PSI Center for Accelerator Science and Engineering

Undulators

Mech. Engineering

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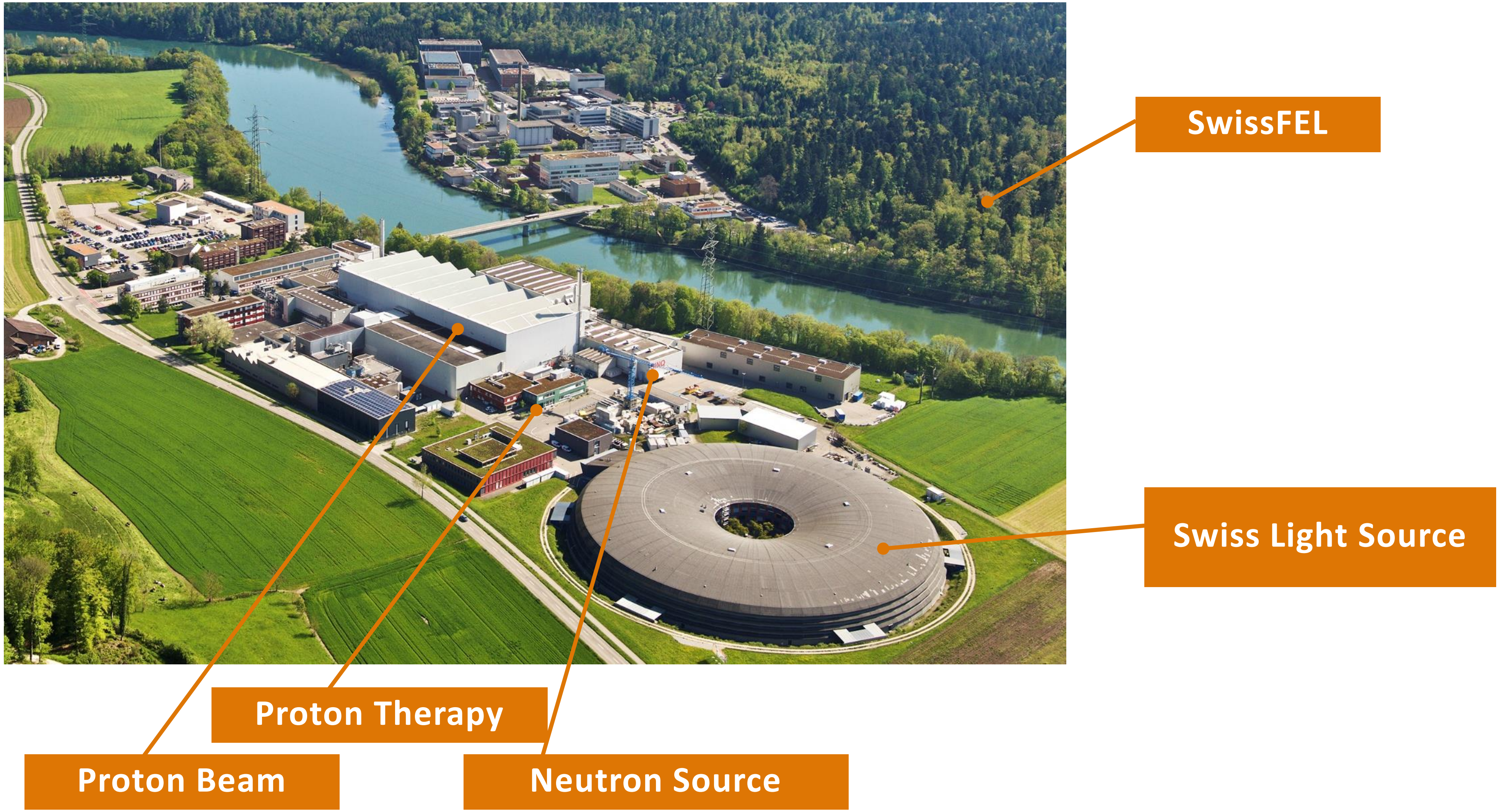
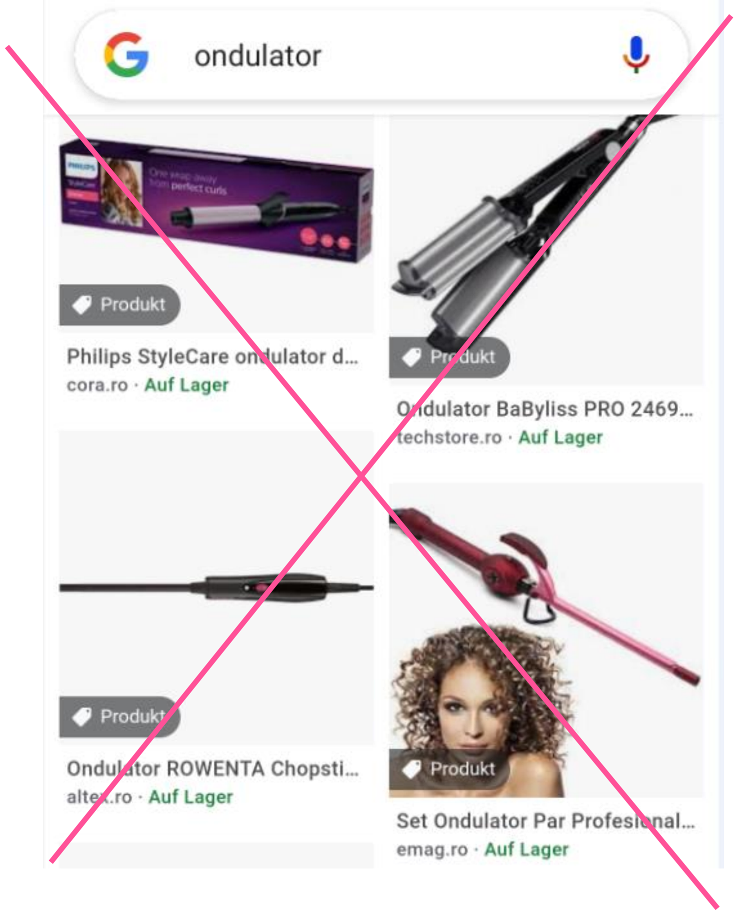
View on Paul Scherrer Institut



Ondulator ?



Undulator for Light Sources

Introduction: Function of Undulator

Guiding the electronbeam to a slalom with magnets to generate sychrotron light

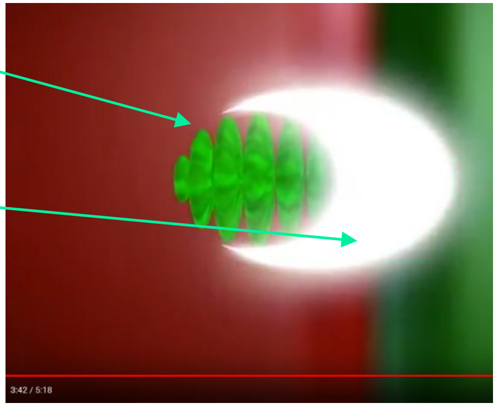
SwissFEL – the new large-scale facility at the Paul Scherrer Institute

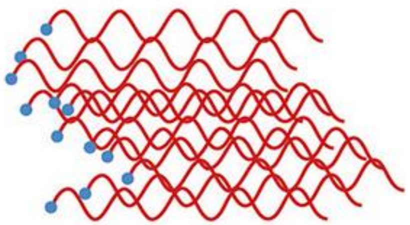
Magnets

Electron Bunch

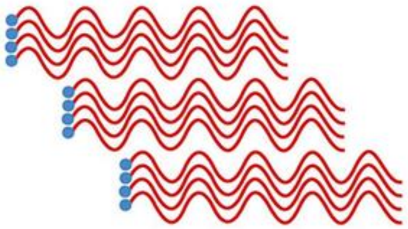
Light

Lasing at Free Electron Laser

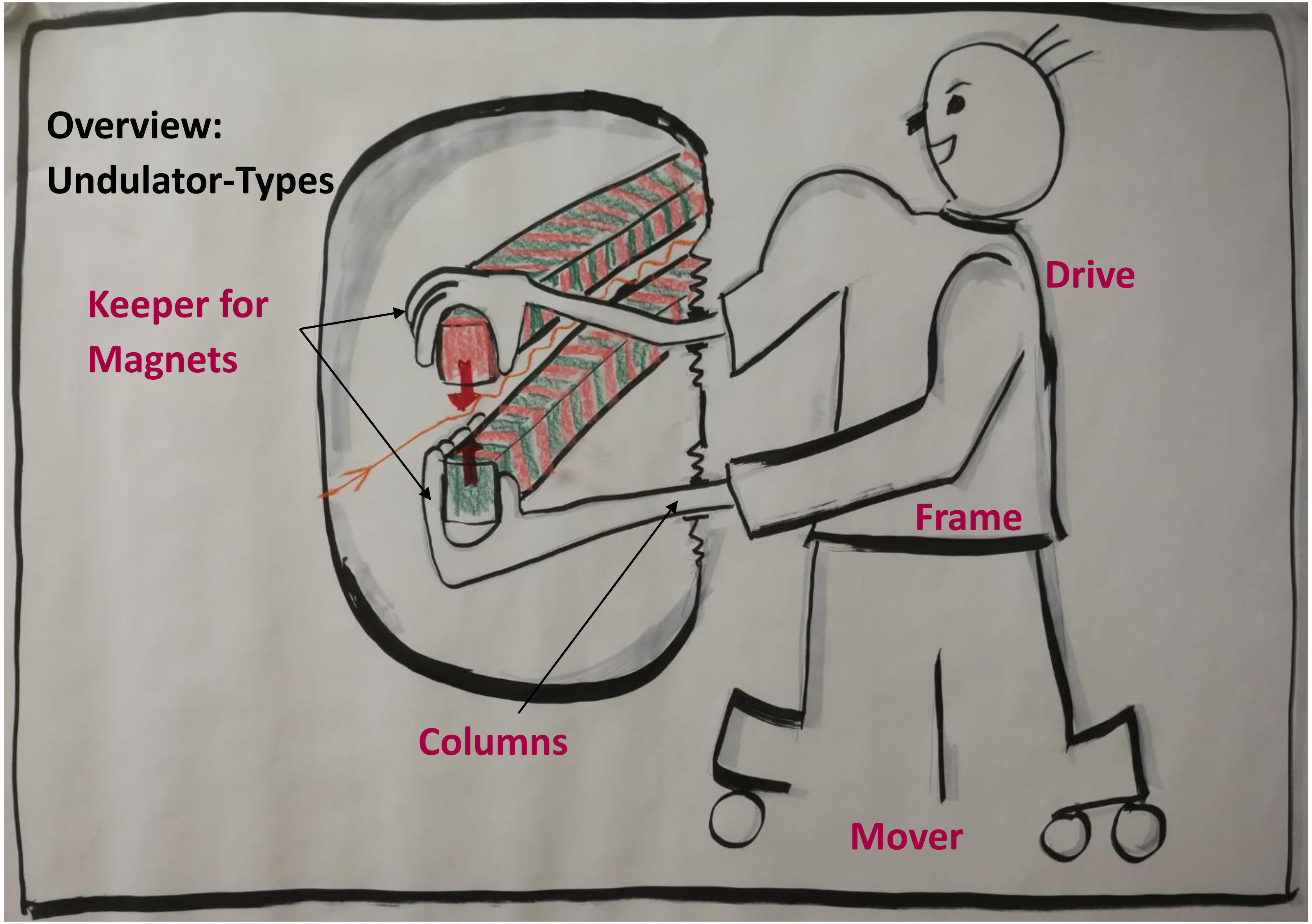




Intensity increasis by a factor of 10^8

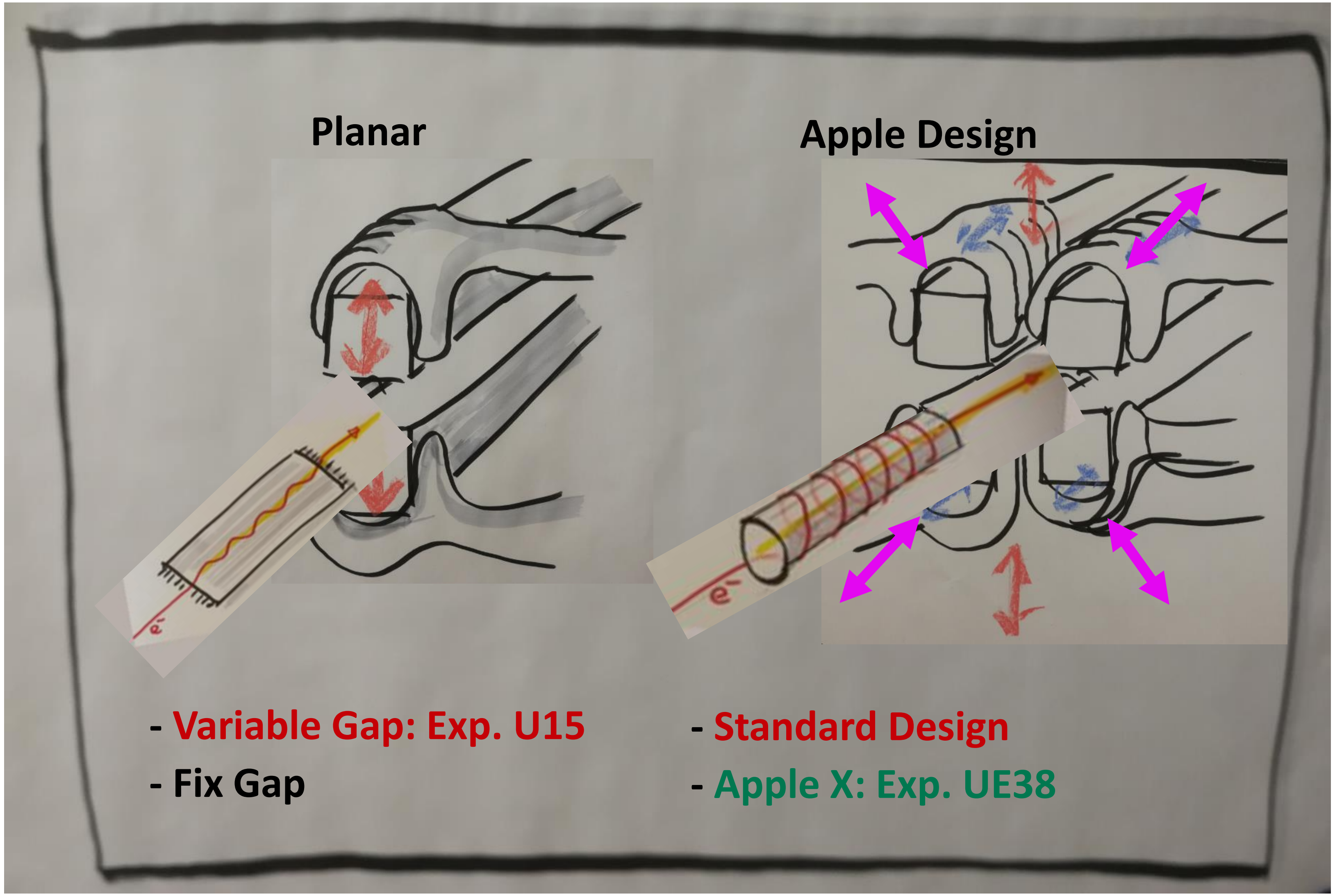


Outline



Overview:
Undulator-Types
Keeper for
Magnets
Drive
Frame
Columns
Mover

Undulator Types



Undulator Types

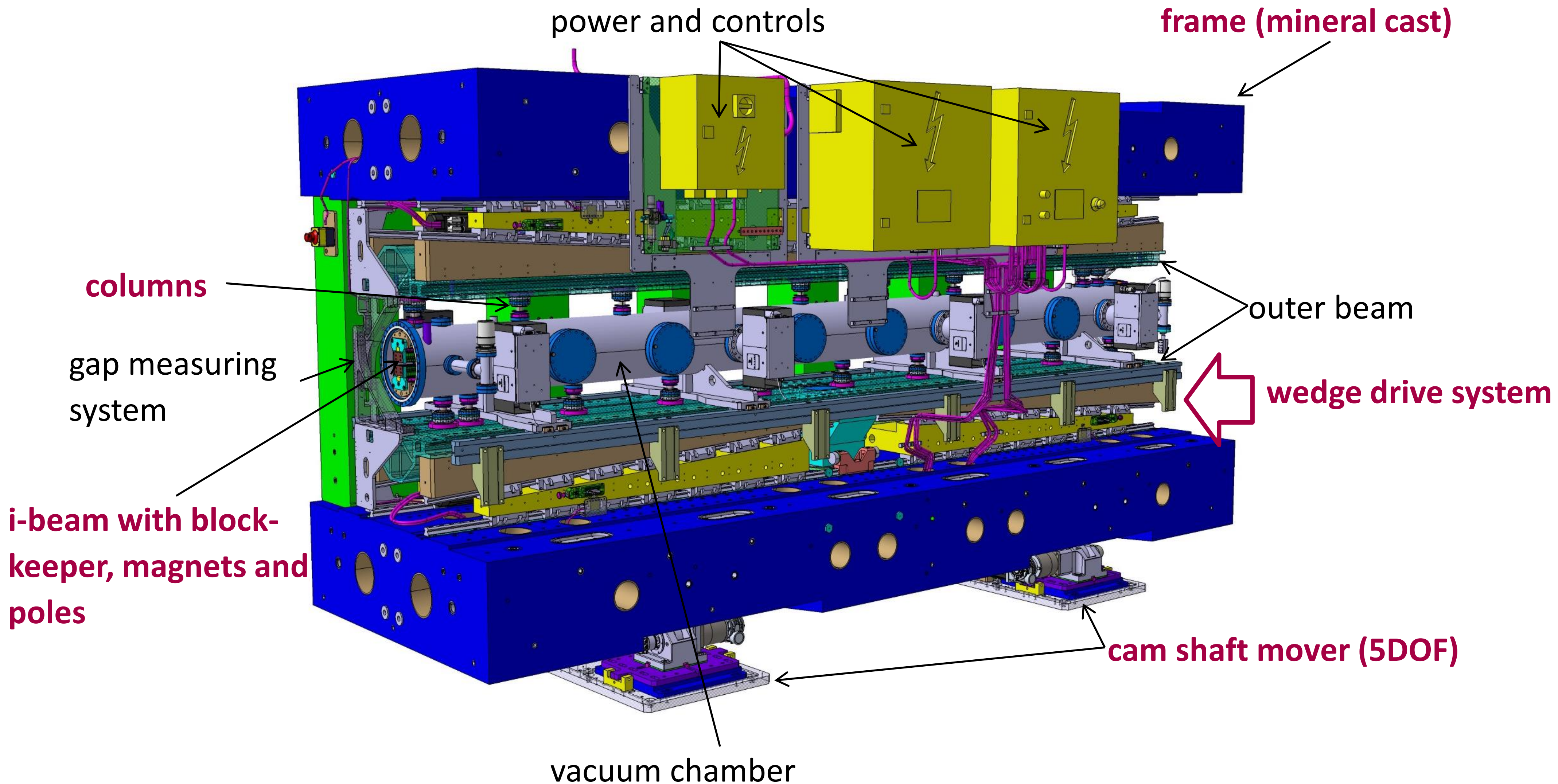
In Vacuum

Out of Vacuum

Other Types (not in this presentation):

