Experimental characterisation of Gridded Electrostatic Lens (GEL) Low Energy Beam Transport (LEBT) for the Laser Ion Source (LIS) and effect of a wire grid on the extraction electrode

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ABSTRACT

In this note we report on the recent experiments performed at CERN to characterise a novel low energy beam transport line based on gridded electrostatic lenses. The line performances are measured by means of a small aperture Faraday cup and of a Faraday cup with an acceptance similar to the LIS RFQ. Emittance measurements are reported elsewhere [1].

This transport line was introduced by P.Ostrumov and built in his institute (INL, Troitzk, Moscow region). Such line was designed to minimise the non-linear space charge aberrations that can arise in the magnetic LEBT based on solenoids [2].

A wire grid on the positive extraction electrode was found both to stabilise the source output and to increase the transmitted current. The effect of such grid would be to fix the plasma boundary at extraction. The shot to shot fluctuations of the transmitted current were reduced to less than 6% level (1RMS) at extracted currents of 80mA.

INTRODUCTION

Recently we characterised a Low Energy Beam Transport (LEBT) for the Laser Ion Source (LIS) based on one or two solenoids [3,4]. Simulations show that the transverse charge separation occurring while the beam is transported inside the solenoid can introduce a large emittance increase. Such non-linear aberrations can entirely spoil the beam quality. On the other hand the charge separation provided by the magnetic beam transport line has the positive effect of reducing the particles having the unwanted charge state in the first accelerator section (LIS RFQ).

We decided to test the concept of a LEBT based on electrostatic lens elements on the hypothesist the RFQ will tolerate such large currents at its entrance, as it was designed for.

In Figure 1 we show a scheme of the extraction system together with the GEL LEBT.

