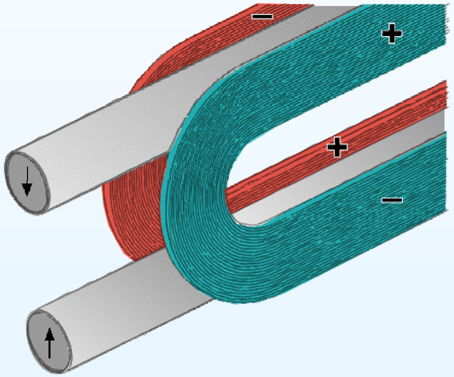
BROOKHAVEN NATIONAL LABORATORY

Superconducting Magnet Division



HTS Cable Magnet Program

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BNL

Overview of the Presentation

- Why HTS accelerator magnets and why start R&D now?
- Results of HTS and high field magnet technology development
- The Next Step
  - 12 T background field magnet to study HTS coil performance under high field and high stress environment
  - IR quadrupole development program

We remain open to new materials.
For our purpose MgB_2 is a sort of high temperature material.

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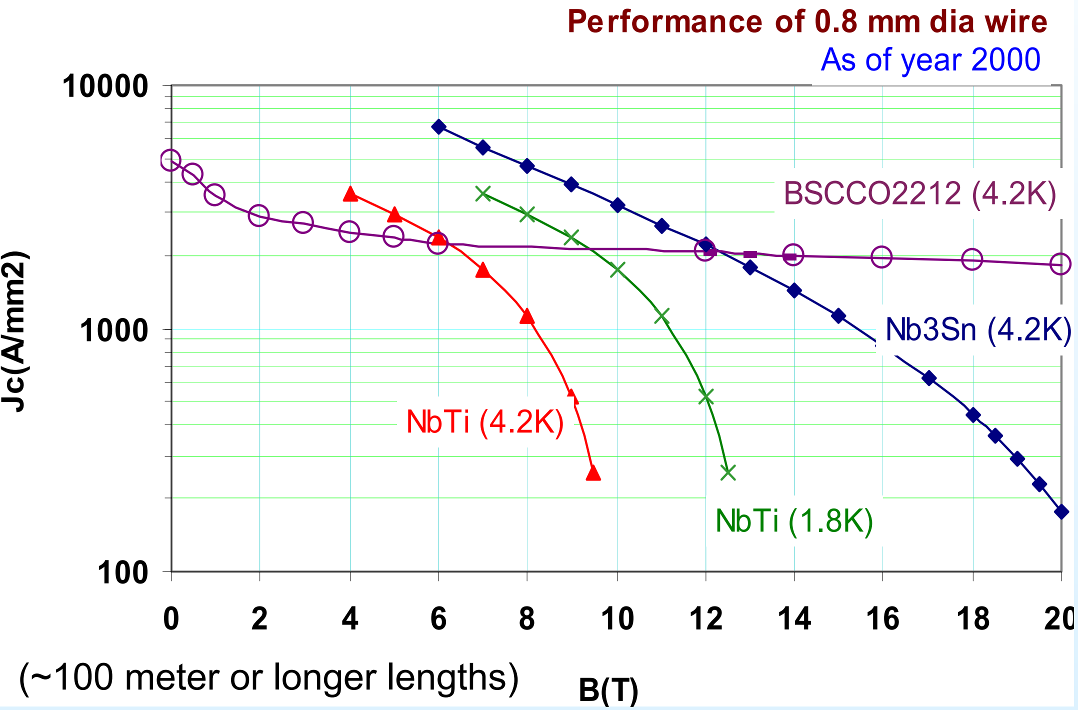
Expected Performance of HTS-based Magnets



(~100 meter or longer lengths)

Year 2000 data for J_c at 12 T, 4.2 K

Nb_3Sn: 2200 A/mm^2

BSCCO-2212: 2000 A/mm^2

Near future assumptions for J_c at 12 T, 4.2 K

Nb_3Sn: 3000 A/mm^2 (DOE Goal)

BSCCO-2212: 4000 A/mm^2 (2X today)

Investment in 2212 has been much less than in 2223, there may be room for relatively more improvement.

Expected performance of all Nb_3Sn or all HTS magnets at 4.2 K for the same amount of superconductor:

Year 2000 Data	
All Nb_3Sn	All HTS
12 T	5 T
15 T	13 T
18 T	19 T*

*20 T for Hybrid

Near Future	
All Nb_3Sn	All HTS
12 T	11 T
15 T	16 T
18 T	22 T

Cu(Ag)/SC Ratio

BSCCO: 3:1 (all cases)

Nb_3Sn: 1:1 or J_{cu}=1500 A/mm^2

First Likely Application of HTS: Interaction Region (IR) Magnets

Interaction region magnets for the next generation colliders can benefit a lot from:

- ▣ the ability to produce very high fields
- ▣ the ability to deal with large energy deposition
- ▣ the ability to operate at elevated temperatures that need not be uniform

→ For these IR magnets, the performance, not the material cost is the issue.

→ IR quadrupoles in LHC may be replaced a few years after first experiment

✓ The first LHC IR upgrade may be possible in ~10 years from now provided the gain is large.

Why Start HTS Magnet R&D Now?

State of HTS is such that we can now do small but credible magnet R&D

- Wire in long lengths available (BNL purchased 1.5 km wire from Showa)
- Standard size cable can carry ~10 kA at high fields (10-20 T)
- Hybrid magnets can create 15^{+}T to address HTS specific issues

Quite often when the magnet R&D is carried out together with the conductor R&D, it brings more energy, more motivation, better overall development as various options either in magnet or in conductor research can be examined together.

HTS and High Field Magnet Technology Development at BNL

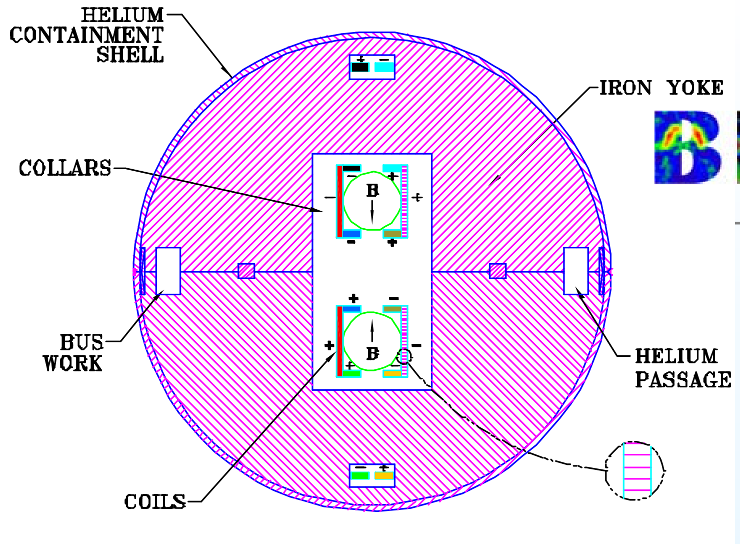
At present "common coil design" with "React & Wind" technology and "rapid turn around approach" remains the work horse of our technology development program.

However, responding to the more likely needs of next 10 years:

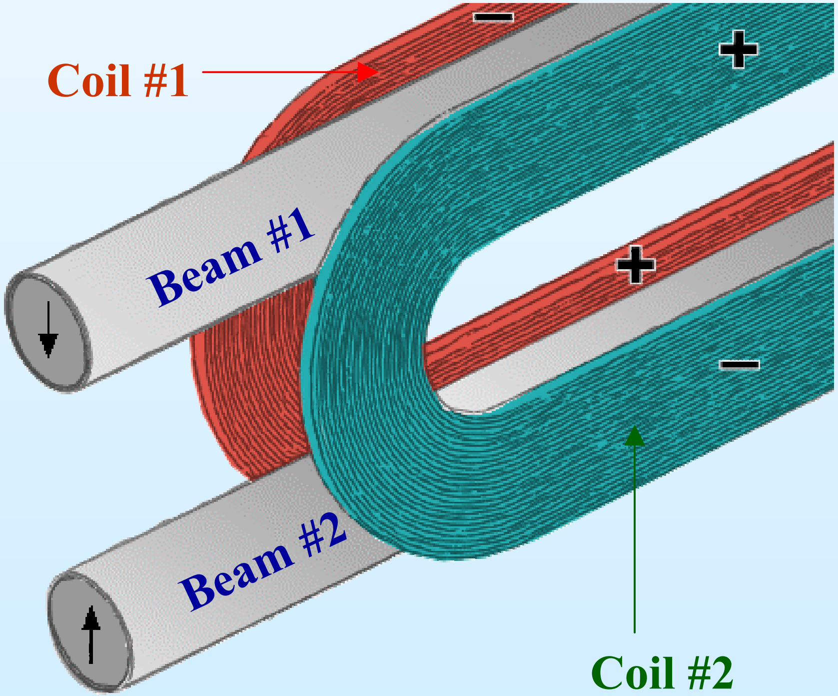
- We are in the process of moving more towards IR quadrupole R&D.
- Though we strongly prefer "React & Wind" approach and see it a more likely candidate for long magnets, we examine elements of "Wind & React" approach.

Since one of the primary reasons for using HTS is to generate high fields, the 12 T background field magnet development remains high on the priority list.

Common Coil Design



- **Simple 2-d geometry with large bend radius** (determined by spacing between two apertures, rather than aperture itself)
- **Conductor friendly (no complex 3-d ends, suitable for brittle materials such as HTS and Nb_3Sn)**
- **Compact (quadrupole type cross-section, field falls more rapidly)**
- **Block design (for handling large Lorentz forces at high fields)**
- **Combined function magnets possible**
- **Efficient and methodical R&D due to simple & modular design**
- **Minimum requirements on big expensive tooling and labor**
- **Lower cost magnets expected**



Main Coils of the *Common Coil Design*

Contributions of HTS and High Field Magnet Development Program at BNL

- Common coil design, a serious candidate for the next hadron collider

- 10 turn coil rapid turn around approach, or a variation of it, as an important element of the future magnet R&D

- HTS test coils with react and wind technology

In addition, we have produced proof of principle hardware and demonstrated feasibility of various technologies.

However, the material and design costs limit further progress as things get more involved.

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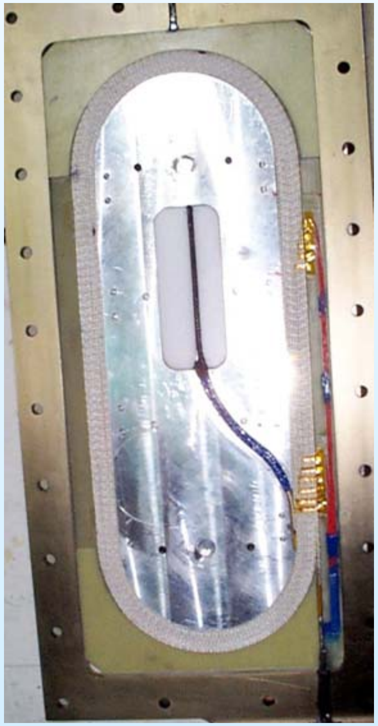
10 Turn Coil Program

GOAL: Experimentally test an item, beginning to end, in ~1 month.



The construction should be as simple as possible and cost should be as low possible.

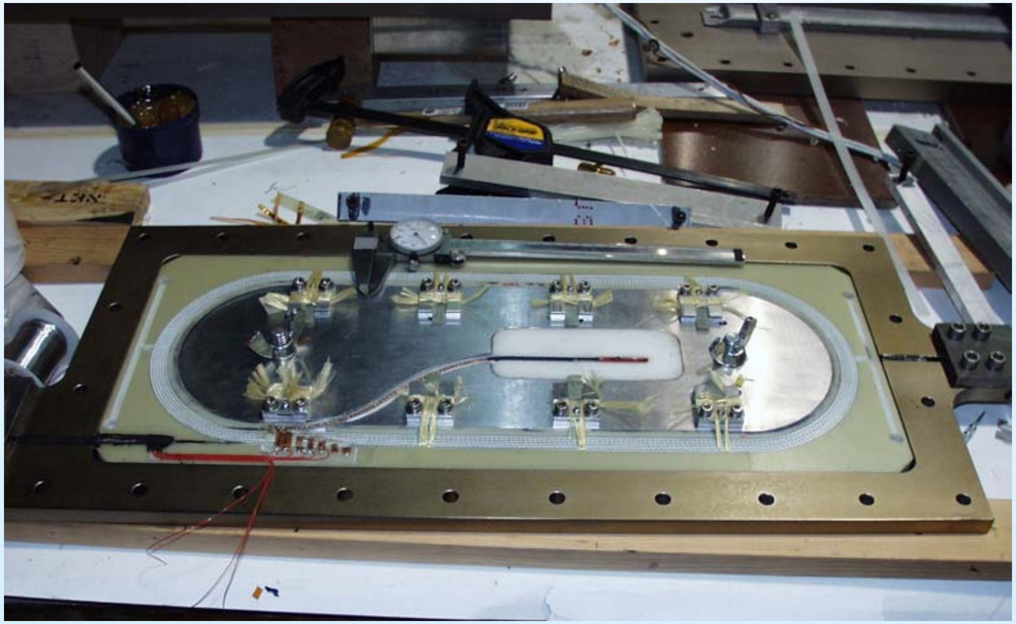
Rapid turn-around encourages test of new ideas and allows iterations in them. It scientifically evaluates the validity of old biases and the limit of present technologies.

In an atmosphere of limited funding, *“designing a magnet R&D program”* is just as important as designing a magnet. It sets the tone and nature of R&D.

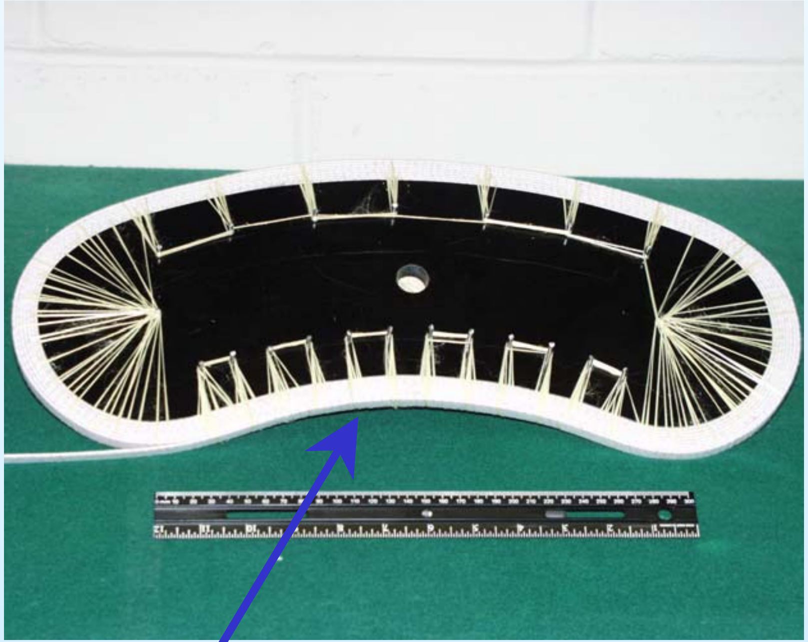
Such a program is must for HTS magnet development given the state of technology and the cost of conductor.

Innovation in Coil Winding
Use of Kevlar Strings

Kevlar strings make well compressed coils with brittle materials in shapes that were thought to be difficult before



Kevlar clamp setup, coil locked into fixturing



Coils with reverse curvature

Innovation in Coil Impregnation Vacuum Bag and Teflon Coating

Vacuum bag table with membrane

Vacuum bag for rapid turn around program where coil design can change widely

Mold side plate with Teflon coating - non sticky against epoxy

Please see coil impregnation set up, etc. during the tour

Basic Features of 10 turn Coils

The following 10 turn coils have been wound in ~1 ½ years. All coils were made for common coil design having a bending radius of 70 mm and straight section of 30 cm.

Test results of only HTS coils/magnets will be discussed.

All Nb_3Sn magnets worked well except one where the problem was traced to reacted cable (the cable itself had worked well in LBL RD3 magnet).

