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MADMAX
Uni. HH activities

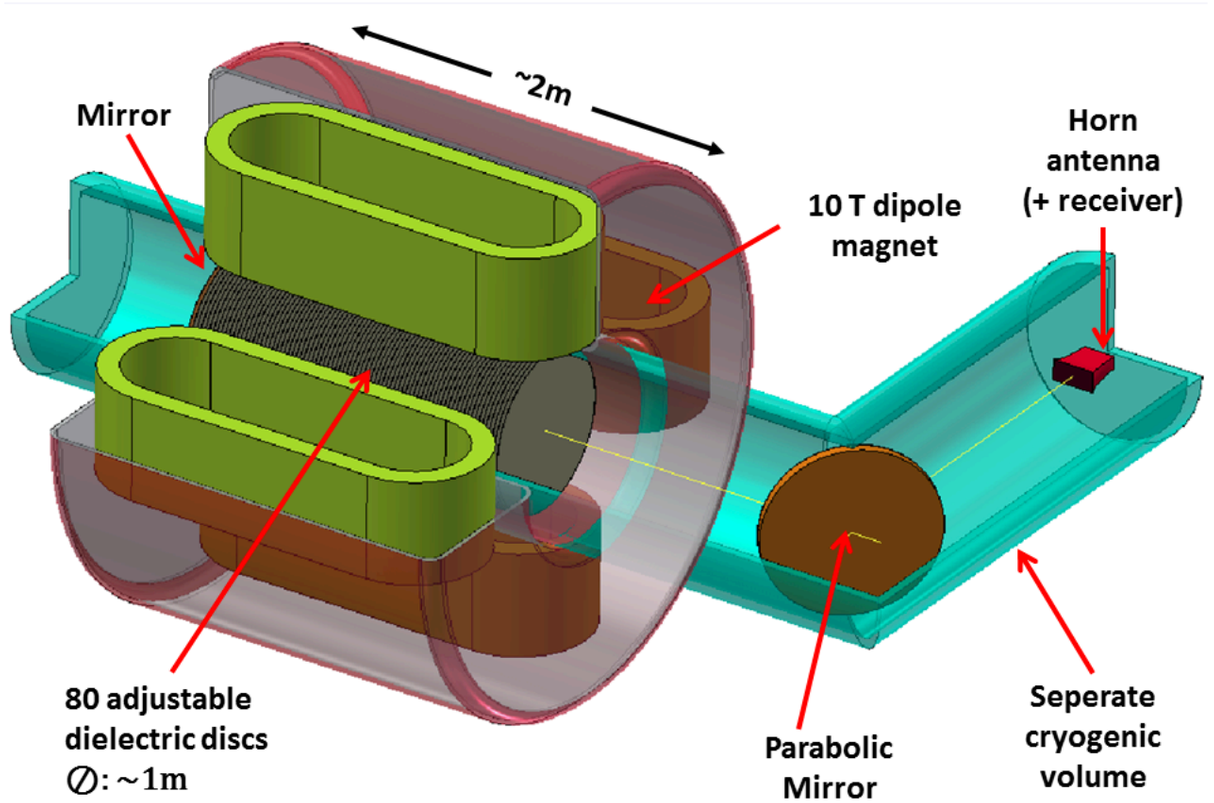
Nils Böhmer, Erika Garutti, Stephan Martens,
Michael Matysek, Jan Schütte-Engel

Uni. HH commitments

Phase-0: collaboration forming / laboratory feasibility test (now)
- 3D simulation studies
- develop dielectric disk tiling procedure
- design disc mechanic support

Phase-I: prototyping (2018-2021)
- build proto-disc (30 cm ∅ & 100 cm ∅)
- design / test booster mechanics
- build porto-booster (20 disks / 30 cm ∅)
- build / operate cryogenic vessel for booster
- integrate proto magnet (4T)

Phase-II: full scale experiment (2021-2031)
- build booster (80 disks / 1 m^2)
- build / operate cryogenic vessel for booster
- integrate magnet (10T)



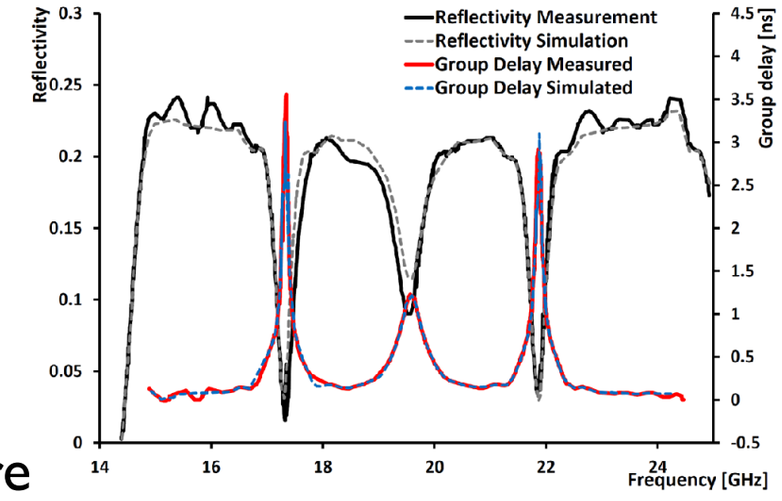
Need an experimental hall with cryogenic facility starting ~ 2019

➔ currently evaluated option: **HERA North hall**

Solving Maxwell-Axion equations numerically in 3D

Jan Schütte-Engel

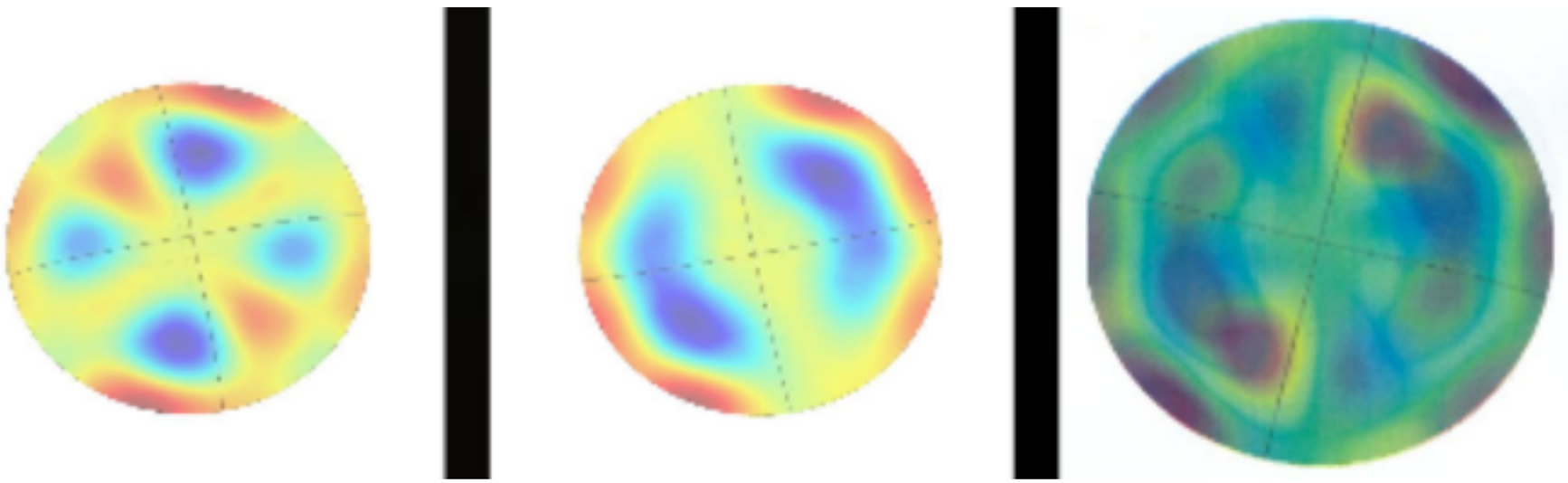
- Solve Maxwell equations for simple examples that can be calculated analytically.
  Compare to numerical results to check that setup works.



- Apply code to simple resonator.
  Goal: Find the physical reason of loss in reflectivity
  in correspondence of group delay peak.

- Solve Maxwell-Axion equations numerically with COMSOL software

Similar work published (cavity-like homogeneous spherical media) in poster [P. Hoang].
But they solve Maxwell-Axion equations with duality symmetry.
Equations do not coincide with our equations.

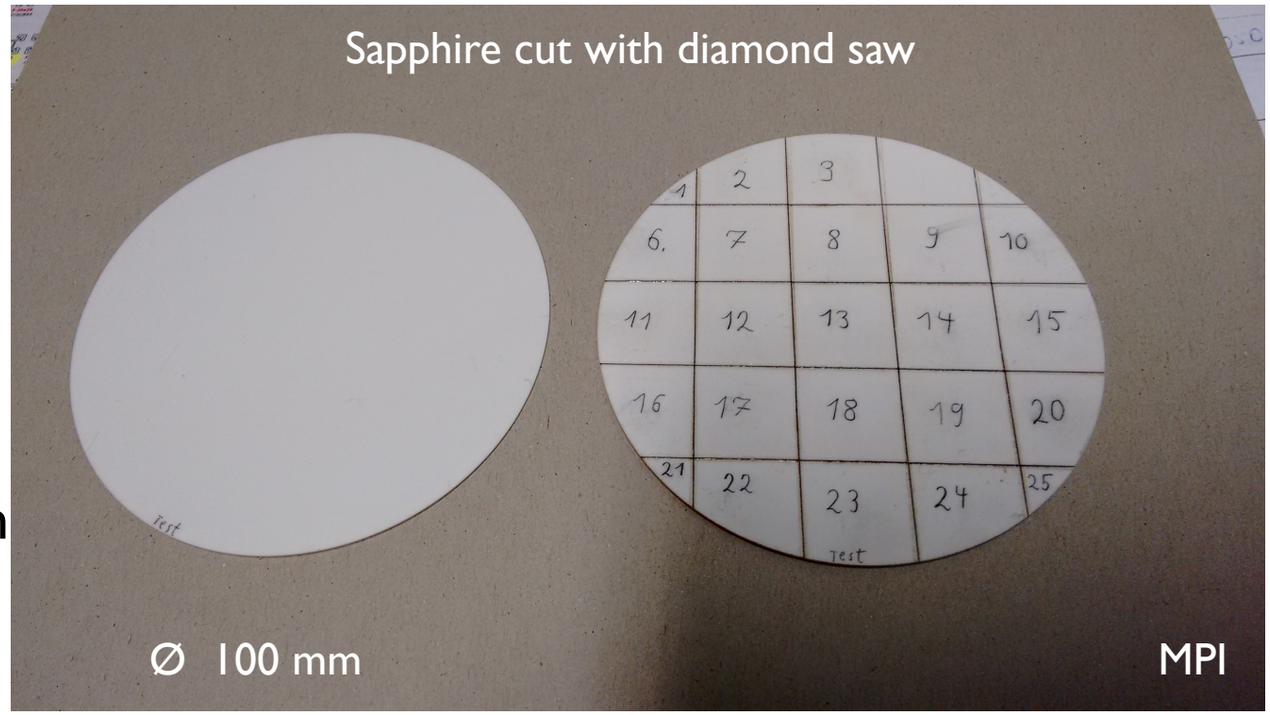


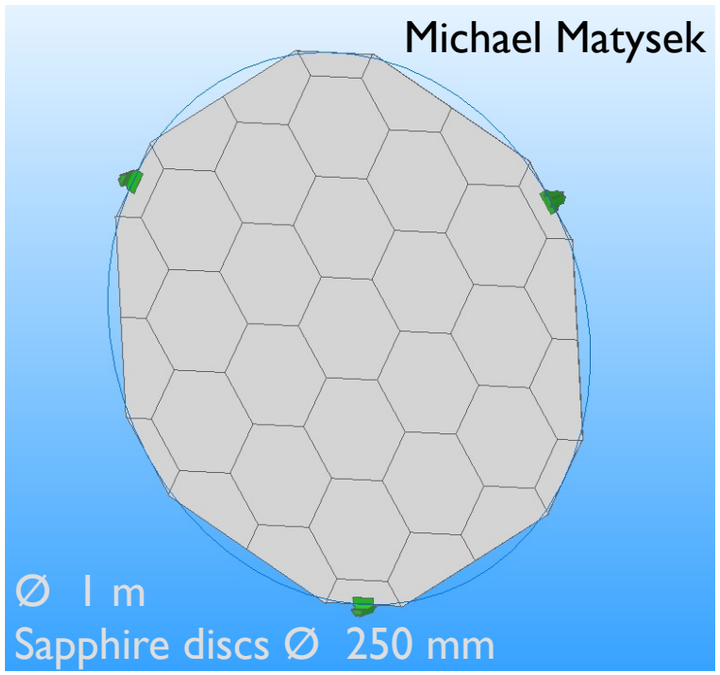
E-field (without axions) E-field (with axions) pure axion effect on E-field

