Updated Timeline of BNL Magnet Division Tasks

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Three introductory slides before the discussion on accelerating schedule

BNL Magnet Division Tasks

- **Develop a magnetic and mechanical design of a 2.5 MJ HTS Coil**
- **Develop a quench protection system to protect these HTS coils**
- **Build and demonstrate a ~24 T, ~100 mm aperture HTS solenoid**

- **This is a significant undertaking. Nothing close to this has ever been done before**
  - **A truly high risk, high reward project.**
- **It is important to understand the challenges and develop a systematic and logical R&D program consistent with the budget - right from the beginning.**

BNL Magnet Division Team for High Field HTS SMES Coil

Success of this program depends on a expertise in several key areas

- **PI: Ramesh Gupta**
- **Magnet Division Interim Head: Peter Wanderer**
- **Electrical Engineering (including protection): Piyush Joshi, George Ganetis**
- **Mechanical Engineering: Jesse Schmalzle, Mike Anerella**
- **Scientific Staff: Bill Sampson, S. Lakshmi Lalitha, Yuko Shiroyanagi**
- **Technicians: Glenn Jochen, Sebastian Dimaiuta, Rick Meier**
- **Designer(s): TBD**
- **Collaboration: Steve Khan, Muons Inc.**
- **Plus other support, as needed**

Budget: ~$300k/year, including material (except HTS from SuperPower)

- **$300k/year translates to about one FTE per year for three years**
- **a challenging undertaking to develop a record high field HTS solenoid with this modest funding**
- **a good synergy with other HTS programs is very helpful**

Synergy with Other HTS Programs

Significant programs currently ongoing:

- **2.5 MJ (24 T, 100 mm aperture) HTS Solenoid for SMES (just started)**
- **~10 T (100 mm) and ~20 T (25 mm) HTS Solenoid for Muon Collider**
- **Medium Field HTS Quadrupole for Facility for Rare Isotope Beams (FRIB)**
- **Low Field HTS Solenoid for Energy Recovery Linac at BNL**

Significant programs that are successfully completed:

- **HTS Quadrupole for Rare Isotope Accelerator (RIA)**
- **Common Coil Dipole for colliders**
- **HTS coils in cryogen-free structure**

Significant program(s) awaiting funding decision(s):

- **HTS solenoids for RHIC e-lens System at BNL**

Since PI/Project Leader is the same in all of above programs, it is simpler to coordinate to take maximum advantage of this synergy

Updated Timeline of Major Milestones

- **Discussion on high level tasks/deliverable**
  - **10 T coil tested (GO/NO GO decision)**
  - **2.5 MJ SMES coil tested (final test at BNL)**
- **Brief discussion on other major tasks**
  - **Limited to those whose schedule is accelerated**

Example:

Q2 → Q4

Revised to

Q3

Two quarter delay (Q2 to Q4) due to delay in funding

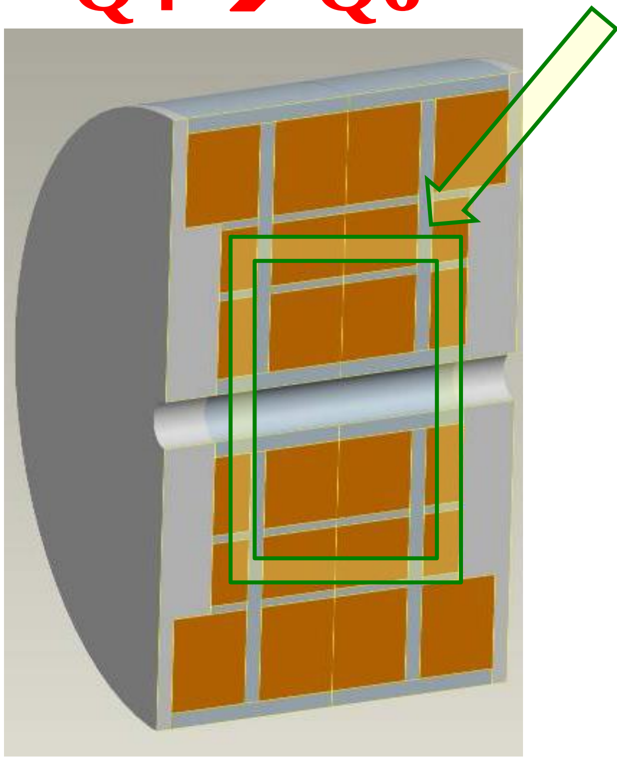
one quarter recovered (Q3)

BROOKHAVEN NATIONAL LABORATORY

Superconducting Magnet Division

10 Tesla Coil Test Schedule

Q4 ➔ Q6



Scheduled to be designed, built and tested in 12 month period from the start (original plan)

