Experience with Hydrostatic Levelling Systems at Diamond

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Diamond Light Source

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Talk Outline

Diamond Ground Stability

specifications
site geology
building solution

Hydrostatic Levelling System

Installation Along a Beamline

impact of 29 T crane
long term settlement

Installation in Storage Ring Tunnel

long term settlement
short term settlement

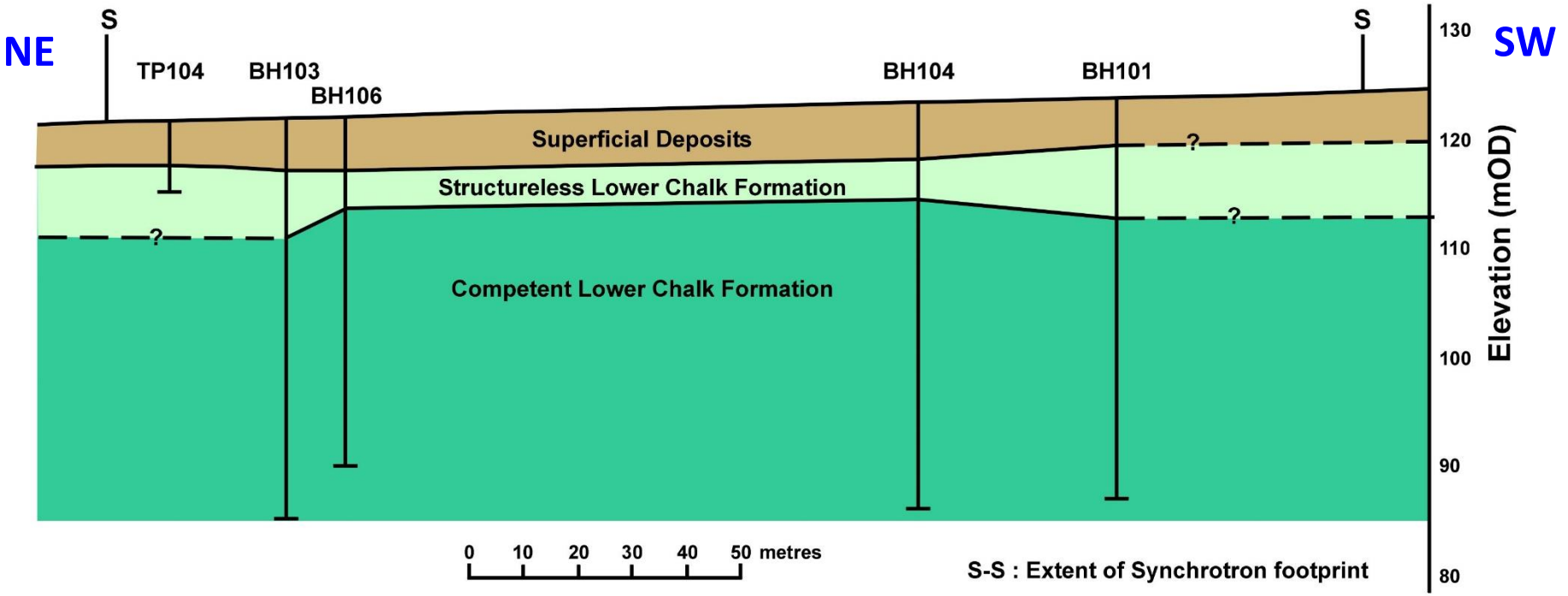
Conclusions

Diamond Floor Stability Specification

- Stability of floor slab key parameter for successful operation of any light source
- Diamond building was designed to minimise short, medium and long term movements of the floor
- Hydrostatic Levelling System (HLS) installed in 2008 in order to monitor the achieved performance

Load Condition	**Target Performance**
5kN applied load	6 micron deflection under the load and 1 micron 2 metres away
Short term settlement	1 micron over 10 metres per hour
Medium term settlement	10 micron over 10 metres per day
Long term settlement	100 micron over 10 metres per year for the Storage Ring and 250 micron over 10 metres per year for the Experimental Hall

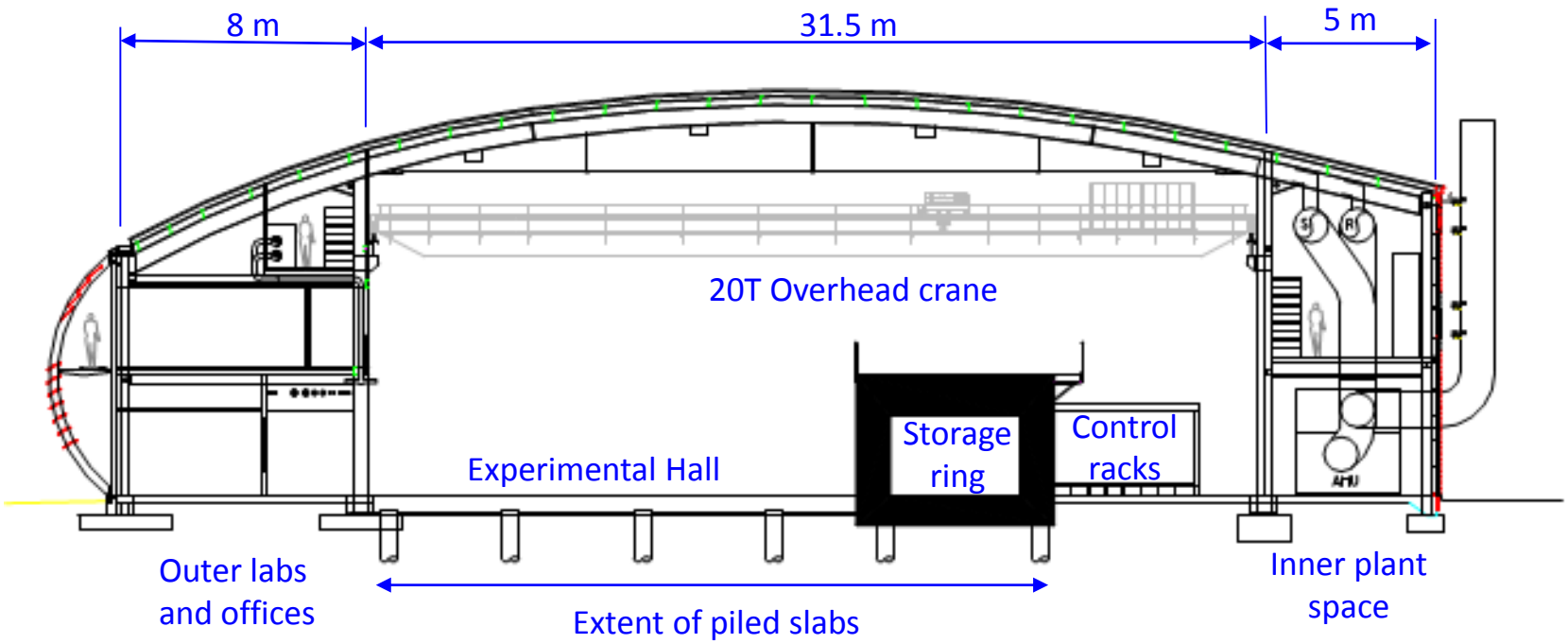
Site Geology



NE-SW Geological cross-section interpreted through the centre of the Synchrotron (based on Norwest Holst Engineering Ltd., 2001)

- **Chalk strata**, stretching to a depth of ~65 m
- Contains aquifer with **varying water table height** (between 12 m to 20 m below surface)
- Expected that **upper layer** of structure-less chalk would **swell and contract**, causing surface **height to change** (dominant factor)
- Anticipated some settlement, decreasing over time
- Some **local non-uniformities**: “soft-spot” in NE of site?

