Magnet Workshop Summary

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vlhc Annual Meeting

June 28-30, 1999

HEPAP SUBPANEL (‘98)

“The Subpanel recommends an expanded program of R&D on cost reduction strategies, enabling technologies, and accelerator physics issues for a VLHC.“

- coordinated ($\Rightarrow$ workshops)
- identify design concepts
- economically and technically viable

Focus of talk

- "Snapshot" - magnet r&d last fall
  - new ideas
- "Context"
  - historical (highlights of magnet R&D)
  - related technical (accelerator physics …)

vlhc Magnet Workshop - 11/98

- Port Jefferson NY
- 74 attendees
- 2 1/2 days + …
- 5 magnet groups/ideas

- Very different idea:

  full-energy injector

  ⇒ DC collider rings

- Other experts:
  - accelerator physics
  - accelerator systems
  - magnet mfgr. (2)
  - superconductor:
    - R&D labs (4)
    - manufacturers (3)

Magnet R&D + Accel. Physics:

size of magnetic field errors

- Look back:
  - SSC aperture increase 40 mm $\Rightarrow$ 50 mm
  - LHC aperture increase 50 mm $\Rightarrow$ 56 mm
  - $\Rightarrow$ early discussion with accelerator physics
- Look ahead:
  - do systematic errors dominate randoms?
  - if so, accelerator analysis much easier

Magnet R&D + Accel. Systems

- High fields (~12T) $\Rightarrow$ synchrotron rad.
  - relaxed tolerance on systematic errors
  - heat
  - gas desorption
- Low fields (2T)
  - low heat leak
  - control of long cryogenic loops

$\Rightarrow$ Early study of integrated system

Magnet R&D + SC Experts

- Look back: developing NbTi (flexible)
  - "zebra" cable (Tevatron)
  - current capacity increased
    - DOE annual conductor workshops
    - R&D at labs, especially U. of Wisc.
- Look ahead: new conductors (B>10T)
  - Nb_3Sn, High Temp Superconductor (HTS)
  - strain sensitive, larger filaments

  ⇒ early development of conductor

Nb_3Sn “context”

- ITER production:
  - – good news:
    - one specification, several vendors, lots made
  - – bad news:
    - AC specifications not a focus
    - conductor specifications frozen early
- Status:
  - – R&D needed for HEP specifications

HTS: High risk/high reward

- Commercial work: BSCCO
  - HEP: leads for Tevatron, LHC magnets
  - transmission lines, motors, …
  - current density low, increasing with time
- Laboratory scale: YBCO
  - current density high enough for HEP
  - YBCO small fraction of support matrix

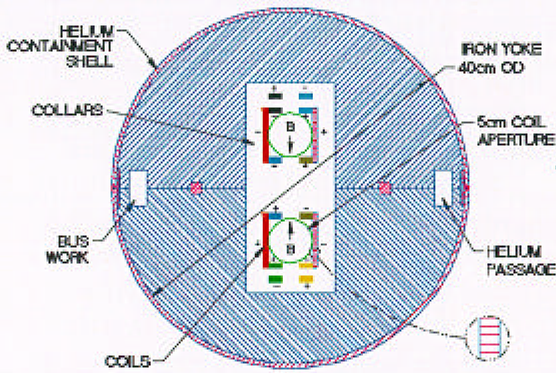
Five New Magnet Ideas

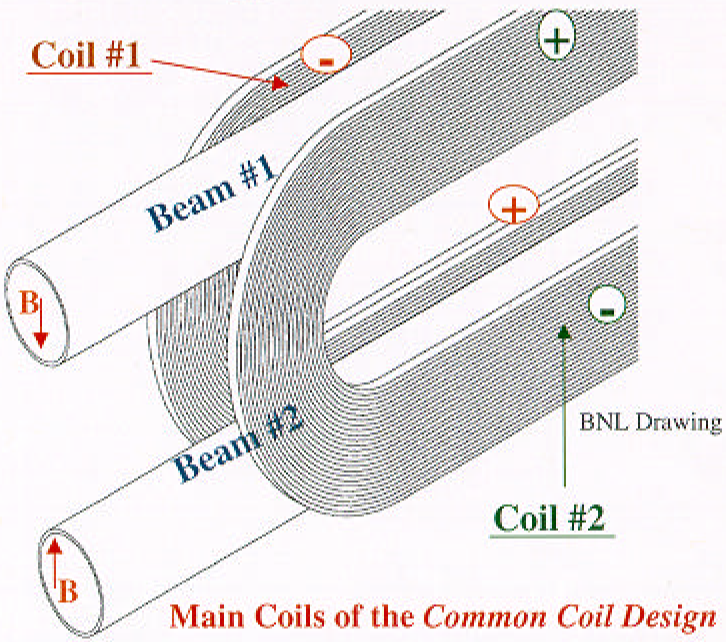
- Minimize $/T.m ⇒ 2T, NbTi
- Near-term high field material + 2 layer cosθ experience ⇒ 12T, Nb3Sn
- Near-term high field material + segmented conductor support ⇒ 16T, Nb3Sn
- High field material + simple coils + 2 apertures ⇒ 12T, Nb3Sn & 12T, HTS

