DESIGN STUDY FOR A PROTOTYPE ALVAREZ-CAVITY FOR THE UPGRADED UNILAC

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Abstract

The design study describes the prototype Alvarez-tank of the new post-stripper of the UNILAC. A prototype with 11 drift tubes (including quadrupole singlets) of 1.9 m of total length and 2 m of diameter will be manufactured. This cavity features new drift tube shape profiles to provide for high shunt impedance at a maximum electric surface field of 1 E_K. Additionally, it allows realization and high power testing of an optimized stem configuration for field stabilization. In case of successful tuning and long-term operation at high power level, it shall be used as a first of series cavity of the new UNILAC post-stripper DTL.

INTRODUCTION

The GSI (Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany) operates two ion injectors (Fig. 1). The High Current Injector (HSI) and the High Charge state Injector (HLI) provide the post-stripper DTL with an energy of 1.4 MeV/u. The UNILAC can deliver beams for many experiments in time sharing mode with individual ion species and energy. The existing Alvarez linac has been in operation for more than 40 years and the repair efforts increase particularly w.r.t. the drift tubes and the included magnets. The upcoming FAIR project [1] depicted in Fig. 2 imposes new requirements to the UNILAC in terms of beam intensity and quality. Additionally, high availability is of utmost importance for the new FAIR main operation injector. In order to meet these requirements the UNILAC will undergo an extensive upgrade program [2]. The today's Alvarez-type post-stripper DTL will be replaced by a completely new Alvarez-DTL. Its cavities feature an increased shunt impedance per surface field [3]. A novel tuning scheme based on varying stem orientations will be employed for significant reduction of the tilt field sensitivity w.r.t. imperfections of fabrication and alignment [4]. Furthermore, it is possible to investigate an optimized stem position to increase the field stability [3,4]. After low level measurements

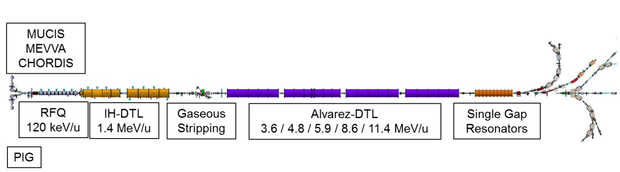

Figure 1: Schematic overview of the GSI UNILAC.

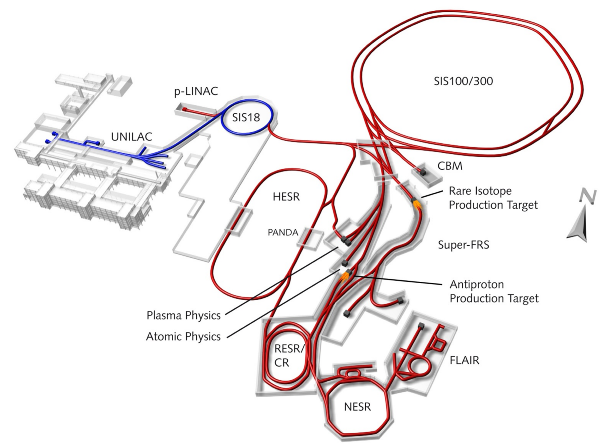

Figure 2: Schematic overview of FAIR.

the prototype will be conditioned and used as the first tank for the new booster injector and can be operated with high power RF.

Table 1: Beam Design 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	1.4
Max. Output energy	MeV/u	3.0–11.7
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-PROTOTYPE

The prototype is the first cavity section of the new Alvarez-DTL with a length of 1.9 m (Fig. 3). The maximum length of the prototype-tank is given by the premisses of GSI's on-site galvanic shop and the tank must end at a gap-center to connect the prototype later to the subsequent section. The new tank will have a constant radius along the beam line, unlike the cone-shaped tanks of the existing first three Alvarez-tanks at GSI. The major changes compared to the existing Alvarez are the optimized beam dynamics [5], a new

