Magnetic Measurement Activities at Fermilab

for the Magnet Systems and Instrumentation and Test Departments of the Technical Division

IMMW15
Aug. 21-24, 2007

Activities

- Booster Corrector Magnet Production
- Technology Quadrupole R&D program
- High Intensity Neutrino Source Solenoid R&D
- Other Magnet R&D and technological development

Activities completed

- measurement and analysis of decay and snapback in Tevatron dipoles and quadrupoles
- LHC IR quadrupole production measurements

Date: Tue, 14 Aug 2007 07:38:45 +0200 (MEST)
From: helpdesk@cern.ch
Subject: Automatic Account Expiration
To: Philip.Schlabach@cern.ch

As a result of the automatic account clean-up, the actions below have taken place. Accounts that have been blocked will be deleted after 12 months, along with all the associated data.

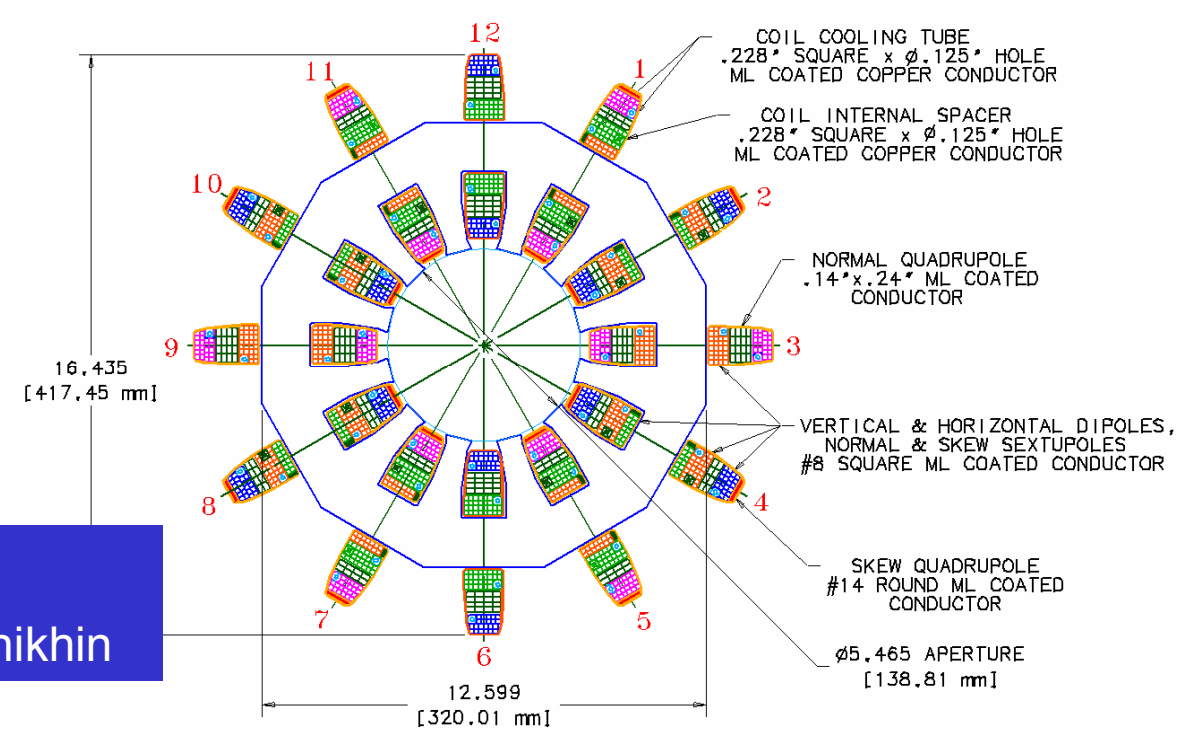
Personal accounts:
AIS ACCOUNT PSCHLABA (Group SA) Blocked (Resource unused for 6 months)

Booster Corrector Magnets

- Part of the “proton plan” to deliver more protons to neutrino experiments
  - Higher strength correcting more orders
  - Reduce losses which limit proton production
- Multi-element correctors replace existing correctors in the booster ring
  - Space constraints
- Booster a rapid cycling machine (15 Hz)
  - fast slew rates

