Alternate High Field Magnet Designs for Future Accelerators

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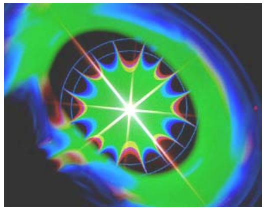


VLHC: The Challenge is the Cost

VLHC can be built with the present technology.

But the cost may be too high.

To change the cost substantially, we have to do things differently.

- Superconducting dipoles are the cost and technology driver and require a large lead time for magnet R&D.
- Their cost is significant (~1/4 of the total machine cost).
- Critically examine all major components and sub-systems. See if some of them can be eliminated. Alternate "magnet system design" can be spring-board for bringing additional savings in the overall machine cost.

Present Magnet Design and Technology

Tevatron Dipole

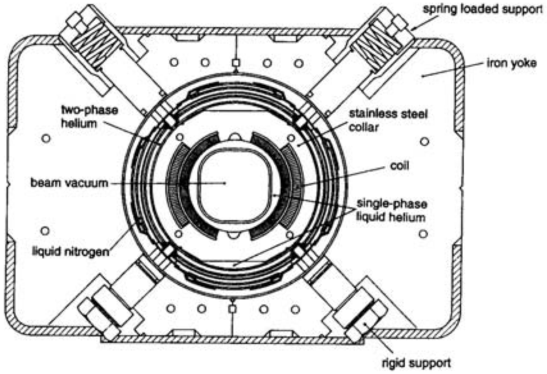
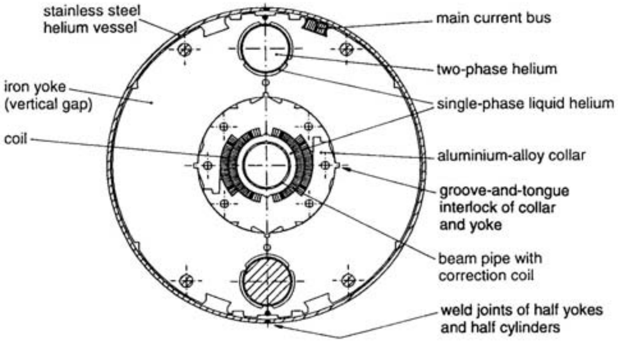
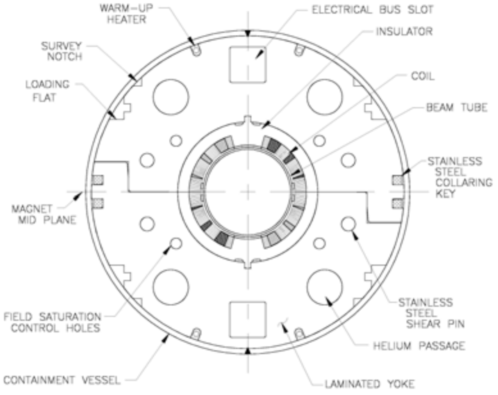


Figure 4.9: The Tevatron 'warm-iron' dipole (Tollestrup 1979).

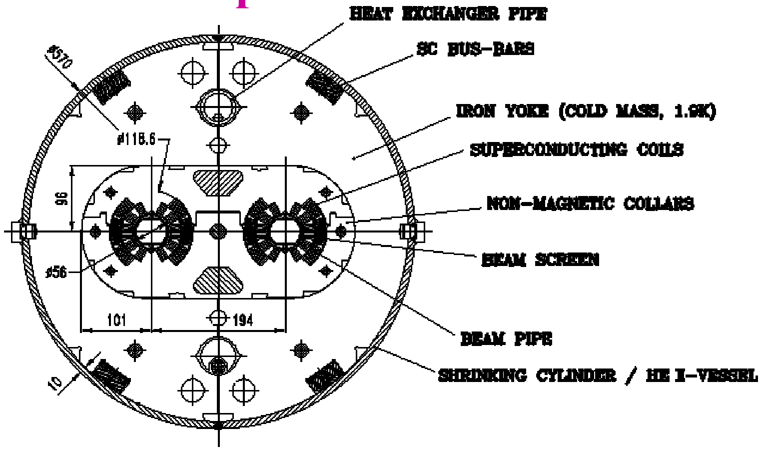
HERA Dipole



RHIC Dipole



LHC Dipole



- All magnets use Nb-Ti Superconductor
- All designs use cosine theta coil geometry
- The technology has been in use for decades.
- The cost is unlikely to reduce significantly.

The Basic Guiding Principles for An Innovative R&D Program

Remember the next machine is 10+ years away

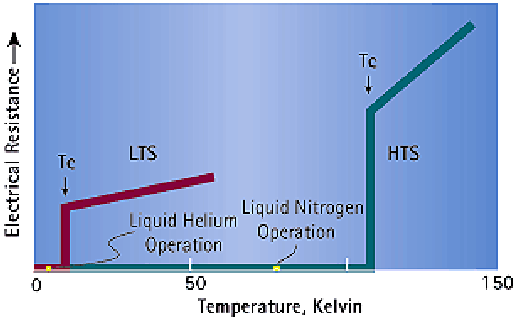
In addition to maintaining the expertise we have acquired,

this is also a unique time to explore

- ☐ **Explore alternate concepts and technologies**
- ☐ **Explore other conductors (Nb_3Sn, HTS) for high fields**
- ☐ **Use the "Magnet R&D Factory" approach:**
  - faster turn-around is important to try ideas outside the "comfort zone"

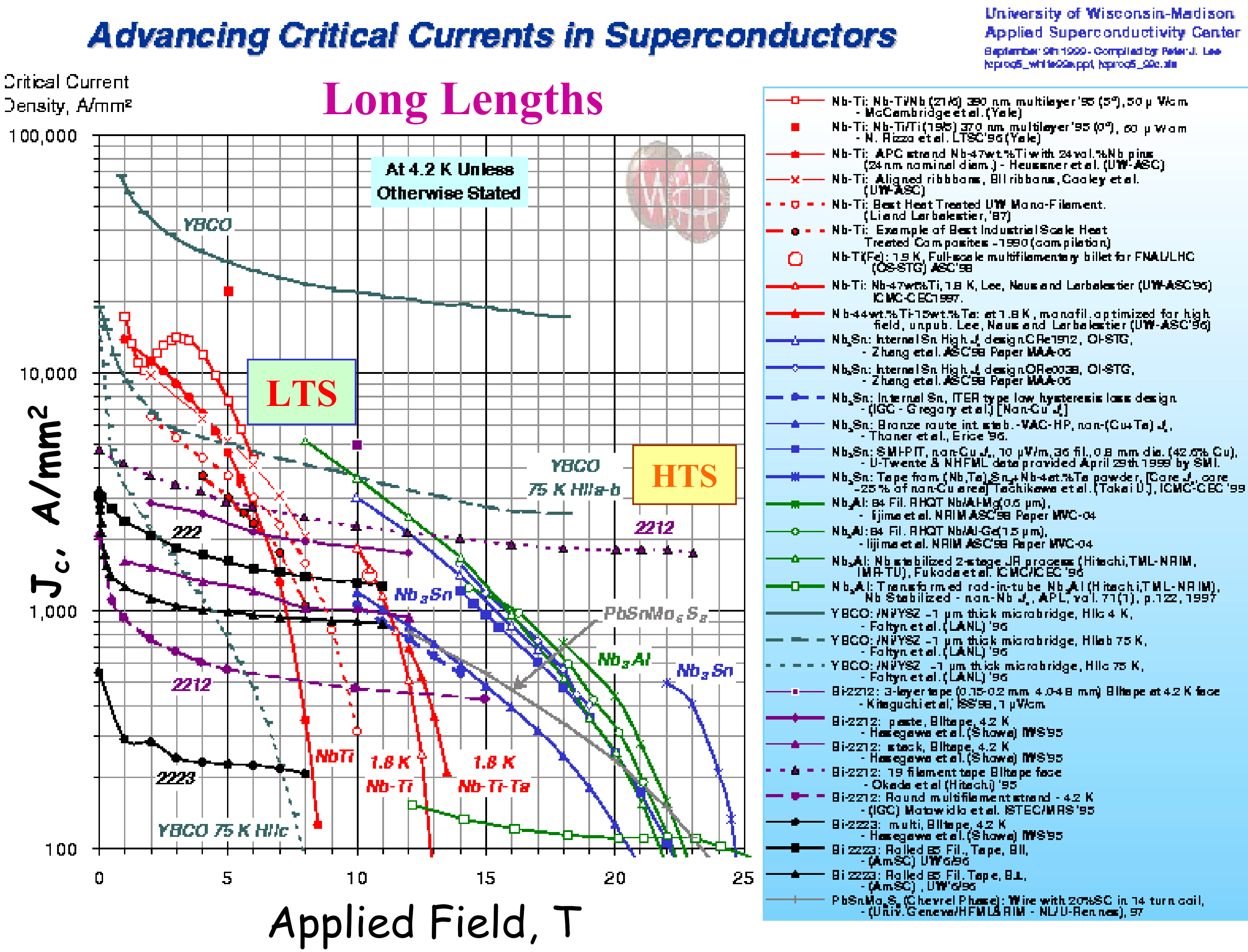
High Field Magnets and High Temperature Superconductors (HTS)

American Supercondctors

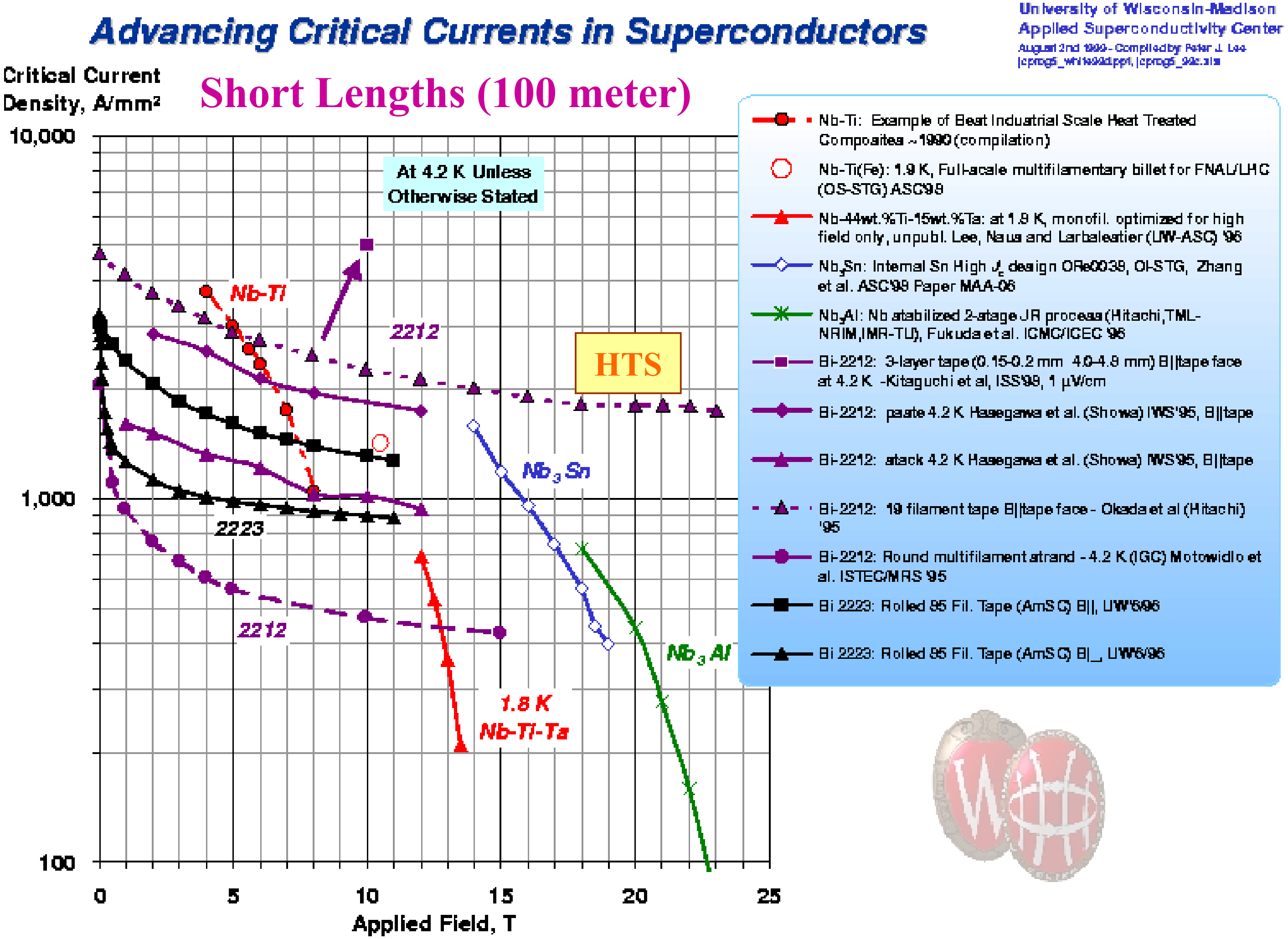


For high field magnets, we are interested in the “Low Temperature”, performance of “High Temperature Superconductors”.

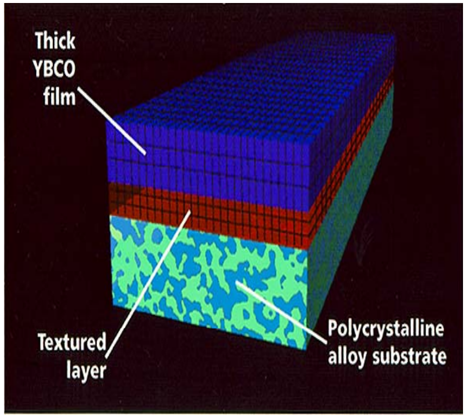
At very high fields, HTS have a better performance.



High Field Magnets and High Temperature Superconductors (HTS)



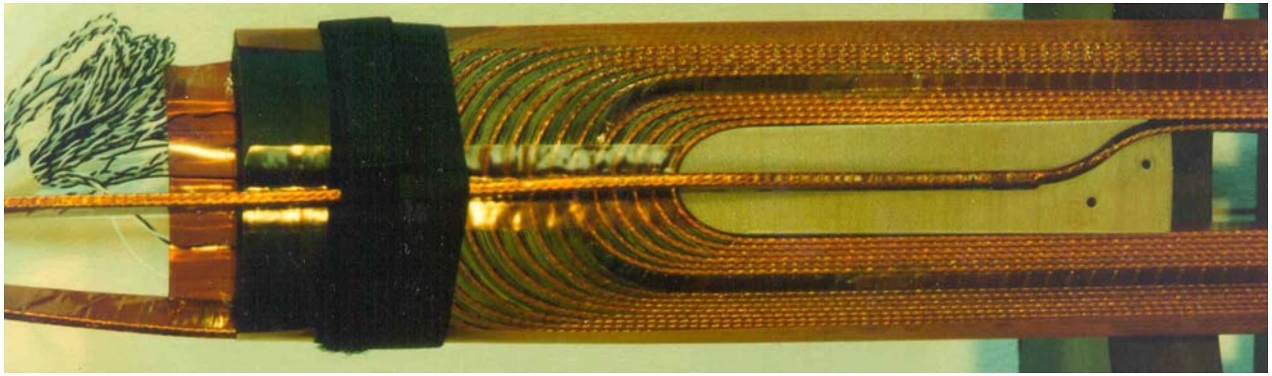
For high field magnets, we are interested in the "Low Temperature", characteristic of "High Temperature Superconductors".



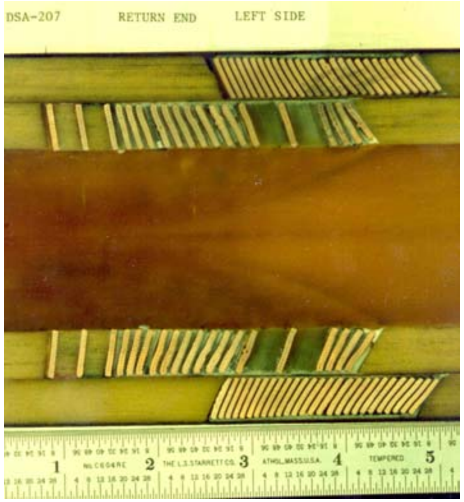
But what really matters is the engineering current density (J_e)!

