Technology Development

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Outline

- LARP Technology Development Program
  - Goals and Approach
- LARP R&D Topics
- Building on the Base Programs
  - Materials
  - R&D Program
- First steps

Goals and Approach

- Provide basis for program planning and development
  - Program will be challenging . . .
- Cost-effective way to investigate new techniques, materials and designs
  - Build on existing Base Program R&D efforts
- Demonstrate that we achieve operational parameters as soon as possible

R&D Topics

- Performance Issues
  - High fields/gradients
  - Large aperture
  - High, radiation induced heat loads
- Program Components
  - Mechanical support structures
  - Quench Protection
  - SC strand and cable
  - Heat transfer
  - Rad hard materials
  - Appropriate IR designs

Same issues for dipoles and quadrupoles

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
- 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

Initial Program

- Conceptual designs
  - Identify primary issues
- Technology Development
  - Range in complexity
  - Many important topics can be studied using a parametric approach
- Build on Base Programs
  - DOE Conductor Development Program
  - LBNL "Sub-scale magnets"
  - BNL "10-turn coils"
  - FNAL "Magnetic Mirror"

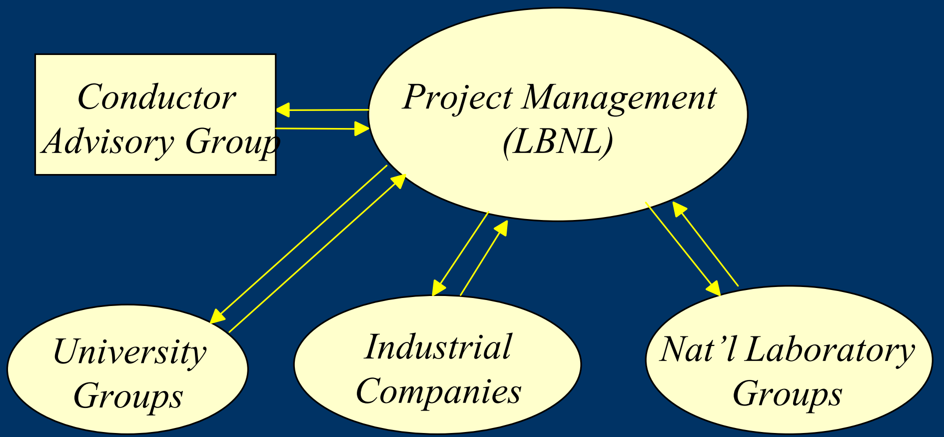
–Technology development and fabrication techniques

