The Compact Muon Solenoid Experiment
Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

19 February 2017

Search for Z'' resonances decaying to tau pairs in pp collisions using CMS detector at the LHC

Amandeep Kaur Kalsi for the CMS Collaboration

Abstract

There are many theories beyond the Standard Model which predict the existence of additional heavy gauge bosons - W s and Z s. In this talk, we will present the results for the search of Sequential Standard Model (SSM) Z'' in the final state consisting of a pair of tau leptons. The search has been performed using the pp collision data collected by the CMS detector at the LHC at center-of-mass energy of 13 TeV.

Presented at *DAE-HEP Symposium XXII DAE-BRNS High Energy Physics Symposium*

Search for Z' resonances decaying to tau pairs in pp collisions using CMS detector at the LHC

Amandeep Kaur Kalsi
On behalf of CMS Collaboration

Abstract Many theories beyond the Standard Model predict the existence of additional heavy gauge bosons such as W' and Z' . In this talk, we will present the results for the search of neutral heavy gauge boson Z' decaying to pair of tau leptons predicted by Sequential Standard Model and Topcolor-assisted Technicolor models. This search has been performed using the pp collision data corresponding to integrated luminosity of 2.2 fb^{-1} collected by the CMS detector at the LHC center-of-mass energy of 13 TeV.

1 Introduction

The Standard Model (SM) of particle physics has been explored successfully by various experimental observations at the LHC. But still, it is not the complete theory of nature. Many models have been proposed to explain physics beyond the SM which predict the existence of new heavy gauge bosons W' and Z' by including an additional $U(1)$ group to the SM gauge group [1]. The universality of couplings is not necessary for these new gauge bosons as they incorporate generation-dependent couplings which results in Z' bosons preferentially decaying to third generational fermions. Such models motivate a search for Z' resonances that decay to a pair of τ leptons such as topcolor-assisted technicolor (TAT) models [2, 3, 4]. A widely used benchmark model in searches for Z' bosons is the sequential standard model (SSM), which predicts a neutral spin-1 Z' boson with the same couplings to quarks and leptons as the SM Z boson. Z'_{SSM} decaying to pair of electrons and muons have been excluded below 3.4 [5] and 3.2 [6] TeV, respectively while limit is 2.0 TeV in tau lepton pair final state [7, 8, 9]. In this paper, searches for Z' resonance decaying to tau pairs in SSM and TAT models have been presented on a data sample of pp

Amandeep Kaur Kalsi
Panjab University, Chandigarh, India e-mail: amandeep.kaur.kalsi@cern.ch

collisions corresponding to an integrated luminosity of 2.2 fb^{-1} at $\sqrt{s} = 13 \text{ TeV}$ recorded with the CMS [10] detector at the LHC.

2 Analysis Strategy

The analysis has been performed in four final states $\tau_h \tau_h$, $\tau_e \tau_h$, $\tau_\mu \tau_h$ and $\tau_e \tau_\mu$ depending upon the decay of tau leptons whether hadronic or leptonic. The signal events consist of high p_T , well-reconstructed and isolated τ leptons. The $\tau\tau$ pairs are required to be oppositely charged and should be back-to-back *i.e.* $\cos\Delta\phi(\tau_1, \tau_2) < -0.95$. The events are required to have missing transverse energy $E_T^{\text{miss}} > 30 \text{ GeV}$ and the CDF- ζ variable [12] defined as $\zeta = p_\zeta - 3.1 \cdot p_\zeta^{\text{vis.}} > -50 \text{ GeV}$. The contribution of events having b-tagged jets have been rejected. The mass reconstructed from visible tau decay products and E_T^{miss} , defined as $m(\tau_1, \tau_2, \vec{p}_T^{\text{miss}}) = \sqrt{(E_{\tau_1} + E_{\tau_2} + E_T^{\text{miss}})^2 - (\vec{p}_{\tau_1} + \vec{p}_{\tau_2} + \vec{p}_T^{\text{miss}})^2}$ is used to distinguish signal from background processes. Broad enhancement in $m(\tau_1, \tau_2, \vec{p}_T^{\text{miss}})$ distribution is looked for the signal region, consistent with new physics. The background contributions in the signal region has been estimated using data-driven control regions wherever possible.

