



***BNL - FNAL - LBNL - SLAC***

# Summary of Magnet Quench Performance

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Long Quad Magnet Support  
Review

28 November 2007



# Model Quadrupole Program

## Technology Quadrupoles (TQ)

1 m long, 90 mm aperture

Coils made jointly by Fermilab and LBNL

## Support structure options:

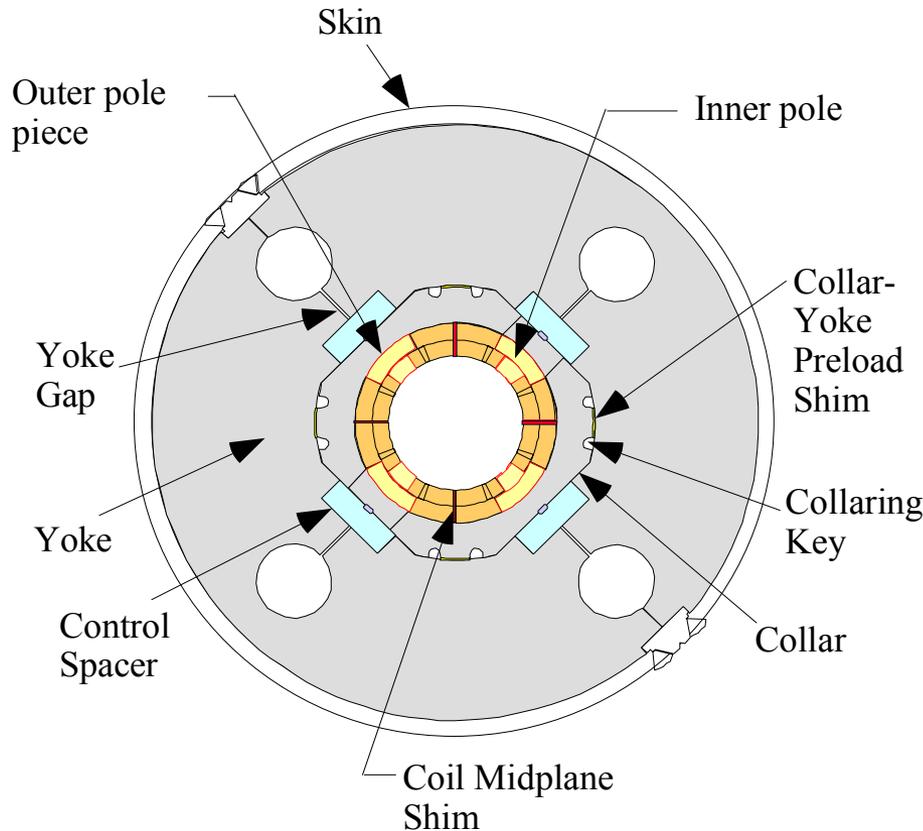
TQC: "collar" support

TQS: "shell" support

Remark: "short sample" current based on extracted strands - should be cable test



# TQC Mechanical Structure



Preload at assembly:

Azimuthal preload via keys that lock collars, welding of ss shell.

Axial preload: coil ends in (light) contact with structure

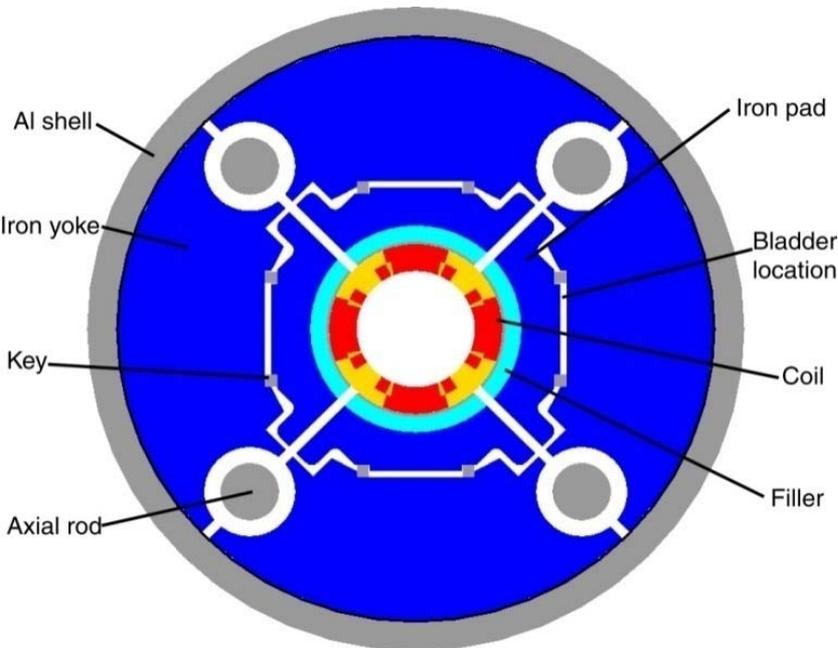


# TQS Mechanical Structure

Preload at assembly:

Azimuthal preload applied via inflatable/removable bladders and keys, between "pad" and yoke, inside aluminum shell.

Axial preload via rods, low  $\Rightarrow$  high during cooldown





# Quench test: same coils in both structures:

Initial test: TQS02

Subsequent test: TQC02E (E = exchange)

note: RRP conductor

## Results:

Both quads reached ~ 90% of the expected maximum performance of the conductor at 4.5 K (no correction for reduction in current-carrying capacity for strain)

Their gradients differ because the ratio  $G/I$  is not the same.

Neither magnet improved at 1.9 K. This is not yet understood.



