Vacuum chamber’s window

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July 27 2021

Intro

- Choices we need to make for the vacuum chamber window:
  - the material itself, its thickness, its radiation tolerance, its mechanical strength with vacuum, damage with beam and how much bkg it will generate (impact on signal is small)

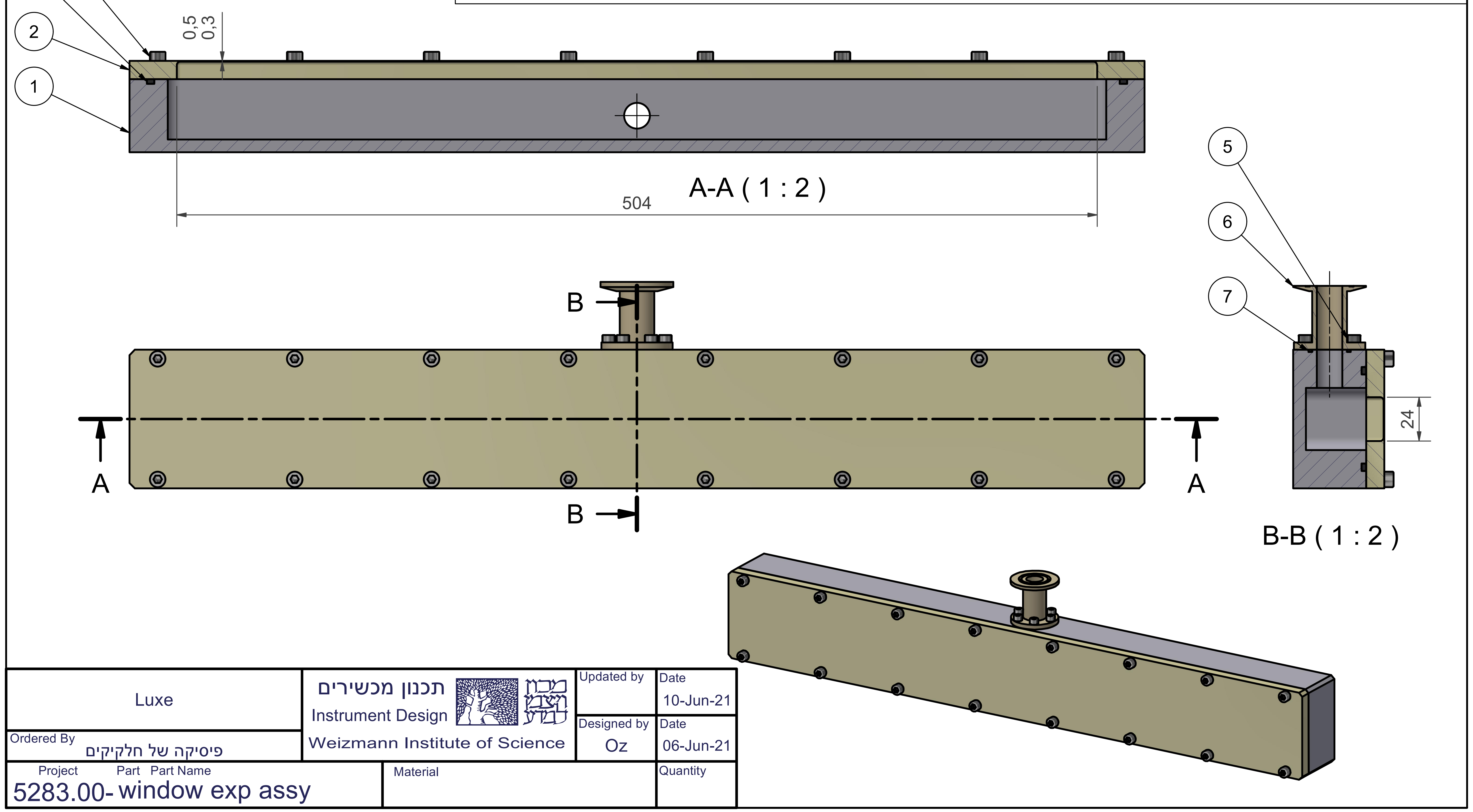
- Very difficult to trust just the simulation in terms of the mechanical stresses (CAD inventor by Oz) and thermal behaviour (FLUKA by Kyle) - will discuss today

- We have produced a few pieces and have checked the strength and deformation with the 200 um window

Design of the mockup chamber

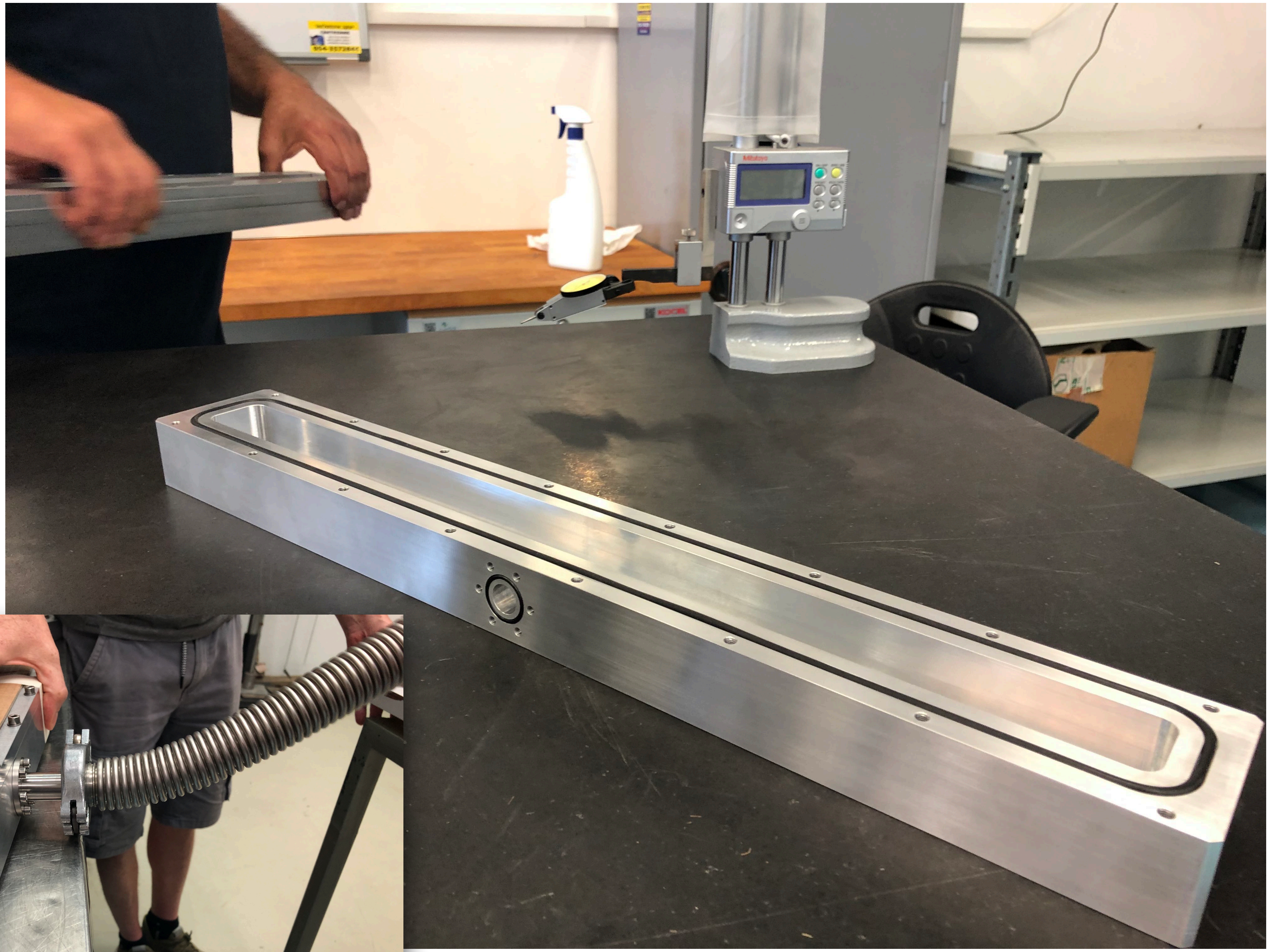
ITEM	PART NUMBER	QTY	MATERIAL	DESCRIPTION	COMMENTS
7	O-ring 18	1	Rubber		
6	NW25 port	1	Stainless Steel		
5	Socket screw	6	Stainless Steel	M4 x 10	
4	Socket screw	16	Stainless Steel	M5 x 20	
3	O-ring 280	1	Rubber		
2	Windowcheck_frame	1	AL 6061-T6		
1	window check chamber	1	AL 6061-T6		

