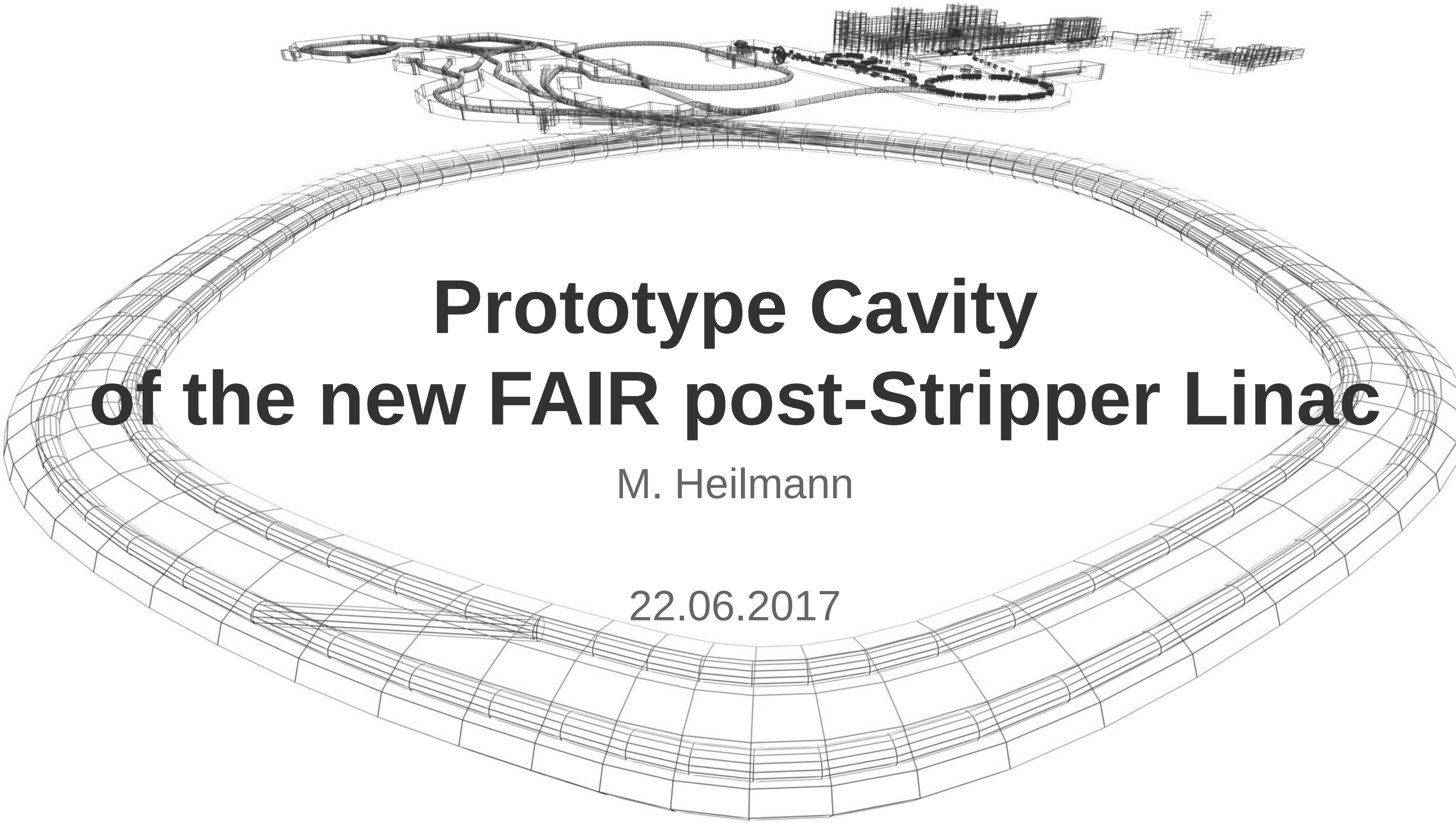


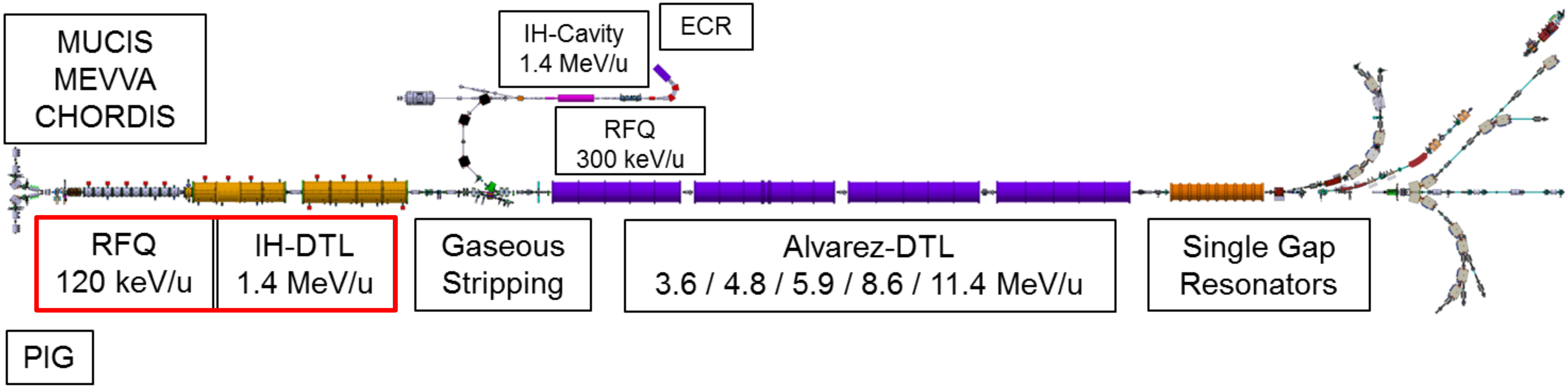
Prototype Cavity of the new FAIR post-Stripper Linac

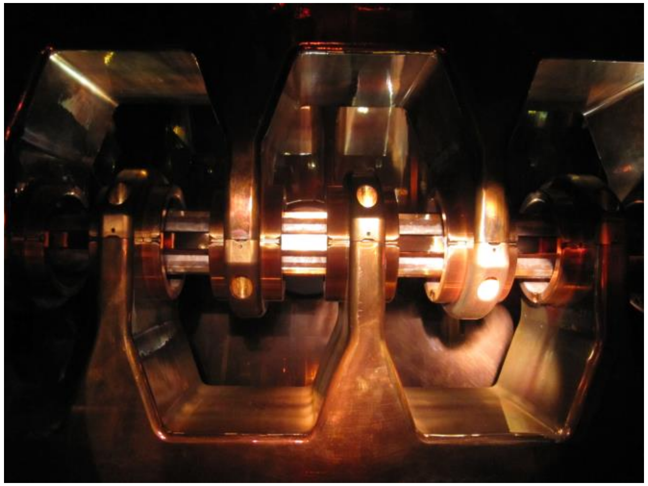
M. Heilmann

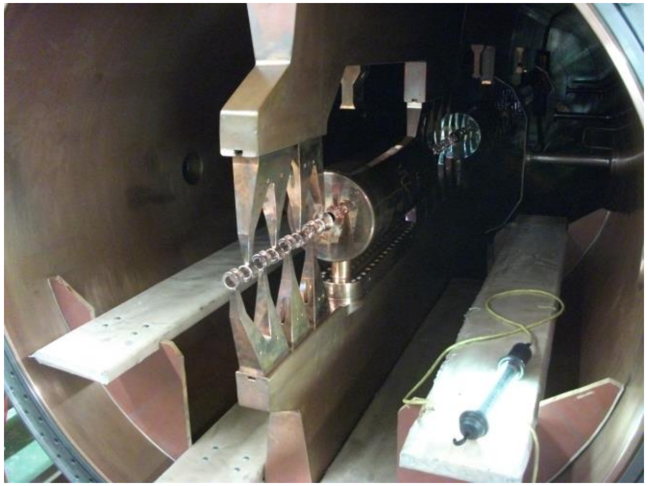
22.06.2017

- Existing and upgraded UNILAC
- Boundary Conditions for Accelerator Design
- Alvarez-Prototype

