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Magnetization Studies in Coils made with HTS Tape in a Hybrid Dipole

(HTS tape aligned in favorable direction)

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Background

- Previous studies under PBL/BNL SBIR (HTS tape aligned in unfavorable direction)
- Present studies under USMDP
- Status (design and construction)
- Present test plan for your feedback
- What each of us can contribute

Retest of Nb_3Sn Common Coil Dipole After a Decade

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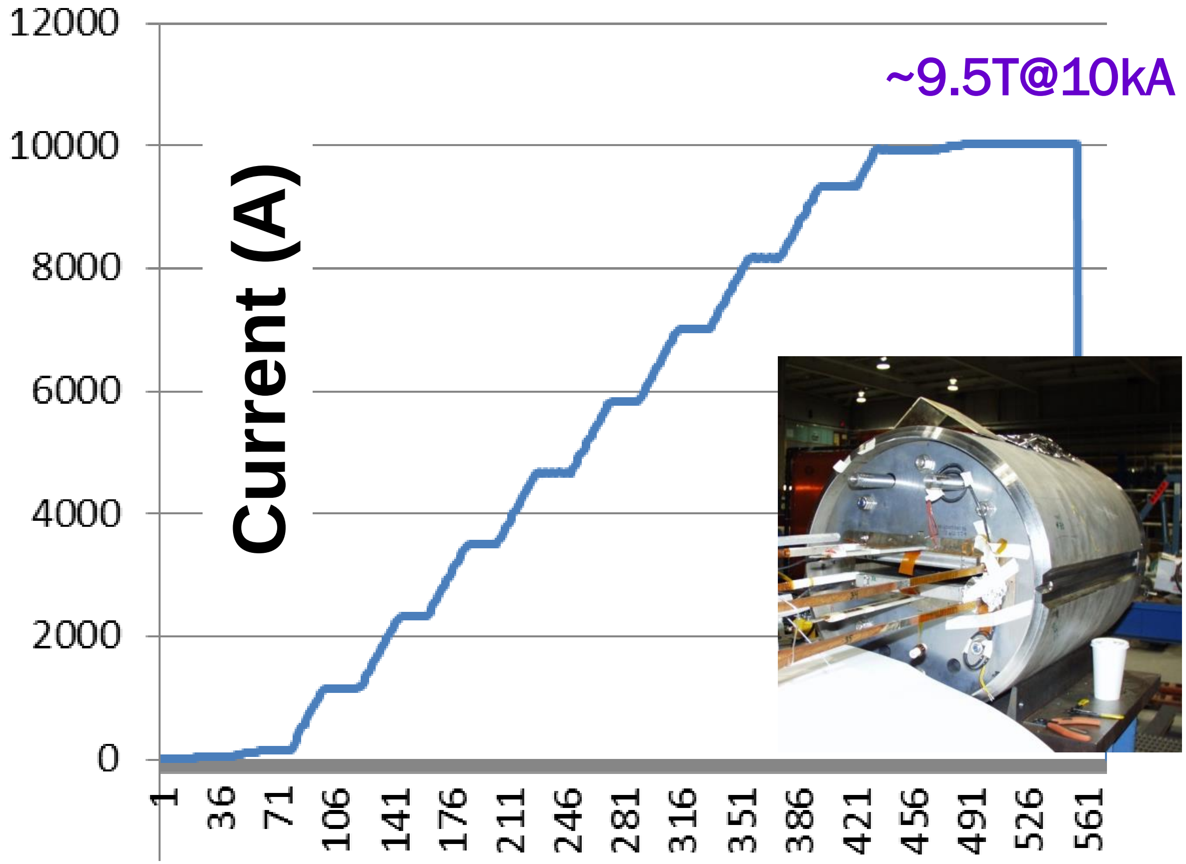
- **Short Sample: 10.8 kA/10.2 T (reached during 2006 test)**
- **Retest: No quench to 10 kA/9.5 T (>92% of quench, leads limited)**



A reliable magnet for test facility

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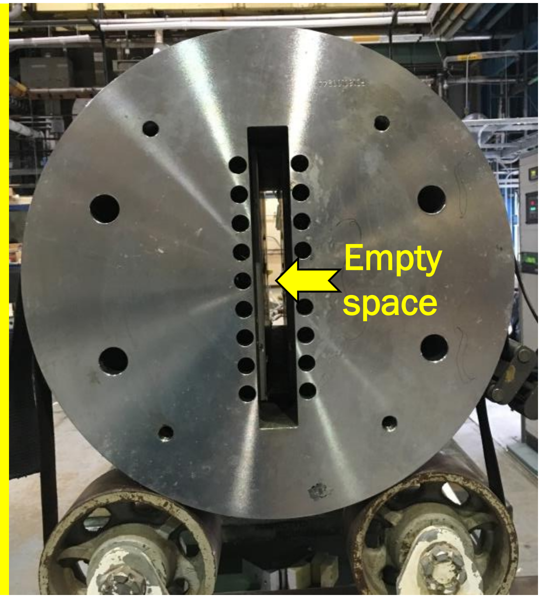
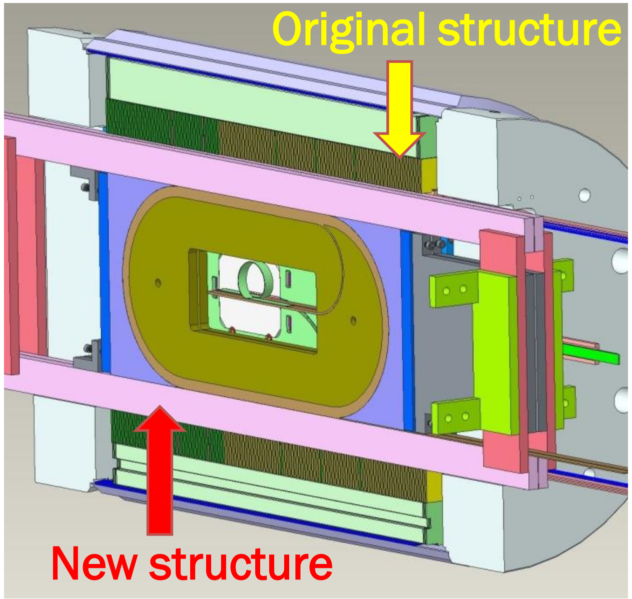
PBL/BNL STTR on HTS/LTS Hybrid Dipole

