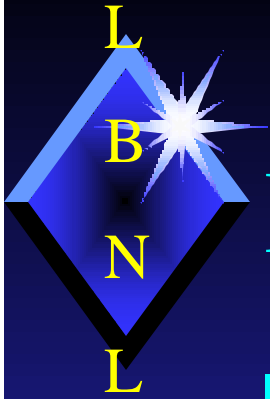




# Race-Track Coil Technology Validation (RT-1) Test Results

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## VLHC Magnet Technologies Workshop



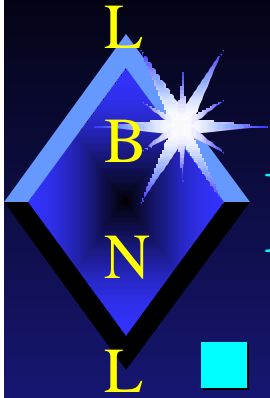
# Introduction

## ■ Goal: 14<sup>+</sup>T VLHC Bending Magnet

- ◆ Accelerator Quality
- ◆ Reliable
- ◆ Affordable

## ■ Path:

- ◆ Nb<sub>3</sub>Sn Race-Track Coils
- ◆ Dual-bore Common-Coil
- ◆ Economical Coil-Support



# Magnet Technology Validation

## ■ RD-2 (6 Tesla Proof-Of-Principle)

- ◆ Cabling Degradation
- ◆ Winding & Reacting 2-Layer Race-track Coils
- ◆ Splicing & Potting
- ◆ Keyed Coil-Pads (K. Chow)
- ◆ Friction Reduction (A. McInturff, A. Lietzke)

## ■ RD-3 (14 Tesla Proof-Of-Principle, 09/00)

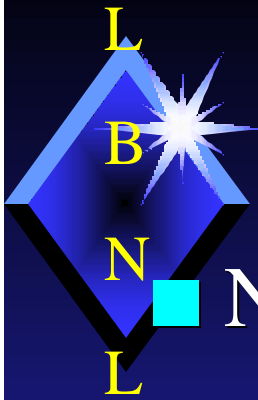
- ◆ 3-Layer (Conductor Grading)
- ◆ Economical Containment



RT-1:

## RD-3 Outer-Coil Validation Test

- 12 T Validation of RD-2 Technology.
- Improved Conductor ( $J_c > 2000\text{A/mm}^2$ ).
- Coil “Skinning” (K. Chow).
- Iron Coil-Islands (R. Gupta).
- Test Conditions:
  - ◆ Maximum Lorentz Stress (zero bore).
  - ◆ “Worst-case” coil-support (separation  $> 5\text{T}$ ).



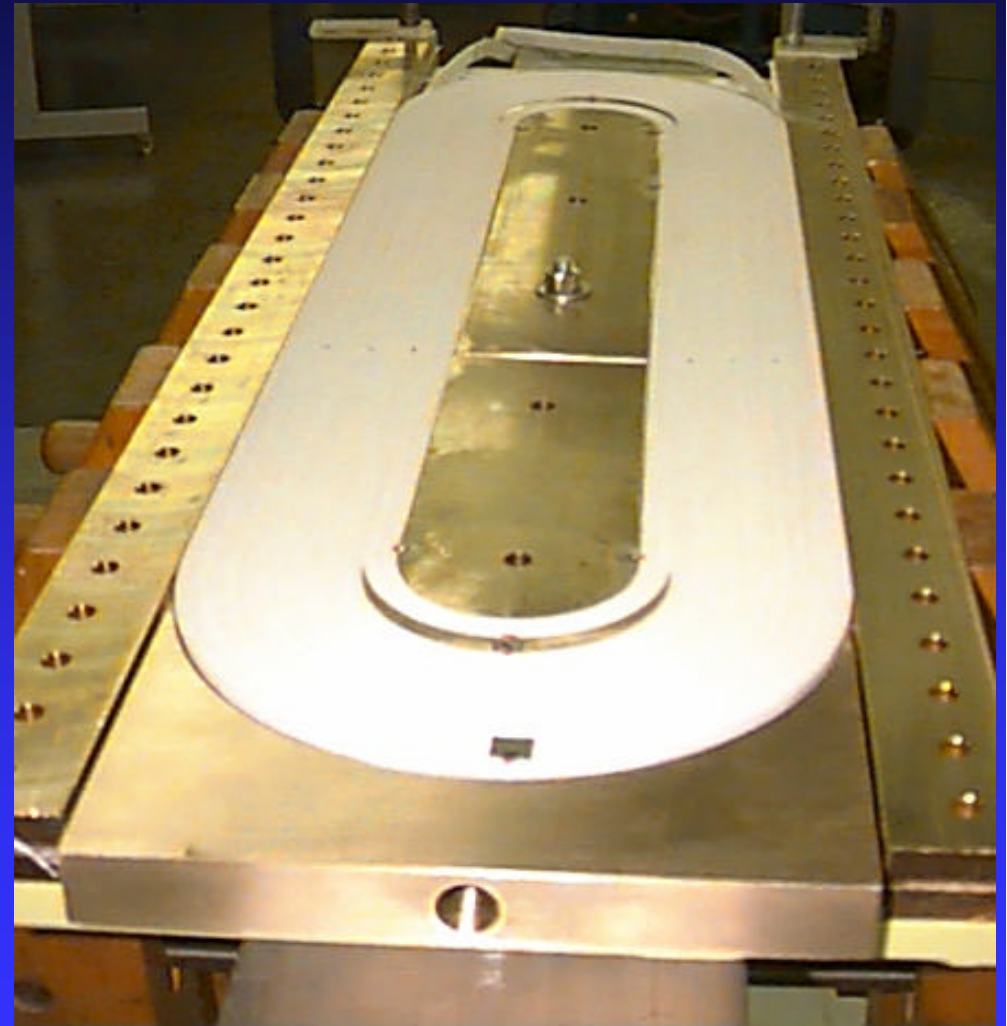
# RD-3 Outer Coil Parameters

## ■ Nb<sub>3</sub>Sn Cable:

- ◆ 26 x 0.81mm wire
- ◆ 59% Cu.
- ◆ MJR (Oxford)

