Construction of an
Actively Cooled MAPS Device
operated in vacuum near a storage ring beam

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on behalf of the PANDA Luminosity Group
01.07.2014

Forum on Tracking Detector Mechanics 2014, DESY Hamburg

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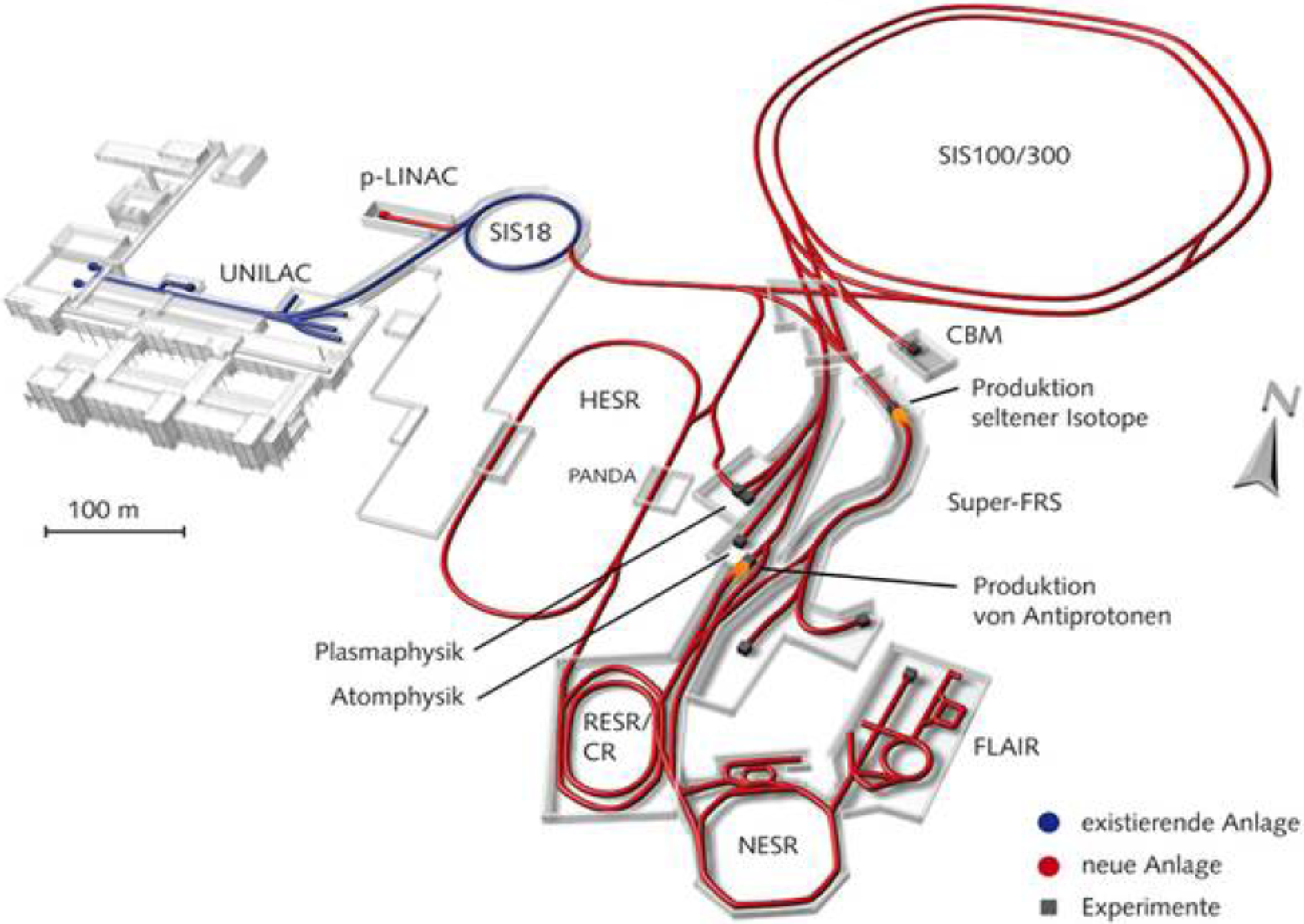
A word on the $\overline{\text{P}}$ANDA Experiment

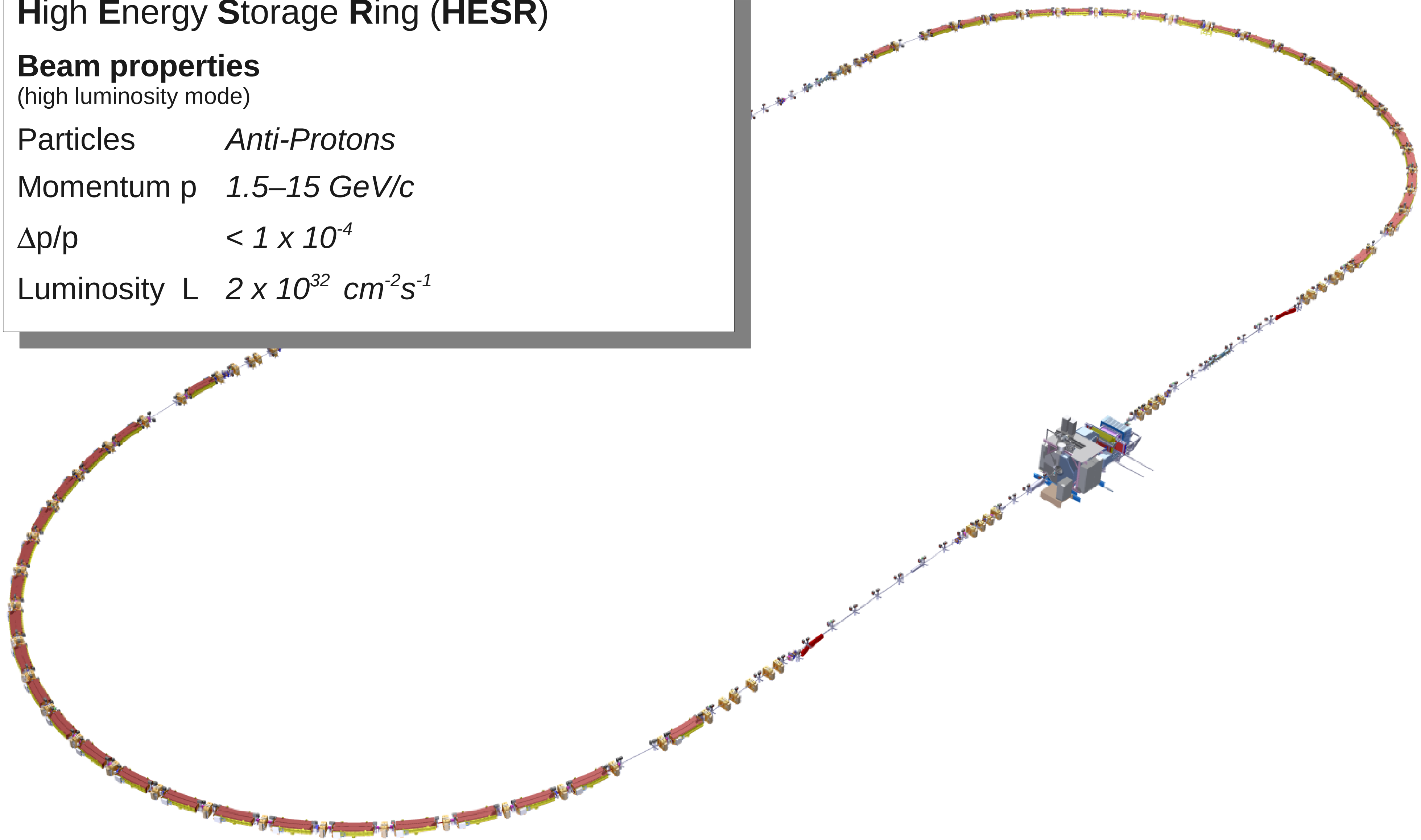


A word on the $\overline{\mathrm{P}}$ANDA Experiment

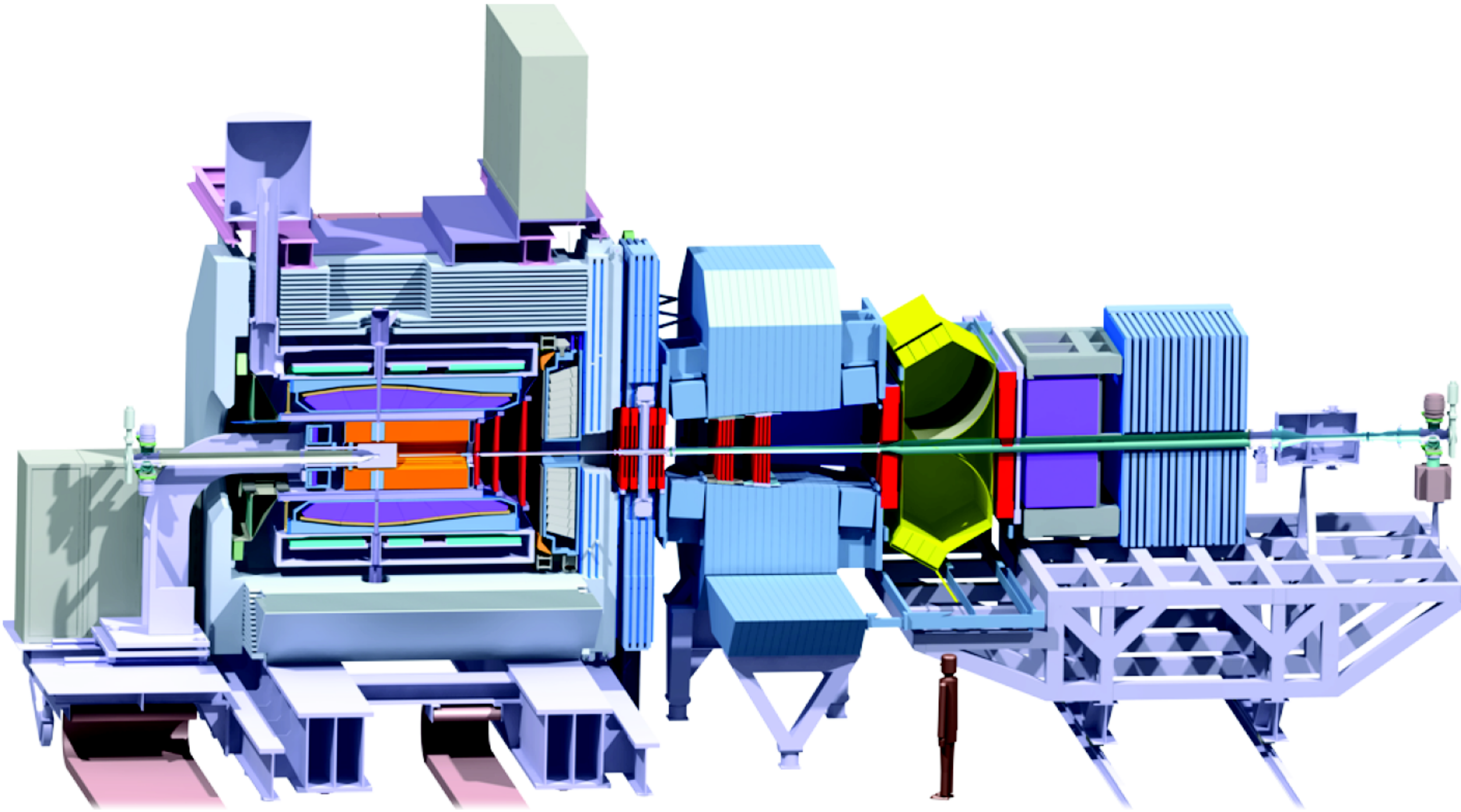
High **E**nergy **S**torage **R**ing (**HESR**)

Beam properties
(high luminosity mode)

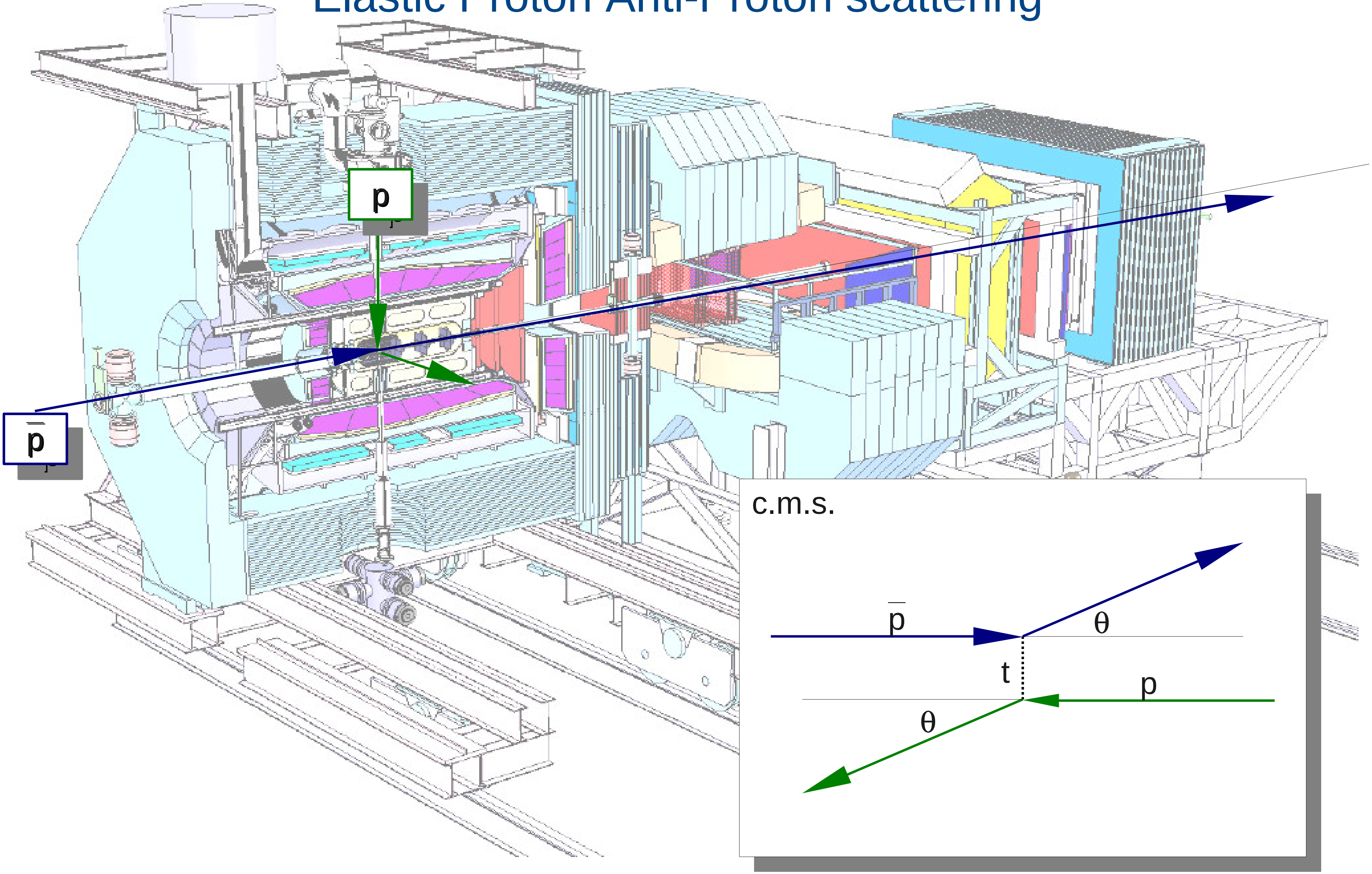
Particles	*Anti-Protons*
Momentum p	*1.5–15 GeV/c*
$\Delta p/p$	$< 1 \times 10^{-4}$
Luminosity L	$2 \times 10^{32}\ cm^{-2}s^{-1}$



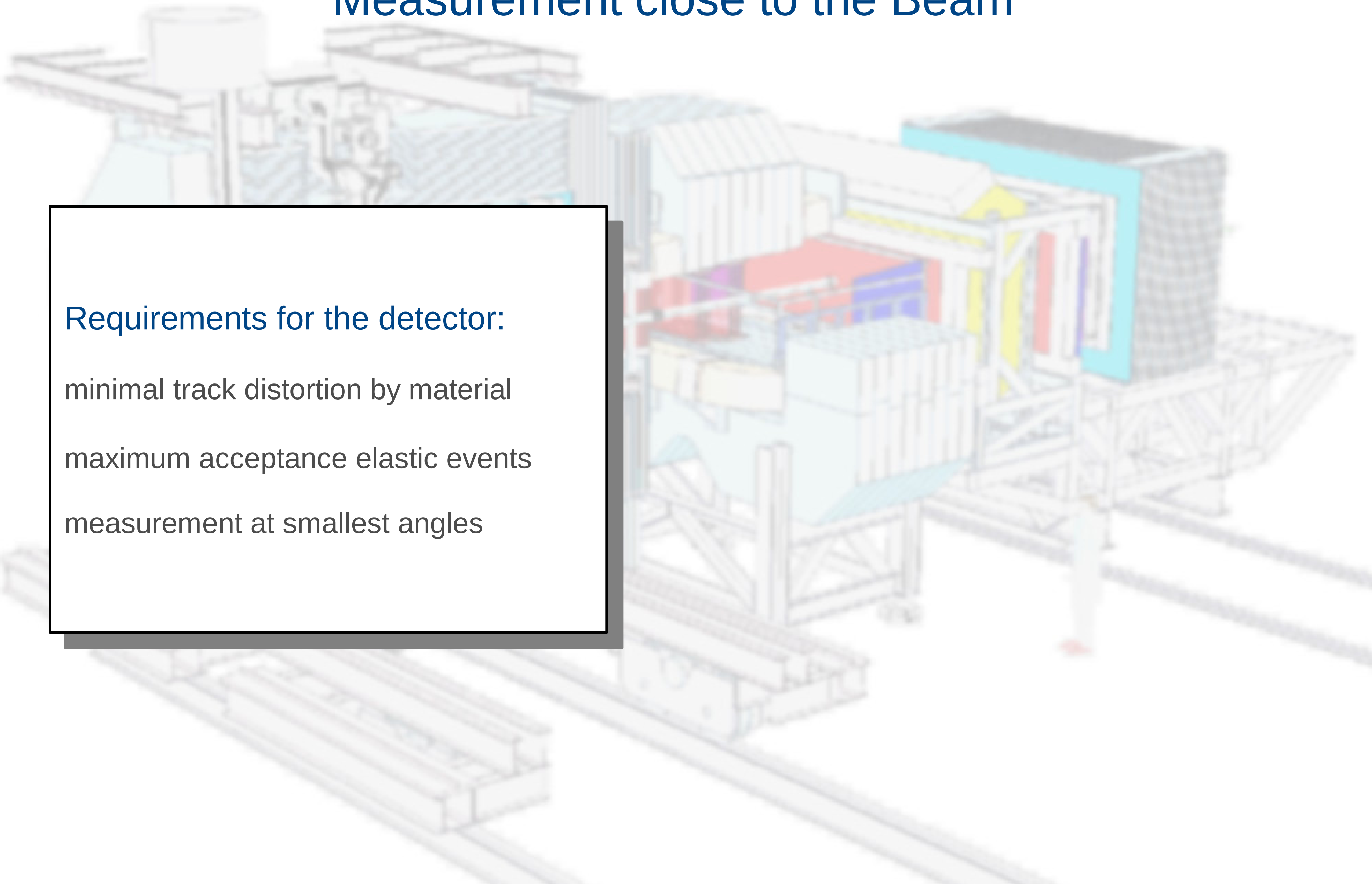
A word on the $\overline{\text{P}}$ANDA Experiment



