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UPDATE ON THE INTENSE HEAVY ION DTL PROJECT ALVAREZ 2.0 AT GSI

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Abstract

The Alvarez-type post-stripper DTL at GSI accelerates intense ion beams with A/q≤8.5 from 1.4 to 11.4 MeV/u. After more than 45 years of operation, it suffers from aging and its design does not meet the requirements of the upcoming FAIR project. Prototyping of a new 108 MHz Alvarez-type DTL has been completed and series components for the 55 m long DTL are under production and have been delivered partially. This report summarizes the actual status of Alvarez 2.0 at GSI and sketches the future path to completion.

INTRODUCTION

Like the current DTL, the new section will accelerate ions up to the injection energy of the subsequent synchrotron SIS18. All species up to the mass-to-charge ratio of A/q=8.5 are accelerated, corresponding to FAIR's reference ion of $^{238}U^{28+}$ [1]. Five cavities with lengths of about 11 m each are operated at 108.4 MHz with peak powers of up to 1.35 MW including beam loading. Figure 1 plots the new DTL together with some RF-design details of the first cavity. The normal conducting DTL covers a beam repetition rate of up to 10 Hz with flat top RF-pulse length of up to 1.0 ms corresponding to the beam pulse length. Within

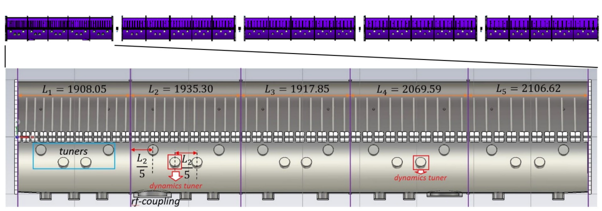

Figure 1: New post-stripper DTL Alvarez 2.0 under construction at GSI.

the cavities, transverse FDDF focusing is provided with a zero current phase advance of 65°. The large intensities cause transverse tune depressions of up to 40% along the first cavity [2]. Longitudinal focusing is from RF-phases of −30° along the first three cavities and −25° along the last two ones. Cavities are separated by four identical inter-tank sections [2] which serve for 3D beam envelope matching by three quadrupoles and one re-buncher. The inter-tank sections provide also for a beam current and phase probe, a sector valve, and a transverse beam profile measurement set-up.

Although the machine is mainly designed as an injector for the synchrotron SIS18, several low-energy experiments shall be served as well. The DTL design allows for switching off the RF-power of the last cavities while the transversely focusing quadrupoles inside the drift tubes remain switched on. Accordingly, the DTL output energies correspond to the individual cavity exit energies of 3.212, 5.173, 7.142, 9.237, and 11.318 MeV/u. The quadrupoles are pulsed, such that focusing can be adapted individually to each ion species and design energy; the latter can be changed between the individual DTL pulses, i.e., within less than 100 ms. The DTL design is described in detail within the dedicated Technical Design Report [3] and the main design parameters are listed in Table 1.

Table 1: Main Design Parameters of GSI's New Post-Stripper DTL Alvarez 2.0 [3]

Parameter	Value
Ion A/q	≤ 8.5 ($^{238}U^{28+}$)
Input beam energy	1.358 MeV/u
Output beam energy	3.212 −11.318 MeV/u
Electrical beam current	1.76 emA· A/q
Transv. tune depression	≤ 40 %
Beam pulse duration	0.2 −1.0 ms
Beam repetition rate	≤ 10 Hz
Number of cavities	5
RF-frequency	108.408 MHz
Max. RF-power per cavity	1.35 MW
RF-sources per cavity	1
Transv. focusing scheme	FDDF
Total length	55 m

PRODUCTION OF CAVITIES

Each of the five cavities comprises five cavity sections from stainless steel. The mantle has a strength of 12 mm. Its roundness with a tolerance of the average radius of −0/+0.3 mm has been achieved by rolling without milling as well as the tolerance in length of ±0.1 mm. The mantle is equipped with external cooling channels. Of special concern is the high quality of the inner surfaces for subsequent bright Cu-plating. The surface must be free of voids and its roughness R_a must not exceed 0.3 µm. Production has been started in summer 2022 at one single manufacturer (see Fig. 2), after successful testing of a fully RF-operated FoS cavity section [4]. Effective duration of production is about seven weeks per section, including also the 5×2 cavity end plates. The sections of the first cavity have been delivered in spring 2024 and those of the second cavity in

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summer. Delivery of the last five sections is expected for fall 2025.

Figure 2: Production of cavity sections and end plates at VA-TEC, Germany.

CU-PLATING OF CAVITIES

The size of one single cavity section (2 m of diameter and length) as well as its weight of about three tons, impose unique challenges to the plating process. To our knowledge, GSI's on-site galvanic work shop is the only one world wide that can deal with such dimensions and requirements. A FoS section has been plated successfully in 2021. Since then the work shop underwent a rigorous modernization, followed by re-commissioning and re-acquiring authorities' approval in summer 2024. The later required successful plating of a dummy section with each dimension exceeding the maximum of the later series plating. Figure 3 shows the finalization of the plating process of this dummy section, i.e, final water rinsing. After this important milestone, plating of the series has just been started.

Effective duration of plating of one section is currently expected as about four month/section. This time is largely given by pre-processing as cleaning, masking, and placing the anodes, and to less extend by post-processing as passivation and de-masking. The actual plating process itself (Nickel-strike and Copper) lasts less that 10 hours.

