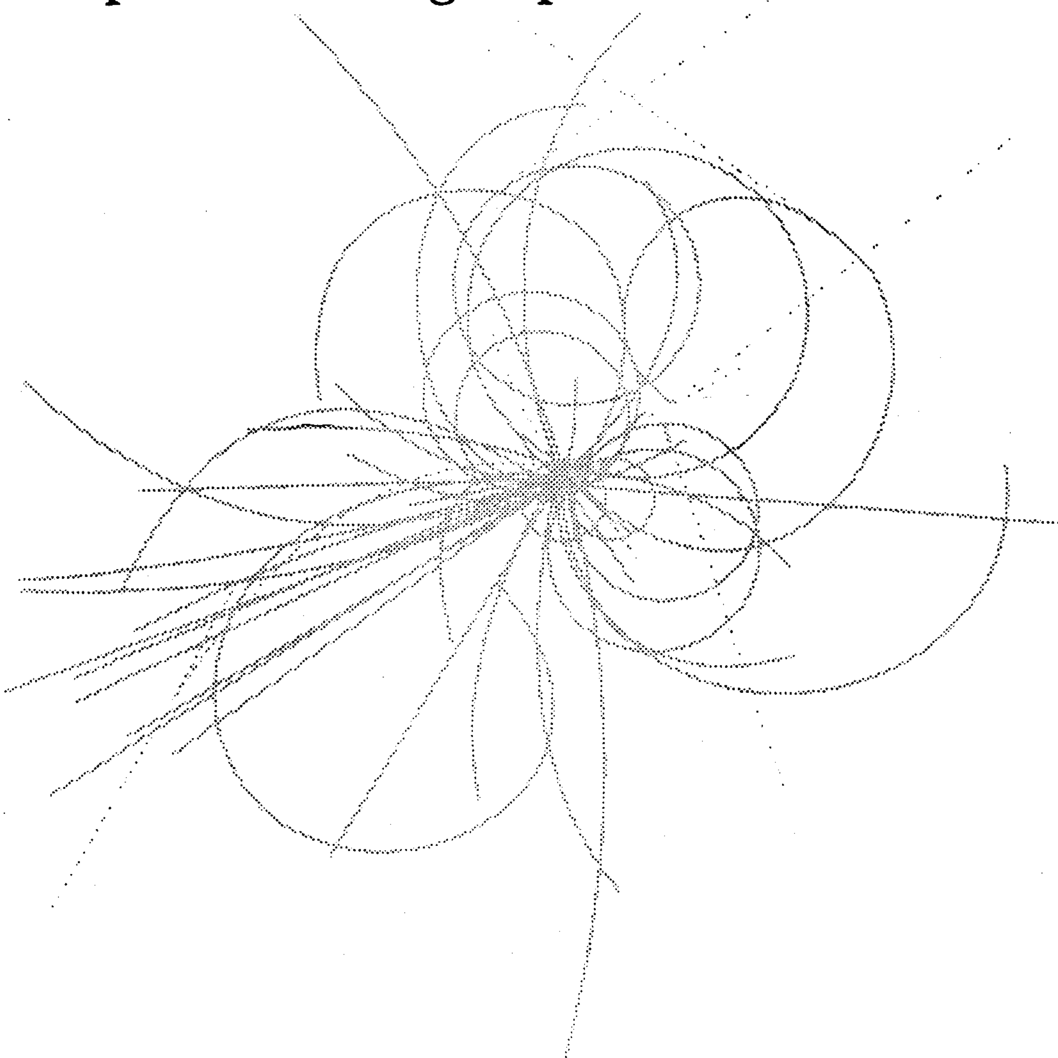
SSCL-312

SSCL-312

Superconducting Super Collider Laboratory



HESQ, A Low Energy Beam Transport for the SSC Linac

D. Raparia

September 1990

SSCL-312

HESQ, A LOW ENERGY BEAM TRANSPORT FOR THE SSC LINAC*

Deepak Raparia

Superconducting Super Collider Laboratory†
2550 Beckleymeade Ave.
Dallas, TX 75237

September 1990

---

*Presented at the 1990 Linear Accelerator Conference, Albuquerque, NM, September 10–14, 1990.

†Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC02-89ER40486.

HESQ, A LOW ENERGY BEAM TRANSPORT FOR THE SSC LINAC

Deepak Raparia

Superconducting Super Collider Laboratory*
2550 Beckleymeade Avenue
Dallas, Texas 75237

ABSTRACT

A Helical Electrostatic Quadrupole (HESQ) is an option for the low energy beam transport (LEBT) of the SSC linac to transport and match a 35 keV H^- beam from a circular symmetric Magnetron ion source to a 428 MHz RFQ. Being an electrostatic focusing lens, the HESQ avoids neutralization of the H^- beam due to the background gas. The HESQ lenses provide stronger first-order focusing in contrast to weak second-order focusing of einzel lenses and is also stronger than alternating gradient focusing. In this paper, we will present a design and results of a PIC code simulation with space charge.

