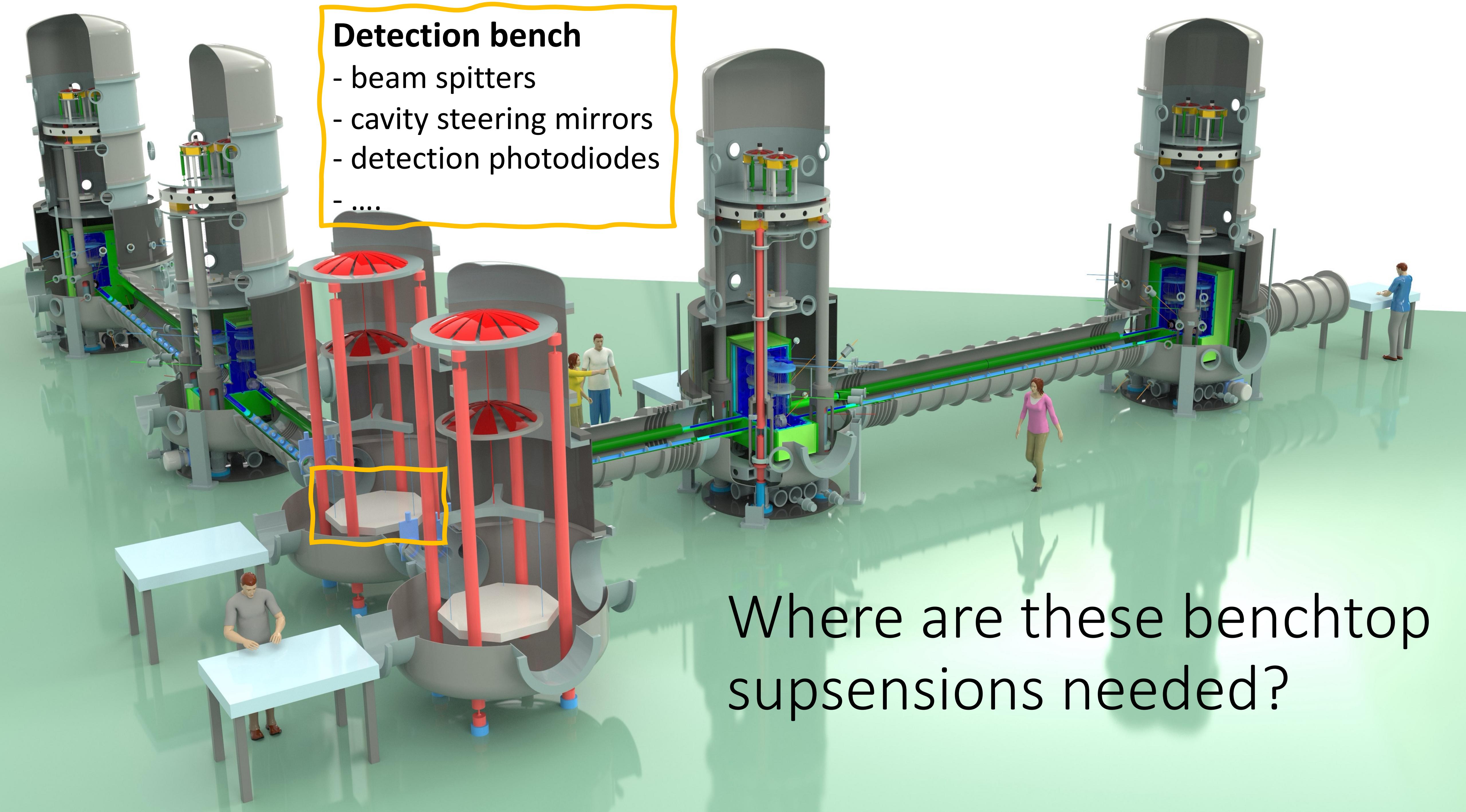
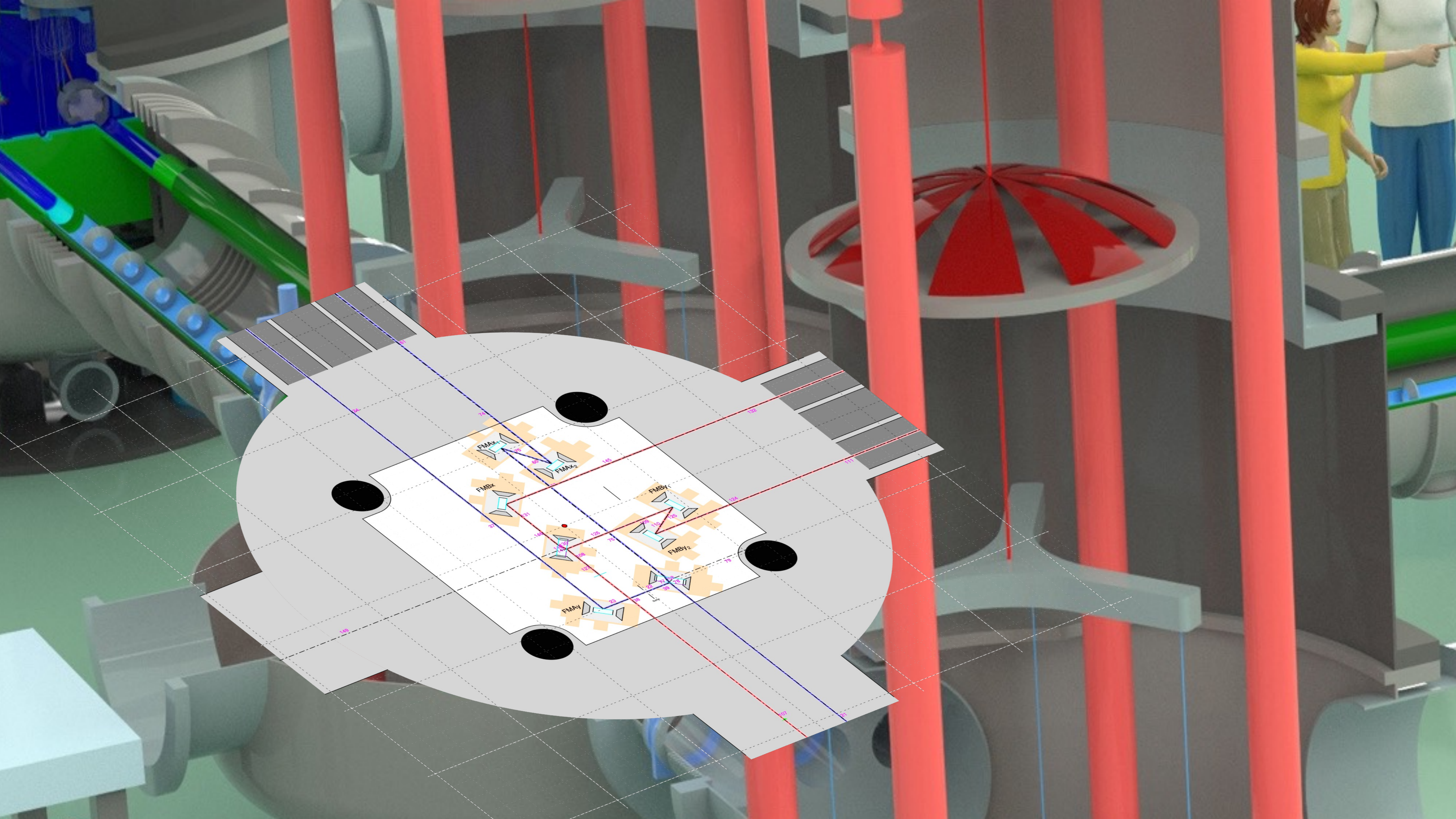

