LCLS NEH floor thermal deformation and mitigation plan

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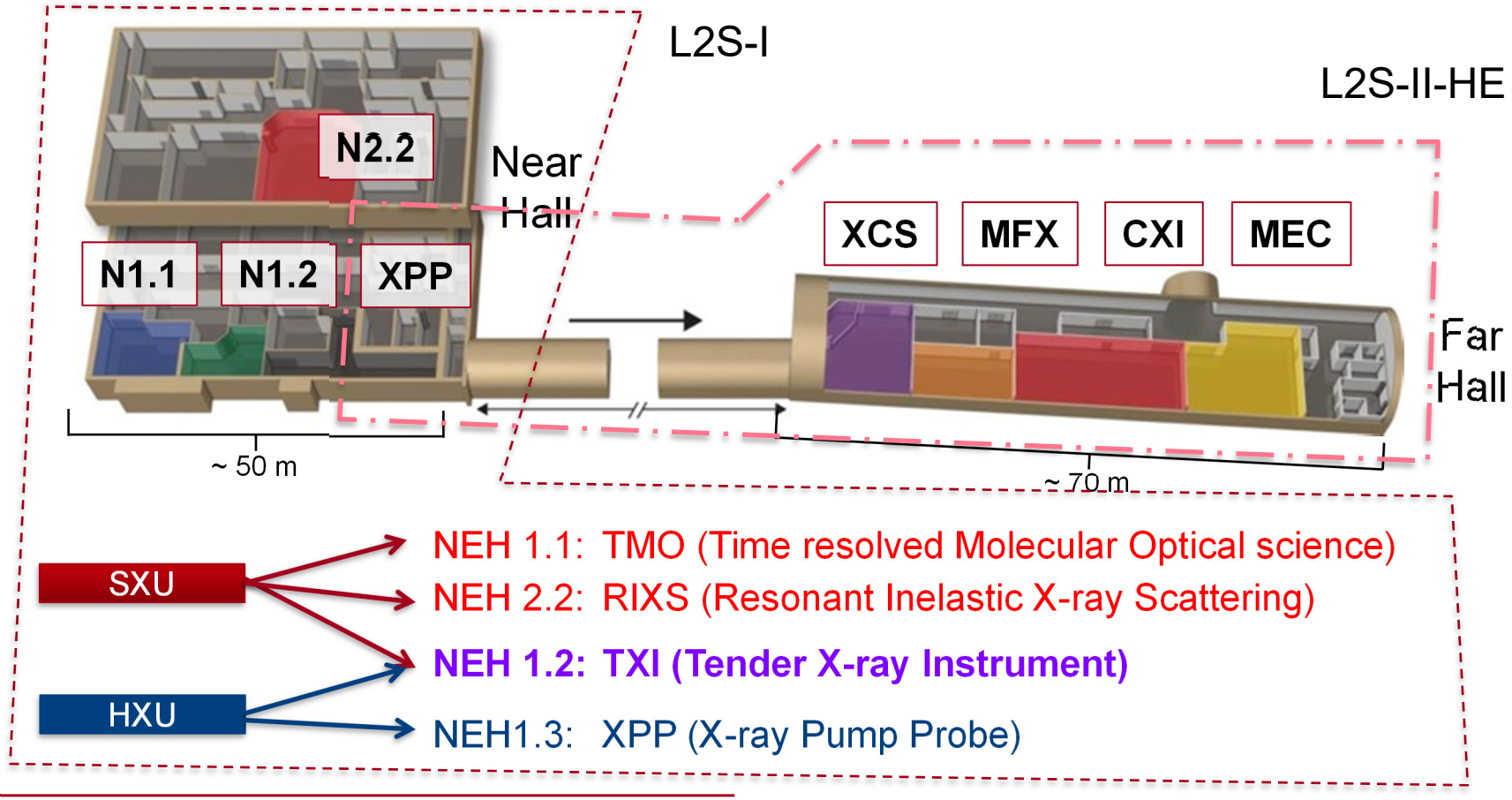
LCLS-II, L2S-I, LCLS-II-HE

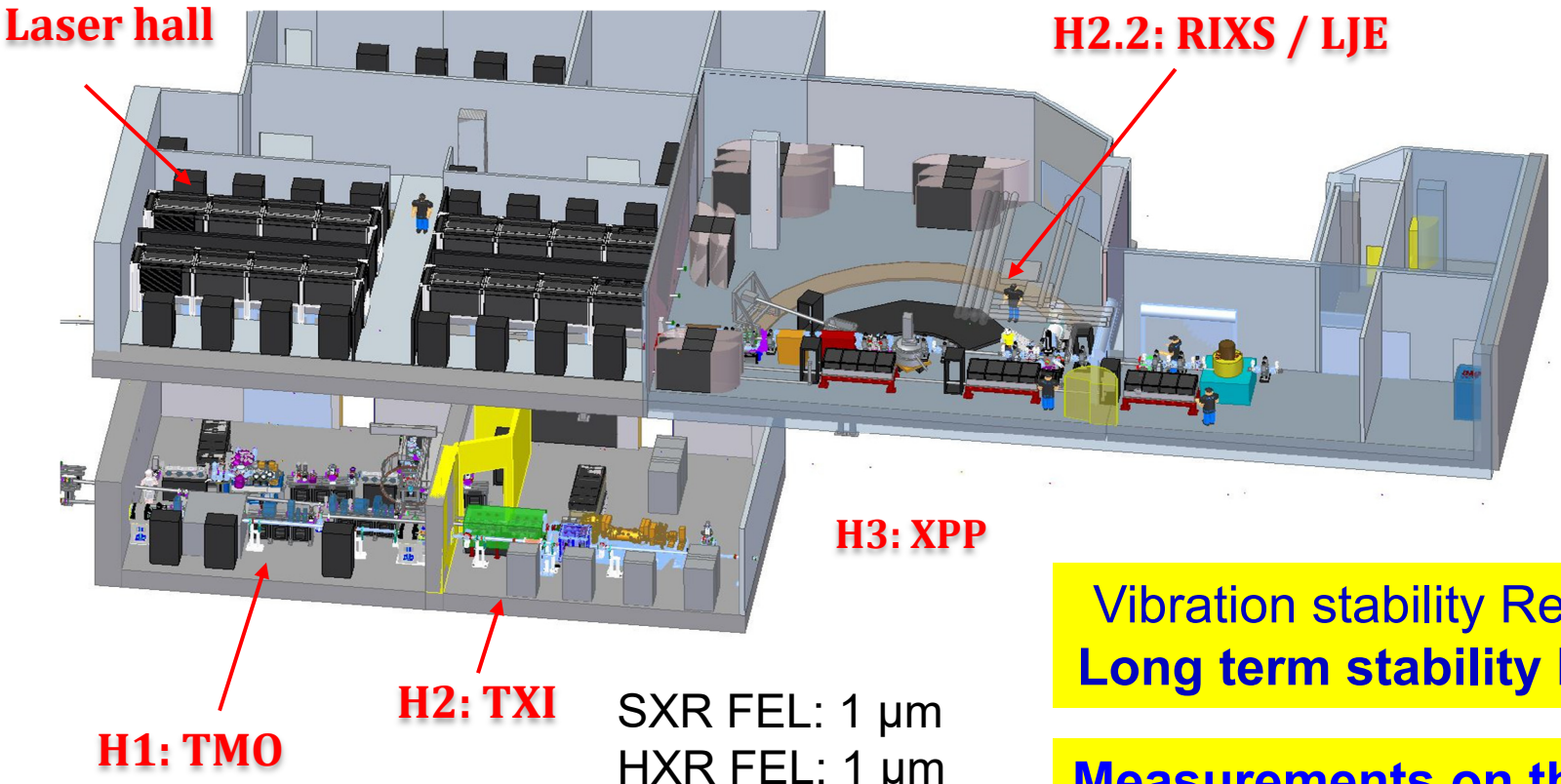
- **LCLS-II: SC Linac driven MHz high repetition rate FEL**
- **L2S-I (LCLS-2 Strategic Initiative) program: Redesign Near Experimental Hall (NEH) instruments**



LCLS Near Experimental Hall (NEH)

Laser beam spot.: 5 μm
Laser timing stability Req.: 3 μm (10 fs)

Grating Mono Exit Slit Ap.: 5 μm



SXR FEL: 1 μm
HXR FEL: 1 μm

FEL focused spot: 0.3 μm
Laser spot: 5 μm

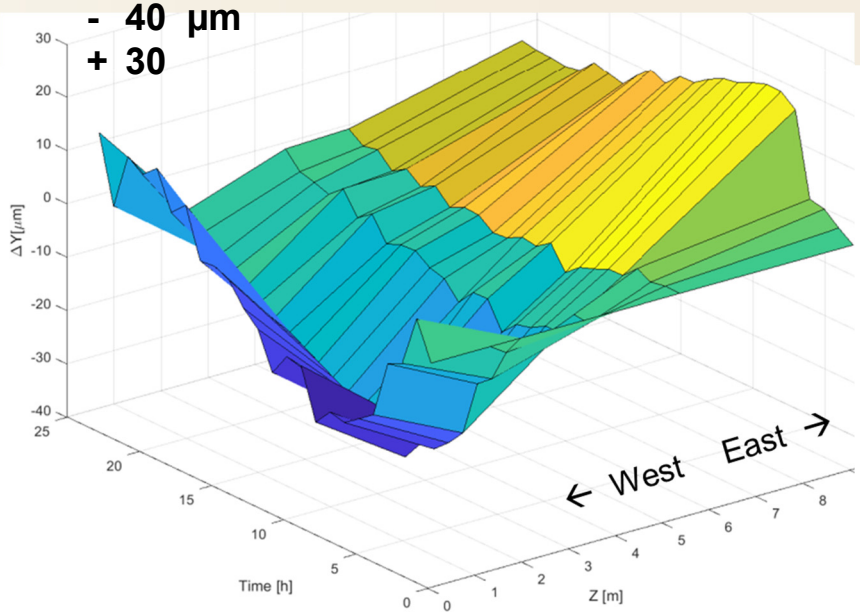
Vibration stability Req.: **0.1 μm**
Long term stability Req.: 1 μm