A unique feature of BNL's common coil dipole: large open space for inserting & testing "coils" without any disassembly (rapid around, lower cost)

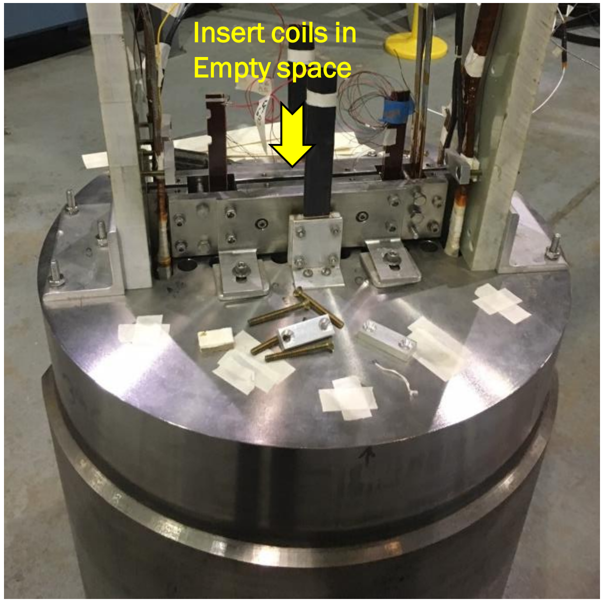
STTR Phase II for (1) Demonstration and protection of High field HTS/LTS hybrid dipole (2) measurement of field ~~parallel and~~ perpendicular field quality



BNL Nb_3Sn common coil dipole DCC017 without insert coils



New HTS coils with the existing Nb_3Sn coils and become part of the magnet



HTS coils inside Nb_3Sn dipole - early experience of HTS/LTS hybrid dipole

