# Open Midplane Dipole Design for LHC IR Upgrade*


Ramesh Gupta[ℜ], Mike Anerella[#], Mike Harrison[#], Jesse Schmalzle[#], and Nikolai Mokhov[+]

BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division www.bnl.gov/magnets


**High luminosity Interaction Regions (IR) present a hostile environment for superconducting magnets due to large amount of particle spray from p-p collisions:**

- The proposed LHC luminosity upgrade increases luminosity from $10^{34}$ $cm^{-2}$ $s^{-1}$ to $10^{35}$ $cm^{-2}$ $s^{-1}$.
- This upgrades creates a large (~9 kW) of power from each beam.
- Several hundred W/m of energy deposition in first dipole (D1).
- Energy deposition raises overall and local coil temperature. This brings a reduction in operating margin or may even cause a pre-mature quench. Radiation damage issues should also be examined.
- Heat removal poses a significant challenge, both in terms of technical performance and in terms of economical operation of IR magnets.
- Energy deposition is anisotropic with a large peak at the midplane.


**Abstract— The proposed luminosity upgrade of the Large Hadron Collider (LHC), now under construction, will bring a large increase in the number of secondary particles from p-p collisions at the interaction point (IP). Energy deposition will be so large that the lifetime and quench performance of interaction region (IR) magnets may be significantly reduced if conventional designs are used. Moreover, the cryogenic capacity of the LHC will have to be significantly increased as the energy deposition load on the interaction region (IR) magnets by itself will exhaust the present capacity. We propose an alternate open midplane dipole design concept for the dipole-first optics that mitigates these issues. The proposed design takes advantage of the fact that most of the energy is deposited in the midplane region. The coil midplane region is kept free of superconductor, support structure and other material. Initial energy deposition calculations show that the increase in temperature remains within the quench tolerance of the superconducting coils. In addition, most of the energy is deposited in a relatively warm region where the heat removal is economical. We present the basic concept and preliminary design that includes several innovations.**



ℜ Email: gupta@bnl.gov; Web: http://www.bnl.gov/magnets/staff/gupta

#Authors associated with the Brookhaven National Lab, NY, USA.

+Author associated with the Fermilab, IL, USA.



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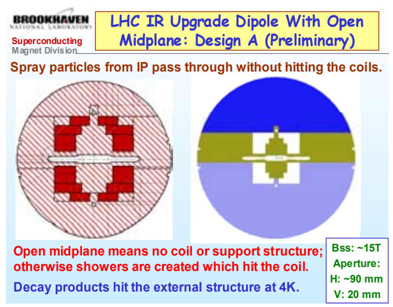


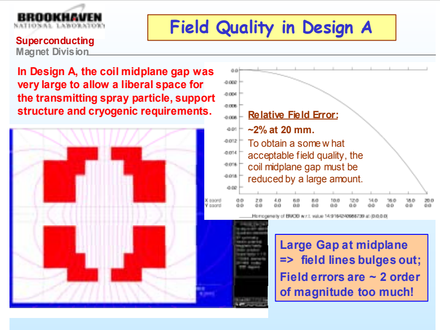


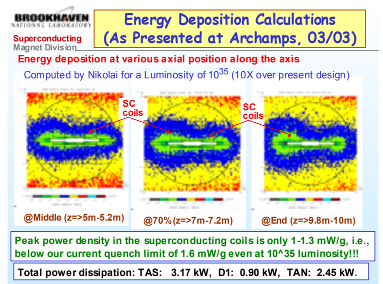


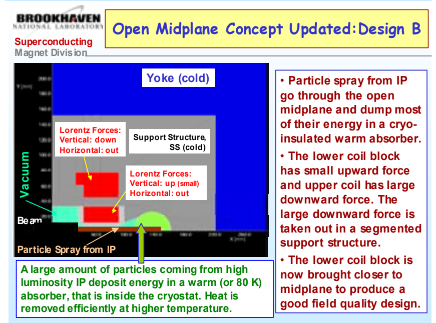


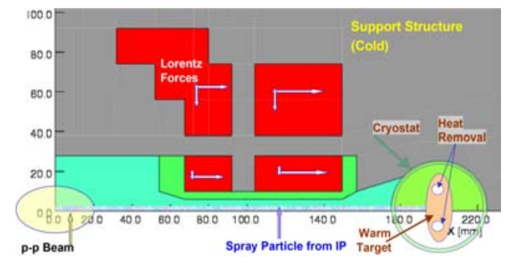


**Fig. : Schematic of the warm intercept Design B (optimized further for 135 mm aperture). Particle spray from the IP deposit heat on a warm target within a cold support structure. The arrows show the direction of the Lorentz force on each block. The design has been developed such that the blocks near the midplane have no net vertical downward force.**

