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THE SLAC LINEAR COLLIDER*

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A report is given on the goals and progress of the SLAC Linear Collider. I discuss the status of the machine and the detectors and give an overview of the physics which can be done at this new facility. I close with some ideas on how (and why) large linear colliders of the future should be built.

I. INTRODUCTION

The two main goals behind SLC are to develop a new colliding beam technique and to do physics experiments at 100 GeV. Construction began in October 1983, and we hope the turn on will be in October 1986. The cost of the machine is $113 M.

Why do we need a new technique? Let's look at the present collider techniques. The first storage ring began construction in 1958. The newest storage ring, LEP, began construction in 1983. In twenty-five years the radius has become 5,000 times larger and the energy has become 100 times larger. The cost scales as $(E)^2$! LEP will cost about $600 M. A circular machine of this type of ten times more energy would have a circumference of 2,700 kilometers and would cost about $60 billion.

So we proposed a new method, that of linear colliders. The scaling is only as the first power of the energy. It has a lower repetition rate than a storage ring (200 compared to 200,000). But it has a tiny beam (1 micron radius compared to 100 microns). So therefore it has the same performance. In Table I are the main parameters.

The overall SLC layout is shown in Fig. 1.

TABLE I

Main Parameters

E^*	50×50 GeV
$n^{\pm}$	5×10^{10}
$< L >$	$6 \times 10^{30}\ cm^{-2}\ s^{-1}$
Repetition rate	180 hz
Bunch length	± 1 mm
Beam radius at collision point	1.3 micron

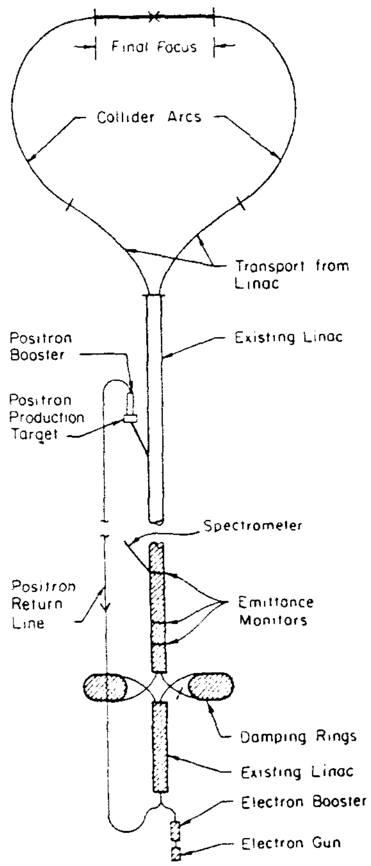

Fig. 1. Schematic layout of the SLC main components.

II. ACCELERATOR DEVELOPMENT

A significant amount of our effort has been in the linac development in the first third of the

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machine. New computer controls are now in and are being tested. New steering and focusing magnets are in and are being tested. A new beam position monitor is in with a 30 micron resolution. At present the RF phase and amplitude controls are being installed. The one third point analysis station is in and has been tested. A noninterrupting emittance monitor is under development.

The damping rings are used to reduce the beam emittance to values low enough to be focused to the small sizes we need. Normally the emittances from the linac gun and injector are too high for this. The south damping ring is expected to have two bunches of 5 x 10^{10} electrons circulating. The two bunches are extracted along with an e^+ bunch from the north damping ring. Then one e^- bunch and the e^+ bunch will be sent to experiments and the second e^- bunch will generate new e^+'s for a later e^+ bunch.

At present we have achieved the following damping ring performance: The energy is at 1.2 GeV. The damping time is that predicted by theory plus 15% (but this last has been understood and fixed). The maximum number of e^-'s that have been stored in one shot is about 1.4 x 10^{10}. (This is limited by sector-1 focussing.) The maximum stored charge is 3 x 10^{10}. A typical injection efficiency is 90% and a typical extraction efficiency is 100%.

An exercise of the system goes as follows: We inject into the damping ring and shrink the beam size in the damping ring. There is a compression in length from 1 cm in the damping ring to 1 mm in the linac. We reinject into the linac and accelerate to the 1 kilometer point. There we measure the beam properties. Before going on I should mention that there are many new technological issues that have been faced at SLC, and, actually, two new issues in accelerator physics. For instance, there are problems with the wake fields which have been dealt with both experimentally and theoretically and there are very strong beam-beam interactions. Theoretical studies have shown how to use this to our advantage.

III. SLC PHYSICS PROGRAM

The main goals of the SLC physics program are shown in Fig. 2.

Main Goals

$$e^+ + e^- \rightarrow Z^0 \rightarrow q\bar{q},\ \nu\bar{\nu},\ \ell^+\ell^-,\ \vdots$$

Explore the energy region where weak-electromagnetic unification becomes manifest.

Search for clues on

- **Strong Unification**
- **Mass Generating Mechanism (Higgs)**
- **Evolution of the Universe (ν #)**
- **New Substructures**

⋮

Fig. 2. SLC Physics Program.