- El. Magnets
- Kryo cooled magnets

Aramis Undulator U15 – main parts

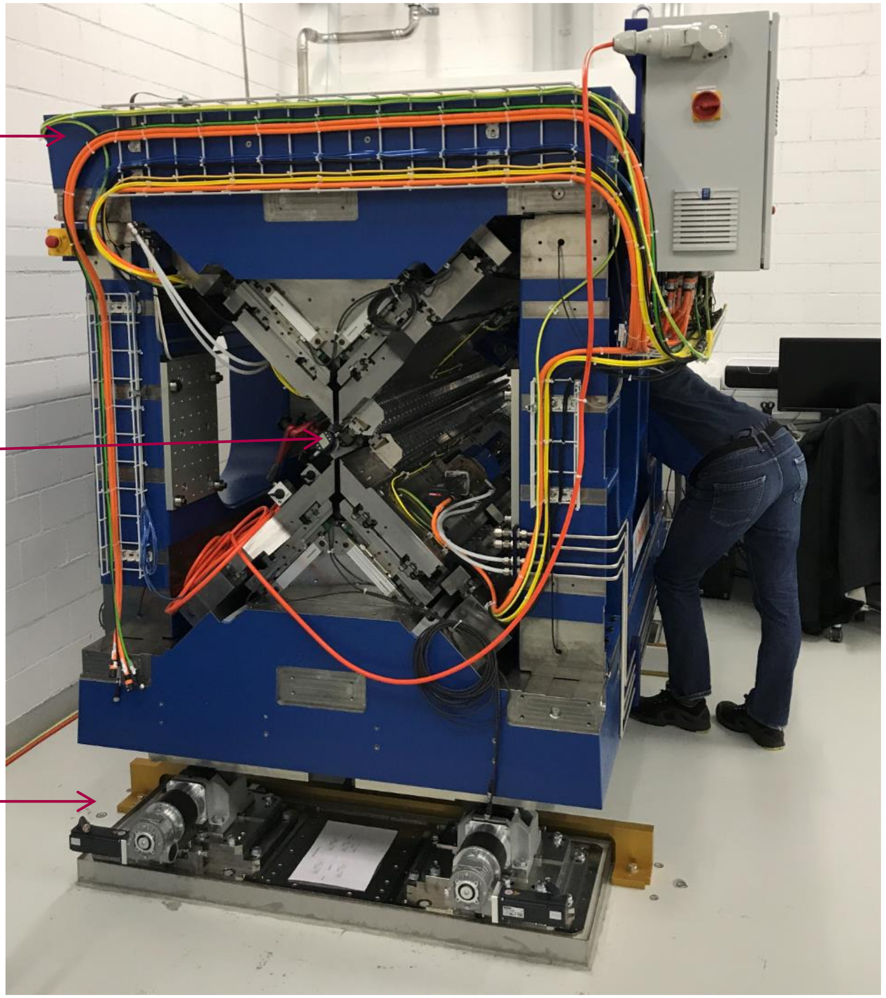


Athos Undulatur UE38 Apple X

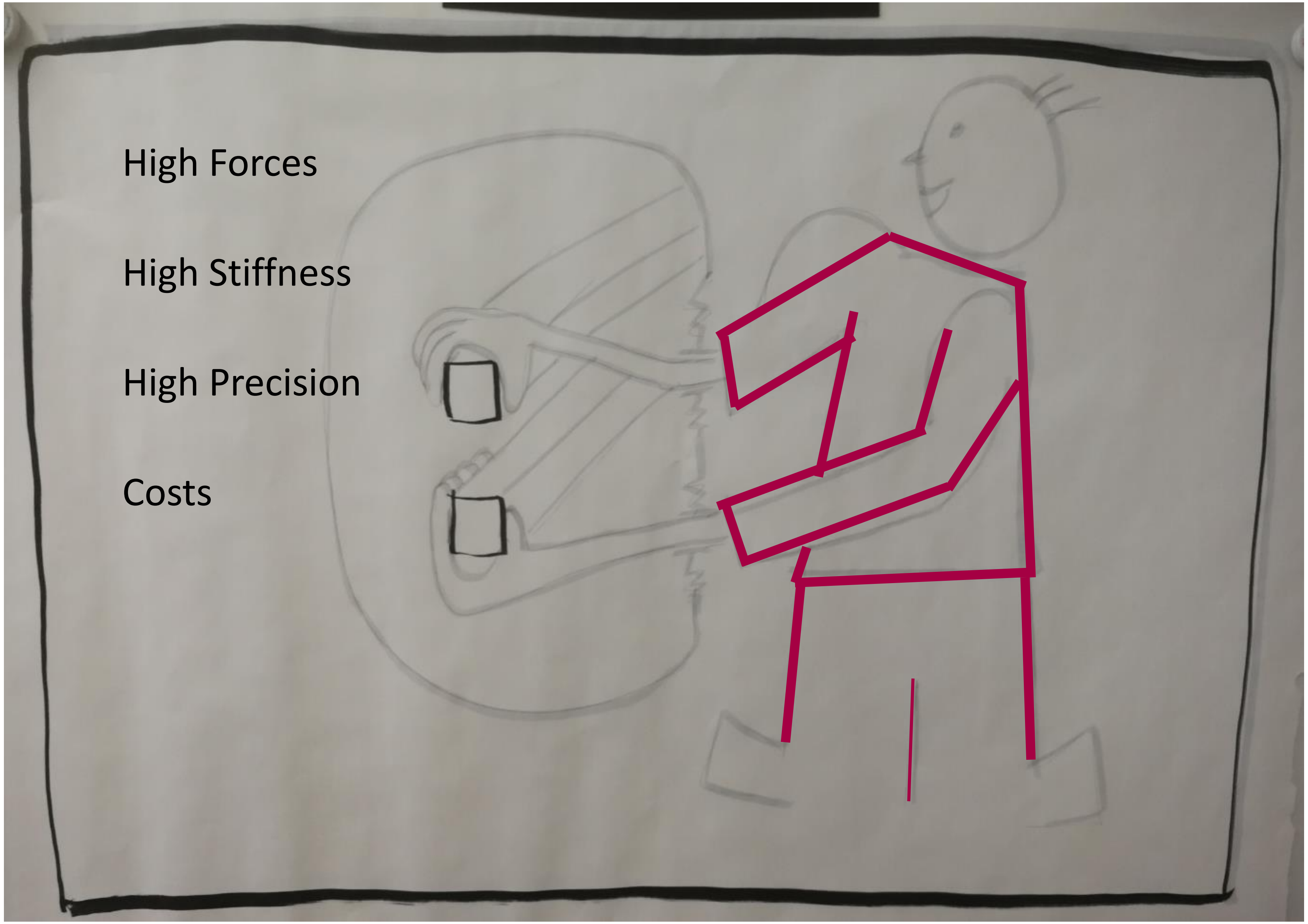
frame (iron cast)

vacuum chamber

cam shaft mover (5DOF)

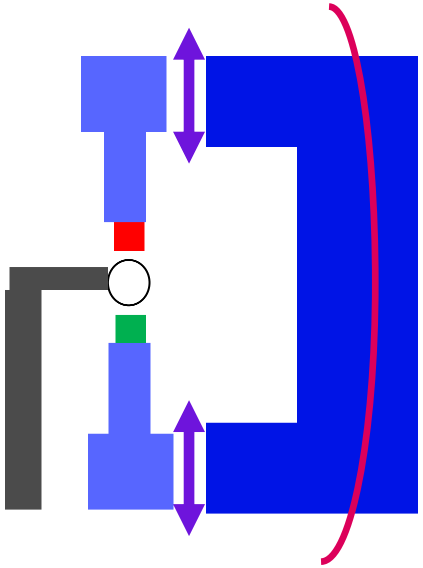


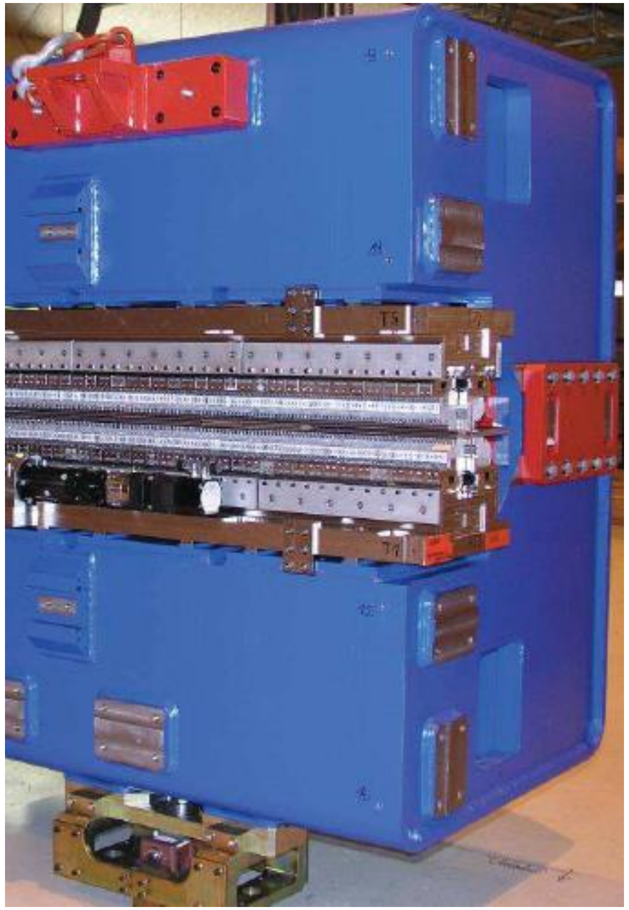
FRAME



Frame: Standard Design – C-Shape

PSI



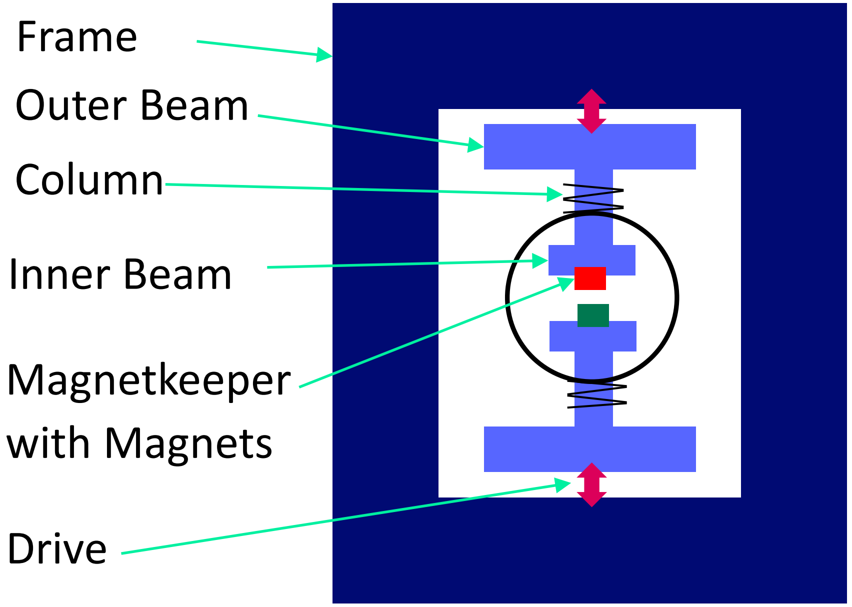


Example: UE44 at PSI

Welded Steel Frame

Vacuum Chamber can be installed after the installation of the Undulator

Frame: New Design -> Closed Frame



Frame: Material of U15

For the U15 wie choosed Mineral Cast because:

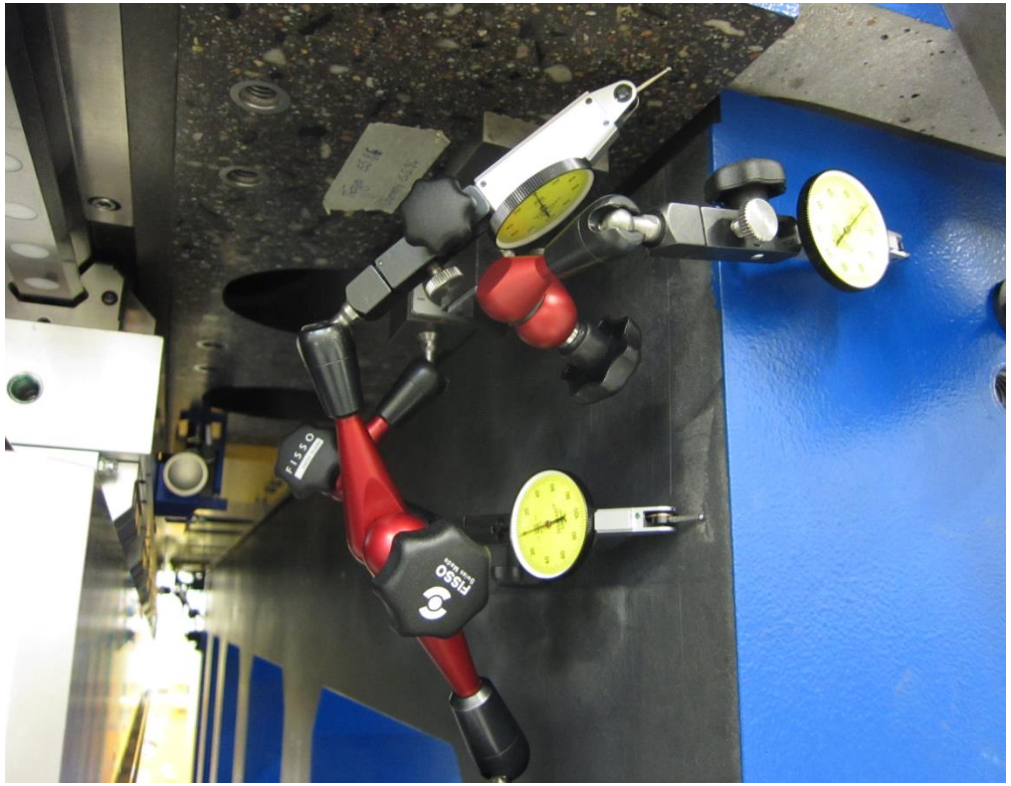
- Cost savings, if you build a serie
- Non magnetic
- By bonding the blocks together with glue, you recieve a massiv and stiff block
- Possibility to integreat tubes for cabeling

But

- You have the design it massiv, because of the low modulus of elasticity
  - 40-45 kN/mm^2
- Take care of thermal expansion : At the end, we had to cool the motors with water
  - $15 * 10^{-6}/K$

