Update on Vibration Measurement Work at BNL

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Topics Covered

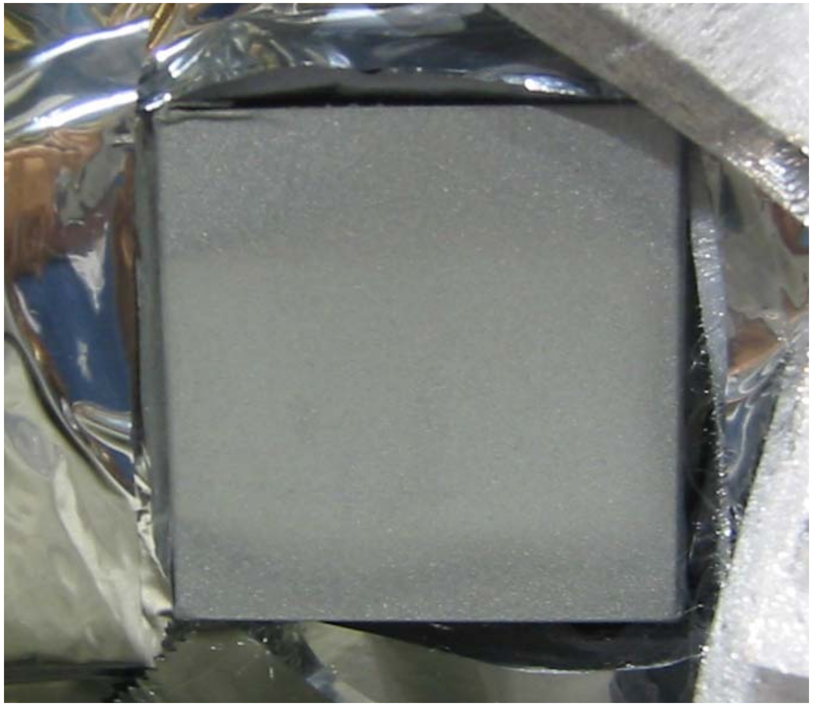
- Failed 3rd cold test of the CQS cold mass.
- Development of a probe to measure motion of quadrupole field center:
  - Basic theory
  - Probe construction
  - Characterization of probe motion
  - Initial test results in a warm quad at low excitation (~ 0.1 T/m)
    - probe alignment in the quad (crude set up!)
    - noise characteristics

CQS Cold Tests

- Laser Doppler Vibrometer system was first used to measure the CQS coldmass vibrations under cryogenic conditions in Sept'2005. The results were presented at Nanobeam 2005.
- A second cold test was performed in March 2006 with an improved set up. The results were reported in the BNL-SLAC-Annecy phone meeting on April 18, 2006.
- During the second cold test, one of the retroreflective laser targets was found to be contaminated, and could not be used. It was still possible to use the target at another end of the magnet.
- The target could be revived by cleaning after the magnet was warmed up.
- A third cold test was scheduled for early September'06, with some simple modifications in superinsulation layout to prevent contamination.
- **Unfortunately, the simple fix did not work!**

No further cold tests are planned.

Laser Reflector Inspection After 2nd Cold Test



Central, exposed region does not reflect. The edges, which were covered by super-insulation, are still reflecting.

Picture taken with a flash, clearly showing the difference in reflectivity.

Laser Reflector Contamination

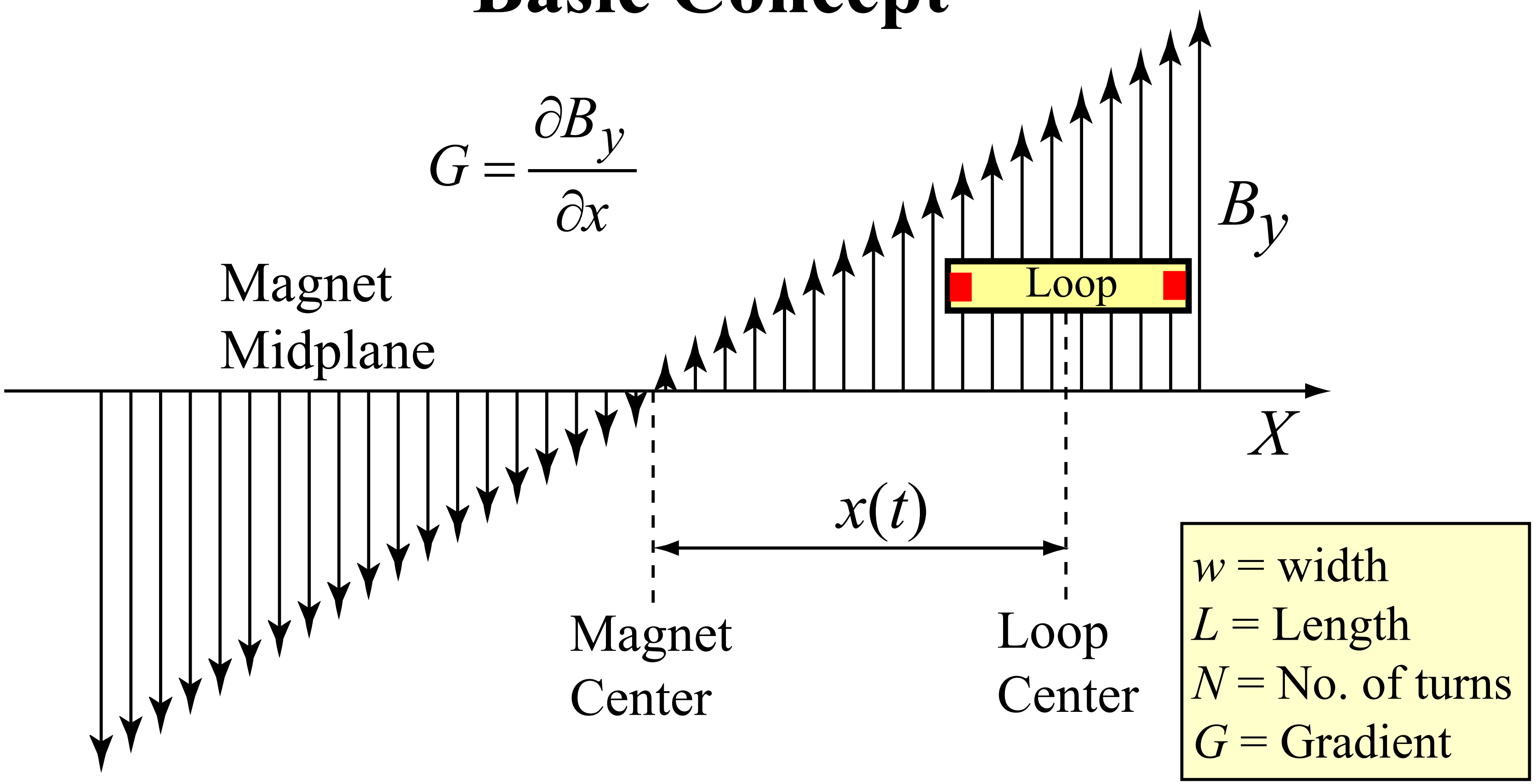
- After the second cold test, the reflector was cleaned with a solvent (*Micro Clean* Flux cleaner), and it worked well.
- For the 3rd cold test, superinsulation near the reflector was loosened to provide more cold surface in the vicinity. It was hoped that it may reduce the chances of contamination.
- The reflector was monitored using the laser during pumping and cool down. It worked well until after the magnet was pumped, but still warm. It stopped working when cold.
- Better means to protect the reflector surface are needed. For example:
  - Cover the target during cool down.
  - Keep the target warmer than the surroundings, at least during the initial cool down. Use G-10 backing to get gradient.

