Design for the Splittable SC Quadrupole Magnets at LCLS-II

Vladimir Kashikhin for Fermilab-KEK Collaboration

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Outline

- LCLS-II Splittable Quadrupole preliminary specification and concept
- Splittable magnet technology transfer from other magnets
- Quadrupole design and modification
- Test results of previous models
- Possible issues
- Quadrupole integration with other systems
- Summary

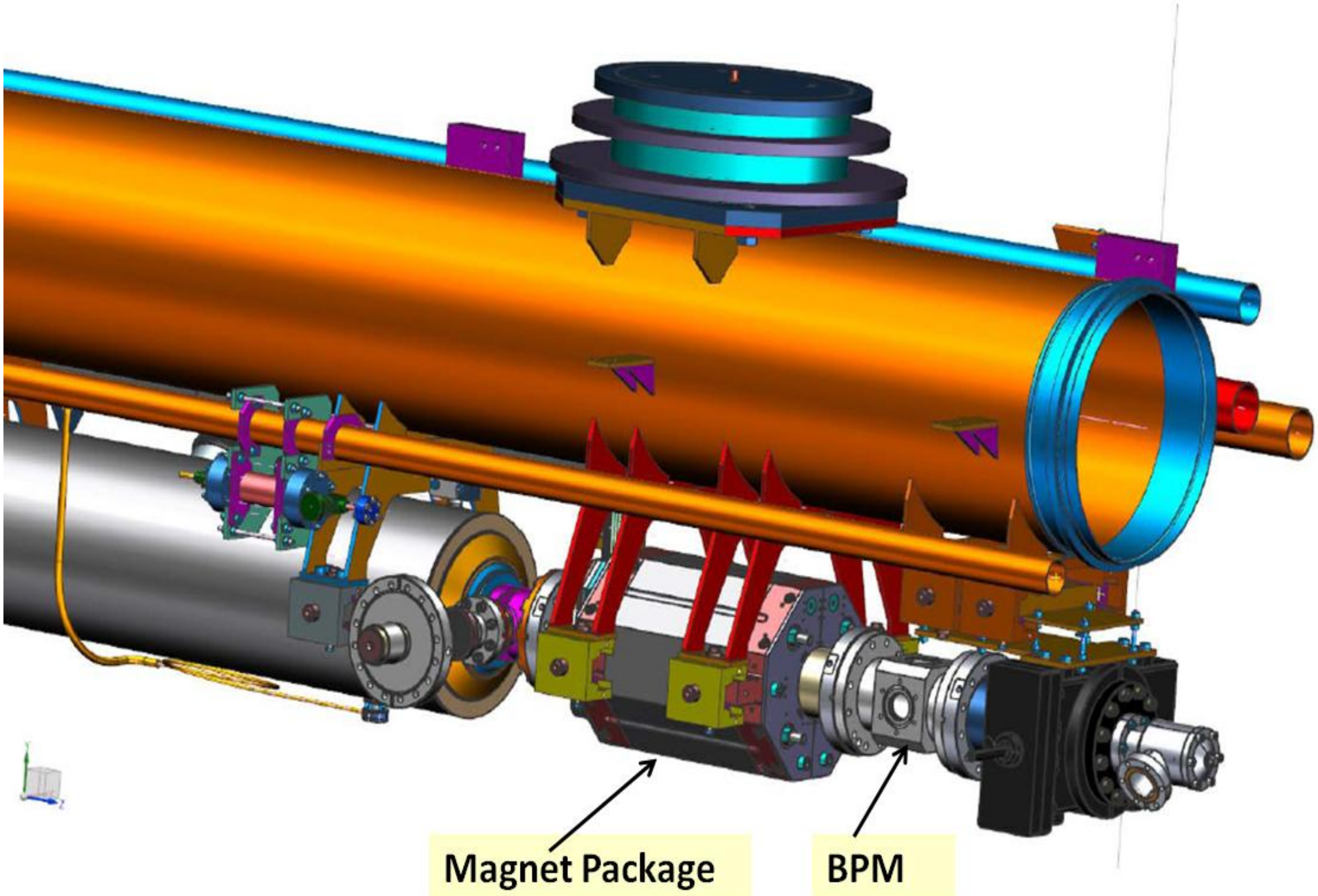
Quadrupole Specification & Superconductor

Integrated gradient, T	1.5
Aperture, mm	78
Effective length, mm	300
Peak gradient, T/m	2.0
Peak current, A	50
Field non-linearity at 5 mm radius, %	<0.5
Dipole corrector integrated strength, T-m	0.01
Magnetic center offset in cryomodule, mm	0.3
Quadrupole azimuthal offset, mrad	0.3
Liquid Helium temperature, K	2.2
Quantity required	40

NbTi wire diameter, mm	0.5
Number of filaments	7242
Filament diameter, um	3.7
Copper : Superconductor	1.5
Insulated wire diameter, mm	0.54
Insulation	Formvar
Twist pitch, mm	25
RRR of copper matrix	100
Critical current Ic @ 4.2K, at 5T	204 A

Magnet should be installed at the end of cryomodule, be splittable, and conduction cooled.