–Field reproducibility

–Length issues

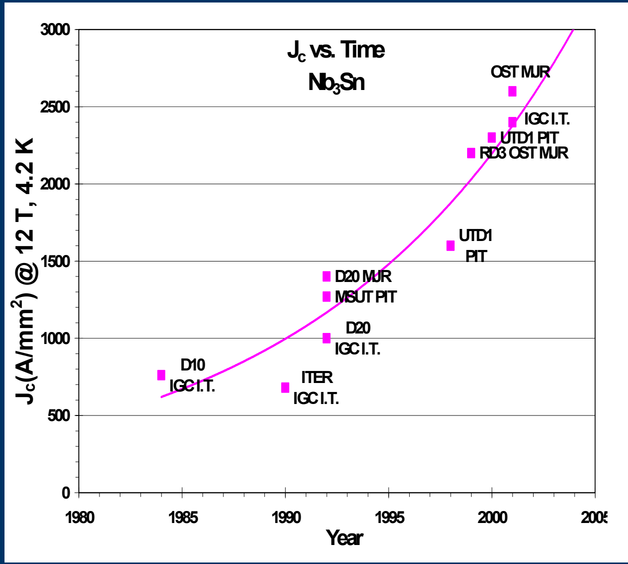
–Field quality reproducibility

DOE Conductor Development Program



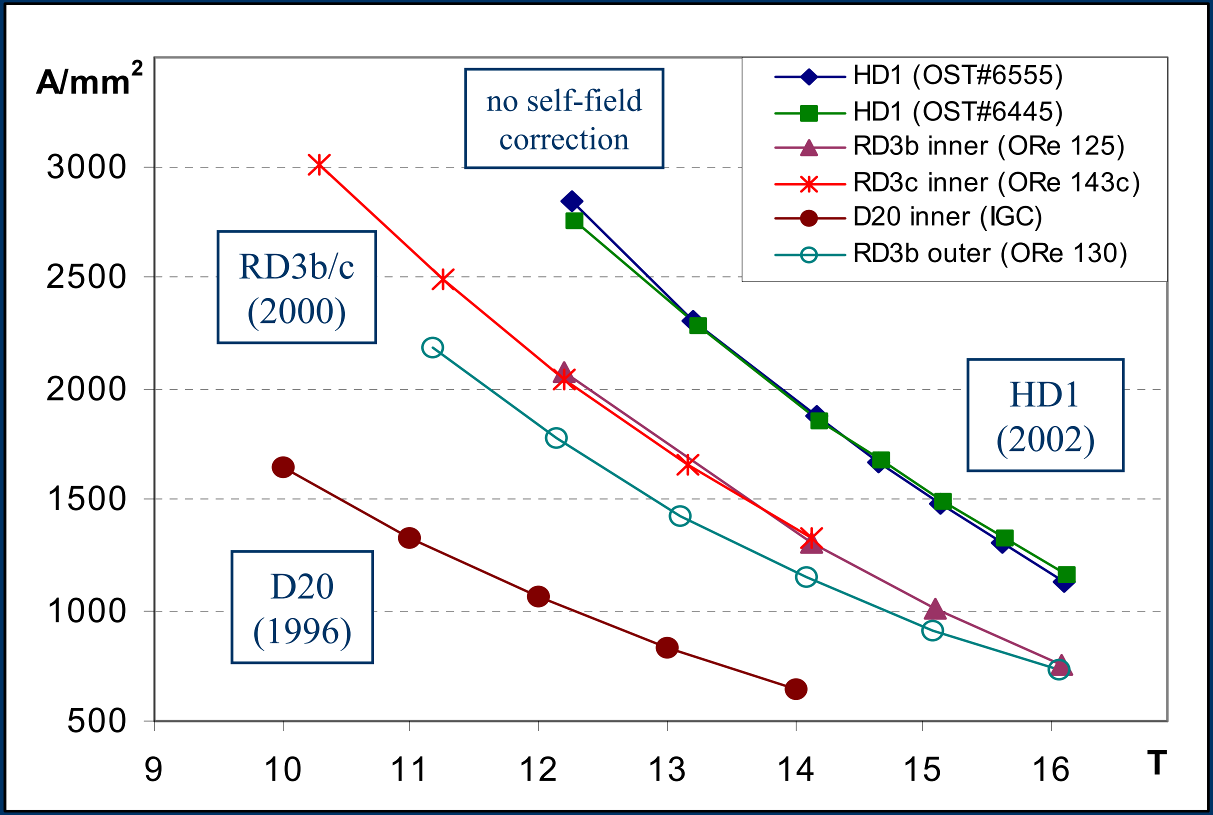
Started in 2000
Phase I : improve performance
Phase II : Scale-up, cost issues

Parameter	Unit	Goal	Progress
J_c	kA/mm^2	> 3.0	2.4-2.6
D_{eff}	μm	< 40	70-100
L_{piece}	km	> 10	1.0-1.5
H.T. time	hr	< 400	150
Cost	$/kA-m (12 T)	< 1.5	6