Coil #	Magnet #	Impreg #	Conductor	Conductor pedigree	Insulation type	Bobbin	Process additions
CC001	None	001	Nb_3Sn	ITER chrome	3 mil glass wrap	Iron	First impreg, single ended
CC002	DCC001&2	002	Nb_3Sn	ITER chrome	2 mil glass wrap	Iron	Double hole impreg
CC003	DCC002	003	Nb_3Sn	ITER chrome	2 mil glass wrap	Iron	Double hole impreg
CC004	DCC003 & 8	005	Nb_3Sn	ITER chrome	2 mil glass wrap	Stainless steel	V taps added
CC005	DCC003 & 8	006	Nb_3Sn	ITER chrome	2 mil glass wrap	Stainless steel	V taps added
CC006	DCC004	004	HTS	Low performance	Tube braided glass	Aluminium	
CC007	DCC004	007	HTS	Low performance	Tube braided glass	Stainless steel	
CC008	DCC005	010	Nb_3Sn	LBL RD3 cable	2 mil glass wrap	Stainless steel	
CC009	DCC005	011	Nb_3Sn	LBL RD3 cable	2 mil glass wrap	Stainless steel	
CC010	DCC006	008	HTS/Ag	2 BSCCO, 16 Ag	2 mil glass wrap	Brass	Teflon tape on mold faces
CC011	DCC006	009	HTS/Ag	2 BSCCO, 16 Ag	2 mil glass wrap	Stainless steel	
CC012	DCC008	012	HTS	High Performance	2 mil glass wrap	Aluminium	New mold plates
CC013	None	013	Nb_3Sn	ITER NEEWC	NEEW braided	Stainless steel	Removable bobbin test
CC014	None	014	Nb_3Sn	ITER NEEWC	2 mil glass wrap	Stainless steel	First vacuum bag impreg
CC015	None	015	Nb_3Sn	ITER NEEWC	2 mil glass wrap	Stainless steel	First kevlar string clamping
CC016	DCC009	016	Nb_3Sn	LBL RD3 cable	2 mil glass wrap	Brass	Kevlar string clamping

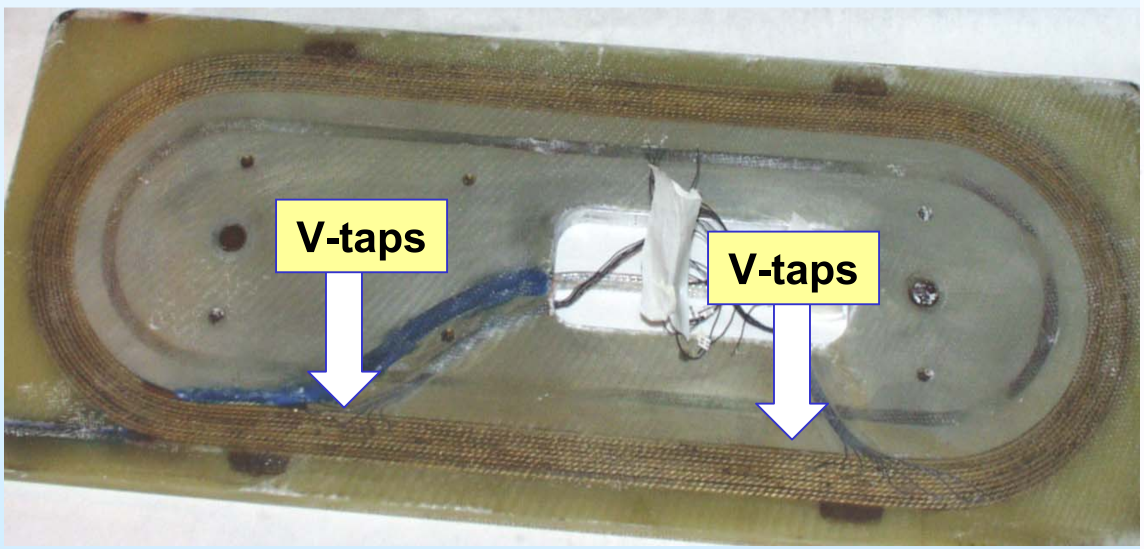
*Not listed here are (a) DCC007, an HTS tape and (b) an earlier NbTi cable common magnet.

Magnet DCC002: 1st HTS Dipole/Quad

Given the aggressive R&D and learning nature of the program, we instrument the magnet, as much as we can.

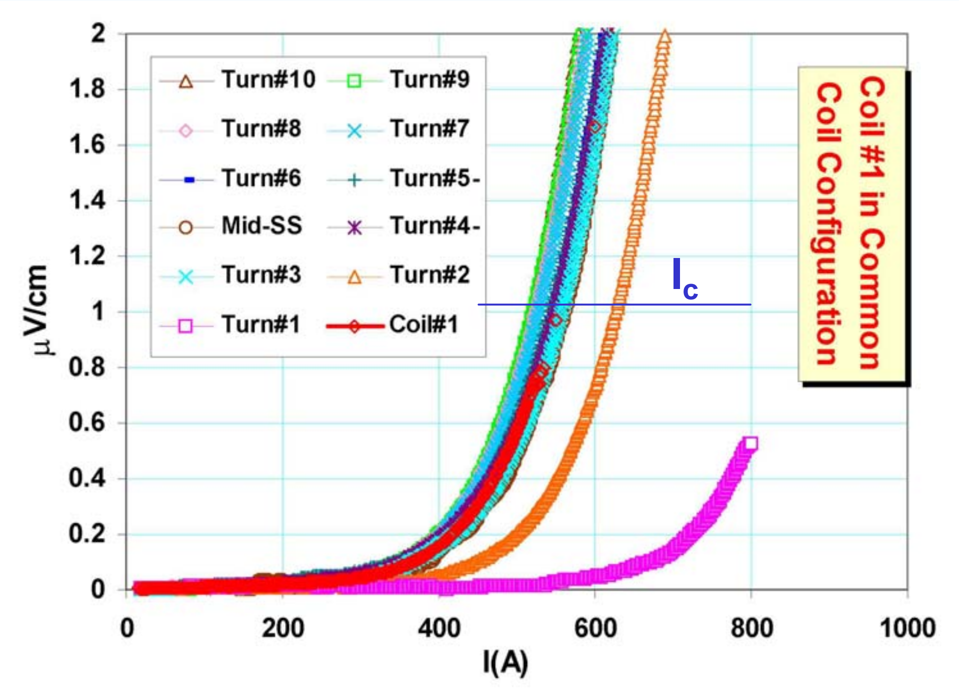
We put at least one voltage tap on each turn

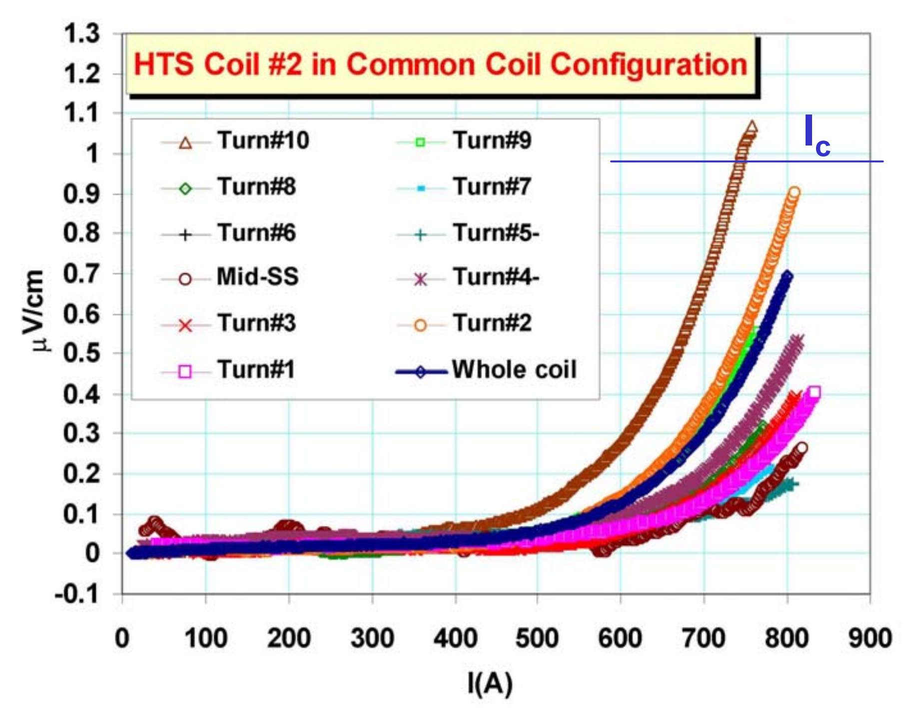
Coils are assembled for a flexible and extensive testing. Four leads are taken out of the cryostat.



Magnet DCC002: 1st HTS Dipole/Quad

Voltage difference between each consecutive turn and on each coil at 4.2 K

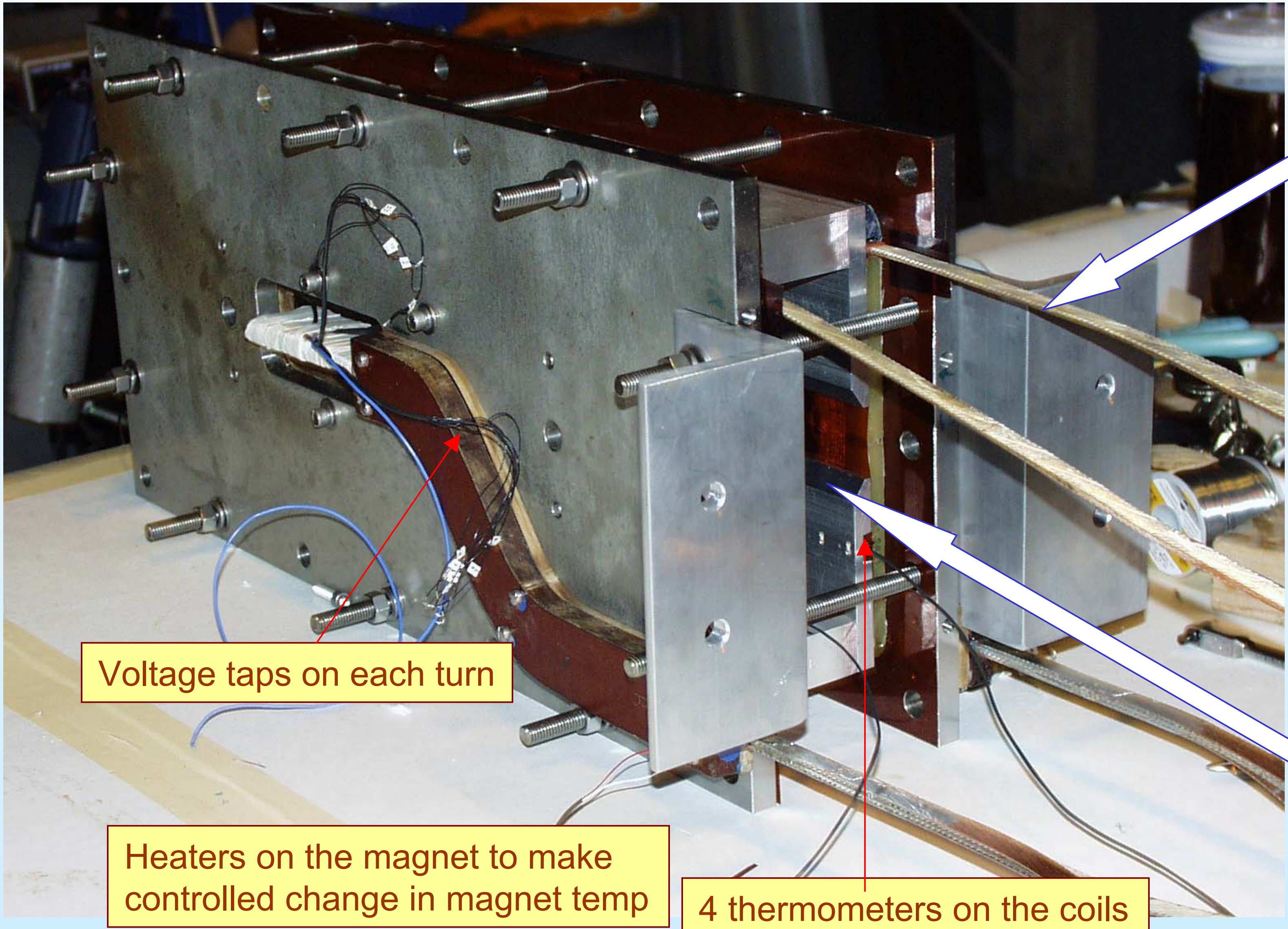




- This test magnet was made with cable from early wire
- The state-of-the-art wire is now about a factor of five better

Magnet DCC006: 2nd HTS Dipole

(Magnet No. 6 in the common coil cable magnet series)



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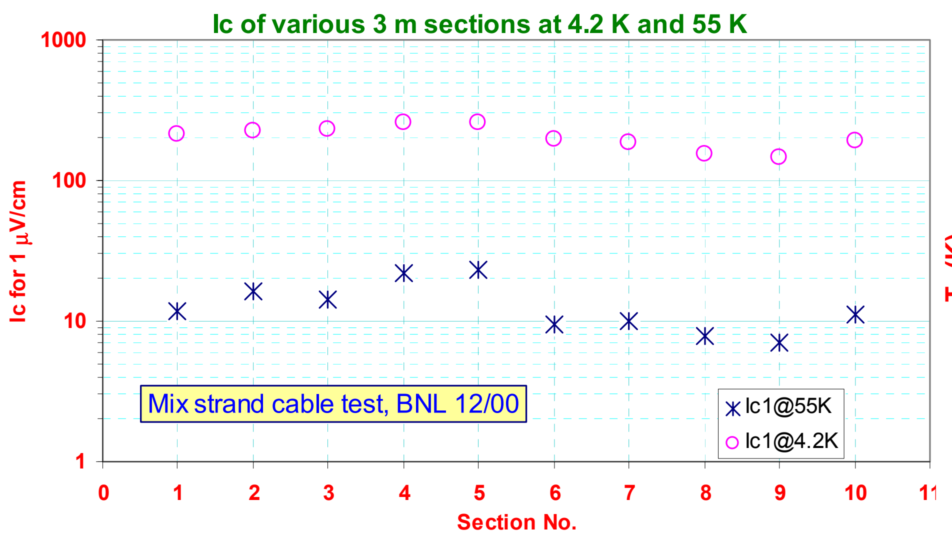
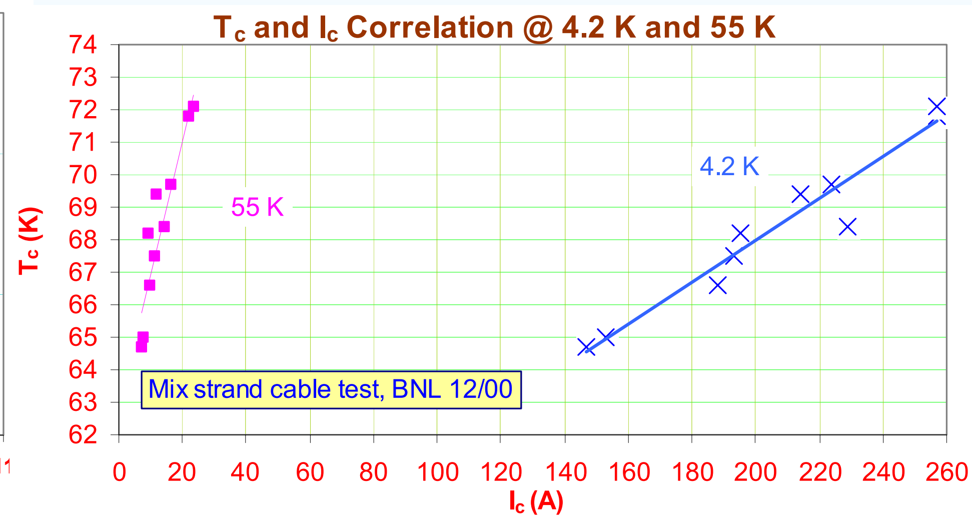
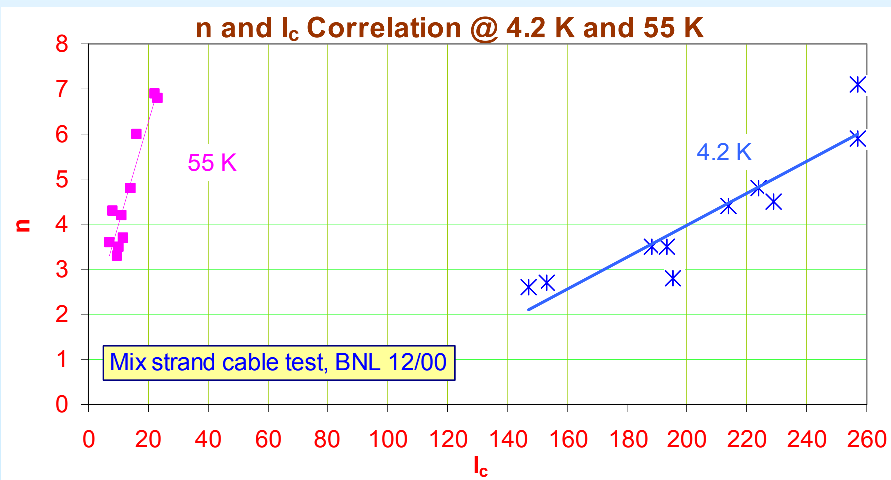
Mixed Strand Cable for DCC006 (tested prior to winding coil)