At the beginning of the Design, you have to define the process of manufactoring

Bonding of the upper plate



Adjustment before bondig

Fixation during the bonding

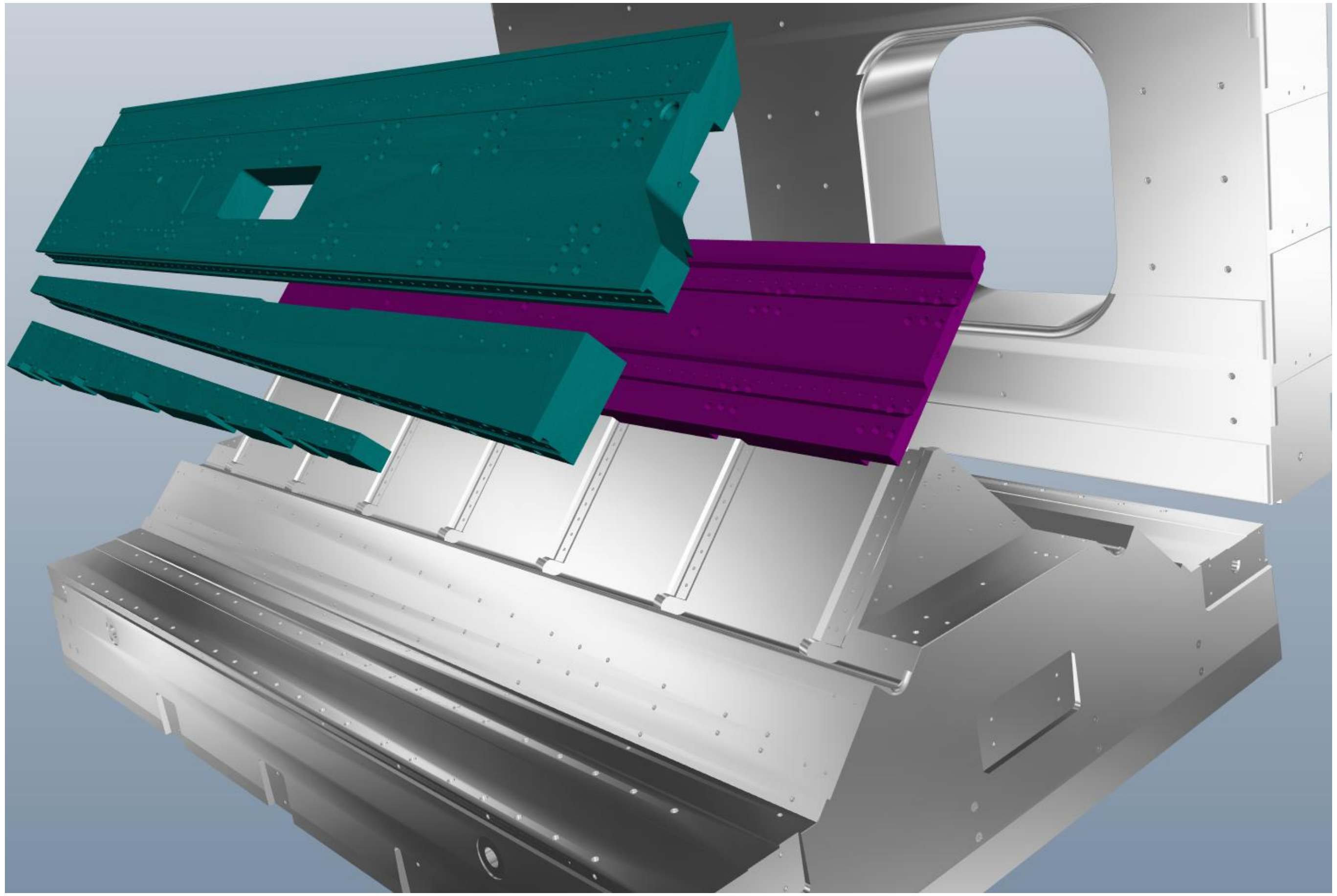
Filling of glue with peristalticpump and tubes

Frame with cast iron

The arragement of the linear guides is **very sensitiv of thermal expension.** Therefore we decided to design the main part with the same material: Cast iron

Compared to mineral cast:

- Milling instead of grinding (costs)
- Higher young's modulus
- More freedom in the design

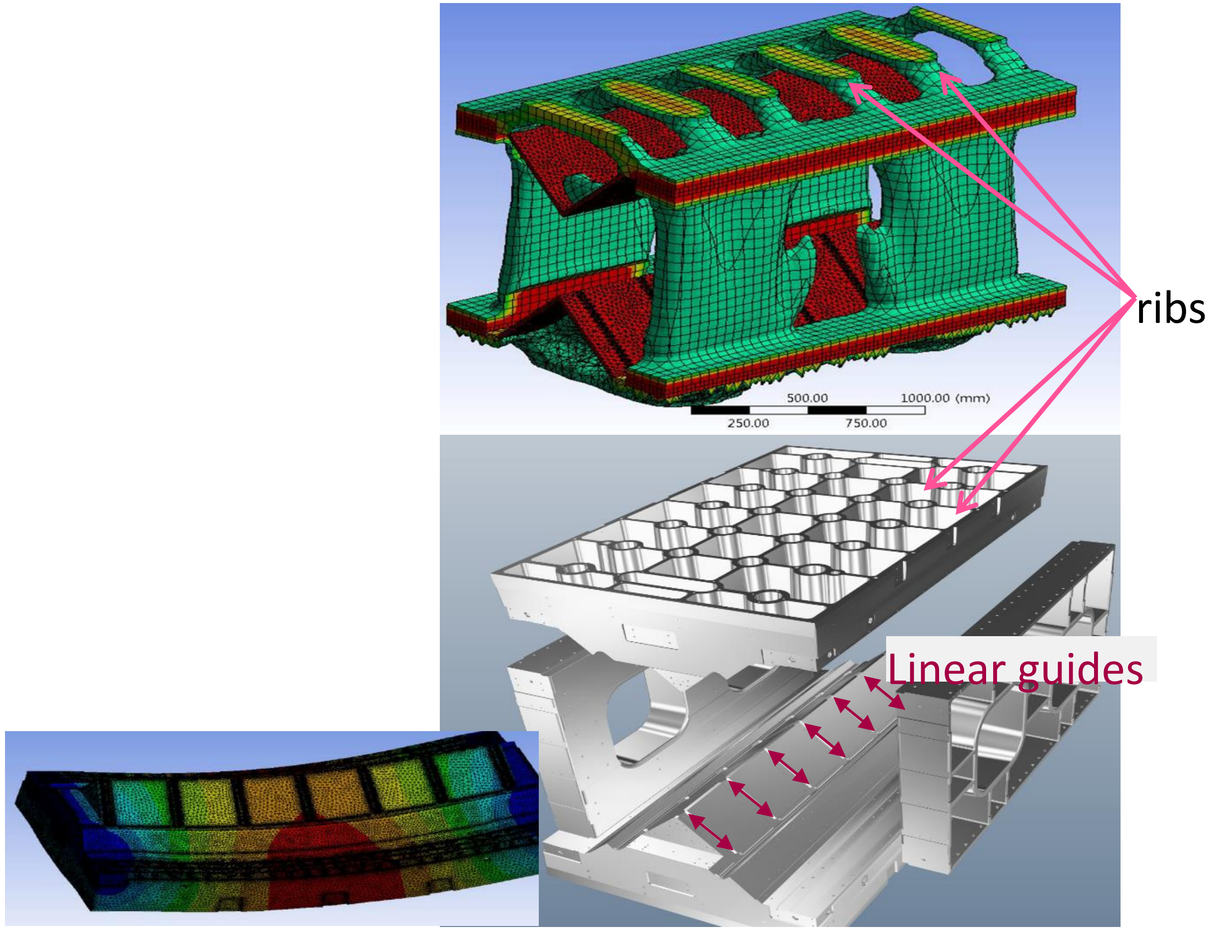


All these parts are in cast iron

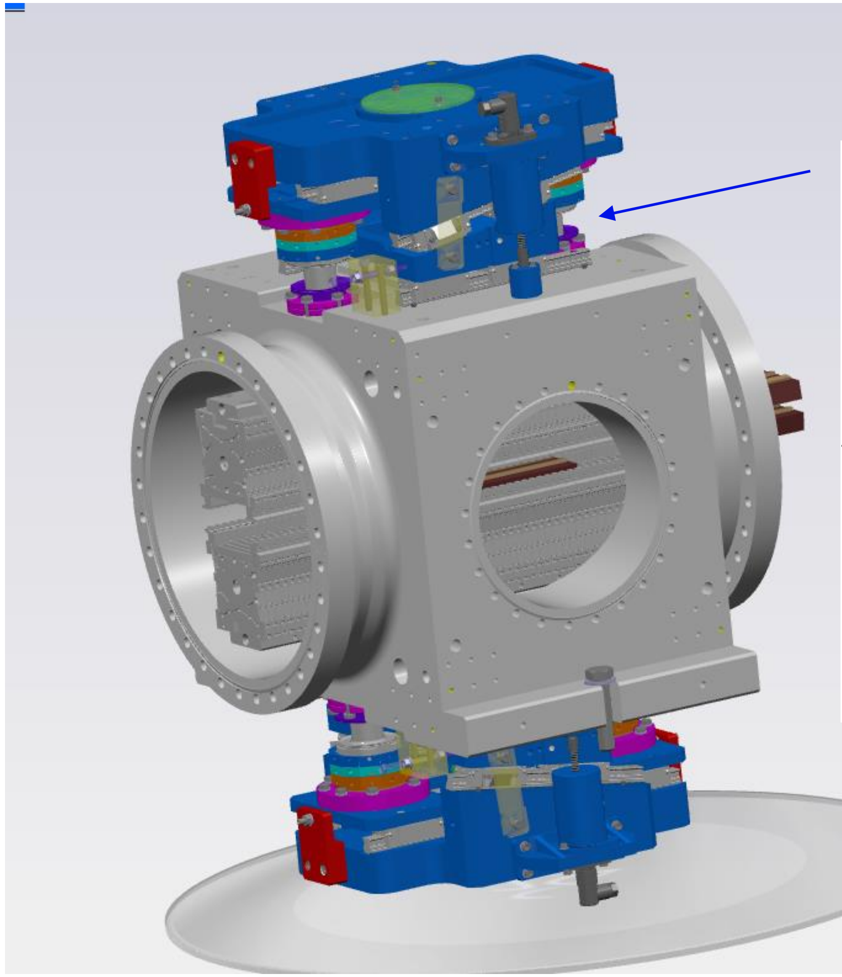
Frame with cast iron

Topology Optimization:

- First impression looks strange, but main finding was, that a rip has to be over each linear guide for the gap
- This principle was taken for the design of ironcast parts
- Upper and lower part identical
- Sidewalls identical
- Main goal is stiftness with changing forces. No clear limit, but we wanted to reach less then 20 micron

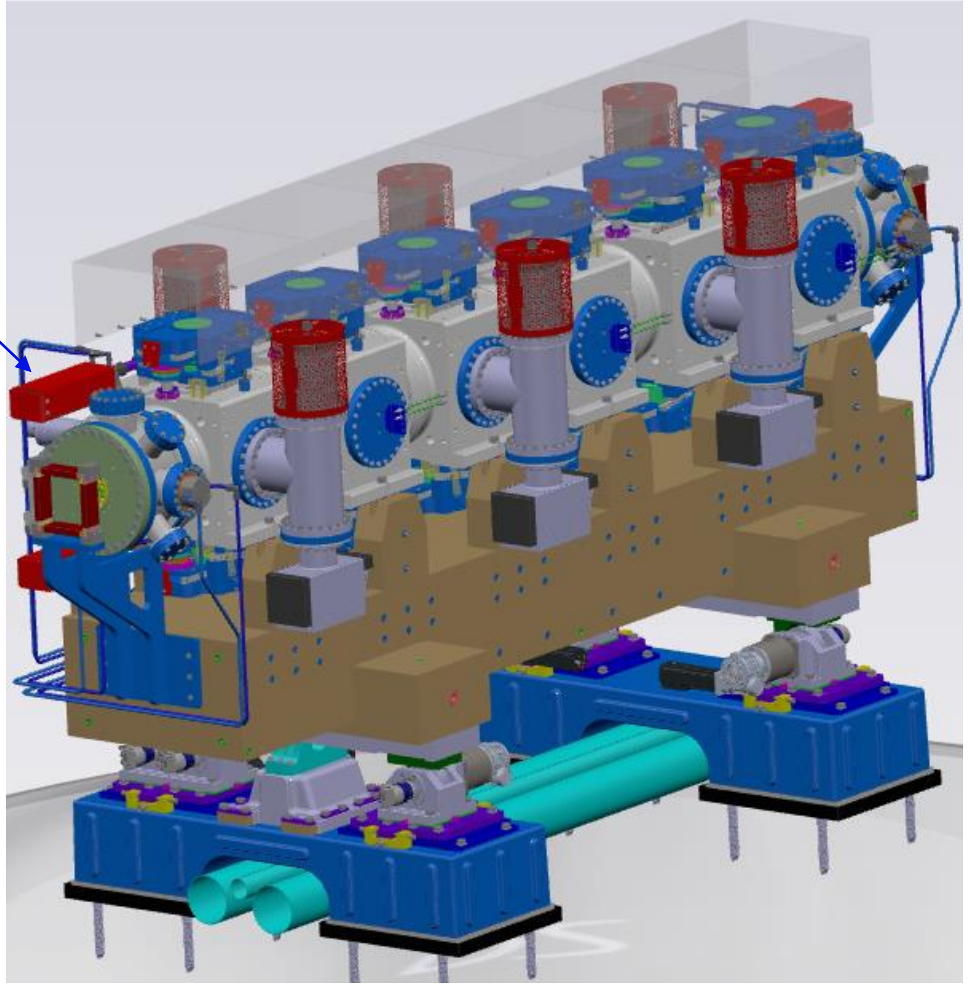


Newest generation for SLS 2.0

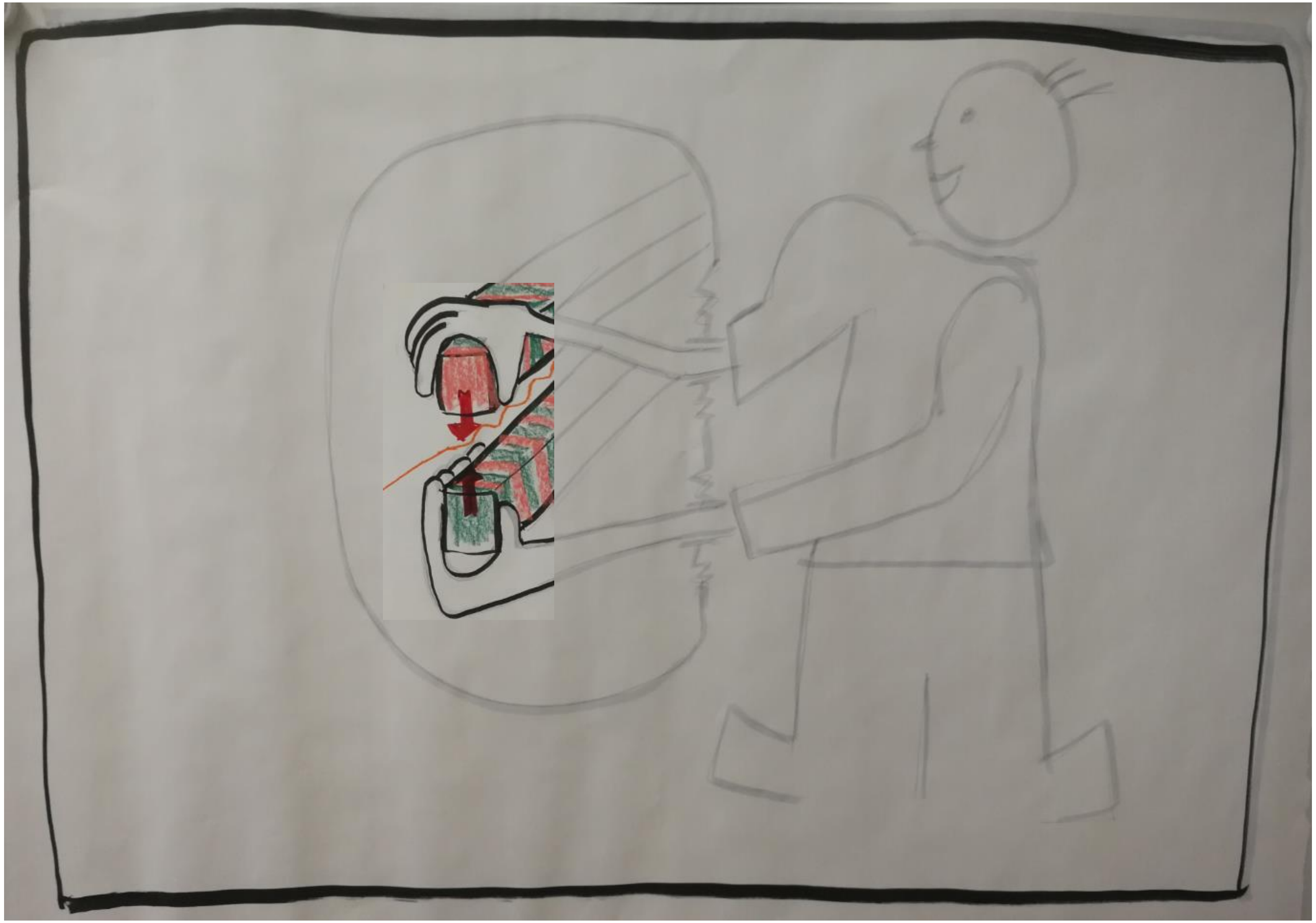


- Wedgedrive
- compact
- ,odular
- Vacuumchamber in Aluminium

But
Magnets with Forcecompensation



Keeper for Magnets



Keeper for Magnets

For the U15 (4m length), there are more then 500 pairs of magnets, that has to be adjusted