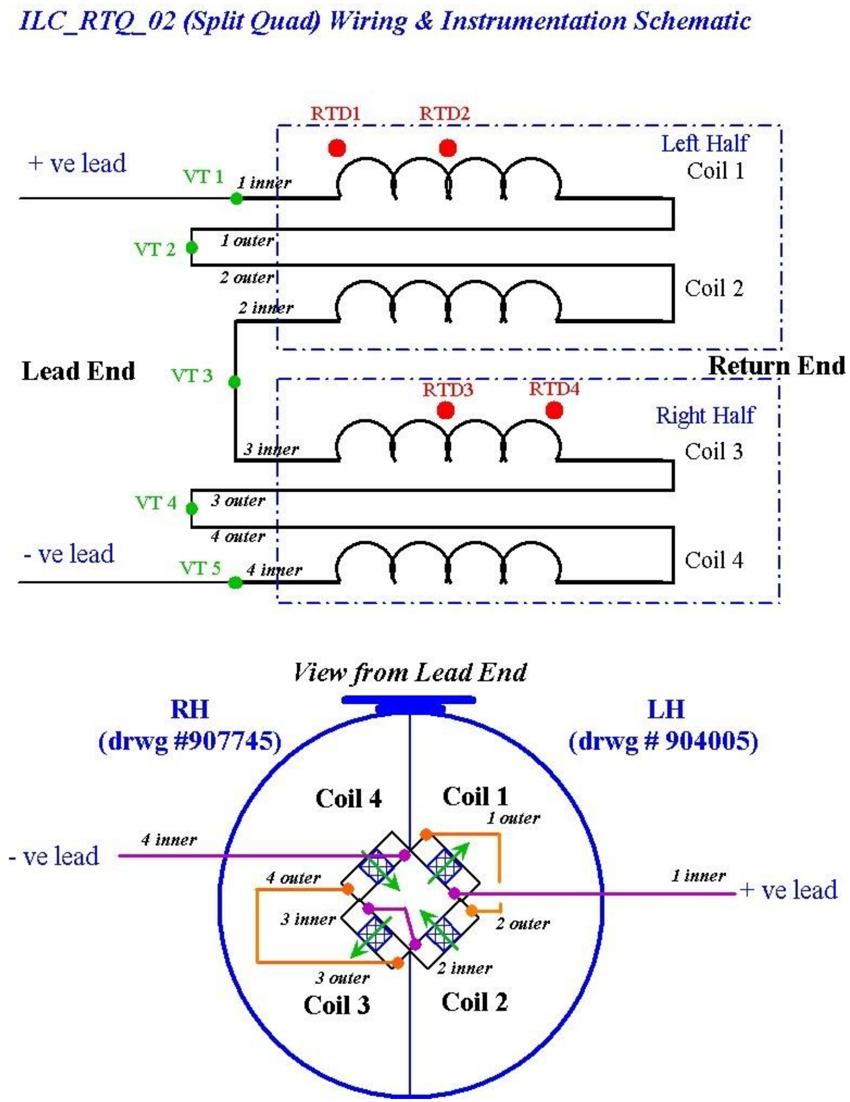
Concept of LCLS-II Splittable Quadrupole



Concept of LCLS-II Splittable Quadrupole

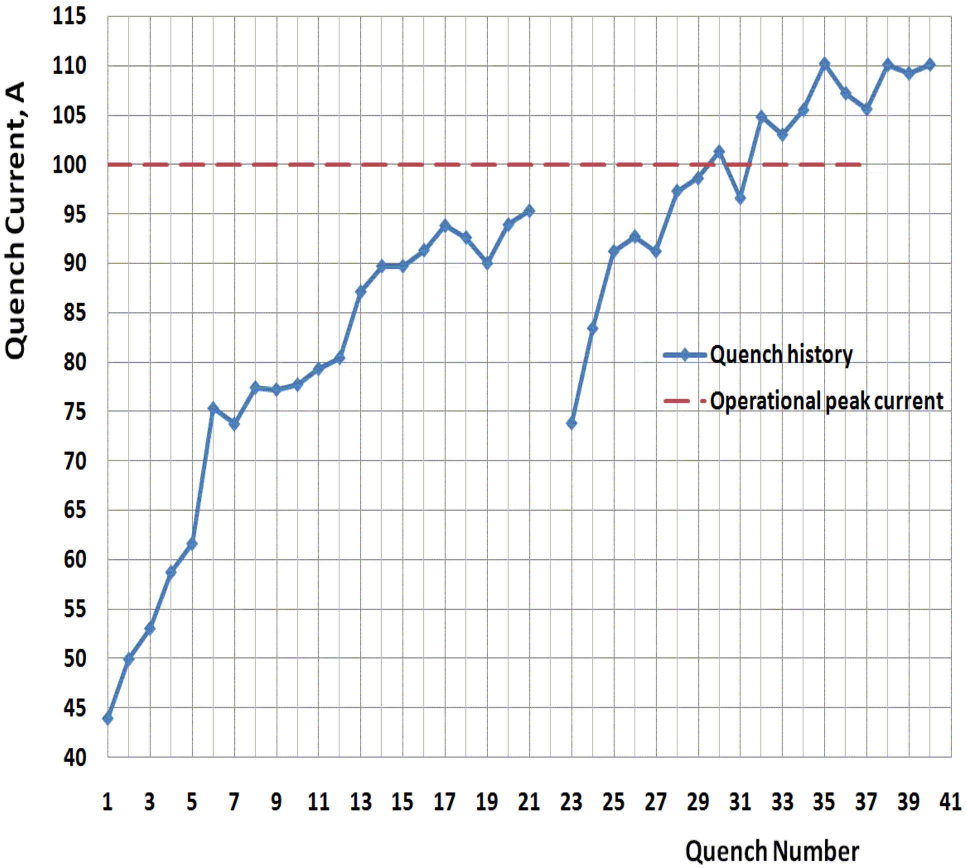
Parameter	Unit	Value
Magnet physical length	mm	315
Magnet width/height	mm	220
Pole tip distance	mm	90
Peak operating current	A	50
Number of quadrupole coils		4
Number of dipole coils		8
Type of superconducting coils		Racetracks
NbTi superconductor diameter	mm	0.5
Quadrupole inductance	mH	30
Liquid helium temperature	K	2.2
Quantity required (with spares)		40