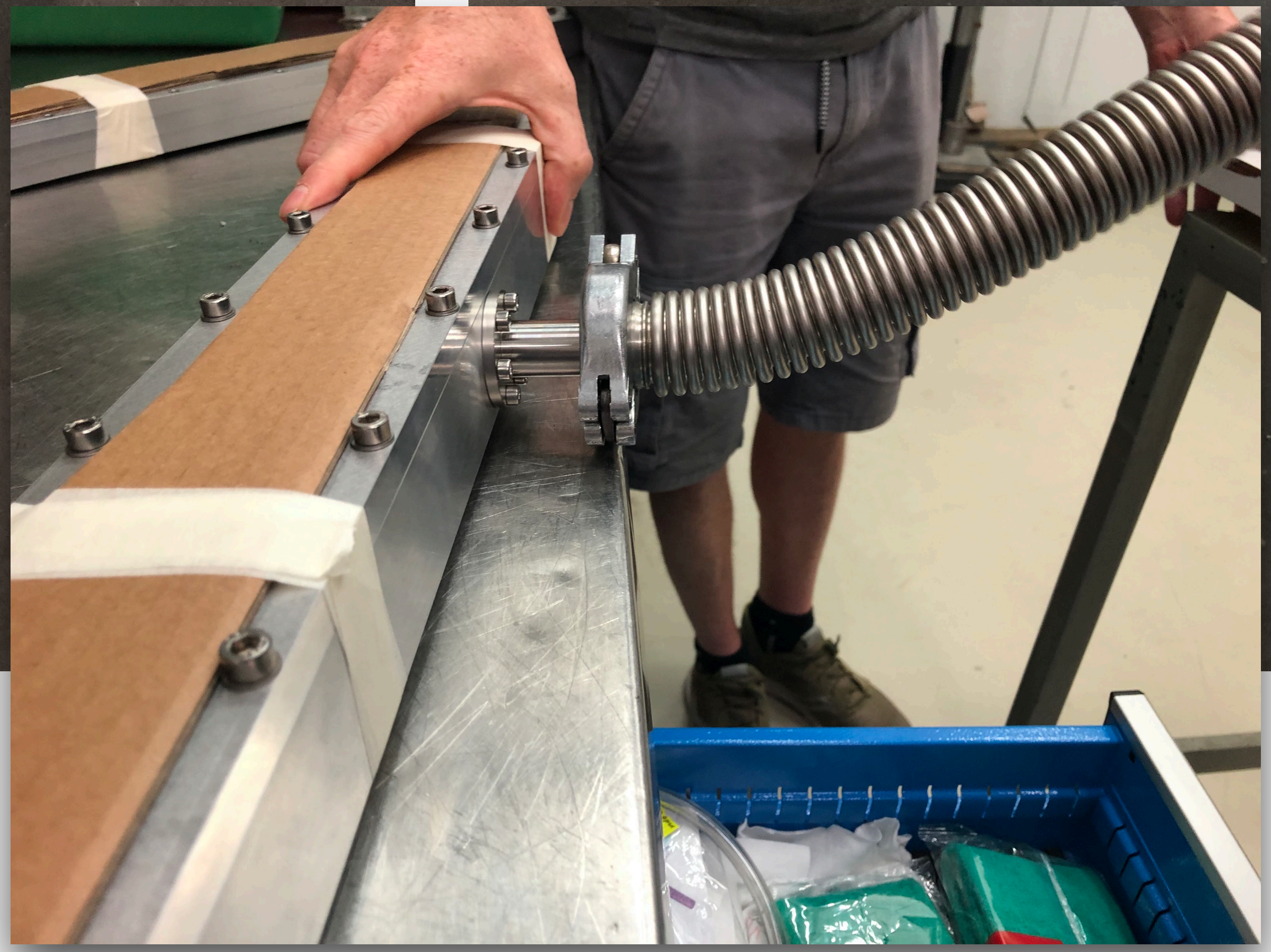
Parts List



- We have produced four windows with thicknesses:
  - 500 um
  - 400 um
  - 300 um
  - 200 um
- All pieces are made of Aluminium 6061

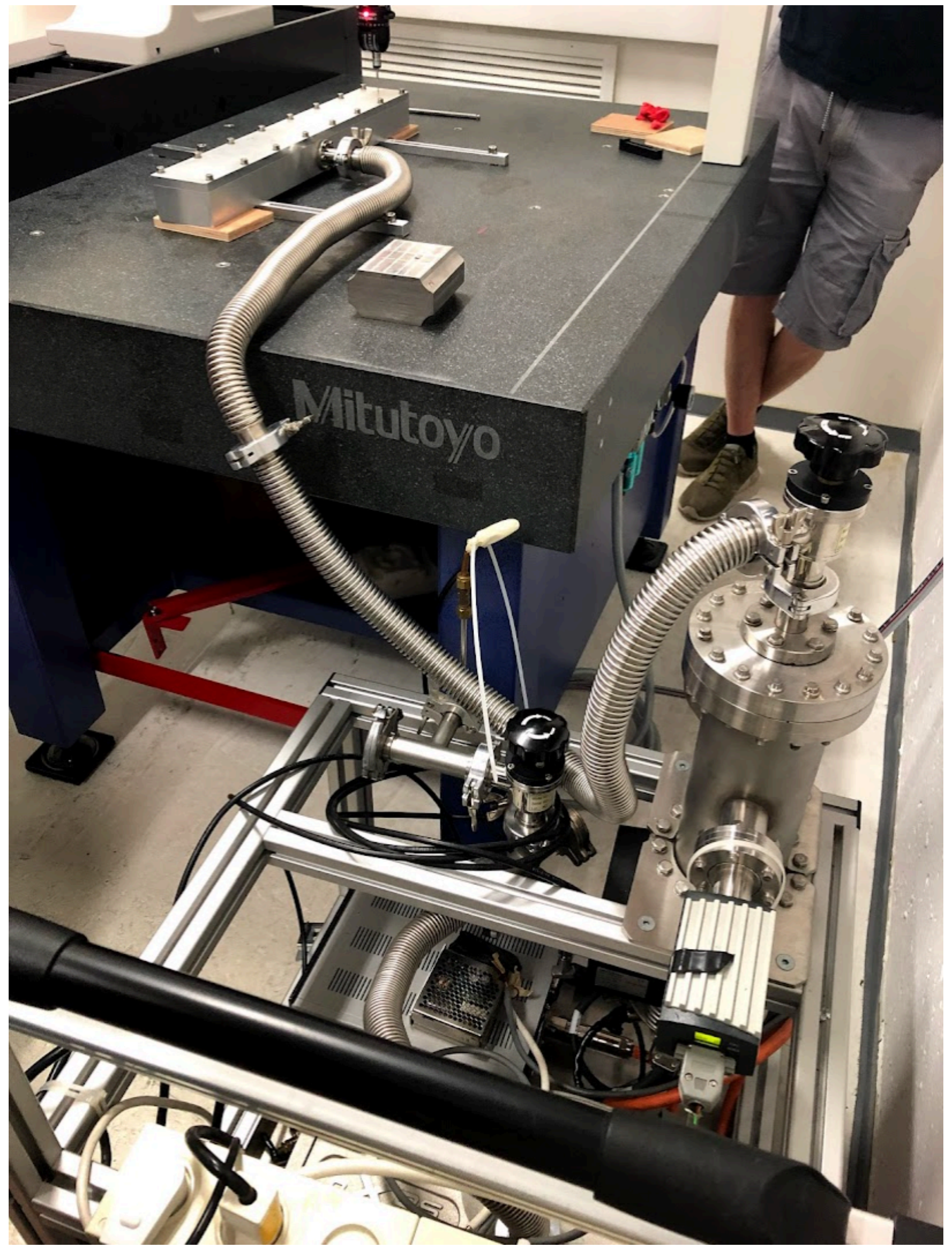
The pieces

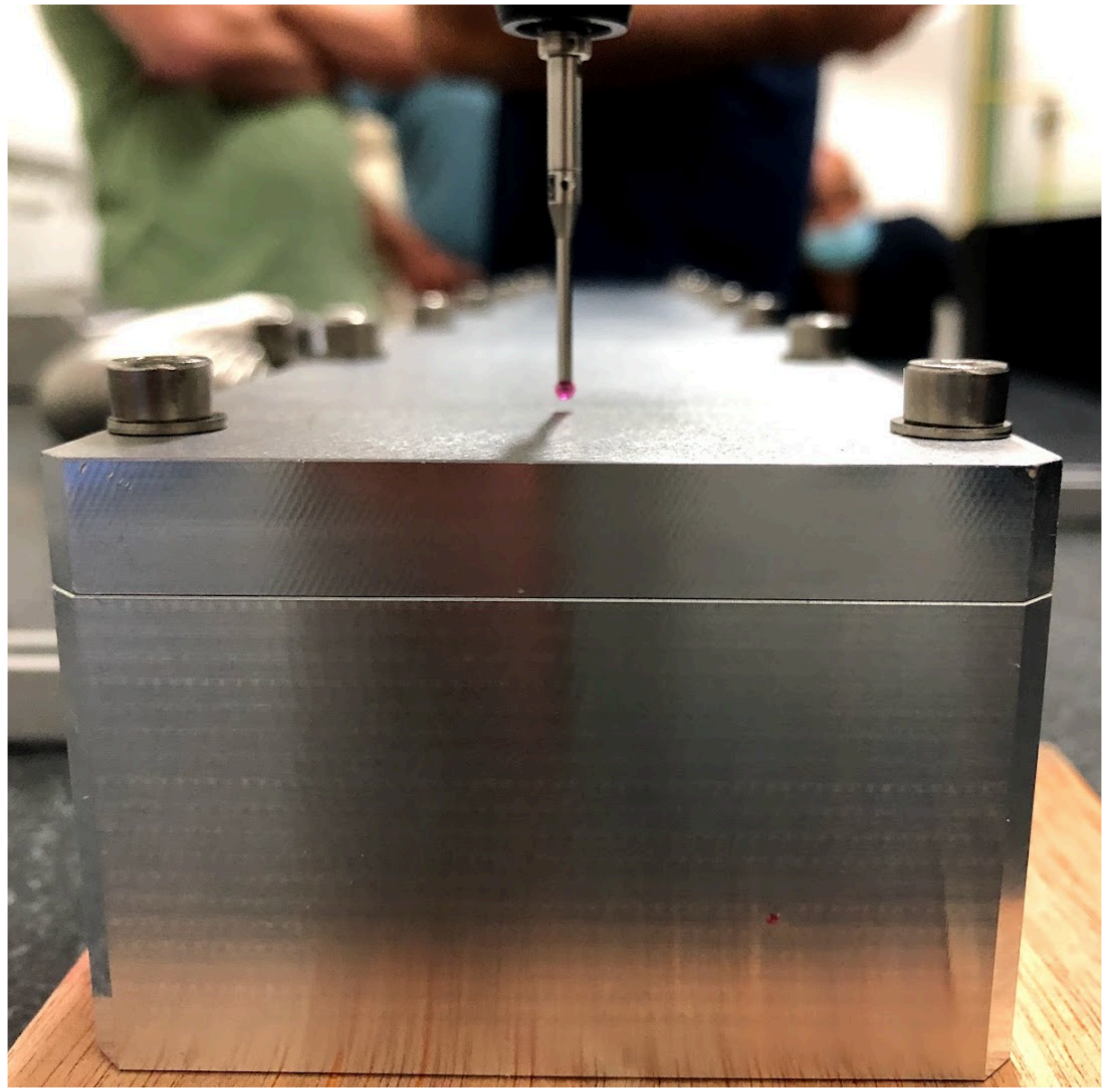




Measurements setup

- Turbo vacuum pump capable of going down to ~1e-8 mbar
- Manual CMM on a granite table
  - known precision of ±8 um (5 um declared)
  - probe is very sensitive: needs <4 grams contact
  - the probe's bridge is moved to the rough location of the point of measurement
  - then it is brought to the point with 3 precision knobs (monitor precision is within ±1 um)



