

# Supeconducting Magnets at Fermilab

## A Short and Personal History

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June 7, 2017

# 50 Years of Fermilab



# 45 Years of Superconducting Magnets at Fermilab

*“Every superconducting accelerator magnet ever built carries the DNA of a Tevatron magnet”!*

- - Alvin Tollestrup

# The Family Tree

Energy Doubler/Saver/Tevatron 1972-1984

SSC 1984-1991

**The Wilderness 1991-1994**

LHC 1994-2007

VLHC 1998-2003

LARP 2003 - Ongoing

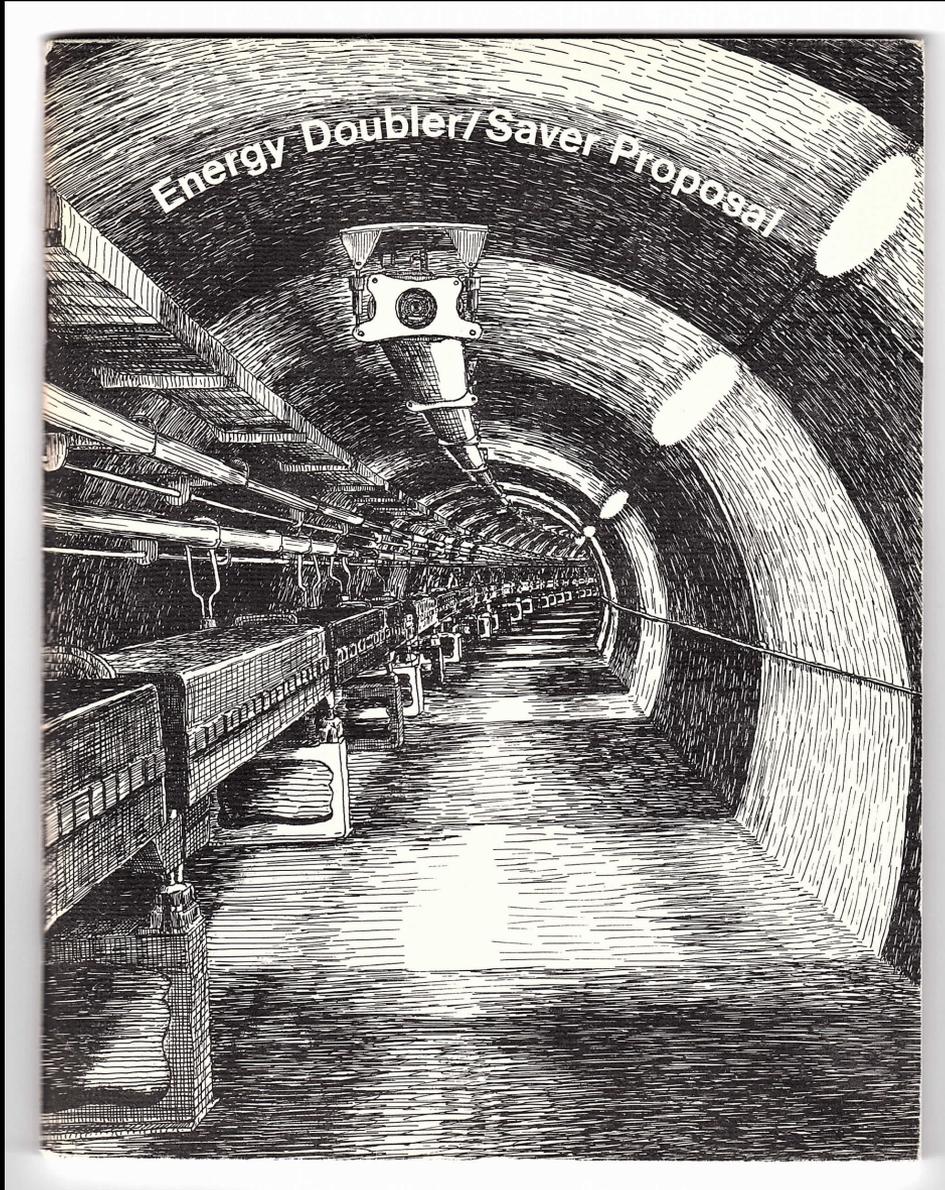
High-field R&D 2003 - Ongoing

Collimation Dipoles

Hi-Lumi Project 2010 - 2020

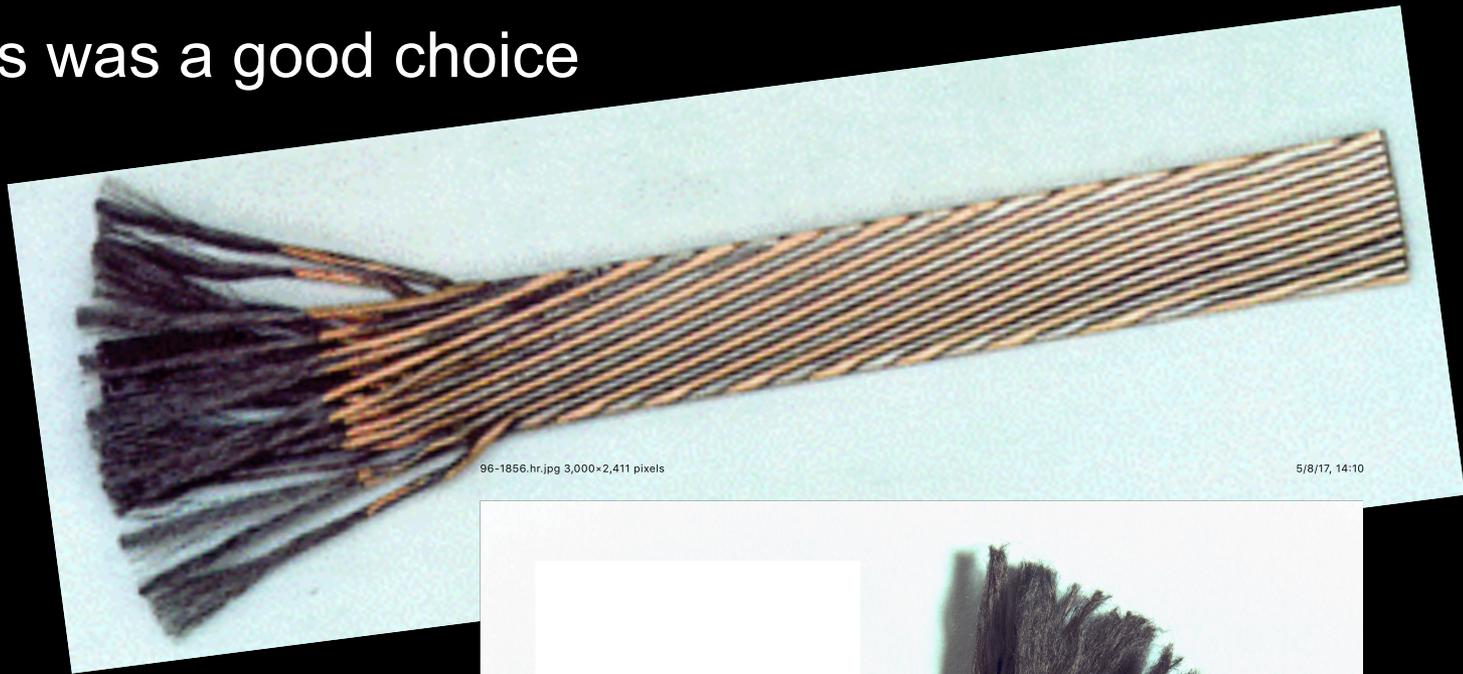
What's next ?