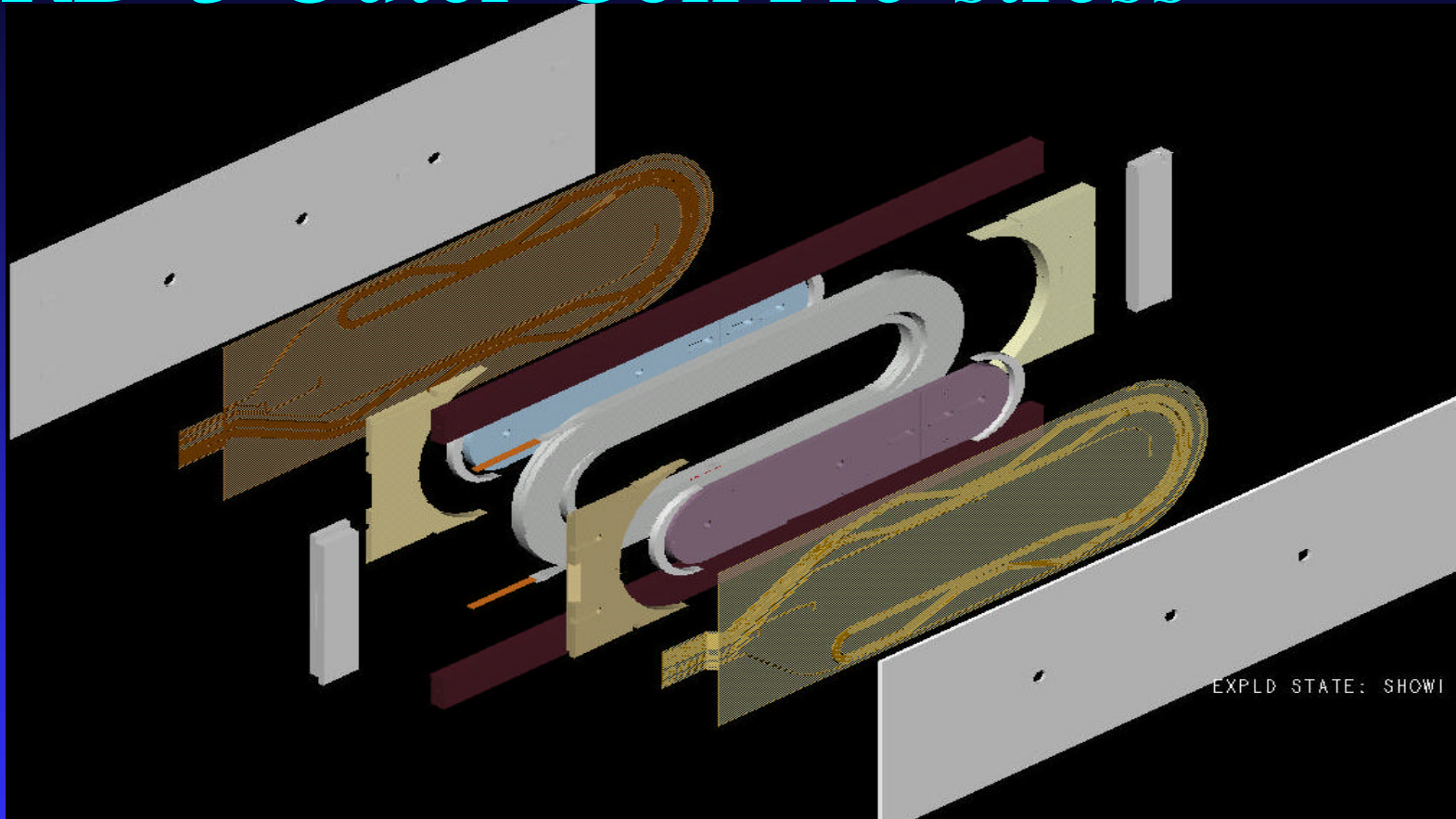
## ■ 2-Layer Coils:

- ◆ 50 Turns/layer
- ◆ Iron coil-island
- ◆ 220 mm (bore-bore)
- ◆ Mica paper (edges)

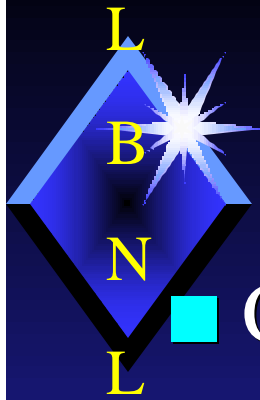


L  
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# RD-3 Outer-Coil Pre-stress