Booster Corrector Magnet Design

- 6 elements: normal/skew dipole, quadrupole, sextupole
- Multiple-winding coils pump flux through the poles
  - 2 types of coils, each have windings contributing to various elements, windings connected externally



design by

Vladimir Kashikhin

Booster Corrector Measurements

- Fast slew rate
  - quadrupole and sextupole specified to have the capability of switching from a full positive field to a full negative field within ~1 ms
  - does the magnet follow the requested slew rates?
- Coupling between windings
- production QA an obvious concern given the many interconnections
- big bore – short length – magnet is all end
  - 138 mm pole tip diameter, 425 mm overall length

Booster Corrector Magnet Measurements

- Various strategies used at different stages in the program
  - prototype (2 magnets)
    - check the coupling between windings
    - check the slew rate performance
  - production (60, 48 installed)
    - QA
    - best characterization of the field for AP use

Prototype Magnet Measurements

- Use existing equipment
  - DC measurements with rotating probe for strength, harmonics, coupling
  - AC measurements using a slowly rotating probe (G. Velev, this workshop)
    - assemble measurement points taking in successive identical current cycles into a map of field vs. current in “one” cycle”
    - time resolution limited by speed of DAQ, how slow the probe can rotate and how long one is willing to take data
  - AC measurements with scope and mutipole probe

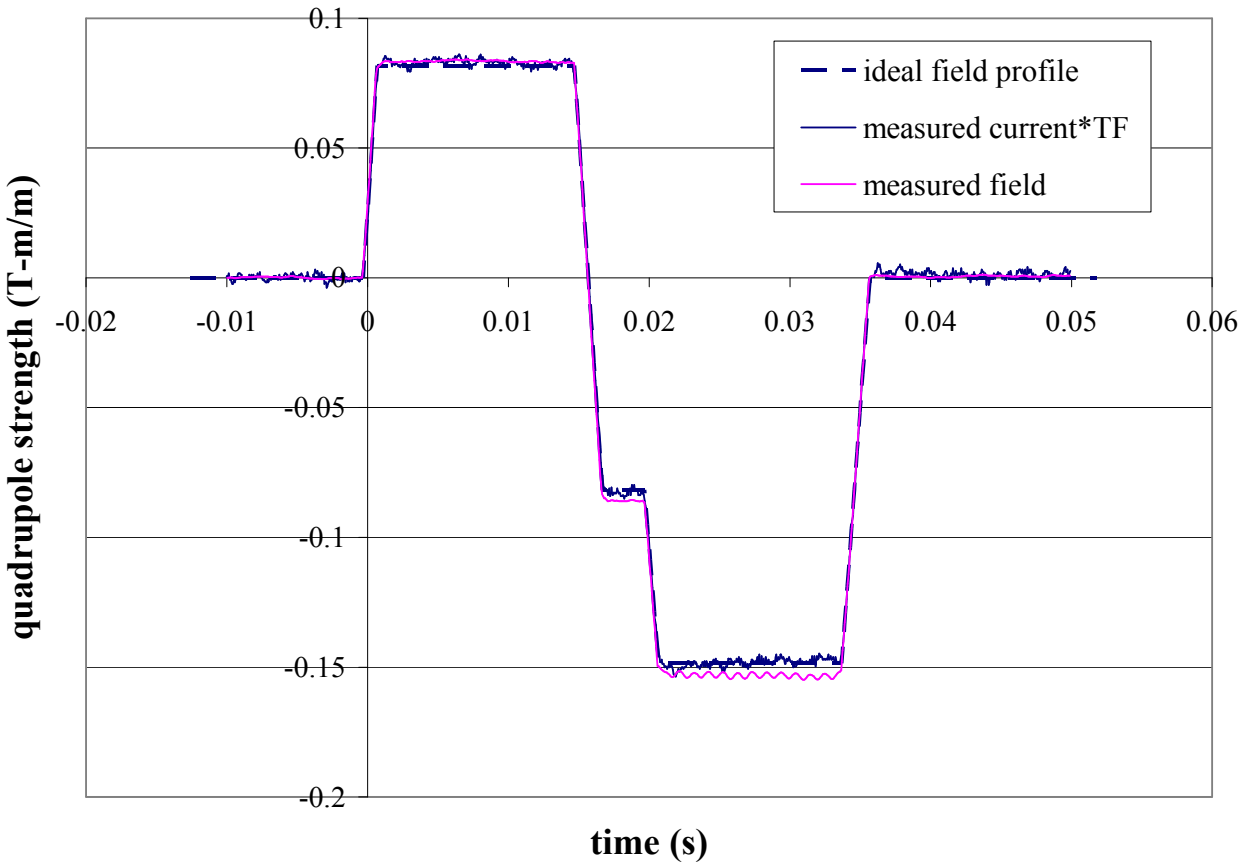
Prototype Magnet Measurements

- little coupling found
- small fields caused much confusion
  - earth's field not negligible!
    - dipole field, angle
    - centering of quadrupole
- slew rate measurements tough

