Haimo Jöhri:: Head of mechanical Engineering :: Paul Scherrer Institut

Undulators

19.3.2021

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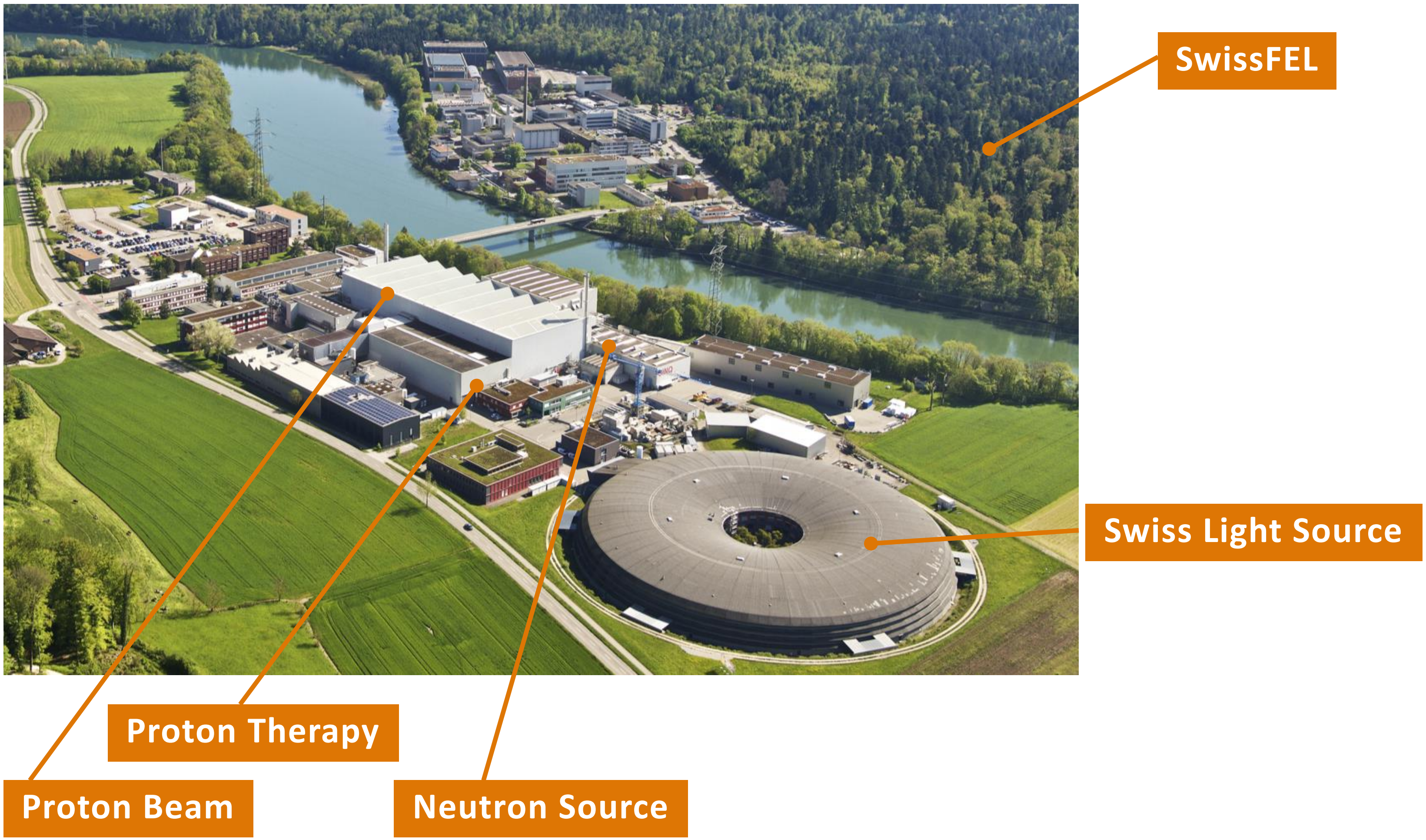
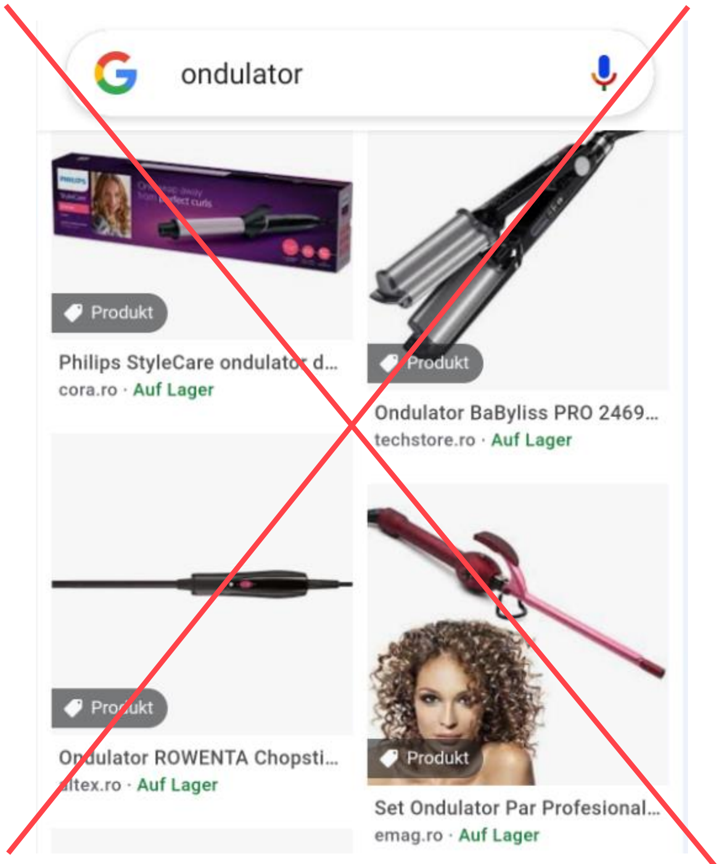

SwissFEL
Swiss Light Source
Proton Therapy
Proton Beam
Neutron Source

Ondulator ?



Undulator for Light Sources

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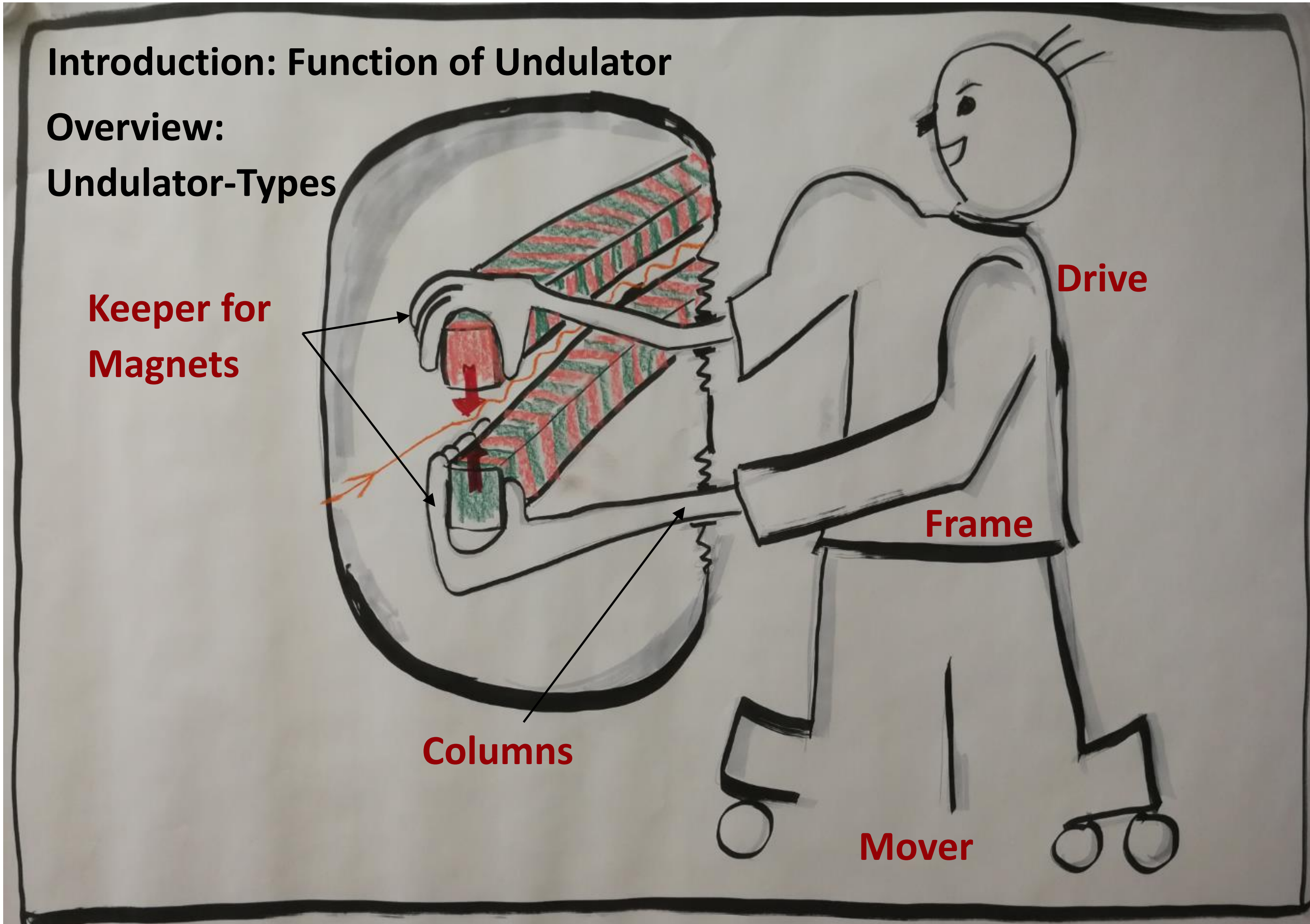
Outline

Introduction: Function of Undulator

Overview:

Undulator-Types



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Introduction: Function of Undulator

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

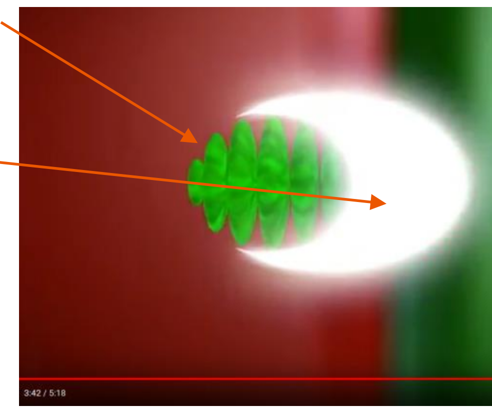
SwissFEL – the new large-scale facility at the Paul Scherrer Institute

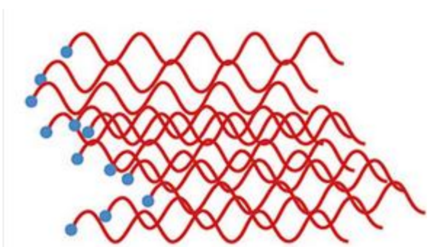
Magnets

Electron Bunch

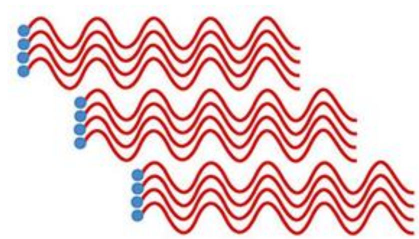
Light

Lasing at Free Electron Laser





Intensity increasis by a factor of 10^8



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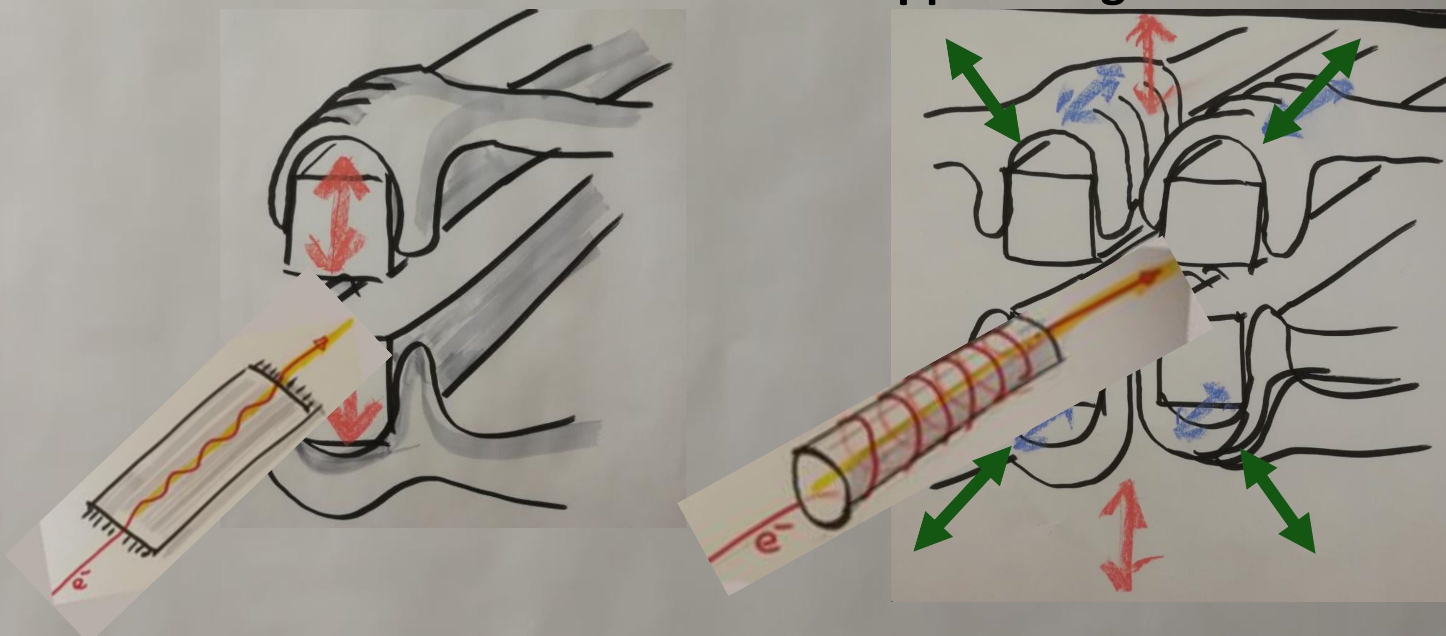
Undulator Types

