U.S. MAGNET DEVELOPMENT PROGRAM

BERKELEY LAB

Status of the Utility Structure design

Mariusz Juchno
US Magnet Development Program
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Fermi National Accelerator Laboratory

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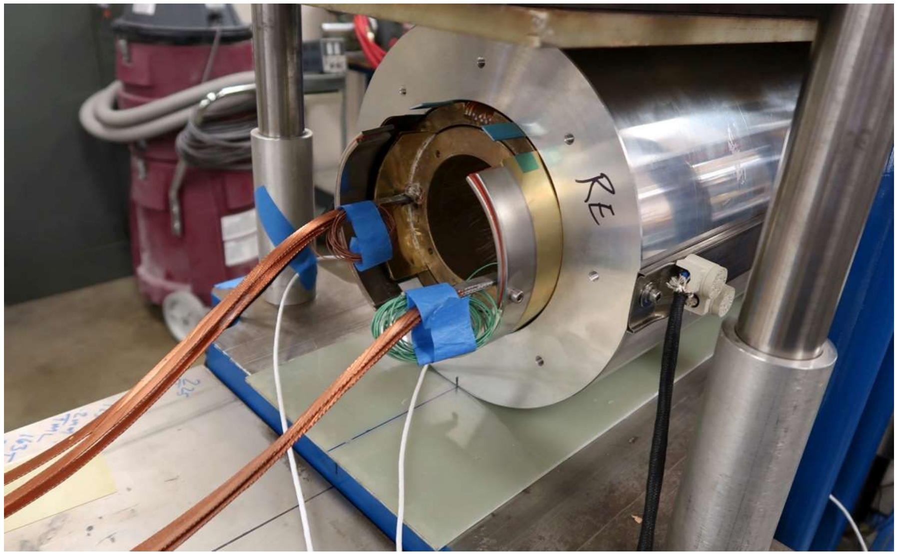
Nb_3Sn magnets



- **15 T Dipole**
  - Dedicated mechanical structure
  - Simple parts and assembly process
  - Full disassembly required for changing pre-load
- **CCT Dipole**
  - New epoxy type and impregnation procedure
  - New “bend and shim” assembly process
  - Thick aluminum cylinder as an external support structure

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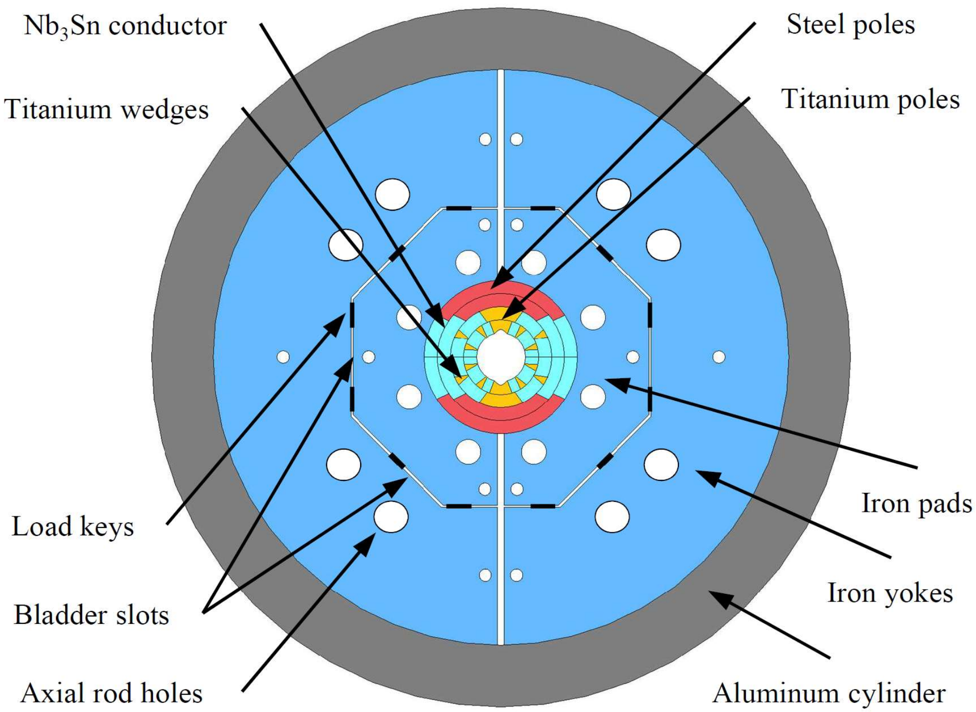
Utility Structure for Nb_3Sn magnets