Tiling: Cutting

- Two materials considered so far:
  Sapphire $\varnothing_{max}$ ~250 mm
  $LaAlO_3$ $\varnothing_{max}$ ~50 mm

- Considerations:
  - large number of cuts / various shapes
  - dielectric thickness: 0.5-1 mm, // 0.05 mm
  - hexagonal shape is favourable





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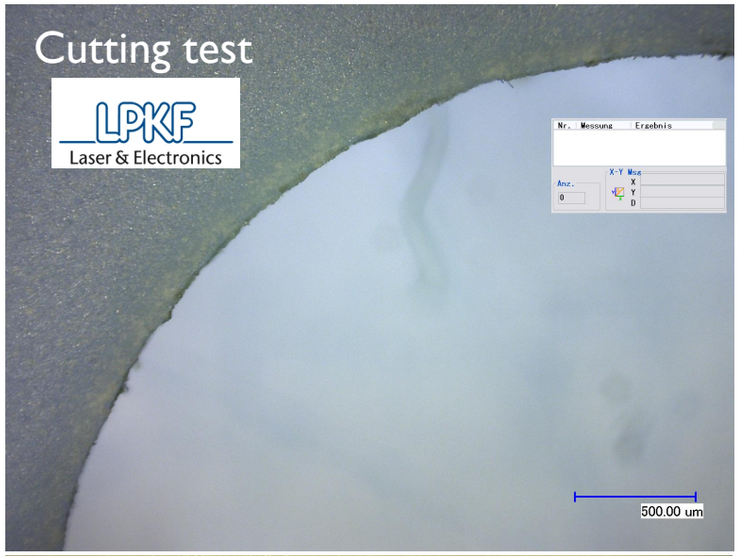
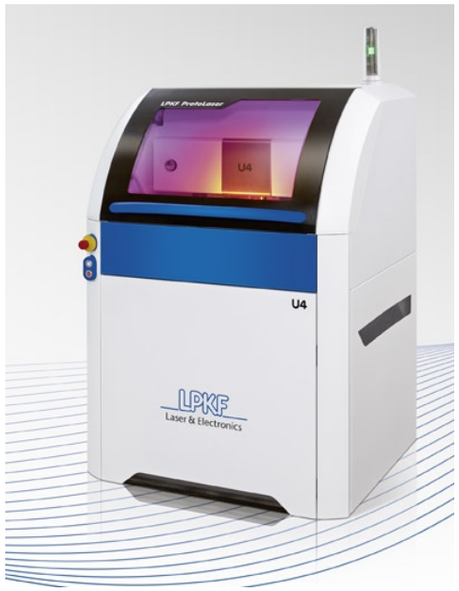
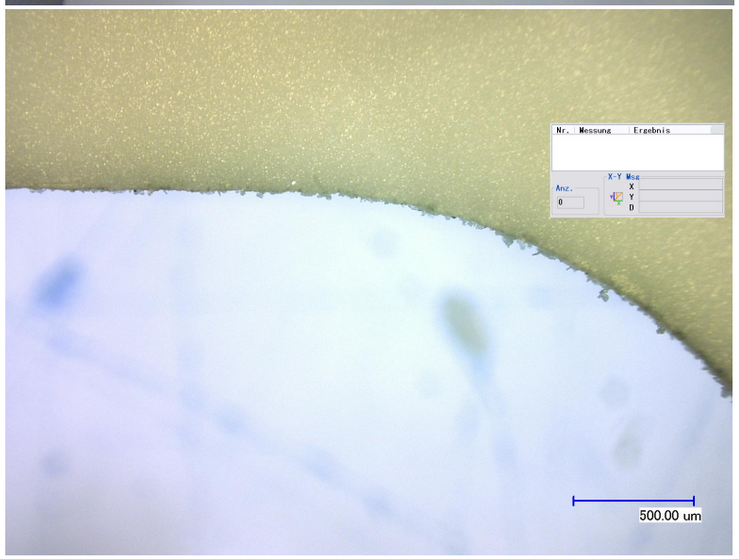
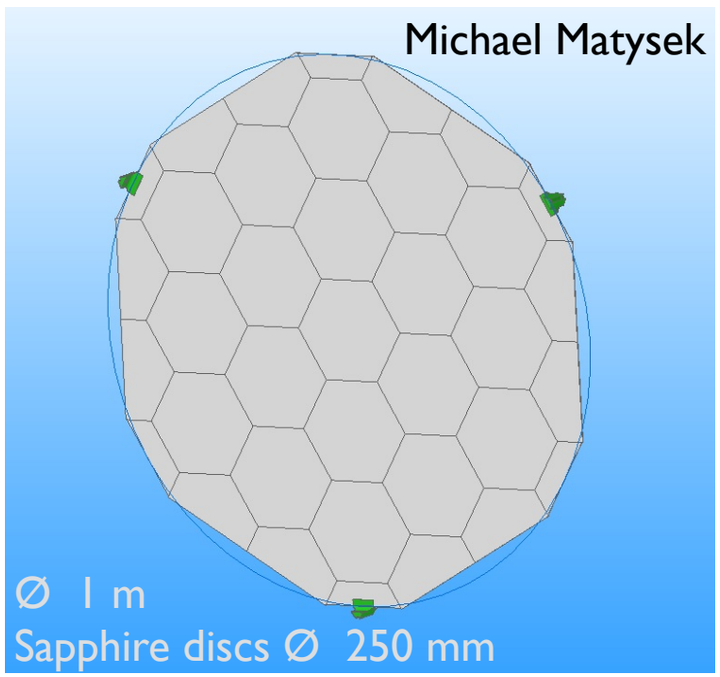


ProtoLaser U4



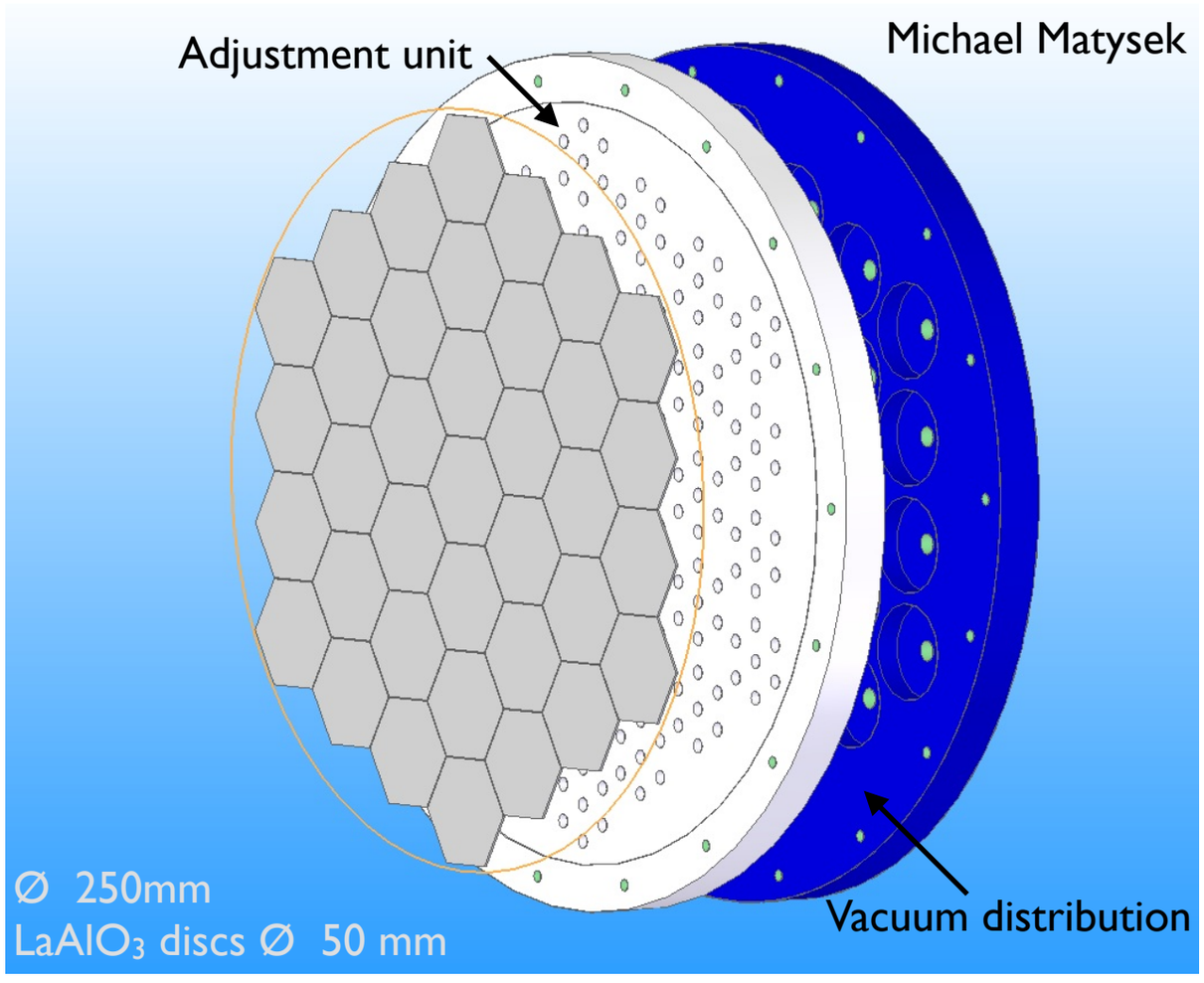




max. dimensions and layout-area	229 mm x 305 mm x 10 mm
laser-wavelength	355 nm
laser-pulse frequency	25 kHz - 300 kHz

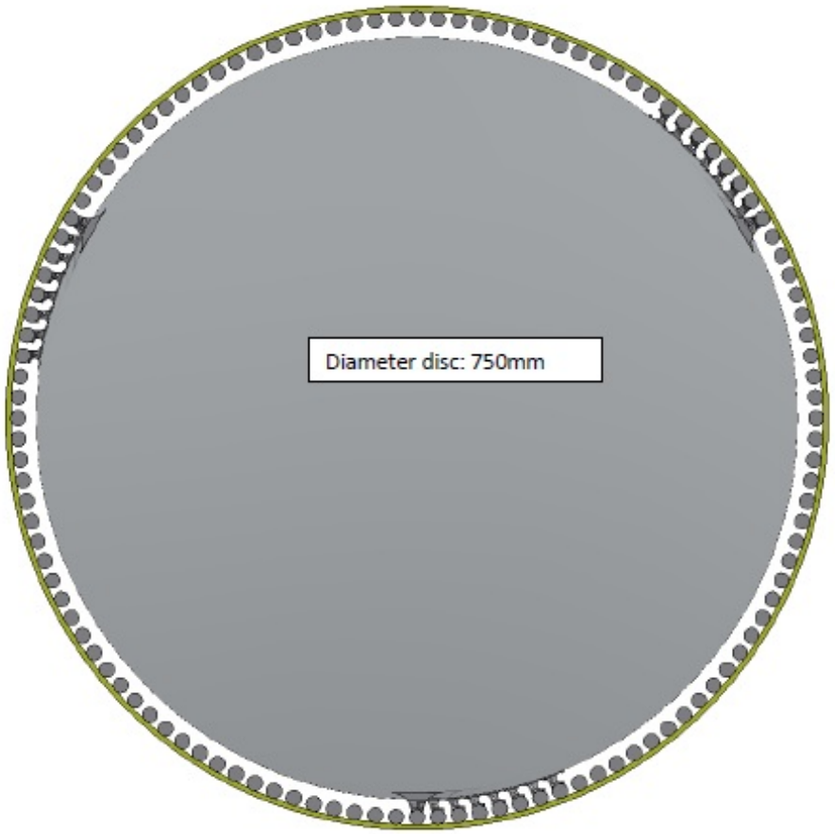
Tiling: Gluing

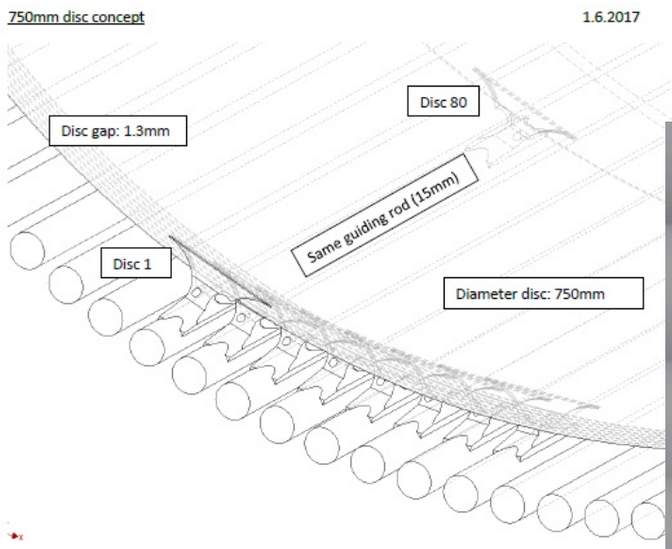
- Develop vacuum fixation jigs to tile dielectric hexagons
- Dispense glue via robotic arm in ~0.2 mm predefined gaps
- Surface polish with robotic arm
- Test on Ø 300 mm ➔ if successful build jigs for Ø 1 m

