HiLumi
HL-LHC PROJECT

Performance of a MQXF Nb_3Sn quadrupole under different stress level

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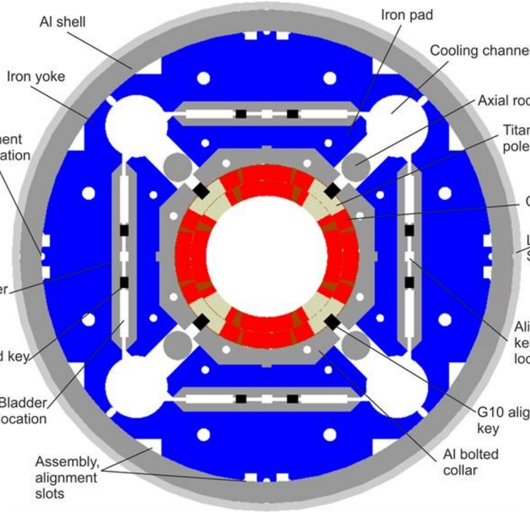
The MQXF magnet

- Large aperture quadrupole for interaction region in the HL-LHC project
- Technology developed in LARP based on Nb_3Sn
  - RRP conductor, 0.85 mm diameter
- Six short model magnets built and tested (MQXFS)
- Eight 4.2-m-long MQXFA built and tested
- Two 7.15-m-long MQXFB built and tested
  - Installation in LHC tunnel starting in 2025
  - 16 MQXFA and 8 MQXFB around ATLAS and CMS
- Here we report about a relevant result of short model program, MQXFS6 obtained in 2019-2020

The MQXF magnet

- Magnet main parameters:
  - Large aperture (150 mm diameter)
  - Peak field of 11.3 T at nominal current (7 TeV)
  - Short sample at 14.5 T
  - Nb_3Sn conductor, Rutherford cable
  - Two layer coils, impregnated with CTD-101K
  - Bladder and key structure, Al shells
  - Scale-up of TQ and HQ LARP magnets

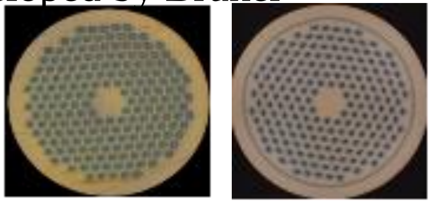
  P. Ferracin, et al., *IEEE Trans. Appl. Supercond.* **26** (2016) 4000207



MQXF cross-section (P. Ferracin, G Ambrosio)

- Short model:
  - All features of the long magnet, but 1.2 m long magnetic length
  - The MQXFS6 coils were wound with PIT-192 strand, developed by Bruker
    - Two coils with PIT 192
    - Two coils with bundle barrier developed by Bruker and CERN

