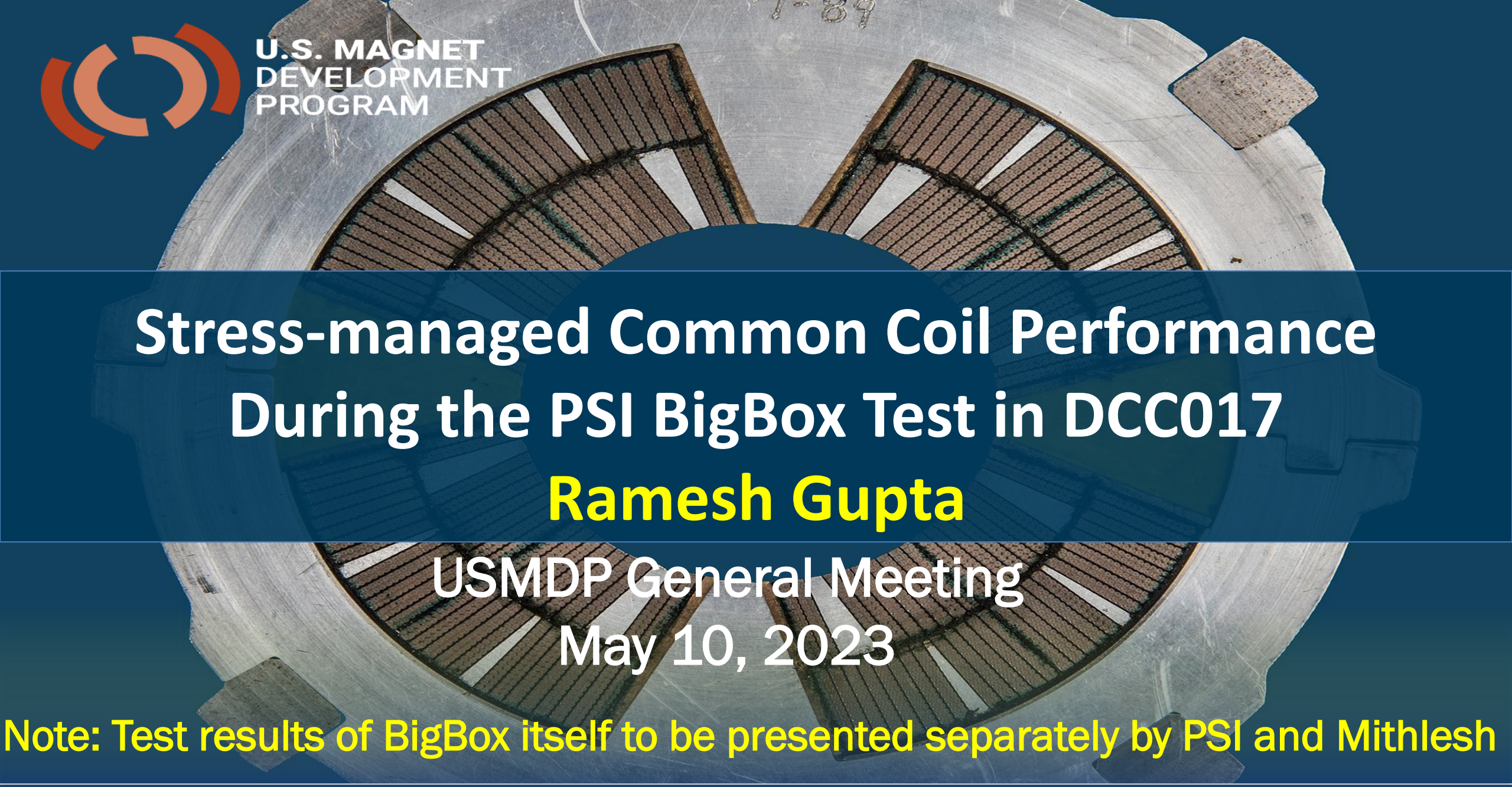

U.S. MAGNET DEVELOPMENT PROGRAM

Stress-managed Common Coil Performance During the PSI BigBox Test in DCC017

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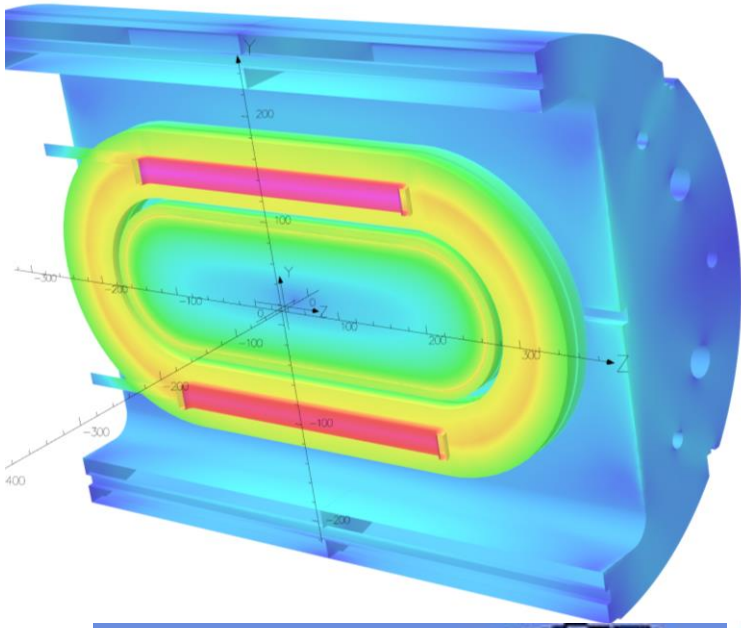
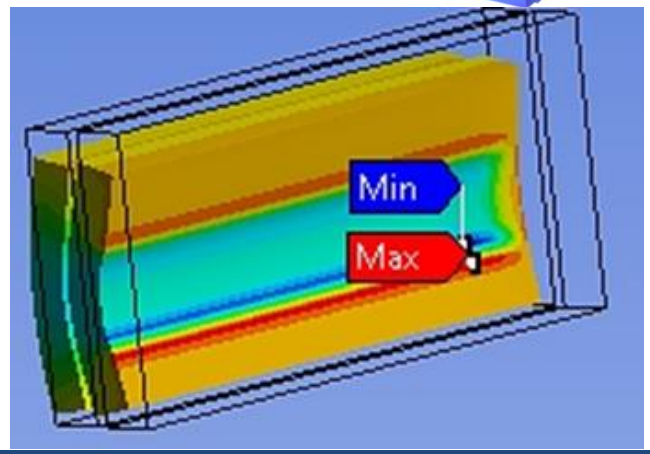
Note: Test results of BigBox itself to be presented separately by PSI and Mithlesh

Background

- During the last HTS/LTS hybrid test, the maximum performance of 12.3 T was limited by the LTS coils, and not by the HTS coils.
- Moreover, it was NOT limited by Nb_3Sn coils themselves, as they by themselves worked well. Performance got limited when Nb_3Sn coils were energized together with the HTS insert coils.
- Theory: Nb_3Sn coils were stress/strain limited locally (no intermediate structure to manage or distribute the stresses).
- This question/issue is important in all high field Nb_3Sn magnets.
- All new inserts are planned with intermediate structures. This PSI/BNL test was became a test to overcome the stress limit.
- It allowed higher peak field in DCC017 coils (10.7 T => ~12 T)
- More interesting what was observed accidently (magnet survived).



