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ATLAS searches for heavy Higgs bosons and supersymmetry using tau decays

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Abstract

Results from the ATLAS experiment from searches for heavy Higgs bosons and supersymmetry with tau leptons in the final states are presented. The analyses discussed use datasets corresponding to approximately 13-15 fb^{-1} of 13 TeV proton-proton collision data taken in the years 2015-2016. No significant excess above the Standard Model is observed, and limits are set on new physics in various supersymmetric scenarios.

Keywords: ATLAS, heavy Higgs bosons, charged Higgs bosons, supersymmetry, tau leptons

1. Introduction

Tau decays play an important role in the physics program of the ATLAS experiment [1] at the Large Hadron Collider (LHC), including in measurements of Standard Model (SM) Higgs decays, $H \to \tau\tau$ [2], as well as several searches for new physics. This talk reviews recent preliminary results from ATLAS searches for heavy Higgs bosons and supersymmetry with tau decays in the final state, using approximately 13-15 fb^{-1} of integrated luminosity from $\sqrt{s}$ = 13 TeV proton-proton collisions during the years 2015-2016 of Run-2 of the LHC. Tau leptons are unique in the SM because they are the only leptons massive enough to have hadronic decays, predominately including one or three charged pions ($\pi^{\pm}$) with possibly additional neutral pions (π^0), which decay promptly to photon pairs. They also can have preferred couplings to new physics. ATLAS reconstructs hadronic decays of tau leptons by using combined calorimeter and tracking information and has sophisticated multivariate techniques for identifying tau decays by selecting well-isolated calorimeter clusters closely associated to one or three tracks, as well as reconstructing additional π^0 clusters [3]. The identification and energy calibration of hadronic decays of tau leptons with $\sqrt{s}$ = 8 TeV collision data from Run-1 has been described [4] and has been updated with $\sqrt{s}$ = 13 TeV collision data from Run-2 [5].

Many of the searches reviewed here are interpreted in the context of supersymmetric extensions to the Higgs sector, in particular the two Higgs doublet model (2HDM). A general class of models of beyond the Standard Model physics, 2HDMs involve two Higgs doublets of complex scalar fields instead of the single Higgs doublet of the SM. The 2HDM is a defining characteristic of the Minimal Supersymmetric Standard Model (MSSM). In 2HDMs, electroweak symmetry breaking results in five spin-0 Higgs bosons, three that are neutral: h^0, H^0, A^0, and two that have electromagnetic charge: $H^{\pm}$. The parameter $\tan\beta$ is defined as the ratio of vacuum expectation values of the Higgs doublets and has a large effect on the phenomenology of 2HDMs.

2. Search for Neutral heavy Higgs bosons

ATLAS searches for heavy neutral resonances decaying to $\tau\tau$, interpreted as possibly CP-even/odd neutral MSSM Higgs bosons (H/A) and also as Z' bosons from grand unified theories (GUTs) [6]. This search has five signal regions requiring $\ell\tau_{\rm had}$ or $\tau_{\rm had}\tau_{\rm had}$, with and without b-tagged jets, and a fifth region passing a $E_{\rm T}^{\rm miss}$ trigger and having offline: selected $\ell\tau_{\rm had}$ and $E_{\rm T}^{\rm miss}$ >

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150 GeV (where throughout ℓ denotes a reconstructed electron or muon; $\tau_{\rm had}$, a reconstructed hadronic decay of a tau lepton; and $E_{\rm T}^{\rm miss}$, the missing transverse momentum).

Figure 1 shows the total transverse mass, $m_{\rm T}^{\rm tot}$, of the two tau candidates and the $E_{\rm T}^{\rm miss}$ in the $\tau_{\rm had}\tau_{\rm had}$ channel, for example. The background is dominated by multijet events with fake taus that is modeled with a data-driven fake factor method, where events in data with fake taus are weighted with a factor measured in the data.

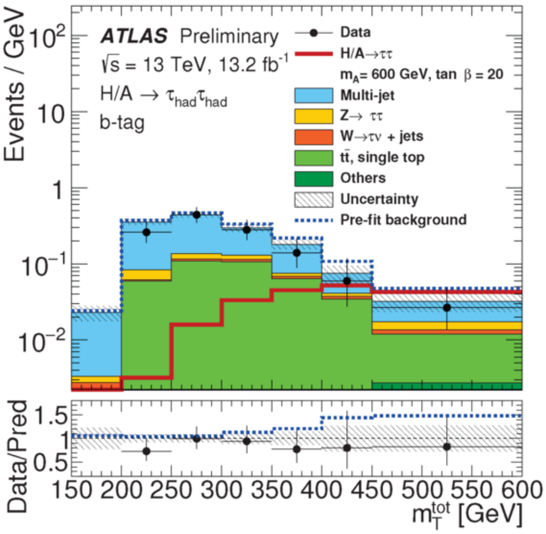

Figure 1: The distribution of the total transverse mass, $m_{\rm T}^{\rm tot}$, of the two tau candidates and the $E_{\rm T}^{\rm miss}$ in the $\tau_{\rm had}\tau_{\rm had}$ channel [6].

