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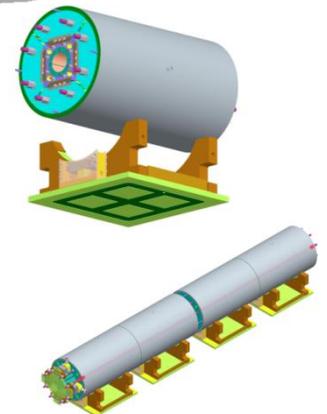
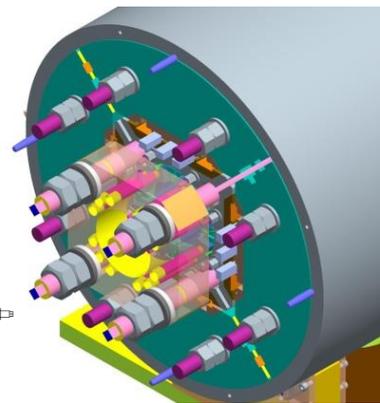
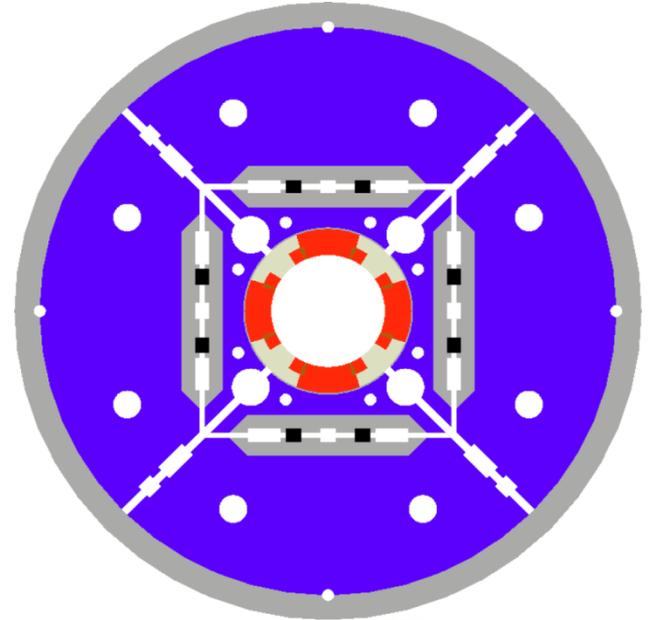
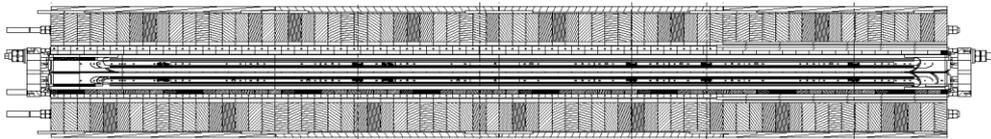
# LQ Support Structure

P. Ferracin

LARP Collaboration Meeting, CM13  
Port Jefferson, NY  
November 4-6, 2009

# LQS01 magnet design

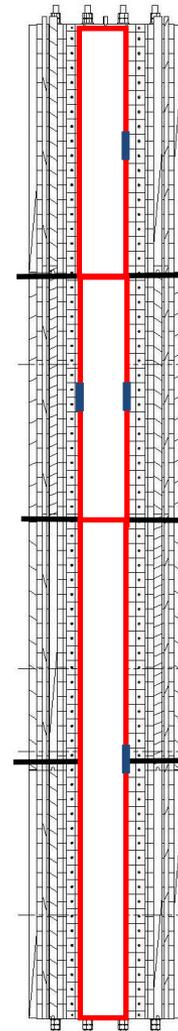
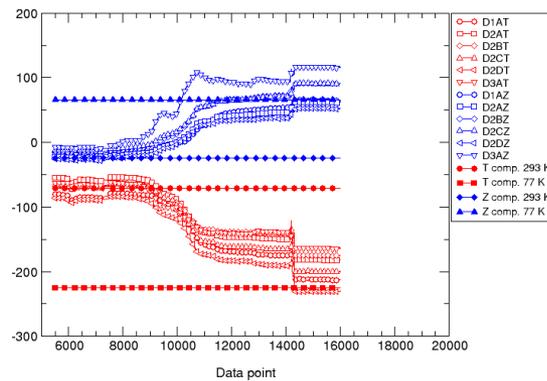
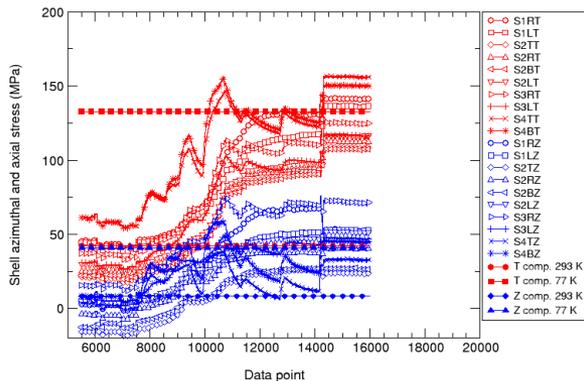
- Iron pads, masters and yokes
  - 20 mm thick Al shell (500 mm OD)
  - Pre-load with bladders and keys
  - End support: plate and rods
  - Assembly of short segments
  - Connection of segments
- 
- Coil length: 3.4 m
  - Magnet length: 3.7



# CM12

## LQSD assembly and cool-down with dummy coils

- LQSD “modular” assembly and loading with bladders completed
  - First time with a 4 m long quad. structure
- Successful test of lifting / tilting operation
- LQSD cooled down to 77 K at FNAL
  - Strain gauge results consistent with targets
- Magnet shipped back to LBNL



# Outline

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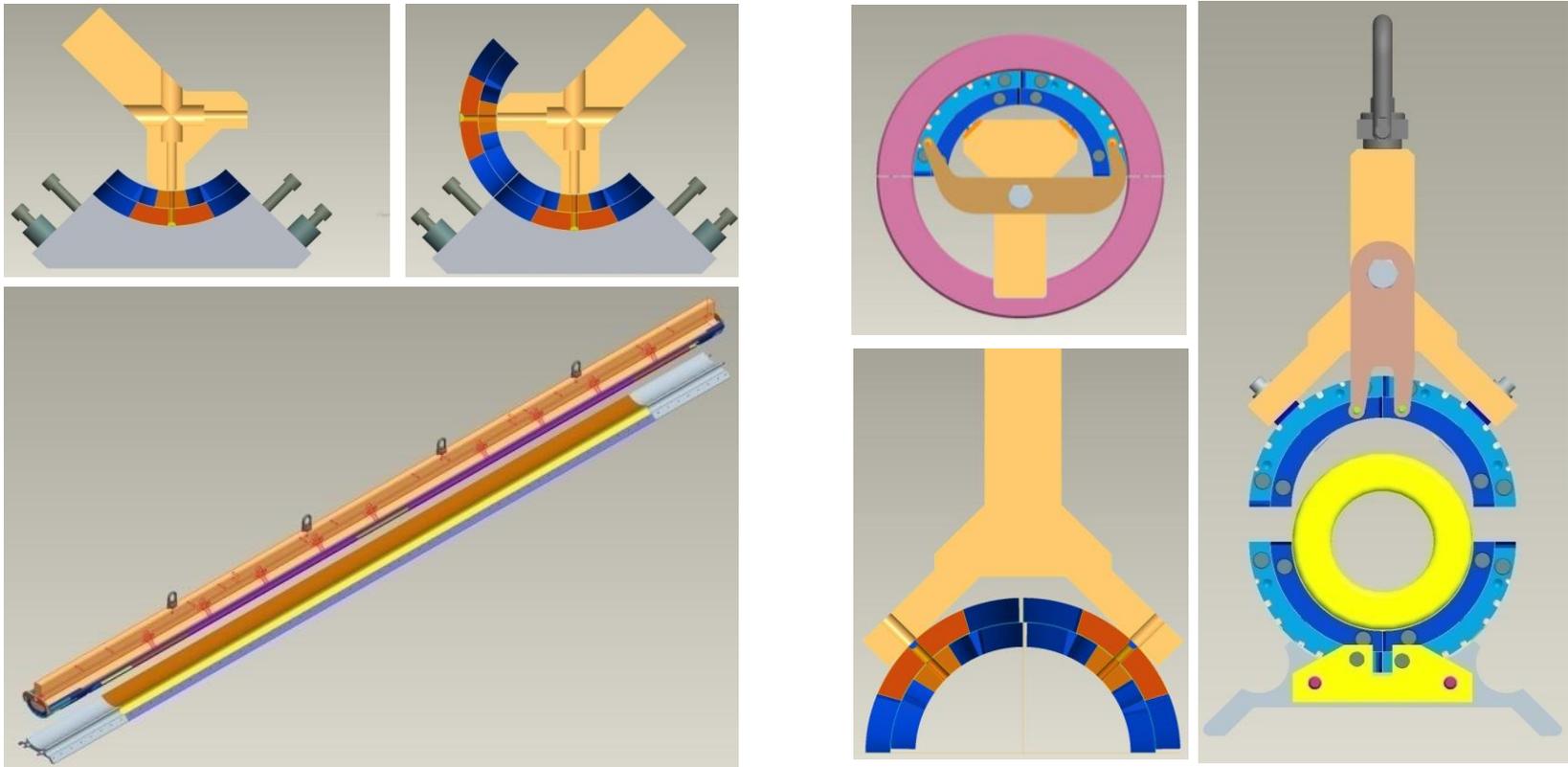
- LQSD disassembly
- Coil-pack practice assembly
- Coil instrumentation
  
- LQS01 assembly and loading
  
- Strain gauge measurements vs. targets
  
- Conclusions

# LQSD coil-pack disassembly



# Coil-pack assembly procedure

- Coils lifted with inner and outer strong backs
- Rotation performed with aluminum wheels