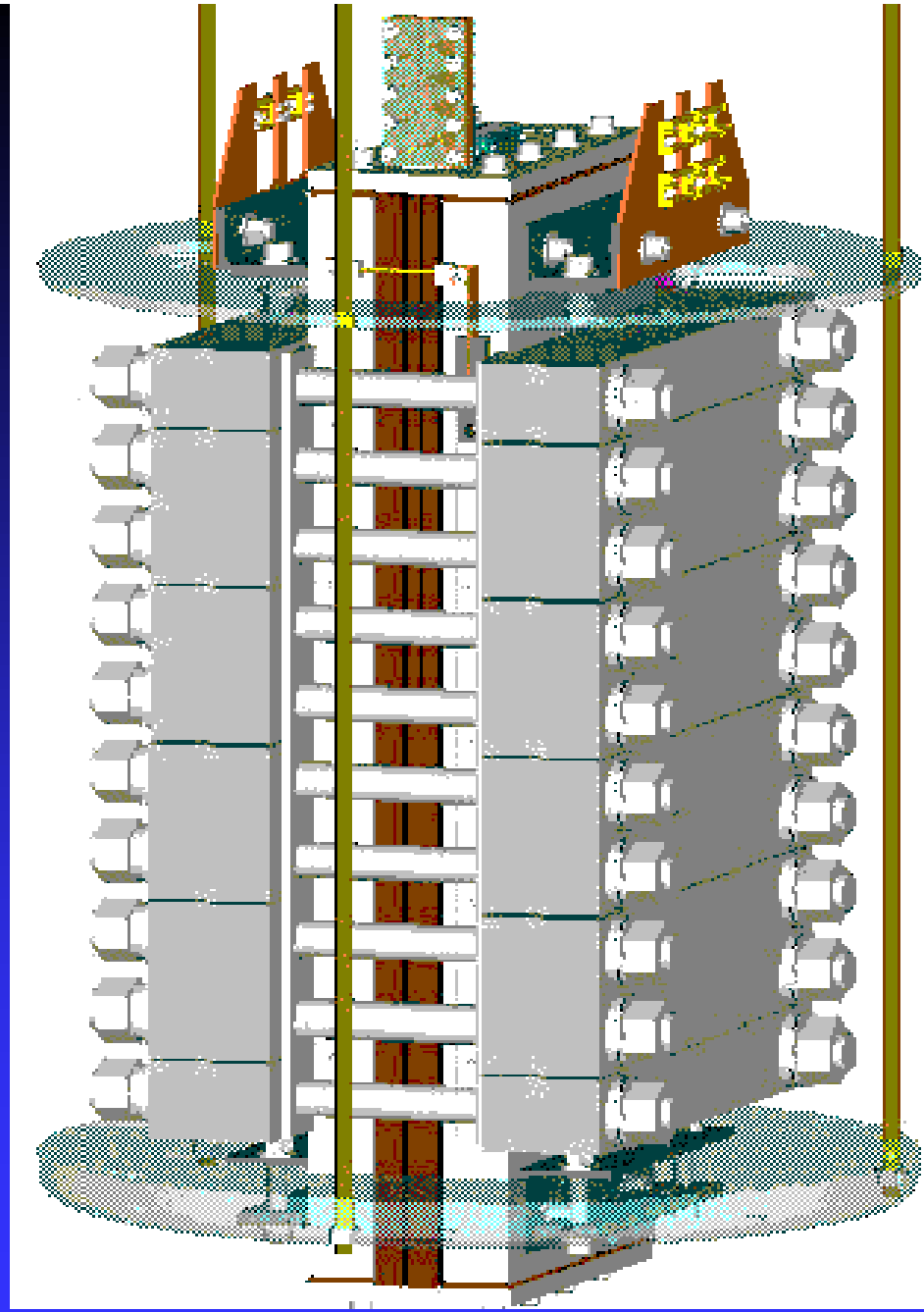


- Welded 4.7mm (SS) “Skins”
- 30-40 MPa (Coil Edges)