Building Solution

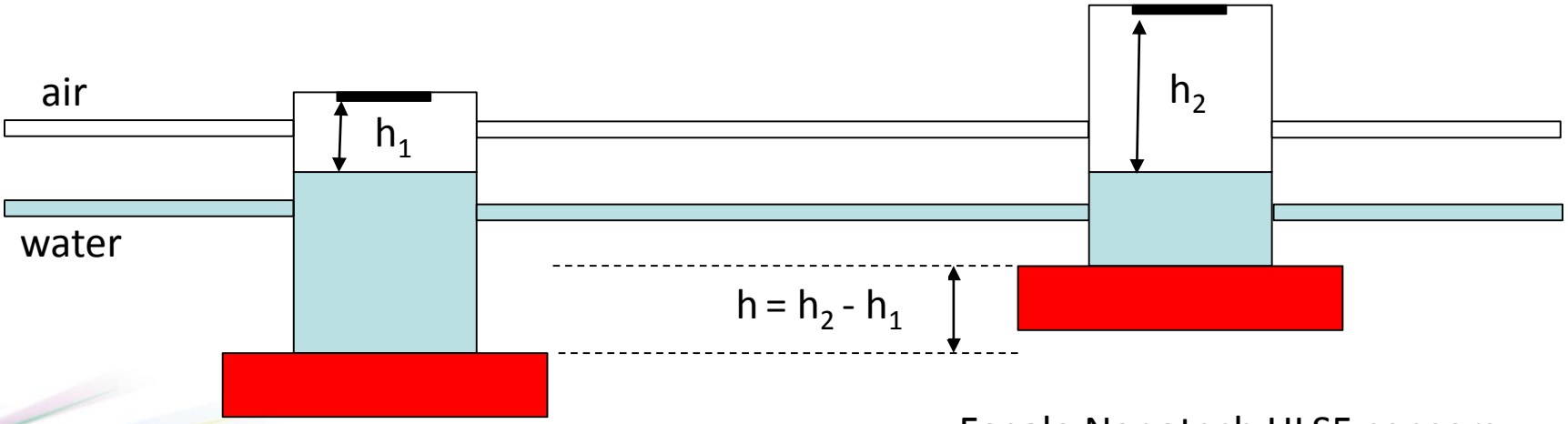


- Outer diameter = 235 m
- 96 columns mounted at inner and outer circumference on pad foundations
- SR tunnel 0.85 m thick, continuous concrete slab (no radial or circumferential joints)
- Experimental hall 0.6 m thick, continuous concrete slab (no radial or circumferential joints)
- Network of 0.6 mm diameter piles on 3 m grid, 12-15 m in depth
- 60 mm void under slabs to allow chalk soils to rise / fall with water table
- Offices, labs, workshops isolated from piled slab by 30 mm wide sealed construction joints

Hydrostatic Levelling System

HLS system

- Series of sensors connected by air/water-filled pipes providing relative elevation
- Each sensor measures capacitance, with the water surface and single electrode forming two plates
- Distance from surface of water extracted from measured voltage



Fogale Nanotech HLS5 sensors

Parameter	Value
Resolution	±0.2 µm
Uncertainty	±1.2 µm

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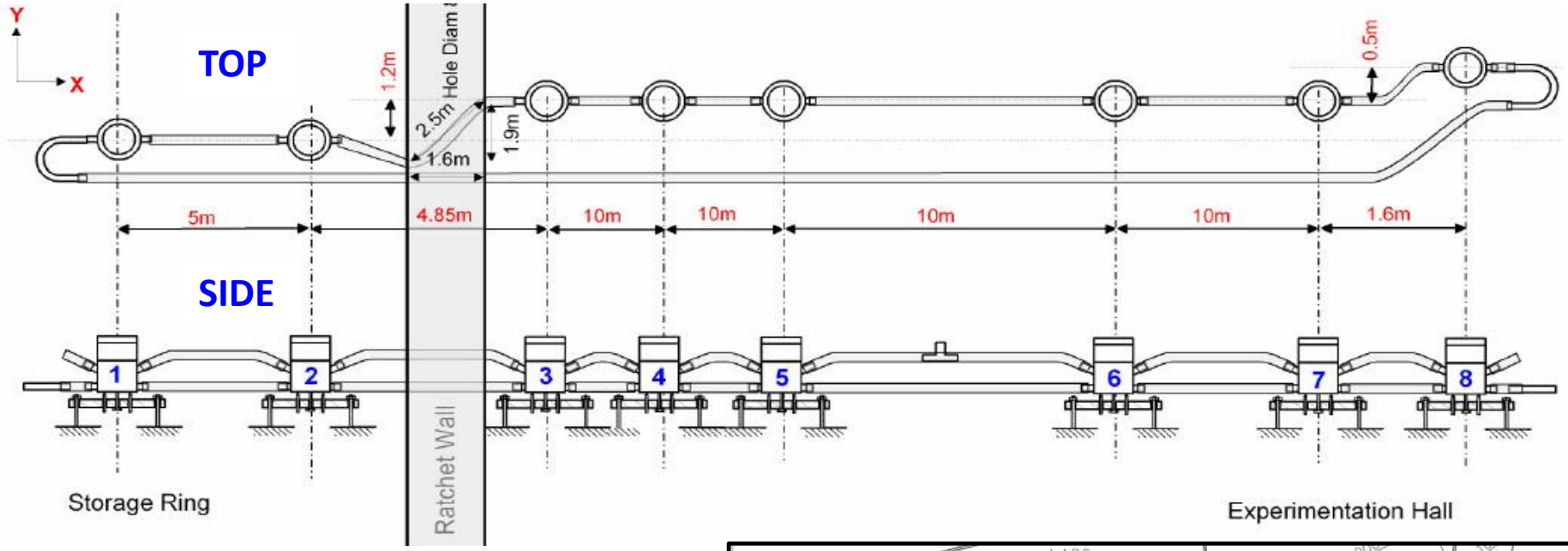
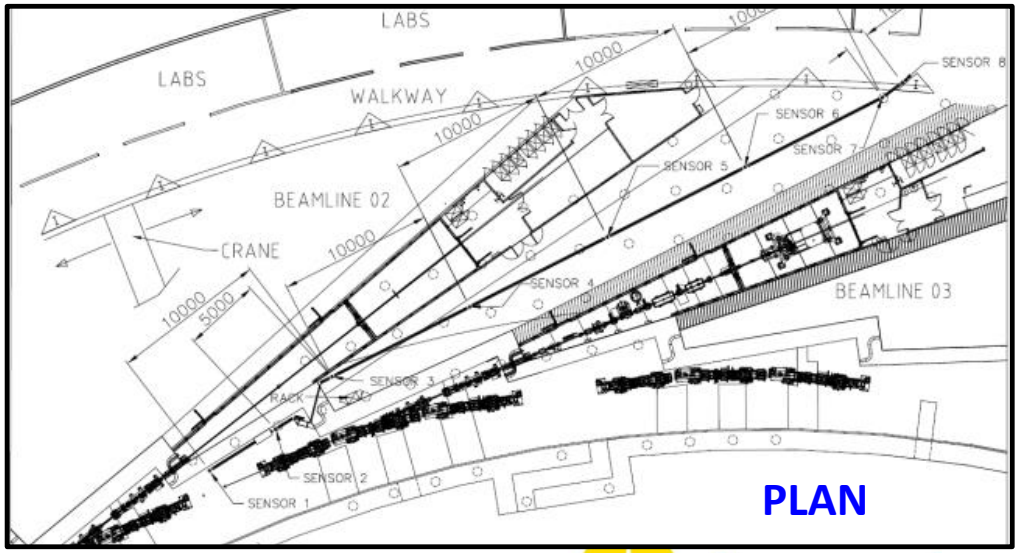
Installation Along a Beamline



- 8 sensors along typical ID to sample line
- Covers SR tunnel, Exp. Hall and outer walkway
- Sensors connected by one water channel and one air channel
- Integrated into EPICS control system



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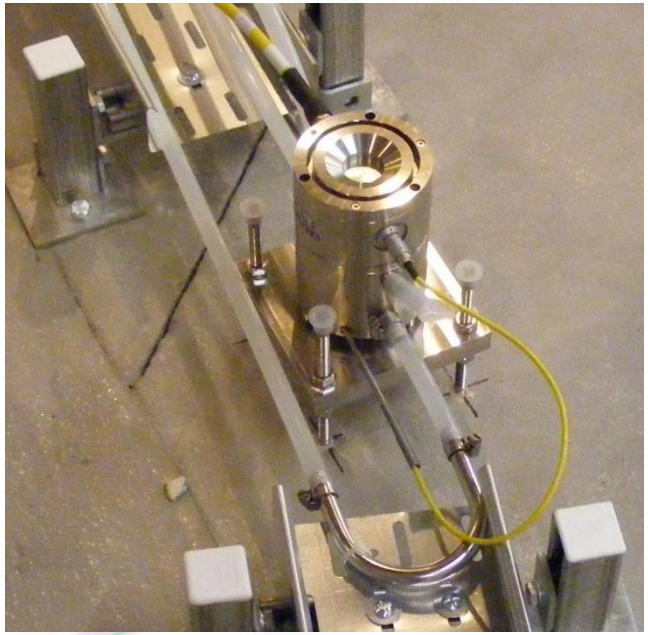
Installation Along a Beamline