Pre-History  
A Proposal in 1975



63 pages including  
appendices

This was a good choice



An important  
advance:  
Fine-filament  
twisted strand in a  
twisted cable



Early magnet coils were locked in place by banding

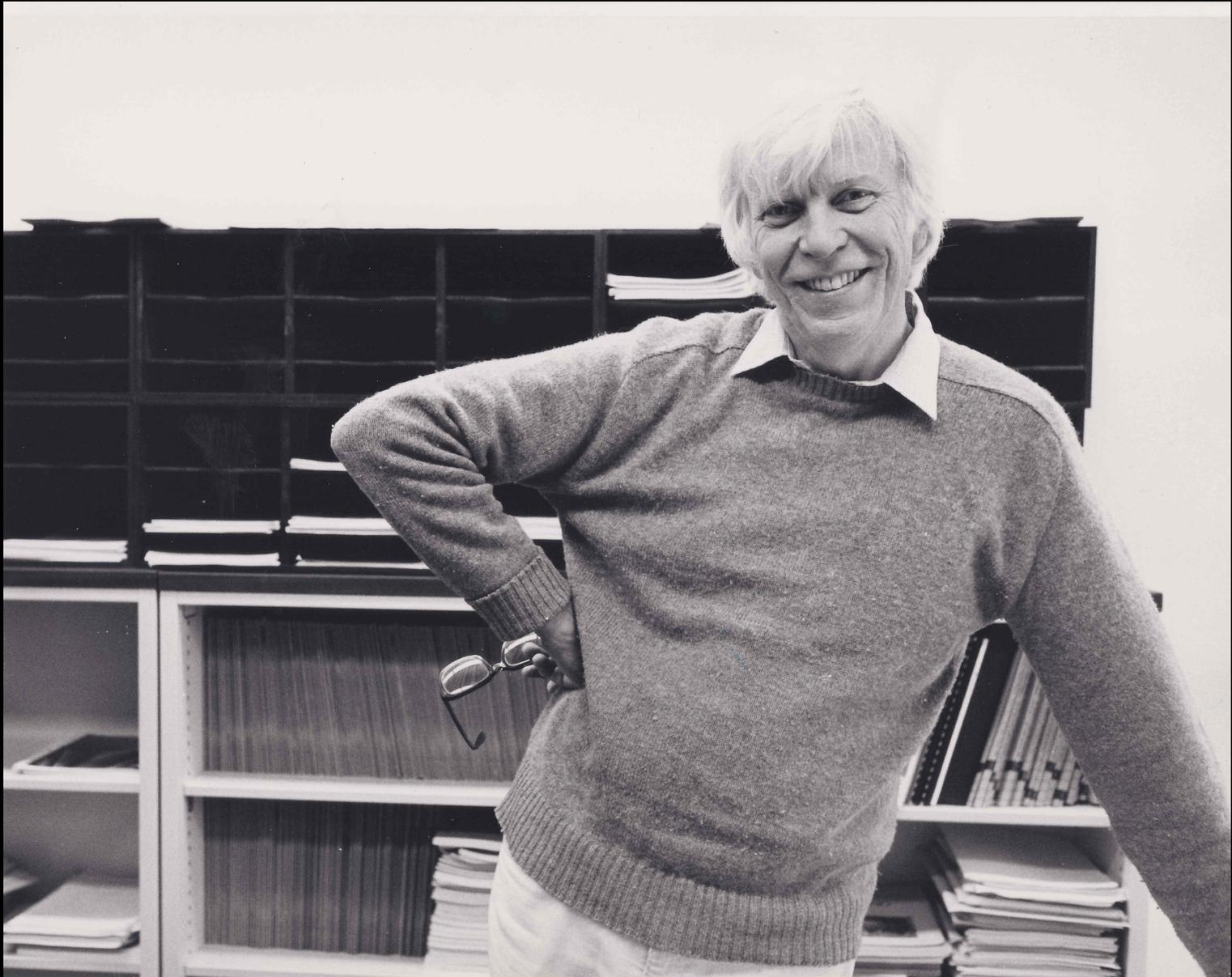
Will Hanson

Bruce Strauss

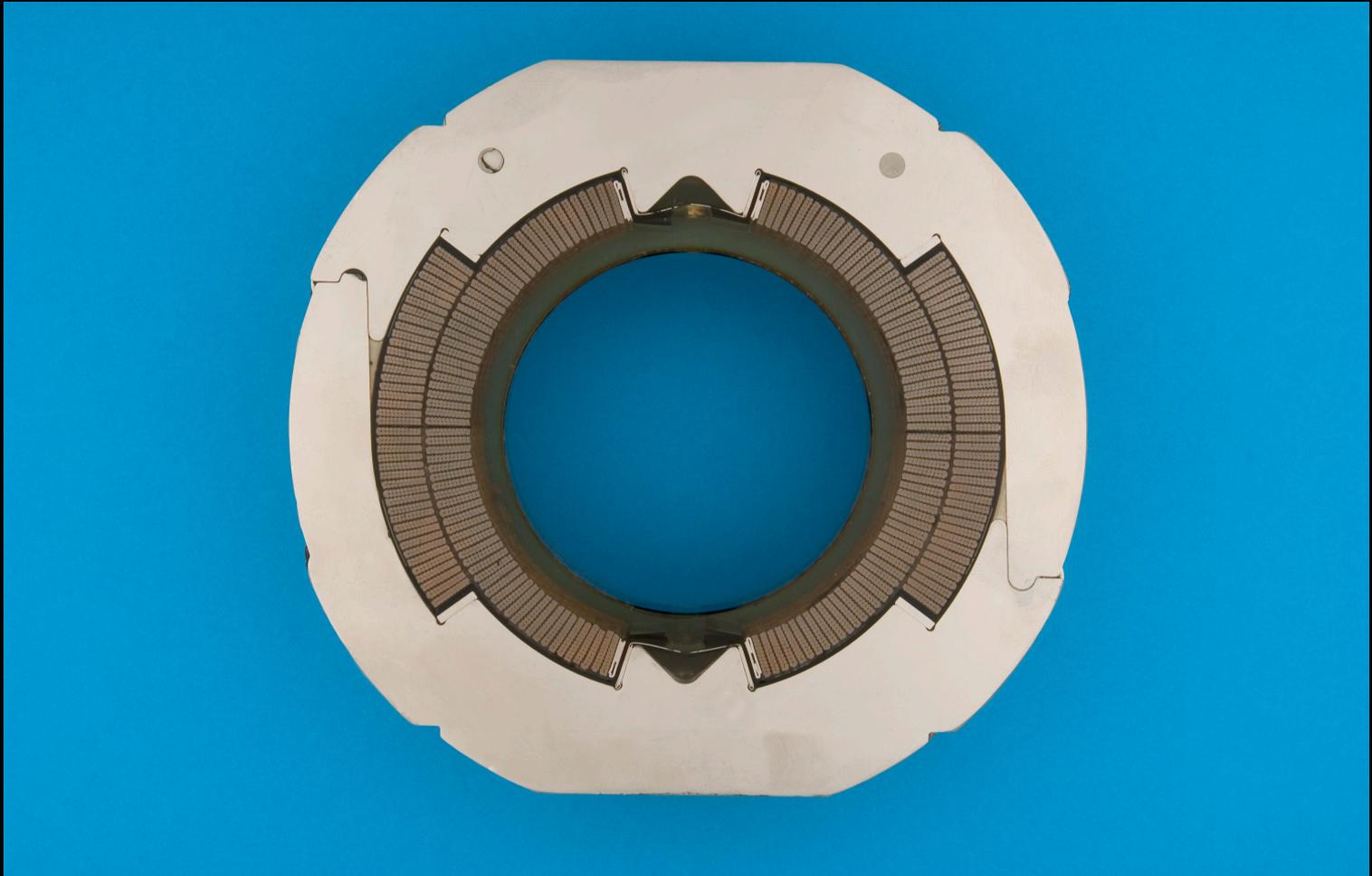


Banded magnets never worked very well.

From out of the West.



