Technology Development

Status and Plans

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R&D Approach

Magnet development goal: fully developed prototype (dipole or quad) by 2012

Pre-requisites for detailed magnet designs & prototypes:

- Demonstration of basic magnet performance parameters
- Experimental feedback on design and technology options
- Integrated understanding of AP, magnet, radiation issues

⇒ **Most efficient strategy to achieve the ultimate program goals: rapid progress on the technology issues in the next three years**

Guidelines for technology development:

- Concentrate on fundamental issues: **focused, "simplified" tests**
- Provide feedback in a cost-effective and timely manner
- Incremental – start simple, each step builds on previous ones

Three-year Plan

The following objectives have been established for FY05-FY07:

1. **Design, fabricate and test simplified "technology quads"**

    ⇒ Explore different options for coil and structure
    ⇒ Select the baseline quadrupole design

2. **Design, fabricate and test simplified "technology dipoles"**

    ⇒ Explore the feasibility of the open mid-plane approach

3. **Demonstrate Nb_3Sn wind-and-react length scale-up**

- Technology development is focused on the 3-year plan goals
- Additional tasks may be included based on cost/benefit
- Need to clearly define priorities to steer the R&D as needed

Technology Development Components

Materials/conductor development and characterization:

- Development of superconducting wires and cables for LARP
- Materials studies (structural, insulation, magnetic etc.)
- Radiation effects, rad-hard components

Fabrication/assembly techniques development and characterization:

- Mechanical tests (coils, support structures)
- Thermal tests (heat transfer, quench parameters)
- Component development/test
- Model magnets for technology evaluation/demonstration

Design, analysis and testing tools:

- Selection/benchmarking of analysis and simulation techniques
- Development/selection of instrumentation for technology tests

Priority Tasks FY05-FY07

- **Mechanical structures for quadrupoles and dipoles**:

  ⇒ *Support the Lorentz forces, deliver the required pre-stress*
  ⇒ *Limit the stress on the conductor*
  ⇒ *Limit the radiation heat deposition*
  ⇒ *Satisfy field quality and alignment requirements*

- **Superconducting wire and cable** (coordinated w/DOE Program)

  ⇒ *Electrical and mechanical stability*
  ⇒ *Degradation due to cabling and stress*

- **Length scale-up** for Nb_3Sn wind-and-react technology

  ⇒ *Fabrication, assembly and mechanical support of long coils*

Additional R&D Tasks

Additional tasks will be performed. Some examples:

- New design and analysis tools, new instrumentation
- Performance of rad-hard insulation/epoxy in magnets
- Development of special components (bladders, end parts…)
- Issues related to field quality (reproducibility, correction…)

Proposals will be evaluated based upon:

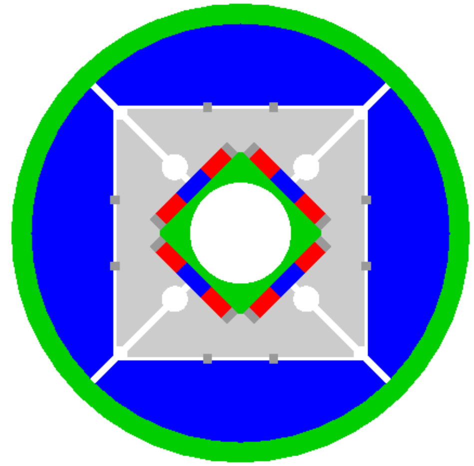
- Benefit, risk and cost assessment
- Direct relevance to LARP
- Coordination with base programs

Progress in FY04: Subscale Quad

1st large-aperture, high-field Nb_3Sn Quad; "compatible" with FY04 funding

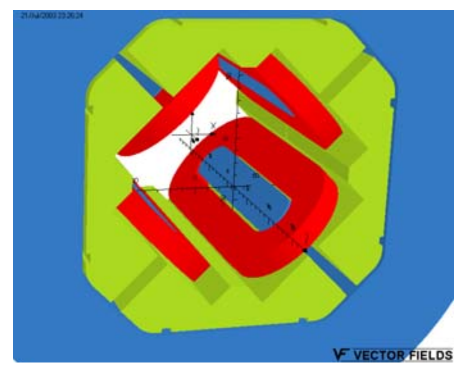
Main design features:

- Four sub-scale coils in racetrack configuration
- Supported by aluminum shell and yoke/pads
- Bladder & key assembly/pre-stress
- Large pre-stress increase during cool-down



Goals for the first test (SQ01, FY04)

- Verify the mechanical support concept
- Experience with quad structure assembly
- Validate the mechanical analysis results
- Investigate any conductor stability issues



Fast feedback on the mechanical structure for the 1-meter model

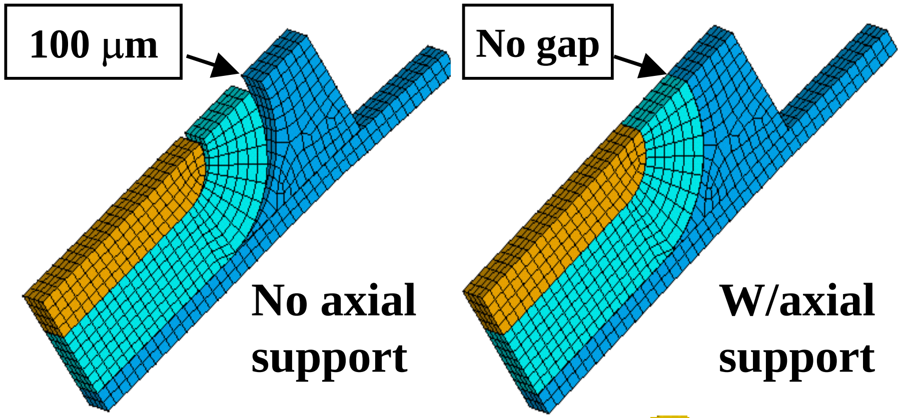
Subscale Quad Design Parameters

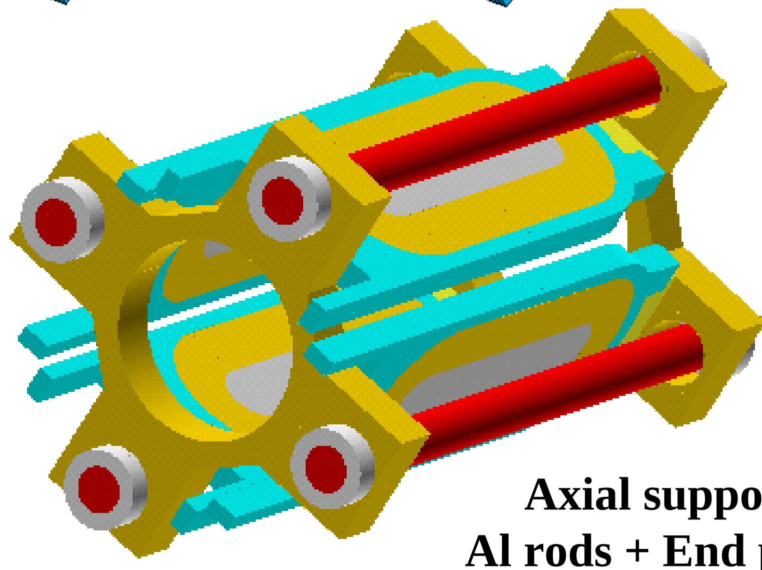
<u>Coil Parameters (SM):</u>

- 20 strands, 0.7 mm diam.
- 20 turn double-pancake