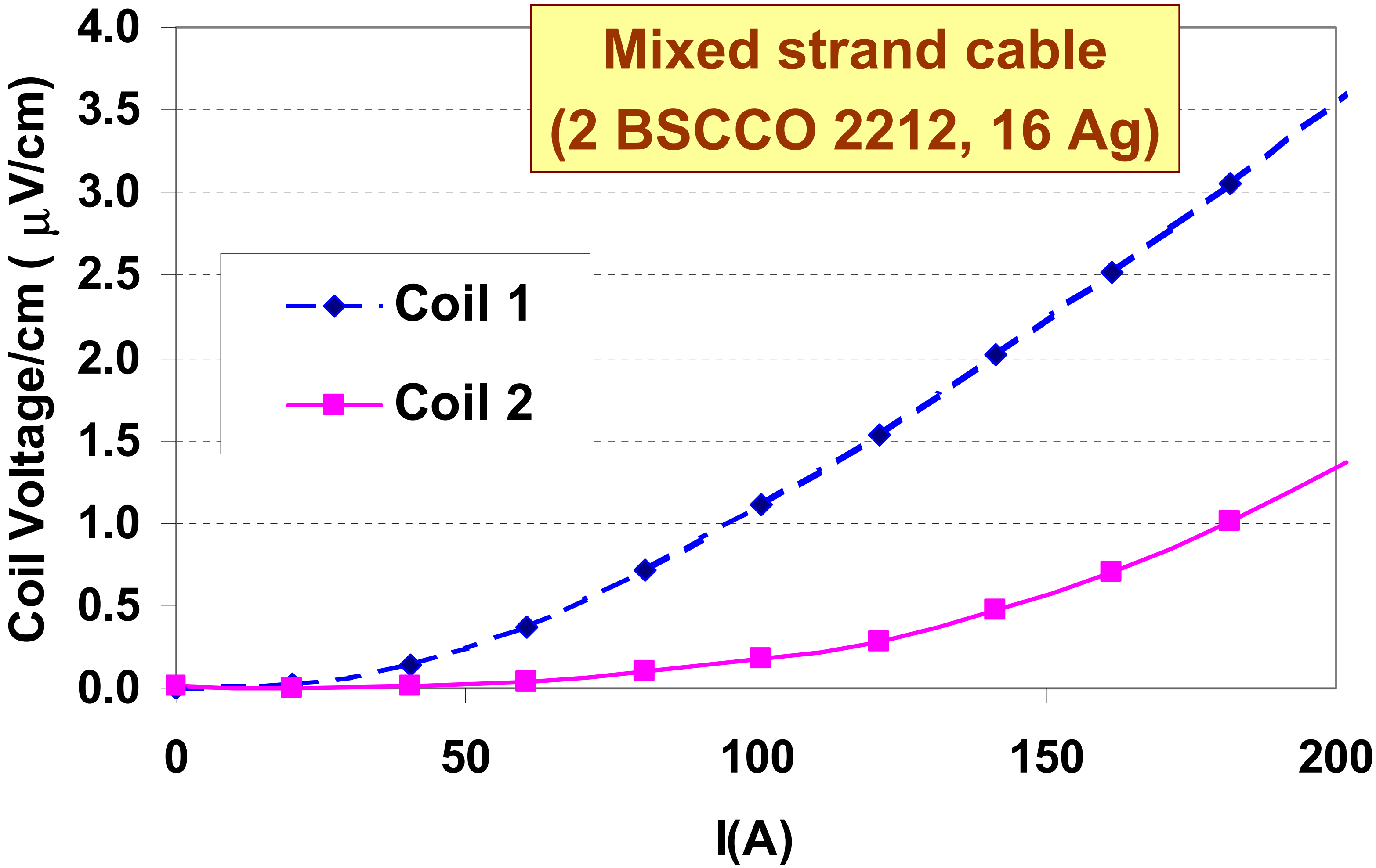




Notes:

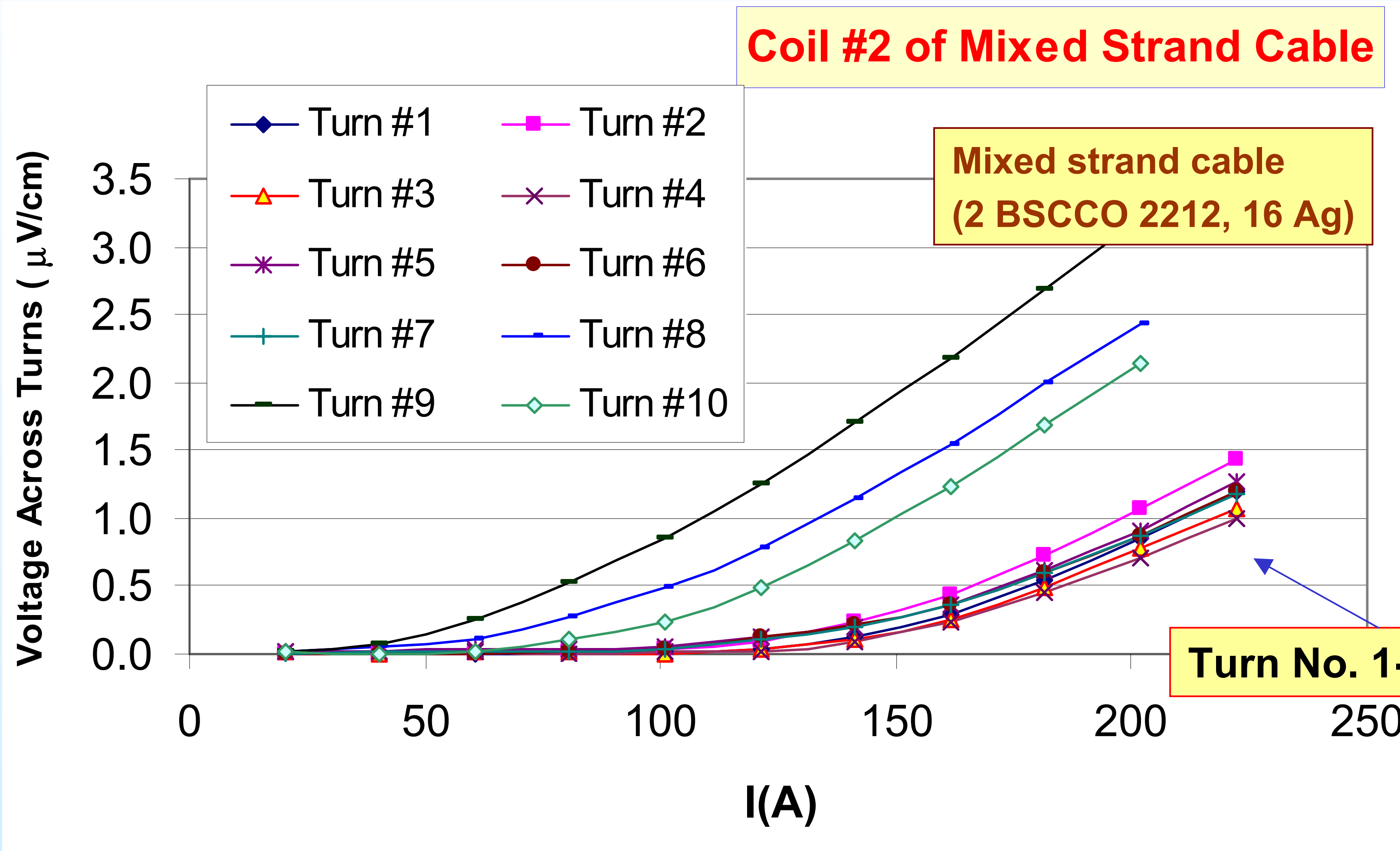
1. A good correlation between LN_2 and LHe measurements offer a valuable QA technique for industry.
2. Better cable has better Tc
3. I_c and "n value" improve together.

Performance of 2 Coils in Muon Collider Dipole Configuration of Magnet DCC006



Coil #2 was made with better part of the cable than coil #1

Measured I_c of Various Turns of Common Coil Magnet DCC006

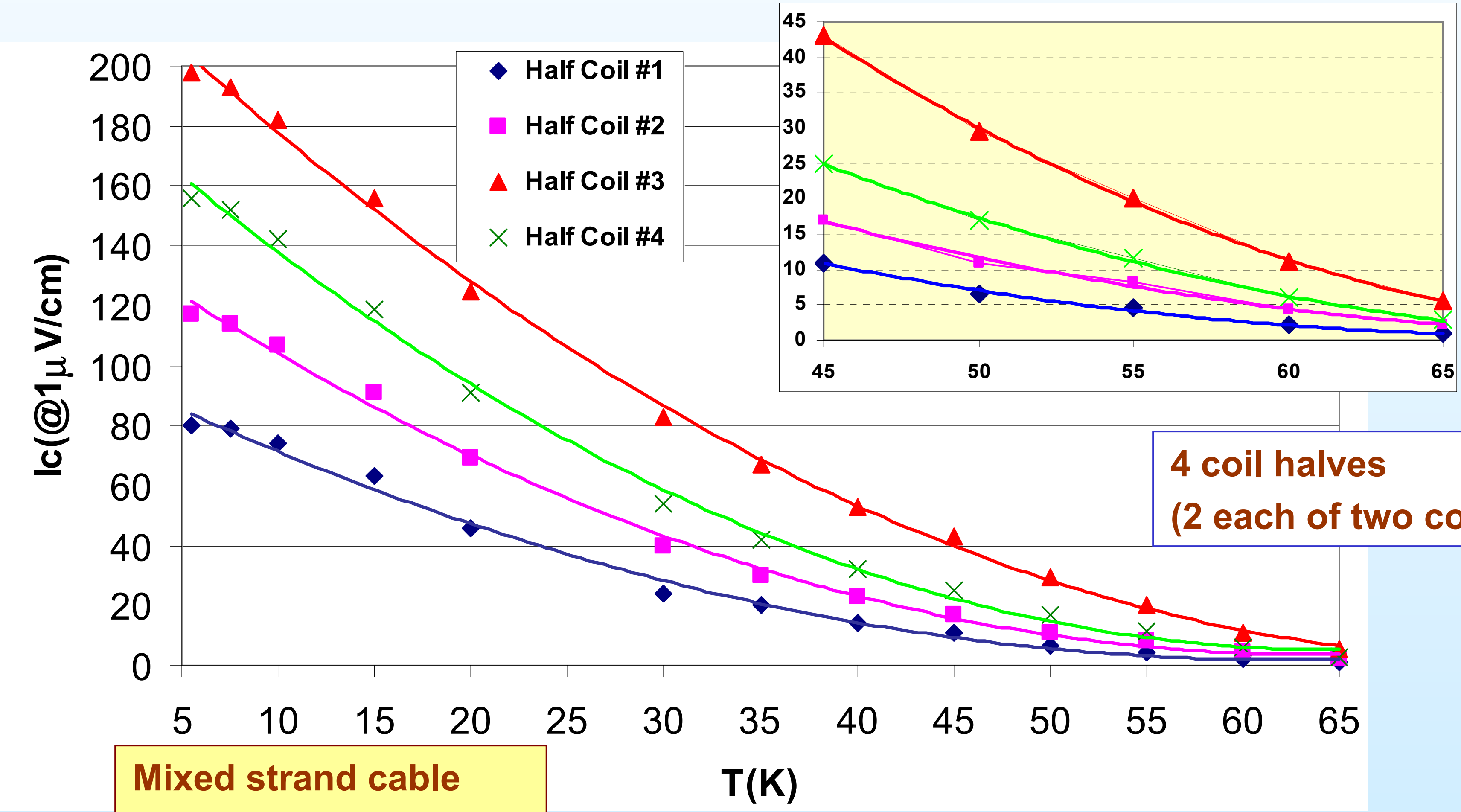


Turns No. 1-7 show an I_c close to the best measured in cable prior to winding.

This suggest a low level of degradation!

Measured Critical Current as a Function of Temperature in DCC006

A few degree change in temperature has a small effect on critical current



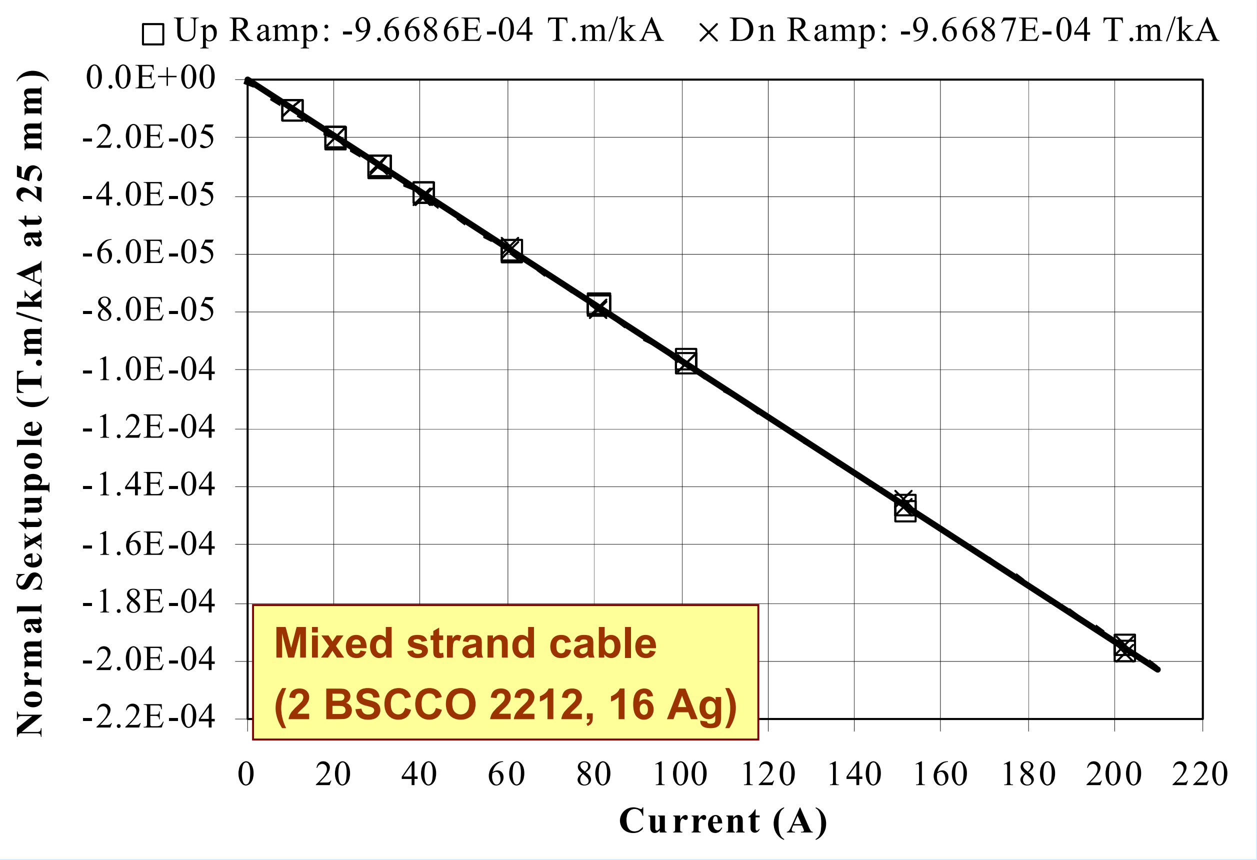
4 coil halves
(2 each of two coils)

Mixed strand cable
(2 BSCCO 2212, 16 Ag)

Field Quality Measurements

DC loop Data (+200A) in DCC006 Dipole Mode

Sextupole Harmonic

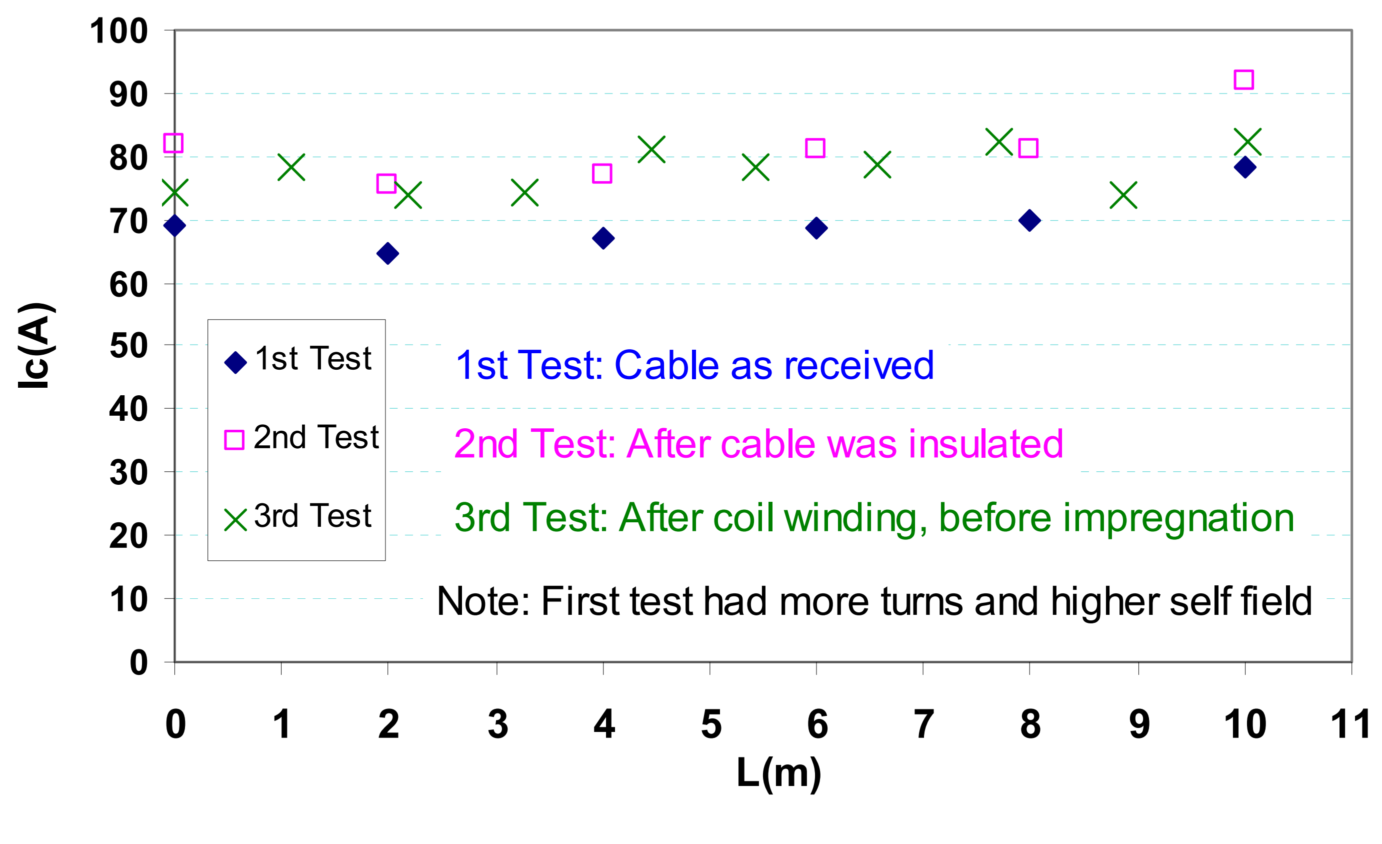


Difference between up and down ramp values is within measurement errors.

