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FIRST BEAM TRANSMISSION MEASUREMENTS IN ION SOURCE AND LEBT AT THE EUROPEAN SPALLATION SOURCE

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Abstract

The Ion Source and the Low Energy Beam Transport (LEBT) have been installed in the European Spallation Source tunnel, in Lund, Sweden, during the summer 2018. The first proton beam was extracted on September. In this paper we present the first set of measurements of protons transmission in combination with the analysis of the species (H^+, H_2^+, H_3^+) extracted by the source. We show that our measurements are compatible with a fraction of 80% of protons transported along the LEBT, as measured at the INFN-LNS, Catania, Italy during the commissioning in 2016-17 [1].

INTRODUCTION

The ESS Ion Source (ISrc) and the Low Energy Beam Transport (LEBT) section of the ESS Proton Linac was delivered to the facility of Lund, from the INFN-LNS, at the end of 2017 [2]. The mounting, connection and powering phases, including the work in the Front-end Building for the infrastructure of water, computer racks, cabling, etc., required nine months. On September 19th 2018, we were able to extract the first beam from the Ion Source.

A first important characterization of the beam quality is the transport of it from the source till the end of the installed structure. The source is Microwave Discharge Ion Source with a Magnetron that produces RF microwaves at 2.45 GHz to generate plasma from the Hydrogen (H_2) gas. The plasma is confined using three coils and the protons are extracted through a high voltage extractor at 75 kV. The following section is the LEBT with a pair of combined magnets composed by a solenoid plus two correctors, one for the horizontal plane and one for the vertical plane. The solenoids are used for the beam focusing while the steerers for the trajectory corrections. Between the two solenoids there are devices for the beam shaping: an Iris for the transversal scraping and a Chopper that will cut-off the longitudinal tails. Both devices are in the hardware commissioning phase and not used for the purpose of this paper.

MEASUREMENTS ON SEPTEMBER 2018

On September 2018 the Ion Source was turned on and we had some weeks for measurements of the beam quality. The mechanical assembly used for the transmission measurements is shown in Fig. 1. The proton beam was extracted from the Ion Source and transported through the LEBT up to the Commissioning tank, where the beam was collected by a Faraday Cup. The optics of the section is represented by two Solenoids (Solenoid 1 and Solenoid 2) adjusted for the optimal transport.

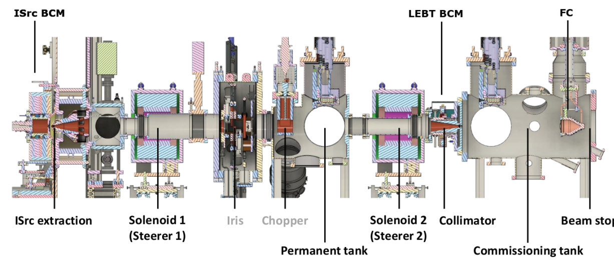

Figure 1: ESS Ion Source and LEBT Layout - September 2018.

The current measurements were performed using three devices: two Beam Current Monitors (BCM) and one Faraday Cup (FC). The first BCM is located within the source and is not on the beam line (it is before the extractor). This BCM measures the discharge current in the High Voltage Power Supply that was calibrated against the particle beams extracted from the Ion Source as explained in [3]. The second BCM is a toroid located around the beam pipe after the second solenoid. The FC was collecting the beam at the end of the LEBT, in the Commissioning tank. A full description of the beam instrumentation in the Ion Source and LEBT is in [4].

With this experimental configuration, we were able to extract an ion beam from the source and transport it along the LEBT in the three beam current measurement devices. The setup of the source was established as in INFN-LNS with little tuning, proving that the source was well reproducible even after the disassembling, transport and reassembling. The extracted beam is visible in Fig. 2.

