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Search for heavy resonances decaying to tau pairs with the CMS detector at the Large Hadron Collider

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Abstract. A search for heavy resonance production decaying to tau pair is performed in the proton–proton collisions at the center-of-mass energy $\sqrt{s} = 7$ TeV using 36 pb^{-1} of data collected with CMS detector at the LHC during the year 2010. The number of observed events are in good agreement with the predictions of Standard Model background processes. Therefore, an upper limit on the resonance cross-section times the branching ratio to tau pair is obtained as a function of the resonance mass. Ditau resonance Z' with Standard Model couplings having mass less than 468 GeV/c^2 is excluded at 95% confidence level.

Keywords. Compact muon solenoid; Large Hadron Collider; Standard Model.

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1. Introduction

The Standard Model (SM) of particle physics has served us for the last few decades in understanding the world around us. However, there are important theoretical arguments which say that SM describes the nature only up to energies of electroweak scale [1] and new symmetries may come into play at higher energies resulting in New Physics beyond SM. Many extensions of SM have been developed in the absence of clear experimental hint or indication about the nature of physics at TeV energy scale and beyond. Some models incorporate additional gauge fields of local broken symmetry leading to the existence of new heavy gauge bosons. Although most models with extra gauge bosons obey universality of the couplings, some models include the generation-dependent couplings resulting in a heavy, neutral gauge boson Z' that preferentially decays to a pair of oppositely charged tau-leptons [2]. This feature provides the opportunity to discover a new gauge boson through its decay to two tau-leptons. Although a Z', if exists, would be discovered in its e^+e^- or $\mu^+\mu^-$ decay modes first, its decay in $\tau^+\tau^-$ mode would be critical to establish its coupling relative to e^+e^- or $\mu^+\mu^-$ mode and also in testing the universality of the coupling constants. The CDF Collaboration reported a search in 2005 [3] which ruled out a Z' gauge boson decaying to $\tau^+\tau^-$ with SM couplings having mass less than 399 GeV/c^2.

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2. Compact muon solenoid detector

The compact muon solenoid (CMS) detector [4] is one of the major experiments at the LHC. The central feature of the CMS detector is a superconducting solenoid magnet which provides a magnetic field of 3.8 Tesla. The solenoid coil houses a silicon-based tracker, lead tungstate-based electromagnetic calorimeter (ECAL) and brass/scintillator-based hadron calorimeter (HCAL). Muons are measured in gas-ionization detectors embedded in the steel return yoke outside the solenoid coil. In addition to the barrel and end-cap detectors, CMS has extensive forward calorimetry including a silicon sensor pre-shower detector in front of the ECAL end-caps.

3. Analysis strategy

The tau lepton is the heaviest charged lepton in SM with a mass of 1.777 GeV/c^2 and a lifetime of 2.9×10^{-13} s. About one third of the taus decay leptonically, while the remainder decay into hadronic jets comprising of one, three or five (rarely) charged mesons accompained by one or more neutral pions. As the tau lepton decays to $e\bar{\nu}_e\nu_\tau$ (17.8%), $\mu\bar{\nu}_\mu\nu_\tau$ (17.4%) and hadrons + ν_τ (64.8%), these decays are referred to as e-decay channel, μ-decay channel and the τ_h-decay channel. The reported search, based on

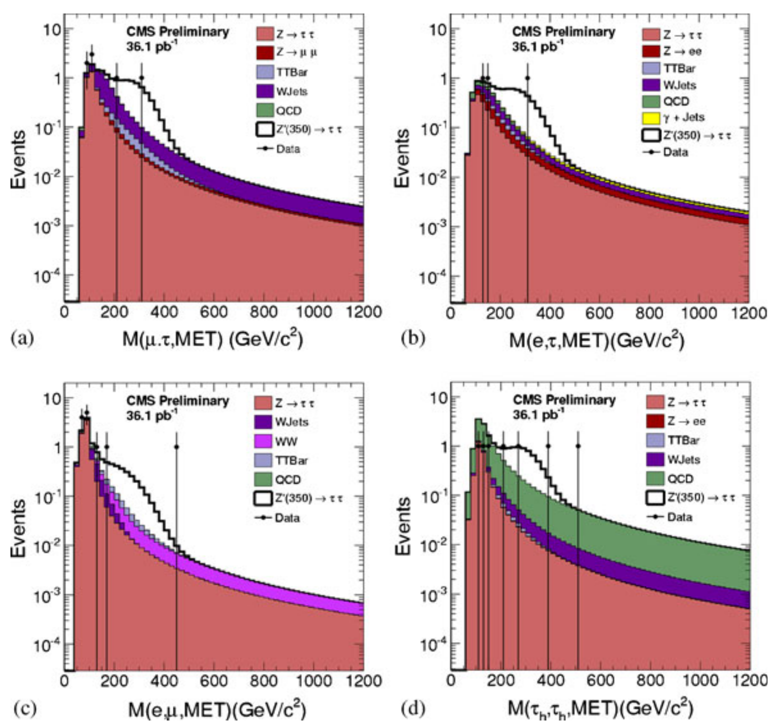

Figure 1. Invariant mass distributions for (**a**) $\mu\tau_h$, (**b**) $e\tau_h$, (**c**) $e\mu$ and (**d**) $\tau_h\tau_h$ channels.