High Temperature Superconductors (HTS) in Accelerator Magnets

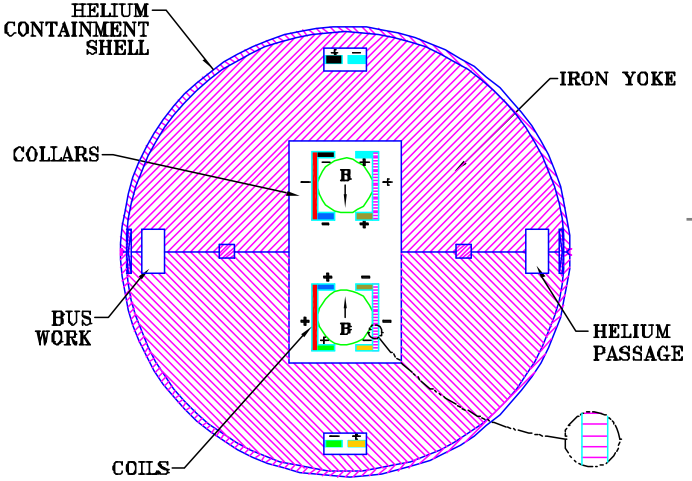
- HTS in accelerator magnets: An exciting possibility, BNL is leading this initiative
- Applications: vlhc & muon colliders/storage rings
- May allow higher fields, higher operating temperature, higher heat loads and less stringent operating conditions
- However, the conventional magnet designs are not well suited for them (HTS is too brittle for them)

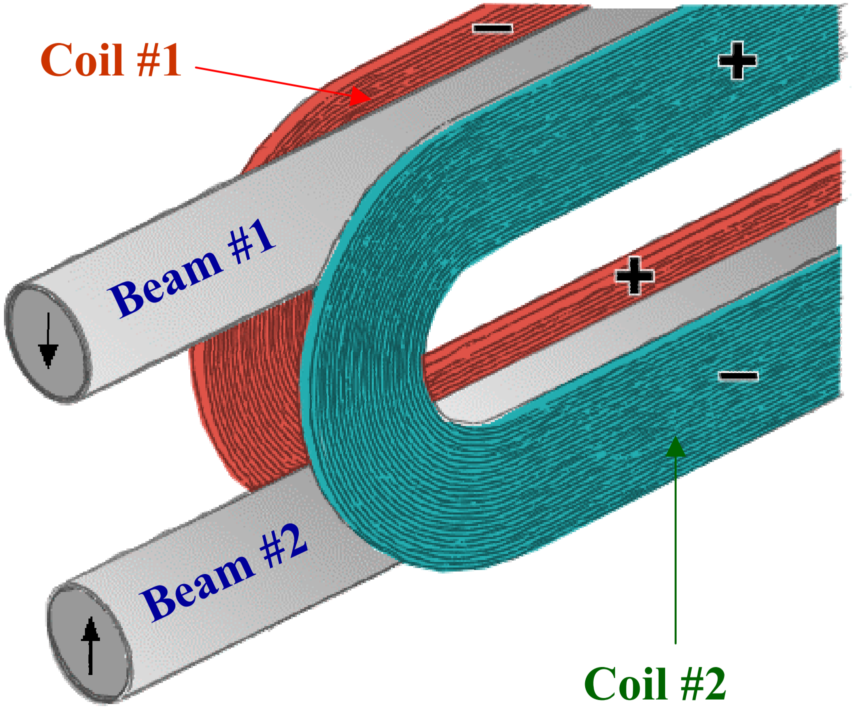


End of a conventional magnet



Common Coil Design
(The Basic Concept)

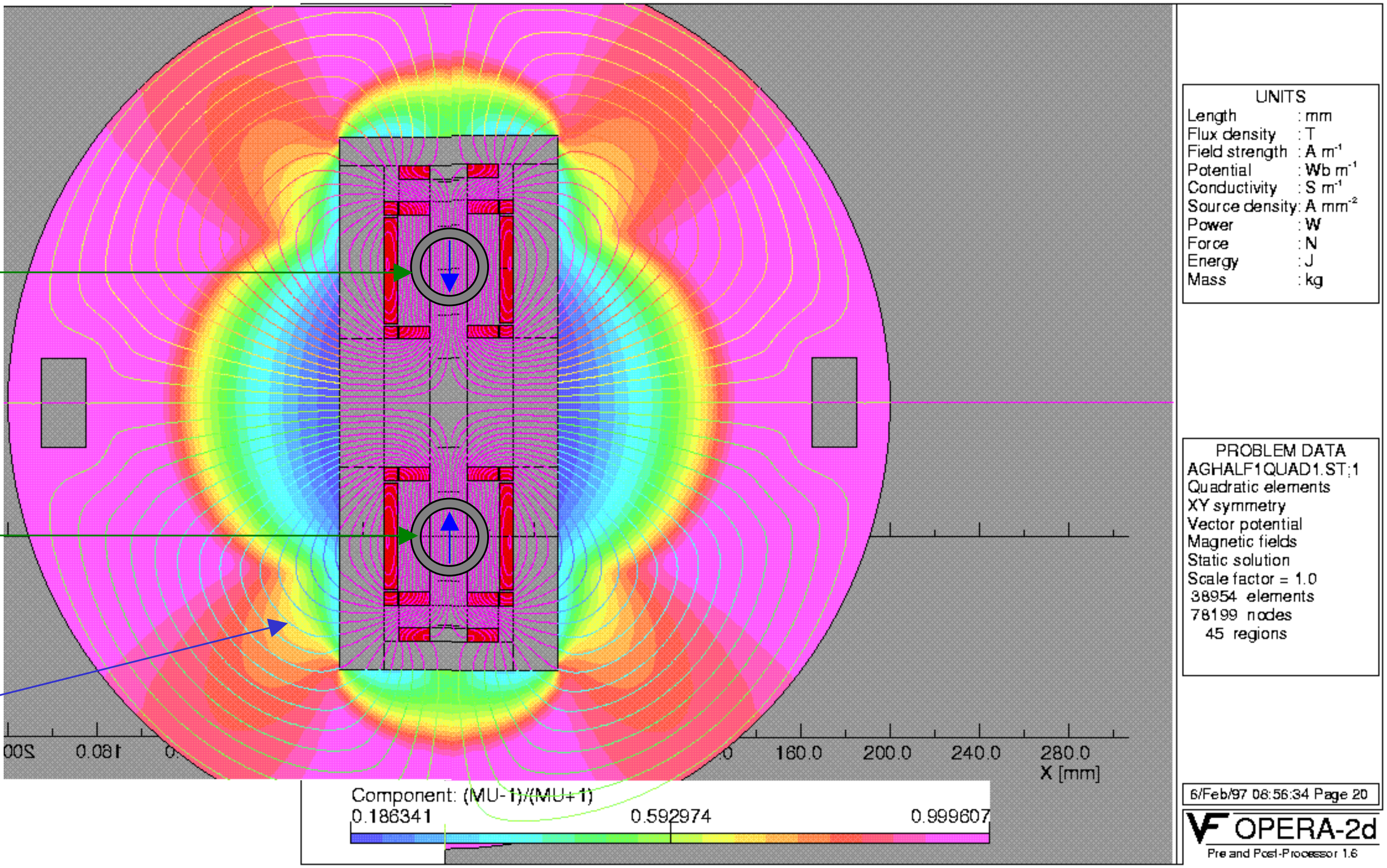




Main Coils of the *Common Coil Design*

- **Simple 2-d** geometry with large bend radius (no complex 3-d ends)
- **Conductor friendly** (suitable for brittle materials - most are - Nb_3Sn, HTS tapes and HTS cables)
- **Compact** (compared to single aperture LBL's 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

Field Lines at 15 T in a Common Coil Magnet Design

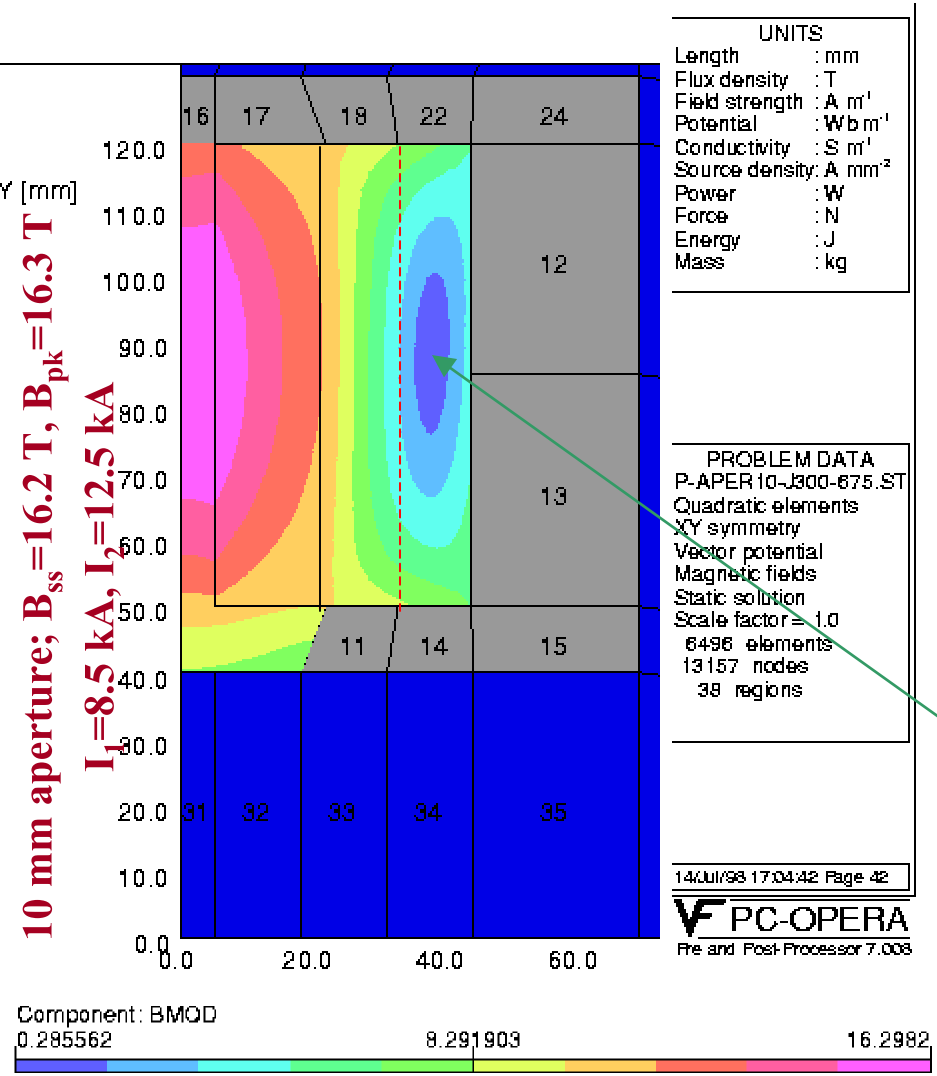


Aperture #1

Aperture #2

Place of maximum iron saturation

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



10 mm aperture; B_{ss}=16.2 T, B_{pk}=16.3 T

I_1=8.5 kA, I_2=12.5 kA

UNITS

Length	: mm
Flux density	: T
Field strength	: A m^{-1}
Potential	: Wb m^{-1}
Conductivity	: S m^{-1}
Source density	: A mm^{-2}
Power	: W
Force	: N
Energy	: J
Mass	: kg

PROBLEM DATA
P-APER10-J300-675.ST
Quadratic elements
XY symmetry
Vector potential
Magnetic fields
Static solution
Scale factor = 1.0
6496 elements
13157 nodes
38 regions

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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

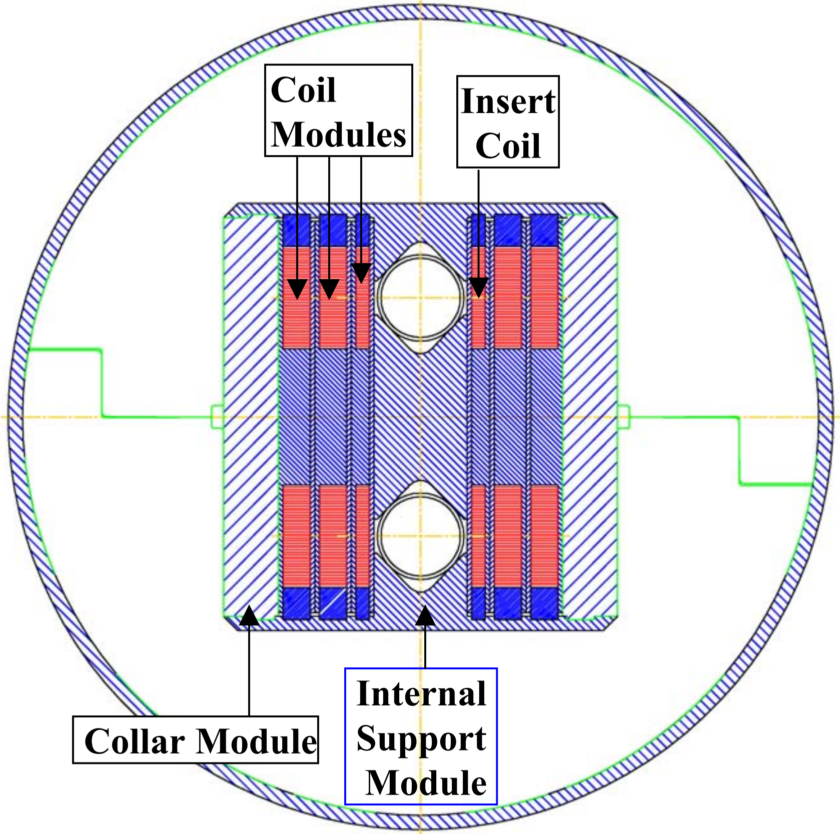
- Max. stress accumulation at high margin region

When do we really need a stress management scheme (cost and conductor efficiency questions), and how much is the penalty?

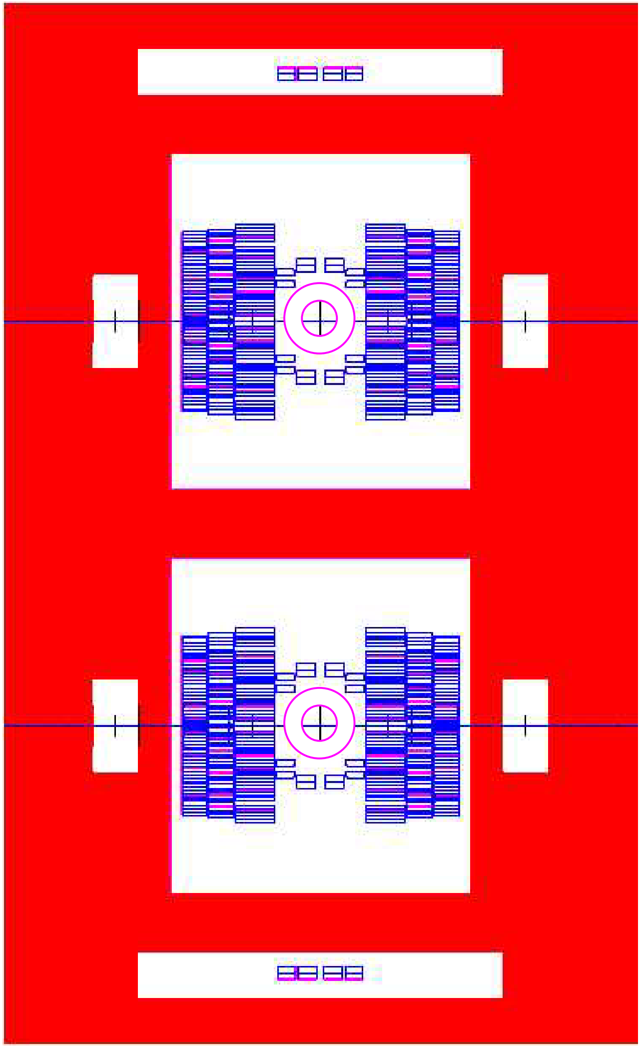
Simulate the future (better J_c) conductor

How Does a Common Coil Magnet Look?

