



# Development and first measurements of a 4-rod-RFQ with dipole compensation

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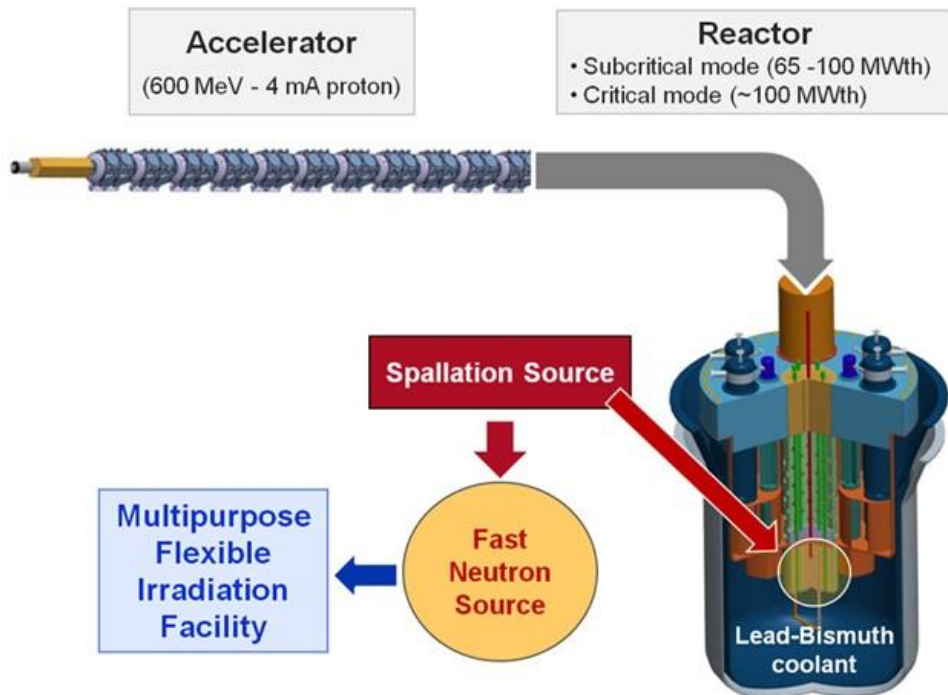
<sup>2</sup>GSI Helmholzzentrum, Darmstadt

<sup>3</sup>NTG Neue Technologien GmbH und Co KG, Gelnhausen

May 17th 2018



## The MYRRHA Project



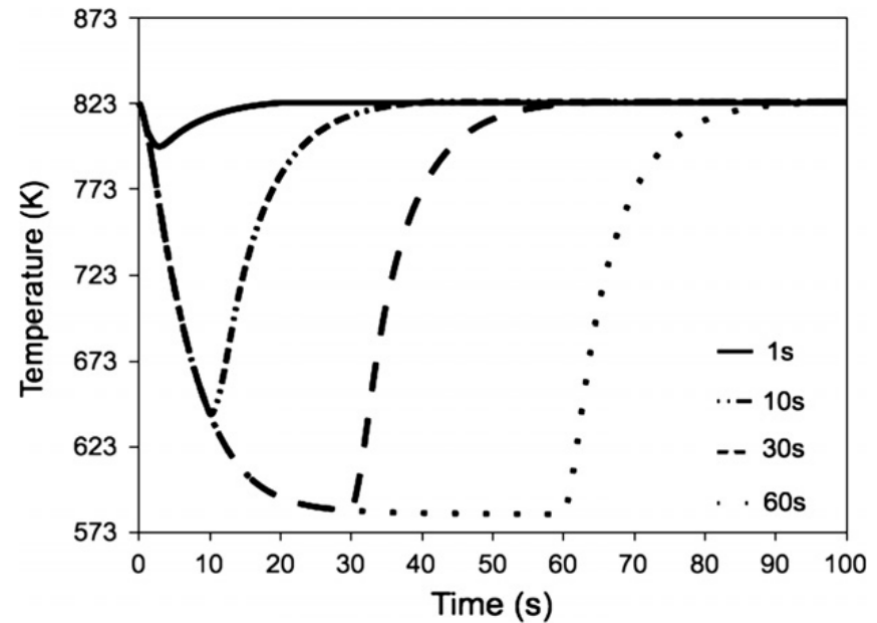
particles	protons	N/A
energy	600	MeV
current	4	mA
beam power	2.4	MW
duty factor	100	%
beam stability	energy $\pm 1\%$ , current $\pm 2\%$ position $\pm 10\%$ , size $\pm 10\%$	N/A
MTBF	250	h

The MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications) Project is a planned accelerator driven system (ADS) which aims to demonstrate the feasibility of large scale transmutation.



„...number of beam trips longer than 3 s remains under 10 during a 3-months operational period of the Myrrha reactor...“ [1]

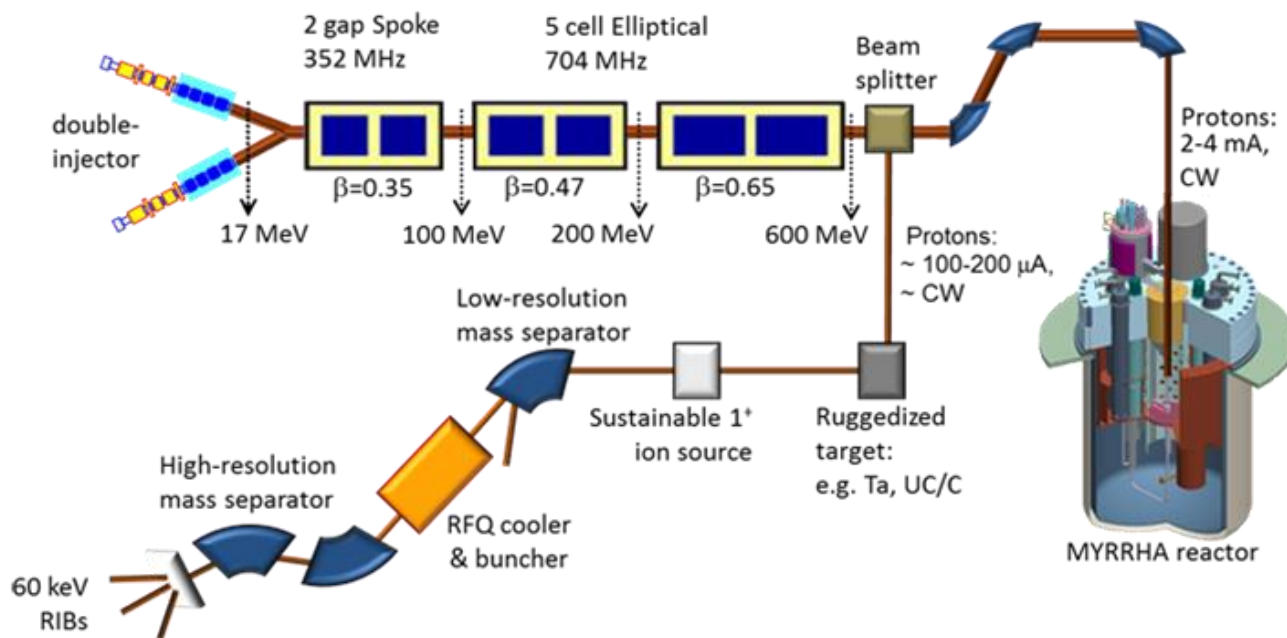
- use of components far from their limits
- redundancy (parallel, serial)
- repairability



[1] D. Vandeplasse, J.-L. Biarrotte, H. Klein, H. Podlech, „The MYRRHA Linear Accelerator“, in *Proc. 2nd International Particle Accelerator Conf. (IPAC11)*, San Sebastian, Spain, Sep. 2011, paper WEPS090, pp. 2718-2720



## The MYRRHA Project

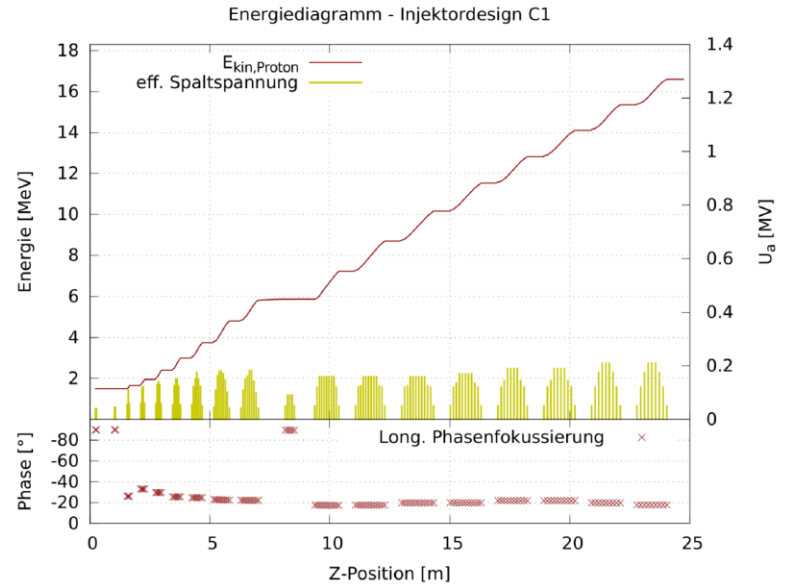


- Parallel redundancy in injector section
- Serial redundancy in sc section

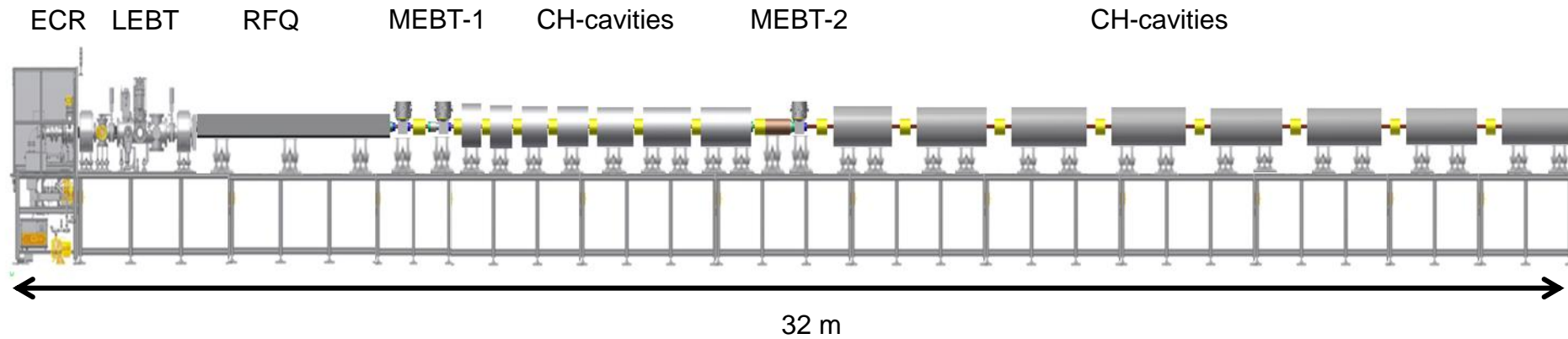


# The MYRRHA Injector

Beam dynamics of the injector  
with constant phase CH cavities.



