Alignment and Stability of the Storage Ring Magnets

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On Behalf of the NSLS-II ME Group

Acknowledgement

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Outline

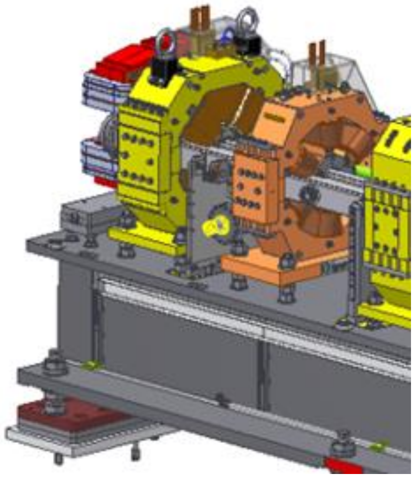
- Alignment and stability topics
  - Alignment and stability requirements
  - Site conditions
  - NSLS-II support system design
  - Support system performance
- Lesson learned
  - Site selection
  - Laser-tracker alignment
  - Girders' long-term gravity sag and creep
- A girder-free magnet support system

SR Magnets Alignment & Stability Requirements

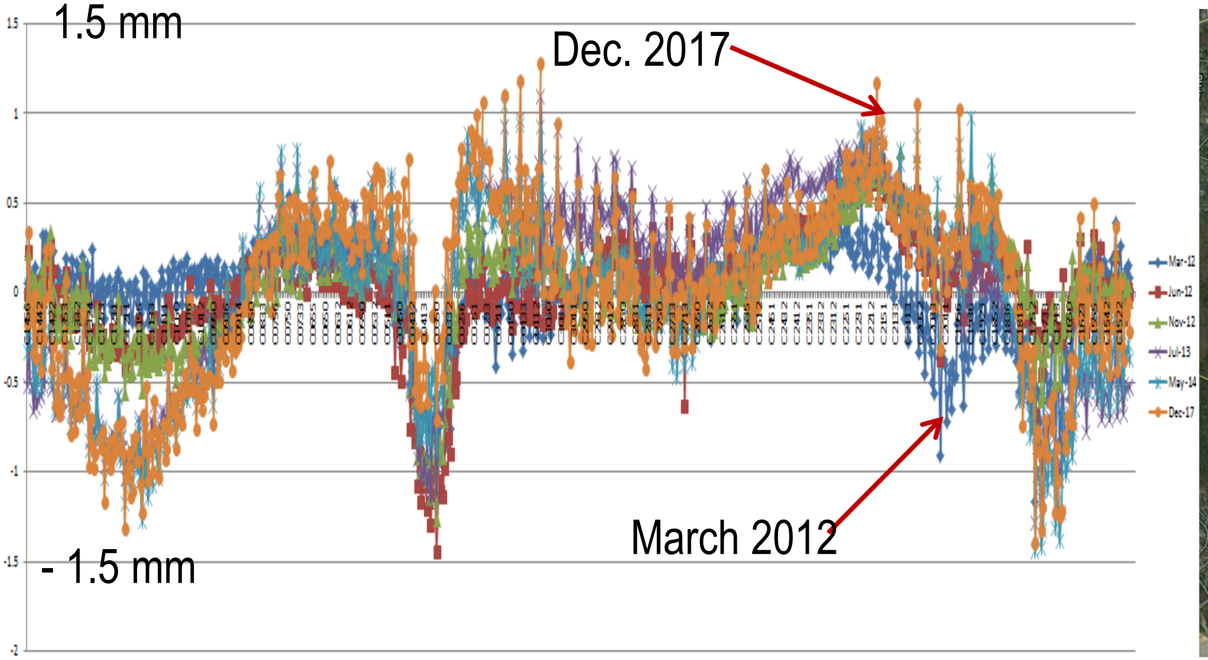
Alignment Requirements	ΔX RMS (μm)	ΔY RMS (μm)	Roll (mrad)
Magnet-to-Magnet Alignment	< 30	< 30	< 0.2
Girder-to-Girder Alignment	< 100	< 100	< 0.2
BPM Stands	< 100	< 100	< 2.0

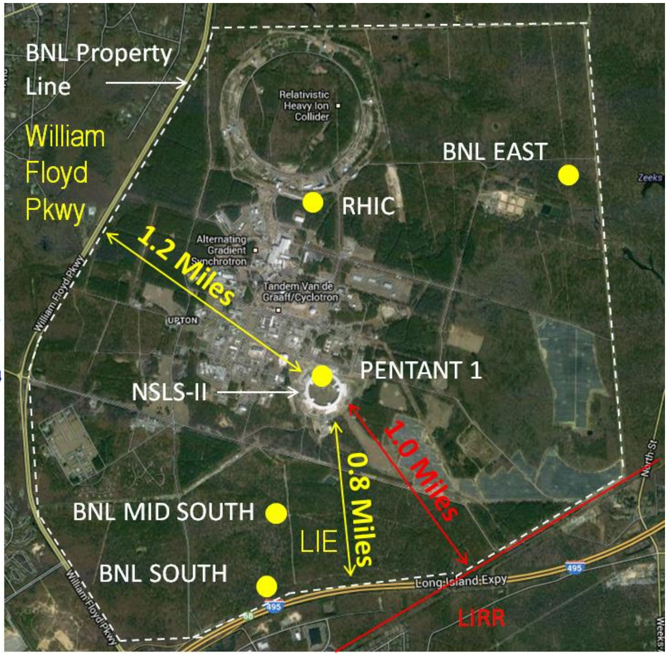
Stability Requirements*	ΔX RMS (nm)	ΔY RMS (nm)
Magnets (uncorrelated)	< 150	< 25
Girders (uncorrelated)	< 600	< 70

* The requirements apply to both vibrational and thermal stability.



