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LUMINOSITY UPGRADES FOR THE SLC*

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Abstract

Recent performance improvements at the SLAC Linear Collider (SLC) have led to a proposal to further increase the luminosity up to a factor of four through a series of modest hardware upgrades. New final focus optics introduced in 1997 combined with permanent magnet octupoles have reduced the contribution to the final beam size due to higher order aberrations. The minimum betas achievable at the IP are presently limited by the increase in detector backgrounds as the beam is focused more strongly. By moving the final quadrupoles closer to the interaction point (IP), one can reduce the synchrotron radiation background while decreasing the IP betas. Other upgrades include increasing the bending radius in the final focus to minimize emittance dilutions due to synchrotron radiation, a fast feedforward from the linac to the final focus to cancel trajectory jitter, and a change in the horizontal damping ring partition number to reduce the emittance of the extracted beam. With these upgrades, the expected disruption enhancement should be 2.4.

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Abstract

Recent performance improvements at the SLAC Linear Collider (SLC) have led to a proposal to further increase the luminosity up to a factor of four through a series of modest hardware upgrades. New final focus optics introduced in 1997 combined with permanent magnet octupoles have reduced the contribution to the final beam size due to higher order aberrations. The minimum betas achievable at the IP are presently limited by the increase in detector backgrounds as the beam is focused more strongly. By moving the final quadrupoles closer to the interaction point (IP), one can reduce the synchrotron radiation background while decreasing the IP betas. Other upgrades include increasing the bending radius in the final focus to minimize emittance dilutions due to synchrotron radiation, a fast feedforward from the linac to the final focus to cancel trajectory jitter, and a change in the horizontal damping ring partition number to reduce the emittance of the extracted beam. With these upgrades, the expected disruption enhancement should be 2.4.

1 INTRODUCTION

In the 1997/98 run, the luminosity of the SLC was increased by a factor of four [1]. This improvement was almost entirely due to changes in operating procedures and to reconfiguration of existing hardware, as opposed to costly upgrades. The luminosity increased steadily throughout the run reaching a peak of $3*10^{30}/cm^2/sec$ or a rate of 300 Z^0/hour. This demonstrates that the SLC remains on a steep learning curve and can continue to provide valuable experience on the physics and operation of linear colliders. Based on the knowledge gained in the last run, SLC/SLD have proposed another factor of three to four increase in the luminosity with modest hardware changes [2]. These include moving the final triplets closer to the interaction point (IP) in order to reduce backgrounds and allow higher angular divergence, a feedforward system from the linac to the IP to correct transverse jitter, and a number of smaller improvements to further reduce the beam emittance. Current research on higher polarization photocathodes could also potentially provide polarization in excess of 85%. The higher polarization together with an average luminosity of 25-50,000 Z^0s per week would support a significant physics program for SLD. These improvements would also allow the SLC to finally reach or surpass design luminosity.

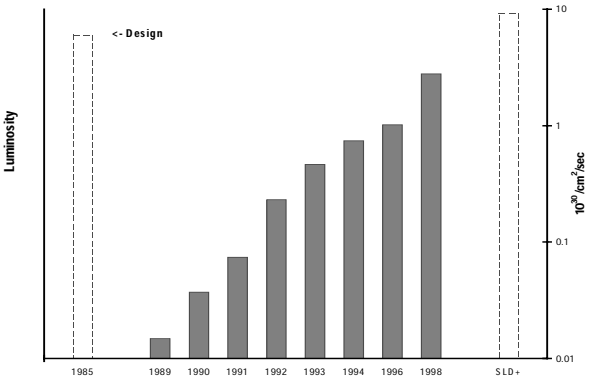

Figure 1: History of SLC luminosity from 1989 through 1998. Bar at left shows design luminosity. Bar at right shows expected luminosity with upgrades.

FINAL FOCUS MODIFICATIONS

With the installation of octupoles in the final focus in early 1998, the minimum beam size achievable at the IP is no longer limited by higher order aberrations. The operational performance is determined by the maximum angular divergence that can be sustained without causing excessive backgrounds in the detector. The primary source of background is synchrotron radiation emitted by the beam in the final triplet of superconducting quadrupoles which scatters into the detector. This can be greatly reduced by moving these magnets closer to the IP and increasing the field of the first quadrupole of each triplet. In this configuration, the clearance across the triplet would be increased by 20-30% in both planes. In addition, the synchrotron radiation swath would have a much shorter lever arm and exit more cleanly. This would allow operation with more optimal angular divergences of 600 by 280 microradians, an increase of 25% in the horizontal and 20% in the vertical. With the resulting smaller beam sizes and additional disruption enhancement, the expected increase in luminosity from this modification alone is about 70%.

