Pair Background Simulations

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The background induced by pairs from beamstrahlung has been studied for six different geometries of the Large Detector. Three different crossing angles (0, 2, 20 mrad) and different masking schemes have been used.

1. INTRODUCTION

The intense beam-beam interaction at the International Linear Collider ILC will produce beamstrahlung photons which may convert into e^+e^- pairs. These pairs are the major source for backgrounds in the ILC detectors. This background has been studied in detail for the TESLA TDR [1]. Recent developments in the design of the ILC lead to changes in the forward region of the working detector model of the Large Detector Concept Study which is based on the TESLA detector design.

2. FORWARD REGION GEOMETRIES OF THE LARGE DETECTOR

The optics of the TESLA beam delivery system foresaw a focus length of the final focus quadrupoles of L*=3 m. As a consequence of this a masking system was designed which surrounds the final focus quadrupoles which are placed in the middle of the detector inside the tracking system. The tungsten masking system absorbs the secondaries created in the electromagnetic showers when the pair particles are over-focused and hit the quadrupoles.

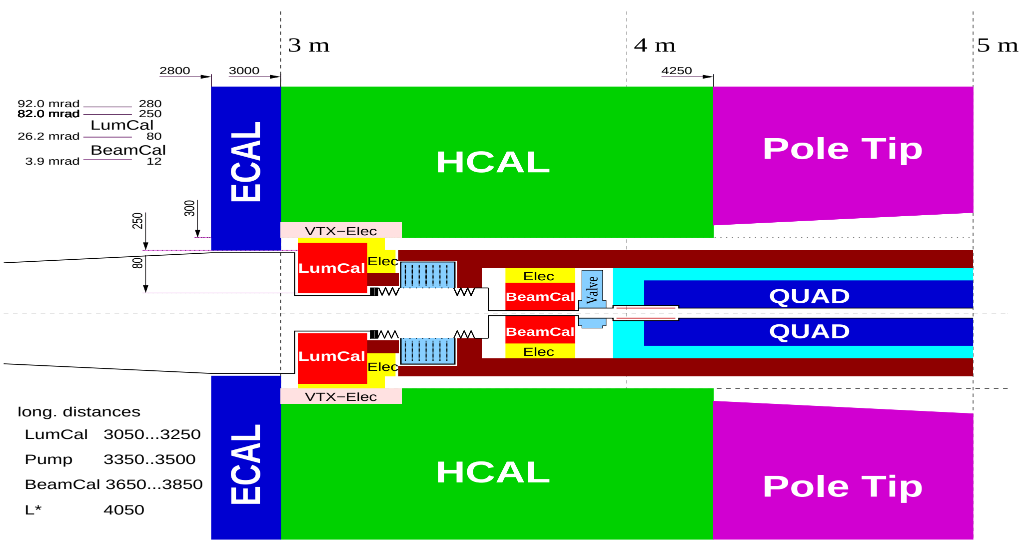

Figure 1: New design of the forward region of the Large Detector as proposed for head-on collisions in [2].

The design of the mask in the TESLA TDR has however shortcomings. The placement in the middle of the tracking system in front of the calorimeters is problematic. Particles coming from the IP and hitting the outer cones of the tungsten mask could scatter from there into the electromagnetic calorimeter without producing tracks in the tracking system thus producing fake photon signals. Additionally the design of the Low Angle Tagger LAT, a calorimeter in the tips of the tungsten mask foreseen for precision luminosity measurement via Bhabha scattering, was not optimised to reach the envisaged precision in the luminosity measurement of $\frac{\Delta L}{L} \leq 10^{-4}$.

New developments in the beam delivery system optics allowed later to chose a larger L*. Therefore a re-design of the forward region has been proposed [2]. This new design is shown in figure 1. While the new design relies on a focal length of L*≥4.05 m, it provides a flat surface for the luminosity calorimeter (the LAT, now called LumCal) which is necessary to reach the high precision envisaged in the luminosity measurement. Furthermore the larger L* allows to move the whole masking system back so that no material is in front of the face of the electromagnetic calorimeter. This design comprises further advantages, e.g. a better vacuum situation.

The new design has been created still with head-on collisions in mind. However the focus of the developments for the beam delivery system of the International Linear Collider ILC shifts to solutions with non-zero crossing angles. The corresponding working group of the First International ILC Workshop decided in November 2004 to define a so called “Strawman Design” which foresees two interaction regions, one with a large crossing angle of the order of 2×10 mrad, the other one with a small crossing angle of about 2×1 mrad [3]. Therefore modifications of the forward region design have been developed and were integrated into the GEANT3 based full TESLA detector simulation BRAHMS [4]. Figure 2 shows the implementation with a crossing angle of 2×10 mrad. Overlaid are the tracks of 25 simulated pair particles and their secondaries.