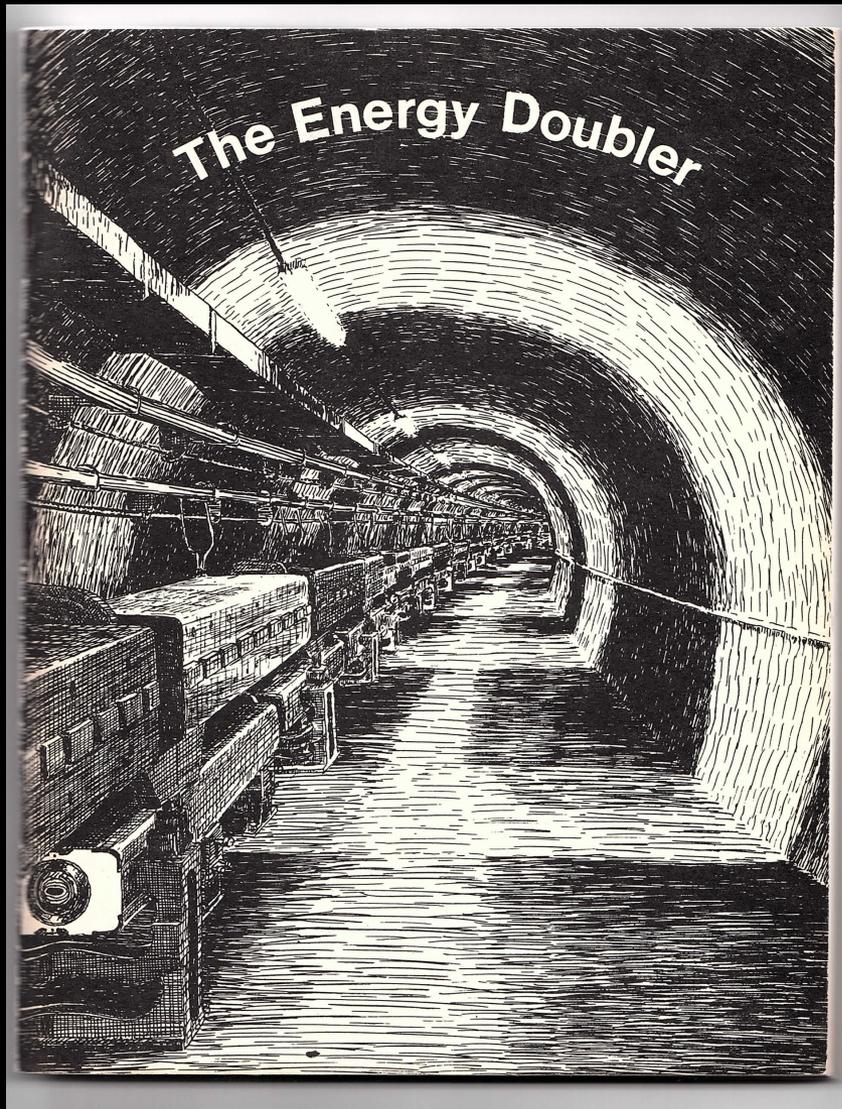
A collared coil



There's no substitute for building and testing lots of models

## Hands on leadership



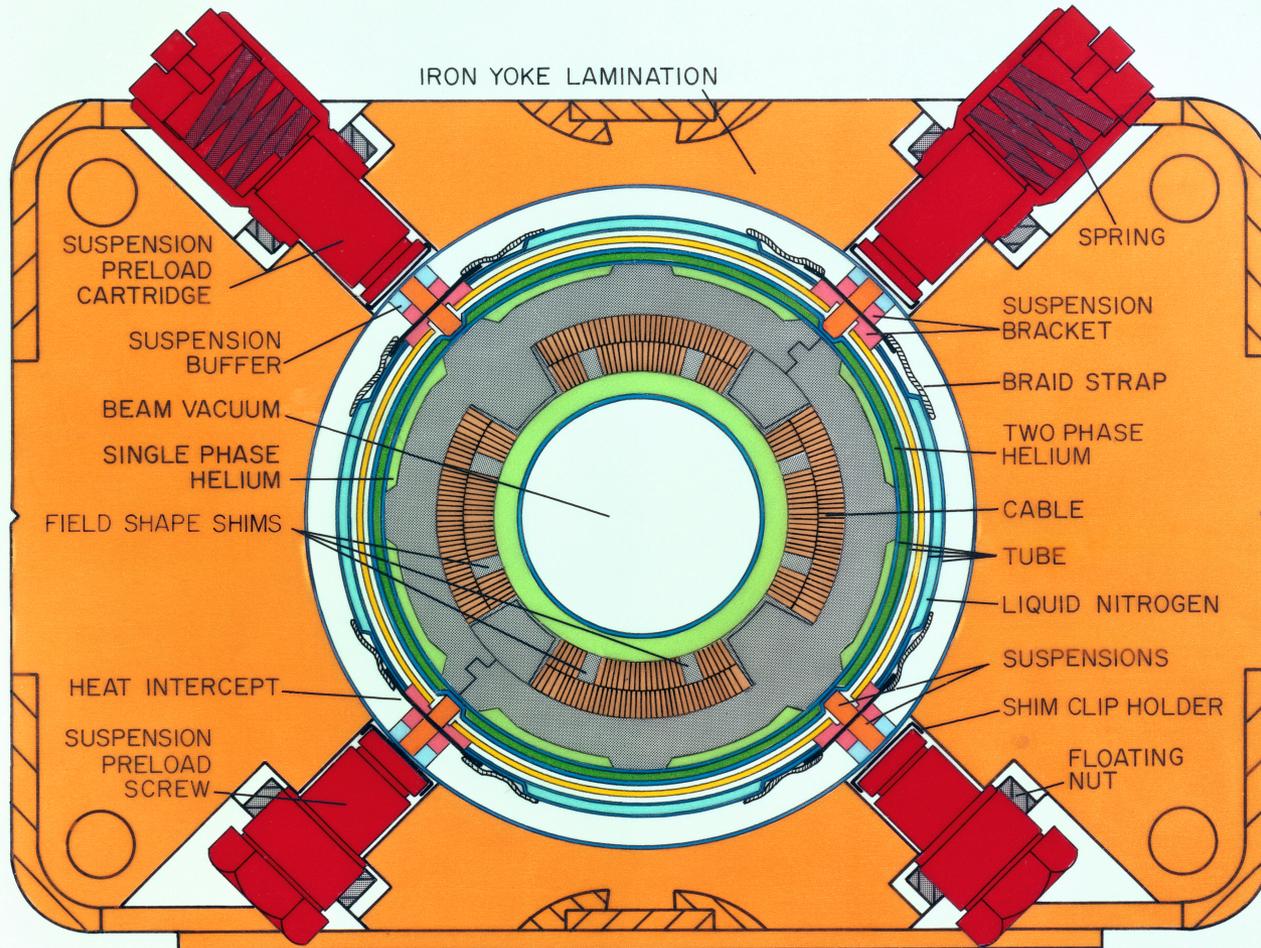


The Doubler has  
moved to its rightful  
place

Real progress. All the way  
up to 173 pages.

Progress Report — 1976

# Smart bolts! What are they?

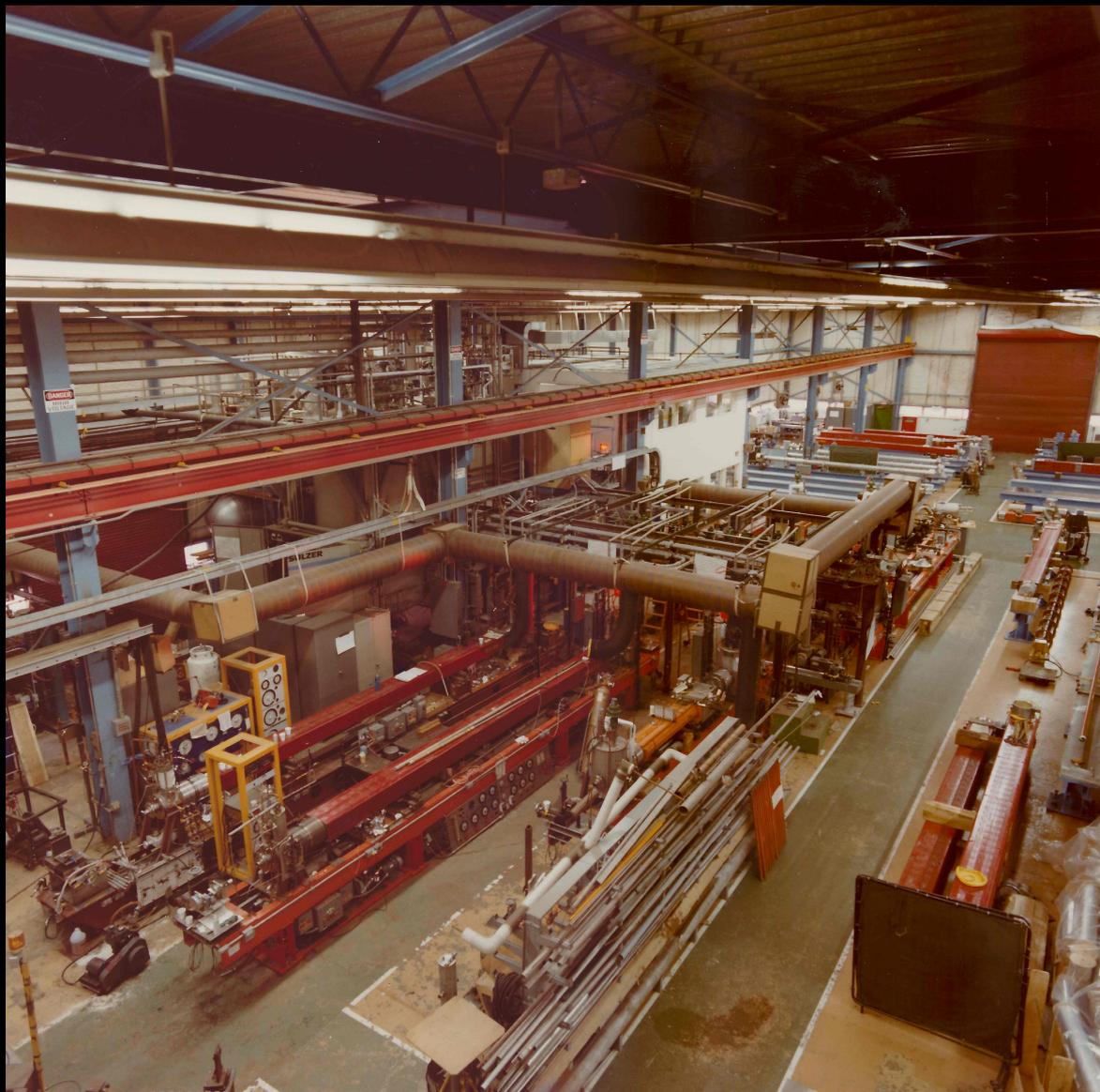


Tevatron Quadrupole



At the peak, we made, tested and measured 13 magnets per week.

