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LLRF MEASUREMENTS AND Cu-PLATING AT THE FIRST-OF-SERIES CAVITY SECTION OF THE ALVAREZ 2.0 AT GSI

M. Heilmann*, T. Dettinger, X. Du, L. Groening, S. Mickat, A. Rubin
GSI Helmholtz Centre for Heavy Ion Research, 64291 Darmstadt, Germany

Abstract

The Alvarez 2.0 will replace the existing post-stripper DTL of the GSI UNILAC. Today's GSI comprises the UNILAC and the synchrotron SIS18 and is going to serve as the injector chain for the Facility of Antiproton and Ion Research (FAIR). The new Alvarez-type DTL is operated at 108.4 MHz providing acceleration from 1.4 MeV/u to 11.4 MeV/u along a total length of 55 meters. The First-of-Series (FoS) cavity section has 12 RF-gaps along a total length of 1.9 m. It is the first cavity section of the new DTL. All main components were delivered in 2019, followed by successful SAT and installation of the 11 drift tubes and copper-plating. Completion of first low level RF-measurements prior to copper plating and the subsequent plating are major project milestones. These proceedings report on the results and compares them to simulation using CST Microwave Studio.

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

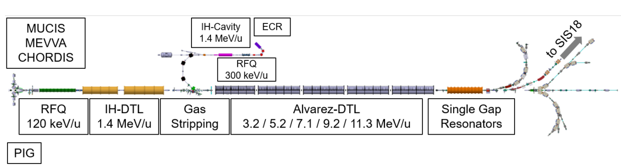

Figure 1: Schematic overview of the new GSI UNILAC.

beams (protons 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 more than 40 years and the repair efforts increase noticeably. In terms of high beam intensities, quality and high availability, an update of the UNILAC for the upcoming FAIR project 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) [3,4]. The copper plated First-of-Series (FoS) Alvarez-Cavity [5] can be used as the first section of the first tank for the new injector. The Alvarez 2.0 DTL will have five individual cavities with identical intertank sections.

* manuel.heilmann@email.de

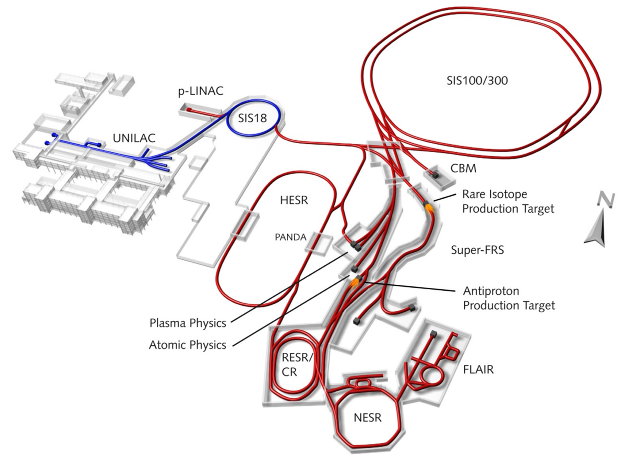

Figure 2: Schematic overview of FAIR.

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 – 11.3
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 CAVITY SECTION

The First-of-Series cavity section (Table 2) [6] is the first tank part of the Alvarez 2.0 in the UNILAC (Fig. 3). The tank and the two end plates were fabricated and delivered at the company VA-TEC [7,8] and all other components like the empty drift tubes, static or dynamical plungers, incoupling loop and half drift tubes were fabricated internally in the GSI workshop [8]. In the half drift tubes and 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. The GSI galvanic has high experience

