THE TRASCO HIGH CURRENT PROTON SOURCE AND ITS LEBT

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Abstract

TRASCO (acronym for TRAsmutazione di SCOrie) is a joint INFN/ENEA program, aiming at the design of the main components of an accelerator driven system (ADS) for nuclear waste transmutation. The front-end of the proposed 30 mA proton linac (TRASCO-AC) consists of an 80 kV ECR source and an RFQ up to 5 MeV. The TRasco Intense Proton Source (TRIPS) is operational since one year at LNS and the RFQ is being built at LNL, where the front-end will be installed. In this paper we summarize the measured performances of the source, and the design of the Low Energy Beam Transport line (LEBT) that will match the beam into the RFQ.

1 TRIPS ION SOURCE

Since the fall of 2000 proton beams are available from the source TRIPS, a high intensity microwave discharge ion source, the goal of which is the injection of a proton current of 35 mA in the following RFQ, with a rms normalized emittance lower than 0.2π·mm·mrad for an operating voltage of 80 kV. Its design is described in [1] and it is shown in Fig.1.

The microwave power obtained with a 2.45 GHz - 2 kW magnetron is coupled to the cylindrical water cooled OFHC copper plasma chamber through a circulator, a four stub automatic tuning unit and a maximally flat matching transformer. Two coils, independently on-line movable and energized with separate supplies, allow to vary the position of the electron cyclotron resonance (ECR) zones in the chamber and to produce the desired magnetic field configuration. The optimum one has two ECR zones at both ends of the plasma chamber and with a value of magnetic field greater than the resonance value inside the plasma chamber. [2]

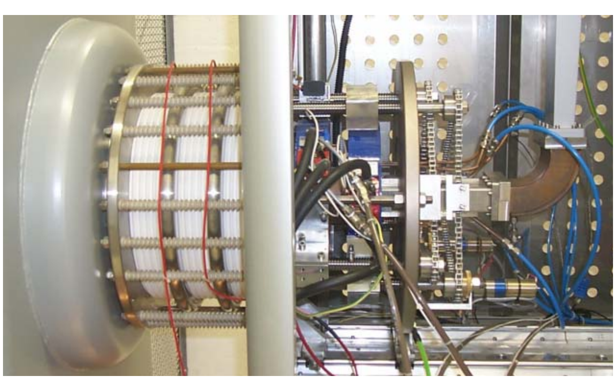

Figure 1: The TRIPS ion source on the 100 KV platform.

The maximally flat matching transformer has proved to be effective to optimise the coupling between the microwave generator and the plasma chamber.

It realizes a progressive matching between the waveguide impedance and the plasma impedance, thus concentrating the electric field at the center of the plasma chamber (in our design the field enhancement ratio is about 2). The automatic tuning unit permits to operate with low values of reflected power (below 5%).

The major result of this enhancement was the high current density, attaining values up to 240 mA/cm^2 in the best case at 80 kV. Fig.2 shows the experimental set-up: the first section of the low energy beam transfer line (LEBT) devoted to the beam analysis consists of a current transformer (DCCT1), of a focusing solenoid, of a four sector ring to measure beam misalignments and inhomogeneities, of a second current transformer (DCCT2) and of an insulated 10 kW beam stop (BS) which measures the beam current.

Two different types of electron donors were used to enrich the plasma density: the BN disk at injection and extraction sides of the plasma chamber, as used elsewhere, and Al_2O_3 coating (40 μm thick). This coating significantly increased the plasma and the current density [2].

The requested reliability at 80 kV was not yet fully achieved, but the source performance has already reached good results in terms of beam intensity, reproducibility and stability. This stringent request will be investigated soon with a long run test at full operating voltage and current.

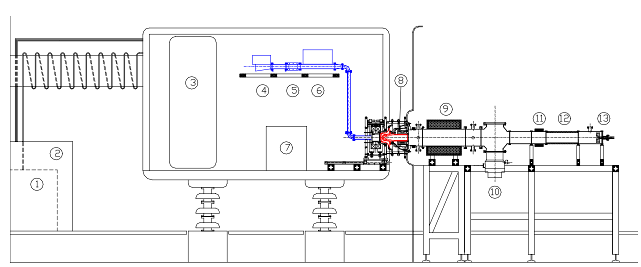

Figure 2: The experimental set-up (1- Demineralizer; 2- 120 kV insulating transformer; 3- 19” Rack for the power supplies and for the remote control system; 4- Magnetron and circulator; 5- Directional coupler; 6 – Automatic Tuning Unit; 7- Gas Box; 8- DCCT 1; 9- Solenoid; 10- Turbomolecular pump; 11- DCCT 2; 12- Diagnostic box; 13- 10 kW Beam stop).

2 EMITTANCE MEASUREMENT UNIT

The emittance measurement unit (EMU), kindly lent from CEA/ Saclay, has been installed in the LEBT just after the diagnostic box (at right in Fig.2). This unit is made of a water-cooled beam stop, with a 0.2 mm diameter aperture tantalum sampler. A Wien filter, integrated in the measuring system, allows the measurement of the species desired (H^+, H_2^+,H_3^+). A photo of the existing LEBT at LNS after the installation of the EMU is shown in Fig.3.