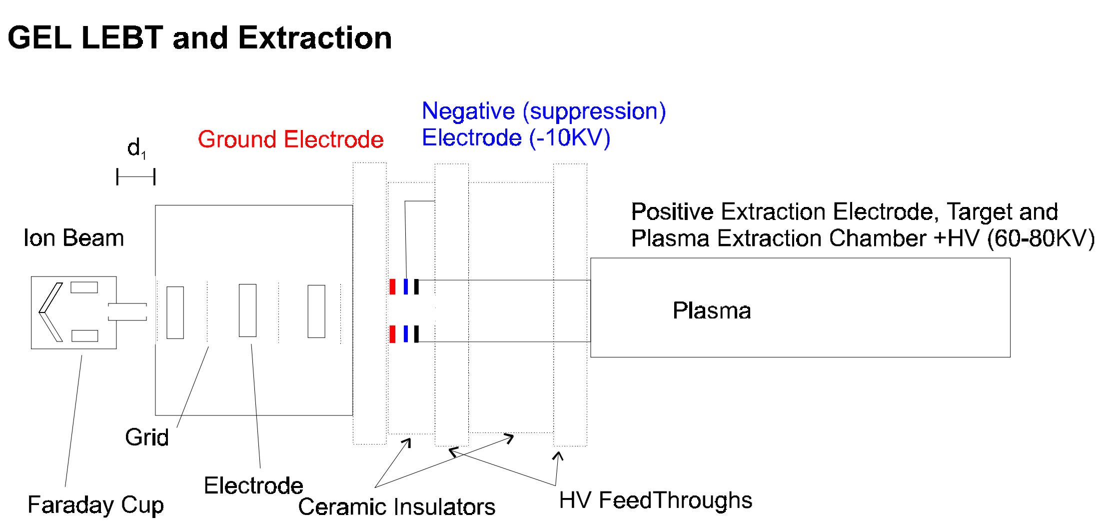


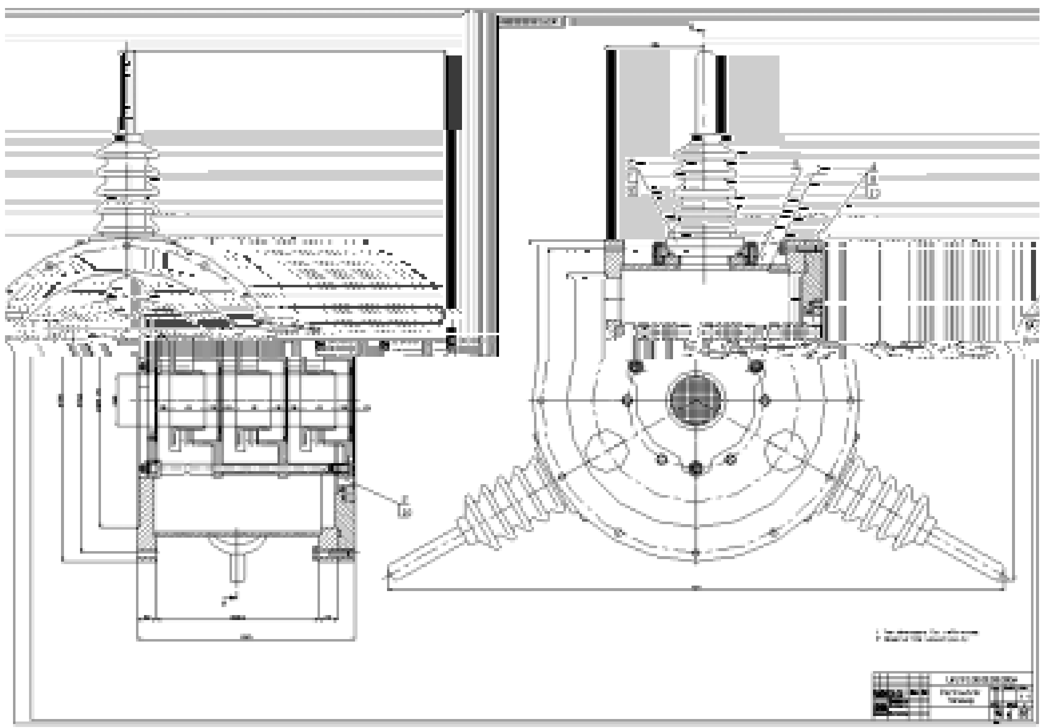
Figure 1 Scheme of the GEL LEBT and the extraction system and the Faraday Cup

ELECTRODE AND FEEDTHROUGH VOLTAGES

In figure 2 we show the detailed drawing of the 4 grids, 3 electrodes system. The positive voltage is applied to the electrodes via 45kV HV feed-through on the vacuum chamber. Each feed-through and electrode were individually tested and voltages up to more than 50kV could be applied after some conditioning. On the other hand, when voltage is applied simultaneously to more than one electrode, the voltage than can be held is generally lowered and it becomes difficult to increase any of the electrode voltages above 40kV. This seems to be related to the high dark current, probably electrons flowing from the grids towards the positive electrodes or along the ceramic insulators due nearby sharp metal edges. This cross talk affects the performances of the GEL LEBT. In particular it makes it difficult to optimise the transport with extraction voltages higher than 60kV.

Although this limited the scope of our measurements, the RFQ sets our extraction voltage at 60kV, making the characterisation meaningful for charge states of 20+ and more (The RFQ Design is for 6.9kV/u).

According to simulations [5] the optimal voltages for the GEL LEBT are 7kV for the first Electrode, 30kV for the second and 38kV for the third one.



INITIAL MEASUREMENTS

The measurements that we performed in order to characterise the device are similar to those done for the magnetic LEBT [3,4].

The characterisation of the GEL LEBT consisted in changing the electrodes voltage and the distance between the last grid of the GEL and the Faraday cup, while measuring the ion current transmission.

It was found that the shortest distance (30mm) between the last grid and the Faraday cup yielded the highet transmission current, while there was no significant loss in performances when this distance was increased up to 100mm.