Mechanical tolerances

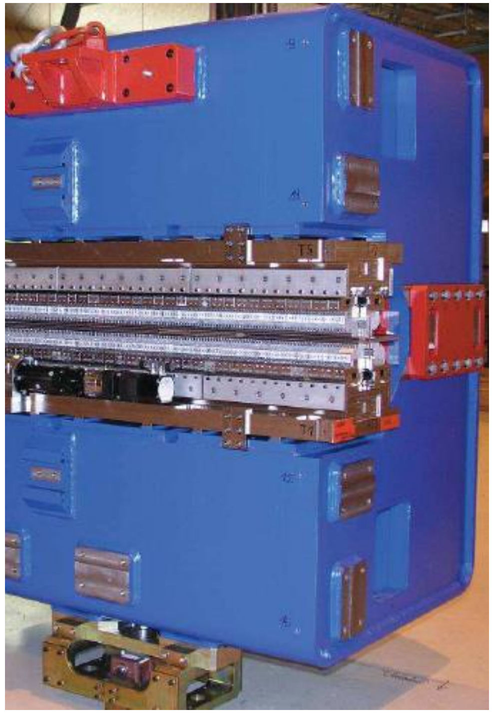
Magnetical tolerances

Objective of precision : 10 Micron

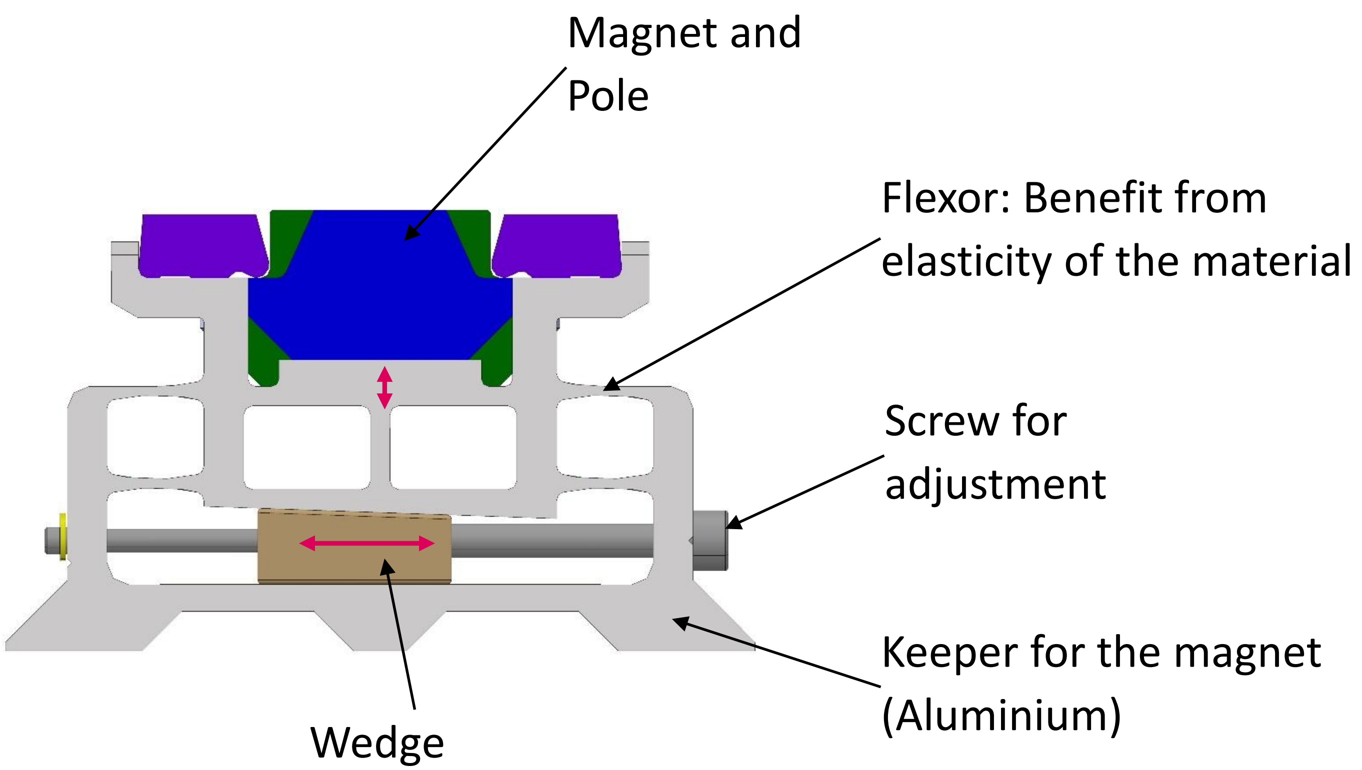
In the past, we optimized by shimming (underlay or remove very thin iron sheets)

→ That optimization can last several weeks

→ For SwissFEL we had to build 12 units for the first Beamline

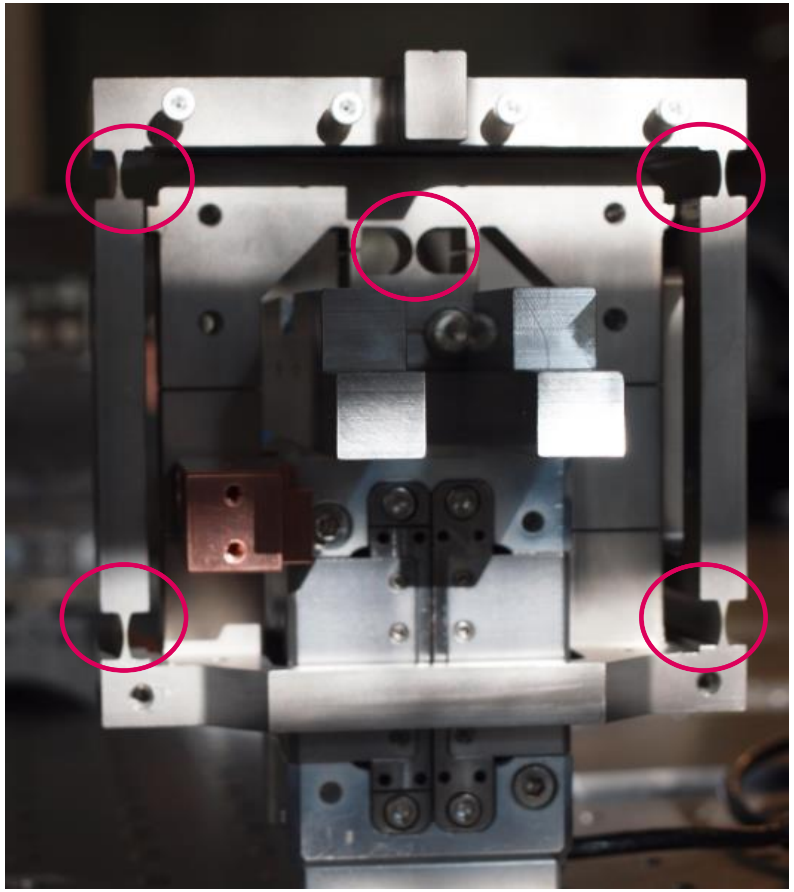


New idea: Flexor, wedge, screw



Other Examples of flexors

High precision in endstations

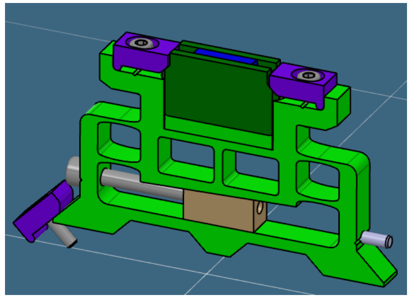


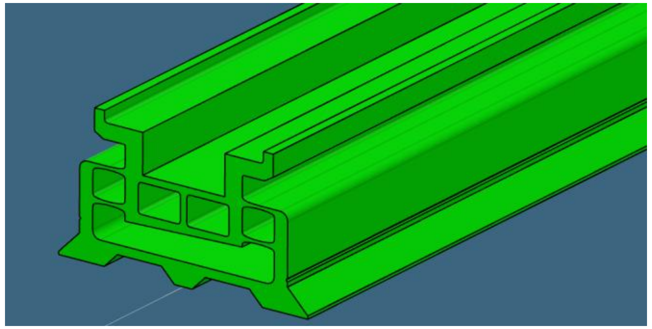
Girder Prototype for SLS 2.0

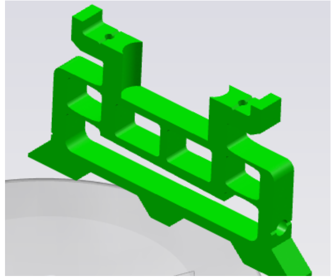
Flexors for roll (Steel)

Flexors for Height

Development in a Team

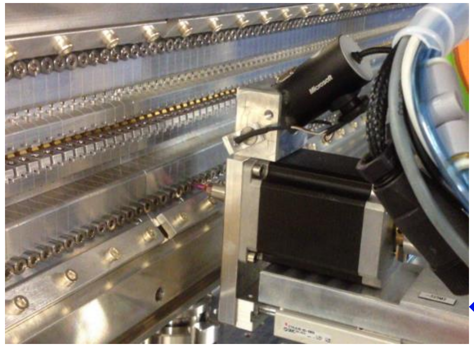




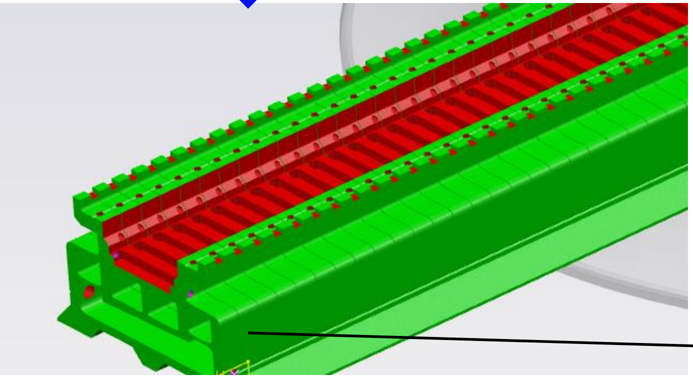


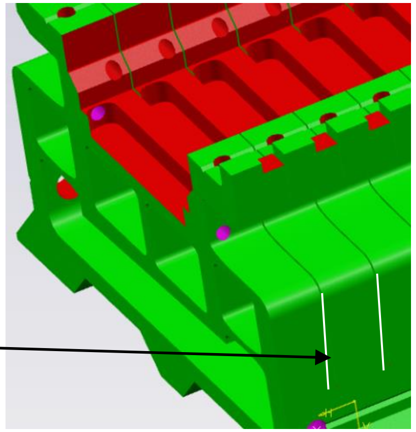
1st idea : Wire roded part for the Keeper