Hands-on introduction

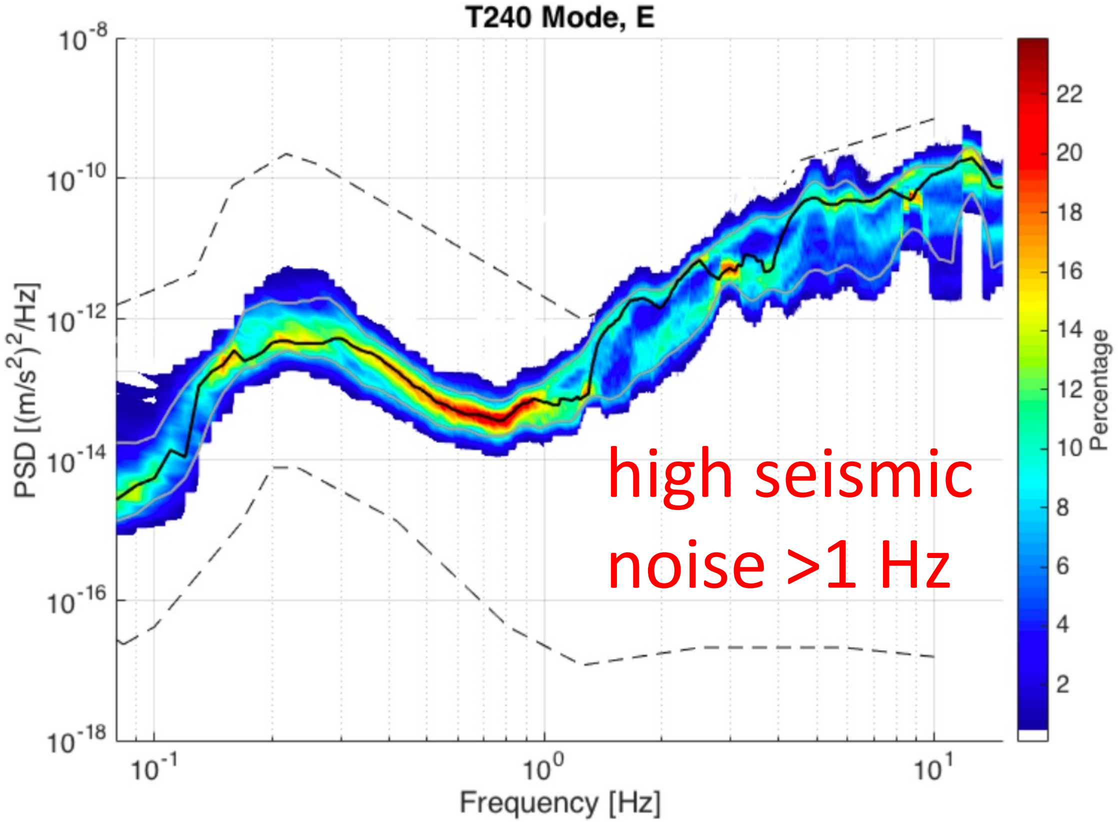


Where are these benchtop supsensions needed?


FMAx1
FMAx2
FMBx
FMBy1
FMBy2
FMAy

Why extra suspensions on already suspended bench?