Planar | **Apple Design**

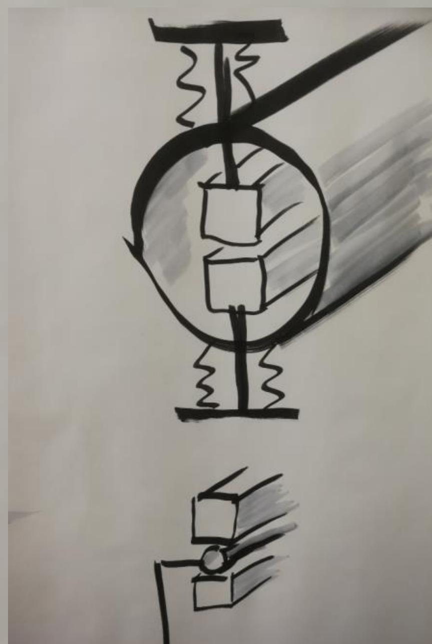


- **Variable Gap: Exp. U15**
- **Fix Gap**

- **Standard Design**
- **Apple X: Exp. UE38**

Undulator Types

In Vacuum

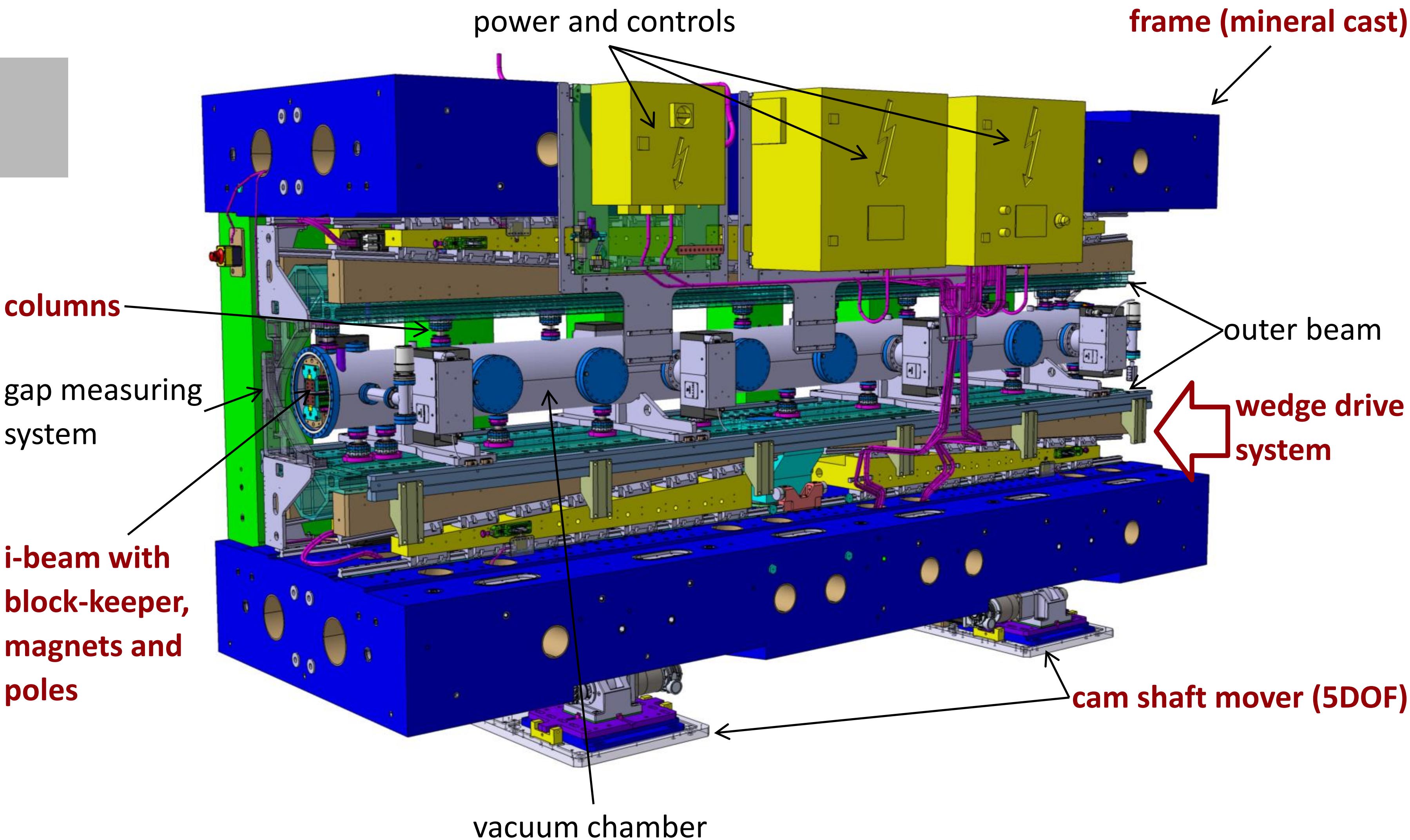


Out of Vacuum

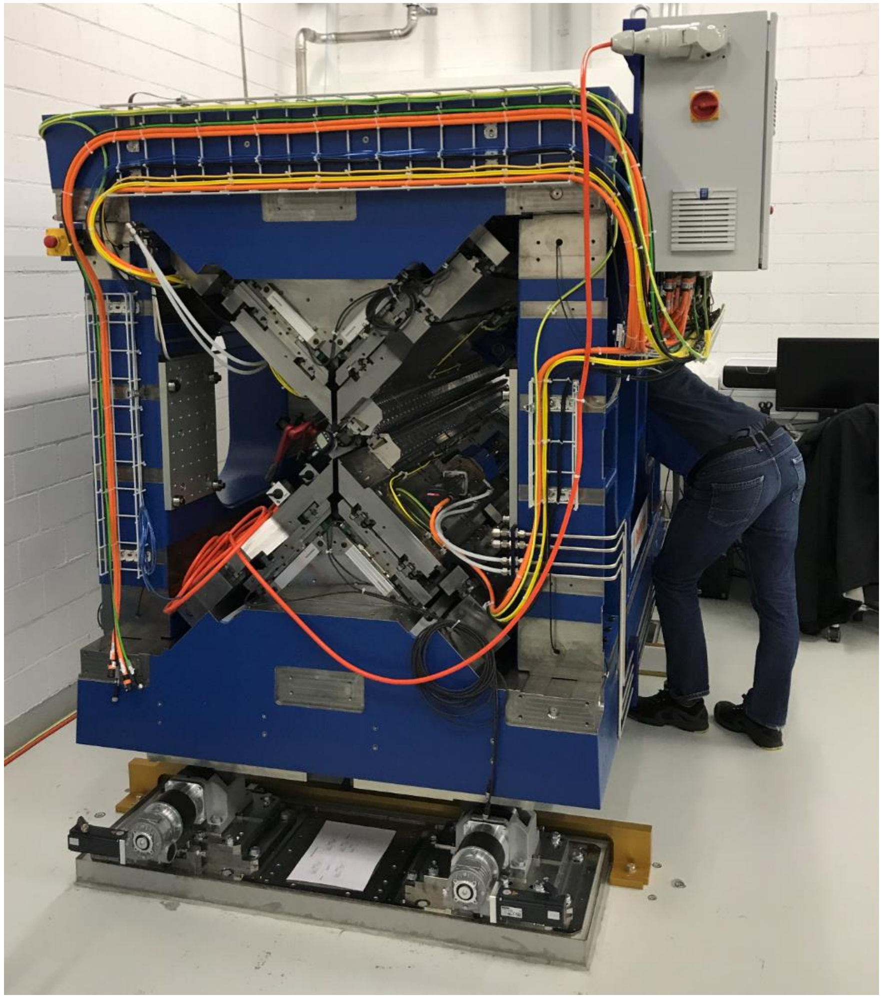
Other Types (not in this presentation):

- El. Magnets
- Kryo cooled magnets

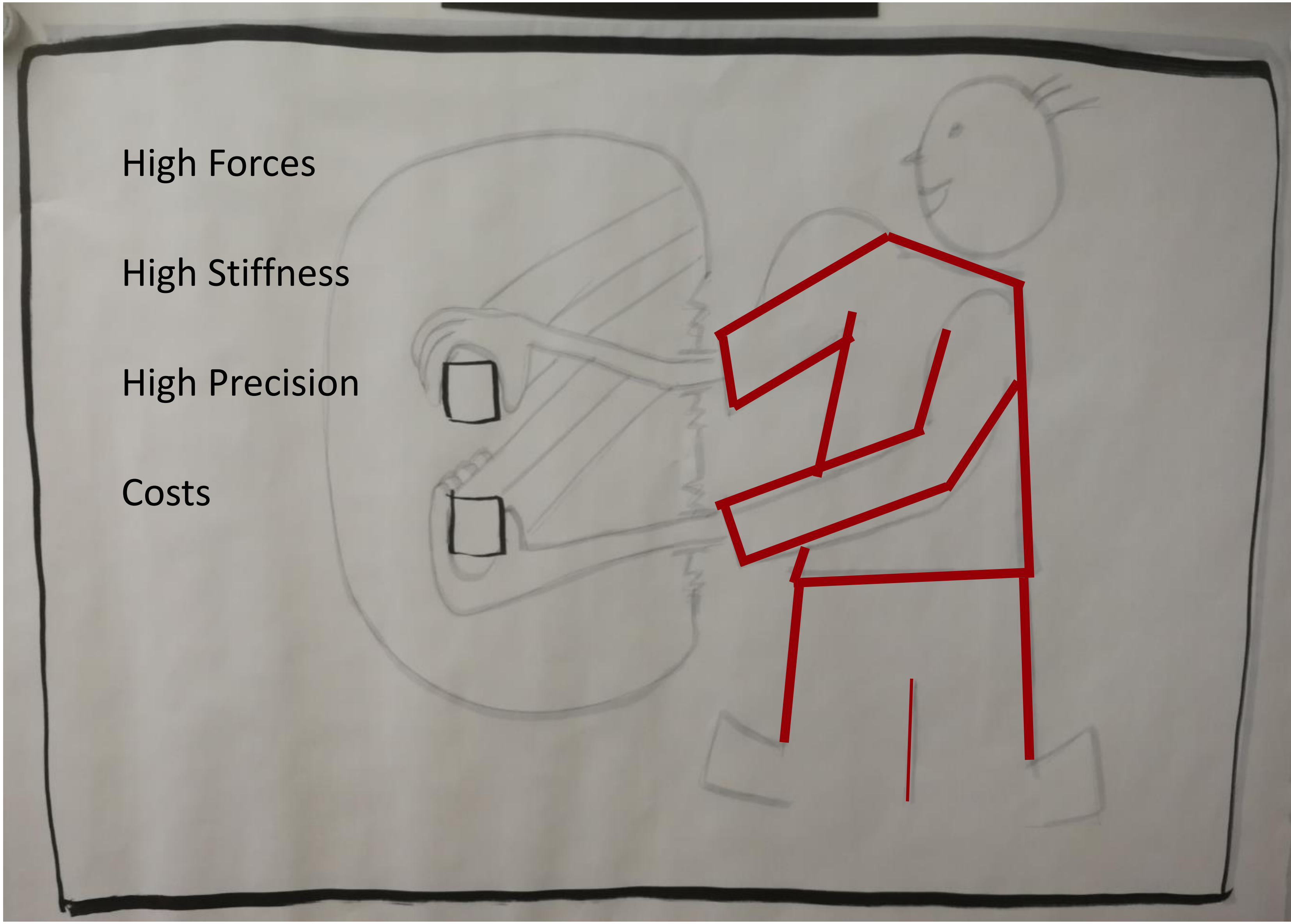
Aramis Undulator U15 – main parts



Athos Undulatur UE38 Apple X



FRAME



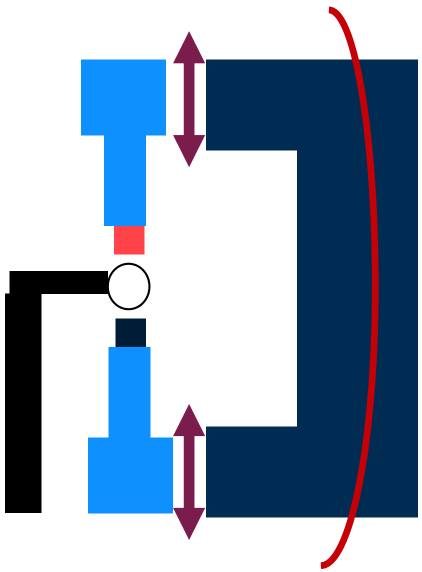
High Forces

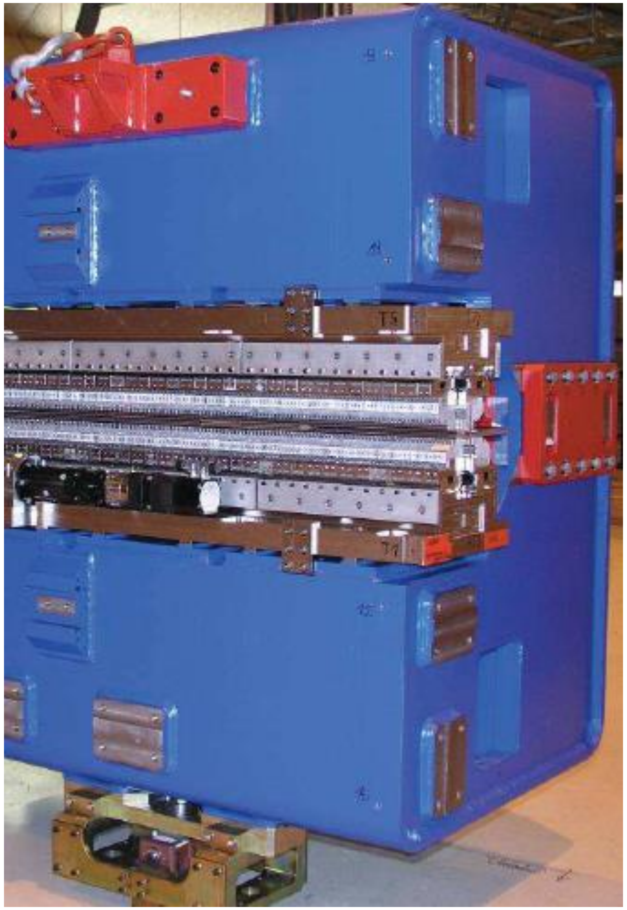
High Stiffness

High Precision

Costs

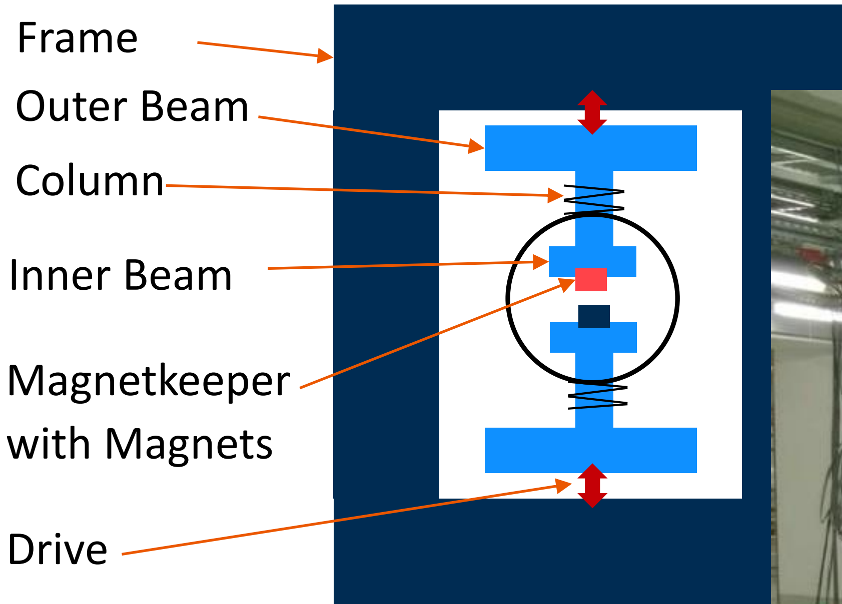
Frame: Standard Design – C-Shape





Example: UE44 at PSI

Frame: New Design -> Closed Frame



Frame: Material

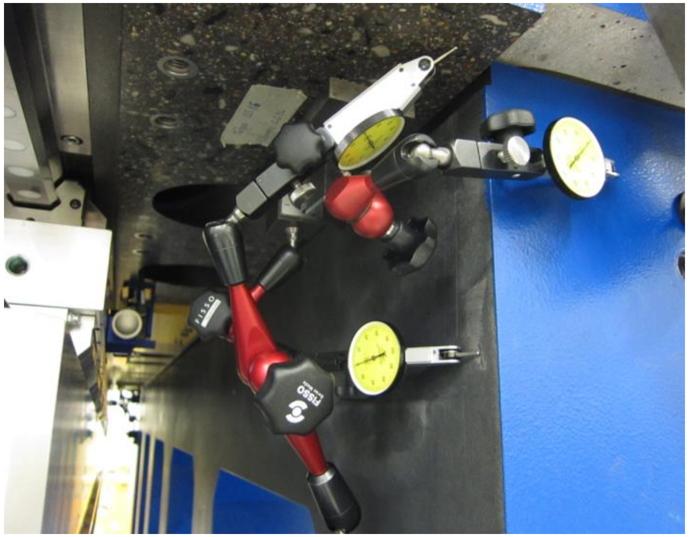
For the U15 wie choosed Mineral Cast because:

- 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
  – $15 * 10^{-6}/K$

Bonding of the upper plate



Adjustment before bondig

Fixation during the bonding

Filling of glue with peristalticpump and tubes

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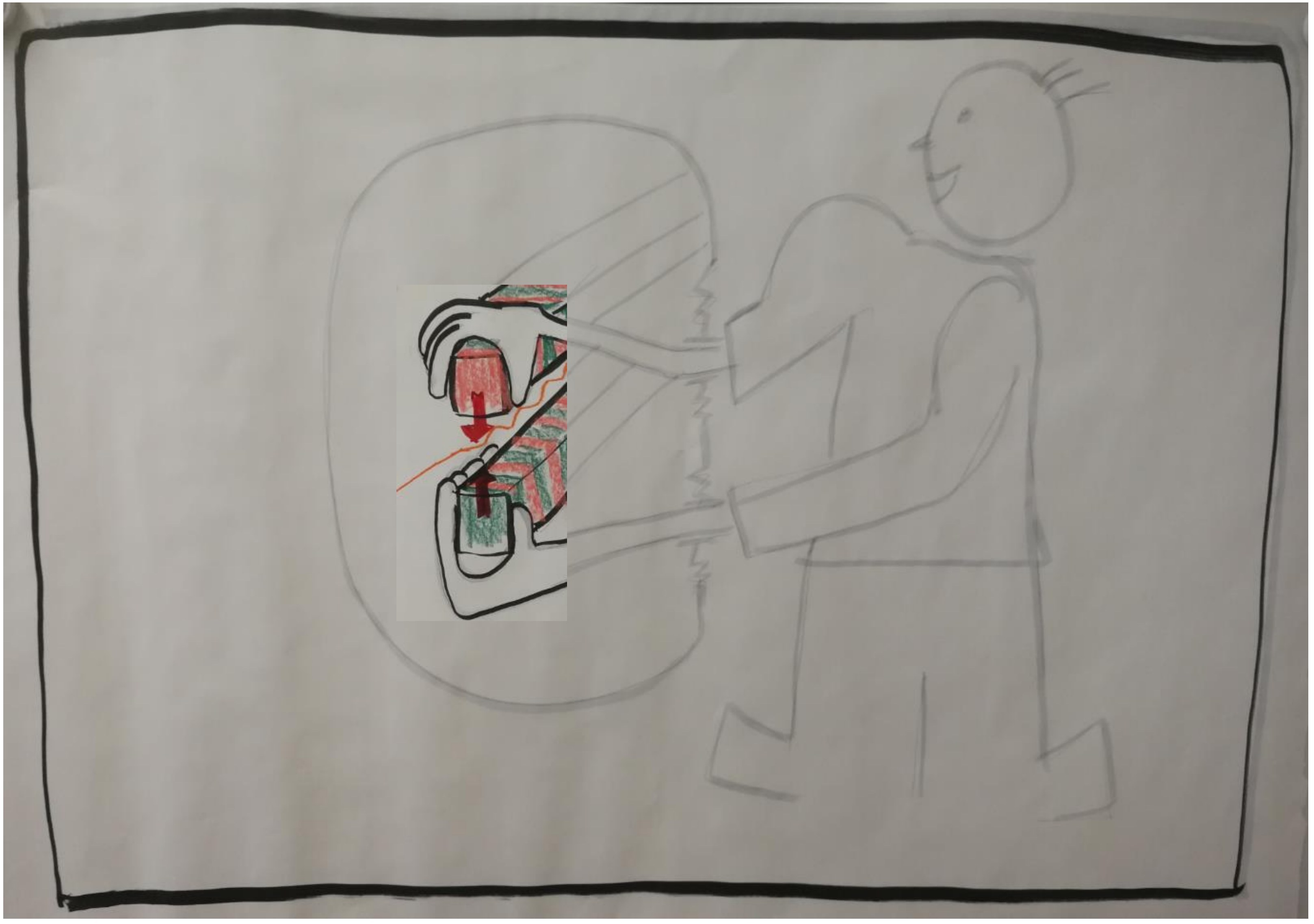
Keeper for Magnets



Keeper for Magnets

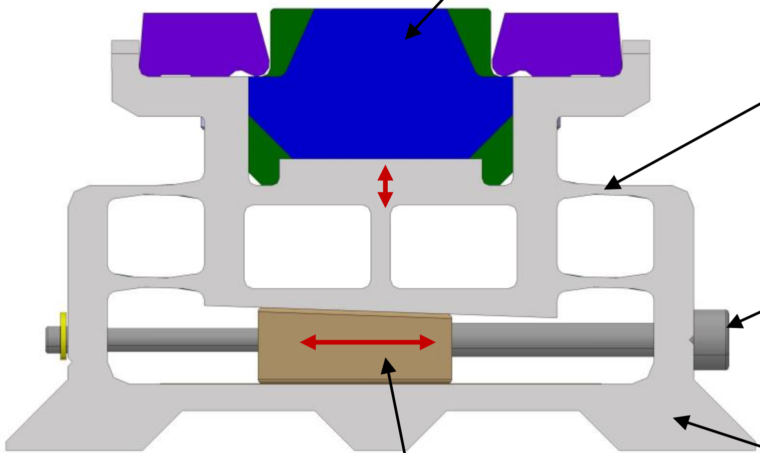
For the U15 (4m length), there are more then 500 pairs of magnets, that has to be adjusted

- Mechanical tolerances
- Magnetical tolerances
- Objective of precision : 10 Micron

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

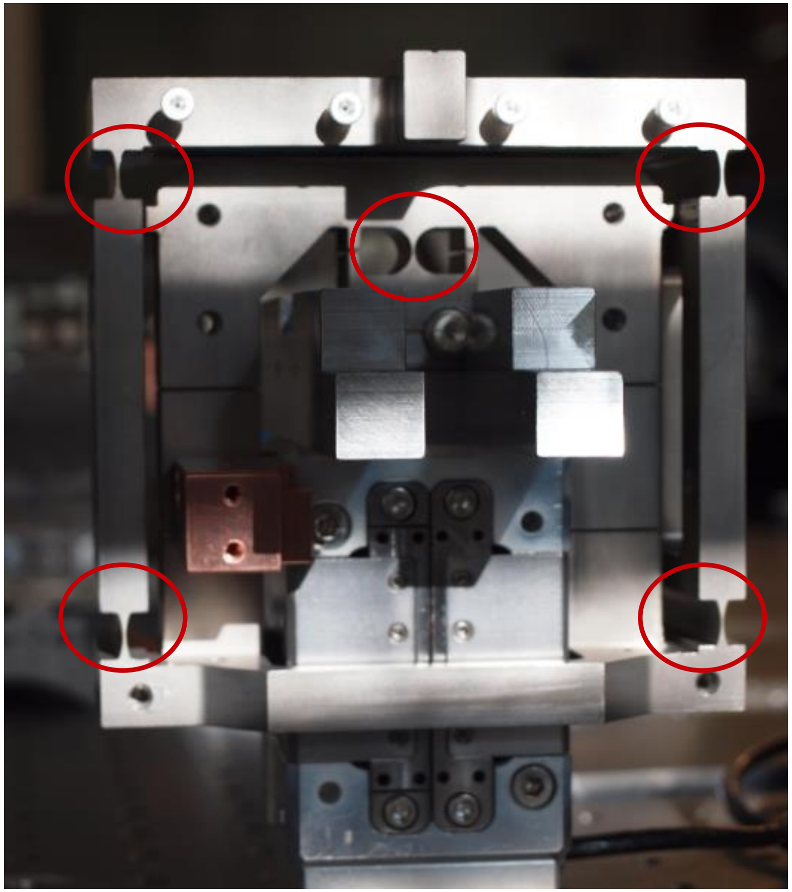
→ That optimization can last several weeks

New idea: Flexor, wedge, screw



Other Examples of flexors

High precision in endstations

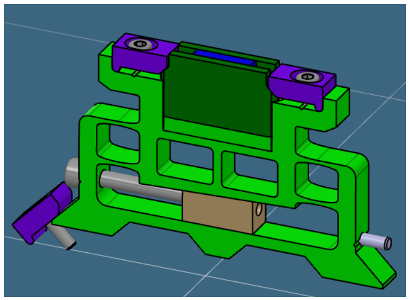


Girder Prototype for SLS 2.0

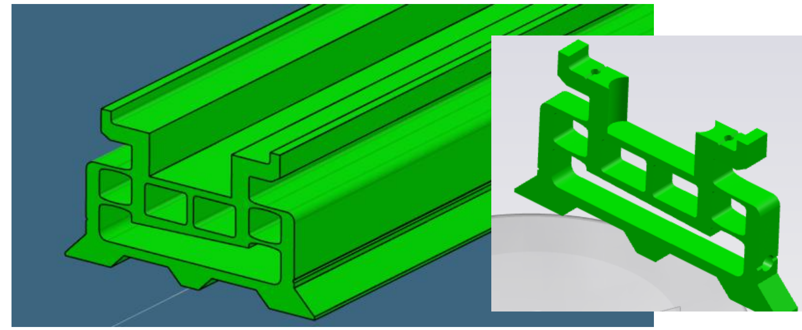
Flexors for roll (Steel)

Flexors for Height

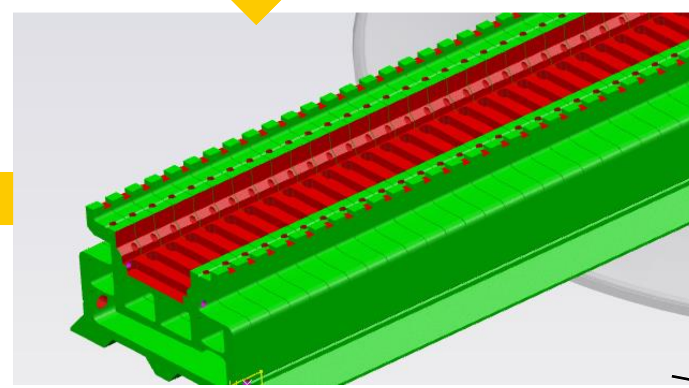
Development in a Team

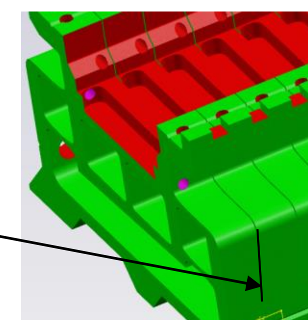


1st idea : Wire roded part for the Keeper

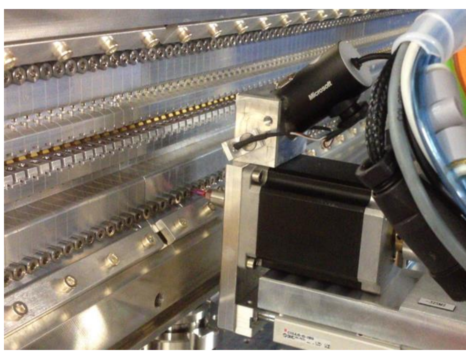


2nd idea : extrude as a profile and cut in pieces





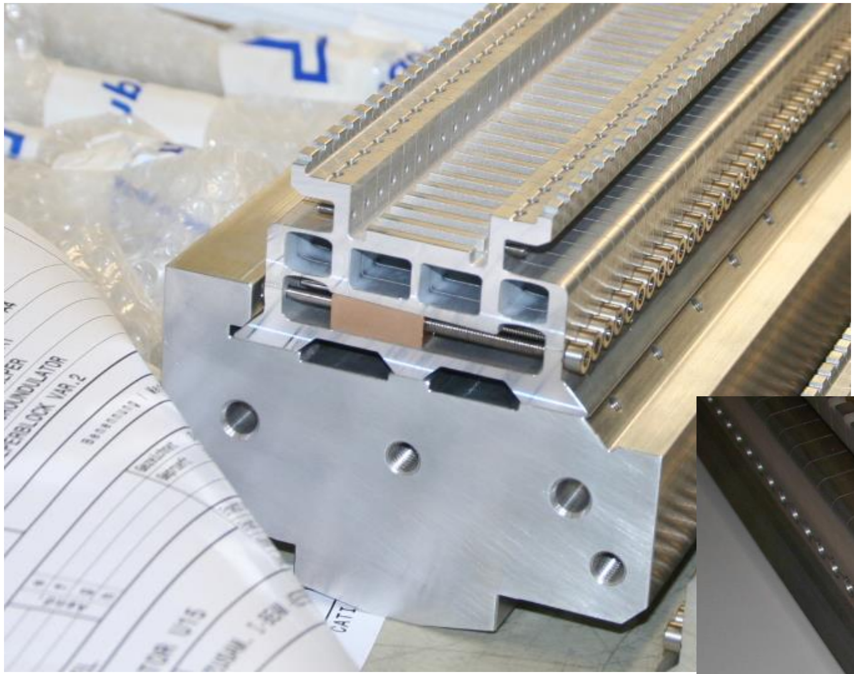
3rd idea: keep the profil and cut only slits for individual adjustments