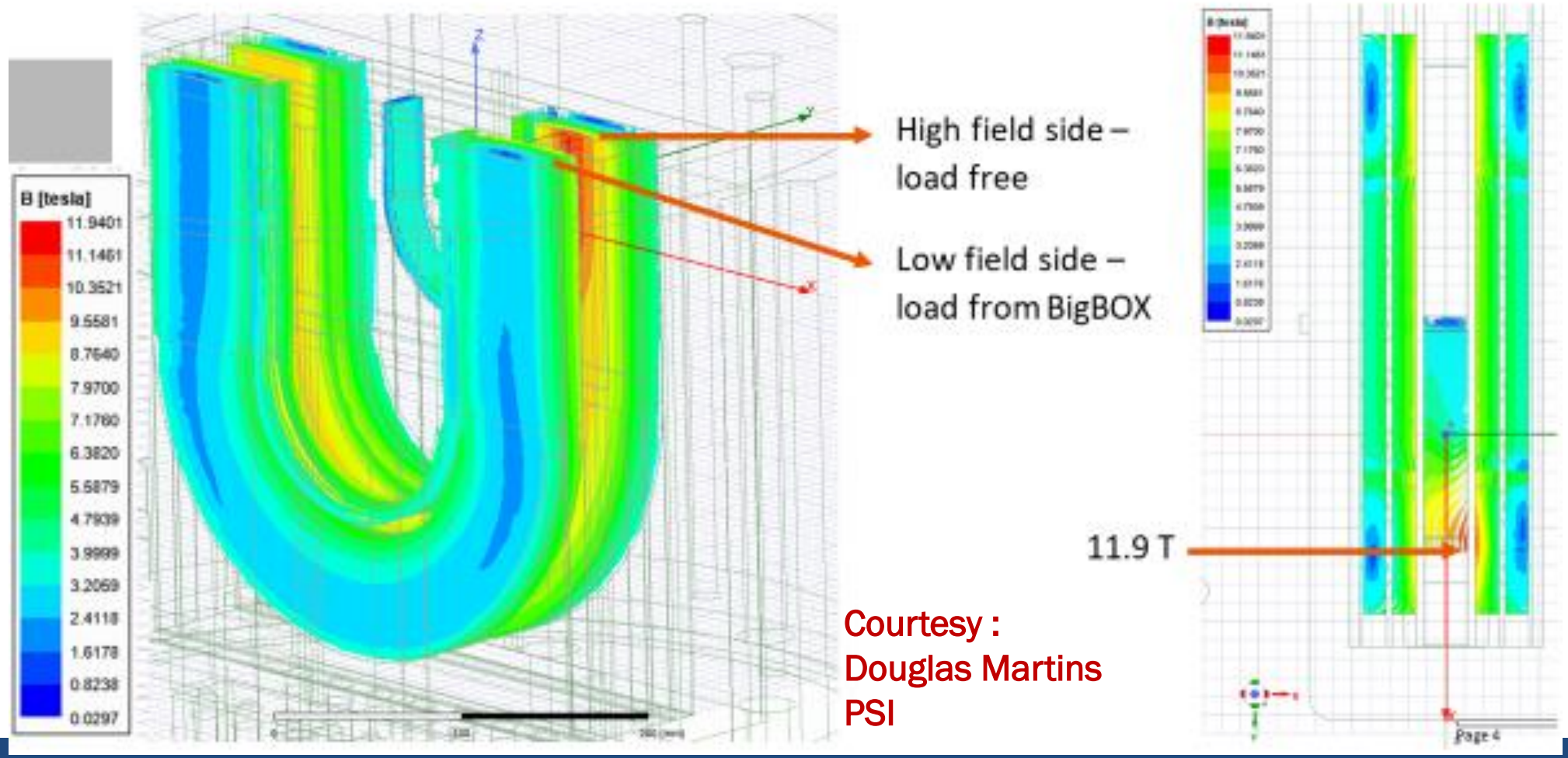


BigBox Coil in DCC017

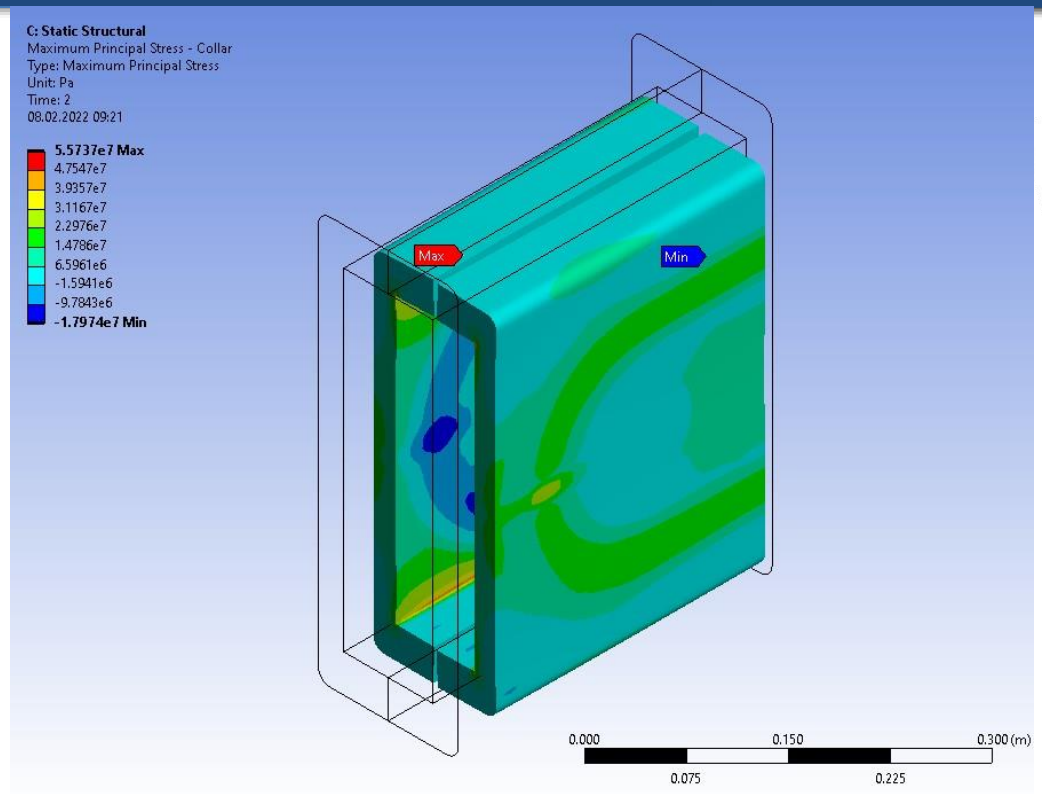
PSI Nb_3SN insert coils are wound with hard way bend.

