FIRST RESULTS FROM BEAM MEASUREMENTS AT THE 3 MeV TEST STAND FOR CERN LINAC4*

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Abstract

The H^- source and the low energy beam transport (LEBT) line will determine to a large extend the performance of Linac-4 [1], the new machine foreseen at CERN as injector into the PS Booster. For this reason a test stand is being set up, consisting of the source, the LEBT, the RFQ and the chopper line. Up to now only the source and LEBT are installed. First measurements have been performed using a Faraday Cup to measure the total source intensity, a slit and grid emittance meter for transverse emittance measurements as well as a spectrometer for energy spread measurements. Beam intensity, profile, transverse emittance and energy spread have been measured. The paper discusses measurements done on H^- beams at 35 kV extraction voltage as well as proton beams at 45 keV.

INTRODUCTION

As shown in Figure 1, the Linac4 LEBT consists of two solenoids, a diagnostic box and two steerers. The aim of the LEBT is to provide the beam matching from the source to the RFQ and to monitor source performance. Due to the small RFQ acceptance, the commissioning of the LEBT is crucial to ensure good beam transmission in the RFQ.

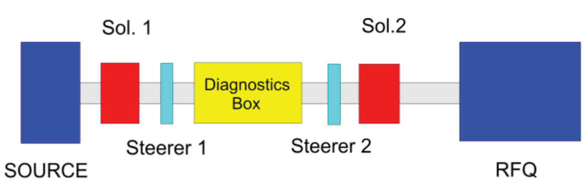

Figure 1 Diagram of the LINAC4 LEBT.

During the commissioning phase, emittance measurements have been done at three different stages:

- after the source,
- after the first solenoid,
- after the second solenoid, i.e at the RFQ input.

In addition, profile measurements at the RFQ input have been done using the emittance meter slit and a Faraday cup. Energy spread measurements have been performed after the first solenoid.

A systematic comparison between measurements and beam dynamics simulations has been done for the two last stages.

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BEAM EMITTANCE AND PROFILE MEASUREMENTS

Emittance Meter

The system consists of two SEM-grids and an L-shaped slit made from stainless steel inclined at 45 degrees relative to the vertical axis. The profiles for each slit position are read out with a 6 µs time resolution.

A Faraday cup is positioned 8 cm downstream the SEM grid measuring the full beam current when the slit is out and performing profile measurements by moving the slit and measuring the beamlet current. In between the SEM grids and the cup two polarization guard rings have been installed in order to minimize the recoil of secondary electrons from the cup to the wires and repel them back into the cup. More details can be found in [2].

From the measurement, the Twiss parameters and emittance values have been determined with a first approximation algorithm, based on the calculation of the RMS distributions (in position and angle) after eliminating all wire signals below a threshold calculated from the maximum signal value.

Emittance Measurement after the Source

During a first source commissioning phase an H^- ion beam at an extraction voltage of 35 kV, a pulse length of 400 µs and a RF power of 20 kW has been measured. In this configuration the source provides 20 mA beam current which has been measured with the emittance meter and its Faraday cup.

The first measurements show that the angular resolution of the SEM grid is not sufficient due to the large distance between two wires (750 µm). In order to increase the angular resolution, 7 steps of 100 µm have been used for the SEM grid, for each slit position.

Examples of measurement results are shown in Table 1. The agreement of the measurement with respect to the expected values for the LINAC4 source [3] is remarkable.

Table 1: Nominal and measured beam parameters of the source for the vertical plane (with 1% threshold on the data).

Value	Emittance [rms]	Alpha	Beta
Measured	0.26 pi.mm.mrad	-35.8	6.24mm/pi.mrad
Nominal	0.25 pi.mm.mrad	-24.4	4.3 mm/pi.mrad

After this phase, the extraction voltage was upgraded to 45 keV. Unfortunately this caused problems with electron currents of too high power destroying the electron dump and it was decided to switch the source to proton mode and continue the commissioning of the source and the LEBT with proton beam

New emittance measurements have been done after the source with an extraction voltage of 45 kV and different RF power. The effect of increasing RF power on the emittance has been measured. Table 2 shows the reconstructed Twiss parameters with 3 RF power settings with a threshold set at 10%.

