HTS Open Midplane Dipole

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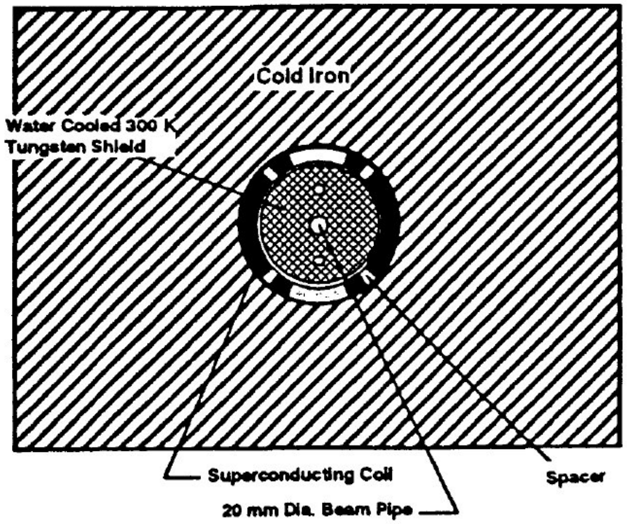
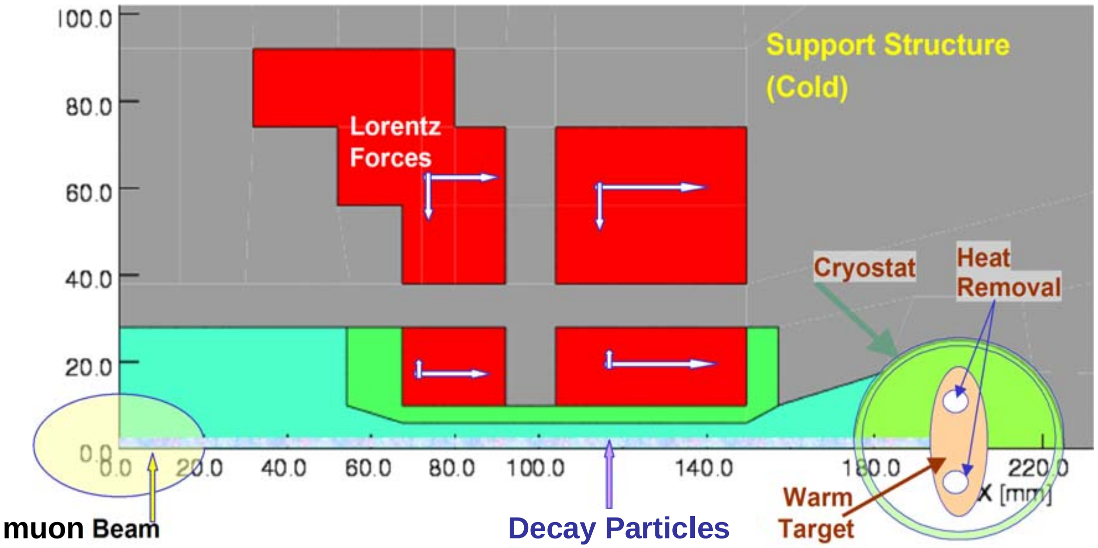
Motivation for HTS Open Midplane Dipole