Max field on conductor was only ~550 Gauss. Expect a relatively smaller measurement error when the total current is high in an all HTS cable.

Systematic Test during the steps of making High Performance HTS coil for DCC008

The coil CC012 is made with the best HTS delivered to date (best claimed is about a factor of 2 better). We want to study degradation, if any, in each and every step of the process. The following LN_2 measurements track the process.



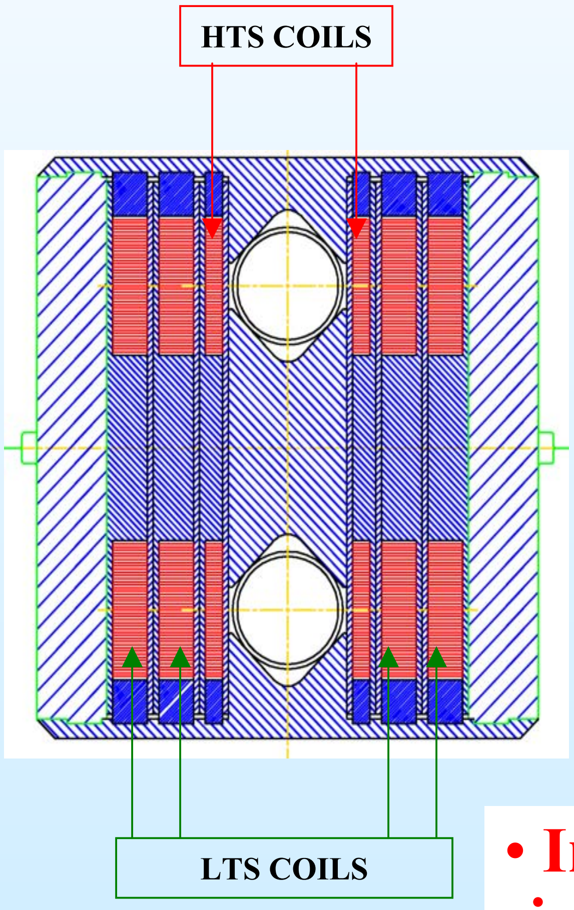
Next Test

Assemble a hybrid magnet to measure the performance of this HTS coil at 4 K in the background field created by Nb_3Sn coils.

Rutherford Cable made with 18 strands of BSCCO2212.

Strand diameter = 0.8 mm.

12 T Magnet: The Important Next Step in HTS R&D Program



- At present, HTS alone can not generate the fields we are interested in.
- Nb_3Sn coils provides high background fields. The HTS coils will be subjected to high field and high stresses that would be present in an all HTS magnet. Therefore, several technical issues will be addressed.
- Since 12 T Nb_3Sn magnet uses similar technology (building high field magnet with brittle material), it also provides a valuable learning experience in building an all HTS high field magnet.

• Important design consideration: Allow a simple mechanism for testing HTS insert coils.

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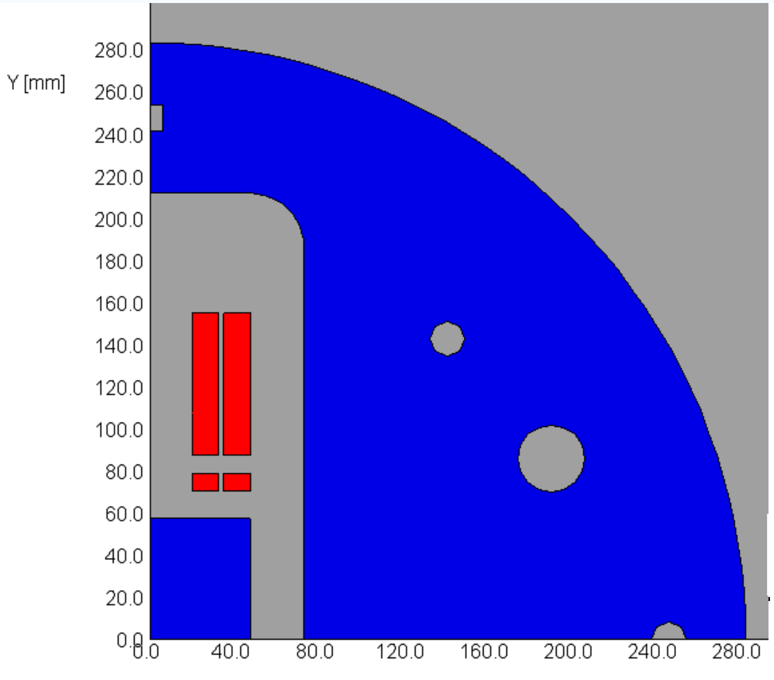
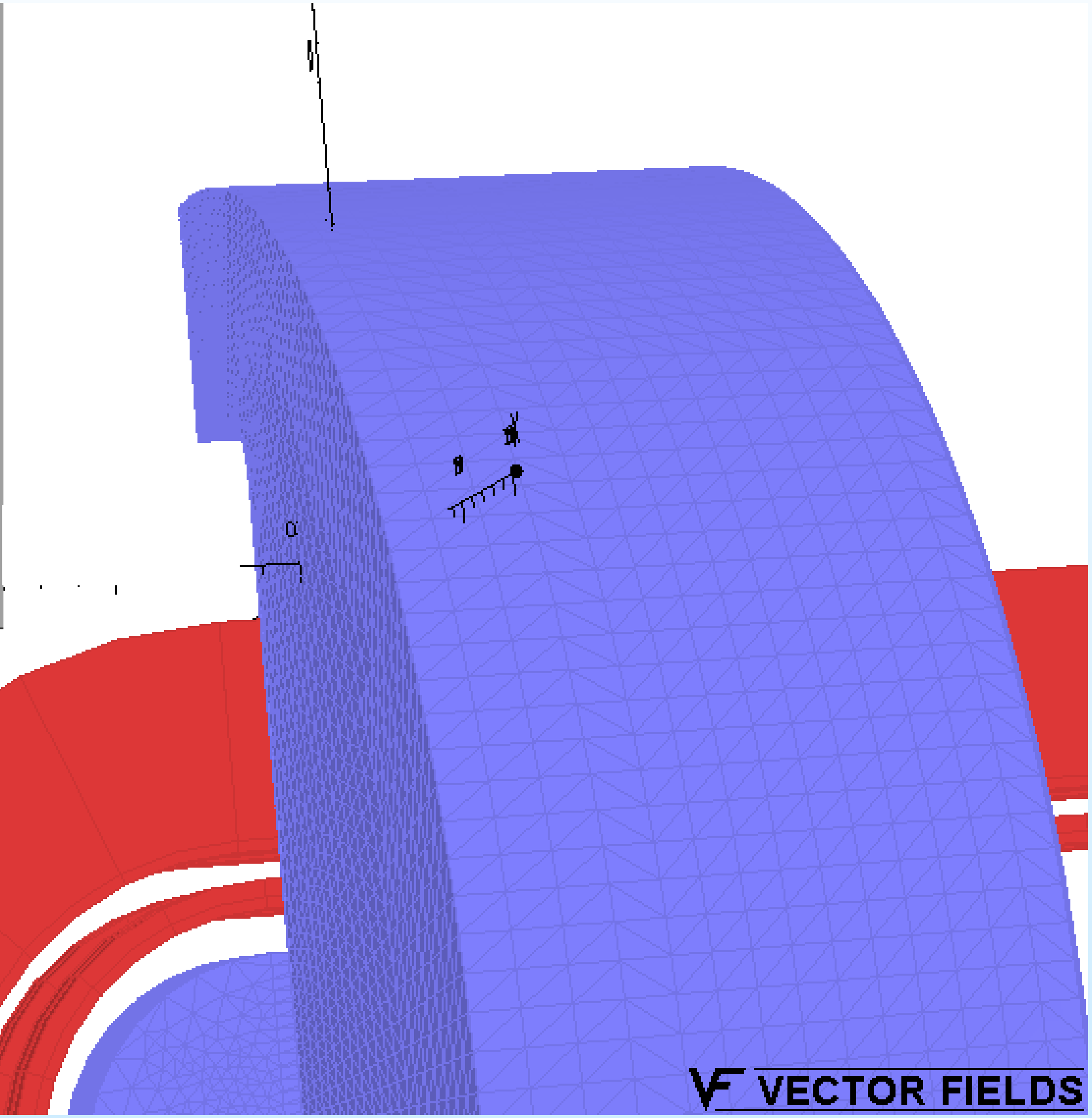
Basic Parameters of 12 T Design

Coil aperture	40 mm
Number of layers	2
Computed quench field at 4.2 K	12 T (12.6 T option)
Peak Fields, inner & outer layers	13.0 T & 8.0 T
Quench current	13.0 kA (11.2 kA, 16.8 kA)
Wire Non-Cu J_{sc} (4.2 K , 12 T)	~2000 A/mm^2
Strand diameter	0.8 mm
No. of strands, inner & outer layers	30, 30
Cable width, inner & outer layer (insulated)	12.5 mm, 12.5 mm
Cu/Non-Cu ratio, inner & outer	0.86, 1.53
No. of turns per quadrant of single aperture	90/2 = 45
Max. height of each layer from midplane	85/2 = 42.5 mm
Bore spacing	220 mm
Minimum coil bend radius (in ends)	70 mm
Outer yoke radius	283 mm

Magnetic Models of the Design

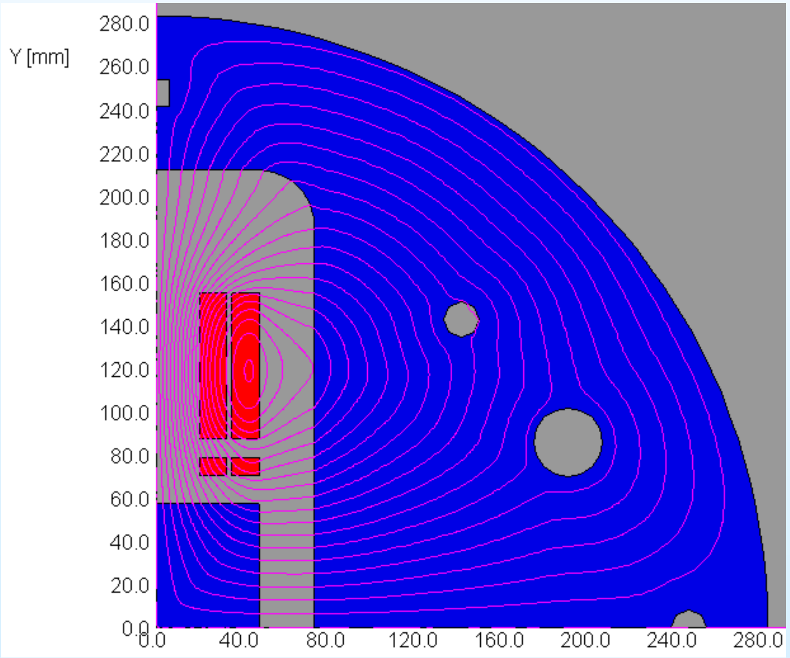




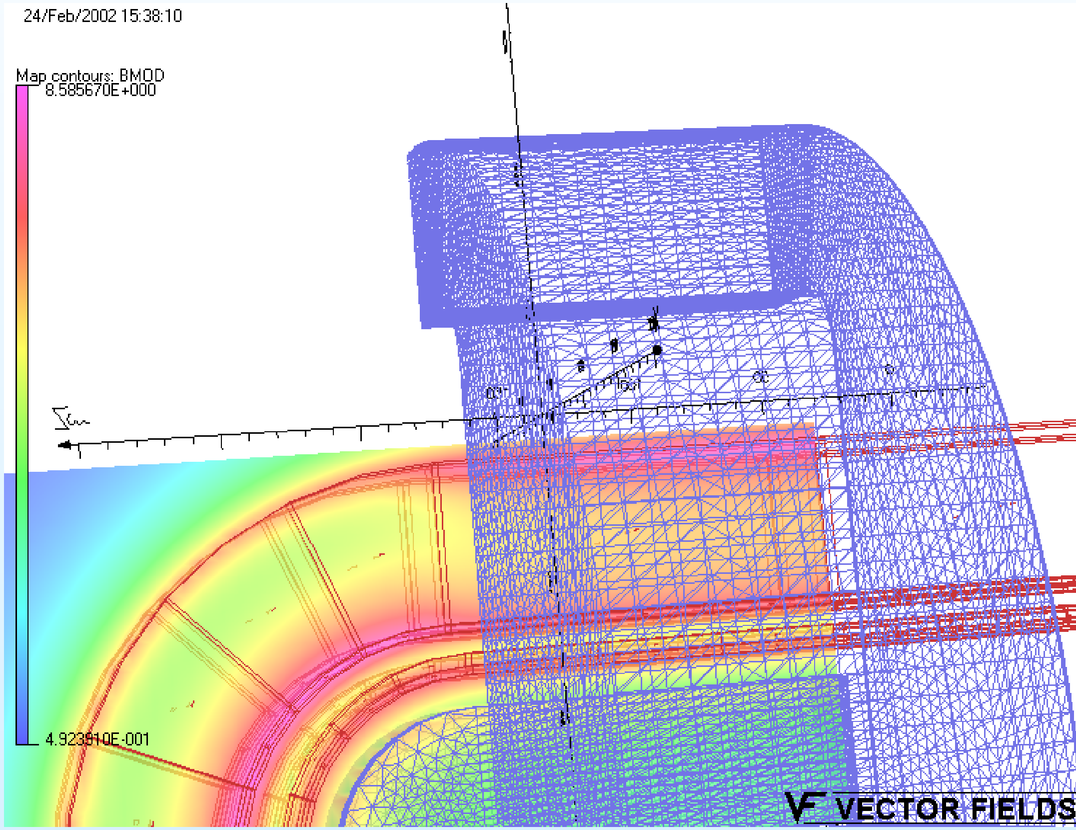
¼ model of the 2-in-1 common coil magnet

Spacers in the Body and Ends to Minimize Peak Fields

¼ model of the 2-in-1 common coil magnet



Field lines in 2-d model.



Field Contours in 3-d model.

Non-magnetic material over coil and end spacers are used to minimize peak field in the end region.