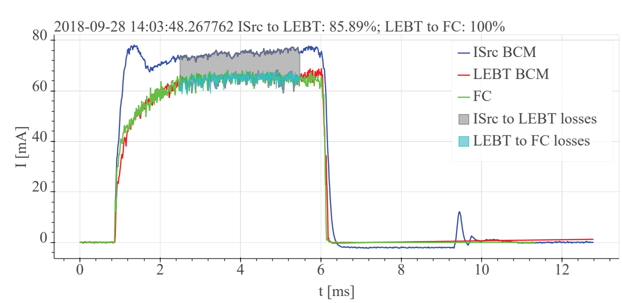

Figure 2: Beam Transmission Measurements - September 2018.

A 75 mA beam was extracted by the Ion Source and a beam of 64 mA was measured in both LEBT BCM and FC. The pulse length was 5 ms in total and the trigger was

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after 1 ms. The region of interest for the beam transmission measurements was between 2.5 ms and 5.38 ms. In this way, the length of the region is 2.88 ms that is the nominal ESS pulse length once the chopper will be operational. It was selected after the ramp and before the exponential drops of the signal.

The transmitted current between the Ion Source and the LEBT BCM was around 85% that is in agreement with the measurements performed in Catania [1]. The transmission between the LEBT BCM and the FC is near 100%. A small fraction of losses is expected but the signal had a significant ripple in the beam shape and this did not allow a clear measurement of few mA of losses. The mitigation of the ripple, as well as many scans of the source parameters, improved the quality of the beam during the second round of measurements starting from March 2019.

MEASUREMENTS ON MARCH 2019

The Ion Source was turned off from October 2018 till the end of February 2019 to consolidate the high voltage grounding, improving the reliability of the source. The full description of the source commissioning is in [5] and [6].

The experimental layout changed from September 2018 to March 2019, in particular the FC was moved from the commissioning tank to the permanent tank, in its final position as shown in Fig. 3. The consequence of this new layout is that

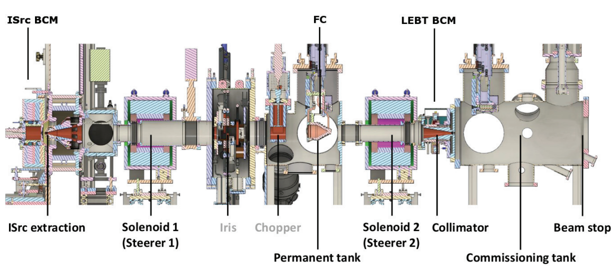

Figure 3: ESS Ion Source and LEBT Layout - March 2018.

the beam transmission cannot be measured at the same time in the LEBT BCM and in the FC as we did in September. The FC absorbs the charged particles, so when it is inserted in the tank the signal into the LEBT BCM is zero. When the FC is retracted its signal is near to zero and the LEBT BCM will measure the beam current.

The beam transmission between the Ion Source and the LEBT BCM is shown in Fig. 4. In order to keep the same source conditions in terms of beam extraction, coil current, magnetron power, hydrogen gas flow etc., the measurement of transmission between the Ion Source and the FC was taken one second after, as in Fig. 5.

Compared with the beam of September, it is possible to notice in Figs. 4 and 5 that the length of the pulse is now 5.5 ms, 0.5 ms longer. The ripple in the shape is much smaller because of the time spent in finding a better setup of the source to have a cleaner beam. The beam current extracted by the source is still around 75 mA.

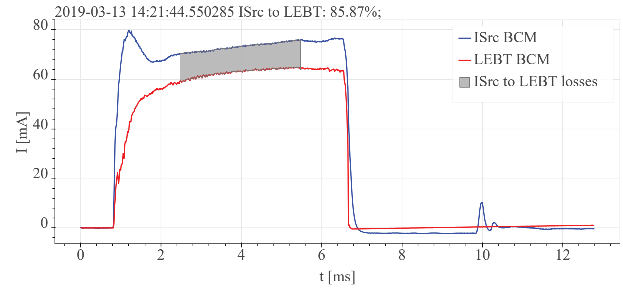

Figure 4: March 2019 Measurements ISrc-LEBT.

