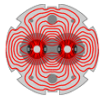


Summary of Magnet Quench Performance

P. Wanderer

Long Quad Magnet Support Review

28 November 2007

Model Quadrupole Program

Technology Quadrupoles (TQ)

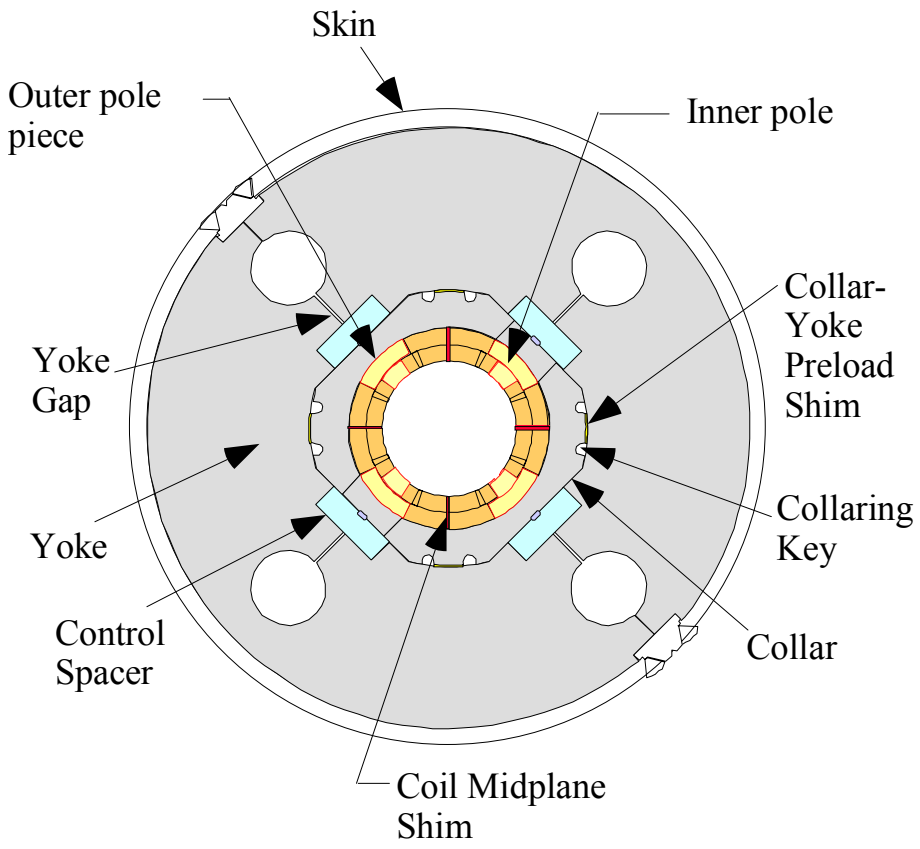
- 1 m long, 90 mm aperture
- Coils made jointly by Fermilab and LBNL

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.

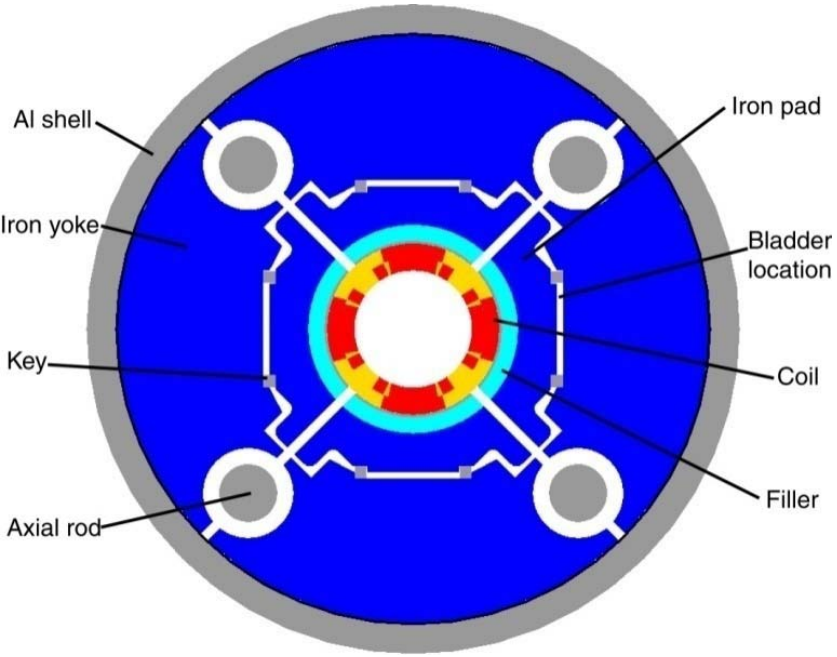
Axial preload: coil ends in (light) contact with structure

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 ⇒ high during cooldown



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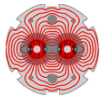


Quench test: same coils in both structures:

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.