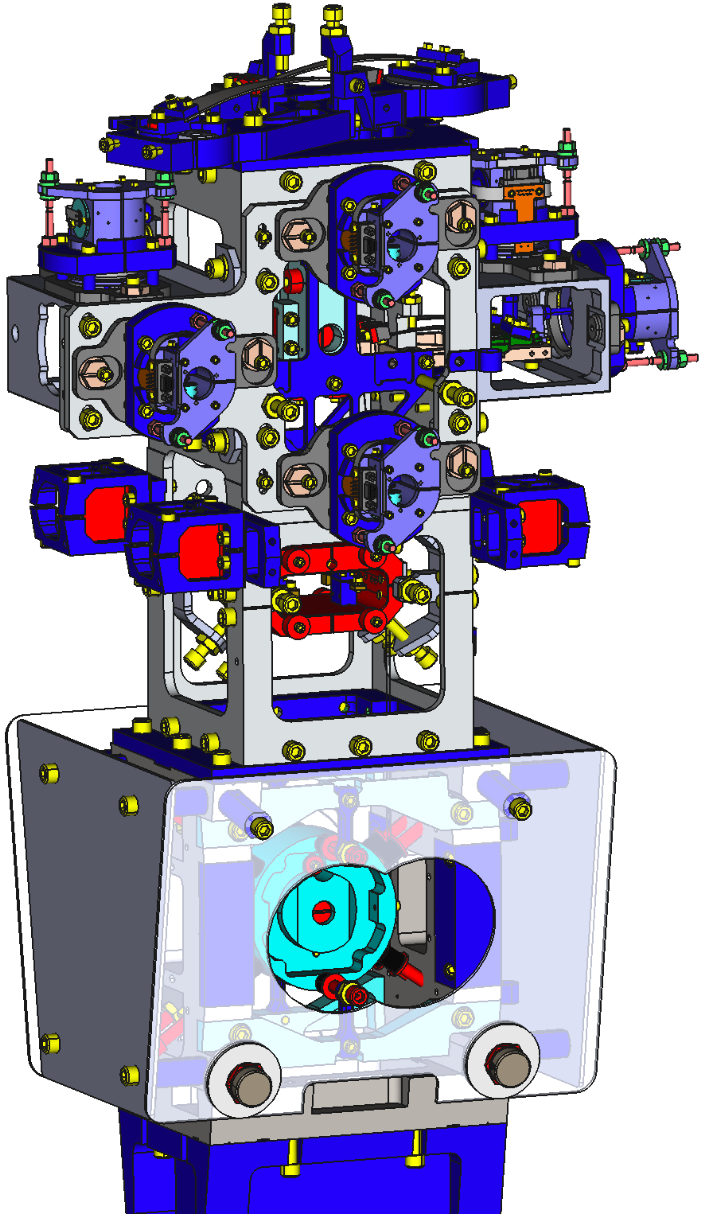
Besides the need for independent motion of each optical component…
…the ET pathfinder site is close to the city, main roads (N278 and A2) and train tracks (near station Maastricht and Maastricht Randwyck)!

