Superconducting Magnet R&D Program

LARP Collaboration Meeting

Port Jefferson, NY

September 16 – 18, 2003

Stephen A. Gourlay

Outline

- Magnet Program Goals and Priorities
- LARP Requirements and Issues
  - R&D Topics
- Program Strategy and Structure
  - Initial Tasks
- Base Program Support and Integration
- Goals for the meeting
- FY04 Program

LARP Magnet Program

- Develop Magnet Technology for LHC Luminosity Upgrade
  - Enhance physics opportunities at the LHC
  - Provide tools to AP for optimal IR design
- An ambitious program focusing on Nb_3Sn
  - Large-aperture quadrupoles
    - **Required in all IR upgrade scenarios under consideration**
  - Large-aperture, high-field, beam-separation dipoles
    - **Required in most IR upgrade scenarios under consideration**
- Production-ready IR component designs by 2012

Ancillary Benefits

- Extend US expertise in high–field accelerator magnets
  - Represents the first large-scale use of Nb_3Sn in an accelerator
  - Advances the enabling technology for the next generation of hadron colliders
- Extend collaborative environment between national lab programs
- Develop world-wide collaboration on high-performance magnets
  - CERN, ESGARD, KEK, EU, etc.
  - Workshop on Advanced Accelerator Magnets (WAAM)
  - Superconducting Magnet Collaboration Network

Fundamental Requirements and Issues

- High fields/gradients
- Large aperture/optimized FQ
- High radiation environment

→ Nb_3Sn

- Program must address
  - Technology development/fabrication techniques
  - Field reproducibility
  - Length issues
  - Field quality reproducibility

Issues derived from requirements:

Mechanical support structures
Coil Geometries
Quench Protection
Heat transfer
Materials
Optimal IR designs

Materials R&D Topics

- Conductor
  - Nb_3Sn
    - **J_c**
    - **Magnetization (D_{eff})**
  - HTS?
- Cable R&D
  - Explore the limits of Rutherford-type cables
    - **New techniques**
  - Fully keystoned Nb_3Sn
  - Cores

- Radiation Resistant Materials
  - Push to limit of Superconductor
  - Then, through IR design, reduce dose to maximize lifetime
  - Need to understand limits better
    - **Nb_3Sn 500 MGy**
    - **Organics 1-100 MGy**