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Magnetization studies in high field at 4 K in magnets made with the HTS tapes

(Hall probe measurements)

- A select data presented in a couple of slides.
- A significantly more data available.

HTS Coils Wound Under PBL/BNL SBIR (for field primarily perpendicular studies)

Conductor:
- **12 mm ASC tape**

Insulation:
- **Nomex**

Two coils used ~300 meters of 4 mm equivalent

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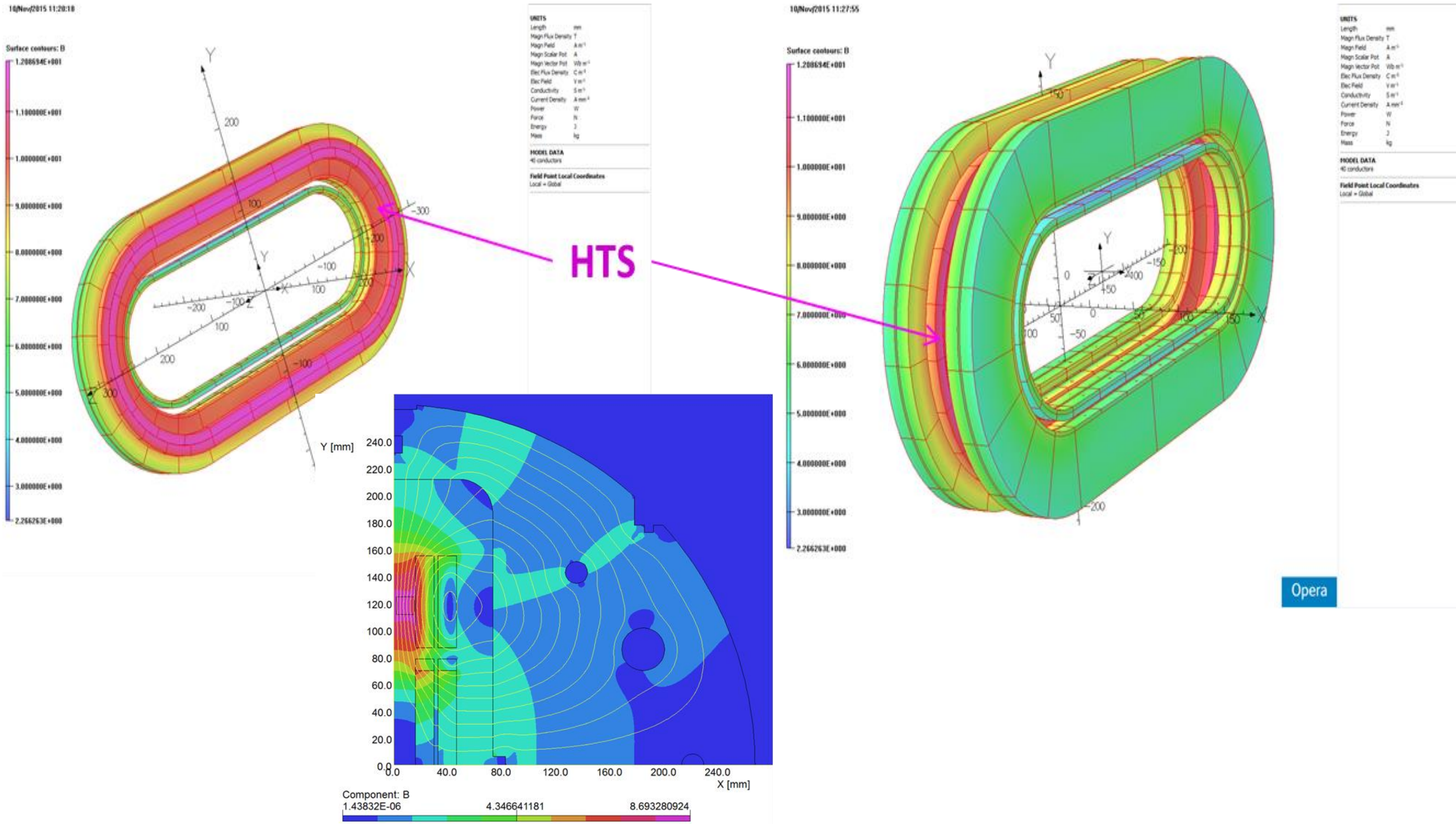
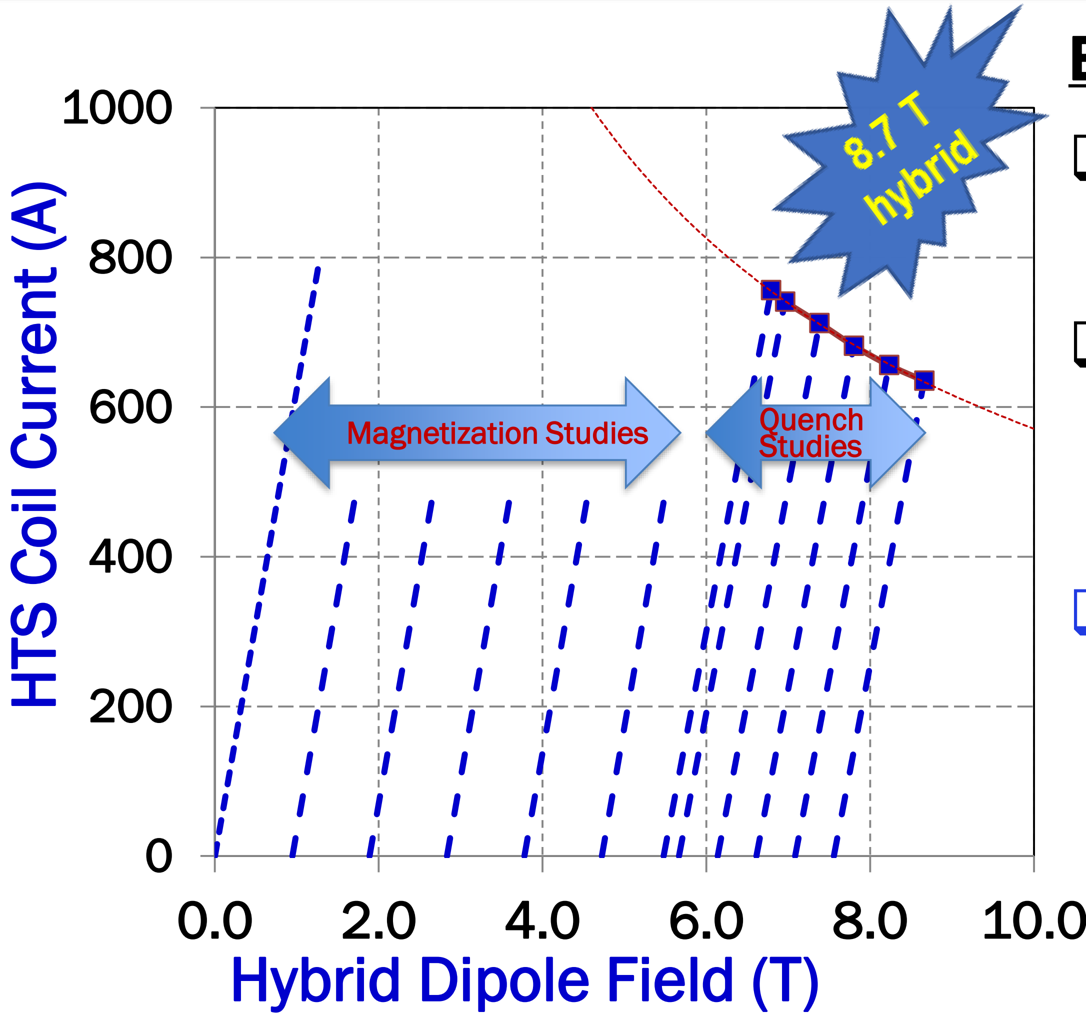
HTS/LTS Hybrid Dipole Model (field on HTS coils primarily perpendicular)