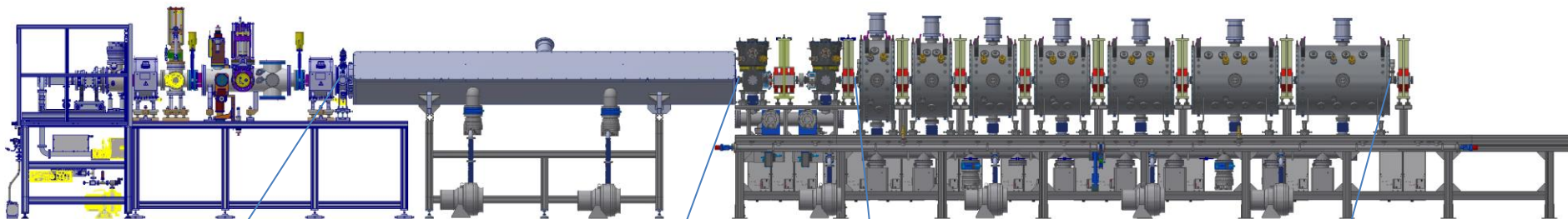
**Design philosophy: As conservative a necessary, as efficient as possible**



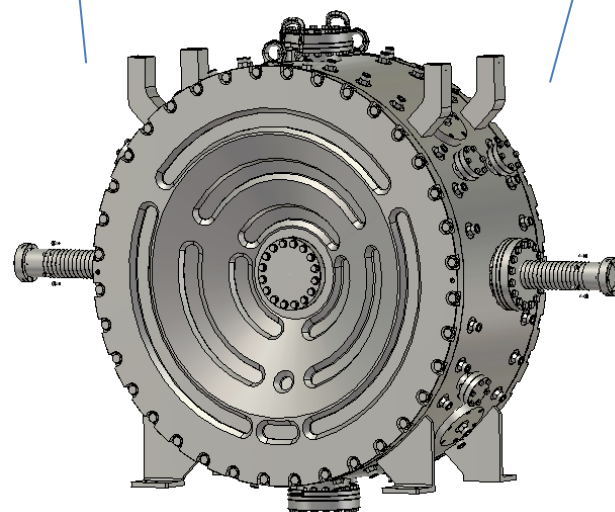




## The injector at LLN

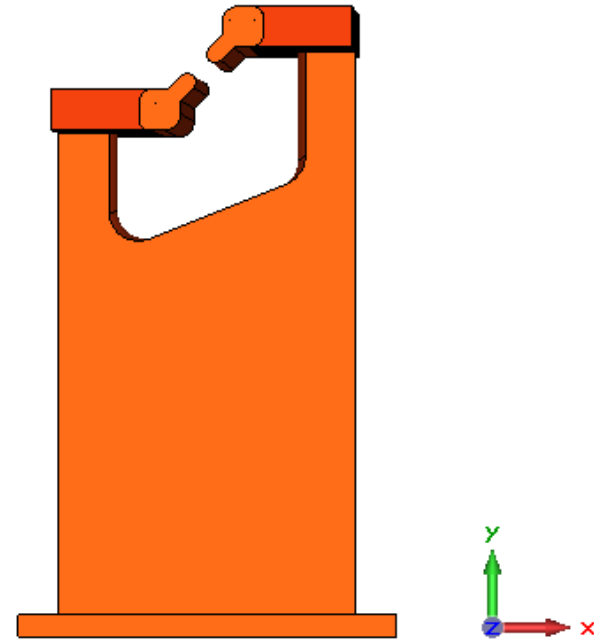
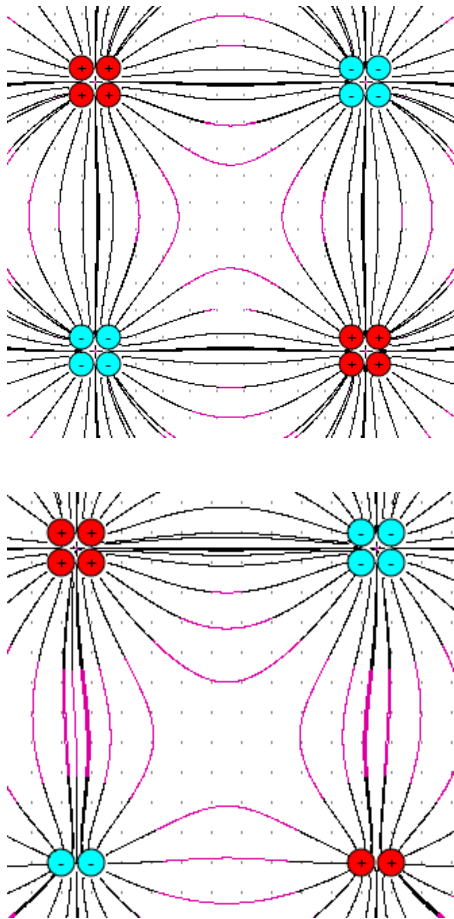


Parameter	MHYRA	Unit
RF Structure	4.Rod	---
Frequency	176.1	MHz
Beam current	4	mA
Duty factor	100	%
$E_{in}$	30	keV
$E_{out}$	1.5	MeV
RF Power	108	kW
Voltage	44	kV
Length	4	m





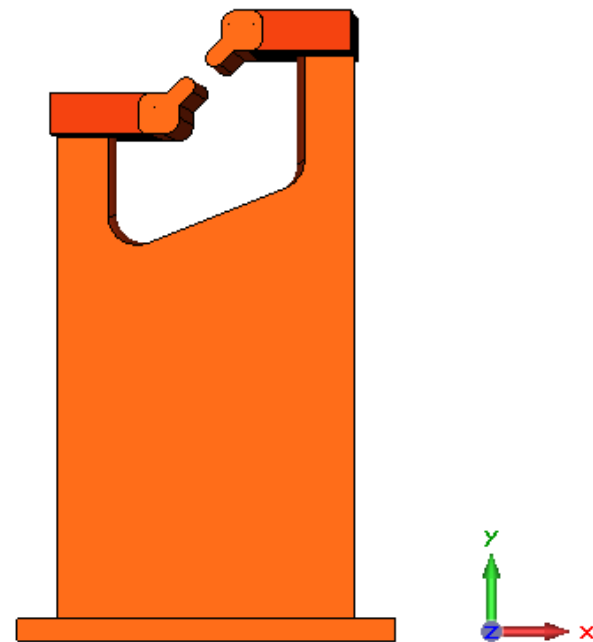
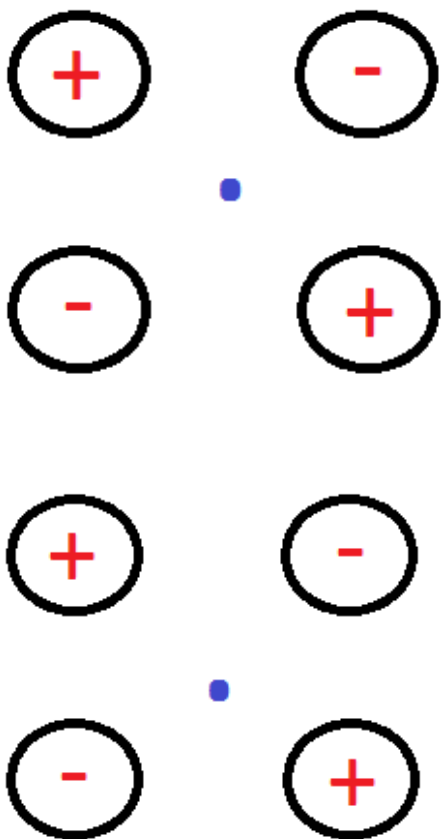
## The Dipole Component



- The Dipole Component is a result of the different lengths of the current paths between the upper and the lower electrode.
- Leads to an asymmetrical field distribution



## The Dipole Component



The Dipole Component is a result of the different lengths of the current paths between the upper and the lower electrode.

Leads to:

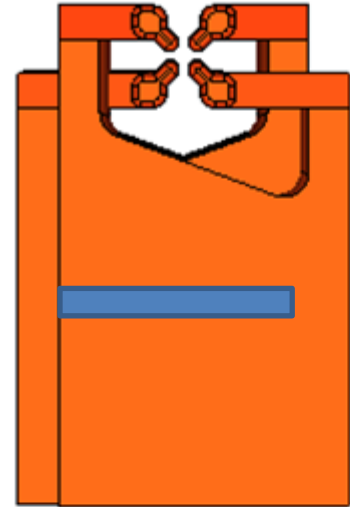
- an asymmetrical field distribution
- a shift of the „ideal beam axis“





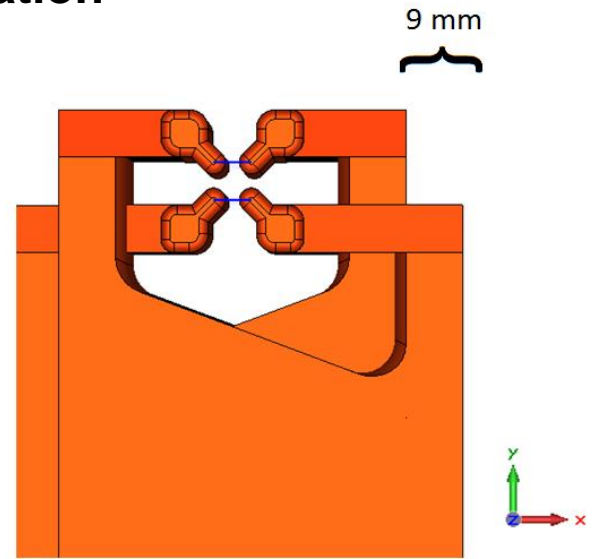
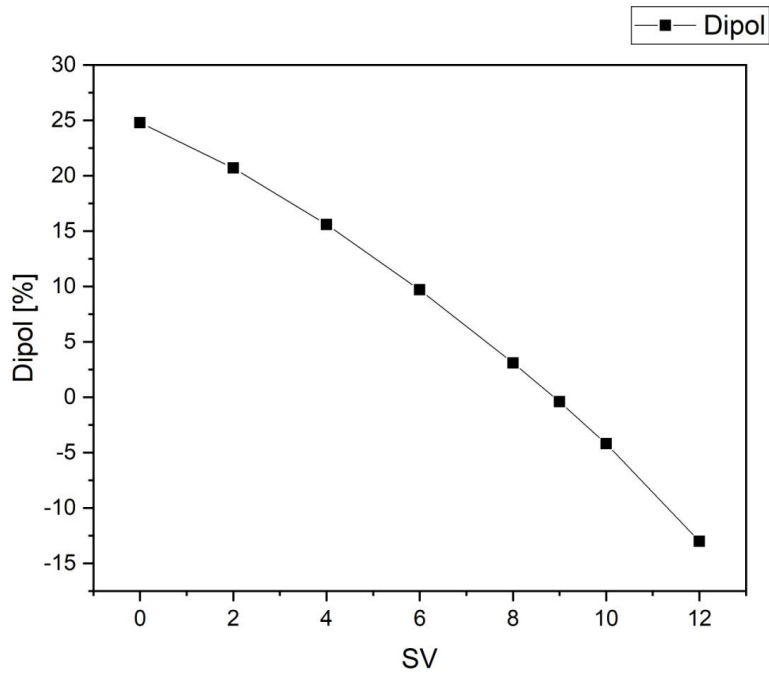
## Dipole Compensation

