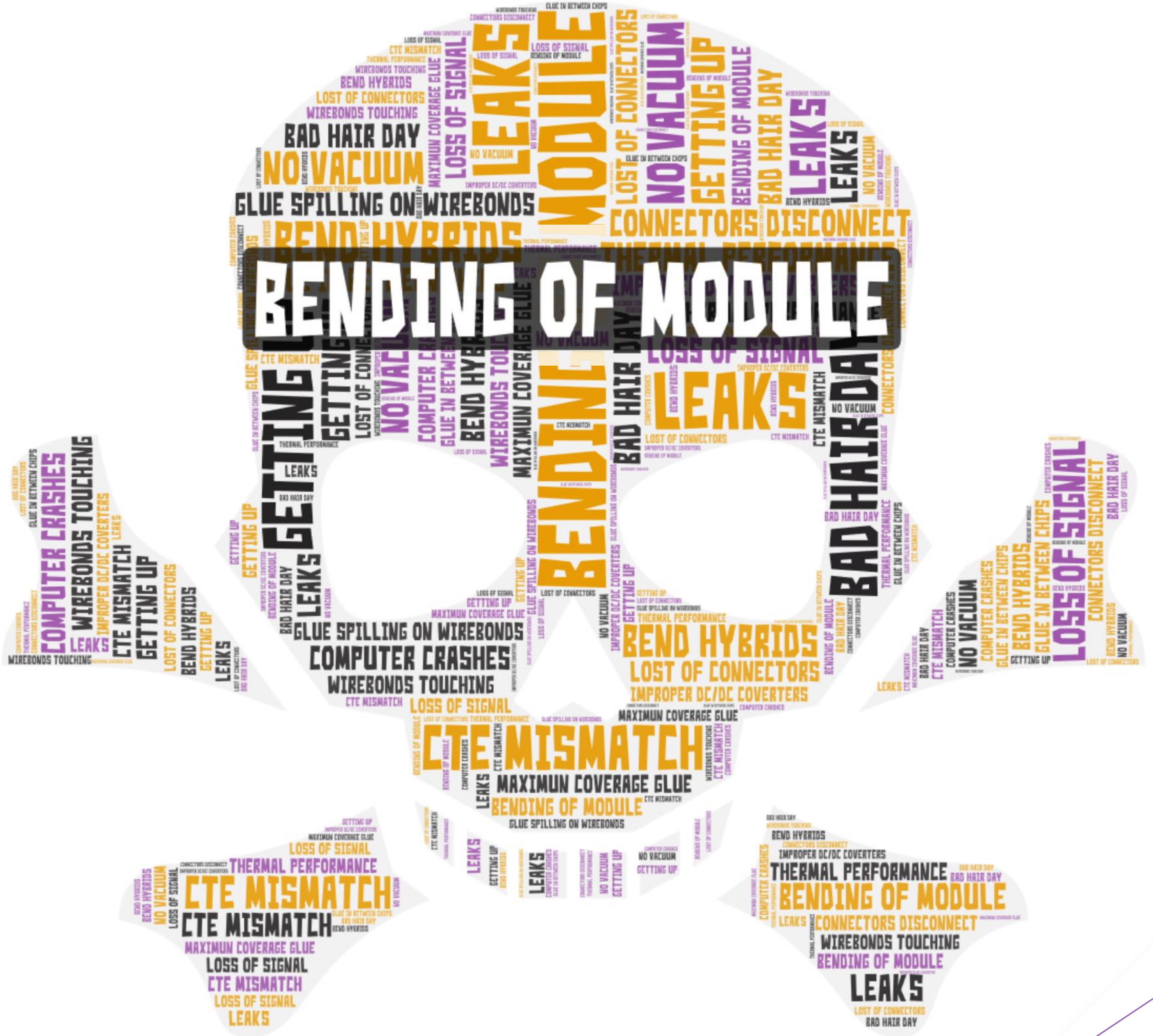
Making modules for the VELO upgrade

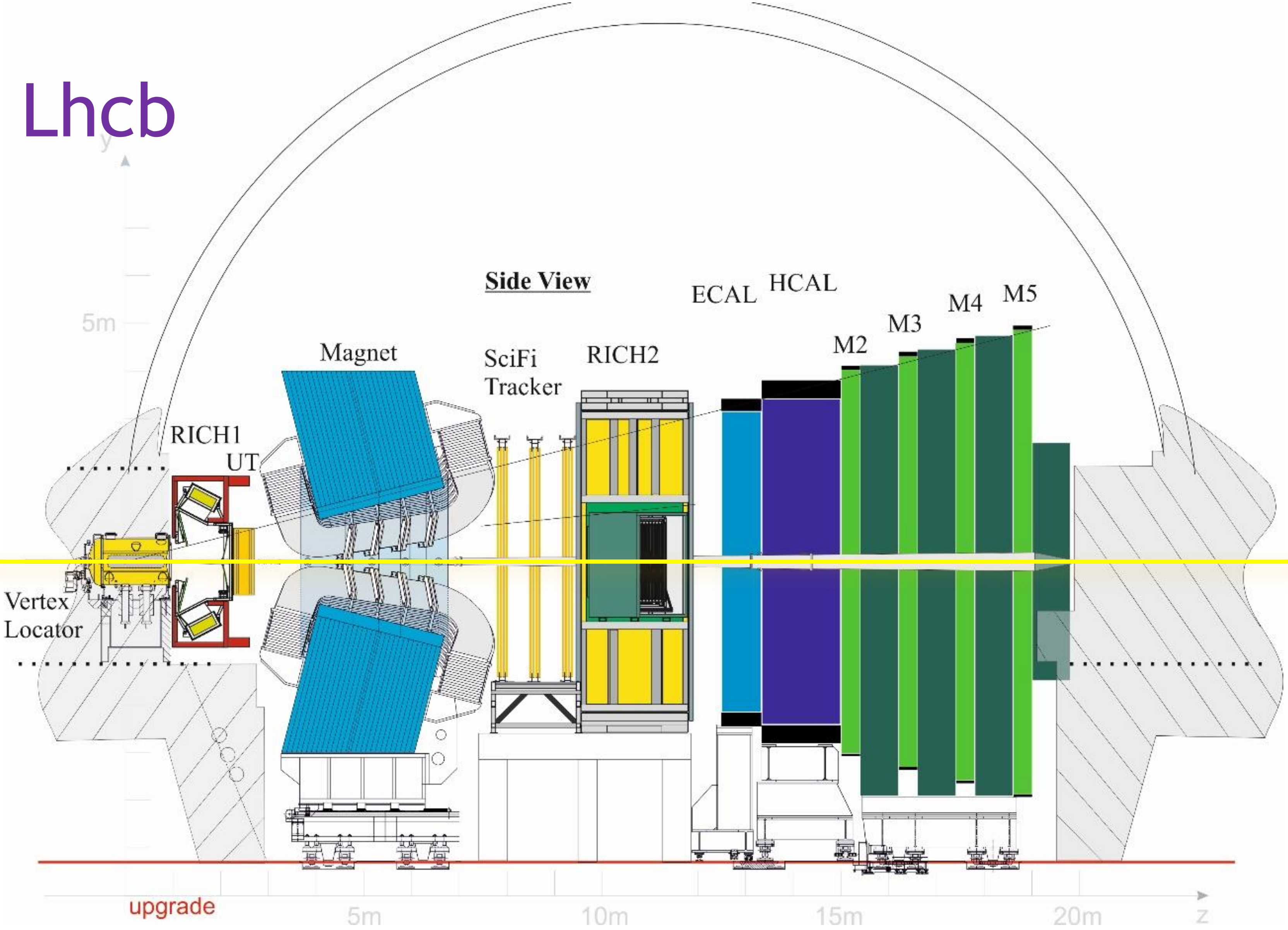
An upgrade LHCb Velo Module talk about bending & building modules

By Freek Sanders

BENDING OF MODULE

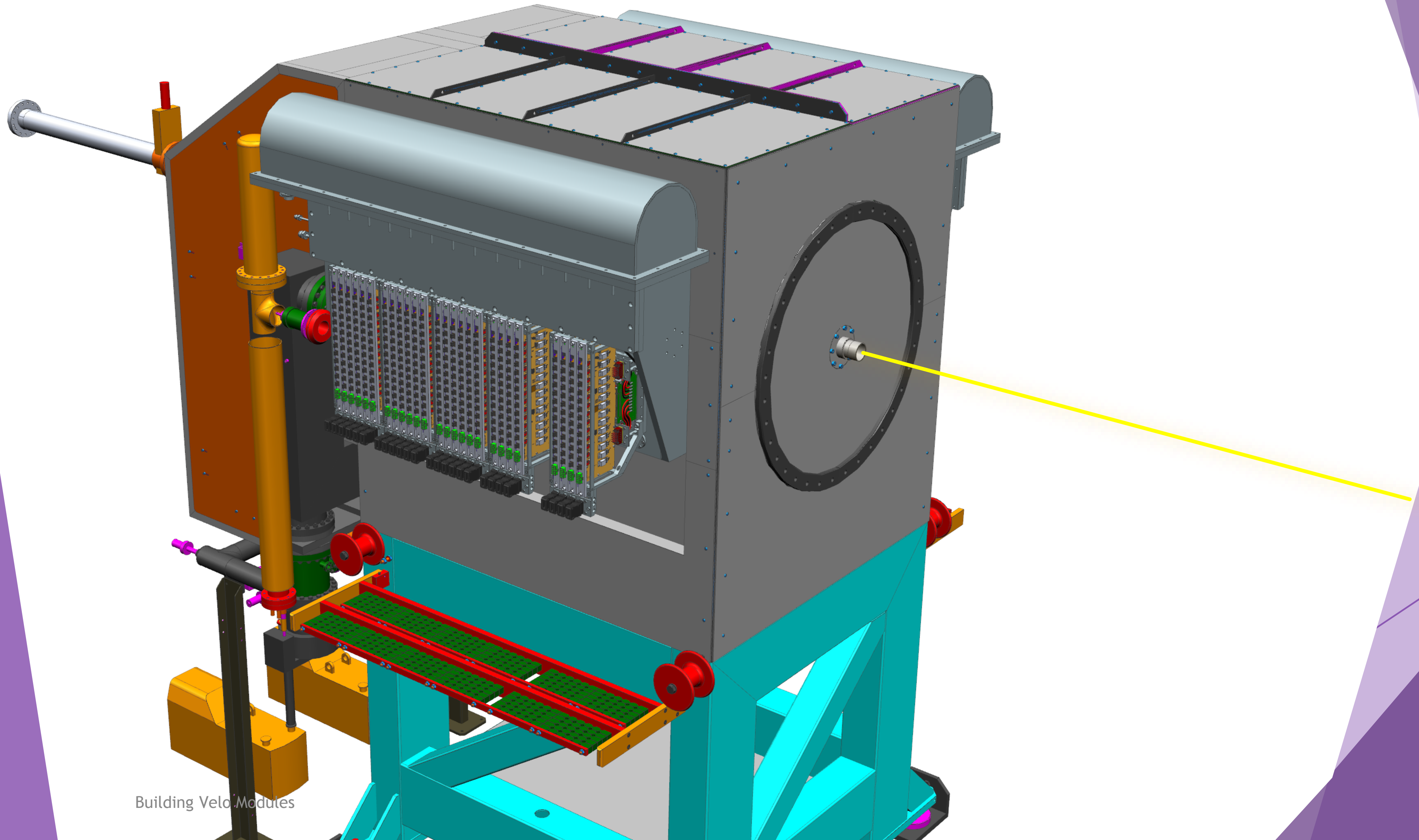


Lhcb

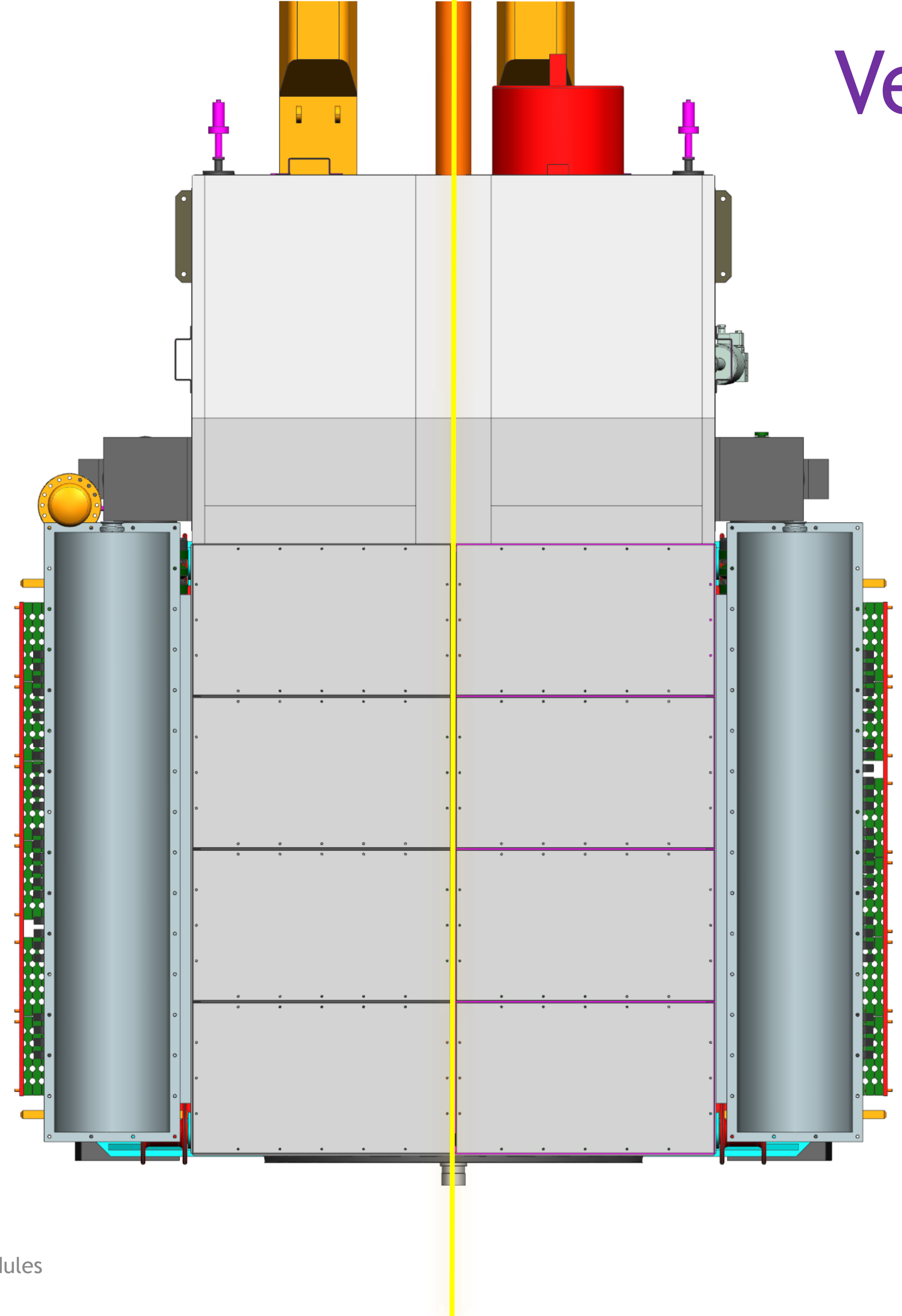


y
5m
Side View
ECAL
HCAL
M2
M3
M4
M5
Magnet
SciFi
Tracker
RICH2
RICH1
UT
Vertex
Locator
upgrade
5m
10m
15m
20m
z

