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Search for New Physics with High Mass Tau Pairs in CDF Run II

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We present the results of a search for new particles decaying to tau pairs. Hypothetical particles, such as Z' and MSSM Higgs boson A can potentially produce such pairs. The low-mass region, dominated by $Z \to \tau\tau$, is used as a control. No significant excess events over the estimated backgrounds is observed in the high-mass region, and we set upper limits on the cross section times branching ratio as a function of the Z' and A mass.

Keywords: Z'; MSSM Higgs; tau pairs.

1. Introduction

We present a search for new physics with high-mass tau pairs in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV with the CDF detector[1] at Run II of the Fermilab Tevatron. Example signal processes include $Z' \to \tau\tau$[2] and MSSM Higgs $A \to \tau\tau$[3]. We use three final states with at least one hadronic tau decay: $\tau_e\tau_h$, $\tau_\mu\tau_h$ and $\tau_h\tau_h$ (Throughout this paper we use the short-hand notations τ_e, τ_μ and τ_h to denote $\tau \to e\nu\bar{\nu}$, $\tau \to \mu\nu\bar{\nu}$, and $\tau \to$ hadrons ν, respectively).

The main backgrounds are from the high-mass tail of $Z/\gamma^* \to \tau\tau$, and jet$\to \tau$ fakes from W+jets, di-jet, and multi-jet events. We define a mass-like quantity m_{vis} using the four-vectors of the lepton, the tau, and the $\not{E}_{\mathrm{T}}$ vector (with z component set to zero, and energy equal to the magnitude of $\not{E}_{\mathrm{T}}$). We perform a blind search in the region $m_{\text{vis}} > 120$ GeV/c^2. The events in the region below this cut are used as control sample.

2. Data Sample & Event Selection

The study of $\tau_e\tau_h$ and $\tau_\mu\tau_h$ channels use data corresponding to an integrated luminosity of 195 pb^{-1}. We select events with a reconstructed isolated electron with $\mathrm{E_T} > 10$ GeV (isolated muon with $\mathrm{p_T} > 10$ GeV/c), a reconstructed isolated tau with $\mathrm{p_T}(\text{tracks} + \pi^0\text{s}) > 25$ GeV/c, and $\not{E}_{\mathrm{T}} > 15$ GeV.

The $\tau_h\tau_h$ analysis uses data corresponding to an integrated luminosity of 72 pb^{-1}. We select events with $\not{E}_{\mathrm{T}} > 25$ GeV and two isolated tau candidates. One of the taus must have $\mathrm{p_T}(\text{tracks} + \pi^0\text{s}) > 25$ GeV/c and the second one $\mathrm{p_T}(\text{tracks} + \pi^0\text{s}) > 10$ GeV/c.

Then we require that $\not\!\!E_T$ points within 30 degree of the direction of the electron (muon) for the $\tau_e\tau_h$ ($\tau_\mu\tau_h$) channel, or the lower-$\mathrm{p_T}$ tau for the $\tau_h\tau_h$ channel. This cut retains most of the signal while significantly suppressing the backgrounds.

3. Signal Acceptance

The acceptance in the high-mass signal region is measured in a combination of data and Monte Carlo. We generate $f\bar{f} \to Z' \to \tau\tau$ and $gg \to A \to \tau\tau$ at $\tan\beta$=20 using the PYTHIA Monte Carlo generator[4]. The taus are decayed using the Tauola package[5]. Trigger efficiency is taken into account. The efficiency for identifying the isolated lepton (electron and muon) is scaled to the value measured in the data using the unbiased leg in Υ and Z^0 decays. The efficiency for identifying the isolated, high $\mathrm{p_T}$ hadronically decaying tau is scaled to the value measured in the data using $W \to \tau\nu$ events. Uncertainties are from the statistical uncertainty, the dominant systematic uncertainty 15% from simulation modeling, and 8% from parton distribution functions (PDF).

4. Background Estimate

After applying tau identification and kinematic cuts the dominant background is $Z/\gamma^* \to \tau\tau$. Other backgrounds come from jet$\to \tau$ fakes, $Z/\gamma^* \to ee$ and $Z/\gamma^* \to \mu\mu$. We use Monte Carlo simulation to estimate the contributions from the Drell-Yan processes. Instead of modeling all processes that could produce jet$\to \tau$ fakes, we estimate their contributions from the data using fake rates measured in the unbiased jet samples. The expected number of background events in the control region and signal region are 99.27±12.55 and 2.83±0.46, respectively.

5. Results

The observed number of events in the control region and signal region are 90 and 4, respectively. The m_{vis} distribution is presented in Figure 1. There is a good agreement between the observed events and the expected background events in the control region, and there is no significant excess events in the signal region.

Since we observe no significant excess of events in the signal region, we set upper limits on the cross section times branching ratio as function of mass. We calculate the 95% CL upper limits of $\sigma \cdot \mathrm{B}(f\bar{f} \to Z' \to \tau\tau)$ and $\sigma \cdot \mathrm{B}(gg \to A \to \tau\tau)$. We intend to use them as the generic limits for $\sigma \cdot \mathrm{B}(f\bar{f} \to X_{\mathrm{vector}} \to \tau\tau)$ and $\sigma \cdot \mathrm{B}(gg \to X_{\mathrm{scalar}} \to \tau\tau)$, which can be interpreted in various models. The results are shown in Figure 2.

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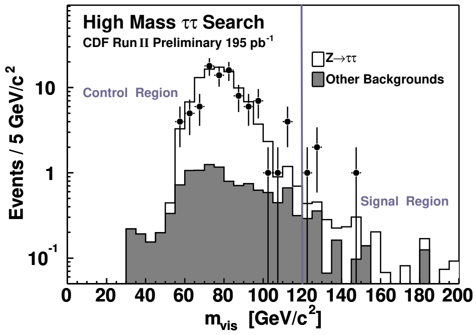

Fig. 1. Distribution of m_{vis} for the events in the control region and signal region.

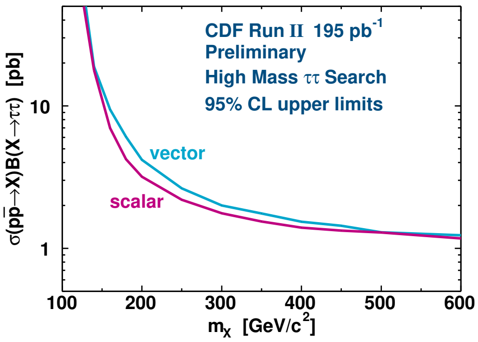

Fig. 2. The upper limits at 95% CL for $\sigma \cdot \mathrm{B}(f\bar{f} \to X_{\text{vector}} \to \tau\tau)$ and $\sigma \cdot \mathrm{B}(gg \to X_{\text{scalar}} \to \tau\tau)$.

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