Long Magnet R&D with Racetrack Coils

LARP Collaboration Meeting 4

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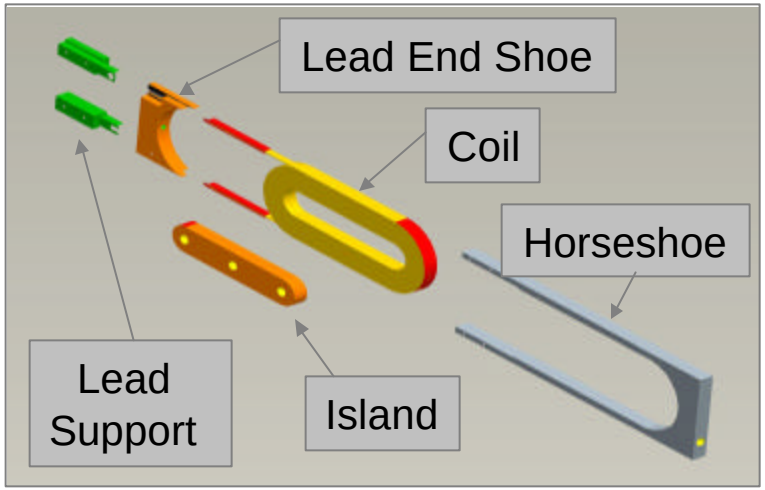
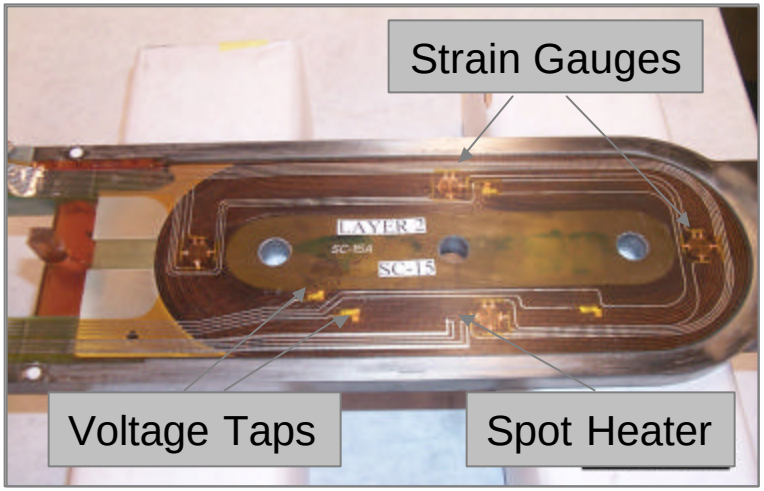
Sub-scale Racetrack (SC) Coil Design

