PRAMANA — journal of physics
© Indian Academy of Sciences
Vol. xx, No. x
xxxx xxxx
pp. 1–5

BeamCal Performance at Different ILC Beam Parameters and Crossing Angles

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Abstract. The ILC accelerator parameters and detector concepts are still under discussion in the world-wide community. As will be shown, the performance of the BeamCal, the calorimeter in the very forward area of the ILC detector, is very sensitive to the beam parameter and crossing angle choice. We propose here BeamCal designs for a small (0 or 2 mrad) and large (20 mrad) crossing angles and report about the veto performance study done. The signal to background ratio in the $\tilde{\tau}$ search in a particular realization of the super-symmetric model is estimated for several beam parameter sets and various crossing angles.

Keywords. BeamCal, electron veto, 2-photon background, accelerator beam parameters, crossing angle, stau analysis

PACS Nos 2.0

1. Introduction

The TESLA machine parameters were chosen to achieve a high peak luminosity with only little room for operational optimization. As a more flexible approach [1] defines a number of different machine configurations achieving the same peak luminosity. We consider here the impact of these schemes on the pair depositions in the BeamCal. The pairs, stemming from the beamstrahlung photon conversions, deposit several TeV of energy in the BeamCal (see Fig. 1) with large local energy density fluctuations from bunch to bunch. Identification of single electrons on top of these depositions is challenging at the inner part of the BeamCal even at highest electron energies [2].

For a 2 mrad crossing angle the depositions of the pairs in the BeamCal are very similar to the ones of the head-on scheme (Fig. 1a). The only change to be done for the BeamCal is a slightly larger inner radius.

The 20 mrad concept is discussed for several version of the magnetic field inside the detector. In the DID[1] field configuration the magnetic field is directed along the incoming

[1]Detector integrated dipole

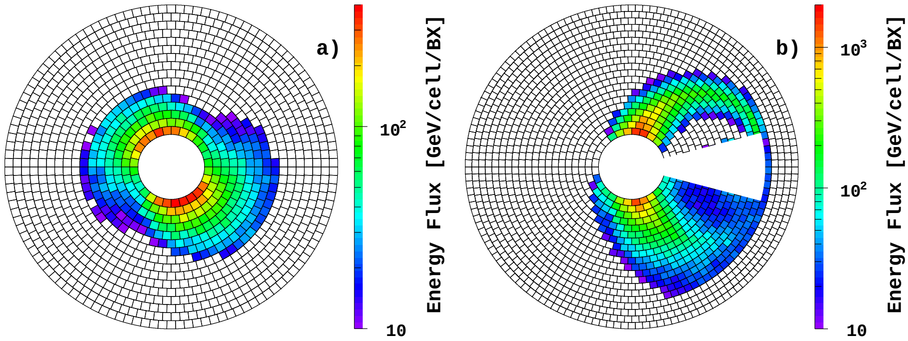

Figure 1. The energy density of beamstrahlung remnants per bunch crossing as a function of position in the $r - \varphi$ plane at the a) 2 mrad and b) 20 mrad with DID field crossing angles.

beam lines with a kink at the transverse plane containing the IP. The incoming beams will not suffer by synchrotron radiation and spin precession before they collide. However, the amount of beamstrahlung deposited in the BeamCal rises considerably (Fig. 1b), causing also higher background in the tracking detectors due to backscattering. Conversely, if the magnetic field is directed along outgoing beam lines with a kink at the IP plane, called Anti-DID, the depositions on the BeamCal and background in the central detector are very similar to the head-on case.

The BeamCal is an important tool to identify two photon events by detecting either electron or positron with an energy near the beam energy. Two photon events constitute the most serious background for many search channels which are characterized by missing energy and missing momentum. In most cases lepton pairs produced in photon-photon processes have significantly different topology and kinematics in comparison to the search channel and can be rejected by simple cuts. However, since the two photon cross-section is typically several orders of magnitude larger, events in the tails of the kinematic distributions become important.

The electron veto performance, obtained from simulations, is used to estimate the suppression of the two-photon background in the different ILC schemes. The search for a $\tilde{\tau}$ super-symmetric particle is taken as a benchmark process. In a particular realization of the super-symmetric model, which we conider here (point 3 in the list of SUSY benchmark points for the ILC detector [3]), the $\tilde{\tau}$'s are the second lightest super-symmetric particles which are pair-produced in e^+e^- annihilaion and decay into lighter neutralinos, which escape undetected, and regular τ's. In context of this model, the $\tilde{\tau}$'s and neutralinos could combine to provide plausible, quantitave explanation for the amount of dark matter in the universe. The amount is directly related to the mass difference between $\tilde{\tau}$ and neutralino and is assumed here to be equal 5 GeV.

2. Simulation and Results

Single electrons and beamstrahlung pairs were simulated for 4 proposed accelerator parameter sets (Tab. 1) at zero crossing angle and Nominal set at 20 mrad crossing angle with

	Nominal	LowQ	LargeY	LowP
Bunch charge [10^{10}]	2	1	2	2
Number of bunches	2820	5640	2820	1330
Gradient [MeV/m]	30			
$\gamma\epsilon_x/\gamma\epsilon_y$ [10^{-6} mrad]	10 / 0.04	10 /0.03	12 / 0.08	10 / 0.035
β_x / β_y [mm]	21 / 0.4	12 / 0.2	10 / 0.4	10 / 0.2
σ_x / σ_y [nm]	655 / 5.7	495 / 3.5	495 / 8.1	452 / 3.8
σ_z [μm]	300	150	500	200
Luminosity [10^{34} cm^{-2}s^{-1}]	2.03	2.01	2.00	2.05

Table 1. Beam and IP parameters for various beam parameter configurations at $\sqrt{s}$ = 500 GeV.

