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FOS CAVITY OF THE ALVAREZ 2.0 DTL AS FAIR INJECTOR

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Abstract

The Alvarez 2.0 DTL will be the new post-stripper DTL of the UNILAC at GSI. The existing GSI with its LINAC and SIS18 comprise the main operation injector chain for the Facility for Antiproton and Ion Research FAIR. The new Alvarez-DTL has an operation frequency of 108.4 MHz, an input energy of 1.358 MeV/u and the output energy is 11.4 MeV/u with a total length of 55 m. The presented FoS section will be part of the first cavity of the Alvarez 2.0 DTL. The FoS-cavity with 11 drift tubes (including quadrupole singlets) and a total length of 1.9 m will be copper plated in GSI for high power tests. The design of the quadrupole singlet magnet is finalized; a prototype of a fully functional magnet with drift tube and stems will be fabricated within a design study. Empty drift tubes and all components of the tank shall be delivered 2019 for first low level RF investigations.

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 able to deliver ion beams (proton up to uranium) for different experiments in parallel (pulse-to-pulse switch mode) with individual ion species and energies. The existing Alvarez-DTL has been already in operation for 40 years and the repair efforts increase particularly. For the upcoming FAIR project an update of the UNILAC in terms of high beam intensities, quality and high availability is required. The beam dynamics of the completely new Alvarez-DTL (2.0) will fulfill these requirements [2] in combination with an increased shunt impedance per surface field on the drift tubes (Table 1) [3]. After low level measurements the First-of-Series (FoS) Alvarez-Cavity [4] will be copper plated and RF power conditioned in 2020. The FoS-Alvarez DTL is designed for being used as the first tank for the new injector.

In parallel to the Alvarez 2.0 an UNILAC upgrade program is in progress [5]: a new quadrupole quadruplet magnet [6], new RFQ electrode design [7] and the vacuum control system at the UNILAC.

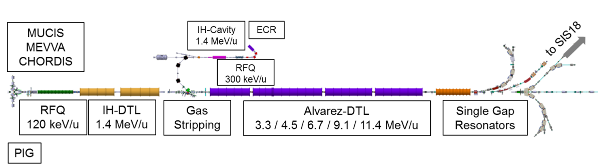

Figure 1: Schematic overview of the GSI UNILAC.

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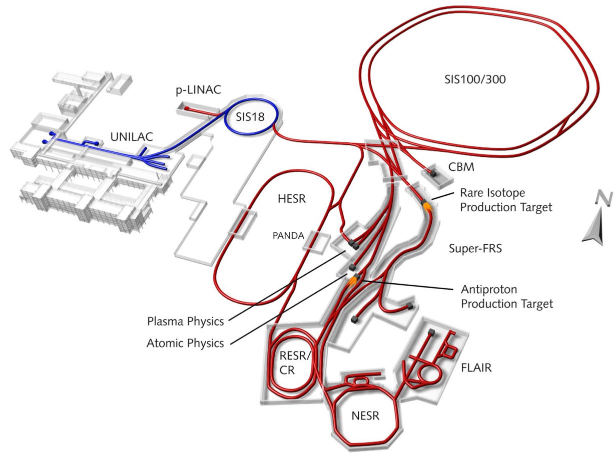

Figure 2: Schematic overview of FAIR.

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 FoS-Alvarez Cavity (Table 2) [8] is the first tank being part of the new post-stripper DTL of the UNILAC (Fig. 3). The tank and the two end plates were fabricated at the company VA-TEC (Germany) [9] and the delivery is scheduled for June 2019, after a factory acceptance test with the main topics: dimensional check, vacuum and surface preparation. The lower deviation of the tolerance for the inner diameter is identical with the diameter in the CST-simulation [10] with middle positions of all tuners (see details for the frequency range in [4]) and the upper deviation was set to plus 2 mm. After rolling the plate to a cylinder and welding the large end flanges to that cylinder, the measured average inner diameter is 0.8 mm larger as the lower tolerance. A possible frequency

