Towards a Very Large Hadron Collider - Accelerator Issues + R&D status

- General Features of a VLHC
- Why now ?
- Potential Approaches
- Accelerator Issues
- R&D activities
- Conclusions

General Features of a 3rd generation hadron collider - (Snowmass 96)

- A discovery machine at the highest energy frontier - 100 Tev center-of-mass
- Luminosity $10^{34} \rightarrow 10^{35} cm^{-2} sec^{-1}$
- Superconducting magnet technology
- Must be as cost-effective as possible (i.e. it will be expensive)
- Will be an internationally-supported effort

The technical feasibility of the machine would not appear to be as big of an issue as other methods to achieve very high energies

Why now ?

Time scales are such that new/different technologies need many years of development before they can be reliably used to make informed decisions about the next collider

- We would like to conceptualise the machine then investigate the accelerator physics questions and define the issues
- This would provide a sense of direction for R&D topics
- Guide magnet development
- Minimise costs of big ticket items

The future is closer than you think !

Potential Design Options

- Snowmass 96 looked at 3 basic machine design options characterised by field strength:
  - Low field ~ 2T (500 km)
  - Medium field 4T - 9T
  - High Field 10T - 12.5T (100 km)
- Medium field represents a 'big' LHC which we presumably understand well enough technically and fiscally. Concentrate on low field and high field. This tends to highlight the differences

Issues:Low & High Fields

- High Field
  - 50 Tev at these fields will provide significant synchrotron radiation damping thus robust beam dynamics
  - Minimize physical size
- Low Field
  - Permits the 'low tech' approach and thus potential for greatly simplifying complex systems
  - Possible cost minimum for well known Nb-Ti technology

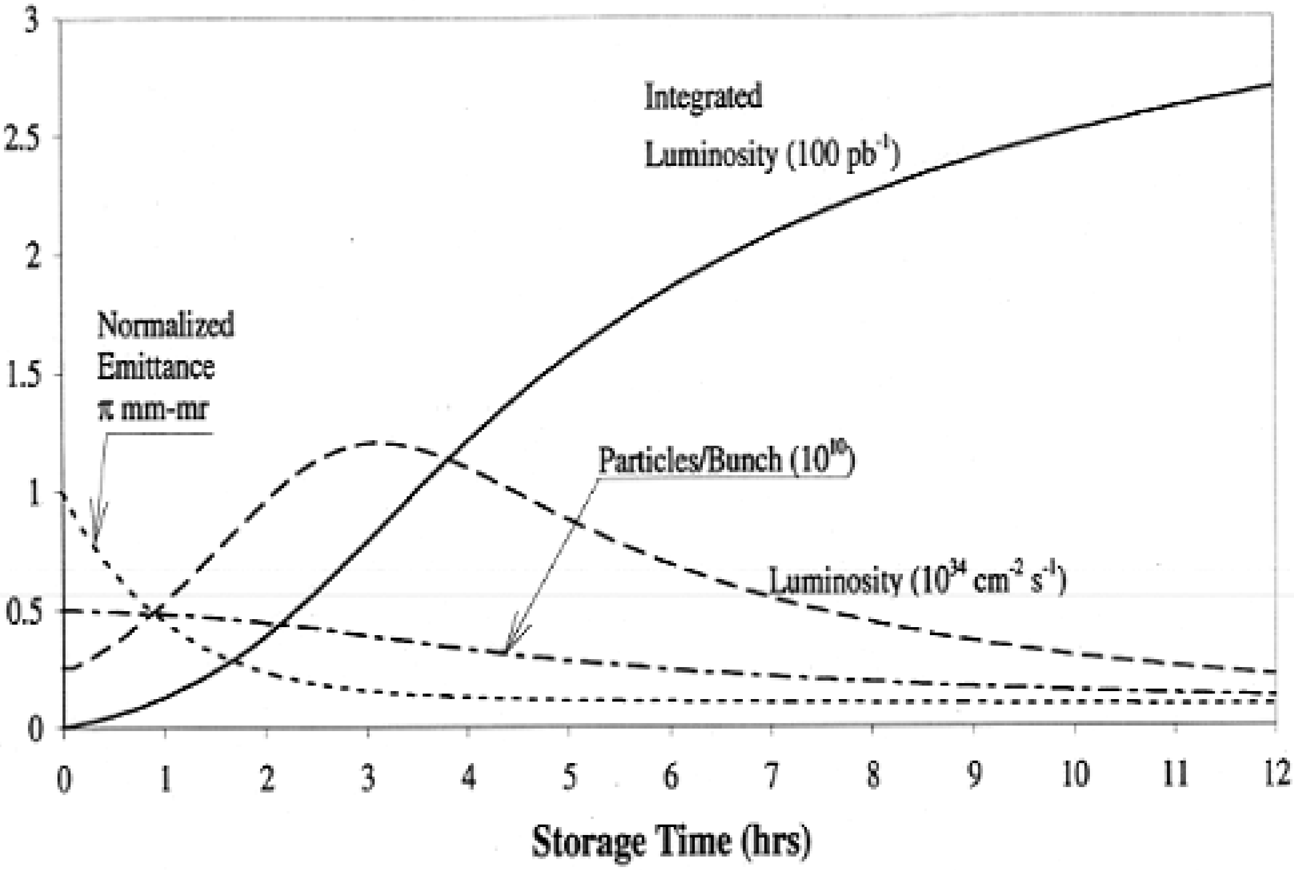
Principal R&D challenges, high field:
the high-field magnet, handling the synchrotron radiation