HTS Coil Test in HTS/LTS Hybrid Dipole Structure



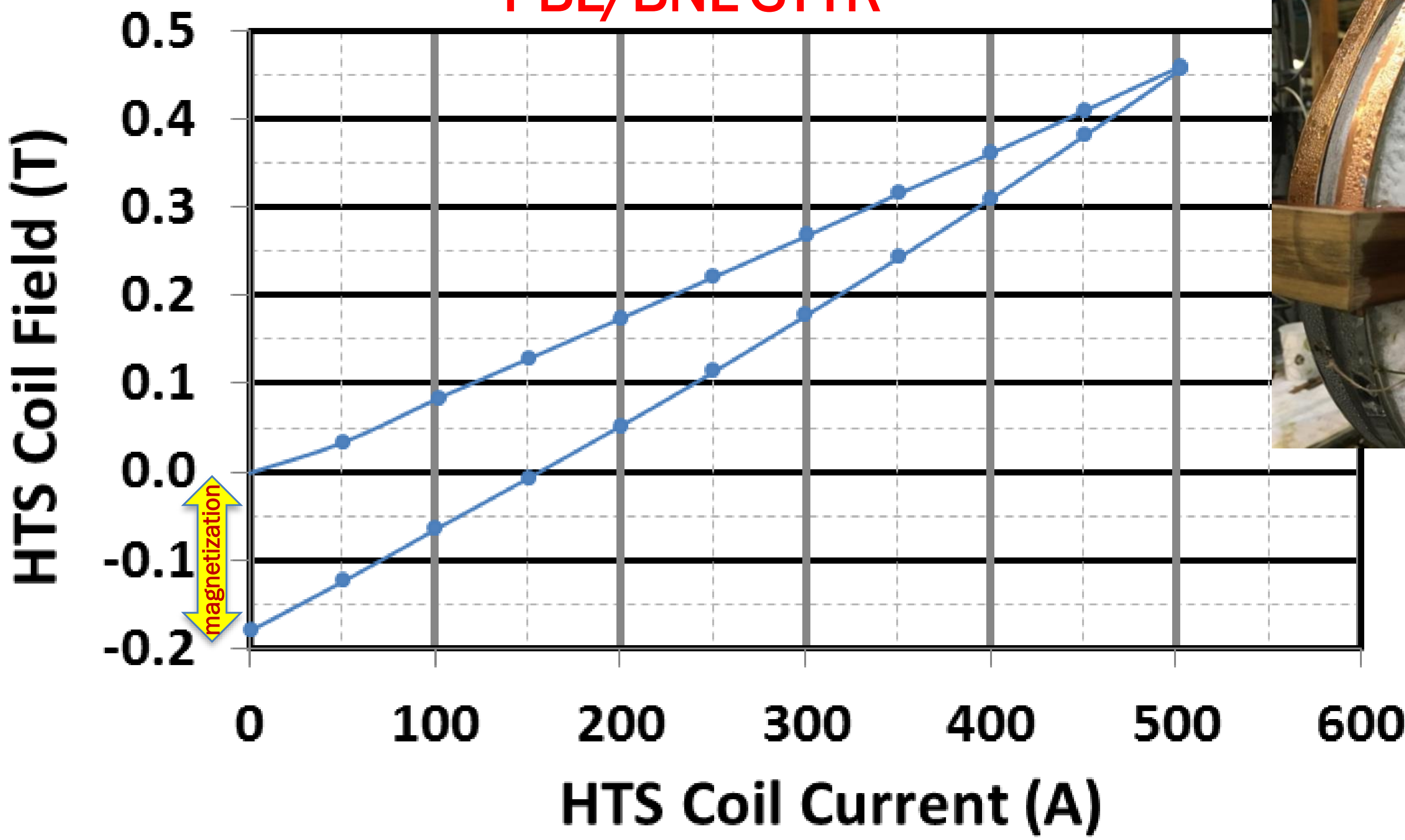
Encouraging Results:

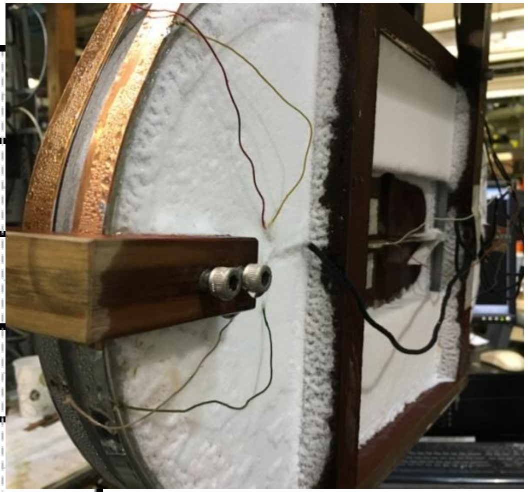
- ❑ HTS coils were ramped to quench, just like LTS coils.
- ❑ No degradation in HTS coils despite a number of quenches.
- ❑ In many of these runs, the field was measured with Hall probe during up and down ramp. The difference is primarily due to conductor magnetization.

Test Run at 4 K (in 2 T background field from Nb_3Sn coils)

Additional field from the HTS coils in up and down ramp (offset to start from zero to start up-ramp)

PBL/BNL STTR

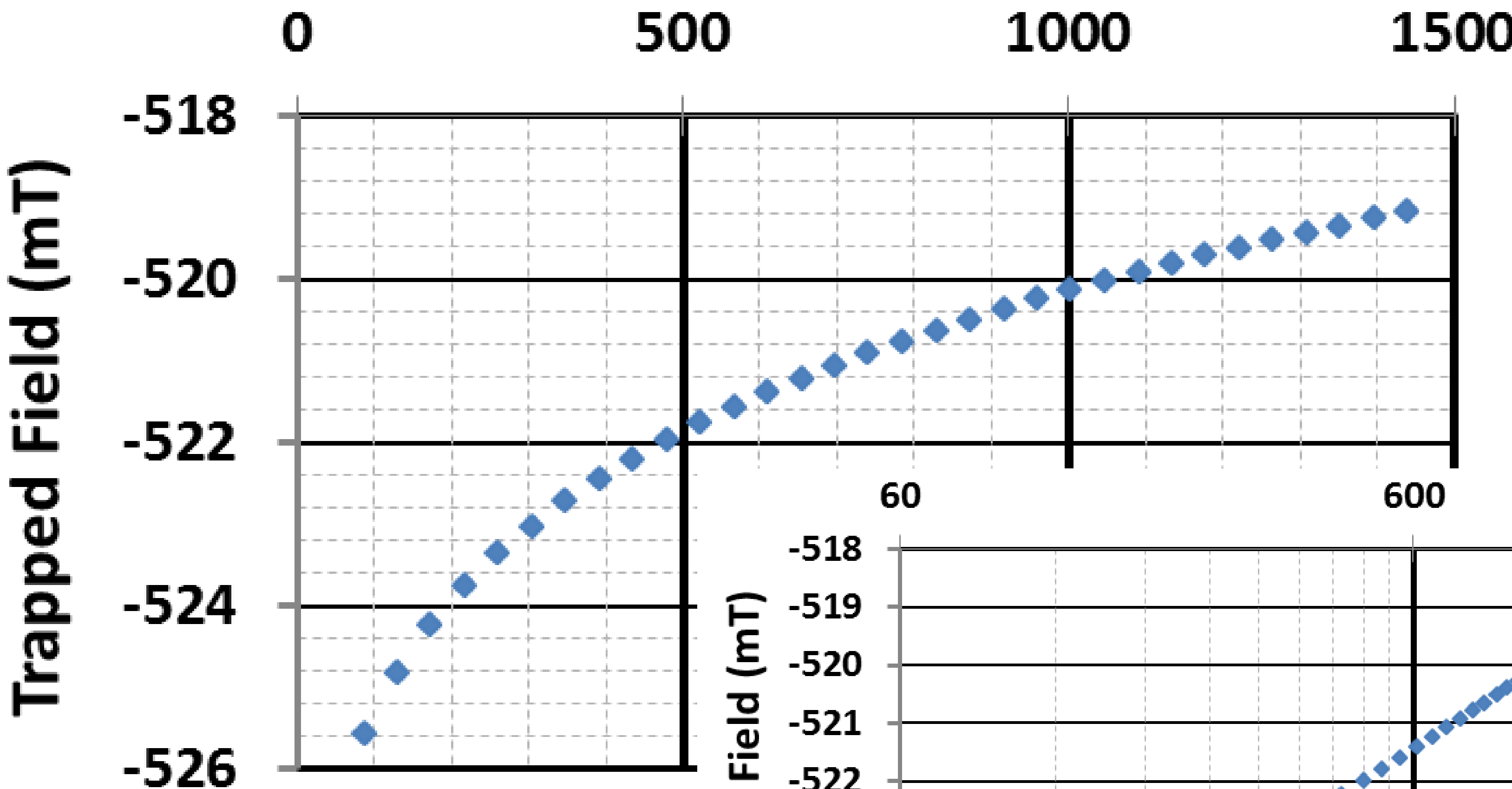


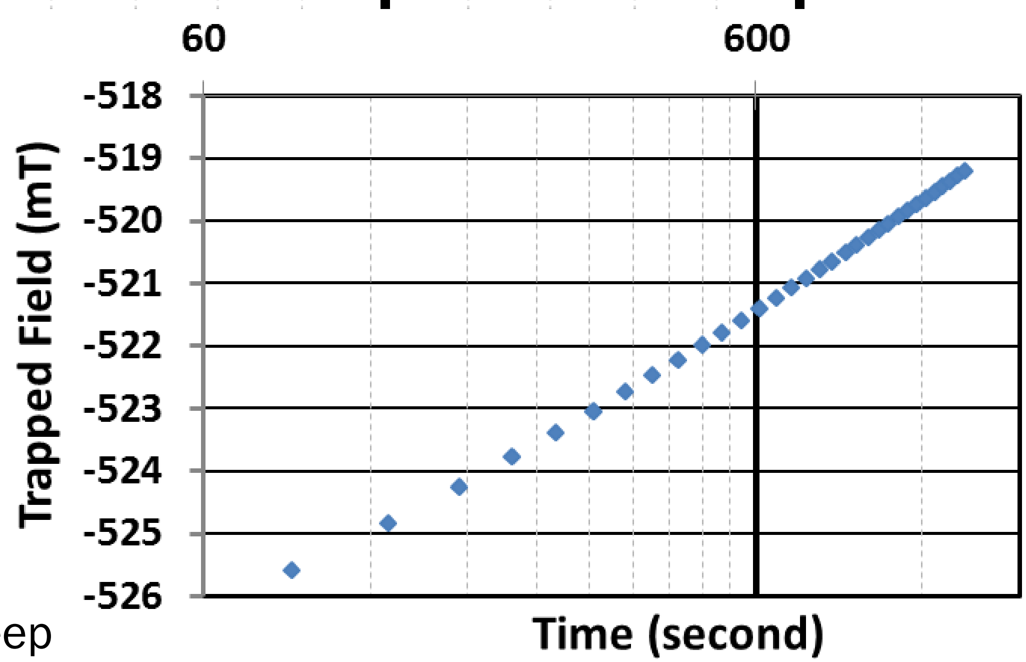


field perpendicular configuration

Decay of Trapped Field

(after the final run to ~8.7 T hybrid field @ 4 K)