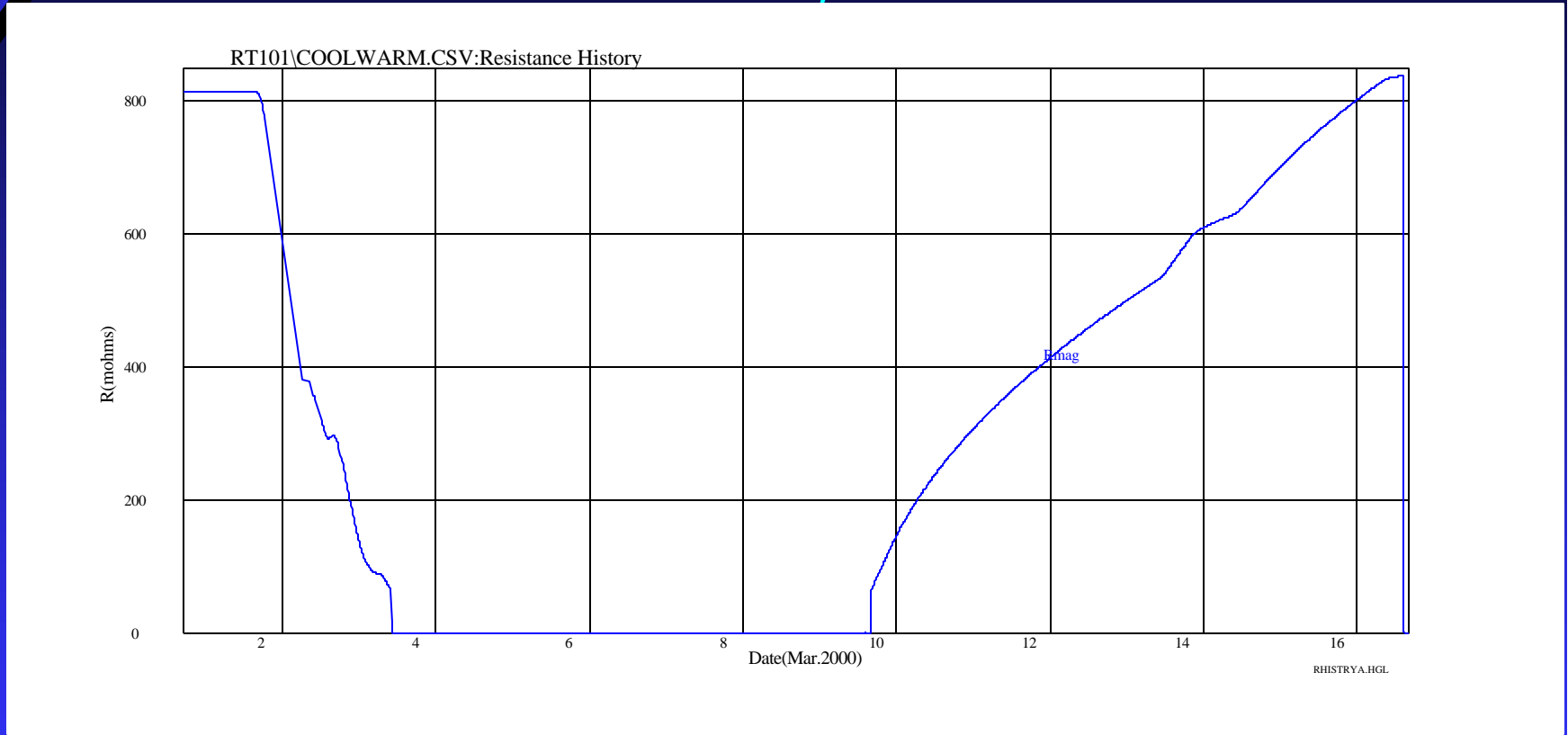
# RT-1 Coil-Support

- Coil-Pads
  - ◆ 60 x 400mm (SS)
- Cross-Beams
  - ◆ 120mm (SS)
- Tension Bolts
  - ◆ 20 @ 38mm (SS)
- Low Pre-stress
