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Search for MSSM Higgs Decaying to Tau Pairs

DONGWOOK JANG*

Physics & Astronomy, Rutgers, The State University of New Jersey,
136 Frelinheynsen Rd., Piscataway, NJ 08901, USA

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We present the results of a search for a neutral MSSM Higgs boson decaying to a pair of tau leptons. The analyzed data sample corresponds to integrated luminosity of approximately 200 pb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. It was collected by the CDF detector during Run 2 of the Fermilab Tevatron. We select tau pairs in which one of the taus decays hadronically and the other to e or μ and neutrinos. We see no evidence of signal and perform a fit to the (partially) reconstructed di-tau mass to set limits on the product of Higgs production cross-section and its branching fraction to taus.

Keywords: MSSM,Higgs,tau,CDF

1. Introduction

The Minimal Supersymmetric Standard Model (MSSM) predicts the existence of three neutral and two charged Higgs bosons. At hadronic colliders, the production cross section of the pseudoscalar neutral boson A scales as $\tan^2\beta$, where $\tan\beta$ is one of the parameters of the theory. The major decay modes of A are $A \to b\bar{b}$ ($\sim 90\%$), and $A \to \tau\tau$ ($\sim 8\%$). While the branching fraction to $b\bar{b}$ is much larger and $b\bar{b} \to Ab\bar{b},\ A \to b\bar{b}$ is considered the most promising channels at the Tevatron, the important production mechanisms $gg \to A$, $b\bar{b} \to A$ are difficult to study in the $A \to b\bar{b}$ channel due to large backgrounds. The addition of the $A \to \tau\tau$ mode expands our reach and is an important part of the MSSM Higgs search effort at CDF.

Detailed information on Higgs production at the Tevatron and detection possibilities by the CDF and D0 experiments can be found in [1].

2. Signal Acceptance and Background Estimation

We used the Pythia MC generator, version 6.216 [4] to simulate the processes $gg \to$ A and $\bar{b}b \to$ A. The Higgs boson was forced to decay to $\tau^+\tau^-$. The taus are decayed using the Tauola package [5]. We generated Higgs masses between 115 GeV/c^2 and 200 GeV/c^2 for $\tan\beta = 30$. Figure 1 shows the *total* efficiency for detecting a Higgs

*for the CDF Collaboration

decaying to specific tau final states. The relevant τ branching fractions are included in the acceptance.

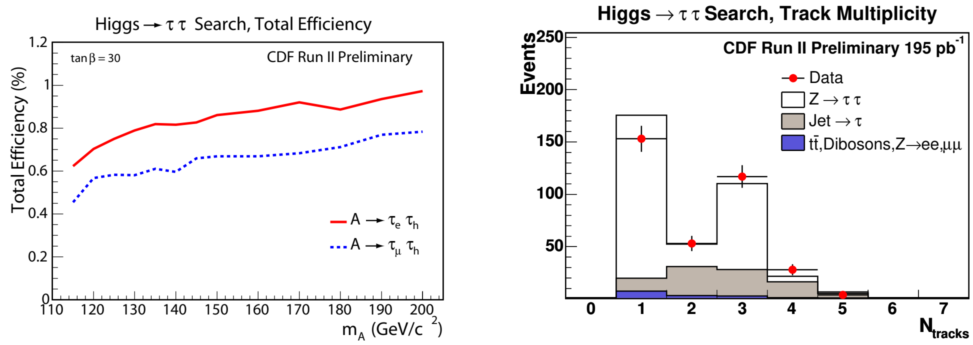

Fig. 1. *The left plot shows the detection efficiency as a function of Higgs mass. The efficiencies were calculated with Monte Carlo sets generated with* $\tan\beta = 30$*. The right plot shows the track multiplicity for the tau candidates. Track multiplicity and opposite charge cuts are not applied on the right plot.*

The biggest source of background are $Z \to \tau\tau$ events which can only be distinguished from the Higgs signal by the ditau parent mass. However, the presence of multiple neutrinos in the final state makes full reconstruction of the parent mass impossible in the general case. We estimate $Z \to e^+e^-$, $Z \to \mu^+\mu^-$, di-boson and $\bar{t}t$ events by using Monte Carlo samples. Backgrounds from $jet \to \tau$ misidentification are estimated using a fake rate function obtained from independent jet samples. The fake rate is parameterized in terms of jet energy, pseudorapidity (η) and track multiplicity.

Figure 1 (right) shows the track multiplicity for hadronically decaying tau candidates. The enhancement at one and three tracks is a characteristic signature of tau decays. For this plot, all selection criteria except the track multiplicity and opposite charge requirement have been applied.

3. Results

Since $Z \to \tau\tau$ decays differ from our Higgs signal only in mass, we define a mass-like discriminating variable $m_{vis}(\ell, \tau_h^{\rm vis}, \not{E}_{\rm T})$. It is constructed using the four-momentum of the lepton ($\ell = e$ or μ), the four-momentum of the visible decay products of the τ_h ($\tau_h^{\rm vis}$) and $\not{E}_{\rm T}$ (also treated as a four-vector). After combining the $\tau_e\tau_h$ and $\tau_\mu\tau_h$ channels we perform a binned likelihood fit of the $m(\ell, \tau_h^{\rm vis}, \not{E}_{\rm T})$ distribution to extract a Higgs signal. The uncertainties in background estimation are incorporated in the imposed Gaussian constraints. Several signal templates were generated to cover the studied mass region. No constraints were applied to the signal. Figure 2 (left) shows the $m_{vis}(\ell, \tau_h^{\rm vis}, \not{E}_{\rm T})$ distribution for data and various backgrounds. The limits on Higgs production cross-section times branching fraction at 95% CL are presented in Figure 2 (right). Presently, we are only sensitive to Higgs production at large $\tan\beta$.

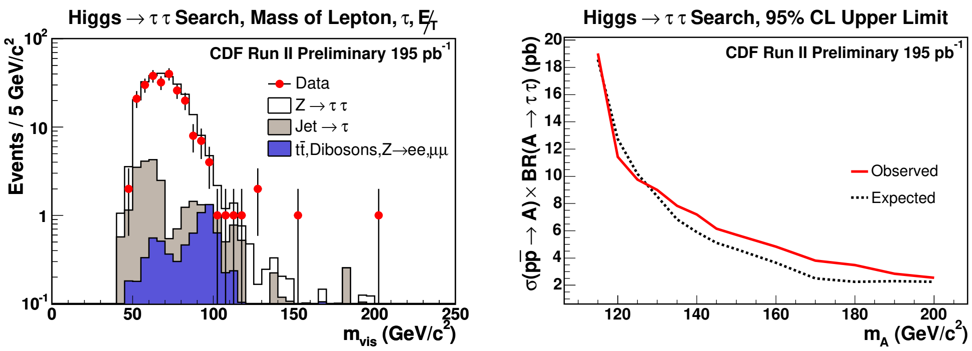

Fig. 2. *The left plot shows the observed* $m(\ell, \tau_h^{\mathrm{vis}}, \not{E}_{\mathrm{T}})$ *distribution and predictions for various backgrounds. The right plot shows the observed (solid) and expected from psuedoexperiments (dashed) limits on the product* $\sigma(p\bar{p} \to A) \times \mathrm{BR}(A \to \tau\tau)$ *in picobarns.*

4. conclusion

We have performed a search for a neutral MSSM Higgs decaying to tau pairs, and set limits on production cross section times branching ratio. We are planning to increase the sensitivity of our search through addition of more data and inclusion of the $\tau_e\tau_\mu$ and $\tau_h\tau_h$ channels.

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