Undulator Measurements

LCLS Undulator Tuning and Fiducialization

by Z. Wolf

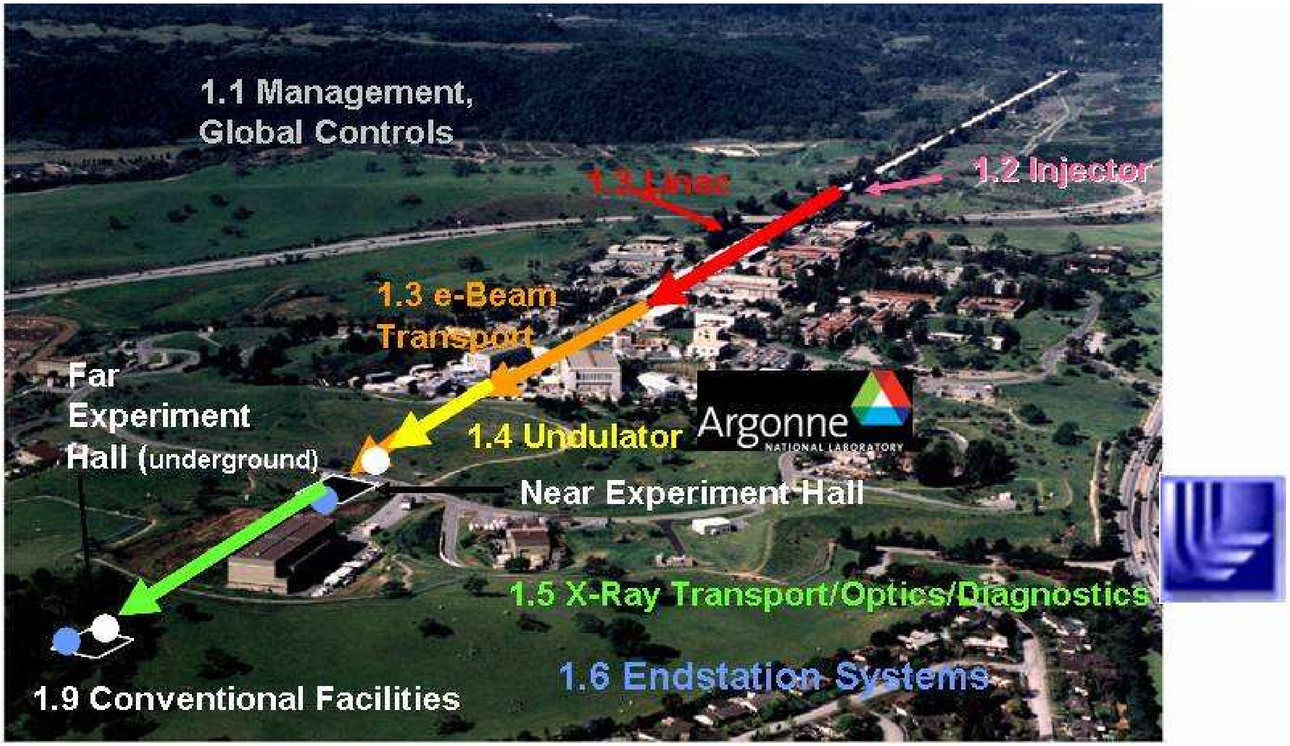
Magnetic Measurements of the Apple-II type Elliptically Polarized Undulator

by A. Madur

Z.Wolf et al.

LCLS: Linac Coherent Light Source (Free Electron Laser)

- SLAC (Stanford Linear Accelerator Center)
- ANL (Argonne National Laboratory)
- LLNL (Lawrence Livermore National Laboratory)
- University of California LA



LCLS Parameters: http://www-ssrl.slac.stanford.edu/lcls

33 undulator segments (last 1/3 of the linac is used to produce the electron beam)

E_{beam} = 13.64 Gev λ_r = 1.5 Å

Planar permanent magnet undulators

Nd Fe B permanent magnets

λ_u = 30 mm Gap = 6.8 mm

Tapered gap, 4.5 mrad

B_{first} = 1.249 T, tapered, nominal field, first undulator

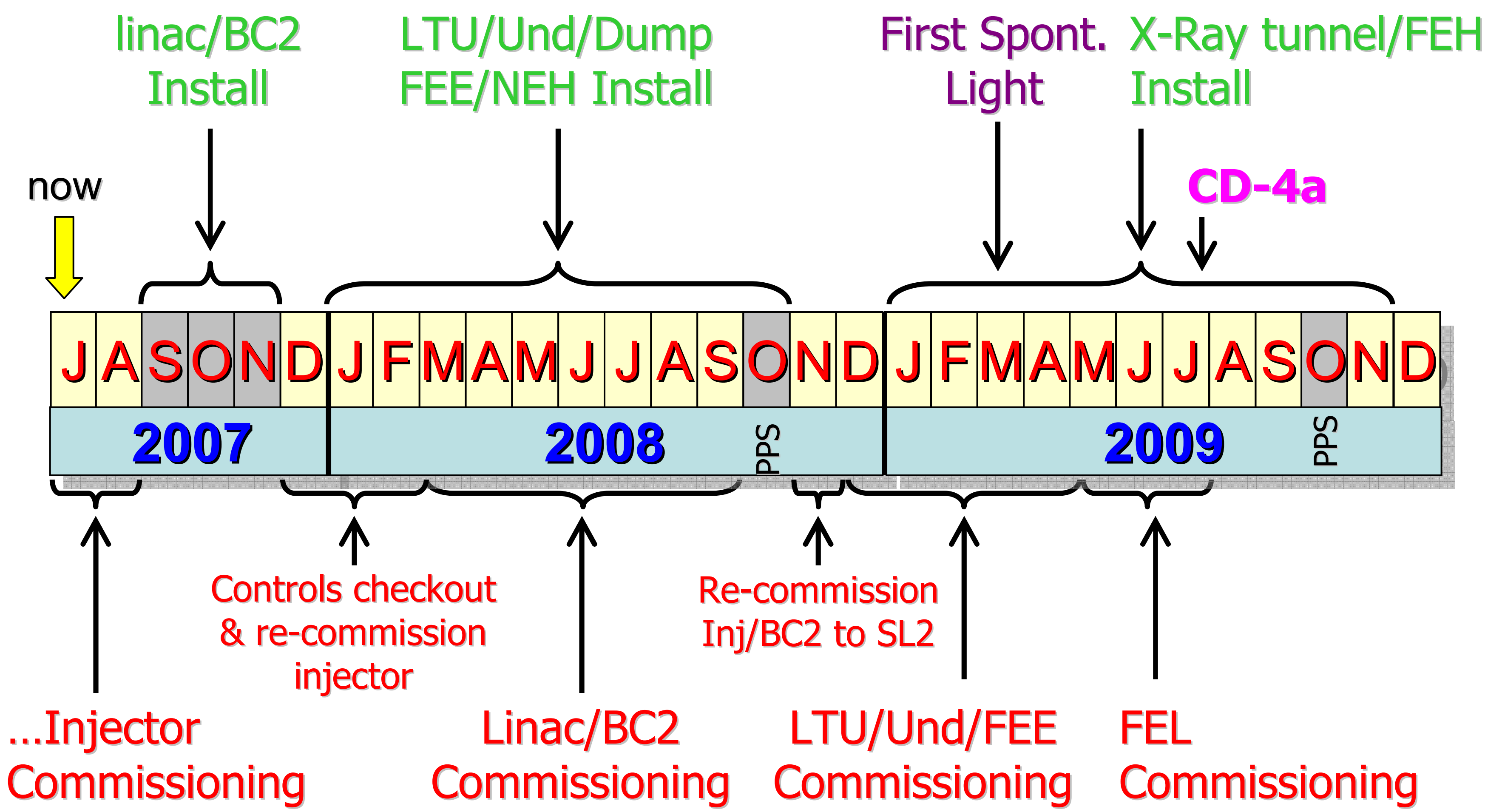
K_{first} = 3.5, tapered, each undulator has its own K

226 poles per segment, Each segment is 3.4 m long

Scientific program includes:

discovering and probing new states of matter, understanding and following chemical reactions and biological processes in real time, imaging chemical and structural properties of materials on the nanoscale, and imaging non-crystalline biological materials at atomic resolution.