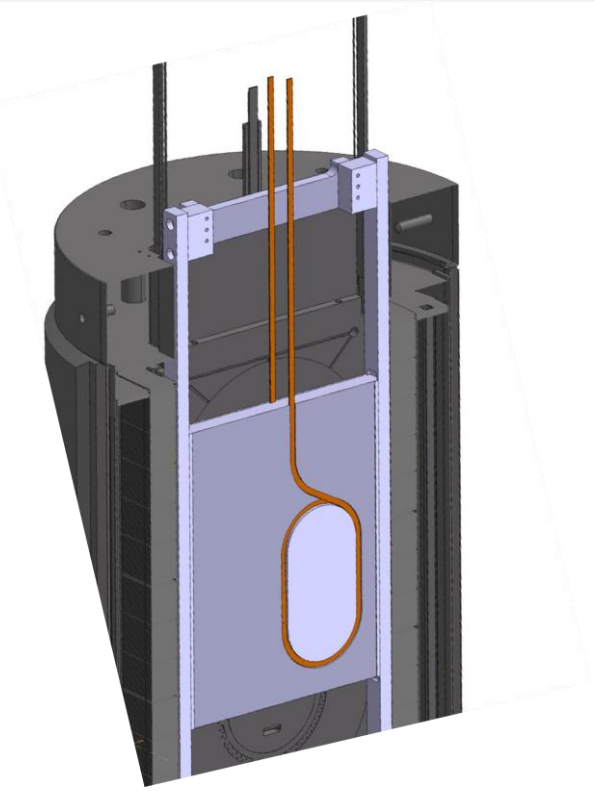
BNL Nb_3Sn coils are wound with easy way bend, as typical in the common coil.

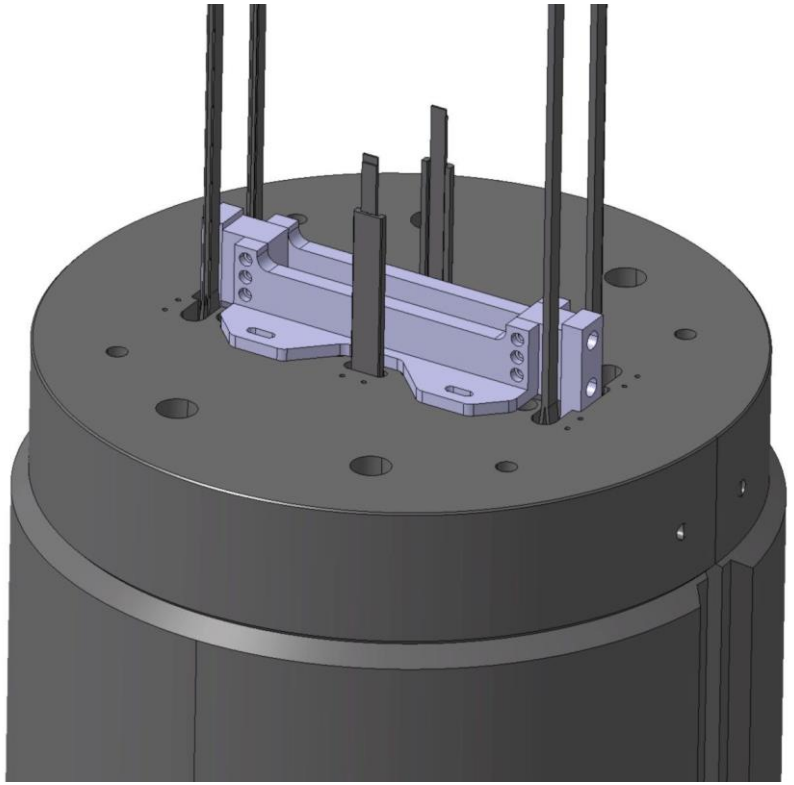
Magnetic Integration – Maxwell model



BigBox Structure for Stress Management (analysis to be discussed by PSI)