Development of a Probe to Measure Quadrupole Field Center Motion

Measuring Quadrupole Field Center

- Place a flat loop of wire in the quadrupole aperture.
- The amount of flux linked through the loop is proportional to the offset of the loop center from the quadrupole field center.
- A relative motion of the field with respect to the loop center will produce a change in flux, and hence a voltage signal.
- Analysis of the voltage signal provides the velocity spectrum.
- Two, or more, loops can be used to monitor both horizontal and vertical motion.

Basic Concept



$V(t) = wNLG \cdot \dot{x}(t)$ (assuming G is constant)

CERN Coil: 2500 turns; 13.5 mm x 125 mm; $wNL \sim 4\ \text{m}^2$

$V(t) \sim 400$ V/(m/s) at 100 T/m => More than a Mark L4 geophone

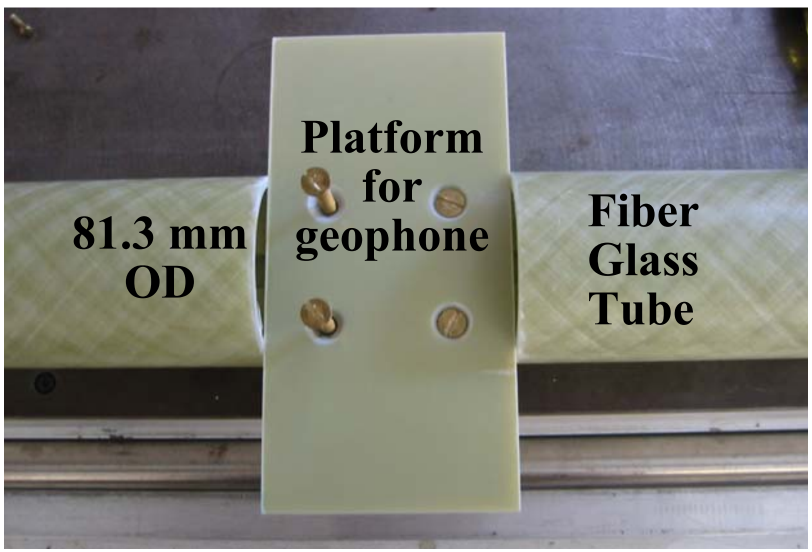
Power Supply Ripple complicates the analysis unless the probe is well centered

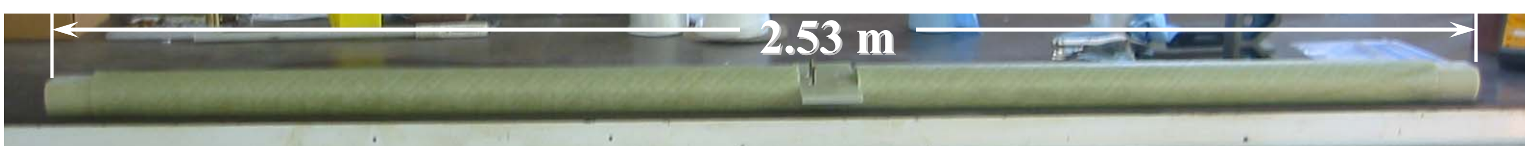
Practical Difficulties to be Solved

- Signal may also be produced if the quadrupole field changes with time, e.g. due to power supply ripple.
- Signal due to ripple may drown the signal due to field motion if the loop is not well centered.
- Signal only tells the relative motion of the pick up coil and the field. How does one know where the pick up coil is?
- Minimize, and characterize, the motion of the pick up coil $\Rightarrow$ Most challenging task!
- Issues of signal strength Vs. noise for very small motion ~ nm.