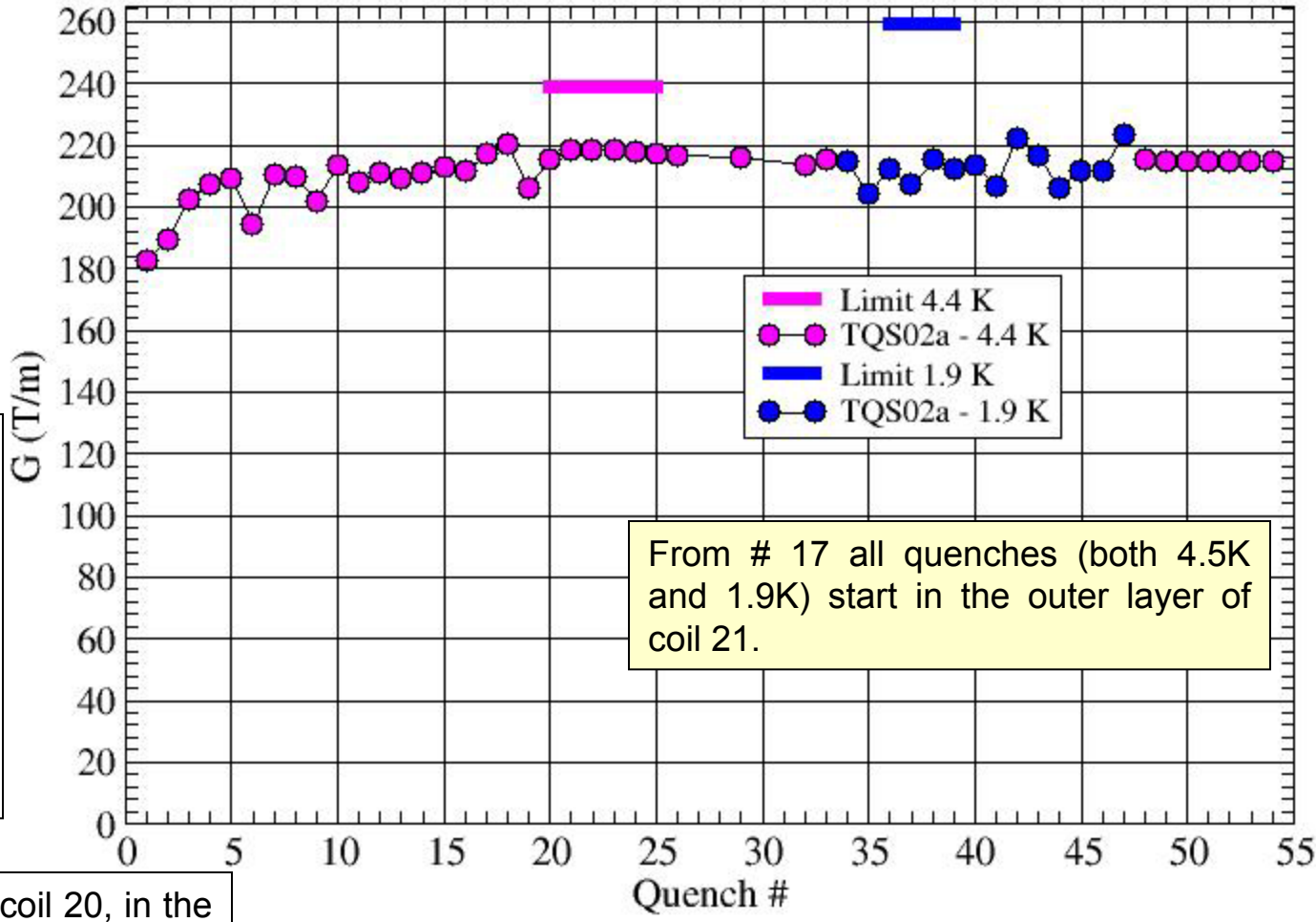
TQS02a Training

TQS02a

180 to 220 T/m, 20 quenches

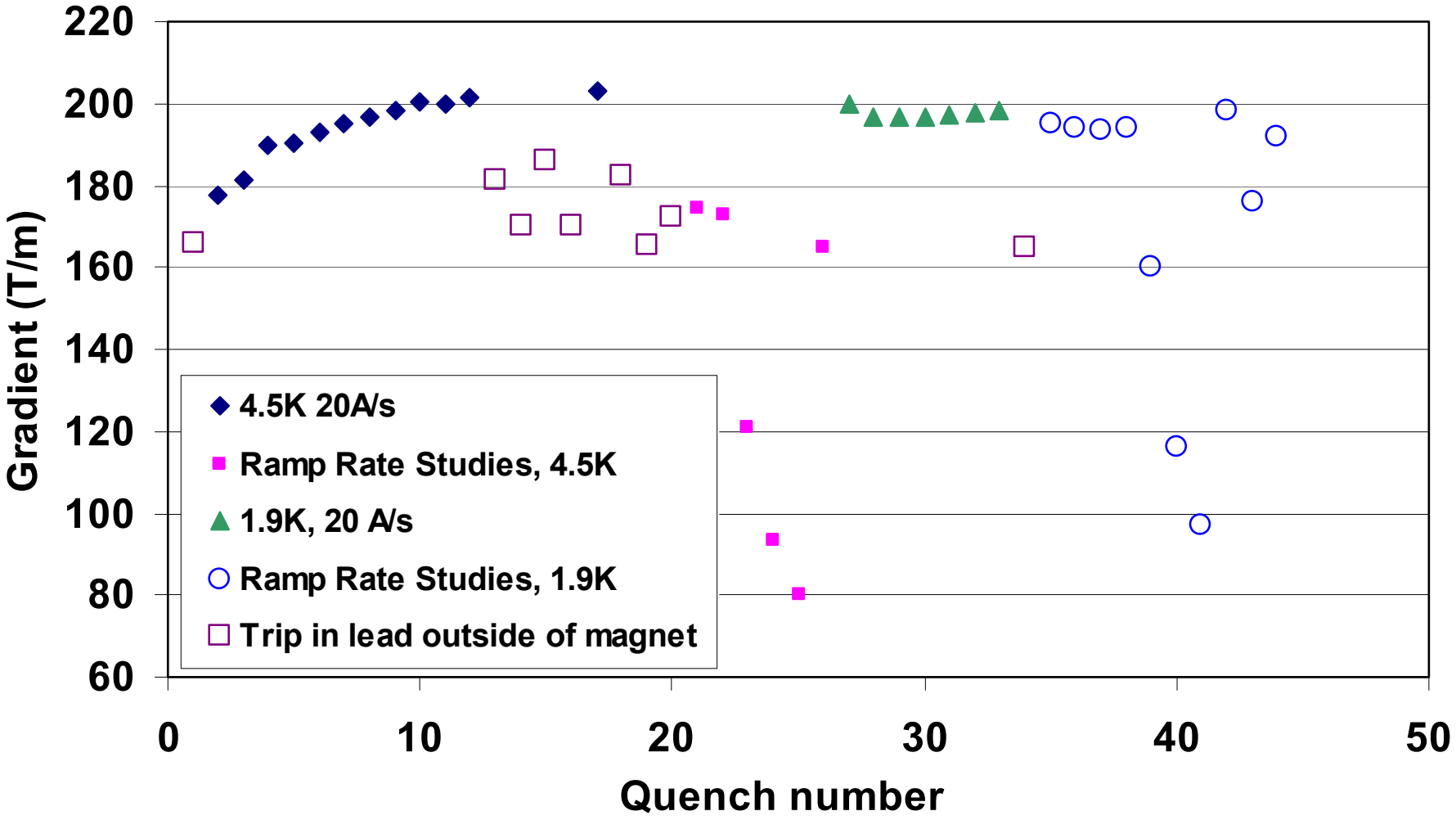
Plateau coil 21 layer 2

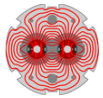
No gain at 1.9 K



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
Gradient (T/m)
220
200
180
160
140
120
100
80
60
0
10
20
30
40
50
Quench number
4.5K 20A/s