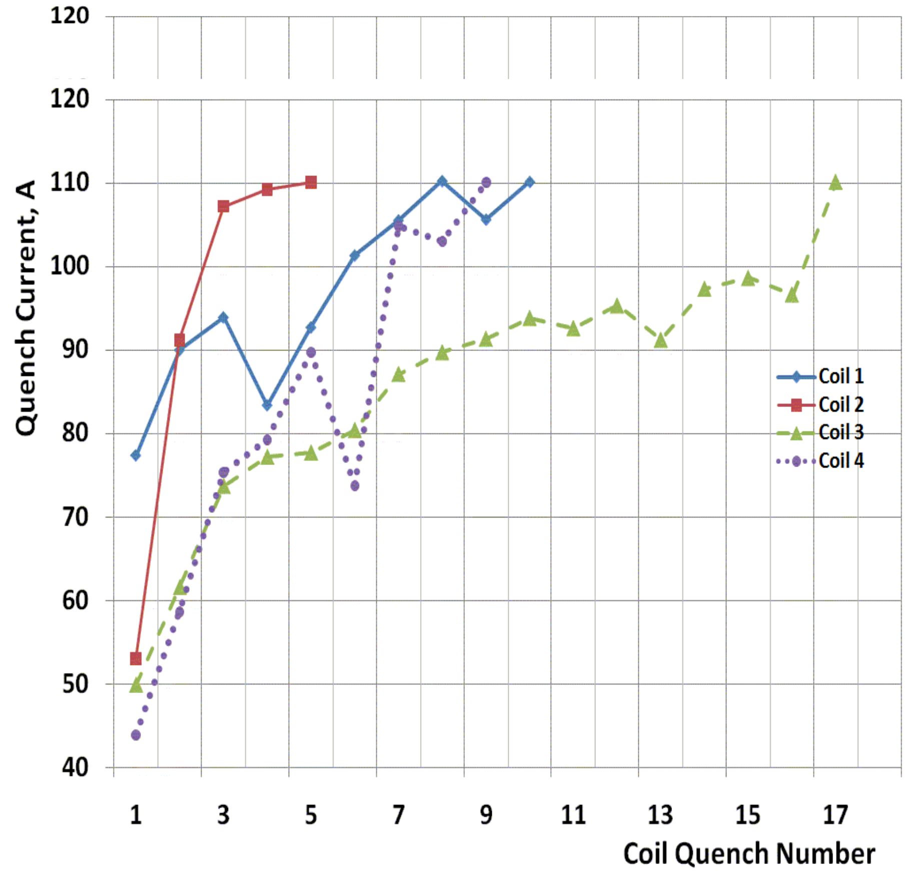
Quadrupole Electrical Scheme



All coils connected in series.
4 RTD's to monitor the temperature.
5 voltage taps to detect the quench.
Quadrupole is protected with 10 Ohm dump resistor.
The peak voltage is < 500 V.