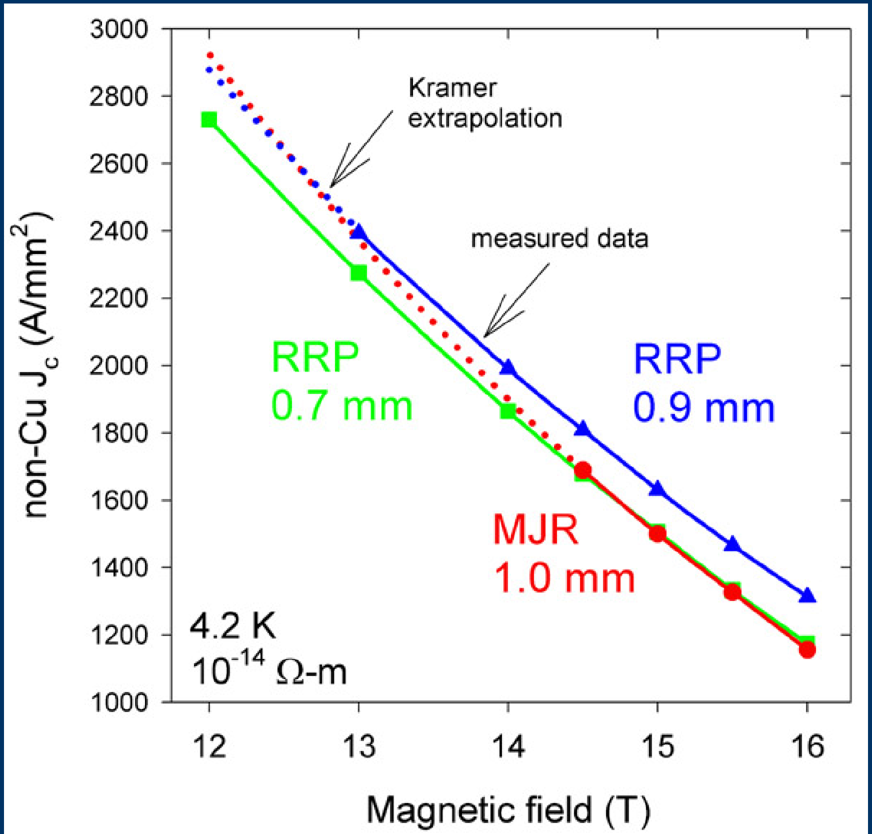
Nb_3Sn Critical Current Density

Nb_3Sn wires for High Field Dipoles, 1996-2002



50% Increase
In 3 years

OST has achieved world record Jc values for Nb_3Sn made by two processes



OST has completed production quantities of high Jc wires for use in HD-1

- MJR process (delivered Aug 2002, meets specification)
  - $J_c > 2250$ A/mm^2; best value > 2440 without self-field correction
  - RRR > 2
  - Yield: > 72 % piece lengths > 250 m
  - $D_{eff} < 120$ microns
- RRP process (delivered Jan 2003, exceeds J_c specification)
  - $J_c > 2750$ A/mm^2; best value > 3000 A/mm^2
  - RRR > 13
  - Yield: 86 % piece lengths > 250 m
  - $D_{eff} < 120$ microns

Status of Jc optimization work

- J_c values exceeding 3000 A/mm^2 (12 T, 4.2 K)have been achieved in a practical Nb_3Sn conductor
- Further increases are expected from heat treatment optimization studies.
- Large gains are still possible in intrinsic Nb_3Sn layer J_c; questions remain on whether these gains can be achieved in practical conductors
- Some “tradeoff” in J_c may be required to meet other HEP goals, espeically D_{eff}

R&D work on reducing magnetization effects include:

- Magnet designs that can accommodate larger magnetization effects
- Changes in composite geometry to reduce filament coupling
- Alternate fabrication approaches

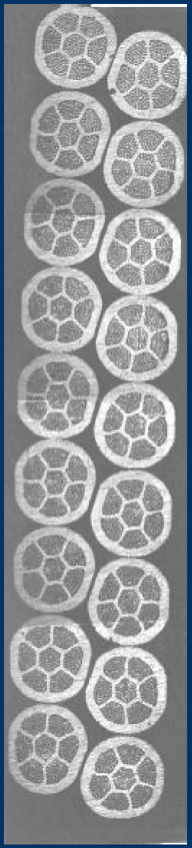
Steady progress toward program goals

- Long Range Goals
  - J_c = 3000 A/mm^2
  - D_{eff}= 40 microns or less
  - Piece length > 10,000 m
  - Heat treatment < 400 hr
  - Cost: < $1.50/kA-m(12 T)

- Progress
  - J_c = 3000 A/mm^2 (FY03)
  - Proof of principle shown;
  - Practical demos in progress
  - 250-1500m for both MJR and internal Sn processes
  - 150 hr
  - $ 5.50/kA-m (Int. Sn)
    $7.75/kA-m (MJR)

