http://seminole.lbl.gov/rgupta/public/common-coil-magnet-system-presentation/
For a higher resolution (~12 MB) postscript file visit:
http://seminole.lbl.gov/rgupta/public/vlhc/common-coil-magnet-system-presentation.ps

For a companion talk, please visit:
http://seminole.lbl.gov/rgupta/public/Field-Quality-presentation/

Common Coil Magnet System

(with a Large Dynamic Range)

Ramesh Gupta, LBNL

VLHC Workshop on Magnet Technologies

Port Jefferson, Long Island, NY

Nov 16-18, 1998

Overview of the Presentation

- **Common Coil Design**
  - *Original design*
    - » *Plus a proposed extension*

- **R&D with Common Coil Design**
  - *R&D magnet factory*
    - » *A modular approach with a faster turn around*

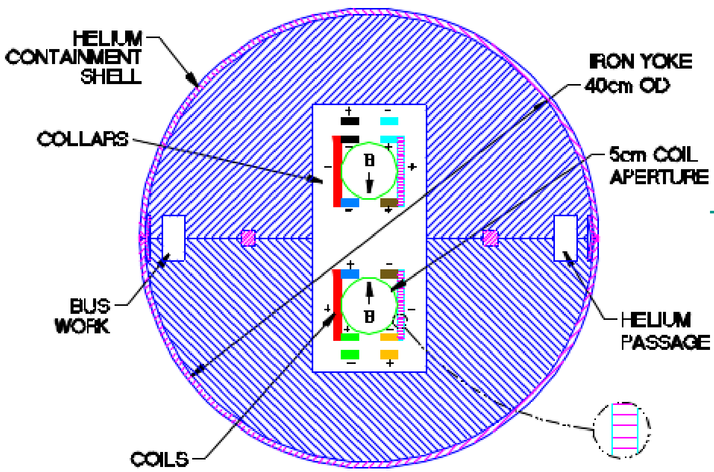
Preface

- **10-15 years to VLHC; 5-10 years to do magnet research**
- **A rare opportunity to explore alternative approaches**
- **Be innovative**

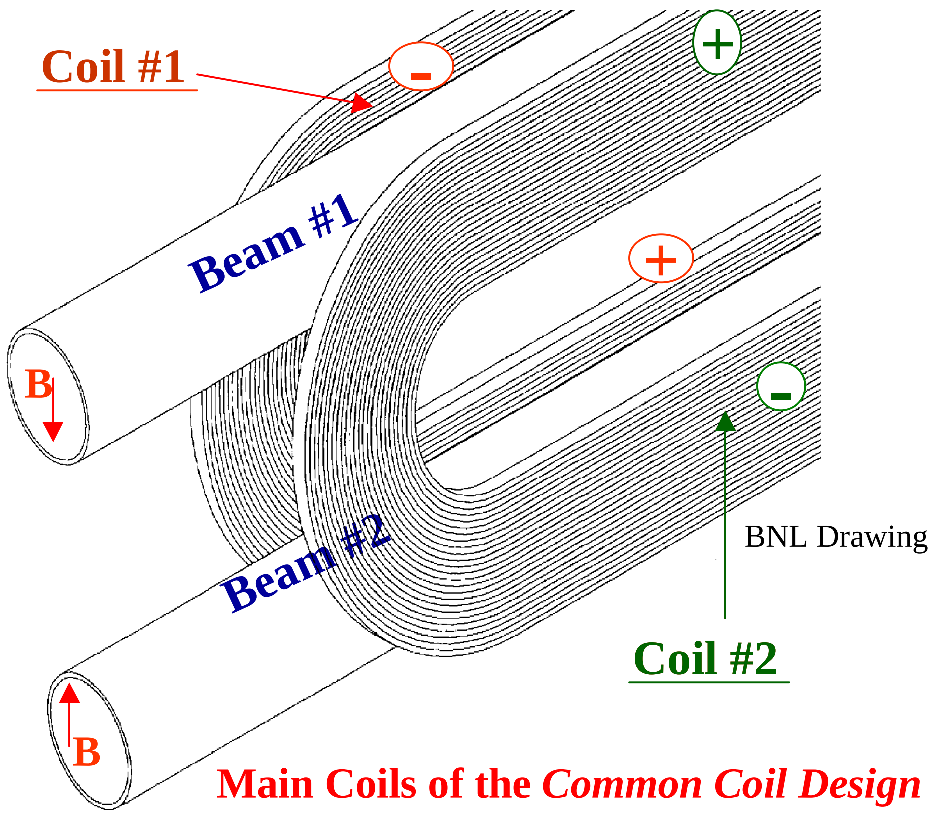
  Alternate design concept

  "Magnet R&D Factory" for faster turn-around

  to explore/develop innovative magnet technology



Common Coil Design
(The Original Concept)

