ISOCHRONOUS 180° TURNS FOR THE SLC POSITRON SYSTEM*

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ABSTRACT

The design of the compact, achromatic, second order isochronous 180° turn for the SLC positron transport system will be described. Design criteria require an energy range of 200±20 MeV, energy acceptance of ±5%, transverse admittance of 25π mm-mr, and minimal lengthening of the 3 to 4 mm (rms) positron bunch. The devices had to fit within a maximum height or width of about 10 ft. Optics specifications and theoretical performance are presented and compared to experimental results based on streak camera measurments of bunch length immediately after the first isochronous turn (200 MeV) and positron beam energy spread after S-band acceleration to 1.15 GeV.

INTRODUCTION

The overall design of the SLC positron system is described elsewhere [1]. Briefly, the operation is as follows: (1) Electrons of 30 to 33 GeV are extracted at about the 2-km point of the 3 km linac and focused on a tungsten-tantalum target. (2) Positrons from the target are captured by a magnetic focusing system and a 1.5 m high gradient linac section, and then accelerated to ~200 MeV by three 3 m linac sections. (3) The positrons are then transported back to the beginning of the main linac, reinserted, and accelerated through the first sector (100 m) to about 1.15 GeV. (4) They are then injected into a damping ring which shrinks transverse and longitudinal emittances and stores the bunch until a later machine pulse. (5) The damped positron bunch is extracted from the ring, reinjected into the main linac and accelerated to 40 to 50 GeV. (6) Positrons and electrons are separated, transported through the arcs and final focus systems, and collided at the interaction point.

Just after the initial acceleration and again before reinjection into the main linac, the positrons must be turned around by 180° (the so-called East Turn and West Turn, respectively). A design which satisfies the rather restrictive optical and physical constraints on these Turns is described below.

DESCRIPTION OF THE SYSTEM

Specifications. The beam-optical criteria of the system are listed in the table:

Design Energy	E_0	200±20 MeV
Admittance	ϵ	25 mm-mr
Energy acceptance	$\Delta E/E$	±5%
Bunch lengthening	δz	≪4.5 mm

The admittance was chosen to match that of the 200 MeV booster linac which has a guide field of 0.5 Tesla and an effective radial aperture of ~8 mm; the admittance then is given by $\epsilon = \frac{1}{2}B_0 a^2/B\rho$. The energy acceptance is chosen to effectively contain the spectrum of shower positrons which have been captured and accelerated to ~200 MeV (See Fig. 3c).

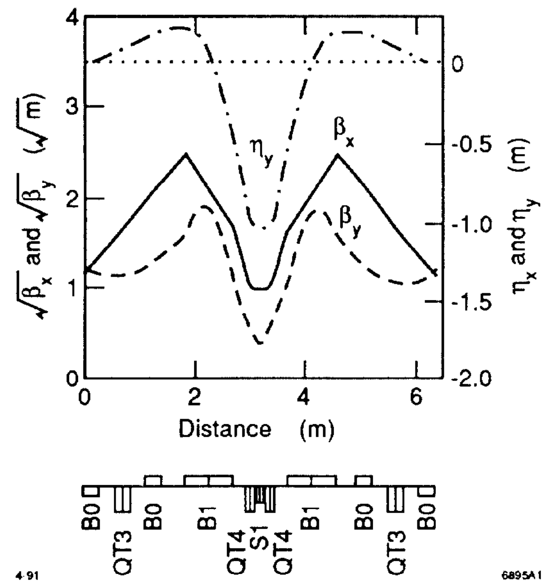

Figure 1. Optical functions of the 180° Turns.

The bunch length criterion is set by the energy acceptance of the damping ring, about ±1%. The energy spread after acceleration to 1.15 GeV is determined mainly by bunch length, *i.e.* $\Delta E/E = (1 - \cos(2\pi\Delta z/\lambda))$. In order to mimimize bunch lengthening we require that the Turns be isochronous to second order in energy spread, that is the matrix elements [2] R_{56} and T_{566} should vanish. At the same time the system should be achromatic to first order, that is the transverse dispersion should vanish outside the Turns.

