Ground Vibration at SSRF Site

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1 Status of SSRF

Shanghai Synchrotron Radiation Facility (SSRF)

A third generation light source

Storage Ring Energy: 3.5 GeV

Circumference: 432 m

Natural Emittance: 3.9 nm-rad

Beam Current: 200 ~ 300 mA

Beam Lifetime: ~20 hrs

Straight Sections: 4×12.0 m, 16×6.5 m

Max. Beam Power: ~600kW

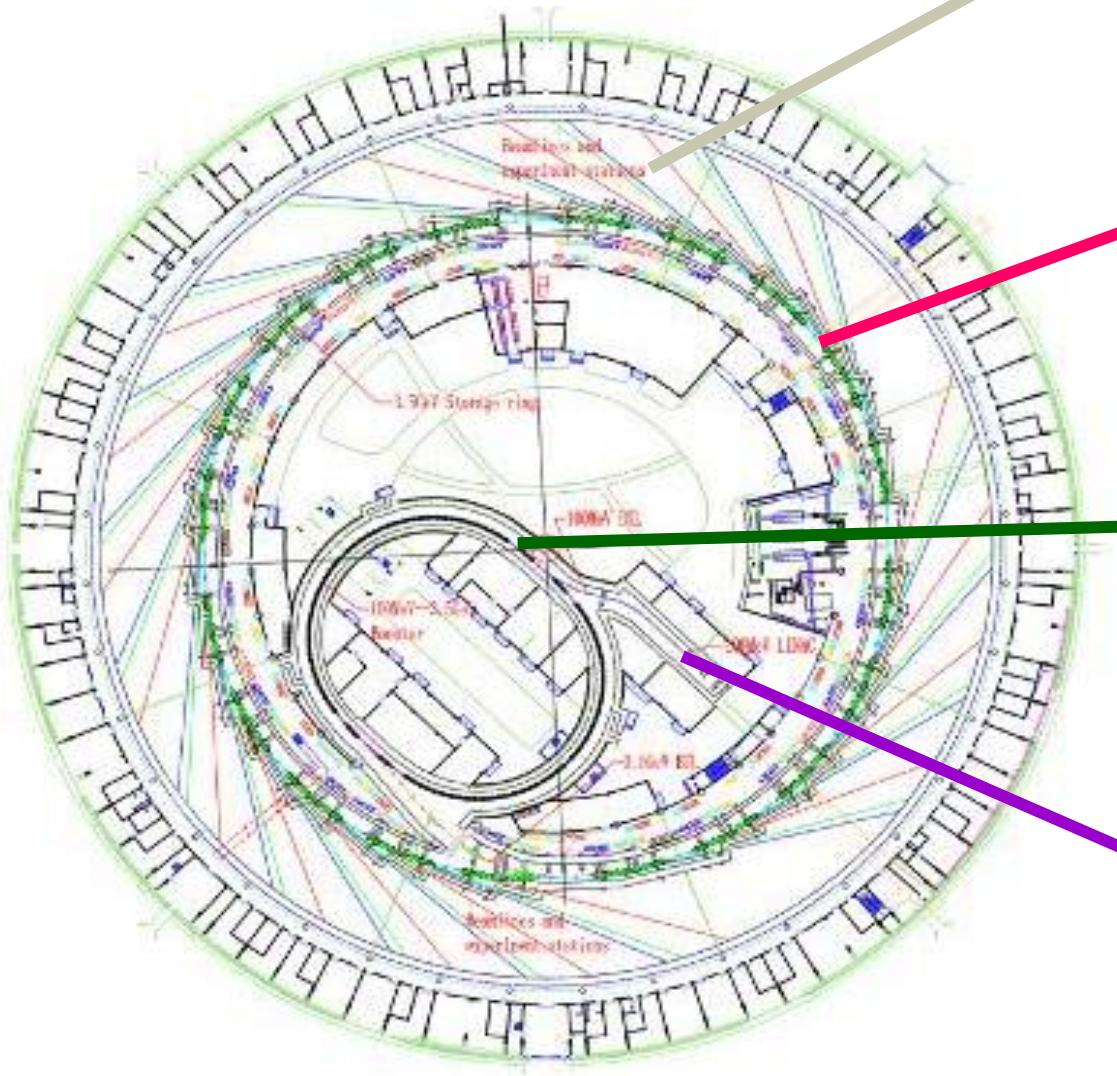
16 beamlines in operation

- 08U Soft X-ray Microscopy
- 13W X-ray Imaging and Biomedical Application
- 14W X-ray Absorption Fine Structure Spectroscopy
- 14B High-Resolution Diffraction
- 15U Hard X-ray Micro-focus and Application
- 16B X-ray Scattering
- 17U Macromolecular Crystallography
- ……

SSRF Campus in 2008

The SSRF Complex

- Dec. , 2004 : Ground breaking
- Dec., 2007: First synchrotron light
- May, 2009: Open to users



Beamlines

Storage Ring
3.5GeV, 432m

Booster
3.5GeV, 180m

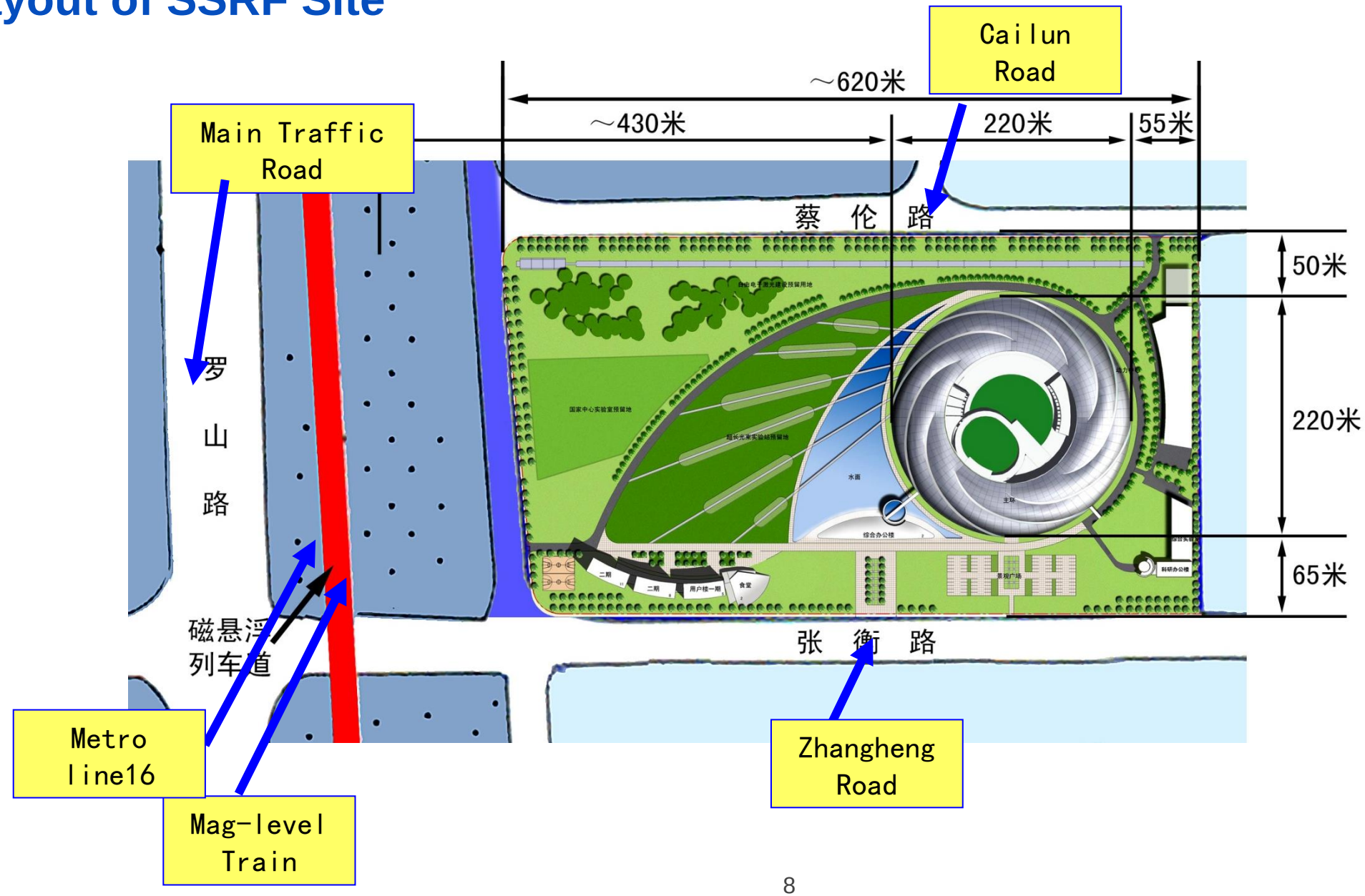
Linac 150MeV


SSRF Campus now

The SSRF Site Location

- Near downtown Shanghai
- New developing area

Layout of SSRF Site



2 Basic Requirement

Beam Stability Criteria

- Electron beam

  Position stability $\Delta\sigma x/\sigma x$ and $\Delta\sigma y/\sigma y$: 10%

  Angular stability $\Delta\sigma' x/\sigma' x$ and $\Delta\sigma' y/\sigma' y$: 10%

- Stability goal in SSRF

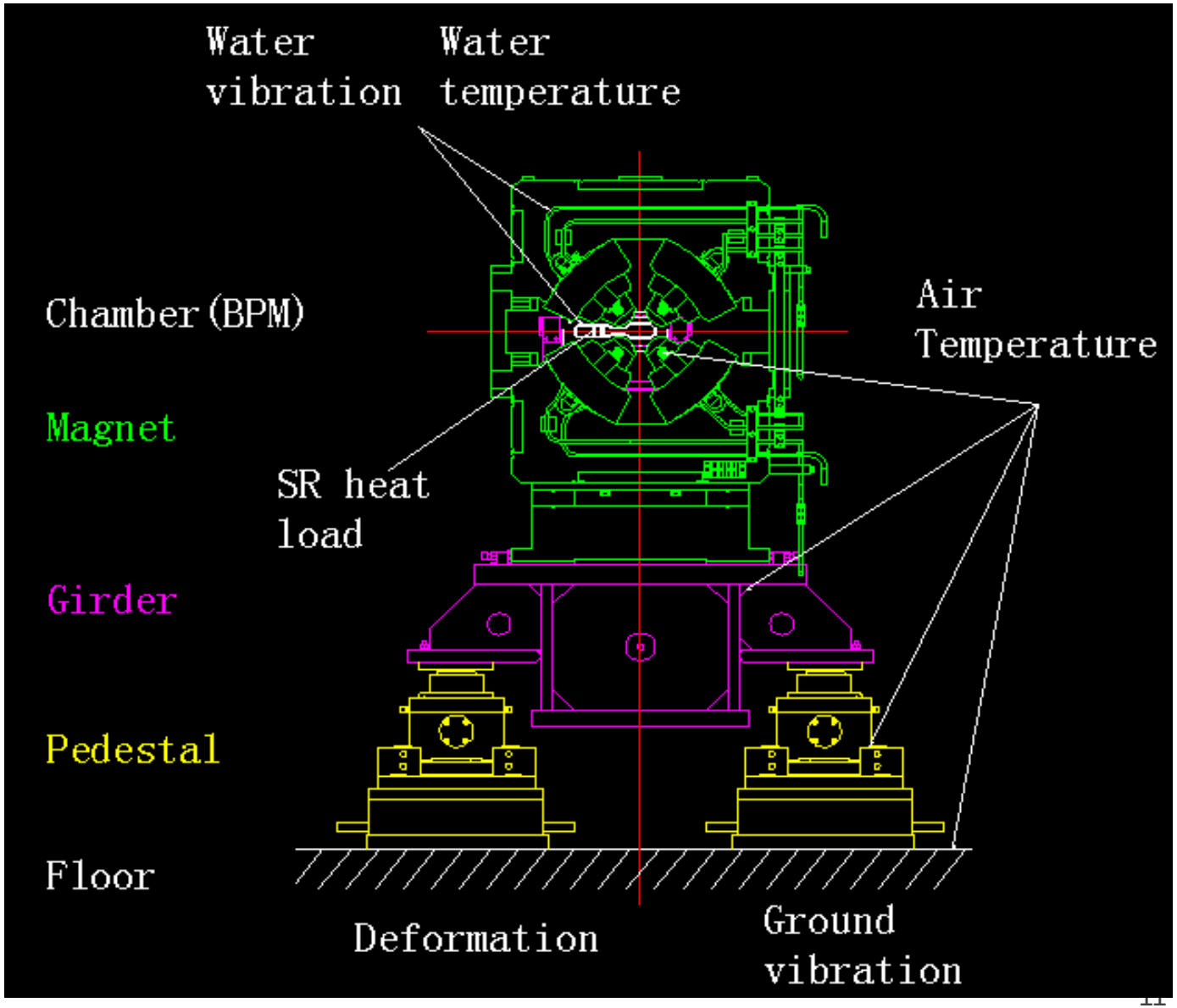
  Horizontal orbit stability < 5μm

  Vertical orbit stability <1μm

Beam Sizes at Source Points

Source Point	σ_x(μm)	σ_x'(μrad)	σ_y(μm)	σ_y'(μrad)
Standard Straight (6.5m)	158	33	9.9	3.95
Long Straight (12.0m)	247	20	15	2.55
1°@upstream of SS	70	114	22	1.97
3.1°@upstream of SS	53	94	22	1.97
1°@upstream of LS	77	116	23	1.79
3.1°@upstream of LS	56	96	23	1.79

