THEA ENERGY

Design and Simulations of Planar-Coil Stellarator Systems

A. T. Cote, D. H. Fort, D. Gates, K. Tang, C. P. S. Swanson, J. Wasserman

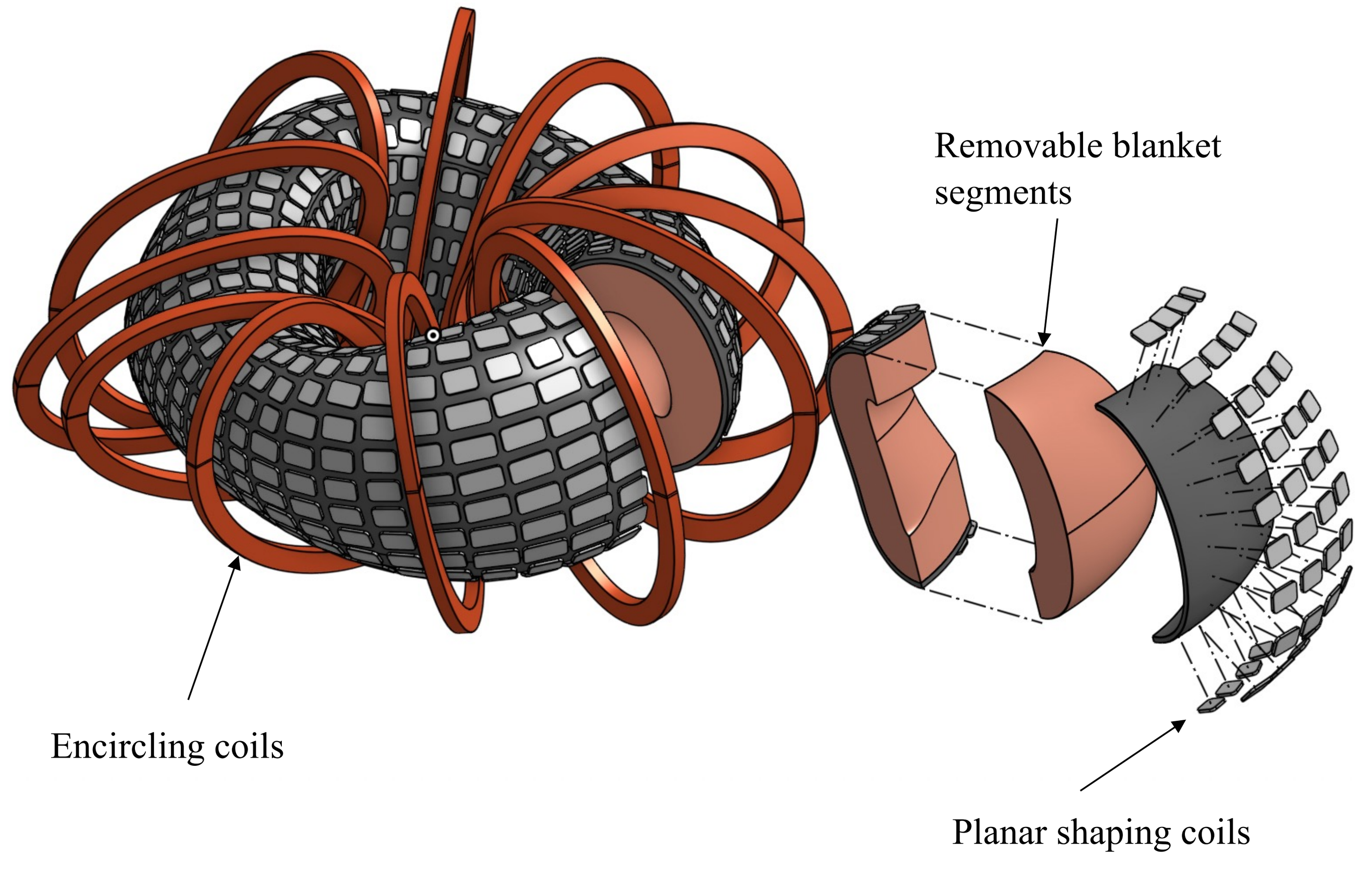
Overview

- Stellarator systems have been designed parametrically using a scripting language and conventional CAD design.
- Simulations on electromagnetic, thermal, and mechanical properties have been simulated using FEM software.
- Construction of prototyping facilities for single-coil testing are now underway, in tandem with design + simulations.