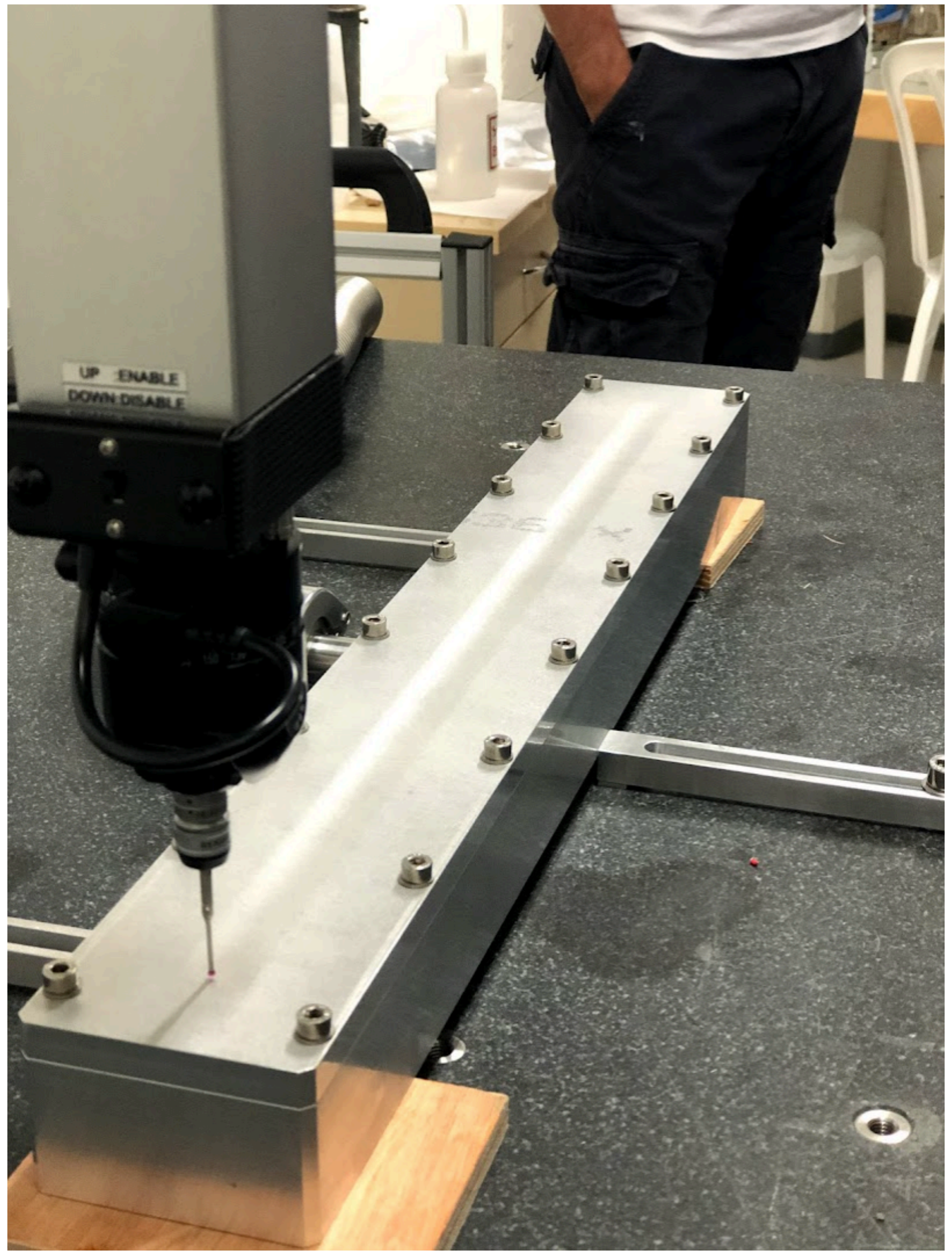
Measurement sequence

- Chamber is mounted with the 200 um window
- Fix the chamber on the CMM table
- Fix the coordinate system and measurement plane

- Measurements (z) are done along the centre of the window short axis (x) along its long axis (y) where we also look at the level of repetetivity in x-y:
  1. Initial reference w/o vacuum (chamber is at atmospheric pressure)
  2. Low vacuum ~8-6e-3 mbar (a few minutes, mechanical pump)
  3. Medium vacuum ~1.5e-6 mbar (a few minutes after turning the turbo on)
  4. High vacuum ~4.5e-7 mbar (over night)
  5. Reference1 w/o vacuum (a few minutes after releasing the vacuum)
  6. Reference2 w/o vacuum (~24 hours after releasing the vacuum)

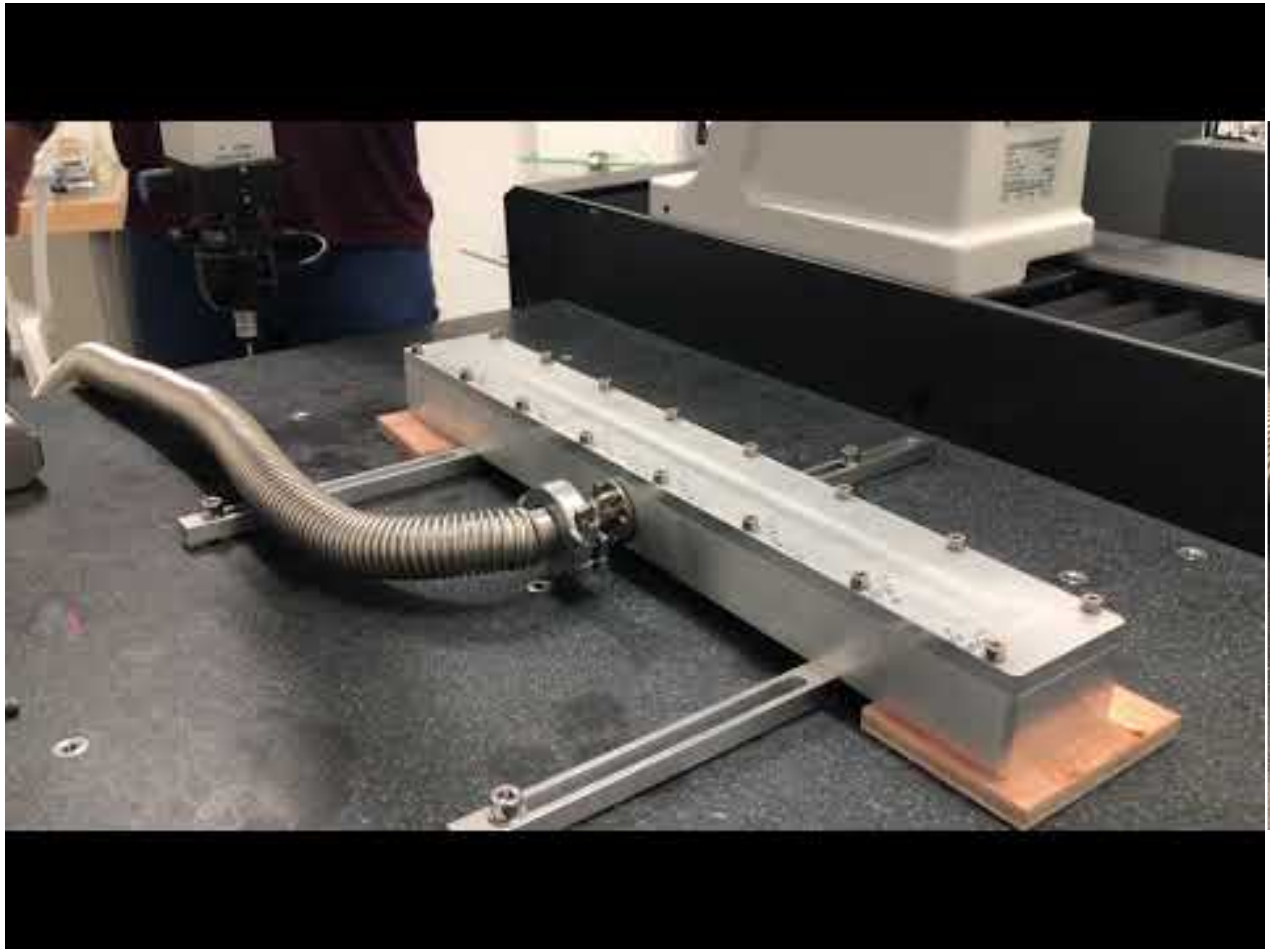
- Aggressive test to check the mechanical integrity:
  1. Chamber is at atmospheric pressure
  2. Go "moderately" to ~1e-5 mbar (mech. for a few minutes and then turbo)
  3. Release slowly (a few minutes) and reach atmospheric pressure again
  4. Go quickly to ~1e-5 mbar

Vacuum [mbar]	Fraction of ultimate outside force [%]
6.0E-03	99.99941
1.5E-06	99.99999985
4.7E-07	99.999999954