Elastic Proton Anti-Proton scattering



Measurement close to the Beam



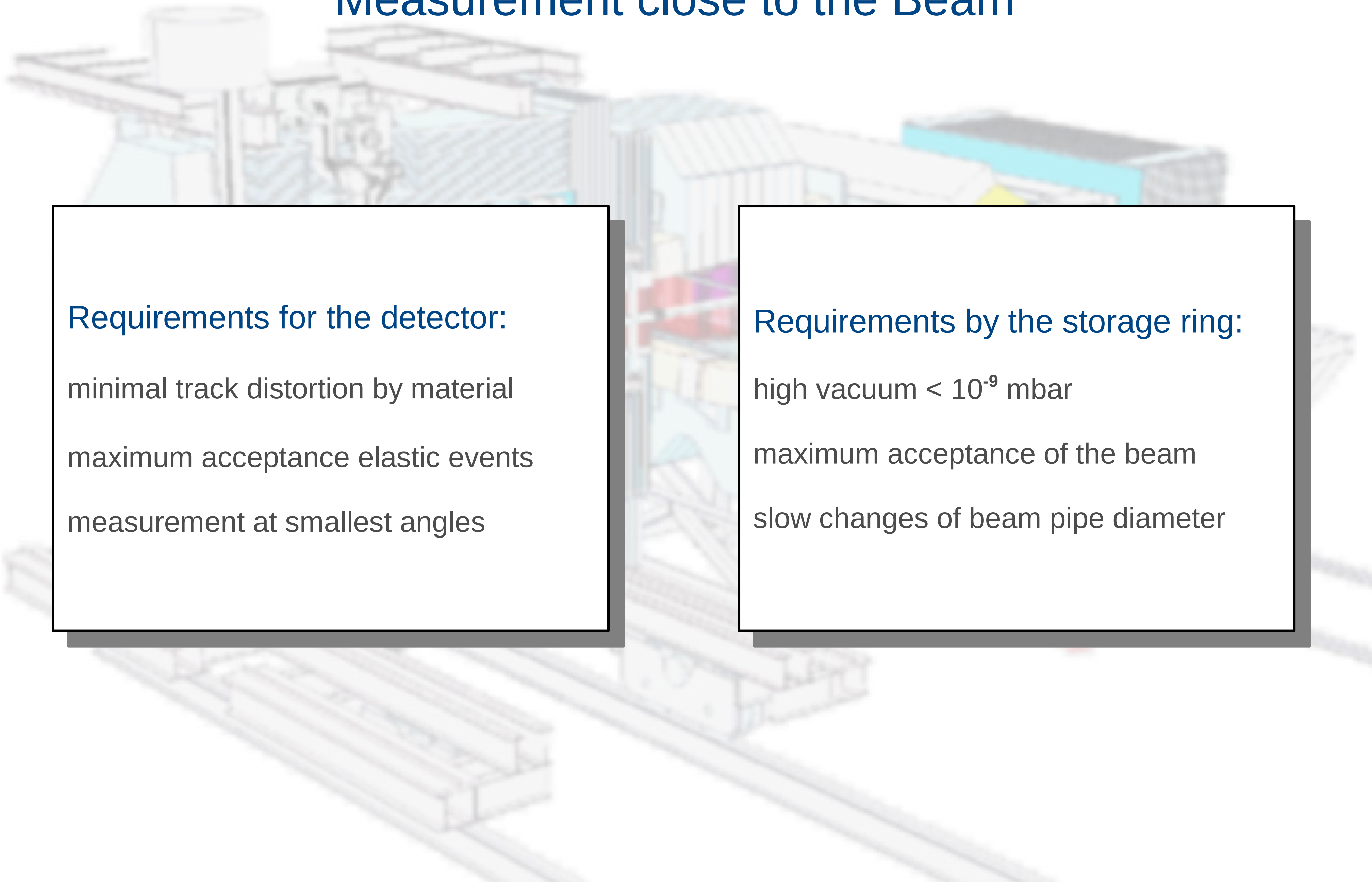
Requirements for the detector:

minimal track distortion by material

maximum acceptance elastic events

measurement at smallest angles

Measurement close to the Beam



Requirements for the detector:

minimal track distortion by material

maximum acceptance elastic events

measurement at smallest angles

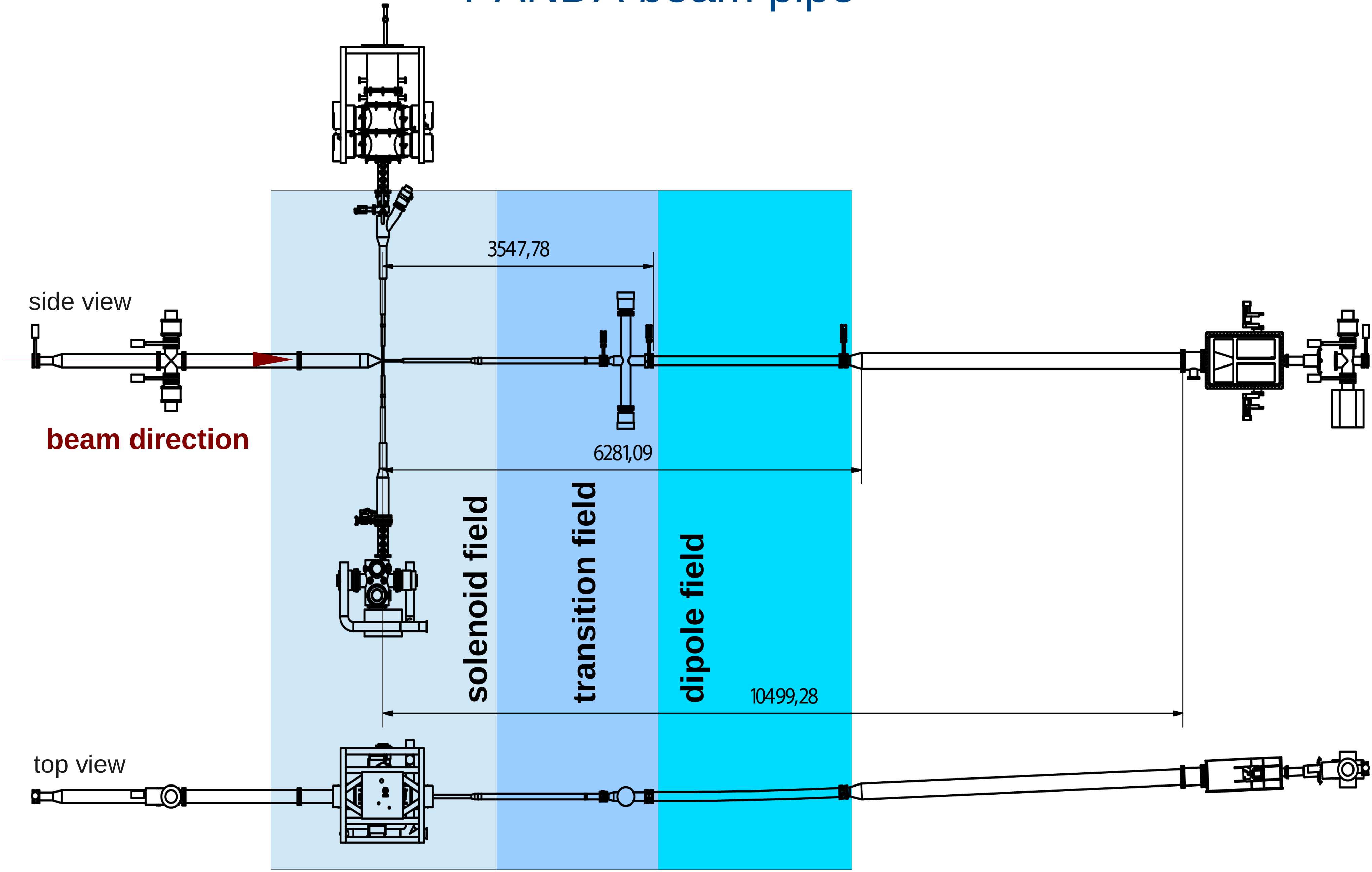
Requirements by the storage ring:

high vacuum < 10^{-9} mbar

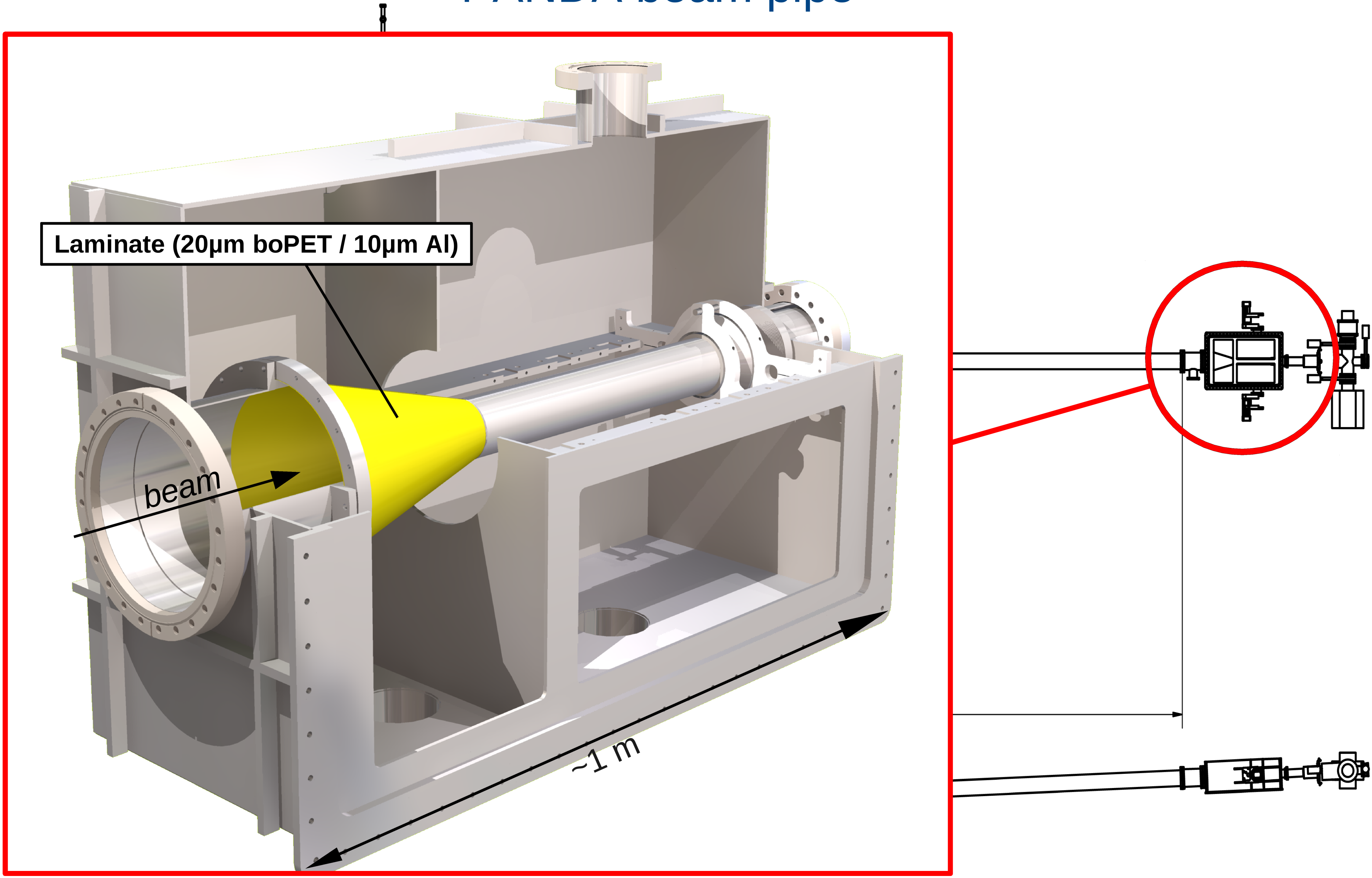
maximum acceptance of the beam

slow changes of beam pipe diameter

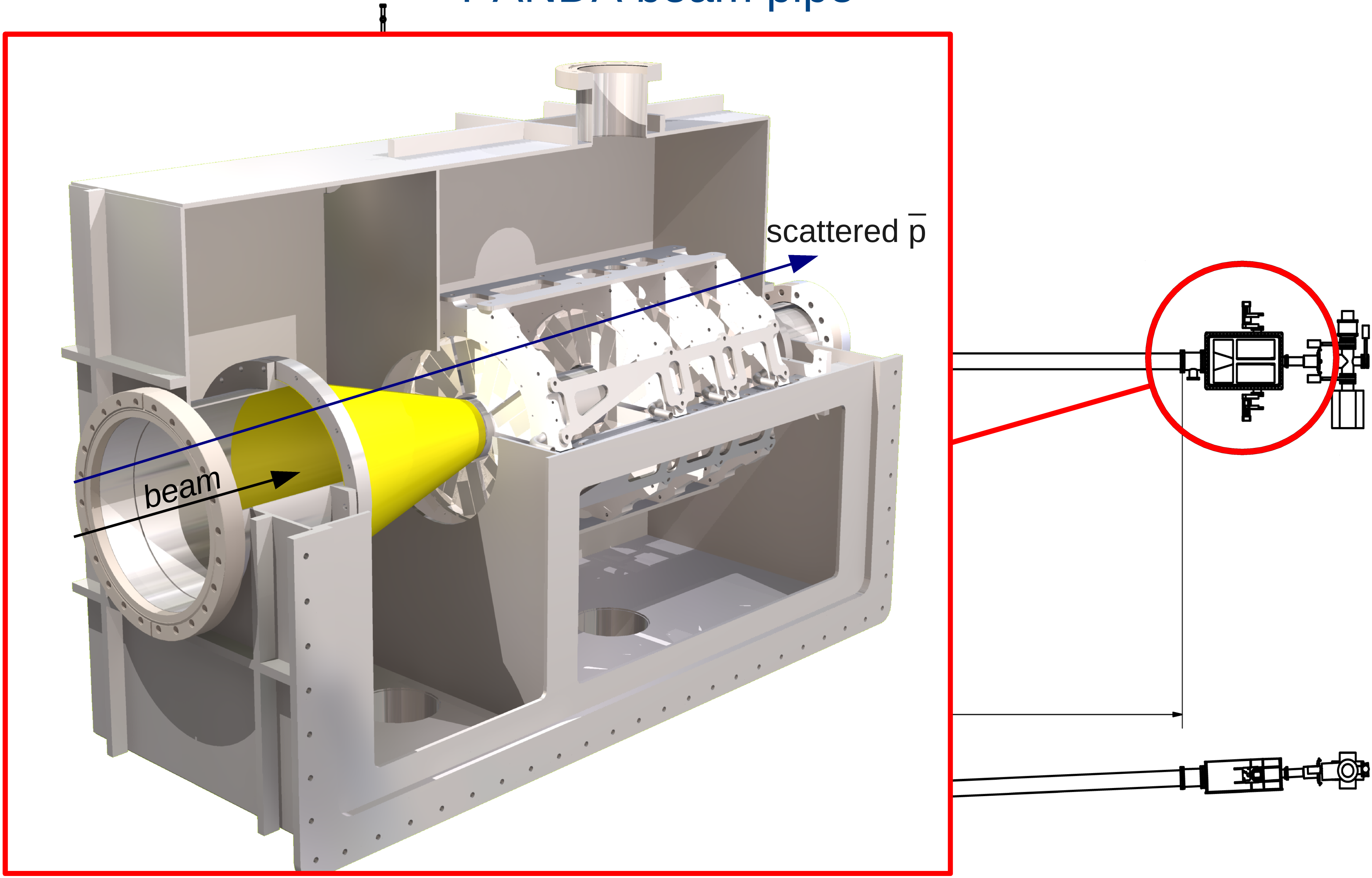
$\overline{P}$ANDA beam pipe



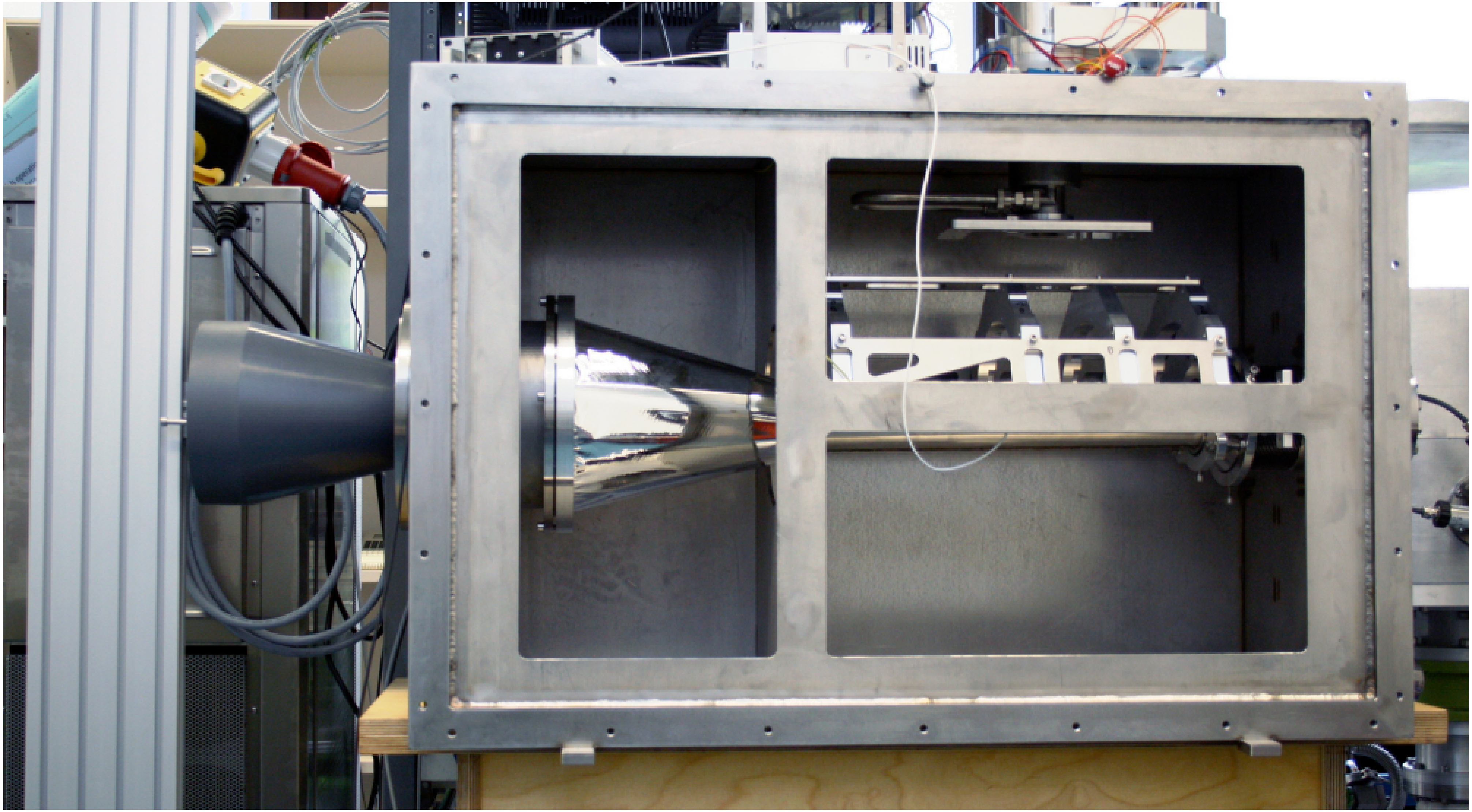
P̄ANDA beam pipe



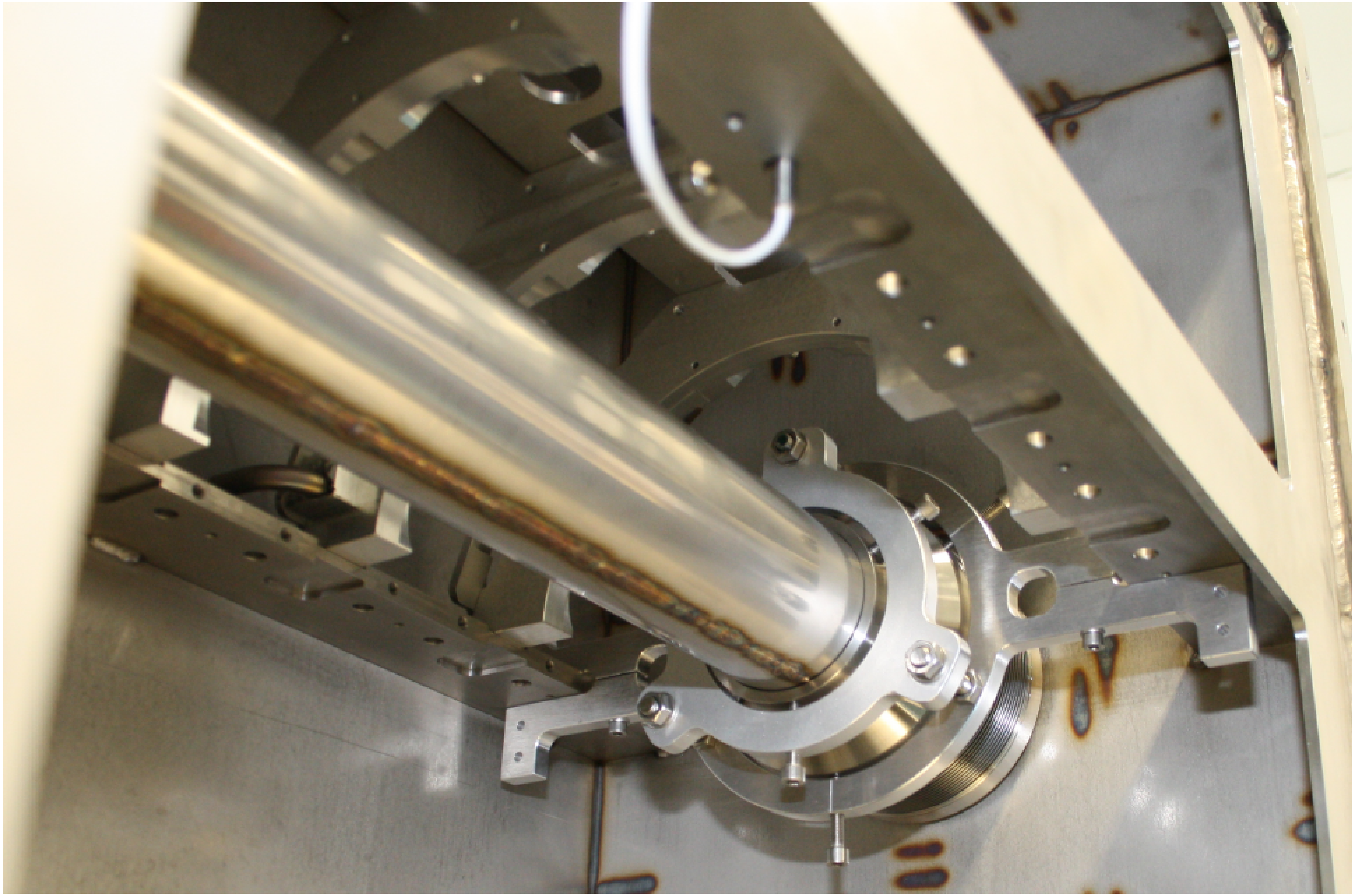
$\overline{\mathrm{P}}$ANDA beam pipe



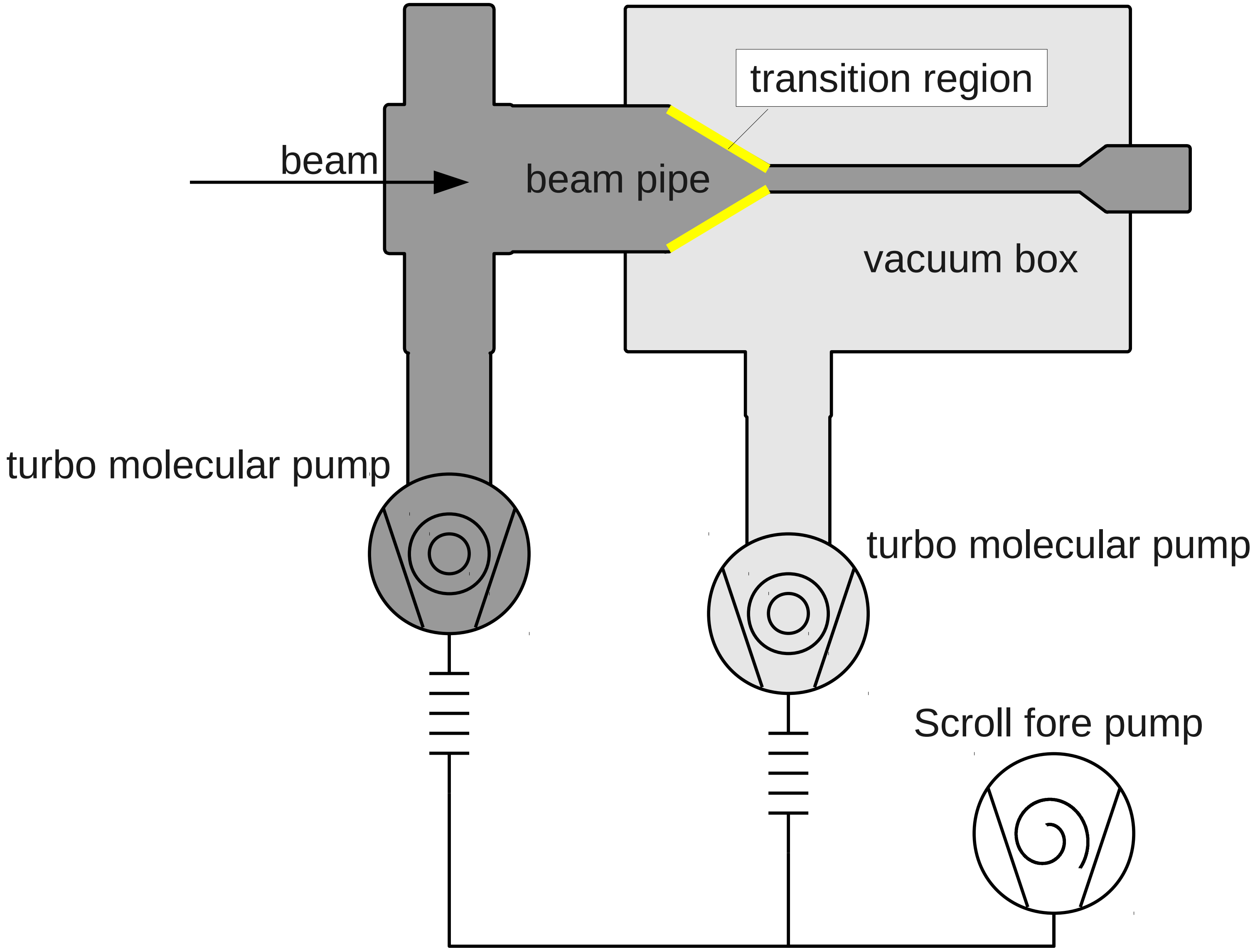
Vacuum Box Prototype



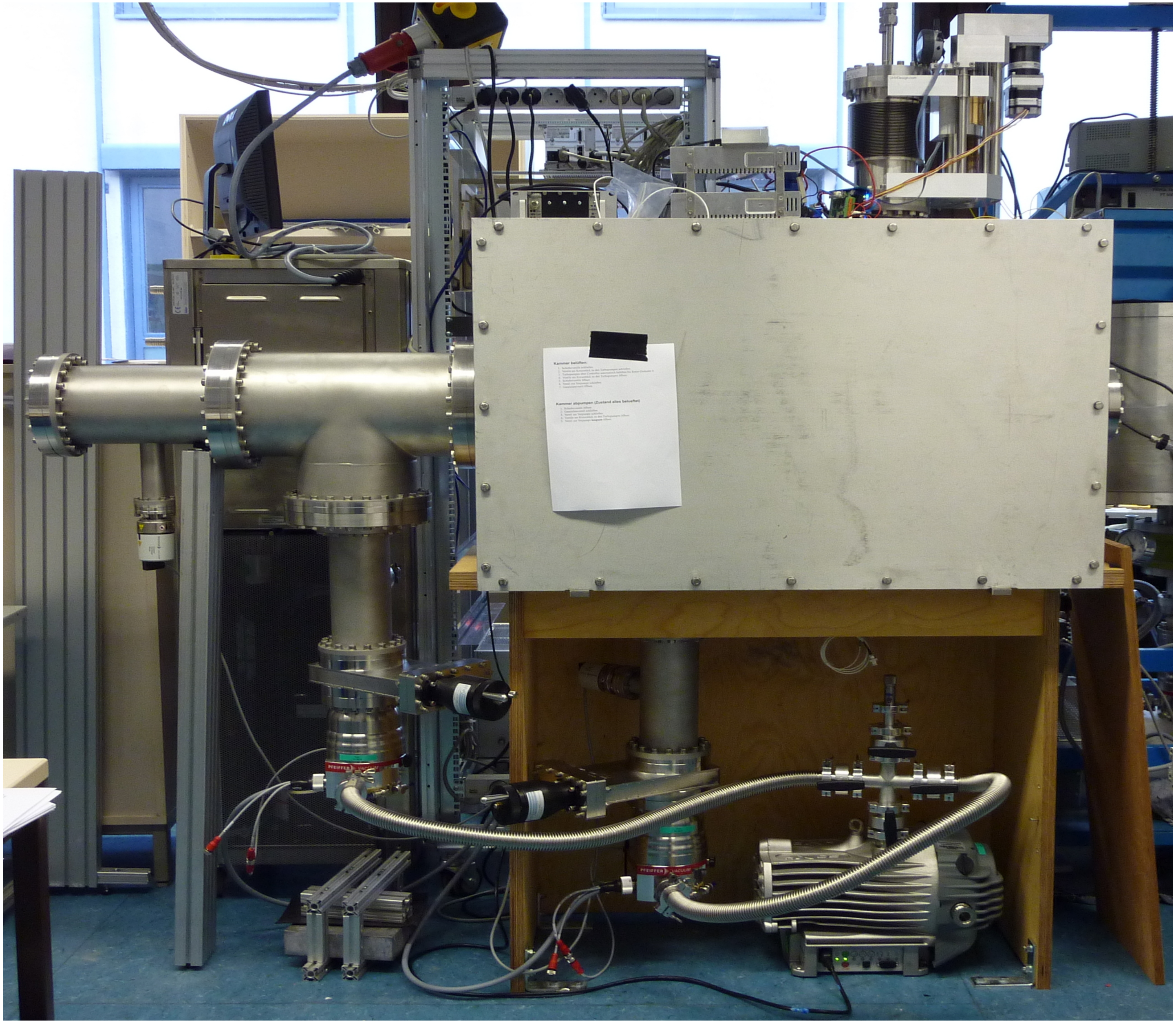
Beam Pipe Prototype



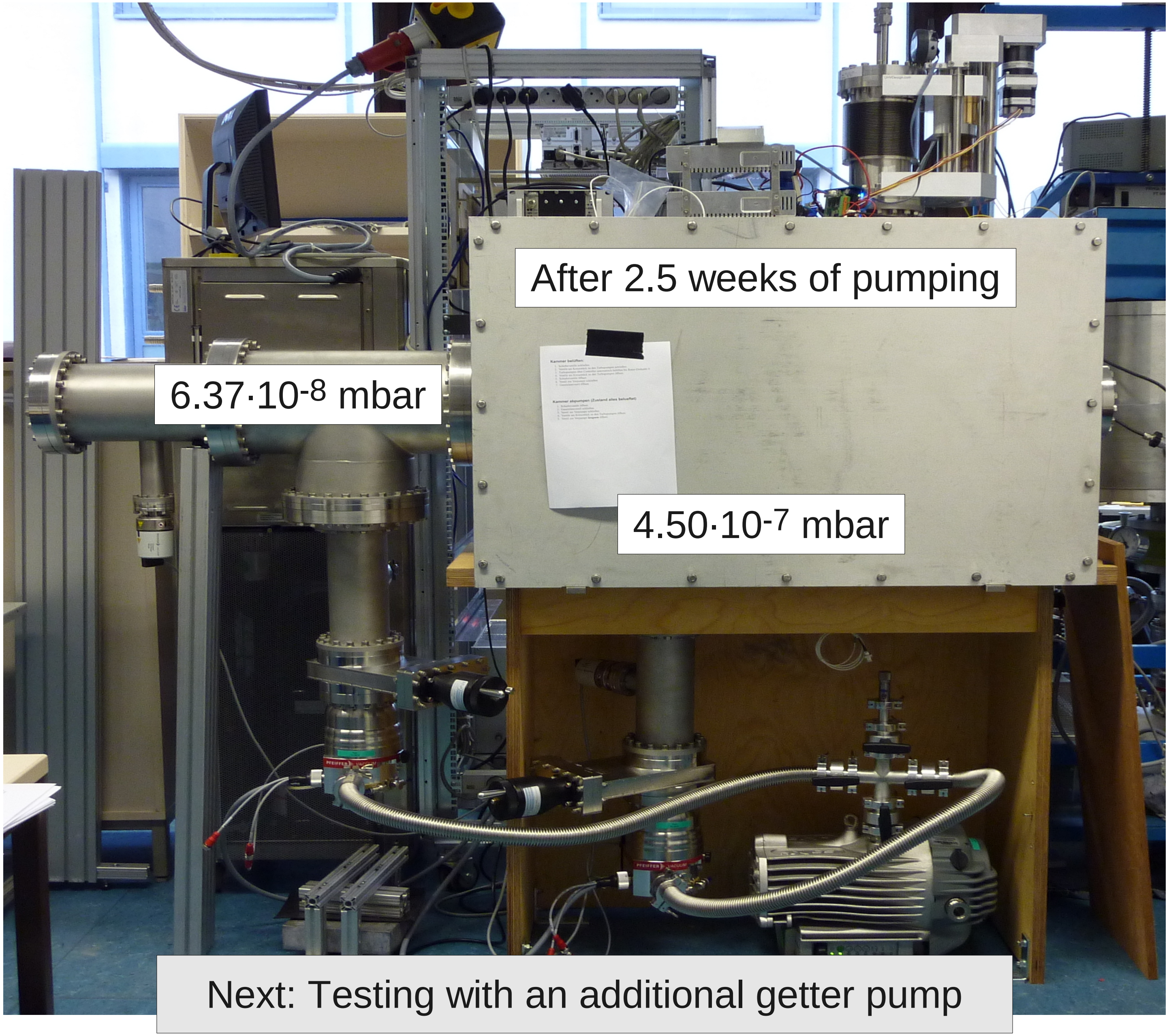
Differential Pumping Scheme



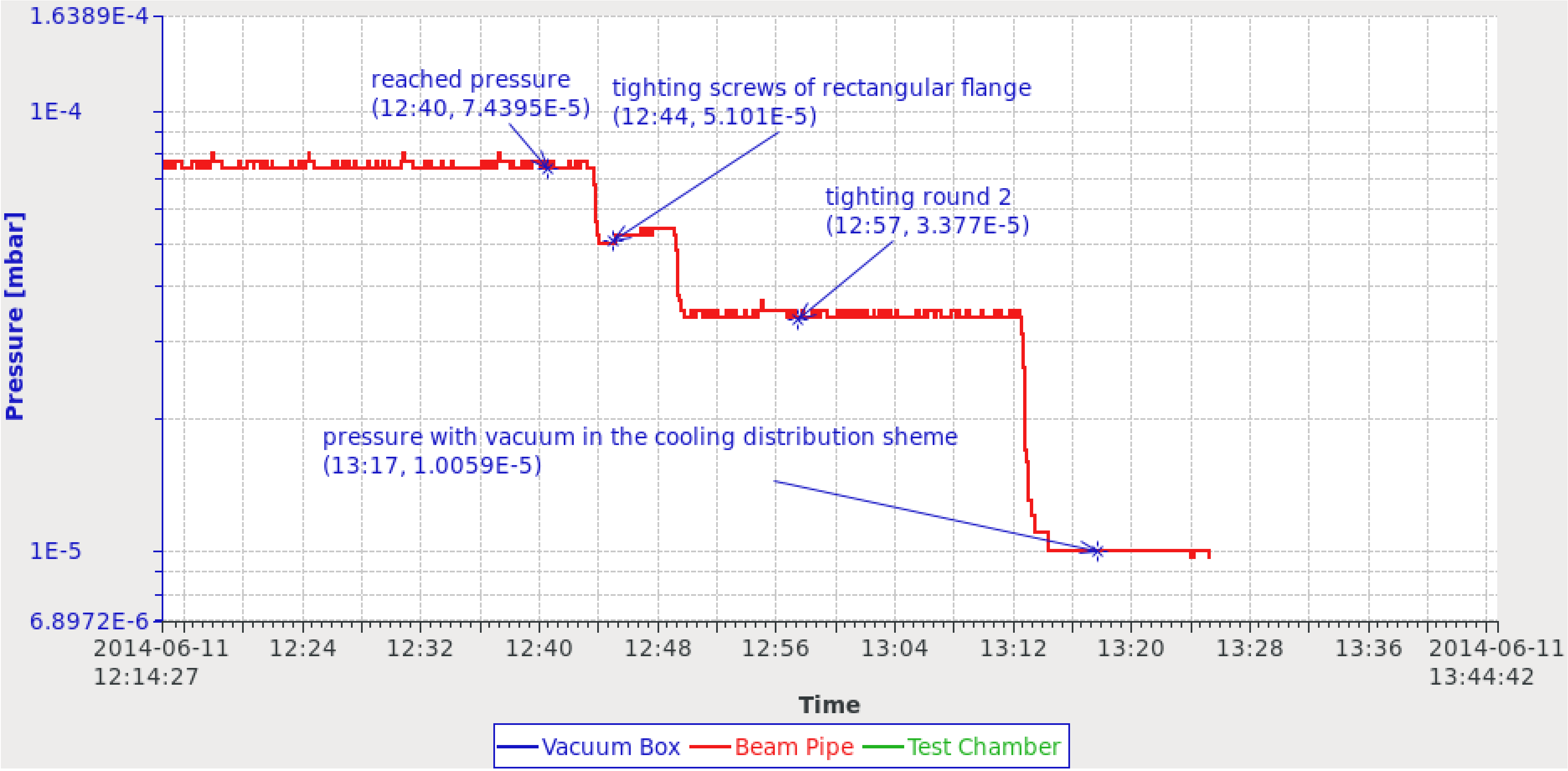