LCLS Installation and Commissioning Time-Line



Magnetic Measurement Facility (see details LCLS-TN-04-1)

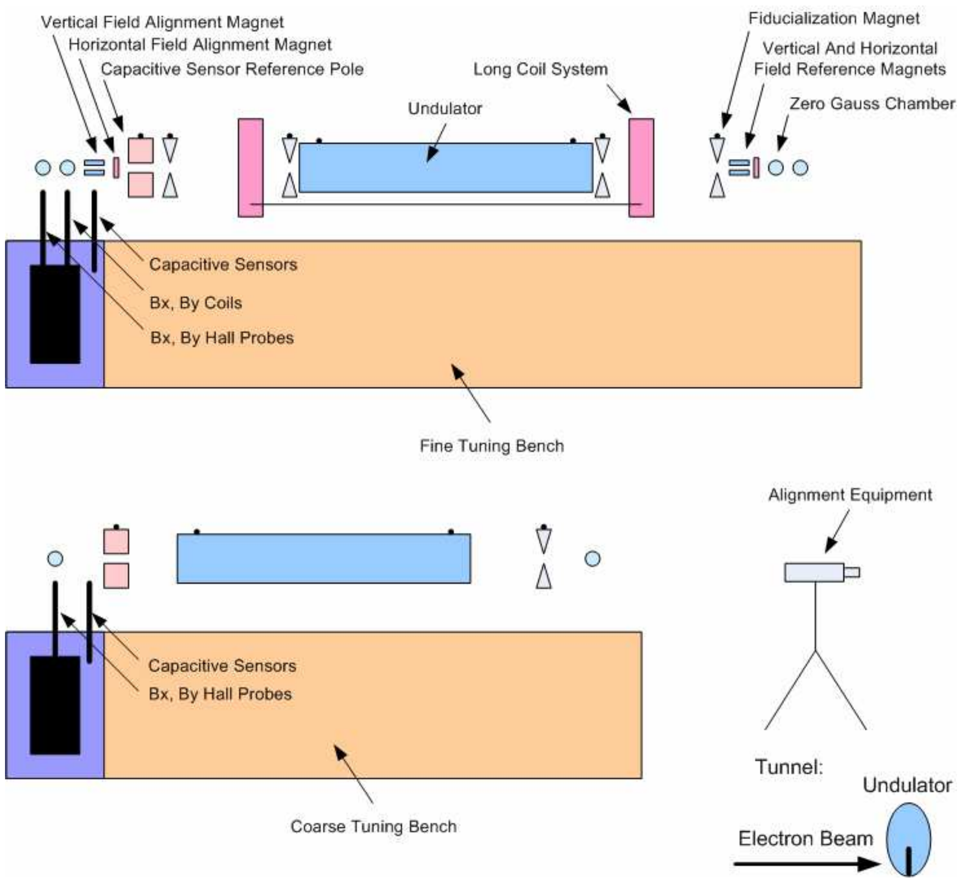
- Floor plan divided into three functional areas
  - Magnetic Measurements (± 0.1º C)
  - Fiducialization and Assembly (± 1º C)
  - Storage (± 2.5º C)

- Test stand lay-out is driven by requirement to match the Earth Magnetic Field conditions in lab to Undulator Hall, i.e. azimuth and gap orientation need to be identical

- Tuning time about 4 weeks
  - Getting to the operational condition (20Cº)
  - Rough tuning, 1 week
  - Fine tuning, 1 week
  - Fiducialization

Peak throughput: 1 undulator per week

Undulator Tuning: (See LCLS-TN-06-17)
Coarse and Fine Tuning Bench Components

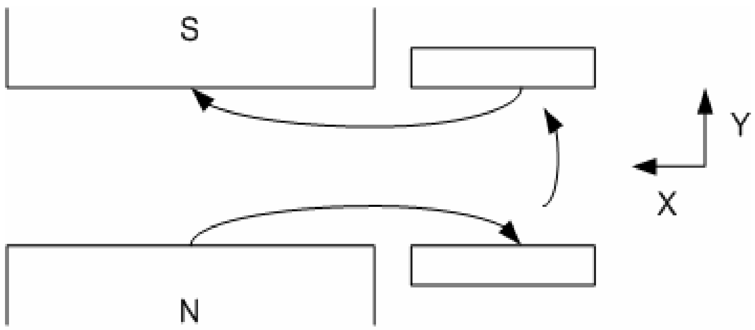


<u>Rough Tuning Steps</u>:
straighten trajectories
set gap (set K and tune phase)
do phase shimming
do phase matching
add magnetic shield

<u>Fine Tuning Steps:</u>
check trajectories, phase
adjust field integrals
shim field uniformity
glue shims in place
perform checks
make final data set
fiducialize

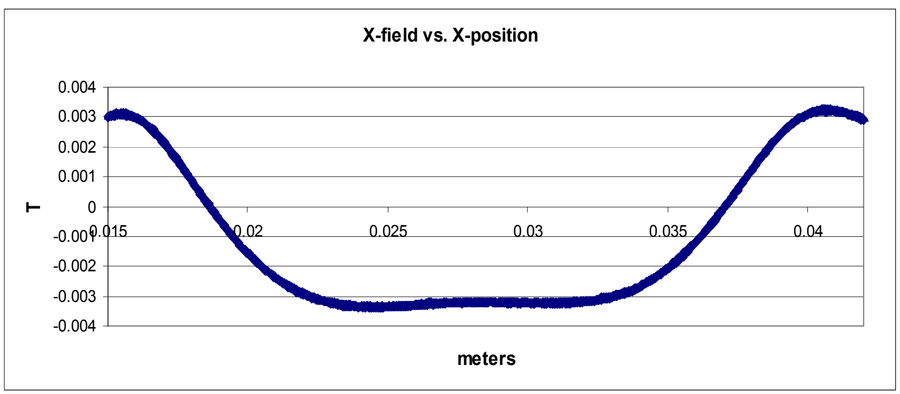
X / Y Trajectory Shims

See ANL/APS/TB-48
LCLS-TN-04-7



- Apply shims to top and bottom poles
- Shims weaken By, don't cause Bx
- Can't strengthen pole, instead place shims on next pole to reduce deflection in other direction

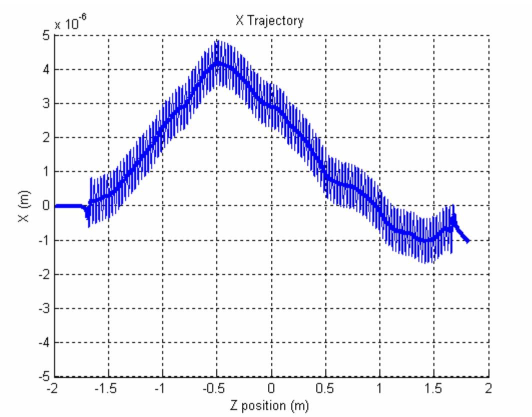
- Developed software to automate shim placement



