SLAC–PUB–6387
November 1993
(I/A)

A Method of Obtaining Parasitic e^+ or e^- Beams during SLAC Linear Collider Operation*

M. Cavalli-Sforza, L. A. Kelley, and S. R. Klein
Santa Cruz Institute for Particle Physics
University of California, Santa Cruz, CA 95064

P. Anthony, R. Becker-Szendy, R. Erickson, R. A. Gearhart,
L. P. Keller, G. Niemi, M. L. Perl,
L. S. Rochester, M. Stanek, and J. B. Truher
Stanford Linear Accelerator Center
Stanford University, Stanford, CA 94309

P. E. Bosted and J. White
The American University
Washington, DC 20016

Presented at the IEEE 1993 Nuclear Science Symposium and Medical Imagining Conference, October 31-November 6, 1993.

*Work supported in part by Department of Energy contracts DE–AC03–76SF00515 (SLAC) and W–4705–ENG–48 (LLNL), and by National Science Foundation Grants NSF–PHY–9113428 (UC Santa Cruz) and NSF–PHY–9114958 (An. Univ).

Abstract

We have developed a technique that allows SLAC to provide parasitic low-intensity secondary e^+ and e^- beams up to 25 GeV to End Stations A and B and to the FFTB during SLC operation. This beam was successfully used for a one-month-long experimental run in End Station A by the SLAC E-146 collaboration. The experiment used 400 MeV to 25 GeV electron beams at intensities averaging one electron per pulse and 120 pulses per second. The method for producing such a beam without the need for dedicated beam time was to operate parasitically from SLC: photons produced in the SLC beam scrapers in linac sectors 28, 29 and 30 were converted to positrons and electrons in a target downstream from the SLC splitter magnet. The secondary e^- (or e^+) were then transported to ESA with the A-line.

I. Introduction

In the 1970s and early 1980s, SLAC provided a large number of users with test beams, as part of normal operations. However, since SLAC moved toward collider operations, in particular SLC, the available test beams at SLAC have fallen into disrepair. In addition, there was no convenient way to produce low-intensity beams without interfering with collider operations, or dedicating the SLAC linear accelerator to fixed target beam production, an expensive proposition.

A low-intensity beam was required by SLAC Experiment E-146 [1], which measured the Landau-Pomeranchuk-Migdal effect (suppression of bremsstrahlung due to multiple scattering). Since bremsstrahlung has a very high cross section, the experiment required a beam with average intensity of only one electron or positron per pulse, but at as high an energy as possible.

To provide this beam, we developed a novel mechanism to use the particles scraped away by the SLC linac collimators during normal operation [2].

II. Beam Generation

The beam originates at the end of the SLAC linear accelerator, as shown in Figure 1. During normal SLC operation, 5–10% of the beam (a few $\times 10^9$ particles) is scraped

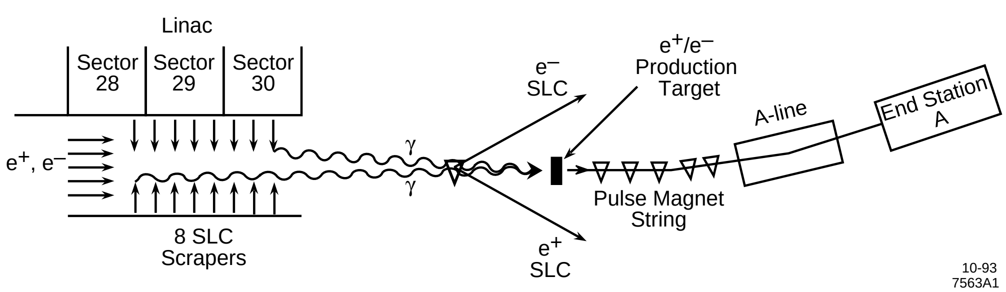

Figure 1. A diagram of the parasitic beam generation. High- energy photons produced in the collimators of sectors 28–30 travel downstream in the SLC beam pipe, past the 50B1 bending magnet that directs electrons and positrons into the SLC arcs, and onto a e^+e^- production target in the beam switchyard. Electrons produced in the target are captured by the A-line and transported to End Station A.

