Backscattering of Secondary Particles into the ILC Detectors from Beam Losses Along the Extraction Lines

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At the International Linear Collider (ILC) the beams will be focused to extremely small spot sizes in order to achieve the desired luminosity. After the collision the beams must be brought to the dump with minimal losses. In spite of all the attention put into the design of the extraction line, the loss of some disrupted beam particles, beamstrahlung or synchrotron radiation photons is unavoidable. These losses will generate low-energy secondary particles, such as photons, electrons and neutron, a fraction of which can be back-scattered towards the Interaction Point (IP) and generate backgrounds into the detector.
In this paper we present an evaluation of such backgrounds, using the BDSIM [2] and Mokka [3] simulations. The event reconstruction in the detector is made with the MarlinReco package from the Marlin tool [4].

1 Introduction

In an e^+e^- linear collider such as ILC, the beams will be focused to extremely small transverse sizes to reach the desired luminosity. This leads to intense beam-beam effects which result in large angular divergence and energy spread for the post-collision disrupted beams, as well as the emission of beamstrahlung photons. The disrupted beams and the beamstrahlung must be brought from the IP to their respective dumps with minimal losses.
The description of the present baseline extraction line design with a 14mrad horizontal crosssing angle at the IP can be found in [6]. Several alternative extraction line studies, with a 2 mrad [7] crossing angle or with head-on collision [8] are also being pursued.
The paper presented here concentrates on the evaluation of the backgrounds in the Large Detector Concept (LDC [5]) from back-scattered photons induced by disrupted beam losses for the specific case of the first collimator in the 2mrad scheme. The methods developed are however general and can be applied to other extraction line designs and and detector concepts. sectionParticles losse on the first collimator in the 2 mrad exraction line The new layout of the 2 mrad crossing angle has relatively good beam transport properties for all machine energies and beam parameter sets [7]. In the case of the 500 GeV center-of-mass machine, beam losses at the kW level are however expected at the first collimator QEX1COLL located at 45 m from the IP. These losses generate back-scattered photons. A fraction of these can reach the detector via direct lines of sight passing through the BeamCal mask aperture.

1.1 Disrupted beam losses at the first collimator

After having simulated the beam-beam collision with GuineaPig [9], the disrupted beam is tracked from the IP to QEX1COLL. The horizontal distribution of the particles lost at QEX1COLL is offset by a mean value of 20 cm with respect to the incoming beam line. The

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number of lost particles represents less than 0.1% of the initial distribution. The energy spectrum of these lost particles is shown in figure 1. The interaction of these high energy

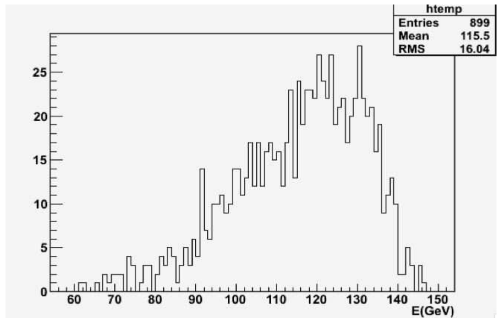

Figure 1: Energy distribution of disrupted beam particles lost at the first collimator QEX1COLL, located at 45 m from the IP.

electrons (with a mean energy of 115 GeV) in the collimator material is simulated using the BDSIM Geant4 based toolkit. In this study, copper was considered.

1.2 Back-scattered photons

The interaction of the high energy electrons in the material produces high energy photons from bremsstrahlung (main process at these energies) which generate a cascade of processes. The high energy photons are converted into a large number of lower energy particles, among which low energy photons travelling backwards. The corresponding spectrum is shown in figure 2. Three main processes relevant to the production of these back-scattered photons

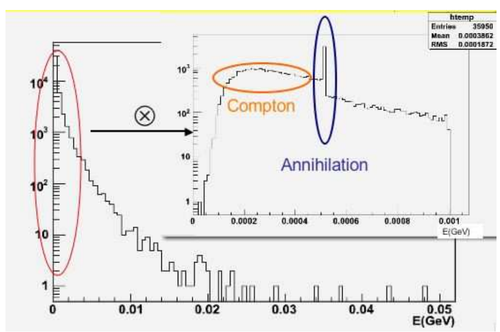

Figure 2: Back-scattered photon energy distribution, including zoom below 1 MeV in the insert.

are :

- Compton scattering
  This process takes place between the incident bremsstrahlung photon and an electron in the material, producing a spectrum with typically an edge at 250 keV.

- Pair production
  If the photon energy exceeds $2 \times m_e$ (m_e is the electron mass), the production of a e^+e^- pair is energetically possible. After thermalisation, the e^+ annihilates in the material, producing two back-to-back photons carrying each of them an energy of m_e, one of which is typically back-scattered.

