



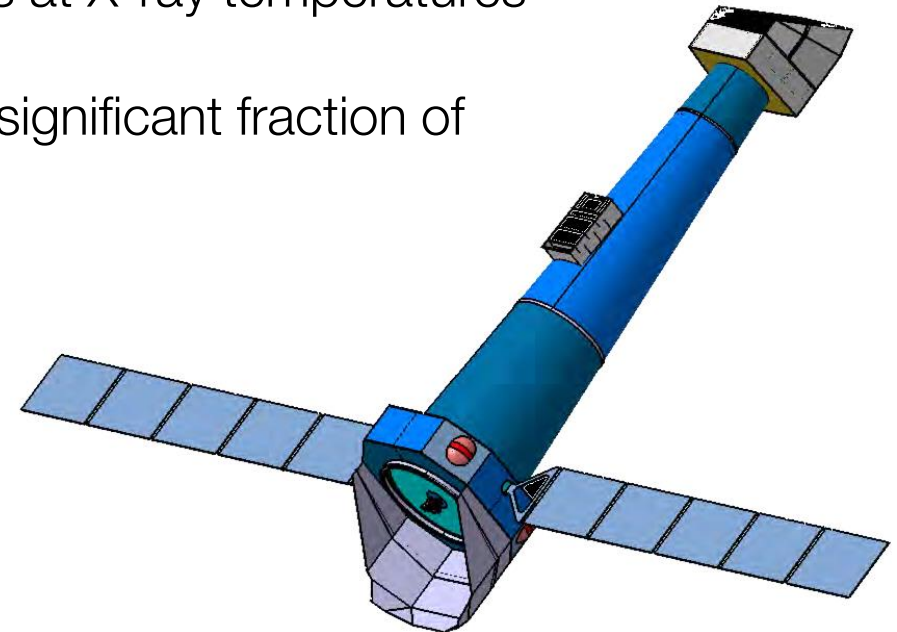
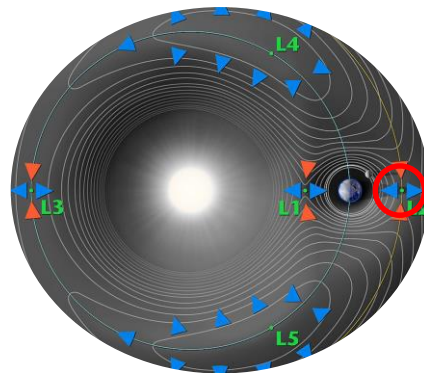
# ATHENA Charged Particle Diverter

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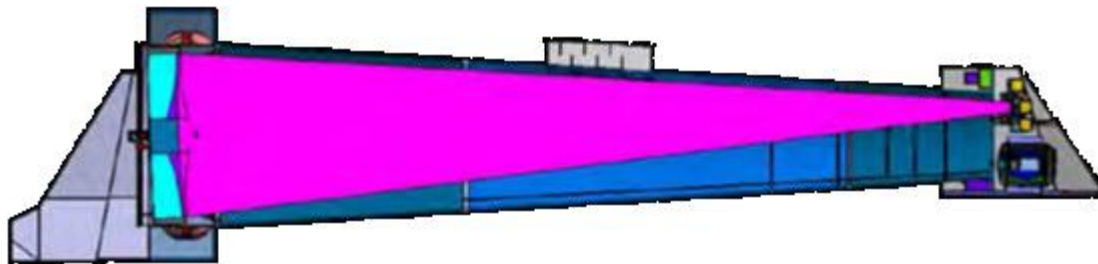
Jakub Zlámál (BUT), Richard Hynek (L.K.Engineering)

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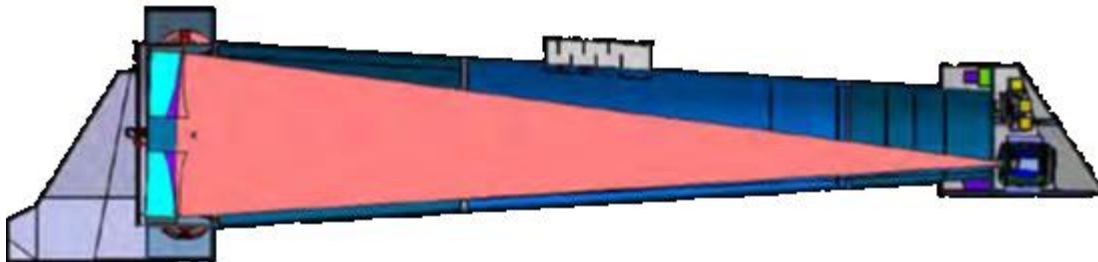
- Large X-ray observatory
- Second L-class mission in ESA “Cosmic Vision” program
- Addresses Science Theme “The Hot and Energetic Universe”:
  - How does ordinary matter assemble in large structures as seen today? Most ordinary matter in the universe is in the form of hot gas at X-ray temperatures
  - How do black holes grow and shape the universe? A significant fraction of the luminous energy in the universe is from accretion
- Periodic L2 “Halo orbit ”



- Protons impinging X-ray detectors cause decrease of signal to noise ratio – they should be deflected away
- Deflection of protons by magnetic field of permanent magnets – no power consumption
- Protons with energies up to 76 keV (WFI detector) and 66 keV (X-IFU detector)
- Magnets cannot shield X-ray photons focused by mirror
- Working temperature range  $\pm 35\text{ }^{\circ}\text{C}$ , survive range  $\pm 50\text{ }^{\circ}\text{C}$



**WFI detector**  
(Wide field imager)



**X-IFU detector**  
(integral field – superconducting  
calorimeters) cooled to 50 mK

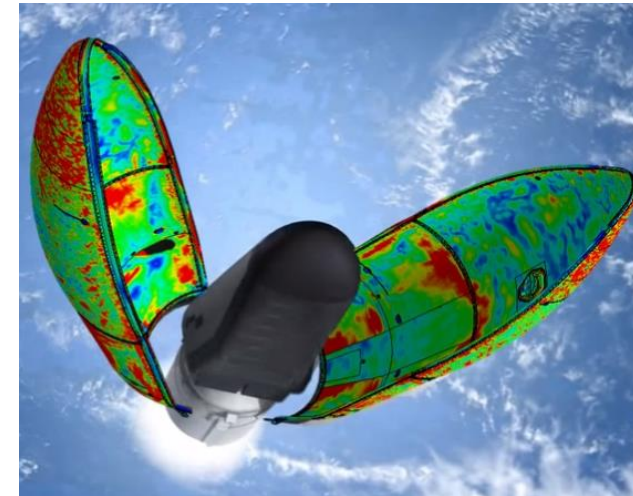
- Technology preparation of Charged Particle Divertor
- Cooperation of experienced science and industrial entities in Brno
  - Frentech Aerospace s.r.o. – prime contractor and manufacturer
  - Brno University of Technology – magnetic design of the divertor
  - L.K.Engineering s.r.o. – structural design of the divertor



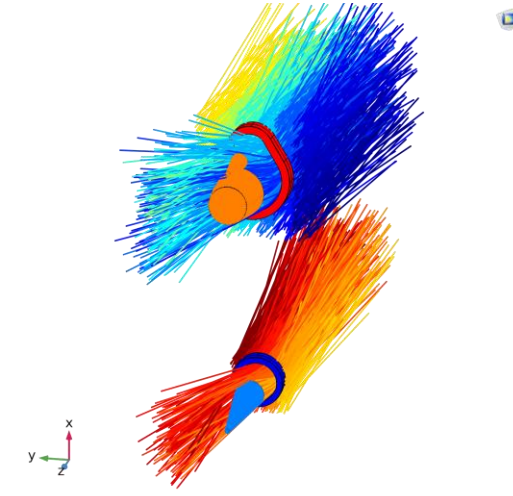
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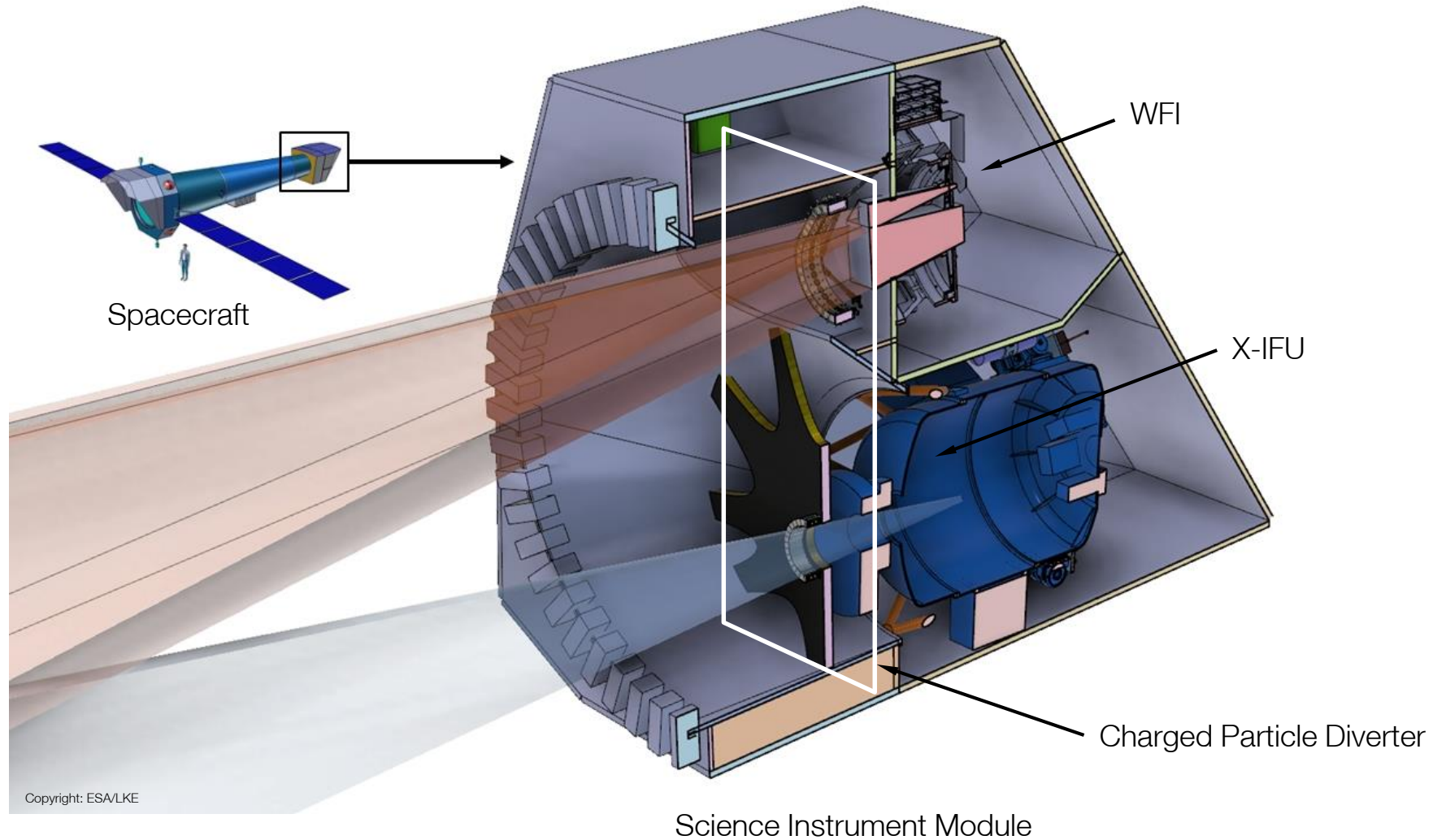


