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STATUS OF THE PULSED HYDROGEN GAS STRIPPER AT GSI

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Abstract

The operation of the specifically upgraded pulsed gas stripper development setup for the user beamtime started in 2024 and is in use since. It is very successful in terms of both, providing stripped ions and gaining valuable experience in the long-term operation of the pulsed stripper. The long periods of high duty nitrogen operation revealed a severe service life time issue of the fast injection valves, which was already anticipated in the risk assessment for the hydrogen operation. This emphasizes the need for the safety measures incorporated in the design of the pulsed stripper facility. During the user beamtime, several measurement campaigns were conducted. Extensive data on the stripping efficiencies for 12 projectile-target combinations could be obtained. In this contribution, the obtained results and lessons learned are presented as well as the necessary next steps to finally bring the hydrogen stripping to routine operation.

GSI UNILAC GAS STRIPPER

The GSI UNILAC (UNIversal Linear ACcelerator) shown in Fig. 1 will serve together with the heavy ion synchrotron SIS18 as a high current, heavy ion injector for the future FAIR (Facility for Antiproton and Ion Research). The ions will be provided by the high current injector HSI. A gaseous stripper, situated at the end of the HSI, is necessary to increase the low charge states of the heavy ions produced by the high current sources in order to enable further acceleration in the post-stripper DTL (Drift Tube Linac) of Alvarez type. The present stripper employs a continuous nitrogen gas jet as stripping target. Out of the charge state spectrum resulting from the stripping process, one charge state has to be separated for further acceleration. For heavy ions like uranium, this results in effective loss of up to 85% of the beam.

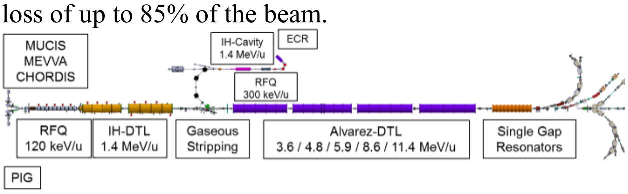

Figure 1: GSI - UNILAC with the gaseous stripping in front of the Alvarez DTL.

In order to increase the yield into the particular charge state desired, the introduction of hydrogen as stripping target was investigated from 2012 – 2016 [1,2]. With hydrogen, in comparison to nitrogen, the width of the charge state distribution is reduced for heavy ions, thereby increasing the stripping efficiency e.g. for 238U28+ by approximately 60%. Additionally, for all ions an increase of the mean charge state can be achieved. This was demonstrated successfully in 2016 and is shown in Fig. 2.

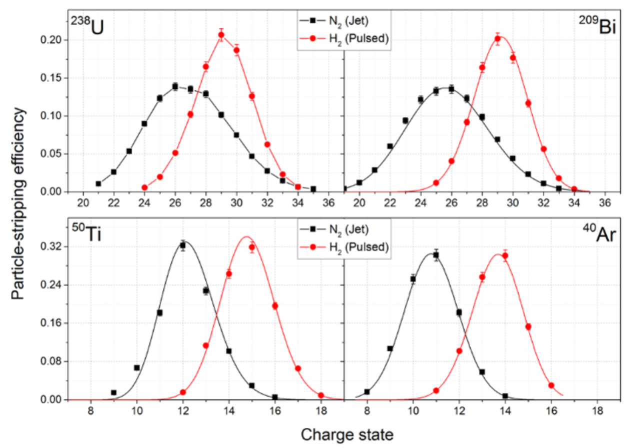

Figure 2: Comparison of the charge state distributions of different ion species using nitrogen and hydrogen as stripping gas [3].

Due to unexpected problems using the jet stripper for the beam time 2024, the pulsed stripper was requested to cover for routine operation during that beam time. This required some fast changes of the until then, experimental setup, to be fit for the beam time. The main adaption being required was to restructure the gas regulation system. It had to allow serving both installed injector valves with two different gasses and individual pressures. To cover all pressure regimes, two low pressure regulators have been installed especially suited for pressures bellow 1.0 bar of absolute pressure.