Principal R&D challenges, low field:
Large scale of the machine, physics of high beam intensities

Issues:Low/High Field Comparison

	Low Field	High Field
Radiation damping	None	1-2 hr damping time
Impedance	High (resistive wall of warm bore beam tube)	Low(impedance/length typical of other machines)
Susceptibility to emittance growth	High (because of very low revolution and synchrotron frequencies)	Low(higher revolution and synchrotron frequencies, plus radiation damping)
Persistent currents at injection	None	Signifcant (with Nb_3Sn)
Beam Stored energy	15 x LHC	1.5 x LHC
Beam Aspect ratio	Round	Flat
Synchrotron radiation power/ring	48 kW (0.08 W/m) into warm bore	190 kW (1.6 W/m) into cold beam screen
Cryogenic system	Modest	Substantial
Wall-plug cryo power	< 40 MW	> 72 MW

High Field - beam parameter evolution



Decouples Collider performance from injector chain (12 hour integrated Lum essentially independent of initial emittance)

High density bunches, minimizes bunch intensity

High Field - Flat Beams

If the vertical dispersion and the linear coupling are well controlled in the arcs, the vertical emittance will damp to a value much smaller than the horizontal emittance resulting in flat beams as in an electron storage ring

Implications:

- The final focus optics can be a doublet rather than a triplet
- The peak beta function is typically x10 smaller which relaxes field quality criteria in the final focus
- Long range tune shifts (mostly vertical) occurring before the beams are fully separated tend to be smaller