Engineering Requirements for SSRF



- **Long term**
  - Slab deformation at ring tunnel and experimental hall
    - Δz <100μm/10m/year
    - Δz <10μm/10m/day
    - Δz <1μm/10m/hour
- **Medium term**
  - Air temperature stability (24hours)
    - Ring Tunnel: T= ~27^{0}C ; ΔT <$\pm$0.2^{0}C
    - Experimental: T=22 ~26^{0}C $\pm$2^{0}C
  - Cooling water temperature stability (24hours)
    - Ring tunnel: T= ~ 30^{0}C $\pm$0.2^0
    - Magnet PS: T= ~ 30^{0}C $\pm$2^{0}C
- **Short term**

Integrated rms displacement above 1Hz:

Vertical: Δz < 0.15μm (quiet)

Δz < 0.3μm (noisy)

Horizontal: Δx < 0.3μm (quiet)

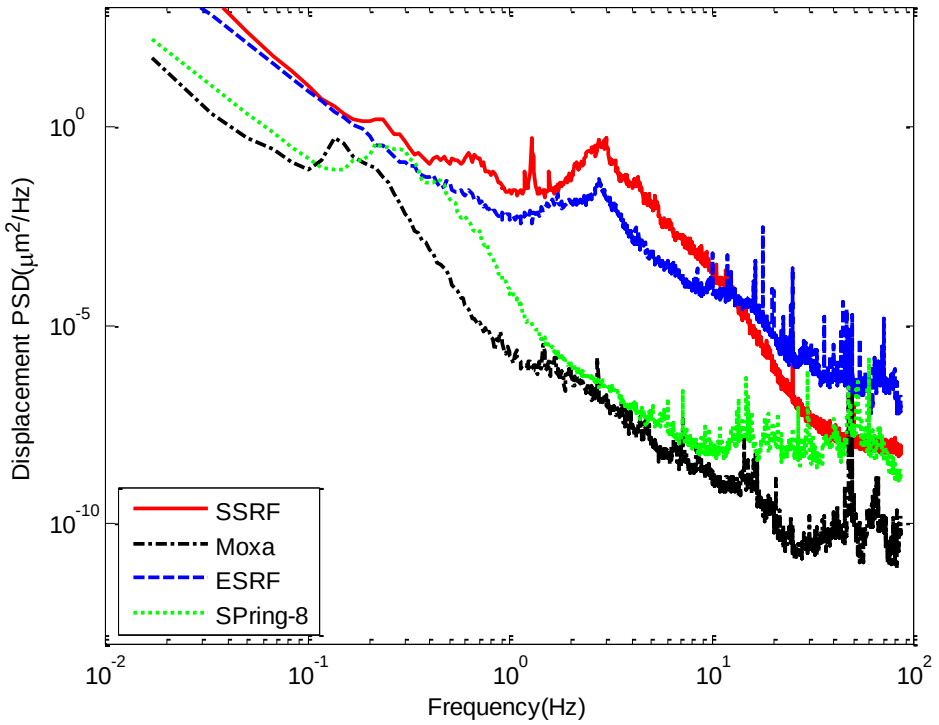
Δx < 0.6μm (noisy)

3 Site Condition and Building

Geologic Conditions

- Alluvium area of Yangzhi river
- Rock bed is about 300m underground
- Soft soil and low ground wave velocity (110m/s)

Ground Vibration



		Peak to Peak distribution		without highest 5%		Selected Data	
		Maximum	FWHM	Average	SD	Quiet	Noisy
Location		pp (nm)	(nm)	RMS (nm)	σ (nm)	RMS (nm)	RMS (nm)
1	Seismic Station Moxa	7	17	0.6	0.1	0.5	0.9
2	Salt Mine Asse	12	35	0.5	0.1	0.5	0.7
3	CERN LHC Tunnel	21	53	1.8	0.8	0.9	2.9
4	Spring-8 Harima	22	40	2.0	0.4	1.8	2.5
5	FNAL Batavia	23	49	2.9	0.9	2.2	4.0
6	LAPP Annecy	35	59	3.3	1.6	1.9	7.0
7	IHEP Beijing	49	18	8.4	0.5	8.1	9.0
8	SLAC Menlo Park	60	105	4.8	1.2	4.1	7.4
9	APS Argonne	68	56	10.5	1.0	9.8	11.0
10	ALBA Cerdanyola	87	125	18.3	9.5	9.1	42.0
11	DESY TESLA	104	160	17.4	8.4	9.3	35.9
12	DESY XFEL Osdorf	150	195	28.9	11.9	19.5	48.4
13	DESY Zeuthen	105	235	64.0	40.4	88.5	75.6
14	ESRF Grenoble	155	175	71.6	34.9	40.2	137.2
15	DESY XFEL Schenefeld	180	245	38.7	16.6	35.1	70.0
16	DESY HERA 170	200	51.8	18.9	34.8	77.0	
17	KEK Tsukuba	170	210	78.0	36.0	38.0	125.1
18	BESSY Berlin	245	160	72.8	28.1	53.1	140.7
19	SSRF Shanghai	550	1000	292	164	102	444

- Ground vibration is the most determinative effect !
- Minimize noise sources.
- Use various feedback.

Courtesy of H. Ehrlichmann

Design of the Slab and Building

- Slab for ring tunnel and experimental hall are separated with building
- Bored piles with base grouting

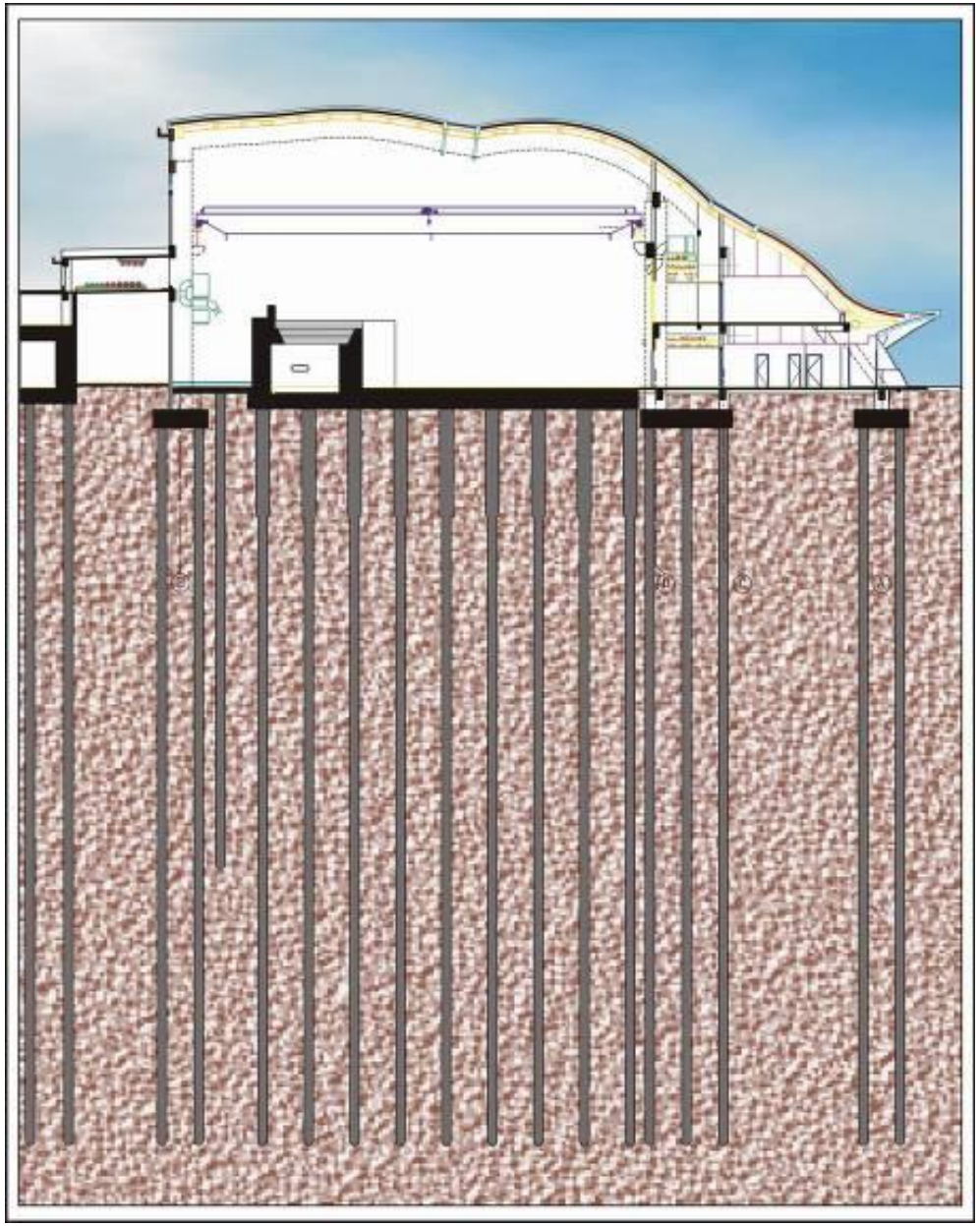
  Number: 2100

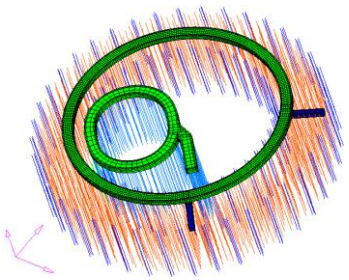
  Diameter: 0.6m (0.9m for top 7m)

  Length: 48m (To silty sand layer)
- Slab Thickness

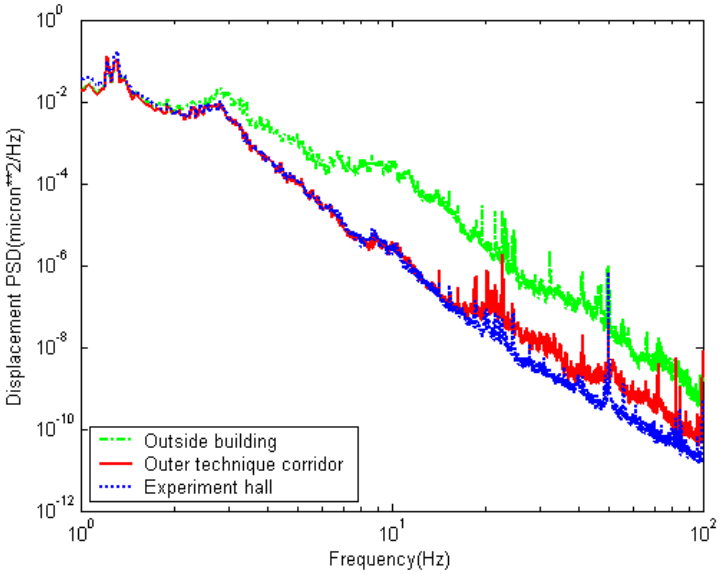
  1.35m (experimental hall)

  1.05m (ring tunnel)

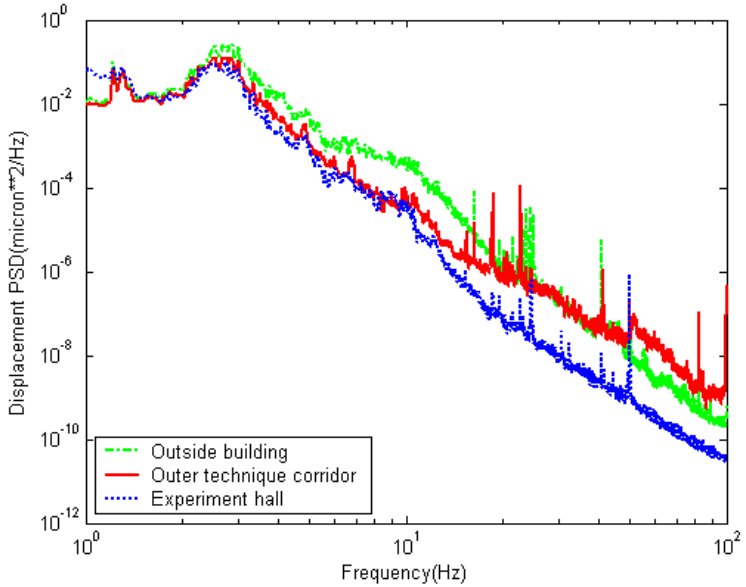




Performance of Slab



PSD in Horizontal Direction



PSD in Vertical Direction

- Slab vibration:
  Vertical rms value
  ~0.15μm (quiet time)
  ~0.25μm (noisy time)