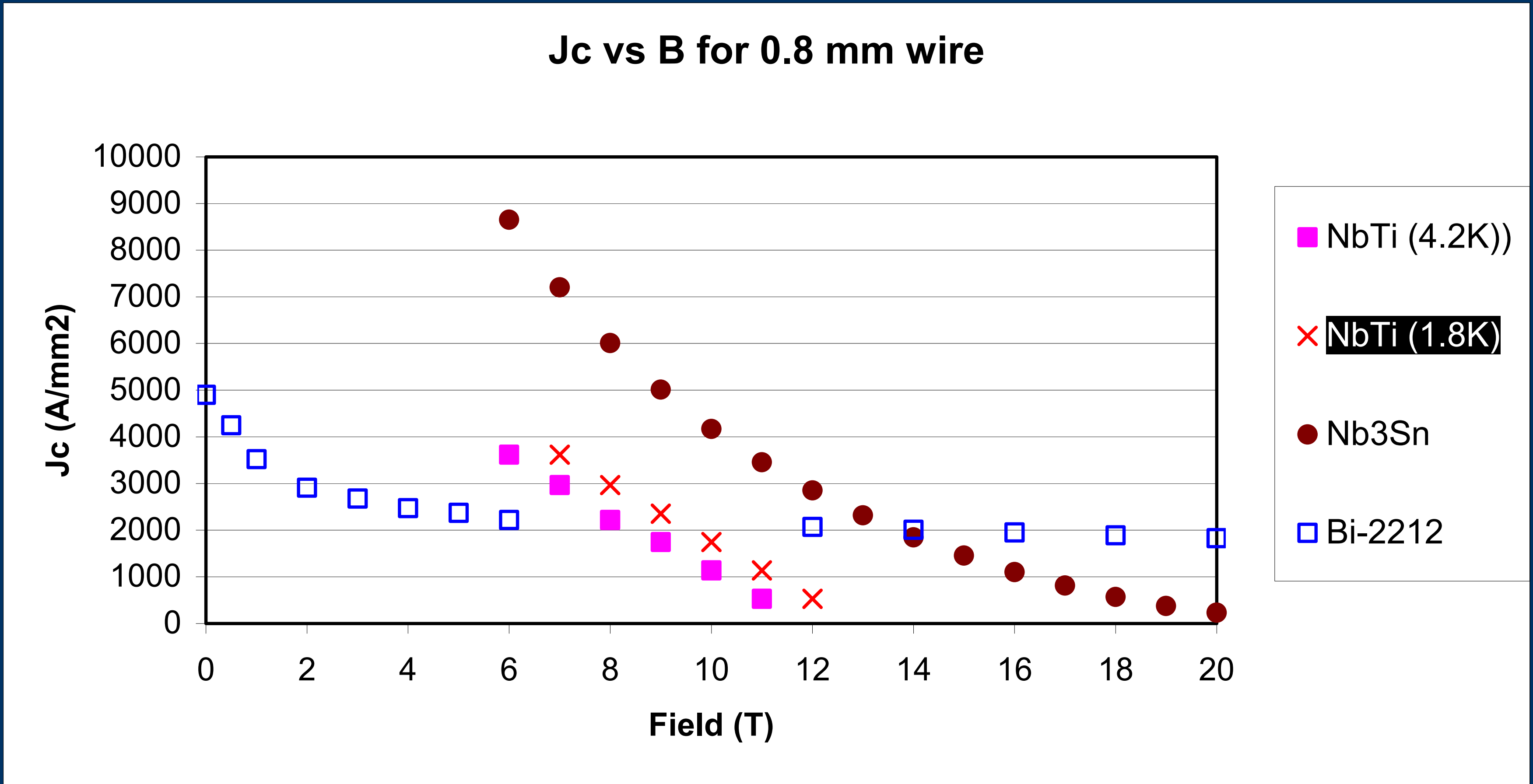
Bi-2212 round wire shows promise for accelerator magnets

