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The optical alignment system of the ZEUS microvertex detector

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Abstract

The laser alignment system of the ZEUS microvertex detector is described. The detector was installed in 2001 as part of an upgrade programme in preparation for the second phase of electron–proton physics at the HERA collider. The alignment system monitors the position of the vertex detector support structure with respect to the central tracking detector using semi-transparent amorphous-silicon sensors and diode lasers. The system is fully integrated into the general environmental monitoring of the ZEUS detector and data has been collected over a period of 5 years. The primary aim of defining periods of stability for track-based alignment has been achieved and the system is able to measure movements of the support structure to a precision around 10 μm.

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Keywords: Alignment; Vertex detector; Laser; Semi-transparent sensors

1. Introduction

A silicon-strip micro vertex detector (MVD) was added to the ZEUS detector in 2001 as part of an upgrade programme for high luminosity running with the HERA-II electron–proton collider at DESY [1]. One of the main physics motivations was to improve the study of heavy flavour production at HERA, particularly charm. With mean decay lengths of the order of 100 μm for charmed hadrons, precise alignment of the MVD active elements is crucial if their intrinsic spatial resolution of 10 μm and better is to be properly exploited. Alignment has been addressed in three stages: (i) during construction the position of the silicon strip detectors was measured with respect to the local support structure using an accurate 3-D measuring machine; (ii) an optical alignment system tracks large movements of the MVD support structure; (iii) individual MVD sensors are aligned precisely using charged-particle tracks from HERA run data. This paper describes the laser alignment system used for the second stage and summarises its performance. The primary aims of the laser system are to track large movements (at the level of 100 μm) of the MVD support structure with respect to the central tracking detector (CTD) and to define periods of stability for the track alignment. A prototype [2] of the system described here was tested and used during the construction of the MVD.

The paper is organised as follows: the MVD is described very briefly in the next section; the optical alignment system is described in Section 3; the readout and online control system is described in Section 4; data reduction and reconstruction is covered in Section 5; the results are summarised in Section 6 and the paper concludes with a short summary (Section 7).

2. The ZEUS MVD

The space available for the MVD is limited by the CTD and the shape of the beam pipe. The space inside the tracking detector has a length of about 2 m and a diameter of 32 cm. The design requirements of the MVD were: polar

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angular coverage of 10°–170°; at least three measurements, in two projections, per track; at least 20 μm hit resolution and impact parameter resolution of around 100 μm at 90° for tracks with momentum of at least 2 GeV/c. In order to meet these requirements within the limited space, the MVD consists of two parts, barrel and wheels, which are supported by a carbon–fibre tube made in two half-cylinders. The barrel has three concentric layers of silicon sensors but only the forward region is instrumented with sensors mounted on four wheels, numbered from 0 to 3. This follows from the unequal HERA beam energies, with 27.5 GeV electrons and 920 GeV protons, reaction products are boosted along the forward proton direction. The layout of the MVD is shown in Fig. 1, and Fig. 2 shows cross-sections of the barrel and a wheel. All the MVD services and readout connections are made through the rear end of the detector. The region at the rear of the MVD (shown to the right of the barrel in Fig. 1) is used for cooling water distribution manifolds. The MVD is described in more detail in Ref. [3,4]. As the MVD has to fit into an existing detector, getting services in and out is not easy. The route that cables follow is close to the rear beampipe, through the beam hole in the rear tracking detector and rear calorimeter. A further challenge is that, as part of the measures to increase the luminosity for HERA-II, a superconducting combined-function magnet (the HERA GG magnet) penetrates the detector around the rear beampipe. Getting all the MVD cables to fit between this magnet and the rear calorimeter was particularly challenging. The special very thin cables designed to keep material at a minimum within the detector run for about five metres from the MVD to four cable patch-boxes located above the first HERA magnets outside the ZEUS detector on the rear (upstream proton) side. From here much more robust cables take services and signals to the MVD services and readout racks about 20 m away.