TABLE I

LORENTZ FORCES ON THE CONDUCTOR BLOCKS AT THE QUENCH FIELD IN DESIGN B WITH 130 MM APERTURE. THE CONDUCTORS ARE GROUPED IN FOUR BLOCKS ACCORDING TO LOCATION.

| Block | Horizontal Component (N/mm) | Vertical Component (N/mm) |
|---|---|---|
| Inner Lower | 1632 | 16 |
| Outer Lower | 728 | -4 |
| Inner Upper | 6908 | -2248 |
| Outer Upper | 1302 | -3909 |

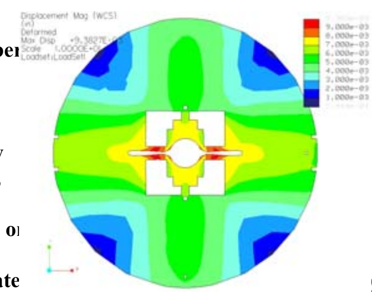

**Fig. 3: Magnitude of deflections in inches at the quench field in the 90 mm aperture "*Design A*" with cold iron structure.**

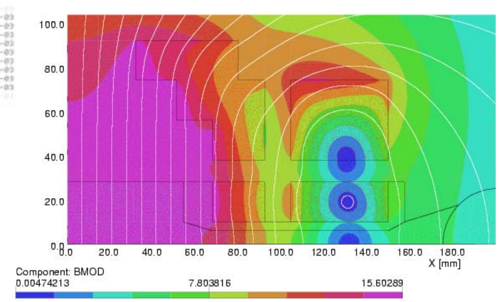


**Fig. : Magnetic model of Design B with 135 mm horizontal aperture with field contour and field lines superimposed. The design creates reasonably good field quality (relative error $10^{-4}$).**

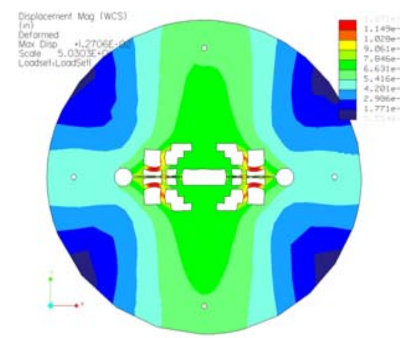

**Fig. : Magnitude of deflections in inches at the quench field in the 135 mm aperture "Design B" with warm intercept in cold support structure.**

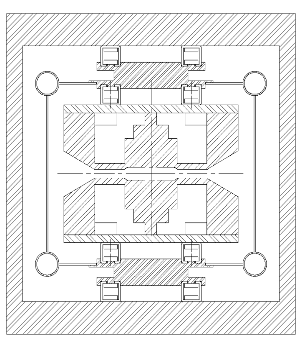

**Fig. 4: Schematic of the support structure for the warm iron design.**

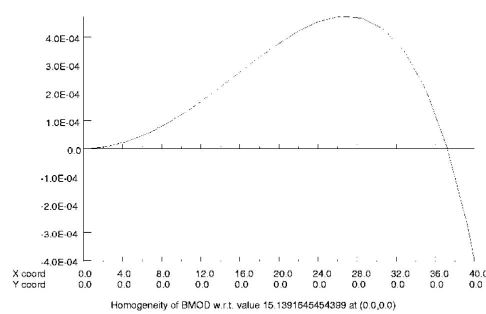


**Fig. : Relative field error on the X-axis for Design B.**

## SUMMARY

- "Open Midplane Dipole Design" seems to offer a good technical and an economical option for LHC luminosity upgrade in dealing with the challenges associated with a large increase in luminosity.
- The concept is exciting and is still evolving. The overall design is yet to be optimized, however, it looks promising with preliminary calculations indicating that:
  - The energy deposition in superconducting coils can be made small so that it remains below the nominal quench limit.
  - It may be possible to remove energy at a higher temperature and therefore, bring a significant reduction in the operating cost.