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THE STATUS OF SLC*

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ABSTRACT

The current construction status of the Stanford Linear Collider (SLC) is described along with a brief overview of the project. Tests of completed parts of the machine are summarized.

INTRODUCTION

The Stanford Linear Collider Project is intended to serve primarily two goals. First it is to make available electron positron collisions at higher energies in order to explore the next area of interest in elementary particle physics. This sets the energy goal of 100 GeV in the center of momentum system, in order to reach the Z^0. The second goal is to explore the feasibility of linear colliders for producing high energy collisions of electrons and positrons. This second goal is important in that this type of machine is different in many aspects from existing colliders and the technical difficulties encountered are often new to the accelerator physics community. If these technical problems are solvable at reasonable cost the linear collider would provide an attractive alternative to electron positron storage rings which suffer increasingly from synchrotron radiation losses as the energy increases.

The SLC project[1] is an adaption of SLAC with additions to provide for bringing small intense beams into collision. Rather than aiming two linacs at each other, SLC utilizes the one existing linac to accelerate both the positron and electron beams. This saves building a second 2-mile long linac or alternately doubling the accelerator gradient. It does of course require transport lines to bring the beams into head-on collisions. A schematic view of SLC is shown in Fig. 1. The various subsystems of the SLC are: an Electron Source to provide two high intensity short pulses; a sector (1 of 30) of acceleration to bring the energy up to 1.21 GeV; two Damping Rings to reduce the phase space occupied by the beams; the existing Linac modified to provide stronger focusing and beam guidance capability; higher power Klystrons for higher energy acceleration in the Linac; a new Positron Source system; an Arc transport for each beam; and a Final Focus system to produce small beams and bring them into collision. In addition there is a new control system with much improved capabilities needed for this kind of machine. Also a considerable amount of conventional construction is required for the ring housings, the Arc tunnels and the Collider Experimental Hall (CEH).

The machine cycle of SLC sends the beams around the above mentioned systems in the following manner. Each of the Damping Rings has stored in it two bunches of their respective positrons and electrons injected in previous cycles and suitably damped. Each cycle one of the positron bunches is kicked out of the Positron Ring and both of the electron bunches from the Electron Ring. Each of the Ring-To-Linac transports contains

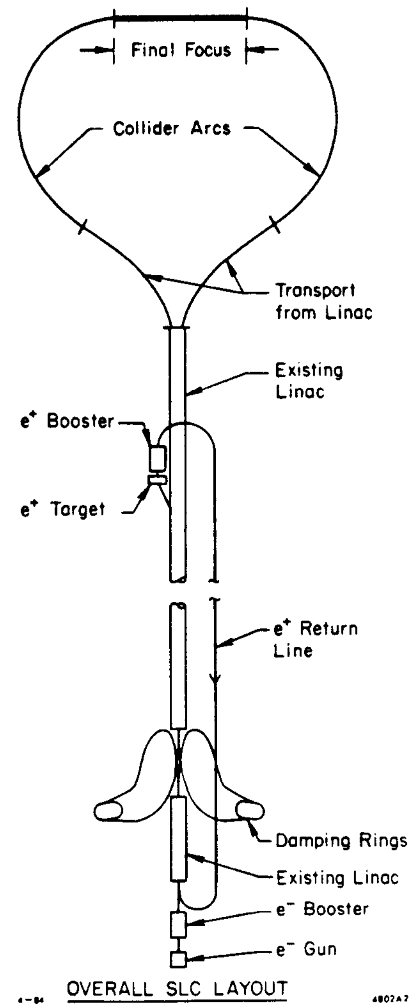

Fig. 1. Overall SLC Layout.

a bunch compressor to match the longitudinal phase space from the rings to the Linac. The timing of the ring extraction systems put the positron bunch first in the Linac followed by the two electron bunches. The three bunches are approximately half the ring circumference apart, 17 m or 59 nanoseconds, in the linac. The first two are accelerated to the end of the linac and transported around their respective Arc and Final Focus transports to collide in the interaction point. After collision the bunches are kicked into a dump and discarded. The third bunch, designated the scavenger bunch as it uses up some of the remaining r.f. in the linac, is kicked out at the two-thirds point and targeted to produce positrons. The positrons are collected and accelerated to 200 MeV in an high gradient strongly focused linac. They are then sent down a 2 Km return transport to the beginning of the linac for subsequent acceleration to 1.21 GeV. Just prior to the arrival of the positrons the electron gun is fired producing two bunches to be accelerated and

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supplied to the electron ring. The three bunches are sent to their respective rings completing the machine cycle. On alternate cycles alternate positron bunches are kicked out of the positron ring so that each of the positron bunches stays in that ring for two machine cycles. This gives the required amount of damping for their larger injected emittance.