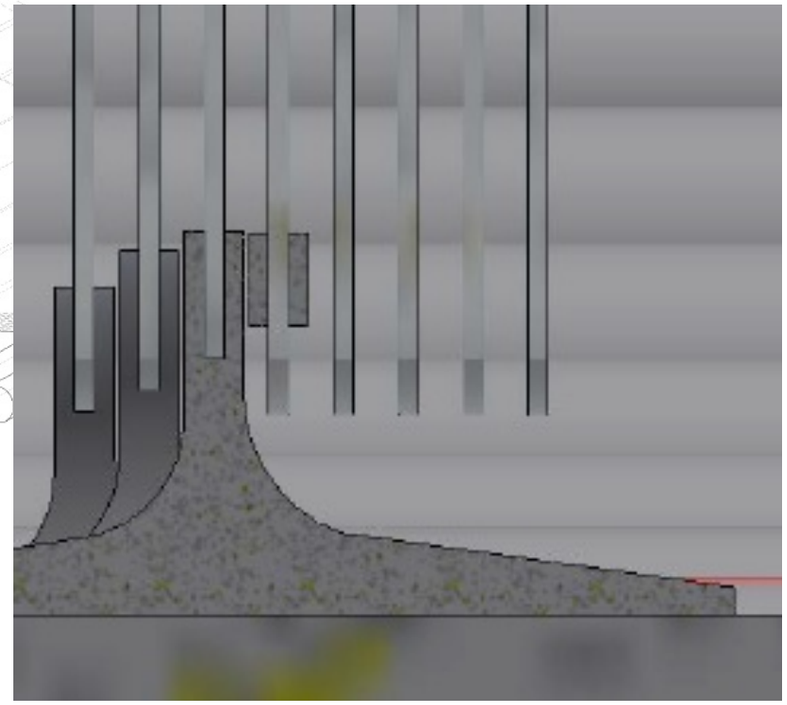


Booster mechanic

- Design mechanic support - inspiration after the 1st MADMAX workshop
- Challenges:
  - Max movement 1.3 m
  - Min disc distance 1.3 mm
  - Adjustment precision ~10 µm
  - Operate in ultra-high vacuum (?? 10^{-8} mbar)
  - … at 4 K
  - … at 8 T
- Idea: use 3 glass rods fixed to one disc to slide along reference guides





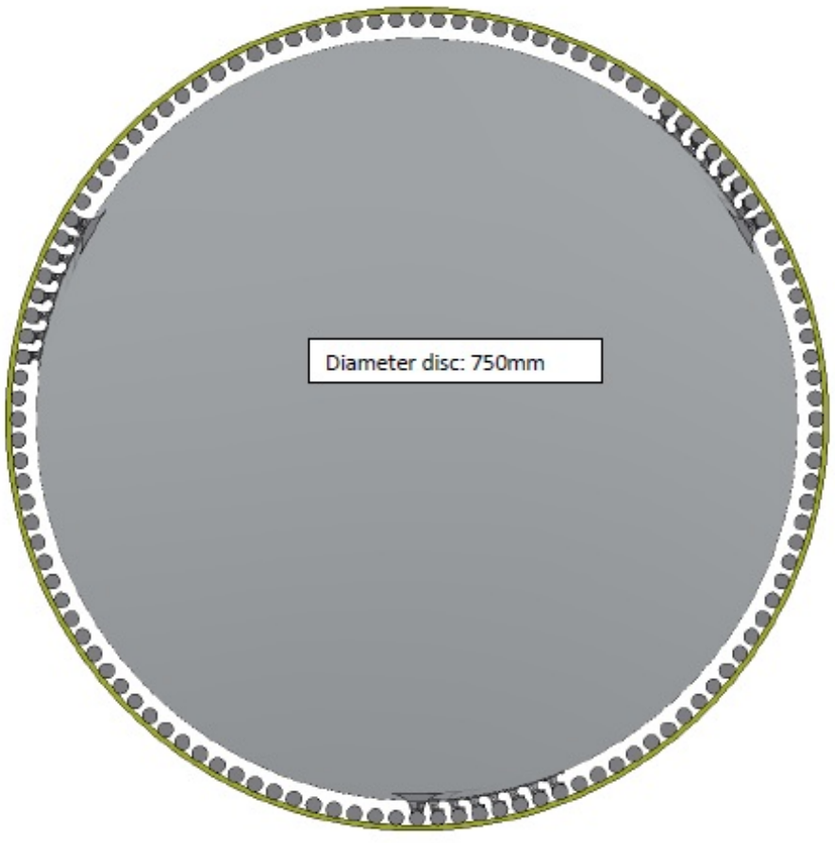


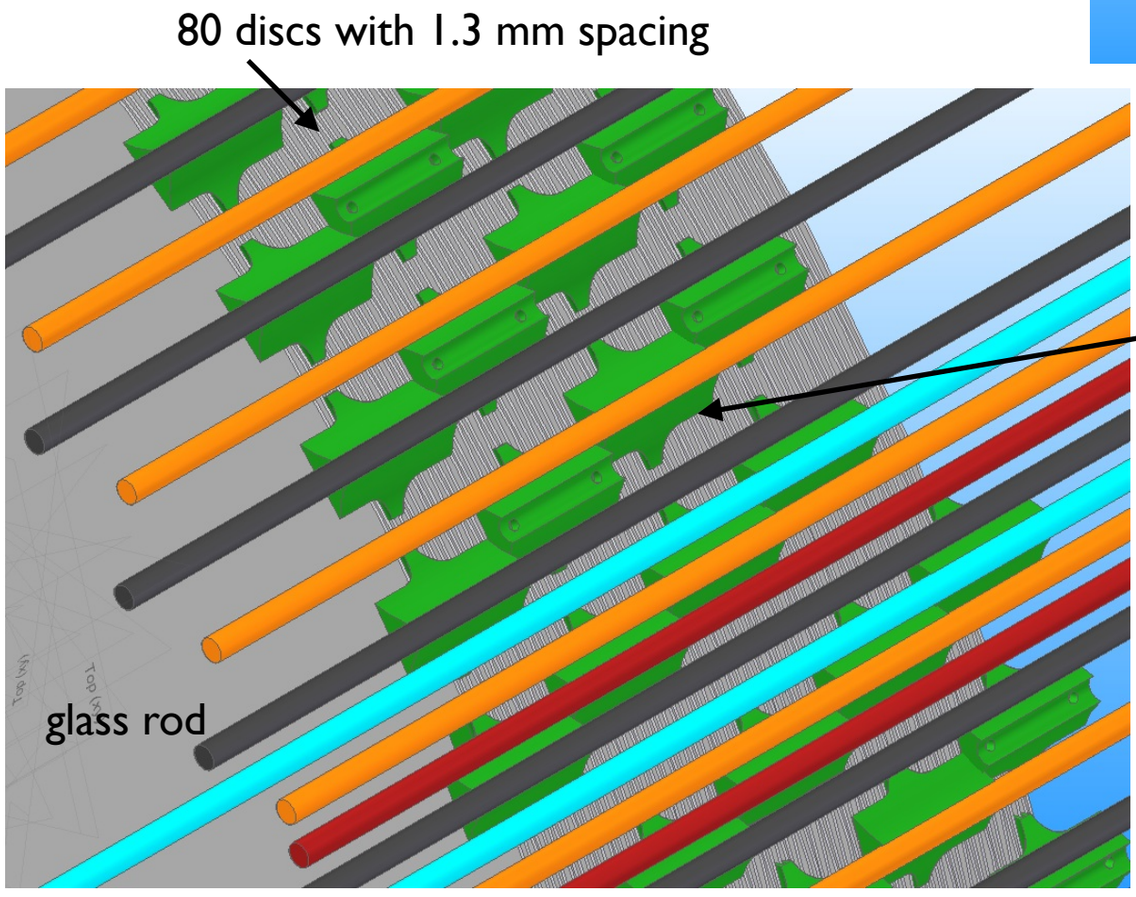
80 Disk move between
1,3 mm to 15,0 mm
pecision // 0.003mm
Disk 80 move ~ 1100mm
from Pos. 184mm to 1280mm

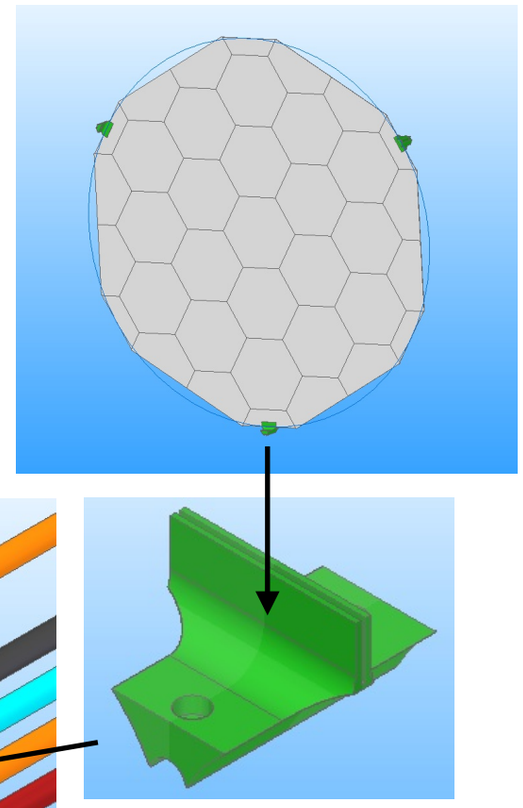
Michael Matysek + David Kittlinger

Booster mechanic

- Slide discs inside mechanical fixation (disc holder)
- 3 disc holders / disc @ 120°
- Disc holder "screwed" to glass rod