# Load test of coil lifting beams



# Bolting of inner lifting beam to practice coils

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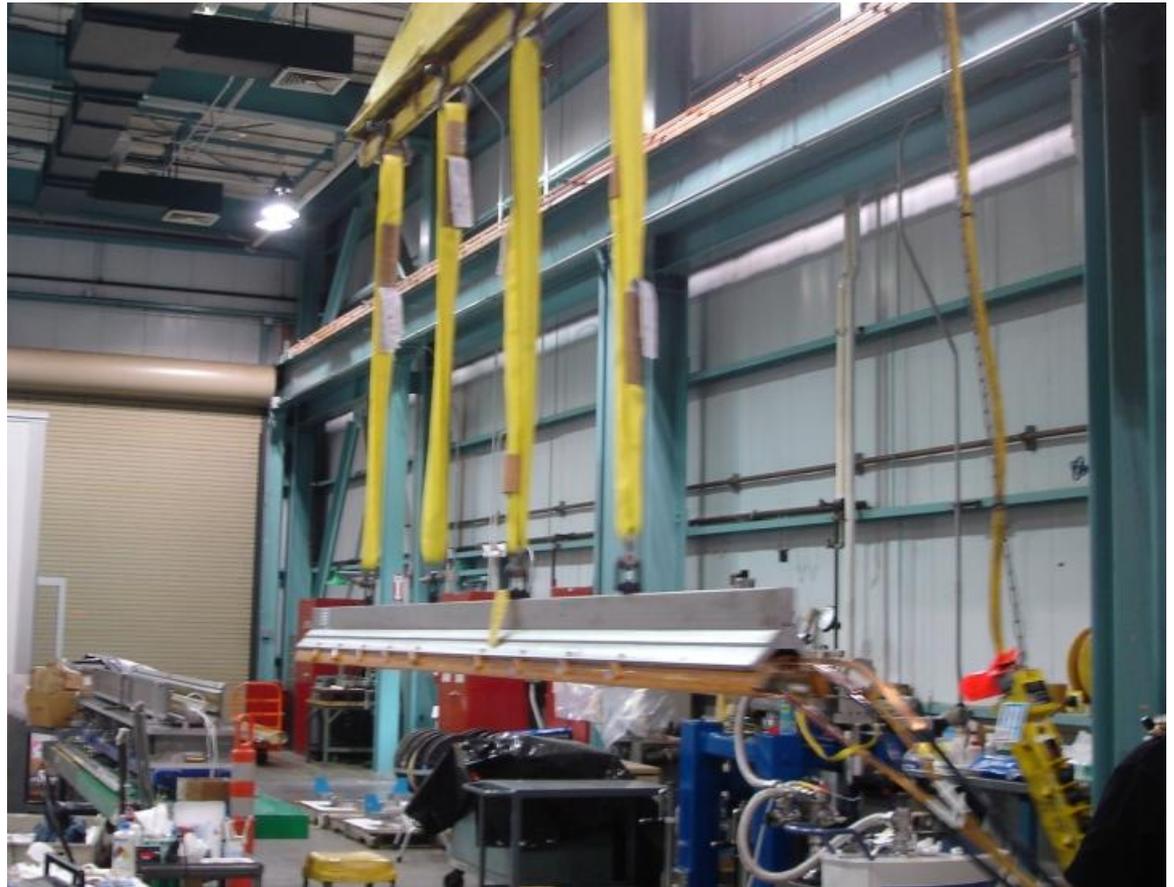


# Rotation of practice coils



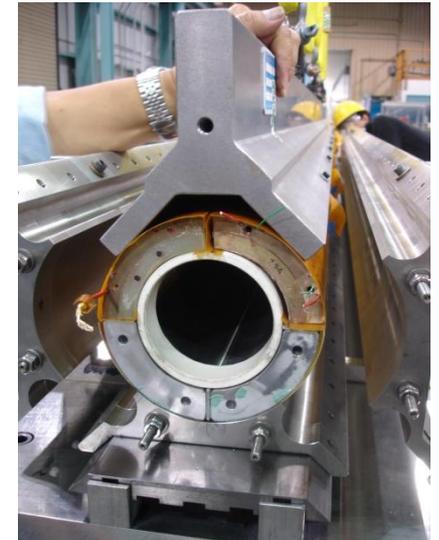
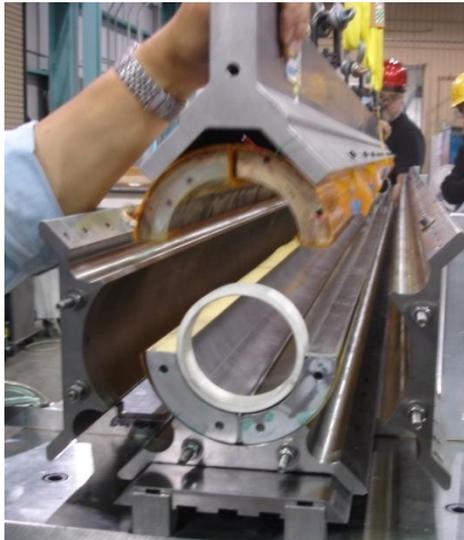
# Bolting of outer lifting beam to practice coils

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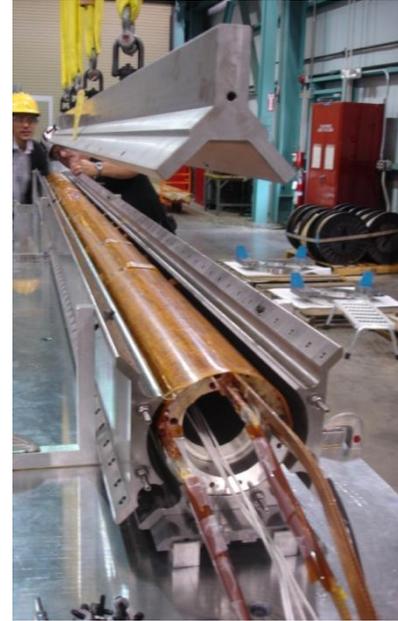
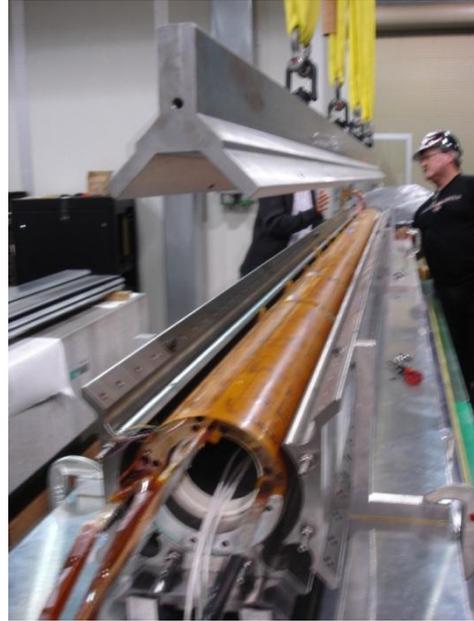
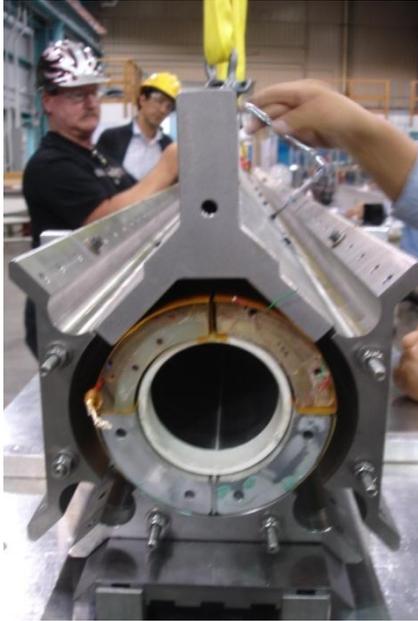


# Placing practice coils on top of dummy coils

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# Coil-pack practice assembly



# Tooling modifications (review #3)

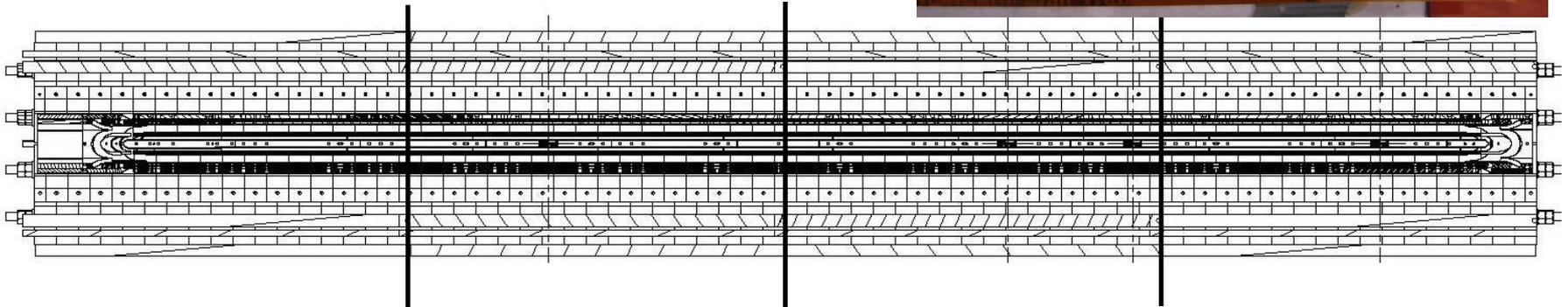
- Scale, new rubber, bracket
- Wheels bolted and machined



# LQ Instrumentation task (H. Felice)

## Coil instrumentation

- 4 strain gauge stations
  - $\vartheta$  and  $z$  with compensators
  - Total of 32 gauges
- Strain relieves, spot heaters, wires for voltage taps and protection heaters
- High-pot and R meas.
  - Individual coils, coil-pack, and magnet assembled