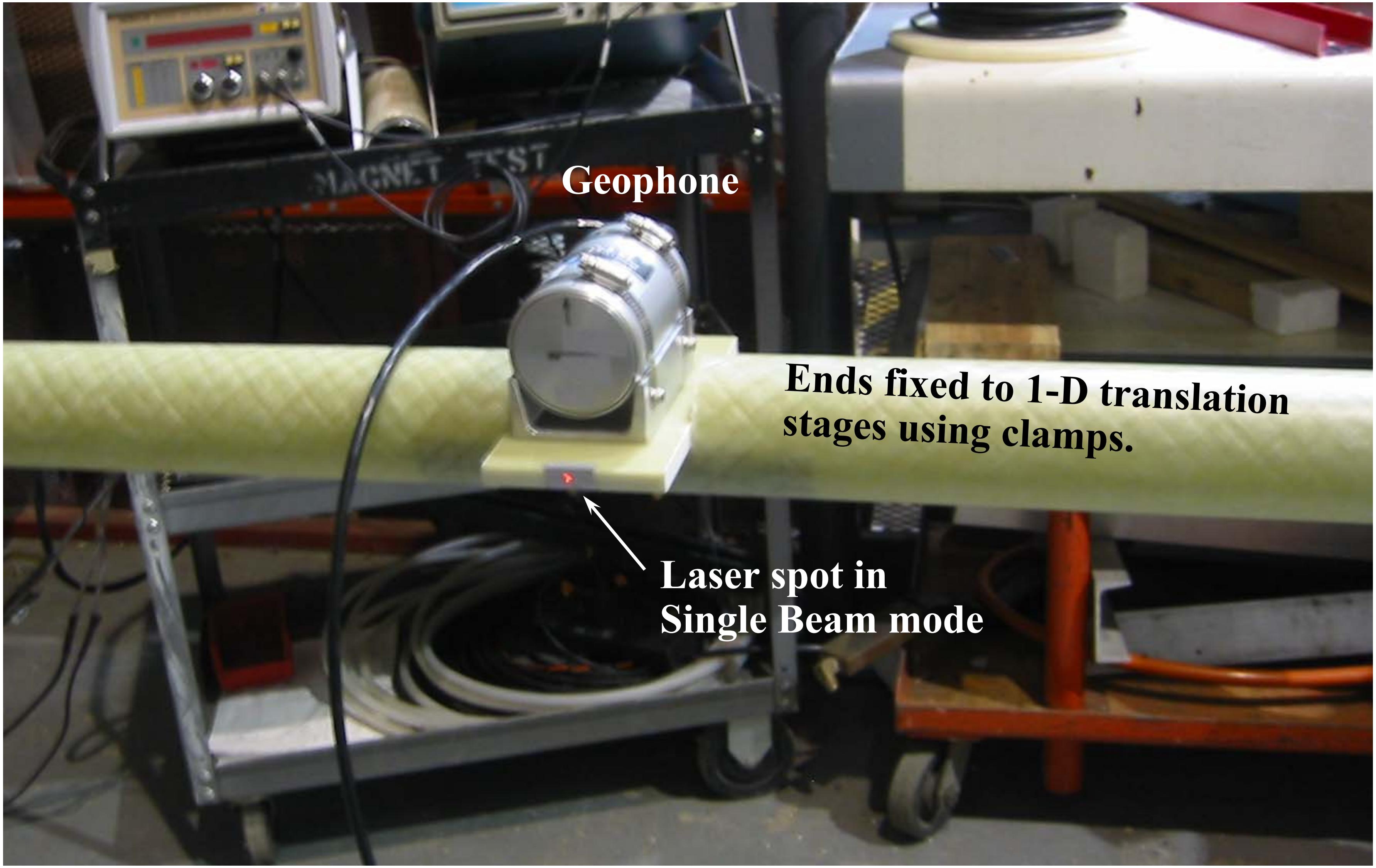
Vibration Pick-up Coil Assembly

2500-turn coil from CERN

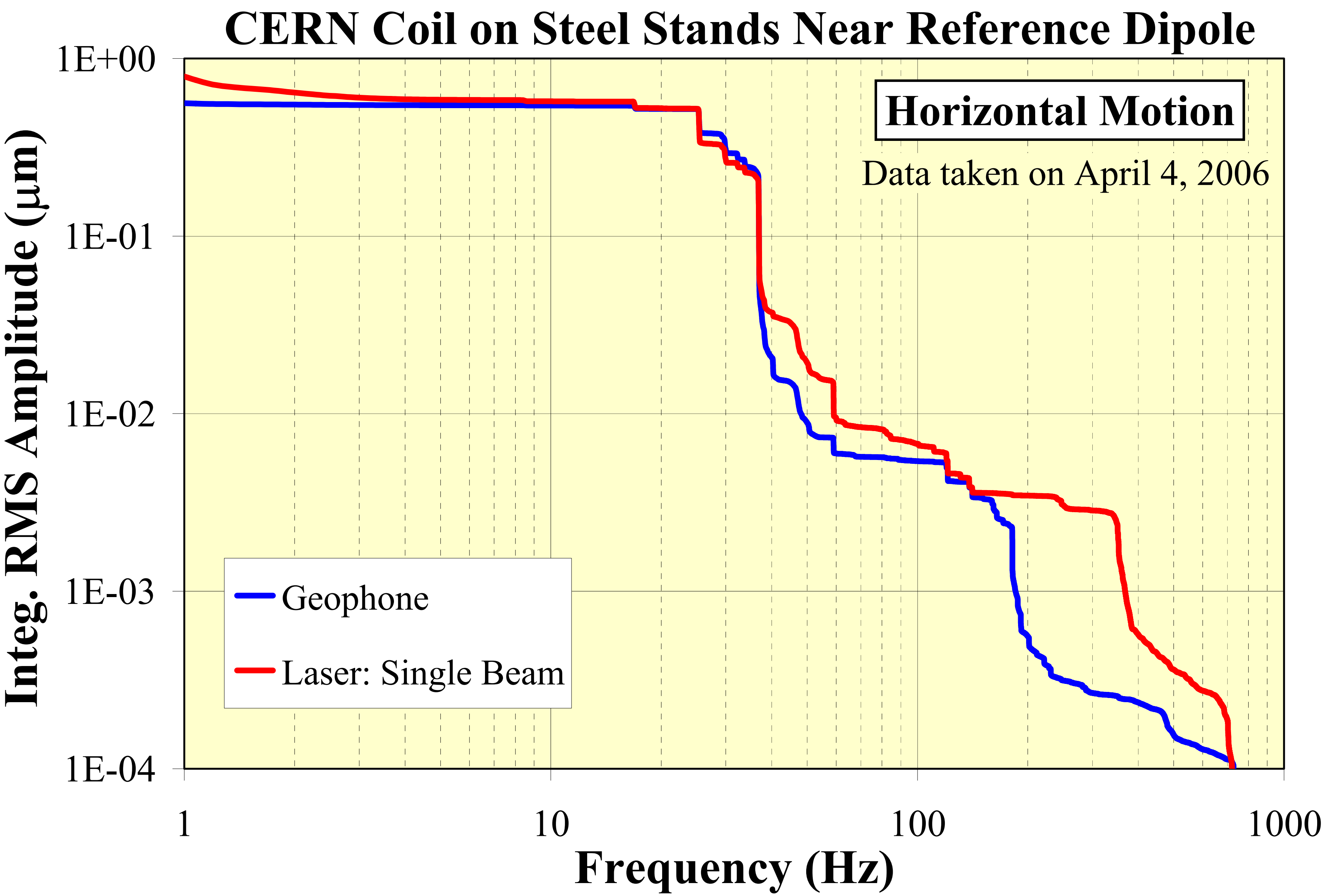




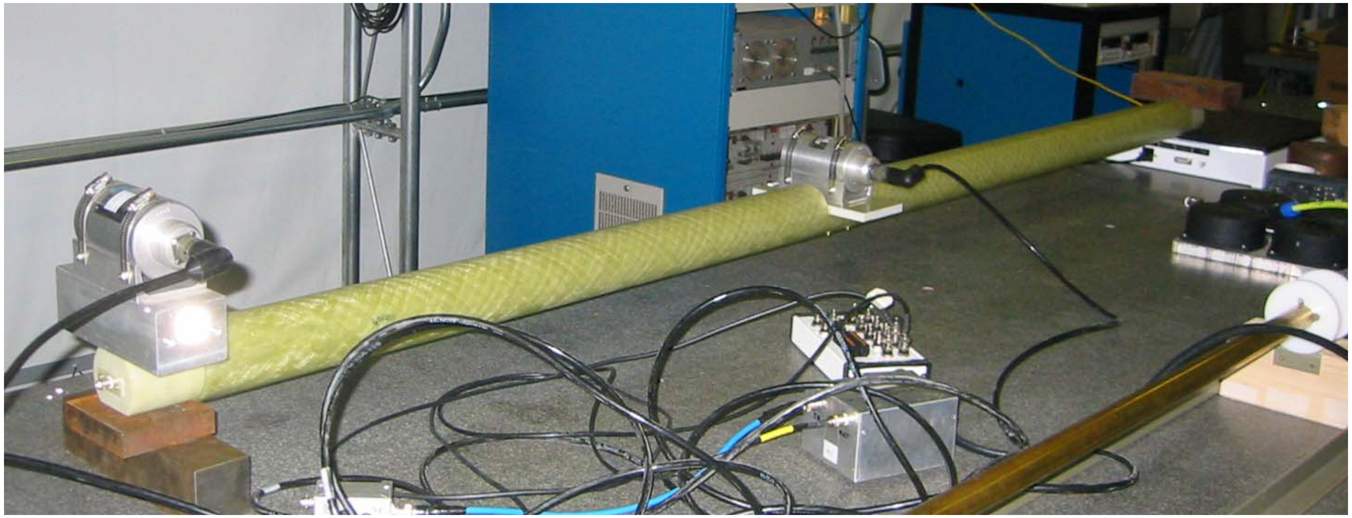
