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DESIGN OF A HIGH YIELD POSITION SOURCE*

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The Stanford Linear Collider (SLC) requires a positron source with a yield large enough to give equal number of positrons and electrons at the interaction point. In addition, the colliding positrons must have an emittance and bunch length similar to the electron beam. This report describes the design of a high yield positron source to give these characteristics. Reference 1 contains more details of the systems of the SLC and positron source.

The overall positron production system in relation to the SLC is shown in Fig. 1. A single bunch of electrons of 33 GeV is extracted from the Linac at the two-thirds point by means of a fast kicker magnet and a pair of septum magnets. The extracted electron beam is transported into the positron vault where it is focused to a spot size of ±0.6 mm at the target. Spoiler foils are placed in the extracted beam path to increase the emittance so that the spot size cannot be made so small that target damage would occur. Positrons are collected in a focusing solenoid system using an iron shaped solenoidal field of 1 Tesla at the target and a pulsed solenoidal field from a flux concentrator with a peak field of 5 Tesla. The positron beam emerging from the focusing solenoid system is accelerated to 200 MeV in a 1.5 meter high-gradient-accelerator of 50 MeV/meter and three 3.05 m standard accelerator sections. The positrons are contained in the accelerator aperture using a 0.5 Tesla solenoidal field in the beginning and quadrupole focusing in the final two standard accelerator sections. The positrons are then transported back to the beginning of the Linac for further acceleration to 1.2 GeV, whereupon they are sent to the positron damping ring. Later they are removed from the damping ring, accelerated to the end of the Linac, and transported around the e^+ arc to the interaction point.

A) Target

Beam tests indicate that a target composed of Ta-10W (tantalum - 10% tungsten) material would give high positron yields. Calculations show that the single pulse temperature rise will be 380°C for a 0.6 mm incident beam radius of 5×10^{10} 33-GeV electrons. This, when added to the expected steady state temperature, results in a peak temperature of 580°C. The resulting stress from each thermal pulse will be approximately 32,000 psi which is well below the expected yield strength of 60,000 psi. To avoid interaction between adjacent pulses of the 180 pps e^- beam and the resulting compounding of stress, the target will be rotated, thus distributing the power deposited over a large area. The target wheel rotates inside a vacuum chamber (see Fig. 2). The rotating motion is attained utilizing a feedthrough which uses a ferromagnetic fluid in order to vacuum seal the drive shaft. The target is cooled by water passages in the drive shaft. Fig. 3 shows stationary test targets after exposure to an electron beam. The target on the left shows damage resulting from stress failure when exposed to a beam intensity per pulse greater than 10^{11} e^-/mm^2. The target on the right survived the expected e^- intensity and pulses of the positron source for SLC.

B) Focusing Solenoid System

The positrons emerging from the target have a longitudinal spatial extent of about 2 mm which is nearly identical to that of the incident electron bunch The transverse momentum extends above 3 MeV/c. The focusing solenoid system is designed to transform a 2 mm × 2.5 MeV/c transverse emittance beam into a 8 mm ×0.6 MeV/c one, which corresponds to the accelerator aperture with a superimposed 0.5 Tesla solenoidal field.

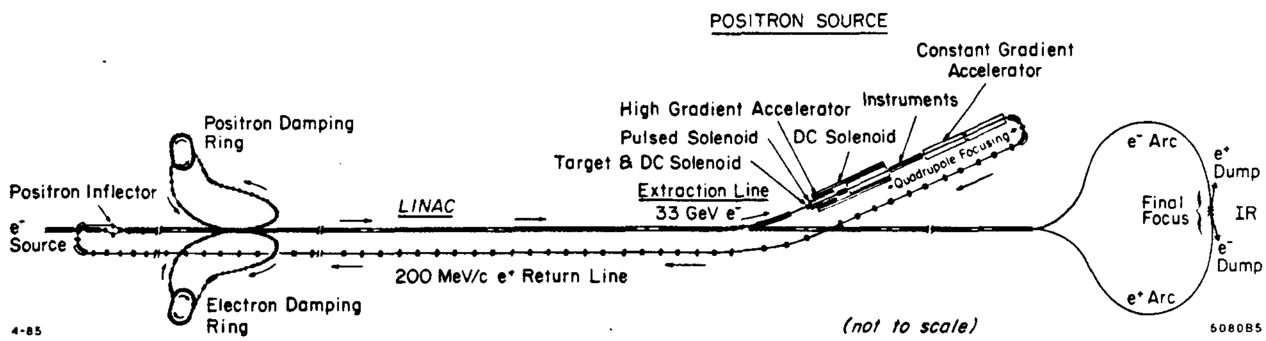

Fig. 1. Schematic diagram of the SLC positron source system (not to scale). The Linac is 3 kilometers long, and the positron source from target to end of constant gradient accelerator is about 15 meters.