ILC Split Quadrupole Quench History



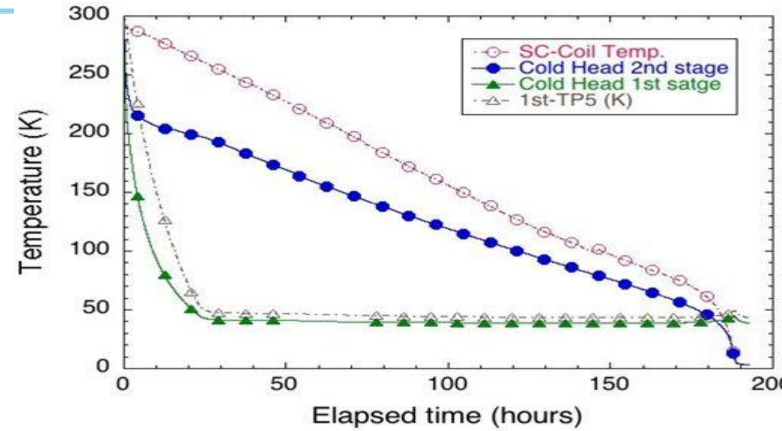


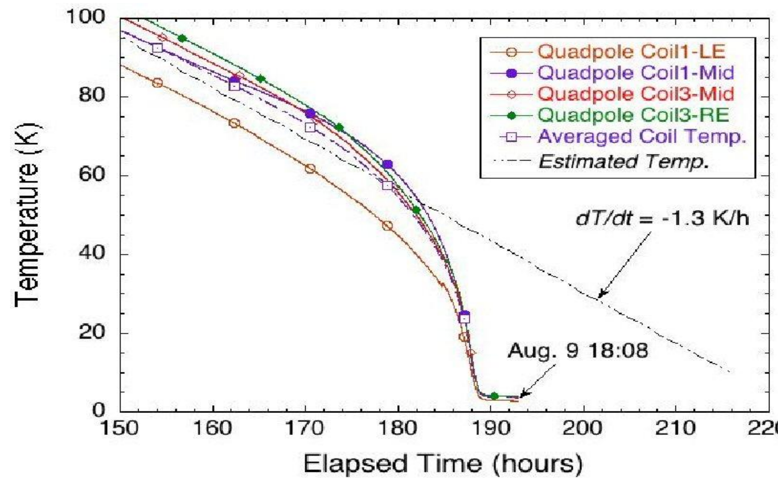
Quench history for two thermal cycles

Quench history for each coil

LCLS-II smaller coils will be more stable to quenches and 50 A peak current is a reasonable value to avoid magnet training.

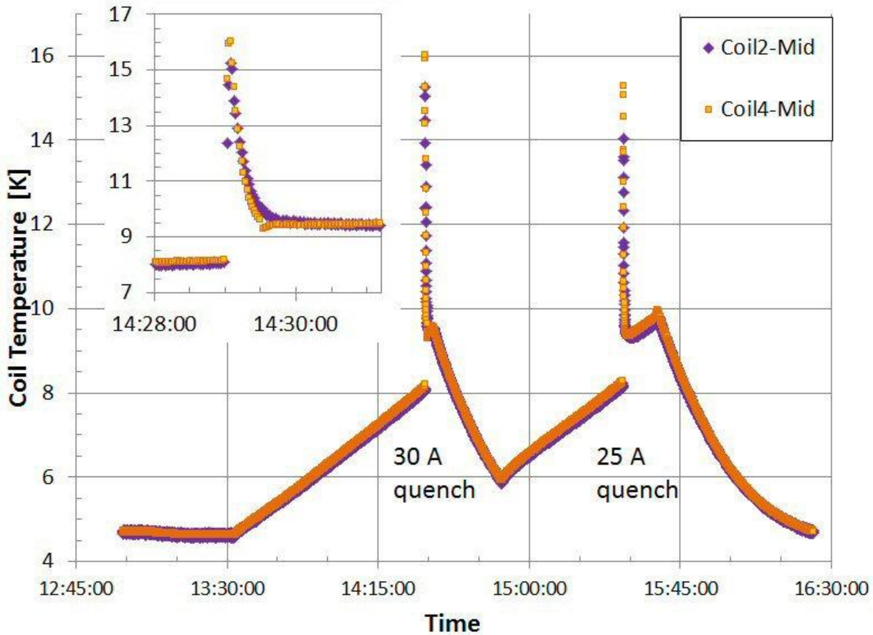
Conduction Cooling Test at KEK [1]



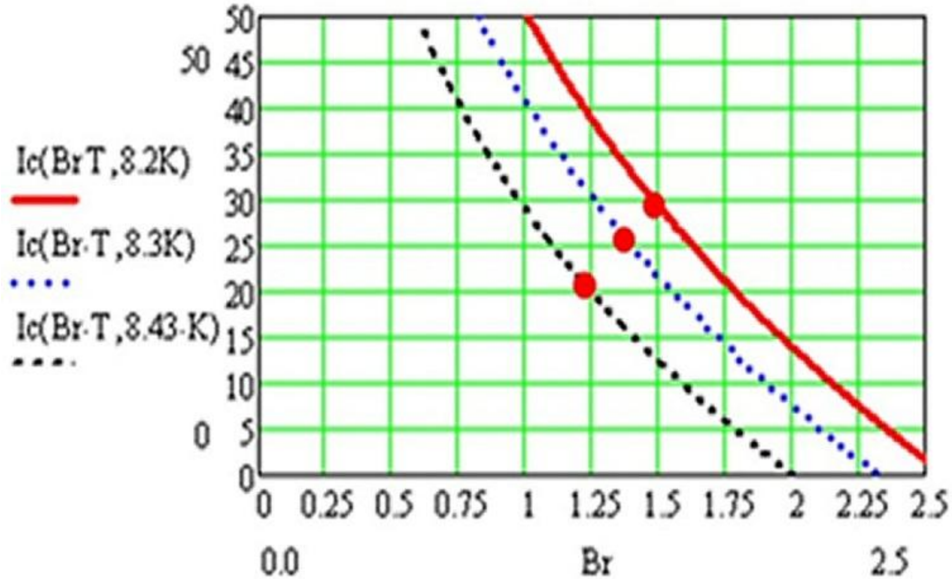


The KEK Test Stand was assembled and the magnet cooled down (8 days) to 4.5 K under supervision of Akira Yamamoto and Hitoshi Kimura

