Magnet Test Stands at Fermilab

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Introduction to Fermilab

National Laboratory operated by Fermi Research Alliance (FRA)

- Located in Illinois, about 56 km west of Chicago

Fermilab

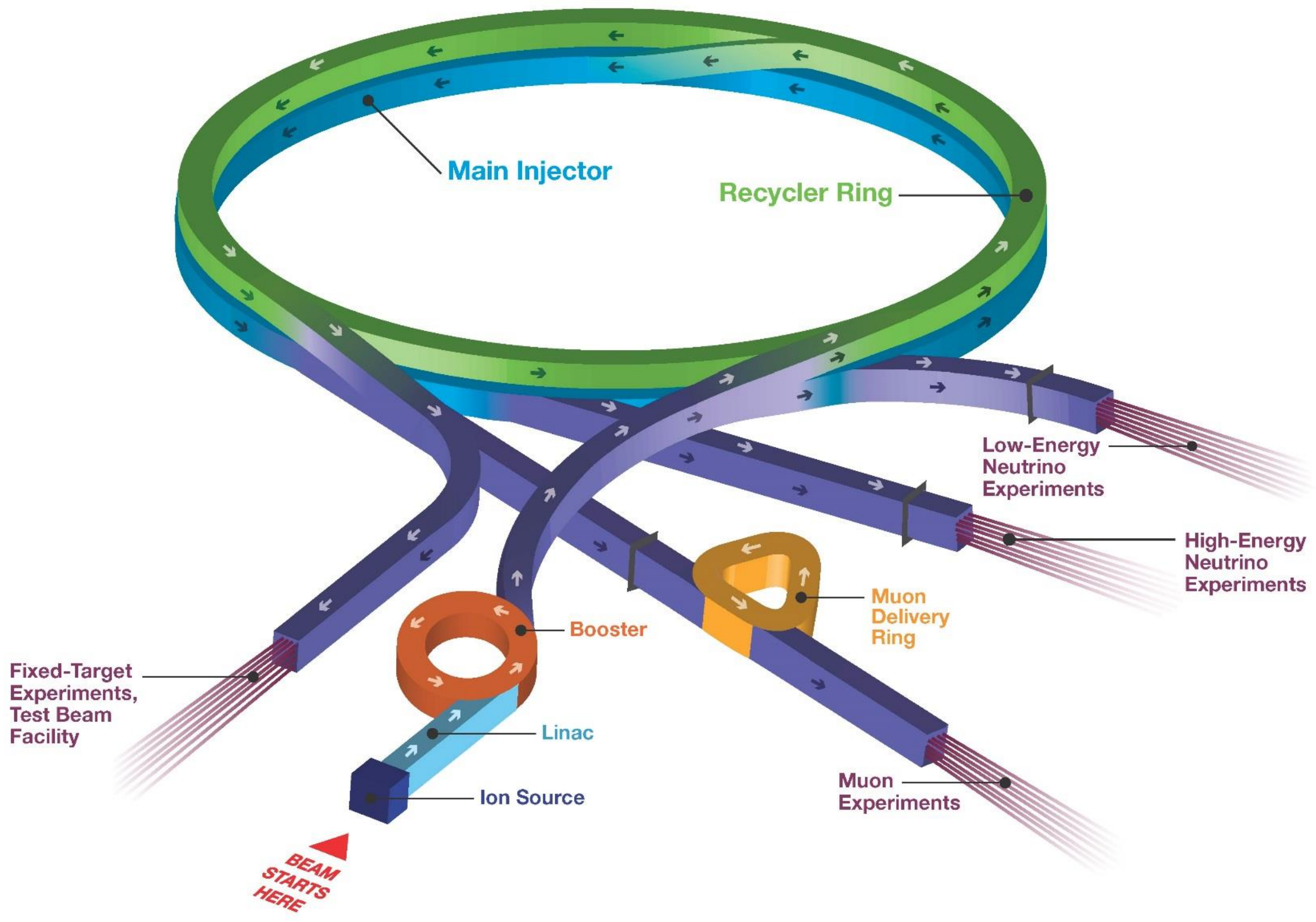
Particle physics and accelerator science laboratory

