2007.6.8

超伝導低温工学センター ・ セミナー
H19年度　基礎開発報告会

A15超伝導コイルの基礎開発

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目的

❑現在KEKで開発中のNb3Al線材を用いてマグネットを試作する

＊Nb3Alケーブル → 少し時間が必要
＊コイル製作技術 → ‘07.7月〜‘08.6月 @LBNL

1. 小型のNb3Snマグネットを製作
   - ❑ 磁石治具・手順など、組み立て技術の習得
     - ❑ LBNLで製作されたレーストラックコイルを用いる
     - ❑ コイル以外の部品を製作、磁石組立を行なう
     - ❑ 基本的構造はLBNLのもの
       - ❑ ブラダー(Bladder), Alシェル etc

LARP: Magnet Program Goals

Provide options for future upgrades of the LHC Interaction Regions

- **Demonstrate by 2009 that Nb_3Sn magnets are a viable choice for an LHC IR upgrade**
  - **Focus on major issues: consistency, bore/gradient (field) and length**

1. **Predictable and reproducible performance**

   TQ models (1 m, 90 mm aperture, G_{nom} > 200 T/m, B_{coil} > 12 T)

2. **Long magnet fabrication**

   LQ models (4 m, 90 mm aperture, G_{nom} > 200 T/m, B_{coil} > 12 T)

3. **High gradient** in **large aperture**

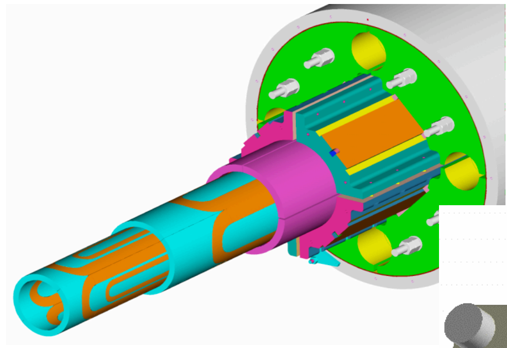
   HQ models (1 m, 90+ mm aperture, G_{nom} > 250 T/m, B_{coil} > 15 T)

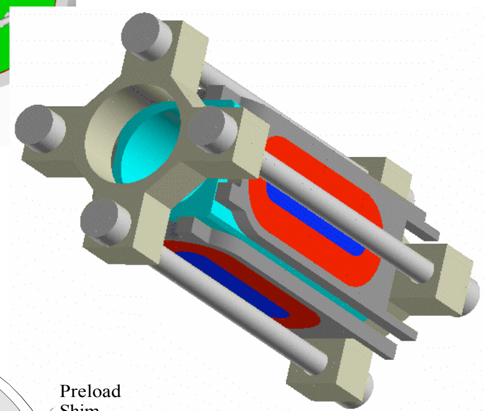
Target Program

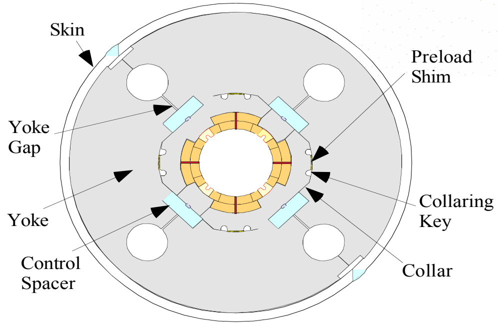
	Length [m]	Aperture [mm]	FY05	FY06	FY07	FY08	FY09
Model Magnets							
Quads							
High Gradient (costheta)	1	90		X X	X	X	
Large Aperture Quad	1	~120			X	X X	X
Field Quality	2						X X
Long Length, High Gradient	4						X
Dipoles							
Open Mid-Plane PoP	1					X	X
Supporting R&D							
Sub-Scale Tests			X X	X X	X X	X X X	X X
Long Coil Tests					X	X X	

Goal #1 Predictable and Reproducible Performance

- Sub-scale Quadrupoles (SQ)
  - Conductor evaluation
  - Analysis validation
- Technology Quadrupoles (TQ)
  - 90 mm aperture
  - Gradient > 200 T/m
  - Explore alternate structures using “identical” conductor
  - Basis for scale-up

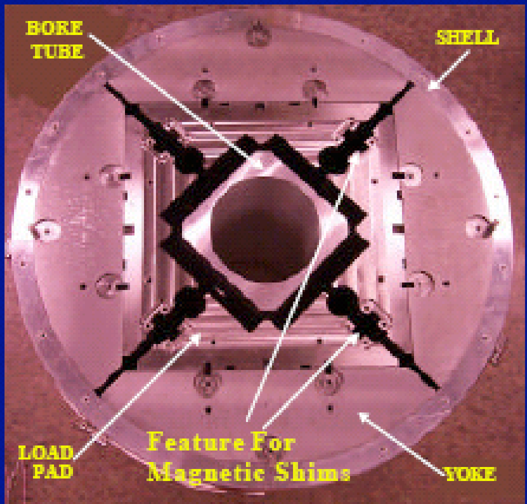






SQ-01 Fabrication and Test

Magnet components

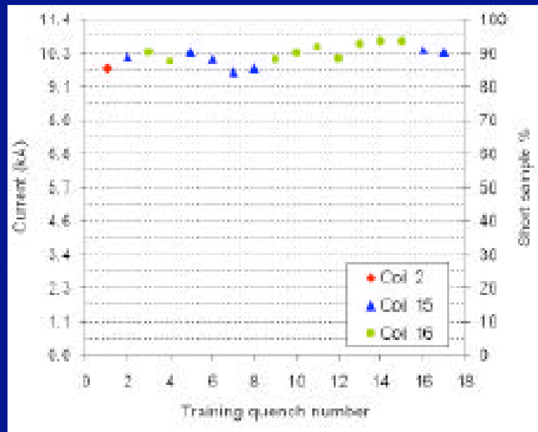


SM Quadrupole

- **6061-T6 Aluminum Shell**
- **1018 Steel Yokes**
- **316 Stainless Steel Load Pads**
- **6061-T6 Bore Tube**
- **Feature for Magnetic Shims in Load Pads**

10/19/2004 Superconducting Magnet Group Scott Bartlett

Quench performance



- 4 low LHe quenches
- 17 training quenches
  - First: 85 % I_{ss}
  - Peak: 93 % I_{ss}
- All quenches but one in SC15 and SC16
- All training quenches triggered by conductor motion

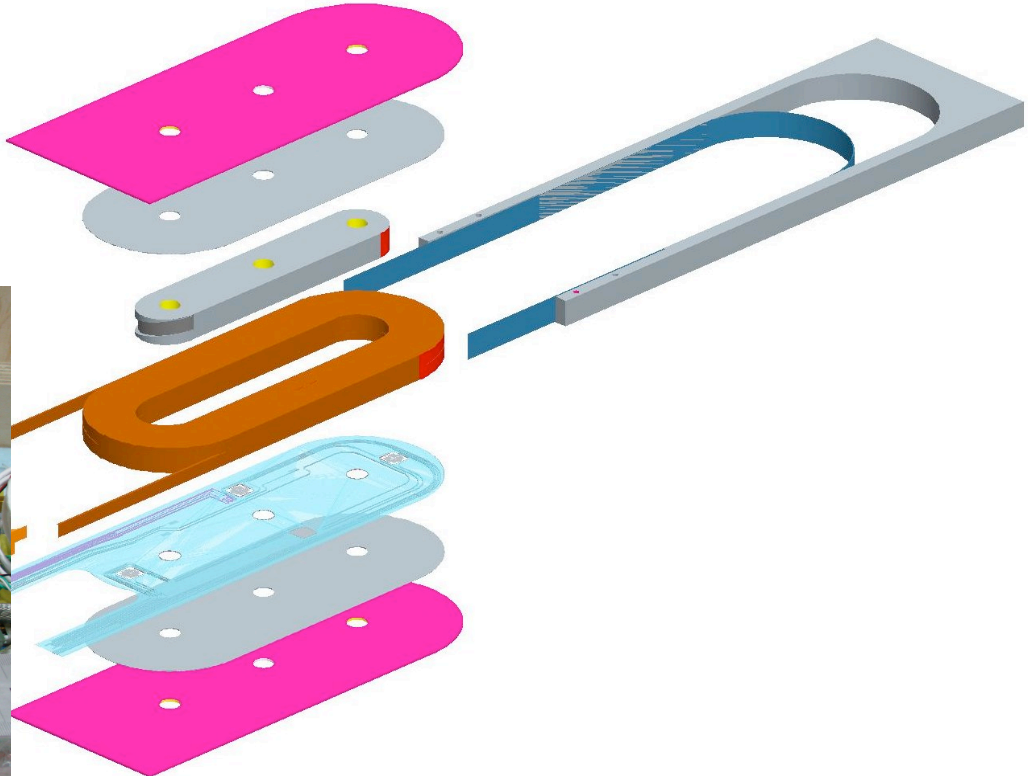
10/19/2004 Superconducting Magnet Group Paolo Ferracin

