DRAFT

US LHC Accelerator Research Program
FY2005 Task Sheet

Date: 6 June 2004

Task 1: Quadrupole design

Responsible Person(s): Alexander Zlobin (FNAL), S. Caspi (LBNL)

FY05

Budget:

	$106k	(FNAL)
	$34k	(LBNL)
	$140k	Total

Statement of work:

- continuation of the conceptual design studies of the double-aperture IR quad
- start the engineering design of the 1st quadrupole short model (TQ4L1a)
- Conceptual design of 2-layer quadrupole to provide input for Cable R&D

Milestones:

Review and evaluate dual-aperture quad concept in March '05.
Review conceptual design of TQ2L1 (2-layer quad) in July '05

FY06

Budget: $177k (FNAL, LBNL), Split TBD

Statement of work:

Work will focus on two possible coil designs (two-layer and 4-layer) and two mechanical structures (conventional collar and yoke and bladder and keys), one at Fermilab and one at LBNL. Provide input for long magnet development.

Milestones:

Evaluation of TQ4L1 performance and decision on bore increase in 4-layer program.

Task 2: Dipole Design Studies

Responsible Person(s) Mike Harrison (BNL), G.L. Sabbi (LBNL)

FY05

Budget: $155k (BNL)

Statement of work:
FY05 will continue to develop the dipole design efforts. The mechanical design will be finalized and a 3-D mechanical analysis will be completed. A thermal analysis will be performed to determine the temperature profile of the magnet under the full design luminosity of 10^{35}.

Milestones:

FY06

Budget: $400.5k (BNL, LBNL)

Statement work

Continuation of this task will be determined by the feasibility of an open mid-plane dipole design based on FY05 design studies and the outcome of the SD-01 test.

The ultimate goal of the initial R&D phase of the dipole program will be to construct a short (~1m) prototype in a cryostat. In addition to the normal testing (field quality, quench performance etc.) this element would be heavily instrumented to allow heat loads to be introduced and the resulting temperature profile to be measured.

Milestones:

TD2L1 design review in November '06.

Task 3: Sub-scale tests

Responsible Person(s): G.L. Sabbi (LBNL), Mike Harrison (BNL), P. Ferracin (LBNL)

FY05

Budget: $60k (BNL)
$46k (LBNL)
$106k Total

Task 3a: SD-01, sub-scale dipole

Statement of work:

Design (supported by Task 2), fabrication and test of SD-01, a sub-scale, open mid-plane dipole using existing sub-scale coils from LBNL base program. A new support structure with features required for the open mid-plane design will be constructed. SD-01 will be tested at BNL.

Milestones:

Start of this task is dependent upon a successful dipole design review in December '05. See task 2.

Task 3b: SQ-01, 02, Subscale Quadrupole

Statement of work for FY04 (task background)

The main goal of the first subscale quad (SQ-01) is to test a mechanical structure based on the key and bladder technology and apply it for the first time to a quadrupole design: the structure behavior will be studied in a realistic Lorentz force configuration, including a significant longitudinal force acting on the magnet's ends. The test will give useful information regarding the assembly procedure, the increase of coil pre-stress after cool-down, and the mechanical behavior during excitation, providing early feedback for the design of the support structure of the IR cosϑ quadrupole prototype. Experimental measurements with strain gauges mounted on the shell, the rods, and the coils will allow validating the 3D finite element model of the magnet. The model was used to study the conductor movements produced by the Lorentz forces in the end region, both for the SQ and the cosϑ quadrupole. The comparison between computations and measurements will help determine the role of friction, making it possible to refine the finite element model of the cosϑ quadrupole. The test will set some initial reference for the acceptable coil stresses, and it will address the issue of the stability of Nb_3Sn cables in a design similar to the first stage (2-layer) of the cosϑ quadupole.

FY05 (SQ-02)

The second assembly/test of the subscale quadrupole will have the following objectives:

1) Investigate a new preload configuration and its effect on training.
2) Study the mechanical and thermal response of the coil during excitation and after a quench through voltage taps and strain gauges
3) An additional sub-scale model may be built and tested if resource allow. This model would address mechanical issues of the proposed open-midplane dipole design in collaboration with BNL.

Additional studies that may be performed using the SQ quadrupole include:

- stress limits/degradation for Nb_3Sn cables
- performance of the racetrack quad without a bore support
- Nb_3Sn coil fabrication tolerances/reproducibility

Milestones:

Evaluation of SQ-01 test results in August ’04.

FY06

Budget: $748k

Statement of work:

The sub-scale program will continue in support of the quad and possibly dipole programs as a cost-effective means to study a variety of issues directly associated with magnet development. In addition, a common coil version of the design will be used to evaluate rad-hard materials, insulation, heat transfer, cable designs, etc.

Milestones:

Based on program profile and priorities.