- ~27 km^2 park-like site
- Multiple accelerators
- 1,700 Employees

Previously hosted Tevatron - the World's largest and most powerful accelerator before the LHC era

- Ceased operation in September 2011

Accelerator Complex Today



Magnet Test Facility

Magnet test facility (MTF) originates from the Main Ring period, when the first main accelerator was built at Fermilab

First conventional magnet tests started by the end of the 1960s

Testing of the first superconducting accelerator magnets started in the late 1970s

- MTF cryogenic plant in operation since 1978
- Today still functional CTI-1500 liquefier installed back in 1977

Vertical Magnet Test Facility (VMTF) - the main R&D stand for the SC magnets, in operation since 1996

Vertical Cavity Test Facility (VCTS) commissioned in 2007 to support the SC RF cavity R&D program at Fermilab

Magnet Test Facility (cont'd)

Total area of MTF today is about 2200 m^2

Two vertical (VMTF, Stand 3) and 3 horizontal test stands for the SC magnet tests (Stands 2, 4, 6)

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

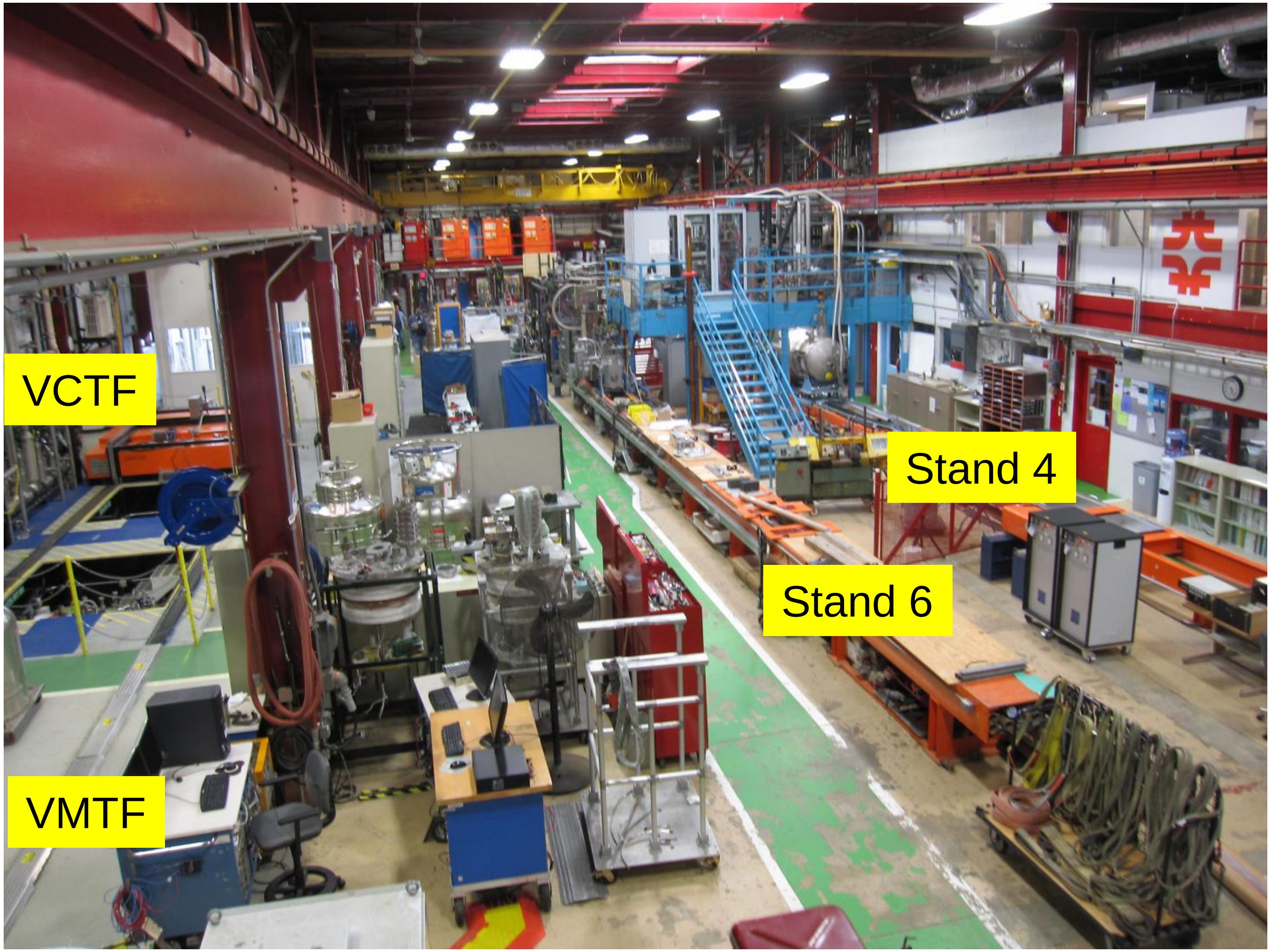
Low Temperature Calibration Facility (LCTF)