R&D Magnet Design



A ~15 T Field Quality Magnetic Design



RHIC: 3.5 T

SSC: 6.6 T

LHC 8.4 T

(forces go as B^2)

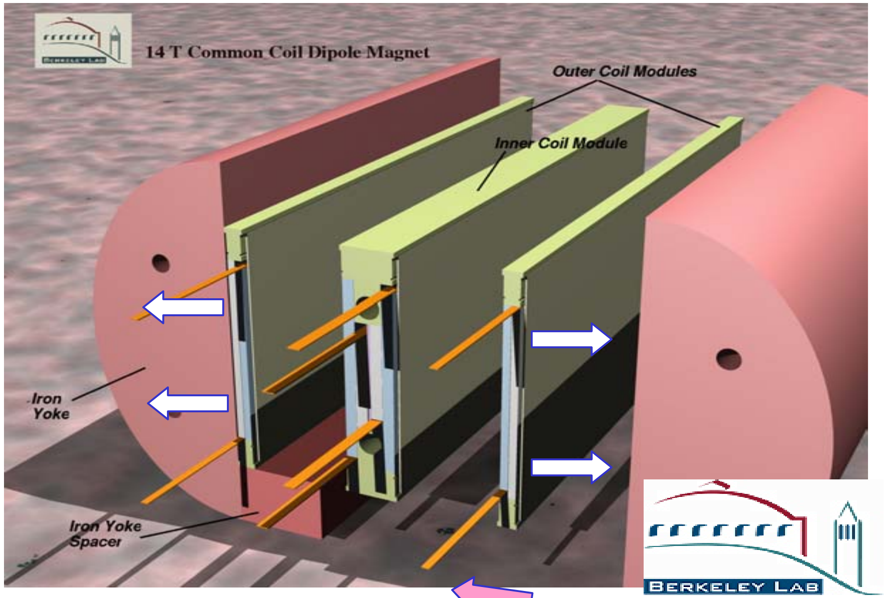
15 T is based on the best available Nb_3Sn conductor available today:

$J_c = 2200$ A/mm^2 (12T,4.3K).

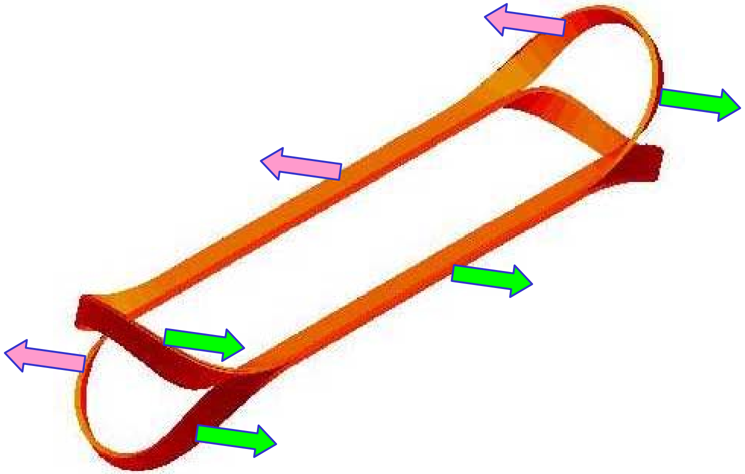
Goal: $J_c = 3000$ A/mm^2.

Common Coil Design in Handling Large Lorentz Forces in High Field Magnets

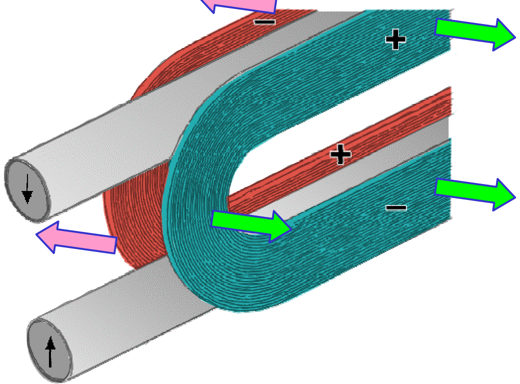
In common coil design, geometry and forces are such that the impregnated solid volume can move as a block without causing quench or damage. Ref.: over 1 mm motion in LBL common coil test configuration).



In cosine theta designs, the geometry is such that coil module cannot move as a block. These forces put strain on the conductor at the ends and may cause premature quench. The situation is somewhat better in single aperture block design, as the conductors don't go through complex bends.



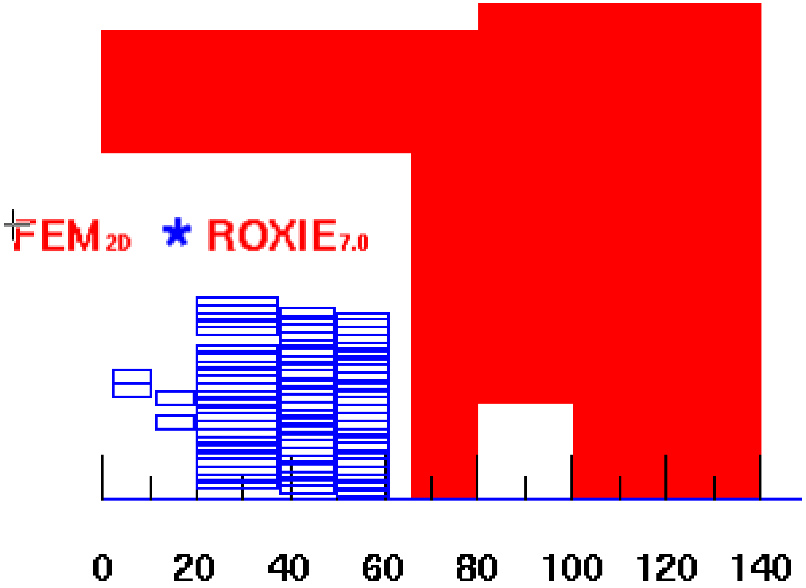
Horizontal forces are larger

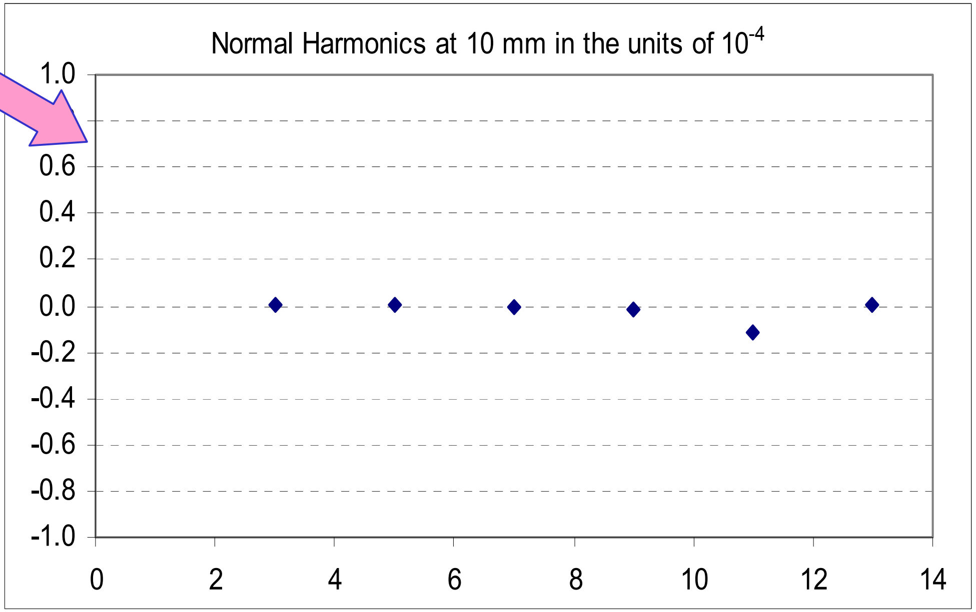


We must check how far we can go in allowing such motions in the body and ends of the magnet. This may significantly reduce the cost of expensive support structure. Field quality optimization should include it (as was done in SSC and RHIC magnet designs).

Progress in Field Quality Geometric Harmonics

Typical Requirements:
~ part in 10^4, we have part in 10^5





Earlier models used slanted auxiliary coils.
The above model uses all flat coils.

BNL design uses very small spacing between modules. Above design is consistent with that.

(from 1/4 model)

MAIN FIELD: -1.86463 (IRON AND AIR):

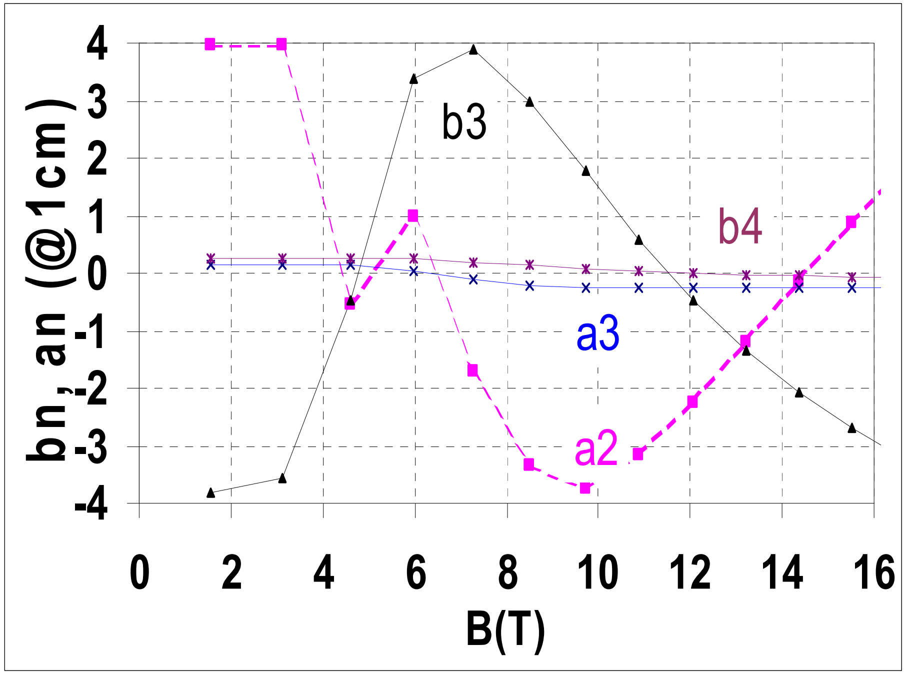
b 1:	10000.000	b 2:	0.00000	b 3:	0.00308
b 4:	0.00000	b 5:	0.00075	b 6:	0.00000
b 7:	-0.00099	b 8:	0.00000	b 9:	-0.01684
b10:	0.00000	b11:	-0.11428	b12:	0.00000
b13:	0.00932	b14:	0.00000	b15:	0.00140
b16:	0.00000	b17:	-0.00049	b18:	0.00000

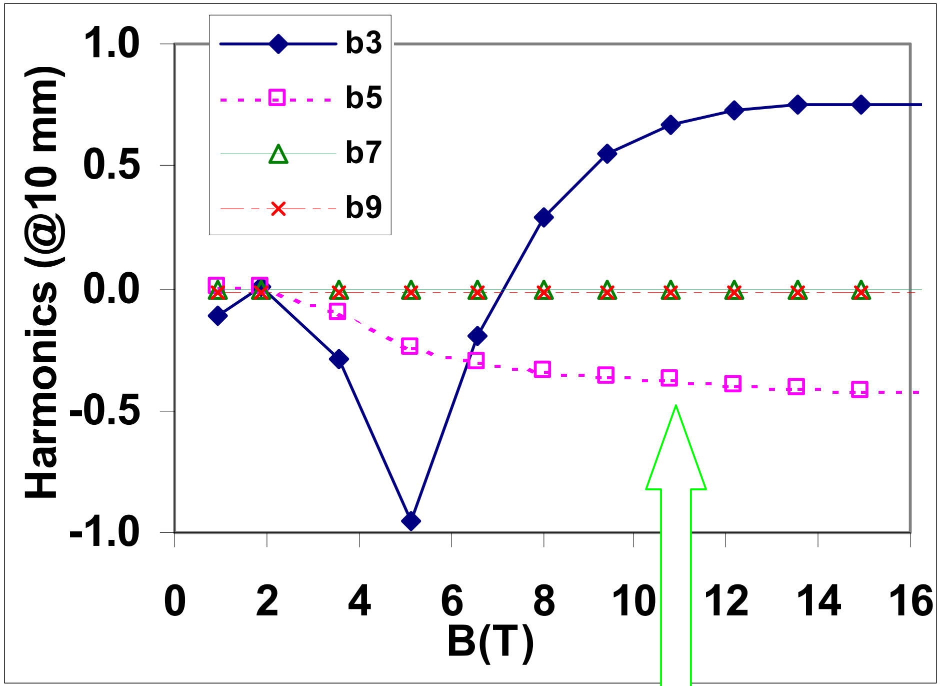
Progress in Field Quality Saturation-induced Harmonics

Use cutouts at strategic places in yoke iron to control the saturation.

New designs: ~ part in 10^4
Satisfies general accelerator requirement

Saturation in earlier designs: several parts in 10^4

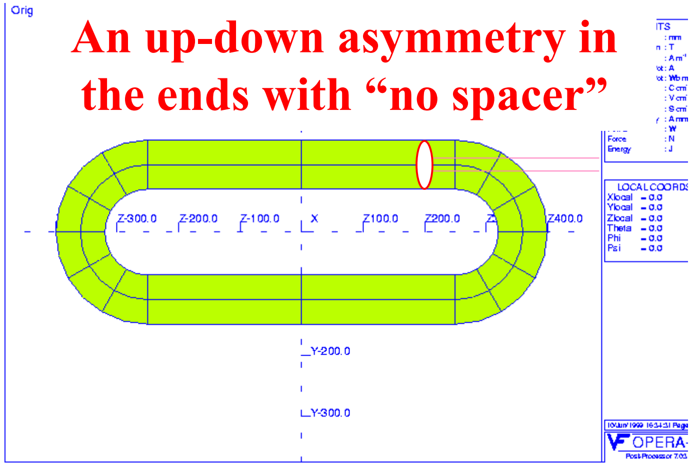


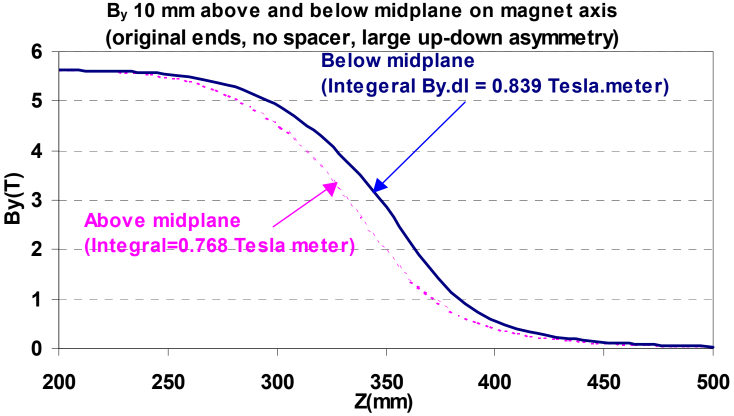


Low saturation induced harmonics till 15 T with a single power supply

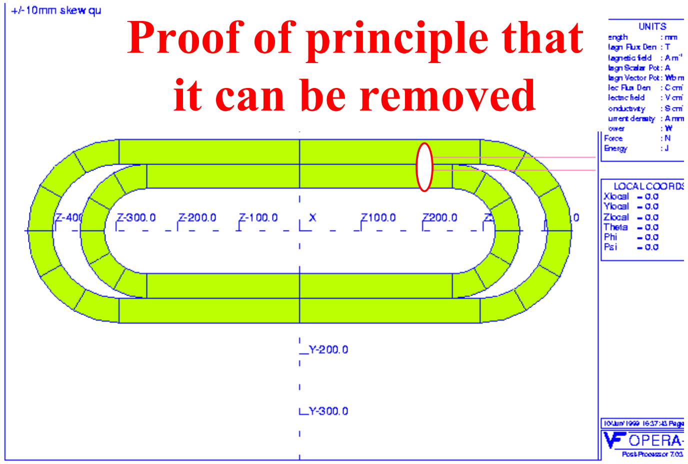
Field Quality Optimization in the Common Coil Design (Magnet Ends)

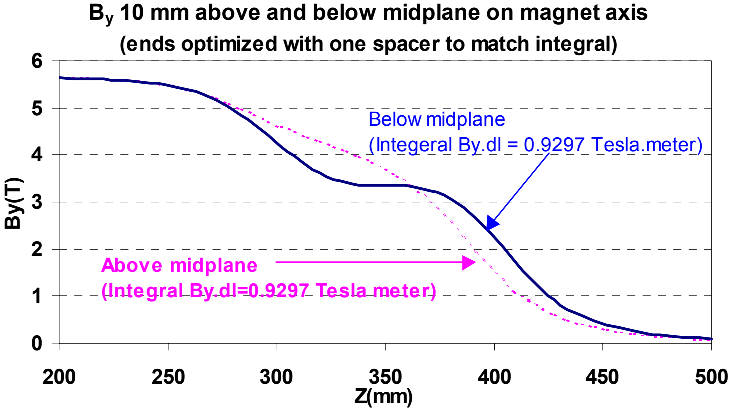
Up-down asymmetry gives large skew harmonics if done nothing. Integrate By.dl 10 mm above and 10 mm below midplane.