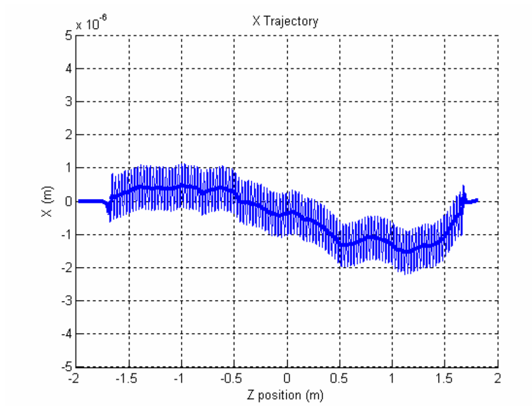
- Bx Shim developed with new design

Straighten X And Y Trajectories

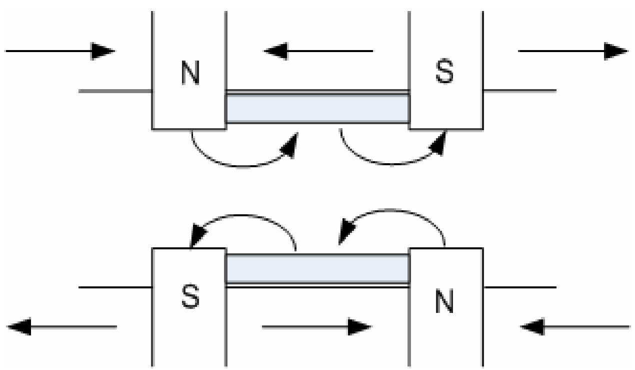
Measured X-trajectory



Measured X-trajrctory after calculated shims applied



Phase Shims



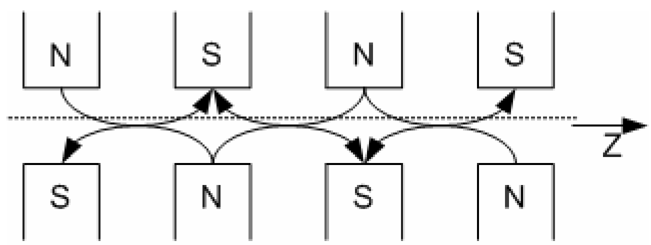
- Measure By with a Hall probe
- Calculate phase error
- Calculate shims to correct error
- Apply shims, repeat

- Developed software to automate shim placement

Hall Probe Position Problem

The vertical trajectories on 2 benches (the Dover bench and Kugler bench) Did not agree.

The horizontal field integrals from the Hall probe had a large y dependence. Coil measurements showed no such dependence.



$B_z \neq 0$ Off The Midplane

Isaac Vasserman's hypothesis: planar Hall effect (See ANL/APS/TB-32)

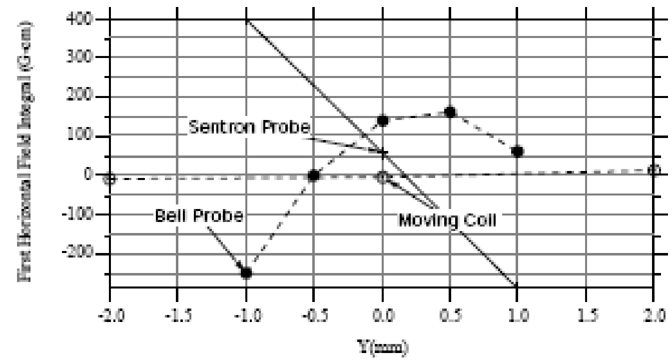
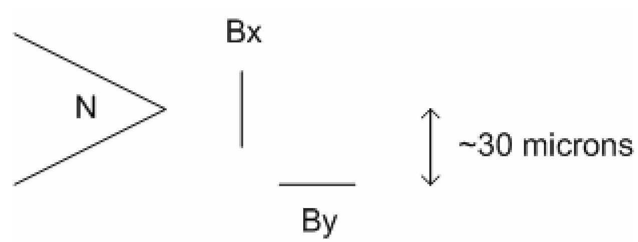


Fig. 2 Sensitivity of Bell and Sentron Hall probes to vertical position

The Sentron probes are sensitive to planar Hall effects



Pointed magnet gives difference in Hall probe positions.

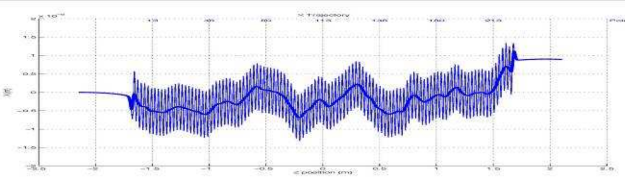
Solution: Measure the positions of the Hall elements.
Tune the horizontal trajectory with the By probe on the midplane.
Tune the vertical trajectory with the Bx probe on the midplane.
Use only the long coil for final field integral measurements.

Effect of Hall Probe Error On Trajectories

μm

2

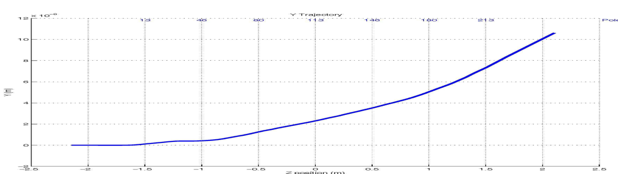
-2



X Trajectory

12

-2

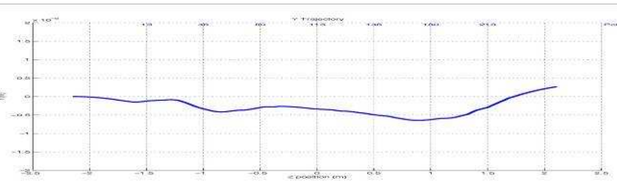


Y Trajectory: y=+200 μm

Constant Bx_0 Corrects Bx To Long Coil Field Integral

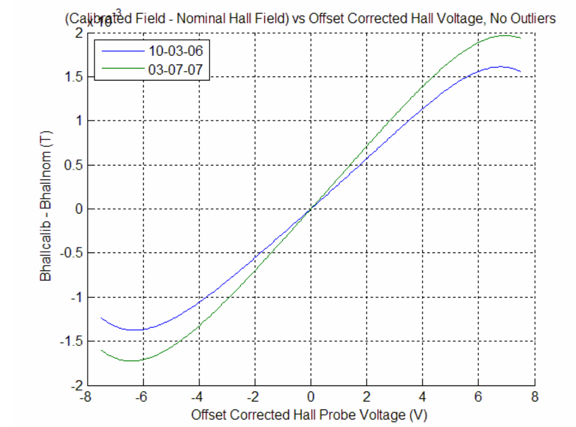
2

-2



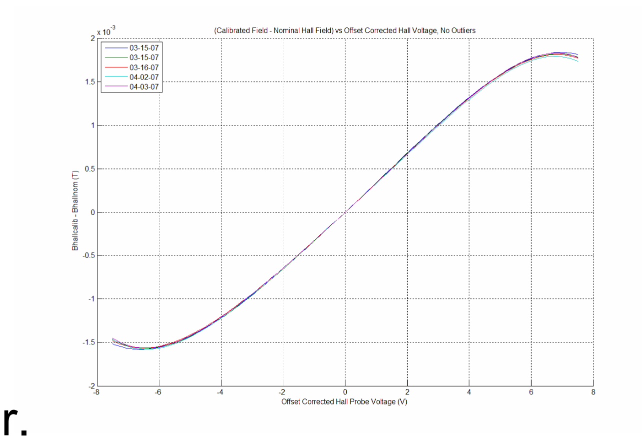
Y Trajectory: y=+200 μm; B_{x0}=+0.52 G

Hall Probe Calibration Problem



Calibration change: Before and after first undulator

Probe temperature? Poor fits?
Probe offset? Calibration magnet non-uniformity? Impurities in copper probe chiller?
Copper non-magnetic Offsets change:
Stress on probe !



The Hall probe is calibrated in the same mount it is used in.

Sentron probes are used (low noise)
Rough tuning bench uses linear motor driver.
Fine tuning bench uses chopped motor driver.
Problem solved by adding heavy filtering to the motor lines

LCLS Undulator Tuning and Fiducialization by Z. Wolf

Conclusions:

- MMF construction is complete, temperature stability and set point accuracy requirements have been met. The fine tuning bench construction met all specifications
- The electrical noise problems are solved
- The planar Hall effect problem is solved
- The Hall probe calibration problem is solved
- The software is complete
- Mechanical alignment takes about 15 minutes
- The field integral measurement system has been tested and is working well
- Test and fiducialization plans available
- Throughput of one undulator per week was demonstrated. Each undulator spends about 4 weeks in the MMF
- One reference undulator gets re-measured every fourth undulator
- 1/3 finished with production undulator tuning.