The Upgrade Velo



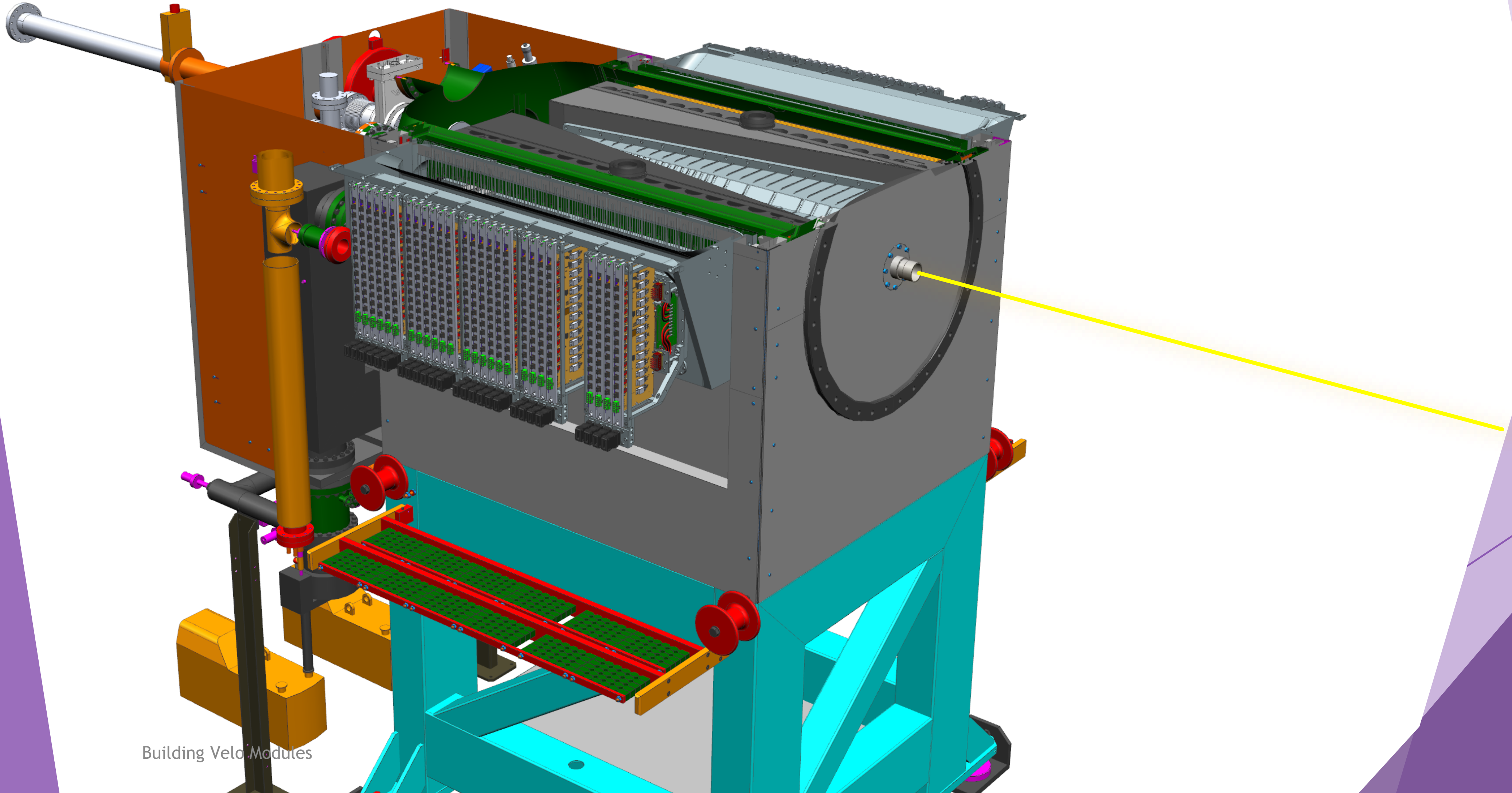
Velo Top View



2 halves
26 modules each

First pixel ~5mm
from the beam

Velo 3D Section View



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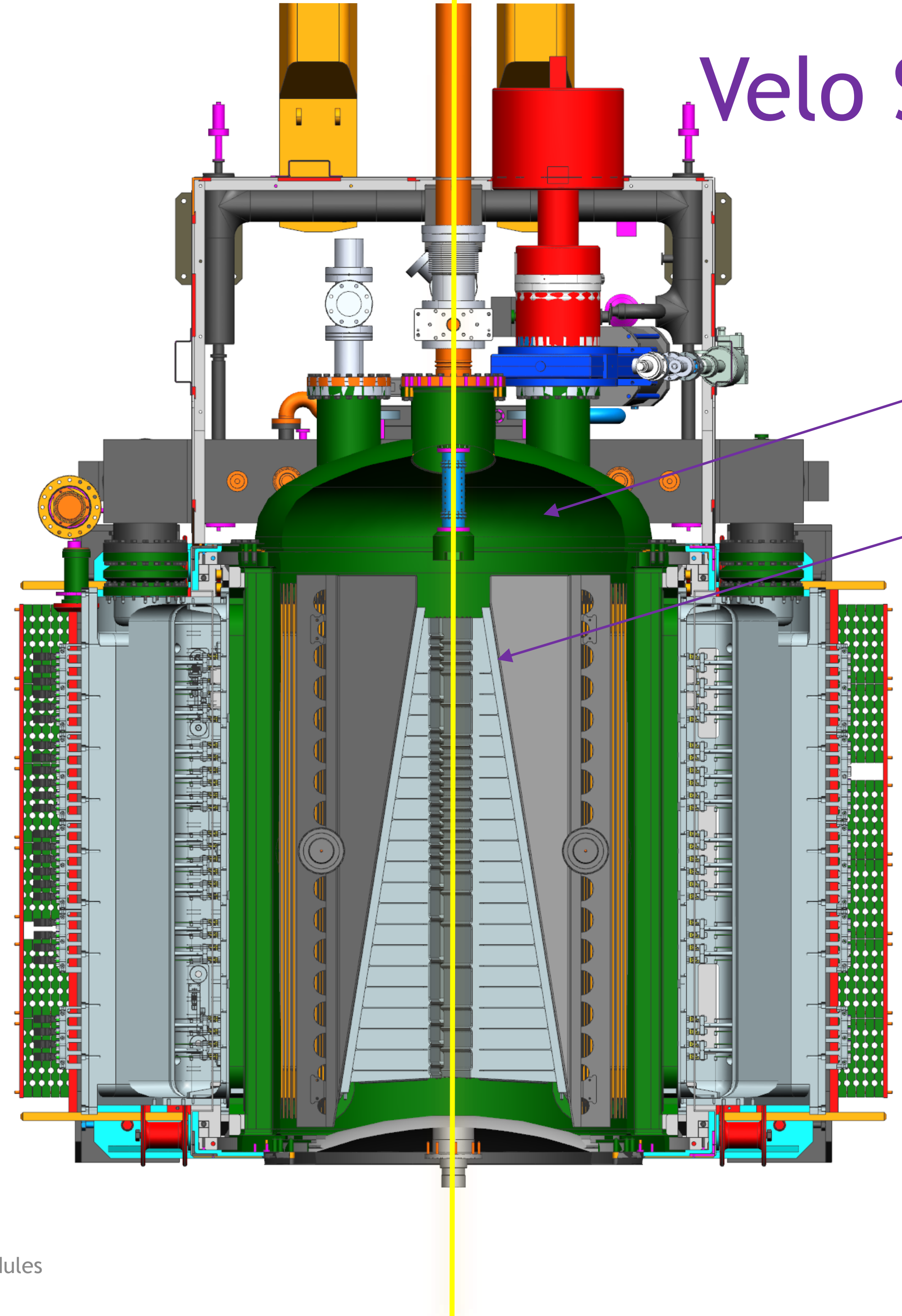
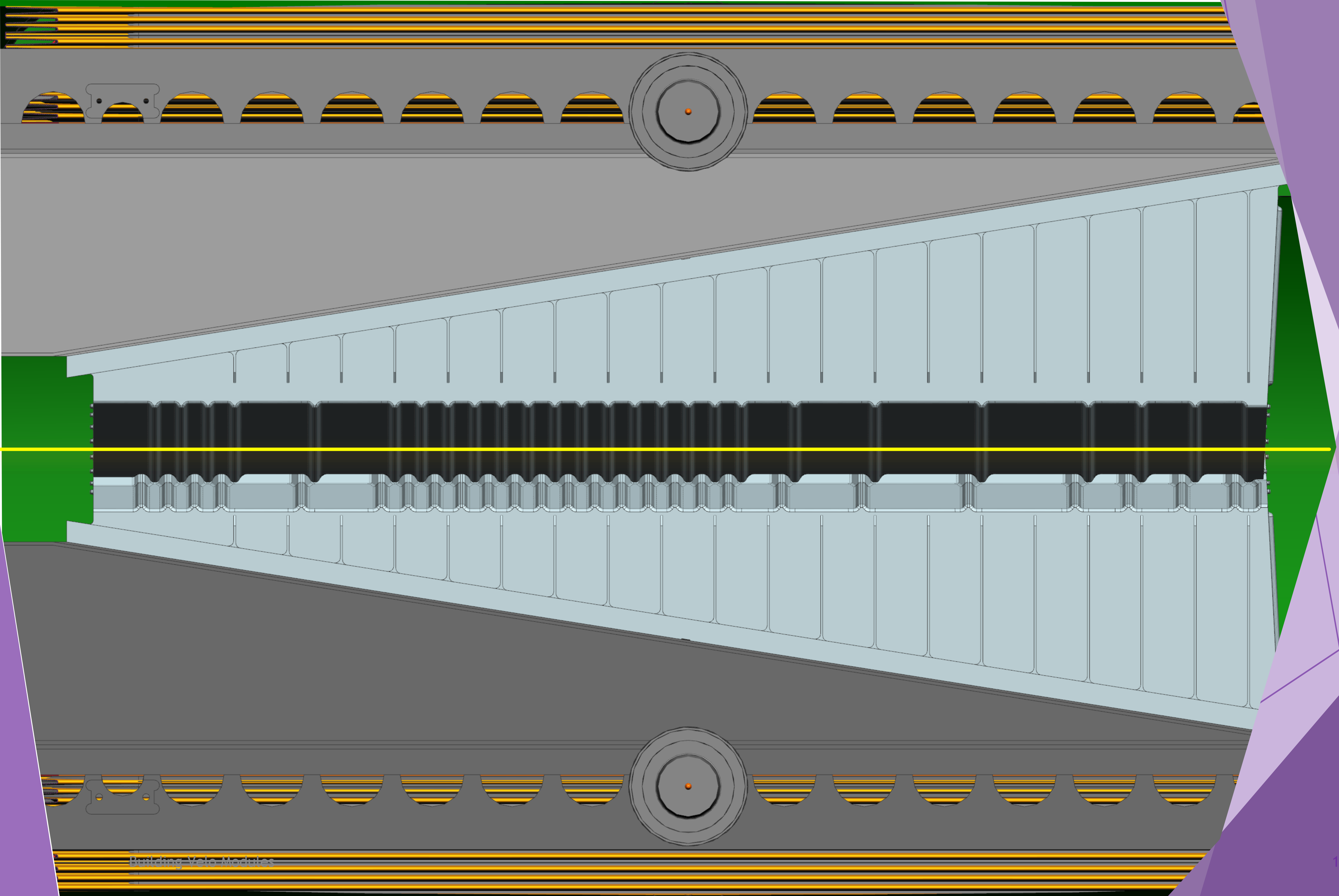
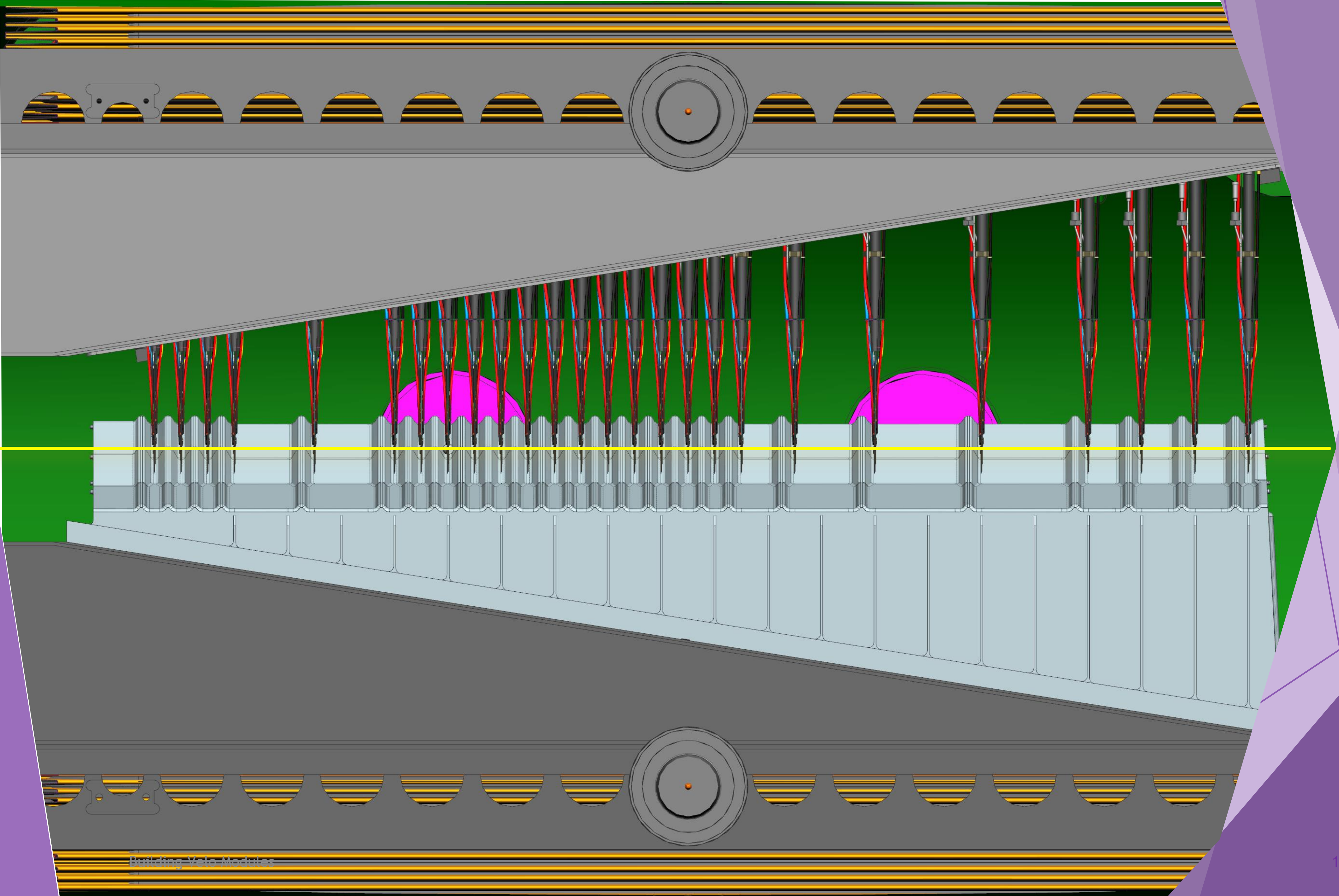
Velo Section View



LHC vacuum

RF foil to separate LHC vacuum & LHCb vacuum





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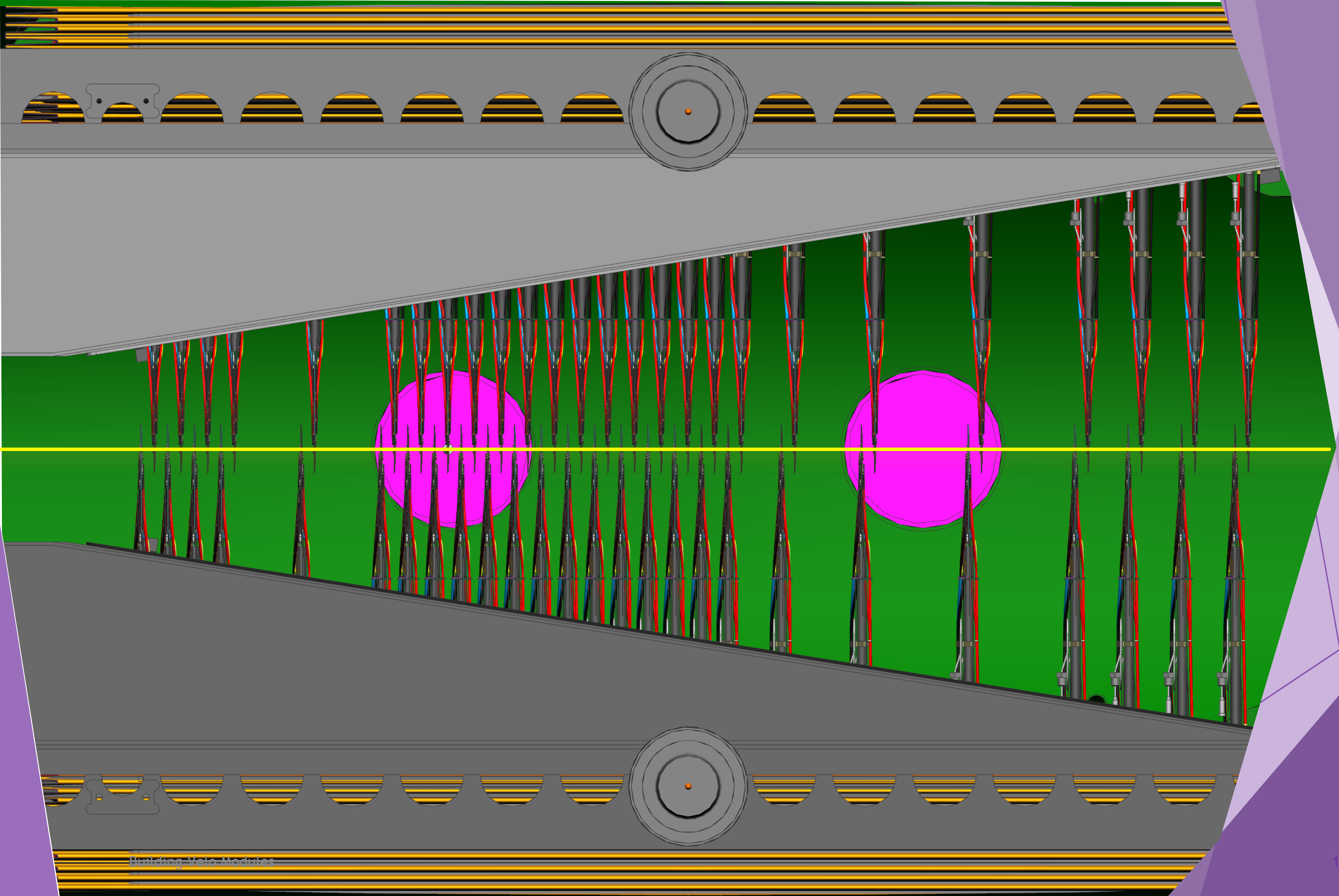
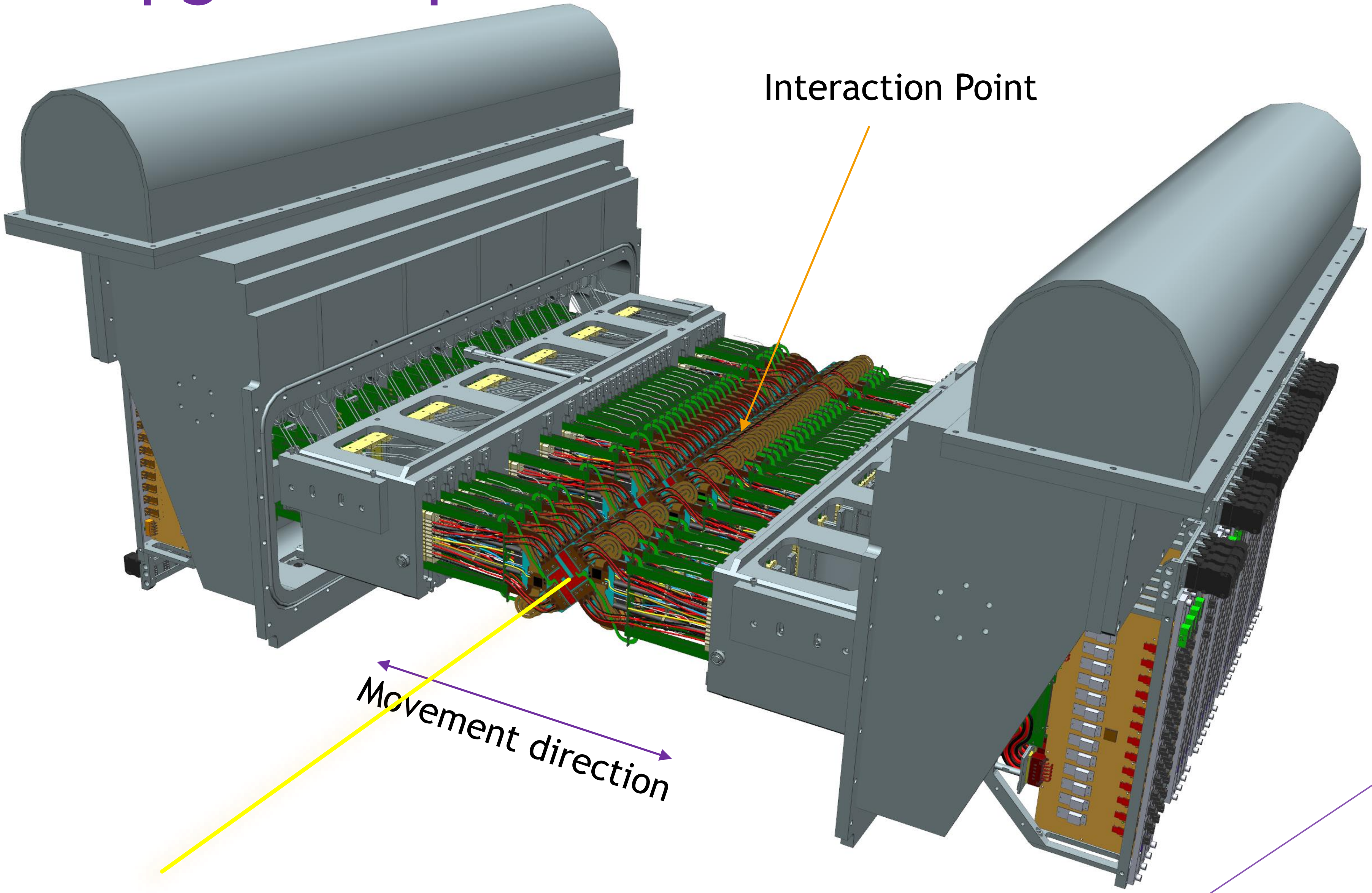


The upgraded parts



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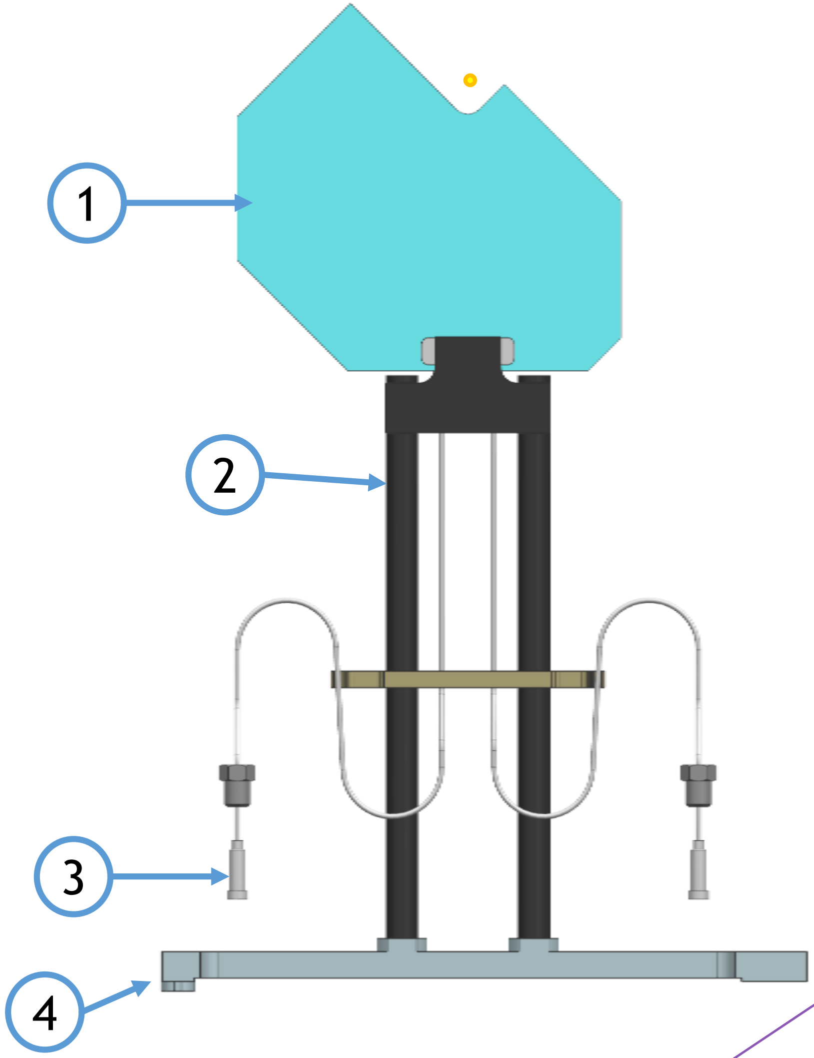
The bare module

