

THE STATUS OF THE SLC*

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1. INTRODUCTION

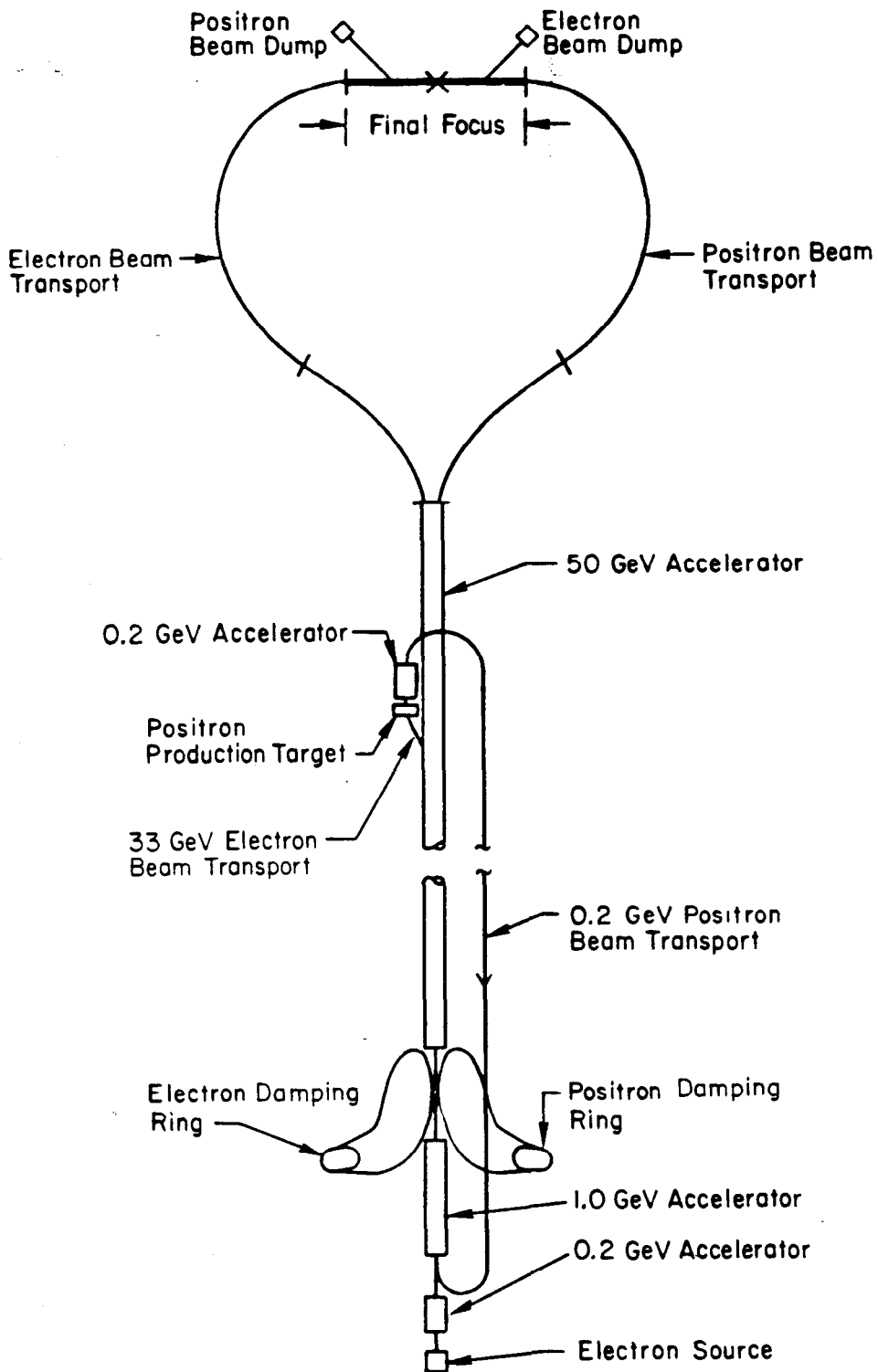
On October 10, 1987, the SLC ceased commissioning activities to move the Mark II detector into the beam line for the spring physics run. The planned shutdown is for a period of 13 weeks. In this paper, the various subsystems and their status as of October 10, 1987 are briefly discussed. For a more extensive but not as up-to-date review, the reader is referred to Refs. 1 and 2.