  - ◆ < 16 MPa (300K)





# RT-1 Test History



■ Low (20K) RRR's

◆ Coil-1: 13.1, 13.0      Coil-2: 11.7, 11.5

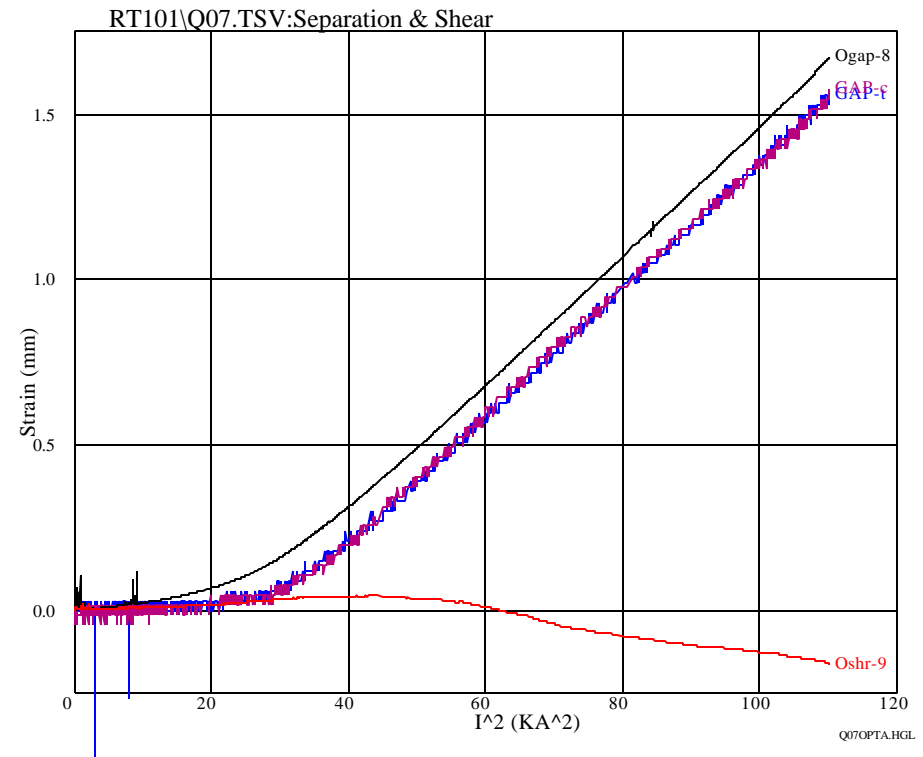
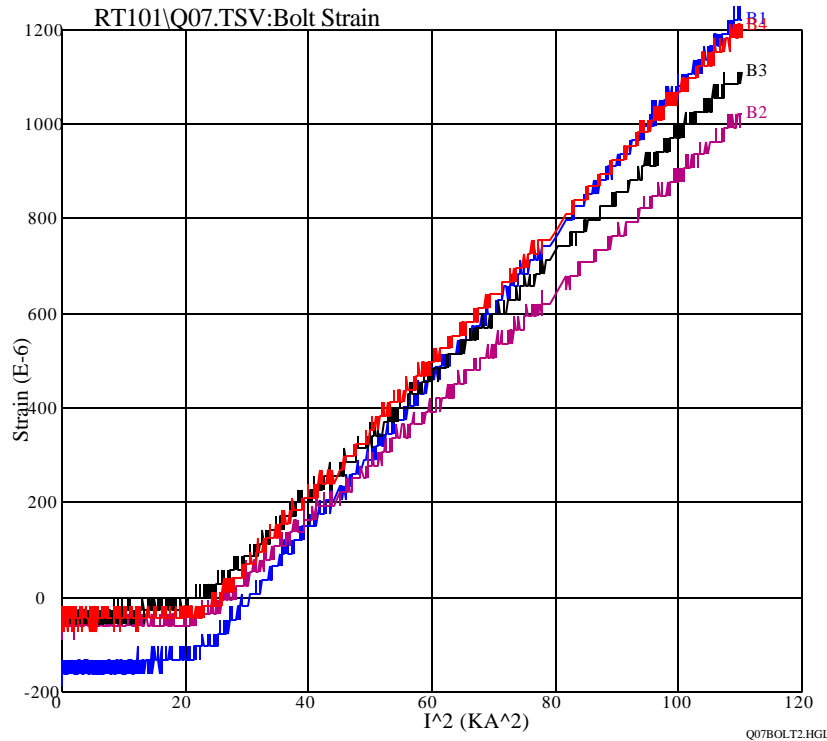