First Pumping Tests



First Pumping Tests

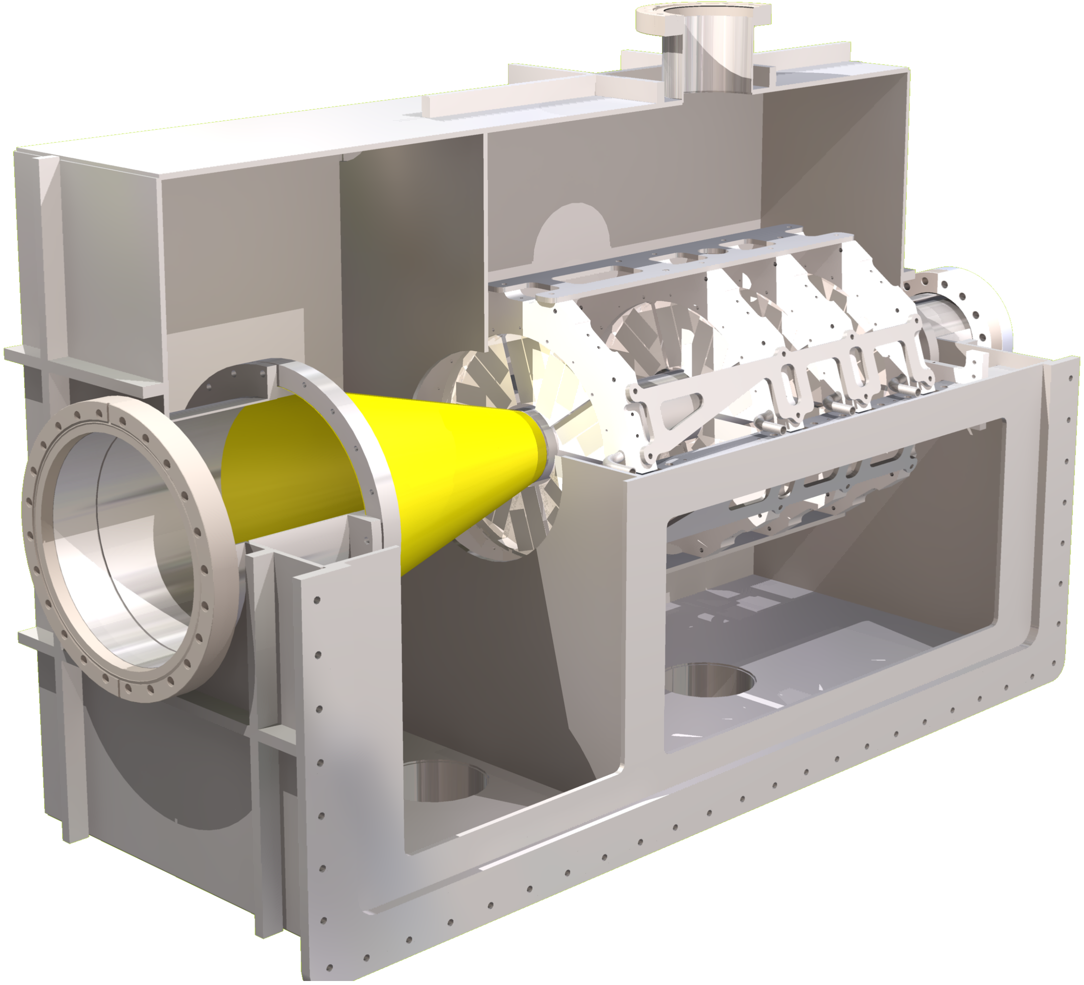


Observations during vacuum tests

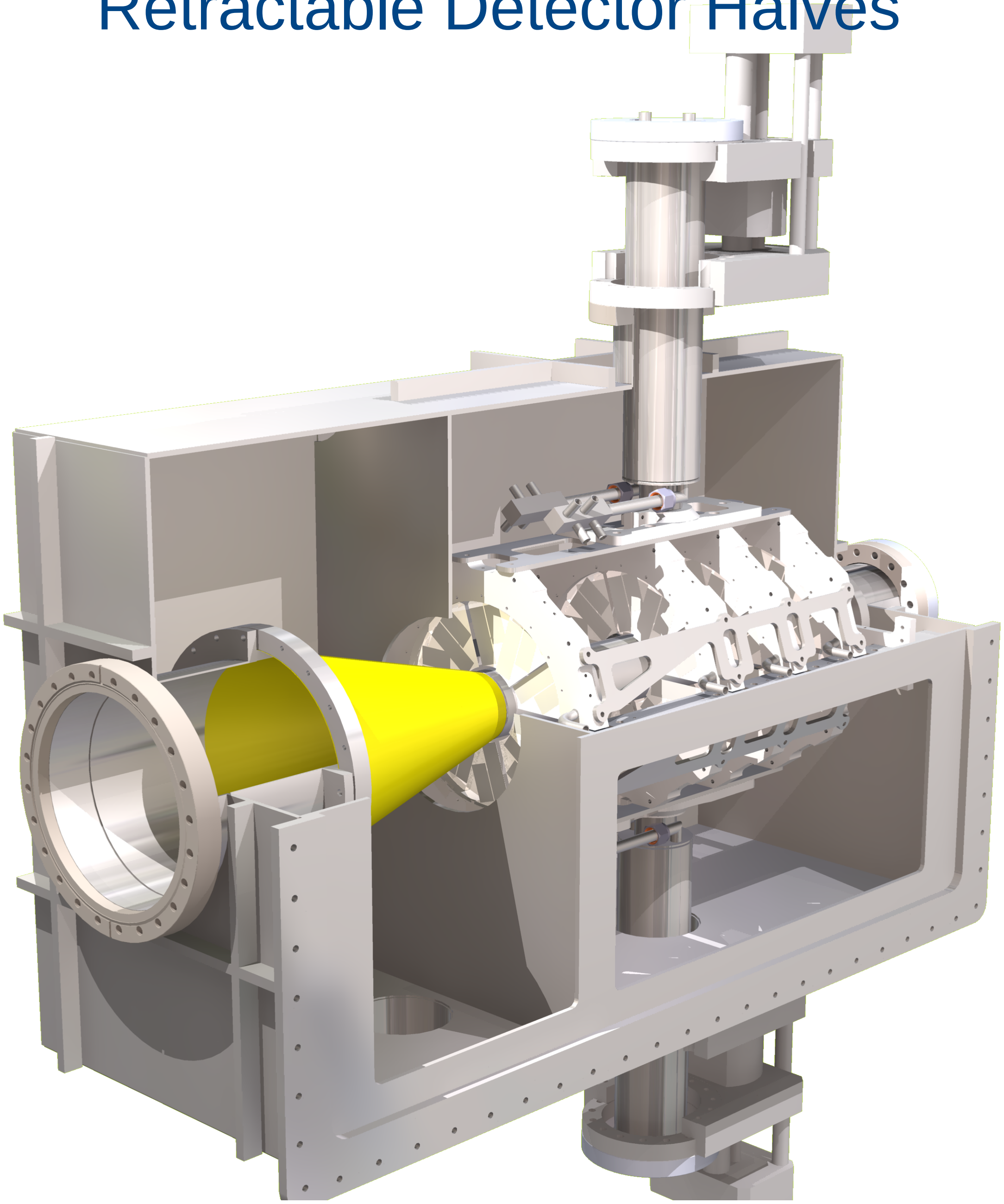


Lessons learned: keep the number of ports and connections as small as possible!
(Not discussed) Permeability of the transition foil is not negligible.

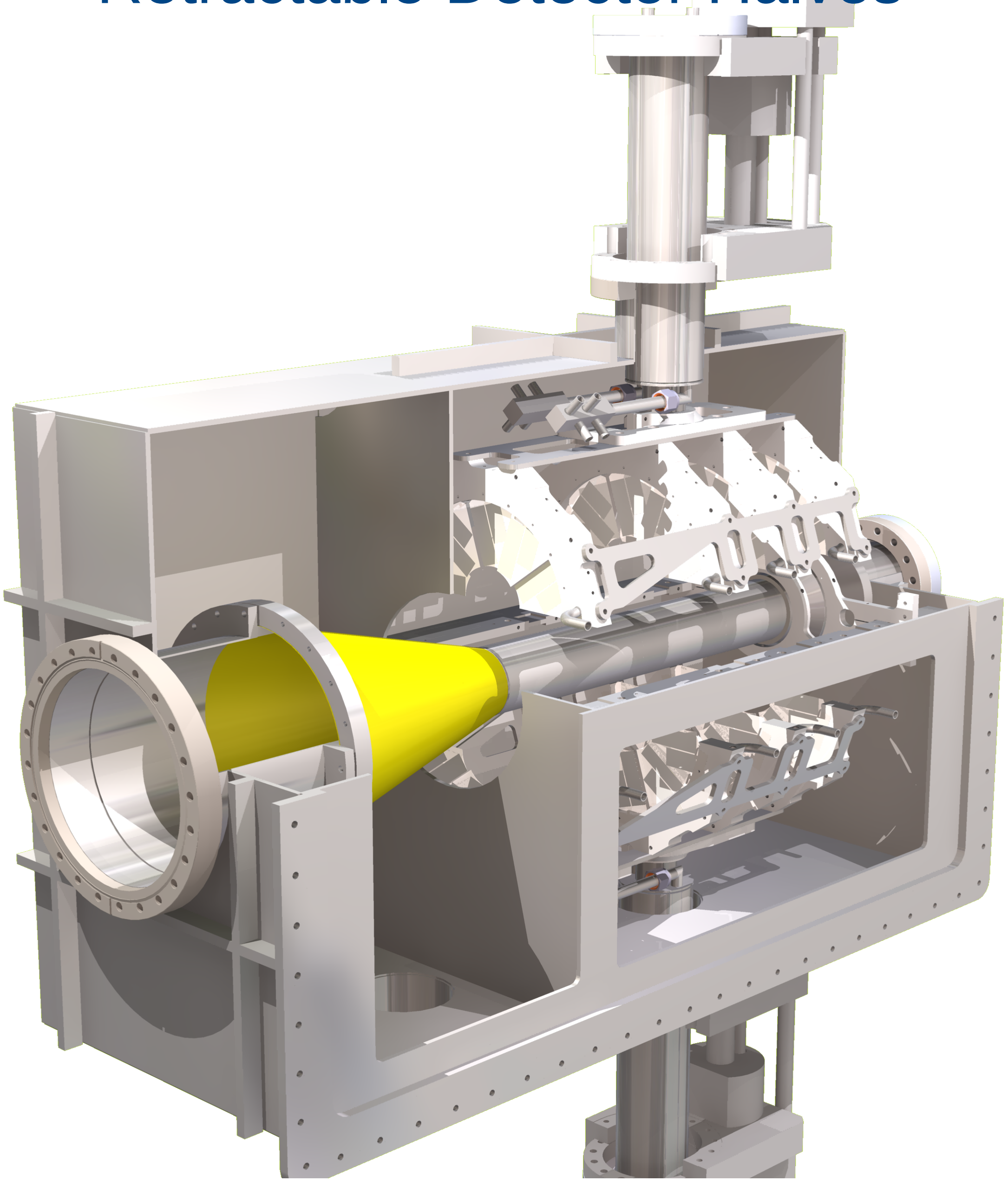
Retractable Detector Halves



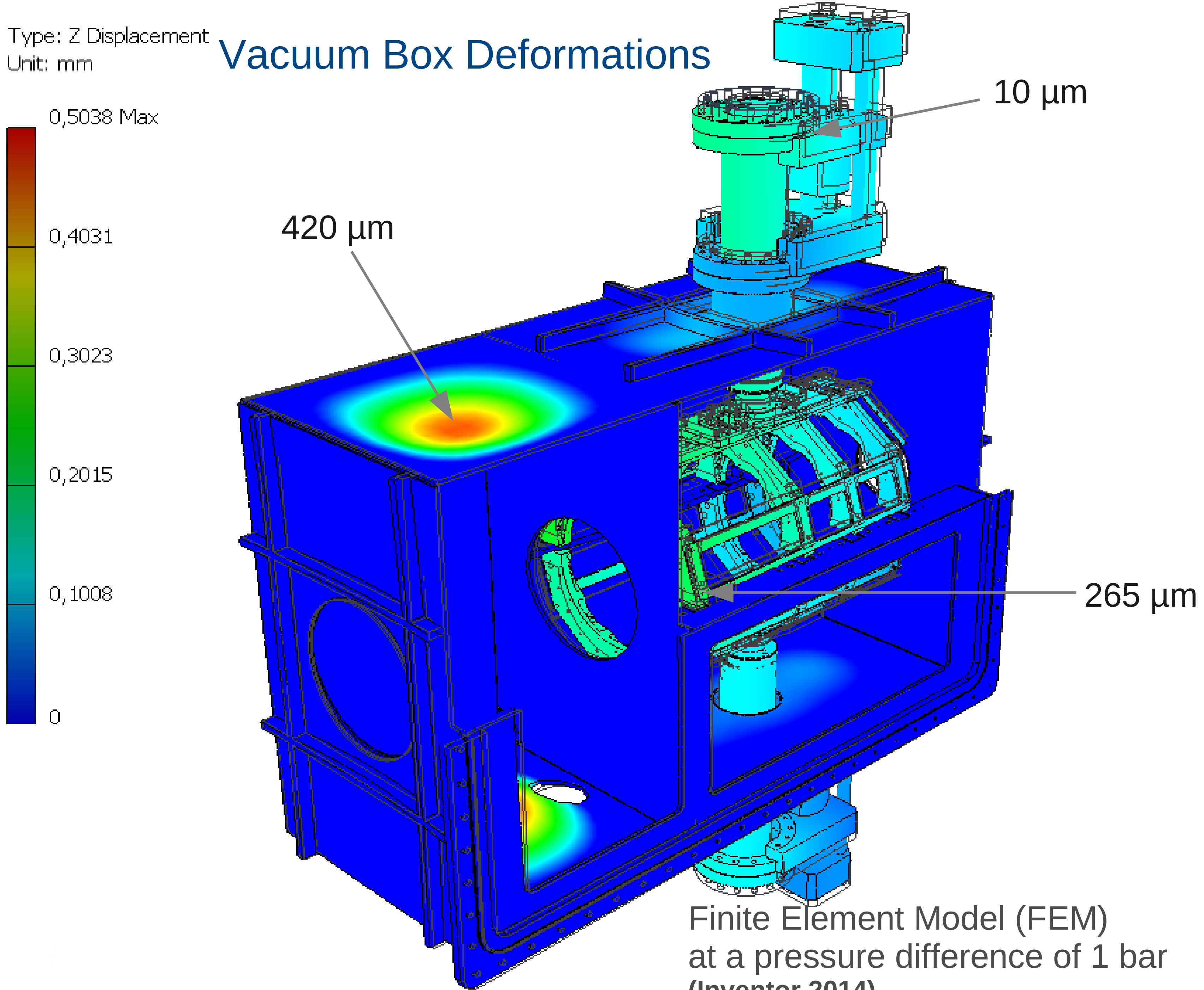
Retractable Detector Halves



Retractable Detector Halves



Vacuum Box Deformations



Finite Element Model (FEM)
at a pressure difference of 1 bar
(Inventor 2014)

