Innovative Magnet Design and Technologies

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DOE Review of Superconducting Magnet Program

The Basic Guiding Principles

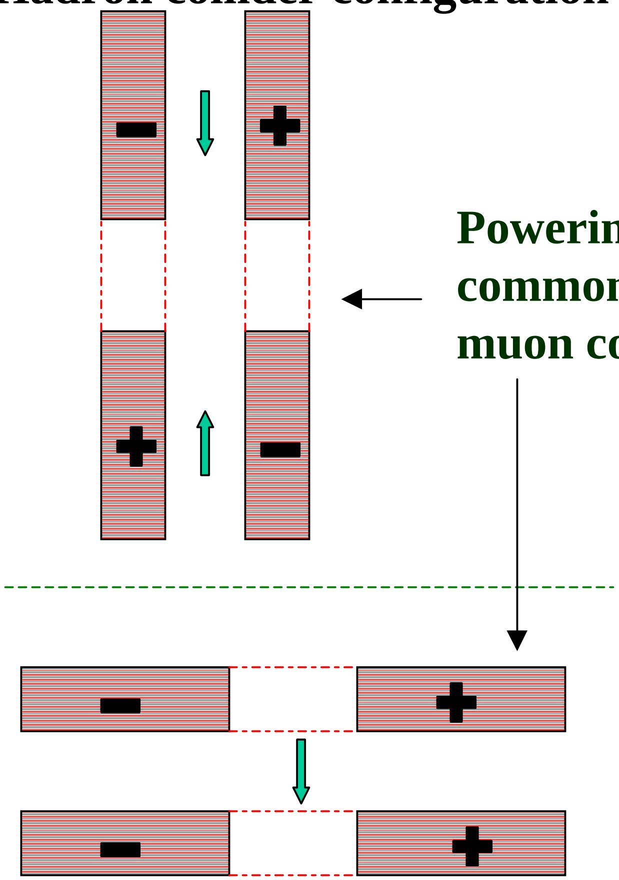
Remember the next machine is 10+ years away

In addition to maintaining the base program, this is also a unique time to explore

- ❒ Explore alternate concepts and technologies
- ❒ Explore the innovative ways to reduce cost
- ❒ Use the "Magnet R&D Factory" approach - faster turn-around for maximum exploration

Muon Collider Dipole Design and Configuration

Hadron collider configuration

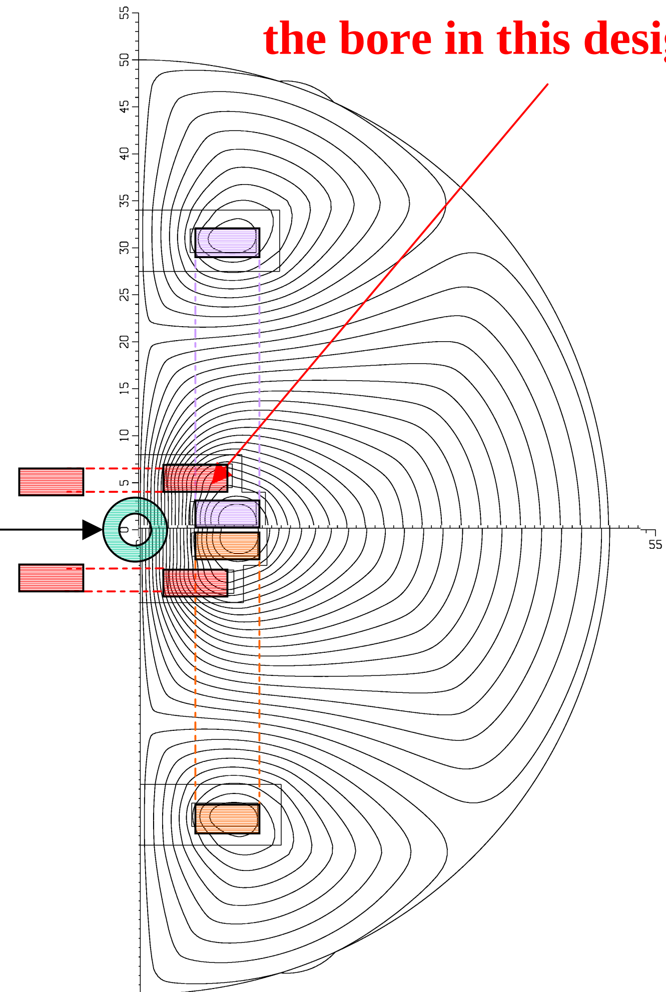


muon collider configuration

Powering differently changes common coil design test to muon collider design test