Retested at Fermilab this year

Improved preload
2.2 K

4. Use coil boundary surfaces to define structural component profiles

COIL MODULE



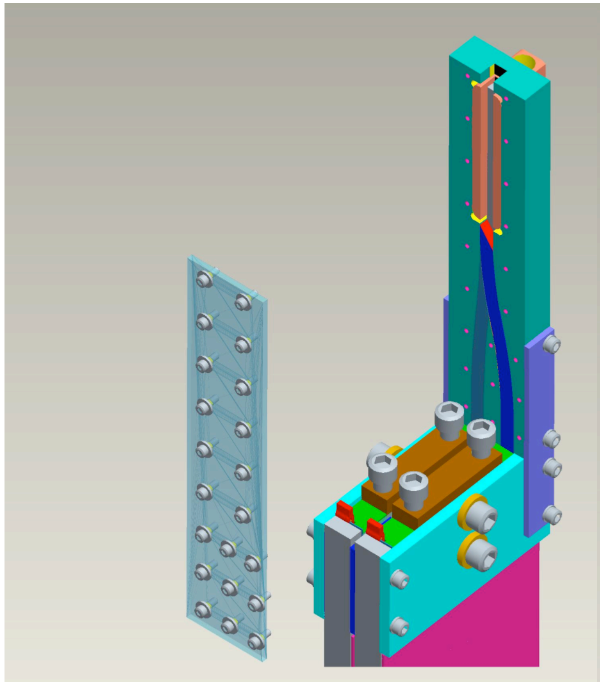
Parameters of SC

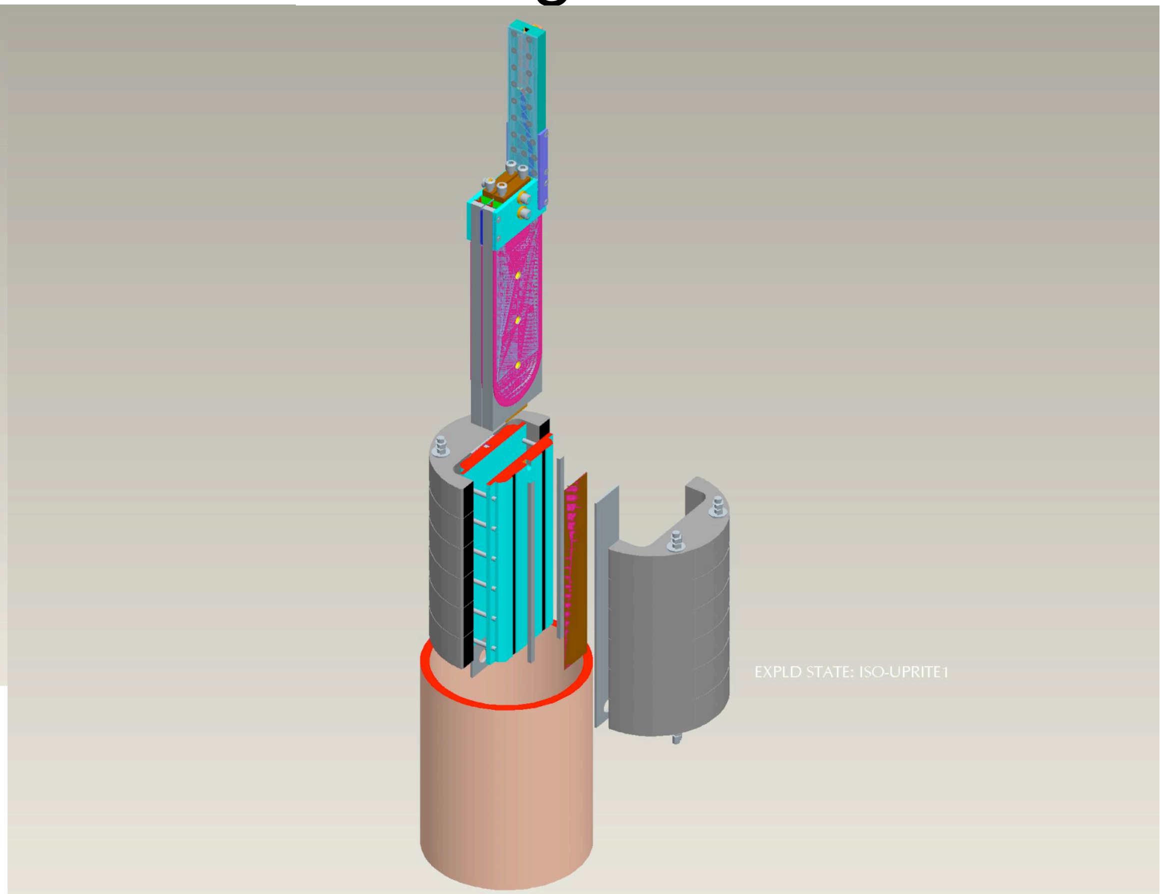
Strand		
	Diameter	0.7 mm
	Rapport cuivre sur non cuivre Cu ratio (Cu ratio?)	0.8
	RRR	37
	Jc	2200 A/mm^2 @ 11.882 T
Cable	Number of Strand	20
	Cable width	7.793 mm
	Cable thickness	1.275 mm
	Insulation thickness	0.1 mm / face
	Critical Current	9871 A @11.882 T
	Twist pitch	54.88 mm

Coil		
	Layer	2
	Number of turns / layer	20
	Pole width	37.2 mm
	Straight section length	152.4 mm
	Coil length	304.8 mm
	Coil thickness	16 mm

