Status/Plans for Technical Division

Marc Ross, Fermilab

April 12, 2007

Technical Division

Fermilab

- **Mission:**

Research, develop, design and build accelerator (or detector) components

To be used here and elsewhere

- **Is one of the lab's 'youngest' divisions**
  - **With a new director (Oct 1, 2006)**
- **Lives in the Industrial Complex (and related outbuildings Village, Meson area)**
- **Supports 'basic' technology;**
- **Owns associated infrastructure**

DoE Labs in the next decade:

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- Expected to become less self-centered
  - Consolidation, cost of energy frontier, time, etc
- More diversified
  - Programmatic orientation
- Broad range of projects – accelerators for varying purposes, non-accelerator physics, other disciplines, tech transfer
- Capitalize costly infrastructure investment leverage
- Concept of ‘core competency’
  - Allows a team of labs respond to a ‘DOE mission need’ across a broad front without start-up development costs
  - (SNS) (ILC)
- Competition among labs for projects
  - Fermilab must choose its technical ‘core competency’

Multi-national programs

Fermilab

- **ILC, XFEL, ITER, FAIR are (will be) examples of accelerator-related projects with international governance**
  - **This will be tough**
  - **Not CERN**
- **Typically:**
  - **Governing council**
  - **Top level leadership as we know it**
  - **Mid-level leadership with inter-regional balance**
  - **More deliberate decision making process**
- **I sense an invigorating 'force of will' to overcome cross-cultural obstacles**

LHC final triplet

- **Example multi-lab, multi-national project**
- **Because of internal support failure, now a focus of extensive scrutiny**
- **Directorate statement:**

- We can find no evidence that the longitudinal loading was ever raised in an issue in the (four) design reviews.
- ANSYS calculations completed independently by Fermilab and CERN on 3/28 show that the G-11 support structure is well beyond shear strength at 20 bar.
- The Director will be setting up an external review to identify how our management and engineering practices allowed this to happen, and to suggest changes to prevent recurrence.
  - This will start up after we have fixed the problem

- **Is the 'new' governance paradigm an issue?**

Reviews & Reviews

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- Two kinds of ‘reviews’ apply to Fermilab (and other) projects:
  - Short ‘subject matter expert’ ~2 days
    - May or may not ‘catch’ omissions or mistakes
    - Depends critically on the obligation (charge) made to the reviewer
    - And review team leader
  - Longer ‘safety committee’ sign-off
    - Principles applied
    - Each and every key computation checked, re-done.
- Industrial vs. Lab process
- Paper by Gus Voss:
  - http://cern.ch/AccelConf/p95/ARTICLES/FPD/FPD01.PDF

What TD does…

- **Background:**
  - Tevatron magnets built/serviced TD complex
  - (SC magnet infrastructure decommissioned during SSC)
  - Large detector development (SDC, CMS)
  - Rebirth of SC magnet center
    - Tev Ops, LHC, HFM
  - Cu magnets for Operations
- **Now:**
  - Nb3Sn for LHC / LARP
    - Fermilab TD is a center for Nb3Sn technology
  - SC RF for proton / electron linacs
- **Future:**
  - 2 core competencies: SC RF / SC Magnets

TD Departments:

Fermilab

- Magnet
- Superconducting RF
- Test and Instrumentation

- Material Control
- Design/drafting – Information systems
- Machine Shop
- Support

TD staff

Fermilab

- Shifted FTE's from support to scientific roles in the past 6 years within the scope of the lab funding situation

TD Staff categories	2000	2006
Scientists / Engineers	60	72
Computer / CAD	25	24
Technician / Machinist / Weld	130	106
Admin / Safety	16	15
TOTAL	231	217

Magnet Systems Department (MSD)

Fermilab

Our Mission:

- **Provide support for the Fermilab Accelerator complex**
  - repair or refurbish existing accelerator components
  - design, fabrication and test oversight of new devices
- **Develop, evaluate and improve technologies for future accelerators**
  - development of new technologies in the area of superconducting and other structural materials and components;
  - magnet design, analysis and fabrication; testing and measurement planning, conduct, and data analysis; magnetic measurement instrumentation..
- **Provide QA/process control and document management services to the division**

Fermilab has a long history of magnet R&D

Fermilab

- **Notable projects include:**
  - **Tevatron dipoles and quadrupoles and correctors**
  - **SSC dipole magnets**
  - **Main injector magnets; Recycler magnets**
  - **VLHC pipetron and HFM magnet**
  - **SC IR quads FNAL/LHC**
  - **Nb3Sn model dipoles and quads for LHC upgrades**
- **We have the personnel and infrastructure for all phases of magnet design, fabrication, test oversight, magnetic field probe development and data analysis**
- **All types of accelerator magnet projects:**
  - **Superconducting/resistive/permanent**
  - **Model magnet R&D, full scale production….**

