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EXPERIMENTAL CHARACTERISATION OF SOLENOID LEBT FOR LIS SOURCE:
Short Solenoid to Extraction Distance

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Abstract

In a previous note we offered a complete set of experimental results to be compared with simulations for a LEBT based on one or two solenoid for the LIS beam. It was found that the one solenoid LEBT achieved higher transmission than the LEBT based on two solenoid. Here we repeated the characterisation of the one solenoid LEBT for a modified extraction system. Such system allows the solenoid to be placed closer to the extraction region (40 mm compared to 226 mm of the previous set-up). The charge state distribution of the ion beam was measured after the LEBT by using a magnetic spectrometer.

INTRODUCTION

In Ref. [1] we characterised a Low Energy Beam Transport (LEBT) for the Laser Ion Source (LIS) based on one or two solenoids. During such measurements the minimum distance where the first solenoid field could be placed after extraction was limited by the extraction region geometry to about 300 mm. The extraction system was then modified in order to allow the solenoid to come closer. In fact simulations predict a considerable increase in transmission into the RFQ acceptance when all the distances are kept small [2]. The beam and the solenoid were aligned by using the same procedure described in Ref. [1]. The extraction distance, that is the distance between the target and the extraction electrodes was kept fixed at 1.0 m.

TWO SOLENOIDS: CSD in the old configuration

For comparison with the measurements we present later we show here the CSD measured for the two solenoid case. Here the old extraction system was used and a distance of 226 mm should be added to d1.

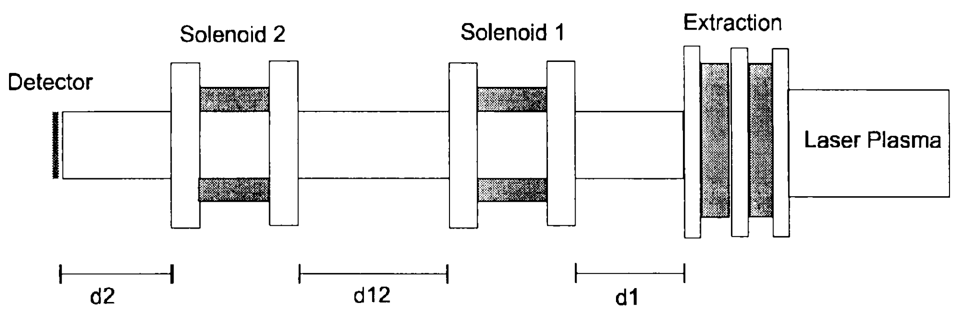

Figure 1. Two solenoid LEBT. The ion beam starts 226mm inside the extraction system. The magnetic spectrometer replaced the "detector".d1 = 80, d12 = 670, d2 = 145.

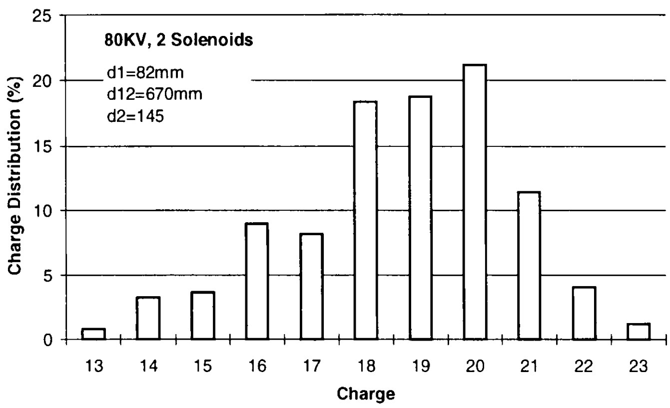

Figure 2. CSD obtained in the two solenoid set-up.

A magnetic spectrometer is placed after the solenoid. The charge state distribution (CSD) is measured by placing a fluorescent screen after the magnetic spectrometer. A CCD camera, gated over the arrival time of the highly charged ions (3-8 μs), records the image. Each peak is then identified according to the magnetic field with a single charge state. The relative area of the peaks (intensity times FWHM width) gives the CSD.

The charge state distribution shows a peak of transmission for the 20+ state of about 20%. The total current measured in a similar set-up using a 6.5 mm aperture Faraday cup was between 10-12 mA.