SUBSCALE MAGNET

Common Coil Configuration

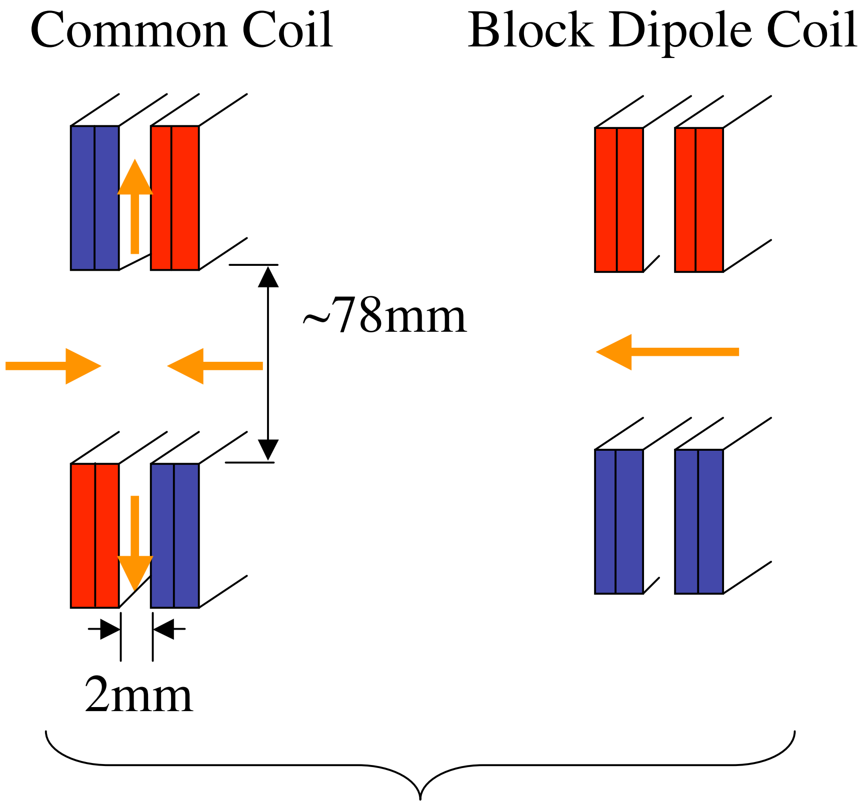




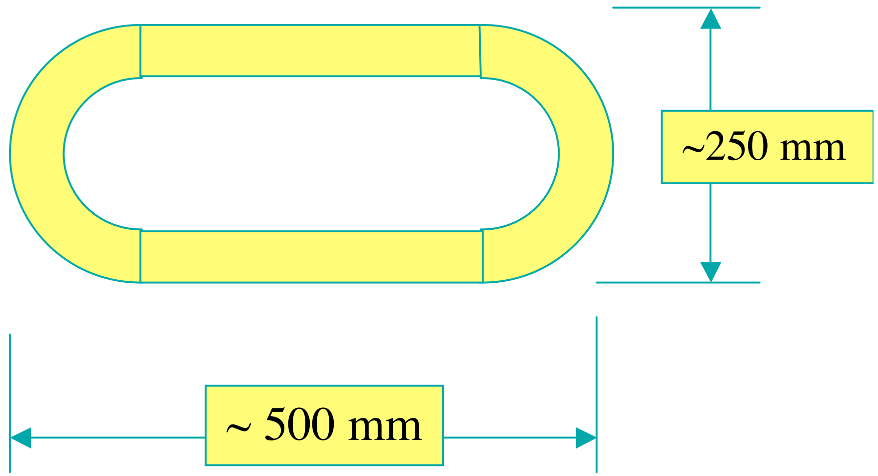
Nb3Al subscale model magnet

- Which is better for R&D?
  - Common coil structure or Block dipole structure

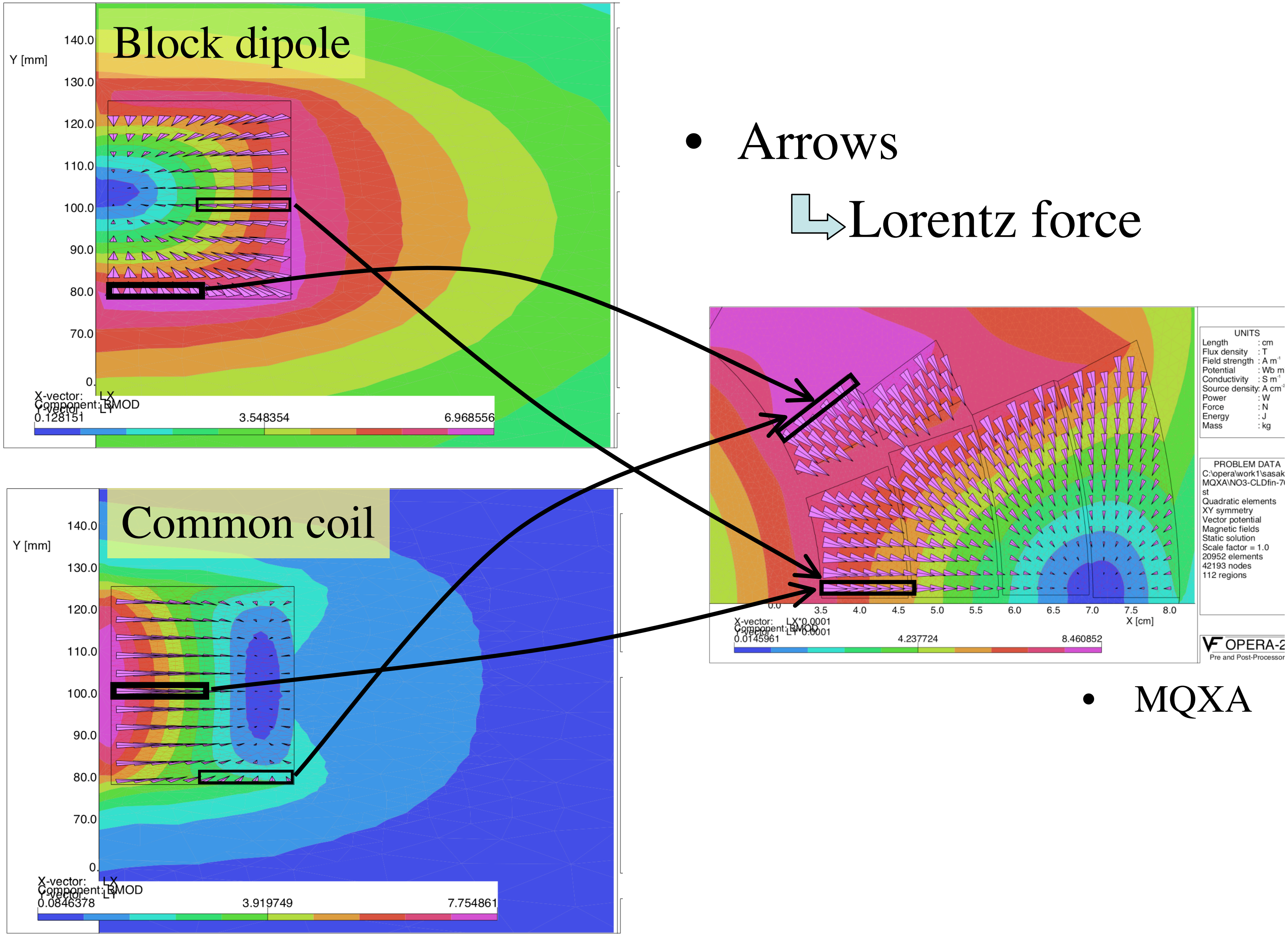
Compare profile of Lorentz force with a simple 2D model



•Same coil size



- 2 layer
- 35 turn / layer
- Cable size : 1.25 x 7.3 mm
  (1.35 x 7.4 mm with insulation)
- Cable Current : 5265 A
- No Iron yoke

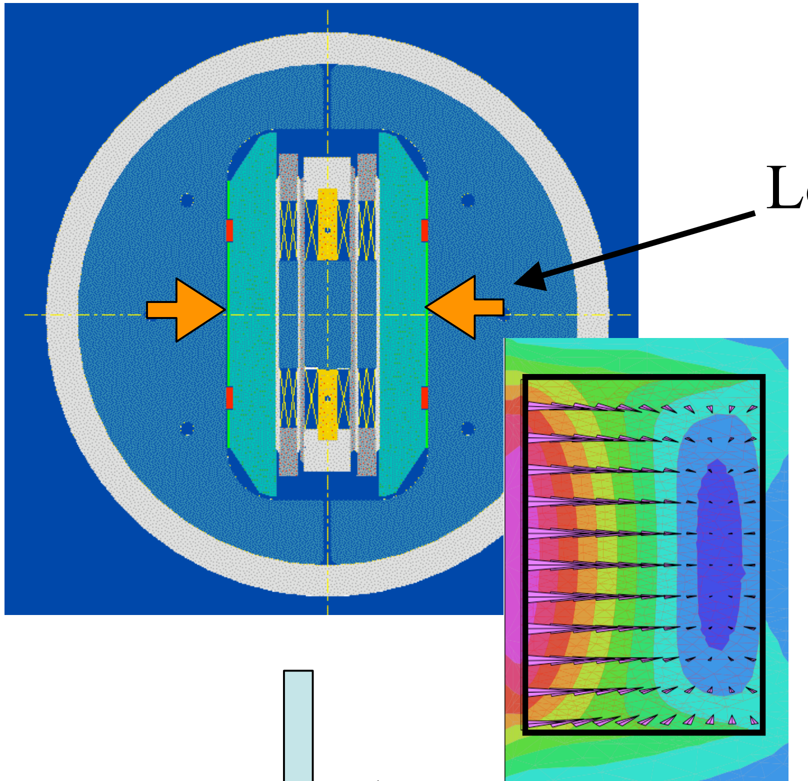


- Arrows
  - ↳Lorentz force

- MQXA

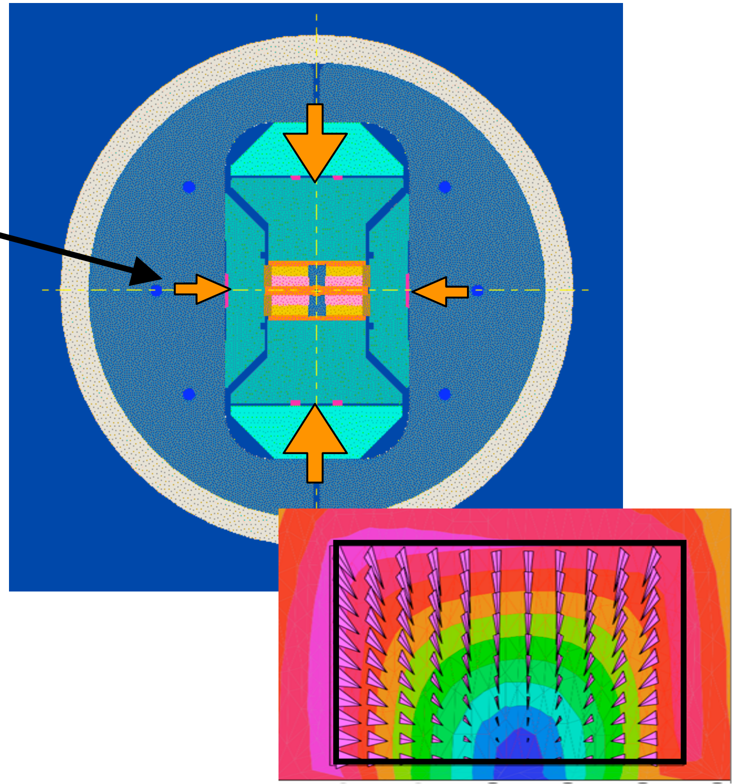
MAGNET CONFIGURATIONS:
COMMON-COIL (RD3B) vs. BLOCK DIPOLE (HD1)
Loading Comparison