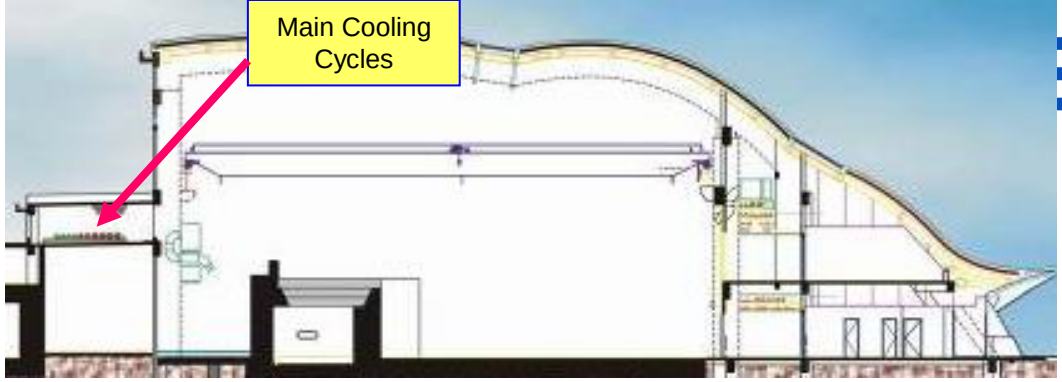
Integrated (1–100Hz) RMS displacement (μm)

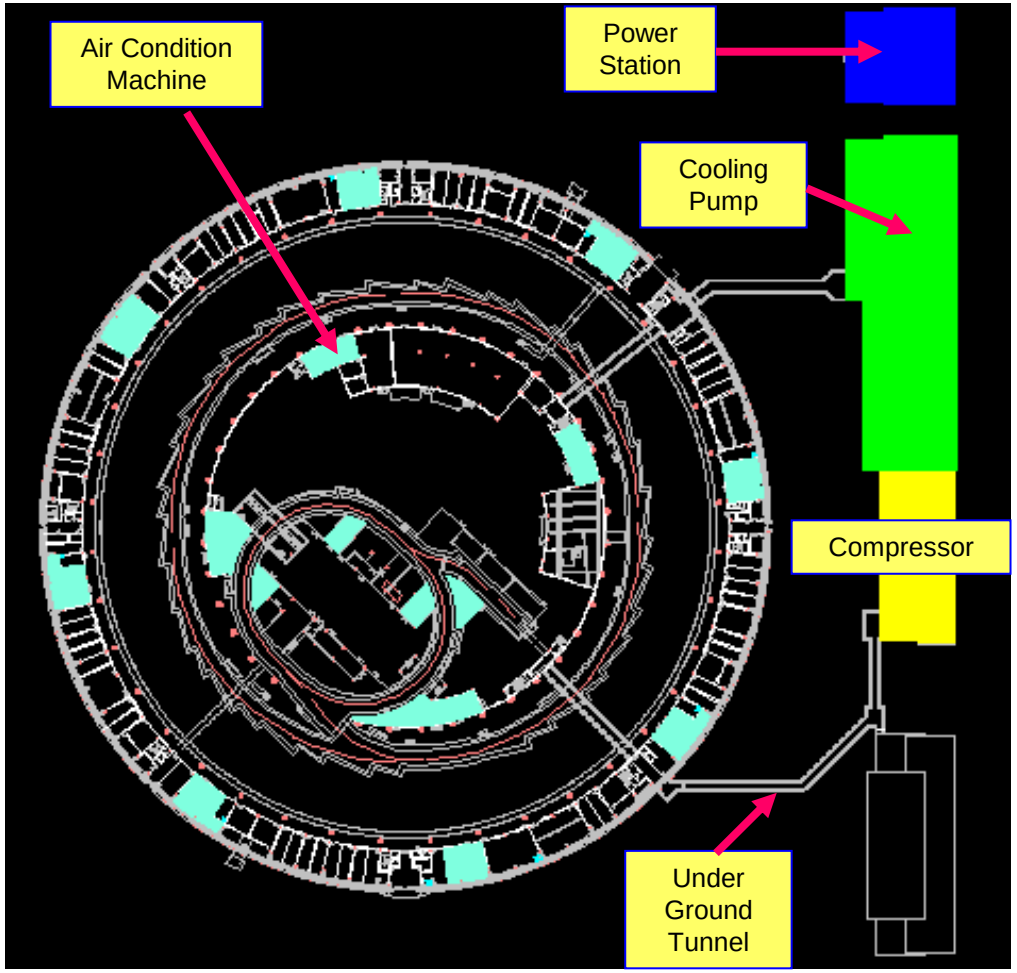
Site \ Direction	Normal condition			Truck passing by		
	W-E	N-S	V	W-E	N-S	V
Field	0.265	0.251	0.258	0.349	0.385	0.672
Slab	0.098	0.130	0.133	0.118	0.166	0.381
Ratio(Slab/Field)	0.37	0.52	0.52	0.34	0.43	0.57

4 Conventional Facility

Conventional Facility Location

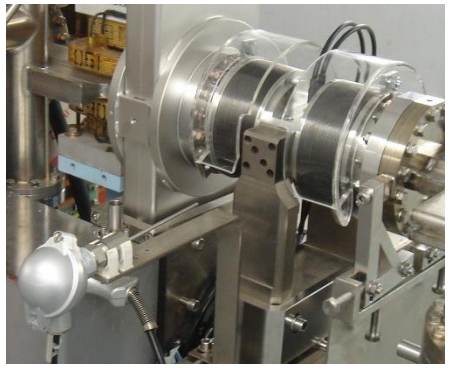
- Keep pumps and compressors far from the storage ring
- Main conventional facilities are arranged outside the main building.
- Two under ground channels for pipes and cables.
- Main cooling cycles are set in the alleyway in the main building.
- Cooling water flow rate: < 2m/s
- Air condition machines with damping are located inside the main building.





Conventional Facility in Tunnel

- Branches from the main cooling loop connect the machine in each cell.
- Soft pipe mechanical isolate the main pipe with accelerator components.
- Keep large curve in cooling path for components.
- Water flow rate is limited to 2m/s in magnet and absorber.
- Air flows to tunnel uniformly.
- No Air blow to machine directly.
- Temperature sensors are set near high precision BPM.



Performance of the Conventional Facility

- Air temperature stability in Tunnel

  Average temperature from the sensors in tunnel

  T= 27^{0}C ; $\Delta T < \pm 0.1^0$C

  24Hrs

- Cooling water temperature stability for magnets and absorbers

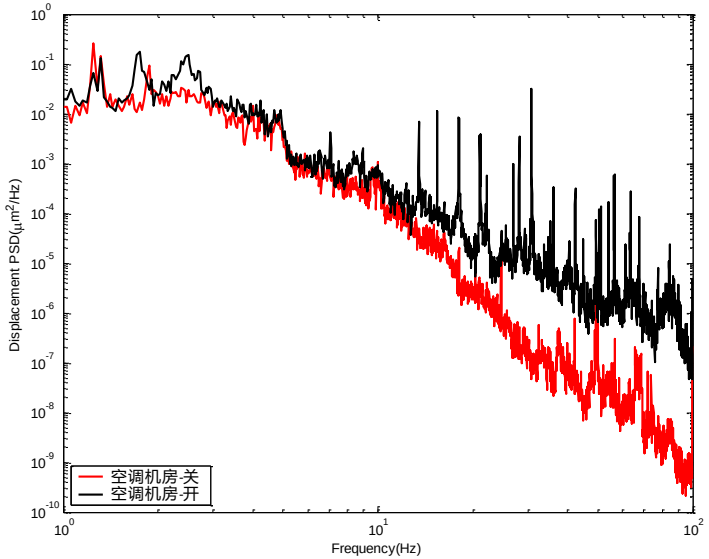
  Sensors at the downstream of the heater in main pipe are used for control.

  Sensors upstream of each sector are used for monitor.

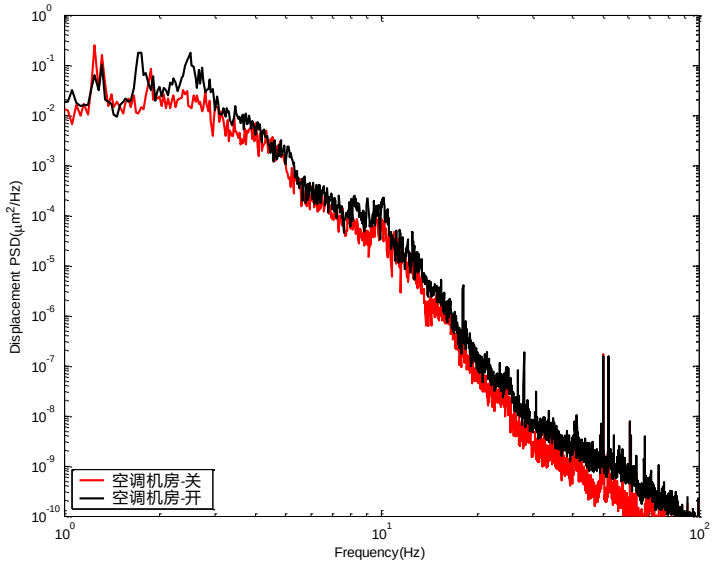
  T= 30^{0}C ; $\Delta T < \pm 0.1^0$C

  24Hrs

Vibration test for air condition



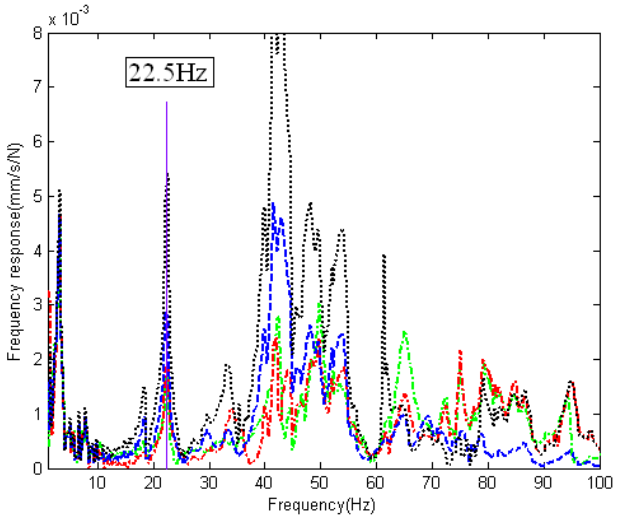
PSD in air condition room floor (V)



PSD in ring tunnel floor (V)

5 Ground Vibration Measurement

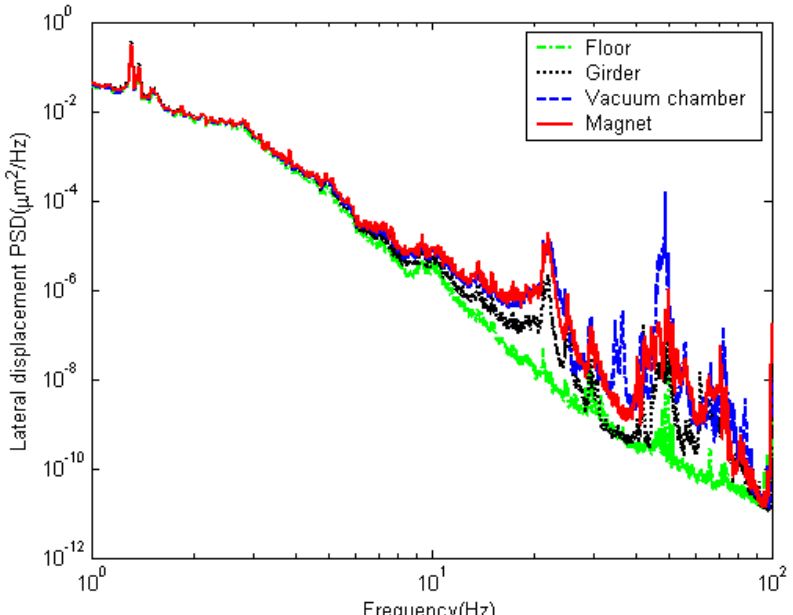
Test for Ground and Machine



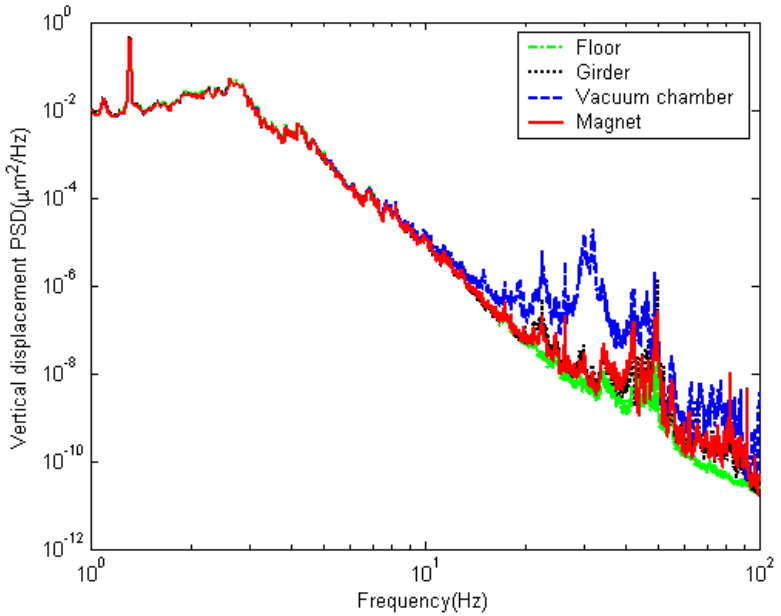
- The first eigenfrequency
  21.9Hz (H)
  22.5Hz (V)
- Response of quadrupole to floor vibration in first eigenfrequency

  34.8 (H); 1.6 (V)
- The first eigenfrequency can be improved to 27.7Hz with assistant support.