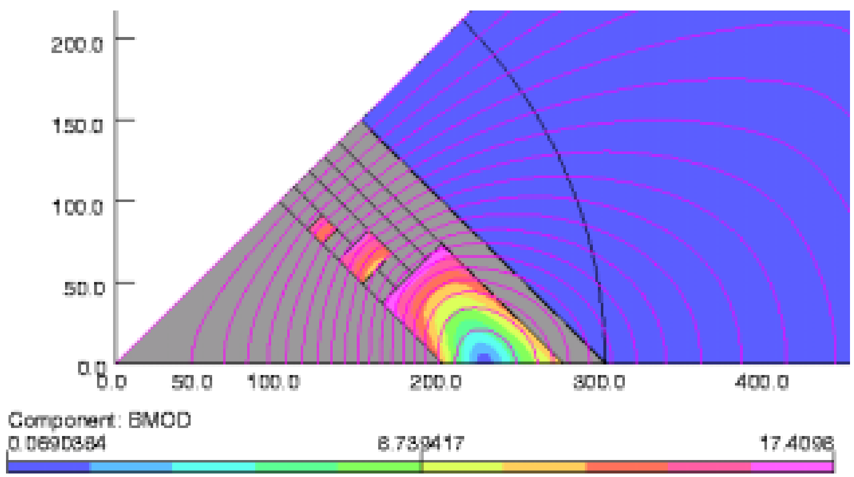
Note : A high stress test is created here

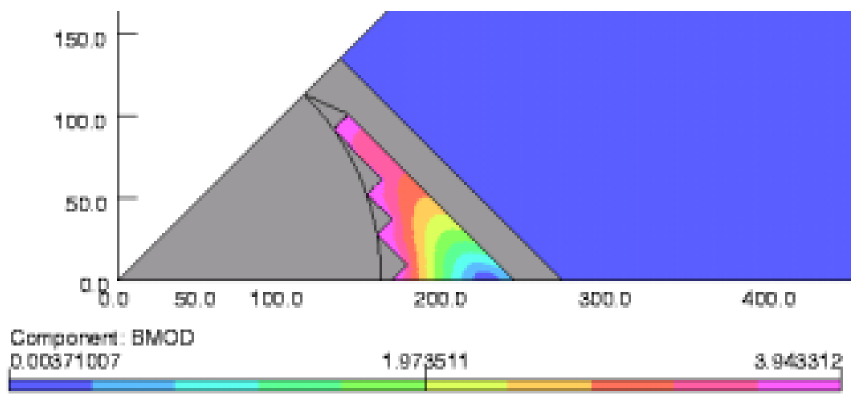
Racetrack coils clear the bore in this design



Tungsten & bore tube

Muon Collider Quadrupole Investigations





Morgan's Design:

Simple 2-d coils, straight ends.

But conductor at midplane are away.

Alternate Design:

Coils with smaller pole angles are inside (unconventional) to put more conductor at midplane.

Ends must be bent-up.

Layers can't be graded (same as above).

Cosine theta is better here.

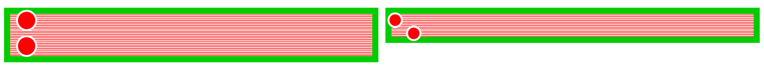
Never mind that it wasn't great this time; new approaches are productive only a few times but that's enough to make them worth exploring.

An Alternate Approach for a More Efficient Cable Grading

Grading cable between layers allows a more efficient use of SC

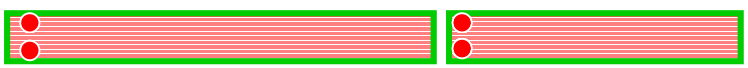
Put more J where field is lower - creates higher B_{ss} - the goal of the program

- **Usual Grading : Change cable thickness between layers**



Works well but increases relative insulation (15% to 20%) - reduces efficiency

- **Alternate Grading : Change cable width between layers**



Keeps fraction of insulation ~same. Almost full gain of grading is realized

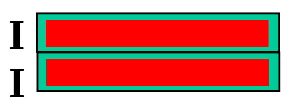
Used in the proposed 14 T design.