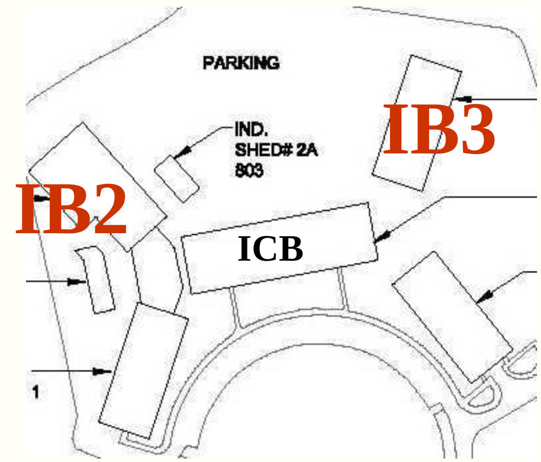
Experienced Staff with Unique Skills

Fermilab

- Physicists and engineering physicists (13)
  - SC/Resistive Magnet development, project management
  - Magnet testing & data analysis
  - quench and thermal processes, SC conductor properties
  - Magnetic probe development
- Engineers (11)
  - Magnetic, Mechanical and Thermal Design (ANSYS, OPERA....)
  - SC conductor characterization, instrumentation development
  - Production and Tooling
- Technicians (33)
  - Specialized in conventional and superconducting magnet fabrication
  - Seasoned, "Tunnel trained" for in situ magnet repair and accelerator shutdown work
- Guests and graduate students (3)

Magnet Facilities

- **IB2 Conventional Magnets**
  - Full service conventional Magnet fabrication facility
  - Tevatron magnet repair
  - Small SC magnet construction
- **IB3 SC Magnets**
  - NbTi, Nb3Sn, also HTS and Nb3Al magnet R&D center
  - SC magnet tooling recently consolidated into this one building
  - Two magnet fabrication lines: short (up to 2m) and long (up to 6m)
  - Recent addition: 6 m reaction oven for full scale Nb3Sn coils
  - 42-strand cabling machine



INDUSTRIAL BUILDINGS

- **SC R&D (SW corner ICB)**
  - 17 T and 15 T solenoids, probes and setups for SC strand and cable characterization

Magnet Programs

Fermilab

Fermilab has a diverse accelerator magnet program to support the HEP accelerator initiatives well into the next decade:

1. *Fermilab Accelerator Complex*
2. *ILC*
3. *LHC Accelerator*
4. *Muon Collider*
5. *Material research*

Support of the Fermilab Accelerator Complex

Fermilab

Accelerator (fixed target booster and main injector) program will run at least into the mid- 2010's

Upgrades to the accelerator for

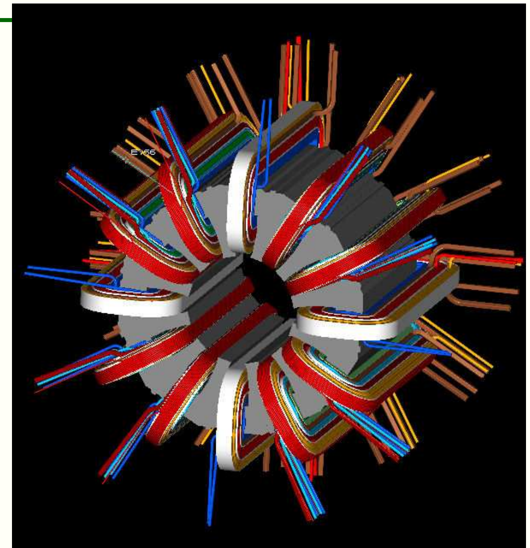
- Accelerator and NuMI Upgrade (ANU) portion of NovA
- Superbeams to NuMI (SNuMI)
  requires several systems of magnets and kickers
  e.g., Booster corrector magnets

Future direction of the lab….

- 6 GeV ILC injection line (more magnets and kickers)
- HINS (SC solenoids being developed now)

Ability to adapt as needs require and support multiple projects

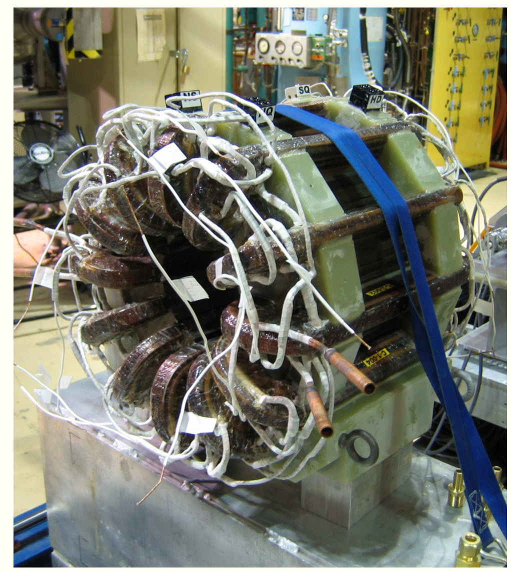
New Booster Corrector Package



- Horizontal dipole
- Vertical dipole
- Normal quadrupole
- Skew quadrupole
- Normal sextupole
- Skew sextupole

- Increase strength
- 15 Hz
- 1 ms peak to peak
- 48 magnets + spares

- Install 2007, 2008



ILC Accelerator Magnets

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Active Program, regardless of construction start date

- As with the RDR, TD will play a central role in EDR including magnet design, prototyping, testing and cost estimation (through early 2010's)
- Major role in development on Main Linac Quads
  - First R&D; then integration into cryomodules
  - As construction nears: final design, production (in industry) and test (here) then installation and commissioning
- IR magnet design and integration. This is a large project that will require multi-lab involvement through the life of the project
- Near construction time, TD scientist and engineers will be required to act as project managers for magnet production systems in the US

LHC Accelerator Magnets

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LHC accelerator support continues throughout 2010's in support of US LHC HEP program