- Used for calibration of cryogenic temperature sensors

Materials Characterization and Test Facility (MCTF)

- Low temperature material properties and cryogenic device studies

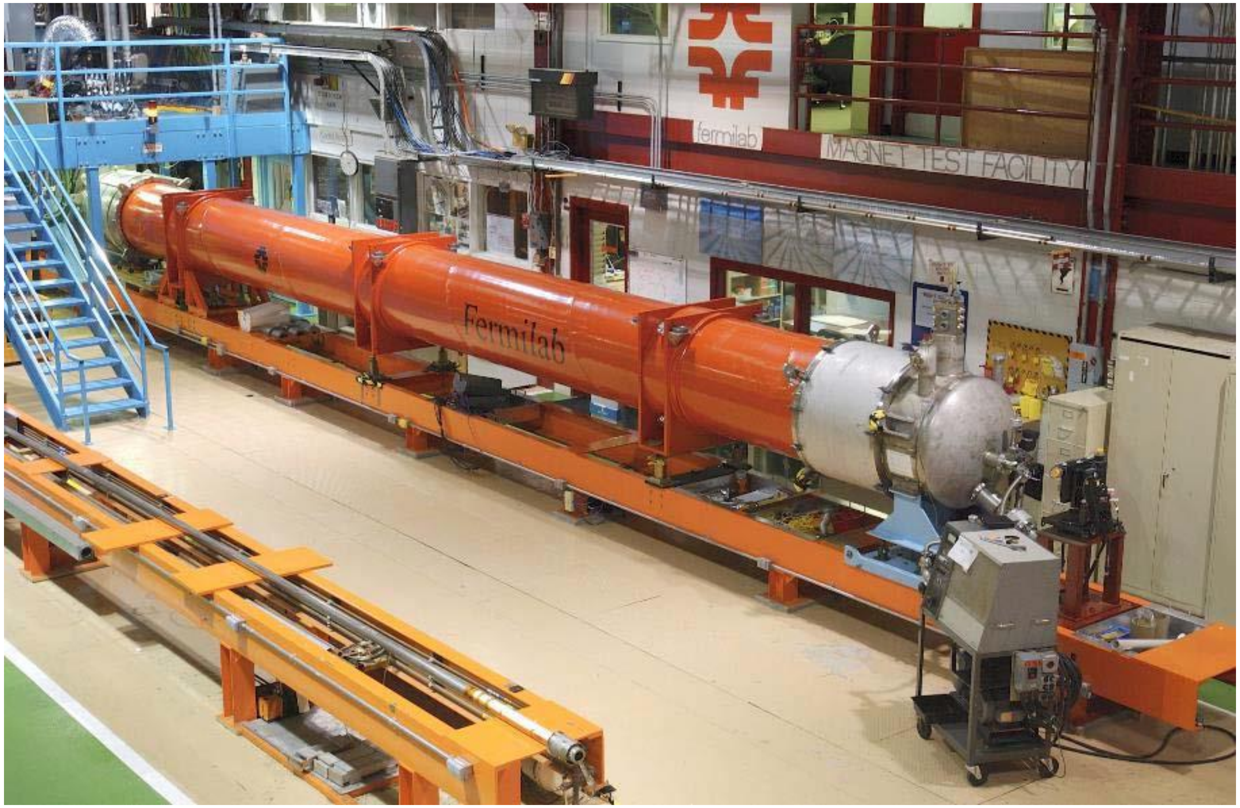