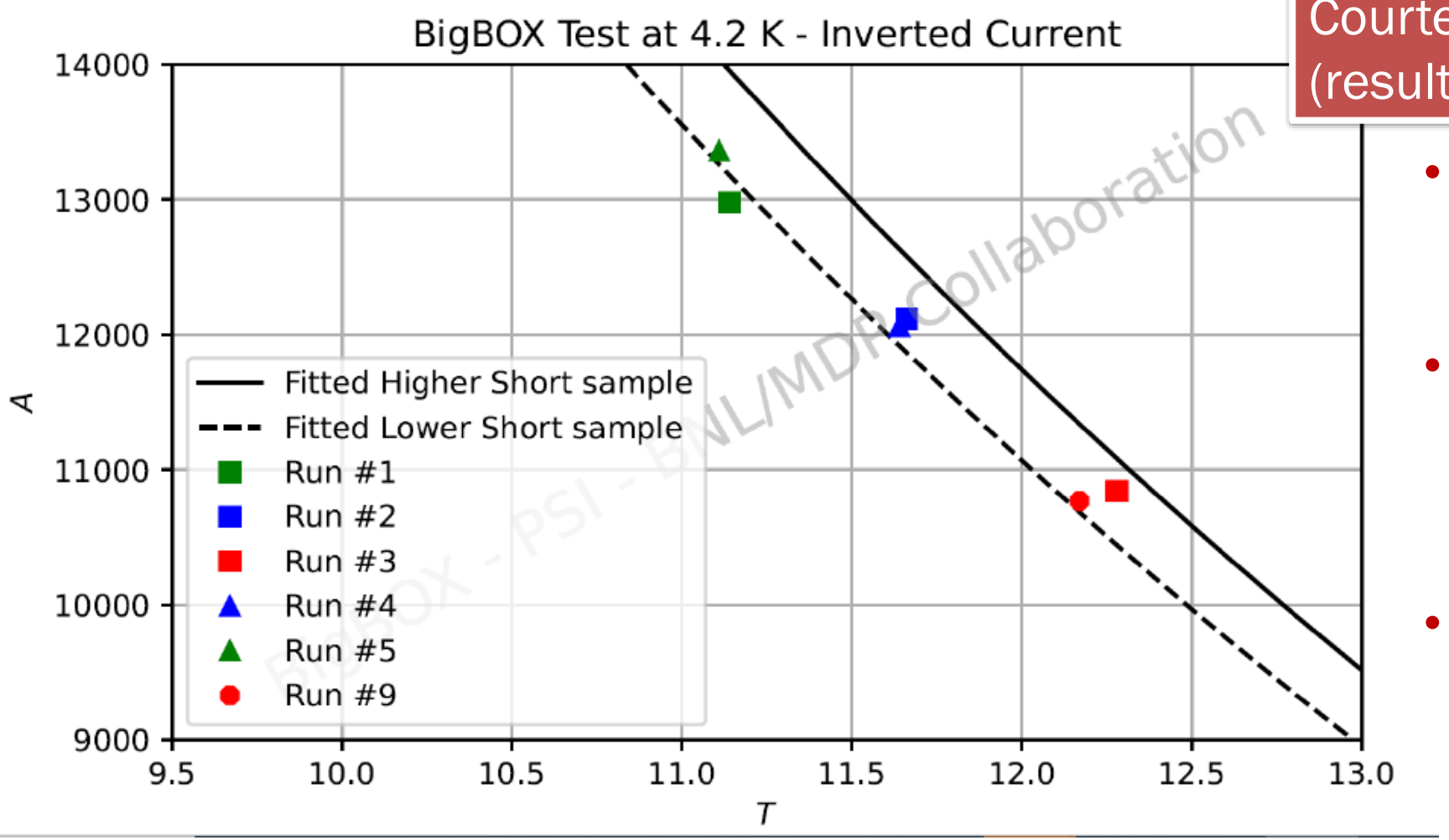






- This brings stress/strain on Nb_3Sn coil of DCC017 below the limit
- Due to the space limitation, the plates were made thicker on the high stress side and thinner on the high field side, with ~2 mm gap at most places.