The number of Z^0's needed to achieve these goals is shown in Table II. Note that these goals divide into two main categories. The first is an obvious and, indeed, almost guaranteed successful program in the energy region of the weak-electromagnetic unification. The second area is more speculative and perhaps more exciting for this reason. One is searching for clues to the unknown. The reason why we can be so optimistic about the success of the first main goal and so hopeful about the second can be seen in Fig. 3, the graph of the luminosity vs energy for SLC. We project about 800 Z^0's per hour maximum production.

IV. DETECTORS

At the Stanford Linear Collider we will have two detectors, the upgraded Mark II and SLD (SLAC Large Detector). The times during which these will be available for use are shown in Fig. 4.

The first detector, the Mark II, will be an upgrade of the Mark II which exists at PEP. The upgrade involves replacing the main tracking

TABLE II

The Z^{o} Physics Program Demands

Physics Topic	Z^{o}'s 10^4	10^5	10^6	Vertex	Tracking	EM Calor.	Particle ID	Had. Calor.	Muon ID	4π Ω
Mass	•				•	•				
Width	•				•	•				
ν Counting		•			•	•				•
Lepton Couplings		•			•	•			•	
Heavy Quark Couplings		•		•	•		•			
Jets	•			•	•	•	•	•		
Higgs Search			•	•	•	•				
Hadronic Studies			•	•	•	•	•	•	•	
Top	•			•	•	•	•	•		
Toponium			•	•	•	•				
CP Violation			•	•	•	•	•	•	•	
Polarization Studies		•		•	•	•	•	•	•	•
Rare Z^{o} Decays			•	•	•	•	•	•	•	•
SUSY		•			•	•		•	•	•
$SU(2)_L \times SU(2)_R \times U(1)$			•		•	•			•	•
Compositeness		•			•	•			•	•
Flavor-changing N. C.'s			•	•	•	•	•	•	•	

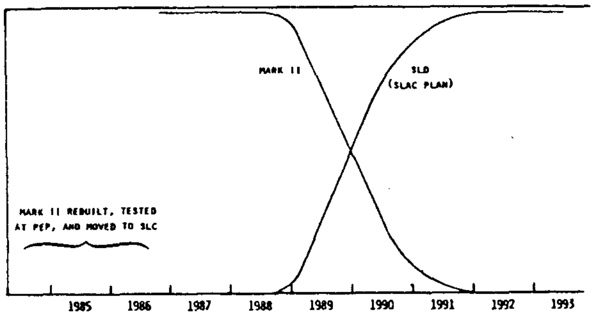

Fig. 4. Availability of detectors at SLC.

The Mark II went off line at PEP on May 1, 1984, and in 1985 it will go back on line with new components. It will go off line again to begin its move to SLC in January 1986. The collaboration for Mark II involves the old Mark II group of SLAC and LBL with the addition of Caltech, UC Santa

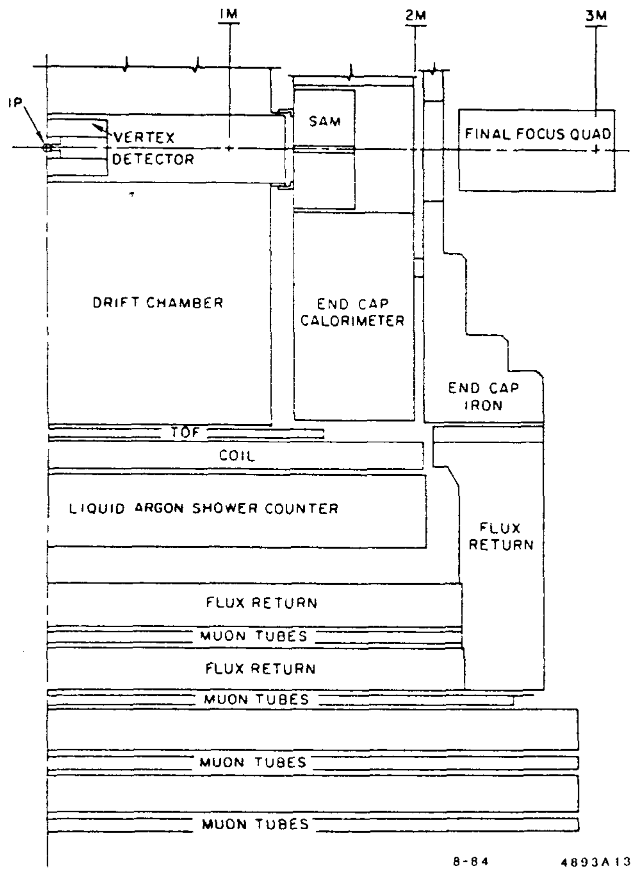

Fig. 5. A quadrant view of the upgraded Mark II detector.

chamber, the endcap and the vertex chambers. This is all to handle the higher multiplicity at SLC. In Fig. 5 a quadrant section of the Mark II upgraded detector is shown.

