LBNL

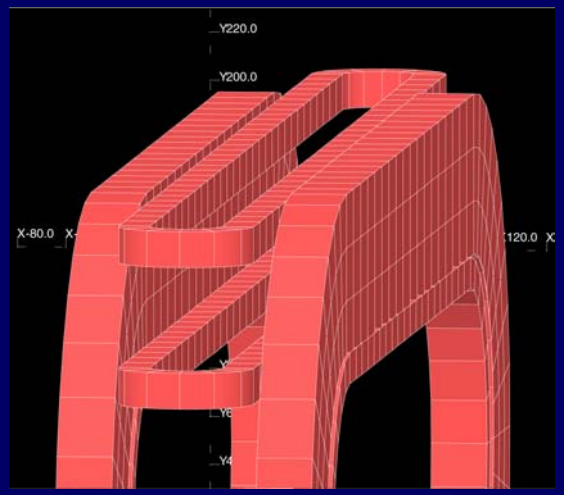
Superconducting Magnet Program

August 5, 2003

Stephen A. Gourlay

Superconducting Magnet Program

- Program Overview
  - Mission and Philosophy
  - History
  - Conductor and Materials
  - Magnets



- Technical Progress, Current Status
- Summary

Mission and Philosophy

- Accelerator Magnet Program emphasizing development of new technology for HEP
  - Issue-driven accelerator magnet program
  - Explore parameter space and challenge existing limits
    - High fields/gradients
    - Accelerator quality
    - Aperture
    - Training
    - Cost effective designs

Prototype Objectives and Features

Magnet	Year	Field	Type	Design Features
D19H	1996	10.2 T	Cos θ	Coil Fabrication Process
D20	1997	13.5 T	Cos θ	Clear bore 50 mm, body/end optim.
RD2	1998	5.9 T	Comm. Coil	New "RD" configuration
RT-1	1999	12.2 T	Comm. Coil	High Field in RD configuration
RD3b	2001	14.5 T	Comm. Coil	New support structure, high stress
RD3c	2002	10.0 T	Comm. Coil	Clear bore 35 mm, auxiliary coils
HD-1	2003	(16.2 T)	Block	New "HD" configuration
RD3d	(2004)	(11.0 T)	Comm. Coil	Bore 40 mm, saturation, end field

Superconducting Magnet Program

Full spectrum development program for superconducting magnet technology

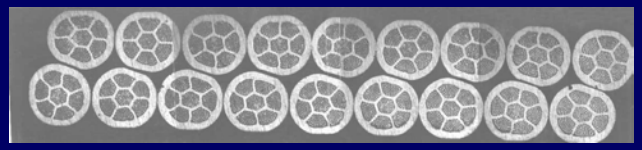
Materials and Conductor → Magnets

- More than two decades at the forefront of magnet technology
  - Our program maintains continuity
    - **Driven by HEP, <u>not</u> lab priorities**
  - Opportunity for innovation – not just an iteration of what was done before
- Strong interactions with industry, labs and universities
  - Exceptional record in materials development with industry
    - **DOE/HEP Conductor Development Program**
    - **SBIR's**
    - **Organizer and sponsor of Low Temperature Superconductor Workshop**

SC Materials and Cable Development

State of the art cabling facility to support HEP technology programs

- Lead Lab for DOE Conductor Development Program
  - Significant progress on Nb_3Sn J_C
    - 50% increase in 3 years
    - ~ 3,000 A/mm^2 at 12 T and 4.2 K
- LHC High Gradient Quad Cable
  - NbTi cable for FNAL completed 2-02
  - Fully keystoned Nb_3Sn for LHC upgrade
- Cable R&D
  - Explore the limits of Rutherford-type cables
    - New techniques
    - New Materials (HTS)



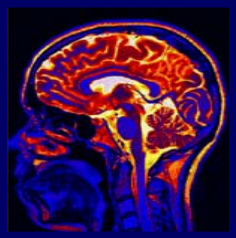
LDRD

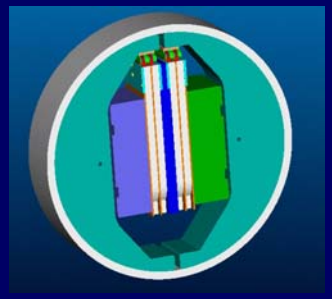
Exploring the limits of technology for new applications

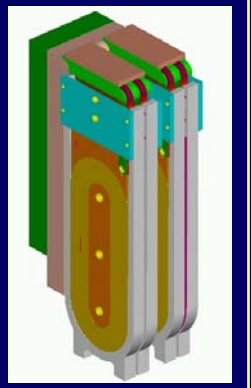
Ex-Situ MRI –

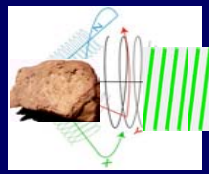
G.L. Sabbi, P. Ferracin, S. Bartlett

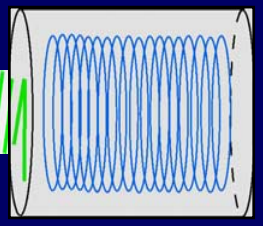
NMR and MRI outside the magnet







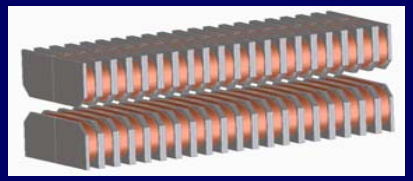


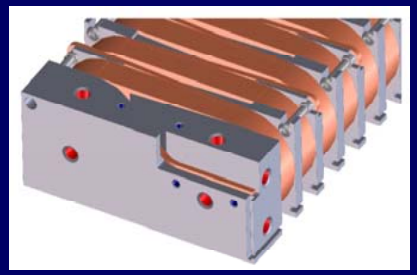


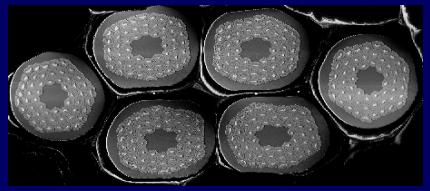
Superconducting Undulator –

D. Dietderich and S. Prestemon (ED)

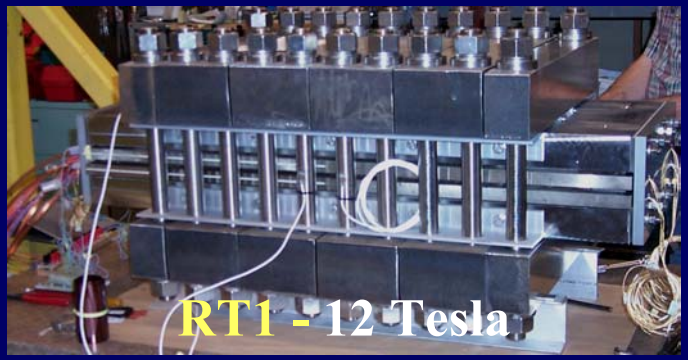
High fields and short periods are required for advancing the field