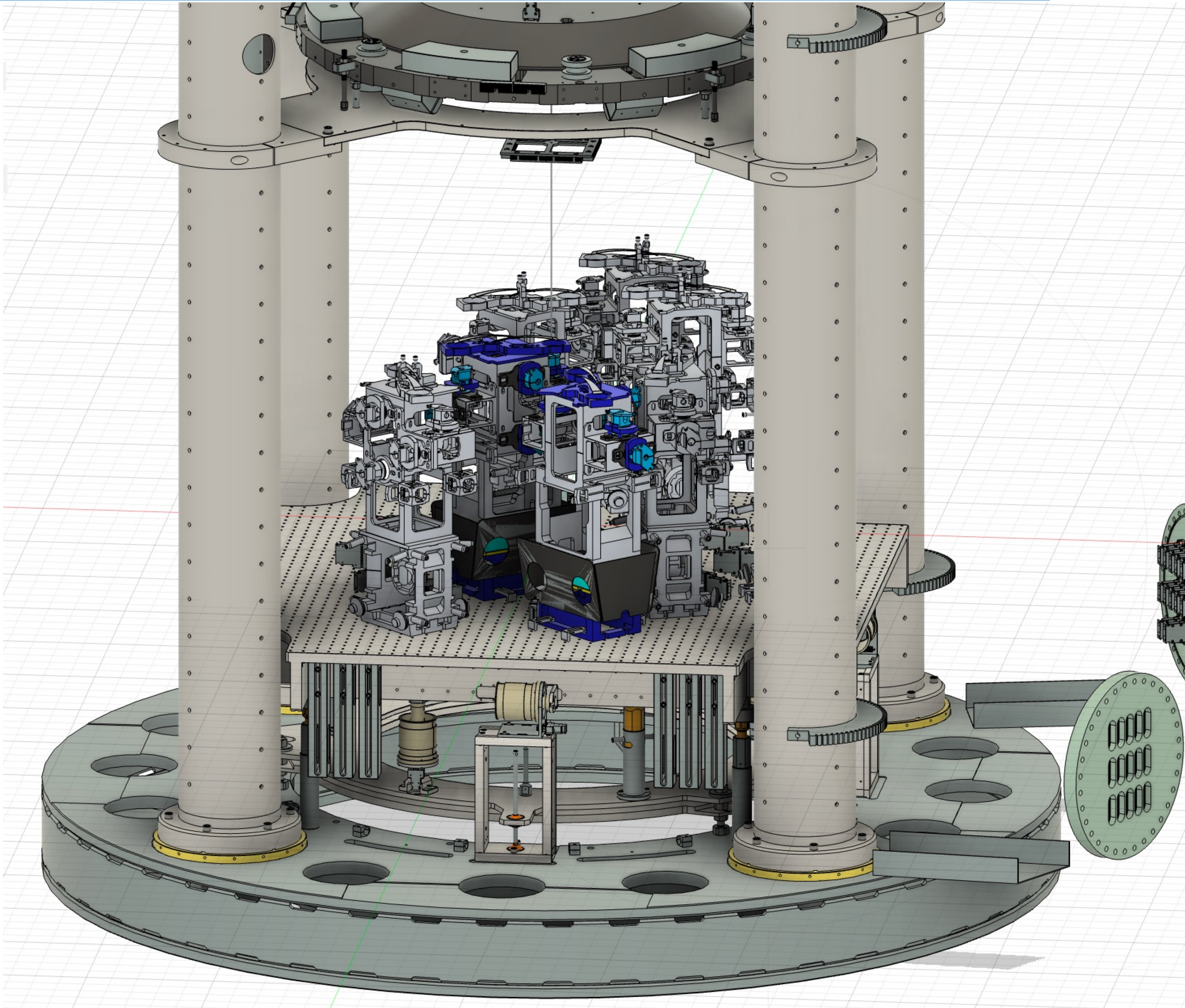


from ETPathFinder CDR

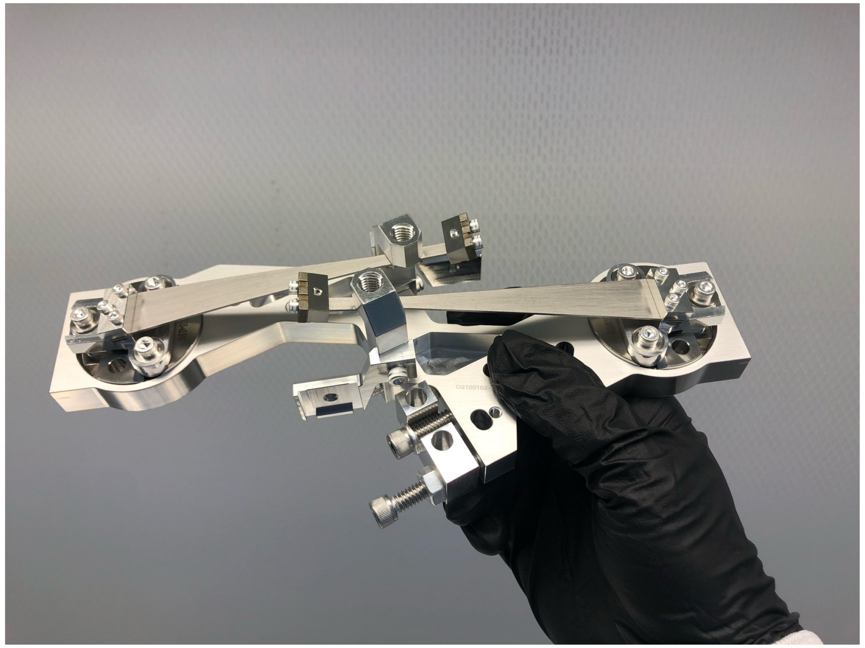
Figure 5.2: ETpathfinder hall horizontal acceleration power spectral density variation as measured

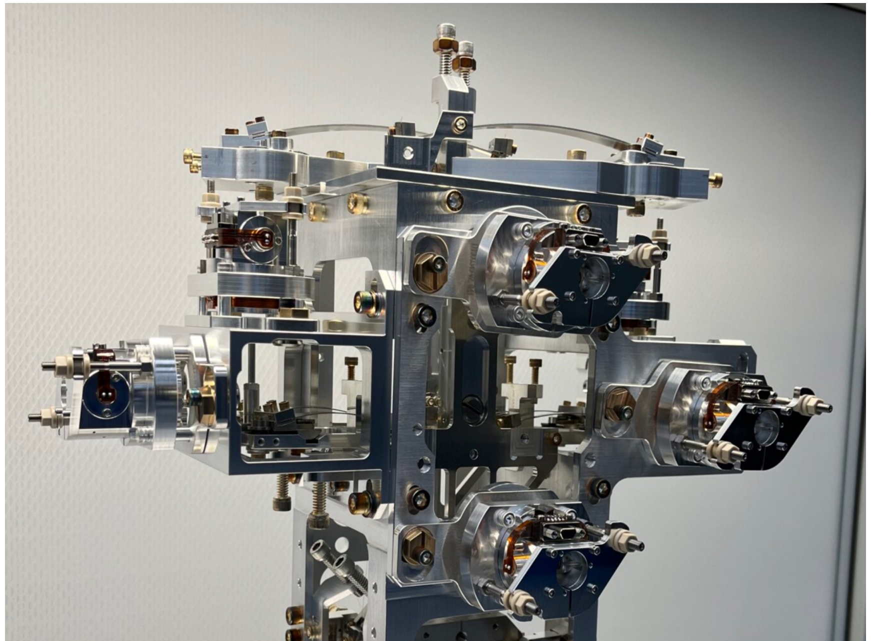
Benchtop HRTS CADs





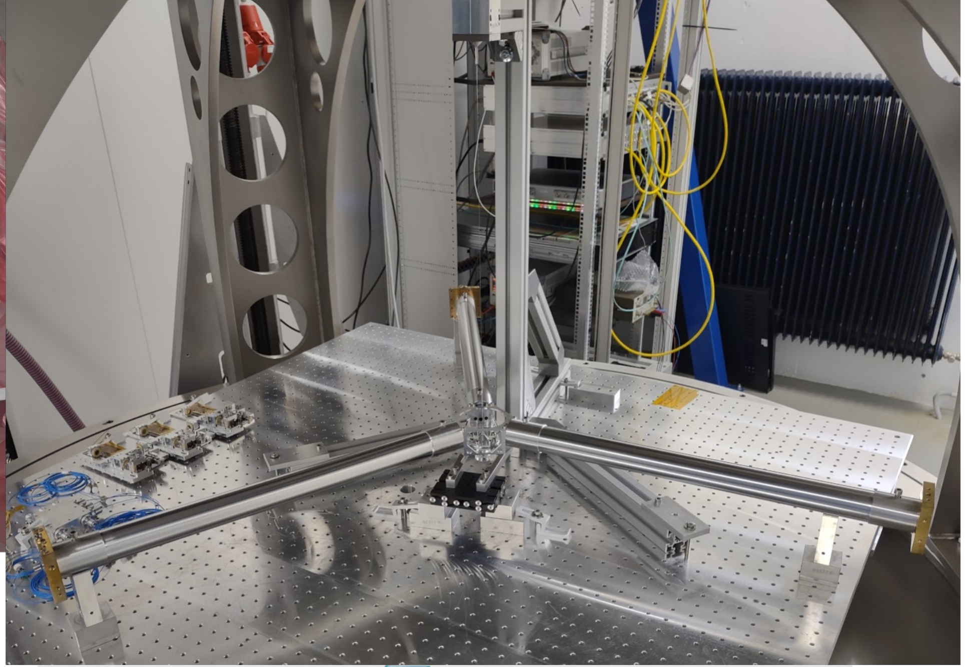
Assembly of HRTSs in ongoing a few 100 m away