PSD in lateral direction

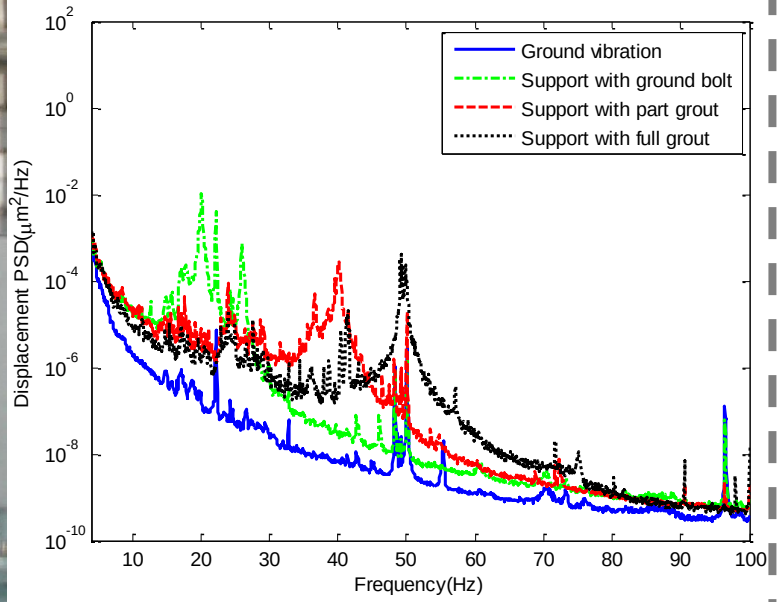


PSD in vertical direction



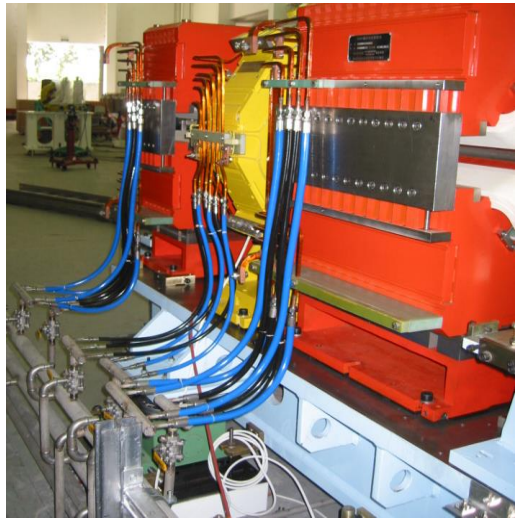
Test for Ground and Machine

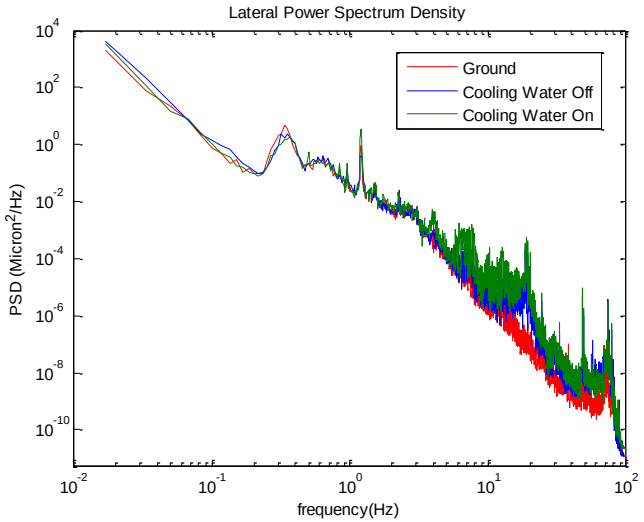
High precision BPM test

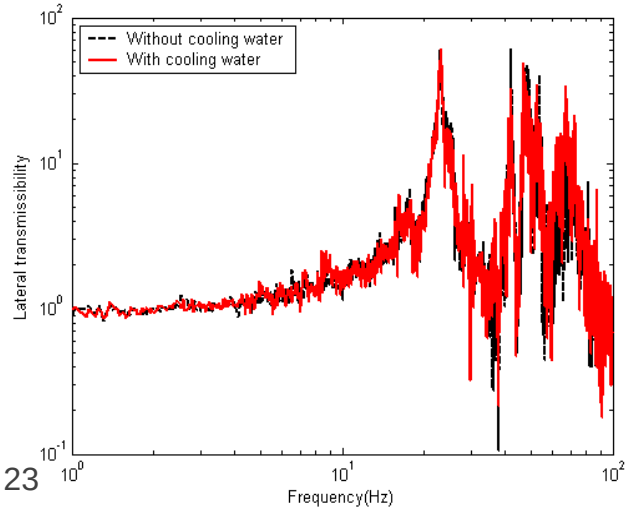


- The first eigenfrequency in lateral direction : 49Hz
- The amplification ratio (4~50Hz) : 1.23

Response of magnet to cooling water

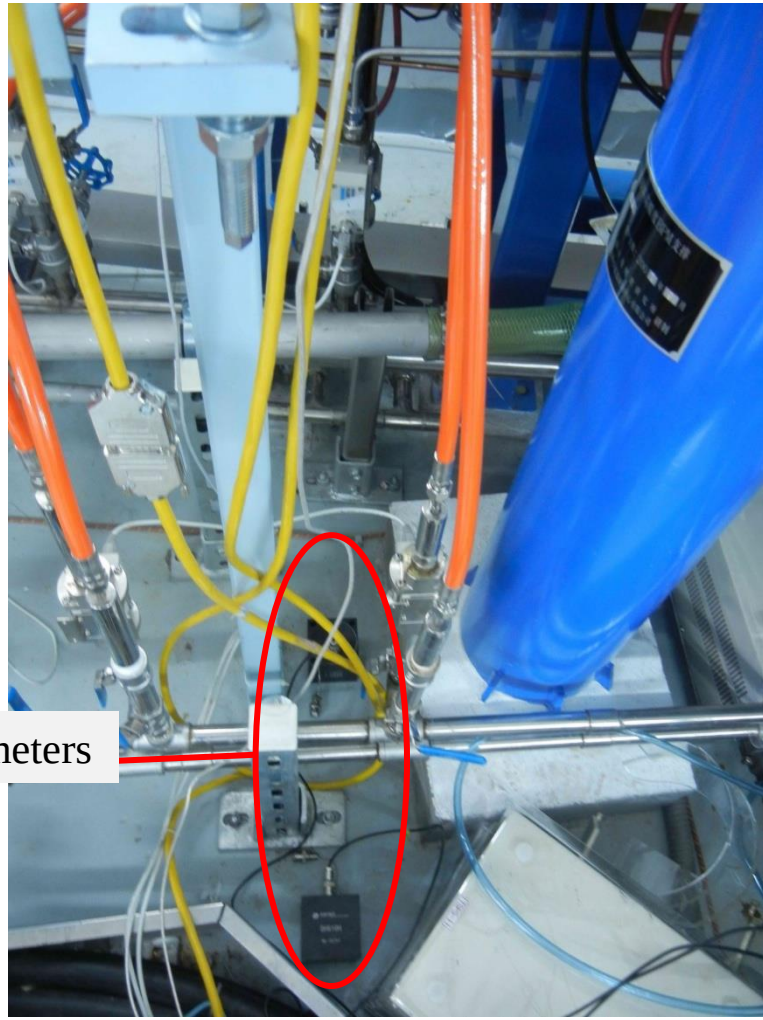






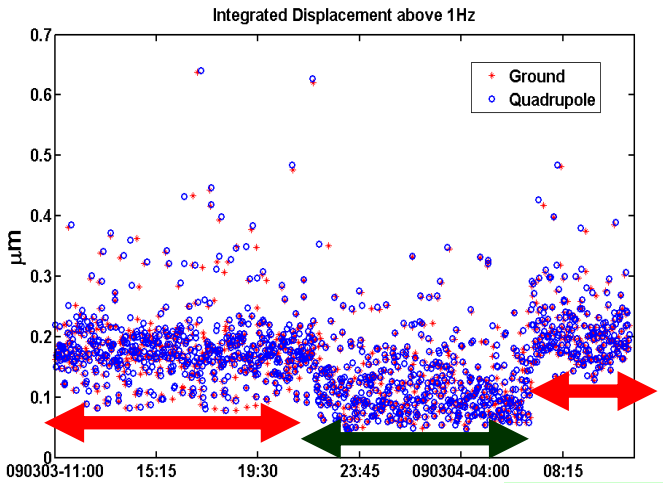
- 4 QM+3 SM
- Pressure drop: 0.65MPa
- Cooling water velocity in magnet coil: 1.8m/s