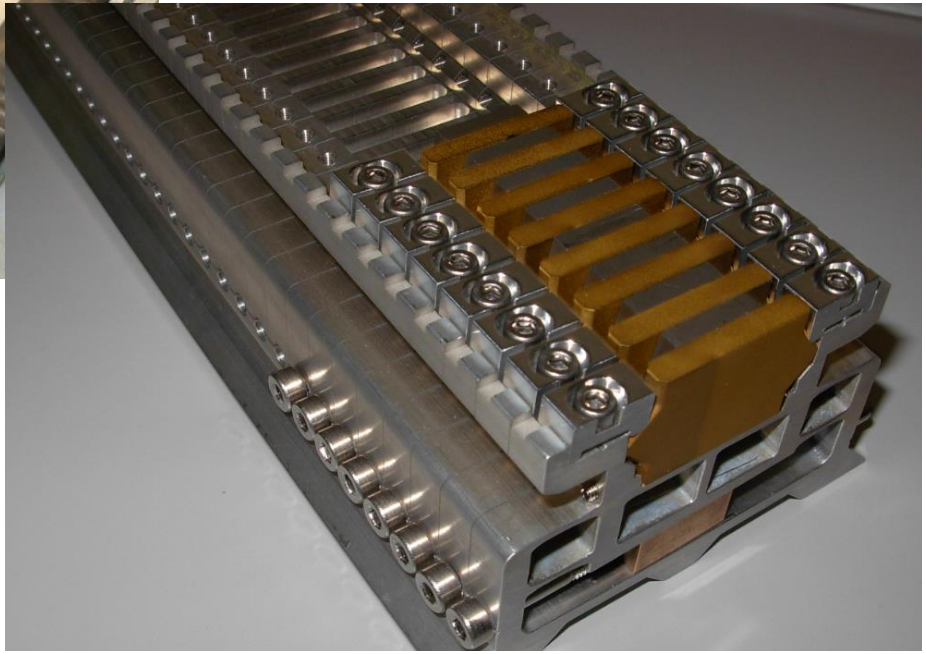


Adjustment by robot-system

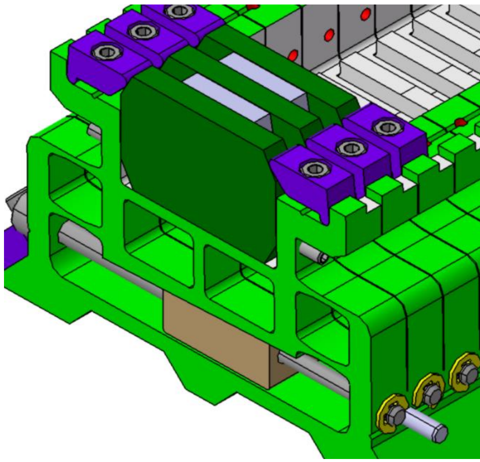
→ Video

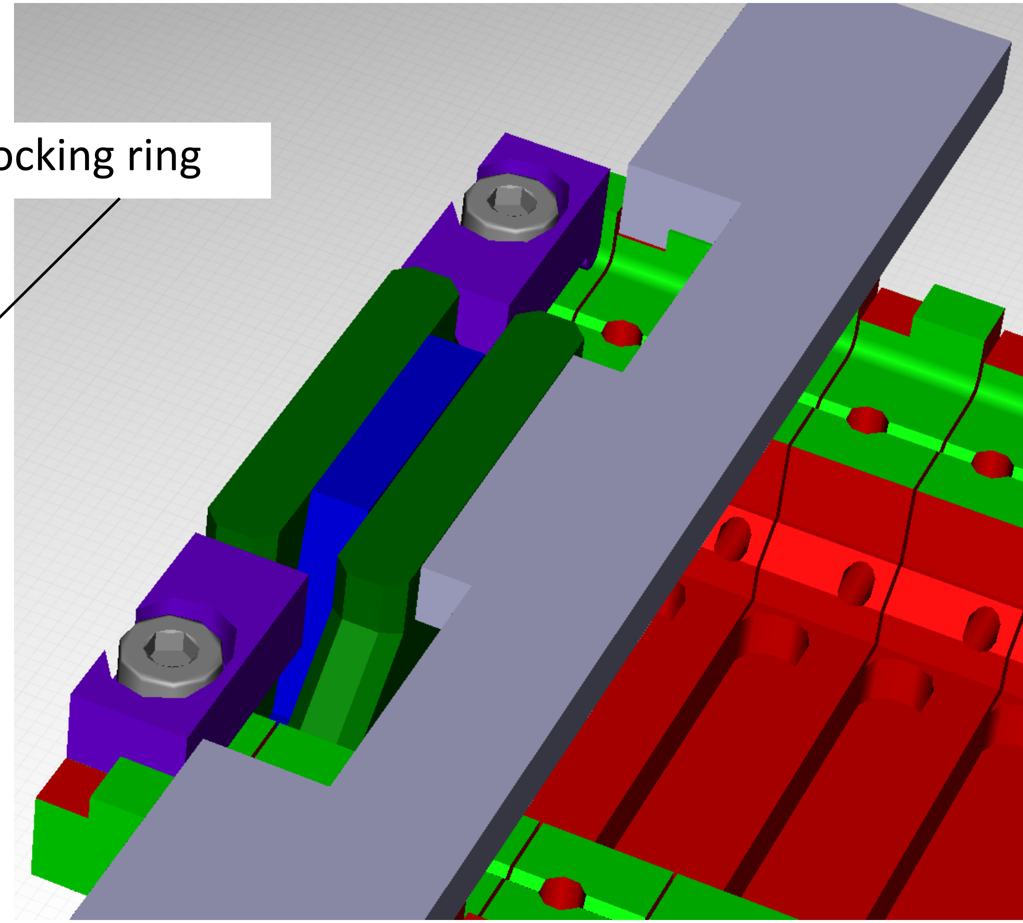
Blockkeeper: Photos

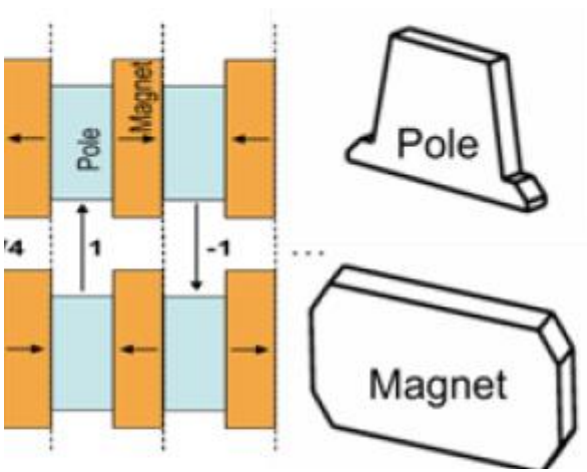




3 Important Details

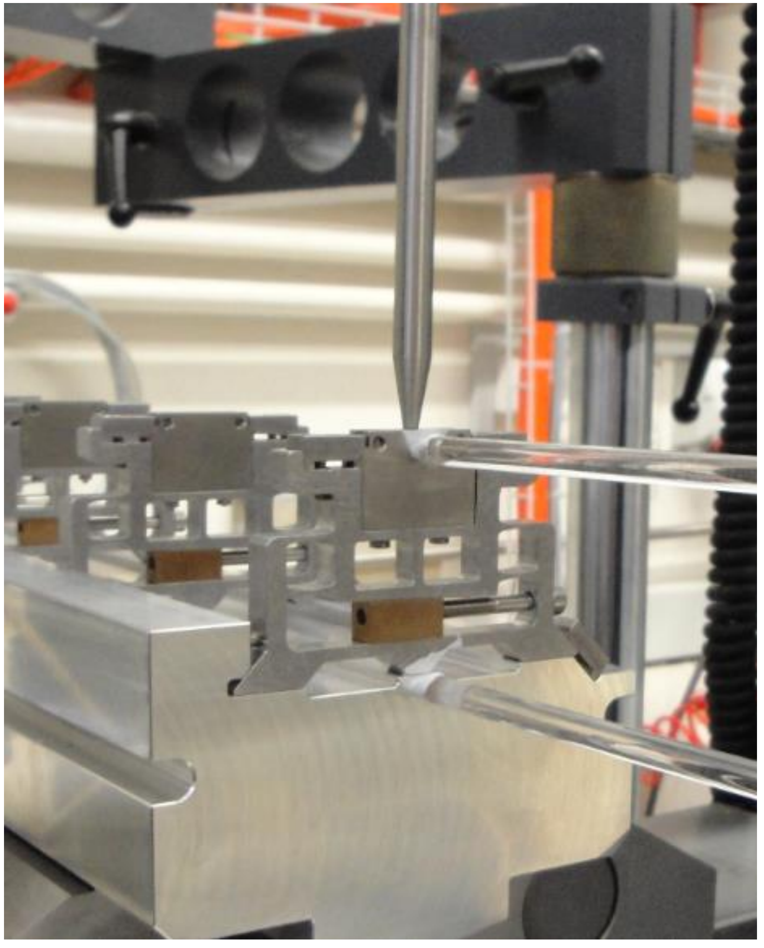




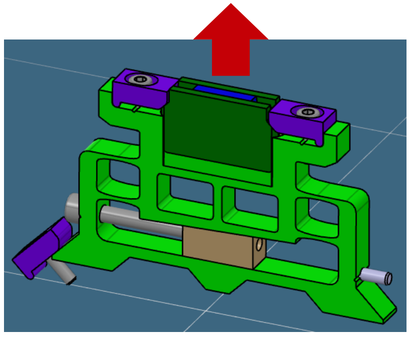


Assembling jig: Magnetic force wants to push the magnet out of position during assembling

Preloaded Flexor



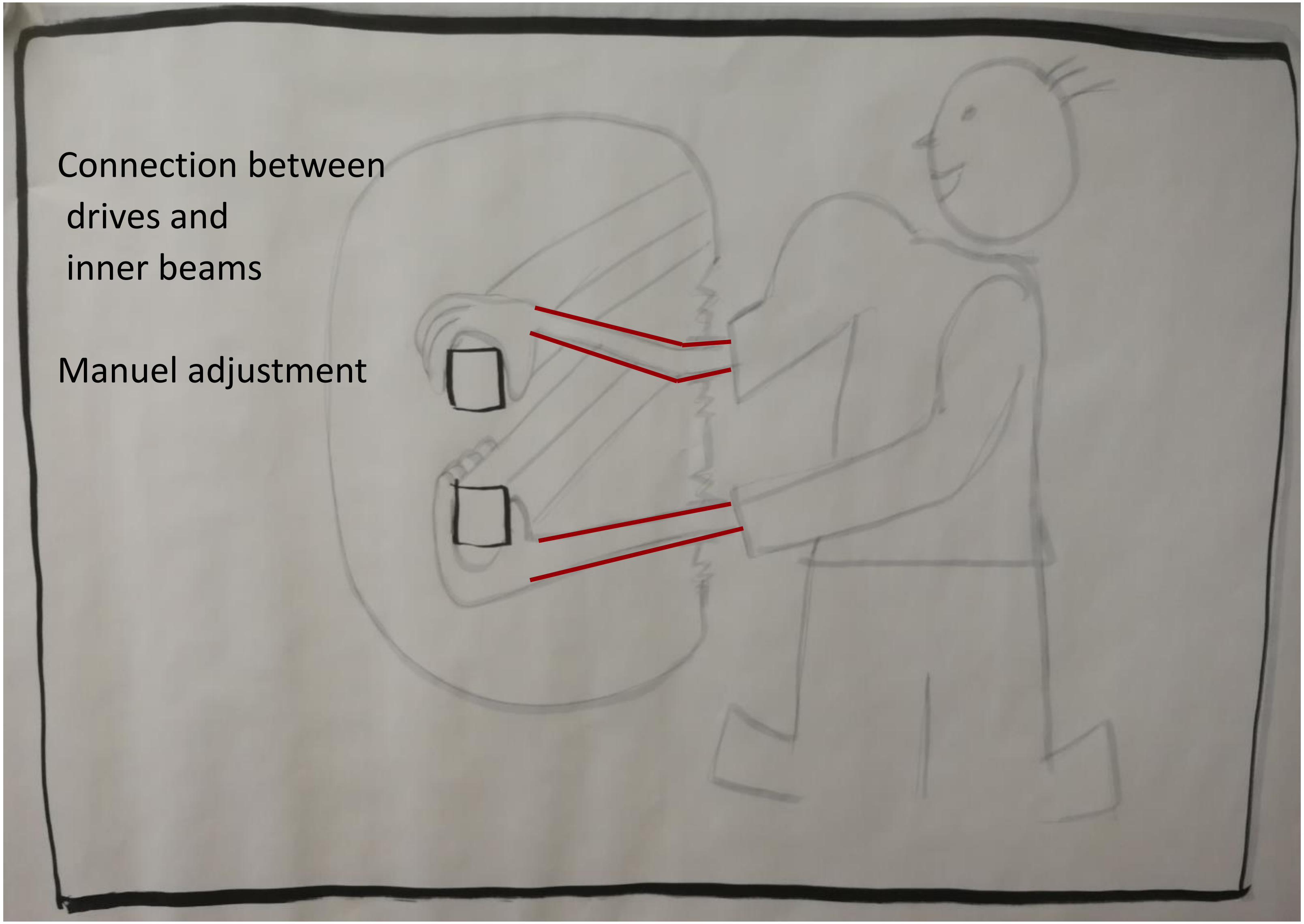
Magnetic force wants to lift the stucture up



Loose the contact:
→ Limited area of adjustment +/- 0.05mm

Testing and simulations in advance

Columns



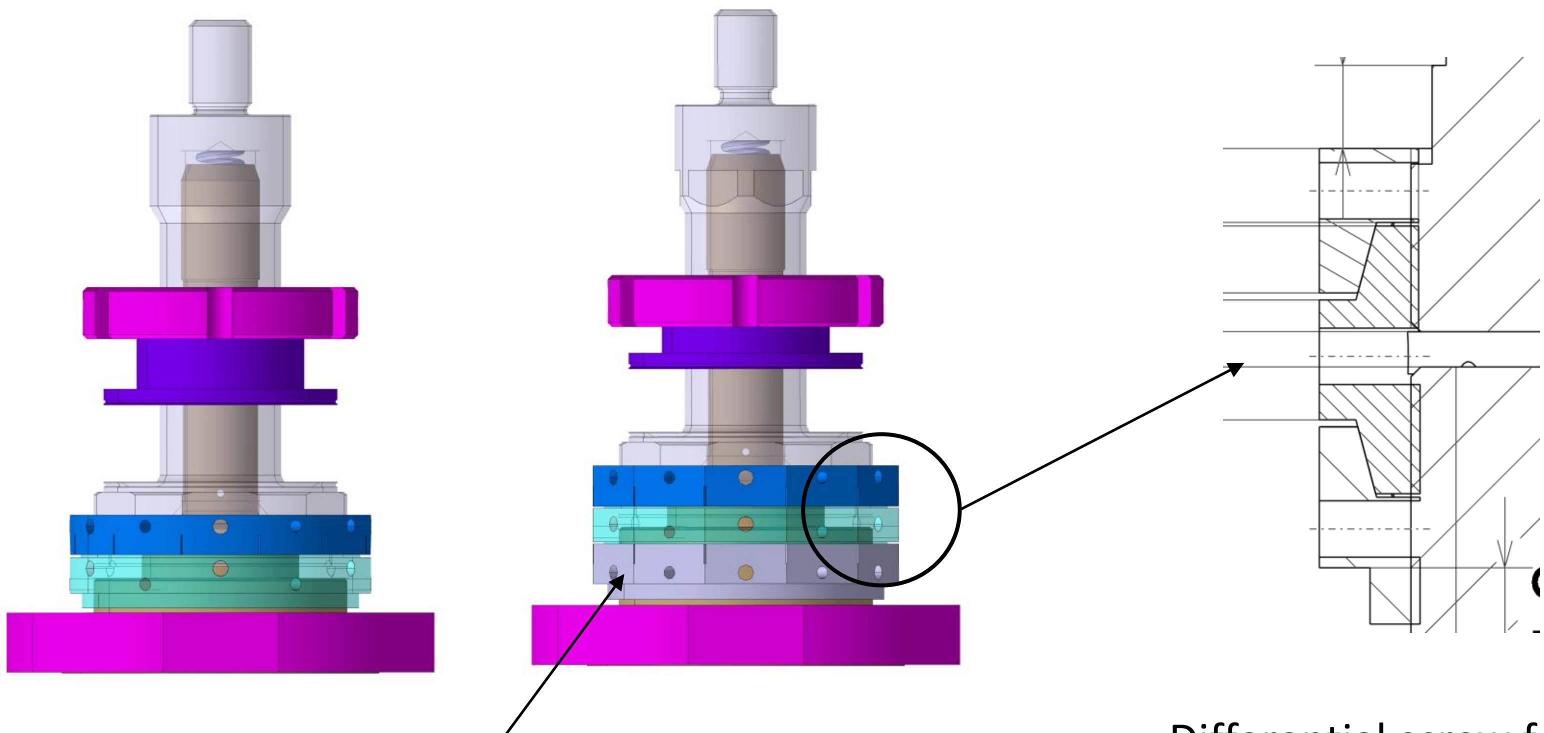
Connection between
drives and
inner beams

Manuel adjustment

Columns: Design

Prototype

Series

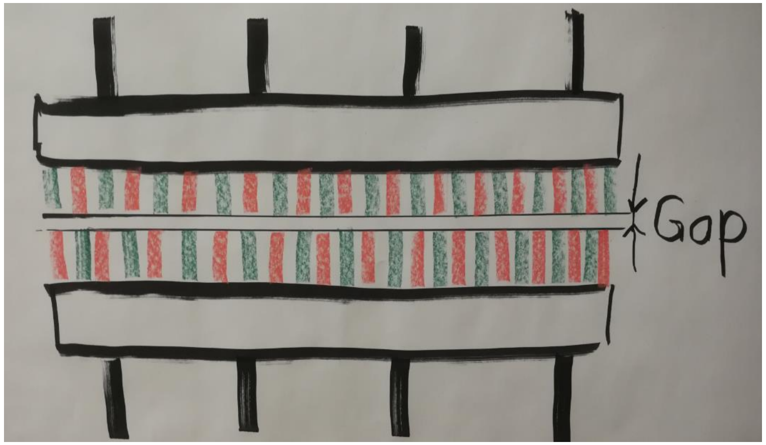


Additional screw nut to eliminate the clearance (backlash)