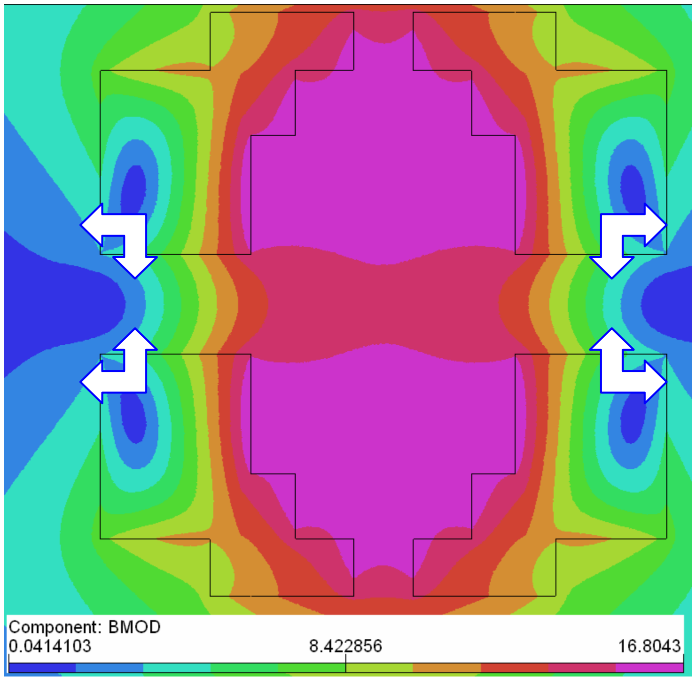


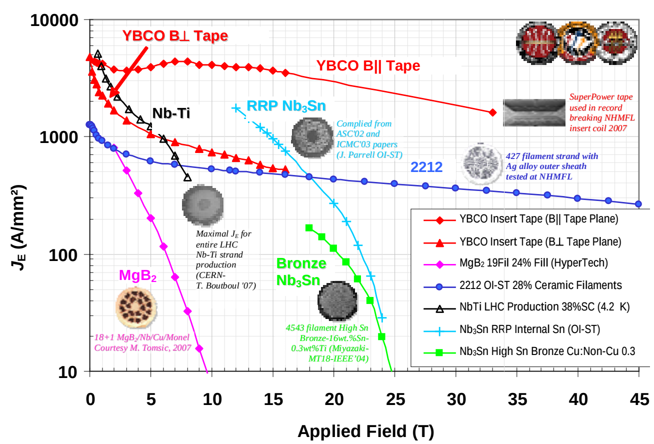
- Superconducting coils in muon collider dipoles are subjected to a large number of decay particles (a few kW/m) from short lived muons. One way to protect the coils is to use Tungsten liner. However, that increases size of the magnet.
- Angular distribution of the decay particles is highly anisotropic with large peak at the midplane. In an “open midplane dipole” design they are transported away from coil. Different versions of this design have been examined earlier by M. Green and P. McIntyre, etc.



- An ideal open midplane design will have no structure on the midplane.
- Racetrack coils are preferred for high field brittle superconductors.
- Use of HTS (a) will allow very high magnetic fields (20 T or above) and (b) can tolerate high heat loads).
- Higher field will allow higher energy and/or higher luminosity.

HTS Open Midplane Dipole
Challenges





#1 In usual cosine theta or block coil designs, there are large attractive forces between upper and lower coils. How can these coils hang in air with no structure in between?

#2 The ratio of peak field to the design field appears to become large for large midplane gaps.

#3 The large gap at midplane appears to make obtaining good field quality a challenging task. Gap requirements are such that a significant portion of the cosine theta, which normally plays a major role in generating field and field quality, must be taken out from the coil structure.

With such basic challenges in place, don't expect the optimized design to look like what we are used to seeing in conventional cosine theta magnets.