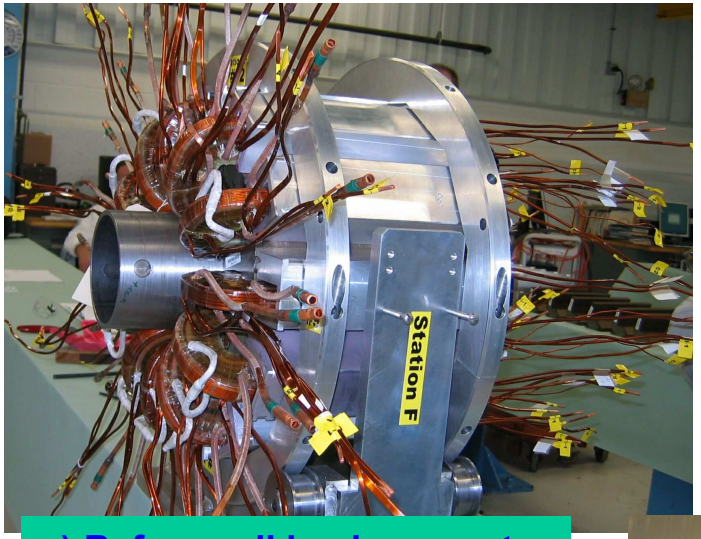
Element	Strength	Integrated Strength	Slew Rate
Dipoles	0.357 T	**0.015 T-m**	3.24 T-m/s
Quad, normal	0.49 T/m	**0.16 T-m/m**	**88 T-m/m/s**
Quad, skew	0.031 T/m	**0.008 T-m/m**	0.8 T-m/m/s
Sextupoles	5.87 T/m^2	**1.41 $T-m/m^2$**	**2350 $T-m/m^2/s$**

Slew Rate Measurements

scope measurement of normal quadrupole

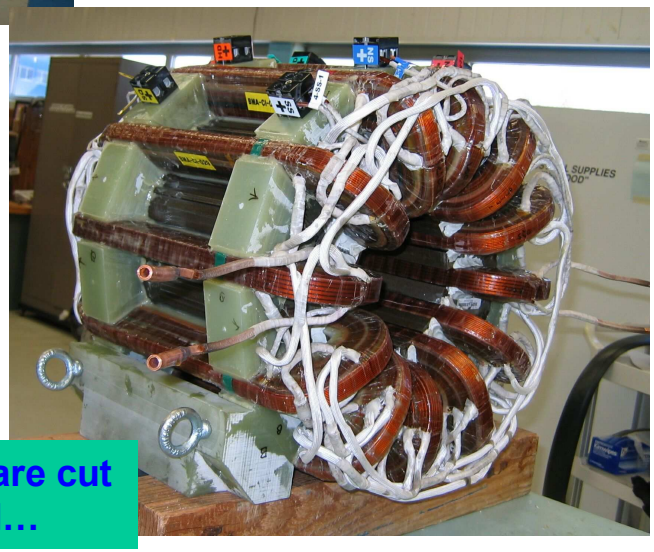


Production Magnet Measurements



a) Before coil leads are cut…

c) Completed corrector package with BPM



b) After coil leads are cut and connected…

Production Magnet Measurements

- Initial plan: stages of QA with AC field measurement
  - flux map with hall probe system after coil interconnection (D. Walbridge, this workshop)
  - full field measurement with probe prior to potting of the magnet
    - fixed coil AC measurement (J. DiMarco, this WS)
  - magnet alignment following potting
    - SSW measurement
    - field center defined by quadrupole
    - field angle defined dipole

Production Magnet Measurements

- flux mapping system worked great
- fixed coil probe wasn't done for the beginning of production
  - hard to get PC boards as long as we wanted
  - commissioning happened during production
- field strengths changed 1-2% after potting
  - discovered during the commissioning of the fixed coil, confirmed by DC measurement
  - some magnets ended up being measured 3 times
- we now measure after potting
- measurements now routinely done by technicians, including alignment

Production Status

- 16 magnets needed for current shutdown
  - 16 potted magnets measured
  - we're catching up on alignment
  - some have already been installed
- Fixed coil system
  - Data look good
  - Still some work to be done on software
    - online QA plots for measurer
    - porting data to data portal