Possible area for university participation

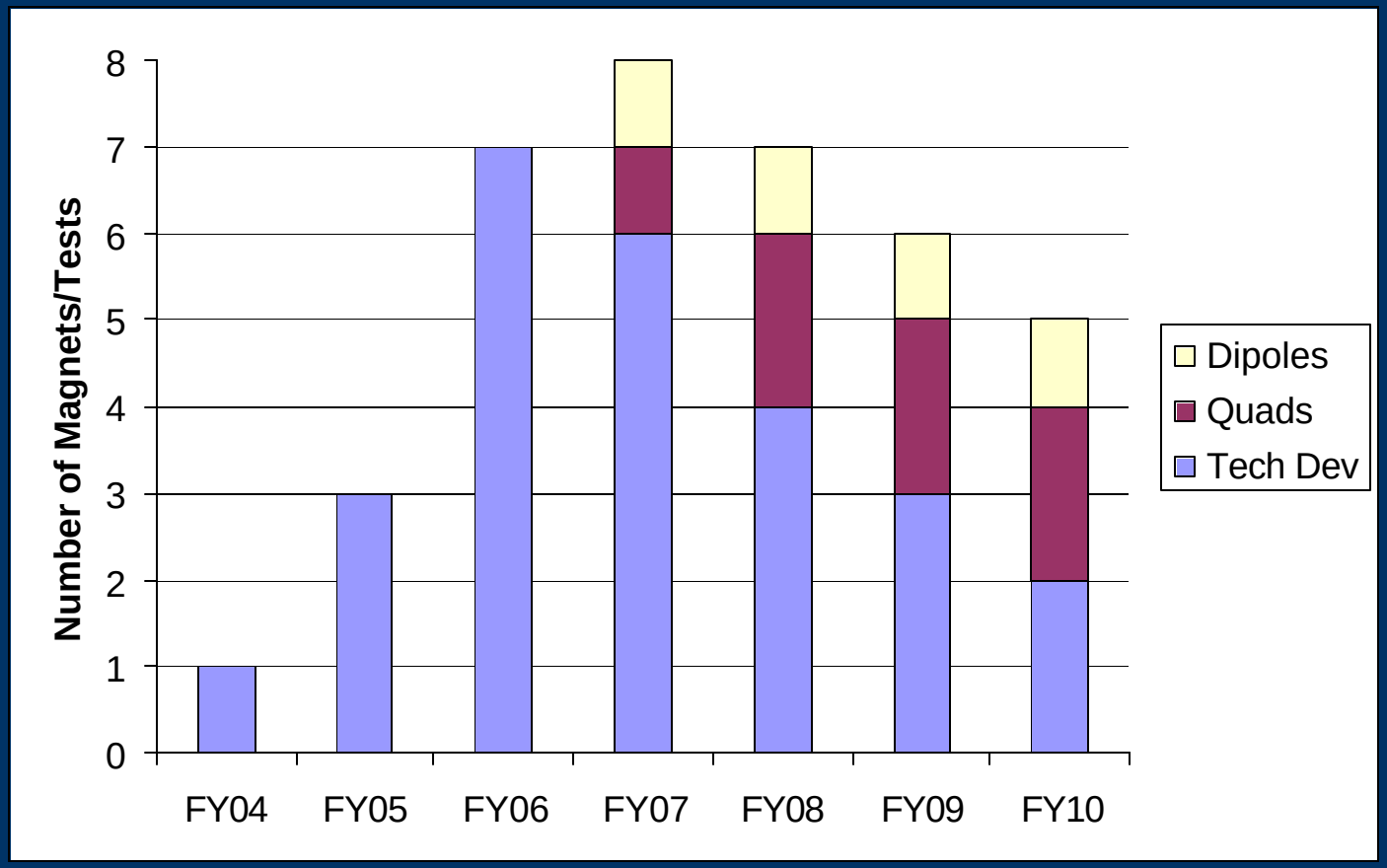
Program Strategy and Structure

- Extend and quantify limits on key performance parameters