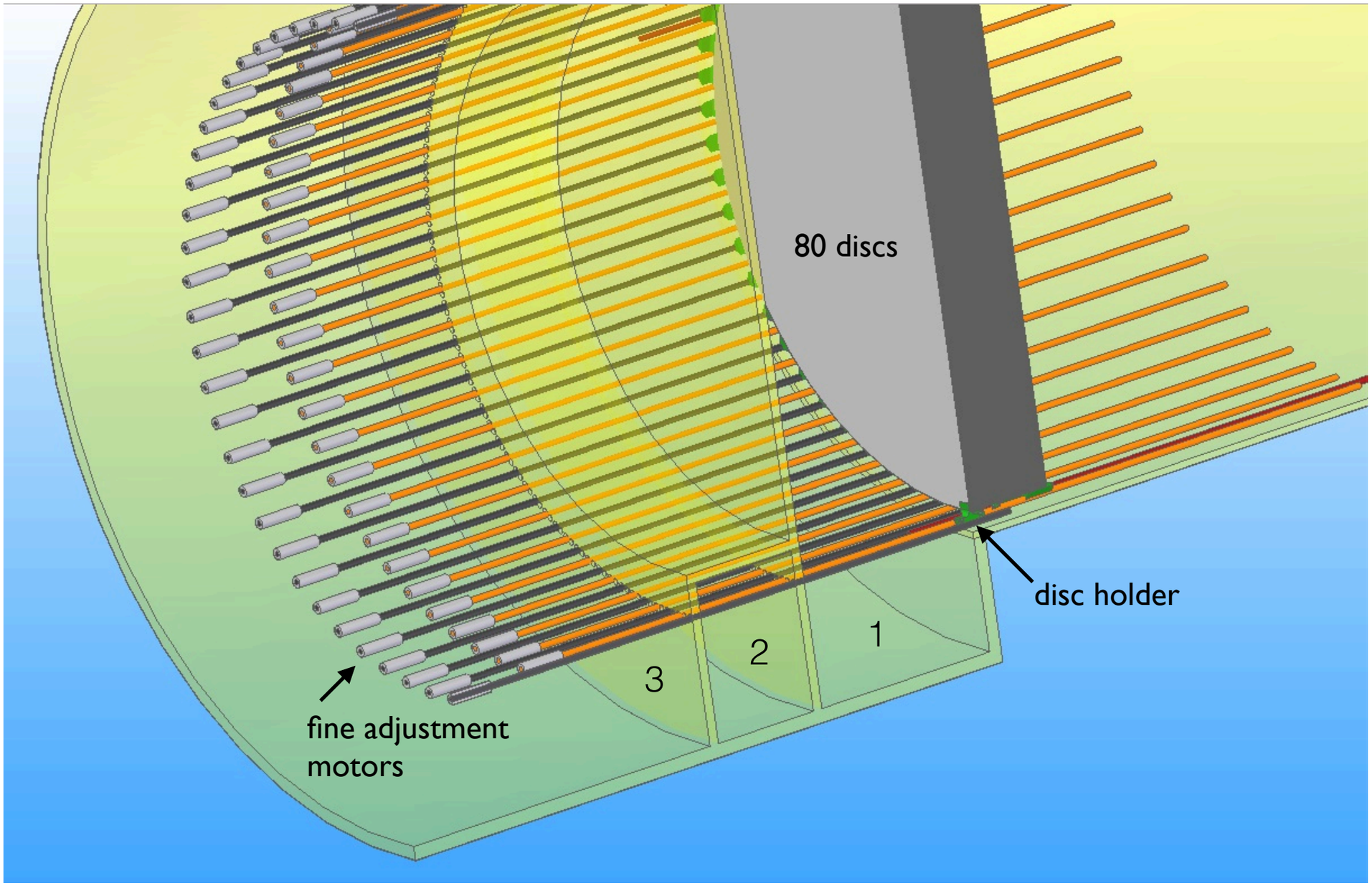


disc holder

No collision between disc holders

Booster vacuum

- Rods are fixed to discs inside the main vessel chamber (1) 10^{-8} mbar
- … move through a pre-vacuum chamber (2) 10^{-5} mbar
- … and are steered from the mechanics vacuum chamber (3) 10^{-3} mbar



Michael Matysek

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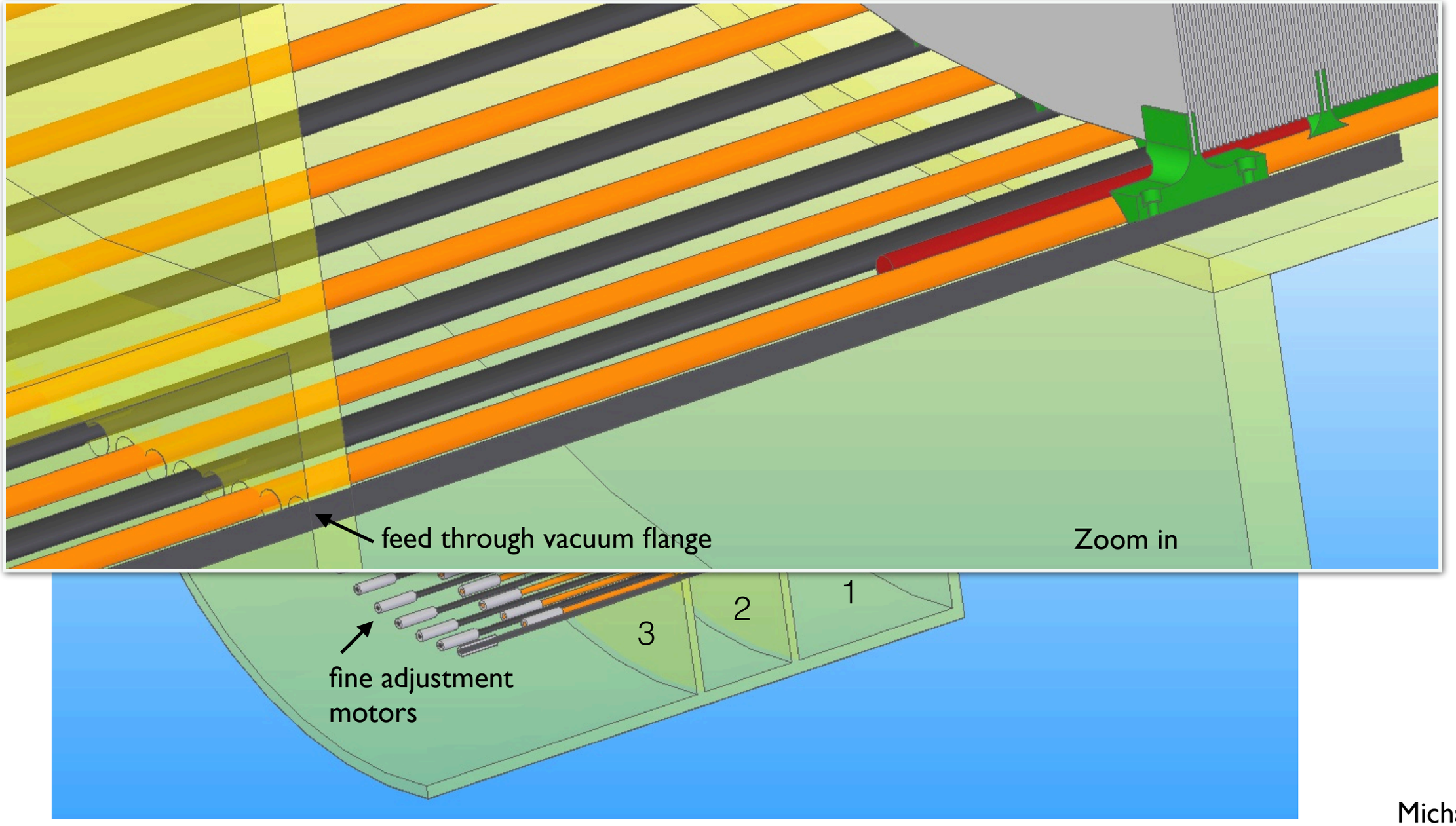
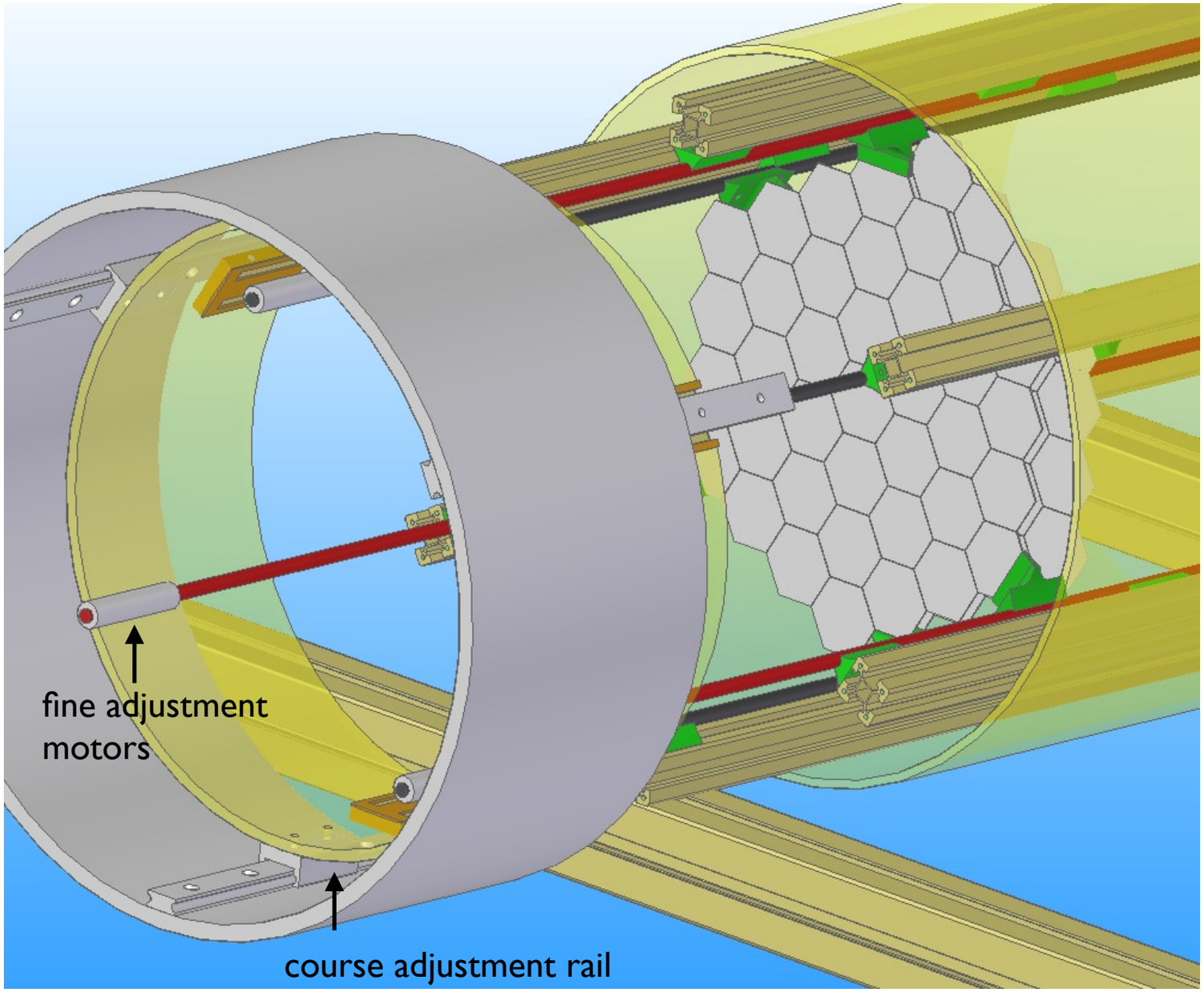


Michael Matysek

Booster motors

- The movement is steered by two motor controlled movement
- Corse movement: max 1.3 m
- Fine movement: ± 2.5 mm



Prototype booster mechanics

Ø 300 mm

Michael Matysek

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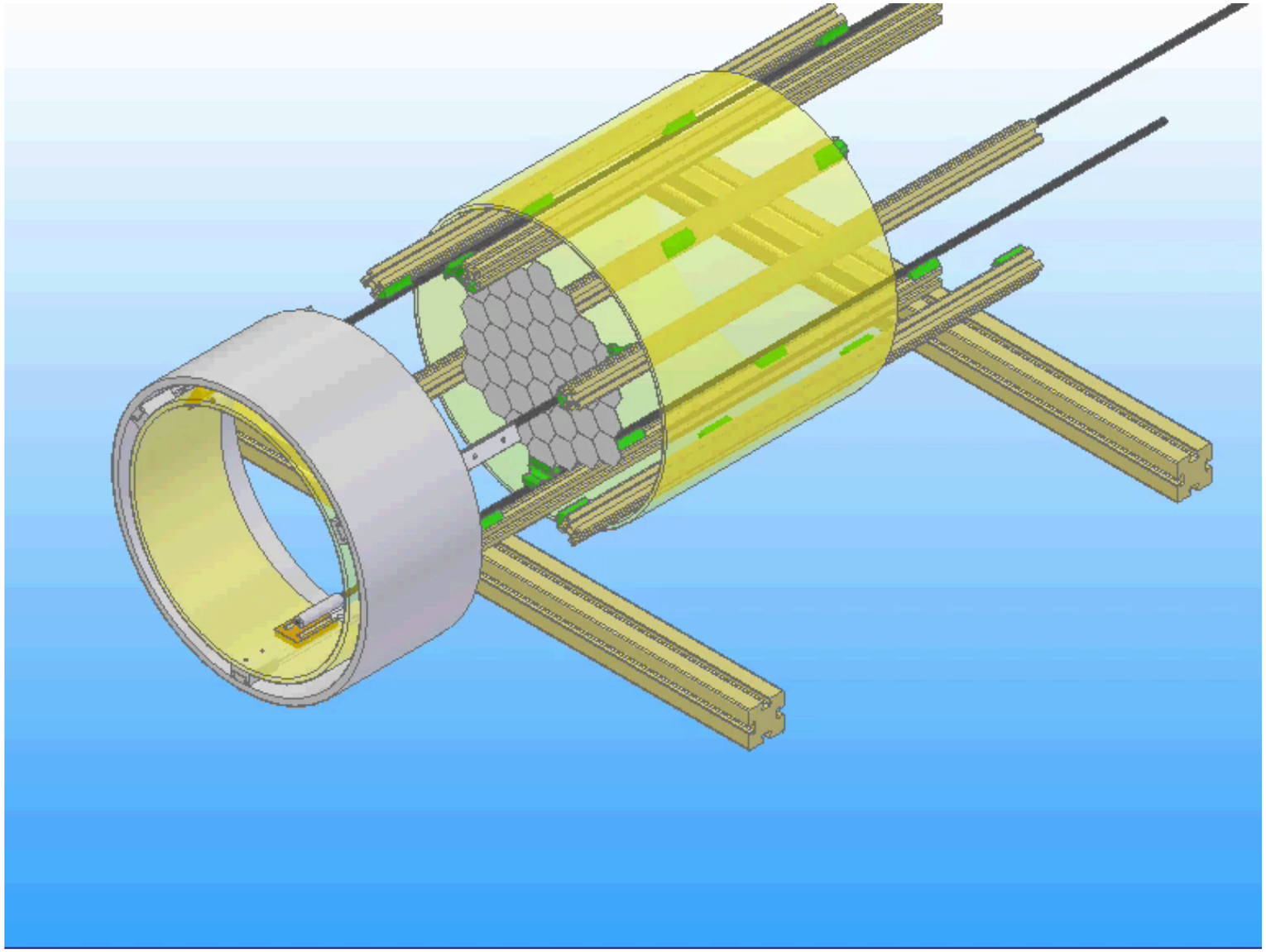

