



US LHC Accelerator Research Program *bnl - fnal- lbnl - slac*

D1 Dipole Design Task (terminated in 2005)

IR Magnet Study Task (conceived in 2005)

Ramesh Gupta

(Presented by Peter Wanderer)

Brookhaven National Laboratory

Upton, NY 11973 USA

LARP Collaboration Meeting
Pheasant Run Resort, St. Charles, IL, USA
October 5-6, 2005



BROOKHAVEN
NATIONAL LABORATORY



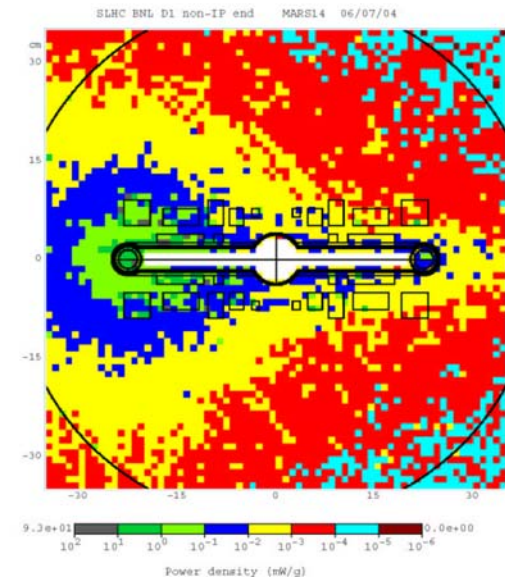
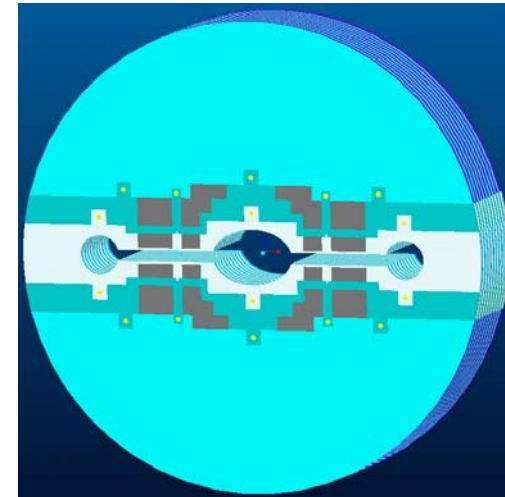
Overview of the D1 Dipole Design (Open Midplane) Task

- The purpose of this task was to study the open midplane dipole design for “dipole first” optics
- The task was terminated in middle of FY2005 to direct most of the magnet R&D funding to quad program
- In the remaining term, a summary was written and presented as a paper in PAC2005

➤ Optimization of Open Midplane Dipole Design for LHC IR Upgrade – R. Gupta, et, al.

- It may be too early to determine from machine physics point of view (prior to any LHC experience), whether for high luminosity operation “dipole first” should be a preferred option or “quadrupole first”

➤ Therefore, some modest investigations on the magnetic design of this and other non-conventional magnets will continue; however, under some AP task.





Summary of Design Iterations (A to F)

	A	B	C	D	E	F
H(mm)	84	135	160	120	80	120
V(mm)	33	20	50	30	34	40
V/H	0.39	0.15	0.31	0.25	0.43	0.33
B_o (T)	13.6	13.6	13.6	13.6	15	13.6
B_{ss} (T)	15	15	15	14.5	16	15
J_c (A/mm ²)	2500	3000	3000	3000	3000	3000
Cu/Sc	1	1,1.8	0.85	0.85	0.85	1
A(cm ²)	161	198	215	148	151	125
R_i (mm)	135	400	400	320	300	300
R_o (mm)	470	800	1000	700	700	700
E(MJ/m)	2.2	4.8	9.2	5.2	4.1	4.8
F_x (MN/m)	9.6	10.1	12.3	9.5	10.4	9.6
F_y (MN/m)	-3.0	-6.8	-8.7	-7.0	-5.1	-5.4



Energy Deposition Summary (Mokhov, 04/05)

SUMMARY

- The open midplane dipole is very attractive option for the LARP dipole-first IR at $\mathcal{L} = 10^{35}$. The design accommodates large vertical forces, has desired field quality of 10^{-4} along the beam path and is technology independent.
- After several iterations with the BNL group over last two years, we have arrived at the design that – being more compact than original designs – satisfies magnetic field, mechanical and energy deposition constraints.
- We propose to split the dipole in two pieces, 1.5-m D1A and 8.5-m D1B, with a 1.5-m long TAS2 absorber in between.
- With such a design, peak power density in SC coils is below the quench limit with a safety margin, heat load to D1 is drastically reduced, and other radiation issues are mitigated. This is a natural two-stage way for the dipole design and manufacturing.



