

Description of the BTeV Detector

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BTeV is an experiment being constructed at the Fermilab $p\bar{p}$ collider, designed to study mixing, CP violation, and rare decays of beauty and charm hadrons. The detector covers the forward region (10-300 mrad), components include silicon pixels, tracking, RICH, PbWO₄ electromagnetic calorimeter, and muon system. Brief descriptions of individual detector elements are presented.

1. Introduction

BTeV is a newly approved program at the Fermilab Tevatron collider.¹ It is designed to make precise measurements of Standard Model parameters and an exhaustive search for physics beyond Standard Model. The most important measurement to make involve mixing, CP violation, rare decay of beauty and charm hadrons.

The detector covers the angular region between 10-300 mrad with respect to both beams, fully exploiting two advantages of the “forward” direction: the correlation in the direction of the $b\bar{b}$ pair produced, and the boost that allows an easier identification of detached vertices. This allows for efficient flavor tagging and sensitivity to a great variety of heavy flavor decays. Here I will give a brief description of the detector. More information can be found elsewhere.²

2. The BTeV spectrometer

In designing BTeV detector, there are several serious challenges. First, only a small portion of inelastic events are from heavy quarks, and the interaction rate is very high; Second, background from beauty events can overwhelm the interesting rare process; And the detector will operate in very high radiative environment.

Fig. 1 shows the two-arm BTeV spectrometer. The major components include: a planar precision vertex detector made from silicon pixels, a forward tracking system comprised of silicon strips near the beam and straw tube chambers at larger radius, a Ring-Imaging Cherenkov Detector (RICH), an PbWO₄ electromagnetic calorimeter, a muon system, and a deadtimeless trigger and DAQ system.

The pixel vertex detector sits at the center of spectrometer,^{3,4} inside an 1.6 Tesla dipole magnetic field. It provides accurate vertex information for offline analysis, and delivers very clean, precision space points to the vertex trigger. The pixel vertex detector consists of 31 stations of doublets along the beam direction, with pixel size

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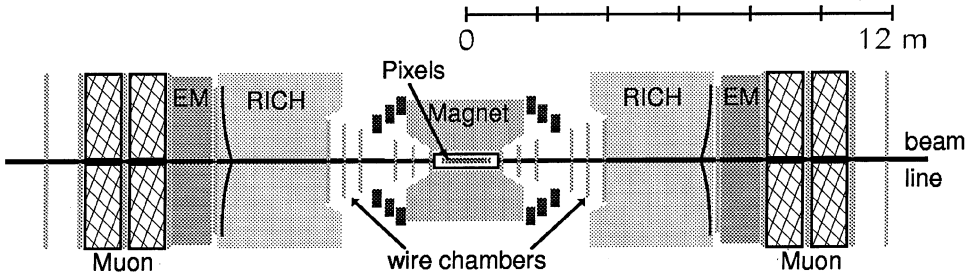


Fig. 1. Layout of the BTeV spectrometer.

$50 \times 400 \mu\text{m}^2$. The pixel geometry is chosen to provide excellent signal-to-noise, spatial resolution, high speed and low occupancy. A beam test of prototype pixel detectors had been carried on at Fermilab. The resolution is excellent, better than the $9 \mu\text{m}$ requirement of BTeV.⁵

The forward tracking system provides track momentum measurement, K_s detection and the Level 2 trigger. It has 7 stations per arm along the beam direction. BTeV uses a combination of straw-tube proportional chambers and silicon microstrip detectors. Straws are chosen because they can be used to make large chambers with small cell size, and can be built to surround the beam pipe without requiring a heavy frame near the beam. At the center part near the beam, where the occupancies are too high for straw tubes, the silicon microstrip detectors are used.

The charged particle ID is absolute necessary for a heavy quark experiment. It is useful for the identification of specific final states, such as $K^+\pi^-$ from $\pi^+\pi^-$, and for flavor tagging. At BTeV, there is sufficient space to install a RICH detector.⁶ The BTeV RICH detector is designed to separate pions from kaons and protons in a momentum range of 3 to 70 GeV, where the lower limit is determined by soft kaons for flavor tagging, and the higher one given by two body B decays. We use gaseous freon (C_4H_{10}) radiator to generate Cherenkov light in the optical frequency range. The light is focused by mirrors onto Hybrid Photo-Diode (HPD) tubes. For the gaseous radiator, the kaon momentum threshold is about 10 GeV. To separate kaons from protons below this threshold, an aerogel radiator will be used.

Photons and electrons are detected using an electromagnetic calorimeter. In BTeV, the lead tungsten crystals (PbWO_4) are chosen, which is a radiation hard, dense and transparent medium that produces scintillation light.⁷ The light is collected by photo-multiplier tubes. The crystals are 220 mm long and have very small transverse cross-section ($26 \times 26 \text{mm}^2$), providing excellent segmentation. The crystals are designed to point at the center of the interaction region. They cover up to about 210 mrad, which is smaller than the 300 mrad acceptance of the tracking detectors, giving about 20% loss in signal for most final states of interest.

The muon detector consists of two 1 m thick magnetized iron toroids and three sets of position detector per arm. Besides providing muon identification, the system is also used to trigger on the dimuon decays of the J/ψ . This is important not only

to gather more signal but as a cross check on the efficiency of our main trigger, the detached vertex trigger. Each toroid is 1m long with an 1.5 Tesla field. It absorbs hadrons and deflects muons with total p_t kick per track of about 1 GeV.

It is impossible to record data from each beam crossing of 7.6 MHz. A prompt trigger must be made to record or discard the data. The detached vertex trigger, the main BTeV Level 1 trigger, is provided by the silicon vertex detector, using lifetime to distinguish B event from others.⁸ This is done by reconstructing all primary vertices and selecting events that have additional tracks with large impact parameters with respect to the nearest primary vertex. Requiring that at least two tracks detached from primary vertex by more than 6 standard deviation, the light quark background reduced to the level of 1%. And the efficiency for a typical beauty decays are greater than 50%. The parallel pipelines are implemented at Level 1, so the processor have long enough time to compute than the beam crossing time of 132 ns. At Level 2 and level 3, there is much more time to do more sophisticated rejection. The event rate passing Level 3 trigger to be recorded is expected to be 2 - 4 kHz.

3. Summary

The BTeV spectrometer provides excellent particle identification for charged and neutral hadrons and photons, excellent mass and decay time resolutions, and a deadtimeless trigger and DAQ system. It is capable of exquisite tests of the Standard Model and has great potential to discover new physics via rare or CP violating decays of heavy quarks.

References

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