Planar Coil Stellarator System Modeling

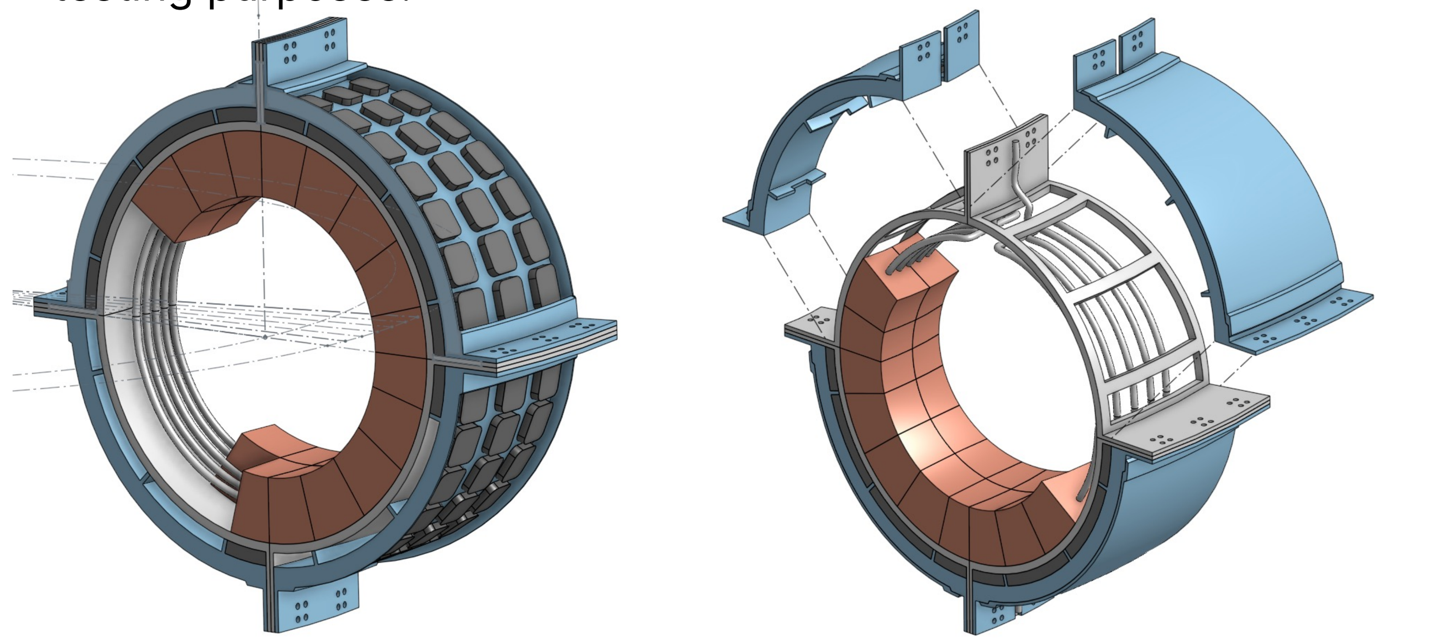
A Planar Coil Stellarator has been under development at Thea Energy.

- Systems are designed with both conventional CAD and via programmatic scripting interfaces to quickly iterate between FEM simulations and design geometry.
- Accessibility of blanket sections has been emphasized to allow regular reactor maintenance.
- Large number of individual planar field-shaping coils demands extensive testing and prototyping of individual coils to maximize performance and minimize cost.
- Mechanical supporting structure for major encircling coils as well as structural supports for attachment of Field Shaping Units which hold planar shaping coils is now underway.