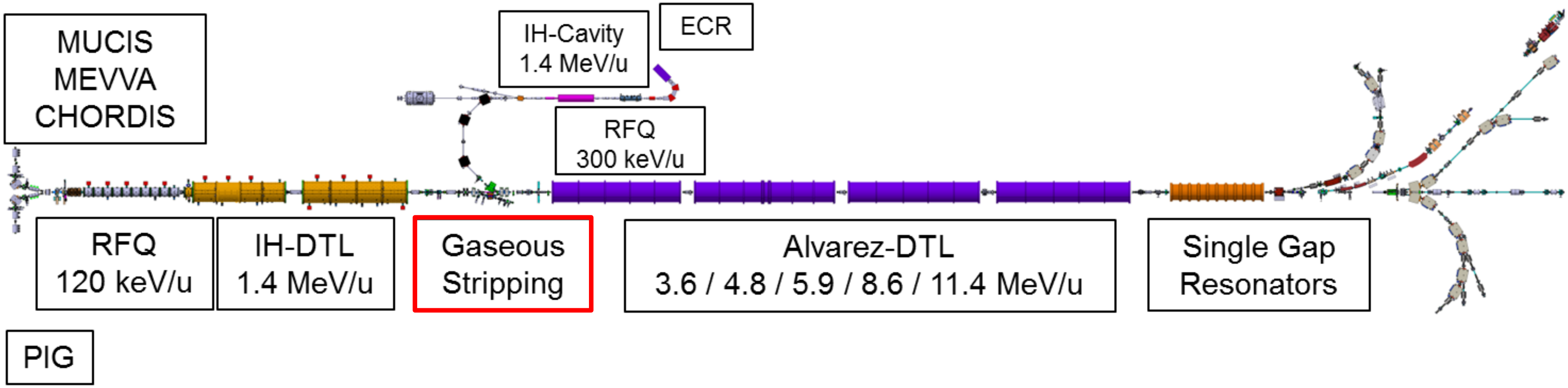
UNIversal Linear Accelerator UNILAC

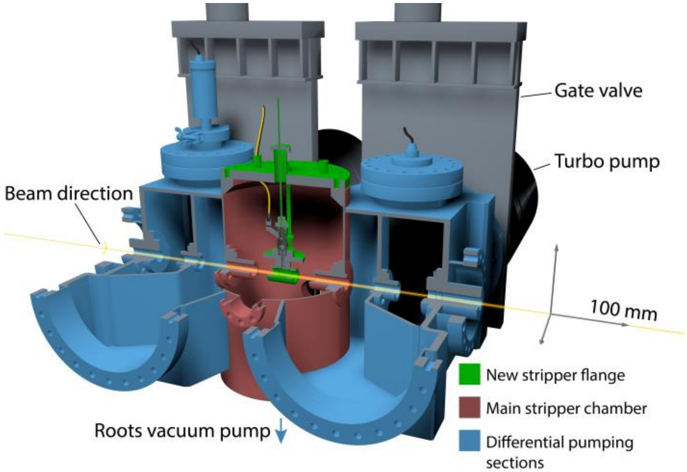






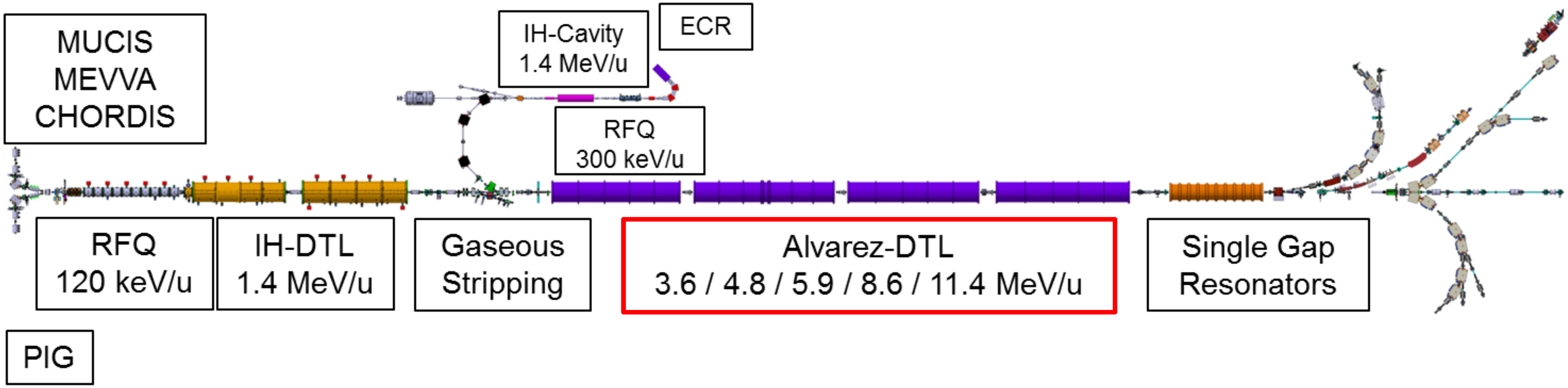
UNIversal Linear Accelerator UNILAC

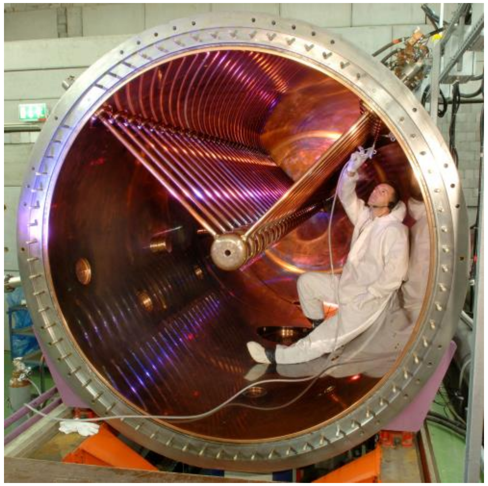




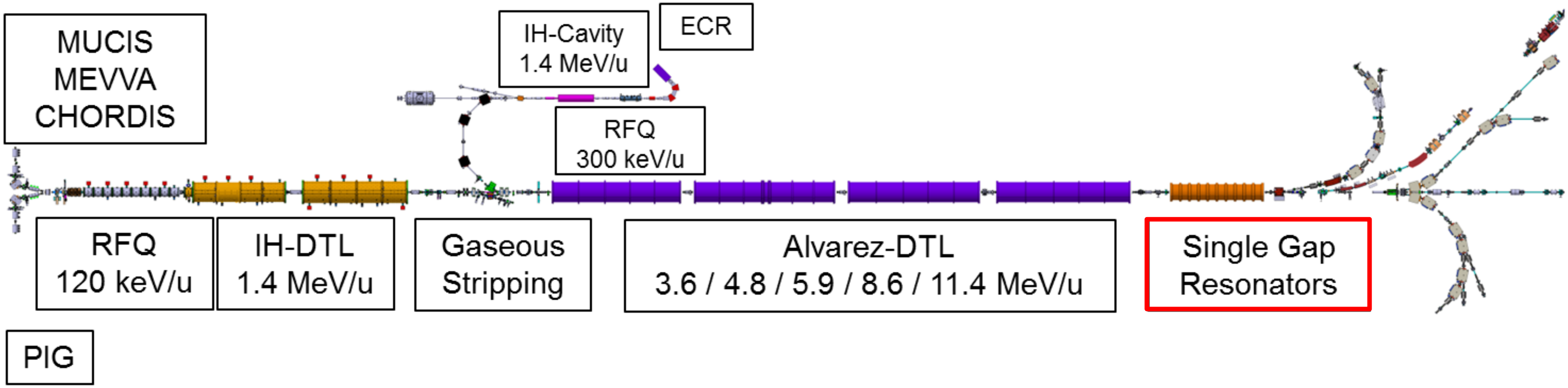
P. Scharrer et at., IPAC-2015, Richmond, VA, USA, p. 3773.