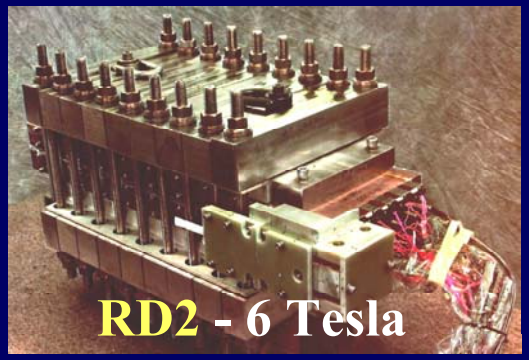


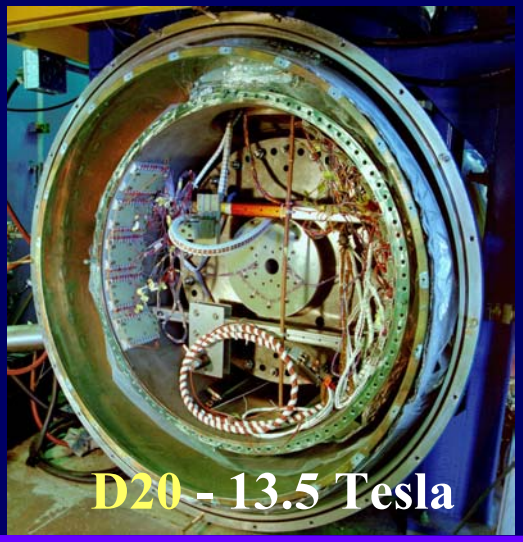


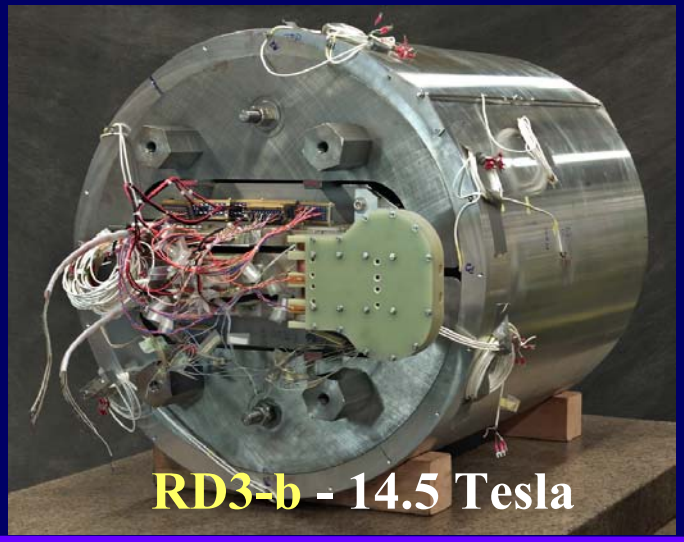


LBNL Prototype Highlights





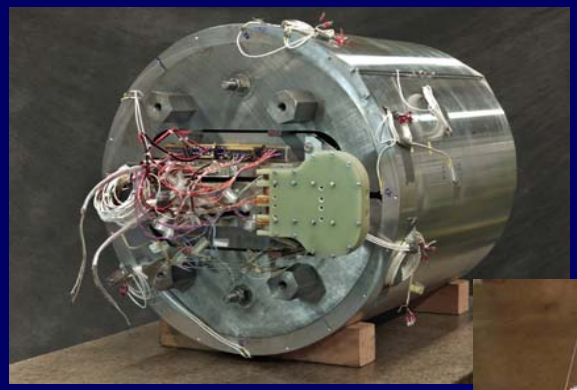


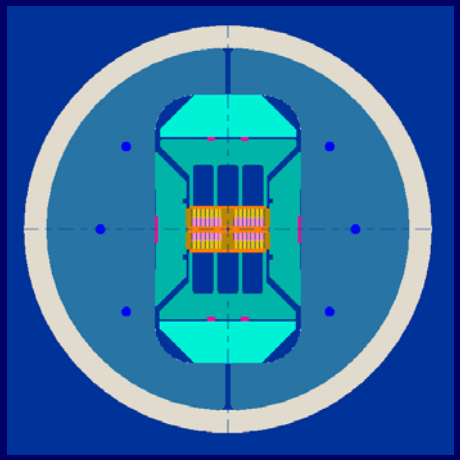


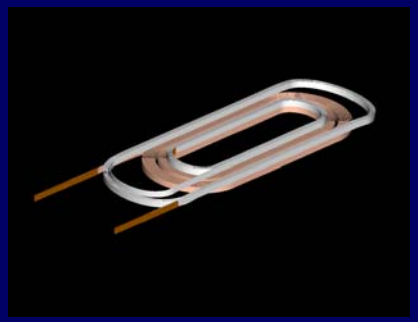
Magnet Development

Fully Integrated Program

- Field quality design options
  - RD Series
- New geometries for high field
  - HD-Series
- Technology Development
  - Sub-scale model program (SM)

