Searches for New Gauge Particles in Dilepton and Diphoton Final States at the Tevatron

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Abstract. The CDF and D0 collaborations have carried out searches for heavy gauge bosons with the data collected from the proton-antiproton collisions in the Run II of the Tevatron. We present the results on the searches for the new physics with the dilepton and diphoton final states at high mass. The models covered include W' and Z' arising from the Grand Unifying Theories and the excited state of the graviton in the Extra Dimensions theories. The analyses are based on an integrated luminosity of 200 - 450 pb^{-1}.

Keywords: New Phenomena, Extra Gauge Boson, Extra Dimensions, CDF, D0, Tevatron
PACS: 13.86.-t, 13.85.Fb, 13.85.Rm

INTRODUCTION

Gauge particles are the carriers of the fundamental forces. The gauge particles observed to the date include photon, $W^{\pm}$, Z and gluons, which are described by the Standard Model (SM) gauge group SU(3)$\times$SU(2)$\times$U(1). However there are theories that complement or extend the SM for various motivations. Usually such theories have richer gauge structure, hence predicting the existance of extra gauge particles which are heavier copies of the known gauge particles [1, 2].

The particles may have eluded the observation because they are very weakly interacting to the known particles or because they have mass beyond the reaches of the past experiments. Since the Tevatron is the high energy frontier with $p\bar{p}$ center of momentum energy $\sqrt{s}$ = 1.96 TeV, the CDF and D0 detectors [3, 4] are most competent in search for the heavy unknown particles. The potential for the discovery is interesting because the weak scale ($\sim$ 1 TeV) is within the reach of the Tevatron and many theories predict new phenomena at the scale.

The Tevatron may also be able to discover the graviton, which is postulated to be the carrier of the gravity. Graviton is the only undiscovered gauge particle of the known interactions, due to its weak interaction and light or zero mass. However according to the theories of extra dimensions (ED), gravitons can have very large mass due to the effect of the ED. There are various models of ED and the mass of the excited graviton (G_{KK}) is determined by the number and sizes of the ED whithin the model. Even if the mass of the G_{KK} is beyond the reach of the Tevatron, the effect of the virtual graviton still can leave signature in the distributions of the dilepton or diphoton final states. Arkani-Hamed, Dimopoulos and Dvali (ADD) proposed a model of ED theory [5], which suggests that the Planck energy scale may be low enough to be within the reach of the feasible experimental facilities. Randall and Sundrum (RS) suggested another model [6] where

TABLE 1. Z' exclusion summary. 95 % CL lower limits on the Z' mass for the selected models.

	CDF 450 pb^{-1}					D0 250 pb^{-1}	CDF 195 pb^{-1}
Decay channel	e^+e^-					$\mu^+\mu^-$	$\tau^+\tau^-$
Model	Z'$_{SM}$	Z$_I$	Z$_\eta$	Z$_\psi$	Z$_\chi$	Z'$_{SM}$	Z'$_{SM}$
Limit (GeV/c^2)	855	650	745	725	735	680	394

the gravitons can propagate into a single extra dimension. The RS model may solve the hierarchy problem and allow for low-energy gauge coupling unification.

In this paper, the searches for the extra gauge bosons in the dilepton or diphoton final states are presented. These final states are of particular interest as the first observation channel for the new gauge particles, because the signal is very clean compared to the final states that include quarks. The Drell-Yan, which is the most dominat SM background, is also highly suppressed in the high mass, enhancing the signal to background ratio.

RESULTS ON THE EXTRA GAUGE BOSONS

The signature for the extra neutral gauge boson has been searched for by the CDF and D0 collaborations in the process $p\bar{p} \to$Z'$\to l^+l^-X$. The events are selected by the two lepton candidates with high transeverse momenta. In addition to the Drell-Yan process, background can arise from the electron faking multijet events and other electroweak processes. Their contribution to the distribution is estimated from the data or Monte Carlo (MC) simulation and appropriately taken into account. The differential cross section in the dielectron invariant mass and the electron scattering angle ($\cos\theta^*$) is compared to the prediction of the SM and that of the Z' models. The SM prediction is calculated from the leading order MC and k-factor is factored in to account for the next leding order effect. No significant deviation from the SM prediction was found and the 95 % confidence level (CL) lower limits are set on the Z' masses. The mass limits for the selected Z' models are shown in the Table 1.

An extra charged gauge boson, W', arises from the left-right symmetric models where an extra SU(2) symmetry is introduced [7]. The decay of W' to an electron (positron) is paired with an anti-neutrino (neutrino), leaving the longitudinal neutrino momentum unknown. Therefore the analysis is performed with the transverse mass distribution to compare with distibution predicted by the SM. The CDF collaboration has searched for the W'$\to e\nu$ decay signature with 205 pb^{-1} of data, to set the 95 % CL lower limit to the mass of the W' at 788 GeV/c^2.

RESULTS ON THE EXTRA DIMENSIONS

The D0 collaboration has pioneered on the seraches for the ED in various models. ADD model G$_{KK}$ has been searched for in the dielectron and the diphoton channels using 200 pb^{-1} of data. The event selection is made requiring two high transverse

TABLE 2. Limits for the ADD mass scale M_S. λ determines the inteference structure between the SM and ADD contributions to the cross section, and n is the number of the extra dimensions.

Parametrization	GRW [8]	Hewett [9]		HLZ [10]					
Model parameter	-	$\lambda = 1$	$\lambda = -1$	n = 2	n = 3	n = 4	n = 5	n = 6	n = 7
Limit (TeV/c^2)	1.36	1.22	1.10	1.56	1.61	1.36	1.23	1.14	1.08

energies deposited in the electromagnetic calorimeter.The background and next leading order effect are estimated from the data or MC and taken into account. The two-dimensional differential cross section in the invariant mass and $\cos\theta^*$ is compared to the SM background prediciton. The analysis have been made with three different ways of parameterizing the model, designated as GRW [8], Hewett [9] and HLZ [10]. No deviation has been found and 95 % CL lower limit for the mass scale M_S is set from the combined e^+e^- and $\gamma\gamma$ channels (Table 2).

The RS model graviton is also probed by the CDF and D0 collaborations with similar techniques. The D0 analysis with 275 pb^{-1} of data has a combined result from the dielectron, dimuon and diphoton channels. The 95 % CL lower limit for the G_{KK} mass is set to 785 GeV/c^2, when the parameter $k/\overline{M}_{Pl}$, the dimensionless coupling of the G_{KK} to the SM filelds, is equal to 0.1.

CONCLUSION

The CDF and D0 collaborations have been searching for the new physics signature in the various models and decay channels. So far no significant signal for the extra gauge bosons or extra diemnsions has been found. However being the high energy frontier, the Tevatron may be the first place to discover the physics beyond the SM as the data is being accumulated.

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