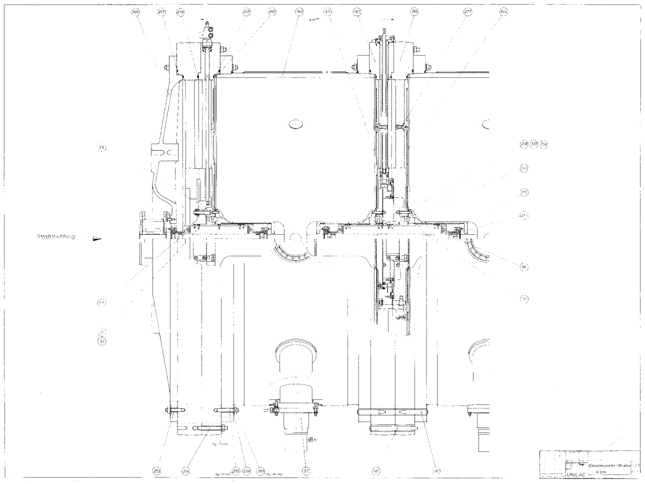
UNIversal Linear Accelerator UNILAC





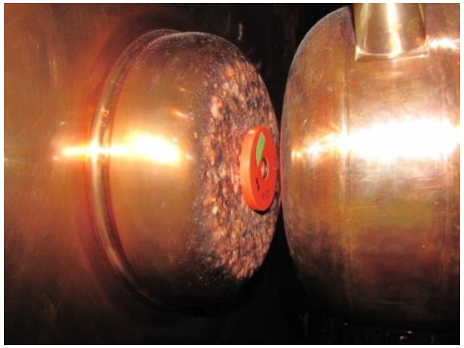
UNIversal Linear Accelerator UNILAC





Why we need a Alvarez-Replacement ?

- Alvarez DTL is more than 40 years in operation (25 years of expected lifetime)
- It has suffered from material fatigue (sparking, beam induced defects, water leaks, iron oxide deposits, bubbles and scars on the inner-tank surface)
- Resources for maintenance increase rapidly
- Higher phase advance through stronger quadrupole gradients is needed to minimize the emittance growth due to the space charge
- A refurbished Alvarez would be strongly limited in beam dynamics with respect to FAIR, new DTL is designed to meet FAIR requirements
- Economically the refurbishment can not compete with a new DTL




Requirements to Upgraded UNILAC

Ion A/q	≤ 8.5, i.e. $^{238}U^{28+}$	
Beam current (pulse) * A/q	1.76 (0.5% duty cycle)	mA
Input beam energy	2.2	keV/u
Output beam energy	3.0 - 11.7	MeV/u
Normalized total output emittance, horizontal/vertical	0.8 / 2.5	mm mrad
Beam pulse duration	≤ 1000	µs
Beam repetition rate	≤ 10	Hz
Operating frequency	36.136 / 108.408	MHz
Length	≈ 115	m

Summary of Recent Design

Design V5	tank I 20160713	tank II 20160713	tank III 20160713	tank IV 20160713	tank V 20160713
Energy [MeV/u]	1.392 – 3.316	3.316 – 4.351	4.351 - 6.621	6.621 – 8.966	8.966 – 11.341
Aperture [mm]	30	35	35	35	35
RF-phase [deg.]	-30	-30	-30	-25	-25
# cells	55	20	43	35	31
L_{gap} / L_{cell}	0.27	0.27 – 0.28	0.23 – 0.25	0.22 – 0.23	0.22 - 0.23
RF-length [m]	10.54	4.99	12.78	12.41	12.53
$E_{surf,max}$ [E_K]	1.00	1.00	0.96	0.98	0.96
$P_{loss,MWS}$ [MW]	0.885	0.555	0.870	0.842	0.853
P_{beam} [MW]	0.245	0.132	0.289	0.299	0.303
$<Z_{eff}>$ [MΩ/m]	28.67	27.95	33.48	38.02	38.13
$E_{eff,mean}$ (MV/m)	1.55	1.76	1.51	1.61	1.61

Outline

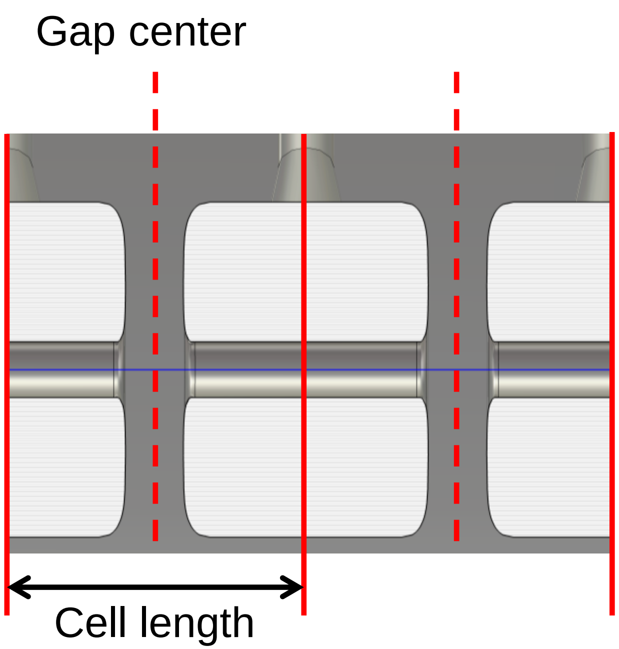
- Existing and upgraded UNILAC
- Boundary Conditions for Accelerator Design:
  - Frequency
  - Beam dynamics
  - Drift tube geometry
  - Magnet geometry
  - Galvanic workshop:
    - Length limitation
    - Max. diameter
- Alvarez-Prototype

Beam dynamics

Parameter list:

- Cell number
- Cell length
- Ratio of gap length and tube length
- Effective voltage
- Transit time factor

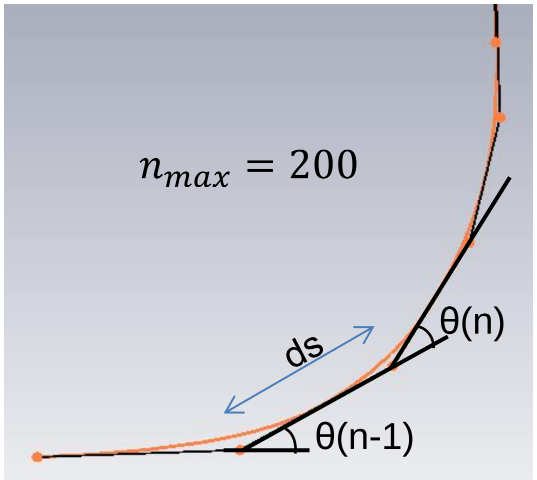
- Frequency
- Energy
- Beta
- E_{peak}(surface)
- Power loss
- Total power (include beam power)
- ...
- Tube shape curve per cavity

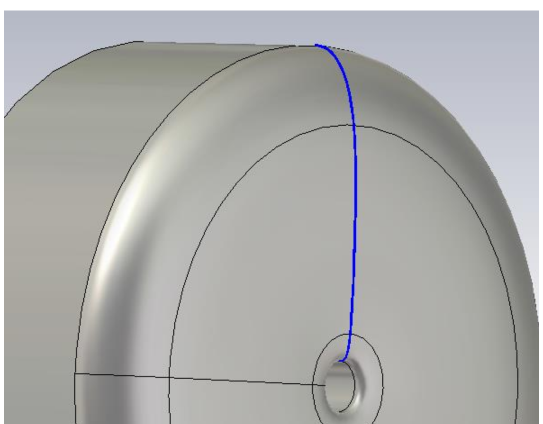


Dr. Xiaonan Du,
RF-Cavity Design of the new FAIR post-Stripper Linac,
GSI-Accelerator Seminar / 1.06.2017

