Test Beam Requirements for the ILC Tracking and Vertex Detectors

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In this report the test beam requirements for the vertex detector and the tracking detector for ILC are discussed. It focuses on the infrastructure needs of the different subsystems. In the second part of this summary the ideas about future infrastructure above the immediate needs are summarised.

1 Introduction

Test beam requirements for tracking and vertex at the ILC are continuously discussed in the community. After the test beam workshop at Fermilab in 2007 all needs were summarised in a document [2]. Within the EU supported project EUDET [3] some test beam infrastructure is being build, but this will and can not cover the world wide needs for position sensitive detectors as for the vertex and tracking detectors will be needed. In this report the requirements as know before the LCWS08 in Chicago are summarised.

2 Vertex Detector

| Accelerator | a [µm] | b [µm] |
|-------------|--------|--------|
| LEP         | 25     | 70     |
| SLD         | 8      | 33     |
| LHC         | 12     | 70     |
| RHIC-II     | 15     | 19     |
| ILC         | <5     | <10    |

Table 1: Impact parameter resolution at different accelerators.

In order to meet the above requirements a vertex detector with small pixels, thin sensors, thin readout electronics, low power (gas cooling) needs to be build. A hit resolution of better than 5µm is required. A figure of merit for the ILC vertex detector is the impact parameter resolution which can be parametrised as $\sigma_{r\phi} \approx \sigma_{rz} \approx a + b \sin^2 3\theta/2$. In table 1 the parameters $a$ and $b$ for all major HEP experiments are listed. This shows that the requirements at the ILC vertex are unprecedented. Currently there are about ten candidate sensor technologies for the ILC vertex detector. A summary about all these approaches is given in [4].

2.1 Important test towards a technology choice

One of the next major steps for all possible technologies is building ladders to show not only the single pixel performance but also the interfacing to the infrastructure, and the mechanical integration. At the level of single ladders an number of parameters have to studied at

LCWS/ILC 2008
test beams: signal-over-noise, single point resolution, efficiency, double hit separation. Also the homogeneity of the detection, the read out and the data handling have to be tested. It also may be of interest to run within "sizeable" magnetic field in order to assess effects on cluster characteristics (e.g. single point resolution). In a further step with multiple layers additionally to the above tests the standalone tracking capabilities, tracking under high occupancy, and low momentum tracking would needed to be studied. Possible further tests are studying the homogeneity of the performances over the ladder surface, the multi-channel and multi-chip operation, the electrical servicing of the chip and the cooling system operation. The last issue include mechanical properties and the influence on the performances such as sagitta and vibrations vs. single point resolution. Also the heating versus the signal-to-noise ratio or fake hits (noisy pixel rate) should be investigated.

2.2 Needed Test Beams

A high energy hadron beam ($\sim$100 GeV) would be needed for position resolution testing and a low energy beam for the low momentum tracking. The beam spots should be adjustable from a about 1 mm$^2$ to a few cm$^2$. A "ILC-like" spill structure could be useful (1 ms beam at 200 ms intervals) to see the effects on the read out when particles arrive and to allow a read out during a "quite" phase. Such a beam structure is not needed for all tests but such a beam would give the opportunity to test all technologies under ILC like conditions. This might be necessary close to the technology decision. Such test beam not available right now and investment would be needed. It is technically feasible and Fermilab is currently following up this issue. In table 2 the test beam facilities suitable for the above tests are mentioned.

| Lab.     | $E_b$ [GeV] | Particles | Availability   |
|----------|-------------|-----------|----------------|
| CERN PS  | 1 - 15      | e, h, m   | LHC prior.     |
| CERN SPS | 10 - 400    | e, h, m   | LHC prior.     |
| Fermilab | 1-120       | e, p, K; m| contin. (5%)   |

Table 2: Test beam facilities, energy range and availability which are useful for the necessary vertex studies.

3 Tracking Detector

Immediately outside the vertex detector a tracking system will follow. The options considered for the tracking detector are large silicon trackers (à la ATLAS/CMS) and Time Projection Chambers (TPC) with $\sim$100 µm point resolution (complemented by Si-strip devices). The performance goals for this systems are: Continuous 3D tracking, easy pattern recognition throughout volume, 98-99% tracking efficiency in presence of backgrounds, time stamping to 2ns together with inner silicon layer, minimum of $X_0$ inside ECAL (3% barrel, 15% endcaps), $\sigma_{pt} \sim$50 mm ($r\phi$) and $\sim$500 mm (rz) 4T, two-track resolution $<$2mm ($r\phi$) and $<5$ mm(rz), and dE/dx resolution $<5\%$. In the following the test beam infrastructure for both concepts are summarised separately.

