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FINAL DESIGN OF THE FOS ALVAREZ-CAVITY FOR THE UPGRADED UNILAC

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Abstract

The final design describes the First-of-Series (FoS) Alvarez-Cavity-section of the first tank being part of the new post-stripper DTL of the UNILAC. The FoS-cavity has an input energy of 1.358 MeV/u with 11 drift tubes (including quadrupole singlets) in a total length of 1.9 m and a diameter of 2 m with an operation frequency of 108.4 MHz. The drift tubes will have a new shape profile at the end plates. The single layered quadruple singlets inside the drift tubes are pulsed with 10 Hz and will have a maximum field gradient of 51 T/m. The new drift tube design combines the new shape profile with the transverse and longitudinal installation space of the magnet. The FoS Alvarez-cavity will be part of the first section of the new Alvarez DTL. It shall be operated at nominal RF- and magnetic fields prior to procurement of the series.

INTRODUCTION

The UNIversal Linear ACcelerator UNILAC (see Fig. 1) at GSI (Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany) will serve as main operation injector for the Facility for Antiproton and Ion Research FAIR (see Fig. 2 and [1]). The UNILAC is capable of delivering ion beams for many different experiments in pulse-to-pulse switch mode with individual ion species and energies. High beam intensities and quality in combination with high availability for the FAIR project require an update of the existing Alvarez-DTL, which has been already in operation for 40 years. An extensive upgrade program is in progress [2]; a new quadrupole quadruplet magnet in front of the RFQ [3], new RFQ electrode design [4], the post-stripper DTL [5], and the vacuum control system at the UNILAC (Table 1), are just some examples.

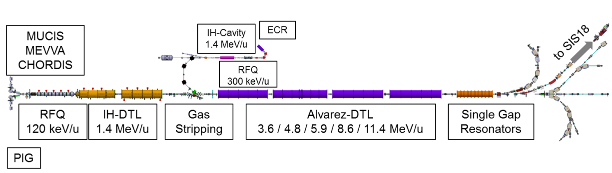

Figure 1: Schematic overview of the GSI UNILAC.

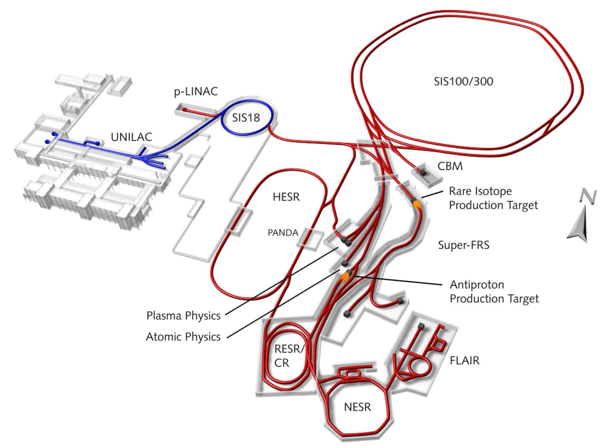

Figure 2: Schematic overview of FAIR.

Table 1: Parameters for the Upgraded UNILAC

Parameter	Unit	Value
RF-frequency	MHz	108.408
A/q		≤ 8.5
Max. Current	mA	1.76×A/q
Synchronous phase	deg.	-30 / -25
Input beam energy	MeV/u	1.358
Output energy	MeV/u	3.0 – 11.4
Hor. emittance (norm., tot.)	µm	≤ 0.8
Ver. emittance (norm., tot.)	µm	≤ 2.5
Beam pulse length	ms	≤ 1.0
Beam repetition rate	Hz	≤ 10
Alvarez-cavities	#	5
Drift tubes / cavity	#	21 – 54
Drift tube length	mm	109.9 – 327.0
Drift tube diameter	mm	180 – 190.3
Aperture	mm	30 / 35

FOS ALVAREZ-DTL

The final design (Table 2) describes the First-of-Series (FoS) Alvarez-Cavity-section [6] of the first tank being part of the new post-stripper DTL of the UNILAC (Fig. 3). The tank is under construction at the company VA-TEC (Germany) [7]. The next tendering for the main components are the two end plates followed by the drift tubes including magnets.