- Issue-driven program designed to develop an enabling technology base for LHC upgrades

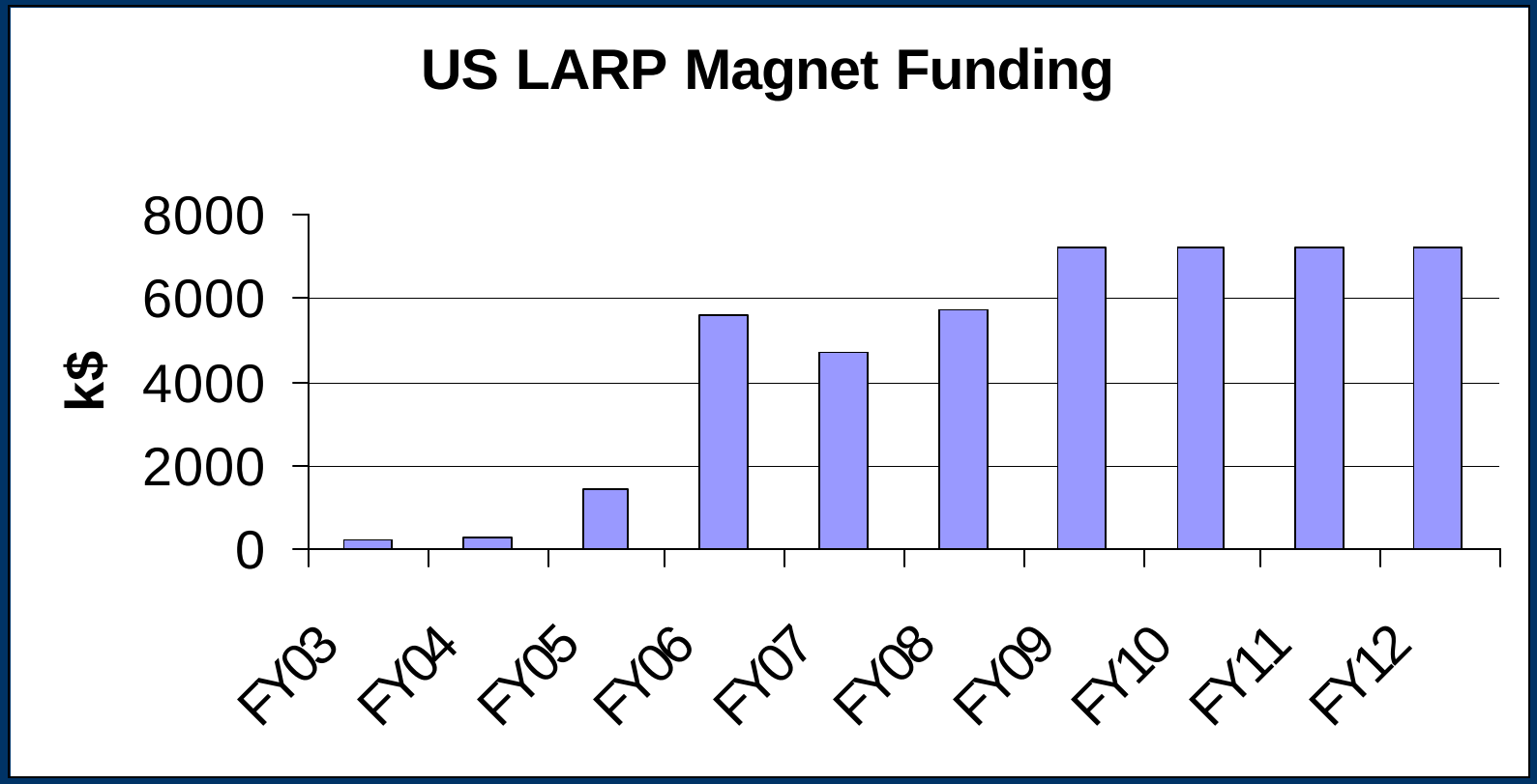
Technology Development – LBNL
Quadrupoles – FNAL, LBNL
Dipoles – BNL, LBNL