This series of measurements, devoted to the optimisation of the LEBT, was performed with the first of the three electrodes held at ground, due to a technical fault of one of the power supplies. When the fault was discovered the complete series of measurements was not repeated, since by applying 7kV on the first electrode we did not increase transmission by more than 10% confirmed by simulations.

The distance d_1 was set at 100mm. In figure 3 we show the transmitted current into the 6.5mm aperture Faraday cup as a function of the third electrode voltage and in figure 4 we show the transmitted currents into a double aperture Faraday cup for the same electrode settings.

The distance d_1 was set at 30mm. In figure 5 we show the transmitted current into the 6.5mm aperture Faraday cup and into a double aperture Faraday cup for the same electrode settings as a function of the third electrode voltage.

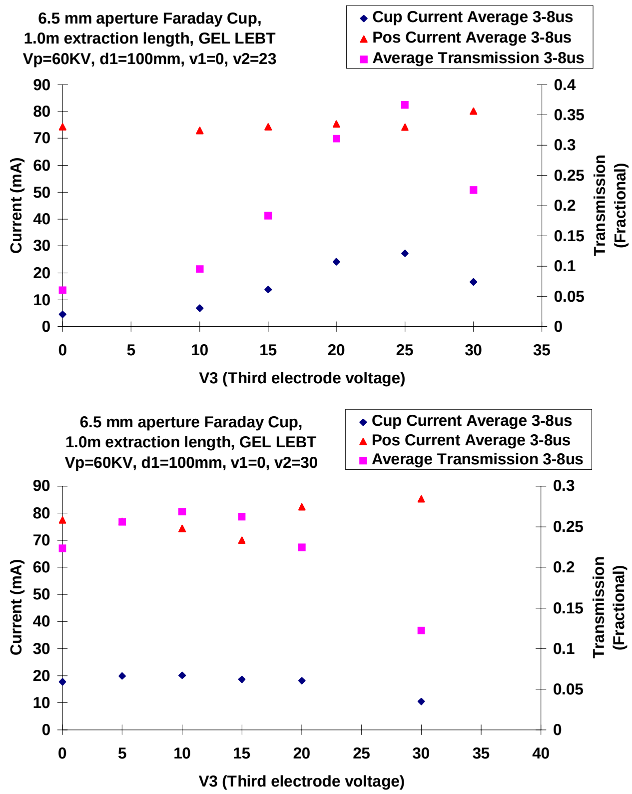


Figure 3 Transmission into a 6.5mm aperture cup 100mm from the last grid. The transmission curves are shown for two different voltage values on the second electrode.