Magnetic Measurements of the Apple-II type Elliptically Polarized Undulator For the ALS MERLIN Beamline

by A.Madur

MERLIN - A meV Resolution Beamline at the Advanced Light Source (LBNL)

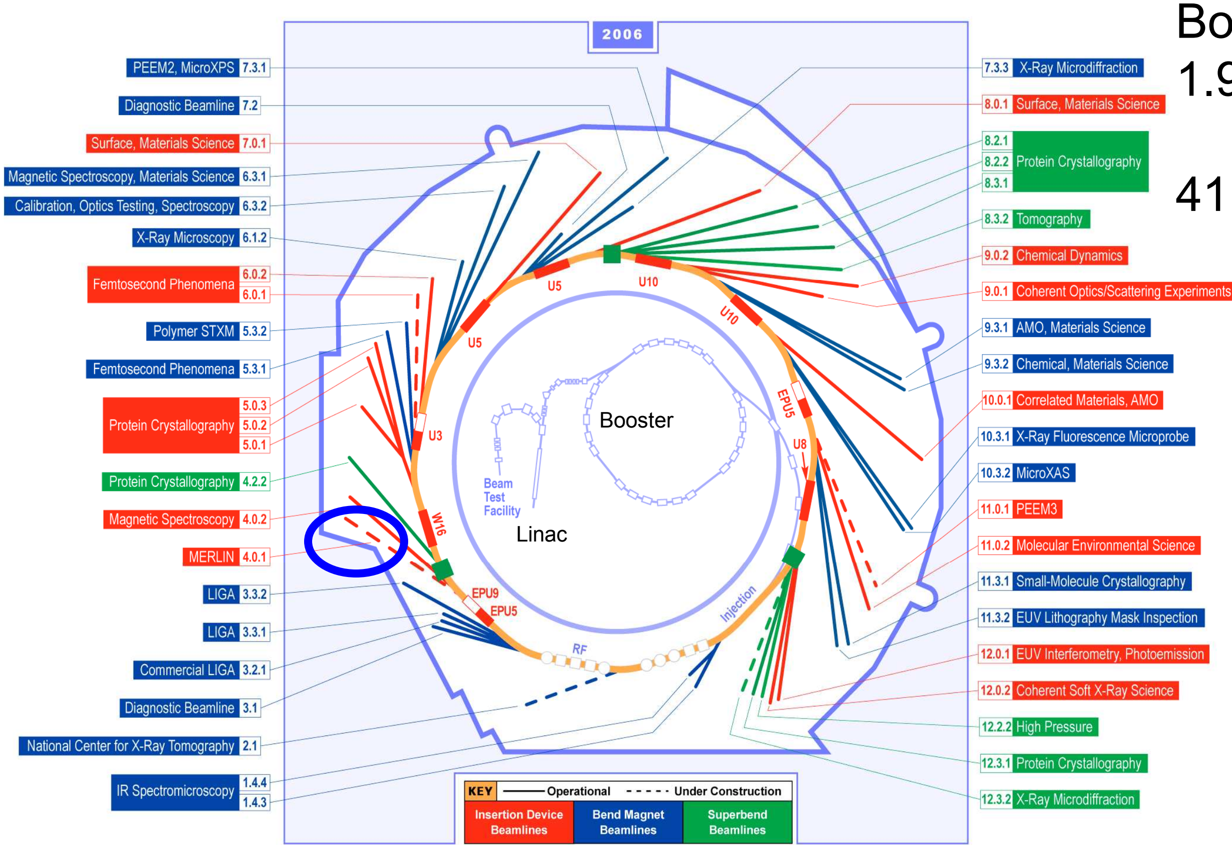
- Ultra-high energy resolution beams: ~10eV to 150eV
  (~1meV resolution up to 100eV)
- Polarization control (linear + circular)
- Dual operation modes: high-resolution (HR) and high-flux (HF) modes

Designed for study of low energy excitations in strongly correlated systems with the use of high-resolution inelastic scattering and angle-resolved photoemission

ARPES = **A**ngle-**R**esolved **P**hoto**E**mi**S**sion

RIXS = **R**esonant **I**nelastic **X**-ray **S**cattering spectroscopy

ALS - one of the world's brightest sources of ultraviolet and soft x-ray beams and the world's first 3rd-generation synchrotron light source in its energy range (http://www-als.lbl.gov/als)



Booster operates at 1.9 GeV

41 Beams

ALS parameters before and after Top-Off upgrade

Before Top-Off

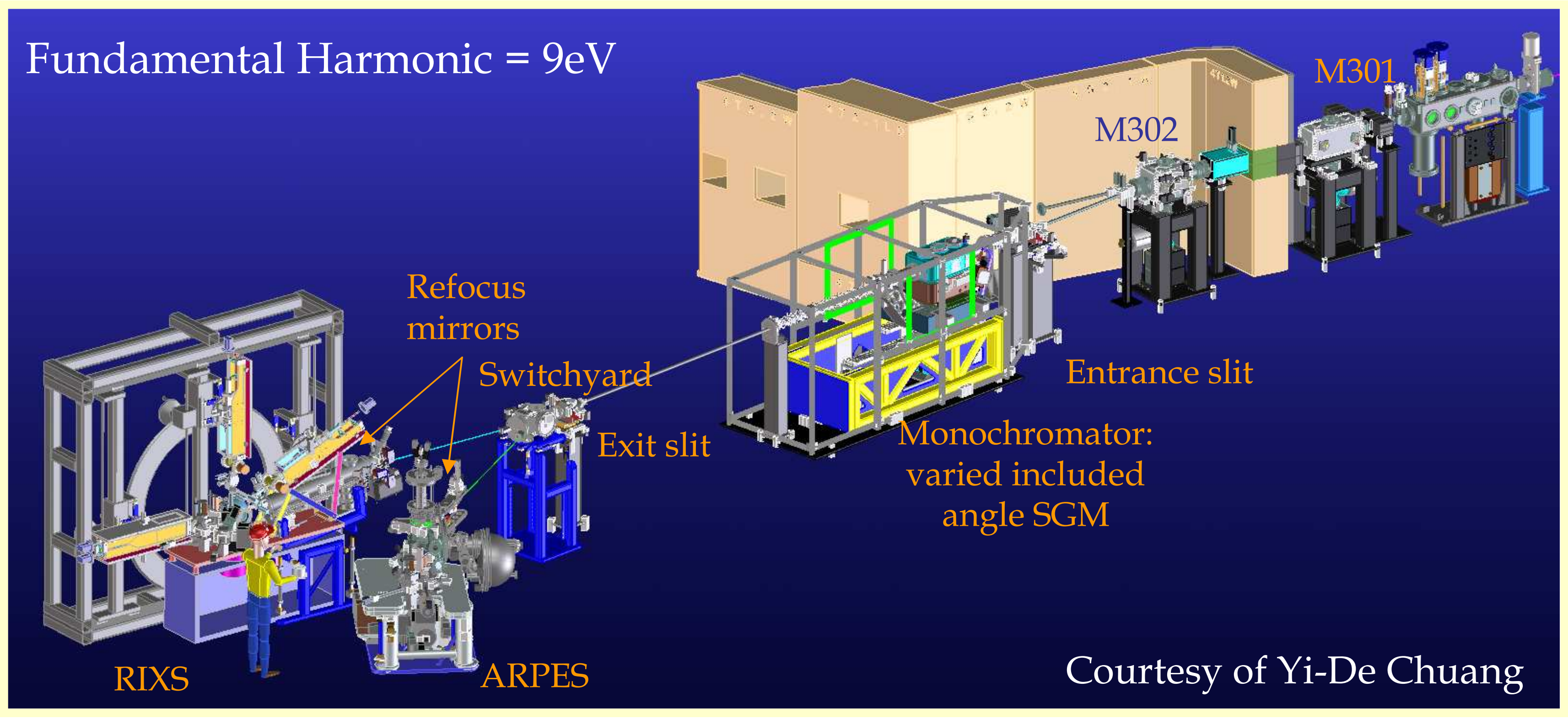
- Injection at 1.5 GeV and then ramp
- Inject with insertion devices open
- Average beam current is 250 mA
- Vertical emittance is 150 pm rad
- Lifetime is 8 hours at 400 mA
- Injection period every 2 to 8 hours
  - 1 Hz injection for 4 minutes
    - From 200 to 400 mA
- Photon shutters are closed during injection