Expected and Observed Test Results

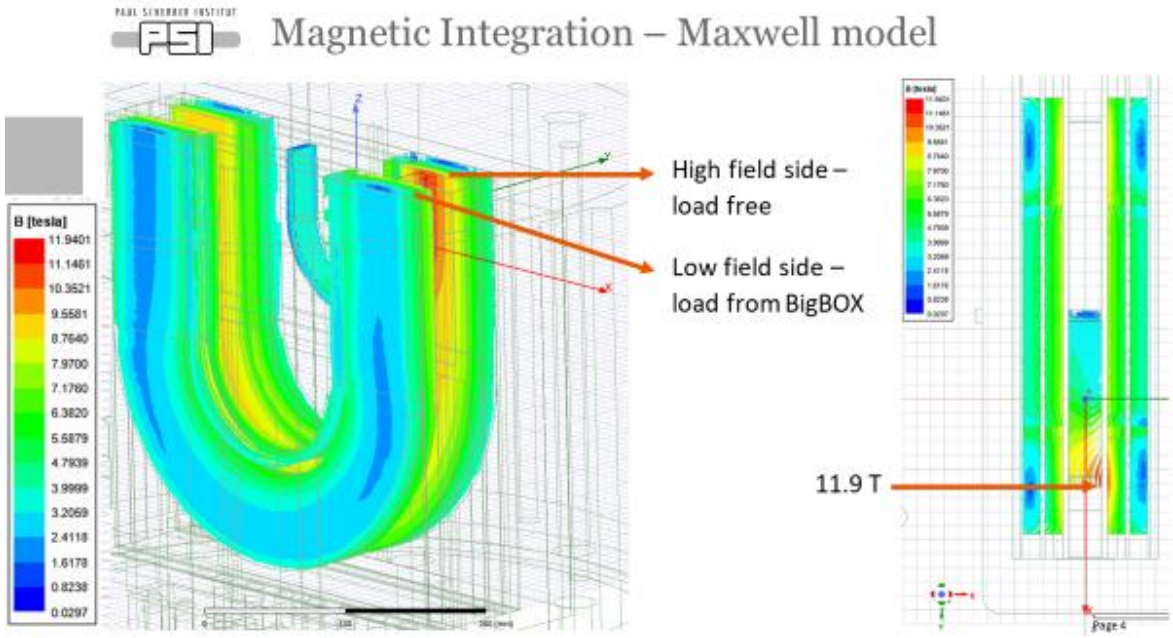


Courtesy: PSI
(results to be discussed by them)

- Field of DCC017 Nb_3Sn coils was not limited by their stress/strain limit
- DCC017 coil didn't quench as it reached ~12 T field (BigBox quenched)
- This was higher than ever reached in DCC017 (DCC017 coils ran at a lower current – ~9 kA)

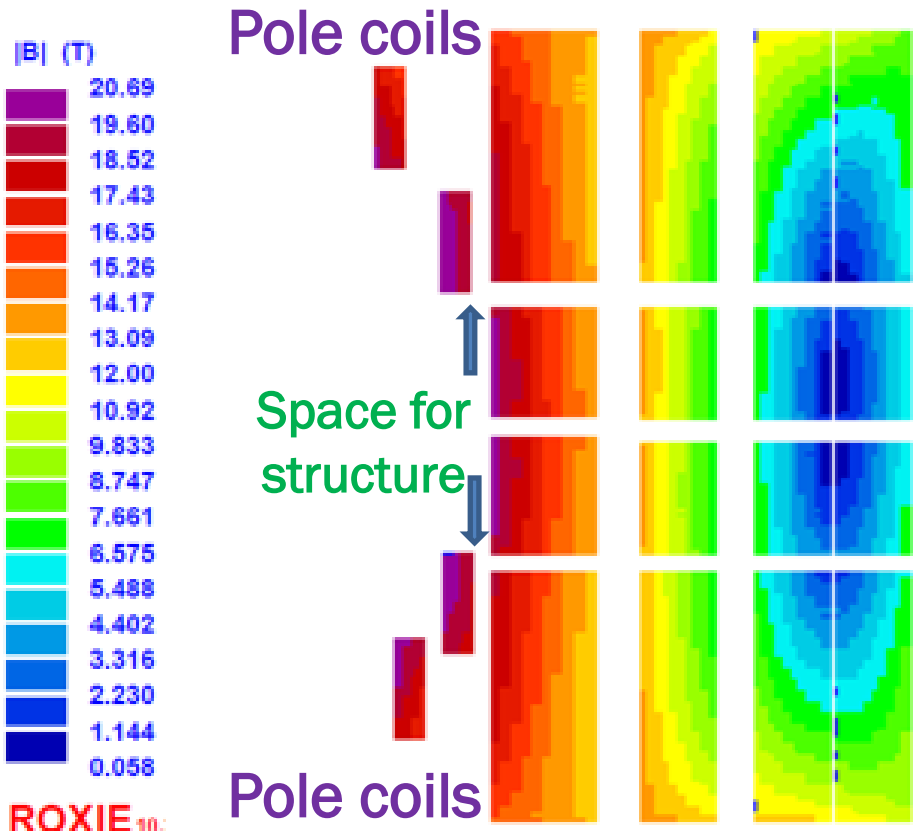
Interesting Oservations

- PSI insert coil was powered in opposite direction then originally intended.
- This means that the coils moved significantly under Lorentz forces to close-in the 2 mm gap
- Many good discovery in science have come unintentionally (or accidently). Here is another one, even though not close to other spectacular discoveries