Ramp Rate Studies, 4.5K
1.9K, 20 A/s
Ramp Rate Studies, 1.9K
Trip in lead outside of magnet



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.

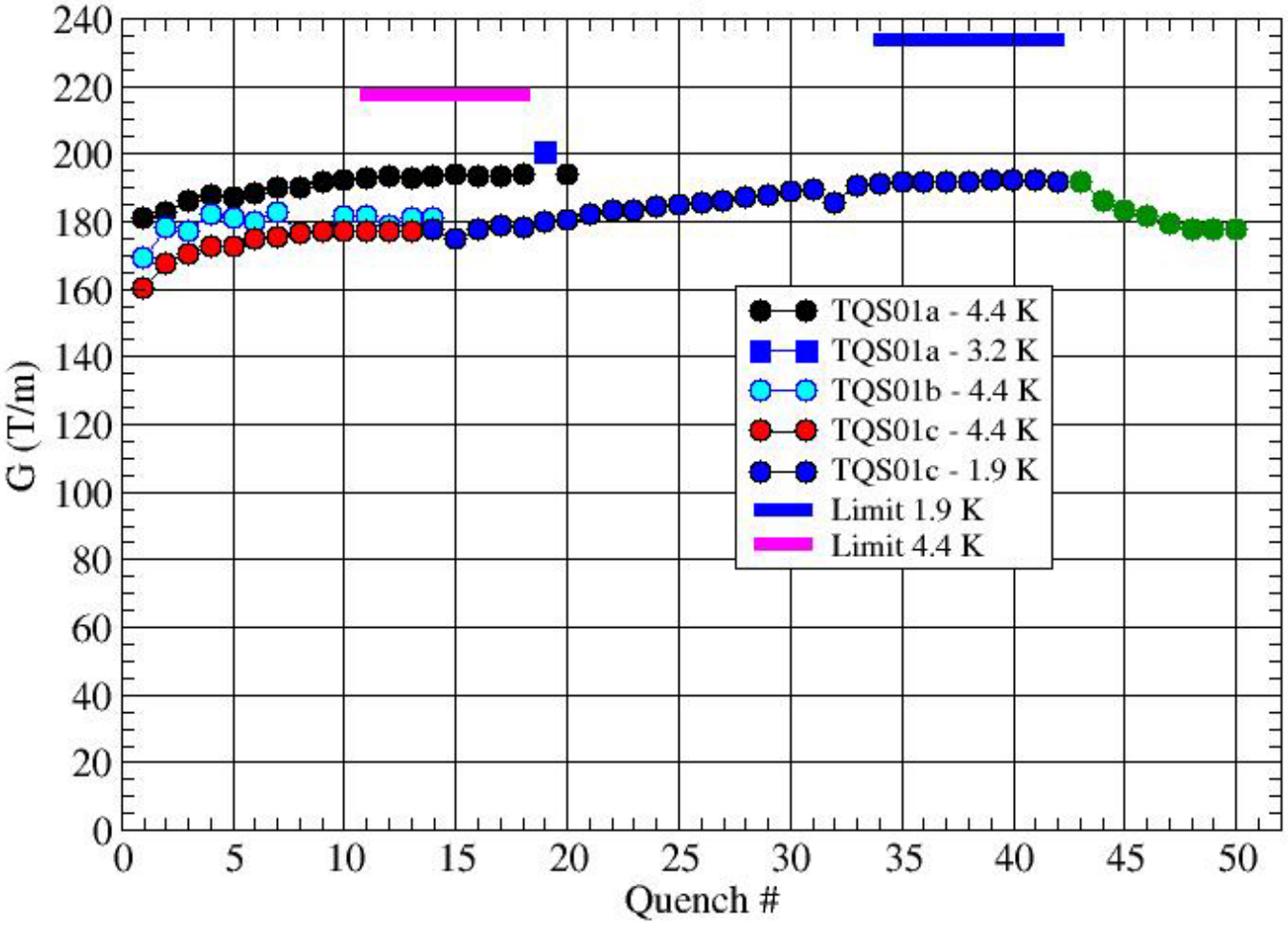
Result: first test with very low pre-stress reached ~70% of conductor limit at 4.5K and ~86% at 1.9K, second test reached ~ 85% of conductor limit at 4.5 K and ~ 90 % at 1.9 K.