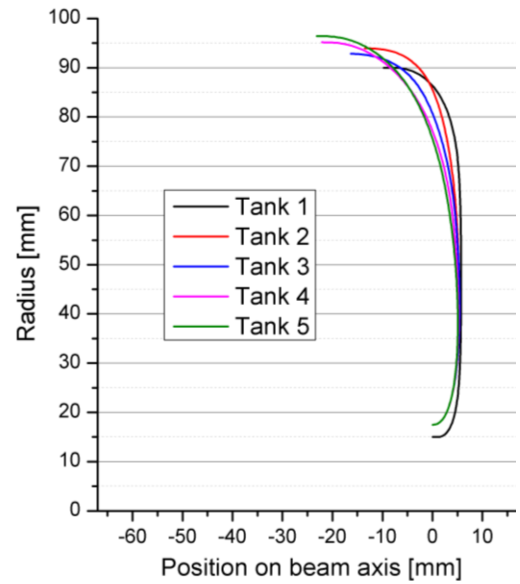
Dr. Anna Rubin,
Beam dynamics Design of the new FAIR post-Stripper Linac,
GSI-Accelerator Seminar / 14.06.2017

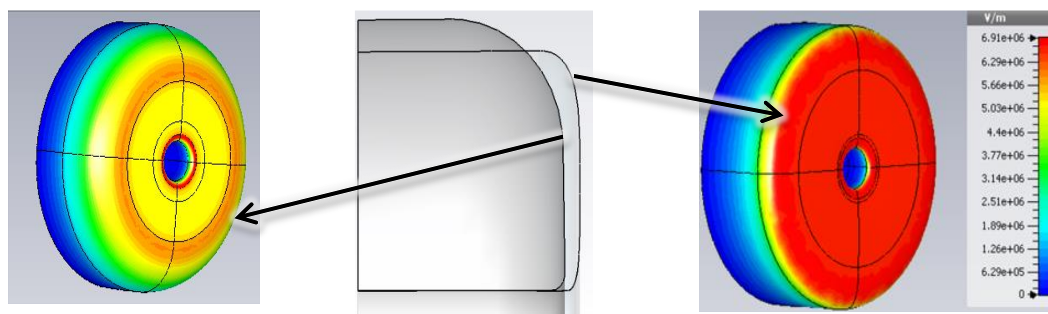
New Drift Tube Geometry





- Individual freeform shape per tank to produce homogeneous surface field
- CST Microwave Studio macro to create a spline curve with up to 200 points





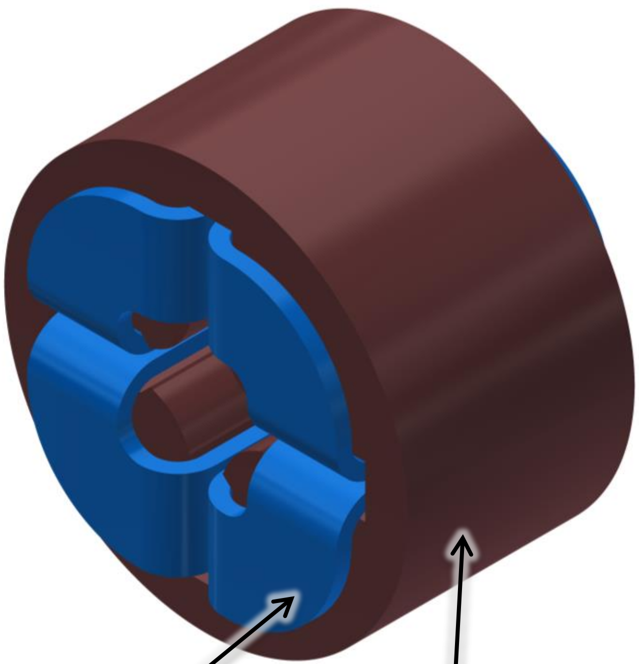
Former shape

new shape

(X. Du et al./ Alvarez DTL cavity design for the UNILAC upgrade / IPAC 15)

Quadrupole Singlet Lens @ new A1

Draft



- beam pipe aperture: Ø30mm
- distance between pole shoe and beam axis: 16 mm
- recheck: decrease of magnet length with Vacuflux 50
- only one cooling circuit for all four coils
- single-layer coil
- water-cooled pipe (Ø5x1) mm
- effective length of shortest magnet @ 1. DT: 96 mm
- max. field gradient (sim.): 51 T/m (FAIR: 48 T/m)
- min. field gradient = 10% of max. field gradient
- + 10% reserve

	10 Hz	50 Hz
Ramp time	25 ms	8 ms
Flat top	1 ms	1 ms
Temperature increase	25 K	25 K
Current (flat top)	932 A	780 A
Pressure loss (check)	(7,2 bar)	(<10bar)
Magnetic flux density (iron)	5.17 T	4.47 T
Magnetic flux density (Vacuflux)	5.35 T	4.51 T

Ref.: D. Dähn, internal report

Outline

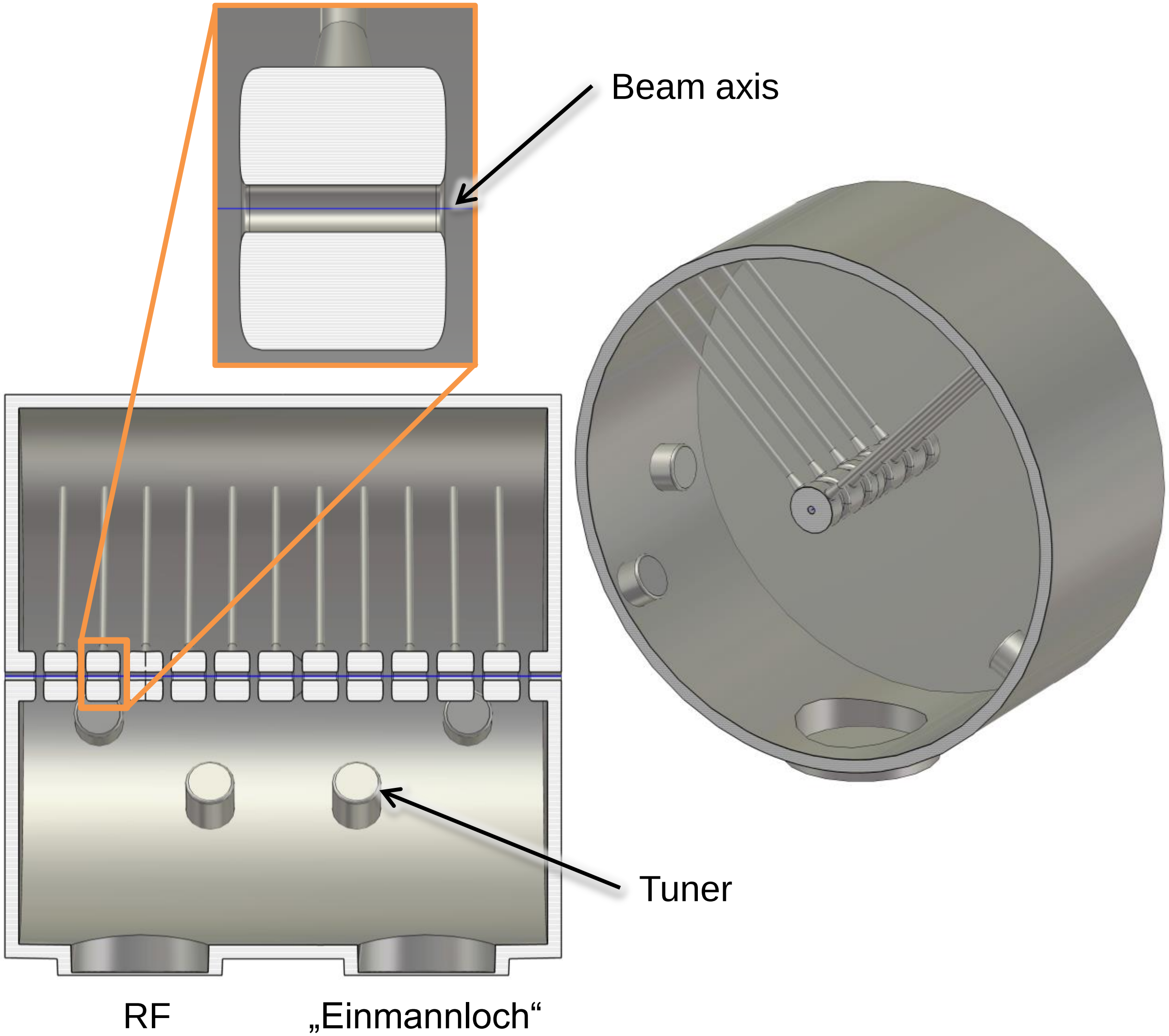
- existing and upgraded UNILAC
- Boundary Conditions for Accelerator Design
- Alvarez-Prototype:
  - RF-Simulation
  - Construction
    - Drift tube
    - Tank
    - Alignment system

