# Study of the anti-DID magnetic Fields' Effects on the Beam-induced Pair Backgrounds in ILD

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The main goal of the study is the update of the hit rates in ILD detectors to account for the changes in the detector geometry and beam characteristics from the time of the LOI [1], to be included into DBD [2]. Both 500GeV and 1TeV options are considered. The comparison of the hits rates with the most up-to-date setup of ILD (o1_v05) with those reported in [1, 3] revealed a dramatic increase (factor $\sim$ 20) of the hit rates in the VTX and other detectors. A detailed study has shown that these are mainly caused by particles backscattering from the BCal area, instead of being guided to the beam exit by the anti-DID field version X03. It has been found that the previous version of the anti-DID, *fieldX02*, despite being slightly unphysical in large radii in the region of the TPC, directs the pair background more accurately into the beam exits, producing significantly less backscatter hits, and hence should be used in the estimate of the hit density in the ILD.

## 1 Introduction

High energies and luminosities that are mandatory requirements for next-generation electron-positron colliders come at the price of the so-called *beamstrahlung* [4] – an intense production of charged electron-positron pairs resulting from bremsstrahlung of initial beam particles pass through the highly focused and boosted EM fields of the oncoming bunches of the colliding beam. While most of these particles are high-energetic and follow the trajectory of the incoming beam and are dumped in the corresponding beam exits, some low-energy particles produce direct hits or showers in the detectors or in the support materials, which then backscatter into the detector. Guided by the solenoid field of the ILD these low-energy particles may curl for a relatively long time and create a large amount of hits in the nearby detectors, possibly saturating these and distorting the physics measurement. Such beam-induced backgrounds can be reduced by applying a special (dipole) magnetic field on top of the usual solenoid field of the detector which would guide those low-energetic background out of the sensitive area. For the ILD with 14mrad crossing angle the minimization of such backgrounds is achieved by applying an anti-DID [5, 6] field. Several studies [7, 8] have been performed in the past with various detector geometries, beam parameters and magnetic field configurations, in order to make sure that the hit loads created by such pair backgrounds in individual detector components are within safe boundaries. This note reports the recent results of the detector occupancies using the most up-to-date (for the moment) version of ILD setup *o1_v05*, included in [2], and compares those with the corresponding values of the previous publication [1].

## 2 Simulation of the events

For this studies *ee*-pairs generated by the *GuineaPig* [9] package were used for beam energies 500GeV and 1000GeV, beam setup options *TDR_ws* and *B1b_ws*, respectively. In comparison with the previous study for [1] where the *nominal* and *low-power* options were considered, the number of bunches is reduced (by factor 2 in 500GeV case, and by 10% for 1TeV), but the bunches are compressed in z-direction, and *travelling focus* technique is used to increase the luminosities[10]. The output of this generator is stored in ascii files, with a single bunch-crossing in each, containing 50-400k particles. As this number of particles is way too large to be digested by the *Mokka*[11] simulation package as a single event, these input are split into chunks of semi-arbitrary size and processed separately, then joined together to calculate occupancies or overlay with physics events, based on luminosity.

The pair background files have been processed with Mokka, initially using the o1_v05 detector geometry with the default settings and ILC softare v01-14-p00. Further studies have been made using the v01-16-01 version of the ILC software, which didn't reveal any differences in the hit rates obtained with the v01-14-p00 version with identical detector setups.

In the simulation, the Mokka options */Mokka/init/TPCLowPtStepLimit true* and */Mokka/init/TPCCut 0 keV* were used. The default value of 10mm for TPC step length has been used (*TPC_max_step_length = 10* in Mokka).

# 3 Calculation of the hit rates

For the sake of consistency the procedure of the hit rate calculation has been kept as close as possible to that used in the LOI. The initial GuineaPig pair background files have been simulated using the corresponding detector geometry model, then processed through a simple Marlin [12] processor looping through all collections and counting the hits in the detectors. One exception was the TPC, where the raw number of hits produced in simulation doesn't reflect the actual detector occupancy due to certain arbitrariness in the choice of the assignment of the spacepoints by Mokka. Hence it was decided to have the TPC hits digitized by the corresponding standard processor (*TPCDigiProcessor*) in Marlin and only then count the hits. Since the previous study made for the LOI [1, 8] lacked the *TPCLowPt* collection where the relevant particles creating the largest amount of hits are stored, the hit rates quoted in both old and new documents are not suitable for direct comparison.