Magnet R&D Underway 11/98

Institution	Magnet type	Bo (T)	Conductor
BNL	Common coil	12.5	HTS
Berkeley	Common coil	12.5	Nb_3Sn
Fermilab – high	Cos theta	11	Nb_3Sn
Fermilab – low	Transmission line/pipetron	2	NbTi or …
Texas A&M	Block/Stress management	16	Nb_3Sn

Common Coil Design
(The Original Concept)





Main Coils of the *Common Coil Design*

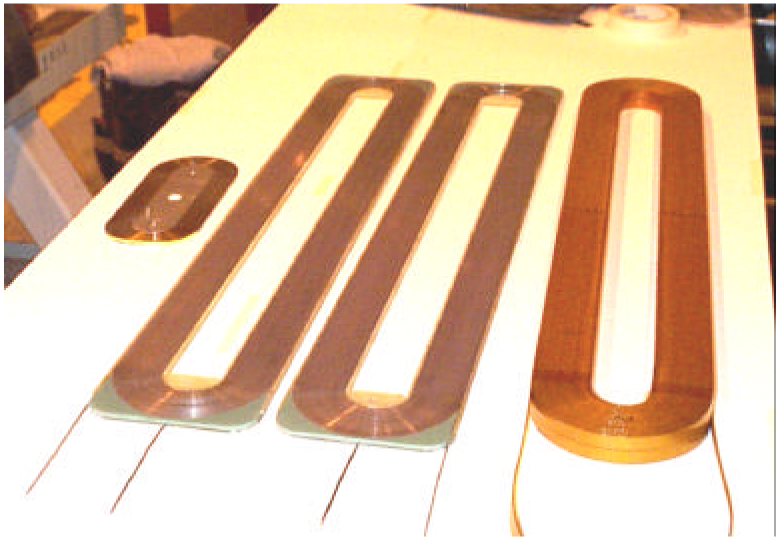
- Simple 2-d geometry with large bend radius (no complex 3-d ends)
- Conductor friendly (suitable for brittle materials - most are, including HTS tapes and cables)
- Compact (compared to single aperture D20 magnet, half the yoke size for two apertures)
- Block design (for large Lorentz forces at high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