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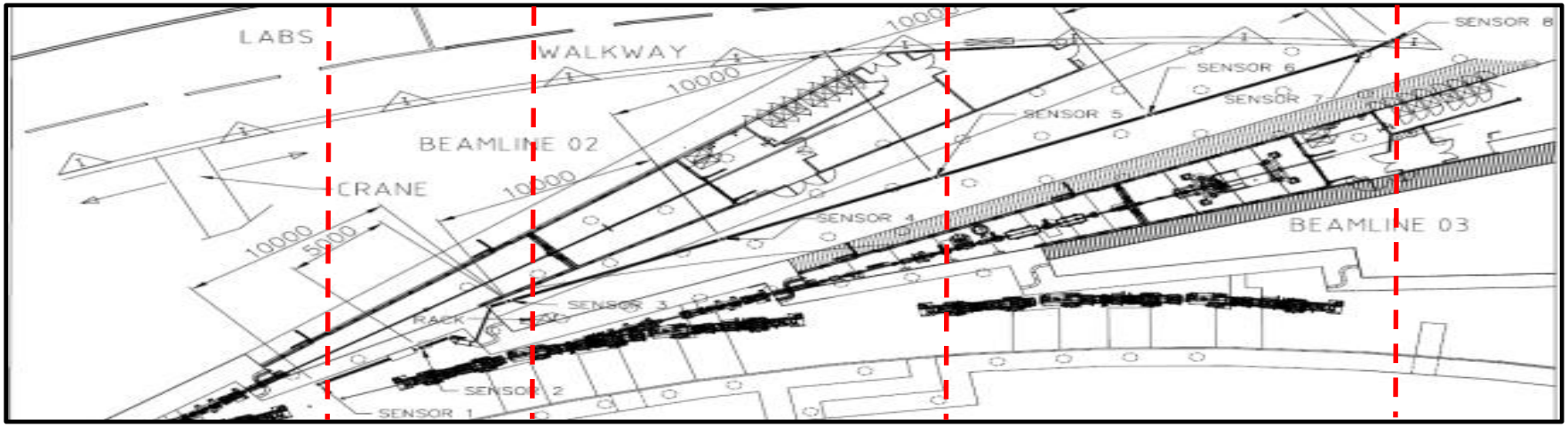
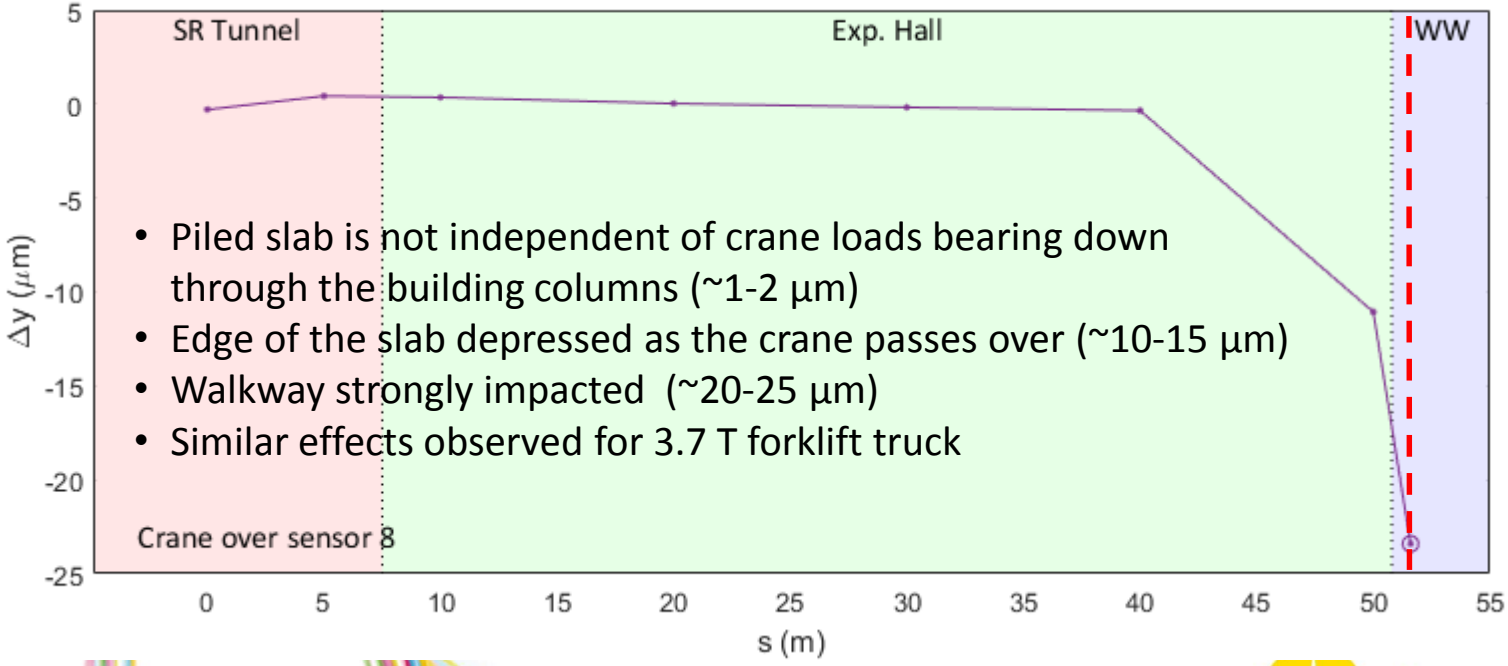
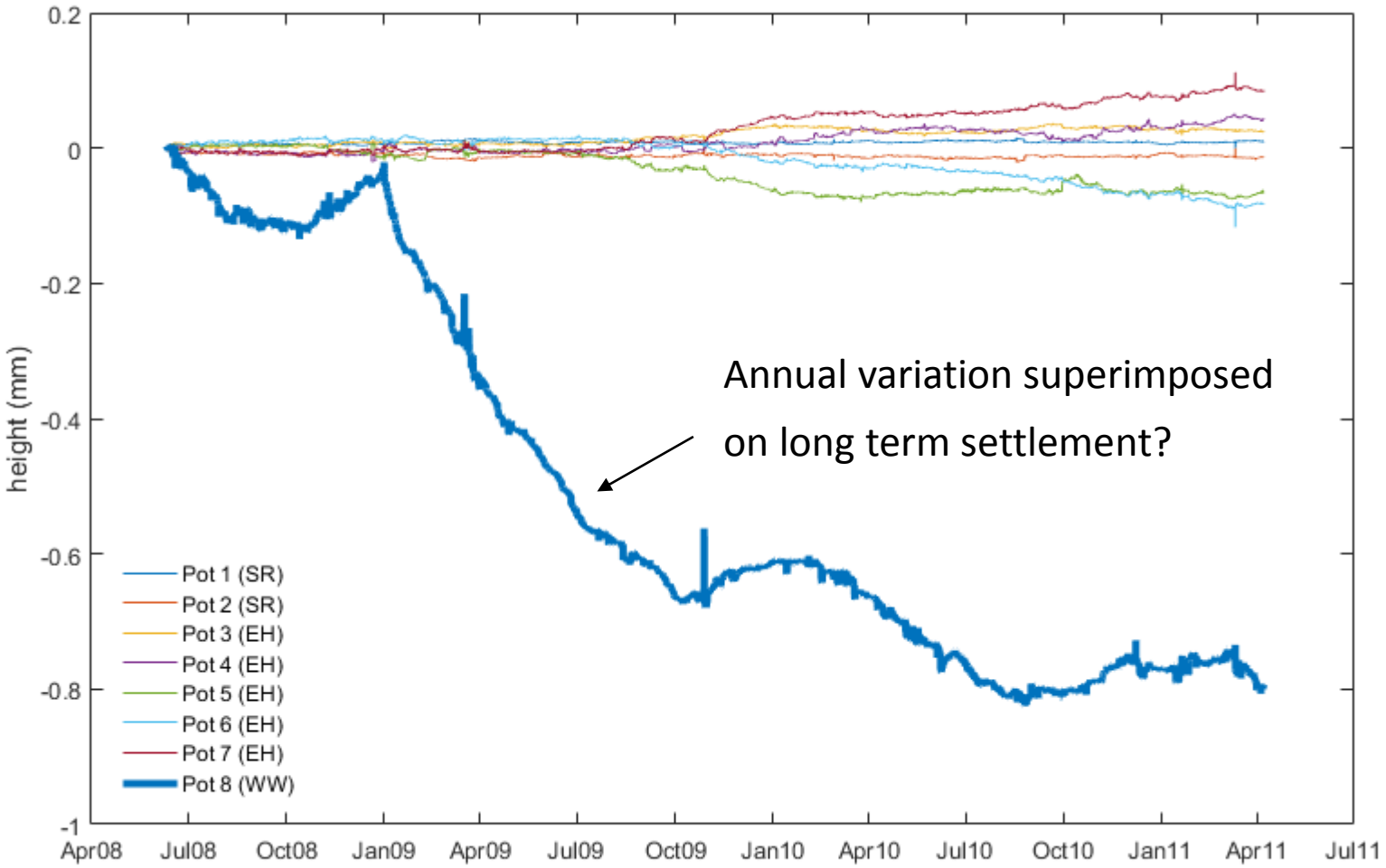
Installation Along a Beamline