ONE SOLENOID: New configuration

The magnetic spectrometer was then placed after the one solenoid LEBT to measure the charge state distribution of the transmitted beam. In figure 3 is a scheme of the set-up.

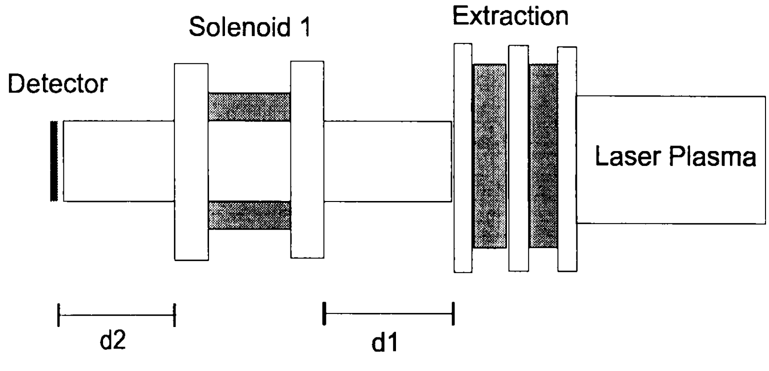

Figure 3. Scheme of one solenoid LEBT The distance d1 = 70mm. The ions are separated from the plasma a further 40 mm inside the extraction chamber. A magnetic spectrometer replaces the "detector"

TRANSMISSION IN FARADAY CUPS

Initially we placed the 6.5 mm aperture Faraday cup close to the solenoid, d1 = 70 mm and d2 =30 mm. According to simulations such short LEBT should have the highest transmission.

In figure 4 we show the transmitted current together with the transmission for three extraction voltages, 60, 70 and 80 kV. These curves are the result of three shots averages. We find that for extraction voltages of 70 and 80 kV the transmitted current is higher than 20 mA.

The same set of measurements was repeated for the two-aperture Faraday cup. Such device consists of two 6.5 mm concentric apertures separated by the distance of 40 mm. Such device should approximately simulate the acceptance of the RFQ. The double cup was placed at two different distances d2, 30 mm and 130 mm. The results are reported in figures 5 and 6.

We notice that in the last set-up up to about 14 mA of current can be transmitted in the double aperture Faraday cup. It is reasonable to think that while the transmission for the single aperture Faraday cup is highest for the shortest LEBT the transmission in the two aperture cup is maximum for a longer transmission line, which keeps the angles smaller.

