Overview of Fermilab Magnet Measurement Activities

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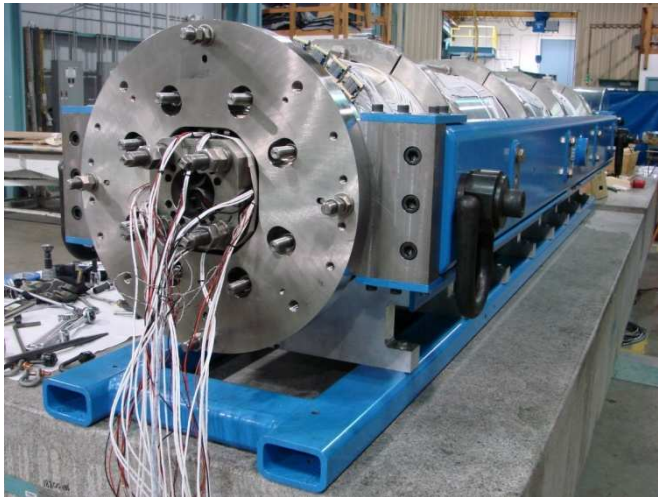
But we continue to have a variety of measurement projects to look forward to …

LHC upgrade

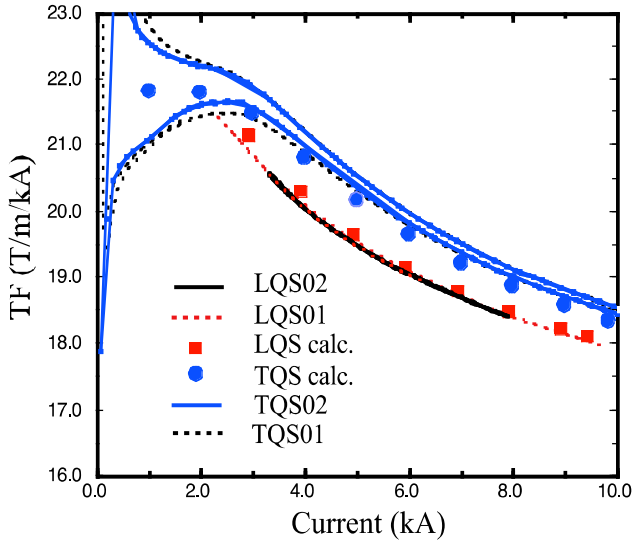
- **LARP -** The U.S. LHC Accelerator Research Program (LARP)
  - Four US laboratories, BNL, FNAL, LBNL, and SLAC, in collaboration with CERN on the Large Hadron Collider
- R&D for future interaction region/luminosity upgrades
- LQ program
  90mm Nb3Sn, 3.7m
  200+ T/m
  LQS01 and LQS02
- HQ ➔ 120mm aperture
- 11T Nb3Sn dipole

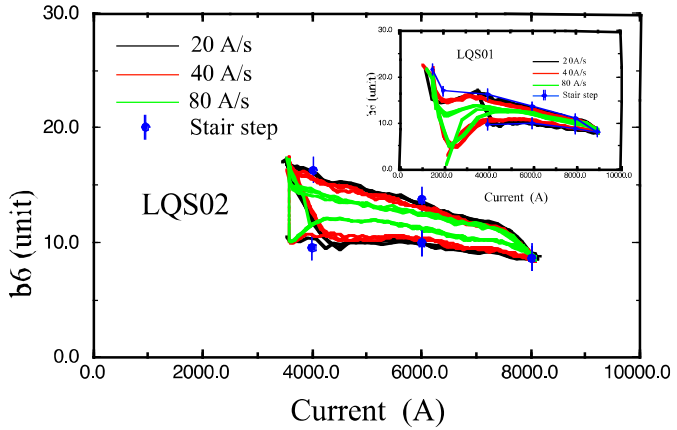


LQ magnet measurements

- MT-22, "Field Quality Study of the LARP Nb3Sn 3.7m-long Quadrupole Models of LQ series", Velev et al.

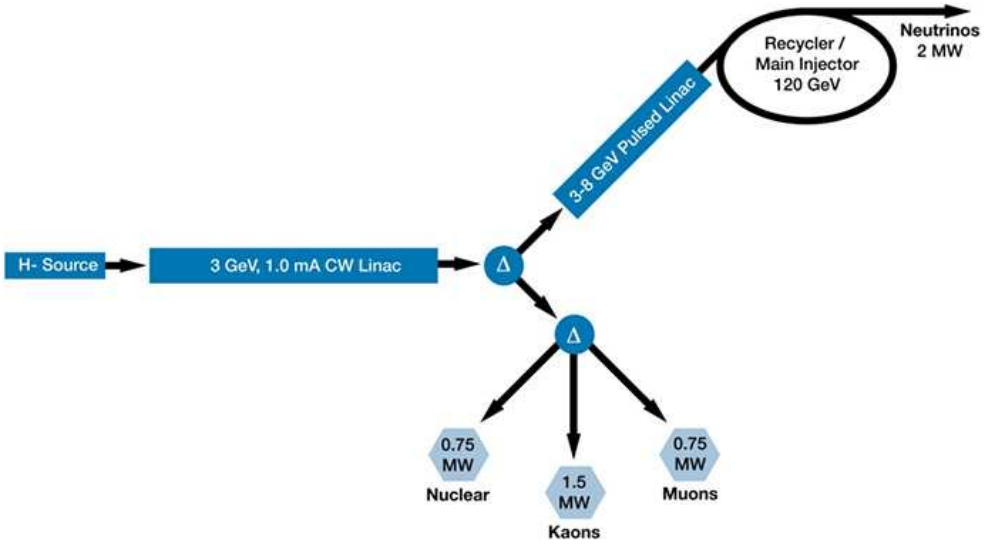
- Rotating coil measurements to characterize the geometric and dynamic performance