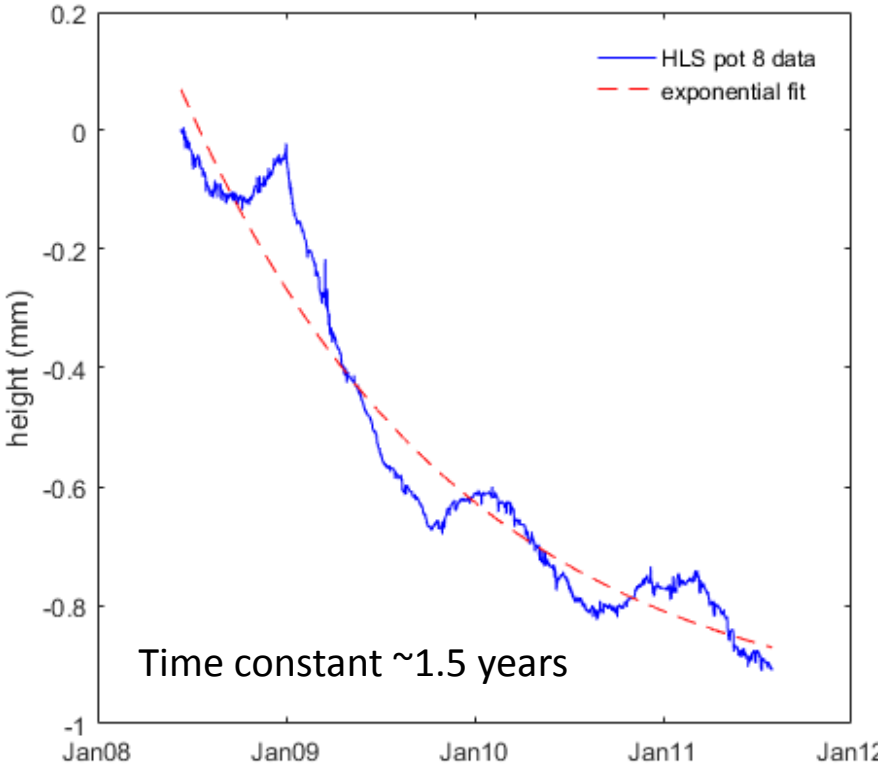
- Piled slab is not independent of crane loads bearing down through the building columns (~1-2 µm)
- Edge of the slab depressed as the crane passes over (~10-15 µm)
- Walkway strongly impacted (~20-25 µm)
- Similar effects observed for 3.7 T forklift truck

Long Term Motion

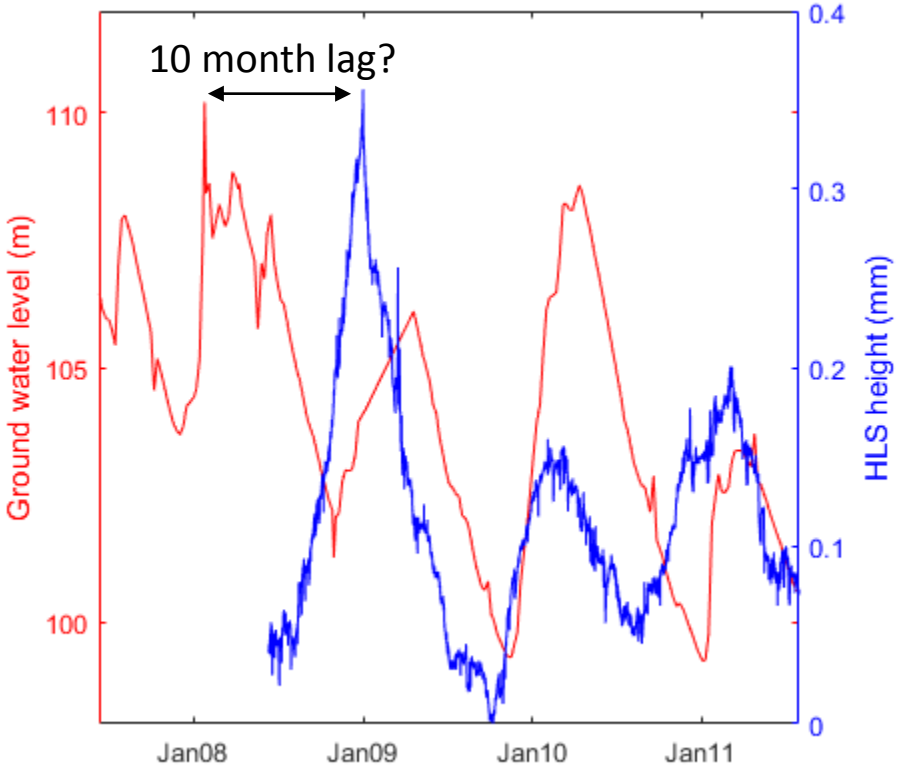


Settlement of Walkway

Long-term settlement of walkway (no piles or void)



Correlation between water table and walkway



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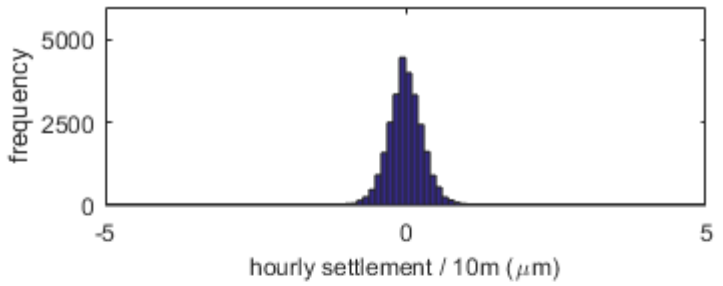
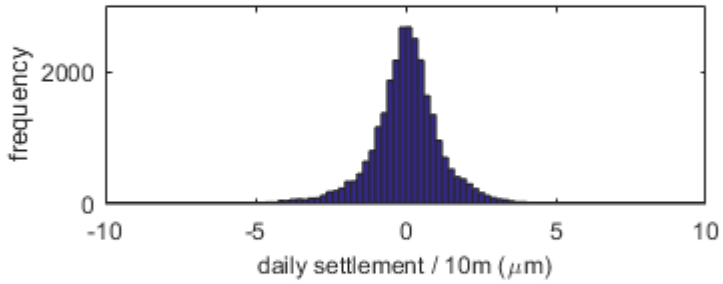
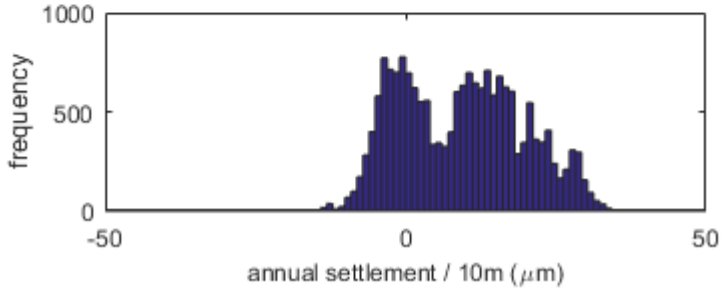
Settlement of Piled Slabs