STATUS

The Stanford Linear Collider Project is presently at the midpoint of its planned 3 year construction cycle. Some areas of the project are complete and others are well along, anticipating completion in 12 to 19 months. In the following sections we will look briefly at each subsystem of SLC and note its present status.

THE ELECTRON SOURCE[2-5]

The Electron Source has been tested and performs at full SLC specification producing two single S-Band bunches 59 nanoseconds apart with intensity over 5×10^{10} electrons per bunch. The system consists of a gun, two subharmonic velocity modulator cavities at 178.5 MHz, and a S-Band buncher and accelerator. This source provides beams for non-SLC use as well as for injection into the electron damping ring. Single bunch beams of 7×10^{10} have been produced and accelerated to 1.2 GeV. Addition of 80 quadrupoles between the source and the damping ring provided the strong focusing needed to overcome the transverse wake fields.

THE DAMPING RINGS[6-11]

The electron damping ring was built as an R&D machine to check its performance as a fast damper. To date it has stored single beams of 4×10^{10} electrons and two beams of 2×10^{10} each. No unexpected storage ring phenomena have been encountered and it is expected that the necessary damping will be possible. Study of this ring has been valuable in indicating improvements to be made to the ring and in improving the design of the positron ring. Indicated improvements are: increasing the sextupole family to better control chromaticity, adding more beam position monitors to better control orbits, and improvements to the injection and extraction septum magnet cooling. The original designs planned for both electron and positron rings to be housed in the same vault, one ring mounted above the other. The actual complexity of these compact rings however made it evident that both installation of the second ring and serviceability of both rings would be improved sufficiently to justify the cost of separate housings. This lead to the present design with two symmetric rings on each side of the linac. The second positron ring housing is complete and being prepared for installation of the ring next October. Newly designed transports for Linac-To-Ring and Ring-To-Linac are installed and working in the south electron ring and will be installed this summer in the north positron ring. Testing of the north ring will first be done with electrons in January of 1986.

THE LINAC UPGRADE[12-19]

In order to accelerate the intense single bunches for the SLC the quadrupole focusing has been increased in strength and a system of beam position monitors has been installed in the first third of the linac. The last two-thirds of the linac will likewise upgraded in the next year. The increased focusing and beam monitoring is to reduce effects of transverse wake fields produced by the beam being off center in the wave-guide. These fields deflect the tail of bunch and cause a effective increase in transverse emittance. The present upgraded configuration has a quadrupole and position monitor between each forty foot linac section. Beams of intensity 1.5×10^{10} are now obtained at the one-third point when injected from the damping ring.

Because of the desire to increase the bunch length at the interaction point to effect a larger beam-beam pinch, the bunch length out of the RTL transport will be increased from a σ of 1 mm to 1.5 mm. This will cause an undesired increase in the transverse wake force on the bunch tail. To counteract this, the linac focusing will be increased to one quadrupole and monitor every ten feet in sector 2, just downbeam of the damping rings and one every 20 feet in sectors 3 and 4. This requires shortening the ten foot sections to 9.5 feet in the locations of the added quadrupole magnets. This work is scheduled to completed in the next year. The first section shortened is now under high power test.

KLYSTRON UPGRADE[20-24]

The existing S-Band r.f. drive of the linac uses 34 MW klystrons to produce beams of up to 33 GeV. In order to explore the particle physics of Z^0 production and decay, beams of about 51.5 GeV are needed at the end of the linac. This increase in energy will be achieved by replaceing the 230 klystrons down beam of the damping rings by new higher power ones. The peak power will be increased to 50 MW and the pulse length to 5 microsec. Lengthing the pulse length increases the SLED gain factor from 1.4 to 1.78. The new system will initially run at a maximum rate of 120 Hz in order to keep average power within existing modulator capability. The thyratron tubes and the output transformer are being changed to provide the higher pulse power of 315 kV and 354 amperes. Future modifications to the modulator will allow operation at a 180 Hz rate.

The klystrons, designated as model 5045 for 50 MW peak and 45 KW average power,are being manufactured at SLAC. At this time 70 tubes have meet specifications and have been accepted for use on the linac. The factory tube start rate is presently 4 per week and has an accepted tube yield approaching 50%. Extensive quality control measures have improved the yield and further improvements to 65% yield are anticipated. The production will be increased to 5 per week in the near future which along with anticipated improvements in yield will provide sufficient linac energy by January 1987. Failures of acceptance tests are typically due to window breakage from overheating and insufficient stable operating region.