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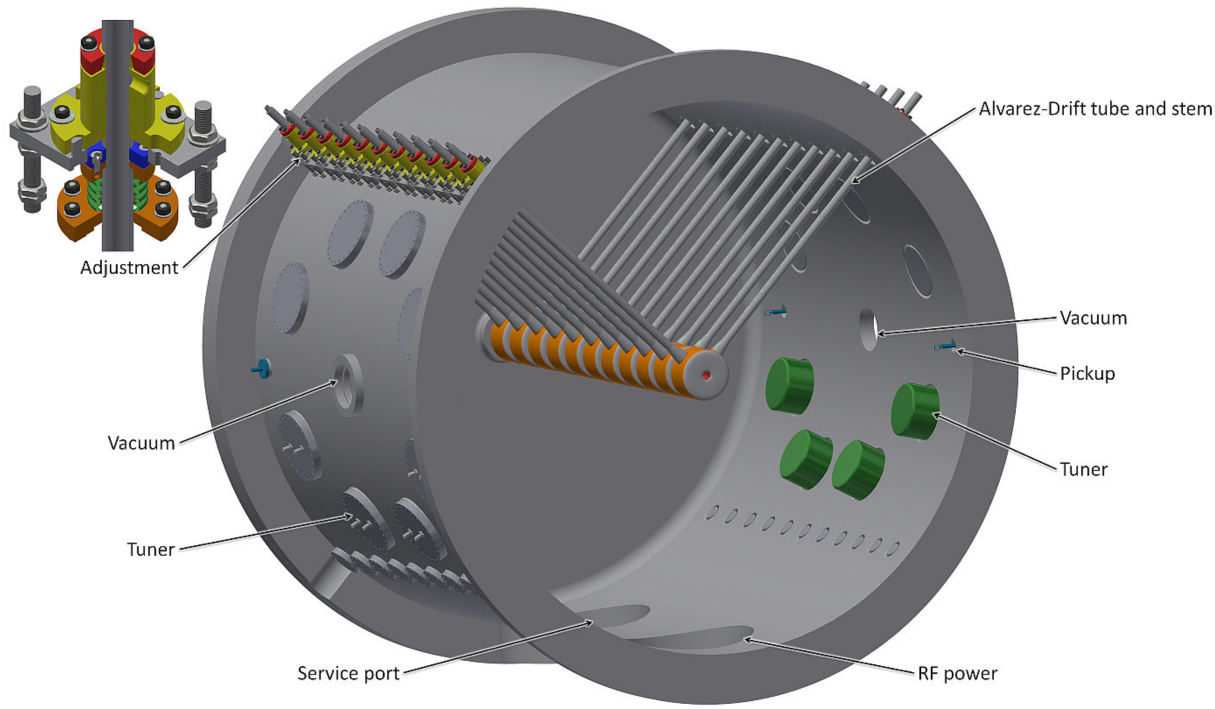

Figure 3: CAD-model of the Alvarez-prototype cavity section with a length of 1.9 m and 11 drift tubes. The drift tubes are installed at the top of the tank, but other combinations can be installed. The bottom houses RF coupling, a support hole, and at the side the vacuum pumps and pickups are installed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

Table 2: Parameters of the Alvarez Prototype Cavity

Parameter	Unit	Value
RF-Frequency	MHz	108.408
Input energy	MeV/u	1.3915
Output energy	MeV/u	1.7046
Gaps	#	12
Gap length	mm	40.9-45.0
Drift tubes	#	11
Drift tube length	mm	111.3-122.2
Drift tube diameter	mm	180.0
Aperture	mm	30.0
Tank diameter	mm	1948.9
Tank length	mm	1917.2
Q - Factor		82000

drift tube profile [3], and the possibility to apply different stem configurations for RF-field stabilization [4]. Using a dedicated 1:3 scaled model cavity this stabilization scheme has been investigated in detail [6]. The measurements with the scaled model confirm the RF-simulations [7]. With the prototype-tank it will be possible to rotate the stems individually in steps of 90° for each drift tube to test it in a real cavity with high power RF.

RF-simulation

Resonance frequency tuning is done with eight inductive plungers in the prototype. The production tolerance of the tank is a major challenge for frequency tuning and the detuning from gravity deformation of the cavity is estimated to about 5 kHz. The prototype will have a larger frequency range as the existing cavities. All eight tuners together have a maximum tuning range of ± 200 kHz and the two dynamical tuners have a range of ± 50 kHz at mean insertion depth (Fig. 4). The voltage distribution along the beam axis for the operation frequency of 108.4 MHz is shown in Fig. 5. The tuners have a negligible effect on the voltage distribution thanks to the large distance between the tuners and the beam axis and there is no parasitic frequency mode close to the operation frequency.