Conduction Cooling Tests at KEK [2]



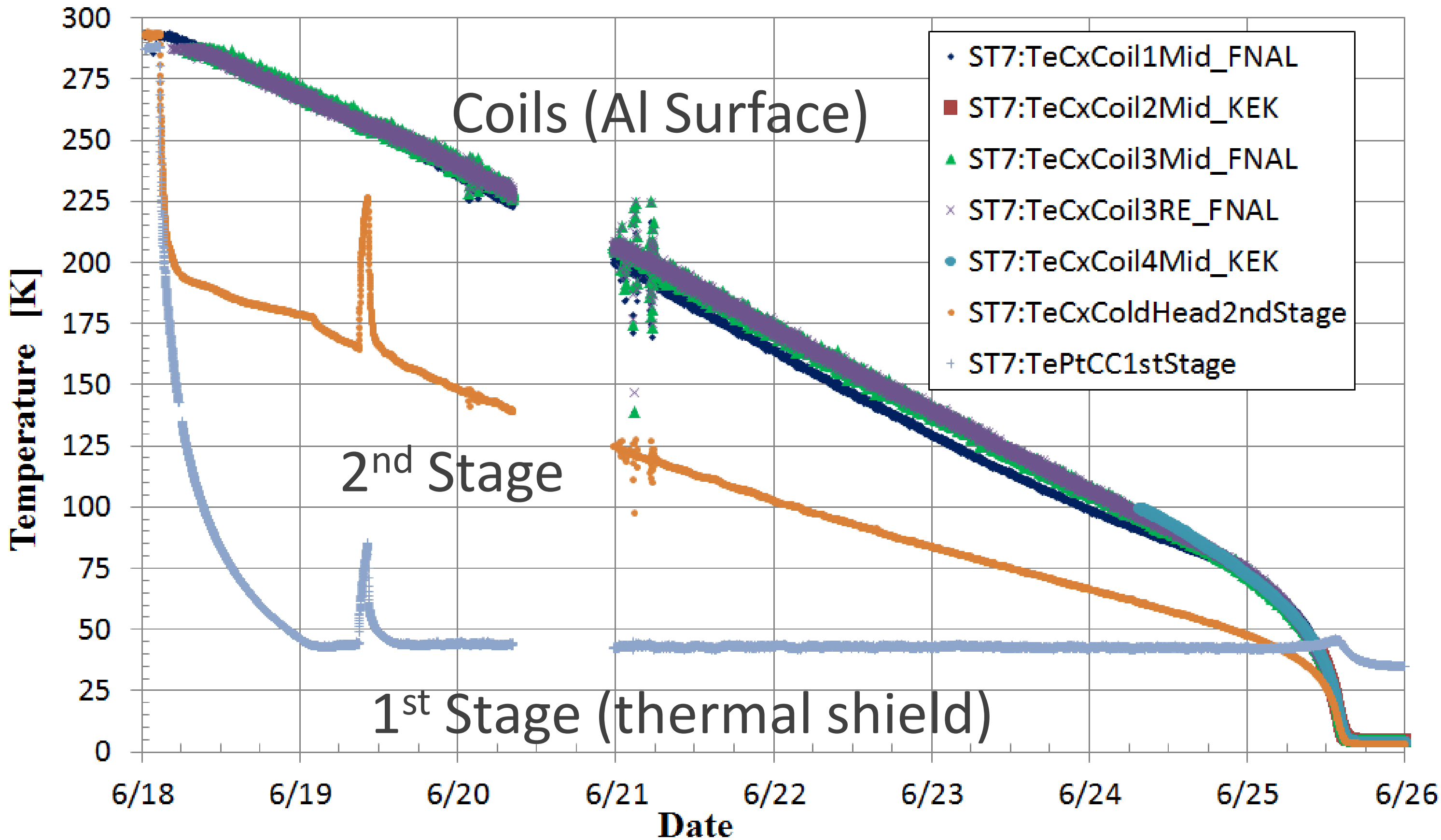
Coil temperature rise due to background heat load when compressor was turned off with magnet powered at fixed currents.



The superconductor critical current as a function of coil peak field. Dots represent the quench currents (20 A, 25 A, 30 A) at elevated coil temperatures (8.43 K, 8.3 K, 8.2 K).

The magnet cooled by conduction with only a single cryocooler (1.5 W), and has a large temperature margin (at 30 A current, and 1.5 T, 8.2 K - 4.2 K = 4 K). This is a very promising result because in the cryomodule the quadrupole will be cooled to 2 K by a LHe supply pipe.