Sequential Standard Model (SSM), comprises four dominant decay modes of tau pair, viz. $e\mu$ (6.2%), $e\tau_h$ (23.1%), $\mu\tau_h$ (22.5%) and $\tau_h\tau_h$ (42%). Signal events are identified as events with two oppositely charged, nearly back-to-back objects (leptons) accompanied by large missing transverse energy. Selection strategy preserves high efficiency for signal events and provides strong background suppression. Although Drell–Yan process, $Z \to \tau^+\tau^-$, is a background for all the four channels, it serves as an important tool to validate the signal selections. Final selections are such that by removing or reversing just a few cuts, a clean sample of $Z \to \tau^+\tau^-$ events can be obtained. Whenever possible, we rely on the collision data in estimating the contribution of various backgrounds by creating some control regions with most of the selections similar to the signal selections but enriched with the events from different backgrounds. The selection efficiencies are measured in those regions and extrapolated to the signal region. When a complete data-driven estimation is not possible, scale factors, i.e., ratio between observed data events and expected Monte Carlo events in the control region, are used to estimate the background contribution in the signal region. To quantify the significance of any possible excess or to set the upper limit on the $Z' \to \tau^+\tau^-$ production rate, we perform a fit of the invariant mass distribution and employ Bayesian technique to interpret the results in terms of the upper 95% confidence level limits for each individual channel. The combined limit is obtained by combining the posterior probability density functions and taking into account the correlation of systematic uncertainties within and across the four channels. Figure 1 shows the invariant mass distributions of tau lepton pair in four different final states involving leptons and hadrons.

4. Results and conclusions

The observed mass spectrum and the number of observed events in the collision data are found to be consistent with the expectations of SM background processes. Hence we determine combined 95% CL upper limits on the $\sigma_{q\bar{q}\to\bar{Z}'} \times \mathrm{BR}(Z' \to \tau^+\tau^-)$ as a function of Z' mass. Figure 2 shows the experimental and expected limits as well as the theoretical

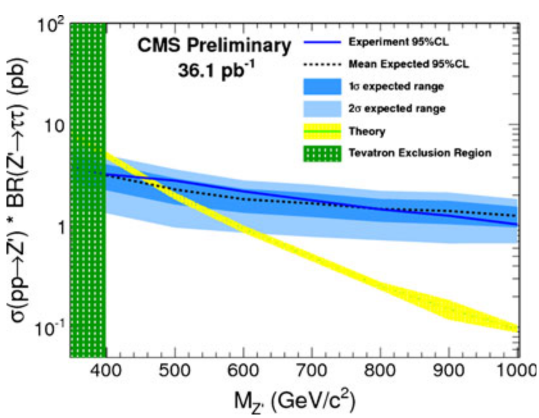

Figure 2. 95% CL upper limit on $\sigma_{q\bar{q}\to Z'} \times \mathrm{BR}(Z' \to \tau^+\tau^-)$ as a function of $M_{Z'}$.

cross-section for various Z' masses. The bands on the expected limits represent the 1σ and 2σ deviations obtained using a large number of pseudoexperiments where the pseudodata are obtained from distributions having only backgrounds using a Poisson-based random event generator. From the figure, one can see that we can exclude a Z' with mass less than 468 GeV/c^2 [5] exceeding the limit provided by the CDF experiment.

References

[1] F R Klinkhamer, *Phys. Rev.* **D82**, 083006 (2010)
[2] G S Diener and T Martin, *Unravelling an extra neutral gauge boson at the LHC using third generation fermions*, arXiv:hep-ph/1006.2845v1 (2010)
[3] D Acosta, *Phys. Rev. Lett.* **95**, 131801 (2005)
[4] A Bresking *et al*, *The CERN Large Hadron Collider: Accelerator and experiments*, CERN Publication Vol 2 (2009)
[5] J Cumalat, N Dhingra, A Florez *et al*, Search for new ditau resonances in *pp* collisions at $\sqrt{s} = 7$ TeV, CMS *Physics Analysis Summary*, CMS-PAS-EXO-10-022 (2011)