B_y 10 mm above and below midplane on magnet axis (original ends, no spacer, large up-down asymmetry)

Up-down asymmetry can be compensated with end spacers. One spacer is used below to match integral By.dl 10 mm above & below midplane.




B_y 10 mm above and below midplane on magnet axis (ends optimized with one spacer to match integral)

Computer code ROXIE (developed at CERN) will be used to efficiently optimize accelerator quality magnet design.

Young Post-doc (Suitbert Ramberger).

A large Bz.dl in two ends (~1 T.m in 15 T magnet).

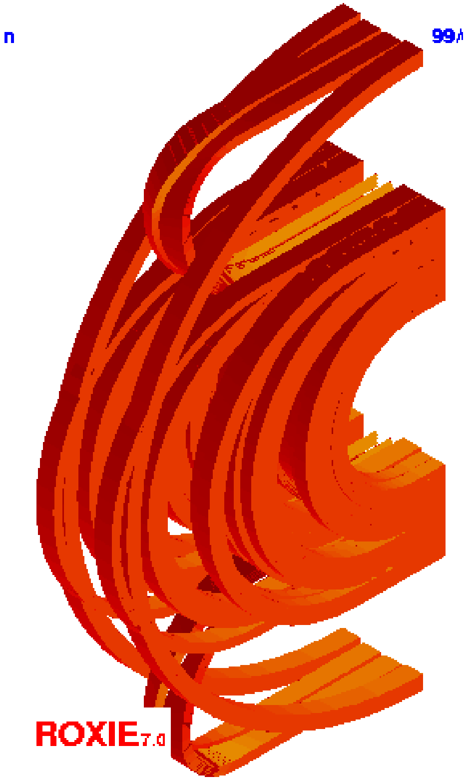
- Is it a problem?
- Examine AP issues.
- Zero integral.
- Lead end of one magnet + Return of the next magnet will make it cancel in about ~1meter (cell length ~200 meters).
- Small v X B.

An Example of End Optimization with ROXIE (iron not included)

Proof:

End harmonics can be made small in a common coil design.

(Very small)

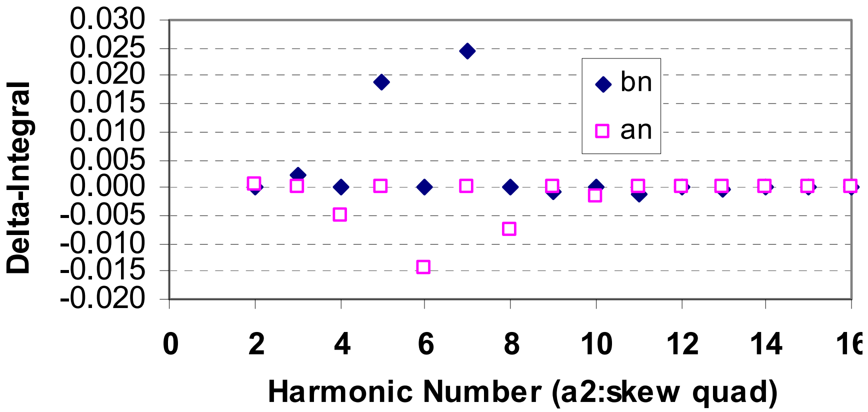


End harmonics in Unit-m

n	Bn	An
2	0.00	0.00
3	0.01	0.00
4	0.00	-0.03
5	0.13	0.00
6	0.00	-0.10
7	0.17	0.00
8	0.00	-0.05
9	0.00	0.00
10	0.00	-0.01
11	-0.01	0.00
12	0.00	0.00
13	0.00	0.00
14	0.00	0.00
15	0.00	0.00
16	0.00	0.00
17	0.00	0.00
18	0.00	0.00

Contribution to integral (a_n,b_n) in a 14 m long dipole ($<10^{-6}$)

n	bn	an
2	0.000	0.001
3	0.002	0.000
4	0.000	-0.005
5	0.019	0.000
6	0.000	-0.014
7	0.025	0.000
8	0.000	-0.008
9	-0.001	0.000
10	0.000	-0.001
11	-0.001	0.000
12	0.000	0.000

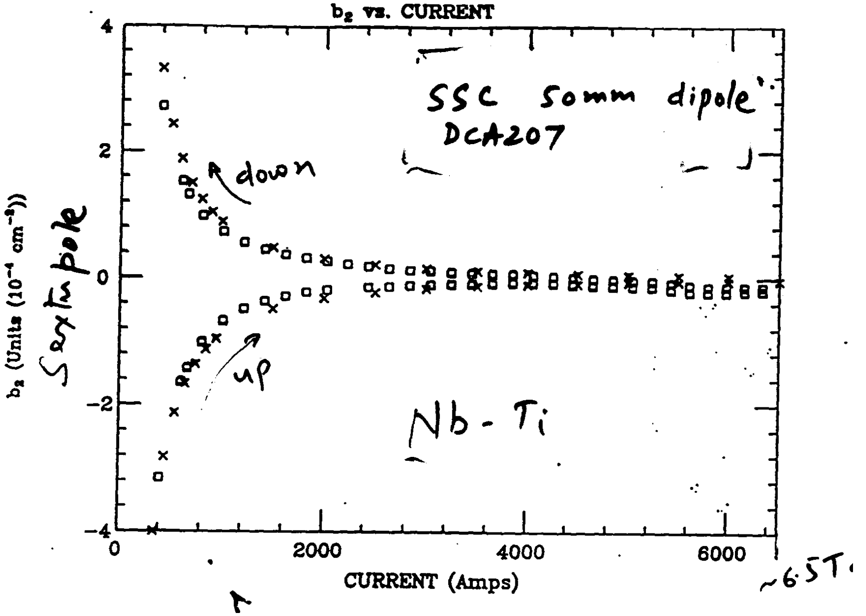


Persistent Current-induced Harmonics
(may be a problem in Nb_3Sn magnets, if done nothing)

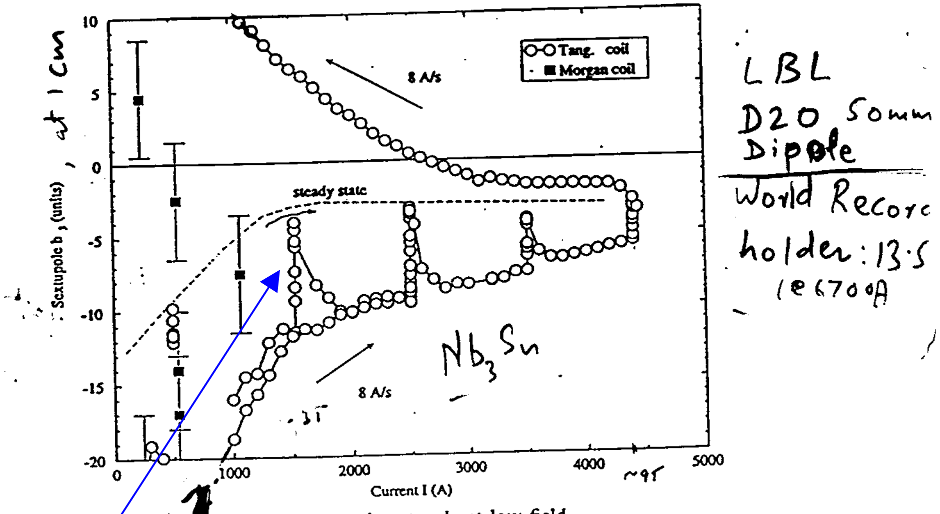
Nb_3Sn superconductor, with the technology under use now, is expected to generate persistent current-induced harmonics which are **a factor of 10-100 worse** than those measured in Nb-Ti magnets.

In addition, a snap-back problem is observed when the acceleration starts (ramp-up) after injection at steady state (constant field).

Measured sextupole harmonic
in a Nb-Ti magnet



Measured sextupole harmonic
in a Nb_3Sn magnet



Snap back

Fig. 6., Measured sextupole at low field (direction of arrow indicates up or down current).

The iron dominated aperture in a common coil magnet system overcomes the major problem associated with magnets using Nb3Sn superconductor.

Persistent Current-induced Harmonics

Traditional solution: work on the superconductor

Persistent current induced magnetization :

$$2\mu_0 M = 2\mu_0 \frac{2}{3\pi} \nu J_c d \qquad ①$$

J_c , CRITICAL CURRENT DENSITY

d , FILAMENT DIAMETER

ν , VOL. FRACTION OF NbTi

$$M_s = M/\nu \qquad ②$$

Problem in Nb_3Sn Magnets because

(a) Jc is higher by several times

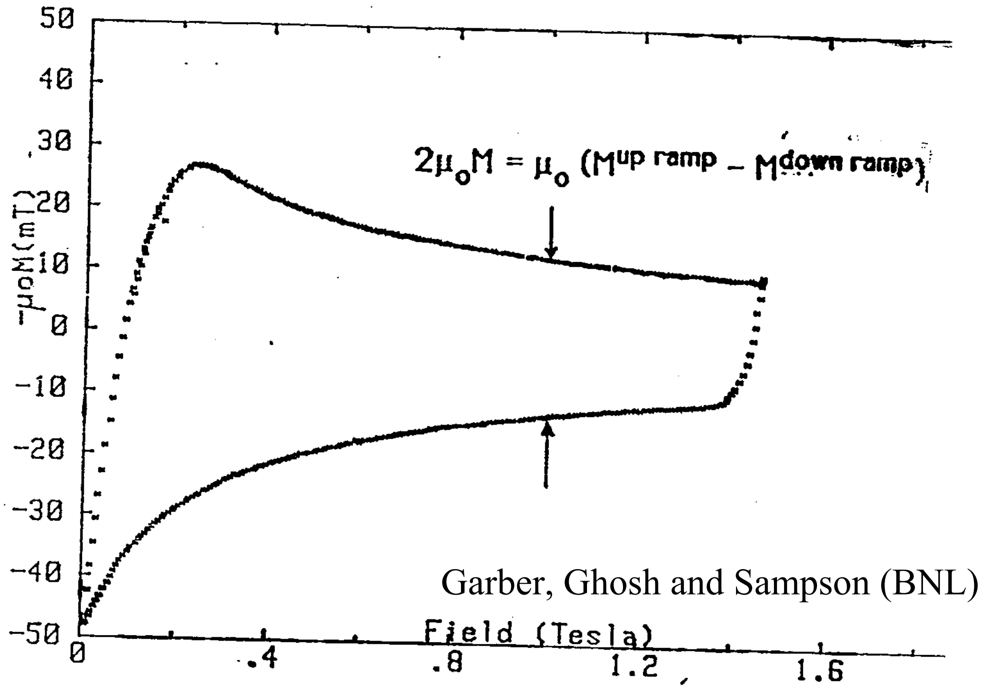
(b) Effective filament diameter is larger by about an order of magnitude

Conductor solution:

Reduce effective filament diameter.

A challenge; in some cases it also reduces J_c.

Measured magnetization



Garber, Ghosh and Sampson (BNL)

Fig. of a typical magnetization loop.

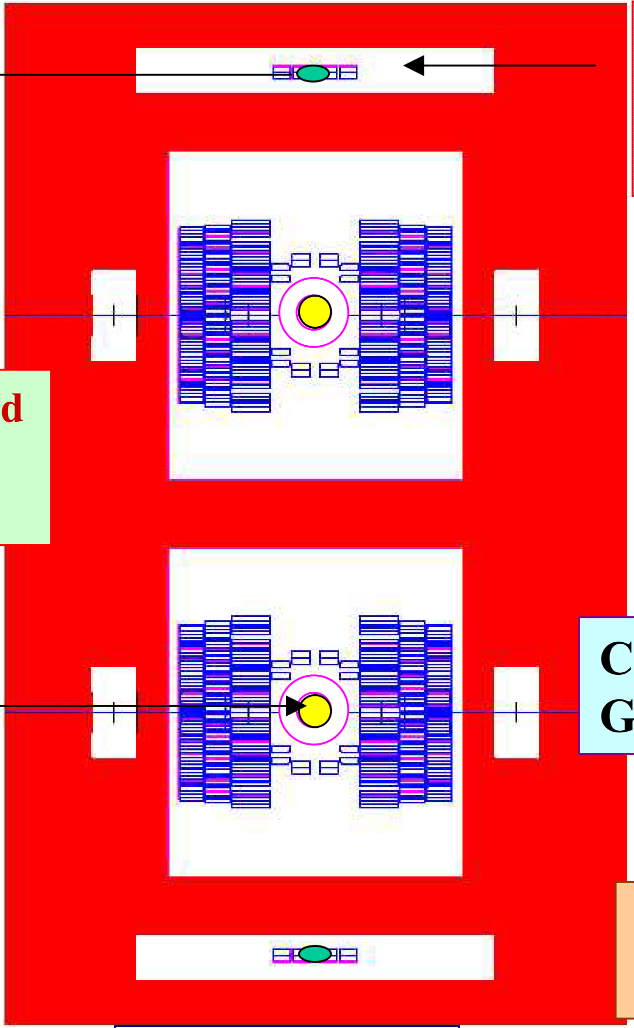
Note: Iron dominated magnets don't have this problem.

A Common Coil Magnet System for VLHC

A Solution to Persistent Current Problem

May eliminate the High Energy Booster (HEB)

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



Inject in the iron dominated aperture at low field and accelerate to medium field

Injection at low field in iron dominated aperture should solve the large persistent current problem associated with Nb3Sn

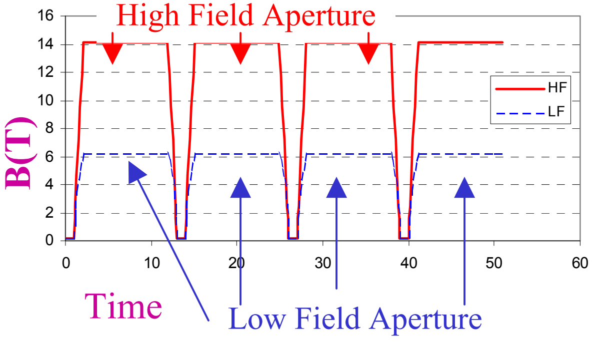
Transfer to conductor dominated aperture at medium field and then accelerate to high field

Conductor dominated aperture
Good at high field (1.5-15T)

Iron dominated aperture
Good at low field (0.1-1.5T)

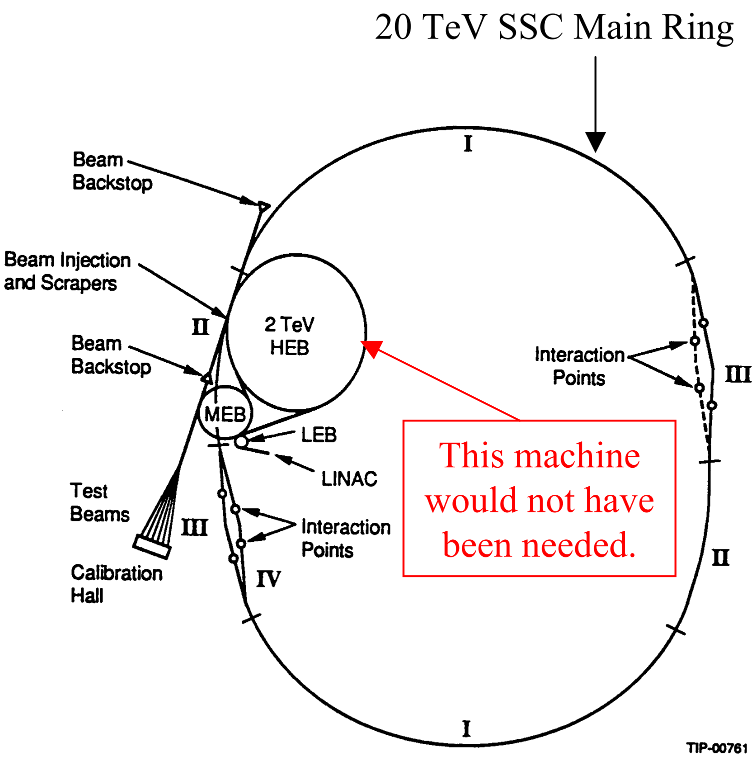
Compact size

Field profile with time



AP issues? Compare with the Low Field Design.

