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ION SOURCE AND LOW ENERGY BEAM TRANSPORT LINE FINAL COMMISSIONING STEP AND TRANSFER FROM INFN TO ESS*

L. Celona†, A. Amato, G. Calabrese, A. Caruso, G. Castro, F. Chines, S. Gammino, O. Leonardi, A. Longhitano, G. Manno, Salvatore Marletta, David Mascali, Antonio Maugeri, Maria Mazzaglia, A. Miraglia, L. Neri, S. Passarello, A. Seminara, D. Siliato, A. Spartà, G. Torrisi
Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali del Sud, 95123 Catania, Italy

Abstract

At the Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali del Sud (INFN-LNS), the beam commissioning of the high intensity Proton Source for the European Spallation Source (PS-ESS) was completed in November 2017. All requirements have been satisfied and certified by the European Spallation Source (ESS).

In the last step of the commissioning a complete characterization of the source has been carried out and some results are hereinafter reported. The shipment of the source was done in December 2017, followed by the installation in January while the beam commissioning is foreseen during summer 2018. The paper describes the final commissioning steps at INFN-LNS, the procedure adopted for a safe transfer of the equipment, the transfer of knowledge needed for the operation and the maintenance.

INTRODUCTION

The contribution of INFN-LNS to the construction of the ESS accelerator is the design, construction and commissioning of the high intensity proton source named PS-ESS [1] and of the LEBT [2-3]. The work has been carried out in collaboration with ESS, responsible of the control system, beam diagnostic and vacuum equipment, and CEA with the developing of the control system and of some beam diagnostic equipment.

The source is a 2.45 GHz microwave discharge ion source with a very flexible magnetic system. Three coils are able to provide magnetic field from few hundreds to two thousand Gauss. The microwave power is provided by a 2 kW magnetron and the impedance matching with the plasma chamber is achieved by using a four stub tuning unit. An MKS flow controller feeds the gas into the OFHC cylindrical plasma chamber to reach a very high level of repeatability, stability and the precision of the injected flux. The insulating column permits to sustain up to 90 kV and the beam extraction was tested up to 130 mA at the nominal voltage of 75 kV without any problem of sparks. The source is housed in the high voltage platform shown in the right part of the Figure 1.

The first element of the LEBT has been designed as compact as possible to minimize the length between the first solenoid and the extraction aperture. This element houses the support of the electrode extraction system, two turbo pumps, three vacuum gauges, a residual gas analyzer, the water feedthrough of the electrode cooling system and the high voltage feedthrough of the repeller electrode. The two solenoids, with embedded X and Y steerers, have been designed in collaboration with CEA.

After the first solenoid a gate valve is inserted to enable the source maintenance without breaking the vacuum in the LEBT or vice versa. A six movable blades iris was designed to be able to reduce the amount of transmitted current without changing the source settings, thus maintaining stable source working conditions. Before the second solenoid two emittance measurement units (X and Y planes), a Doppler shift measurement unit, two cameras for the beam alignment, two turbo pumps and the chopper were integrated in a short as possible vacuum chamber, to reduce the beam emittance growth. The LEBT ends with a conical collimator that works as a beam dump for the H_2 beam produced by the source and the part of the proton beam pulse which is deflected by the chopper. The collimator works also as a differential pressure vacuum sector dividing the region of low pressure needed for the rest of the accelerator from the LEBT where a pressure of a few 10-5 mbar is needed to activate the beam space charge compensation. For the commissioning in Catania and for the first part of the commissioning phase in Lund, a commissioning tank was designed to house the beam diagnostic equipment and measure the beam performance reached at the LEBT-RFQ beam lattice interface.

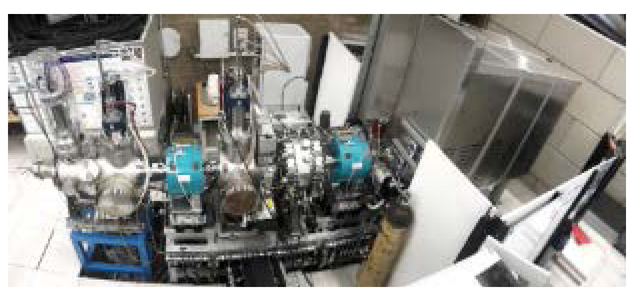

Figure 1: A top view of the proton source at INFN-LNS.

FINAL COMMISSIONING STEPS

In the design of the proton source and the LEBT several degrees of freedom were introduced to have the possibility to choose the best working conditions due to the ESS high demand in terms of beam current and stability.

