IMMW15

Magnetic Measurements Overview Session Summary

J. DiMarco

Magnetic Measurement Activities at Fermilab

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

P. Schlabach

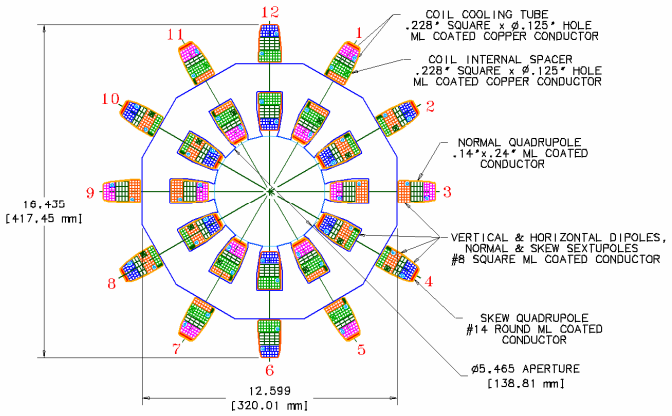
IMMW15 Aug. 21-24, 2007

Activities

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

Production BMA 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

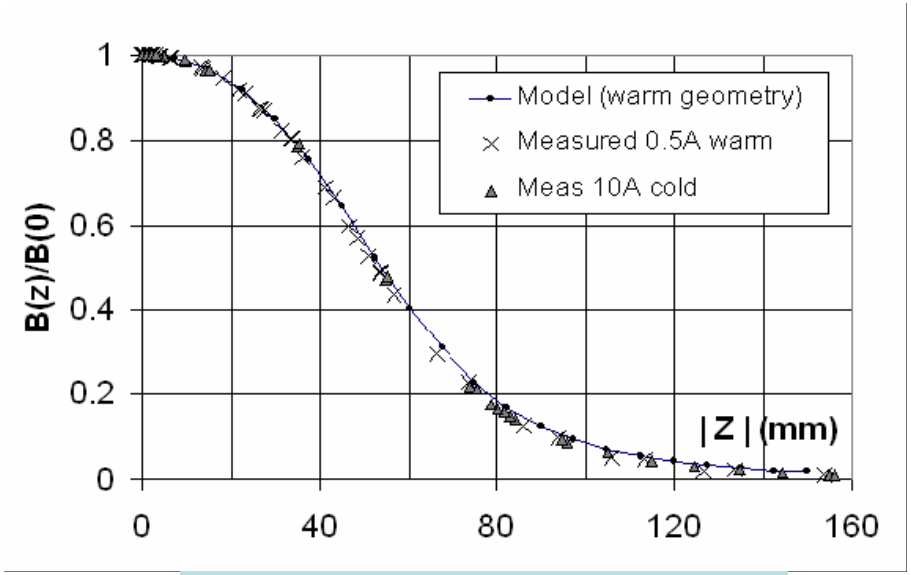


Technology Quadrupole R&D

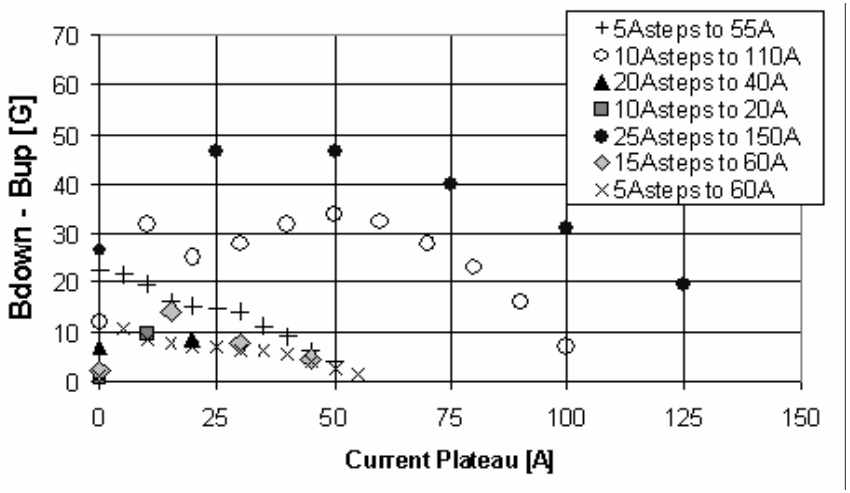
- Model magnet program
  - Demonstrate viability of Nb3Sn quadrupole for LHC IR upgrade
  - 1 m long
  - ≥205 T/m gradient in 90 mm bore
- Concentrating on quench performance up to now
- More or less standard superconducting measurement program

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

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

Magnetic Measurement Activities planned for LHC at CERN

L. Walckiers, AT-MTM
CERN

Components Entering in the FiDeL Description

Static (DC) Components: these are steady-state in nature and are reproducible from cycle-to-cycle provided the magnet is cycled with th same procedure. Static components are solely dependent on the excitation current and include:

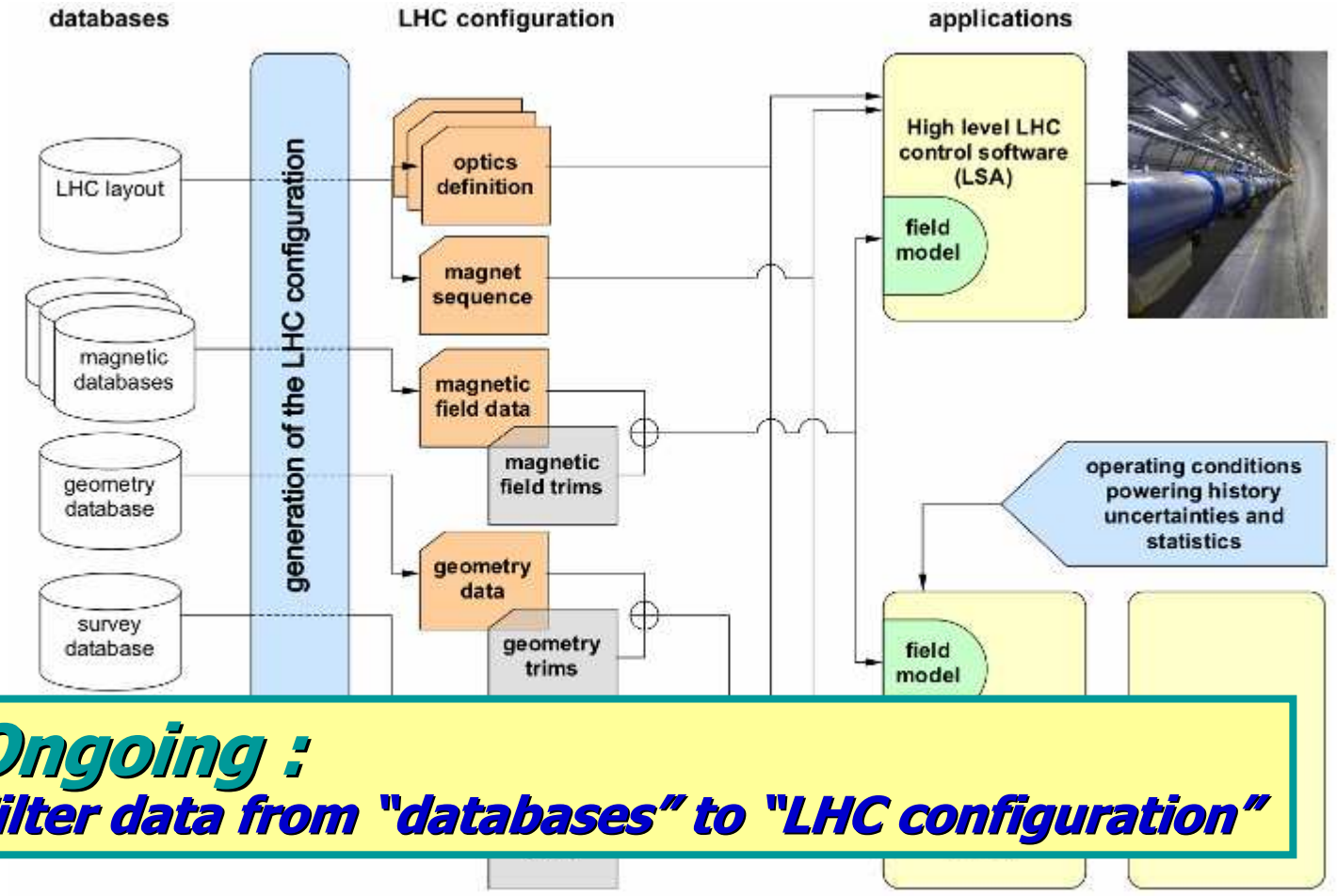
- **a. geometric contribution (Cn geometric).**
- **b. DC Magnetisation Contribution (Cn MDC).**
- **c. Saturation contribution (Cn saturation).**
- **d. Displacement contribution (Cn deformation).**
- **e. Residual Magnetisation Contribution (Cn residual)]**

Dynamic (AC) Components: These components are both current and time dependent and are not reproducible from cycle-to-cycle. They include:

- **a. Decay (Cn decay).**
- **b. Snap-back (Cn snap–back).**
- **c. Coupling-Currents (Cn MAC).**

FiDeL : FIeld DEscription for the LHC

Operation of the machine based on a mathematical model (**FIDEL**: FIeld DEscription for the LHC to predict integrated strength and harmonics based on magnet current value and history.



Ongoing :

Filter data from "databases" to "LHC configuration"

LHC Commissioning with Beam : Still needed

FAME [Fast Measuring Equipment]

Tool needed to measure multipoles on Magnets in SM18 with enough bandwidth

Includes :

- 15 m shaft rotating at 3 to 10 Hz [O. Dunkel talk]
- FDI : Fast Digital Integrator [J. Garcia]
- New acquisition software [M. Buzio]

MIFI : Measurement to Improve FiDel

- Scaling laws for
  - Different maximum energies
  - Different durations fo physics, pre-injection, and injection plate

Magnetic measurements for accelerators @ CERN: an overview

L Bottura, N. Brooks[1], M Buzio, R Chritin, D Cornuet, G Deferne, JM Dutour,
P Galbraith, D Giloteaux, J Garcia Perez, P Leclere, G Peiro, L Walckiers

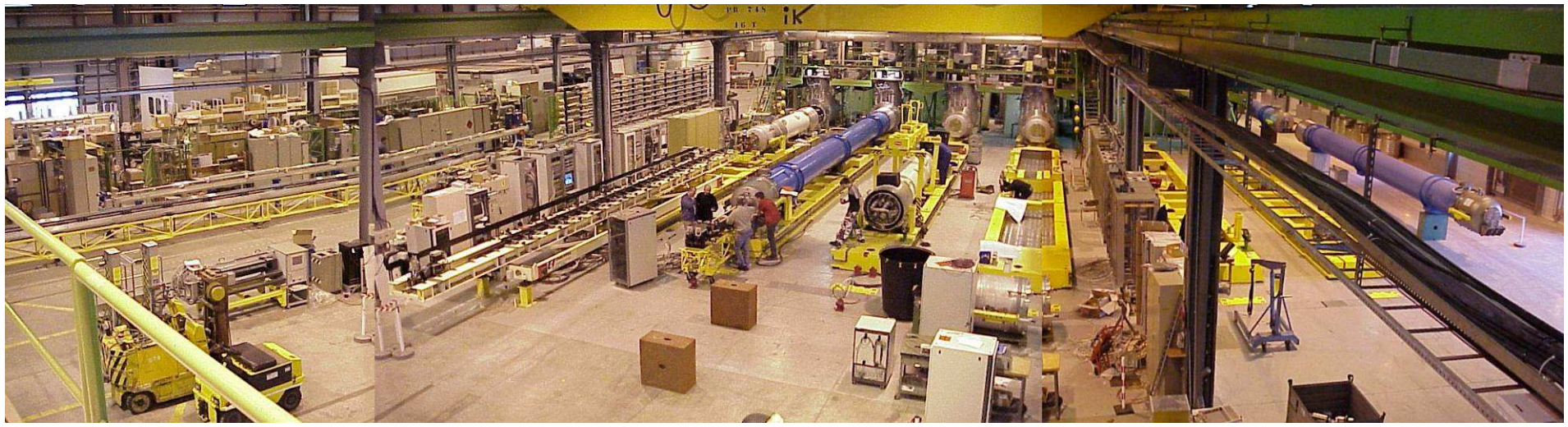
1=University of Texas

Contents

Projects involving magnetic measurements:

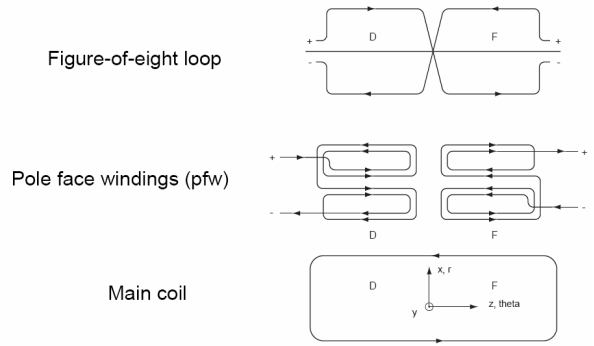
1. Tests for the construction of the LHC
2. Tests for the operation of the LHC
3. Tests for CERN's accelerator chain (PS & SPS)
4. Tests for the upcoming Clic Test Facility CTF3
5. Tests for the upcoming Linac4

- **Final series tests for the LHC**:
  - standard cryogenic tests of spare cryodipoles (MB) and quadrupoles (SSS)
  - warm re-test of repaired low-β quadrupoles
  - sporadic checks of magnet polarity/electrical integrity in the tunnel (esp. correctors)
  - special tests left pending from the series tests period: e.g. detailed characterization of warm quadrupoles (MQW), measurement of cold magnetic axis in SSS and MB, etc.

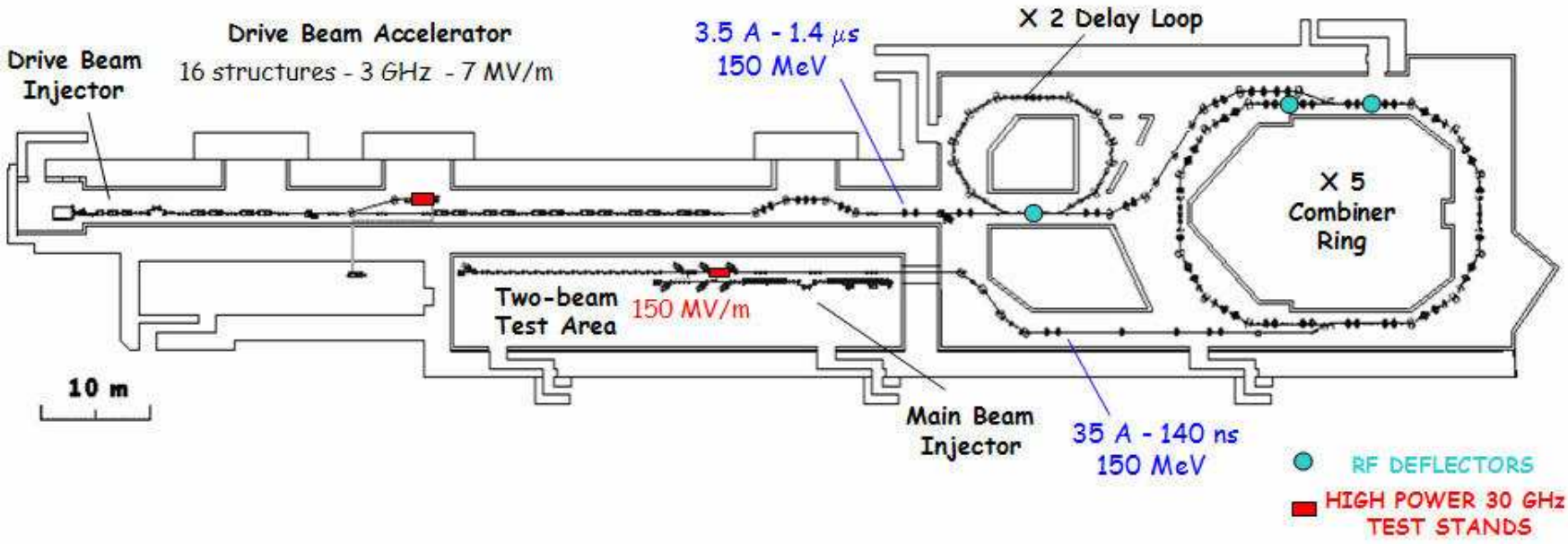


- **Proton Synchrotron (PS) magnets**
  - main combined-function dipole/quadrupoles:
    - one extensive campaign carried out in 2001 to characterize new corrector coil circuits;
    - possibility of an additional campaign for the non-linear interaction of different circuits under discussion (*difficult* test: 30-ton, 6 m long magnet, 5 power circuits to test in combination, benefit of MM vs. beam measurements to be assessed)
  - sporadic tests of other magnets: e.g. elliptic gamma-jump quads, etc…

- combined function magnets (half-focusing, half-defocusing)
- pole-face and figure-of-eight windings to trim quadrupole and sextupole



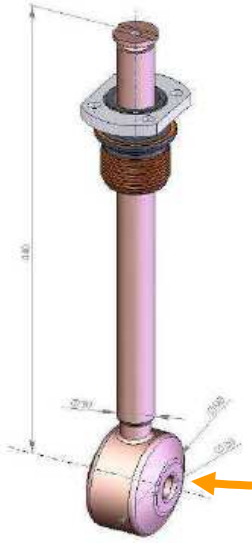
CTF3 is a test facility for CLIC, aiming at demonstrating the drive beam concept testing components at nominal power. CTF3 is now being built at CERN using ~30 and (mostly) second-hand magnets, recuperated from machines throughout Eur