- J_c(12T, 4.2K, non-silver) > 2000 A/mm^2 in new material (Showa)
- Long lengths(> 1500 m) are being produced
- New result: 30 strand cable; Ic = 6.8 kA at 6 T
- React/wind (BNL) and Wind/react (LBNL) coils are being made
- ***Not part of base LARP plan, but we will keep an eye on it … may be important for dipole-first IR.***



Cable made at LBNL

J_c "Crossover" for Bi-2212 and Nb_3Sn is near 14 T, but J_{eng} is x2 lower



Conductor Development Program Priorities

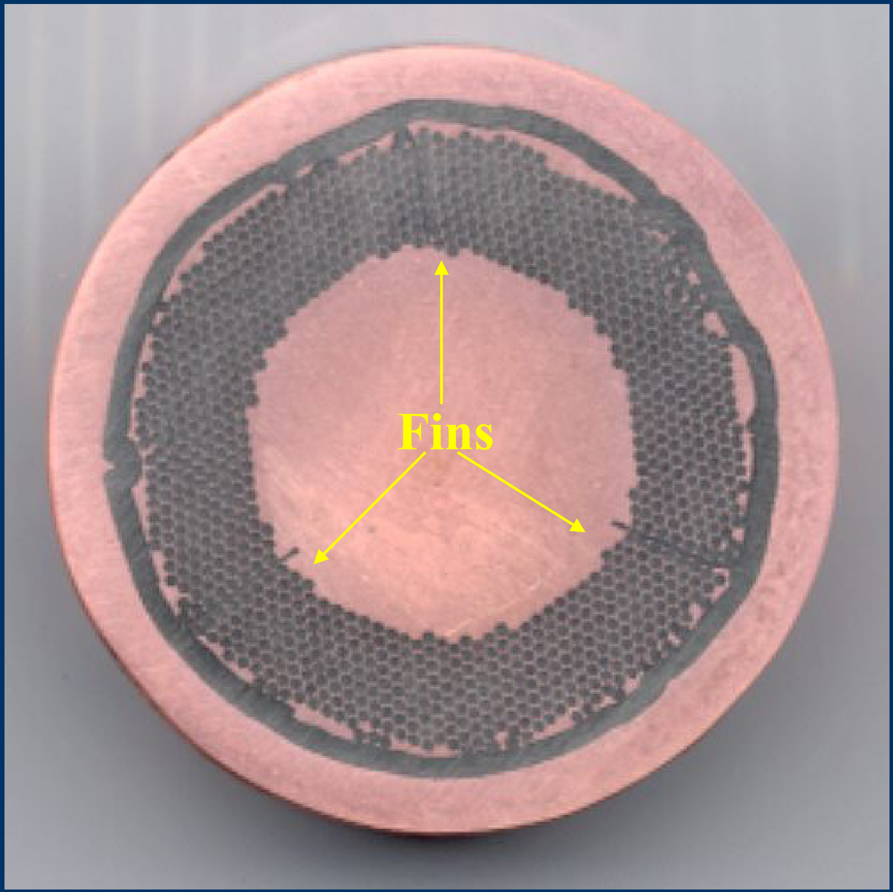
FY03

OST

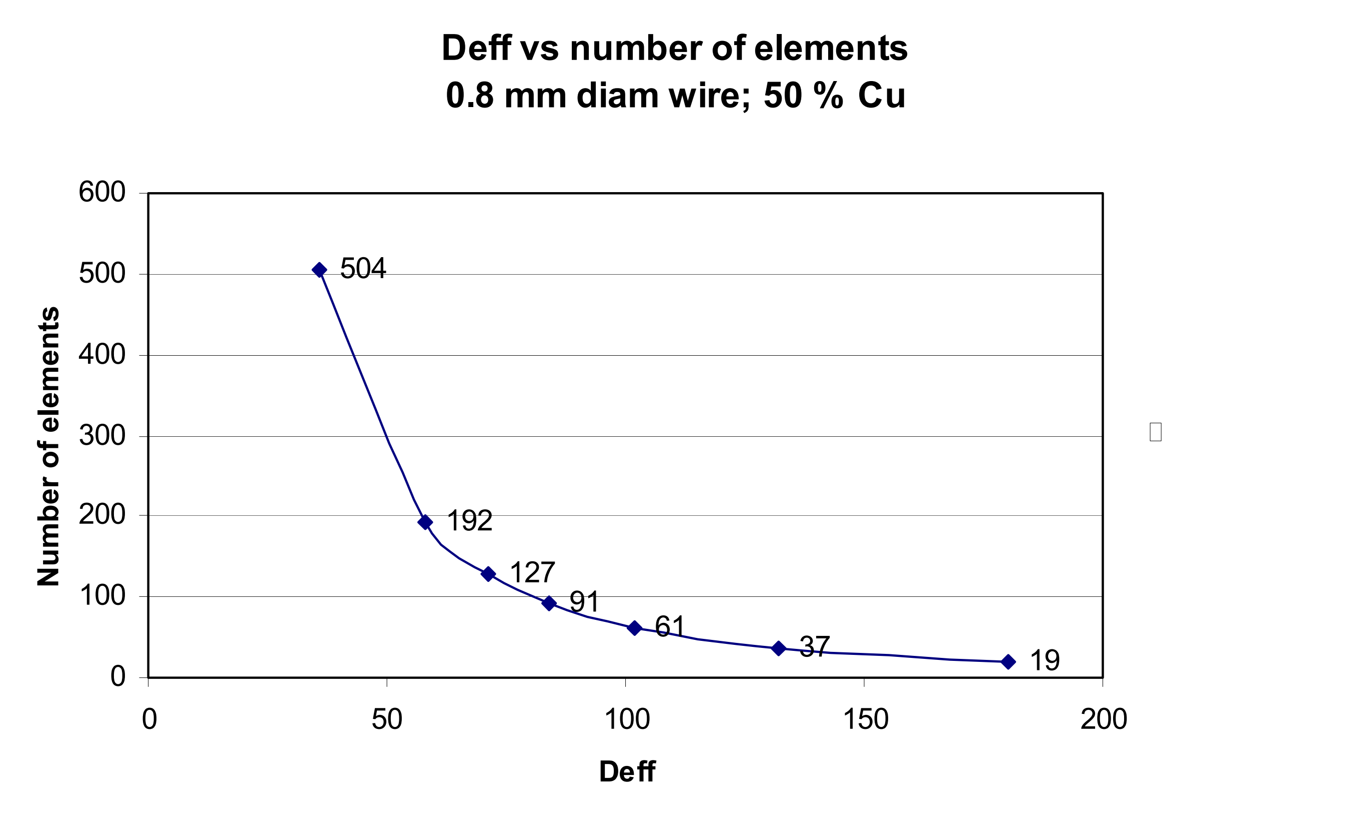
- Reduce D_{eff} from 120 to 50 microns
- Improve diffusion barriers to increase Cu RRR
- Scale up HER (Hot Extruded Rod) billet size

OKAS

- Reduce D_{eff} from 120 to 50 microns with internal fins



Low D_{eff} in high J_c Nb_3Sn



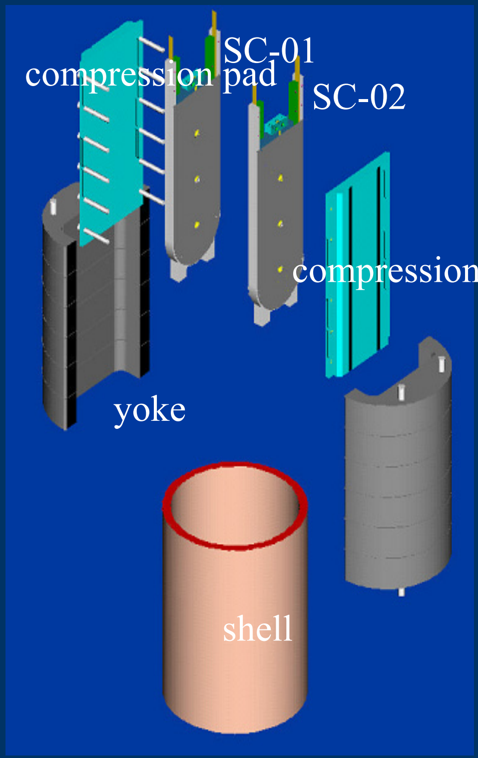
Fundamental issue is restacking large numbers of subelements