1. Microchannel Cooling Substrate
2. Hurdle, support structure
3. VCR Fitting for CO_2 in- & outlet
4. Interface with rest of detector



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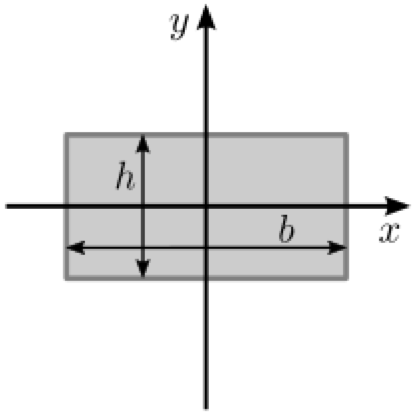
Area moment of inertia - *I*

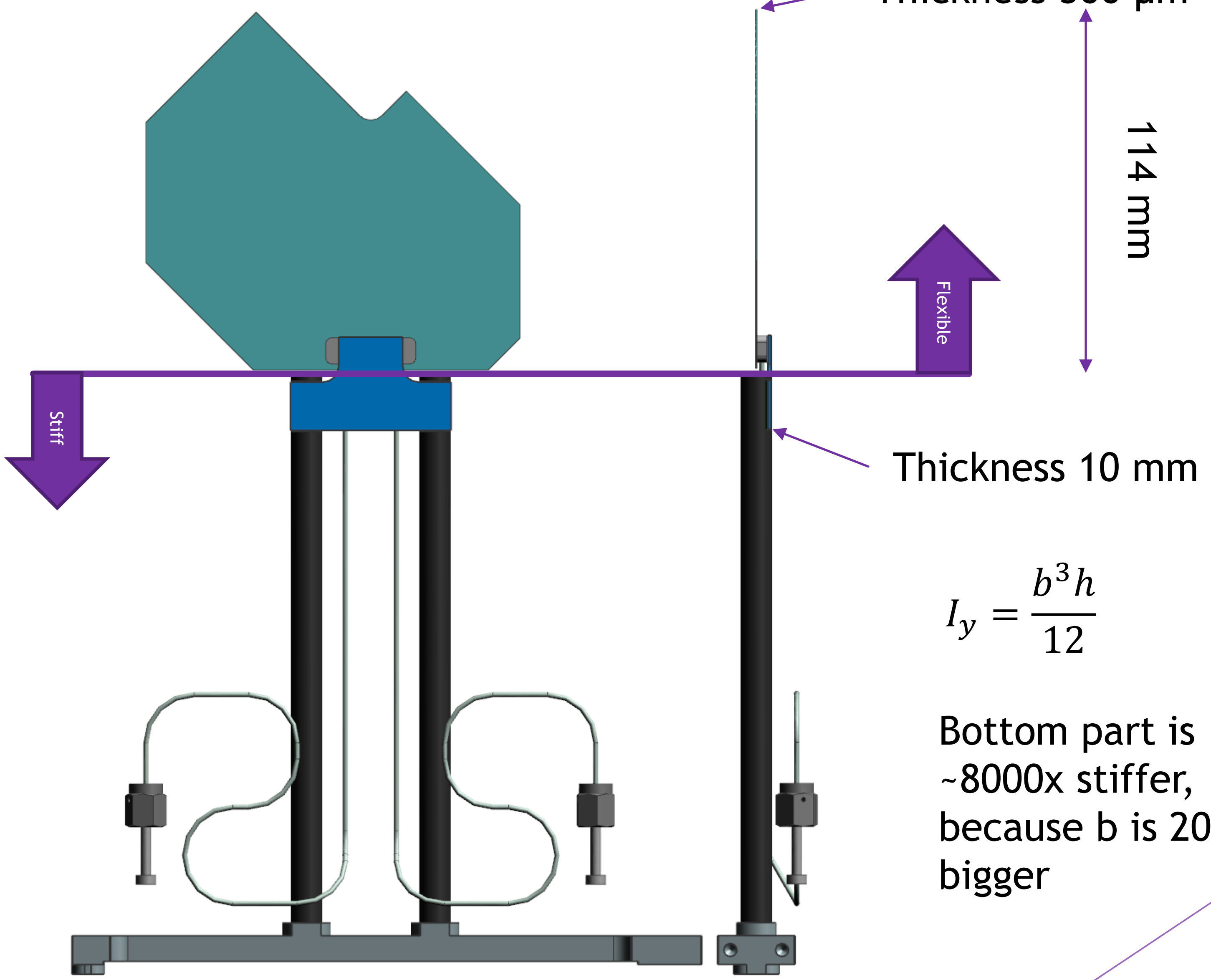
Gives resistance against bending, the higher *I* the more it restricts bending.



$$I_x = \frac{bh^3}{12}$$

$$I_y = \frac{b^3h}{12}$$

Stiffness of the module

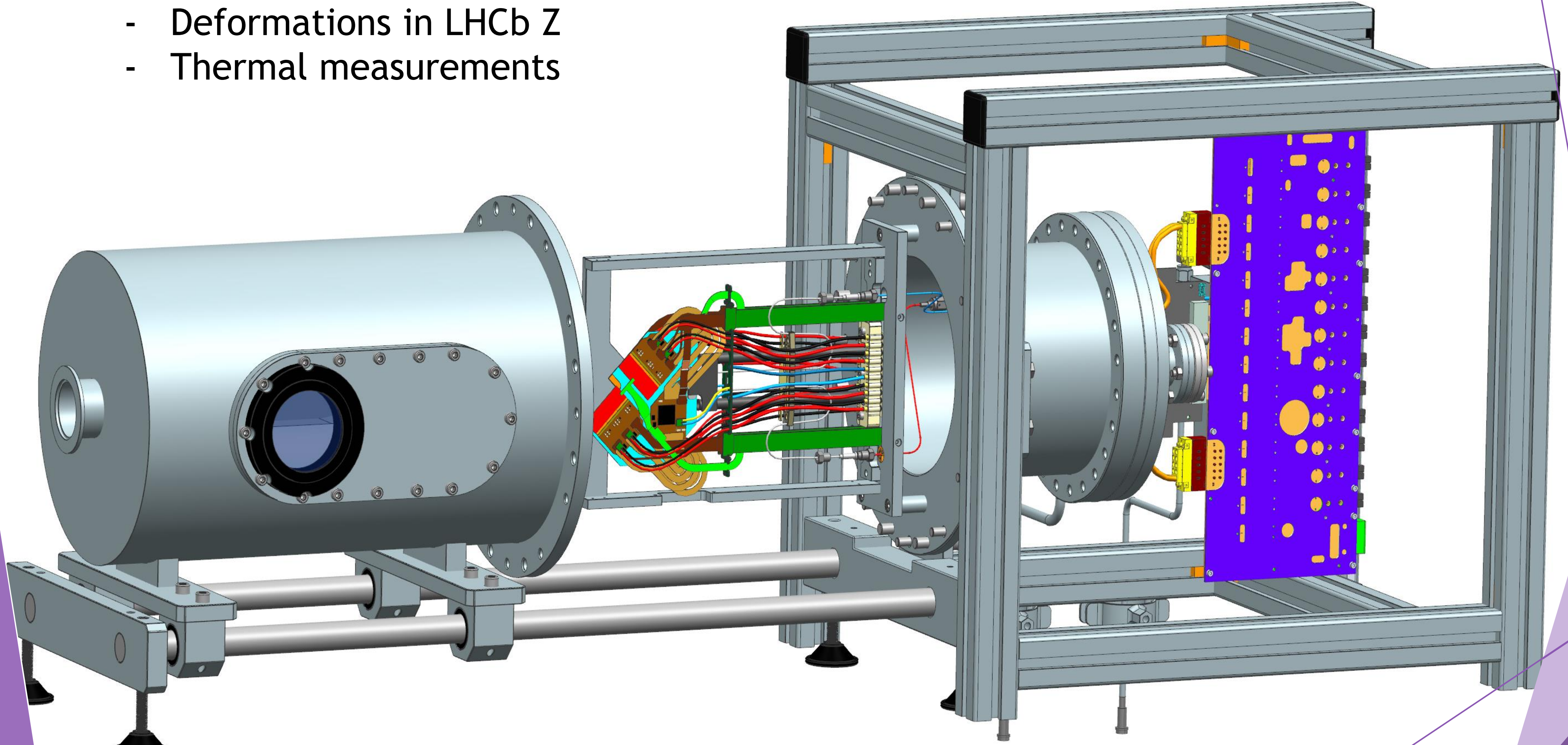


$$I_y = \frac{b^3 h}{12}$$

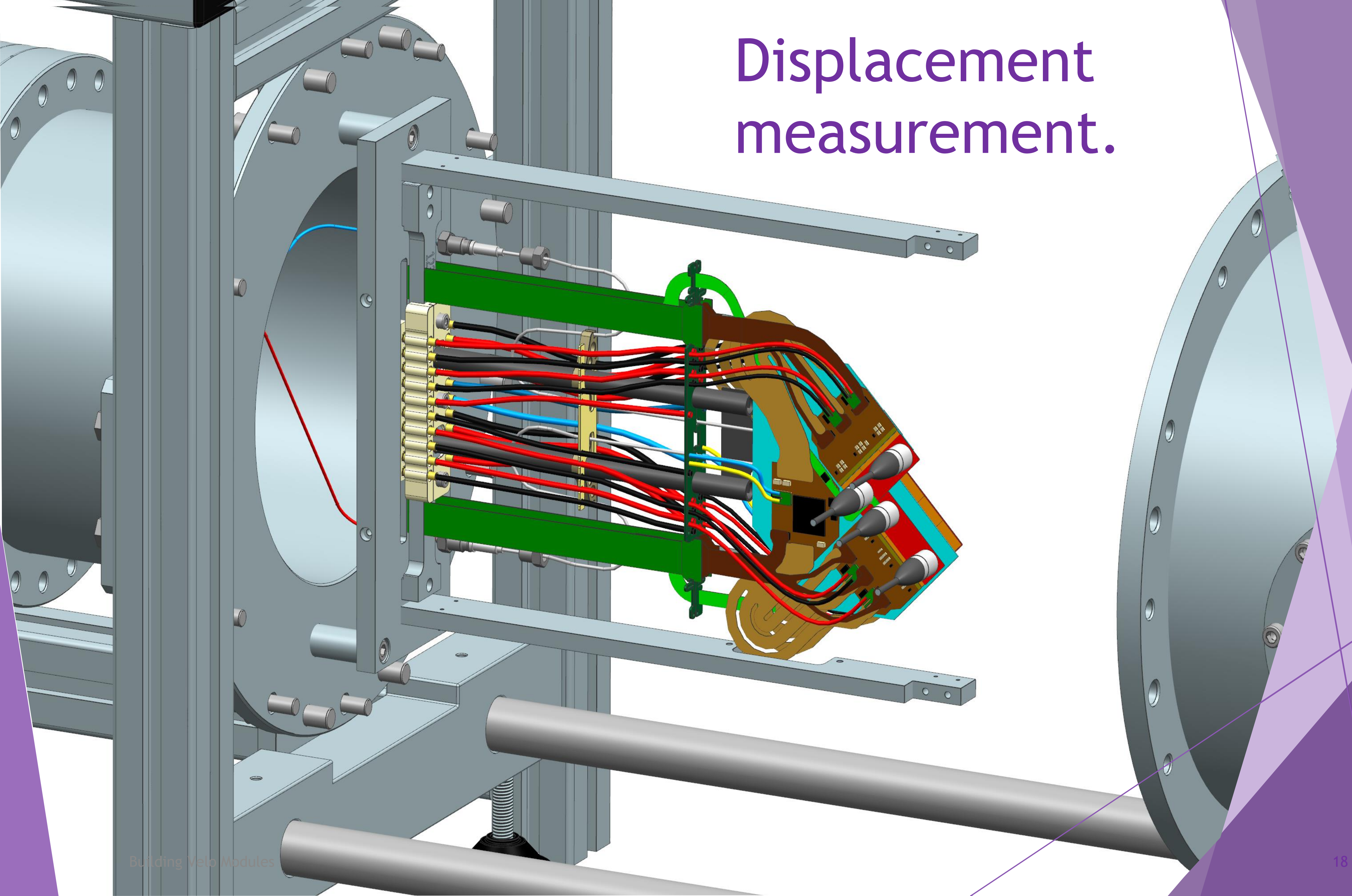
Bottom part is ~8000x stiffer, because b is 20x bigger

Setup for validating the modules.

- All electrical test in vacuum
- Deformations in LHCb Z
- Thermal measurements



Displacement measurement.



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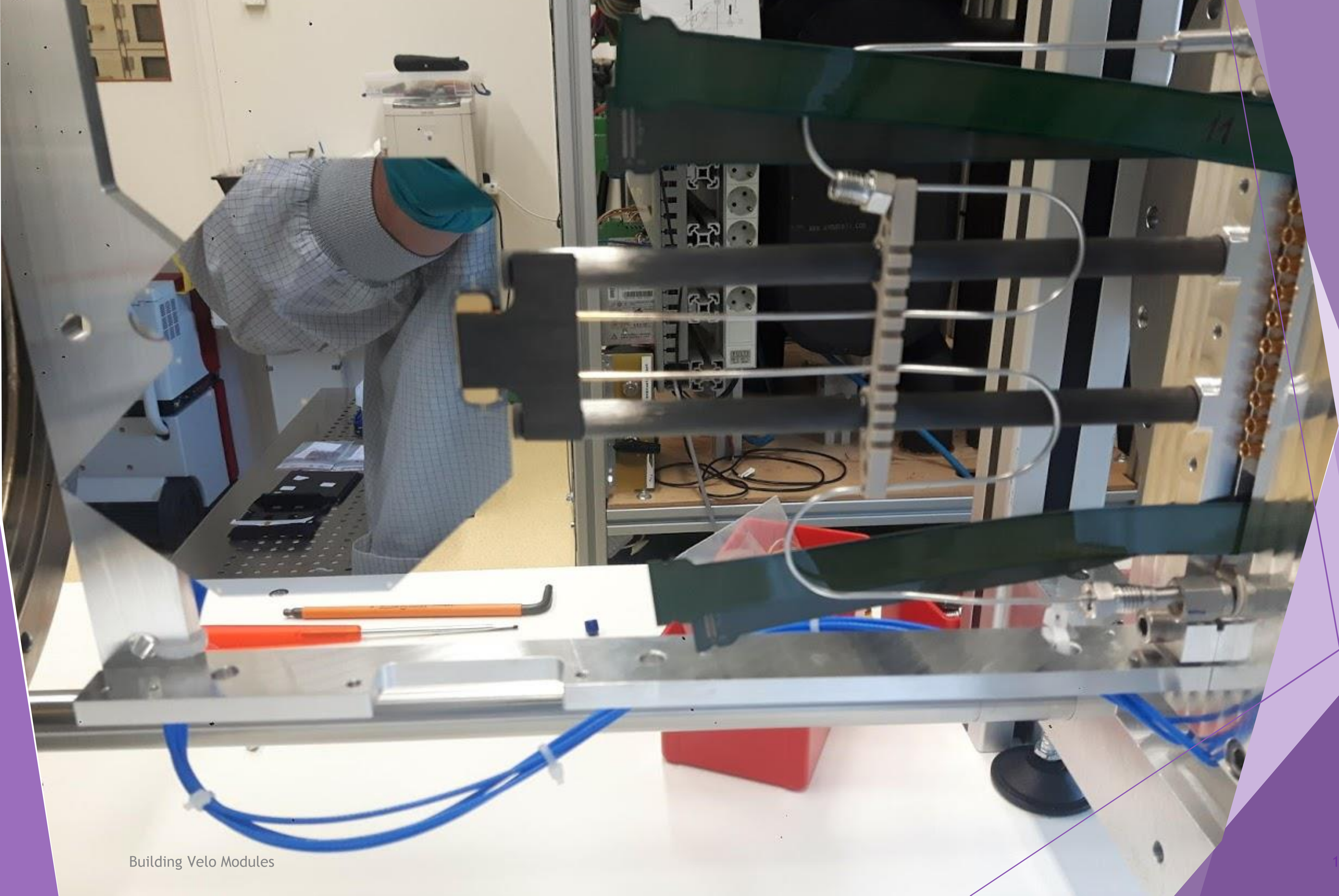
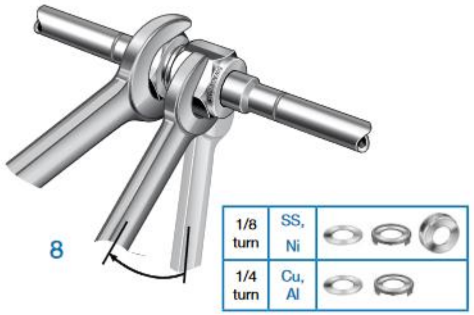


VCR induced torque

7 Finger-tight



By connecting the VCR a torque on its pipes is introduced. This is due to the metal/metal seal

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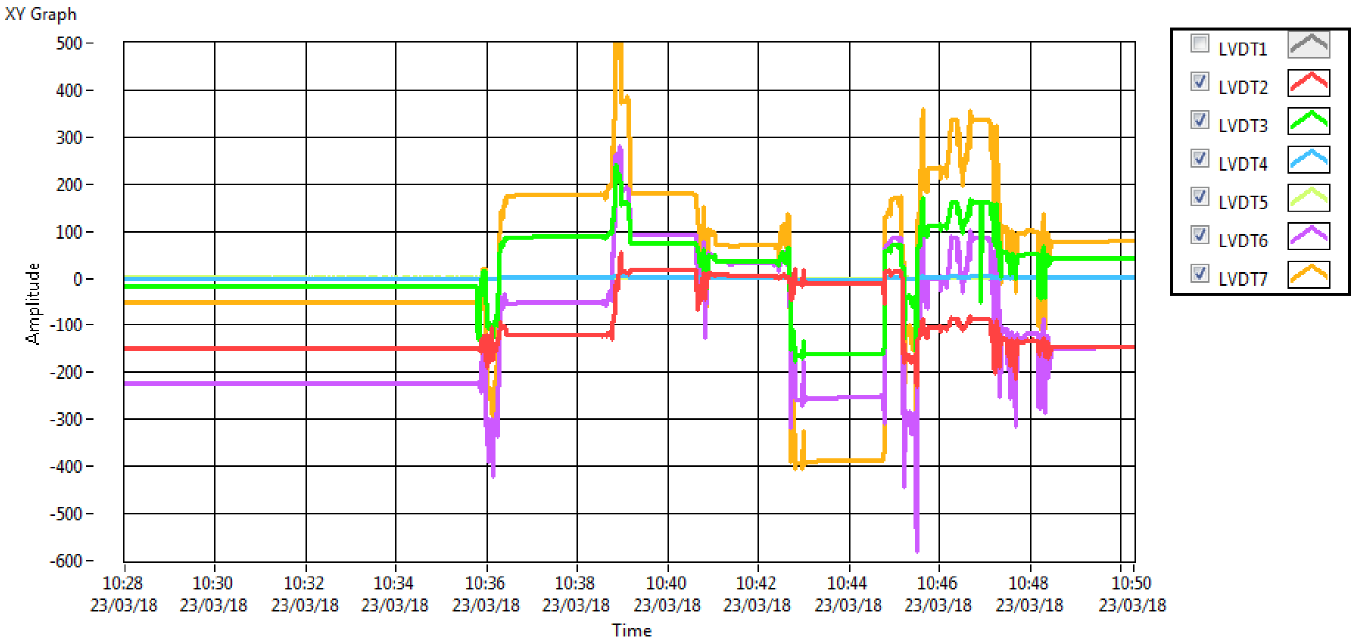
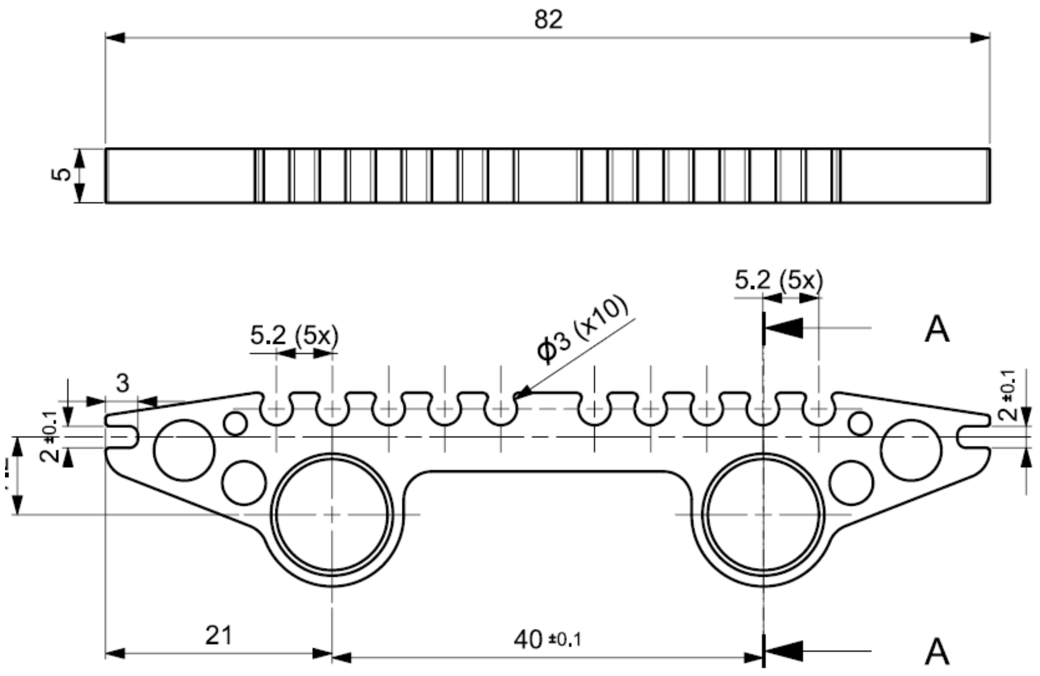
Connecting VCR induces displacements