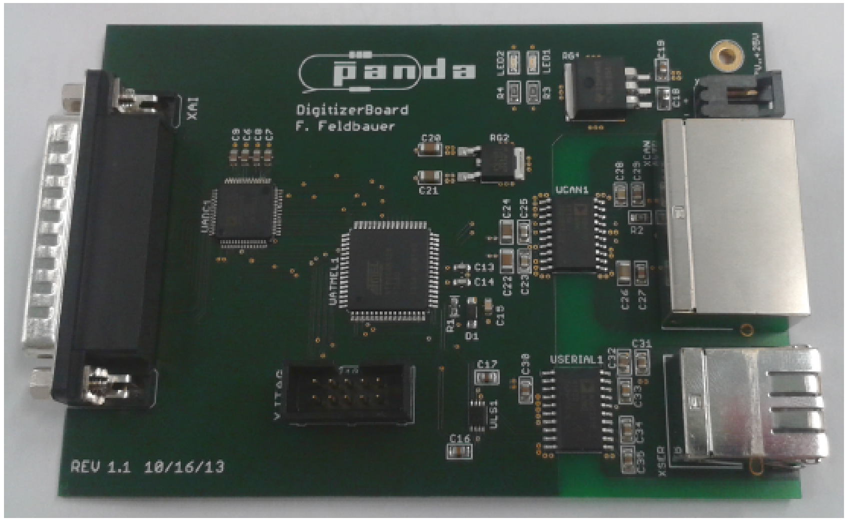
Displacement Measurement in Vacuum

Capacitive probes:
Capacitec 208-ACU

2 mm range ~ 40 nm resolution

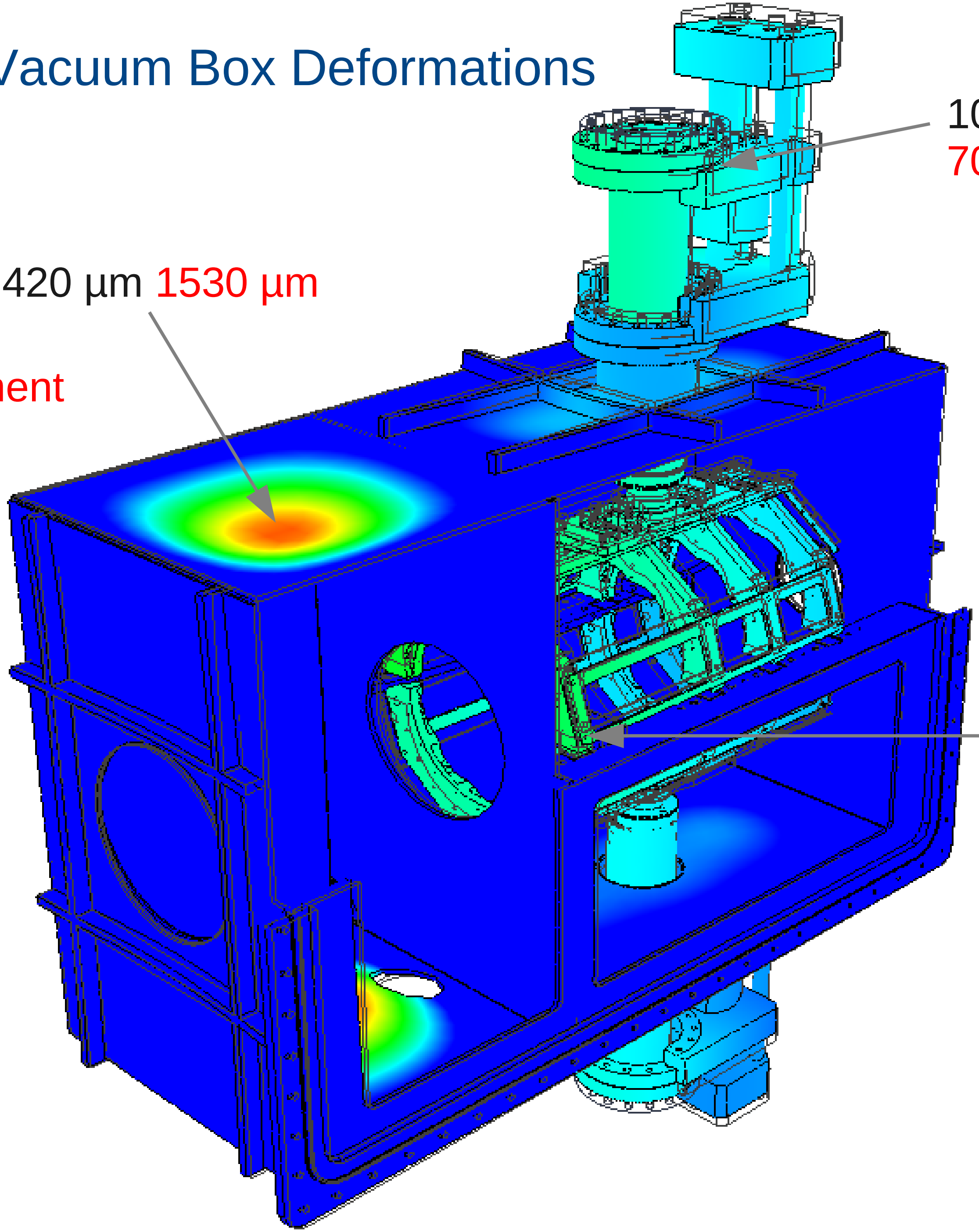
Aquisition via 18-bit differential ADC
and microcontroller with CAN interface

-> final resolution ~(400-500)nm

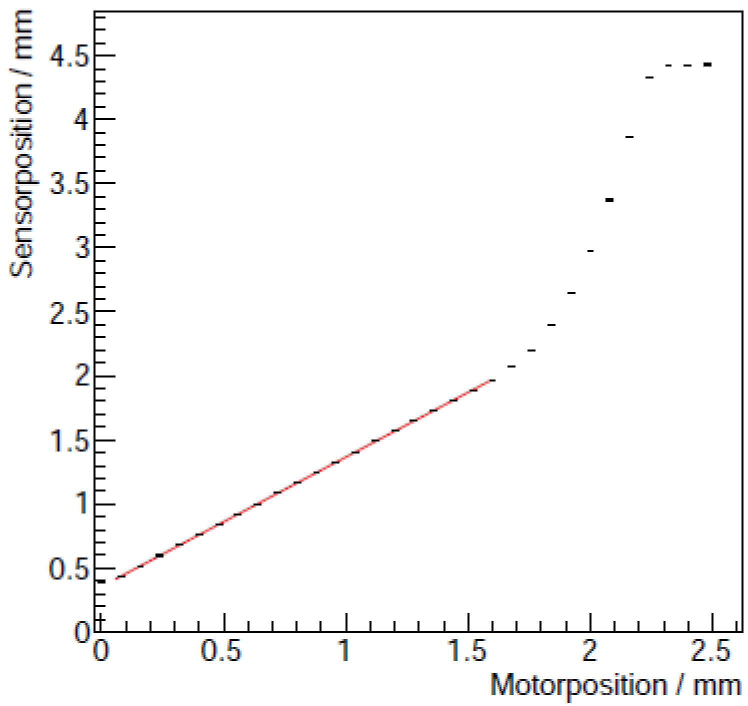


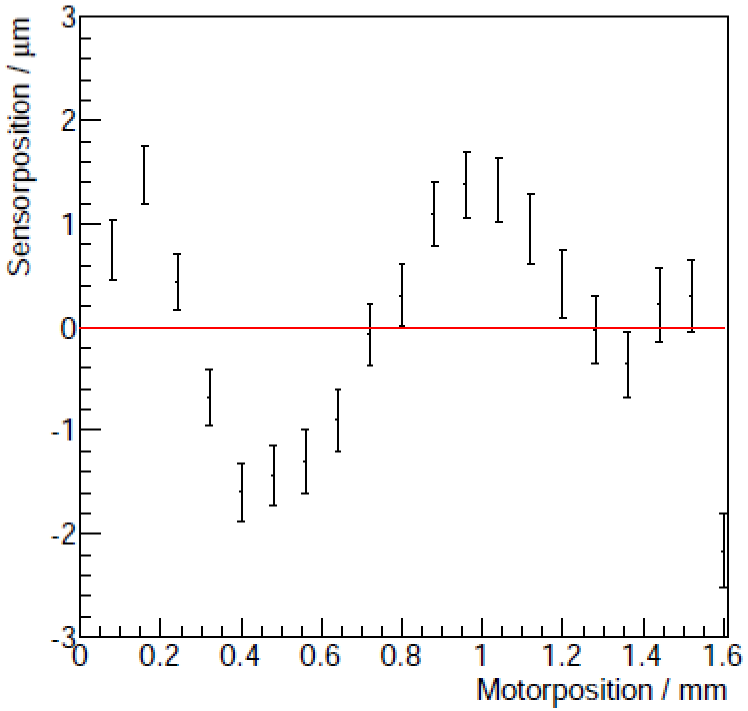
Vacuum Box Deformations

simulation vs measurement



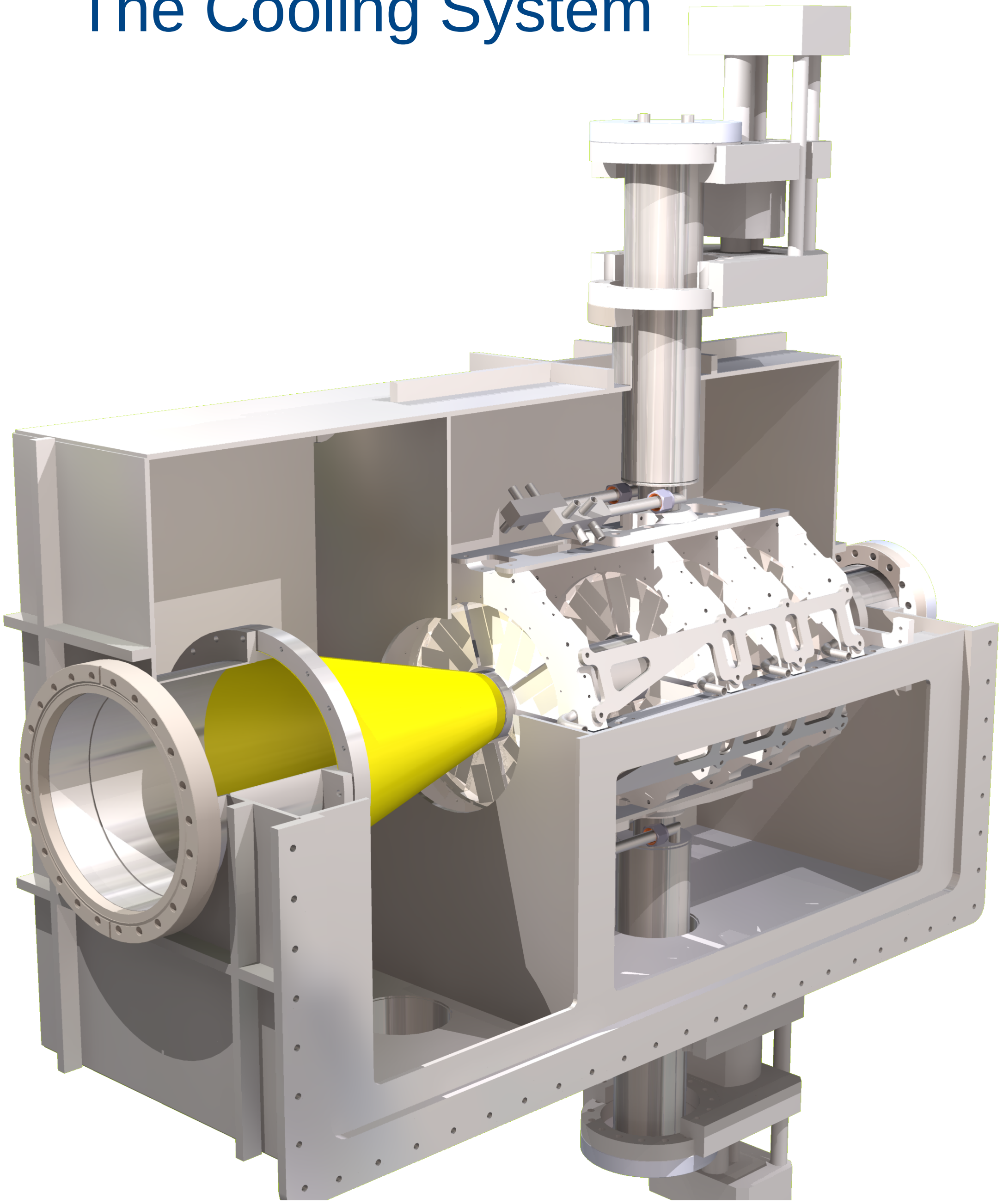
Linearity of the linear shift mechanism





Lesson: High resolution does not necessarily mean a high linearity!

The Cooling System



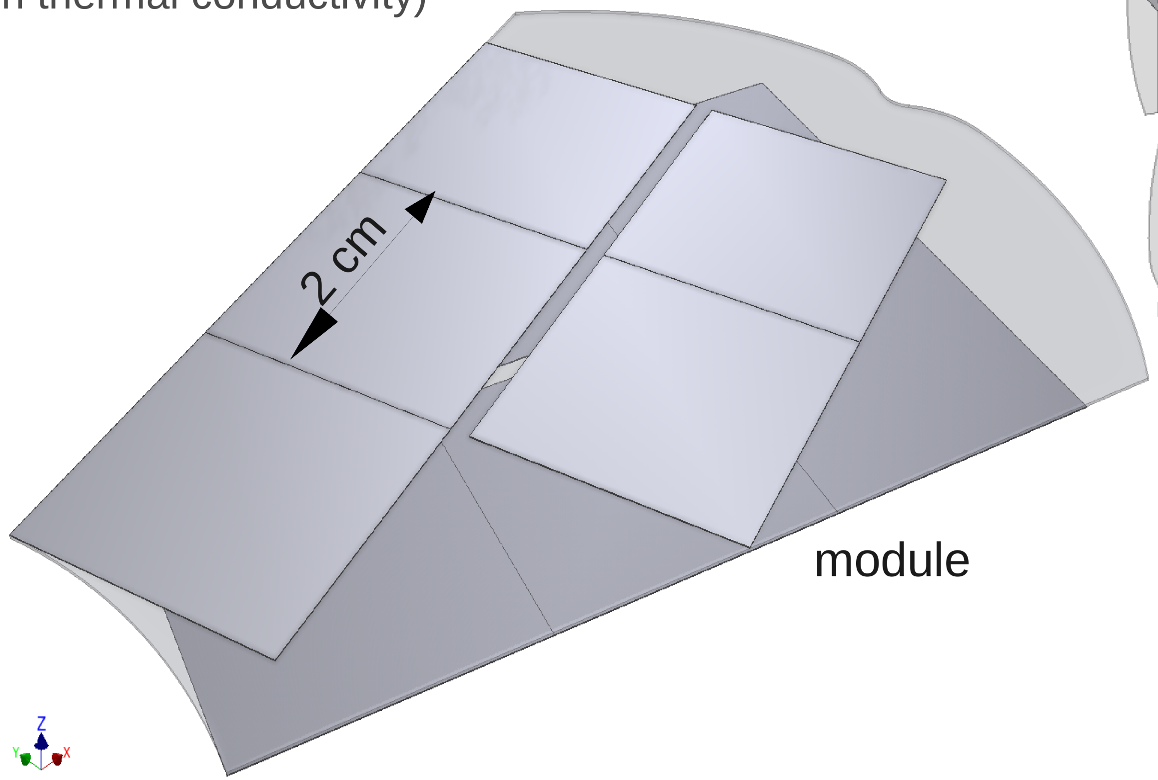
Cooling of HV-MAPS

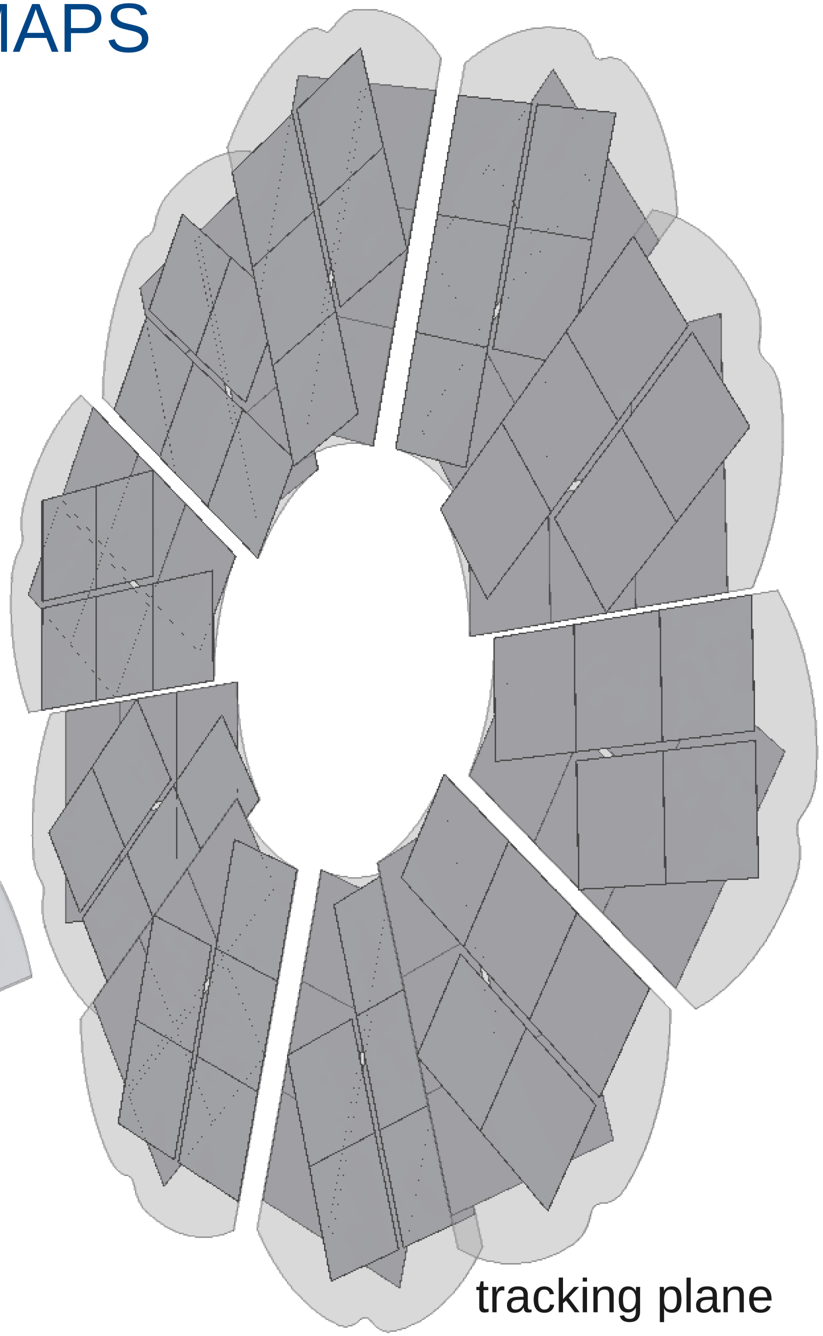
2 x 2 cm² individual HV-MAPS (50 µm)
400 in total