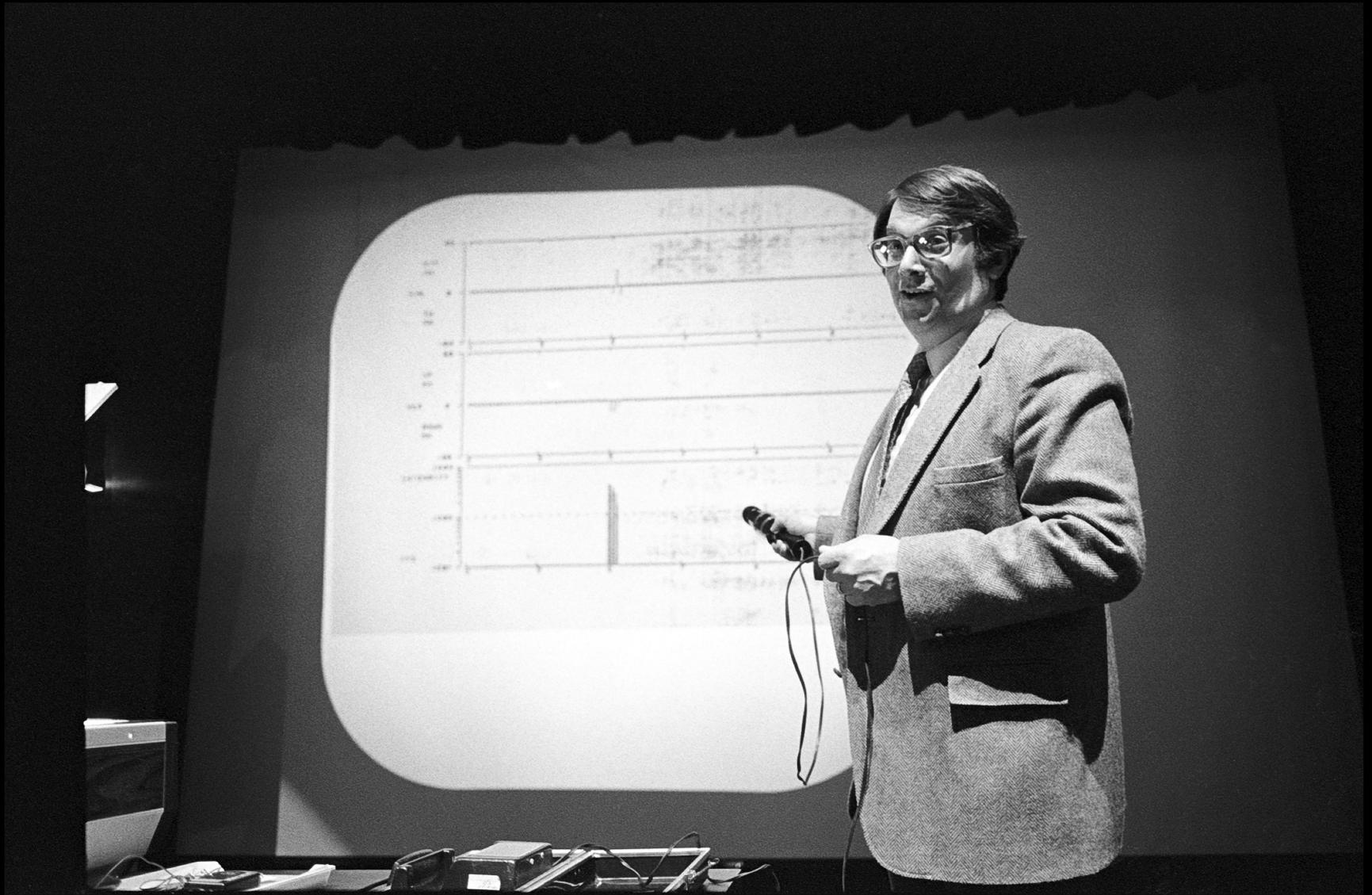
The Magnet Factory at full throttle



Magnet Test Facility



Magnets waiting for installation

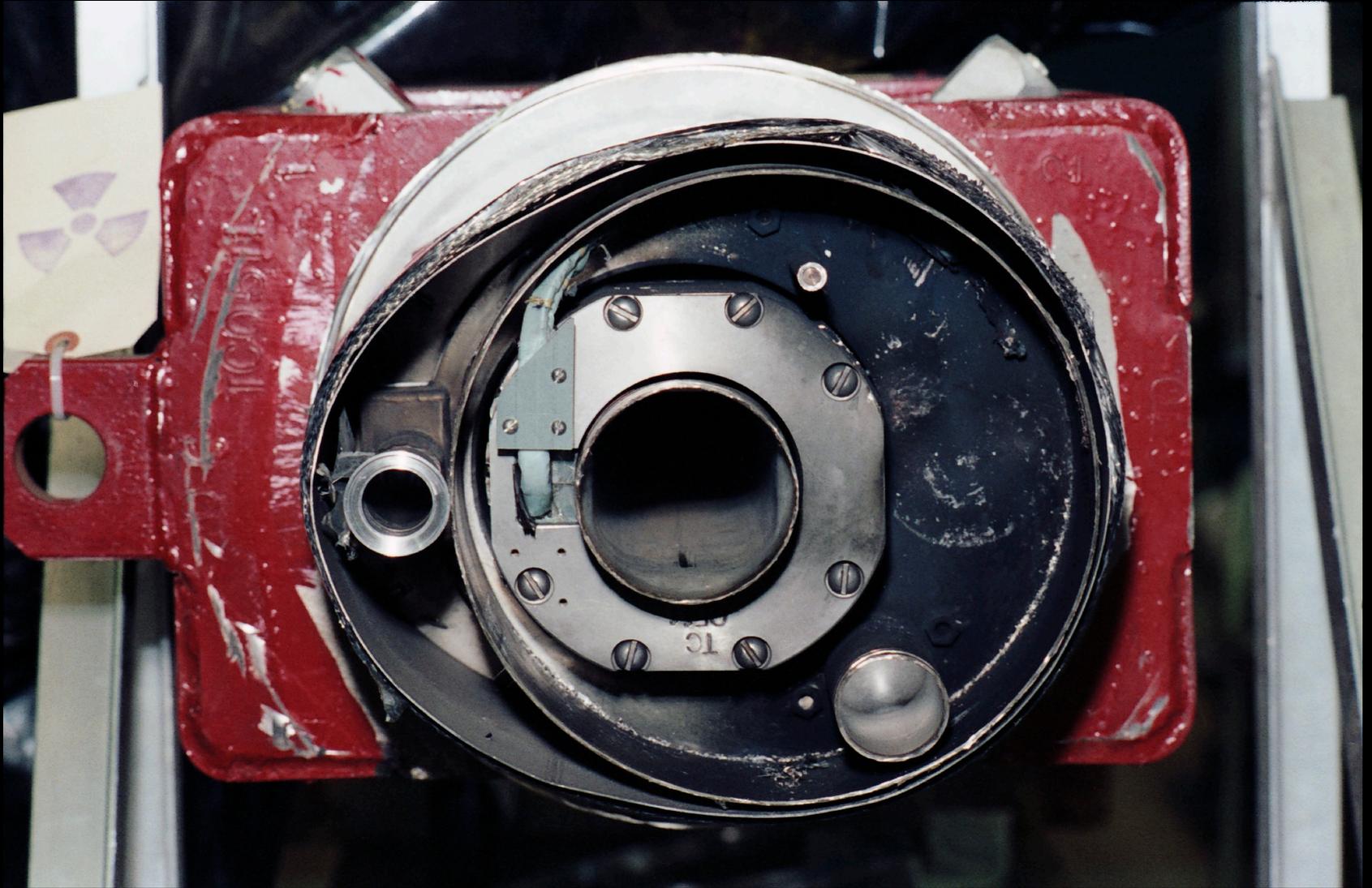


1983 Users' Meeting — 34 years ago





512 GeV! A record!