2nd idea : extrude as a profile and cut in pieces



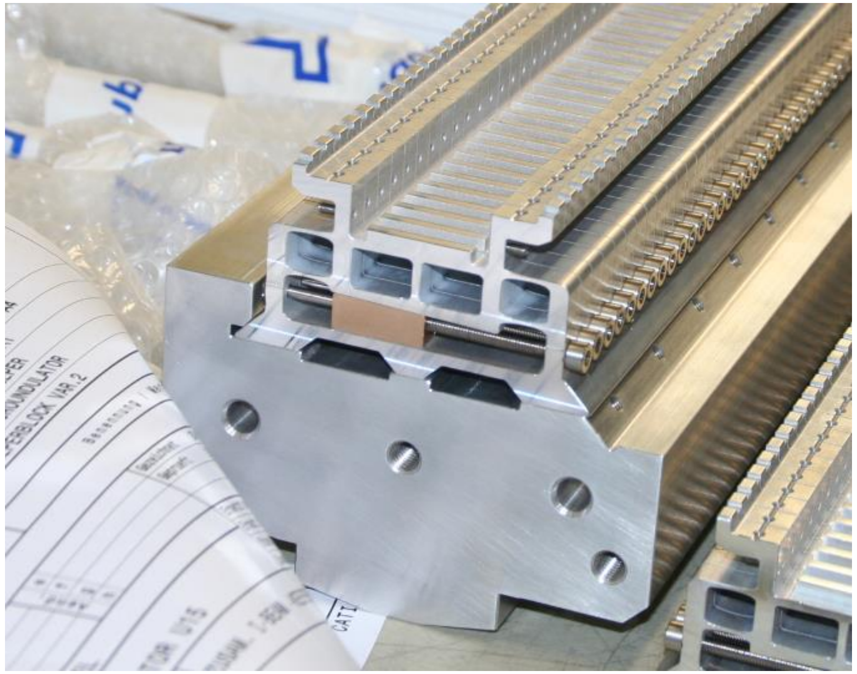
Adjustment by robot-system → Video

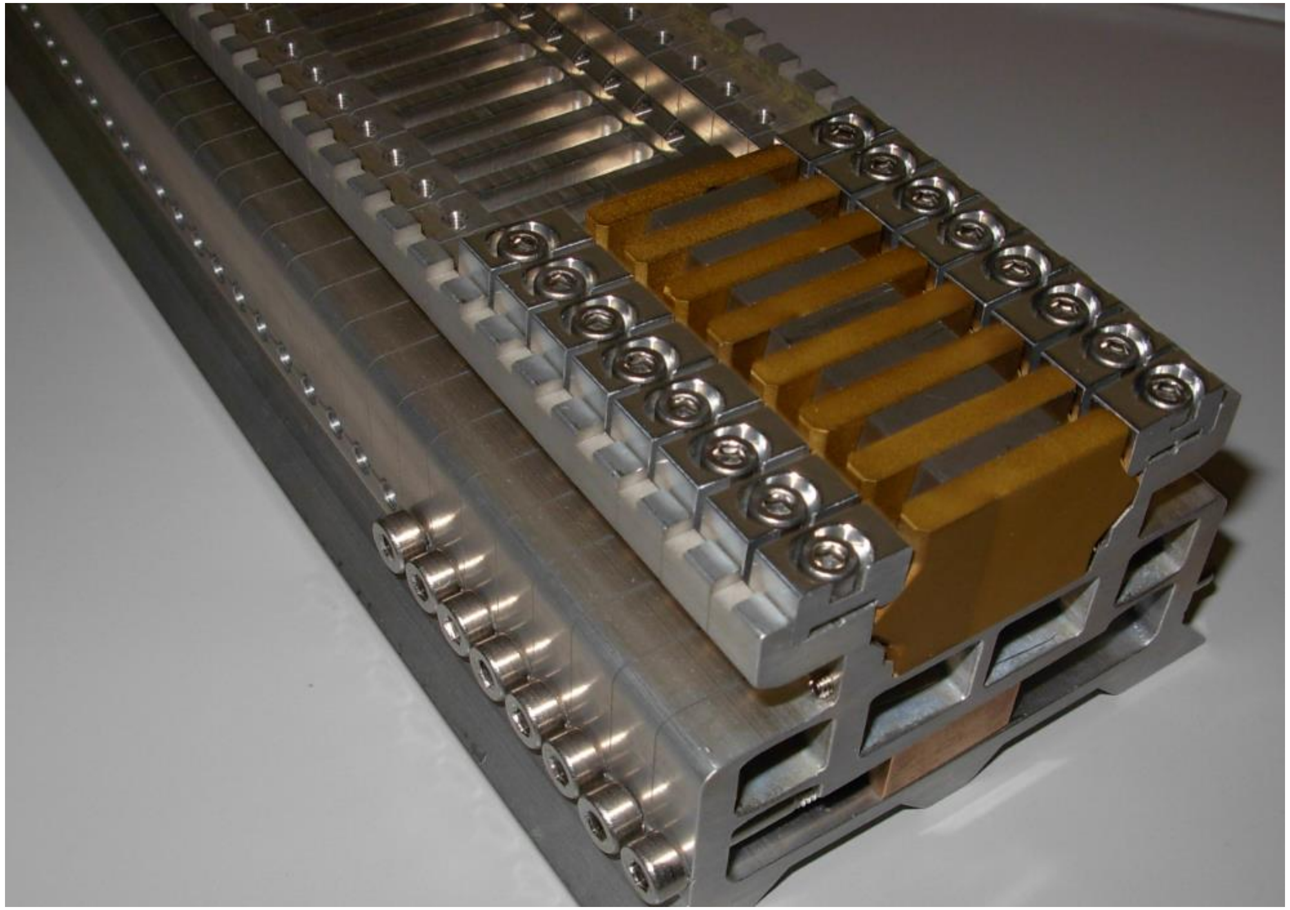




3rd idea: keep the profil and cut only slits for individual adjustments

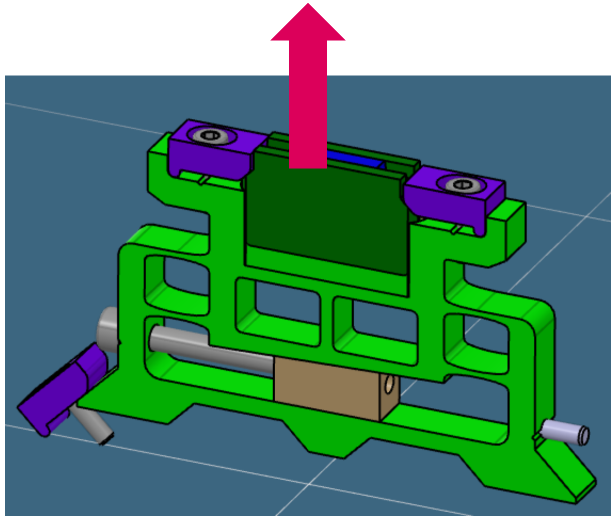
Blockkeeper: Photos





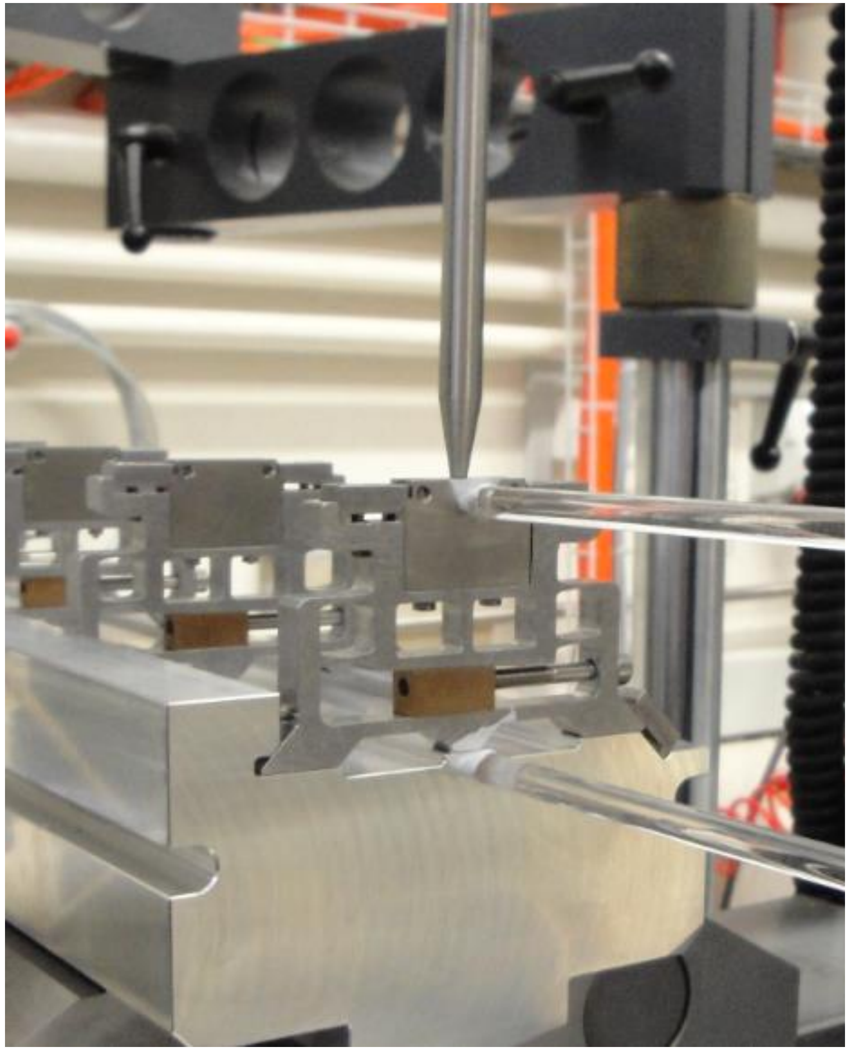
Preloaded Flexor

Magnetic force wants to lift the stucture up



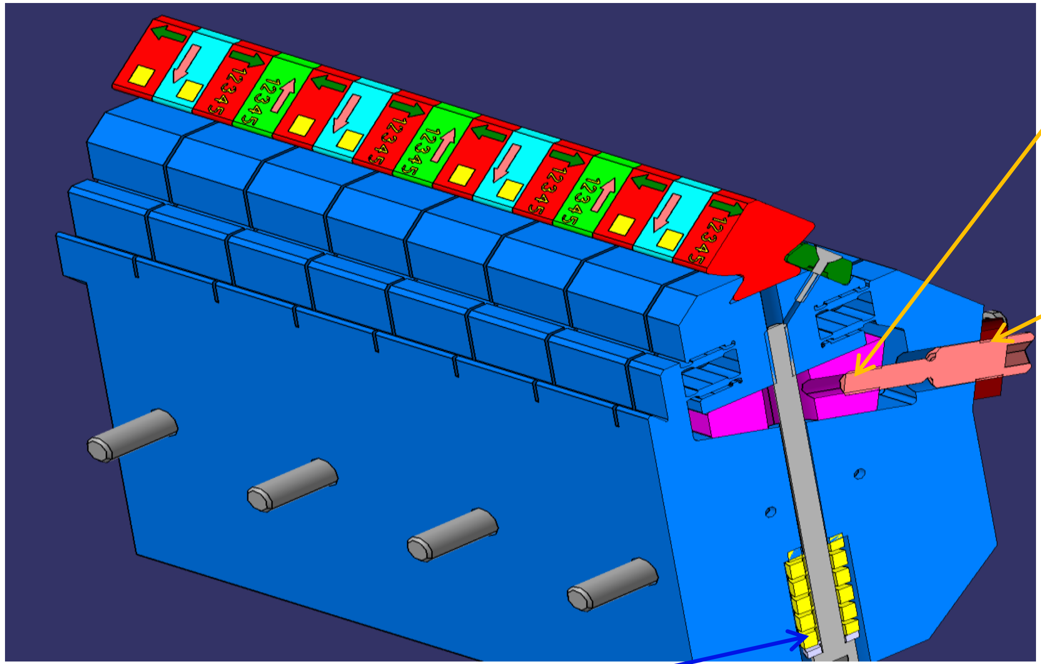
Loose the contact:

→ Limited area of adjustment +/- 0.05mm



Testing and simulations in advance

Keeper Design: Optimazations for UE38



Differential screw thread

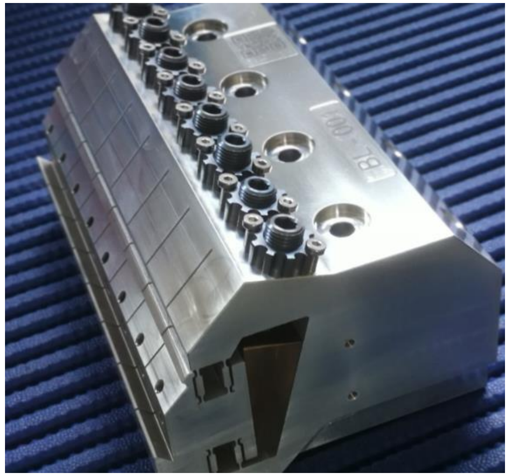
1/4 – 28 UNF : 0.907 mm

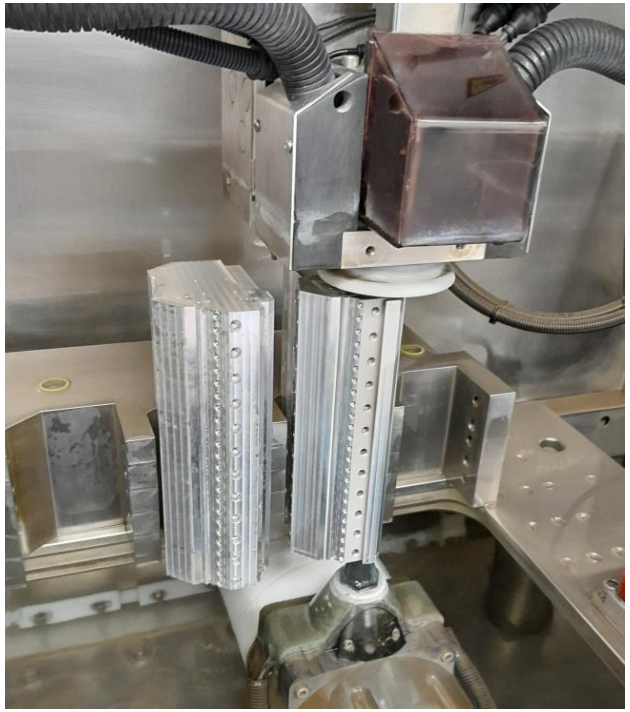
M10 x 1 : 1.0 mm

-> 0.1mm Movement by one turn

Wedge: Bronce (CuSn12-C-GC) with Dicronite coating

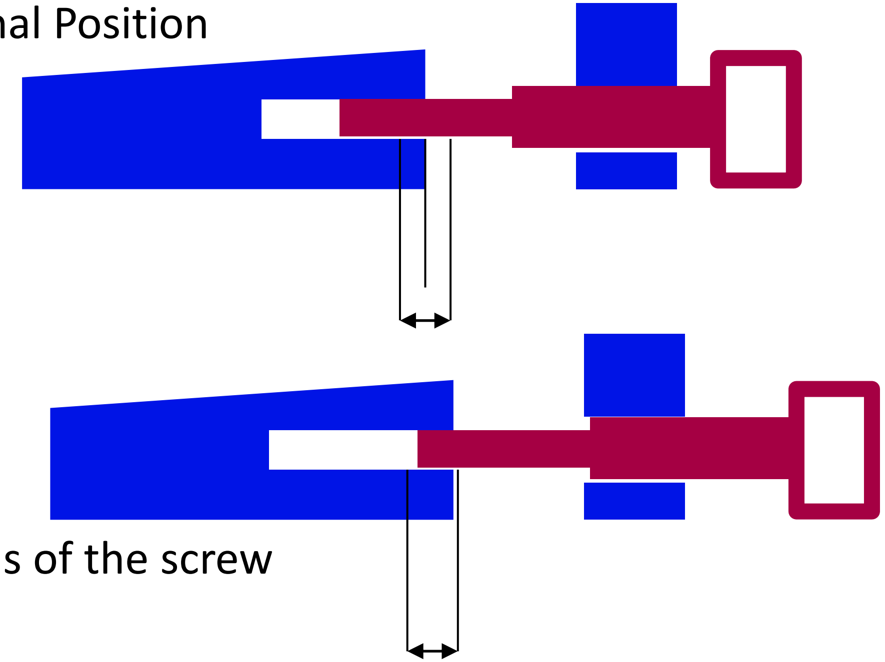
Spring to pull the keeper to the wegde





Keeper Design: Differential Screw

Nominal Position



For 0.5mm → 5 turns of the screw

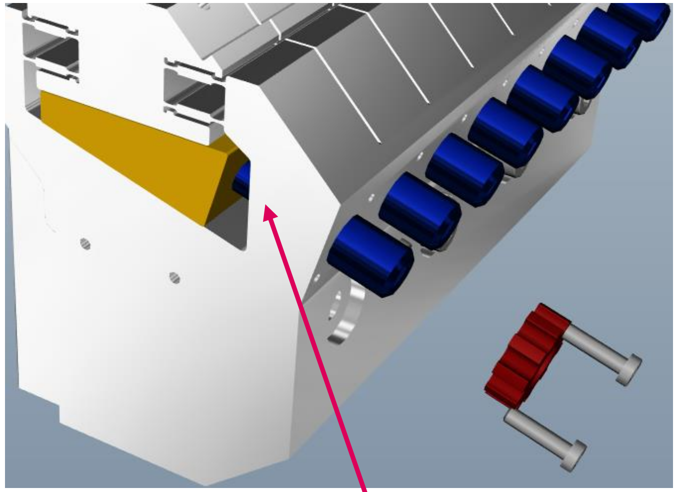
The stroke of the screw is around 10x the stroke of the wedge

Attention: The startingpoint of the thread is random
→ In worst case, you need 10 turns of the screw to come to the nominal position

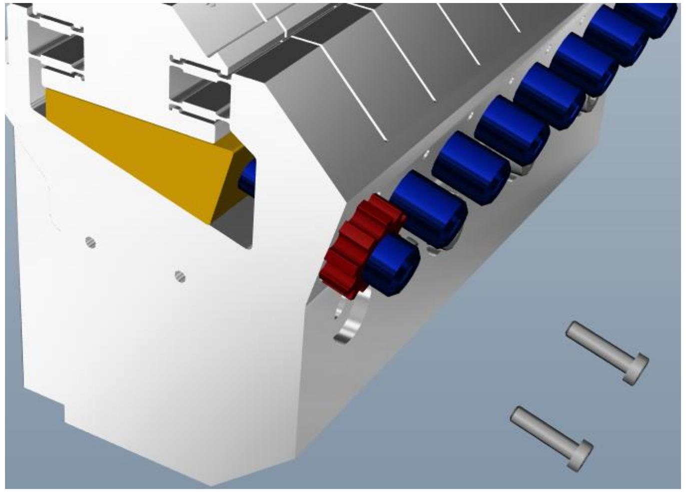
Differential Screw:

Assembling of the wedge with e separat nut

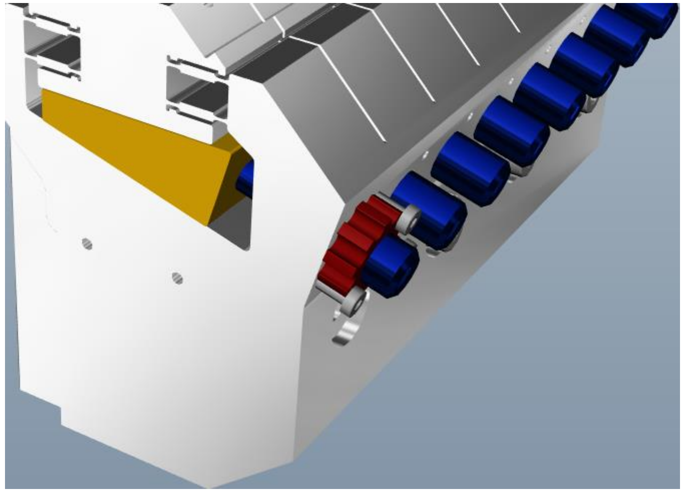
1. Step: Wedge and screw
In correct position



2. Step:
Ad nut (tighten by hand)



3. Step:
Fixation of nut by two screws



No thread in the keeper

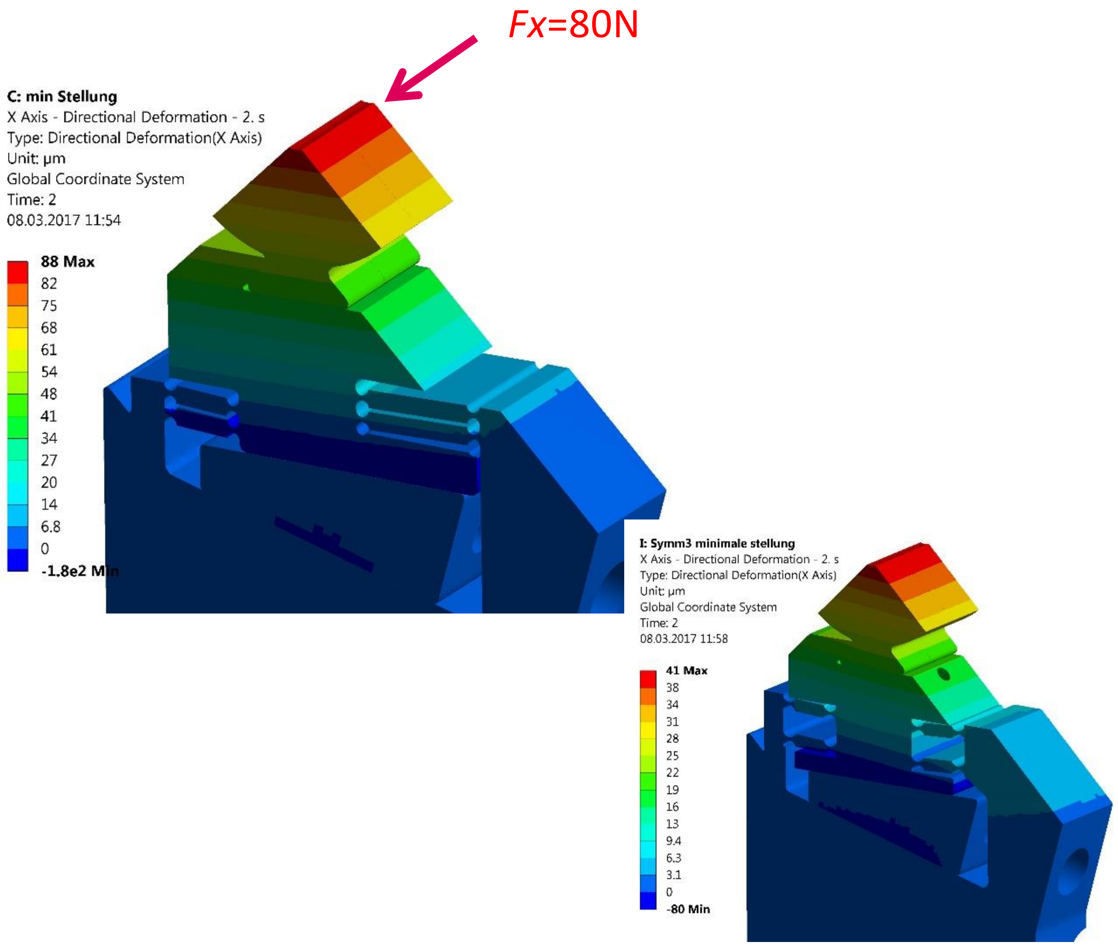
Keeper Design: Simulation of forces

Simulation of various geometries.