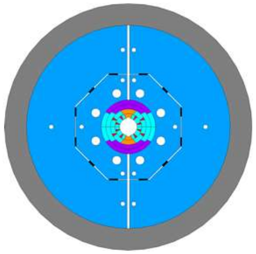
- 15 T Dipole
  - Secondary structure
  - Simple and reversible assembly and loading with fast turnaround
  - Minimal modification required for future designs (potentially for Stress Managed coils)
- CCT magnet
  - Utility Structure provides more rigid support than a thick aluminum cylinder
  - Minimal modification for 4-layer design
- Hybrid HTS/LTS magnets
  - With a proper outsert magnet, it could serve as a as a test facility for HTS inserts
- **Flexibility comes at the price of dimensions and requirement for a bigger test facility**

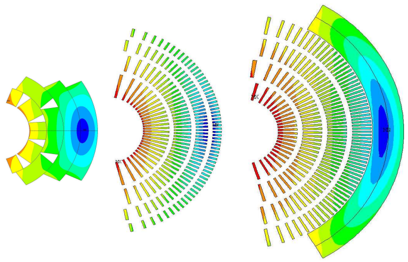
Utility Structure overview

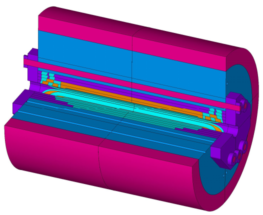


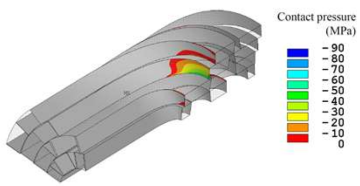
- Shell based structure
  - Bladder and key assembly
  - Adjustable RT pre-load
  - Reversible assembly
- Reusable components
  - Yoke-shell assembly
  - Axial pre-load system
  - Only pads customized for coil OD
- Currently considered for calculation
  - Coil pack width 320 mm
  - Shell OD 750 mm
  - Shell TH 75 mm
- Preload capabilities
  - ~12 MN/m force per magnet quadrant
  - Assuming that yoke remains open
  - Assuming max. 45 MPa bladder pressure

