Proposal for Data Taking with a Silicon Envelope at the DESY Test Beam

Thomas Bergauer - project leader

Proposal for data taking with a silicon envelope using the DESY test beam in the periods 23.11. - 27.11.2009 and 02.11. - 06.11.2009, and financial support application for Stephan Hänsel[a], Alexander Dierlamm [b] and Yifan Yang[c]:
test beam preparation: 21.10 - 23.10.2009
data taking: 02.11 - 06.11.2009
Remark: It is not possible to install the silicon envelope inside the cold magnet. Since the magnet needs one week to go from room temperature to operating temperature we have a work break during the magnet cool down.

1 Introduction

The International Large Detector (ILD) [1], shown in Fig. 1, is a detector concept for the International Linear Collider (ILC) [2].

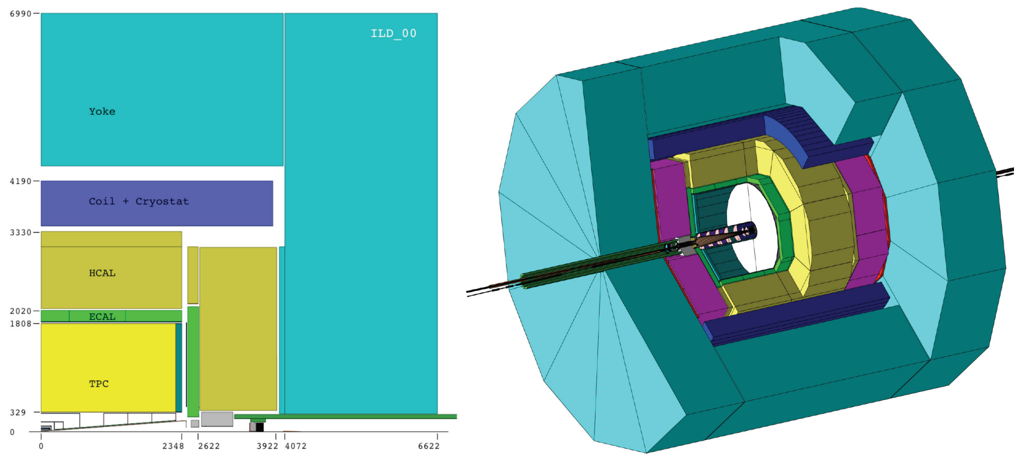

Figure 1: The ILD 00 detector model: from the inside to the outside, the detector components are the: VTX, SIT, TPC, SET, ECAL, HCAL and Yoke. In the forward region the FTD, ETD, LCAL, LHCAL and BCAL are shown.

Between the vertex detector (VTX) and the electromagnetic calorimeter (ECAL), the ILD foresees a combination of a TPC and silicon strip sensors. The silicon tracking system is divided into two parts:

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1. In the barrel region between the vertex detector and the TPC it consists of the Silicon Internal Tracker (SIT) which improves the linking efficiency of vertex detector and TPC. It drastically improves the momentum resolution of charged particles (Fig. 2) and it will enable the reconstruction of charged particles with low momentum. Just outside the TPC the Silicon External Tracker (SET) will deliver a precise entry point to the ECAL after the Field Cage of the TPC ($\approx 3\% \ X_0$). In the current design of the ILD the SIT consists of two and the SET consists of one layer of false double sided silicon strip detector modules, together providing three very precise space points.

2. In the forward region the End-cap Tracking detector (ETD) will help to reduce the material effect of the TPC End Plates ($\approx 15\% \ X_0$) and the Forward Tracking Detector (FTD) will cover the very forward region down to about 0.15 radians.

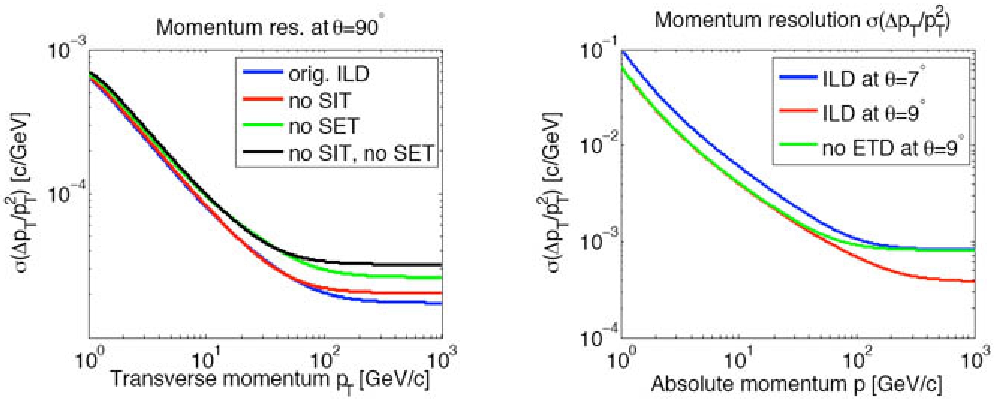

Figure 2: Fast Monte Carlo simulations: left: resolution of the transverse momentum as function of the transverse momentum in the barrel region, right: transverse momentum resolution as function of absolute momentum p in the forward region.