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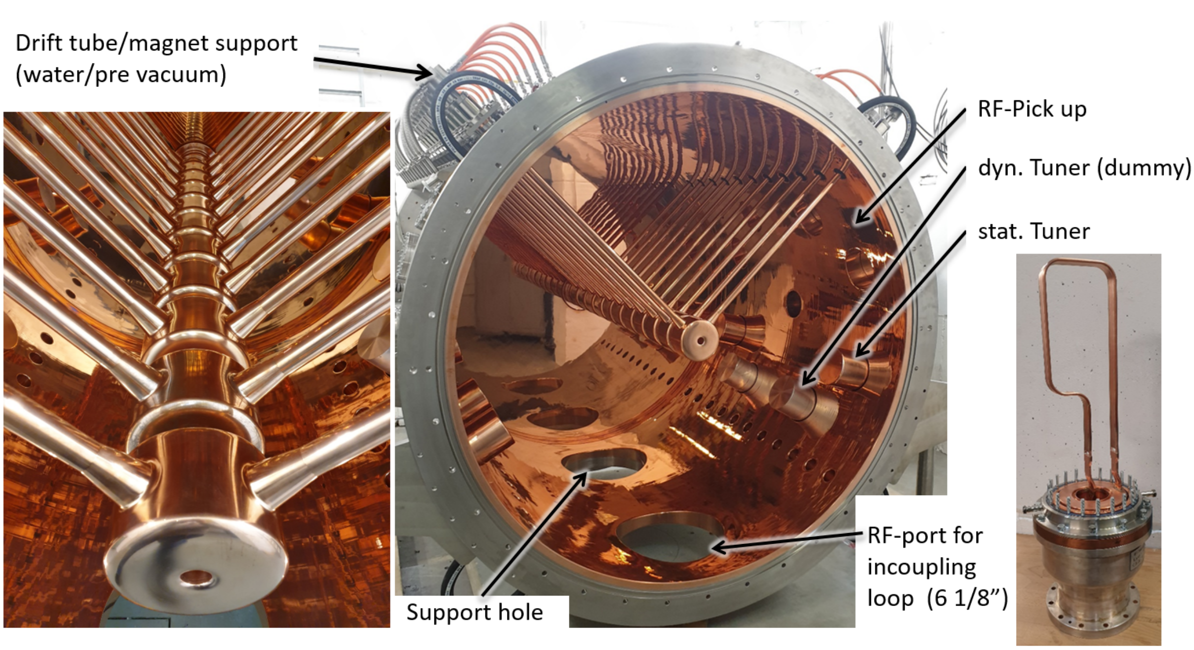

Figure 3: The copper plated FoS-Alvarez cavity section with a length of 1.9 m and 11 drift tubes. The drift tubes are installed at the top of the tank, but other combinations are possible. The bottom houses RF coupling, a support hole. Two vacuum pumps are installed from the side at the FoS cavity. (right) The new inductive incoupling loop for a 6 1/8" rigid line.

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

in copper plating accelerator tanks and other large parts like magnets with housings. It was very unfortunate that the GSI galvanic had to change the composition of the copper bath, because the manufacturer has stopped the production of an important basic ingredient. After many tests regarding copper layer thickness depending on the new liquid composition including a real sized dummy-Alvarez tank, the GSI galvanic was able to copper plate the FoS cavity successfully. All small components like the drift tubes or tuners were copper plated at the company Galvano-T [9]. The copper plating was one major milestone of that sub-project concerning the new galvanic liquids, tank size and availability of a qualified external copper plating company.

All RF-measurements presented within these proceedings were made with the uncoppered FoS-Alvarez. The Low Level RF frequency measurements were used to define the length of the static frequency tuners (Fig. 4) and compared to CST-simulations [10]. The RF-measurements of the frequency has a parallel shift at the operation frequency in compare to the RF-simulation (mesh deviation: $\pm$ 5 kHz): $\Delta f = |f_{sim} - f_{meas}|$ = 175 kHz. The investigations at an 1:3 scaled Alvarez-model already inhabited this frequency shift [11], and the assumption made at that time of approximately three static tuners per meter to compensate the differences of the frequency between simulation and re-