NSLS-II Site



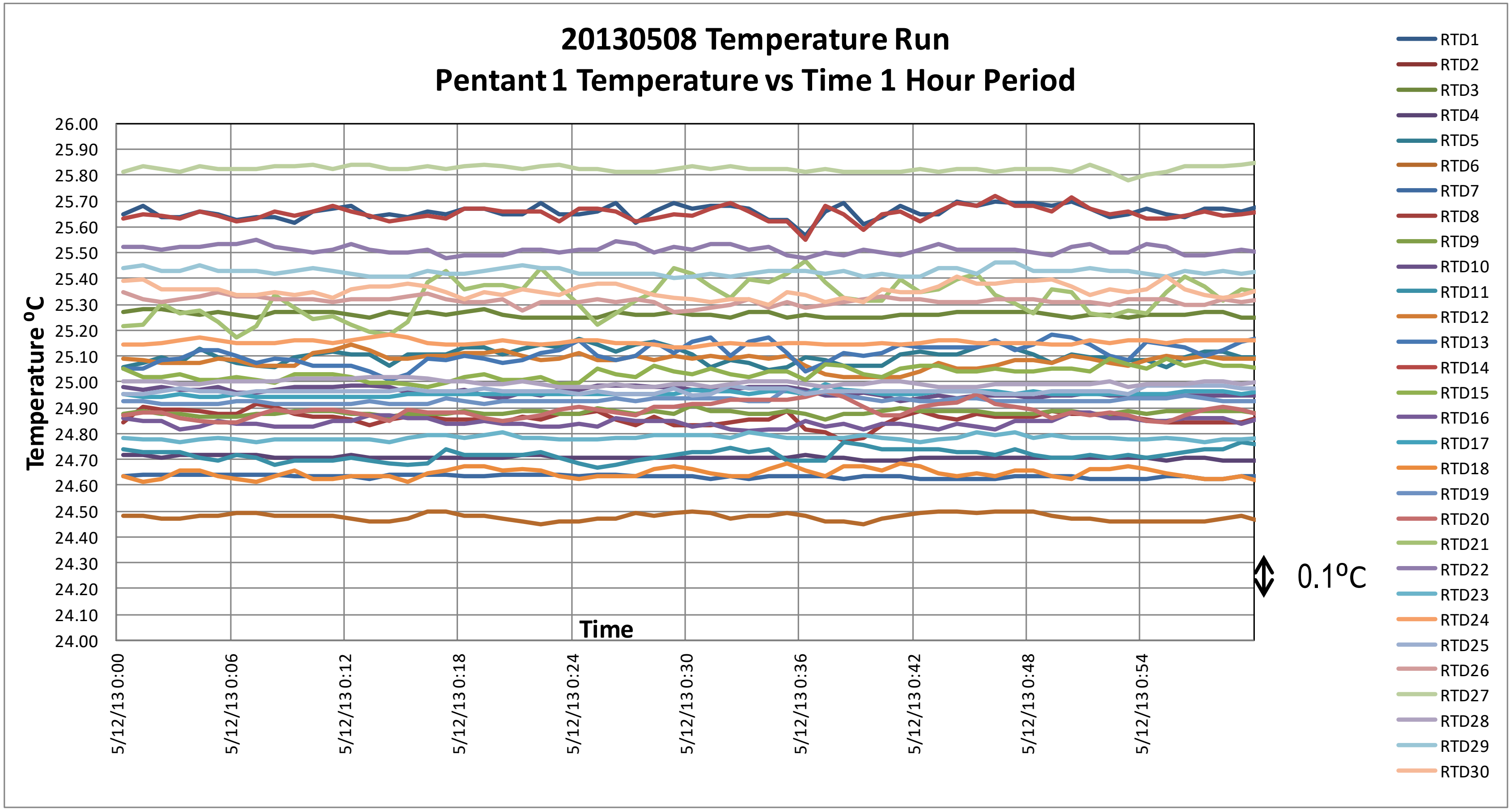


C. Yu et al., 2017

SR Floor Settlement

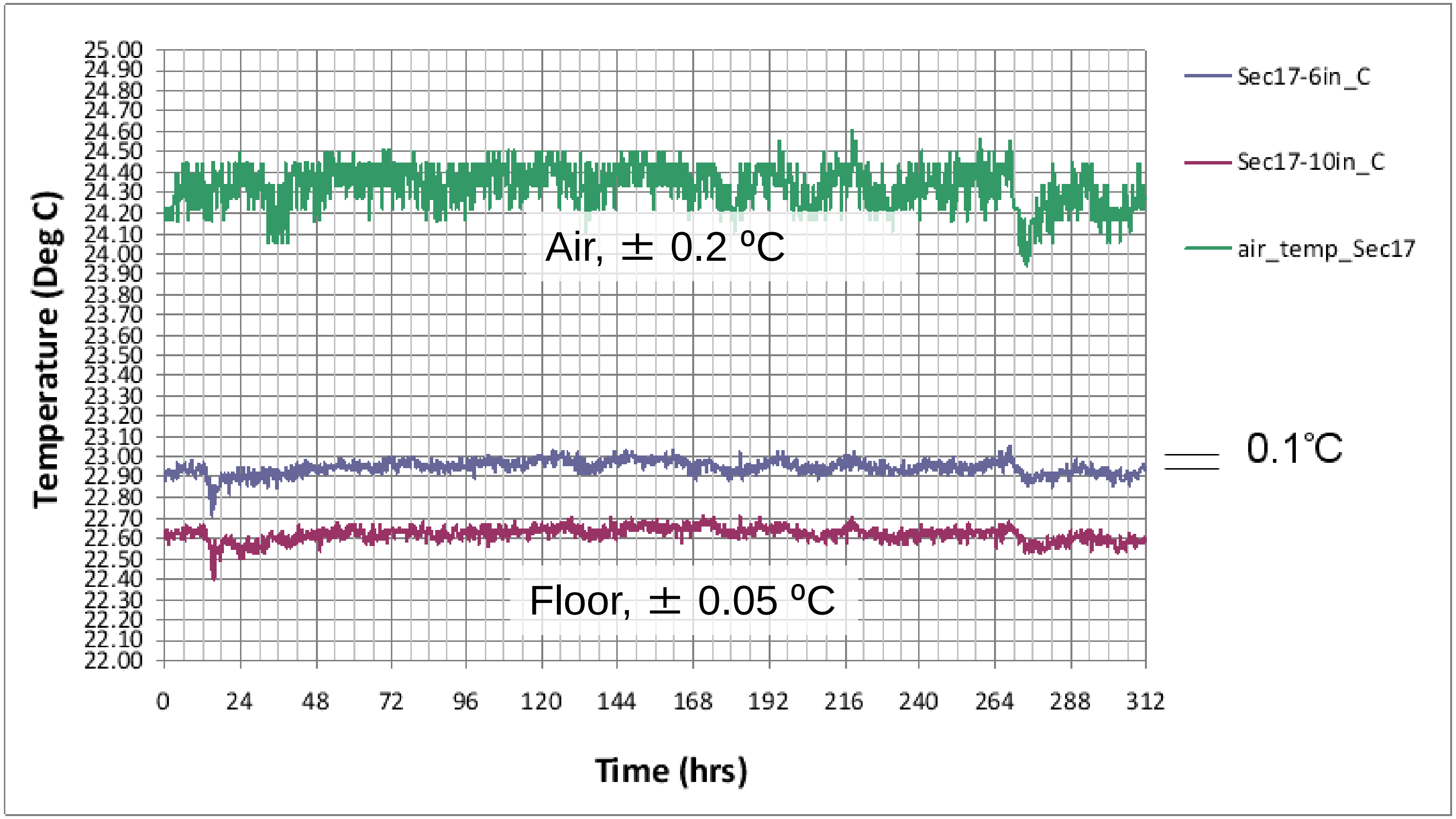
The NSLS-II site and SR floor are quite stable. The site is specified as “Stiff Soil Profile” by NY State Building Code.

Temperature Stability in Pentant 1



NSLS-II tunnel air meets the temperature specifications (± 0.1 °C) by a factor of ~ 2.

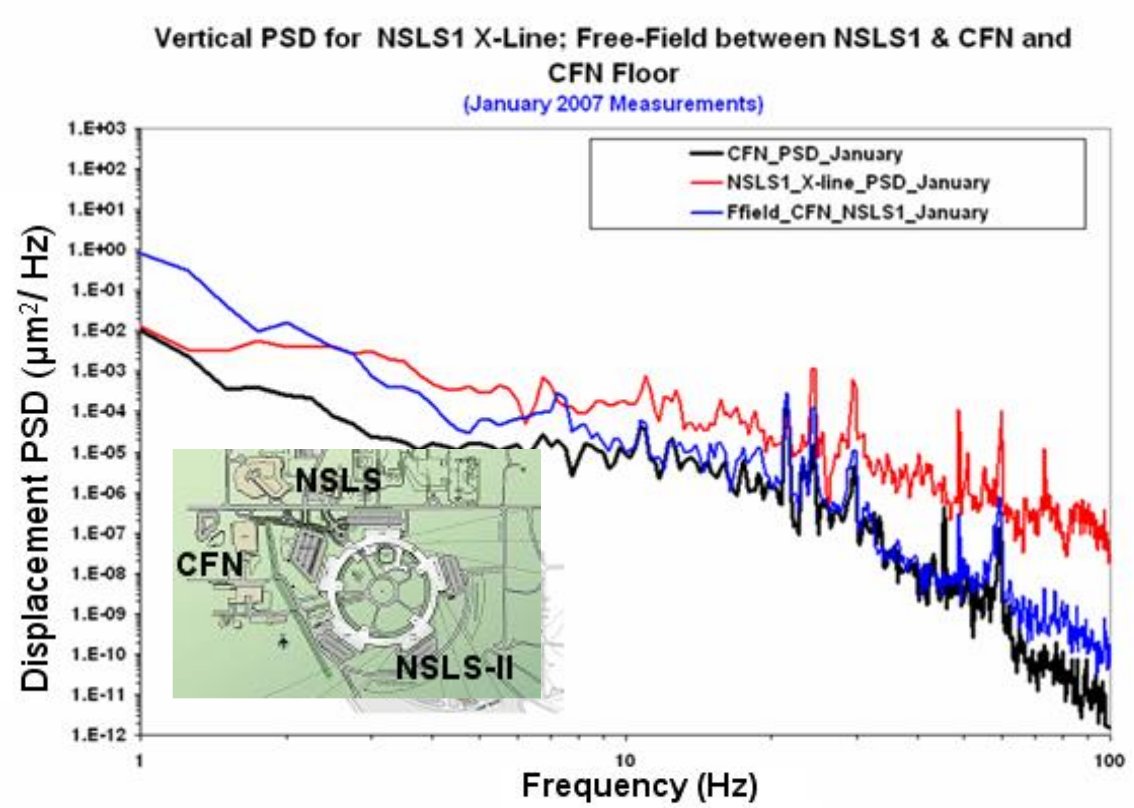
Temperature Stability of the Floor



APS, Sector 17
August 2009

The floor temperature is expected to be stable to within ± 0.05 ºC.