INTRODUCTION

The low energy beam transport (LEBT) is the section of the linac that provides the matching between the ion source and the radio frequency quadrupole accelerator (RFQ). The LEBT consists of lenses that focus the beam into the RFQ. The beam from an ion source is relatively large in radius and divergence and must be matched to the RFQ.

Existing LEBT systems for H^- beams use magnetic focusing solenoids [1-3] or permanent magnetic quadrupoles[4]. These LEBT systems utilize charge neutralization in the background gas to minimize the required focusing strength. The neutralization time must be short compared to the pulse length; otherwise, much of the beam at the front of the pulse will be lost due to inadequate focusing. During this neutralization time the space charge force changes. Because of this the beam phase space ellipse rotates, making it difficult to match the beam to the RFQ acceptance. Additional problems arise due to beam-plasma instability and the fact that the beam becomes charged again, when it enters the electric field of the accelerating structure which sweeps away the charge neutralizing ions formed in the collisions. Improper matching in such transitions and emittance growth from sheath transitions into and out of gas neutralized regions may caused particle loss.

The Superconducting Super Collider (SSC) linac requires 7-35 μsec pulse lengths. The neutralization time is of the order of 100 μsec with hydrogen as the residual gas. During the first 100 μsec the beam focusing would be changing. That means one would use a pulse length from the ion source of 107- 135 μsec and considerably reduce the lifetime on the ion source. The neutralization time can be reduced by introducing xenon in the LEBT; however, full neutralization will always considerably increase the pulse length required from the source. We have chosen to avoid neutralization by using focusing in the form of electric forces which can be provided by: (1) Einzel lenses, (2) Electrostatic quadrupole FODO channel (ESQ), (3) Helical electrostatic quadrupole (HESQ), or (4) Radio-frequency quadrupole (RFQ). The FODO channel typically uses very high voltage and have typically had significant reliability problems. The RFQ can probably transport higher currents with less aberration, but it is more complex and adds another RF system. Einzel lenses [5] and HESQ[6-8] are the leading candidates for the SSC linac.

HELICAL ELECTROSTATIC QUADRUPOLE LEBT

The buildup of plasma and charge neutralization cannot occur in electrostatic lenses, as it does in magnetic lenses, since the electron-ion pairs produced in collisions between beam particles and background gas are swept out of the beam region by the electric field between the electrodes. Furthermore, magnetic focusing is particularly ineffective at low beta because of the velocity term in the force equation. Electric focusing, on the other hand, has no such velocity term in the force equation and should be a prime candidate for the focusing role at low velocities. The main problems in electrostatic focusing is breakdown and aberrations. The problem of the breakdown can be overcome by providing lower but spatially continuous focusing forces, as in a HESQ, instead of spatially discreet but higher focusing forces as in a FODO structure. The spatially continuous focusing forces also help keep the beam size smaller all the time, thus minimizing aberration.

Our new approach for transport of H^- beams uses HESQ focusing instead of usual combination of magnets and gas neutralization or the ESQ[9]. The HESQ is merely a continuously twisted electrostatic quadrupole (figure 1). The

* Operated by the Universities Research Association, Inc., for the Department of Energy under contract No. DE-AC02-89ER40486.

HESQ lenses provide stronger first-order focusing in contrast to weak second-order focusing of einzel lenses, stronger focusing than the alternating gradient type and an axially symmetric beam which is necessary for the RFQ matching. The idea of a helical quadrupole is not new[10-14]. Past works were about `magnetic helical quadrupoles' for different purposes. Some of the features of our plasma-free LEBT are: (1) gas independence permits beam with arbitrarily short pulse lengths, (2) gas independence improves reproducibility, and (3) emittance growth from plasma noise and from sheath transition into and out of gas neutralized regions is eliminated.

BEAM SIMULATION

The main parameters for the SSC HESQ are shown in table I . HESQ electrodes will be built by the nickel electroforming. Individual elements will have through - tapped holes near each end for installation of studs for ceramic standoff mounting. The beam cannot directly hit the ceramic and there should not be charge buildup (figure 2). The HESQ is longitudinally divided into four sections to provide four degrees of freedom for matching to the RFQ. Each section is 0.75 λ long. The first and third sections electrodes are powered individually so that steering can be provided.