After Top-Off

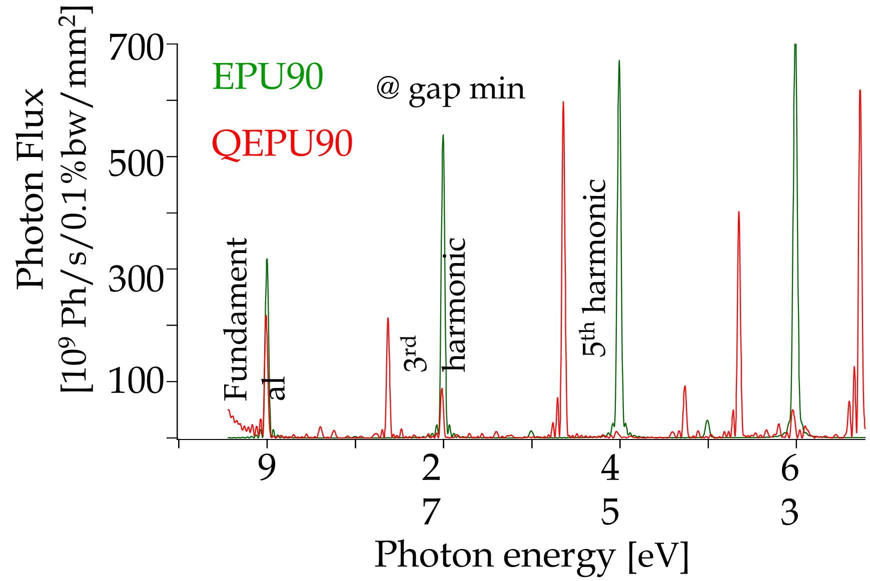
- Full energy injection (1.9 GeV)
- **Inject with insertion devices closed**
- Average beam current is 500 mA
- Vertical emittance is 30 pm rad
- Lifetime is about 3 hours at 500 mA
- Injection period about every 30 seconds
  - 1 pulse
    - From 498.5 to 500 mA
- Photon shutters remain open during injection

MERLIN: Beamline layout

The Source of beamline is a 1.9m long quasi periodic Elliptically Polarized Undulator (90mm period)



MERLIN EPU: 2 main features



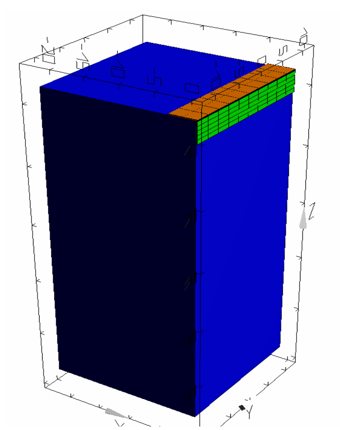
Quasi periodic:

In the case of low energy undulator, Monochromators are unable to distinguish integer multiple of the fundamental harmonics (here 3rd and 5th).

Dynamic ticklers:

Beam Dynamics issue - EPU fields reduce the dynamic aperture of the beam.

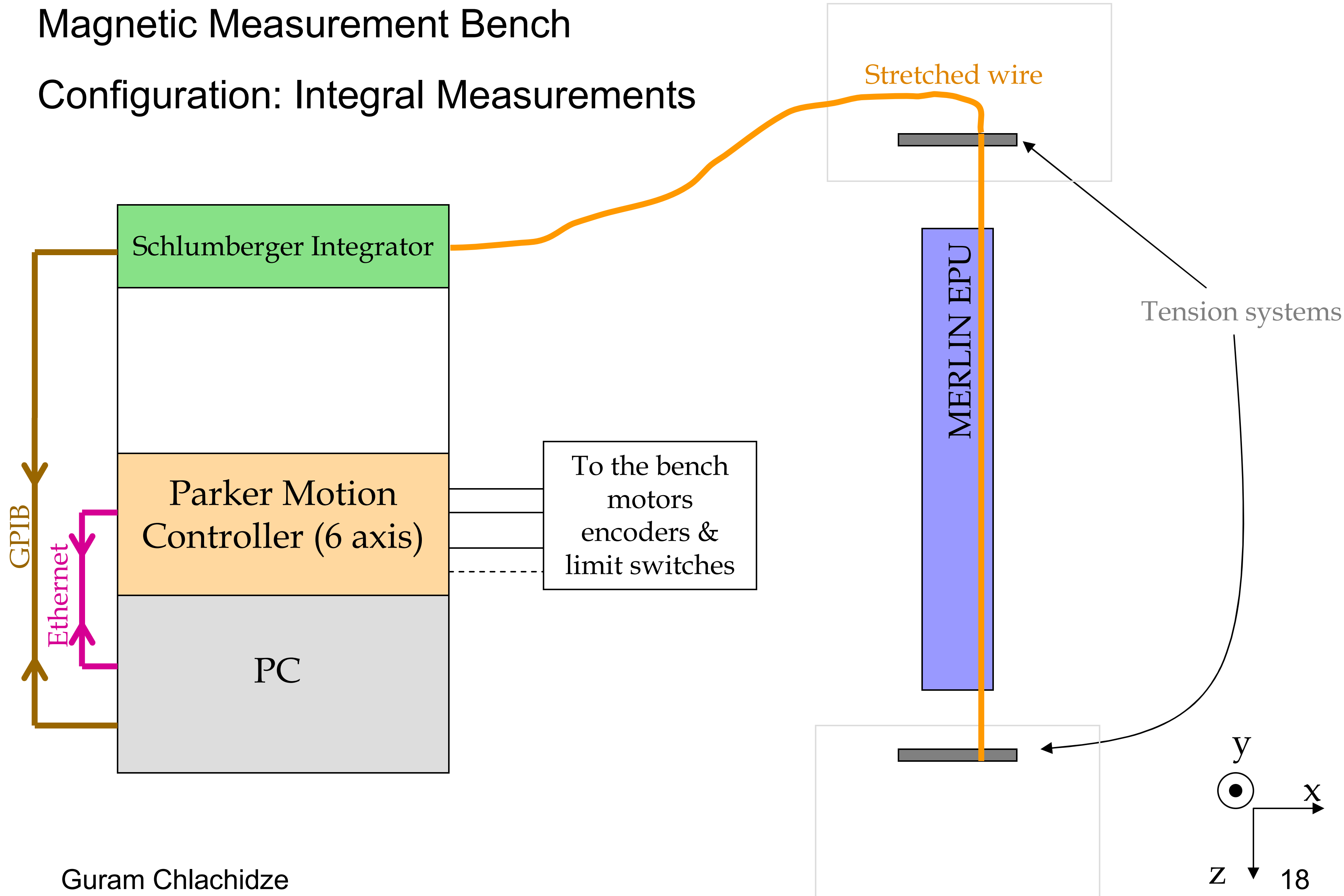
- Especially harmful in Top-off mode operation (Injection with a closed EPU)
- These effects are polarization mode dependent.



