MCINTYRE

We have seen a range of local optima

to the collider magnet challenge:

NbTi

- 2T
  - warm-bore transmission line
  - cold-bore superferric
- 5T
  - single-shell cos θ
- 8T
  - two-shell LHC

Nb_3Sn

- 11T
  - two-shell cos θ
- 14T
  - common coil block
- 16T
  - stress management

HTS / Nb_3Al

- → reduce S.C. mass
- → increase field further

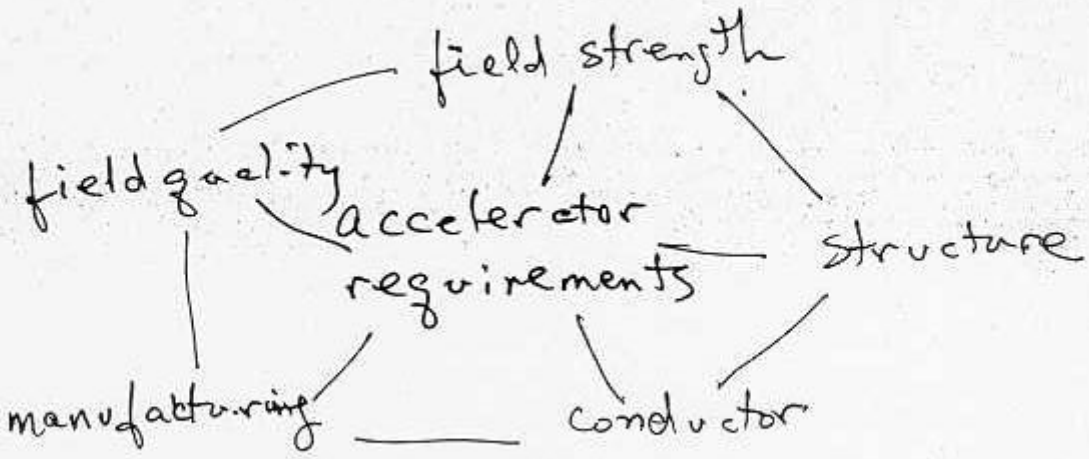
A common theme:

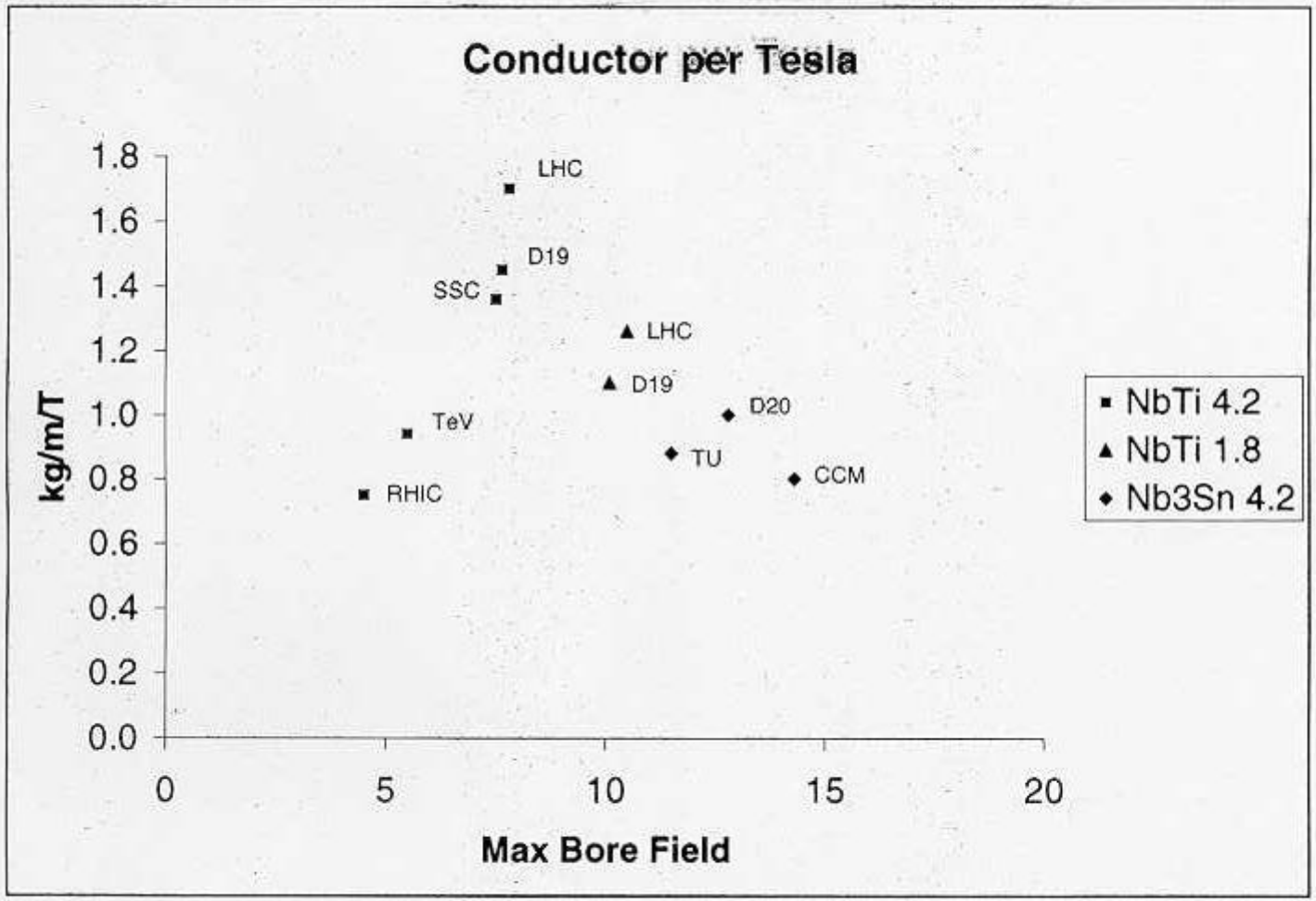
Structure optimization has two big drivers:

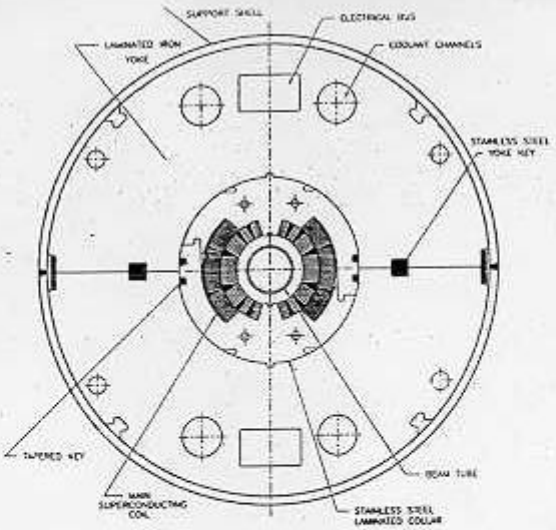
Aperture: what <physical / dynamic> aperture is needed?

Stress: if stress approaches j_c degradation → manage

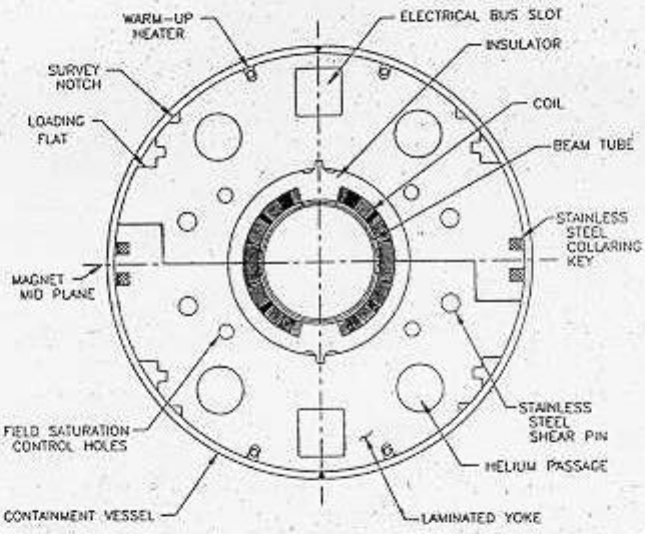
It's the conductor, stupid!




Conductor per Tesla
kg/m/T
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
Max Bore Field
LHC
D19
SSC
LHC
D19
D20
TeV
TU
CCM
RHIC
NbTi 4.2
NbTi 1.8
Nb3Sn 4.2

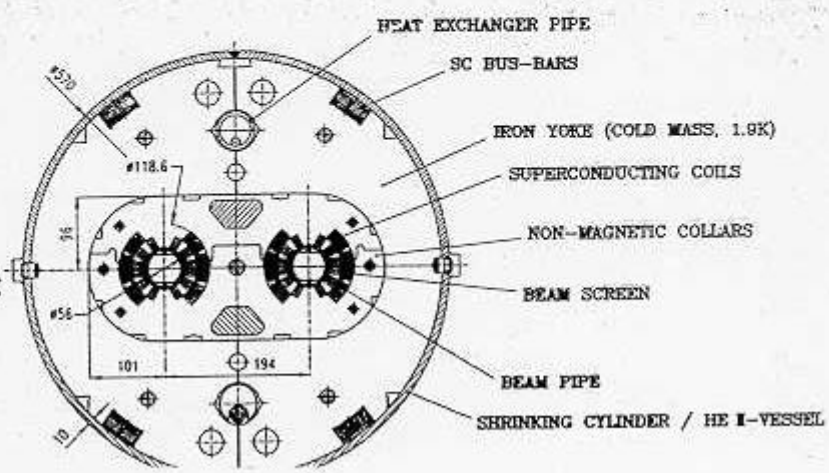


SSC
6.6 T
50 mm
15 m long
~20 of final design



RHIC
3.5 T
80 mm
10 m long
373 built by industry

LHC
8.4T (@1.8K)
56 mm
14 m long
2 prototypes next yr.



