Technical Resources for Users

Stoyan Stoynev /Technical Division/

51st Annual Users Meeting

21 June 2018

Outline

- Technical Division Mission
- Fields of Expertise
- Material Science Resources
- Accelerator Component R&D and Testing Facilities
  - Magnets
  - SRF Cavities
- Machine Shop Support
- Users Computing

Mission of Technical Division (TD)

http://td.fnal.gov

- Pursue highly innovative R&D program in superconducting *magnets and SRF for accelerators to advance the lab's scientific mission and to help in defining the lab's future* direction

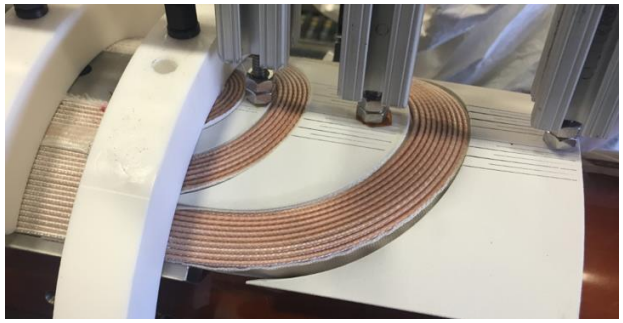
- Operate accelerator test facilities *to maximize the lab's* scientific productivity and impact

- Develop and build next generation accelerators and detectors using cutting-edge technologies

- Educate and train the next generation of physicists and engineers

Fields of expertise

- Magnets
  - Superconducting materials R&D (wires, cables)
  - High field accelerator magnets R&D (Nb_3Sn dipoles/quads)
  - Magnet fabrication (superconducting and conventional)
  - R&D of magnet diagnostics



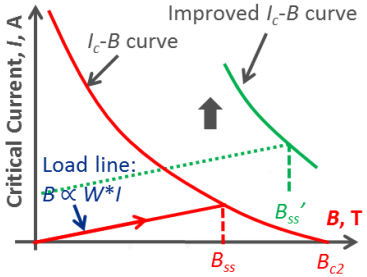
- Superconducting Radiofrequency (SRF) cavities
  - Nitrogen Doping
  - Efficient Meissner Expulsion
  - Nb3Sn-Coated Cavities
  - Fundamental Material Investigations
  - High Gradient Nb Cavities

- Manufacturing and quality engineering subjects, cost estimates, procurement

Superconducting Strand and Cable R&D Lab

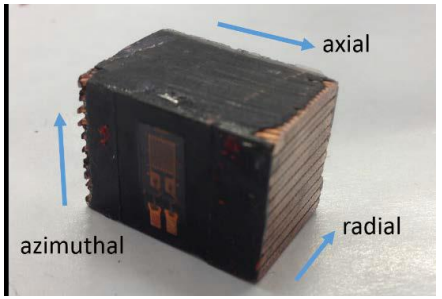
- In support of advanced superconductor and accelerator magnet development
  - High heat capacity Nb_3Sn wire
  - Developing APC Nb_3Sn conductors to improve J_c

Critical current density (J_c) with APC



- Cable development by designing and fabricating samples of different geometries
  - Tight quality control

"10 stack" studies



- Coil technology and mechanical properties

- Training of 34 (and counting) graduate students in Physics and Engineering
  - on superconductivity, materials science, mechanics, heat transfer, cryogenics, electronics, computing and automation during summer internships or PhD theses

Superconducting S&C R&D Lab Main Equipment

- Four Teslatron cryostated solenoids
  - 10-17 T field, down to 2.2 K;
    64-147 mm apertures
  - Power supplies to 1875 A
  - DAQ and quench protection
- Furnaces
  - Four tube furnaces of 12” (up to 1500 ºC)
  - Two meters long furnace (up to 1250 ºC)
  - A metrology well calibrator for ovens calibration
- A motorized flat-rolling system to impart plastic strain
- Compact cabling machine with 42 spools and electronic synchronization

General view of the Lab and the four magnet cryostats (right)

Measurements include:
- Strain sensitivity
- Magnetic field
- Short sample limit
- Critical current
- RRR
- Flux jump stability and magnetization

Material studies for SRF

- Scanning electron microscopy (SEM)
  - energy-dispersive X-ray spectroscopy capabilities
  - electron backscatter diffraction capabilities
- Physical property measurement system
- Instron tensile testing
- Keyence laser confocal microscopy
- Surface topological replicas
- Chemical treatment of samples

SEM

Instron apparatus for tensile testing

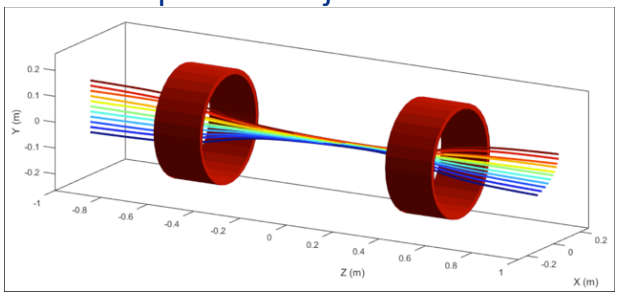
Keyence apparatus

Research areas are led by an expert staff recognized by multiple awards including three DOE Early Career awards, Hogil Kim prize, PAST awards, as well as various conference poster and presentation prizes.