Pick-up Coil Characterization

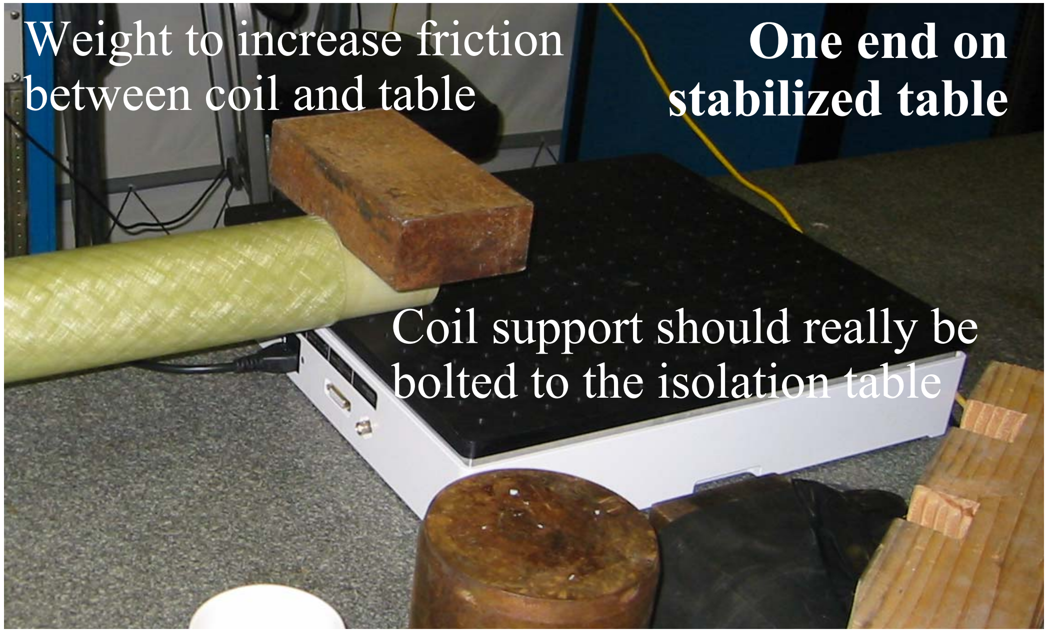


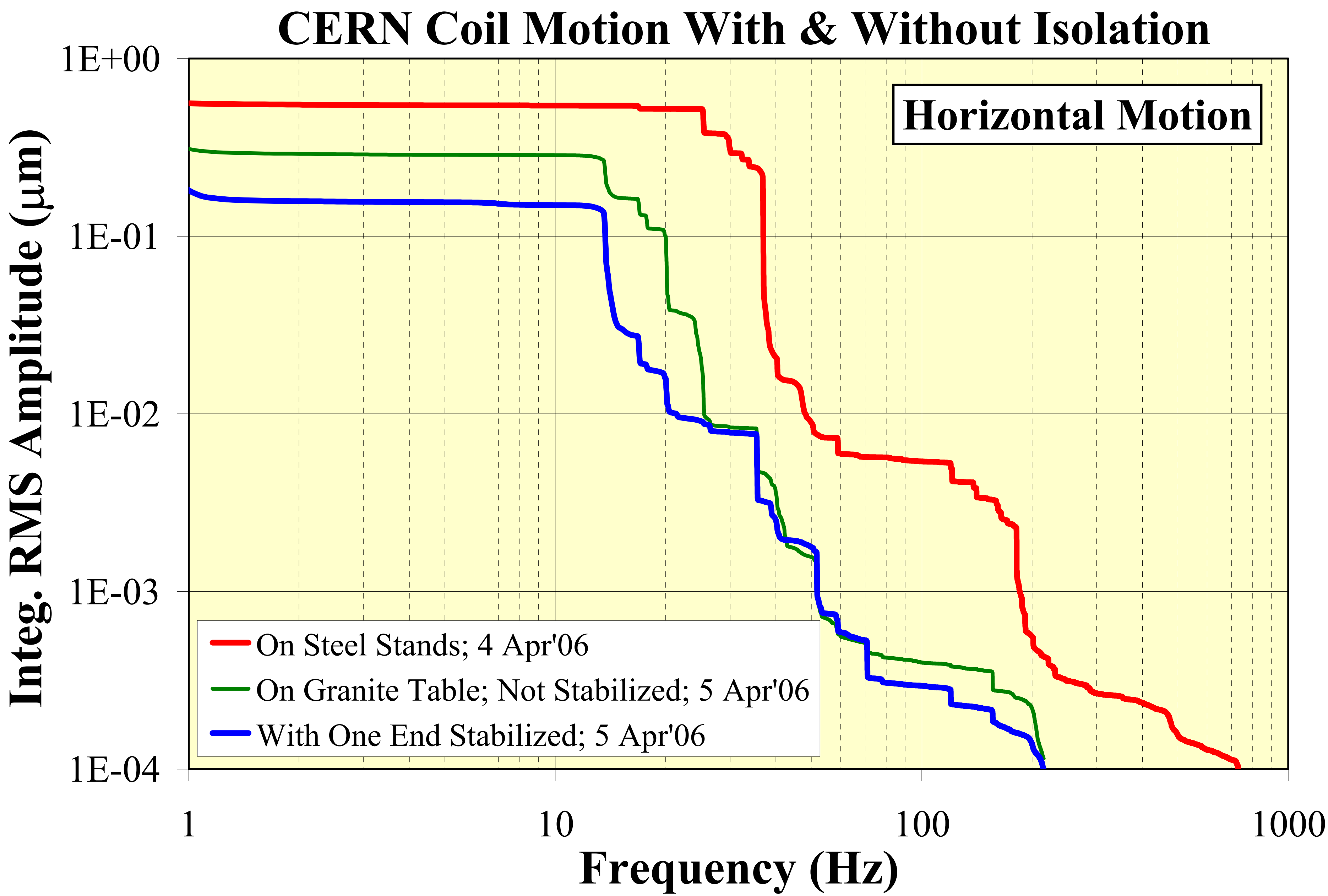
Pick-up Coil Characterization



Pick-up Coil Stabilization (Crude!)





