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The Muon System Upgrade for the CDF II Experiment

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Abstract

During Run II the Tevatron collider will operate with a 20-fold decrease of bunch crossing time and a similar increase of luminosity with respect to Run I: these new running conditions called for extensive improvements and extensions of the CDF muon system. The low light yield of aging scintillators has been effectively fixed by gluing light fibers to the long sides of these counters for added light output. The higher backgrounds of the Main Injector era will be suppressed by custom-shaped steel shielding structures. A new muon system has been developed to extend rapidity coverage up to $|\eta| = 1.5$ with performances comparable to those of the central muon system. New front-end electronics will handle the reduced gas gain set in the central muon system. Several mechanical problems have been solved to allow the completion of azimuthal coverage.

1 Introduction

The muon system of CDF was extremely successful during Run I: the fraction of $t\bar{t}$ events collected by muon triggers were critical in the top quark discovery, 20,000 $W \to \mu\nu$ decays allowed a competitive measurement of the W mass, and 200,000 $J/\psi \to \mu^+\mu^-$ decays enabled a wealth of first-class measurements of B hadron properties. We obviously want to preserve these performances in view of the next run. However, the Tevatron collider has recently completed a massive upgrade, most notably with the addition of a high luminosity preaccelerator, the Main Injector. This machine will allow the Tevatron to operate with a bunch crossing time as low as $132 ns$; the instantaneous luminosity delivered will be a few times $10^{32} cm^{-2} s^{-1}$. In order to meet the higher demand for performance of the shorter bunch crossing time and higher fluxes, most of CDF muon subsystems have undergone major improvements and modifications(1). I will briefly highlight the most interesting aspects of these upgrades in what follows.

2 Modifications

The CDF muon system consists of multiple layers of single wire chambers topped by scintillation counters. During Run II, scintillation counters will be critical for associating a muon track to the $p\bar{p}$ interaction that produced it, since the typical drift time in the wire chambers will largely exceed the bunch crossing time. Unfortunately a problem was discovered in many of the central muon system counters: these $320cm$ long scintillators showed a considerable decrease in both their total yield and attenuation length with respect to the original values, causing a significant degradation in the detection efficiency for particles entering at the far end. To fix this problem, a wavelength-shifting fiber ribbon has been glued to the long side of the counter, to collect light locally and thus reduce the average photon path in the scintillating material. The fibers carry efficiently these additional photons to the photomultiplier, and increase the yield at the far end to several photoelectrons per minimum-ionizing particle.

In the past, the wire chambers covering the central rapidity interval $|\eta| < 0.6$ were operated in limited streamer mode. To safely handle the higher rates, and to prevent excessive aging, these detectors will be operated in proportional mode during Run II. New preamplifiers have been installed at the point of signal extraction, to strengthen the smaller signal due to lower gas gain, and new ASD boards have been supplied.

The forward toroids, once used to measure the momentum of forward muons, have been moved closer to the central system by 5.5 meters. During Run I, particles exiting the central detector at high rapidity could hit these structures and generate secondaries that produced high background fluxes in the muon chambers covering the rapidity interval $0.6 < |\eta| < 1.0$. These particles were effectively separated from real muons by tight timing gates exploiting their longer path to the scintillation counters from the interaction point. In Run II, however, the path difference between direct and rebound hits will be smaller, and the timing gate might not be sufficient to reject the latter. New shielding structures have therefore been added to the forward toroids; detailed simulations show that they will strongly reduce chamber exposure to both the flux of secondaries and the products of high luminosity beam-gas interactions occurring outside of the central detector.

3 Additions

CDF II will be able to track particles up to rapidities of $1.5 \sim 2.0$, thanks to its standalone seven-layer silicon system. A new muon detector, consisting of a barrel of single wire chambers, has been installed on top of the forward toroids to cover the rapidity interval $1.0 < |\eta| < 1.5$, thus considerably increasing the acceptance for tracked muons. The 1728 installed tubes have a cross section of 8 by $2.5cm$ and are 3 meters long; they are arranged in a staggered four-layer geometry and are complemented by a new system of scintillators. These 432 counters are equipped with a ribbon of wavelength-shifting fibers glued to the long side. The fibers collect light and carry it to a miniature Hamamatsu 5783 phototube lodged in a notch of the scintillating material; the compact design includes a small amplifier and discriminator circuit that controls the gains, amplifies the small 5 mV signals and generates differential ECL outputs for signal above an adjustable threshold.

In the rapidity interval $|\eta| < 0.6$ four layers of drift chambers, installed on top of a $0.6m$ steel shield, provide additional confirmation to the signals collected by the inner layers installed on top of the calorimeter arches. These chambers have been refurbished with new front-end electronics; the existing azimuthal gaps have also been instrumented for Run II by installing new chambers and counters on the ceiling of the CDF collision hall and under the central detector.

In the interval $0.6 < |\eta| < 1.0$ two thirds of the azimuthal acceptance were covered during Run I with eight layers of drift tubes and two layers of counters, arranged in four arches extending for 120 degrees each and set at the four corners of the central detector. The uninstrumented regions between the arches have been filled by the insertion of two 90 degrees *miniskirts* for the lower gaps and a 30 degrees *keystone* at the top. The keystone hangs from the ceiling of the collision hall, while the miniskirts, subdivided in 30 degree and 10 degree sections, fit in the tight gap between the concrete floor of the collision hall and the central detector, and are designed to be quickly removable if needed, to allow maintenance access to the side of the central detector.

4 Conclusions

The Tevatron improvements performed in view of the new run have imposed tough demands on the CDF II muon system. These demands have been met or exceeded. During the next run, CDF II will likely collect more than one million $W \to \mu\nu$ decays, hundreds of $t\bar{t}$ decays yielding a muon, and several million B-hadron events involving a $J/\psi \to \mu\mu$ decay. The physics advances these datasets warrant can be easily foreseen.

References

[1] *The CDF II Technical Design Report*, Fermilab-Pub-96-390-E, Nov 1996.