Table I: HESQ Specification

Length	22.5	cm
Voltage	7.0	kV
Break down voltage	100.0	kV
Pitch of the Helix (λ)	15.0	cm
Electrode spacing	1.46	cm
Bore radius	1.5	cm

Beam dynamics and the constraints of the HESQ has been discussed previously [8]. Here we will present the PIC code simulation results only. This code is a two dimensional code which uses a 4 X 4 matrix representation for each component. The code also includes nonlinear space charge effects. Figure 3 shows the x and y profiles through the HESQ. Notice that the beam size is always lass then equal to 1 cm, i.e. 66 % of the aperture. Figure 4 shows the input and output phase space plots of the HESQ. Figure 5 shows the input and output phase space plots for a misaligned injected beam. Table II shows the input and output beam emittances for different currents for the waterbag input distributions.

Particle distributions obtained from the HESQ were used to simulate the RFQ performance using the code PARMTEQ.The transmission was more than 90% with 15 % transverse emittance growth. The main parameters of this RFQ are: bore radius=3mm,max field=1.73 x Kilpatrick, length 2.2 meter, freq=428 MHz, output energy 2.5 MeV.

Table II: Emittances (RMS)

Current	Input	Output
0 mA	0.18 π mm mrad	0.19 π mm mrad
30 mA	0.18 π mm mrad	0.22 π mm mrad
50 mA	0.18 π mm mrad	0.24 π mm mrad

CONCLUSIONS

The use of a HESQ in H^- LEBTs avoids neutralization problems for short pulses. It provides an axially symmetric beam which is necessary for the RFQ matching. The HESQ is presently being developed and may have superior performance and reliability than other LEBTs for short pulsed beam.

ACKNOWLEDGMENTS

We wish to thanks to C. R. Chang and R. Bhandari for useful discussions, R. Cutler for suggesting the electroforming techniques for manufacturing the electrodes, D. Evans for the engineering support, and J. Watson for his support and encouragement.

REFERENCES

[1]. J. Alessi, et al, Proc. of the European Particle Accelerator Conf., Rome, Italy. (June 1988)
[2]. S. H. Wang, DESY report, DESY 84-092. (Sept. 1984)
[3]. F. Cole et al., Proc. of the 1987 IEEE Particle Accelerator Conf., Washington D.C. p.1985 (1987)
[4]. P. G. O'Shea, et al., Proc. of the 1989 IEEE Particle Accelerator Conf., Chicago. p. 354 (1989)
[5]. C. R. Chang, This conference.
[6] D. Raparia and S. Machida, Proc. of the 1989 IEEE Particle Accelerator Conf., Chicago. p. 981 (1989)
[7] P. A. Tompkins, F. R. Huson and D. Raparia, Proc. of the IEEE Particle Accelerator Conf., Chicago. p.331 (1989)
[8] D. Raparia, to be published in the Proc. of the Fifth International Symposium on Production and Neutralization of Negative Ions and Beams, Brookhaven, NY. (1989)
[9] O. A. Anderson, et al., to be published in the Proc. of the Fifth International Symposium on Production and Neutralization of Negative Ions and Beams, Brookhaven, NY. (1989)
[10] L. C. Teng, Argonne National Lab. Report, ANLAD-55, (1959)
[11] S. Ohnuma. TRIUMF Report, TRI-69-10, (1969)
[12] G. Salardi, et al., Nuclear Instruments and Method in Physics Research 59, p.152 (1968)
[13] R. M. Pearce, Nuclear Instruments and Method in Physics Research 83, p. 101 (170)
[14] R. L. Gluckstrn, Proc. of the 1979 Linear Accelerator Conf., Montauk, p.245 (1979)

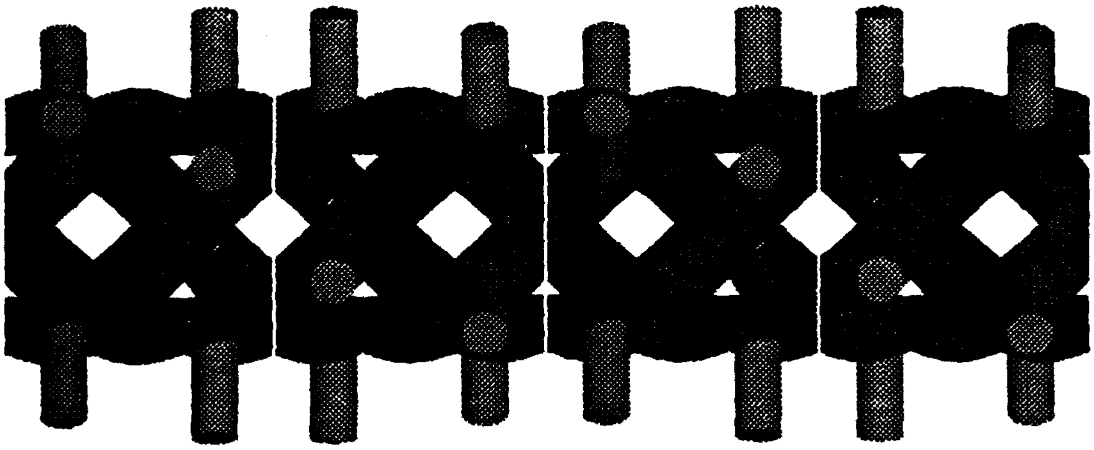


Figure 1. HESQ with electroformed nickel electrodes and ceramic insulators.