First Cool Down at FNAL

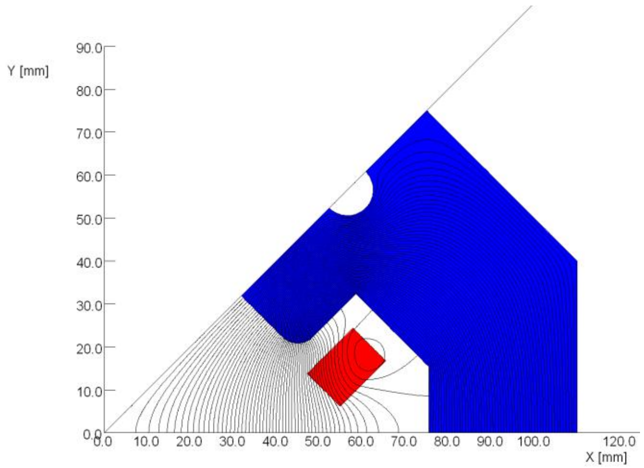


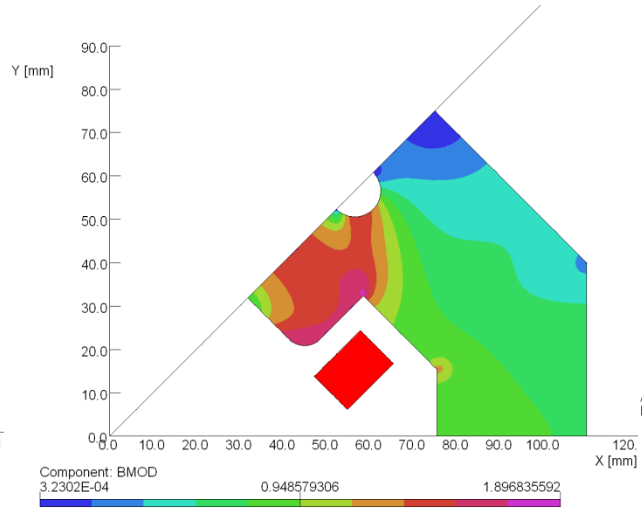
First Cool Down to 4K: 8 days, same as at KEK.

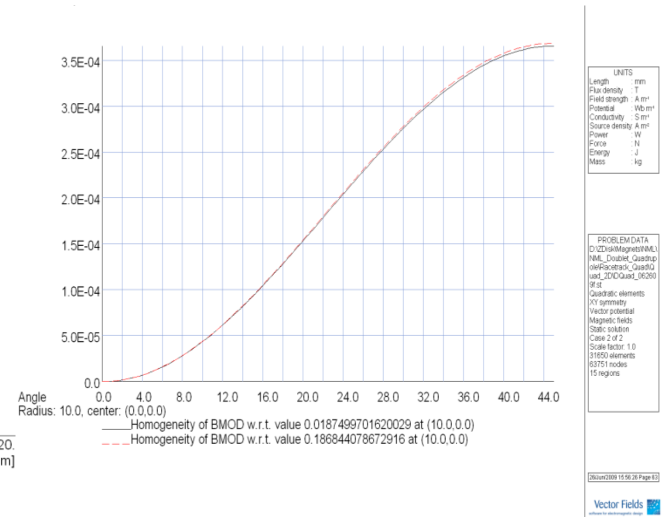
Magnet Package for KEK #CM 1

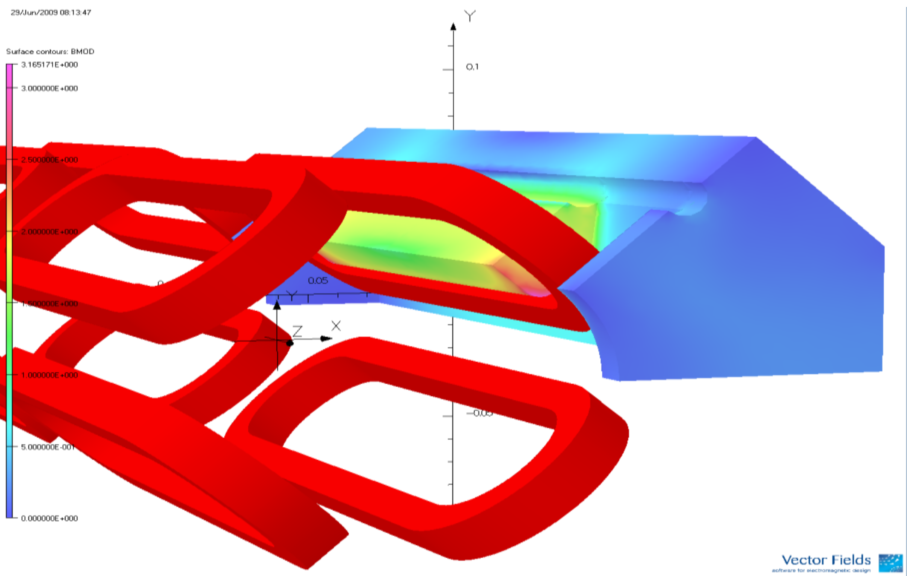
1. The first KEK-STF Cryomodule will be assembled and tested with the beam in 2014.
2. Akira Yamamoto proposed that FNAL built the splittable quadrupole for this Cryomodule.
3. Because the slot space is short it was decided to use one Quadrupole designed for ASTA Splittable Quadrupole Doublet.
4. Such approach saved time and funds of US-Japan collaboration.
5. Two magnets were built. One of them shipped to KEK, upgraded by Toshiba and installed in KEK-STF cryomodule.