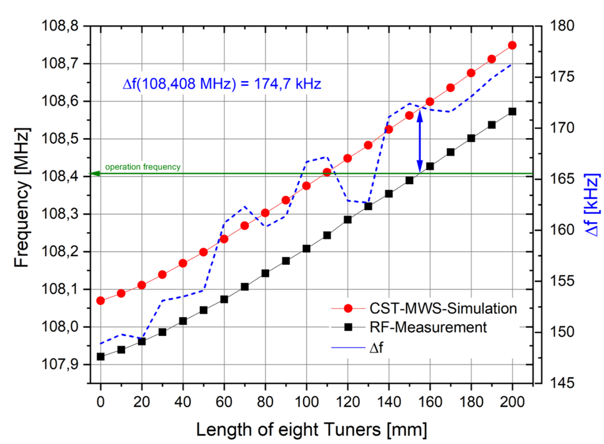

Figure 4: Simulated and measured frequency of the FoS-Alvarez depending on the position of the plungers (RF-measurement: uncoppered cavity). (blue) Frequency difference between simulation and measurements.

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ality, agree very well to the measurement at the FoS-Alvarez. Detailed investigations of the frequency range of the different plungers for the FoS-Alvarez are described in [5]. The two dynamic plungers will be moved with linear actuators of Pfeiffer Vacuum [12] to change the frequency in operation in a range of $\pm$ 50 kHz and this adjustable frequency is within the linear range. The optimized incoupling loop has an S11-parameter of -35 dB at the operation frequency and is at an angle of about 45 degree in the electric field. The voltage distribution on the beam axis (Fig. 5) from the

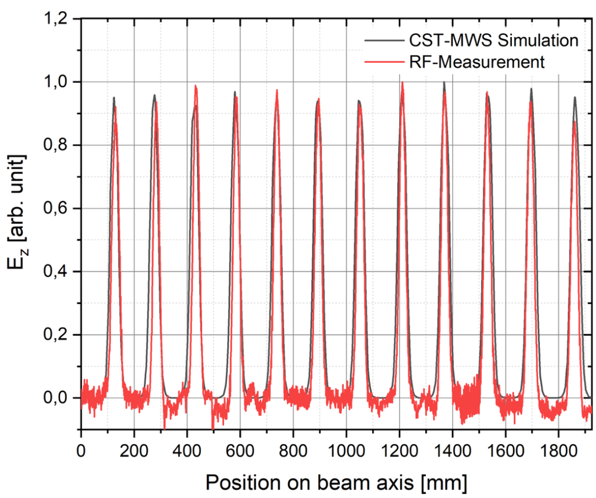

Figure 5: Simulated and measured electric field distribution on the beam axis of the FoS-Alvarez (RF-measurement: uncoppered cavity).

bead pull measurements fits with a minimal deviation to the CST-MWS simulation. The length of the cavity increases the sag of the nylon cord and the nylon cord must be corrected very often. A digital push pull gauge sensor will be used to have a comparably tensioned nylon cord for bead pull measurements at the Alvarez 2.0 series because of cavity lengths of more than 10 m.

After time-consuming mounting and a challenging adjustment of the drift tubes including the water and pre-vacuum support of the empty drift tubes, the currently vacuum tests are ongoing and then the high power RF tests are scheduled for Q3 of this year. A new 6 1/8" rigid line between the RF gallery and the test cave is already installed. The THALES 1.8 MW RF cavity amplifier for low duty-cycle operation (2 ms RF pulse length at 10 Hz repetition rate) [13, 14] is already an upgraded amplifier and in beam time operation. The RF-conditioning and high power tests with the FoS-Alvarez will use this THALES amplifier. The designed electrical field is reached with a RF-pulse power of 300 kW.