MTF at Fermilab



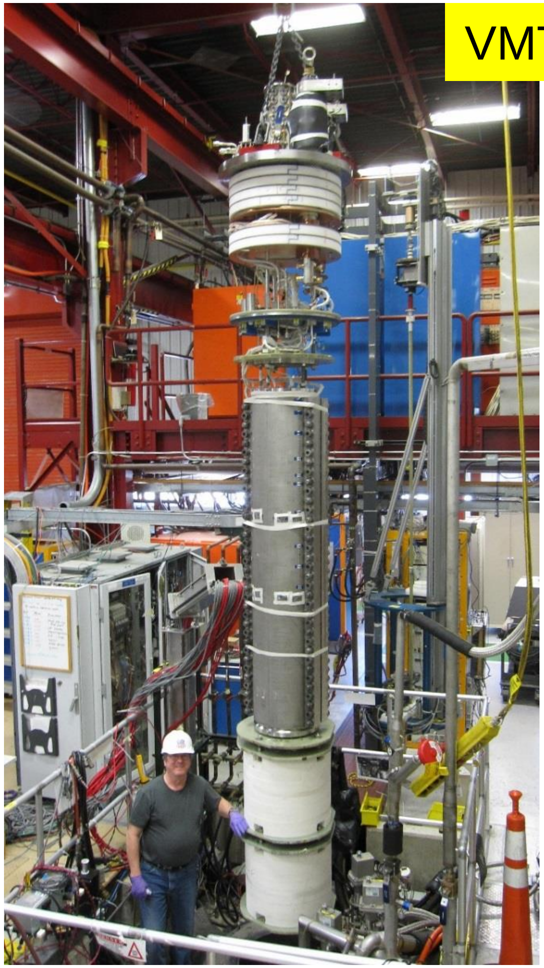
Horizontal Test Stand 4

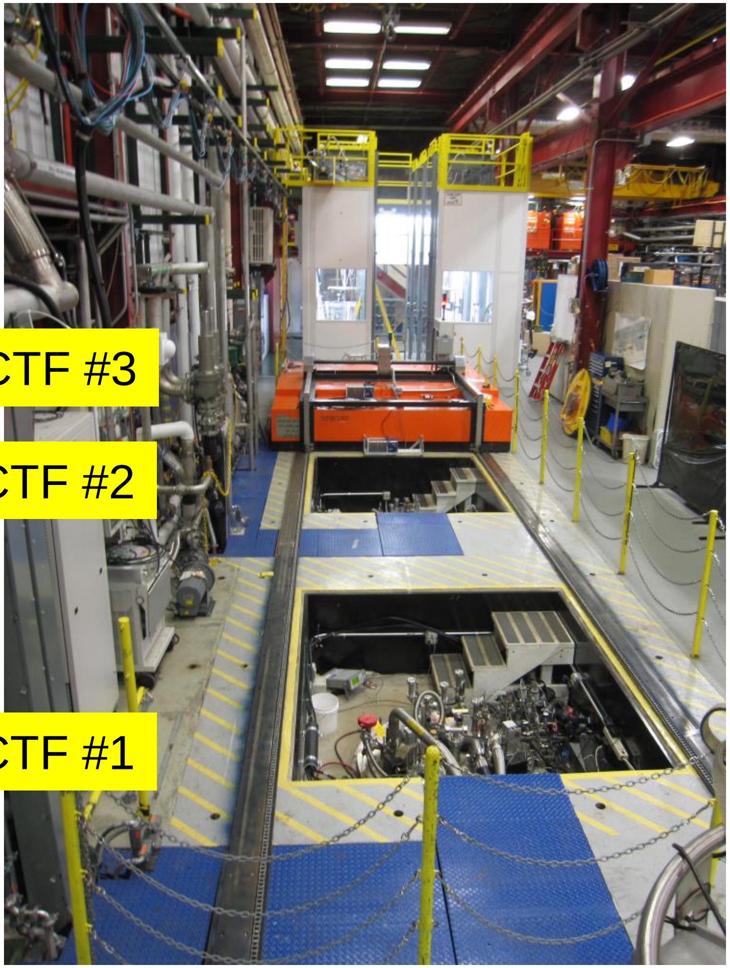
Previously used for testing Q2 optical elements for the LHC IR final focus

