Overview of Magnetic Measurement Activities at SLAC National Accelerator Lab (SLAC)

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Terrassa-Barcelona

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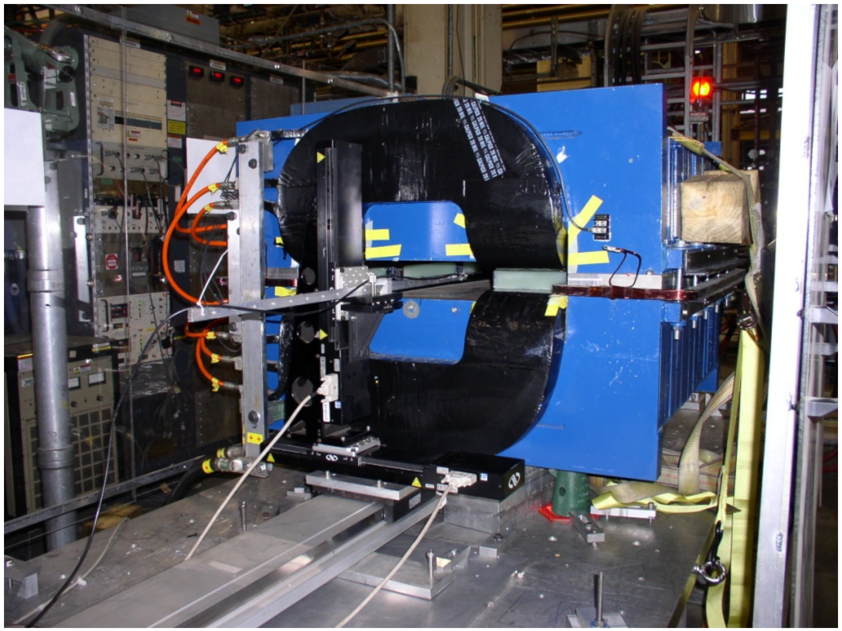
SLAC Projects

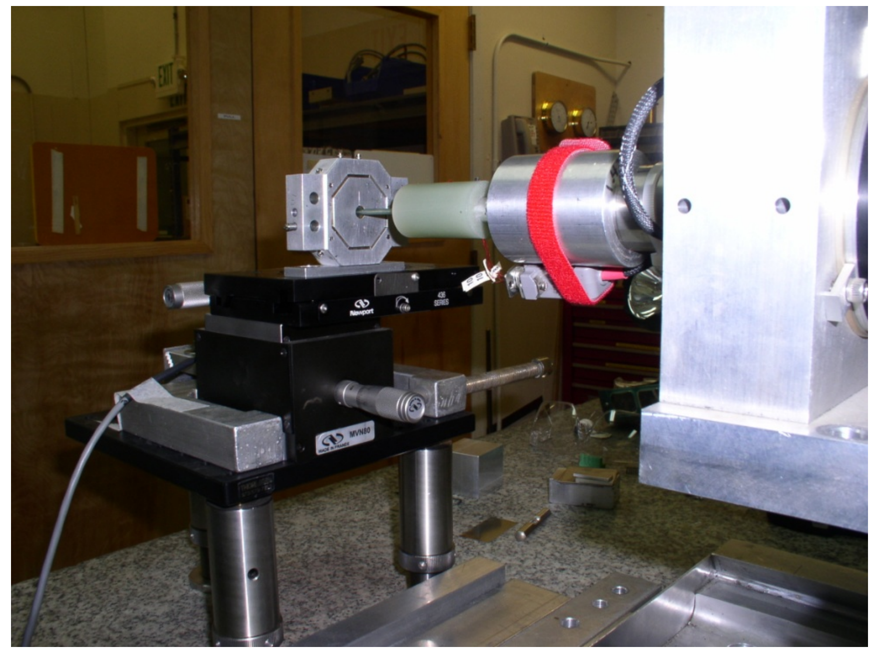
- FACET (Facility for Advanced Accelerator Experimental Tests) – 46 magnets
- ECHO7 - Echo-Enabled Harmonic Generation – 22 magnets
- LCLS – Undulator Tuning and Reconfiguration. (Yuri Levashov).
- LCLS - HRXSS (Self Seeding Dipoles)
- Magnets for smaller projects and upgrades

Magnets in last 2 years

Large Magnets



Small Magnets

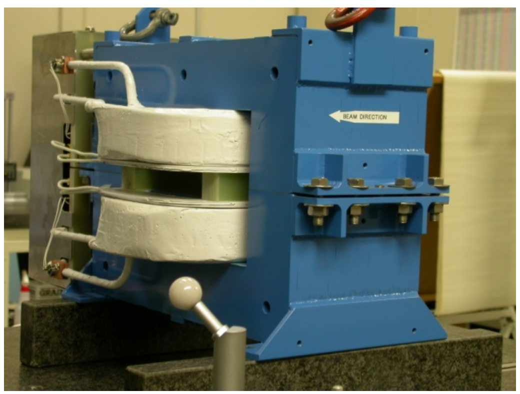


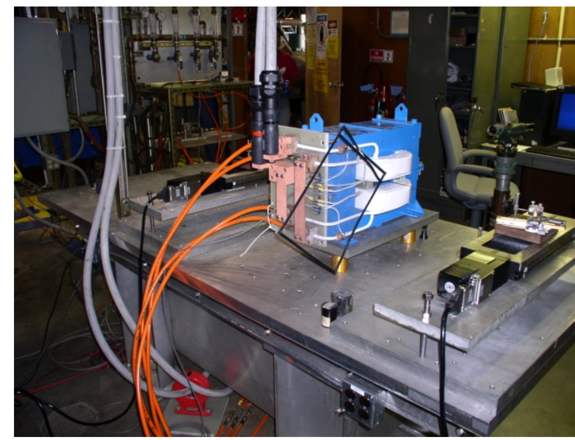
Measurement Process n = 1

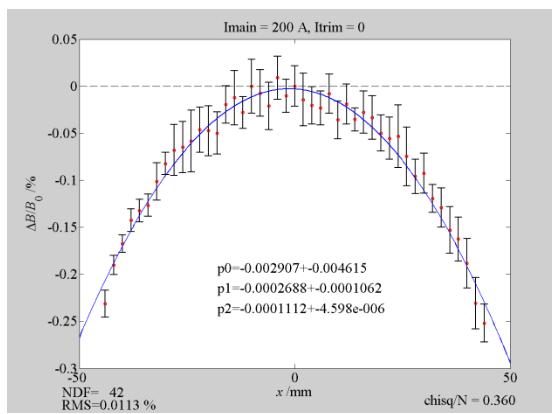
Water Flow, Temperature and Resistance

Mechanical Fiducialization

Stretched Wire
Integrated Strength vs. Current
(Transfer Function)