Ambient Ground Motion



RMS Displacements at CFN
(N. Simos, 2007)

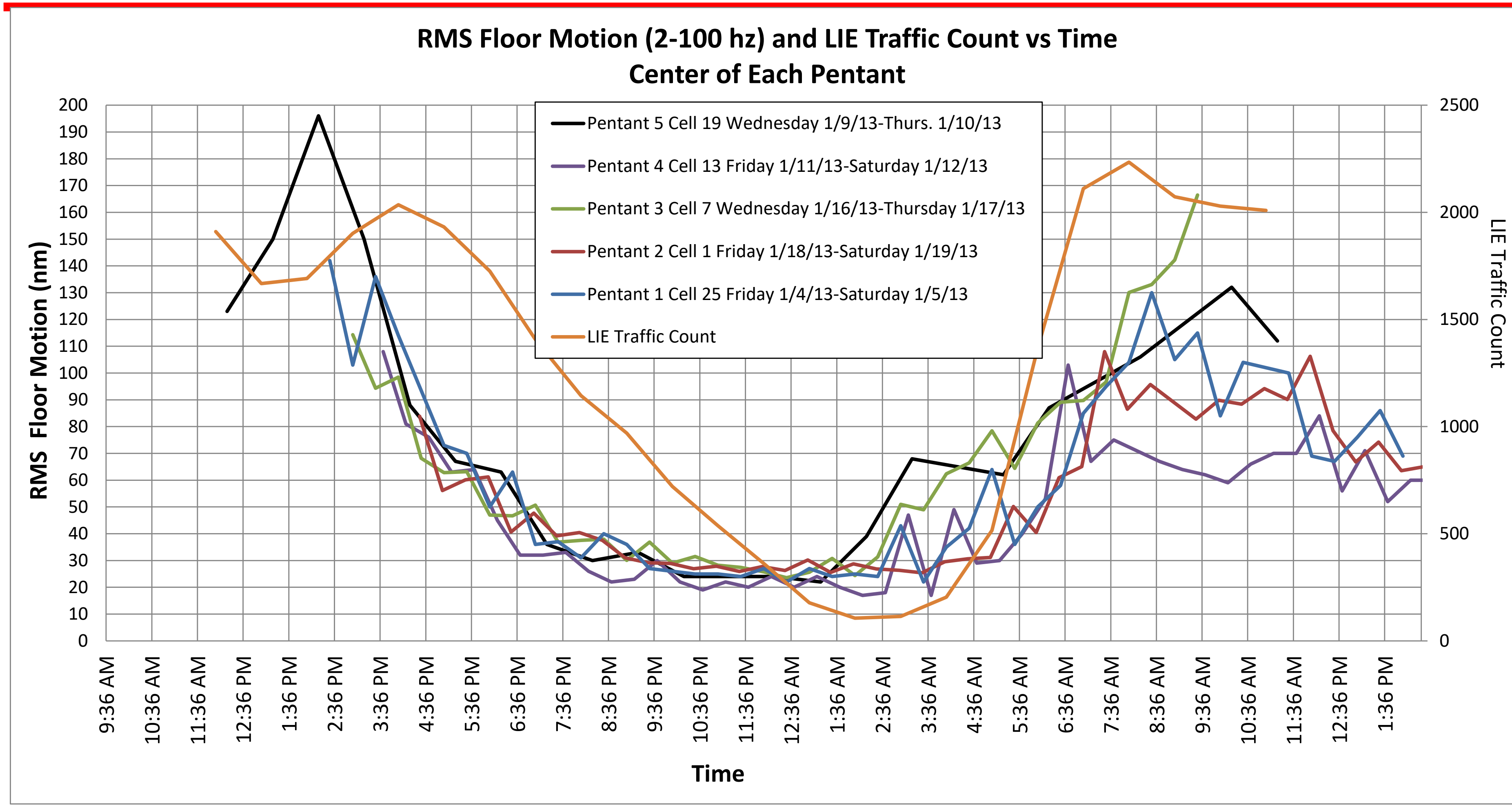
(0.5 - 4) Hz : 145 nm

(4 - 30) Hz : 14 nm

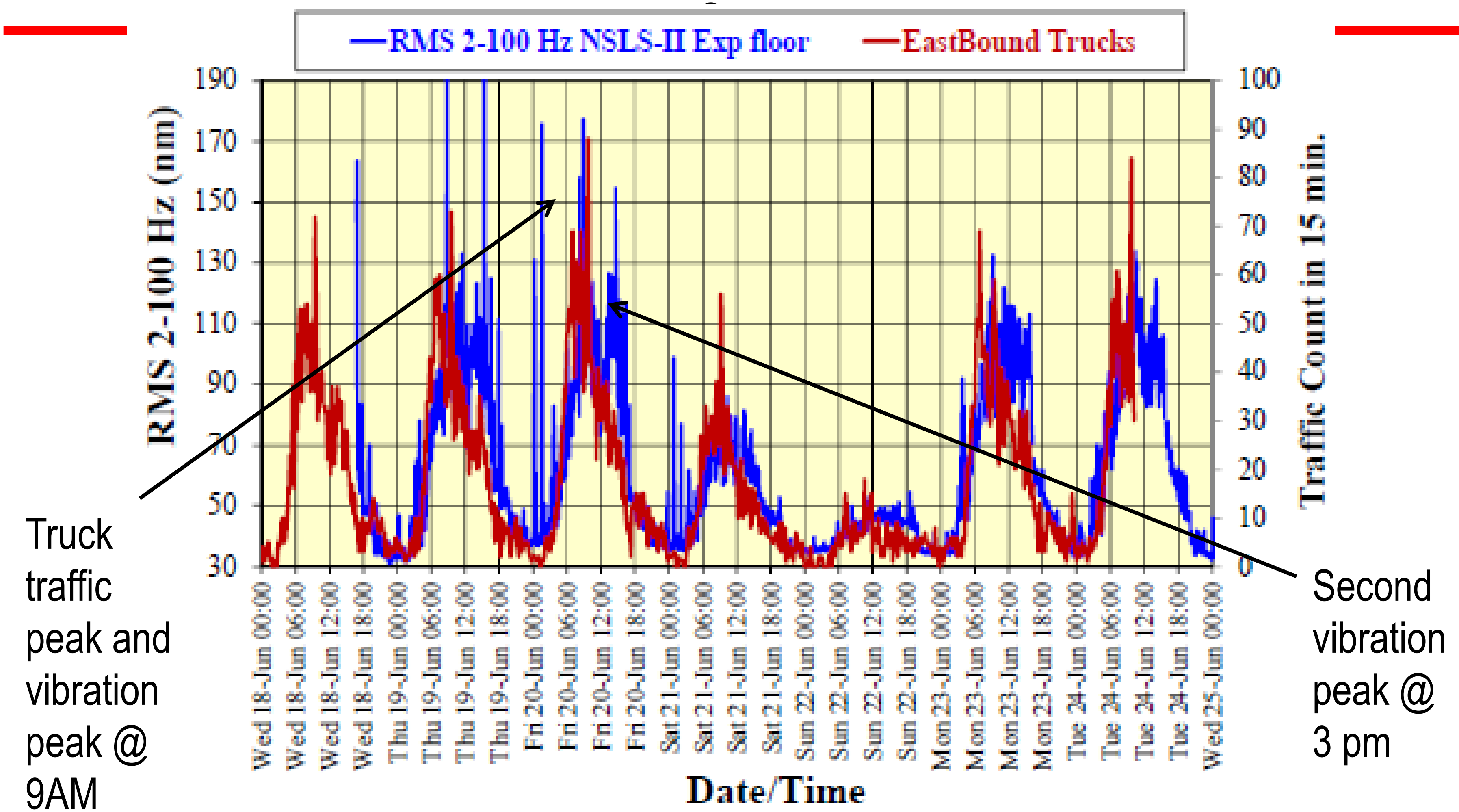
(30 - 100) Hz : 1 nm

No correlation measurements were done, but the ambient floor motion below 4 Hz was assumed to be correlated for < 25 m.

NSLS-II Vibration Studies LIE Traffic



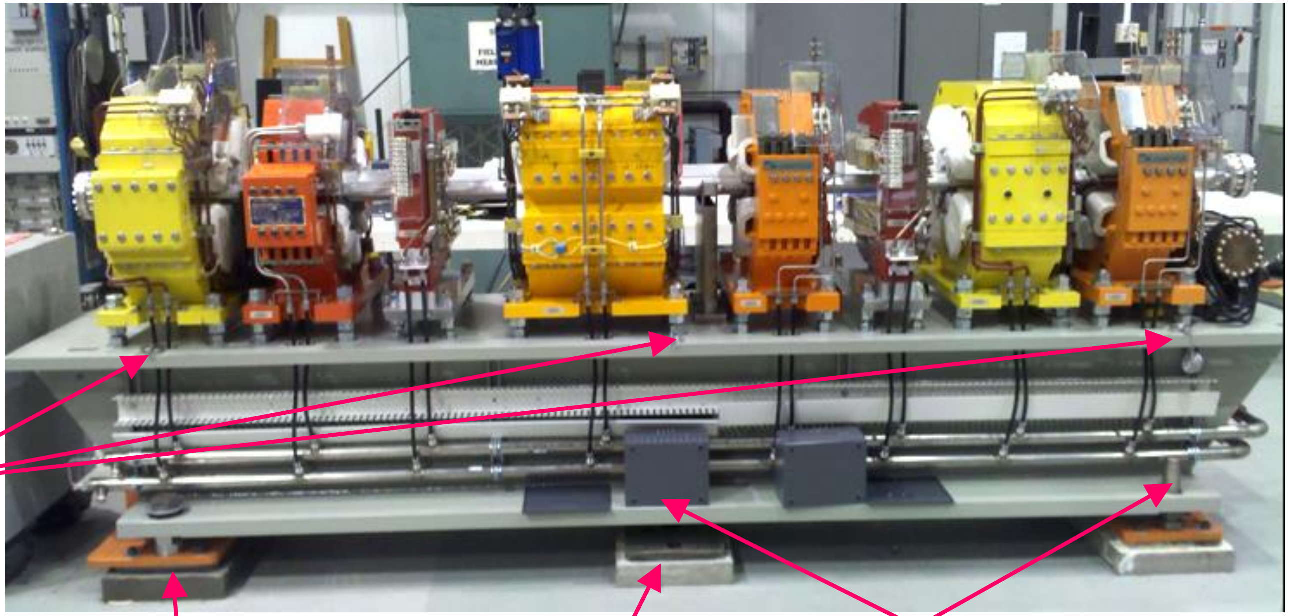
Exper. Floor Vibration Levels vs LIE Eastbound Truck



The eastbound truck traffic shows a peak in the morning consistent with the vibration pattern.