Long-term Mechanical Stability Monitoring of C14-7 BPM



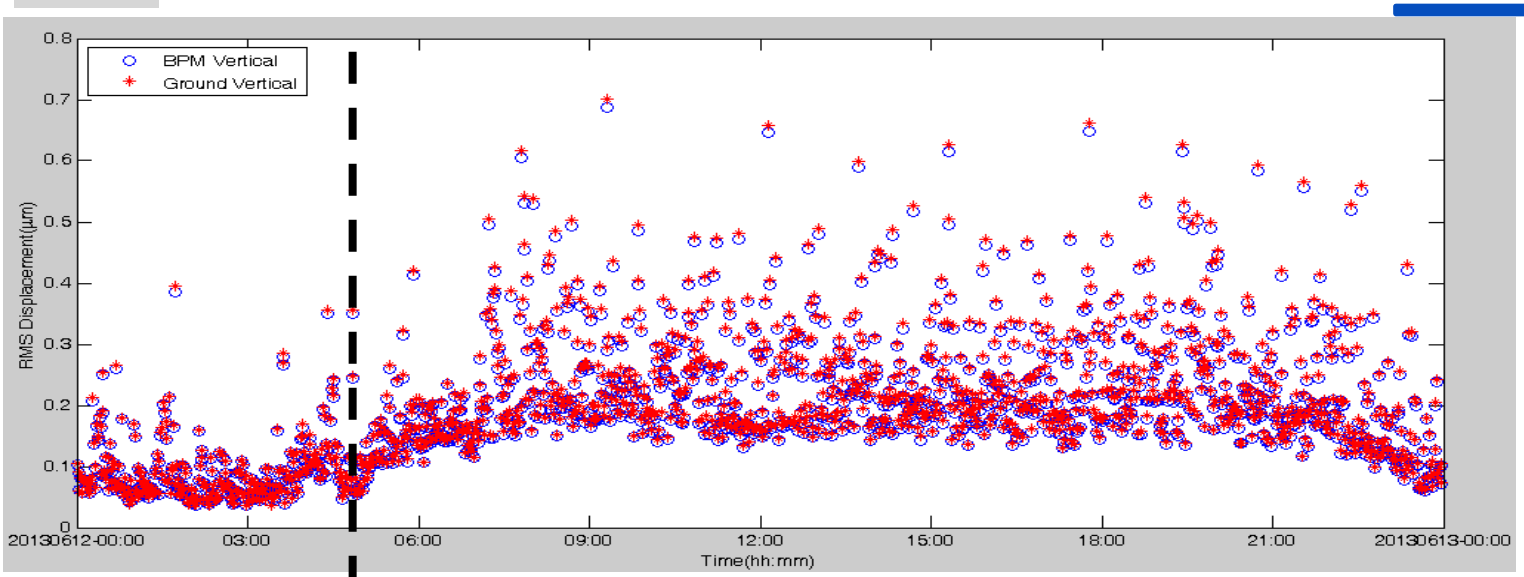
24 Hours

2009

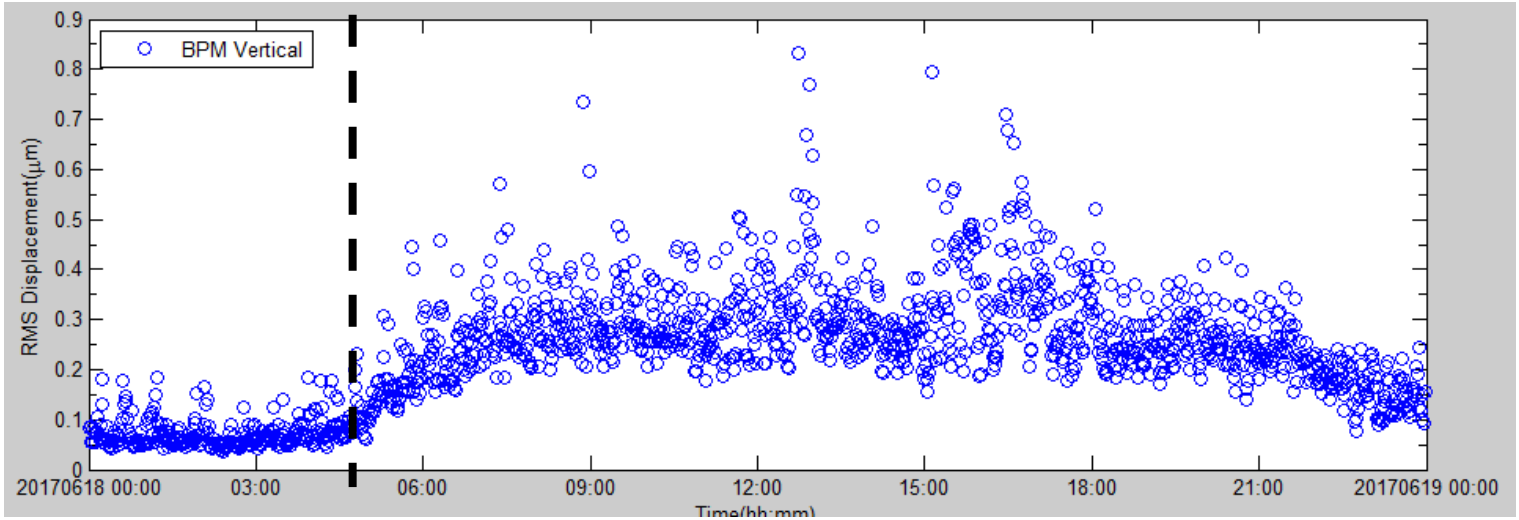


Noisy Hours | Quiet Hours | Noisy Hours

2013

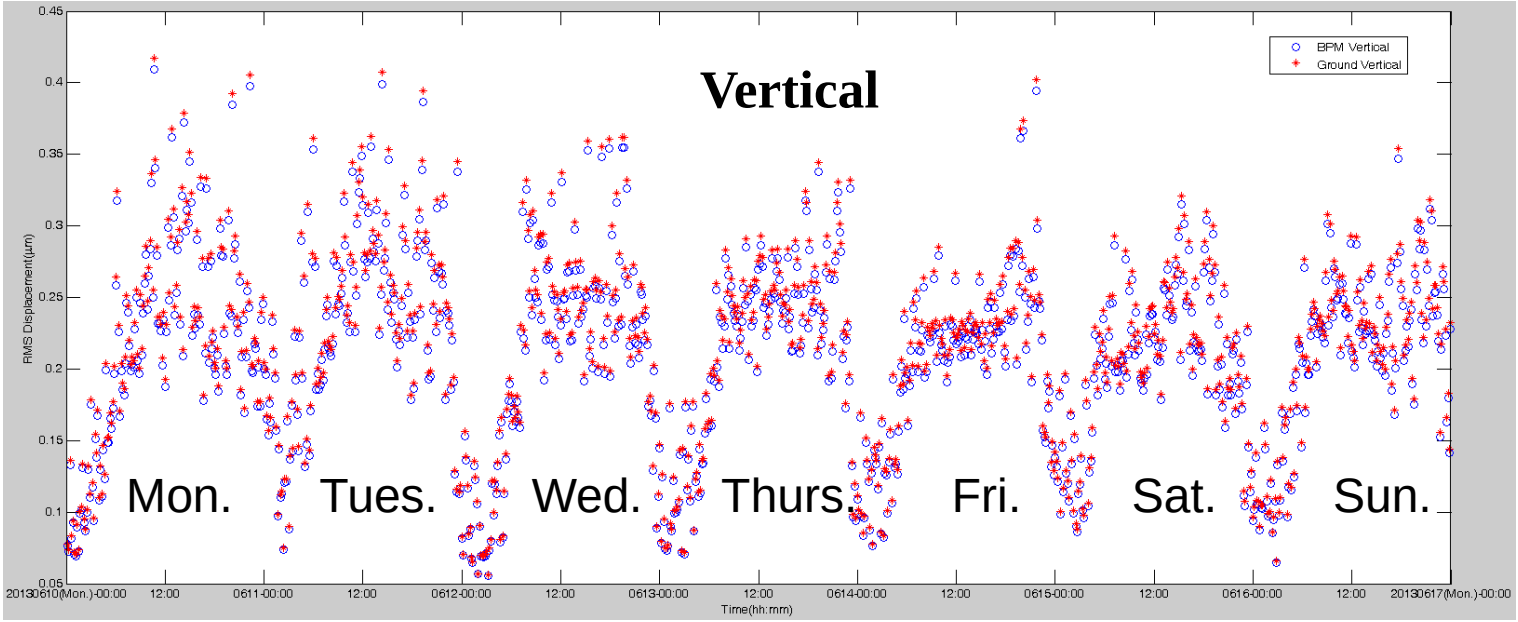


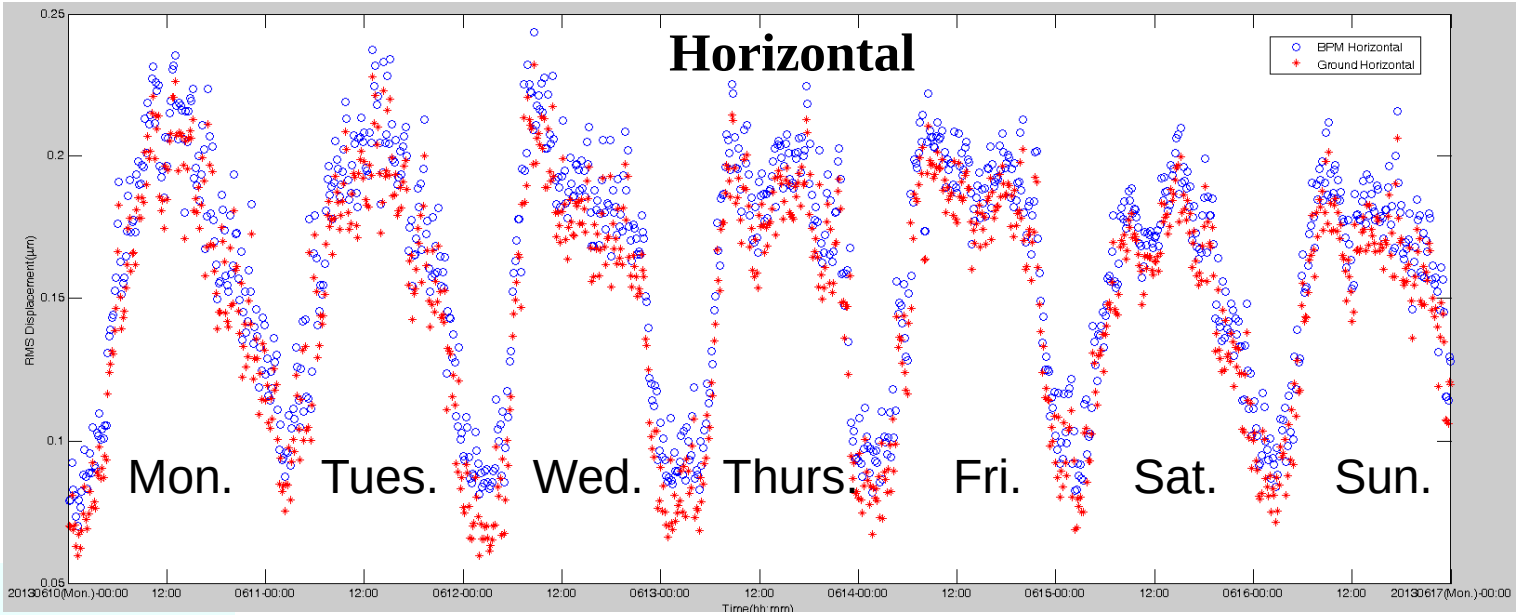
2017



Quiet Hours | Noisy Hours

1 Week


Vertical
BPM Vertical
Ground Vertical
RMS Displacement(μm)
Time(hh:mm)
Mon.
Tues.
Wed.
Thurs.
Fri.
Sat.
Sun.

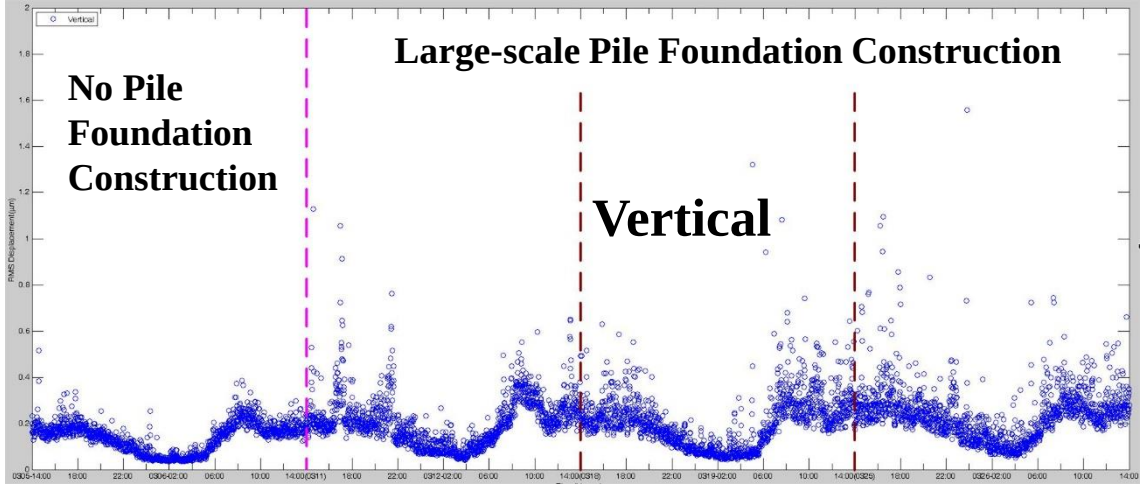

Horizontal
BPM Horizontal
Ground Horizontal
RMS Displacement(μm)
Time(hh:mm)
Mon.
Tues.
Wed.
Thurs.
Fri.
Sat.
Sun.

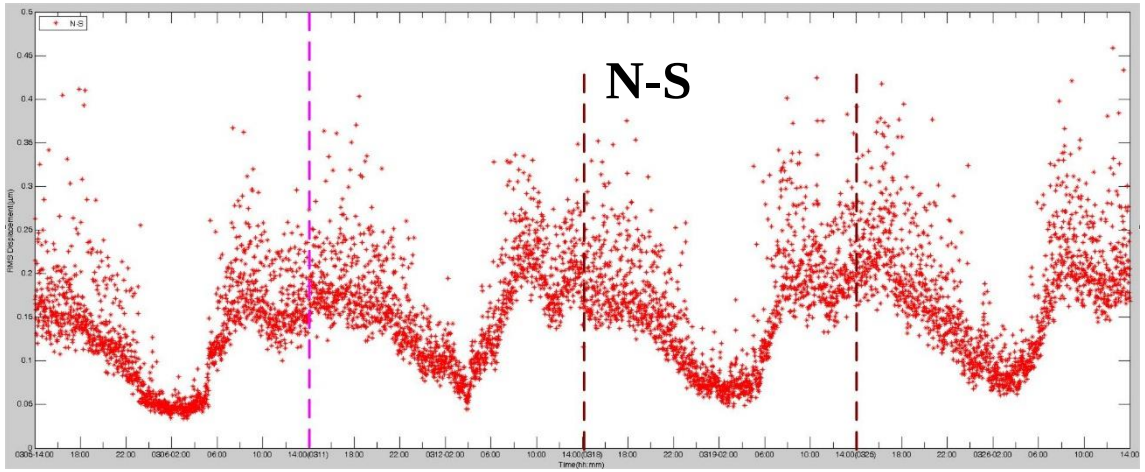
Ground Vibration Monitoring for SXFEL Construction at SSRF