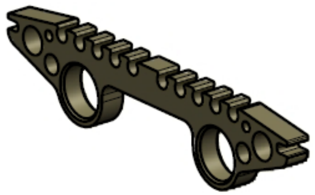
Displacement of +500 μm to – 400 μm

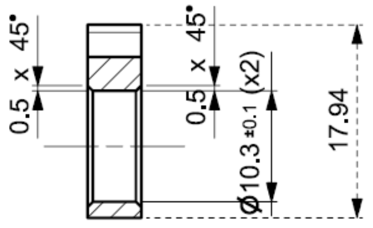


10:36 - Tighten VCR long side, less then finger tight, so there should be no torque. but the capillary is in the right position
10:39 - Tighten VCR long side, first finger tight, then 1/8 turn.
10:40 - Tighten VCR short side, less then finger tight, so there should be no torque. but the capillary is in the right position
10:42 - Tighten VCR short side, first finger tight, then 1/8 turn.
10:45 - Loosen all VCR first short then long. (the gasket got stuck under the module. Took some effort to get it out. That is why the signal does not get stable until 10:48)

Add a Clamp to hold pipes

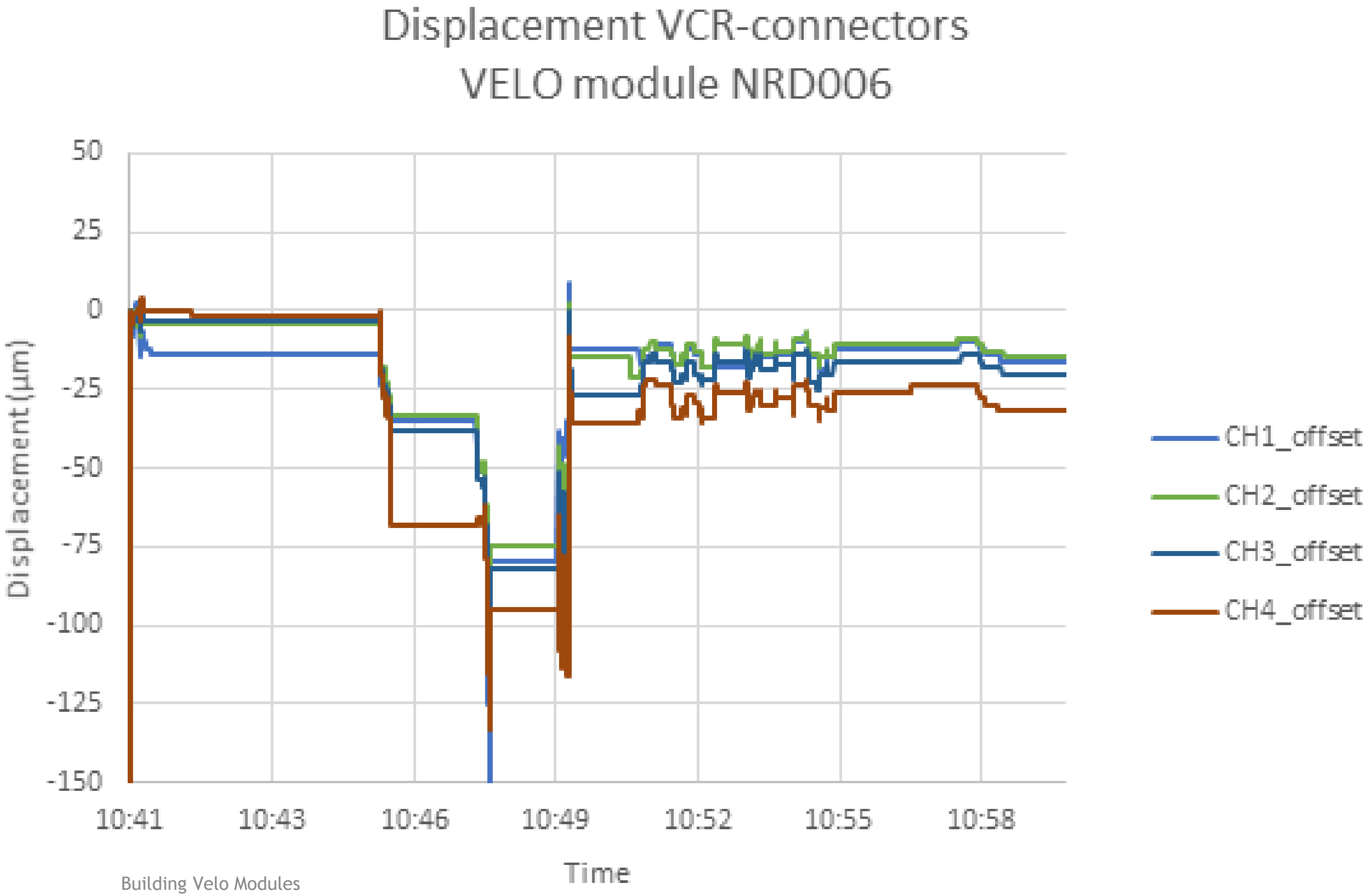






Made from Peek

Displacement measurement with clamp



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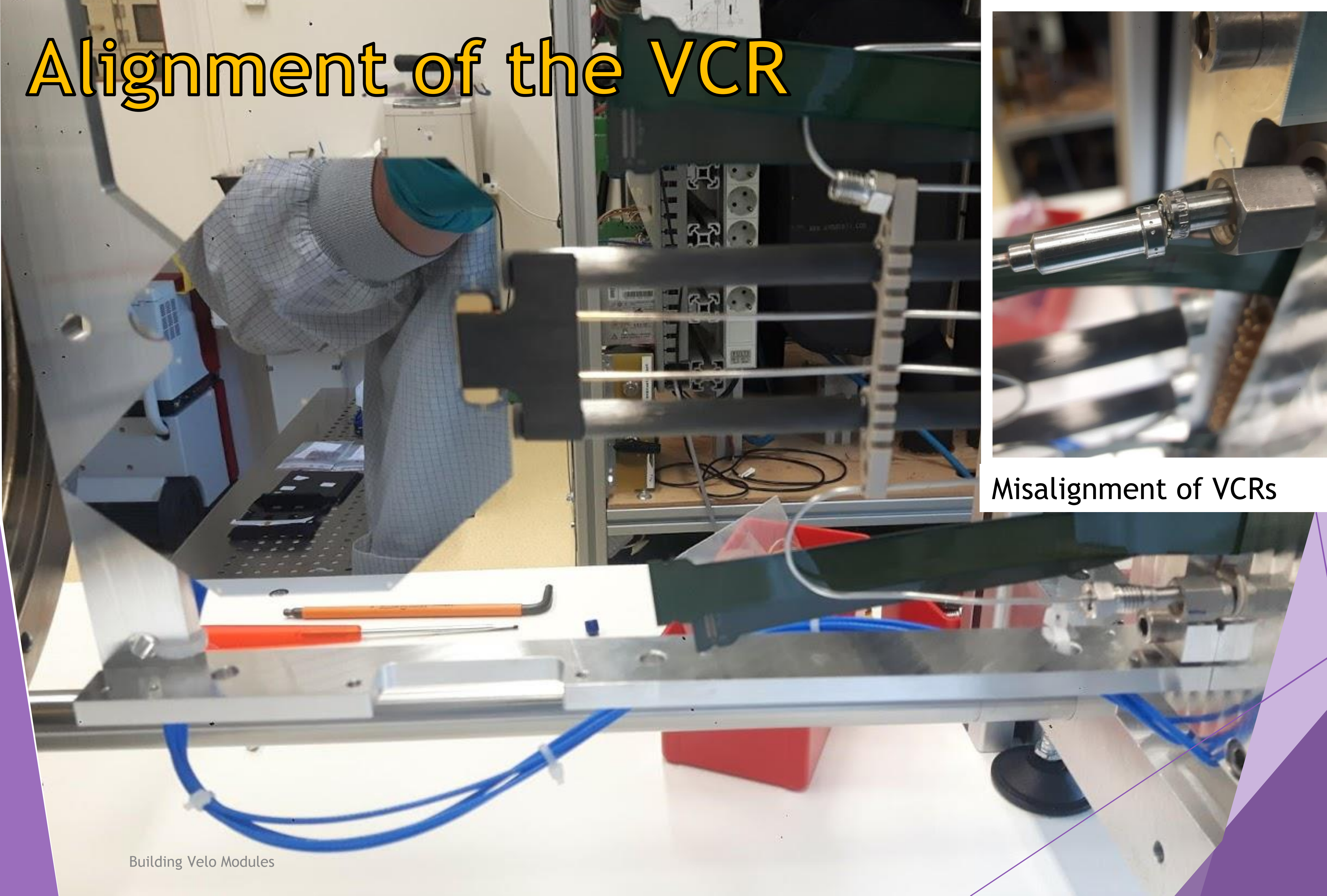
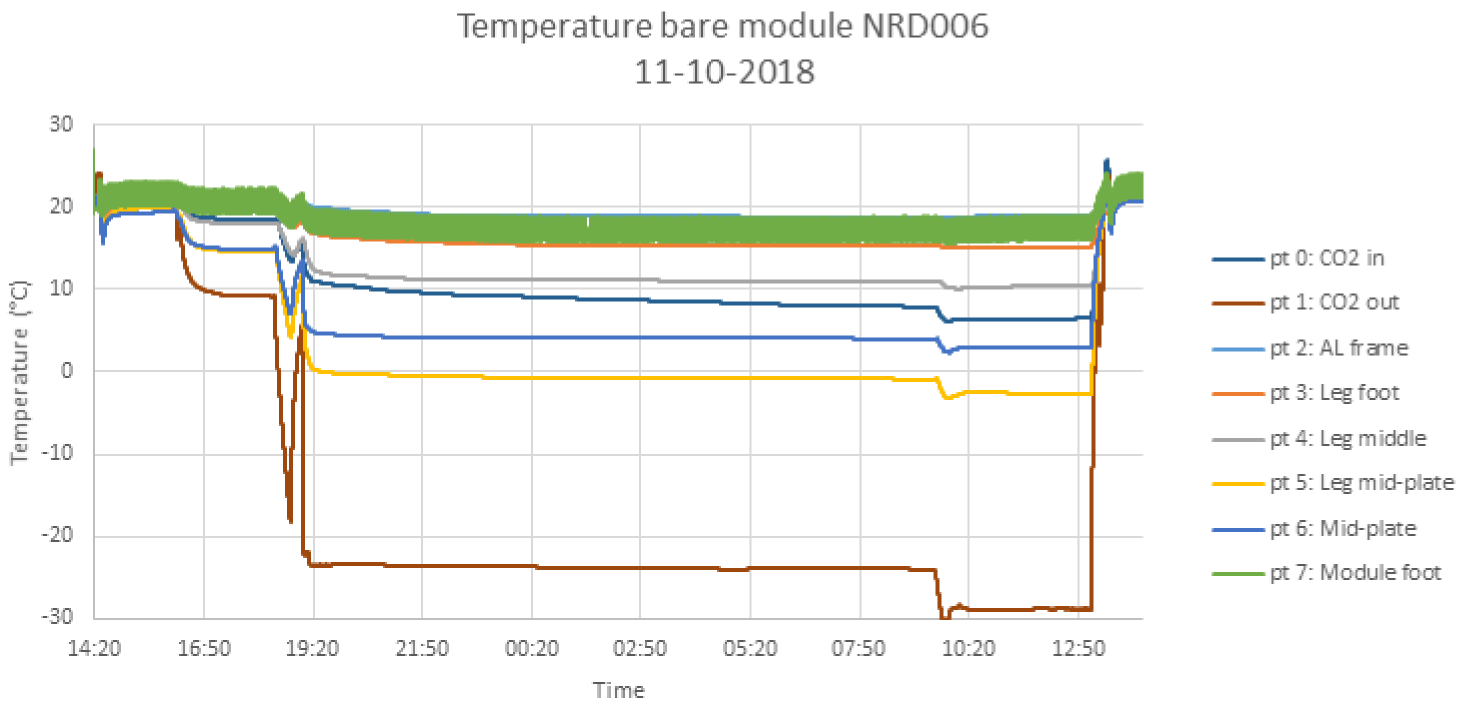
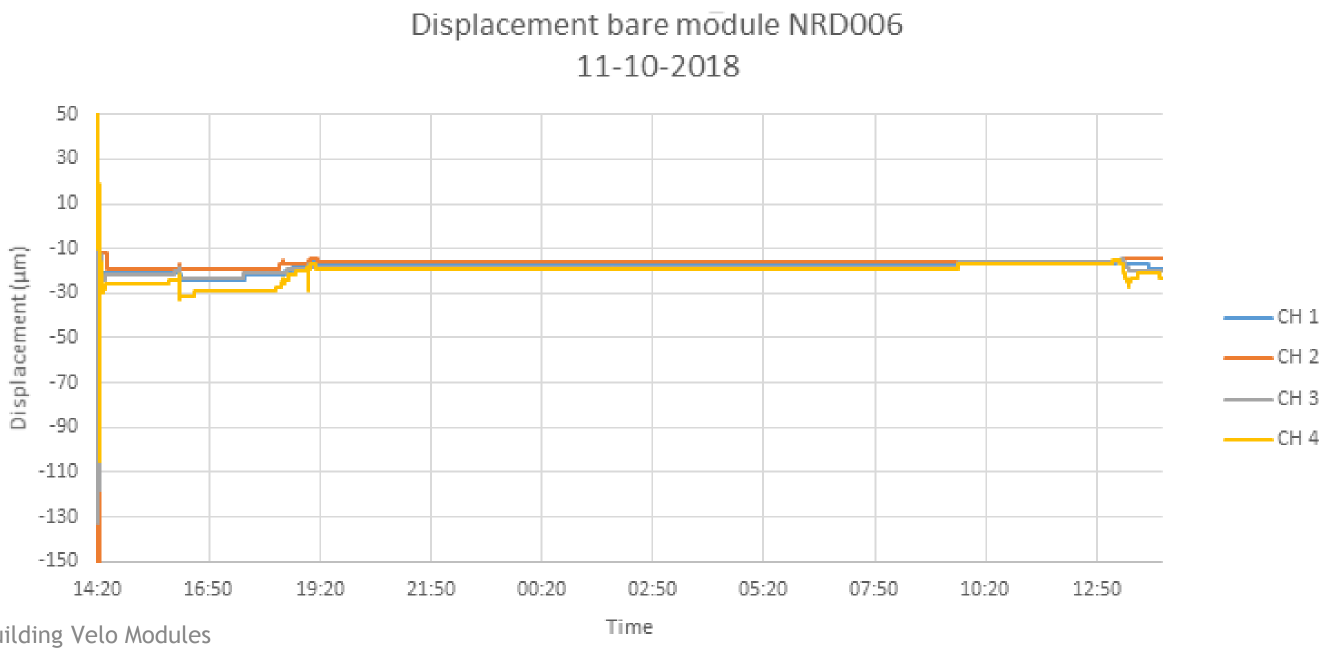
Alignment of the VCR



Misalignment of VCRs


Temperature bare module NRD006
11-10-2018
Temperature (°C)
30
20
10
0
-10
-20
-30
14:20
16:50
19:20
21:50
00:20
02:50
05:20
07:50
10:20
12:50
Time
pt 0: CO2 in
pt 1: CO2 out
pt 2: AL frame
pt 3: Leg foot
pt 4: Leg middle
pt 5: Leg mid-plate
pt 6: Mid-plate
pt 7: Module foot


Displacement bare module NRD006
11-10-2018
Displacement (µm)
50
30
10
-10
-30
-50
-70
-90
-110
-130
-150
14:20
16:50
19:20
21:50
00:20
02:50
05:20
07:50
10:20
12:50
Time
CH 1
CH 2
CH 3
CH 4

The bare module

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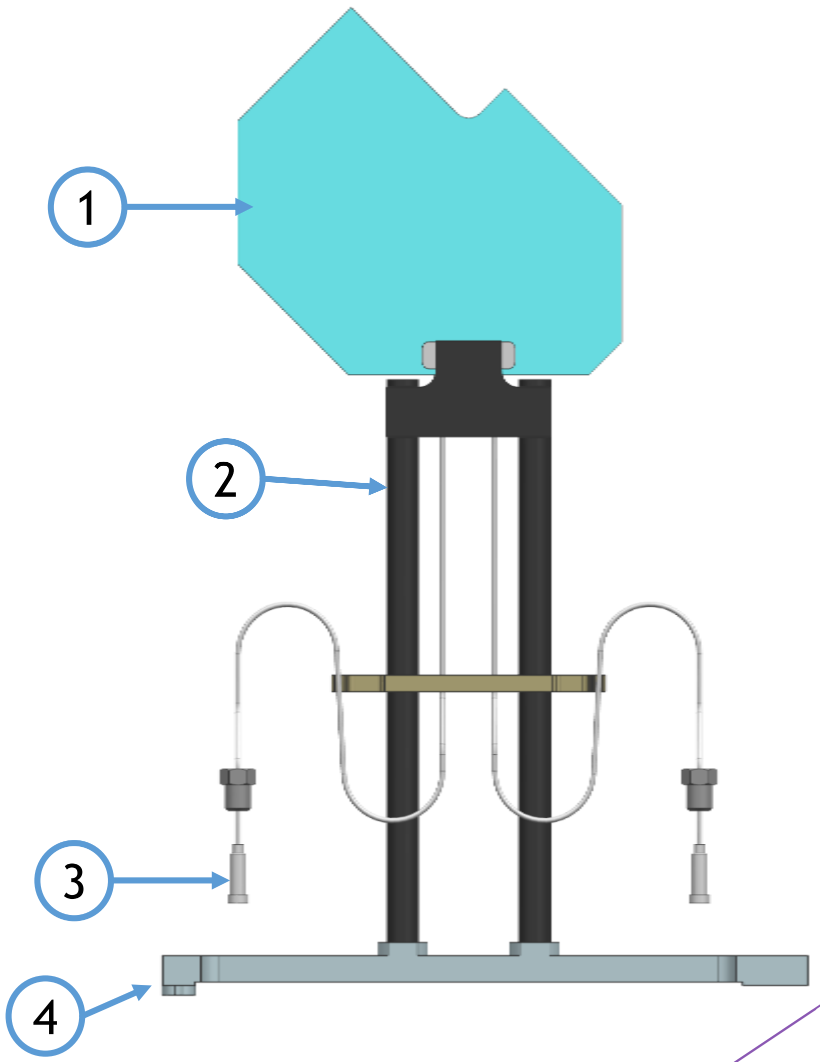
2. Hurdle, support structure
3. VCR Fitting for CO_2 in- & outlet
4. Interface with rest of detector



