Design, manufacturing and testing of a unique coil collaring system for the Jefferson lab's large superconducting magnets SHMS Dipole and Q2Q3 quadrupoles

A. Porhiel, F. Forest, M. Delbecq, D. Ramauge, S. Antoine, V. Sigalo, P-E. Maillard, ***SIGMAPHI***, *Vannes, France*
P. Brindza, E. Sun, S. Lassiter, ***JEFFERSON LAB***, *Newport News, Virginia*

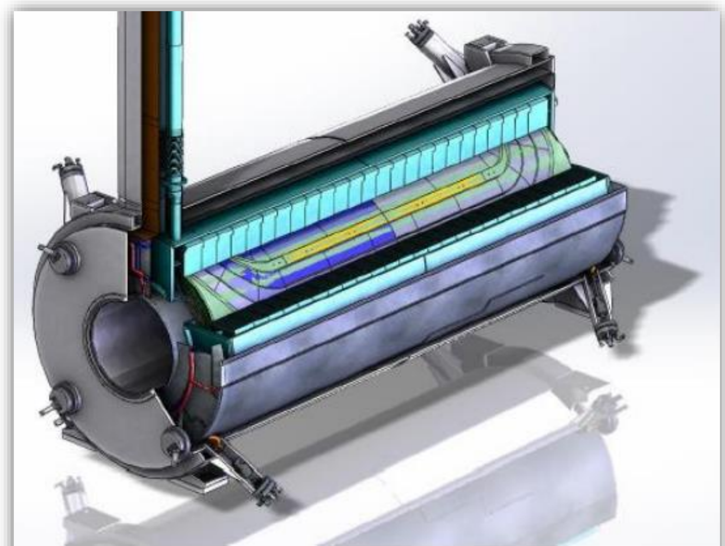
Poster ID: Mon-Af-Po1 #203
Presented at the 25th international conference on Magnet Technology

ABSTRACT

Three large superconducting magnets have been designed and built by Sigmaphi (France) for the Jefferson Lab's 11 GeV/C Superconducting Spectrometer. These SHMS Dipole and Q2/Q3 quadrupoles use the same collaring system based on aluminum force rings designed to ensure coil integrity and avoid conductor motion. The coil properties have been determined thanks to mechanical tests at room temperature and at 4.2K. Conclusions of the FEA analysis performed by Sigmaphi have been verified thanks to strain measurements on a collaring prototype and during final collaring. Manufacturing steps and final acceptance tests done at JLAB are also presented.

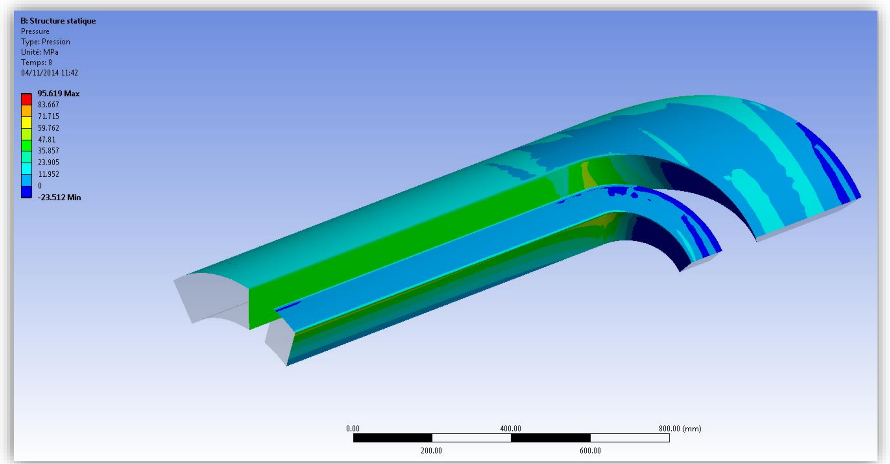
DESIGN

- Magnetic FEA analysis
- Mechanical FEA analysis (collaring interference temperature / verification of normal & shear stresses / positive contact pressure along coil pole)
- Quench calculations
- Calculation of Eddy currents in force rings
- Pressure safety analysis on helium vessel according to ASME VIII division 1 & 2
- Mechanical & Thermal FEA analysis of suspension links
- Mechanical FEA analysis of vacuum vessel