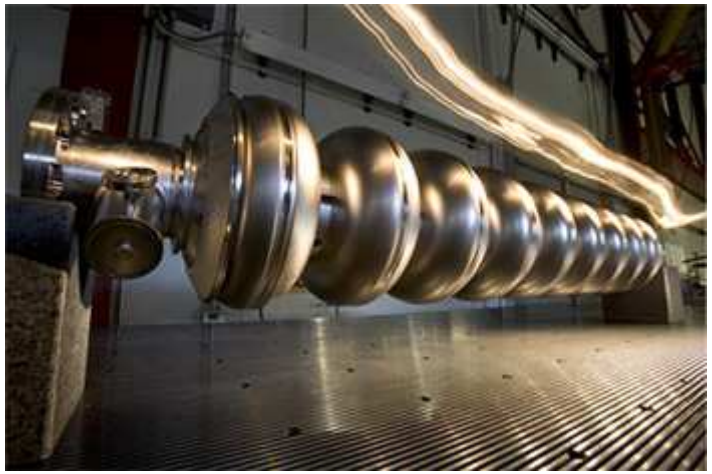




Project-X

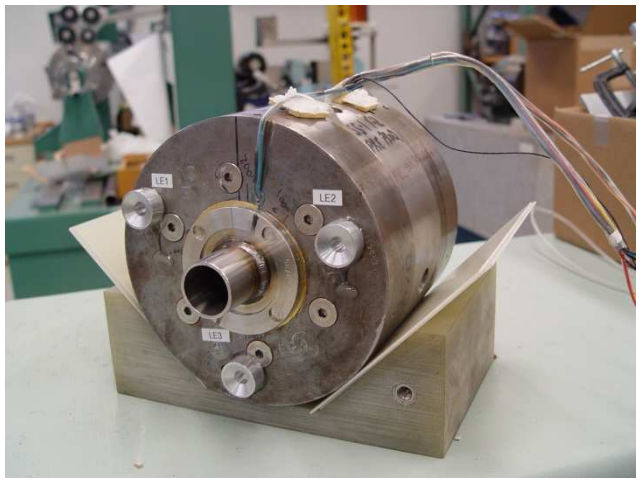
- Project X is a multi□MW proton accelerator facility proposed for construction at Fermilab
- H□ linear accelerator based on superconducting rf
- Similar technology as required for proposed ILC
- Could also provide the basis for a future Muon Collider or Neutrino Factory.

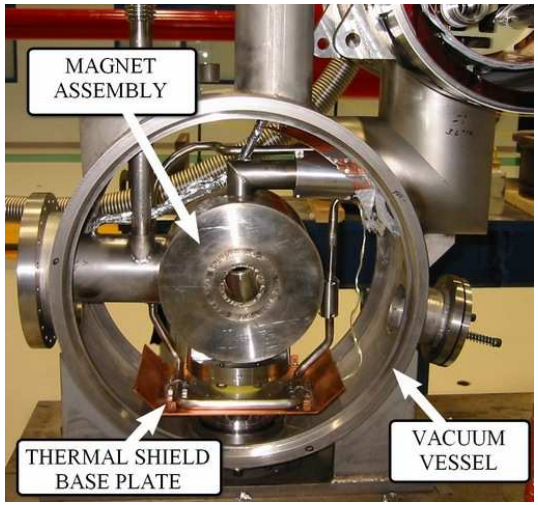


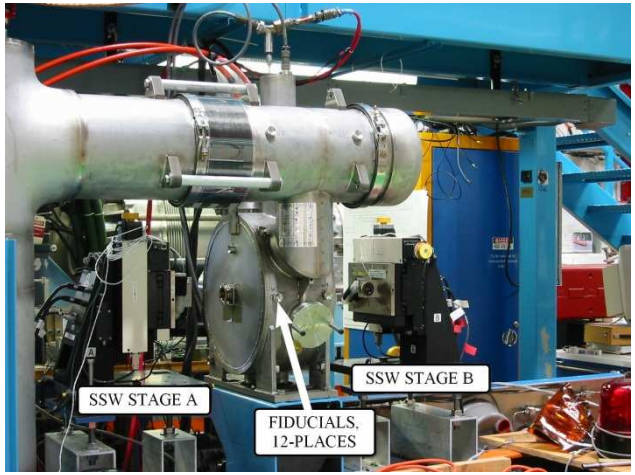


Project-X Magnet activities

- Production of some ~25 solenoid lenses:
  - Cold masses fabricated and tested
  - Hall probe scans to characterize field
  - Waiting to be assembled into cryostats
- Alignment (vibrating wire)
- Proceeding slowly…