- 2003 – 05
  - Technology, simple models
- 2006 – 09
  - More complex models (~ 3/yr)
- 2010 – 12
  - Accelerator-ready prototype

Program Profile

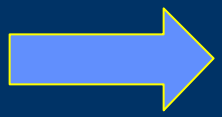


LARP Magnet Program



Near-Term Approach

- Delayed funding turn-on
- Need to establish basis for future planning



- Highly subsidized, cost efficient start
- Focus on technology development

Initial Tasks

- Driven by IR options/needs - development of enabling technology
  - Need input from AP/CERN on priorities
    - **What parameters to push. Most benefit to IR design**
    - **FQ requirements**
- Specifications and Requirements Book
  - Working document
- Provide basis for program planning and development
  - Program will be challenging . . .
- Develop cost-effective ways to investigate new techniques, materials and designs
  - Build on existing Base Program R&D efforts
- Demonstrate that we can achieve operational parameters as soon as possible

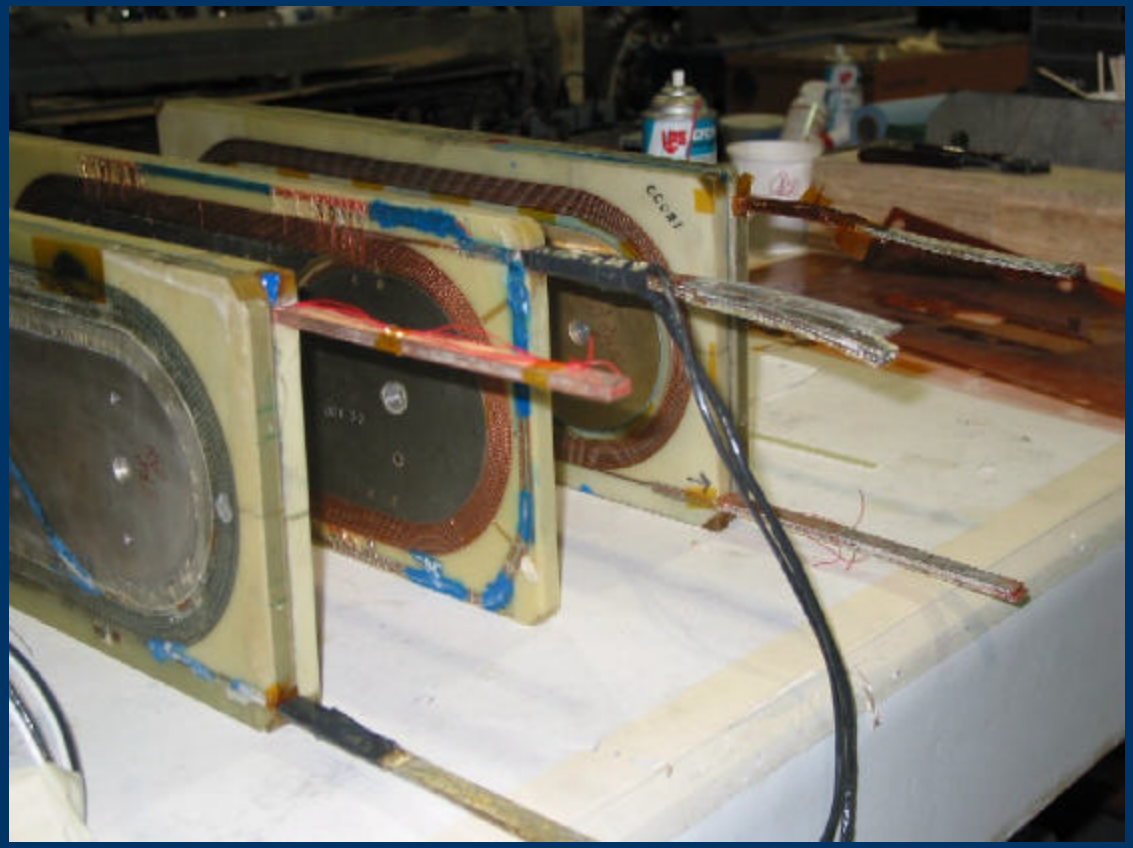
Base Program Support

- Integrate the three US laboratories and include university participation
  - Leveraged by
    - **Existing technology base**
    - **Intellectual resources**
    - **Facilities**

Existing Programs are essential to the success of LARP

- BNL – React and wind Nb_3Sn and HTS studies
- FNAL – Wind and react Nb_3Sn cos-theta dipoles
- LBNL – High field, Nb_3Sn dipoles
- DOE/HEP Conductor Development Program

BNL 10-turn Coils



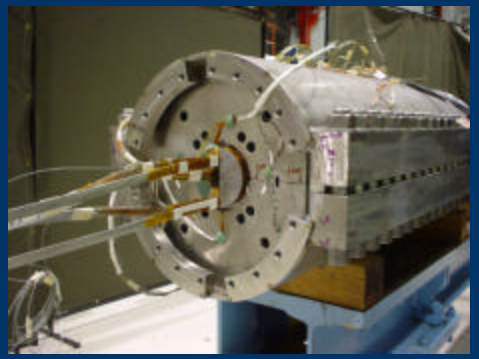
BNL makes 10-turn racetrack coils in modular structure. These modules (cassettes) can be mixed and matched for a variety of experiments in a rapid turn around fashion.

For example, one can easily change aperture, number of layers, type of magnet, etc.