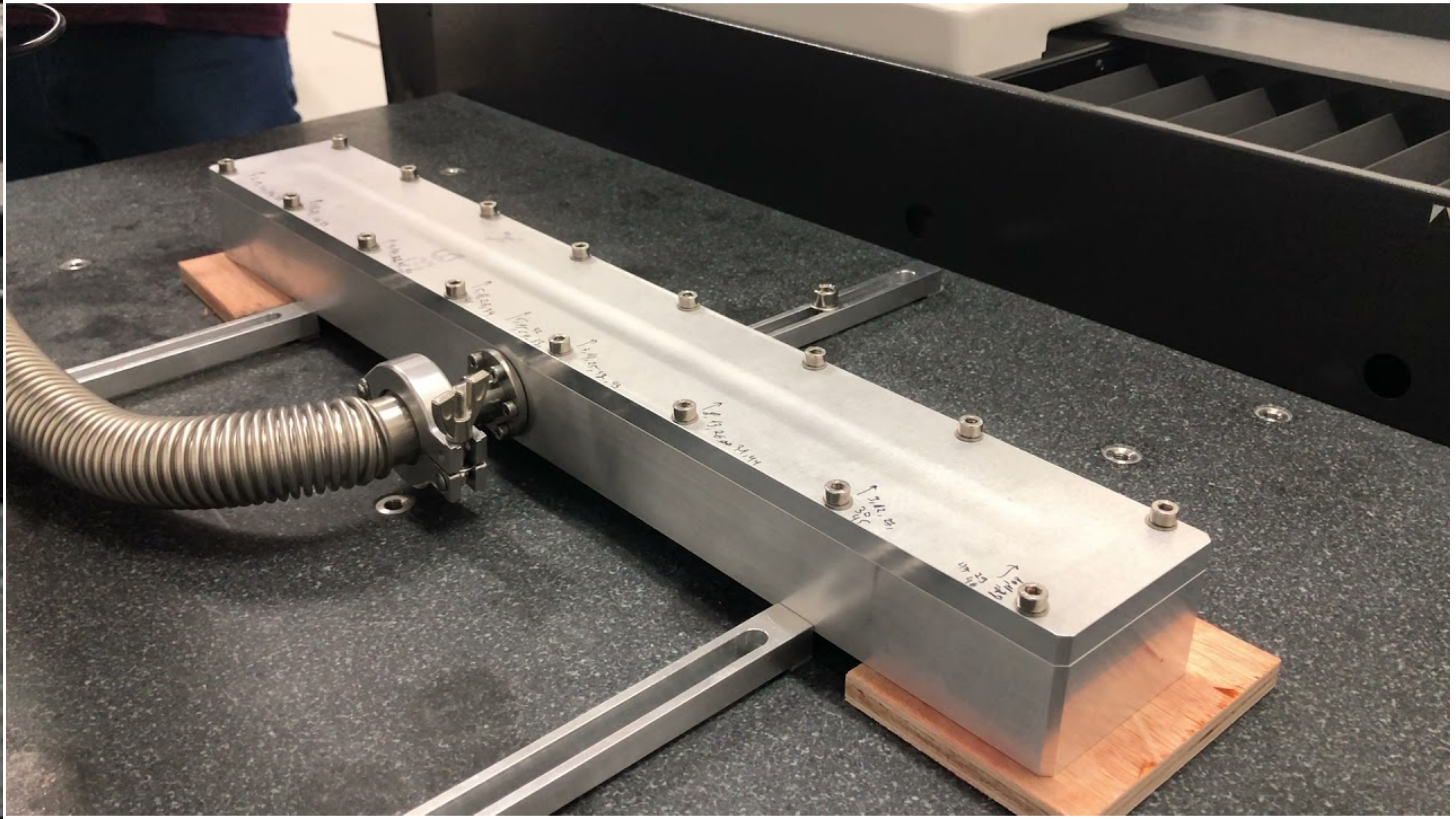


Videos

Pumping moderately

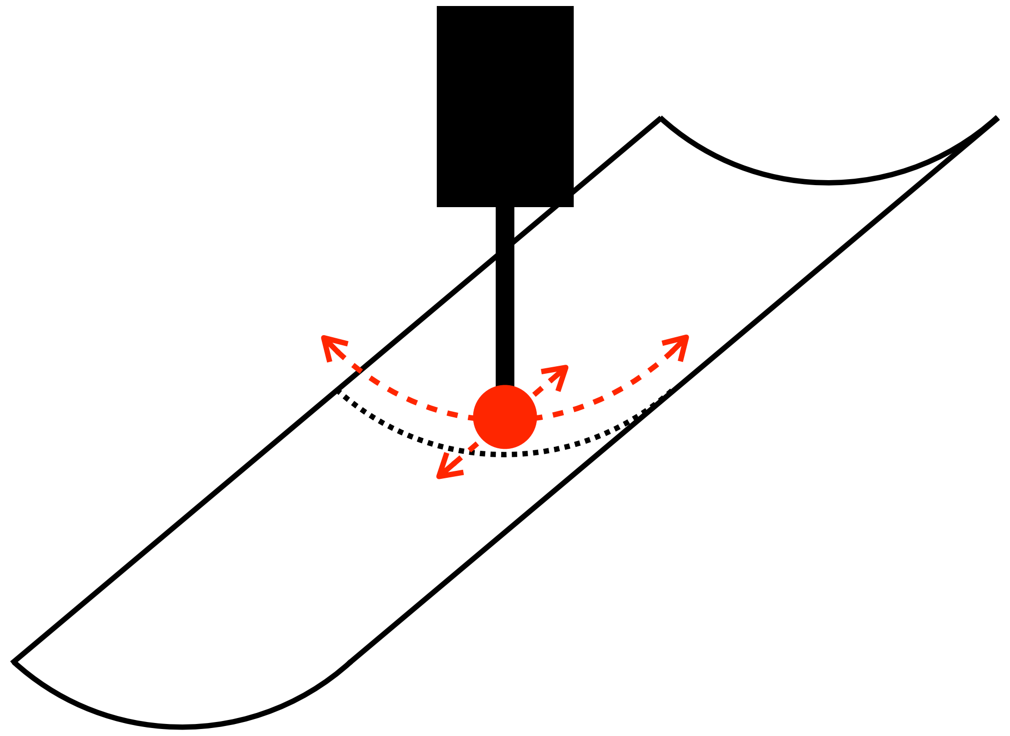


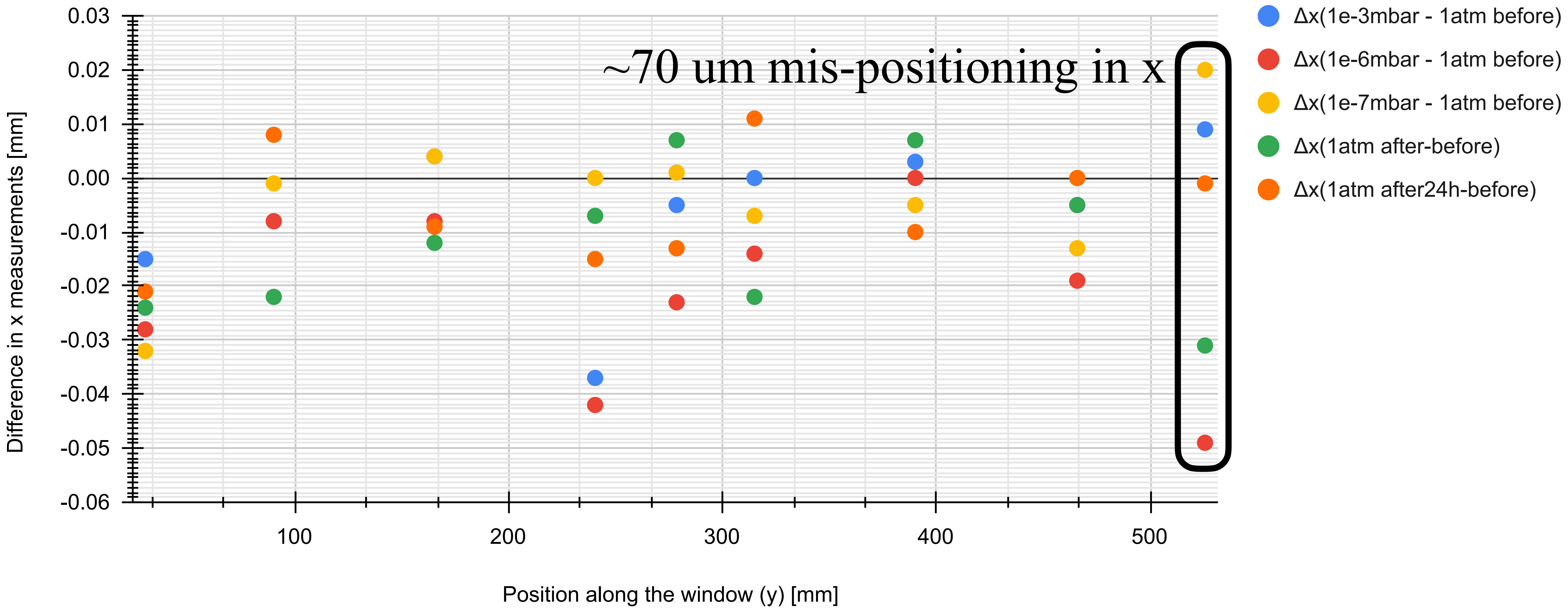
Releasing quickly

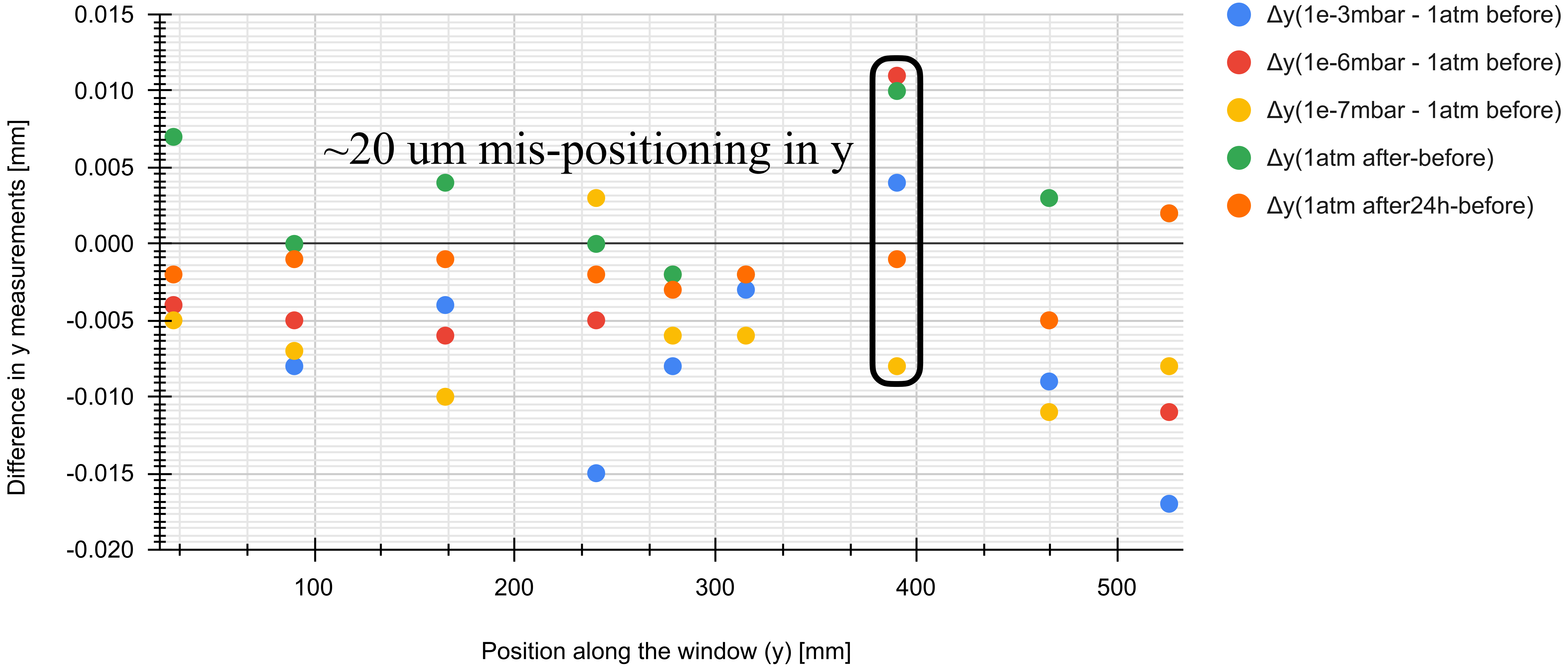


Results
Δx, Δy

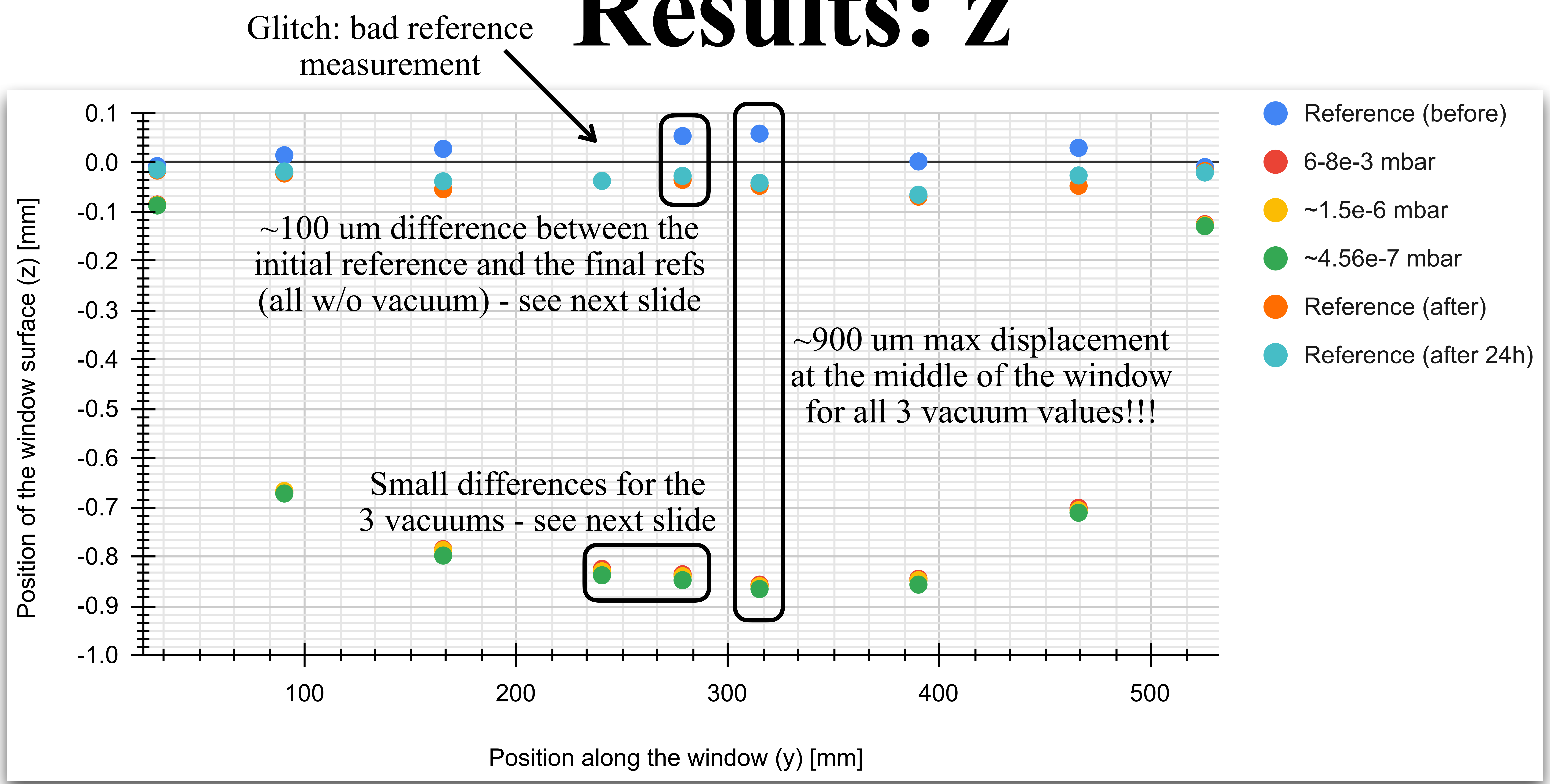
- Repetitiveness in y is OK, within ~20 um
- Repetitiveness in x is not great (~70 um)
- Probably due to the shape and the softness of the surface along x as well as the freedom of the probe itself



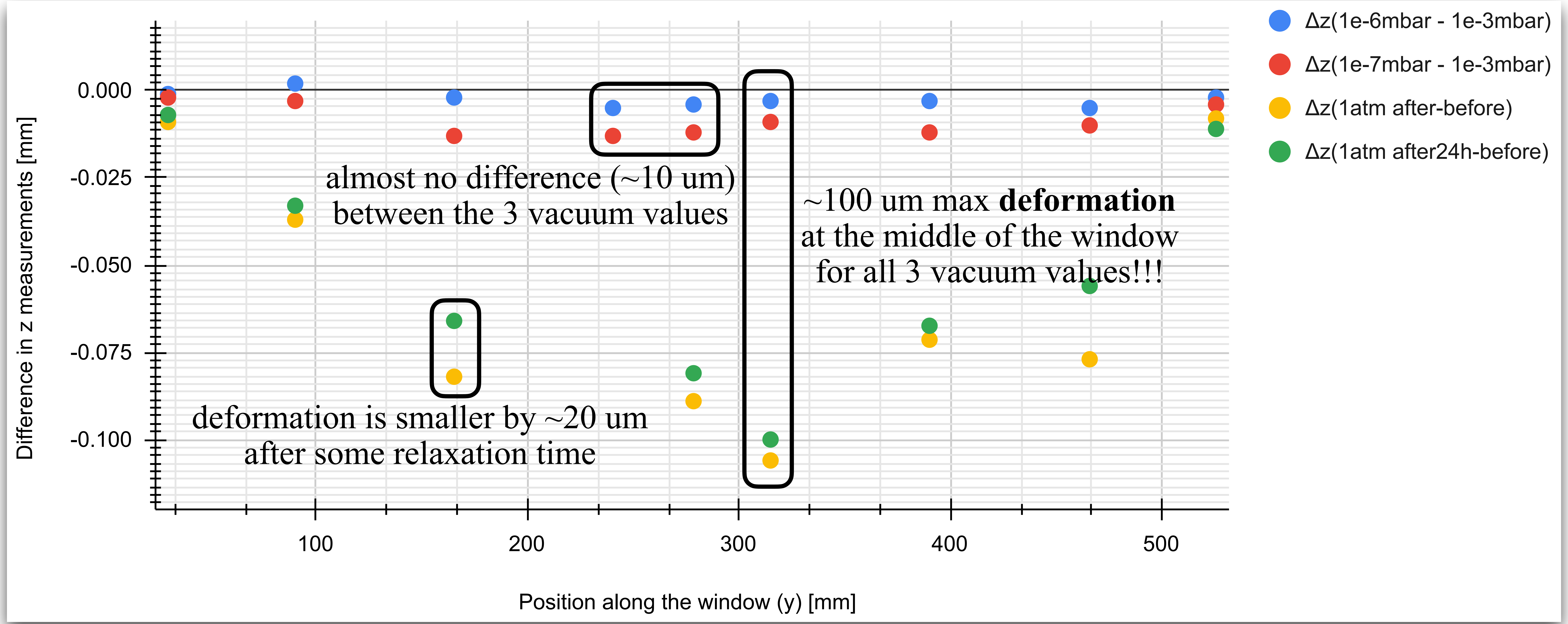




Results: z


Glitch: bad reference measurement
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
Position of the window surface (z) [mm]
100
200
300
400
500
Position along the window (y) [mm]
Reference (before)
6-8e-3 mbar
~1.5e-6 mbar