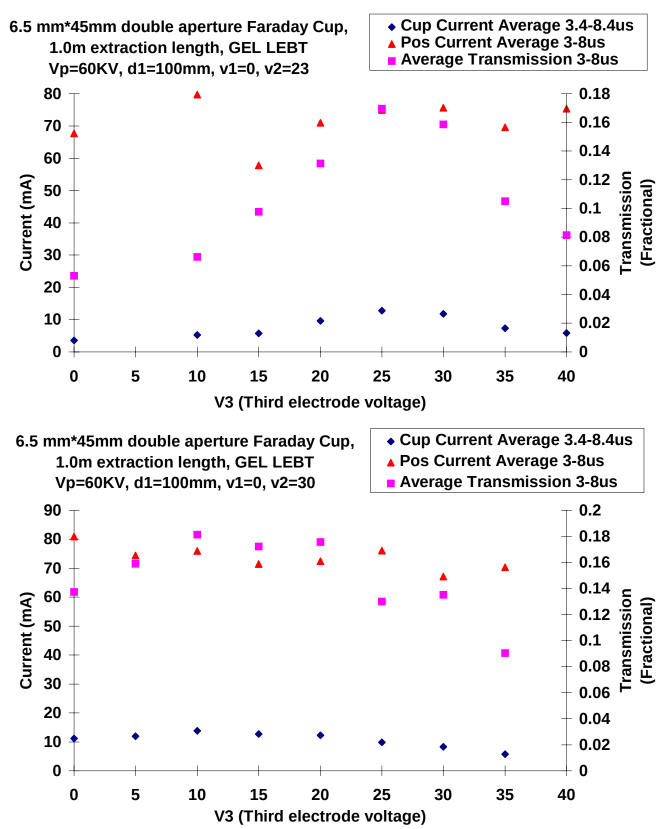


Figure 4 Transmission into a 6.5mm*45mm double aperture cup 100mm from the last grid. The transmission curves are shown for two different voltage values on the second electrode.

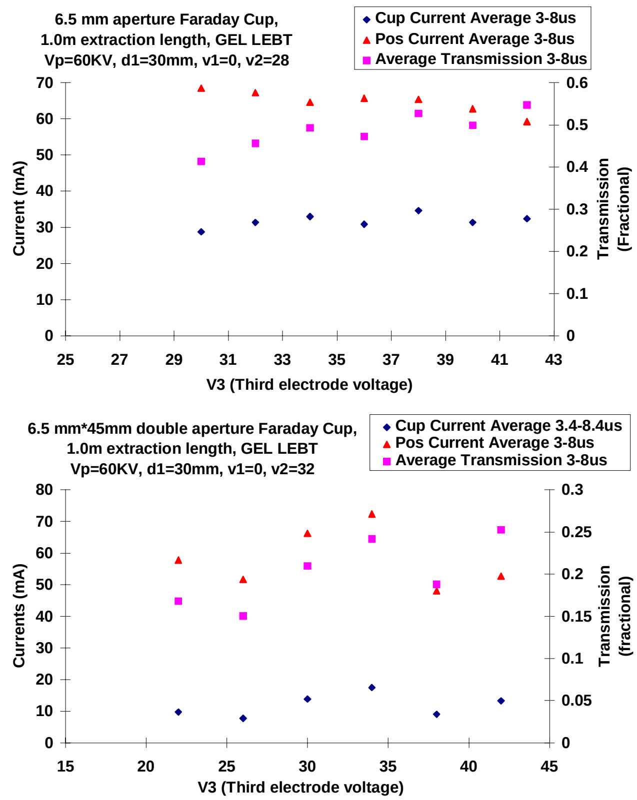


Figure 5 Transmission into a 6.5mm aperture and 6.5mm*45mm double aperture cup. The cup is laying 30mm from the last grid. For the case of the two-aperture cup, the mid-plane between apertures is 30mm from the last grid. The transmission curves are shown only for one optimum value on the second electrode.

When a 30 mm aperture Faraday cup is placed immediately after the GEL we measure the fraction of the beam that is captured by the GEL itself. The results of this measurement are shown in figure 6.
It should be taken into account that:

a) The transparency of each grid is 97.5%, so that the 4 grids should transmit about 90% of the beam
b) When the 30mm aperture cup is placed immediately after extraction the total measured current inside the cup is about 88.9% of the source current. This can be due both to the Pearson coil calibration, large electrical noise or the presence of a high divergence halo in the beam.

This means that practically all the beam measured after extraction is captured and transmitted through the GEL LEBT.

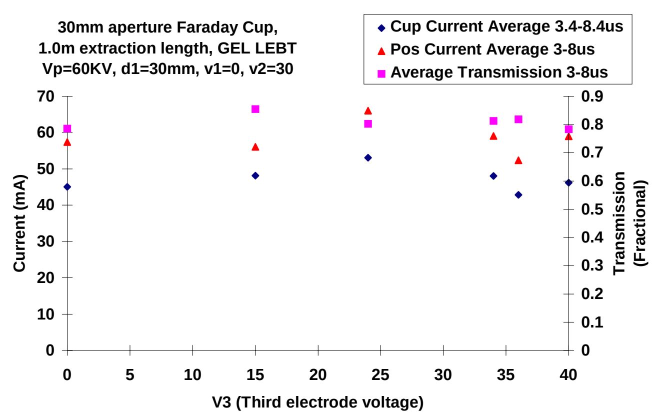


Figure 6 Transmission into a 30mm diameter cup. The cup is positioned 30mm from the last grid.