Table 2: Twiss parameter calculated with a threshold at 10% and different RF power.

	Horizontal plane		
RF Power (kW)	**Emittance**	**Alpha**	**Beta**
20	0.07	-54.97	9.47
40	0.19	-44.77	7.96
60	0.29	-45.73	8.25
	Vertical plane		
RF Power (kW)	**Emittance**	**Alpha**	**Beta**
	0.06	-65.09	10.9
40	0.19	-44.77	7.96
60	0.29	-45.73	8.25

The emittance increases with RF power. With the largest value, aperture limitation due to the beam pipe appears.

A comparison between the results on the emittance reconstruction between the proton and H^- mode of the source is show in Figure 2.

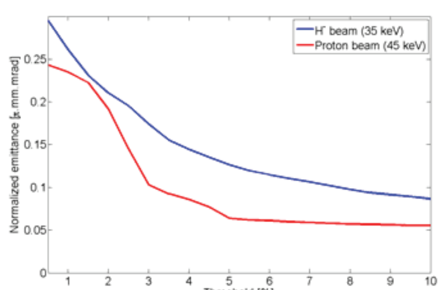

Figure 2: Normalized emittance measured for a proton beam at 45 keV and H^- beam at 35 keV as a function of the threshold applied to the data.

The RF power on the source was the same for the both modes (20 kW), the emittance is smaller for the proton beam. This can be explained by the lower space charge effects at 45 keV.

These results have been used as initial values for beam dynamics simulations of the LEBT.

Emittance and Intensity Measurement after the First Solenoid

Once the measurements on the source were terminated the emittance meter was moved after the first solenoid, which separates different particle types coming from the source. The current in the solenoid was varied from 0 to 1000 A. Figure 3 shows the result of such a measurement which clearly displays 4 different species of ions coming from the source. As expected, the result shows that heavier ions are less focused by the solenoid and are separated in phase space from the protons. Simulations allowed identification of the particle types as indicated in Figure 3.

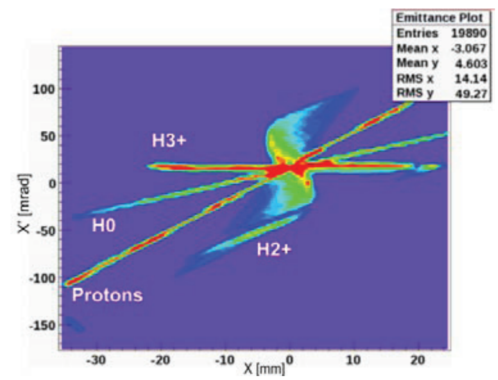

Figure 3: Different particle types separated by solenoid.

Beam dynamics simulations and measurements show a remarkable agreement as show in Figure 4.

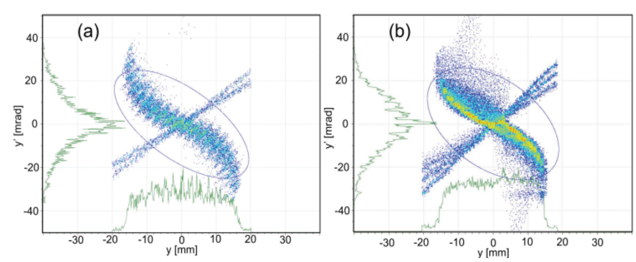

Figure 4: Simulated (b) and measured (a) phase space after the first solenoid, for I_{sol1}=600 A.

Different solenoid currents have been tested and for each setting the emittance has been measured in both planes.

