Experience with the ZEUS Micro Vertex Detector

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Abstract

In view of the anticipated HERA accelerator upgrade the ZEUS experiment was equipped with a silicon strip detector in 2001. The HERA upgrade was partly motivated by the desire to determine the contribution of heavy quarks and gluons to the proton structure more accurately. The vertex detector was designed such that short lived c- and b-hadrons produced in deep inelastic scattering can be selected using impact parameter distributions. The HERA collider suffered from background problems and therefore the ZEUS experiment collected significant luminosity only since the end of 2004.

Key words: Vertex, Silicon, Zeus.

1 Micro Vertex Detector

The silicon strip detector consists of a barrel with three layers and three disks in the forward region. The cross section of the detector can be seen in the event display in figure1, that shows the decay of D meson produced in deep inelastic *ep* scattering. Both barrel and foward silicon sensors have p-on-n strips, implanted with a pitch of 20μm, but only every sixth strip is (AC) connected to the readout. In a test beam a position resolution of 7 μm has been achieved. The 20 ladders that make up the barrel are based on identical carbon fiber frames, each holding 10 (half) modules. The frames support hybrids, cables and cooling pipes and provide stiffness. The design and performance of the silicon sensors have been extensively described in references [1,2].

Relevant to the interpretation of the material distribution is the fact the front end chips are water cooled, running at 15 C. The stainless steel cooling tubes run directly underneath the ceramic hybrids. Dry air is continuously supplied.

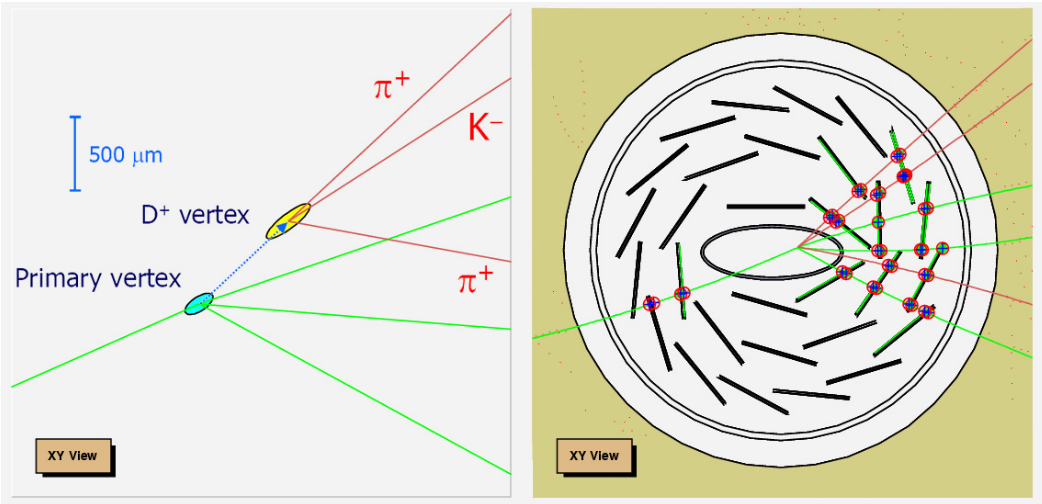

Fig. 1. *Event display of an ep collision with a D meson decaying to $K\pi\pi$. On the left side of the display the reconstructed vertex is shown. On the right the cross section of the vertex detector is displayed with the hits in it.*

In the discussion of the detector alignment it is relevant to mention that the positioning of sensors within a stave was performed with 10 micron precision and measured afterward with a precision of a few micron. The position of the ladders in their support of two carbon fiber cylinder halves was estimated to 10μm in the vertical and horizontal direction and 0.1 mm in the beam direction. The total number of analog readout channels is 208 k.

After the detector was installed in March 2001 no access has been possible and the detector has been running reliably ever since. When HERA restarted in the summer of 2001, the accelerator faced serious problems with the beam and vacuum conditions. There were some beam loss accidents and periods with increased synchrotron background. The radiation levels in the vertex detector are monitored with three radiation monitoring systems: PIN diodes, radfets and TLD's. The diodes are used for a fast beam abort signal. Comparison of the absolute dose measured with the different systems is complicated due to the fact that there positions differ and the dose is not expected to be uniform. The typical dose is estimated to be around 50 kRad. Although small radiation damage effects are observable in the detector characteristics (visible in increased leakage current and noise and a decrease in gain), it has not lead to a significant loss of performance.

Just after completion of the detector 1% of all channels were dead. Now, a total of 6% of the modules is either dead or causes problems during readout, for very different reasons. Total luminosity that is collected by the ZEUS experiment is 350 pb^{-1}.