NSLS-II Support System Design

Profiling Fiducials

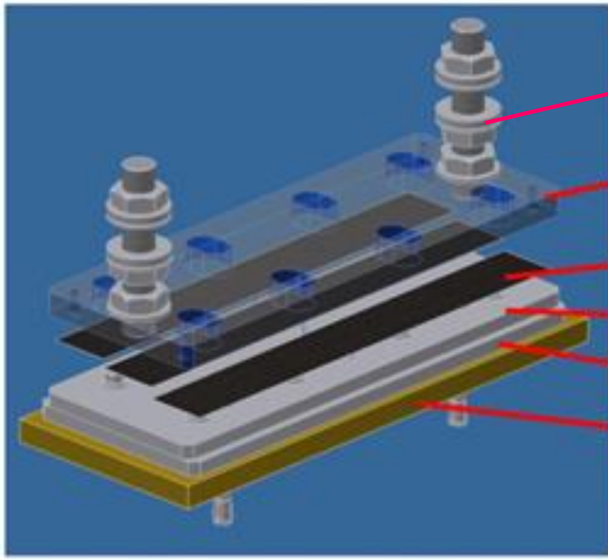


Viscoelastic Pad Fixed Support Alignment Studs

The support design was based on the assumption that the girders' profiles will change (because of sag and creep) from the alignment room to the SR tunnel

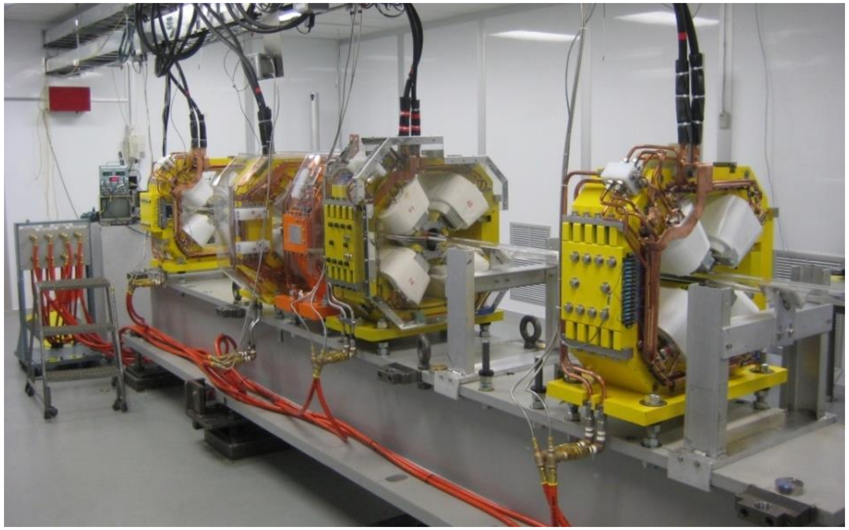
- Multiple support points
- Girder profiling
- Viscoelastic pads for thermal stability

Viscoelastic Pads

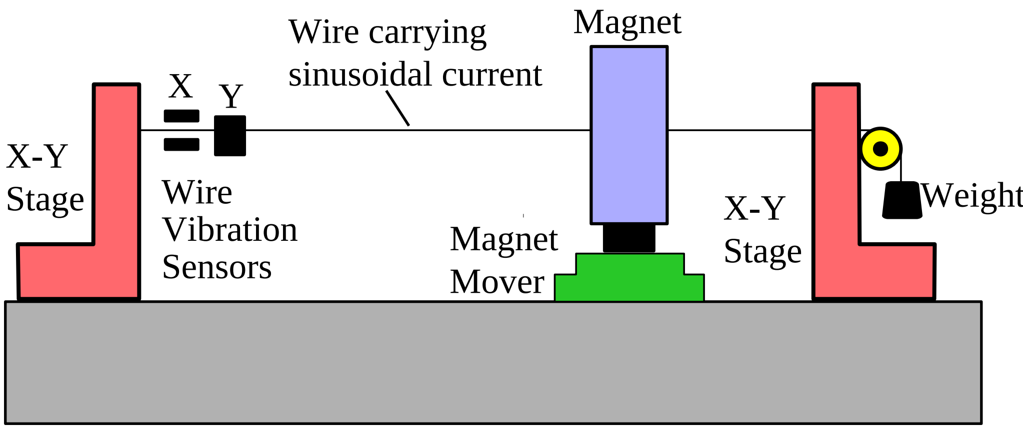


The viscoelastic films allow top plate to move relative to the bottom plate freely at slow time cycles (< 0.1 Hz). This allows the girders to expand or contract without bending for any change in the tunnel air or floor temperatures.

Magnet Alignment



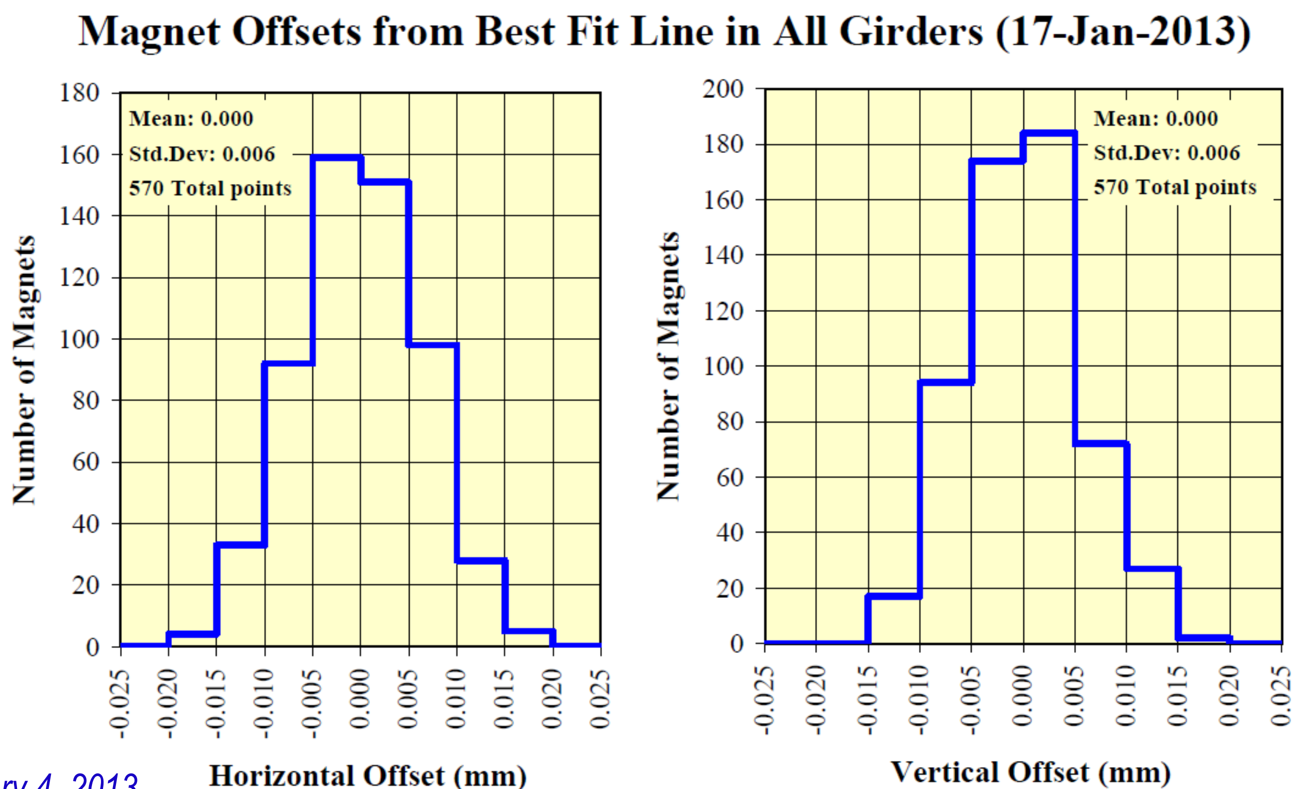
Temperature-Controlled Alignment Room (± 0.05 ° C)



A. Jain, LER2010

- Initially (in 2006) it was assumed that 30 µm level magnet alignment was not possible using only laser trackers.
- The magnets were aligned by the vibrating wire method. In this method a magnet is aligned by minimizing the vibration amplitude of a stretched wire carrying AC current and passing through the center of the magnet.