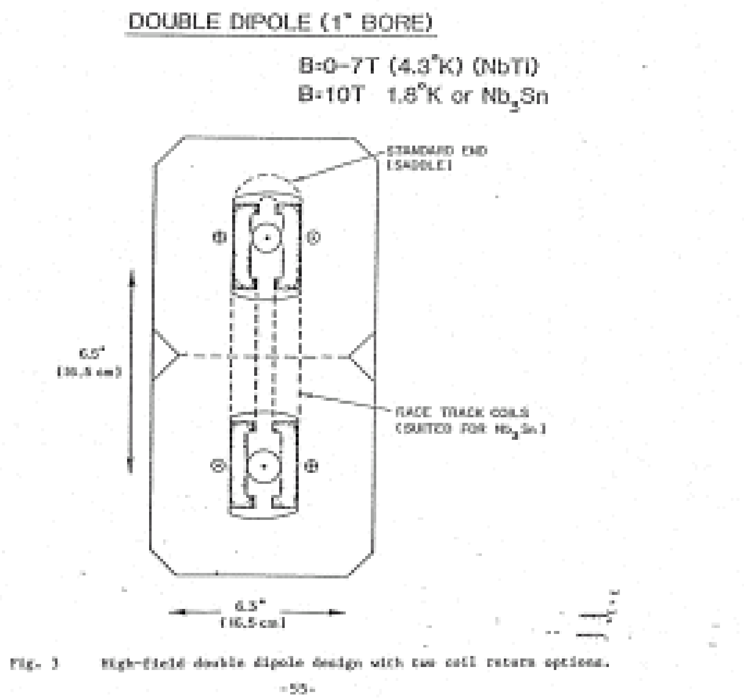


Main Coils of the *Common Coil Design*

- **Simple 2-d geometry with large bend radius (no complex 3-d ends)**
- **Conductor friendly (suitable for brittle materials - most are, including HTS tapes and cables)**
- **Compact (compared to single aperture D20 magnet, half the yoke size for two apertures)**
- **Block design (for large Lorentz forces at high fields)**
- **Efficient and methodical R&D due to simple & modular design**
- **Minimum requirements on big expensive tooling and labor**
- **Lower cost magnets expected**

I am not the only one to have suggested this type of crazy geometry

Danby, BNL (1983)



Had to come out of BNL to find what a very respected scientist thought there before I was born as a magnet person.