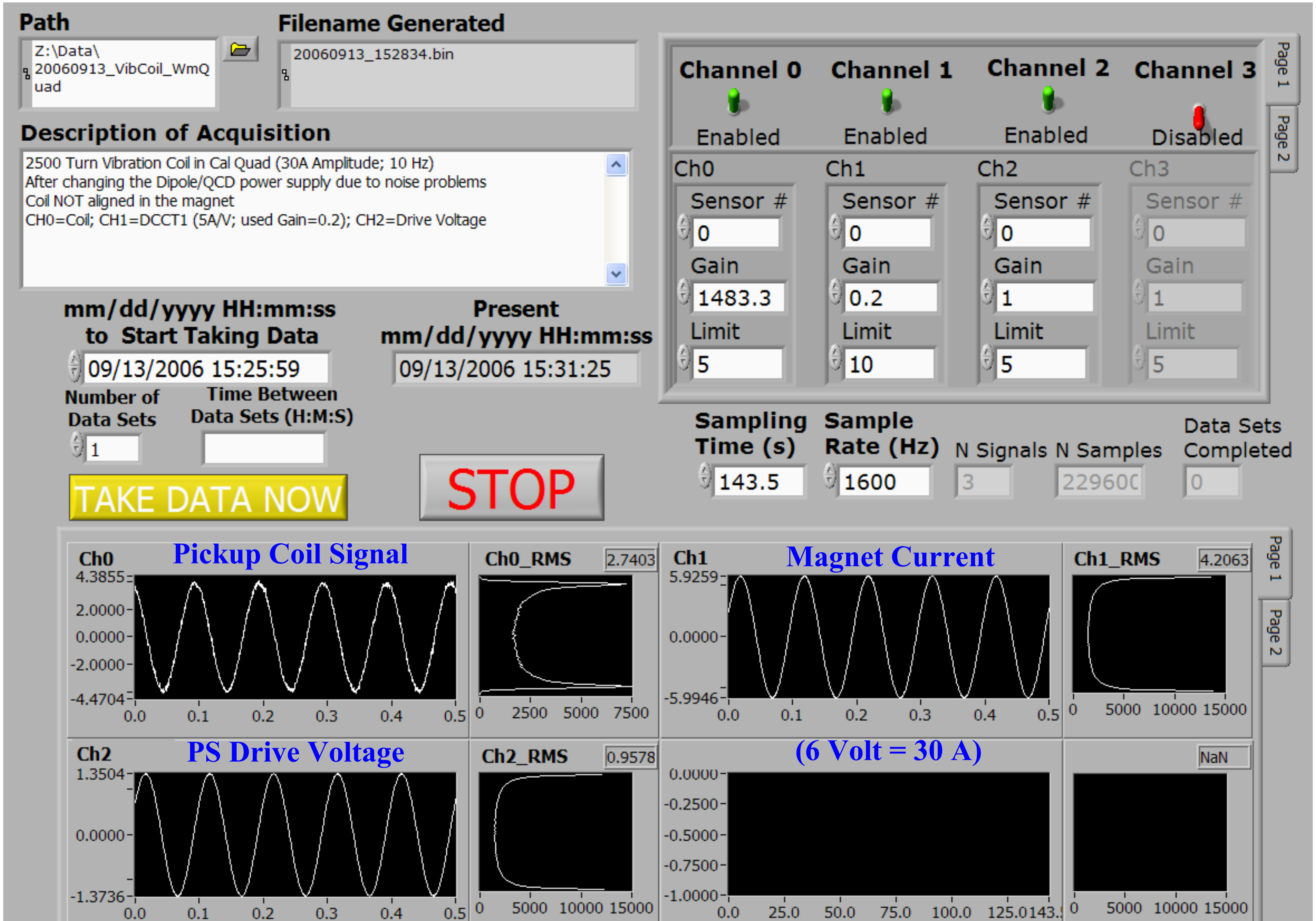

CERN Coil Motion With & Without Isolation
Horizontal Motion
Integ. RMS Amplitude (μm)
1E+00
1E-01
1E-02
1E-03
1E-04
1
10
100
1000
Frequency (Hz)
On Steel Stands; 4 Apr'06
On Granite Table; Not Stabilized; 5 Apr'06
With One End Stabilized; 5 Apr'06

Alignment in Quad & Noise Studies

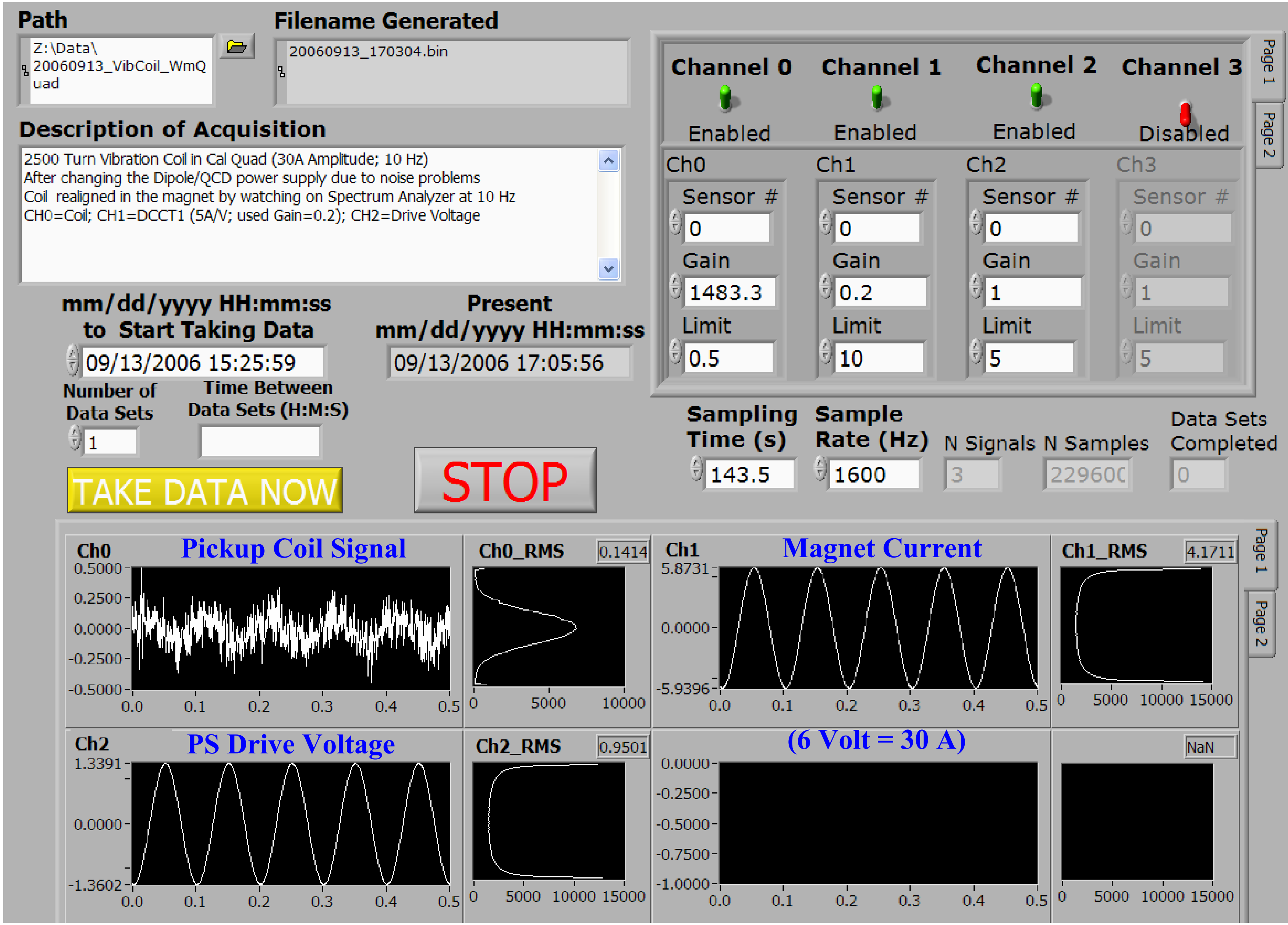
- The probe was installed in a room temperature, large bore quadrupole, normally used for calibration purposes at BNL.
- The probe was installed, without any stabilization, on steel supports and a rather crude moving mechanism to align the coil.
- The magnet was excited at low fields with sinusoidal current (30 A; 0.1 T/m amplitude). This large "ripple" can be picked up if the probe is not centered in the quad.
- The pick up signal under AC excitation was used to align the probe in the quad.
- Measurements were made at 30 A DC excitation, and at 0 A to study noise.