- Support the existing "US deliverables" now being installed (especially during commissioning)
- Nb_3Sn IRQ short model R&D and full scale quad prototypes for IR upgrades (now till ~2010)
- Develop quad or dipole designs and prototyping actual luminosity upgrade magnets (through mid 2010's)
- We hope to position ourselves to be a major contributor to the production of those luminosity upgrade magnets (middle 2010's)

Muon Collider

Fermilab

As longer time scale effort, muon Collider R&D could greatly increase over the next 15 years, particularly if muon cooling can be demonstrated

- Fermilab is planning to build full scale helical solenoid for 6D cooling demonstration experiment MANX (the present through 2010)
- Magnet R&D for HTS solenoids, collision ring and IR magnets as well as design of cooling channel helical solenoid suitable for practical Muon Collider design (the present and well beyond 2010)
- Effort will be coordinated through the Fermilab muon program, as well as international collaboration for muon colliders and neutrino factory. It will involve a broad collaboration of DOE magnet laboratories.

Material R&D

Fermilab

In support of all of the above magnet programs we will continue to have an active materials research program

- Improving the properties of now-available materials such as NbTi and Nb3Sn.
- New materials such as Nb3Al and different HTS materials continue to improve, and will be needed for higher field/higher mechanical stress or higher temperature applications (such a very high field HTS solenoid)
- This work is done in conjunction with superconductor vendors and university collaborators
- Other material R&D interests:
  - SC cables for accelerator magnets
  - Ceramic Insulation for Nb3Sn and Nb3Al magnets
  - Radiation-hard Insulation materials and components

SRF

Fermilab

- Infrastructure developed over 20 years (CERN, DESY, KEK, Cornell, JLab…)
- Fundamentals
- Design
- Material controls, Mechanical / Chemical processing, Testing
  - Vertical test is the equivalent of 'short sample cable test'
  - Vertical testing is coming to Fermilab in mid-07
  - Diagnostic innovation required!

SRF Development Department

Fermilab

- **Technical department devoted to the R&D, development, production and industrialization of Radio Frequency components (conventional and superconducting) for use in High Energy Physics applications.**
  - **Rich history based on:**
    - **NLC achievements (first 65 MeV/m cavities)**
    - **3rd Harmonic Contributions**
  - **Present applications**
    - **ILC**
    - **HINS**
  - **~10 years future**
    - **Muon Collider**
    - **…**

SRF Department Core Competencies

Fermilab

- (S)RF Cavity and Power System design know-how
- Strong Mechanical and Cryogenic engineering skills
- Scientific know-how on Cavities and Power system testing
- Tight-loop interplay between Mechanical/Cryogenic engineering, Testing/Analysis results and (S)RF design tasks.
- In-house chemical capabilities for SRF applications
- In-house capabilities on beam dynamic studies (with APC)
- Operational and Safety excellence

SRF Major Existing/planned Infrastructure

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- General
  - Chemical Lab
- Project Specific
  - ILC CAF (MP9)

- Planned:
- Project Specific
  - ILC-CAF (ICB)
  - HINS CAF (ICB)
  - Large Scale Chemical Facility (?)
    - 9-cells cavities/Spoke Resonators at R&D level
  - Larger Scale Chemical Facility (?)
    - 9-cells cavities/Spoke Resonators at Production level

Test and Instrumentation (T&I) Vision

Fermilab

- To be a flexible world-class test facility for R&D and small-scale production testing of both accelerator magnets (conventional and superconducting) and accelerator SRF cavities.
- To support the development of Instrumentation technologies for test facility systems and Technical Division deliverables.

T&I Core Competencies

Fermilab

- Magnets and SRF cavities testing know-how
- Instrumentation technology development expertise
- Operational and Safety excellence