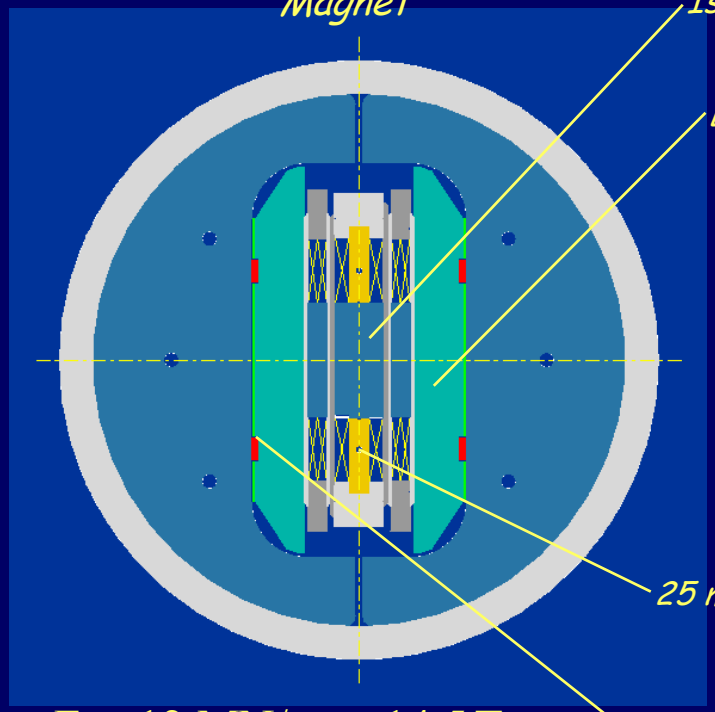






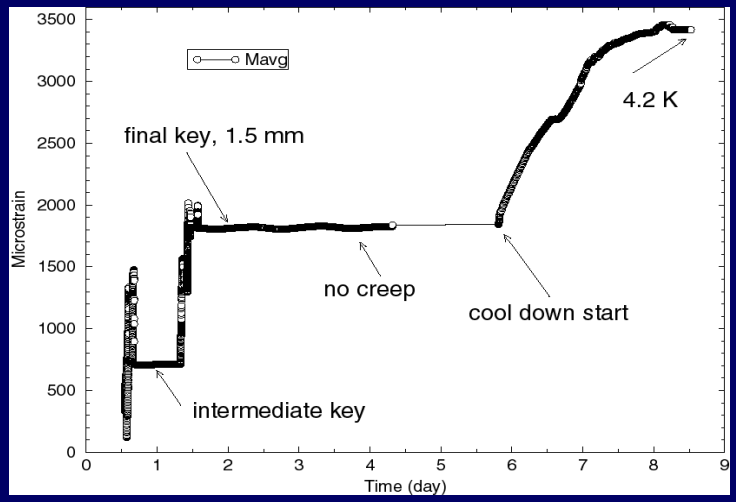
RD Series: Support Structure

RD3b Common Coil Magnet



$F_x = 12$ MN/m @ 14.5 T

RD3b Magnet Assembly and Cooldown



Pressurized Bladders

RD3c Objectives

For the first time in a common coil dipole:

1. Demonstrate central geometric harmonics at 10^{-4} level in a 35 mm bore
2. Perform measurements of other relevant geometric and dynamic effects
3. Compare experimental data with calculated values

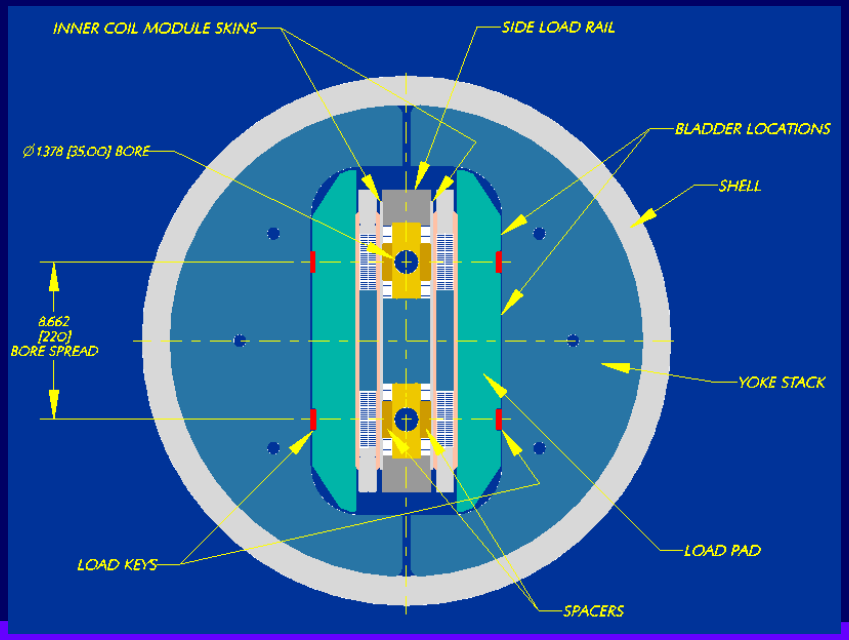
Simple coil configuration:

- RD3B Outer Modules
- New, RD3B-type inner module

Geometric field quality features:

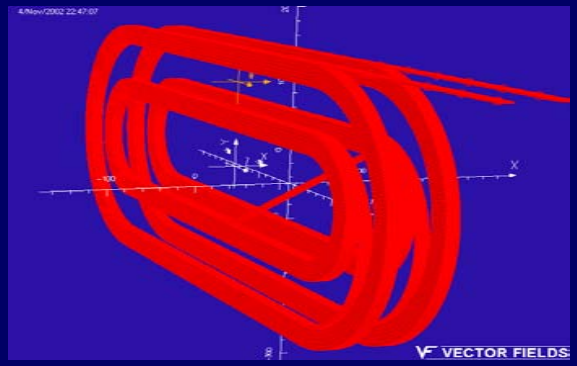
- Auxiliary (pole) turns
- Central spacer