FURTHER MEASUREMENTS

After completing the characterisation, we discovered that all the previous measurements had been performed with the first electrode at ground. When we applied a potential (up to 7kV) we found a small difference in the transmission (about 10% increase) around similar working points as for the previous measurements, so that we did not repeated a complete characterisation but we limited ourselves to probe the around the previously found working points.

The “two aperture Faraday cup”, the Faraday cup with an acceptance was then modified in order to better approximate the acceptance of the RFQ. In all the previous measurements we used two circular apertures while in the present set of measurements we did replace them with square apertures. By doing so we decouple the acceptances in the x and y plane (increasing the total acceptance). This should be taken into account when comparing with the previous results. We decided nevertheless to upgrade to the new device to have a better idea of which current could be fed into the RFQ.

In figure 7 we show the effect of the potential on the first electrode for the double square aperture device.

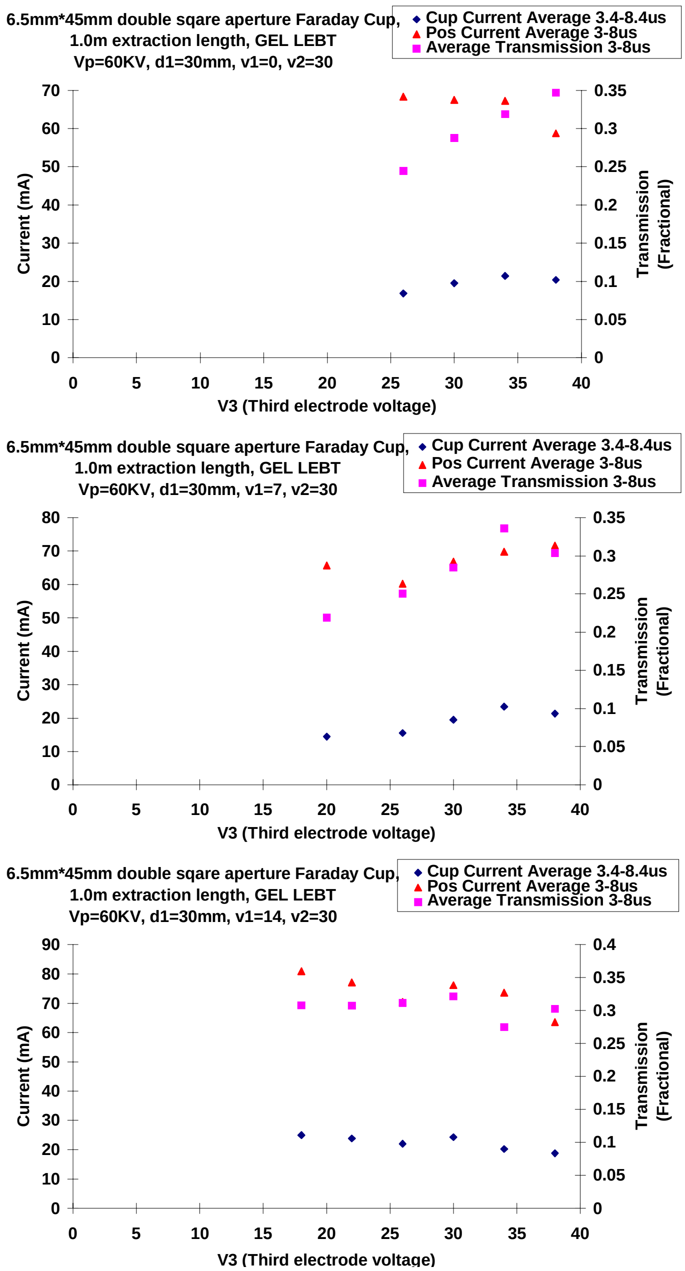
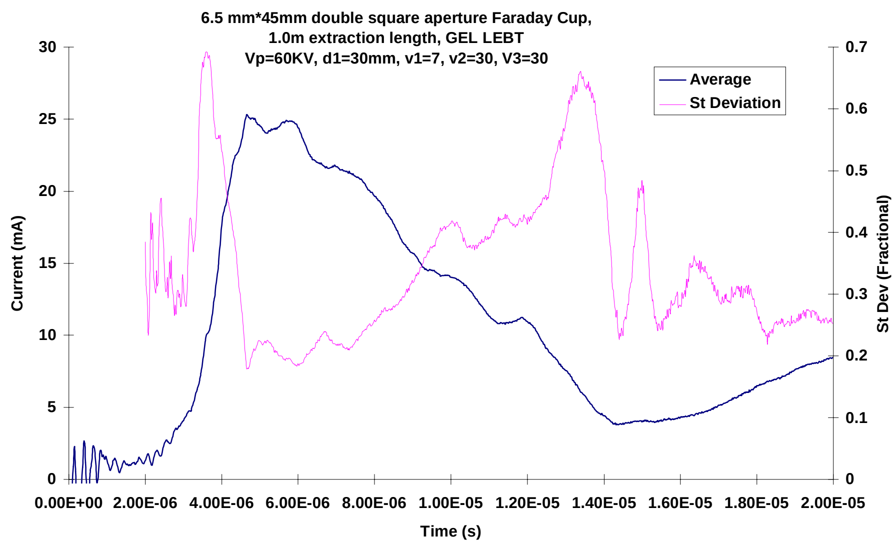