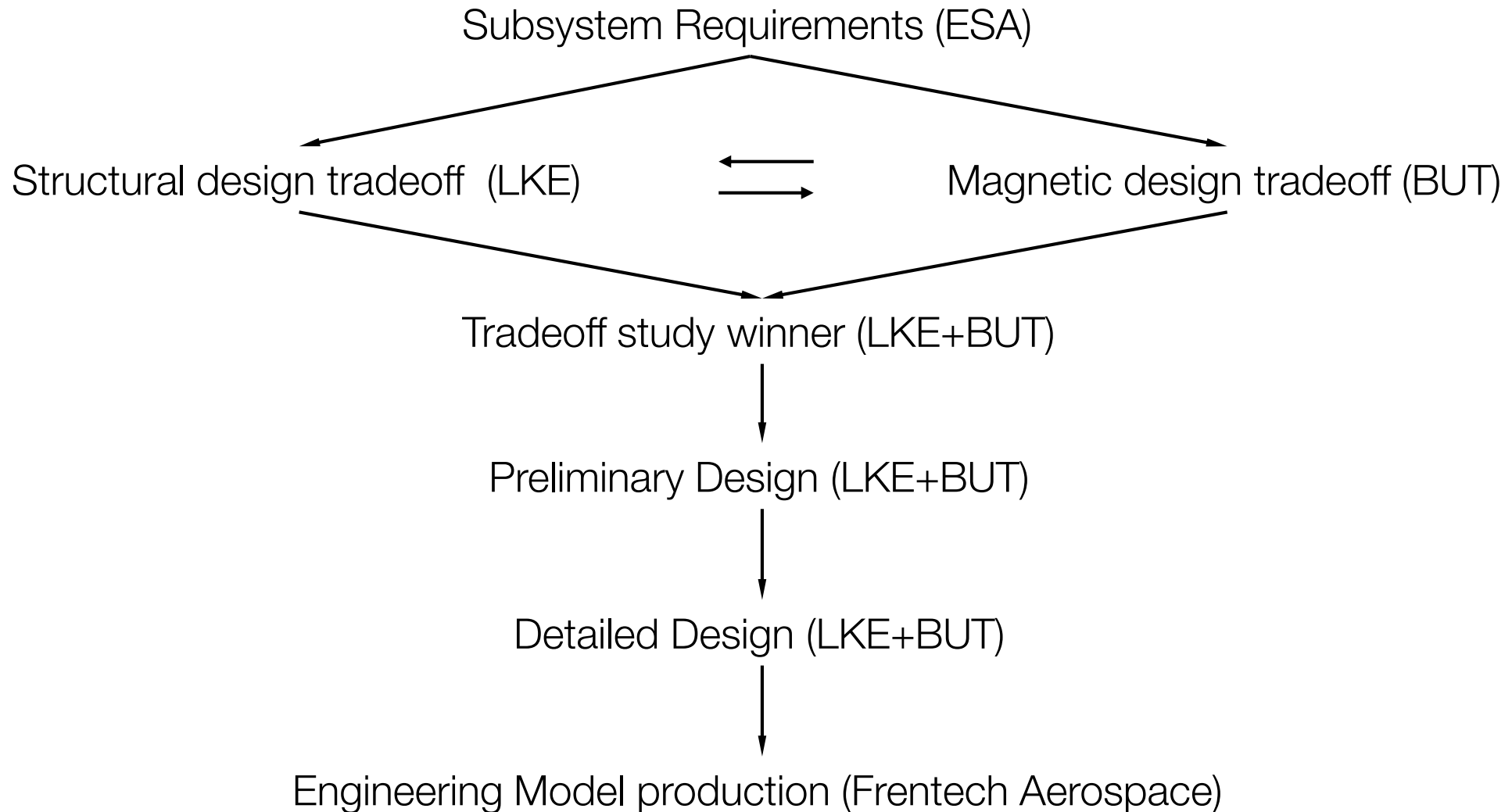
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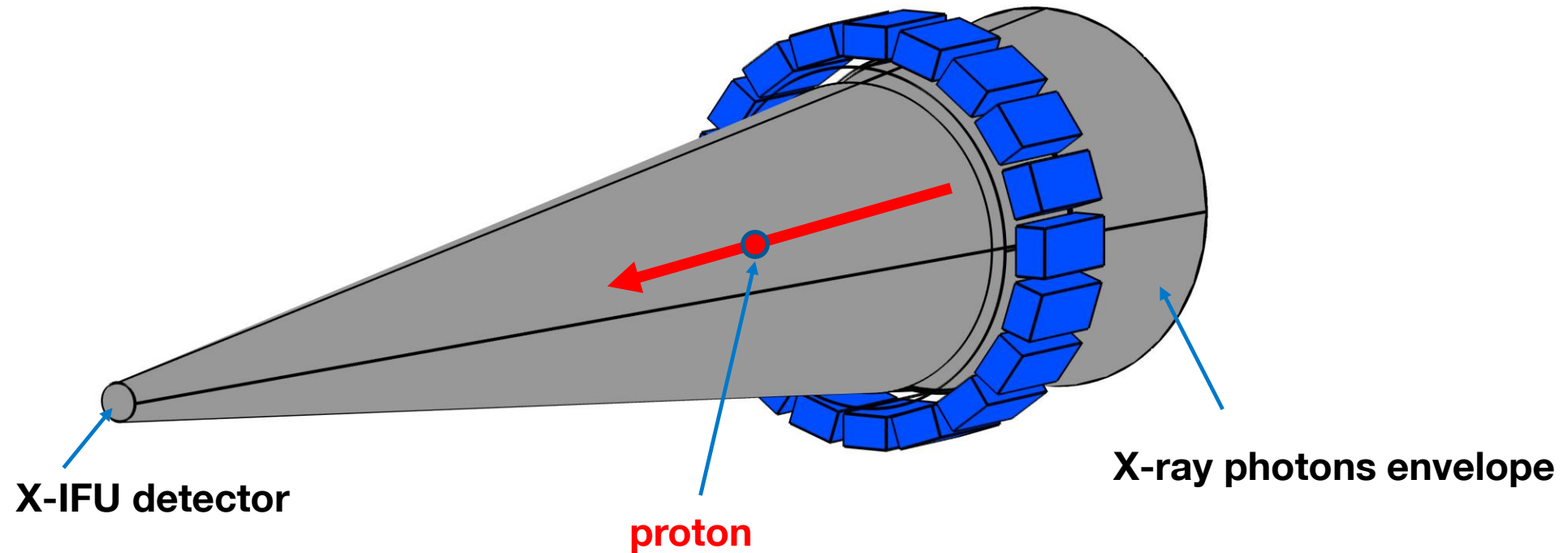
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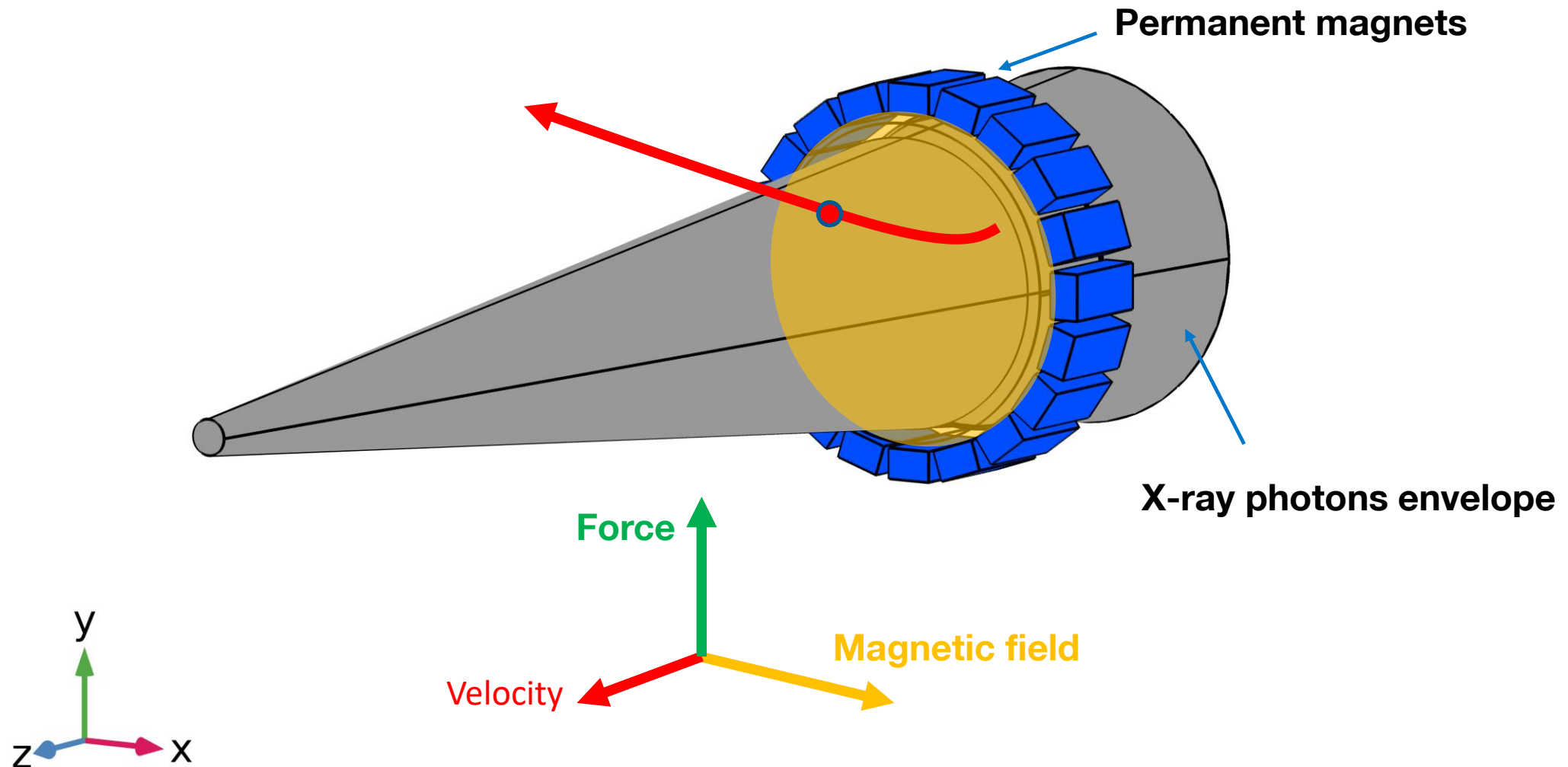