Expected Performance When Coils in Both Layers Carry Equal Current

Bss = 12 T

Expected Performance of BNL 12 T Design 45 turn (equal current)

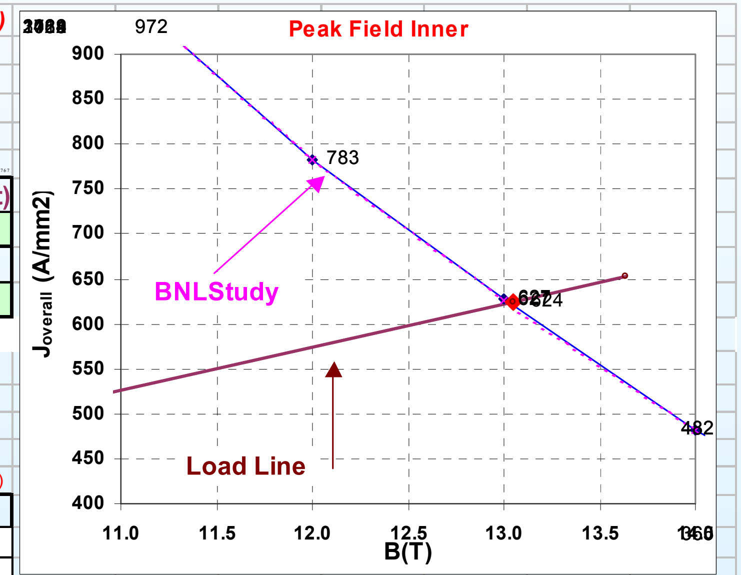
	Jsc-in	Joverall-in	Jsc-out	Joverall-out	
	1598	624	2167	624	
Bss(T)	Iss-in(kA)	Bpeak(in)		Iss-out(kA)	Bpeak(out)
12.08	12.94	13.05		12.94	7.98
Bss		Enhcment			Enhcment
		1.080			0.660
		Inner		Outer	
J_{cu}(A/mm^2) @Quench		1854		1421	
	Cu/Non-Cu	0.86	Cu/Non-Cu	1.53	

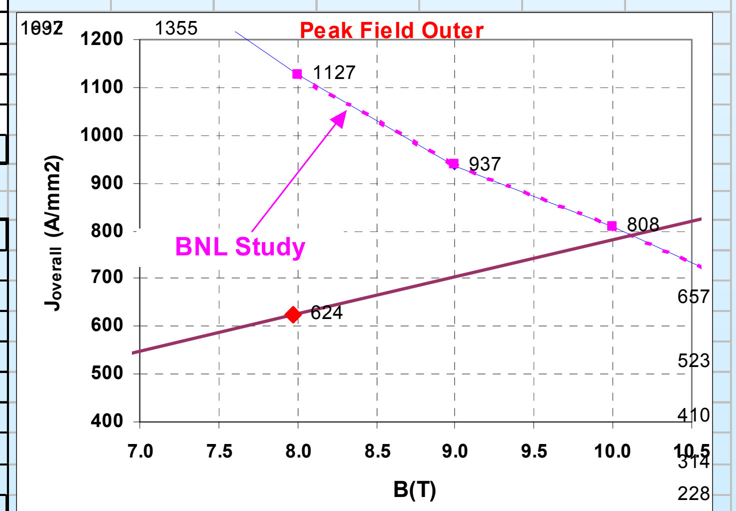
Inner wire & cable expected performance — 30 strand (0.8 mm) cable

Non-Cu(%) 53.7		(LBL Spec=59%)	Iwire(15T)	252	(LBL Spec=305)
B(T)	Jc(A/mm2)	Jwire(A/mm2)	Iwire(A)	Icable(A)	Joverall
10	3026	1625	817	24503	1182
11	2488	1336	672	20149	972
12	2005	1077	541	16239	783
13	1605	862	433	12997	627
14	1234	662	333	9989	482
15	934	501	252	7560	365
					Insulated

Outer wire & cable expected performance — 30 strand (0.8 mm) cable

Non-Cu(%) 39.6		(LBL Spec=37%)	Iwire(10T)	559	(LBL Spec=537)
B(T)	Jc(A/mm2)	Jwire	Ic (wire)	Ic Cable	Joverall
8	3915	1550	779	23377	1127
9	3255	1289	648	19438	937
10	2808	1112	559	16770	809
11	2282	904	454	13628	657
12	1817	720	362	10852	523
13	1425	564	284	8508	410
14	1092	432	217	6518	314
15	791	313	157	4724	228
					Insulated





Expected Performance When Coils in Both Layers Carry Different Currents

Bss = 12.6 T

Apart from producing higher field, the different current option would scientifically examine the influence of Cu/Sc ratio and Jcu on coil performance.

Expected Performance of BNL 12 T Design (different current case)

Jsc-in	Joverall-in	Jsc-out	Joverall-out
1372	536	2790	803

Bss(T)	Iss-in(kA)	Bpeak(in)		Iss-out(kA)	Bpeak(out)
12.62	11.11	13.62		16.66	9.22
Bss		Enhcment			Enhcment
		1.080			0.731
		Inner		Outer	
J_{cu}(A/mm^2) @Quench		1591		1829	
	Cu/Non-Cu	0.86	Cu/Non-Cu	1.53	

Inner wire & cable expected performance — 30 strand (0.8 mm) cable

Non-Cu(%) 53.7		(LBL Spec=59%)	Iwire(15T)	252	(LBL Spec=305)
B(T)	Jc(A/mm2)	Jwire(A/mm2)	Iwire(A)	Icable(A)	Joverall
10	3026	1625	817	24503	1182
11	2488	1336	672	20149	972
12	2005	1077	541	16239	783
13	1605	862	433	12997	627
14	1234	662	333	9989	482
15	934	501	252	7560	365
					Insulated

Outer wire & cable expected performance — 30 strand (0.8 mm) cable

Non-Cu(%) 39.6		(LBL Spec=37%)	Iwire(10T)	559	(LBL Spec=537)
B(T)	Jc(A/mm2)	Jwire	Ic (wire)	Ic Cable	Joverall
8	3915	1550	779	23377	1127
9	3255	1289	648	19438	937
10	2808	1112	559	16770	809
11	2282	904	454	13628	657
12	1817	720	362	10852	523
13	1425	564	284	8508	410
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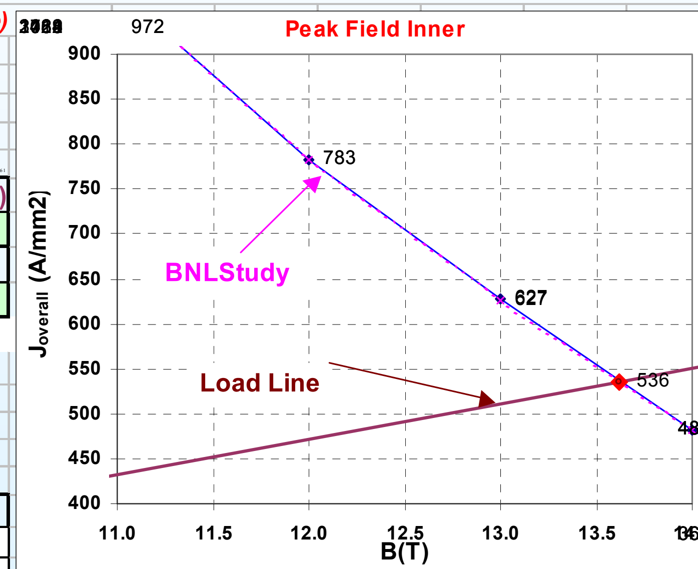
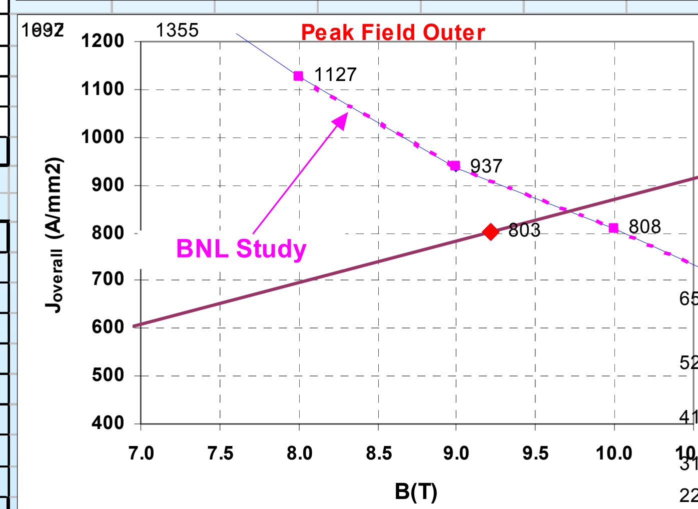
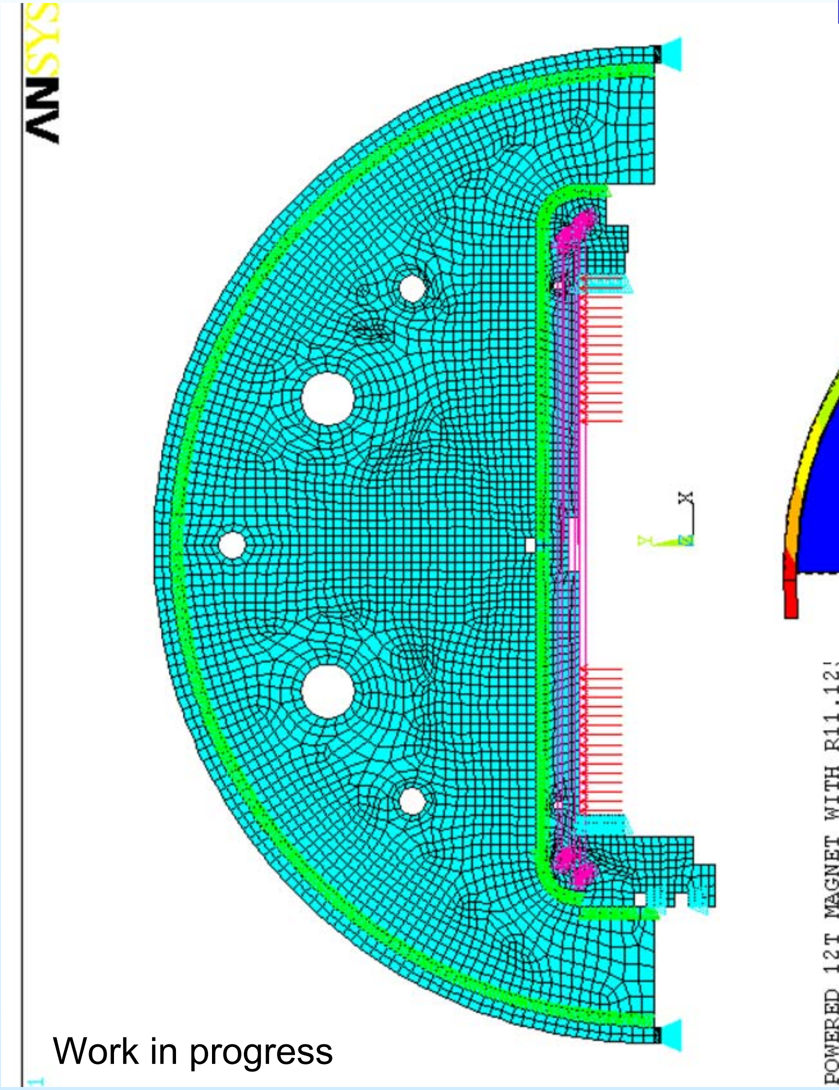
					Insulated



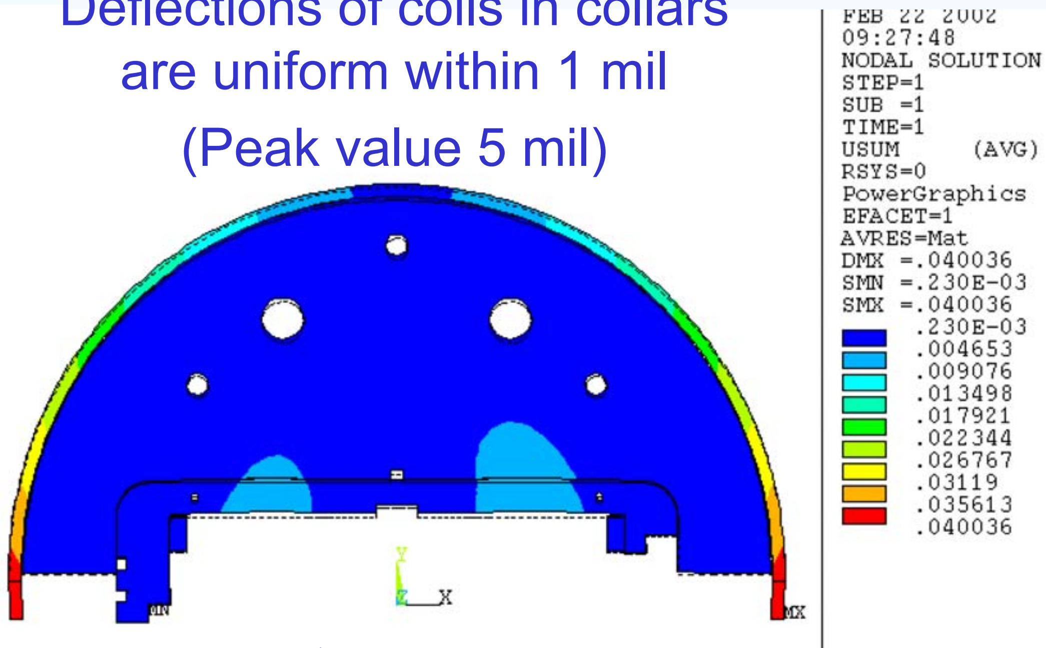


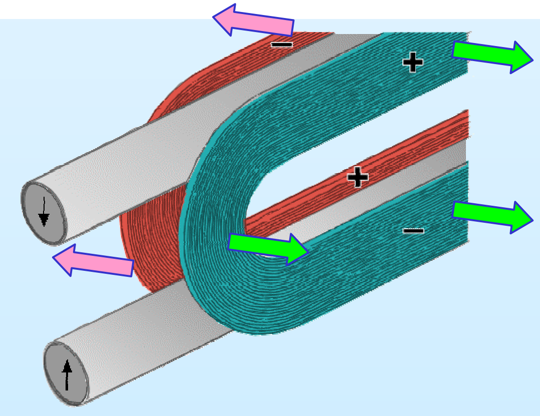
ANSYS Analysis of 12 T Magnet



Deflections of coils in collars are uniform within 1 mil

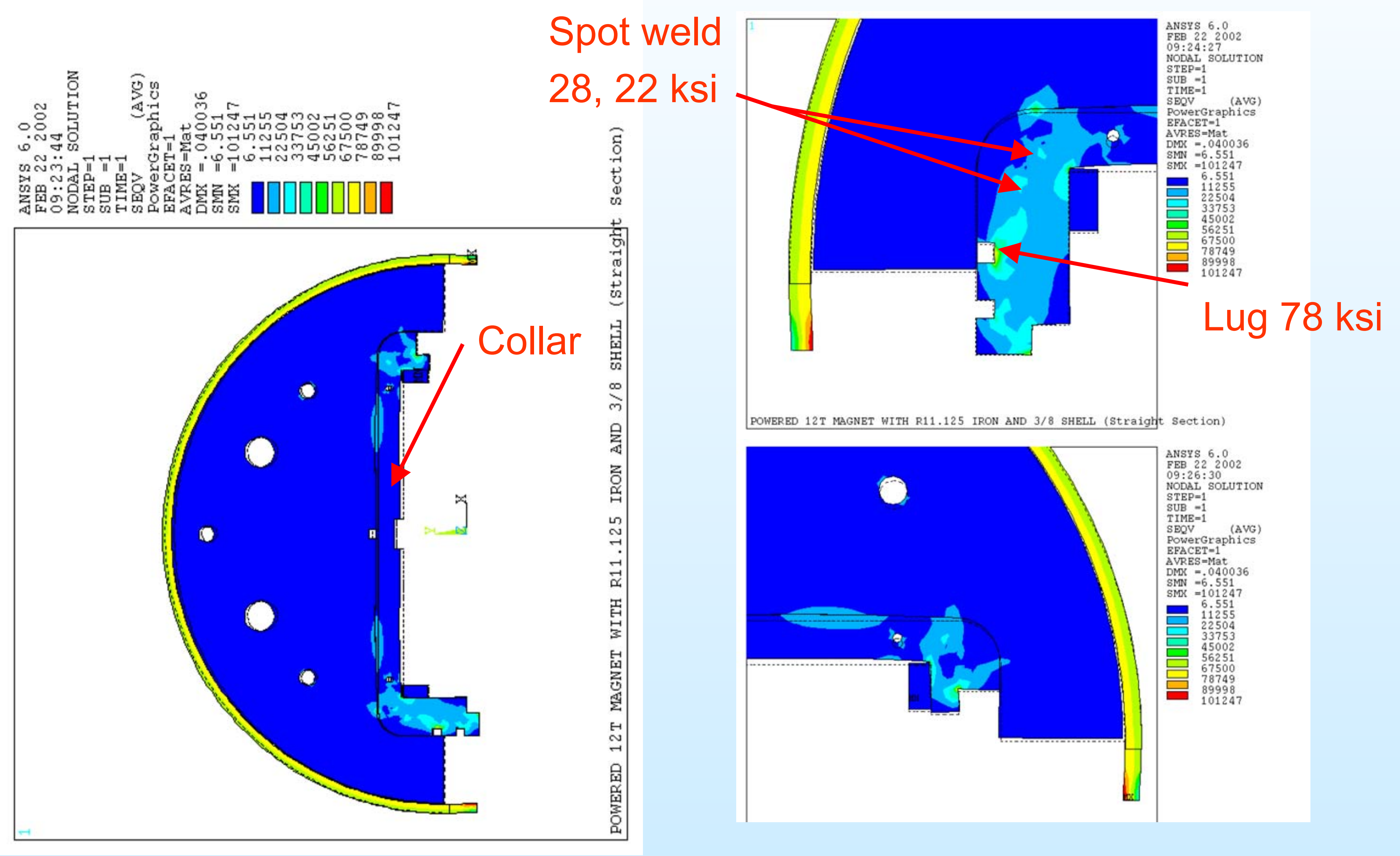
(Peak value 5 mil)