Measurements on the floor :

- **Vibration: ~ 0.03 μm (OK)**
- **Deformation:~ 20~40 μm, period of 24 hours**

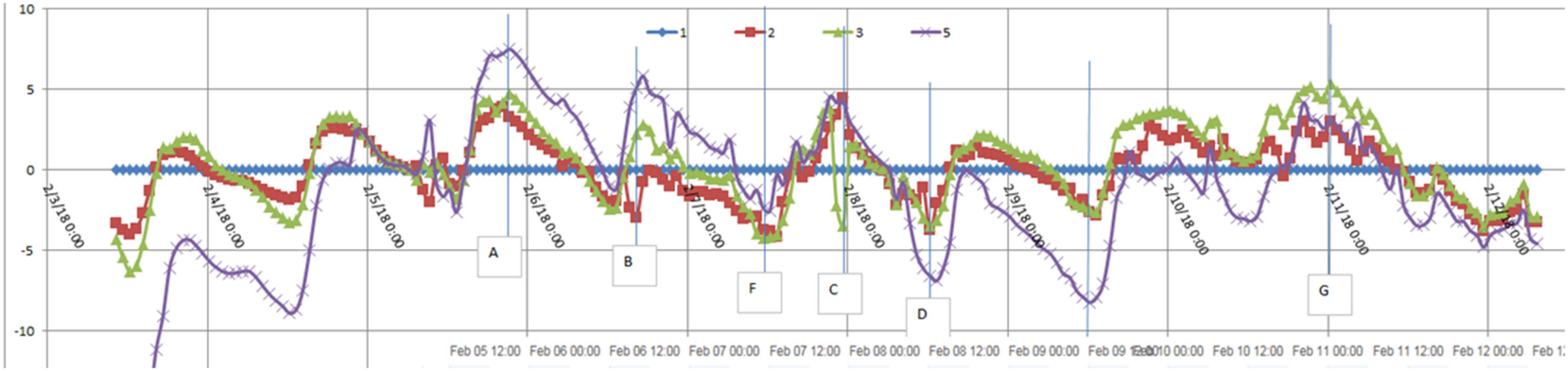
Some measurement results in NEH1.1

Lase Interferometer Measurements



- **Problem !!**
- **Why**
- **How to solve it**

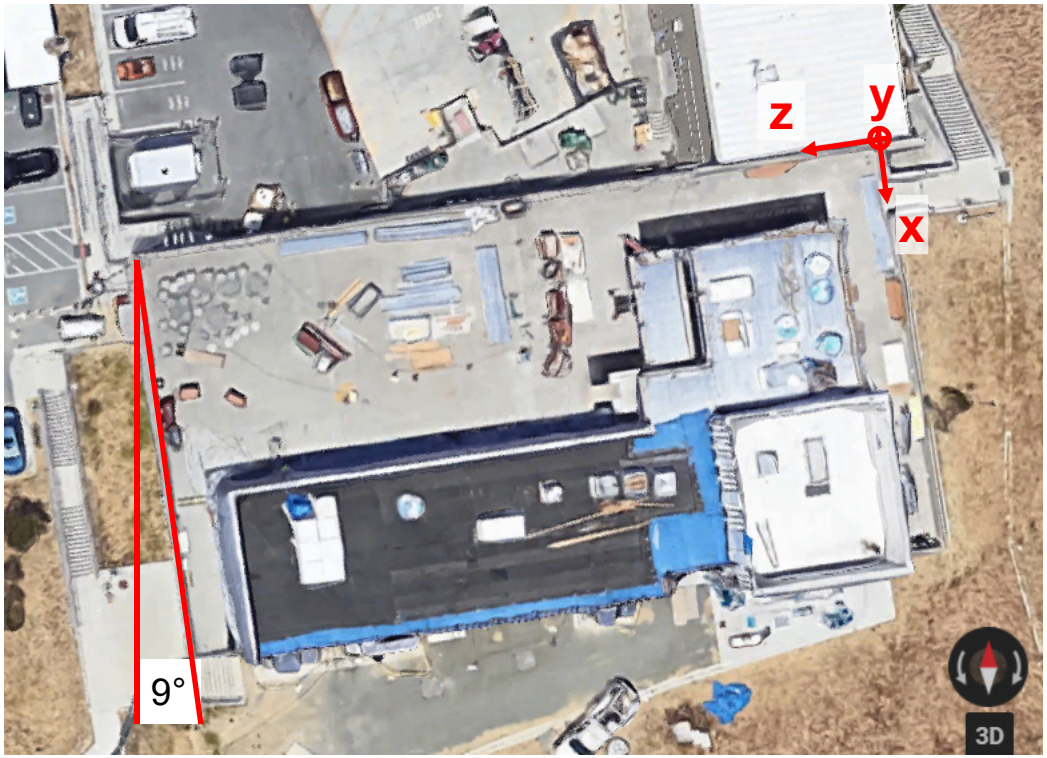
HLS Measurements



NEH building

North

West



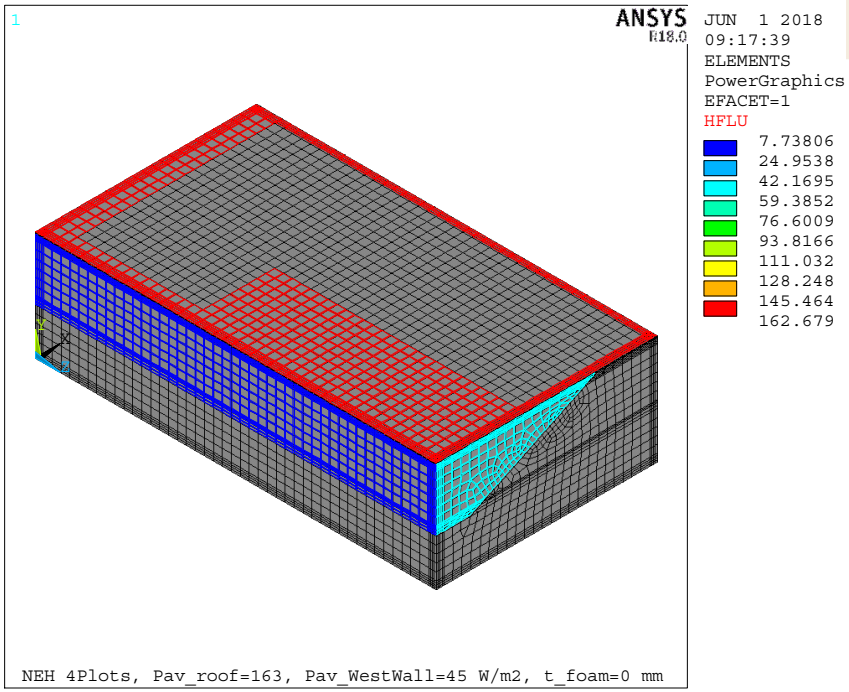
Lz=47.5 m
Lx=26.2
Ly=12.7

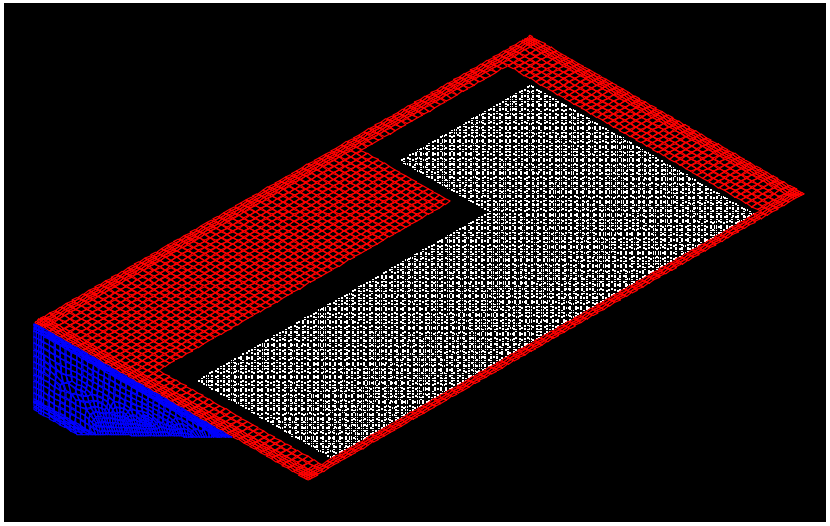
t_roof=0.6
t_mid=0.91
t_thin=0.3
t_floor=0.914

t_wall=0.9

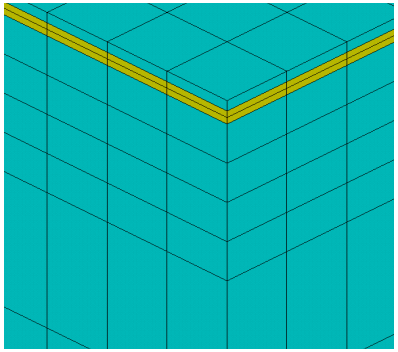
Solar Radiation absorption coefficient by Concrete	60%