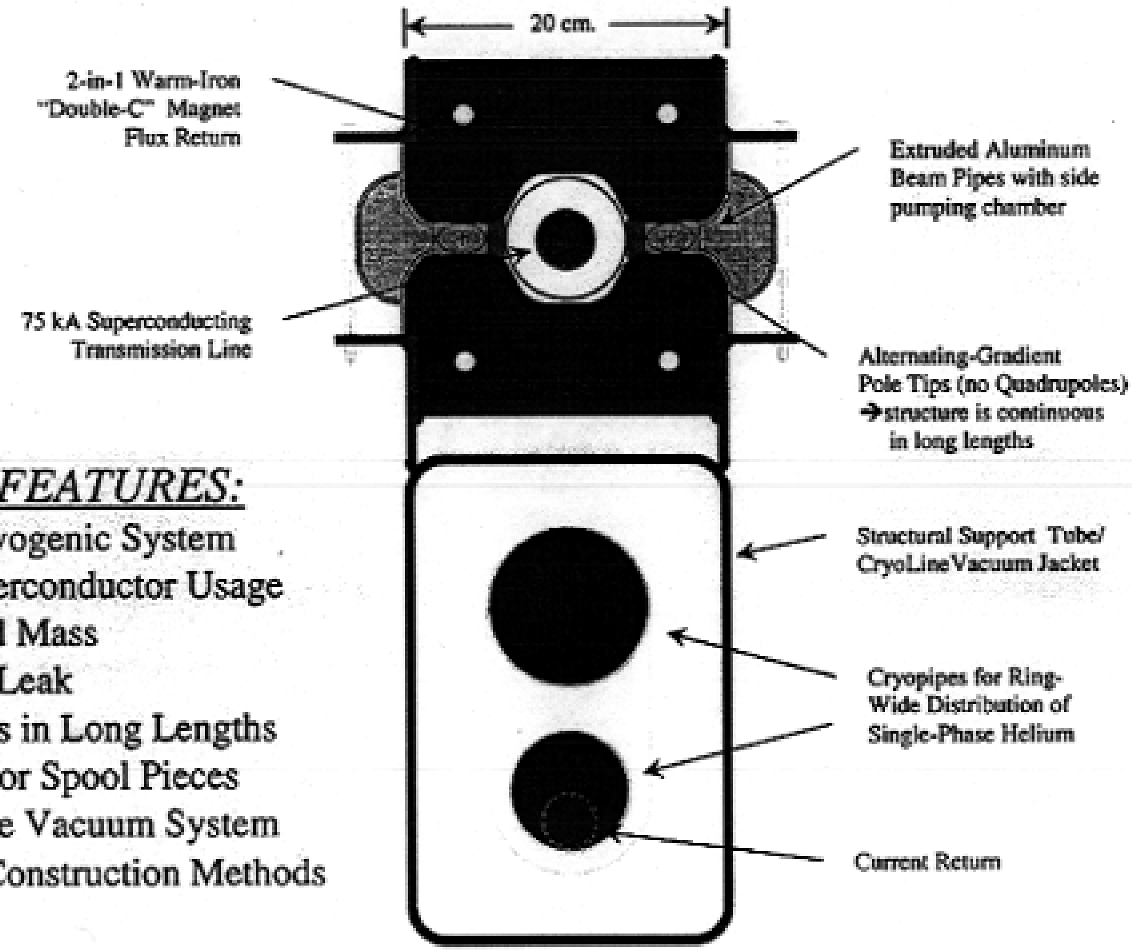
R&D Activities

- Low field program at Fermilab. Starting to look at systems issues as well as at the magnet
- High field magnet programs at LBL, Fermilab, Texas A&M & BNL. Requires the development of A-15 compounds like Nb_3Sn, Nb_3Al, or high temperature superconductors (HTS)

U.S. national efforts in accelerator physics, technology, and magnets co-ordinated by a steering committee