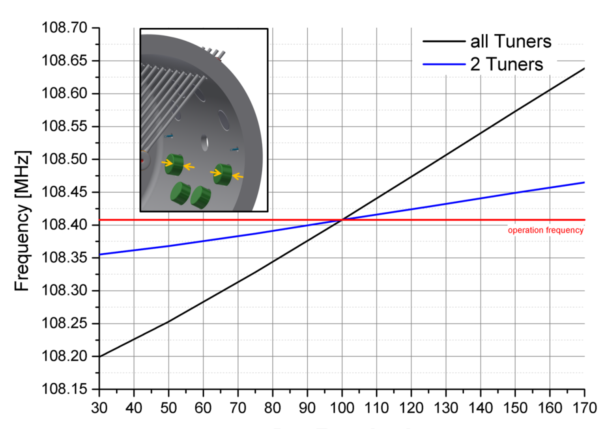

Figure 4: Simulated tuning range of the Alvarez-prototype.

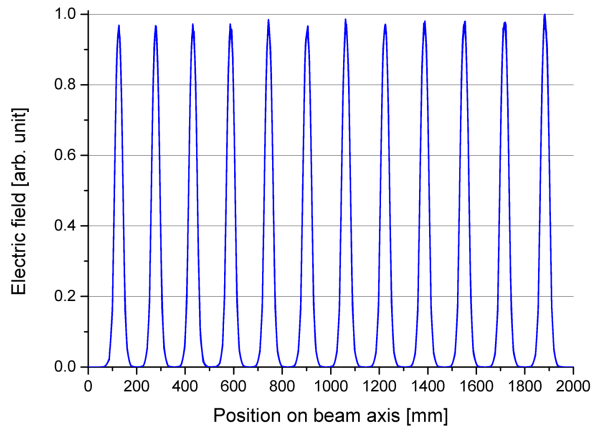

Figure 5: Simulated electrical field distribution on beam axis at 108.4 MHz for the Alvarez-prototype.

Mechanical Integration

For first power RF tests the drift tubes are installed from the top of the tank (Fig. 3). A total of four different stem orientation combinations per drift tube can be realized with this cavity section. However, it must be ensured that the section is accessible for installation and maintenance work. The bottom of the tank houses RF coupling and a service hole. At the center position at the side of the section two vacuum pumps (turbo- and ion getter pump) are installed. For the tanks produced in series these ports will be placed at the bottom.

The end caps of the drift tubes (Fig. 6) will have a new shape profile [3]. To build these end caps with the required precision is more demanding w.r.t. the more simple shape used today. However, for the scaled model they were successfully machined. For the full size section the single parts comprising the drift tubes have to be welded under preservation of the shape. In the drift tube casing a water cooling system is implemented along the cylindrical shell surface.

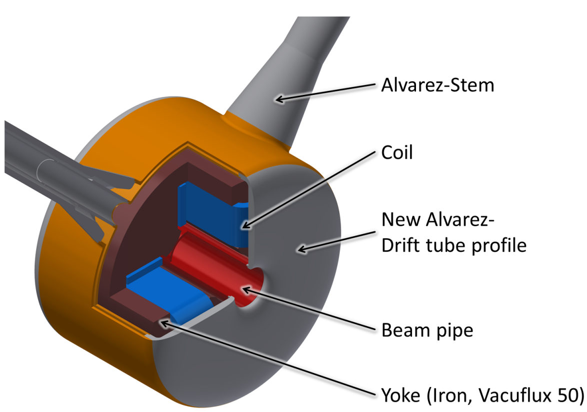

Figure 6: CAD-model of the drift tube with the new shape profile and an integrated quadrupole singlet. The first and shortest drift tube has a total length of 111.3 mm, an aperture of 30 mm, and its diameter is 180 mm.

The electric current and water supply for the magnet are integrated in just one stem but both stems are water cooled. After low level RF-tuning all components will be copper plated at GSI, followed by high power RF-testing.

Each drift tube contains a single quadrupole magnet with an integrated gradient of 5 T, operated with a repetition rate of up to 10 Hz with a flat top duration of up to 1 ms and a ramp time of 25 ms. However, the maximum applicable duty cycle depends on the rigidity of the delivered ion beam, i.e. for uranium it will be lower than for argon, for instance. The single-layered coils will have a water-cooled copper conductor (∅5 mm) with an individual cooling circuit (without a solder connection).

OUTLOOK

In this design study an Alvarez-type cavity section was investigated concerning RF-simulations and mechanical layout. Tendering of the cavity mantle and the end plates shall start in summer, followed by copper plating in early 2018. High power tests are currently planned for 2020.

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