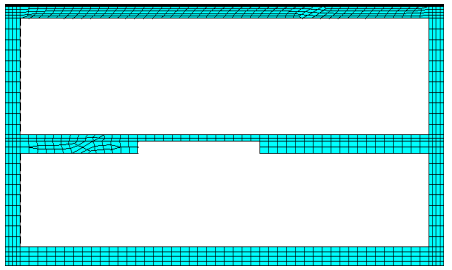
FEA model of NEH



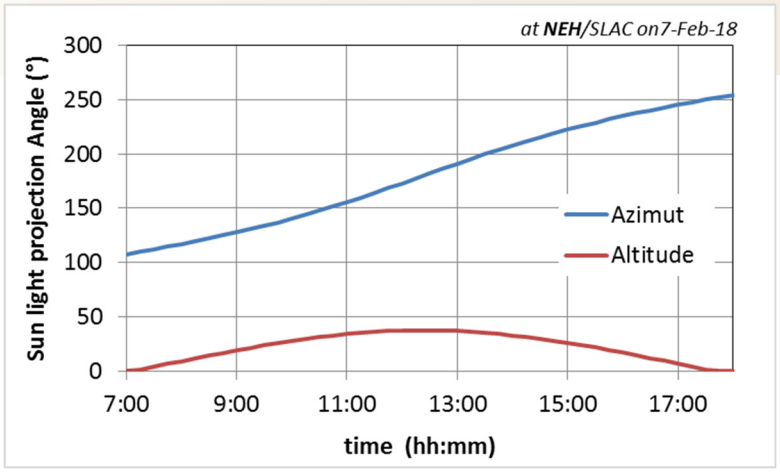


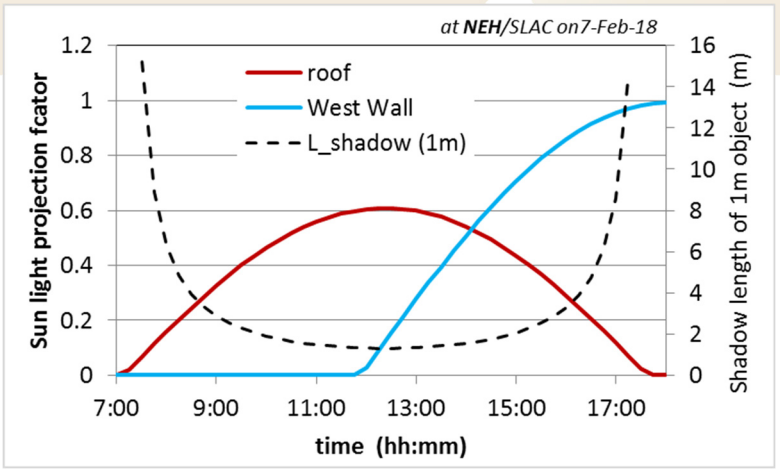
- Monolithic structure
- Footprint of Mechanical room
- **Footprint for solar power projection**
- Roof insulator (10 or 20 cm, k=0.04 W/m^2/°C ➔ R15, R30) + 4-cm Slab
- Thermal insulation by soil
- Time-dependent Pure thermal deformation





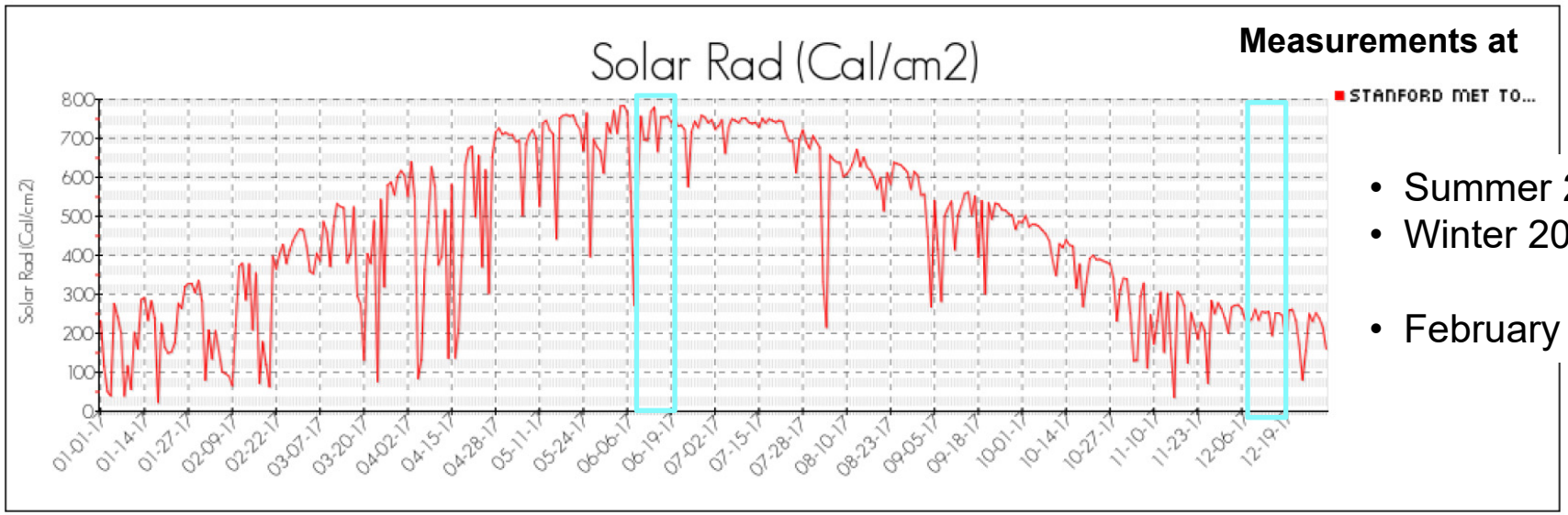
Solar light projection





- **Azimuth angle**
- **Altitude angle**

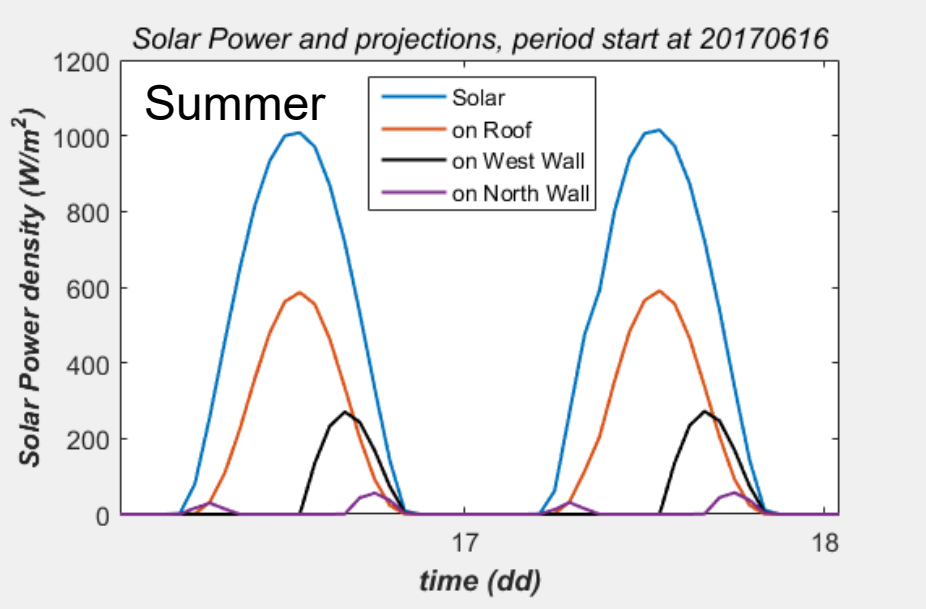
versus time (day, hour) → **Projection factor versus time**