## PRINCIPLE OF MAGNETIC DIVERTER



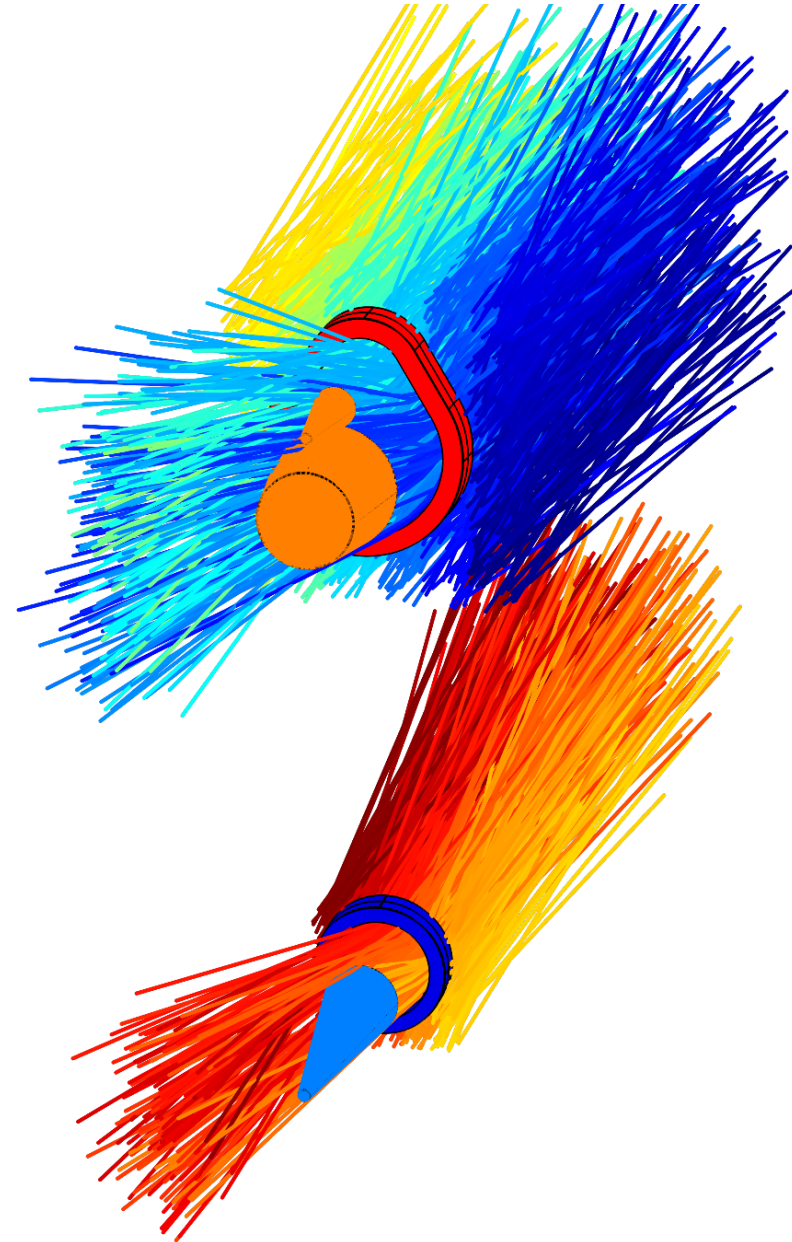
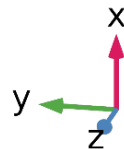
## PRINCIPLE OF MAGNETIC DIVERTER





- WFI detectors
- WFI pear-shape Halbach Array

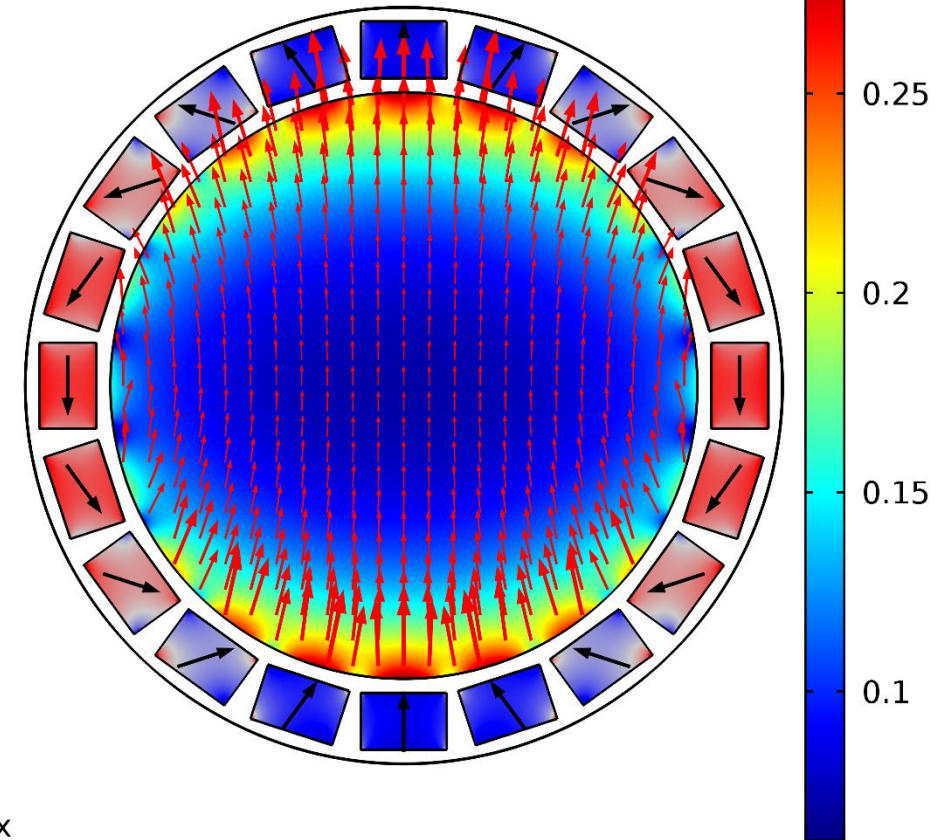
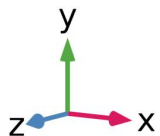
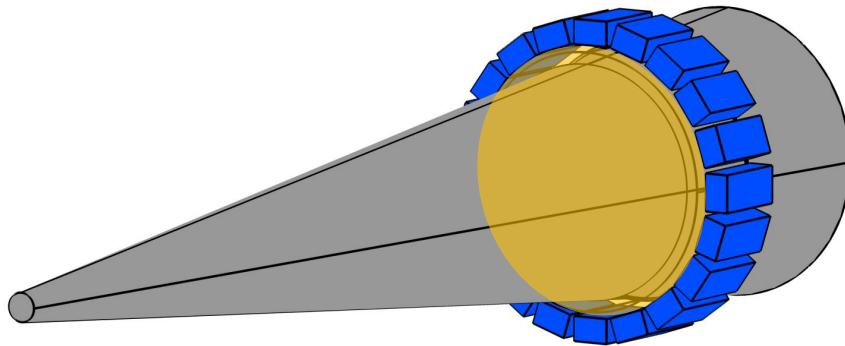
- X-IFU detector
- X-IFU Halbach Array



## Circular Halbach Array

Uniform field

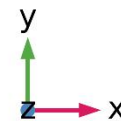
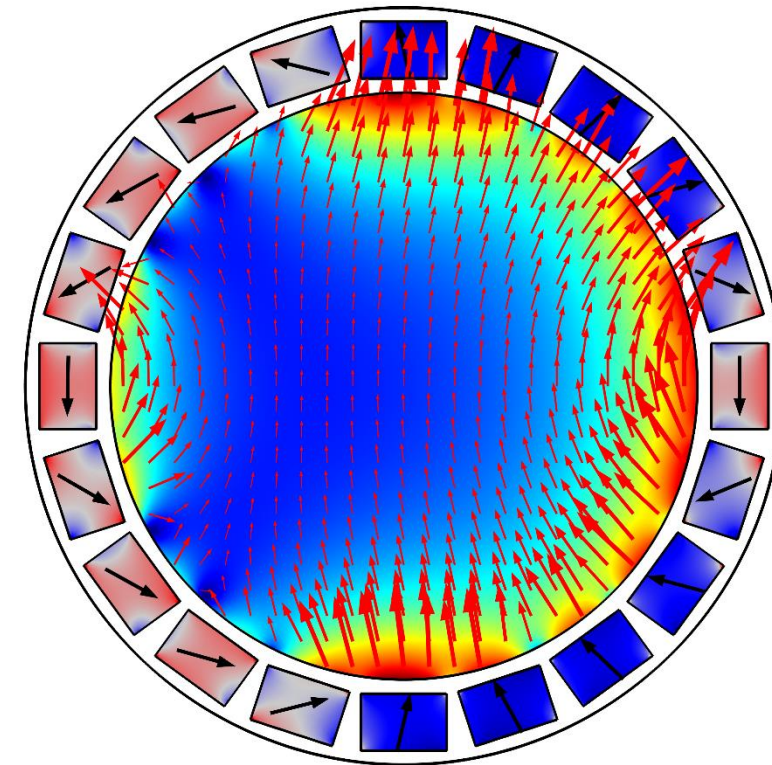
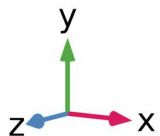
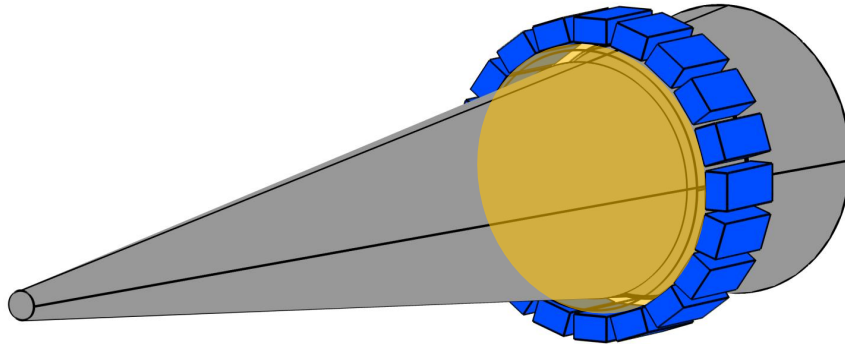
- Permanent magnets
- Strong magnetic field inside
- Small magnetic field outside



