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COMMISSIONING OF THE RFQCB AT THE ISOLDE OFFLINE 2 TARGET TEST FACILITY

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Abstract

The Offline 2 mass separator laboratory is part of the CERN-ISOLDE Offline facilities - a suite of installations required to perform essential quality control on target and ion source units before irradiation at CERN-ISOLDE. The facility is also used for offline studies as a prerequisite before conducting any beam development on-line, especially establishing systematic effects. The Offline 2 separator resembles the online CERN-ISOLDE Frontend and employs identical services such as beam instrumentation, gas system, laser ionization and the equipment control system. The facility is able to generate dc as well as bunched non-radioactive beams up to an energy of 60 keV. The ion beams can be cooled and bunched in an unmodulated RFQ. In order to study effects of the RFQ buffer gas on the formation of molecular species, a dedicated identification setup is required.
This work presents the current status of the commissioning of RFQ and results of its first operation. Furthermore, we show the first results of beam emittance measurements, which are compared to 3D beam dynamic simulations. We present the ongoing installation of a MagneToF ion and Wien filter behind the RFQ, respectively.

INTRODUCTION

At the on-line RIB facility CERN ISOLDE (Isotope Separator On-Line DEvice) [1] beam time for machine development (MD) is very limited. For quality control of targets and ion source units the Offline 1 facility has been established. MD time is in competition between beam delivery at ISOLDE and target production at Offline 1. Without interrupting beam time shifts the targets and new equipment can be tested offline. The newly built Offline 2 facility [2] aims to resemble the on-line facility in order to have an equivalent testing environment - specifically in respect of the Frontend and the RFQcb (Isolde Cooler ISCOOL [3–6]. Without the drawbacks of radiation and demanding on-line beam times, any new developments are supposed to be realised and tested offline prior to implementing at ISOLDE on-line. Offline 2 will facilitate systematic studies for new targets and ion source developments including Resonance Ionization Laser Ion Source (RILIS) [7], the research of molecular beams [8], as well as technical projects as HV switching and gating studies on the RFQcb. In addition, both the Frontend and the RFQcb serve as a test bench for any modifications and as spare parts for the on-line facility.

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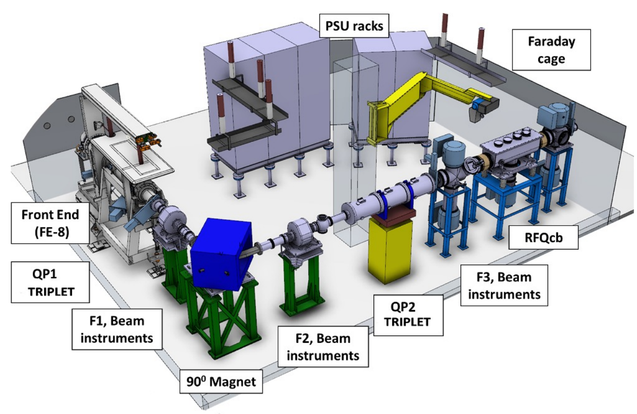

Figure 1: Digital Mockup of the Offline 2 facility [9].

BEAMLINE SIMULATIONS

The layout of the Offline 2 facility is shown in Fig. 1. The target including the ion source is mounted on the Frontend and kept on HV up to 60 kV which in return determines the ion energy. The Frontend contains an electrostatic quadrupole triplet as well as a double x/y steerer. In the first section after the Frontend, a Allison-type scanner [10] has been installed to verify the emittance after extraction of the target (Fig. 2). A 90° dipole with a resolution of $R \approx 500$ and a radius of ρ 373.5 mm is embedded between two diagnostic sections at the horizontal focal points consisting of wire scanners and faraday cups. Besides the magnet's focusing effect in the horizontal plane into a slit located at the focal point, the dipole edges have a

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vertical focusing effect due to positive end angles of α 28.2°. A second quadrupole triplet after the dipole is used to focus the beam into the Radiofrequency Quadrupole Cooler-Buncher (RFQcb). The detector beam line downstream the RFQ is currently in the design phase. It will consist of beam diagnostics (faraday cup + wire scanner), a Wien filter, an Einzel lens and a single ion detector (MagneToF). In order to