digitization on chip

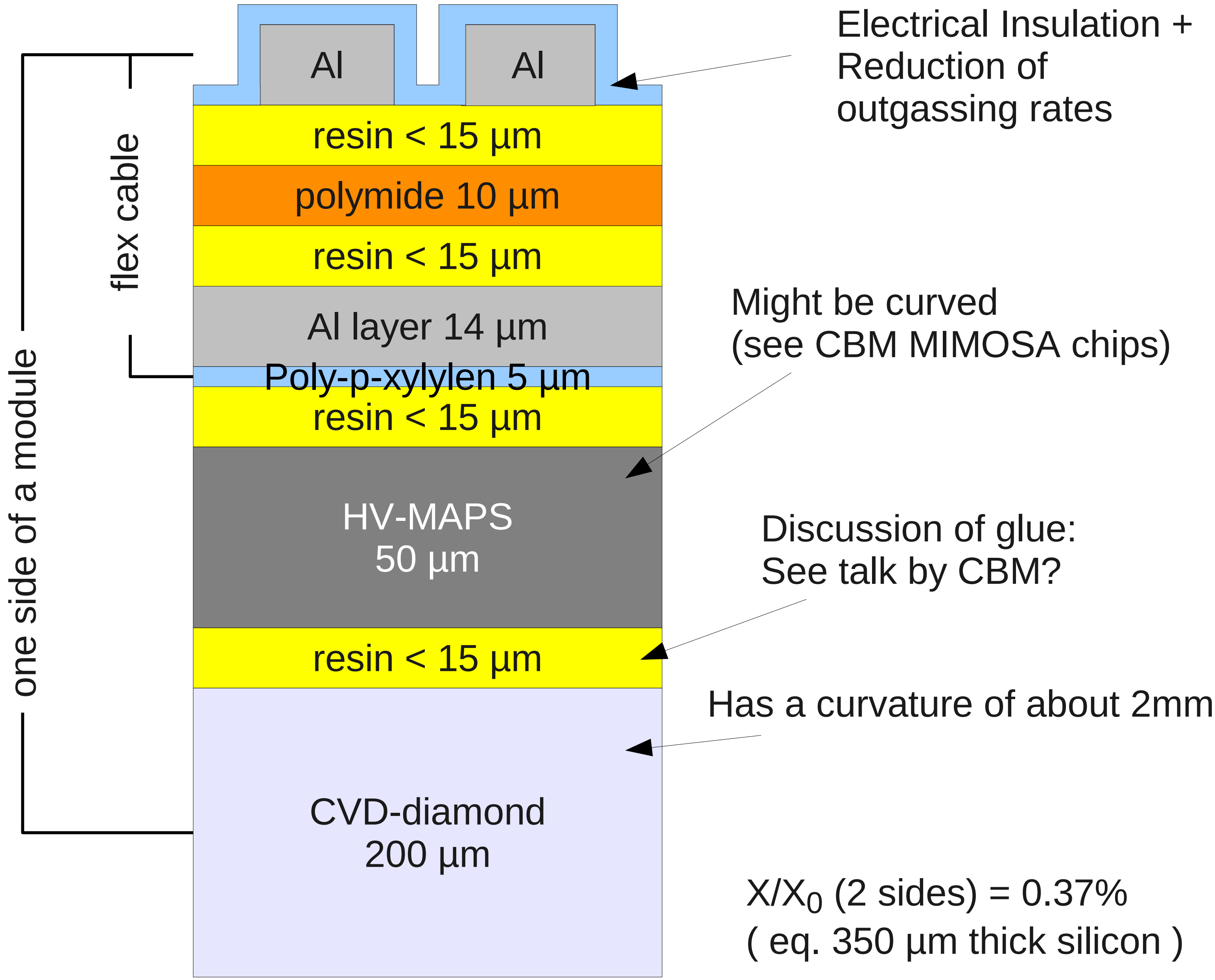
expected power consumption :
2 mW/mm²

glued on a
diamond wafer (200 µm)
(high thermal conductivity)



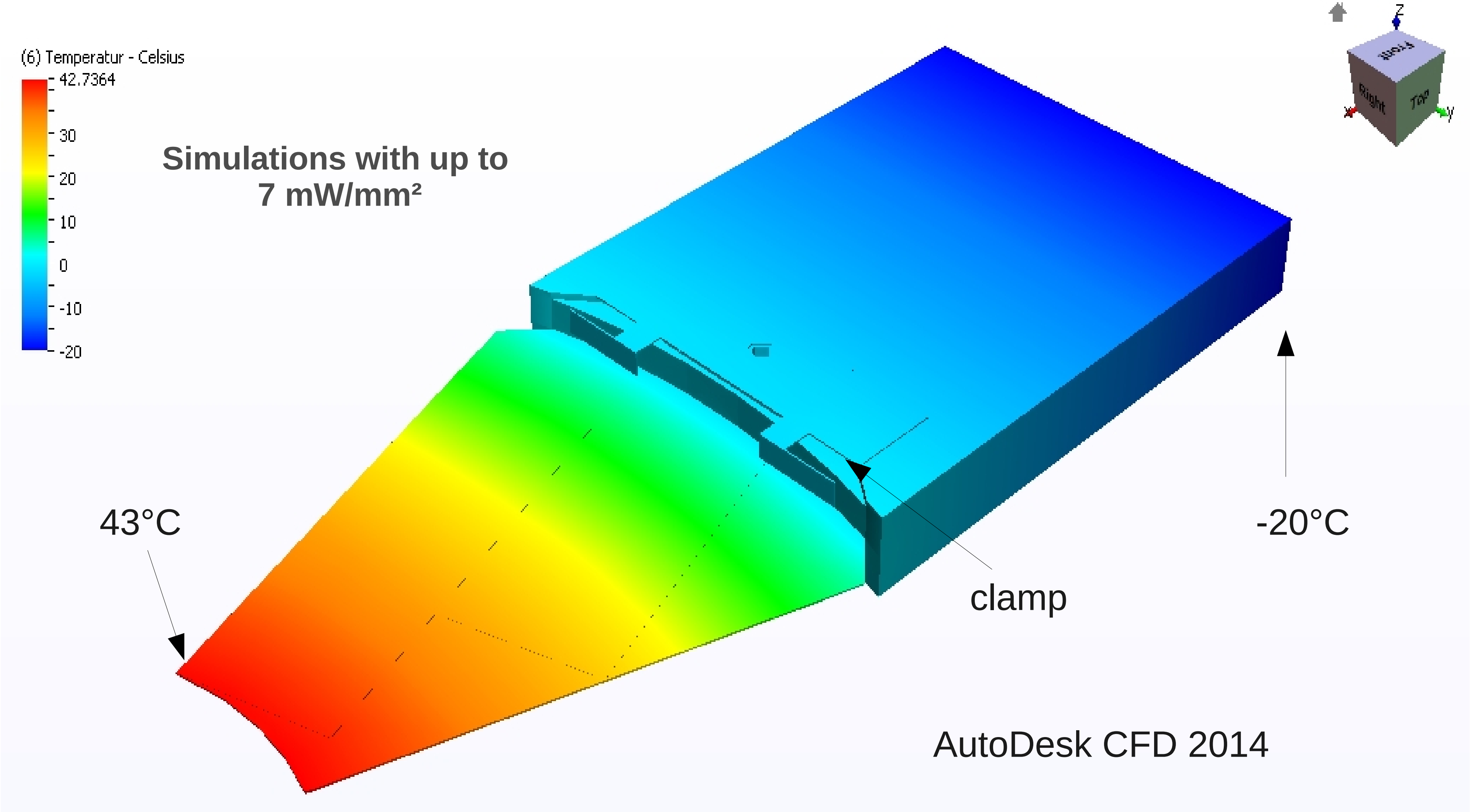


Section through one side of a Plane

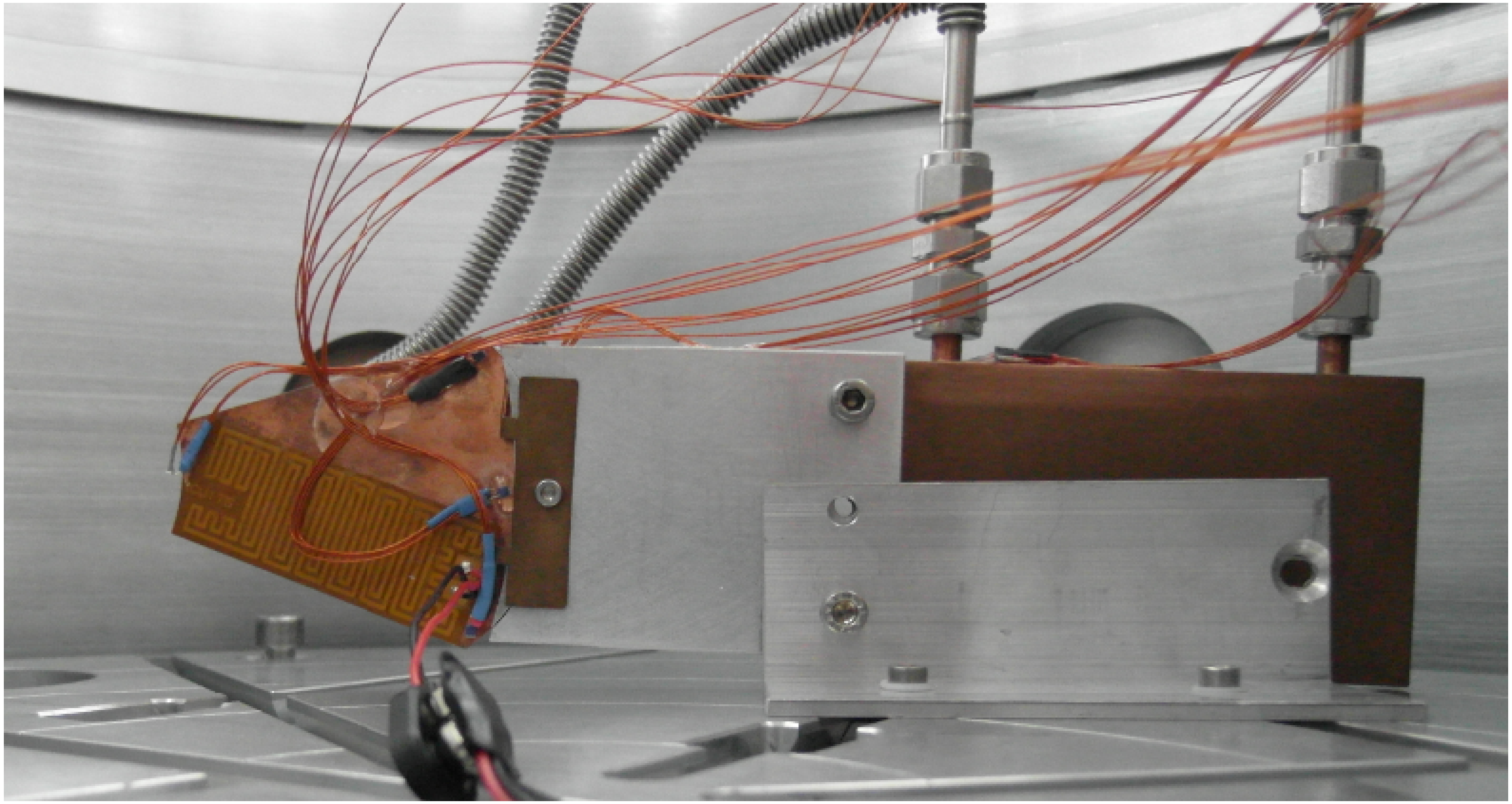


X/X_0 (2 sides) = 0.37%
(eq. 350 µm thick silicon)

