Cold powering test requirements for HL LHC: MQXF

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CERN, June 13th – 14th, 2016
Outline

- MQXF Magnets
- MQXFA Functional Test Requirements
  - Test Objectives for Prototypes
  - Test Requirements
MQXFA/B: Magnets for LHC Inner Triplet Upgrade

International collaborations: an opportunity and a challenge, also for testing!
MQXFA/B Magnets

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>Unit</th>
<th>MQXFA/B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coil aperture</td>
<td>mm</td>
<td>150</td>
</tr>
<tr>
<td>Magnetic length</td>
<td>m</td>
<td>4.2/7.15</td>
</tr>
<tr>
<td>N. of layers</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>N. of turns Inner-Outer layer</td>
<td></td>
<td>22-28</td>
</tr>
<tr>
<td>Operation temperature</td>
<td>K</td>
<td>1.9</td>
</tr>
<tr>
<td>Nominal gradient</td>
<td>T/m</td>
<td>132.6</td>
</tr>
<tr>
<td>Nominal current</td>
<td>kA</td>
<td>16.5</td>
</tr>
<tr>
<td>Peak field at nom. current</td>
<td>T</td>
<td>11.4</td>
</tr>
<tr>
<td>Stored energy at nom. curr.</td>
<td>MJ/m</td>
<td>1.17</td>
</tr>
<tr>
<td>Diff. inductance</td>
<td>mH/m</td>
<td>8.2</td>
</tr>
<tr>
<td>Strand diameter</td>
<td>mm</td>
<td>0.85</td>
</tr>
<tr>
<td>Strand number</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Cable width</td>
<td>mm</td>
<td>18.15</td>
</tr>
<tr>
<td>Cable mid thickness</td>
<td>mm</td>
<td>1.525</td>
</tr>
<tr>
<td>Keystone angle</td>
<td></td>
<td>0.4</td>
</tr>
</tbody>
</table>

Cold Test Requirements

- MQXFA (magnet) Functional Test Requirements
  - For Vertical Test
  - US-HiLumi DocDB # 7
# MQXFA Magnet Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MQXFA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Quadrupole</td>
</tr>
<tr>
<td>Aperture</td>
<td>150 mm</td>
</tr>
<tr>
<td>Overall Length</td>
<td>4961 mm</td>
</tr>
<tr>
<td>Max Support Structure OD without/with He vessel</td>
<td>614/630 mm</td>
</tr>
<tr>
<td>Magnet Weight</td>
<td>6800 Kg</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>1.9 K</td>
</tr>
<tr>
<td>Operating Current</td>
<td>16471 A</td>
</tr>
<tr>
<td>Operating Gradient</td>
<td>132.6 T/m</td>
</tr>
<tr>
<td>Peak Field at Operating Current</td>
<td>11.41 T</td>
</tr>
<tr>
<td>Magnetic Length</td>
<td>4200 mm</td>
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<tr>
<td>Stored Energy at Operating Current</td>
<td>4.91 MJ</td>
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<tr>
<td>Inductance at Operating Current</td>
<td>34.5 mH</td>
</tr>
<tr>
<td>Short Sample Gradient</td>
<td>168 T/m</td>
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<tr>
<td>Short Sample Current</td>
<td>21.2 A</td>
</tr>
<tr>
<td>Short Sample Peak Field</td>
<td>14.5 T</td>
</tr>
<tr>
<td>Maximum Coil MIITs</td>
<td>36</td>
</tr>
</tbody>
</table>
Test Objectives for Prototypes

- At room temperature:
  - HiPot Measurement
  - Magnetic Measurements
    - Rotating probe measurements

- Measurements during cooldown and warmup
  - RTD measurements
  - Strain Gauge measurements
  - Residual Resistivity Ratio (RRR) Measurements
Test Objectives for Prototypes

- Measurements at 1.9 K:
  - HiPot Measurement
  - Magnetic Measurements
    - Rotating probe measurements
  - Quench Training
    - Up to 120% operating current (19.7 kA)
  - Quench Characterization
    - Voltage taps measurements
    - Quench Antenna measurements
  - Quench Protection Studies
  - Quench Propagation Studies
  - Ramp Rate Dependence Measurements
  - Voltage Spikes Measurements
  - Energy Loss Measurements
  - Splice Measurements (at 1.9 or 4.5 K)
Test Objectives for Prototypes

- Measurements at 4.5 K:
  - Assess short sample limit percentage at 4.5 K after 1.9 K training
  - Ramp Rate Dependence at 4.5 K in case of issues at 1.9 K

- A thermal cycle will be included to verify that the magnet retains its training.
Requirements

- Cooldown and Warmup requirements:
  - Max temperature gradient btw magnet ends < 150 K

- Temperature measurement:
  - Accuracy +/- 10 mK
  - Precision +/- 20 mK

- HiPot requirement:
  - Coil-Ground and Heaters-Ground up to 3500 V
  - Heaters-Coil up to 2500 V
  - At room temperature in air, and at cold in LHe
  - Note: MQXF High Voltage requirements TDB
Current requirements
- For prototypes: up to 19.8 kA
- For production magnets: up to 17.8 kA (108% $I_{nom}$)

Ramp Rate requirement:
- Max test current ramp rate is 300 A/s
- Ramp rate changeable during current ramp

Magnetic measurements requirements:
- Warm finger (anti-cryostat) for magn meas with rotating probe up to 100 mm diameter
Quench Protection requirements:

- Detection channels (minimal list): Whole coil, Whole coil – Idot, Half coil – Half coil;
  - with current-dependent thresholds
- Quench heaters: 24 strips powered as pairs in series
  - HFU voltage up to 450 V per strip
- Energy extraction: up to 50 mOhm dump
  - Variable dump delay: 0-1000ms
- Power supply phase back with no delay after detection trigger
- CLIQ: 2 leads for CLIQ units
Quench Characterization:
- Up to 80 voltage taps
- Minimum sampling rate: 10 KHz
- Minimum time window for logging data 4 sec

Quench Antenna
- Will be installed in the warm bore
- Details TBD

Voltage Spike measurements:
- Minimum sampling rate: 100 kHz
Test Stand should be able to do these measurements:

- Energy loss measurements
- RRR measurements
- Splice measurements
LARP & CERN have started testing short models,
- MQXFS1 tested at FNAL in Spring 2016
- MQXFS3 to be tested at CERN in August 2016

In June/July BNL is going to commission the Vertical Test Facility, and to test a single 4m QXF coil in mirror structure

Thank you!