Pick-up Coil Setup in Room Temp. Quad

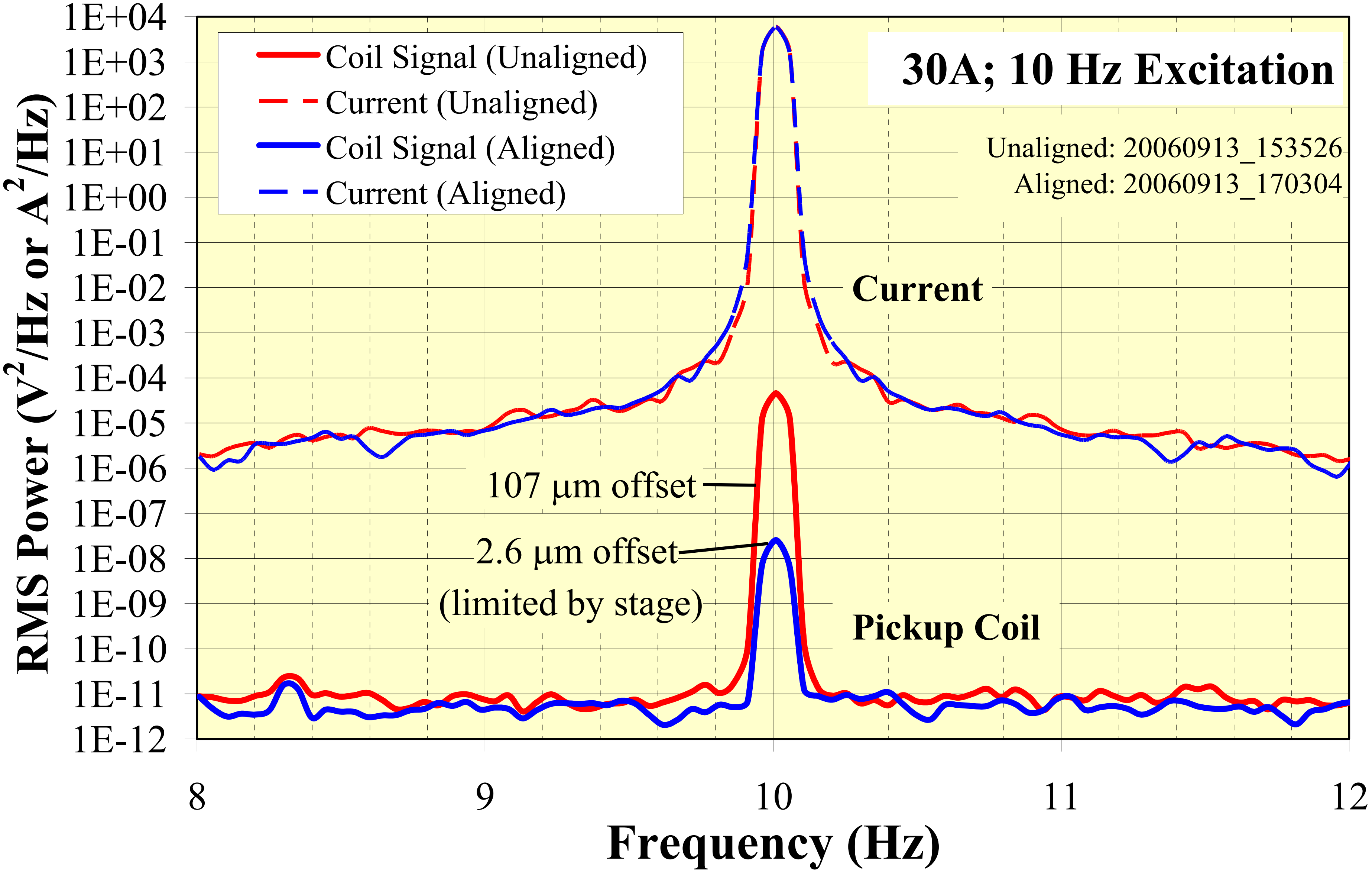
30 A Excitation at 10 Hz (Coil not aligned)



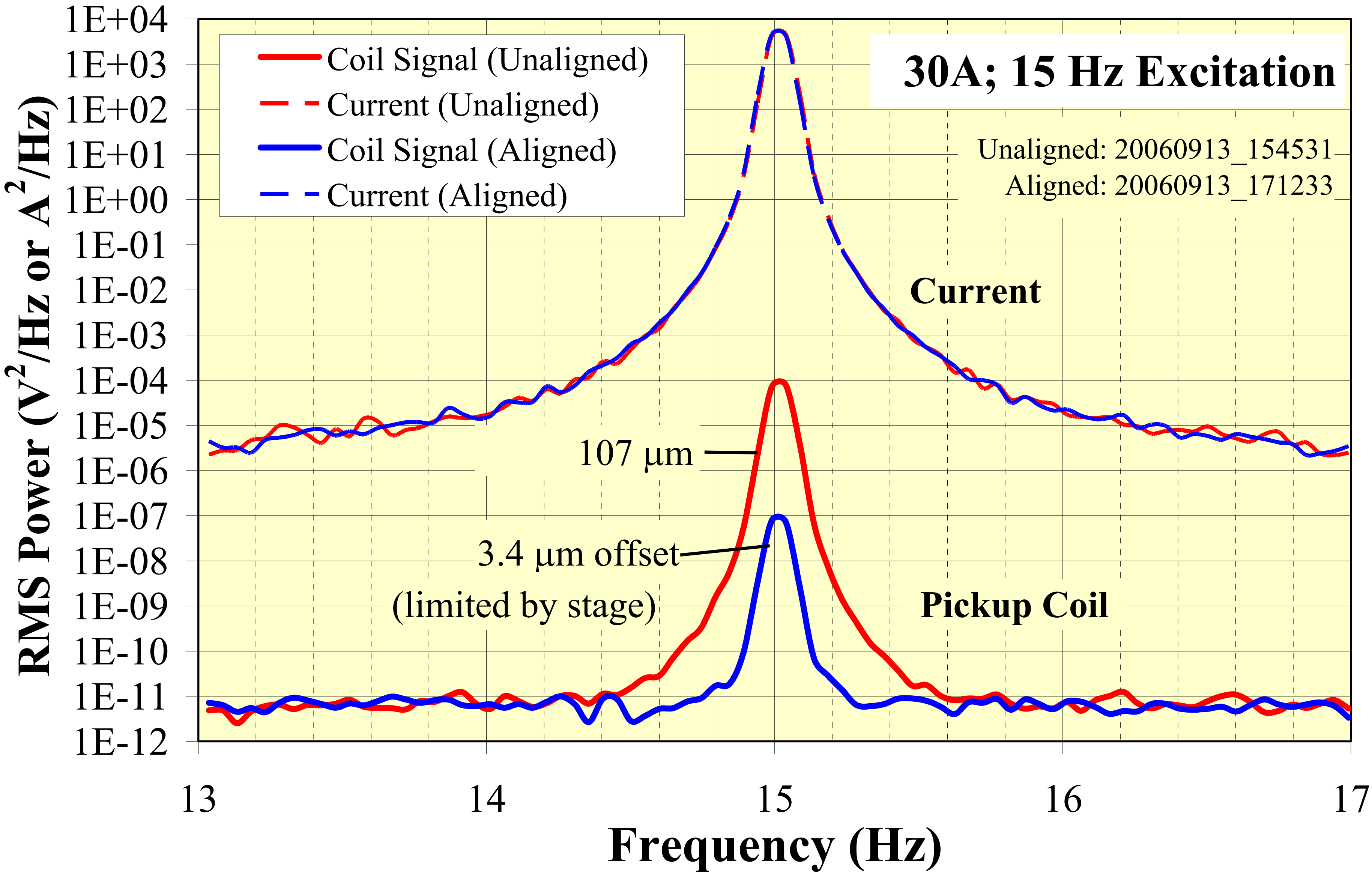
30 A Excitation at 10 Hz (Coil aligned)