## Circular Halbach Array

Nonuniform field – better performance

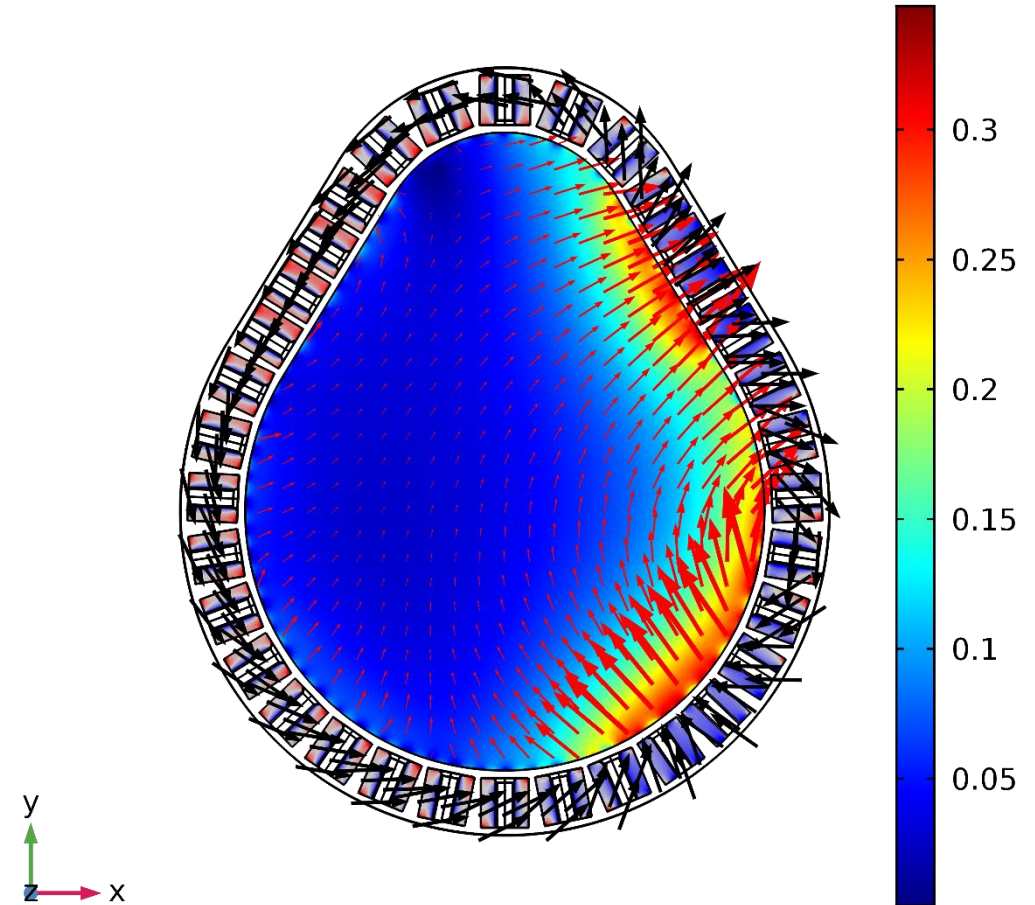
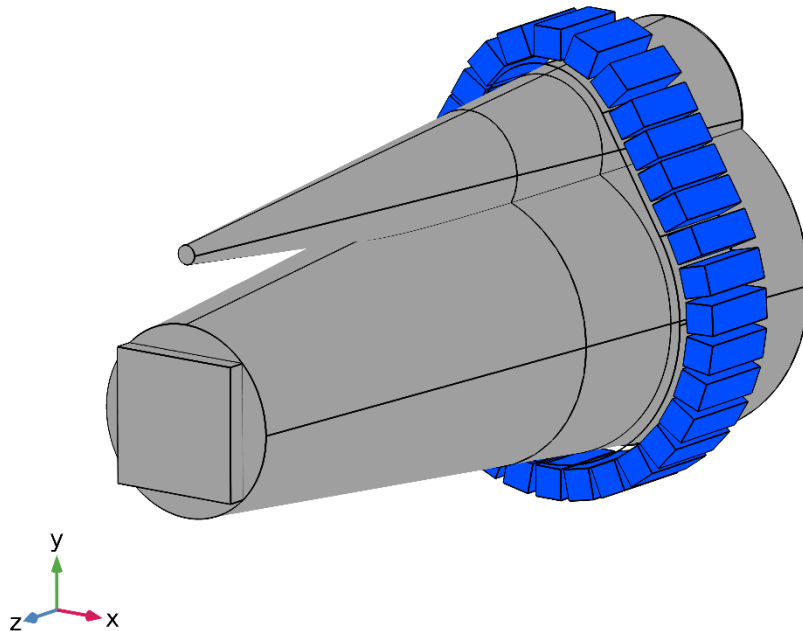
- Permanent magnets
- Strong magnetic field inside
- Small magnetic field outside
- Weight of magnets 6 kg