~4.56e-7 mbar
Reference (after)
Reference (after 24h)
~100 um difference between the initial reference and the final refs (all w/o vacuum) - see next slide
~900 um max displacement at the middle of the window for all 3 vacuum values!!!
Small differences for the 3 vacuums - see next slide

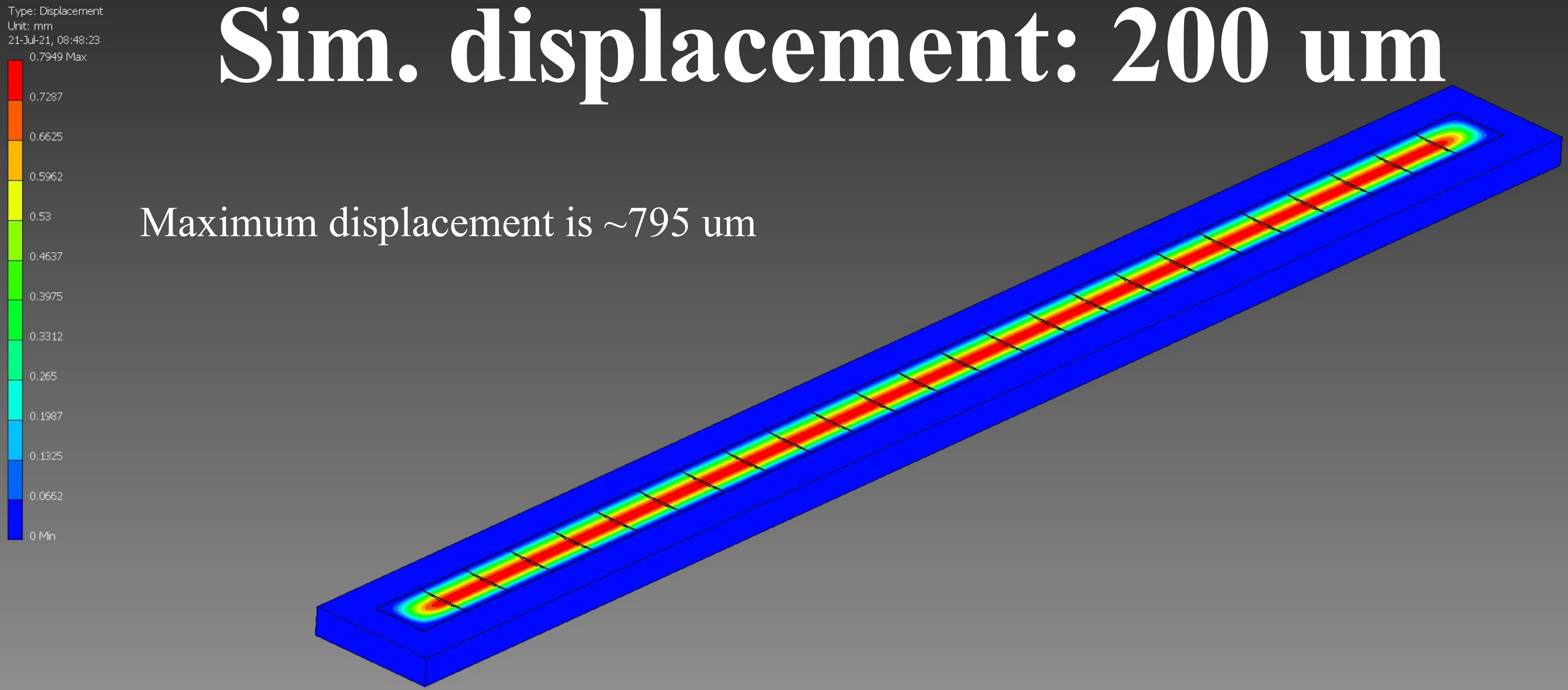
Results: Δz



Δz(1e-6mbar - 1e-3mbar)
Δz(1e-7mbar - 1e-3mbar)
Δz(1atm after-before)
Δz(1atm after24h-before)
Difference in z measurements [mm]
0.000
-0.025
-0.050
-0.075
-0.100
100
200
300
400
500
Position along the window (y) [mm]
almost no difference (~10 um) between the 3 vacuum values
~100 um max **deformation** at the middle of the window for all 3 vacuum values!!!
deformation is smaller by ~20 um after some relaxation time