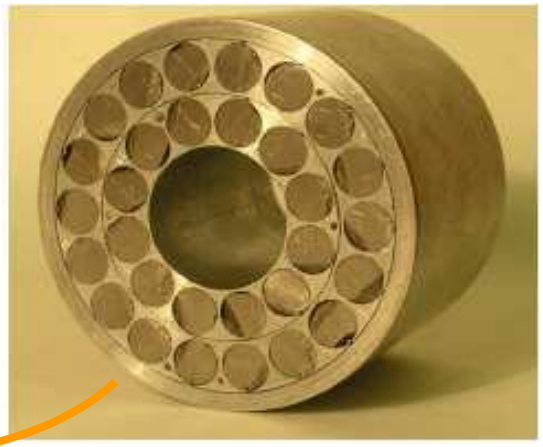
- **CTF3 magnets**
  - one-two magnets per type to be tested
  - ~10 magnets tested up to date, ~20 more expected until mid 2008 (dipoles, quads & sext
  - mostly standard tests (integrated strength, field homogeneity) using a flux meter
  - specs and methods yet to be fixed in some cases (e.g. trapezoidal-pole dipoles)

The 160 MeV Linac4 is the recently approved upgrade to the LHC injector chain, designed to doub
output intensity of the PS Booster thus allowing LHC to reach and surpass its nominal luminosi

- **Linac4 magnets**
  - most magnets recycled from Linac2: only some quads to be remeasured
  - permanent quadrupoles: ~60 magnets to be fully tested (integral, harmonics, axis, field direction) to a high accuracy (0.05 mm axis budget) in 2008/2009.
    Under discussion: need to test after welding in the drift tube to verify any possible heat-ind degradation. Prototype tests started.
  - pulsed quadrupoles: ~60 magnets also coming in 2008/2009.



drift tube



prototype permanent magnet quad

Linac2-type pulsed quad

Status and prospects for different instrumentation families:

1. Rotating coil systems
2. Traveling probes (moles)
3. Fluxmeters
4. Hall probe systems
5. Stretched wire systems
6. Material property instrumentation
7. B-trains

- **Harmonic Moles**[1]
  - 750 mm, ∅19 mm coil, dipole- or quadrupole-compensated with tilt sensor and fully motorized longitudinal transport system
  - 12 dipole units (DIMM) + 6 quadrupole units (QIMM) used for LHC cryomagnet series tests in the industries and at CERN
  - a few units to be kept operational for future LHC cryomagnet testing + as a general-purpose instrument

- **AC moles**[2]
  - 200 mm, 4× tangential coil with retro-reflector for accurate axis finding at low power, AC powering with synchronous detection, stepwise rotating mode for harmonics/field direction measurements
  - 6 warm units + 2 optimized for cold tests, at low field (∅40 mm, Ti body, non-magnetic tilt sensor, piezo motor)
  - 1-2 units to be kept operational for future LHC cryomagnet testing + as a general-purpose instrument

- **IPT Fraunhofer moles**[3]
  - 750 mm, ∅19 mm coil with LED source + telescope detection for axis finding
  - two warm units + one optimized for cold tests at high field (∅40 mm, Ti body, non-magnetic tilt sensor, piezo motor)
  - cumbersome operation & calibration + LabWindows software very difficult to debug, upgrade or maintain ⇒ system discontinued since 2003 [bitter lesson about externally source software !]

future integration of functionality in a "superr DC/AC modes, high field harmonic coil, tilt sensor tracking …

1=see J.G. Perez's talk, this workshop; 2= J.G.Perez, IMMW 14; 3=M. Buzio, IMMW XI

Which directions to go for our Group at the end of the LHC series era ?

- **simplification:** needs disappear, personnel for maintenance and operation is cut down ⇒ we must consolidate our instrument park, eliminate redundant systems, integrate functionalit in polyvalent hardware and software

- **performance:** we prepare to upgrade our systems to the foreseeable demands of the next generations of magnets:
  - high fields and ramp rates
  - both larger and smaller apertures than LHC
  - comparable accuracy

  starting with the basic components (fast integrators, unified software)

- **autonomy:** flexible and reliable software prototyping requires programmers and users to be close ⇒ we should internalize software development to become more efficient