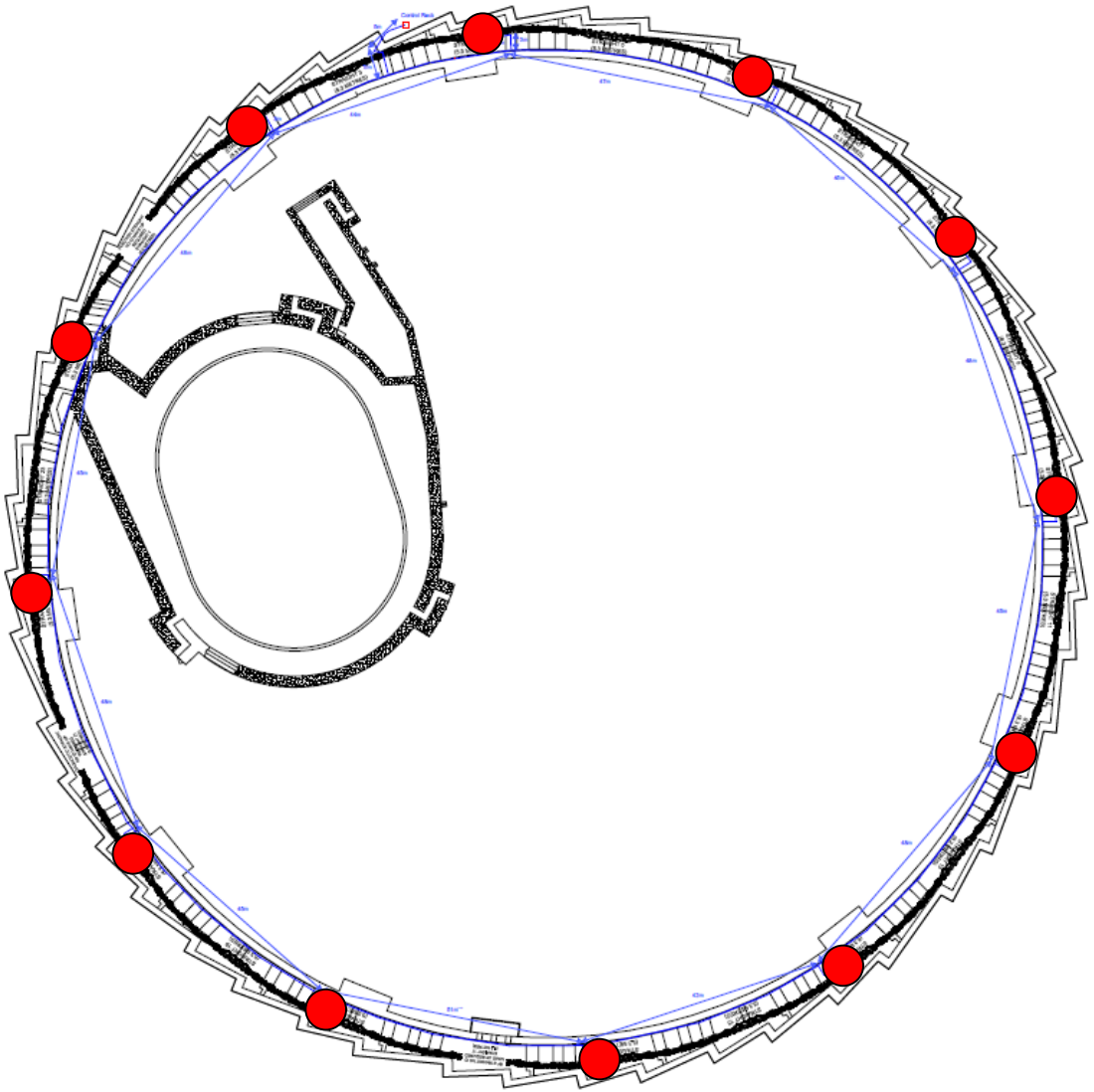




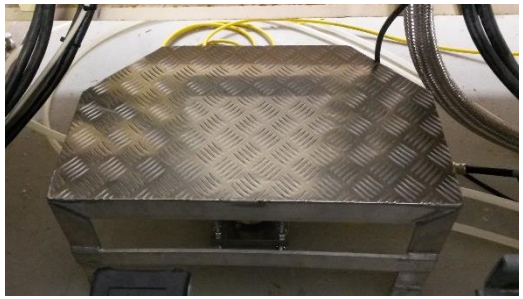
Locations on SR and EH slab have met the stability requirements:

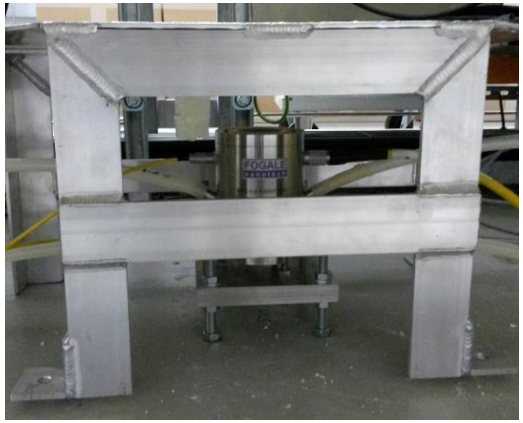
Hourly (4σ):	**1.3 µm**	(target 1 µm)
Daily (4σ):	**4.7 µm**	(target 10 µm)
Annual (4σ):	**41.1 µm**	(target 100 µm)

Installation in Storage Ring Tunnel



- HLS system moved to SR tunnel in 2012
- 12 sensors
- Evenly distributed
- Located under girders