- Stems have been widened alternately perpendicular to the beam direction
- This lengthens the current paths on the lower electrodes
- ...and increases the voltage on the lower electrode



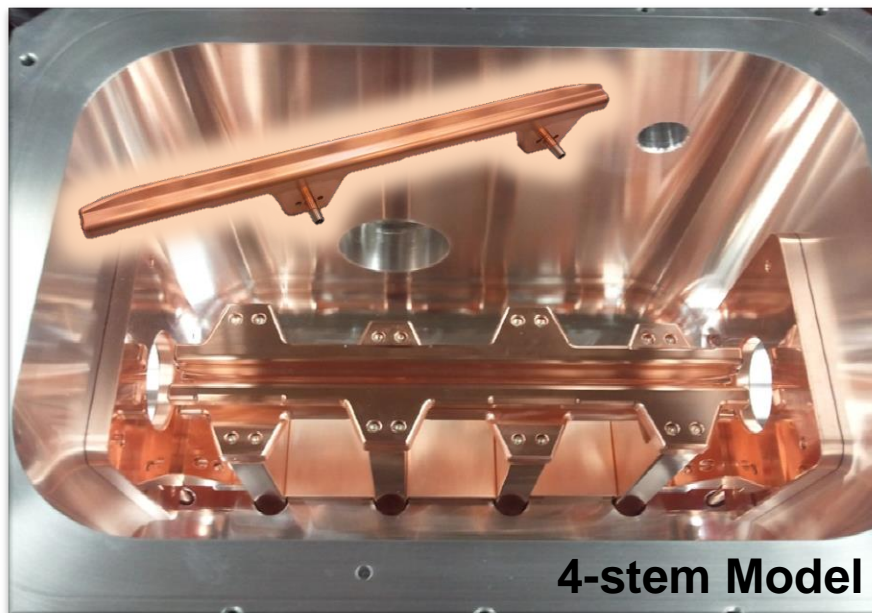


# Dipole Compensation





# NEXT GEN HIGH POWER CW-RFQ



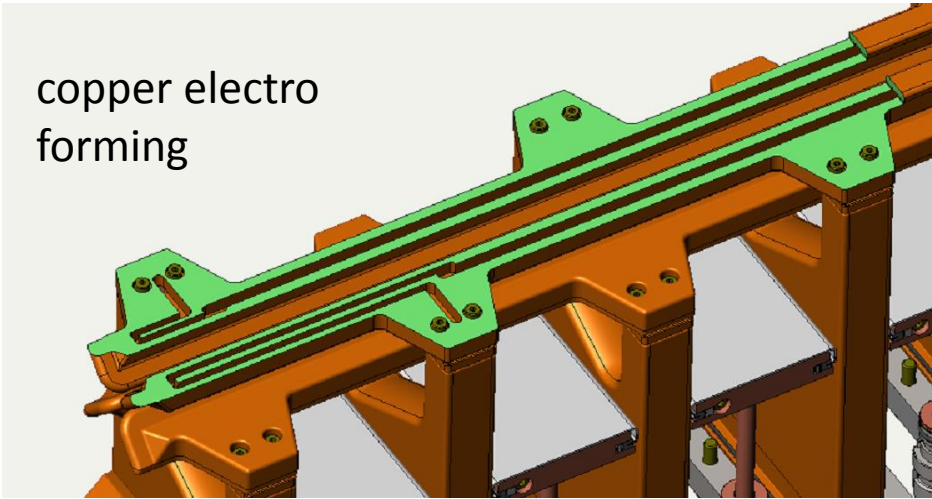
keeps cool at even 130 kW/m  
(limit not yet reached)



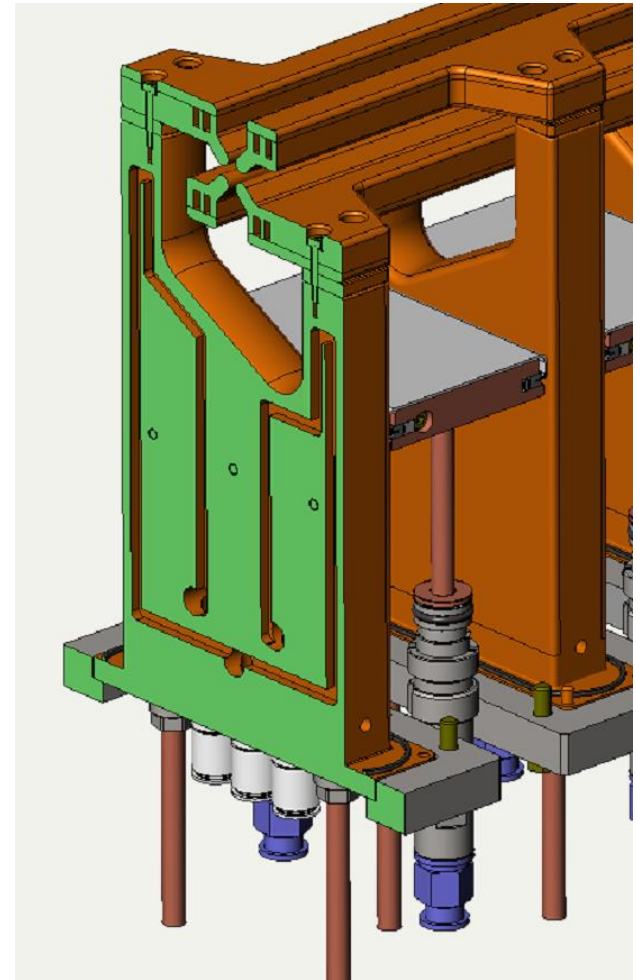
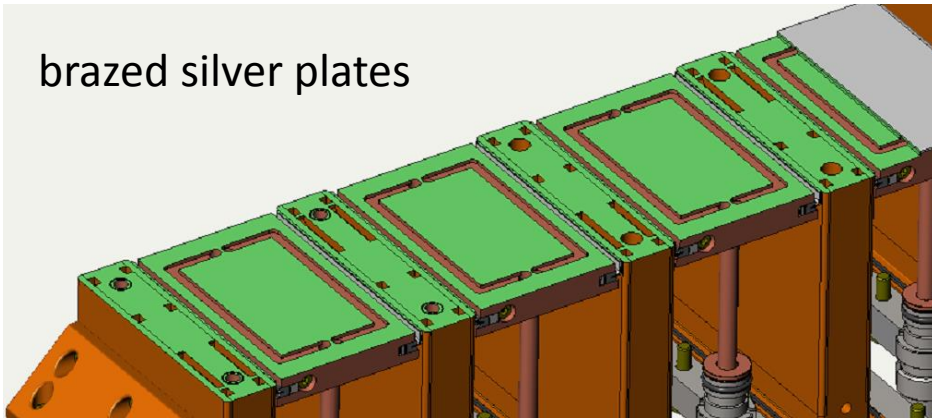


# Cooling System on Main Parts of the RFQ

copper electro  
forming



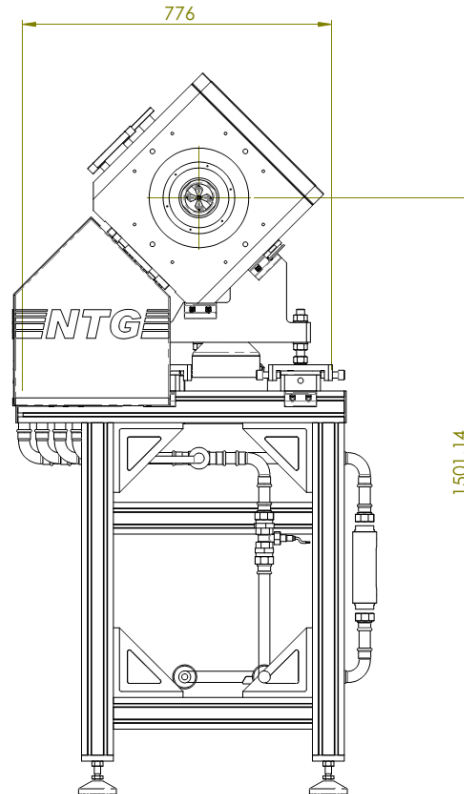
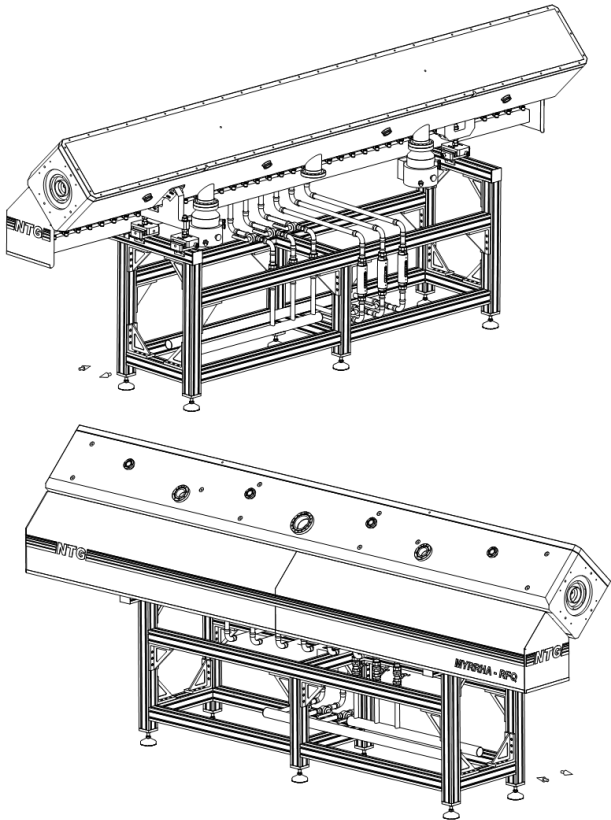
brazed silver plates