FNAL Magnetic Mirror

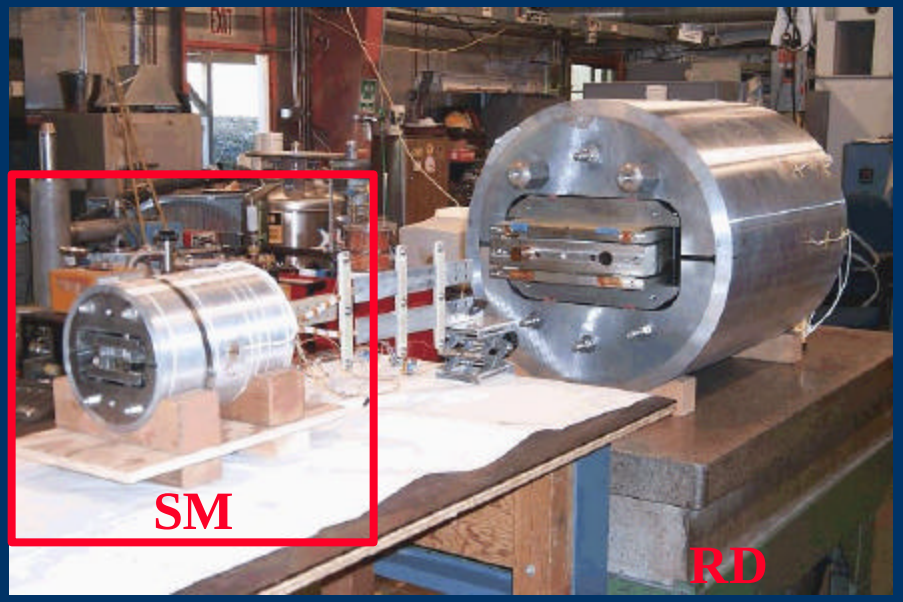
Optimizing magnet technology and quench performance using half-coils and a magnetic mirror:

- Advanced instrumentation
  - **Voltage taps, spot heaters, thermometers, strain gauges**
- Short turnaround time, cost effective
  - **Bolted skin, same yoke and spacers**
- Can be used to test quadrupole coils, as well as dipole coils.



LBNL Sub-Scale Magnets

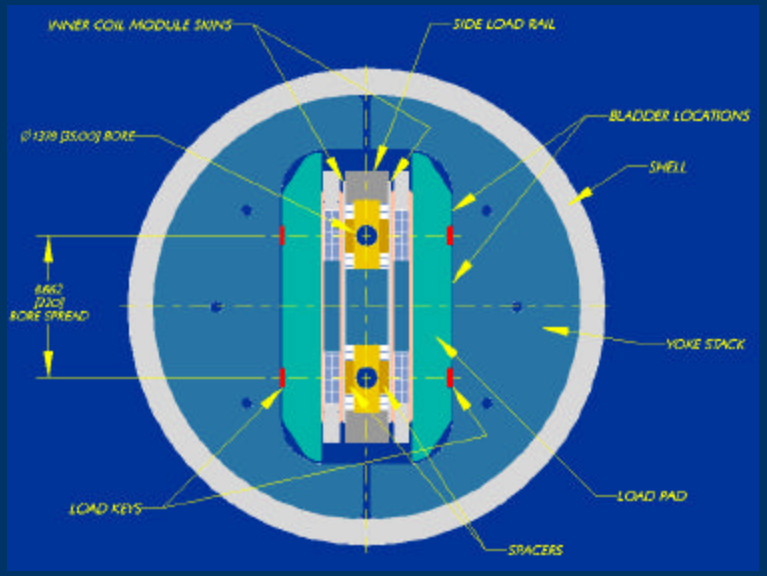
- Scaled version of main magnet
  - Approx. 1/3 scale
- Field range of 9 – 12 Tesla
- Two-layer racetrack coils
  - 5 kg of material per coil
- Streamlined test facility
  - Small dewar
  - Basic instrumentation

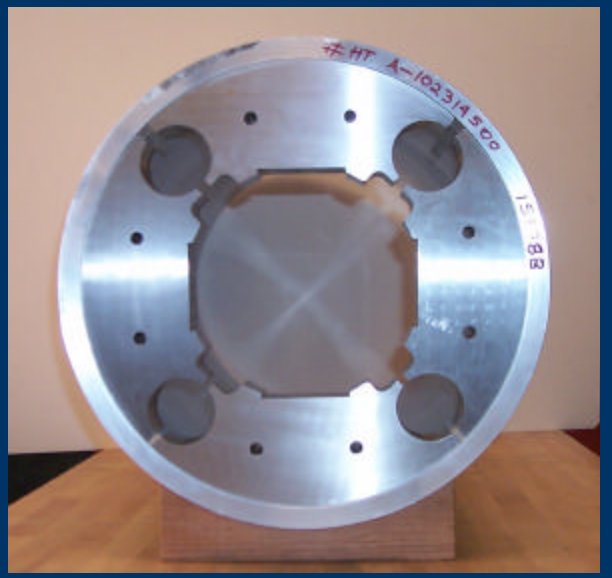


- Can be used by LARP to test, for example,
  - Heat transfer
  - Alternate conductor insulation systems

