Studies on the Electron Reconstruction Efficiency for the Beam Calorimeter of an ILC Detector

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In this talk [1] recent simulation results on the single high energy electron (sHEe) reconstruction with the Beam Calorimeter (BeamCal) for the ILD detector are presented. Guinea Pig is used to generate the e^+e^- pair background and Geant4 for the simulation of electron showers in the calorimeter. An algorithm was developed for the sHEe reconstruction on top of the large e^+e^- background. The efficiency of the sHEe reconstruction is estimated for the nominal and SB-2009 ILC beam parameters.

1 Challenges for the Beam Calorimeter

For the future International Linear Collider (ILC) [2], the Beam Calorimeter is proposed for beam diagnostics and sHEe reconstruction at low polar angles (5.6 - 45 mrad). In this region close to the beam pipe, a large number of e^+e^- pairs is predicted [3] due to beamstrahlung photon conversion. Hence, radiation hard sensors are needed, several materials are under investigation. SHEe must be detected on top of a widely distributed pair background. This is a challenge for BeamCal geometry optimization and the analysis of the signals from this detector. Such single electrons or positrons are a product of Standard Model processes, which form a high background e.g. for SUSY particle searches. Reconstruction with high efficiency of sHEe in BeamCal has therefore a crucial importance for ILC physics.

2 Simulation tools

2.1 Guinea Pig

For the simulation of the beam-beam interactions at ILC ($\sqrt{s} = 500$ GeV), Guinea Pig(GP) [4] was used. Input parameters for GP are the number of particles per bunch, the energy of the particles, vertical, horizontal and longitudinal beamsizes, emittances, offsets, etc. The output file "pairs.dat" contains e^+e^- pairs from one bunch crossing: the energies, momenta and initial coordinates of each particle at the interaction region of the ILC.

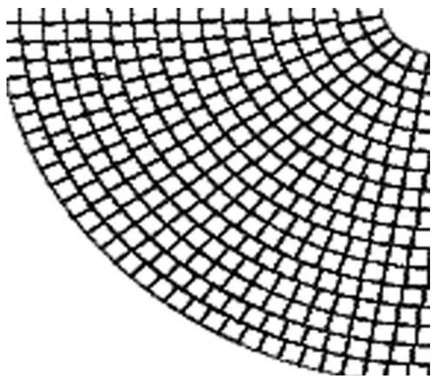

Figure 1: A quarter of the front plane of the Beam Calorimeter. Example of sensor segmentation

2.2 BeCaS

For fast simulation and geometry studies, a Beam Calorimeter simulation tool (BeCaS) [5] was written. BeCaS is based on Geant4 [6] and includes a detailed geometry and material description of BeamCal as well as a simplified description of surrounding detectors. A detector solenoid field including an anti-DID field [7], and a beam crossing angle of 14 mrad are included. The BeamCal coordinates and dimensions in BeCaS are $z = 3550$ mm, $r = 20 - 165$ mm, and $length = 120$ mm. In the BeCaS the BeamCal is a sandwich calorimeter with 29 layers and 10 cm thick graphite block on the IP side. An additional layer in front of the calorimeter plays role of Pair Monitor. Each layer consists of an absorber, made of 3.5 mm thick tungsten, a sensor plate of 0.3 mm diamond with gold metalization, a kapton foil of 0.15 mm thickness and an air gap 0.05 mm thick. The pad size of the sensors is about 8×8 mm^2. A sketch of the sensor segmentation is shown in Figure 1.

2.3 Beam parameters

Two sets of beam parameters are used to generate beamstrahlung pairs: the ILC nominal beam parameters (NOM) [8] and the recently proposed straw-man baseline 2009 beam parameters (SB-2009) [9]. SB-2009 beam parameters have smaller horizontal (470 nm) and vertical (5.8 nm) beam sizes than NOM (640 nm and 5.7 nm, respectively). As a result, the beam-beam effect is stronger and the number of electron-positron pairs in BeamCal is enhanced.

3 Single High Energy electron reconstruction algorithm

To determine sHEe reconstruction efficiency, an algorithm was developed. First, the average values and the standard deviations of the deposited energy in every pad of BeamCal are calculated for the pair background alone, from 10 bunch crossings. The average values of the deposited energy are then subtracted pad by pad from the deposited energies obtained from bunch crossings containing sHEe. One standard deviation of the deposited energy for each pad is applied pad by pad as a threshold for rejecting number of the opportunities to detect background fluctuations as a sHEe, in this case called fake electrons. After this steps, the clustering algorithm is applied.

