Open Midplane Dipole

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Overview

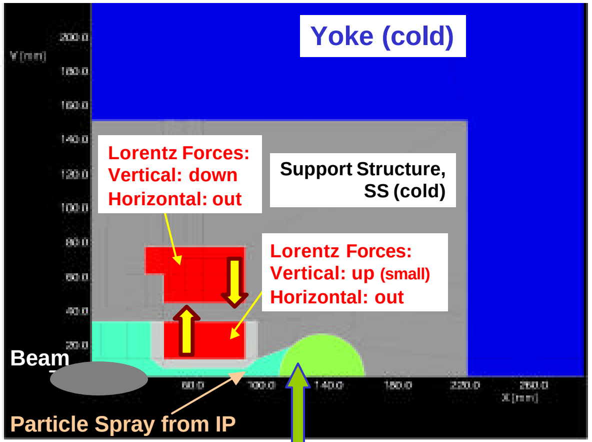
- **Important Features of Open Midplane Design** **(1 slide)**
- **Program Elements**
  - **Current D1 Open Midplane Dipole Design** **(3 slides)**

    X-section and magnet parameters remain the same even if D1 is split in D1A & D1B (see Mokhov's presentation) - optics & layout are adjusted
  - **Proof of Principle (POP) Design** **(1 slide)**
  - **Reconfigured 12 T Common Coil Dipole as the Open Midplane Dipole** **(1 slide)**
- **Summary** **(1 slide)**

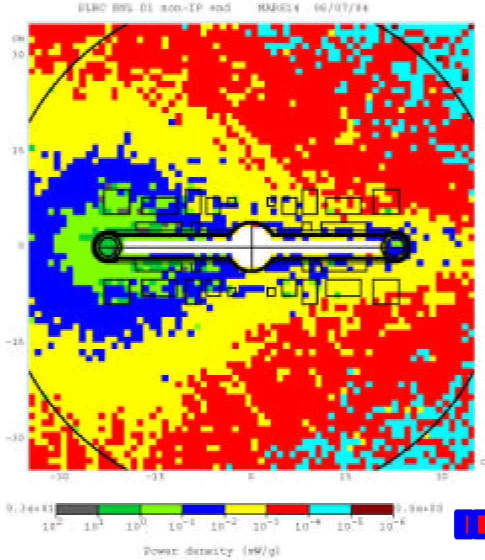
➢ See Jesse Schmalze talk for structure analysis.

Open Midplane Dipole for LHC Luminosity Upgrade

Motivation and Important Features



A large amount of particles coming from high luminosity IP deposit energy in a warm (or 80 K) absorber, that is inside the cryostat. Heat is removed efficiently at higher temperature.



- ~ 9kW/side energy for 10^{35} upgrade in LHC luminosity.
- In conventional designs it may cause a large reduction in quench field, impact magnet life, requires large increase in CERN cryogenic infrastructure and in annual operating cost.
- In the proposed design the particle spray from IP deposit only a small fraction of the total energy in superconducting coils. A significant fraction is deposited in the warm absorber located within the coldmass in its own “cryo-insulated enclosure”.
- This is a truly open midplane design - meaning no structure at the midplane between the coils. This avoids secondary shower in superconducting coils that prevented previous “pseudo: non-coil midplane design” from becoming attractive.
- However, such a design poses several challenges:
  - Large vertical forces towards midplane with no structure.
  - Obtaining low peak field enhancement.
  - Obtaining high field and reasonable field quality despite a large gap at midplane.
    (B ∝ I. cos(Θ); so if gap is large what part of cos (Θ) is left?)
  - Accommodating warm absorber within the collar structure.

⇒ Design developed here overcomes above challenges.