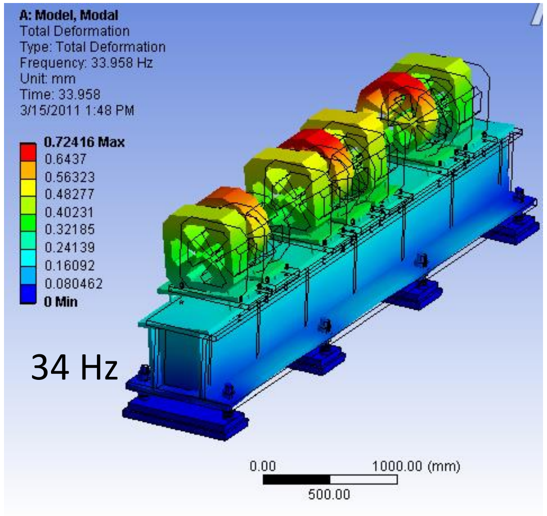
Statistics of the Magnet Alignment Data

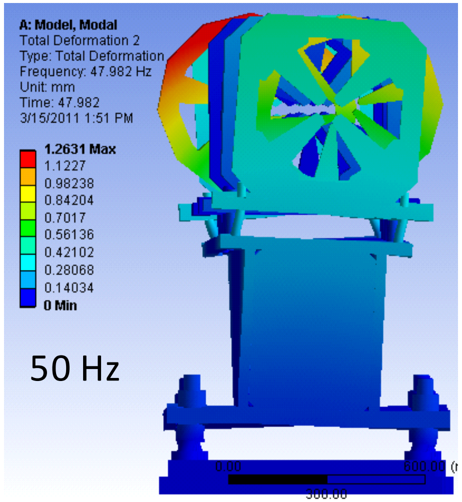


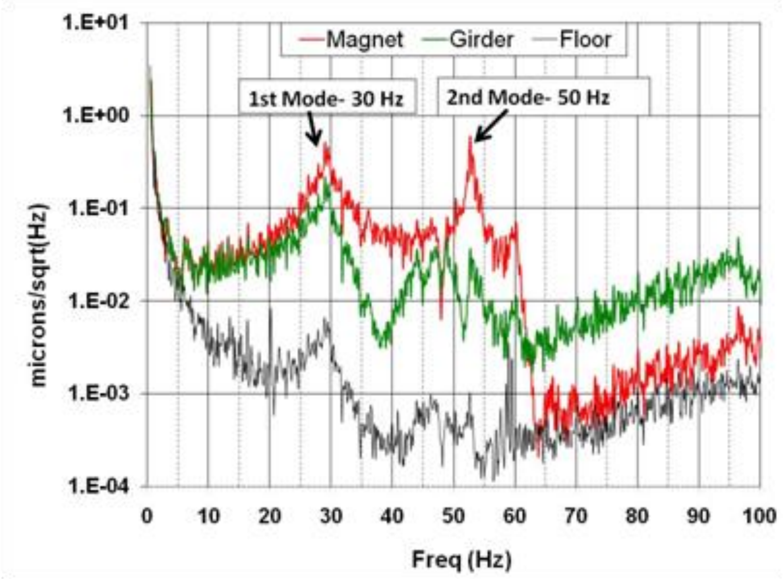
A. Jain, February 4, 2013

All multipole magnets were aligned to within ~ ± 15 µm, well within the specification of ± 30 µm.

Natural Frequencies and Mode Shapes







Modal Analysis

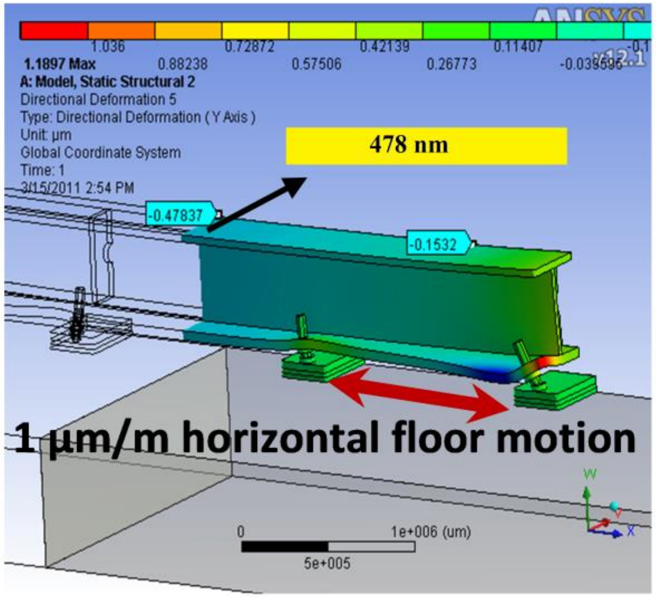
Test Data

- Lowest Natural Frequencies: 30 Hz (rocking), 50 Hz (torsion)
- Integrated (2-100 Hz) Values*:

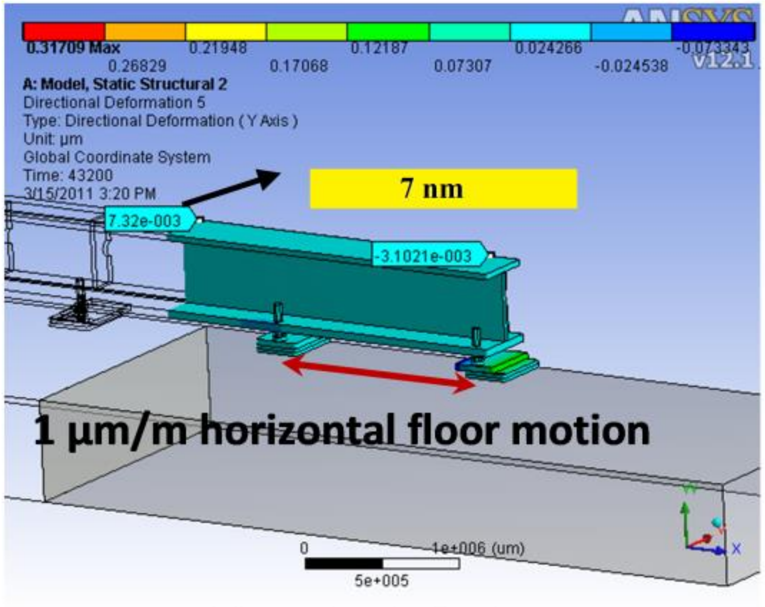
Amplification (floor to magnet): (X: 1.39, Y: 1.18)
Relative motion: Magnet-to-Magnet (ΔX = 5.2 nm, ΔY = 7.9 nm)

** Spataro 10/8/2013*

Floor Expansion – Fixed Supports versus Viscoelastic Pads



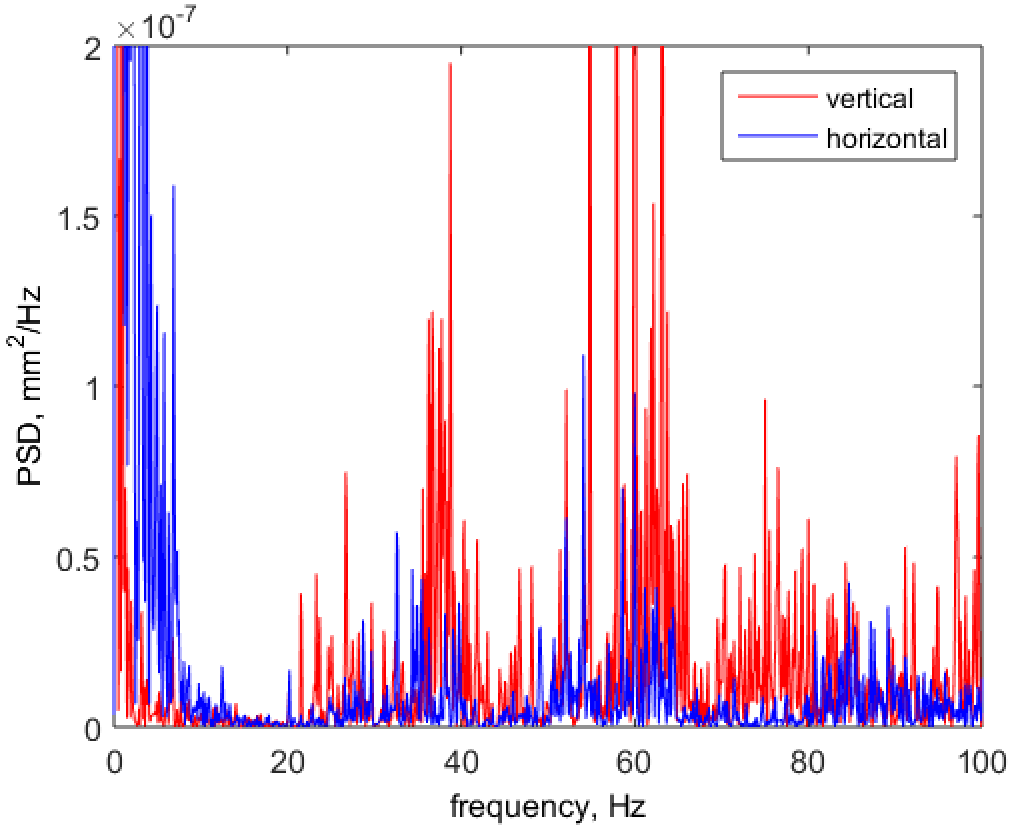
Fixed Supports



Viscoelastic Pads

- A diurnal floor expansion/contraction of ~ 1µm/m is expected.
- Bending deformations in the girder are up to 478 nm with the fixed supports, but only 7 nm with the viscoelastic pads.