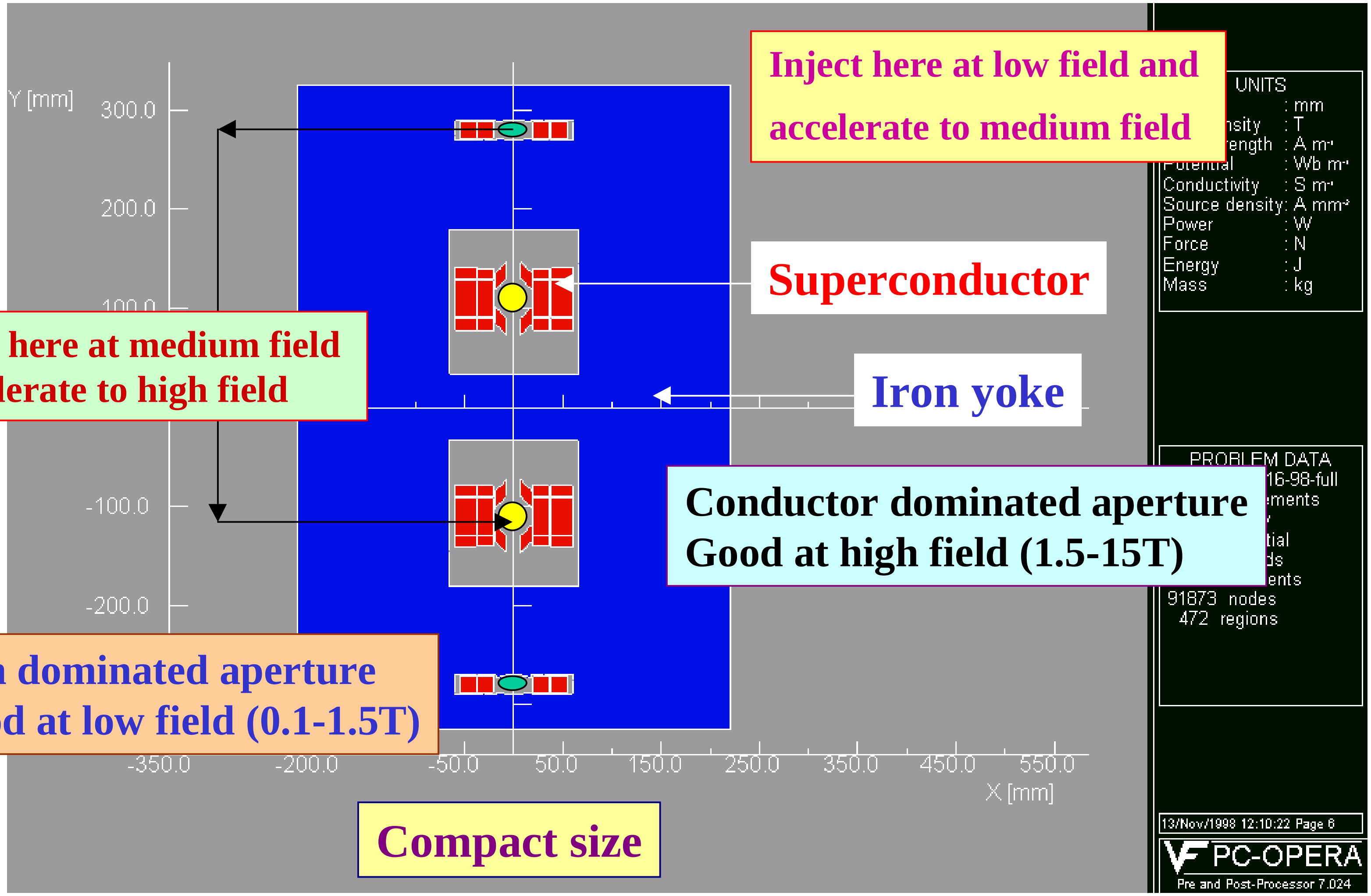
Similar, except that in Danby's design the pole coil must to be bent in a tight radius.

Common coil design has some more advantages in terms of compact, flexible and modular easy-to-fabricate structure, etc.

A Common Coil Magnet System for VLHC

(May eliminate the need of a high energy booster)

A 4-in-1 magnet for a 2-in-1 ring



Common Coil Magnet System with a Large Dynamic Range
(Possible Advantages)

• Large Dynamic Range

~150 instead of usual 8-20.

May eliminate the need of the second largest ring. Significant saving in the cost of VLHC accelerator complex.

• Good Field Quality (throughout)

Low Field: Iron Dominated
High Field: Conductor Dominated.

Good field quality from injection to highest field with a single power supply.

• Possible Reduction in High Field Aperture

Beam is transferred, not injected
– no wait, no snap-back.

Minimum field seen by high field aperture is ~1.5 T and not ~0.5 T.

The basic machine criteria are changed!
Reduce high field aperture, say to 25 mm?

Reduction in high field aperture => reduction in conductor & magnet cost.

• Compact Magnet System

As compared to single aperture D20, 4 apertures in ~70% of the yoke mass.

Apertures used in the example

- **High field (conductor dominated) aperture**
  Nominal circular clearance: 40 mm

- **Low field (iron dominated) aperture:**
  Horizontal: 40 mm (same as in HF aperture)
  Vertical: 20 mm (same as in LF proposal)

These apertures are to be changed as per beam dynamics studies.

Reducing HF aperture would significantly save on the conductor volume.

Increasing LF aperture might require small amount of extra conductor and may be a separate power supply.