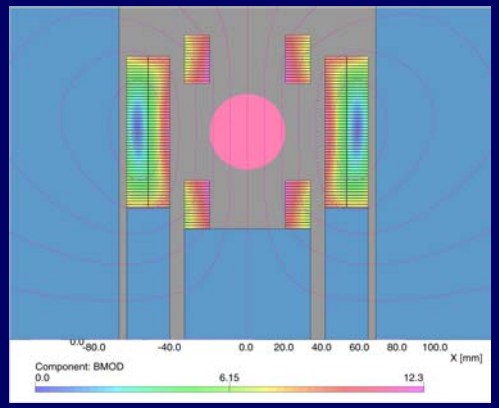
Design field: 10.9 T



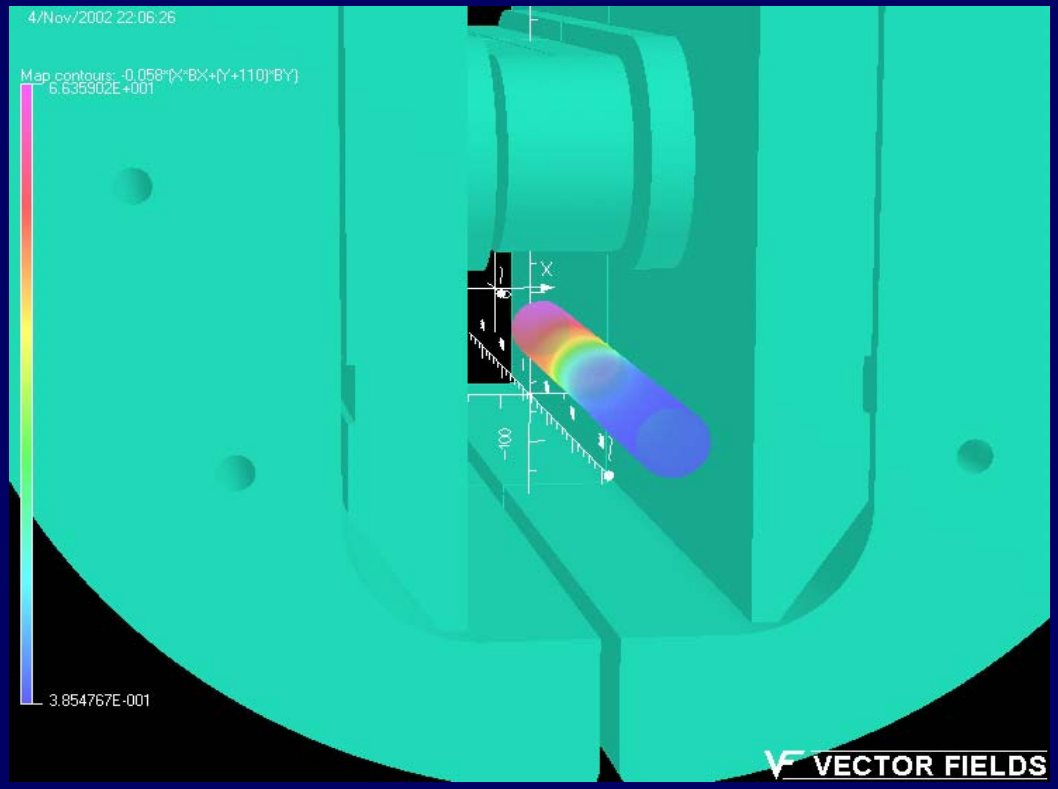
RD3c Magnetic Design

Coil geometry





Field at the probe



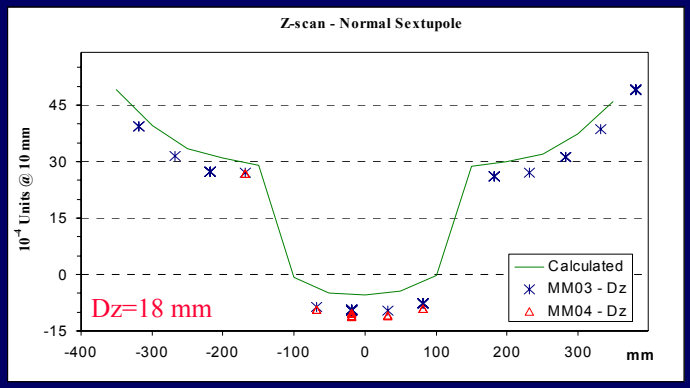
RD3c Test Results: Field Quality

Central harmonics

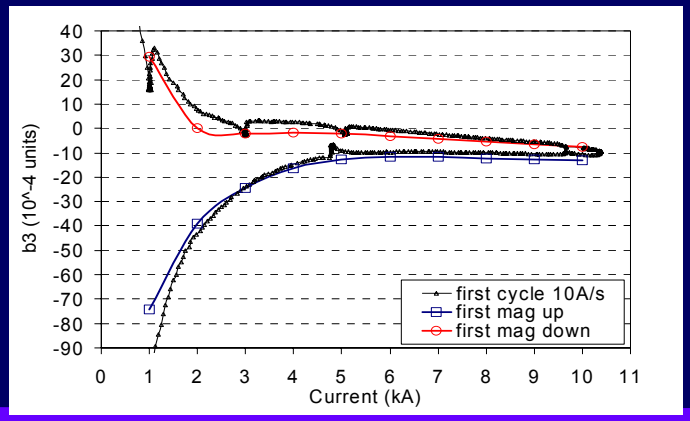
Normal	calculated	measured
b_3 (unit)	-5.44	-10.39
b_5 (unit)	-0.24	-0.02
b_7 (unit)	0.58	0.61
b_9 (unit)	<0.01	<0.01