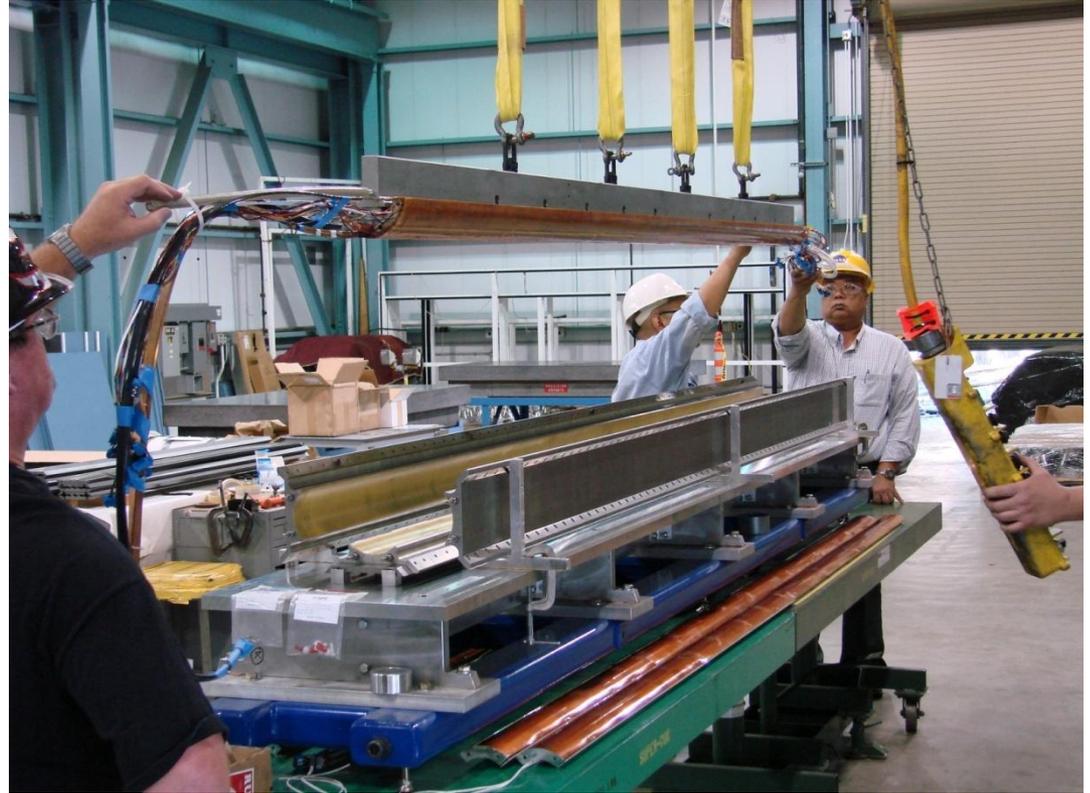


# Outline

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- LQSD disassembly
- Coil-pack practice assembly
- Coil instrumentation
  
- **LQS01 assembly and loading**
  
- Strain gauge measurements vs. targets
  
- Conclusions

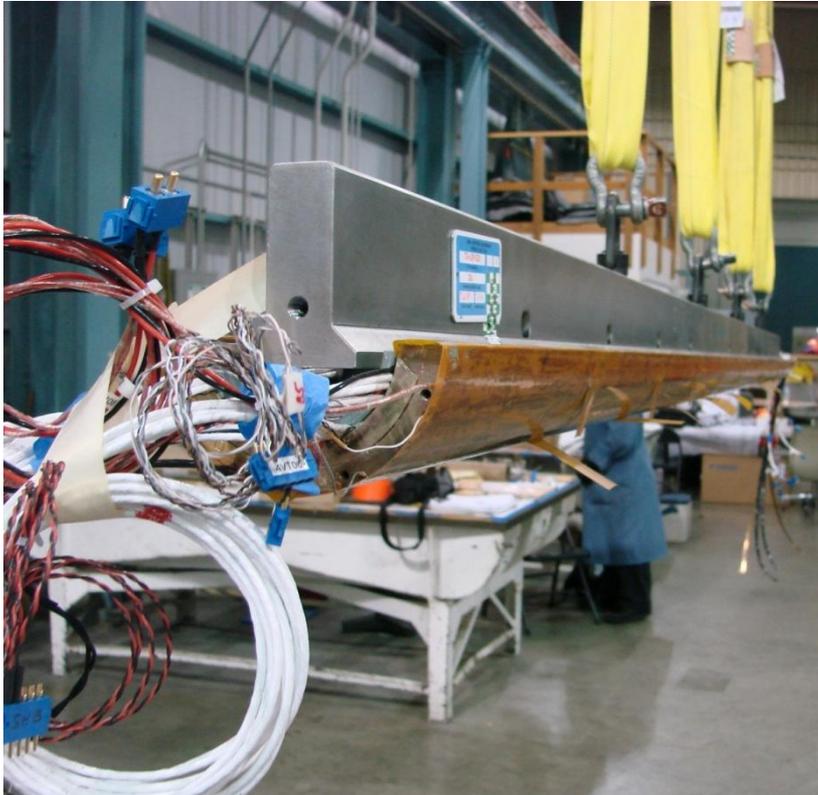
# Placing coil 6 and coil 7 on bottom pad



# Placing coil 6 and coil 7 on bottom pad



# Repeating lifting procedure with coil 8 and 9 and placing rotating wheels



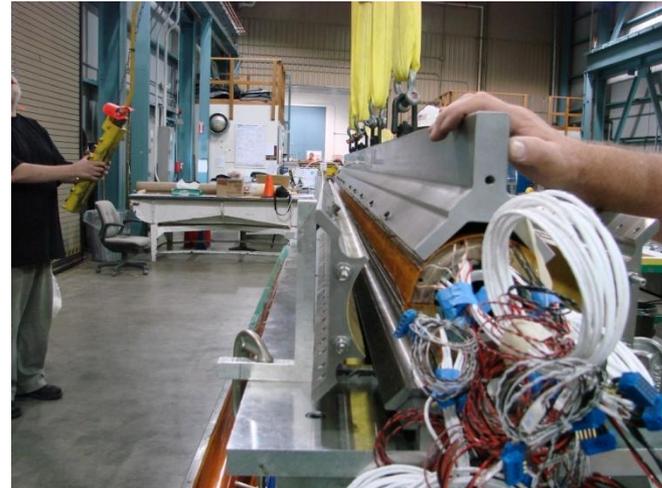
# Rotating coil 8 and coil 9



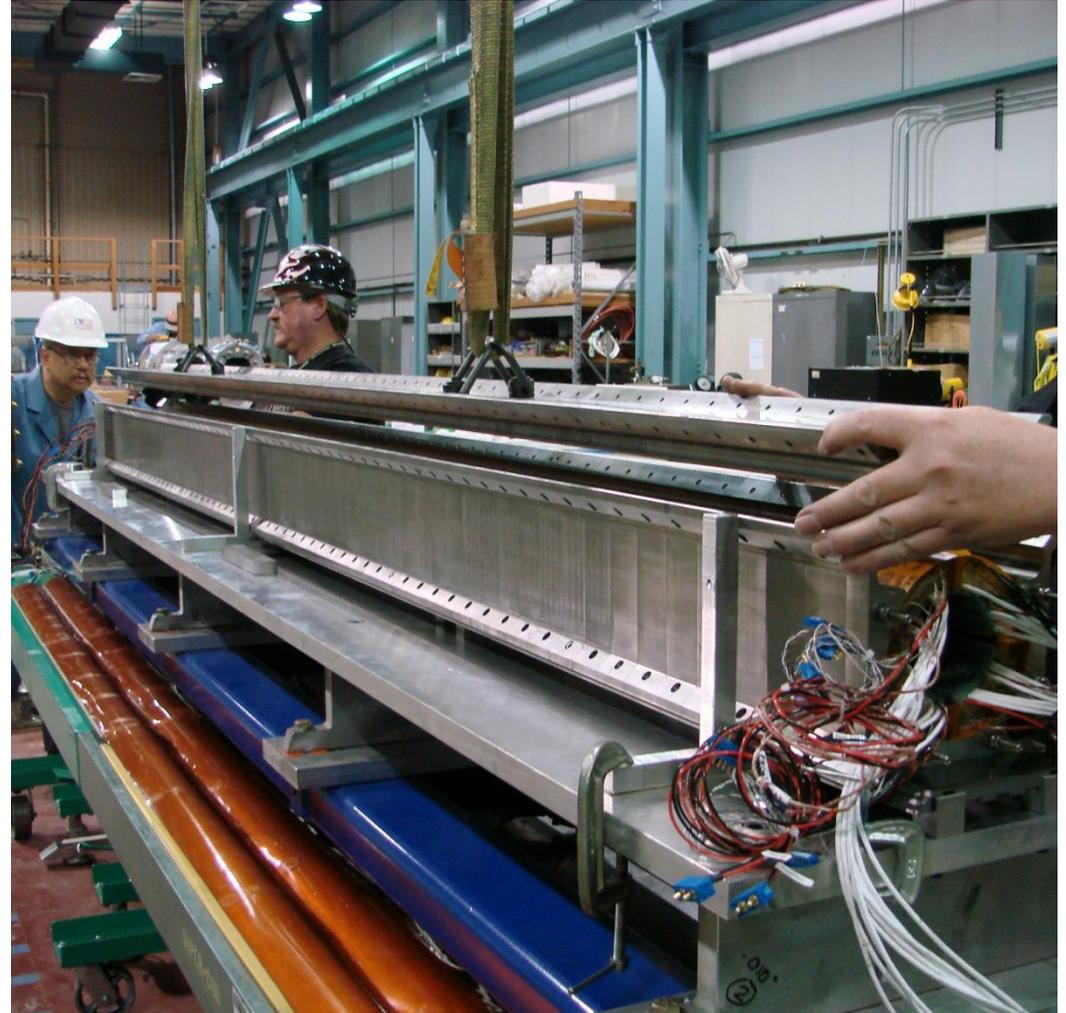
# Placing outer lifting beam and lifting coil 8 and coil 9