Magnet work at BNL

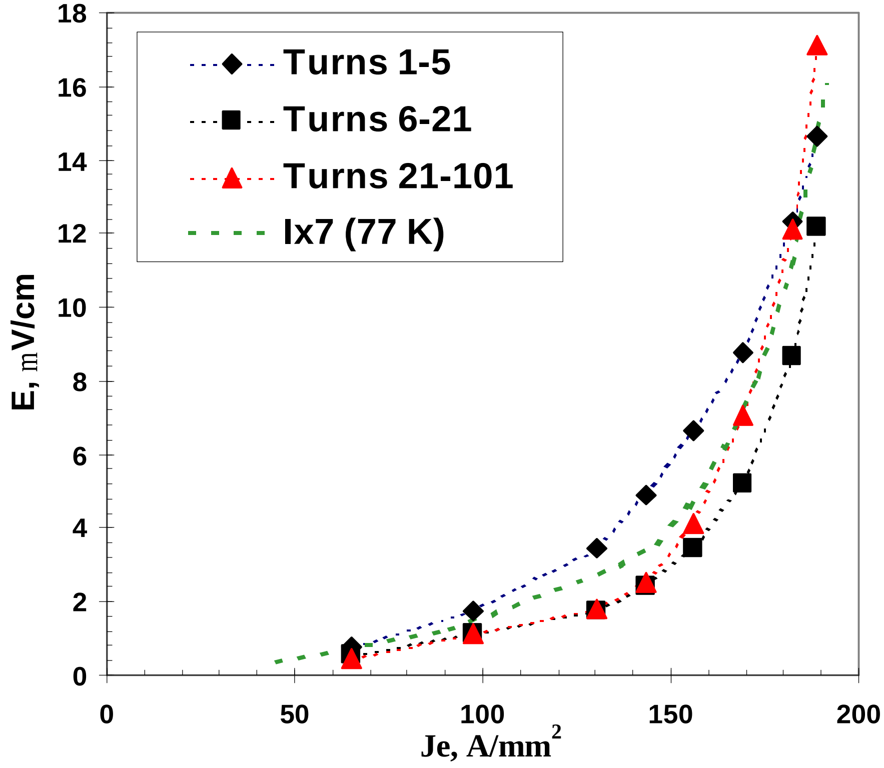
- Focus on HTS tape (eventually YBCO?)
- HTS BSCCO tape, successful coil test,
  - 30 cm racetrack coils
  - 30 cm quad coils made in industry
- Common coil magnet (1 m):
  - NbTi coils produced ~ 6T background field
  - Nb_3Sn coils reached expected current
    - Nb_3Sn, HTS tape: same size, strain tolerance

BNL Common Coils

- HTS coil (30 cm)
  - tape
- Nb_3Sn coils (1 m)
  - tape
- NbTi coil (1 m)
  - background field
  - SSC cable



BSCCO-2223 coil (30cm)