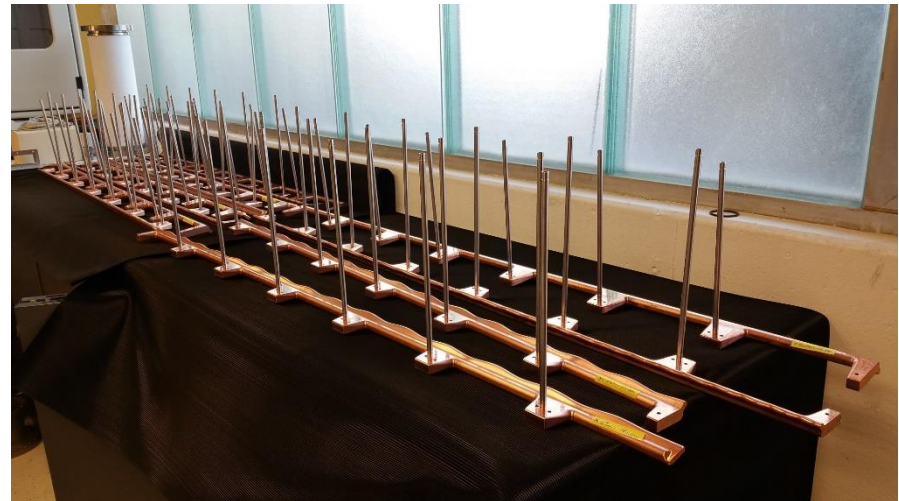
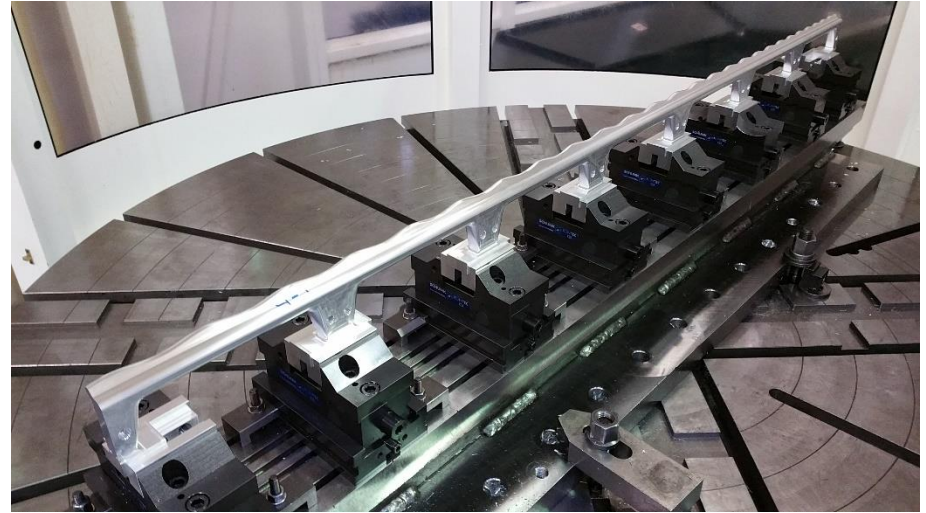
# Mechanical MYRRHA RFQ Design



- No. of stems: 40
- Distance of Stems: 100 mm
- No. of electrode sections: 3
- Pumping ports: 2 + 1 DN100CF
- Height of beam axis: 150 cm
- No. of tuner ports: 1 + 1
- Adjustable three-point-support



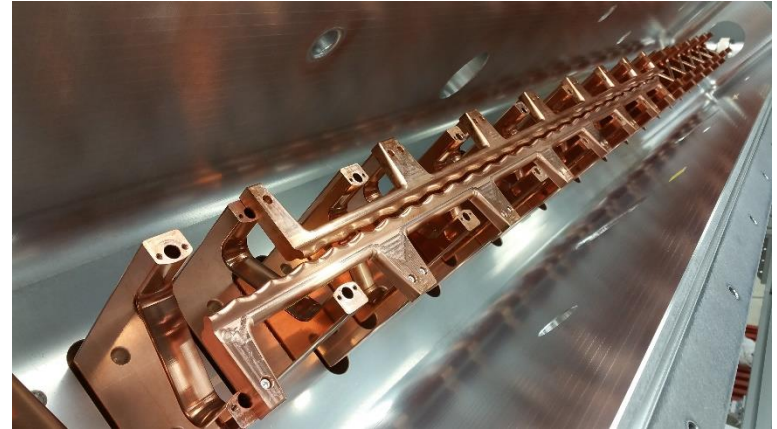
## Construction of the electrodes







## Assembly of the RFQ





## Low Level RF Measurements

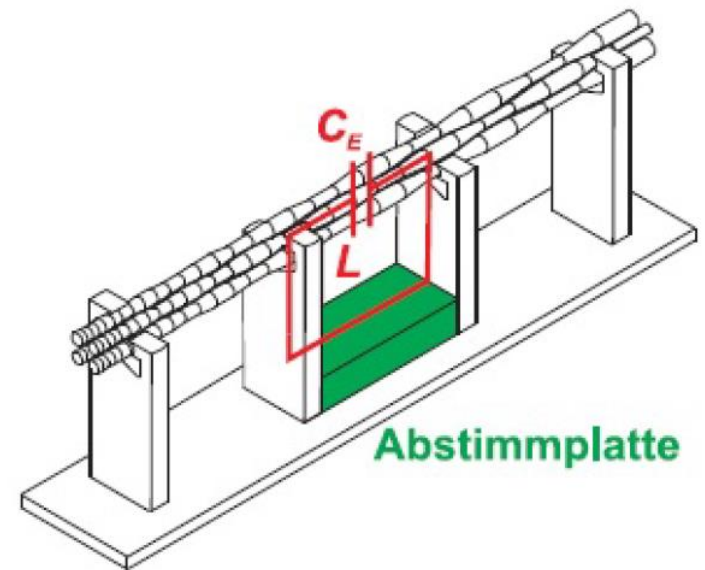


The first low level RF measurements (e.g. frequency and field flatness) have been performed at NTG.





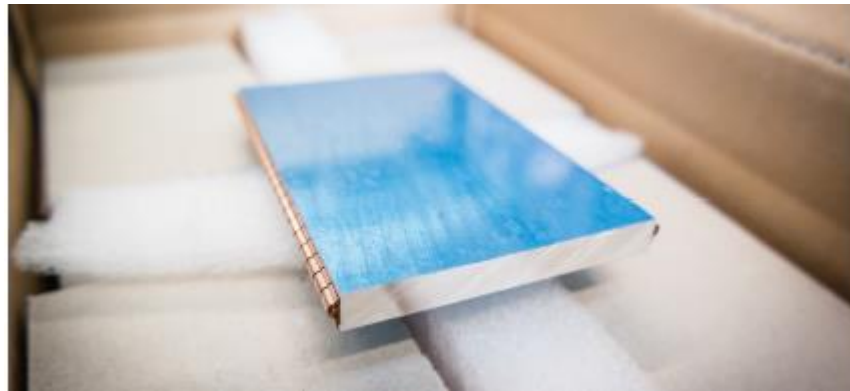
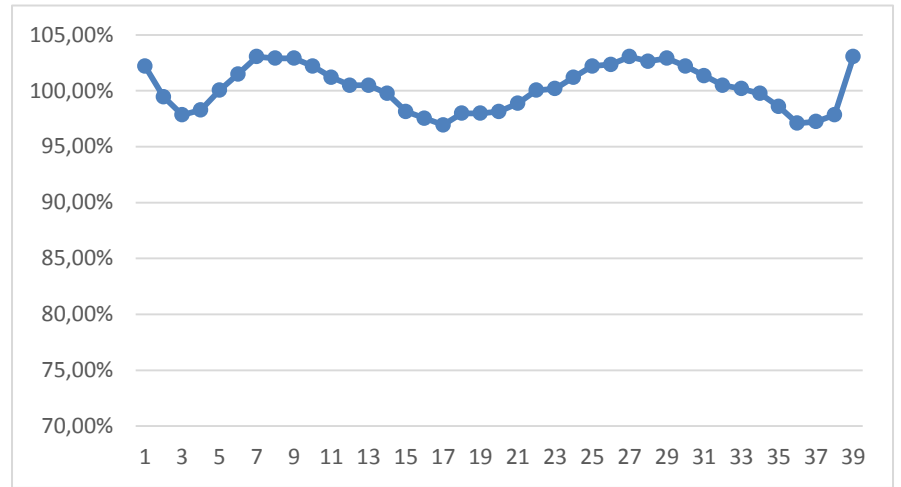
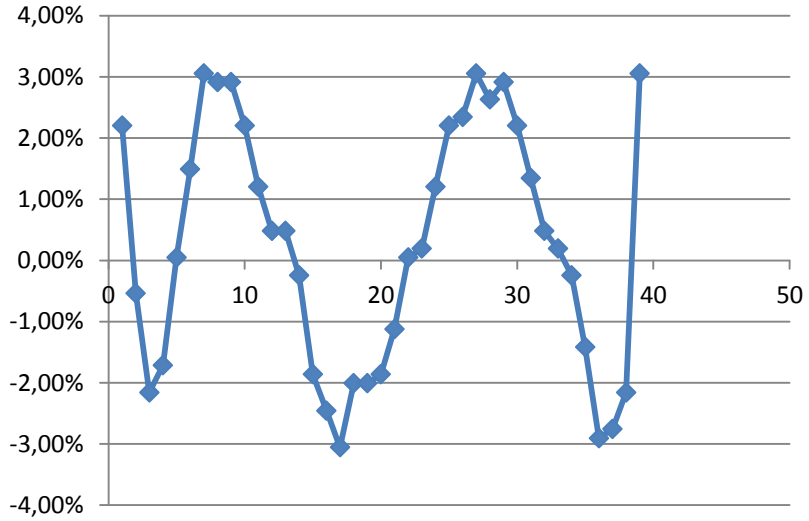
## Field Flatness



$$U \propto \sqrt{\Delta f}$$



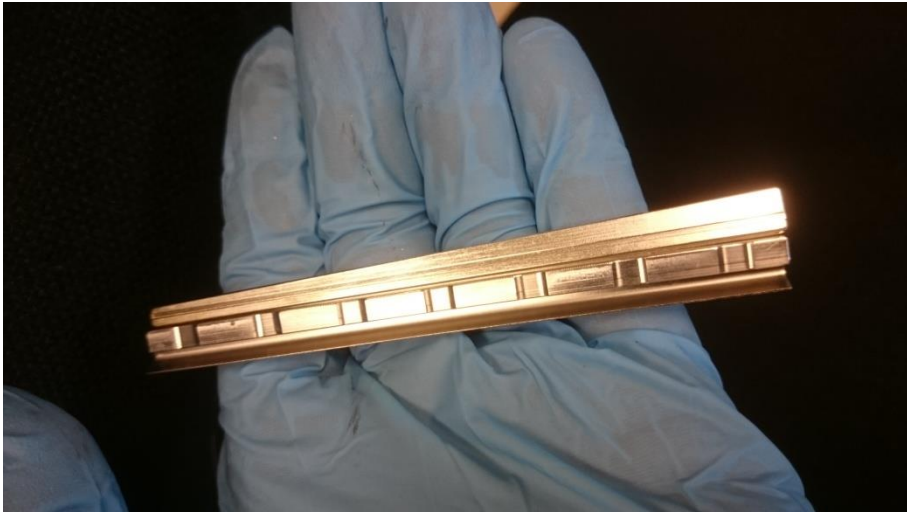
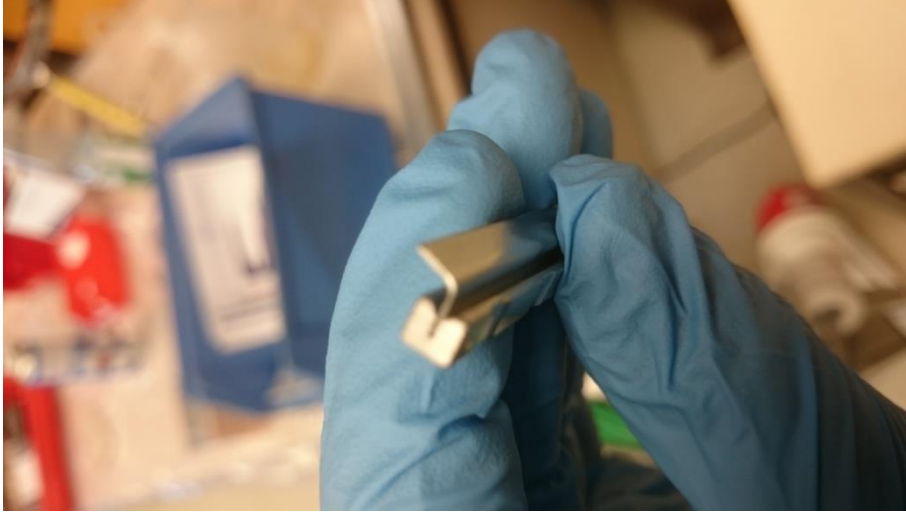
## Field Flatness