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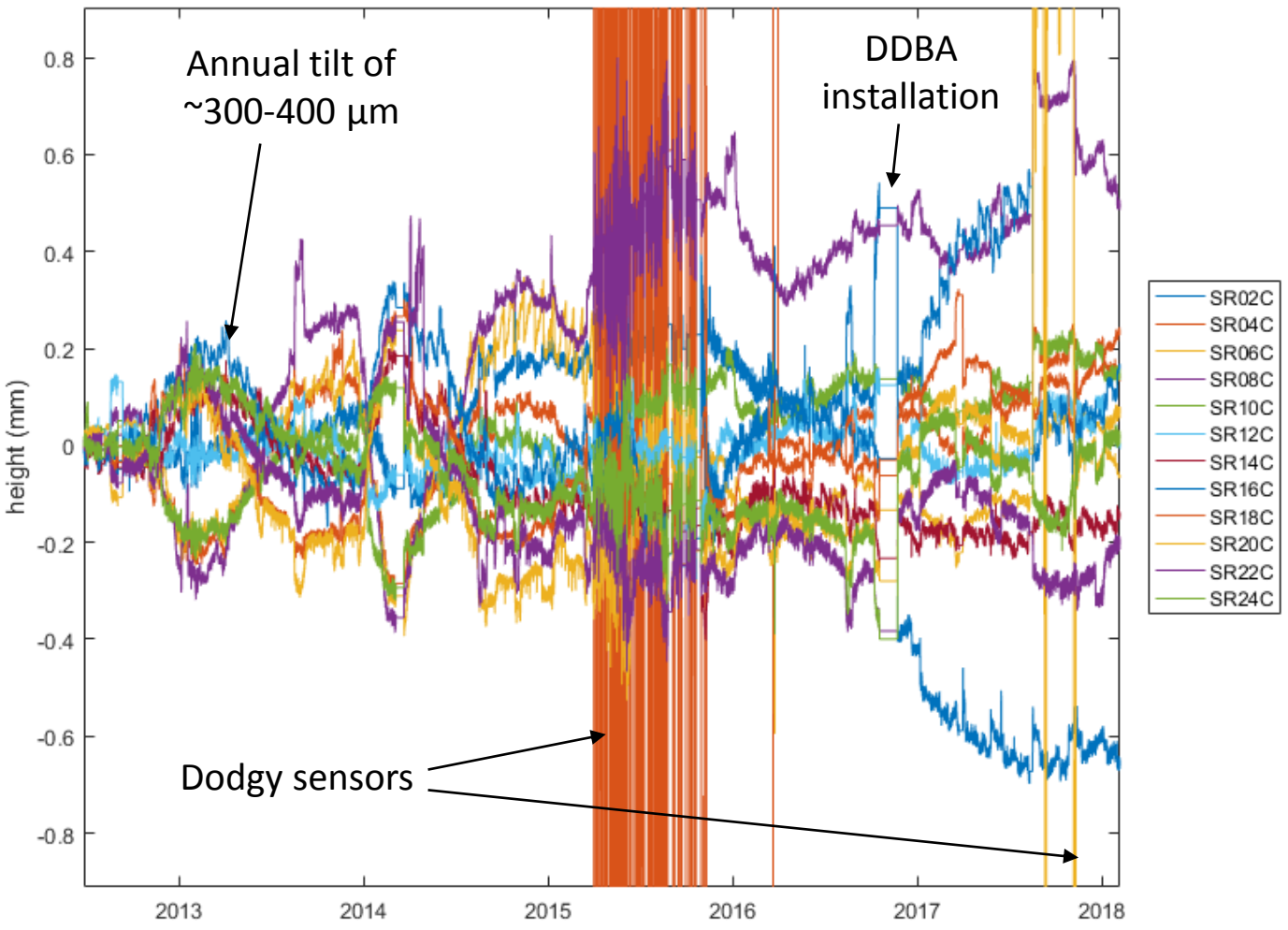
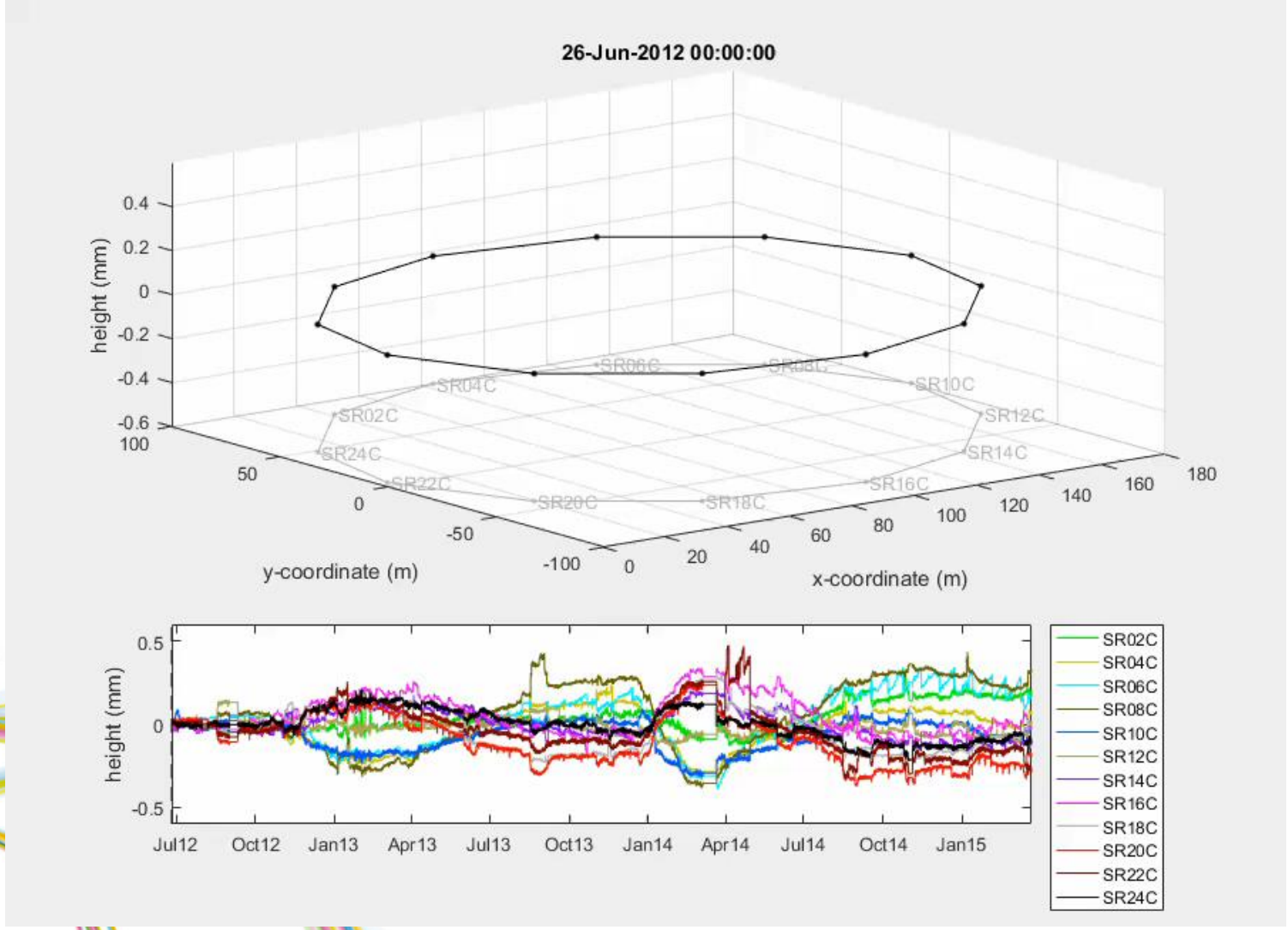
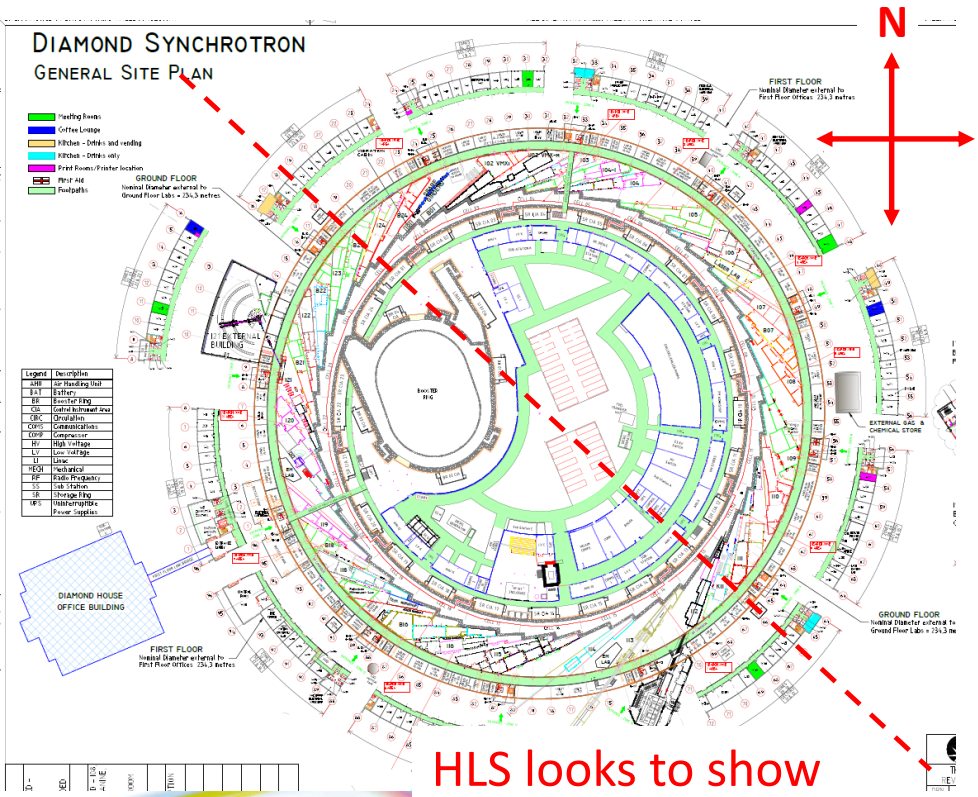
Long Term Motion