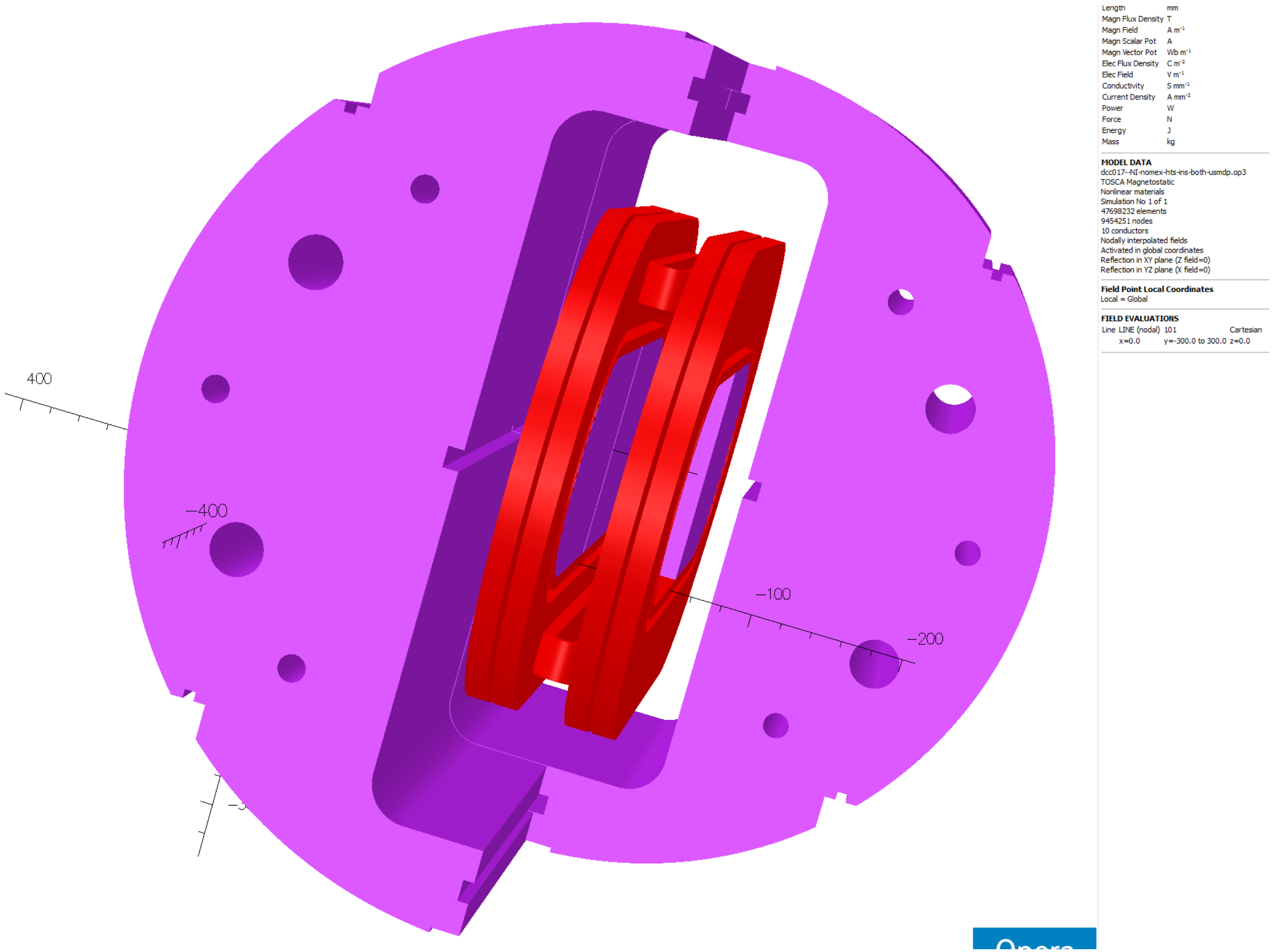


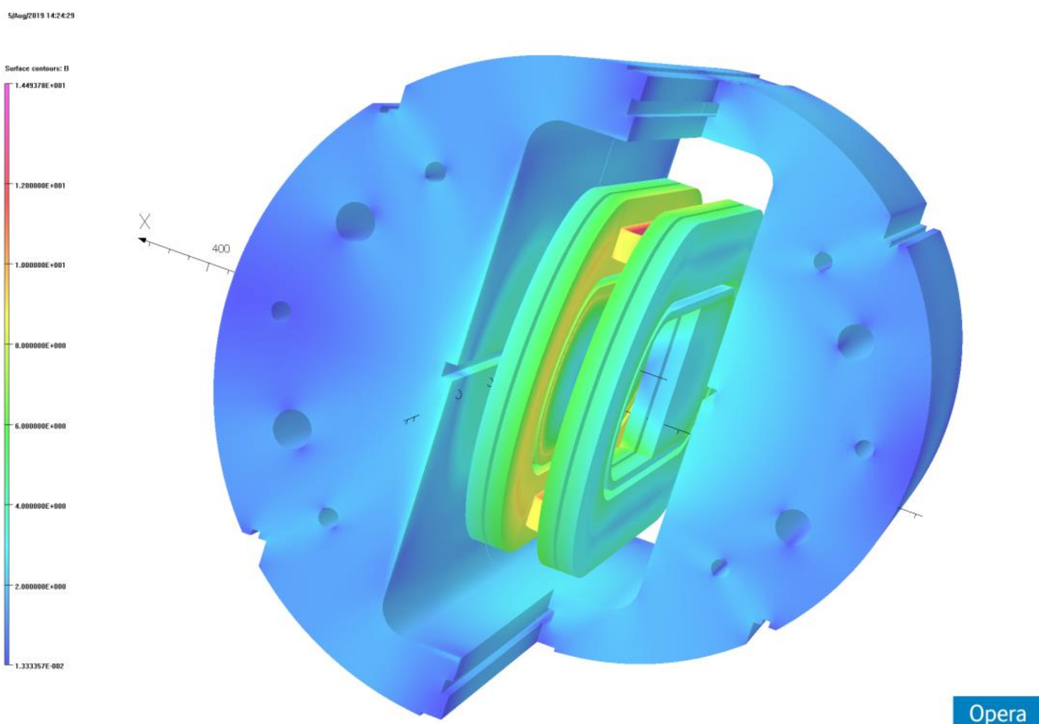


Flux creep

Magnetization Studies for USMDP

USMDP Studies

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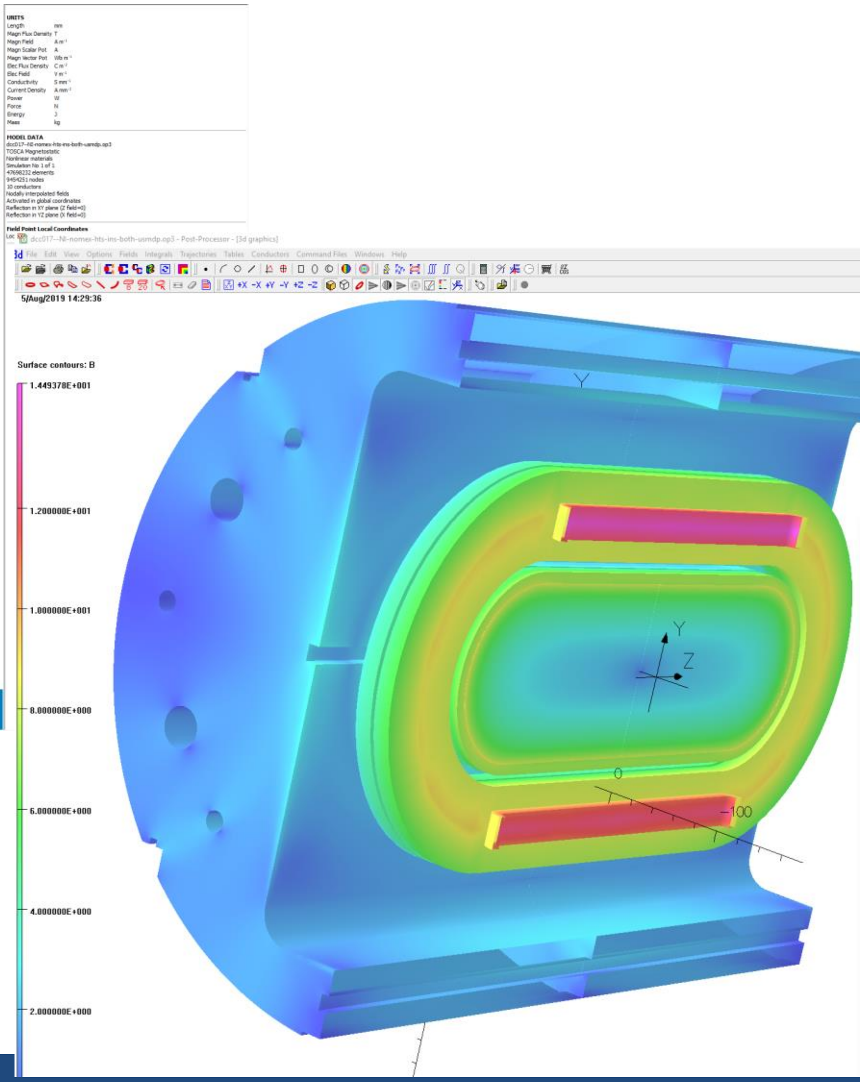