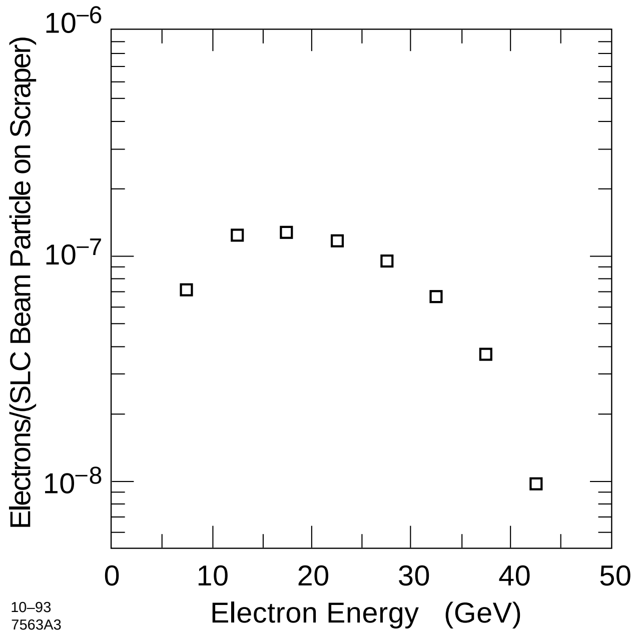

Figure 2. The parasitic yield for the full A-line angular acceptance and 1% energy spread as a function of secondary electron energy.

away by a series of eight collimators in sectors 28–30 of the linac. Each collimator is 2.2 radiation lengths (X_0) of titanium. Bremsstrahlung by scraped electrons in the collimators produces a usable photon flux that emerges from the sides and back of the collimator. Some of these photons follow the beam downstream, past the 50B1 magnet that bends the electrons and positrons into the SLC arcs, and into the beam switchyard. There, a 0.7 X_0 remotely-insertable copper target converts these photons into e^+e^- pairs. Electrons within the A-line fixed angular and adjustable momentum acceptance [3] enter the A-line and are transported to End Station A. Although E-146 used electrons exclusively, positrons could also be used by reversing the polarity of the A-line magnets.

The parasitic beam was simulated using the electromagnetic shower Monte Carlo EGS4 for electromagnetic showering, and the ray tracing program TURTLE to transport the electrons through the A-line. The simulations showed that this beam should produce a flux of 1–100 electrons per pulse at 25 GeV, the highest energy that could then be transported by the A-line. Figure 2 shows the predicted yield as a function of energy.

Unfortunately, the yield is sensitive to a number of factors, chief among them the relative positions of the collimators.

SLAC Experiment E-146 used this technique for a one month run. The E-146 experience generally matched the simulation, although the observed intensities were lower than the simulations indicated. This is probably because of imperfect collimator alignment, coupled with uncertainties as to the relative losses in the collimators in different sectors of the linac. The latter is important because the effective collimator solid angle seen by the electron production target drops significantly as the distance between the target and collimator increases. Typically, E-146 ran with the A-line momentum defining collimators almost closed, set around $\Delta p/p \sim 0.05\%$, compared with the typical high-current operational setting of $\Delta p/p \sim 1 - 2\%$, providing a beam intensity of about one electron per pulse.

To understand the beam generation, it is convenient to divide the system into two parts: photons impinging on the e^+e^- production target, and electron production and transport in the A-line. The source size for the A-line optics system is determined by the spatial distribution of the photons on the production target. EGS4 simulations indicate that for photons from the first collimator in Sector 29 the source size is approximately ± 1 mm, and for photons from the last collimator in Sector 30 the source size is approximately ± 10 mm. In typical SLC operation, most of the photons originate from the first few collimators in Sector 29.

The A-line transport was modeled using the ray tracing program TURTLE. With the A-line optics adjusted to focus the beam at the ESA pivot, a source size of 2 mm radius, and an energy defining slit of 0.1% full width results in a beam whose rms half widths are $x = y = 4$ mm and $\theta = \phi = 0.2$ mrad. This corresponds to an acceptance of $3.7 \times 10^{-3} \mu\text{sr} \cdot \%$. Since the primary beam intensity and linac collimator openings, are set to optimize SLC operation, the only way to vary the parasitic beam intensity is with the energy defining slit and emittance defining collimator in the A-line. With the emittance defining collimator attenuating 50% of the secondary beam, the calculated rms half widths at the ESA pivot become $x = y = 2.5$ mm and $\theta = \phi = 0.12$ mrad. With the energy slit set to 0.1% full width, the measured yield is $\sim 10\ e^-$/pulse at 8 and 25 GeV for a typical SLC beam loss of 5×10^9 on the linac collimators. The measured rms half-widths are 3–4 mm, in agreement with the calculation.