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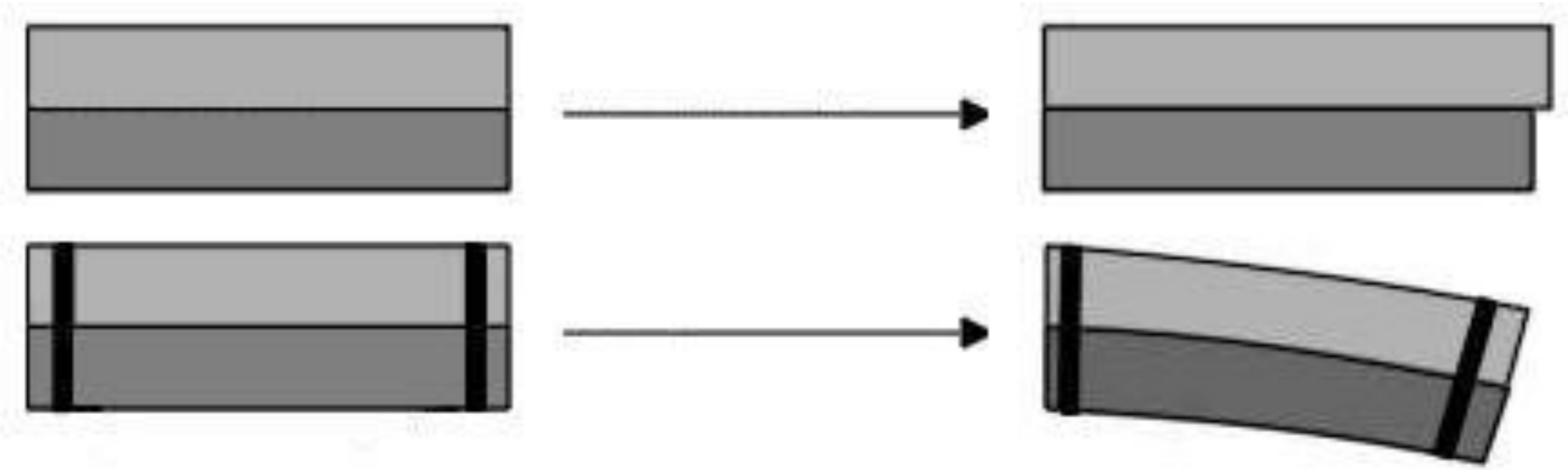
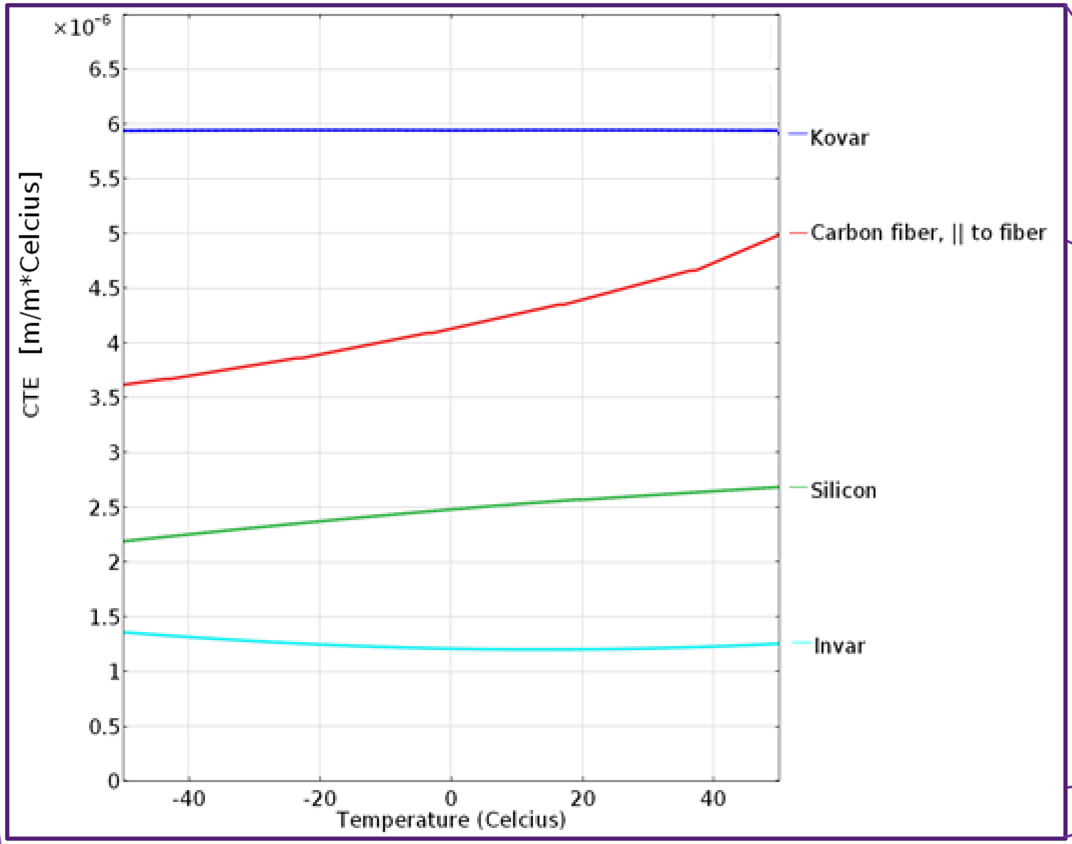
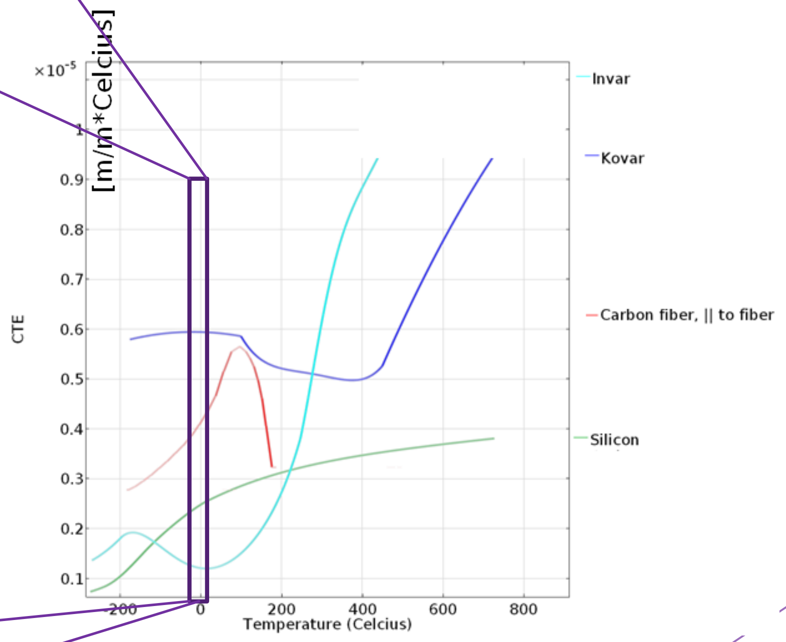
Coefficient of thermal expansion



Coefficient of Thermal Expansion

Temperature dependent material properties





Stolen from younger me https://indico.cern.ch/event/469996/contributions/2148100/

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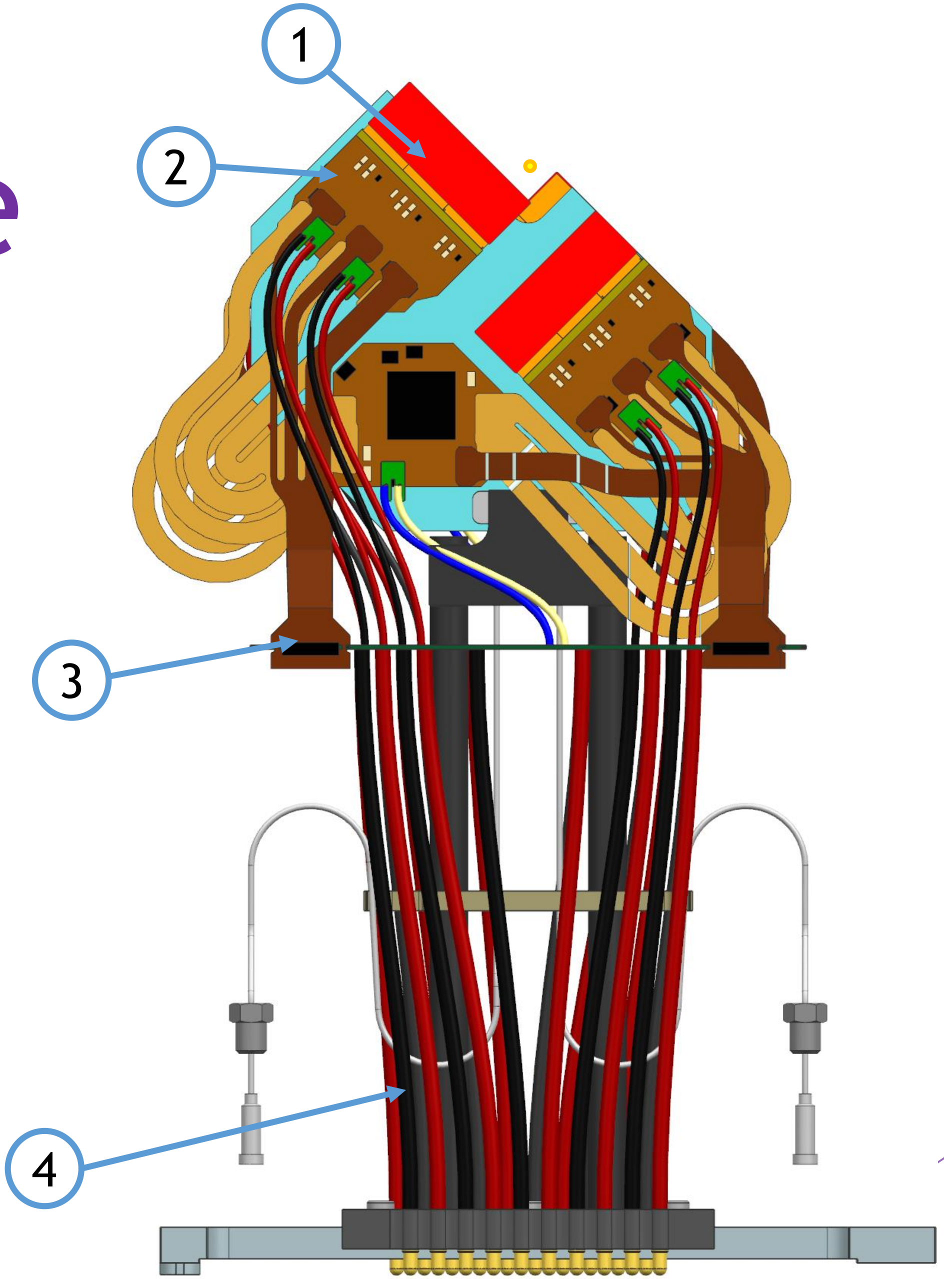
Full module

1. Tiles
2. Readout Hybrids
3. Data Cable
4. Low voltage cable



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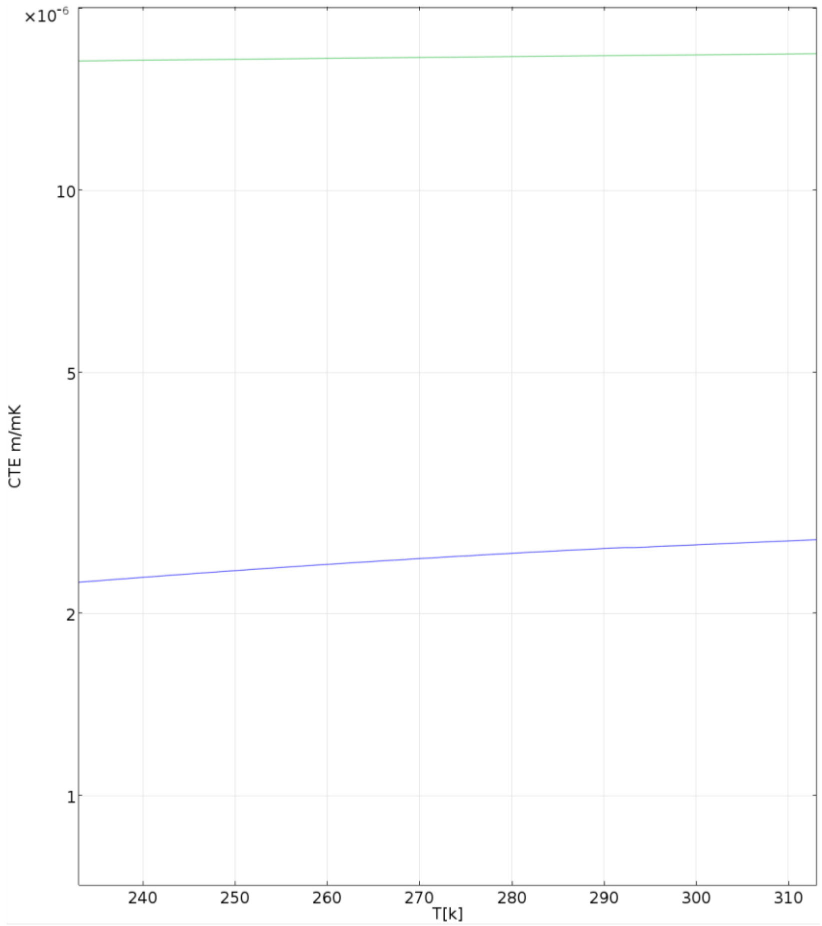
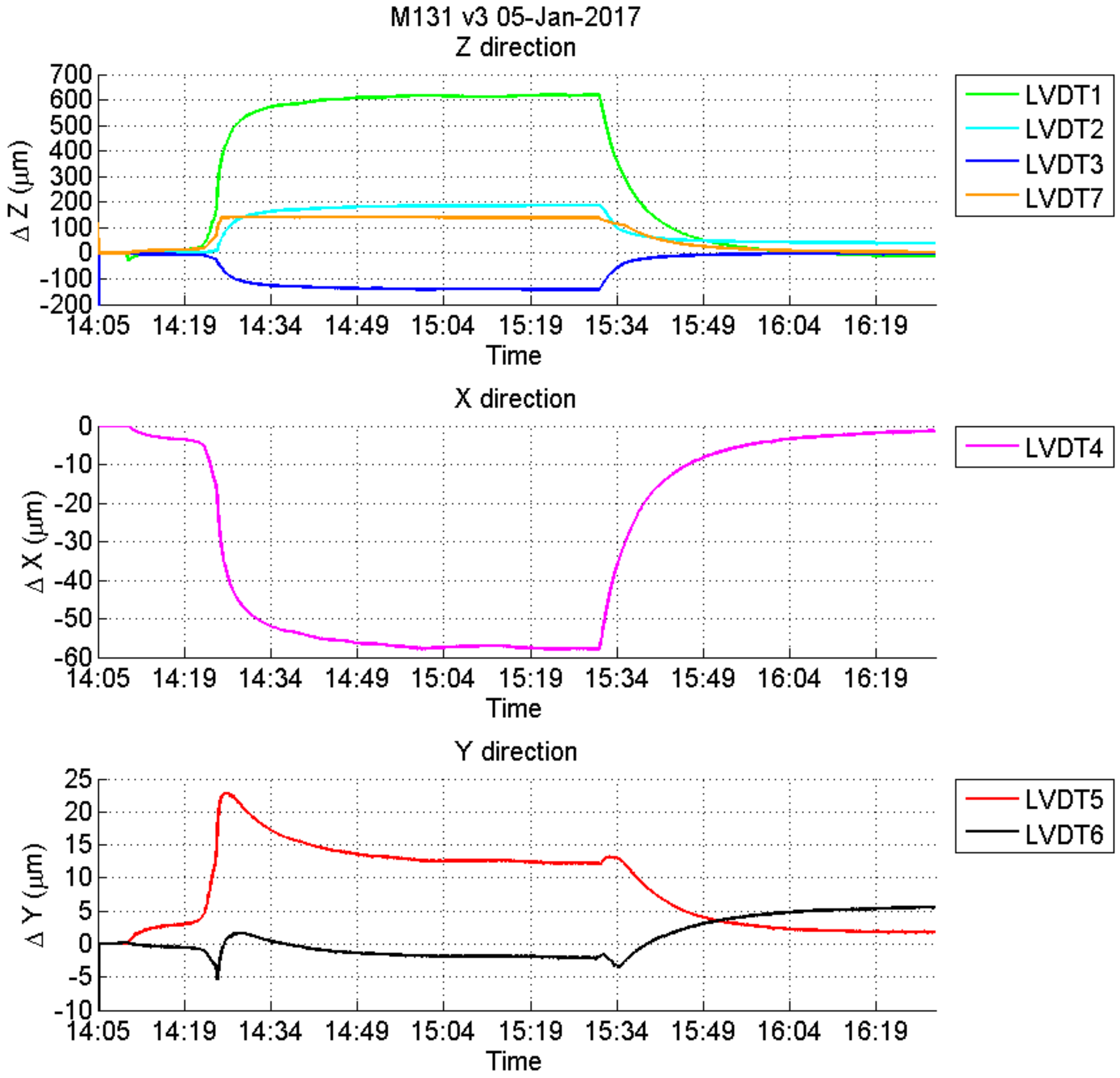
Coefficient of Thermal Expansion



Copper ~ 16,7

Silicon ~ 2,6

Where we came from



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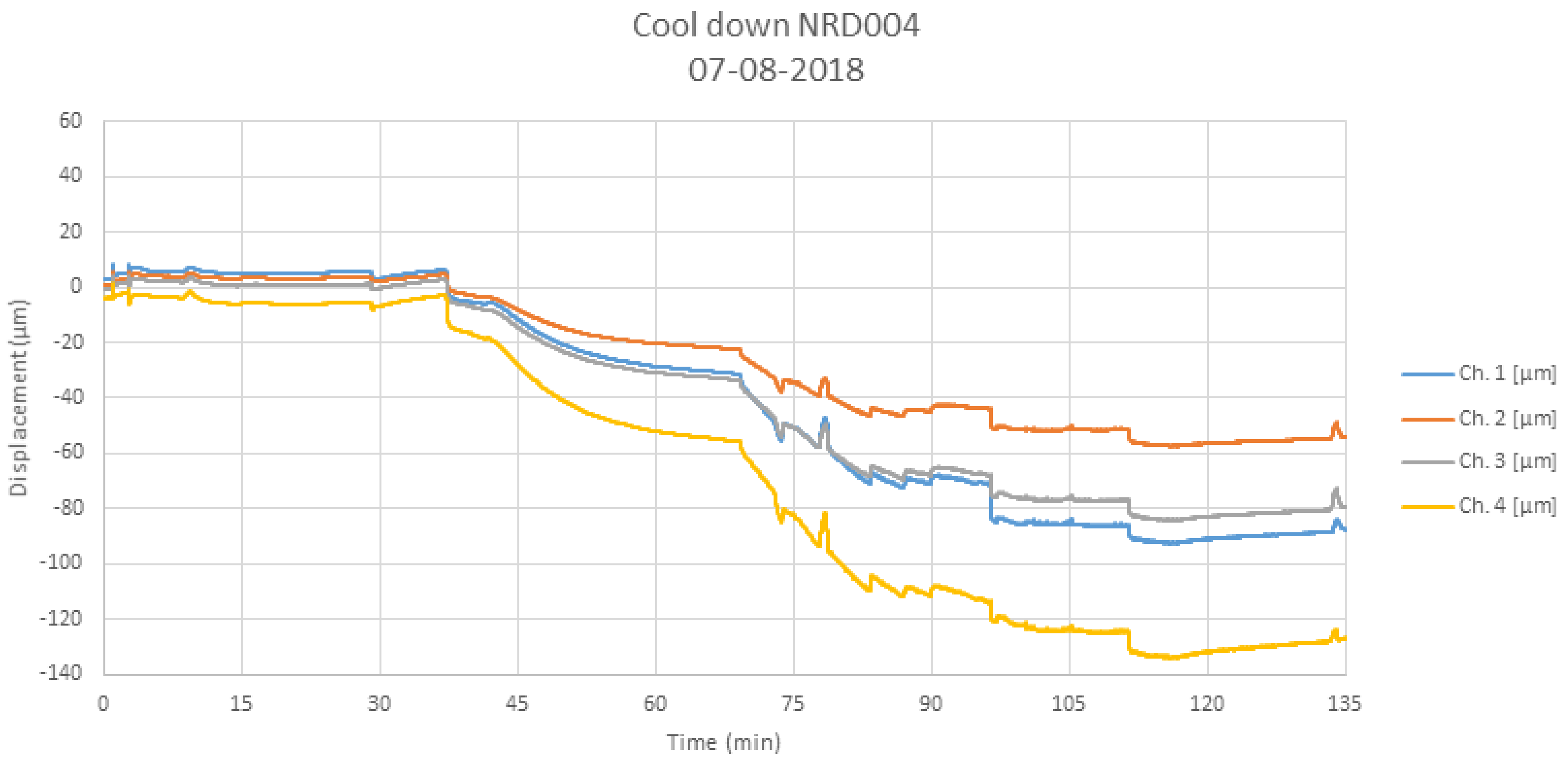
A 3 part readout hybrid attach to microchannel with Araldite 2011