Low Field - Magnet concept

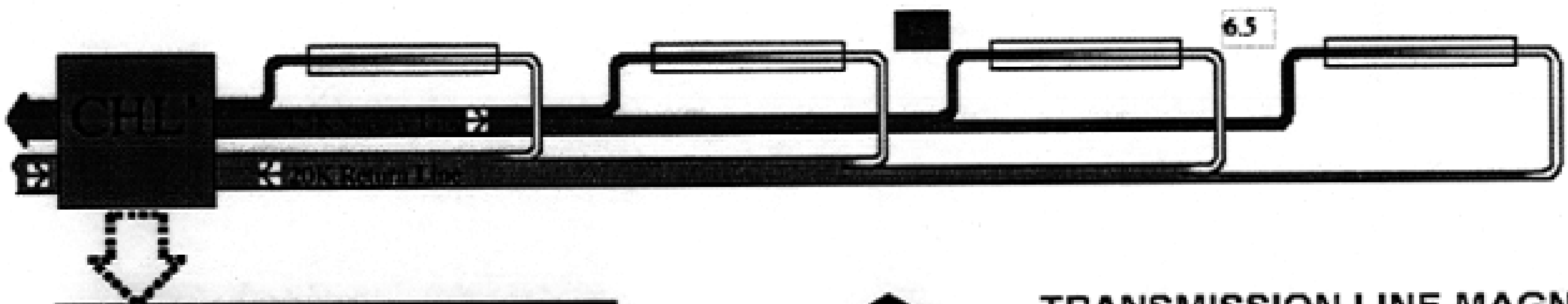
Transmission Line Magnet

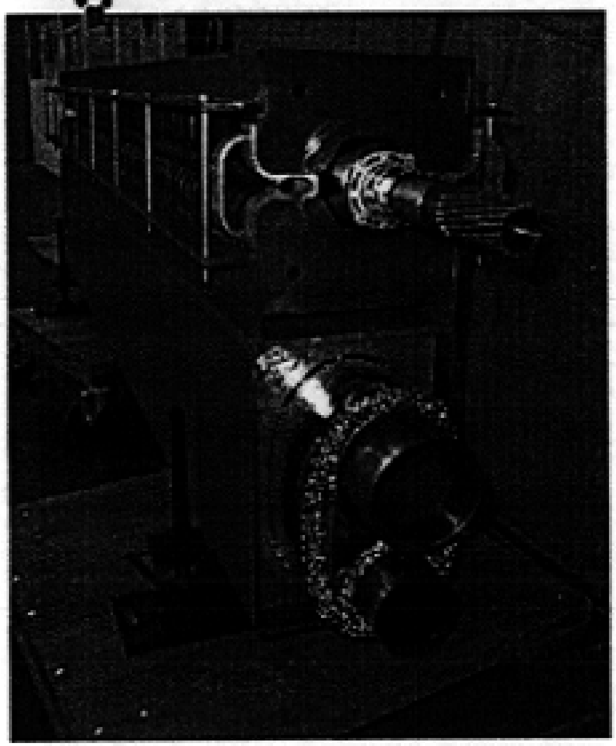


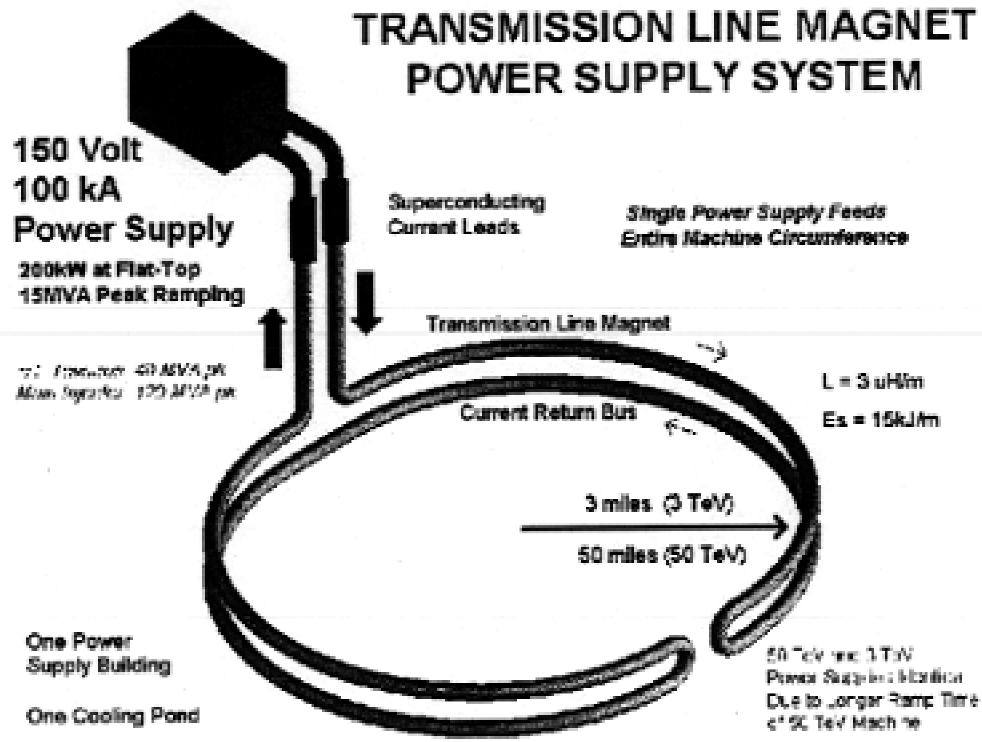
KEY FEATURES:

- 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

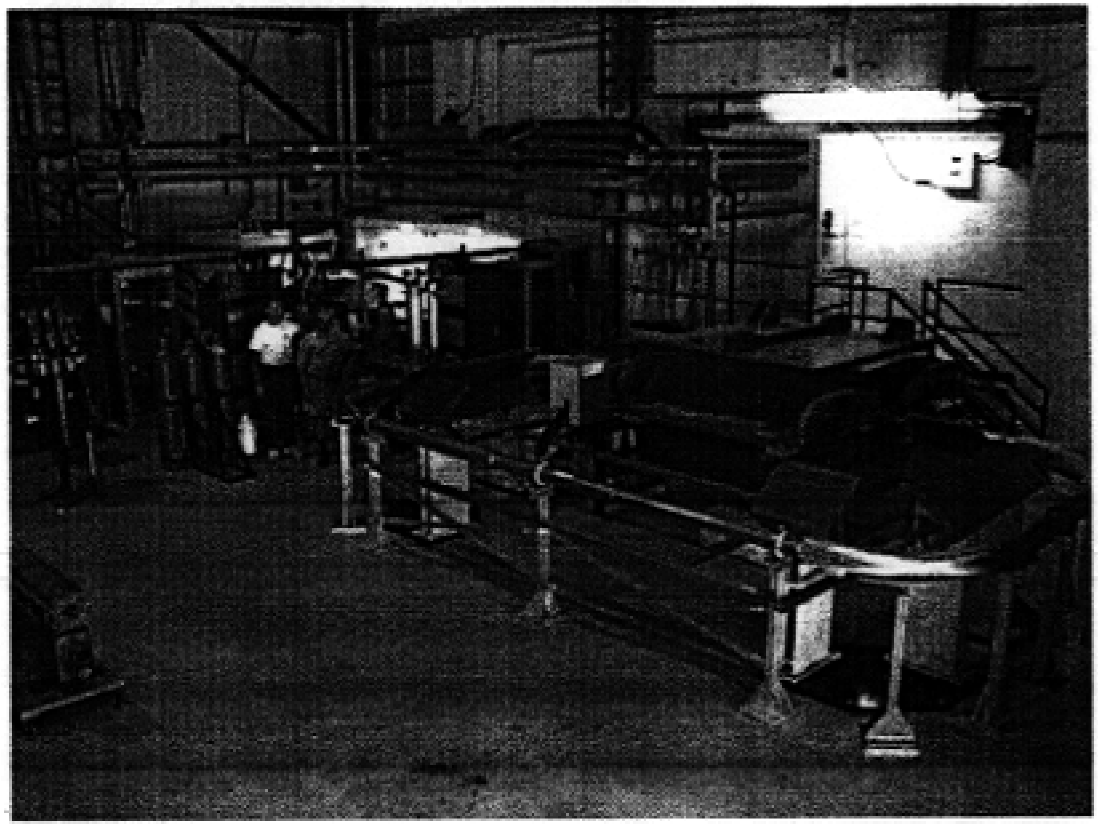
Low Field - Simplified Systems





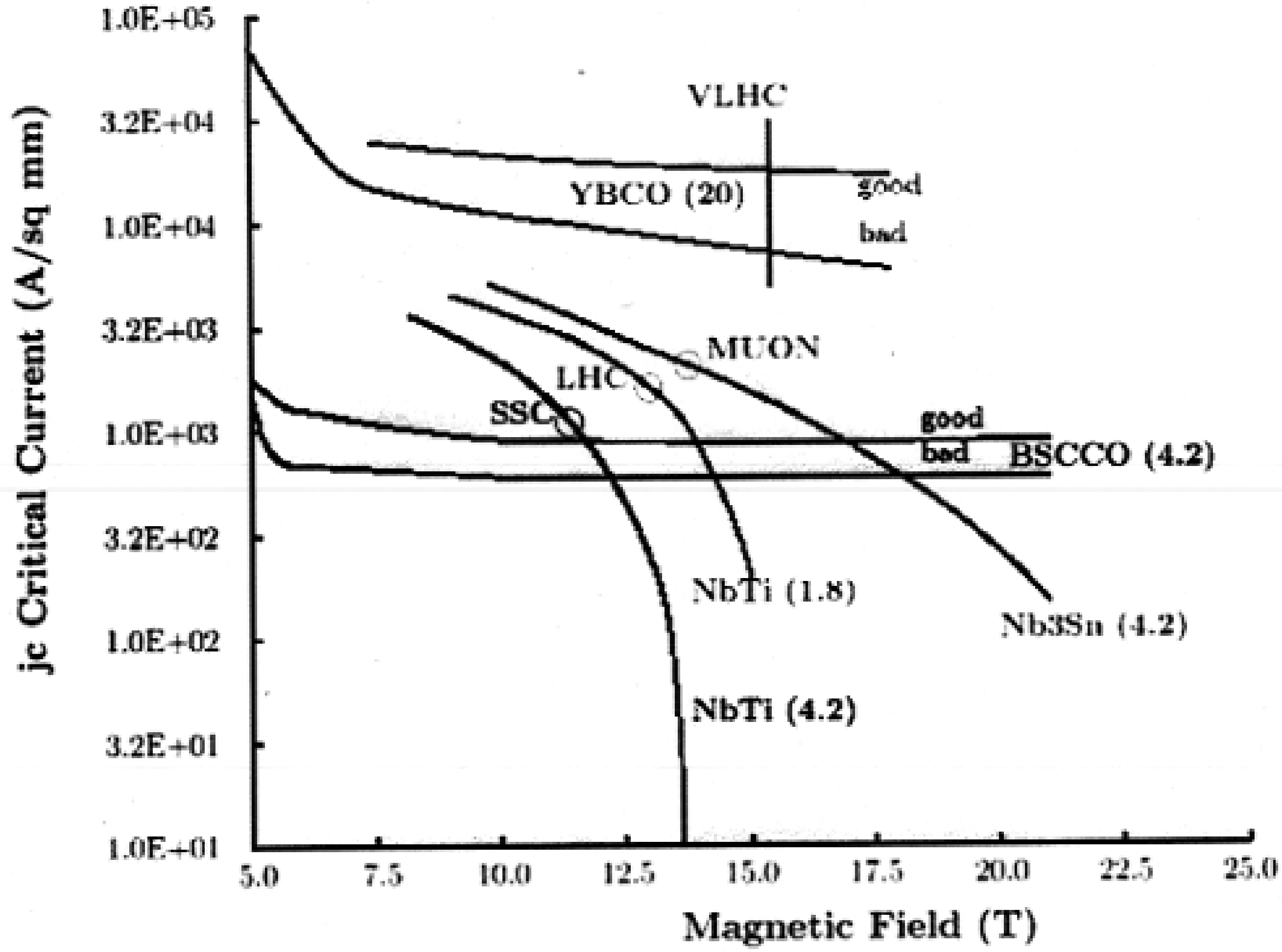