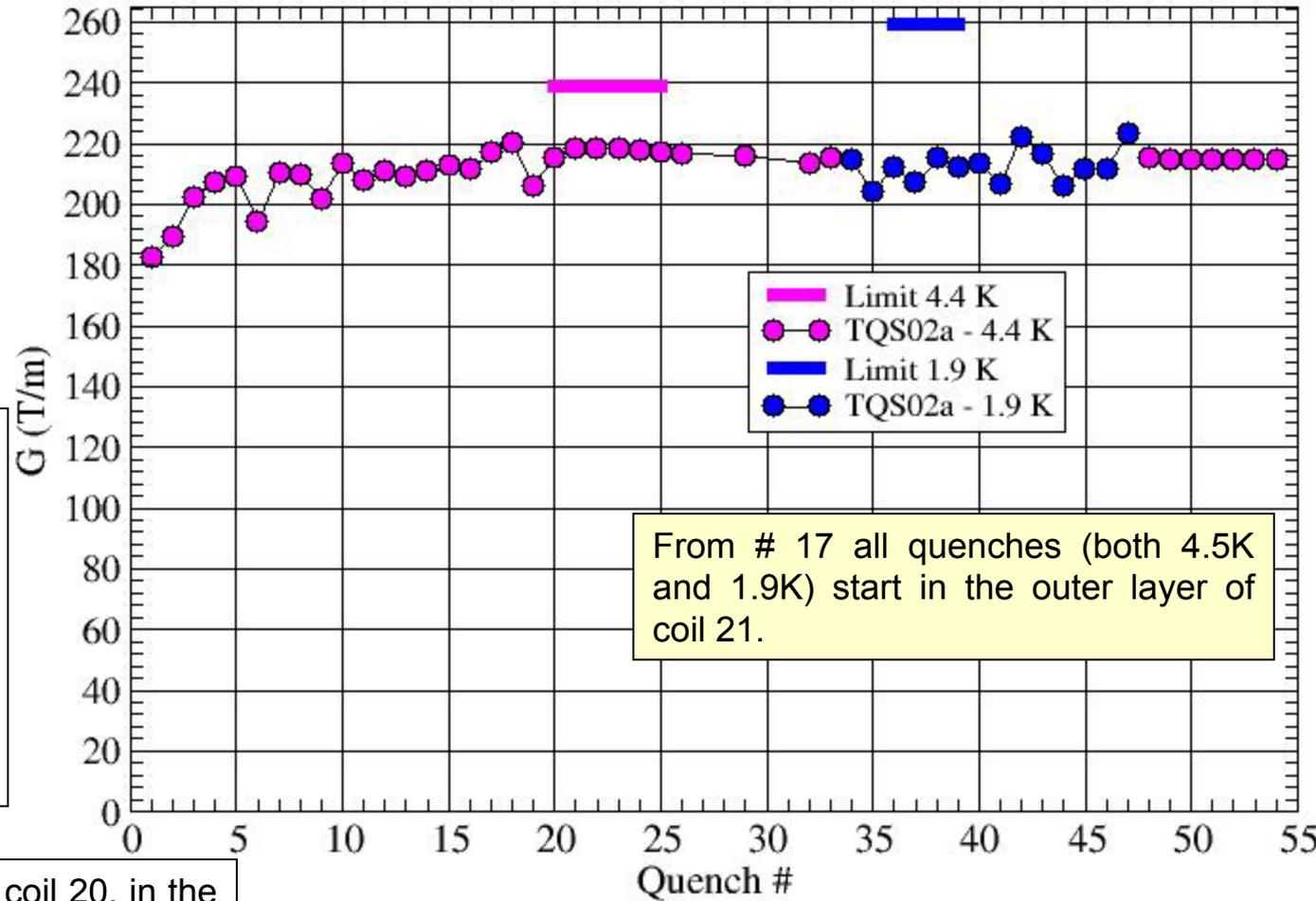
# TQS02a Training

## TQS02a

180 to 220 T/m, 20 quenches

Plateau coil 21 layer 2

No gain at 1.9 K

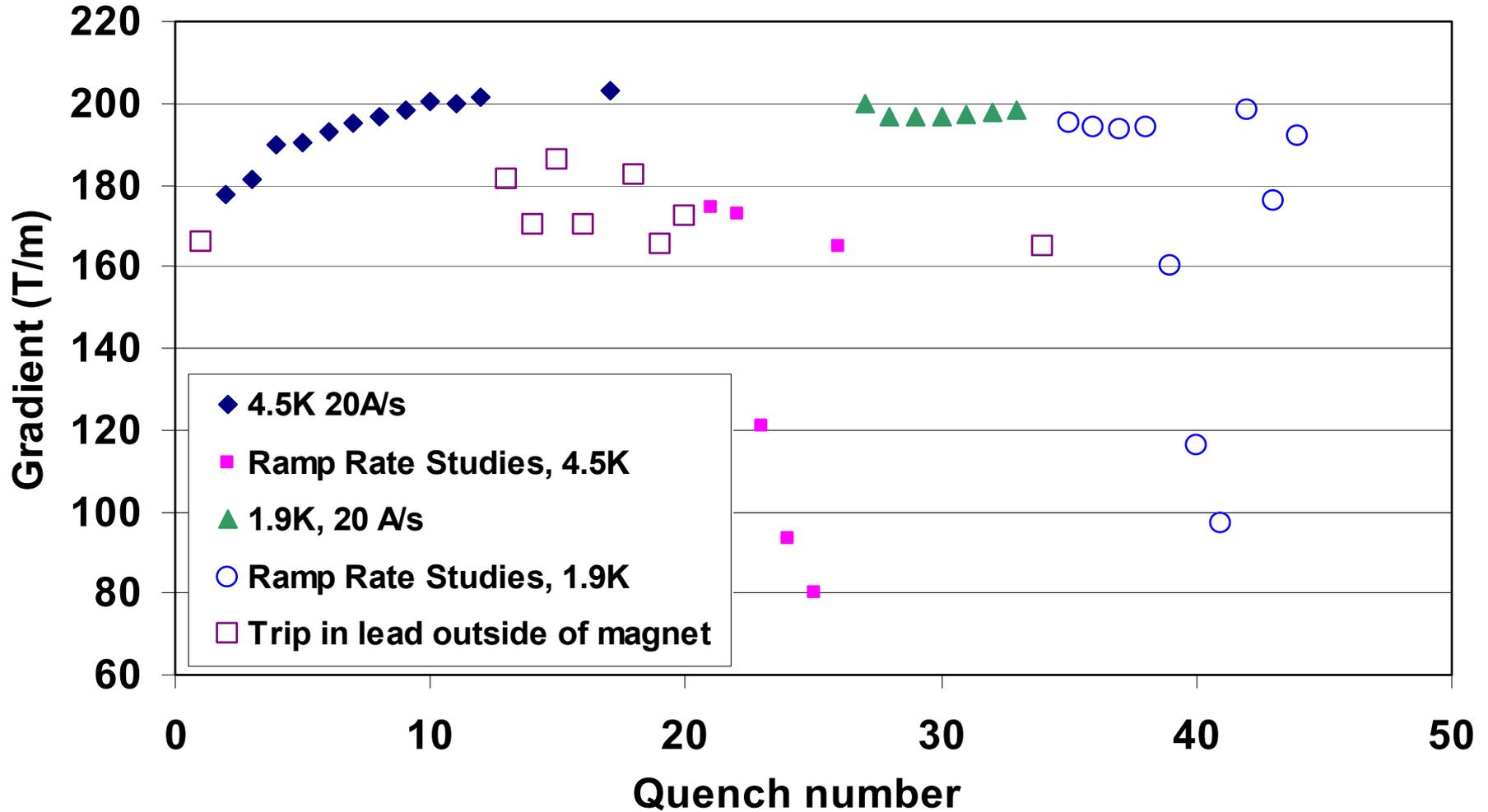


Quench 1: inner layer pole turn, ramp and multi-turn  
Quench 2-3: outer layer multi-turn followed by return end.  
Quench 4: inner layer pole turn and multi-turn segment inside wedge.  
Quench 5-6: outer layer multi-turn followed by pole turn.

Quench 8 to 16, inner layer of coil 20, in the turns inside the wedge.