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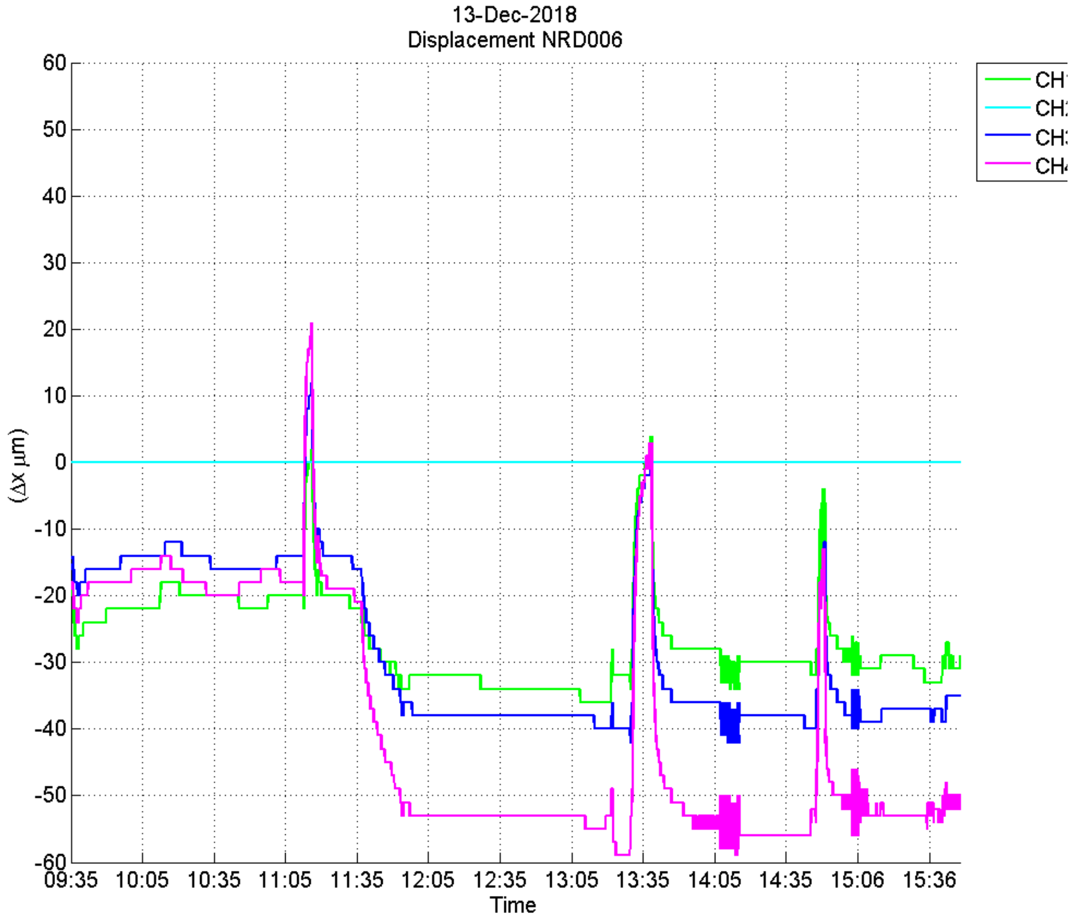
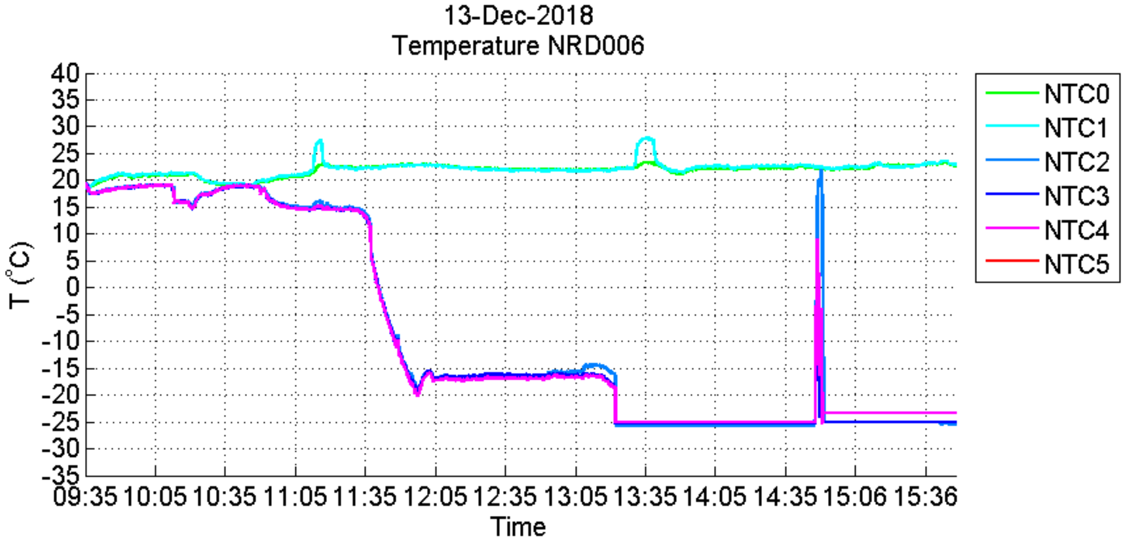
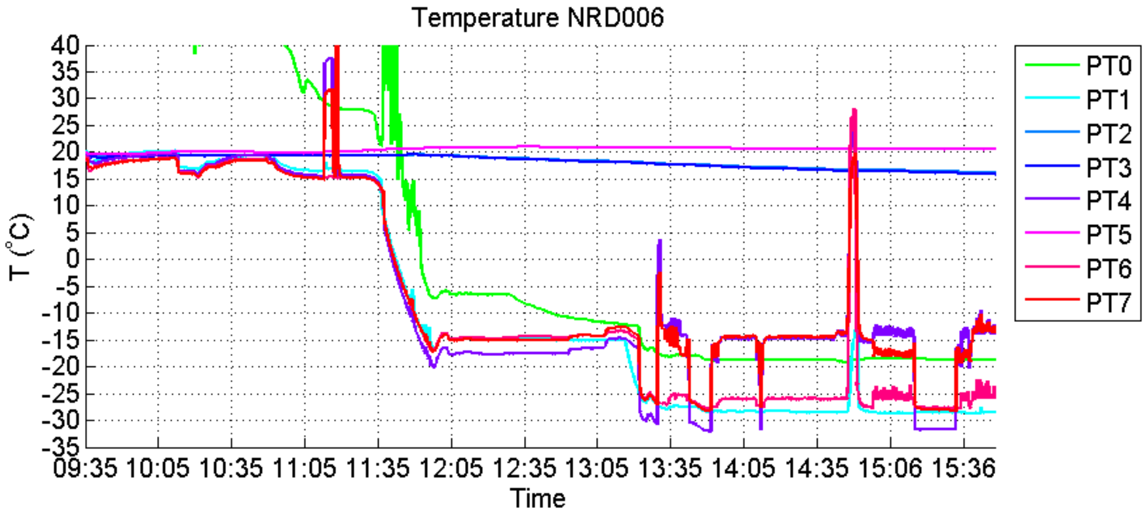
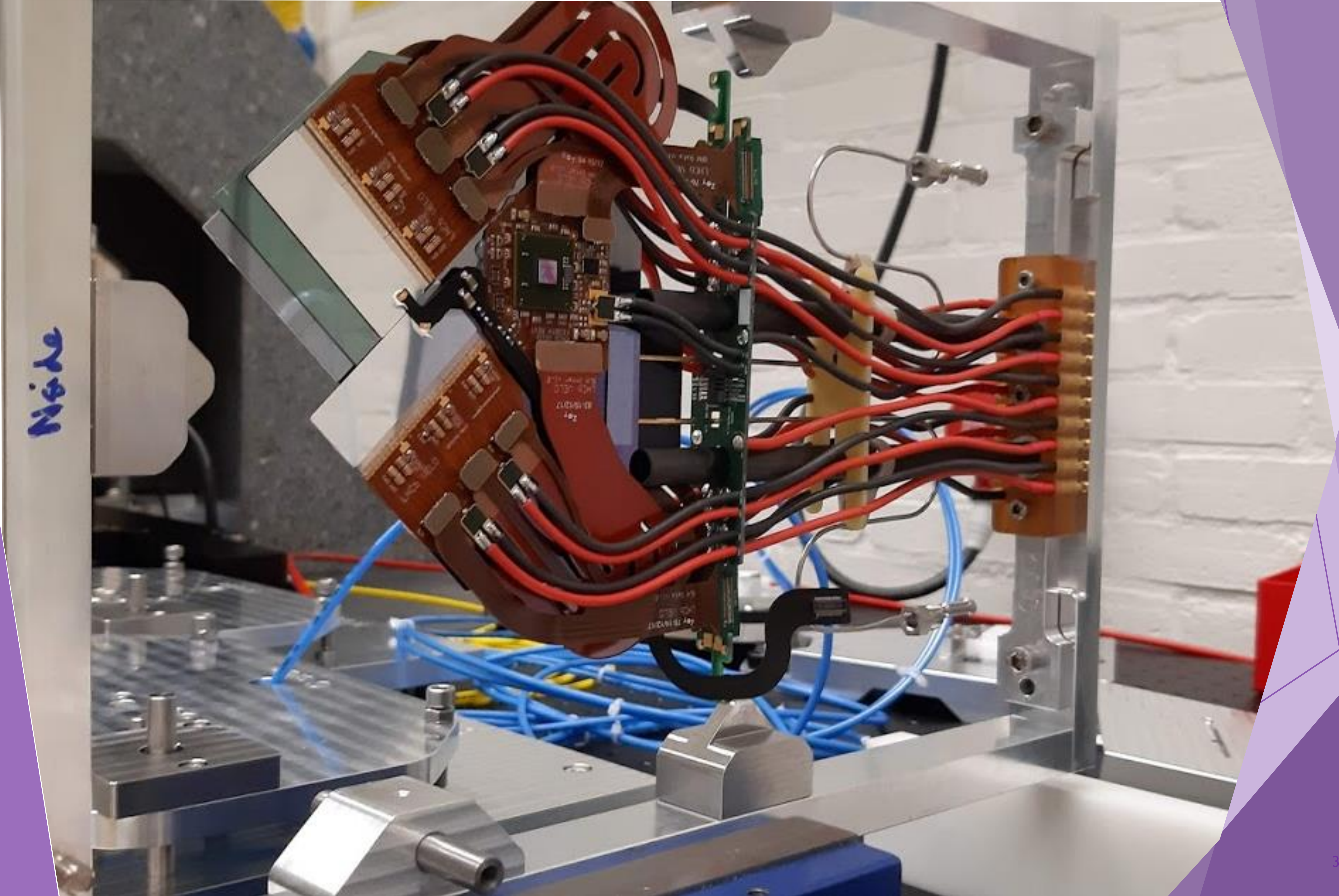
Changed glue to a flexible glue.



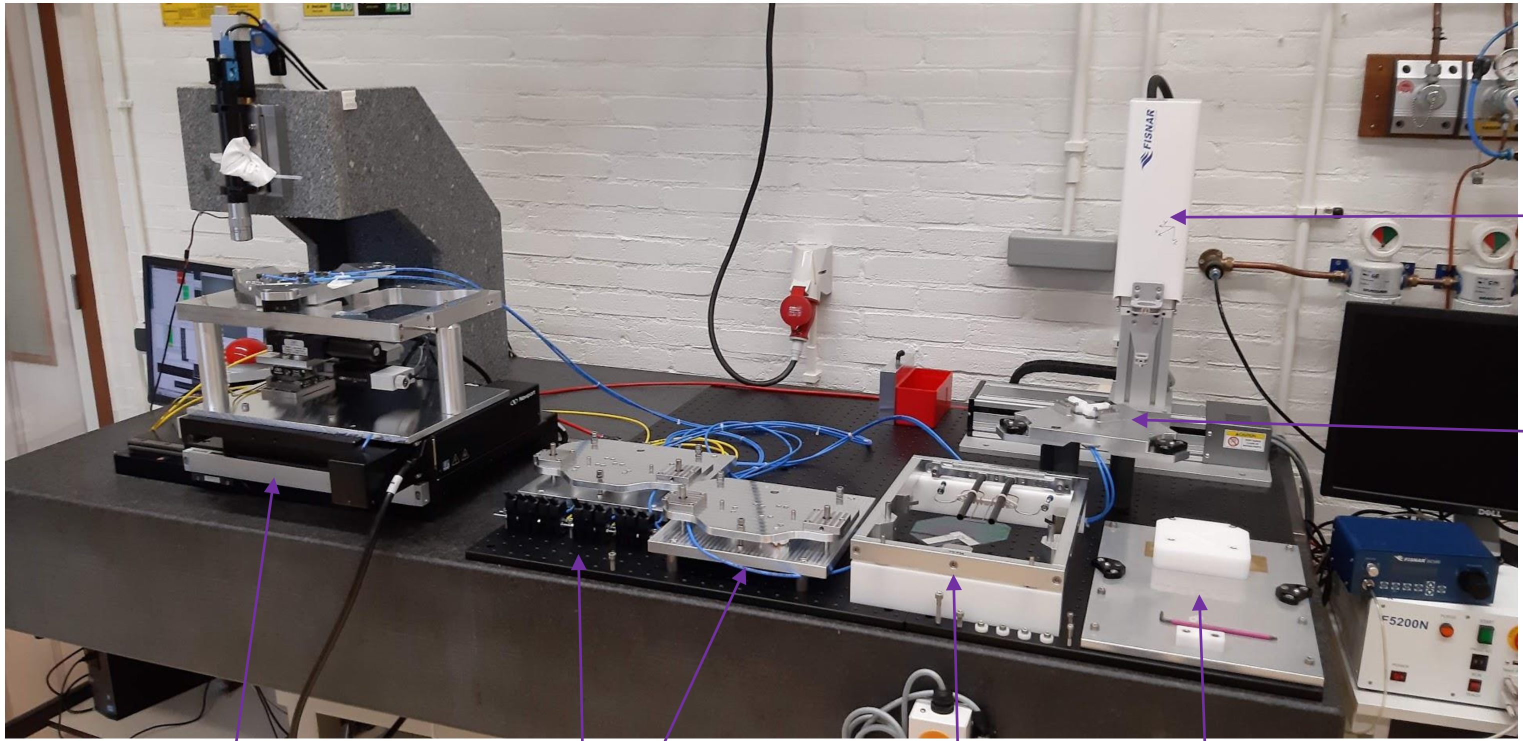




Used a flexible glue to absorb the CTE difference, Loctite SI 5145



Overview of jigs used in production



Glue robot

Glue station

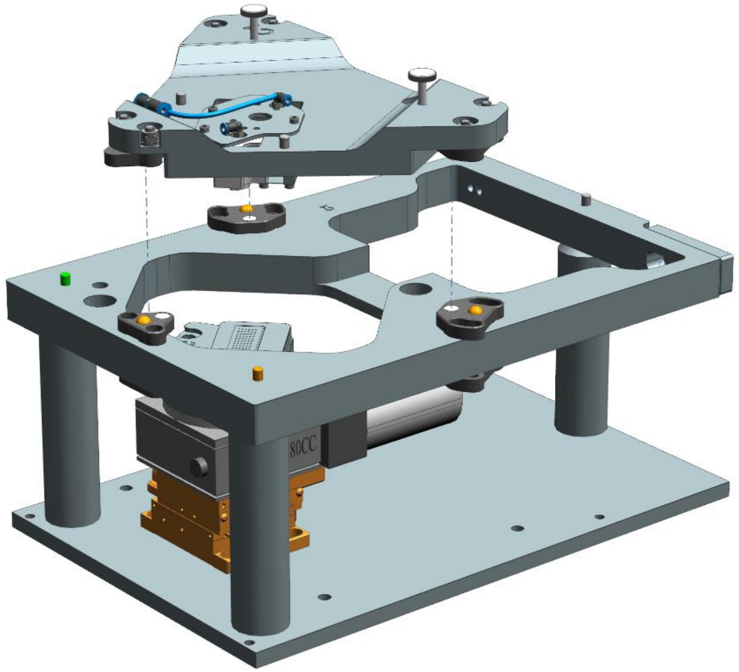
Sensor Pick up

Hybrid pick up

Hybrid cure

Sensor cure

Placement and gluing of Tiles, the important bits.



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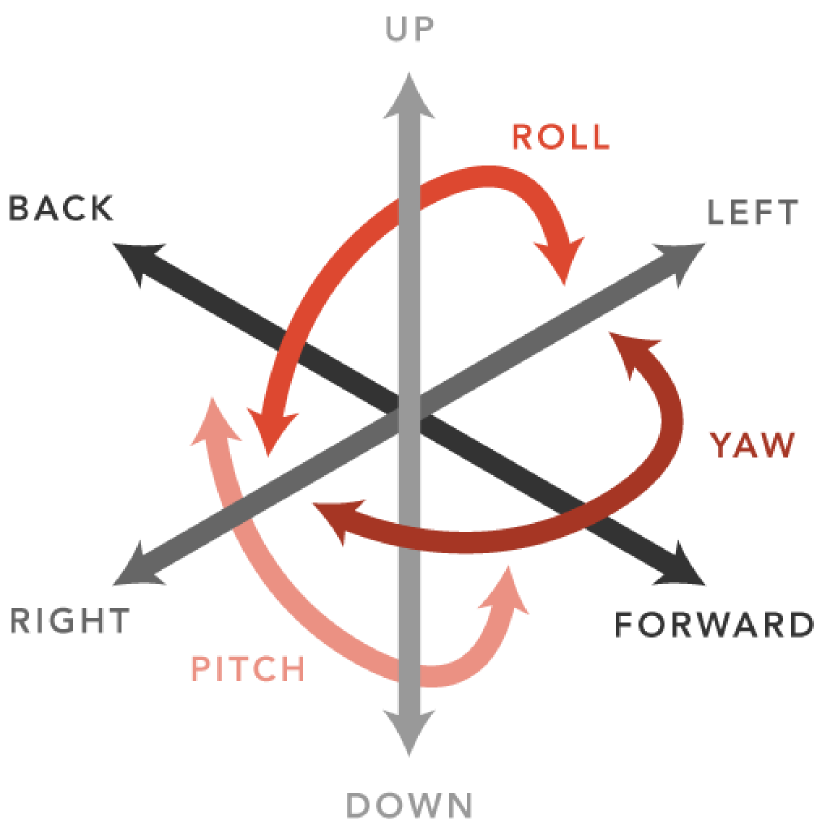
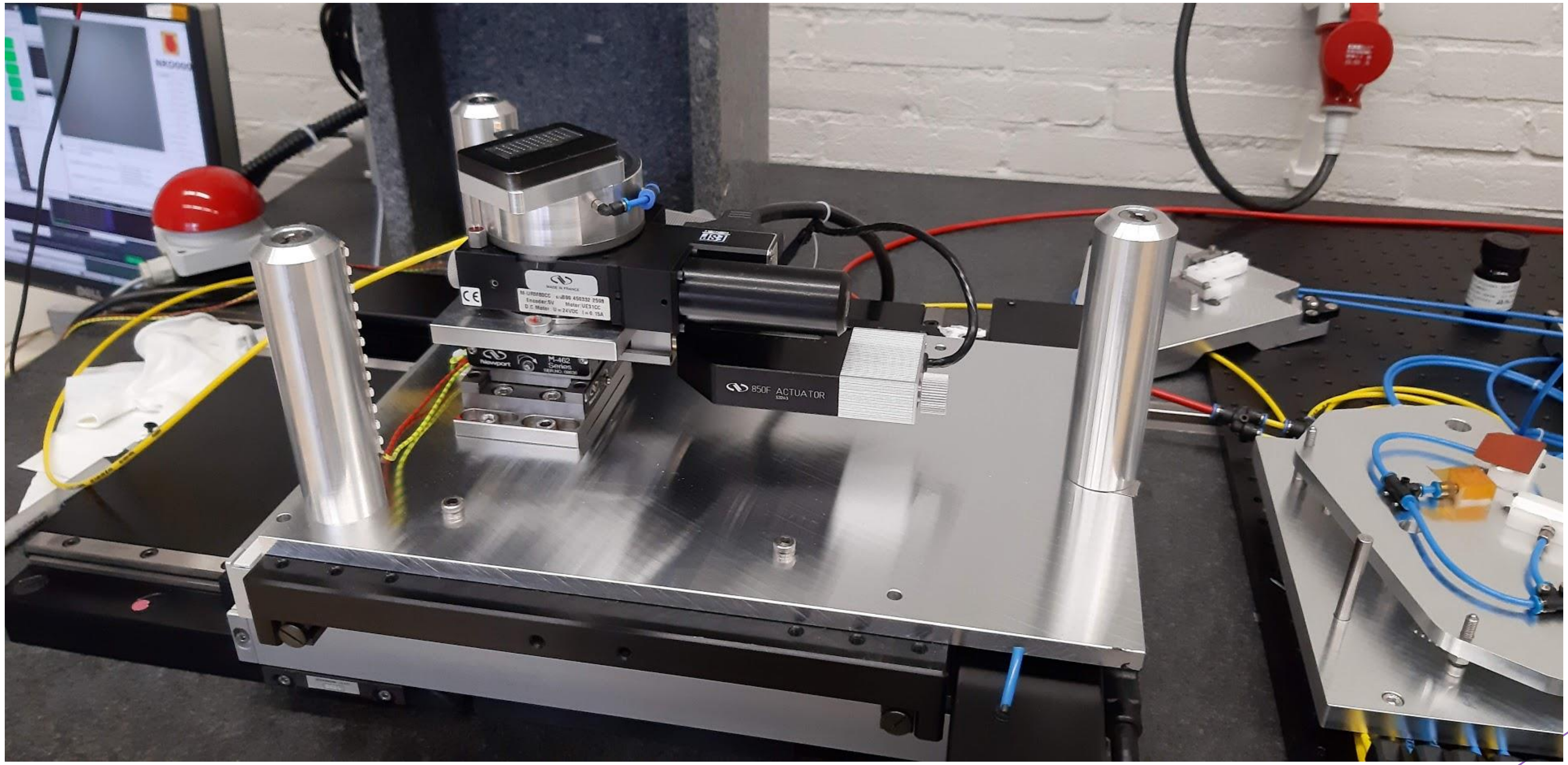
Degree of freedom (DoF) refresher