Possibility of Removing the Second Largest Machine (HEB) from the vlhc complex



This machine would not have been needed.

Figure 4.1.1.1-4. Schematic layout of SSC.

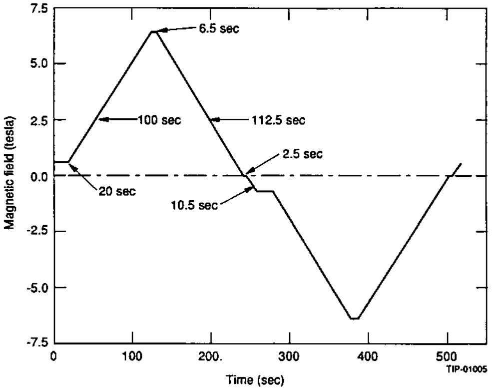


Figure 4.1.2.4-1. The suggested slow, alternating ramp scenario of the HEB.

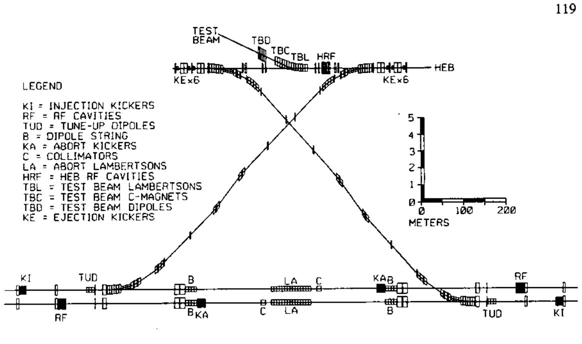


Figure 4.1.1.3-4. Elevation view of collider utility region.

- In the proposed system, the High Energy Booster **(HEB)** - the entire machine complex - will not be needed. Significant saving in the cost of construction and operation.
- Many consider that HEB, in some ways was quite challenging machine: superconductor (2.5 μ instead of 6 μ filaments), bipolar magnets, etc.

Common Coil Magnet System
(Estimated cost savings by eliminating HEB)

SSC: 20+20 TeV;
VLHC: 50+50 TeV

Based on 1990 cost in US$

2 TeV HEB Cost in SSC (derived):
$700-800 million

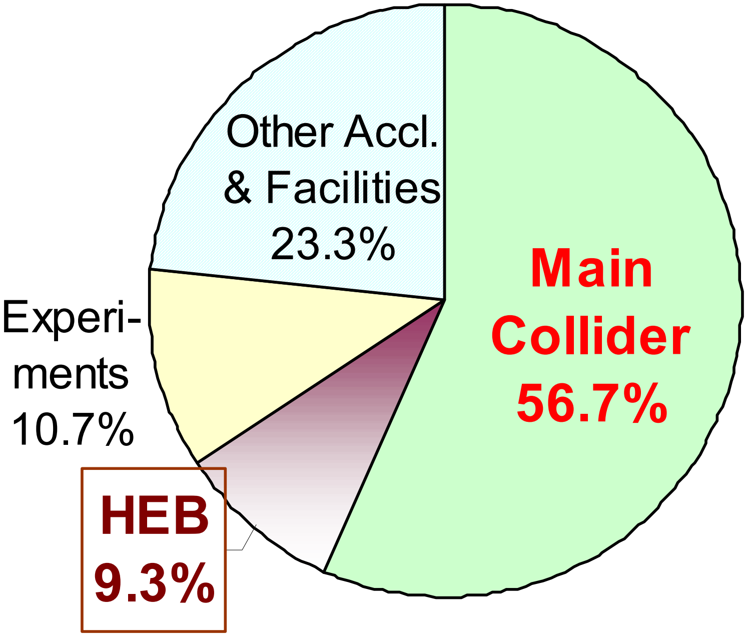
Estimated for 5 TeV (5-50 TeV vlhc):
~$1,500 million (in 1990 US$)

A part of this saving (say ~20-30%) may be used towards two extra apertures, etc. in main tunnel. Estimated savings ~ $1 billion.

Cost savings in equivalent 20xx $?

Cost Distribution of Major Systems

(Reference SSC Cost: 1990 US $7,837 million)



(Derived based on certain assumptions)

Advantages of Common Coil Magnet System with 4 Apertures (2-in-1 Accelerator)

- **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.

- **Compact Magnet System**

*As compared to single aperture D20,
4 apertures in less than half the yoke.*

- **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!
Can high field aperture be reduced?

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

Magnet Aperture: MT and AP Issues

Main magnet aperture has an appreciable impact on the machine cost. The minimum requirements are governed by the following two issues:

Magnet Technology Issues

The conventional cosine theta magnets are hard to build below certain aperture as the bend radius and the end geometry would limit the magnet performance. In the common coil design, the magnet aperture and magnet ends are completely de-coupled. The situation is even better than that in the conventional block designs as not only that the ends are 2-d but the bend radius is much larger, as it is determined by the spacing between the two apertures rather than the aperture itself. This means that the magnet technology will not limit the dipole aperture.

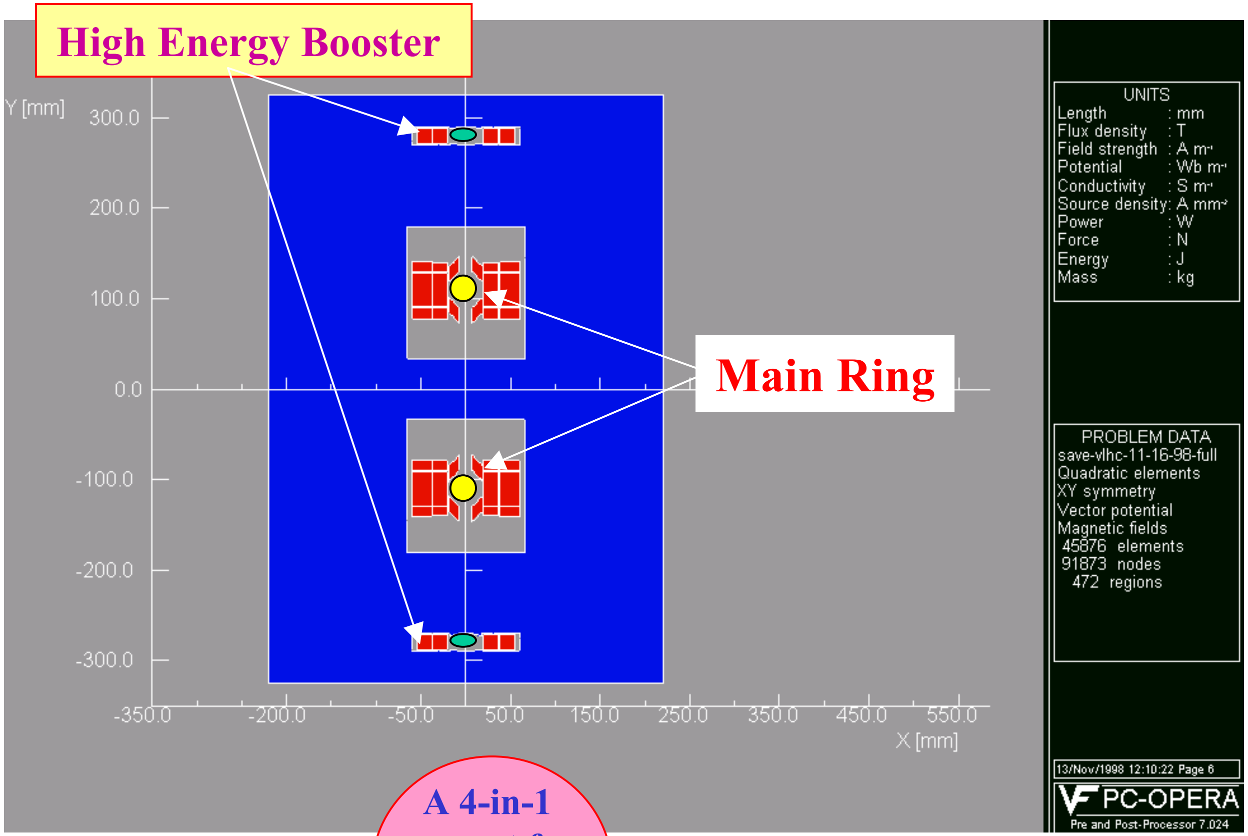
Accelerator Physics Issues

The proposed common coil system should have a favorable impact. The aperture is generally decided by the injection conditions. In the proposed system, the beam is transferred (not injected) in a single turn, on the fly, and the transfer takes place at a higher field. The magnets continue to ramp-up during beam transfer and thus the “snap-back” problem is bypassed. There is a significant difference at the injection from the conventional injection case. This and other progress in the field (feed-back system, etc.) should encourage us to re-visit the aperture issue.

A Combined Function Common Coil Magnet System for Lower Cost VLHC

In a conventional superconducting magnet design, the right side of the coil return on the left side. In a common coil magnet, coil from one aperture return to the other aperture instead.

- A combined magnet design is possible as the coils on the right and left sides are different.
- Therefore, combined function magnets are possible for both low and high field apertures.
- Note: Only the layouts of the higher energy and lower energy machines are same. The "Lattice" of the two rings could be different.



UNITS
Length : mm
Flux density : T
Field strength : A m^{-1}
Potential : Wb m^{-1}
Conductivity : S m^{-1}
Source density: A mm^{-2}
Power : W
Force : N
Energy : J
Mass : kg

PROBLEM DATA
save-vlhc-11-16-98-full
Quadratic elements
XY symmetry
Vector potential
Magnetic fields
45876 elements
91873 nodes
472 regions

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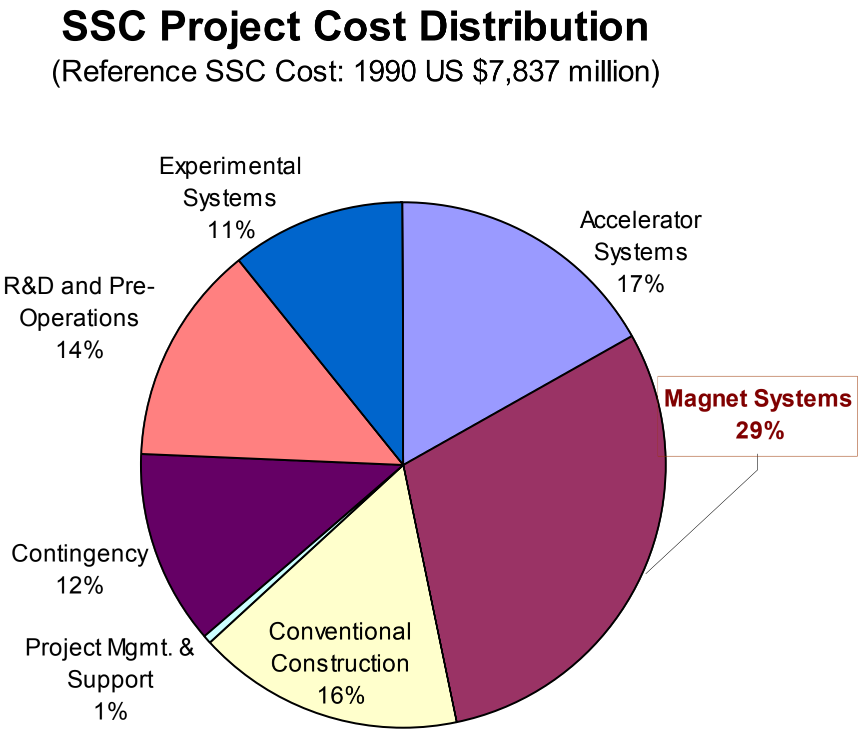
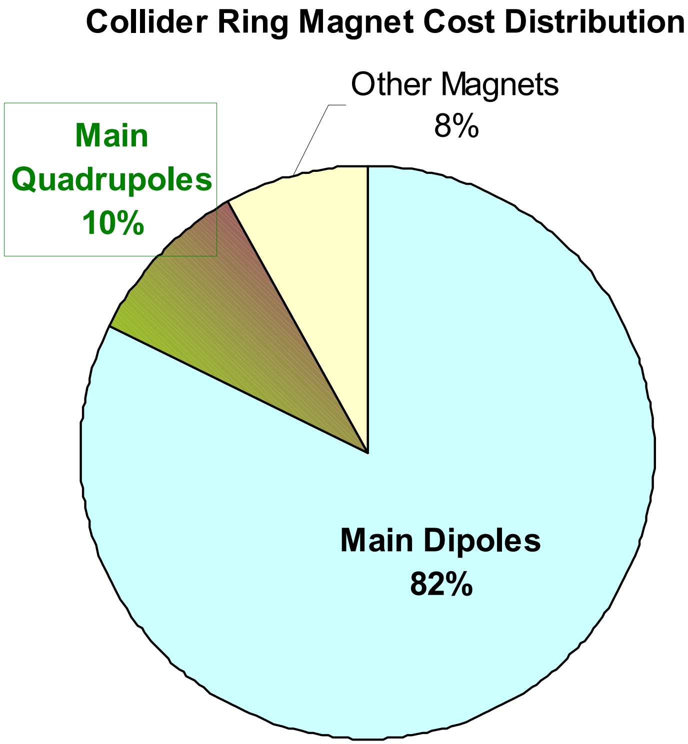
A 4-in-1 magnet for a 2-in-1 machine

A Combined Function Magnet Option (Estimated cost savings for VLHC)





Total:
$2,037 million

AP Challenge:

Retaining the benefits of the *Synchrotron Damping* in the *High Field Magnet* vlhc option.

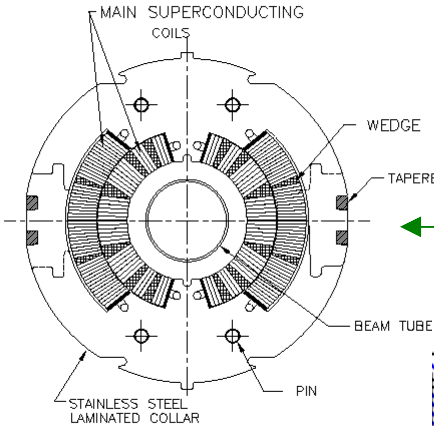
SSC (20 TeV) Main Quads: ~$200 million; VLHC (50 TeV) Main Quads: ~$400 million (x2 not 2.5).

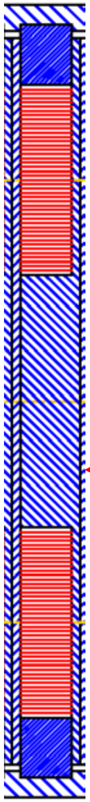
Additional savings from tunnel, interconnect, etc.

Estimated potential savings: ~$0.3-0.5 billion (1990 US$).

Cost savings in equivalent 20xx $?

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)**

Recap on Cost Saving Possibilities in VLHC

A multi-pronged approach:

- Lower cost magnets expected from a simpler geometry.
- Possibilities of applying new construction techniques in reducing magnet manufacturing costs.
- Possibilities of reducing aperture due to more favorable injection scenario in the proposed common coil magnet system design.
- Possibility of removing the high energy booster (the second largest machine) in the proposed system.
- Possibility of removing main quadrupoles (the second most expansive magnet order) in the proposed combined function magnet design.

Need to examine the viability of these proposals further; need to continue the process of exploring more new ideas and re-examine old ones (they may be attractive now due to advances in technology, etc.); need to keep focus on the bigger picture...

VLHC cost reduction may also come from other advances: cheaper tunneling, development in superconductor technology, etc.