The mechanical modifications required to move the triplets 71 cm closer to the IP are straightforward. One radiation shielding mask and the beam position monitor between the triplet and the IP would be removed, and the monitor reinstalled upstream. Turtle ray traces indicate

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that in the new configuration, the mask to be removed is no longer critical and, if desireable, additional masking could be installed inside the triplets. The choice of 71 cm allows the SLD luminosity monitors to remain without modification although their electronics would need to be relocated.

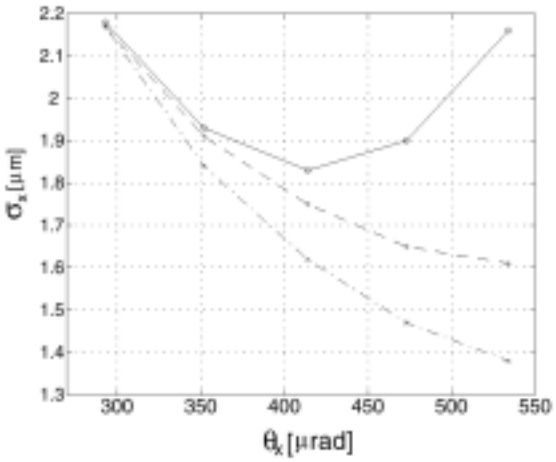

Figure 2: Horizontal beam size vs angular divergence at the SLC IP showing the reduction in beam size with increased divergence. The upper curves are for the 1996 optics, calculated using the RMS beam size (solid) and correct luminosity-weighted effective beam size (dashed). The lower curve (dot-dashed) is for the 1998 optics.

To take full advantage of the increased angular divergence and produce the smallest possible beams at the IP, it would also be desirable to reduce the residual aberrations due to synchrotron radiation from the bends in the chromatic correction section (CCS) of the final focus. A softened bend configuration was partially implemented at the end of 1997 using offset quadrupoles and steering dipoles. The radius of curvature can be further increased by adding more bend magnets in the CCS using existing magnets which are available and spare power supply channels. The expected luminosity increase from both final focus upgrades is 120%, including disruption.

3 LINAC-IP FEEDFORWARD

During present operation, transverse beam jitter is typically 20-40% of the beam size in the linac which causes a significant increase in the effective emittance. This can be reduced by a system to measure the beam trajectory at the end of the linac and correct it with fast kickers near the IP. It is possible to make a correction on the same pulse by taking advantage of the shorter communication path directly to the collider hall rather than the longer path followed by the beams around the arcs. Such a system was considered for the SLC several years ago and a similar system is under study for the NLC. Either a simple microwave or optical link would be used to send a fast signal to the collider hall. A digital signal processor would calculate the necessary corrections from position monitor data in the linac. Since the deflecting field needed is small, existing position monitors can be used as simple stripline kickers, driven by solid-state electronic pulsers.

An added benefit of reducing the sensitivity to jitter is the possibility of using a better linac lattice. The present lattice is a compromise between jitter control and chromatic emittance dilution. Reduced transverse jitter would also improve the resolution of the final optimization of the beams at the IP. The proposed feedforward system should increase the luminosity by about 30%, assuming a 60-80% reduction in the present jitter.

4 EMITTANCE REDUCTION

Several smaller upgrades would reduce the emittance of the beams at the end of the linac by 15-20% in X and Y for both electrons and positrons. These include an RF frequency shift to reduce the emittance from the damping rings, bellows shields in the ring to linac transfer lines (RTL) and additional independent supplies for a few RTL magnets. Improved feedback and steering methods would allow better optimization and stabilization of the linac orbits. Together these should increase the luminosity by 50-75% taking into account the additional disruption enhancement.