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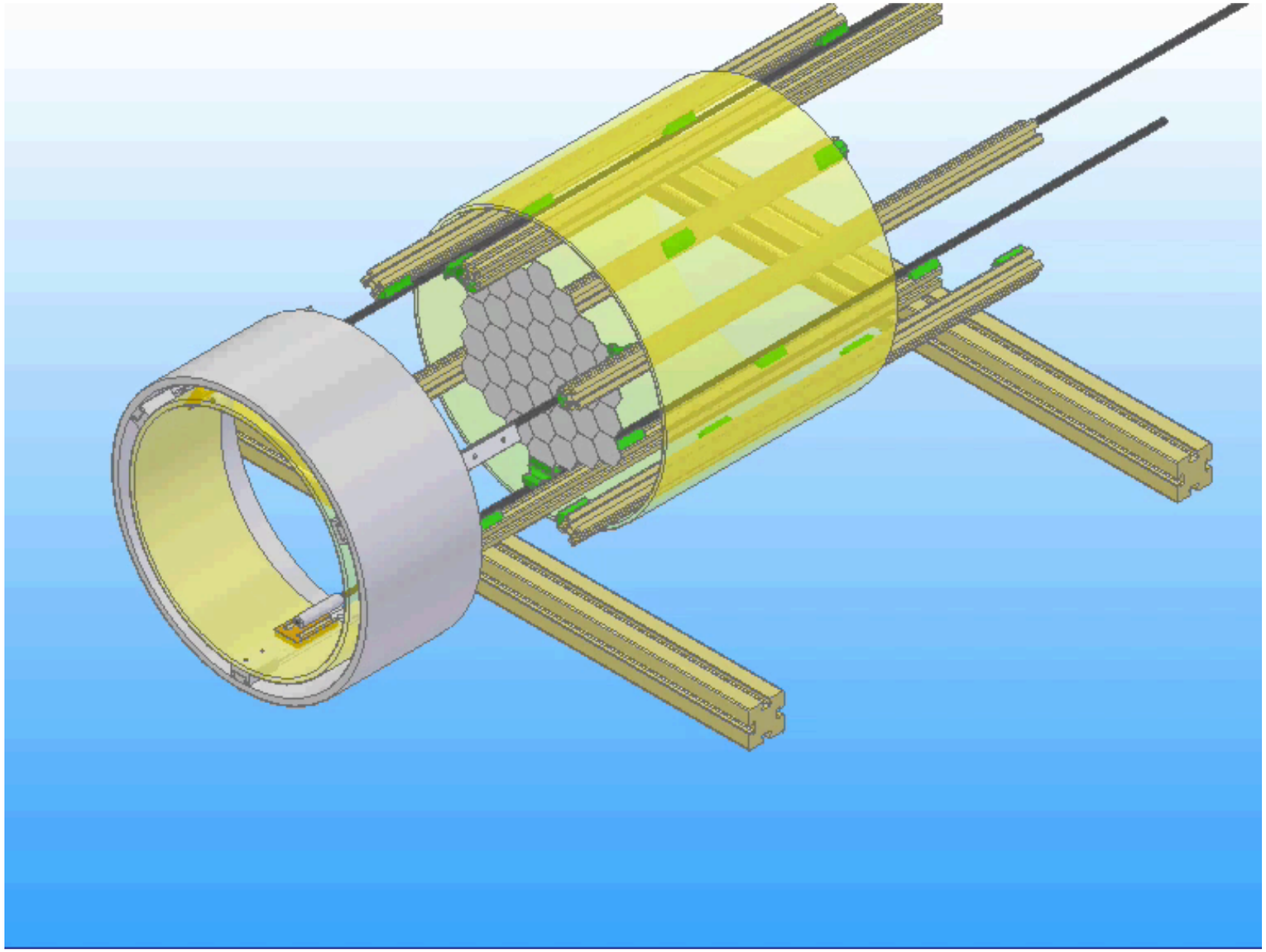


Prototype booster mechanics

Ø 300 mm

Michael Matysek

Plan

- Booster mechanics
  - thinking work has started, will require discussion and many iterations with MPI, magnet designers, Uni Tübingen for laser alignment system

- Dielectric disc tiling
  - cutting machine needs further qualification for Sapphire
  - gluing jigs: thinking work started
  - setup for characterisation measurements discussed with Olaf / under assembly in our lab.

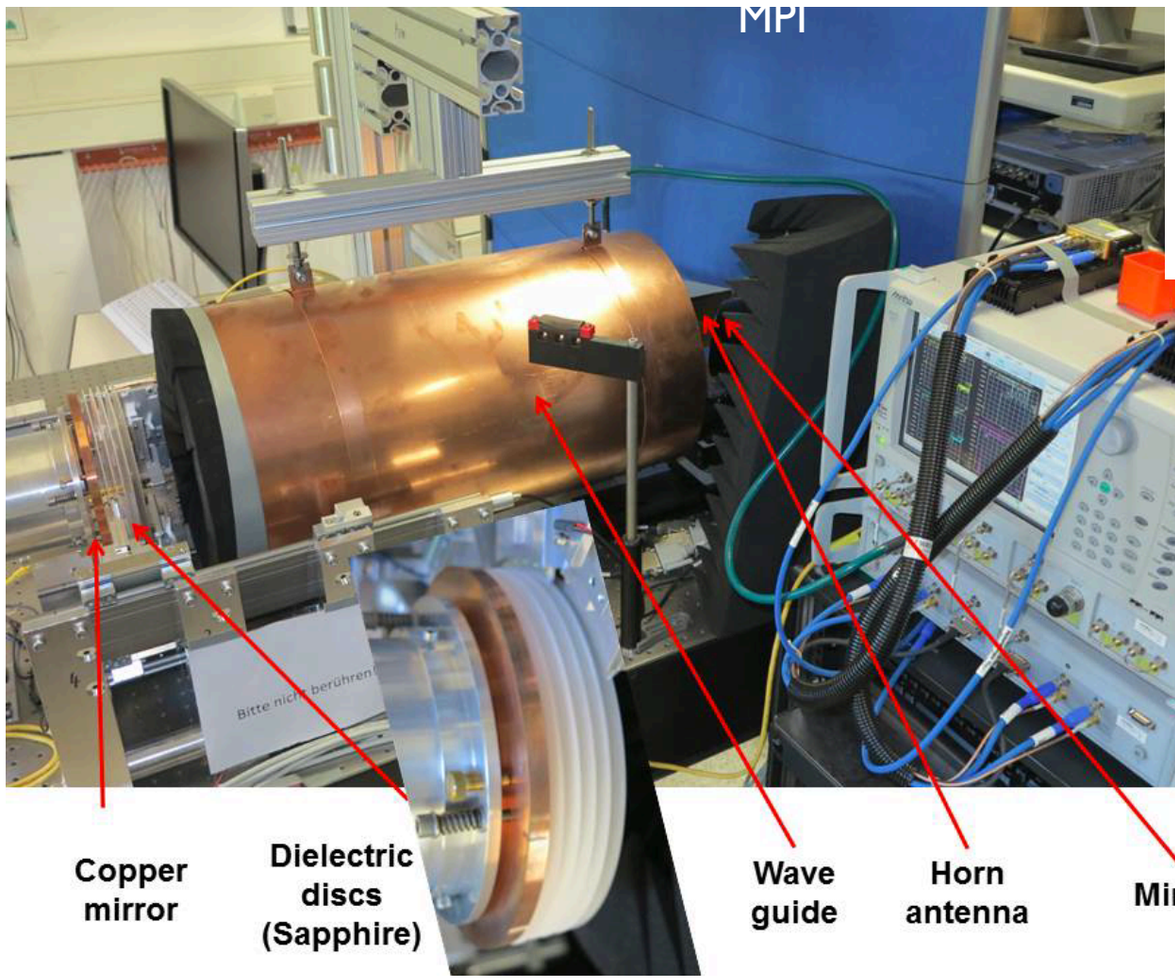
- 3D experiment simulation
  - thinking work has started, in cooperation with Andreas Ringwald
  - more exchange with MPI needed

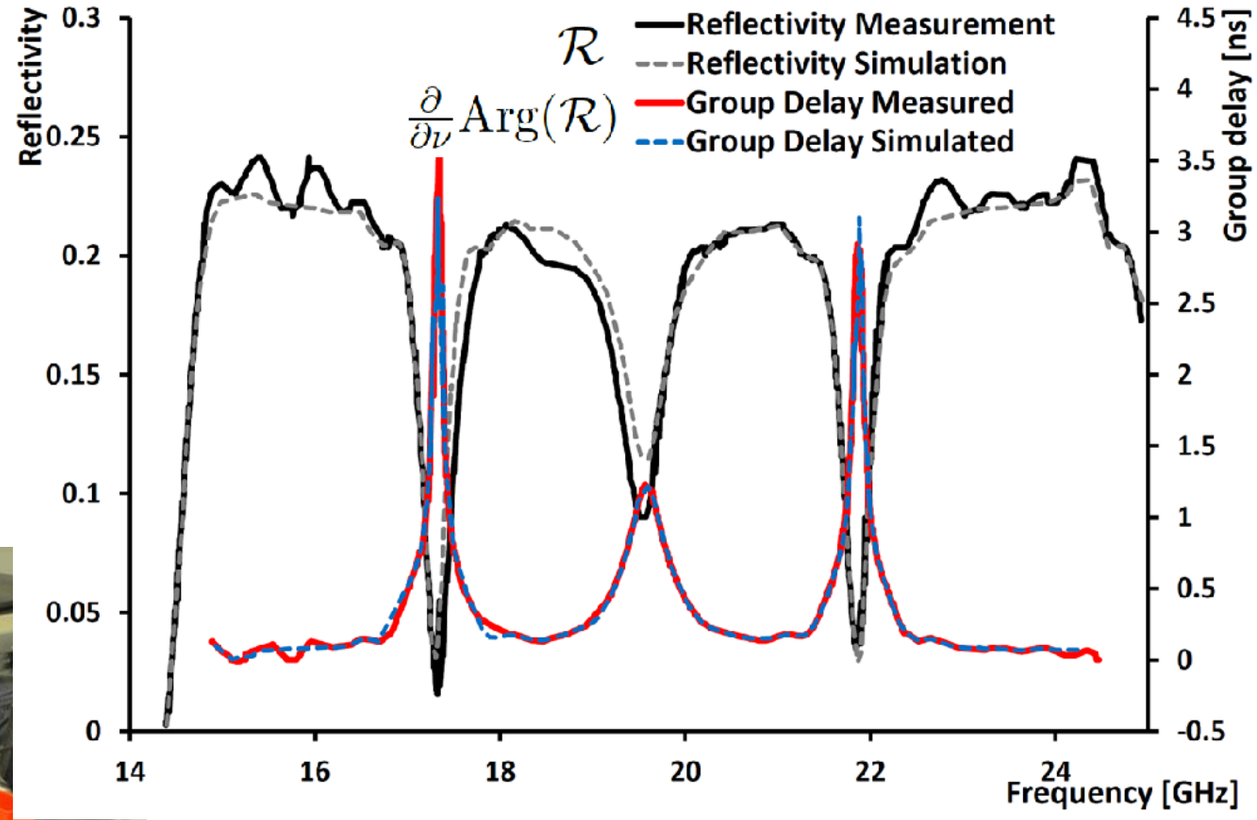
- Funds procurement
  - started (BMBF, Excellence Cluster)
  - details in the CB