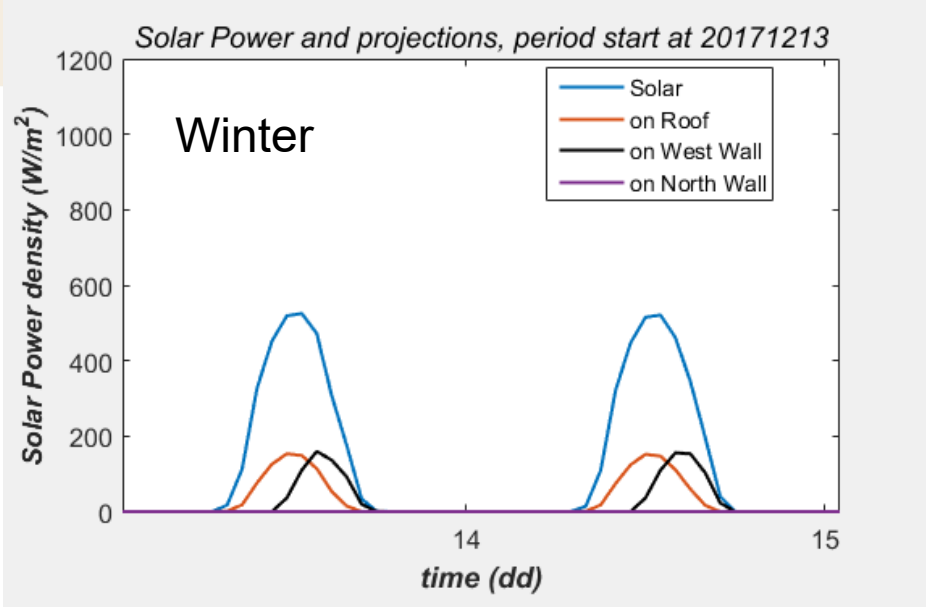


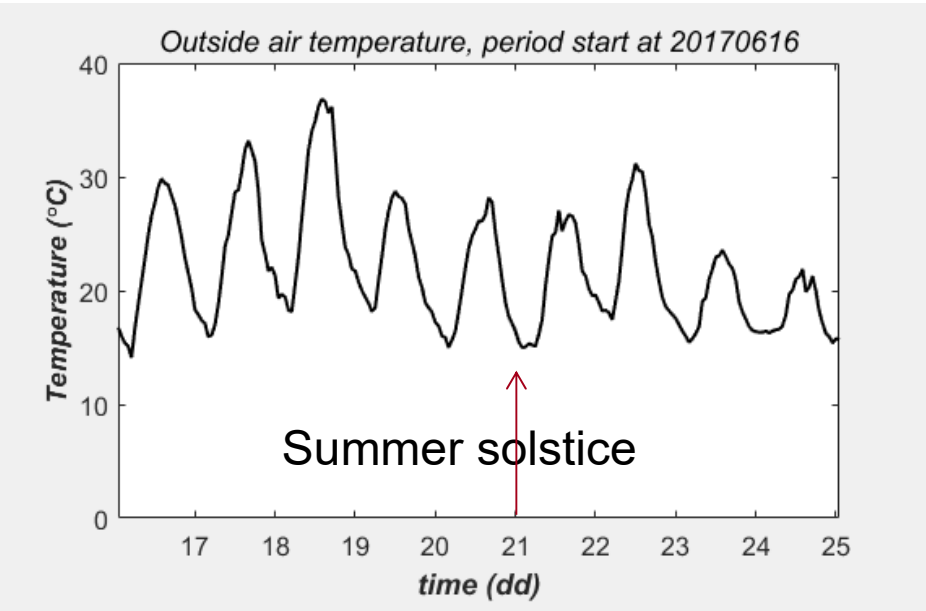
- Summer 2017
- Winter 2017

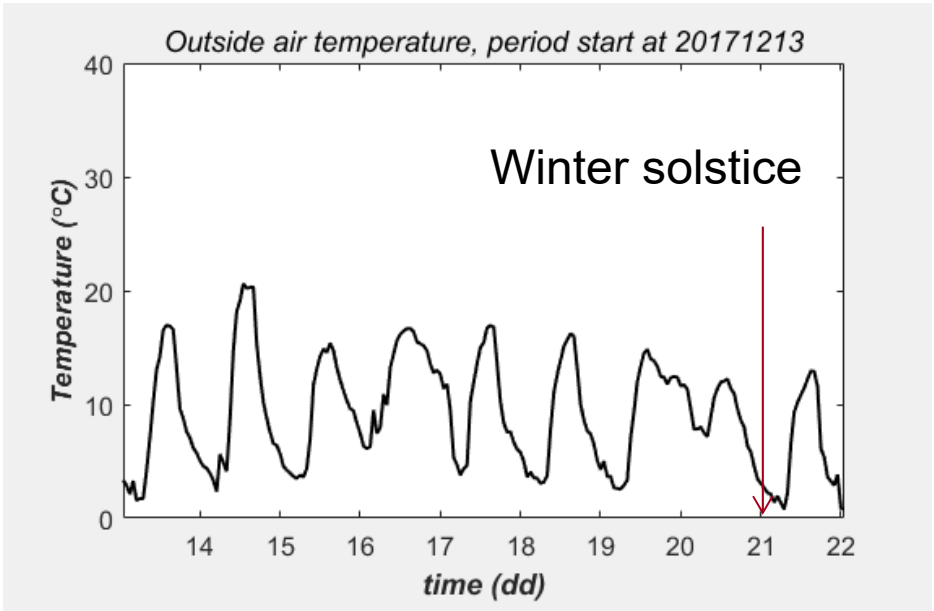
- February 2018

Solar power density, outside air Temperature

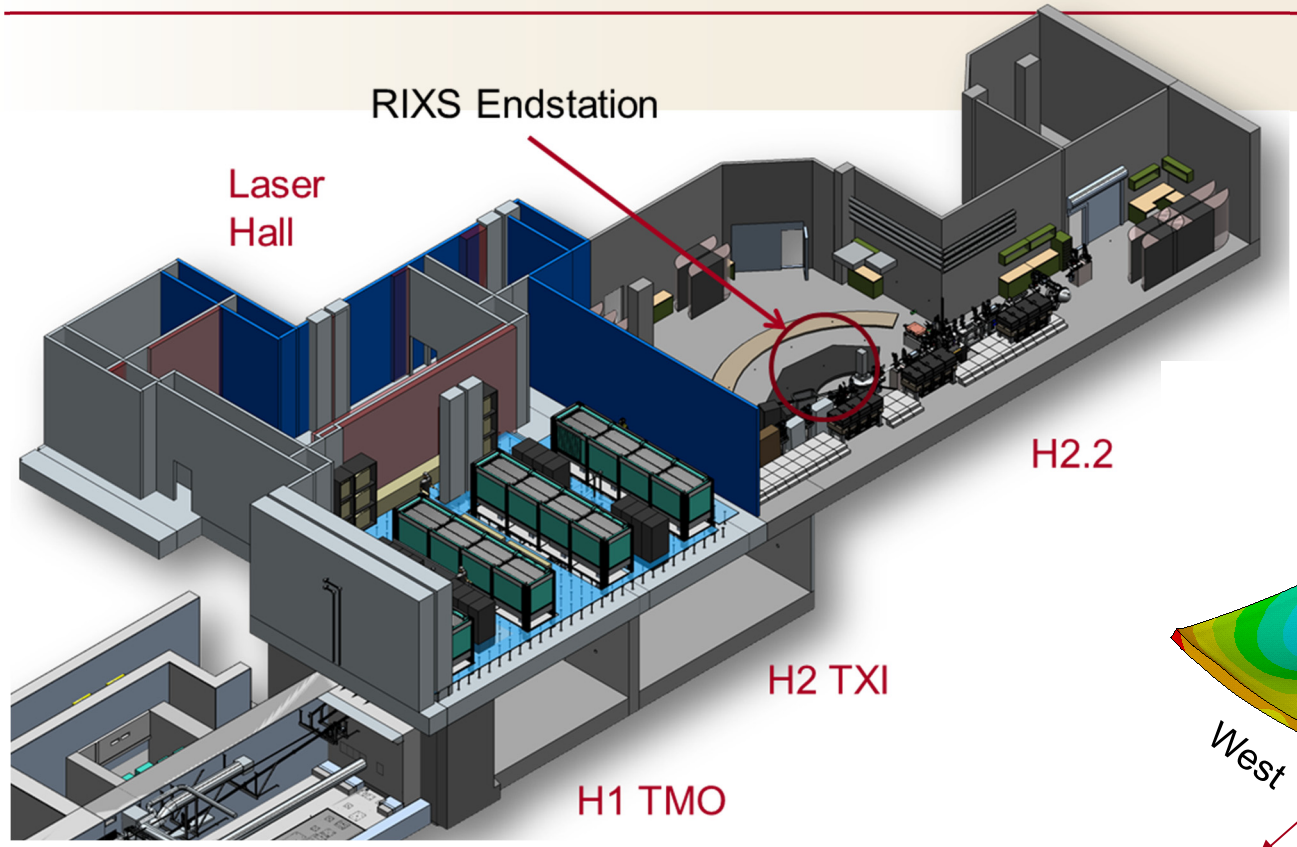


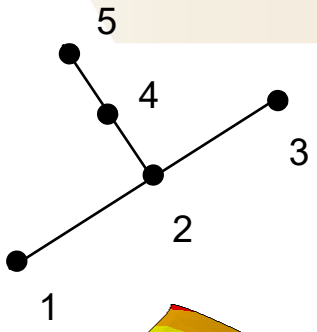


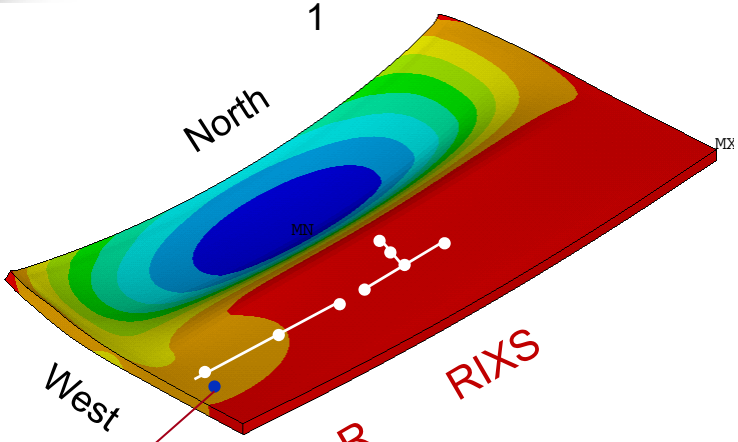




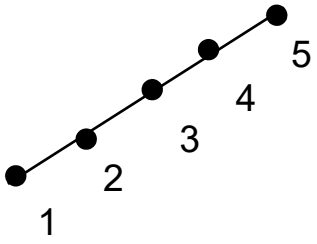
Floor displacement calculation points

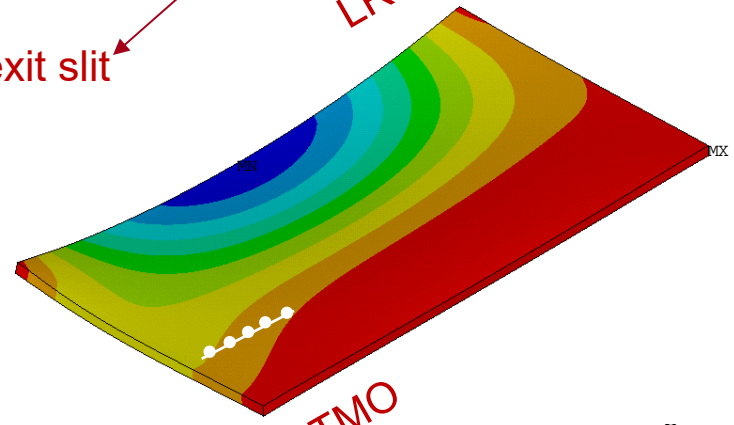


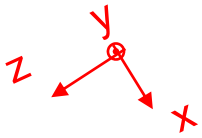




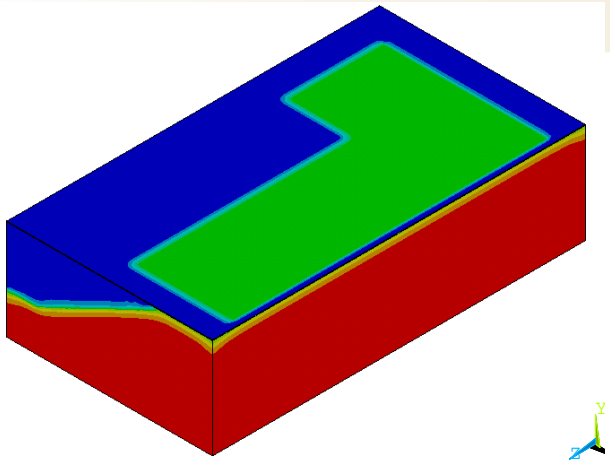
2.2 mono exit slit