Small mistakes can lead to big problems

# Presidential Medal of Science!!

Alvin  
Rich  
Dick  
Helen



Moving right along

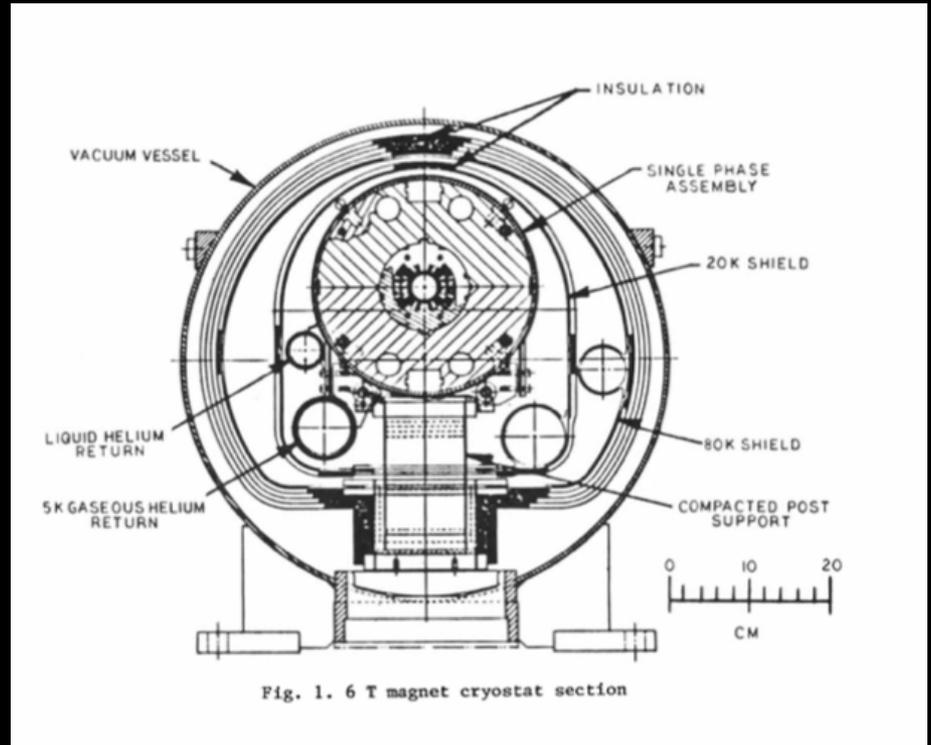
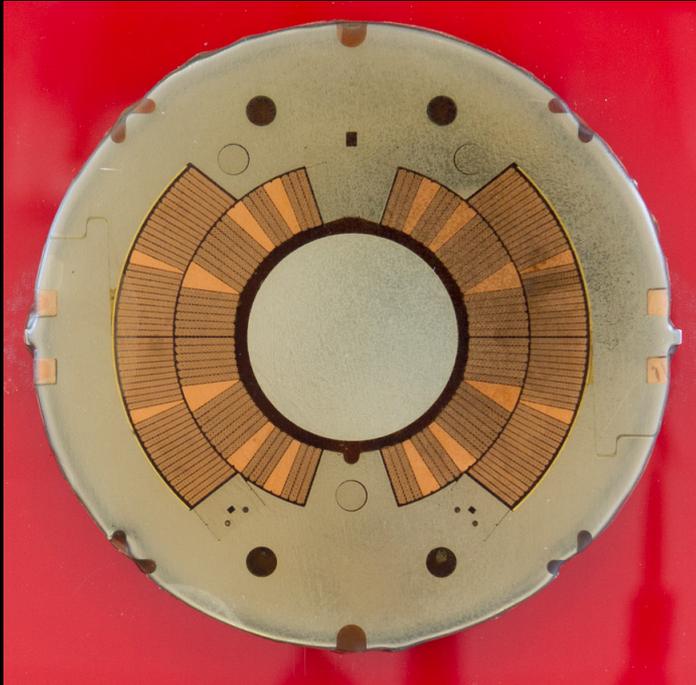
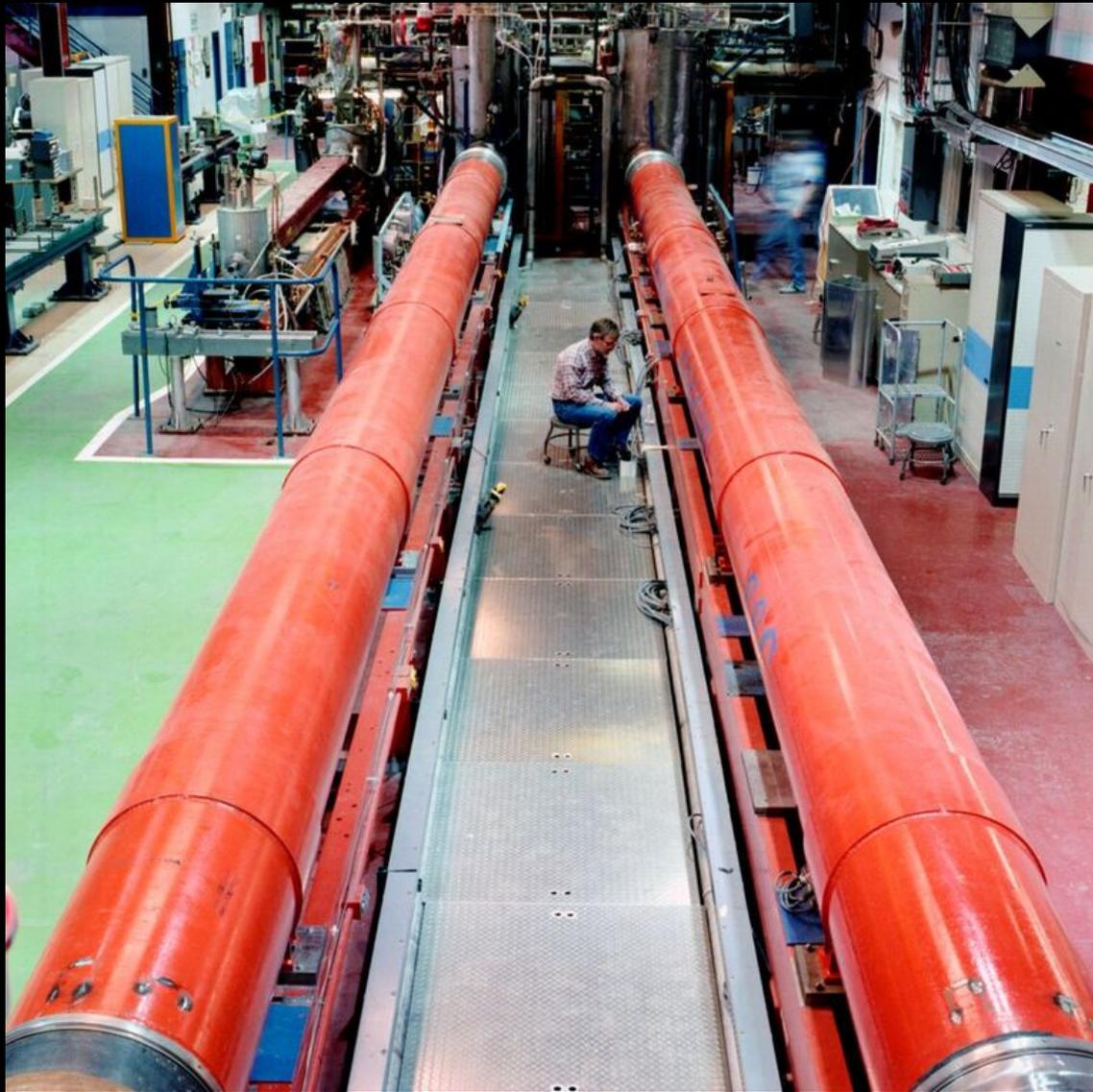