No significant excess is observed, and frequentist upper limits using the CLs method [7] are set on the cross section × branching ratio of H/A as a function of $m_{H/A}$. These are further interpreted as exclusions in the $\tan\beta$–m_A plane in two MSSM scenarios: m_h^{mod+} (shown in Figure 2) and hMSSM. This extends a previous result that only used data from 2015 [8].

3. Search for charged heavy Higgs bosons

In the MSSM, for $\tan\beta \gtrsim 2$, charged Higgs bosons decay dominantly to tau leptons through $H^\pm \to \tau^\pm\nu$, making tau final states important for searching for charged Higgs bosons. If the mass of the charged Higgs boson is less than the mass of the top quark, then charged Higgs bosons are produced at hadron colliders dominantly in $t\bar{t}$ events, where the $H^\pm$ takes the place of an emitted $W^\pm$ when the top decays promptly to a bottom quark. Therefore searches for charged Higgs

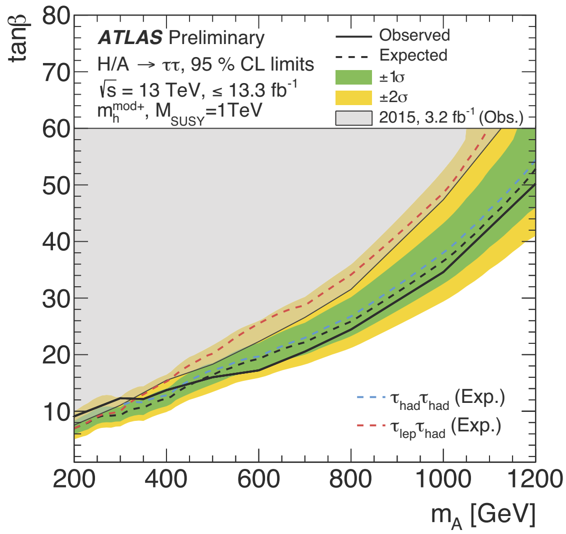

Figure 2: The expected and observed 95% CL limits on the production of a scalar particle decaying to $\tau\tau$ in the m_h^{mod+} scenario [6].

bosons involve looking for an excess of tau final states in $t\bar{t}$ events.

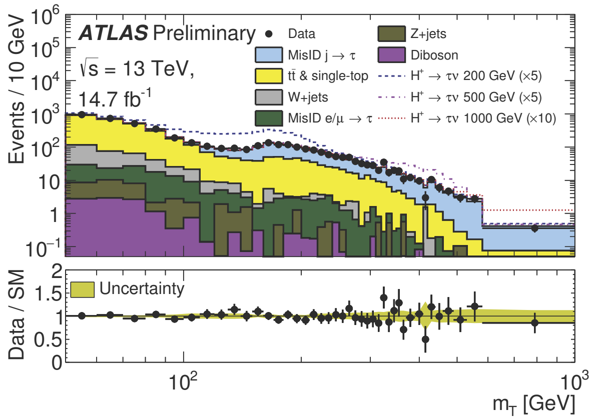

Figure 3: The distribution of the transverse mass, $m_{\rm T}$, between the tau candidate and the $E_{\rm T}^{\rm miss}$ [9].

In this search, ATLAS selects events with a $E_{\rm T}^{\rm miss}$ trigger, and requires offline: $E_{\rm T}^{\rm miss} > 150$ GeV, a $\tau_{\rm had}$ with $p_{\rm T} > 40$ GeV, and three or more jets $p_{\rm T} > 40$ GeV, at least one of which b-tagged [9]. An important kinematic variable is the transverse mass, $m_{\rm T}$, between the $\tau_{\rm had}$and the $E_{\rm T}^{\rm miss}$(shown in Figure 3), which peaks near the W mass for the dominant $t\bar{t}$ background, but has a long tail with more contribution from fakes at high-$m_{\rm T}$. This search uses a data-driven fake factor method to model the fake taus, where the background model is constructed from events in data failing tau identification weighted by fake factors (shown in Figure 4) measured in a sample of data enriched in fake taus in events with low $E_{\mathrm{T}}^{\mathrm{miss}}$.

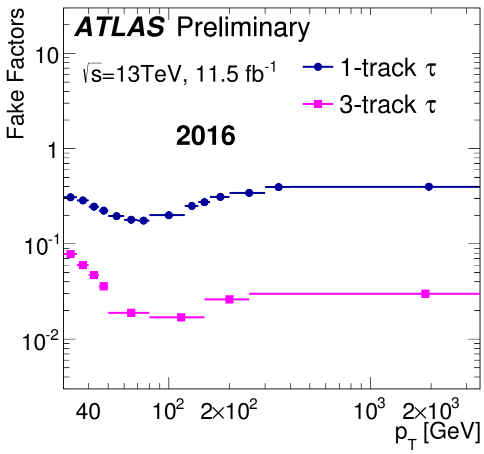

Figure 4: Fake factors for jets to fake the identification of hadronic tau decays, measured in the charged Higgs search [9].