RF-Simulation with CST MWS

- Beam dynamics: parameter list
- new drift tube geometry

- Tuner (#, Position, Ø)
- RF-coupling hole
- Support hole

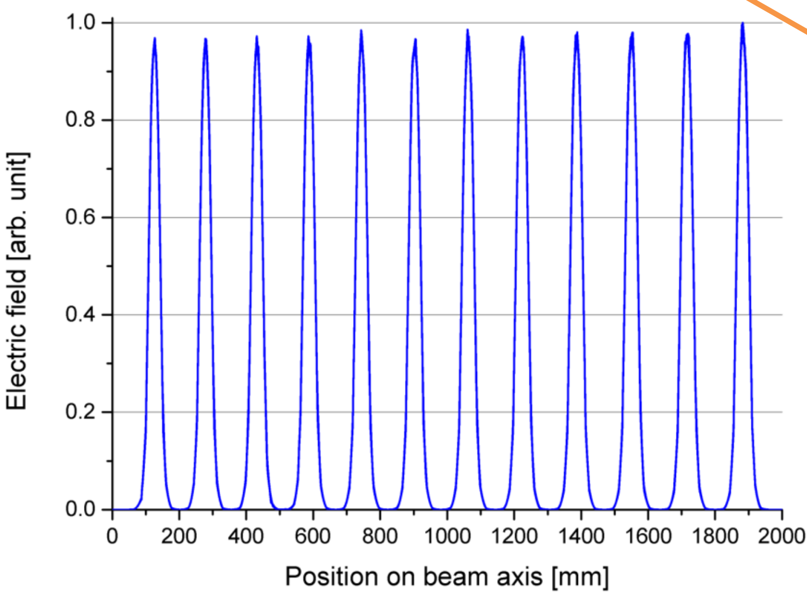
- No magnets
- No RF-coupling loop
- Model: as simple as possible



Electric and magnetic field

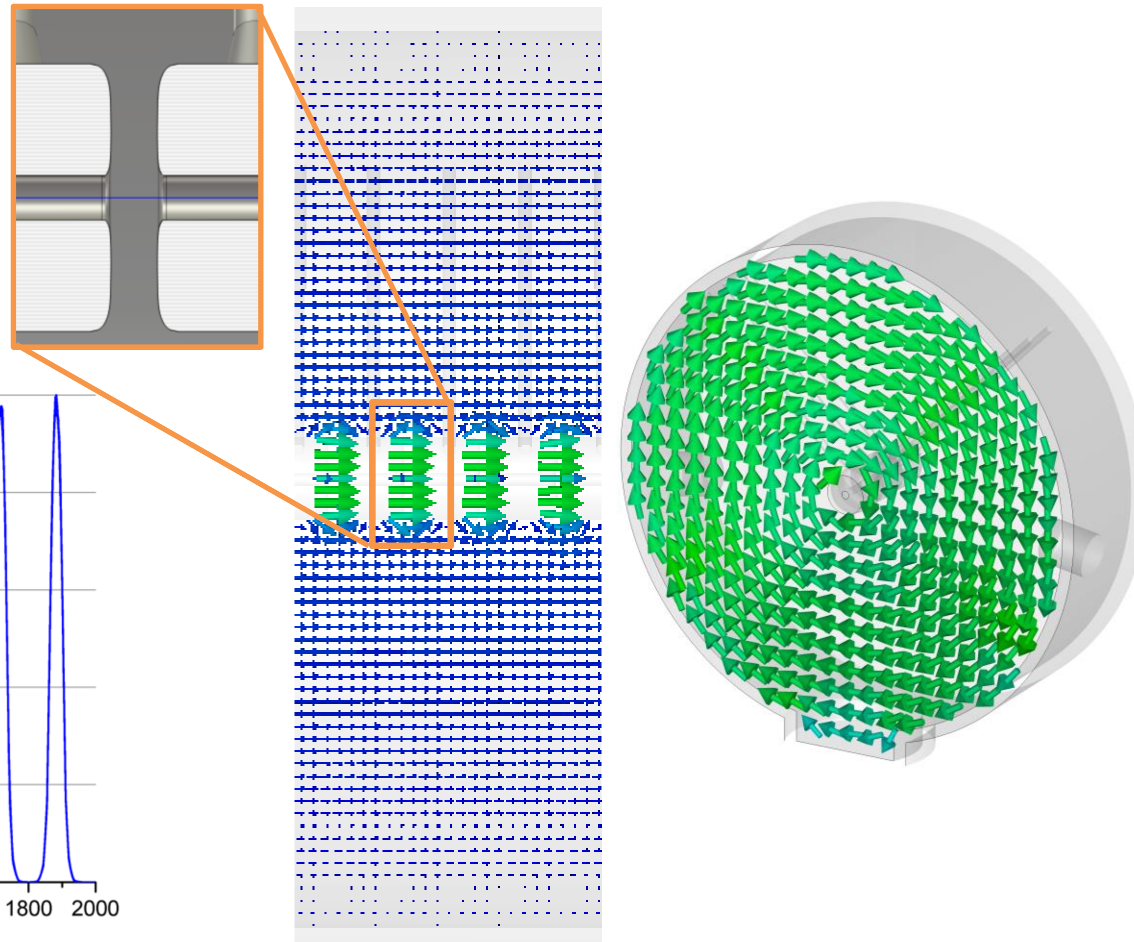
- Good flatness
- The tuners have a negligible effect on the voltage distribution
- No parasitic frequency mode close to the operation frequency

