A Low Energy Beam Transport System for the Superconducting Proton Linac

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Abstract

A low energy beam transport system from the H^- source to the radio frequency quadrupole at the beginning of the proposed Fermilab superconducting proton Linac is designed and analyzed. The system is robust, simple, and allows the ion source to be quickly replaced.

Introduction

For the superconducting proton Linac [1], the beam will be transported and matched from the source to the radio frequency quadrupole (RFQ) using a short low energy beam transport (LEBT). The present ion source produces 45 mA of H^- beam at 50 keV. At the entrance to the RFQ, the beam has to have following Twiss parameters [2]:

	Normalized rms Emittance	alpha	beta
x-plane	0.25 mm-mrad	1.6	0.0552 mm/mrad
y-plane	0.25 mm-mrad	1.6	0.0552 mm/mrad

The design of the line is based on the following requirements [3]:

- No electrostatic elements
- No bunching at low energy
- Pressure > 10E-6 torr to have more than 90% neutralization
- Pressure < 10E-5 torr to avoid stripping more than 10% per meter
- No potential wall traps for ions
- Fast Ion Source replacement
- Accurate and fast beam diagnostics
- Transport line as short as possible to avoid emittance growth.

Layout of Transport Line

The line has one solenoid [4], two trim magnets, two vacuum valves with pumping ports, and a quick disconnect before the second vacuum valve, as shown in Figure 1.

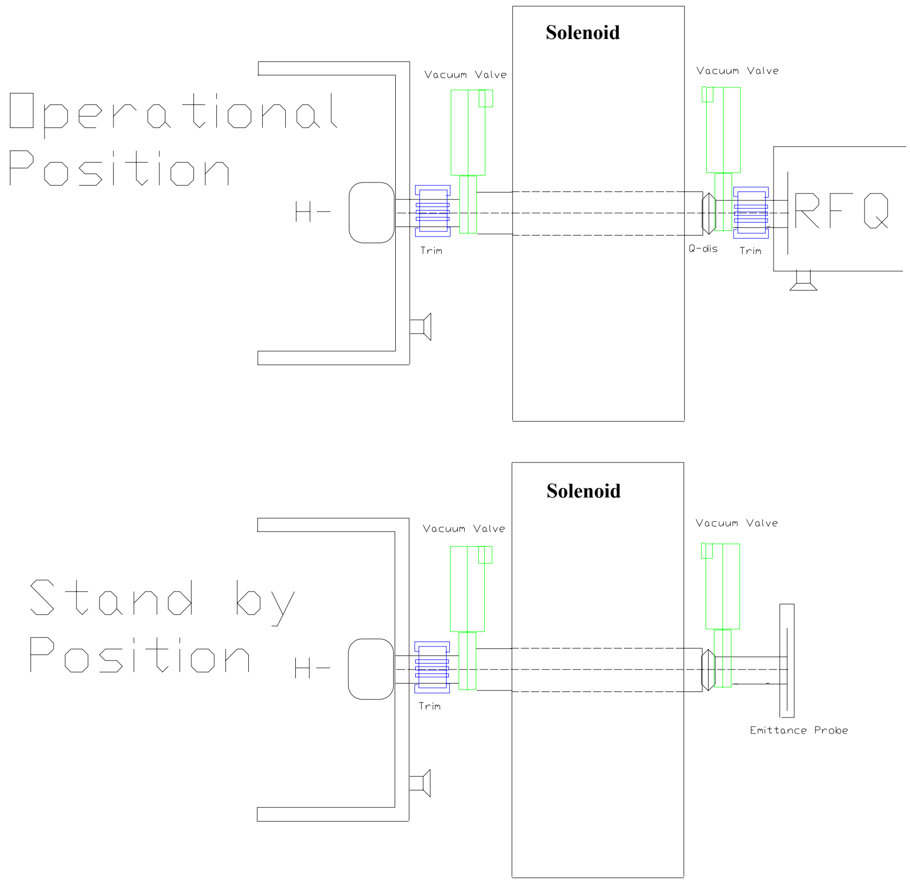

Figure 1.

The ion source, which is held at negative high voltage, the grounded column terminal that contains the ion source, the first correction trim magnet package, the first vacuum valve, and the solenoid make up the first unit. The second vacuum valve and the second correction trim magnet package are attached to the RFQ and are a second, separate unit. The main pumping ports are on the grounded ion source container and on the body of the RFQ. The two units are connected together using quick disconnects and the two pumping ports on the gate valves are used to quickly pump down the interconnecting region to operational pressure. The Solenoid has an inner bore radius of 50 mm and can be moved along the beam pipe between the first gate valve and the quick disconnect. The total length of beam transport from the source aperture to the matching point of the RFQ is about 700 mm. The distance from the quick disconnect to the RFQ matching point is about 100 mm.