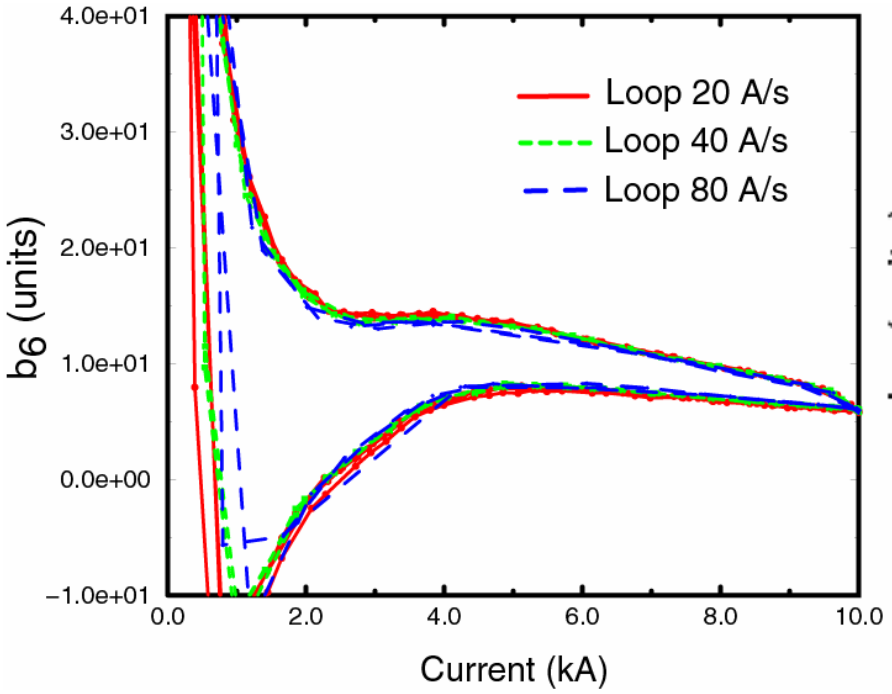
Fixed Coil Array Assembly

Technology Quadrupole R&D

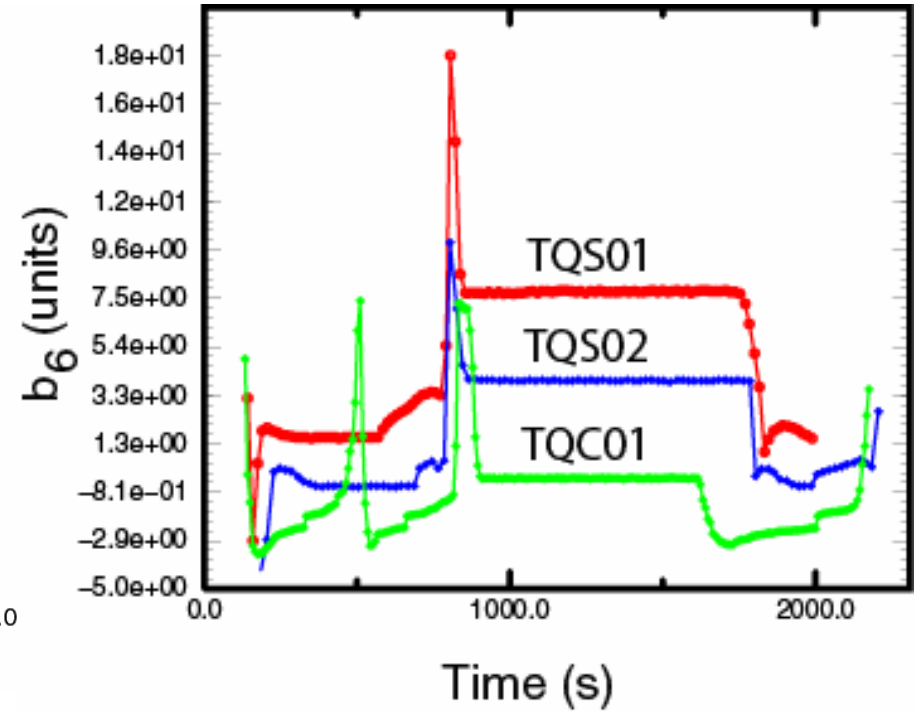
- Model magnet program
  - Demonstrate viability of Nb3Sn quadrupole for LHC IR upgrade
  - 1 m long
  - $\geq$205 T/m gradient in 90 mm bore
- Concentrating on quench performance up to now
- More or less standard superconducting measurement program