Main goal: Smallest deformation in beam direction

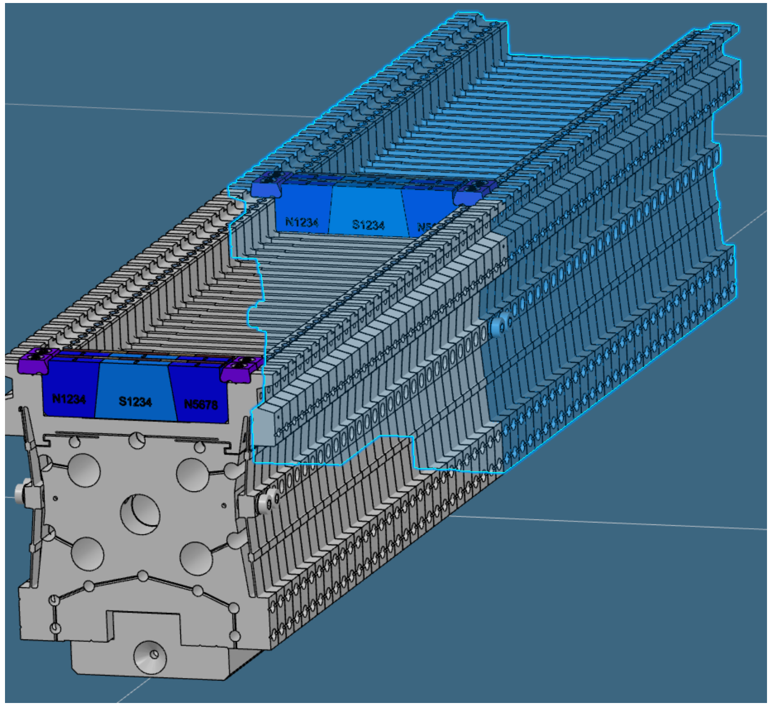
Main findings:

- Flexure has to be weak (this is important, if the flexor is in a lower position)
- Spring has to be strong
- Displacements in the other directions are not critical
- Flexures has to be symmetric



New Keeperdesign with two degrees of freedom

PSI



Force

Compensation

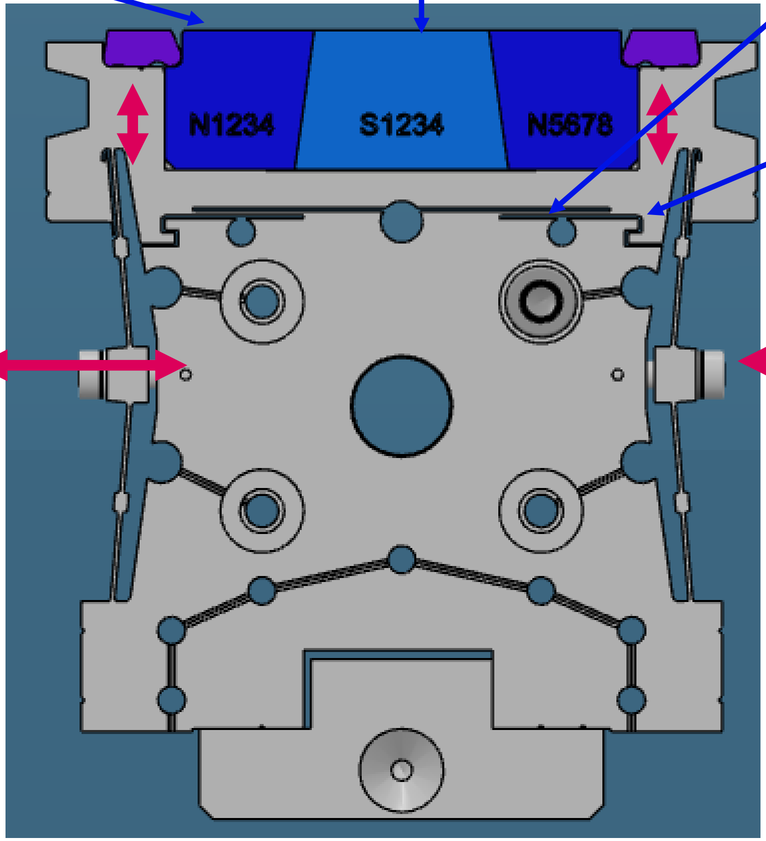
Magnet for

the Beam

Flexor

Limitation of

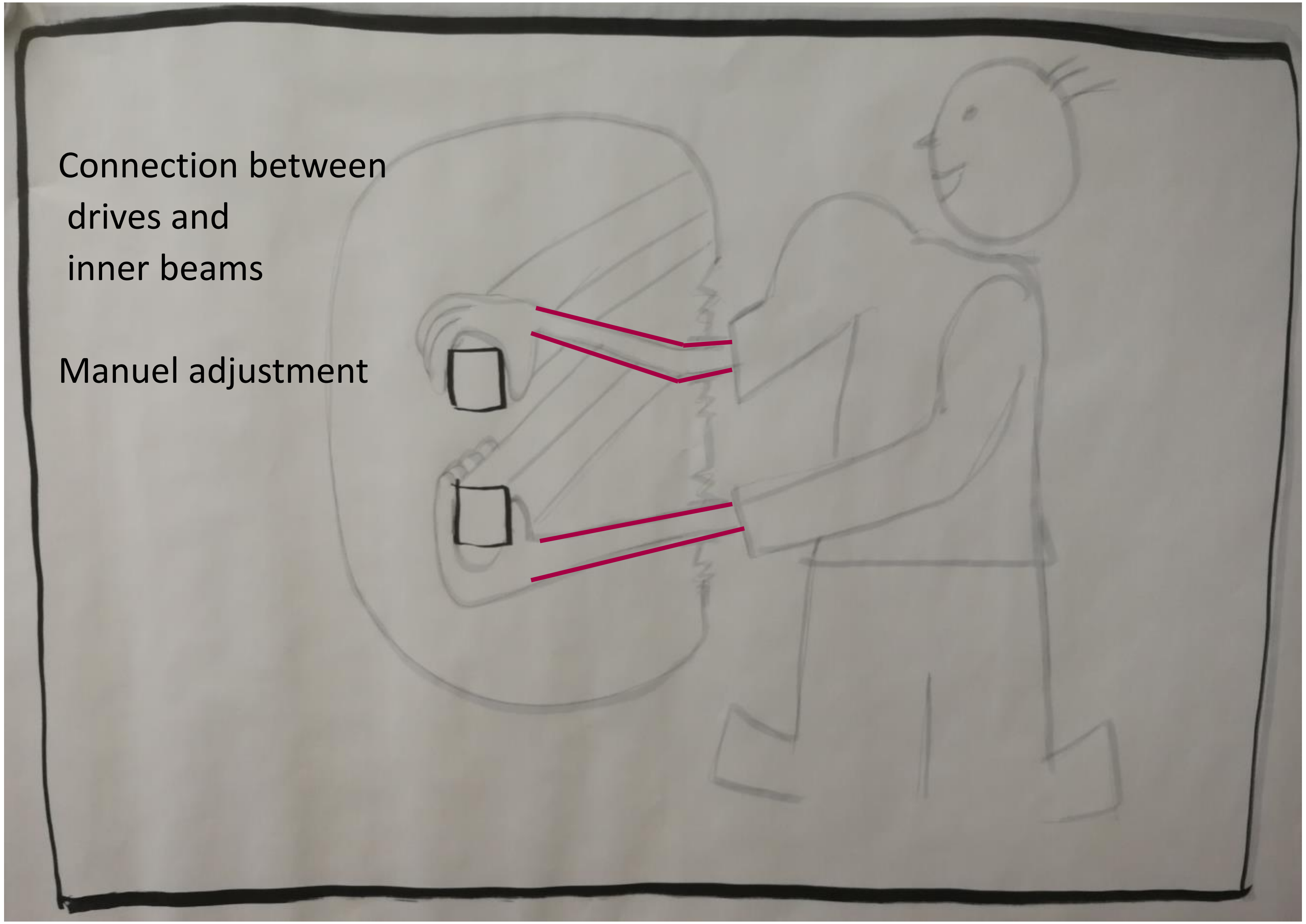
Stroke



Screw for

adjustment

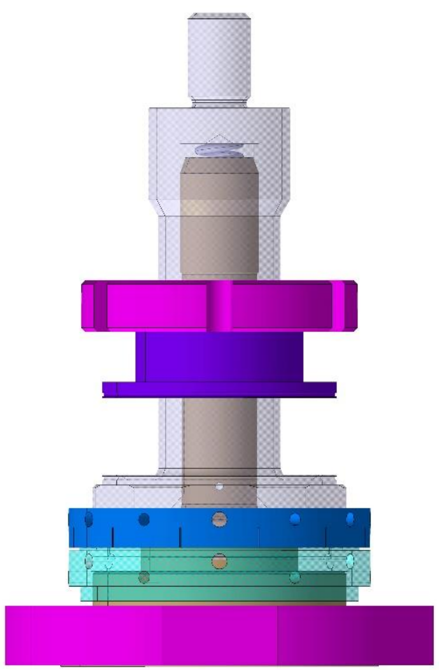
Columns (for in Vacuum Undulators)

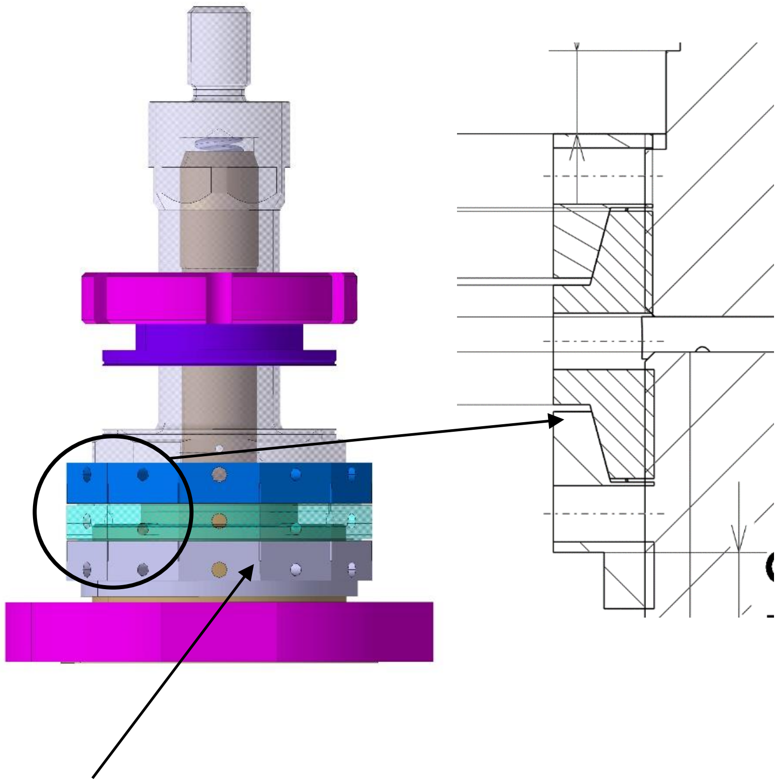


Columns: Design

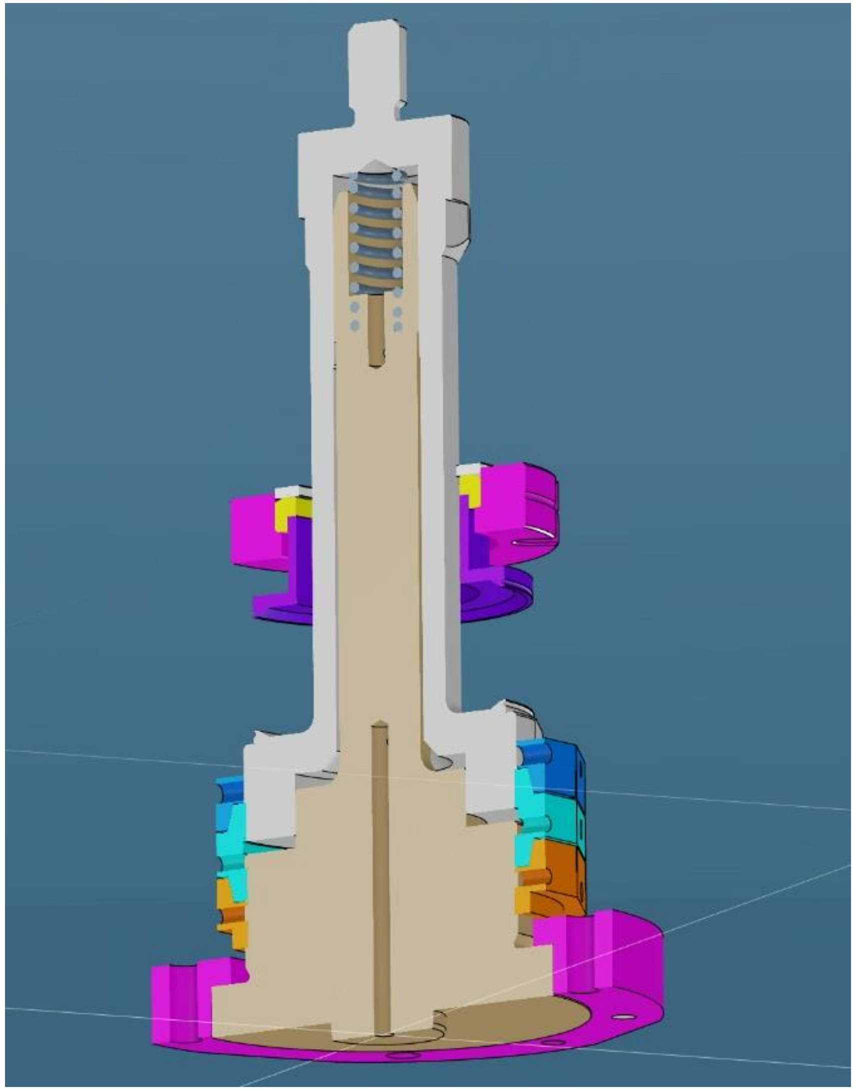
Prototype

Series



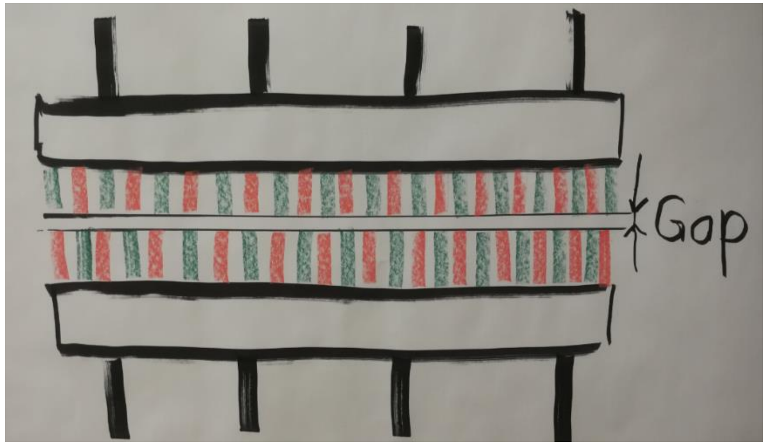


Additional screw nut to eliminate the clearance (backlash)

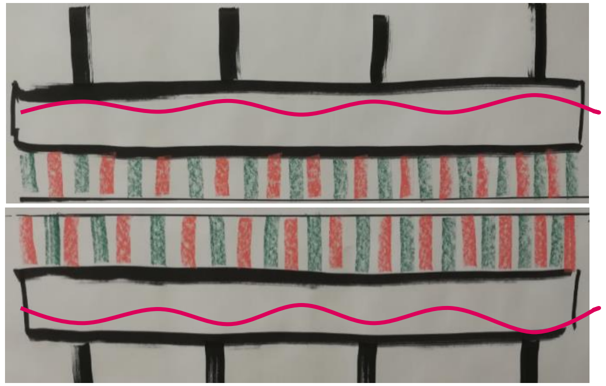


Column: Adjustment

Columns: arrangement

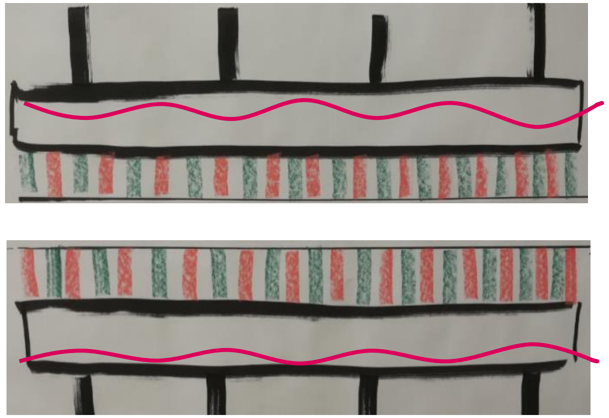


At nominal Gap: By the adjustment,
the magnetic field is perfectly aligned



Smaller Gap

Higher Force



Bigger Gap

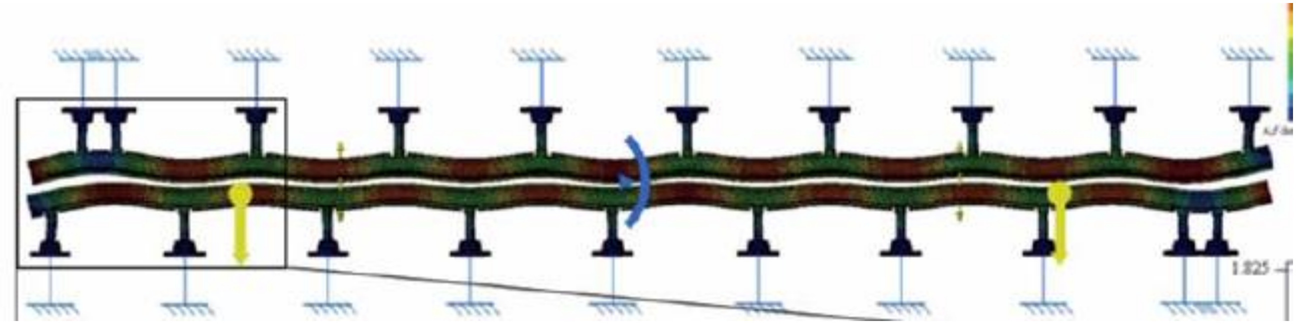
Lower Force

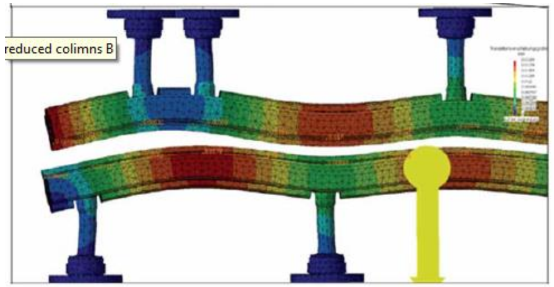
Reduction of number of columns

First approach: Two rows of 32 columns = 64 columns

First optimization: Only one row with 32 columns (increasing of the diameter)