MUON COLLIDER SLOTTED DIPOLE

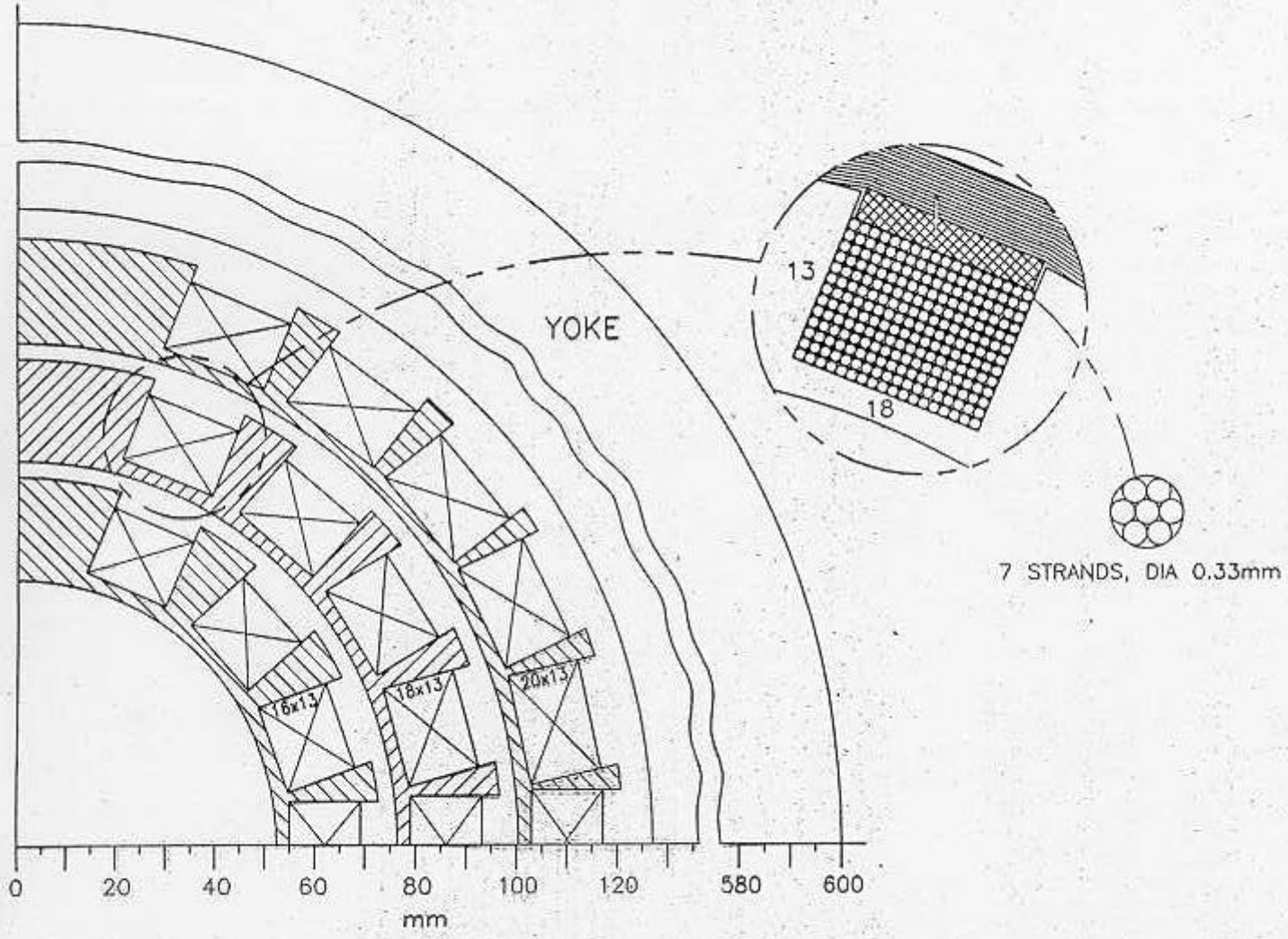
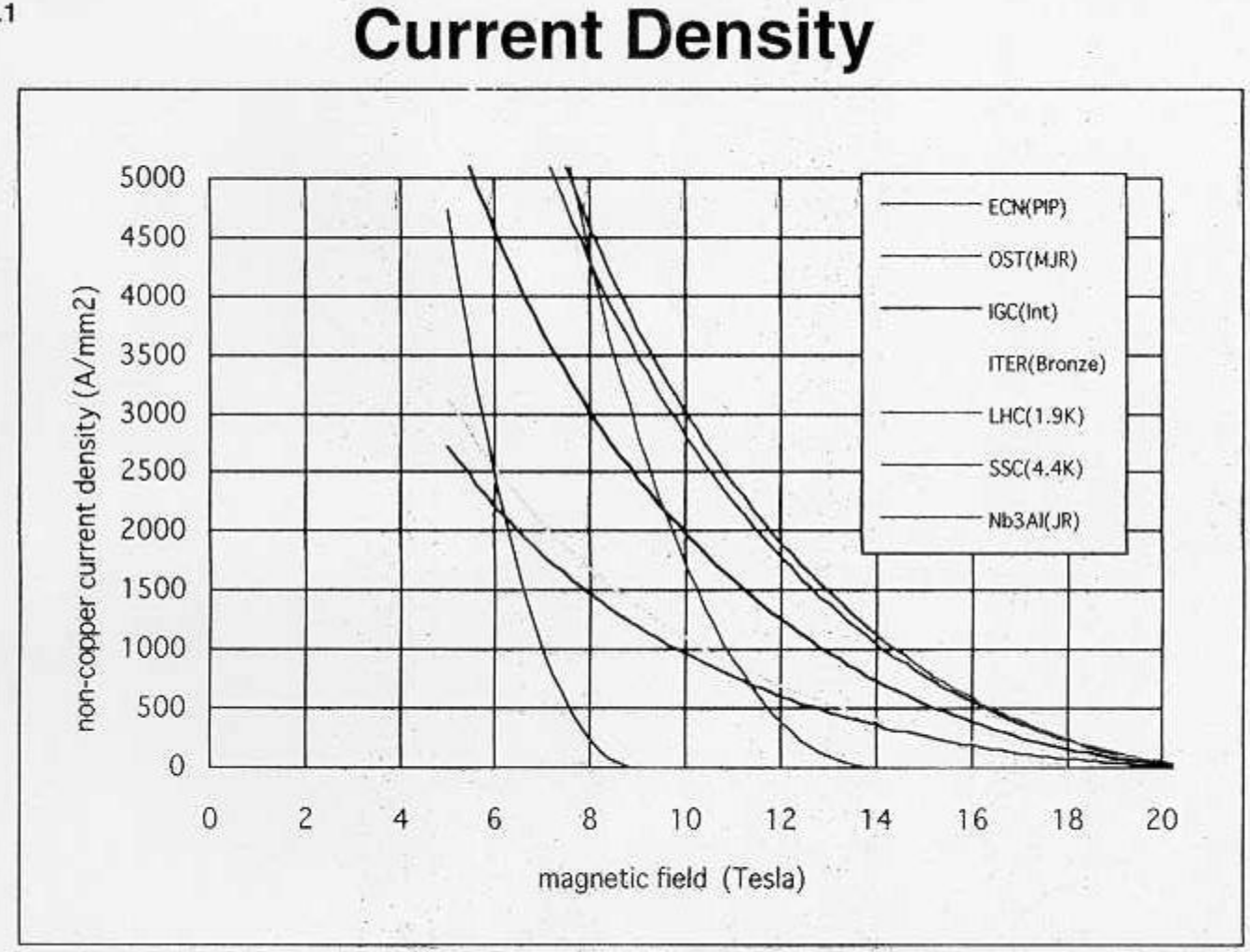
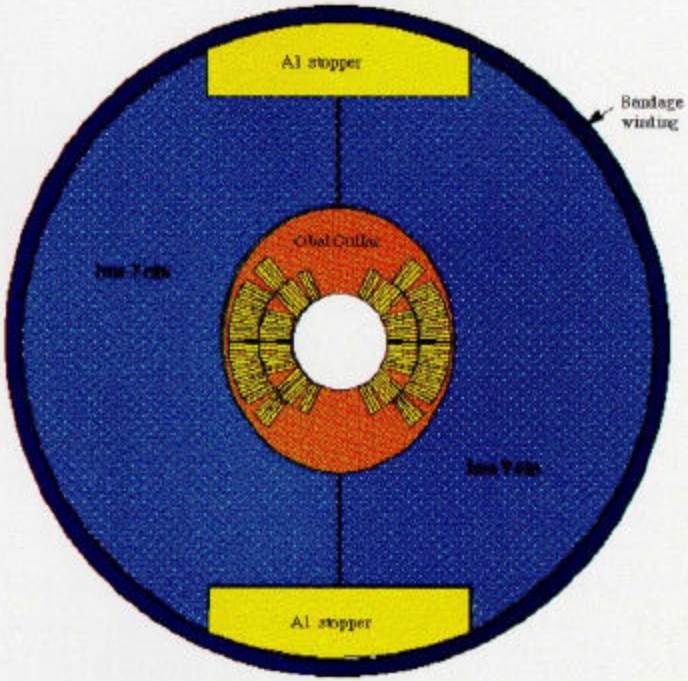