# TQC02E Quench Behavior





# Quench data - two additional model quads (TQ)

## TQS01a,b,c

Three tests varying coils (i.e., replace the worst performing coil) and end preload. MJR ("old style" conductor)

Result: reached ~ 90% of conductor limit at 4.5 K, did not advance much beyond this at 1.9 K.

## TQC01a,b

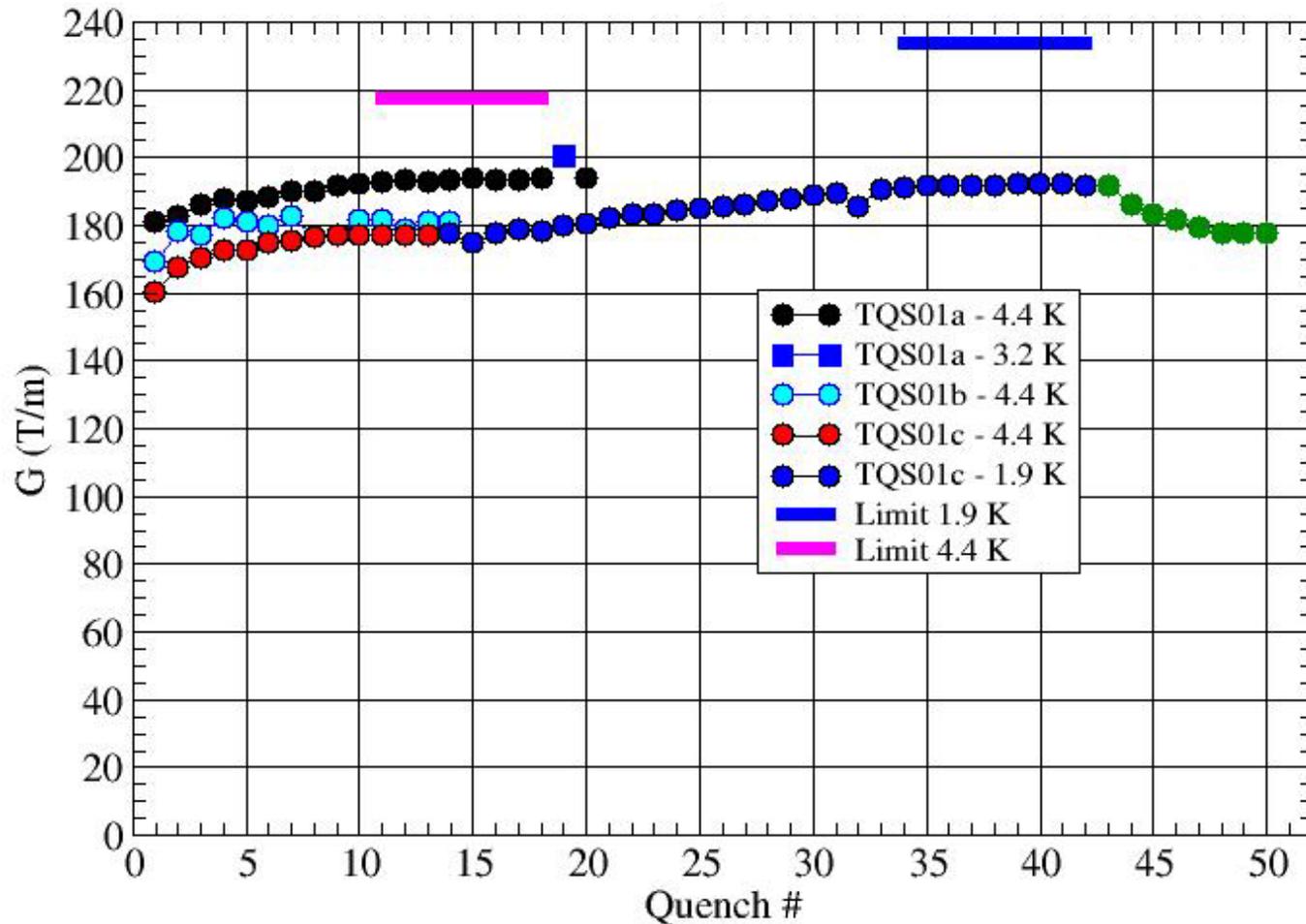
Two tests varying coils (in second test 2 limiting coils were replaced with 2 TQS coils tested 3 times). MJR strand.