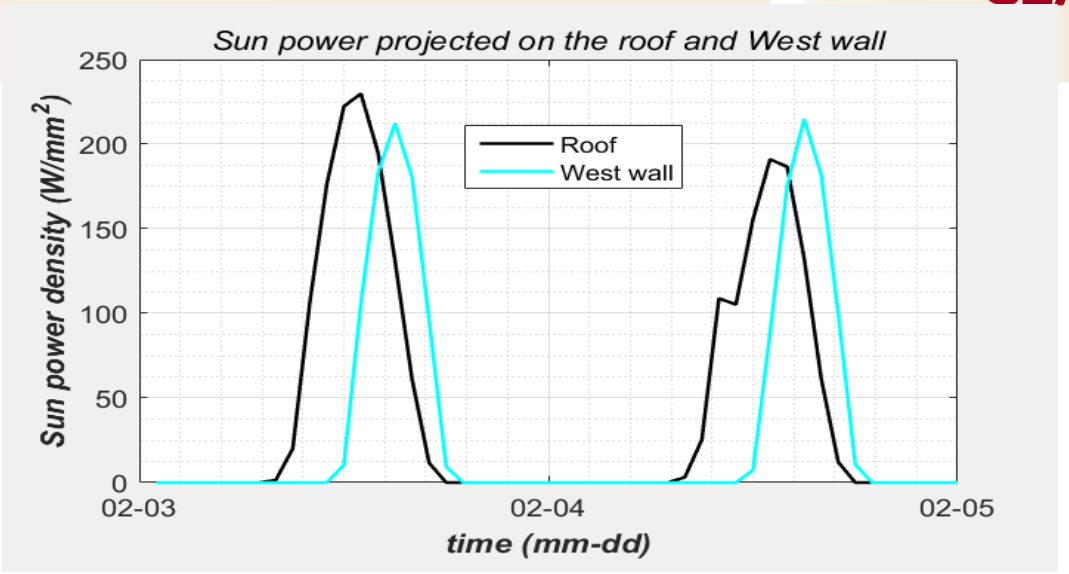




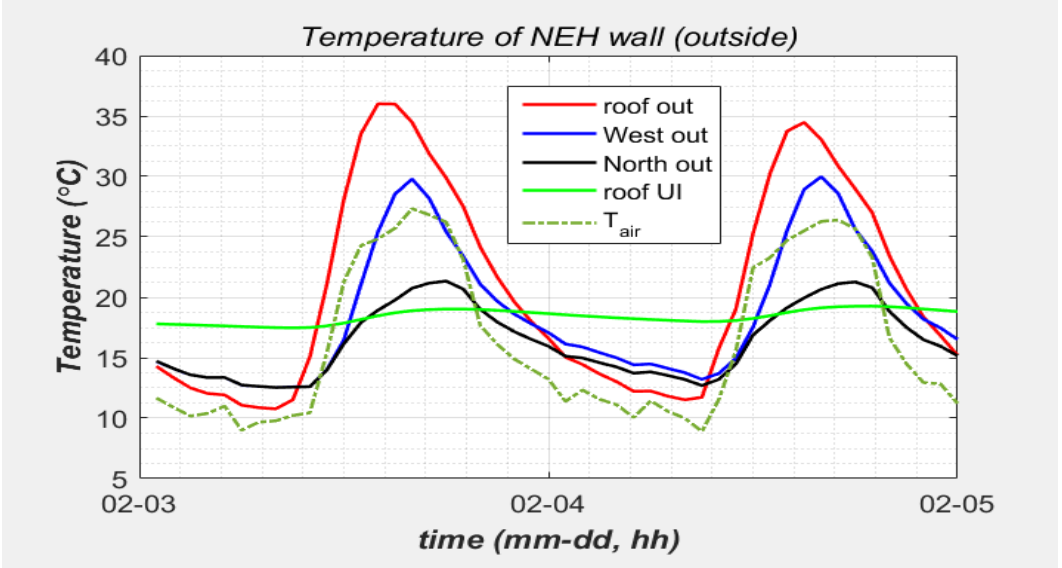


Temperature over 2 days on Feb.



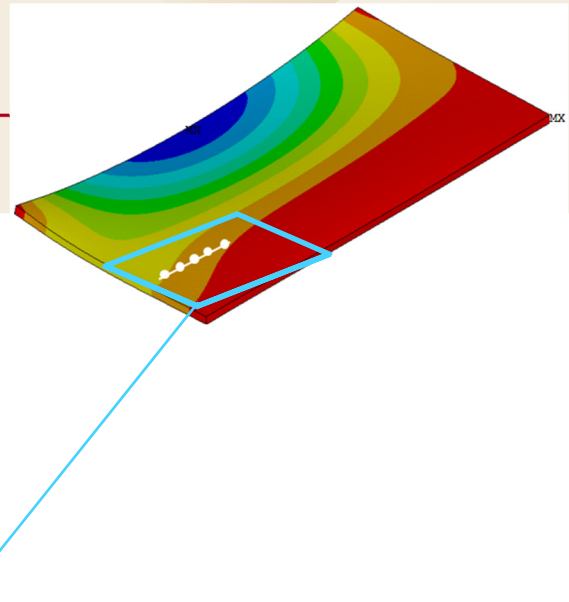


Temperature follows Sun light power projected on the roof and West wall



Solar power projection and air temperature (T_{air}) are measurement results

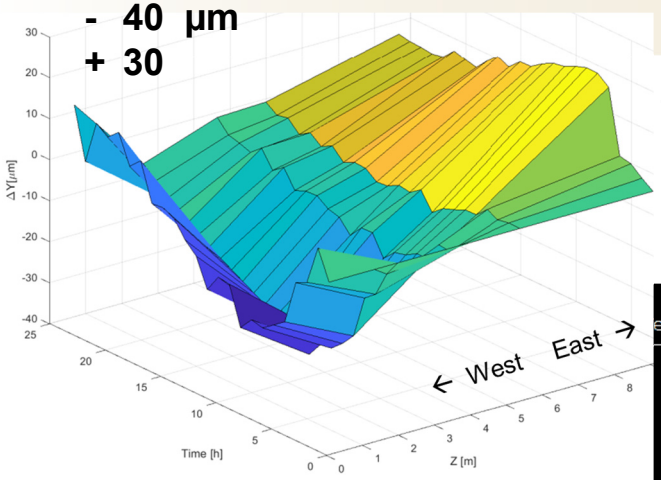
TMO floor displacement (baseline)



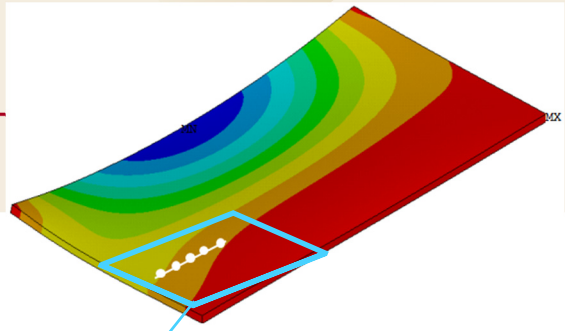
TMO floor Sub-Basement simulation results

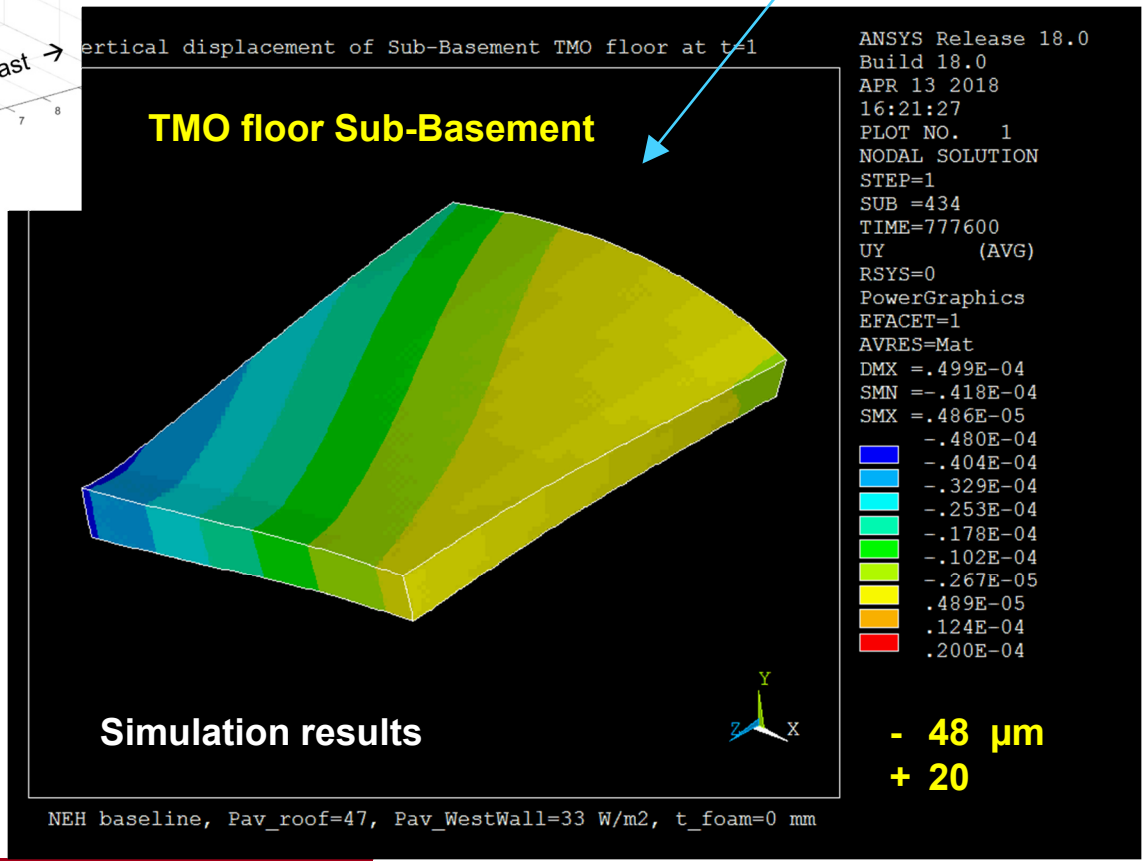
- 48 µm
+ 20

TMO floor displacement (baseline)