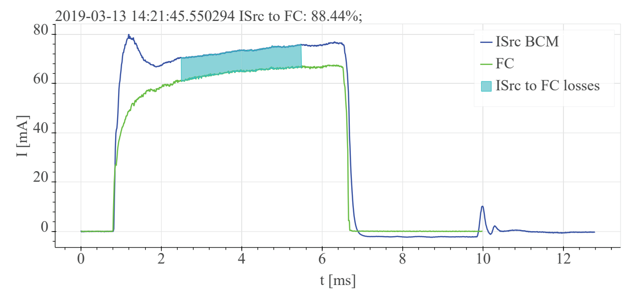

Figure 5: March 2019 Measurements ISrc-FC.

The beam transmission is of 88% between the Ion Source BCM and the FC, and of 86% between the Ion Source BCM and the LEBT BCM. The values are very stable during more than one hour of data acquisition, within 0.2% of fluctuation in the transmission. This suggests that we loose 2% of the beam between the FC and the LEBT BCM.

At the end of April, the FC was moved back to the end of the commissioning tank in order to perform several scans of the solenoids to search for optimal transmission. The result is summarized in Fig. 6.

DISCUSSION ABOUT THE TRANSMISSION

Why do we lose 12% of the beam in the first meter of the particle accelerator? The beam current that we extracts from the Ion Source is not composed entirely by protons. There is a fraction of the beam that is composed by H_2^+ and H_3^+ ions that contribute to the total charge of the particle beam. The hypothesis is that this fraction of other species is 12% of the total beam [1]. These ions possess a mass that is double, for the H_2^+ and triple, for the H_3^+ compared to the mass of the protons, so the effect of the first solenoid is two and three times weaker respectively. This means that the ions are not focused properly and are lost before reaching the FC (and consequently the LEBT BCM).

To prove this hypothesis a direct measurement of the ions extracted by the source has to be performed. In the ESS LEBT there are two instruments capable of performing such measurements: one is a camera that can detect the differences in the Doppler effect of the light emitted by the collisions of the different ions with the residual gas in the vacuum

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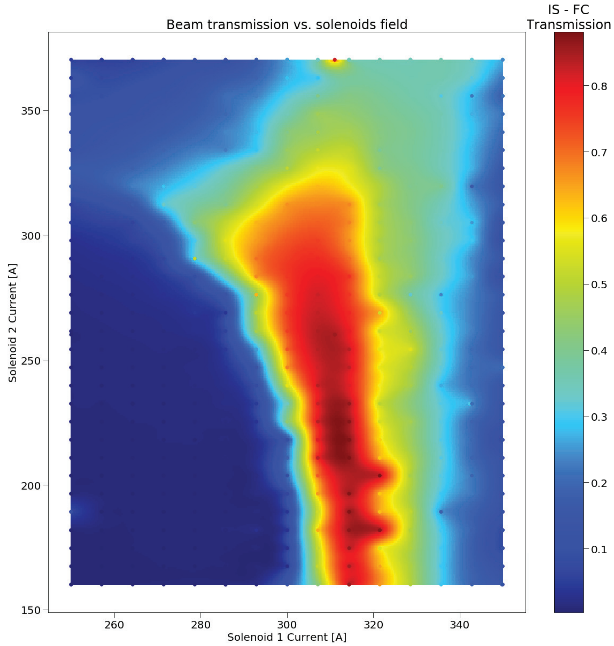

Figure 6: Transmission vs. solenoids.

pipe [7]. The second device is the Emittance Meter Unit [8] that is an Allison scanner capable of reconstructing the phase space of the different ion species giving an estimation of the fraction of protons with respect to the total amount of particles.

CONCLUSIONS

Two different beam runs, on September 2018 and on March 2019 were performed at the European Spallation Source in Lund. In both cases, a beam transmission of 85% was measured in the Beam Current Monitors and in the Faraday Cup installed in the Low Energy Beam Transport section. These results are compatible with the previous measurements performed by INFN-LNS, Catania, before the delivery of the Ion Source and LEBT in Sweden, Lund. The missing fraction of particles during the transmission can be due to the different ion species extracted by the proton source but a direct measurement with the Doppler shift device or the Emittance Meter Unit is required to confirm this hypothesis.

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