# Placing coil 8 and coil 9 on top of coil 6 and coil 7



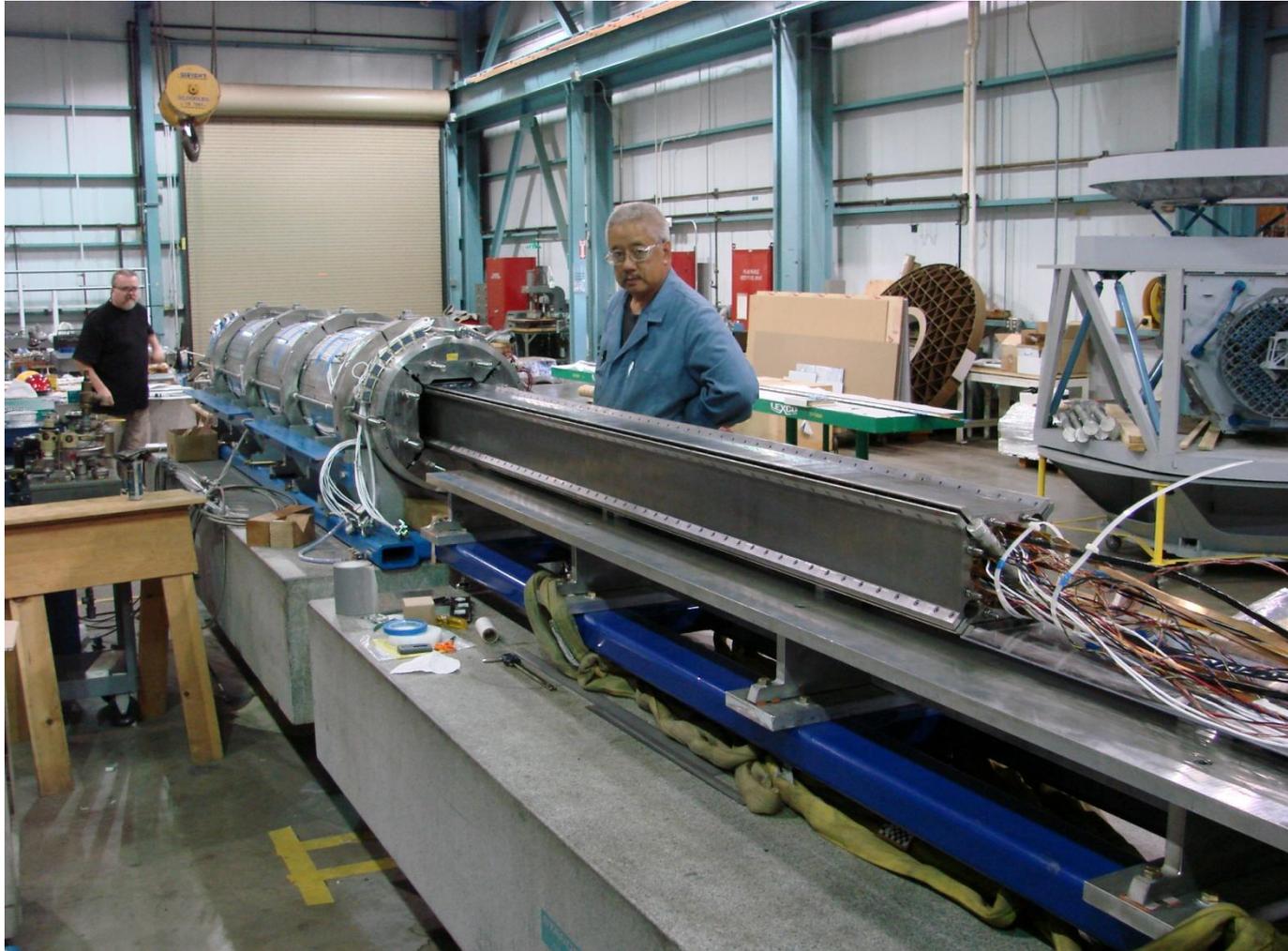
# Lifting outer lifting beam and placing top pad on top of coils



# Coil pack assembly

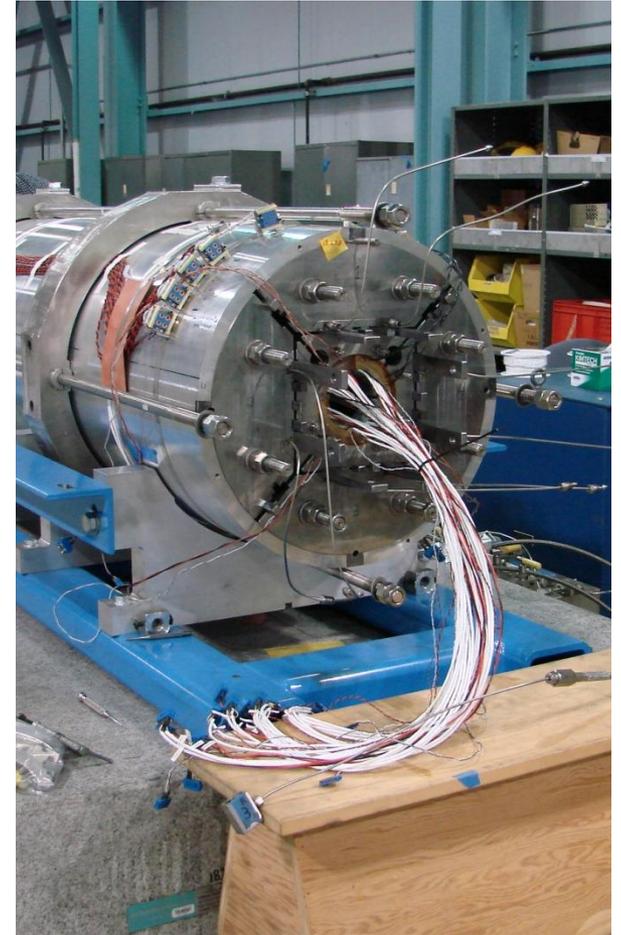
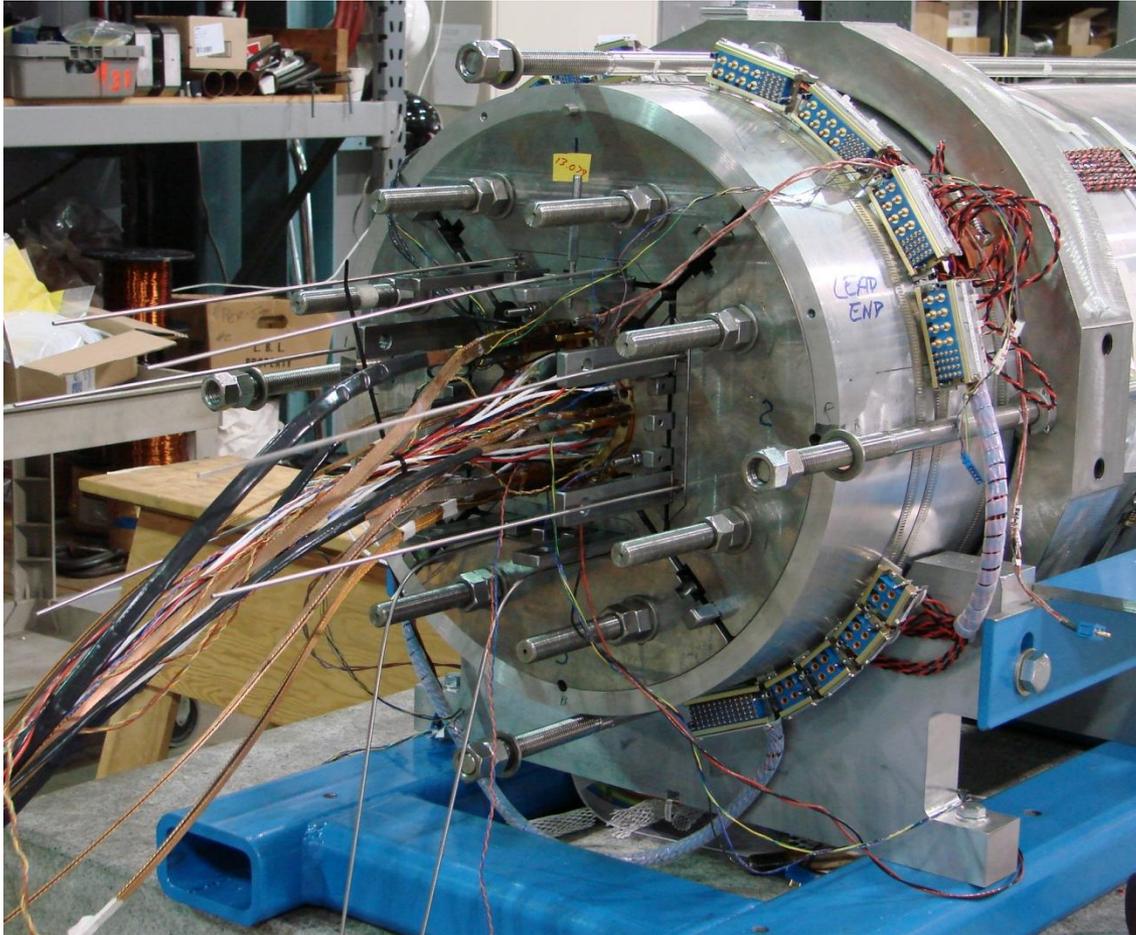