# RT-1 Coil-Coil Separation

■ Bolt-strain

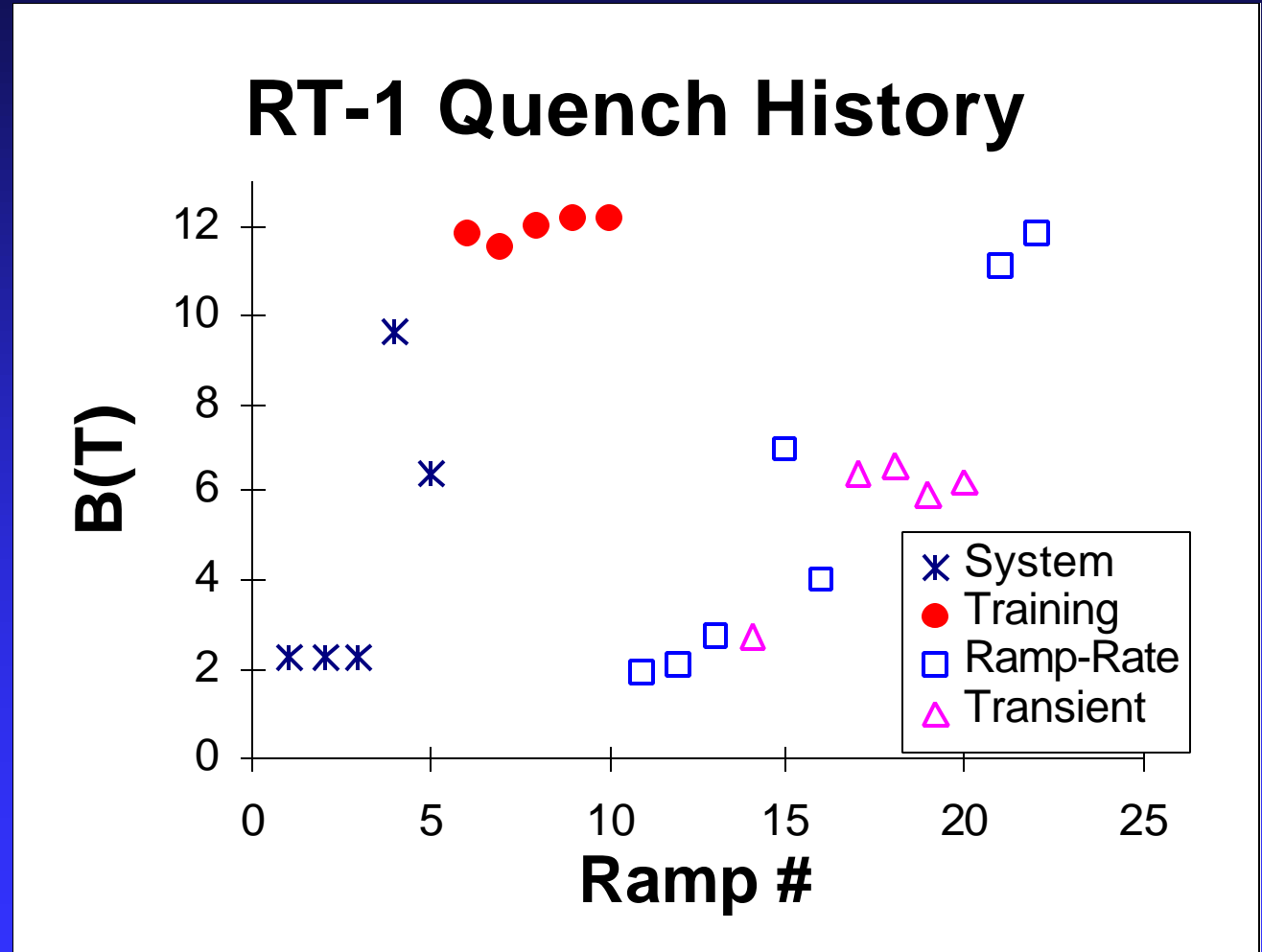
■ Coil Displacement





# RT-1 Quench History

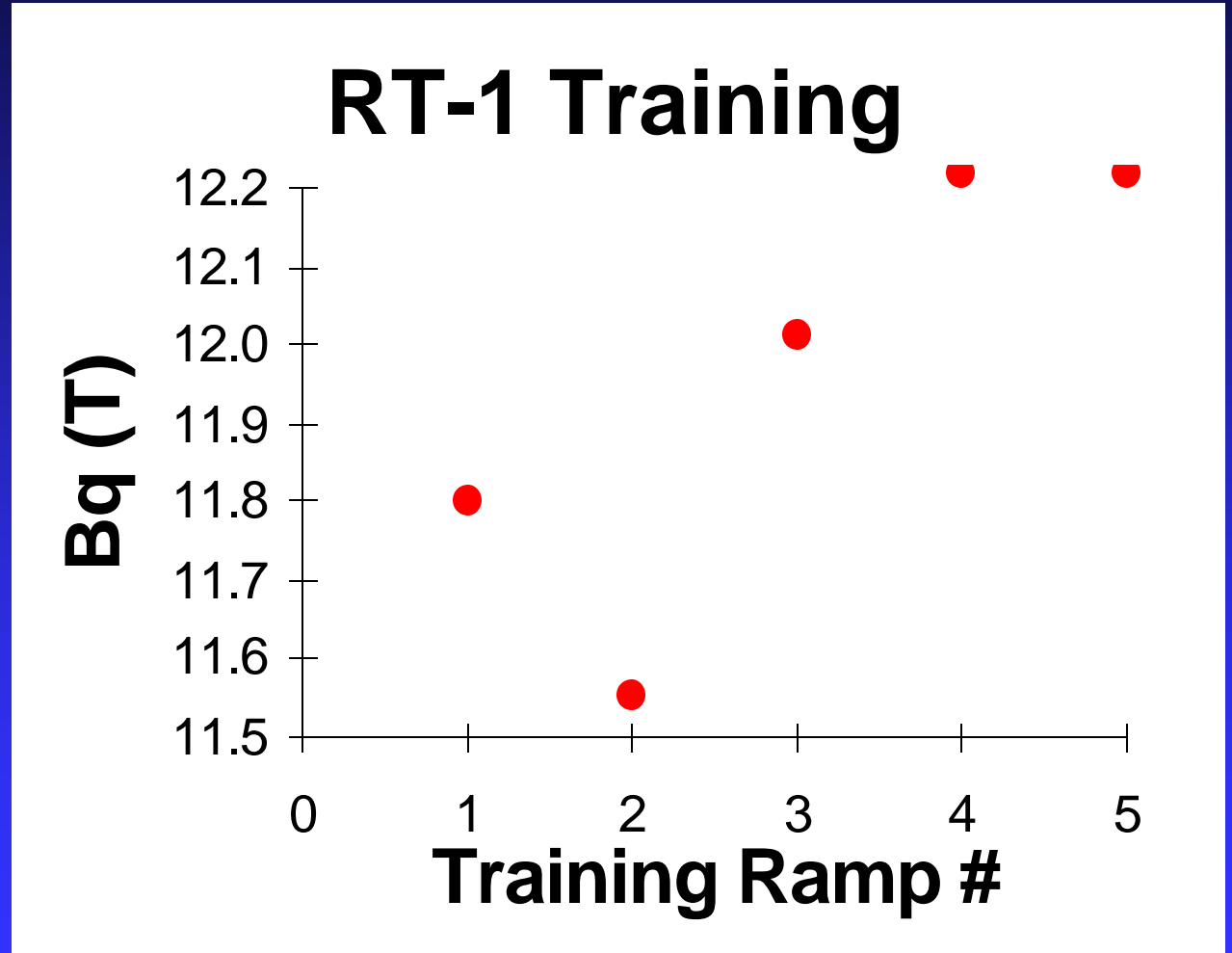
- System Validation
- Training
- Ramp-Rate
- Voltage-Transient