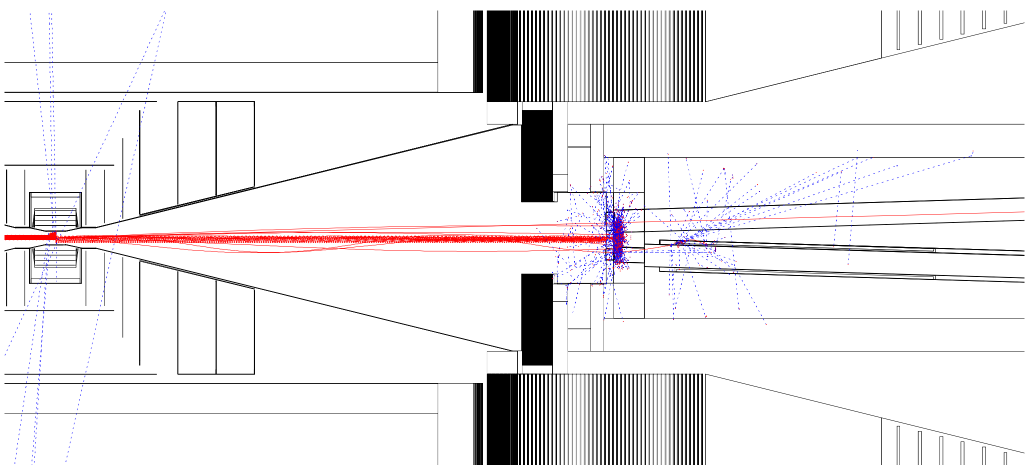

Figure 2: Implementation of the new forward region adapted to a 2×10 mrad crossing angle in BRAHMS. Overlaid are the tracks of a few pair particles and their secondaries.

Other parameters under discussion right now are the sizes of the holes for the outgoing beam in the very forward calorimeter BeamCal. As the BeamCal serves as the last protection collimator for the vertex detector, it is understood that the radius of the hole for the incoming beam should be smaller than the radius of the inner layer of the vertex detector. For the hole for the outgoing beam the situation is different. Its size has a consequence for the requirements on the collimation system which has to make sure that the synchrotron radiation fans created by the beams in the final focus quadrupoles can be extracted through the hole in the BeamCal without backscattering in the detector. In the case of a large crossing angle, the holes can be optimised independent of each other. In the case of the small or zero crossing angle the incoming and the outgoing beam pass through the same hole. Therefore an optimisation has to be performed which balances the requirements from the collimation system and the background on the vertex detector.

3. PAIR BACKGROUND SIMULATIONS

3.1. Geometries Under Study

Six different geometries of the forward region have been implemented in BRAHMS:

G1: The standard TESLA TDR geometry with a radius of 1.2 cm for the hole in the BeamCal

G2: The new geometry as shown in figure 1 with a radius of 1.2 cm for the hole in the BeamCal

G3: The same geometry adapted to a 20 mrad crossing angle (c.f. figure 2) with a radius of 1.2 cm for both the hole for the incoming and for the outcoming beam

G4: The same geometry with an increased radius of 2.4 cm of the hole for the outgoing beam

G5: Same as G2 geometry but with a crossing angle of 2 mrad

G6: Same as G5 geometry with an increased radius of 2.0 cm for the hole in the BeamCal

The pairs from Beamstrahlung have been simulated with GUINEA-PIG [5] using ideal TESLA beam parameters. The numbers of hits quoted in this document are the hits per one bunch crossing (BX) averaged from the simulation of 25 ideal bunch crossings per geometry. The errors given are the corresponding root mean squares. The magnetic field configuration in the detector is a pure solenoid 4T field.

3.2. Simulation Results

The hits on the vertex detector (VTX) layers are shown in figure 3 for the six studied geometries. The results for the geometries with head-on collisions (G1 and G2) are very similar. Hits on the vertex detector are predominantly caused by pair particles with larger transversal momenta which come directly from the IP. The geometry of the forward region, if done properly, has no influence on that.