2 Motivation

During the proposed test beam period it is foreseen to take data with both, the first prototype of a TPC for the ILD - the Large Prototype TPC - and a first prototype for the SET of the ILD using the DESY T24 electron beam. Due to the limited space of 35 mm between the TPC and the surrounding magnet the silicon envelope consists of one layer of false double sided silicon strip modules on both sides of the TPC. This makes it comparable to a half SIT and the SET as proposed for the ILD. In addition this will be a good opportunity to verify some of the results from a SiLC test beam performed at the SPS in 2008 [3]. During that test, the resolution of different sensor geometries was determined using small multi geometry test sensors. Now we have the opportunity to test one of these strip geometries on a sensor with comparable size to sensors used in large scale detector systems like the ILD. We will evaluate the resolution and the signal to noise ratio of these sensors in a realistic scenario inside a magnet by measuring the cluster sizes and residuals when using tracks from the TPC. This analysis is a very important step towards the definition of the SET and the tracker alignment strategies in the ILD. The results will be a used in the PhD thesis of Stephan Hänsel.

3 Silicon sensors

The used sensors are single sided AC coupled silicon strip sensors with a size of 91.5 × 91.5 × 0.320 mm^3 were designed by the SiLC-collaboration and manufactured by Hamamatsu Photonics, Japan. Each sensor has 1792 readout strips, with a readout pitch of 50 μm, biased with a 20 MΩ poly-silicon resistor. Each sensor was electronically tested, showing leakage currents below 300 nA up to a biasing voltage of 800 V. The sensors reached full depletion at a voltage of about 55 V. Single strip measurements revealed single strip currents of around 130 pA (at 100 V), values for the poly silicon resistors of above 20 MΩ and coupling capacitances in the order of 150 pF, indicating the excellent quality of these sensors.

4 Silicon detector modules

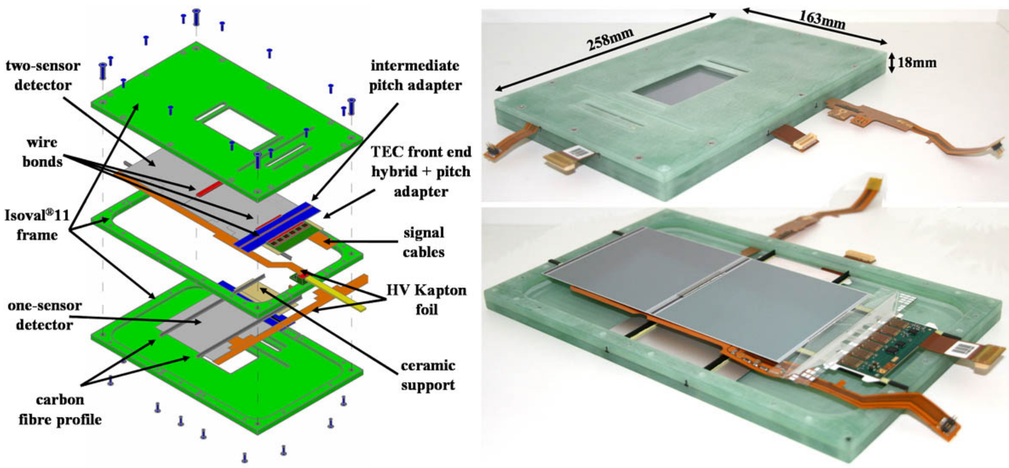

Figure 3: left: technical drawing of one silicon detector module; top-right: closed silicon module without light-tight cover; bottom-right: module without top layer of the frame

The two detector modules, a picture of one is shown in Fig. 3, were build and electronically tested in Vienna. The tests confirmed the good sensor quality and revealed no problems. Both detector modules consist of a one-sensor and a two-sensor silicon detector forming a false double sided silicon detector module. The silicon strip sensors have a spatial resolution of about 9 μm, which was determined using dedicated mini sensors during a SiLC test beam at the SPS in 2008 [3]. To provide this resolution in both directions (Rφ and z), the two silicon detectors in each module are assembled at an angle of 90°. The horizontal detector, consisting of two daisy-chained sensors, is located closer to the magnet than the other silicon detector, which is composed of one sensor.