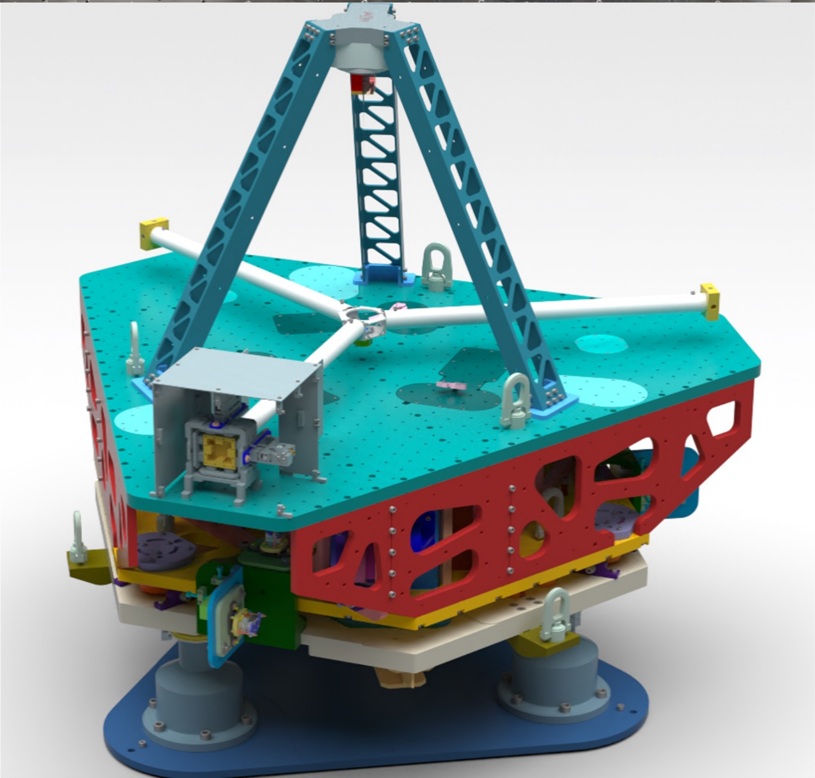


Who am I?