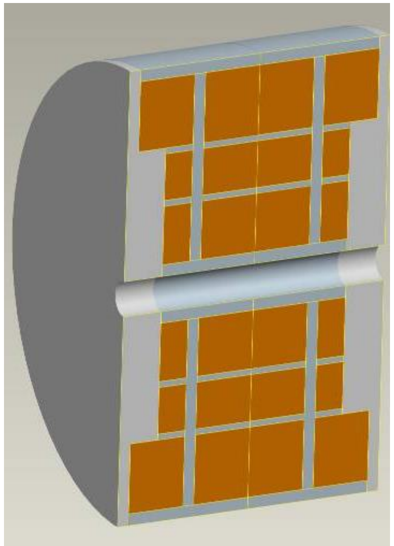
- This task involves building and testing the center inner most coil block.
- Since this is a part of the overall magnet, detailed design must be completed prior to completing this coil block.
- Quench protection system should be developed before this test as we would like to minimize risking this coil.
- In addition, we would likely to test a few small coils prior to committing this test (already part of the original plan).
- Since this coil will be tested in the part of the support structure of the whole magnet, that should be ready too.
- Completing all of above tasks in a 12 month period reflects an aggressive schedule.
- For reference similar 10 T, 100 mm solenoid for muon collider has taken about 2 years and has not yet been tested. However, experience from that program is highly useful.

2.5 MJ Final SMES Test at BNL

Q10 → Q12

Revised to

Q11



• Two quarter delay in the schedule would move the original BNL test scheduled of Q10 to Q12. Since this takes us to the project completion date, it would not leave any time for ABB to conduct its test.

• We would work as hard as we can to move it ahead by one quarter to allow time for ABB to carry out those tests.

• It must be recognized that making a 100 mm, 24 T solenoid is a major undertaking. Nothing like this has ever been done. Since the forces are large, a complex support structure has to be developed and coil blocks must be assembled in this structure such that the stresses on conductor (due to large Lorentz forces at high fields) remain within acceptable limit.

• In addition each section of the coil must remain protected.

• Since there is no time for recovery in schedule to deal with surprises, we know we are increasing the risk by accelerating (both in the completion date and in the performance).

Other Major Tasks

(only those that are moved ahead)

Initial Quench Protection System Design

Q2 ➔ Q4

Revised to

Q3

- **Description of the Milestone:**

Initial quench protection system design.

- **Details: Low noise electronics for quench protection system designed to detect 1 mV signal per coil section**

We will accelerate this task so that it gets completed a quarter earlier.

Quench Protection System Proven in Simulated Environment

• **Description of the Milestone:**

Q3 ➔ Q5

Electronics detects and protects coil.

Revised to

Q3

• **Details: develop electronics to detect resistive voltage signal < 5 mV despite large inductive and noise voltage (1st phase of quench protection)**

- **We will accelerate this task so that it gets completed two quarter earlier and thus we will recover the time lost.**
- **This is based on the confidence gained from the similar work performed on other HTS projects. In fact, we are hopeful that we may be able to do much better than 5 mV.**

Support Structure Design

Q6 ➔ Q8

Revised to

Q6

- **Description of the Milestone:**

  Support structure and mechanical robustness.

- **Details: Demonstrate a design with deflection < 200 μm**

  - **This is the most critical part of the overall engineering design defining the performance of the high field magnet. This also drives the fabrication of parts for support structure, coil winding tooling, etc.**
  - **We will have three persons working on it right away.**
  - **We will accelerate this task so that it gets completed two quarter earlier and we will recover the time lost.**

Quench Protection and Energy Extraction

Q6 → Q8

Revised to

Q6

- **Description of the Milestone:**
  - ❖**Energize a coil module.**
  - ❖**Demonstrate that it remains protected (not destroyed) during the ramp-up and ramp-down cycle.**
- **Details: Energy from the coil removed and dumped into external circuit; coil remains protected**
  - ➢ **We will accelerate this task so that it gets completed by two quarter earlier and we will recover all time lost.**
  - ➢ **Programmatic benefit of completing this task earlier is that this system can be used in protecting the 10 T coil for "GO/NO GO" test. This minimizes the risk to the overall program.**

Intermediate Tests

Q7 → Q9

Removed

Integrated with other tests

Q8 → Q10

Removed

Integrated with other tests

- **Description of the Milestones:**
  1. **Q7- All individual coils tested to reach >80% computed design current (as computed during the design phase).**
  2. **Q8 - Coil blocks in intermediate structure tested.**
- **These intermediate tests are removed to save time.**
- **These tests become part of the final system test.**
- **This is a calculated risk to accelerate the final phase of the schedule in order to complete project in time.**

Quench Protection in HTS Magnets

- Protection is one of the most challenging issues in HTS magnets, primarily because of slow quench velocities.

- We are developing an advanced quench protection system to detect small coil voltage rise in short time in presence of noise and large inductive voltage.

- In consultation with SuperPower, the amount of copper in HTS tape is being increased from 45 micron to 100 micron thickness. This will improve the protection of HTS in an event of a quench or thermal runaway. A safer SMES for field applications may require even higher amount of copper.

- We are performing a number of experiments and also exploring possibilities of collaborations with other institutions .

Summary

- High field HTS option provides a promising option to SMES. However, this is a new and very challenging technology.
- The original schedule, which was already very aggressive, has been further accelerated in an attempt to cover lost time in accommodating delays in receiving funds at BNL.
- There is “NO FLOAT” and no recovery time to deal with surprises usually associated with high risk R&D programs.
- Accelerated schedule further increases the risk to the project.
- This must be understood that these increased risks are to meet overall program need to complete this project in original time despite funding delays.