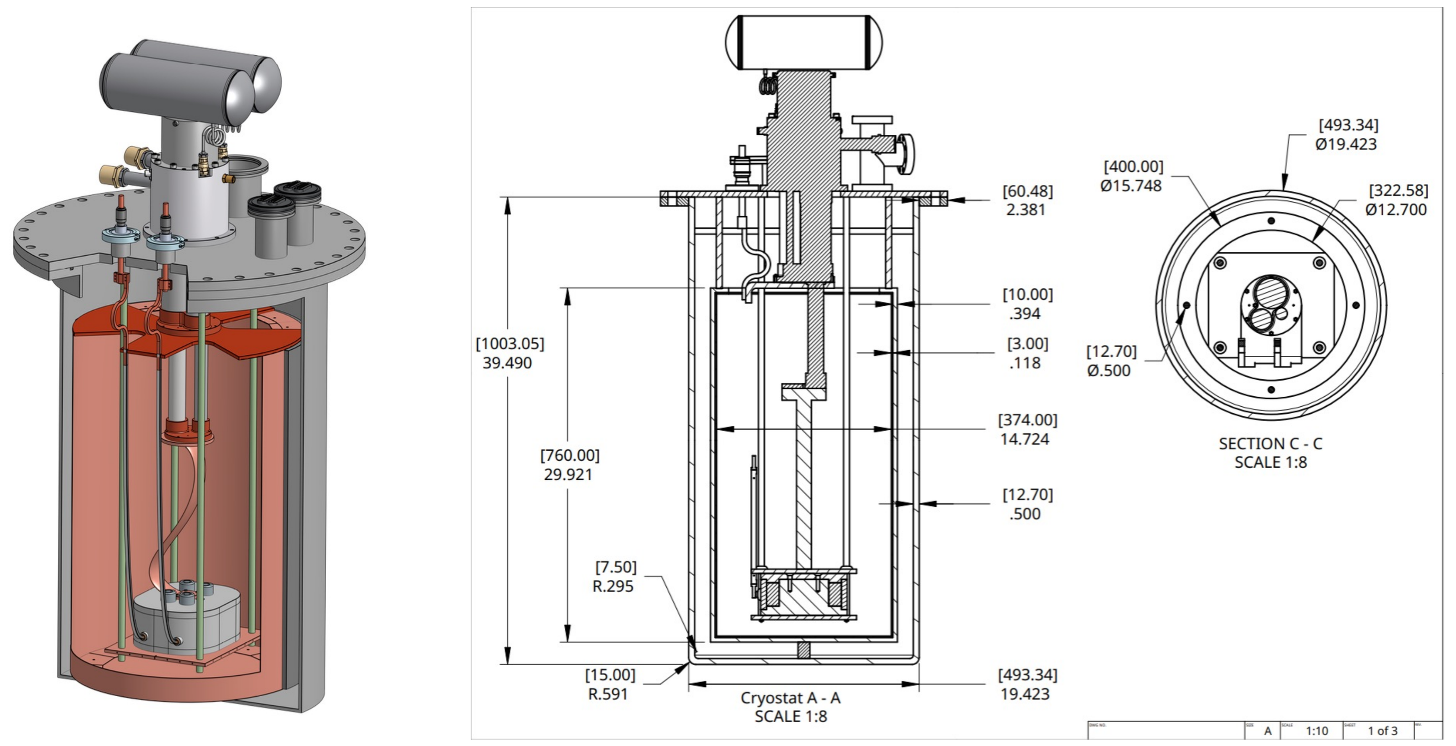
Field Shaping Units and Accessibility

- Individual planar shaping coils are mounted onto removable panels called Field Shaping Units that contain mechanical, cryogenic, and electrical subsystems.
- Field Shaping Units provide flexibility in maintenance, design, and testing.
- Designs have been patented and inform our coil testing strategy in operating multiple small coils together in close proximity.
- A single coil and 3x3 coil cryostat has been designed for prototype testing purposes.



Single Coil Cryostat Thermal Design + Simulations

- Cryostat has been designed and simulated to operate a half-field, half-scale HTS magnet at 25K using a two-stage Sumitomo Cryo-Cooler.