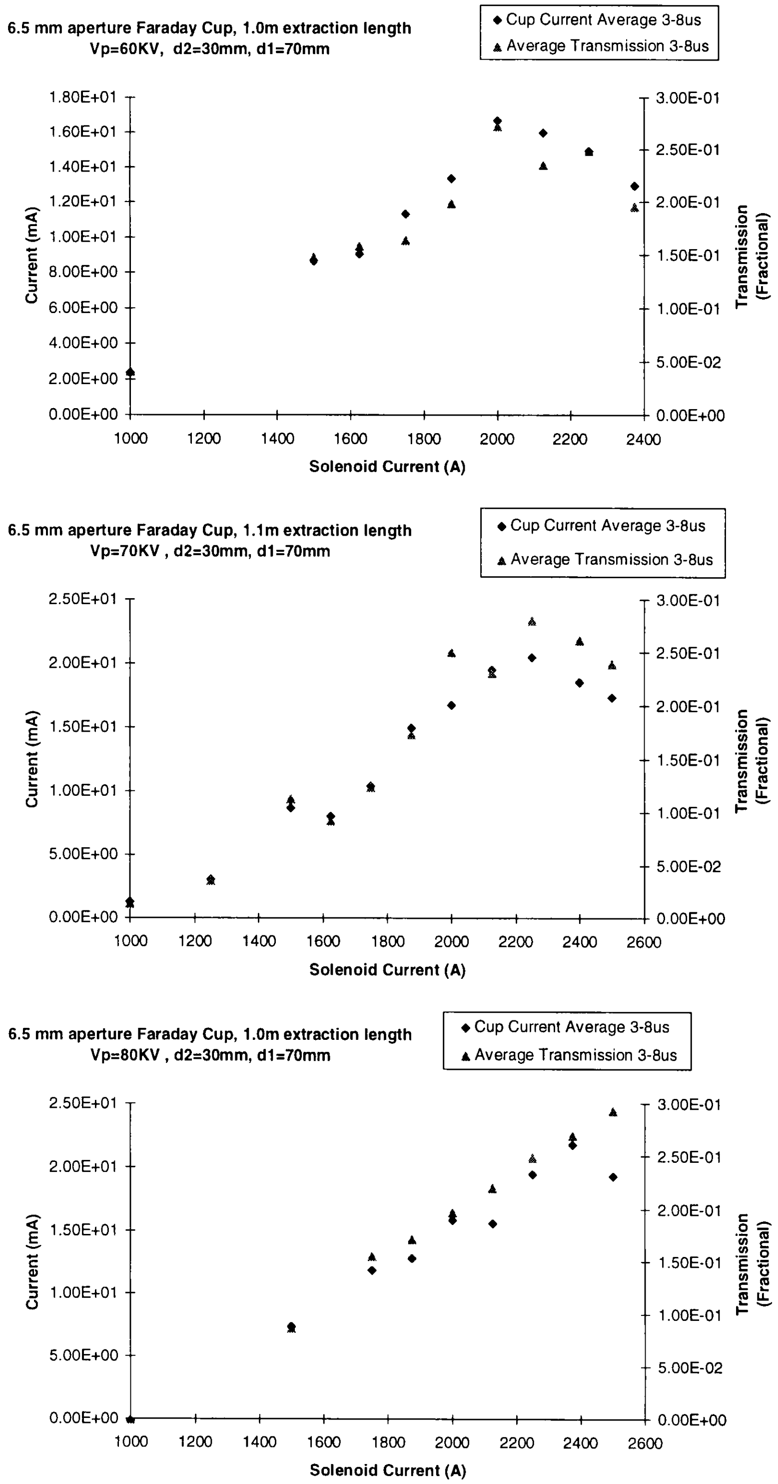

Figure 4. Transmitted current in a 6.5 mm aperture Faraday cup. Short one-solenoid LEBT.