Abstract for PAC'99 Paper on
Field Quality in a Common Coil Design Magnet System

PAC99 Abstract #3338 revision of 04-NOV-98

Paper type: Poster . Sort code T10

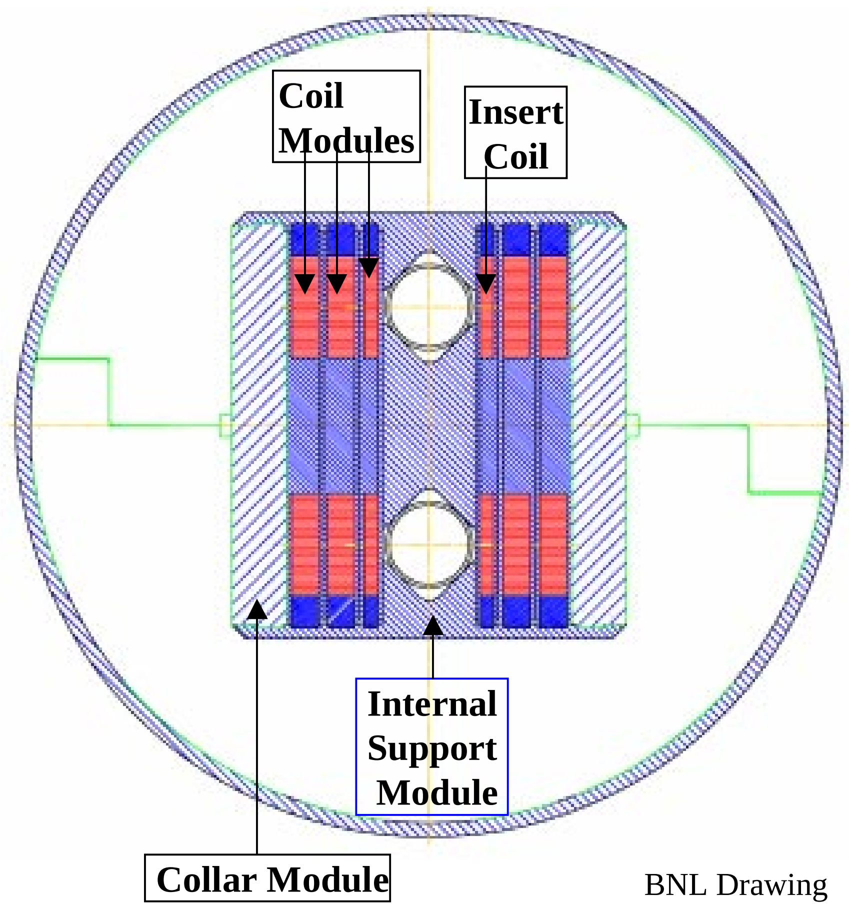
MAG- 00120 Field Quality in a Common Coil Design Magnet System. *

R. GUPTA, LBNL;

This paper makes an initial estimate of the field quality in the accelerator magnets based on the "Common Coil Design" for a very large hadron collider (VLHC). In the common coil design, the main coils are shared between the two apertures in an over-and-under geometry. The auxiliary coils, used for field quality purpose, do not cross the bore tube either. Some of these auxiliary coils, like the main coils, are shared between the two apertures while some "other auxiliary coils" return away from the high field magnet apertures. It is proposed that within the same cryostat and coldmass these "other auxiliary coils" make two additional iron dominated magnet apertures where the field quality is good for beam injection for a field as low as 0.1 T. The beams are transferred from the low field apertures to the high field apertures at about 1.6-2.0 T. The estimated systematic errors in the field harmonics at 10 mm radius in a 40 mm high field (~15 tesla) aperture is expected to be a few parts in 10,000 with a single power supply. Past experience have shown that the random errors would be smaller than the systematic. The proposed "common coil design magnet system" is expected to significantly reduce the cost VLHC with the required field quality magnets having a dynamic range of 150. In the proposed system, the need of a separate outside ring for high energy booster is eliminated. Moreover, this may also help reduce the size of conductor dominated high field aperture as the beam is not injected in the conventional sense - it is transferred during an up-ramp.

*Work supported by the U.S. Department of Energy under Contract No. DE-A
D03-76SF00098.