    B. Bordini, et al., *IEEE Trans. Appl. Supercond.* **27** (2017) 6000706



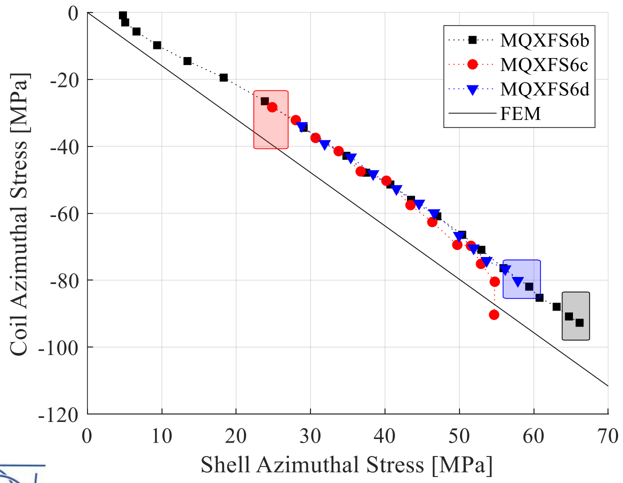
PIT-192 and PIT-192 with bundle barrier

The MQXFS6 experiment

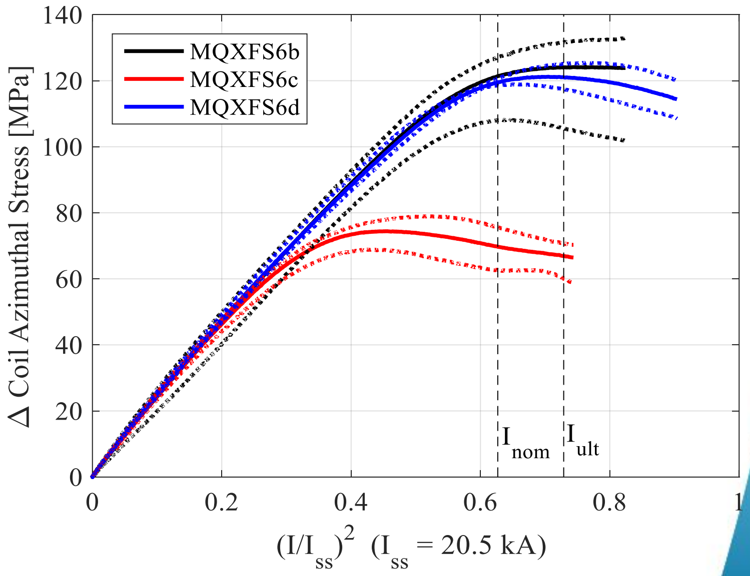
- The coil of the MQXFS magnet is preloaded via the mechanical structure to balance the effect of the electromagnetic forces at nominal current
  - This corresponds to having electromagnetic forces compensated by preload up to 80% of short sample current, and having 110 MPa azimuthal compression of the coil at 1.9 K
  - Careful control of preload is achieved, and the unloading a nominal current is measured via strain gauges
- In this experiment we verified the possibility of a lower preload
  - There is evidence in previous literature that a lower preload does not prevent to reach target currents (since SSC in the early 90's, A. Devred, et al., *AIP Conference Proceedings* **249** (1992) 1309)
  - We tried a configuration with half of preload at 1.9 K (60 MPa), therefore giving electromagnetic forces compensated up to 60% of short sample
  - This is the lowest achievable preload with bladder and key structure, since
    - One has a positive contribution of cool-down to preload
    - One needs a minimal preload at room temperature to be able to handle the magnet

The mechanical data

- MQXFS6b: preload for nominal current (80% of short sample)
- MQXFS6c: preload for 60% of short sample
- Mechanical data during powering confirm the expected behaviour
  - MQXFS6b: unloading at $(I/I_{ss})^2=(0.8)^2\sim 0.64$
  - MQXFS6c: unloading at $(I/I_{ss})^2=(0.6)^2\sim 0.36$



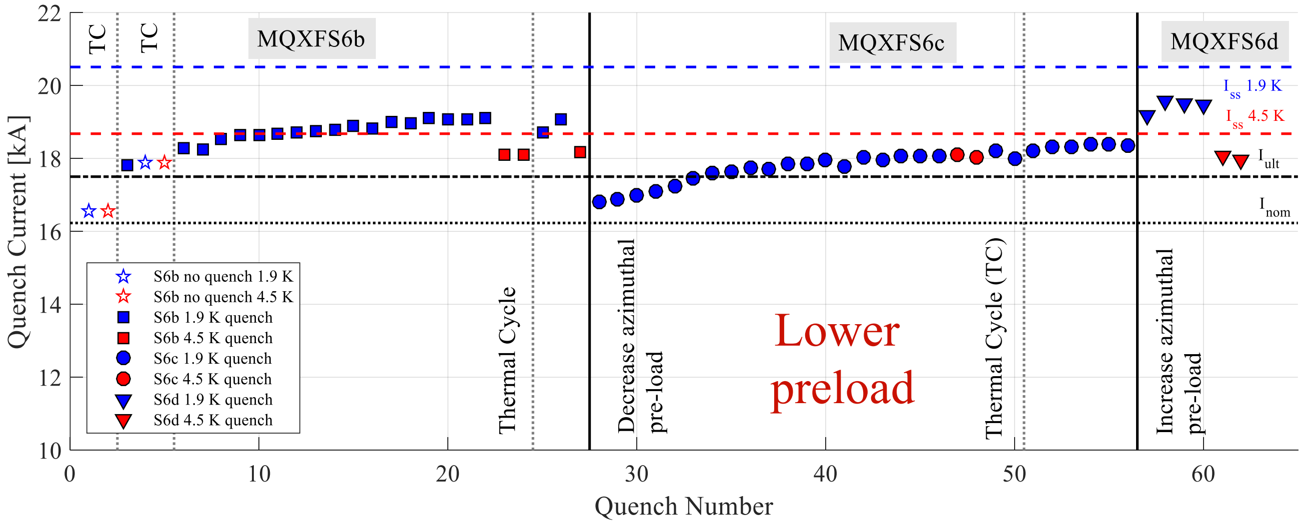
Measured stresses during assembly, and FEM



Measured unloading during powering
(M. Guinchard, et al)