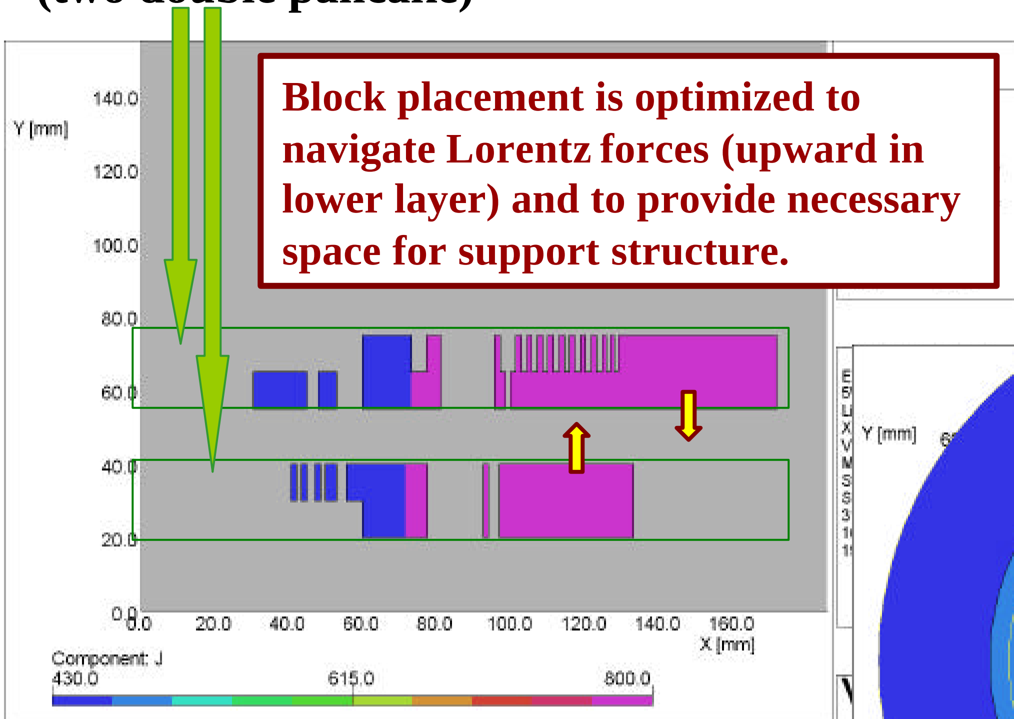
Basic Layout of The Current D1 Design

Magnet is consisted of simple racetrack coils (two double pancake)

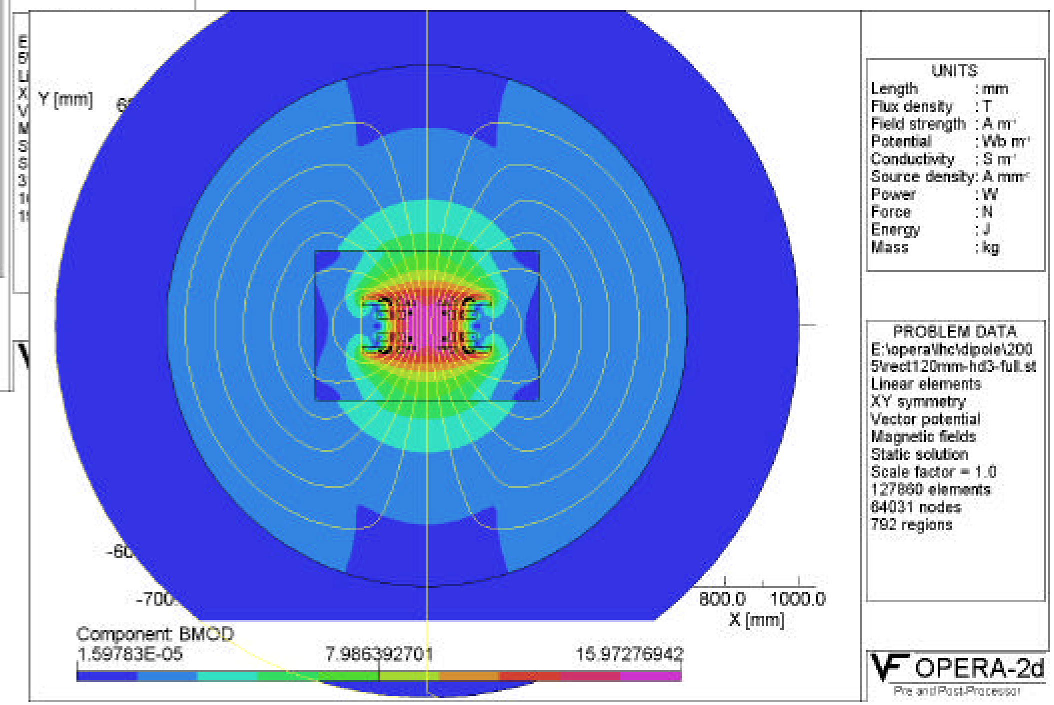
Design/Quench/Peak Field: 13.5 T/15 T/16 T
Nominal horizontal coil spacing : 120 mm
Nominal vertical coil spacing : 40 mm