- Length 30 cm

<u>Magnet Parameters:</u>

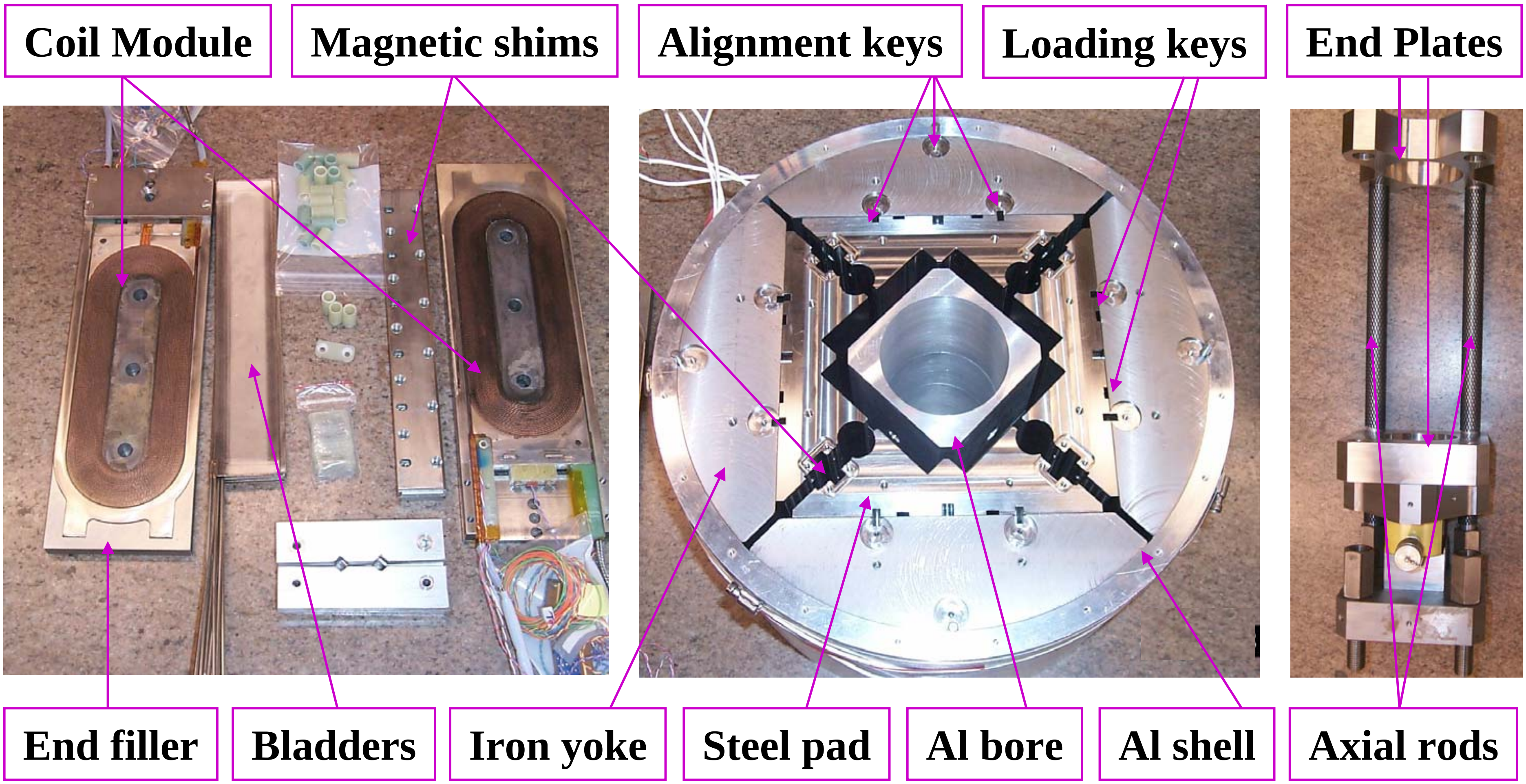
- **Aperture 120 mm**
- Clear bore 110 mm
- **Peak field 11 T**
- Gradient 100 T/m
- **Current 11.2 kA**
- Energy 425 kJ/m
- **Pre-stress 80 MPa**
- **Z-force 360 kN**





Axial support:
Al rods + End plates

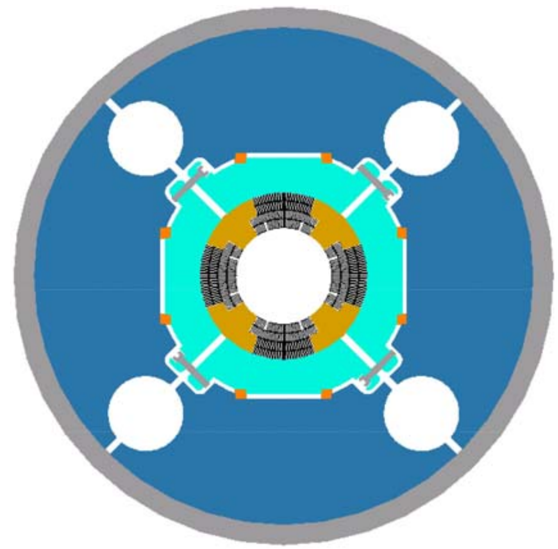
Subscale Quad Assembly



Total expense for sub-scale quad parts procurement (excluding coils): **23 k$**

Progress in FY04: IRQ Structure

- Mechanical support by aluminum shell
- Assembly based on bladders and keys
- Large pre-stress increase after cool-down
- Applied for the first time to a cos2θ design