Simulations on cooling

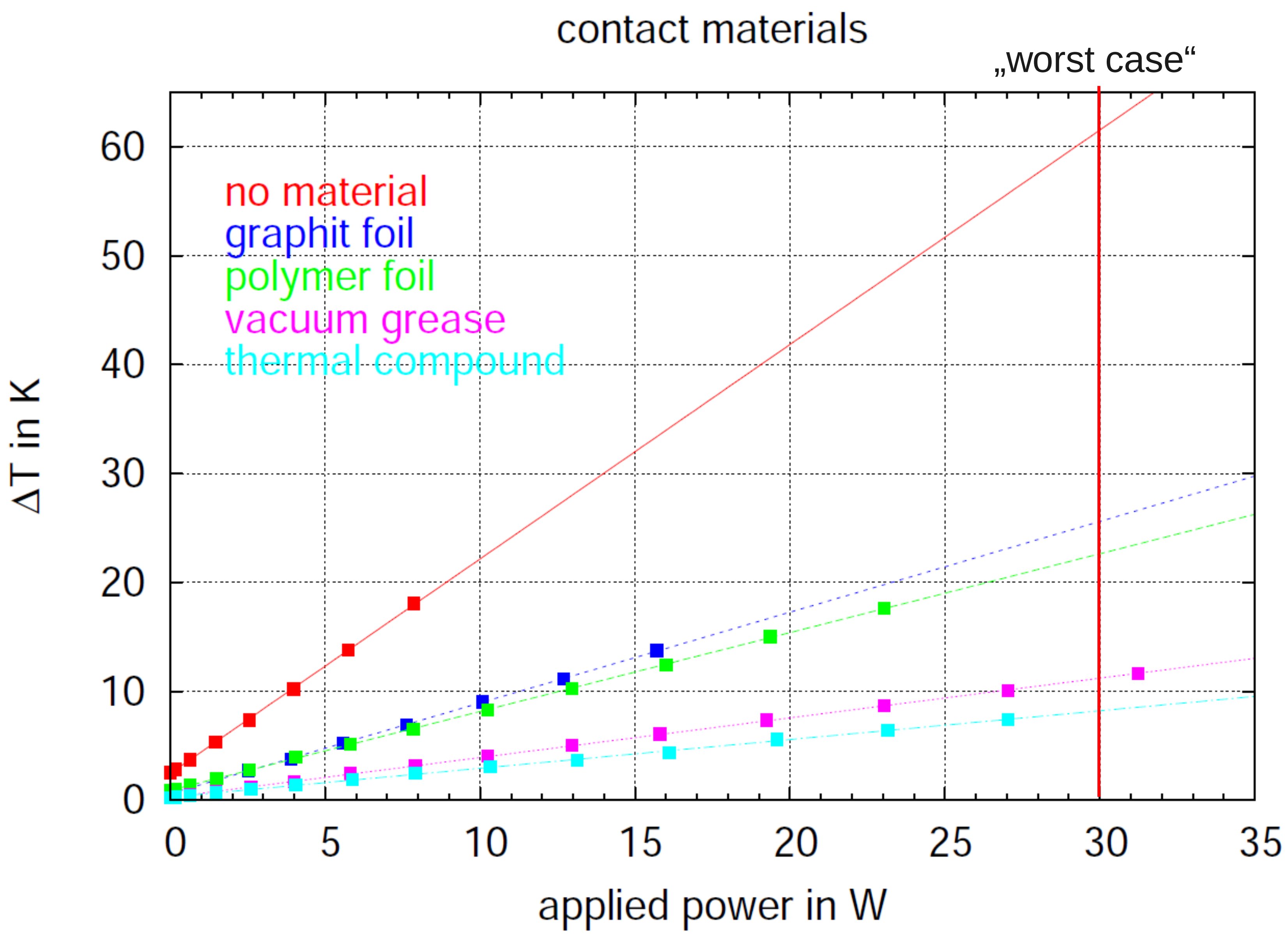


Simulations vs. Reality

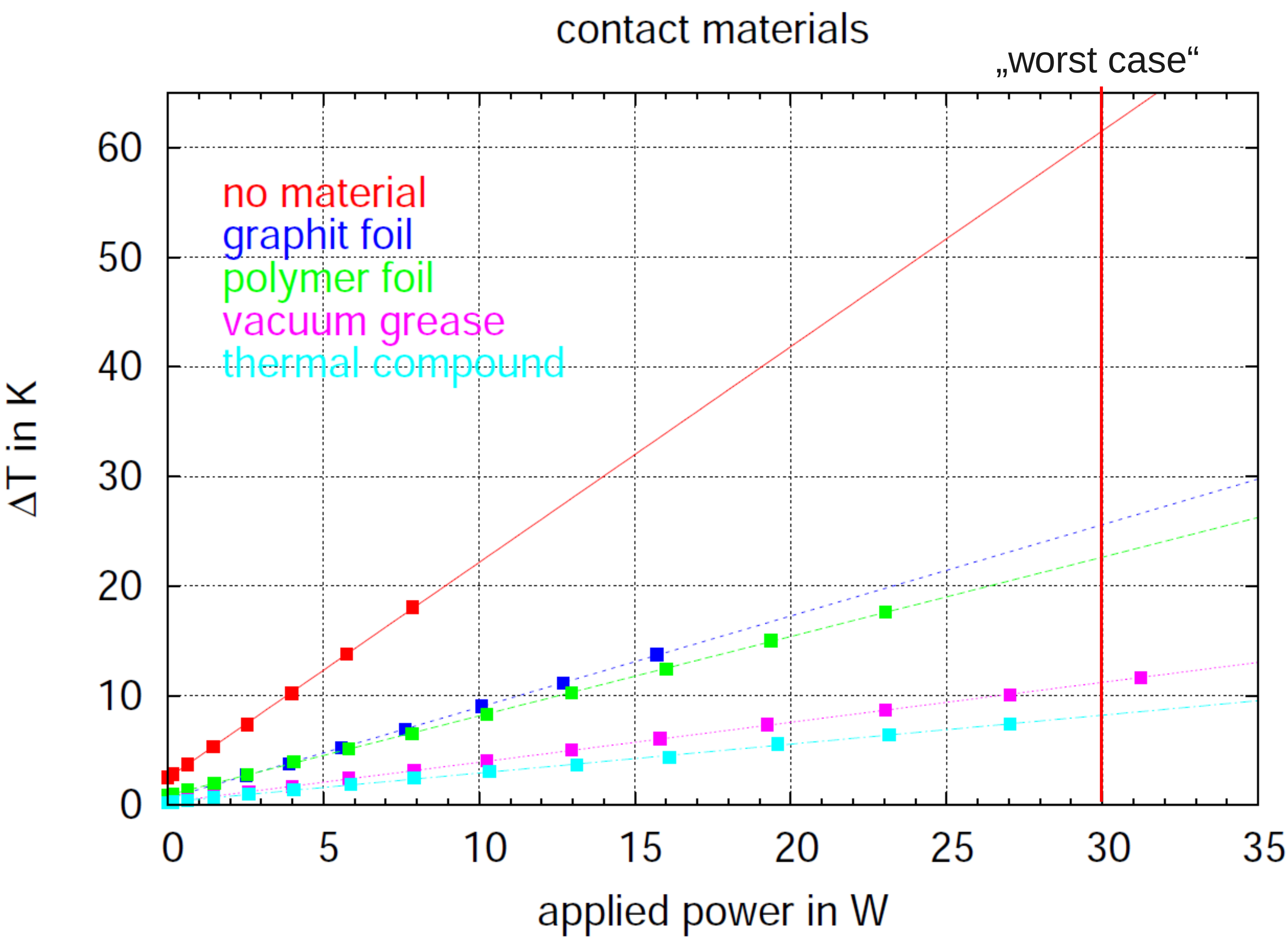


Testing contact materials for the module clamp and a copper dummy

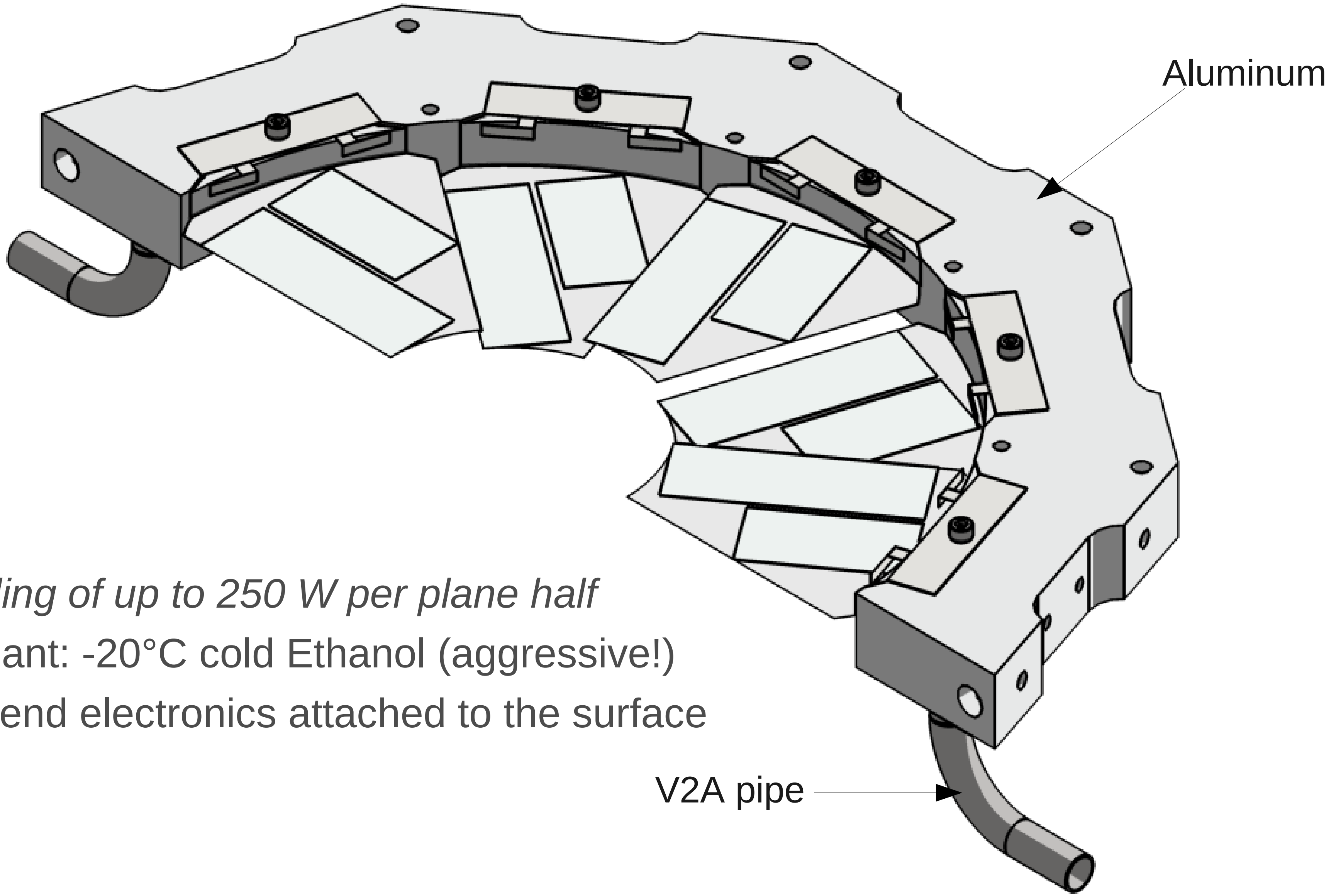
Simulations vs. Reality



Simulations vs. Reality



A Support Structure as a Heat Sink



Cooling of up to 250 W per plane half

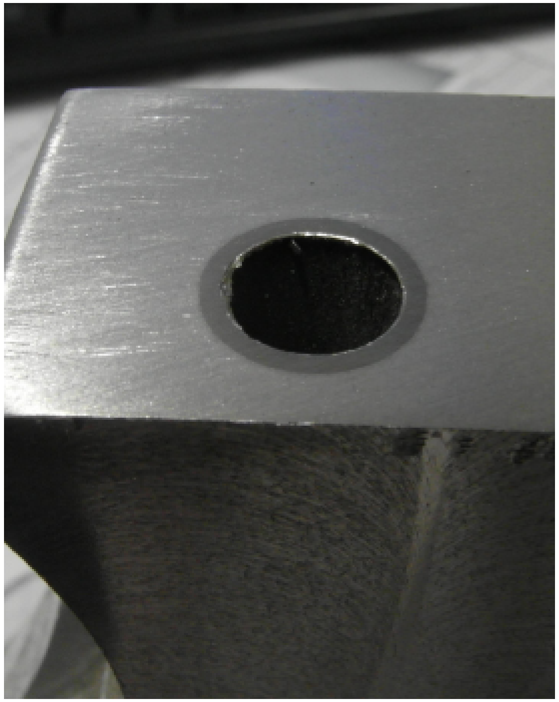
Coolant: -20°C cold Ethanol (aggressive!)

frontend electronics attached to the surface

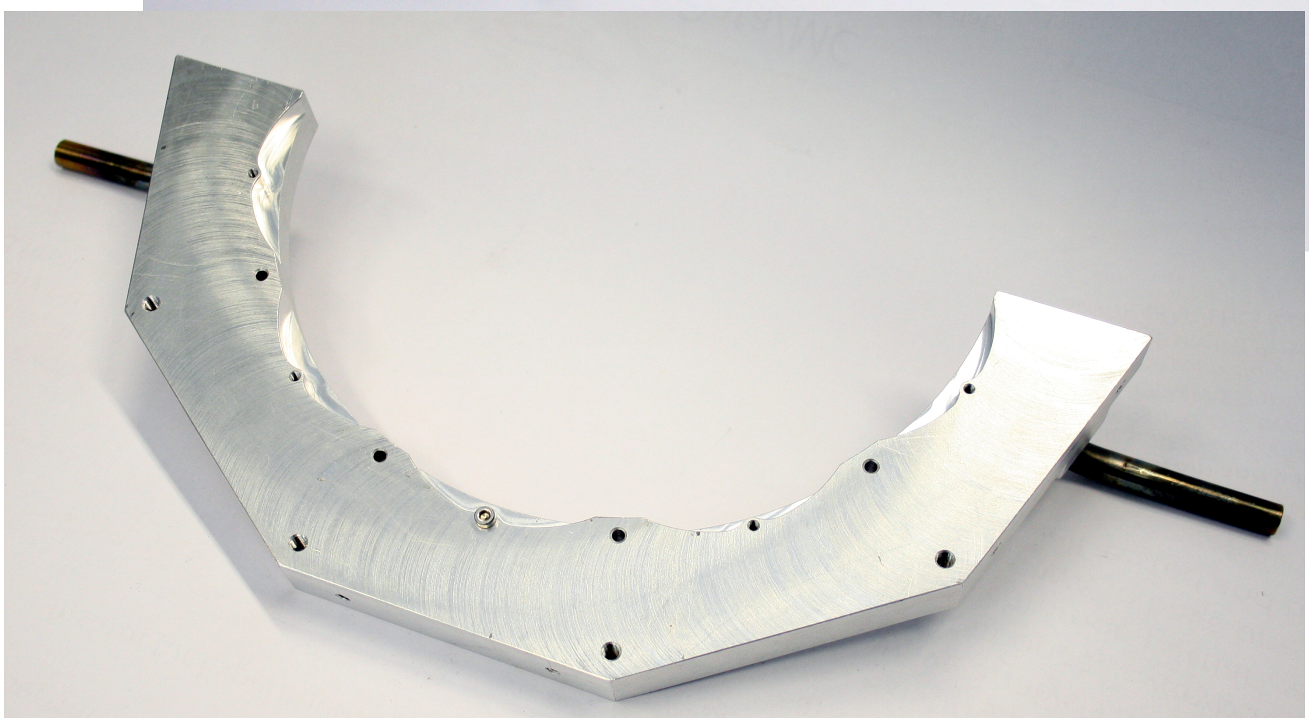
Production of Heat Sink Supports

Original idea: LHCb Velo Detector

melting AlMg4.5Mn alloy for 730°C 90 min in argon atmosphere



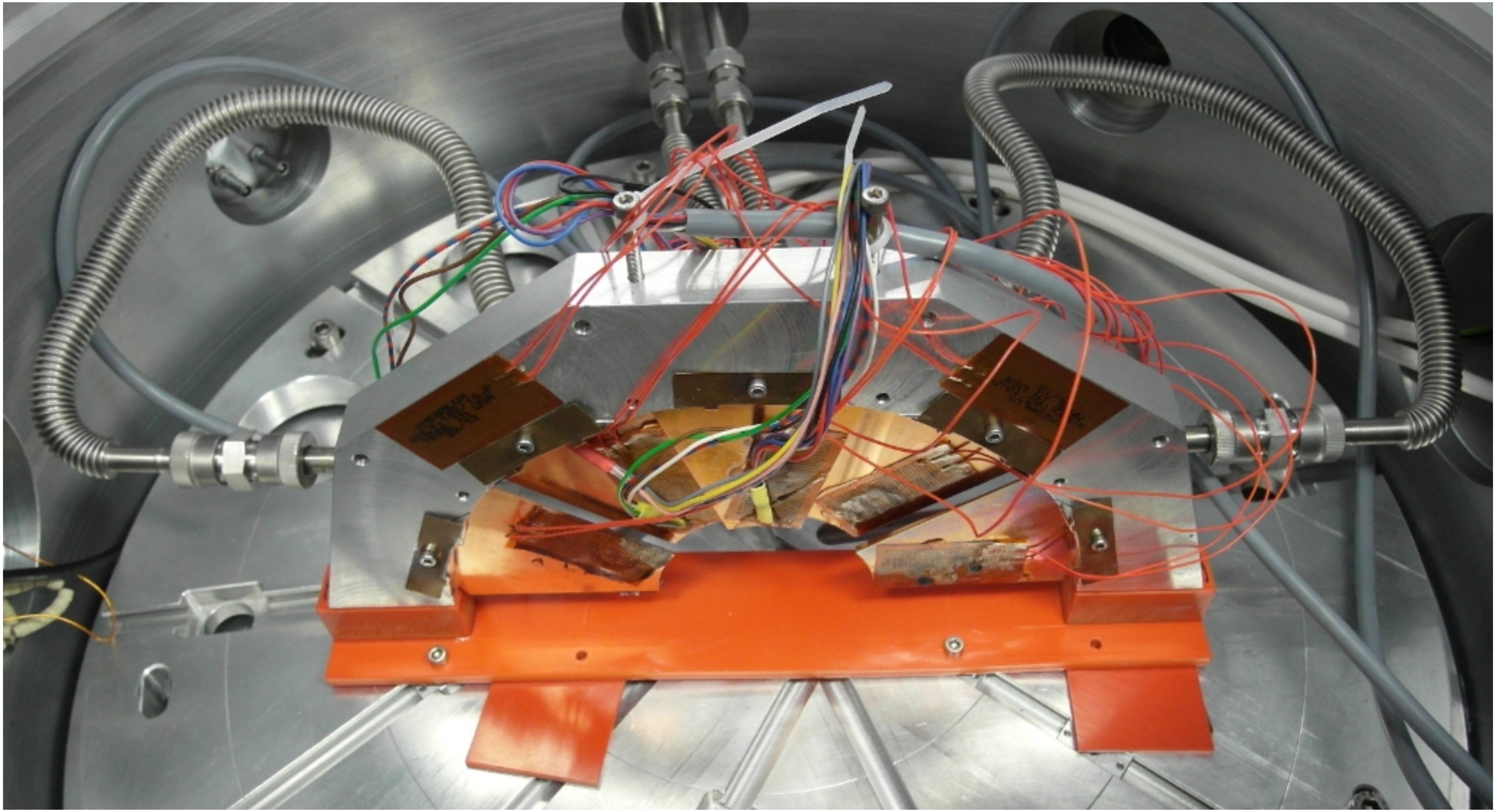
Production of Heat Sink Supports



Complications? Not really,

But challenging
for the workshop!

Temperature uniformity tests



Trapped air bubbles are removed by evacuation procedure prior to coolant fludding.
Observations: Temperature increase by 3° between inlet and outlet without applied loads!
Heat from Radiation? Contact of temperature sensors? Turbulences?

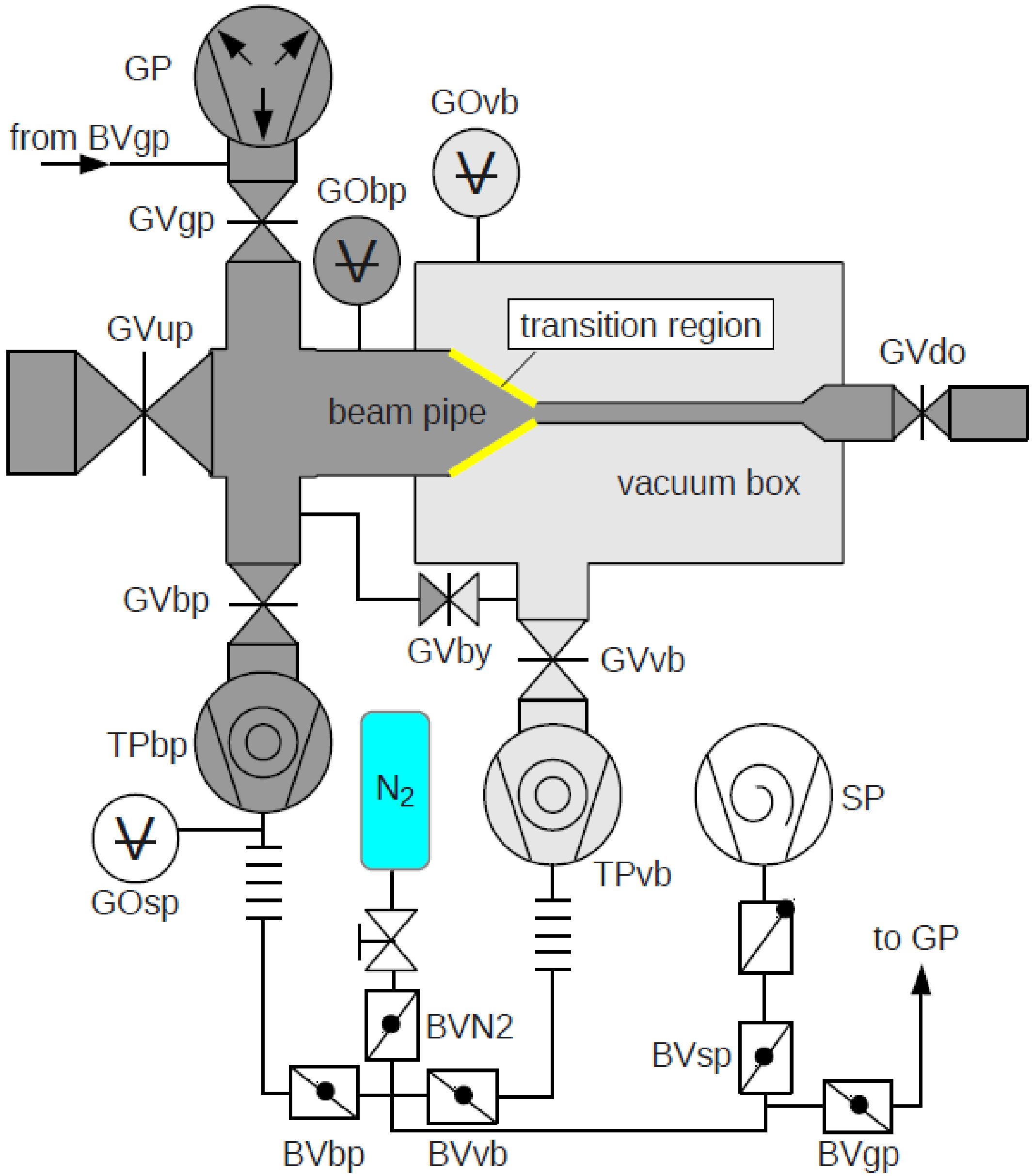
Conclusion

Always perform experimental tests

(specially if you have doubts)