Task 4: TQ4L1a, 2 layers of a 4 layer, 1 m long, quadrupole model

Responsible Person(s): S. Caspi (LBNL), A.V. Zlobin (FNAL)

FY04/05

Budget:

FY04: $0 k

FY05: $80k (BNL)
$285k (FNAL)
$378k (LBNL)
$743k (Total)

Statement of work

The ultimate goal is to build a 1m, 90 mm aperture, 4-layer quadrupole. The FY05 task will be to build the inner or outer 2 layers of this quadrupole and test it using the key and bladder-based support structure developed and tested in FY04. The cost-effective test should demonstrate:

- That the magnet can reach the expected short sample performance
- Require minimum training
- Ability to meet minimal field quality requirements

The inner double layer will be built and tested in FY05 followed with an outer double layer in FY06. The final 4-layer quad will be assembled and tested in FY06.

FY04
By the end of FY04 the 4-layer conceptual design and a mechanical test of the structure should be complete. Funds for the remaining FY04 work will come from the lab's base program

FY05

LBNL will be responsible for designing the coils, wedges, end spacers, end-shoes and end splices. Magnetic analysis will be done to ensure sufficient field margin in the end. LBNL will provide the conductor (via the DOE Conductor Development Program), reaction and potting tooling, end splices, quench heaters and traces. The coils sub-assembly, final assembly and electrical checks will be done at LBNL

FNAL will be responsible for the conceptual design of the mandrel, insulation build-up, winding procedure, tooling for curing, reaction and potting. FNAL will manufacture the mandrel, curing cavity, insulation, wedges, end-spacers and shoes. They will also wind the first 2 layers.

BNL has testing responsibility; provide readout for strain gauges, voltage taps, thermometers, etc. along with execution of the test plan including training, field quality measurements and ramp rate studies.

Other technology development associated with the first model is ----- advance structures and pre-stress delivering system, new winding curing techniques and assembly procedures and implementation of instrumentation such as strain-gauges. The mechanics of the magnet assembly and operation will be followed closely and compared with 3-D ANSYS models.

Milestones:

TQ4L1a test by September '05

FY06

Budget: $2478k (Split TBD)

Statement of work:

Complete final 2 layers of TQ4L1 and test. Based on evaluation of this test, start engineering design of TQ4L2. It is conceived that this magnet could have a bore greater than 90 mm or be a continuation of the same design, again, depending performance of TQ4L1. In any case, it will not be started until test is complete. The two-layer design will start at the beginning of FY06.

Milestones:

Test of TQ4L1 in March '06.
Evaluate TQ4L1 and possibility of bore increase in April '06.
Test of TQ2L1 in August '06.

Task 5: Technology development for long Nb_3Sn magnets

Responsible Person(s): G. Sabbi (LBNL), A. Zlobin (FNAL), M. Harrison (BNL)

Time period: FY04-FY07(-FY08) (For reference only, no LARP budget in FY05)

Budget:

- FY04: Base program support
- FY05: Base program support
- FY06: 1206 k$
- FY07(-FY08): TBD

Statement of work:

Length dependent effects for Nb_3Sn magnets include thermal expansion issues during coil reaction, handling and impregnation of reacted coils, fabrication/assembly of long mechanical support structures, containment of the axial forces. Dealing with such issues could have critical influence on magnet designs and fabrication methods. The LARP proposal recommends that length dependent effects are investigated as early as is practical. In order to respond to this recommendation, and taking into account the budget constraints, we propose to fabricate and test in "common coil" configuration a pair of 3-meter long racetrack coils with sub-scale cross-section. One additional practice coil would be fabricated to check the procedures prior to fabrication of the two main coils. This approach is consistent with our basic technology development strategy: start from simpler systems that can be rapidly tested before progressing towards more complex ones. In this way, potential difficulties can more easily be identified and resolved at the earlier stages.

The design can reach ~11 Tesla peak field and is suitable to address the fundamental R&D issues related to long Nb3Sn magnets, in preparation for the fabrication of the 4-

meter long LARP models. At the same time, this task can be carried out at affordable cost thanks to reduced conductor volume, minimal tooling requirements, and compatibility with existing test facilities. With respect to the baseline schedule in the 3-lab proposal[1], we propose to shift by one year (from FY07 to FY06) the procurement of the basic infrastructure for coil reaction (long oven, 250 k$) and design of the associated handling, impregnation and reaction fixtures. The magnet fabrication/test effort, as currently planned, takes place in FY07. An option to shift part of this effort to FY08 is considered but depends on progress in quadrupole development and overall funding. Long magnet development is a high priority of the program and all means required to push forward as quickly and efficiently as possible will be investigated.

Task 6: Conductor and Cable

Responsible Person(s) D. Dietderich (LBNL), E. Barzi (FNAL), A. Gosh (BNL)

FY05

Budget: $114k split equally between BNL, LBNL and FNAL

Strand and cable testing and characterization in support of FY05 program. It also includes evaluation of keystoned, Nb_3Sn cables.

Milestones:

Initial evaluation of keystone cable limits (Wide cable design review in March ’05)

FY06

Budget: $513k (split TBD) Strand and cable measurements, cable R&D
$473.4k (LBNL) Conductor procurement

Continue mapping parameter space for keystoned, Nb_3Sn cables using most recent strand (particularly finer filament material). Expand program to included investigation of tapered cores and rectangular cores, RRR and stability issues.

Milestones:

TBD

[1] *R. Kephart et al., “The U.S. LHC Accelerator Research Program: A Proposal”, May 2003.* http://www-td.fnal.gov/LHC/USLARP/LARP_Proposal.pdf