Fig.1


Current Density
non-copper current density (A/mm2)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
14
16
18
20
magnetic field (Tesla)
ECN(PIP)
OST(MJR)
IGC(Int)
ITER(Bronze)
LHC(1.9K)
SSC(4.4K)
Nb3Al(JR)

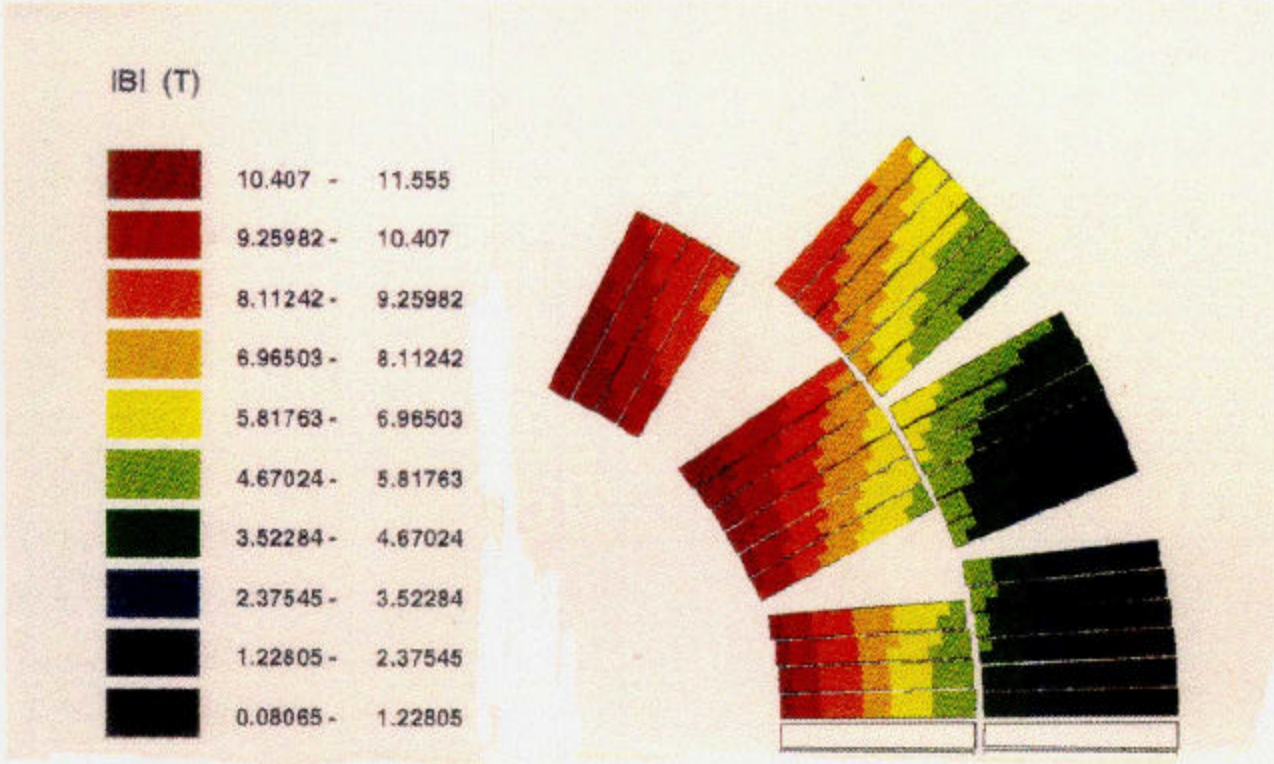
First Nb_3Sn Short Dipole Model



Magnet Parameters:

- two-layer shell design;
- Ø 50 mm bore;
- B = 11.8 T at 17.6 kA;
- $dB/B < 10^{-4}$ at R < 1.5 cm;
- length ~ 1 m

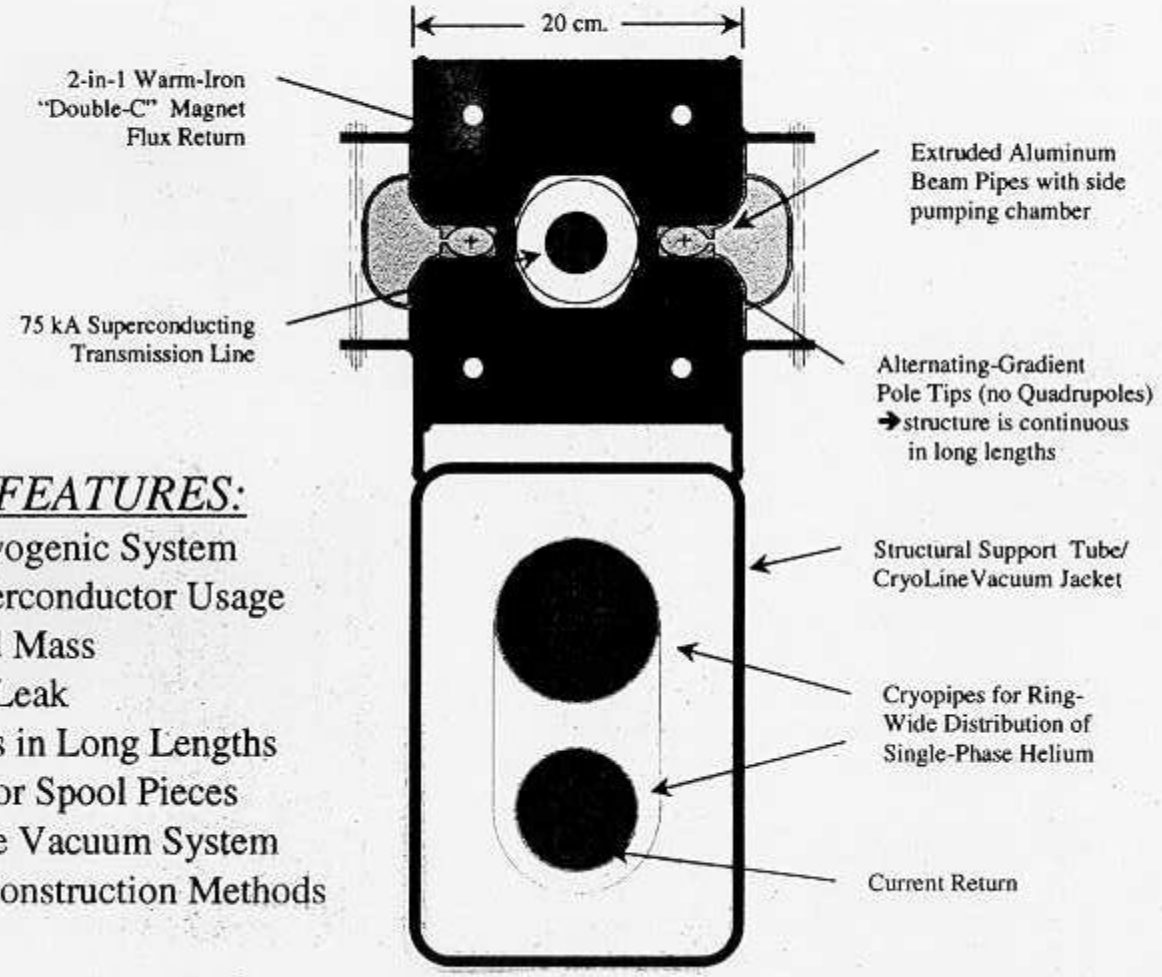
High Field Dipole Model Cross-Section



Bc = 10.8 T

b3 = -0.026
b5 = 0.0012
b7 = -0.00465
b9 = -0.254
b11 = 0.273
b13 = -0.0009

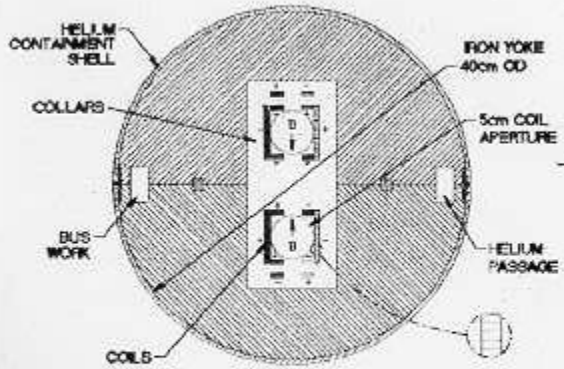
Transmission Line Magnet

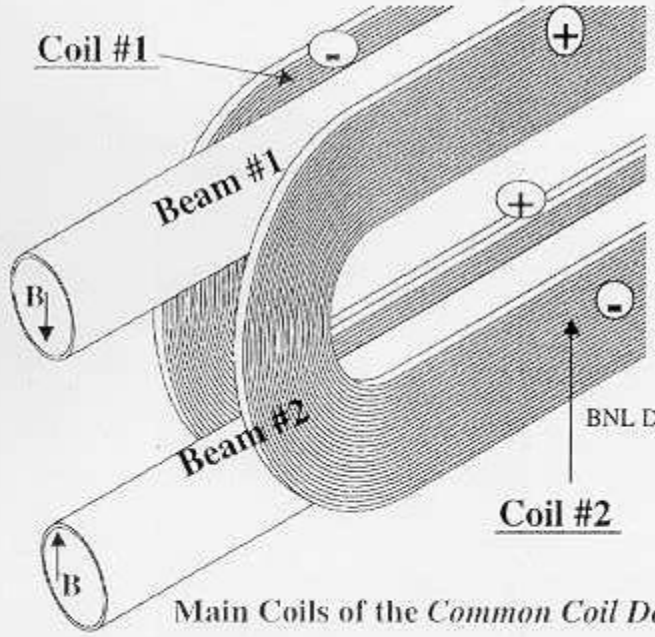


KEY FEATURES:

- Simple Cryogenic System
- Small Superconductor Usage
- Small Cold Mass
- Low Heat Leak
- Continuous in Long Lengths
- No Quads or Spool Pieces
- Warm Bore Vacuum System
- Standard Construction Methods