5 Mechanical support of the silicon detector modules

The mechanical support has to position the two detector modules on each side of the TPC inside the gap of 35 mm between the magnet and the TPC. Since the sensitive areas of the modules have to be in the beam line, the support has to compensate vertical and horizontal movements and even horizontal rotations of the magnet which are foreseen to enable a scanning of the TPC volume. The $r\varphi$-position of the modules will be assigned by screwing them at different positions onto a curved sledge. This sledge will then be moved manually in and out of the magnet along two sliding rails, which will be mounted on the TPC support structure.

6 Data aquisition of the silicon

The silicon DAQ system is a CMS petal test readout system which was adapted in Karlsruhe. The signals from the silicon sensors are read out by the APV25 chips on the CMS front end hybrids. Electrical cables bring the data to the Inter Connect Cards (ICC), sitting outside the magnet. There the electrical signals get converted to analogue optical signals in the Analogue OptoHybrids (AOHs). Via optical links these signals are transferred to the Optical Front End Driver (O-FED), re-converted to electrical signals, delivered to the FED card of our DAQ PC and stored. The readout is controlled from the DAQ PC via a Front End Control (FEC) card which steers the Central Control Units (CCU). The CCUs provide I^2C control sequence and clock via the ICC cards to the front end hybrids.

To synchronise the TPC DAQ and the silicon DAQ a Trigger Logic Unit (TLU) will be used to centrally distribute a timestamp and the trigger signal, received from scintillators in front of the experiment.

7 Final test of the silicon envelope with cosmic Muons in Karlsruhe

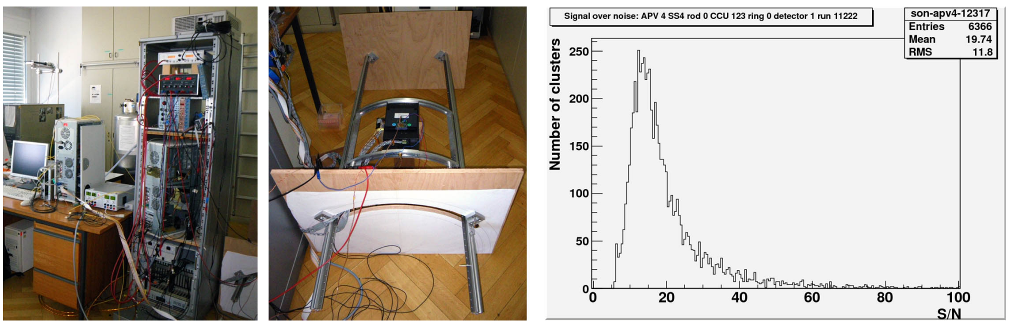

Figure 4: left: silicon DAQ; centre: silicon detector mounted on the support structure; left: signal to noise of one silicon strip detector

In May 2009 the silicon detector modules were brought to Karlsruhe. There they were mounted to the support structure which used wooden plates as dummy for the TPC-support and simulated the gap between TPC and magnet (Fig. 4 centre). Since no TLU was available a common NIM logic with two scintillators were used for triggering (Fig. 4 left and centre). Data taking was no problem and first analysis steps were performed (Fig. 4 right).

8 People and funds

The preparation of the test beam is coordinated by Stephan Hänsel (HEPHY Vienna), who is in close contact to Klaus Dehmelt at DESY. Three people from different institutes will participate at the test beam in person for installation, setup and data taking:

- Yifan Yang (ULB Bruxelles) - only 21.10. - 23.10.2009
- Alexander Dierlamm (IEKP Karlsruhe) - both periodes
- Stephan Hänsel (HEPHY Vienna) - both periodes

Therefore, we would like to request the costs for the trip and stay for these people.

9 Summary

This test beam is a very important step towards a future Silicon External Tracker (SET) for the International Large Detector (ILD) concept at the proposed International Linear Collider (ILC). It will be a verification of the combined data taking, allowing alignment and resolution studies of a TPC with a first prototype of a Silicon External Tracker. In addition it will enable the comparison of the used large are silicon strip detectors in the DESY test beam with the resolution studies done on the small multi geometry test sensors at the SPS in 2008.

References

[1] ILD Concept Group, ILD Letter of Intend (2009) `http://www.ilcild.org/documents/ild-letter-of-intent/LOI.pdf/at_download/file`

[2] ILC Group, ILC Reference Design Report (2007) `http://www.linearcollider.org/cms/?pid=1000437`

[3] S. Haensel *et al.*, arXiv:0901.4903 (2009)