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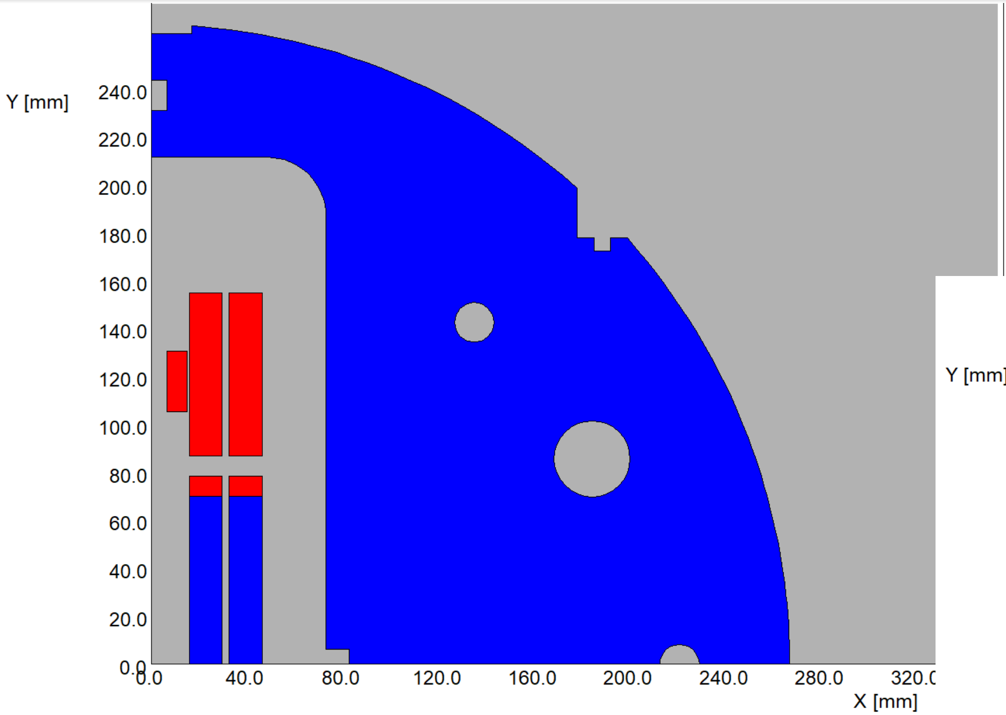
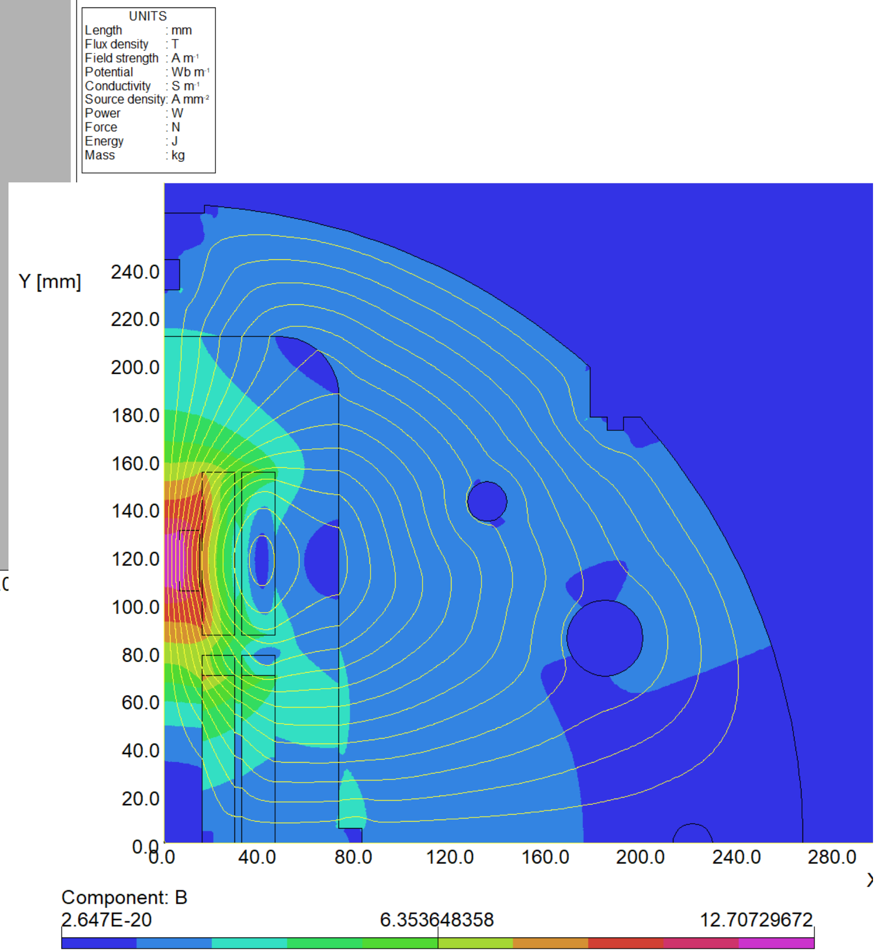
Opera

Model of a Quadrant





Field and Magnetization in Coils (field component parallel to the wide face of tape – favorable direction on double pancake coil)