Technical Summary of D1 Dipole Design Study Task

The “Open Midplane Dipole Design” offers a good technical and an economical option for LHC luminosity upgrade in “*Dipole First Optics*”

- The challenging requirements of the design have been met:
 - A design that can accommodate a large gap between upper and lower coils with no structure in between.
 - A design with good field quality design despite a large midplane gap.
 - Energy deposition on the s.c. coils can be kept below quench limit and the component lifetime can be kept over 10 years.
 - Heat can be economically removed at a higher temperature with a warm absorber within coldmass.
- A proof of principle design has been developed and many iterations have been carried out to optimize the overall parameter space.
- The design brings a significant new addition to magnet technology.



Overview of IR Magnet Study Task

This task will have the following components:

- **IRQ Parameter Space Study**
 - Present acceptable values of gradient/aperture combination to AP group that can be used in optimizing future IR upgrade lattice.
- **Field Quality Analysis / Error Tables**
 - Based on model calculations, and on the construction and measurements of Nb₃Sn magnets built for LARP and other projects, create error tables for Nb₃Sn magnets (both dipole and quad).
- **Complete Remaining Work on Some Previous Tasks**
 - Comparison between cosine theta and race-track quad designs.
 - Generic design study of 110-mm aperture, G>200 T/m quad.

This group will be responsible for communicating with AP group on various issues related to general magnetic design and field quality.



Field Quality in IR Quadrupole

Field Quality optimization is not the primary purpose of the present LARP Quadrupole Development Program.

The goal of this task is that at the end of LARP program, we :

- understand the differences between expected and measured harmonics (computation of expected harmonic is done in other tasks)
- understand the sources of field errors and able to estimate the magnitude of construction errors associated with the Nb₃Sn magnets
- able to generate standard error tables for future Nb₃Sn magnets
- and if the errors are large, develop techniques to reduce them

To be able to do this at the end of the program, the analysis should continue in parallel with the magnet construction and testing.

This require only a small amount of resources, but it needs to go in parallel. If done later, very often important details get missed.



Info Needed from Individual Magnet Task Leaders

Magnetic Design Parameters

Computed harmonics as a function of current

Mechanical Design Parameters

Size of wedges, coil width, pole angle, collar, yoke, etc.

Magnet Construction Parameters

Actual component sizes (wedge, coil, collar, yoke, etc)

- Pass inspection, meet tolerances will not be enough.
- Record and provide actual dimensions since small errors add.



Error Tables for IRQ

- How to make error tables for magnet made with new technology ?
- Is “error table (sigma)” the right approach for a few IR magnets ?
 - Irrespective of whether it is a proper approach or not, error tables for future Nb_3Sn magnets must be created.
- Develop ways to correct/compensate construction errors after the coils (not necessarily magnet) are made.
 - How to generate expected field errors in that case?



List of Participants

The following have indicated that they would participate in this task:

- Ramesh Gupta, BNL
- Vadim Kashikhin, FNAL
- Giorgio Ambrosio, FNAL
- Shasha Zlobin, FNAL
- Paolo Ferracin, LBNL
- Gianluca Sabbi, LBNL

Any one else interested? Please contact.



Summary of IR Magnet Study Task

- **IR Magnet Study Task is a new task that is starting now (FY06).**
- **This group will be responsible for communicating with the AP group on various issues related to field quality and general variations in magnet design (including describing parameter space and creating expected error tables in Nb₃Sn magnets).**
- **Detailed milestones, schedule, etc. of various subtasks are yet to be determined. Current budget for FY06: 69k\$ (BNL:48 k\$, FNAL:21 k\$, contribution from base programs not included).**