RD3B Common Coil Magnet



Loading

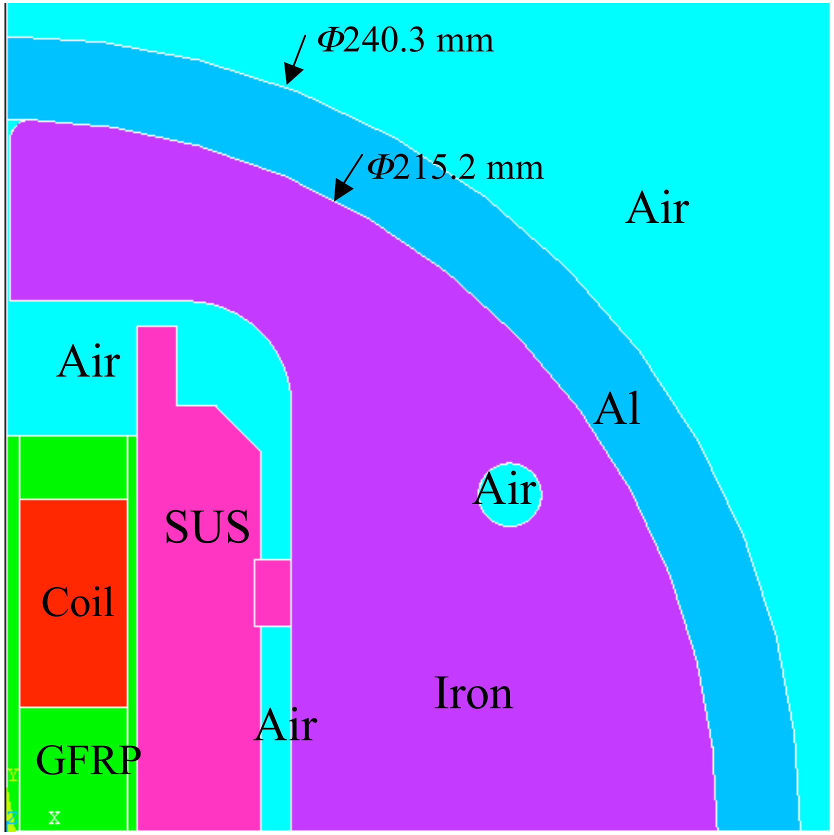
HD1 Block-Dipole Magnet



Loading structure is simple

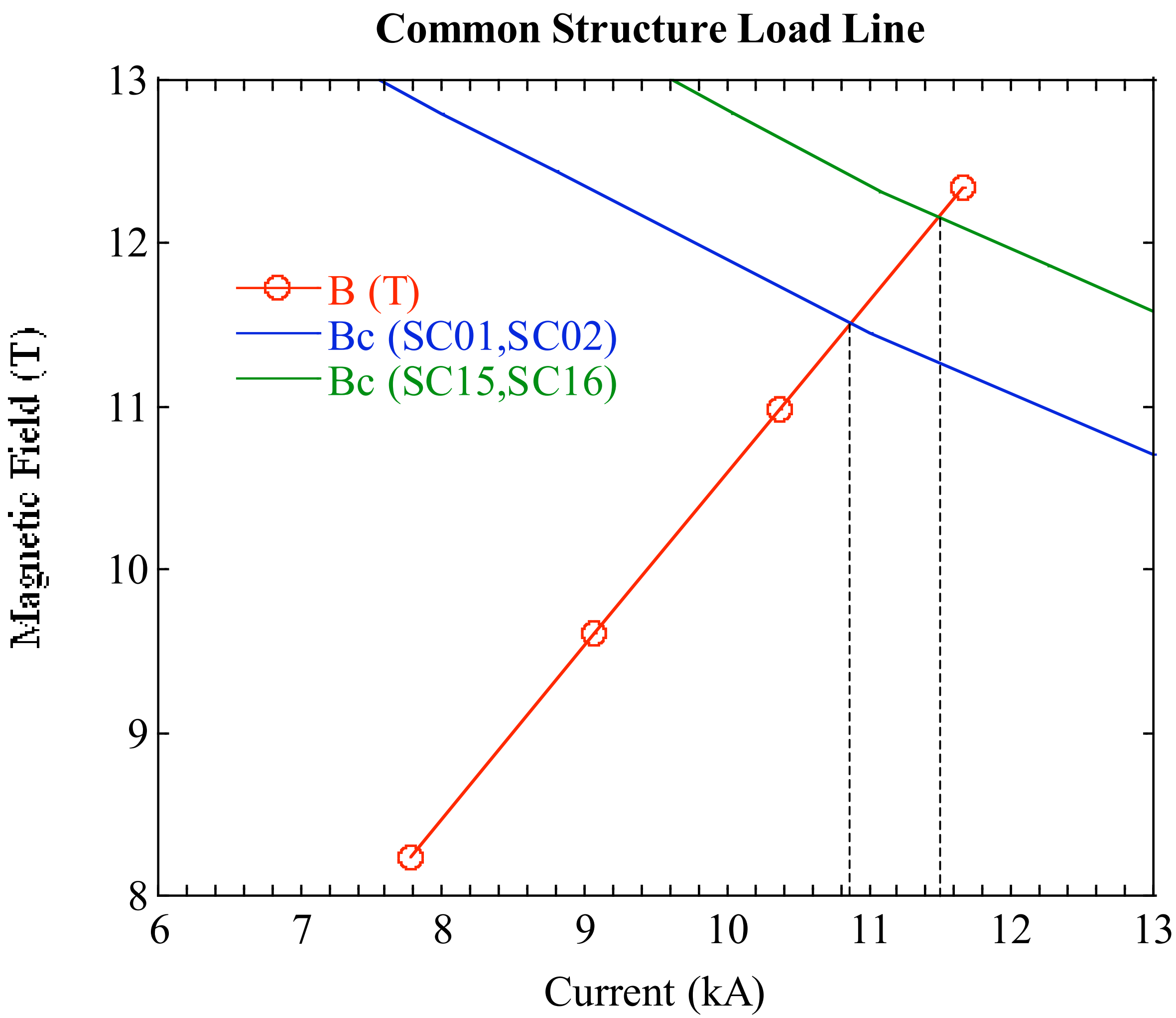
Common structure is better as a first model magnet fabricated by KEK