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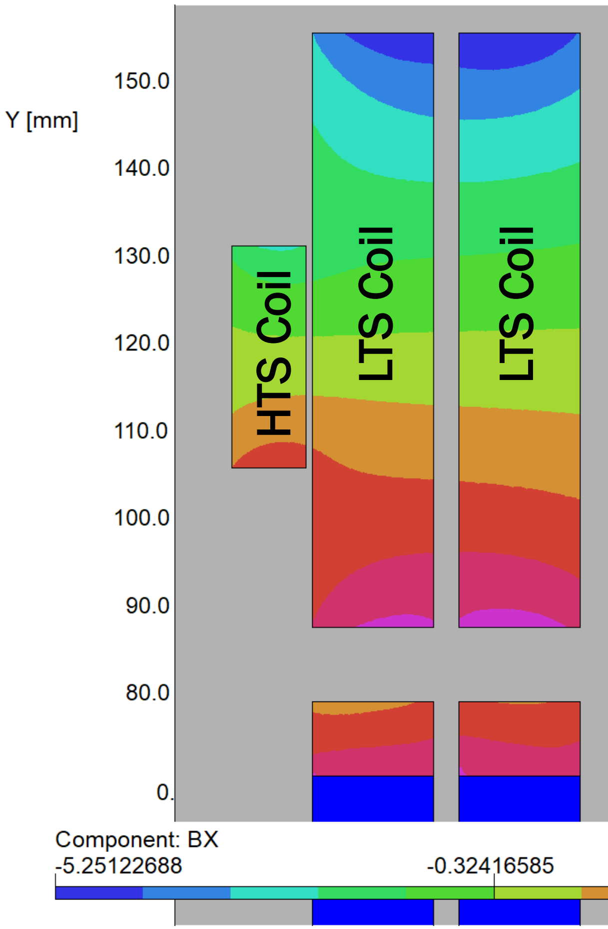
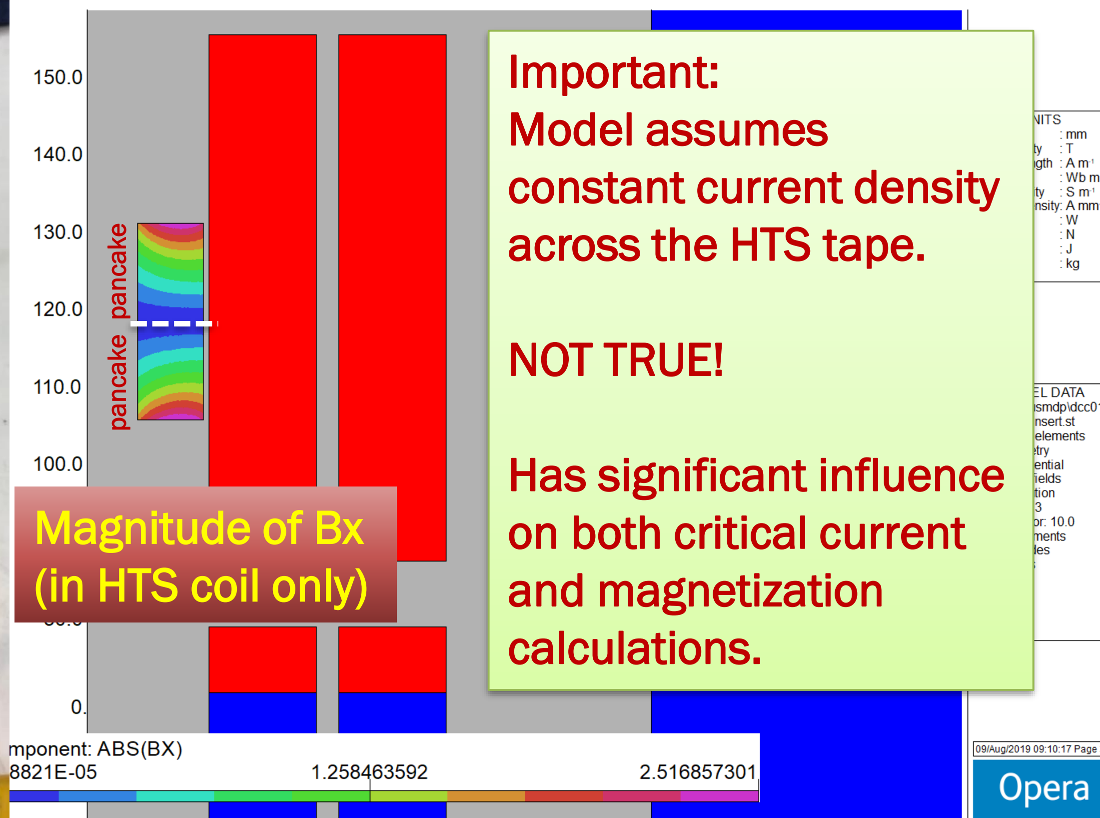
Bx
(field perpendicular component)





Magnitude of Bx (in HTS coil only)

Important:
Model assumes constant current density across the HTS tape.

NOT TRUE!

Has significant influence on both critical current and magnetization calculations.

Common Coil Hybrid Magnet Test Goals

Two HTS double-pancake insert coils inside the React & Wind Nb3Sn 2-in-1 common coil dipole DCC017

<u>Main Purpose/Goal</u>:

- Magnetization studies
  - Measure magnetization of insert coils made with HTS tape with field predominately aligned parallel to the wide face.
  - Magnetization is measured with the Hall probe by measuring the field at the center of HTS coils which are centered at the place where the field from Nb3Sn coil is maximum
  - Earlier measurements under SBIR were performed for field predominately aligned perpendicular to the wide face of the tape.
  - Magnetization (particularly in relative terms) is more at lower current/field. Therefore, we don't have to push to the highest fields. Even powering to the same current densities as in last test will be great from the magnetization point of view. However, we can push for the purpose of understanding the quench behavior in HTS coils, particularly in hybrid structure. HTS coils can be compromised to seek the limit and to study quench after the initial magnetization data is taken. LTS coils are part of the magnet which is intended for other usage and can't be put at risk.

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Present test plan for your feedback
Initial Test Plan (will evolve)

The purpose of this test is to do magnetization studies of HTS coils first by themselves and then in the background field of Nb3Sn coils. Following is the list of three essential tests during which field will be measured by Hall probe and should be continuously recorded. Two Hall probes are placed at the center of the HTS coil.

HTS Coils Only, one at a time

- Ramp up to 100 Amp and down to 0 A
- Ramp up to 200 Amp and down to 0
- Ramp up to 400 Amp and down to 0 A
- Ramp up to 600 Amp and down to 0 A
- Ramp up to 800 Amp and down to 0 A
- After reviewing above test data, make plan for ramping to higher currents

Nb3Sn Coil Only

- Ramp gradually to 10,000 A (the coil didn't quench at 10,000 A during the last run in 2017 and earlier in 2006 it has reached 10,800 A)

HTS/LTS Hybrid Test

- Hold Nb3Sn coils at various currents and ramp HTS coil up and down to whatever current safely possible without quenching (nominal maximum 800 A in HTS coils).
- Start with lower background field from Nb3Sn coils and move to higher
- The values of holding currents in Nb3Sn coils while HTS coils are ramped up and down: 500 A, 1000 A, 2000 A, 4000 A, 6000 A, 8000 A and 10000 A.

Discussion

What each one of us can contribute?

Other test in parasitic mode

If MgB_2 tube is available in time then it can be placed somewhere for shielding experiment as a part of Phase I SBIR with HyperTech.

4K test was not in the plan of the original Phase I proposal but that test can be carried out in a parasitic mode.