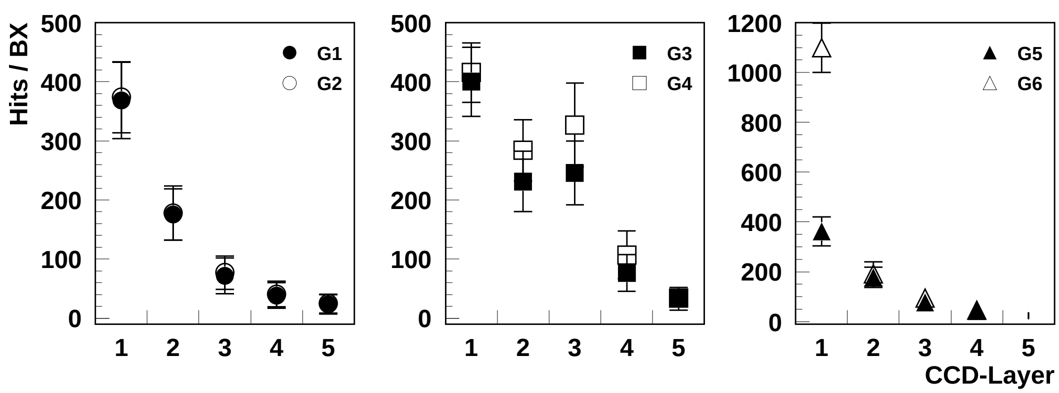

Figure 3: Hits on the vertex detector layers (CCD option) for the six different geometries. Note the different scale in the right plot.

While the geometry with the small crossing angle and the small radius for the hole in the BeamCal (G5) shows a very similar behaviour to the head-on collision geometries, a clear effect can be seen if the hole is enlarged (G6). The number of hits on the inner layer of the vertex detector is increased by a factor of 3. Reason for that are charged particles which are produced inside the mask and which scatter back through the hole of the BeamCal. These low energetic particles are guided by the 4T solenoid field of the detector coil and eventually hit the inner layer of the vertex detector if the radius of the inner layer is smaller than the radius of the hole in the BeamCal.

The behaviour for the geometries with the large crossing angle (G3 and G4) is different. Compared to the other geometries, an increase of the number of hits on layer two and three is clearly visible. Reasons for this effect is again backscattering out of the holes for the incoming and the outgoing beam. Charged particles coming out of the hot zones inside the mask are focused by the holes and drift in the magnetic field in longitudinal direction until they eventually hit layers two and three of the vertex detector. This can be seen in the azimuthal distributions of the hits on the vertex detector layers in figure 4.

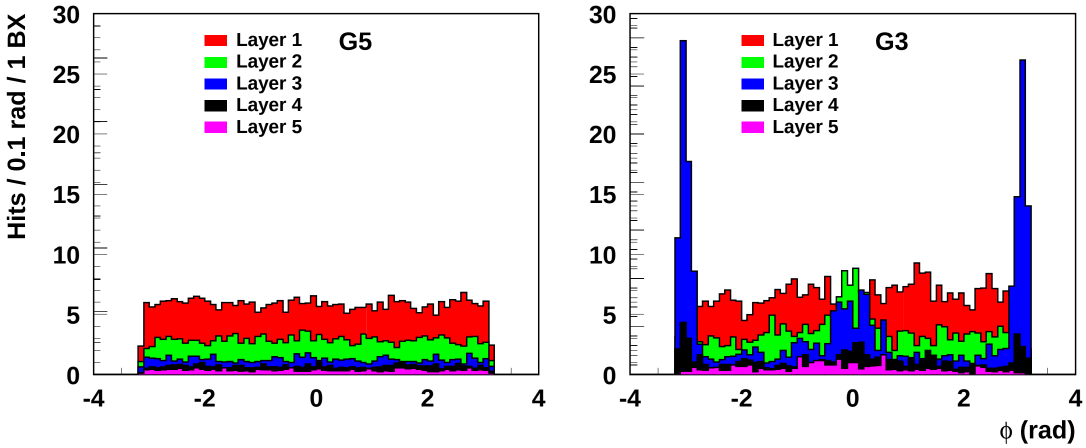

Figure 4: Azimuthal distribution of the hits on the vertex detector layers for the geometry G5 (left) and G3 (right).

While the distribution is flat for the small crossing angle geometry (G5, left), the hits caused by the particles coming out of the holes in the BeamCal can clearly be seen in the peaks of the distributions for layers two and three in the large crossing angle geometry (G3, right). The peaks in the distributions correspond to the positions of the holes for the incoming and outgoing beams left and right from the longitudinal axis.

Figure 3 shows also for the large crossing angle geometries that an enlargement of the radius of the outgoing beam hole results in an increase in the number of hits of the respective layers.

The effect of the holes can also be seen in the hit distributions of the Forward Tracking Disks. The number of hits on the disks is shown in figure 5 (left).