## 3.1 Error calculation

The errors on the hit rates are calculated by merely extracting the RMS from a certain number of bunch crossings analyzed (between 100 and 300, depending on the setup). While the statistical accuracy of the extraction was sufficient for most of the detectors, in some rare cases the low-energetic back-scattered particles created an enormous amount (e.g. an order of magnitude higher than usual) of hits in some detectors by curling around the solenoid field lines. Hence the uncertainty on the hit rates remained high despite the abundance of statistics generated.

# 4 Differences in setups of LOI and DBD

For the LOI studies the hit rates were extracted using the *v01-06-fw* version of the ILC software, with Mokka version *06-07-patch02* and the geometry model *ILD_00fw*. The current study uses *v16-01* of the ILC software, Mokka version *08-00-03* and the geometry model *ILD_o1_v05*. While there were plenty of changes within the two geometry models, the main focus of this study was on the BCal geometry and the anti-DID field map. The BCal was changed from model version BCal08 (with circular holes for incoming and outgoing beams) back to BCal01 (with a keyhole shape filled with graphite to reduce the soft backscattering). Similarly, the anti-DID field version *fieldX02* used for the LOI studies was shown [13] to have slightly unphysical field lines at high radii (roughly at TPC level), and has been replaced by *fieldX03* which has more natural shape of the field lines, while being slighly larger in magnitude.

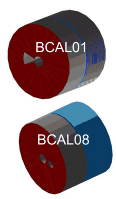



Figure 1: Different BCal models used

# 5 Background rates with the default settings of o1_v05

The comparison of the hit rates using the default setting of the ILD_o1_v05 geometry (e.g. BCal08+fieldX03) with the older ones revealed significantly higher (roughly factor 20!) counts in the vertex detector as well as different angular distribution of the hits, as can be seen on Fig. 2 . The hits in the new study are clearly asymmetric, hitting mostly one side of the vertex detector.

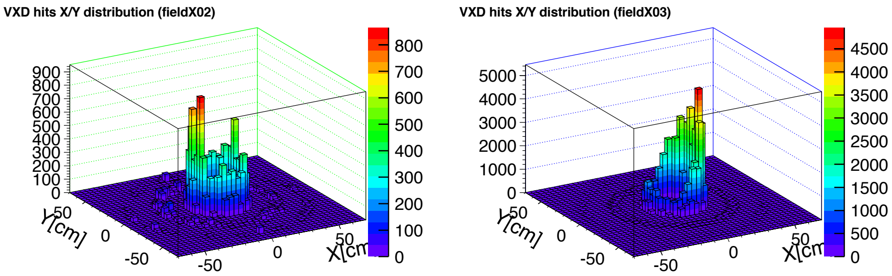



Figure 2: Left: LOI, Right: DBD. The pair background hit distributions in VXD X/Y plane.

The study of the origin of the particles (*MCParticle* collection) revealed that the majority of the extra hits in the new geometry arise from the area close to BCal and further downstream beampipes (see Fig. 3 *need to redo the figure to correct the labels*).

To study the cause of the increased background rates additional simulations were made using combinations of old and new BCal geometries (BCal08 and BCal01) and magnetic field versions (fieldX02, fieldX03 or SField01). Each simulation for 1TeV case was made using 100 bunch crossings.

Already the first results proved that the difference in the BCal geometry didn't cause any serious differences in the hit rates, but rather the changed anti-DID field. A comparison of the field strengths has revealed that fieldX03 has slightly larger magnitude than fieldX02, as can be seen on Figure 4. This results in a stronger than necessary kick sideways for a large amount of low-energetic pair particles that hit the tungsten and graphite in the BCal and therefore cause backscatter hits. In fact, the increase in the background rates have been observed in [13] already, but not directly attributed to the changed field.