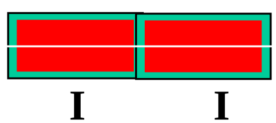
Flexible :

can change relative grading in cable after the strand is purchased

Cables for Higher Efficiency
(exploring ways to reduce insulation fraction)

- **Currently insulation takes ~15% of the cable volume**
  - **If layers are graded, it goes to ~20% in outer layer**
- **This is large and we must attempt to reduce it**
  - **Examine alternate insulating materials**
  - **Examine alternate cabling+insulating schemes**



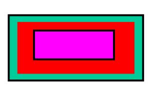


Same current, same inductance but less fraction of insulation (15% => **8%**)

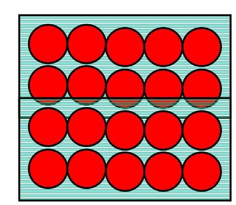
Pair of cable during coil winding

Cable on cable during cable winding

or



Current sharing issues



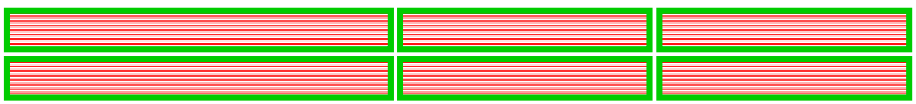
Possible Use of Proposed Cable in the High Field Magnet Design

Current High Field Design

inner layer 40 strand single pancake,

outer 2 layers 26 strand double pancake

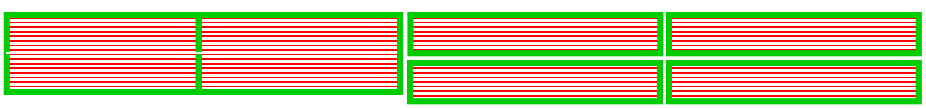
uses width-grading for high efficiency (fill factor)



Possible Higher Field Design

inner 2 layers 20 strand double pancake,

outer 2 layers 26 strand double pancake



Will have more turns in critical inner layers and thus create even higher field

Grading in High Field R&D Magnet
(when the magnet aperture changes)

The common coil design has a unique feature:

The magnet aperture can be changed after the coils are made.

This creates higher field in the aperture; changes field distribution between layers

A relative change in field distribution requires a different grading for efficiency.

To use the same coils the relative grading is changed by changing the relative current between layers. Note : the same coils get used - it's like a new design.

Example:

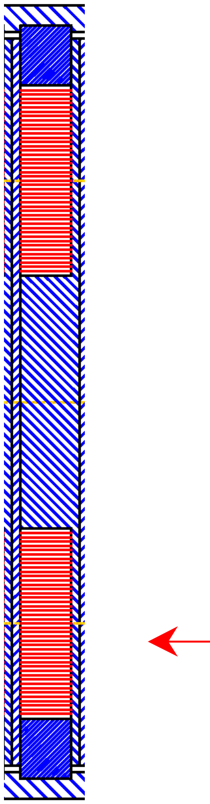
Case 1 : 13.8 T for 40 mm aperture : $I_1 = I_{2,3}$ = 12 kA

Case 2 : 16.3 T for 10 mm aperture : I_1 = 8.5 kA, $I_{2,3}$ = 12.5 kA (~+50%)

It also facilitates "stress degradation" examination in an actual magnet configuration

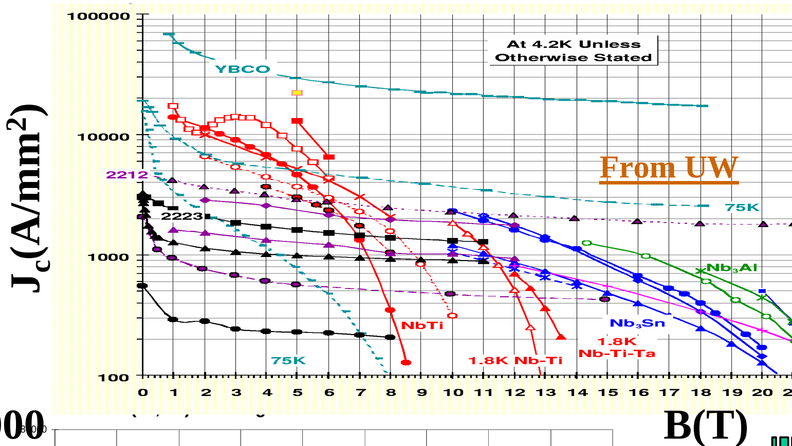
An important issue in Nb_3Sn conductor in very high field magnet designs