Result: first test with very low pre-stress reached ~70% of conductor limit at 4.5K and ~86% at 1.9K, second test reached ~ 85% of conductor limit at 4.5 K and ~ 90 % at 1.9 K.



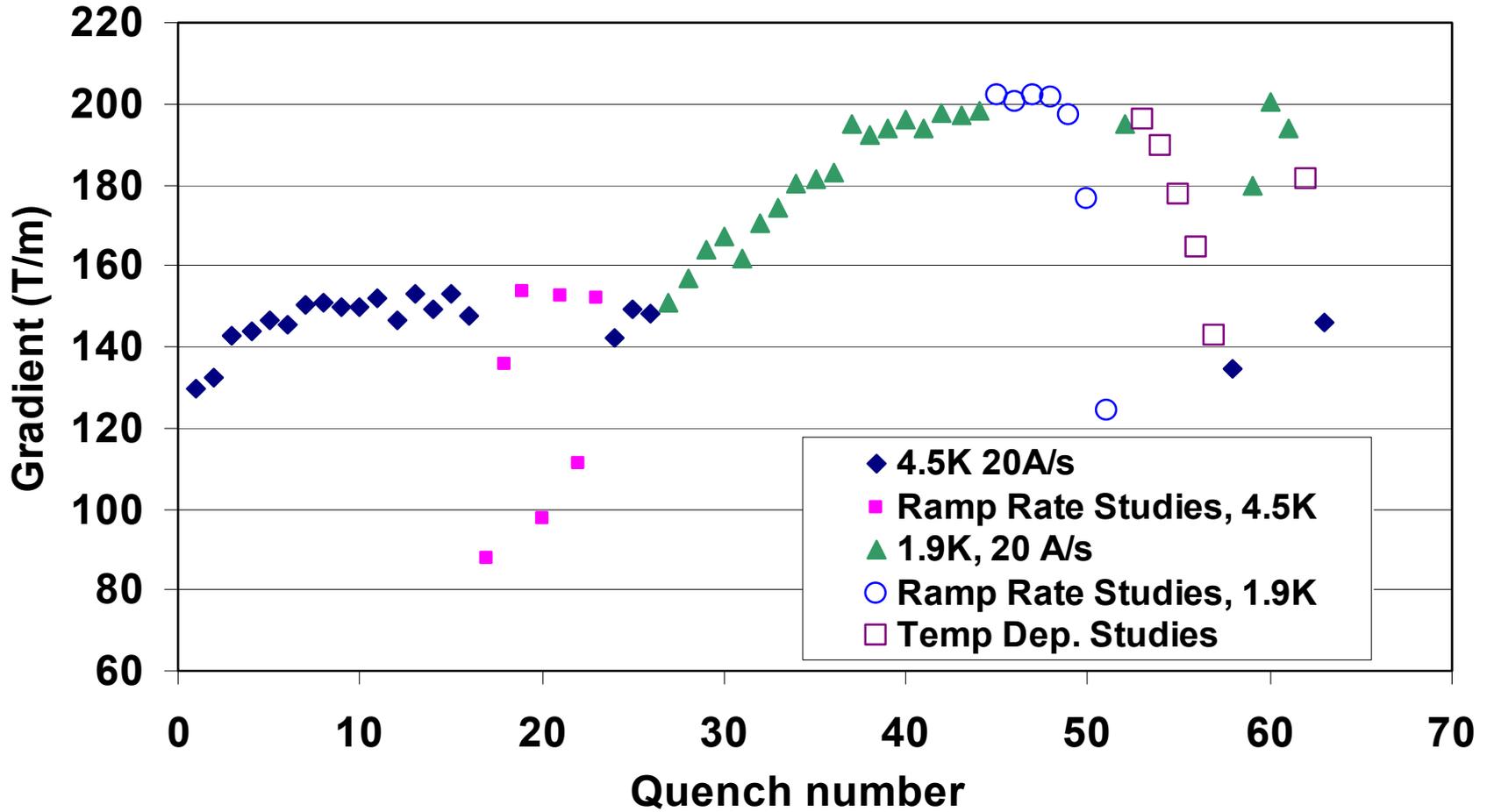
# TQS01 Training

- TQS01a
  - 180 to 193 T/m  
11 quenches
  - Plateau coil 6
- TQS02b
  - 170 to 180 T/m  
4 quenches
  - Plateau coil 14
- TQS01c
  - 160 to 175 T/m  
8 quenches (4.4 K)
  - (max at 182 T/m at high MIITS)
  - 175 to 192 T/m  
20 quenches (1.9 K)
  - Plateau coil 15
- All layer 1 pole quenches in the straight section