Number of layers : 4
Number of turns: 230

Block placement is optimized to navigate Lorentz forces (upward in lower layer) and to provide necessary space for support structure.



Midplane gap is determined by energy deposition calculations.

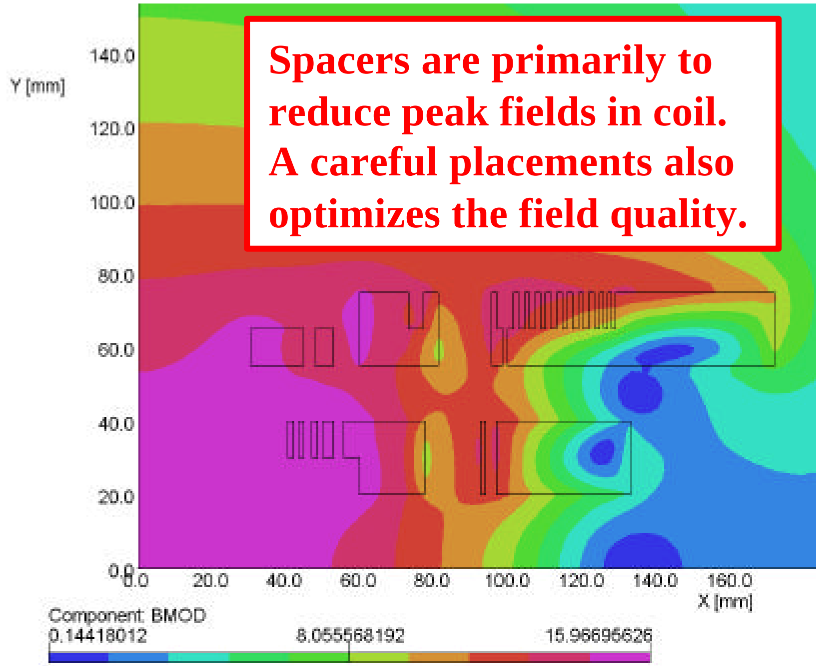


Lorentz force is upward in lower blocks. This eliminates the need of midplane support structure to contain vertical Lorentz forces.

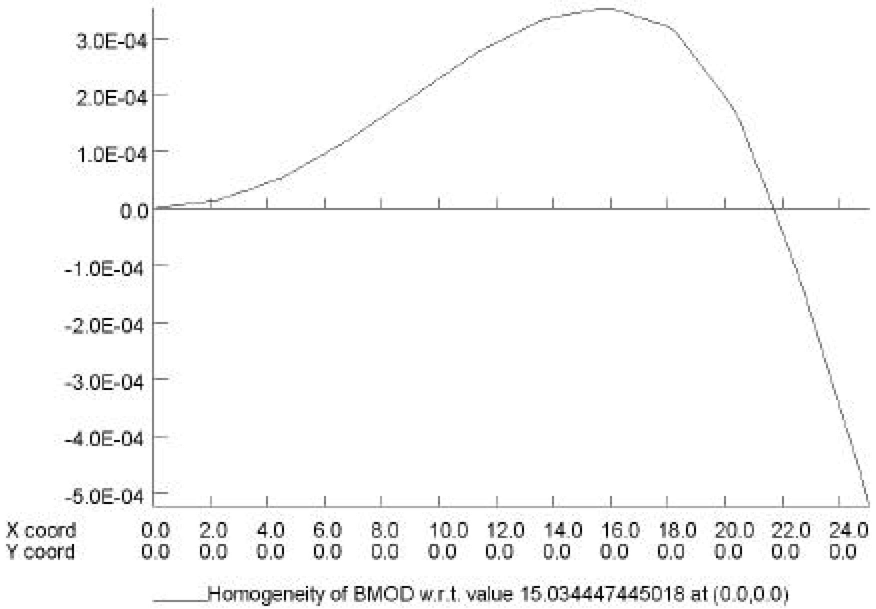
Current grading rather than cable grading.