- To be upgraded for testing Q1/Q3 optical elements of the HiLumi-LHC



MTF at Fermilab





Magnet Test Facility

Operating temperatures:

VMTF 1.8 K - 4.5 K

VCTF 1.5 K - 4.5 K

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

Shared cryogenics: All cryogenic stands share the same LHe storage dewar. VMTF and VCTF also share most of the transfer lines

Lifting and Handling tools:

One 25-top crane, two 10-ton cranes

Cooling Capacity

CTI-1500 liquefier with liquefaction rate of 300 L/hour

10000 L storage dewar for the LHe

- Effectively using ~7000 L of volume only due to the lower and upper limits for the LHe level in the dewar

Five 30000 Gal (~114 m^3) buffer tanks are used for storage of helium gas

Cooling Capacity (cont'd)

Buffer tank pressure 50 to 150 psia, suction pressure 16.2 psia

- 1st stage compressor discharge pressure 35 psia, 2nd stage – 300 psia

One 30000 Gal buffer tank is used for the helium gas recovery after high-current quenches at VMTF

- Longer transfer line helps to warm up the GHe

Cooling Capacity (cont'd)

Purifier system to control contamination level of H_2O, N_2 and O_2 at different locations

10000 Gal LN_2 dewar

- Filled twice a week
- Dry gas in warm bore
- 1st stage cooling of the cold box

Industrial Cooling Water (ICW)

- Feeds the low conductivity water (LCW) for cooling power supplies or conventional magnets
- 3 ton water chiller for operation in summer

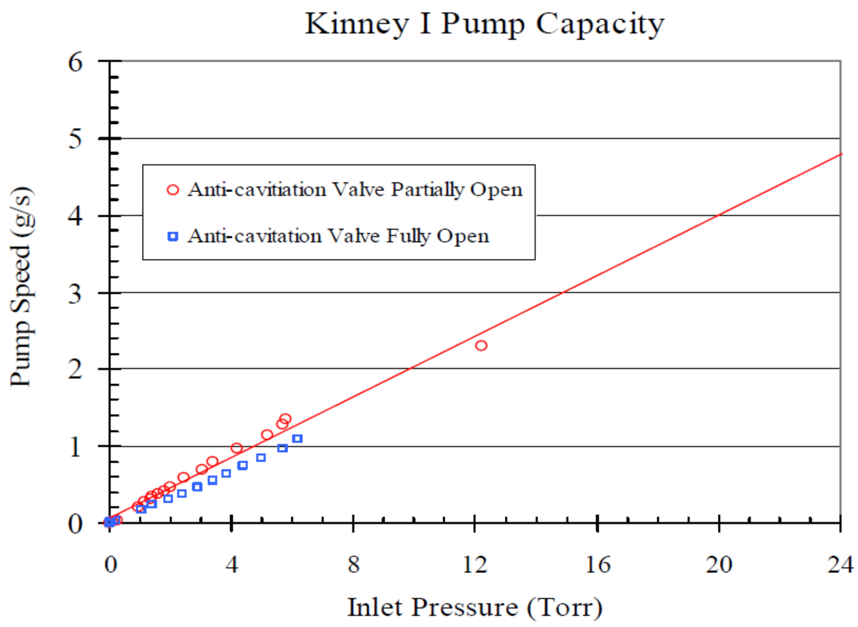
Pumping Capacity

New Helium compressor skids - 4 Kinney pumps in parallel used for VMTF and VCTF

- Total pumping speed of 10 g/s at 12 torr (4.5 K operation) and 15 g/s at 20 torr (1.9 K operation)