# Training

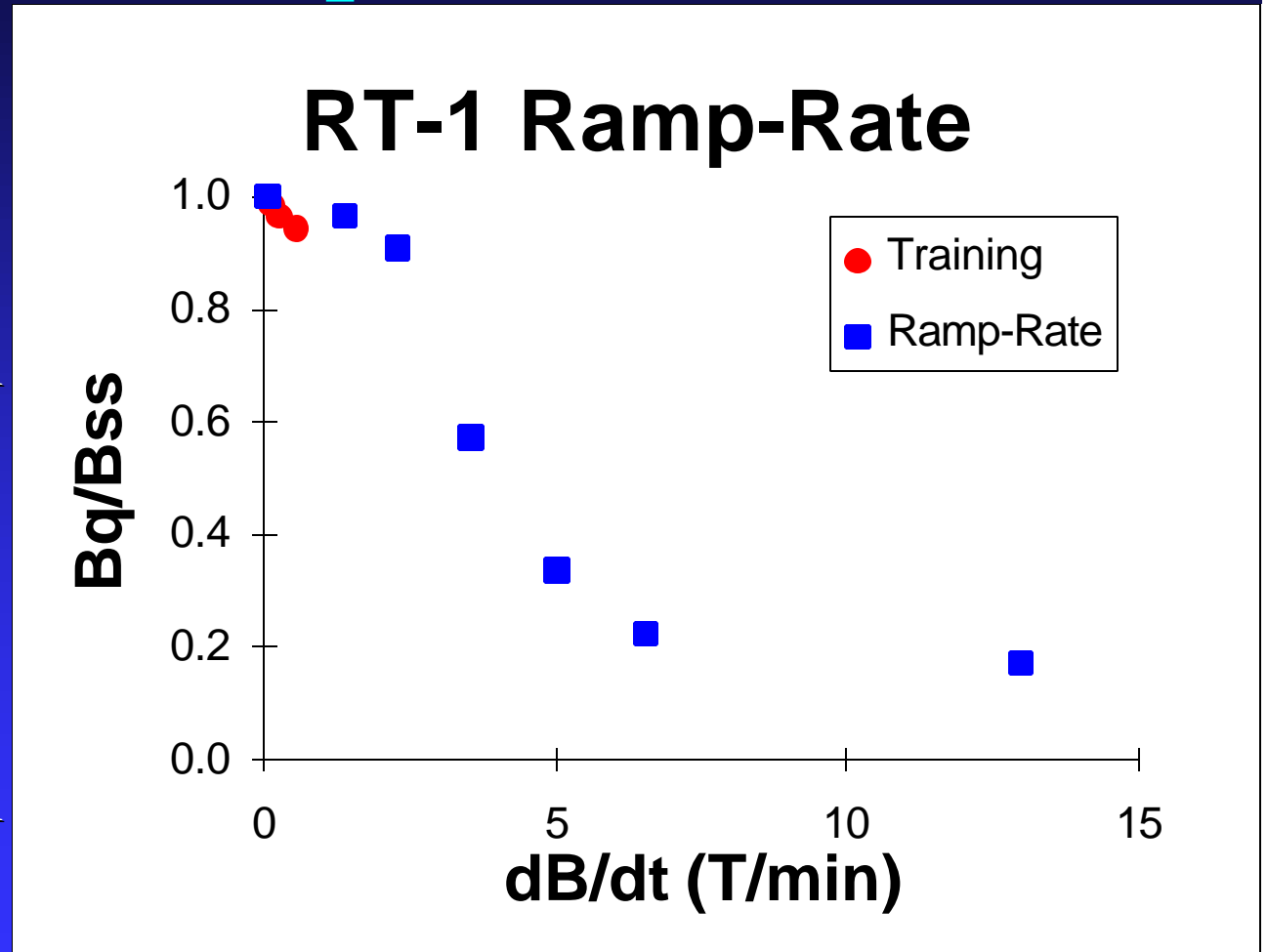
- First Try
  - ◆ 10.2 KA
  - ◆ 11.8 T
  - ◆ 96%
- Plateau
  - ◆ Try #4
  - ◆ 10.5 KA
  - ◆ 12.2 T





# Ramp-Rate Dependence

- 0.9 (11T)
  - ◆ 33 A/s
  - ◆ 2.3 T/min
- 0.2 (2.5T)
  - ◆ Plateau
  - ◆ 94 A/s
  - ◆ 6.6 T/min