2nd optimization: Reduction to 20 with a new arrangement → Gap remains constant. Beam is not precicely in the middle of the magnetic field, but this error is smaller → **Cost savings for hardware and assembling/adjustments**





Optimizing the end is a bit difficult

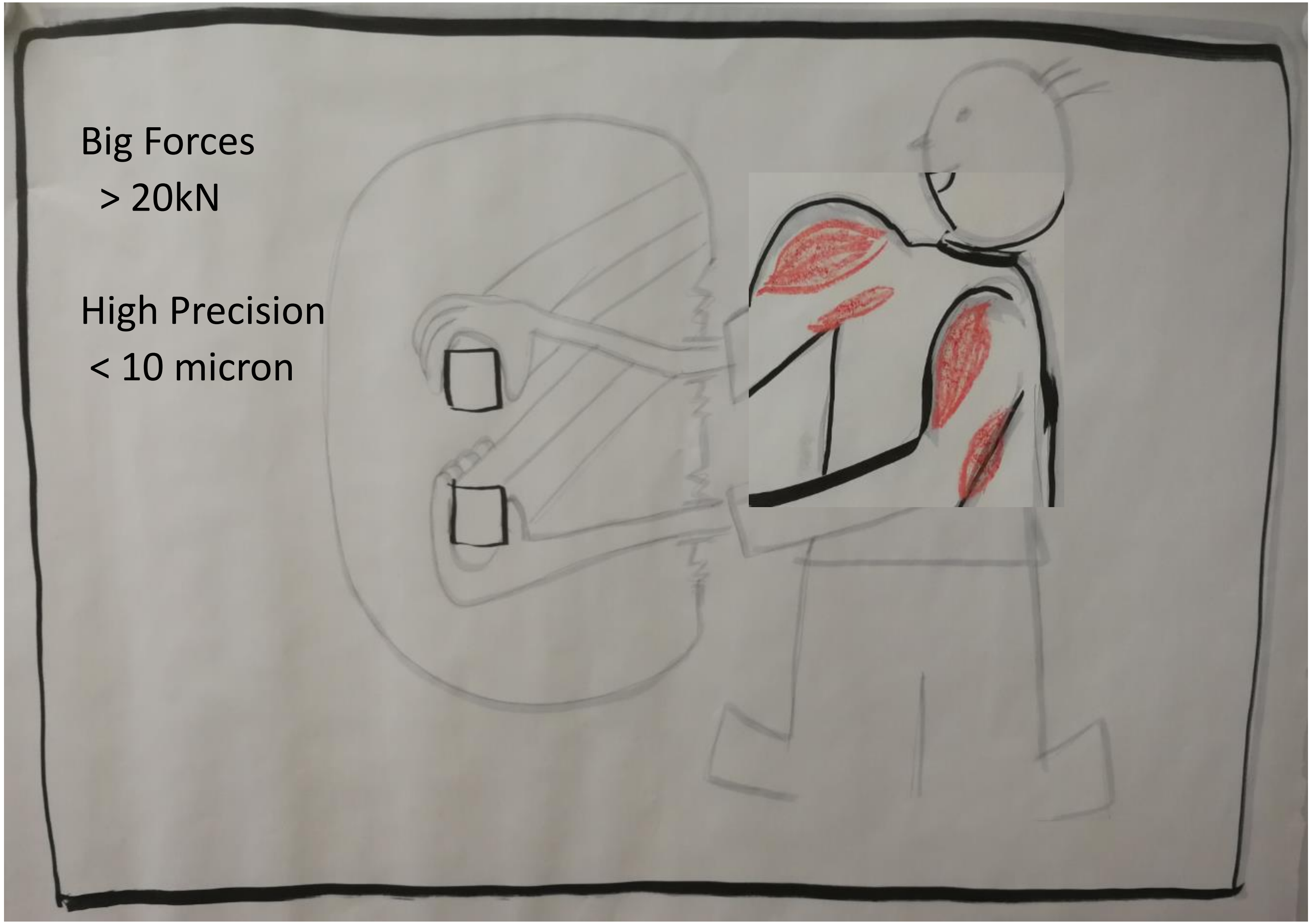
Drives

Big Forces

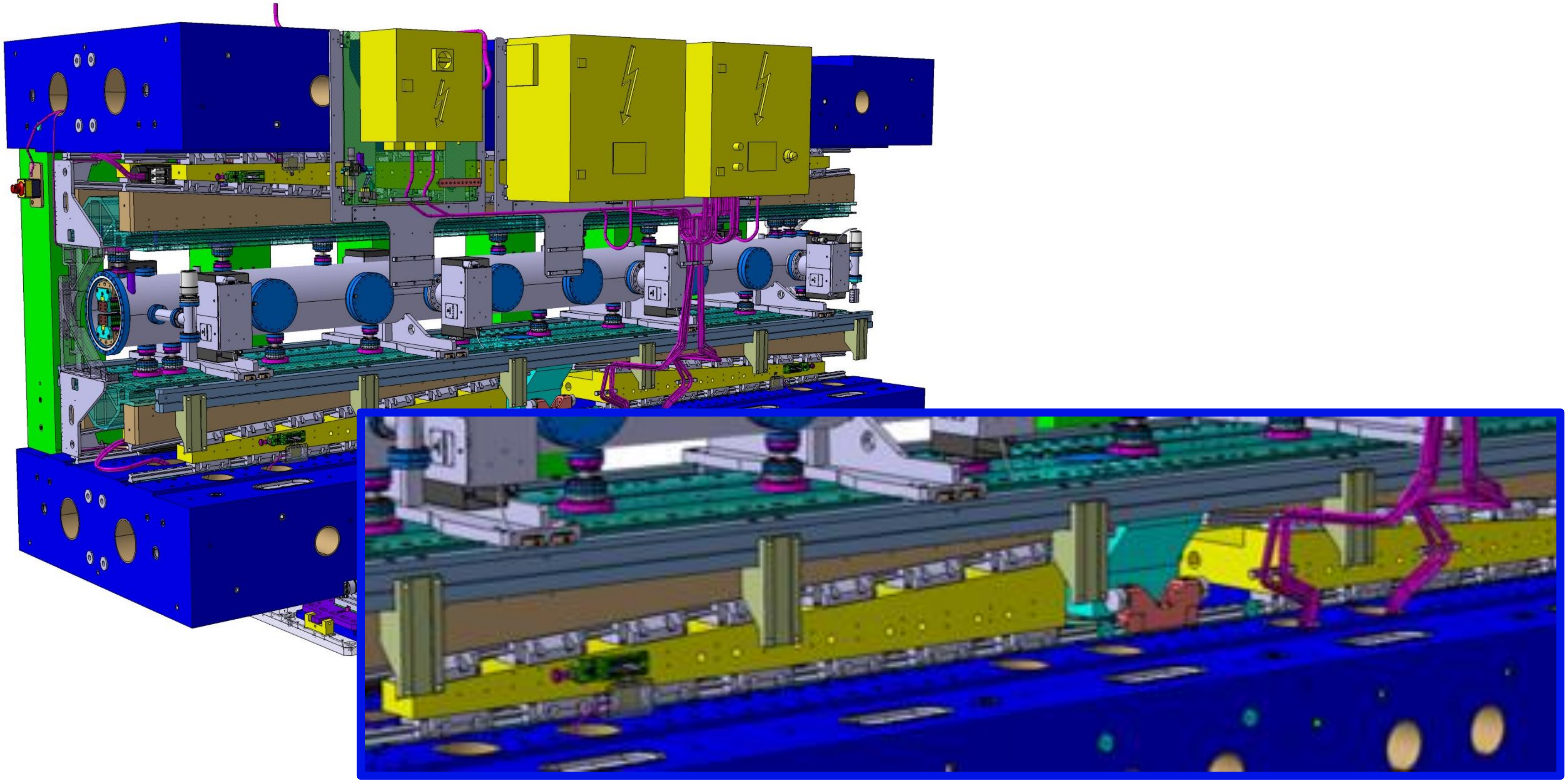
> 20kN

High Precision

< 10 micron



Drives for Gapadjustment

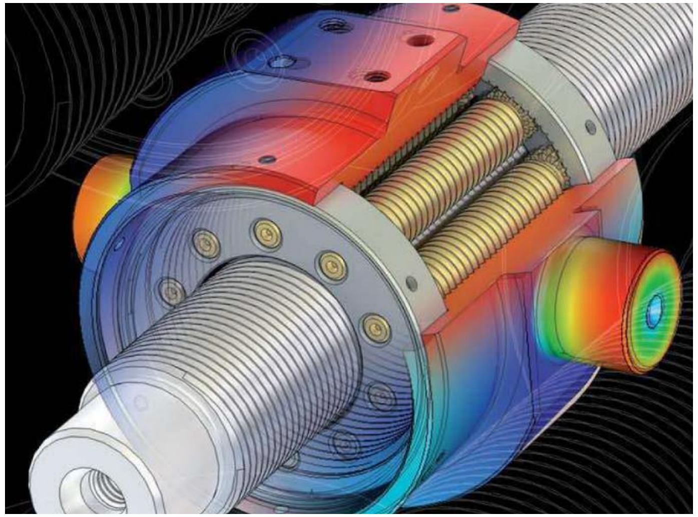


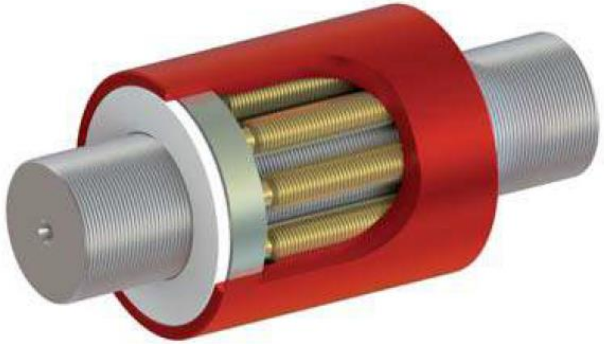
Drive with roller screws

Very small slope (0.5mm per turn)

Very little backlash

No gear required





SATELLITE ROLLER SCREWS

ROLLVIS®
SWISS

RVD screws

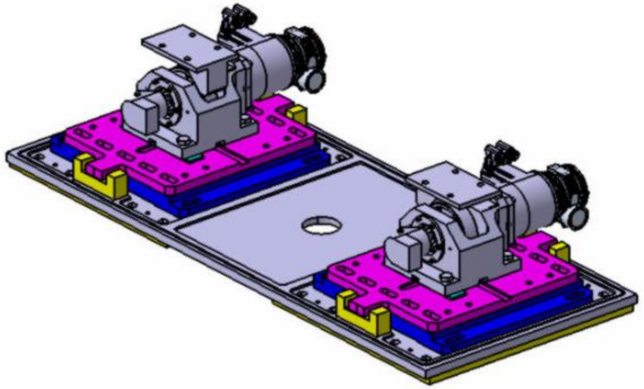
The RVD roller screw is ideally suited for high precision applications, when a high accuracy is needed. Its specific designed and adjusted components allow extremely thin leads down to 0.05 mm or even 0.02 mm. Available strokes are relatively smaller for this type of roller screw. RVD screw requires very specific tools and very high manufacturing accuracy to ensure an extreme a high quality standard.