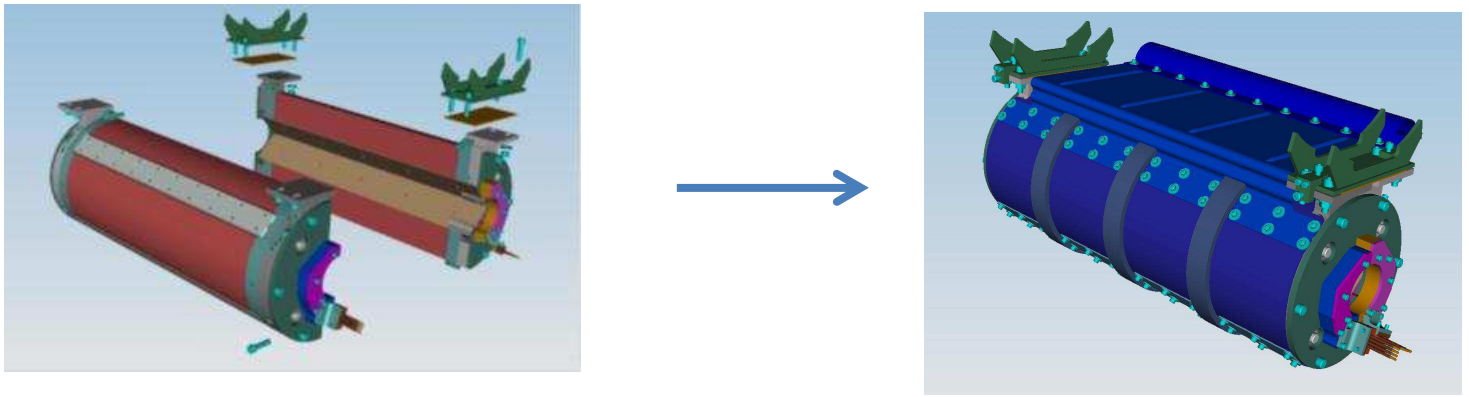




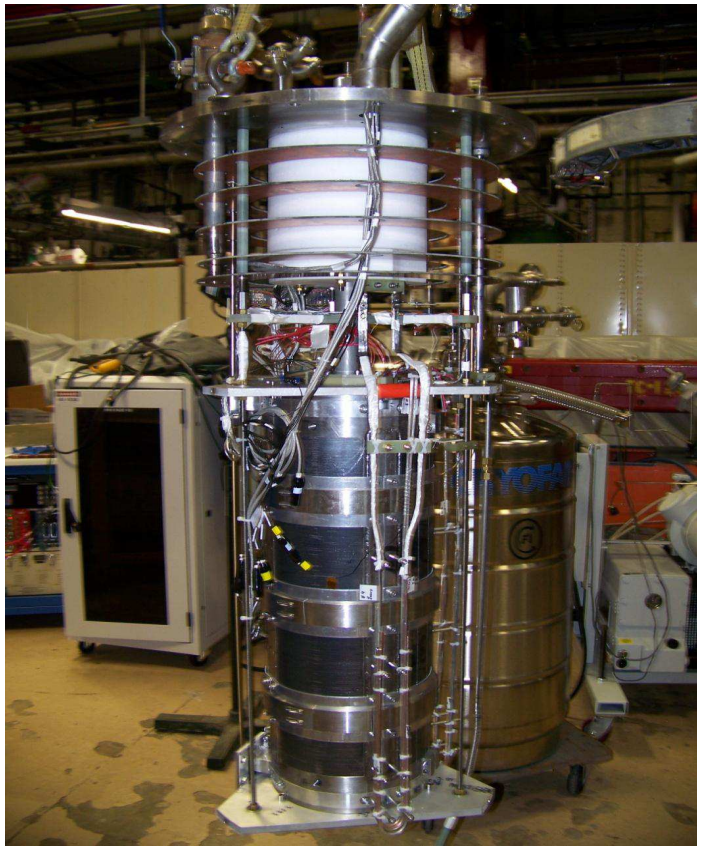


ILC

- Some research funding is available…
- Design and test of ‘split-quad’ that can be installed over beam line that has cavities assembled in a clean-room etc.



- The steel bands keep the structure together. Additional aluminum ones provide conduction cooling (cryogen-free magnet).

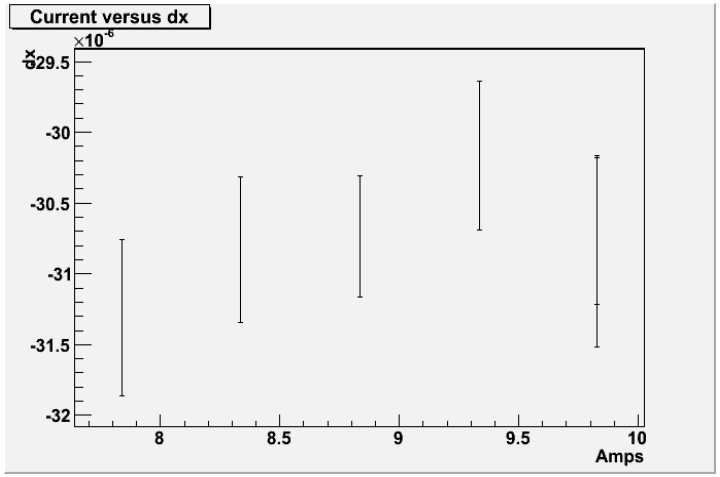


"Cryogen Free Superconducting Splittable Quadrupole Magnet for Linear Accelerators"
V.S. Kashikhin, et al.

Split quad was tested recently (in liquid He)

Magnet measurements with 3D Hall probe to characterize strength

Also rotating coil for harmonics and ***center stability***



LBNE

- Long Baseline Neutrino Experiment
- High-intensity neutrino beam (from e.g. project-X) sent from Fermilab to detectors housed in the proposed Deep Underground Science and Engineering Laboratory (DUSEL) in South Dakota (about 1000km).