2D Model ~ANSYS

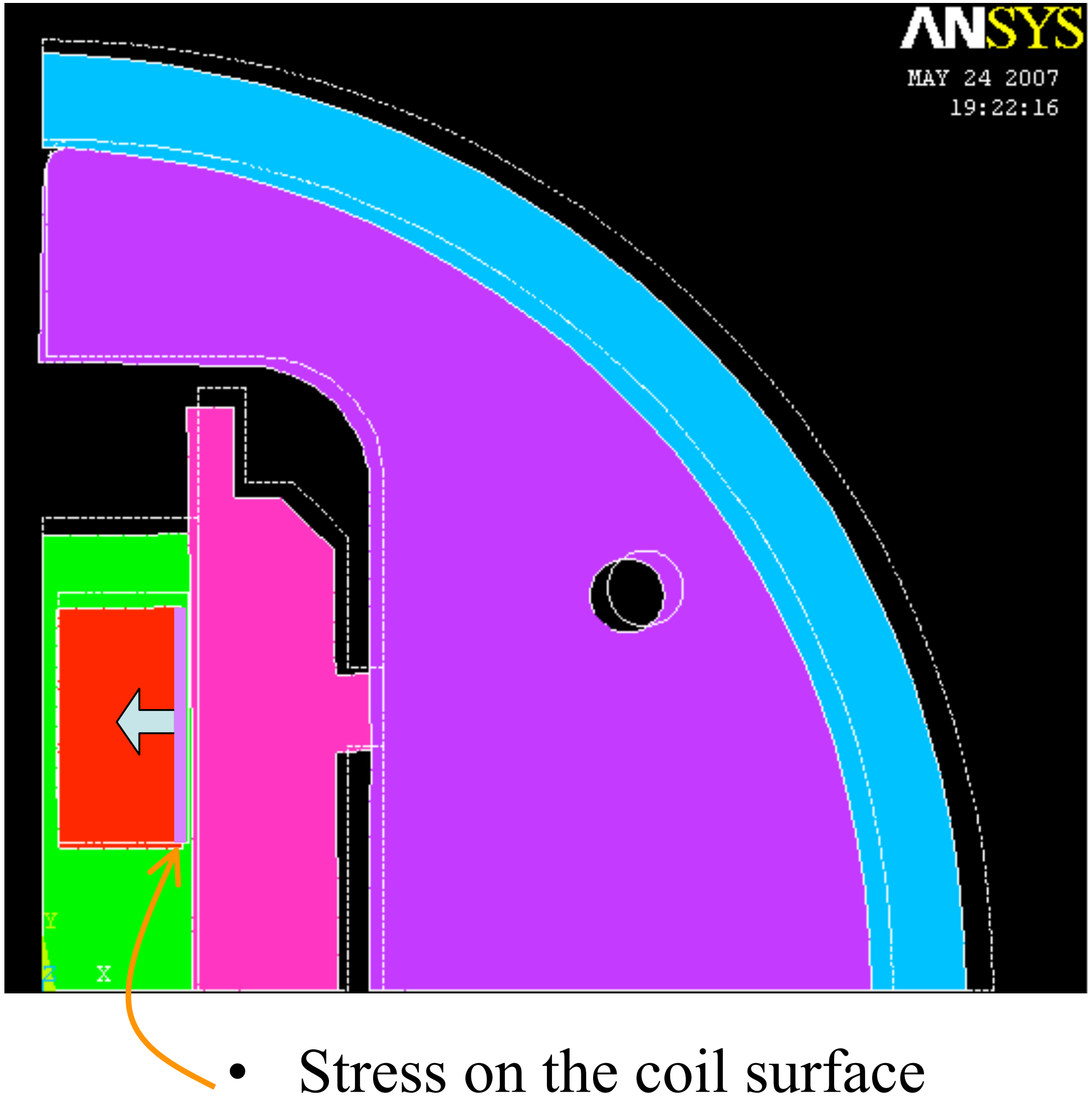


- Cable
  - No. of Strand : 20
  - Ic:
    - 9871 A @ 11.9 T (SC01, SC02)
    - 12280 A @ 11.9 T (SC15, SC16)
- Coil
  - 2 layer
  - 20 turn / layer
  - 16.4 mm x 31.6 mm

Load Line (2D model)



Thermal Contraction

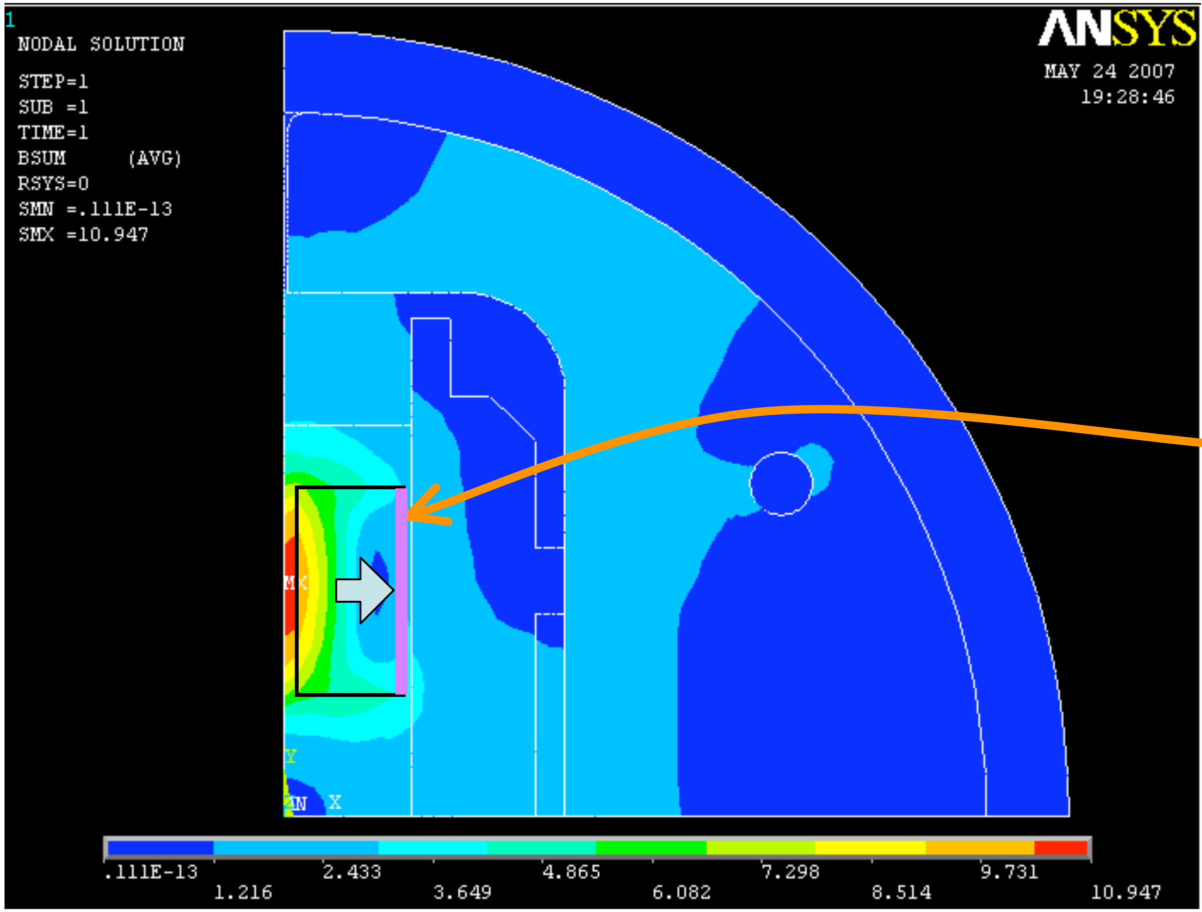


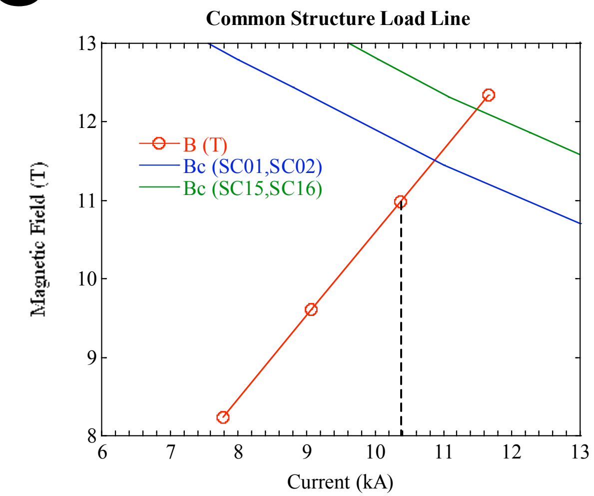
273 K → 4 K

Material	E (GPa)	Poisson's Ratio	Coefficient of Thermal Exp. (%)
Iron	210	0.3	0.15
SUS	210	0.3	0.3
Al	70	0.3	0.41
GFRP	22	0.15	0.4
Coil	42	0.3	0.39

- Stress on the coil surface = ~15.9 MPa

Lorentz force





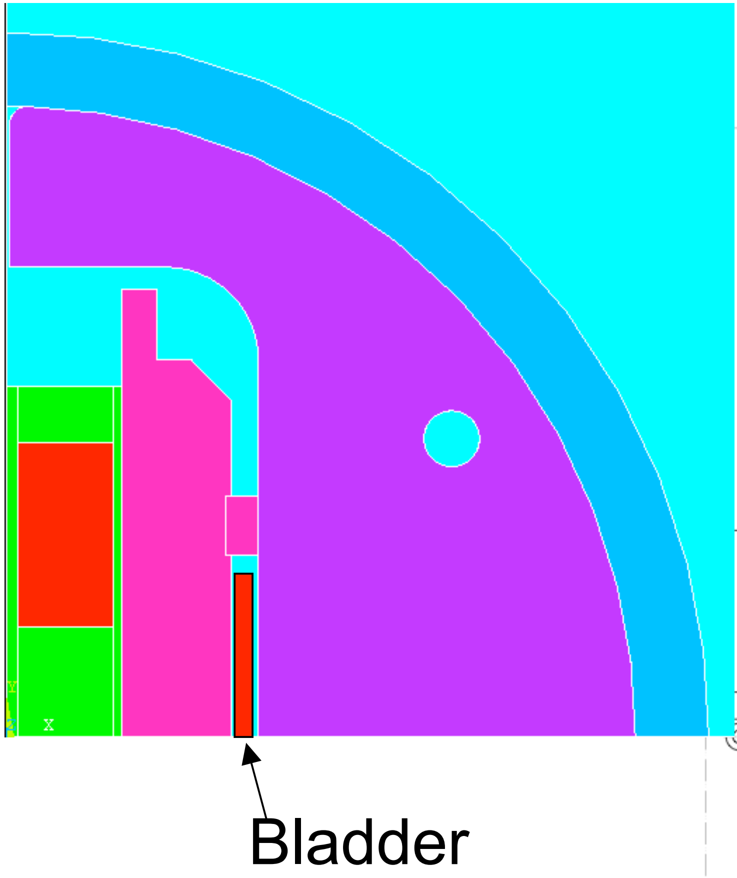
- Stress on the coil surface = ~39.8 MPa

