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G. Goldhaber

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A BRIEF STATUS REPORT ON THE SLAC LINEAR COLLIDER (SLC)*

Gerson Goldhaber
Physics Division, Lawrence Berkeley Laboratory†
#1 Cyclotron Road
Berkeley, California 94720 USA

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ABSTRACT. Some aspects of SLC operation and running conditions in 1988 are discussed.

1. The SLC

The SLC, shown in Fig. 1, operated with 3 bunches - 2 electron bunches (separated by 59 ns) and one positron bunch¹. All bunches are stored in North (electron) and South (positron) damping rings. The positron bunch and the first electron bunch are accelerated to the full LINAC energy. The second electron bunch is accelerated to 33 GeV and is then deflected by a kicker magnet to the positron target to supply the next positron bunch. The positrons are then collected and brought back to the front end of the LINAC to be accelerated.

The e^+ and e^- beams are extracted from the damping rings at the front end of the SLC and accelerated, one behind the other, in the LINAC. At the end of the LINAC they are deflected into their respective arcs and brought around into the final focus region whose function it is to generate tiny spots at the interaction point. (Design specifications are $2\mu \times 2\mu$).

The energy upgrade of the LINAC readily achieved 50 GeV beams. The machine is routinely run with 46 GeV $e^\pm$, corresponding to an estimate of the Z^0 mass of 92 GeV/c². In order to achieve

Figure 1. SLC Layout.

MASTER

small spots at the interaction point, the damping rings are required to provide the LINAC with very low-emittance beams. Emittances measured at the exit of the damping rings are now within design specification for both beams. At this time emittance growth occurs in the LINAC so that typically the emittance of the beams is about $\pm$ twice nominal as they enter the arcs. This problem is being worked on at present.

With the present setup of the arcs and final focus, small beam sizes are achieved routinely for both e^+ and e^- , $3\mu \times 5\mu$ ($4\mu \times 4\mu$) being the best achieved for $e^-(e^+)$ beams.

2. Luminosity

The luminosity at the interaction point (IP) can be written as follows:

$$L = 1.5 \times 10^{27} \text{ cm}^{-2}\text{s}^{-1} \frac{f}{30\text{Hz}} \frac{N_-}{10^{10}} \frac{N_+}{10^{10}} \frac{4\mu}{\sigma_x} \frac{4\mu}{\sigma_y} \quad (1)$$

where f is the collision frequency, N_- and N_+ are the number of electrons and positrons per bunch at the IP, respectively, and σ_x and σ_y are the transverse beam sizes at the IP for the larger of the two beams. The achieved values for these parameters are summarized in Table I. The first column lists the best achieved value, the second column lists typical values for recent colliding-beam runs, and the third column lists possible values expected for 1989. The rate of Z^0 production at the peak of the Z^0 resonance can be written in terms of the luminosity as follows:

$$Z^0 \text{ rate} = \frac{4}{\text{day}} \frac{L}{1.5 \times 10^{27} \text{ cm}^{-2}\text{s}^{-1}} \epsilon \quad (2)$$

where ϵ is the average efficiency for colliding beams.

The entire machine was recently operating at a repetition rate of 30 Hz with parts of the LINAC running at 60 Hz in preparation for an increase to that frequency. One of the major difficulties so far has been a low value of ϵ (typically 1-4%). During the present SLC shut down a considerable effort is directed at improvement of the reliability of critical components. This should result in considerably higher values of ϵ .

TABLE I. SLC parameters at the interaction point for colliding beams

Parameter	Best Achieved Values	Typical Value for Recent Running	Possible Values for 1989
f	30 Hz	30 Hz	60 - 120 Hz
N_-	1.5×10^{10}	0.9×10^{10}	$2.0 - 3.0 \times 10^{10}$
N_+	0.9×10^{10}	0.5×10^{10}	$1.5 - 2.0 \times 10^{10}$
$\sigma_x \times \sigma_y$:			
electron beam	$3\mu \times 5\mu$	$6\mu \times 6\mu$	$3\mu \times 3\mu$
positron beam	$4\mu \times 4\mu$	$8\mu \times 8\mu$	$4\mu \times 4\mu$

3. Wire Scanner

The beam size is measured by scanning the beam across a thin carbon fiber, "wire" which can be "flipped-up" into the path of the e^+ and e^- beams at the collision point. Each beam is measured separately on both a horizontal and vertical wire²⁾. The wire flipper has three wire diameter sizes - 4μ , 7μ and 28μ . Usually we use one of the two smaller diameter wires. As the beam is scanned across the wire the current in the wire is digitized allowing one to extract a beam profile. Thus by allowing for the contribution from the wire the beam size in both x and y is obtained (Fig. 2a). At larger e^+ beam currents $\geq 5 \times 10^9$ the wire signal becomes non-linear and bremsstrahlung from the intercepted beam is used instead of the current in the wire. The bremsstrahlung photons are detected upstream in a monitor which generates Čerenkov light after the photons traverse a converter (Fig. 2b). Wire scans are done under automatic software control, the magnets are capable of $\leq 1\mu$ size scan steps. Fits are performed on the data providing the beam sizes. Both beams can be measured in less than a minute with good reproducibility.