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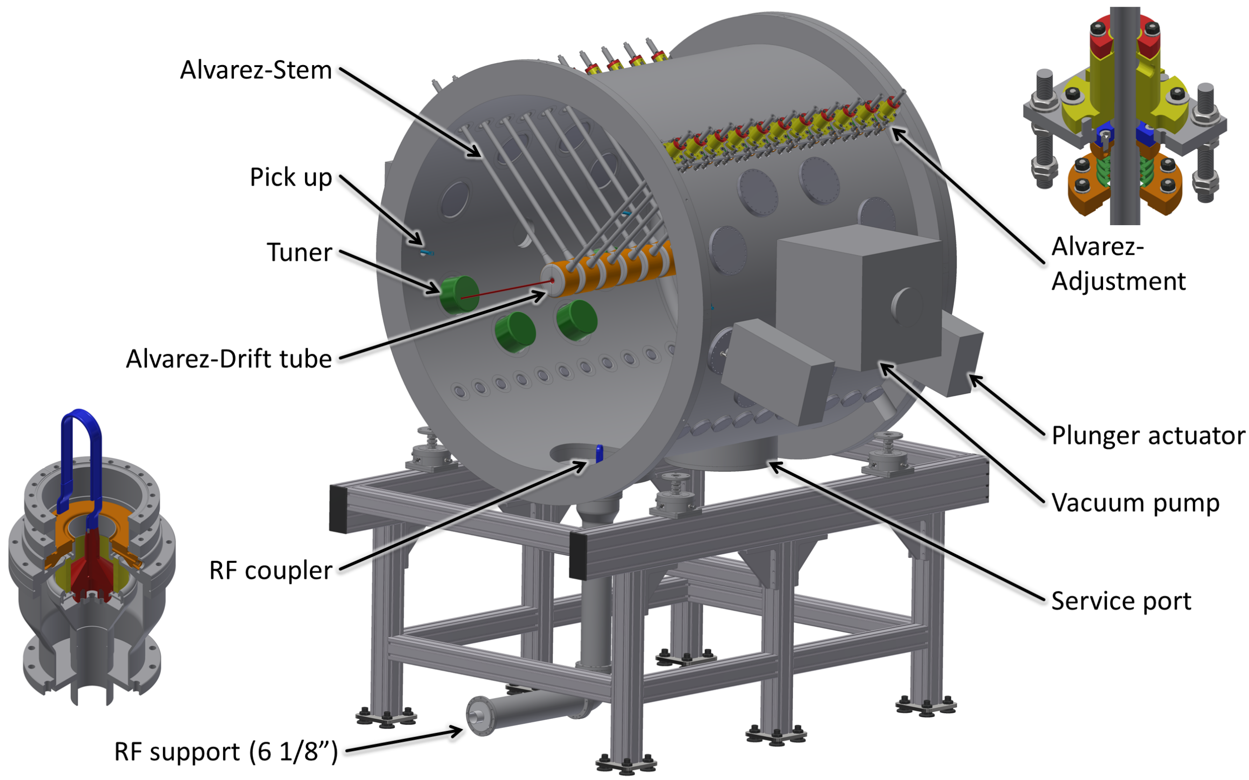

Figure 3: CAD-model of the Alvarez-FoS cavity section with a length of 1.9 m and 11 drift tubes. The drift tubes are installed at the top of the tank, but other combinations are possible. The bottom houses RF coupling, a support hole, and at the side the vacuum pumps and pickups are installed (light blue).

Table 2: Parameters of the FoS-Alvarez-Cavity

Parameter	Unit	Value
RF-Frequency	MHz	108.408
Input energy	MeV/u	1.358
Output energy	MeV/u	1.705
Gaps	#	12
Gap length	mm	40.5 – 44.6
Drift tubes	#	11
Drift tube length	mm	109.9 – 121.0
Drift tube diameter	mm	180.0
Aperture	mm	30.0
Tank diameter	mm	1952.6
Tank length	mm	1880.5
Q - Factor		82000

The planar end plates contain a modular half drift tube with a quadrupole singlet as in the drift tube no. A.I/1. Furthermore, all connections at the end plates will be installed to mount the intertank section (beam diagonstics, gate valve, quadrupole singlet, re-buncher of spiral type) between the Alvarez cavities (A.I-A.II, A.III-A.IV, A.IV-A.V). An integrated re-buncher of Alvarez type is installed between cavities A.II and A.III for reduced beam energy operation.

For RF-coupling, a well-established coupler-type will be used [8, 9]. The drift tube prototype is still under technical development and was simplified such that all components can be built at GSI and only the magnets must be stocked as spare parts.