In order to characterize the beam performances in a wide range of parameters [4] a custom high level code was developed [5]. This code is able to change the value of all source parameters and read the output data of all diagnostic equipment (beam, vacuum, temperature, environmental),

† email address celona@lns.infn.it

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thus allowing to explore a wide parameter space and permitting to define the source settings able to satisfy the ESS requirements.

The results shown below (Figs. 2 to 4) correspond to the nominal source configuration required by ESS with 70 mA of proton at the end of the LEBT, intra-pulse stability less than ±2% and pulse to pulse stability less than ± 3.5%.

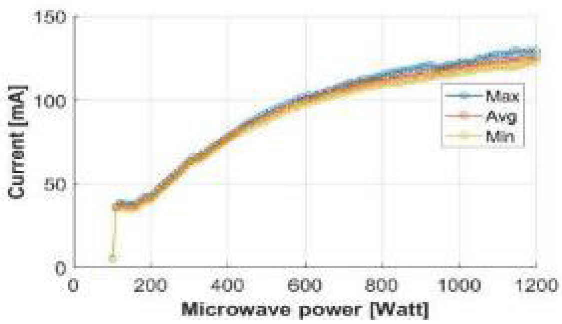

Figure 2: Total current vs. microwave power at nominal source configuration.

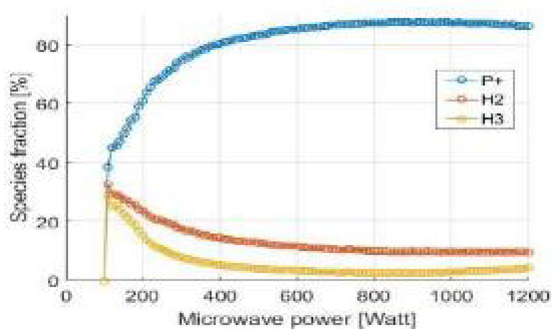

Figure 3: Proton fraction produced vs. microwave power at nominal source configuration.

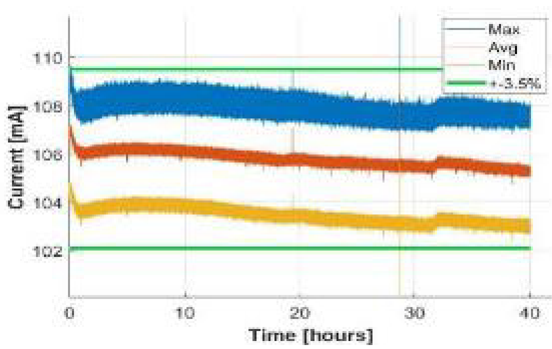

Figure 4: Pulse to Pulse stability at nominal source configuration.

The beam pulse after the electrostatic LEBT collimator is shown in the Figure 5. The measurement of the current is done with the Faraday Cup located in the commissioning tank. The two red line represent the limit of interest for the calculation of the av-erage beam current value and the fluctuation between max-imum and minimum.

Figure 6 shows an accurate measurement of the rise time where the ACCT of the LEBT collimator was acquired with a 4GHz oscilloscope. Rise time analysis is shown in the upper part of the picture while in the bottom part the histogram of the rise time value is shown.

It is clear that the rise time is of about 440 ns and that there is a very high repeatability between the different produced pulses. The maximum deviation was of ±10 ns collected for one thousand pulses.

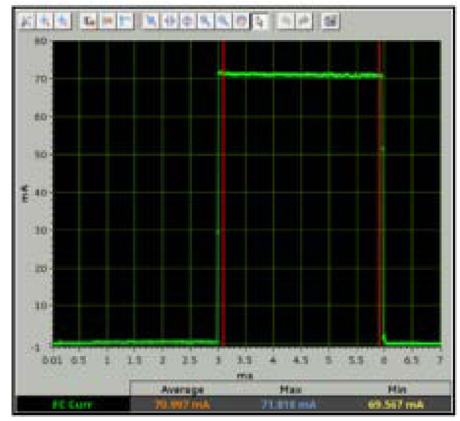

Figure 5: Beam pulse measurement with a Faraday Cup located after the LEBT-RFQ beam lattice interface, the first three millisecond of beam produced by the source are stopped by using a chopper in the LEBT.

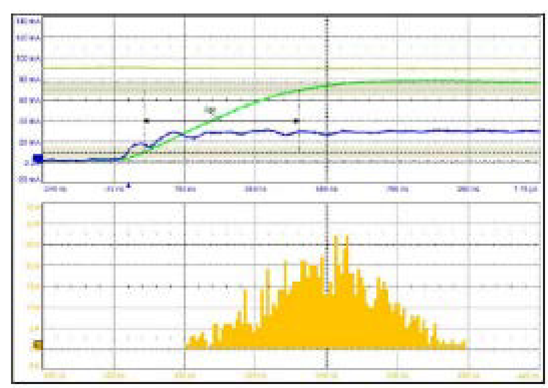

Figure 6: Beam pulse rise time analysis made with a 4GHz oscilloscope: (top-green) beam pulse current measured with the ACCT, (bottom-yellow) histogram of the measured beam pulse rise time.