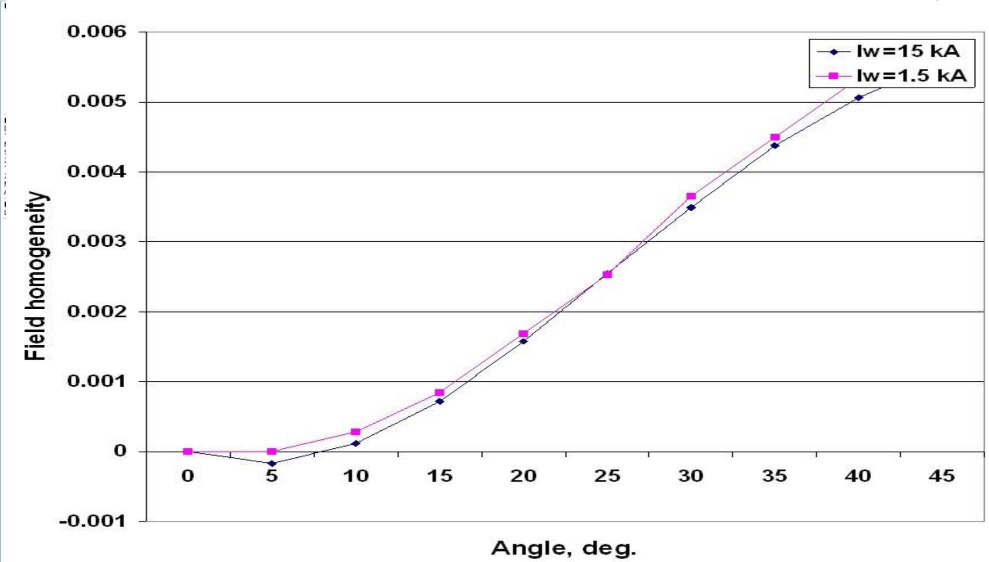
FNAL ASTA Quadrupole Doublet Magnetic Design











Integrated field homogeneity at 10 mm radius 0.6%, at 5 mm 0.18% (Spec. 0.5% at 5 mm).

FNAL ASTA Quadrupole Doublet for #CM3

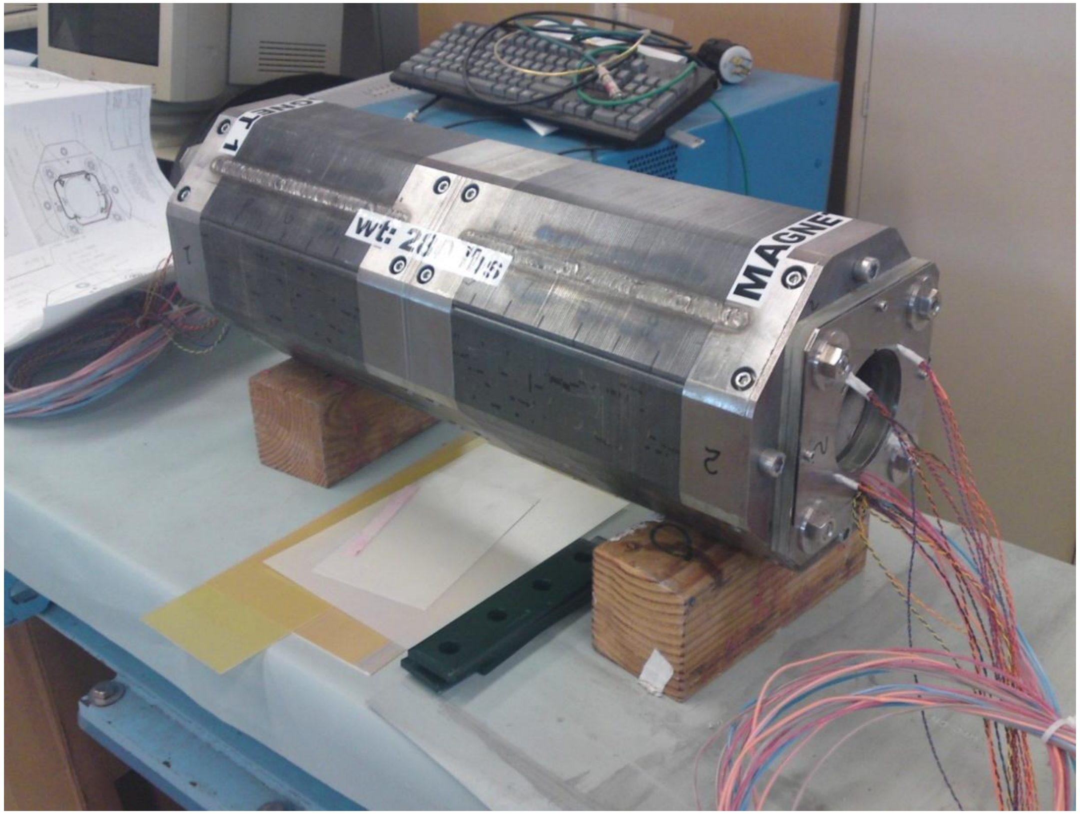
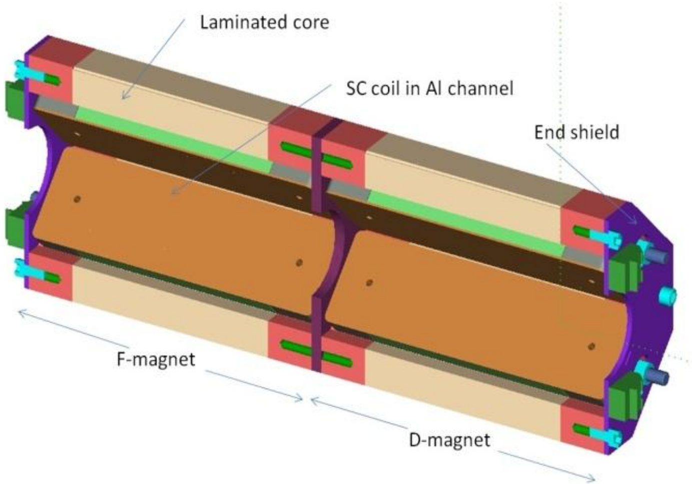


