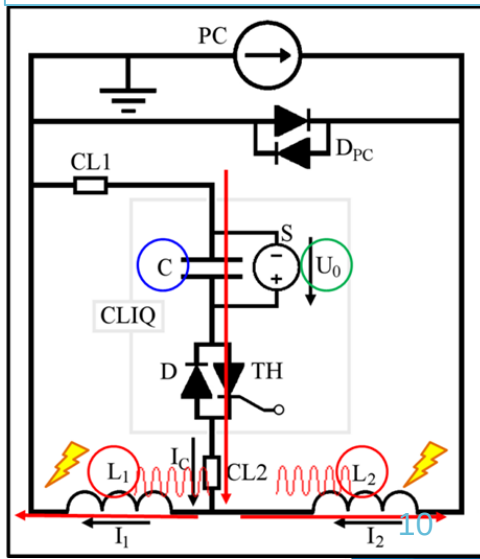
- **Outer Layer Heaters are performing as expected**
- **CLIQ is performing as expected**
  - **➔ We can protect triplet magnets with redundancy**
- Inner Layer Heaters have some detachment issues
  - ➔ Work in progress

Table 11. Failure case analysis. Simulated hot-spot temperature, peak voltage to ground and peak turn to turn voltage obtained for one failure or two simultaneous failures of QH circuits, at nominal and at ultimate current. Uncertainty ranges are due to the different locations of the initial quench and of the failing QH circuits

Configuration	T_{hot} [K]			$U_{g,peak}$ [V]			$U_{t,peak}$ [V]		
	No f	1	2	No f	1	2	No f	1	2
Nominal current									
O-QH	330-345	345-362	363-384	577	702	868	113	122	132
O-QH + I-QH	251-253	255-266	277-283	561	716	928	83	90	100
O-QH + CLIQ	236-237	238-240	239-242	641	668	666	83	84	86
Ultimate current	**Req. T_{hot} < 350 K**								
O-QH	352-369	364-385	379-406	808	916	1068	133	141	152
O-QH + I-QH	276-279	279-292	301-310	725	898	1128	101	109	120
O-QH + CLIQ	260-262	261-264	262-267	874	910	909	101	103	105

Courtesy of:
E. Ravaioli

Coupling-Loss Induced Quench

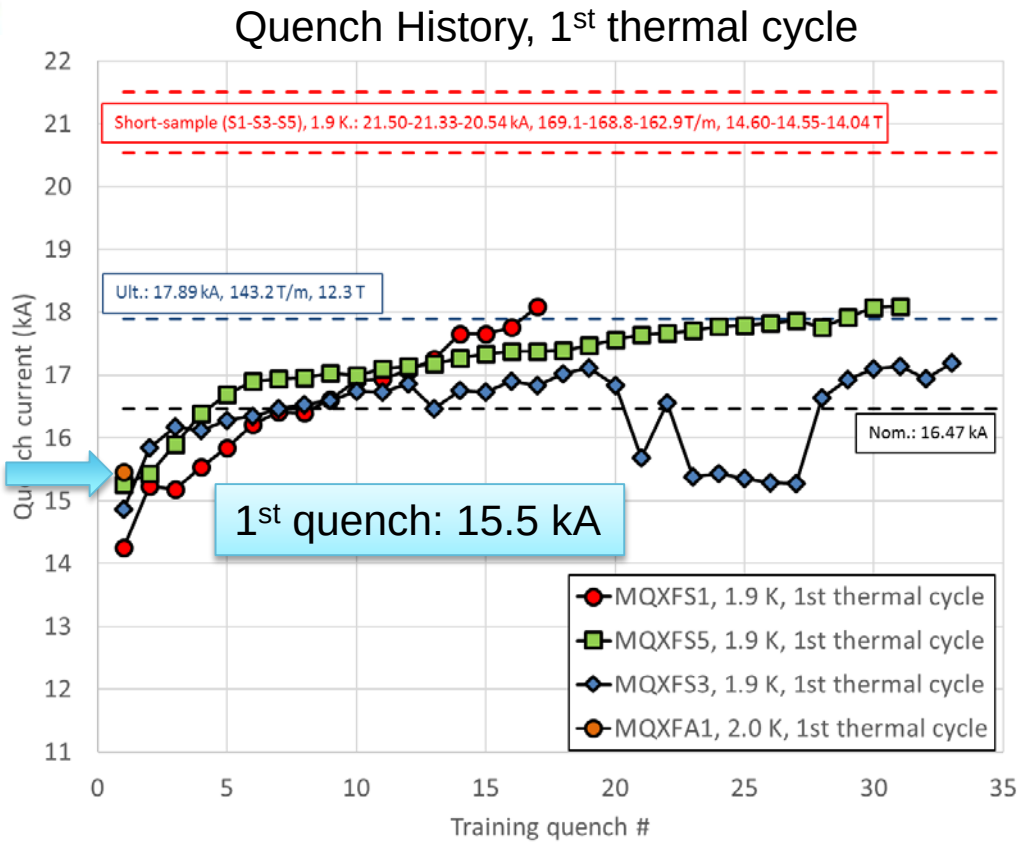


E. Ravaioli, "Quench Protection Studies for HiLumi Inner Triplet circuit" CERN EDMS #1760496

1st MQXFA Prototype

Talk by D. Cheng
Wed-Af-Or23-01

- 4 m long coils (magnetic length)
  - Conductor: RRP 108/127, 132/169, 144/169
- Full length structure (for 4.2 m coils)



Courtesy of:
M. Anerella

Courtesy of:
P. Ferracin,
S. Stoynev,
H. Bajas,
M. Bajko &
J. Muratore

Summary

- Single coil tests have demonstrated that coil fabrication technology is fine
- Short models have demonstrated that MQXF design can meet requirements
- In progress:
  - Optimization of pre-load
  - Optimization of shimming for Field Quality
  - Fixing inner layer trace/insulation bonding
- Prototype tests are starting…

Thank you!