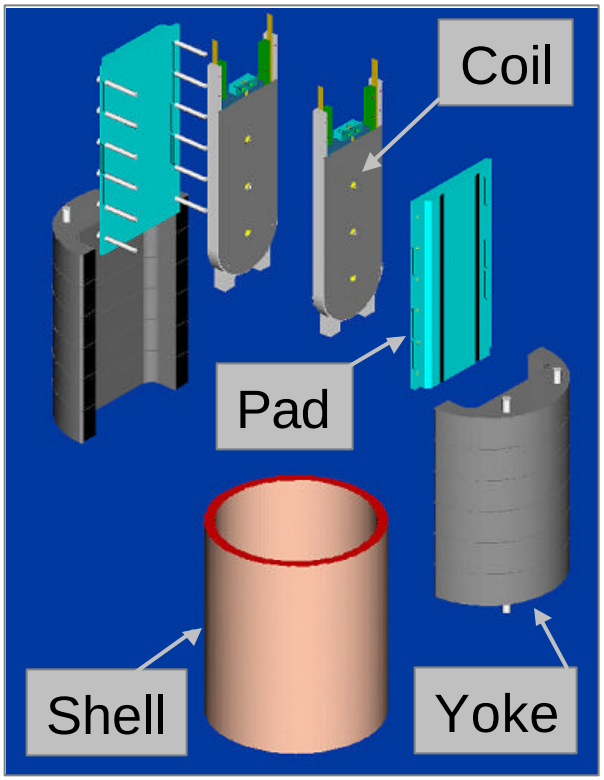


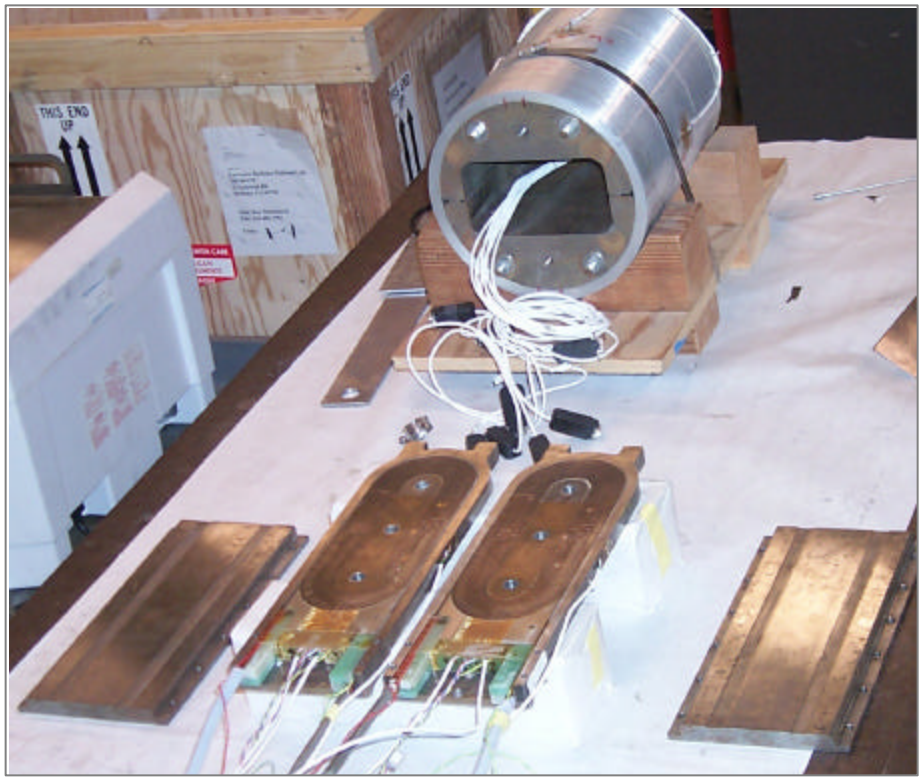


<u>Design Features:</u>

- Double Layer Racetrack, single block (no spacers)
- Cable: 20 (0.7 mm) strands, 0.7 mm, 1.3 x 7.9 mm
- S-glass sleeve
- Conductor for 1 coil: **2.5 kg** (22 meters of cable)
- Dipole & Quadrupole Configuration
- Instrumentation: Voltage Taps, Strain Gauges, Spot Heaters

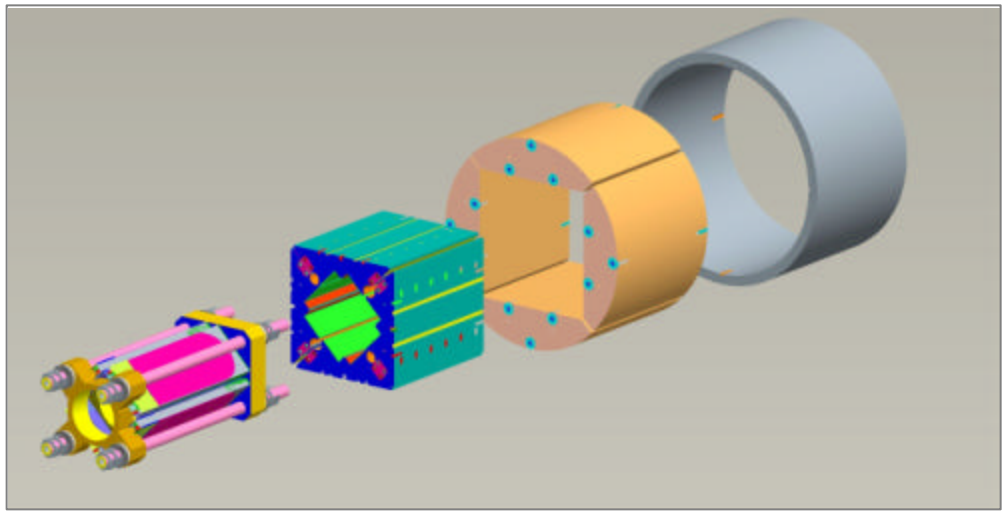
Common Coil Dipole Structure (SM)