- Potentially could see fairly large production run (~300) of various magnets needed for beam lines.
- Mostly straightforward characterization measurements, but there may be some fairly large sagitta magnets

- Because of the continuing need for 'standard' rotating coil measurements of beamline and research magnets, and the fact that existing measurement infrastructure is ~20 years old, we will be upgrading magnetic measurement software and hardware systems (Jerzy Nogiec talk).

NOvA

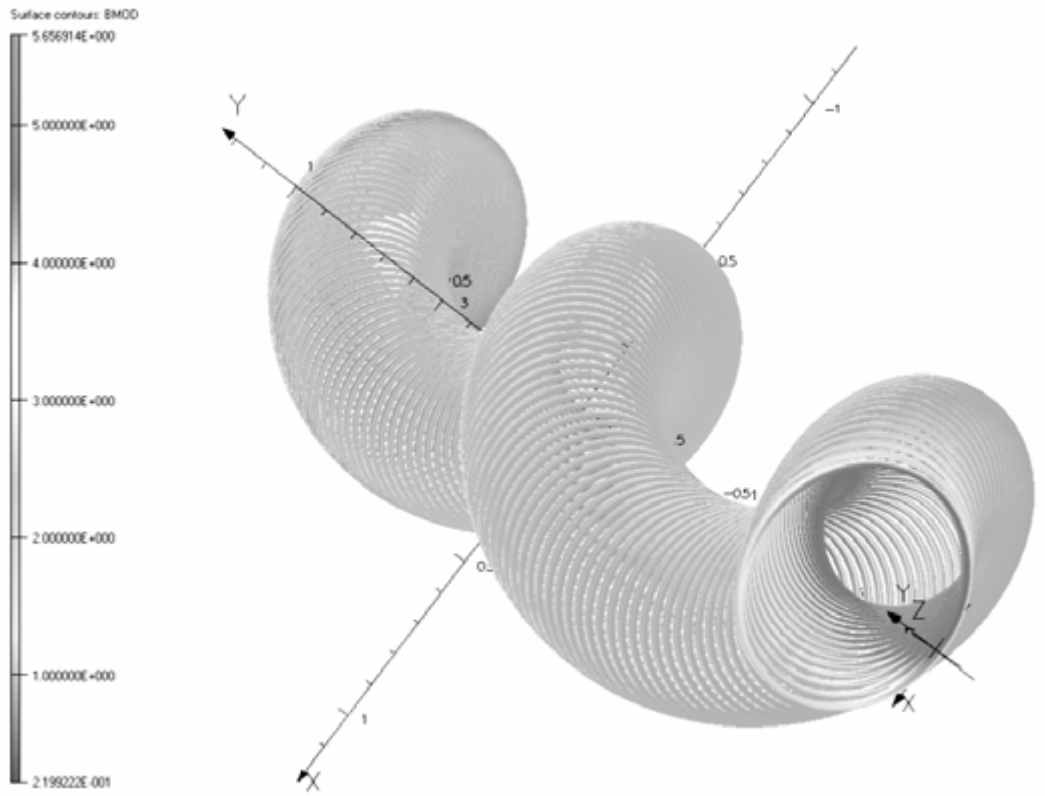
- On-going – will start to take data in 2013
- NOvA will use the existing "Neutrinos at the Main Injector" (NuMI) beam at Fermilab that is currently producing neutrinos for the MINOS experiment. Beam will be sent to a detector in Minnesota to look for neutrino oscillations.
- As part of the NOvA project, the accelerator infrastructure and the NuMI beam line will be upgraded to provide higher neutrino intensities than are currently possible in the NuMI beam. With the conclusion of the collider run at Fermilab, the Recycler ring, which is currently used to store anti-protons, can be converted to pre-injector to the Main Injector.

- Currently we are re-working permanent magnet quadrupoles to increase their strength ➔ involves a fair number of standard rotating coil measurements

Helical solenoid

- **Needed for Muon beam cooling experiment (MuCool) ➔ explore potential for Muon collider**
  - **Muons 200 times heavier – less synchrotron radiation loss**
  - **Muon accelerator could fit on Fermilab site.**
  - **Muons decay (2.2μs at rest, 35μs at 0.998c)**
- **Magnet system has to generate longitudinal and transverse dipole and quadrupole helical magnetic fields - providing a muon beam motion along a helical orbit.**
- **Complicated field configuration, but can be formed by a set of circular coils shifted in transverse directions in such a way that their centers lay on the center of the helical beam orbit.**