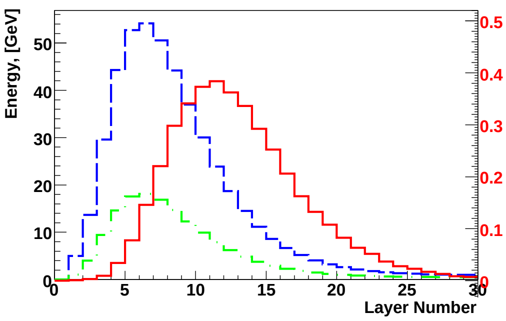

Figure 2: Total deposited energy per layer as a function of layer number: 250 GeV sHEe (solid line), SB-2009 pair background (dashed line), Nominal beam parameters pair background (dash-dotted line)

3.1 Clustering algorithm

Electrons and positrons from beamstrahlung pairs have an energy spectrum around 10 GeV. the maximum deposited energy from beamstrahlung pairs is located around the 5th layer of BeamCal for both ILC beam parameter sets, as shown in the Figure 2. On the other hand, the maximum of the sHEe showers is found around the 9th layer. As mentioned above, and shown in Figure 2, in ILC with SB-2009 beam parameters more beamstrahlung e^+e^- pairs are created. Therefore the deposited background energy in BeamCal for SB-2009 is higher than for nominal ILC beam parameters. In a first approximation, an sHEe shower is searched for as a cluster consisting of towers. Every tower must contain 10 or more consecutive pads with non-zero deposited energy after the 5^{th} layer of the BeamCal. A cluster candidate must consist of a minimum of two towers. First, all towers are found, then the tower with the maximum deposited energy starts a cluster. After this, all neighbouring towers are searched for and added to the cluster. If a neighbouring tower has a deposited energy of more than 90% of the deposited energy of the initial tower, further neighbouring towers of it are searched for and added to the cluster. For every cluster, the deposited energy and the center of mass in radius and polar angle coordinates are calculated.

3.2 Fake electron subtraction

Fluctuations of the background, which are interpreted by the clustering algorithm as a sHEe, are called fake electrons. By applying the clustering algorithm to samples of pure background events the fake rate was determined. The background distribution decreases with increasing radius, therefore fake electrons are more likely to appear at inner radii. Using the method of subtraction of the average value, and using a threshold of one sigma of the background fluctuations of signals from every pad, the fake electron rate is reduced.

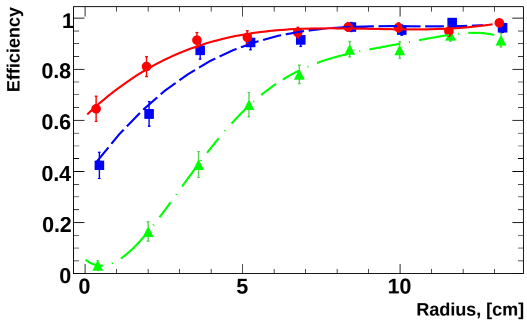

Figure 3: Reconstruction efficiency as a function of Radius (as measured starting from the outer adge of the beam-pipe) for 50, 150, 250 GeV sHEe for nominal beam parameters

3.3 Reconstruction efficiency

The reconstruction efficiency is estimated as the ratio between number of reconstructed and generated sHEe,

$$\varepsilon = \frac{N_{\text{rec}}}{N_{\text{gen}}},$$

Where N_{rec} - number of reconstructed sHEe, N_{gen} - number of generated sHEe. The reconstruction efficiency as a function of the radial hit position on BeamCal is shown in Figure 3 and 4 for nominal and SB-2009 beam parameter sets. Single high energy electrons of 50 GeV(triangle, dash-dotted line), 150 GeV(square, dashed line) and 250 GeV(circle, solid line) are simulated. For every sHEe energy, 1000 files of electrons were simulated and the clustering algorithm was applied for each case. A cluster is accepted as a reconstructed sHEe when the deduced cluster position in radius and polar angle correspond to the primary position of the sHEe. The efficiencies for nominal beam parameters shown in Figure 3 are approximated by

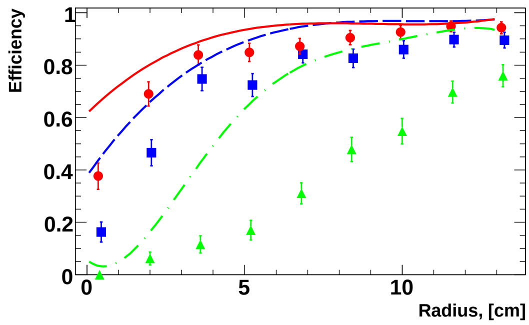

Figure 4: Reconstruction efficiency as a function of Radius (as measured starting from the outer adge of the beam-pipe) for 50, 150, 250 GeV sHEe for SB-2009 beam parameters

polynomial functions (dotted line curves), which are then overlaid to the result for SB-2009 parameters in Figure 4. The comparison show that the higher number of e^+e^- pairs created in SB-2009 reduces the reconstruction efficiency considerably, in particular for lower energies of sHEe.

4 Summary and outlook

A preliminary analysis of single high energy electrons detected in the ILC BeamCal in the presence of the large background from beamstrahlung pairs has been presented. So far, the calculations have been performed with low statistics for the beamstrahlung background. The clustering algorithm has been developed and applied for nominal and SB-2009 ILC beam parameter sets for the calculation of the sHEe reconstruction efficiency. In comparison with nominal beam parameters, the new SB-2009 beam parameters show a higher pair background and therefore a lower reconstruction efficiency. The reconstruction efficiencies of lower energetic sHEe for SB-2009 drops to less than half the value obtained for the nominal beam parameters. For higher energetic sHEe, the reconstruction efficiency is worse by up to 30%. This work will be pursued further with adjustment of clustering algorithm parameters, by adding angular and energy resolutions calculations, applying the algorithm within the Mokka [10] simulations and by using higher statistics.

5 Acknowledgments

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