$$V = \int E \, dz$$

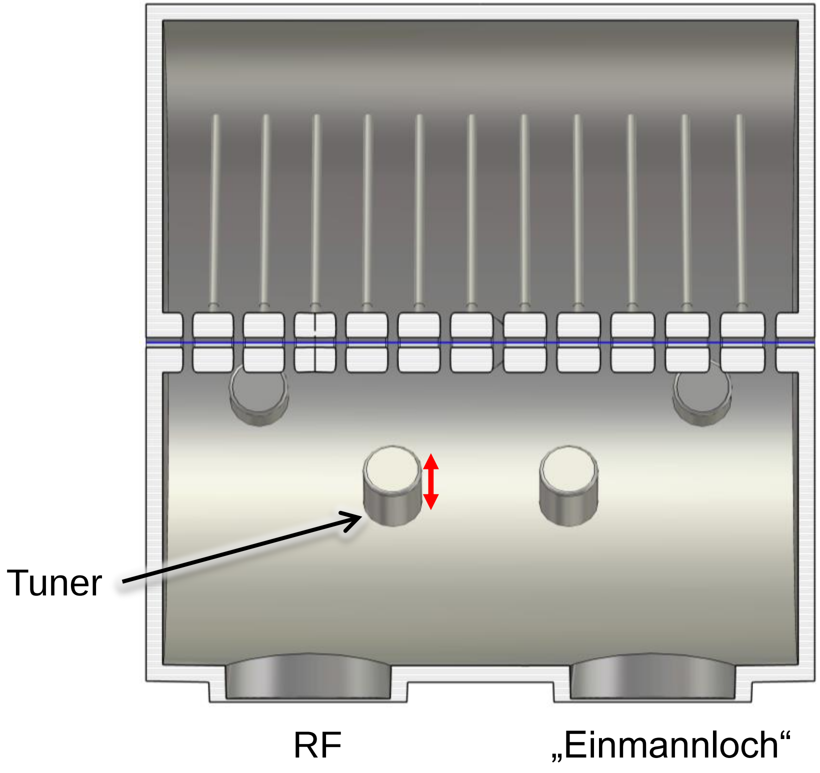


Electric field

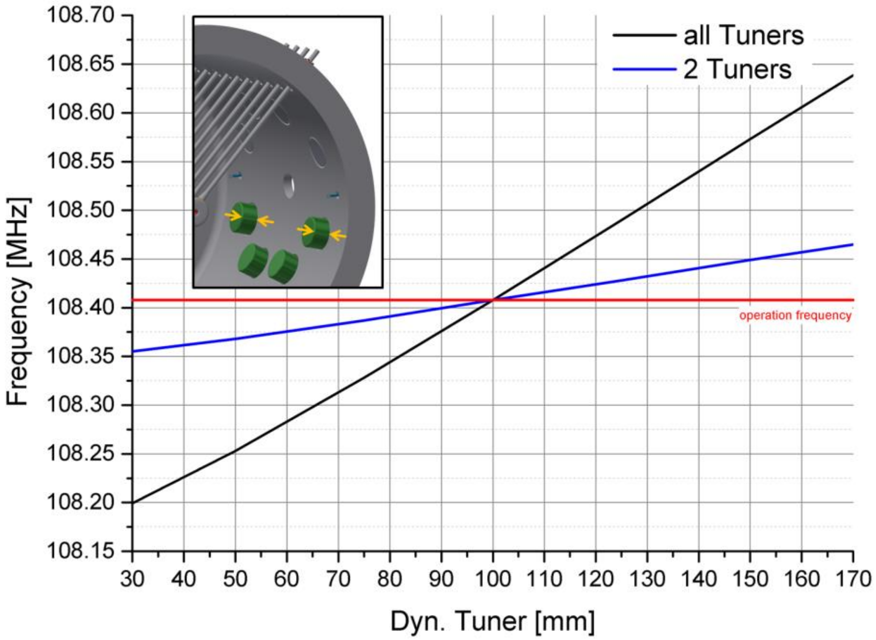
Magnetic field



Frequency



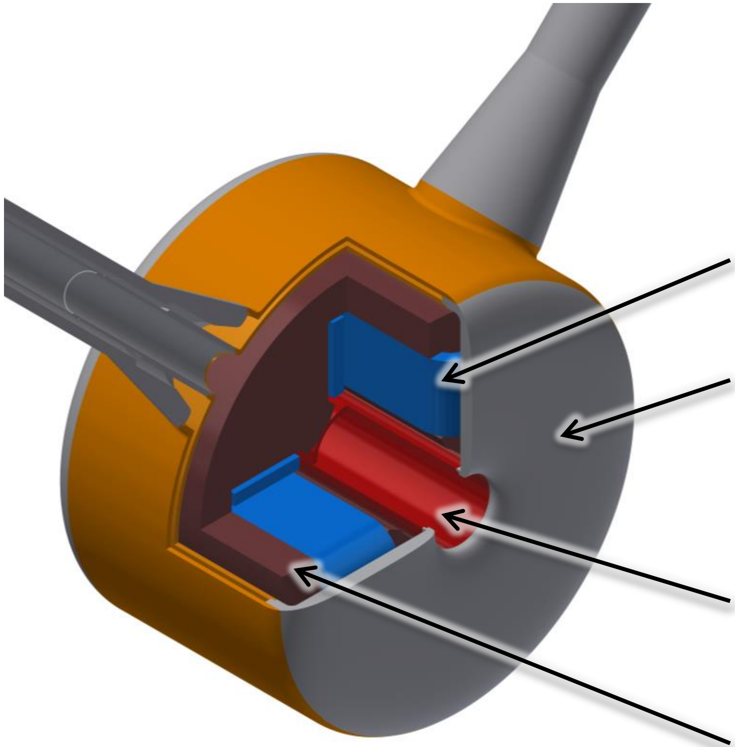
- 8x Tuners (Ø180 mm / CF200)
- 1x RF (Ø500 mm)
- 1x „Einmannloch“ (Ø500 mm)
- 2x Vacuum (CF160)

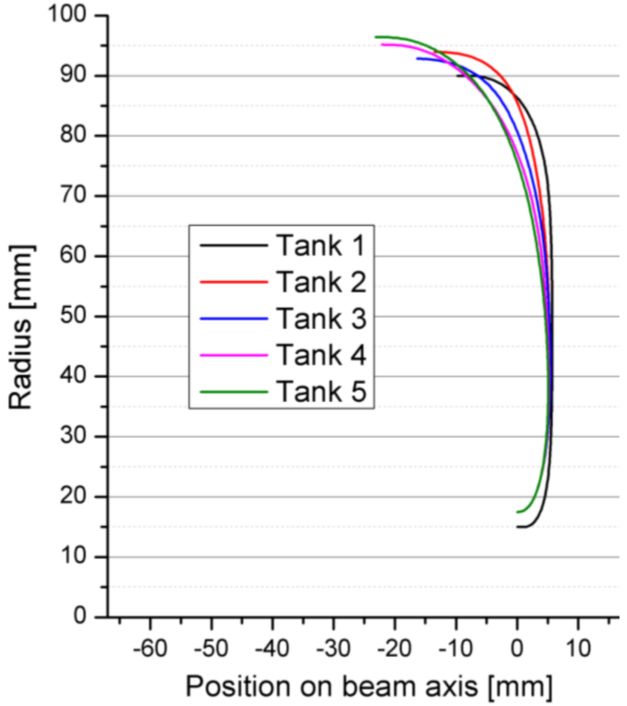


Outline

- Existing and upgraded UNILAC
- Boundary Conditions for Accelerator Design
- Alvarez-Prototype:
  - RF-Simulation
  - Construction
    - Drift tube
    - Tank
    - Alignment system