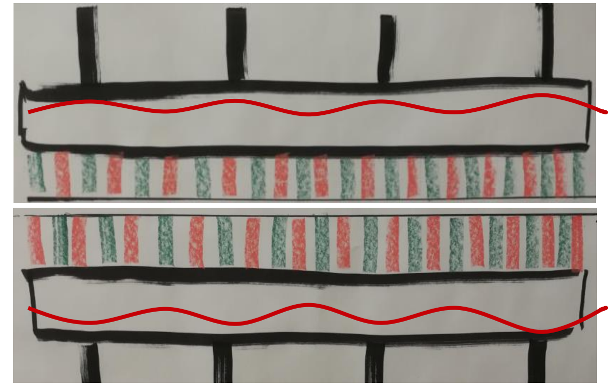
Differential screw for fine adjustment

Column: Adjustment

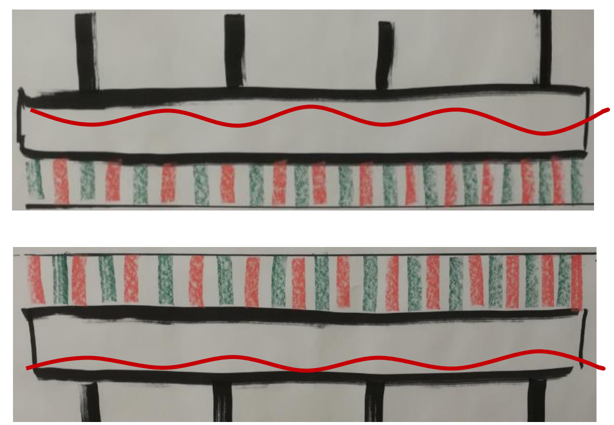
Columns: arrangement



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



Smaller Gap



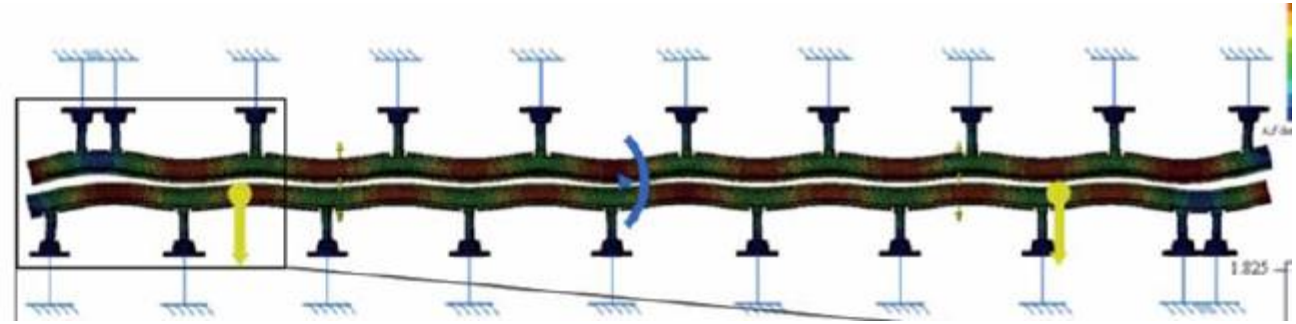
Bigger Gap

Reduction of number of columns

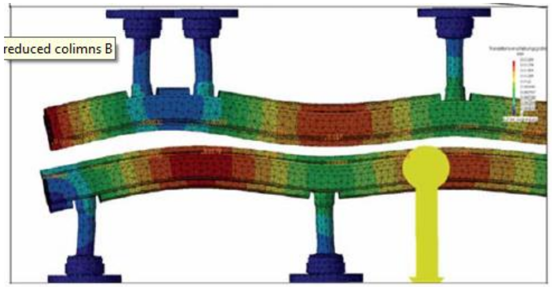
First approach: Two rows of 32 columns = 64 columns

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

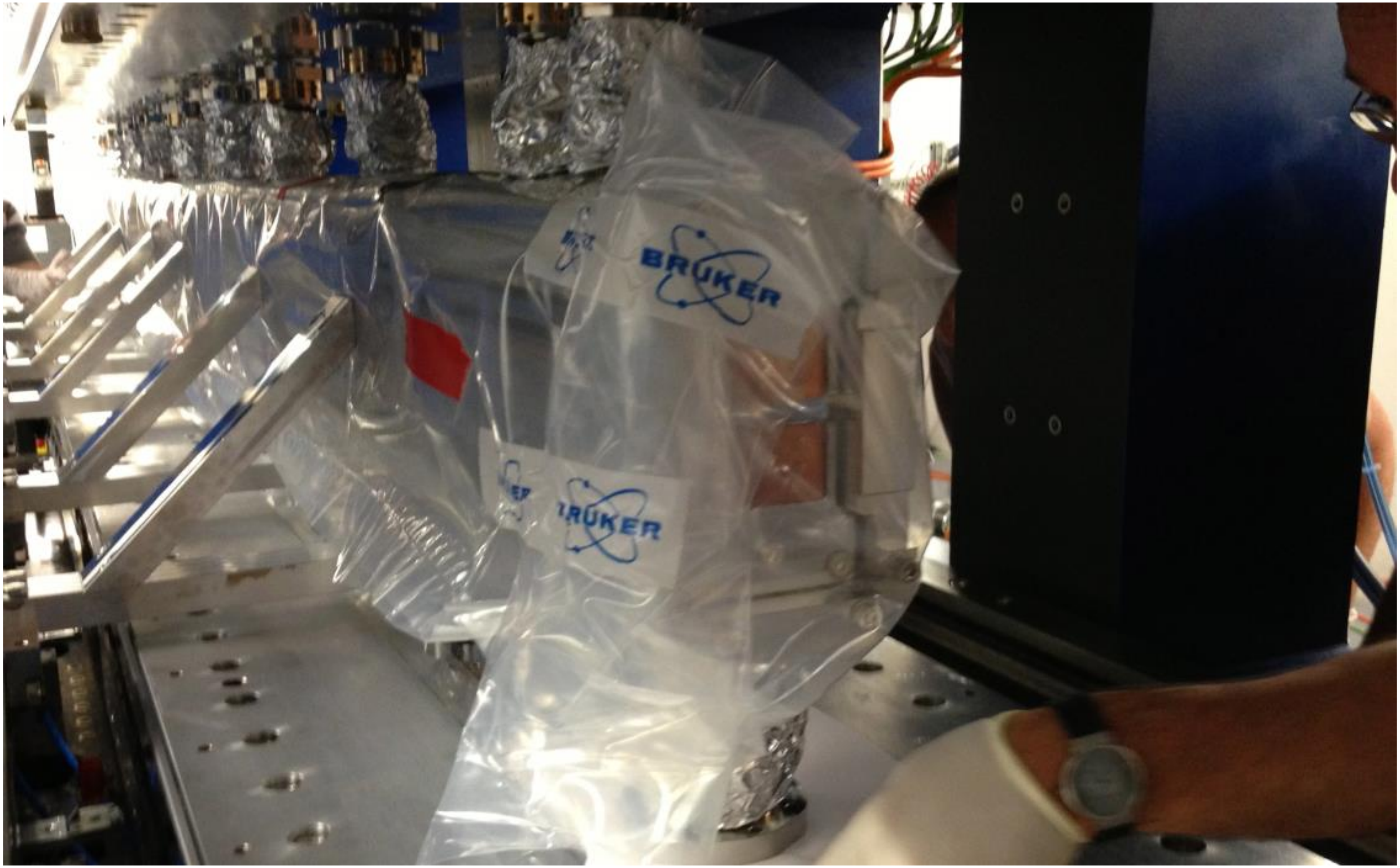
2nd optimization: Reduction to 20 with a new arrangement → Gap remains constant. Beam is not precicely in the middle of the magnetic field, but this error is smaller → **Cost savings for hardware and assembling/adjustments**



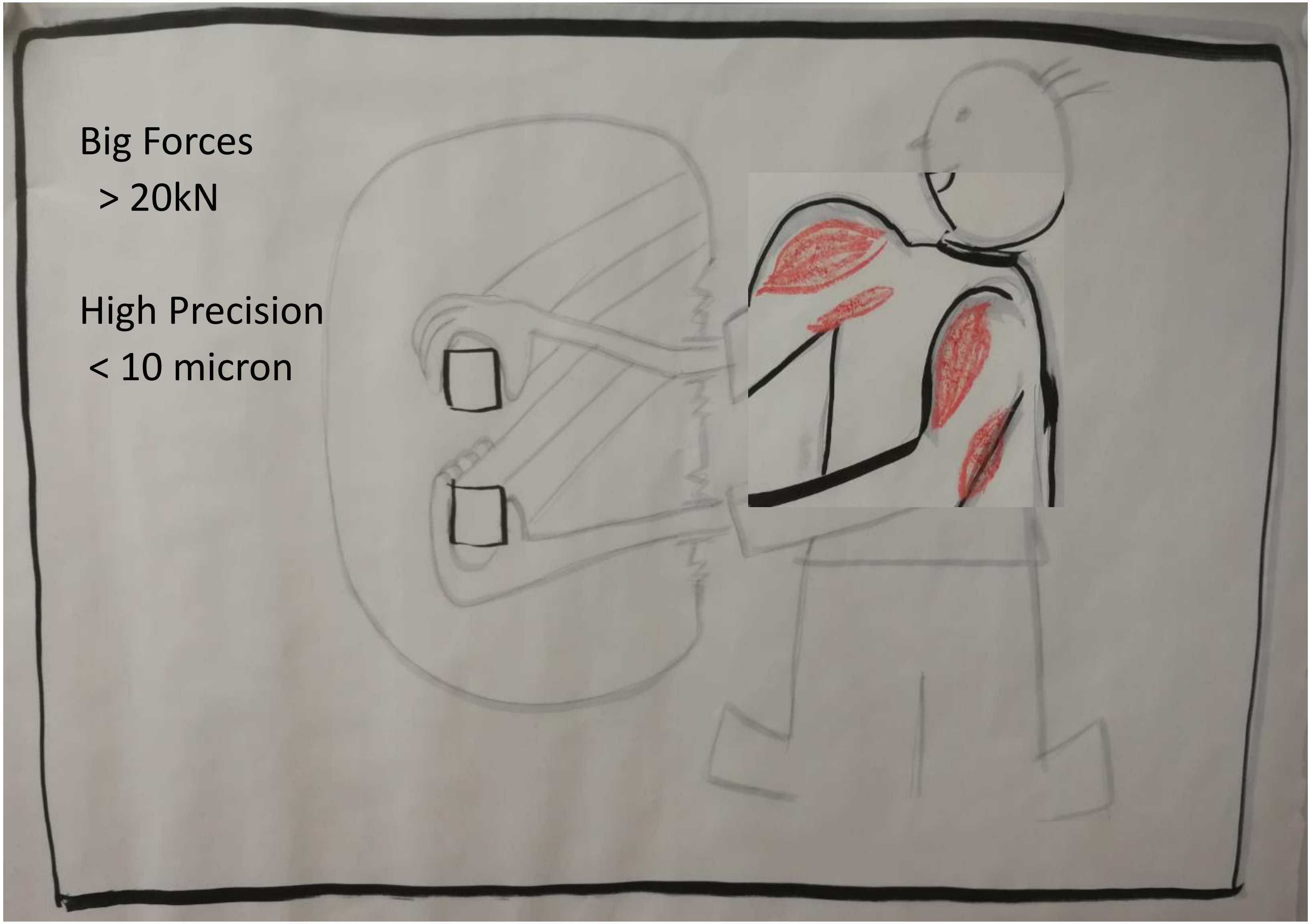
Optimizing the end is a bit difficult



Assembling of inner Beam (without vacuumchamber)



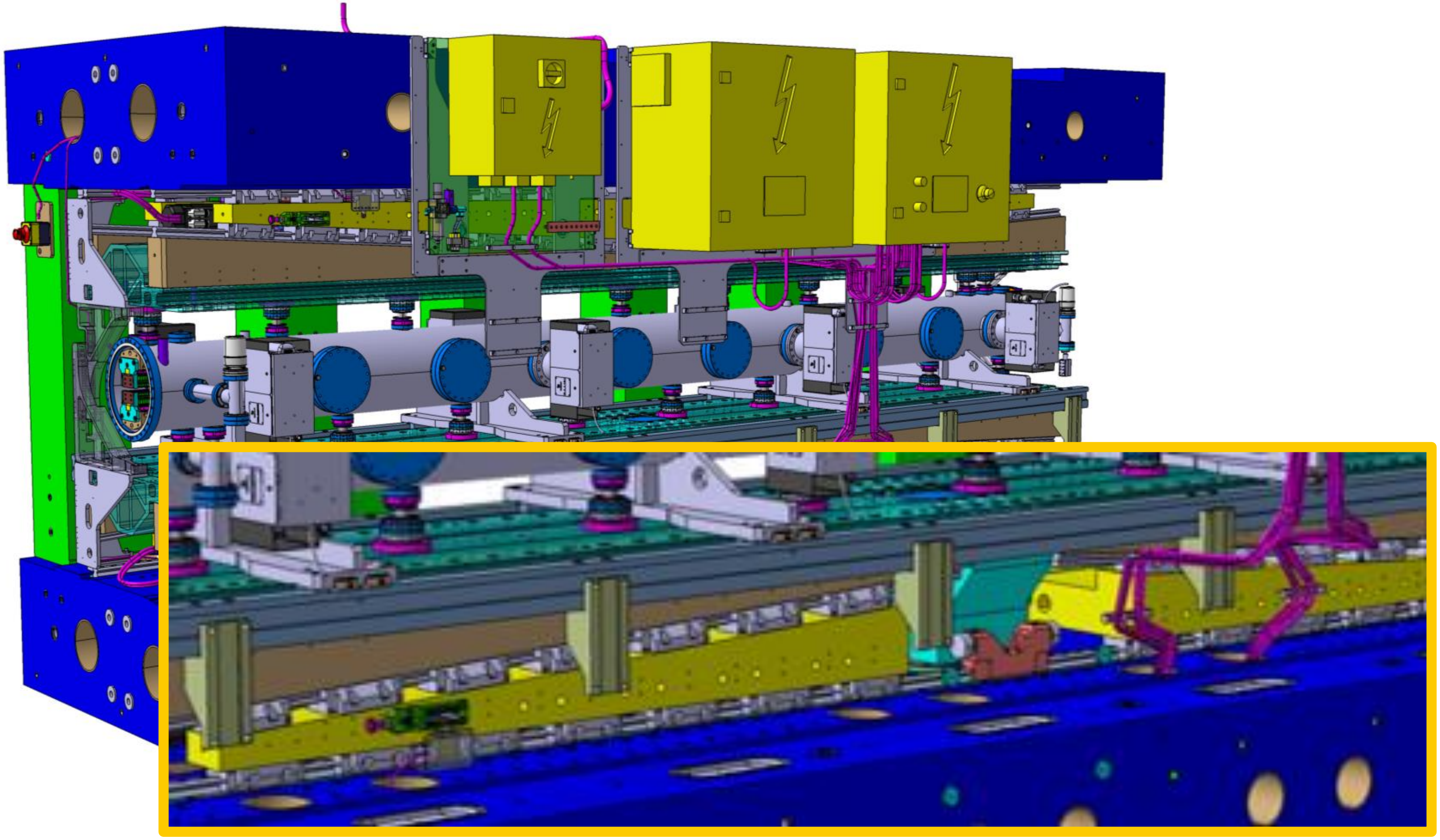
Drives



Big Forces
> 20kN

High Precision
< 10 micron

Drives for Gapadjustment



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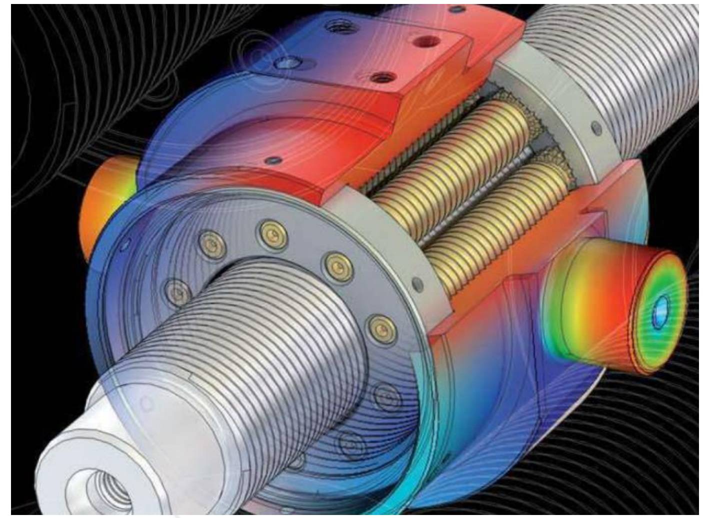
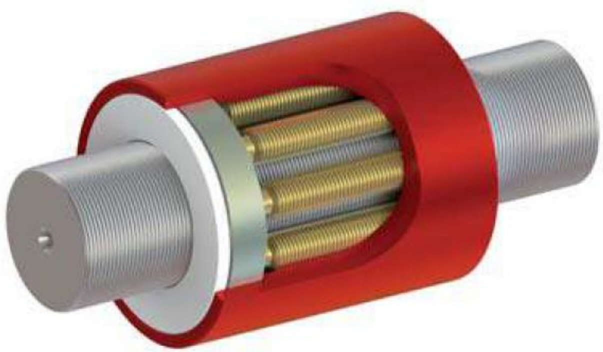
Drive with roller screws