## Adjustment of the Tuning Plates





## Adjustment of the Tuning Plates





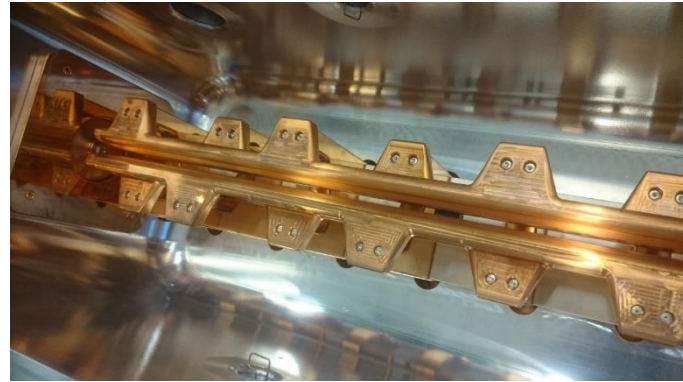
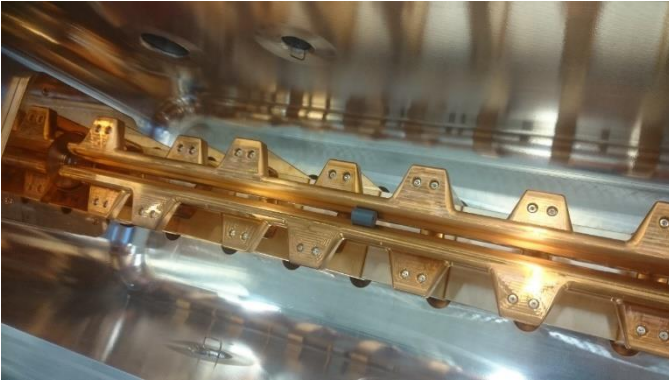


## Low Level RF measurements at IAP





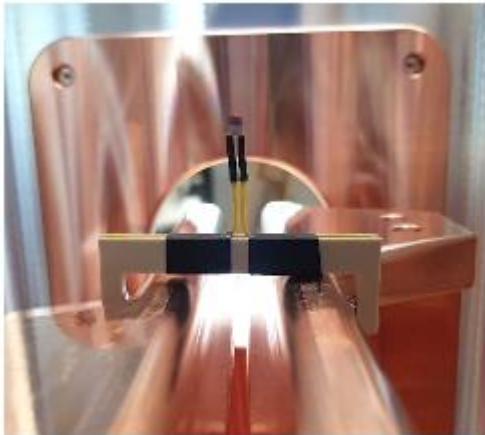
## Dipole measurement



## Comparison of Measurement and Simulation

	FRANZ RFQ	MYRRHA RFQ
Simulation	22,6 %	-0,4 %
Messung	23,1 %	-4 %

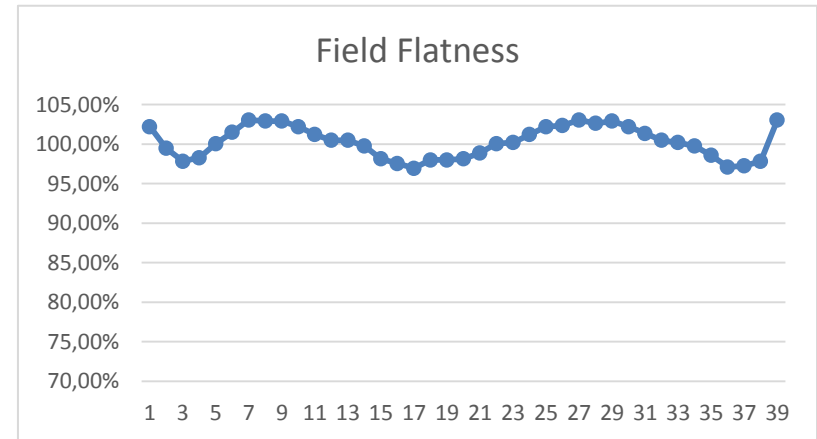
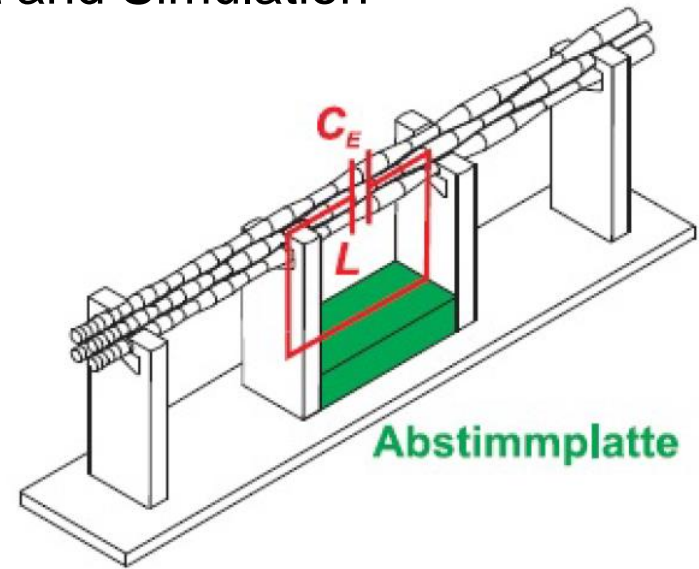
$$U \propto \sqrt{\Delta f}$$





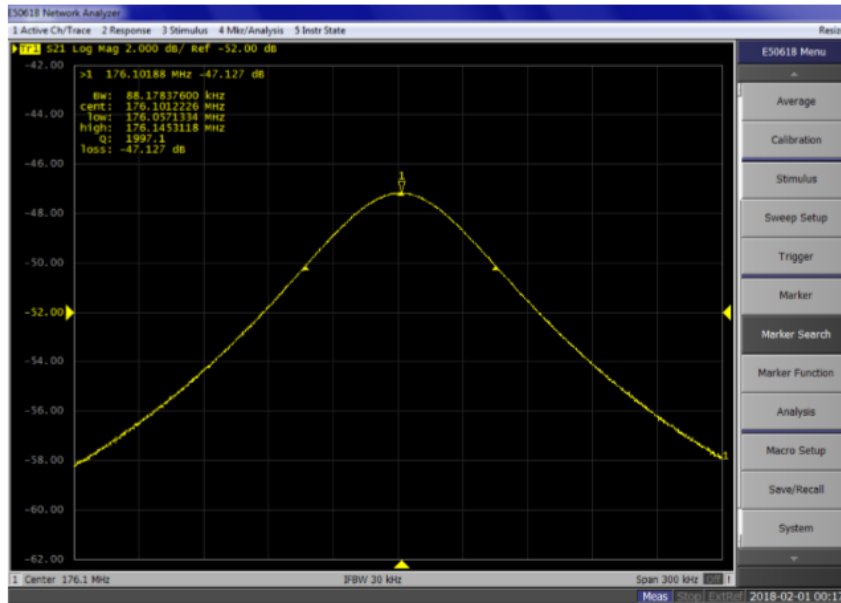
## Comparison of Measurement and Simulation

- Vibrations of cardboard/aluminium foil lids
- Simulated tuning plates are on different positions compared to the tuning plates of the real RFQ
- Position of the dynamic tuner