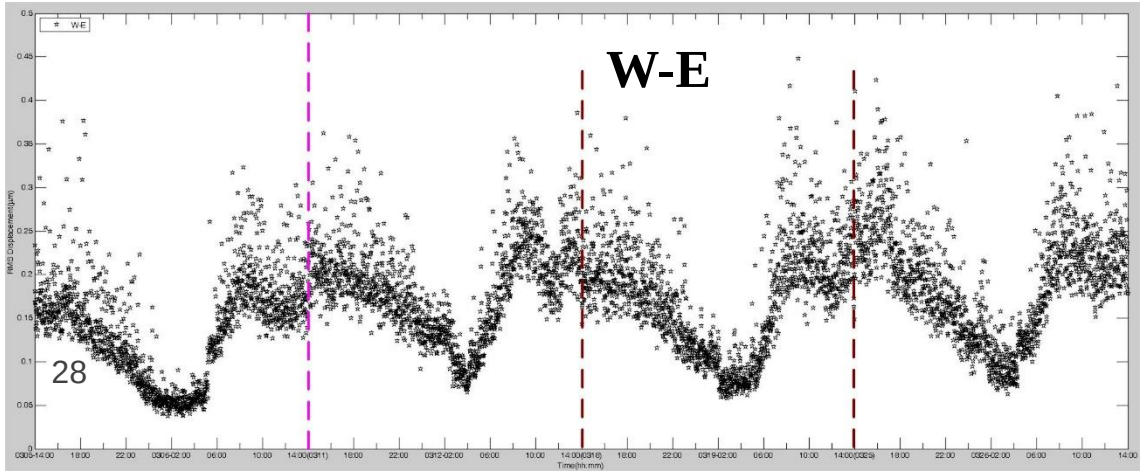
➢**SXFEL-TF Construction Schedule**

Dec. 30,2014 -May 20,2015	Pile foundation construction
May 6, 2015 -Aug.2,2015	Surface foundation construction
Jul. 27,2015 -Oct. 27,2015	Construction of main structure
Oct. 27,2015-Mar. 2016	Construction of decoration engineering
Mar. 2016- Jan.2017	Equipment installation

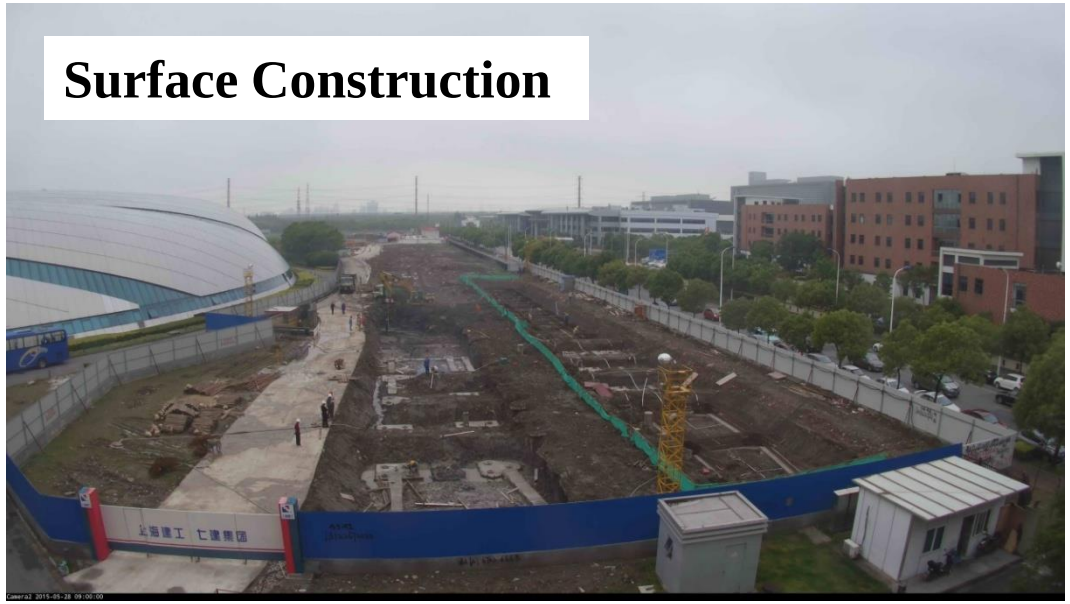
Comparison of vibration with and without pile foundation construction

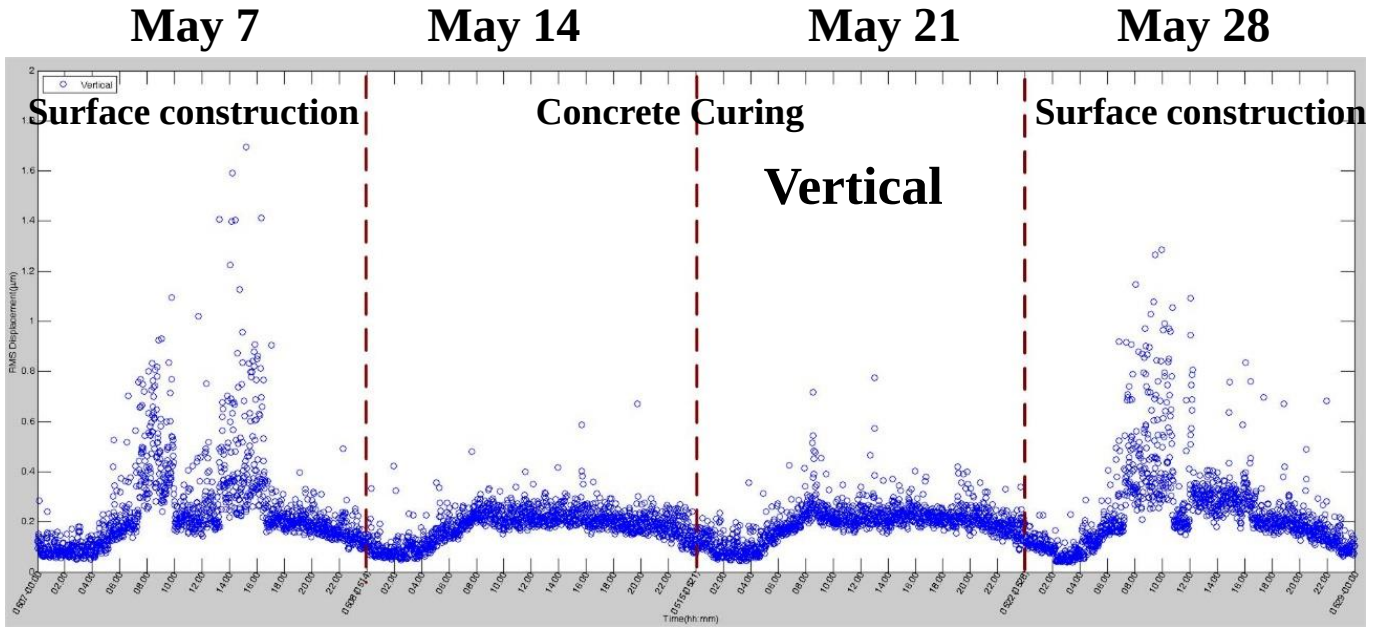


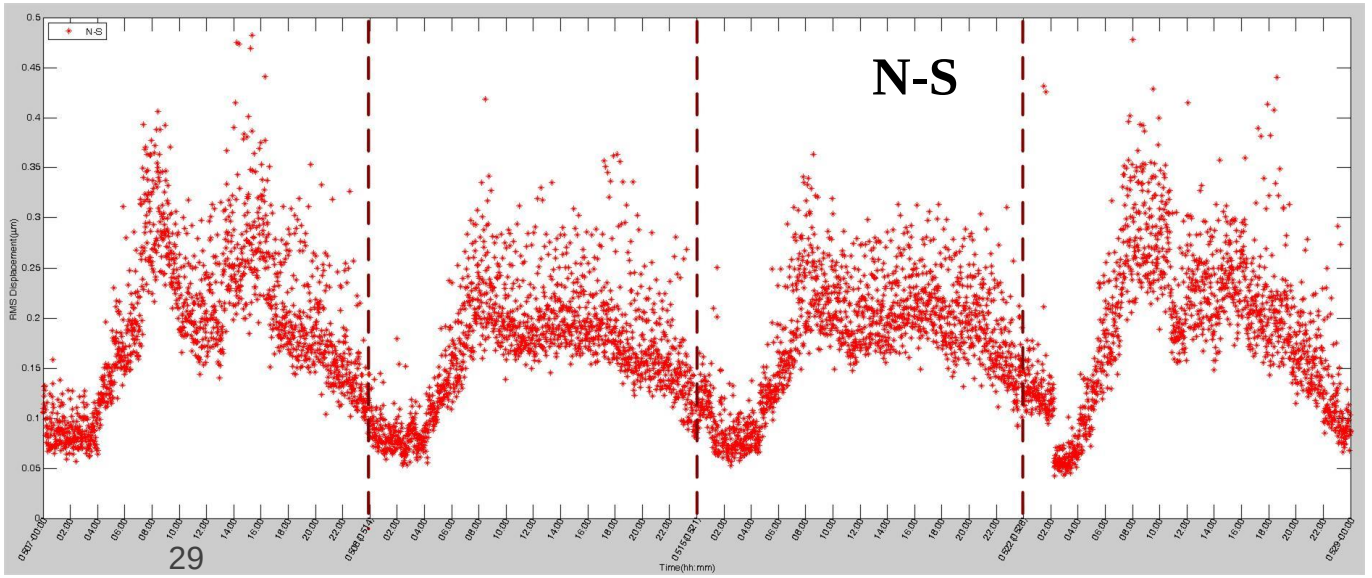




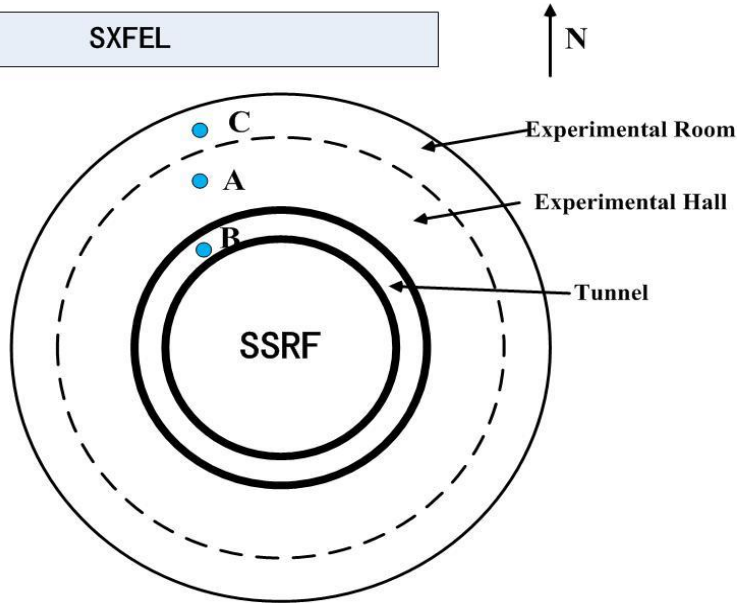
Comparison of vibration with and without surface construction