Old Helium compressor skids – 2 Kinney pumps for the Horizontal Test Stand 4

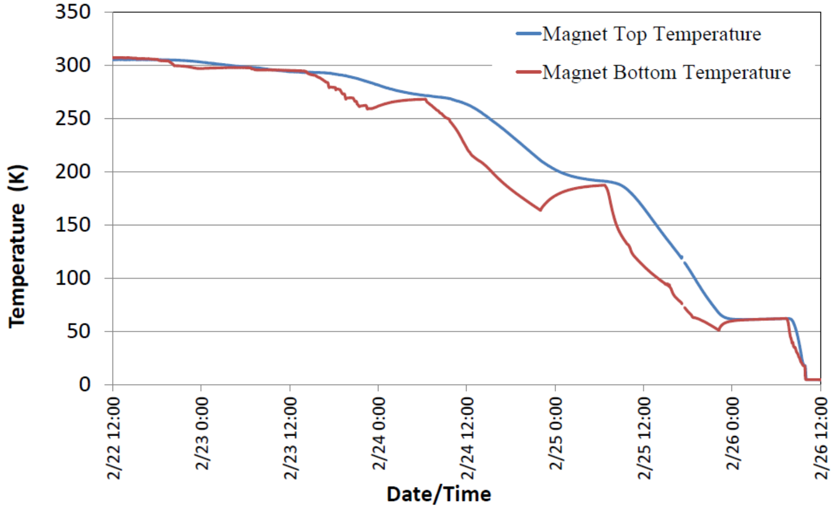
- Pumping speed 2.5 g/s in Kinney I, 1.5 g/s in Kinney II
- Total 4 g/s at 12 torr, or 6 g/s at 20 torr

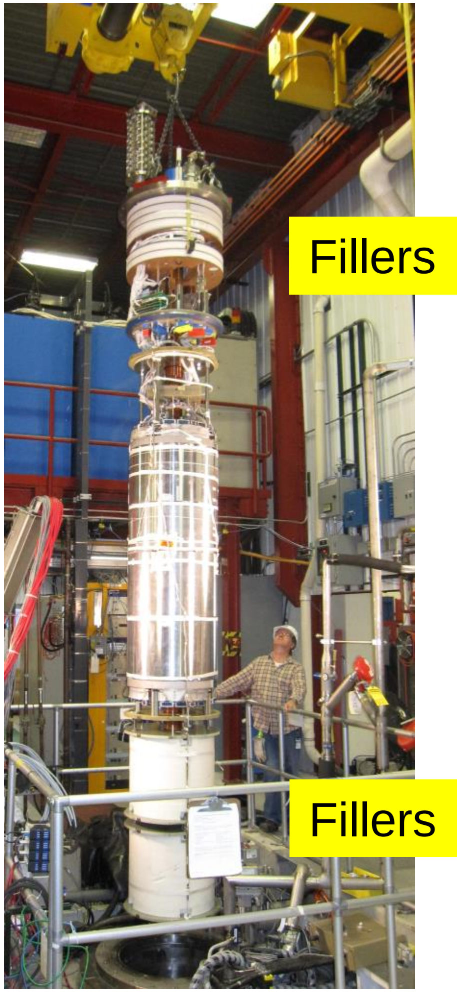


Cool down time at VMTF

Controlled cool down to 4.5 K takes 3-4 days for MQXFS magnets (2-m long, 0.6 m diameter, 4000 kg magnet)