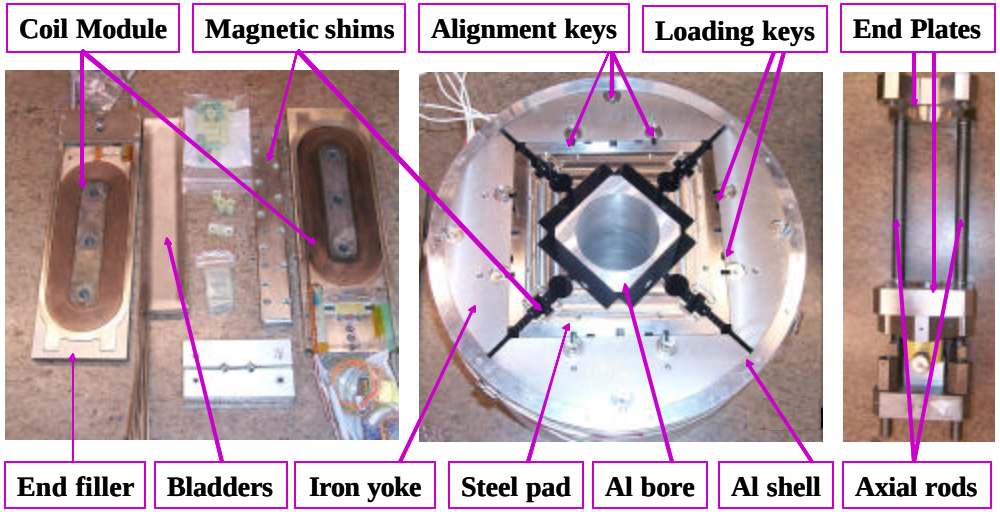




- 10-12 T peak field (straight section)
- Fast assembly/disassembly
- Six magnets tested
- Different preload configurations

Racetrack Quadrupole Structure (SQ)





Quadrupole configuration:

- ~11-12 T Peak field
- 130 mm aperture
- High stored energy
- High axial forces

Suitable for:

- Mechanical studies
- Quench strudies
- Field measurements

“SC” Coil Fabrication & Test Summary

Coil	Strand	N. strands	N. turns	RRR	Comments
SC01	ORe 143C	20	20	41	Tested
SC02	ORe 143C	20	20	38	Tested
SC03	EP-214	21	20	226	Mix-strand
SC04	ORe 163B	20	20	8	Not tested
SC05	ORe 143C	21	20		Mix-strand
SC06	ORe 143C	21	20	167	Mix-strand
SC07	EP-214	21	20		Mix-strand
SC08	ORe 143C	20	20	42	Fermilab
SC09	ORe 162A	21	20		SS-core
SC10	ORe 163B	20	21	54	Linda exp.
SC11	ORe 186	20	21	7	Ex-situ
SC12	ORe 186	20	21	5	Ex-situ
SC13	ORe 186	20	21	7	Instrum.
SC14	ORe 186	20	21	13	Instrum.
SC15	S30-B0877R	20	20	99	SQ-01
SC16	S30-B0877R	20	20	87	SQ-01

“SC” Length Scale-up

First step towards long Nb_3Sn coils/magnets:

- simple coil design → focus on length issues
- well understood SC (SM) baseline
- cost effective: conductor, parts, tooling
- suitable for iterating on parts/tooling and fabrication
- suitable for testing in incremental steps:

  1. Stand-alone coil test – mechanical models
  2. Common coil dipole – lower forces, energy, pre-stress
  3. Block-coil dipole – peak field in straight section
  4. Racetrack quadrupole – high (axial) forces, energy

- coil disassembly/reassembly in different configurations
- opportunity for scale-up of bladder & key technology

LC Coil Parameters

Overall Coil Length with Rails and Shoes	3.6 M
Overall Coil Length without Rails and Shoes	3.5 M
Overall Coil weight	60 Kg
Coil Thickness	17 mm
Coil Width	120 mm
Required Conductor Length	340 M
Conductor Mass	22Kg

Length was selected for compatibility with FNAL/BNL test facilities.

LC Tooling Cost

Part	Description	Burden
	Infastructure	
Furnace	Suitable For LC Series	?
Winding	Designate Facility	?
Impregnation	Suitable For LC Series	?
Assembly	TBD	?
Testing	TBD	?
	Reaction Fixture	
Edge Plates	304 CRES	$5K
Face Rail	304 CRES	$1K
Face Pusher	304 CRES	$3K
End Pusher	304 CRES	$0.2K
Strong Back	304 CRES	$2K
	Potting Fixture	
Seal Plates	6061-T6	$4K
Face Rails	6061-T6	$1K
Face Pusher	6061-T6	$1K
End Pusher	6061-T6	$0.2K
Strong Back	6061-T6	$0.50

Infrastructure
$?

