SLAC–PUB–6326
LBL–34488
August 1993
(A/E/I)

SIMULATIONS OF LOW ENERGY e^+e^- PARTICLE BACKGROUNDS*

MICHAEL T. RONAN
Lawrence Berkeley Laboratory
Berkeley, California 94720, USA

Representing the NLC Interaction Region Working Group
Stanford Linear Accelerator Center
Stanford, CA 94309

ABSTRACT

A progress report on simulations of low-energy e^+e^- backgrounds from the beam-beam interaction at future linear colliders is given. Characteristics of the primary particles and detailed calculations of the backgrounds from backscattering into the detector volume are presented.

1. Introduction

Collisions between real and virtual photons in the beam-beam interaction at future linear colliders will generate significant backgrounds due to the copious production of low-energy e^+e^- pairs and from hard scattering of the photon's constituents. In the latter case, encouraging new calculations[1] indicate that the "Mini-Jet" background, dominated at high energies by gluon-gluon scattering, is not as large as originally estimated and can be reduced to a quite manageable level. In this report, progress on the calculation of primary and secondary backgrounds associated with low-energy pair production is given.

1.1. Pair Creation Processes

The ABEL beam-beam simulation code[2] has been enhanced recently to include production of low-energy e^+e^- pairs.[3] The modified program, ABELMOD, includes the three incoherent pair creation processes: Breit-Wheeler (BW: $\gamma\gamma \rightarrow e^+e^-$), Bethe-Heitler (BH: $\gamma e^\pm \rightarrow e^\pm e^+e^-$) and Landau-Lifshitz (LL: $e^+e^- \rightarrow e^+e^-e^+e^-$). Reactions involving only virtual photons, like the LL process, have been used to

*This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, of the U.S. Department of Energy under Contract Nos. DE–AC03–76SF00098 and DE–AC03–76SF00515.

Presented at the 2nd International Workshop on Physics and Experiments at Linear e^+e^- Colliders, Waikoloa, Hawaii, USA, April 26–30, 1993.

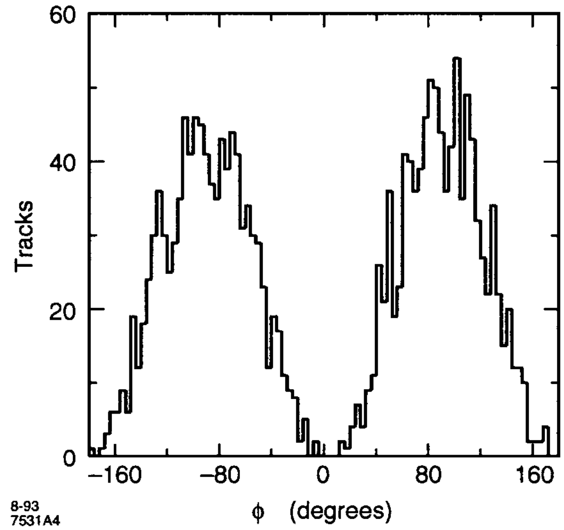

Figure 1: Azimuthal angle distribution for the primary electrons from the ABELMOD simulation.

study two-photon collisions in circular colliders over the past decade. The additional BW and BH processes arise from the creation of real beamstrahlung photons in beam-beam interactions at linear colliders. In current designs with small disruption parameters[4] the coherent (Schwinger) pair-production process is negligible.

1.2. Machine Parameters

We use the NLC machine parameters for a 0.5 TeV Linear Collider:[4] $E = 250 \times 250\ GeV$, $N = 0.65 \times 10^{10}$ particles per bunch, and σ_x, σ_y, and $\sigma_z = 300\ nm, 3\ nm$, and $100\ \mu m$, respectively. With a luminosity of $L = 3.7 \times 10^{29}/cm^2$ per bunch crossing and a total cross section of order 10^{-25} cm^2, more than 10^4 e^+e^- pairs would be produced each bunch crossing. There would be 90 such crossings each 126 ns-long machine pulse. Operating at a repetition rate of 180 pps, the full luminosity for a machine of this design would be $L = 6.0 \times 10^{33}/cm^2/sec$.