Peak Field Enhancement and Field Quality

Field Contour at 15 T Central Field



Field Errors at the Midplane



Peak Field Enhancement :

16T/15T = ~6.6%

(a typical value is obtained despite a large midplane gap)

Appears to meet the present design guidance. Detailed field harmonics are yet to be optimized. However, 10^{-4} relative errors at midplane suggest that we should be able to meet the typical goals.

Basic Parameters of The Current D1 Design

(after Dec. review and based on the feedback from Mokhov's energy deposition calculations)

Nb_3Sn wire and cable parameters:

J_{sc}(12T,4.2K)	3000 A/mm^2
Cu/Non-Cu ratio	1
Strand diameter	0.7 mm
No. of strands in cable	26
Cable width (bare)	9. 5 mm
Cable thickness (bare)	1.25 mm
Insulation	Nomex /Fiberglass
Cable width (insulated)	10 mm
Cable thickness (insulated)	1.45 mm
Max. J_{cu} (@quench)	~ 1.5 kA/mm^2

Magnet parameters:

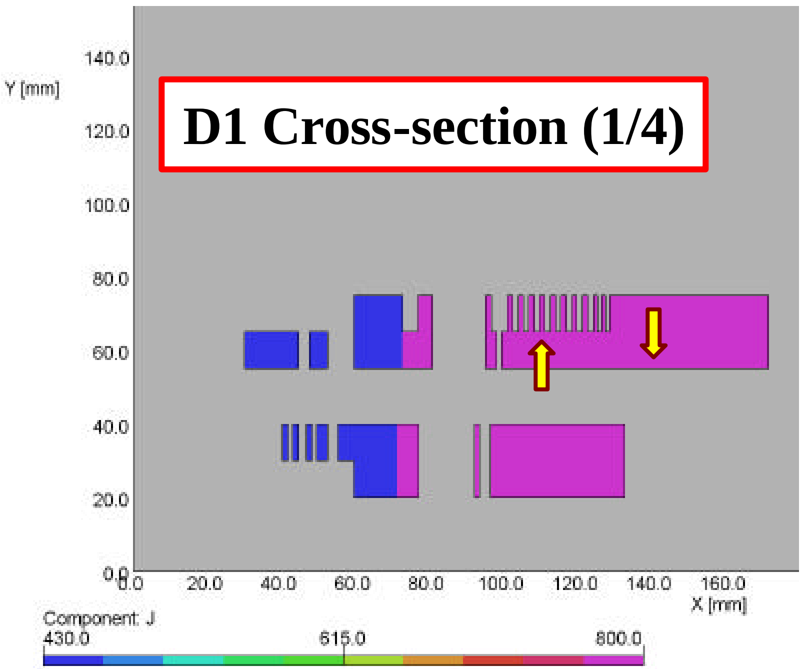
Design Field	13.5 T
Quench Field	~15 T
Quench Current*	6.2, 11.6 kA
Horizontal Spacing	120 mm
Coil Midplane Gap	40 mm
Collar	300mmX200mm
Yoke Outer Radius	700 mm
Stored Energy@Quench	6 MJ/meter

*Two values of quench currents, since current grading, rather than the cable grading is used.