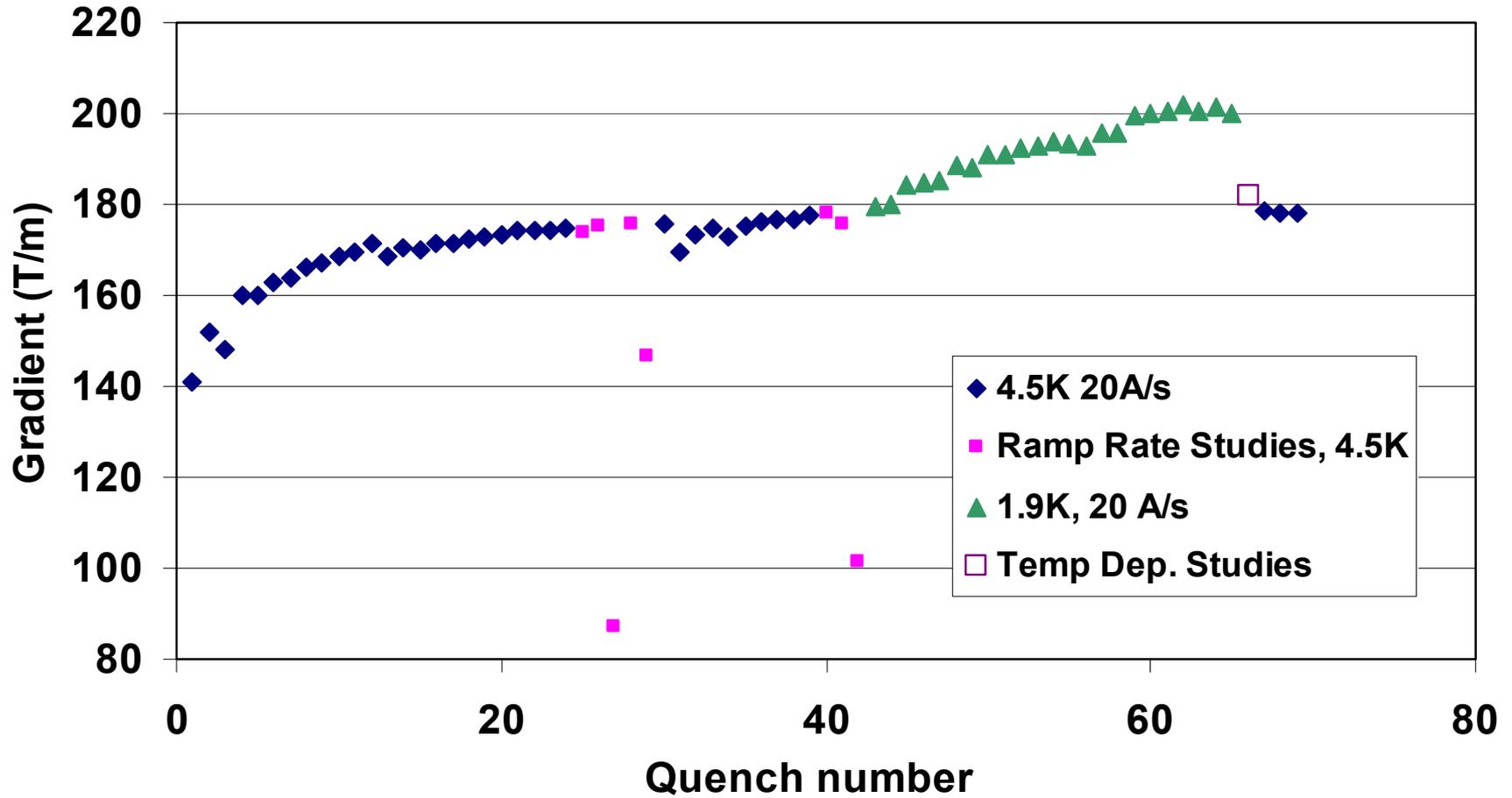


## TQC01 Quench Behavior



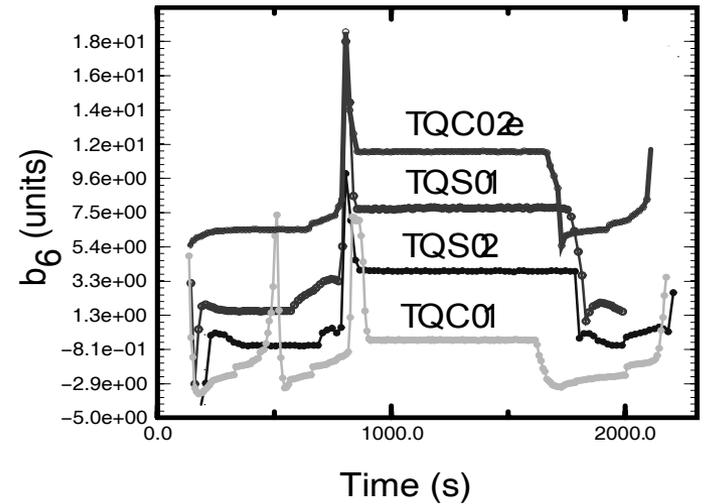
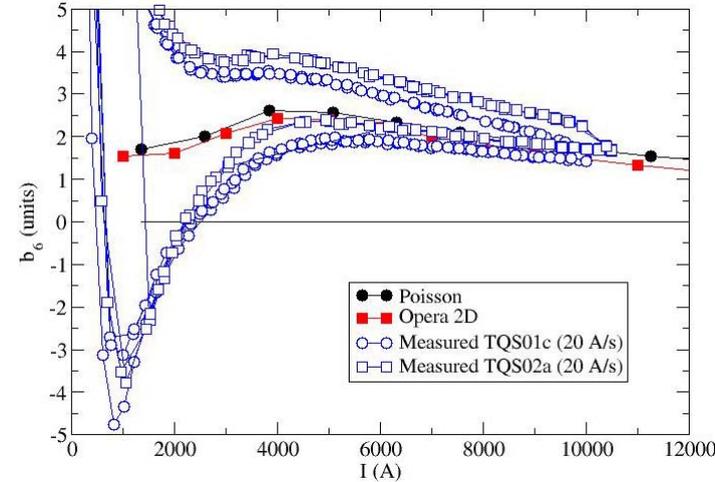
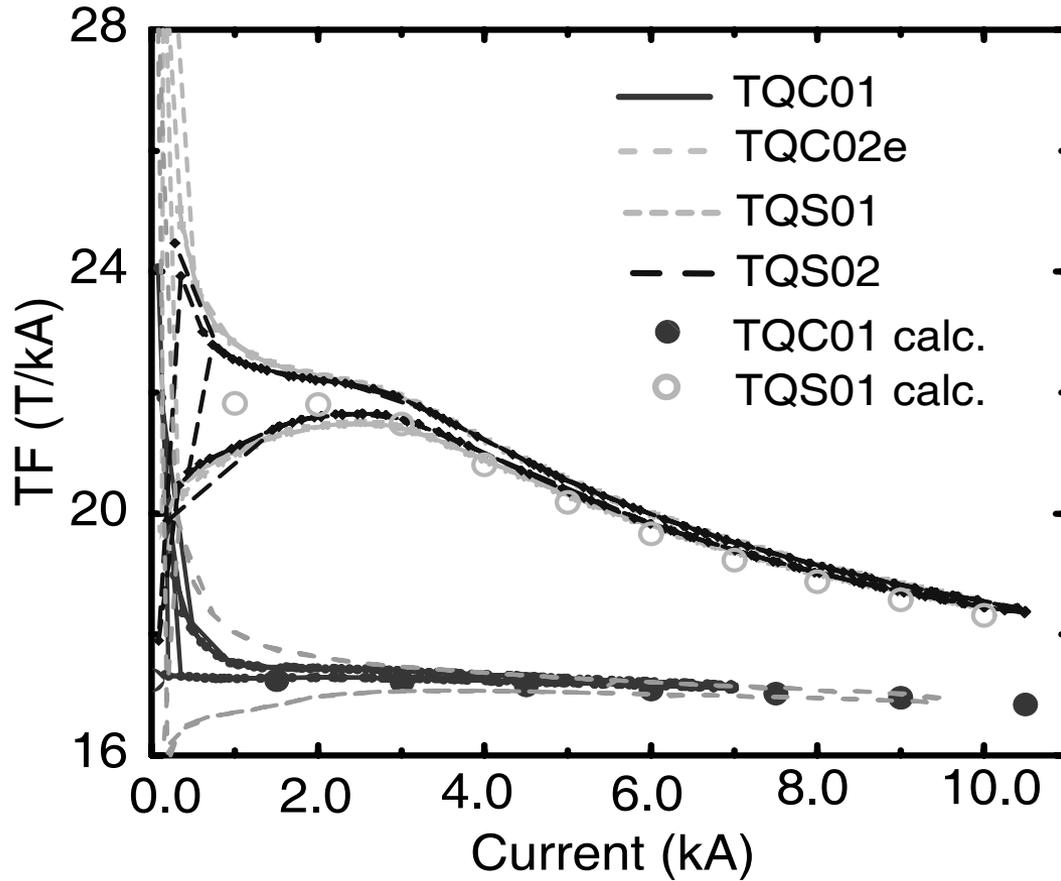