Backup

The measurement setup

- The setup in Munich





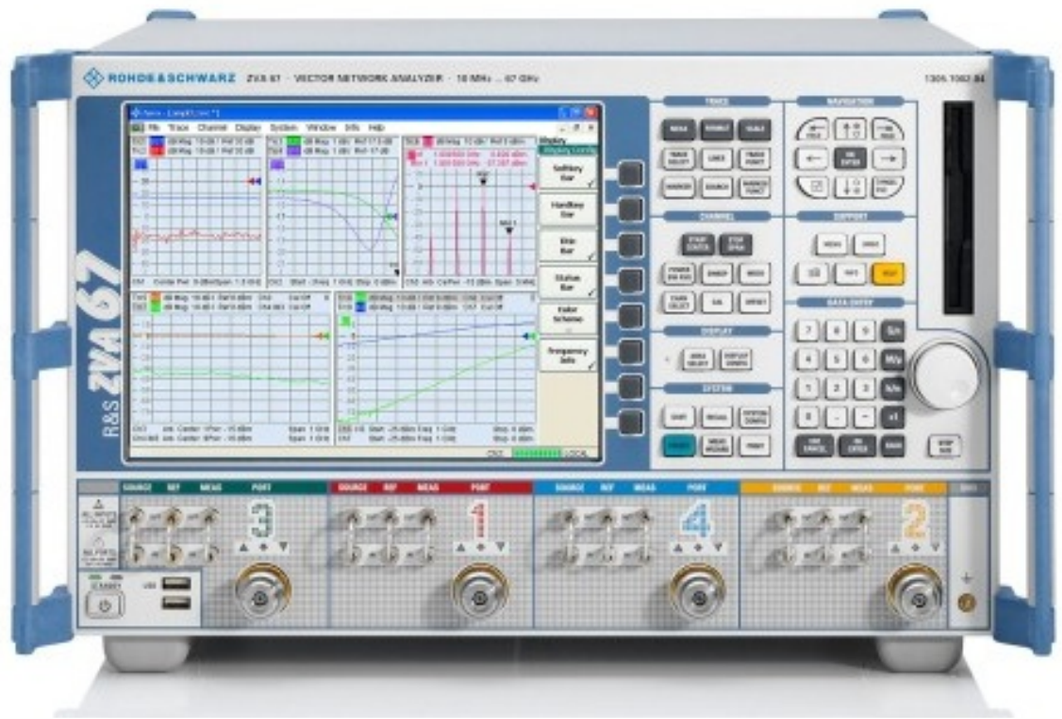
Signal detection based on heterodyne mixing of a pre-amplified signal:

- after low noise preamplifier
- signal shifted to intermediate frequencies and further amplified and filtered
- a digital sampler providing real time fast Fourier transform is used to integrate and store the signal