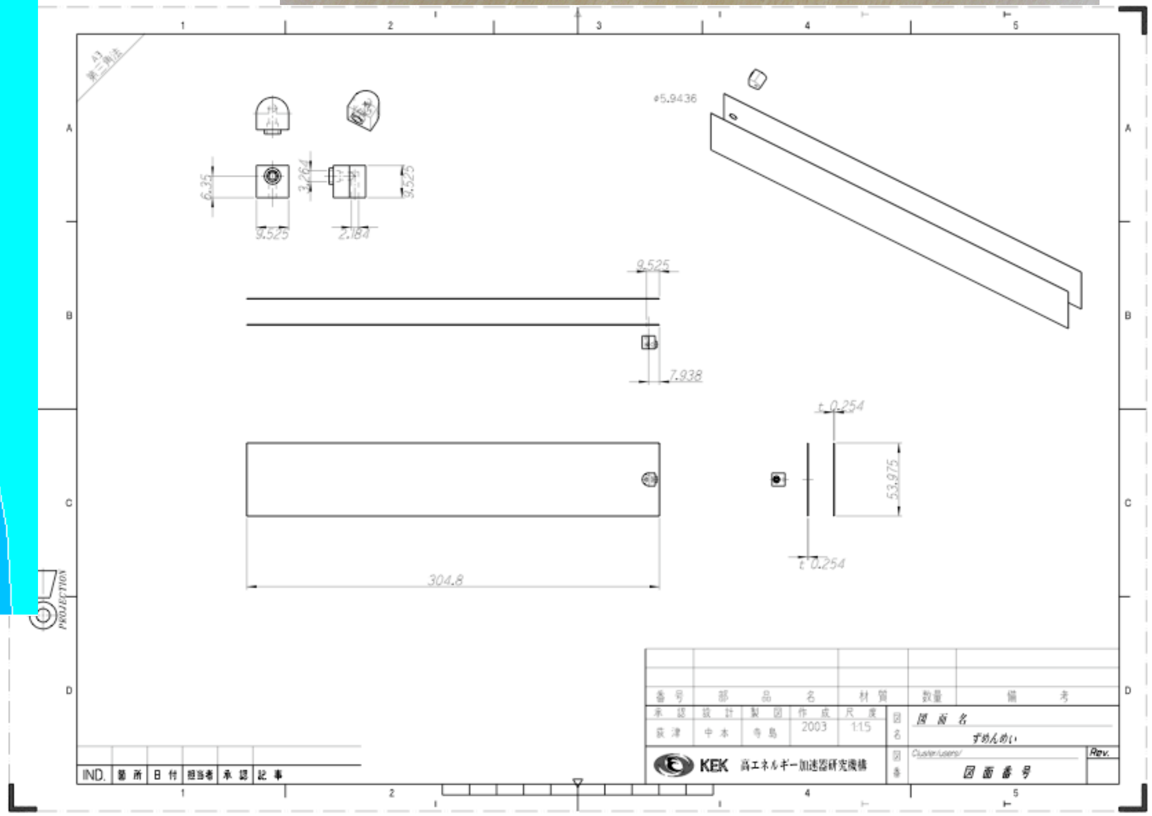
@10.4 kA

- *Pre-Stress* = 39.8 - 15.9 = 23.9 MPa

Bladder

- First, a bladder will be made and tested before visiting LBNL.





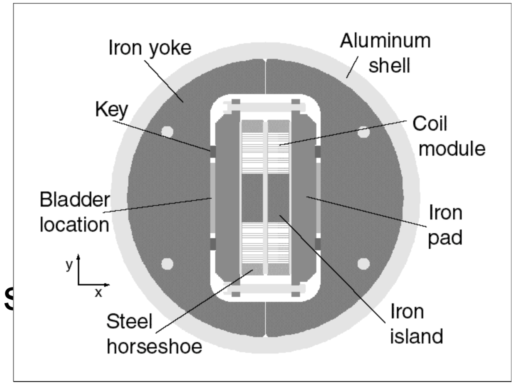
まとめ

- Nb3Alマグネットの開発を目指して、まずはNb3Sn小型マグネットを製作
  - 現在はBladderの試作中 → 今月中にテスト予定
  - 部品図等、詳細設計はこれから

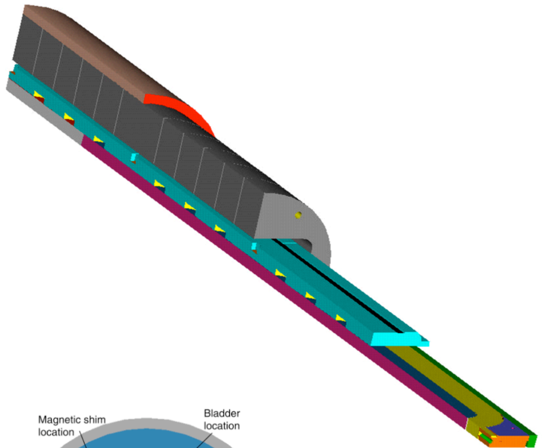
LBNLのものを参考

•LBNLとの図面交換を円滑にするため、LBNL側で使用されているCADソフト、Pro/Engineeringを導入予定

Goal #2 Long Magnet Fabrication



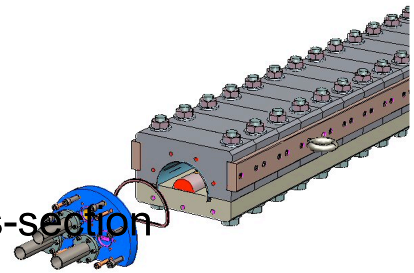
- Long Racetrack
  - Coil fabrication scale-up based on well-understood s
    scale coils
  - Explore scale-up of shell-based support structure

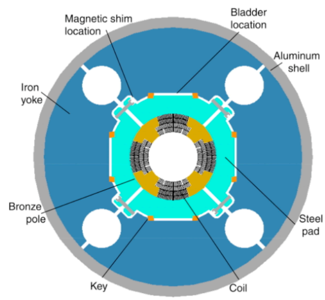


- Mirror dipole scale-up via FNAL core program

Followed by . . .

- Long quadrupole (LQ)
  - 3.6 m quadrupole based on TQ cross-section

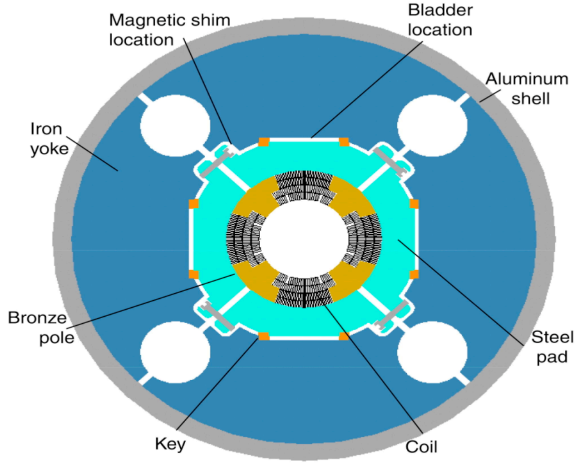




Goal #3 High Gradient in a Large Aperture

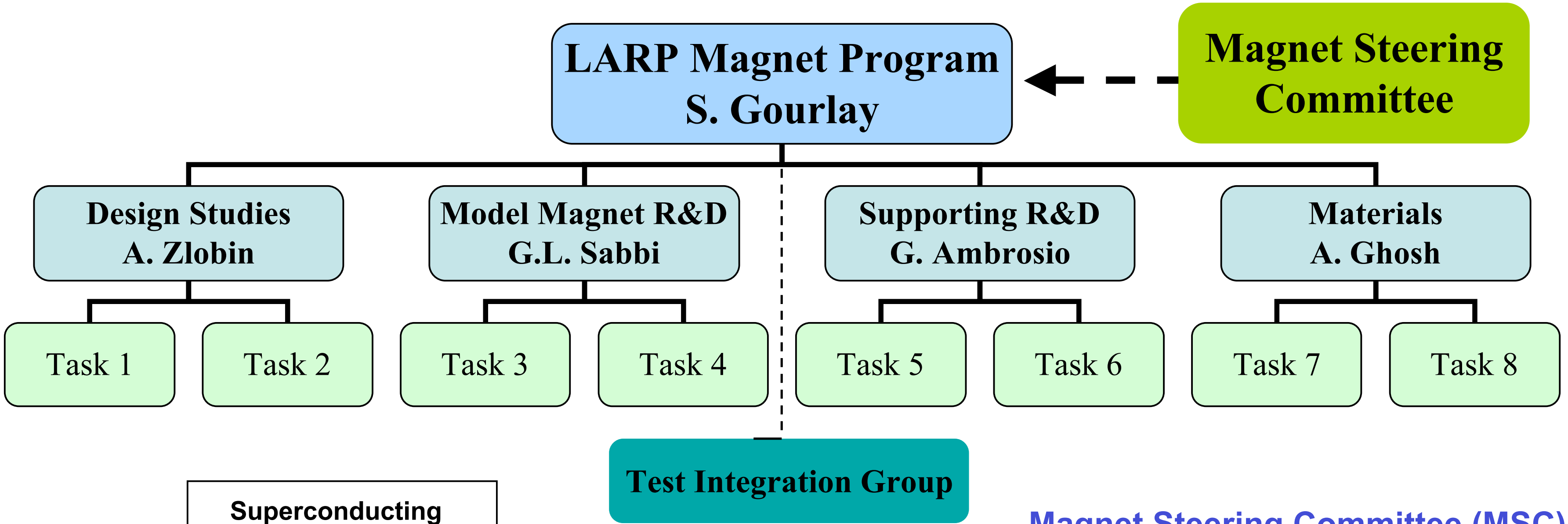
- High Gradient Quadrupole (HQ)
  - Explore ultimate performance
    - Increase peak field on the coil to ~ 15 T
    - Precursor to larger aperture