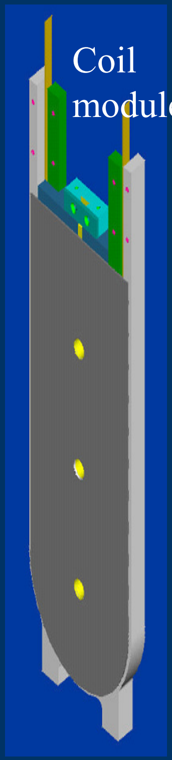
SM Series: Subscale Prototypes

- 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

SM Magnet Features



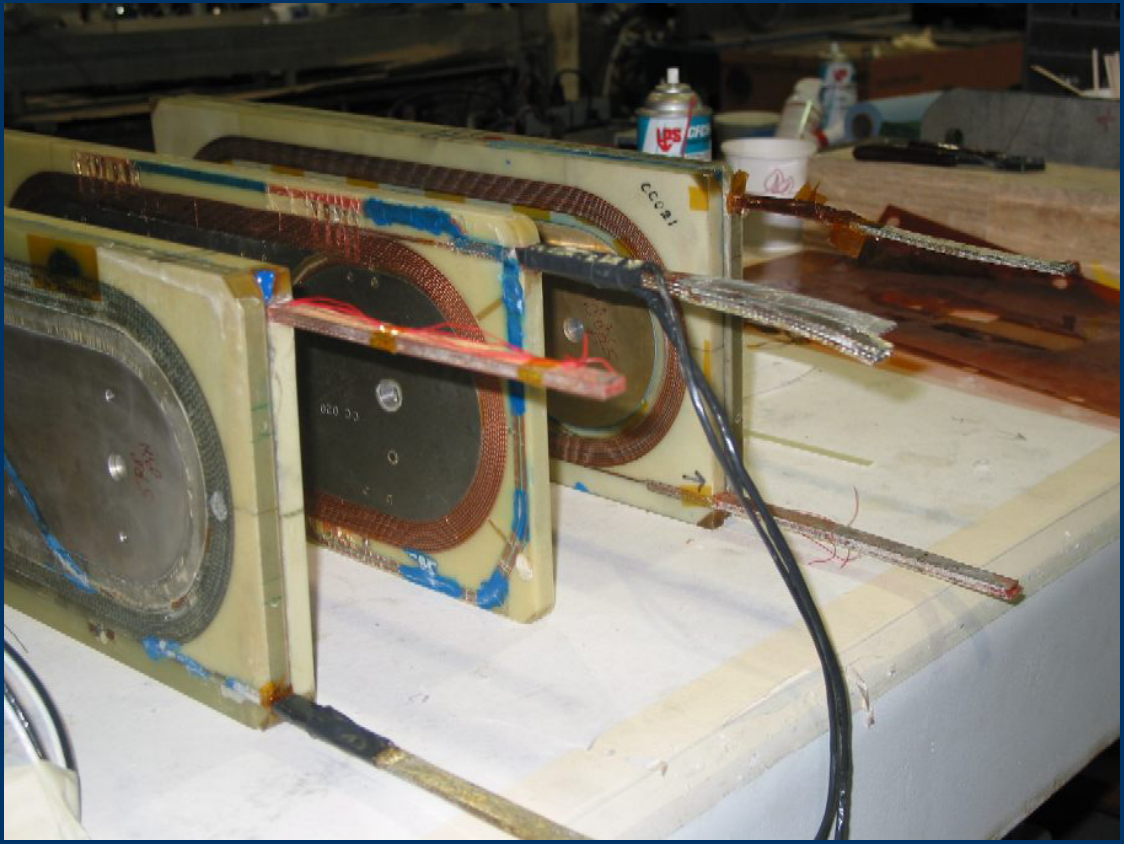


Two layer coil

Assembled Magnet

Modular, reusable components

BNL 10-turn coils



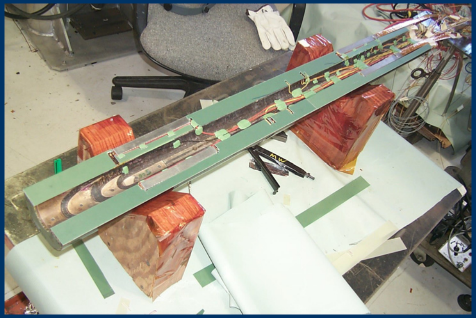
BNL makes 10-turn racetrack coils in modular structure. These modules (cassettes) can be mixed and matched for a variety of experiments in a rapid turn around fashion.