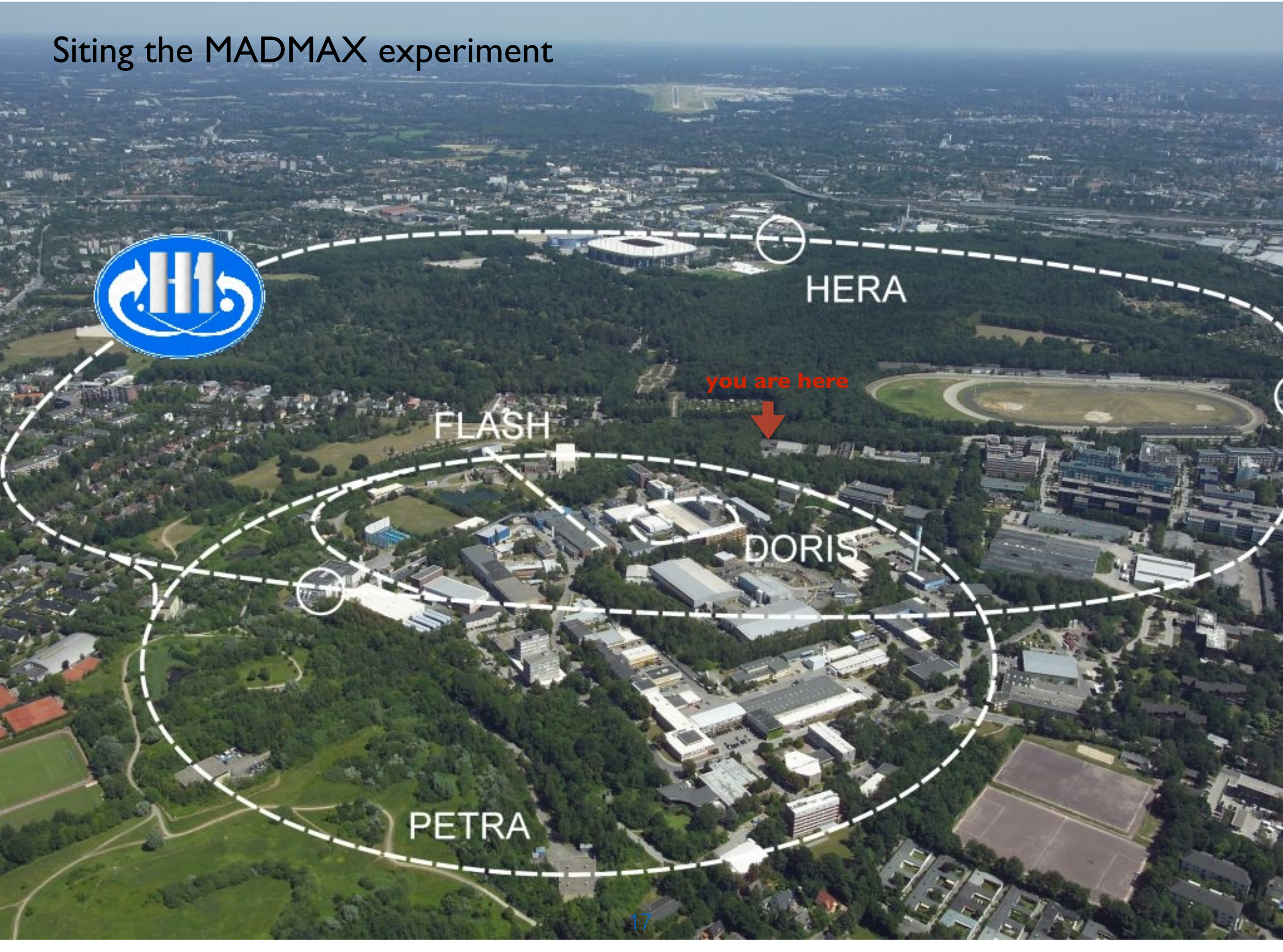
The measurement setup

- The setup in Hamburg
- … for now we have the new network analyser

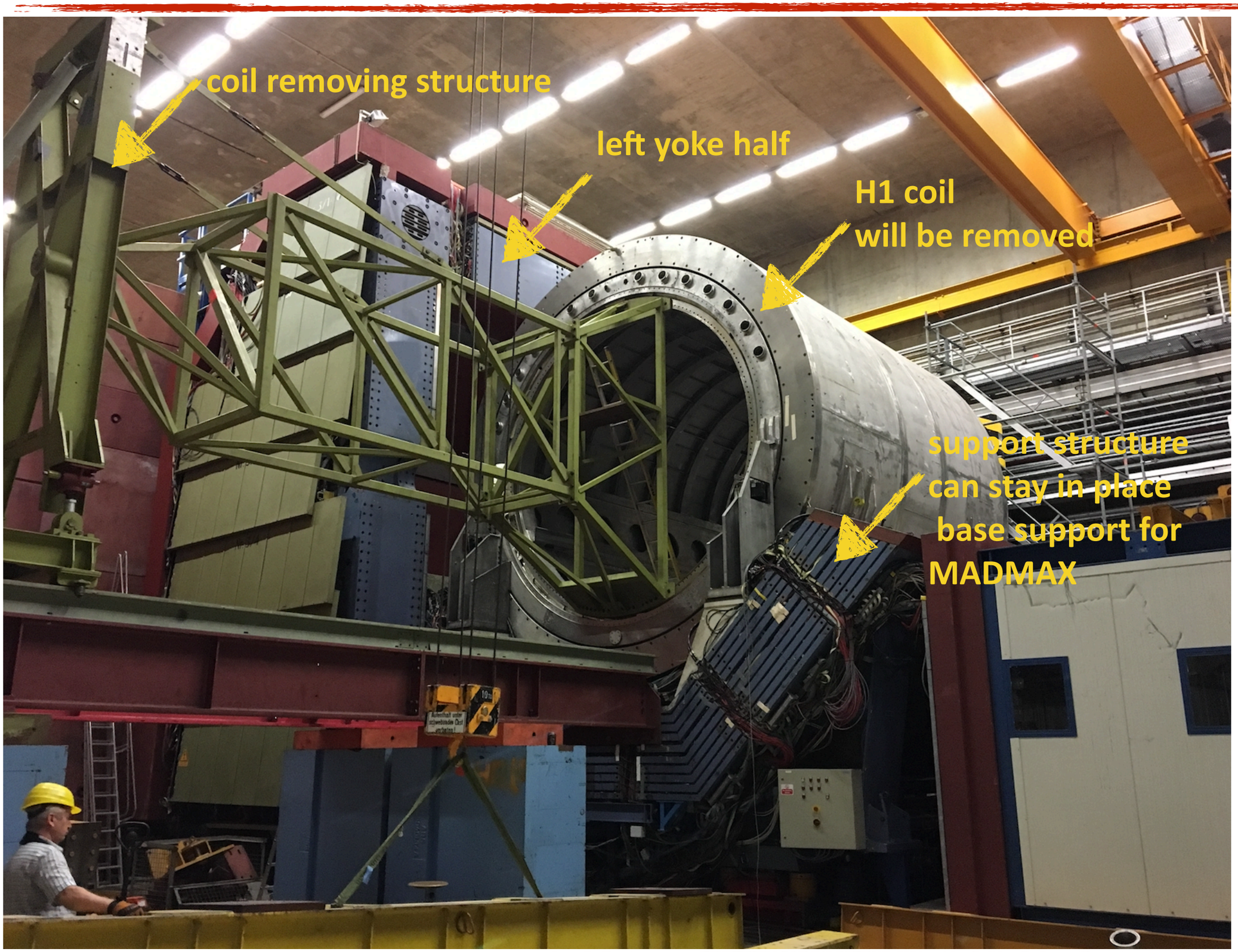
ROHDE & SCHWARZ ZVA67/110



Siting the MADMAX experiment



The H1 magnet yoke



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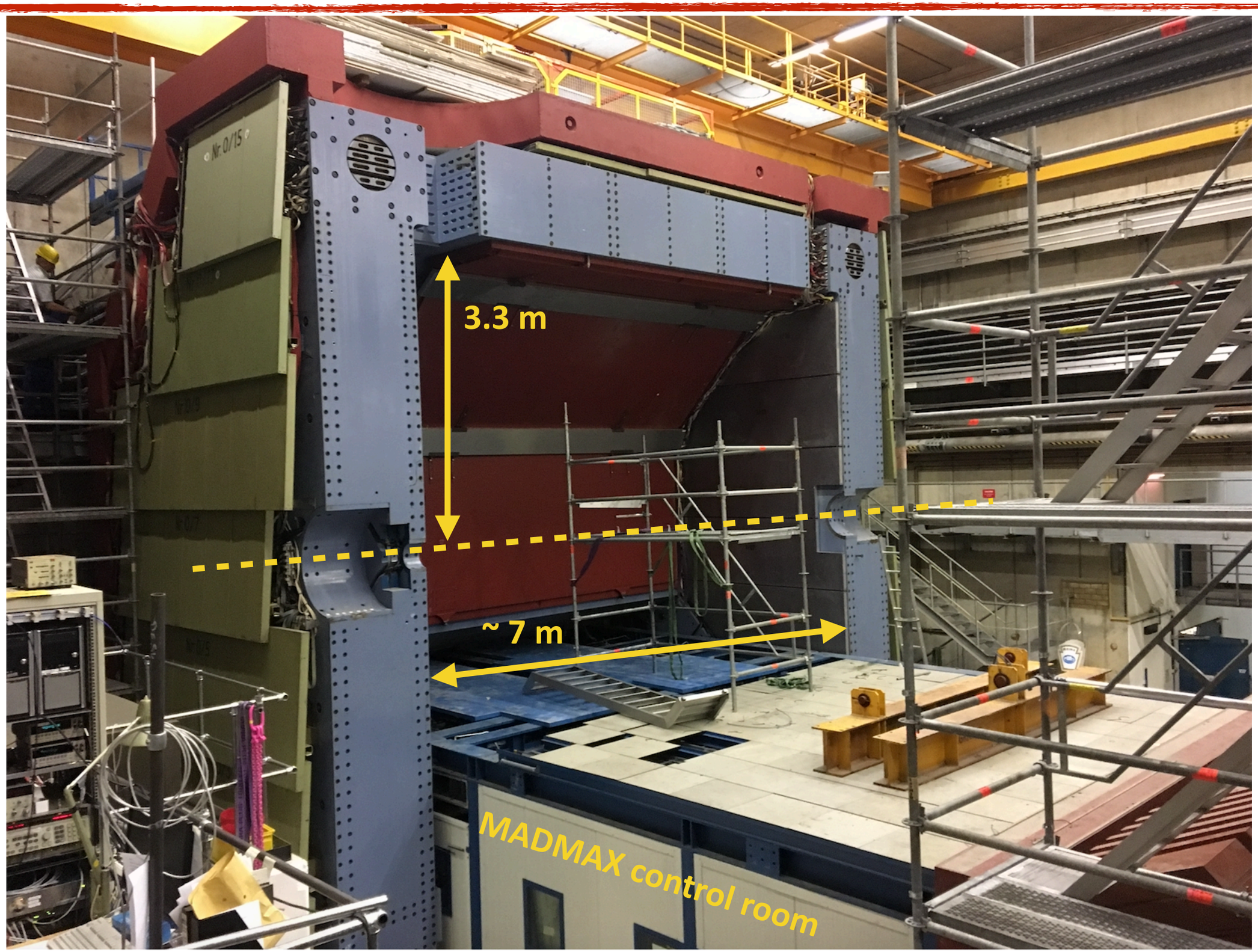
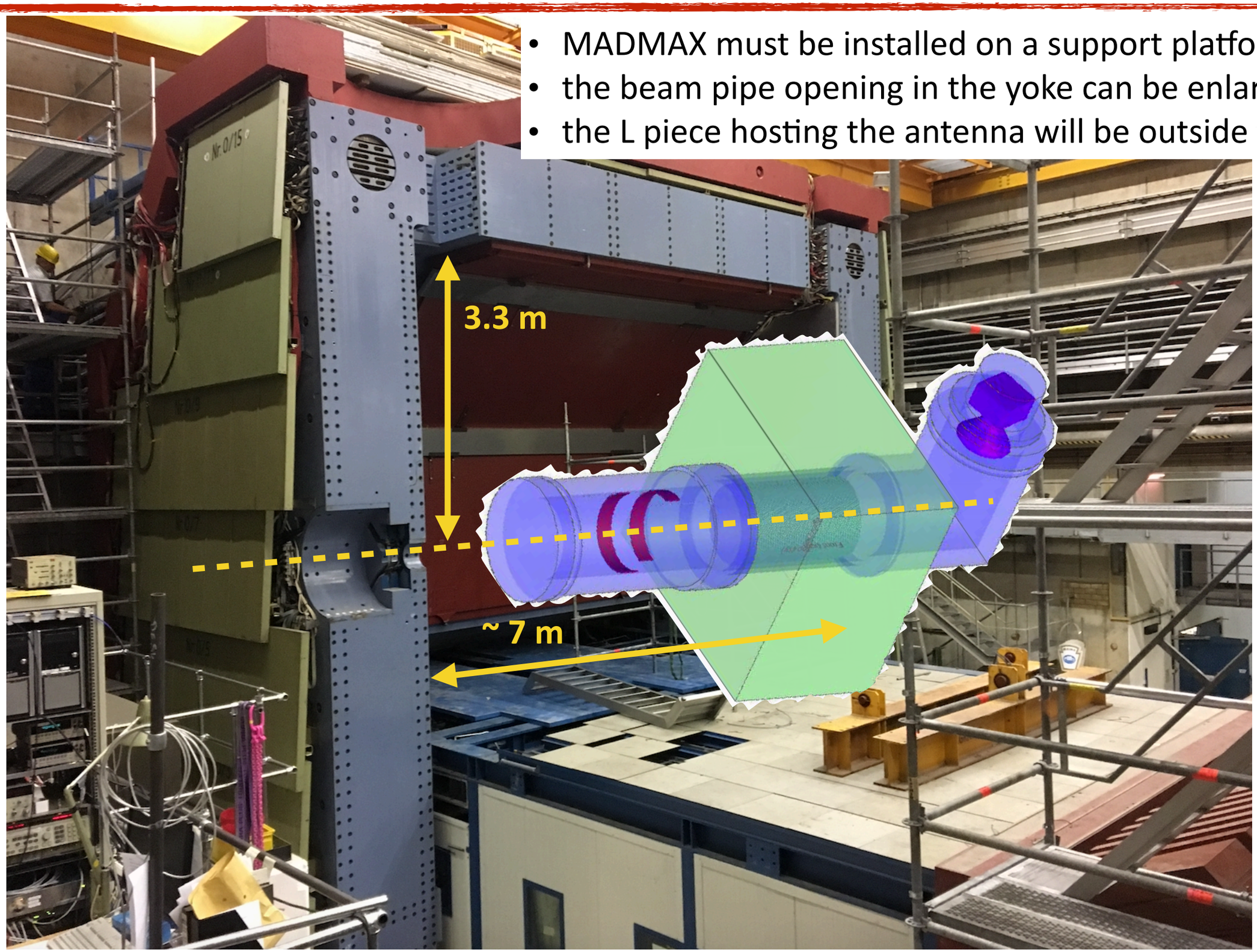


The H1 magnet yoke

- MADMAX must be installed on a support platform
- the beam pipe opening in the yoke can be enlarged
- the L piece hosting the antenna will be outside the yoke



MADMAX in the DESY North Hall

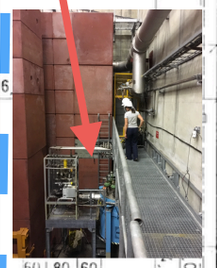
Phase-II

25 m

Park position
outside beam line

HERA beam line
ALPS- II experiment site

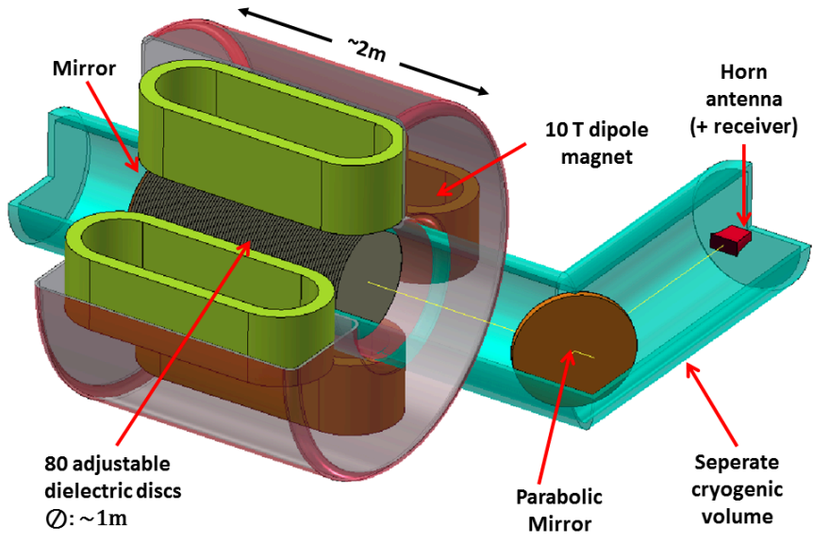
switch box
ALPS /
MADMAX



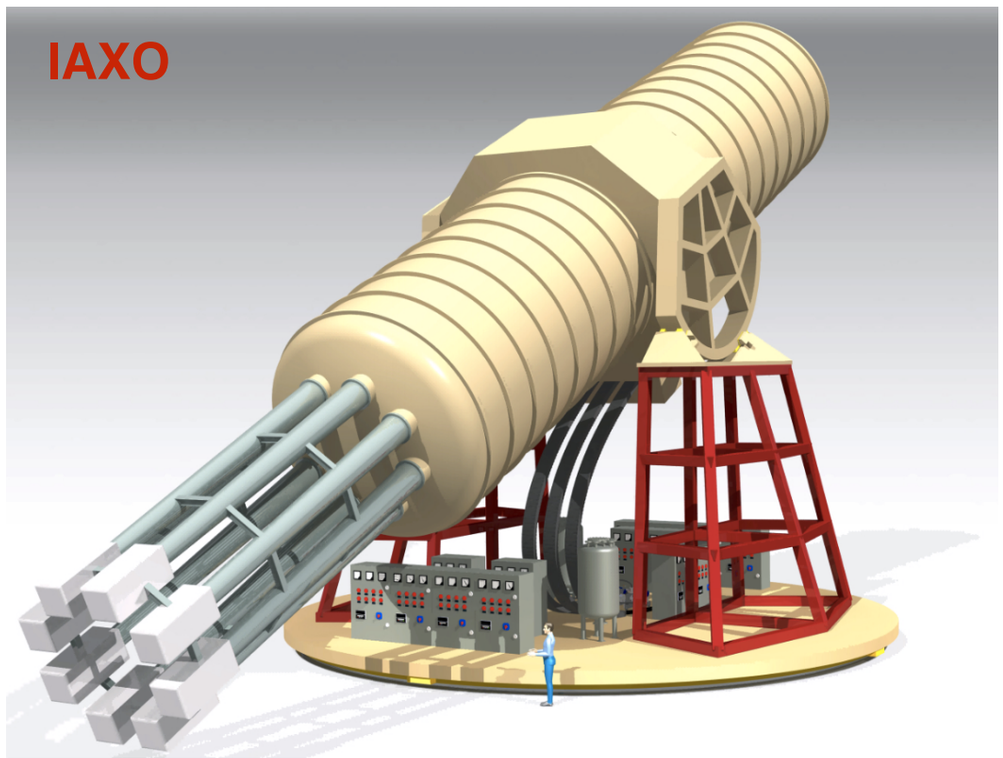
AXION park in HH

Source	Experiments	Model & Cosmology dependency	Technology
Relic axions	ADMX, CAPP, Casper, HAYSTACK, MADMAX, BRASS, …	High	New ideas emerging, Active R&D going on,…
Lab axions	ALPS, OSQAR, PVLAS, ARIADNE,…	Very low	
Solar axions	SUMICO, CAST, IAXO	Low	Ready for large scale experiment

MADMAX



IAXO



ALPS

MADMAX in the DESY North Hall

Phase-II

Proposal

for a new experiment on the search
for dark matter Axions at DESY

Jörn Schaffran, Axel Lindner, Alexander Schmidt, Erika Garutti, Michael Matysek, XYZ

costs of operation

description	number or length	power [W/m]	power [W]	comments
transfer line 80K	1 500	1	1 500	
transfer line 4K	3 000	0.2	600	
LHC magnet 80K	6	8	48	assumption as
LHC magnet 4.5K	6	0.3	1.8	discussed in text

description	equivalent power [W]	primary power [kW]	power 300 days [kW]	costs 300 days
transfer lines (west-north)	684.4	205.3	1 478 250	147.8
distribution system	300	90	648 000	64.8
MADMAX	??? 4.5	1.4	9720	1
total				213.6 kEUR

Table 2: Description costs for operation of the MADMAX cryostat and magnet.