- Very small slope (0.5mm per turn)
- Very little backlash
- No gear required





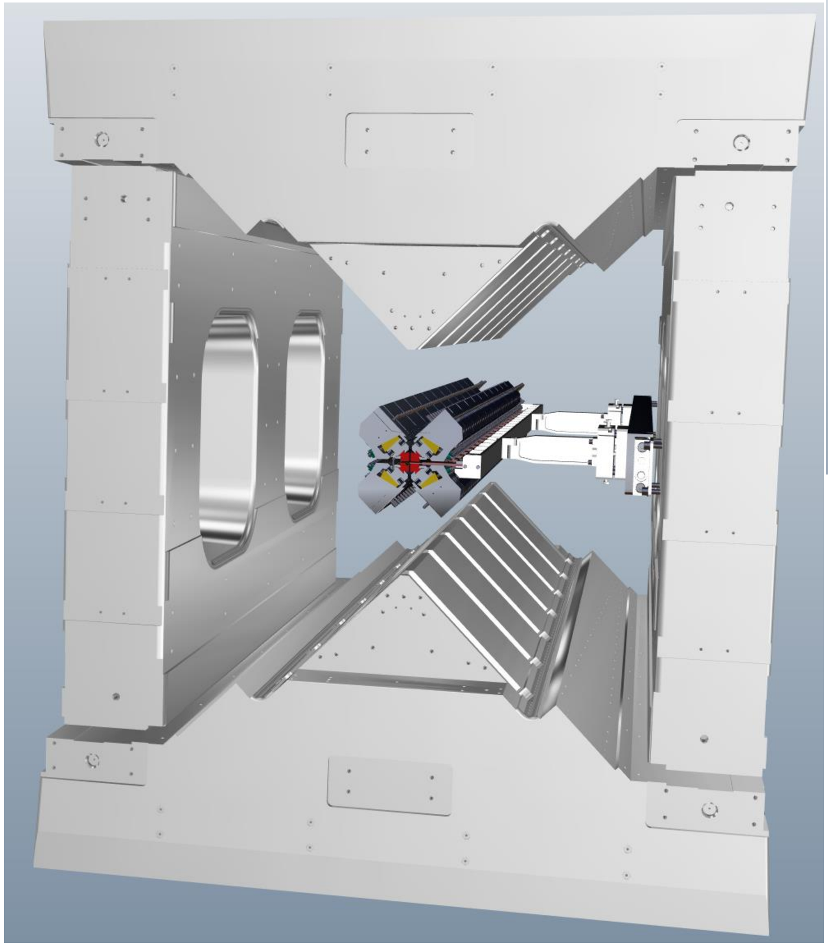
SATELLITE ROLLER SCREWS

ROLLVIS® SWISS

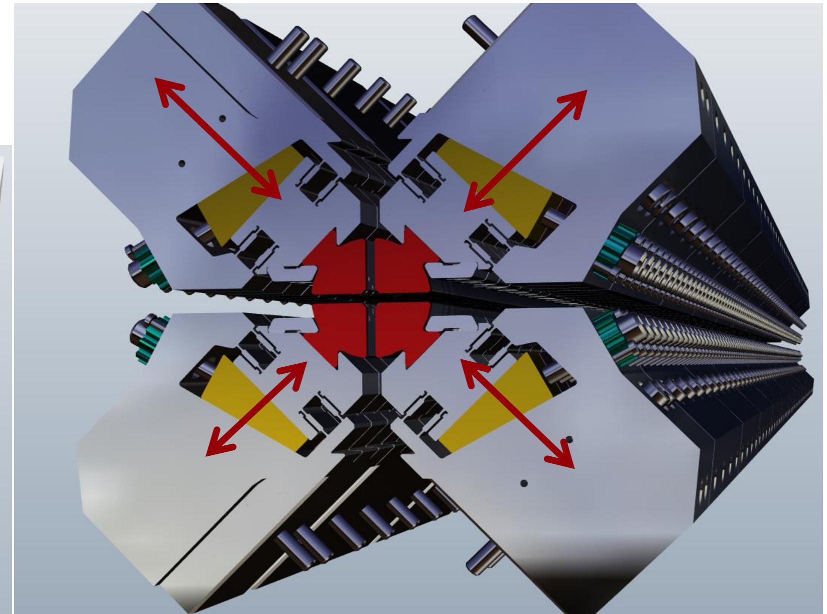
RVD screws

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.

UE38 (Apple X)



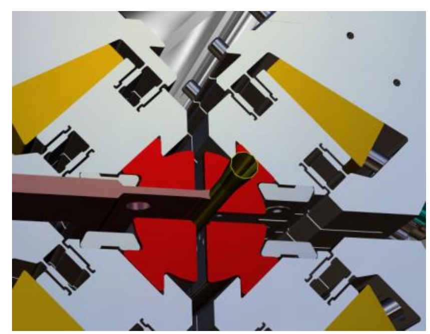
Frame



Flexors with spring

Differential screw

Vacuumpipe



Overview

Main Specification:

Length : 2m

Periods : 52

Gap Range : 3 – 21mm

Shiftrange : +/- 21mm

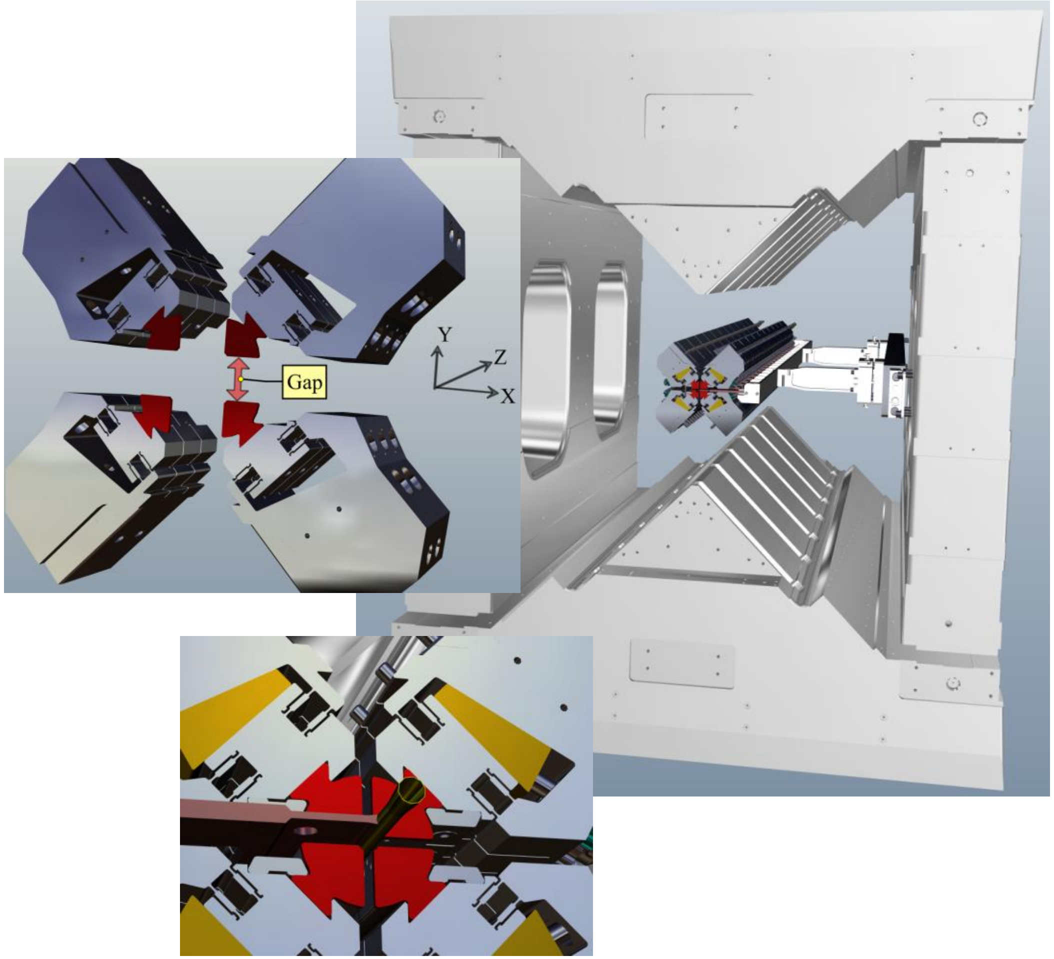
Magn. Forces in X : 1.6 tons

Magn. Forces in Y : 1.6 tons

Magn. Forces in Z : 2.0 tons

Stroke for shimming : +/- 0.1mm

Shimming precision : 1.5 µm (with robot screwdriver)

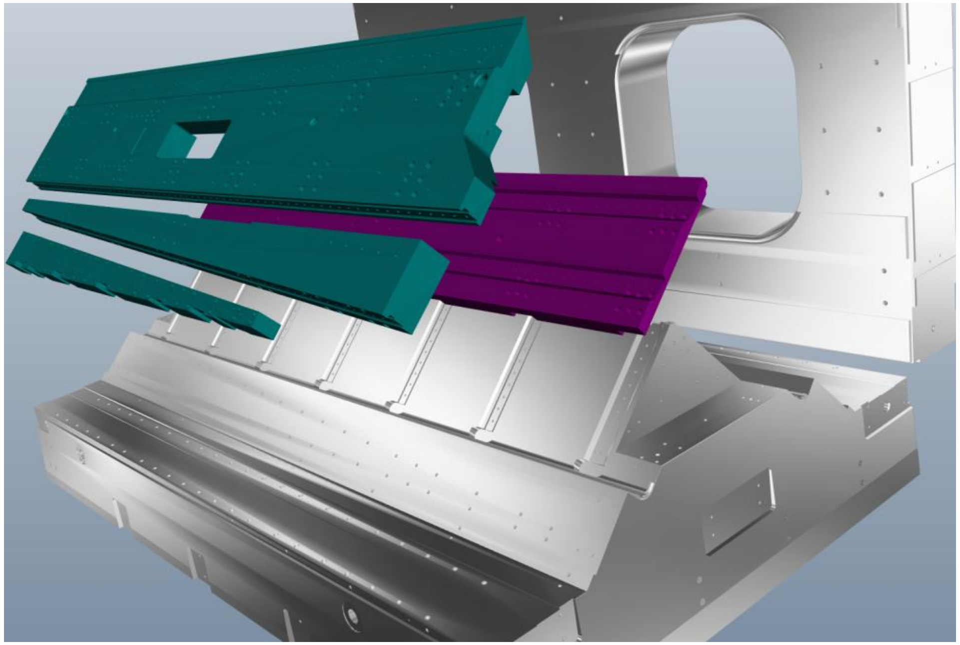


Frame with cast iron

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

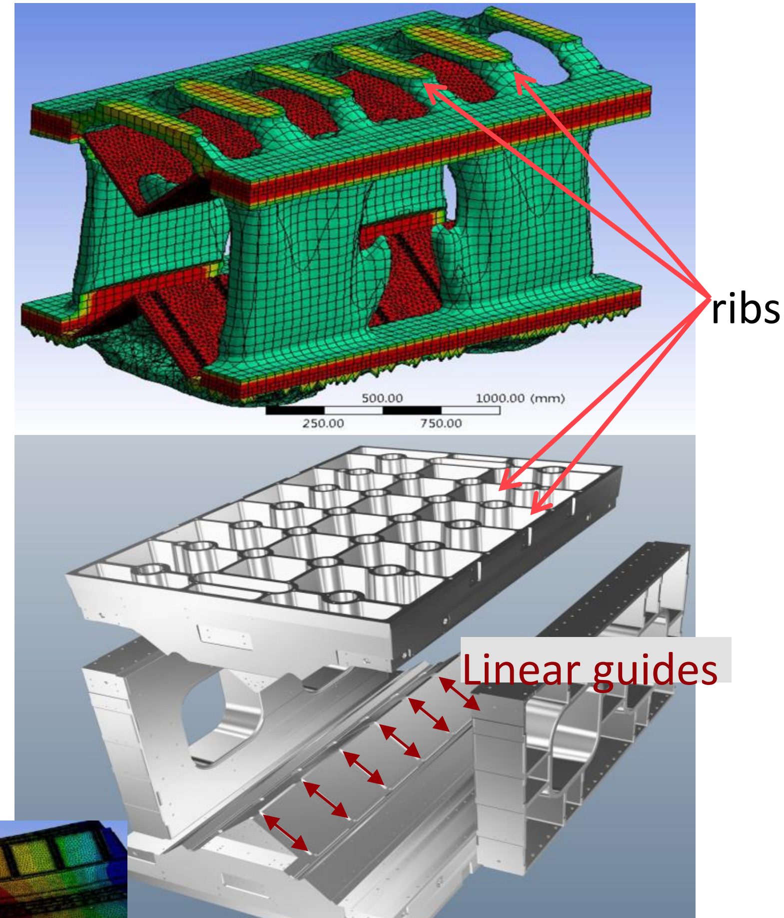


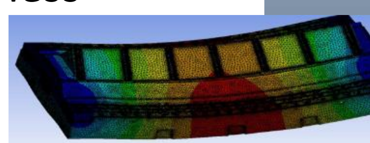
All these parts are in cast iron

Frame

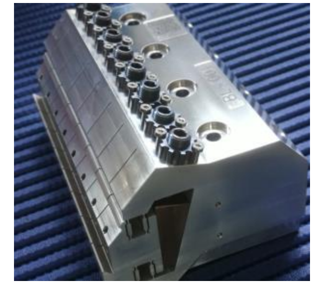
Topology Optimization:

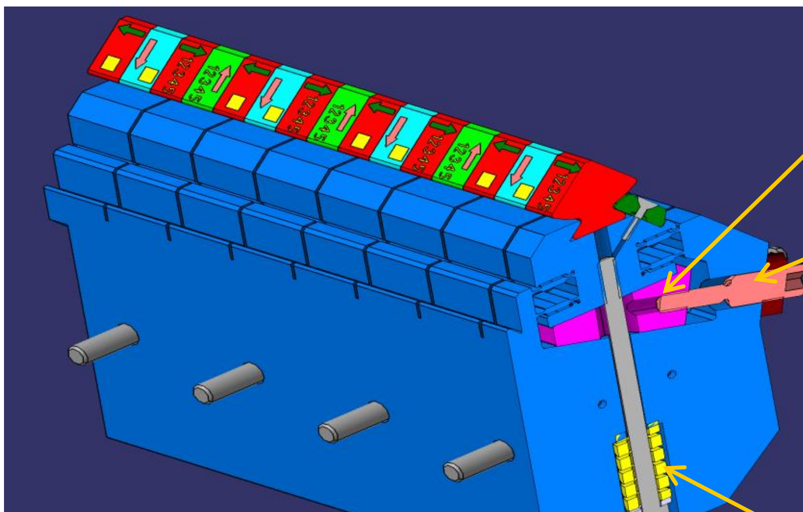
- First impression looks strange, but main finding was, that a rip has to be over each linear guide for the gap
- This principle was taken for the design of ironcast parts
- Upper and lower part identical
- Sidewalls identical
- Main goal is stiftness with changing forces. No clear limit, but we wanted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