Wire - Integrated Strength vs X (across pole)

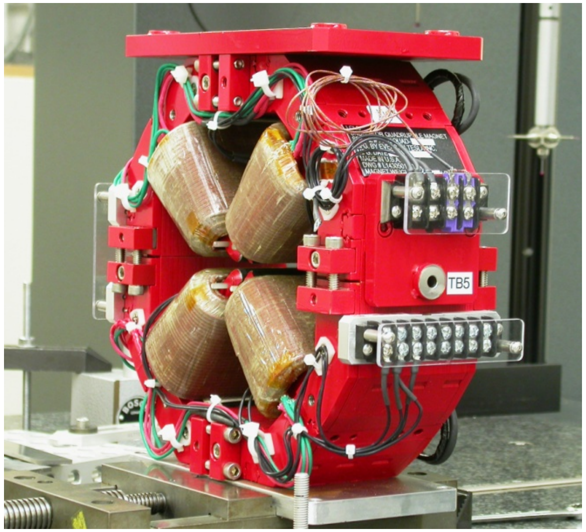
Extra Measurements

- Hall probe maps
  - Correlate with stretched wire.
- Magnet Proximity Effects
  - Stretched Wire for integrated strength
- Pole Tip Field
- Rotating Coil measurements

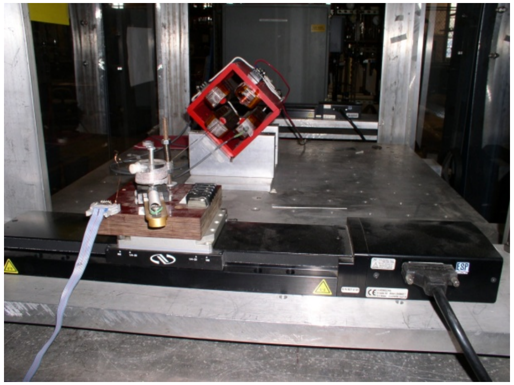
Measurement Process n = 2,3,4

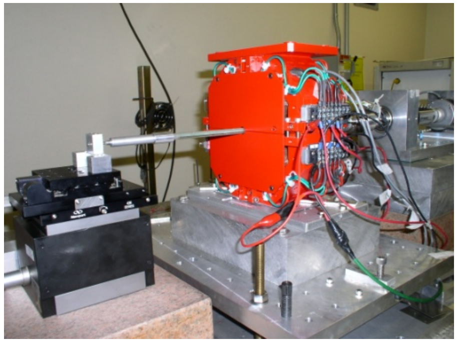
Water Flow, Temperature and Resistance

Mechanical Fiducialization



Stretched Wire
Integrated Strength at 1 Current





Rotating Coil – Transfer Function & Harmonics

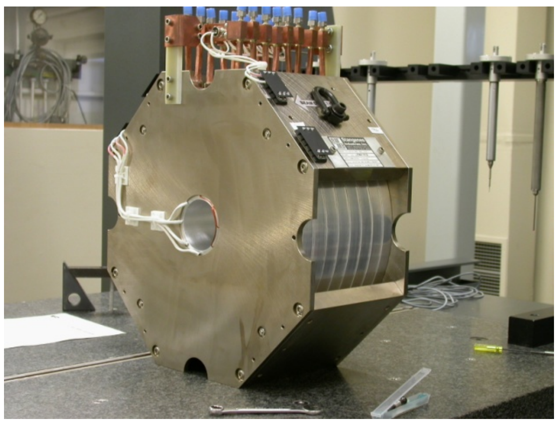
Extra n =2,3,4 Measurements

- Hall probe maps
  - Effective length
- Vibrating Wire Fiducialization
- Magnet center change with +/- 20% current.
  - Simulate Beam Based Alignment.
- Magnet Proximity Effects
  - Rotating Coil if possible or Stretched Wire.
- Pole Tip Field.