- **To measure field (at room temperature) use 3D Hall probe and map the volume**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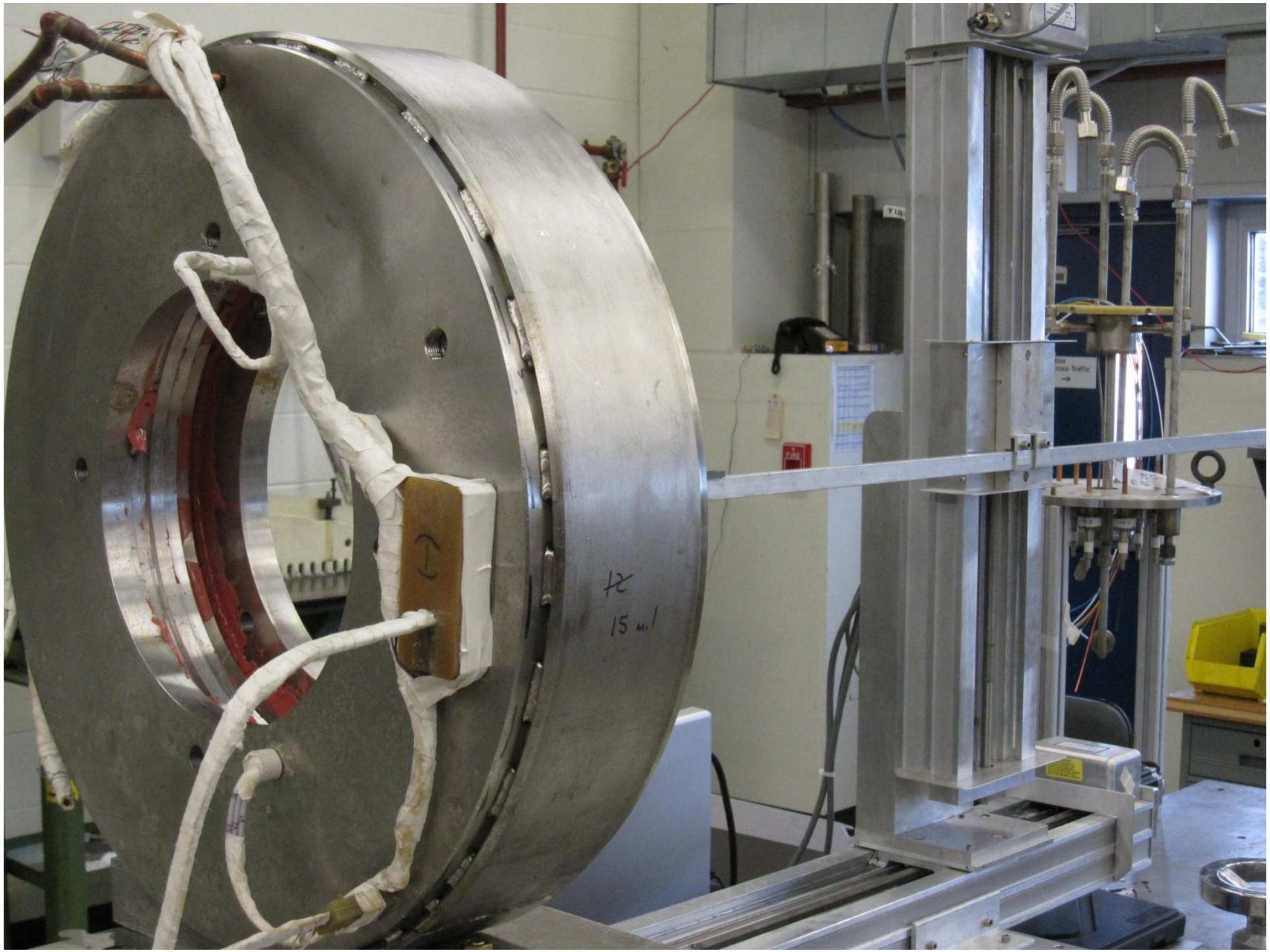
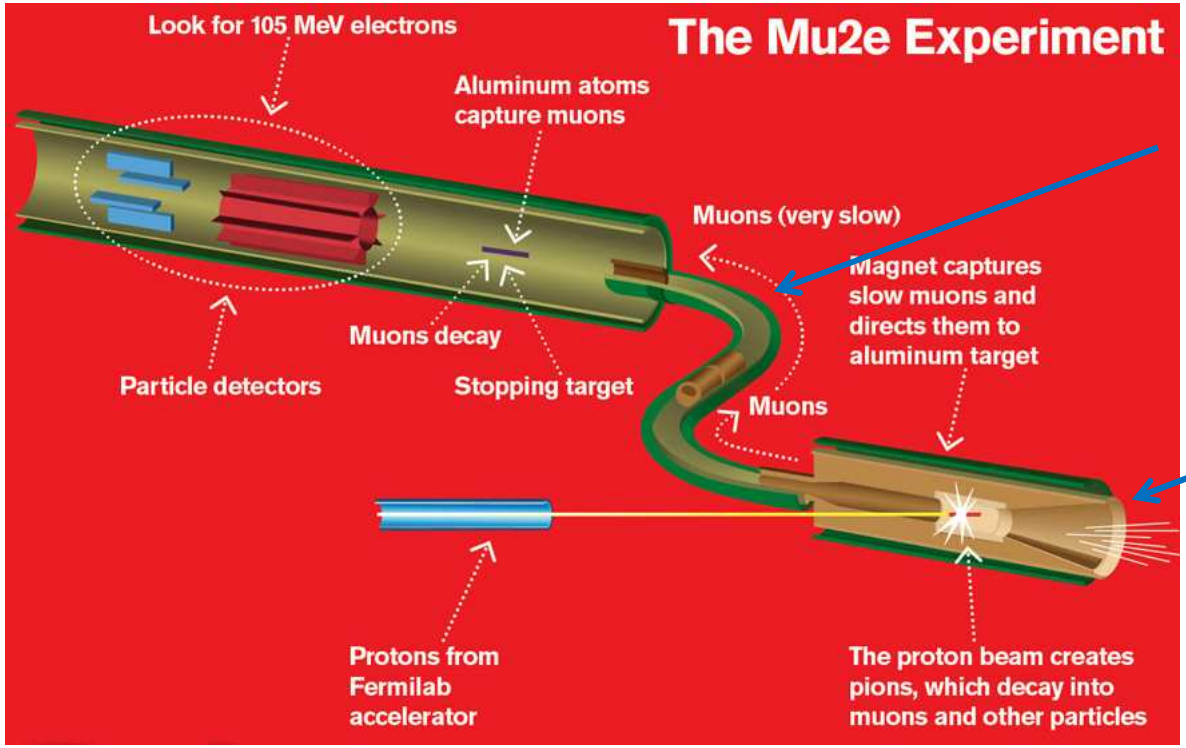