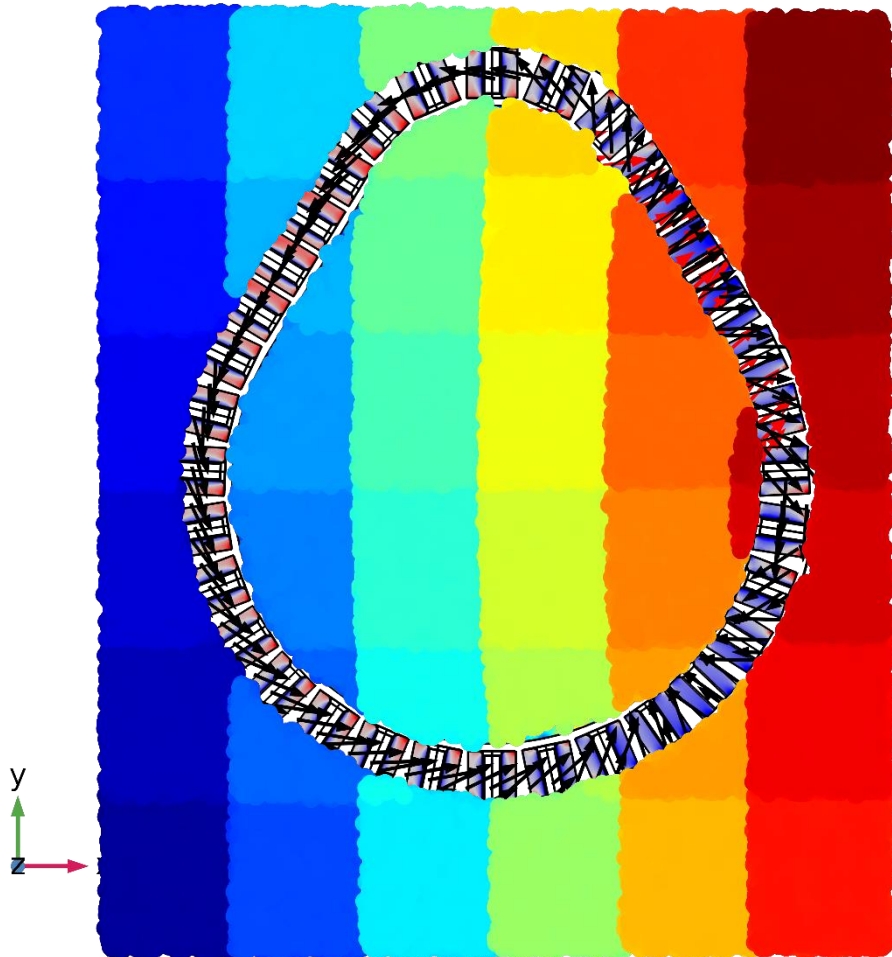
## Pear-shape Halbach Array

- In front of WFI detector
- Inner diameter of 35 cm
- Weight of magnets 21 kg

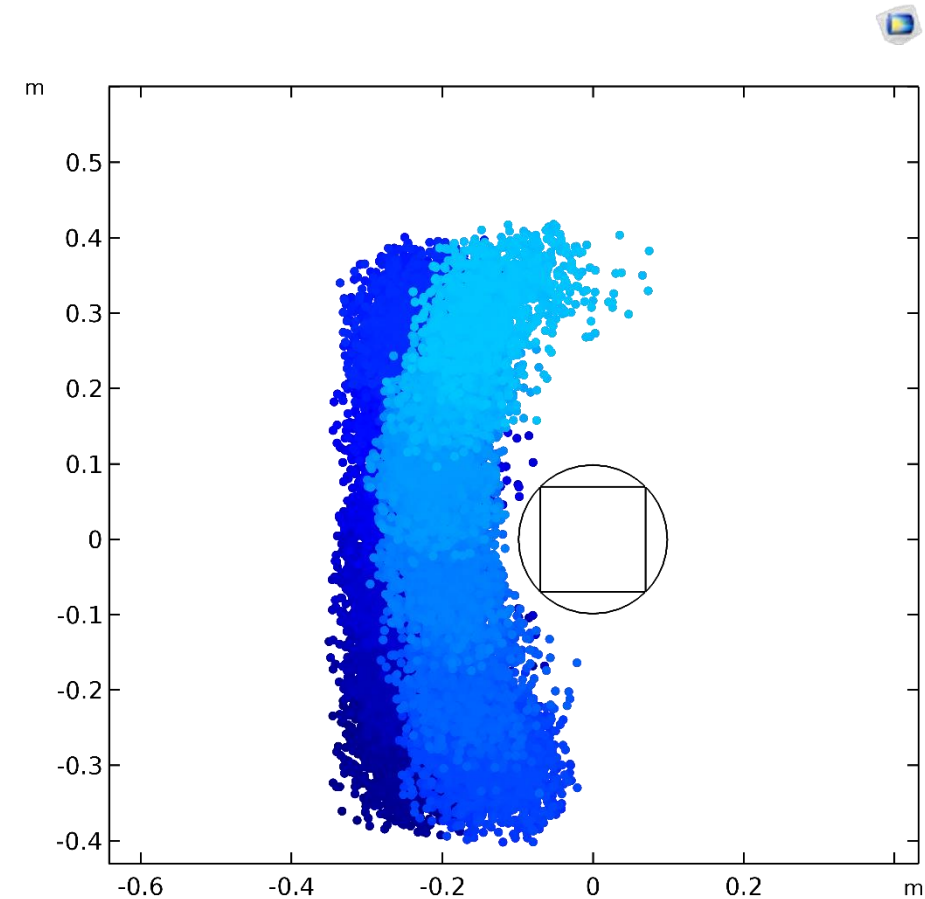


## Pear-shape Halbach Array optimization

Entrance of Halbach Array



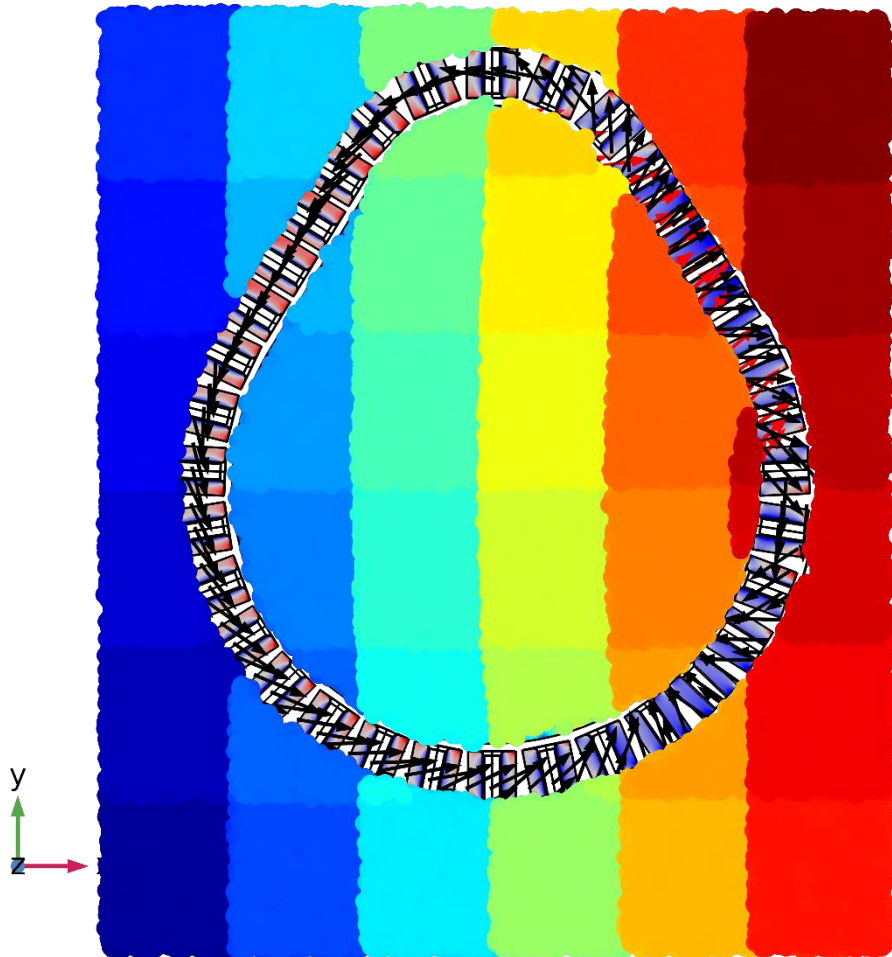
WFI detector plane



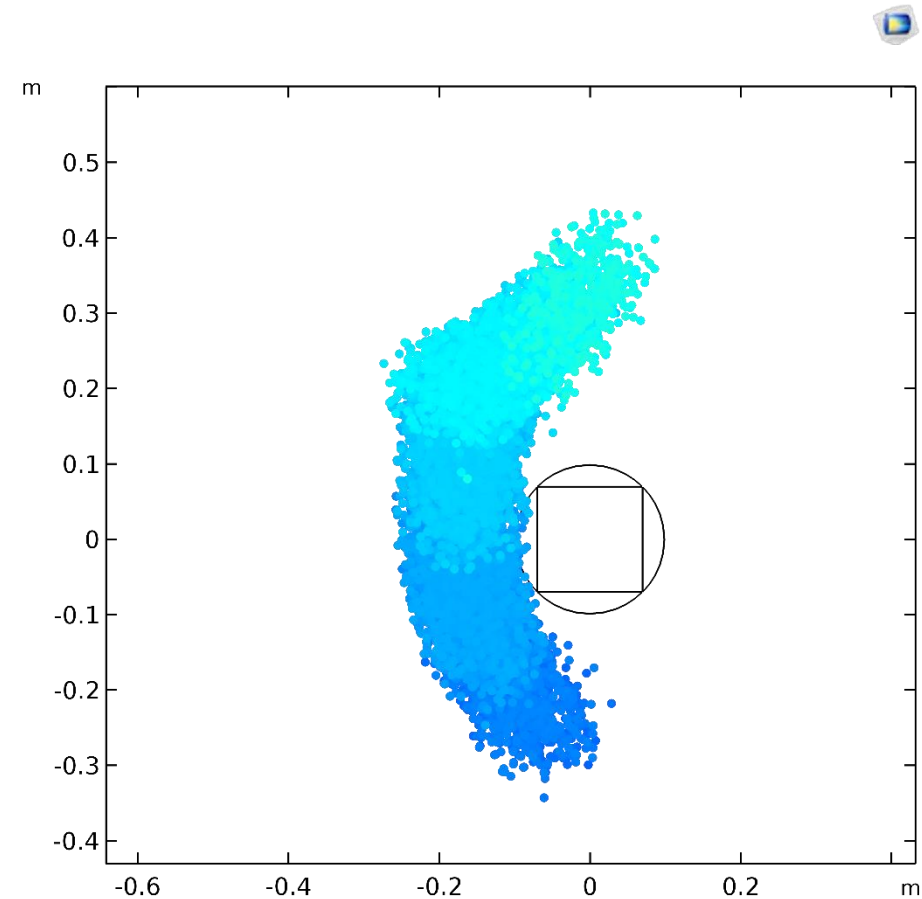


## Pear-shape Halbach Array optimization

Entrance of Halbach Array

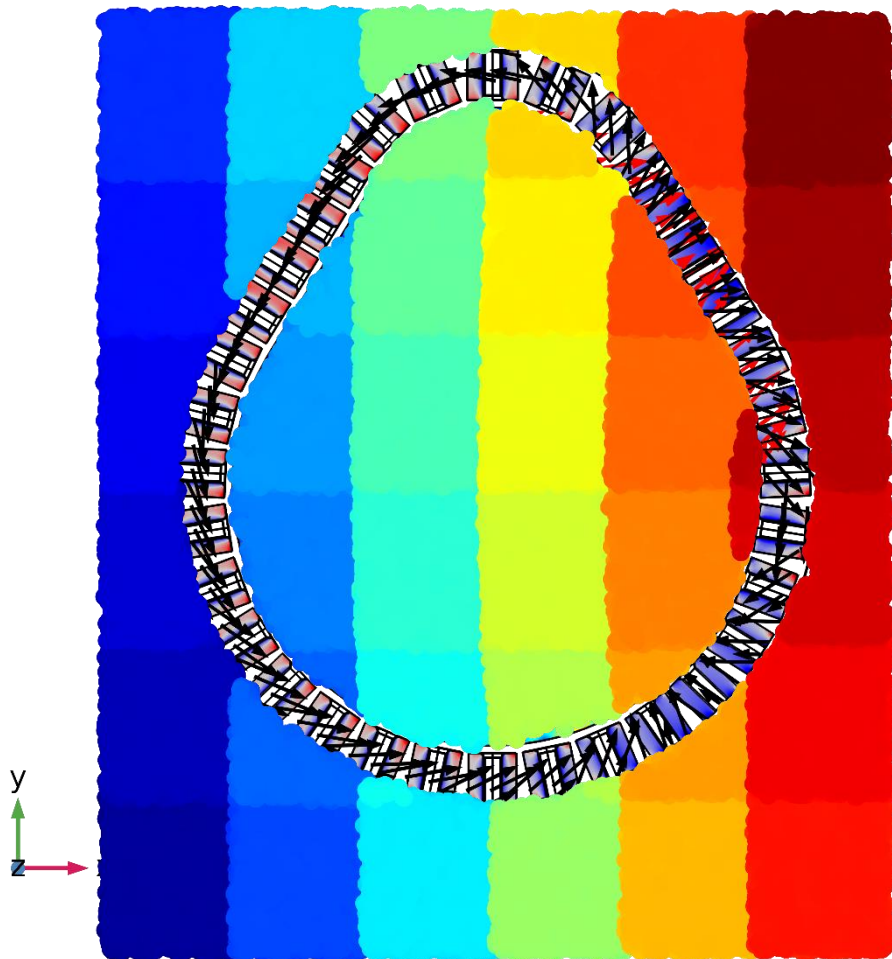


WFI detector plane

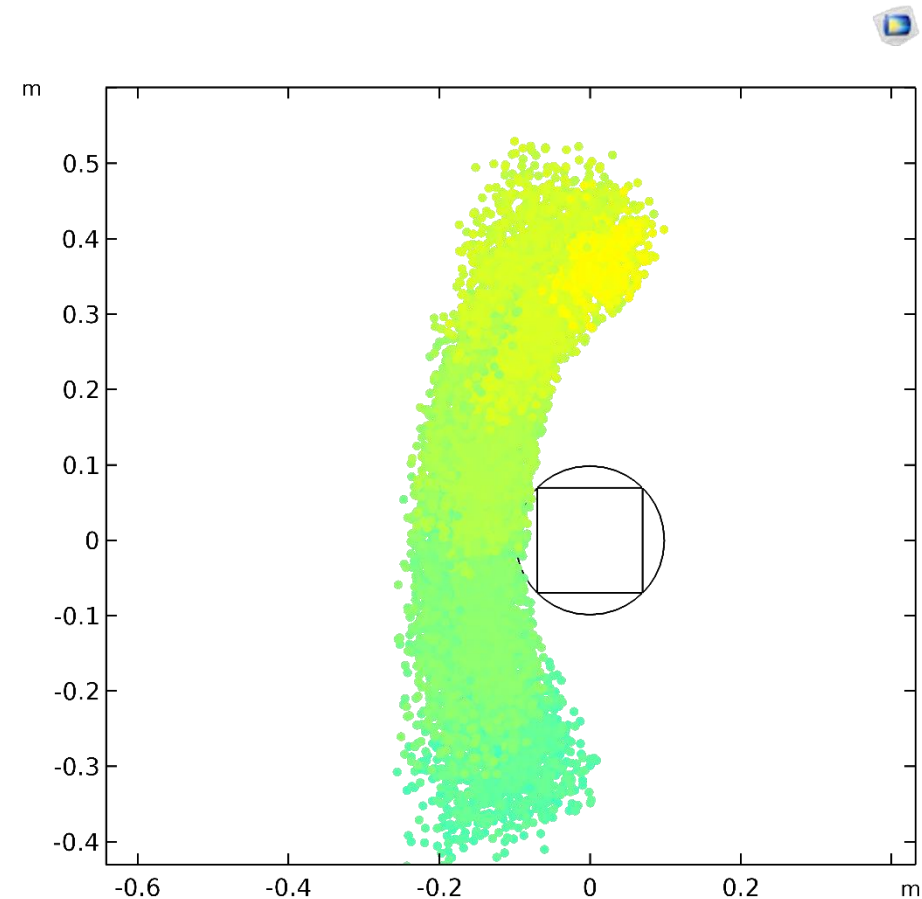