Keeper Design: Optimazations





Differential screw thread

1/4 – 28 UNF : 0.907 mm

M10 x 1   : 1.0 mm

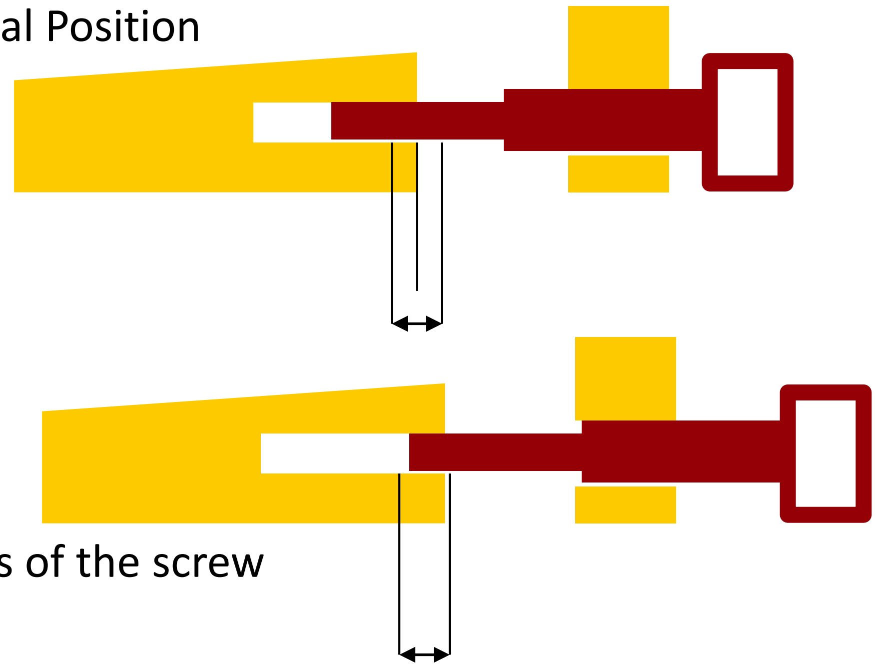
-> 0.1mm Movement by 1 turn

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

Spring to pull the keeper to the wegde

Keeper Design: Differential Screw

Nominal Position

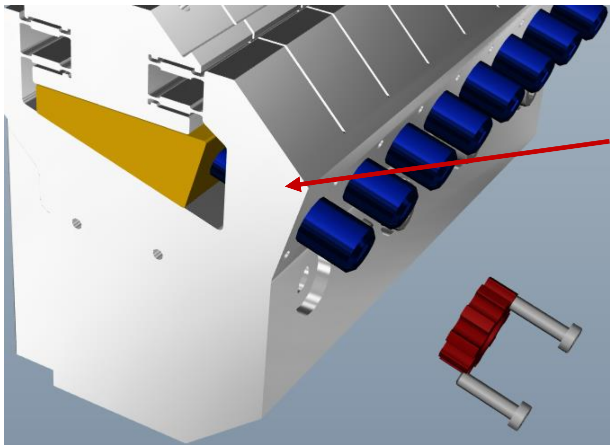


For 0.5mm → 5 turns of the screw

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

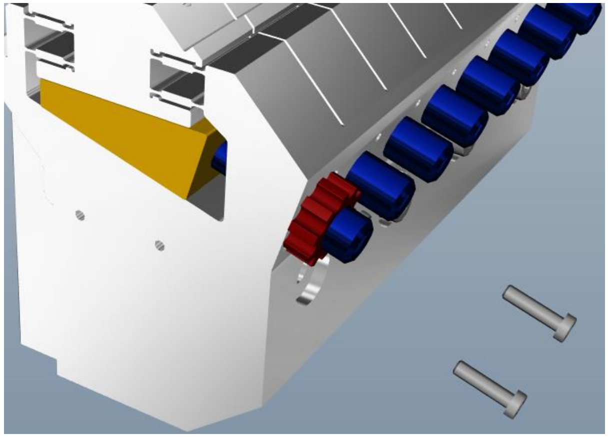
Differential Screw:

Assembling of the wedge with e separat nut

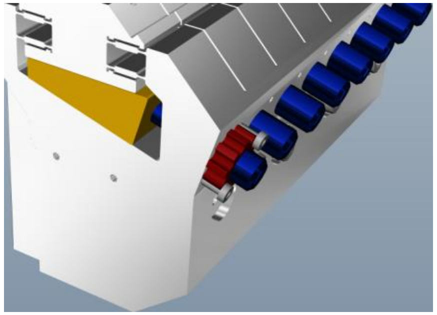


No thread in keeper

1. Step:
Wedge and screw
In correct position



2. Step:
Ad nut (tighten by hand)



3. Step:
Fixation of nut by two screws

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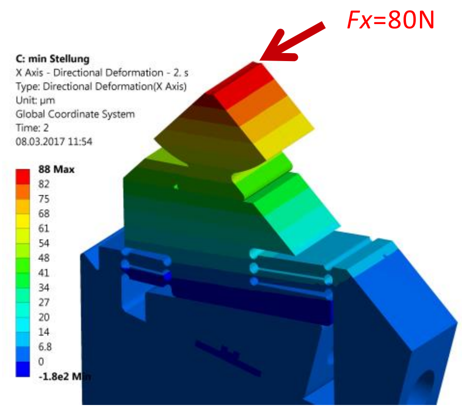
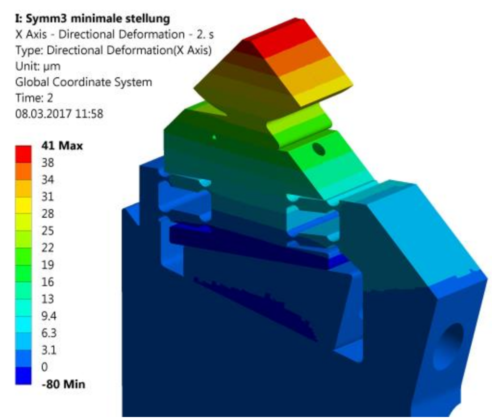
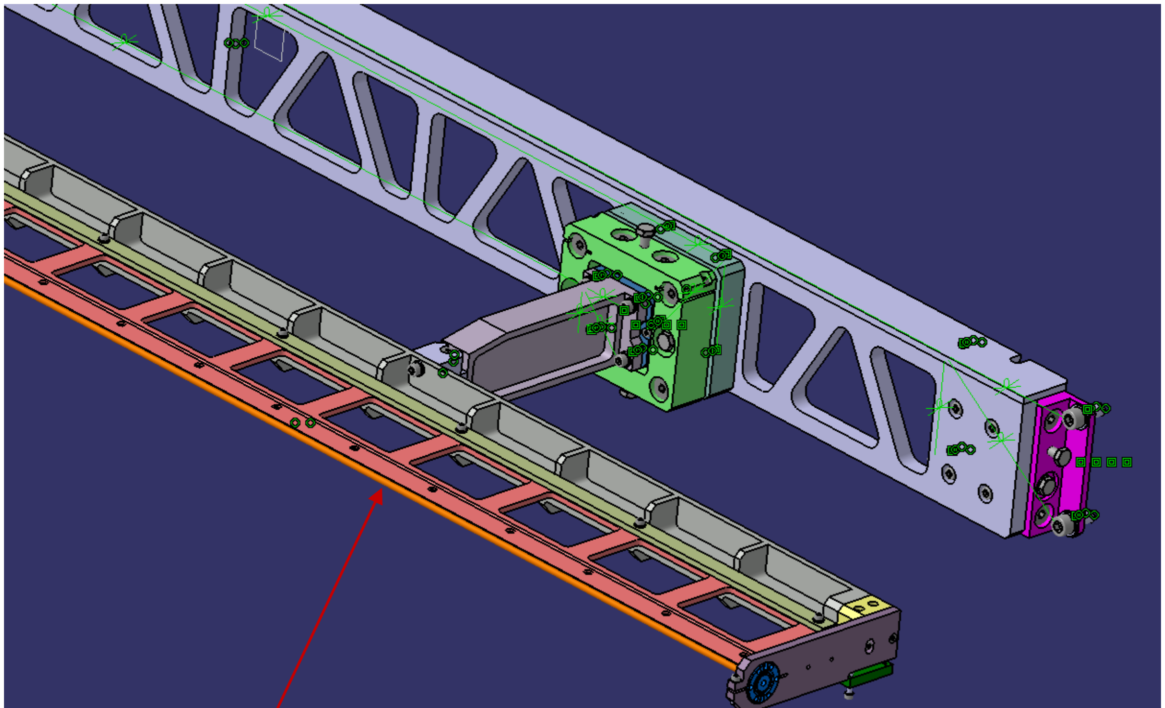
Keeper Design: Simulation of forces

- 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





Vacuum Chamber with support

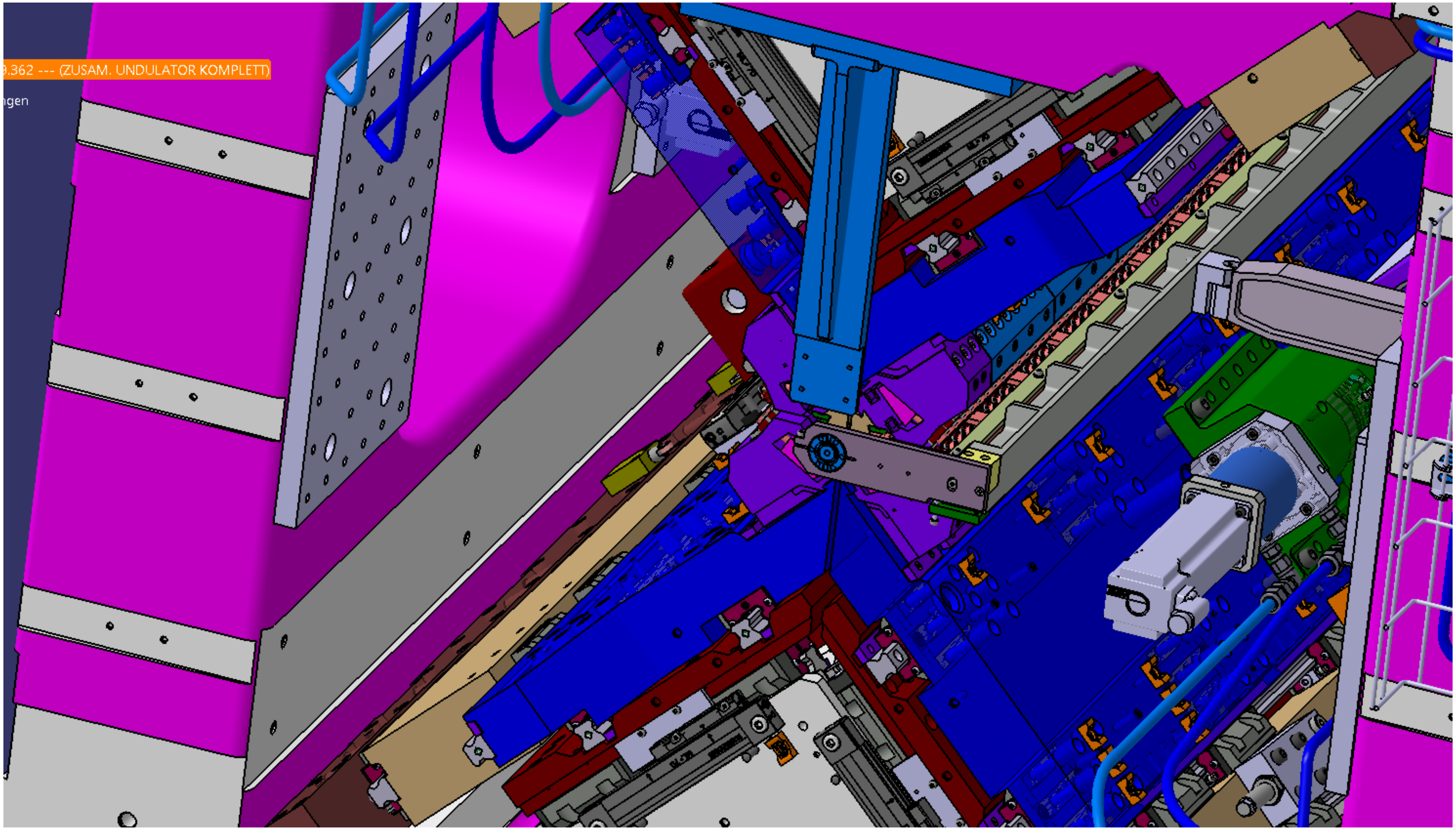


Support and possiblility to adjust, to keep the tube straight and in the correct postion

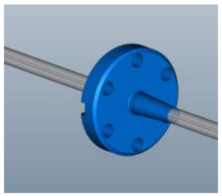
Vacuumchamber:
Inner Diameter : 5.0mm
Wall thickness : 0.2mm

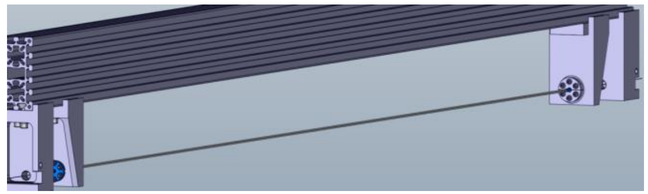
Limited space beside the tube

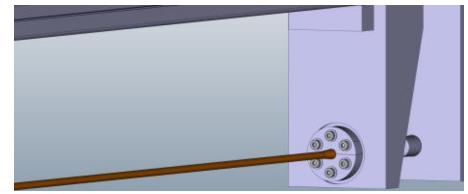
Vacuum Chamber: Limited space



Vacuum Chamber: Manufacturing

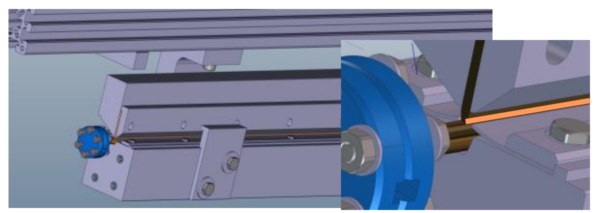






1. Step: Flanges and a silicone wire with a coating of silver powder. The wire has to be strechted and fixed in a frame

2. Step: Galvanize the tube with copper. All the rest has to be insulated



3. Step: Pulling out the silicone wire

4. Step: Add (galvanize) the support

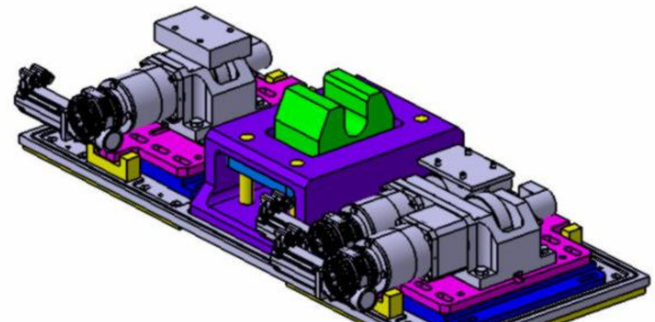
Manufacturing by:
Galvano-T
51570 Windeck
Germany