The most important beam parameter for a good beam matching between the LEBT and the RFQ is the beam transversal emittance figure. A good matching is essential also to reduce the beam losses in the high energy part of the accelerator. The measurement done at the center of the LEBT is shown in Figure 7 together with the TRACEWIN calculation of the Twiss parameters. The achieved value of 0.1769 pi.mm.mrad (rms norm) fully satisfy ESS requirements. Space charge compensation studies with multiple gas injection in the LEBT have been also carried out and they are extensively reported in ref [4].

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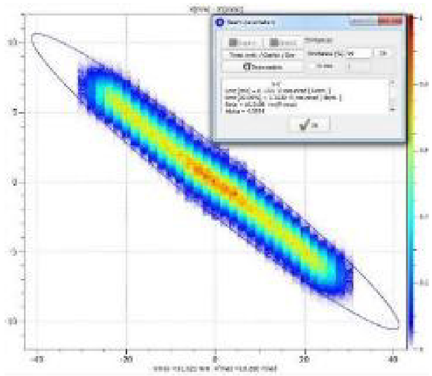

Figure 7: Emittance measurement at the center of the LEBT.

TRANSFER TO LUND

The disassembly of the Ion Source and LEBT and the relative packaging of all the parts started in the early November 2017 and thanks to an appropriate schedule of the involved activities, it was completed in just 19 days.

An "ad-hoc" set of wooden boxes have been realized taking into account the shape and weight of the individual components. During the packaging phase all the humidity-sensitive devices have been packed under anaerobic nitrogen atmosphere in order to avoid oxidation of metal part.

Dedicated track with air suspension and shock monitoring system was used to transfer the overall setup to Lund.

The shock monitoring system consisted of a real time GPS system to monitor and alert the driver if a pre-set levels are breached and equipped of 2 shock, vibration, acceleratio and environmental (temperature, humidity and pres-sure) data loggers and recorders.

For the transportation of the IS and LEBT a 3-axis shocks were used in order to alarm the driver, through an acoustic sound and a flashing light, when the acceleration on one of the three axes exceeded the pre-set level (x>=0.9 G; y>=1.1 G; z>=1.2 G) for a time greater than 25 msec. Figure 8 and 9 show the web monitoring user interface and a typical measured values data diagram, respectively. The continuous monitoring of such values provided a safe and valuable bases for future transportation in order to prevent damage. After a journey of 8 days and more than 2.925 km, no damage was found on the devices at destination.

The unpacking and reassembly has been carried out by the LNS-staff in collaboration with ESS agents in only 14 working days (Fig.10). The re-commissioning of the ion source and LEBT to-gether with the long duration test are planned in the middle of the summer 2018.

ACKNOWLEDGMENTS

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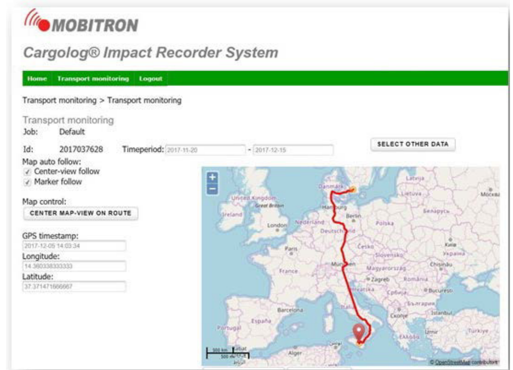

Figure 8: GPS web monitoring user interface.

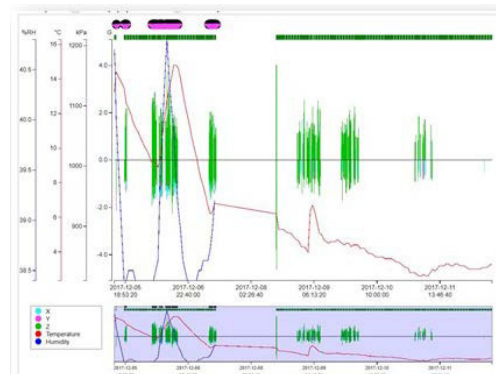

Figure 9: Measured values.

Figure 10: LNS-staff in Lund with the ion source and LEBT reassembled behind.

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