Two of the thirty sectors or 16 stations have been outfitted with the new tubes for in-field testing. The beam energy as measured in a spectrometer indicates the energy gain per klystron is correct and full 51.5 GeV will be obtained. By the end this year, modulators in 16 sectors will be converted for operation with the new klystron tubes leaving 13 to be done in the following year.

THE POSITRON SOURCE[25]

The positrons are produced by pair production in a tantalum - 10% tungsten target. Down beam of the target a 5 Tesla pulsed magnet and DC focusing solenoids is used to collect a large transverse emittance. A high gradient accelerator immediately follows the pulsed magnet to achieve a good longitudinal capture. After acceleration to 200 MeV the positrons are transported from the source location back to the sector one. This return transport consists of two 180 degree turn-arounds, one at each end and a FODO array 2 Km long with quadrupoles, position monitors, and steering every 12.7 meters. Present status has about 70% of the return transport installed and the remainder scheduled to be complete by October 1985. The target area is scheduled for completion by May 1986 at which time testing with beam will begin.

THE ARC SYSTEM[26–29]

The purpose of the Arc transport is to bend the high energy electron and positron beams from the linac around to allow head-on collisions with a minimum of phase space dilution and energy loss. Quantum effects of synchrotron radiation will cause growth proportional to L^3/r^4 where L is the length of a single focusing or defocusing magnet and r is the bending radius. This suggests a dipole guidence field of modest stength for large bending radius and many short but high gradient magnets. The design utilizes alternating gradient magnets with guide fields of 5.98 KG at 50 GeV and a corresponding gradient of 7.02 KG/cm. A betatron phase advance of 108 degrees per cell is used with 10 cells grouped together to form an achromat. A total 940 magnets are used in the Arc system. Each achromat lies in a plane but at a slope to allow the tunnel to follow the earths terrain. This terrain following simplifies the civil construction.

Magnets for the Arc transport are now in production at a rate of six per day with 144 completed. Extensive measurements are being made to insure correct gap dimensions and correct field components. Only about 5% of the magnets fail specifications and are unusable. Installation of the magnets in the tunnels is scheduled to begin July 1985 and be completed by July 1986.

THE FINAL FOCUS[30–32]

The Final Focus system has the job of producing micron sized beams and bringing two such beams into head on collision. The transport optics design utilizes telescopic modules with simultaneous point-to-point and parallel-to-parallel focusing. This feature tends to minimize the magnitude of higher-order optical distortions. Because the beams will have a finite momentum spread of 0.2 to 0.5% the line requires a chromatic correction section. The final set of quadrupoles near the interaction point need to be as strong as feasible. Optical designs exist for both superconducting and conventional quadrupoles in this location. Initial operation will be with conventional magnets to alleviate worrys of beam induced quenches. Later operation at the highest luminosity will require the higher gradient of the superconducting magnets. There are 160 magnets of 13 different designs in this system. Being the last system to see beam, this will be the last to be installed. At this time magnet design is 80% complete with 33% of the magnets on order. About 4% of these magnets are built. Various beam control and monitoring systems are now under design and study.

THE CONTROL SYSTEM[33–40]

The SLC project requires good monitoring and control of a large number of systems. A new control system was developed and now runs all the new SLC installations. It consists of a Vax 780 with a Broadband cable network connecting multibus microcomputers which in turn control CAMAC crates. One of the new features is the control and monitoring of the r.f. systems on the linac. At present one-third of linac is equiped with control and readback of the amplitude and phase of each klystron in relation to a reference line. This has improved the ease with which beams are setup and maintained by the operators. Full control of the klystrons will be installed this summer.

CONVENTIONAL CONSTRUCTION

The Arc tunnels are essentially complete at the time of this report with officially 2 weeks until completion. The Collider Experimental Hall (CEH) is well along with excavation now reaching the floor level. The CEH provides one interaction location of size 16 by 19 m with two assembly areas, 23 by 19 m, and 32 by 19 m, on each a side, in order to house two detectors in a push-pull arrangement. The CEH is scheduled for completion by March 1986.

PROJECTED PERFORMANCE

Checkout running of all systems upbeam of the arcs will begin in May 1986 and continue throughout the summer. At the completion of the construction project, Oct. 1, 1986, the arcs and final focus systems will be also tested with beam. The initial luminosity is expected to be around 5×10^{28}. The final design value is 6×10^{30}. To reach this it will be necessary to: increase the intensity to 7.2×10^{10}; increase the repetition rate to 180 Hz; and improve the final focus quadrupole triplet using superconducting magnets.

ACKNOWLEDGEMENTS

This report is a summary of the work of many people; too many to enumerate here. A number of contributions to this conference contain more specific and detailed reports on the various aspects of the SLC systems.

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