The quench perfomance

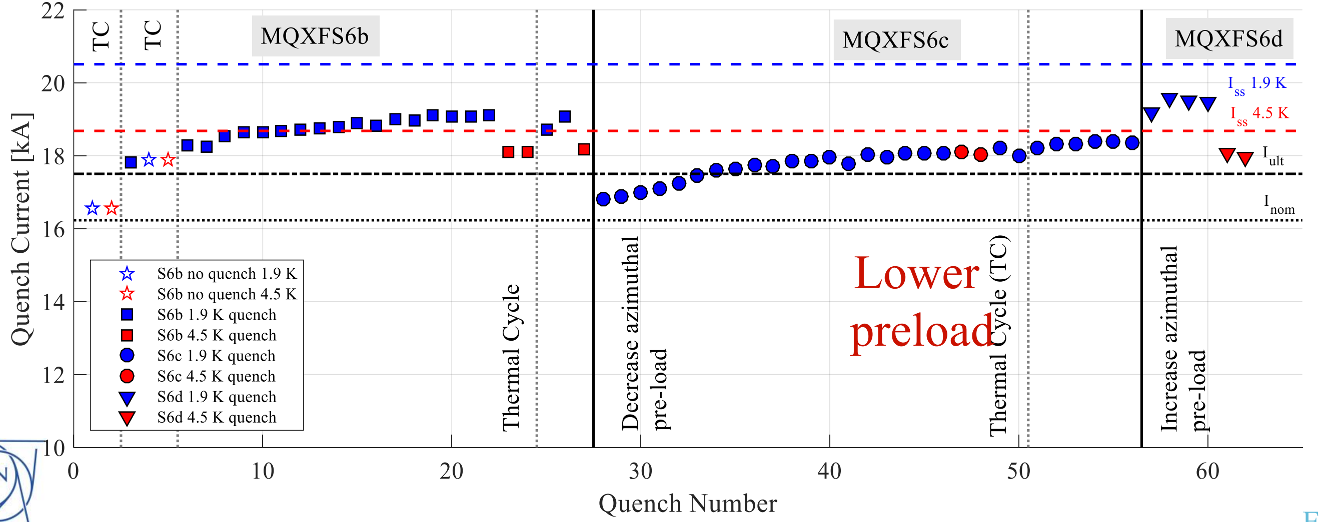
- MQXFS6b: (preloaded for 80% of short sample): 93% of short sample reached
- MQXFS6c: (preloaded for 60% of short sample): 89% of short sample reached
- MQXFS6d: (preloaded back to 80% of short sample): 95% of short sample reached, 13.4 T peak field



Powering of MQXFS6b-c-d (S. Ferradas Troitino, F. Mangiarotti, S. Izquierdo Bermudez at el.)

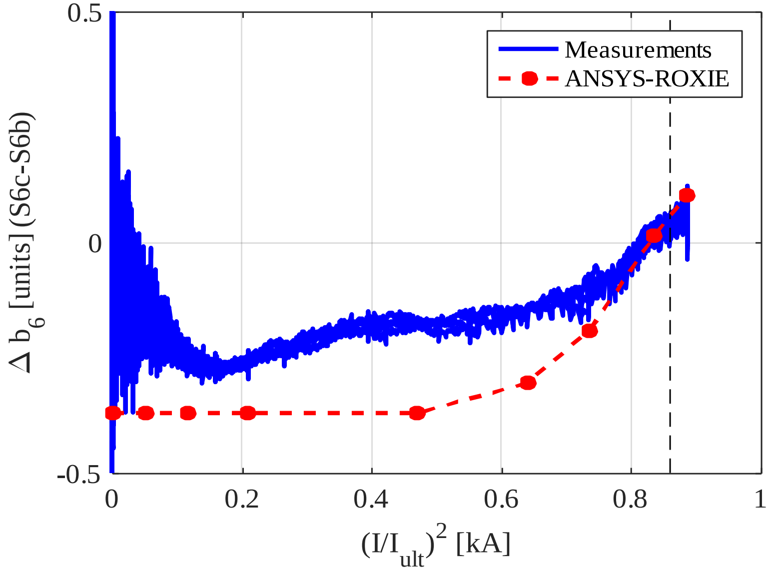
The quench perfomance

- As known in the literature since more than 30 years, currents larger than the corresponding preload value can be reached
  - In our case, preload as low as 60% of short sample allows reaching >85% of short sample
- In our case, higher preload reduces training in the region above 80% of short sample
- In our case, 80% preload rather than 60% allows reaching the highest performances (90%-95% of short sample)



Magnetic measurements

- A further cross-check of the lower preload: the variation of b_6 along the magnet ramp
  - Expected pole detachment provokes a change in first allowed multipole b_6
  - Measurements confirm that the lower preload has larger pole detatchment



Measured difference in b6 versus current between MQXFS6b and MQXFS6c, and comparison to model