## Pear-shape Halbach Array optimization

Entrance of Halbach Array

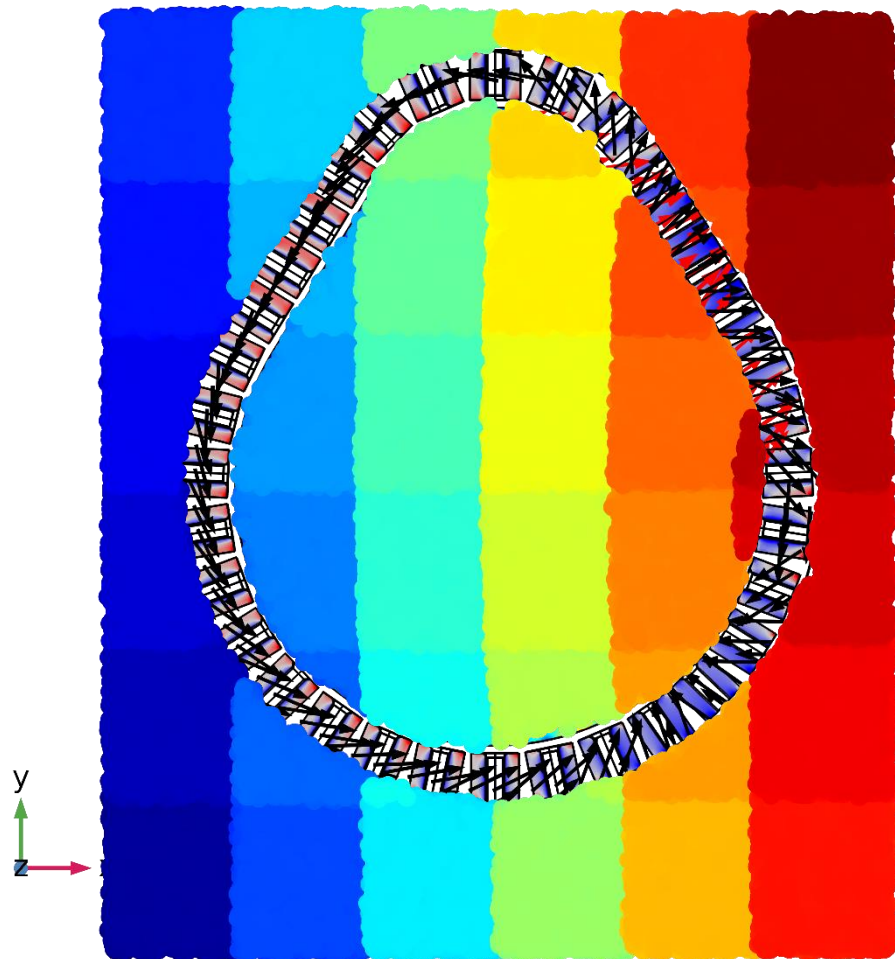


WFI detector plane

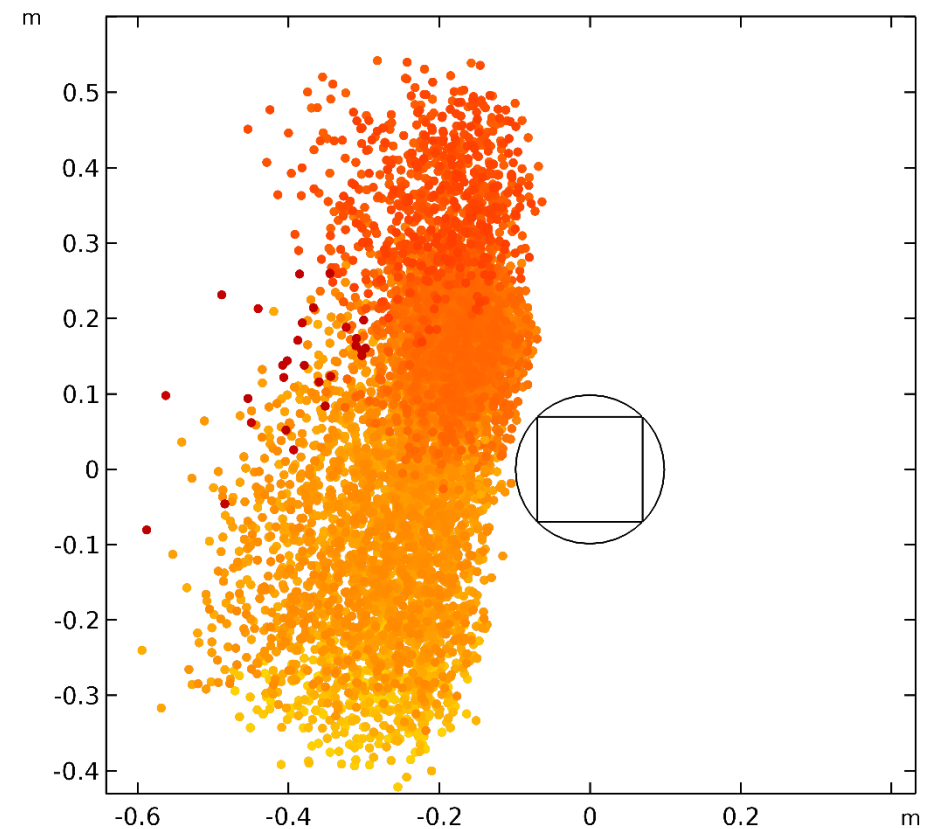


## Pear-shape Halbach Array optimization

Entrance of Halbach Array



WFI detector plane



## STRUCTURAL SOLUTION SHOULD:

Be compliant to magnetic requirements

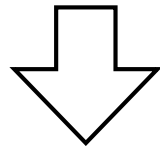
Be as light as possible

Be as stiff as possible

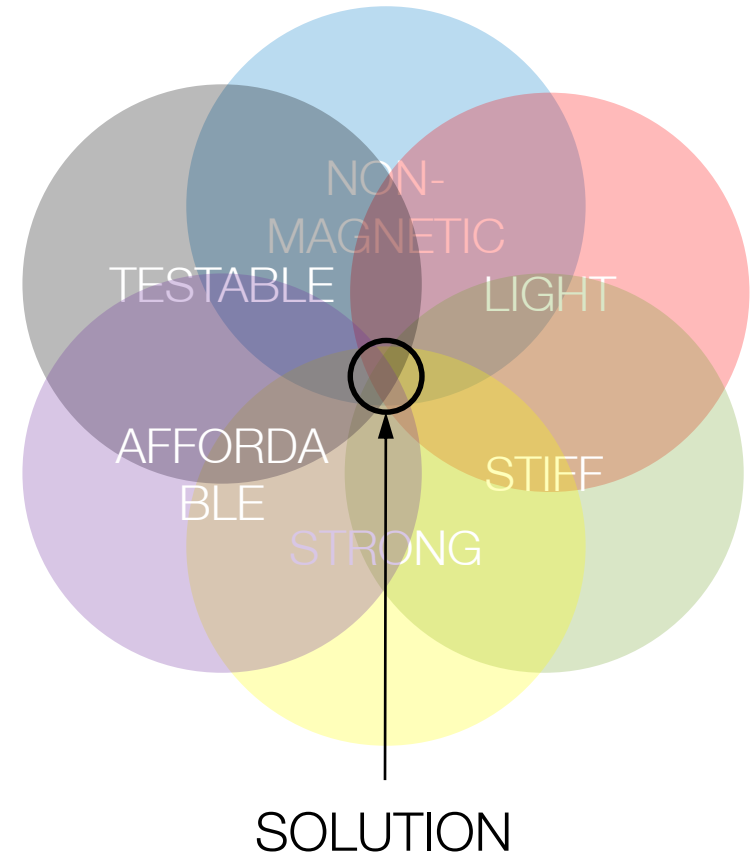
Survive all loads with margin

Be economically feasible

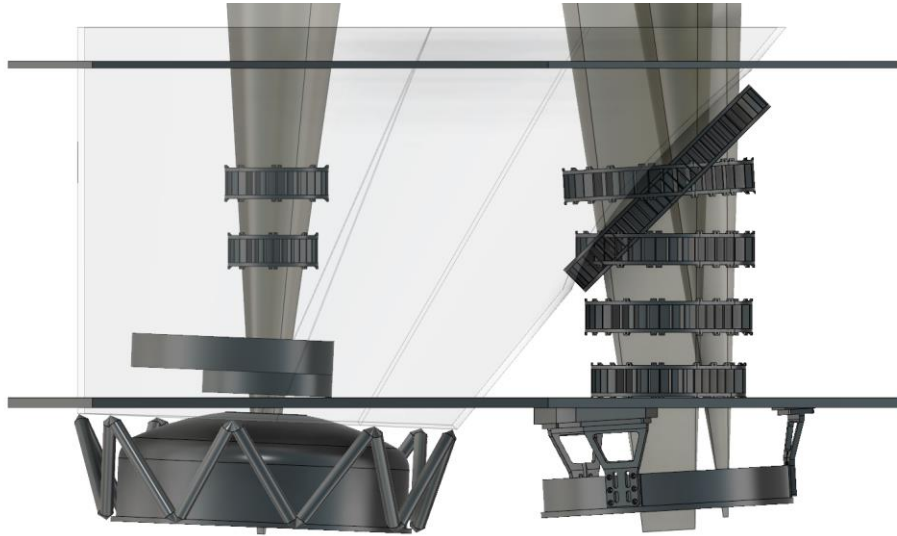