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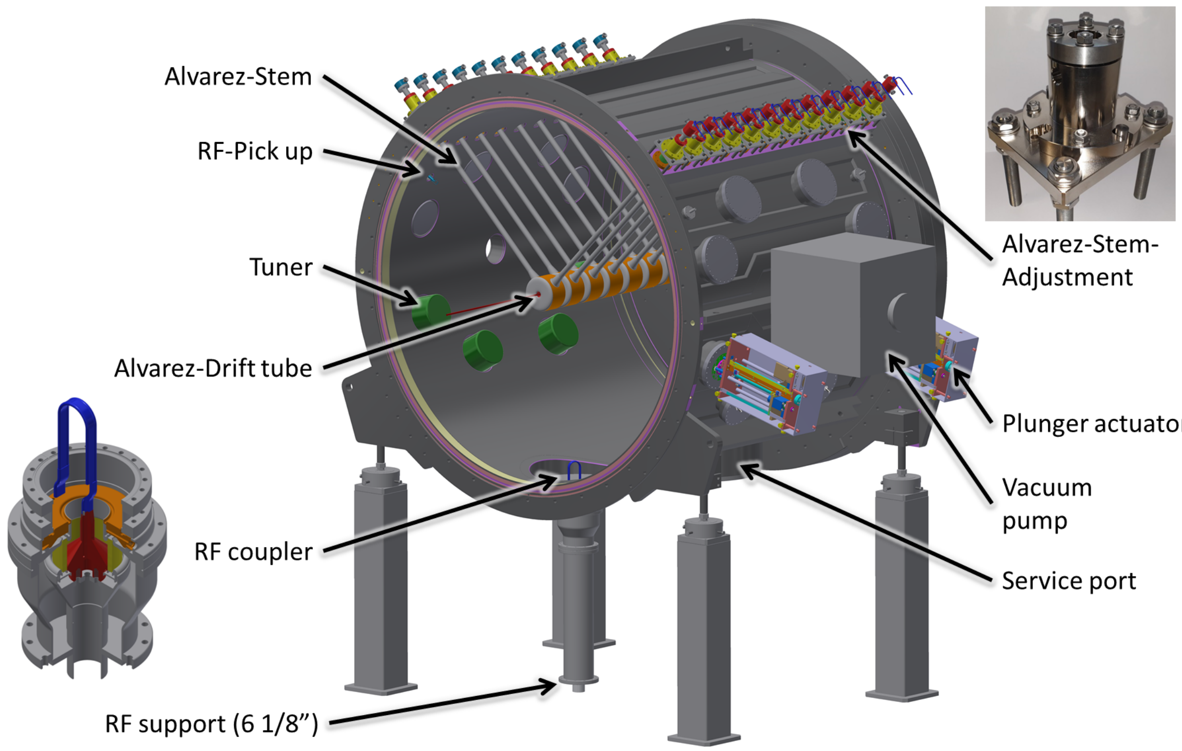

Figure 3: CAD-model of the Alvarez-FoS cavity section with a length of 1.9 m and 11 drift tubes. The drift tubes are installed at the top of the tank, but other combinations are possible. The bottom houses RF coupling, a support hole. Vacuum pumps and pickups are installed (light blue) at the side.

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
Total power	kW	334
Q - Factor		82000

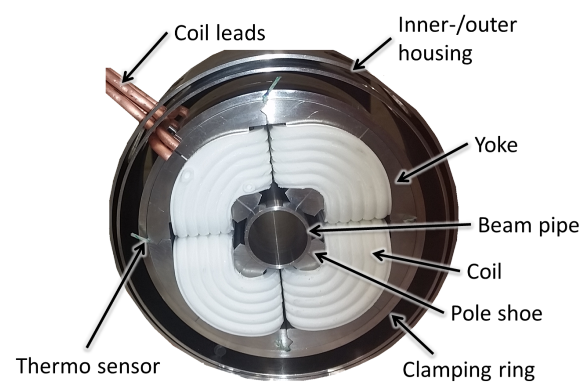

Figure 4: Mechanical development of the first prototype drift tube including a dummy magnet with 3D printed coils.

shift [11] of a larger diameter can be fixed with larger tuners, a too small diameter of the tank requires additional special tuners. The special frequency tuners are in case of the FoS-Alvarez 2.0 the "Support-Hole"-tuner (see [4]) and the heating of the tank.