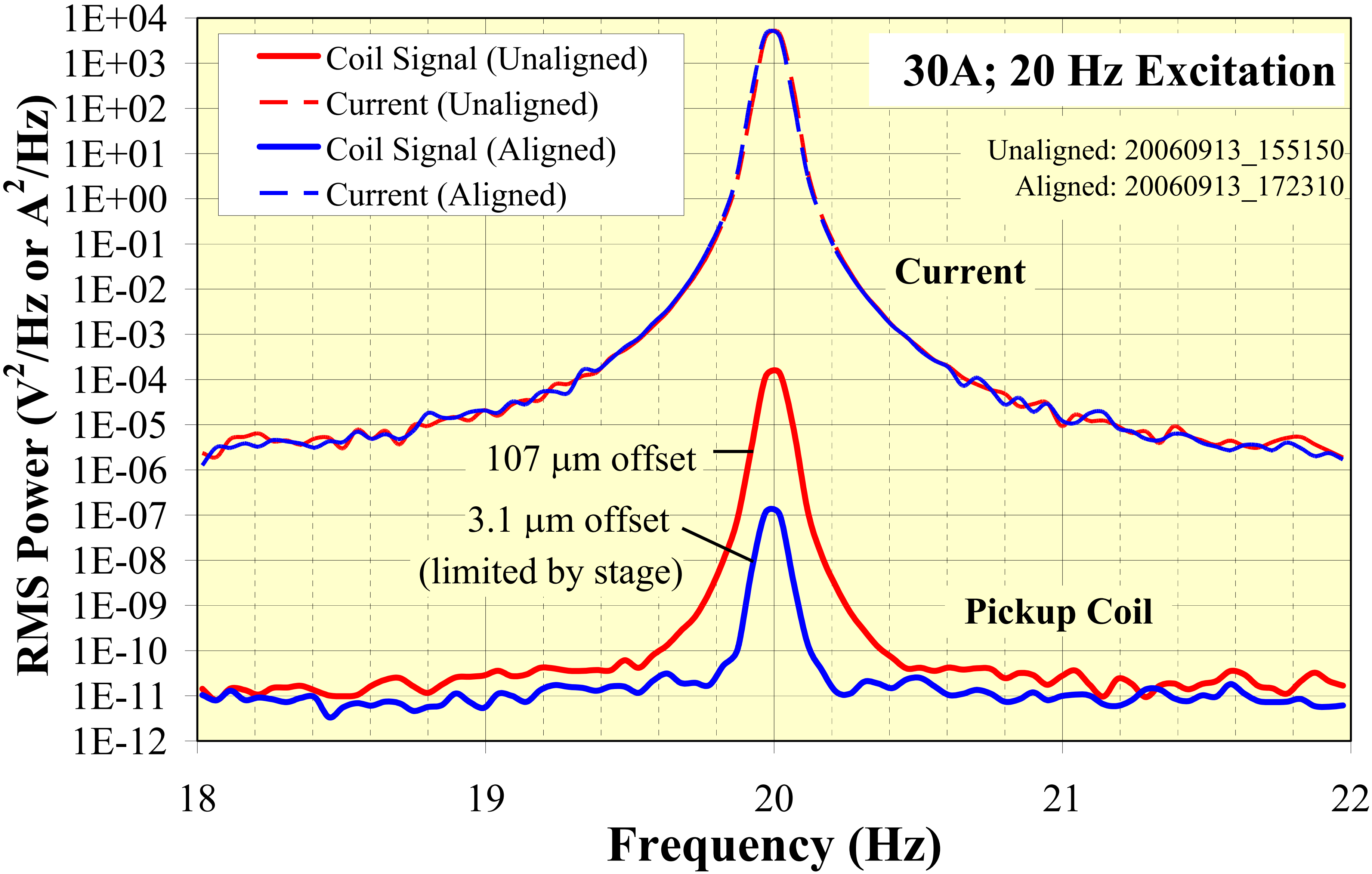
Current and Pick Up Coil Spectra in Cal. Quad