Figure 7 Effect of the potential on the first electrode. There is little difference between 0 and 7kV

CURRENT STABILITY

After finding the best working point for the electrode potentials we decided to take several shots (40) for statistics in order to quantify the reproducibility of the source.

We set the electrode voltages at 7, 30 and 30 kV for the first, second and third electrode respectively. The GEL had some problems in supporting higher voltages on the third electrode, so that we could not take the many shots necessary for statistics at higher voltages. In figure 8 we show the average and standard deviation waveforms for the cup current for a 40 shot run.



During this average of the Cup Current in the interesting time interval (3-8µs) is 21mA with a 12% RMS fluctuations, while the fluctuations of the source current were 16%.

GRIDDED EXTRACTION

We tested the concept of reducing the current fluctuations due to extraction by placing a grid onto the positive extraction electrode. The grid was of the same type as in use in the GEL LEBT with a nominal transparency of 97.5%.

We expected the current to be more stable due to the suppression of the strongly convex plasma boundary which appears when the plasma current is low.

In figure 9 we show the transmission curve for such conditions

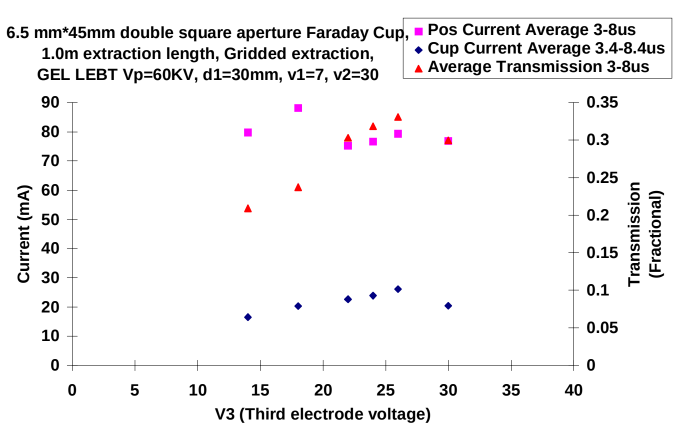


Figure 9 Grid on the extraction electrode, Transmission Curve

The operations of the source with the grid on the positive electrode were found to be more reproducible. In figure 10 we report the average and standard deviation waveforms of the cup current for a 40 shot run.