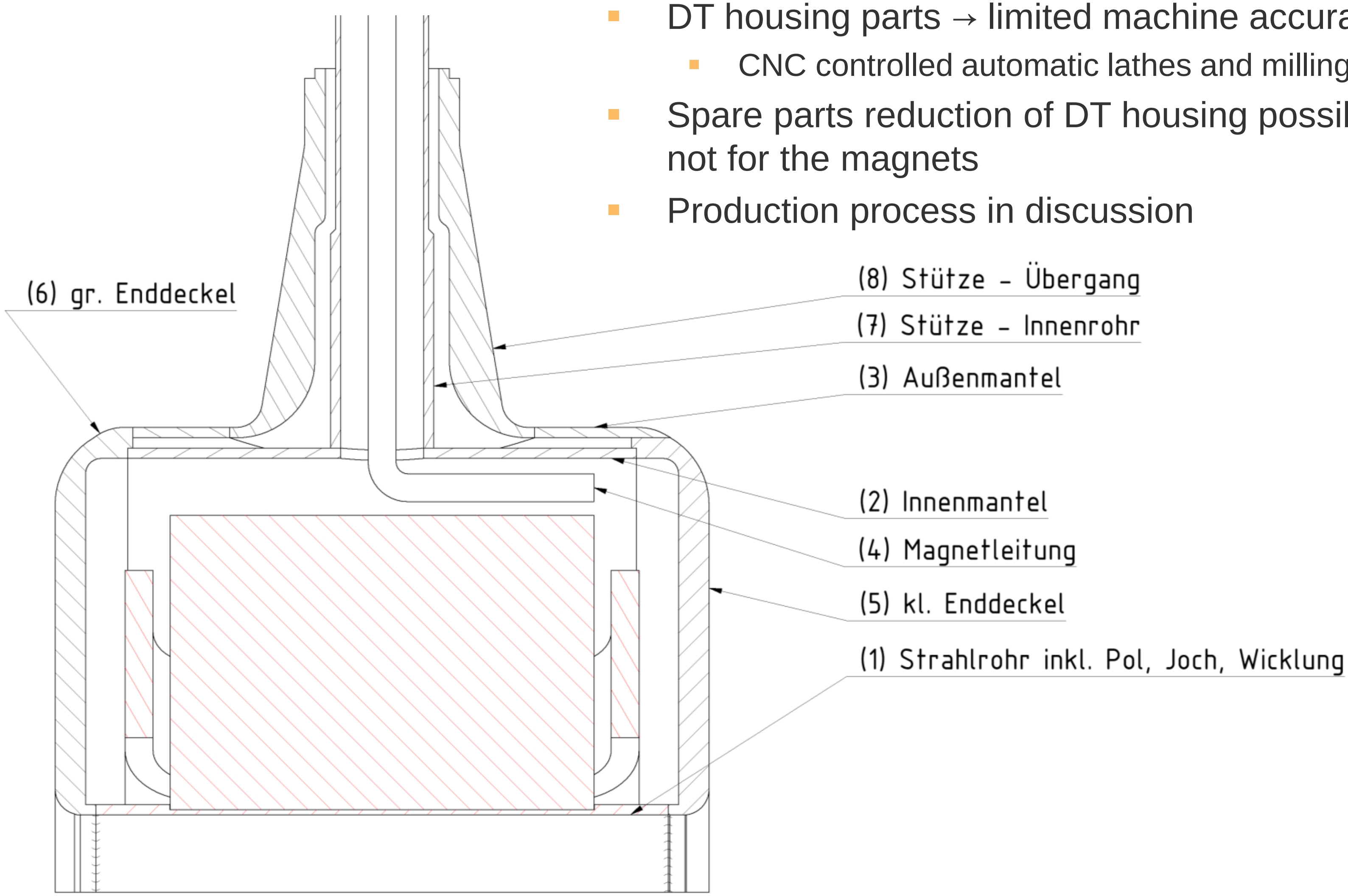
new Alvarez-Drift Tube Shape Profile





Alvarez-Drift tube

- DT housing parts → limited machine accuracy
  - CNC controlled automatic lathes and milling machine
- Spare parts reduction of DT housing possible, but not for the magnets
- Production process in discussion

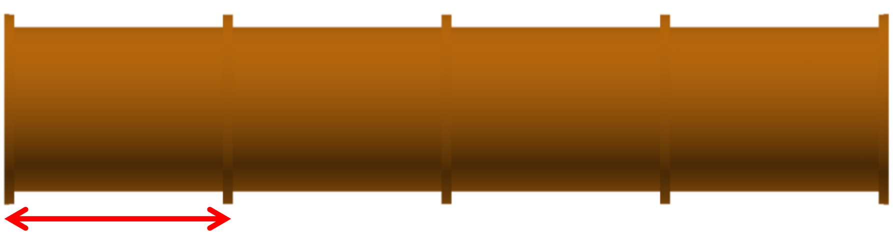


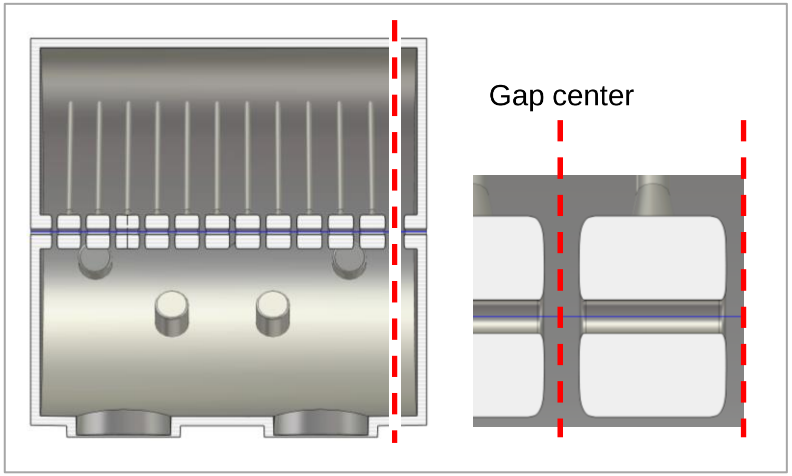
Tank Length of the Prototype

Standard plate width
2m x 6m

Limitation @ Galvanic workshop

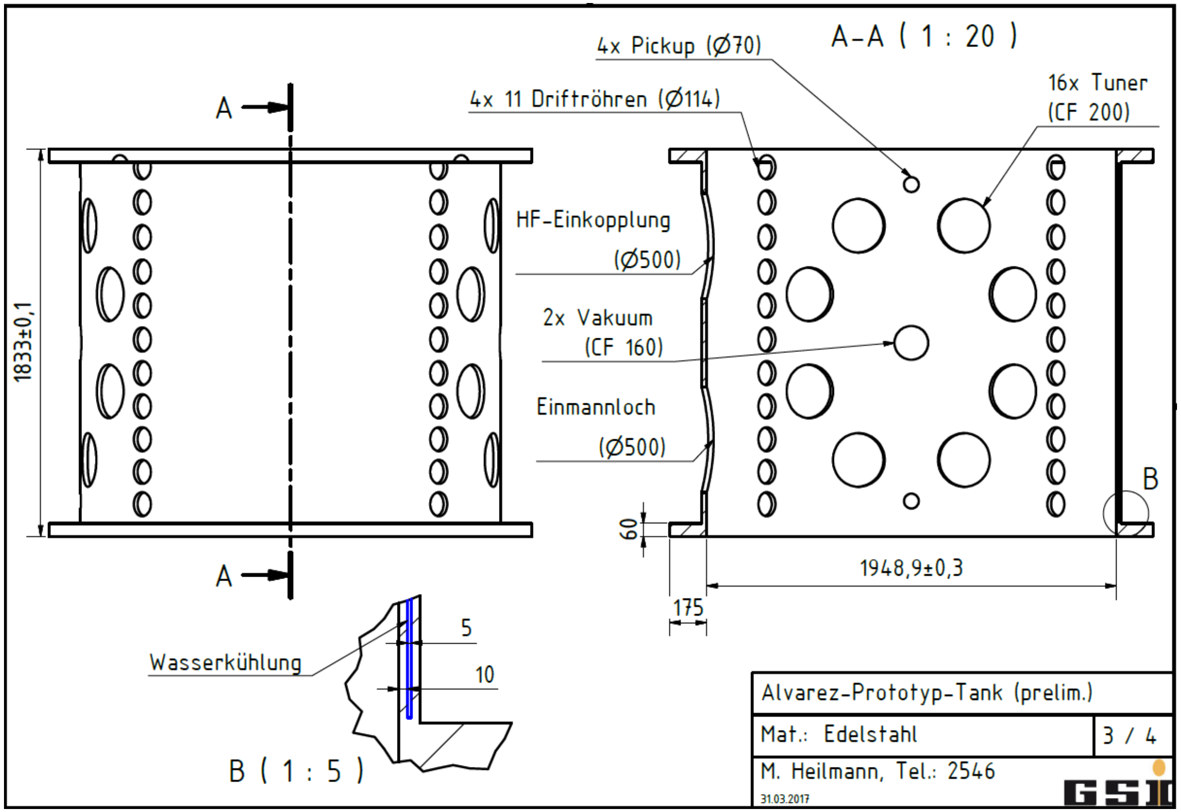
<2m	<2,1m	<2,2m	~~<2,3m~~	<2,4m	<2,5m	<2,6m	<2,7m	<2,8m
1833,03	2001,57	2171,59	2171,59	2343,08	2343,08	2516,04	2690,49	2690,49
1935,25	1951,54	2155,64	2155,64	2364,23	2364,23	2577,30	2598,12	2794,87
1915,31	1930,23	2164,29	2164,29	2197,16	2405,88	2441,77	2674,44	2693,89
1851,52	2079,70	2124,65	2124,65	2378,35	2394,85	2427,86	2576,87	2360,66
1972,92	1771,72	1923,74	1923,74	1257,09	1031,88	576,94		
1031,88	805,16							