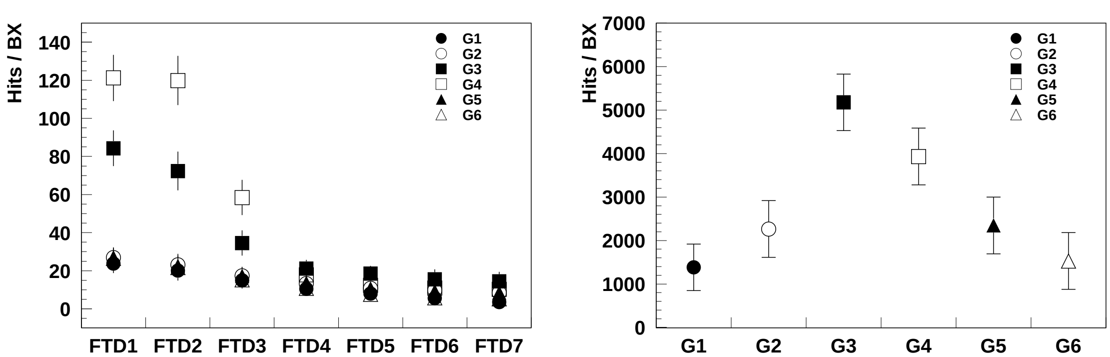

Figure 5: Hits on the Forward Tracking Disks (left) and in the TPC (right) for the six geometry implementations.

While the hit distributions for the zero or small crossing angle geometries are similar, a clear increase can be seen on the first three disks for the larger crossing angle. Those three disks have a smaller inner radius than the other four. The beam of low energetic particles out of the BeamCal holes therefore just hits these three disks.

The numbers of hits in the Time Projection Chamber (TPC) are shown in figure 5. Two trends are visible: the geometries with a 20 mrad crossing angle produce more background hits in the TPC and increasing the holes in the BeamCal reduces the background in the TPC. Background hits in the TPC are mainly caused by photons which backscatter from the surface of the BeamCal. These photons are not focused in the magnetic field but scatter back isotropically into the tracking system. They traverse the TPC and eventually produce charged low energetic particles via Compton scattering or pair production in the TPC gas. As the total deposited energy on the BeamCal is about a factor of two larger in the 20 mrad crossing angle case than in the head-on collision case [6], the number of backscattered photons is also increased. This leads to about twice as much background in the TPC for the 20 mrad crossing angle cases. When the holes in the BeamCal are increased, more pair particles enter the masking system and less energy is deposited on the BeamCal surface. Therefore the number of backscattered photons and the number of background hits in the TPC is reduced.

Table I shows for completeness the hits on the remaining tracking detector, the Forward Chambers (FCH) and the Silicon Intermediate Tracker (SIT).

Table I: Number of hits in the Forward Chambers (FCH), summed over all planes, and in the Silicon Intermediate Tracker layers (SIT n).

Detector	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**
FCH	107 ± 7	182 ± 8	358 ± 12	246 ± 10	185 ± 8	121 ± 7
SIT 1	21 ± 15	15 ± 9	34 ± 14	22 ± 14	16 ± 9	16 ± 14
SIT 2	17 ± 9	38 ± 10	83 ± 17	51 ± 14	42 ± 12	27 ± 11

4. CONCLUSION AND OUTLOOK

The background situation in the detectors for the ILC depends critically on geometrical details. Critical parameters are the choice of a crossing angle and the size of the holes for the incoming and outgoing beams in the masking system. The results of these simulations show that the background situation is better for geometries with a zero or 2 mrad crossing angle compared to those with a 20 mrad crossing angle. The larger crossing angle produces about a factor of two more background in the TPC and introduces asymmetries in the azimuthal hit distributions on the vertex detector.

The size of the holes for the incoming and outgoing beams have different effects on the vertex detector and on the TPC. Increasing the holes produces less backscattered photons and with that less background in the TPC. On the other hand more charged particles can scatter back out of the holes and are focused by the solenoid field directly onto the vertex detector. While this effect produces azimuthal asymmetries in the large crossing angle geometries, it increases the numbers of hits on the inner layer for the small crossing angle by a factor of three.

It has recently been proposed to use a dipole field, the so-called Detector Integrated Dipole DID, to compensate locally for the vertical orbit change and rotation of the polarisation vector when the beams pass the detector solenoid under a large crossing angle [7]. This DID field will change the distribution of the energy which the pair particles deposit on the BeamCal and therefore the background situation for the whole detector. The effect on the detector backgrounds has to be studied in detail taking into account realistic field maps for the solenoid and DID configurations.

In general a detailed study of the detector tolerances to backgrounds is needed. This is essential to judge the impact of the backgrounds on the performance of the detector and the consequences on the detector geometries like crossing angles and the details of the masking system.

Acknowledgments

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