DRIFT TUBES

The DTL is equipped with 177 full size drift tubes and 10 half size drift tubes. Each of them (except the first half tube) is equipped with a single e.m. pulsed quadrupole [5]. The tubes have individual lengths and the magnets are grouped into seven families. The small size and the pulsed operation require notable production efforts w.r.t. placing, aligning, and fixing the quadrupole inside of the drift tube mantle. The pulsed operation causes considerable forces especially onto the current leads inside of the stems. The leads, stems, and the drift tube mantle are water cooled, while the drift tube end caps are left without enforced cooling, being possible because of the low RF-duty cycle of just 2%.

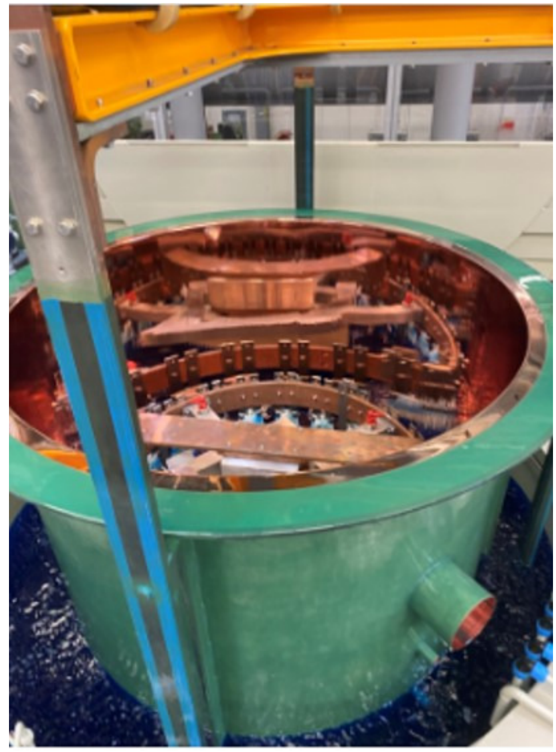

Figure 3: Full-size dummy cavity just after Cu-plating at GSI's on-site galvanic work shop.

A first prototype of the shortest full size tube (123 mm in length) has been successfully built and tested without beam but at nominal pulsed current. Series production of the 40 full size tubes of the second cavity has been started recently at the same manufacturer (DANFYSIK, Denmark). A second prototype represents the longest tube (319 mm in length). It is currently built at another manufacturer (RI, Germany together with SCANDITRONIX, Sweden). It is shown in Fig. 4 and is expected to be delivered and tested at the end of this year. Spares are included such that for each magnet family, two spare tubes (with additional length) are included into the series production. Series production shall last until spring 2027.

GSI's plating work shop is fully loaded with plating of the cavity sections. Eleven full size drift tubes w/o internal quadrupoles have been plated at an commercial work shop (GALVANO-T, Germany) and one example is depicted in Fig. 5. Concerning the series, full size drift tubes will be plated at CERN's plating facility. For this purpose, it will be equipped with a dedicated area, comprising five basins, which is currently under construction externally. It shall be commissioned this winter and series plating is expected to start in spring 2025 and to last up to fall 2027. The ten half drift tubes will be plated at an commercial work shop.

ADD-ON PARTS

Especially the cavities are equipped with a manifold of various add-on parts as plungers, RF-coupling loops, media connectors, stem alignment supports, bellows etc. Some

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Figure 4: Winding of coil for the prototype of the longest drift tube internal quadrupole at SCANDITRONIX, Sweden.

Figure 5: Drift tube and two stems after copper plating at an external galvanic work shop (GALVANO-T, Germany).

examples are shown in Fig. 6. Several of these pieces have already been delivered, others have been ordered recently. A major fraction w. r. t. production efforts is given by the 180 statical tuners and the 20 dynamical tuners [6]. The static ones are currently produced on-site with intended overlength each. Their final length is to be determined during the cavity tuning process, once the drift tubes have been installed. After imposing their length, they will by Cu-plated at a commercial work shop. Prototypes for actuators of the dynamic tuners have been successfully operated and one FoS device with some improvements has been ordered in spring.

Figure 6: Examples for several add-on parts during production.

OUTLOOK

Current planning foresees the DTL section to be ready for installation in 2034. However, measures to move forward this milestone are under discussion, notably the augmentation of infrastructure and personnel for plating of the cavity sections. The exact date of installation will be matched to the overall progress of the commissioning of the FAIR accelerator chain [1], i.e., albeit being ready for installation, the installation might be postponed for practical reasons.

REFERENCES

[1] H. Gutbrod (Ed.), "FAIR baseline technical report volume 2: accelerator and scientific infrastructure", GSI Darmstadt, Germany, Rep. GSI-2013-04791, p. 12, Mar. 2006.

[2] A. Rubin, L. Groening, and I. Hofmann, "Simulation study of a high-intensity linear accelerator operated at longitudinal phase advances above 90°", *Phys. Rev. Accel. Beams*, vol. 23, p. 124202, 2020. `doi:10.1103/PhysRevAccelBeams.23.124202`

[3] L. Groening *et al.*, "Technical design report of the Alvarez 2.0 post-stripper DTL (V13b) for the UNILAC", GSI internal report, 2021.

[4] M. Heilmann *et al.*, "RF Commissioning of the first-of-series cavity section of the Alvarez 2.0 at GSI", in *Proc. 31st Linear Accelerator Conf. (LINAC'22)*, Liverpool, UK, Aug. 2022, pp. 106–109. `doi:10.18429/JACoW-LINAC2022-MOPOPA17`

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

[6] C. Xiao, X. N. Du, L. Groening, M. Heilmann, and S. Mickat, "Investigation of impact of Alvarez-type cavity RF-field tuning on final beam quality using a longitudinal tracking method", *Nucl. Instrum. Methods Phys. Res. Sect. A*, vol. 1027, p. 166295, 2022. `doi.org/10.1016/j.nima.2021.166295`