Overview of Measurement Activities at BNL

Animesh Jain

on behalf of

Superconducting Magnet Division

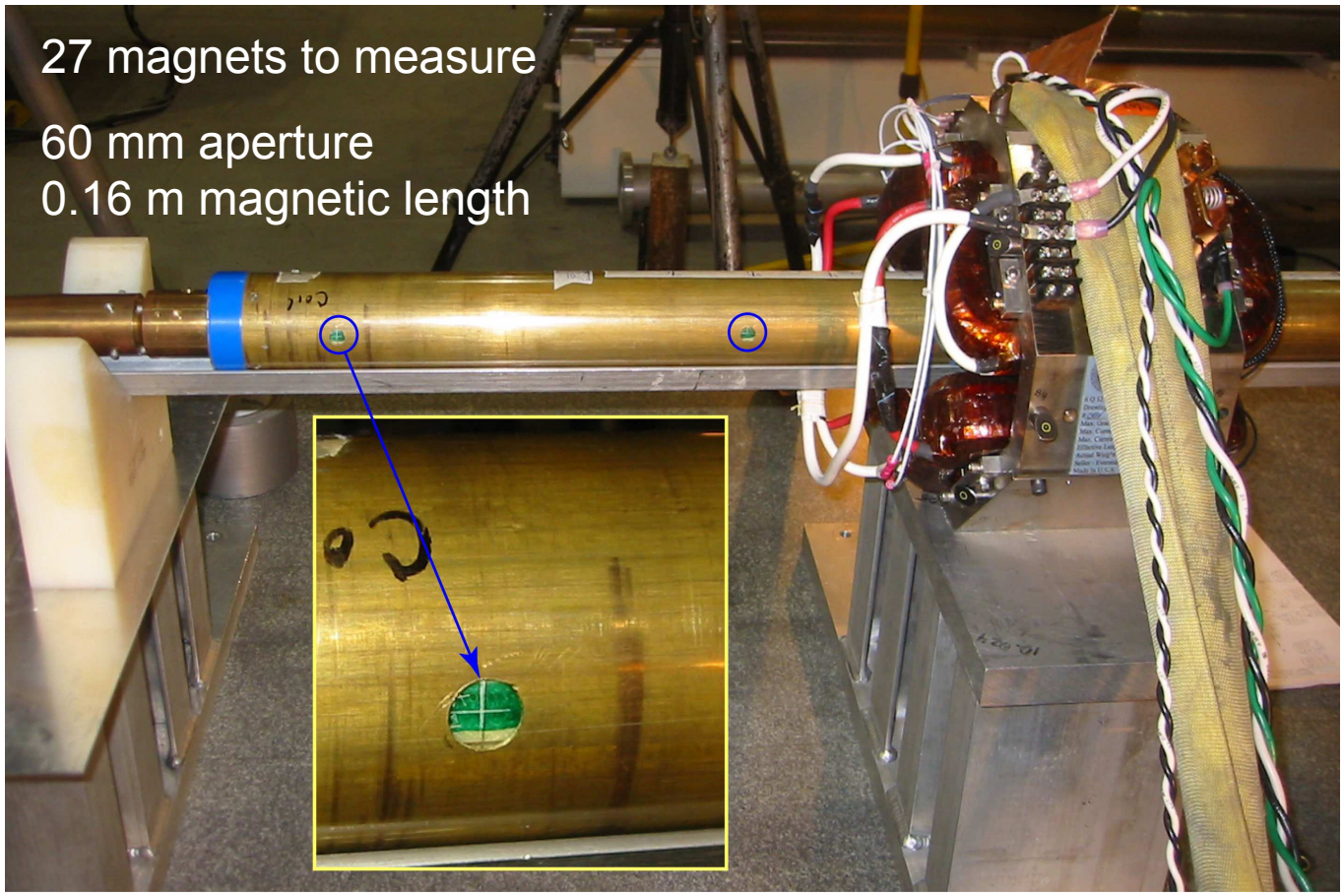
Brookhaven National Laboratory, Upton, NY 11973

15th International Magnet Measurement Workshop, Fermilab, August 21-24, 2007

Introduction

- In the past, the Superconducting Magnet Division at BNL has been actively engaged in designing, building and testing superconducting magnets for large projects (RHIC, LHC).
- We also completed successfully production testing of conventional magnets for the Spallation Neutron Source.
- No such large production measurements in the past two years.
- Ongoing activities:
  - Fast ramp measurements (GSI, BioMed, NSLS-II) (another talk at IMMW-15)
  - Measurements of quadrupoles ✓ and dipoles ✓ for ERL project at BNL.
  - Field quality measurements in Swiss Light Source magnets to understand field quality issues relevant to NSLS-II (integrated correctors, interference)
  - Vibrating wire alignment system R&D for NSLS-II (with Cornell).
  - Magnet vibration measurements for International Linear Collider (ILC).
  - Activities of NSLS group (superconducting undulator).

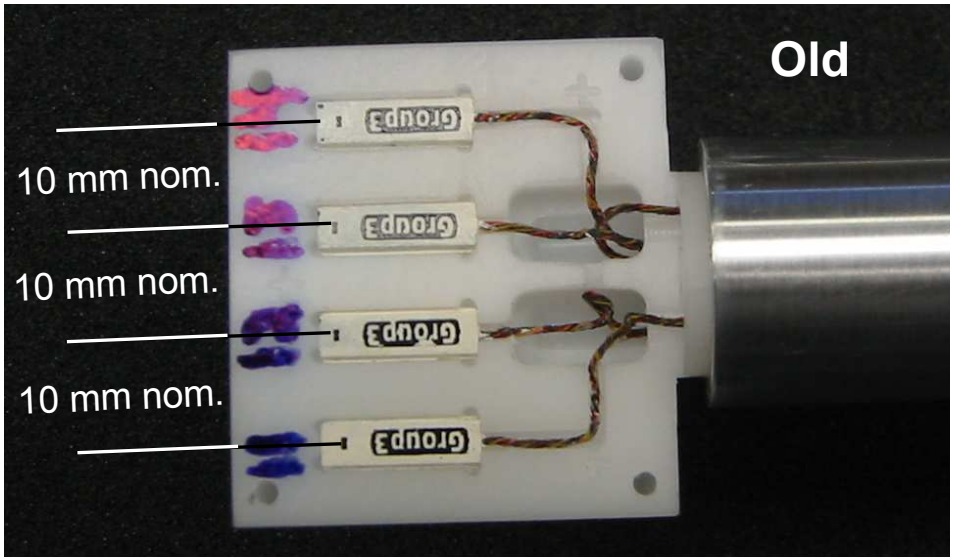
ERL Quadrupole: System Using A Mole

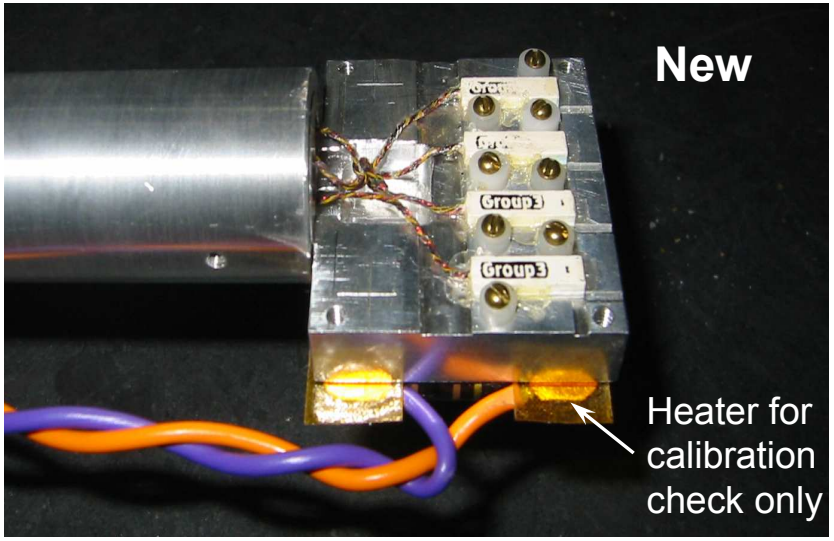


Mole has fiducials on the coil, and is accurately calibrated using dipole, quadrupole and sextupole fields.