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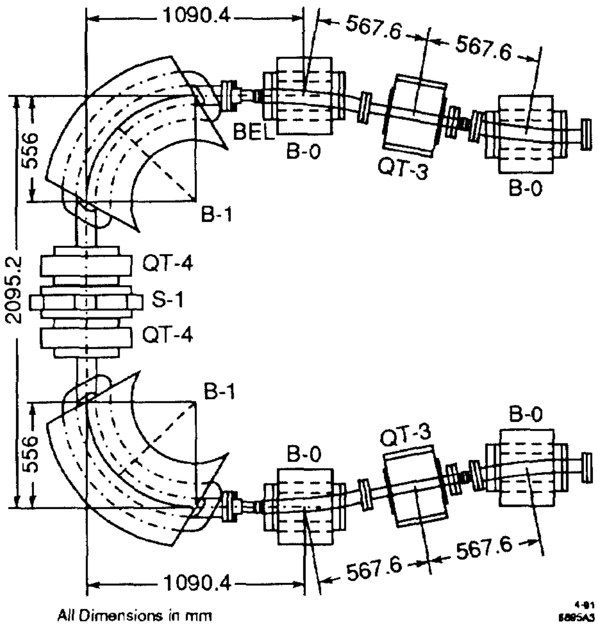

Figure 2. Mechanical layout.

Optics design. Figure 1 shows the beam envelope functions and dispersion and Fig. 2 shows the mechanical layout. (We refer here to the East Turn wh·-h bends in the vertical plane.) Dispersion is initiated by the first 10° bend (B0). The quadrupoles labled QT3 force the dispersion to cross the central axis in such a way that the net path length is independent of energy to first order in $\Delta E/E$. The central pair of quadrupoles labled QT4 focus the dispersion function so that the system is achromatic. The sextupole (S1) at the symmetry point corrects the dispersion function so that the net path length is independent of energy to second order. The sextupole has minimal effect on the transverse optics because it is located at a point where β_x and β_y are small. Transverse focusing is provided by the edge angles of the bending magnets and by external quadrupoles (not shown) which match the Turns to the adjoining lattice. The actual edge angles of the 90° bends were determined by magnetic measurements on the finished magnets, and were used subsequently in simulation and on-line modeling.

By suitable variation of the quadrupoles the longitudinal dispersion R_{56} may be tuned over a small range in order to match any residual phase-energy correlation from the positron capture and acceleration.

The choice of reverse bending for the first and last small bends tends to maximize the space available for the 90° bends within the existing housing. With the design radius of 55.6 cm; which is about as large as we were able to fit in, the 90° bends require 1.2 Tesla at 200 MeV.

The program TRANSPORT [2] was used in the optics design.

Instrumentation. Orbit correction in the bending plane is provided by independent adjustment of the B0 (10°) bends. Transverse steering magnets and beam position monitors are located just before the first 90° bend and after the second 90° bend. Steering and position monitoring are also located near the entrance and exit of the Turns. Adjustable energy-defining slits are located upbeam of the first QT4 quadrupole. At the sextupole is a nonintercepting 6-foil strip monitor which provides an analogue display of the spectrum. A retractible fluorescent screen is placed after the second QT4.

SIMULATION AND EXPERIMENT

Simulations were performed by tracking a set of rays which was first generated by the program EGS [3], tracked through the capture and high-gradient accelerator section by the program ETRANS [4], and then through the rest of the system by the program TURTLE [5].

Figures 3a–c are longitudinal phase-plane plots just ahead and just after the East Turn. The effect of the sextupole may be seen by comparing 3(b) and 3(c) (sextupole on/off, respectively). In practice the sextupoles

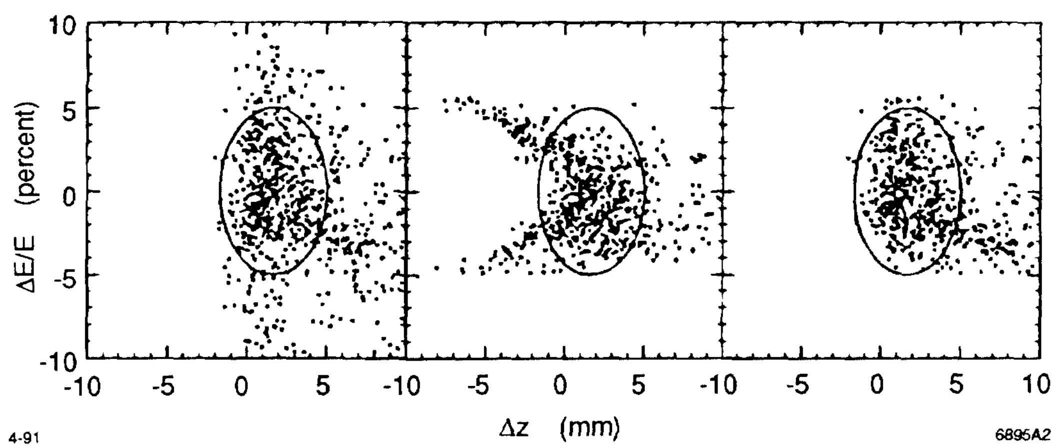

Figure 3. Longitudinal phase-plane plots (a) ahead of the East Turn; (b) after the East Turn, sextupole off: (c) after the East Turn, sextupole set for $T_{566} = 0$. The solid elipse is the estimated admittance boundary of the positron system including the damping ring.

have very little effect on final yield, probably because the "tails" which have been saved in Fig. 3(c) actually do not contain many particles.