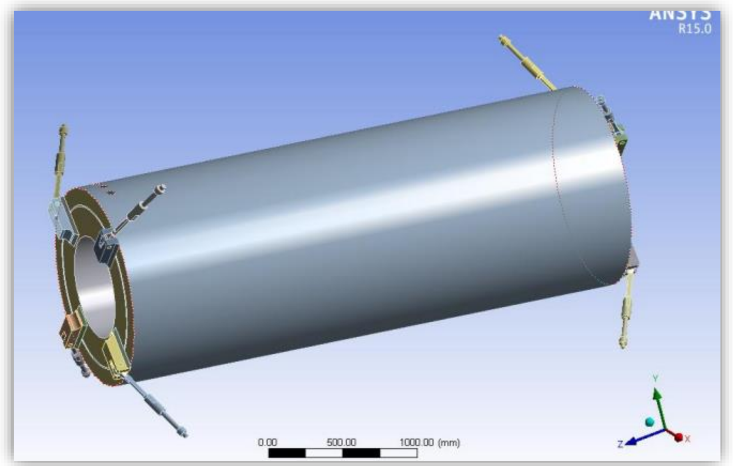


DIPOLE SHMS – Quantity 1
24 tons
Warm bore 600mm
Field 4.25 Tesla – 3500 A
Superconducting NbTi Liquid helium bath

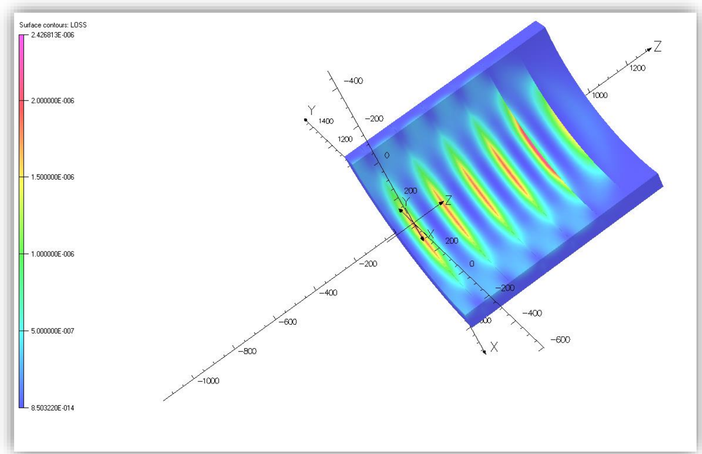
Quadrupole Q2&Q3 – Quantity 2
15 tons
Warm bore 600mm
Gradient 16 T/m - 4250 A
Superconducting NbTi Liquid helium bath



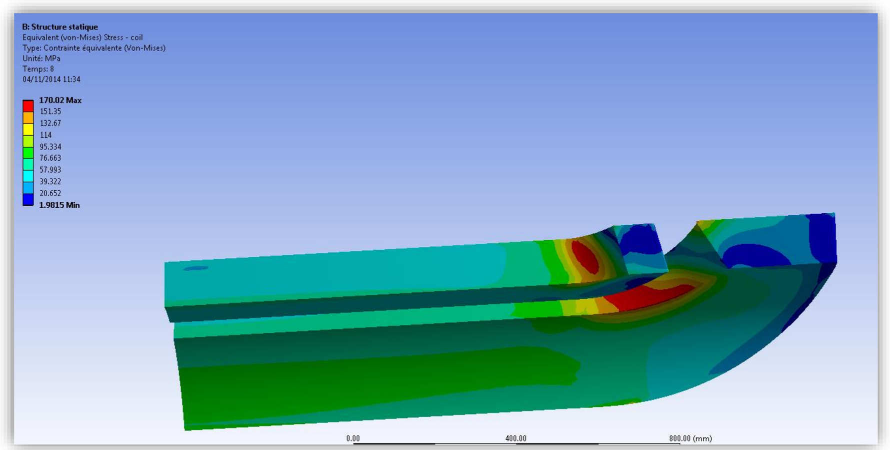
Contact pressure between spacers and coil under magnetic forces