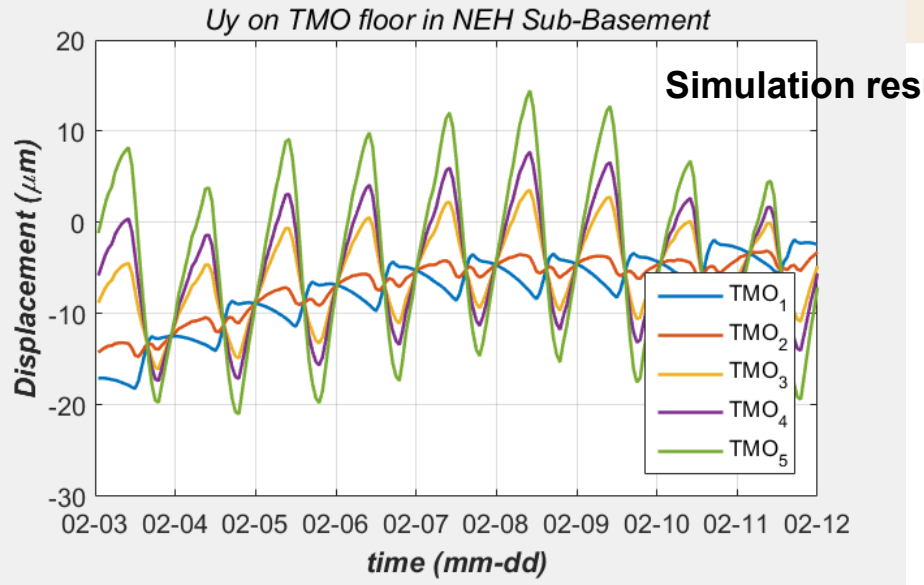


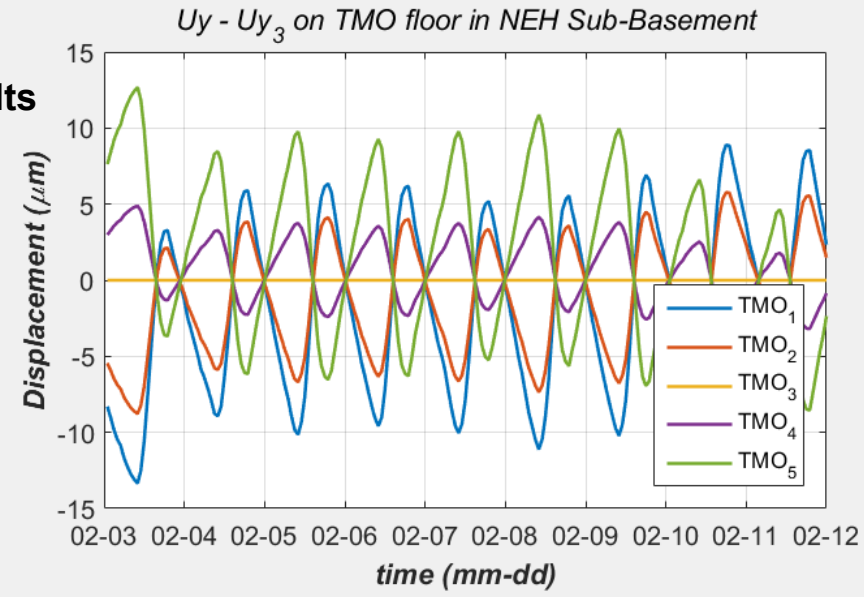
Measurements at TMO

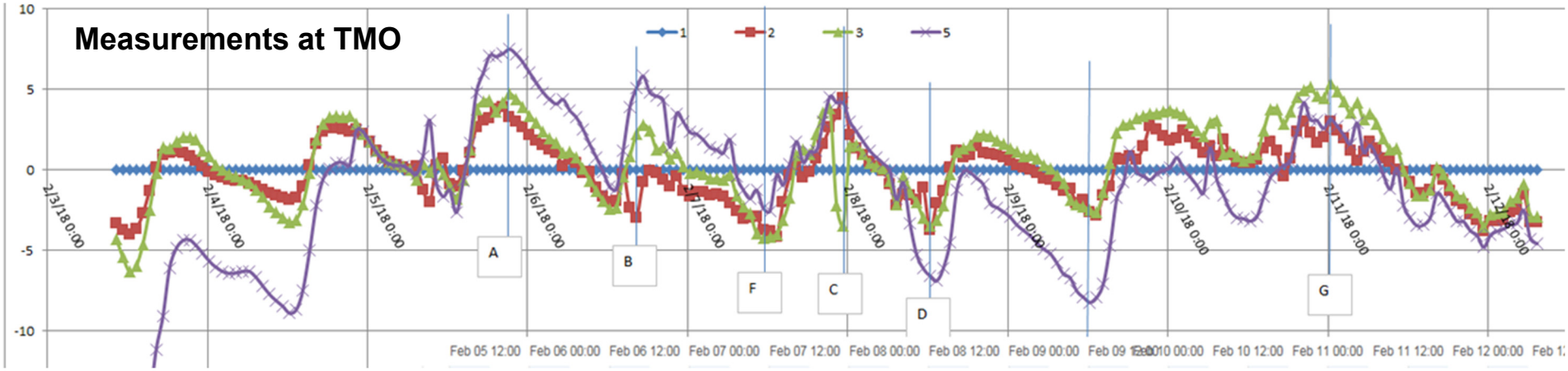




TMO floor displacement over 9 days in Feb. 2018

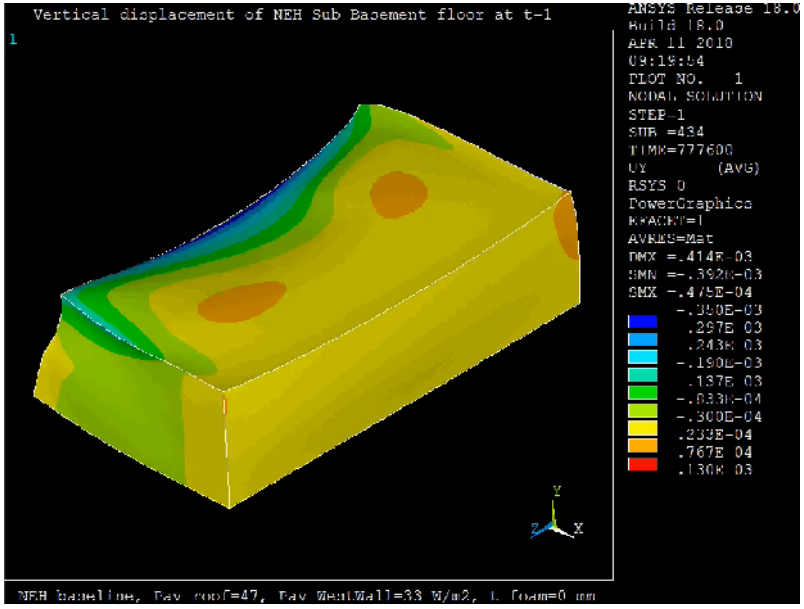




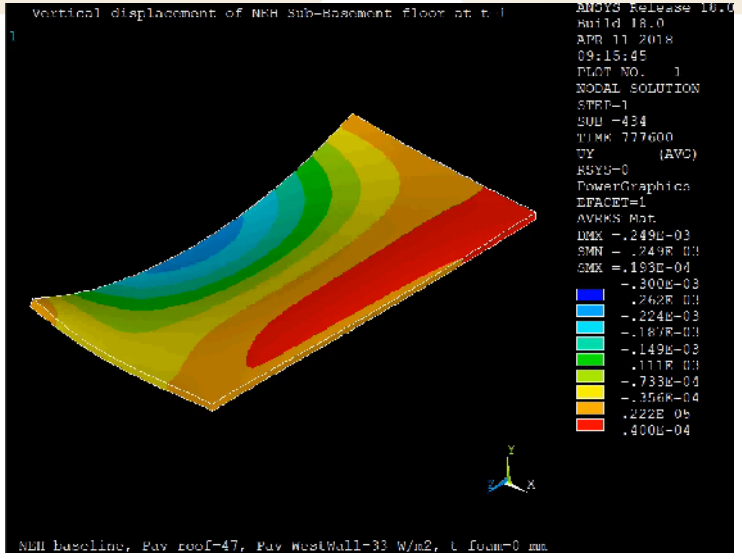


FEA Results: displacement (baseline)