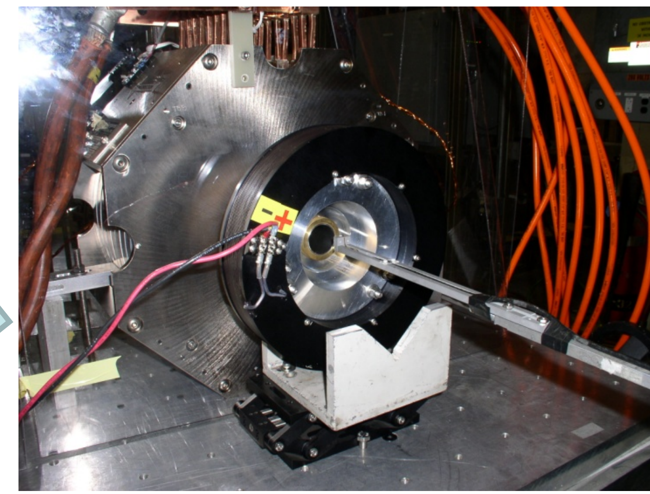
Solenoid Measurements

Water Flow, Temperature and Resistance

Mechanical Fiducialization



Hall Probe along Axial field



Short Rotating Coil to measure
Dipole and higher Harmonics

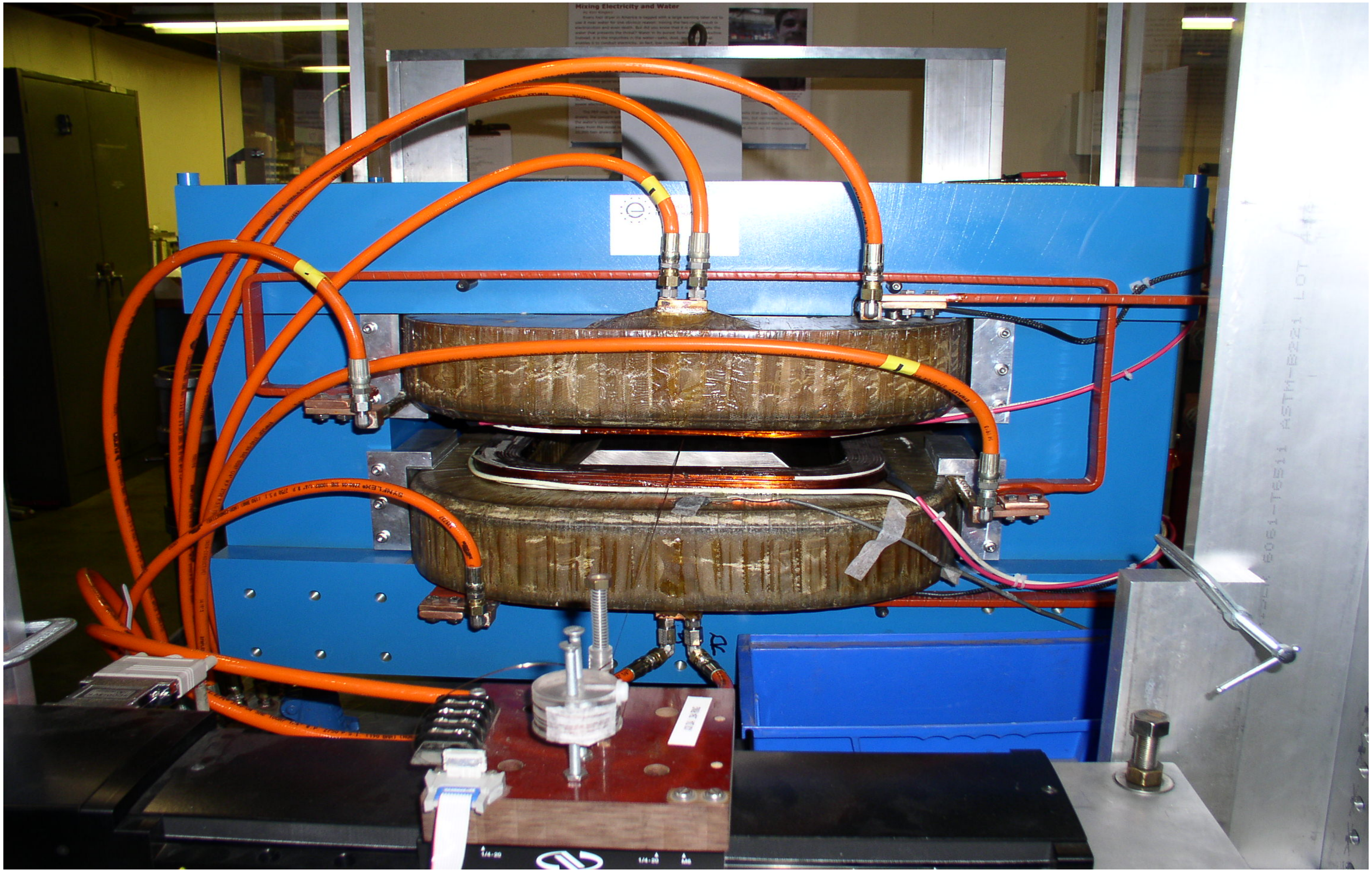
Extra Solenoid Measurements

- Long Rotating Coil.
  - Can compare to short coil measurements.
  - Characterize trim coils
  - Integrated Harmonics

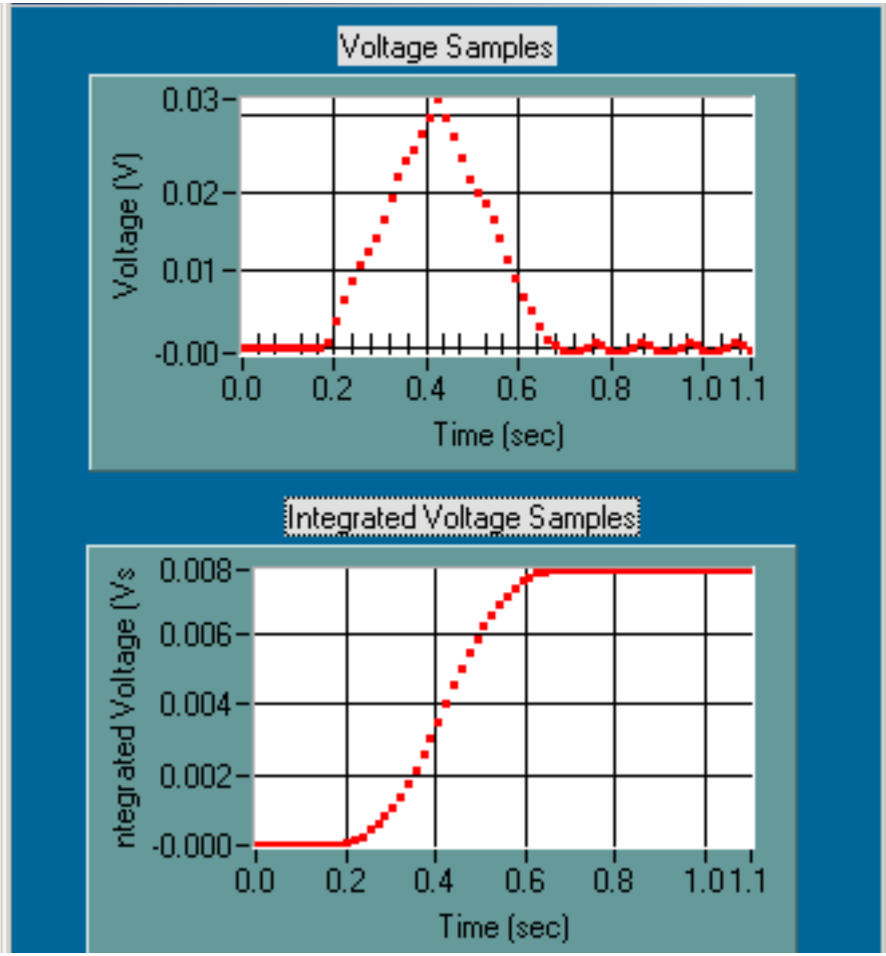
Stretched Wire

- 10 wire Cu Multifilar wire
- Linear stages with DC motors and Linear Encoders (0.1 μm resolution).
  - PID control loop must be tuned to get best performance.
- For long magnets Cu wire is supported with CuBe wire. Single wire CuBe also used for small apperatures
- Signal is integrated. Drift must be minimized.