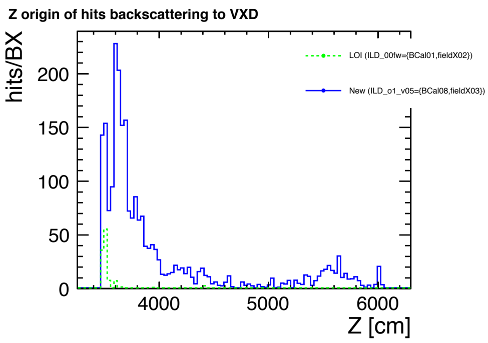
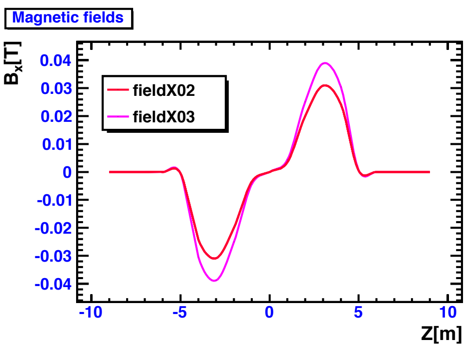



Figure 3: The z-origin of MCParticles creating hits in the vertex detector.

# 6 Background hits with fieldX02




As the geometry of the BCal has been shown to play no significant role in the surplus of the background hits it has been decided to use the simulation with the default BCal geometry for ILD_o1_v05 and only "downgrade" the anti-DID field to fieldX02, as used in LOI studies. The resulting hit rates are presented in Table 2. In comparison with the values obtained for the LOI (see Table 1) the hit rates in the vertex detectors have increased slightly due to the modified beam parameters (shorter bunches, higher luminosity per bunch etc.). Similarly, the increase of the hit rates in the ECal and HCal also gets contribution

Figure 4: The z-origin of MCParticles creating hits in

| Subdetector | Units | Layer | Nom-500 | Low-P-500 | Nom-1000 |
|---|---|---|---|---|---|
| VTX-DL | hits/cm$^2$/BX | 1 | 3.214±0.601 | 7.065±0.818 | 7.124±1.162 |
| | | 2 | 1.988±0.464 | 4.314±0.604 | 4.516±0.780 |
| | | 3 | 0.144±0.080 | 0.332±0.107 | 0.340±0.152 |
| | | 4 | 0.118±0.074 | 0.255±0.095 | 0.248±0.101 |
| | | 5 | 0.027±0.026 | 0.055±0.037 | 0.046±0.036 |
| | | 6 | 0.024±0.022 | 0.046±0.030 | 0.049±0.044 |
| SIT | hits/cm$^2$/BX | 1 | 0.017±0.001 | 0.031±0.007 | 0.032±0.012 |
| | | 2 | 0.004±0.003 | 0.016±0.005 | 0.008±0.002 |
| FTD | hits/cm$^2$/BX | 1 | 0.013±0.005 | 0.031±0.007 | 0.019±0.006 |
| | | 2 | 0.008±0.003 | 0.023±0.007 | 0.013±0.005 |
| | | 3 | 0.002±0.001 | 0.005±0.002 | 0.003±0.001 |
| | | 4 | 0.002±0.001 | 0.007±0.002 | 0.004±0.001 |
| | | 5 | 0.001±0.001 | 0.006±0.002 | 0.002±0.001 |
| | | 6 | 0.001±0.001 | 0.005±0.002 | 0.002±0.001 |
| | | 7 | 0.001±0.001 | 0.007±0.002 | 0.001±0.001 |
| SET | hits/BX | 1 | 5.642±2.480 | 57.507±10.686 | 13.022±7.338 |
| | | 2 | 5.978±2.360 | 59.775±8.479 | 13.711±7.606 |
| TPC | hits/BX | - | 408±292 | 3621±709 | 803±356 |
| ECAL | hits/BX | - | 155±50 | 1176±105 | 274±76 |
| HCAL | hits/BX | - | 8419±649 | 24222±744 | 19905±650 |

Table 1: (LOI) Pair induced backgrounds in the subdetectors for nominal (500 GeV and 1 TeV) and Low-P (500 GeV) beam parameters. The numbers for the ECAL and the HCAL are summed over barrel and endcaps. For the vertex detecor, the double-layer option has been chosen for this simulation, the numbers for the single-layer option differ. The errors represent the RMS of the hit distributions of the simulation of $\approx$ 100 bunch crossings (BX).

from more complete description of the cabling and holding structures of the detectors. As mentioned in Chapter 4, the numbers obtained for the TPC use somewhat different counting scheme, hence a direct comparison isn't fully valid here. While the hit rates in FTD increased significantly w.r.t. the values of the previous study (still remaining in the safe boundaries), the SET and SIT register only very few hits per bunch train in the current setup, a feature isn't yet studied thoroughly.