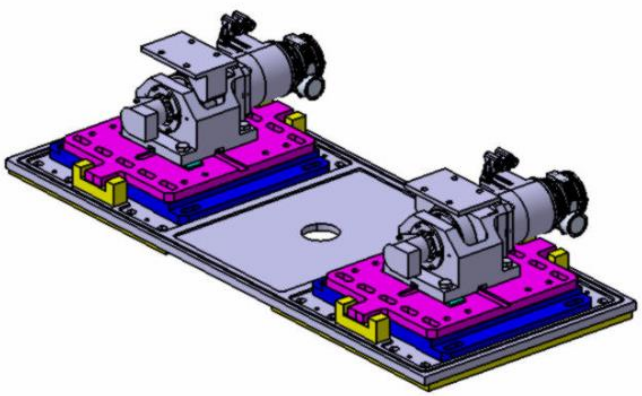
Mover : Principal

5 Motors

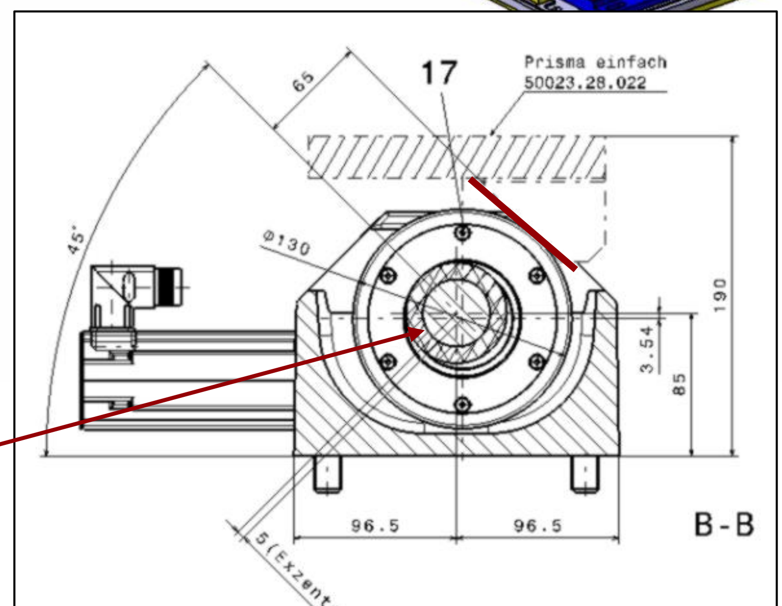
→ 5 Degrees of Freedom

Fixid in Beamdirection

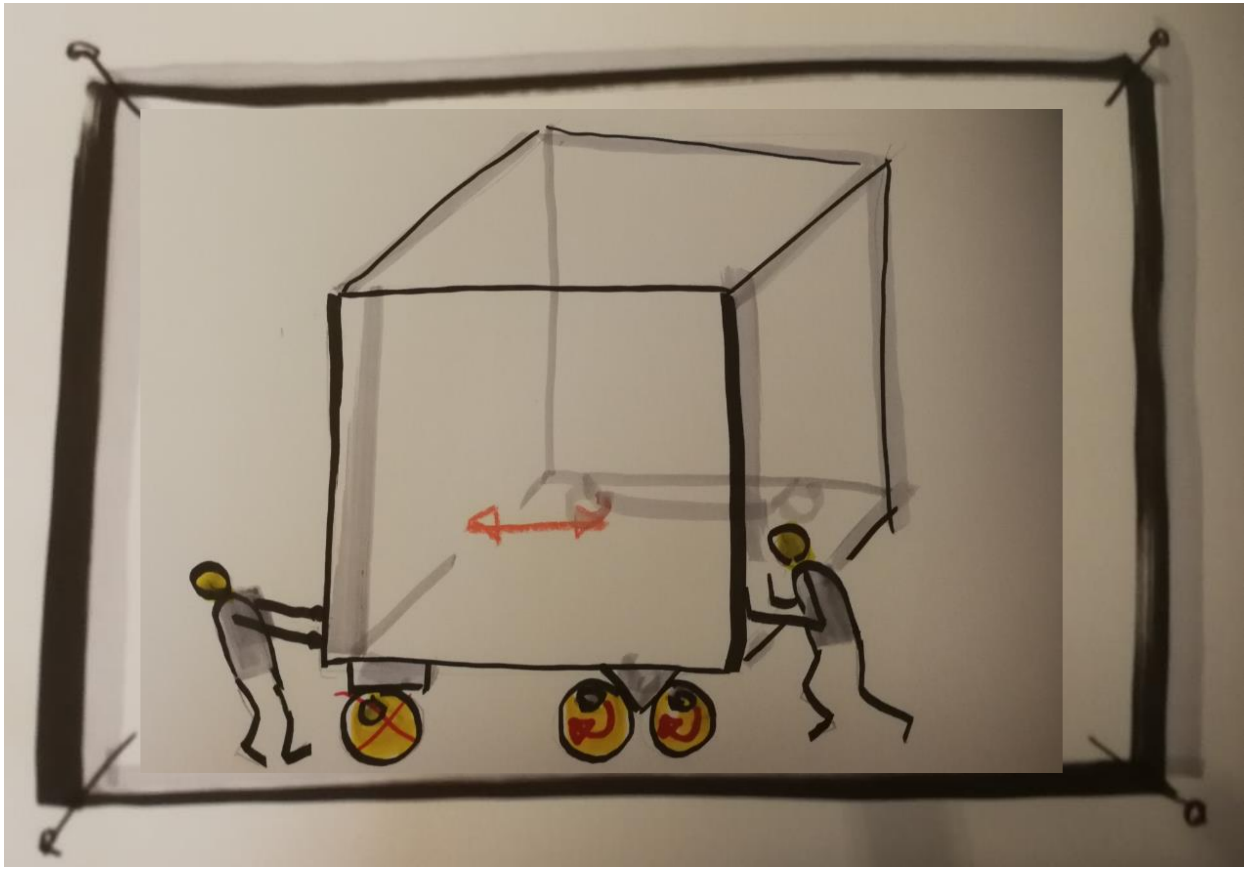


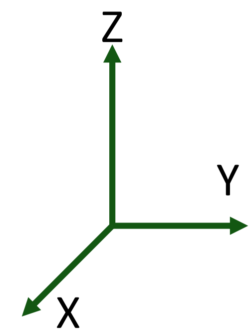


Excenter



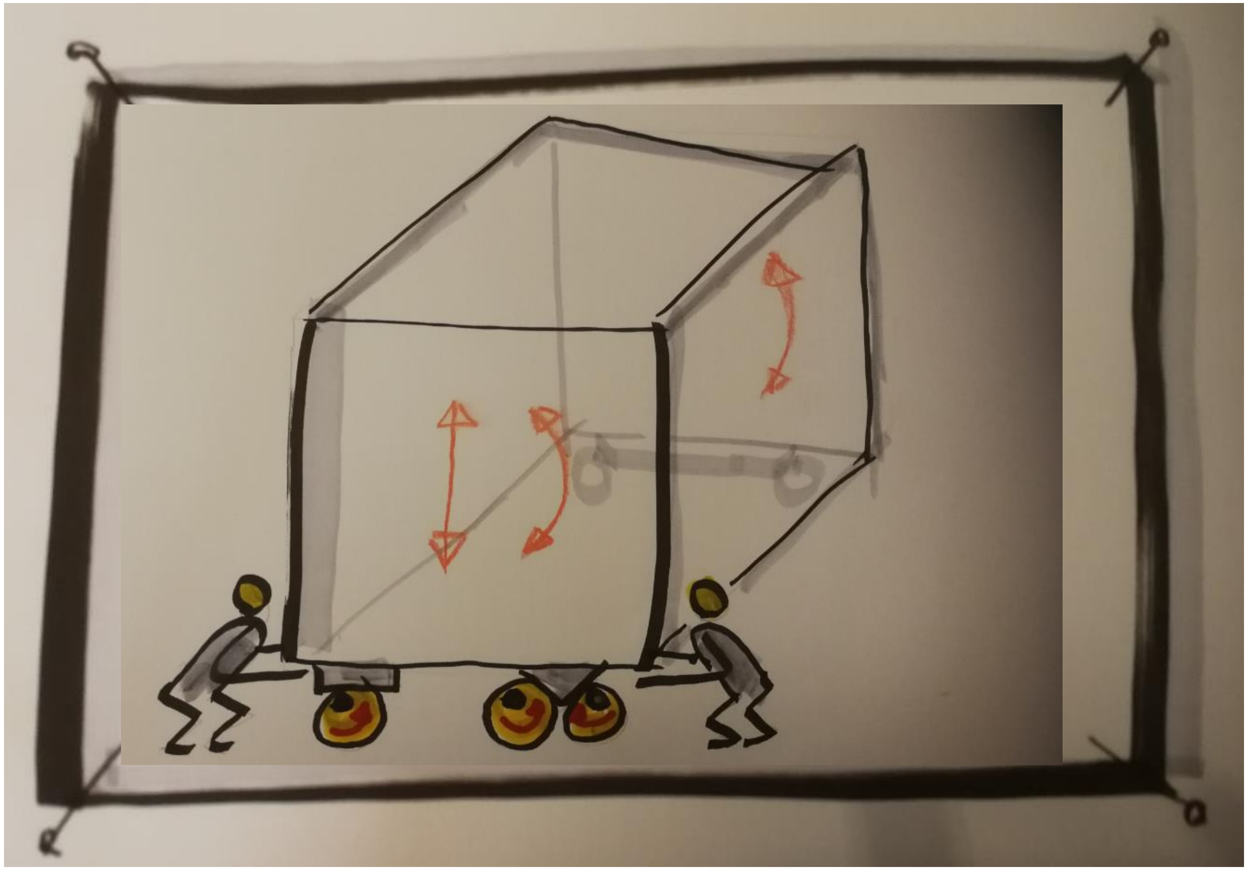
Mover: Principal

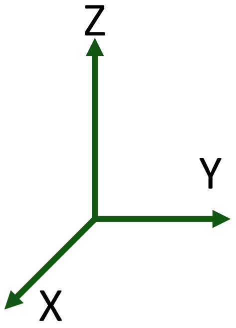




Left – Right of Frontside (also turning around Z-axis)

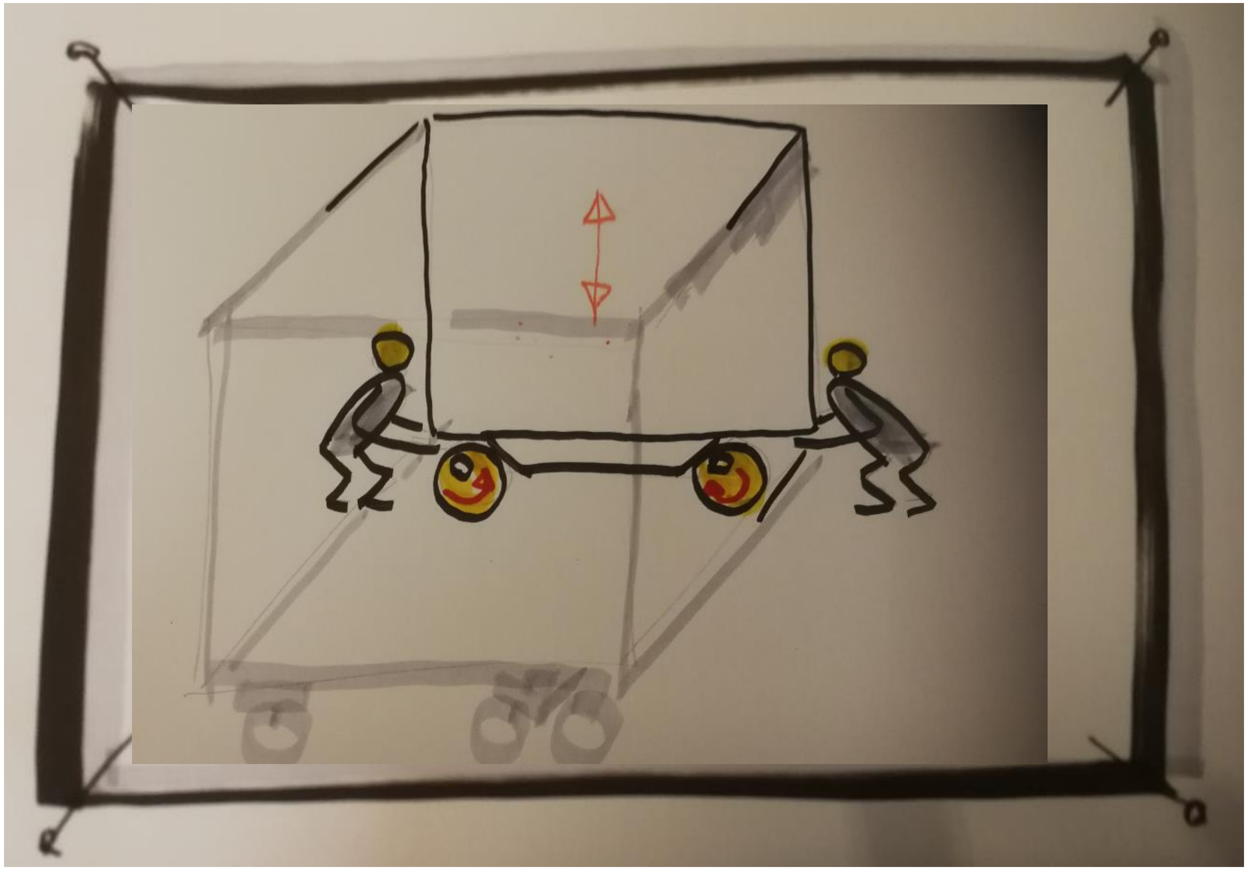
Mover: Principal

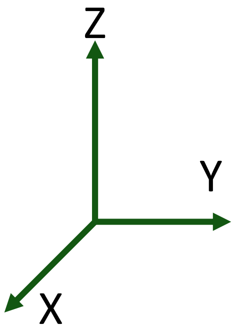




Up – Down of Frontside (also turning around Y-axis)

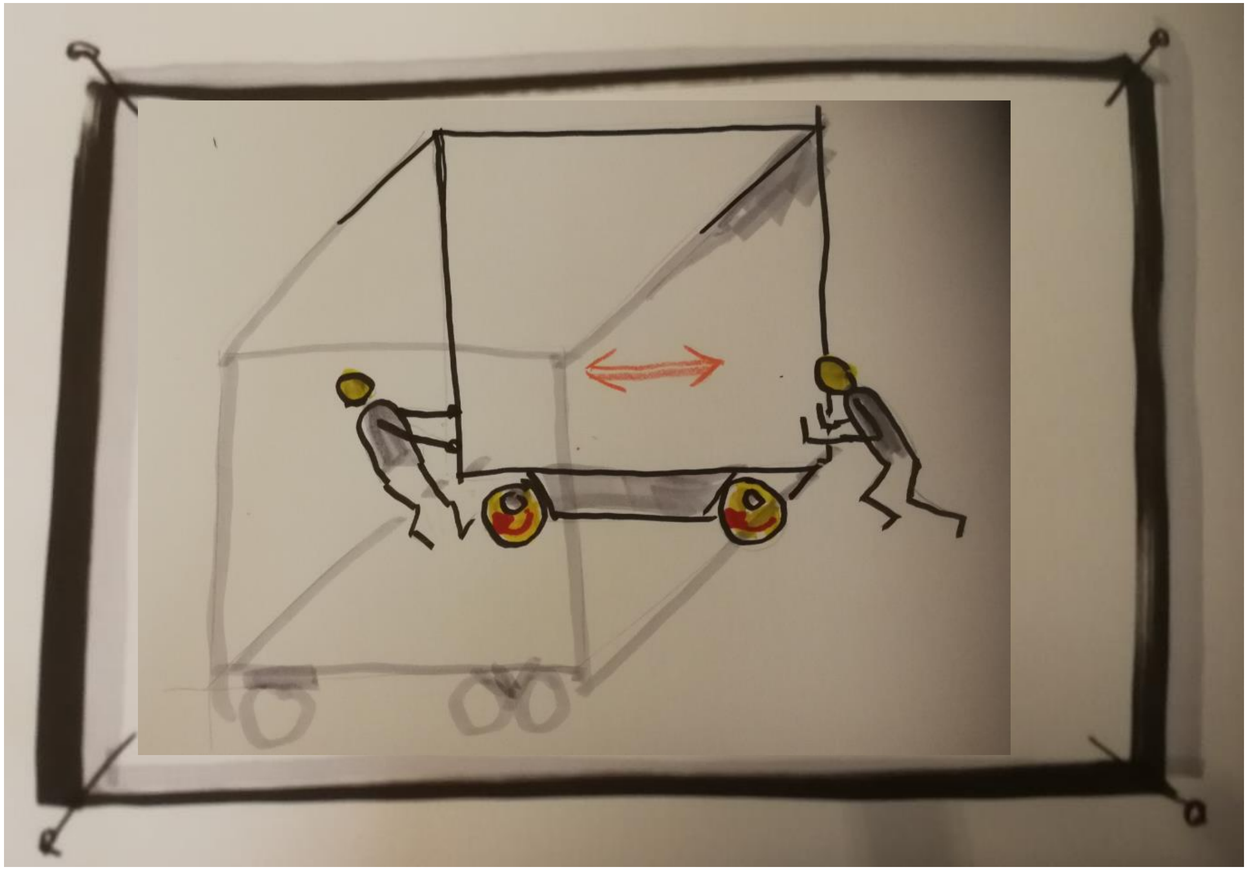
Mover: Principal

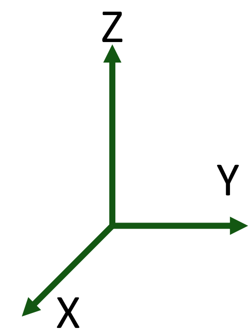




Up – Down of Backside (also turning around Y-axis)

Mover: Principal





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

Mover: Installation of First U15

Questions

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