A Modular Design for a New R&D Approach



BNL Drawing

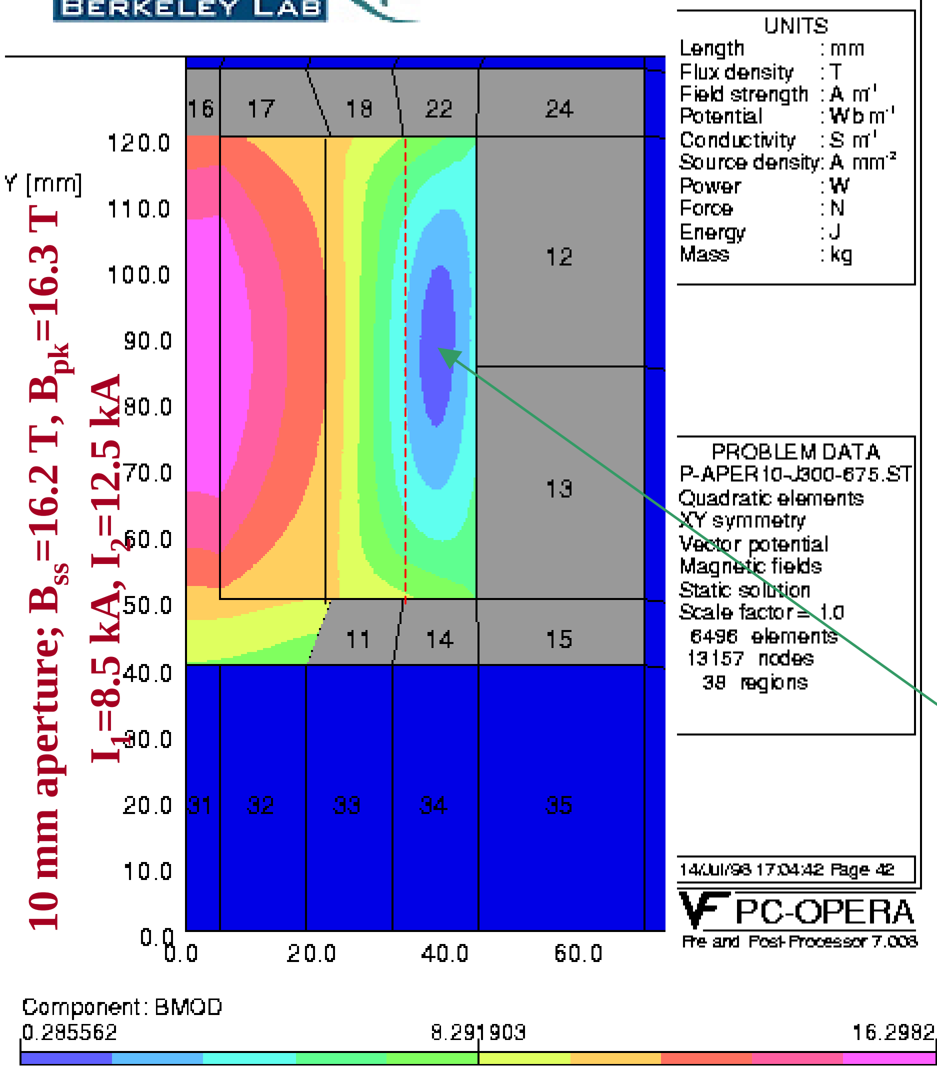
- Replaceable coil module
- Change cable width or type
- Combined function magnets
- Vary magnet aperture
- Study support structure

Traditionally such changes required building a new magnet

Also can test modules off-line

This is our Magnet R&D Factory

Investigations for Very High Field (to probe the limit of technology)