Simulation of transmission through the East Turn is shown in Fig. 5. The small loss after the first turn comes mainly from the energy tails. The energy slit between B0 and QT4 accounts for most of the loss. The simulated transmission factor of ~.66 agrees reasonably well with operating results.

Figure 4 shows the simulated energy spectrum after energy collimation. The spectrum shape and the width $\sigma_\delta = \simeq 2.46\%$ agree fairly well with a typical experimental result, 2.13% (See Fig. 6).

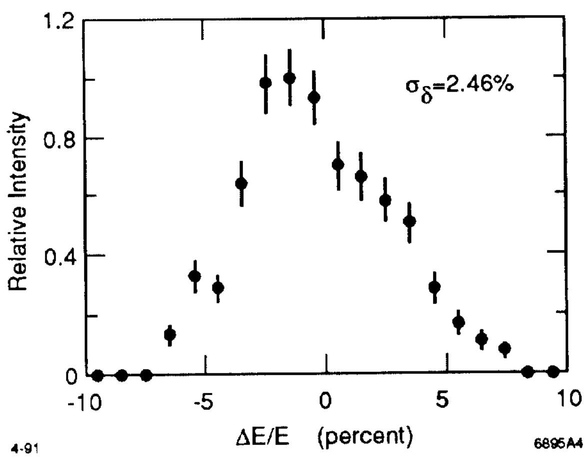

Figure 4. Simulated energy spectrum after the East Turn.

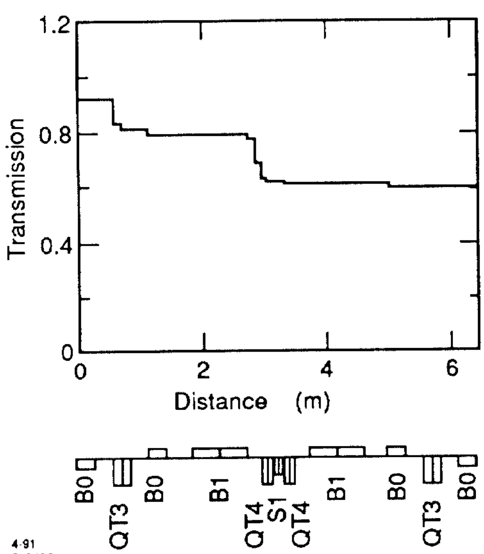

Figure 5. Simulated transmission through the East Turn.

Experimental information on bunch length was obtained in two ways. A direct measurement by means of a streak camera gave 3.5±.5 mm, in agreement with simulation (Fig. 3). Indirect information comes from spectrum measurement after acceleration to 1.15 GeV, where energy spread results mainly from bunch length. Unfortunatly the beam profile shown in Fig. 7 is dominated by betatron size (estimated at ~4 mm); however the observed value of ~4.2 mm implies σ_z no greater than the simulated and streak camera results.

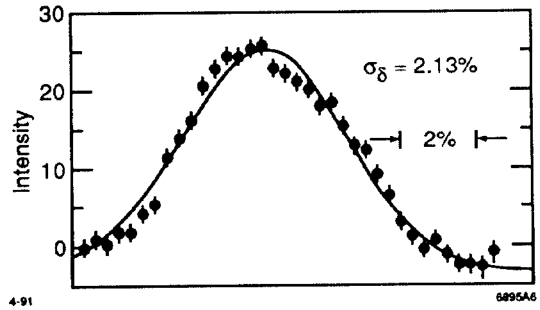

Figure 6. Experimental energy spectrum at 210 MeV, after energy collimation.

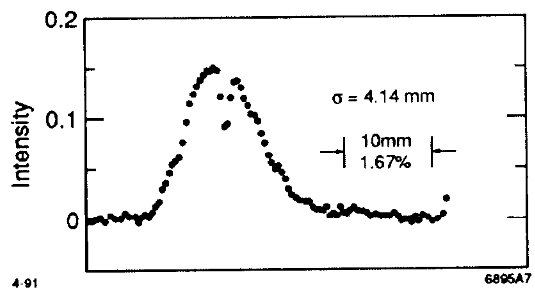

Figure 7. Profile of dispersed beam after acceleration to 1.153 GeV. The dip near the peak is an instrumental effect.

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