Figure 2. Typical electron beam profiles for (a) the secondary emission signal and (b) the bremsstrahlung signal.

4. Beam-Beam Deflection

Once the two beams are small they are brought into collision. To do this we utilize the deflection of one beam by the other as they pass by each other³⁾. One beam is kept at a fixed x, y location while the other is scanned across it. The deflection of this beam is monitored by beam position monitors about 3 meters downstream of the collision point. The deflection is mapped out as a function of the position of the moving beam. The point of zero deflection gives the maximum overlap of the beams. For typical beam parameters, the maximum deflections measured are 50-100 μ rad. This procedure is under computer control and takes about twenty seconds. The process can thus be repeated at regular intervals to ensure that the beams remain in collision. Figure 3 shows an example of this deflection.

Figure 3. Example of the deflection angle in the (a) $x-z$ plane (horizontal) and (b) $y-z$ plane (vertical) for a positron beam scanned across an electron beam in the x direction. The beams are offset by approximately 10μ in the y direction.

5. Backgrounds

Machine backgrounds have been studied by the MARK II group. The detector is both triggered using a random coincidence with the beam-crossing signal and a physics trigger which is designed to capture almost 100% of all visible Z^0 decays. The physics trigger used to study the backgrounds has two main pieces, a) small angle luminosity monitors (for Bhabha scattering) and b) a Z^0 trigger.

In addition to the detector elements, the radiation levels in monitors strung along the e^+ and e^- final focus beamlines are also recorded. In this way background sources can be isolated by studying correlations. Two major background sources have been observed: a) electromagnetic debris resulting from $e^\pm$ striking the beampipe and synchrotron masks close to the MARK II and b) muons which are produced when tails of the $e^\pm$ beams impinge on final focus, fixed aperture machine protection masks and movable final focus scrapers needed to trim halo from the beams. In most cases the muons are produced 30-60 meters from the detector, are deflected by magnetic elements on the beamline and enter the MARK II roughly parallel to the beam axis. The number of muons hitting the detector varies from 5 to 100 depending on beam conditions.

During a current SLC shut down both additional collimators (near the beam switchyard) and toroidal iron magnets (placed around the beam pipe near the muon sources) are being installed. These new additions should reduce the muon background substantially.

6. Recent Achievements

6.1. BNS OR LANDAU DAMPING⁴⁾

This involves introducing a momentum spread in the early part of the acceleration in the LINAC and removing it in the latter part. This results in reducing resonant emittance growth due to the action of the head on the tail of the beam. The technique resulted in reducing sensitivity to launch conditions into the LINAC, yielding gains in intensities of about a factor of two in both e^- and e^+ beams.

6.2. FAST FEEDBACK LOOP

The introduction of a fast feedback loop (pulse to pulse corrections) has helped improve beam stability in the LINAC. Slower loops controlled by the mainframe VAX were replaced by microcomputer based loops to provide positional and energy stability of the beam entering the arcs.

6.3 EXTRACTION LINE ENERGY SPECTROMETERS

Two spectrometers were introduced, one in each of the two extraction lines. The purpose is to measure both beam energies on a pulse to pulse basis. The method is to measure the relative position of two synchrotron light strips on a fluorescent screen, before and after deflection in the spectrometer. These devices are very successful and will allow significant $M(Z^0)$ and $\Gamma(Z^0)$ measurements. So far they achieved beam energy measurements with an absolute accuracy of ± 40 MeV per beam and after a careful survey a ± 15 MeV accuracy is expected.

6.4 TWO PHOTON EVENT

One candidate of the type $e^+e^- \rightarrow e^+e^-e^+e^-$ was observed in the MARK II detector for a total luminosity corresponding to about $0.5 Z^0$. This event - as well as beam gas events observed - indicates clearly that even with present background conditions Z^0 events could be readily observed. When the SLC running starts again in early 1989 background conditions and luminosity should be considerable improved.

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