Figure 3: Trips source with EMU installed.

3 EMITTANCE MEASUREMENT AND OFF LINE ANALYSIS

At the beginning, a non-optimised source condition created many problems, such as a very poor proton fraction (60%) and an evident misalignment of the beam exiting from the source. Nevertheless we have been able to solve both the problems (the misalignment problem was compensated by a strong beam focalisation), however the rigorous off line analysis of the raw data permitted to obtain a clean measurement as shown in Fig.4.

Not linear effects are visible. Emittance values obtained in these conditions are shown in Tab.1. Injecting Argon in the line, we are able to reduce non-linearity and consequently to reduce emittance growth. An example of this neutralized measure is presented in Fig.5.

4 LEBT PRELIMINARY DESIGN

The first choice for a beam transport is the use of a two-solenoid beam transport system, which takes advantage of background gas ionization to neutralize the beam space charge (sc). The TRASCO baseline LEBT design is shown in Fig.6. It is 2.84 m long and its functions include beam focusing and steering at the RFQ match point, dc beam current diagnosis and video beam profile monitors located at two stations along the beam line. An insertable plunging beam stop is planned to stop the 30 mA-80 KeV beam.

Table 1

	Un-neutralised	Neutralized
Emit.n.rms(mmmrad)	0.153	0.09
Alpha	-3.45	-5.39
Beta(mm/mrad)	1.56	2.28
Vacuum (mbar)	6.9E-6	3.6E-5

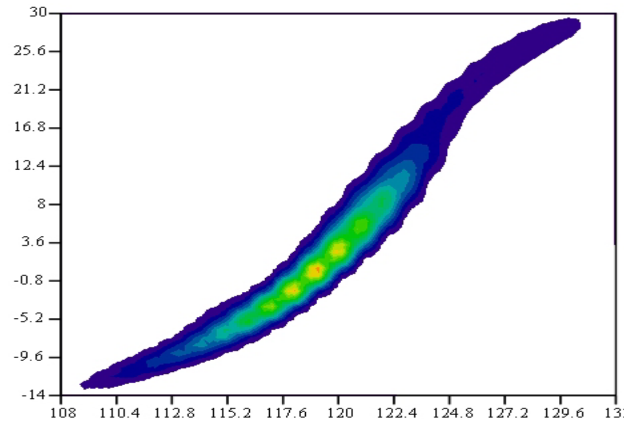

Figure 4: Proton beam emittance measurement without neutralization. V_{ext}=80 KV, V_{puller}=35 KV, I_{magnet}=280 A, P_{source}=1.3 E-5 mbar, P_{line}=6.9 E-6 mbar.

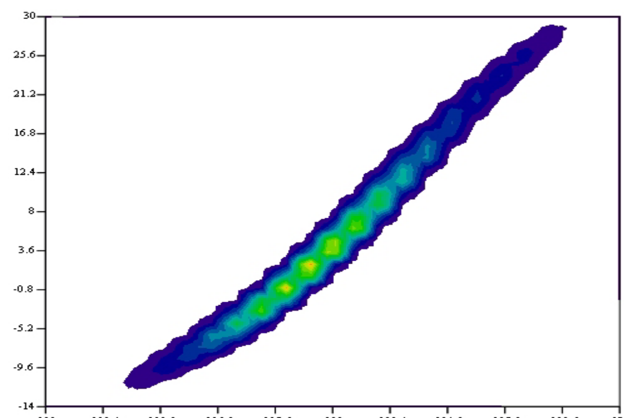

Figure 5: Proton beam emittance measurement with neutralization. V_{ext}=80 KV, V_{puller}=35 KV, I_{magnet}=280 A, $P_{source+Ar}$=2.5 E-5 mbar, $P_{line+Ar}$=3.6 E-5 mbar.

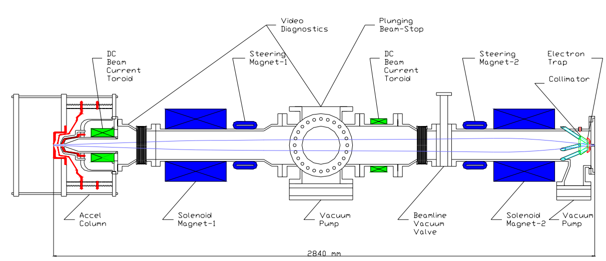

Figure 6: A preliminary 2.84 m long LEBT for the TRASCO project.

The insertion of a water-cooled collimator, a second pump and an electron trap at the RFQ entrance completes the line. Even if 30 mA is the design current, beam dynamics has been checked up to 60 mA. The codes AXCEL, TRACE3D and PARMTEQM have been used to model the injector beam at the TRASCO RFQ match point. AXCEL has been used to carry the beam up to 55 mm axial distance after plasma extraction hole. Extraction geometry forces neutralization to begin at this axial point. TRACE code has been used to find the first order of solenoid parameters, while PARMTEQM has been used to operate the final tuning of the magnets. The advantage in using PARMTEQM to simulate LEBT is related to the opportunity of changing beam current depending on the neutralization. Due to the electron trap, effective beam current rises from 1 mA up to 60 mA near RFQ entrance. We have used this code to simulate this ramping behavior and to transport the beam through the RFQ.