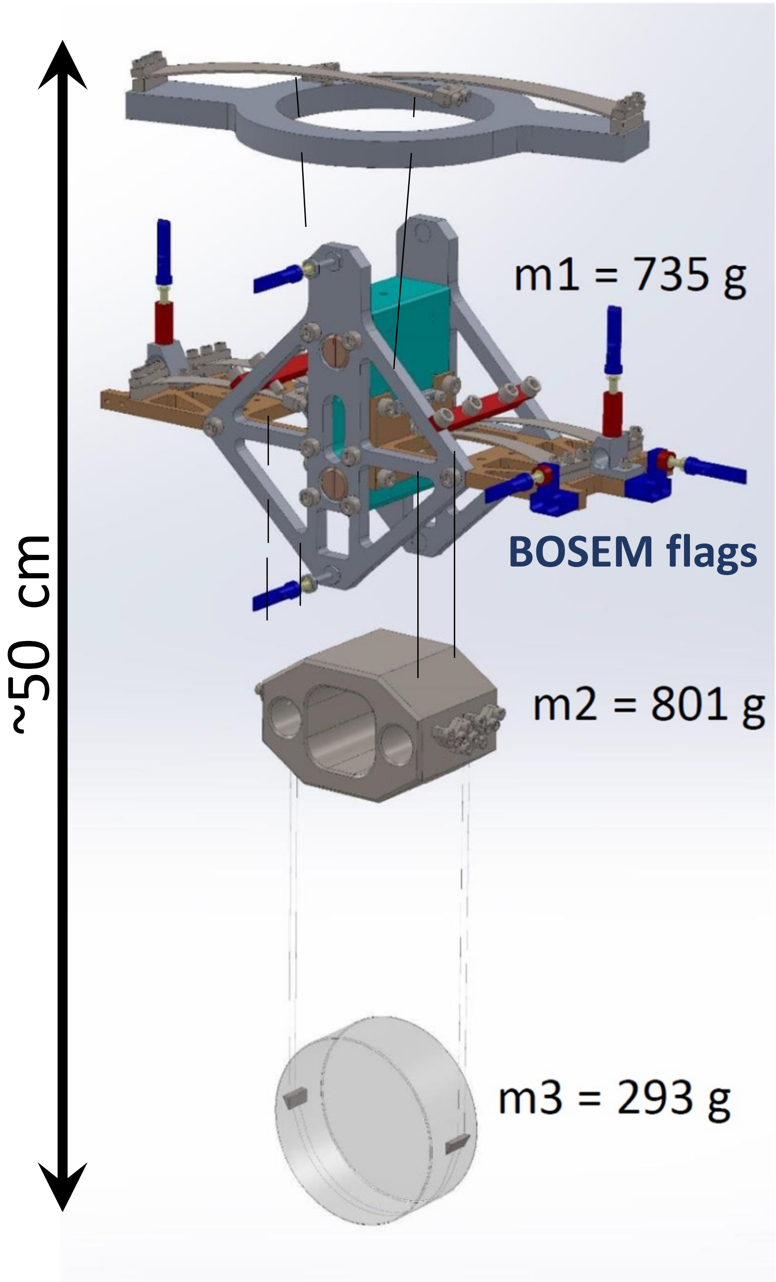
Michele Valentini

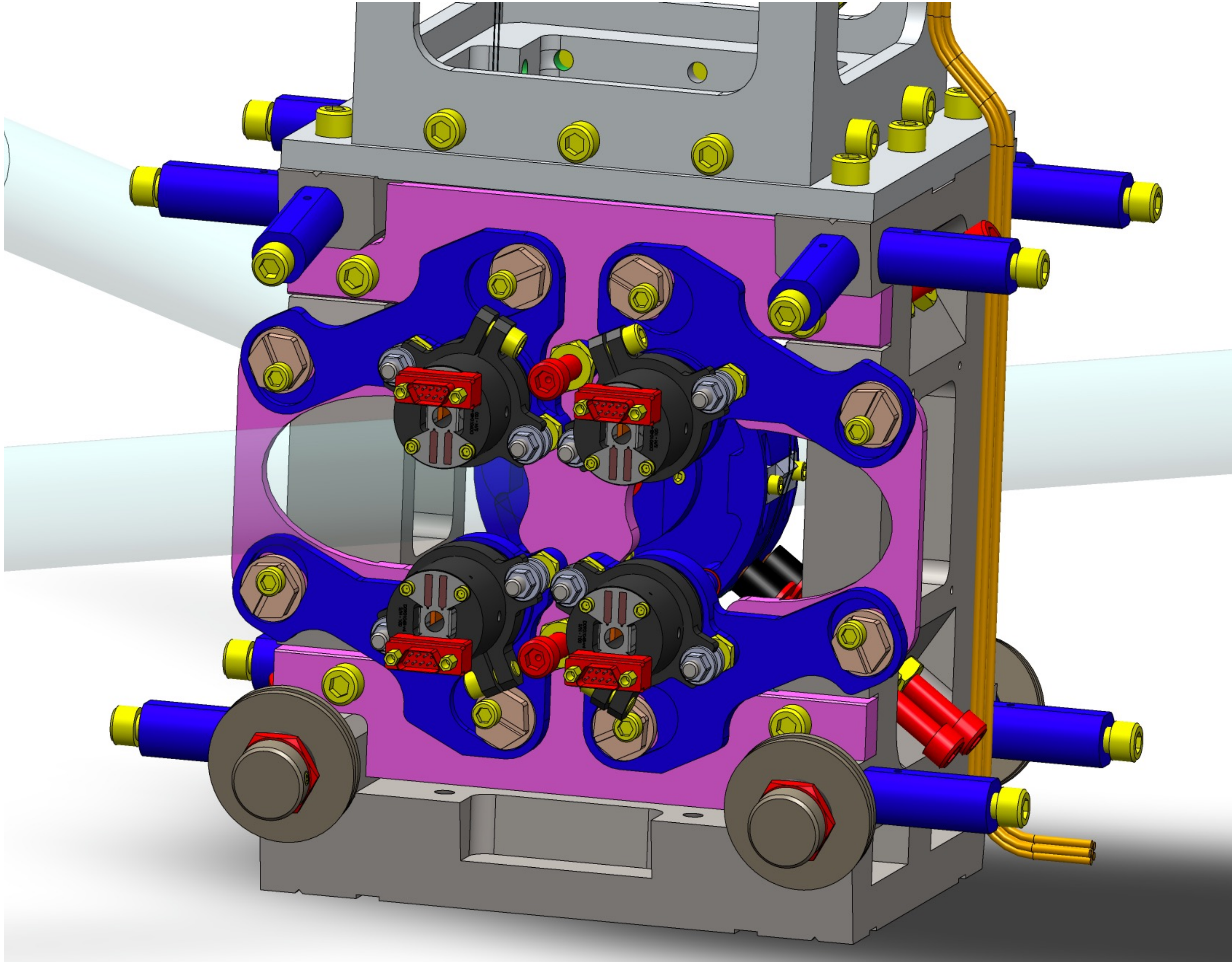


Virgo start of O2 photo (month of its first detection and the neutron star merger)