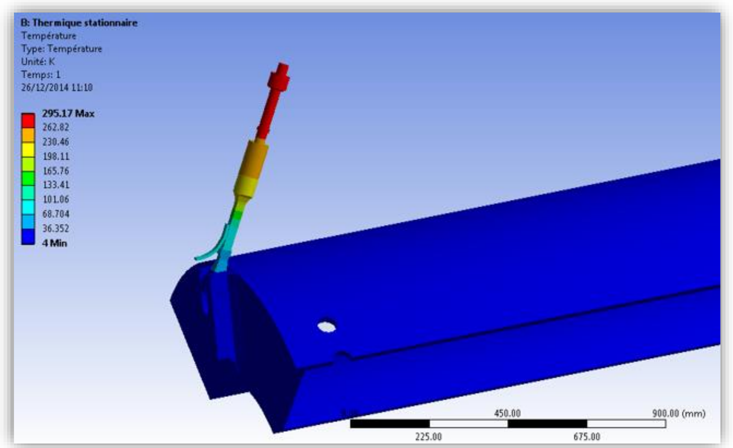
FEA analysis on Helium vessel according to ASME code



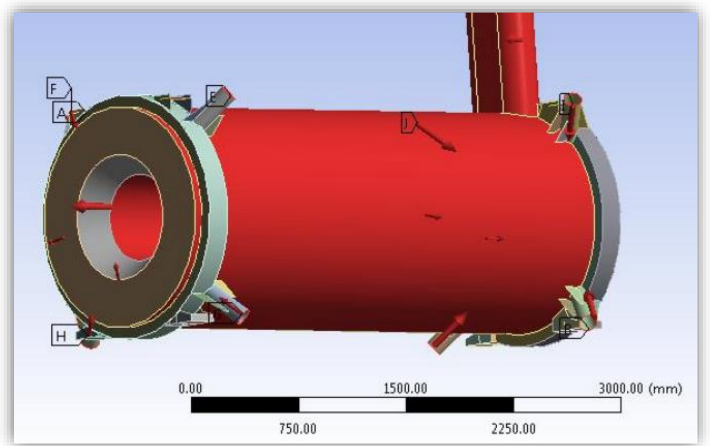
Eddy currents calculation on Force rings



Von Mises stress through the winding under magnetic forces



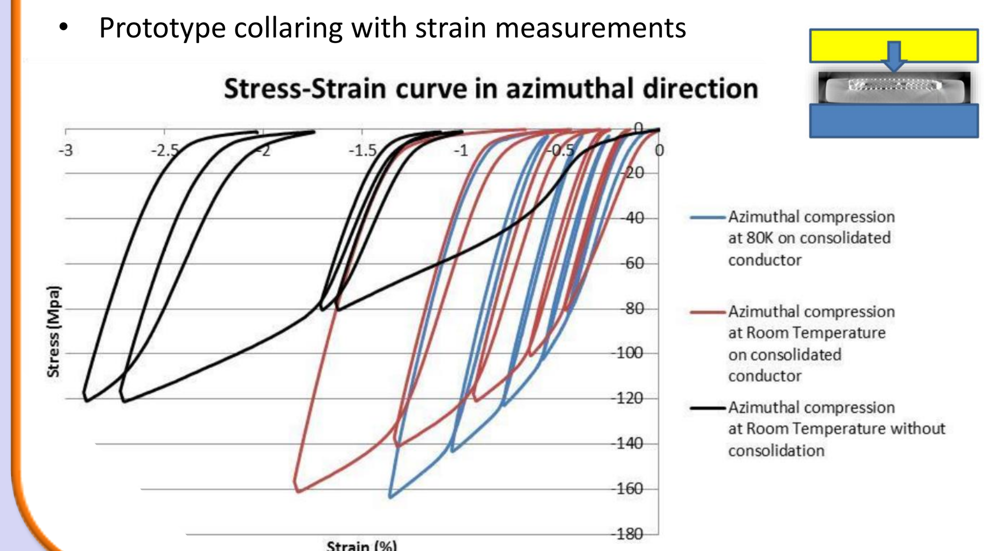
Optimization of suspension links dimensions & materials