Preliminarily, we studied beam properties variation as a function of puller electrode voltage. In particular we have calculated the effect of this voltage variation on current and on some phase space parameters such as alpha and emittance. The latter simulation results are presented in Fig.7. As expected, there is a strong influence of puller electrode on phase space parameters.

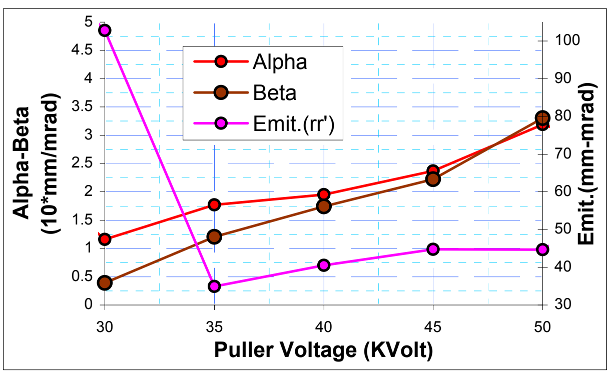

Figure 7: Phase space parameters as a function of puller electrode voltage.

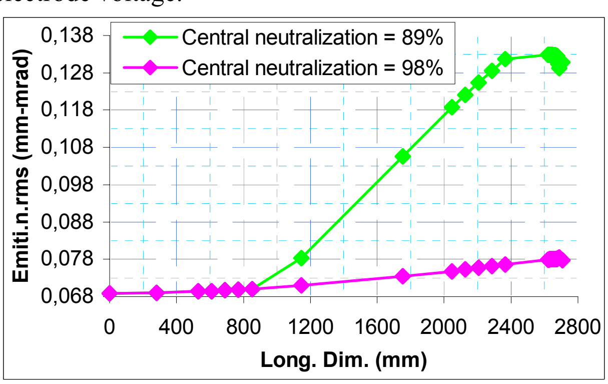

Figure 8: Normalized emittance increase as a function of longitudinal distance.

4.1 Magnetic Solenoid Beam Transport

LEBT has been simulated in two different conditions: a constant neutralization of 98 percent throughout the line and a three-zone neutralization, which is 98 percent before the first solenoid and after the second and which is 89 percent between them [3]. Although a neutralization increase affects little the transverse beam dimensions, nevertheless it has dramatic effects on emittance behaviour (Fig.8). Simulations are made using 100000 macro-particles [4].

TRASCO RFQ matching parameters are α=2.76, β=0.0845 mm/mrad for input current and emittance of 63 mA and 0.08 πmm-mrad respectively. These conditions are achieved for B_1=1600 G and B_2=2615 G and are within the capability of the LEBT solenoid magnets. In reality there is a wide stability range that permits good transmission through RFQ (Fig.9), but only the right match parameters guarantee a not too high emittance increase. With the right magnet field values and with 98 percent neutralization, PARMTEQM predicts about 16% emittance increase through the LEBT. The 98.6% of the proton beam (62 mA) will be transmitted through the RFQ with the output 5 MeV emittance being 0.11 (πmm mrad).

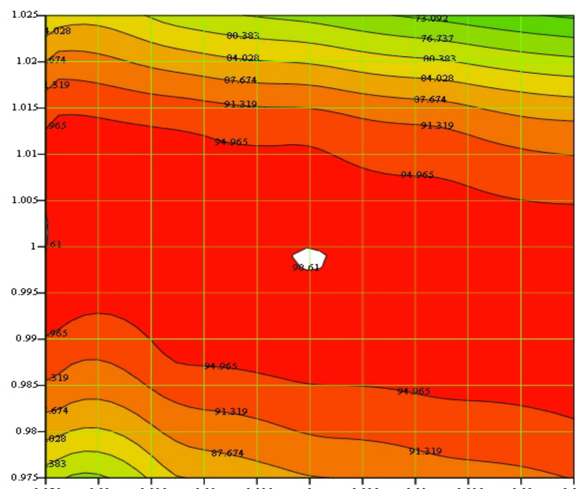

Figure 9: Beam transmission through LEBT and RFQ as a function of the two LEBT solenoid currents, normalized at the nominal value.

5 REFERENCES

[1] L. Celona, G. Ciavola, S. Gammino, R. Gobin, R. Ferdinand, Rev. Sci. Instrum. 71 (2), (2000), 771.

[2] G. Ciavola, L. Celona, S. Gammino, F. Chines, C. Campisano, Rev. Sci. Instrum. 73 (2), (2002), 1030.

[3] P-Y. Beauvais *et al.*, Rev. Sci. Instrum. 71 (3), (2000), 1413.

[4] M. Comunian, A. Pisent, G.V. Lamanna, Proc. of 7th Eur. Part. Acc. Conf., Wien, (2000), 927