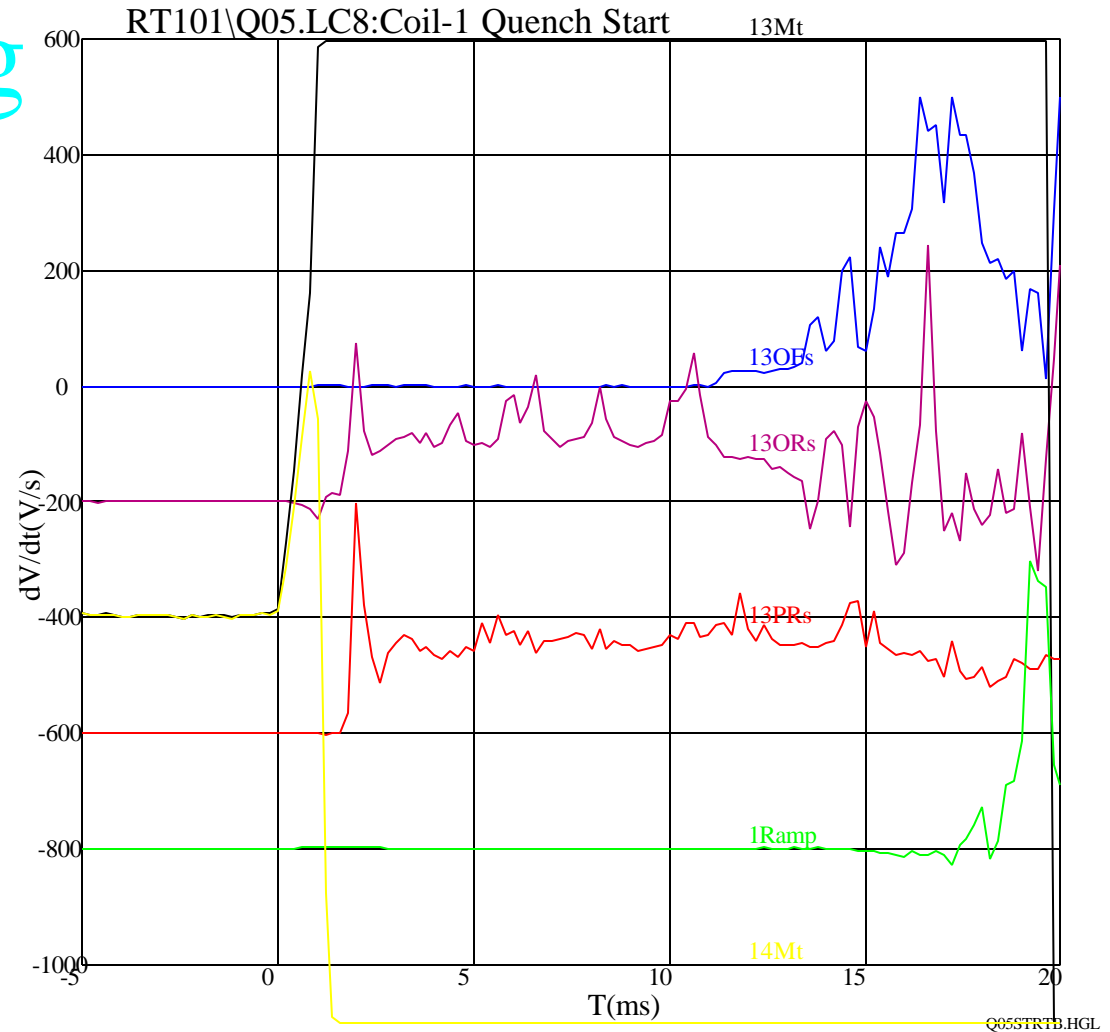
# Quenching

## ■ Training

- ◆ Multi-turn
- ◆ Simultaneous

## ■ Ramp-rate

- ◆ Same
- ◆ Both coils





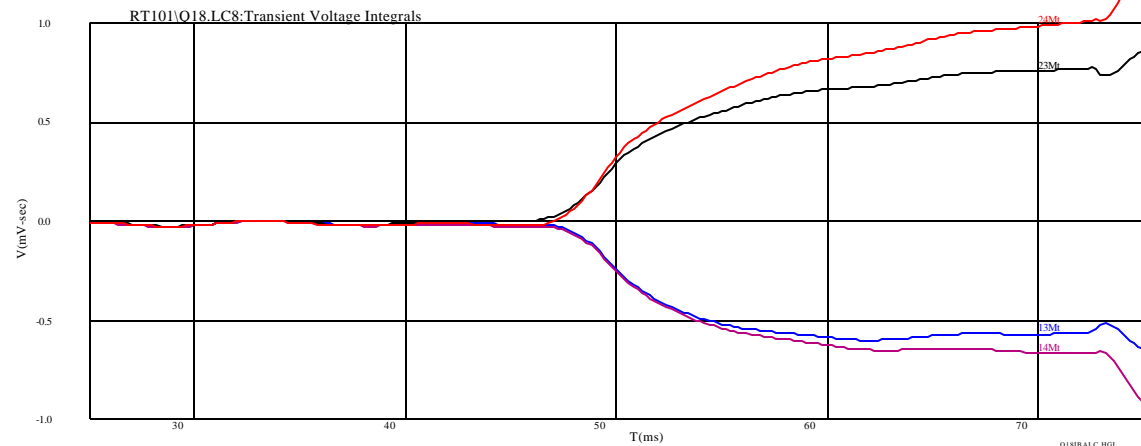
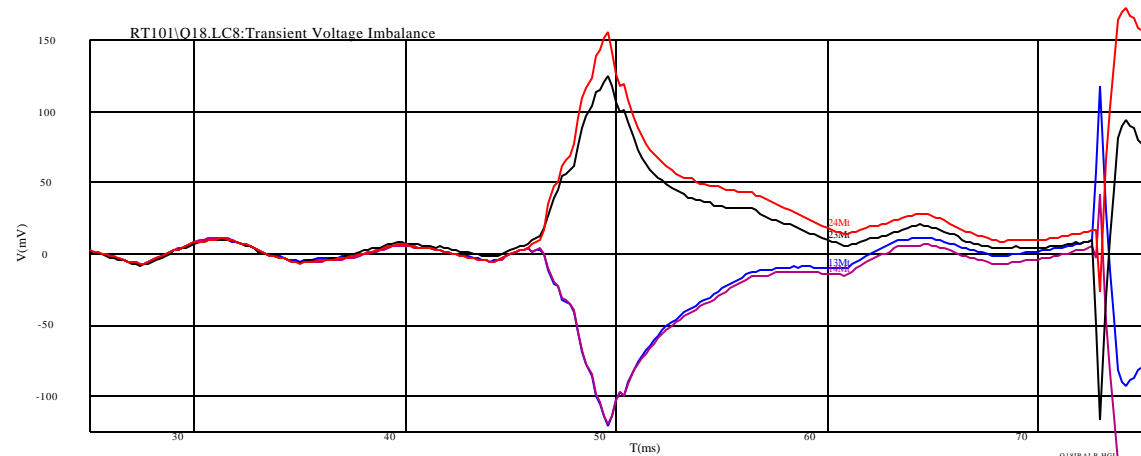
# Surprise Transient Imbalances

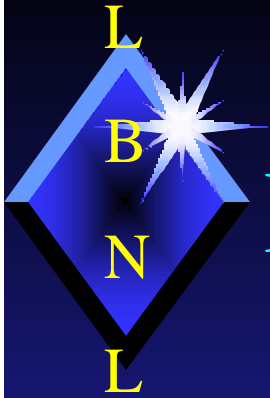
## Voltage

- ◆ 120-150 mV
- ◆ 0.5 V Imbal.

## Integral

- ◆ 0.6-1.0 mV-s
- ◆  $\text{dB}/\text{B} = 3-5\text{E}^{-4}$





# Exceeded Expectations

- No conductor degradation.
- Satisfactory ramp-rate dependence.
- Very good training:
  - ◆ Despite low RRR.
  - ◆ Despite low pre-stress.
  - ◆ Despite compliant support structure.



## Next Steps

- RD-3: Max. Stress (14T) Validation
  - ◆ Outer + Inner coils
  - ◆ Iron yoke
  - ◆ Accelerator-Quality Coil-Support
- RT-2(?): Cost, Je Improvements
- RD-4(?): Harmonic Control.