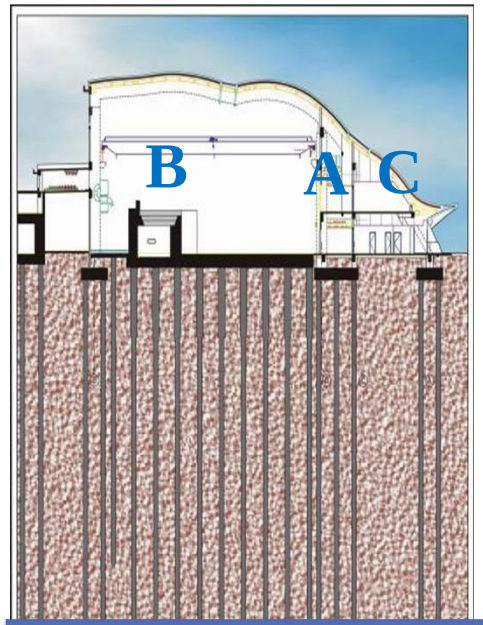




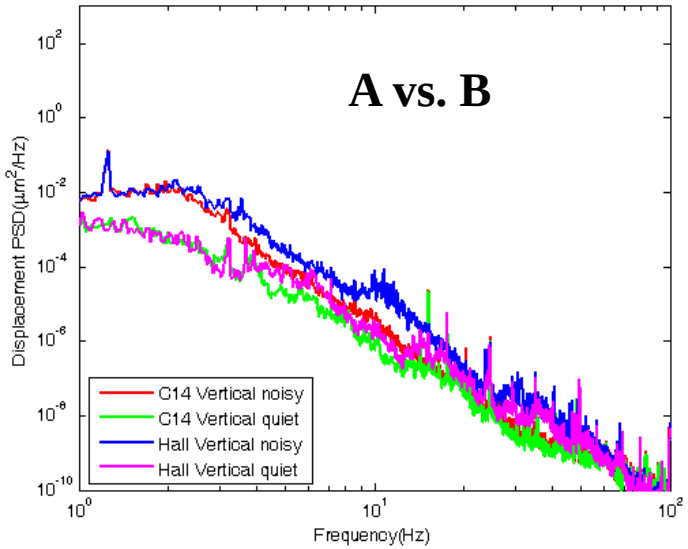


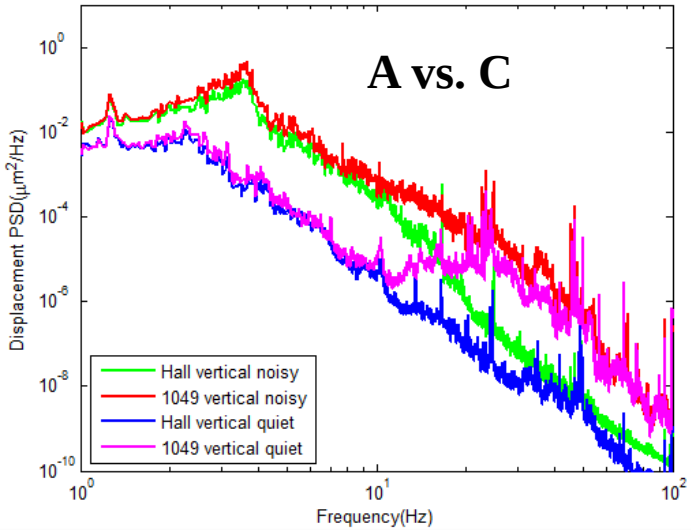
SXFEL





Comparison of vibration on different floor



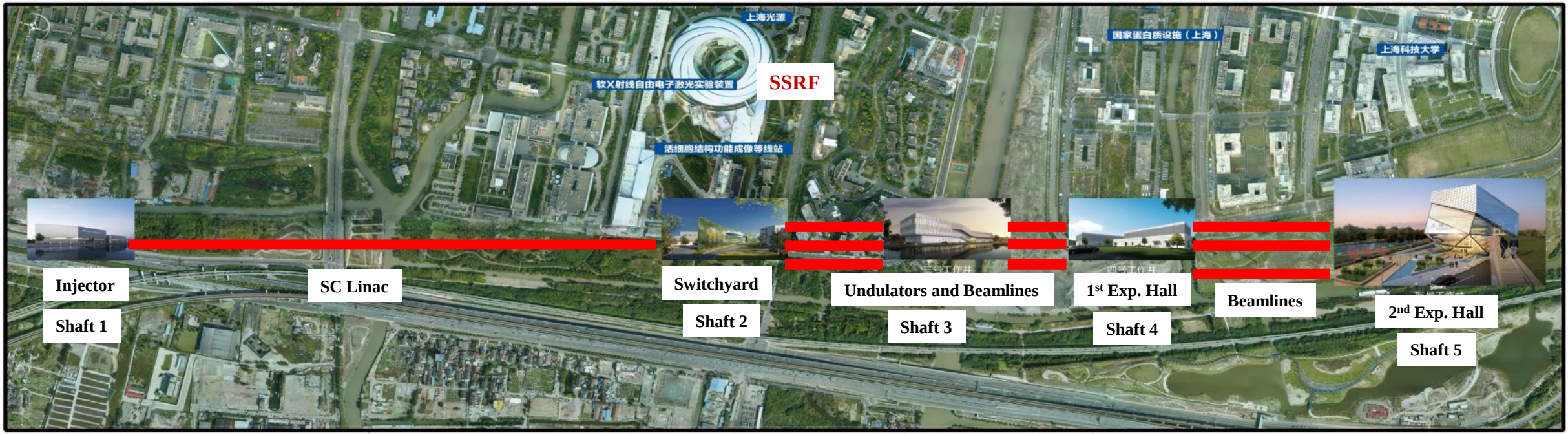


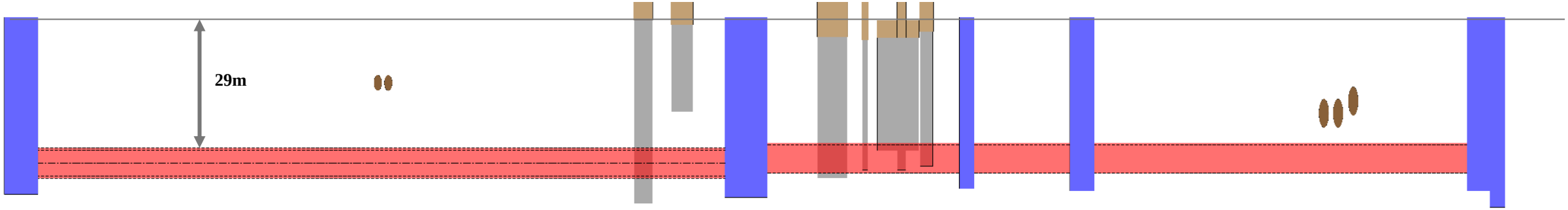
A:Foor of Experimental Hall
B:Floor of Tunnel
C:Floor of Room 1049

- **The floor of Tunnel and Hall has a better damping effect to vibration above 10Hz.**
- **Difference between noisy time and quiet time is relatively large whether in the vibration of Tunnel, Hall floor or floor of Room 1049, especially between 1 and 10Hz.**

RMS (1-100Hz)	Noisy Time			Quiet Time		
	Tunnel	Hall	Room 1049	Tunnel	Hall	Room 1049
Vertical	420.4 nm	441.8nm	612.6nm	107.3 nm	110.9nm	126 nm
N-S	231.2nm	234.7nm	239nm	102.7nm	105.8nm	109.7nm

SHINE (Shanghai HIgh repetitioN rate and Extreme light facility) Project



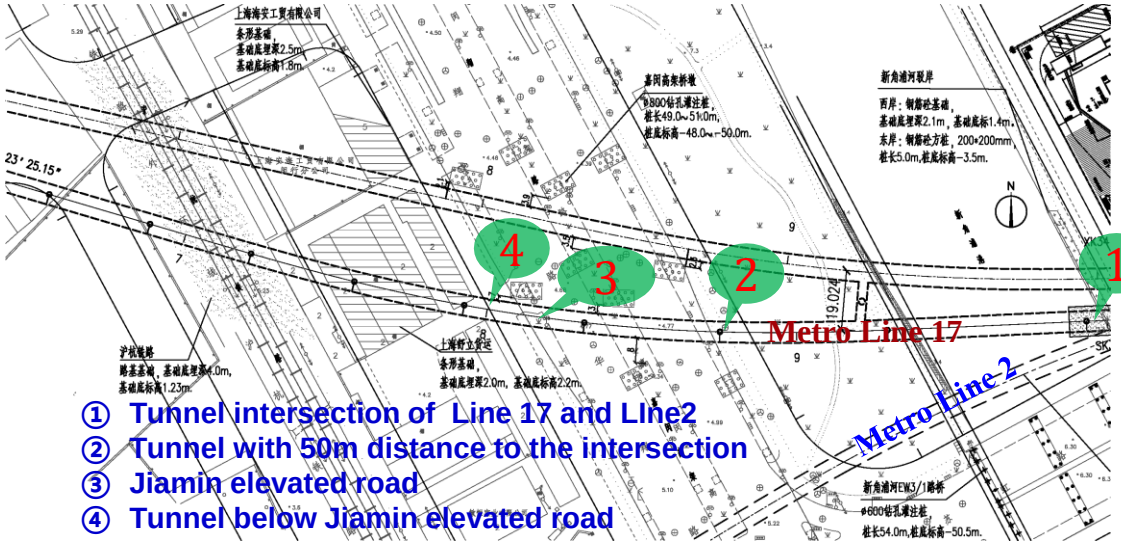


- 2018-2025
- 3.1 km length, 29m underground
- 8GeV CW Linac, 3 FEL undulator lines, 3 beamlines and 10 end-stations

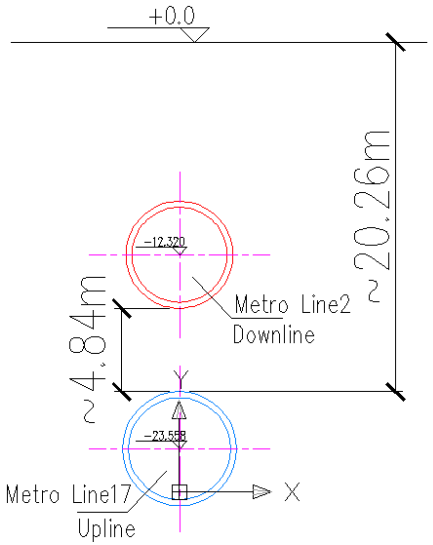
Vibration test at Similar Tunnel

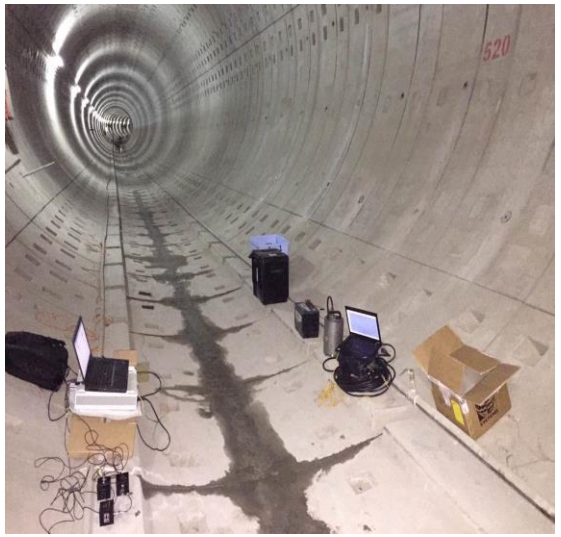
Goal:

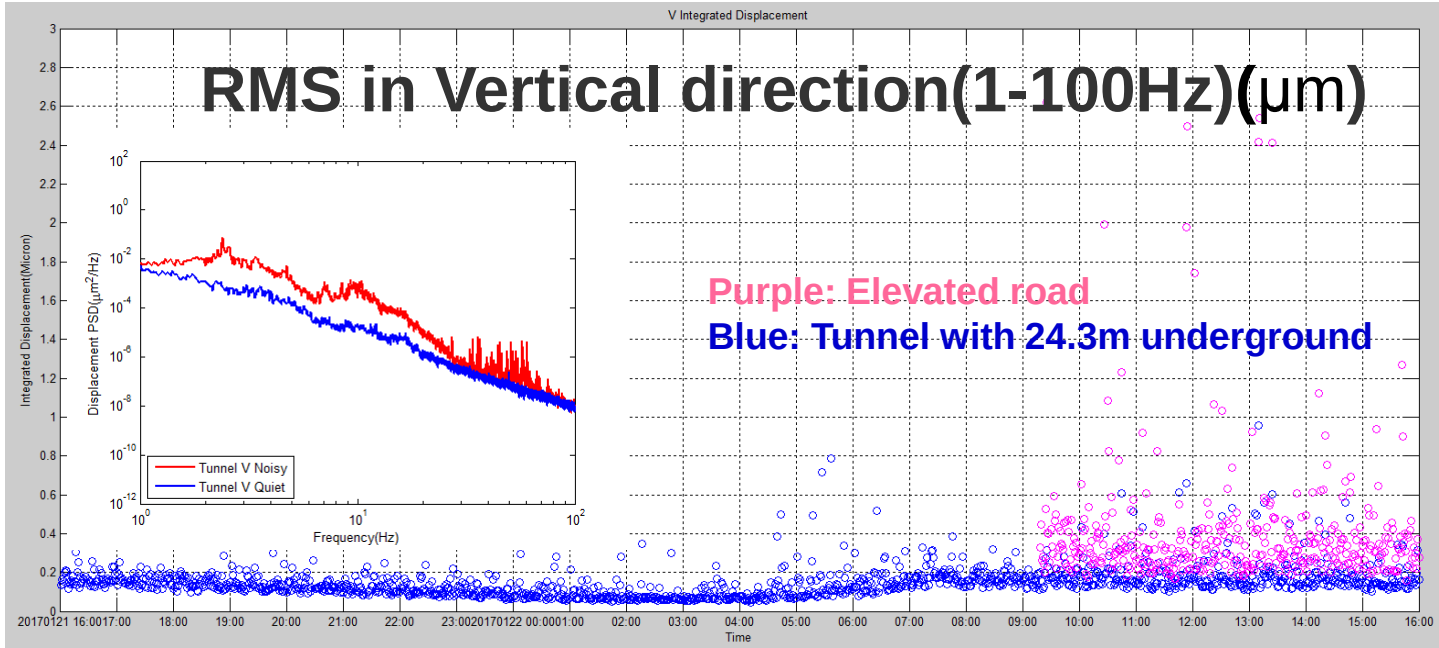
1. Get tunnel vibration 24m under ground.
2. Compare the influence of metro train and surface traffic



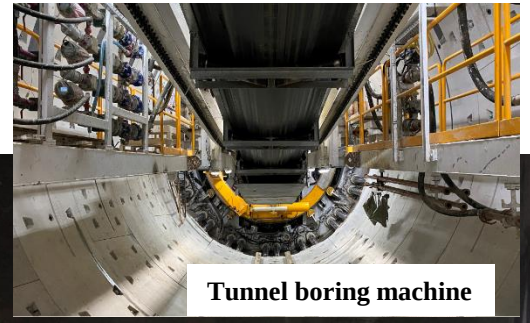
	20170121			RMS(1-100Hz) (μm)		
	Distance between Line2 and Line17	Depth	Time	Vertical	N-S	W-E
1	0m	24.8m	Service time at noon with metro passing	0.4378	0.5238	0.1879
			Service time at noon without metro passing	0.1767	0.1202	0.1426
			Non-service time at midnight	0.0754	0.0853	0.0794
2	50m	24.7m	Service time at noon with metro passing	0.2644	0.2219	0.1510
			Service time at noon without metro passing	0.1940	0.1279	0.2015
			Non-service time at midnight	0.0827	0.0946	0.0825