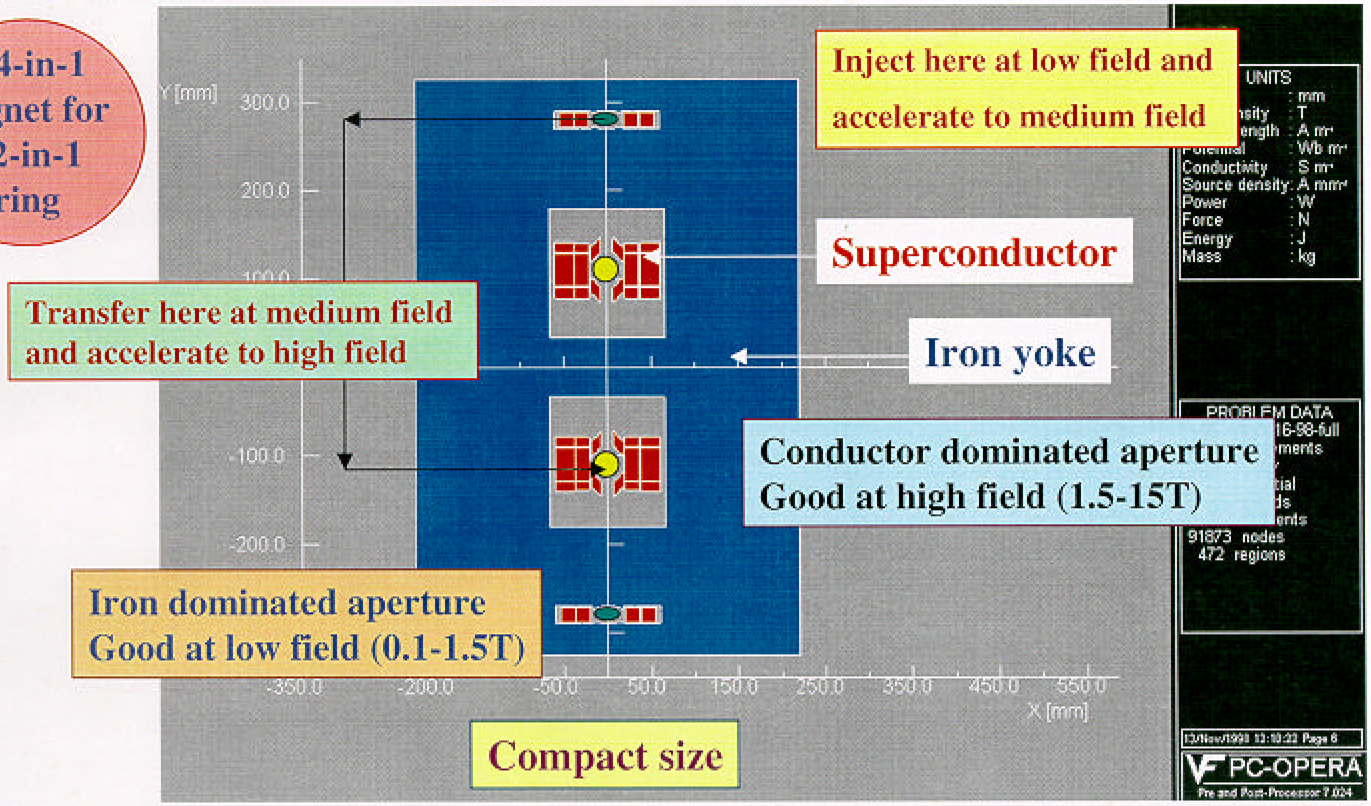
Magnet work at Berkeley

- Common coil design, Nb_3Sn cable
  - wind and react
- First magnet (existing material): reach conductor limit (~ 6T) - no training
- Immediate future: better Nb_3Sn, 14T
- Further off: HTS
- Common coil “system”: a booster?

A Common Coil Magnet System for VLHC

(May Eliminate the Need of a High Energy Booster)

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

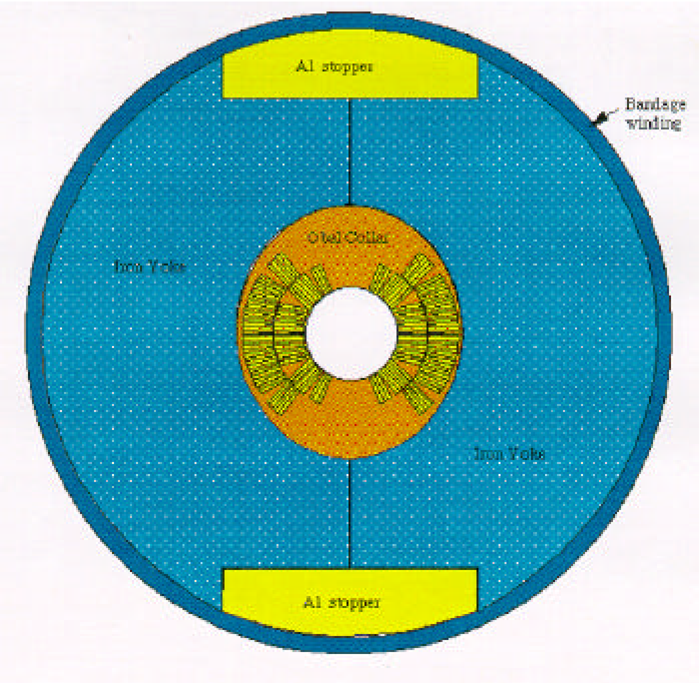


High-field work at Fermilab

- Decision to reenter magnet R&D
- Nb_3Sn only feasible high field material
  - two-layer magnet (cost effective)
  - $B_0 \sim 11$ T $\Rightarrow$ some radiation damping
- Activities (10 FTE's):
  - purchase improved superconductor
  - facility work: conductor test, reaction oven
  - study magnet designs, materials

FNAL High Field, Cosθ

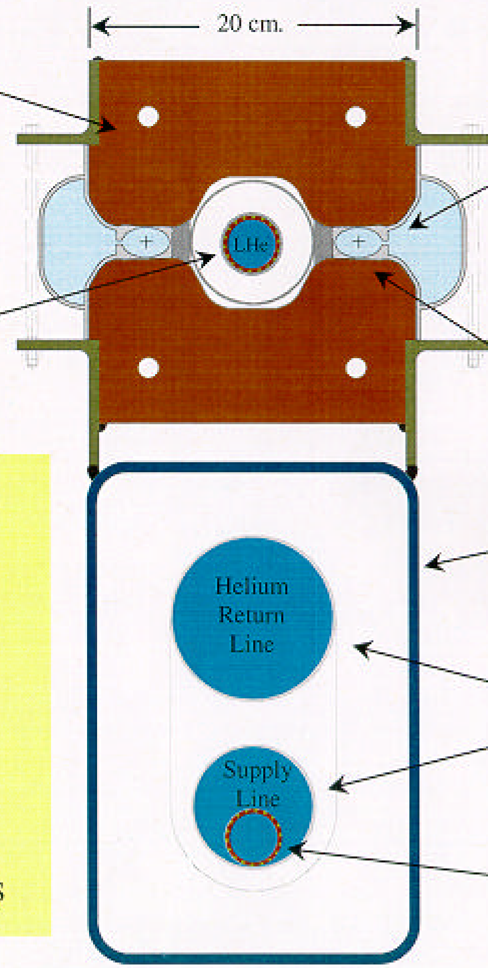
- Use lessons learned in previous cos θ magnets (mostly NbTi)
- Brittle materials:
  - wind & react vs react & wind
  - coil impregnation