I_{op}=10 kA, R_{ref}=10 mm

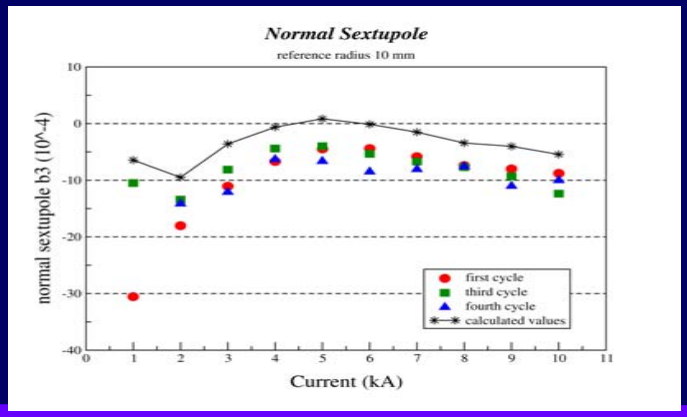
End Field



Magnetization – Eddy Currents



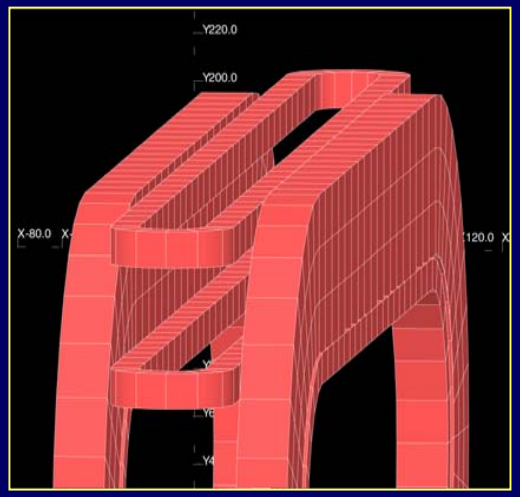
Iron Saturation



RD Series: Next Steps

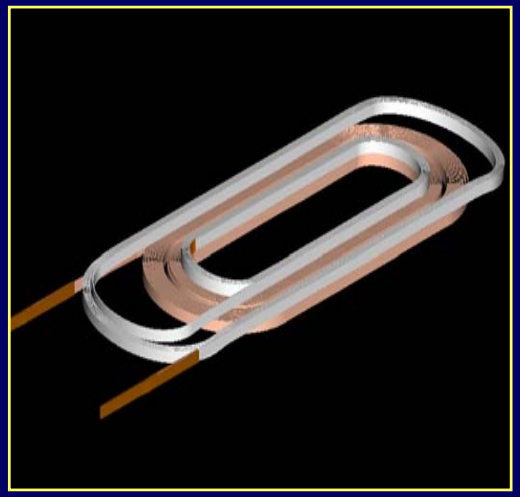
RD3D

- Single layer aux. coils
- End optimization
- 10^{-4} geom. harmonics
- 11 T, 40 mm clear bore



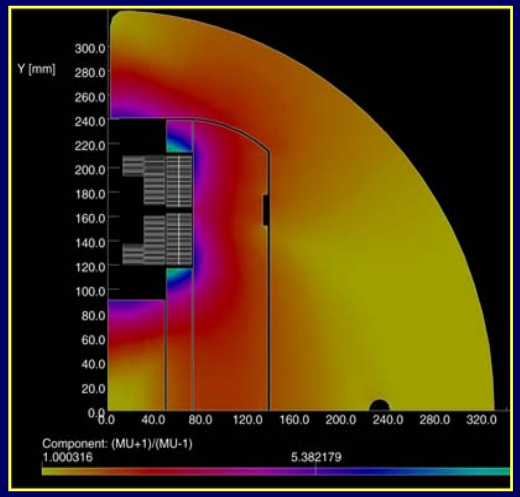
RD4

- Two-layer inner module
- Flared ends for aperture
- 10^{-4} geom. harmonics
- 13 T, 40 mm clear bore



RD5

- Four layers, flared ends
- 10^{-4} geometric, end harm.
- Saturation, magnetization
- 15 T, 40 mm clear bore

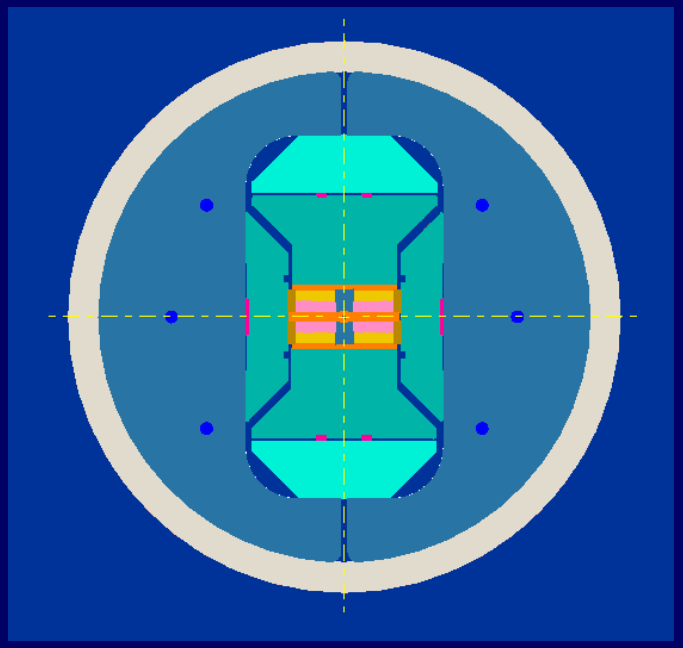


HD Series: 15–18 Tesla

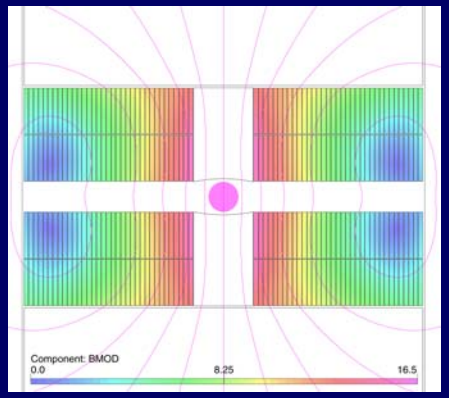
New High Field Dipole Test Configuration

Design Features:

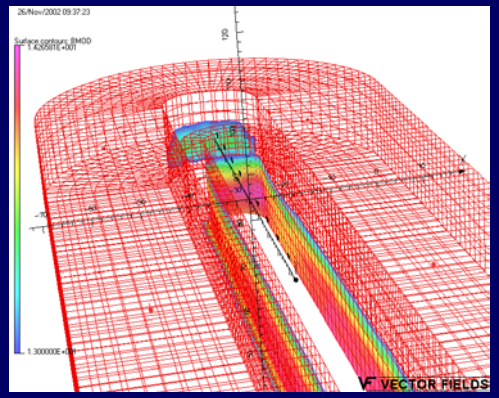
- Single bore
- Two flat double pancakes
- Horizontal configuration
- Dipole field 15-18 T



Magnet cross-section



Coil cross-section

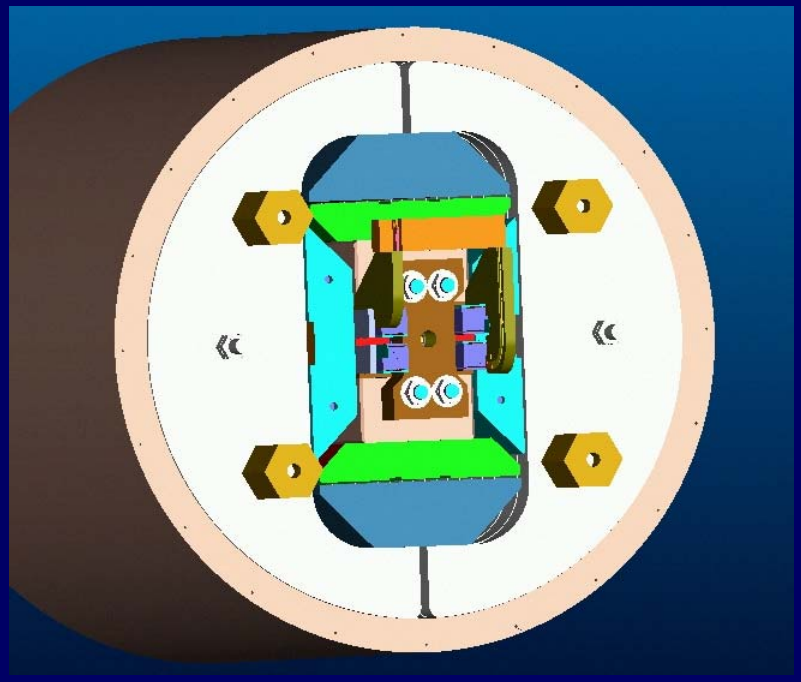


Coil end field

Next Step: HD1 Dipole

Goal (and challenge):