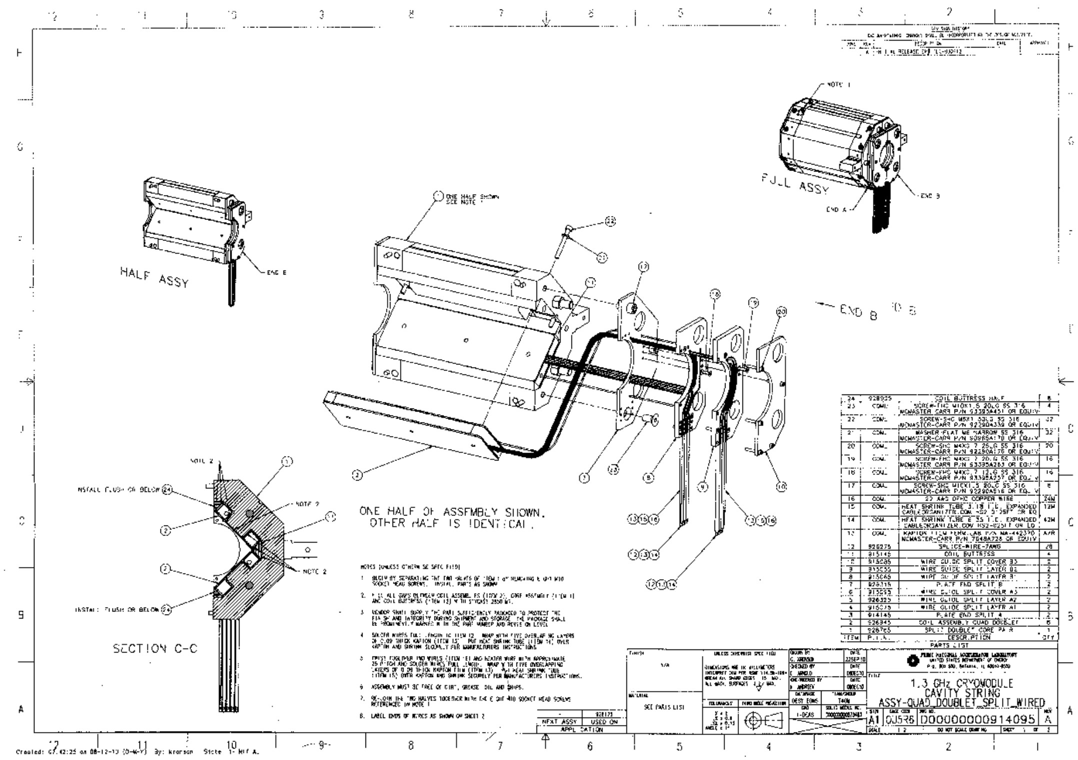
Table 1. Quadrupole Doublet Parameters

Parameter	Unit	Value
Beam pipe OD	mm	78
Integrated strength	T	3.0
Distance between quadrupole centers	m	0.3
Integrated dipole corrector strength	T-m	0.01
Quadrupole field quality at 5 mm radius	%	< 0.5
Dipole field homogeneity at 5 mm radius	%	< 5
Peak coil ampere-turns	kA	15
Operating temperature	K	2

Two unsplittable Quadrupole Doublets were built for ASTA #CM3. They will operate in the bath cooling mode.

New Magnet for KEK-STF #CM1





Because of a very tight schedule and space it was decided to use the Splittable Quadrupole Doublet design for ASTA and manufacture only one part of the Doublet. The quadrupole is also combined with dipole correctors as in the Doublet.

SUMMARY

1. The splittable conduction cooled quadrupole magnet technology was proved for using in SLAC LCLS-II Linear Accelerator.
2. LCLS-II quadrupole will be modified for two times lower strength 1.5 T than have ASTA and KEK-STF .
3. The reasonable value of peak current defined as 50 A.
4. The low currents ~ 3 A effects (iron and superconductor magnetization) should be carefully investigated on the prototype.
5. Special attention should be paid on the magnet integration: BPM and Quadrupole position accuracy, conduction cooling thermal sinks, and current leads.
6. It is supposed to built 3 magnets for FNAL and JLAB cryomodule prototypes.