Fig. 1. 6 T magnet cryostat section

SSC Magnet

Fermilab test stands modified for SSC. Note Tevatron magnet





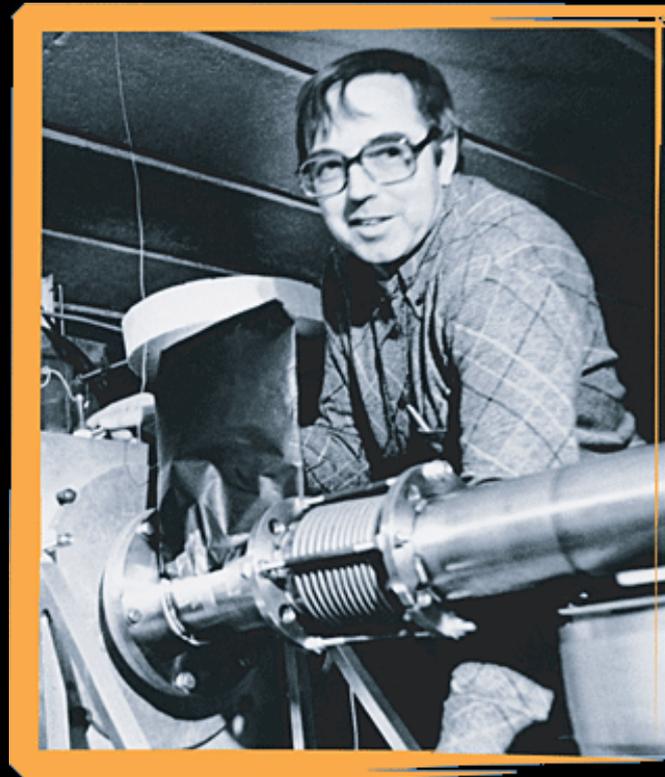
First SSC dipole



Last SSC dipole

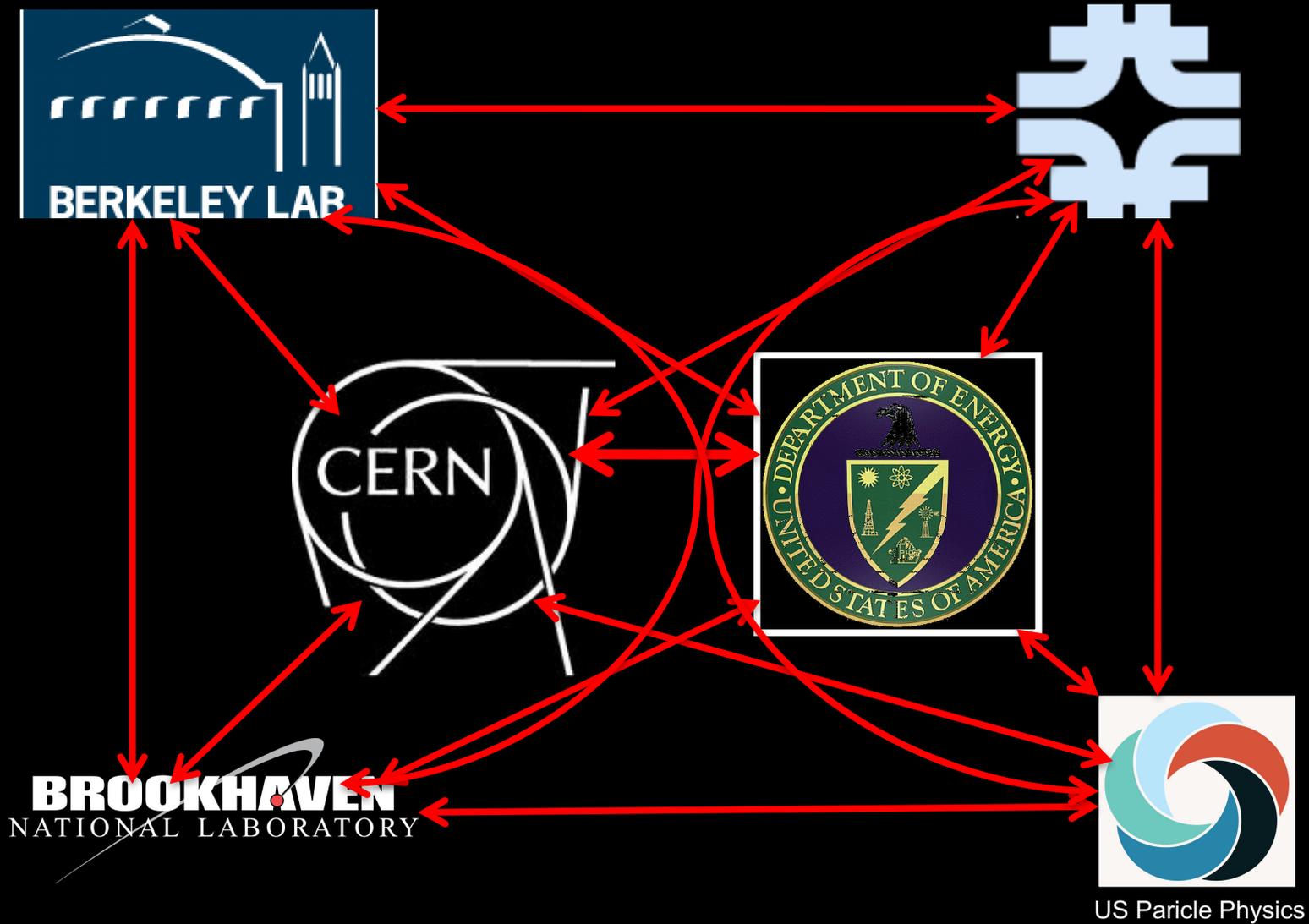
# Fermilab Magnet Program vaporized in 1991

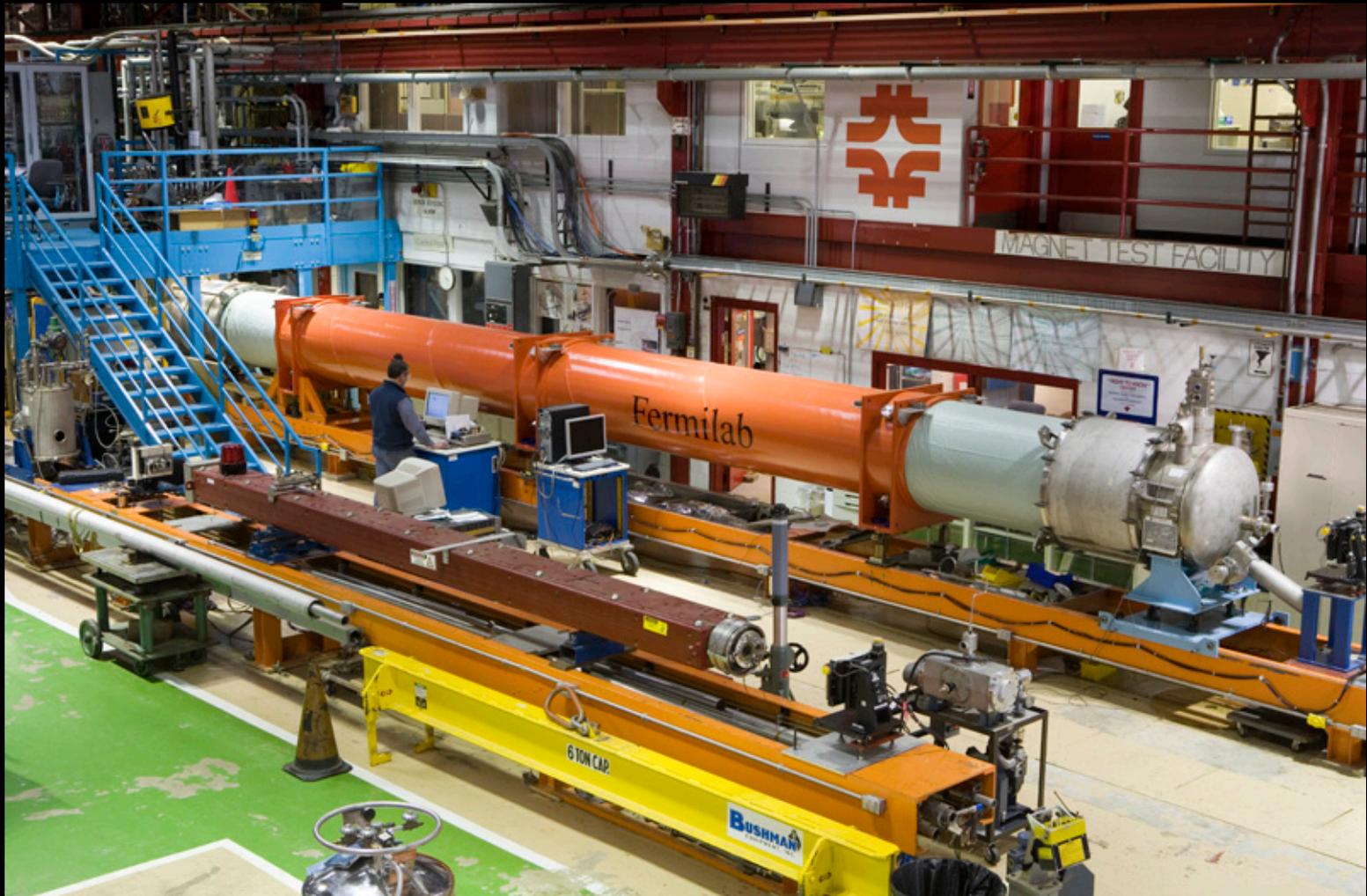
It didn't start up again until the SSC was canceled in 1993.