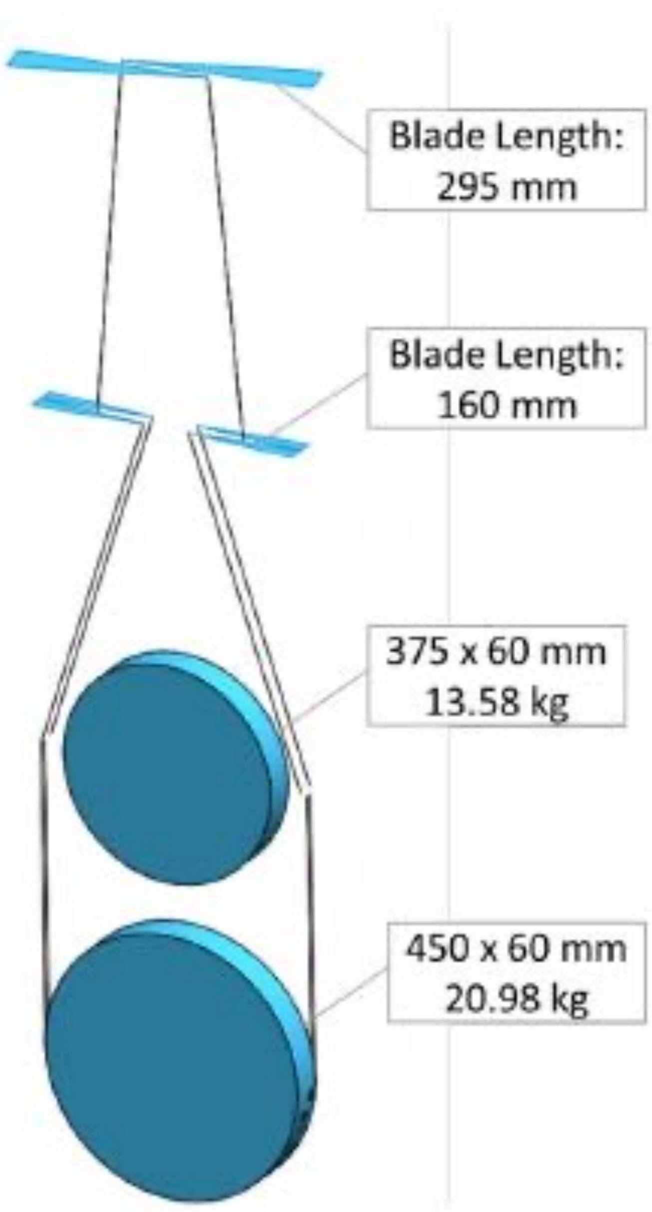


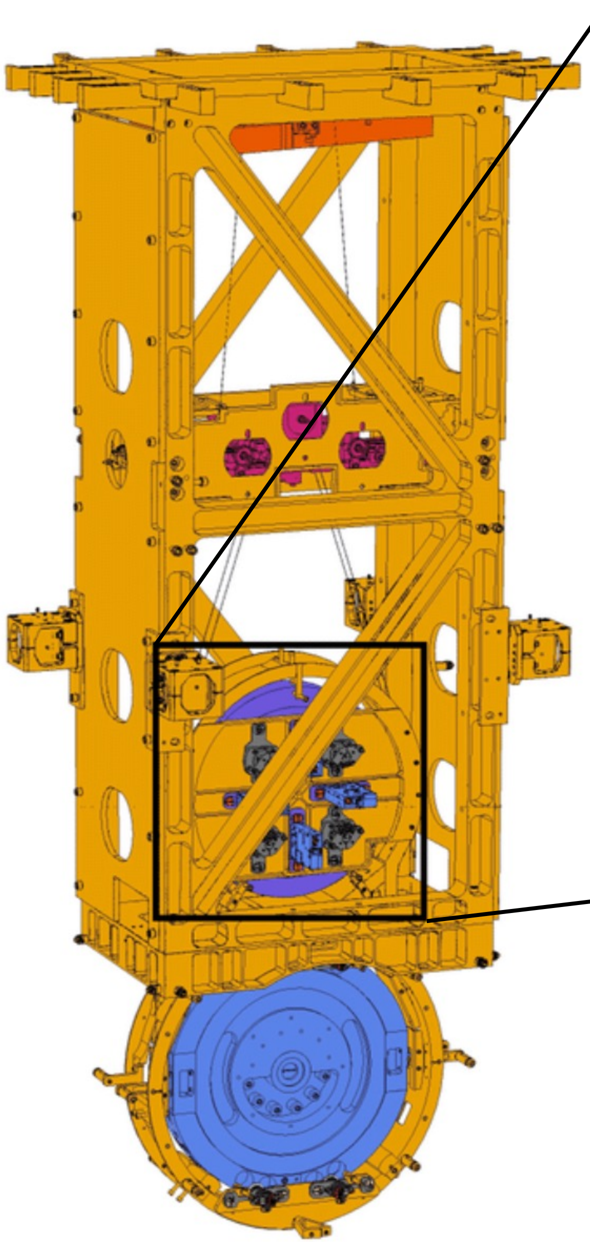
HRTS pendulum modes can be controlled at M1 and M3