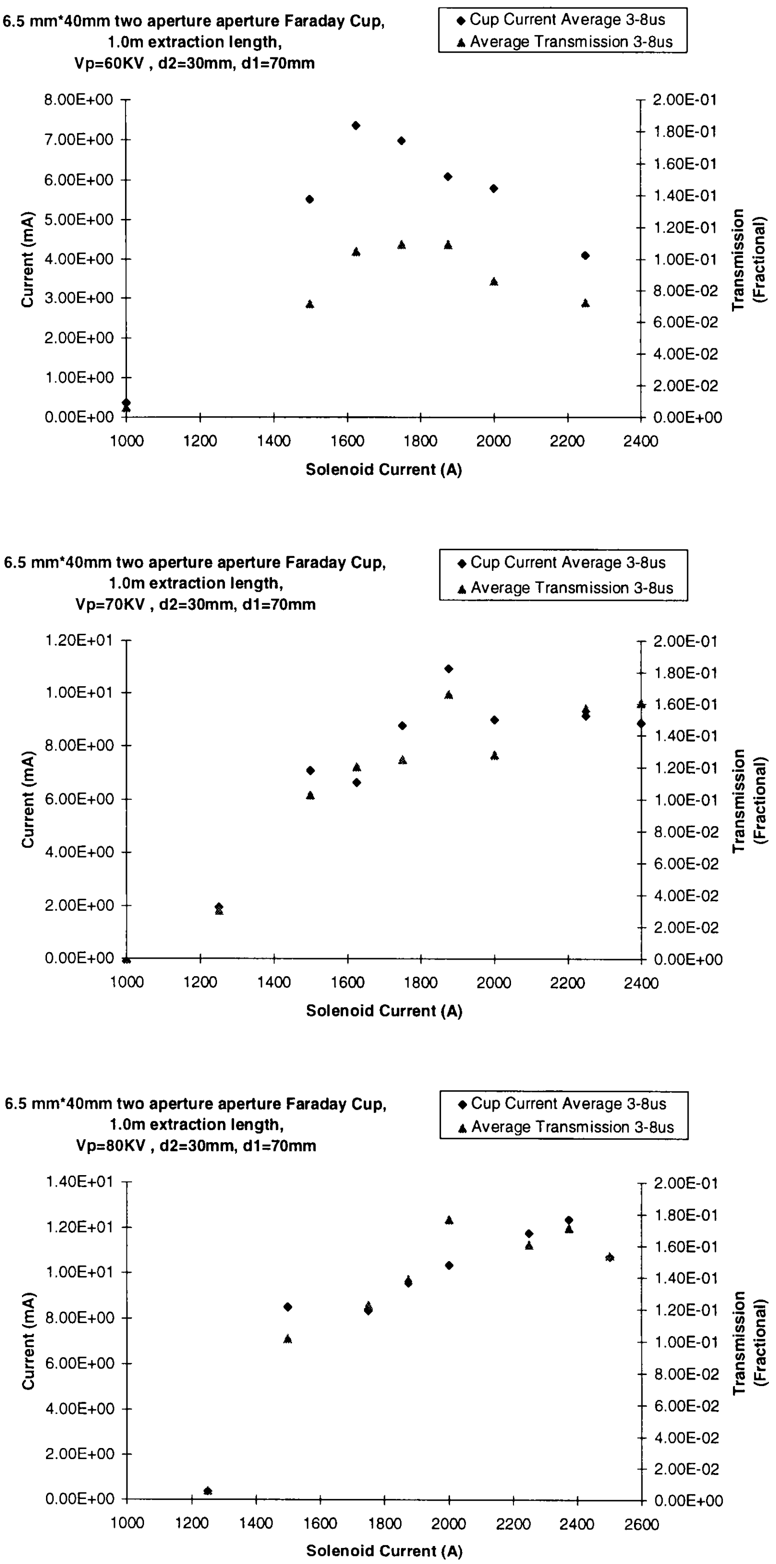

Figure 5. Transmitted current in a double aperture 6.5 mm × 40 mm aperture Faraday cup. Short one-solenoid LEBT, d2 = 30mm.