Magnets

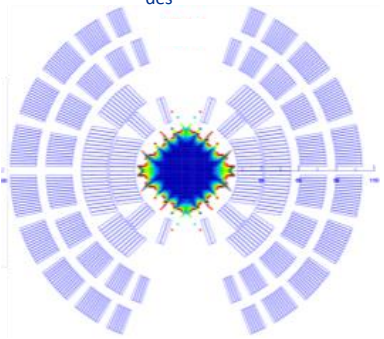
- Design and fabrication
  - For accelerators and experiments
  - Conventional and superconducting
  - Resolving challenging requirements
  - Active collaborations outside FNAL

Simulation of particle trajectories in a solenoid

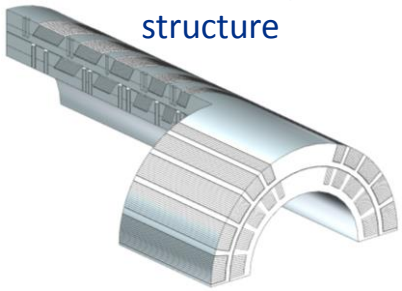


We designed and fabricated the Booster Multi-pole magnet assembly for correction of the Fermilab Booster beam orbits

60 mm aperture
B_{des}~17 T

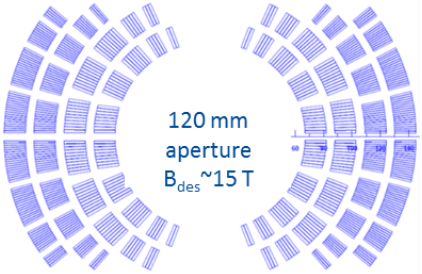


Coil stress-management structure

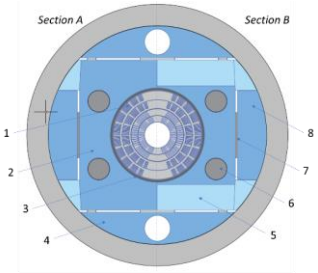


Fabrication of 15 T Nb_3Sn dipole demonstrator

Coil designs



Mechanical structure



Coil fabrication as part of US HL-LHC-AUP

Fermilab

Magnet facility capabilities

- Vacuum-pressure impregnation for large objects
- Winding of large not regular magnet coils, including SC coils
- Curing and reaction of SC coils
- Producing small SC magnetic devices
- Producing accelerator, non-common type, magnets for field injections and extraction
- Manufacturing small batches of non-standard superconducting cables
- Reaction and test of the HTS strands or any other materials in oxygen/argon environment
- Support for the FERMILAB accelerator complex by repairing or refurbishing existing accelerator magnets and magnet components