15 m.l

Mu2e

Detector solenoid



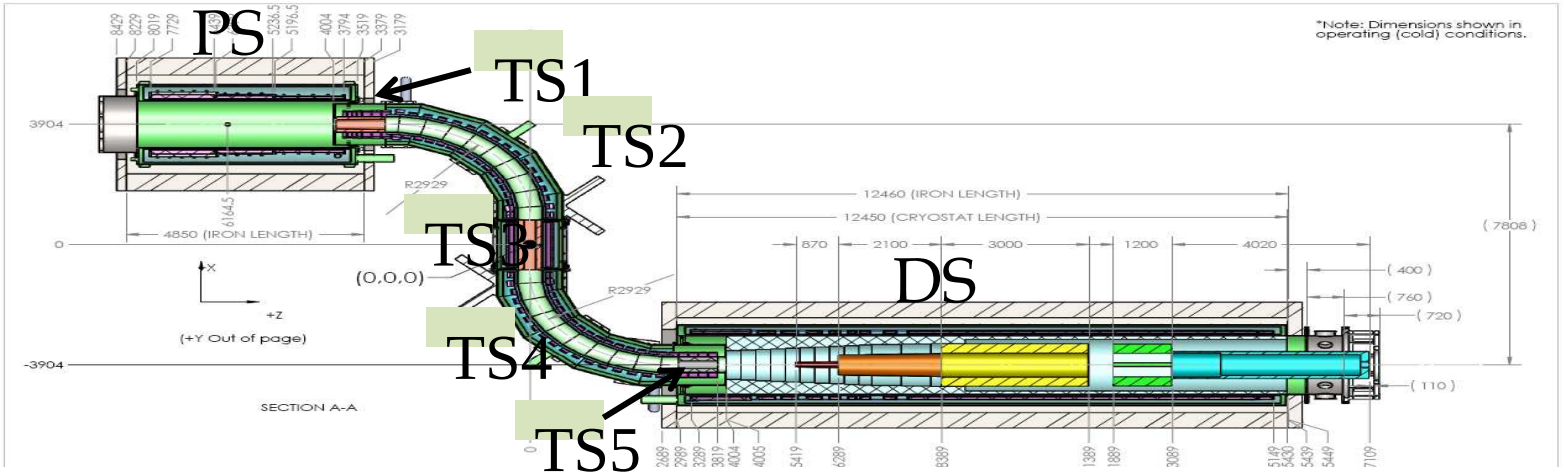
Transport solenoid

Production solenoid

Needs clean beam and good electron energy resolution… Sensitivity of 1 part in 1e-16 (!)
Opportunity to push Muon technology and at the same time search for ‘new physics’

Mu2e field measurements

- Need to map fields in solenoids
- Long length (PS is 4m) and large aperture (1m),
- Irregular geometry (TS)
- Gradient Fields in Mu2e play a vital role throughout the design
- Bz = 5T (PS)
- = 2.5T (TS_i)
- = 2T (TS_f)
- = 1T (DS)
- "push" muons out of PS into TS and into DS so we can study them