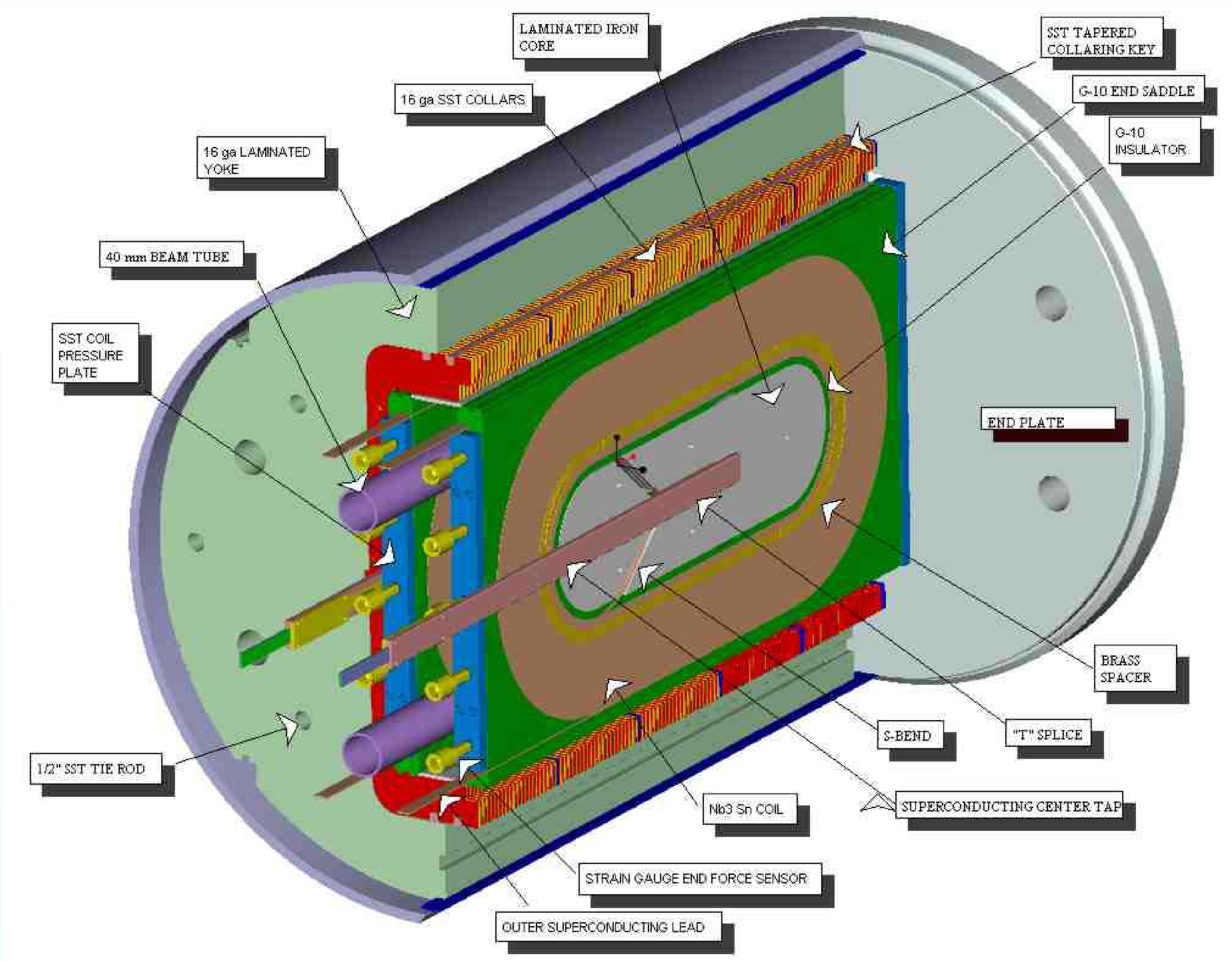


Common coil design can tolerate much larger overall coil motion as long as the relative variation is small

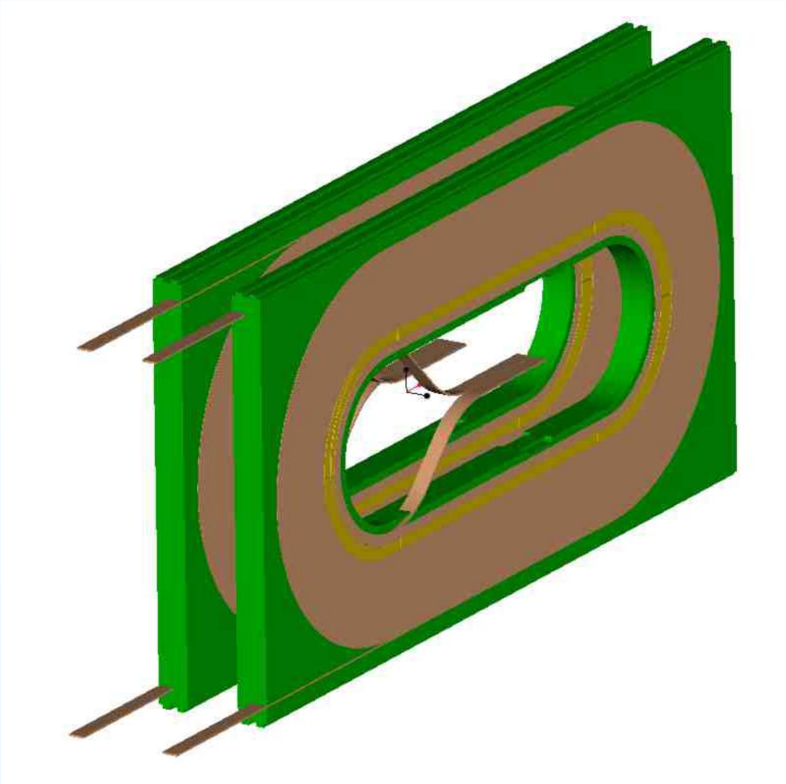
Stresses in Collar Region

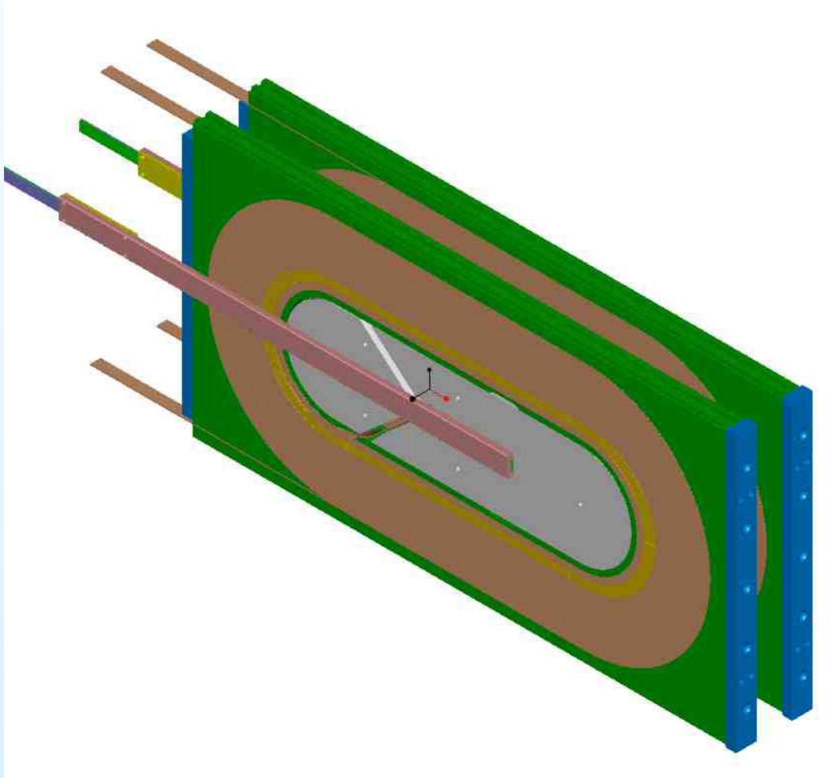


Overall Design of BNL 12 T Common Coil Background Field Dipole



Coils in BNL 12 T Background Field Nb_3Sn React & Wind Dipole





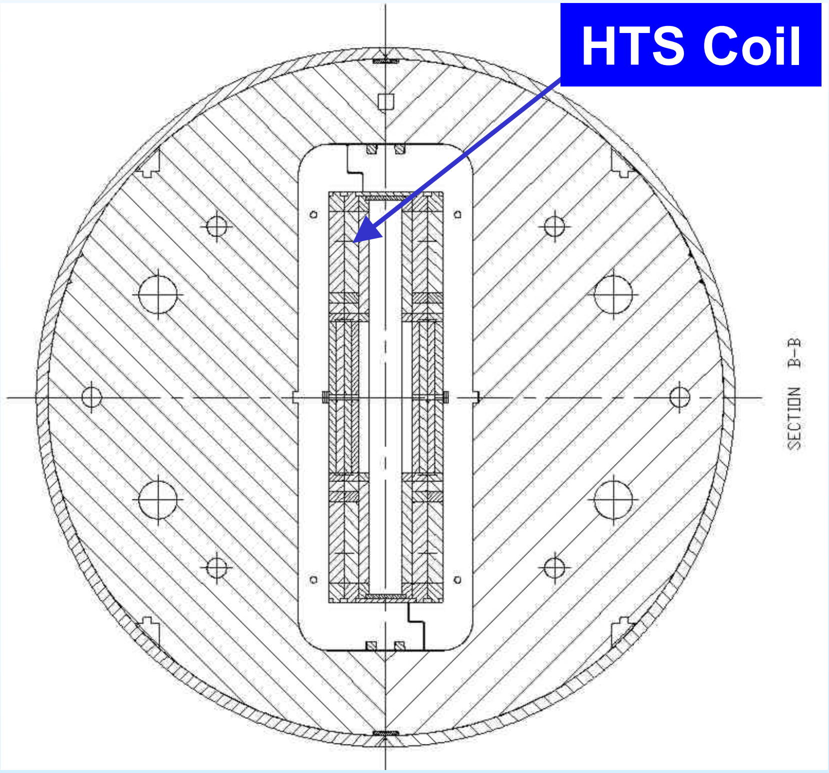
Internal splices are made in low field region (a unique feature of common coil geometry).

All four coils have the same design.

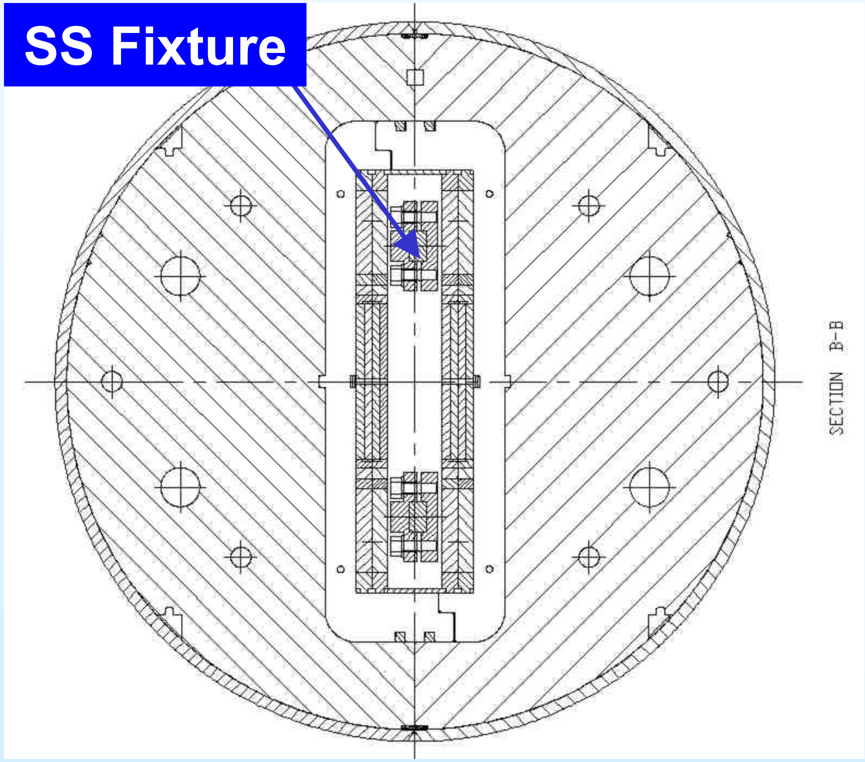
Internal lead incorporated for shunt current to run two coils on different current. Max. shunt rating 6 kA.

Insert Coil and Sample Test Scenarios

An interesting feature of the design, which will make it a truly facility magnet, is the ability to test short sample and HTS insert coils without disassembling it.