In Fig. 1, you see a schematic layout of the SLC. Before beginning the discussion of the subsystems, it is useful to trace the e^+e^- beams through the SLC. At the beginning, two 20 cm long bunches are emitted from a thermionic gun and accelerated to 160 KeV. These bunches are compressed in two stages to an rms bunch length of 2 mm each and then accelerated in a linear accelerator at 2.8 GHz to 200 MeV. At this point, the electrons join a positron bunch which was created on the previous pulse. All three bunches are then accelerated to 1.2 GeV.

At the 1.2 GeV point, a D.C. magnet deflects the electron bunches north into the north damping ring while the positrons are deflected south into the south damping ring. After a storage time longer than about 5.5 msec, the low emittance positron bunch is extracted from the south damping ring and re-injected into the linac. About 60 nsec later, the first low emittance electron bunch is extracted and 60 nsec after that the final low emittance electron bunch is extracted.

The positron bunch and the first electron bunch are accelerated in the linac up to 51 GeV and separated at the end of the linac where the electron bunch travels in the north arc and the positron bunch travels in the south arc. After transport in the arcs, they are

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Fig. 1 The overall layout of the SLC

focussed to a small spot by the final focus system for a collision at 2×50 GeV and then finally they are deflected into beam dumps.

The second electron bunch, the third bunch in the train, follows the first two up to the 2/3 point of the linac where it is extracted at an energy of 33 GeV. It is then used to produce positrons which are accelerated to 200 MeV and then transported back to the injector to be injected and to start the whole process over again.

To put the next few sections into perspective, in Table 1 you see a list of parameters of the SLC which distinguishes the design goals of the SLC from the initial performance goals. The initial goals are those for the spring 1988 physics run and yield a luminosity of $6 \times 10^{27} \text{cm}^{-2} \text{sec}^{-1}$. This will produce about 15 Z^0 's per day.

Table 1. BASIC PARAMETERS FOR THE SLC

	Design Goal	Initial Goal	Achieved	Units
Beam energy at IP	50	46	46	GeV
Beam energy at end of linac	51	47	53	GeV
Electrons at entrance of arcs	7×10^{10}	10^{10}	3.5×10^{10}	
Positrons at entrance of arcs	7×10^{10}	10^{10}	0.6×10^{10}	
Repetition rate	180	60	5	Hz
Normalized transverse emittance at end of linac (electrons)	3×10^{-5}	10×10^{-5}	$3 - 20 \times 10^{-5}$	rad-m
Spot radius at IP	1.6	2.8	5.0	μm
Luminosity	6×10^{30}	6×10^{27}	-	$\text{cm}^{-2} \text{sec}^{-1}$

2. DAMPING RINGS

2.1 STATUS

The SLC damping rings provide an emittance of $\epsilon_N = 3 \times 10^{-5} \text{m}$ at 1.2 GeV. Both the electron and positron rings operate routinely and reliably to provide low emittance beams for the linac, arcs and final focus commissioning effort. Both rings have achieved the design emittance. The north ring has achieved an intensity of $4.5 \times 10^{10} e^-$ while the south ring has achieved 1.0×10^{10} . Both of these are limited by upstream intensity and thus they are not hard limits.