Proof of Principle (POP) Magnet

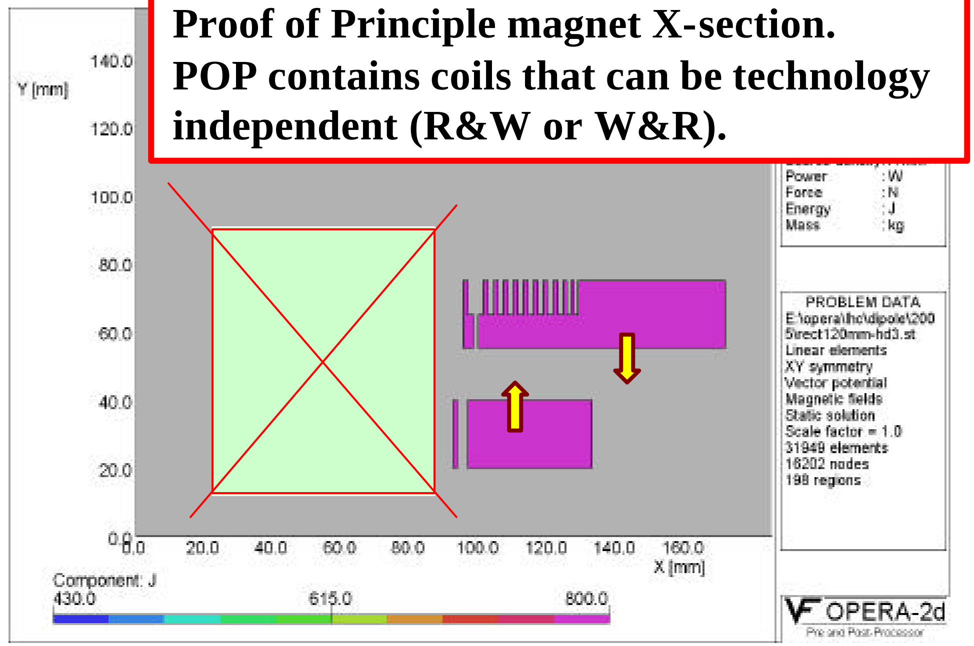
POP is simpler. It doesn't require "Inner Coil Blocks" or "Current Grading".

- ➢ POP addresses most of the critical features of the "Open Midplane Dipole" design.



Coil length (end to end) : ~1 meter

Proof of Principle magnet X-section. POP contains coils that can be technology independent (R&W or W&R).

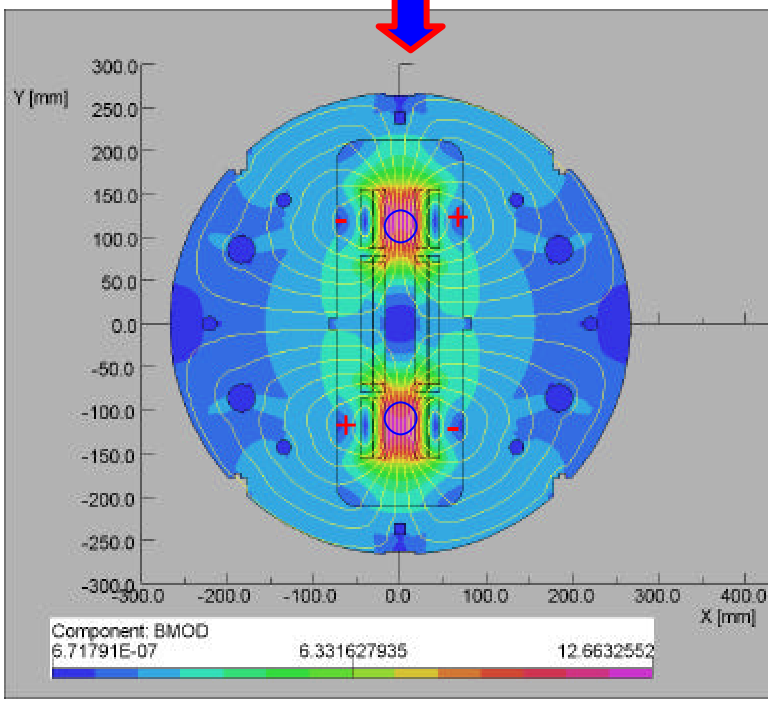


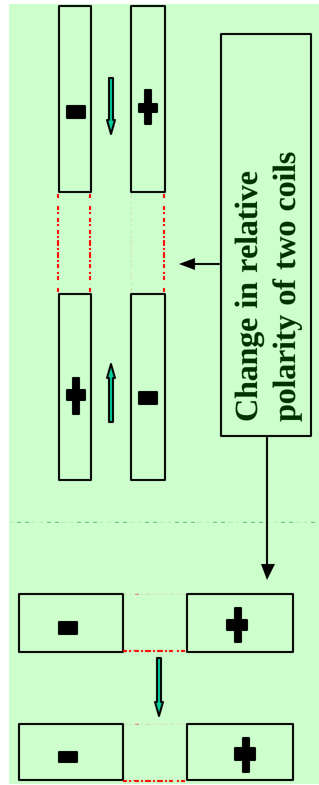
Present Design of POP:

Nominal horizontal coil spacing: 190 mm
Nominal vertical coil spacing: 40 mm
Number of turns (layers): 140 (4)
Central/Peak Field: 9.8 T/13. 6 T
Total Lorentz Force, Vertical (Horizontal): -3.4 (5.5) MN/m

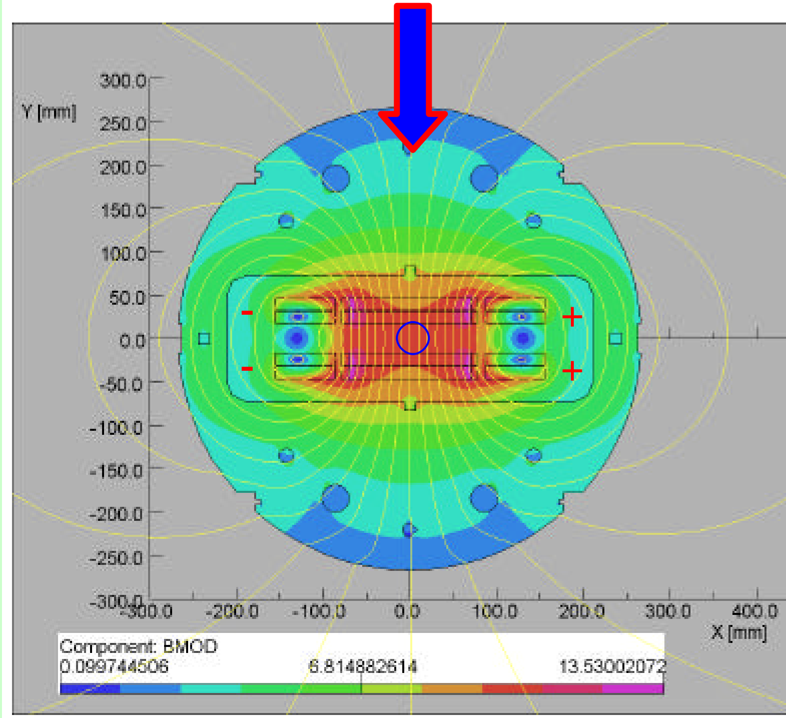
Twin Aperture Common Coil Dipole Reconfigured As A Single Aperture Open Midplane Dipole

BNL 12 T Common Coil Dipole
(now under construction)





BNL 12 T Common Coil Dipole
(to be reconfigured as Open Midplane Dipole)



Common Coil as POP (J_c=1800 A/mm^2, 3000 A/mm^2)

Nominal horizontal coil spacing: 140 mm
Nominal vertical coil spacing: 34 mm
Number of turns (layers): 90 (2)

Central/Peak Field (for 1800 A/mm^2): 9.3 T/11.4 T
Total Lorentz Force, Vertical (Horizontal): -2.71 (2.73) MN/m

Central/Peak Field (for 3000 A/mm^2): 11.2 T/13.8 T
Total Lorentz Force, Vertical (Horizontal): -4.0 (4.1) MN/m

SUMMARY

• The "Open Midplane Dipole Design" seems to offer a good technical and an economical option for LHC luminosity upgrade for "Dipole First" optics.

• Current design is the result of optimization over several competing requirements: energy deposition, navigation of Lorentz forces, support structure, field quality and overall magnet size.

• The basic design parameters have been chosen. A more detailed analysis, optimization and detailed design will continue in coming years.

• Based on the analysis performed so far, the current open midplane design appears to meet the basic design requirements.