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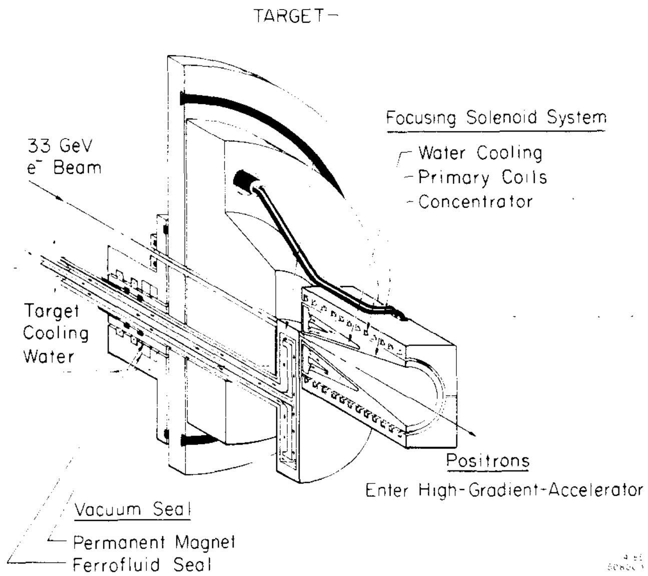

Fig. 2. Drawing of target and focusing solenoid system. Surrounding the target wheel and flux concentrator is a DC solenoid giving 1 Tesla axial field at the target.

Figure 2 shows a drawing of the flux concentrator. The primary coils are pulsed with a ~ 30 kilo-amp current source. They are held in place by stainless steel blocks. The half cones are inserted inside the coils and the induced current produces the 5 Tesla axial field. The pseudo-adiabatically changing axial field has an initial-to-final field ratio as the square of the end to beginning radii ratio of the cone. The axial component of the pulsed field expected as a function of distance from the target is shown in Fig. 4.

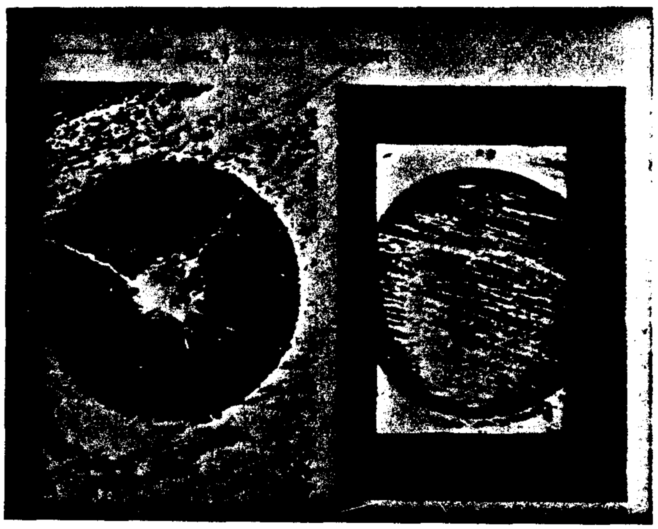

Fig. 3. Targets composed of Ta-10W material after exposure to an electron beam. The target on the left shows the damage resulting from stress failure when exposed to a single bunch intensity of 10^{11} e^-/mm^2. The target on the right survived the expected e^- intensity and pulses of the SLC.

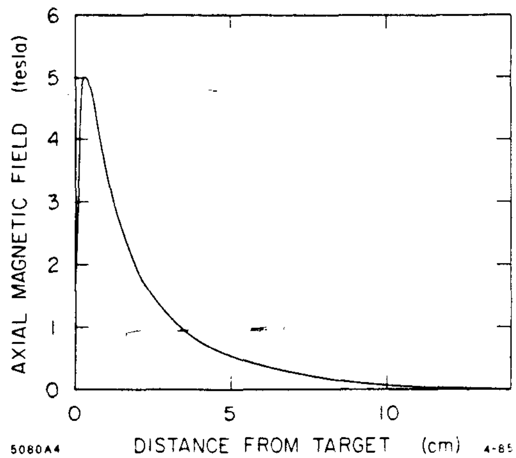

Fig. 4. Axial component of the pulsed solenoid field as a function of the distance from the target.