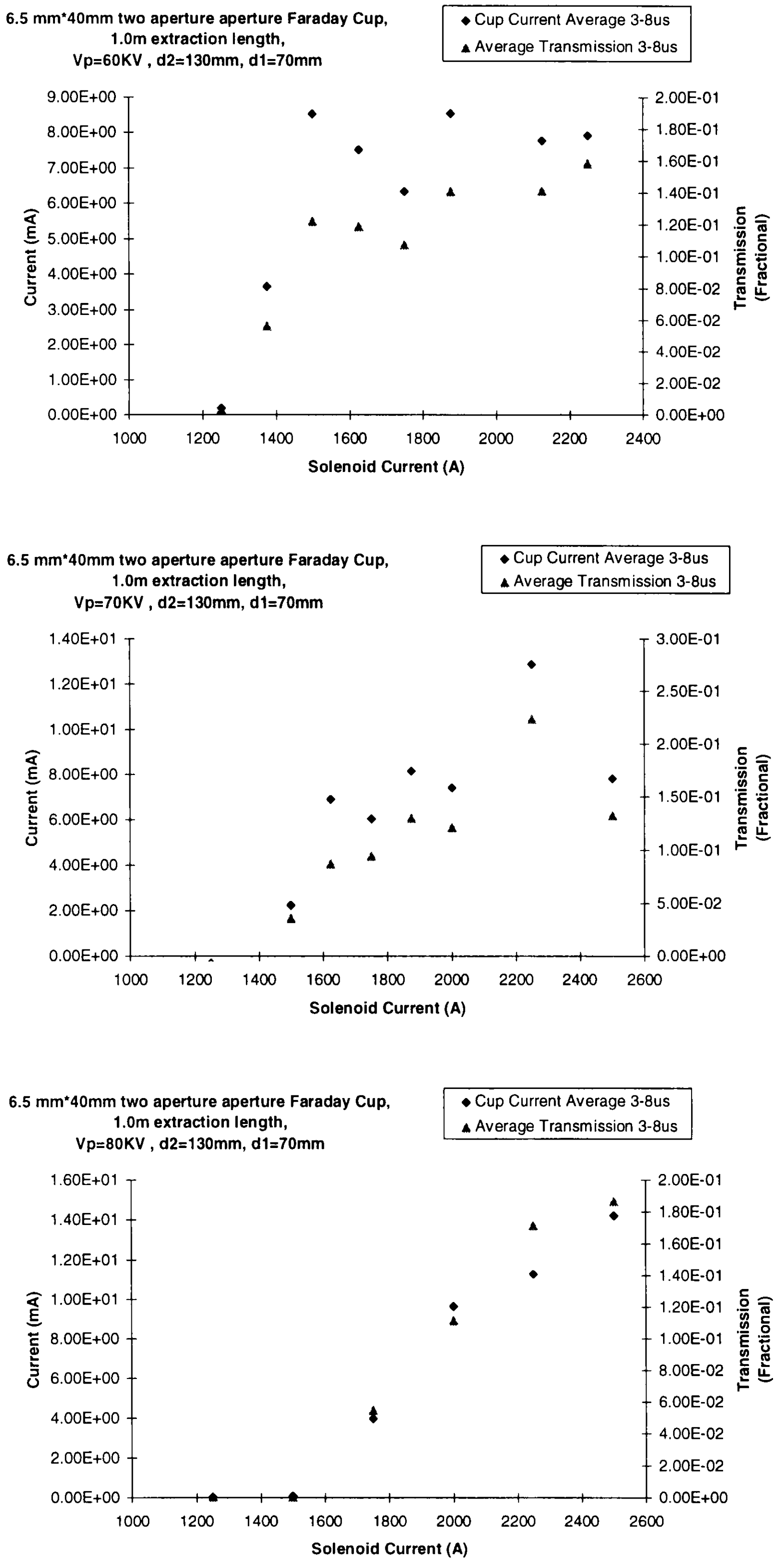

Figure 6. Transmitted current in a double aperture 6.5 mm × 40 mm aperture Faraday cup. Short one-solenoid LEBT, d2 = 130 mm.

ONE SOLENOID LEBT: CHARGE STATE DISTRIBUTIONS

The magnetic spectrometer was installed after the one solenoid LEBT in order to study the charge state distribution of the transmitted currents.

Before presenting the results it is appropriate to underline the limitation of the measurement. In fact the spectrometer is built to image a beam parallel on the incoming plane to a line focus on the output plane. This is achieved by the shaping of the magnetic field. It is important that such incoming parallel beam has low current so that space charge does not blow up the beam thus increasing the losses.

1) Our beam is focused by the solenoid, thus it is not parallel.
2) The current is high as several mA of current are transmitted through the input slit
3) The solenoid is a dispersive element and different charge will be entering the magnet with different angles. Consequently, they could experience different losses. In particular higher charge state could experience higher losses due to stronger focusing.

Under the hypothesis that the losses will be approximately the same for the high charge state group and that we are looking for a comparison between the one and the two solenoid case we will trust the results. Moreover, it is very difficult to think of a better measurement.

In order to measure the CSD the procedure is the following. First the charge state is selected (20+) by choosing the appropriate magnetic field, then the solenoid current is varied in order to maximise the signal for such state. Once optimised the transmission for 20+, the magnetic field is varied over the all spectrum to obtain the full charge distribution

The charge state distribution was measured at different distances d1 and d2. For d2 = 192 mm the results are in figures 7 and 8 for respectively 70 kV and 80 kV extraction. In figures 9 and 10 is the CSD for d2 = 40 mm for 60 kV and 80 kV respectively.

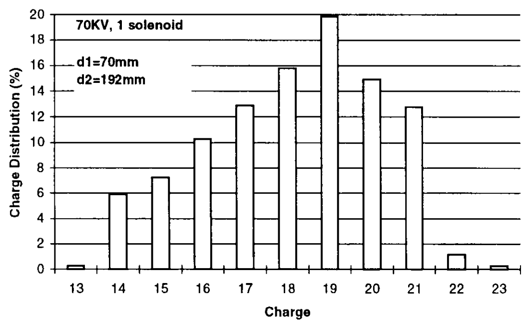

Figure 7. 70 kV extraction, CSD after one solenoid.

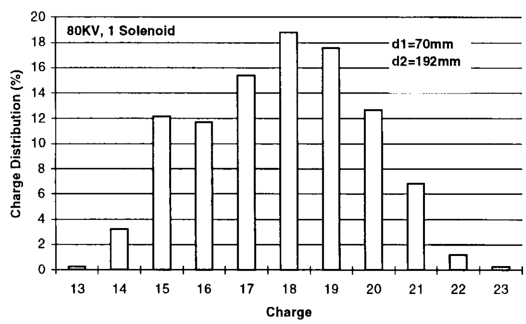

Figure 8. 80 kV extraction, CSD after one solenoid.