Stretched Wire Setup - Dipole

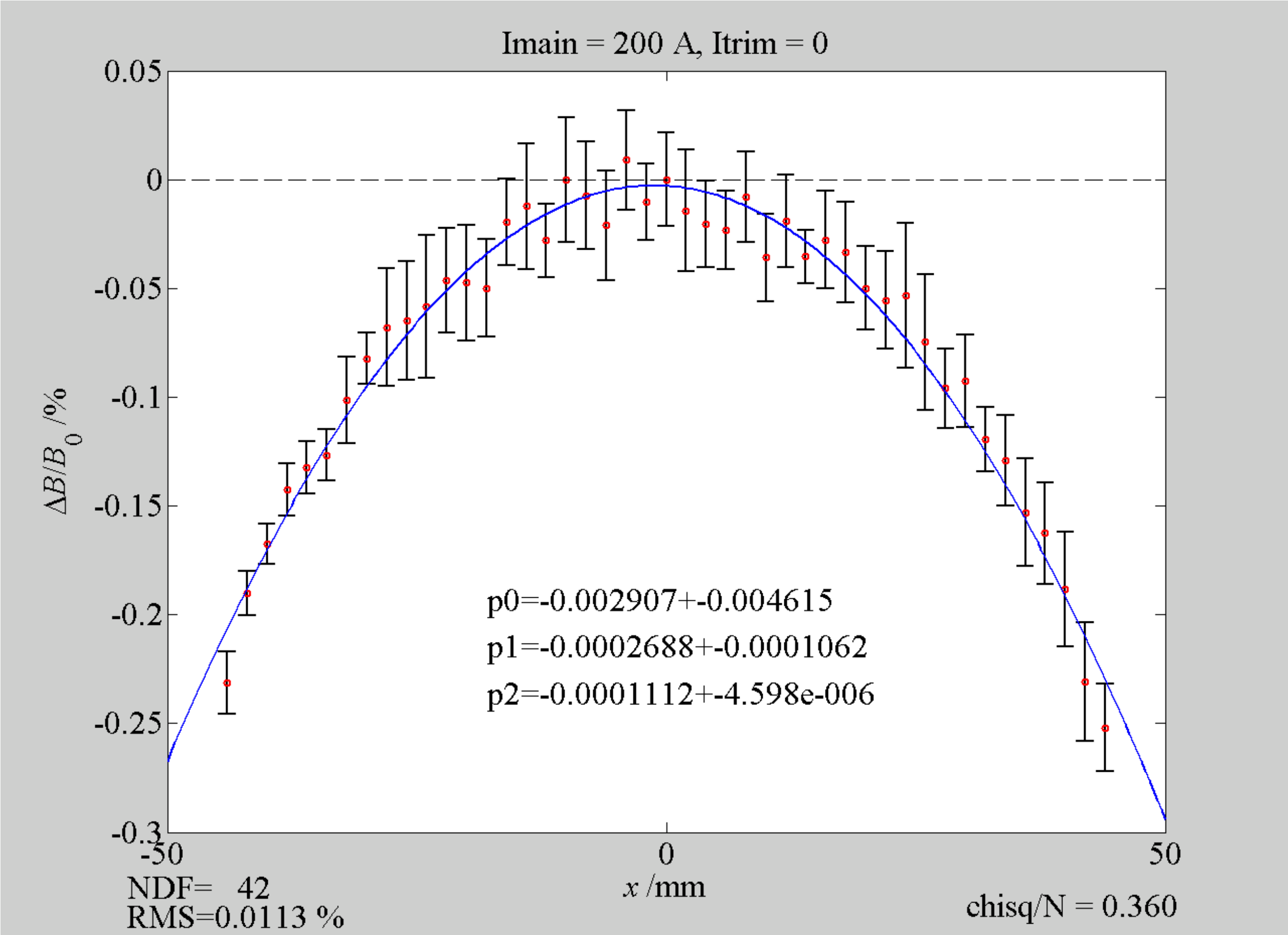


Wire Data One Pass



- Average positive and negative movement, reduce systematic error.
- Subtract linear drift.
- Average last 10 points to reduce vibration effects.

Integrated Wire Data Plot



Rotating Coil

- Use Radial Coils.
- Use stretched wire data to calibrate coil for main harmonic.
- PC board coils. Fermi Lab 4 coil BC.
- Coil designed using Matlab and Eagle PCB layout software.
- Small boards sandwiched between two G-10 rod halves. Larger boards are put in slots in G-10 rod

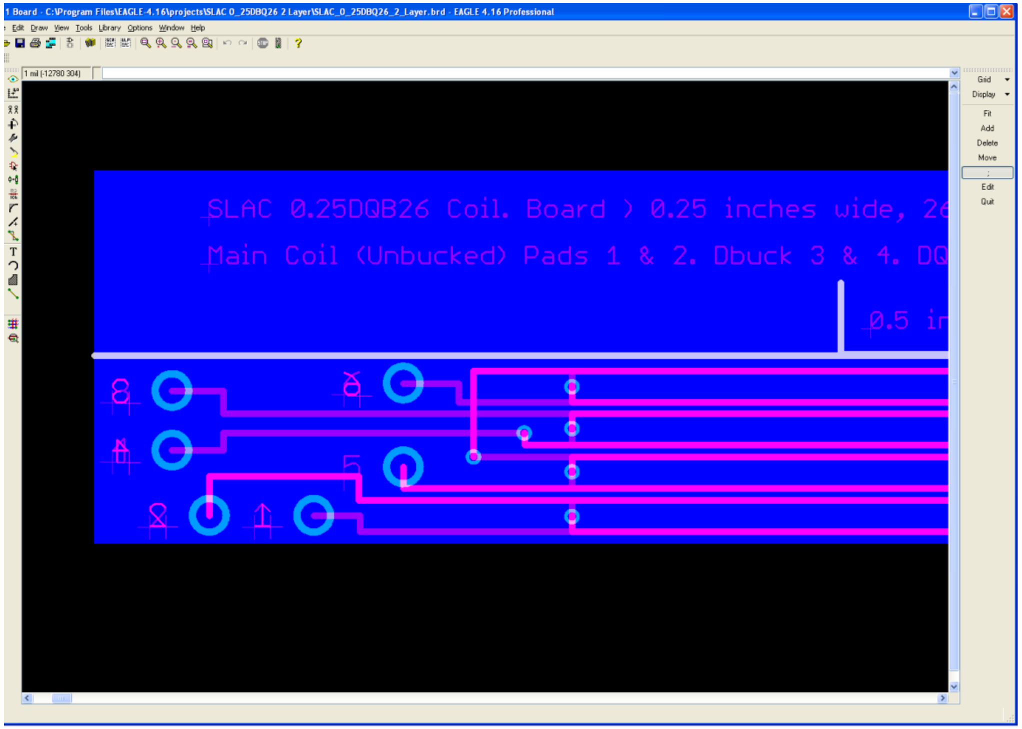
PC Board Coil design in Matlab

- PC Board coils traces are calculated and laid out. Vias and output traces and Pads are also calculated. All data is written to script file made for import Eagle PC board software.