Idea: Introduce passive correction by adding sheets of iron called here “Dynamic Ticklers”

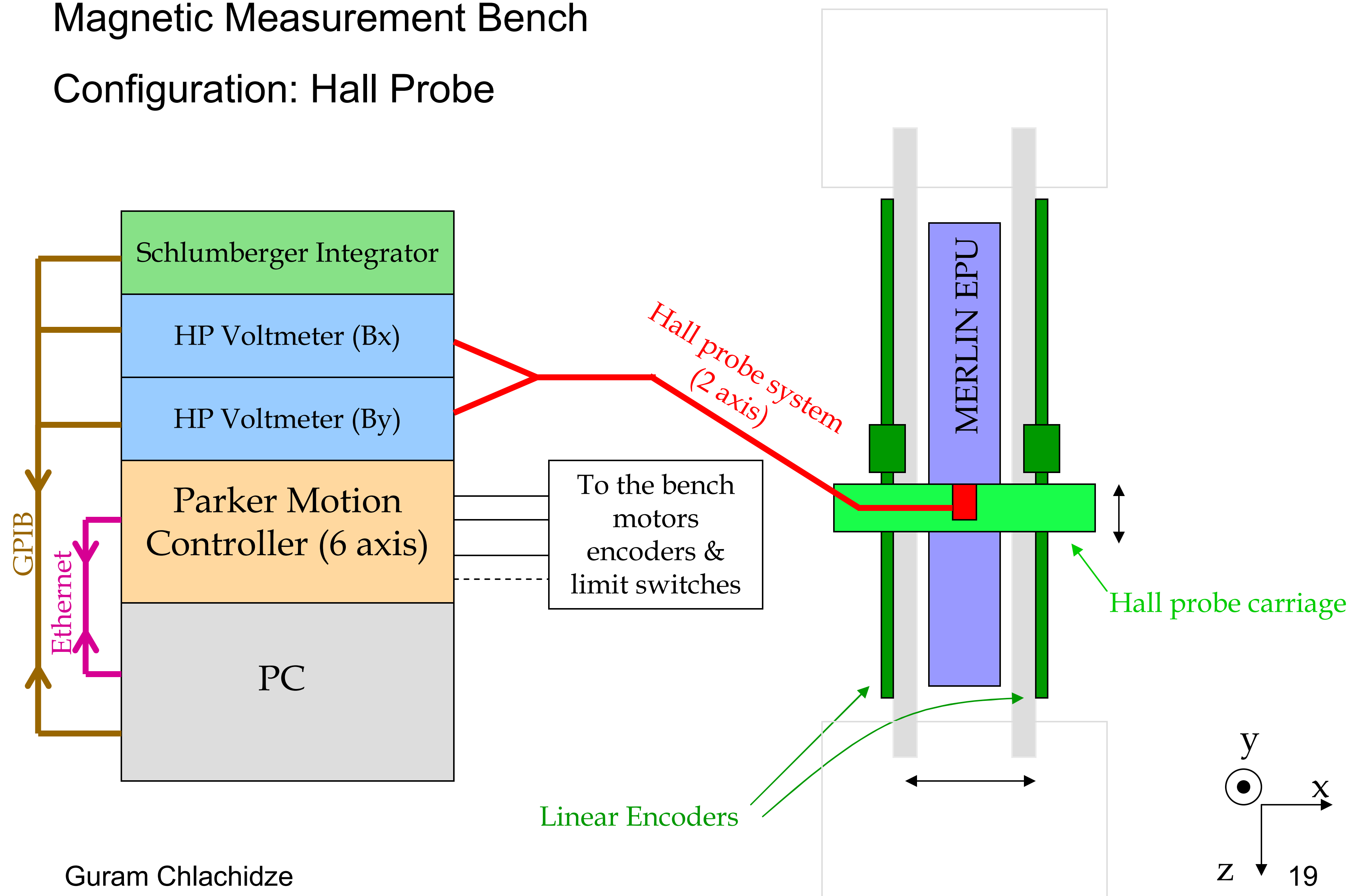
Magnetic Measurement Bench

Configuration: Integral Measurements

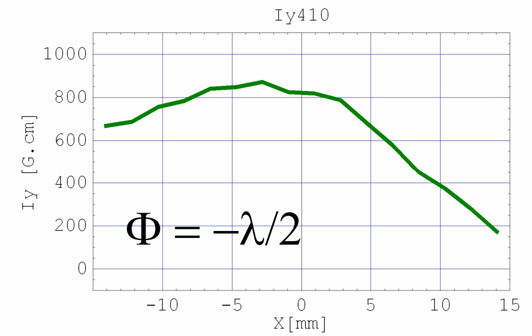


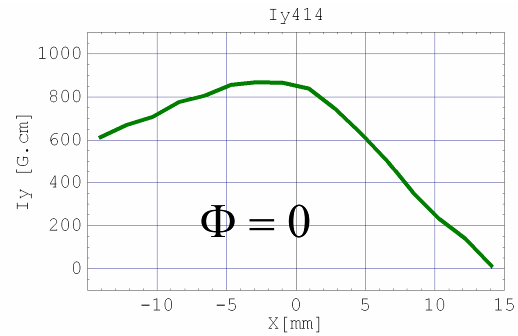
Magnetic Measurement Bench

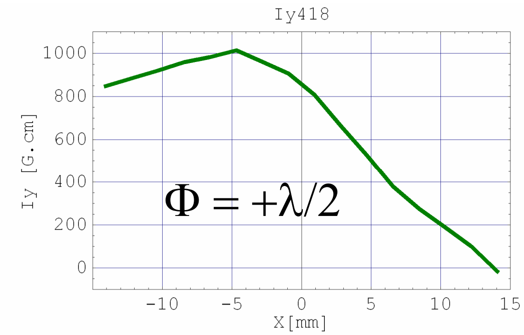
Configuration: Hall Probe



Integral Measurements: Vertical Component

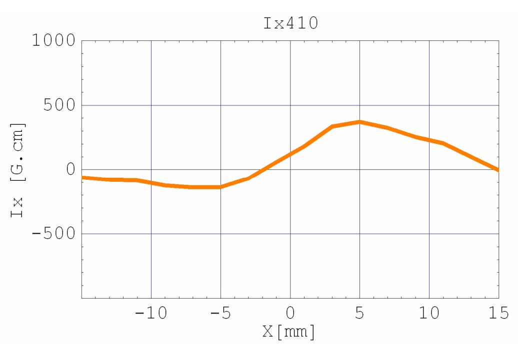


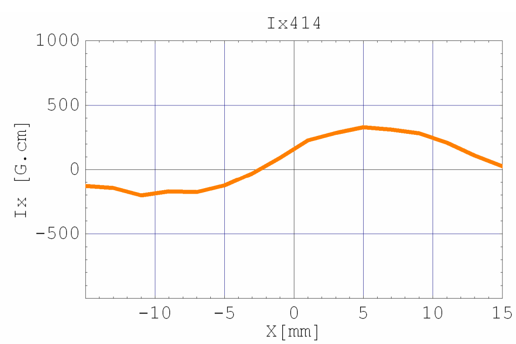


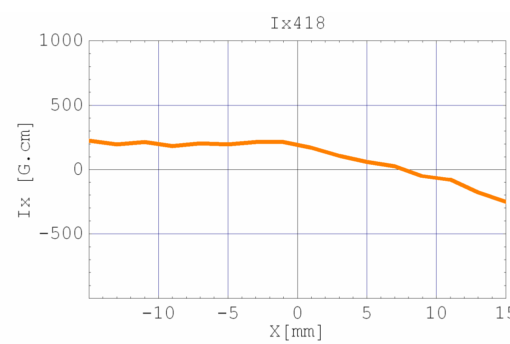


Main offset can be corrected by shimming (magnet block displacement)

Horizontal Component





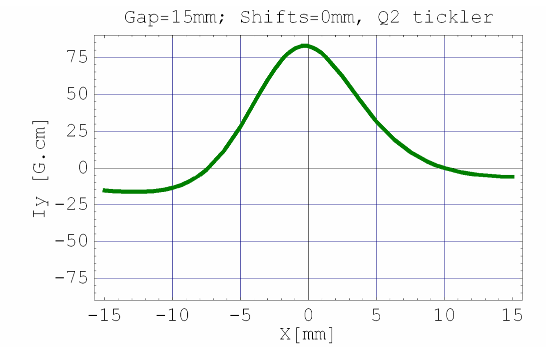


Ongoing investigations to understand Ix(Φ) evolution

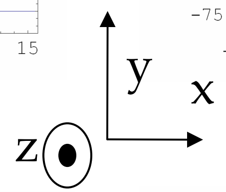
Signature of Dynamic Ticklers: Iy/Ix integral