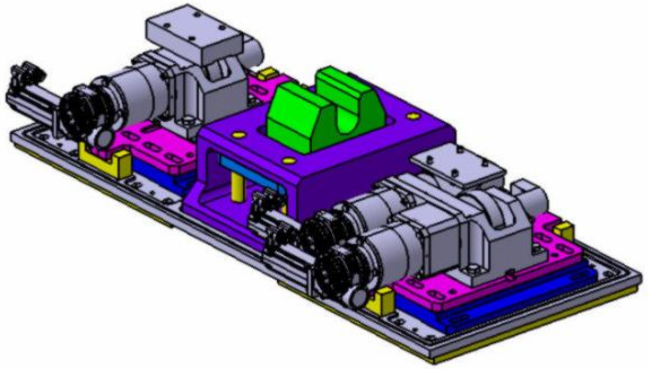
Mover : Principal

5 Motors

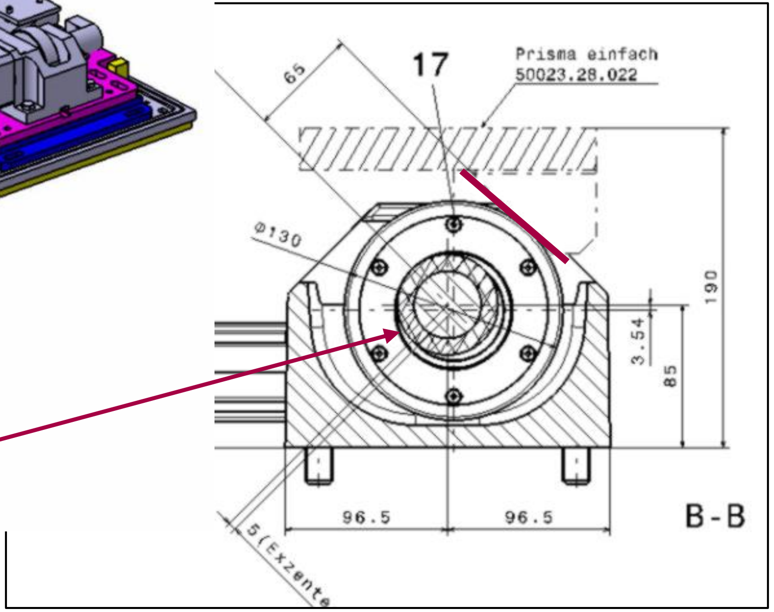
→ 5 Degrees of Freedom

Fixid in Beamdirection

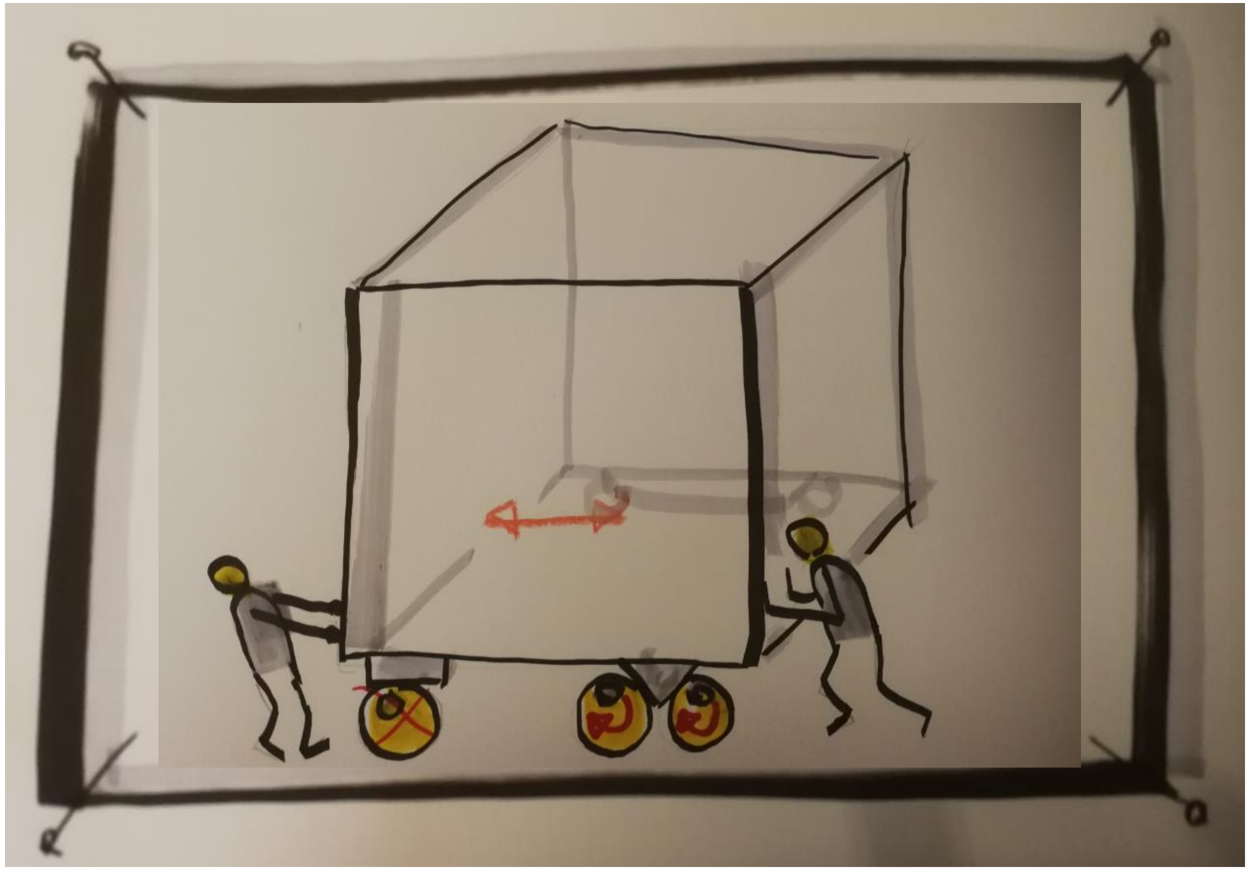


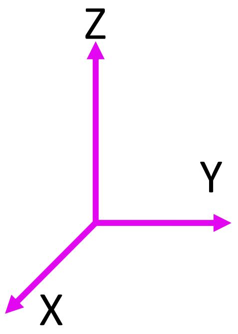


Excenter



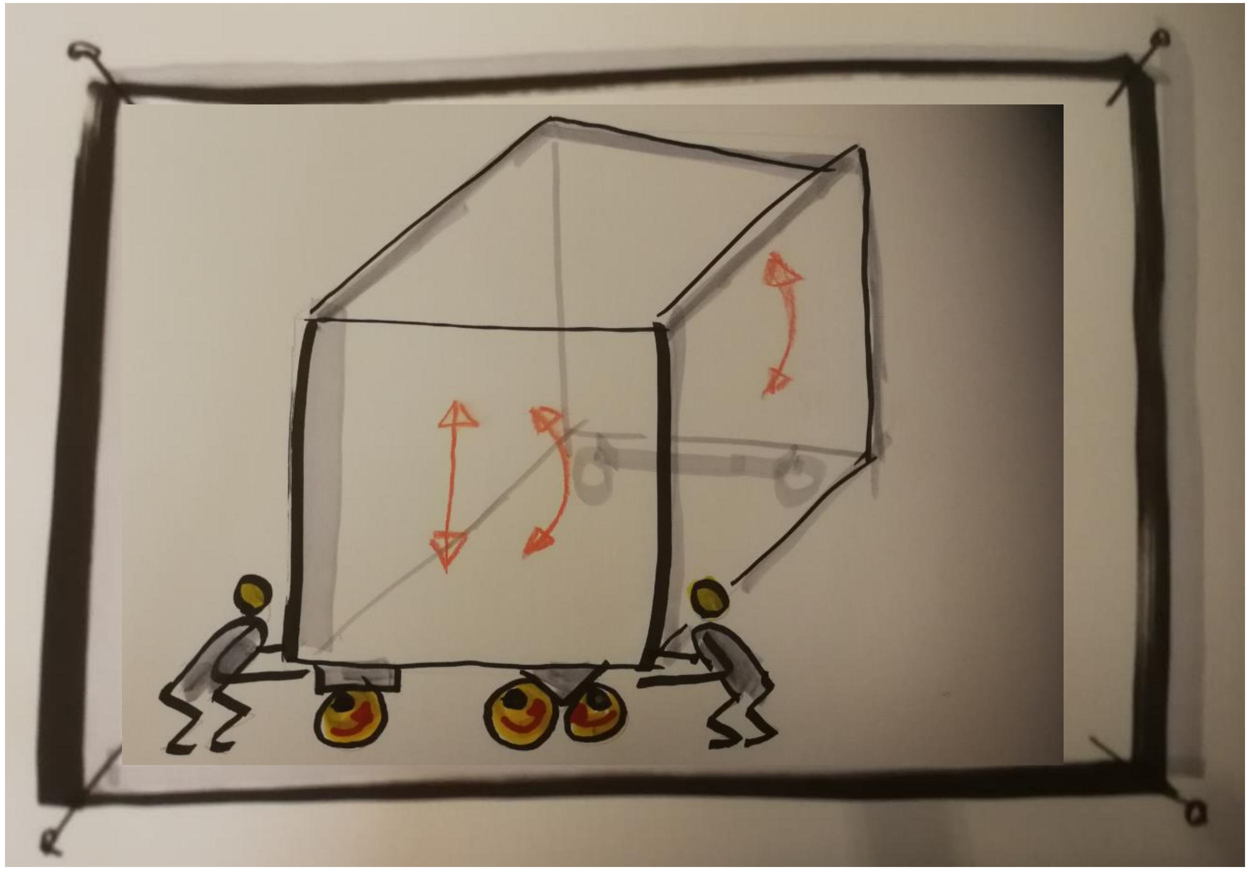
Mover: Principal

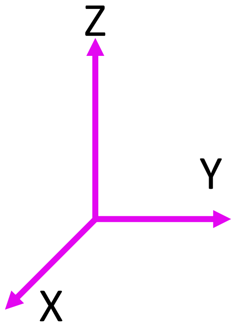




Left – Right of Frontside (also turning around Z-axis)

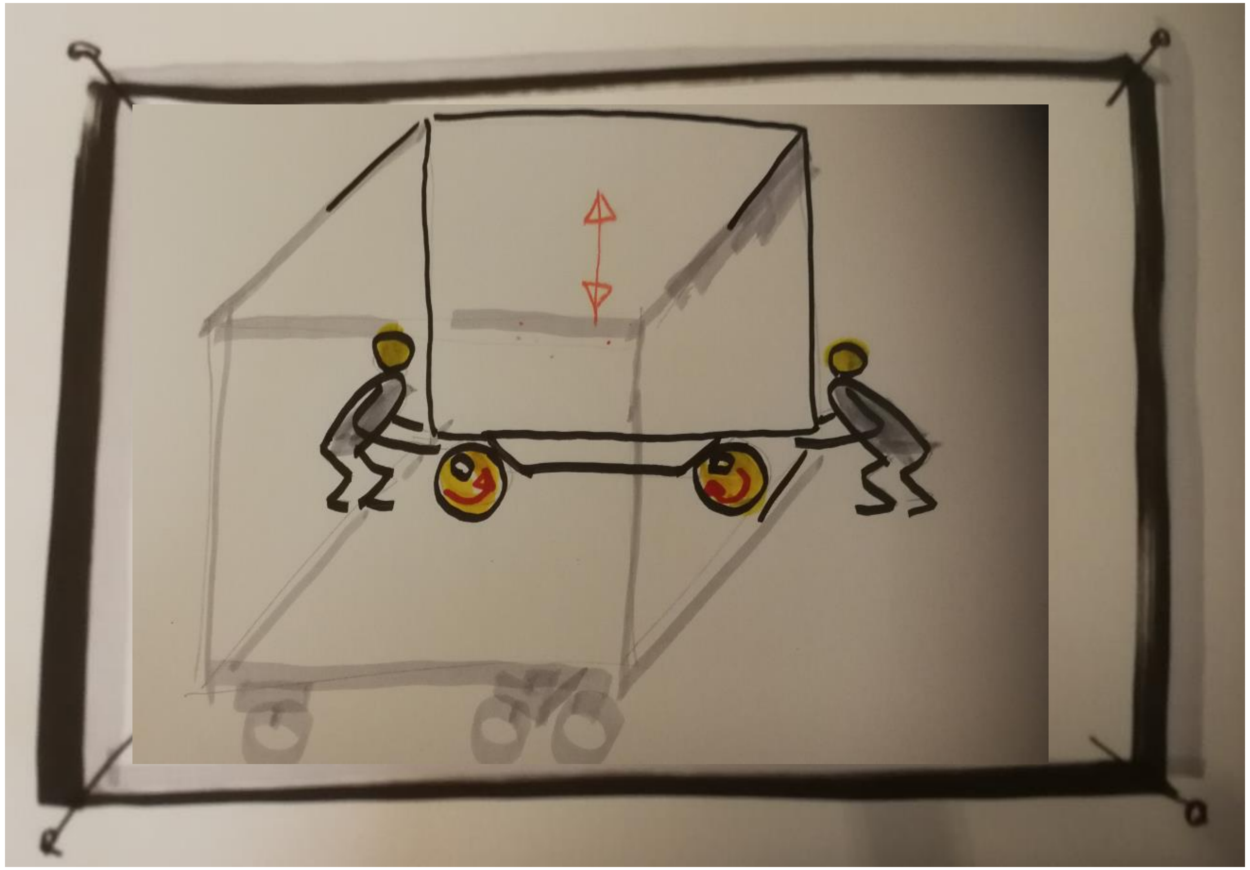
Mover: Principal

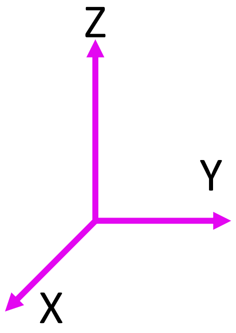




Up – Down of Frontside (also turning around Y-axis)

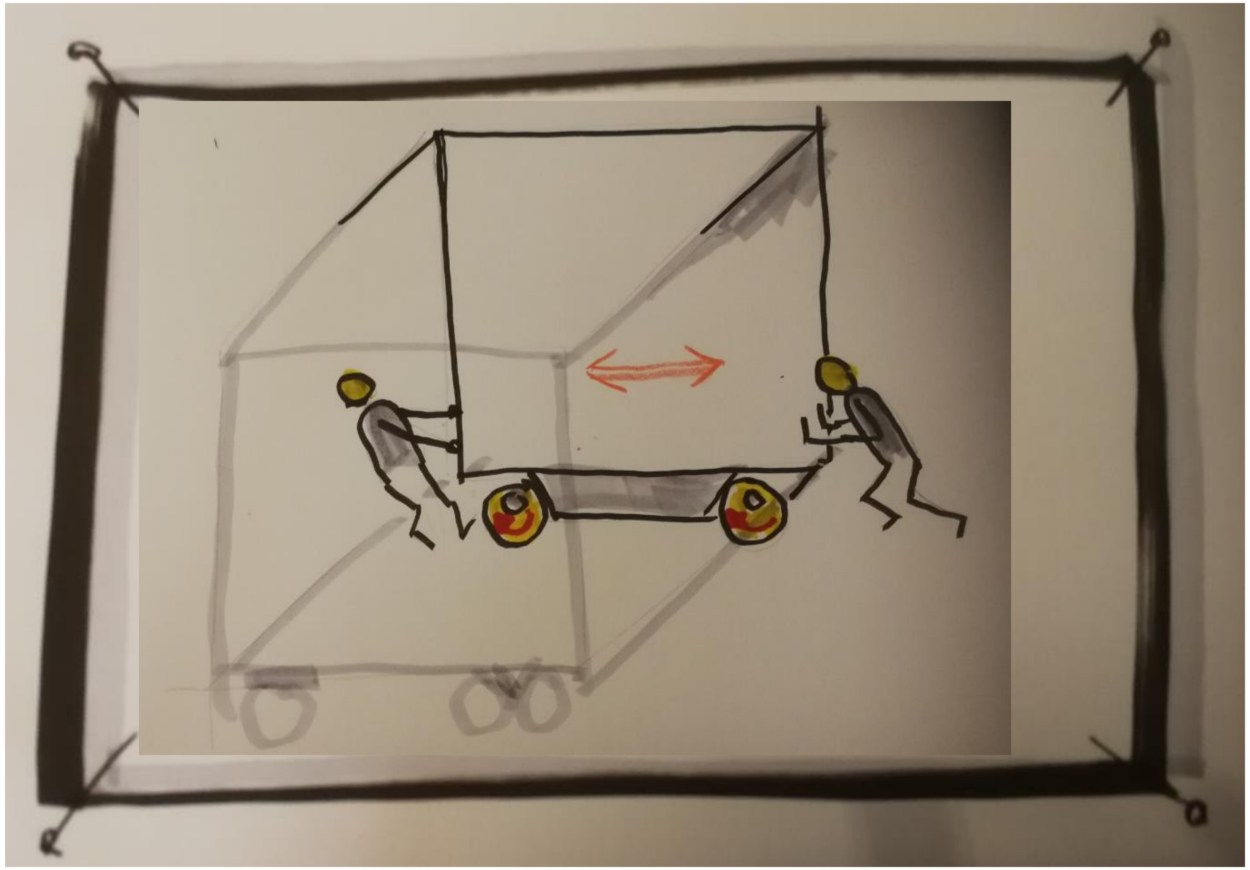
Mover: Principal

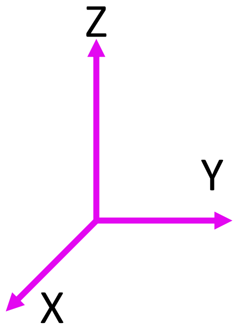




Up – Down of Backside (also turning around Y-axis)

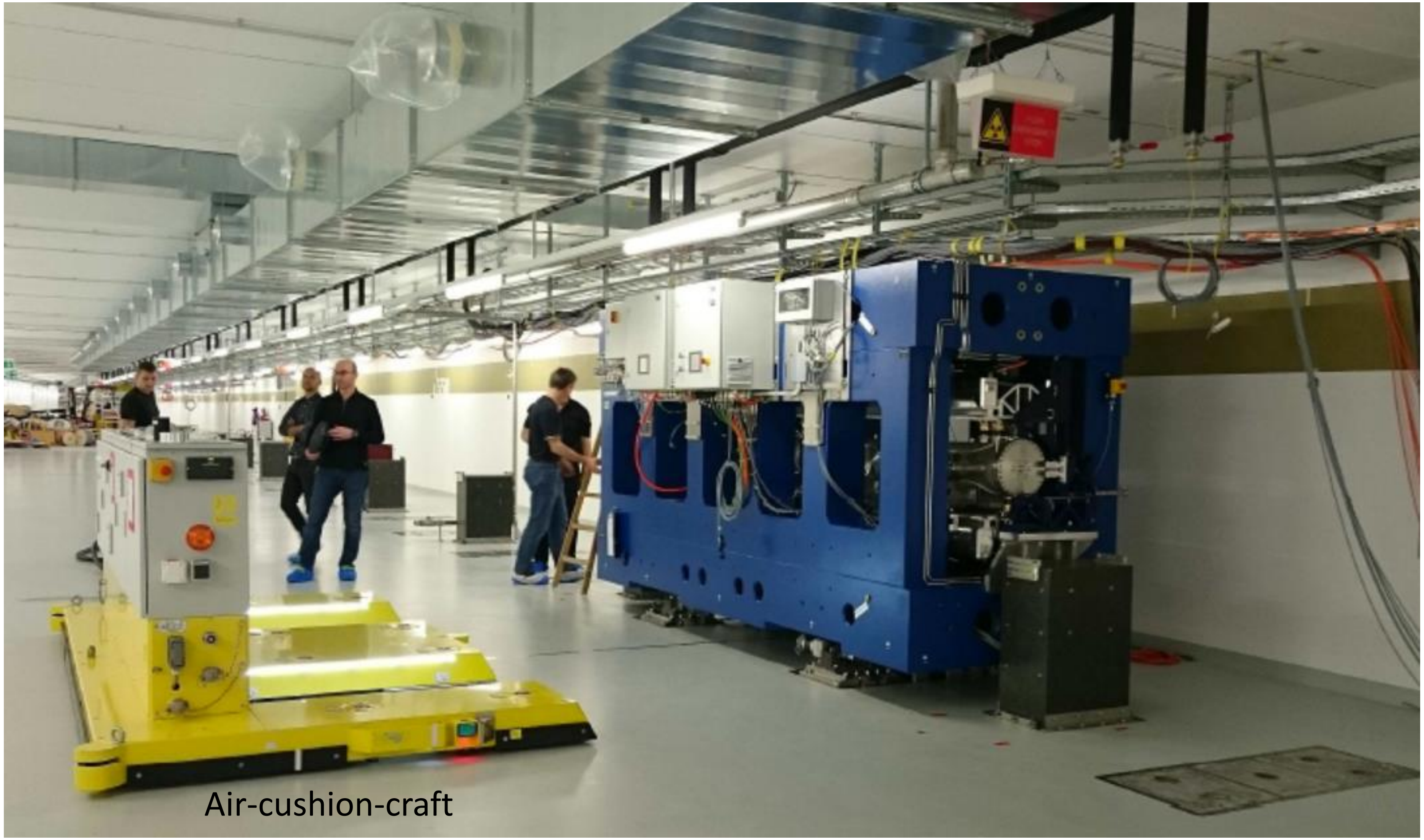
Mover: Principal





Left – Right of Backside (also turning around Z-axis)

Mover: Installation of First U15



Questions

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