Coil winding machine

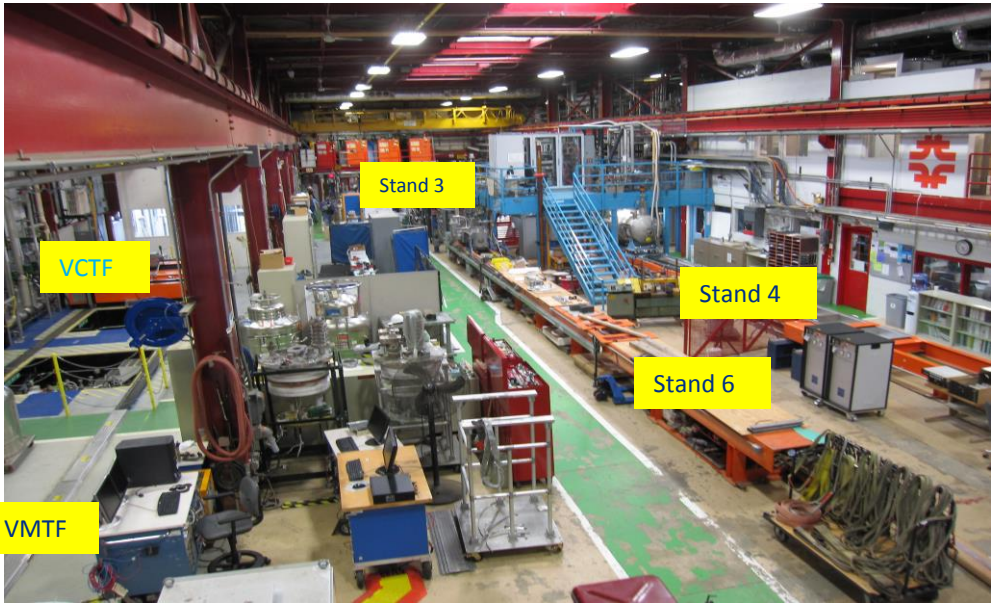
"Reaction" oven

Large vacuum oven for outgassing and impregnation

Magnet testing

Measurements : Magnet Strength, Field uniformity, Quenches, Calibration

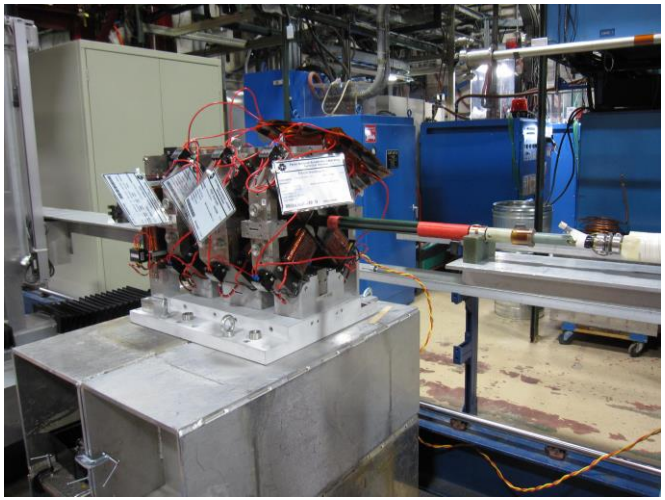
Cold Test Facility at FNAL (main areas)



Number of cryostats
1 cryostat at VMTF - 4 m deep, 0.65 m diameter
1 cryostat at Stand 3 for 1 m long, 0.4 m diameter magnets
3 cryostats at VCTF, each 4 m deep, 0.7 m diameter
(VCTF used for cavity testing)

Major upgrades under way

Conventional magnet magnetic measurements (PIP-II triplet)



Operating temperature: 1.8-4.5 K

Cooling phases: 300 to 4.5 K,
4.5 to 1.8 K

Lifting and Handling tools:
One 25-top crane, two 10-ton cranes

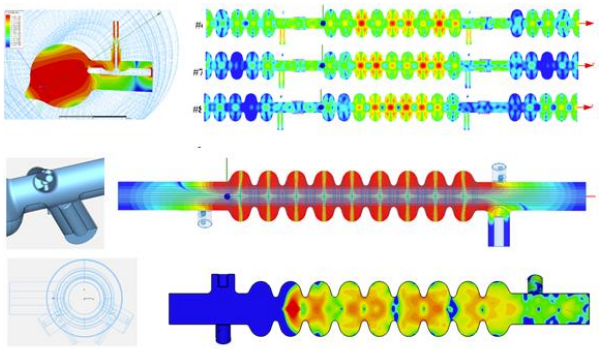
30 kA power supply

Fermilab

SRF cavities

- Design
  - reducing peak surface fields
  - higher order modes extraction and damping
  - structural and thermal stability analysis
  - and more…

Simulations of higher order modes and wakefields in the 1.3 GHz and 3.9 GHz cavities for LCLS II



- Surface processing and Post-processing
  - To remove contaminants from the Niobium surface
  - Heat treatment for improved performance
  - Clean rooms for cleaning and assembly

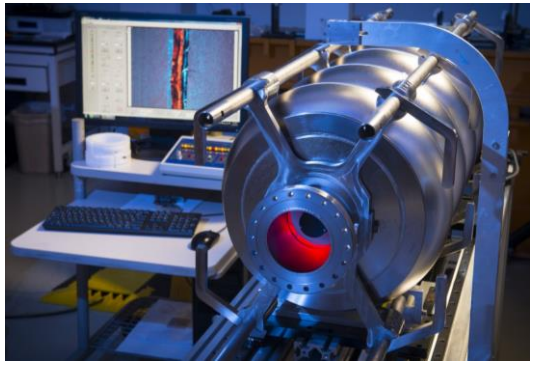
Ultra-high-vacuum vacuum furnace at 800 C for H-degassing and N-doping

SRF cavity testing

- Optical Inspection & Eddy Current Scanning
  - camera and lighting system
  - routine inspection of cavities
  - computer-aided close inspection
  - Eddy current scanning to examine (for impurities) niobium sheets before cavity fabrication