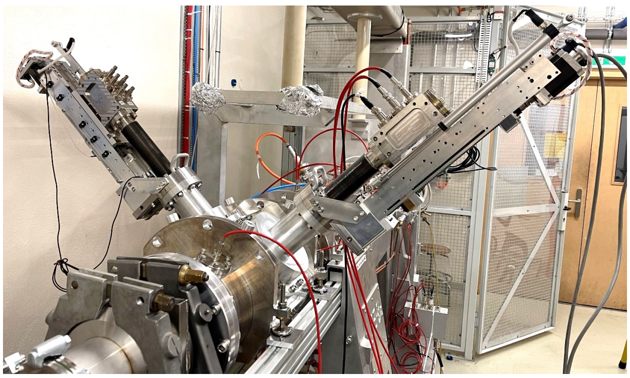

Figure 2: Allison type emittance meter installed at Offline 2.

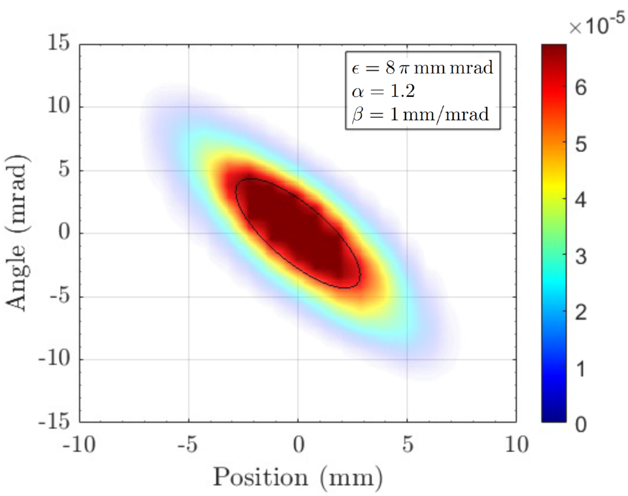

Figure 3: Emittance measurement at Offline 2. The ellipse is $1-\sigma$ RMS unnormalized with an unnorm. emittance of 8 π mm mrad at a beam energy of 30 keV.

find a suitable beam dynamics solution the following constraints have to be considered: to increase mass separation, a slit with a width of 4 mm is integrated at the second focal point (F2) 624 mm behind the dipole. The RFQ has an entrance aperture of 4 mm. Therefore, the quadrupoles have to be adjusted in both horizontal and vertical planes, to focus the beam into the RFQ. The beamline simulations are calculated with the PIC code Tracewin [11] including space charge (linear force on R matrix). The input beam is a cw ^{40}Ar with a transverse norm. RMS emittance of 0.01 π mm mrad and a current of 1 µA. The Twiss parameters have been adjusted according to the worst assumption of a beam fitting through the extraction electrode of the ion source being defocused [12]. The emittance has been measured and confirmed after the first quadrupole triplet (Fig. 3). The results of the optics simulation are shown in Fig. 4.

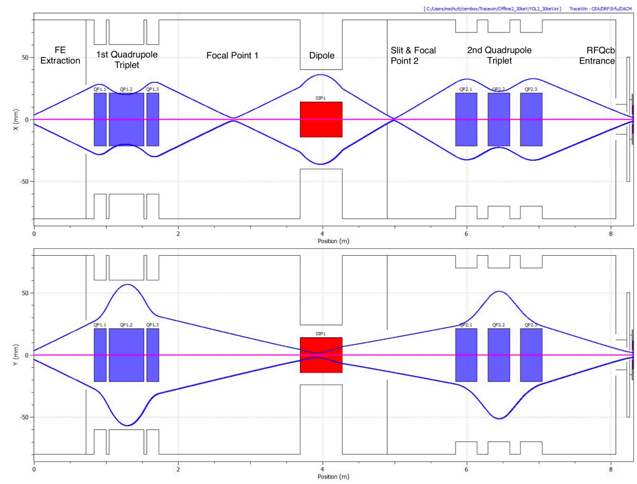

Figure 4: Beamline envelopes in the horizontal and vertical plane of the Offline 2 facility from the ion extraction electrode to the entrance of the RFQ.