3 Results

The $m(\tau_1, \tau_2, \vec{p}_T^{\text{miss}})$ distribution in four final states is used as a discriminating variable. The observed mass spectra do not reveal evidence for new particles decaying to $\tau\tau$ pairs as shown in Figure 3(left) [11]. Therefore, the upper limits have been placed at 95% confidence level (CL) on the product of the signal cross section and the branching fraction as a function of Z' mass using modified frequentist approach for a Z' decaying to $\tau\tau$ pairs. Figure 3(right) [11] represents the combined observed and expected limits including the theoretical predictions from SSM and TAT models. Z'_{SSM} and Z'_{TAT} have been excluded having masses less than 2.1 TeV (1.9 TeV expected) and 1.7 TeV (1.5 TeV expected), respectively, at 95% CL combining four final states [11].

References

1. P. Langacker, “The physics of heavy Z' gauge bosons,” *Rev. Mod. Phys.*, vol. 81, pp. 1199–1228, Aug 2009.
2. K. R. Lynch, S. Mrenna, M. Narain, and E. H. Simmons, “Finding Z' bosons coupled preferentially to the third family at cern lep and the fermilab tevatron,” *Phys. Rev. D*, vol. 63, p. 035006, Jan 2001.

Fig. 1 Observed $m(\tau_1, \tau_2, \vec{p}_T^{\text{miss}})$ distribution in $\tau_\mu\tau_h$ final state (left). The dashed blue line shows the distribution expected for a Z' with mass 1.5 TeV. The lower panel represents the ratio of the observed events to total predicted background. The shaded bands shows the total uncertainty in the background prediction. The observed 95% CL upper limits on the product of the cross section and branching fraction into τ lepton pairs as a function of the Z' , for the combined four channels are shown in right plot [11].

3. C. T. Hill, “Topcolor assisted technicolor,” *Phys. Lett.*, vol. B345, pp. 483–489, 1995.
4. K. D. Lane, “A New model of topcolor assisted technicolor,” *Phys. Lett.*, vol. B433, pp. 96–101, 1998.
5. ATLAS Collaboration, “Search for high-mass new phenomena in the dilepton final state using proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector,” *Phys. Lett.*, vol. B761, pp. 372–392, 2016.
6. CMS Collaboration, “Search for narrow resonances in dilepton mass spectra in proton-proton collisions at $\sqrt{s} = 13$ TeV and combination with 8 TeV data,” *Submitted to: Phys. Lett. B*, 2016.
7. CMS Collaboration, “Search for high-mass resonances decaying into τ -lepton pairs in pp collisions at $\sqrt{s} = 7$ TeV,” *Physics Letters B*, vol. 716, no. 1, pp. 82 – 102, 2012.
8. ATLAS Collaboration, “A search for high-mass resonances decaying to $\tau^+\tau^-$ in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector,” *Phys. Lett.*, vol. B719, pp. 242–260, 2013.
9. ATLAS Collaboration, “A search for high-mass resonances decaying to $\tau^+\tau^-$ in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector,” *JHEP*, vol. 07, p. 157, 2015.
10. CMS Collaboration, “The CMS experiment at the CERN LHC,” *JINST*, vol. 3, p. S08004, 2008.
11. CMS Collaboration, “Search for heavy resonances decaying to tau lepton pairs in proton-proton collisions at $\sqrt{s} = 13$ TeV,” *JHEP* **1702**, 048 (2017) doi:10.1007/JHEP02(2017)048 [arXiv:1611.06594 [hep-ex]].
12. CDF Collaboration, “Search for neutral higgs bosons of the minimal supersymmetric standard model decaying to τ pairs in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV,” *Phys. Rev. Lett.*, vol. 96, p. 011802, Jan 2006.