Tim Toohig

Complex negotiations with CERN, other labs, HEP scientists & DOE

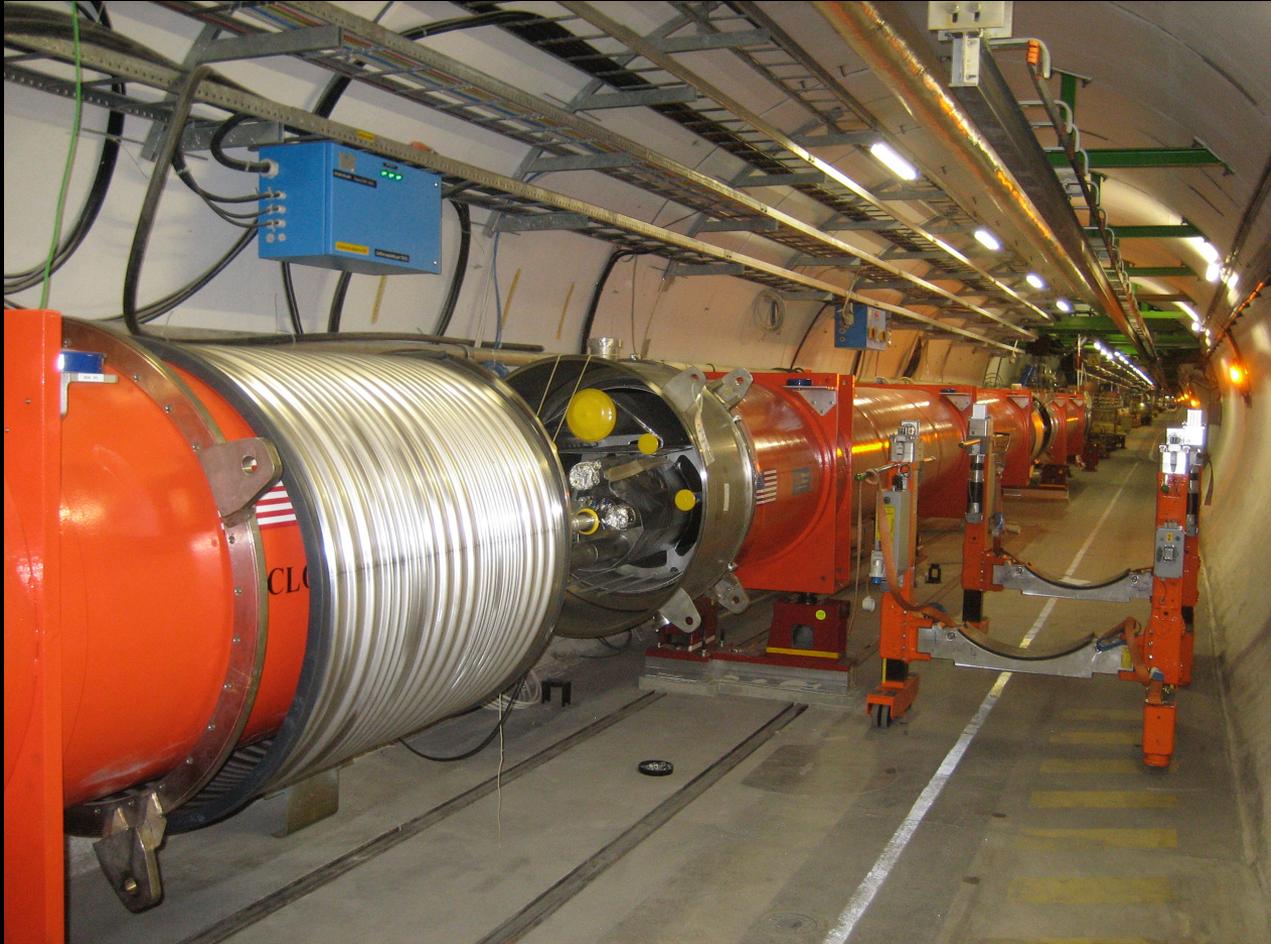




LHC insertion quadrupole on its test stand



LHC inner triplet—warm assembly at CERN



Installation in LHC tunnel



Small mistakes can lead to big problems



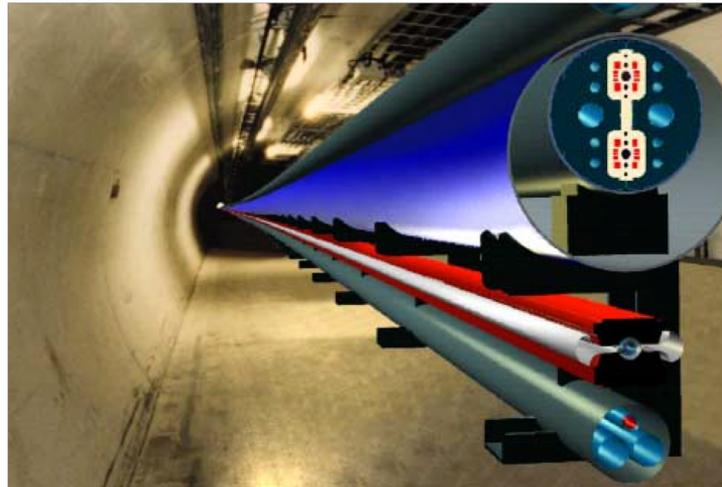
Il marche!



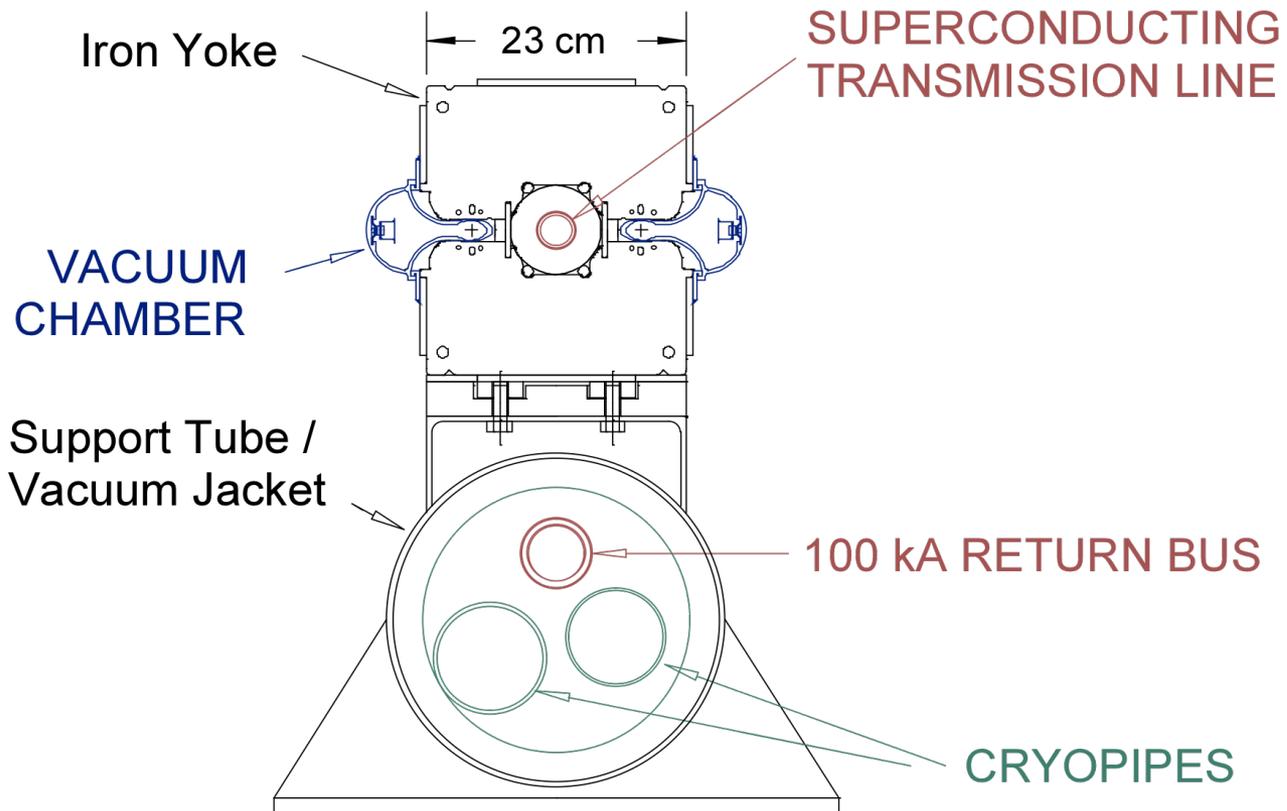
SLAC-R-591  
Fermilab-TM-2149  
June 4, 2001