## Measurement of the unloaded Q-value



$$Q_0 = Q_L(1 + \beta)$$

for  $\beta = 1$

$$Q_0 = 2Q_L$$

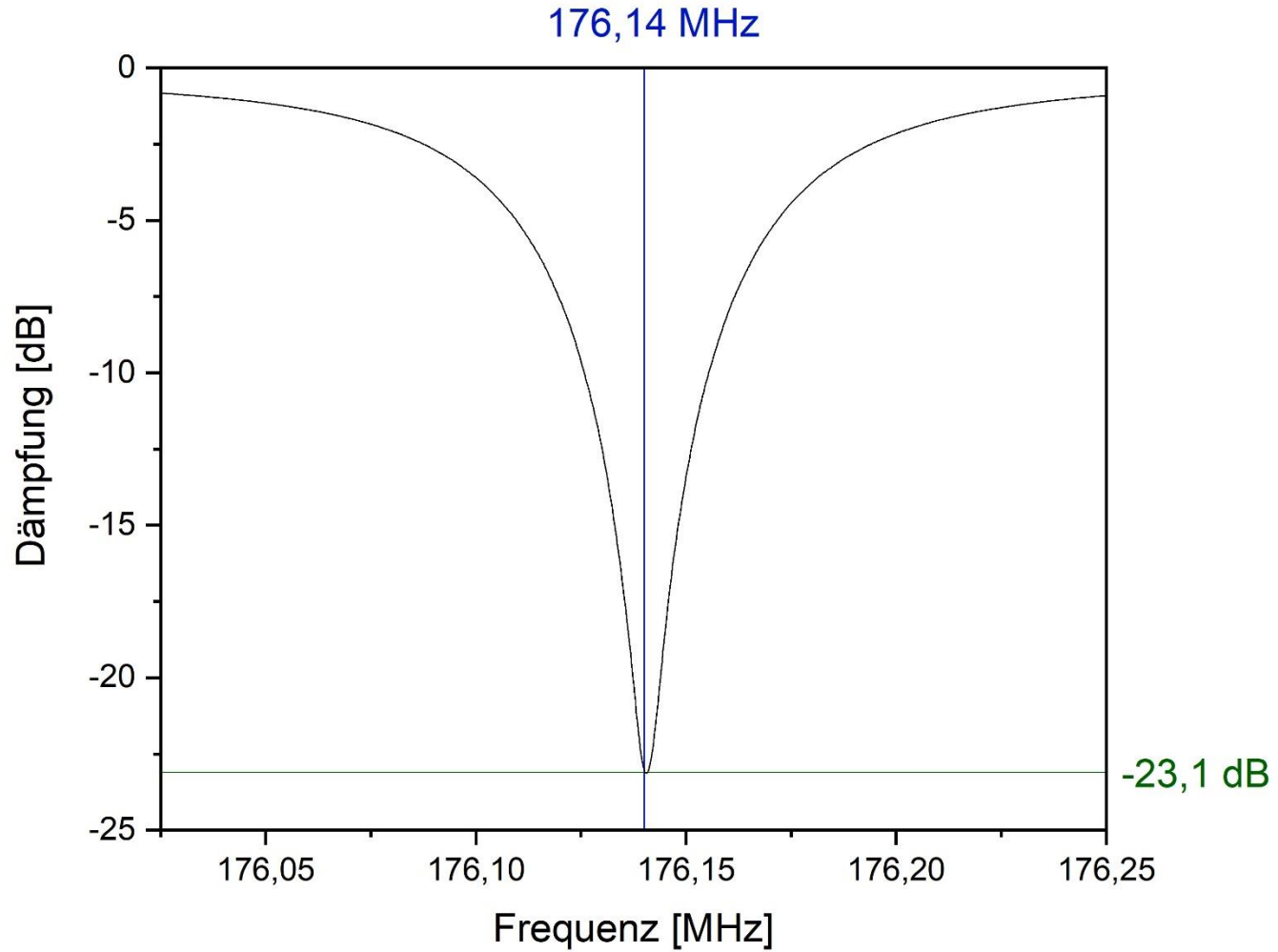
$$Q_L(\text{measured}) \approx 2000$$

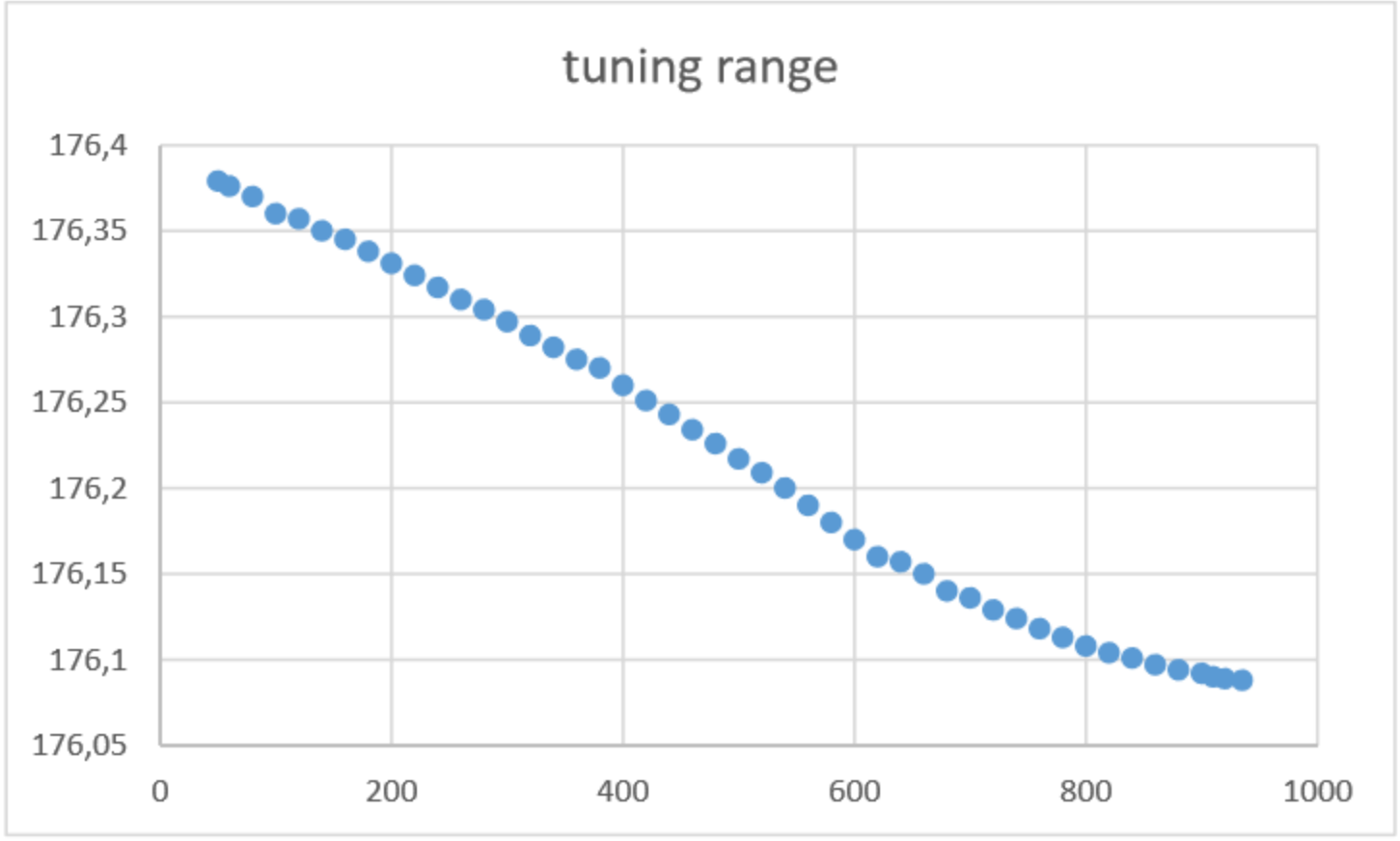
$$\rightarrow Q_0 \approx 4000$$





# Power Coupling









# Power Coupler

Pickup

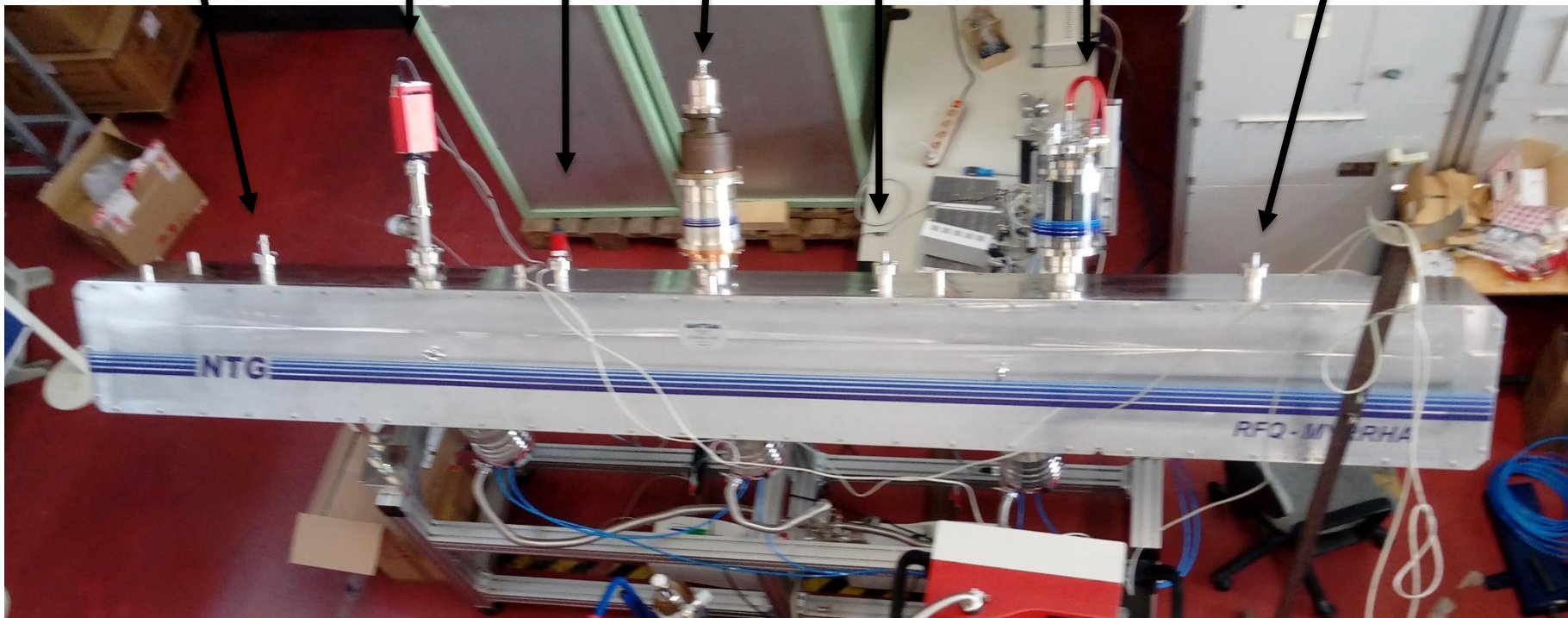
QMS

Gauge

Pickup

Tuner

Pickup







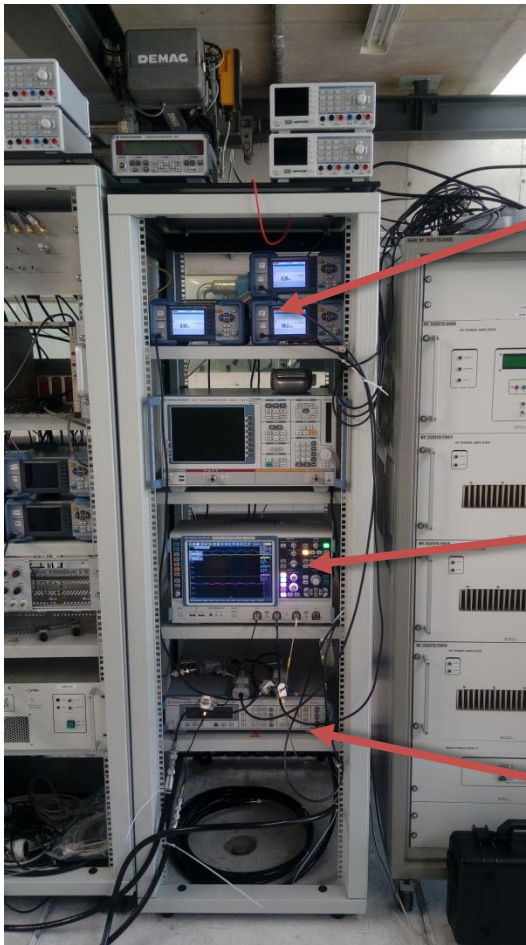
## Measuring Setup for the High Power tests at IAP