In one step, new coil configuration and new field record: 15+ T



SHORT SAMPLE PARAMETERS

Parameter	Unit	HD1	RD3B
$B_0^{(ss)}$	T	16.2	14.5
$I^{(ss)}$	kA	10.5	10.8
B_{max}	T	15.6	14.8
$J_{cu}^{(ss)}$	kA/mm^2	1.2-1.4	1.1/1.5

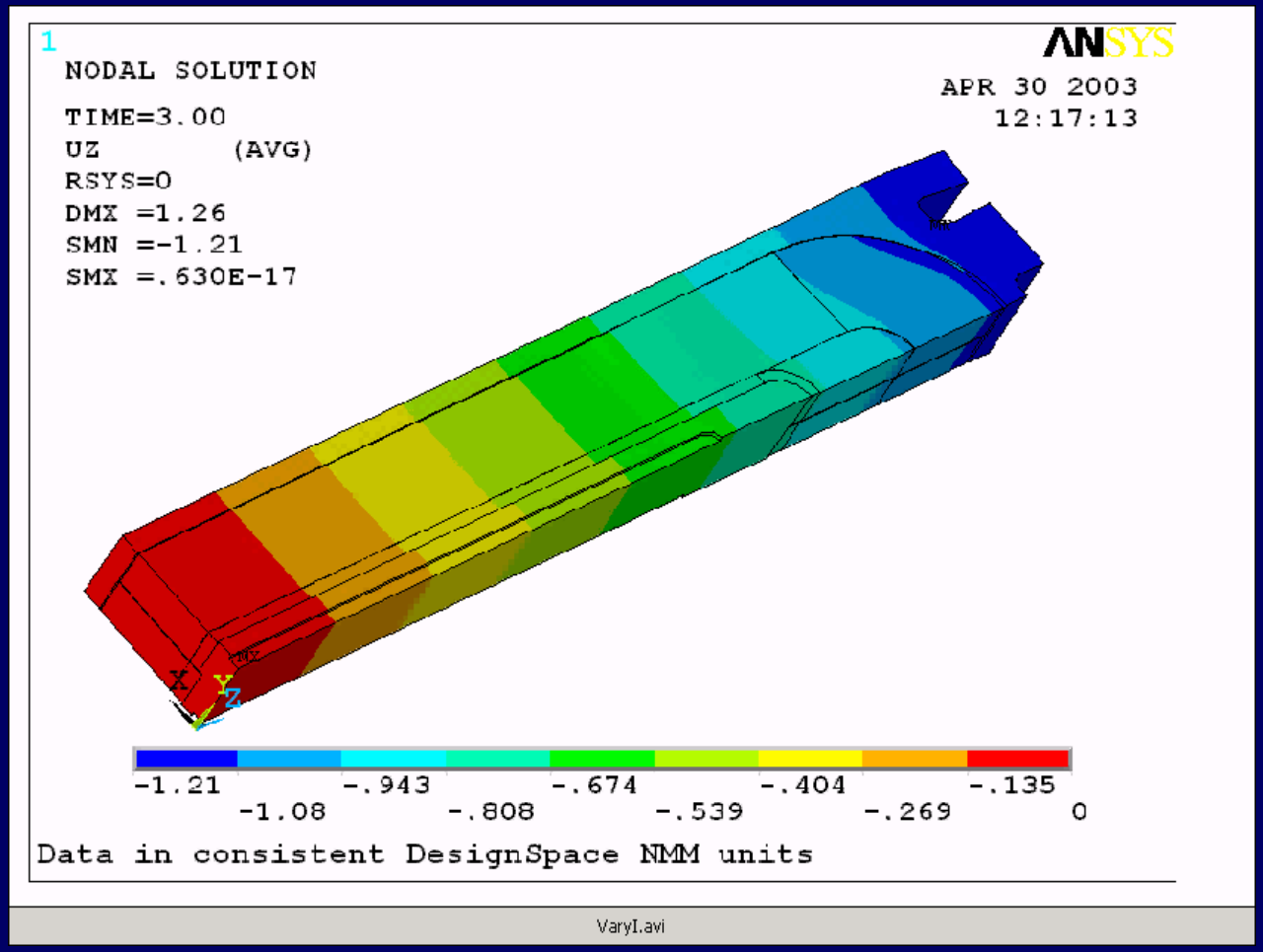
Status:

Coils in reaction oven

Test in September

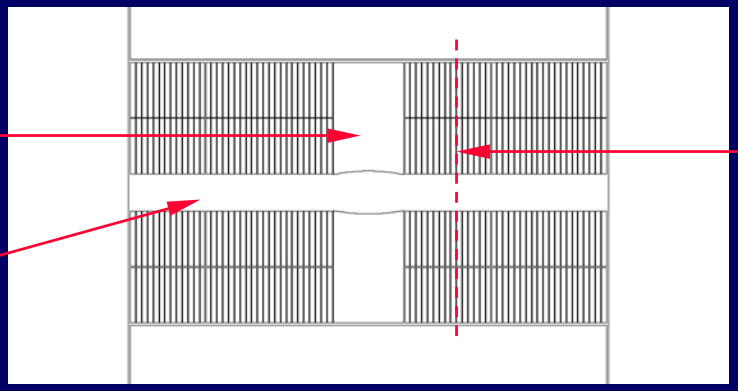
Full 3D Analysis

- Magnetic
- Thermal
- Structural
- Electrical



HD Series: High Field

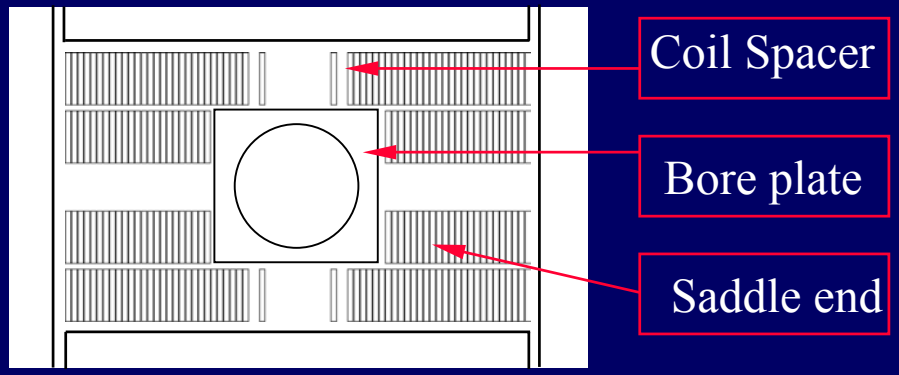
Design features	Dipole field (T)	Iss (kA)
HD1 reference	16.2	10.5
RD3B conductor	15.3	10.0
Nb_3Sn graded coil (8 turns half density)	17.5	14.0
HTS insert 7 turns 0.8 mm 361 A @ 18 T	18.6	13.0



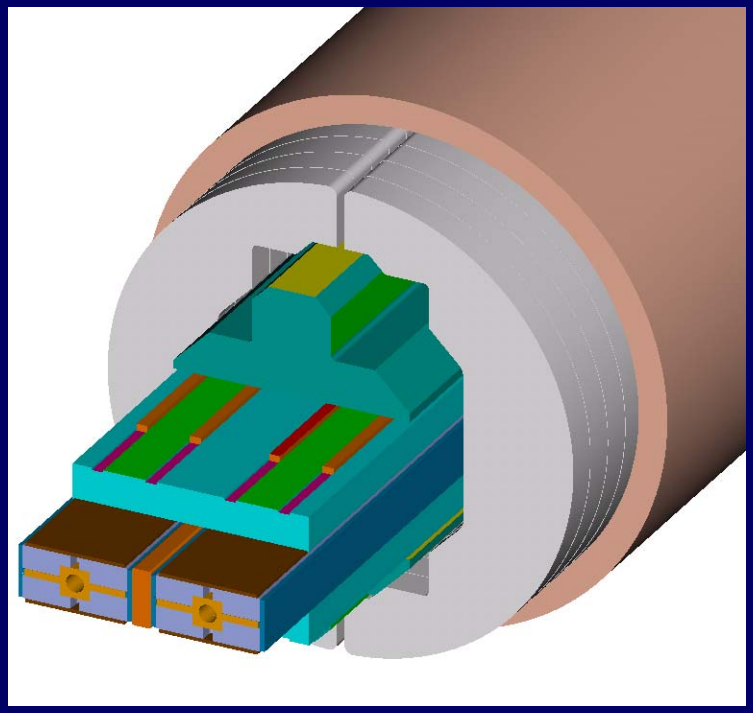
HD Series: Accelerator Quality

Design issues (and priority):

1. Saddle ends for efficiency
2. Clear bore size and support
3. Spacers & field quality

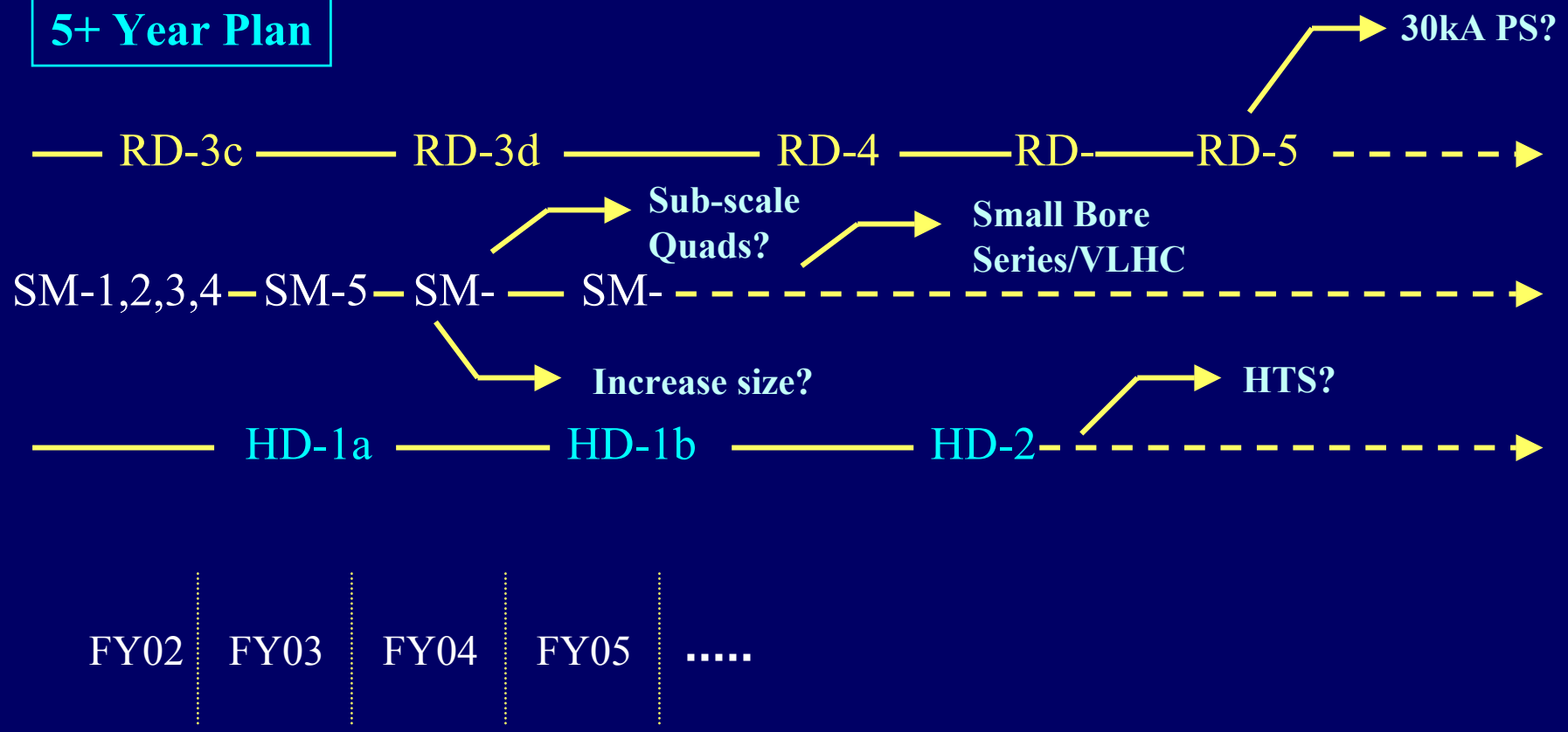


Dual bore configuration: Super LHC?



