Pad Occupancy in the LDC TPC with the TDC-based Readout Electronics

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Electron-positron background in the ILC puts a constrain on the design of a readout electronics for the LDC TPC. The memory size of a Time-to-Digit Converter is estimated from the simulation of the background.

1 Introduction

The requirement of high luminosity in ILC leads to necessity of the large number of electrons in a single bunch. Due to the pinch effect[2] a large number of hard beamstrahlung photons (order of 10^{11} per bunch crossing) is generated. Although the beamstrahlung photons produce no hits in a gaseous detector like Time Projection Chamber(TPC), they serve as a source of a secondary background. It is anticipated that the main contribution to the background in the TPC comes from the e^+e^- pairs, originating from the beamstrahlung photons.

Preliminary TPC studies[3] found occupancy in the TPC detector ≈1%, but give no information on the occupancy of a single pad. The subject of this work is to study the pad occupancy in the LDC TPC[4], which is one of the design constraints for the TPC readout electronics.

2 Simulation of the e^+e^- pair background in the LDC TPC detector

GUINEA-PIG program[2] was used to simulate the e^+e^- pair background. Input for the simulation is the beam parameters in a linear collider, for example the number of electrons in a bunch. For this simulation the TESLA parameter set is used, which is close to the nominal parameter set of the ILC[5]. Result of the simulation shows that on average, there are 10^5 pair particles in a single bunch crossing. Data from the GUINEA-PIG are used in the Monte Carlo simulation.

Simulation of the LDC TPC response has been performed with Mokka `06-03`[6]. In the `LDC01_02Sc` model, maximal drift path of the TPC is 2 m. Energy cut in TPC set to 32 eV (twice larger the ionization potential of Argon).

On average, there are 5000 energy depositions(hits) in the TPC volume per bunch crossing. In the main, one observes tracks oriented along the z-direction in the TPC detector. These tracks come from low energy particles which have so small helix radius and many turns, that they appear as the tracks pointing to the end-plate of the TPC. Similar tracks will be found from muons, which appear at the earlier acceleration stages in the ILC, but there will be only 0.07 muons per bunch crossing. In both cases, such pointing tracks will occupy the readout of few neighbouring pads on the end-plate. In order to estimate the pad occupancy one needs to count the number of signals registered by a pad.

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3 Pad occupancy in the LDC TPC

Collisions of the beams in the ILC will occur every 369 ns[5], while the full drift time of the electrons in the TPC volume is $\sim 47\ \mu s$. It is assumed that the drift velocity of electrons in the TPC gas is 4.5 $cm/\mu s$. This implies that the background signals from 128 bunch crossings will overlap in the TPC. Since no trigger is foreseen in the ILC TPC, signals during complete bunch train (2625 bunch crossings within 1 ms) have to be recorded by the TPC data acquisition.This sets stringent requirements on the compactness and the power consumption of the TPC readout electronics, if it is installed directly on the end-plate of the LDC TPC.

It is assumed, that there is no attachment. Diffusion is neglected in $r\phi$ and z directions. Due to the charge sharing, several pads can record a signal, but this currently not addressed.

In the Time-to-Digit Converter(TDC)-based readout electronics[7], charge of a signal from a pad is encoded into the pulse width of a digital signal with the help of a charge-to-time converter(QTC). Signals from the QTC are digitized with a TDC and stored in its memory. The QTC has a variable dead-time. For smaller input signals, the output pulse width is shorter, so that the QTC will be able to re-trigger earlier. If two hits arrive close in time they will not be resolved – the QTC will produce single pulse on the output.

The QT conversion characteristics has logarithmic dependence and was calibrated in such a way, that the output pulse width of 200 ns(corresponds to 1 cm in the drift direction of the TPC) relates to the energy deposit of hits appearing most often, Figure 1. For this simulation, a simple QT conversion was considered: a hit which arrives on a pad first, sets an integration window to 50 ns; the energy deposits from all hits which are found in this window are summed up; the pulse on the output of QTC is derived according to Figure 1.

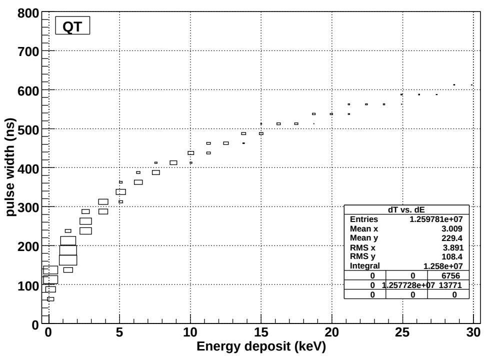

Figure 1: QT characteristics for the TDC-based readout electronics for the ILC TPC.

The time of appearance of a hit on a pad for a given bunch crossing is given by

$$T_i = \frac{L_{half} - |Z_i|}{V_{drift}} + \mathcal{T}_i, \qquad (1)$$

where Z_i- z-coordinate of a particle in TPC volume, L_{half} - the maximal drift path in the LDC TPC, V_{drift} - the drift velocity, $\mathcal{T}_i$ - time of appearance of the hit in the TPC volume. With the help of equation (1) and QT-characteristics, signals from the QTC can be counted. 128 bunch crossing have been simulated and analyzed.

A distribution of the number of hits has the mean value of 2.6, Figure 2.

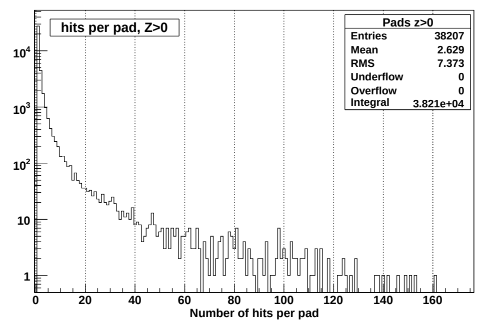

Figure 2: Hits per pad for 128 bunch crossings.

The maximal number of hits observed on a pad (size of a pad is 1 mm in the ϕ-direction and 6 mm in the radial direction) is $\sim$160. Assuming a 64 channel TDC chip and the maximum number of hits on all channels per 128 bunch crossings is equal to 160, one obtains 210000 data records (signal measurements) to be stored in the TDC memory. If a single "arrival time/charge/TDC-channel" data record is represented by a 32-bit word, the memory size would be 820 kbytes.

Consider, for example, 64 pads on the same radius of the TPC end-plate. Repeating analysis for such a cluster of pads and assuming that the TDC has a common memory for all 64 channels, one obtains $\approx$800 data records per TDC chip, Figure 3. In this case the TDC memory size is 64 kbytes.

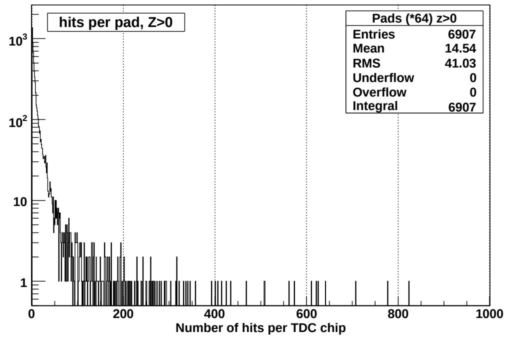

Figure 3: Hits per TDC chip for 128 bunch crossings.

4 Conclusion

Effective way of data readout with the TDC-based electronics leads to smaller size of the TDC memory. Collected data can be transferred with smaller number of cables, thus simplifying the design of the TPC end-plate and improving the material budget.

Energy depositions originating from the e^+e^- background will distort the electric field in the TPC volume. Corrections of the electric field distortions can be made if the background data is available.

5 Bibliography

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