Be feasible to test in Czech facilities



TRADEOFF STUDY



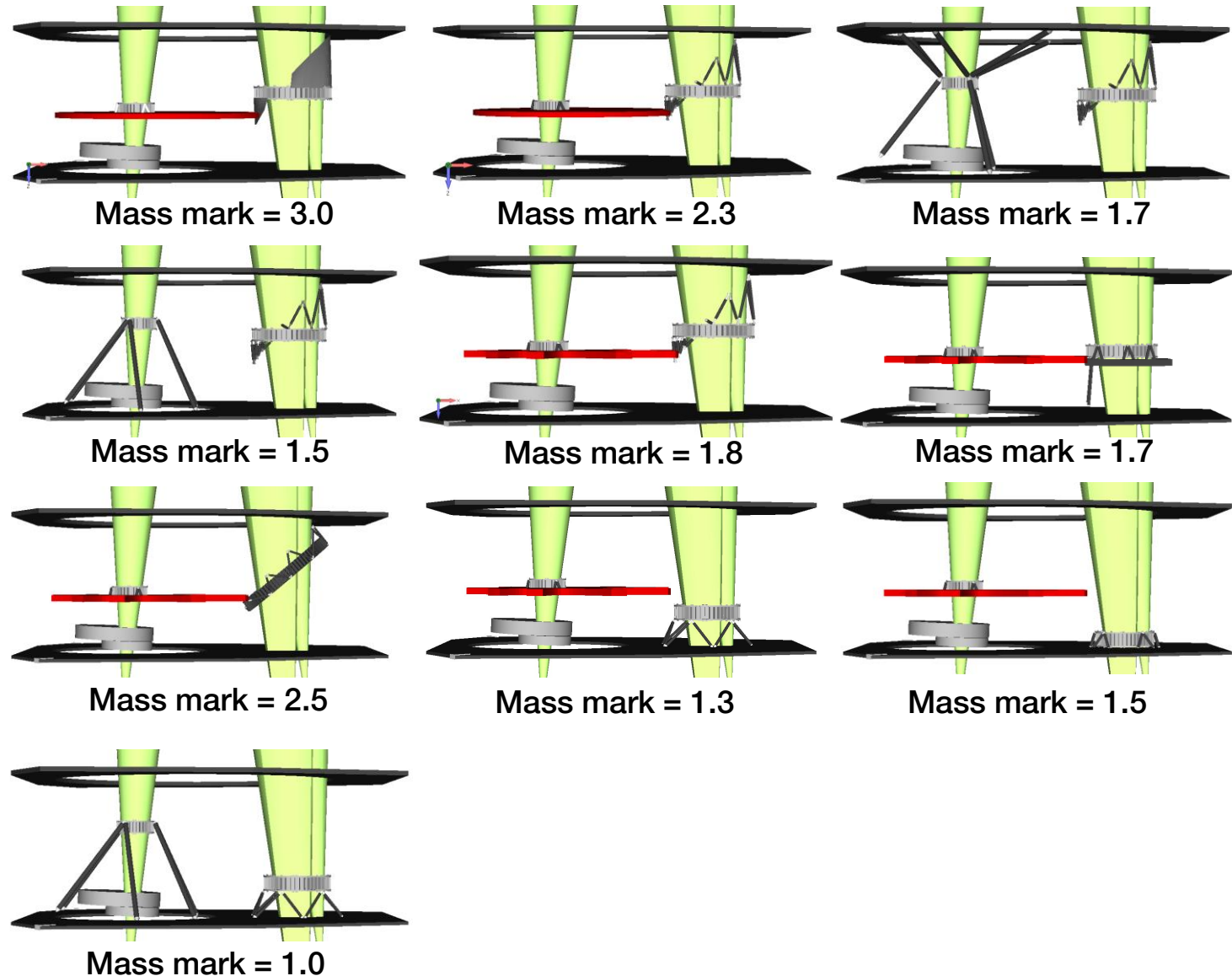




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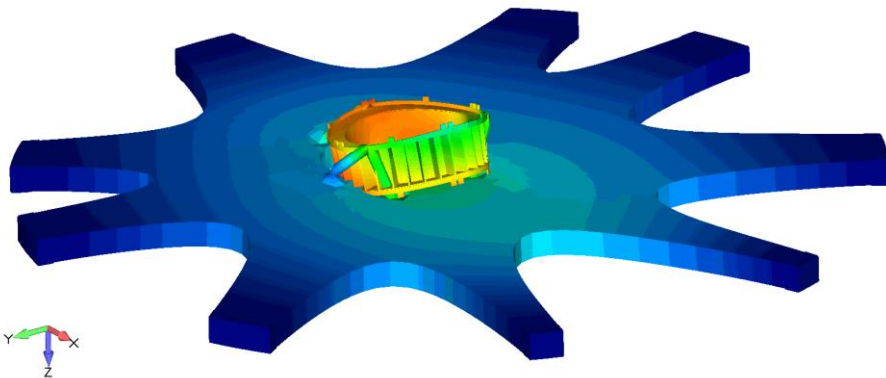
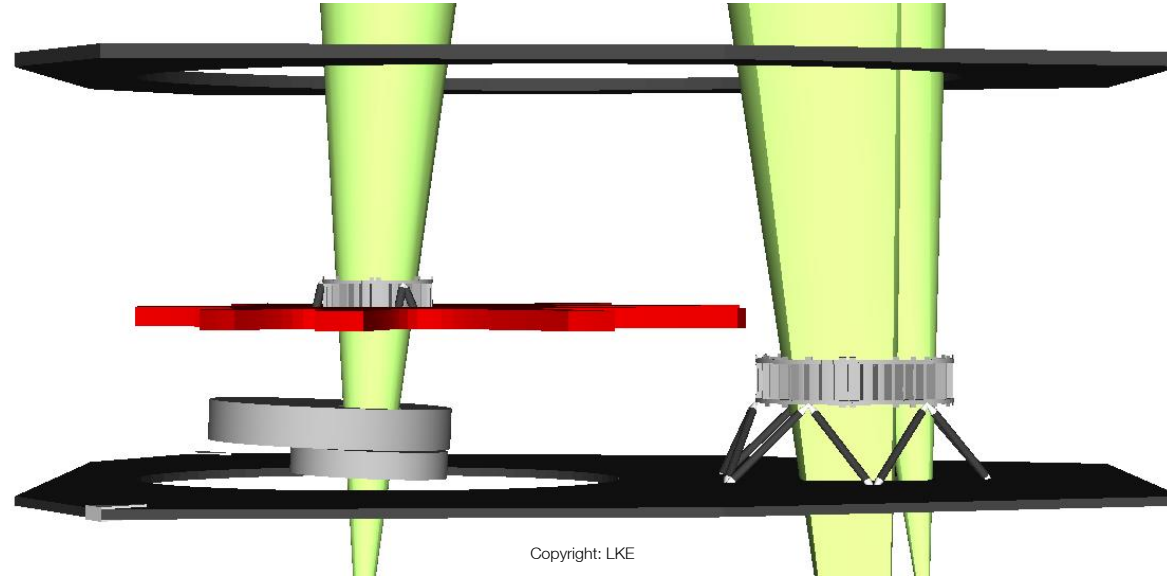
## 10 semi-final configurations

- Mass performance
- Modal performance
- Strength performance
- Test feasibility

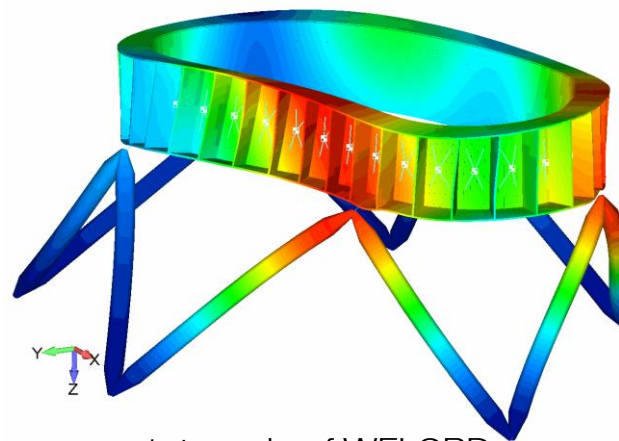




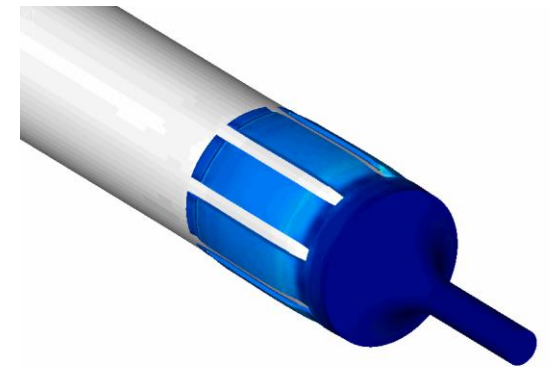
Trade-off winning configuration – **Mass mark 1.3 | compliant eigenfrequency | feasible for test and production**