R&D Program Tree (RD, HD, SM)

5+ Year Plan



LBNL Superconducting Magnet Group

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  - **B. Lau**
  - **N. Liggins**
  - **J. Swanson**
- Engineering/Design Staff
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  - **S. Caspi (ME) – Magnet Design**
  - **P. Ferracin (ME Post-Doc)**
  - **R. Hafalia (ME)**
  - **R. Hinkins (Retiree)**
  - **M. Nyman (EE)**
- Scientific Staff
  - **S. Mattafirri**
  - **D. Dietderich**
  - **S. Gourlay**
  - **A. Lietzke – Test Facility**
  - **A. McInturff (1/2)**
  - **G. Sabbi (1/2)**
  - **R. Scanlan**
- Administrative Support
  - **M. Barry (1/8)**
  - **S. Buckley (1/8)**
  - **J. Smithwick (1/4)**
  - **K. Weber**
- Students
  - **B. Byer (UCB)**
  - **D. Faessler (UCB)**
  - **R. Hafalia, Jr.**

Superconducting Magnet Program

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K. Weber (Administrative Assistant)
M. Barry (Budget Analyst)
S. Buckley (Admin)

EH&S

N. Liggins, K. Weber (Coordinators)

QA/Documentation

R. Hafalia (Coordinator)

Advisory Committee

G. Sabbi (Chairman)
Science and Engineering Staff

SC Materials and Cable Development

R. Scanlan (Leader)

SC Magnet Development

S. Gourlay (Leader)

Matrixed Projects

A. Lietzke (Coordinator)

Superconducting Magnet Program

SC Materials & Cable Development

R.M. Scanlan

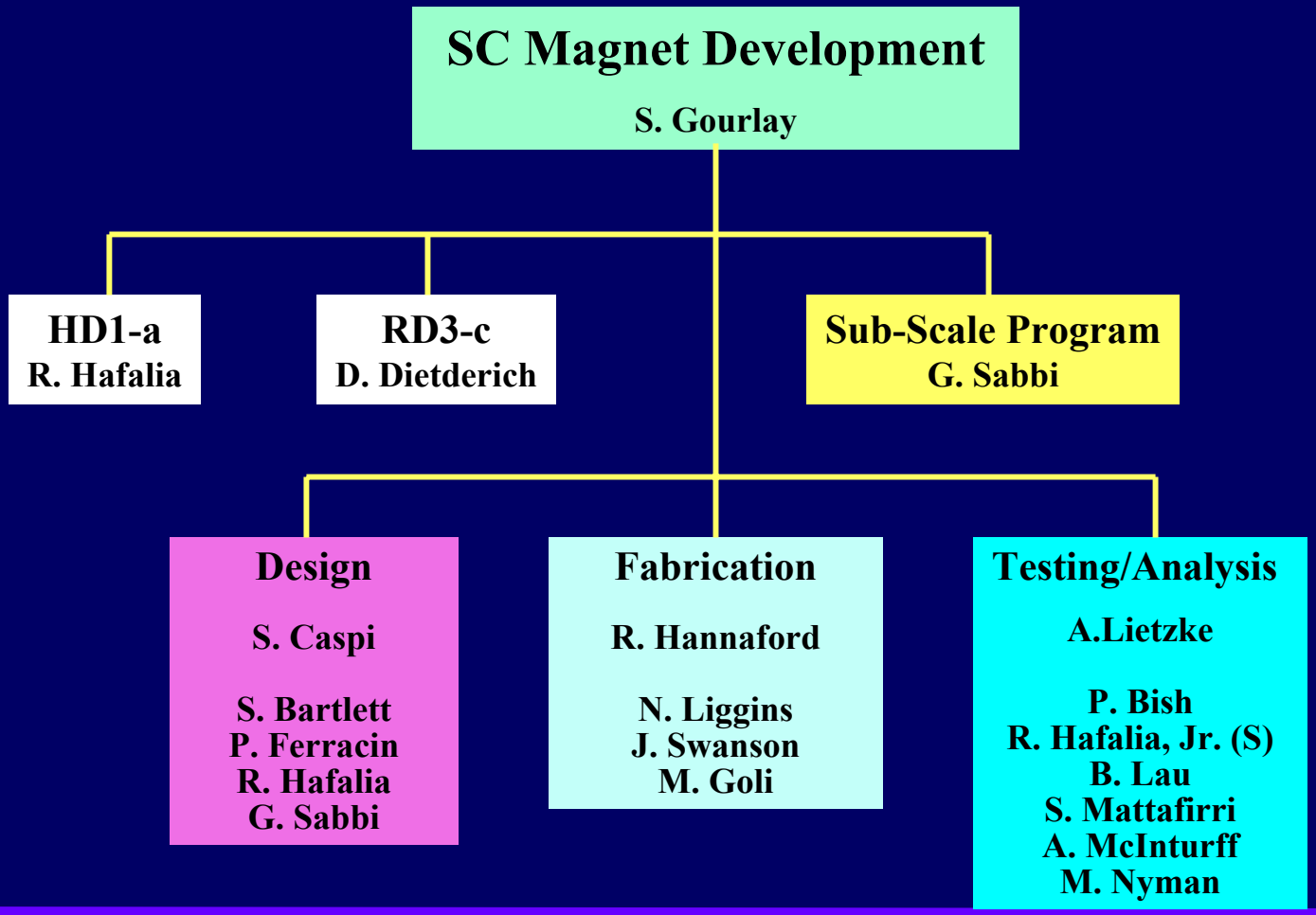
National Conductor Development Program

R. Scanlan

Materials Testing and Characterization

D. Dietderich
D. Faessler
B. Byer

Cabling Facility

H. Higley
N. Liggins

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