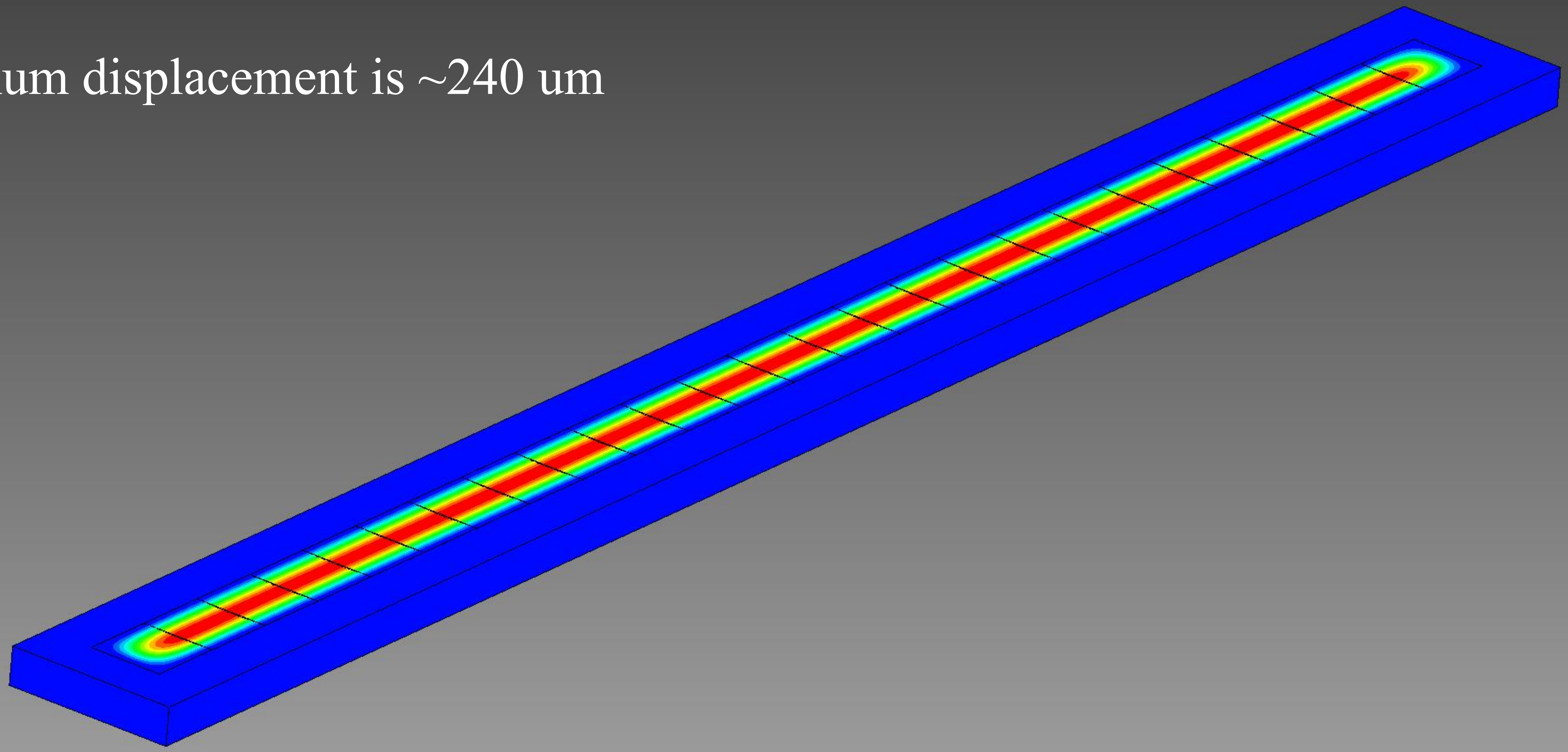
Sim. displacement: 200 um

Maximum displacement is ~795 um

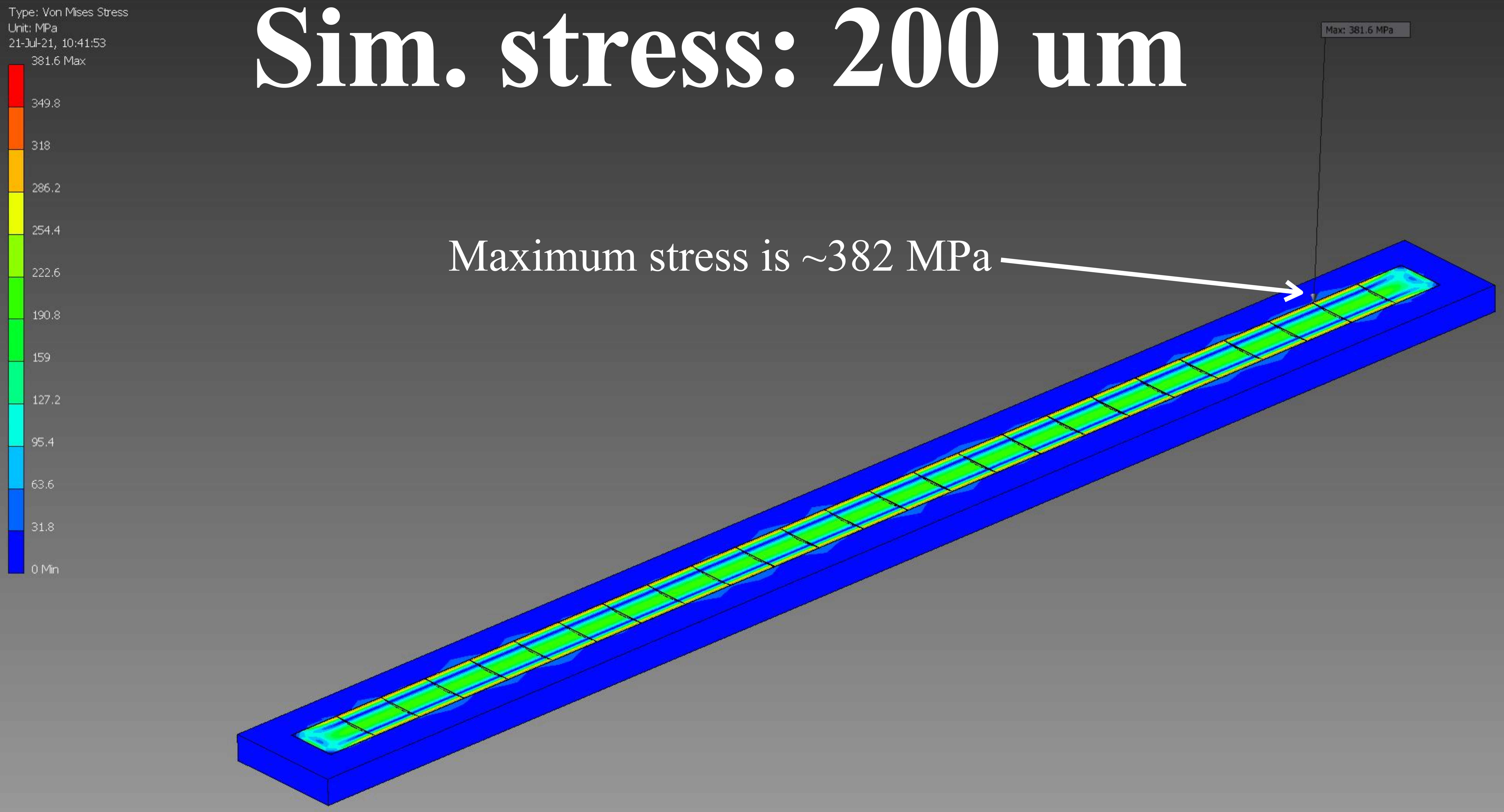


Sim. displacement: 300 um

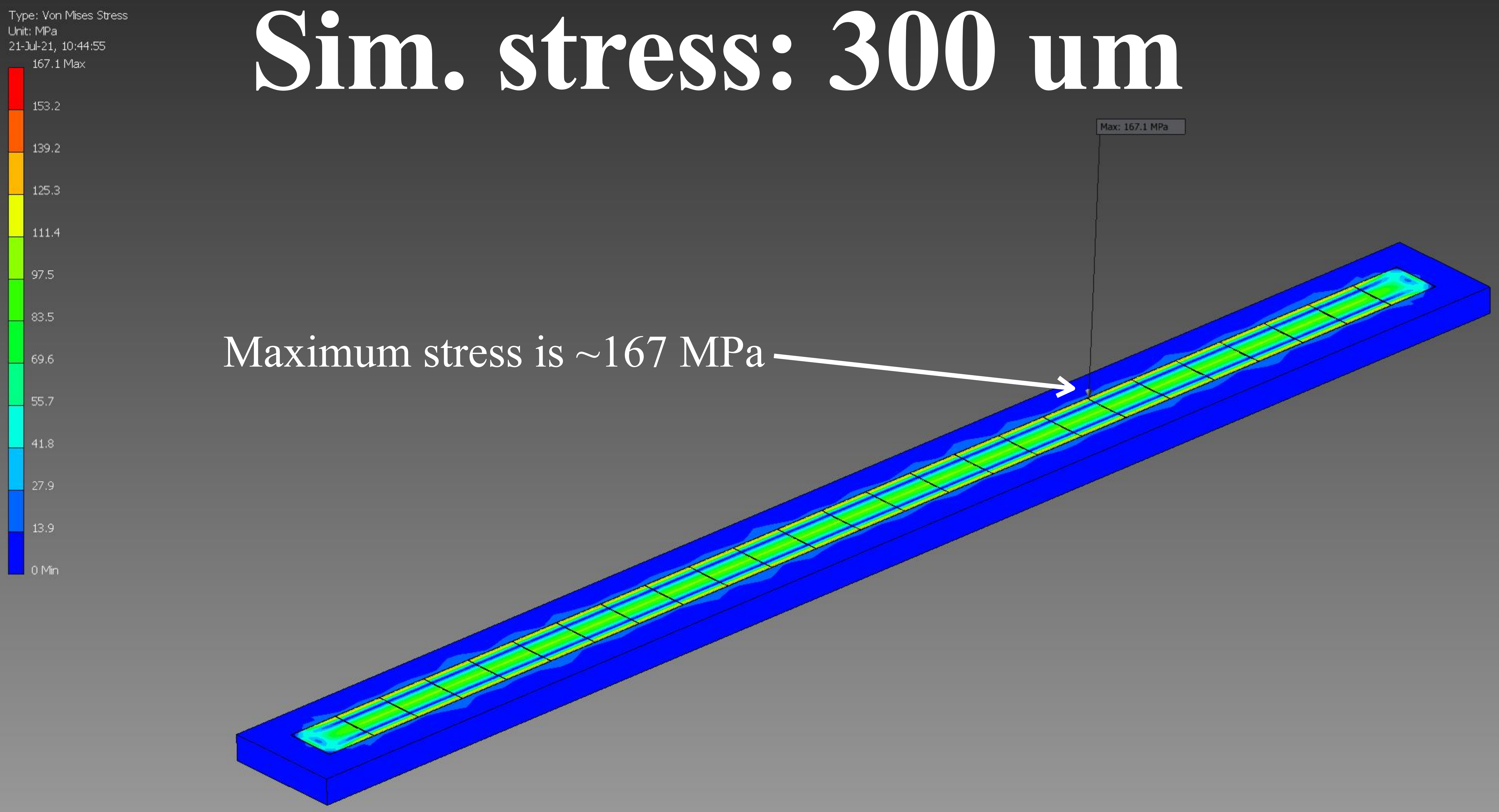
Maximum displacement is ~240 um



Sim. stress: 200 um



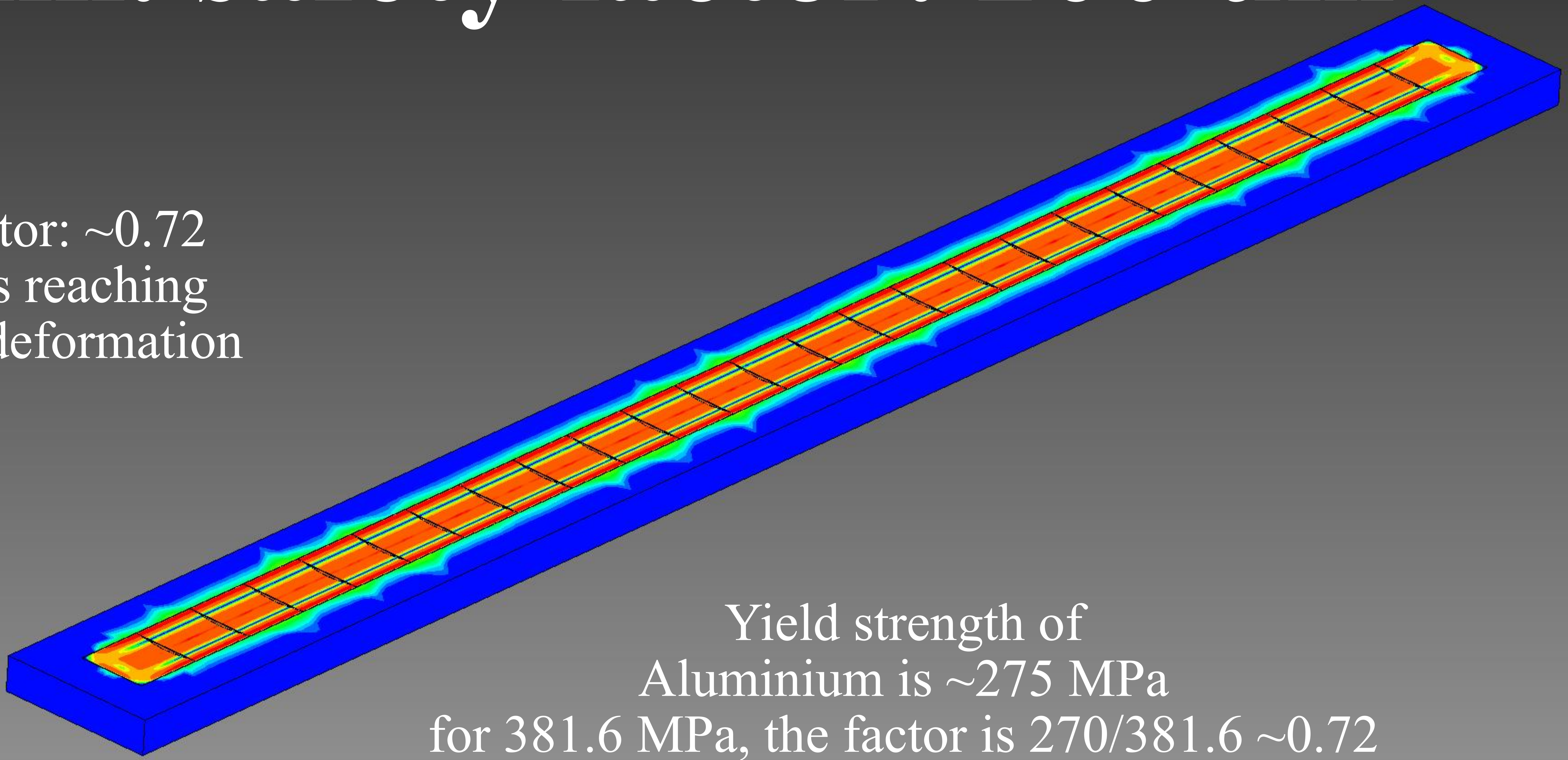