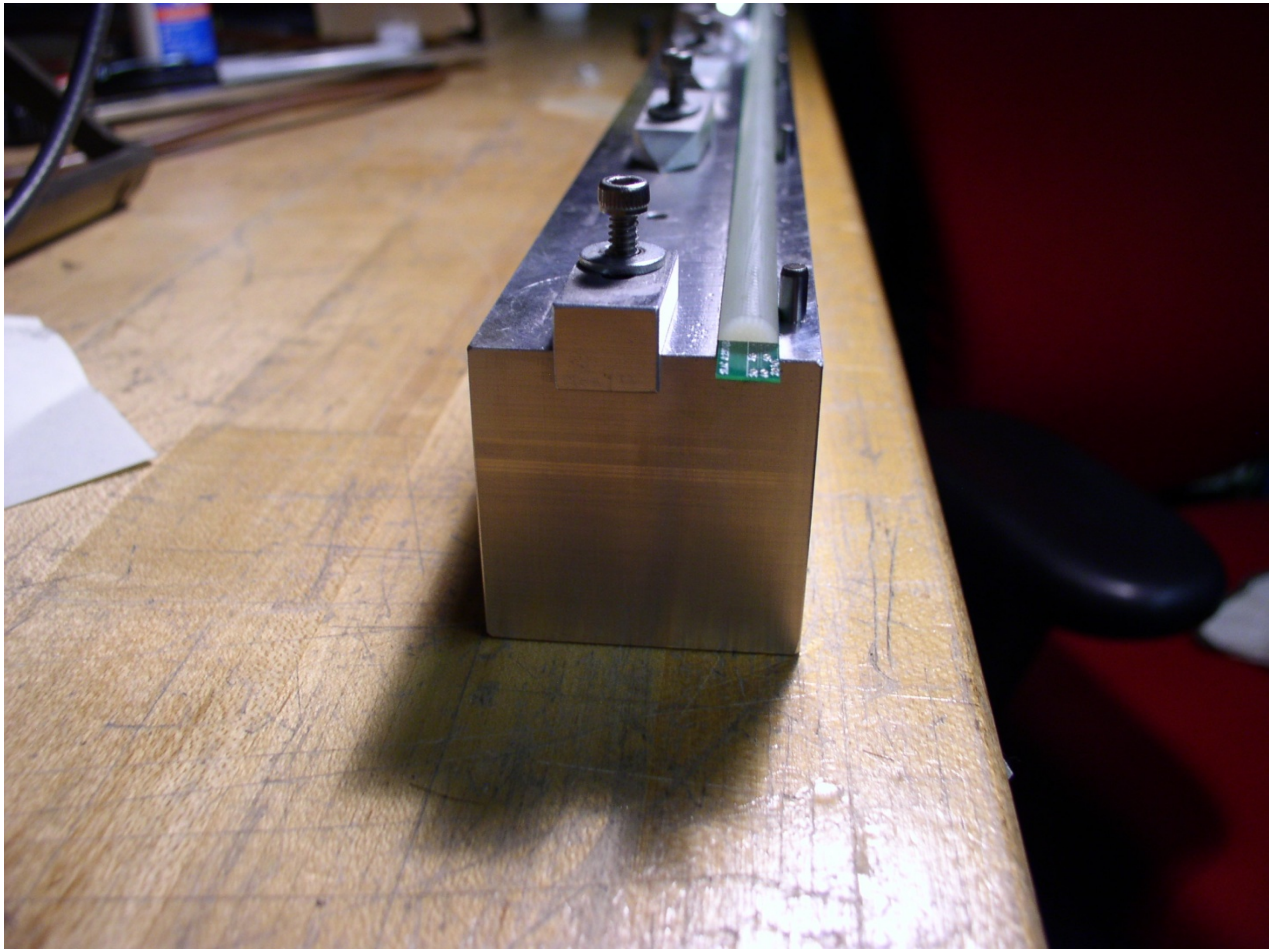
```
function [Coil_m, Coil_Bottom_m] =
DBQ_2_Layer_Coil_Gold(File_Name)
% This function does the layout for the DBQ Fermi Type coils
DBQ_params;

if Turns < 1
    error('Board is too small to fit one turn for each coil');
end

% Calculate Top coils
[Coil(1).Points] = Bottom_CCW_Coil(Coil_Start_X, SpTr, 1,
File_Name); % Start at the Bottom CCW Coil Position 1 (closest
to center)
[Coil(2).Points] = Top_CW_Coil(Coil_Start_X, 2*Coil_Width +
2*SpTr,  2, File_Name); % Start at the Top CW Coil Position 2
[Coil(3).Points] = Top_CW_Coil(Coil_Start_X, 3*Coil_Width +
3*SpTr, 3, File_Name); % Start at the Top CW Coil Position 3
[Coil(4).Points] = Bottom_CCW_Coil(Coil_Start_X, 3*Coil_Width +
4*SpTr, 4, File_Name); % Start at the Bottom CCW Coil Position 4
(farthest from center)

% Calculate Bottom coils

coil_offsets = Coil(3).Points(1,2) - Coil(2).Points(1,2);

 n = length(Coil(1).Points);
coil_y_add = [zeros(n,1, 'int32'),ones(n,1,
'int32')*coil_offsets];
coil_y_subtract = [zeros(n,1, 'int32'),ones(n,1,'int32')*-
coil_offsets];

Coil_Bottom(1).Points = Coil(3).Points(n:-1:1,:) +
2*coil_y_subtract;
Coil_Bottom(2).Points = Coil(4).Points(n:-1:1,:) +
2*coil_y_subtract;
Coil_Bottom(3).Points = Coil(4).Points(n:-1:1,:) +
coil_y_subtract;
Coil_Bottom(4).Points = Coil(3).Points(n:-1:1,:) + coil_y_add;


% Write Eagle script file to make coil

% Open file
 fid = fopen([File_Name,'.scr'],'w');
% Write header
fprintf(fid,'# DBQ Coil Builder Config Script \n');
fprintf(fid,'#\n');
```

Transfer to Eagle

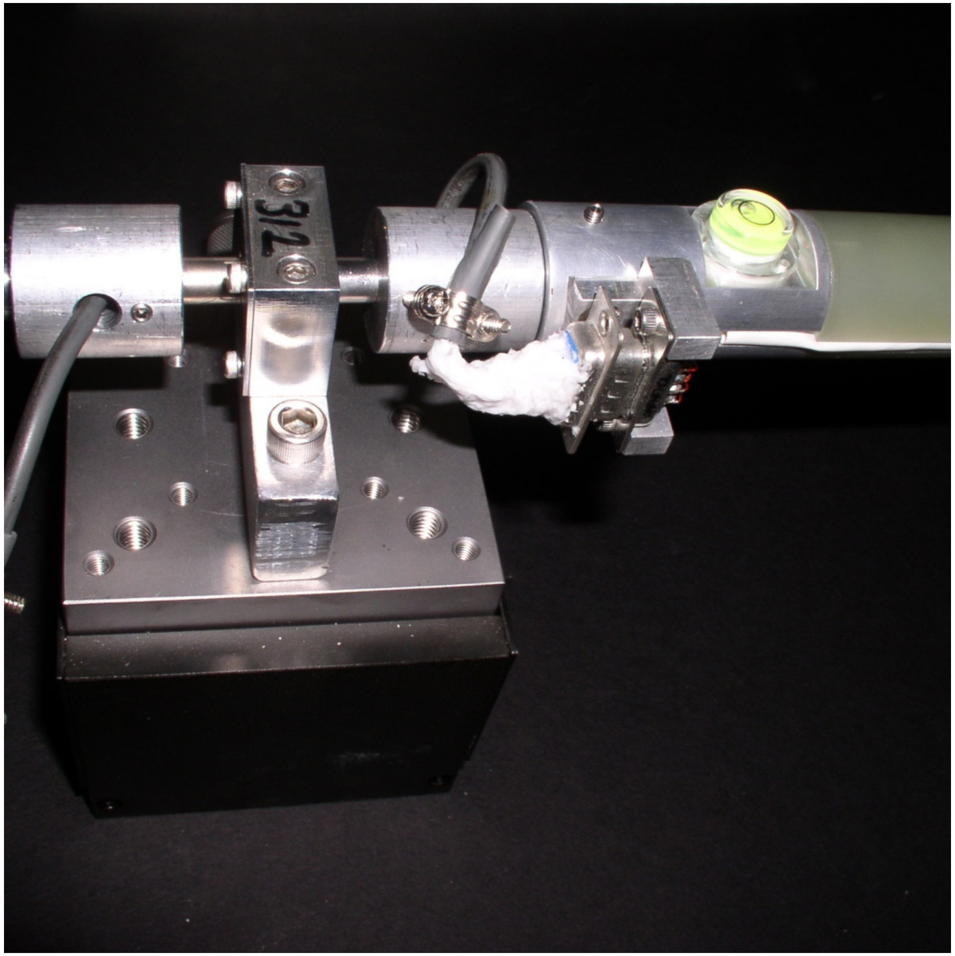
- Eagle imports Script File to and coil is complete, for the most part.



