Simulation Study for EUDET Pixel Beam Telescope using ILC Software

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A pixel beam telescope which is under development within the EUDET collaboration will provide a test environment for different pixel sensor technologies as well as for large tracking devices such as TPC. The telescope will consist of 4-6 sensor planes. The setup has already passed first tests at a 1-6 GeV/c electron beam at DESY in Hamburg. The device is flexible for using at other beam lines, e.g. at CERN pion beam. In this paper a simulation study for different telescope configurations will be presented [1].

1 Introduction

EUDET is a coordinated European effort towards research and development for the next generation of large-scale particle detectors [2]. The project covers different activities for vertexing, tracking, calorimetry as well as networking activities which support information exchange. The JRA1 subgroup is dedicated to develop a test beam infrastructure and a pixel beam telescope. The planes of the beam telescope are equipped with monolithic active pixel detectors constructed in CMOS technology. The objective of the future device is to achieve a precision of the predicted impact position of beam particles on the DUT plane of less than 3 μm at 5 GeV/c. To fulfil this requirement it is necessary to find an optimum configuration of the telescope mechanics. For this purpose a simulation study of different telescope geometries has been done.

The general layout of the considered beam telescope geometries is shown in Fig. 1. The setup consists of three separate insulating boxes (for two telescope arms and the device under test (DUT)), which allows better flexibility for the overall setup. In the cases of 2- and 4-plane geometries the closest telescope planes to the DUT have been considered in the simulation. The thickness of the telescope planes has been assumed to be 110 μm which corresponds to the thickness of the thinned sensors. The DUT is assumed to be 300 μm thick.

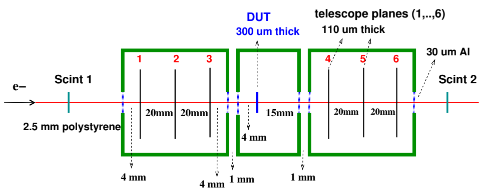

Figure 1: Geometry layout of the pixel beam telescope.

The simulation of the beam telescope has been done using the package Mokka [3], which is a Geant4-based simulation program for a future International Linear Collider (ILC). All parameters for different detector models have been stored in a MySQL database. The output files are in LCIO format [4, 5]. For the analysis of simulated data the Linear Collider analysis framework Marlin [6] as well as C++ and ROOT software have been used. For every detector setup 50000 events have been simulated (without magnetic field) with a 1-6 GeV/c electron beam. In the simulation the effects of multiple scattering (MS) have been taken into account. The validity of the MS model has been verified by comparing simulation results with theoretical description [1, 7]. For every event hit positions and deposited energies in every telescope plane and the DUT have been stored. An intrinsic resolution of 3 μm for every telescope plane has been assumed. For this purpose in the analysis every hit position in telescope plane has been smeared.

2 Simulation results

The analysis procedure is done as follows. Through the hits in the telescope planes a straight line as a track model using a least squares fit has been fitted [8]. The telescope planes have been considered as perfectly aligned. To reduce the effects of multiple scattering the cuts for χ^2_{track} and the track slope have been introduced. The residuals in the DUT plane $r_{x\ \text{DUT}}$ and $r_{y\ \text{DUT}}$ are calculated as the difference between the DUT hit position predicted by the extrapolated track and the real hit position in the DUT. After fitting a Gaussian function to the DUT residual distributions $r_{x\ \text{DUT}}$ and $r_{y\ \text{DUT}}$ the standard deviation values σ_x and σ_y have been extracted. The dependence of σ_x on the electron beam energy is shown for different telescope configurations in Fig. 2. At low energies the contribution of multiple scattering is large and, therefore, the 2-plane configuration gives better results. With increasing energy the 4-plane geometry is an optimal variant. For the case of the availability of two closest to the DUT telescope planes of higher resolution (1.5 μm), which can be achieved by using sensors with smaller pixel size, the performance of the telescope will improve significantly [1].

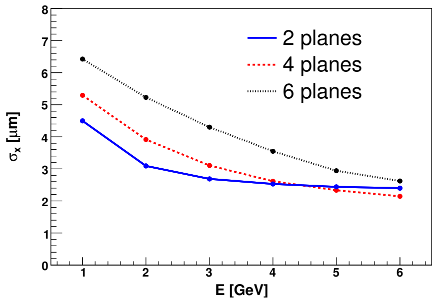

Figure 2: Standard deviation value of the residual distribution in the DUT plane σ_x as a function of the electron energy for different telescope geometries.

The present telescope setup is foreseen to be used in different test beam environments. The performance of the telescope within hadronic beams has been investigated by simulating a pion beam of 100 GeV/c. The same intrinsic plane resolution of 3 μm is assumed. The results of the study are presented in Fig. 3. As is expected, the 6-plane geometry will show the best performance due to negligible multiple scattering effects.

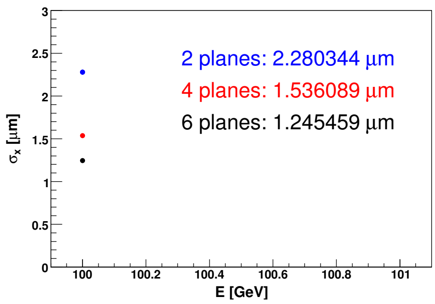

Figure 3: Standard deviation value of residual distributions in the DUT plane σ_x as a function of the pion beam energy.

When the detector is ready a proper software alignment will be an important issue for telescope precision. Therefore it is useful to test different alignment procedures in order to arrange the setup in such a way as to make alignment later on easy. A popular alignment program in use is Millepede [9] which is widely exploited in H1, ZEUS and CMS experiments for tracker alignment. The package is based on a linear least squares fit and especially suited for systems with big numbers of fitted parameters. There are two types of parameters used in the fit:

- local parameters: track parameters (here, track slopes and curvatures);
- global parameters: alignment coefficients (here, x and y shifts).

For testing the package 50000 events for 6 GeV/c electron beam have been simulated for 6-plane telescope geometry without the DUT. A misalignment has been introduced into the analysis by randomly shifting hit positions in telescope planes. Very preliminary results of the alignment procedure are shown in Fig. 4 for x shifts. Blue dots indicate true shifts which have been introduced in the analysis and red dots represent the output of the alignment package Millepede. In general good performance of the program is demonstrated however more detailed and systematic study is needed, e.g. for taking into account rotations of the telescope planes as well as finding a minimal number of events necessary for precision alignment.

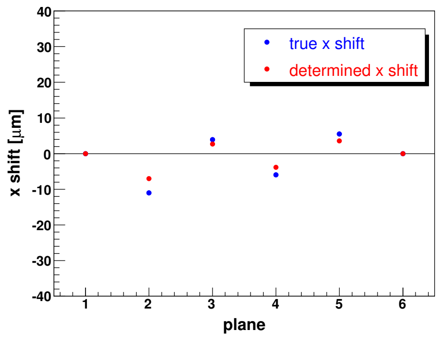

Figure 4: The results of the alignment procedure for x shifts as a function of the plane number.

Currently, a common analysis framework based on Marlin for the telescope operation is under development [10]. It will comprise all the steps of data analysis and possibility of its comparison with the simulation.

References

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