THEA ENERGY

Prototyping HTS Stellarator Magnet System

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Prototyping helps us to validate models and infer performance of production coils.

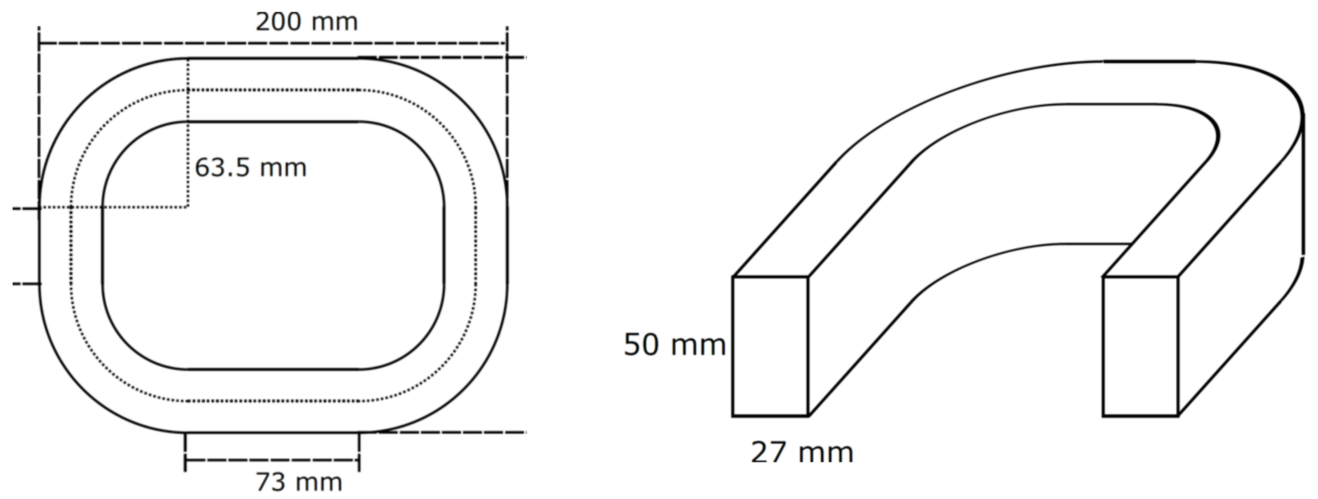
Aims of prototyping activity:

- Develop in-house expertise in building, testing and troubleshooting HTS coils.
- Demonstrate current ramp-up/ramp-down without quenching.
- Demonstrate coil controllability.
- Characterize thermal and mechanical stresses.
- Optimize cooling scheme.
- Characterize quench propagation scenario and develop a quench detection and mitigation system.

A half-size, half-field coil will be the first prototype.

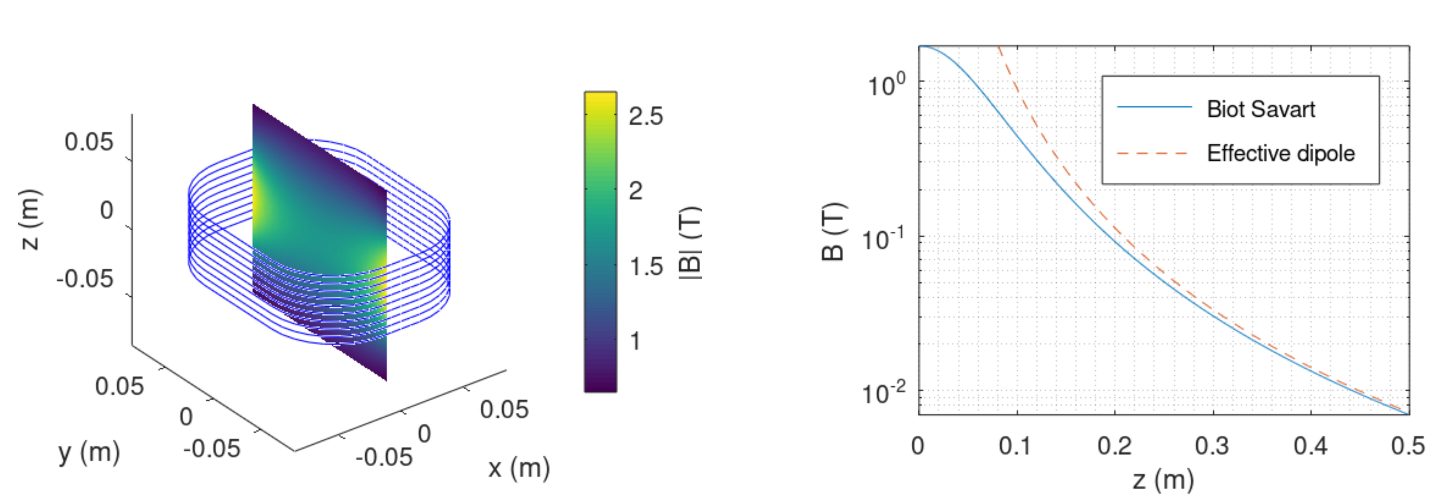
	Half-size Half-field coil Prototype	Production coil
Amp-turns	225 kA	1 MA
Per-turn current	150 A	150 A
B_0	~2 T	~4 T
B_{max}	~3 T	~6 T
Stress	~5 MPa	18 MPa

Prototype winding pack will have 5 double pancake coils with a total of 1,500 turns.