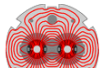
TQS01 Training

- 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)

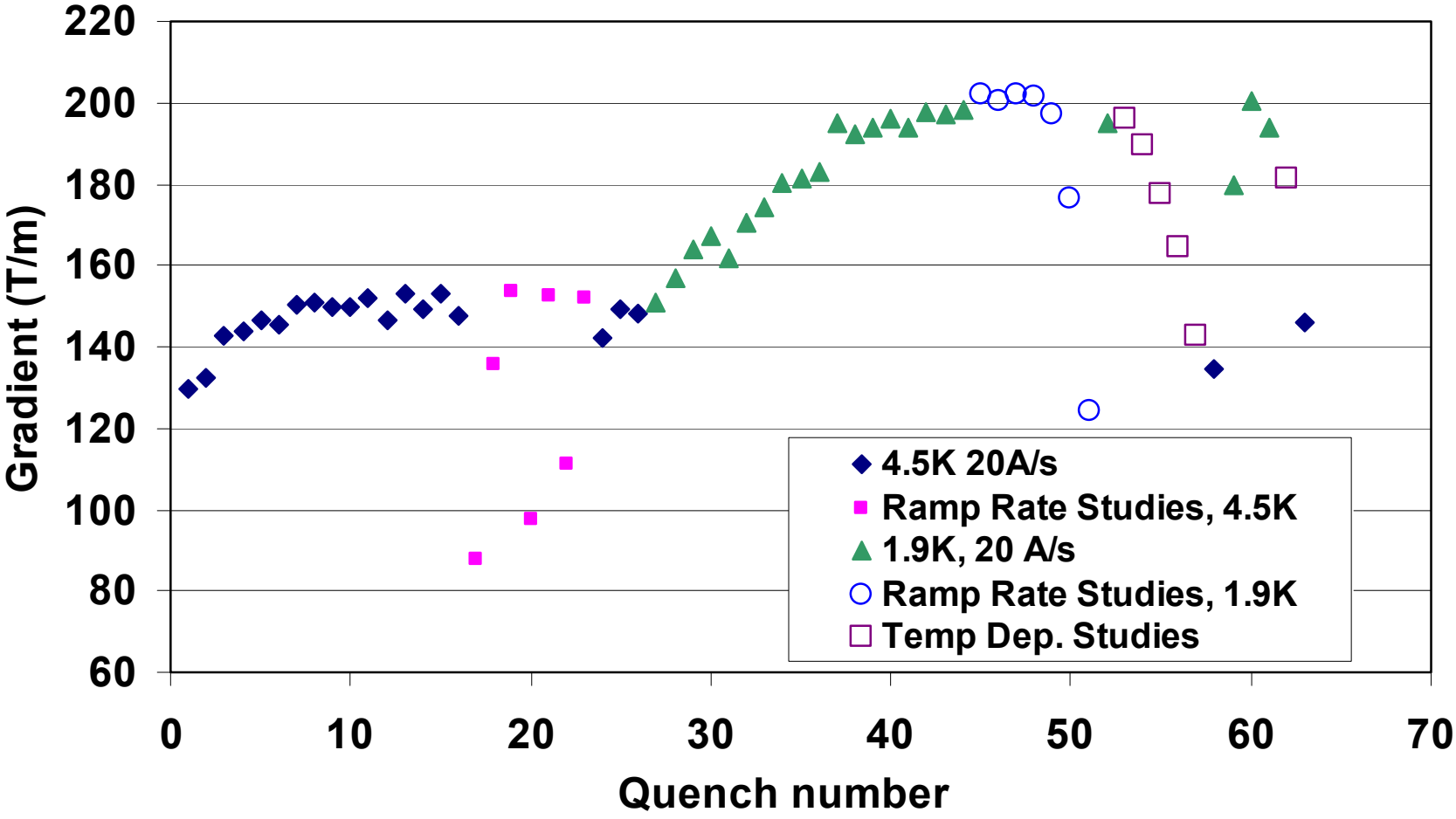
(max at 182 T/m at high MIITS)

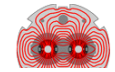
  - 175 to 192 T/m
    20 quenches (1.9 K)
  - Plateau coil 15
- All layer 1 pole quenches in the straight section