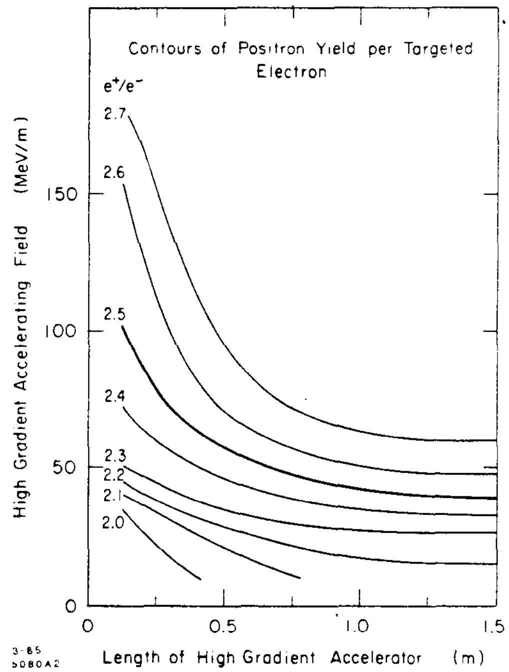

Fig. 5. Contours of positron yield per targeted electron for high-gradient-accelerators as a function of their length and accelerating field.

C) High Gradiant Accelerator

The positrons accepted by the focusing solenoid system have a large spread in energy from roughly 2 to 20 MeV with most concentrated at low energies. At the lower energies the positrons are sufficiently non-relativistic that they slip in phase, so that after the positrons have been accelerated in the booster to 200 MeV there is a distinct energy-phase angle correlation. Additional phase slip occurs for positrons that leave the target with non-zero transverse momentum because the resulting helical motion has a longer path length than straight motion down the axis. To minimize the phase slip, the drift regions before acceleration have been minimized and the positrons are accelerated initially with a

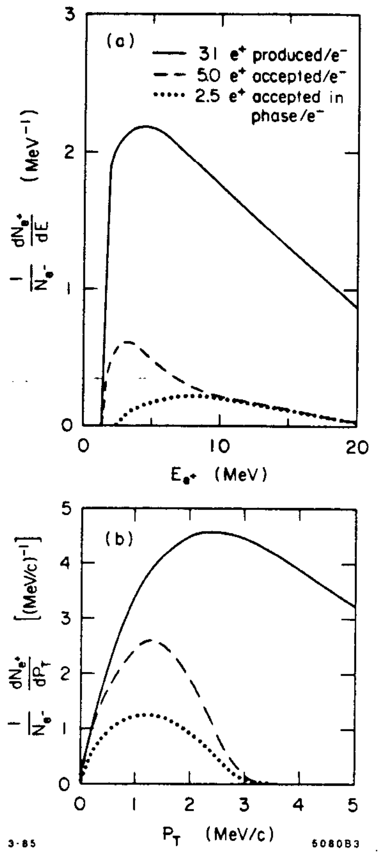

Fig. 6. Energy and transverse momentum of the positrons as they leave the target. Full curve shows all positrons produced, dashed curve gives the yield for positrons reaching the end of the accelerating system and the dotted curve shows those positrons in phase that would be accepted by the damping ring.

high field accelerator section. Figure 5 shows contours of positron yield per targeted electron for high-gradient-accelerators as a function of their length and accelerating field. A 1.5 meter accelerating section with 50 MeV/m will be used.

D) Positron Capture Efficiency

The optimization of the design was done using computer simulation. The program EGS was used to calculate positron yields from the target, and these positrons were traced through the magnetic and accelerating fields and apertures of the focusing and accelerating systems. The program TURTLE was used to transport the positrons back to the inflector where they enter the first sector of the Linac for acceleration to 1.2 GeV for the positron damping ring. Figure 6 shows the initial energy and transverse momentum-spectra of the positrons produced at the target, those reaching the end of the accelerating systems and the positrons in-phase within FWHM = 15 picosec. The acceptance for in-phase positrons is approximately 2.5 positrons per incident electron.

These studies do not take into account effects due to space charge and wake fields. Longitudinal wake fields in the high-gradient-accelerator section have been estimated to cause 2 MeV lower energy of the tail of the positron bunch than at the head. Transverse wakes are on the order of 100 keV/c per mm offset of the bunch centroid.

REFERENCES

1. SLC Design Handbook, Positron Source, December 1984.