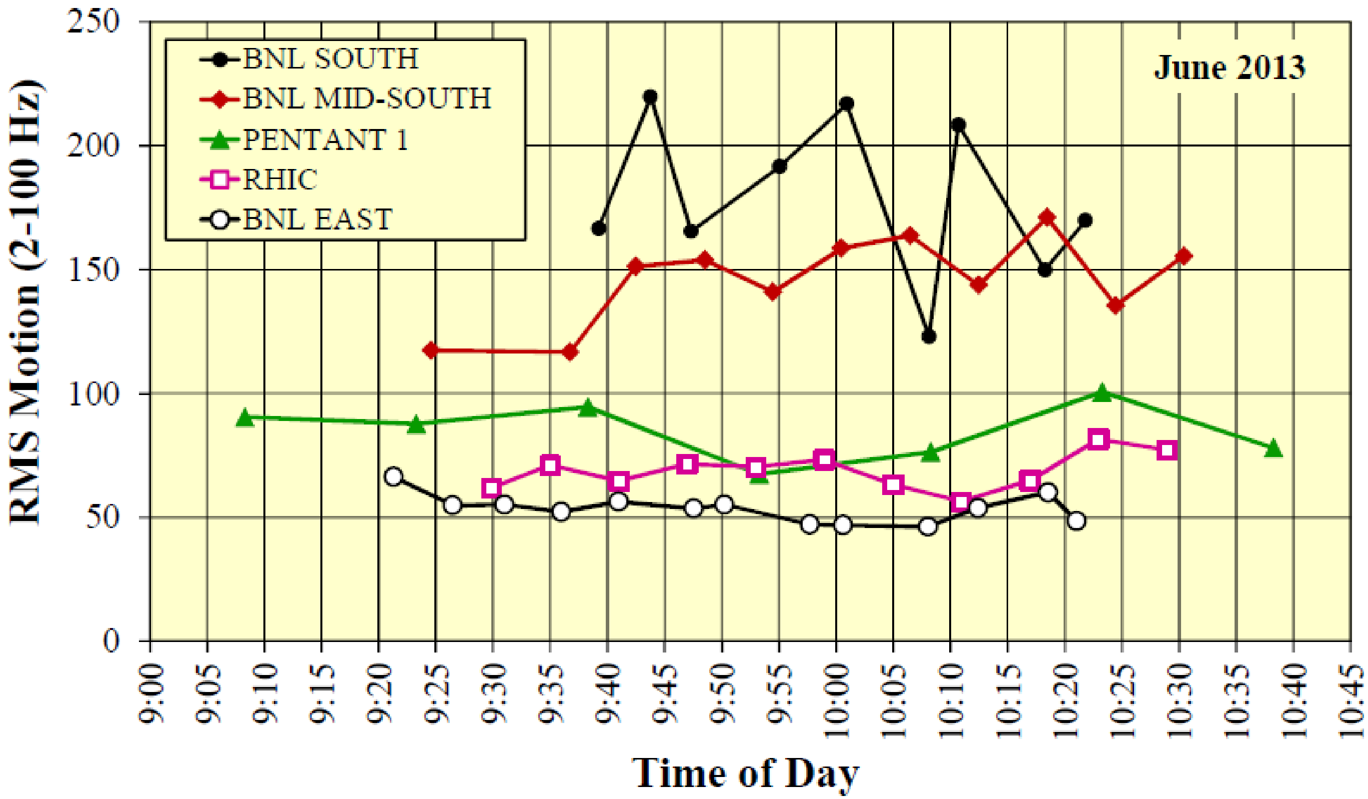
PSD of Beam Motion



B. Podobedov (2017)

BPM (C02BPM6) data with active orbit feedback off. Integrated beam motion (37- 43 Hz) is ~ 100 nm vertical and ~ 10 nm horizontal.

Lesson Learned: Site Vibration Levels



C. Spataro
Eng. Seminar (2016)

The vibration amplitude and short term time variation decreased with increasing distance from the LIE. The BNL east location were found to have the lowest vibration level.

Laser Tracker Alignment

Rough alignment accuracy for all NSLS-II multipole magnets. The specification for rough alignment was ± 200 μm.

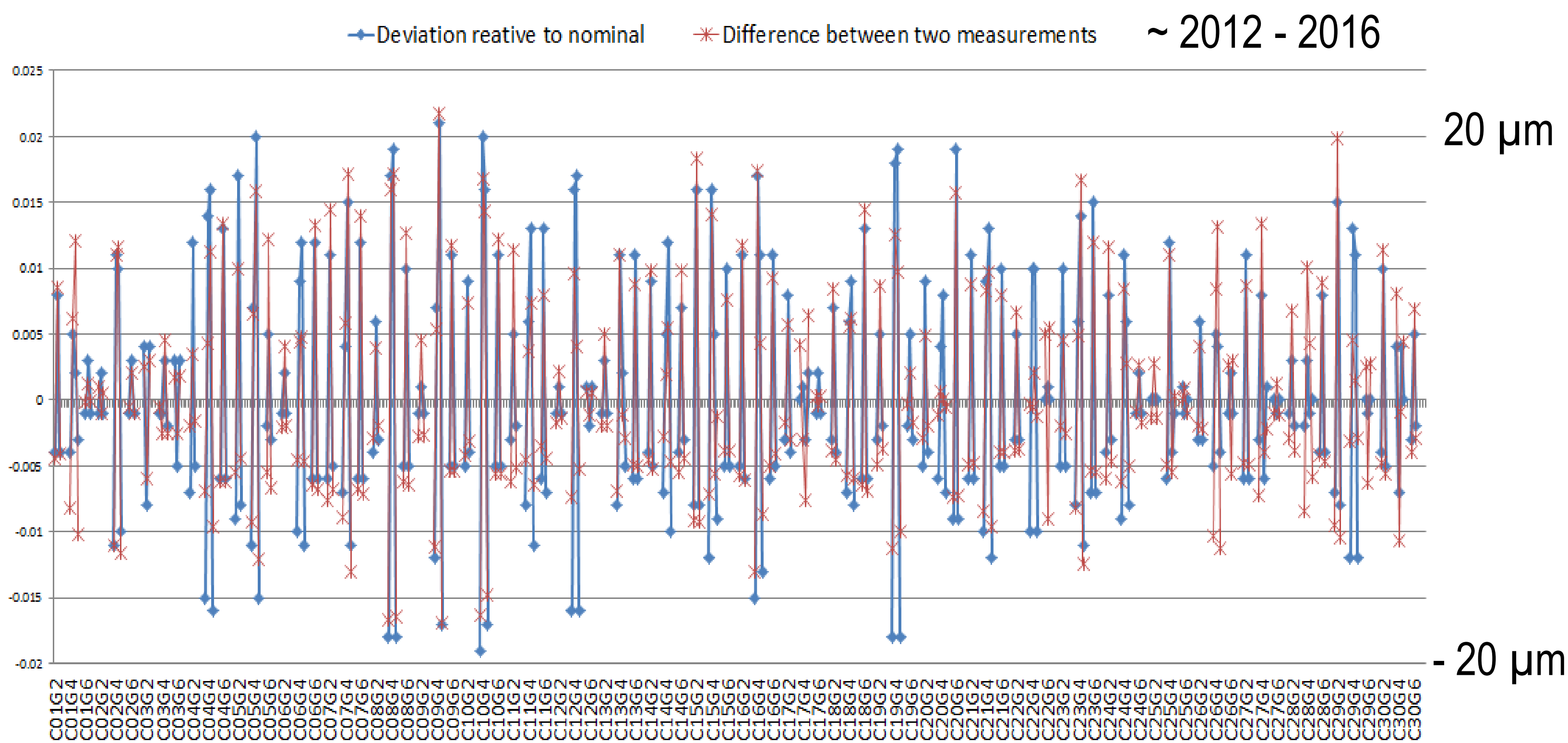
	RMS (μm)		Stand. Deviation (μm)	
	dX	dY	dX	dY
Average	42	33	46	36
Maximum	130	77		
Minimum	11	5		

S. Seiler, Tech Note 120 (2013)

- The table above shows the difference between the rough-aligned and precision-aligned positions of the magnets. The rough alignment was done with a single laser-tracker set up in an assembly area where the air temperature changed by ~ ± 2 ^{o}C.
- Girder profiling in the tunnel was achieved within ~ ± 10 μm.