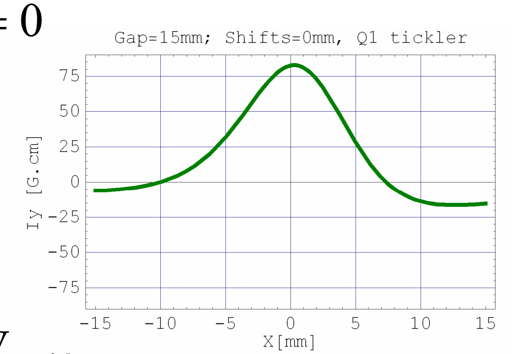
Adding iron shim on positive vertical blocks

$\Phi = 0$

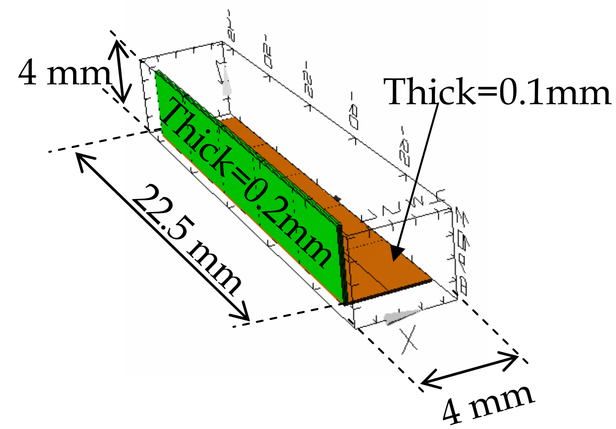


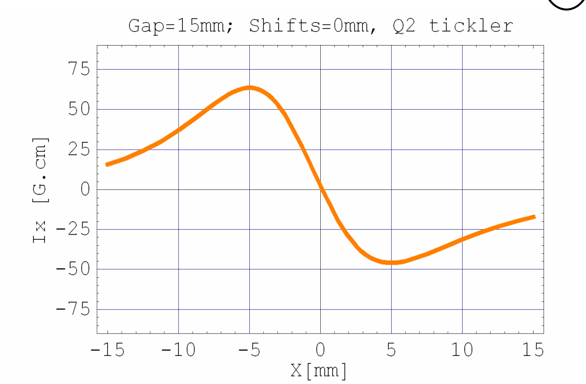
Q2

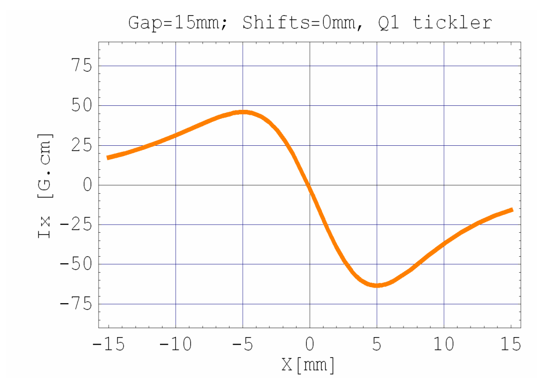


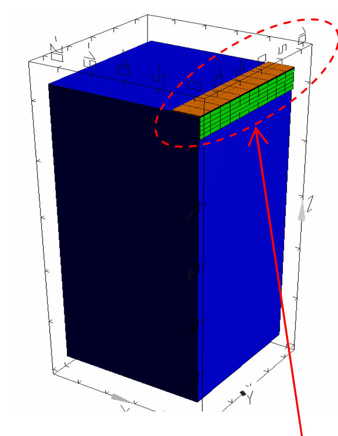


Q1









Dynamic ticklers

For the negative vertical blocks - the opposite of the shown ones

Effect of Dynamic Ticklers: Optimization

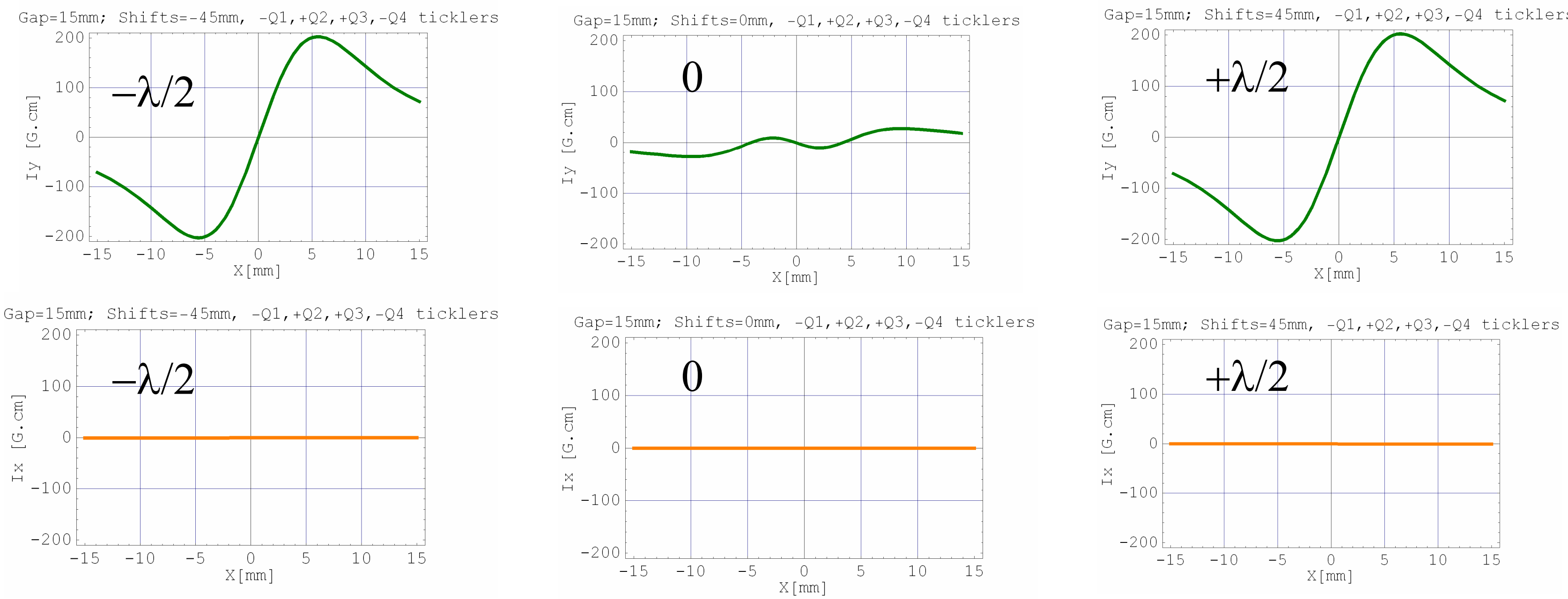
- Correct the horizontal "kick" (px)

- Get a gradient (dIy/dx) without skew quadrupole (dIx/dx)

Maximum at maximum phase positions (± λ/2)

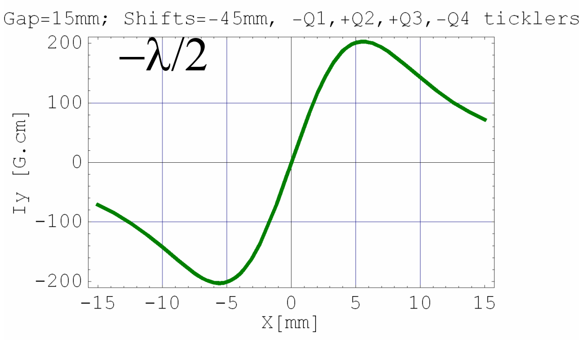
16 Combinations possibilities with one tickler per quadrant on <u>positive</u> or <u>negative</u> vertical blocks.