Reaction Tooling
$11.2K

Impregnation Tooling
$7K

Industrial Ovens For Coil Reaction

- Max temp 676°C
- ±2.5°C Temperature Gradient
- Gas tight interior, no retort required
- Truck and dolly provide method of material handling

(SC) LC Parts & Labor Cost

Part	Description	Burden
	SC Series	
Conductor	22 Meters (2.5Kg)	$2.5K
Insulation	S-Glass Sleeve (22 Meters)	$.25K
Island	1018 Steel	$0.15K
Horseshoe	304 CRES	$0.5K
End shoes	304 CRES	$0.2K

SC Series M&S
$3.6K

Part	Description	Burden
	LC Series	
Conductor	340 Meters (22Kg)	$22K
Insulation	S-Glass Sleeve (340 Meters)	$3K
Island	Aluminum Bronze 61400	$0.5K
Rails	304 CRES	$0.5K
End shoes	304 CRES	$0.5K

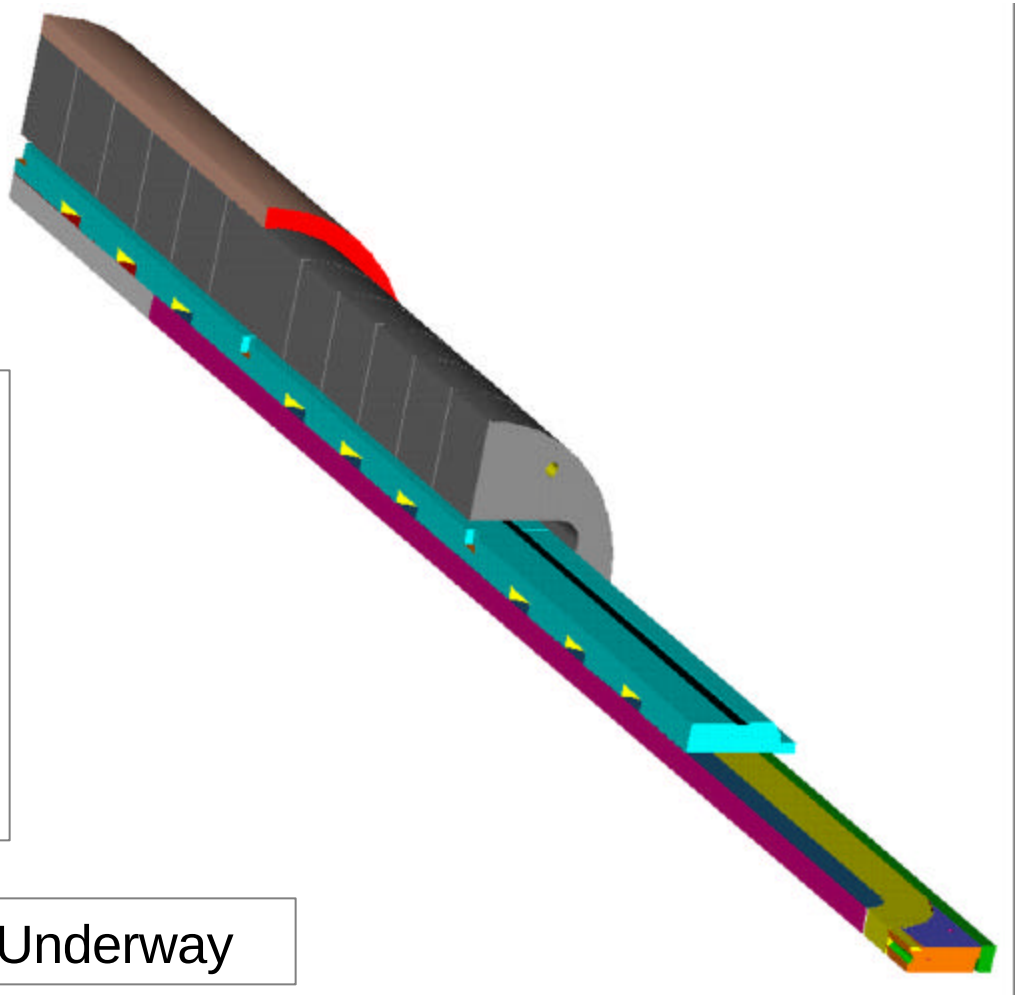
LC Series M&S
$27K

Series Coil Fabrication Labor	
Winding&Pre-Reaction	0.15 FTE (D/T)
Reaction Prep	0.05 FTE (D/T)
Post Reaction&Potting	0.30 FTE (D/T)

Labor Should decrease with technology development

LC01 Labor
0.5 FTE (D/T)