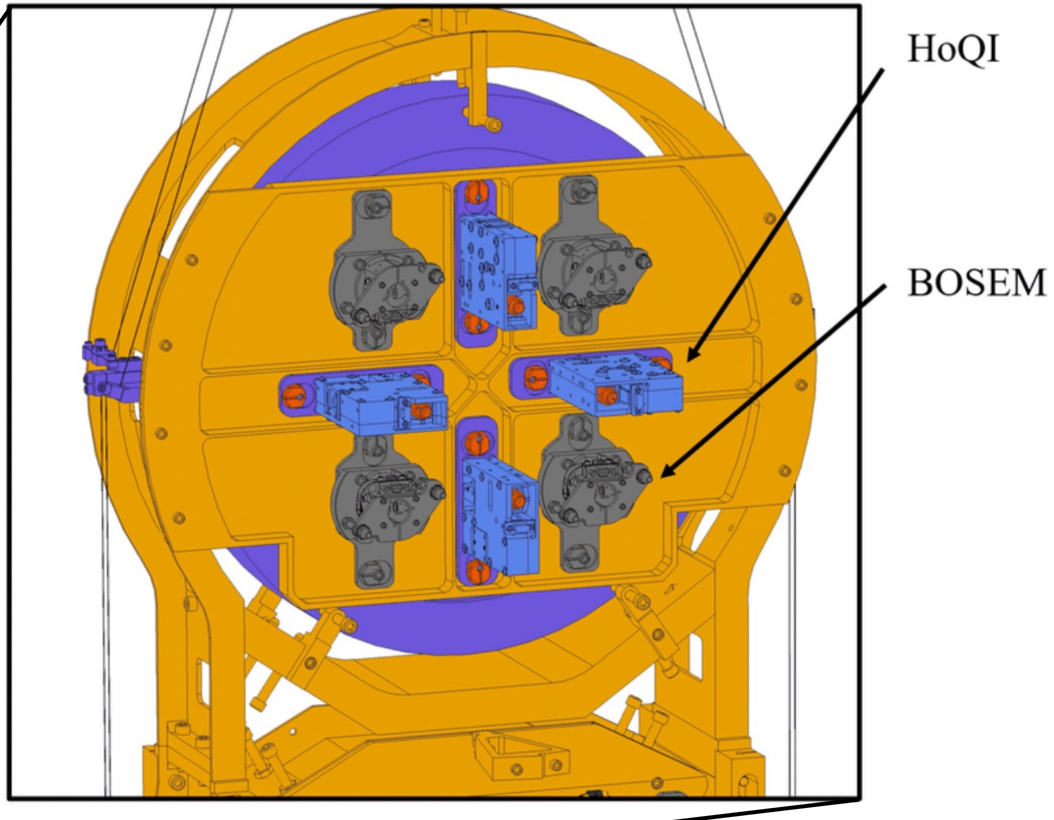




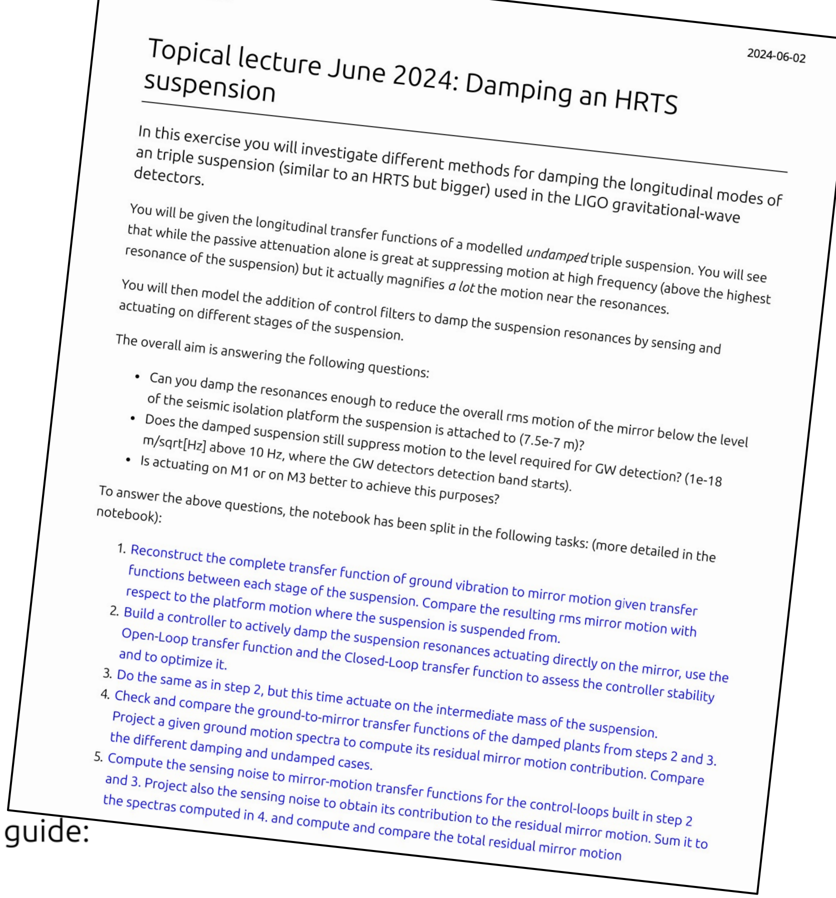
Using another triple pendulum model (LIGO’s BS)







- HRTS model not functioning.
- Pendulum frequencies lower.


2024-06-02

Topical lecture June 2024: Damping an HRTS suspension

In this exercise you will investigate different methods for damping the longitudinal modes of an triple suspension (similar to an HRTS but bigger) used in the LIGO gravitational-wave detectors.

You will be given the longitudinal transfer functions of a modelled *undamped* triple suspension. You will see that while the passive attenuation alone is great at suppressing motion at high frequency (above the highest resonance of the suspension) but it actually magnifies *a lot* the motion near the resonances.

You will then model the addition of control filters to damp the suspension resonances by sensing and actuating on different stages of the suspension.

The overall aim is answering the following questions:

- Can you damp the resonances enough to reduce the overall rms motion of the mirror below the level of the seismic isolation platform the suspension is attached to (7.5e-7 m)?
- Does the damped suspension still suppress motion to the level required for GW detection? (1e-18 m/sqrt[Hz] above 10 Hz, where the GW detectors detection band starts).
- Is actuating on M1 or on M3 better to achieve this purposes?

To answer the above questions, the notebook has been split in the following tasks: (more detailed in the notebook):

1. Reconstruct the complete transfer function of ground vibration to mirror motion given transfer functions between each stage of the suspension. Compare the resulting rms mirror motion with respect to the platform motion where the suspension is suspended from.
2. Build a controller to actively damp the suspension resonances actuating directly on the mirror, use the Open-Loop transfer function and the Closed-Loop transfer function to assess the controller stability and to optimize it.
3. Do the same as in step 2, but this time actuate on the intermediate mass of the suspension.
4. Check and compare the ground-to-mirror transfer functions of the damped plants from steps 2 and 3. Project a given ground motion spectra to compute its residual mirror motion contribution. Compare the different damping and undamped cases.
5. Compute the sensing noise to mirror-motion transfer functions for the control-loops built in step 2 and 3. Project also the sensing noise to obtain its contribution to the residual mirror motion. Sum it to the spectras computed in 4. and compute and compare the total residual mirror motion

Setup instructions

0. Open and enable EDUvpn for 'Institute Access' (installation guide: https://kb.nikhef.nl/ct/eduVPN.html)
1. go to https://callysto.nikhef.nl/ and login with your nikhef credentials.
2. Open a terminal from the callysto jupyter lab (file->New->Terminal) and then execute:

```
/data/gravwav/topical_lecture_2024/setup_environm.sh
```

This will make the 'Topical lecture GW 2024' conda environment available for use on your jupyterlab instance and copy the Exercise folder in your home folder.

1. Using the filebrowser on the left select the the folder you just created in your home and the jupyter notebook inside it (Damping_a_triple_suspension.ipynb).
2. Choose 'Topical lecture GW 2024' as kernel to use (by clicking on the 'python 3 button top right). If this kernel is not available, try creating an empty notebook first and then retry.