Common Coil Design Concept

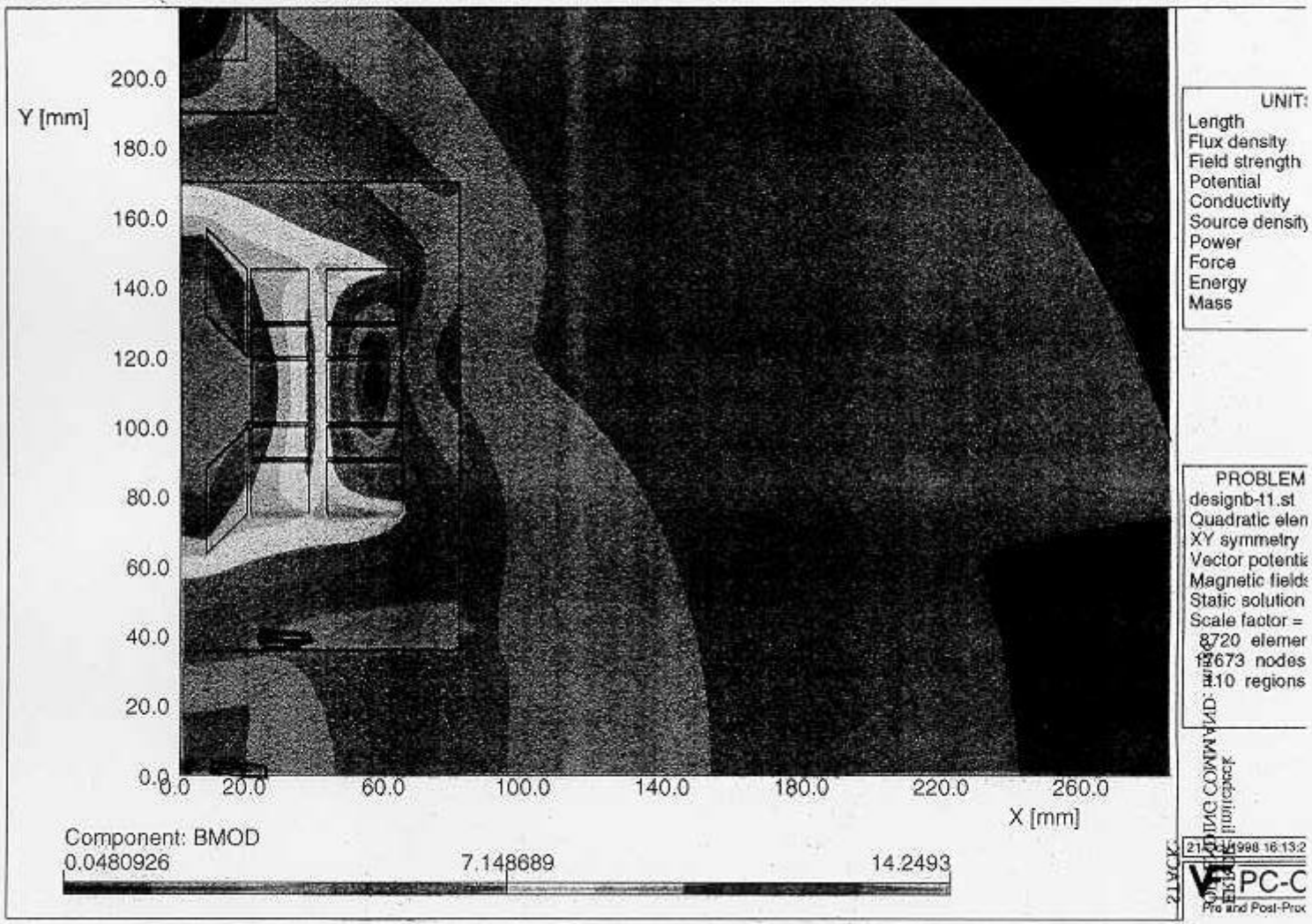




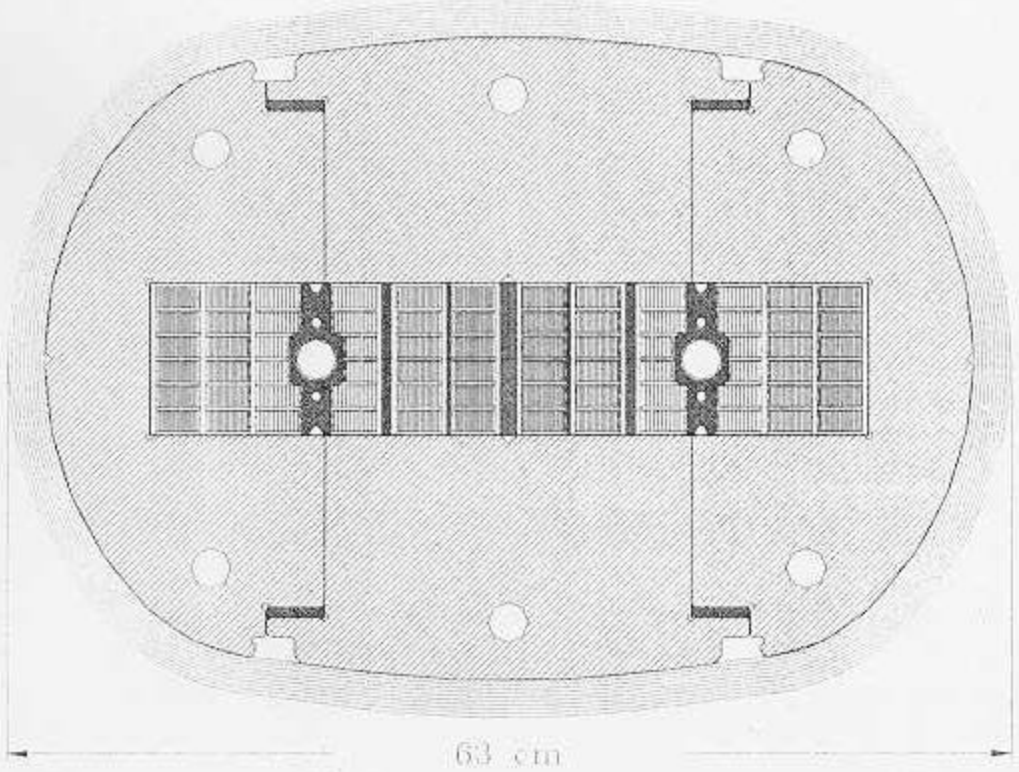
Main Coils of the *Common Coil Design*

- 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 D20, half the size for twice the 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 is lower in the middle of the magnet w/ a Splice
(Unique to common Coil Design)



16 Tesla Block-Coil Dual Dipole



Issues & Observations

Superferric:

- Is small aperture, warm bore feasible for high $\mathcal{L}$ collider
- $\exists$ "8" dipole, 35m long built in U.S. indust