2. Simulation of Beam-Beam Interactions

The ABELMOD simulation uses the flat beam approximation (KFld=3) with particle cell divisions of 56 by 0.56 nm in the transverse (x, y) plane and 10 μm longitudinally. All produced pairs were folded into the hemisphere of the oncoming e^- beam. The simulation of a single bunch-crossing, which was done in several runs with different minimum and maximum energy cutoffs, generated 1965 electrons with transverse momentum (p_T) greater than 5 MeV and polar angles (θ) greater than 40 mrad. (Unsigned reference to electrons implies electrons and positrons.) The particles considered in the background calculations below are predominantly negative electrons defocused by the e^- beam; however, at large p_T and θ, roughly equal numbers of electrons and positrons with large inherent angles are found as expected. The azimuthal angle distribution of the electrons, Fig. 1, shows a clear vertical-horizontal asymmetry.

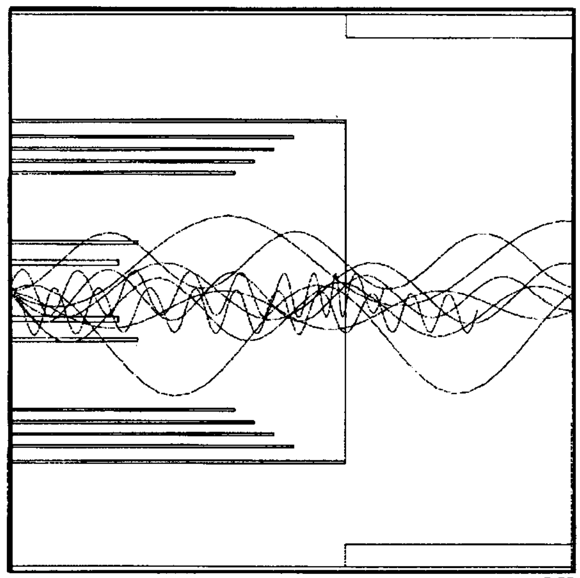

Figure 2: Display of large angle primary tracks in the central detector—scale: 20 cm radius, 50 cm longitudinally.

3. Primary Background Simulation

The primary backgrounds associated with low-energy pair production are being studied in a GEANT detector simulation environment[5] which includes both electromagnetic and hadronic shower simulations, and flexible detector description codes with excellent graphics. A solenoidal magnetic field of 2.0 Tesla was chosen with only the following tracking elements being defined at this time: a 1 mm think Be beam pipe, a 5-15 cm radius intermediate tracker/trigger chamber and a 25 cm-2 m radius central tracker. In addition, a luminosity monitor, tungsten masking and final focus magnets are included in a cylindrically-symmetric, zero crossing-angle geometry.

To avoid saturation in displaying background tracks for one bunch crossing, electrons were selected according to two algorithms. For the first, electrons with $p_T > 10\ MeV$ and $\theta > 300\ mrad.$ were chosen to display the tracks giving rise to the primary background in the vertex detector, as shown in Fig. 2. One can see that the innermost vertex detector layers would have many hits per bunch (and hundreds of hits per pulse train) from primary tracks with large inherent angles or which have been widely deflected by the oncoming beam.

On a different scale, Fig. 3 displays the trajectories of a sample of electrons selected with increasingly larger energy and angle cuts. The large flux of particles at these smaller angles gives rise to primary backgrounds in the luminosity monitor, and secondary backgrounds due to backscattering on the face of the final-focusing quadrupole.

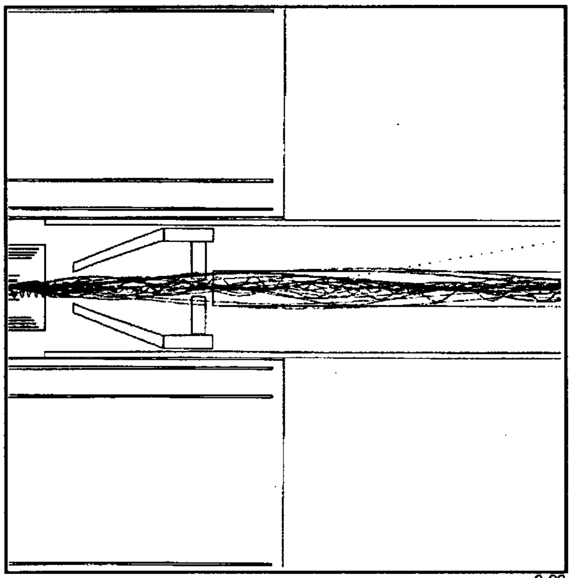

Figure 3: Display of small angle primary tracks in the forward region—scale: 1 m radius, 4 m longitudinally.