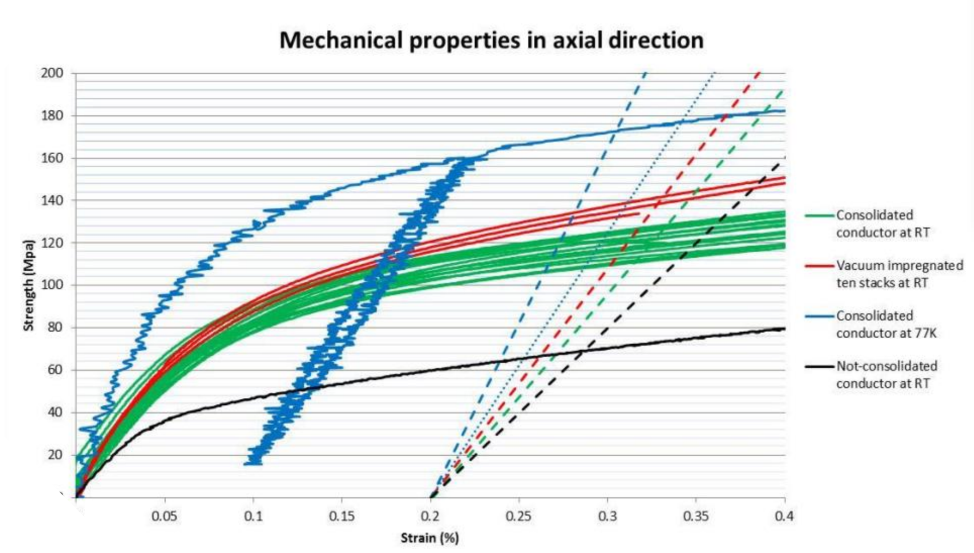


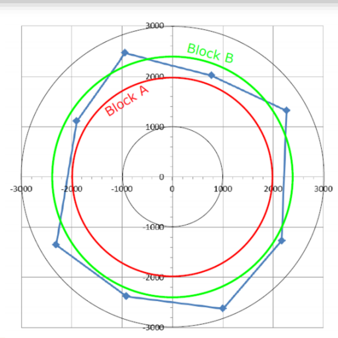
FEA analysis on Vacuum vessel

PROTOTYPING

- Improvement of conductor mechanical properties
- Mechanical measurements (properties under tension & compression, Poisson ratio, Shear strength, CTE) at room temperature, 77K and 4K
- Prototype collaring with strain measurements







MANUFACTURING

Conductor consolidation (22km consolidated)

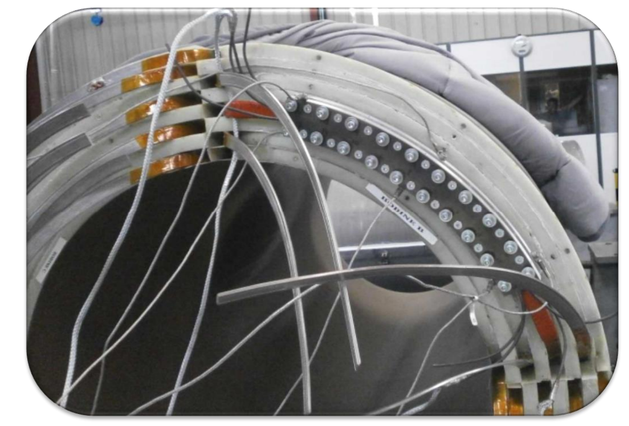
Winding (dipole: 6 layers, Q2/Q3: 8 layers)

Molding (Resin CTD 101K, a unique molding per pole)

Assembly, ground insulation & final impregnation

Machining (collars machined after coil OD measurement)

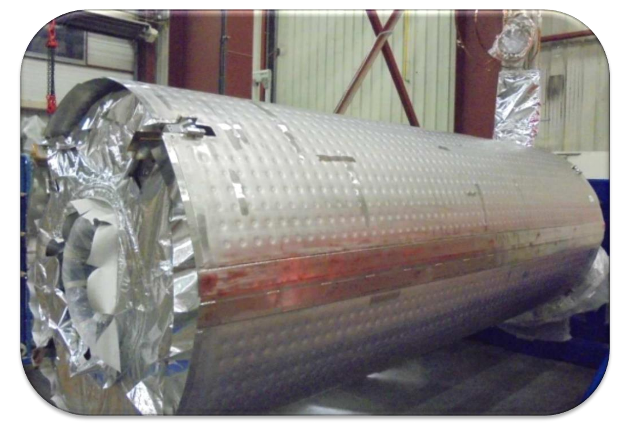
Collaring (interference temperature = 95°C)



Splicing (process validated with pulling tests)

Instrumentation (PT100, Carbon Ceramic sensors & voltage taps)

Integration in Helium vessel (ASME welds & controls, pressure & leak tests)