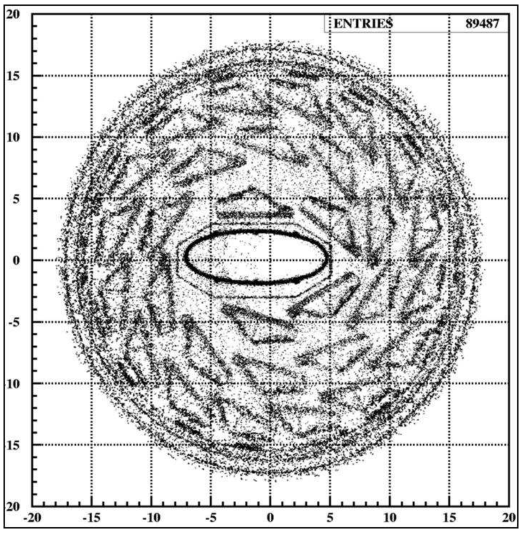

Fig. 2. *Map of the material distribution in the barrel part of the vertex detector recorded with data. Hadronic interactions are used selected by multitrack vertices.*

2 Material budget

A very detailed bookkeeping provided the composition of all detector components. Most components were even put on a balance to cross check the description. The estimated material thickness was 3% χ_o and proved to be accurate. Major culprits were sensors, cooling and power lines. The material that is used outside the active volume of the vertex detector was underestimated in the original Monte Carlo description. An accurate description was made in the 2005 based on mechanical design drawings. Recently a study has been performed using hadronic interactions. Two or more tracks are vertexed and no mass or pointing constraints are used. Material can now be seen very accurately and some components were clearly missing when plots from data and Monte Carlo were compared (like cooling pipes on the beampipe). A detailed cross section of the material in the barrel is shown in figure 2

3 Alignment

Although extensive metrology measurements were performed they were only used to help define alignment structures and to interpret the first alignment results that were obtained by the analysis of tracks. Soon after the installation cosmics were used to get ladder alignment constants. Details on alignment with cosmic rays were reported in the previous workshop [3] The shifts of the ladders in the beam direction was in the order of hundreds of microns. The expected 100 um and the uncertainty in the position of the two halves is consistent with these numbers. The alignment in the perpendicular (xy) plane

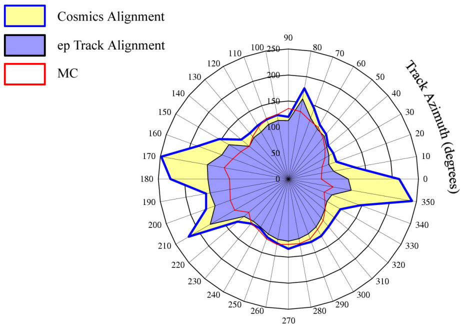

Fig. 3. *The azimuthal impact parameter resolution after the introduction of the ep-track alignment.*

showed smaller shifts and reveal a small underlying torsion in the cylinder.

Alignment with tracks from ep-collisions was tedious and it took several years for it to succeed. Main reasons for this delay are probably the already good alignment from cosmics ray tracks and the lack of physics data that normally motivates and pushes for fast progress. Over the last year the alignment has been redone and is now in very advanced state. Refining the cluster distribution and track reconstruction solved the last irregularities. The residuals of hits on the fitted tracks is 25 μm (a residual is calculated by omitting the from the fit). It now seems that the non-flatness of the sensors is limiting the position reconstruction accuracy. From figure 3 it can be seen that the impact parameter resolution. ps very close to what is expected from Monte Carlo simulations. The azimuthal asymmetry is explained by the asymmetric beampipe resulting large variations in the extrapolation length from the first hit to the interaction point. This beampipe was designed to minimize the effects of synchrotron radiation.

The hardware alignment monitor based on laser beams shining through small transparent laser diodes shows possible movements when the quadrupoles are switched on. These magnets were installed during the HERA upgrade and are quit close to the interaction point Confirming these movements is difficult since no data without quadrupoles has been recorded.

In part of the available ep-data the D-meson signal has been analyzed. In the decay channel $D \rightarrow K\pi\pi$ the selection on impact parameter significance greatly reduces the background. The results is shown in figure 4.

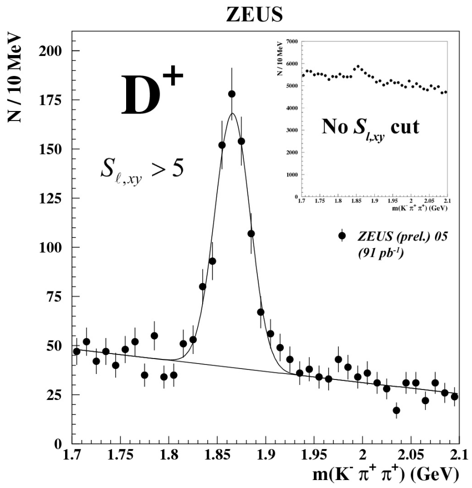

Fig. 4. *Reconstruction of D mesons. The effect of using the impact parameter significance in the selection is clearly visible.*

4 Concluding Remarks

The ZEUS vertex detector has been successfully operated for (nearly) six years without any intervention. Software alignment and calibration procedures have been finalized over the last year, reaching design specifications. In designing detectors one should consider that software calibrations may not be readily available during commissioning.

References

[1] Nuclear Instruments and Methods A, Volume 505, Issue 3, 11 June 2003, Pages 663-682 D. Dannheim, U. Kotz, C. Coldewey, E. Fretwurst, A. Garfagnini, R. Klanner, J. Martens, E. Koffeman, H. Tiecke and R. Carlin

[2] Nuclear Instruments and Methods A, Volume 501, Issues 2-3, 1 April 2003, Pages 340-358 L. A. T. Bauerdick, E. Borsato, C. Burgard, T. Carli, R. Carlin, M. Casaro, V. Chiochia, F. Dal Corso, D. Dannheim, A. Garfagnini et al.

[3] T Kohno, Performance of the ZEUS Micro-Vertex Detector Nuclear Instruments and Methods A , Volume 569, Issue 1, 10 December 2006, Pages 12-15