3.1 Gaseous Tracker

The groups working on a gaseous tracker for ILC are currently taking advantage of the EUDET infrastructure of a 1 Tesla Magnet at the 6 GeV electron beam at DESY. A full field

LCWS/ILC 2008
cage is set up in the magnet. But this system would after initial tests need to be moved to a \( \sim 50 \text{ GeV/c} \), hadron beam. Preferable a mixed hadron beams with particle ID for \( \text{dE/dx} \). The intensity should be variable from low to high. As the LCTPC has a Silicon tracker already included, additional tracking systems are not urgently needed. A number of studies should be performed in a large volume high field magnet (\( \sim 2 \text{ T} \)), but not necessarily at the test beam facility. RD51 is planning a dedicated beam area for micro gas detectors at CERN SPS also want to provide infrastructure to help test of gaseous detectors.

### 3.2 Si Tracker

The Si-tracker group expressed that the existent test beams are adequate for their needs but improvement in the overall infrastructure is required. A beam telescope and associated DAQ and trigger logic such as the EUDET pixel telescope would be of advantage. A general DAQ framework in the ILC fashion would help to accelerate the turn around of test beam results. A high field magnet with up 3 Teslas would be needed at a later point, but not necessarily for all test beams. Furthermore it was expressed that access to a mechanical workshop and support for last minute needs during installation would be very helpful. Further items of use are: 3D table(s) to install and properly move the prototypes wrt the beam, easy access to computing facilities and LabNet, control room(s) with enough space (for several users), lab staff responsible for the good running of the test beam, and a crane to install and move heavy prototypes. Most of these items are available at the test beams but generally not easy to access for users from outside institutes. The ILC community should help to improve the situation.

### 4 Beyond the immediate needs

The next logical step for ILC is assess system aspects of the proposed detector concepts. The principle integrating factor in linear collider event reconstruction is the concept of "energy flow" where the reconstructed objects from different detectors are combined into physics objects such as leptons, photons, or jets. The particle flow approach relies on robust identification and precise momentum measurement of charged particles. It needs to be established how to form these particle-flow objects, how to do the mechanical integration, and also the common DAQ systm. This requires the definition of interfaces and their implementation. In the beginning of 2007 a group of European research institutes involved in ILC detector R&D submitted a proposal to the EU to work on this concept. The idea of EUVIF idea was to build an unique infrastructure to integrate commensurate prototypes of LC detector components and install this in a test beam with different particles and in appropriate energy range. The proposal was not granted, but within the proposal the ideas for such a concept where phrased and describes essential what is needed by the vertex and tracking groups beyond the immediate needs described above.

#### 4.1 Vertex

A small-scale full vertex detector could be build. interface to be able to replace the ladders by different type ladders Building a global mechanical infrastructure to host multi-layer modules for vertex detectors in different technologies (design independent) Developing the

\[ \text{LCWS/ILC 2008} \]
data acquisition system including hardware from EUDET to suit the new infrastructure
Software for reconstruction and analysis (calibration, alignment, pattern recognition) - based on existing software for EUDET telescope Producing a target system to create jet-like structures Integrating the EUDET telescope upstream of the target

4.2 Tracker

4.2.1 Intermediate Tracker infrastructure

Lightweight structures for both module carrier and overall support Prototype silicon small area modules equipped with single sensors up to daisy-chained ladders Overall support structure for modules/ladders arranged in layers (lightweight, ultra-thin) Improving the existing EUDET readout chip and developing a front-end hybrid prototype suitable for testing silicon sensors with conventional (wire-bonding) or novel (bump-bonding) techniques Integration of the front-end electronics developed in EUDET into the central DAQ system

4.2.2 Gaseous Infrastructure

The EUDET TPC infrastructures could be provided for combined tests of the particle flow concept. This would allow the optimisation of the overall detector design. An interface to the common DAQ and slow control system should be facilitated. Within EUVIF is was planned to develop and provide the readout software, to improve a slow control system, and to integrate in the overall EUVIF system.

5 Summary

In this report the immediate needs of the ILC tracking and vertex community for test beam infrastructure is summarised. In the second part of the report the ideas of the so-called EUVIF proposal are described. This proposal was forseen to provide test beam infrastructure above the immediate needs. The proposal was not granted but other funding agencies might accept it in the future.

6 Bibliography

References
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[3] for more information: http://www.eudet.org
[4] http://www.linearcollider.org/wiki/doku.php?id=drdp:drdp_home

LCWS/ILC 2008