- Fillers are used for short magnets
- Uncontrolled cool down of a magnet of this size could take 1.5 days





Cool down from 4.5 K to 1.9 K takes 2-3 hours depending on magnet size and weight

Quench Recovery at VMTF

Quench recovery is required to handle high pressure He gas after violent high-current quenches

- Increased pressure automatically switches the transfer lines to the quench recovery tank
- Manual handling is more efficient

Quench recovery depends on amount of stored energy - quench current and magnet inductance, as well as on operation temperature

- Less recovery is required at 1.9 K compared to 4.5 K

MQXFS quenches at currents above 9 kA at 1.9 K required recovery

Average quench recovery time for MQXFS magnet was 1.5 hours

Power Systems

VMTF: 6 PEI-150 (150 kW) units are connected in parallel

- Each PEI delivers 5 kA at 30 V
- Maximum current of 30 kA at 30 V

External energy extraction system based on a solid state dump switch

- SCRs mounted in water cooled heatsinks
- Dump resistor configurations from 2 to 120 mΩ

Due to overheating SCRs there is a limit on continuous operation for currents above 26 kA:

- 27-28 kA current can be provided for 10-15 minutes, and
- above 28 kA for few minutes only

One 240 kW and two 150 kW PEIs are used for the conventional magnet stands

Power Systems (cont'd)

150 kW Power Energy Industries (PEI) PS module (left)

Dump Resistor Cabinet (right)

Magnetic measurements at MTF

Fermilab has World-recognized expertise in magnet measurement systems development

Printed Circuit Board (PCB) Probes

- Developed since ~2007 for Booster BMA correctors
- Different dimension probes were used for LQ, HQ and now MQXF magnets
- Rapid Development/Fabrication, low cost

Self-contained Rotating Coil assembly

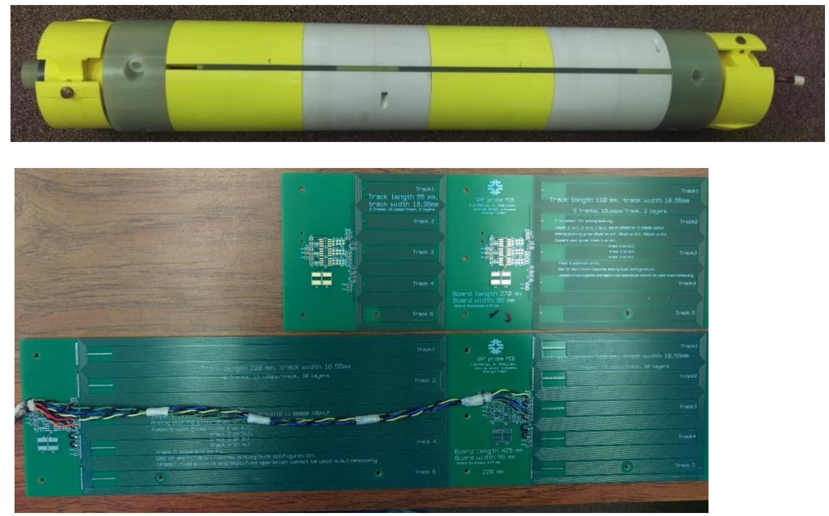
- “FERRET” (formerly known as “MOLE”)
- Warm horizontal magnet scans at different locations

All cold magnetic measurements are performed in the warm bore

PCB probes

Probe for LQS magnet

Probe for MQXFS magnet



Mobile Measurement Carts

Several generations of easily transported measurement systems developed at MTF

Metrolab's PDI based measurement cart built 1997

- PDI not available anymore
- FDI very expensive
- New integrator developed at Fermilab based on commercial low noise, low drift ADC and FPGA

DSP measurement cart developed in 2002

- Fast ADCs with DSP integration, for high throughput
- Used for study of LHC dynamic effects, and LARP magnet measurements

SSW carts in use since 2000

- Work-horse for all quadrupole magnetic axis and alignment needs

Thank you

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