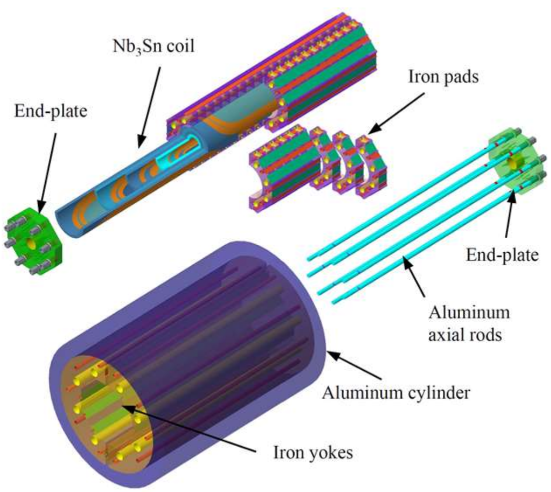
Summary of past work





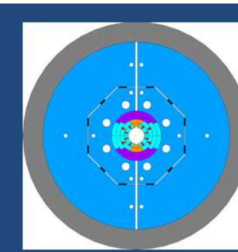


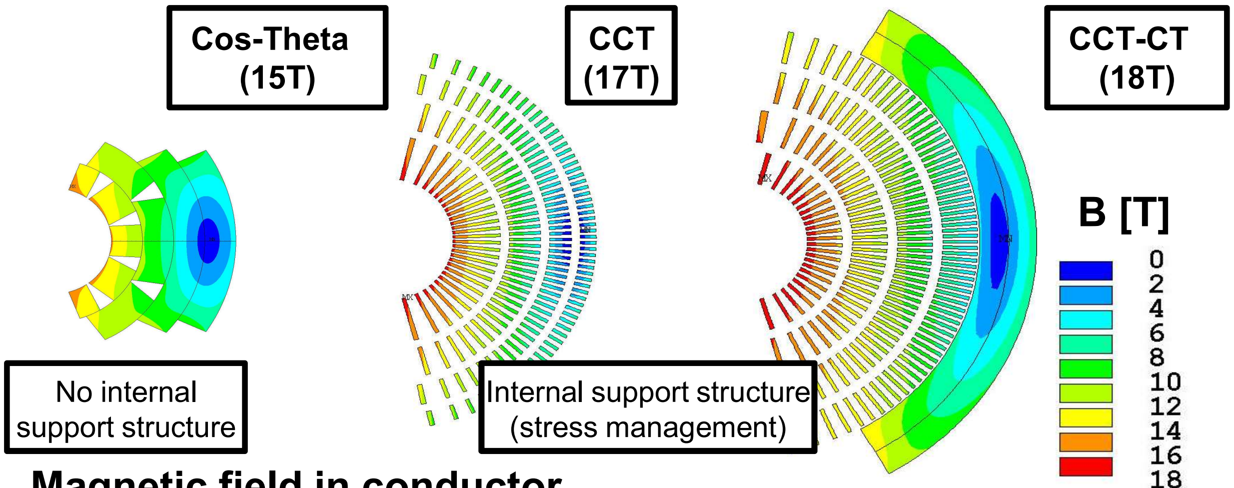




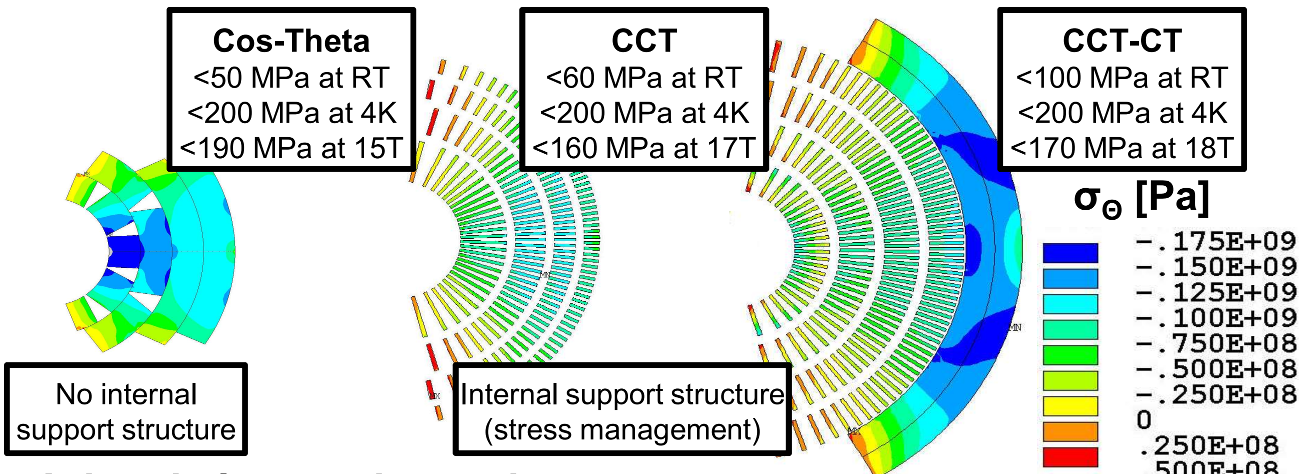
- Development of the 2D model
  - Investigation of the geometrical parameters and pre-load capabilities for cos-theta dipole
  - Pre-load optimization for 15 T Dipole and comparison with FNAL/FEAC results
  - Investigation of pre-load capabilities for other coil types (CCT, CCT-CT)
- Development of the 3D model
  - Axial and azimuthal pre-load optimization for 15T Dipole coils
  - Validation against 2D model results
- Initial engineering design
  - CAD model of the structure