Plus challenges with HTS

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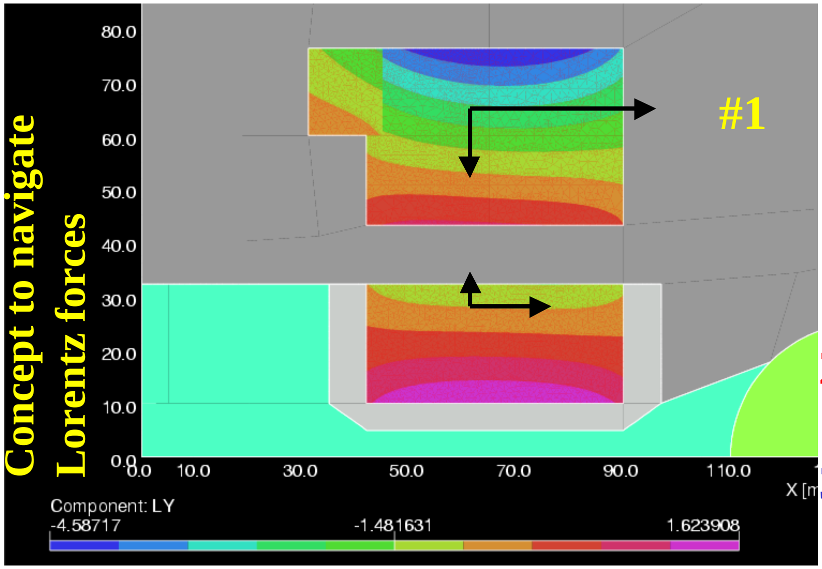
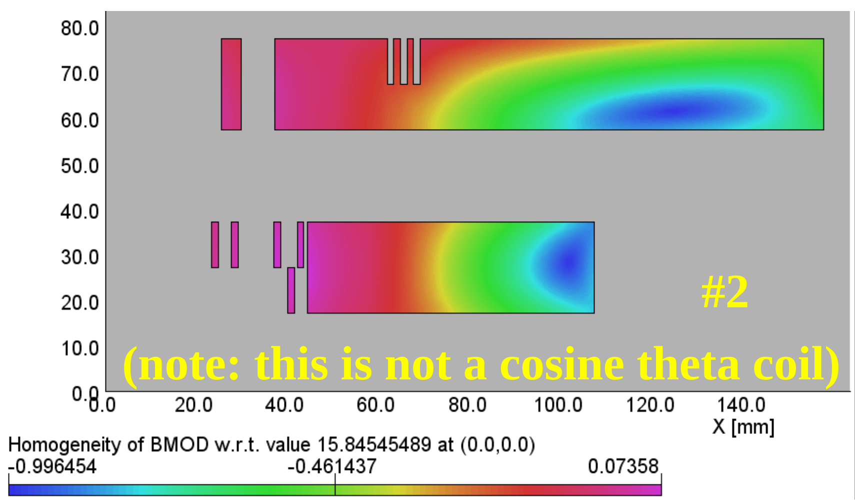
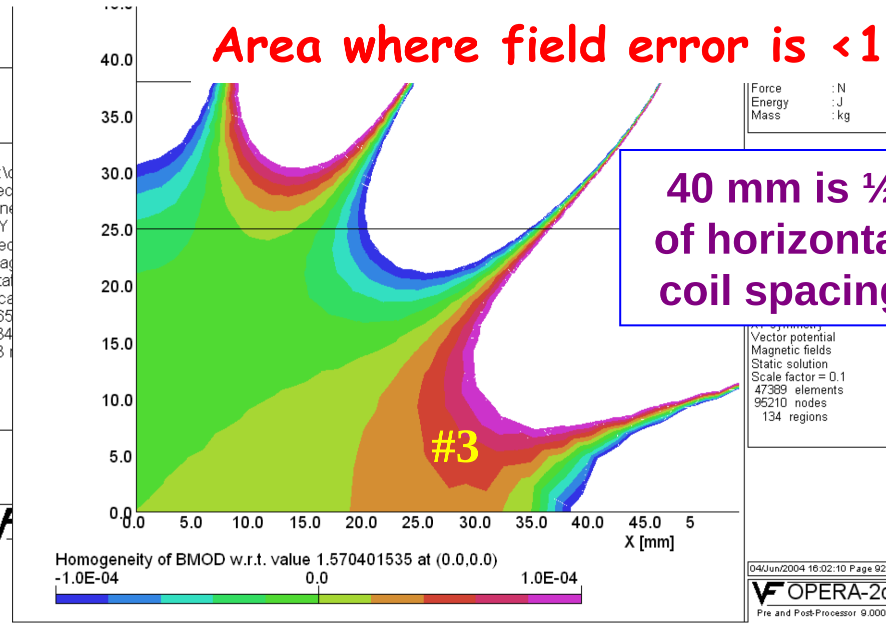
HTS Open Midplane Dipole
Approaches to overcome challenges



- **A significant conceptual development during the LARP R&D on Open Midplane Dipole**

1. Magnetic design is optimized such that there is no downward force on coils closer to the midplane. This is different from previous open midplane designs and it minimizes structure below coils.
2. The peak field enhancement can be made is as low as in conventional designs.
3. It is shown that the field errors can be made small.