Sim. stress: 300 um



Maximum stress is ~167 MPa

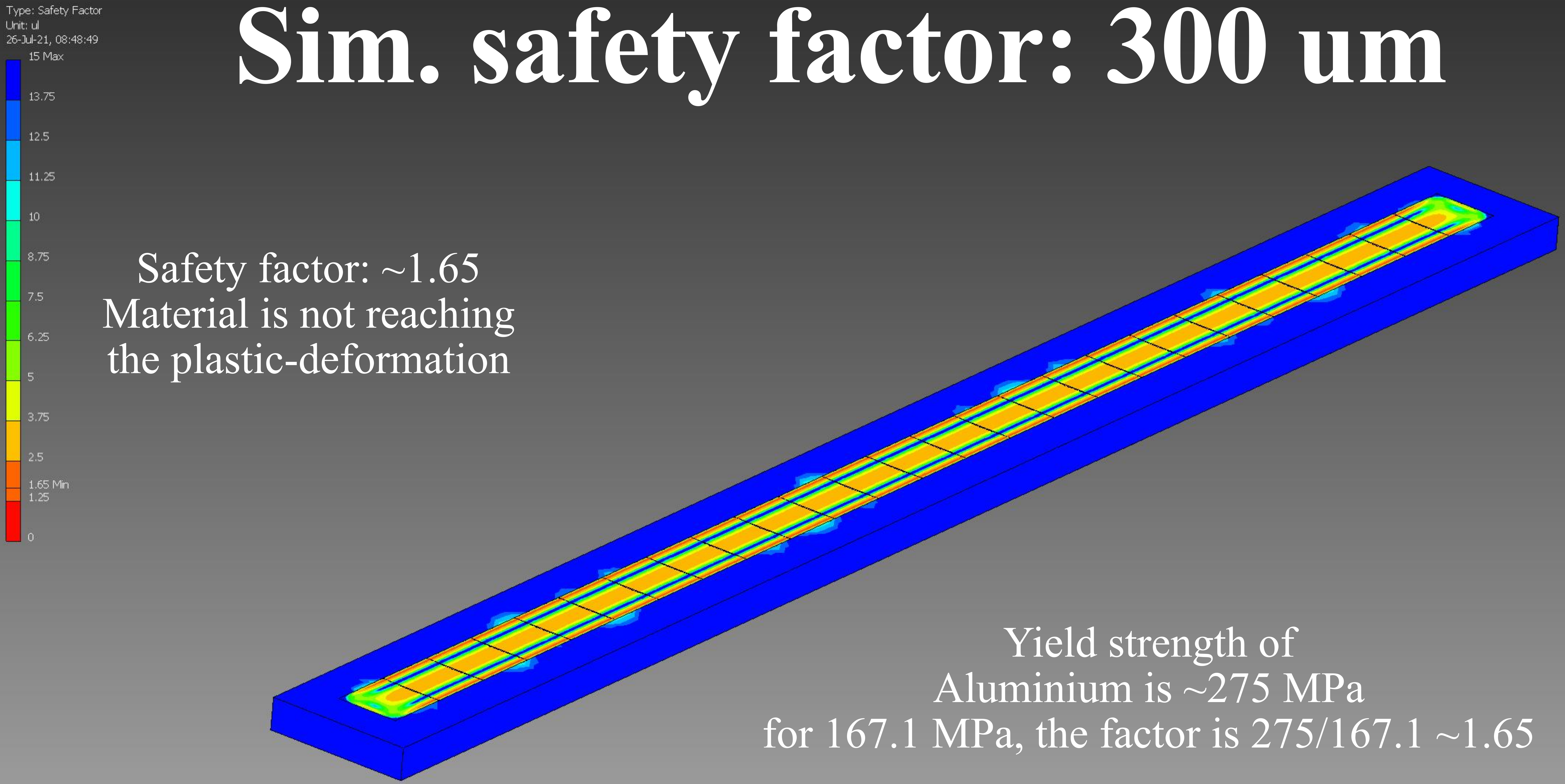
Sim. safety factor: 200 um

Safety factor: ~0.72
Material is reaching
the plastic-deformation



Yield strength of
Aluminium is ~275 MPa
for 381.6 MPa, the factor is 270/381.6 ~0.72