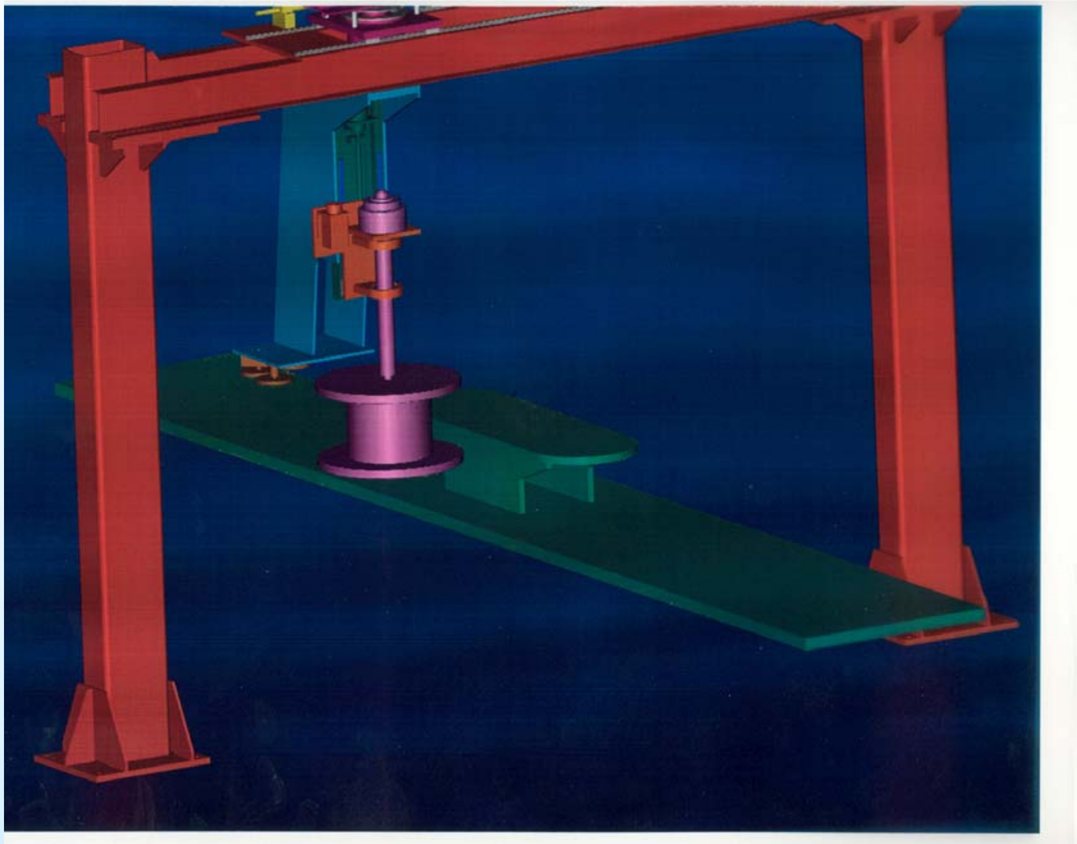


HTS insert coil test configuration



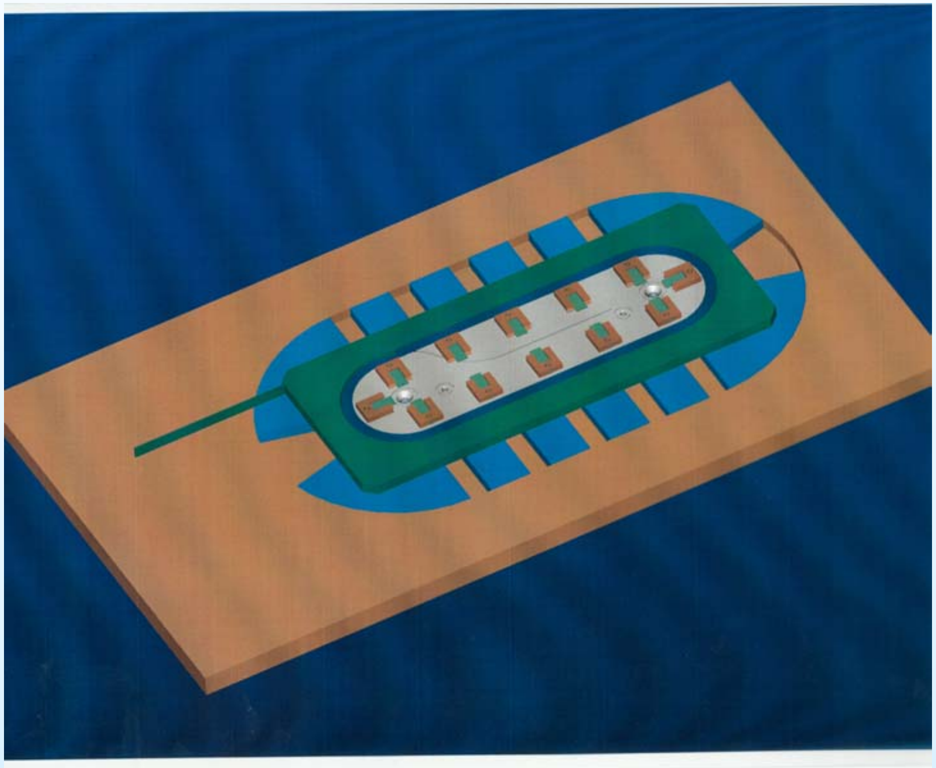
Short sample test configuration

New Versatile Coil Winder Now Under Design

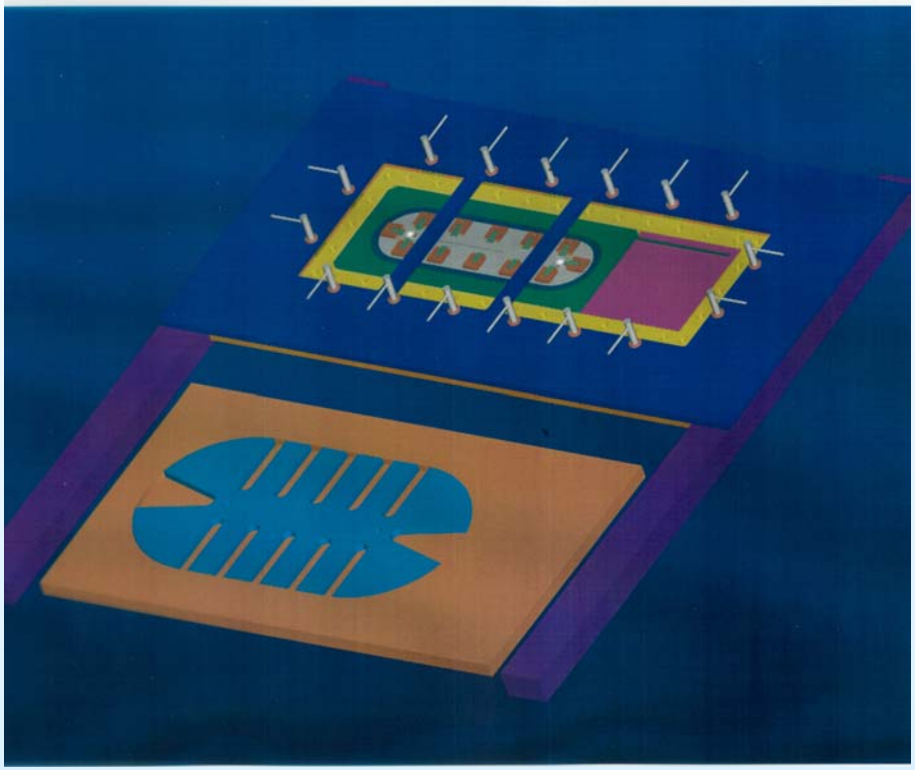


The new winder will be used in winding future HTS and Nb_3Sn coils. This versatile winder will handle brittle materials better and will wind coils having different number of turns in various geometries.

Parts of Coil Winding and Curing Fixtures

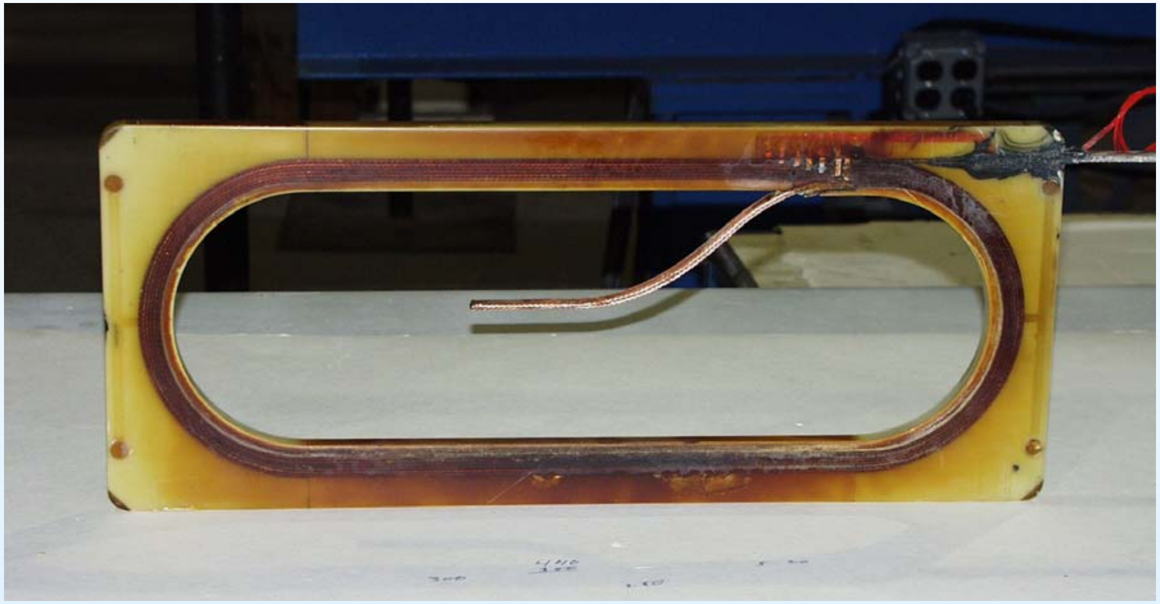


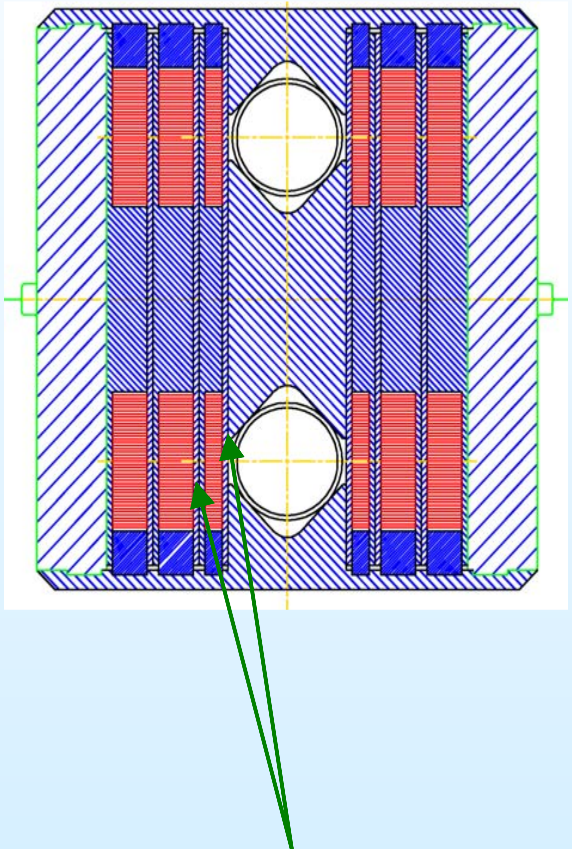
10 turn coil shown wound on tooling mandrel with g-10 fillers in place. Coil is positioned into receiving plate of curing fixture. At this stage coil windings are held in place with kevlar cord (not shown) but notice cinch clamps on tooling mandrel.



Coil shown in fixture with frame (yellow) and fully constrained for squareness and symmetry to the tooling mandrel. Camlocks hold it together as it was slid from receiving plate to heater plate. It can now be bolted to the heater plate have the camplate removed and is in position for final cure.

Bobbinless Coil With No Additional Structure

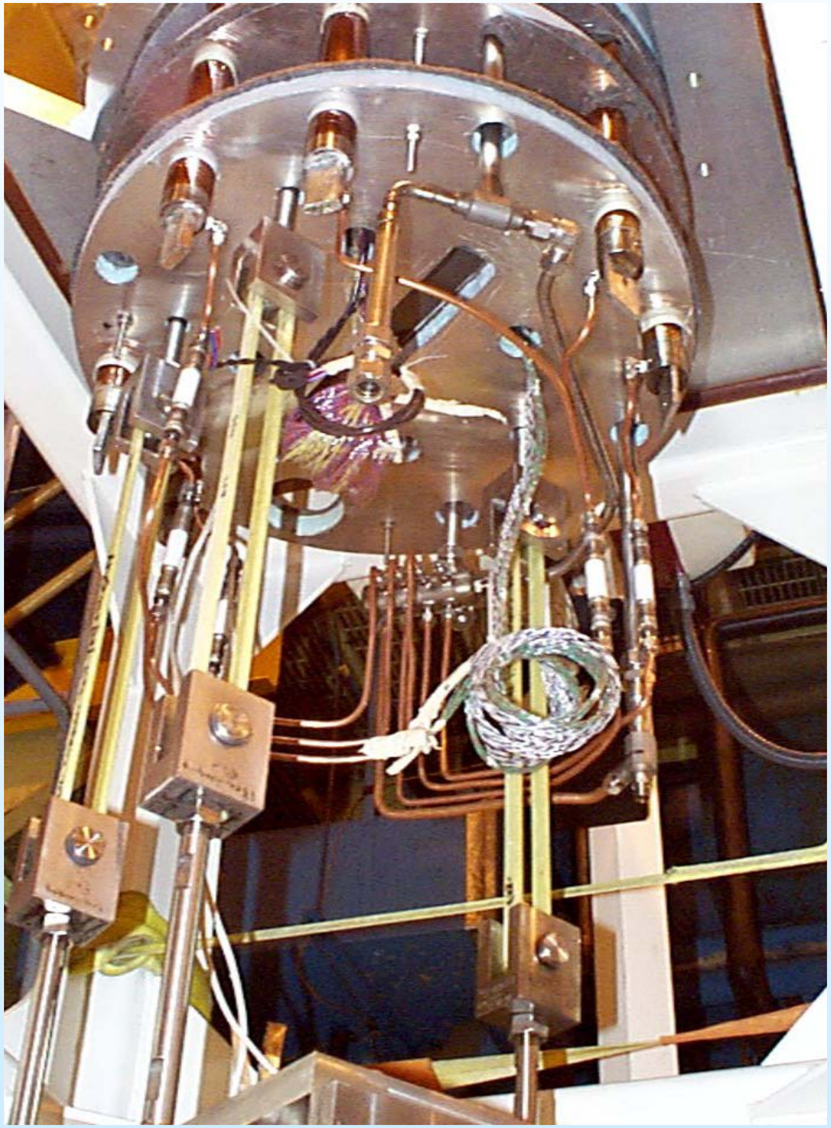




Bobbin (Island) is not suitable for long and accelerator magnet. Here the technology is demonstrated that the bobbin can be removed from the coil. Also please note that there is no additional structure on the two sides of the coil.

Minimizing valuable "Real Estate", minimizes conductor requirements.

New Top Hat and Commissioning of High Current Test Facility



IR Magnet Design Considerations

Differences between the IR magnets and main magnets:

- Only a few IR magnets as compared to a large number of main magnets.
- A few magnets may make a large difference in luminosity performance.
- The cost of material is a fraction of the overall cost of R&D and production.

These contrasts suggest that we should be open to adopting different design strategies for IR magnets as compared to what we do in main magnets.

- They can use much more expensive materials.
- They can be more complicated in construction, as we need only a few.

$\Rightarrow$ This makes a good case for HTS in IR magnets.

LHC IR Quadrupole Design

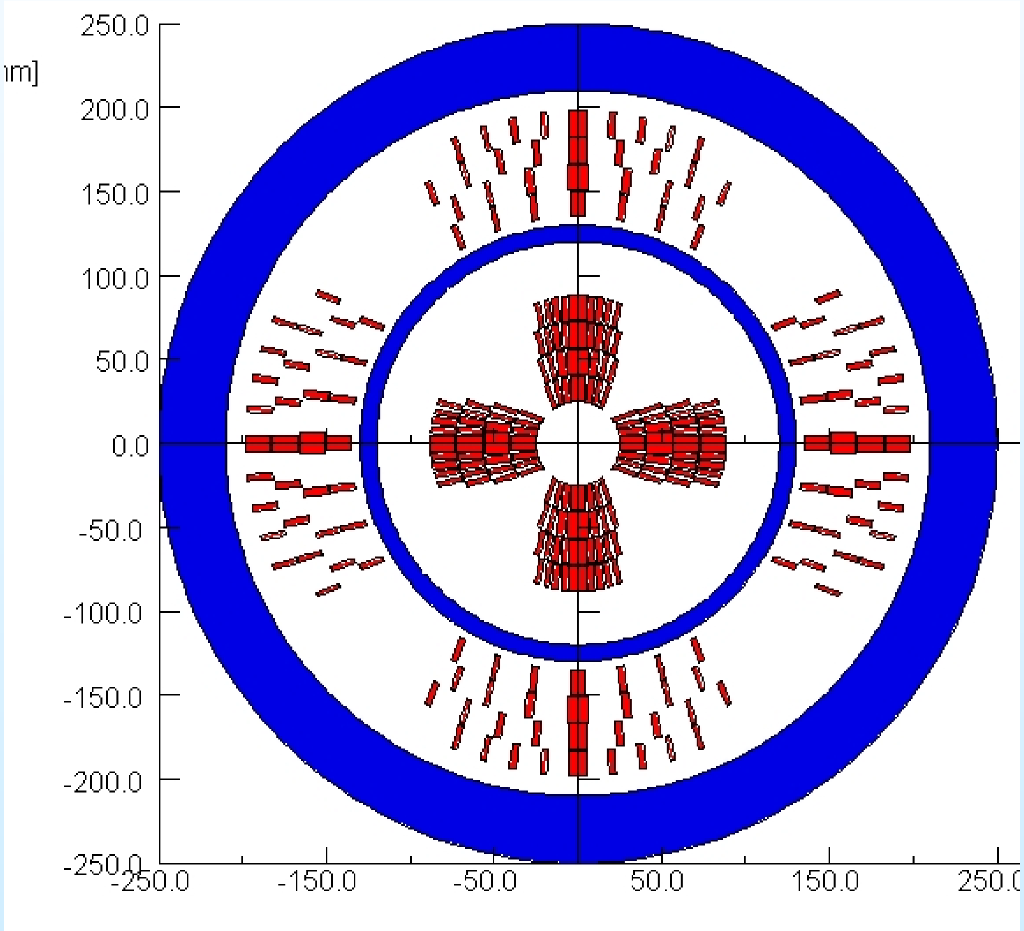
LHC Interaction Region (IR) quadrupoles are single aperture magnets.

The common coil philosophy of “large bend radii” does not work so nicely here.

At this stage we are considering several R&D design options, as one must in the beginning of such program.