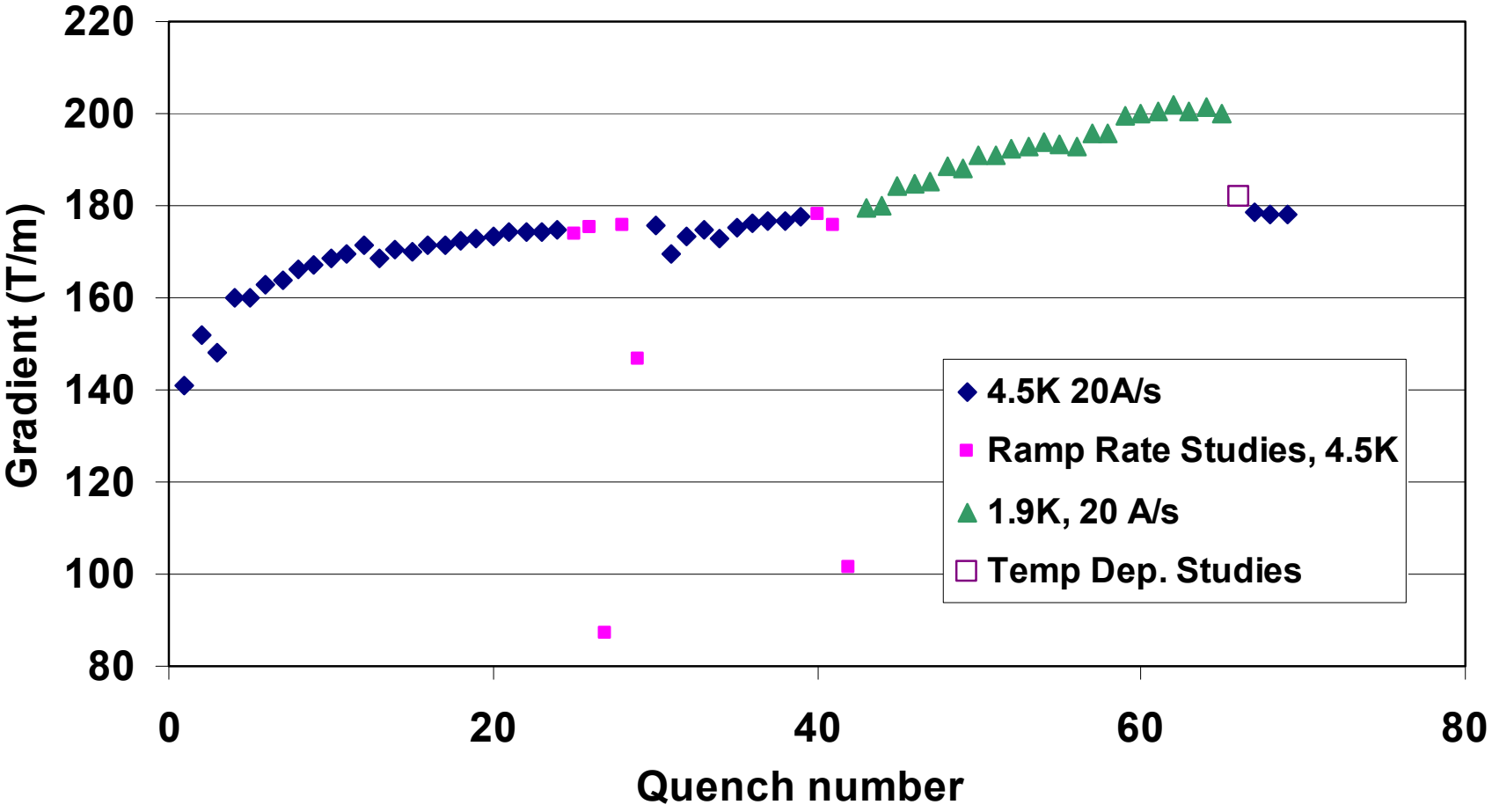


TQC01 Quench Behavior

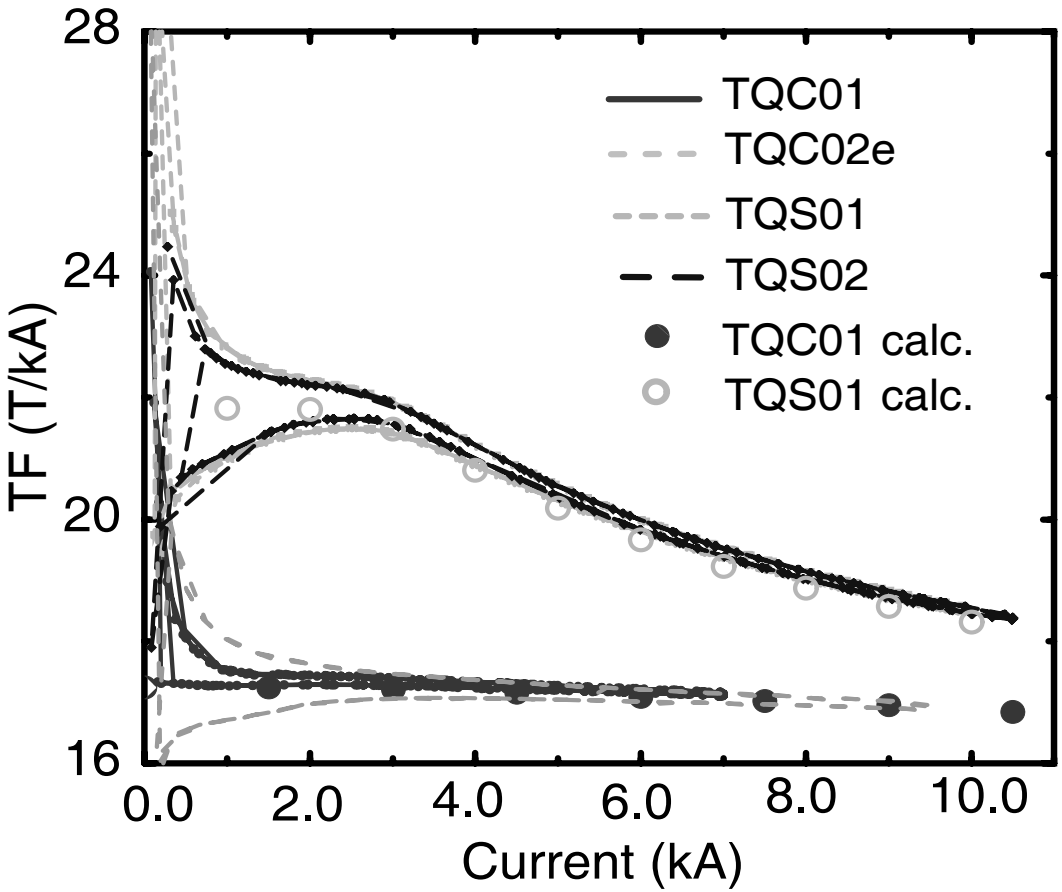


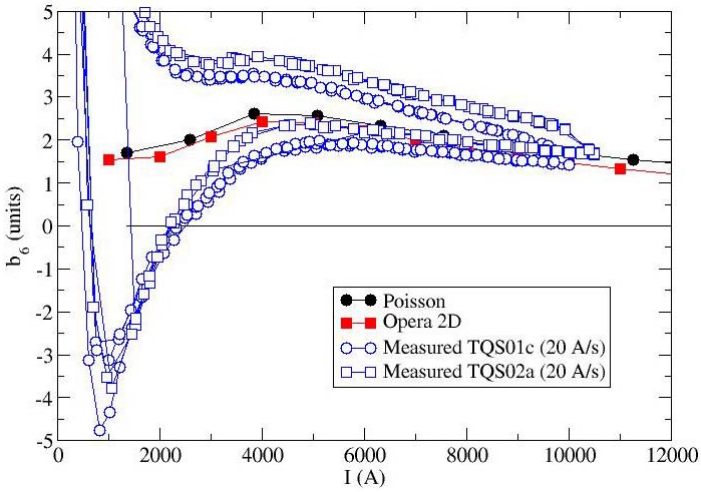


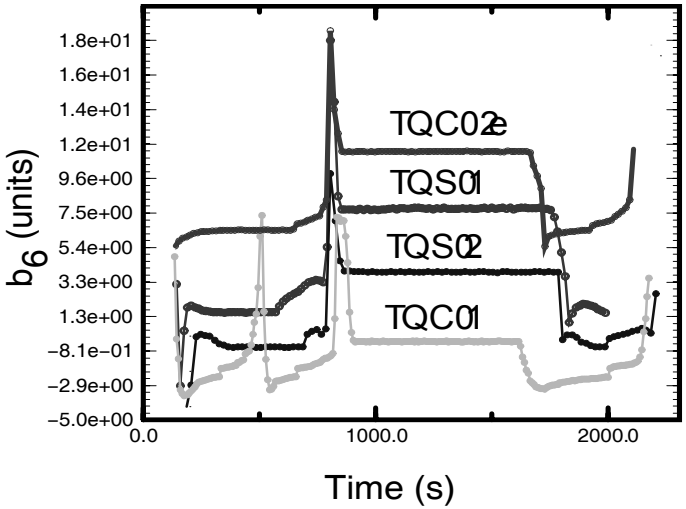
TQC01b Quench Behavior