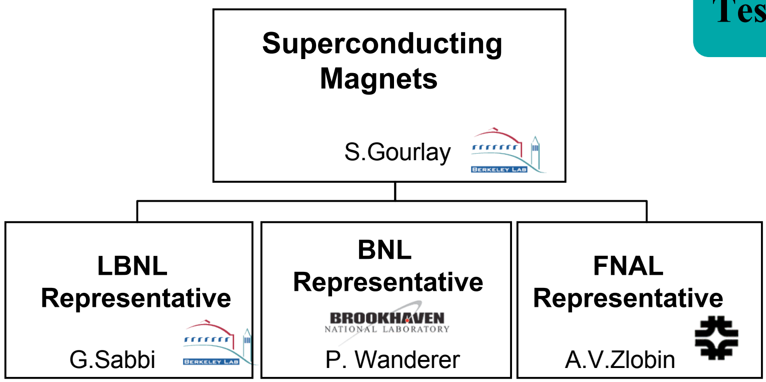
4-layer: G=280-310 T/m



Subject of Design Studies

Organization





Lab representatives oversee tasks/sub-tasks at host laboratory

Magnet Steering Committee (MSC)

– Define program, identify tasks and assign task managers

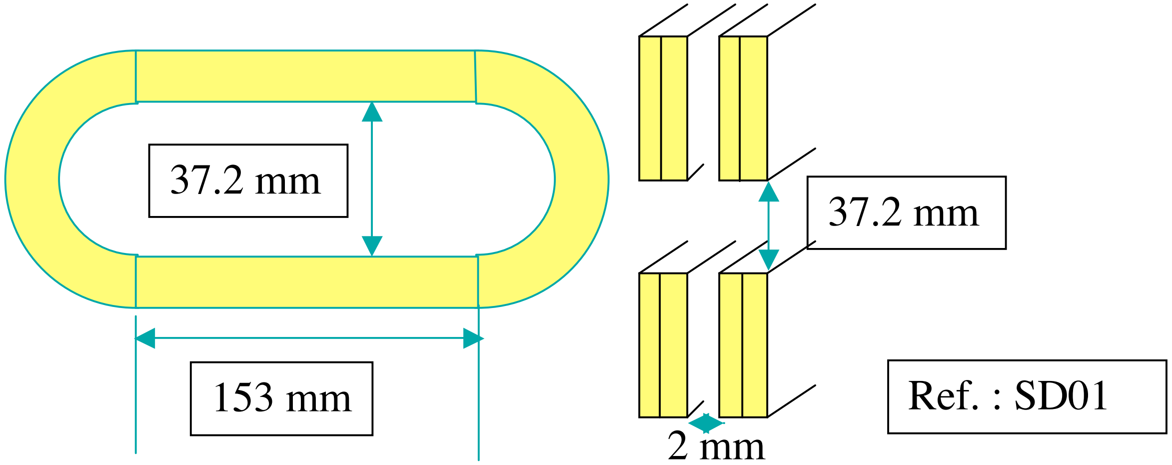
Lab Representatives and L2's

G. Sabbi, A. Zlobin, A. Ghosh,
G. Ambrosio, S. Gourlay,
P. Wanderer, M. Lamm

Cable Length Study

- Target : Peak Field = 15 T w/o yoke

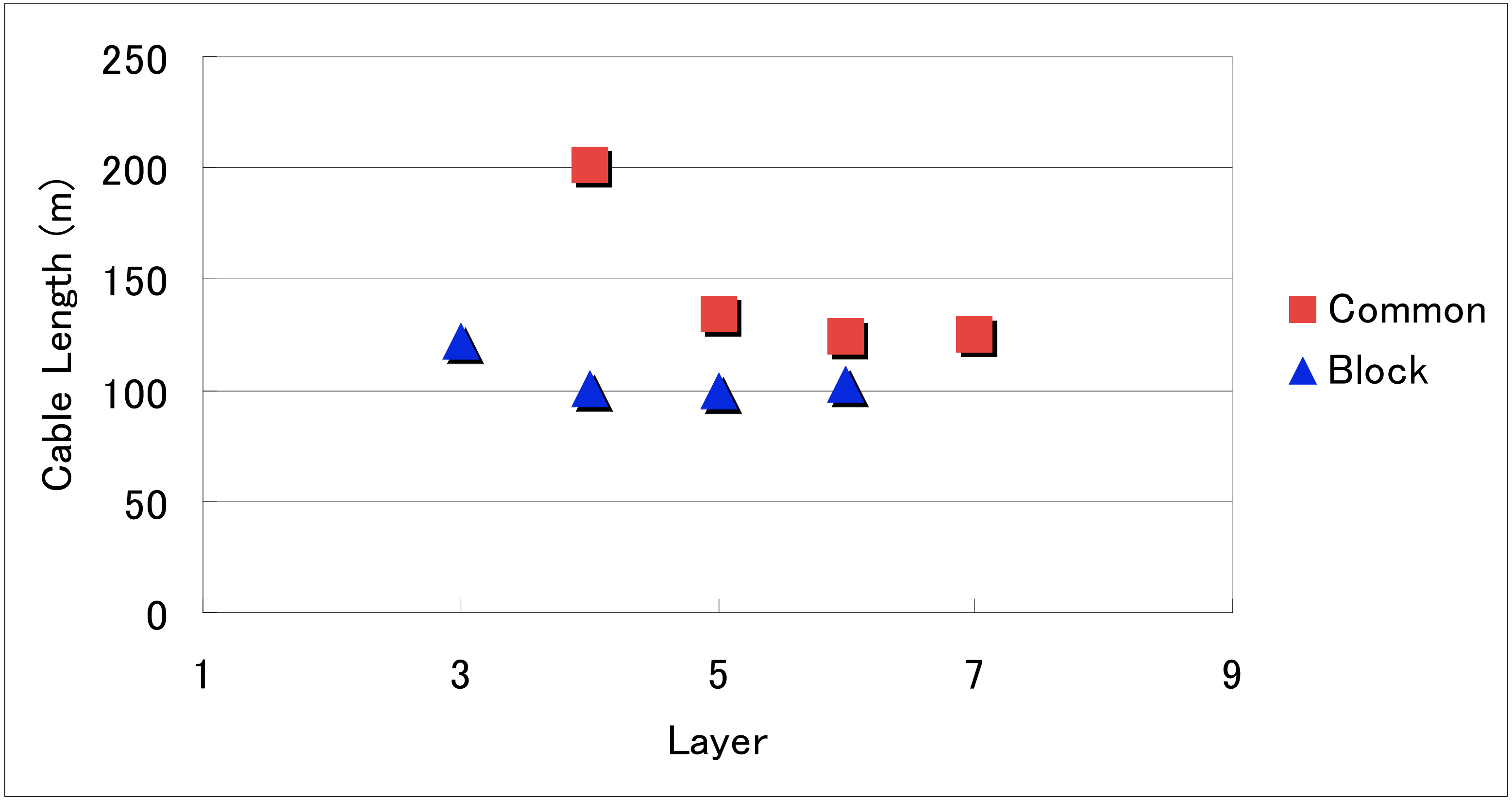
Cable:
No. strands : 20
Size : 1.25 x 7.4
Insulation thick. : 0.5 mm



	Common	Block
Current (A)	5265	
Number of Coils	2	
Peak Field (T)	15.1	15.0
Turns/Layer	36	42
Layers/Coil	6	4
Total Cable Length (m)	125 x 2 = 250	101 x 2 = 202