T&I IB1 Major Existing Infrastructure

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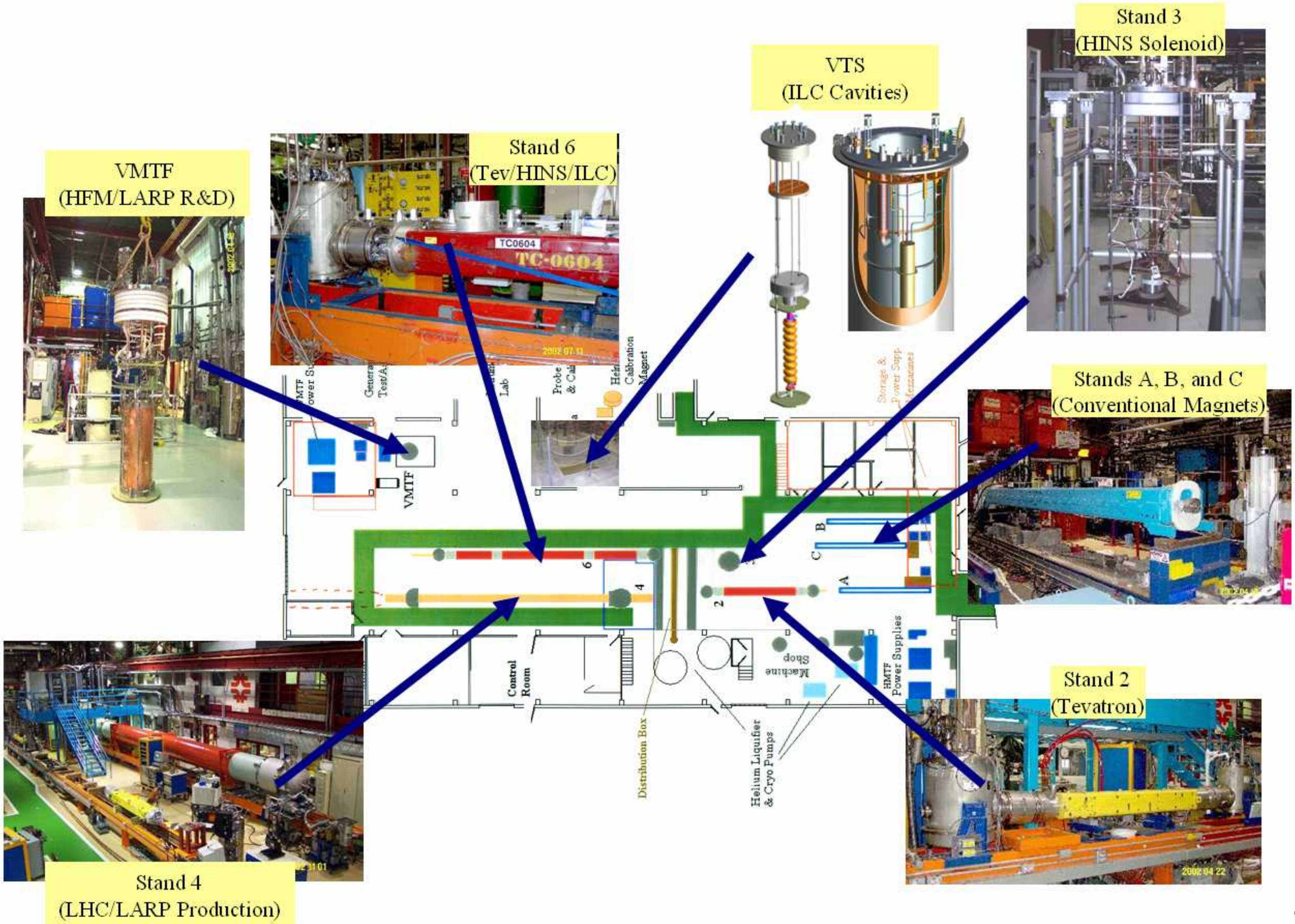
- A 25,000 sq. ft. test facility (Industrial Building 1, IB1)
- Magnets and SRF Cavities Test Stands
  - 3 Conventional Magnet Test Stands
  - 5 Superconducting Magnet Test Stands
  - 1 SRF Cavity Vertical Test Stand (under construction)
- A 1500 W @4.5K Helium Refrigerator with a 10,000 liter Liquid Helium Storage dewar and a 90,000 Gallon Gas Helium storage tanks
- A 6 g/s Vacuum Pump System for superfluid operation support
- A 30,000 Amps Power System with solid state dump switch and dump resistors for Superconducting Magnet testing
- A 10,000 Amps Power System with solid state dump switch and dump resistors for Superconducting Magnet testing
- A 5 kA/5kA/10 kA DC Power System for Conventional Magnet testing
- A closed-loop 330 GPM, 150 psia Low Conductivity Water (LCW) system
- An Instrumentation Lab

T&I IB1 Infrastructure Upgrade Plans

Fermilab

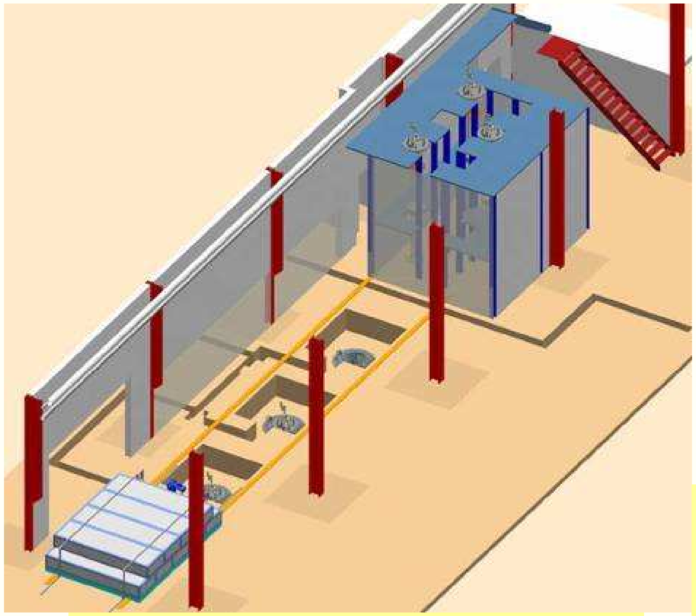
- Two more SRF Vertical Test Stands
- A 10 g/s Vacuum Pump dedicated to SRF Vertical Test Stands
- A Compressor/Purifier System at the Vacuum Pump system outlet
- 60,000 Gallons of additional Gas Helium storage
- A 1,500 KVA transformer
- Upgrade and standardize magnet test stands data acquisition systems, control systems, and power distribution systems
- Increase facility automation and deploy data management tools

T&I IB1 Test Stands



T&I IB1 Infrastructure Upgrades

Fermilab



Two more SRF Vertical Test Stands plus staging area

A 10 g/s Vacuum Pump dedicated to SRF Vertical Test Stands (example from ILCTA_MDB)