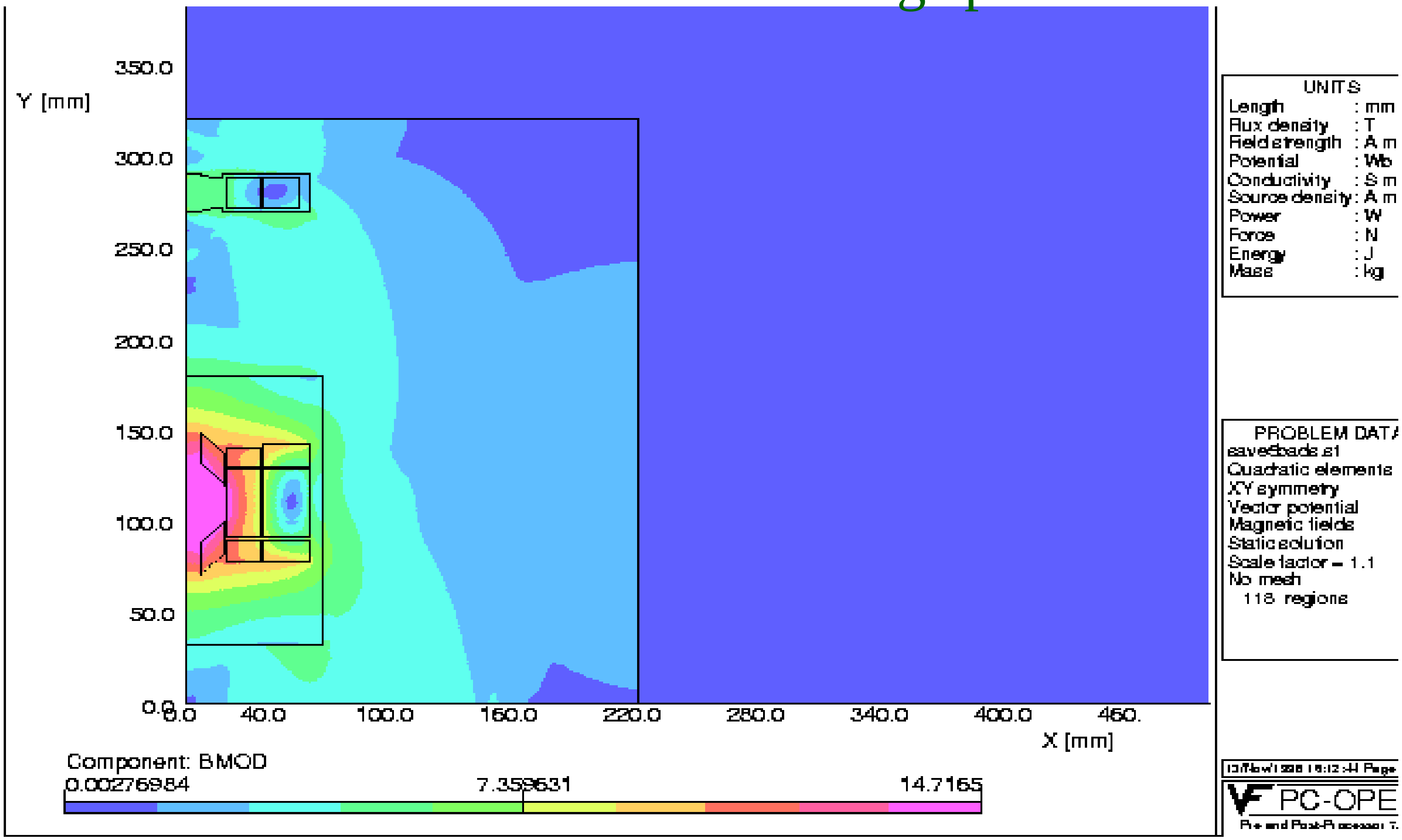


- Vary aperture after the coils are made
  - a unique feature of this design
- Lower separation (aperture)
  - reduces peak field, increases T.F.
    - => Higher B_{ss}
- May not be practical for machine magnet
  - but an attractive way to address technology questions
- Determine stress degradation in an actual conductor/coil configuration
  - Max. stress accumulation at high margin region
- When do we really need a stress management scheme (cost and conductor efficiency questions), and how much is the penalty?
- Simulate the future (better J_c) conductor

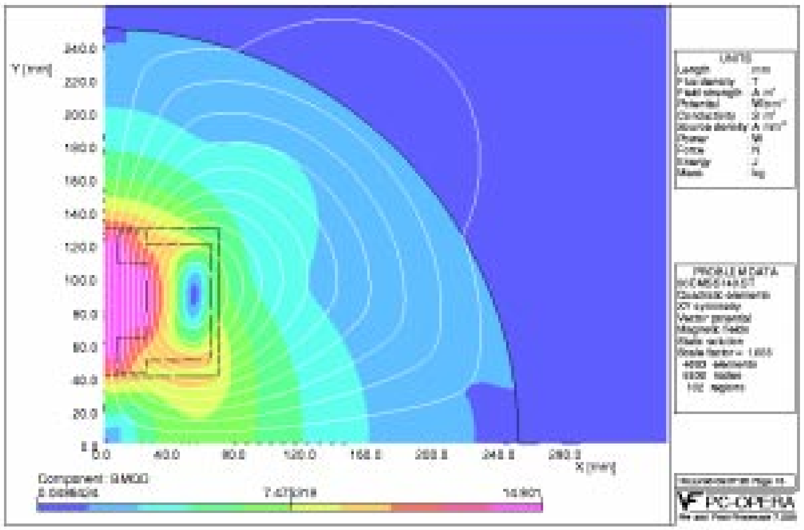
Another Unique Advantage of the Common Coil Design

A Low Field Region in the middle of the two apertures

Good for making splices



50 mm Aperture Investigations (for comparison to D20)