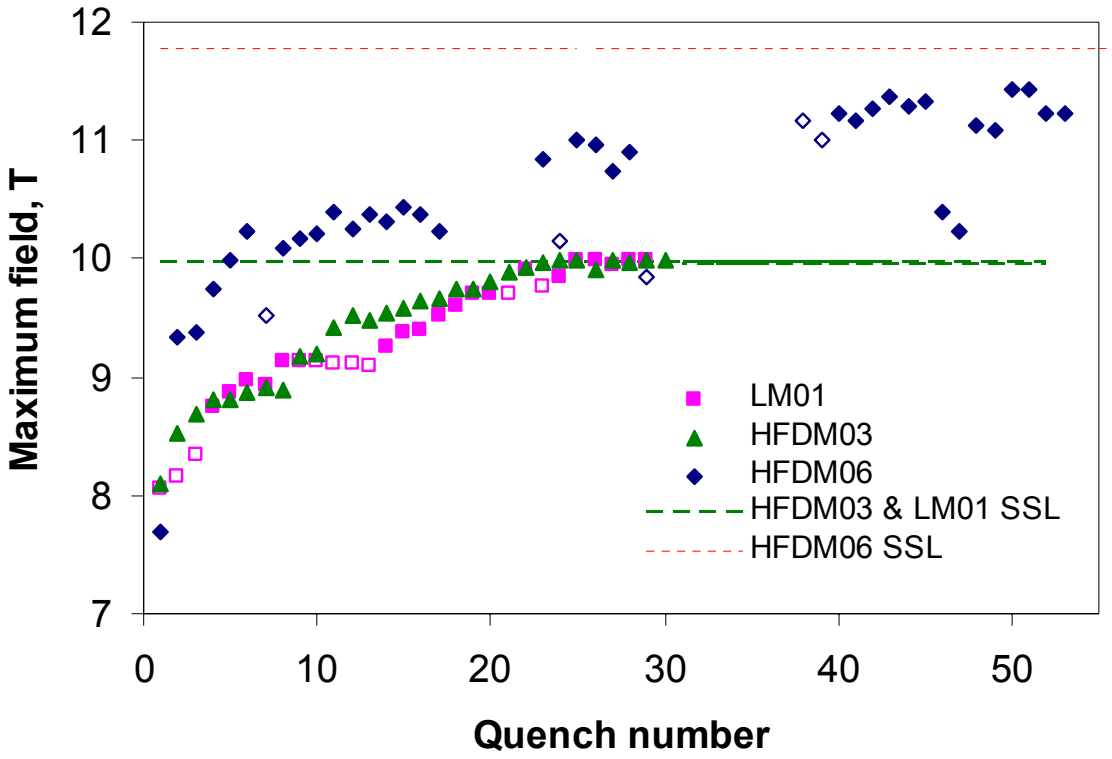
TQS and TQC – measured field







Nb_3Sn Mirror Dipole Quench Performance



Fermilab base program

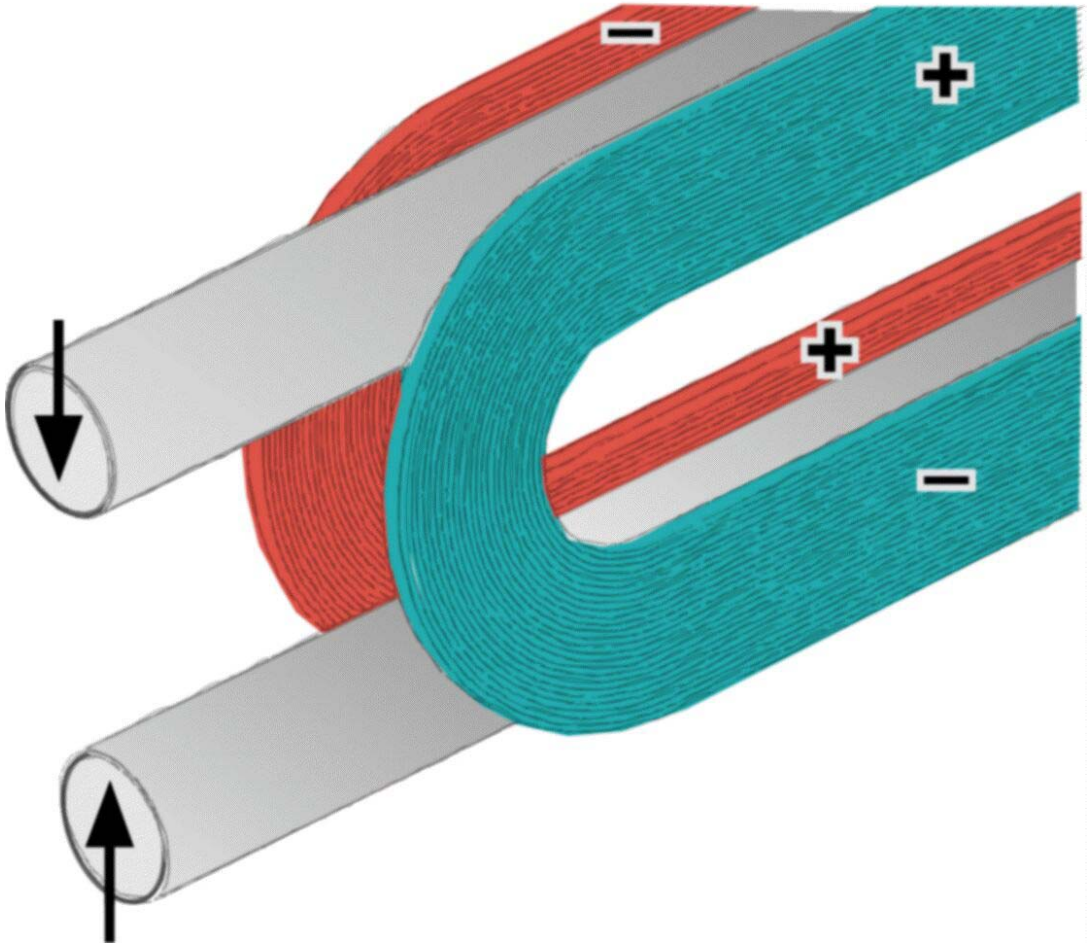
1-m (HFDM03) and 2-m long (LM01) **PIT** mirror models reached SSL and Bmax ~10 T. Their quench performance is practically identical

1-m long mirror model (HFDM06) with **1-mm RRP-108/127** strand reached 97% of its SSL and Bmax>11 T.