FY02-FY03:

- Conceptual design studies (base program)

FY04:

- Engineering design & procured structure
- Assembled on instrumented Al tube
- Strain gauges to determine symmetry
- *Cool-down to verify design calculations*

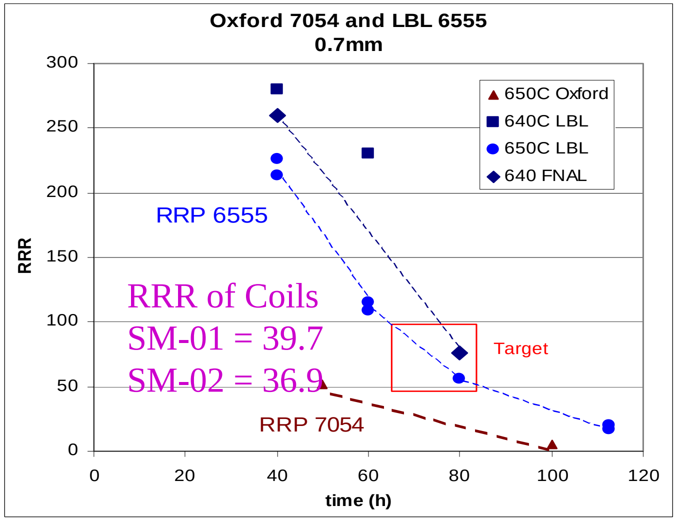
FY05:

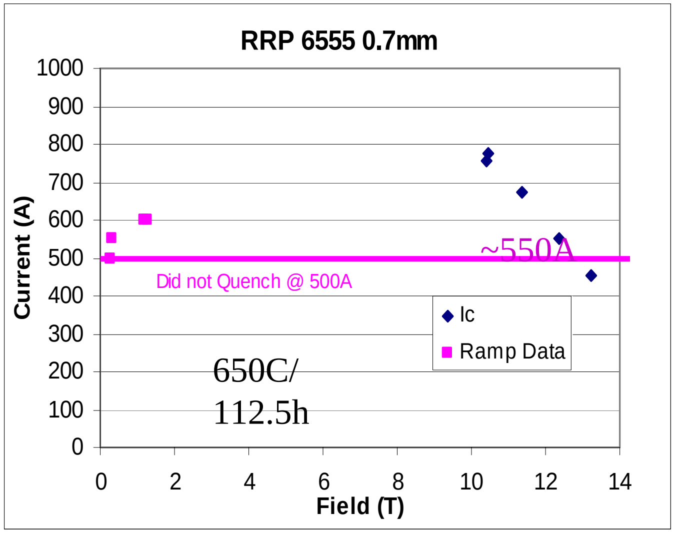
- Test w/"simplified" Nb_3Sn coil: TQ(4L)1a

Progress in FY04: Conductor R&D

FY04 activities (in progress):

- Mapping of cable parameter space
  - ⇒ check proposed cables vs. existing data
- Fabricate cable samples
  - ⇒ evaluate samples
  - ⇒ establish TQ(4L)1a cable parameters
- Strand stability measurements
  - ⇒ in support of SQ01, TQ(4L)1a
- Optimization of reaction cycle for SQ01
- Strand procurement issues
  - ⇒ FY05 conductor from DOE reserve





Progress in FY04: Base Program R&D

LARP activities need to be coordinated with base programs to make the most efficient use of resources & avoid overlap

Examples of FY04 base program R&D directly relevant to LARP:

- Strand stability studies (BNL, FNAL, LBNL; FNAL workshop)
- Study of stress and temperature limits during a quench (LBNL)
- Improved instrumentation (LBNL)

The base programs have also directly supported LARP in FY04

FY05 Technology Plan

- **Fabrication and test of a simplified cos2θ quad: TQ**(4L)**1a**

  ⇒ inner or outer double-layer of a four-layer design
  ⇒ 90 mm (inner) bore for risk & cost reduction: **focused R&D**
  ⇒ assembled in the existing mechanical structure
  ⇒ joint effort LBNL+FNAL (design/fab) & BNL (test)

- **Fabrication and test of one subscale model:**

  ⇒ two proposals, dipole or quadrupole: discuss and select
  ⇒ joint effort LBNL (design/fab) + BNL (design/fab/test)
  ⇒ work not funded in FY05 will be considered for FY06
  ⇒ options to increase scope: strand tests, insulation test etc.