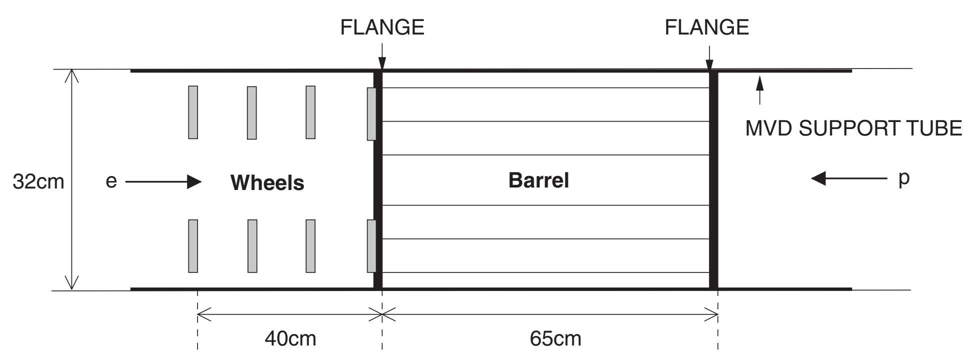

Fig. 1. Layout of the ZEUS MVD along beam axis. The barrel part covers the interaction region. Four wheels cover the forward direction of the proton beam.

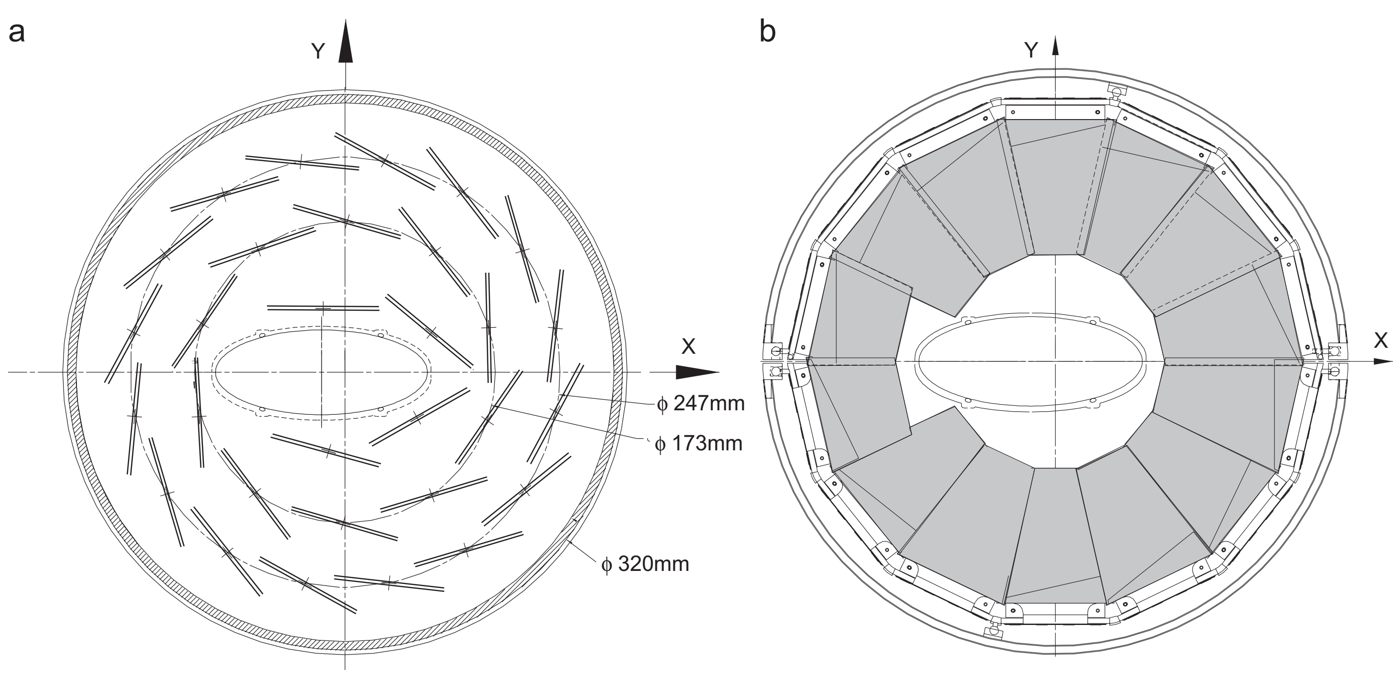

Fig. 2. Cross-sections of the MVD. Left and right are barrel and wheel, respectively. The coordinate system is that of the ZEUS experiment, with the z-axis along the proton beam direction, the x-axis pointing towards the centre of the HERA ring and the y-axis vertical.