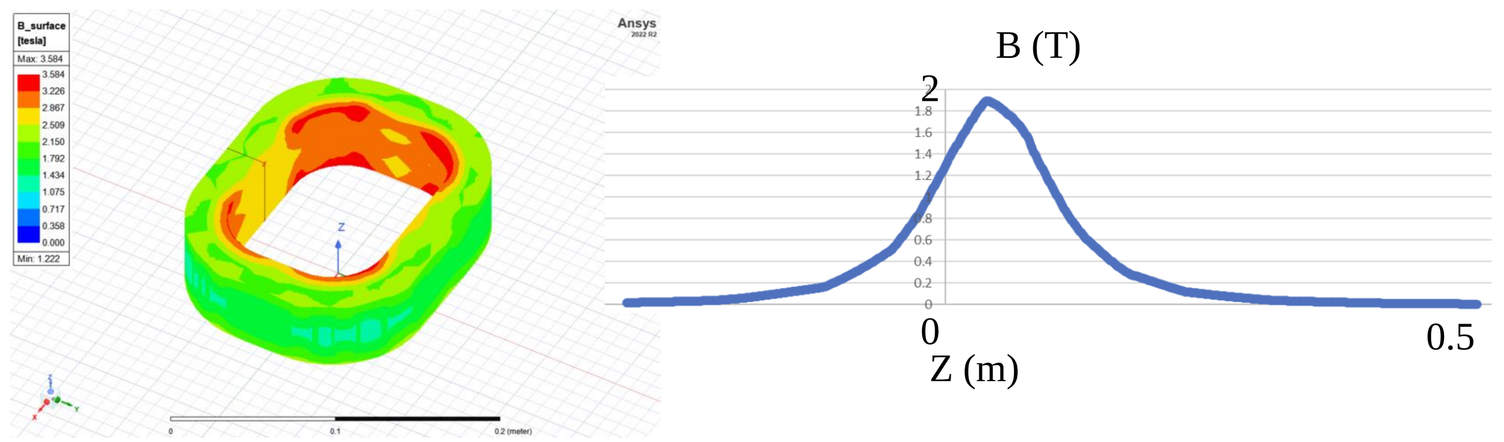


Biot-Savart Calculation has been benchmarked with ANSYS modeling for the single coil.