# Design Study for a Staged Very Large Hadron Collider

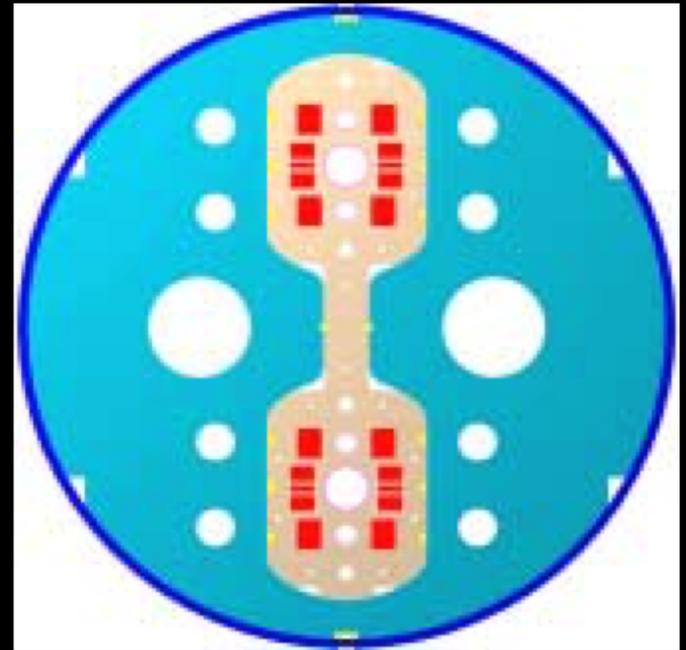
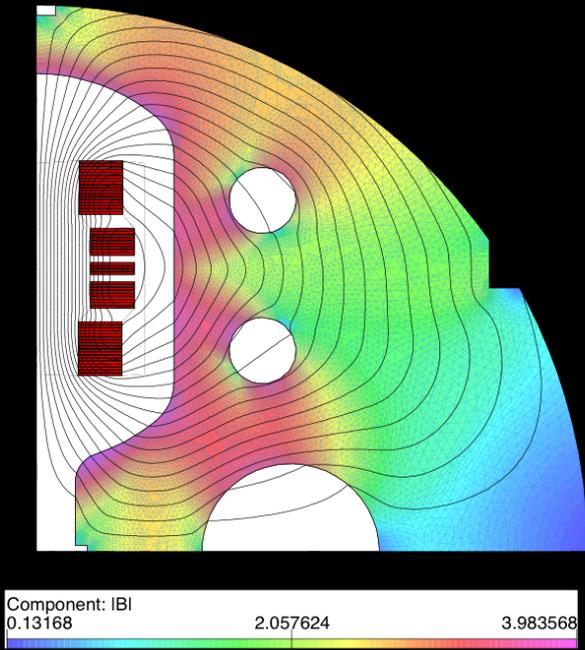
*Report by the collaborators of  
The VLHC Design Study Group:*  
**Brookhaven National Laboratory**  
**Fermi National Accelerator Laboratory**  
**Laboratory of Nuclear Studies, Cornell University**  
**Lawrence Berkeley National Laboratory**  
**Stanford Linear Accelerator Center**  
Stanford University, Stanford, CA, 94309



Work supported in part by the Department of Energy contract DE-AC03-76SF00515.



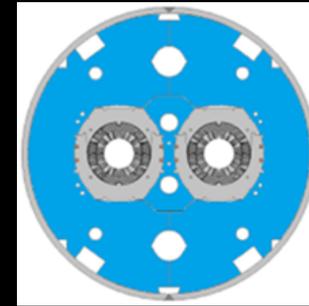
Low-field magnet for a 40 TeV collider



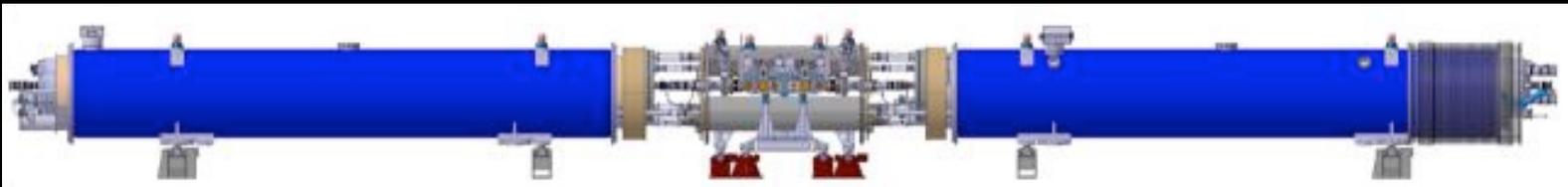
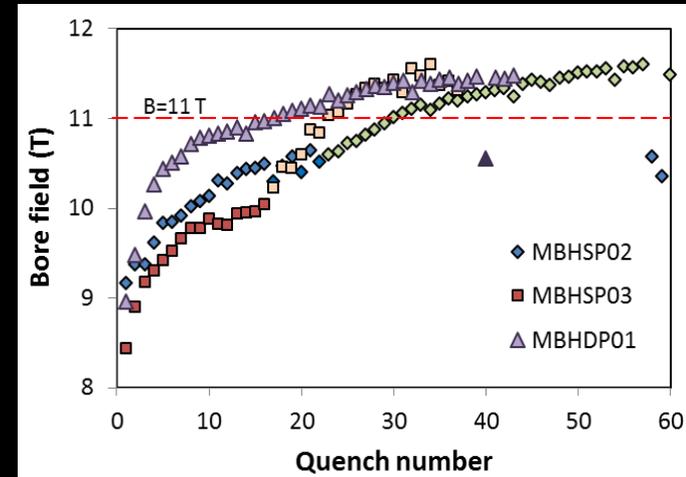
A possible 2-in-1 high-field magnet for a 200 TeV collider

# 11 T Nb<sub>3</sub>Sn Dipoles for LHC upgrades

- Collaboration with CERN on the 11 T dipole for the LHC collimation system upgrade
  - Several models built and tested at Fermilab
  - Including a 1-m long 2-in-1 Nb<sub>3</sub>Sn dipole
- **B<sub>max</sub> = 11.7 T at 1.9 K**
- **Magnet technology was transferred to CERN in 2015**
  - Several models built and tested at CERN
  - 5.5-m long prototype fabrication has started
- **Two units, each with two 5.5-m long 11 T dipoles and a collimator in between, will be produced and installed during LS2 in 2019**
- **This will be the first use of Nb<sub>3</sub>Sn magnets in a real accelerator**



MBHDP01  
60 mm 11 T dipole

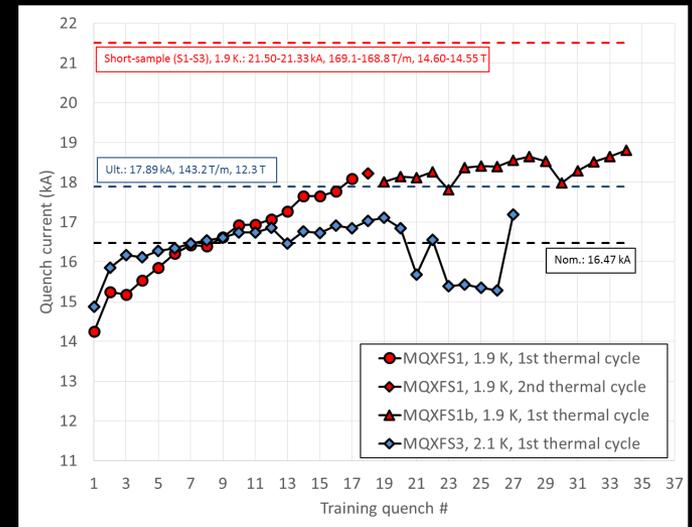


# LARP+CERN: Short Quadrupole Models

- Completion of quadrupole prototypes is the highest priority for LARP
- Identical design between Q1/Q3 and Q2 maximizes collaboration between the LARP and CERN
- 3 mechanical models assembled
- 1 coil tested in mirror structure
- 2 quadrupoles assembled & tested
- Eventually, half will be made by LARP, half by CERN



First MQXF Short Model



# What's Next ?

- As usual, that depends. Does the tunnel already exist, or not?
  - 15 T would result in  $> 20$  TeV at LHC
    - Fermilab's high-field program is starting a 15 T effort
  - On a green-field site, choose an optimum field.
    - Tunnel is cheaper than magnets.
    - Synchrotron radiation becomes a serious problem at very high energy.

# What did we learn in 45 years ?

- Lots and lots of technical knowledge, and...
- Development takes a long time—order 10 yrs
- Continuity is important
- Production capability along with magnet R&D
- Technical management should be technical
- Small errors can lead to big problems
- The whole is greater than the sum of its parts.

# Most Important

Regular people, not very different from you and me, can do spectacular and even heroic things when they work together as a team, with high scientific goals and courageous leadership.