# Insertion of coil-pack

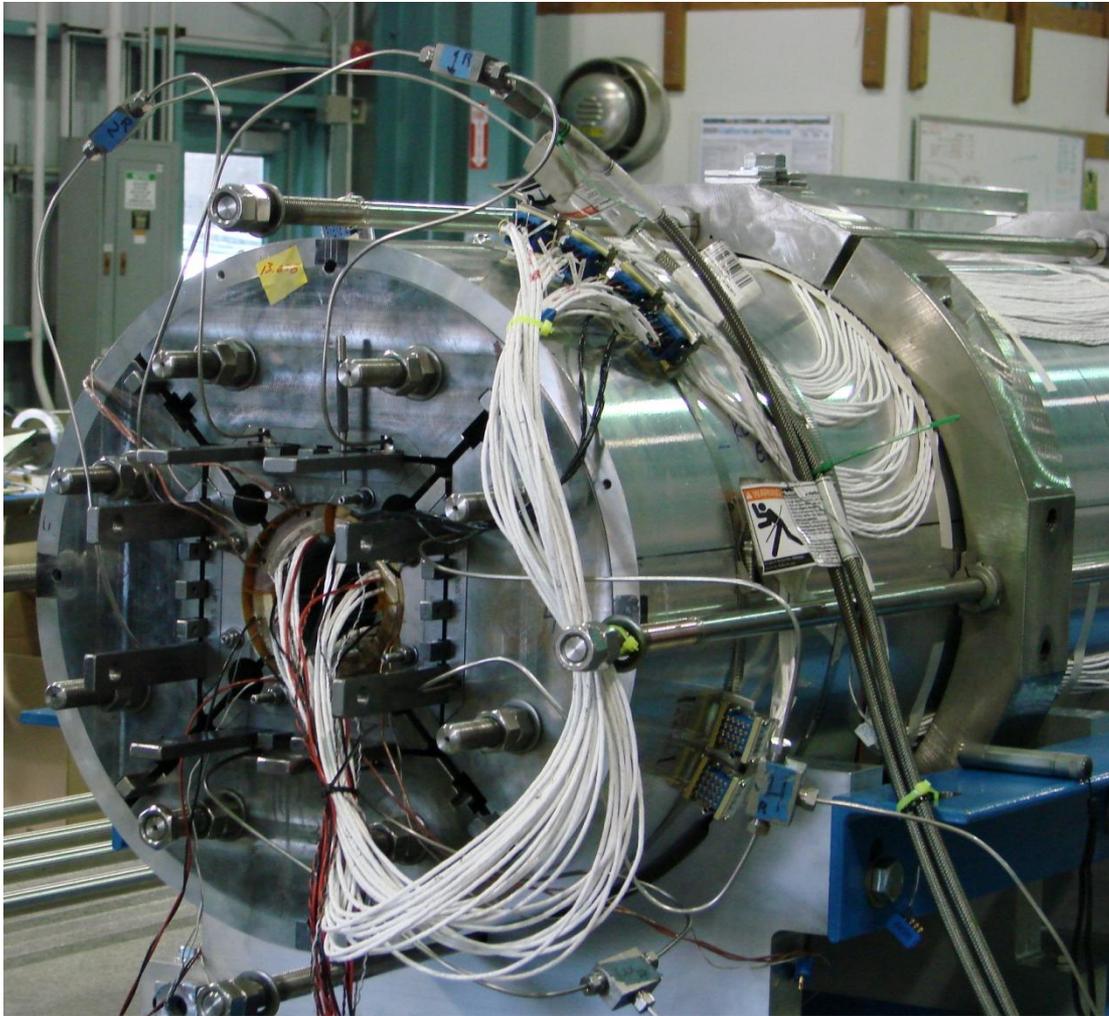


# Coil-pack after insertion

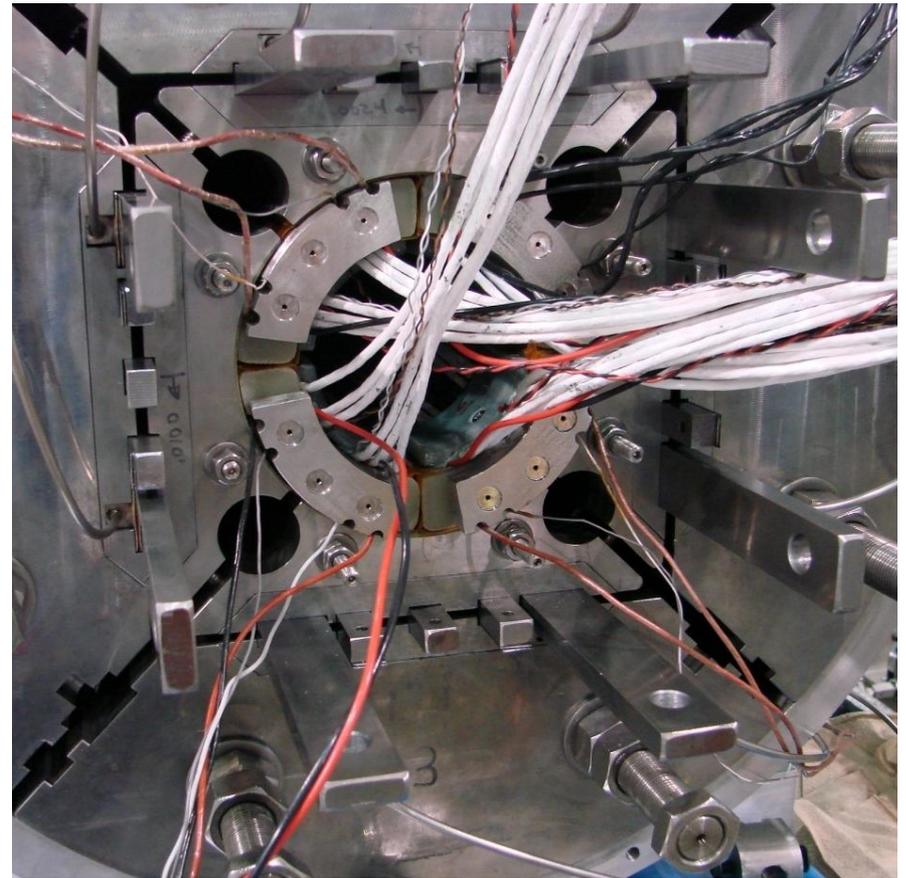
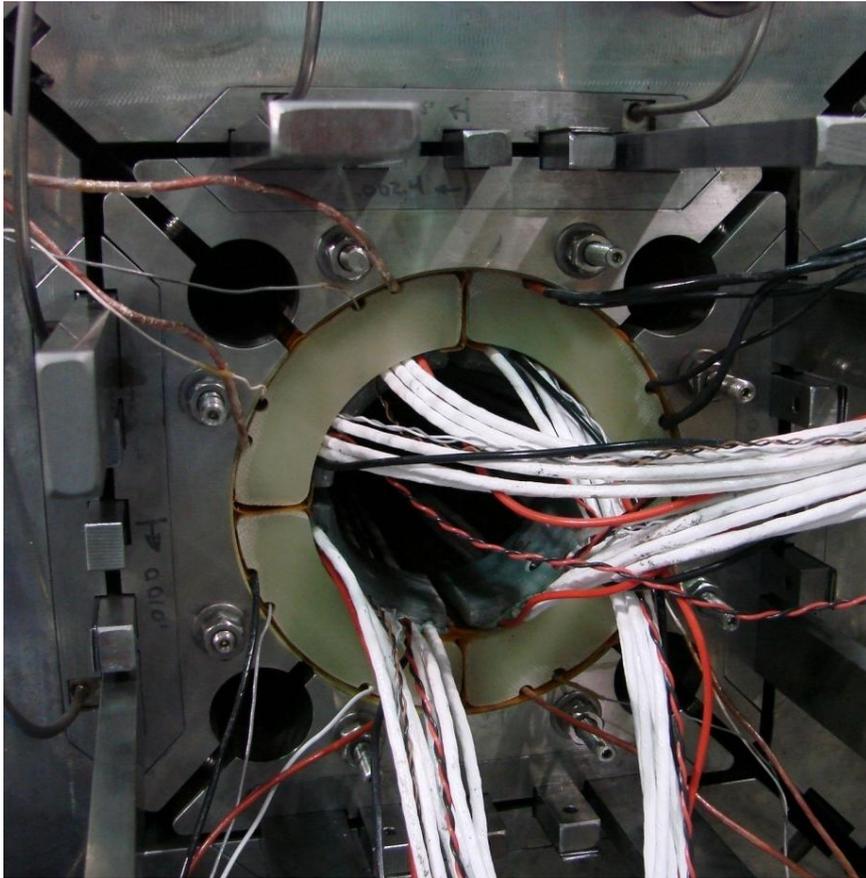
## Lead end – return end



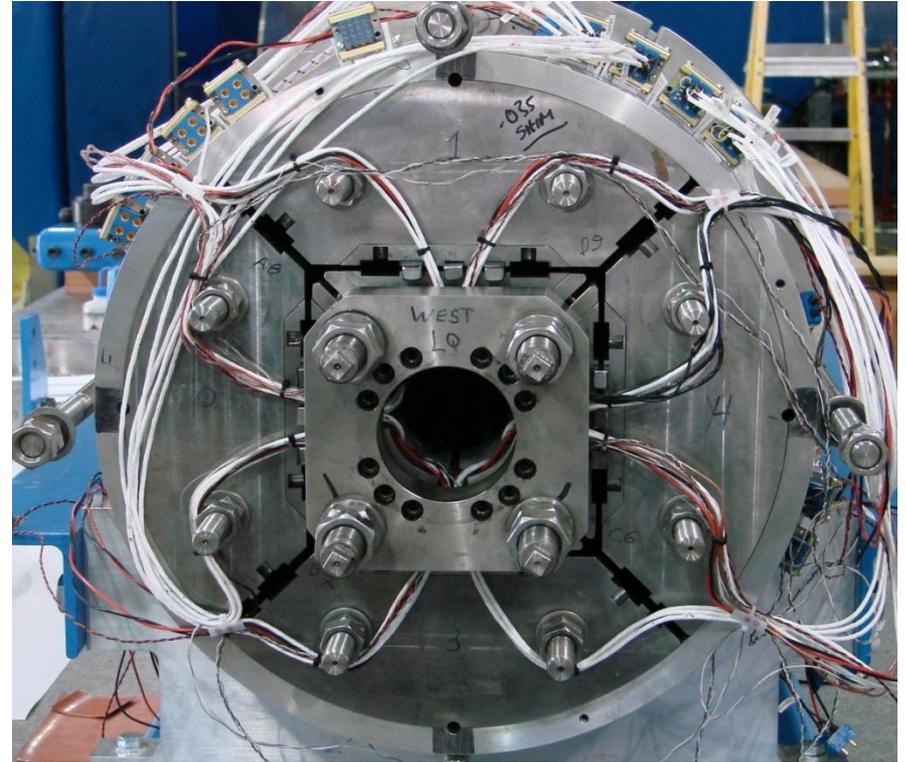
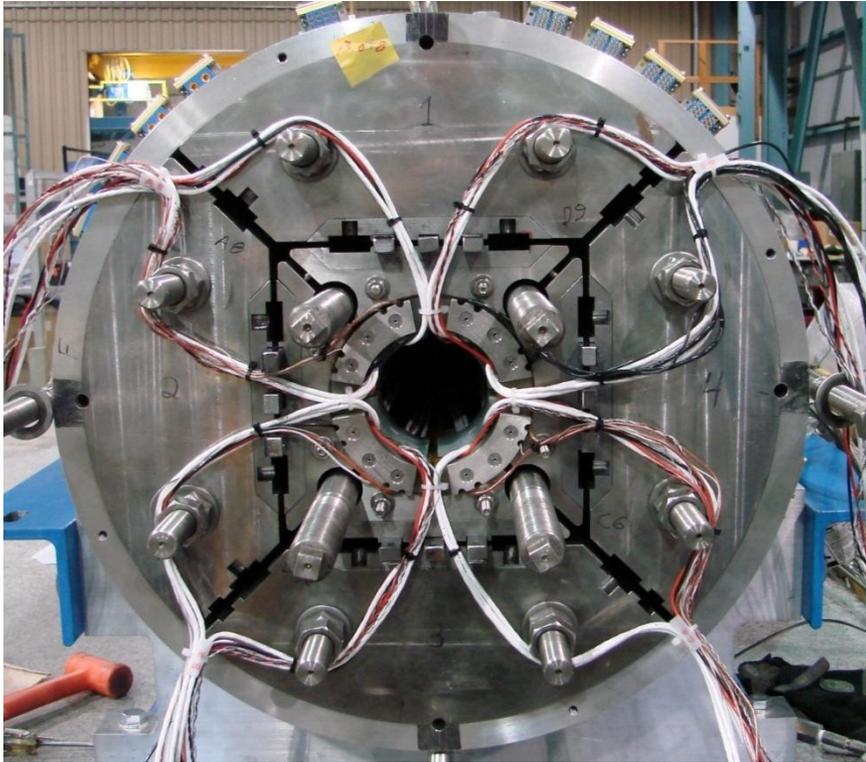
# Bladder operation