Thank you

Differential Pumping Sheme



Cooling stations for cooling liquids

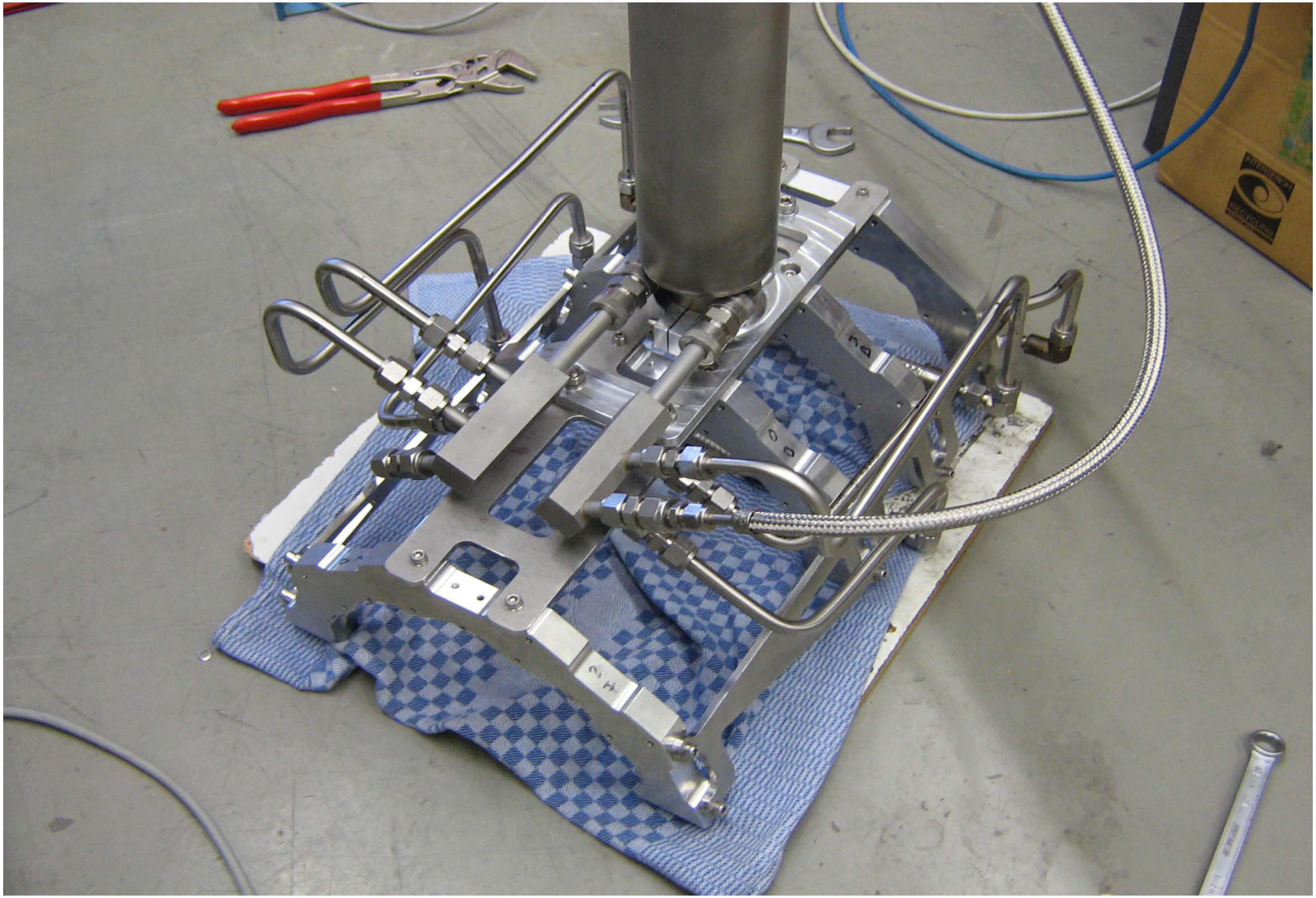
Huber Unistate 425 w

versus

Cooling power @-20°C
1.9 kW 2.2kW
max. pumping speed
105 l/min 45 l/min
max. pumping pressure
2.5 bar(special version) 2.9 bar

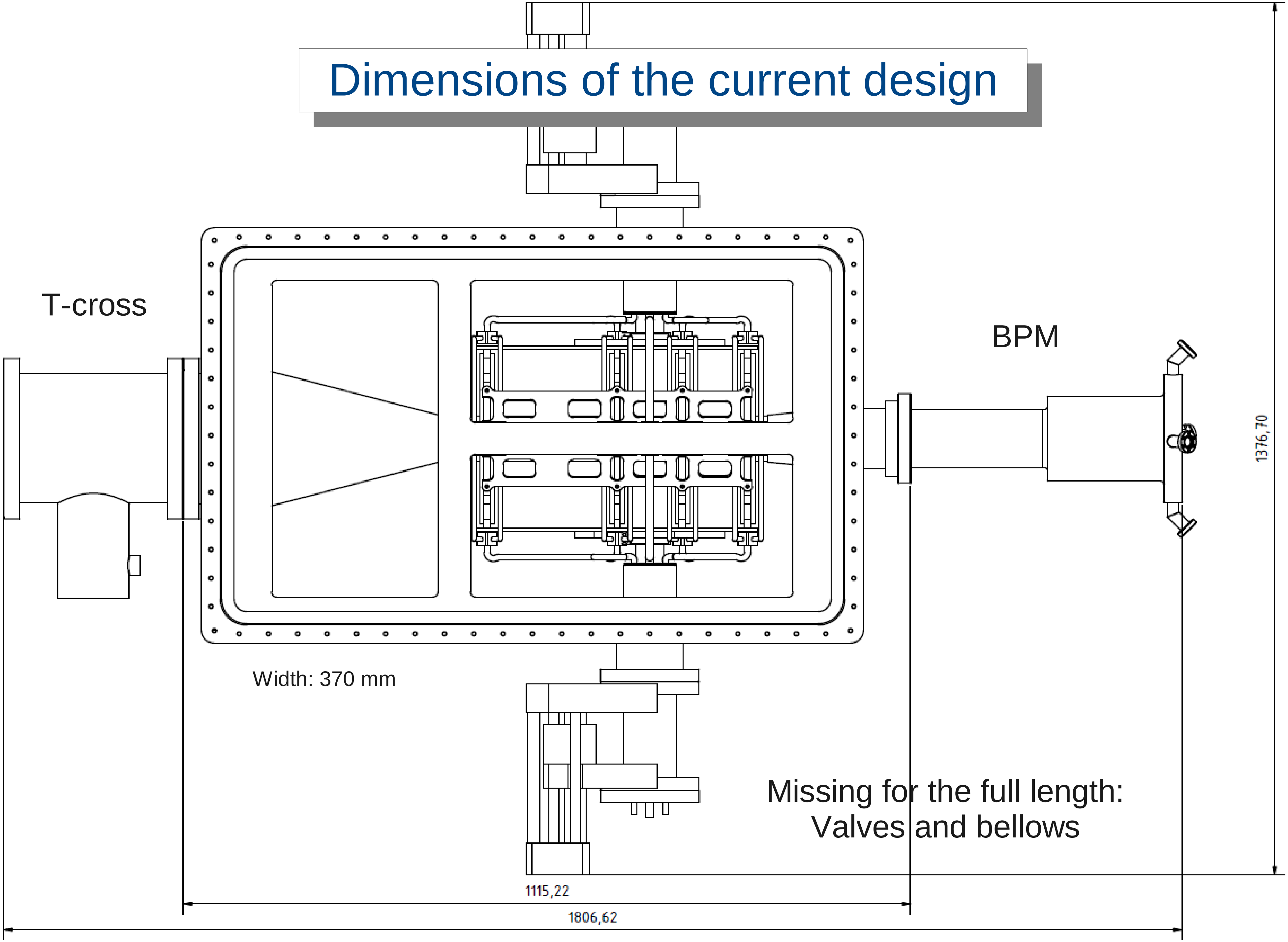
Lauda XT 550 (W)

Setting up a distributed cooling circuit

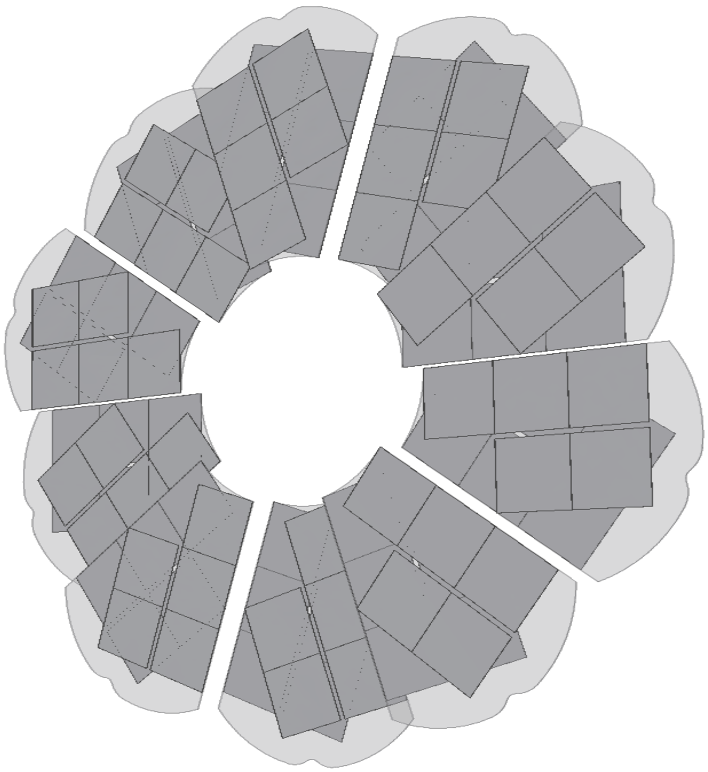


Testing the tightness with 4 bar overpressure (argon)

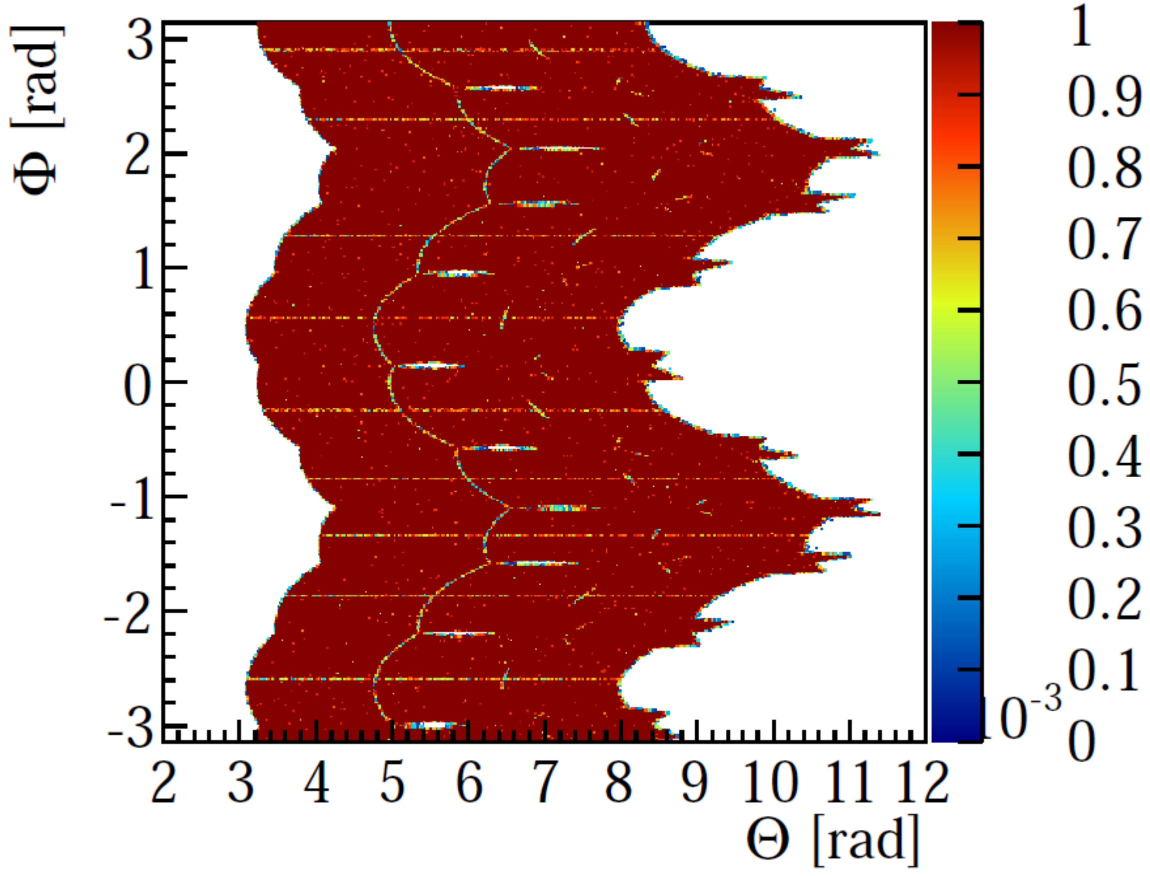
Dimensions of the current design



Geometrical Acceptance



Acceptance at 1.5 GeV/c beam momentum



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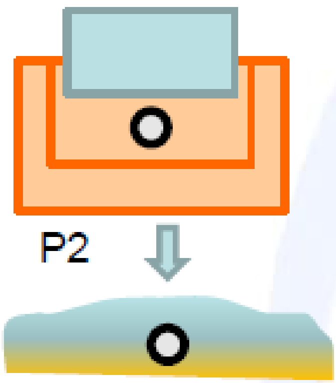
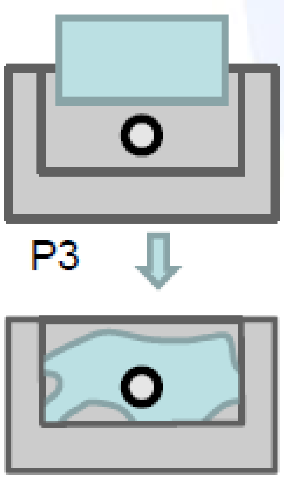
The biggest fun we had: *"Baking cookies"*

Welding tube inside



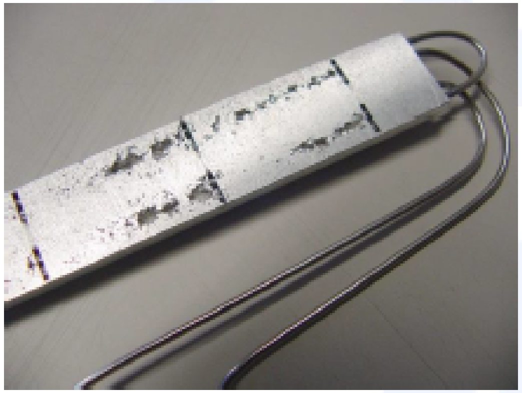
Melting in a copper mold



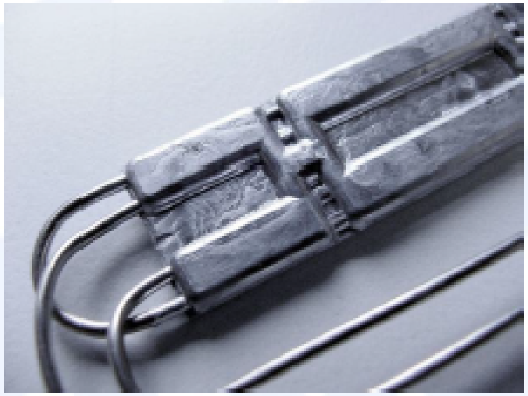
Melting in a SS mold with inert gas

- Question was: Can we melt aluminum cooling blocks around a stainless steel pipe?
  - As Aluminum crimps more we must get a nice crimp contact though?

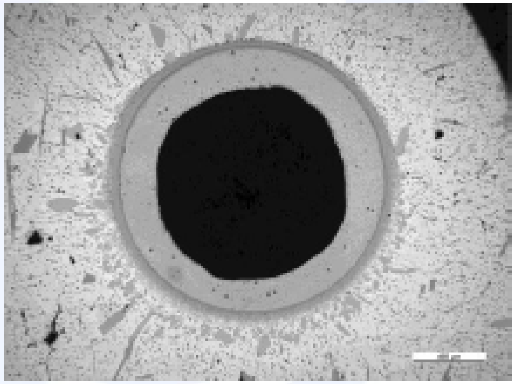
Prototype 4: Mg vapor bubbles due to vacuum



Prototype 5: Vacuum melting / pressurized freezing.. Perfect!



Applied vacuum method bonded SS to Alu by diffusion of Fe into Al



Result of vacuum baking:
A: Perfect contact around the pipe, B: perfect contra shape of the mold

- Aluminum cookie recipe:
  - Take a stainless steel tin and fill with aluminum blocks or bars (AlMg4,5Mn)
  - Melt aluminum under vacuum <1e-3 mbar at 700°C for 1.5 hour
  - Apply 1 bar Argon pressure for 10 minutes
  - Switch of oven and let cool down.
  - Remove cookies from the mold and machine

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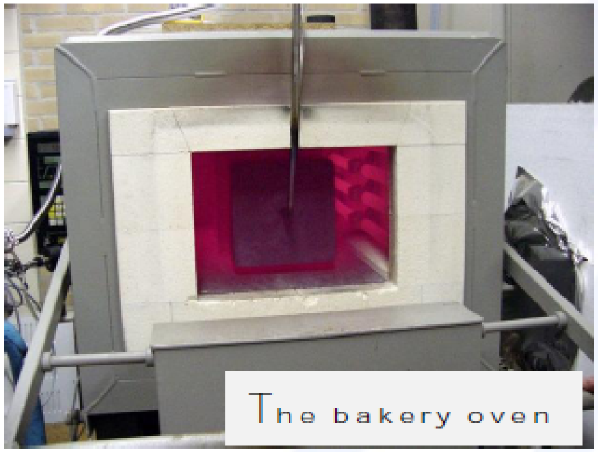
"The cookie bakery"

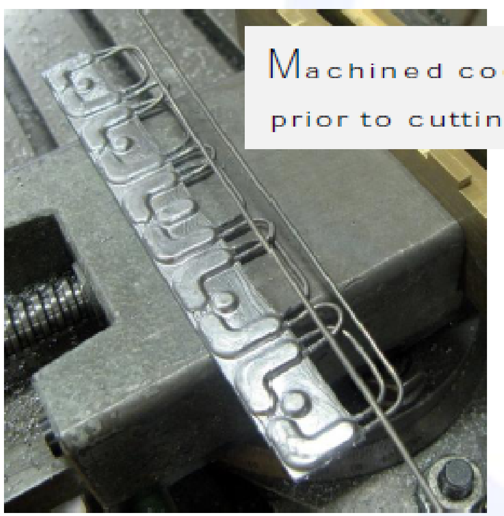


The bakery oven

Serial production baking

A bare cake

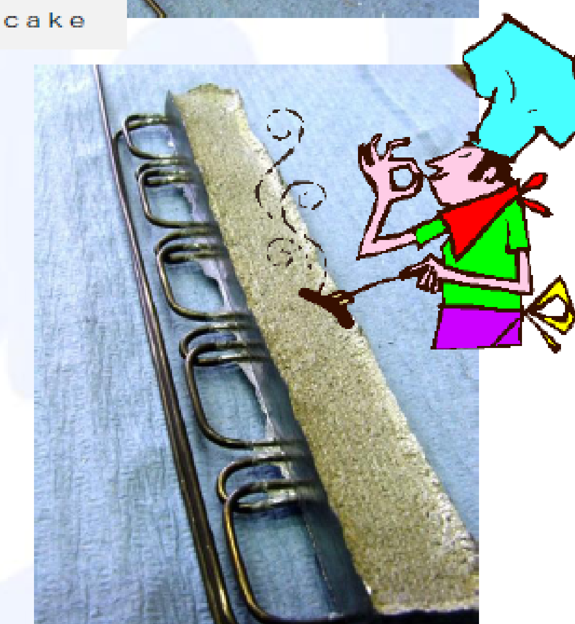
A sliced cake



Machined cookie prior to cutting

Tube bend jig

Mold detail



A delicious aluminum cake!

Magic pen to stop "super fluid aluminum"

First Pumping Tests