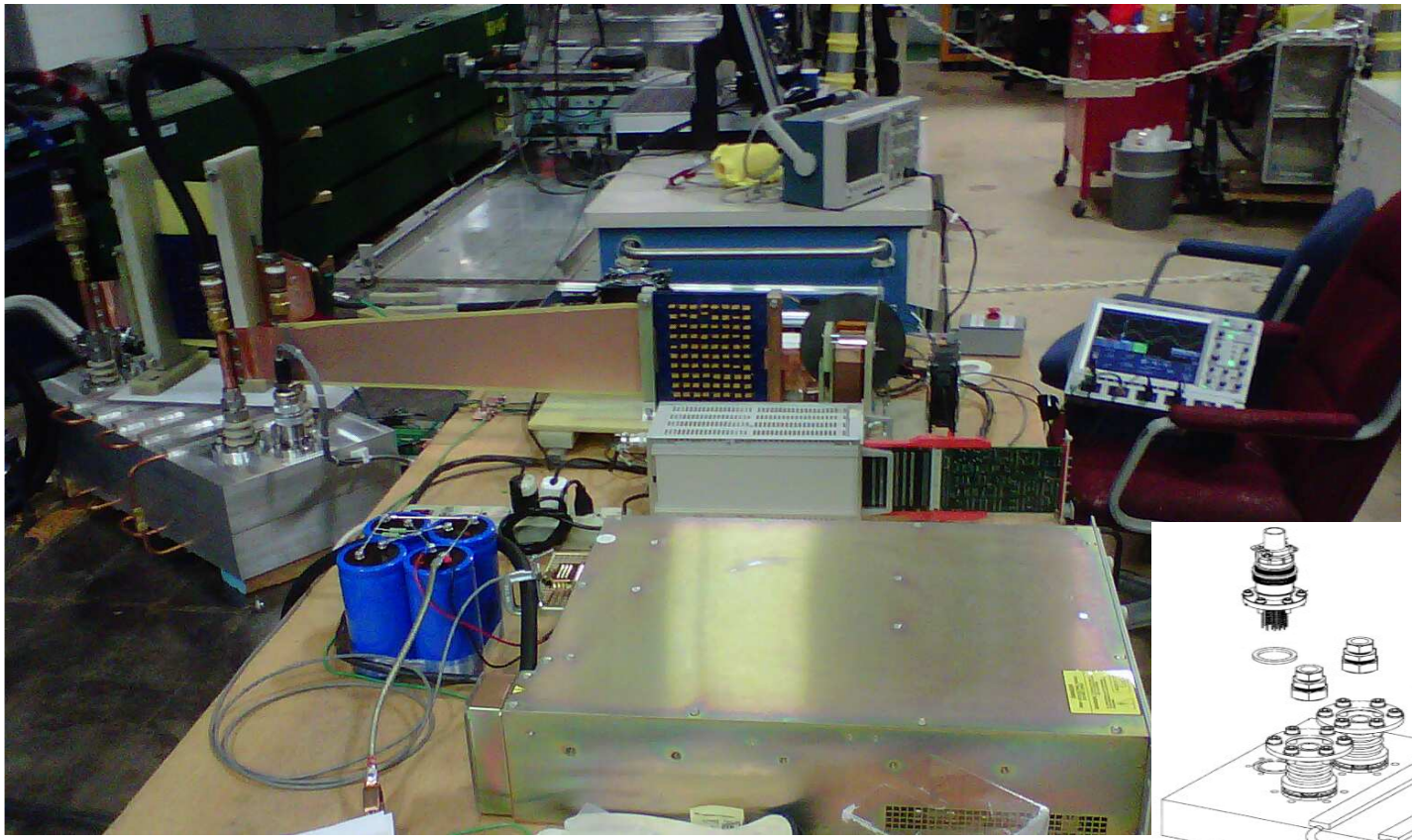


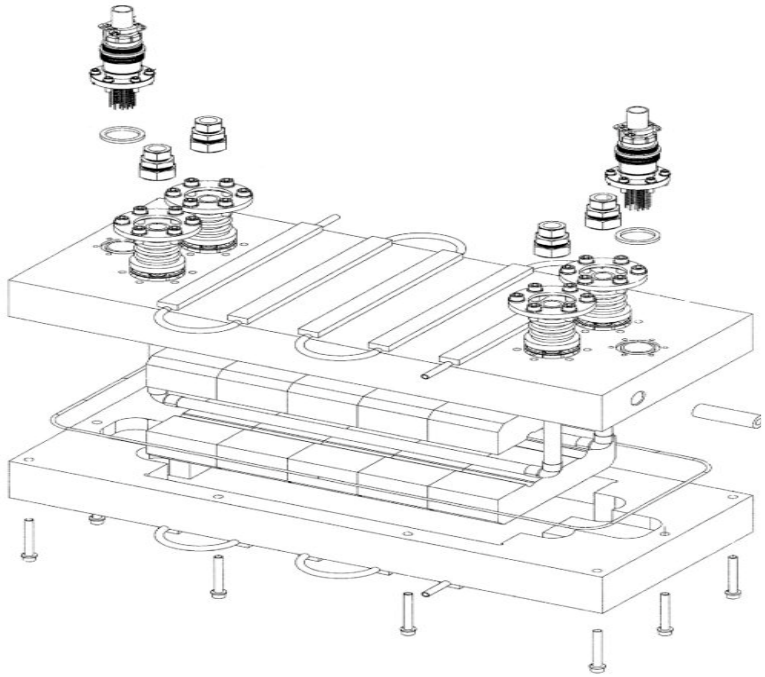
- Require 1e-3 field measurements in PS and TS
- In uniform tracker region of DS require 1e-4 map of field (!)
- Also need passive sensors in magnet to monitor changes during power cycles, cooldown, etc.

- Construction of a mapper is in the planning stages – considering Hall/NMR arrays on rotating arms – movement along magnet axis guided by rails.

- 3D Hall probes with NMR

Mu2e 300kHz, 5.1MHz dipole



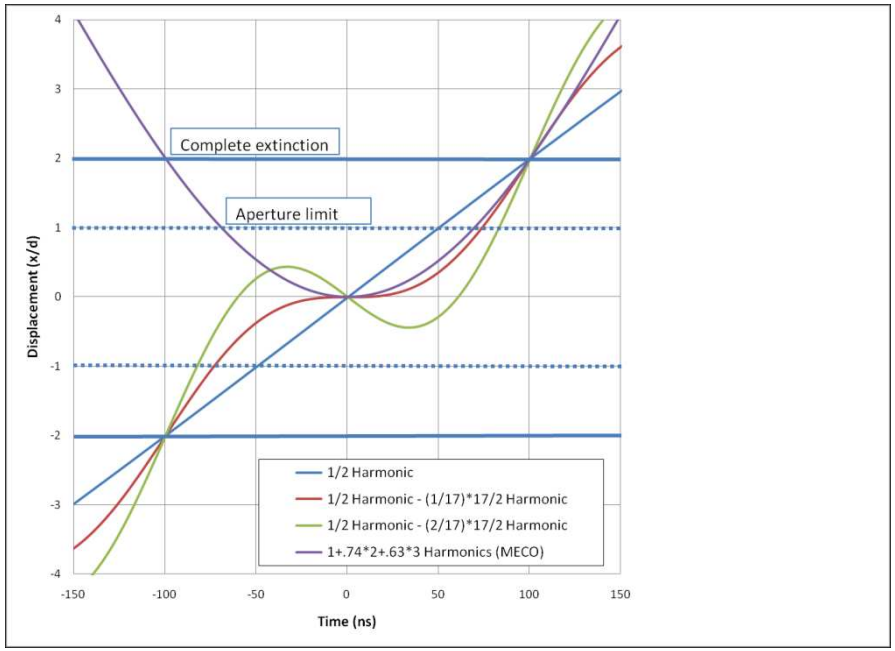


Needed to suppress background events which may appear during the muon transport - crucial that protons are extinguished at the level of 10^{-9} between the bunch gaps.