# G10 and stainless steel end pushers

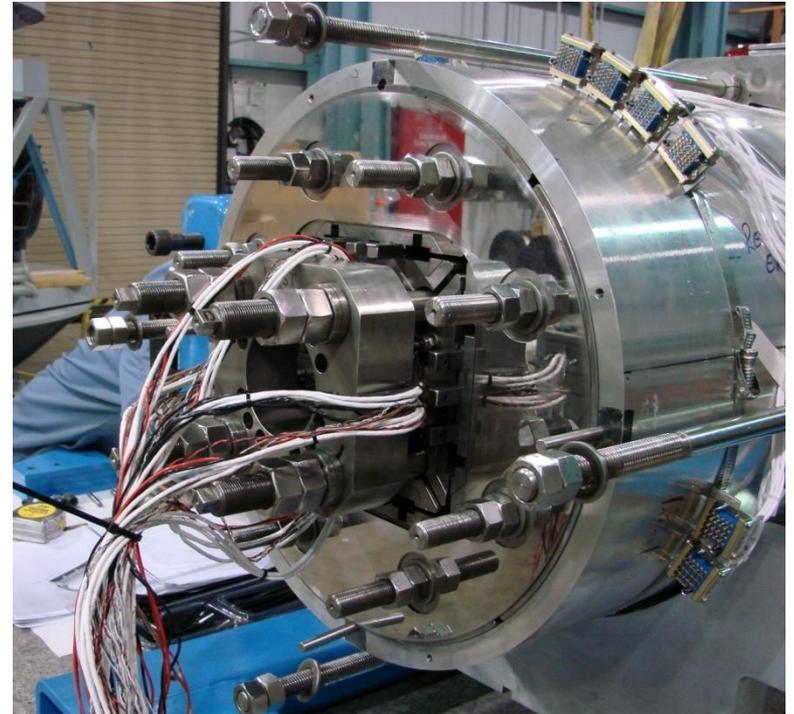
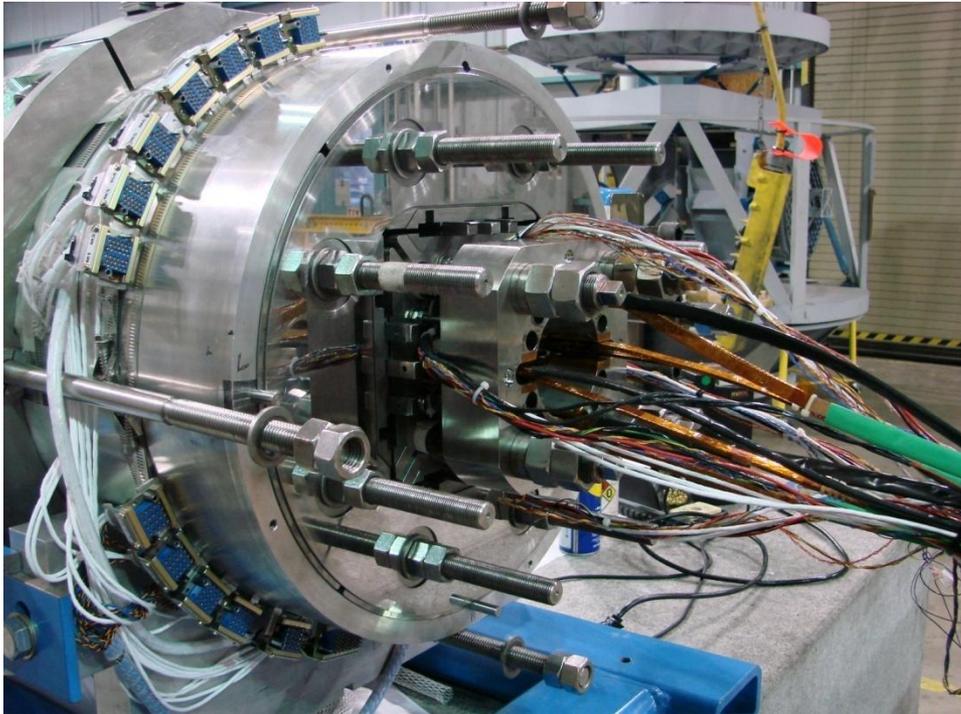


# Connecting coil instrumentation to shell connectors and placing coil axial support

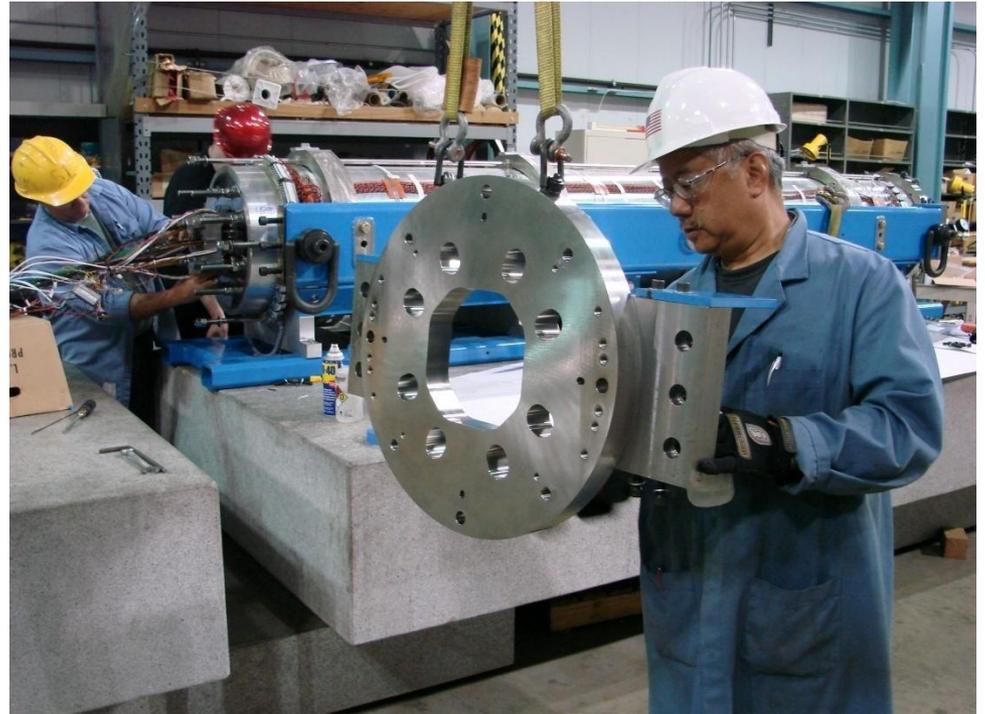
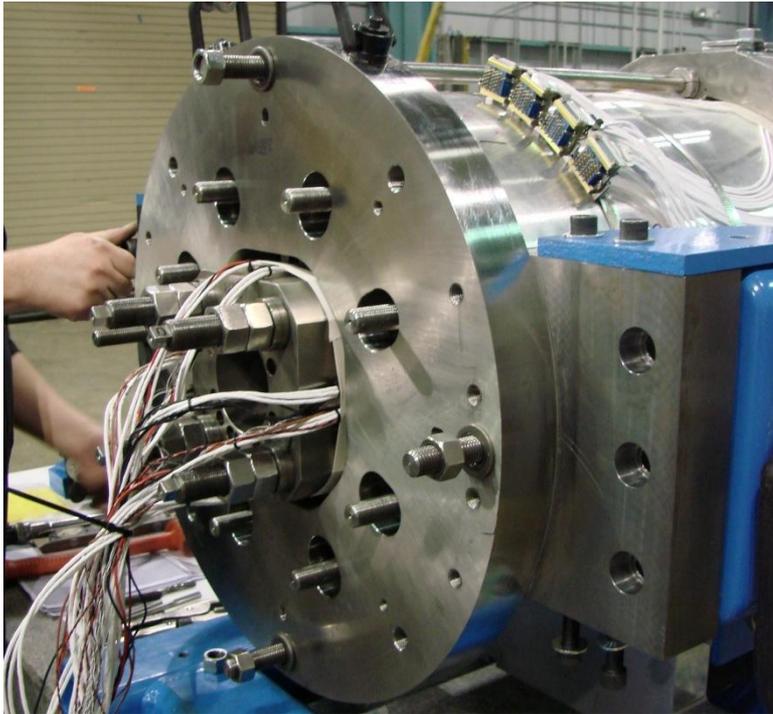