Drawback: Optical survey is slow and gives axis only within ±50 μm

Hall probe Holder





Hall probes were mounted into grooves in a plastic holder.

Initial calibration showed departures from factory calibration.

The calibration changed further during measurements of the prototype, possibly due to changes in strain with temperature.

Made of Aluminum to minimize temperature gradients.

Probes mounted in a manner similar to a commercial holder to avoid strain.

Calibration checked again in a reference dipole against NMR.

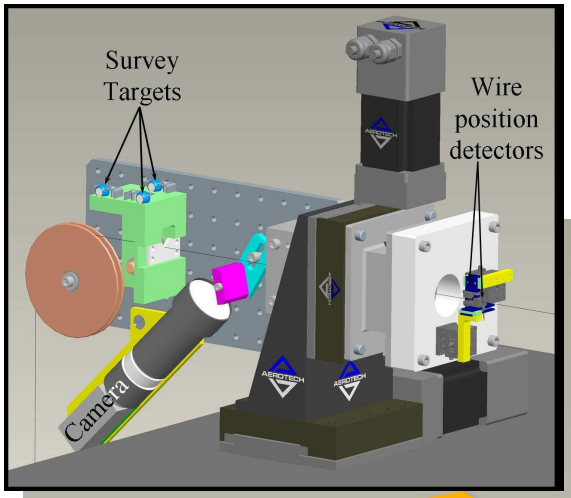
A temporary heater used to study stability with temperature.

Effect of Neighboring Magnets on Field Quality

Easy to measure effect on the quadrupole field with unpowered sextupoles.

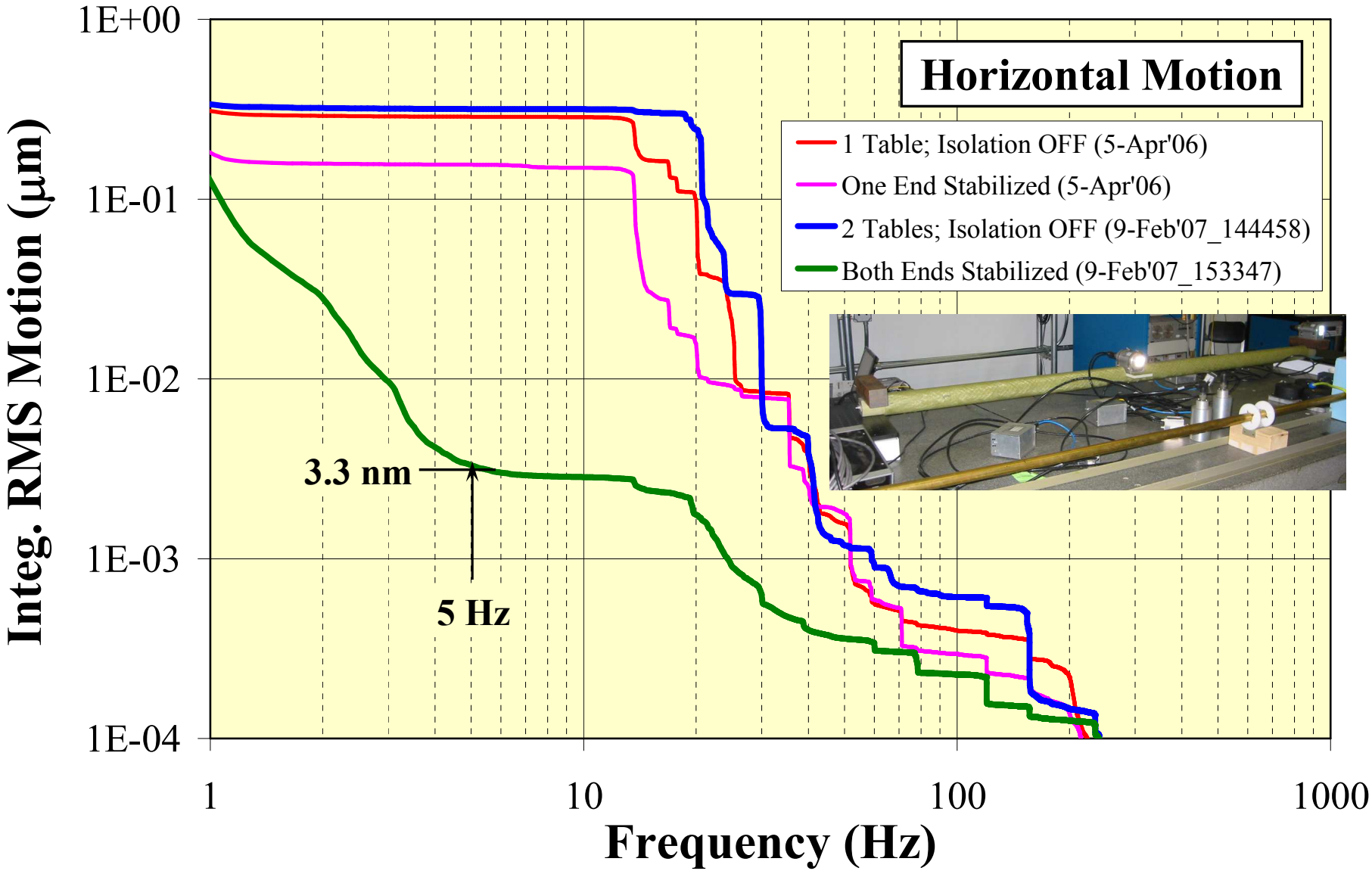
It is a challenge to make good measurements with the sextupoles powered – there are TWO equally strong field components $\Rightarrow$ Bucking scheme does not work very well!

