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The LDC detector concept

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Abstract. In preparation of the experimental program at the international linear collider (ILC), the large detector concept (LDC) is being developed. The main points of the LDC are a large volume gaseous tracking system, combined with high precision vertex detector and an extremely granular calorimeter. The main design force behind the LDC is the particle flow concept.

Keywords. International linear collider; large detector concept.

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1. Introduction

The large detector concept (LDC) detector concept group [1] was formed early in 2004. Its goal is to design a complete detector concept for the LDC, based on a gaseous central tracking detector, and on granular calorimetry. The concept is heavily based on the concept of particle flow for event reconstruction.

LDC started from the TESLA detector, developed for the TESLA TDR [2] and published in 2001. The basic philosophy of the detector and its main components are the same as for TESLA, but there has been significant development of the sub-components since then.

LDC has members from all three regions, though its biggest contributors still come from Europe. About 70% of the people subscribed to LDC are from Europe, 27% from the Americas, and only 3% from Asia.

Since its formation in 2004 one of the main tasks of LDC has been the specification of the detector, and the writing of a conceptual design report, the 'Detector Outline Document' (DOD). The DOD for LDC has been presented for the first time at this conference, and will continue to evolve until the summer of this year, when a more or less final version is expected. In figure 1, a side-view of one quarter of the LDC detector is shown.

2. The detector concept

The LDC has three main components: a high precision vertex detector, surrounding the interaction region, a large gaseous tracking system, which is backed up by

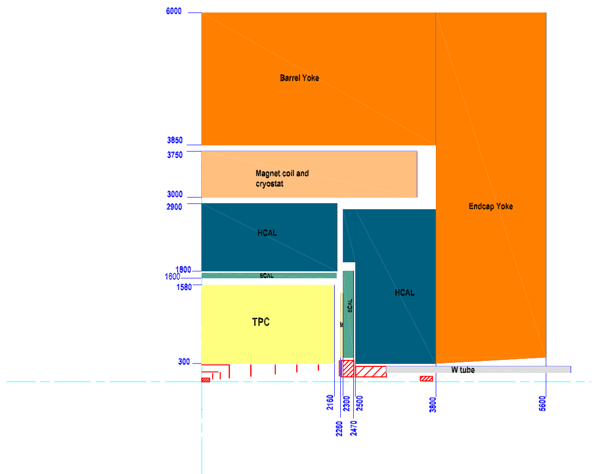

Figure 1. Side-view of the LDC detector concept.

a sophisticated system of tracking devices mostly made from silicon, and a very advanced and granular calorimeter. In the following the main components and their layout will be briefly reviewed, and the reasoning behind them will be explained.

2.1 *Vertex detector*

The vertex detector at the LDC is a SI-based pixel detector. It is installed as close as possible to the interaction point. Currently an inner radius of 1.5 cm is thought to be compatible with constraints from the accelerator. The baseline design has five layers of pixel detectors, equally spaced at a radial distance of approximately 1 cm. The innermost layer has a length of 7.5 cm, the others are twice as long.

The vertex detector has to function in the presence of significant backgrounds, mostly from beam–beam interactions. The anticipated level of background hits makes it mandatory that the vertex detector layer be read out quickly, and integrate over at most 40–50 bunch crossing.

A number of different pixel technologies are currently studied in detail by R&D collaborations. No decision has been taken as to which of these technologies will eventually be used in the LDC detector.

2.2 *Tracking detectors*

The central part of the tracking detector is a large volume TPC. This is backed up by a number of thin precision tracking devices at the inner and outer radii of the TPC.

The tracking at the ILC has to be highly efficient – efficiency is in many respects more important than precision. Particle flow requires that all particles are

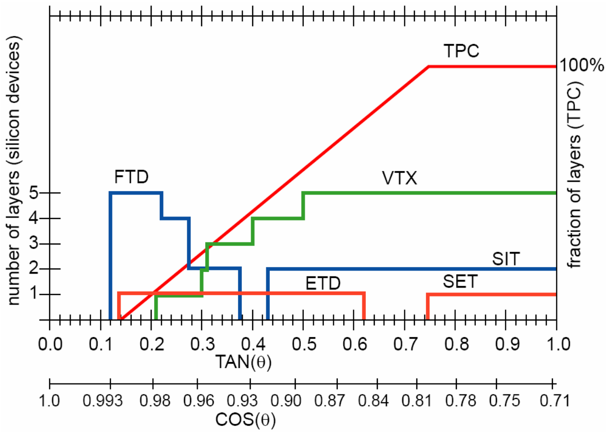

Figure 2. Number of points measured on a track as a function of $\tan(\theta)$.

reconstructed, and a highly efficient tracking system is a pre-requisite for that. The ultimate precision in tracking is needed for a number of specific reactions, in particular the reconstruction of the Higgs boson in the ZH recoil analysis.

A TPC has a number of advantages when used as a tracking detector at the ILC. It provides three-dimensional reconstruction of charged particles with a large number of points along a track. At the same time the material in a TPC is small, thus minimizing the disturbance of a particle before it reaches the calorimeter.

Compared to previously built TPCs, the ILC TPC has to have a point resolution and a double track resolution significantly improved. The current baseline design foresees a TPC with around 200 points measured along a track, and read out by a system of micro-pattern gas detectors. These novel gas amplification devices promise to provide a stable, reliable readout system, which can be realized with comparatively little material in the endplate compared to a traditional wire readout.