# Preparation for lifting / shipping tooling

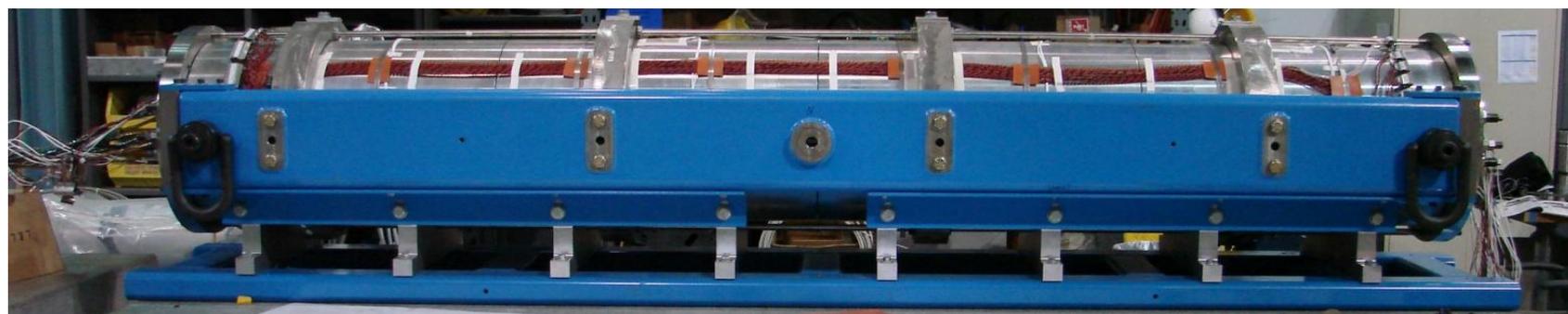
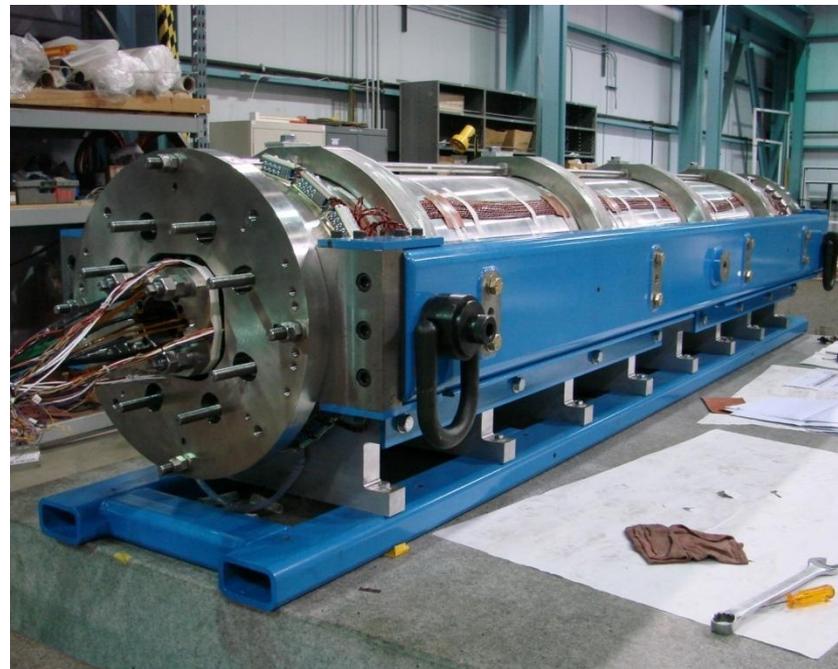
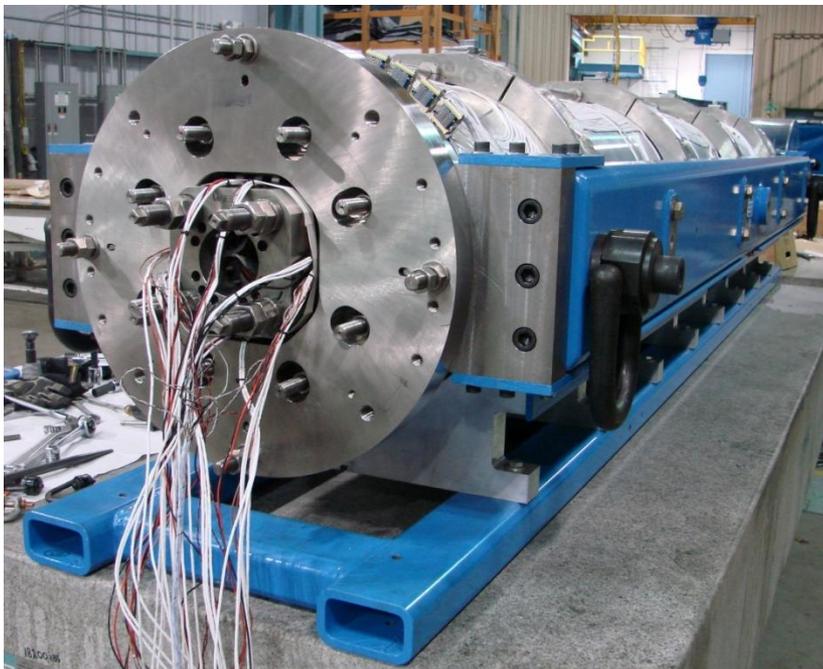
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# Support plates



# LQS01 before shipment



# Outline

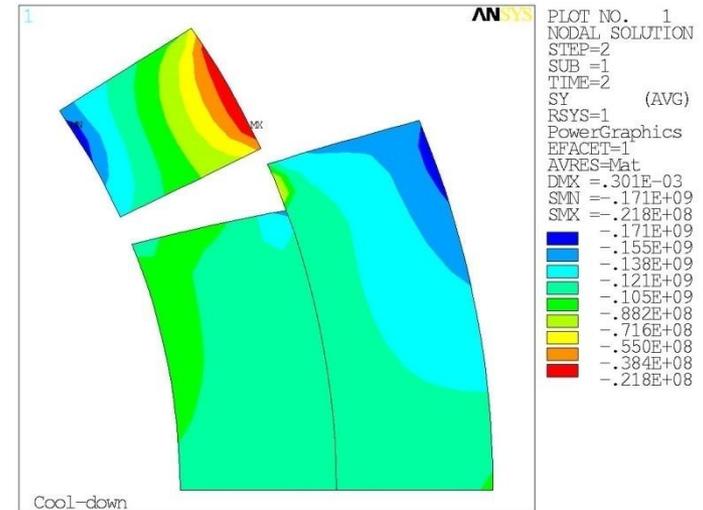
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- LQSD disassembly
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- **Strain gauge measurements vs. targets**
  
- Conclusions

# LQS01 target pre-stress

## Pre-load for 230/240 T/m (13.2/13.8 kA)

- Shell
  - Strain
    - From +390/+520 to + 1710/+1860  $\mu\epsilon$
  - Stress
    - From +30/+40 to +150/+170 MPa
- Coil pole
  - Strain
    - From -300/-400 to -700/-820  $\mu\epsilon$
  - Stress
    - From -40/-60 to -110/-130 MPa
- Coil peak stress: +160/+170 MPa



# Shell and rod strain after loading

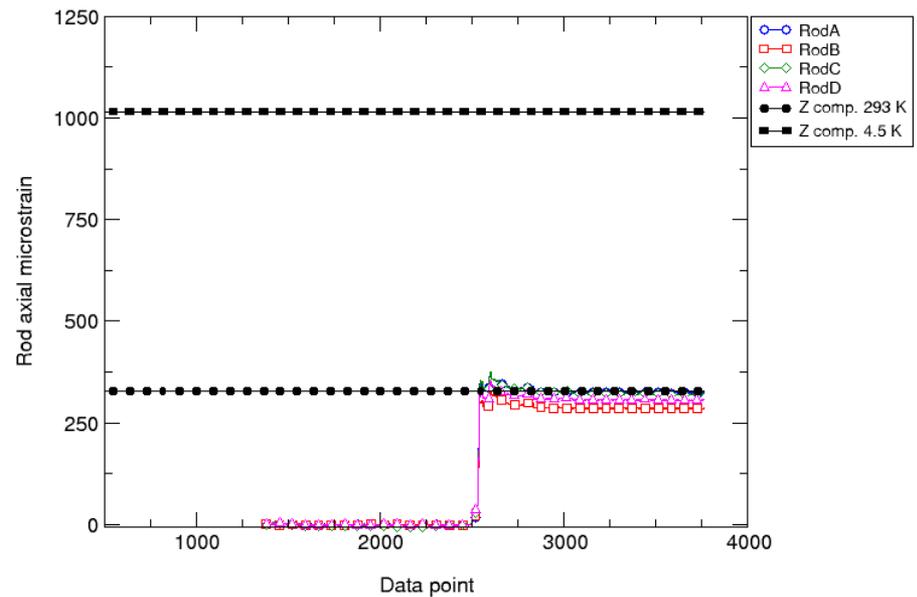
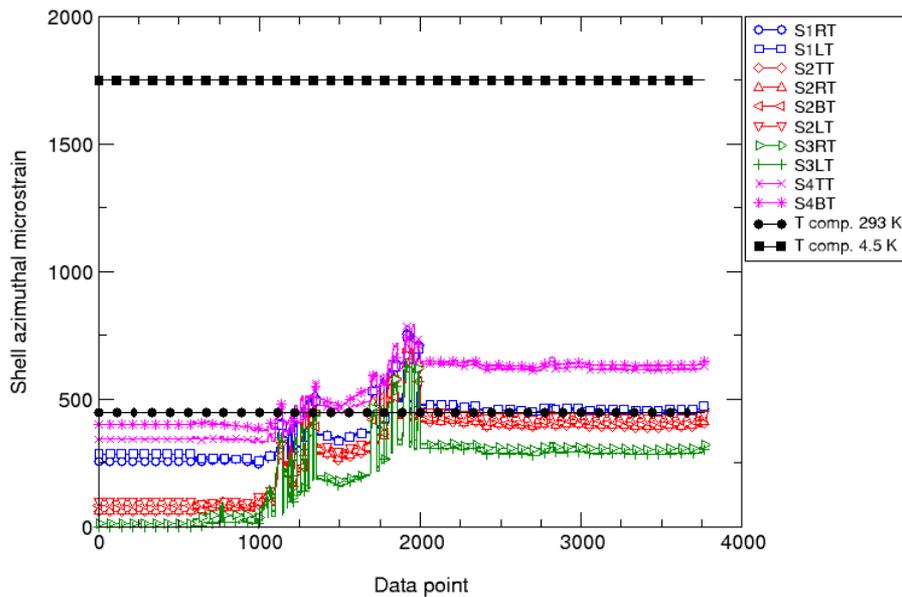
## Measurements vs. computations