Biot-Savart model of a single coil

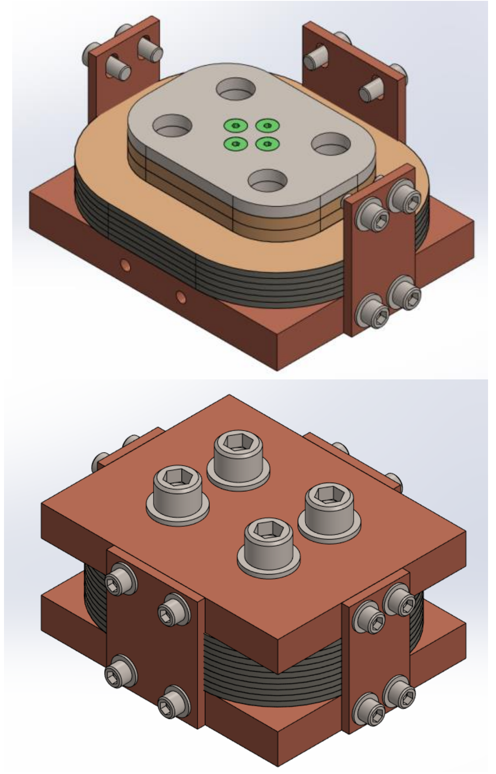


ANSYS model of the single coil

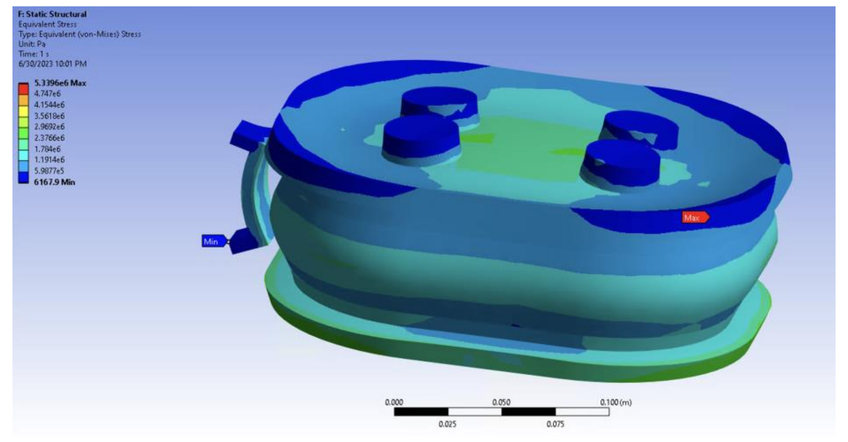


A single coil prototype will be made first.

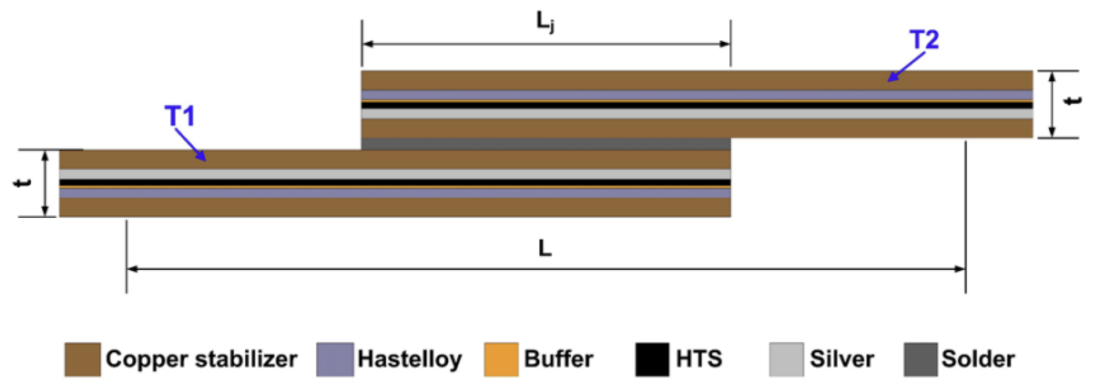
Single coil assembly. CAD drawing



Benchmarked stress calculation with ANSYS. Maximum stress ~6 MPa



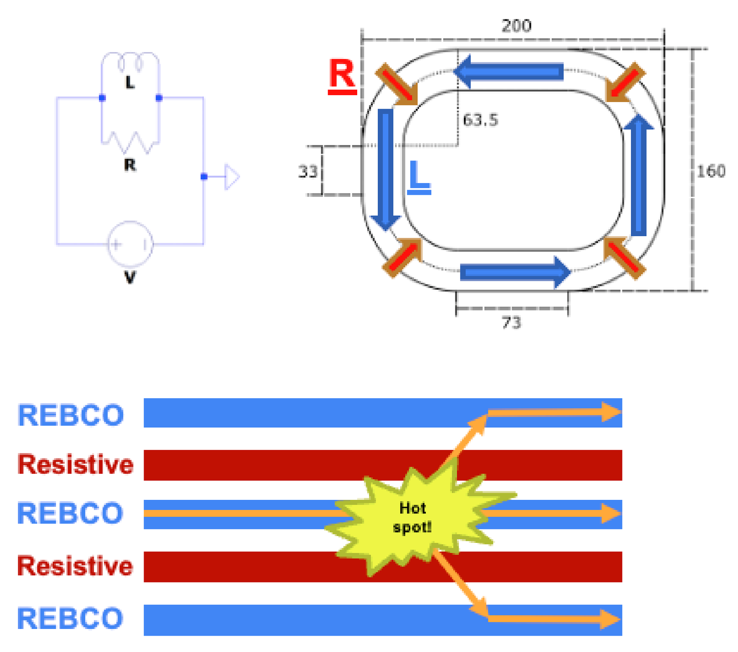
Tape splicing was analyzed to determine effects from resistive power dissipation and temperature elevation.