RFQCB AND DETECTOR BEAM LINE

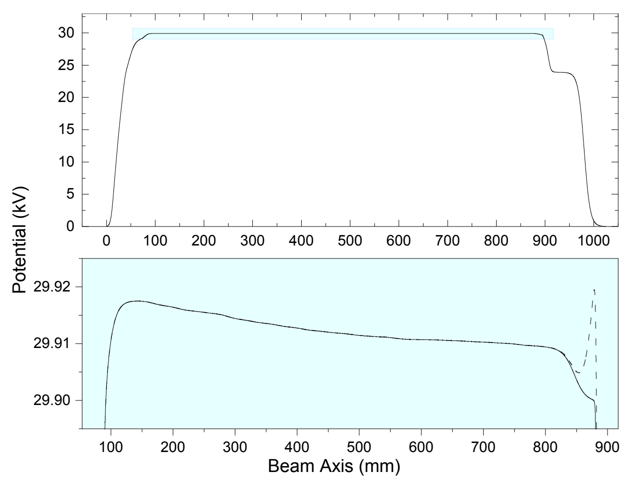

Figure 5: Longitudinal DC potential along the full RFQcb beam axis in transmission mode (solid) and bunching mode (dashed). The graph below shows a zoom on the inner ramped DC field where the RF field is present.

The whole RFQ is lifted to the HV potential of the Frontend minus a small voltage difference of up to ≈ 200 V max. The entrance acts as an Einzel lens and the ions are decelerated drifting with an energy of the chosen voltage difference through the RF fields. The inner aperture of the RFQ is filled with a buffer

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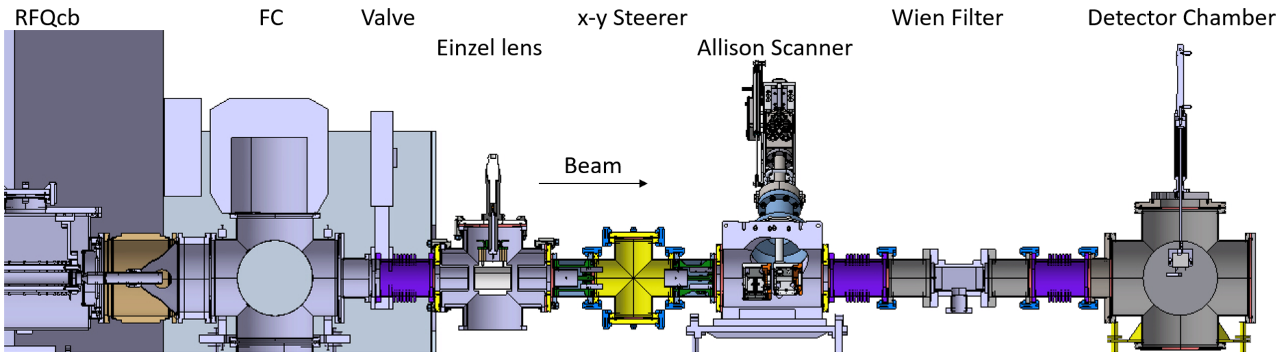

Figure 6: Cut view of the new detector beam line downstream the RFQcb.

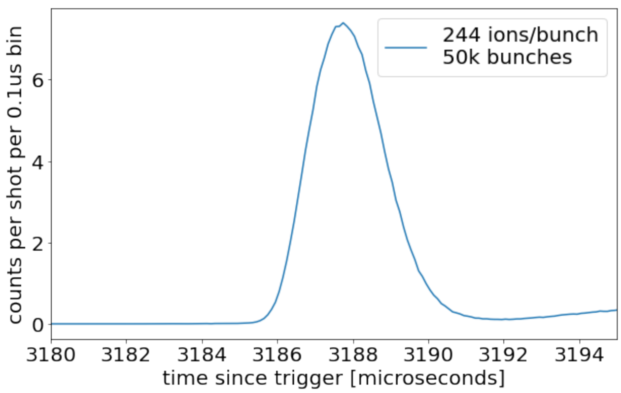

Figure 7: MagneToF single ion count bunch length measurement of the ISOLDE ISCOOL RFQcb.