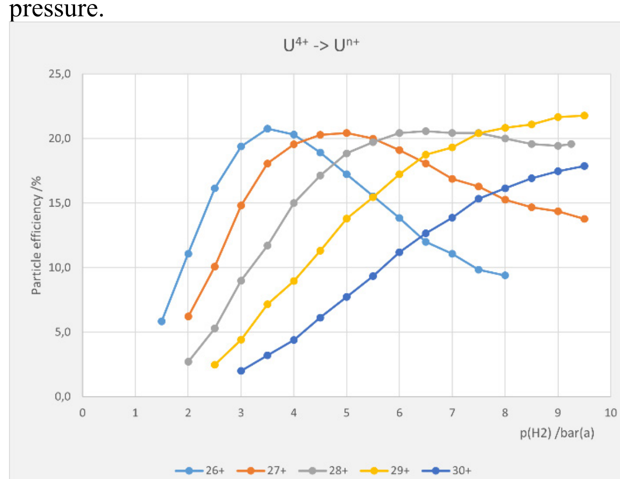

Figure 3: Stripping efficiencies of uranium beam in hydrogen gas as a function of the gas pressure.

The opportunity to test the pulsed gas stripper in routine operation led to a strong increase of knowledge about the system. To provide efficient stripping, the stripping

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efficiency for many ion target combinations was measured and documented for future runs as for example shown for U beam in Fig. 3 and Fig. 4 using hydrogen and nitrogen as stripping gas. The full list of stripping efficiencies measured with the pulsed stripper can be found in Table 1.

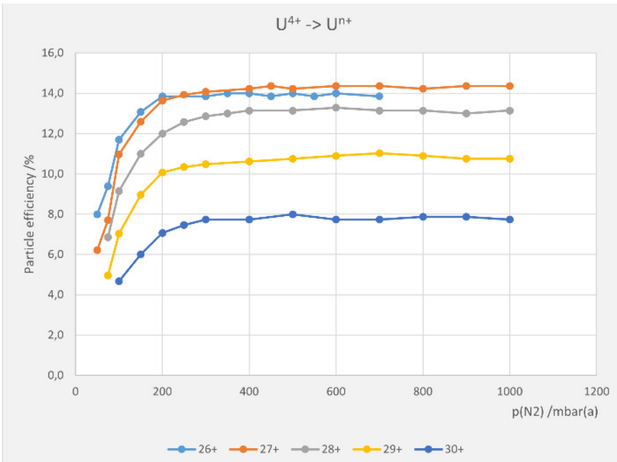

Figure 4: Stripping efficiencies of uranium beam in nitrogen gas as a function of the gas pressure.

Table 1: Measured Stripping Efficiencies Using the Pulsed Gas Stripper Setup During the Beam Times 2024 and 2025

Element	Beam Time	Charge States
^{6}C	2025 (CH_4)	2 - 6
$^{8}O_2$	2024	5 - 8
^{18}Ar	2024	9 - 12
^{22}Ti	2024	12 - 13
^{24}Cr	2024	12 - 14
^{26}Fe	2024	11 - 15
^{28}Ni	2024	14
^{36}Kr	2025	15 - 18
^{42}Mo	2024	16 - 20
^{47}Ag	2025	17 - 22
^{68}Er	2024	21 - 25
^{79}Au	2025	24 - 28
^{82}Pb	2025	24 - 28
^{83}Bi	2025	23 - 28
^{92}U	2024	26 - 30

On the other hand, there were also many lessons learnt about the deficits of the system. During the beam time, for the explosion safe roots blower pump a more than expected consumption of oil of the floating ring seal has been observed. Several operation parameters have been applied to the roots pump station in order to determine their impact on the consumption and an oil dump has been installed to drain the excessive floating ring seal oil of the pump bearing. In the end the oil consumption increased further and the floating ring seal had to be exchanged in February 25.

As the first contact to industry for a gas control station revealed worries about stable pressure regulation in our pulsed operation scheme, it was decided to facilitate the tendering process for the gas control station. Electronic pressure regulators shown in Fig. 5 were purchased, installed and successfully tested. These electronic pressure controllers are routinely used in the running beam time 2025 and thus this uncertainty is removed for the bidders.