- Shell

- Computed: +447  $\mu\epsilon$
- Measured: +451  $\pm 113 \mu\epsilon$

- Rod

- Computed: +327  $\mu\epsilon$
- Measured: +310  $\pm 18 \mu\epsilon$



# Shell and rod stress after loading

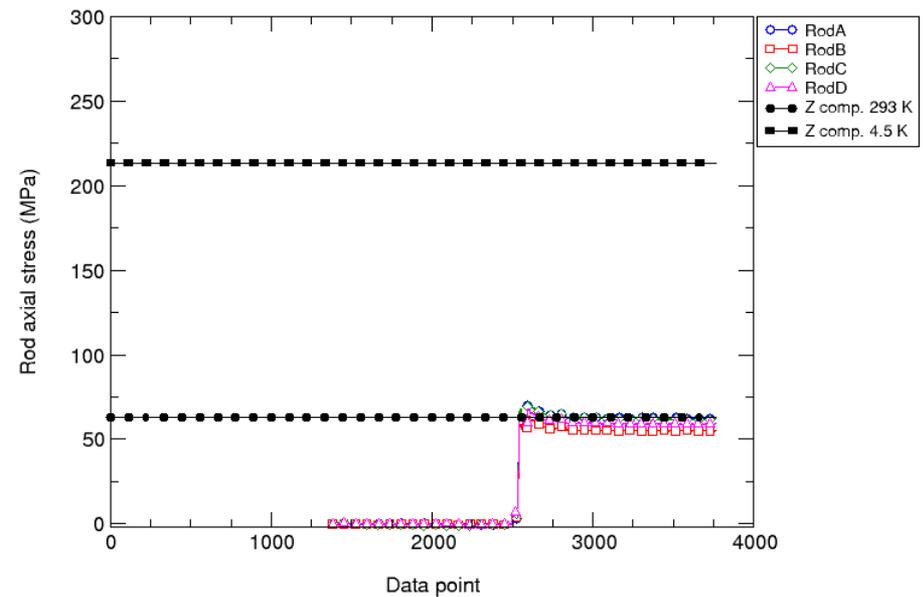
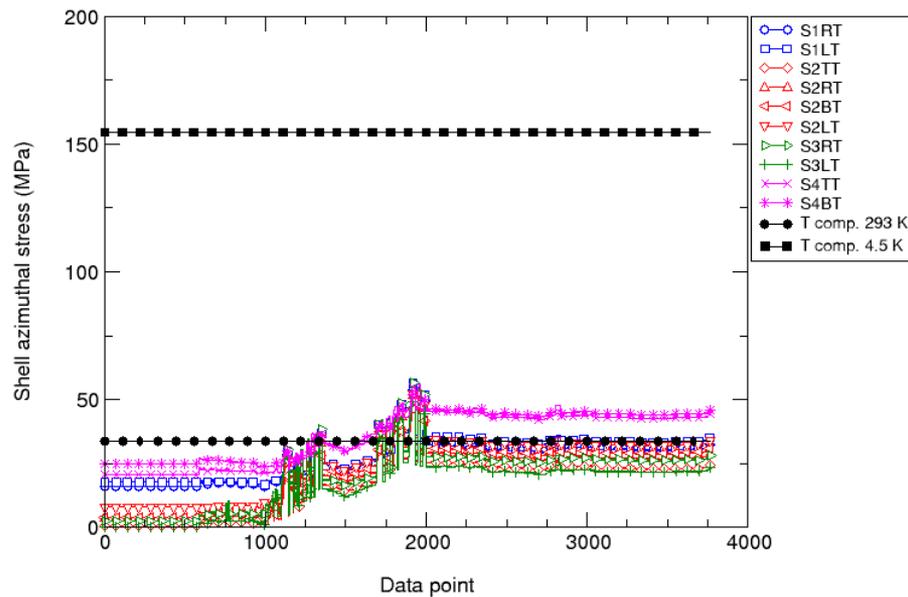
## Measurements vs. computations

- Shell

- Computed: +34 MPa
- Measured: +33 ±8 MPa

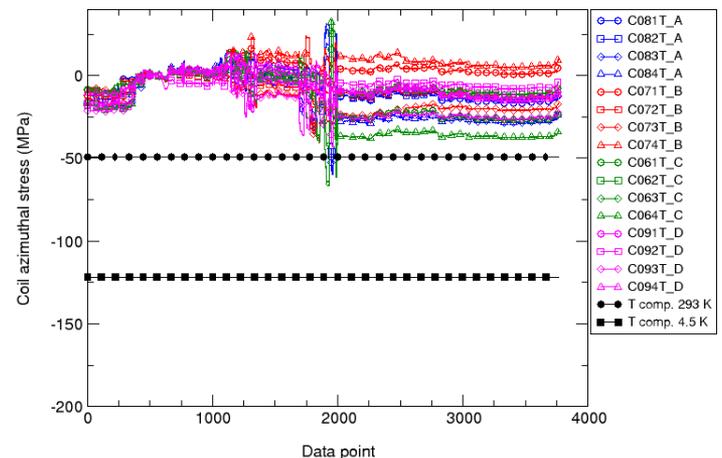
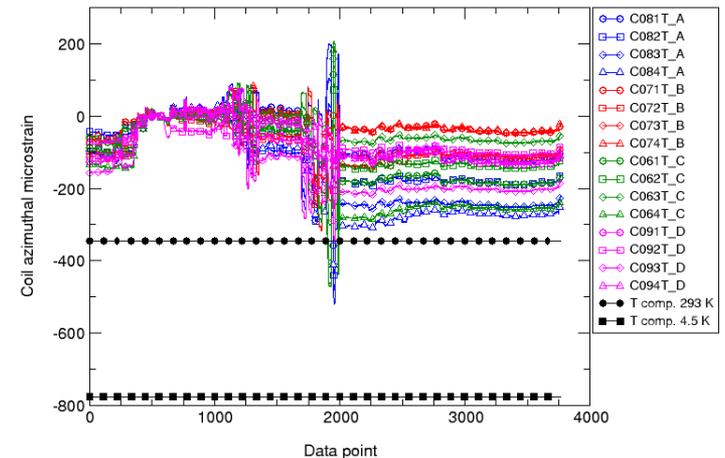
- Rod

- Computed: +63 MPa
- Measured: +60 ±3 MPa



# Coil pole strain and stress after loading Measurements vs. computations

- Coil  $\sigma_{\theta}$  to **-12 ±11 MPa**
  - Lower than comp. **-49 MPa**
    - Not observed in LQSD
    - Possibly related to coil dimensions
- Pre-loading strategy
  - Shell tension chosen as reference
    - Conservative approach for 1<sup>st</sup> test
  - Corrections will be applied based on cool-down, excitation



# Outline

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- **Conclusions**

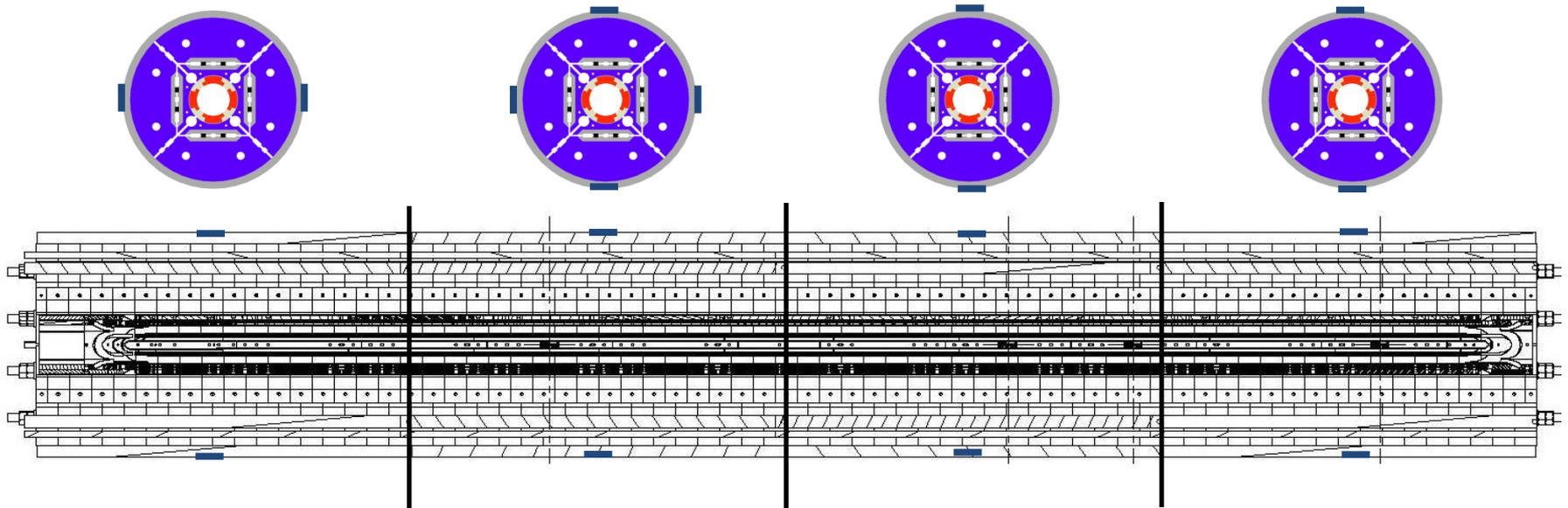
# Conclusions

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- Successful scale-up of quadrupole shell-based structure
  - 3.7 m long Nb<sub>3</sub>Sn magnet LQS01 assembled and loaded
- Structure characterized through cool-down tests
  - Strain gauges data consistent with FEM predictions
- Shipping-lifting-tilting operations qualified
- LQS01 pre-load based on shell and rods gauges
  - Room temperature targets for a 230-240 T/m reached
- Coil pre-load level to be verified during cool-down and test
  - If required, it will be increased in next tests
- LQS01 now ready for its first test

# LQSD strain gauges location Shell

- 2 + 4 + 2 + 2 stations at the center of each shell segment
- Each station with y and z gauges with temperature compensators



# LQSD strain gauge locations

## Stainless steel rods

- Each rod instrumented with 2 steel half bridge biaxial gauges on opposite sides
  - Compensation for bending and temperature effect