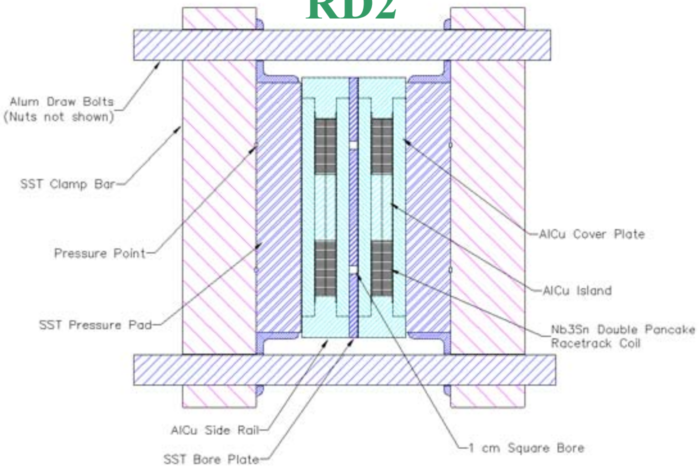
Performance of the First magnet Based on the Common Coil Design

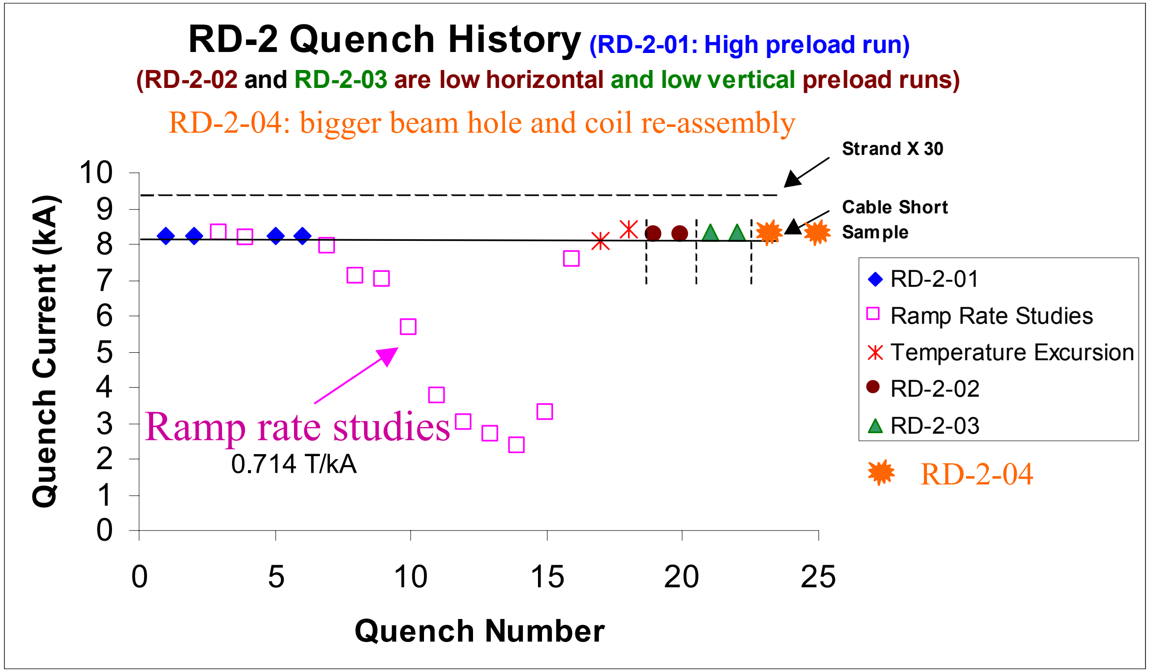
The first common coil magnet was built and tested at LBL

BERKELEY LAB

A 6 T magnet using low grade (free) Nb_3Sn

RD2




RD-2 Quench History (RD-2-01: High preload run)

(RD-2-02 and RD-2-03 are low horizontal and low vertical preload runs)

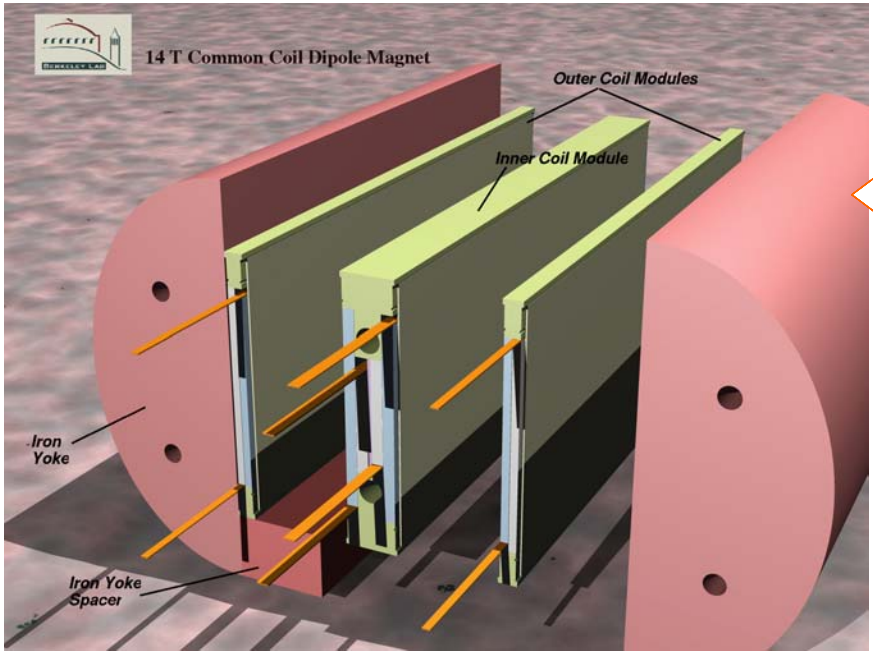
RD-2-04: bigger beam hole and coil re-assembly

1. The magnet reached plateau performance right away (plateau seems to be on the cable short sample, not wire short sample).
2. Didn’t degrade for a low horizontal pre-load (must for this design).
3. Didn’t degrade for a low vertical pre-load (highly desirable).
4. Didn’t degrade for a bigger hole (real magnets).

On To A High Field Common Coil Magnet

Now under construction at LBL:

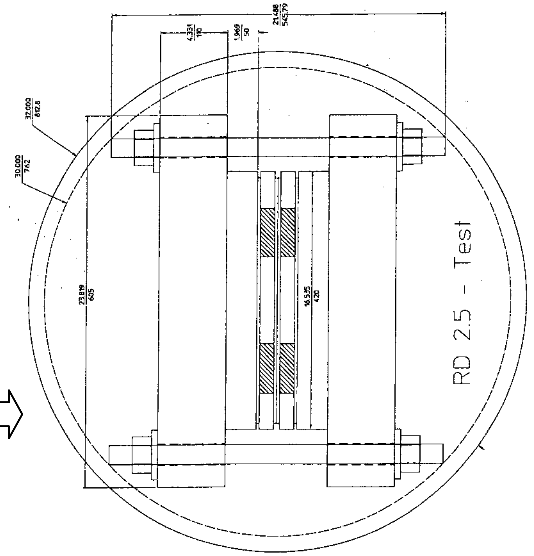
~14 T common coil design with the best available Nb_3Sn conductor today.



RD3

The first step towards high field common coil magnet: test outer coils with minimum gap.

RT1



Bss ~12.3 T

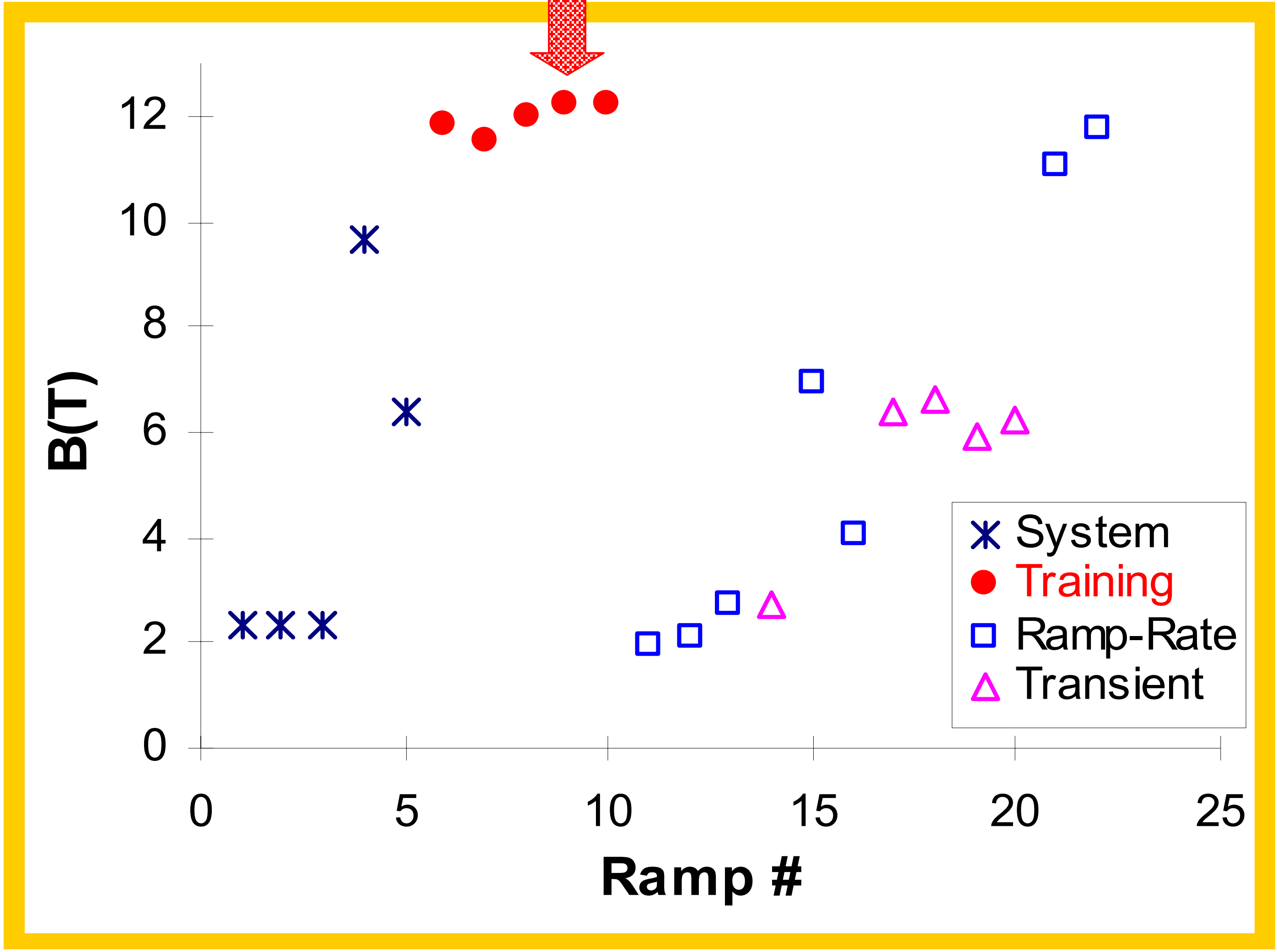
The magnet reached the short sample field (~12.3 T) with only a few quenches.

RT-1 Quench History

RECENT RESULTS FROM LBL:

A pair of coils in “Common Coil Configuration” reached 12 T with little training

- System Validation
- Training
- Ramp-Rate
- Voltage-Transient



Common Coil Work at BNL- Phase I

Charge:

Build and Test a common coil magnet with NbTi

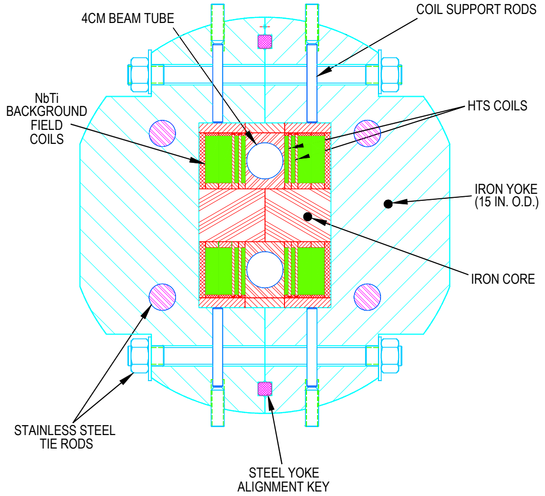
Purpose:

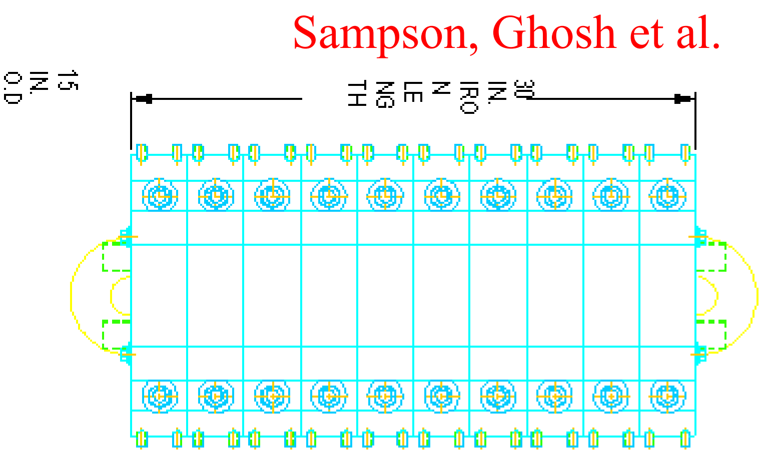
Validate “Common Coil Design” and provide a simple and efficient background field test facility for HTS coils

Resources:

None (almost)

Sampson, Ghosh et al.





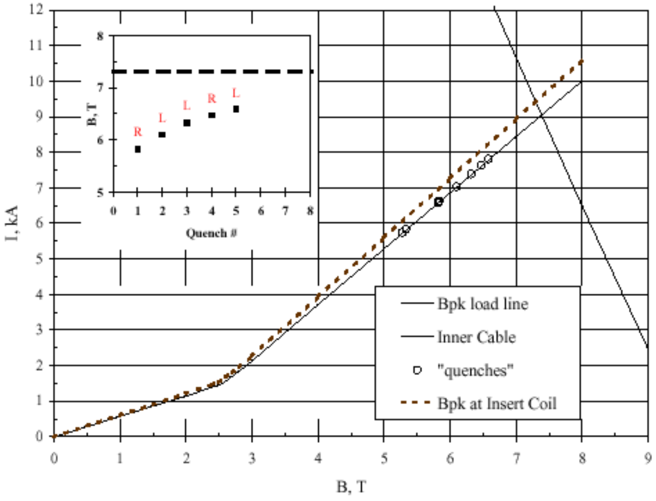
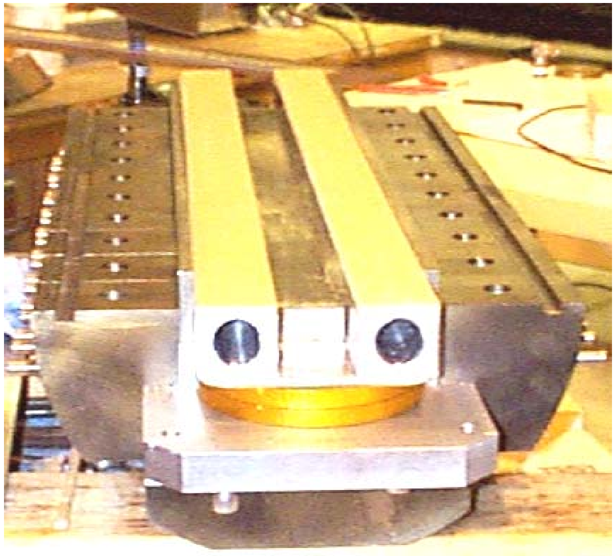
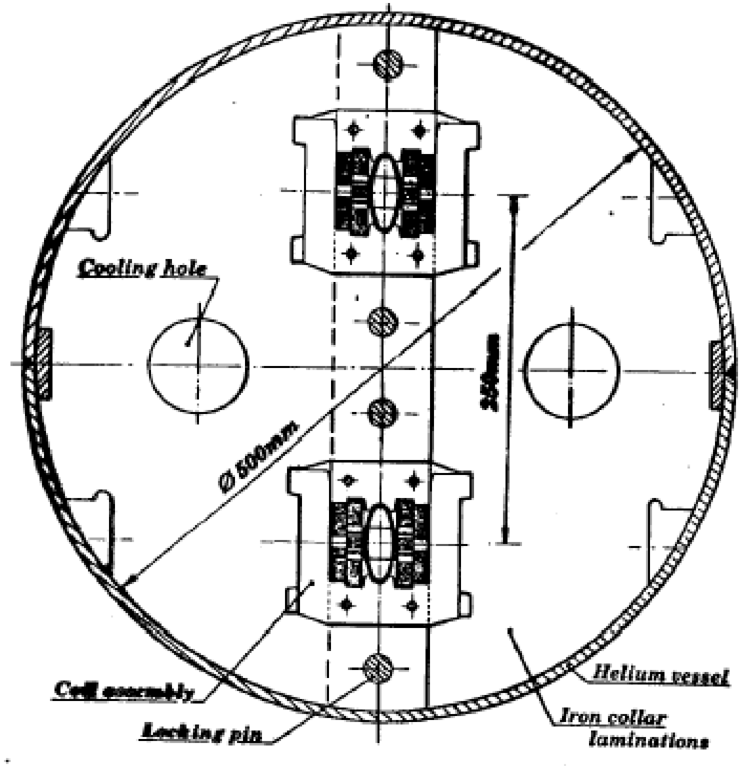


Figure 4. The training behaviour of the main winding of the common coil magnet.