## Measuring Setup for the High Power tests at IAP



**Power Meter**

**Oscilloscope**

**Signal Generator**



## Installation of the cooling system



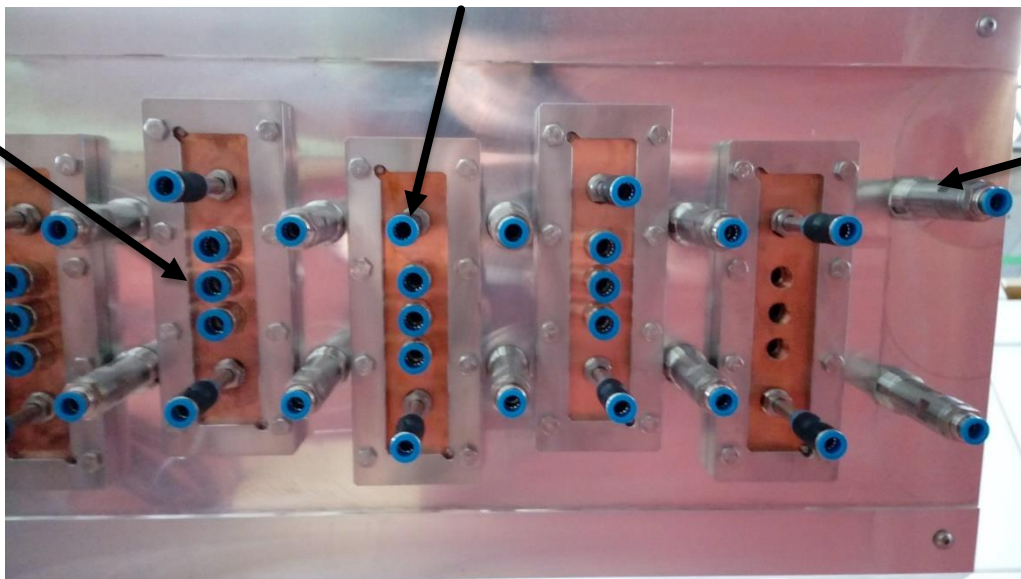


## Installation of the cooling system

**Stems**

**Electrodes**

**Tuning-  
plates**

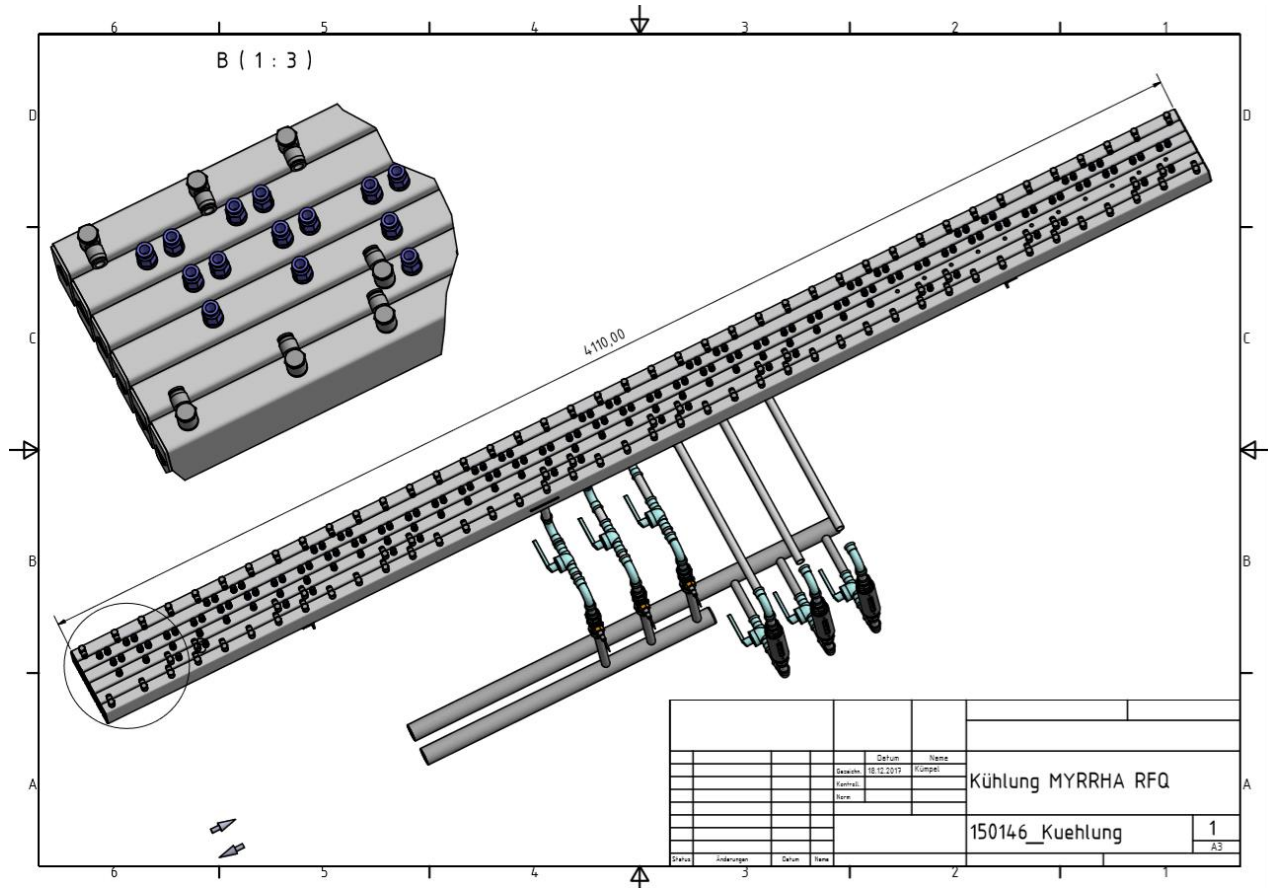


- More than 270 Connectors
- Stems: 40 entrances, 80 exits
- Elektroden: 36 entrances, 36 exits
- Tuningplatten: (39 + 2) entrances, (39 + 2) exits