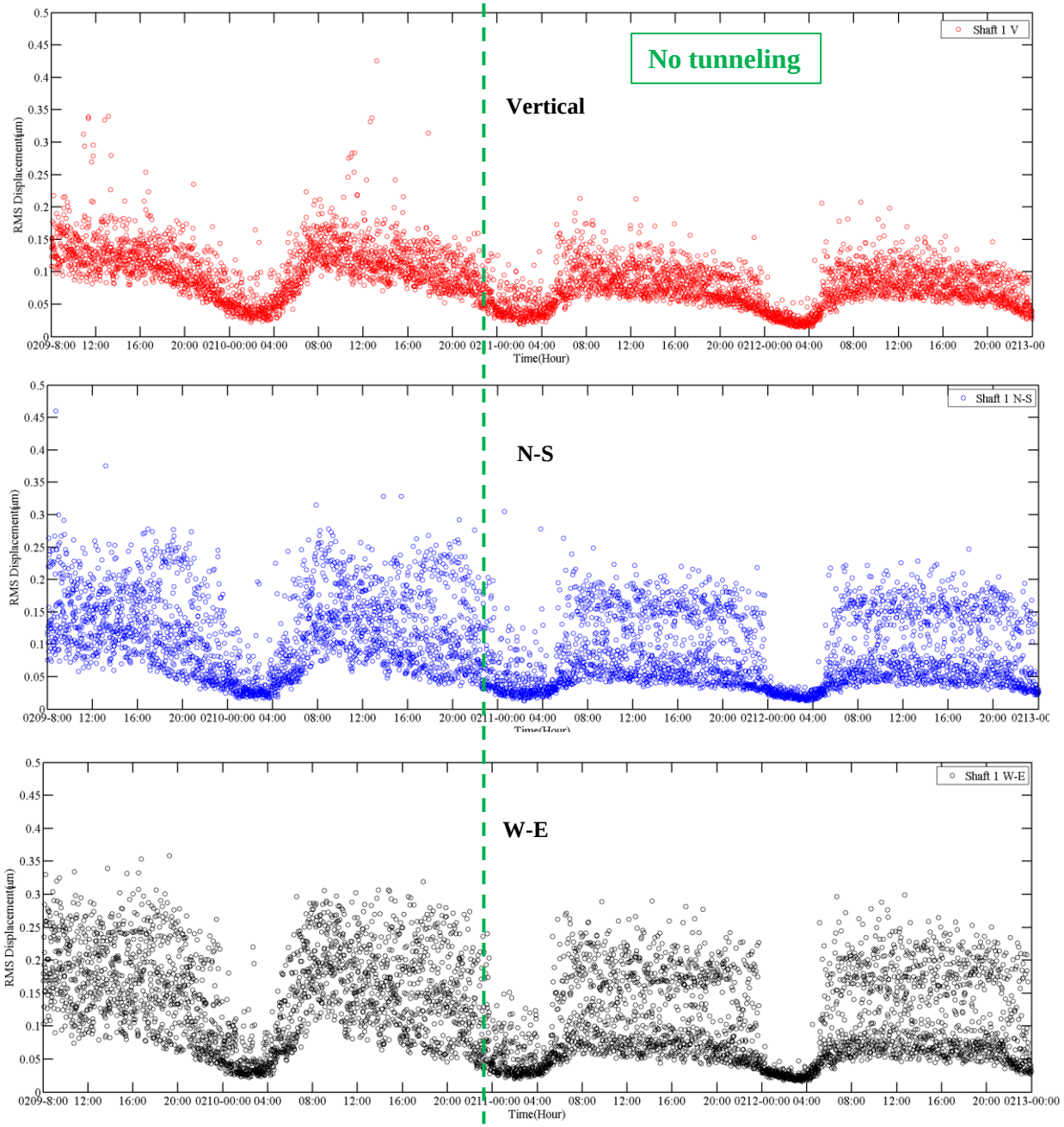
Vibration in Shaft #1



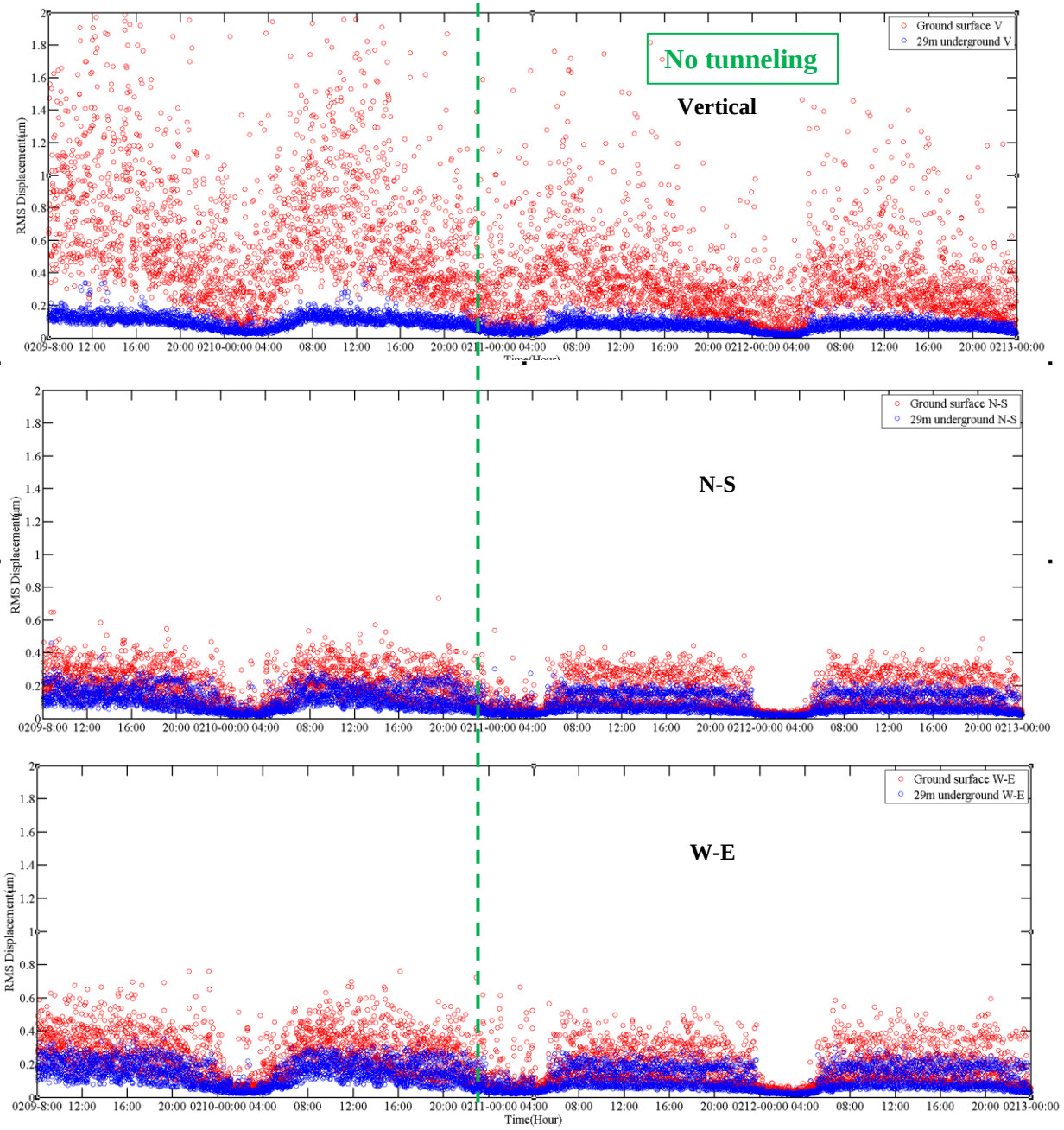
1 **Seismometer at 29 underground in Shaft #1**

2 **Seismometer on the surface ground**

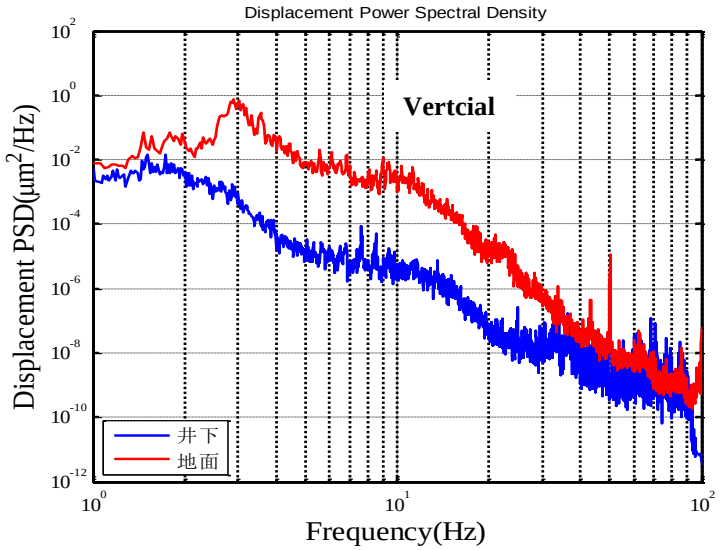
Vibration at 29m underground in Shaft #1

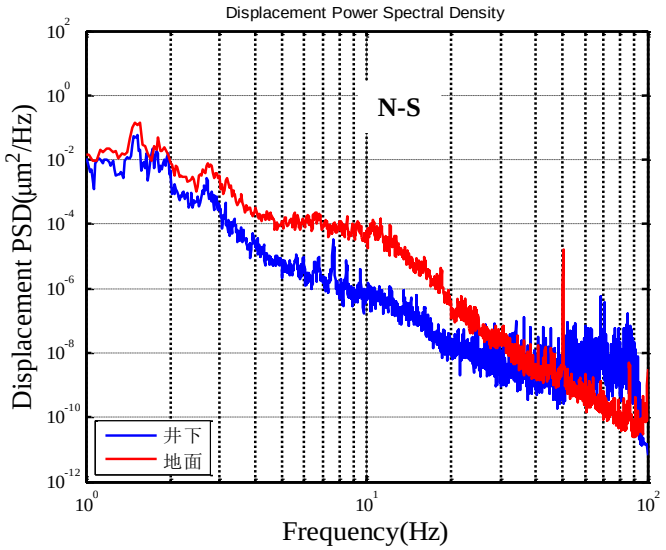


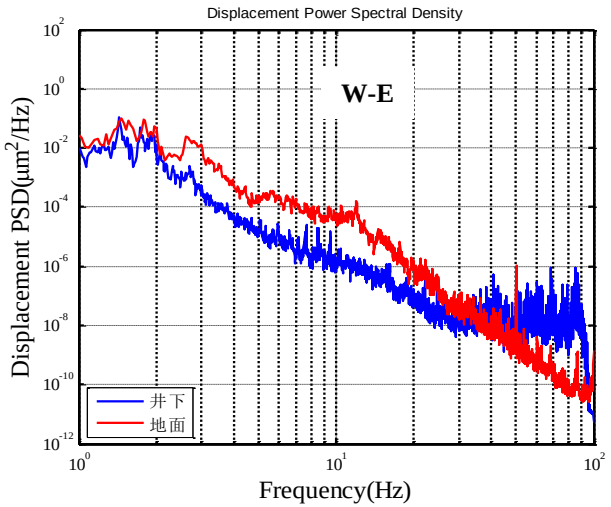
Vibration comparison between surface ground and shaft



PSD of surface ground and shaft1 in the daytime







- **Vibration at 29m underground in Shaft #1 when tunnel boring machine does not work**
  - **20-130nm RMS(1-100Hz) in the vertical direction**
  - **20-200nm RMS (1-100Hz) in the N-S direction**
  - **20-230nm RMS (1-100Hz) in the W-E direction**
  - **Note: The minimum RMS 20nm (1-100Hz) is measured at midnight during spring festival.**
- **Compared with surface ground, vibration at 29m underground in Shaft #1 decreases greatly in the daytime.**
  - **Drop to about 20% in the vertical direction**
  - **Drop to about 50% in the N-S direction**
  - **Drop to about 50% in the W-E direction**

6 Summary

Summary

➢**Some strategies were adopted in the design of the slab and the building to suppress the higher vibration of the site.**

➢**Conventional facility was located outside of the main building to isolate the vibration generated by mechanism.**

➢**A long-term vibration monitoring system is built to monitor the ground vibration of SSRF.**

➢**Detailed measurements are performed along with the SXFEL and SHINE project.**

➢**More investigation and optimization for the mechanical engineering are doing along with the operation of the accelerator to realize the beam stability goal for SSRF.**

THANKS