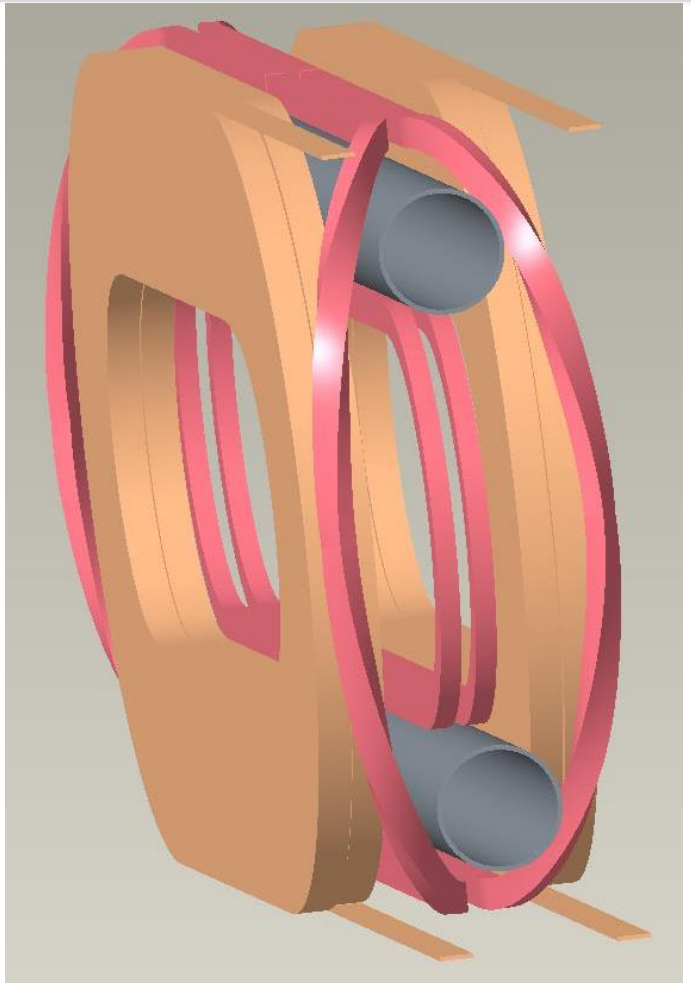
- No quenches in Nb_3Sn coils, means that the gap tolerances can be relaxed in such structures (though a large variation in the gap should perhaps be avoided)
- Structure of ~2.3 mm rather than ~4 mm was sufficient
- Stress diffusion – avoiding local stress/strain to spreading the stress worked

Proof-of-Principle Test of Field Quality Pole Coils in the Common Coil Design



20 T MDP Hybrid Design

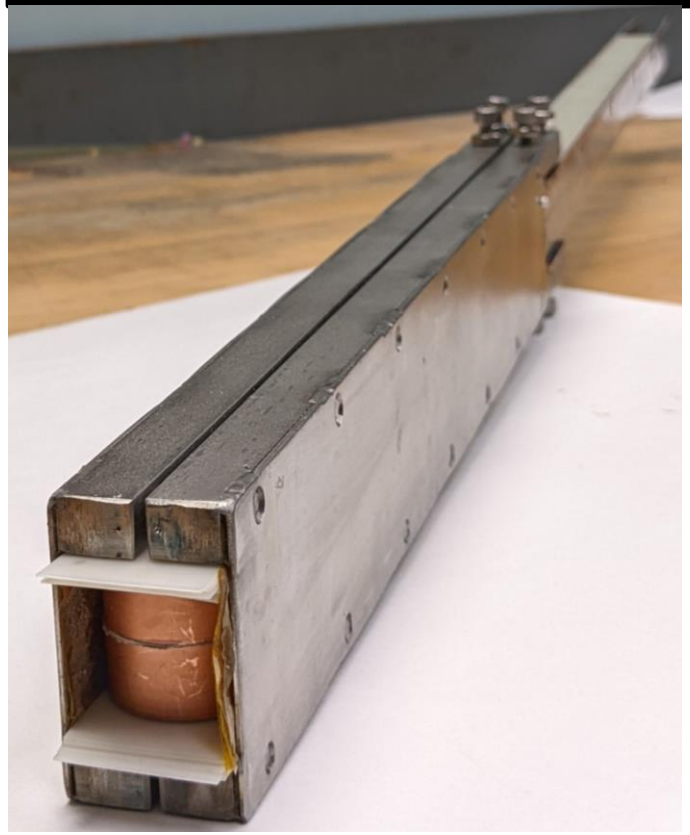
- In this case pole coils are oriented differently (hard way bend) from the main coils (soft way bend), same as in the PSI test.
- Pole coils are inserted in an intermediate structure inside the mail coils, same as in the PSI test.
- Therefore, in a way PSI test was the proof-of-principle test of the incorporation of the field quality pole coils in the common coil design



Concept from: PBL/BNL SBIR

MDP HTS Coil in a Support Structure

Question: Can a higher hybrid field be reached with some intermediate structure on HTS coil (stress management) ?