## TQC01b Quench Behavior



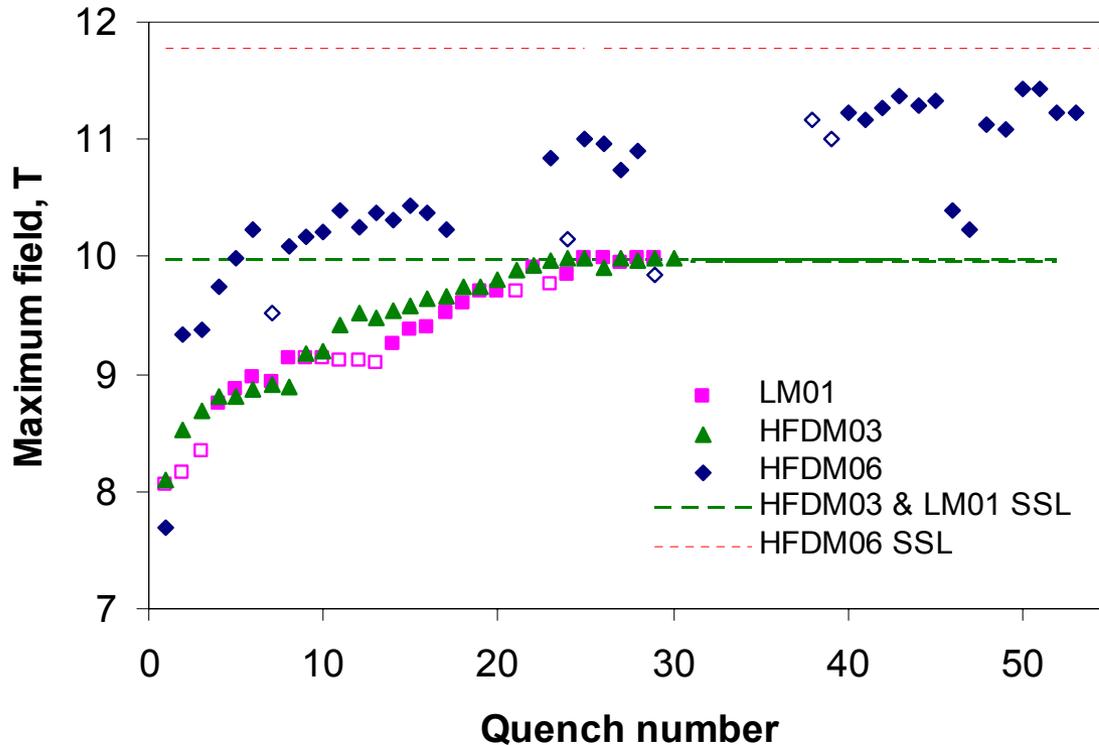


# TQS and TQC – measured field





# Nb<sub>3</sub>Sn Mirror Dipole Quench Performance



Fermilab base program

1-m (HFDM03) and 2-m long (LM01) PIT mirror models reached SSL and  $B_{max} \sim 10$  T. Their quench performance is practically identical