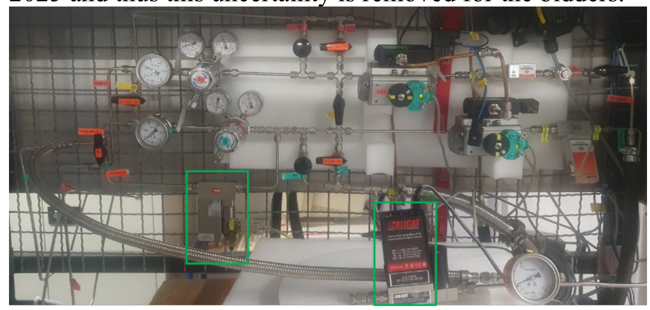

Figure 5: Photo of the gas control station with the two electronic pressure controllers that were successfully tested during the beam time.

To address the observed lifetime issue of the valves as well as the complication to guaranty stable operation with the very low pressures well below atmospheric pressure, required for nitrogen stripping, reduced orifice valves shown in Fig. 6 were constructed and tested. This orifice reduction allows for a forward pressure increase of about a factor 5 without any observable negative effect on the stripping efficiency as shown in Fig. 7.

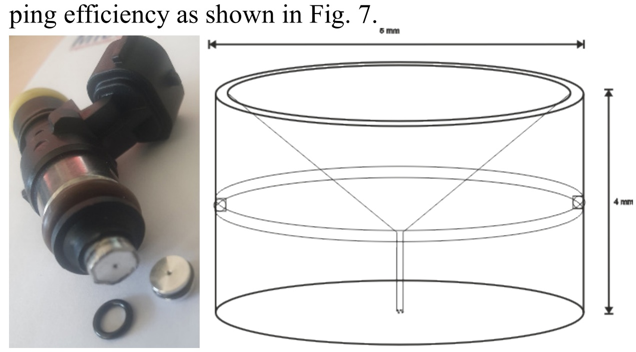

Figure 6: Picture (left) and drawing (right) of the tested valve orifice reduction. With an effective pinhole of 0.6 mm a factor 5 in forward pressure was reached.

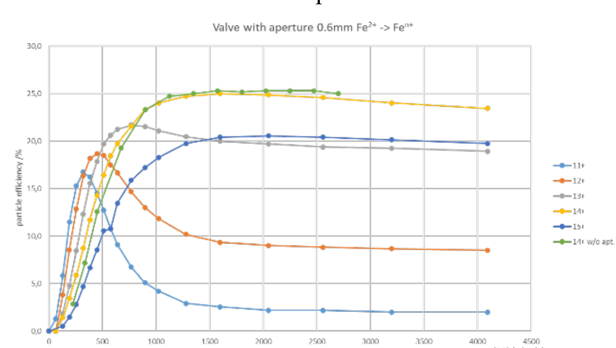

Figure 7: Stripping efficiencies for iron beam with nitrogen as stripper gas comparing the valve types with and without reduction aperture.

This will facilitate the pressure control and hopefully also increase the valve lifetime, as they are built to operate in the few bar regime and are not suited for vacuum applications. They might need the damping and cooling of the gas to reach their nominal lifetime.

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OUTLOOK

Besides full beam time coverage in 2025 using the pulsed stripper setup, it is necessary to proceed towards routine operation within the GSI control system allowing for full hydrogen coverage of the beam time. On the way to full hydrogen operation of the stripper, all measures defined in the risk assessment need to be implemented. To achieve this, various steps were taken. As the risk assessment defines a number of reliable pressure measuring points, the possible candidates of pressure sensors are installed in the accelerator and tested concerning their reliability.

A vacuum exhaust mixing chamber, to render the hydrogen inert and safely channel it through the regular GSI vacuum exhaust line, is needed. Simulations of such a mixing chamber are in progress and a practical solution is expected by autumn 2025. The preliminary simulation result of a first version of the mixing chamber is shown in Fig. 8. In this worst-case scenario of a not closing valve failure, the hydrogen concentration at the exit of the mixing chamber stays below the required 2% of the lower explosion limit.