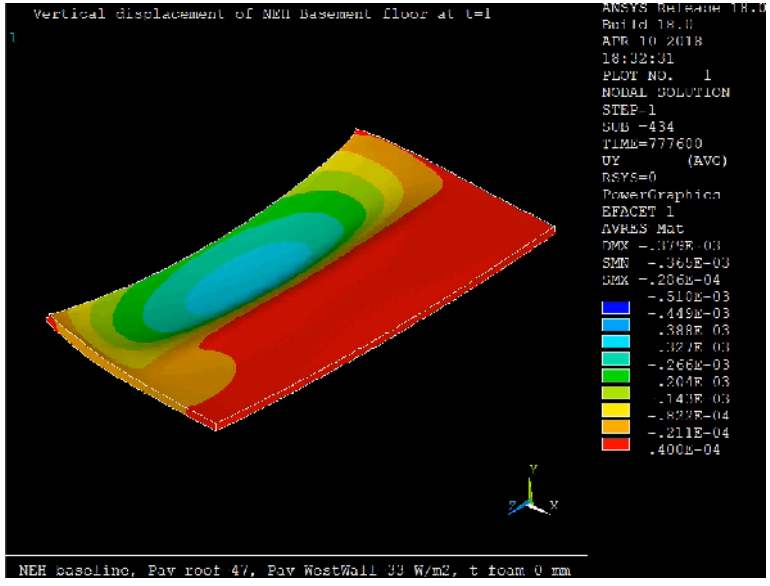
NEH building
- **350 μm**
+ **130**



Basement
- **510 μm**
+ **40**



Sub-Basement
- **300 μm**
+ **40**



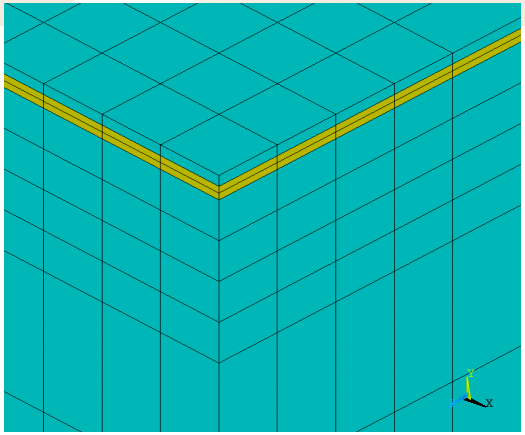
FEA discussion, Mitigation plan

- **Checked parameters:**
  - Convection coefficient h_{NC}
  - AC set point inside building
  - Temperature in new mechanical room
  - Variable shade length on the roof
  - Element size
- **Pure thermal deformation varying versus time**
- **Meaningful FEA model**
- **Simulation to asses mitigation plans**
  - Insulation of the building
  - Shading
  - Island slab
  - Island slab + pillar
- **Temperature difference across the wall and roof → building deformation**

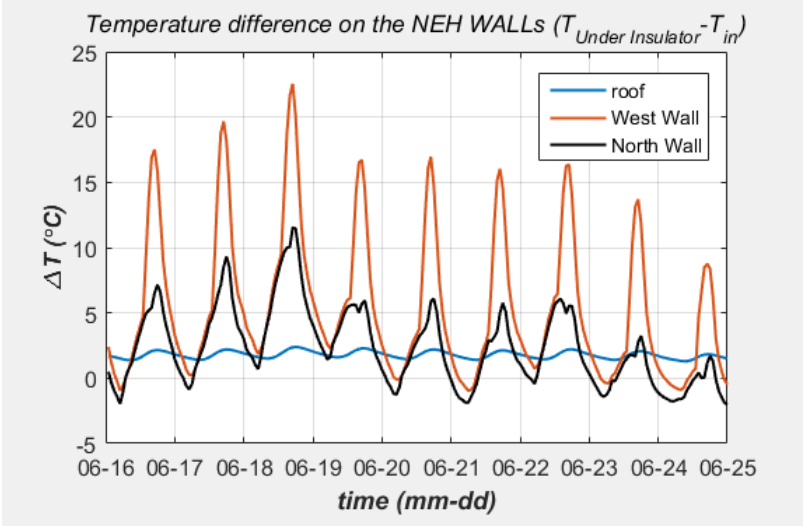
→ THE solution is INSULATION of the building

Temperature difference across concrete walls (roof)

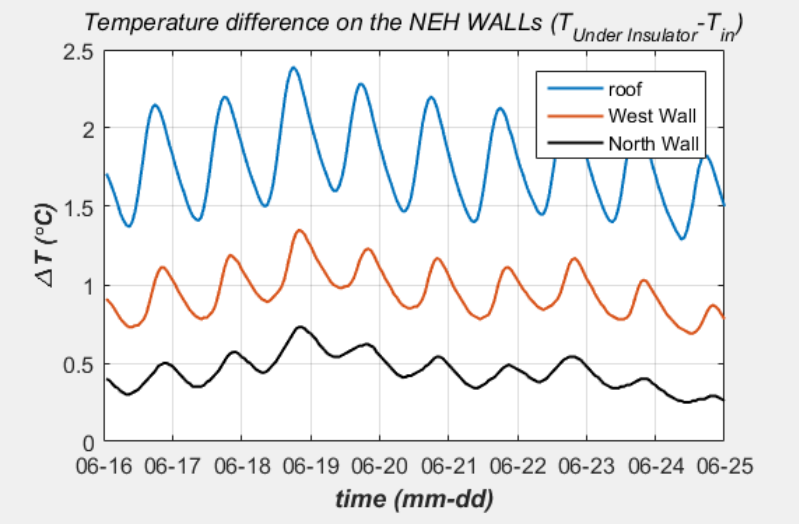
20 cm thick insulator with k=0.04 W/m^2/°C
(~ **R30** = t/k) on the Roof, Walls



Summer



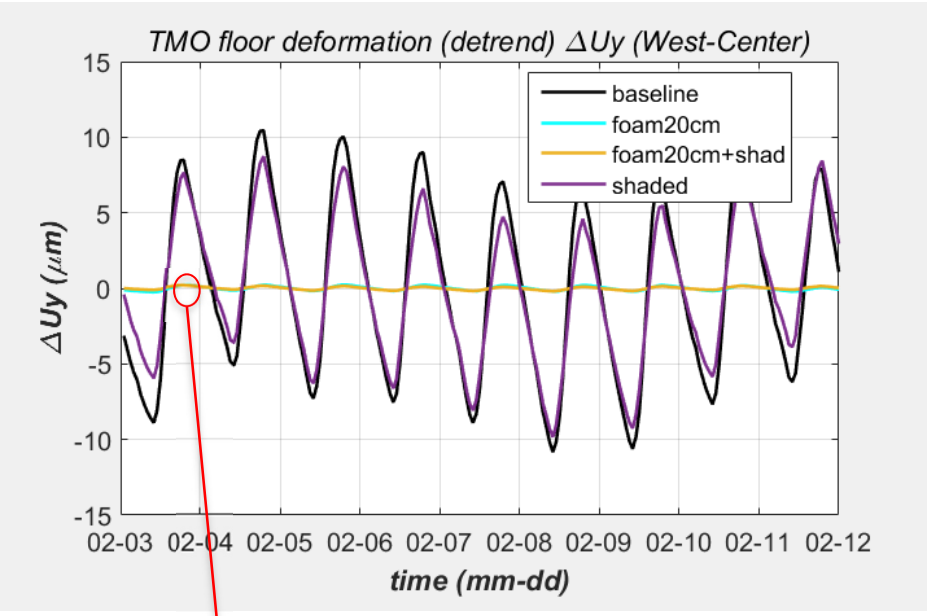
Baseline

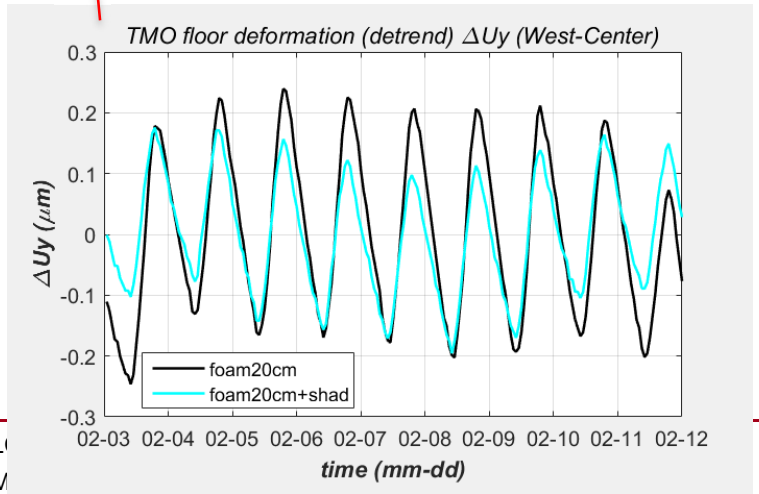


R30 insulation

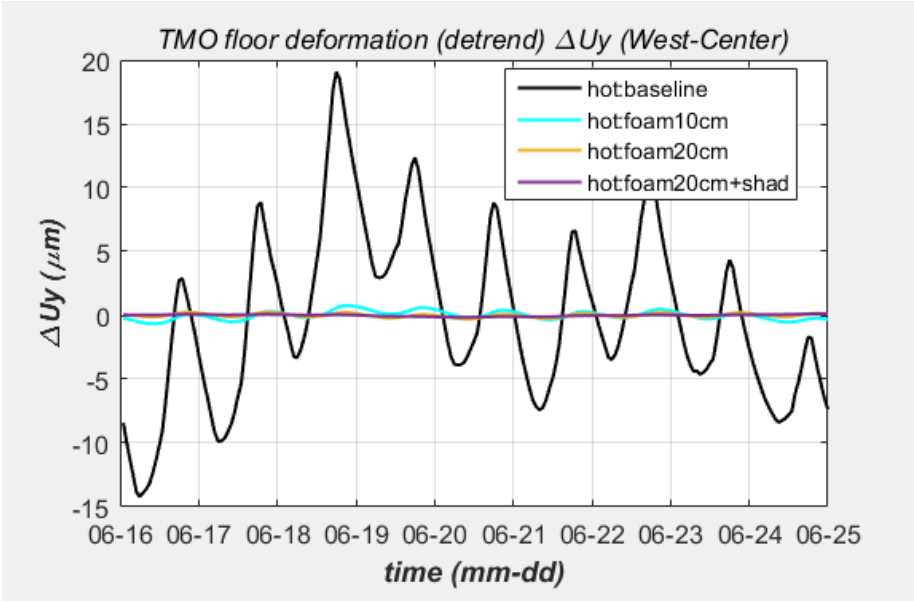
TMO Differential displacement versus time