Vibrating Wire R&D



System to be commissioned soon

2500-Turn Coil Motion With & Without Stabilization



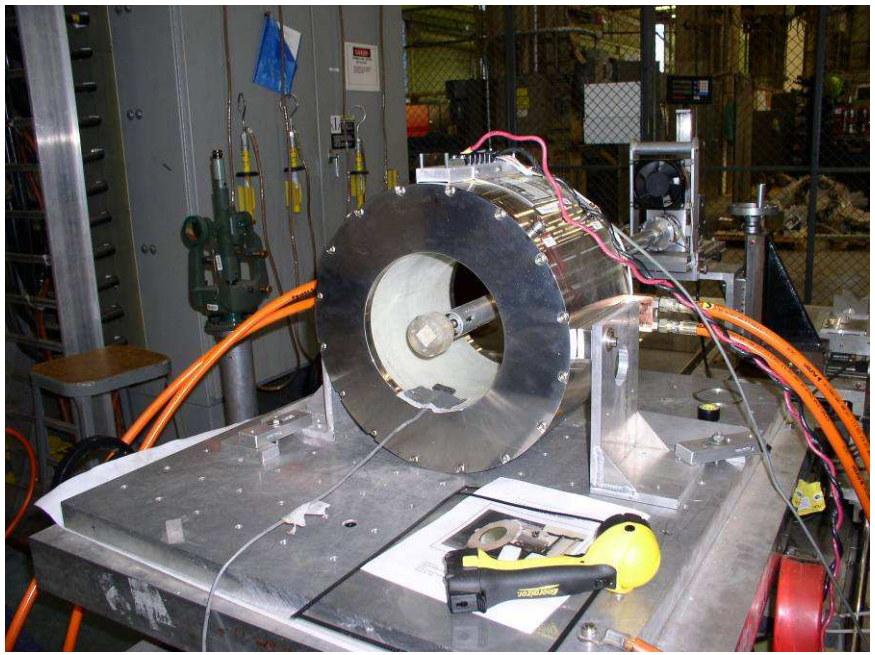
Magnetic Measurements At SLAC

Zack Wolf, Yurii Levashov,
Achim Weidemann, Seva Kaplounenko,
Scott Jansson, Ralph Colon, Dave Jensen,
Scott Anderson, Andrew Fisher,
Luis Juarez, Andrew Hau,
Brendan Dix

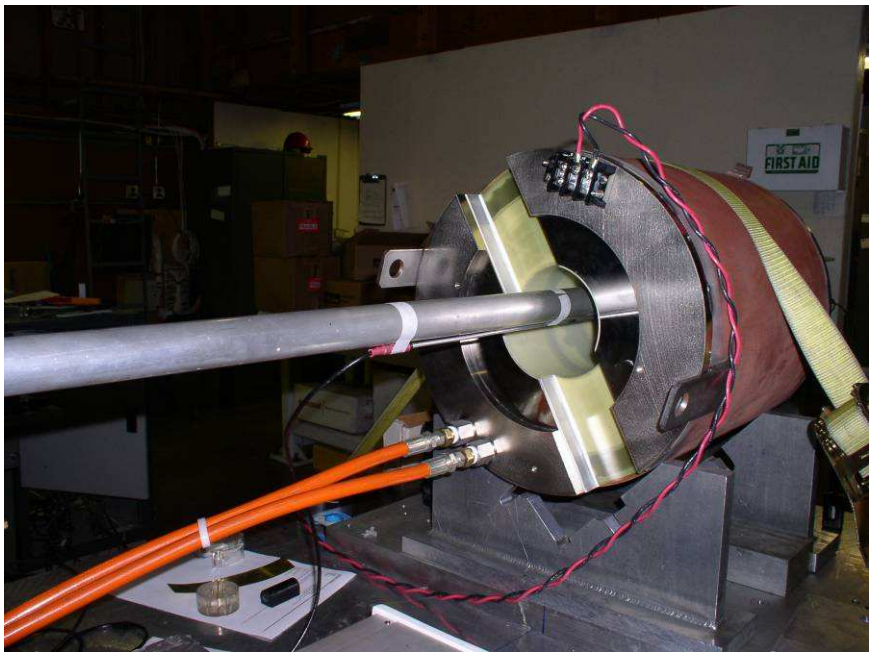
LCLS, The Current Large Magnetic Measurement Project

Linac Coherent Light Source
1.5 Å Free Electron Laser

Solenoid Measurements (Electron Gun)