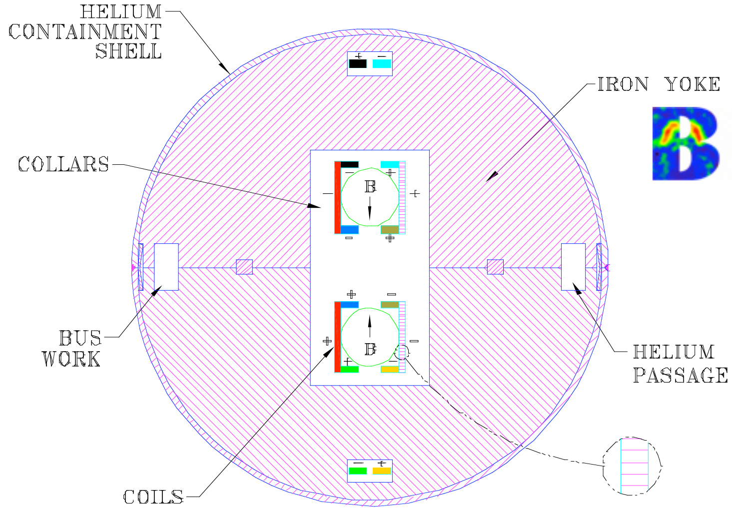
Appendix

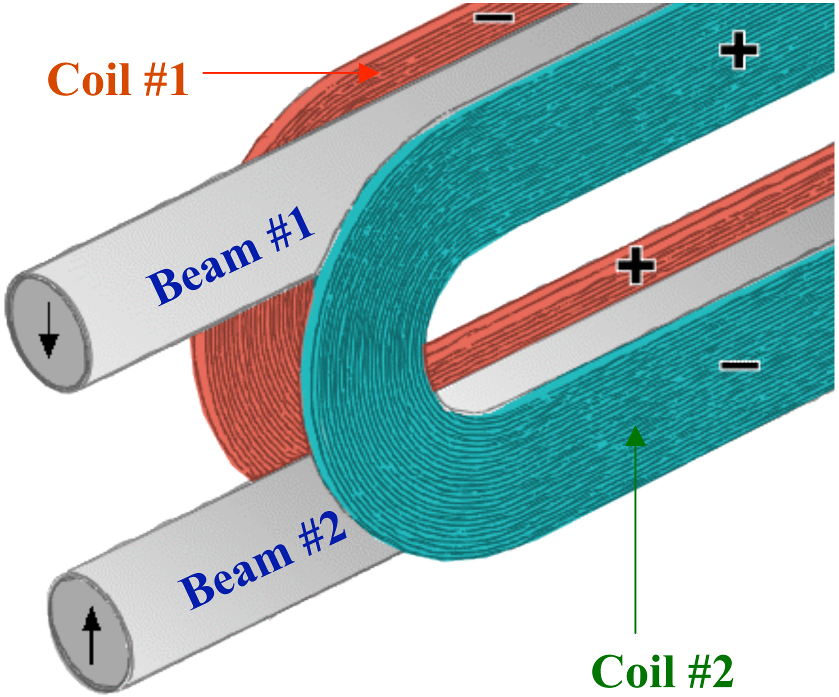
- <u>Required cable length for 15 T</u>



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 Nb_3Sn, Nb_3Al and HTS)**
- **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**

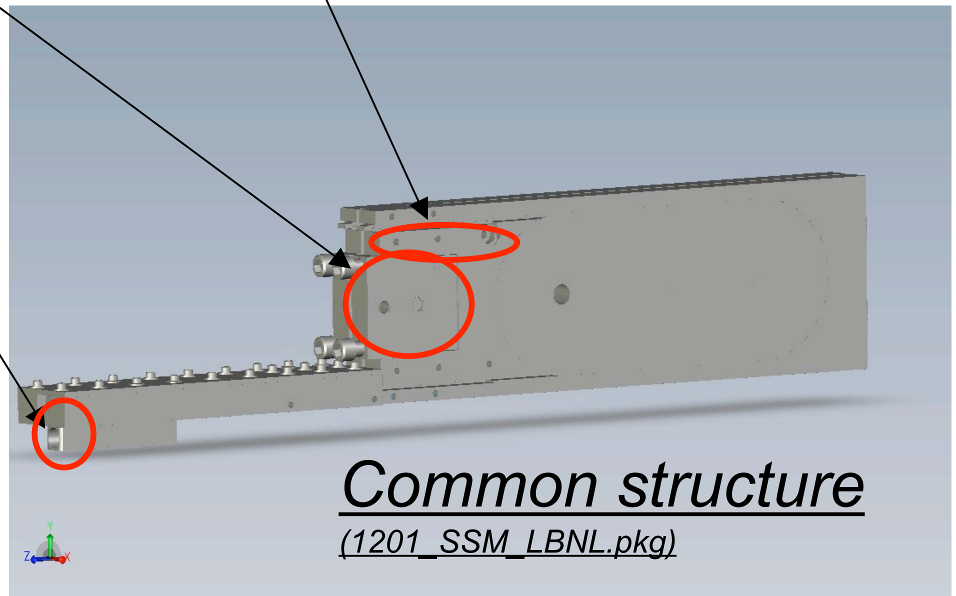




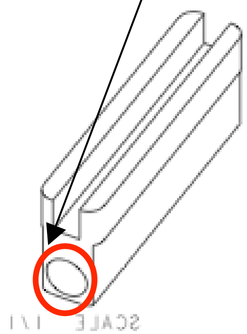
Main Coils of the *Common Coil Design*

Questions

1. If we can borrow the Nb3Sn coils, Are assembled coils provided?
   - Are the coils separated ? (not soldered in series ?)
   - Are the coils including <u>Lead End Shoe</u>, <u>Splice Support Post</u>, and so on?

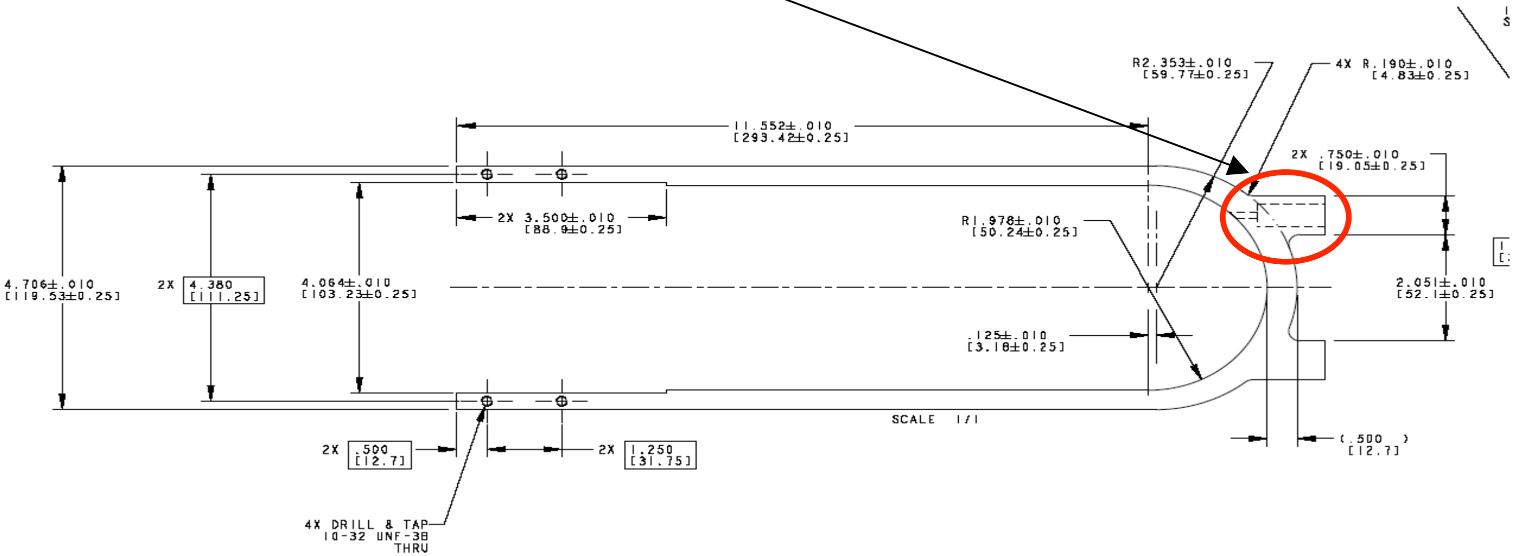


2. What is the purpose of <u>the hole</u> in the Splice Solder Block ? (for attaching a heater?)



Questions

3. What is the purpose of <u>the hole</u> in the Horse Shoe ?



4. Why is the groove on the Coil-Coil Splice Block the shape shown below ?