DID magnetic field. Beamstrahlung was generated using GUINEA-PIG [4]. The detector was simulated in GEANT4 [5].

The BeamCal is 370 cm apart from the interaction point. The inner radius is 1.5 cm for 0 mrad crossing angle and 2 cm for 20 mrad. The outer radius is 16.5 cm. For 20 mrad crossing angle area of 30 degree in $r - \phi$ plane between beam pipes supposed to be 100% inefficient for particle detection. This assumption is made due to foresight of instrumentation problem of that area.

Fine granularity is necessary to identify the depositions from high energy electrons and photons on top of energy depositions from beamstrahlung remnants. The simulated sampling calorimeter is longitudinally divided into 30 disks of tungsten, each 1 X_0 thick (3.5 mm) interleaved by diamond active layers (0.5 mm). The sensitive planes are divided into pads with a size of about half a Molière Radius (5 mm) in both dimensions, as shown in Fig. 1.

The energy depositions from pairs and the single electrons depositions are superimposed in the sensor pads. A reconstruction algorithm applied to the output. The reconstruction procedure is described in more details in [6].

After applying all selection cuts except electron veto 20 $\tilde{\tau}$ events are left, while the number of survived 2-photon background events is about 2.7×10^5. Fig. 2 shows the energy and spatial distribution of the electrons of background events. Most of the electrons have nearly beam energy and hit the BeamCal outside the area affected by pairs, though the distribution has tails down to smallest angles and energies. It is important to notice that the distribution depends on mass difference, e.g. if it is larger than 5 GeV the distribution is broader and shifted to larger angles.

The average efficiency to veto electrons is shown in Fig. 2 for several electron energies at head-on collision and Nominal beam parameter configuration. An electron of 250 GeV is vetoed even in regions with high background with almost 100% efficiency. The efficiency drops near the innermost radius, partly due to shower leakage. Electrons of 75 GeV are identified with high efficiency only at larger radii.

Performing reconstruction, fake particles can be found. This can be either high energetic particle in beamstrahlung remnants or background fluctuations which mimic the electron signal. In this study the recognition algorithm was tuned with the rate of fake electrons of 10%.

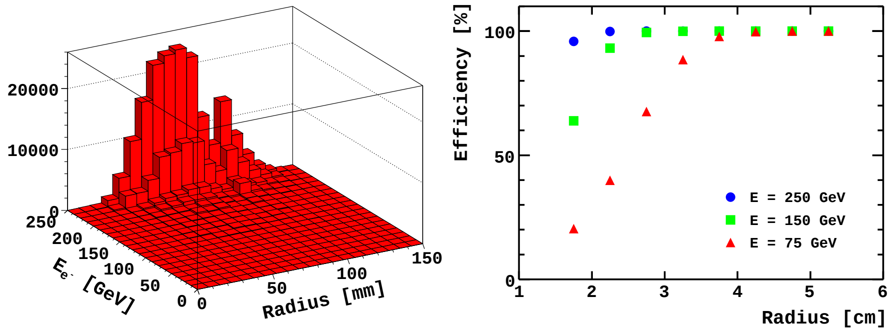

Figure 2. Left: Electron energy and spatial distribution of the 2-photon background events passed all selection cuts except the BeamCal veto. Right: The efficiency to veto an electron of energy 75, 150, 250 GeV as a function of the radius in the BeamCal.

For each beam parameter set in table 1 veto efficiencies are estimated from simulations. These efficiencies where included into the $\tilde{\tau}$ search analysis. The number of unvetoed 2-photon events for each beam parameter set is listed in table 2. Results are given for energy cuts of 50 and 75 GeV, showing that a relatively low energy cut of 50 GeV improves the signal-to-noise ratio considerably. For the chosen benchmark physics scenario the chances to see $\tilde{\tau}$ particles are very good for most of the accelerator designs. Only for the LowP scheme the remnant background dominates the selected event sample. By far the best situation is given for the LowQ scheme.

In the cases of crossing angles of either 2 mrad or 20 mrad with Anti-DID field we expect the BeamCal performance similar to the head-on scheme, as the coresponding pairs deposition distributions are similar. In case of 20 mrad crossing angle with DID field we would have no chance to see $\tilde{\tau}$ production for this benchmark scenario.

Energy cut [GeV]	75	50
Nominal, 0 mrad	45	5
LowQ, 0 mrad	40	0.1
LargeY, 0 mrad	50	9
LowP, 0 mrad	364	321
Nominal, 20 mrad, DID	396	349

Table 2. The number of unvetoed background events. The number of $\tilde{\tau}$ events is 20.

Acknowledgements

I would like to thank Z.Zhang (LAL, Orsay) for providing the samples of the simulated $\tilde{\tau}$ events and helpfull discussions.

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