- cost/performance comparison transmission $\leftrightarrow$ window frame

Cos θ:

- RHIC 1-shell probably least cost/mTeV of any dipole
- 2-shell @ 11T probably end of road for Nb_3Sn cos θ.
- with separated shells, 2-shell (3 shell) cos θ might use HTS inner shell.

blocks / common coil ?

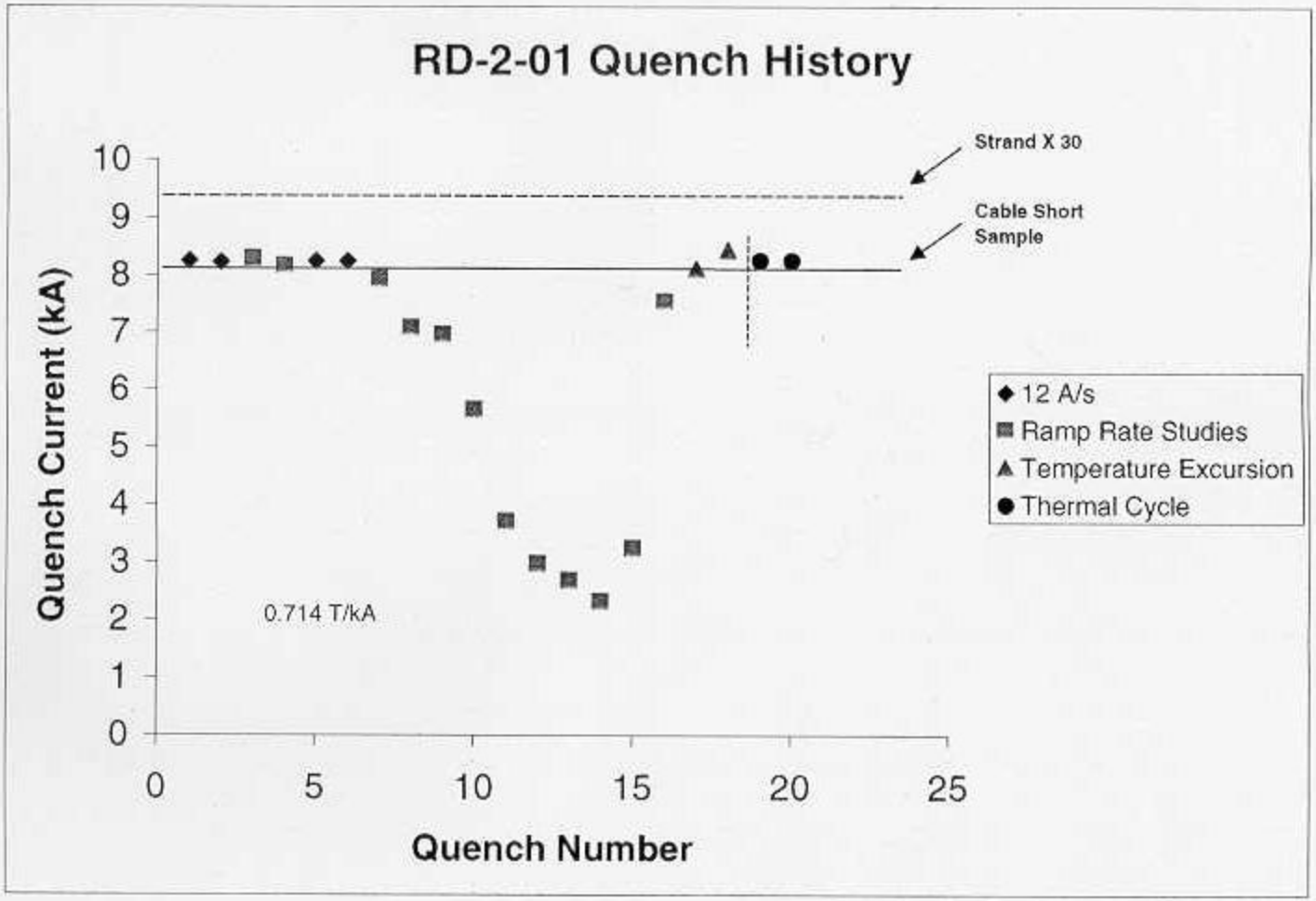
- There could be a revolution in $j_c(B)$ waiting to happen for Nb_3Sn. We haven't done the μphysics / metallurgy as for NbTi.
- Can stress management be made to work in dipoles?
- Push S.C. packing / field quality.
- Planar steel boundary suppresses b_6.