G-10 Coil Sandwich

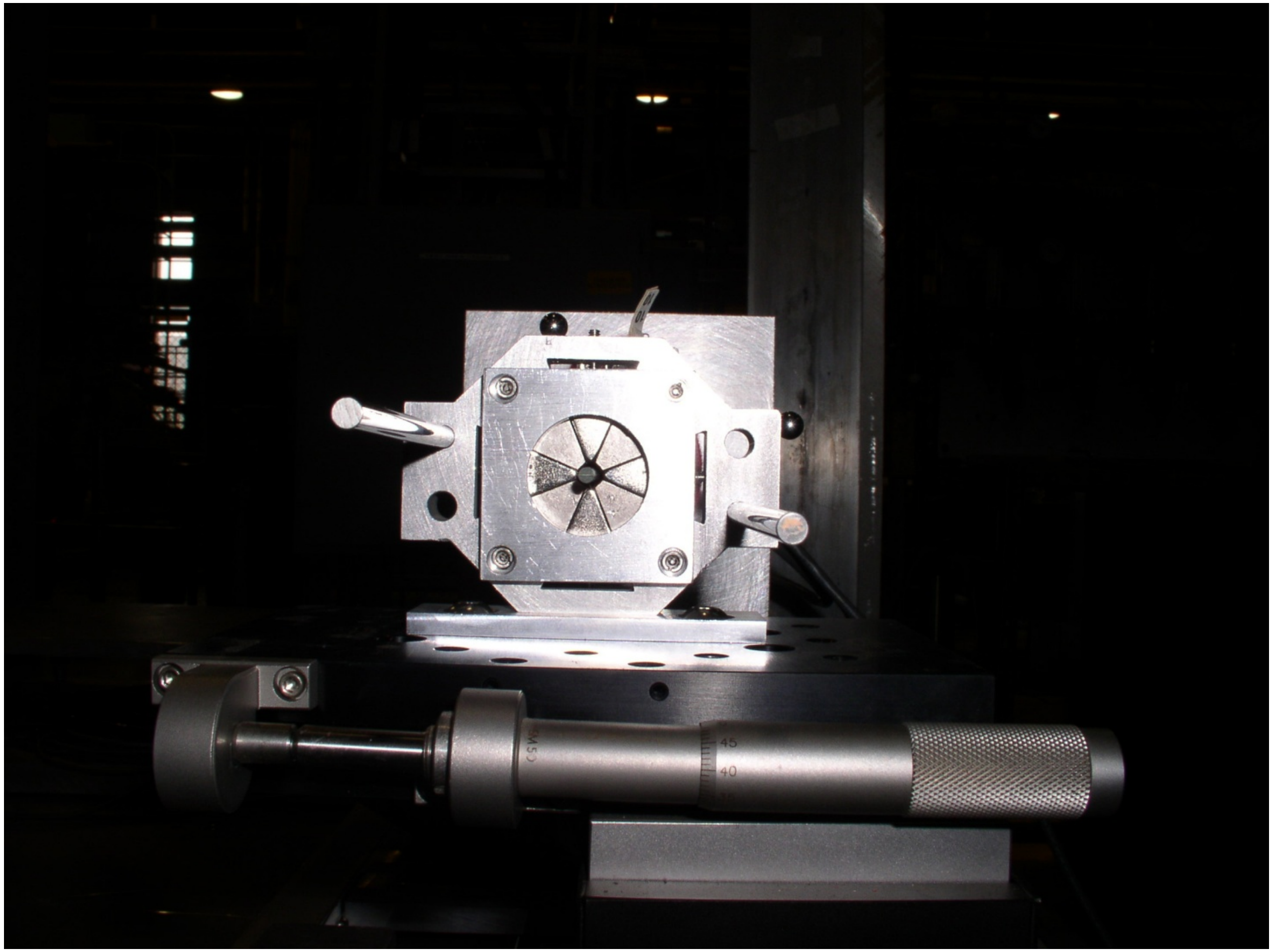


Sapphire Bearing for Coil to Motor Connection.