2.2 OUTSTANDING ISSUES

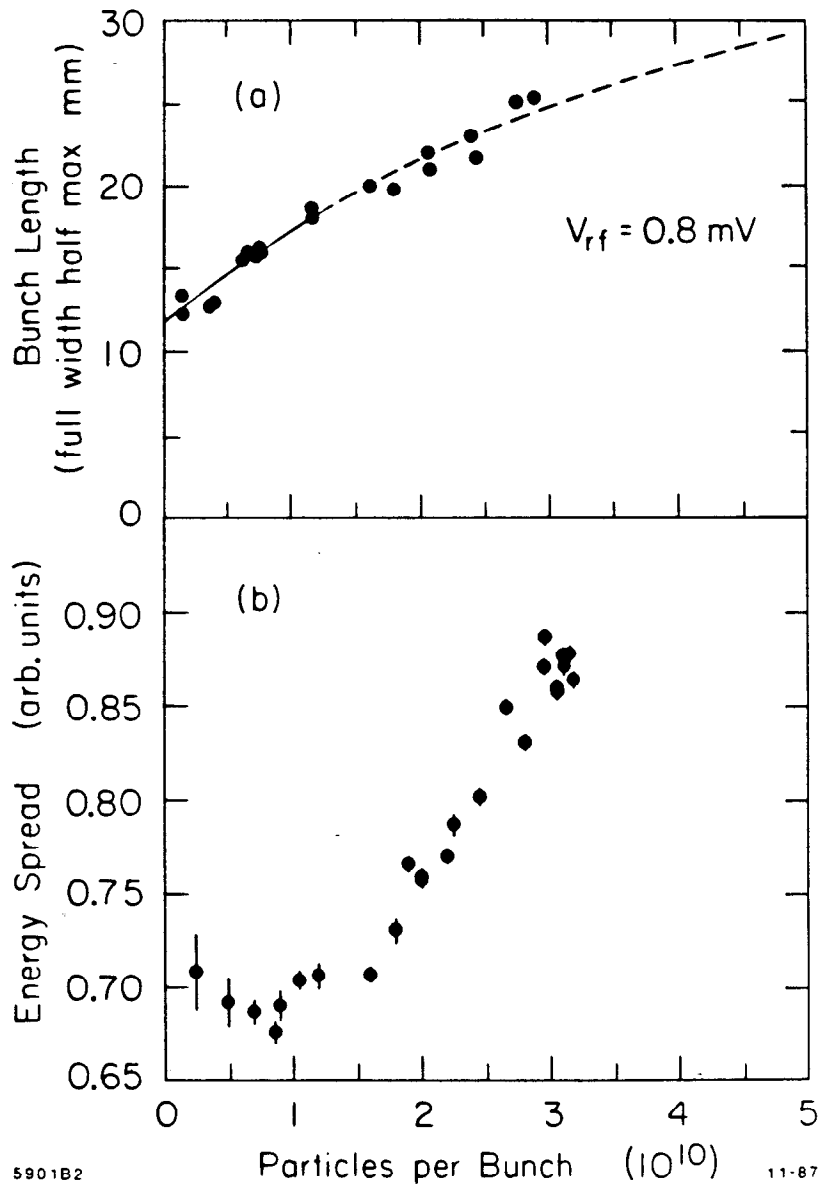
Bunch lengthening has been observed in the north damping ring and has limited the intensity which can be injected into the linac. Since the two rings are essentially identical, the south ring is expected to have the same problem although at the present lower intensity it is not a problem. The lengthening is caused by a combination of potential well distortion and turbulent bunch lengthening. The lengthened bunch, after passing through the compressor, has a larger than nominal energy spread. Due to finite aperture in the ring-to-linac transport line, this results in beam scraping and intensity losses. Thus far, this has limited routine running to $2 \times 10^{10} e^-/\text{bunch}$.

The data for the increase in bunch length and energy spread are shown in Figs. 2a and 2b. Notice that the energy spread starts increasing at around 1.5×10^{10} which signals the start of turbulent bunch lengthening. The bunch lengthening at lower currents is entirely due to potential well distortion.

Both of these effects are due to an excess longitudinal impedance from discontinuities in the vacuum chamber. The wake fields of all the discontinuities have now been calculated, and the theory is plotted on top of the data in Fig. 2a. From the excellent agreement, we believe we understand in detail the source of the bunch lengthening.

We are taking a stepwise approach to curing the effects of bunch lengthening in both rings. First, during the fall shutdown 1987, we will open the aperture in the ring-to-linac

transport line. Next we will use the RF in the ring to induce a quadrupole oscillation in order to pre-compress the bunch. This has been tested and works well. After testing these two modifications, we will determine the extent of the vacuum chamber modifications and/or RF power increases necessary to achieve the design current.



(a) Bunch length (b) Energy spread vs. current in the Damping Ring.

3. POSITRON SOURCE

3.1 STATUS

At 33 GeV in the linac, electrons are targeted on a W-Re target to produce positrons. These are captured by a high gradient acceleration section immersed in a high solenoidal field. After acceleration to 200 MeV, they are transported 2 km back to the beginning of the linac to be injected and accelerated to 1.2 GeV for injection into the south damping ring. Due to a sequence of small losses in the entire system, the yield of the system is only 50%; 2 electrons on target yield one positron out of the south damping ring.³

3.2 OUTSTANDING ISSUES

The key problem in the positron system is to increase the yield to 100%. There are several improvements which should accomplish this.