Matching to the Source Parameters

There are two parameters that are not known and can change during operation:

- The level of charge neutralization in the transport system, and
- The level of beam divergence from the source.

Charge neutralization depends on the gas pressure in the transport line and can be relatively easily compensated by changing the field of the solenoid. Figure 2 shows Trace3D [5] runs for two beam currents, 0 current (100% neutralization) and 45 mA (0% neutralization). The magnetic field of the solenoid was changed from 3518 to 3965 Gauss to have same values of Twiss parameters at the entrance to the RFQ.

The beam divergence, the alpha beam parameter, from the source in this note is assumed to be between 0 and -3 for currents between 0 and 45 mA, Figure3.

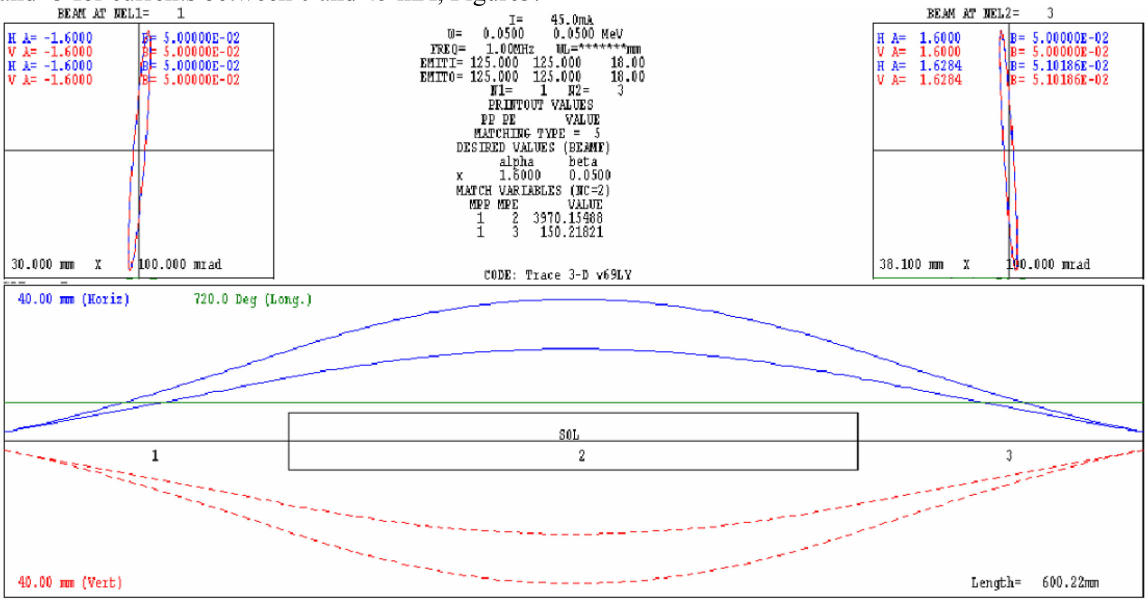

Figure 2. Matched position of solenoid with solenoid current adjusted for 0 and 40 mA beam current. It is clear that different degree of neutralizations can be compensated changing solenoid current.

These input parameters are in accord with measured values by the Brookhaven group. For their source, with extraction energy of 35kV, current of 100mA, normalized beam emittance of 325 mm-mrad for 95% of the beam, alpha is -0.36 and beta=0.018.

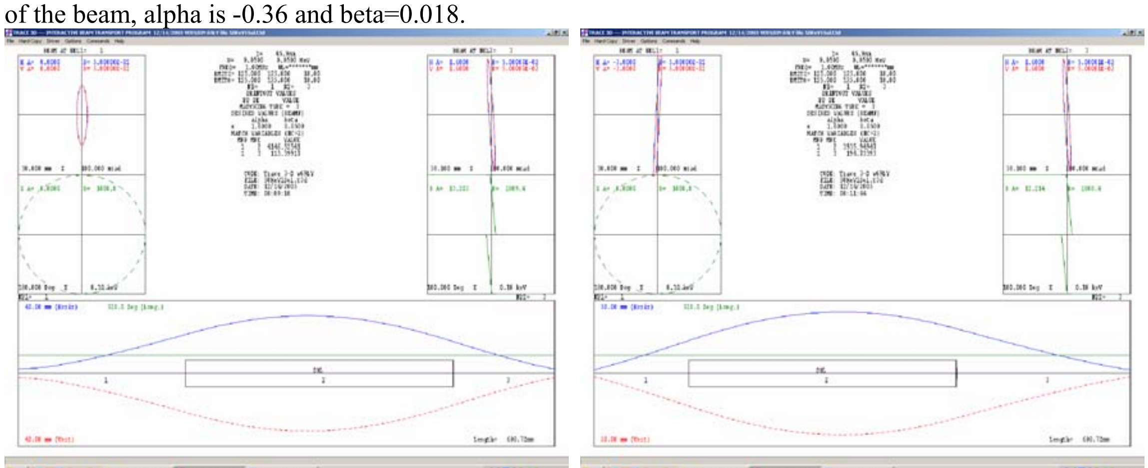

Figure 3. Solenoid position adjusted for input beam Alpha=0 and Alpha=-3 to match the beam at the RFQ.