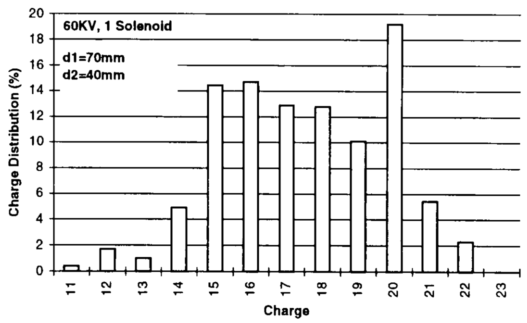

Figure 9. 60 kV, CSD after one solenoid. Short solenoid LEBT.

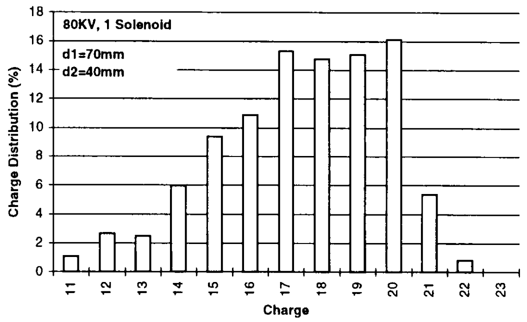

Figure 10. 80 kV extraction, CSD after one solenoid. Short solenoid LEBT.

CONCLUSIONS

In conclusions, it seems likely that about 20% of the current transported to the RFQ by a short one-solenoid LEBT could be made of the selected charge state, 20+. In the present set-up we achieved a transported current of more than 20 mA into a similar aperture Faraday cup and about 12-14 mA into a double aperture faraday cup with a similar acceptance.

Still it is possible that we already achieved a higher transmission without being able to measure it, this would be the case if the losses into the spectrometer where higher for the higher charge states. This is likely to happen due to the stronger focusing of the higher charge states in the solenoid transmission line which could lead to a steeper entrance angle.

Figures 11 and 12 show the typical traces obtained from the CCD images taken after the spectrometer. The 20+ peak is broader than, for example the 15+. This seems to imply higher losses inside the spectrometer.

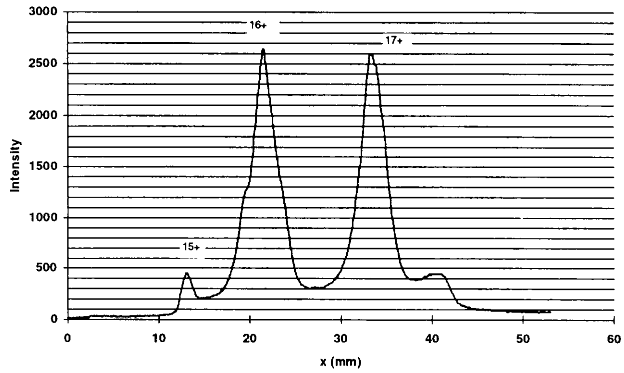

Figure 11. Trace from the CCD after the spectrometer. The peaks for lower charge states are narrow.

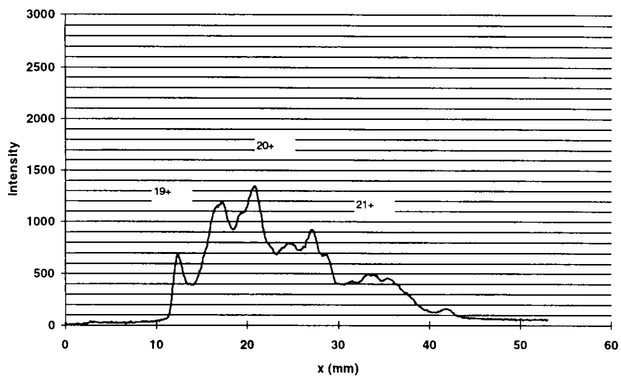

Figure 11. Trace from the CCD after the spectrometer. The peak for the optimised charge state (20+) is broader (figure.10).

REFERENCES

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

[2] M. Breese, J.C. Schnuriger, *PATH Simulations of a Solenoid LEBT.*
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