First, the septa will be replaced by one with a larger aperture to eliminate losses at extraction from the linac. The high gradient capture section was initially designed to operate at 40 MeV/m. Due to initial vacuum problems associated with a leak in the rotating target, the section was damaged and so has been commissioned at the reduced field of 20 MeV/m. A new acceleration section will be installed during the fall shutdown 1987 to bring the field back up to 40 MeV/m. Finally, the high field solenoid has had some problems with turn-to-turn shorts which limit its performance to about 4 kG. This is being replaced by a new solenoid which will produce a field of 5.8 kG.

The combination of all these improvements is expected to increase the yield by about a factor of 2. This will bring the entire positron system (including the positron damping ring) up to the design value of 1 positron per electron on target.

4. LINAC

4.1 STATUS

The linac at SLAC has been upgraded with over 200 new 67 MW klystrons. Thus far, beam energies of 53 GeV have been measured, but commissioning and initial running will be at 47 GeV since this yields an energy at the interaction point corresponding to the Z^0 mass.

Positrons and electrons are routinely accelerated on the same RF pulse without significant emittance increase. The energy spectrum for both beams is 0.2–0.3%, and the routine intensity is typically $2 \times 10^{10} e^-$ and $5 \times 10^9 e^+$.

The single beam trajectory has been corrected to 150 μm . Two beam steering has yielded about 300 μm for both beams; however, this number is improving as hardware is debugged. The linac dilutes the emittance of the beam by about a factor of two. This is complicated by matching into the linac and bunch lengthening.

4.2 OUTSTANDING ISSUES

The two most important issues for the linac are stability and trajectory correction. As for stability, there is ongoing work on both slow and fast feedback for position and angle in both planes, energy, and energy spread. Much of this work is complete.

To aid the trajectory correction, the linac is being realigned and hardware checks on faulty beam position monitors are continuing.

To control the beam matching, a system is being finished to automatically measure the emittance and beta function. The klystron replacement program which controls the scaling of the lattice as klystrons cycle on and off is very nearly working.

5. ARCS

5.1 STATUS

Both the north (e^-) arc and south (e^+) arc routinely supply beams to the final focus now. However, due to large systematic errors, the arcs have introduced coupling and magnification of the betatron oscillations.

5.2 OUTSTANDING ISSUES

In Fig. 3a, you see measurements of the phase advance per cell showing the systematic errors. The procedure to correct these errors involves moving magnets and adjusting the backlegs to achieve the proper dipole and quadrupole field on the orbit. (The arcs magnets are combined function dipole-quadrupole-sextupoles.)

In Fig. 3b, you see measurements taken after the "phase fix" described was applied. This required a movement of all magnets by values which were typically around $200 \mu\text{m}$. After these corrections, the optical functions are matched much better in the arcs, but there is still residual coupling and some residual magnification.

Work is ongoing to locate the sources of the residual errors and to calculate small modifications to the arc lattice to render it less sensitive to errors.

6. FINAL FOCUS

6.1 STATUS

Due to the problems mentioned in the arcs, the final focus has had limited commissioning time with a good input beam. In spite of this, a spot size of about $5 \mu\text{m}$ has been achieved in the north final focus (see Fig. 4), and a spot size of $20 \mu\text{m}$ has been achieved in the south final focus. In addition, the location of the collision point was measured with a streak camera and found to be 1 mm south of the surveyed point.