Summary of Common Coil Magnet Work at Various National Labs

Common Coil Magnet Design at Fermilab



Fermilab

BNL

Invented it.

Phase 1: Built and commissioned NbTi magnet with Nb_3Sn insert coils. Built and tested HTS insert coil in low field common coil mode. HTS coils are now ready to go as a part of a hybrid design with common coil magnet as a background field test facility.

Phase 2: High Field ~12.5 T, "React and Wind", Nb_3Sn dipole, R&D Magnet Factory, HTS insert coils.

LBL

Got maximum support for building it.

Built and tested 6 T, "Wind and React", Nb3Sn magnet. Tested high performance coils in common coil mode for 12 T field. Both had excellent performance.

Next step ~14 T magnet with third coil.

FNAL

Design and support work for an initial ~11 T magnet.

A Possible Application of High Field Magnet Program

URHIC: Ultra Relativistic Heavy Ion Collider in RHIC Tunnel

URHIC

Heavy Ions: 500 GeV + 500 GeV (1 TeV center of mass)

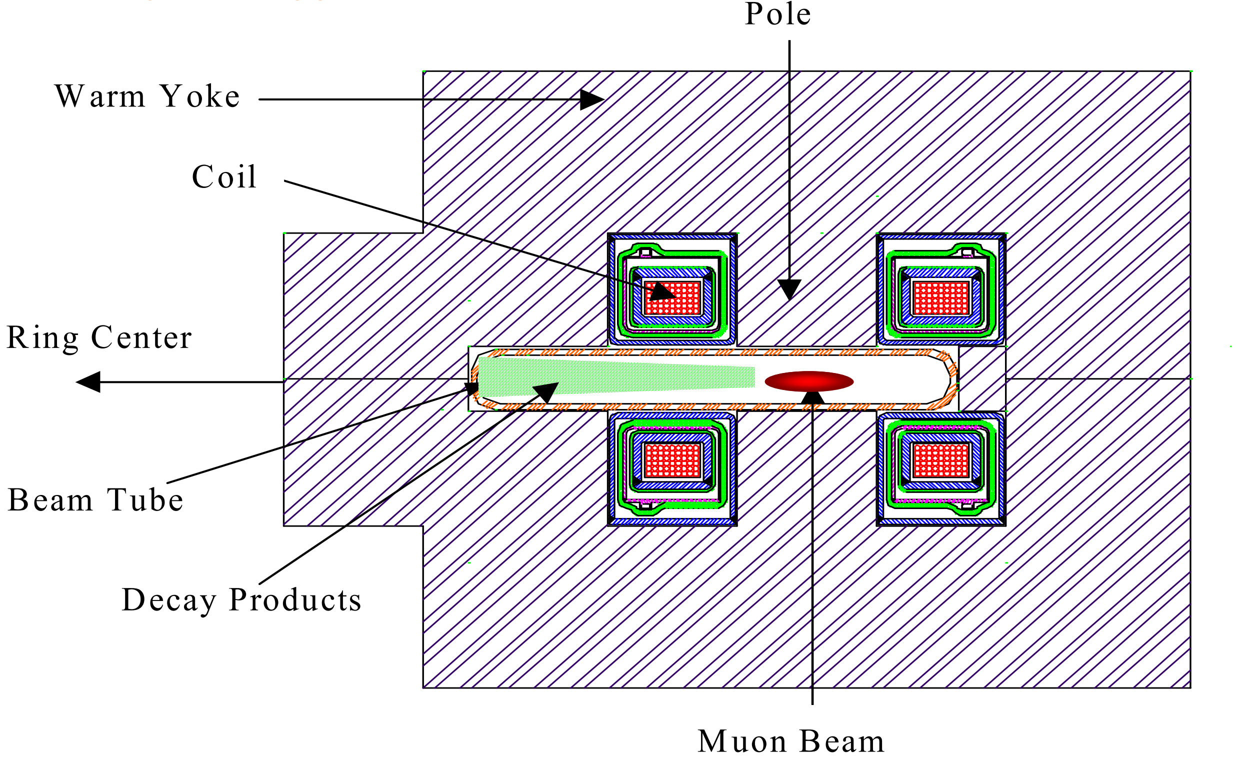
Protons: 1.25 TeV + 1.25 TeV (2.5 TeV center of mass)

	RHIC	**URHIC**
Energy (GeV/u)	100 GeV + 100 GeV	500 GeV + 500 GeV
Injector	AGS	RHIC
Lattice	Separated Function	Combined Function
Dipole Fill Factor	~65% (+quad)	~85-90% (no quad)
Dipole Design	Cosine Theta	Common Coil
Operating Field	3.5 T	~ 13 T

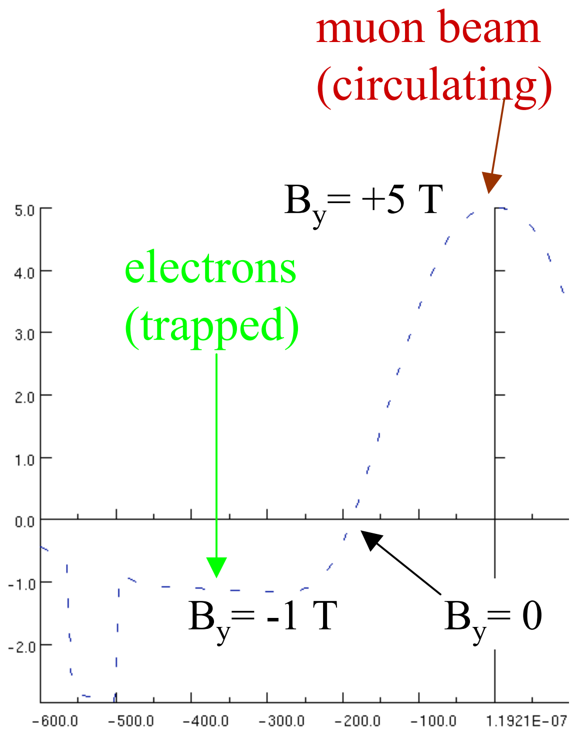
Physics Potential?

Dipole for ν Storage Ring

Mike Harrison



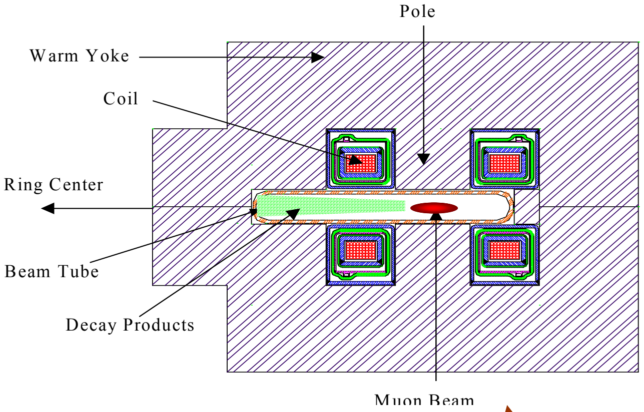
With Nb-Ti, Bo ~ 5 T



A Conceptual Design

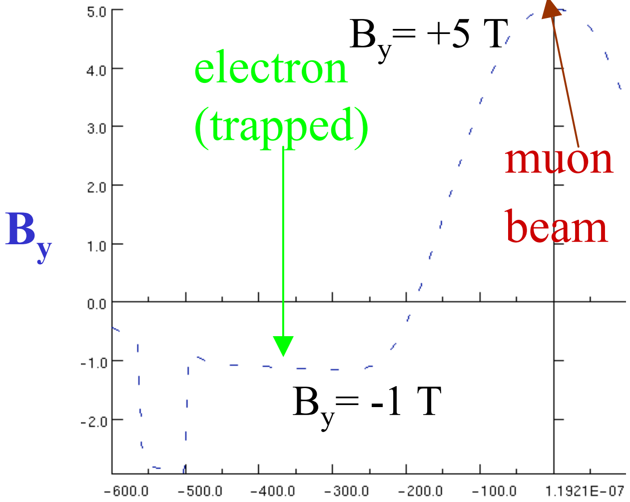
In neutrino storage ring ~10% energy deposition may be acceptable

Possible Extension of Neutrino Storage Ring Dipole for Higher Energy Muon Collider Storage Ring



Nb_3Sn Version, B_o ~ 8-9 T
(for higher energy ring)

Another Possibility
HTS - higher field
higher temperature



Challenge:

- A higher field magnet is required for higher luminosity.
- A much lower energy deposition will be tolerated.

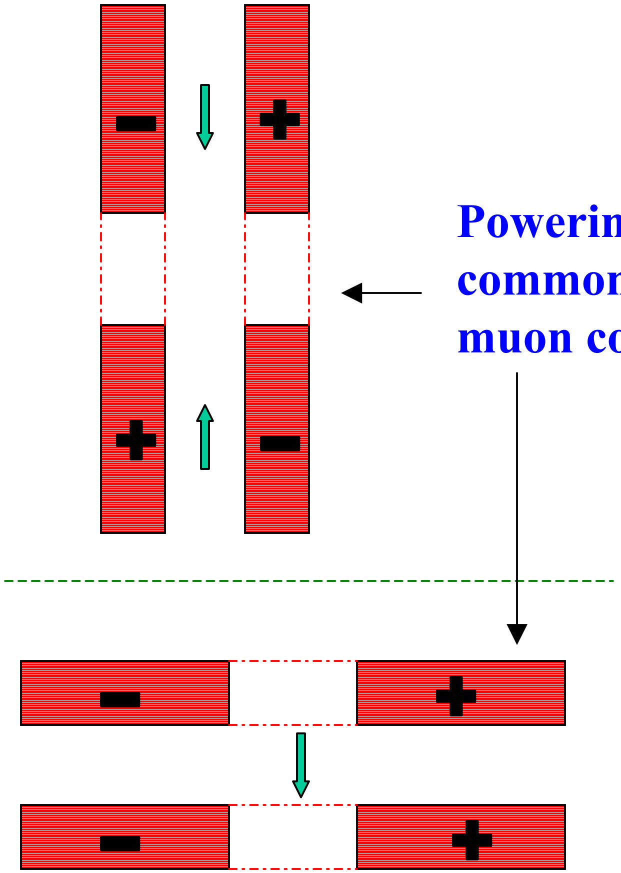
Possible scenarios for manipulating energy deposition:

- Make reverse field much higher that 1 T with additional coils to trap higher energy electrons
- Extend positive field region much further out by adding conventional coils on one side.

This will make decay particles hit metal further out and away from superconducting coils.

Muon Collider Racetrack Dipole Design (15 T, Nb_3Sn and 10^{-5} Field Quality)

Hadron collider configuration



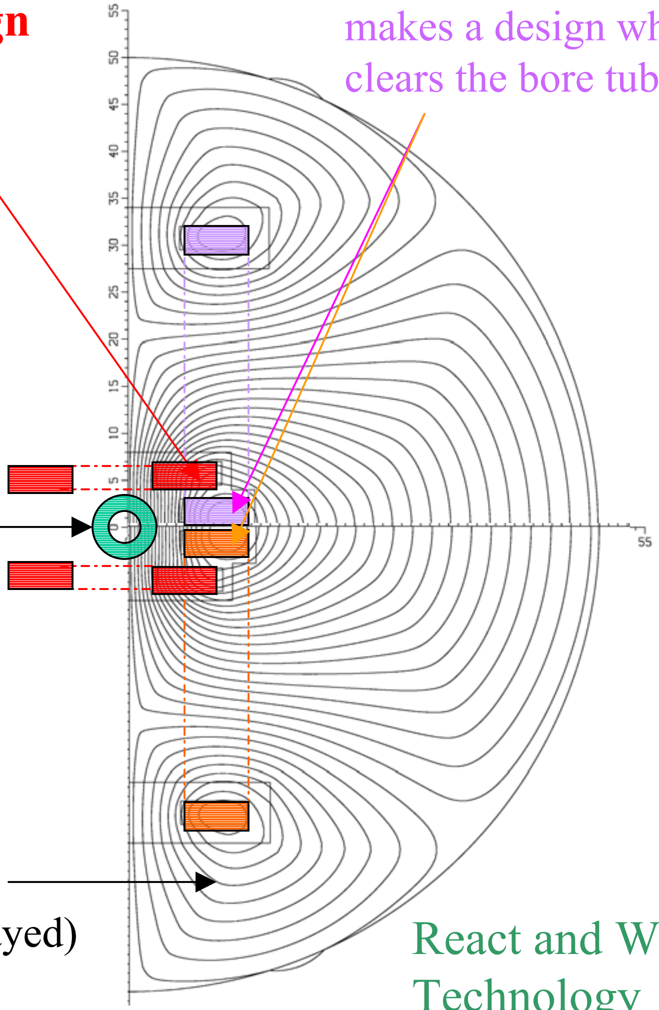
Powering differently changes common coil design test to muon collider design test

muon collider configuration

Note : A high stress test is created here

Racetrack coils clear the bore in this design

Eliminating these coils makes a design which clears the bore tube



Tungsten & bore tube

Iron yoke with field lines
(only half model is displayed)

React and Wind Technology

Advantages of HTS

A significant efforts by Sampson & Ghosh at BNL on HTS cables (tapes), coils and magnets

Advantage of HTS: A slow transition to non-superconducting stage.

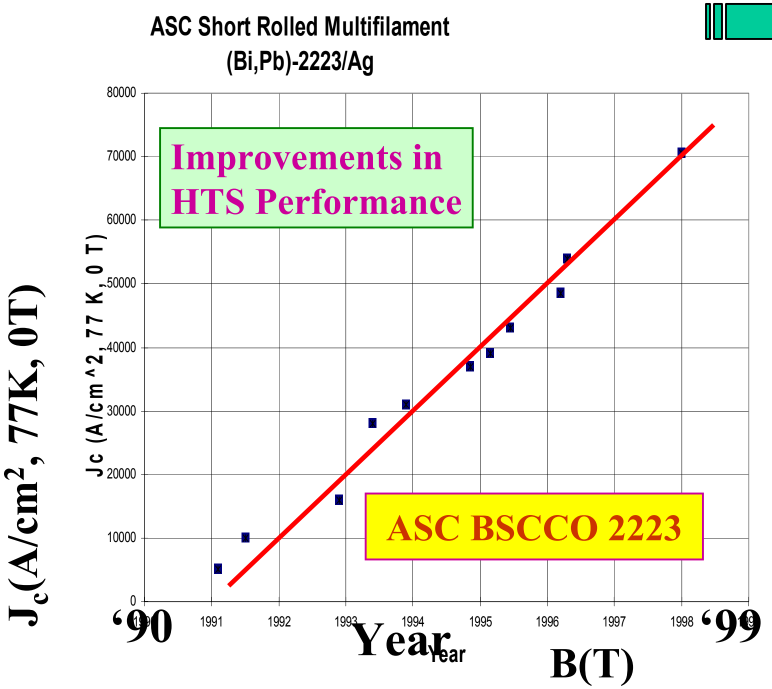
If there is a degradation or if the operating conditions become such that a part of the magnet can no longer remain in an ideal superconducting stage, then there is only a modest temperature rise locally. If the local temperature rise can be tolerated and if the heat can be removed, the magnet will continue to operate in a superconducting stage.