Utility Structure
With different coil types





Magnetic field in conductor

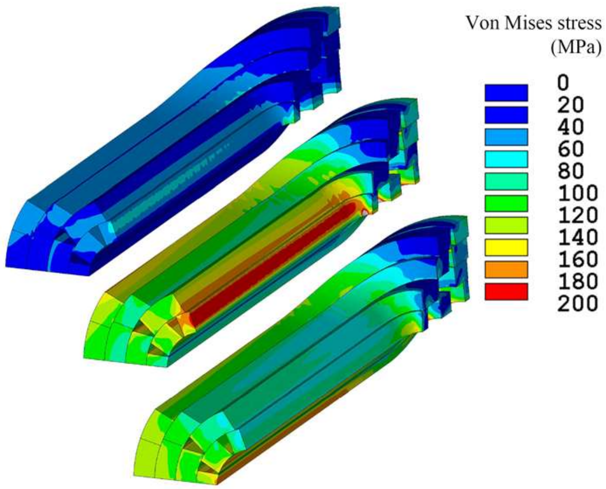


Azimuthal stress in conductor

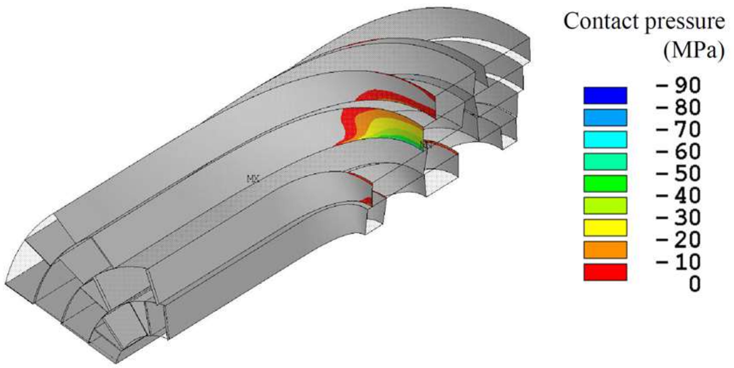
- **Benefits**
  - Same structure used, only pads are custom
  - Conductor stress level
    - <100 MPa at RT
    - <200 MPa at 4K and with mag. forces
- **Challenges**
  - Azimuthal preload for external CT layer in CCT-CT hybrid
  - Deformation and stress in the CCT mandrel at fields > 16 T

3D modeling overview with 15T dipole coils

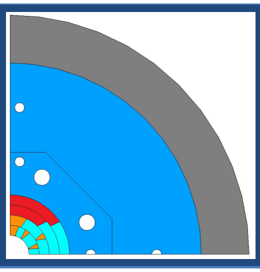
- 3D calculation at 15T field
  - Stress in the straight section below 200 MPa
  - High stress spots in the ends of 1st layer
    - Isotropic coil properties
- Coil-end pre-load
  - Tension in the outer layer reduced non-magnetic pad-ends
  - Axial pre-load system analyzed
    - Friction on coil-structure interface prevents efficient inner-outer layer pre-load distribution
  - 20-40 MPa tension can cause epoxy de-bonding in outer layer
- Maximum Von Mises stress in the structure (MPa)