4. Secondary Background Simulation

To shield the detector from the secondary backgrounds generated by electrons hitting the face of downstream elements a "lobster-trap" geometry has been chosen for the masking, as shown in Fig. 4. Electrons and photons backscattered from the luminosity monitor at $z = \pm 140$ *cm* and the quadrupole face at $z = \pm 150$ *cm* are trapped by the conical tungsten mask extending from ± 50 *cm* to ± 150 *cm*.

The secondary background is calculated using EGS4[6] which tracks electron and photon scattering and fluorescence down to 1 keV. The simulated detector is similar to the one described above except that it also includes a detailed Silicon vertex detector and support structure. Backgrounds are estimated for three different vertex detector and beam pipe options with inner radii of 6, 2.5 and 1 cm. The number of electrons and photons hitting scoring planes at the inner and outer radius of the vertex detector and at the entrance to the central tracker are tabulated in Table 1. Note that the numbers given include both the primary and secondary backgrounds within the EGS4 calculation, for each bunch crossing, and the total numbers of particles hitting per square millimeter for a full pulse train. Backgrounds at these levels are manageable, especially with a pixel vertex detector.

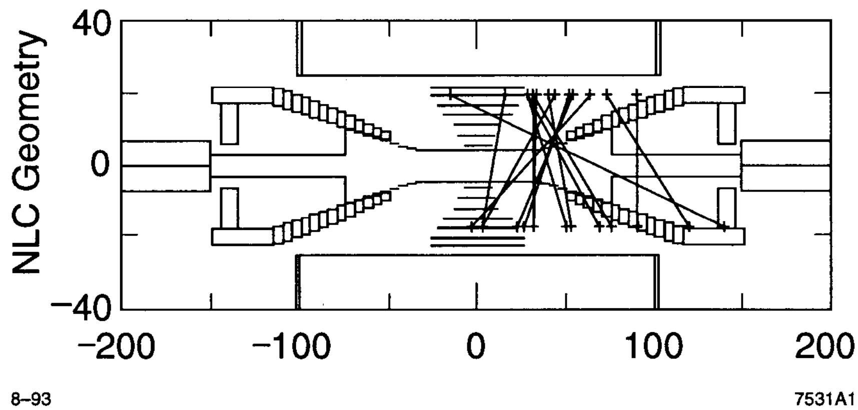

Figure 4: Vertex detector and masking for the 6 cm radius geometry. Lines drawn from simulated hits in the outer vertex chamber scoring plane through the interaction region are used to locate apparent sources of the secondary backgrounds.

Table 1: Estimated vertex detector and central tracker backgrounds.

6 cm VXD	Innermost Si Layer	Outermost Si Layer	Central Tracker
# e^-/bunch	1	0	0
# γ/bunch	1	5	21
# part/mm^2/train	0.002	0.0006	
2.5 cm VXD			
# e^-/bunch	12	2	0
# γ/bunch	3	6	270
# part/mm^2/train	0.11	0.016	
1 cm VXD			
# e^-/bunch	31	4	1
# γ/bunch	1	0	209
# part/mm^2/train	0.97	0.17	

5. Future Plans

We plan to continue developing detailed descriptions of detector and interaction region elements within the GEANT framework. This model, including finite angle crossings and allowing for non-cylindrical elements, will be used to simulate primary electrons hitting all exposed surfaces. The production and backscattering of secondary electrons and photons would then be simulated using EGS4 in an approximate cylindrical geometry.

The simulation work described in this report is the continuation of studies initiated by P. Chen, T. Tauchi, V. Telnov and K. Yokoya in previous linear collider workshops and summer studies. The ABELMOD simulation of the beam-beam interaction was run by T. Tauchi of KEK, while the detailed EGS4 simulations were carried out by G. Punkar of SLAC. Work on checking the azimuthal angle distribution, shown in Fig. 1, and on studying its sensitivity to the beam profile is in progress on several fronts.

I'd like to thank the organizers for a well organized meeting and for choosing the spectacular setting of the big island of Hawaii.

References

1. P. Chen, these proceedings. Also in P. Chen, T.L. Barklow and M.E. Peskin, SLAC-PUB-5873.
2. K. Yokoya, KEK-Report-85-9, 1985, also *Nucl. Inst. Meth.* **B251** (1986) 1.
3. T. Tauchi, K. Yokoya and P. Chen, *Particle Accelerators* **41** (1993) 29.
4. *LC92 Proceedings*, R. Settles, ed. ECFA Report 92/46, 1992.
5. GEANT 3.15, CERN Program Library, 1993.
6. W.R. Nelson, H. Hirayama and D.W.O. Rogers, SLAC-265 (1985).