Motion stages to control 3 DoF

- The jig only takes over these 3.
- The rest are determined by natural deformity of the substrate. +/- 80 um



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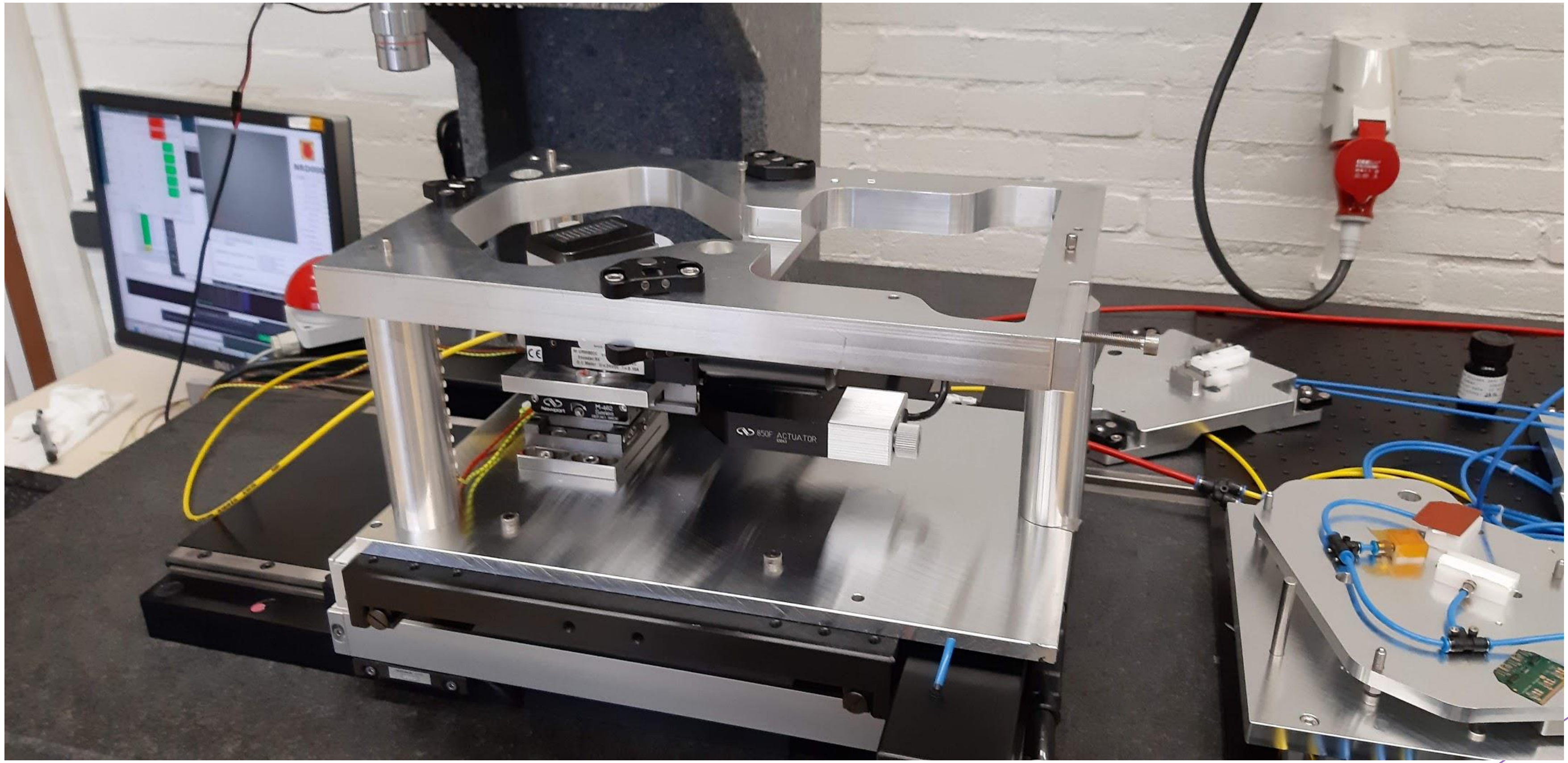
Main jig, which hold the module



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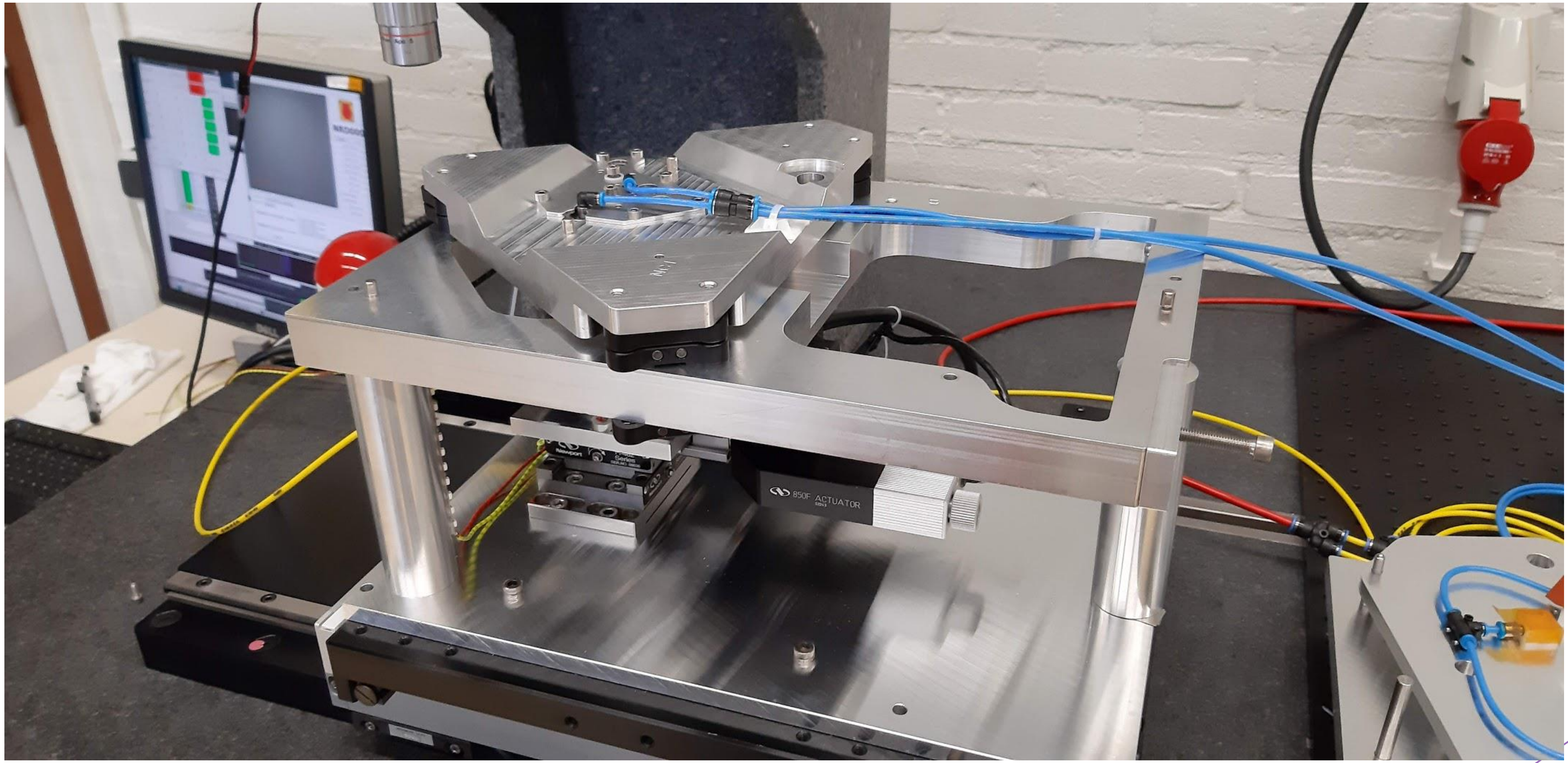
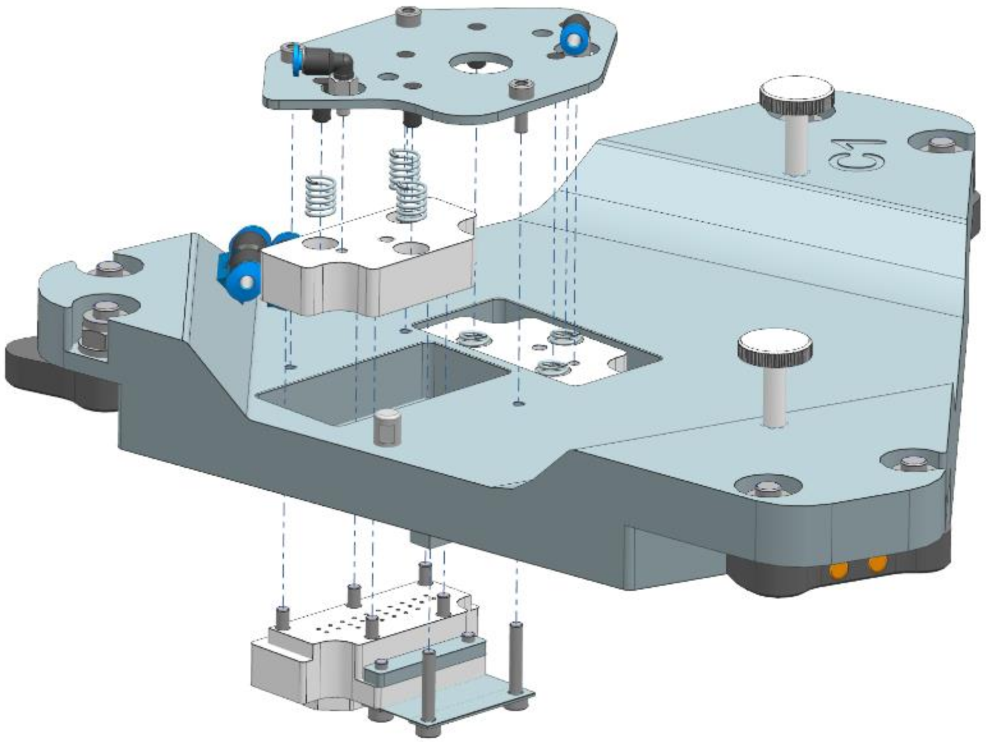
Vacuum pick up



Constant force springs



Hooke's Law

$$F = k * x$$

To cope with
small variation
in tile thickness

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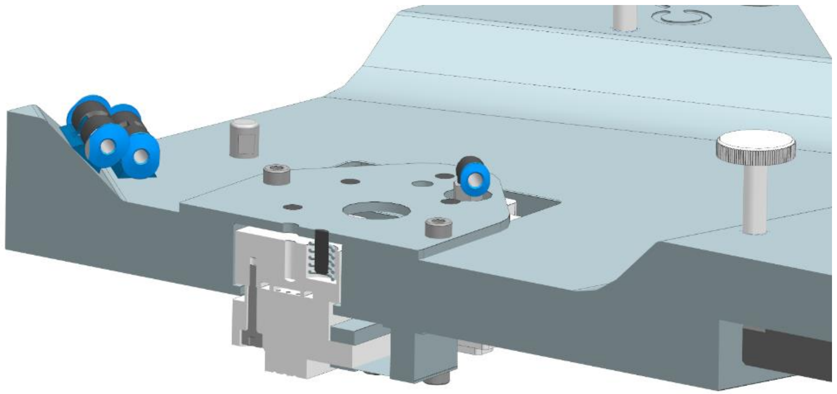
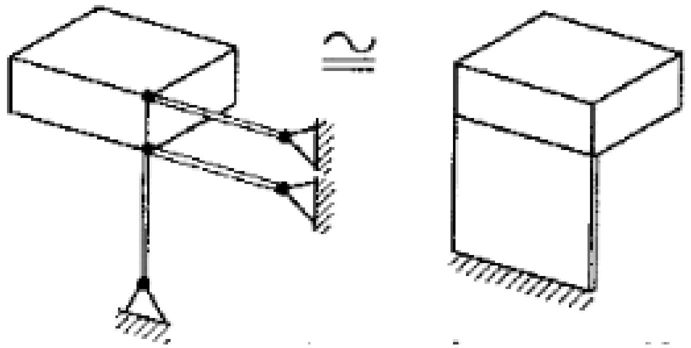
Constraining 3 DOF from the motion stages.



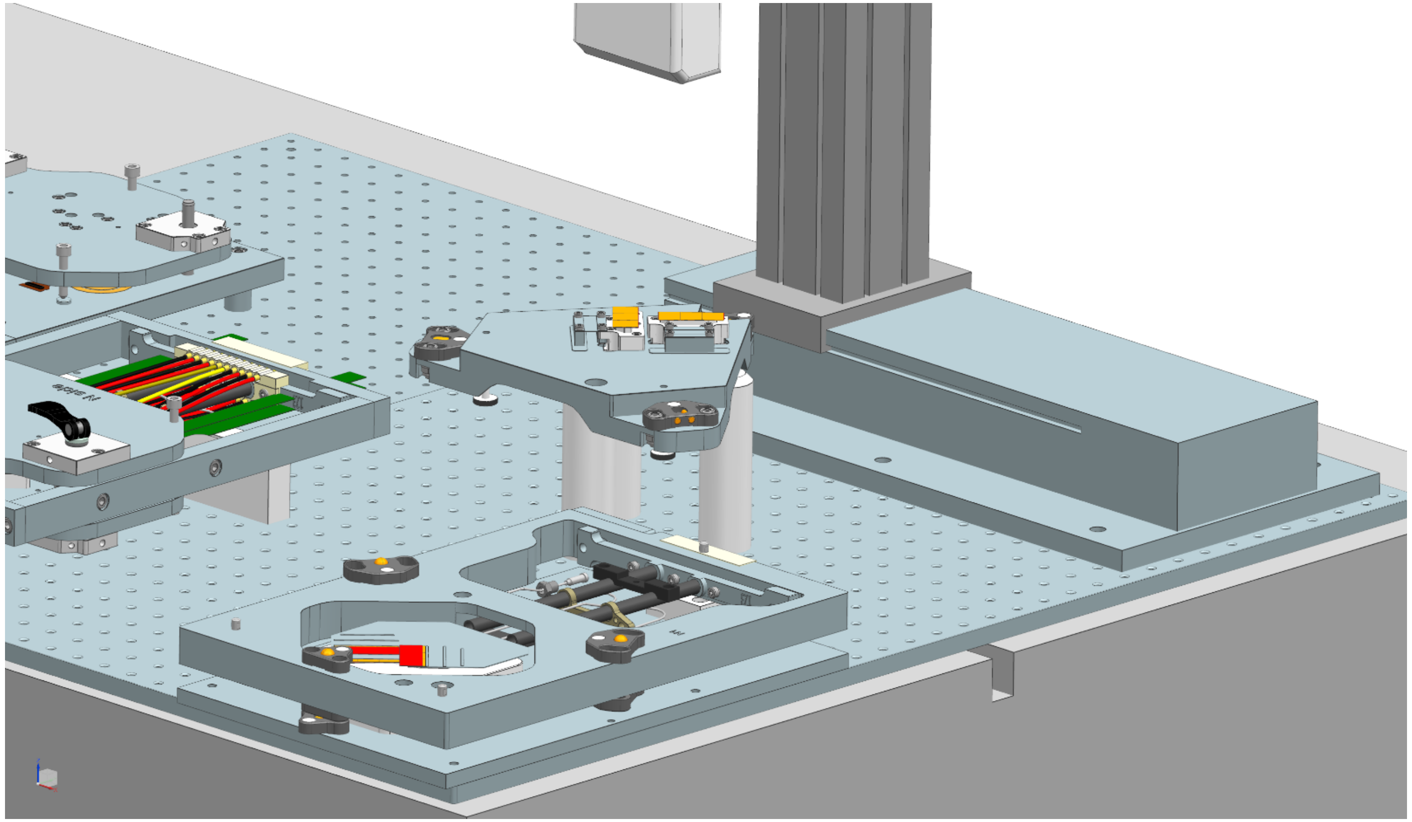


2 movements 1 rotation constraint

Problems with the Jigs

- Positional accuracy,
  - Changed material from Teflon to POM-C
  - Increase of Vacuum surface, increase of vacuum power.
- Still some issues
  - Stages moves when tiles are picked up. This is due to spring force.
  - Could be solved, but need major changes to jig.

The gluing step.



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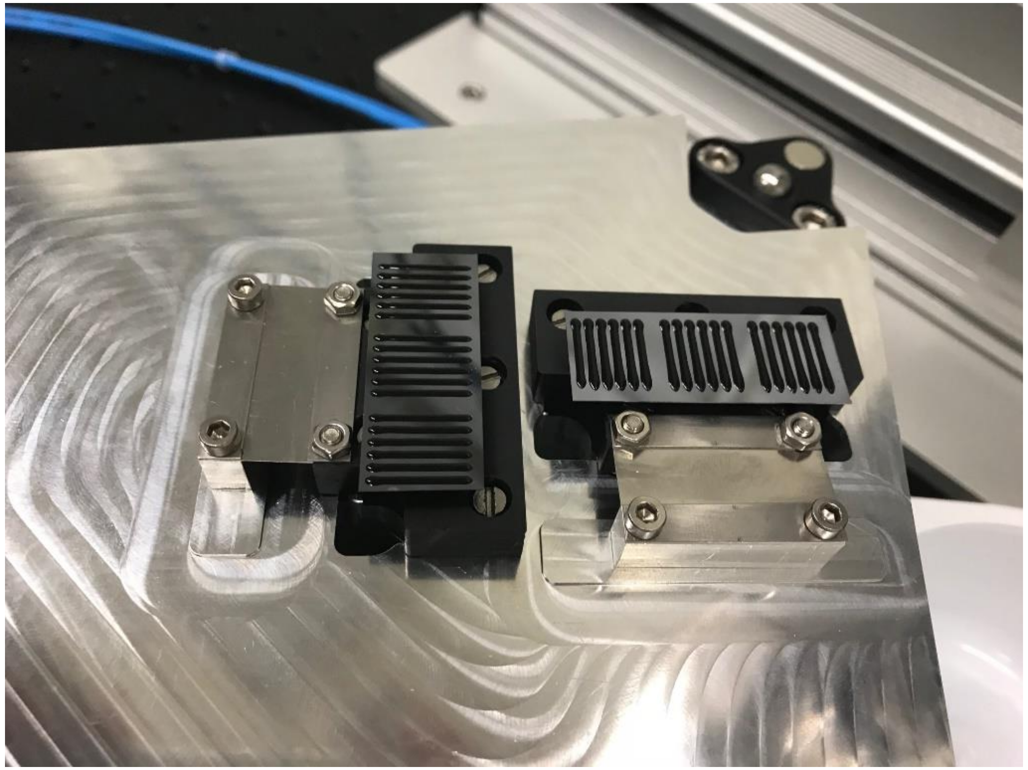
Trouble with glue trapping air.