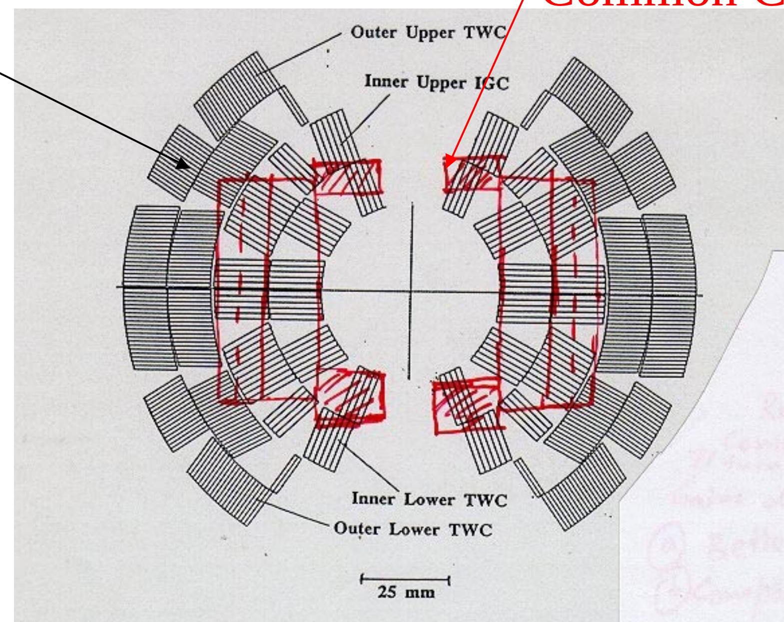


Figure 1 The Coil Cross-section for the LBNL D-20 Niobium Tin Dipole

Use 40 mm coil (not optimized for 50 mm aperture)

B_{ss} (at 4.3 K) 14.3 T, B_{pk} = 14.9 T

Compact design (Yoke cross-section half of D20)

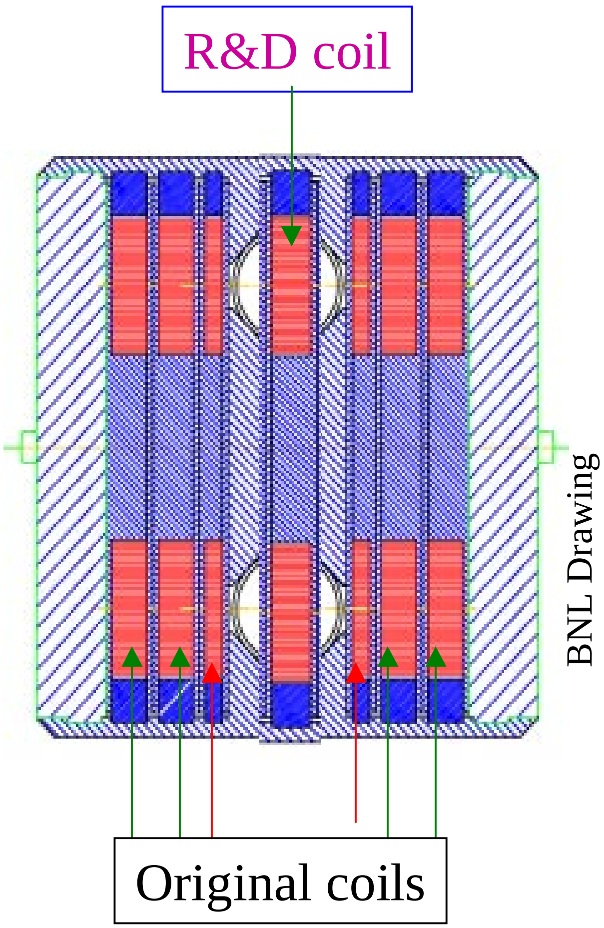
Number of turns per quadrant per aperture = 71

(D20 used 118 turns)

Uses much less conductor volume:

- No wedges for arc shape
- Pole turn in outer layers of D20
- Compact Design
- Better Conductor

Possible use of R&D funding to small labs to support VLHC Magnet Research



- An important part of this high field magnet research is the coil module -- be it conductor manufacturing or coil manufacturing or stress management, etc.
- The best is to test the concepts and further developments in a "real magnet" situation.
- It perhaps has a moderate price tag to allow innovative R&D by small labs or a large scale/number dynamic R&D by bigger labs.
- PROPOSAL: Make this module anywhere and develop magnet design which can accommodate such a component as an integral part it.
- **BUT IT DOES REQUIRE A MODULAR DESIGN APPROACH FROM THE BEGINNING.**