1st mode of X-IFU CPD

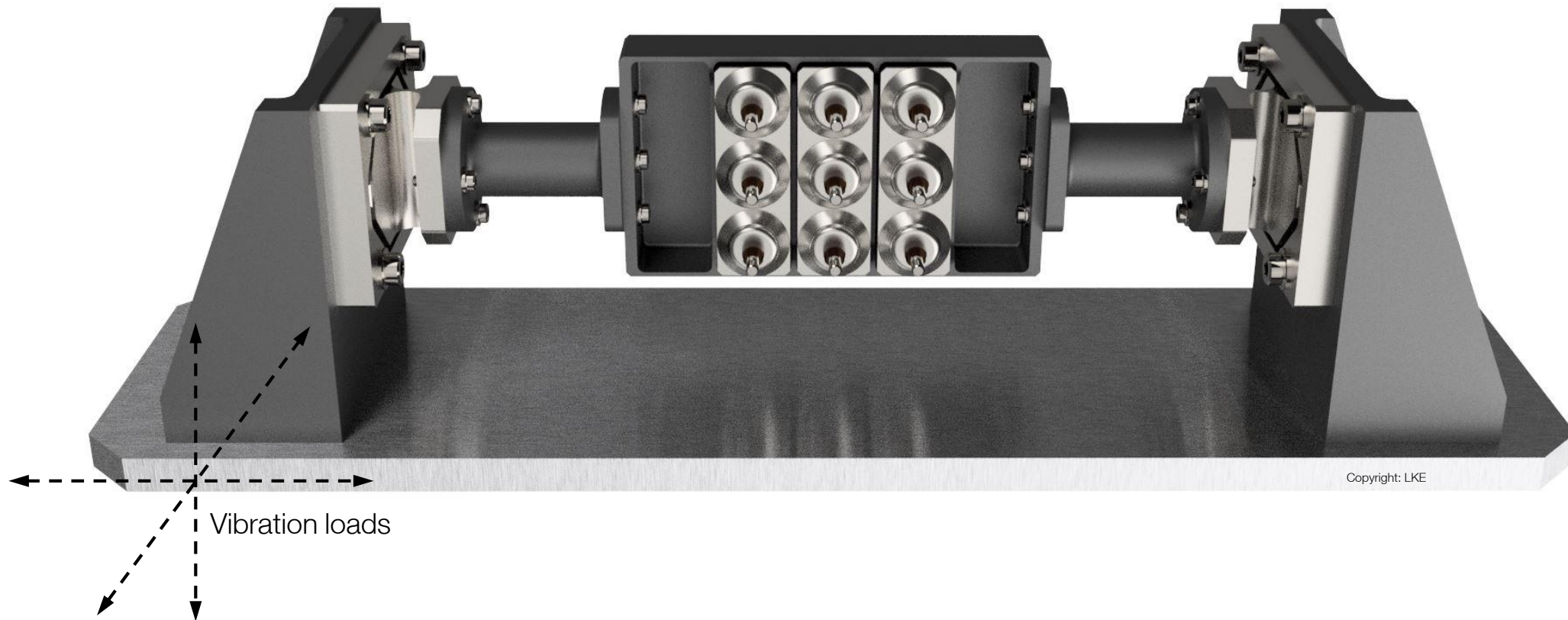


1st mode of WFI CPD

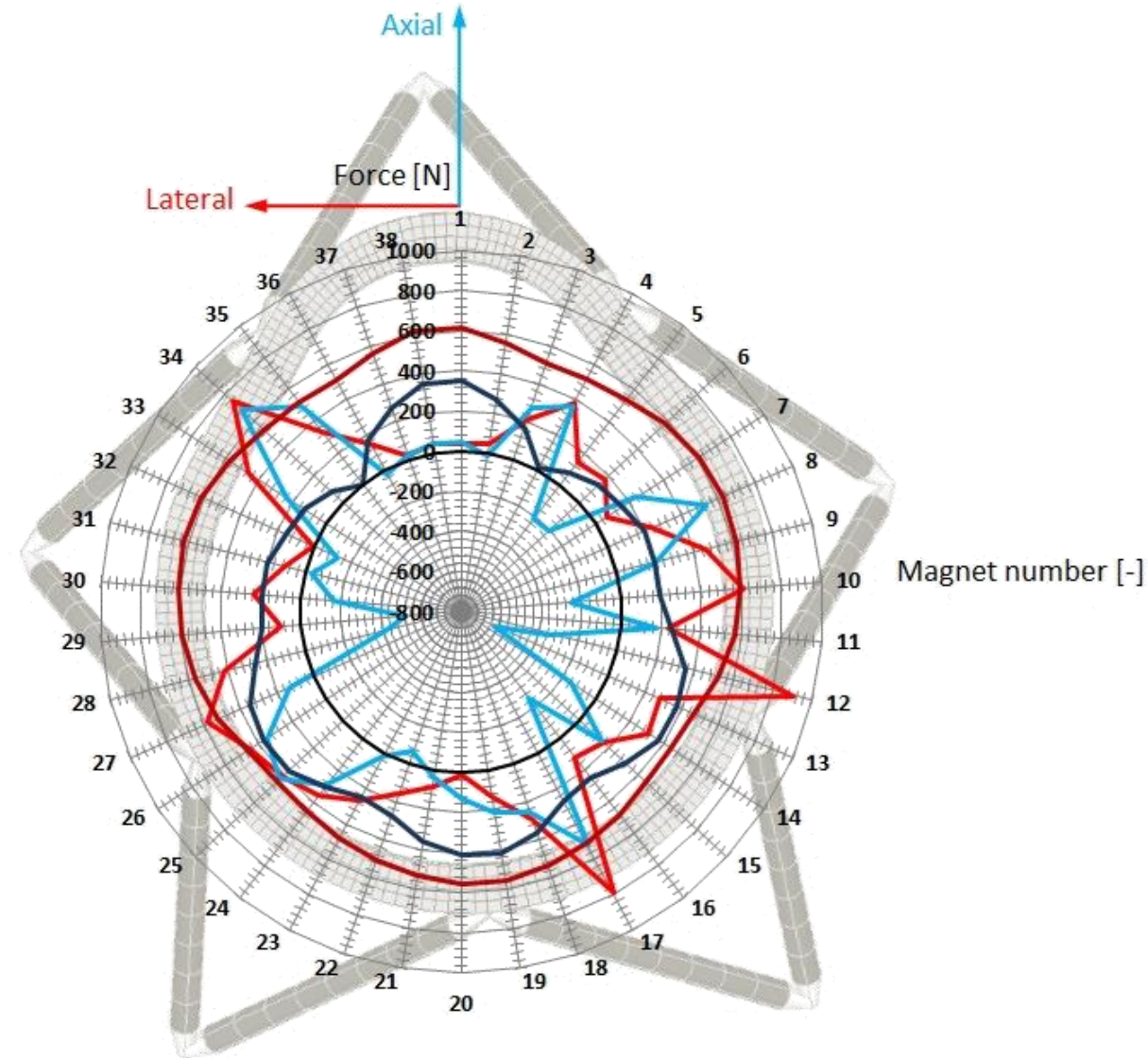


Thermoelastic deformation of strut fitting

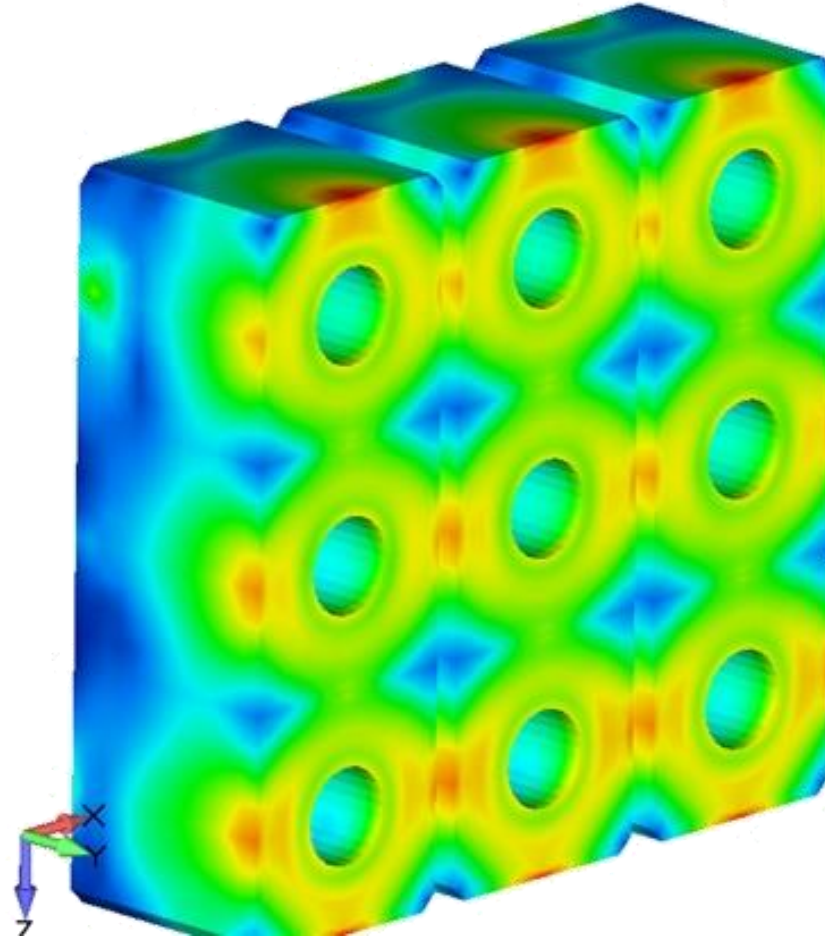
## BREAD BOARD MODEL



## BREAD BOARD MODEL



## BREAD BOARD MODEL





Optimized sandwich panel

X-IFU

CFRP strut system

WFI

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- Preliminary magnetic & structural design
- Preliminary Design Review **january 2019**
- Critical Design Review **spring 2019**
- Engineering qual. model **summer 2019**



Qualification tests late 2019 ⇒ Roadmap to flight model

Thank you for your attention

Ask us

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