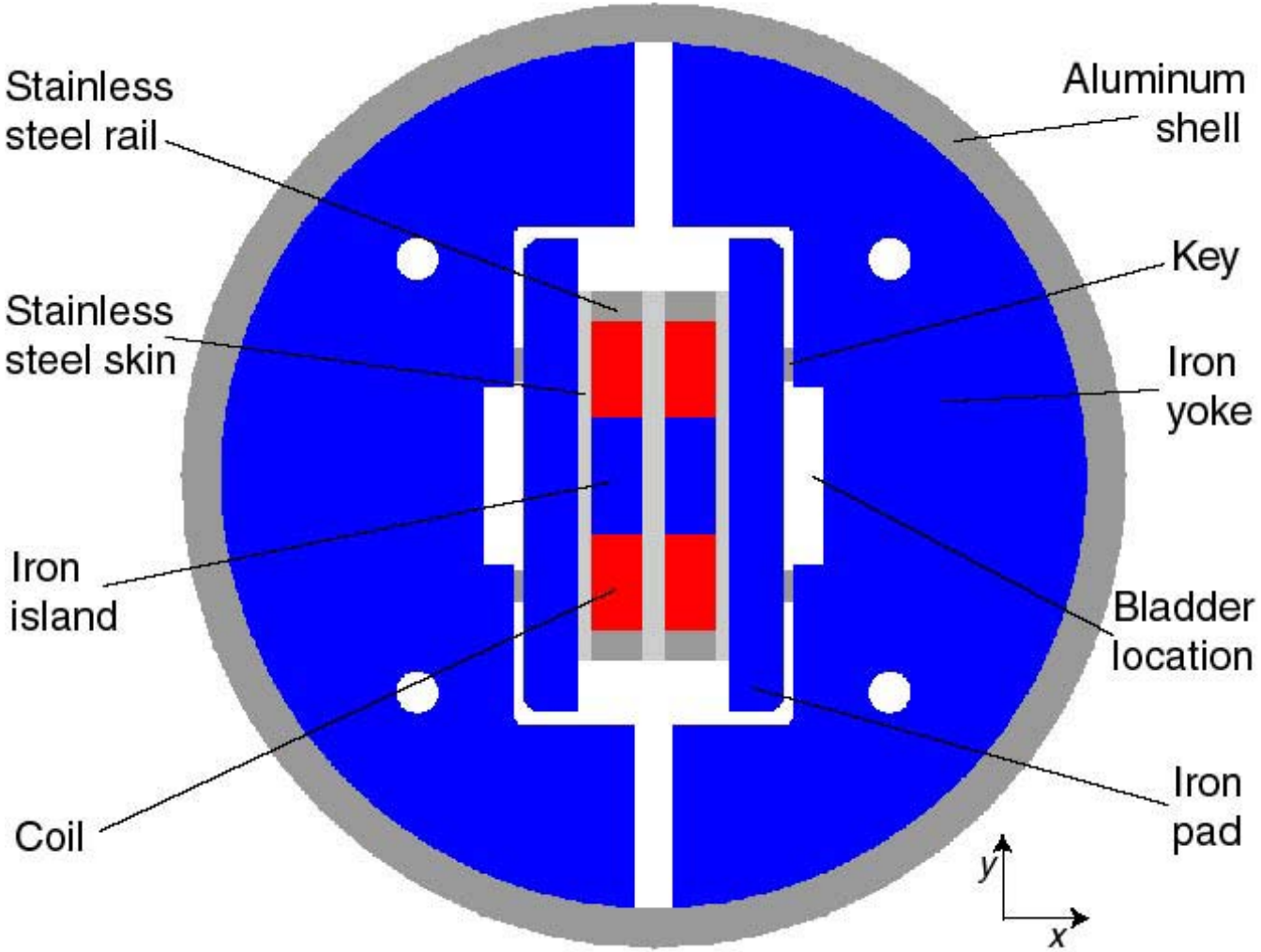
LR (long racetrack) 3.6 m, common coil

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

Coil from BNL, structure from LBNL.

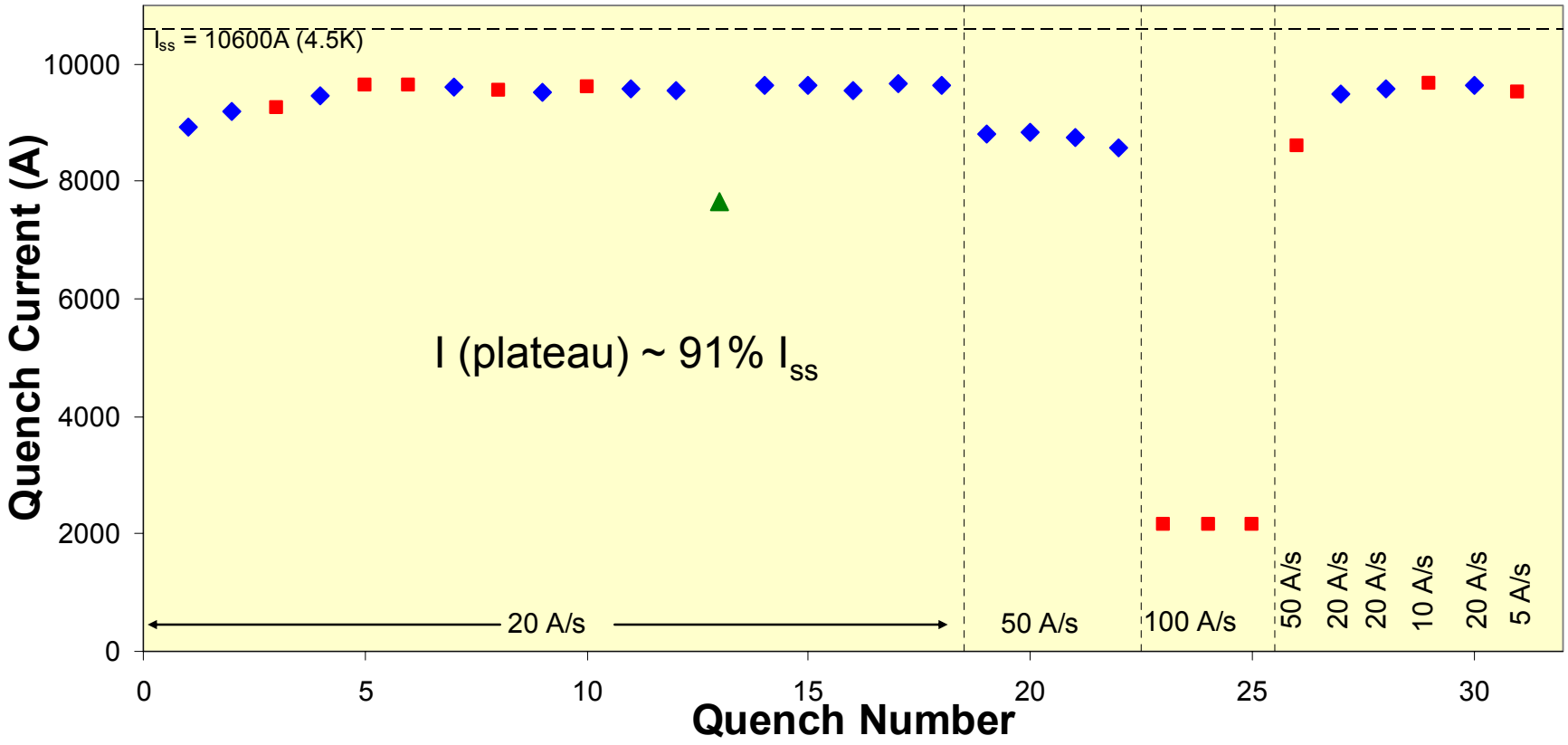


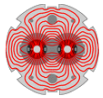
LRS01 (long racetrack coils in shell support structure)



LRS01 – long racetrack, shell 3.6 m (4.5 K)

Peak field on the coil 11 T (no aperture)





Magnet	Nb3Sn	4.5 K (nom.) tests			1.9 K (nom.) tests			Notes		
		max G	% Iss		max G	% Iss				
	type	(T/m)			(T/m)					
TQS01a	MJR	193	89							
TQS01b	MJR	182	84					1 coil replaced		
TQC01c	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		
HFDM03	PIT	~ 10 T	~ 100%					1m cos theta mirror		
LM02	PIT	~ 10 T	~ 100%					2m cos theta mirror		
HFDM06	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 quads that reliably reach 200 T/m (90% I_{ss} at 4.2 K) with coils wound from RRP conductor . 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).