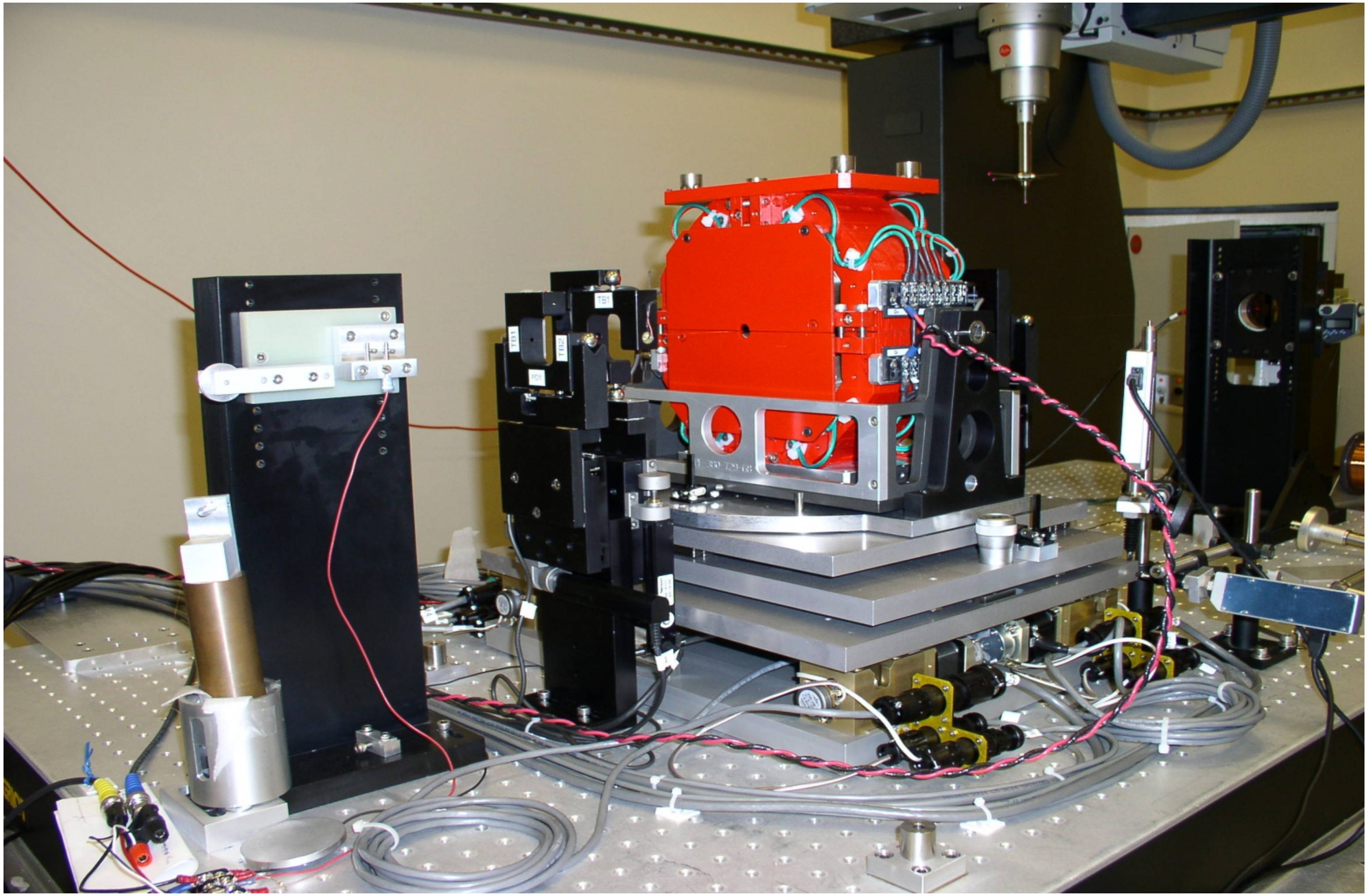


- Coil electrical signals brought through the center of Coil to Motor connector. Wire is passed through a drilled stainless steel rod.
- Rod turns on Sapphire (jewel) bearing.

Tiny Coil – Use Planar Bucking Coil



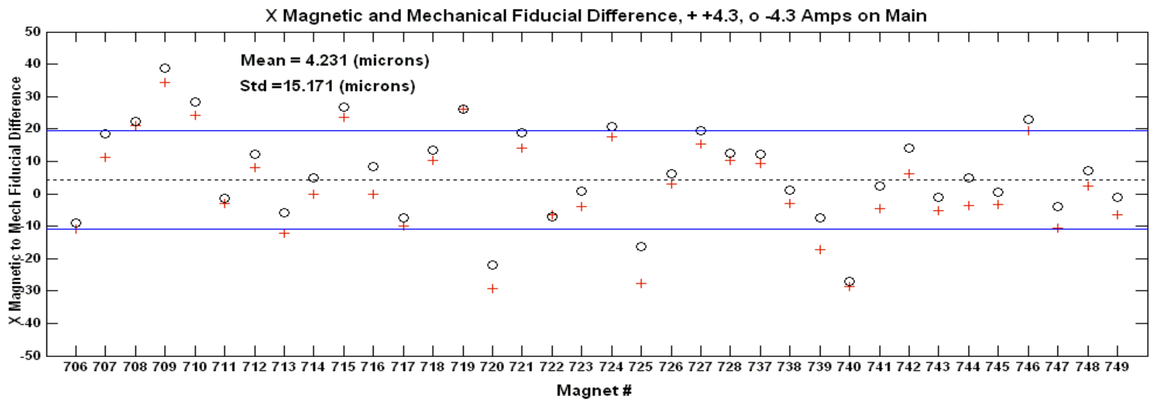
Vibrating Wire - Magnet Center

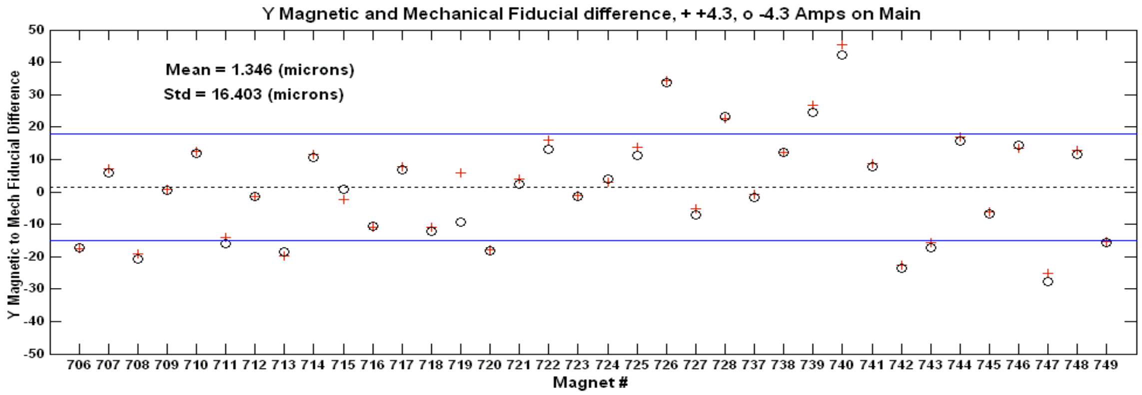


Vibrating Wire Fiducialization

- Use wire mechanical 1st and 2nd vibration frequency to detect offsets in x, y (1st) and pitch and yaw (2nd).
- Cam mover system scans magnet in x, y, pitch and yaw and finds zero for each.
- Wire is located with wire finders.
- CMM locates magnet and wire finders.