Lap joint splicing together two pieces of HTS tape.
S.L. Lalitha, "Low resistance splices for HTS devices and applications," in Cryogenics, vol. 86, pp. 7-16, 2017

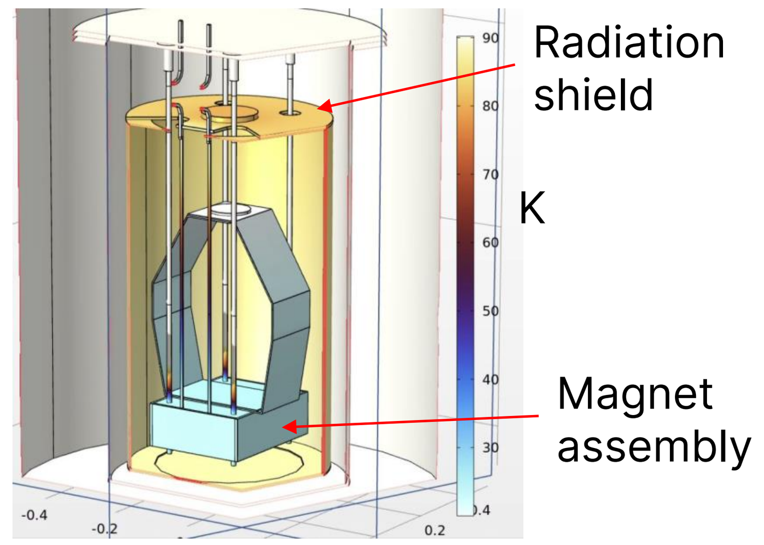
- For the prototype coil, the number of tape splices needed will be 19 at most.
- Lap joints will be used—each splice has overall resistance of ~2 nΩ.
- Each splice has resistive power dissipation of 45 μW, total dissipation for all splices will be < 1 mW.
- At worst, splice temperature locally elevates by 0.23 mK.
- Power dissipation and temperature elevation effects are well within constraints.

Turn-to-turn resistance is carefully chosen to balance coupling loss with hotspot propagation.

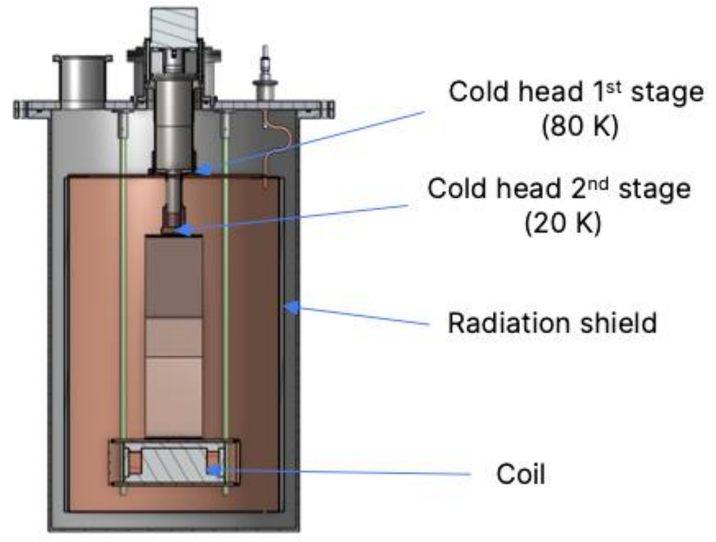


- The coil has high inductance/low resistance along the length of the conductor and low inductance/higher resistance radially.
- By carefully choosing the turn-to-turn resistance, ramp heating (I^2R) will be limited to <2 W so that the cryocooler can handle it.

Thermal simulations with COMSOL are carried out to determine the cryostat specifics.



COMSOL simulation



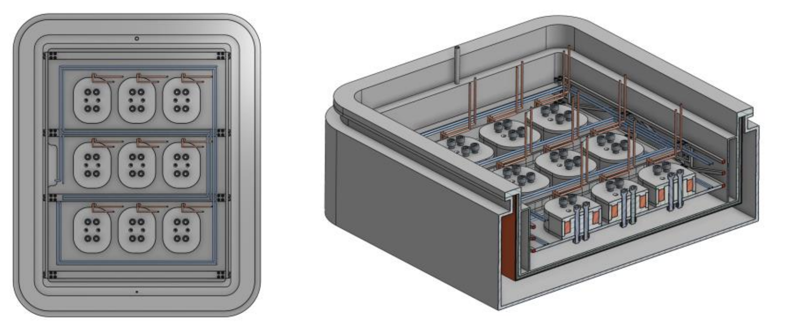
Cryostat CAD model

- A dual-stage cryocooler is needed to cool the magnet assembly to 20 K.
- A radiation shield with copper sheet and a multi-layer insulation is needed to reduce the heat loss.

Next prototyping activity is the creation of a 3x3 panel of coils.

- To validate the differential control of the highly inductively coupled coils.
- To validate survivability of neighboring coils upon quench.

Preliminary design of 3x3 array with cryostat



Conclusion

- Thea Energy has begun magnet prototyping activities.
- A single coil prototype that is approximately half the size of the full shaping coil will be built first.
- Design of the winding pack is complete; coil winding has begun.
- Our calculations are benchmarked against ANSYS and COMSOL models.
- A testing plan is in place to validate our models.
- A follow-on activity is the creation of a 3x3 array of coils.

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