- Photoelectric effect
  When an electron is ejected from the K shell, the vacant place is filled by a free electron with a X-ray emission at 9keV. Due to the 10 keV energy threshold used in Geant4, this peak is not present in figure 2.

subsectionPhoton rate reaching the Vertex Detector The back-scattered photon angular distribution is shown in figure 3. As can be seen, it is broadly isotropic, even if some

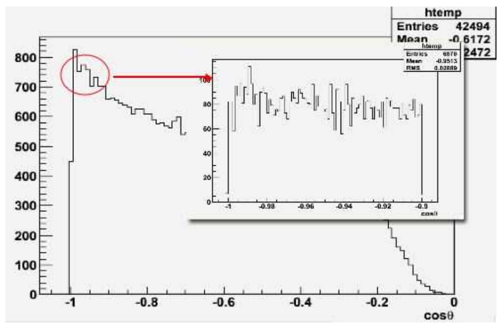

Figure 3: Polar angle distribution of back-scattered photons, including zoom around the backward direction at $\cos\theta = -1$ in the insert.

peaking occurs in the backward direction. For this reason, the fraction which can reach the IP directly without rescattering is very small, as it is limited by the apertures in the beam line. The tightest of these apertures is that of the BeamCal located inboards of the last final focus magnet, thus serving as an efficient mask for these photons. In the 2 mrad extraction line design, a 12 mm radius is used in order to shadow the innermost vertex detector layer at 15 mm. To estimate the fraction of back-scattered photons passing through this small hole, the flatness of the $\cos\theta$ distribution around the backward direction is exploited to obtain the number of photons and the probability distribution within the corresponding solid angle, by rescaling.

With this method, after appropriate normalisation to the total beam power, 40 photons per bunch crossing are estimated into the detector volume per kW of beam power lost at the QEX1COLL collimator 45 m after the IP. sectionHits in the LDC VD

1.3 Mokka simulation

The geometry of the LDC detector in the Geant4 based Mokka simulation is shown in figure 4. At 3.5 m, photons are generated within the 12 mm radius of the BeamCal with a flat spatial distribution, the energy spectrum shown in figure 2 and a fixed horizontal angle of 4.4 mrad corresponding to the 20 cm mean offset of the lost beam particles at 45 m.
The Mokka output is then treated using the MarlinReco package from the Marlin reconstruction software.

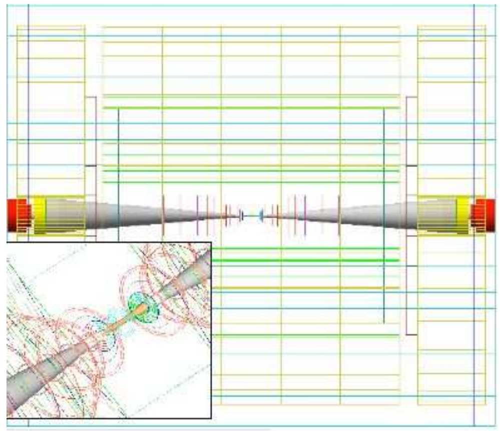

Figure 4: LDC concept detecteur simulated in Mokka.

1.4 VD hits

The spatial distribution of the hits in the VD is shown in figure 5. Most of hits occured at 15 mm, corresponding to the first layer [a]. A strong left-right assymetry is visible, resulting from the fact that the emission points of the photons are offset to one side. The distribution

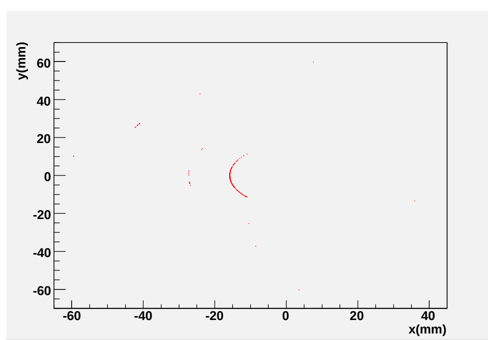

Figure 5: Location of the hits in the VD.

of deposited hit energies in the silicon is shown in figure 6.

The most probable value is about 15 keV, corresponding to approximately twice that obtained for high energy muons in similar conditions. This large value is explained by the very low electron momenta involved.

The number of hits observed in the VD is about 3% of the incident photon rate. A 1 kW beam power loss at QEX1COLL would hence amount to about 1 hit per bunch crossing. This is negligeable in comparison to the number of hits from incoherent e^+e^- pairs produced in the beam-beam interaction and reaching the VD directly (estimated to be around 250 per bunch crossing [10]).

[a]The VD in LDC has a total of 5 layers.

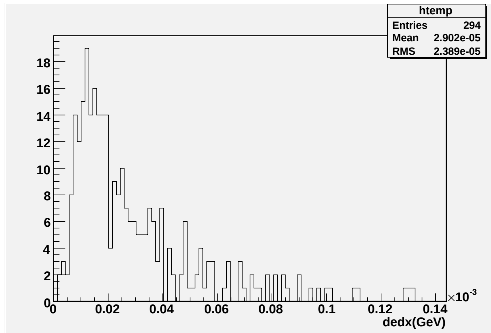

Figure 6: Distribution of deposited hit energies in unit of GeV.

2 Conclusion and prospects

It has been shown that photon back-scattering from disrupted beam losses at the first collimator QEX1COLL in the 2 mrad crossing angle scheme produce negligible effects in the detector.
Further studies planned include a more complete analysis of all photon emission sources along both the 2 mrad extraction line and the other IR geometries under consideration, including from the main beam dump and taking into account multiple reflections in the beam pipe.

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