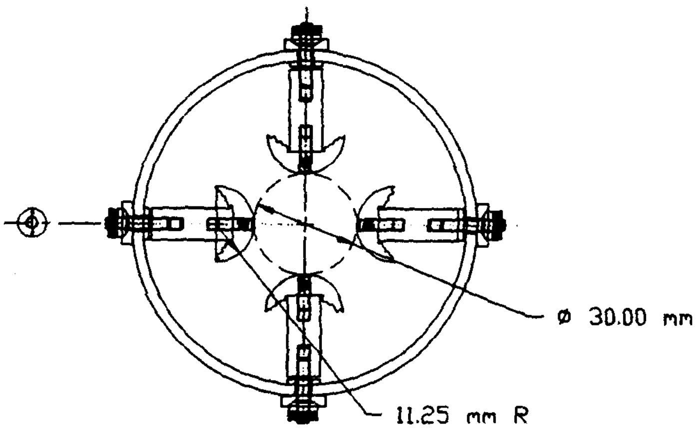


Figure 2. Planer section view of the HESQ.

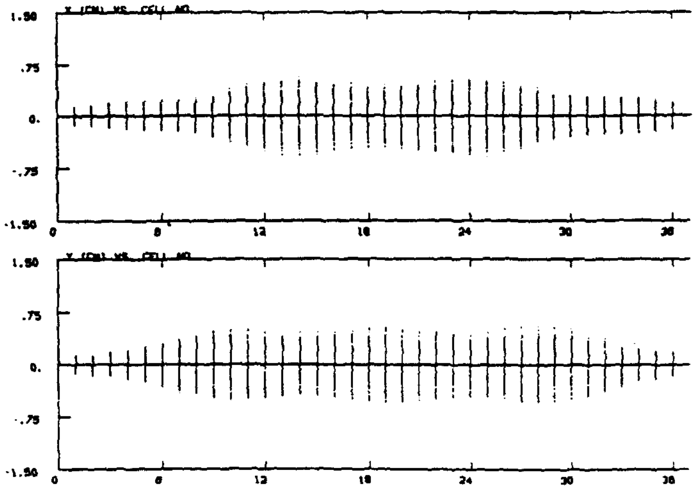


Figure 3. X and Y beam profile through the HESQ.

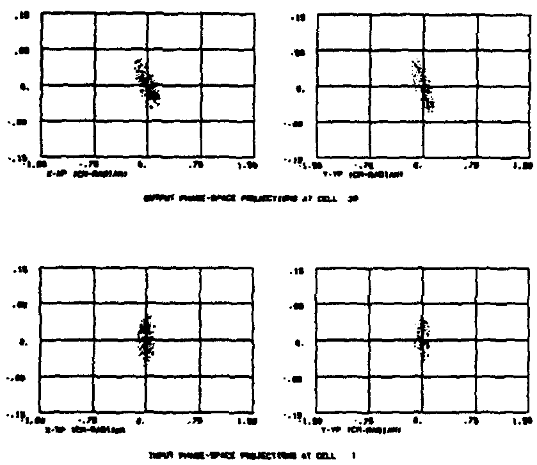


Figure 4. Input and Output phase space plots.

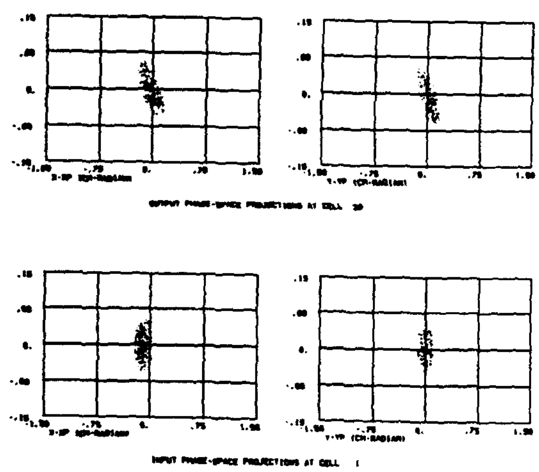


Figure 5. Input and output phase space plots of the HESQ for a misaligned injected beam