To breach the gap between the vertex detector and the TPC two layers of Si-based strip detectors are foreseen at intermediate radii. They provide a link between the VTX and the TPC, and improve the efficiency to find long-lived particles which decay between the VTX and the TPC. On the outer radius of the TPC, and behind the endplate, a small number of precision tracking layers are under study, to improve the linking between the tracking detectors and the calorimeters. Among the candidates for these detectors are Si strip detectors, and, in particular in the end cap direction, gaseous detectors like straw tubes of GEM-based chambers. In figure 2 the number of available points on a track as a function of the polar angle is shown. At any direction at least two points, in most cases five points, supplement the TPC measurement.

2.3 *Calorimeters*

The central piece of a detector at the ILC is the calorimeter. Particle flow works under the assumption that all particles in an event can be reconstructed individually. For charged tracks, the tracking detectors are used and for neutral ones, the calorimeters have to do the work. To be able to measure the direction and the energy, and to be able to separate them even inside dense jets, very granular devices are needed.

The electromagnetic calorimeter for the LDC is based on a tungsten absorber structure, sampled by pixelated silicon detectors. The readout pixels are of the order of 0.5×0.5 cm^2, and up to 30 samples are to be read out through the full thickness of the ECAL of one interaction lengths.

To minimize the dead space and to simplify the readout structure, the electronics is supposed to be integrated into the readout boards between absorber plates. The digitization will take place on these boards as well, so that the number of lines which leave the detector is significantly reduced. It is currently studied whether the electronics will only record the hit, or in addition determine the time of the hit, to support bunch tagging and background rejection.

The hadronic calorimeter, primarily for cost reasons, is built with iron plates as absorbers. The readout is done either through scintillator tiles, or through gas-filled resistive plate chambers or GEM-based chambers. Both options have their relative merits, and no decision has been taken so far on a technology selection.

Both ECAL and HCAL follow an octagonal geometry in the barrel region. Two endcaps close the solid angle coverage down to small angles. The very forward region is covered by two special purpose calorimeters, the beam-Cal and the lumi-Cal, which provide coverage down to approximately 3 mrad. These latter devices are, in addition, used to measure the beam–beam induced background radiation, and to determine the luminosity of the machine.

2.4 *Magnet and muon system*

Outside the calorimeters a large superconducting coil provides a magnetic field of up to 4 T, along the beam direction. The coil has been designed in such a way that it is very similar to the already built and tested CMS coil. Apart from the main field generating windings the coil will include a small number of special windings, mostly at the end of the coil, which can be used to tune the homogeneity of the field in the central region.

The magnetic flux from the field is returned through an external iron flux return. This contains the detector nearly entirely, thus ensuring proper return of the field, and, at the same time, a self-shielding detector. The iron return yoke is instrumented with a few layers of muon chambers, most probably resistive plate chambers, to measure the momentum of those muons which penetrate the calorimeter and the coil. Together the very granular calorimeters, which themselves will do an excellent job of the identification of muons, promise to provide a spectacular muon performance of the detector.

3. Detector performance

The detector performance has been studied in some detail based on a full reconstruction program developed within the GEANT4 toolkit. The MOKKA program

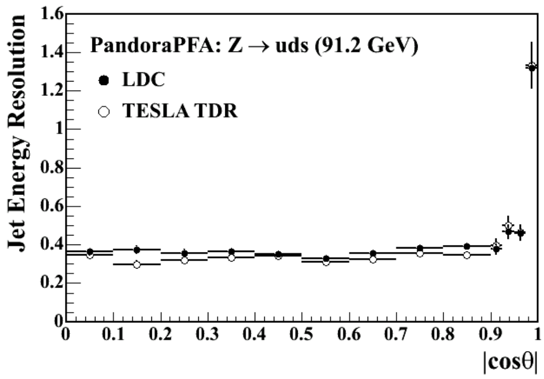

Figure 3. Simulated resolution of the LDC detector concept as a function of $\cos(\theta)$, using a particle flow approach.

provides an easy way to define geometries, and to allow the variation of most parameters at run time for systematic studies.

As stated previously the detector design has been heavily influenced by the idea of particle flow. Particle flow wants to improve the overall event reconstruction by an approach where each particle in the event is reconstructed individually. Charged particles are reconstructed by the tracking detectors. Their hits in the calorimeter are identified and removed from the event. In this way fluctuations of the total energy in the event, which are introduced by a calorimetric measurement, are removed. The remaining hits in the ECAL and in the HCAL are then searched for neutral particle candidates. Particle identification is attempted based on tracking and calorimeter information, and particles are grouped according to the photon hypothesis, the electron hypothesis, pion and neutral hadron hypothesis. A crucial role in this is played by a very granular electromagnetic and hadronic calorimeter, which is a pre-requisite to find the traces of individual particles, and to make a high quality assignment between tracker hits and calorimeter hits. The particle flow algorithms are still very much under development, and none has demonstrated the wanted performance of $30\%/\sqrt{E}$. Nevertheless significant progress has been made over the last few years, and first promising results are being presented. In figure 3 the performance of the LDC for Z events on the Z pole is shown as a function of the polar angle.

In future one of the main priorities of the LDC will be to further improve the particle flow algorithms, to reach a point where the algorithms are good and stable enough that a real detector optimization can be attempted. The results from such a study might well change the layout of the LDC detector once again.

4. Summary and outlook

The LDC concept group has presented the first version of the LDC detector at this meeting. The LDC detector has been re-optimized with respect to its size compared to earlier versions. This should result in some significant cost savings. First studies suggest that the loss of performance is acceptable, but more detailed studies will be needed in the future.

Acknowledgement

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References

[1] For details, see http://www.ilcldc.org
[2] T Behnke *et al* (eds), TESLA TDR, volume 4 DESY 2001-011