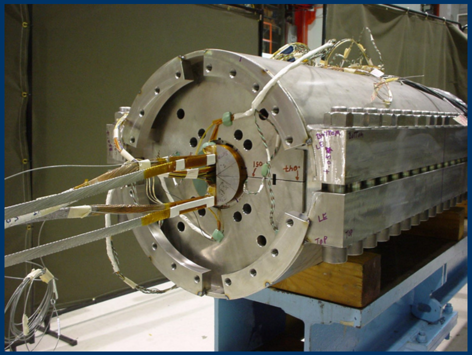
For example, one can easily change aperture, number of layers, type of magnet, etc.

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.



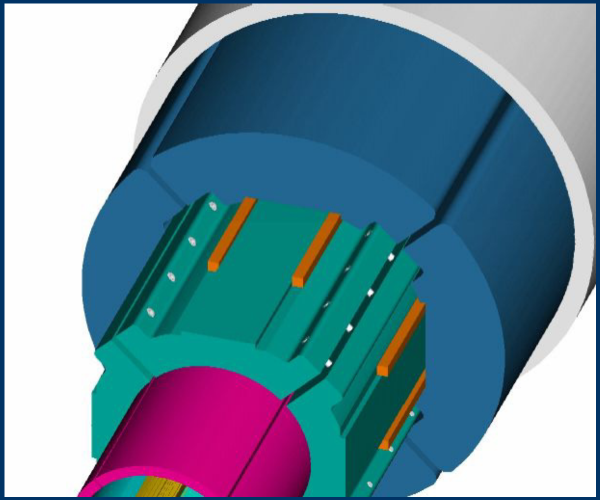


A Broad Variety of Topics

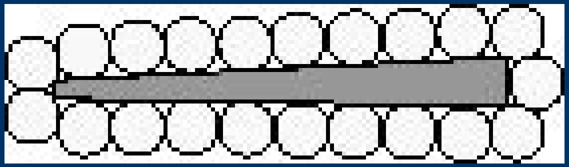
- Mechanical Structures
  - Racetrack quads
  - Open mid-plane dipoles
- Rad Hard Materials
  - Insulation
  - Impregnation materials
- Heat Transfer
  - Geometry
  - Internal structures
- Cable Design
  - High keystone angles
  - Cores
  - Intrastrand Resistance

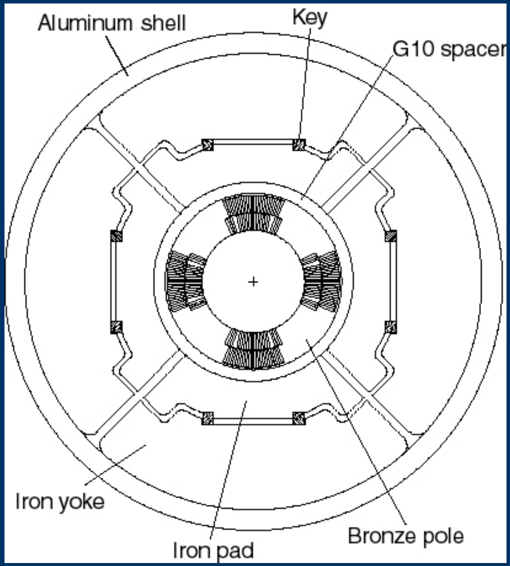
LARP Technology Development

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



230 T/m
90 mm bore





Summary

- Technology Development is foundation of the program
  - Initially to address LARP-related issues
    - Technology choices
    - Fast evaluation of critical issues and program scope
  - Later for program support
    - Investigate problems
    - Test new ideas