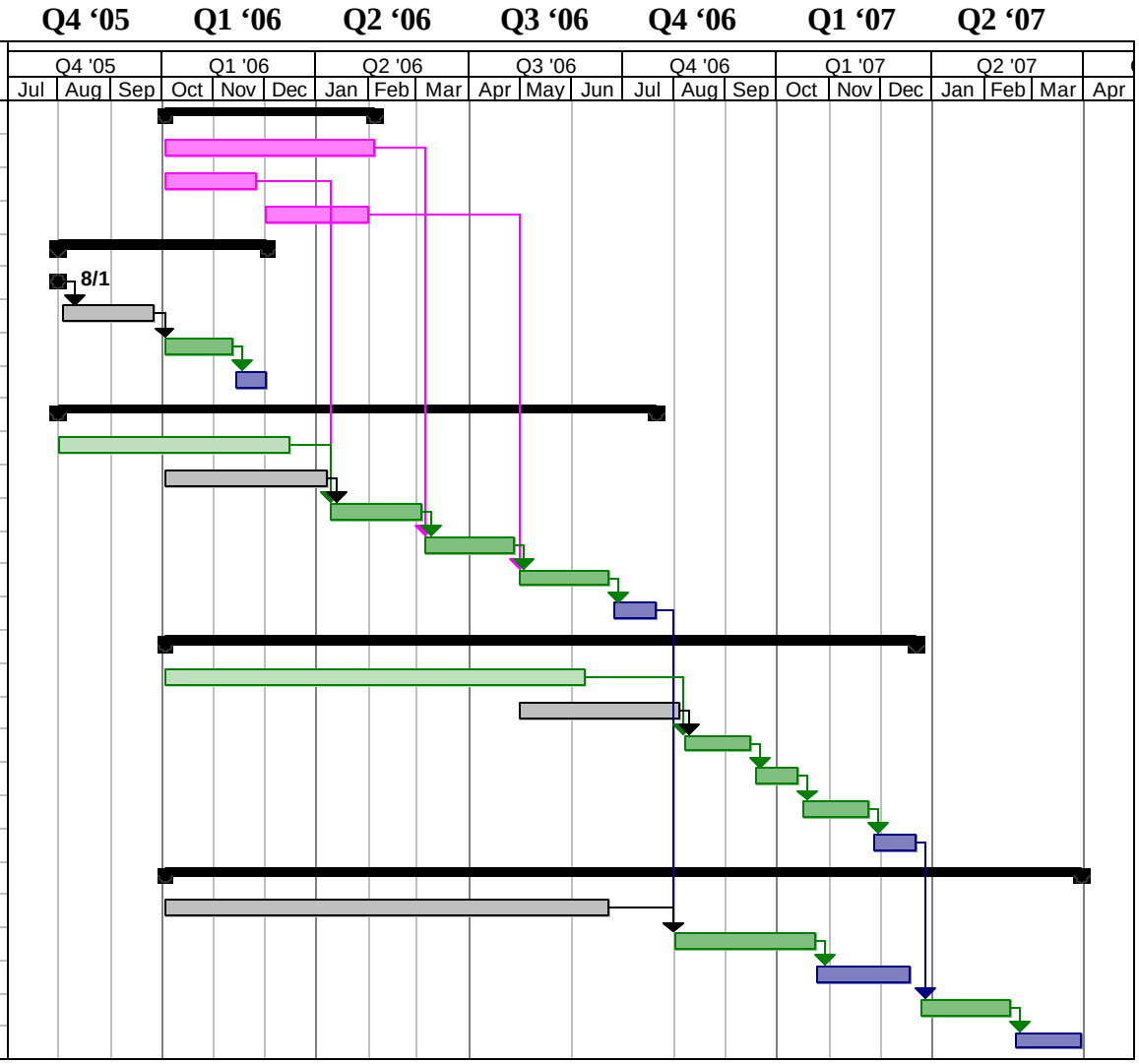
LC Structure Cost (Common Coil)



Preliminary Cost Analysis

Shell……$7K
Yokes……. $8K
Load Pads……..$6K
Bladders…….$2K
Total……$23K

4 Meter SQ Cost Analysis Underway

Accelerated Schedule

ID	Task Name
1	**Infrastructure**
2	Reaction Oven
3	Coil Winder
4	Potting Vessel
5	**LC Design Validation**
6	LC Design Review
7	SC conductor/parts
8	SC fabrication/assembly
9	SC test (common coil)
10	**LC01-LC02**
11	Conductor & cable
12	Tooling & parts
13	Winding
14	Reaction
15	Potting
16	Evaluation
17	**LC03-LC04**
18	Conductor & cable
19	Tooling & parts
20	Coil Winding
21	Reaction
22	Potting
23	Evaluation/Test
24	**LC Structure**
25	Parts
26	LC01-02 assembly
27	LC01-02 test
28	LC01-02 assembly
29	LC01-02 test