# 7 Summary

The active ongoing development of both the accelerator and the detector components requires also a regular monitoring of the pair backgrounds as one of the largest contributions in some of the detector occupancies, and a corresponding adjustment of the protective magnetic fields. The current study has shown that the current version of the anti-DID fieldX03 overcorrects the trajectories of the low-energetic pair particles causing subsequent backscattering which could potentially distort the physics measurement. Using an earlier version of the fieldX02 allows a reasonable estimate of the pair backgrounds, despite some minor deficits of that field at higher radii. In comparison with the earlier results, there is a slight increase of the backgrounds in the vertex detector, caused by the modifications in the beam parameters and more complete description of the detector holding structures and cabling in GEANT. It is obvious that the elimination of these unphysical features of the anti-DID field shall be performed while keeping the background levels at acceptable levels.

Data file locations Guinea-Pig generated files for beam energies of 500GeV and 1TeV are located (on GRID) in directories */grid/ilc/prod/ilc/mc-dbd/generated/500-TDR_ws/eepairs* and */grid/ilc/prod/ilc/mc-dbd/generated/1000-B1b_ws/eepairs* , respectively, with one full bunch train in each.

The simulated LCIO files for standard geometry setup can be found on GRID in */grid/ilc/prod/ilc/mc-dbd/ild/sim/500-TDR_ws/eepairs/ILD_o1_v05/v01-14-01-p00* and */grid/ilc/prod/ilc/mc-dbd/ild/sim/1000-B1b_ws/eepairs/ILD_o1_v05/v01-14-p00* for 500 and 1000 GeV beam energies, respectively.

| Sub-detector | Units | Layer | TDR_ws 500 GeV | B1b_ws 1000 GeV |
|---|---|---|---|---|
| VTX-DL | hits/cm$^2$/BX | 1 | 6.320 ± 1.763 | 11.774 ± 0.992 |
| | | 2 | 4.009 ± 1.176 | 7.479 ± 0.747 |
| | | 3 | 0.250 ± 0.109 | 0.431 ± 0.128 |
| | | 4 | 0.212 ± 0.094 | 0.360 ± 0.108 |
| | | 5 | 0.048 ± 0.031 | 0.091 ± 0.044 |
| | | 6 | 0.041 ± 0.026 | 0.082 ± 0.042 |
| SIT | hits/cm$^2$/BX | 1 | 0.0009 ± 0.0013 | 0.0016 ± 0.0016 |
| | | 2 | 0.0002 ± 0.0003 | 0.0004 ± 0.0005 |
| FTD | hits/cm$^2$/BX | 1 | 0.072 ± 0.024 | 0.145 ± 0.024 |
| | | 2 | 0.046 ± 0.017 | 0.102 ± 0.016 |
| | | 3 | 0.025 ± 0.009 | 0.070 ± 0.009 |
| | | 4 | 0.016 ± 0.005 | 0.046 ± 0.007 |
| | | 5 | 0.011 ± 0.004 | 0.034 ± 0.005 |
| | | 6 | 0.007 ± 0.004 | 0.024 ± 0.006 |
| | | 7 | 0.006 ± 0.003 | 0.022 ± 0.006 |
| SET | hits/BX | 1 | 0.196 ± 0.924 | 0.588 ± 2.406 |
| | | 2 | 0.239 ± 1.036 | 0.670 ± 2.616 |
| TPC | hits/BX | - | 216 ± 302 | 465 ± 356 |
| ECAL | hits/BX | - | 444 ± 118 | 1487 ± 166 |
| HCAL | hits/BX | - | 18049 ± 729 | 54507 ± 923 |

Table 2: (DBD) Pair induced backgrounds in the subdetectors for nominal 500 GeV and 1 TeV collision energy beam parameters. The numbers for the ECAL and the HCAL are summed over barrel and endcaps. For the vertex detecor, the double-layer option has been chosen for this simulation. The TPC hits are the digitised hits that would be written to the data acquisition system. The errors represent the RMS of the hit number fluctuations of ≈ 100 bunch crossing (BX) simulations.

The simulated LCIO files for ILD_o1_v05 with fieldX02 for 1TeV can be found on NAF(HH) in subdirectories of */scratch/hh/dust/naf/ilc/user/dich/projects/beam/mokka/* . The simulated files for 500GeV case with the anti-DID fieldX02 can be found on GRID in */grid/ilc/prod/ilc/mc-dbd/ild/sim/500-TDR_ws/eepairs/ILD_o1_v05/v01-14-01-p00_fieldX02* directory.

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