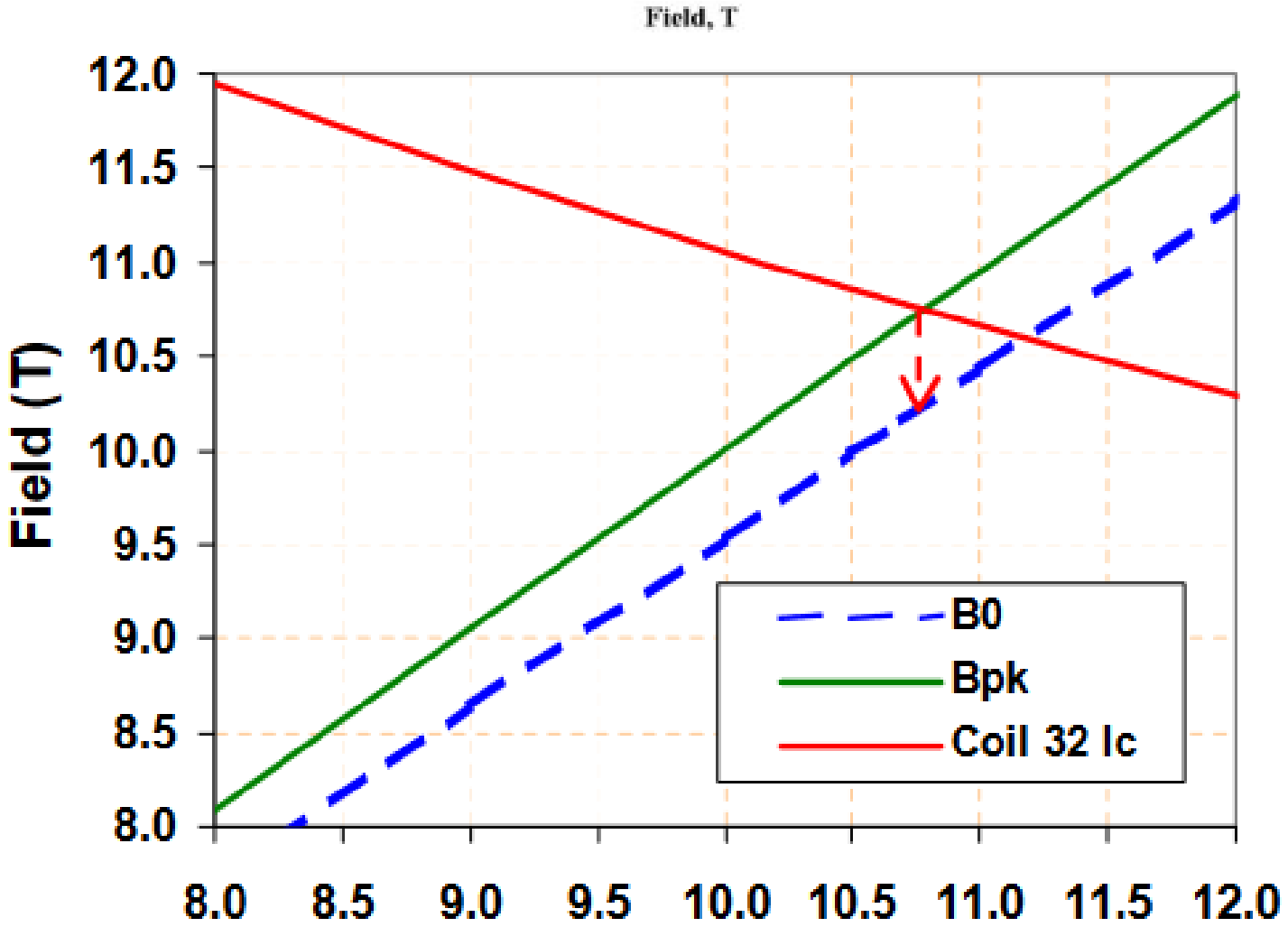


- HTS coils with leftover conductor.
- Coils tested at 77 K in the structure
- Intermediate structure provides stress management
- This structure was inserted in the second aperture
- Similar structure is being used in US-Japan collaboration

Acknowledgement

This test was made possible by the heroic effort of several magnet division staff and close collaboration between PSI and BNL staff, together with the discussion and contributions of other US labs

From ASC2006 Paper on DCC017



High field Nb_3Sn coils should include strain as a parameter in such plots