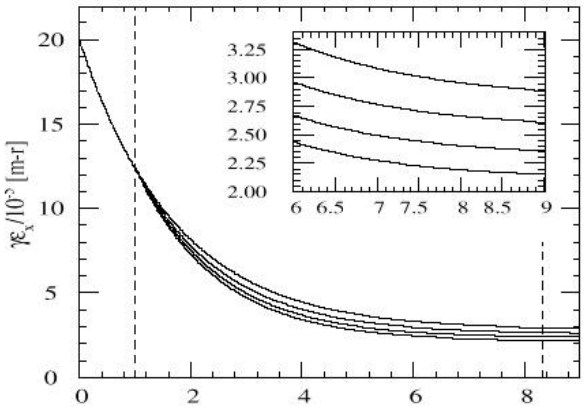

Figure 3: By changing the frequency in mid store the emittance extracted from the damping ring can be reduced by up to 25%. The normalized beam emittance is plotted as a function of store time in ms for different frequency shifts (25,50,100,150 kHz).

In the damping rings, the horizontal damping time and equilibrium emittance can be reduced by increasing the horizontal partition number [3]. This can be accomplished by modifying the closed orbit to go off-axis through the quadrupoles in dispersive regions. To shift the orbit, one can either physically displace the magnets or change the accelerating frequency. A mid-store frequency shift allows full aperture for injection while reducing the emittance. This has been tested in the both damping rings

Table 1: Parameters and Luminosity

	1998 parameters	Final Focus improvements only	Emittance improvements only	2000 parameters (All upgrades)
I (particles/pulse)	$4.0*10^{10}$	$4.0*10^{10}$	$4.0*10^{10}$	$4.0*10^{10}$
ε_x^{FF} (10^{-5} m-rad)	5.5	5.5	4.5	4.5
ε_y^{FF} (10^{-5} m-rad)	0.9	0.9	0.7	0.7
θ^*_x (μrad)	470	600	470	560
θ^*_y (μrad)	240	280	240	260
σ_x^{IP} (μm)	1.5	1.1	1.3	1.0
σ_y^{IP} (μm)	0.65	0.50	0.55	0.40
Z_n (Z/hr)	10	18	15	26
H_d	1.9	2.2	2.3	2.4
Luminosity (Z/hr)	300	630	550	1000
($cm^{-2}sec^{-1}$)	$2.8*10^{30}$	$5.8*10^{30}$	$5.1*10^{30}$	$9.3*10^{30}$

Table 1: Comparison of 1998 parameters and luminosity with those projected from the different upgrades. Column 1 lists recent operating parameters from the 1997-98 run. Column 2 shows the improvement from moving the final triplets closer to the IP and softening the FF bend radius. Column 3 shows the impact of emittance reduction in the damping rings and linac without the FF upgrades. Column 4 contains projected parameters with all upgrades.

and a 15% decrease in the horizontal emittance was measured for e^+ and a 10% decrease for e^-.

Two modifications are planned for the transfer lines (RTLs). A new optics was installed in 1997 to reduce the beam size in tight apertures where there were losses. Independent power supplies for a few quadrupoles near the end of the RTL would be added to allow the flexibility to further improve the optics. Wakefields from the bellows were identified as a source of emittance growth and some of the RTL bellows were shielded during the 1997-8 run. This reduced the positron vertical emittance by almost 50%. Shields should be installed for the rest of the RTL bellows. With these improvements one can expect a 10% decrease in the horizontal emittance of both beams, a 20% decrease in the electron vertical emittance, and about a 5% increase in throughput.

5 HIGHER POLARIZATION

The strained-layer GaAs/GaAsP photocathodes used in the SLC electron source until 1998 resulted in polarizations in the range of 76-80% while maintaining full SLC intensity. In principle such cathodes should produce polarizations >90% [4]. SLAC has an active photocathode research program with the short-term goal of raising the polarization to a value of over 85%. The two most promising directions are the further optimization of the strained-layer structure and the development of the superlattice structure. Thinner epilayers and gradient doping (lower dopant density in the bulk, higher in the final few nanometers at the surface) should help in the former case. Rapid advances in understanding the properties of superlattice structures combined with the larger number of adjustable parameters point to the strained superlattice as the strongest candidate for the future although the total effort to optimize is expected to be greater [5]. Both directions are being investigated.

6 SUMMARY

A series of modest hardware upgrades have been proposed which would increase the luminosity of the SLC by up to a factor of 4 to nearly $10^{31}/cm^2/sec$. This is significantly above the original design luminosity of $6*10^{30}/cm^2/sec$. In this parameter regime, the disruption enhancement should be 2.4, implying that nearly 60% of the total luminosity is due to disruption.

7 REFERENCES

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