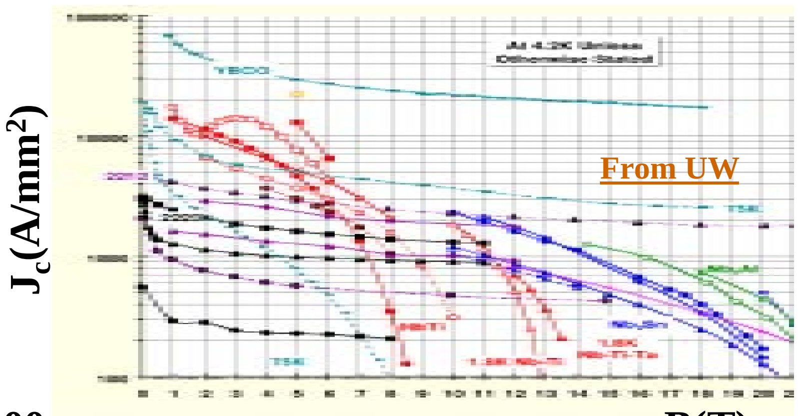
What can one study with these modules

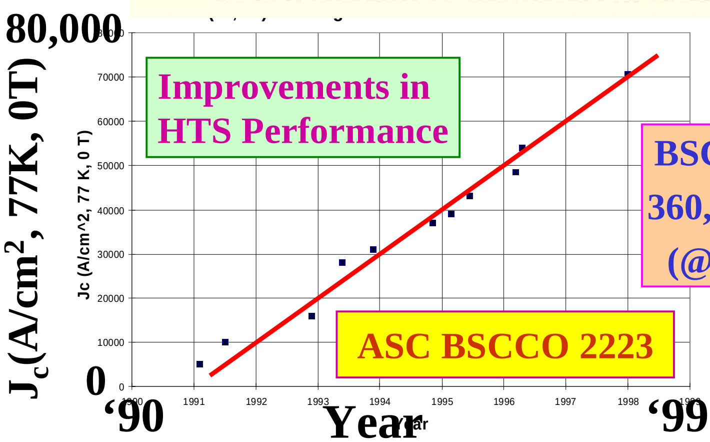
Examples of systematic studies in a modular approach

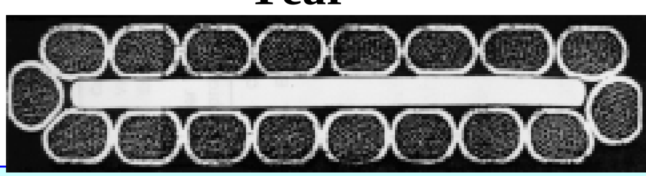
- Different technologies
  - Wind & React Vs. React & Wind
- Different conductors
  - Nb_3Al, HTS, etc.
- Different insulation
- Different geometry's
  - Tape, cable
- Stress Management/High Stress Configuration
- Coil Winding/Splice

*** A Dynamic Program with fast turn-around time for exploring new frontiers/ideas ***

Emerging Technologies : HTS







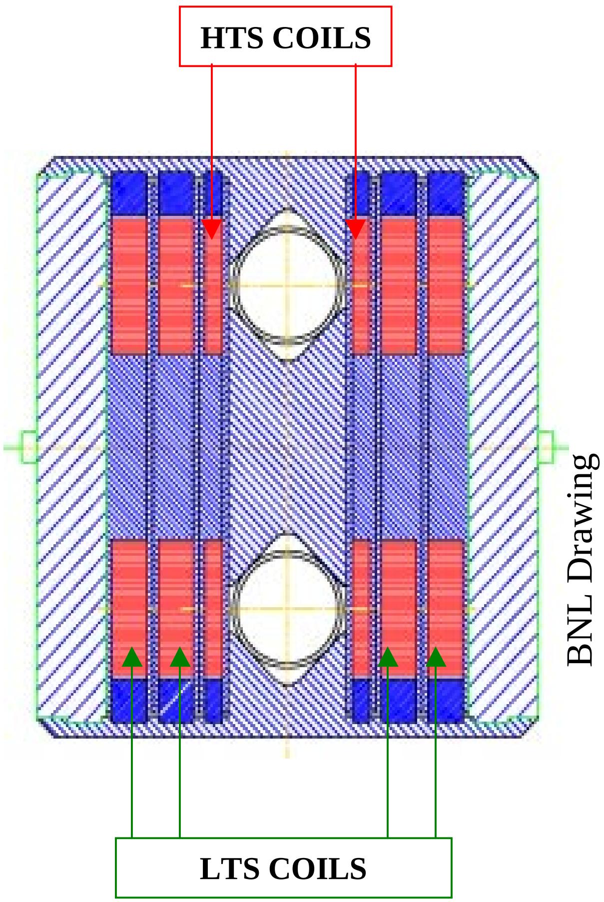
KAmp Rutherford cable : LBL-industry collaboration

- 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.**

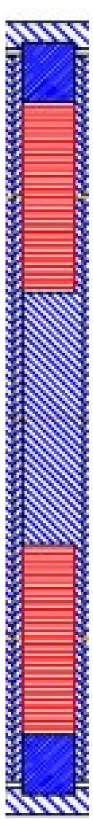
  HTS is subjected to the similar forces that would be present in an all HTS magnet. Therefore, the most technical issues will be addressed.

- **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.**

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)**

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.**