# Installation of the cooling system



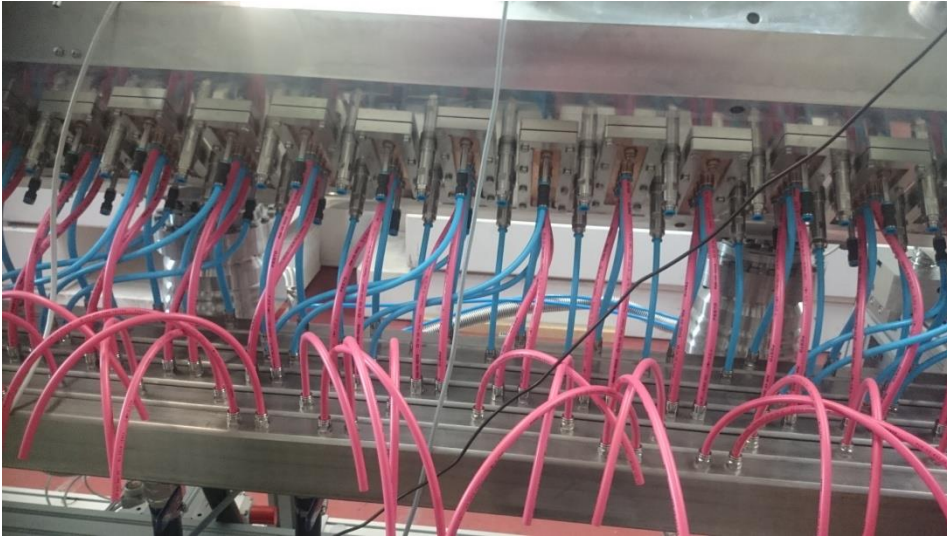


## Installation of the cooling system





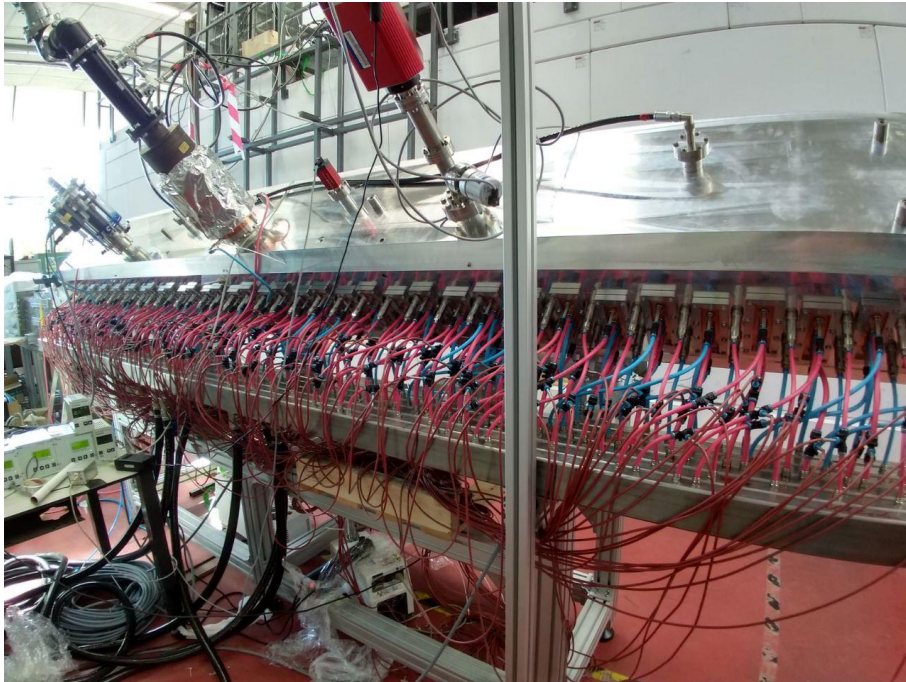
## Installation of the cooling system

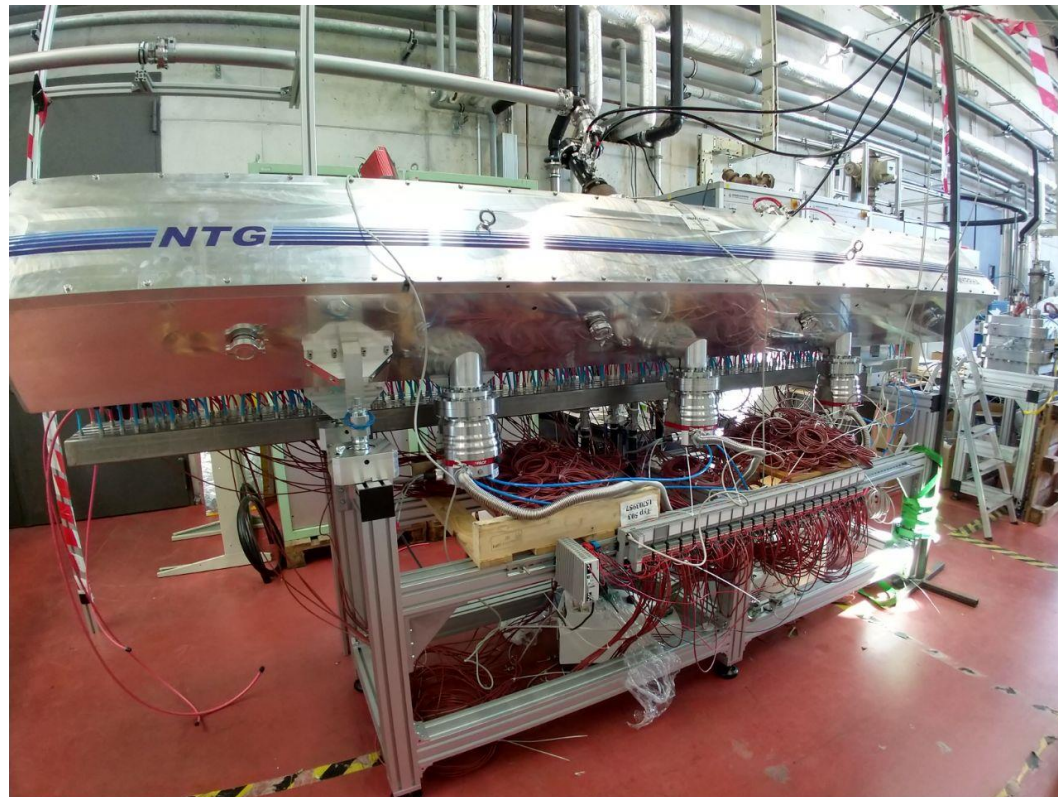






## Installation of the temperature sensors

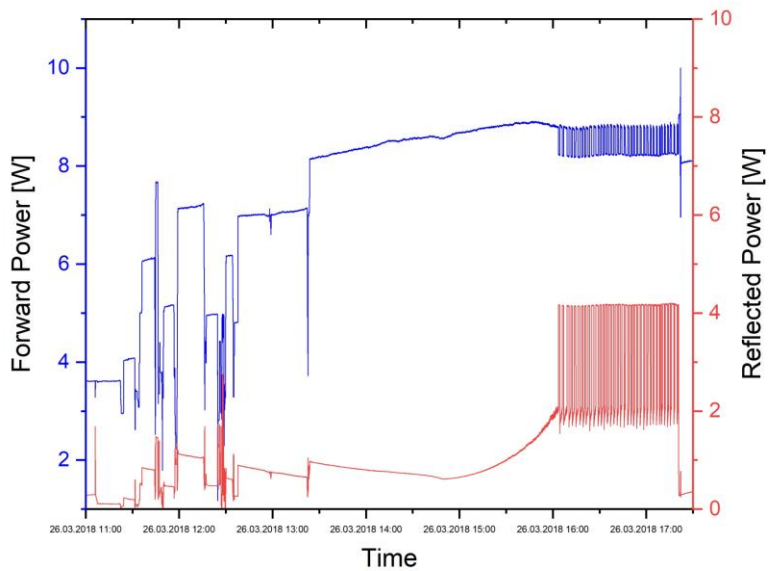




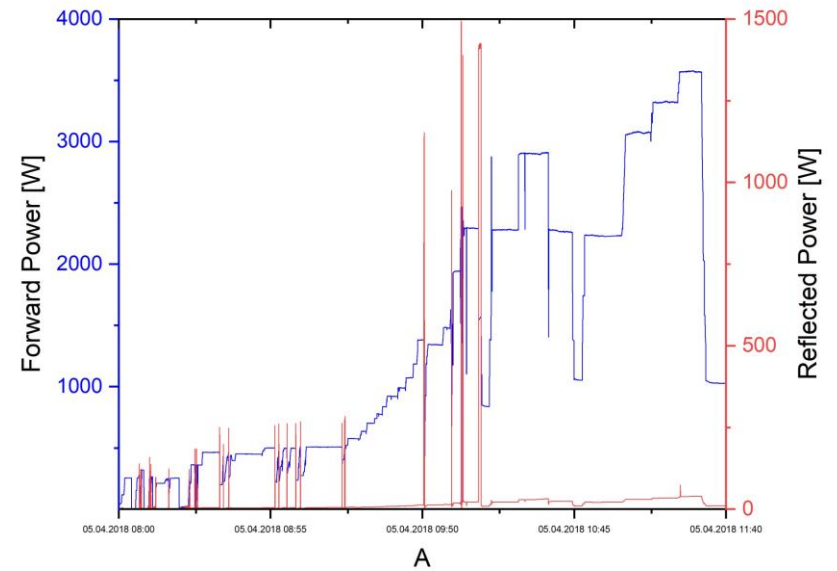




## Power tests Up to 10 W

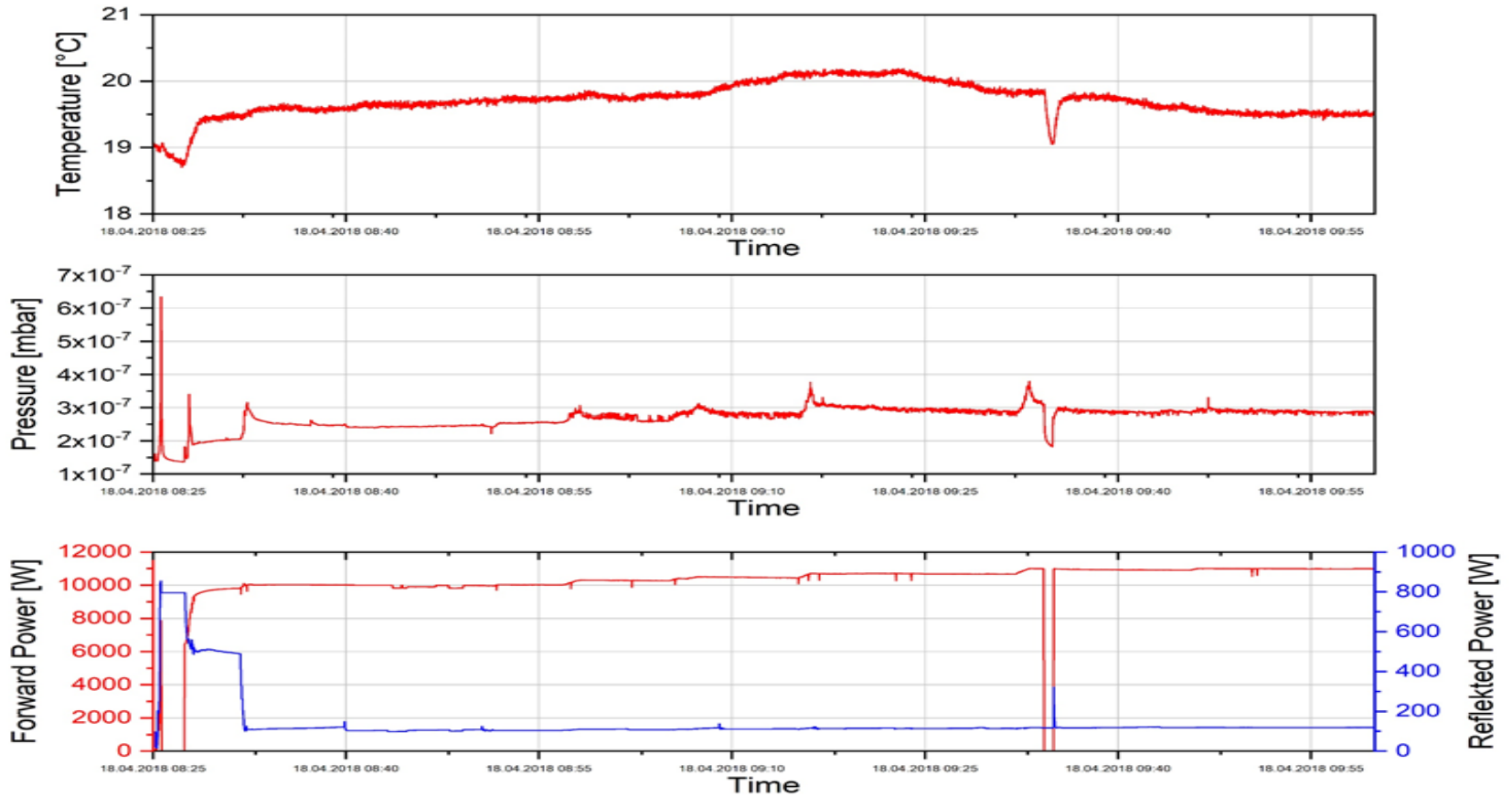


## Power tests Up to 3.5 kW



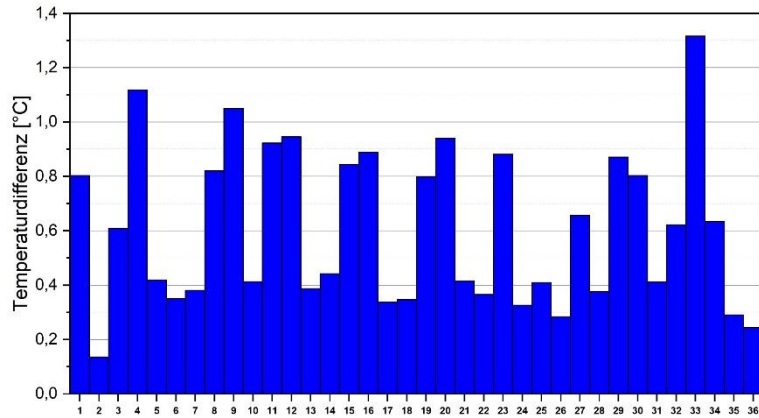


# Last day of conditioning at IAP

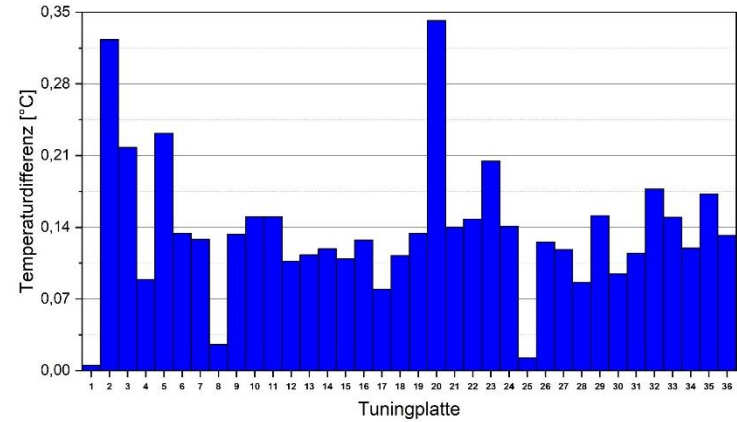




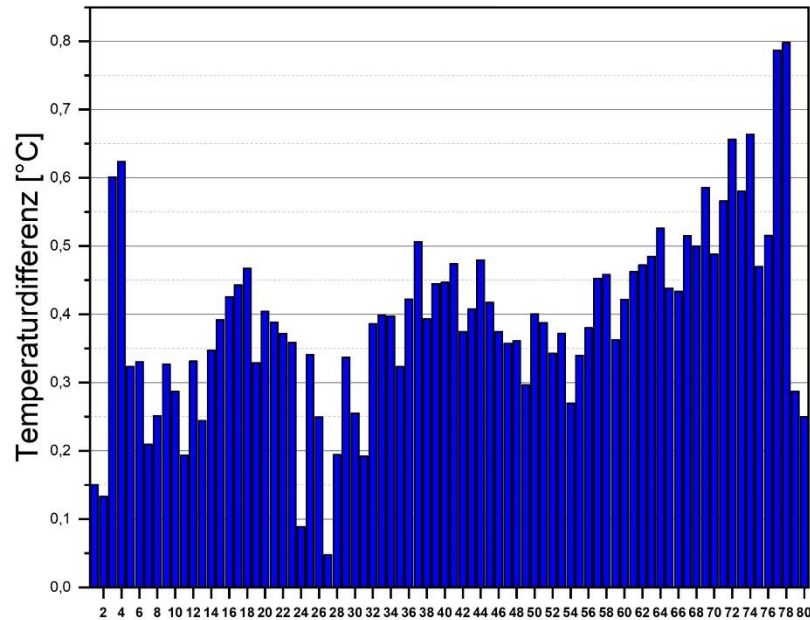
# Last day of conditioning at IAP



Elektrode



Tuningplatte



Stütze



## Next steps

- Shipping of the RFQ to LLN
- Adjustment of the Tuner Position
- High Power tests up to 108 kW
- BEAM !!!



**Danke für Ihre Aufmerksamkeit!**