overall

aperture ← field quality
liner
warm bore

we need vigorous magnet building
testing
evaluation.

What every design must achieve: NO TRAINING

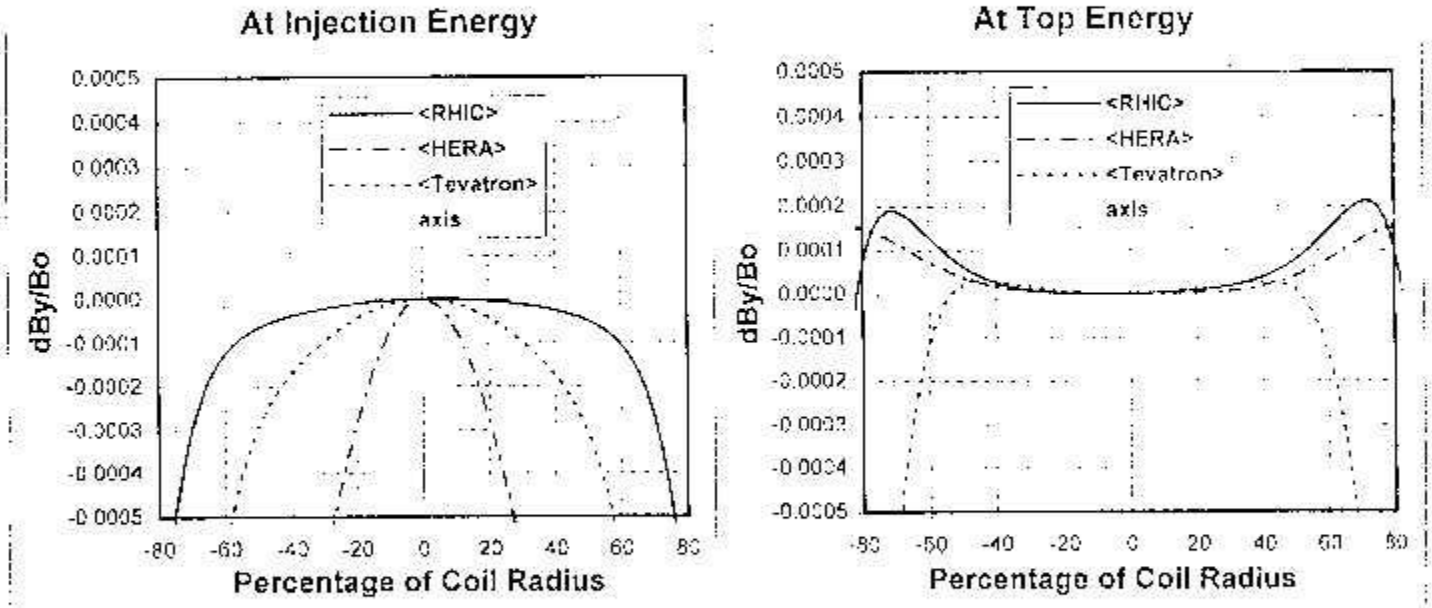


WHAT EVERY DESIGN MUST ACHIEVE:

$\Delta B = 10^{-4}$ @ 80% aperture !

Average Field Errors on X-axis in RHIC, HERA and Tevatron Main Ring Dipoles

COIL ID : RHIC = 80 mm, HERA = 75 mm and Tevatron = 76.2 mm



1. Warm-Cold correlation has been used in RHIC dipoles to estimate cold harmonics in all magnets.
2. Harmonics b1 through b10 are used in computing these curves.