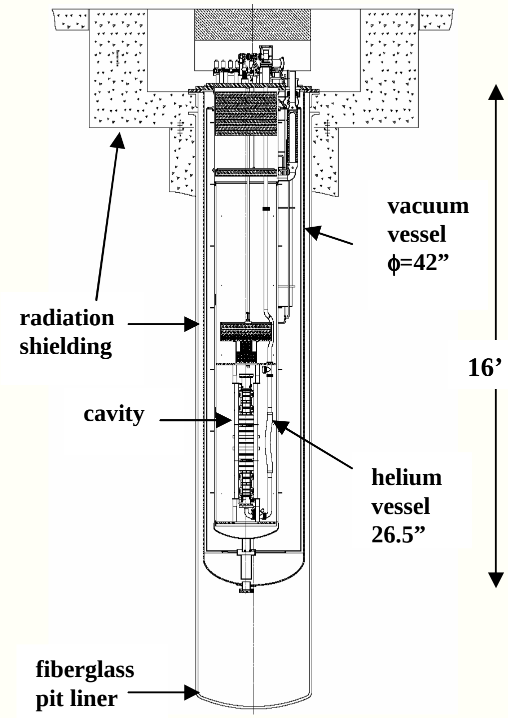
A Compressor/Purifier System (example from ILCTA_MDB)

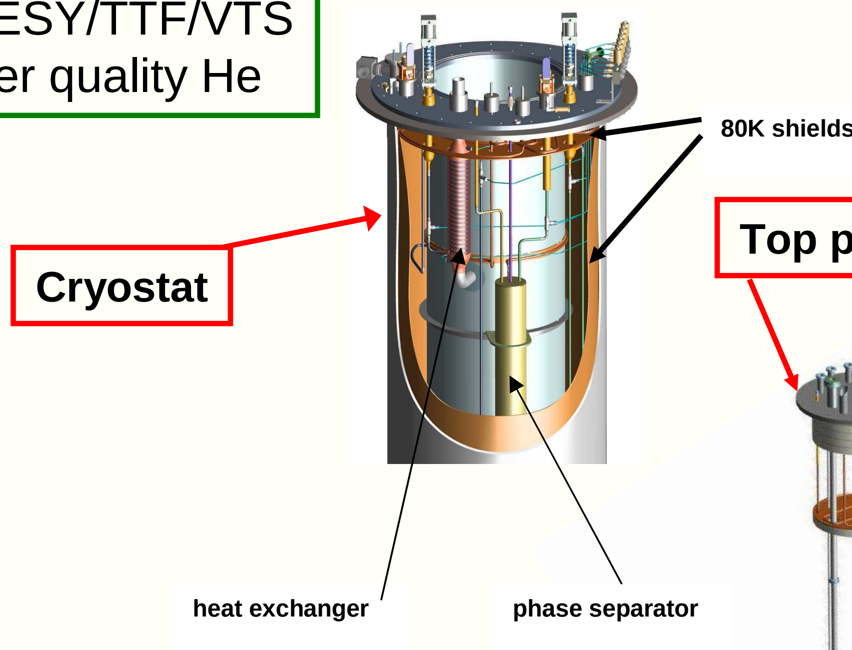
Two more Helium Gas Storage Tanks (example from ILCTA_IB1)

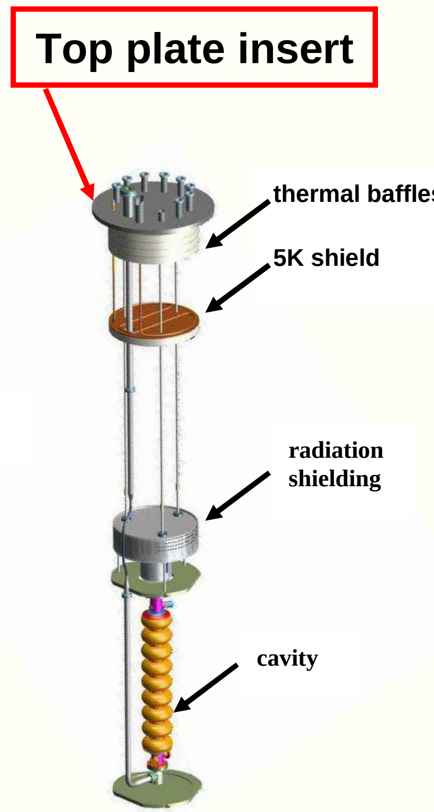
Vertical Testing SCRF

VTS Cryostat/Insert Design

Based on Fermilab design of DESY/TTF/VTS
Added phase separator for better quality He