Peak enhancement: ~7% over B_o

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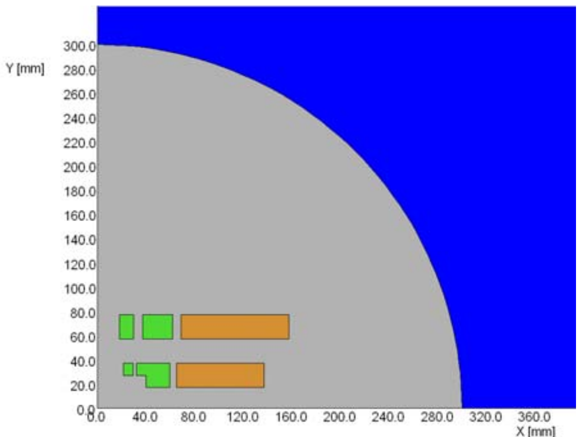
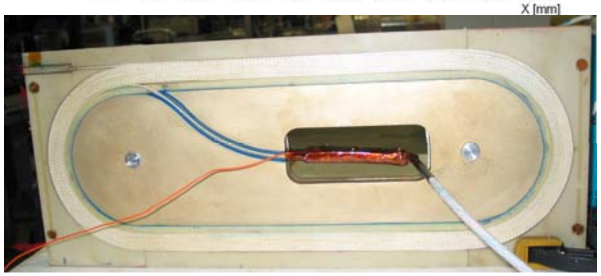
20 T Hybrid Open Midplane Dipole for Muon Collider





Racetrack coil made with Bi2212 Rutherford cable

Roebel cable - SuperPower YBCO

- **A 20 T open midplane dipole could look like the one shown on left. To save cost, we made it a hybrid design (HTS is green and LTS is gold).**
- **Generally, the places in the coil where we need high field superconductors are also the place where we need high temperature superconductors to deal with large energy deposition (fortunately the same conductor serves both).**
- **The design on left gives ~20 T field with conductor available today. However, it is not yet optimized for "navigation of forces", "field quality", "energy deposition", and mechanical structure, etc. (work for a future proposal).**
- **In terms of the use of HTS, the coils could be made with Bi2212 (see left – one of several coils built at BNL).**
- **Another interesting possibilities for high currents are Roebel cable (see left) or wider YBCO tapes.**
- **One can also consider MgB_2.**