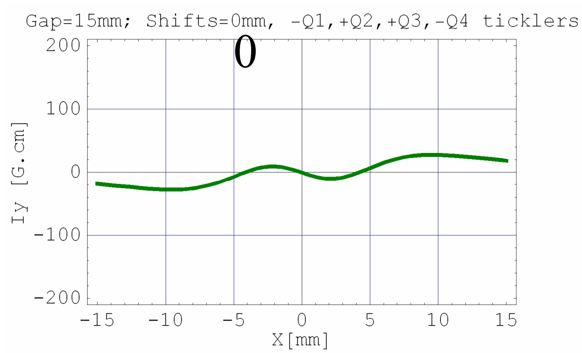
Right Dynamic Ticklers Combination : -Q1,+Q2,+Q3,-Q4 on vertical blocks

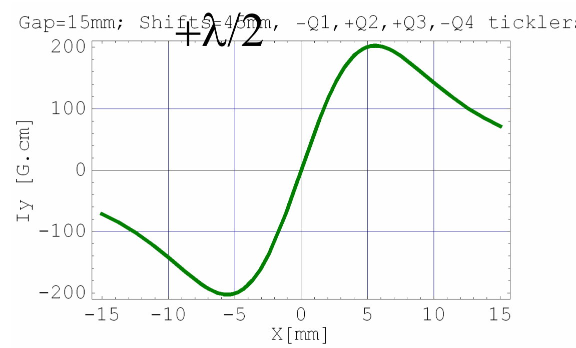


Effect of Dynamic Ticklers: Simulation vs. Measurements

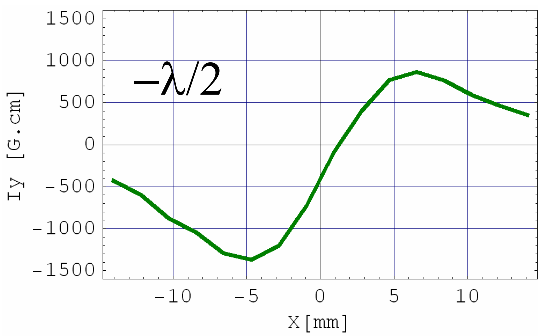
Simulations (for 1 set of Ticklers)

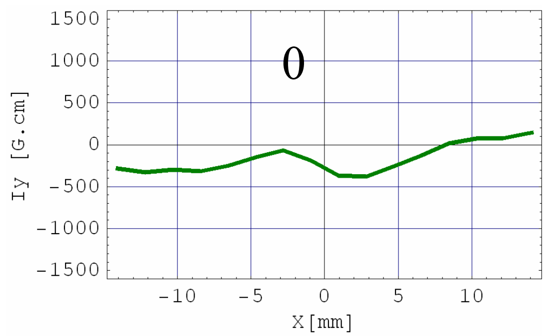


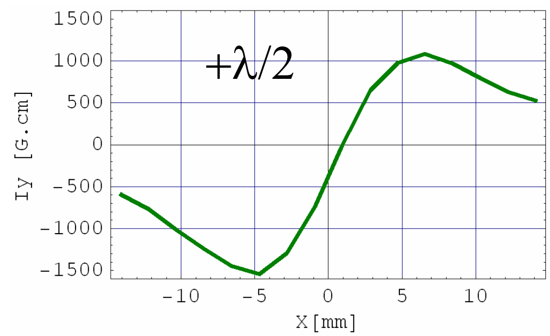




Measurements (for 6 sets of Ticklers)



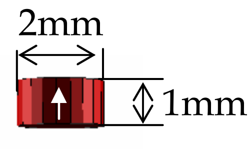




No measured Ix contribution from ticklers on axis

Conclusion : The measured signatures fit the simulations

Optimization of the residual Ix/Iy integral:



Magic Fingers with vertical magnetization

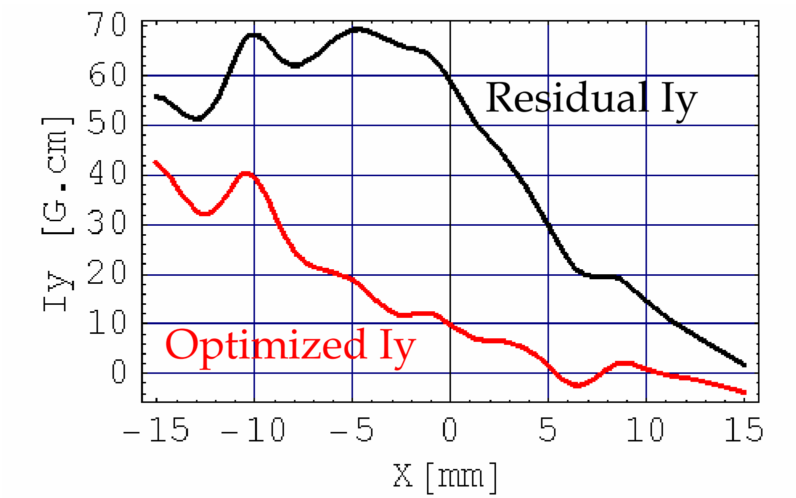
Max correction with 200 magic fingers: 250 G.cm

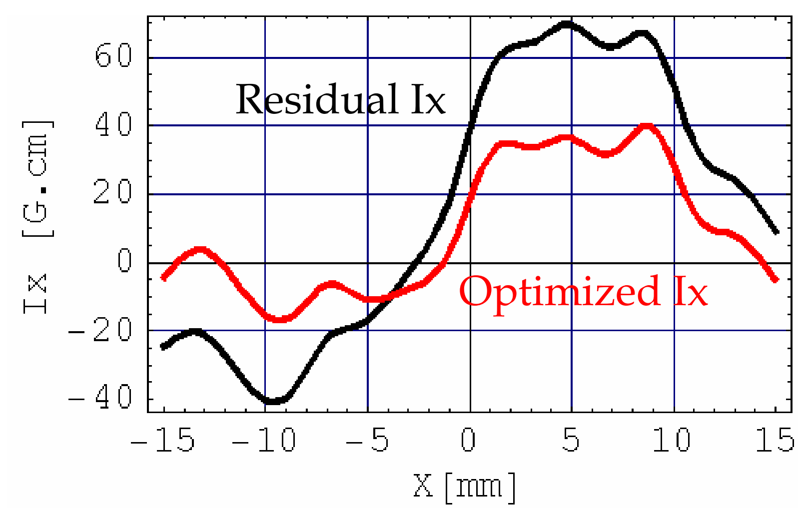
Objective: magic finger distribution optimization

Main Issue: To combine Ix and Iy corrections

Method: Radia simulations coupled with genetic algorithm

Solution example with 136 magic fingers





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Conclusions:

-The magnetic measurement bench is operational

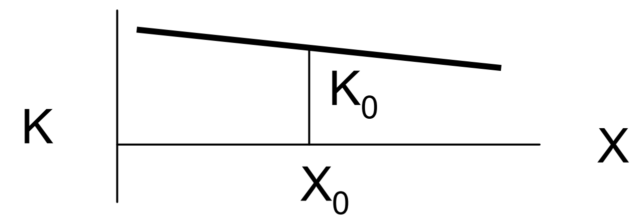
-MERLIN Elliptically Polarized Uundulator will be optimized soon

- Optimization of Ix versus phase variations
- Shimming: Rough integral correction
- Dynamic ticklers: Effectiveness was demonstrated
- Magic Fingers: Preliminary tests will be performed

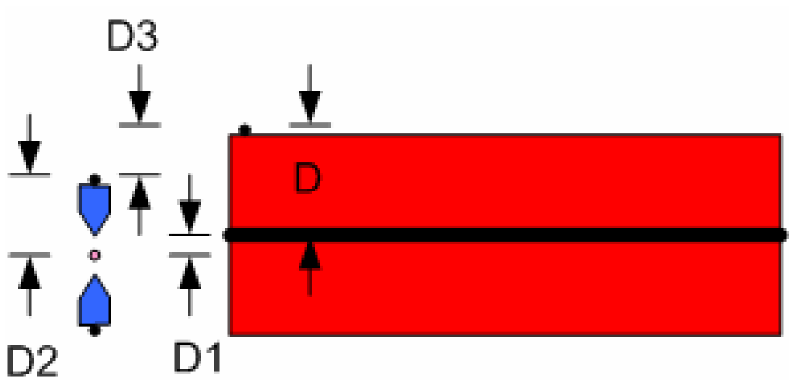
-MERLIN EPU will be installed by the end of 2007

Backup Slides

Fiducialization: Determine K vs X



Set the probe position to give the nominal K value.



- Reference fiducialization magnets
- Optical alignment check
- Optical fiducialization check