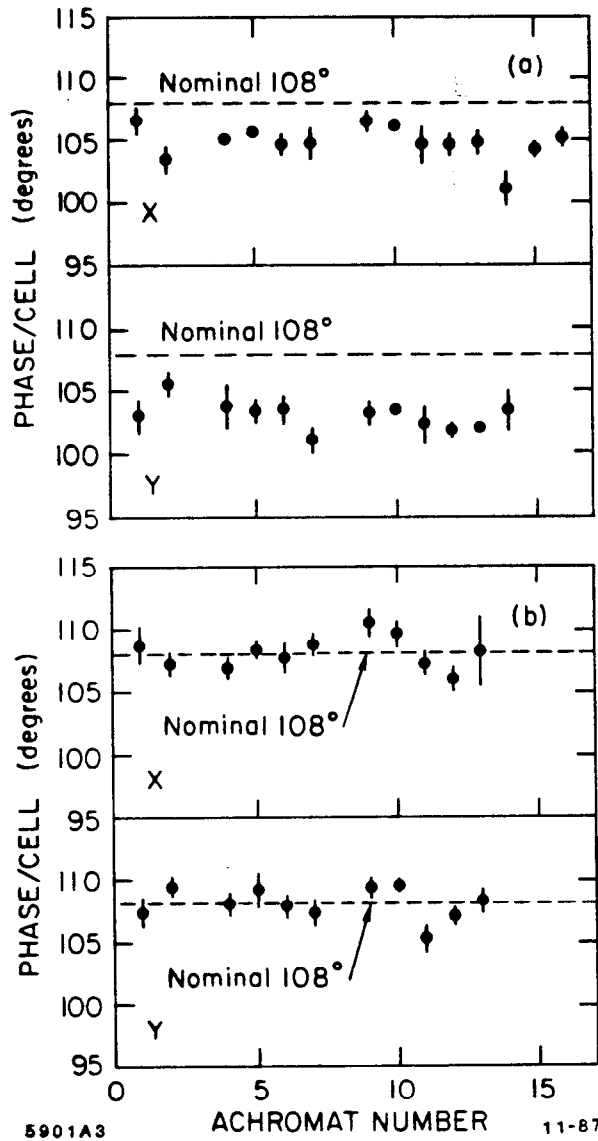


Fig. 3 Phase advance per cell (a) before and (b) after 'phase-fix'.

6.2 OUTSTANDING ISSUES

In spite of the fact that $5 \mu\text{m}$ spots have been achieved several times; it is not routine. A key effort in the final focus commissioning will be to reliably make small spots. This is greatly influenced by the upstream conditions and puts heavy demands on the linac and arcs. Once $5 \mu\text{m}$ spots are routine, the second order chromatic correction needs to be commissioned in order to go from $5 \mu\text{m}$ to $2 \mu\text{m}$.

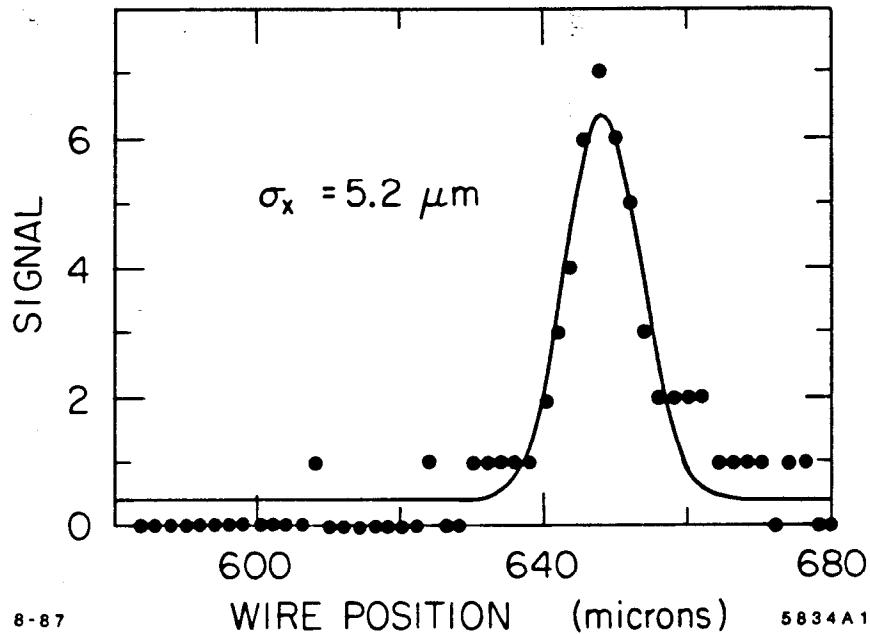


Fig. 4 Measurement of the Final Focus spot size.

In the area of beam-beam monitoring and control, the beamstrahlung radiation monitor is not yet complete and the beam-beam deflection monitor to aid steering must be commissioned.

7. CONCLUSION

As noted in the introduction, the SLC began a 13-week shutdown to move the Mark II detector and to upgrade various subsystems on Oct. 10, 1987. During that time, as the various subsystems are finished, they will be re-commissioned. The north damping ring will be turned on in late November followed by the positron system and south damping ring. Finally around mid January, beams are scheduled to pass through the final focus.

At this point, commissioning of the final focus and arcs will resume to prepare the SLC for the spring physics run.

REFERENCES

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3. S. Ecklund, in *Proc. of the Workshop on Intense Positron Beams*, Idaho Falls, Idaho, 1987, and SLAC-PUB-4437.