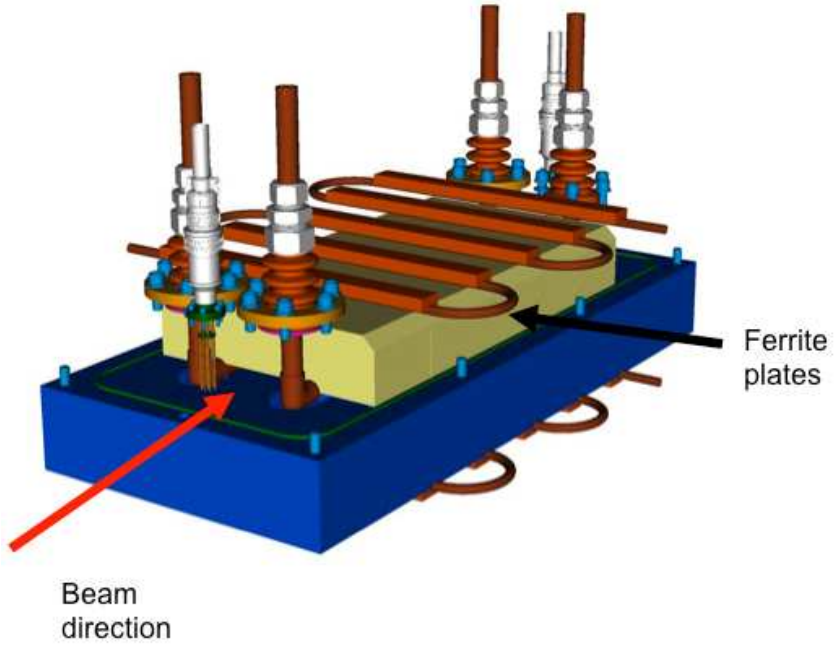
achieving 1e-10 is hard; normally get 1e-2 – 1e-3

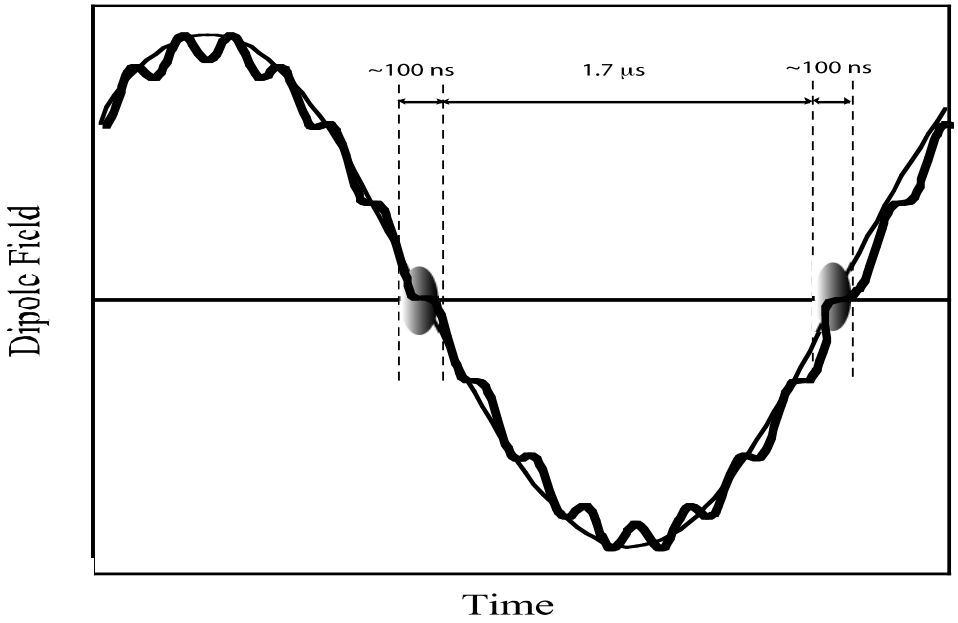
Extinction Scheme

- Internal (momentum scraping) and bunch formation in Accumulator
- External: oscillating (AC) dipole
- high frequency (300 KHz) dipole with smaller admixture of 17th harmonic (5.1 MHz)
- Sweep Unwanted Beam into collimators
- Calculations (MARS) show this combination gets ~1e-12



- "Selection Tests of MnZn and NiZn ferrites for Mu2e 300 kHz and 5.1 MHz AC dipoles", G.V. Velev et al.
- Prototype built with NiZn ferrite (high resistivity)
- Field measurements consist of wire loop and high-speed oscilloscope or fast ADC





Bunches pass during the dipole zero crossings but otherwise protons are bent away by the field

Summary

- Future field measurements at Fermilab will involve an assortment of activities:
  - More or less standard rotating coil measurements for LARP and beamline magnets for neutrino projects
  - Stretched (vibrating) wire alignment measurements of solenoids
  - Stationary loops for AC magnets
  - Hall probe mapping of magnet volumes

- In addition, upgrading magnetic measurements acquisition and data management systems to new standardized platform.

- A big challenge will be building Hall/NMR probe mapping expertise for the tight tolerances and large scale of the Mu2e project measurements.