Feb. 2018





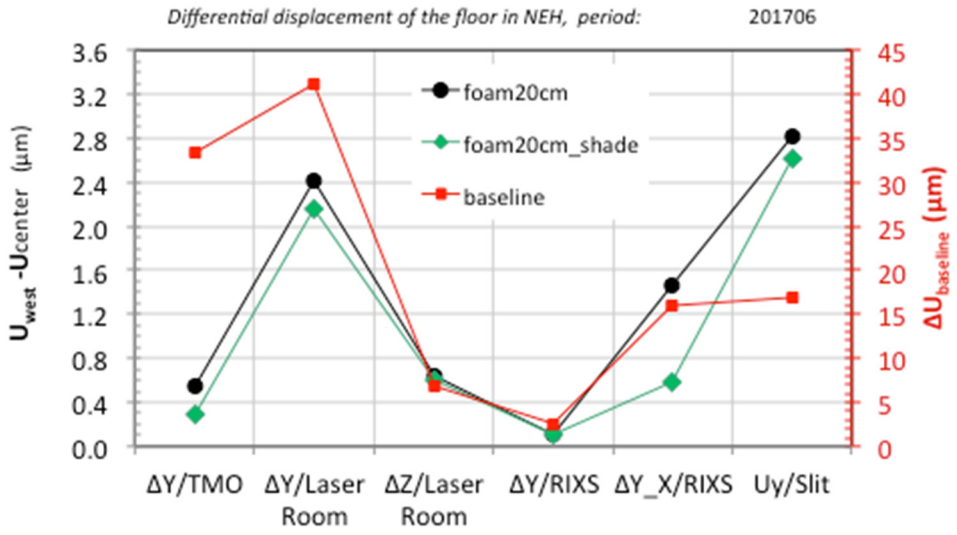
Summer 2017



- **Shading only has limited improvement**
- **Insulation (20cm) gives sufficient performance improvement**

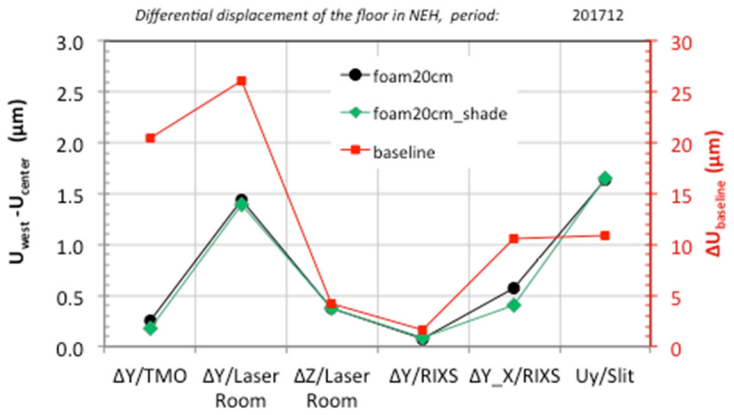
Peak-to-Valley differential displacement (summer, winter)

Summer

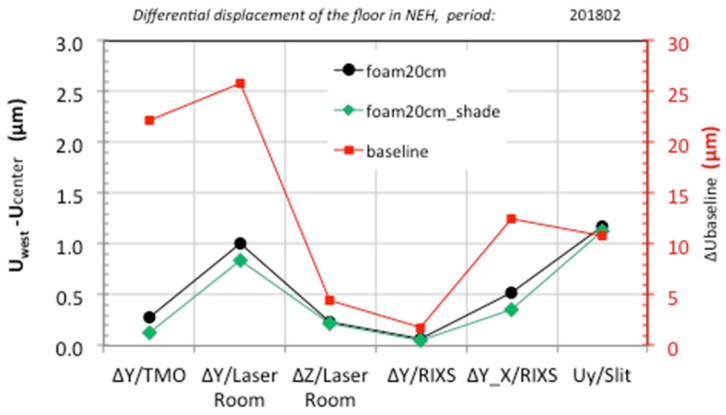


- **20 cm thick insulator with k=0.04 W/m²/°C (~R30) is recommended**
- **Shading (+Insulation) can further improve the performance, especially during summer**

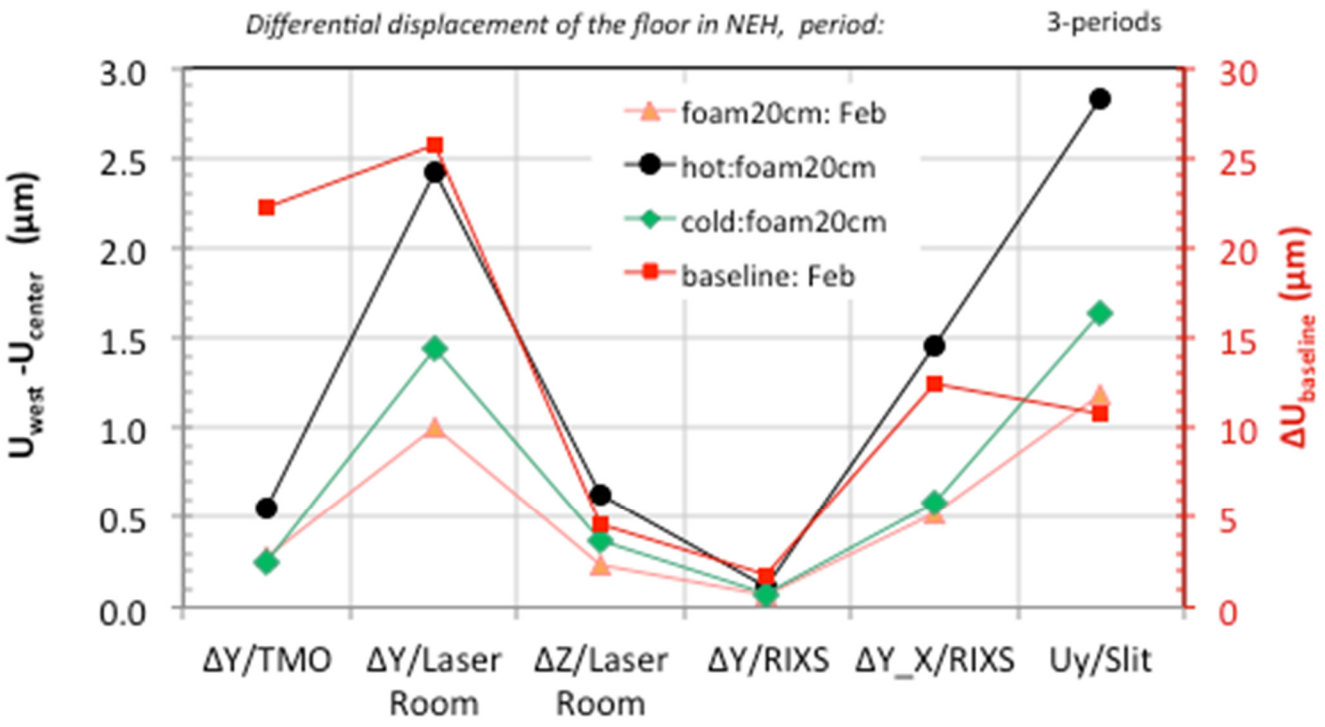
Winter



Feb



Floor deformation with R30 insulator – 3 periods



$\Delta Uy_{February} < \Delta Uy_{December} < \Delta Uy_{June}$

➔ Spring / Fall season: low deformation

Summary

Floor deformation with R30 insulator – 3 periods

peak-to-valley ΔU (μm, °C)		baseline		with R30 insulator			gain (baseline/R30)	
		February	June	February	June	December	February	June
T_{UI}-T_{in}	Roof	0,43	1,06	0,43	1,06	0,40	1,0	1,0
T_{UI}-T_{in}	West wall	19,43	24,53	0,44	0,65	0,40	44	38
T_{UI}-T_{in}	North Wall	11,20	14,64	0,30	0,47	0,30	37	31
Uy_{west} -Uy_{center}	$\Delta Y/_{TMO}$	22,2	33,3	**0,29**	**0,55**	**0,26**	78	60
Uy_{west} -Uy_{center}	$\Delta Y/_{Laser\ Room}$	25,7	41,1	1,00	2,42	1,44	26	17
Uz_{west} -Uz_{est}	$\Delta Z/_{Laser\ Room}$	4,5	6,9	**0,23**	**0,63**	**0,37**	19	11
Uy_{west} -Uy_{center}	ΔY/RIXS	1,8	2,6	**0,06**	**0,11**	**0,08**	29	24
Uy_{north} -Uy_{center}	ΔY_X/RIXS	12,4	15,9	**0,52**	**1,46**	**0,57**	24	11
Uy_{slit}	Uy/Slit	10,8	17,0	1,18	2,82	1,64	9,2	6,0

- **20 cm thick insulator with k=0.04 W/m²/°C (~R30) is recommended**
- **Time-dependent Floor motion can be limited to sub-μm**
- Shading only has limited performance
- Shading can further improve the performance significantly during summer
- $\Delta Uy_{February} < \Delta Uy_{December} < \Delta Uy_{June}$ ➔ Spring / Fall season: low deformation

Acknowledgement

Contribution from

- M. Holmes
- X.C. Cheng
- J.C. Castagna
- F. O'Dowd
- K. Chan
- G. Gassner
- N. Kurita

Thank you for your attention