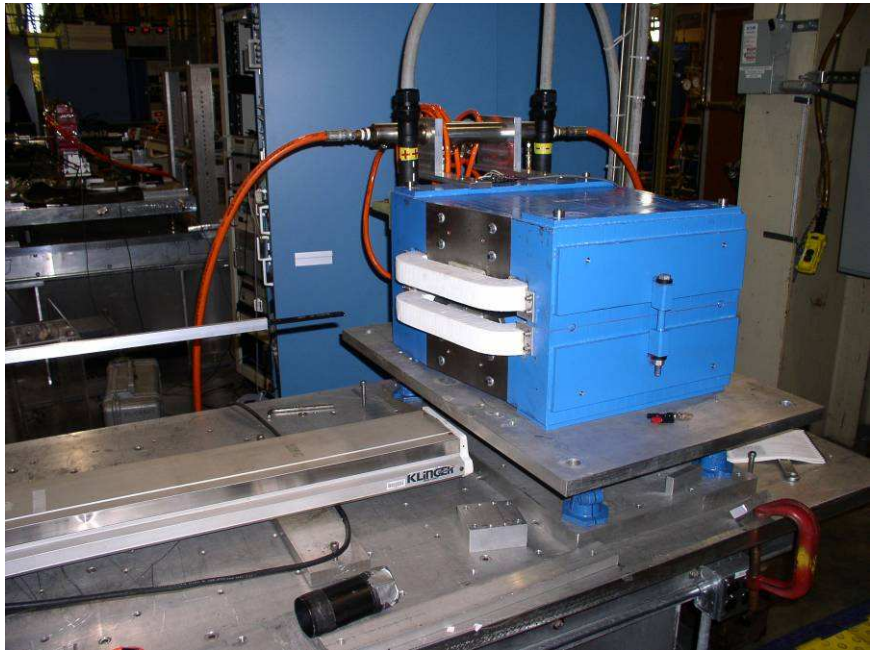


Spinning Coil:
Transverse Fields,
Magnetic Axis,
Multipole Fields vs Z



Hall Probe:
Axial Field

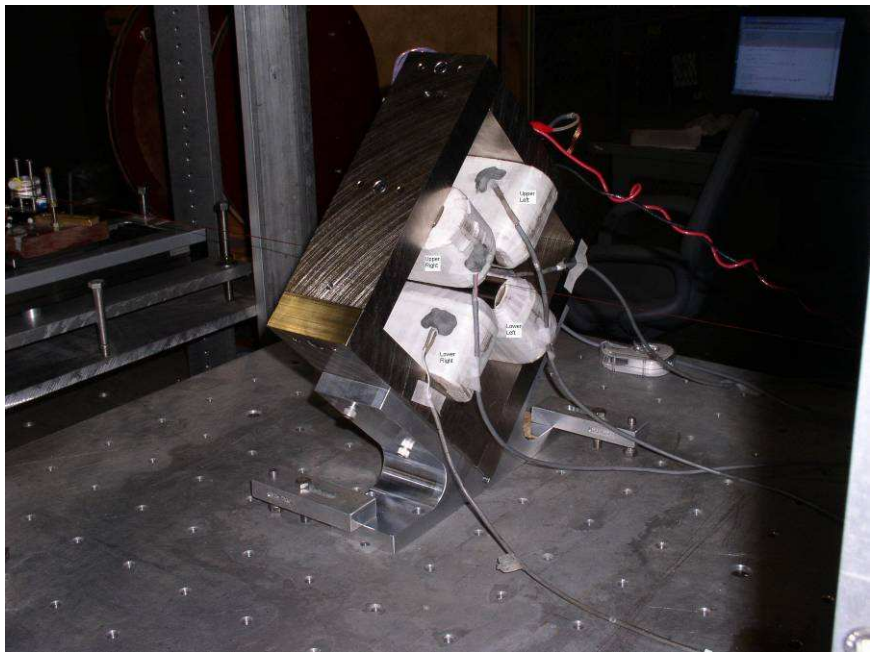
Dipole Measurements
(Bends, Bunch Compressors)



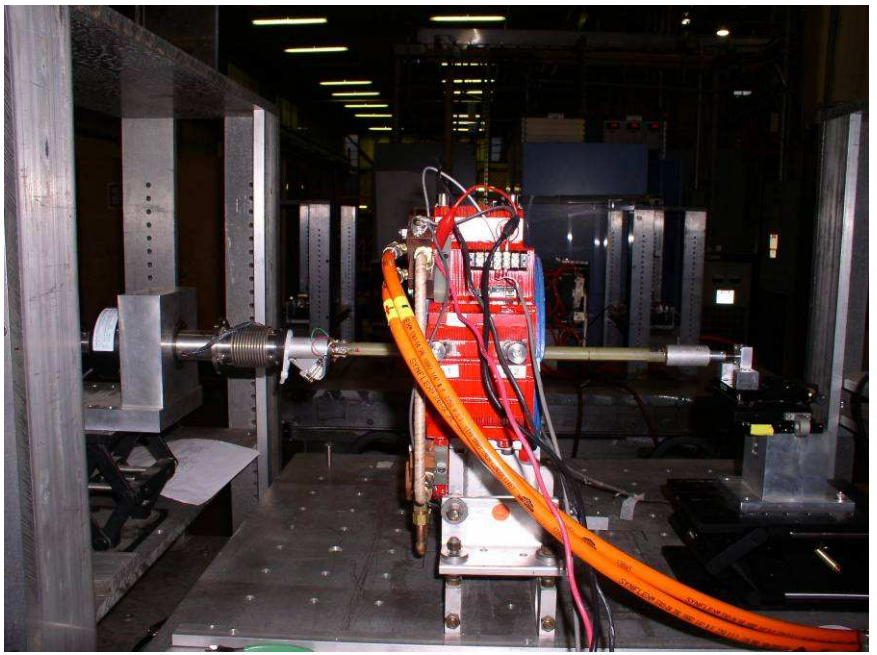
Hall Probe Maps:
End Fields,
Map For High Curvature Beam

Stretched Wire:
Integrated Strength,
Field Uniformity

Quadrupole Measurements
(Gun, Linac, Transport Line, Undulator)



Stretched Wire:
Integrated Gradient,
Coil Calibration



Rotating Coil:
Strength vs Current,
Harmonics

Undulator Measurements

Two Test Benches

CMM

Magnetic Measurement Facility,
Detailed Talk To Follow

Undulator Quadrupole Measurements

Rotating Coil:
Strength vs Current,
Harmonics

Vibrating Wire:
Fiducialization

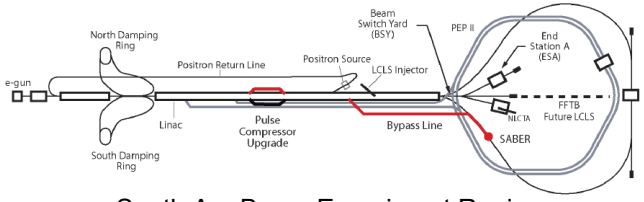
The Magnetic Measurement Future At SLAC

The B Factory shuts down in 2008.

ILC studies: quad center stability

Spear3, small upgrades

Accelerator studies, SABER



South Arc Beam Experiment Region

LCLS
- check 3 undulators monthly
- possible 2'nd undulator in tunnel

The mission appears to be shifting away from
- HEP at SLAC.