Low Field - Conceptual testing



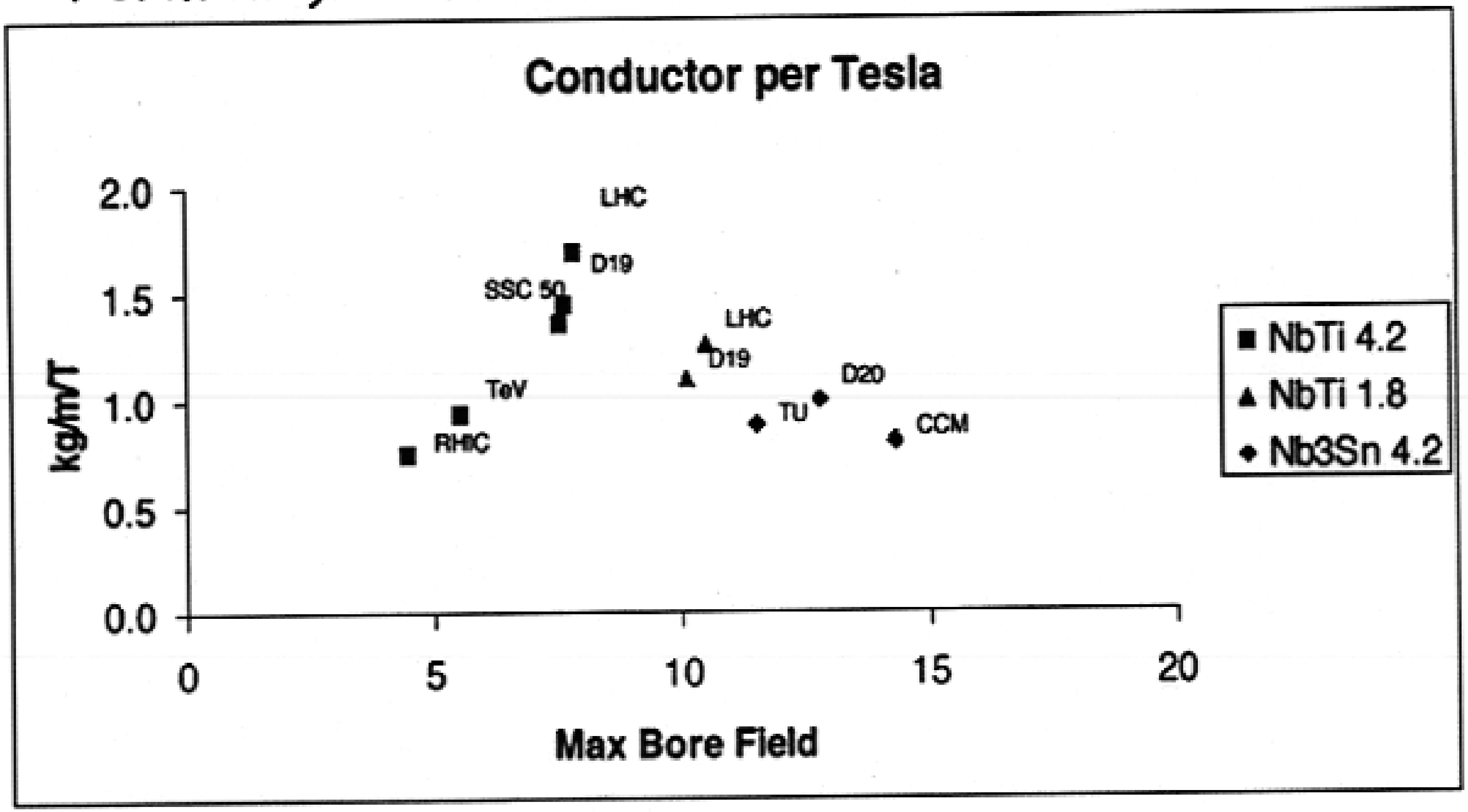
- Transmission line test loop into operation
- Verify cryogenic loads
- Next step - fabricate a long magnet