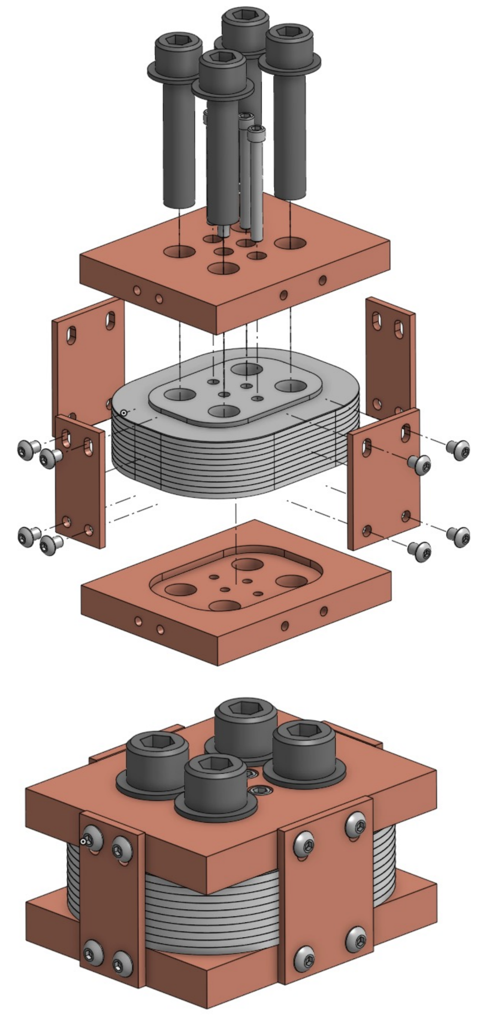


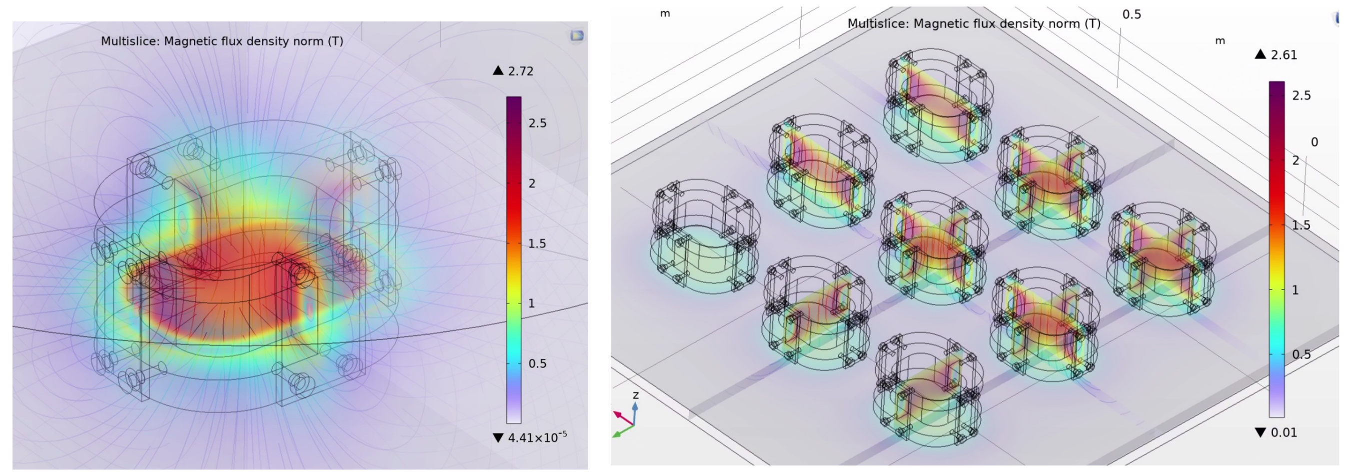
Single Coil and 3x3 Panel Design and Testing

Design and simulation efforts have been centered around developing a half-scale, half-field prototype coil representative of future planar shaping coils.

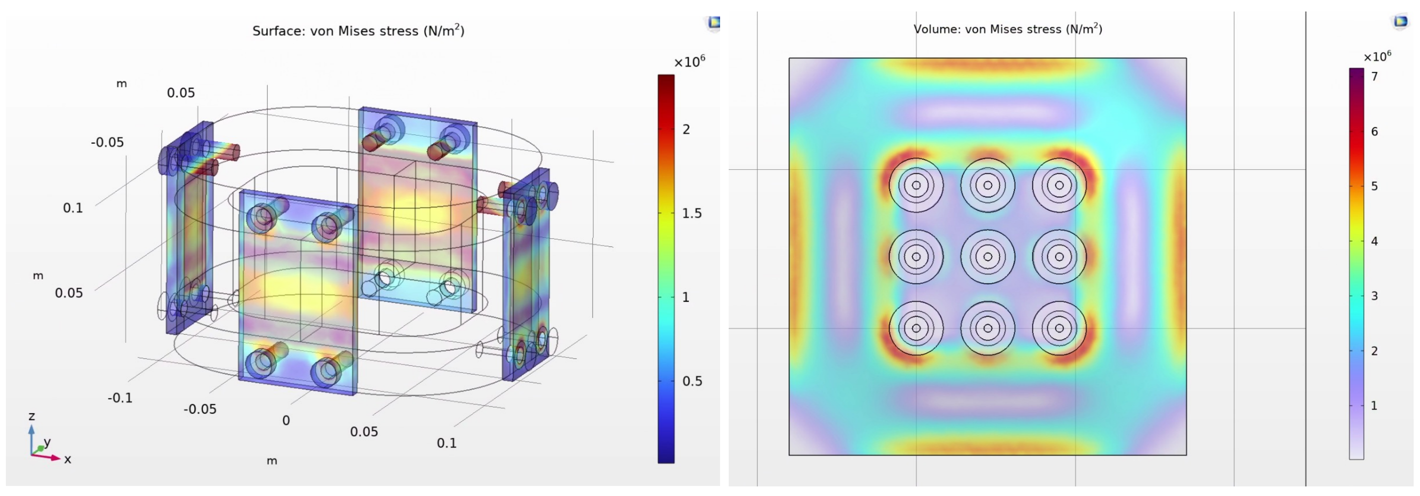
1.8 Tesla center field strength
10 Pancake layers of 150 turns each
150 amps through each turn