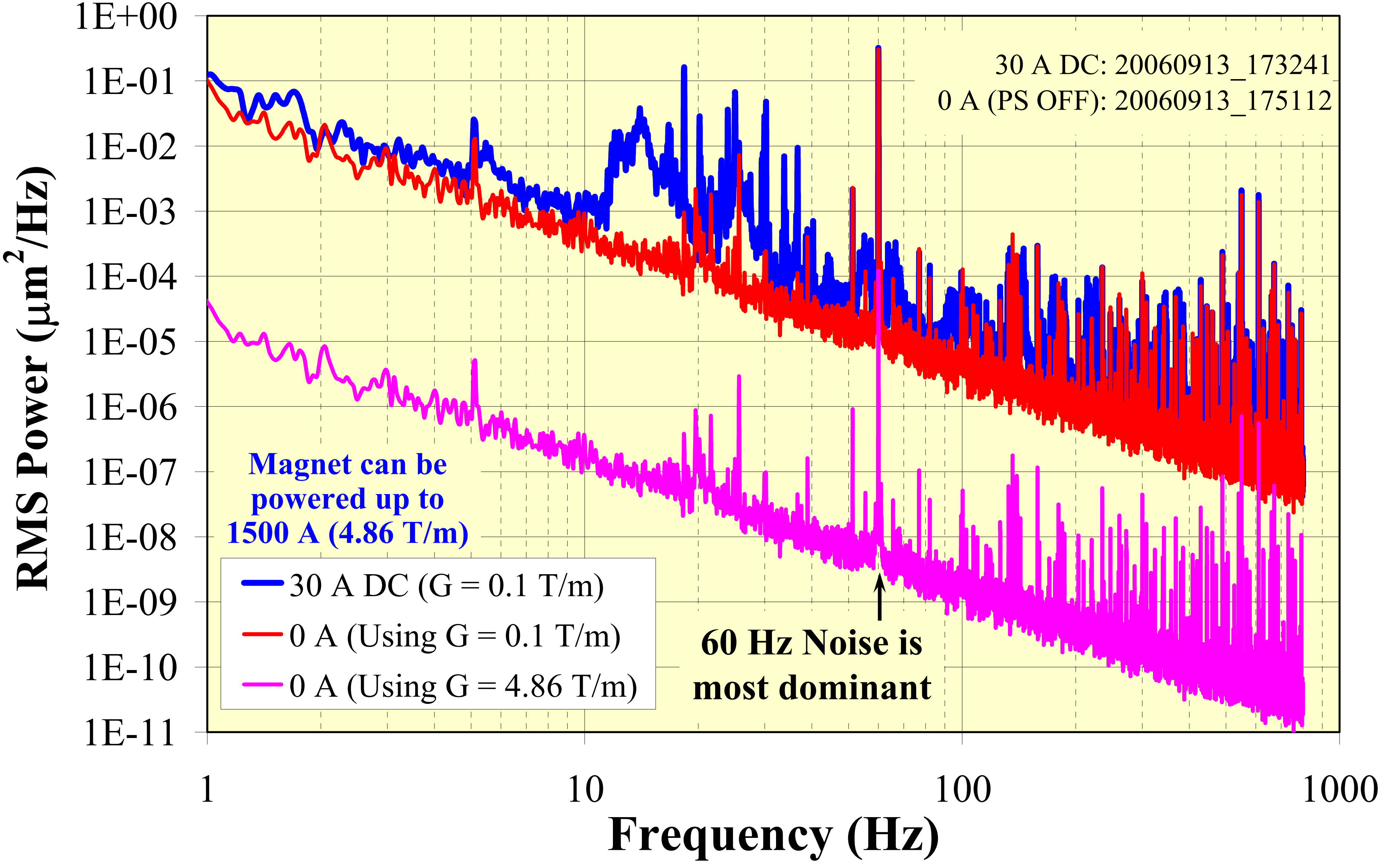
Current and Pick Up Coil Spectra in Cal. Quad



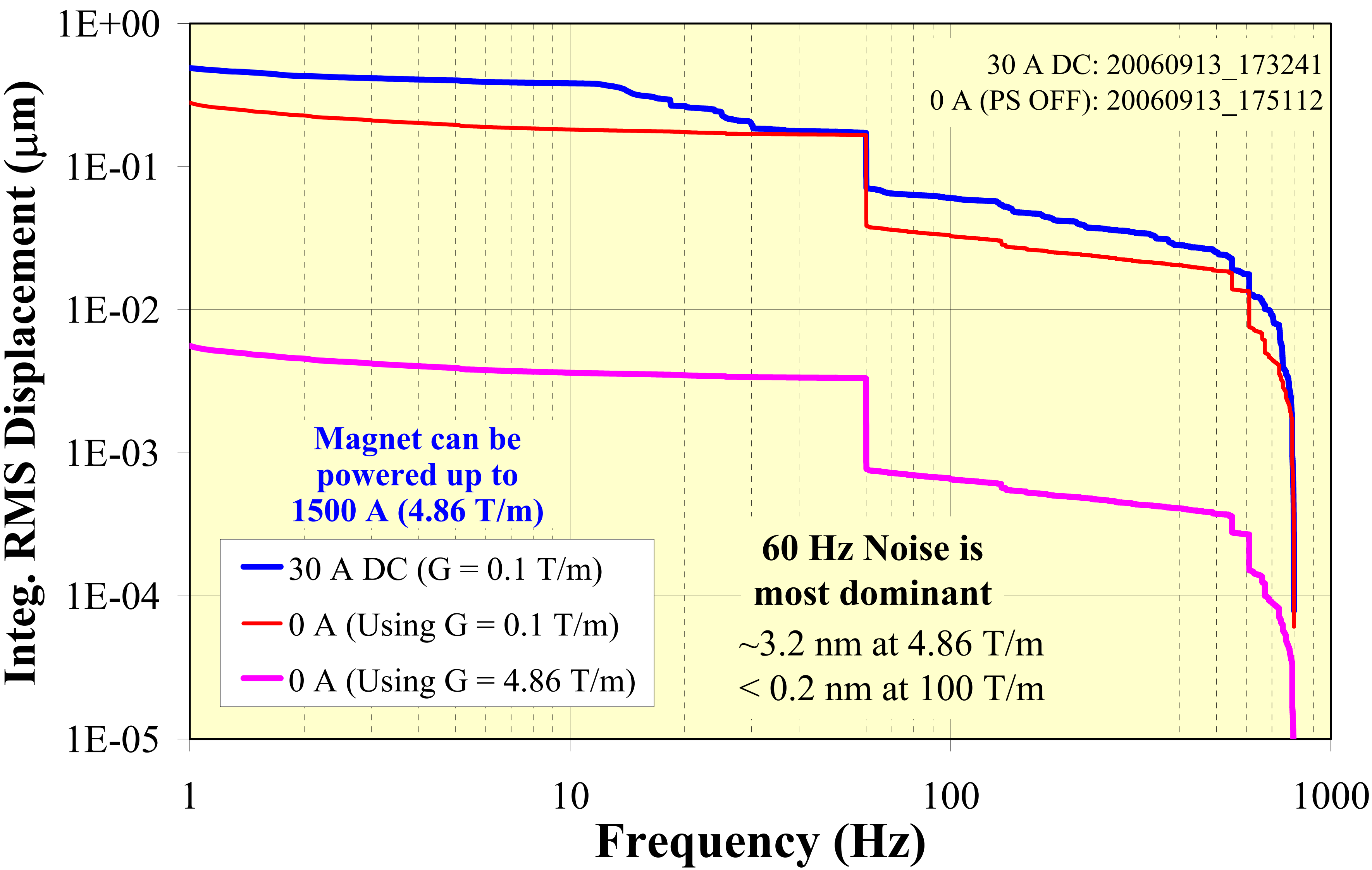
Current and Pick Up Coil Spectra in Cal. Quad



Pickup Coil Spectra in Calibration Quad (DC)



Pickup Coil Spectra in Calibration Quad (DC)



Summary

- Reliability of retroreflector on cold surfaces is a concern for vibration measurements of cold masses using the laser system. This issue needs to be addressed.
- Results of the first ever tests of the pick up coil to measure quadrupole field center motion are quite encouraging.
- AC excitation can be used to accurately align the probe, easing the requirements on power supply ripple.
- *Noise* levels are ~5 nm RMS integrated above 1 Hz, based on a gradient of only ~5 T/m.
- Further work requires stabilizing the coil and a better alignment stage.
- Resolution of ~1 nm above a few Hz can be easily achieved at gradients of interest for ILC, limited only by the ability to stabilize the probe.