The experience of the E-146 run showed that the secondary beam intensity and position remained stable for long periods of time and required only infrequent adjustments of collimators and steering magnets. Typically, the pulse to pulse intensity was dominated by Poisson fluctuations in the number of electrons. On a time scale of days, the average intensity varied by a factor of order 2, as the SLC beam conditions changed.

In addition to the 25 GeV running, E-146 also collected data at 8 GeV, with similar intensities and ease of operation, and tuned the beam briefly to 2 and 6 GeV. Data were also collected with the beam tuned to 400 and 500 MeV, to calibrate a calorimeter. At these energies, a number of factors complicated operation. These included an inadequate number of dipole correctors to compensate for the earth's magnetic field over the several-hundred-meter beam-line length, difficulties with the magnet power supplies regulating at low current, and a burned out magnet. At 400 MeV, the maximum intensity was about one per minute; at 500 MeV, it peaked at about one per second. At these energies, the beam dispersion was considerably increased, filling the beam pipe; however, the momentum dispersion remained small, as shown by the histogram in Figure 3. While low, the flux was adequate for calibration purposes.

The time structure of the beam that reaches ESA follows that of the SLC—two subnanosecond pulses separated by 59 ns at a repetition rate of 120 per second. E-146 used the 59 ns separation to monitor the relative electron yield from the two bunches; typically the electron intensities generated by the two bunches were about equal.

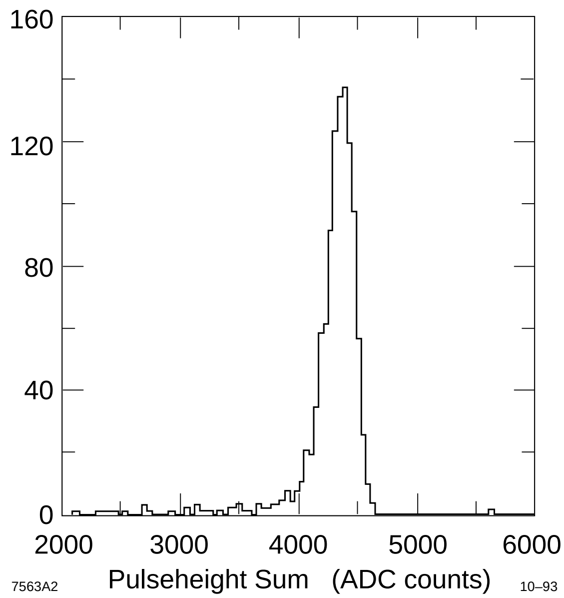

Figure 3. The pulse height observed in the E-146 calorimeter with the A-line tuned to 500 MeV. The width is consistent with the calorimeter resolution.

III. Future Possibilities

The possibility of using the same parasitic technique to provide beams to other beam lines has been considered. It would be possible to direct the beam into the B target room; however this would interfere with a number of current projects.

Alternatively, it appears possible to use the same technique to provide low-intensity beams in the new Final Focus Test Beam (FFTB). Simulations indicate that the parasitic technique should work in the FFTB, and provide similar beam intensities. There are two differences due to the different FFTB transport: the beam momentum spread should be larger, $\Delta p/p \sim 2\%$, and the beam should be smaller. The former is due to the limited bend in the FFTB line; the latter is due to the better focusing optics.

The same technique to generate a low-intensity pion beam. Although the pion photoproduction rate is much lower than the pair production rate, by using a low-Z target and a non-zero production angle, Monte Carlo simulations indicate it may be possible to produce a usable pion beam, with a flux in the range 0.1 to 1 particle per second.

Acknowledgments

We thank the SLAC directorate and operational groups for their excellent support. In particular, the entire MCC Operations Section provided invaluable help in setting up and delivering the beam, the Power Conversion Group was invaluable in keeping the magnets working, and the ESA crew helped greatly with the experimental setup.

References

[1] M. Cavalli-Sforza et al., SLAC Proposal E-146, June 1992. S. Klein et al., invited talk presented at the XVI International Symposium on Lepton-Photon Interactions, Ithaca, NY, August 1993, to appear in the proceedings; Stanford Linear Accelerator Center preprint SLAC–PUB–6378 (October 1993).

[2] Al Odian, personal communication, May 1992.

[3] H. S. Butler, S. K. Howry, and C. H. Moore, Stanford Linear Accelerator Center internal report SLAC Report–29, June 1964.