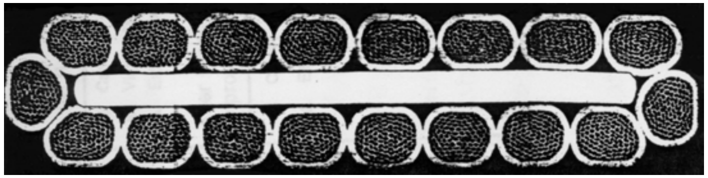
This is in contrast to a sharp transition to “normal zone” in conventional low temperature superconductors where the whole magnet must be switched to normal stage for protection.

This implies a more relax design and operating conditions for a magnet built with HTS.

The cost and performance issues still remain.

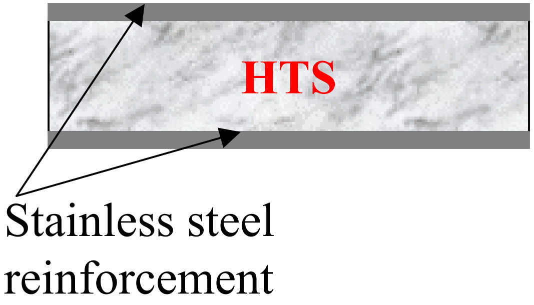
Improvements in HTS Technology And Challenges for Magnet Design





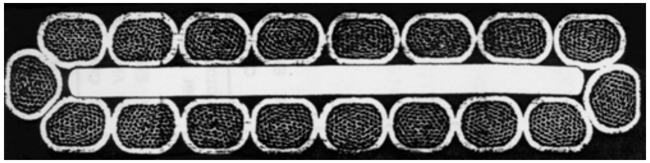
KAmp Rutherford cable :
LBL-industry collaboration

- HTS have made significant progress, enough to make R&D magnets
- 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

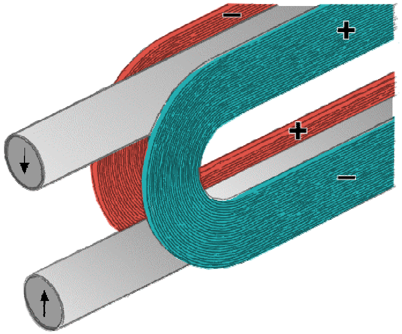


HTS Common Coil Program

BNL is embarking on a promising BSCCO 2212 common coil “cable” magnet program.



kA quality Rutherford cable. A very good collaboration between labs (BNL, LBL) and industries (IGC, Showa).



10kA type Rutherford cable may be possible in near future!

Over 80 meter of kA class cable (over 1.5 km of wire) to be shortly available (weeks to months, in installments) to BNL for testing cables, winding coils, making short magnets, etc.

Current plan:

First test a pair of 10-turn coils in common coil configuration.

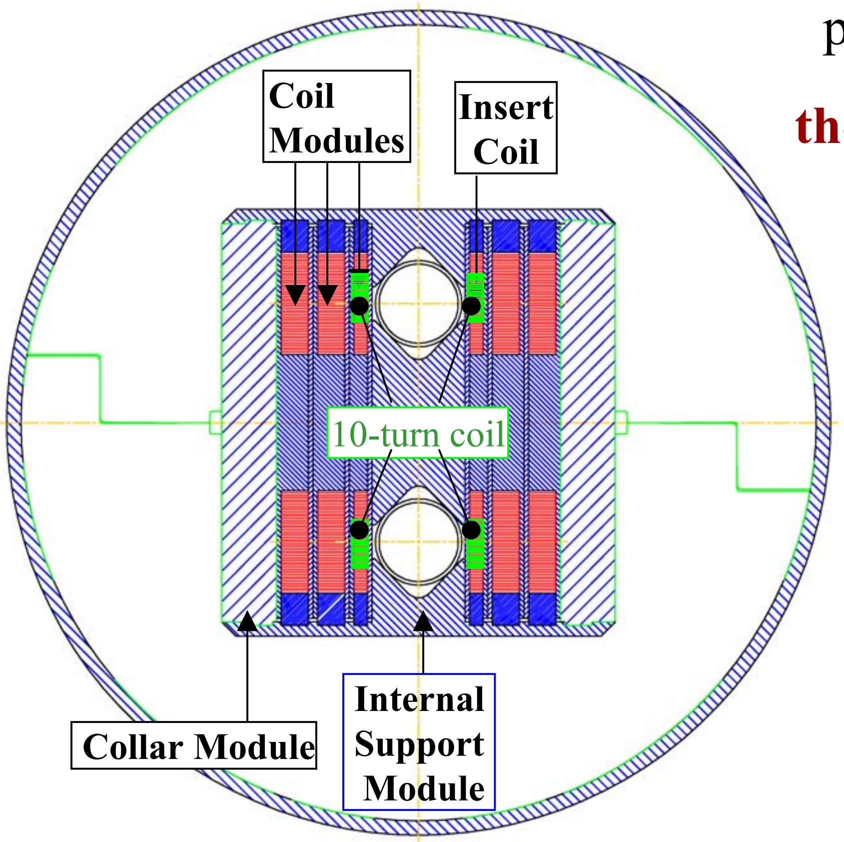
Then depending on the progress, continue with more 10-turn coils and/or go for full 40-turn cable (either Ag and mix or all HTS strands) coil.

Test a pair of coils in a stand-alone mode and in a hybrid high field configuration.

More on HTS in a later talk by Arup Ghosh.

*** Special thanks to Robert Sokolowski (IGC) and Ron Scanlan (LBL).

Life of 10-turn Coil Program After 12.5 T Magnet



While we optimize the 12.5 T design for cost, performance and large scale production,

the 10-turn coil program continues in parallel!

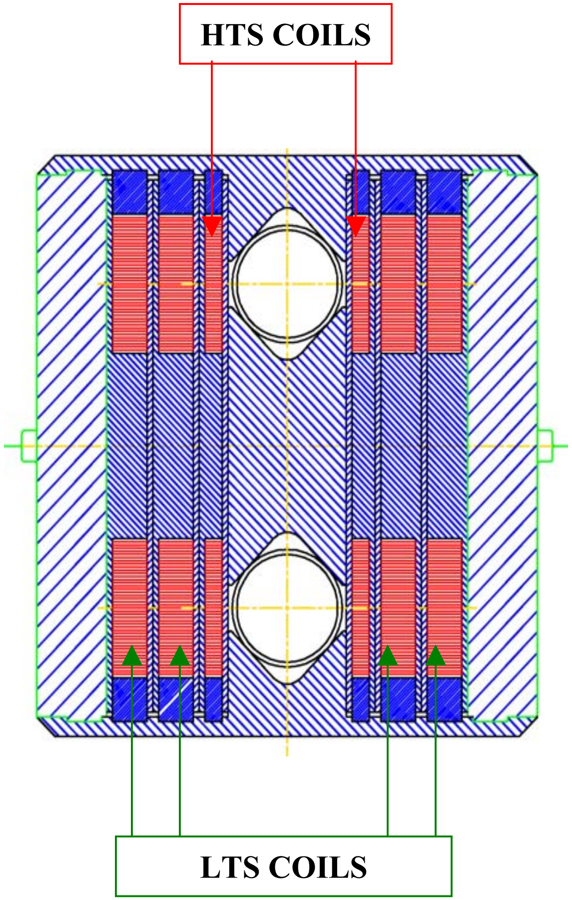
12.5 T magnet becomes a part of "magnet R&D test factory"

The 12.5 T magnet provides a significant background field facility for testing coil modules with large Lorentz forces on them -- try to simulate high field magnet situation.

Can test insert/auxiliary coil for field quality configuration also.

☺ Good approach for HTS magnet development as well.

HTS in a Hybrid Magnet


HTS COILS

LTS COILS

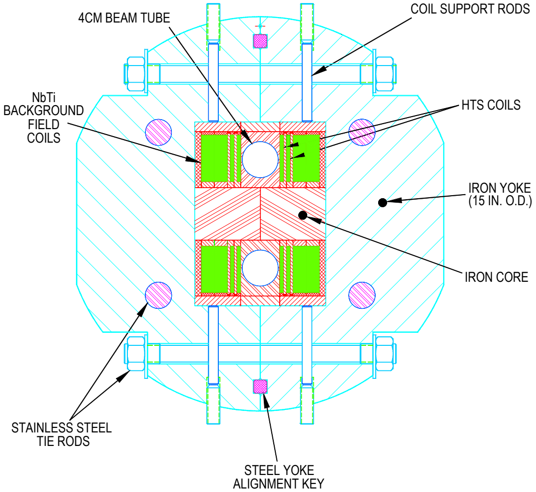
- Perfect for R&D magnets now.

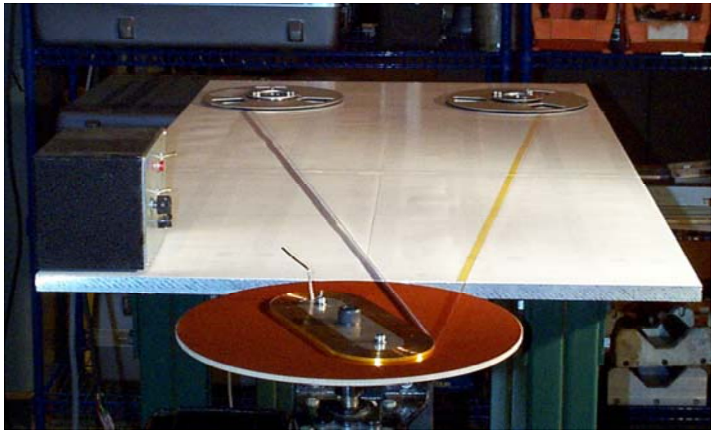
  HTS is subjected to the similar forces that would be present in an all HTS magnet. Therefore, several technical issues will be addressed.

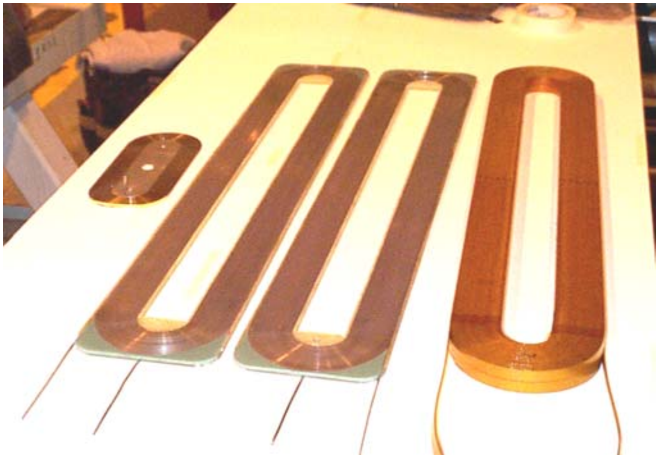
- Also a good design for specialty magnets where the performance, not the cost is an issue. Also future possibilities for main dipoles.

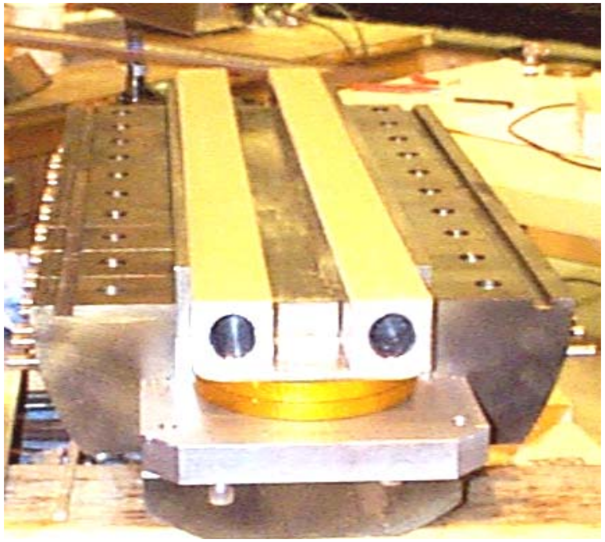
- Field in outer layers is ~2/3 of that in the 1st layer. Use HTS in the 1st layer (high field region) and LTS in the other layers (low field regions).

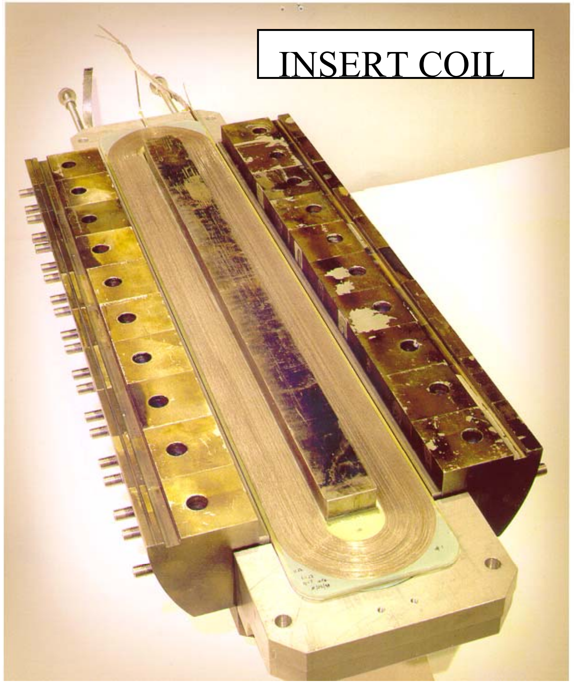
Hybrid Common Coil Magnet at BNL



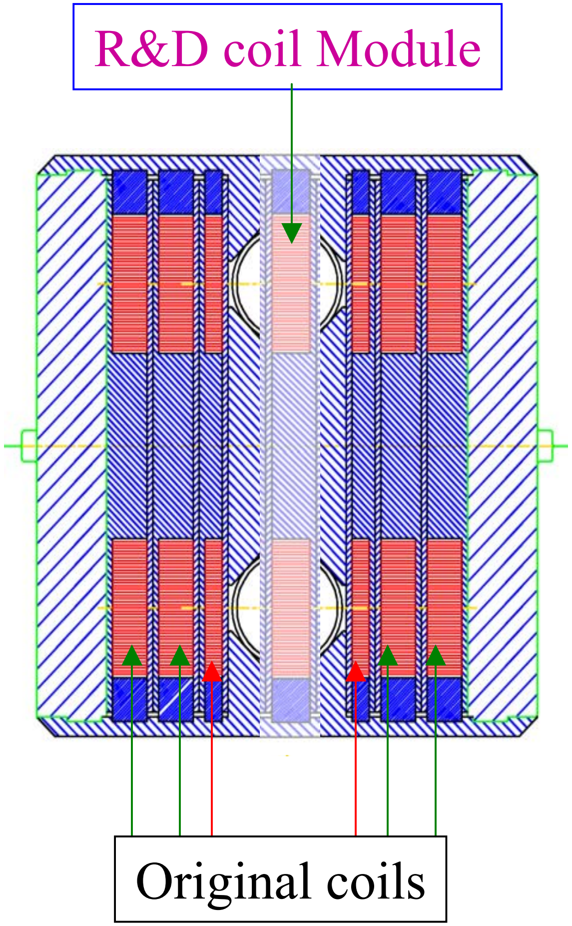








Uses of Smaller R&D Funding to Labs and Industries for a Collaborative and Innovative Magnet Research



- **A Modular Design approach allows a dynamic R&D that was not possible before.**
- **An important part of this high field magnet research is the coil module -- be it conductor manufacturing, coil manufacturing, insulation, stress management, or whatever.**
- **The best is to test these concepts in a "magnet like" situation to avoid surprises/unknowns.**
- **The critical module has a relatively moderate price tag. This allows different ideas, innovative R&D by small labs (or big labs) and industries.**
- **Make this module anywhere and test it in the BNL common coil magnet facility. The forces, etc. are similar to that as in a future all HTS magnet.**
- **Use the positive results in the next magnet.**

What can one study with these modules

A few 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 and Splicing

… and a variety of other things that are not included (especially those that are not included)

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

Summary

- **An exciting program for developing innovative magnet designs and technologies**
    - » **This is the need of the hour (year) to bring a large reduction in cost**
- **A new magnet system design for a possible lower cost VLHC or a future LHC upgrade (2X energy)**
- **A conductor friendly approach for using *“brittle”* conductors (HTS, Nb_3Sn, etc.) in a competitive way**