Low-field work at Fermilab

- Goal: minimize $/T m
- Superferric (warm iron)
- Single turn excites both apertures
- Issues:
  - – Ring circumference:
    - 500 - 650 km (vs. 100 km)!
  - – Aperture (field quality, vacuum)

Transmission Line Magnet



KEY FEATURES:

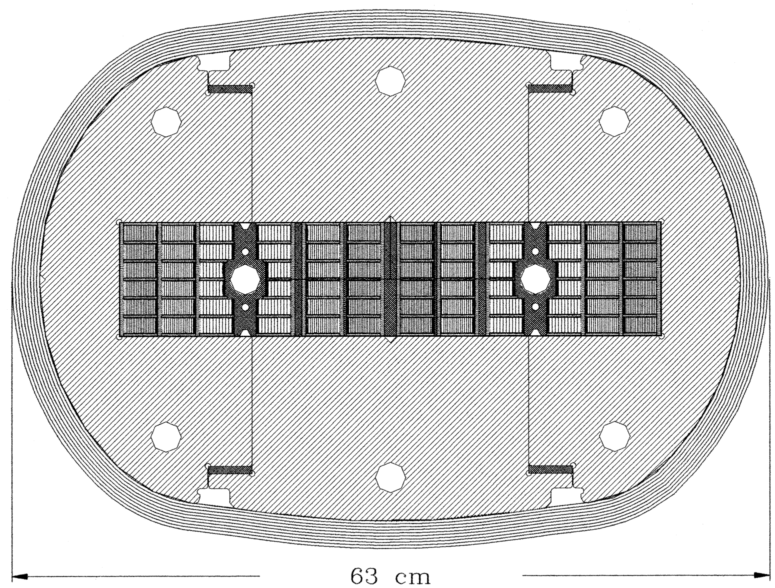
- Simple Cryogenic System
- Small Superconductor Usage
- Small Cold Mass
- Low Heat Leak
- Continuous in Long Lengths
- No Quads or Spool Pieces
- Warm Bore Vacuum System
- Standard Construction Methods

Stress management at Texas

- 16 T not possible with $\cos\theta$ design
  - azimuthal Lorentz forces accumulate
- Design structure to prevent accumulation of forces (stress) $\Rightarrow$
  - straight-section: block coils
  - ends: bend midplane coil in low B region
- Status (11/98): component development

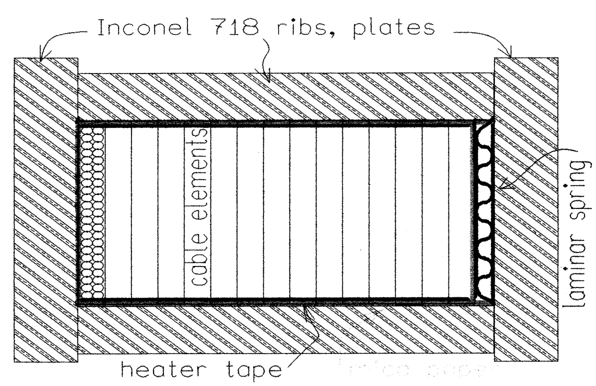
Texas A&M 16T Dipole

- Stress management
  - ribs and plates take the cumulative load
- Dual/single aperture
- Graded conductor
  - wind/react Nb_3Sn
  - improved Nb_3Sn
  - NbTi



Texas A&M Building Block

- "Devil is in details"
- Laminar spring maintains preload under all conditions (warm, cold, power)
- Mica slip plane⇒ no stick-slip motion
- Quench protection heater



Magnet R&D in Brief

- Short magnets tested:
  - LBL
  - BNL
- Magnet design, development underway:
  - Fermilab high field
  - Fermilab low field
  - Texas A&M