OUTLOOK

In parallel to the ongoing preparations of the high power testing, the tendering procedure of the cavity series production has been launched. The call comprises the 25 cavity sections and the 10 cavity endplates. It is aimed to merge the two project milestones "FoS successfully power tested" and "placing series order" at the beginning of next year. Additionally, many standard small parts will be procured within this year as plungers, bellows, flanges, etc. Their tendering is anticipated since copper plating is a critical path of the project. GSI's plating workshop will be fully booked by the Alvarez 2.0 large components. Hence the copper plating timeline shall be de-stressed by timely procurement and external plating of the numerous standard series components. In parallel, the production of drift tubes with internal quadrupole singlets is studied, and the SAT of the prototype is expected this summer. In anticipation of its success, the tendering for the first two corresponding magnet power supply units (for 15 quadrupoles) has been started as well.

REFERENCES

[1] P. J. Spiller *et al.*, "Status of the FAIR Project", in *Proc. 9th Int. Particle Accelerator Conf. (IPAC'18)*, Vancouver, Canada, Apr.-May 2018, pp. 63–68. doi:10.18429/JACoW-IPAC2018-MOZGBF2

[2] A. Rubin, X. Du, L. Groening, M. Kaiser, and S. Mickat, "Status of the Beam Dynamics Design of the New Post-Stripper DTL for GSI-FAIR", in *Proc. 8th Int. Particle Accelerator Conf. (IPAC'17)*, Copenhagen, Denmark, May 2017, pp. 4414–4416. doi:10.18429/JACoW-IPAC2017-THPVA003

[3] X. Du, L. Groening, O. Kester, S. Mickat, and A. Seibel, "Field stabilization of Alvarez-type cavities", *Phys. Rev. Accel. Beams*, vol. 20, no. 3, pp. 032001, Mar. 2017. doi:10.1103/PhysRevAccelBeams.20.032001

[4] X. Du, L. Groening, S. Mickat, and A. Seibel, "Alvarez DTL Cavity Design for the UNLAC Upgrade", in *Proc. 6th Int. Particle Accelerator Conf. (IPAC'15)*, Richmond, VA, USA, May 2015, pp. 2786–2788. doi:10.18429/JACoW-IPAC2015-WEPMA017

[5] M. Heilmann *et al.*, "Final Design of the FoS Alvarez-Cavity-Section for the Upgraded UNILAC", in *Proc. 9th Int. Particle Accelerator Conf. (IPAC'18)*, Vancouver, Canada, Apr.-May 2018, pp. 920–923. doi:10.18429/JACoW-IPAC2018-TUPAF080

[6] M. Mickat *et al.*, "Concept towards a new Alvarez type post-stripper DTL for the UNILAC", Technical Note, Internal Report, Dec. 2017.

[7] VA-TEC GmbH & Co KG, http://www.va-tec.de/

[8] M. Heilmann *et al.*, "FoS Cavity of the Alvarez 2.0 DTL as FAIR Injector", in *Proc. 10th Int. Particle Accelerator Conf. (IPAC'19)*, Melbourne, Australia, May 2019, pp. 871–874. doi:10.18429/JACoW-IPAC2019-MOPTS015

[9] Galvano-T electroforming-plating GmbH, https://galvano-t.com/

[10] Dassault Systemes Deutschland GmbH, https://www.3ds.com/simulia

[11] M. Heilmann *et al.*, "Scaled Alvarez-Cavity Model Investigations for the UNILAC Upgrade", in *Proc. 9th Int. Particle Accelerator Conf. (IPAC'18)*, Vancouver, Canada, Apr.-May 2018, pp. 916–919. doi:10.18429/JACoW-IPAC2018-TUPAF079

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB208

[12] Pfeiffer Vacuum GmbH, https://www.pfeiffer-vacuum.com/

[13] B. Schlitt *et al.*, "Modernisation of the 108 MHz RF Systems at the GSI UNILAC", in *Proc. 28th Linear Accelerator Conf. (LINAC'16)*, East Lansing, MI, USA, Sep. 2016, pp. 898–901. doi:10.18429/JACoW-LINAC2016-THPLR025

[14] Thales Electron Devices S.A., https://www.thalesgroup.com/