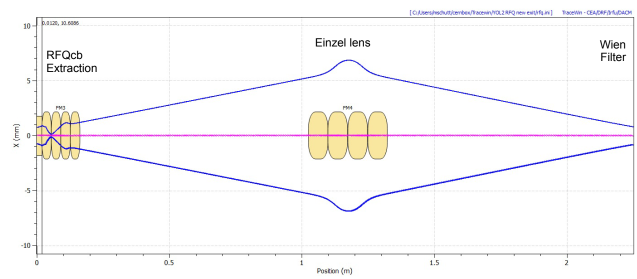

Figure 8: Envelope in the transverse plane of the beam transport simulation from extraction of the RFQcb, re-acceleration of the bunches, the Einzel lens up to the entrance of the Wien filter.

gas (He) to reduce transverse momentum and emittance [13–16]. The longitudinal potential along the beam axis is shown in Fig. 5. At the entrance the potential rises to the energy of the particle and is slightly ramped from 80 V to 0 V at the end of the RFQcb. To transversely confine the ions the longitudinal DC potential is overlayed with a quadrupole RF field [17]. The ions are gathered at the end of the quadrupole channel with the exact timing of extraction being controlled by the extraction plate potential. It can be switched between a positive potential for trapping the ions and ground for the extraction of short pulsed bunches (Fig. 7), respectively. The extraction electrodes reaccelerate the bunches to the corresponding HV having the effect of an Einzel lens. The extraction out of the RFQ and through the detector beam line (Fig. 6) has been simulated in Tracewin. The corresponding beam envelope is shown in Fig. 8. In order to be able to focus into the Wien filter with its small entrance aperture of 2 mm, an additional focusing element is required and Einzel lens is integrated after the RFQcb into the detector beam line (Fig. 6). The detector beam line will consist of a double x-y-steerer to steer the beam into the Wien filter with the possibility of emittance measurements after the RFQcb. The last element is a 6-way cross for the suspension of various detectors like a MagneToF, Faraday cup or a MCP. The suspensions for both Einzel lens drift tubes and steerer plates are designed using topology optimization and manufactured out of Ultem 9085 using 3D printing.

OUTLOOK

With the beam dynamics simulation of the Offline 2 beam line, an optimum ion optics for the beam transfer from the target to the RFQcb including entrance beam matching and could be confirmed by the emittance measurement as well as matching wire scanner measurements. The DC and RF fields of the RFQcb have been simulated being the basis for future field map PIC simulations. Offline 2 will be used for testing hv switches as a preparation for a beam switching project on-line as well as timing and gating the extraction out of the RFQcb. The parts of the detector beam line are currently in production and will be installed in mid 2023. The 3D printed parts need to be tested for their UHV compatibility.

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REFERENCES

[1] R. Catherall et al., in *J. Phys. G Nucl. Partic.*, vol. 44, pp. 094002, 2017

[2] S. Warren et al., in *Nucl. Instrum. Meth. B*, vol. 463, pp. 115-118, 2020

[3] A. Jokinen et al., in *Nucl. Instrum. Meth. B*, vol. 204, pp. 86-89, 2003

[4] I. P. Aliseda, in *Dissertation*, 2006

[5] E. Mané et. al., in *Eur. Phys. J.A.*, vol. 42, pp. 503-507, 2009

[6] C. Babcock, in *Nucl. Instrum. Meth. B*, vol. 317, pp. 484-487, 2013

[7] R. Heinke et al., in *Nucl. Instrum. Meth. B*, vol. 539, in review

[8] M. Au et al., in *Nucl. Instrum. Meth. B*, vol. 539, in review

[9] R. Moberg et al., `https://cds.cern.ch/record/2844586`, 2022

[10] P. W. Allison, J. D. Sherman, D. B. Holtkamp, in *IEEE T. Nucl. Sci.*, vol. NS-30, pp. 2204-2206, 1983

[11] D. Uriot, `https://www.dacm-logiciels.fr/tracewin`, 2023

[12] M. Schuett et al., in *Nucl. Instrum. Meth. B*, vol. 539, in review

[13] G. Savard et al., in *Phys. Letters A*, vol. 158, pp. 247-252, 1991

[14] A. Kellerbauer et al., in *Nucl. Instrum. and Meth. A*, vol. 469, pp. 276-285, 2001

[15] D. J . Douglas, J.B. French, in *J. Am. Soc. Mass Spectr.*, vol 3, pp. 398-408, 1992

[16] T. Kim, in *Dissertation*, 1997

[17] S. Warren et al., in *J. Instrum.*, vol. 16, P07058, 2021