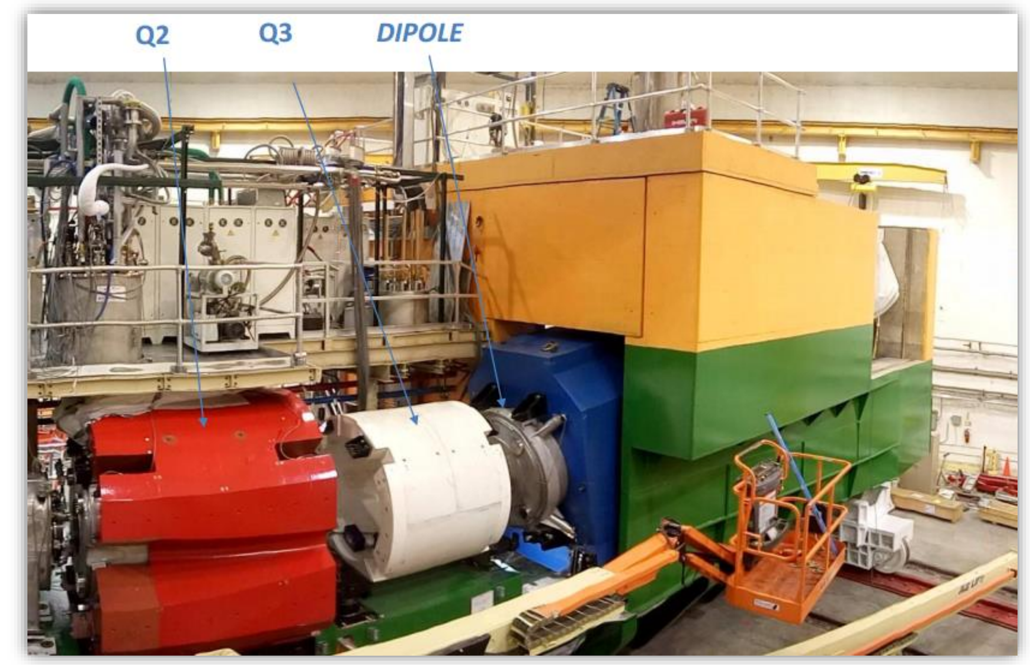
Thermal shield installation (ASME welds & controls, pressure & leak tests)

Outer vessel installation (final leak tests on the 3 vessels)

Magnetic measurements with Sigmaphi's mapping table

INSTALLATION

- Shipping & installation in Hall C at Jefferson Lab.
- Leak tests and electrical checks after shipping.
- Splicing between dipole and its cryogenic reservoir by Sigmaphi.
- Final welding & connection to the cryogenic system by JLAB.
- Magnets cool down and heat loads measurements.
- Alignment at low current thanks to strain gauges on suspensions.



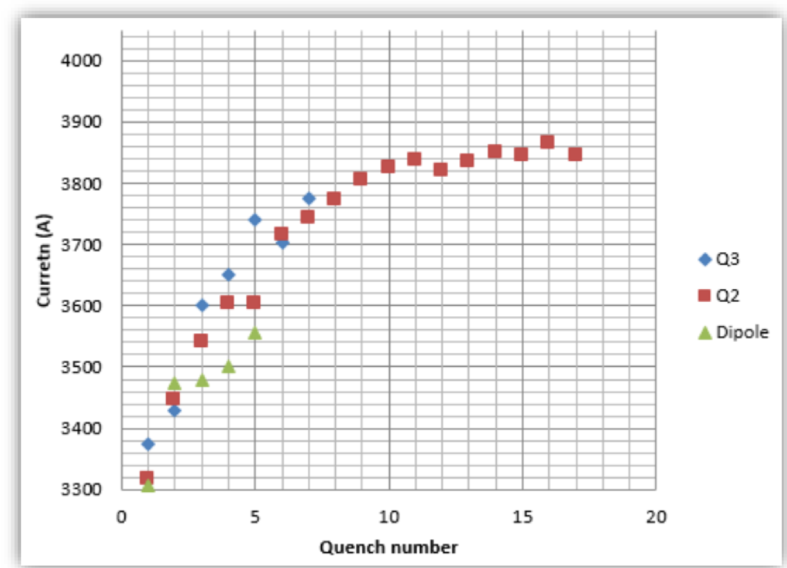
TESTING

The 3 magnets reached successfully their acceptance test current after few quenches:

Dipole: 103% I_{nom}

Q2: 106% I_{nom}

Q3: 153% I_{nom}



CONCLUSIONS

The Dipole, Q2 and Q3 magnets reached successfully their nominal performances not only thanks to the significant efforts put on design, mechanical tests and prototyping but also thanks to the precautions taken and the numerous controls performed during manufacturing. This success is the result of a close collaboration between Sigmaphi and Jefferson Lab technical experts.