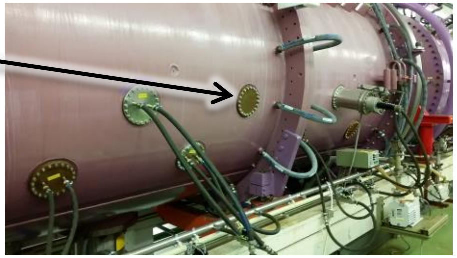
- Tank length reduction to use standard plate

Prototype-Tank



- Length: 1916.9 mm
- Øi: 1948.9 mm
- 11 drift tubes
- 12 gaps
- 2x V-stem orientation (±45°)
- 8x Tuner (= 6 stat. + 2 dyn.)
- 3x Pickup
- 2x Vacuum
- RF-coupling
- „Einmannloch“

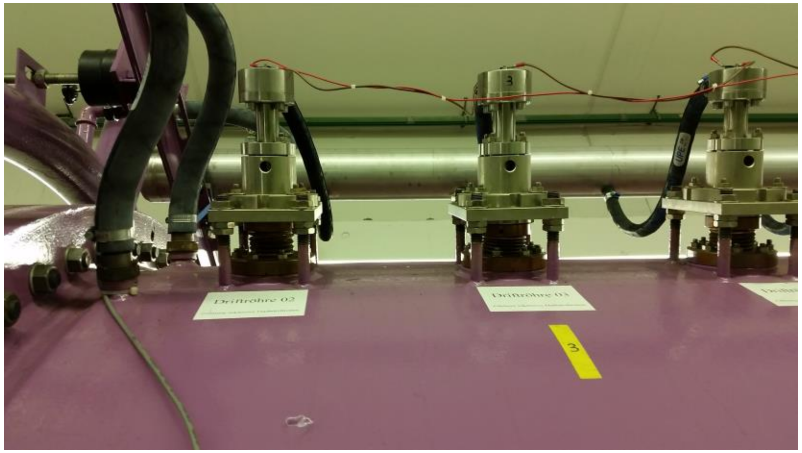
flange

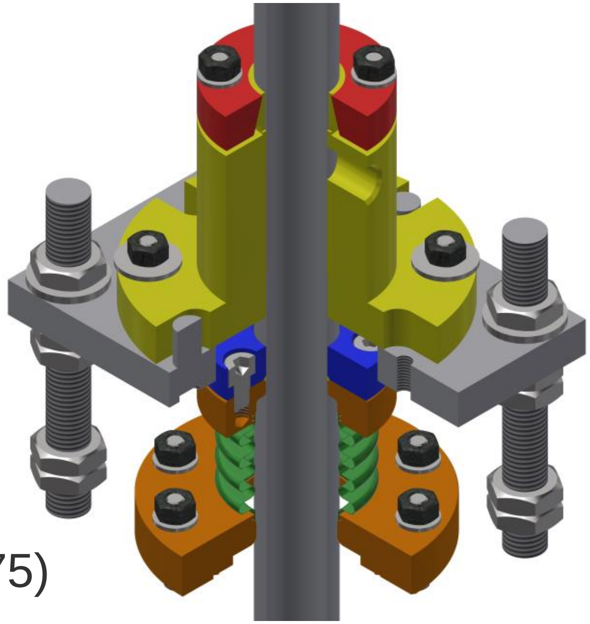


static tuners

dynamic tuners

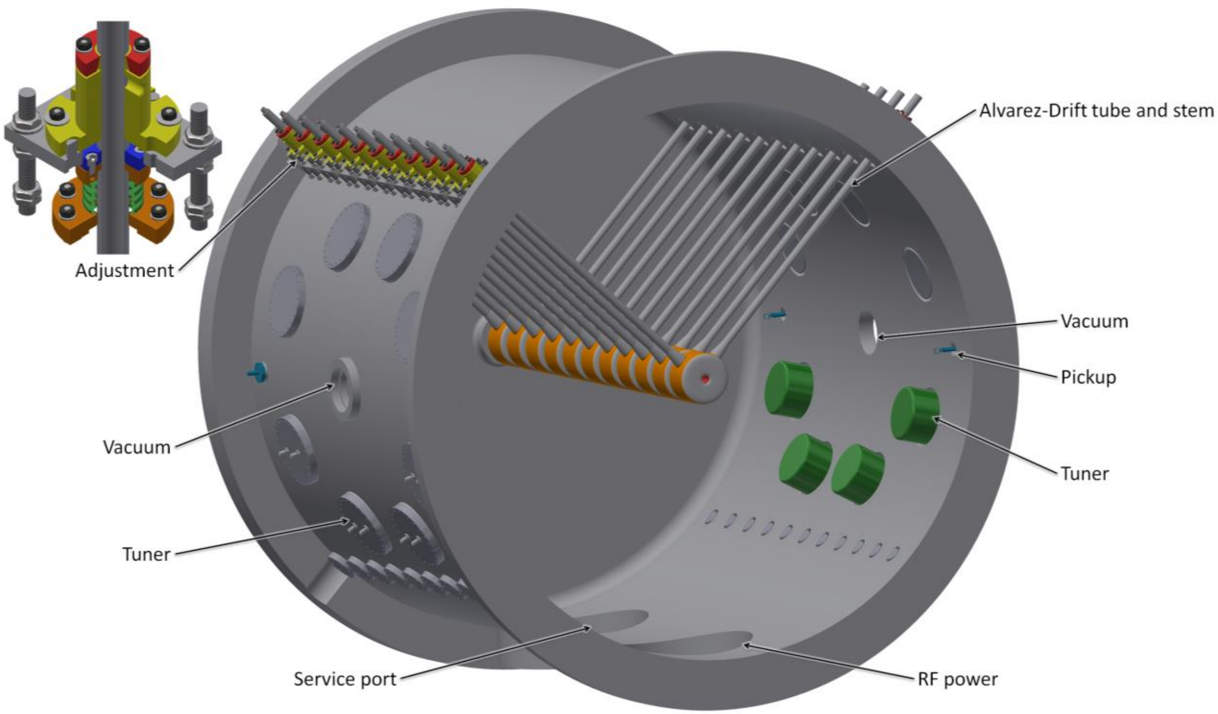
Adjustment





A4 (AJ075)

Alvarez-Prototype



Parameter	Unit	Value
Frequency	MHz	108.408
A/q		≤8.5
Max. Current	mA	15.0
Synchronous phase	deg.	-30
Beam pulse length	ms	≤1.0
Beam repetition rate	Hz	≤10
Input energy	MeV/u	1.392
Output energy	MeV/u	1.705
Gaps	#	12
Gap length	mm	40.9-45.0
Drift tubes	#	11
Drift tube length	mm	111.3-122.2
Aperture	mm	30.0
Tank diameter	mm	1948.9
Tank length	mm	1916.9
Q - Factor		82000

Thank you for your attention