Errors and Tuning

Steering errors are corrected using two trim magnets, one right after the source and the other at the entrance to the RFQ. The trim magnets are window frame magnets with horizontal and vertical correction coils on the same frame, as shown in figure 4. The magnet next to the RFQ is 40 mm long, with an effective length of 30 mm such that a field of 100 Gauss will give an angle of 10 mr. This angular kick will be more than enough to correct for any positional misalignment of the source or solenoid. The field can be produced with 600 Amp-turns per coil.

The trim magnet near the source corrects for any misalignment of the source and the ground terminal. This magnet can be 70 mm long with an effective length of 60 mm and will be used to center the beam in the aperture of the RFQ. The main adjustment will be done in stand-by position using an emittance probe. The magnet will be used to correct for any tilt left over after mechanical adjustment of the source and the ground terminal. Any additional adjustment will be done with the RFQ, after adjusting the solenoid and the second trim magnet. The required steering power of the trim magnet will be determined from the maximum expected mechanical errors.

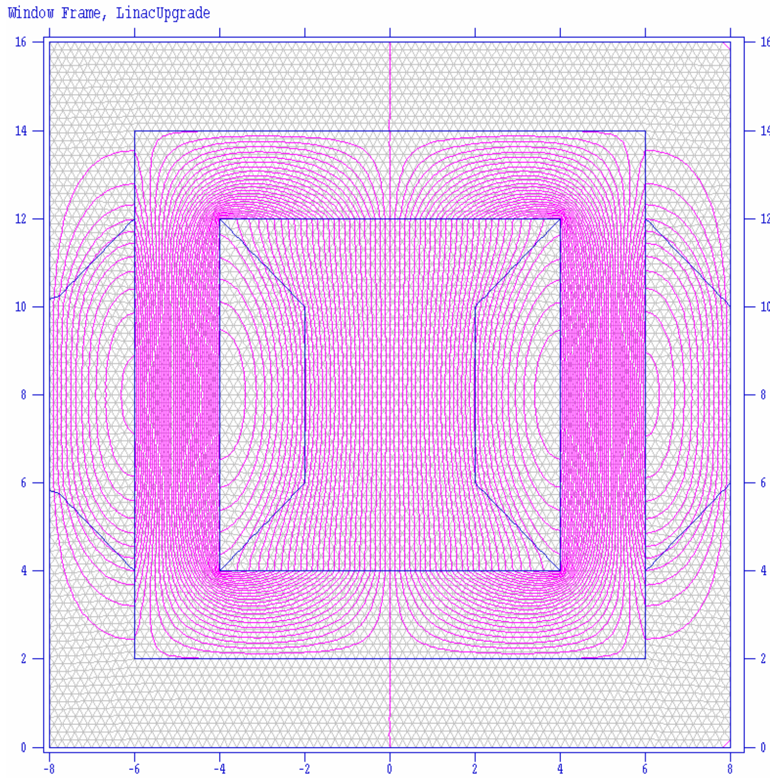

Figure 4

Operational Aspects

Present experience at Fermilab and other labs shows that the ion source does not need a lot of maintenance and has a lifetime of about four months. In the scheme described here, we assume that there will be a second source in stand-by mode such that the source, trim magnets, and the position and current of the solenoid have been adjusted using the emittance probe. When the stand-by probe is put into its operational position the second trim can be adjusted, and if necessary for very fine tuning, the solenoid can be moved and its current adjusted. Positioning, connecting, and pumping down of the short line will take less than 30 minutes. The LEBT and RFQ will be accessible while the beam is operating such that the solenoid can be moved while the beam is on.

Summary and Conclusion

A simple LEBT based on a consistent set of assumptions has been designed. The LEBT length was chosen to be able to use an existing solenoid that was used for a previous project (PET), an off-the-shelf gate valve, and to match a large range of ion source input beam parameters. Measurements of the ion source beam divergence and the level of neutralization will define the length and field strength of the solenoid and the length needed for tuning. In the design described here, the LEBT is 600 millimeters long and could be made even shorter.

References

[1] G.W. Foster and J. A. Maclachan, Proceedings of LINAC 2002, Gyeongju, Korea
[2] Ostrumov Design Note

[3] R. Baartman, TR30-DN-25,TRIUMF Note, 1989
[4] PET Project Papers, http://www-linac.fnal.gov/pet/papers/
[5] Trace3D, LA-UR-97-886, 1997, Los Alamos