Once glued you can not see the glue anymore. How well did we glue?

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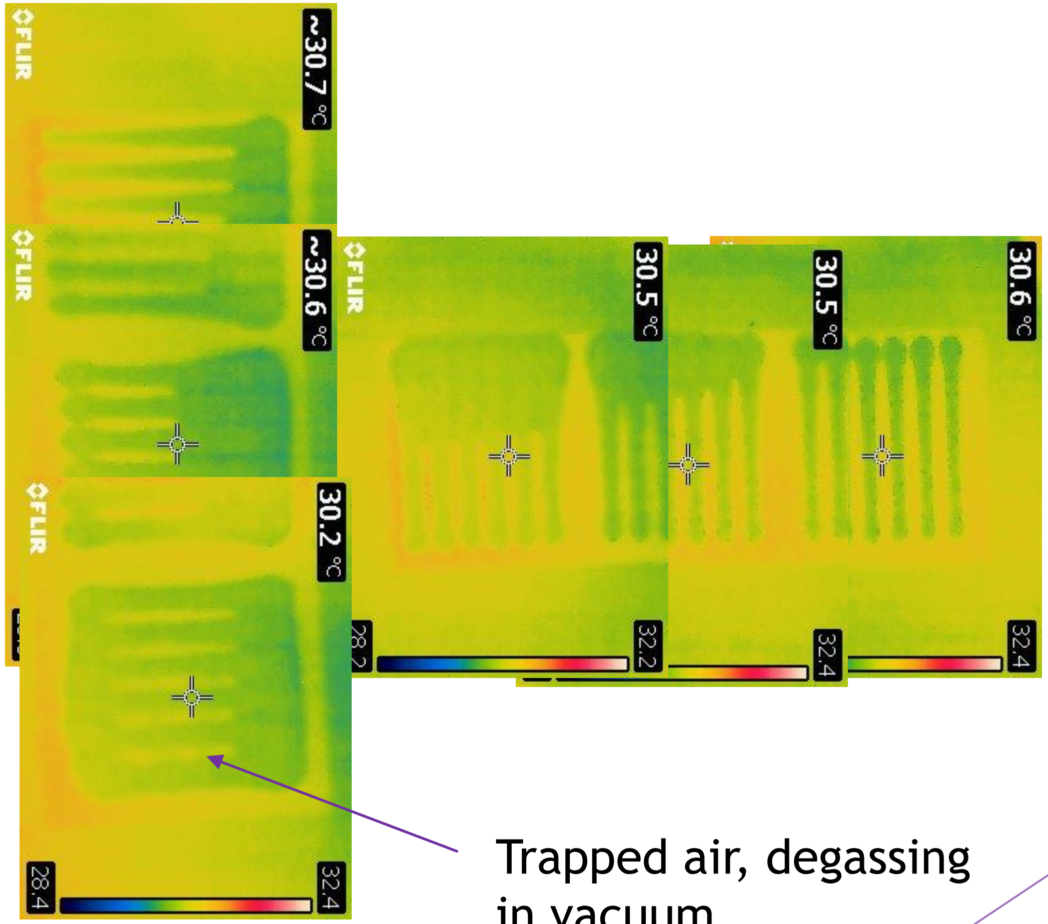
Silicon is invisible to infrared.

You can see through the silicon and see the glue!

Merged glue lines.

It is not always good to see your work.



Trapped air, degassing in vacuum

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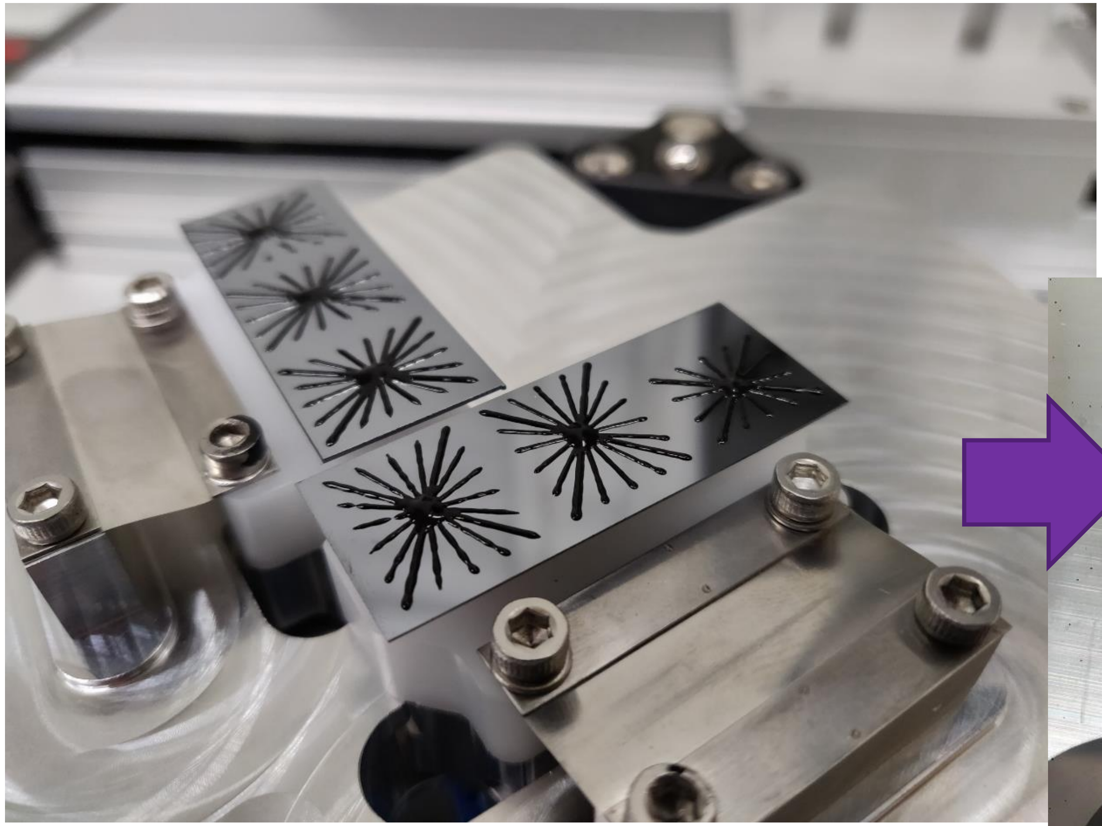
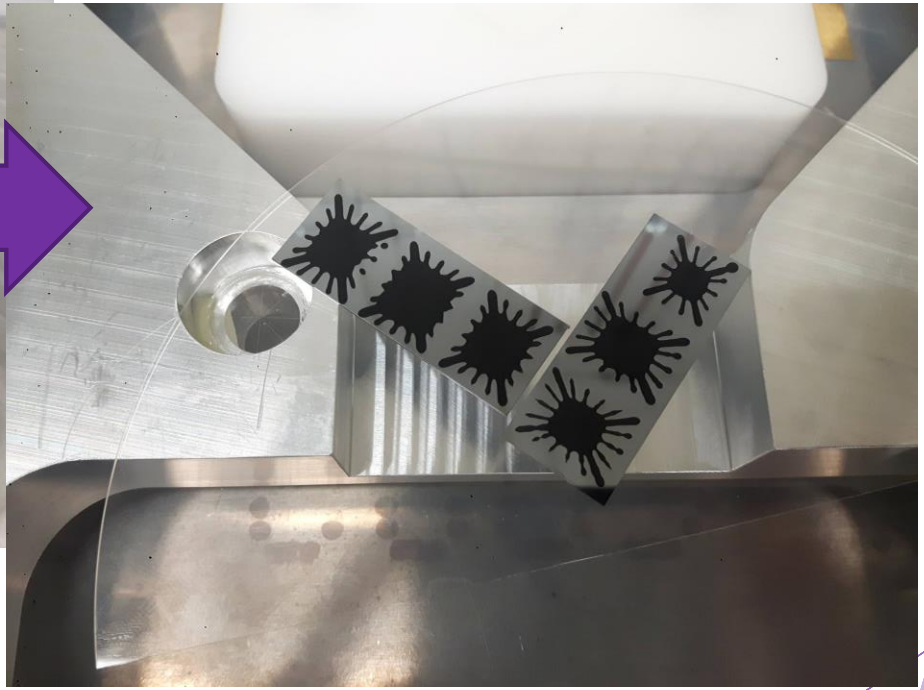
Gluing without trapping air!





Glued to a glass plate, to check for spread.

Production sites

2 Module production sides

- Almost everything the same. Except the placement of the tiles mentioned in this talk.
- The results are comparable.

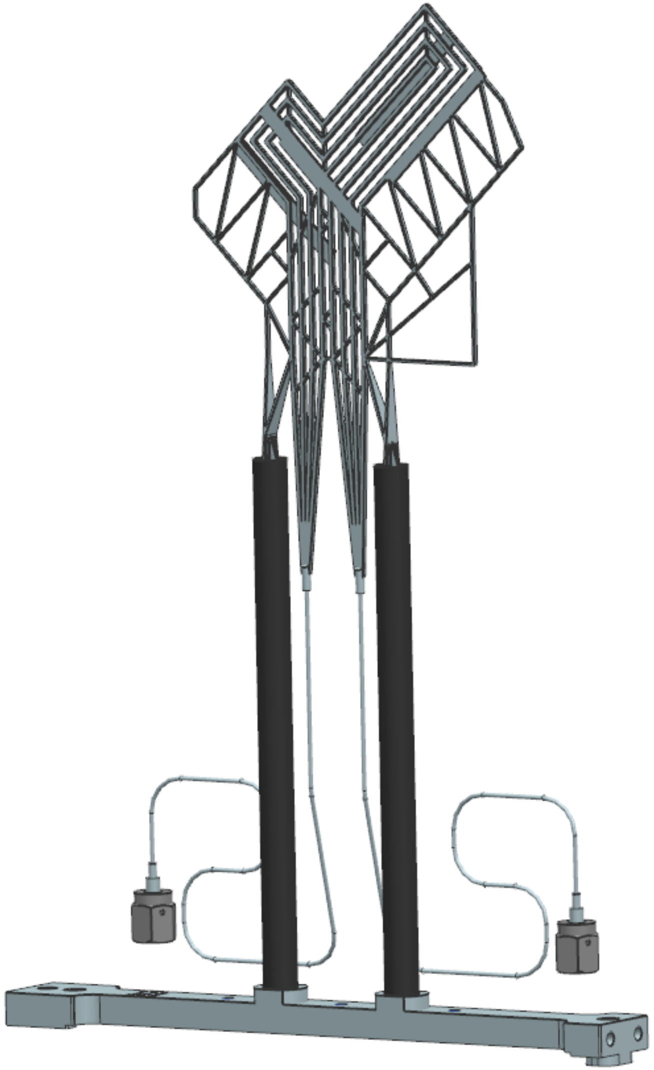
What are we still doing

- Measuring thermal performance of modules.
- Optimizing glue coverage of modules.

- Getting experience, every module we make, becomes a better module.
- I dare to say that our current module is detector grade.

The Past

- 1,5 year ago, there were some doubts about the microchannel. So a side research project was launched.
- Plan Z, the ‘final’ solution.
- But before it could prove it self the microchannel proved it was ready for use in the upgrade Velo.



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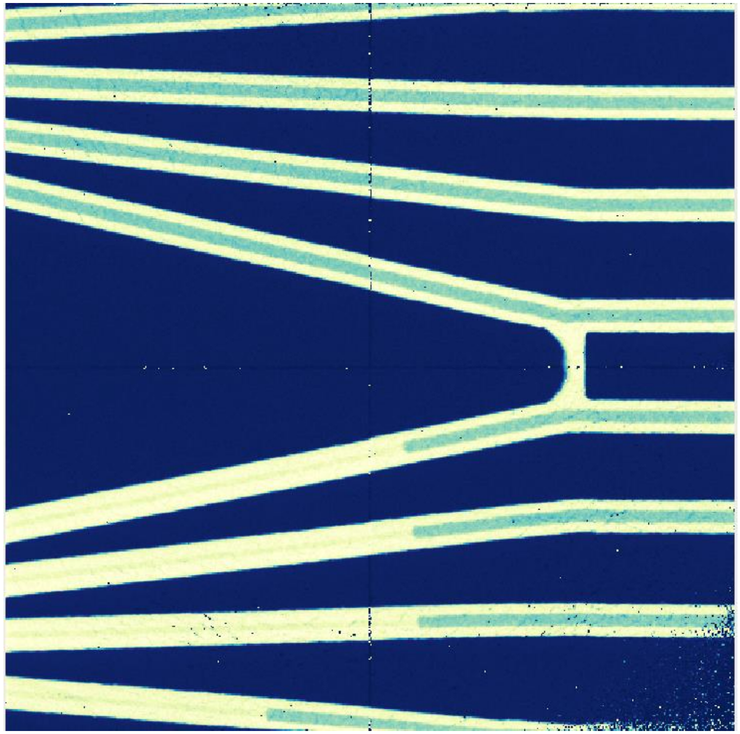
Titanium 3d printed “micro” channel.

- CTE of SI is 2,6 Copper Kapton is 16, Meet in de middle. Titanium CTE 8,6
- Titanium grade 5 is the mostly used for printing, but a bad conductor 6,7 $Wm^{-1}K^{-1}$
- Titanium grade 2, 16,4 $Wm^{-1}K^{-1}$ not great but al lot better.
- Restriction of 200x200 µm
- Channel of 500x500 µm



Xray of first titanium subtrate

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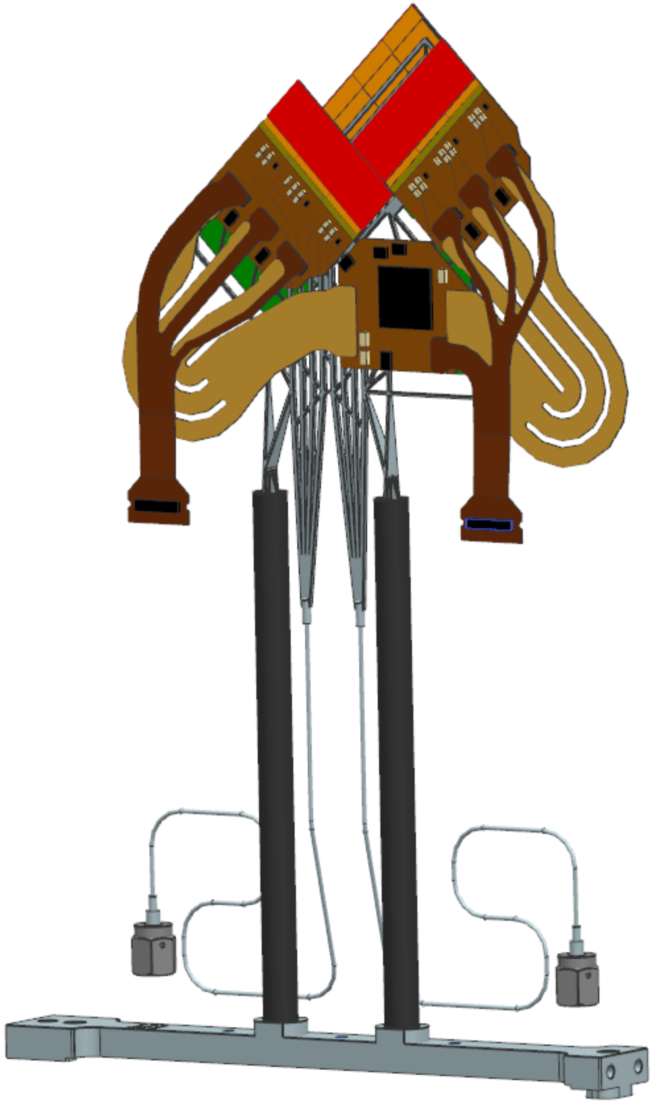
Pro’s for titanium modules

- They are cheap 300 euro for a finished substrate with connectors.
- They are sturdy, high pressure.
- Fast lead time. 7 weeks for drawing to production quality substrates
- 3D printing, lots of room to optimize shape/performance
- Once well understood précises substrates can be made.
- They could serve as disposable modules in high radiation environments.

Secret Plan to make a Titanium Module*



- Mircochannel are the critical component in Velo production.
- Other parts are ‘less’ scarce.
- Can be made with the same production jigs.
- Could also be used to test other ASIC’s

* Will not be installed with the velo, but used for validation titanium printed cooling substrates

Velo Institutes

WARWICK
THE UNIVERSITY OF WARWICK

USC
UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

CERN

AGH

University of BRISTOL

University of Glasgow

UNIVERSITY OF LIVERPOOL

UNIVERSITY OF OXFORD

LOMONOSOV MOSCOW STATE UNIVERSITY
MSU

MANCHESTER 1824
The University of Manchester

Nikhef

UNIVERSIDADE FEDERAL DO RIO DE JANEIRO

Nikhef

Liked the talk?

- We are looking for a house/apartment in Nyon
  - 3 bedroom, or living room that can be split for guests.
  - Max 3000 Fr, all-in

+

Questions

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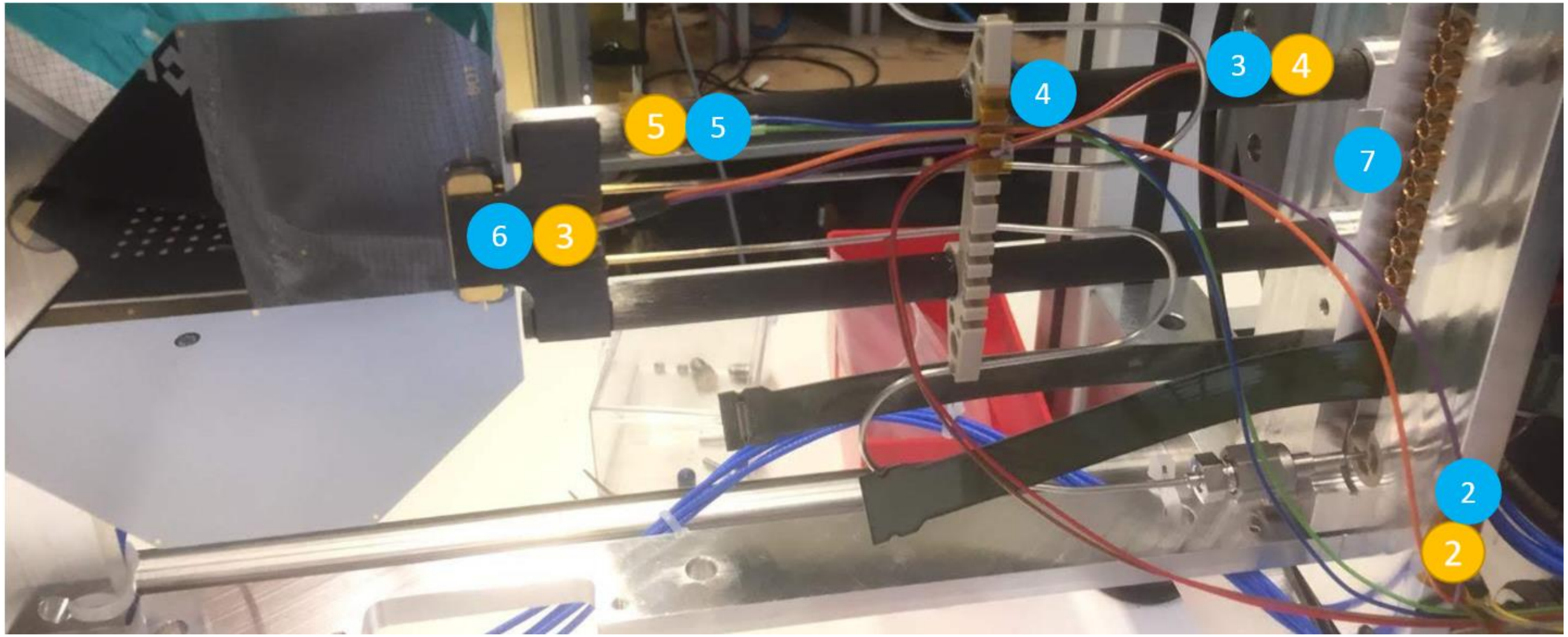
The back up


There is no
backup, RUN!!

Positions pt100 – Bare module NRD006



Numbers in blue are the PT100s that are on slide 26, In orange are the positions of the previous module.

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