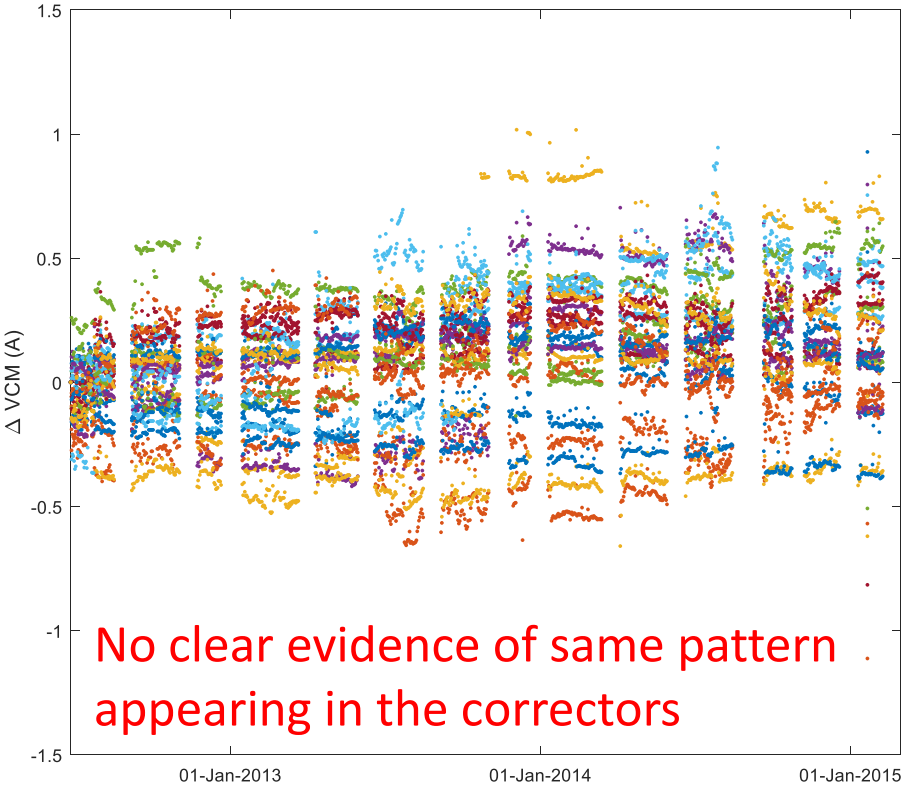
Long Term Motion



Long Term Motion

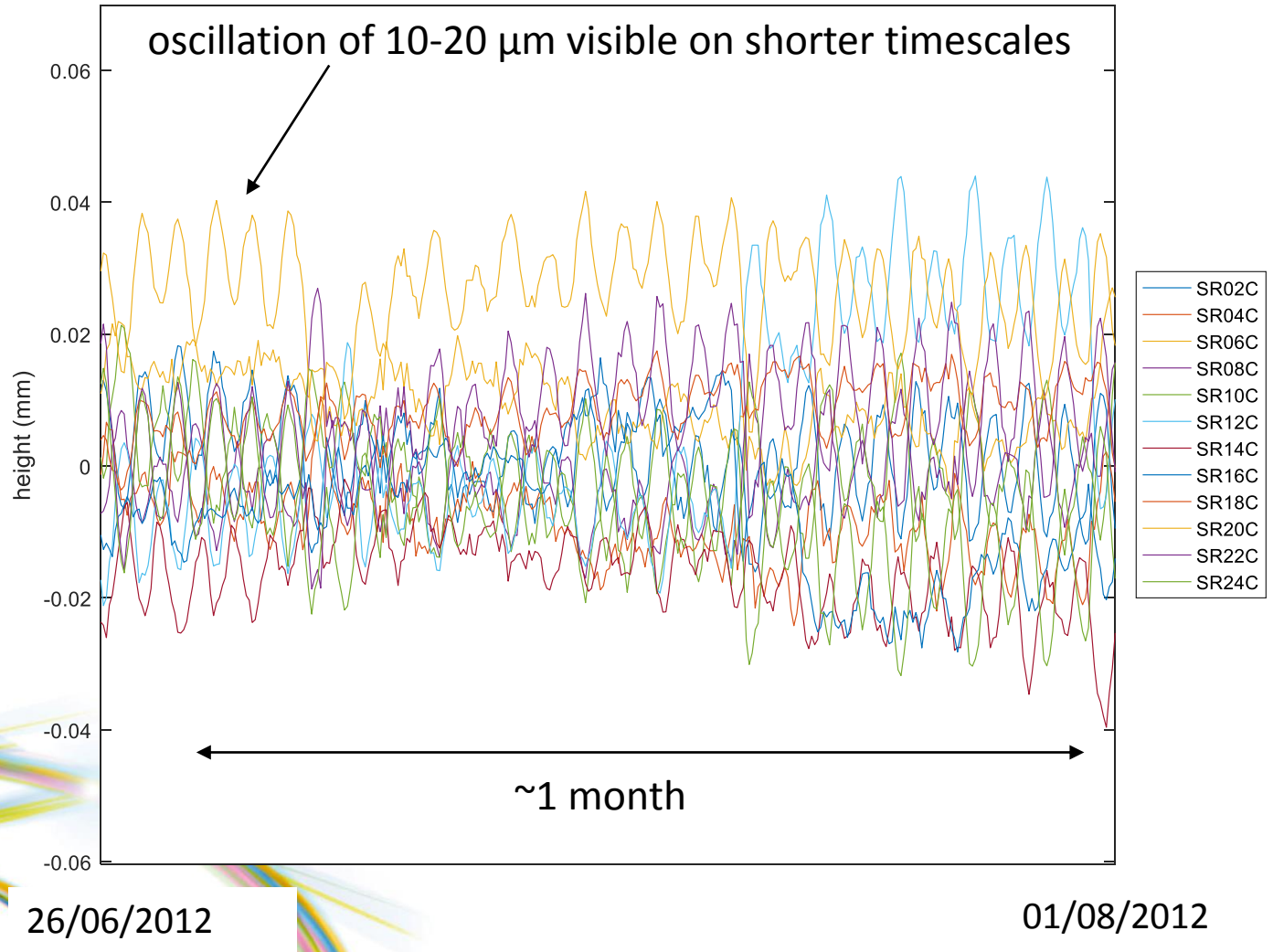


HLS looks to show a seasonal pivot along this line

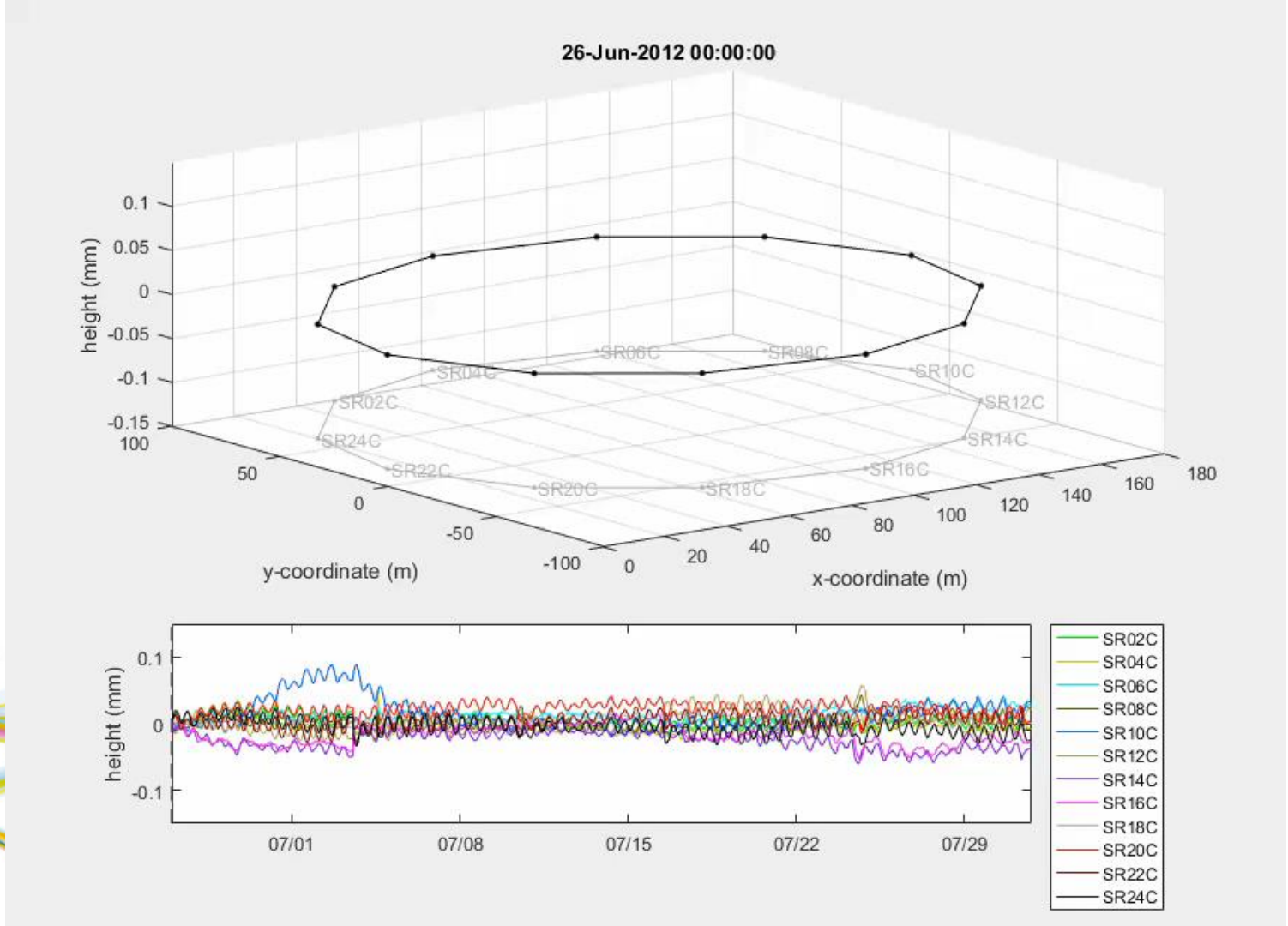


No clear evidence of same pattern appearing in the correctors

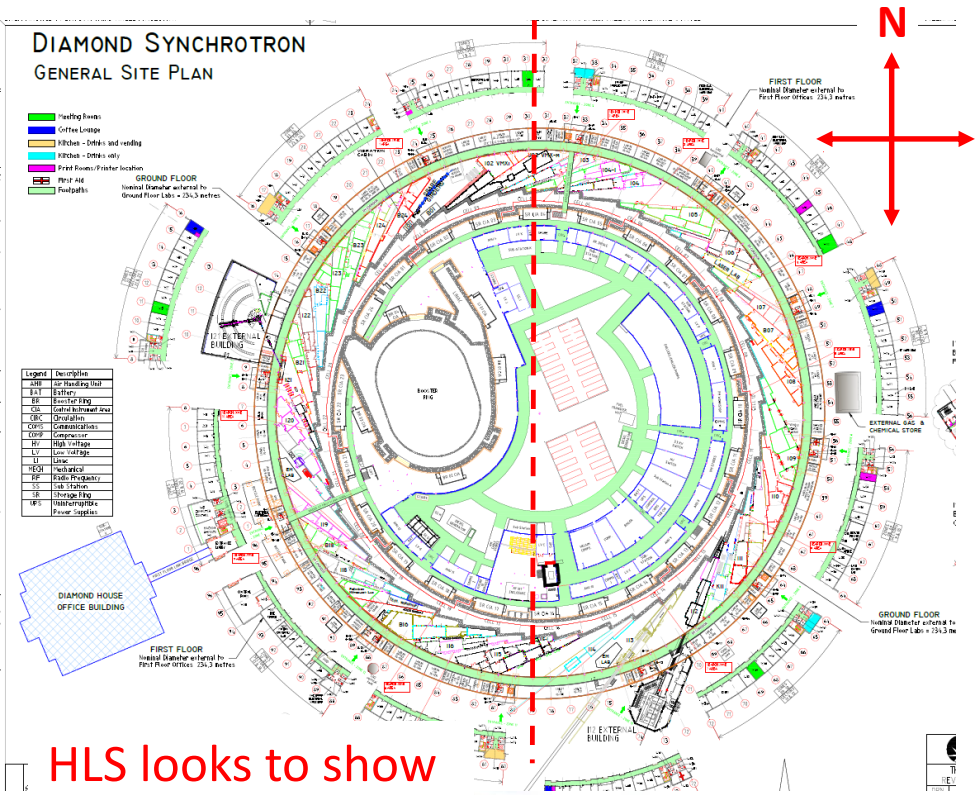
Short Term Motion



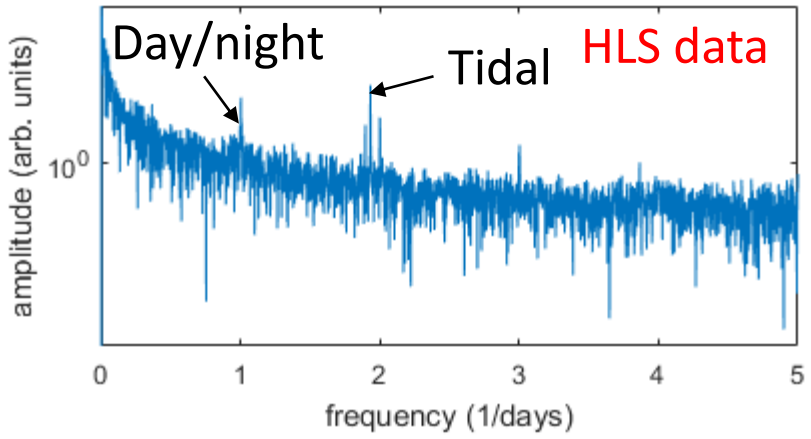
Short Term Motion

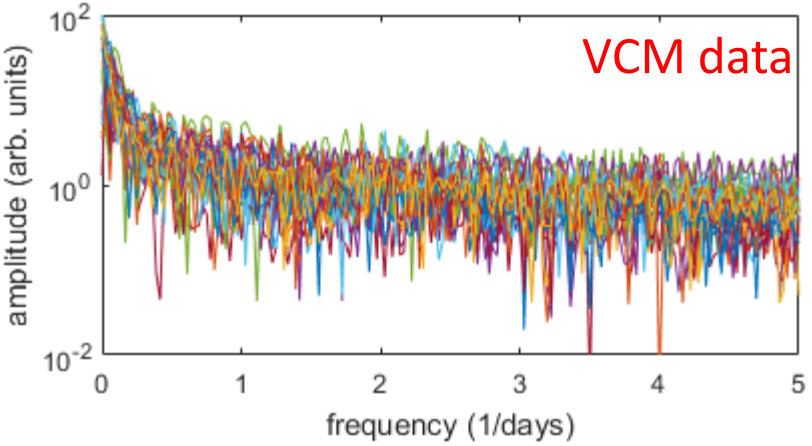


Short Term Motion



HLS looks to show a tidal pivot along this line





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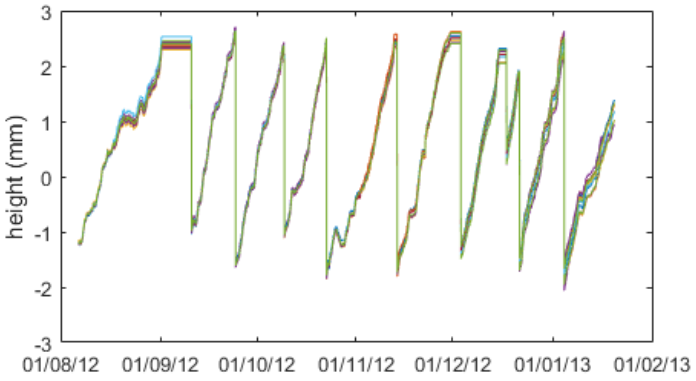
HLS System Issues

Some issues:

- **Regular top-ups** to water level required
- **Thermal effects** apparent for sensors close to external loading doors (improved when garden cloches added)
- **Air bubbles trapped** in system (some high points particularly problematic)
- **Adjustments in pipework** during beamline installations
- **Faulty sensors**
- **Slow leaks** – water level has to be regularly topped-up giving discontinuities and settlement times in data (typically ~300 ml every 3 weeks, but up to 100 ml per day in worst case)
- **Water in air pipes** after DDBA installation



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Conclusions

HLS system installed:

- Along typical beamline path from source to sample (2008-2012)
- Around SR tunnel (2012+)

Building Floor Stability specifications have largely been met

- validates original design choices
- outer edge of EH slab affected by items on outer walkway

Significant movement of slab can be detected

- seasonal variation along NE-SW axis
- daily / tidal variation along N-S axis

No evidence that this movement impacts either the e^- beam or beamlines