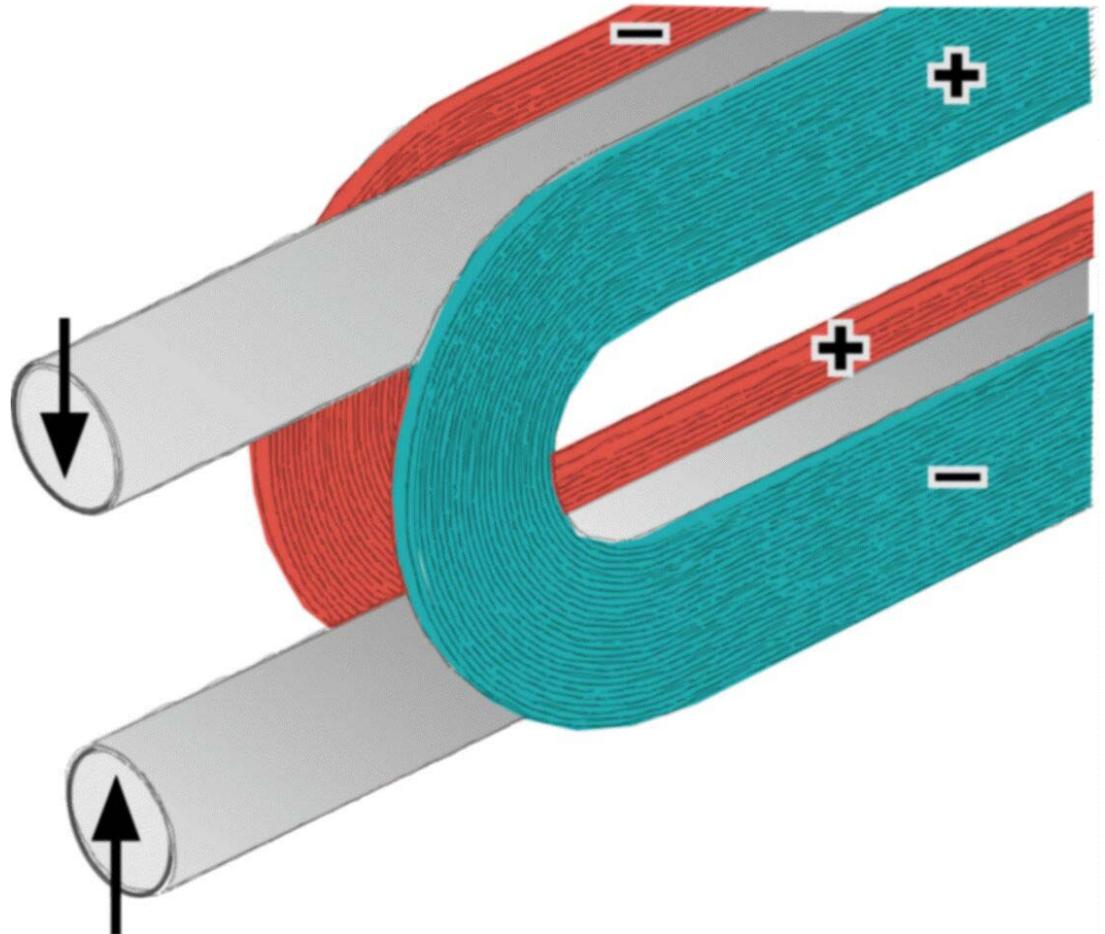
1-m long mirror model (HFDM06) with 1-mm RRP-108/127 strand reached 97% of its SSL and  $B_{max} > 11$  T.



# LR (long racetrack) 3.6 m, common coil

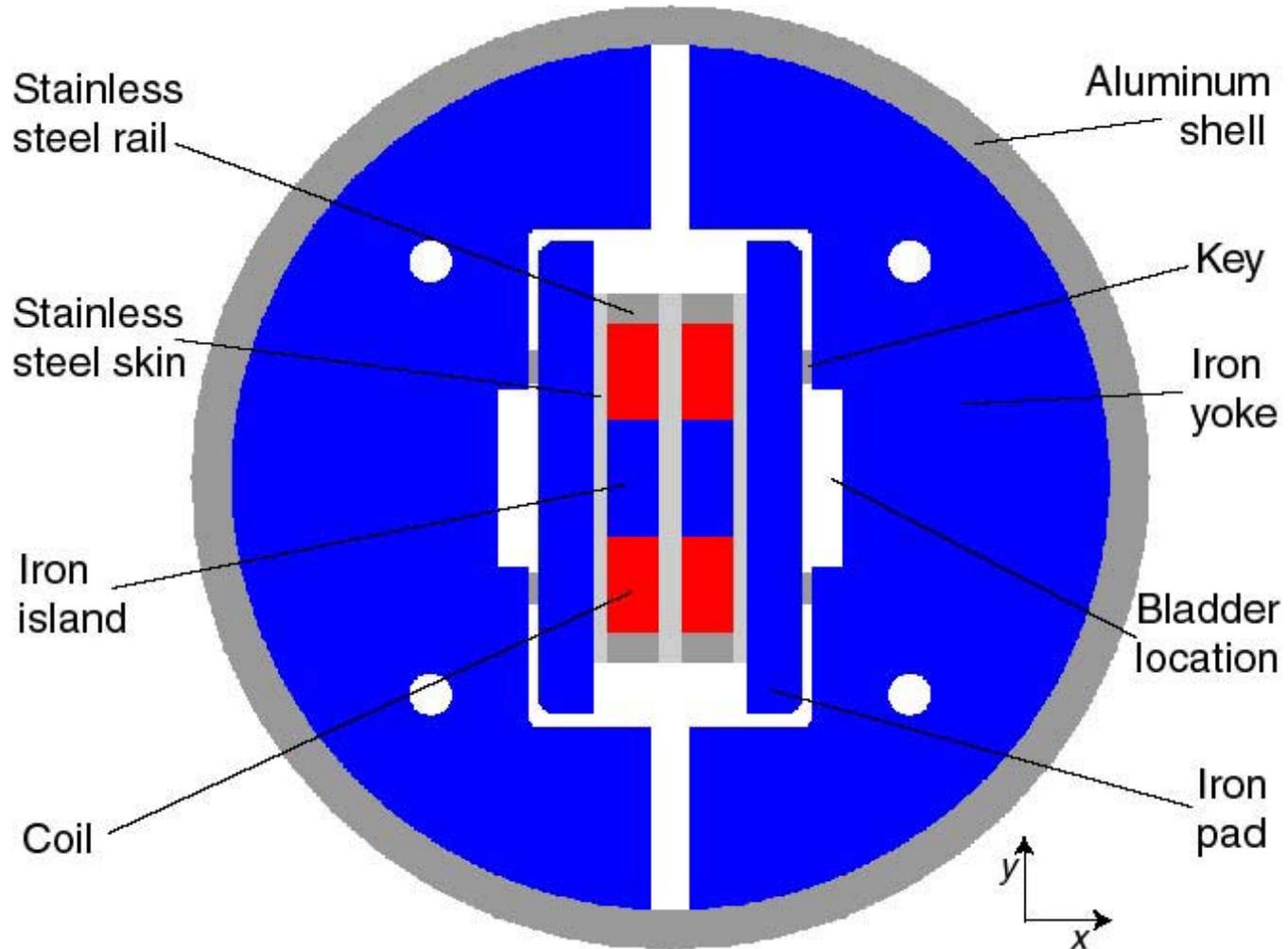
Relatively quick  
check for length  
effects in coil and  
shell support  
structure.

