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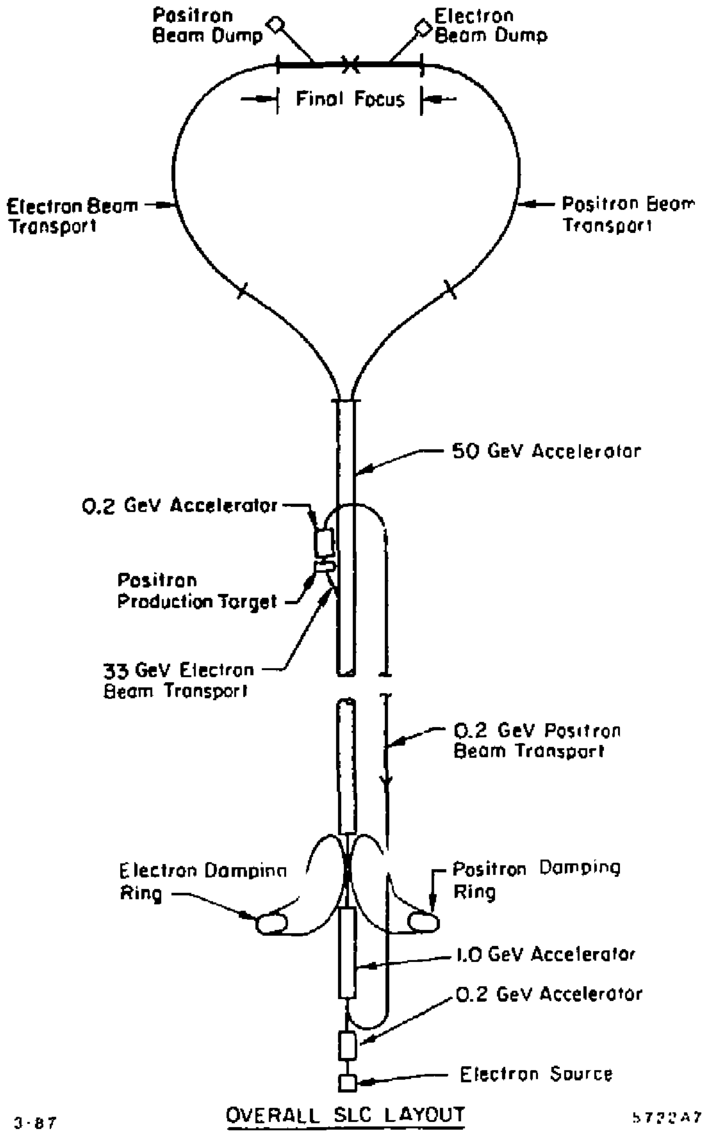

Figure 1

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THE STANFORD LINEAR COLLIDER POSITRON SOURCE*

STAN ECKLUND

Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

ABSTRACT

A description of the positron source used in the Stanford Linear Collider is given. The performance to date is reviewed.

1. SLC

The Stanford Linear Collider (SLC) is an accelerator construction project which upgrades the Stanford Linear Accelerator and adds components to bring about head on collisions of low emittance beams of positrons and electrons. The energy of each beam is adjustable up to over 50 GeV and will be set to investigate production and decay properties of the Z^0 particle at a center of mass value about 94 GeV. The machine construction is now complete and machine commissioning is in progress at this time.

2. OVERALL DESCRIPTION

The positron source is just one of several new components required for SLC [1]. Principal items are indicated in Fig. 1.

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Two single bunches of electrons with charge up to 8 nanocoulombs and time separation of about 50 nanoseconds are produced by an electron source at one end of the accelerator. A 100 meter section of linac accelerates these beams to 1.21 GeV before injection into a storage ring. The storage ring holds the beam between linac pulses which occur at rates up to 120 Hz. The synchrotron radiation damping in the storage ring reduces the emittance of the beam during this period. The resulting small emittance electron bunches are extracted from the ring and sent down the linac together with one low emittance positron bunch from the corresponding positron storage ring. The positron bunch and the leading electron bunch go to the end of the linac being accelerated from 1.21 GeV to about 50 GeV. Two transport lines bring the beams around and into collision. A special final focus produces a small transverse size of 2 micron sigma in order to obtain high density beams and a sufficient number of interesting collisions. The second electron bunch is deflected out of the linac 2/3 of the way and targeted at an energy of 33 GeV in order to produce positrons for the next machine cycle.

3. POSITRON SOURCE REQUIREMENTS

The intensity of a linear collider is limited by wake field effects in the accelerator structure. Both longitudinal forces which cause energy depression of the trailing parts of a bunch and transverse forces which cause disruption of the beam perpendicular to its direction of motion are present. The limiting currents are the same for positrons and electrons. Thus in the absence of other constraints, a positron system is required to produce as many positrons as there are electrons in the accelerator. As in most accelerator positron sources, positrons are produced by targeting electrons thereby initiating an electromagnetic shower cascade of positrons, electrons and gamma rays. It is required therefore for the yield of the system to be at least one produced positron for each electron incident. The design intensity for SLC is 5×10^{10} particles in each single bunch. The bunch length distribution is parameterized by a Gaussian with standard deviation of 1.5 mm. This short a bunch implies a large instantaneous current and peak power to be absorbed in the target.