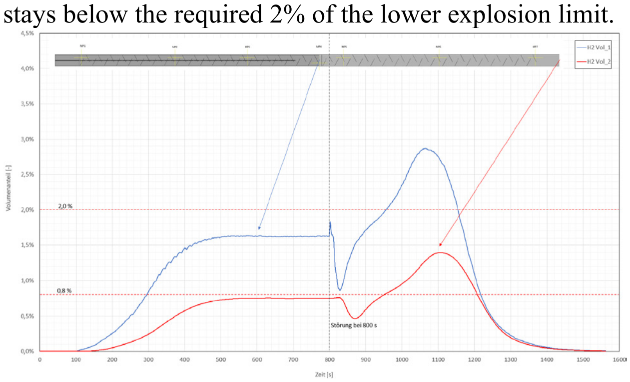

Figure 8: Time dependent hydrogen concentration at two monitor points along the mixing chamber for a worst-case scenario.

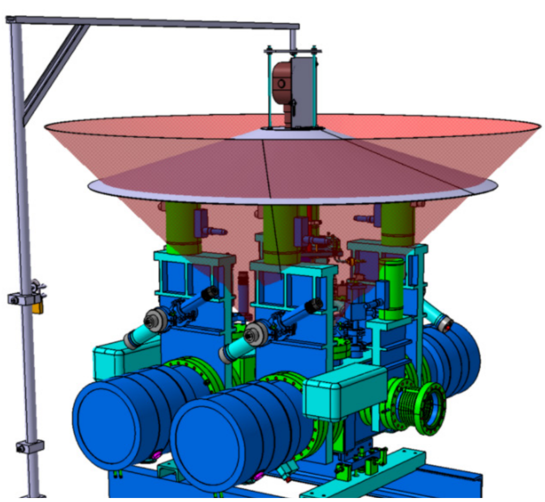

Figure 9: Gas warning hat above the stripper vacuum chamber with a warning sensor at the highest point in the center. The red cone is the expected expansion cone of leaking hydrogen from the stripper vacuum chamber.

All foreseen gas warning sensors have been installed and are in use already, although their final place of action is still under construction. Like for example the gas warning hat above the stripper setup to collect the hydrogen in case of a small leakage and guide it toward a warning sensor in its center as shown in Fig. 9. This is ready for installation, just waiting for the upcoming shutdown to be installed.

The stripper setup itself will get an upgrade from the actual V-shape stripper, hosting two valves, to a X-shape configuration hosting four valves as shown in Fig. 10. This will increase the flexibility of offered stripper settings for the users, as well as the service lifetime of the pulsed gas stripper.

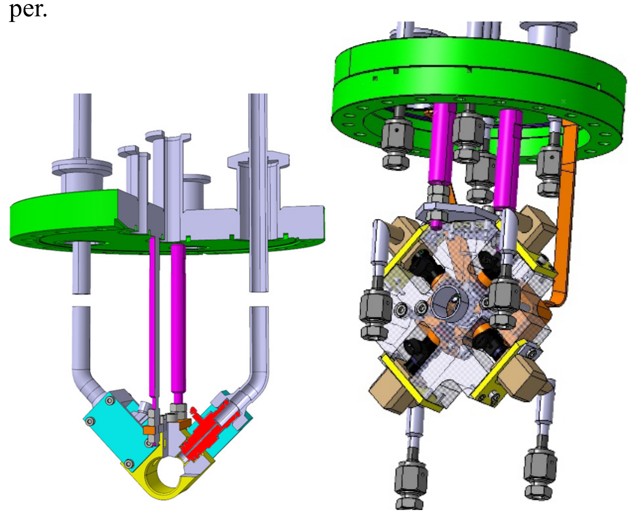

Figure 10: V-shape gas stripper hosting two valves, as used in the current beam times (left) and the planed X-shaped Stripper setup hosting four valves (right).

Last but not least, the gas control cabinet needs to be ordered to have an intrinsically safe gas handling system that is remote controllable and connected to the GSI accelerator control and the interlock system. Contact to industry has been established the tender will be published in June 25. It is planned to have the pulsed hydrogen gas stripper fully operational by end of 2026.

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