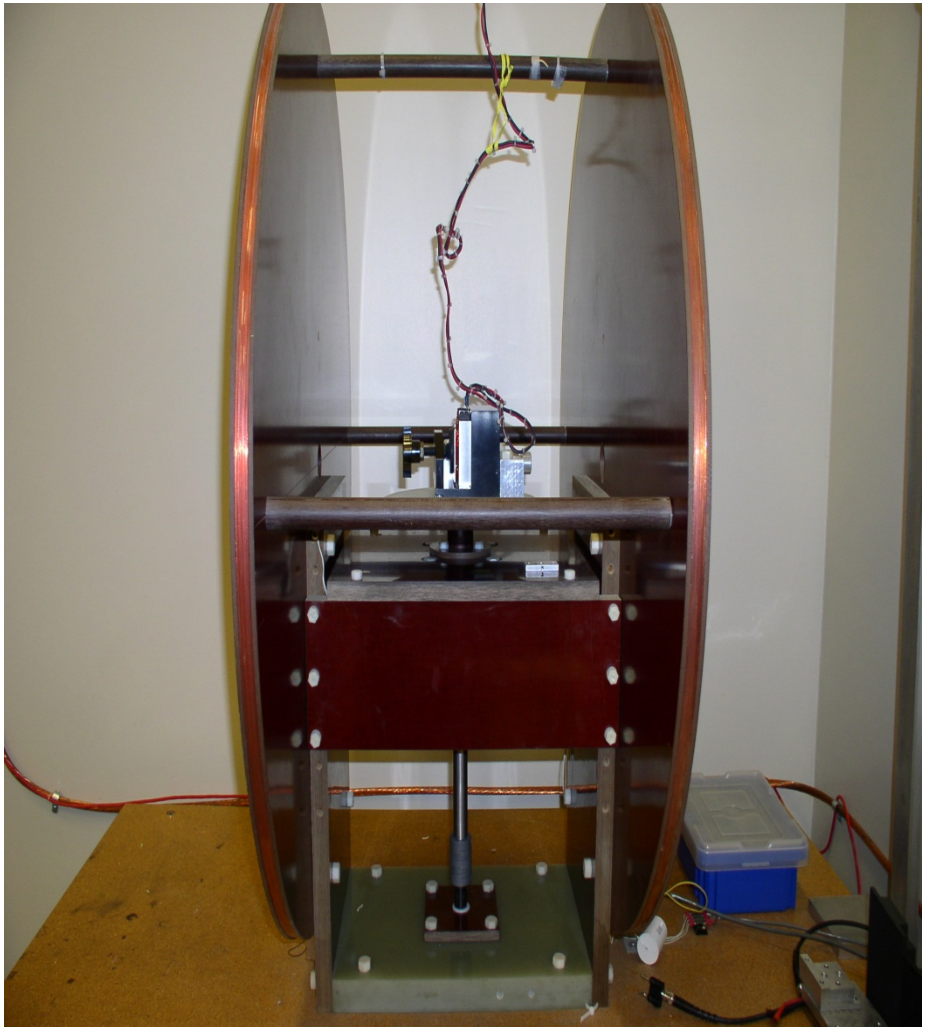
LCLS Undulator Quads Mechanical vs. Magnetic Center





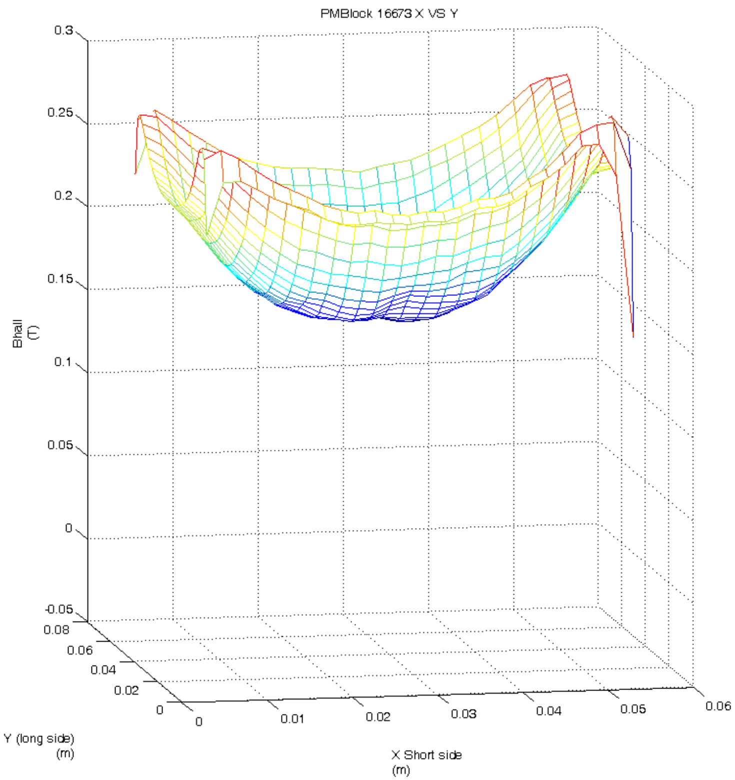
Helmholtz Coil

- PM Blocks magnetization
  - Sorting
  - Radiation damage tests
- Calibration Electromagnet
- Use reference block from set for normalization.

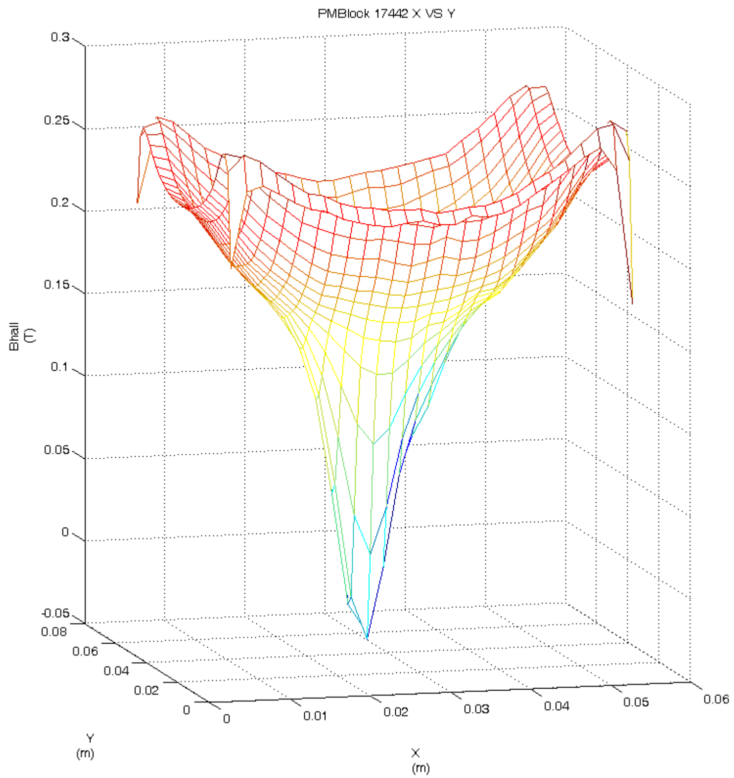


Hall probe map of block

No Damage



With Damage



Conclusion

- SLAC measures many varieties of magnet on a yearly basis.
- Thank you for listening!