The eleven empty drift tubes for the FoS-Alvarez DTL were produced at GSI mechanical workshop (Figs. 4 and 5). The mechanical design and the structural change of the Alvarez 2.0 drift tubes shall allow to produce all single parts or spare parts with required accuracy on GSI campus. Later just the magnets must be stocked as spare parts.

The Low Level RF investigations are important to get the right tuner lengths for the operation frequency and a cross check whether the electric field inside the accelerator gaps fits with the theoretical beam dynamics [2]. The FoS-Alvarez 2.0 will be LLRF tested in summer 2019, initially without copper plated surfaces.

The high power RF tests are scheduled for 2020 after delivery of RF-coupling [12, 13] and installation of the new

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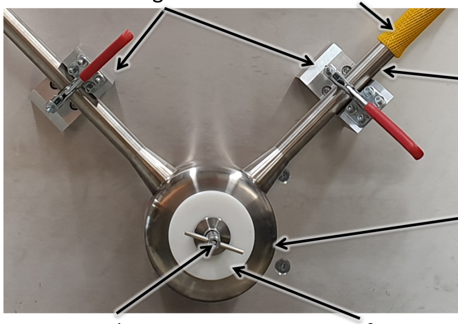

Figure 5: Empty drift tube for RF tests produced at GSI mechanical workshop. The picture shows the drift tube in the last welding frame for welding on the stems.

6 1/8" rigid line between the RF gallery and the test cave. In parallel all components must be copper plated.

In the planar end plates a modular half drift tube with quadrupole singlet is installed. The entrance half drift tube houses the same quadrupole magnet as drift tube no. 1 of that tank and in the exit half drift tube is the same magnet as in the last drift tube. Outside of the end plates all connections for the intertank section will be installed [14]. In the centre of the intertank sections will be installed a quadrupole singlet (like in A.I/DT.1), one gate valve, beam diagnostics and a three gap spiral re-buncher. The technical design of the intertank section is ongoing.

QUADRUPOLE SINGLET

The shortest quadrupole singlet magnet is installed into the first drift tube of the Alvarez I cavity (A.I/DT.1, Fig. 6), this magnet will be also installed in the centre of all intertank-sections. The design is finalized and the results of the magnetic- and geometric parameters [3, 15] are summarized in Table 3. A dedicated study (at an external manufacturer) about this important component of the new Alvarez 2.0 will be a cross check of the GSI design. That study includes simulations, drawings and a fully functional magnet inside of a water cooled drift tube with stem. The challenges with this magnet are the short longitudinal space inside the drift tube, the small bend radii of the coil, the secure against axial rotation and the pulsed operation mode. The scheduled delivery of the drift tube with the fully functional magnet is in spring 2021.

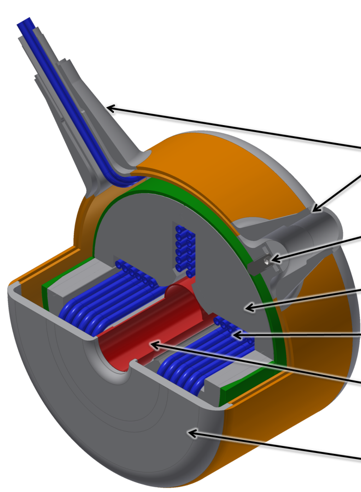

Figure 6: CAD-model of the integrated quadrupole singlet.

Table 3: Parameters of Quadrupole Singlet in DT.1 [16]

Parameter	Unit	Value
Yoke $\varnothing_i$ / $\varnothing_o$	mm	115 / 146
Aperture	mm	32
Conductor $\varnothing_i$ / $\varnothing_o$	mm	3.5 / 5.5
Yoke length	mm	82
Eff. length	mm	94.8
Current	A	1109
Turns per pole	#	5
Pulse length	ms	1
Rise time	ms	25
Flattop	ms	1
ΔT	K	25
Water flux	l/min	1.8
Magnetic gradient	T/m	53.5

OUTLOOK

The main components of the First-of-Series Alvarez-DTL will be finished soon and after the delivery the installation starts immediately. Low level measurements of the complete FoS Alvarez-DTL are currently scheduled in summer 2019. After copper plating of a dummy tank end 2019, the high power tests begin after copper plating of the FoS tank in 2020.

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