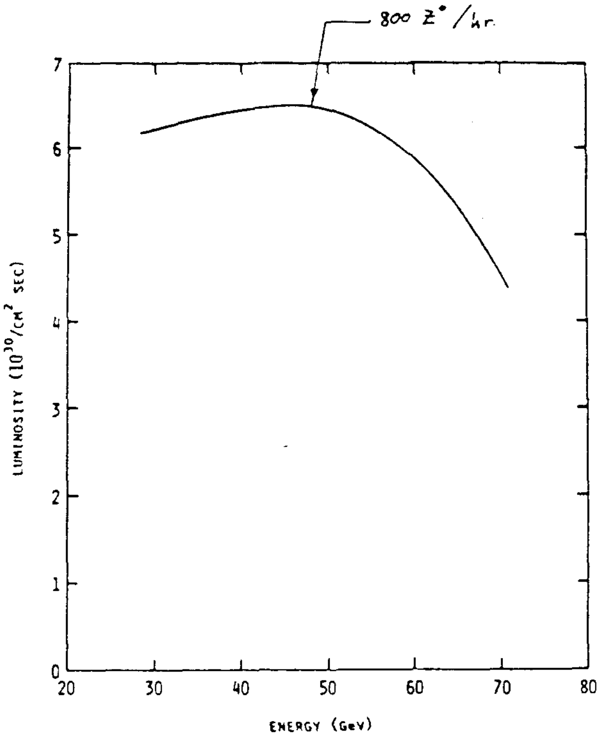

Fig. 3. SLC luminosity vs energy.

Cruz, the University of Hawaii, the University of Michigan, the University of Colorado, and Johns Hopkins University. It involves fifty-four physicists plus postdocs and students, and it is still expanding.

The SLD collaboration involves many institutions: Caltech, the University of Cincinnati, the University of Colorado, Columbia University, Laboratori Nazionale di Frascati, the University of Illinois, MIT, Rutherford Appleton Laboratory, SLAC, UC Santa Barbara, the University of Tennessee, Vanderbilt University, the University of Victoria, the University of Washington, and the University of Wisconsin. There are sixty-five physicists plus research associates and students involved. The co-spokesmen are Baltay of Columbia and Briedenbach of SLAC. Figure 6 shows a quadrant view of the SLD detector on a log scale.

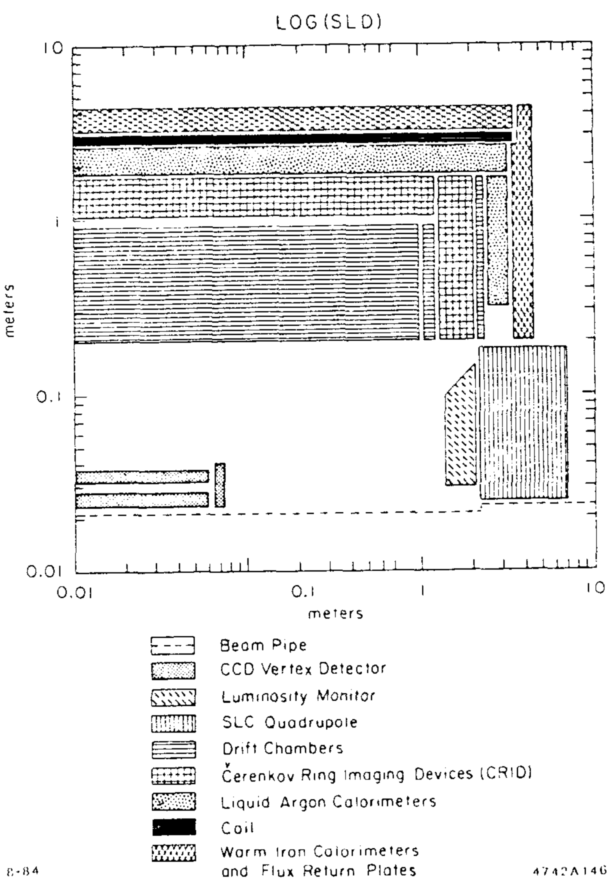

Fig. 6. A quadrant view of the SLD detector on a log scale.

V. CONCLUSION

The SLC will be ready to begin operations in October of 1986. Since is is a new type of colliding beam machine, I can make no promises on how fast the luminosity of this facility will come up to its design value. Our current plans are to devote the first three months of operation to pure machine studies and to move the first detector on to the beam line in early 1987. The cross section for the production of Z^0's will be so large at the SLC that it will only take a few percent of the design luminosity over a period of a few months to produce ten thousand Z^0's and begin to answer some of the detailed questions on the weak interactions.

As far as machine technology is concerned, SLAC (as well as other laboratories) is engaged in a vigorous program of systems studies and technology development on future big machines. I am often asked how long it will take before a detailed design of a very high energy linear collider could be available. That is a hard question to answer for we will need to see how the SLC performs to know whether we have indeed understood the fundamental beam dynamics problems of this kind of machine, and we will have to generate some improved technology to make large systems cost effective.

The jump in energy over that of the SLC will be a large one if the goal is to produce a machine capable of reaching the TeV mass scale, which is the goal of the large proton colliders now under discussion. Since electrons and positrons are elementary particles and not composite particles, as are protons, one need only produce an energy of a TeV in the center of mass to reach this mass scale. But none-the-less, that is an order of magnitude bigger than what we are developing with the SLC. It is too early to talk seriously about the time schedule for big electron colliders--ask again in a few years.