Girder Profile Change

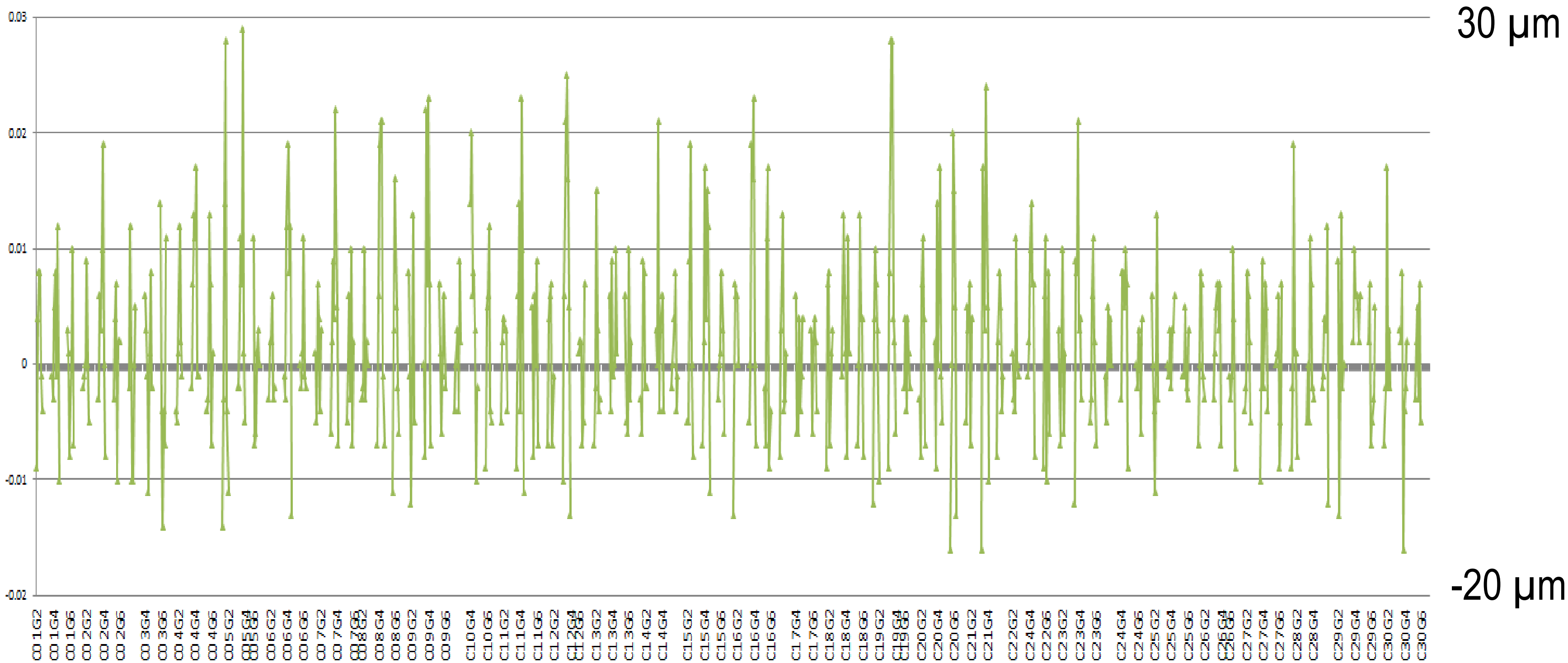
All girders are undergoing long-term gravity sag and stress relaxation.



C. Yu, et al, "NSLS-II Epoch 8 Survey Report," (2016)

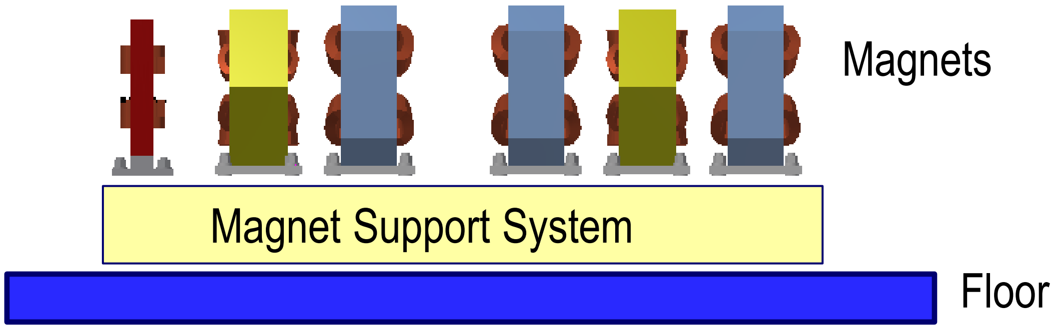
Magnet-Center Alignment

C. Yu, et al, “NSLS-II Epoch 8 Survey Report,” (2016)



The SR magnets were within the alignment specifications (± 30 µm) in 2016.

Girder-Free Magnet Support System



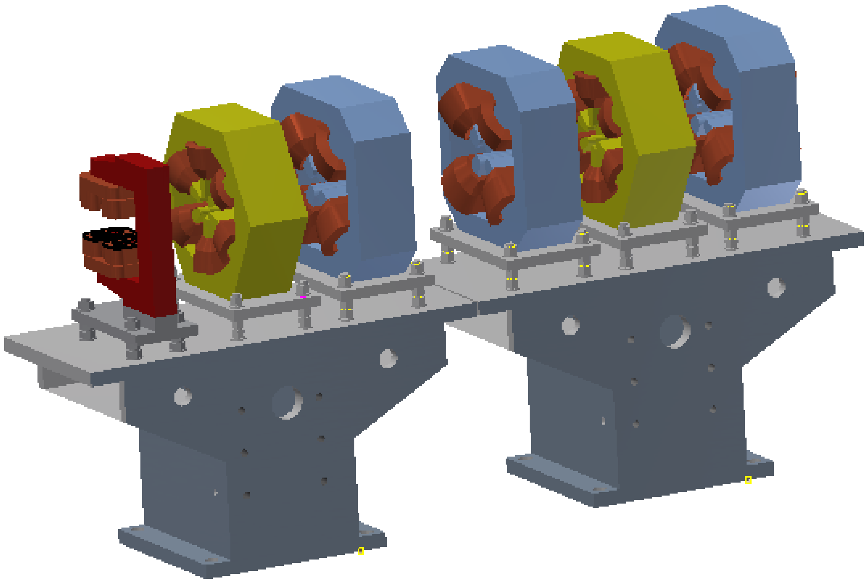
The storage ring floor itself is ideal for both alignment and stability:

- Alignment: Long term settlement does not affect magnet-to-magnet or girder-to-girder alignment.
- Relative ambient motion (vibration) over 10 m length is small (< 5 nm).
- Floor temperature stability over 24 hours (~ $\pm$ 0.05º C) is comparable to the tunnel air-temperature stability (~ $\pm$0.1º C)

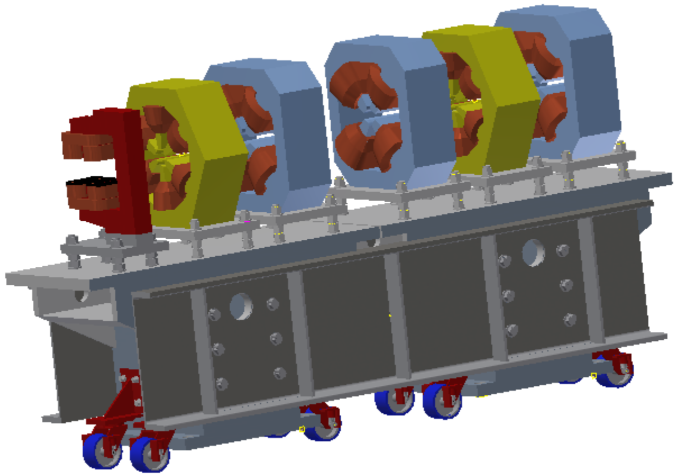
A support system should basically raise the floor height. A girder does that but introduces alignment and stability issues. This is because the primary deformation mode in a girder is bending as opposed to compression in a column or plinth.

