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The BTeV pixel detector

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For the BTeV Collaboration

Abstract

The pixel vertex detector is critical to the success of the BTeV experiment. It will provide very high-precision space points along charged particle trajectories with a readout fast enough so that this information can be used by the lowest level trigger. The detector will be placed in a 1.6 T dipole magnet, inside the beam vacuum, and with the innermost region as close as 6 mm from the colliding beams. The status of the technical design of this unique vertex detector is presented in this paper.

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Keywords: BTeV; Pixel; Detector; Mechanical support; Cooling; Vacuum system

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1. Introduction

BTeV is an experiment expected to begin running at the CZero interaction region at Fermilab in the year 2009. Its physics goals are to achieve unprecedented levels of sensitivity in the study of CP violation, mixing, and rare decays in the *b* and *c* systems [1]. In order to realize this, the detector will employ a state-of-the-art first level trigger (L1) [2] that will look at every beam crossing to identify detached secondary vertices from charm and beauty hadron decays. The key element to this triggering approach is the pixel vertex detector. This provides high-resolution space points near the interactions, which are used both online and offline to reconstruct tracks and associate them with their parent vertices. Pixel detectors are chosen because they can provide high-precision space points with very few noise hits, and be quite radiation hard. Radiation hardness enables the detector elements to be placed very close to the beam (in vacuum, separated from the beam only by a thin RF shield made out of wires or strips), minimizing track extrapolation errors.

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2. Overview of the BTeV pixel detector

The design of the pixel detector system is driven by the long interaction region at the Tevatron which has a σ_z of 30 cm. This forces one to have a rather long vertex detector. The BTeV pixel detector consists of 30 stations (doublets of planes) distributed along the interaction region separated by 4.25 cm and placed inside a 1.6 T dipole magnet. The individual planes are composed of two half-planes, each about 5×10 cm. They are mounted left and right of the beam and are arranged so that a small square hole of $\pm 6 \times \pm 6$ mm is left for the beams to pass through. The two halves of the detector are displaced along the beamline by up to half-spacing between the stations to allow overlap between the two halves.

To minimize the extrapolation error, the pixel detector will be placed as close as 6 mm from the beams, and hence will be exposed to a significant level of irradiation. At our maximum projected luminosity of 2×10^{32}/cm^2/s, the innermost pixel detector will receive a fluence of 1×10^{14} minimum ionizing particles/cm^2/year. This significant radiation environment means that all components of the pixel system have to be radiation hardened. A schematic of the detector is shown in Fig. 1.

Each half-plane will have detector modules mounted on two sides of a graphite substrate with excellent thermal conductivity. On one substrate, the modules will have the narrow pixel dimension lined up in the y-direction (vertical) and the active area measures about 5 cm × 10 cm. On the other substrate, the modules will have the narrow pixel dimensions lined up in the x-direction (horizontal) with a total active area of 3.8 cm × 7.3 cm. A reasonable momentum measurement can be made using information from three or four stations. The momentum information can be used to reject very soft tracks that would adversely affect the trigger algorithm because of multiple scattering. Each half of the pixel detector will be sitting in vacuum and will be separated from the beams by a thin RF shield. During beam refill, the two halves of the detector will be moved away to about ± 2 cm from the beams. When the beam is stable, the detectors will then be moved close to the beam for data taking.

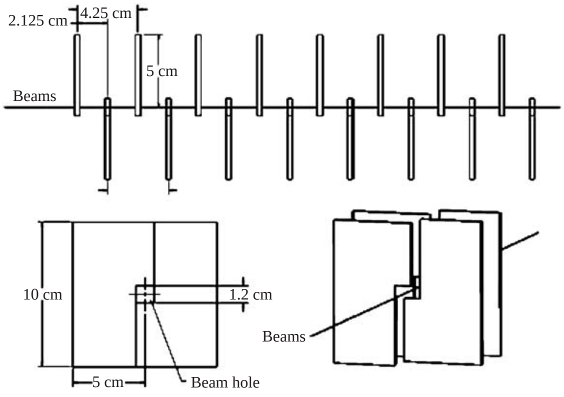

Fig. 1. Schematic drawing of part of the pixel detector.

All together, the BTeV pixel system has $\sim 22 \times 10^6$ pixels, each $50 \times 400\,\mu\text{m}^2$, and covers a total active area of $\sim 0.5\,\text{m}^2$. Each sensor pixel is read out by a dedicated electronics cell. The sensor pixel and the readout cell are connected by a bump bond. Each readout chip has 22 columns × 128 rows, corresponding to 2816 channels. BTeV test beam studies performed with prototype detectors have demonstrated a spatial resolution between 5 and 9 μm in the narrow dimension of the pixel (50 μm), depending on the track angle of incidence [3]. This result shows that excellent resolution can be obtained using charge sharing, even with very coarse digitization. Therefore, the final BTeV pixel readout chip (FPIX2) has a 3-bit FADC in each cell [4].

3. Technical design

3.1. Detector module

The basic building block of the pixel detector is a module which is a hybrid assembly consisting of a piece of silicon sensor bumped bonded to a number of readout chips, a high-density interconnect [5] flex circuit, and two interconnect flex cables: one for the power and the other for data and control signals. The sensors are sized to accept variable numbers of readout chips to make the required half-plane shape.

The silicon sensors are based on $n^+/n/p^+$ technology as developed by the LHC experiments.