LBNL Key and Bladder Technology

- Used in dipole base program for mechanical structure
- Application to quad R&D





Goals for the meeting

- Joint meeting with AP group
  - AP input – preliminary goals and requirements
    - e.g. Field quality requirements from injection to operating field/gradient
- Work on details of FY04 activities
  - Discussion
  - Collaborative plan for FY04 tasks
- Generate FY05 Plan

FY04 Magnet Program

- Quadrupoles
  - Support Structure R&D
    - **Labor + most M&S supported by base programs**
- Dipoles
  - Mechanical analysis of BNL design
  - Heat transfer
    - **Modeling**
    - **Measurements via sub-scale model(s)**
- Cable R&D
  - Keystoned cable
    - **Map parameter space, new techniques?**
  - Evaluation
    - **Extracted strand measurements**

This is all technology development!

FY04 Labor Breakdown

- Heat Transfer
  - Analysis — BNL 0.2 S/E
  - Studies — BNL 0.1 S/E, FNAL 0.1 S/E, LBNL 0.2 S/E, 0.2 D/T
- Dipole
  - Design — FNAL 0.2 S/E
  - Dipole mechanical structure — BNL 0.2 S/E
- Cable studies — FNAL 0.1 S/E, 0.1 D/T; LBNL 0.1 S/E, 0.1 D/T

Labor Summary

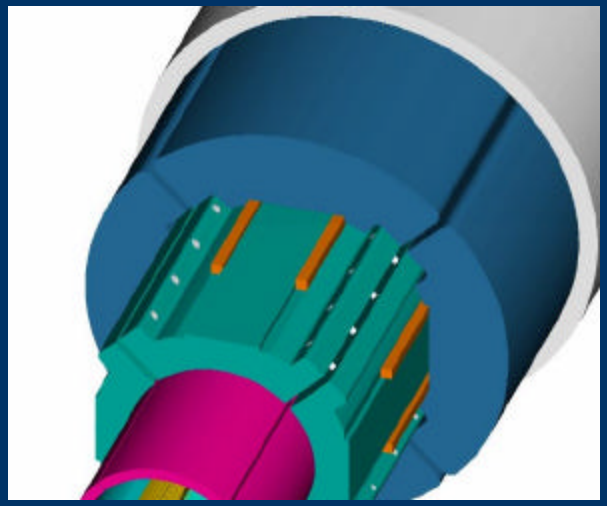
	S/E	D/T
BNL	0.5	0.0
FNAL	0.4	0.1
LBNL	0.3	0.3
Total	1.2	0.4

FY04 M&S Breakdown

• Heat transfer studies	LBNL $5k
• Cable studies	FNAL $2k, LBNL $5k
• Quad structure	LBNL $10k

Technology Development Proposal

- Rapid, cost-effective start using existing techniques and infrastructure
  - Support structure based on LBNL bladder and key assembly technique
  - Use existing D20 tooling for 2-layer coils



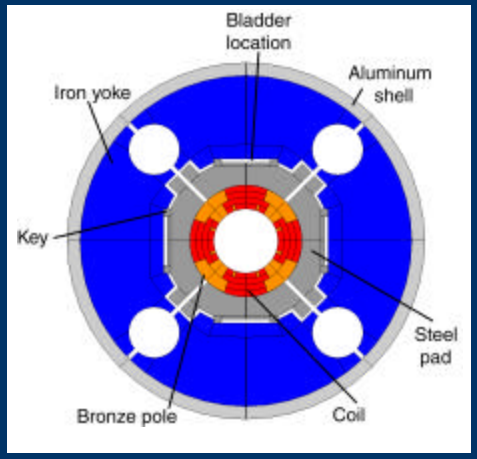
Phase I_a – Mechanical Studies

Phase I_b – 2-layer coil

142 T/m
120 mm bore

Phase I_c – 4-layer coil

230 T/m
90 mm bore



Summary

- Delayed funding turn-on
- Need to establish basis for future planning

- Highly subsidized, cost effective start
  - Fundamental issues specific to LARP requirements
- Focus on technology development

Goal: Accelerator-ready design – production start ~ 2012

A Very Challenging Task