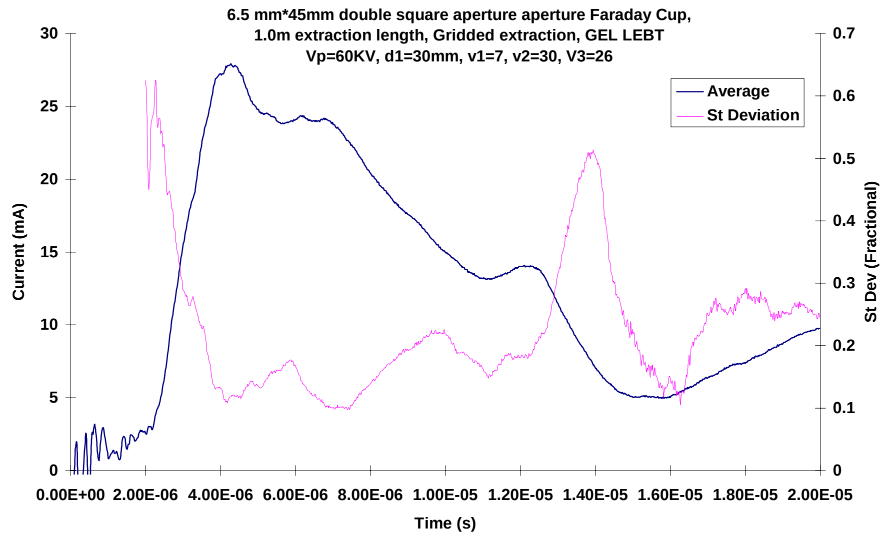


Figure 8 Average and Standard Deviation Waveform, 40 shot statistics

During this run the average of the Cup Current in the interesting time interval (3-8µs) is 24mA with a 5.5% RMS fluctuations while the fluctuations of the source current were 17%. Moreover it can be noticed that the current pulse is longer, indicating a better plasma extraction matching for lower plasma current densities.

CONCLUSIONS

In conclusion the GEL LEBT allows to feed a current of about 25mA (of which 12% of Ta^{20+}) in an acceptence of about 450mm.mrad. The next step will be the test of the GEL, and eventually of the one solenoid LEBT [4], with the LIS RFQ in order to compare the results with the old measurements performed with the two solenoid LEBT [6].

A considerable improvement of the extracted ion beam stability has been achieved by putting a grid on the extraction electrode.

BIBLIOGRAPHY

[1] *Emittance measurements by scanning slit device* R.Scrivens, B.Wolf.. 1999.

[2] R.Scrivens. PhD Thesis. 1999

[3] *Experimental Characterisation of Solenoid LEBT for LIS source.* N.Lisi, C.Meyer, R.Scrivens, F.Varela Rodriguez. PS/HP/Note 98-14 (Tech.)

[4] *Experimental Characterisation of Solenoid LEBT for LIS source: Short Solenoid to Extraction Distance*. P.Fournier, N.Lisi, C.Meyer, R.Scrivens, F.Varela Rodriguez. PS/HP/Note 99-02 (Tech.)

[5] *LIS LEBT on the base of electrostatic gridded lenses* P.Ostrumov, , Private Comm,1999.

[6] *High charge-state ion beam production from a laser ion source*. M.Bourgeois, G.Hall, H.Haseroth, S.Kondrashev, H.Kugler, K.Langbein, A.Lombardi, K.Makarov, W.Pirkl, Y.Satov, R.Scrivens, B.Sharkov, A.Shumshurov, A.Ster, A.Tambini, E.Tanke

Proc. XVIII Inter. Linear Accelerator Conf. CERN 96-07, p378-380 (1996).