- Mechanical simulations at steady state show internal stresses should not exceed 10 MPa at steady state.
- Magnetic field energy deposited via Joule heating under quench has estimated to not increase winding pack temperatures beyond a few 10s of degrees Kelvin.



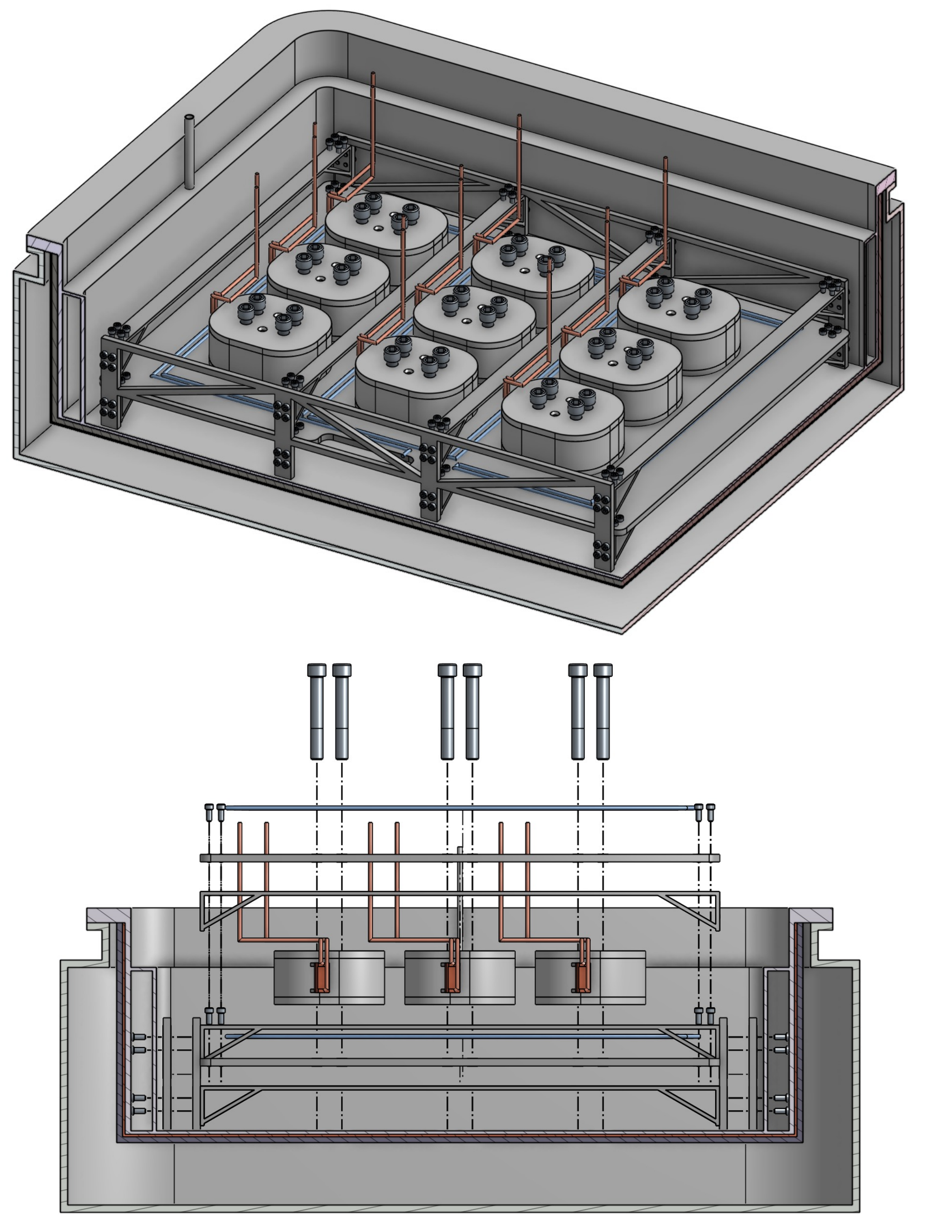


Magnetic Field Strength (T)



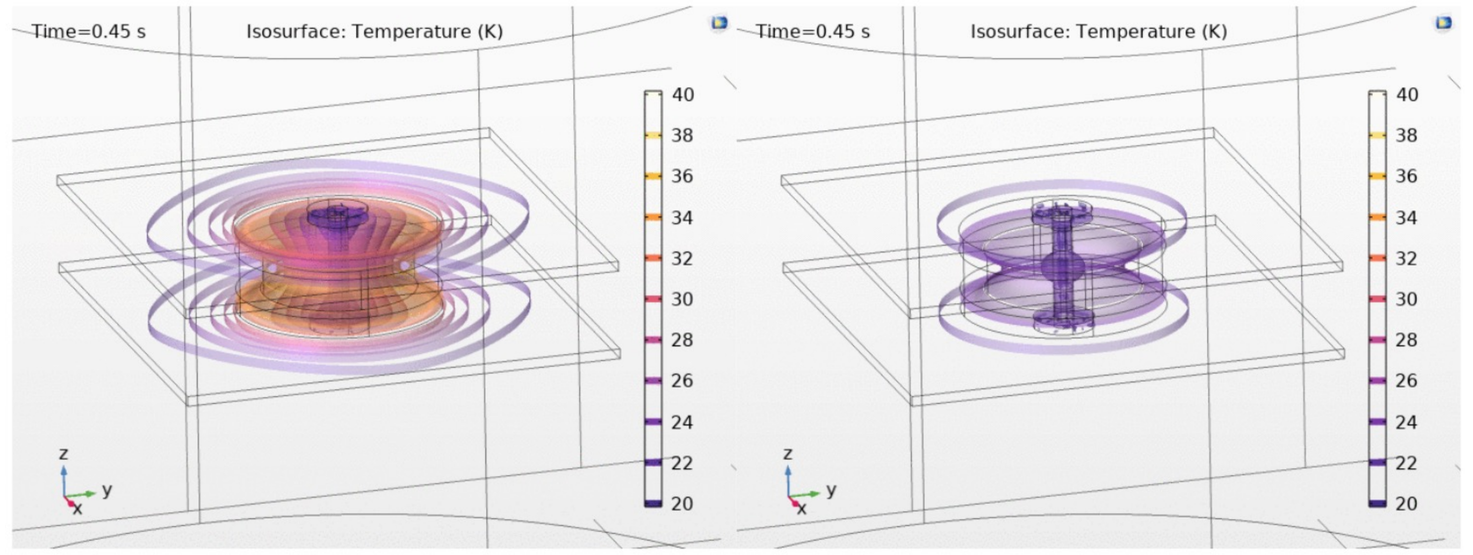
Induced von Mises Stress at Steady-State (Pa)

- A 3x3 coil array cryostat is under development to understand the risks of quench propagation when coils are operated in close proximity.
- Mechanical supports are necessary to brace against electromagnetic forces developed between coils.
- Simulations are design still in progress for final manufacture.



Magnet Quench and Materials Choice

- Transient quench analysis suggests copper may be a suitable material for thermal transport of deposited magnetic field energy to prevent runaway quench of nearby magnets.
- Copper provides greater thermal inertia than aluminum, and greater heat conduction than steel – both desirable properties in a quench scenario.



Isothermal contours 0.45 seconds post-quench

65th APS-DPP, October 30-November 3, 2023, Denver, CO
This work is supported by Thea Energy.

www.thea.energy
info@thea.energy