Technology Quadrupole R&D

b_6 hysteresis loops (TQS02)



b_6 before, during, after injection plateau

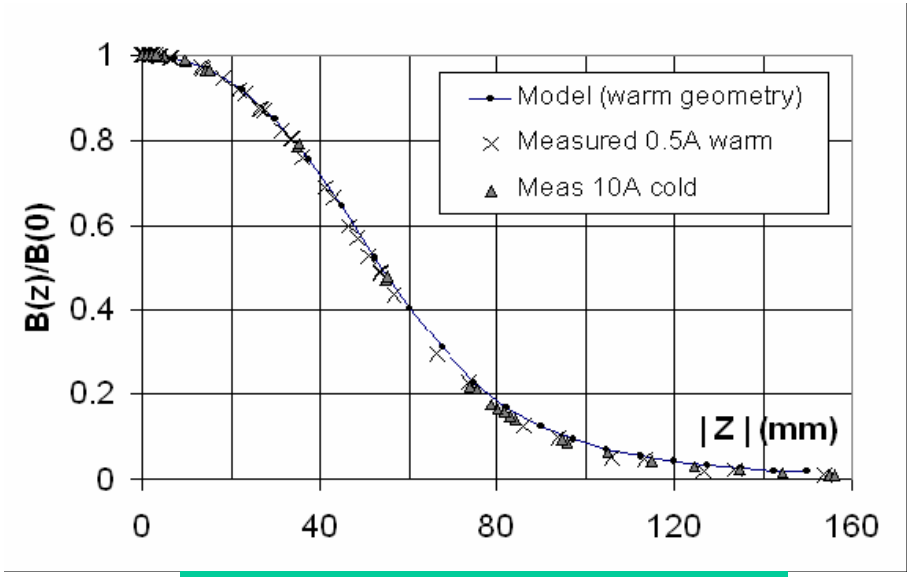


HINS Solenoid R&D

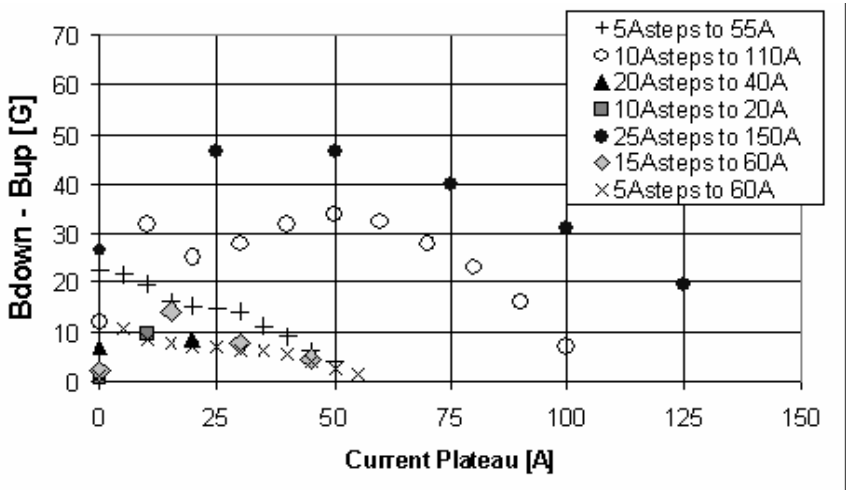
- Superconducting solenoid
  - focusing element in the front end of a high power H^- RF linac
  - ~5T (+ 30% operating margin) central field with low stray field at adjacent cavities
  - short package
  - design: central main coil with bucking coils at each end, iron yoke surrounds coils to further capture stray flux
- Tested in 1 m vertical test dewar in the Magnet Test Facility

HINS Solenoid Measurements

- Axial field measured by one-axis Hall probe in a warm bore
  - motion stage to move probe



axial field measurement



hysteresis measurements

HINS Solenoid Measurements

- Additional measurements
  - Axis measurement warm with SSW
- Future development
  - 3-D field mapping to locate solenoid axis
  - stray field measurement at “cavity” locations
- Note the talks in this workship by J. DiMarco (axis measurement) and M. Tartaglia (hall probe measurements)

Other magnet R&D development of technology

- Linear collider related ativities
  - Magnetic center stability measurements
- Design and development of printed circuit board probes
  - (J. DiMarco, this workshop)
- Continuing development of the extensible measurement system
  - (J. Nogiec, this workshop)
- Fast data acquisition for rotating coil measurement
  - (G. Velev, MT-19)
- Development of a data portal concept

Center Stability Measurement