- **Conductor development**

  ⇒ support TQ(4L)1a and prepare for FY06

FY05: TQ(4L)1a Development

Motivation/goal: feedback on cable, coil and structure development

- check design/fabrication, *demonstrate good quench performance*
- feedback on mechanical structure, conductor, quench protection
- evaluate (keystone) cable performance: stability, stress limits

Must be economical:

- One double-layer (inner or outer coil of 4-layer design)
- narrow cable, full keystone, minimum/no wedges
- bladder/key assembly (structure available)
- upgradable to a four-layer model: TQ(4L)1

Parameters/Features:

- 0.6-0.8 mm strand, ~8 mm cable width (SM)
- Aperture: 90 mm or 120 mm; Peak field: 10-11 Tesla

TQ(4L)1 Development: FY04-FY06

FY04:

- Develop/test mechanical structure
- **Finalize cross-section & parameters**
- Cable samples, procure conductor
- Check/adapt existing D-20 tooling

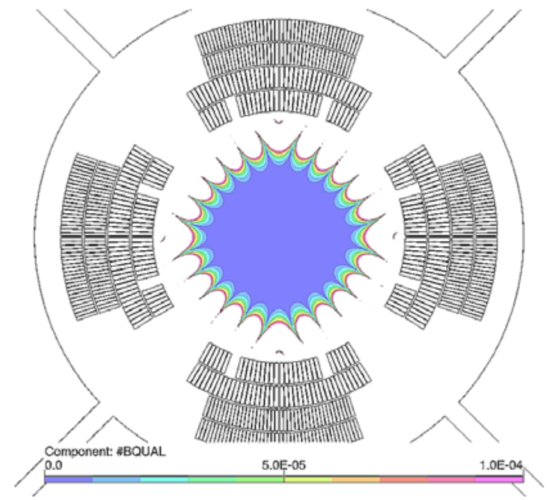
FY05:

- Fabrication of the 1st double-layer
- Assemble/test in existing structure
- Design tooling for 2nd double-layer

FY06:

- Fabrication of 2nd double-layer
- Assembly/test of complete 4-layer magnet

Reference coil cross-section



Parameter	Unit	4-layer Inner	4-layer Outer
Strand diameter	mm	0.8	0.65
Cu/Sc ratio		1.2	1.6
No. strands		17	22
Cable width	mm	7.7	7.7
Cable mid-thickness	mm	1.43	1.13
Keystone angle	deg	1.63	0.89
Insulation thickness	mm	0.1	0.1
No. turns/octant		35	42

![US LARP logo]

FY05: Subscale Test (Quad)

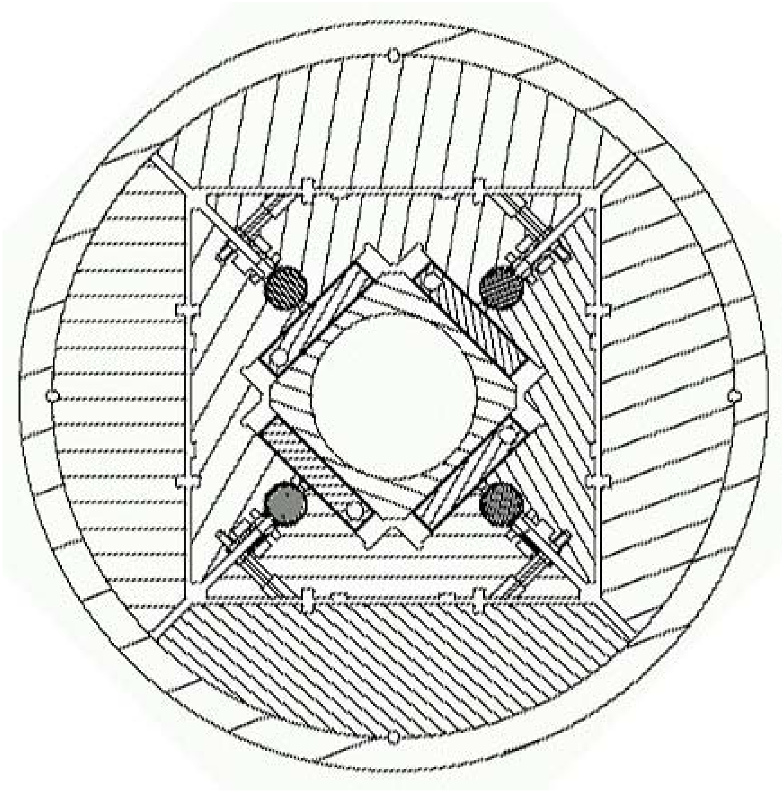
Very cost-effective, efficient tool to study many design/technology issues:

1. General application:

⇒ Mechanical support structure optimization
⇒ Stress limits, pre-stress options
⇒ Validation of mechanical analysis models
⇒ Assembly/alignment with bladder & keys
⇒ Coil fabrication tolerances/reproducibility
⇒ Field correction (coil & magnetic shims)
⇒ Thermal and quench protection studies

2. Racetrack quad specific:

⇒ Evaluation of magnet performance
⇒ Internal bore support requirements



Subscale quad can also be effective as a tool for dipole-relevant R&D

FY05: Subscale Test (Dipole)

<u>Goal:</u>

Feedback on the open mid-plane dipole mechanical design

- Design to address the design issues of the full-scale dipole
  - ⇒ Open mid-plane
  - ⇒ Coil impregnated in the structure *(also relevant to quad)*
  - ⇒ Coil displacement/gaps due to low/no pre-stress
- Several tests with changes in force configuration
- Joint effort LBNL+BNL
  - ⇒ LBNL: Coil design and fabrication
  - ⇒ BNL: Structure design/fab, magnet assembly, test

FY05: Conductor R&D

The conductor R&D effort in FY05 will focus on:

- Development of LARP strand specifications
- Conductor procurement
- Strand characterization/optimization (coordinate w/DOE program)
- Superconducting cable development for future LARP models:

  ⇒ cable design for the 2-layer and 4-layer cos2θ designs
  ⇒ general optimization studies of cable parameters
  ⇒ study of cable electrical and mechanical properties
  ⇒ stress limits, in particular for keystone cables
  ⇒ cabling degradation, extracted strand measurements
  ⇒ cable testing in background field or subscale coils

FY06-FY07 Plan

- Conductor/materials:
  - ⇒ **Strand procurements** (return loans and procure new)
  - ⇒ **Continued strand and cable R&D**
  - ⇒ Initial radiation studies (start testing rad-hard epoxies)
- Technology Quads:
  - ⇒ TQ(4L)1: complete with all four layers
  - ⇒ **TQ**(2L)**1**: **2 layer (wide cable) & alternative mechanical design**
  - ⇒ Technology tests, e.g. for impregnated collar laminations
  - ⇒ Subscale quads: alignment, reproducibility issues
- Dipole models:
  - ⇒ **1-meter model using either BNL dipole coils or HD1 coils**
- Long coil R&D:
  - ⇒ **Procure infrastructure, build practice coils, first experiments**

Nb_3Sn Coil Length scale-up

Main R&D issues:

- stress control during coil reaction, cable treatment, pole design
- tooling/handling of reacted coils
- support structures (alignment, segmented shells, He containment)
- assembly issues; design/fabrication/test of long bladders

LARP Proposal: start to investigate length scaling issues as early as feasible

Proposed approach:

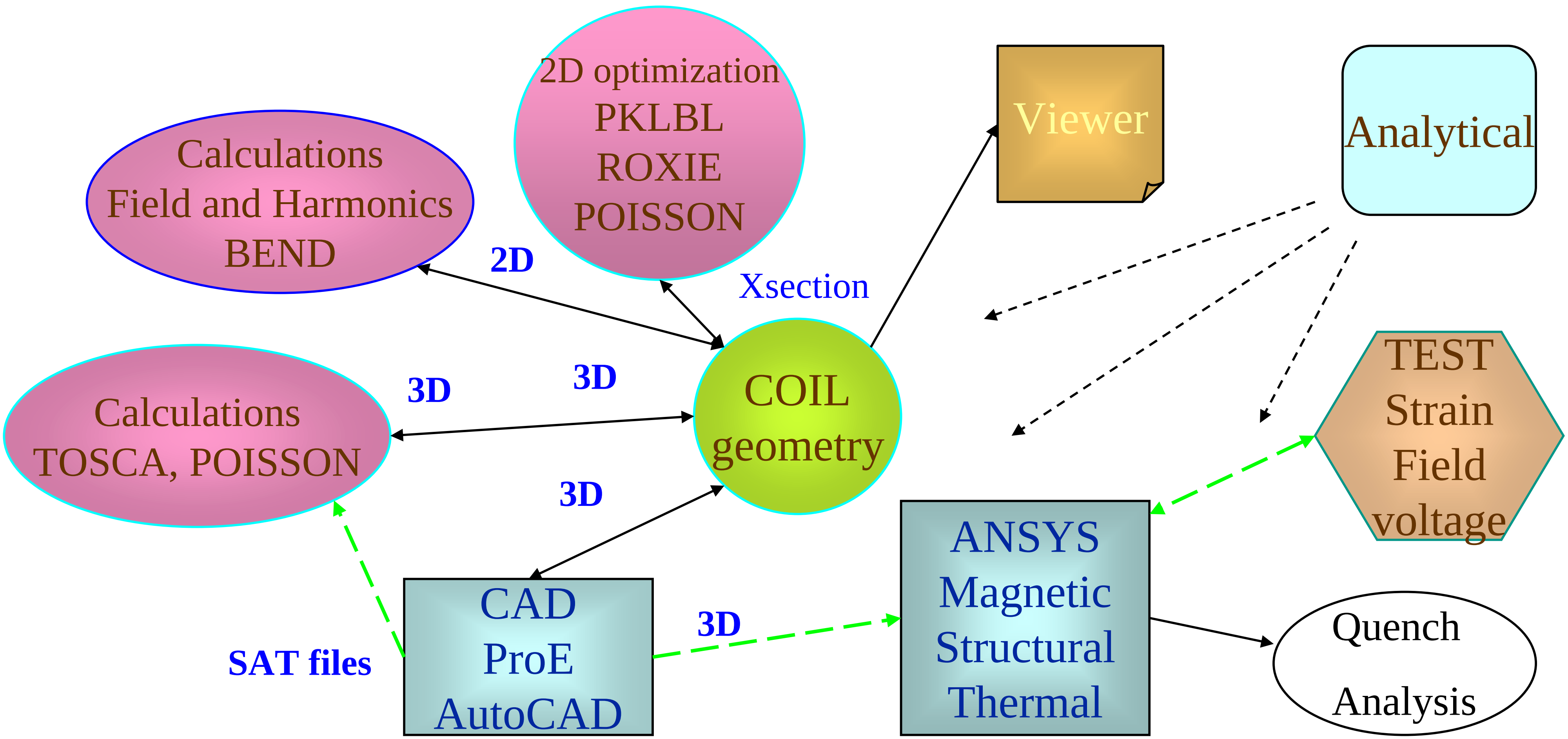
FY04-FY05: base program support

FY06: infrastructure procurements (originally scheduled for FY07)

FY07 (FY08):
- Fabricate practice coils ("subscale" x-section for low cost)
- Test two coils in common-coil dipole configuration

Design and Analysis Tools

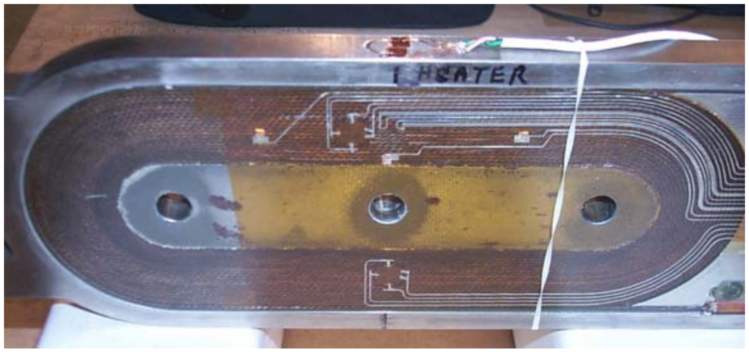
Fully integrated modeling environment applied to SQ1, TQ1 design & analysis:



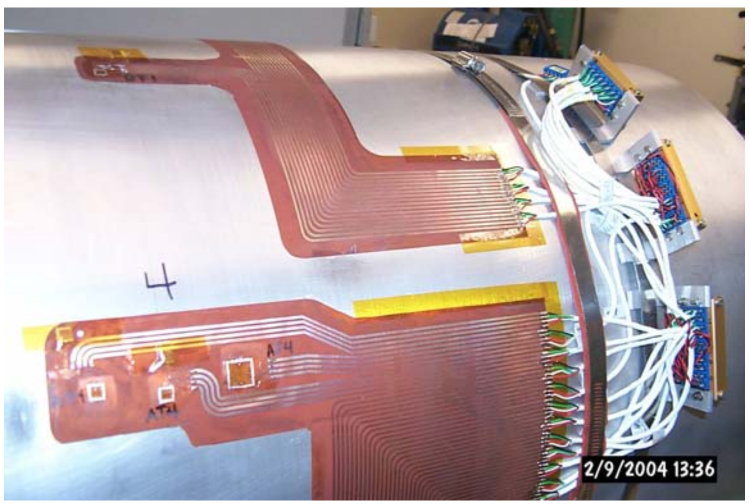
LARP: cross-check methods developed by base programs, choose/apply best

Test Instrumentation

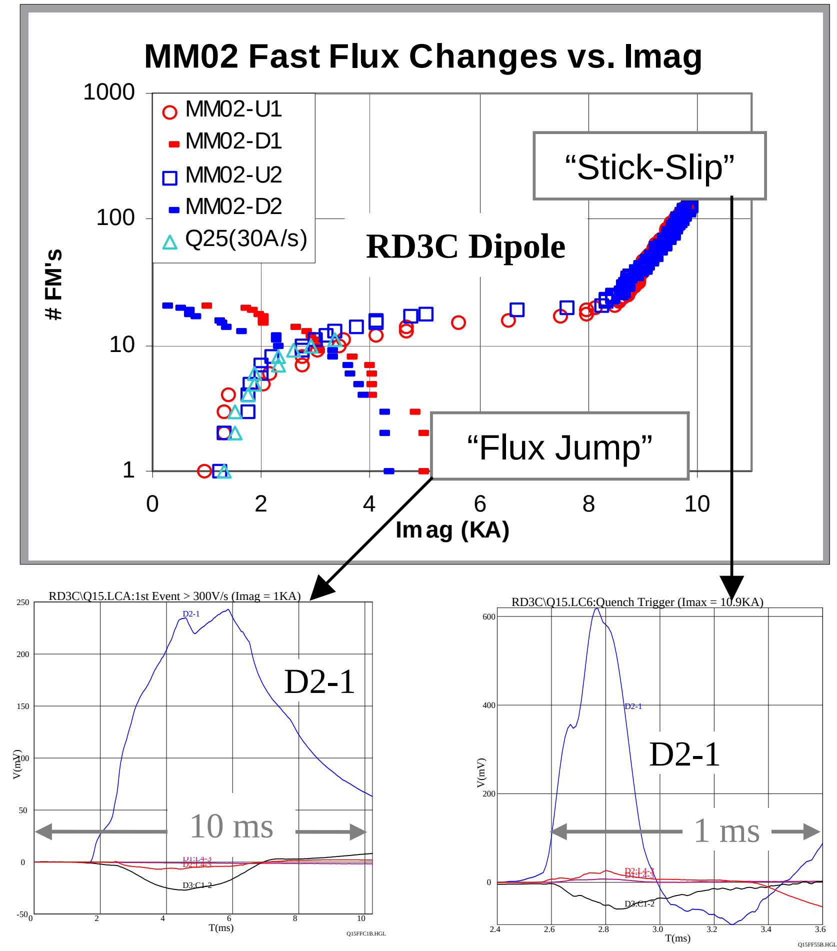
Coil



Support structure



Fast flux changes in magnets



LARP: cross-check methods developed by base programs, choose/apply best

Summary

<u>The near term magnet R&D will focus on technological models:</u>

- Subscale quads/dipoles for fast feedback
- 1-meter IR Quad models with two and four layers
- 1-meter dipole structure test using existing coils
- Standard SM coils for material, conductor, quench studies
- A "long subscale" to start addressing magnet length issues

Three-year program goals:

- Demonstration of basic magnet performance parameters
- Experimental feedback on design and technology options

Integrated understanding of AP, magnet, radiation issues will be required for the following steps