Preparations in the course of the ALPS-II Project (initial costs)

description	nr.	cost/piece	total cost	comments
valves	16	5 000	80 000	controller, regulator, valve socket
controllers, sensors	1	20 000	20 000	
bypass	2	20 000	40 000	bypass until used by MADMAX
vacuum system for boxes	1	30 000	30 000	
total			170 000	

Link to the MADMAX magnet (later)

description	nr.	cost/piece	total cost	comments
transfer lines	20	5 000	100 000	depends on magnet design
connection for transfer line	1	20 000	20 000	
cooling system	?	?	?	depends on type of cooling
warmgaspanel (?)	12	3 000	36 000	power lines, ramping circles
panel for power lines	2	1 500	3 000	
distribution box - valve	12	35 000	420 000	for magnet/cryostat
transfer line (experiment)	30	1 200	36 000	connection distribution box
connection transfer line	6	20 000	120 000	2 cryostats + 1 magnet
total			735 000	

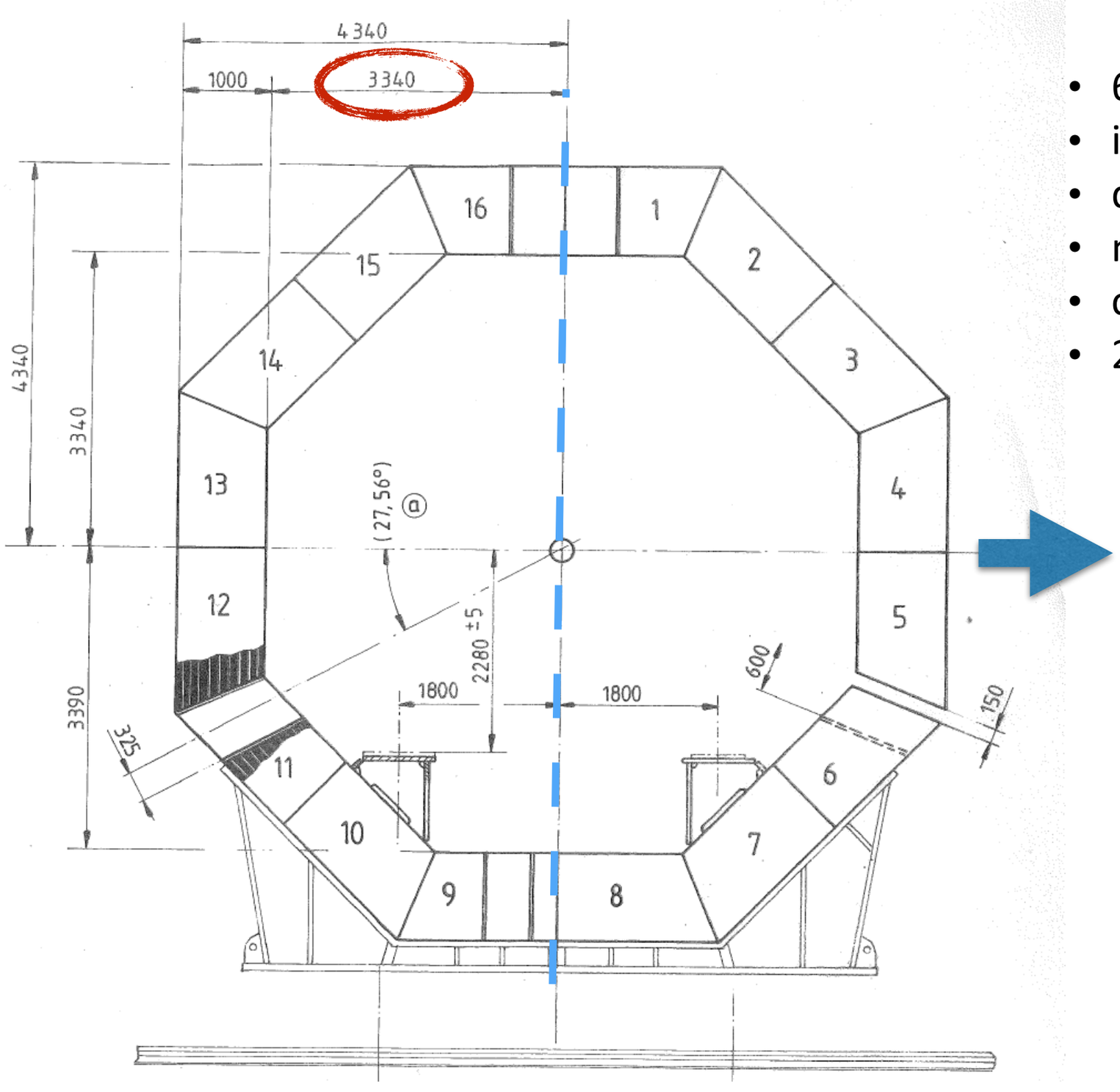
total			905 000	

Considerations to host MADMAX in the HERA-North hall @ DESY

- Is it advantageous to site the MADMAX experiment inside the existing H1 yoke?

- H1 magnet: ~ 1 T, ~6 m diameter
- The yoke is designed to allow work in the hall around the magnet when powered
- For the MADMAX magnet it could be an additional tool (NOT replacement) to the anti-anti-Helmoltz coil to reduce fringe field
- The whole vacuum vessel will not fit in the ~7m long joke, so part of the experiment will be outside the yoke

The H1 magnet yoke



- 60 cm thick stainless steel
- inner radius 3.3 m
- divided in two vertical halves
- mounted on movable rails
- can be opened to access inner volume
- 2 m movement in ~ 20 min.

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The H1 magnet yoke

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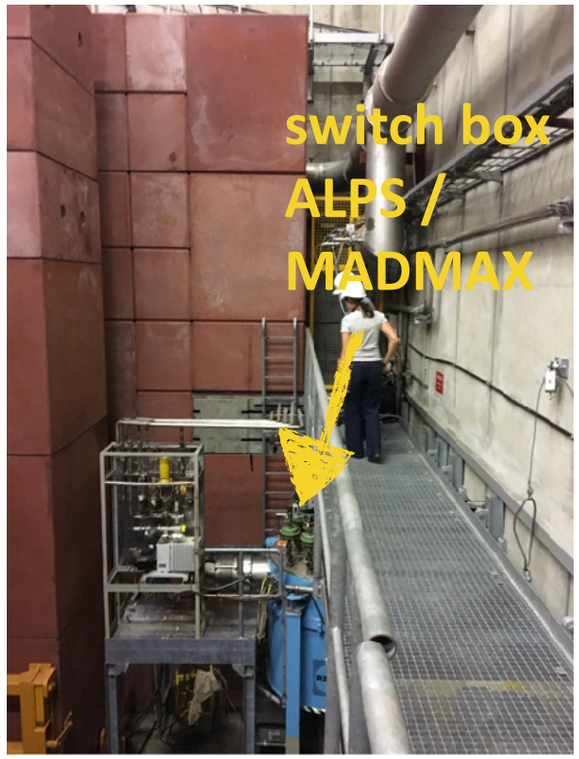
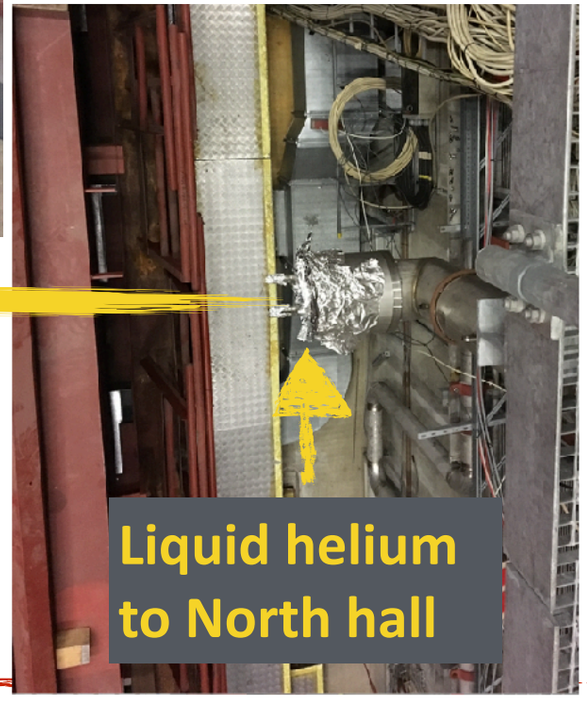
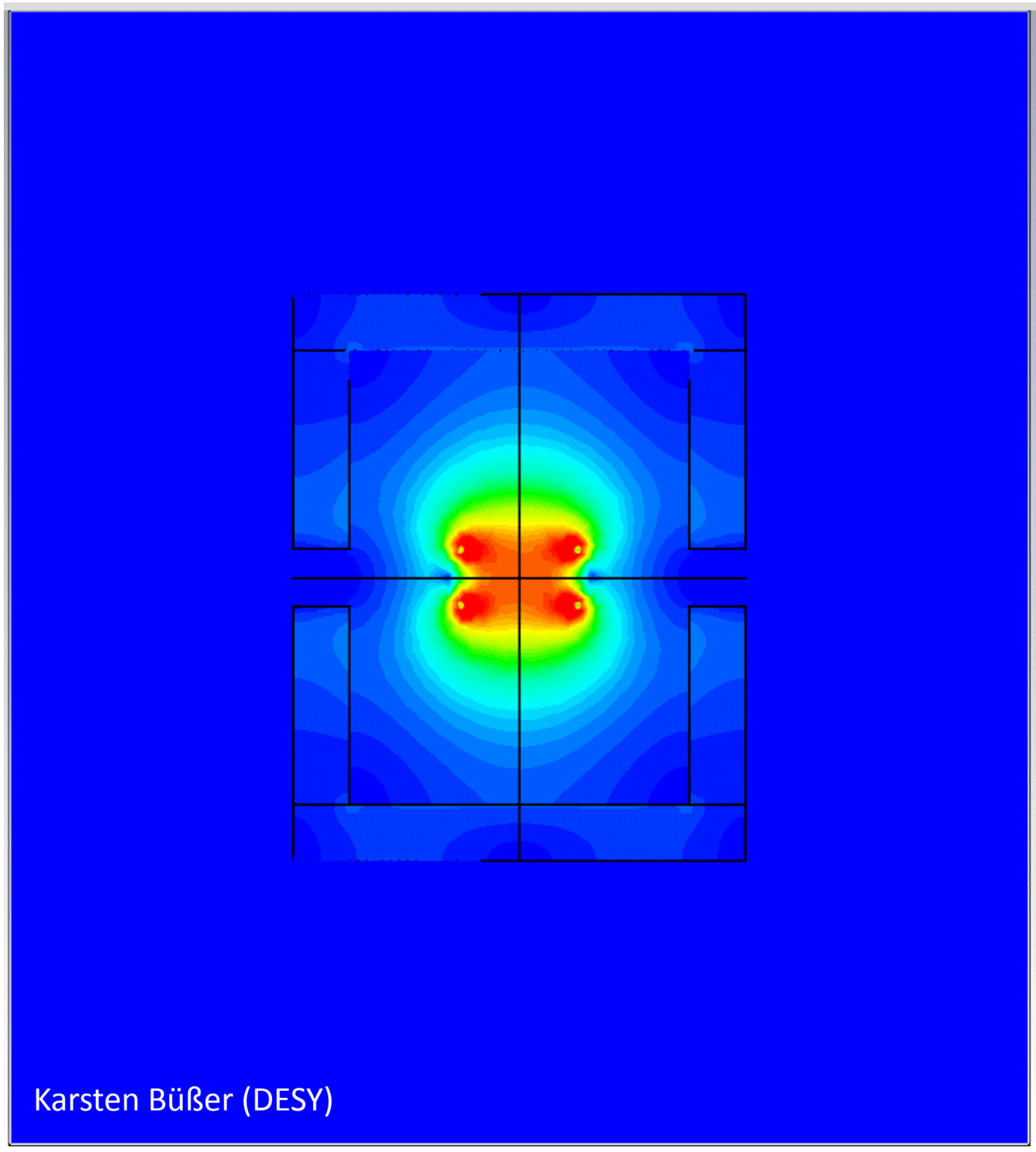
Cryo cooling line

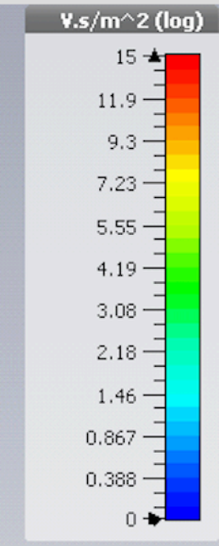


transfer line to yoke exists, but needs recommissioning



Magnetic field simulation





Very naive simulation:

- 12 T dipole / no anti-coil design
- field outside the yoke ~ 1 Gauss
- more realistic study will follow …

work in progress