Sim. safety factor: 300 um



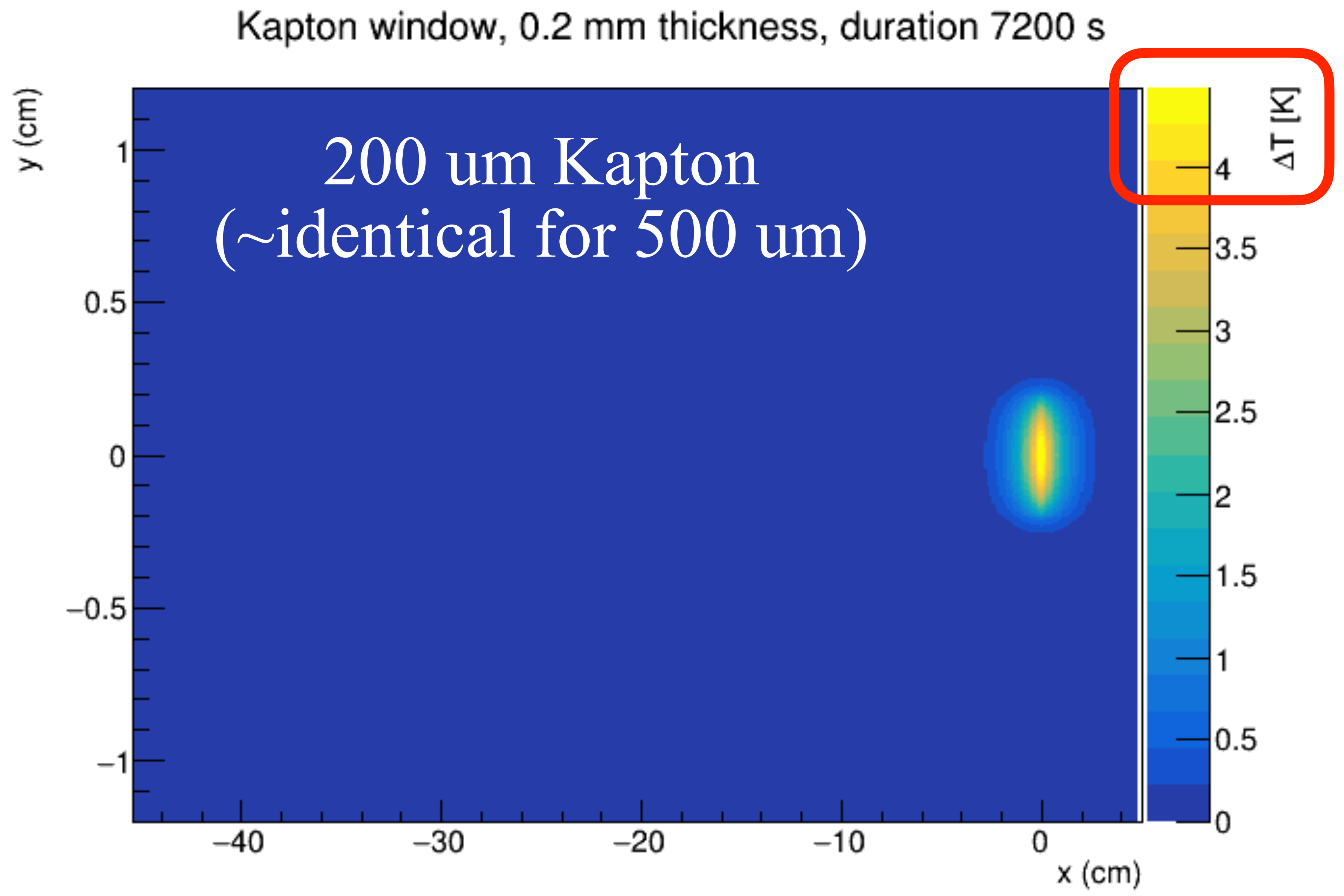
Safety factor: ~1.65
Material is not reaching
the plastic-deformation

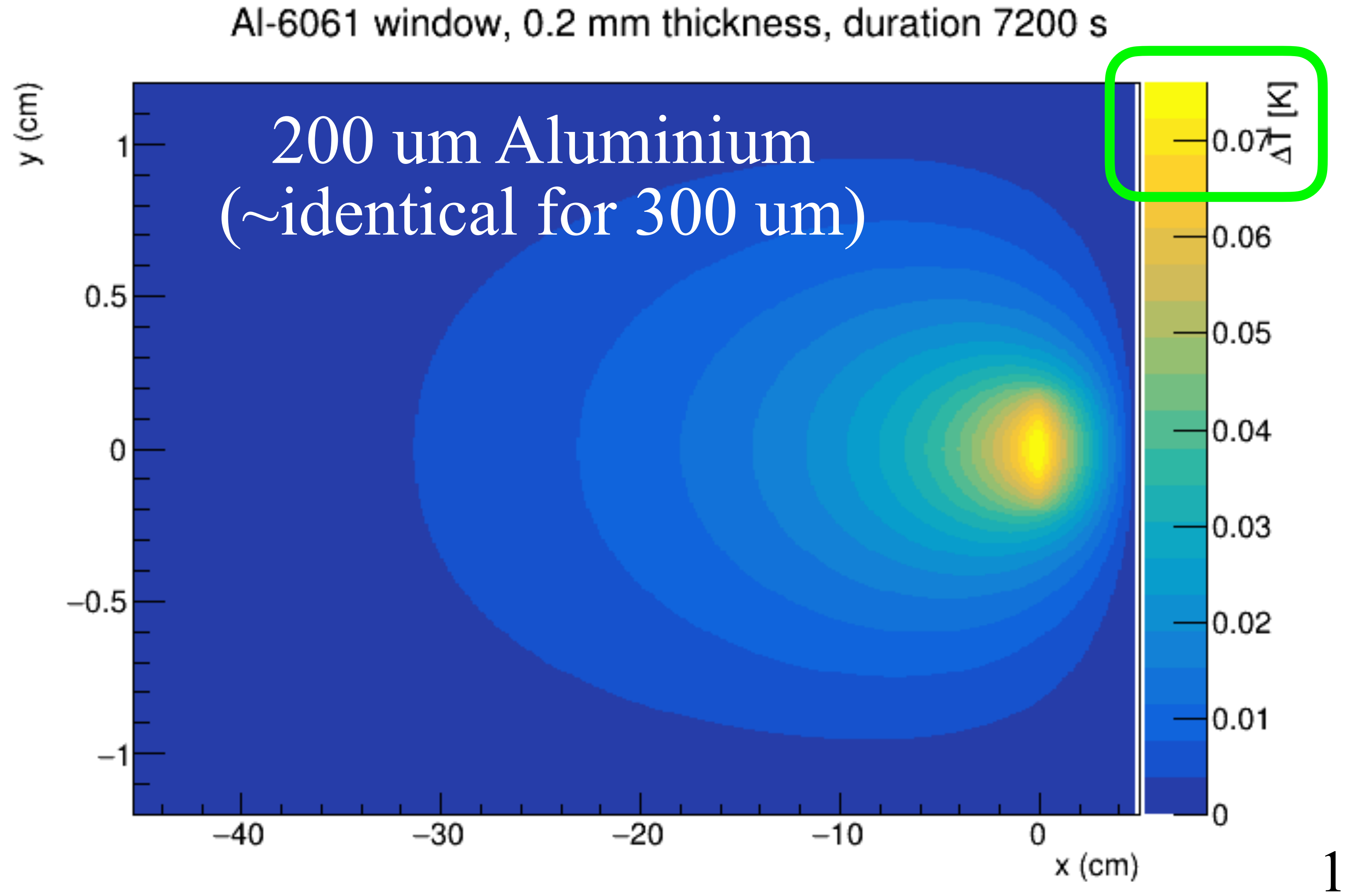
Yield strength of
Aluminium is ~275 MPa
for 167.1 MPa, the factor is 275/167.1 ~1.65

Beam impact from Kyle

- FLUKA: simulate the accumulation of heat in the material
- Shooting many BXs (equivalent to 2 h of operation at 10 Hz) on the material and recording the increase in temperature
- The sim. doesn't take into account thermal misbehaviour at high T
- Assuming no passive dissipation to the environment and no active cooling of the material (i.e. no boundary conditions)
- Assuming the environment is at $T_0 = 22$ºC
- Assuming that we don't want to go e.g. above $T_{melt}/2$ ever
  - will have to be also tested in situ with vacuum and a pencil-like heating source - the requirement could be much less than that
  - in reality we should expect some dissipation to the environment (i.e. the temperature will not keep rising indefinitely) and of course cooling will help

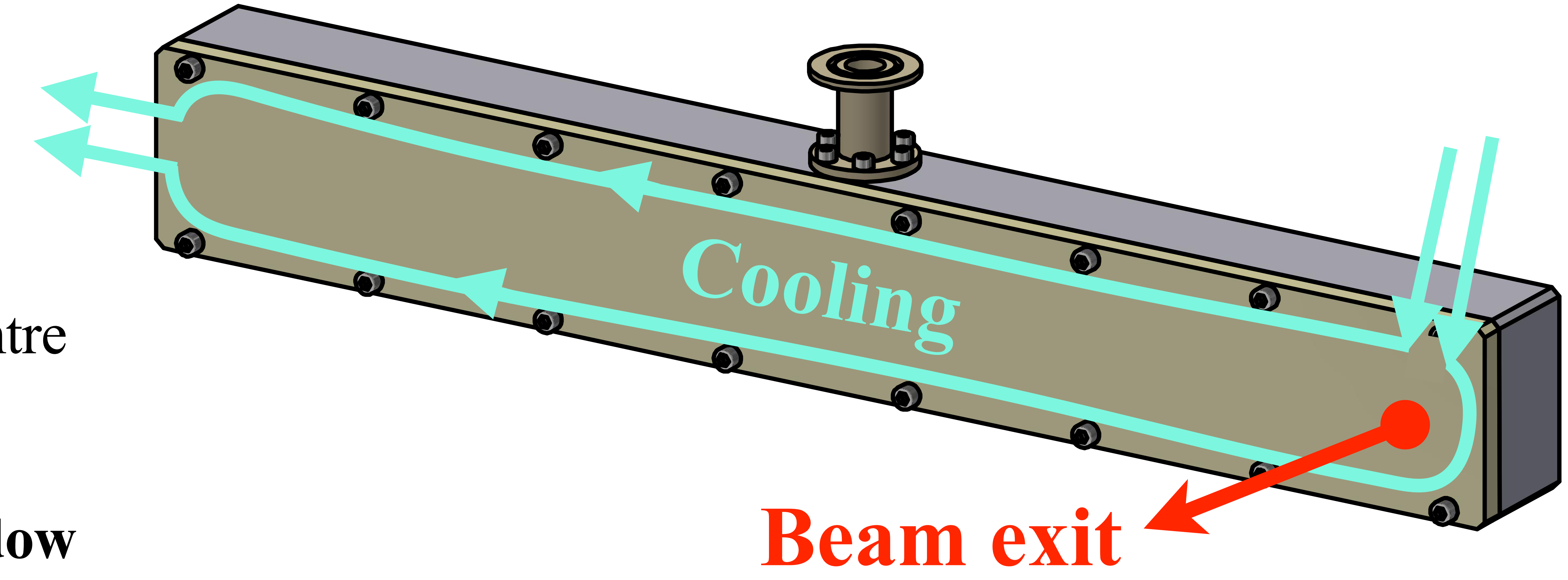
	Aluminium	Kapton
Thermal diffusivity cm²/s	0.69	0.23
Melting temp. T_{melt} [ºC]	660.3	401
ΔT within 2h at 10 Hz [ºC]	0.075	4.5
Initial temp. T_0 [ºC]	22	22
Days until $T_{melt}/2$ at 10 Hz	342.4	3.3





Summary

- The window the survives!
  - even when we generate a displacement of ~0.9 mm at the centre
  - even when we turn the vacuum on and off multiple times
  - even over a long period of time (i.e. >24 h)
  - even if we go quickly to ~1e-5 mbar
  - even when we release the vacuum promptly



- However, there's a permanent deformation of ~100 at the centre
  - probably too risky at 200 um thickness
  - mechanically we should prefer 300 um
  - **will redo the same measurements with the 300 um window**

- Mechanics simulation:
  - recreates the experimental results for the max displacement (up to ±100 um)
  - **clear preference for 300 um thickness**

- Thermal simulation:
  - For $T_{max}=T_{melt}/2$, the Aluminium window plate will have to be replaced after just less than 1 year of continuous operation at 10 Hz (160 days for $T_{max}=T_{melt}/4$)
  - Kapton cannot hold more than a few days.
  - **Cooling the periphery of the window will help a lot**