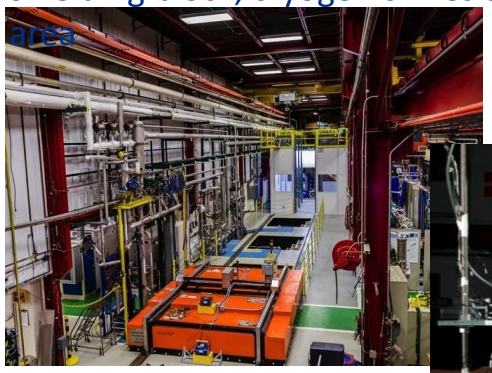
- Horizontal and vertical testing
  - three large liquid helium dewars
  - high power operation over a wide frequency range
  - liquid helium baths as low as 1.4 K
  - three horizontal test stands (with ancillary systems)

A 650 MHz 5 cell cavity on the inspection test stand



Eddy current scanning of niobium sheets

Three vertical test dewars with sliding radiation shielding block, cryogenic lines and preparation staging area



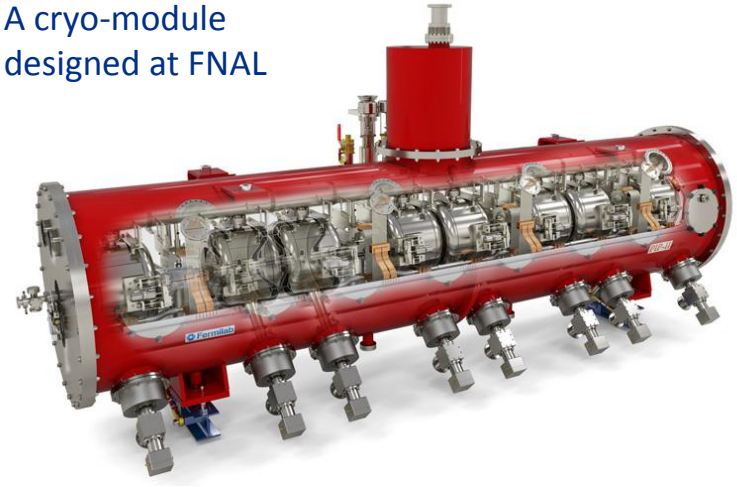
Preparation for vertical and horizontal cavity testing

Fermilab

Cryomodules

- Cryomodule Engineering
  - Complex assemblies of cavities and hardware (and often magnets)
  - wide range of mechanical, thermal and electrical engineering skills and experience

A cryo-module designed at FNAL



- Cavity String and Cryomodule Assembly
  - two independent cavity string assembly facilities
  - cleanroom areas with several levels of cleanliness

Cryomodule assembly floor of ICB

Coldmass insertion to a vacuum vessel in ICB

Completed cavity string in a cleanroom ready for leak-checking

Machine Shop

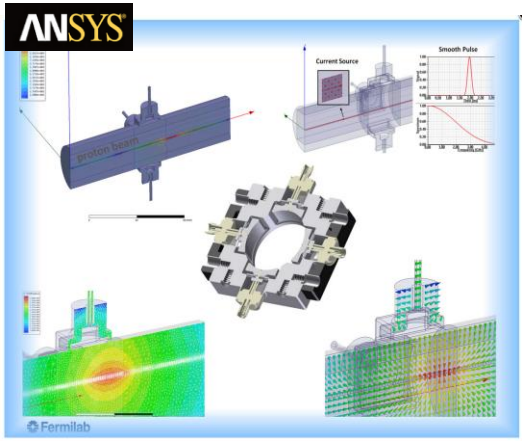
- Serving FNAL experiments and operations
- Provides high tolerance prototype and small run machined parts
- Certified welding processes
  - SMAC – (Arc)
  - GMAW – (Mig)
  - FCAW – (Flux-Core)
  - GTAW – (Tig)
  - PAW – (Plasma Arc)
  - And others
- Certified to weld a variety of metals

CNC Horizontal DeVlieg Milling Machine

Aluminum welds certification

TD/HPC Cluster

- The High Performance and Parallel Computing (HPC) cluster is a world-class facility available for users
- Six dedicated servers in TD for engineering analysis
  (TD-SRF-TS1, -TS2, …, -TS6)
- Available licenses include
  ANSYS, COMSOL, CST, LabView,
  SigmaPlot, Mathcad, Mathematica
- Supporting variety of projects
  - PIP-II, LCLS-II, Mu2e, HL-LHC upgrade and more



Each server has standard environment and available by the RDP access (lab wide) after permission granted /submit a service ticket/

Resources for users

http://td.fnal.gov

- TD provides expertise in a wide range of fields
  - from materials through magnet and cavities to complex structures such as cryomodules
  - from early design phases to complete operation (of the above mentioned)
  - procurement
  - safety (people, environment, machinery) is a top priority in all of our operations
- TD also provides a rare set of material bases you may need
- By following FNAL rules and procedures you can get support from TD for your experiment or work

Thank you for your attention