Coil from BNL,  
structure from  
LBNL.





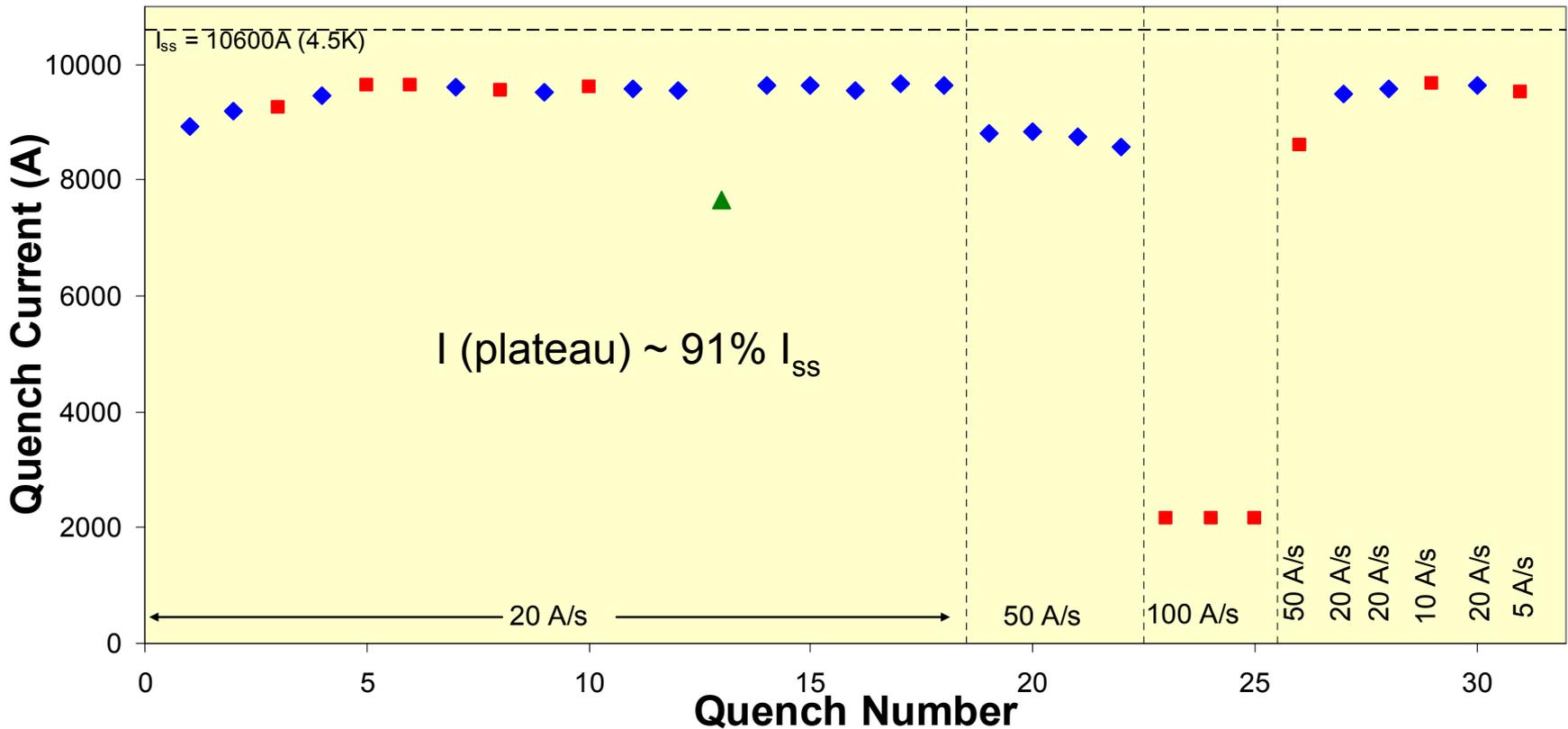
# LRS01 (long racetrack coils in shell support structure)





# LRS01 - long racetrack, shell 3.6 m (4.5 K)

## Peak field on the coil 11 T (no aperture)





LARP

Magnet	Nb3Sn	4.5 K (nom.) tests		1.9 K (nom.) tests		Notes
		max G (T/m)	% Iss	max G (T/m)	% Iss	
TQS01a	MJR	193	89			
TQS01b	MJR	182	84			1 coil replaced
TQS01c	MJR	183	85	191	82	low end preload
TQS02a	RRP	219	92	221	85	
TQC01	MJR	154	74	200	88	azim preload low
TQC01b	MJR	178	88	200	92	
TQC02E	RRP	200	89	198	81	coils from TQS02a
Other Nb3Sn magnet test results						
		max B	% Iss	max B	% Iss	
SQ02	MJR	~ 11 T	97%		98%	0.3 m, racetrack coils
LRS01	RRP	~11 T	~ 90%			3.6 m common coil/racetrack coils
HFD03	PIT	~ 10 T	~ 100%			1m cos theta mirror
LM02	PIT	~ 10 T	~ 100%			2m cos theta mirror
HFD06	RRP	> 11 T	~ 97%			1m cos theta mirror; 108/127
LARP quad data compiled by Rodger Bossert, Shlomo Caspi						



# Conclusion

LARP has developed 1 m, 90 mm Nb<sub>3</sub>Sn quads that reliably reach 200 T/m (~90% I<sub>ss</sub>). However, the factors affecting quench performance (e.g., at 1.9 K) are not yet fully understood.

Quench performance of common coil and mirror dipole generally supports quad results (i.e., reach fields > 10 T).