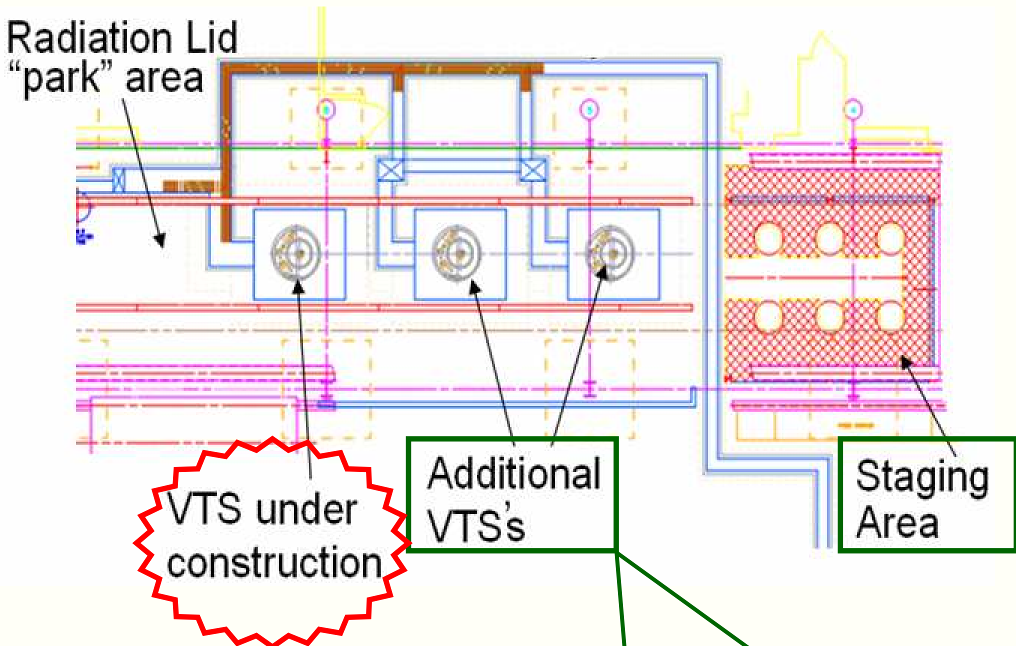


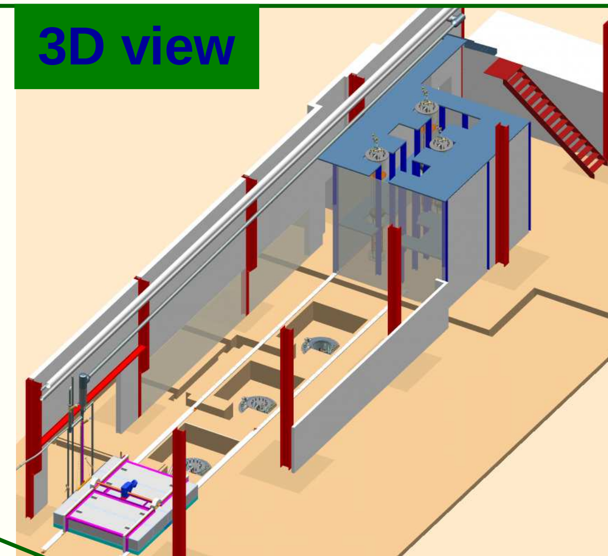




Cryostat construction at PHPK Technologies, Columbus OH

Two additional VTS's and staging area




3D view

- RF test one cavity at a time (weak constraint)
- Common RF/DAQ system, except amplifier
- Common radiation shielding lid
- As similar as possible to VTS-1 to minimize design and procurement costs

- Accommodate 6 top plate inserts, each supporting 2 cavities
- *not* clean room: HEPA fan filter assemblies, plastic curtain (JLab model)

~180 tests/year (!)

Vertical test

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- Most critical need for diagnostic development:
  - Radiation
  - Thermal
  - Microwave
- (ILC) Cavity gradient is limited for 3 basic reasons:
  - Cryo load
  - Radiation
  - Quench

JLab Multi-cell Tests:

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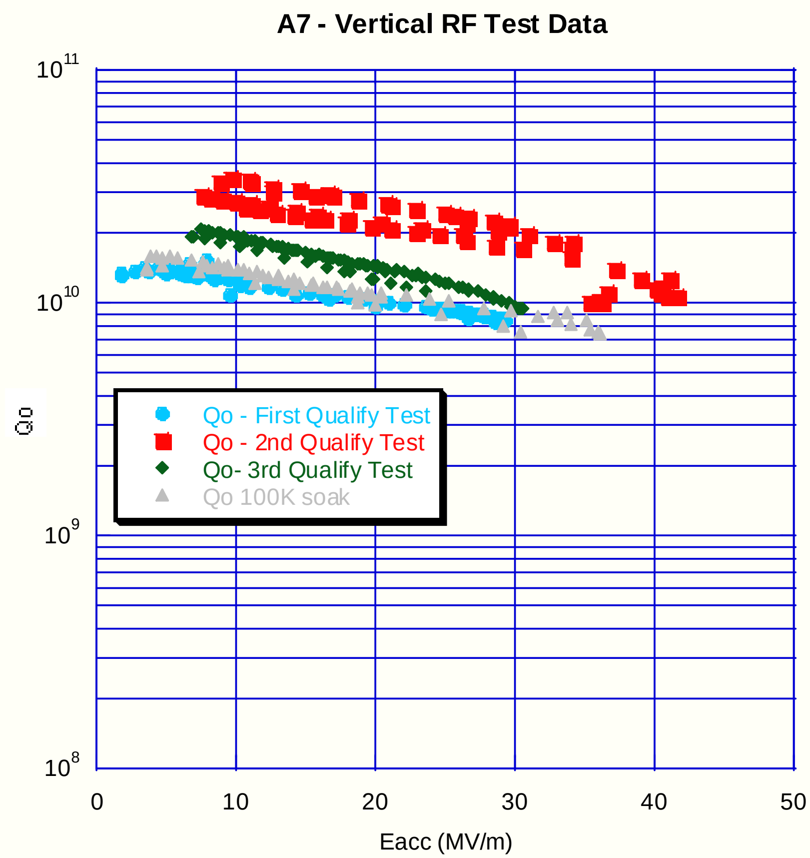
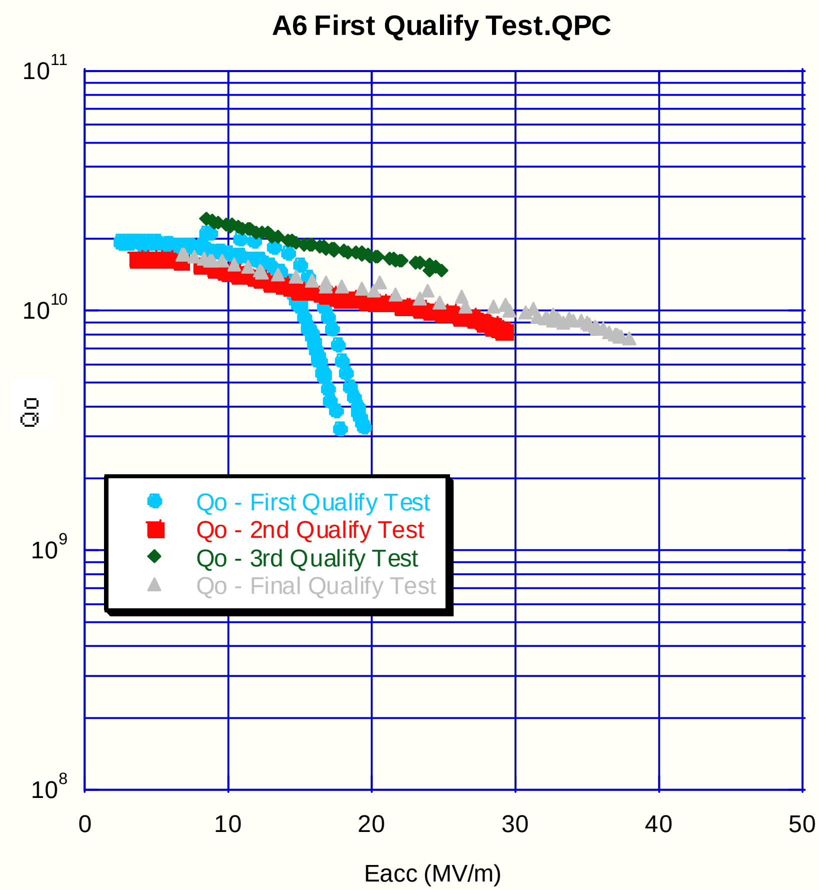
- All curves but one limited by quench
- Field emission in one test (A6 final test)

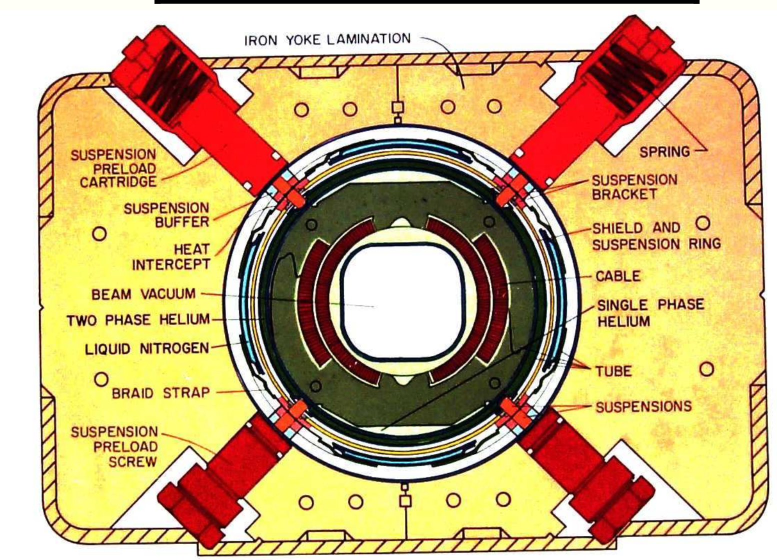




Tevatron Dipole Reshimming

- Reshim to correct for creeping G-11 suspensions
- Reduce skew quadrupole, betatron coupling

Fall 2003	106
Spring 2004	12
Fall 2004	412
Spring 2006	244



Transition from Tevatron to 1.3GHz

- The end of tevatron operation is on our horizon
  - TD has spare dipoles; does not expect serious future Tev magnet work
- Our next challenge:

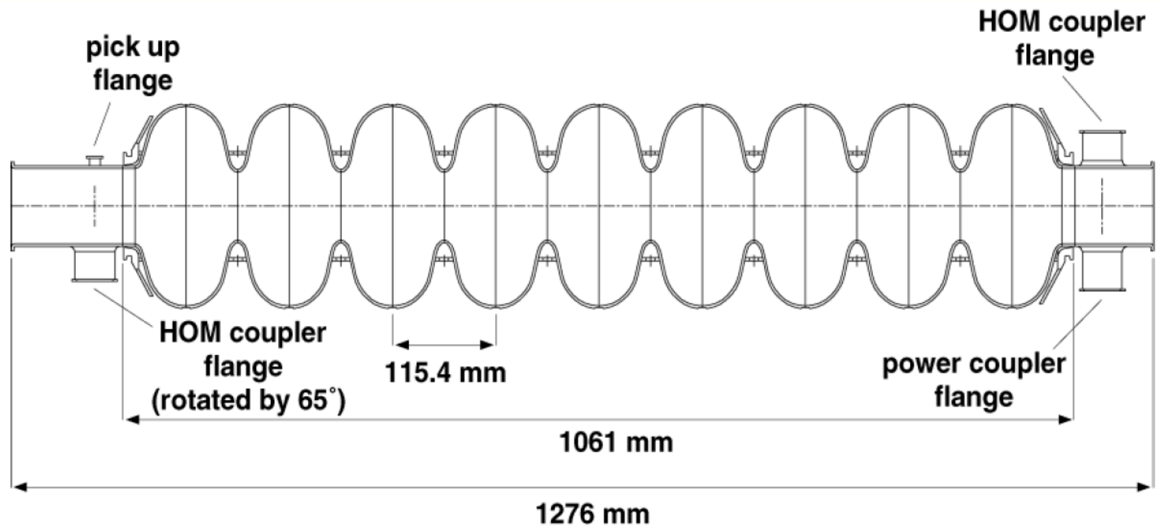


Figure 1.2-1: A TESLA nine-cell 1.3 GHz superconducting niobium cavity.

Ray Orbach – DOE 22.02.07

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- DOE is committed to continuing a vigorous R&D program of accelerator technology. SCRF is a core capability having broad applicability, both to the ILC and to other future accelerator-based facilities as well. Our FY2008 request for ILC R&D and SCRF technology confirms this commitment. We welcome our R&D partnerships with those around the world, in Asia, in Europe, and the Americas. *The science is indeed very exciting*.
  - (italics MCR)

What you can do:

- **New technology / new applications involve a variety of small experiments and analysis**
  - **Nice offset to CMS / ATLAS**
  - **Smaller teams, room for individual contribution**

- **Basic technology is OK but…**
- **Plenty of challenges & problems:**
  - **Magnet field precision**
  - **SC RF infrastructure**
  - **SC RF basics**
  - **Beam tests**

- **We would like to request your participation**

How you can help (2)…

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- Understanding SRF technology:

- 1) Nothing is known about cavity performance before vertical test
- 2) quantitative measurements radiation ‘patterns’ from cavities at their limit
- 3) thermal / quench sensing techniques
- 4) peak power processing

- there remains a lot to learn…

Beyond:

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- What is the impact of a given surface flaw/debris? How does it depend on location?
- What causes the performance difference between 1 and 9 cell cavities?
- What is the interaction between the cavity and the 'end group'?
- What is the correlation between vertical, horizontal and cryomodule (final) radiation?
- What are the beam-related cryogenic loads?
- The cavity end groups are a big fraction of the cost – how can this be reduced w/o sacrificing performance?
- There is a low-temperature bake used to decrease surface resistance. What does the bake really do?

After Vertical Test:

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- Horizontal test
  - Test of cavity ‘system’ with power coupler, cryogenic circuit
- Module assembly
  - Complex task of sealing it all up
    - Like satellite launch
- Beam test

- Each of the above has a similar list of challenges and need for innovation – primarily in instrumentation and monitoring
  - Omitted here

TD and the future of FNAL

Fermilab

- Establish the viability of new technology / new applications
  - Nb3Sn
  - Next generation TESLA 1.3 / 3.9 Ghz SRF
- Compete for projects
  - LARP / LHC Upgrades
  - ILC
- TD is at the forefront;
  - our performance determines your future…
  - For accelerator based science.

Relationship with APC

Fermilab

- Fermilab established and 'Accelerator Physics Center' during contract negotiation
- APC will provide leadership for ILC EDR
  - Partnership between SRF engineers and ILC linac physicists
- APC will be conduit for LHC, Muon … projects
- APC may have scope beyond direct HEP

Industrial Participation

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- In contrast to the Tevatron
  - Where construction was done on site…
- we cannot build a very large number of SCRF accelerator cryostats here
  - Have to use supporting organizations who will profit from our endeavor.
  - Naturally adversarial context
  - How to engage?

Relationship with ILC

Fermilab

- TD will provide cryomodules for test in NML
- AD will provide 'beamline' and beam infrastructure for testing
- TD will provide infrastructure for cavity preparation
- Fermilab engineers will do 'value engineering' – bringing the RDR design to maturity.
  - 'Engineering Design'
- AD / APC physicists to partner in this critical work.

TD in 2017

- Core competency – SCRF
  - From the mine to the beamline – a fully 'understood' technology
  - Includes material lab, cavity fab, small systems test, RF design, low/high power test, diagnostic systems, ability to cost-effectively deploy in a variety of applications, mass-production monitoring skills, cavity fab/process partnerships…
- Core competency – Superconducting magnets
  - From wire design to beamline
  - Includes wire lab, wire vendor partnerships, coil forming and treatment facilities, magnet design and integration, cost-effective deployment, magnet assembly and test
- Core competency - Cryogenic system design
- Beam-based testing with AD

Support

- **I assembled this talk and invented scenarios and policies**
  - **Full ownership**
- **Supporting material from:**
  - **TD managers:**
    - **Giorgio Apollinari**
    - **Mike Lamm**
    - **Ruben Carcagno**
    - **Gregg Kobliska**
    - **Bob Andree**
    - **Charles Matthews**
    - **Romesh Sood**
    - **Jim Kerby**
    - **Victor Yarba**
  - **TD project managers and scientists and …**