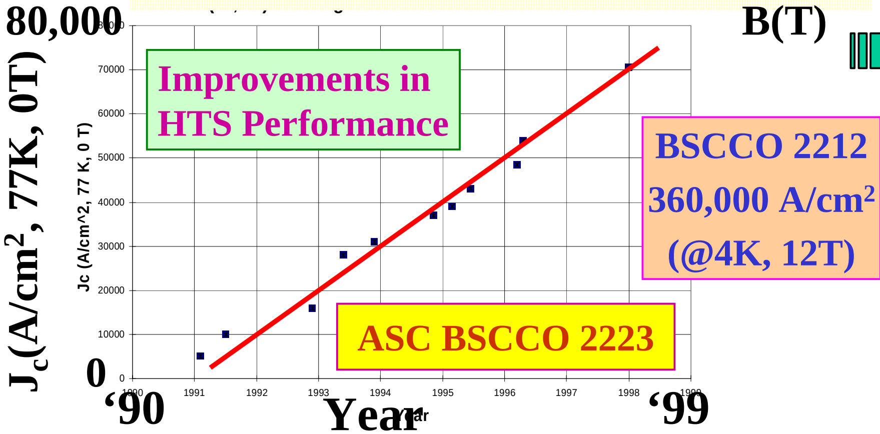
A Possible Low-cost Magnet Manufacturing Process

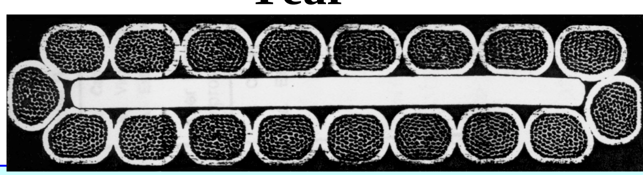


- **Reduce steps and bring more automation in magnet manufacturing**
- **Current procedure : make cable from Nb-Ti wires => insulate cable => wind coils from cable => cure coils => make collared coil assembly**
- **Possible procedure : Cabling to coil module, all in one automated step - insulate the cable as it comes out of cabling machine and wind it directly on to a bobbin (module)**

Emerging Technologies : HTS







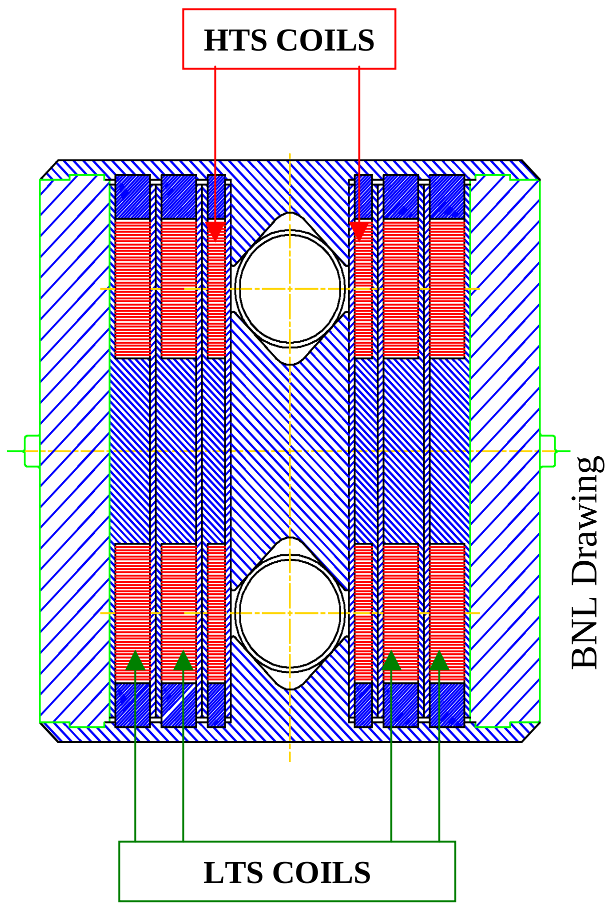
KAmp Rutherford cable : LBL-industry collaboration

- HTS have made significant progress
- To be shown that it's practical for large production (cost & technology)
- It takes long time to do magnet R&D (many technical questions remain)
- Start magnet R&D now, so that if the cost situation improves and if it can be made technologically feasible, we can use it in the next machine

☆ Examine other conductors and related technologies also :

- ✧ Newer Nb_3Sn, Nb_3Al
- ✧ React & Wind magnet technology
- ✧ etc.

HTS in a Hybrid Magnet



- **Perfect for R&D magnets now.**

  HTS is subjected to the similar forces that would be present in an all HTS magnet. Therefore, the most technical issues will be addressed.

- **Field in outer layers is ~2/3 of that in the 1st layer. Use HTS in the 1st layer (high field region) and LTS in the other layers (low field regions).**

- **Good design for specialty magnets where the performance, not the cost is an issue. Also future possibilities for main dipoles.**

Conclusions and Summary

Proposals to use a rare window of opportunity

to significantly influence the next hadron collider

- **Exploring new magnet designs and technologies.**
- **An approach to produce lower cost magnets.**
- **Systematic and faster R&D ("*Magnet Factory Approach*") to evaluate and explore a larger number of ideas.**