RF-simulation

The major challenge in an Alvarez-DTL is to hit the operating frequency and [5] describes the tuning with the eight inductive plungers (±200 kHz) in total. The FoS will have two dynamical tuners with a range of ± 50 kHz and all tuners

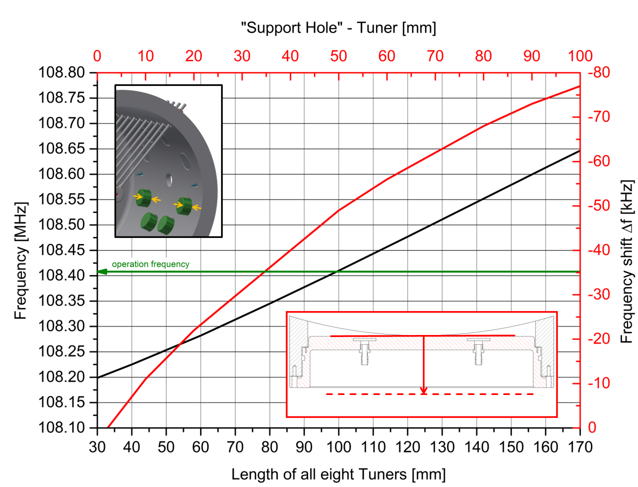

Figure 4: Simulated tuning range of the Alvarez-prototype.

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have a larger frequency range in comparison the existing Alvarez-DTL. The comparison between the frequency simulation and the measurements at a 1:3 scaled Alvarez model cavity [10, 11] shows a frequency deviation of 2.7 ‰ (details in [12]). With the frequency range of the eight plungers inside the FoS-cavity it is not possible to compensate the deviation of 2.7 ‰ between the CST-simulation [13] and a real cavity. In order to further increase the tuning range, the support port can be used as a static tuner to change the frequency. Additionally it can be used to decrease the frequency of 80 kHz (Fig. 4) when needed.

Quadrupole Singlet

The presented quadrupole singlet magnet is installed into the first drift tube of the Alvarez I cavity (A.I/DT.1) and in the center of the intertank-section (Fig. 5). The simulations to design this magnet were made with Opera3D [14] and the preliminary results of the magnetic- and geometric parameters are summarized in Table 3. The single-layered quadrupole

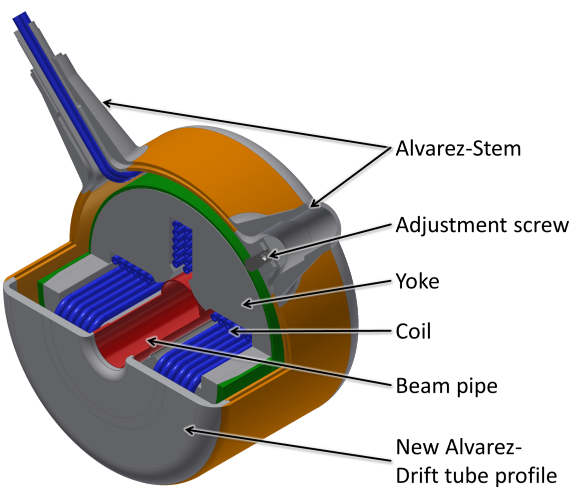

Figure 5: CAD-model of the integrated quadrupole singlet.

Table 3: Parameters of Quadrupole Singlet in DT.1

Parameter	Unit	Value
Yoke $\varnothing_i$ / $\varnothing_o$	mm	115 / 146
Aperture	mm	32
Conductor $\varnothing_i$ / $\varnothing_o$	mm	4 / 6
Yoke length	mm	82
Eff. length	mm	94.8
Current	A	1100
Pulse length	ms	100
Rise time	ms	25
Flattop	ms	1
ΔT	K	25
Water flux	l/min	2.1
Magnetic gradient	T/m	51

singlets inside the drift tubes are pulsed up to 10 Hz and will have a maximum field gradient of 51 T/m. The complete Alvarez-DTL will have seven different groups of quadrupole magnets; with unique aperture, effective length and gradient. The new beam dynamics [15] and the new design of the end plates of the drift tubes [16, 17] reduce the installation space inside all the drift tubes, especially inside the shortest drift tube (A.I/DT.1). The first quadrupole group must have yokes of VACOFLUX 50 [18] to increase the magnetic flux density at the pole shoe, and to reduce the longitudinal installation length of the magnet while maintaining the same magnetic gradient. The magnet is supplied with one water-cooled circuit consisting of a (∅ 6×1) mm pipe.

The mechanical design of the drift tube is a technological development based on the existing Alvarez drift tube in particular w.r.t. the accuracy of all drift tube components and the welding procedure. The prototype drift tube is currently under production at GSI mechanical workshop.

OUTLOOK

The design of the First-of-Series Alvarez-DTL is finished and the tank shall be delivered in this year. The tendering of the end plates and the drift tubes shall start in summer, and the copper plating of the tank is in 2019. Low level measurements of the complete FoS Alvarez-DTL are currently planned for 2020, followed by high power tests in 2021.

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