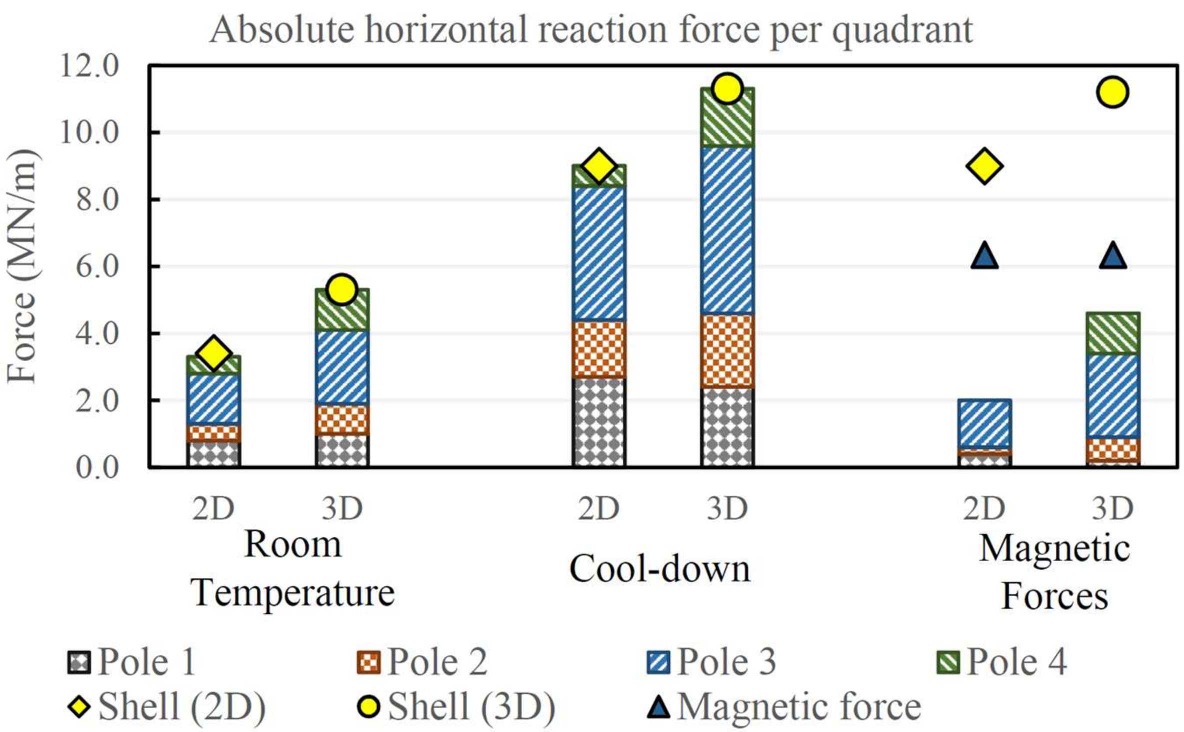


	RT	4K	15T
Coil	50	200	190
Shell	140	210	210
Iron	150	260	260
End-plate	260	460	480
Axial rods	210	350	355



Azimuthal pre-load balancing and overshoot





- Nominal parts assumption
- Coil properties
  - 2D – Orthotropic
  - 3D – Isotropic
- Reaction forces showed at symmetry plane

- Significant overshoot of the applied pre-load required to maintain coil compressions
- Actions:
  - Model improvement: orthotropic 3D properties of the coil
  - Pre-load balancing with mid-plane shims
  - Tolerance analysis

Things needed to progress from here

- New test facility
  - Alternative is testing magnets at 4.2 K in LBL
- Program direction
  - Better understanding of a target coil architecture, dimensions, field level and forces especially for HTS insert testing
- Modeling
  - 15T Dipole coils
    - Orthotropic coil properties (axial stiffness and CTE effect)
    - Pre-load balancing (mid-plane shims usage)
    - Detailed tolerance analysis (including friction impact)
  - CCT and hybrid designs
    - Minimizing deformation and stress of the coil mandrel
- Mature engineering design

Thank you!