Hammerhead Column Supports

S. Sharma, MEDSI2016



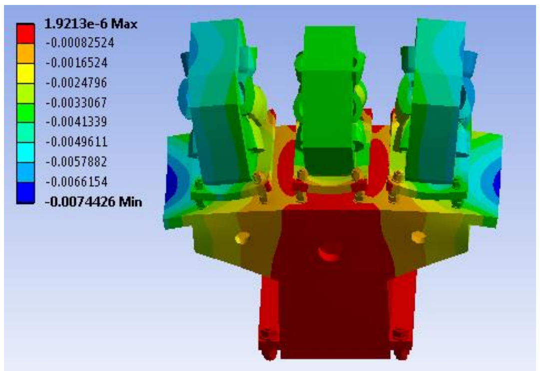
Assembly



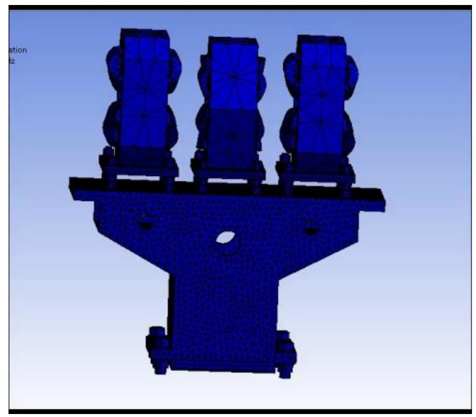
Transportation

- Assemble magnets, vacuum chambers and other components on 2 hammerhead supports each of ~ 1.5 meter length.
- Align the magnets and vacuum chamber. Magnet alignment is simpler because of shorter span.
- Join the supports with two removable C-Channel beams for transportation and installation.

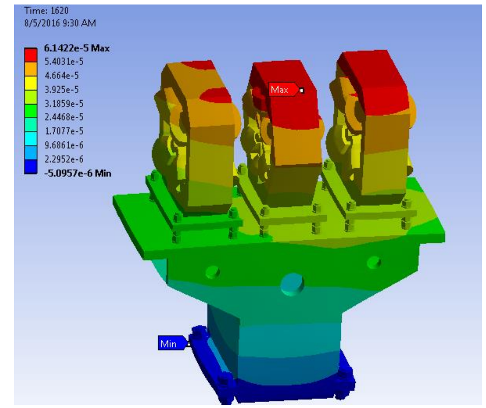
FE Analysis of a Hammerhead Support



Relative gravity deflection: 5 µm



Transverse mode natural frequency: > 100 Hz

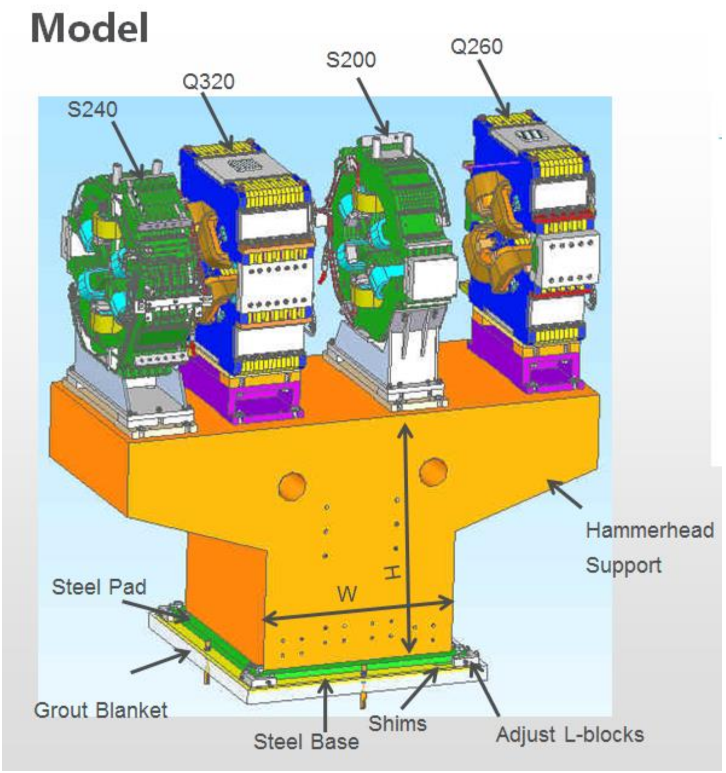


Thermal Stability: 7 nm

- A hammerhead support can easily meet all alignment and stability criteria.
- The support will have negligible long-term sag or creep deformation.

Hammerhead Magnet Support System

Hammerhead supports are being considered for DLSR (Hefei) and SuperB Cell at SSRF-II.

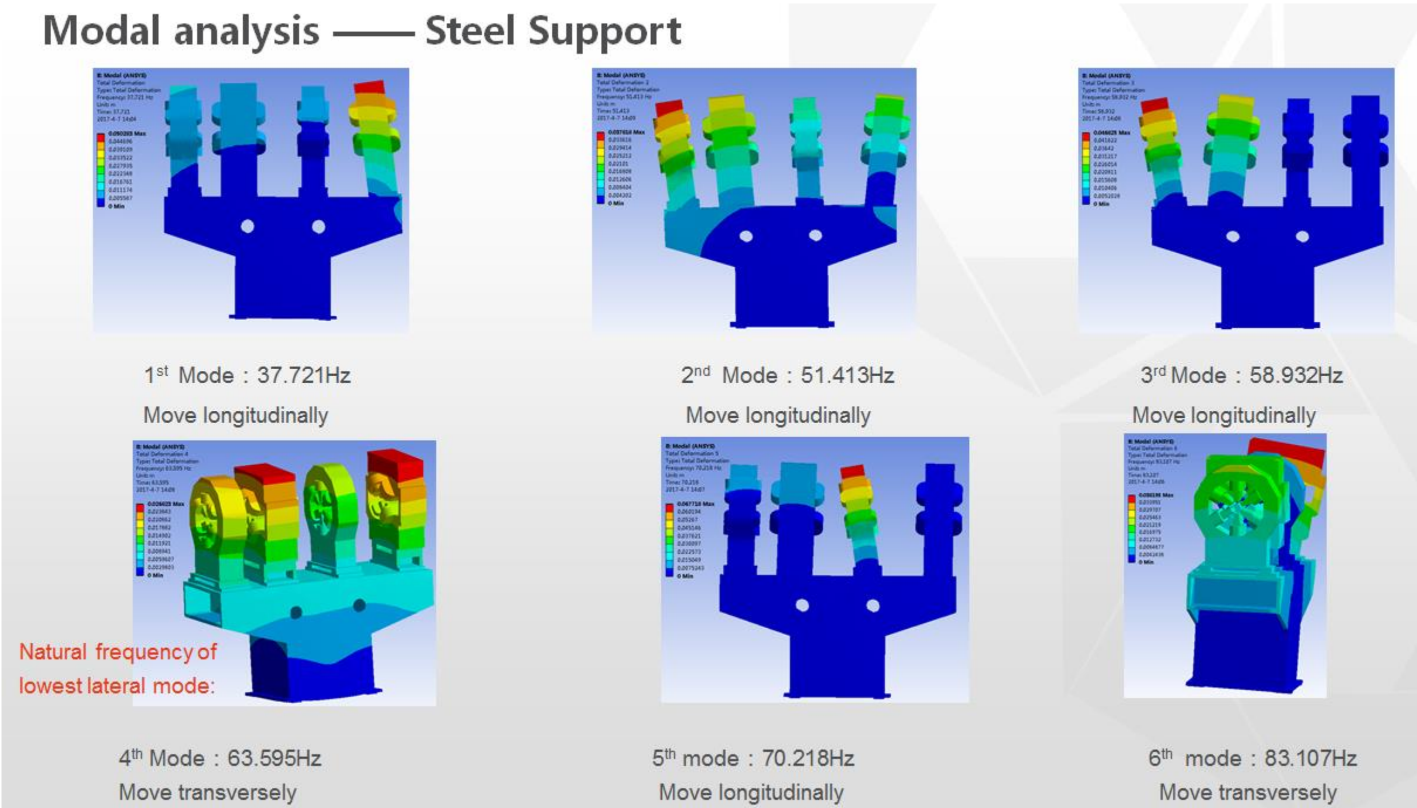


Courtesy, R. Deng , SSRF, (2017)

Hammerhead Support of DLSR:

- **Dimensions:**
  - **H=1000mm;**
  - **W=800mm**
- **Material:**
  - **Granite**
  - **Welded Steel**
- **Shims are included in the model for the consideration of easy adjustment of height in practice.**

Model Analysis of DLSR (Hefei) Hammerhead Support



Courtesy, R. Deng , SSRF, (2017)

Conclusions

- The NSLS-II storage ring magnets are meeting all alignment and stability specifications due in part to a stiff support-system design with viscoelastic pads.
- The girders are undergoing long-term sag and creep deformations leading to magnet-to-magnet misalignments reaching close to their specifications.
- A simple hammerhead support-system is proposed for high brightness storage rings that can easily meets all alignment and stability specifications over long durations.