The beam current as a function of the solenoid current has also been measured with the Faraday cup positioned at the rear of the emittance meter. The results show that a current of 600-700 A maximizes the transmission of the particles onto the faraday cup. It also shows that the current increases linearly with the RF power between 20 kW and 40 kW. The current difference between 40 and 60 kW is negligible due to beam losses on the solenoid. A solenoid current of 600 A is needed to match the beam parameters to the RFQ acceptance and will be used as reference for the rest of the commissioning phase.

Due to the separation of the particles, the emittance analysis is difficult. (At this time, the calculation of the emittances of the different species has not yet been done).

Only a g lobal emittance was calcu lated, and offline analysis is still in progress.

Emittance Measurement at the RFQ Input

Finally emittance measurements have been done with the complete LEBT. The current on the second solenoid was varied from 250 A to 400 A.

The different scans show that the beam is moving with the second solenoid current. Excursions of 11 mm in the horizontal plane and 4 mm in the vertical plane have been calculated. This shows that the beam is not centered in the second solenoid and has to be steered.

In a first step, the emittance meter slit and the faraday cup have been used to make profile measurement with the solenoid off. This has been done in order to calibrate the steerers in the LEBT. The results show that the kick in the horizontal plane given by the both steerers is -5.4 mrad/A and 5.4 mrad/A in the vertical plane.

These values have been used to find the setting of the steerers. Despite the steering, the beam is still moving as a function of the second solenoid current. A measurement of the alignment of the second solenoid and the emittance meter has been done and show some errors in the alignment.

This problem has been fi xed and new measurements are under completion to find the good settings for the steerers and the solenoid.

ENERGY SPREAD MEASUREMENT-INTENSITY MEASUREMENT

The energy spread has been measured with a spectrometer and a grid. A slit is positioned downstream the first solenoid, its aperture can be modified from 1 mm up to 5 mm.

At the SEM grid location the beam size is due to:

- Energy spread of the beam
- Slit opening size
- Space charge effects after the slit
- Divergence of the beam

Figure 5 shows the reconstructed profile with a slit aperture of 4 mm.

The calibration factor found by decreasing the extraction voltage by 500 V is 50 eV.mm-1. With this factor, the energy spread interpolated for a slit aperture of 0.2mm is +-170 eV.

Depending on the source parameters, the beam, measured with the faraday cup and Isol1=600A , is around 50 mA. A new acquisition channel will allow us to sample the signal at 250 kHz.

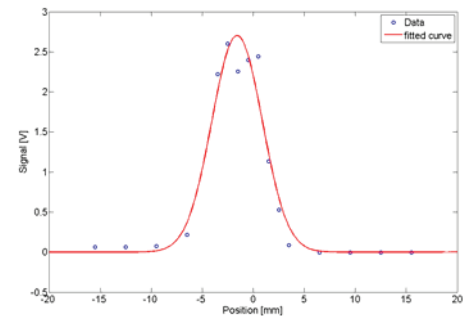

Figure 5: Reconstructed profile and Gaussian fit at the end of the spectrometer line.

CONCLUSIONS AND OUTLOOK

The source and LEBT of the new injector Linac into the PS Booster have been characterized. Intensity, profile, transverse emittance and energy spread have been measured at different locations on the line

The measurements show a misalignment of the line. This has been fixed in the meantime and t he beam matching will restart at the beginning of May 2011.

In addition to the instruments describes in the paper, a SEM grid will be installed in the diagnostic box as well as a current tra nsformer between the solenoids. This will allow us to perform beam current, beam profile after the first solenoid and emittance measurement at th e RFQ input at the same time.

Some weeks of the year 2011 will be also dedicated to source development.

REFERENCES

[1] Linac4 technical design report, CERN-AB-2006-084 ABP/RF.

[2] B. Cheymol et al., Commissioning of the LINAC4 ion source transverse emittance meter, IPAC 2010.

[3] R. Scrivens, Engineering parameters for diagnostics for a source test line for LINAC4.