High Field - Superconductor performance



High Field - Magnet development

- Focus on Nb_3Sn for conductor development (LBL & Fermilab). Difficult material however.

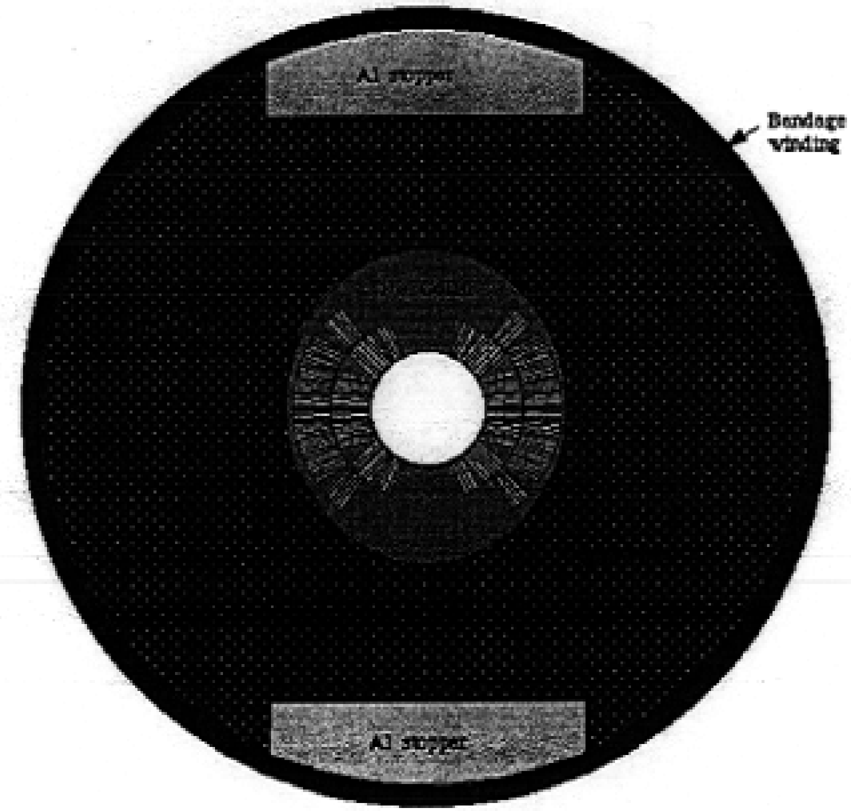


High Field - Magnet Development

Use lessons learned in previous cos θ magnets (mostly NbTi) I.e. focus on the conductor only

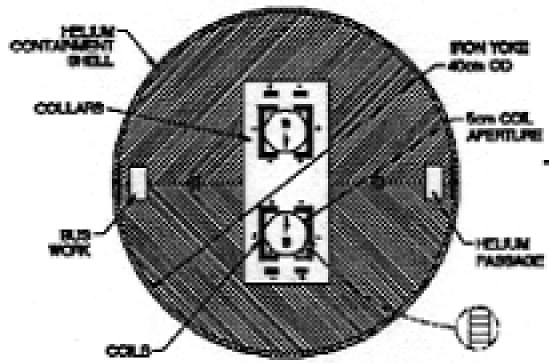
Brittle materials:

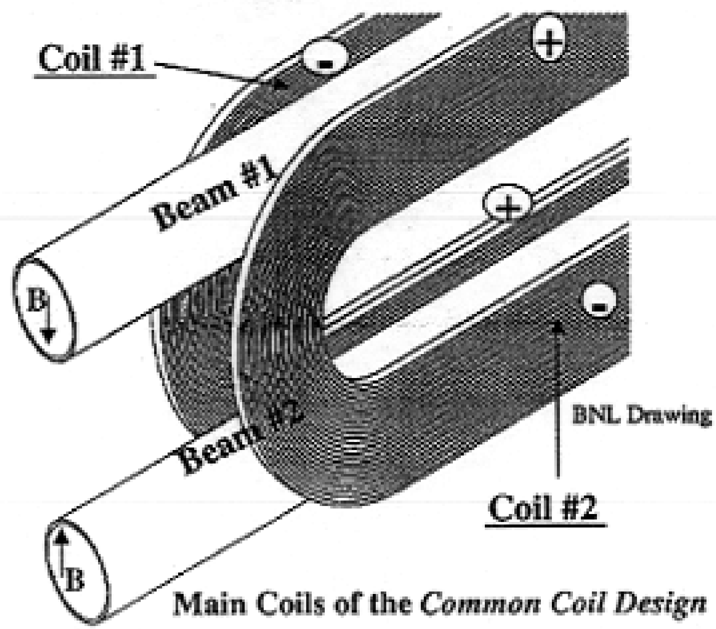
- wind & react vs react & wind
- coil impregnation



Fermilab

High Field - Magnet Development





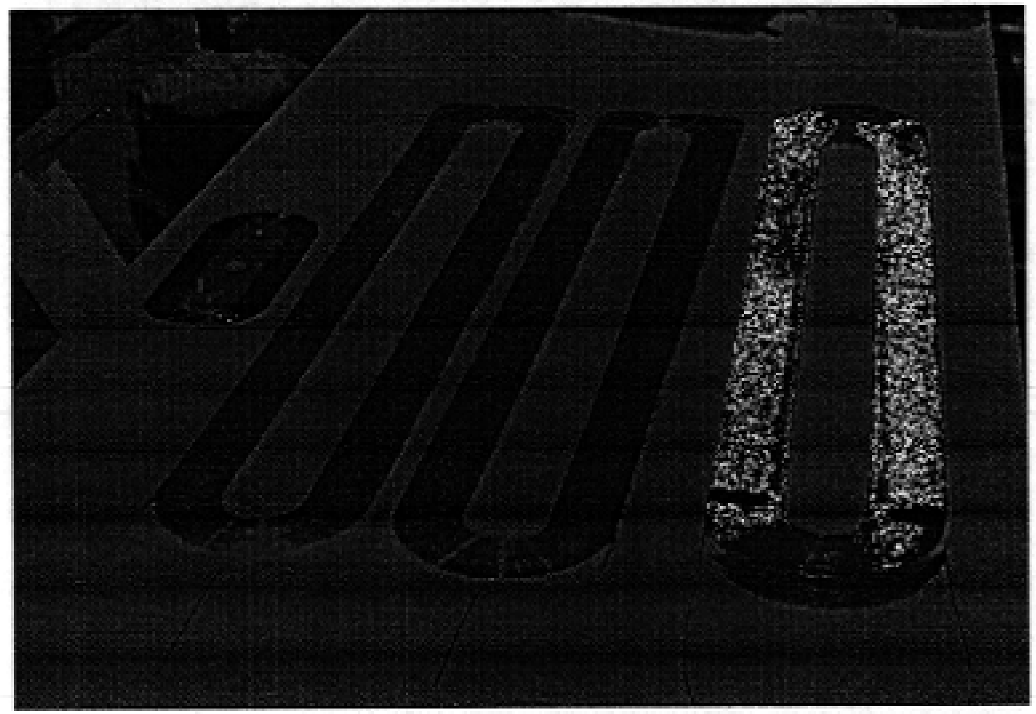
Main Coils of the *Common Coil Design*

Common Coil Design (The Original Concept)

- 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

High Field - Magnet Development

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



Brookhaven

Conclusions - Future Hadron Colliders

- The production of ultra high center of mass energies in a 3rd generation hadron collider would appear to be technically feasible
- There are alternative design philosophies and technologies from those used today
- Technology development to the sophistication necessary for such a facility is a long term process
- It is important to devote a certain amount of resources to a long term R&D effort