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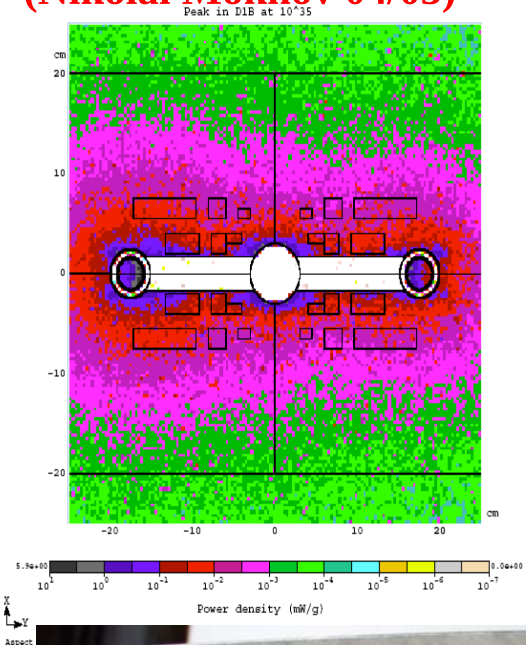
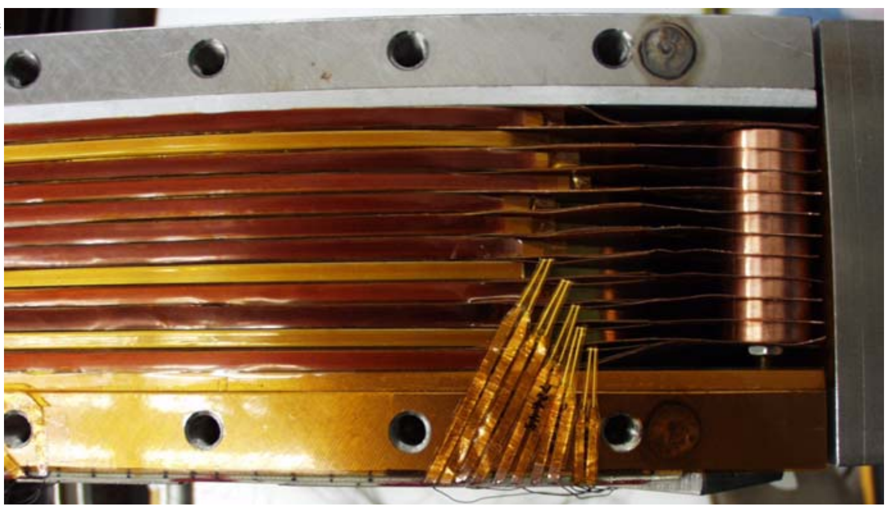
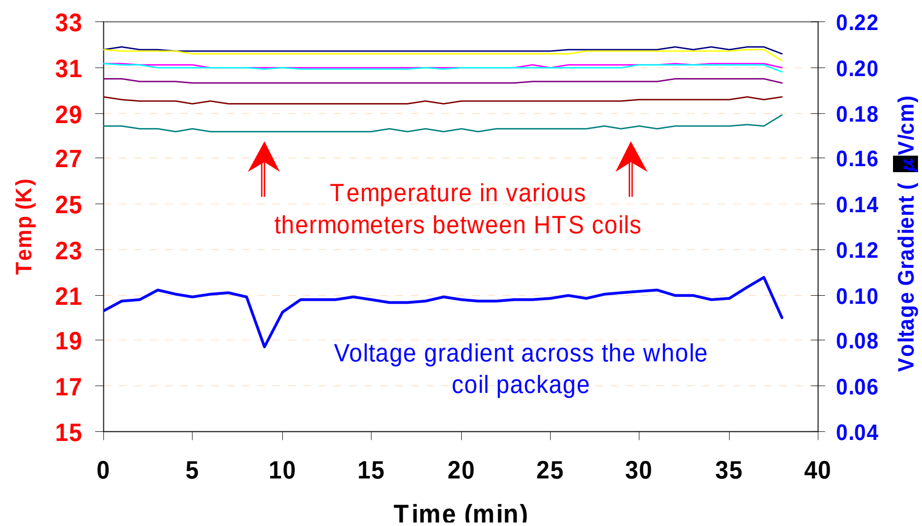
Energy Deposition and HTS

(Nikolai Mokhov 04/05)



- **During the LARP R&D, it was shown that in dealing with energy deposition issues, the open midplane dipole design has significant advantage over the conventional designs (Mokhov's calculations). In fact only open midplane design survived those high doses. One may expect a similar situation in muon collider magnets.**
- **During FRIB/RIA R&D, large energy deposition (5 kW/m^3) experiments were carried out. HTS coils in magnet operated stably for extended period of time. One may expect similar advantages of HTS in muon colliders. In fact, HTS, with large temperature margin, should provide a more robust operation.**





SUMMARY

- **HTS is beneficial in a variety of magnets in $\mu^+\mu^-$ colliders. HTS can generate very high fields and can tolerate large heat loads due to large temperature margin.**
- **The development of open midplane dipole design option is very important for $\mu^+\mu^-$ colliders. In LHC upgrade "dipole first optics", large magnitude of decay particles at the midplane limited the performance of superconducting coils. Muon collider may face a similarly situation.**
- **A design with managed Lorentz forces offers a true open midplane high field dipole design which significantly reduces energy deposition on s.c. coils.**
- **A ~20 T HTS (or hybrid) open midplane dipole, as compared to the present 10 T conventional design, would help increase the luminosity and/or energy of the proposed muon collider. Alternatively, one can develop a more efficient design.**
- **However, this is not a proven design and requires further R&D (both in conductor and in magnet development). A part of this R&D (development of design to a reasonable level, demonstration of some key components, etc.) can be carried out with a modest funding (< million $) in a couple or so years.**