4. POSITRON SOURCE COMPONENTS

The essential components in the SLC Positron source [2] are a beam transport to bring 33 GeV electrons to a target room, a high power target, a pulsed magnet to produce a 5 Tesla solenoidal field near the target, a dc solenoid magnet of 0.5 Tesla to provide extended focusing while the positrons are being accelerated, and an high gradient accelerator. In addition a 200 MeV beam transport brings the positrons 2 kM to the far end of the linac for acceleration and subsequent damping in a positron storage ring.

5. TARGET

The target must be capable of withstanding a rather large pulse energy beam of 200 joules in a small area of 1 mm square in a very short time of order 5 picoseconds. In addition the cycle repetition rate of 120 Hz gives a beam power of 24 kWatt of which about 25% is absorbed in the target. The target length is chosen to be 6 radiation lengths, or about 20 mm, corresponding to the cascade shower maximum for the beam energy of 33 GeV. Optimal yields are obtained from high Z materials which results in high volume energy deposition and temperature rise.

Two types of targets have been designed and built for SLC. The first is a six inch diameter rotating wheel of Ta-10%W alloy. The wheel is cooled by water fed though concentric passages on the wheels shaft. The target is in the vacuum system of the downstream accelerator. Drive motion for the wheel is accomplished utilizing a ferro-fluid rotary vacuum seal.

The second target design is a stationary target and has been used only for low repetition rate running. This target is a 6 mm diameter, 20 mm long rod of Ta-10%W alloy or W-25%Re allow brazed into a Copper holder which is cooled by water. All the beam running to date has been with the fixed targets at repetition rates less than 40 Hz.

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to 1.21 GeV and reduced in emittance in a damping storage ring before acceleration to 50 GeV. To economize on active accelerator length, the positrons are transmitted to the electron source end of the linac and co-accelerated with the electrons. This transport includes 180 degree bends to turn the beam direction around. Again so as to not dilute the longitudinal or transverse phase space density of the beam, the transport system must be isochronous and achromatic. This is accomplished to first order with appropriate quadrupole and dipole elements. Second order correction of the path-length/momentum correlation is accomplished using two sextupoles.

9. PERFORMANCE TO DATE

The SLC positron source has been operating for 9 months at a cycle rate of 5 Hz. Beam intensities of the target are typically in the range of 1 to 3×10^{10} electrons. The positron yield is 2 positrons/targeted electron at 200 MeV and 1 positron/targeted electron at 1.21 GeV for delivery to the damping ring. The damping ring has a through put of as much as 80%.

10. IMPROVEMENTS

Several components of the SLC positron source will be changed to meet specification and provide a greater number of positrons. The high gradient accelerator was originally tested up to a gradient of 43 MeV/m, but suffered R.F. break down later and is presently is limited to 20 MeV/m. This component will be replaced is several months with a new accelerator section which is expected to achieve 40 MeV/m. The solenoidal guide field is presently running as 0.39 Tesla due to a inadequate cooling. It will be replaced as well. The changes are expected to improve the yield nearly a factor of two.

11. ACKNOWLEDGEMENTS

The work on the SLC Positron Source involves many people from SLAC and other institutions. I am indebted to them for their contributions to the design and for many hours of hard work commissioning the system.

6. FLUX CONCENTRATOR

Positrons produced in the target are hot in the sense of occupying a large phase space volume, both in transverse angle and longitudinal energy. This angular divergence introduces the need for a strong magnetic lens of short focal length near the target to collect a good fraction of the positrons and match to a down stream transport system. This is accomplished in the SLC positron source by using an Eddy current transformer pulsed magnet called a flux concentrator. The flux concentrator is driven by a half wave sinusoidal shaped current pulse of 10 kAmp to produce a peak field of 5.8 Tesla a few millimeters from the target. This magnetic field is aligned parallel to the beam direction. Additional DC magnets supply a guide field tapering from 1 Tesla at the target to 0.5 Tesla downstream. This solenoidal guide extends to 5 meters from the target; at this point the beam is of sufficient energy and sufficiently monochromatic to be focused by a magnetic quadrupole array.

7. HIGH GRADIENT ACCELERATOR

The longitudinal energy distribution from the target has a very large spread; for energies over 2 MeV the distribution is roughly inversely proportional to energy. The SLC positron source is designed to capture energies between 5 and 20 MeV. Since a single short bunch is needed for collisions and injection into the damping ring, any large amount of drift of a beam with a spread in velocities will cause a longitudinal increase in the size of the beam. Too long a positron bunch will not be accepted fully in the downstream systems. The solution is to accelerate the positrons quickly before longitudinal dispersion occurs. A 1.5 meter long S-Band (2856 MHz) accelerator section is driven by a 50 MWatt Klystron to provide an acceleration gradient of 40 MeV/m. This is followed by 9 meters of accelerator to provide a beam of 200 MeV mean energy.

8. TRANSPORT LINE OPTICS

The 200 MeV positron bunch has an energy spread of $\pm 5\%$ and a transverse emittance of 25×10^{-6} meter radian. This beam needs to be accelerated

12. REFERENCES

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[2] Bulos, F., DeStaebler, H. C., Ecklund, S. D., Helm, R. H., Hoag, H., Leboutet, H., Lynch, H. L., Miller, R. H. and Moffeit, K. C. (SLAC), "Design of a High Yield Positron Source," SLAC-PUB-3635, April 1985; 1985 Particle Accelerator Conference, Vancouver, B.C., Canada, May 13-16, 1985; and IEEE Trans. Nucl. Sci. **NS-32**, No. 5, 1832-1834 (1985).