An Initial Concept for HTS based Q0 Quads LHC IR Upgrade

The following design is made to allow large bend radii



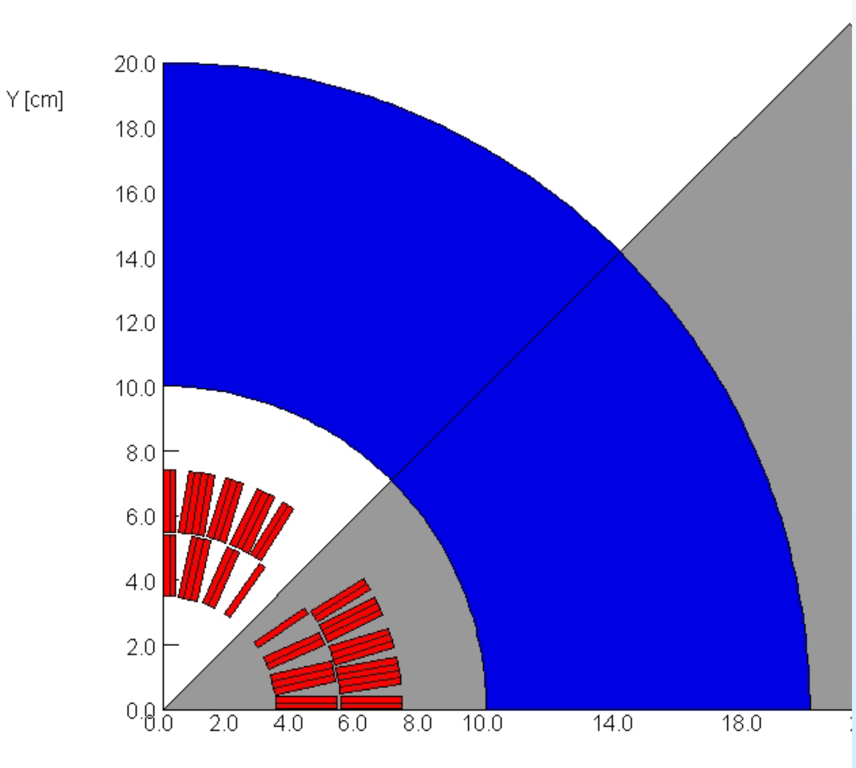
	Q0A	Q0B	
Aperture	50	70	mm
$G_{operating}$	540	320	T/m
B_{peak}	16	13	T
$P_{Luminosity}$	> 1000		W

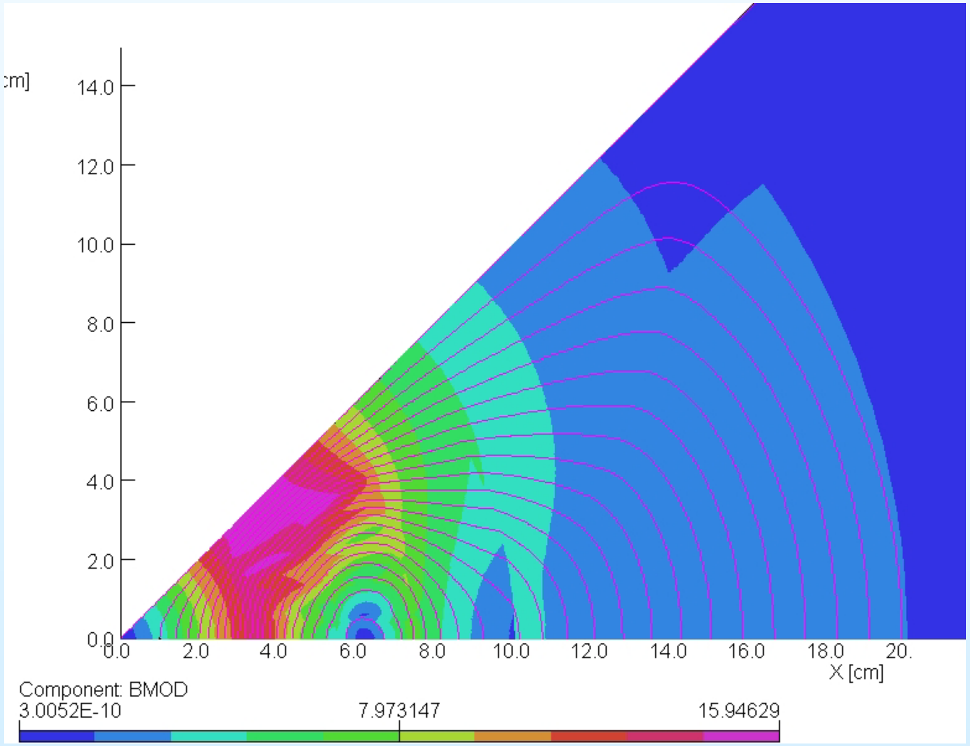
Requires a factor of 2-3 improvement in J_c over the present value.

HTS Quad for LHC IR
(70 mm Aperture, 400 T/m Gradient)

2 Layers, 20 mm X 2 mm Cable, 8 turns inner and 14 outer

Jo = 1 KA/mm^2, Jc ~ 4-5 kA/mm^2





Note: **Peak field is not a major concern in HTS quadrupole designs.**

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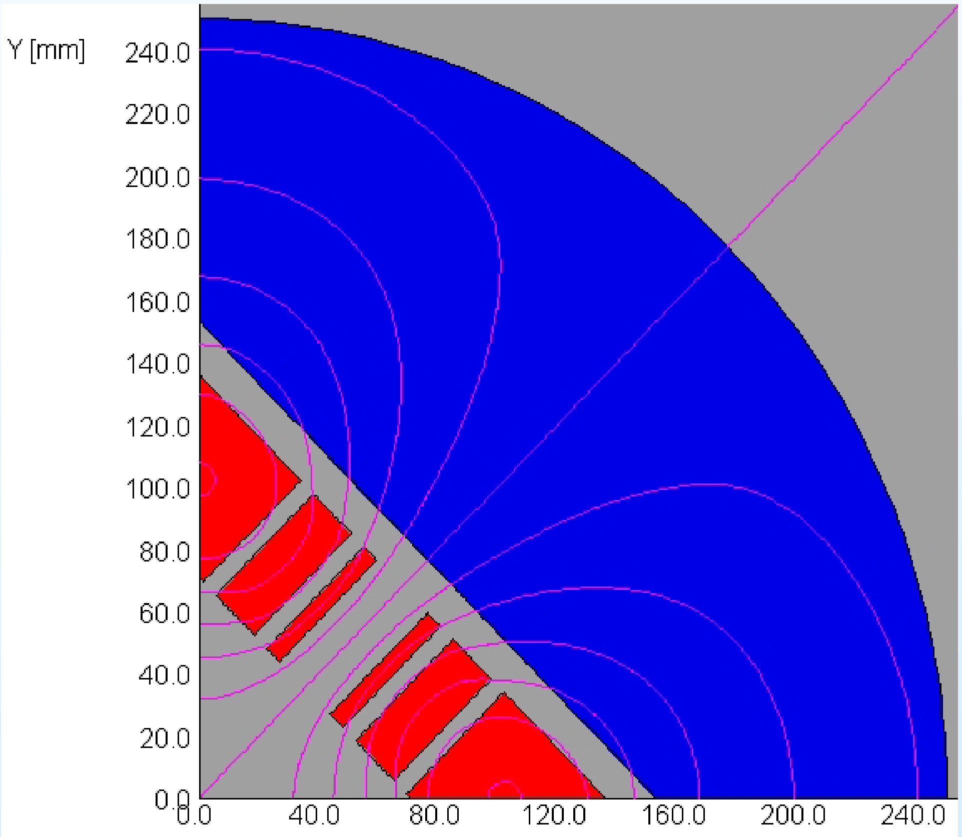
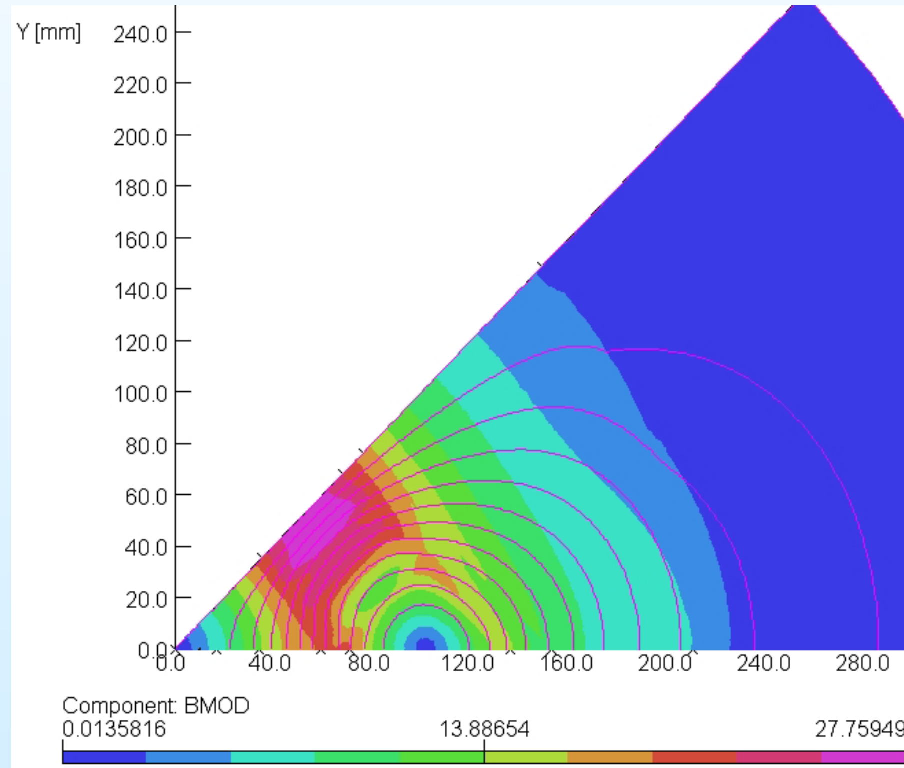
HTS Quad for LHC IR (Racetrack Coil Geometry)

Gradient: 400 T/m; Jo = 1 KA/mm^2, Jc ~ 4-5 kA/mm^2

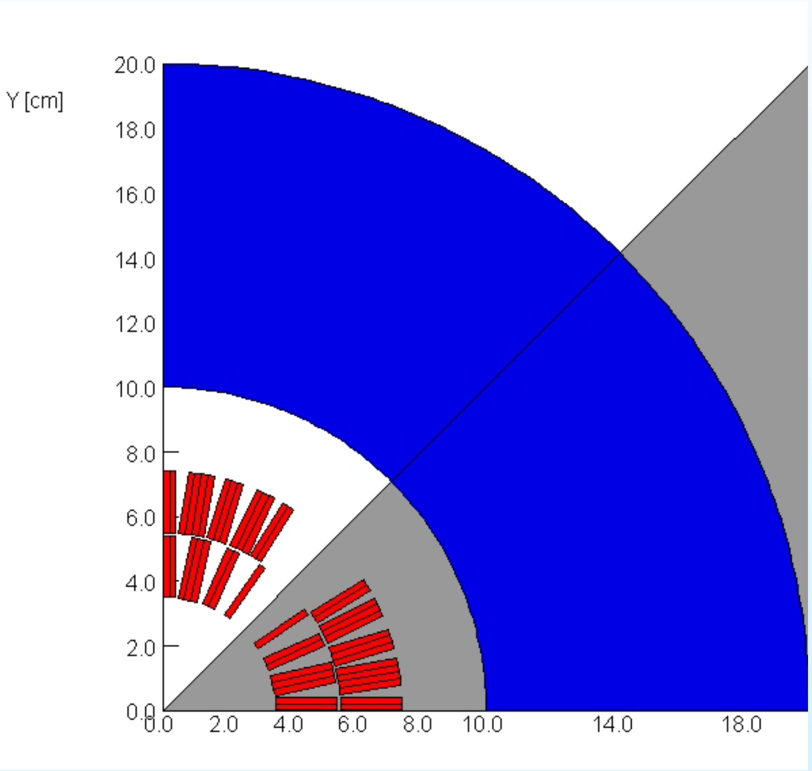




Note: Peak field is not a major concern in HTS quadrupole designs.

Magnet/ Conductor Technology Options for HTS Quads

Superconducting Magnet Division



• One option is to use "Wind and React" Approach. We are evaluating that.

We prefer "React & Wind" approach over "Wind & React" for reacting long (~5 m) magnets at ~885 C while maintaining ~0.5 C temperature control. Also "React & Wind" approach allows more options for insulation and structure materials.

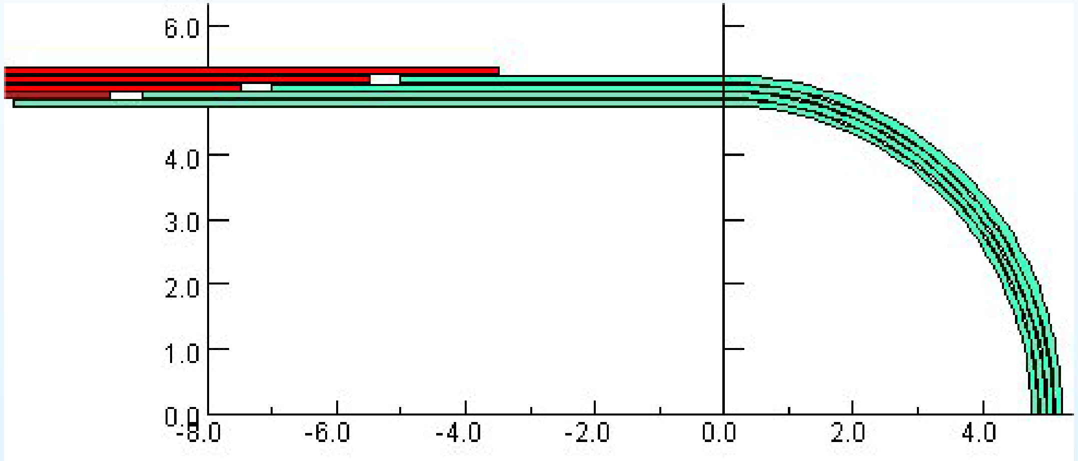
• One option under consideration under "React & Wind" approach is to evaluate possibilities of very small diameter flexible cable/wire, especially since the magnet need not ramp fast.

➢ This requires a significant conductor R&D.

Primary goal of our program is to develop HTS technology, rather than "React & Wind" or any sub technology. We would use whatever is best.

A React & Wind HTS Quadrupole Design

Pre-fabricated and pre-reacted ends spliced to straight section turns



The end turns are bent in small diameter before reaction.

➢ Requires significant R&D on splice joint technology: improve reliability and minimize contact resistance.

Note:

HTS allow much larger temperature rise for a small degradation in critical current.

This labor intensive construction should be acceptable for a few critical magnets.

Each segment could be pre-tested in LN_2.

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Superconducting Magnet Division

List of Publications at SMD Website Search with Common Coil Magnet Type

Superconducting Magnet Division Publications

Paper #	Date	Author	Title	Topic	PDF	PS
MDN-591-33	3/2000	R. Gupta	Superconducting Magnets for Future Colliders and Storage Rings	Common Coil Design		
MDN-594-33	6/2000	R. Gupta	BNL Phase II Common Coil Magnet Program	Common Coil Design		
BNL-68285	9/2000	W. Sampson, A. Ghosh, J. Cozzolino, M. Harrison, P. Wanderer	Persistent Current Effects in BSCCO Common Coil Dipoles	Common Coil Design		
BNL-68014	9/2000	R. Gupta, M. Anerella, J. Cozzolino, J. Escallier, G. Ganetis, A. Ghosh, M. Harrison, G. Morgan, J. Muratore, B. Parker, W. Sampson, P. Wanderer	Common Coil Magnet program at BNL	Common Coil Design		
MDN-595-33	9/2000	J. Escallier	Vacuum Impregnation Techniques for Common Coil Test Cassettes	Common Coil Design		
MDN-597-32	10/2000	J. Escallier, A. Jain	Temperature Rise in a Copper Wire During a High Current Pulse	Common Coil Design		
BNL-68236-AB	4/2001	A.K. Ghosh, R. Gupta, W.B. Sampson	Batch Testing of BSCCO 2212 Cable in Subcooled Liquid Nitrogen	Cable Manufacturing and Magnetization, Industrial Manufacture		
BNL-68270-AB	5/2001	R. Gupta	Common Coil Design for Various Applications	Coil Geometry Analysis, Coil Manufacturing Development, Common Coil Design		
BNL-68262-AB	5/2001	R. Gupta, M. Anerella, J. Cozzolino, J. Escallier, G. Ganetis, A. Ghosh, M. Harrison, A. Marone, J. Muratore, B. Parker, W. Sampson and P. Wanderer	R&D for Accelerator Magnets with React & Wind High Temperature Superconductors	Coil Geometry Analysis, Common Coil Design		
BNL-68445-AB	7/2001	J. Escallier, M. Anerella, J. Cozzolino, G. Ganetis, A. Ghosh, R. Gupta, M. Harrison, J. Muratore, B. Parker, W. Sampson, P. Wanderer	Technology Development for React and Wind Common Coil Magnets	Common Coil Design		
BNL-68591	8/2001	Ghosh, R. Gupta, M. Harrison, A. Marone, J. Muratore, B. Parker, W. Sampson, P. Wanderer	Technology Development for React and Wind Common Coil Magnets	Development, Common Coil Design		
MDN-617-33	2/2002	J.Escallier	Assembly Techniques for Common Coil Magnet Cassettes	Common Coil Design		
MDN-616-33	2/2002	J. Escallier	Vacuum Impregnation of Short Sample HTS and Niobium Tin Superconductors	Common Coil Design		
MDN-615-33	2/2002	J. Escallier	Testing HTS Common Coils at Intermediate Temperatures	Common Coil Design		
MDN-614-33	2/2002	R. Gupta	The HTS Magnet R&D Program at BNL	Common Coil Design		

Near Term R&D Program at BNL

- Continue to build a series of 10 turn coils with better HTS cable.
- Build ~30 turn HTS coil from the material ordered.
- In parallel, build ~12 T magnet with Nb_3Sn to provide background field.
- Assemble hybrid magnet to study issues related to the performance of HTS coils in high field, high stress environment.
- Examine various design options for IR quads. Test small coils with splices and carry out similar R&D.

Present the results of this R&D to accelerator community so it can make a more informed decision about the viability of HTS.

SUMMARY

- **HTS has potential to make a significant impact on IR Design**
  - Can generate high fields
  - Can work at elevated temperature
  - Can simplify cryogenic system

- **HTS has reached a level that a meaningful magnet R&D can now be carried out**

  - 12 T magnet will address several basic technical issues related to HTS coils in high field, high stress environment.

- **Time to start HTS magnet R&D is now so that we can make a better informed decision in ~5 years on the feasibility of HTS based magnets in next project or in LHC IR upgrade.**