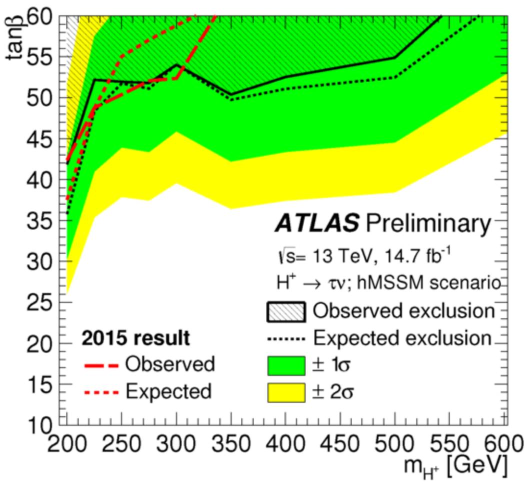

Figure 5: The expected and observed 95% CL limits on the production of a $H^{\pm} \to \tau^{\pm}\nu$ in the $\tan\beta$–m_{H^+} plane for the hMSSM scenario [9].

Figure 5 shows the frequentist exclusion derived in the $\tan\beta$-m_{H^+} plane for the hMSSM scenario, significantly excluding $\tan\beta \gtrsim 50$ for $m_{H^+} \lesssim 600$, extending the previous result that only used data from 2015 [10].

4. Search for stop to stau decays

Theoretical arguments for electroweak naturalness and others partially motivate the interest in possible scenarios with a stau as the Next-to-Lightest Supersymmetric Particle (NSLP), subsequently decaying the LSP, undetected but observable with $E_{\mathrm{T}}^{\mathrm{miss}}$, and a tau lepton.

This search is optimized and interpreted using a simplified model where only three sparticles are light enough to effect the phenomenology: the lightest squark (strongly produced), the lighter stau lepton, and a nearly massless gravitino [11]. This compliments the interpretations from other recent searches for evidence of supersymmetry in events with taus from ATLAS [12].

Events are selected with single electron or muon triggers. A selected hadronic tau decay, and significant $E_{\mathrm{T}}^{\mathrm{miss}}$ are required offline. The analysis makes use of a variable called "stranverse mass," m_{T2}, (shown in Figure 6) that is kinematically bounded from above at the W mass for $t\bar{t}$ background events but has a longer tail for higher mass decays [13].

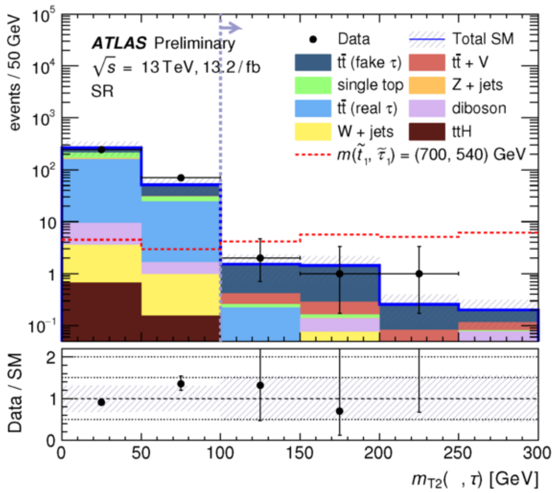

Figure 6: The distribution of the stranverse mass, m_{T2}. The signal region selection further requires $m_{\mathrm{T2}} > 100$ GeV [11].

No significant excess is observed and limits are set in the stau-stop mass plane (shown in Figure 7). This extends the previous Run-1 limit [14] to stop masses of about 850 GeV at most.

5. Search for electroweak production of staus

Complimenting the previously mentioned search for strongly produced sparticles decaying to taus, ATLAS searches for electroweak production of chargino-chargino or neutralino-chargino pairs with decays to tau leptons [15].

Events are selected with a ditau+$E_{\mathrm{T}}^{\mathrm{miss}}$ trigger. At least two identified hadronic tau decays with opposite-

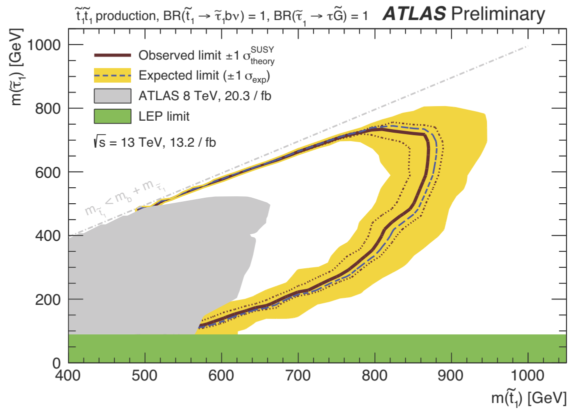

Figure 7: The expected and observed 95% CL limits on the simplified model [11].

signed charges and significant $E_{\mathrm{T}}^{\mathrm{miss}}$ are required offline. The previously mentioned stranverse mass, m_{T2}, is again an important discriminant for signal.

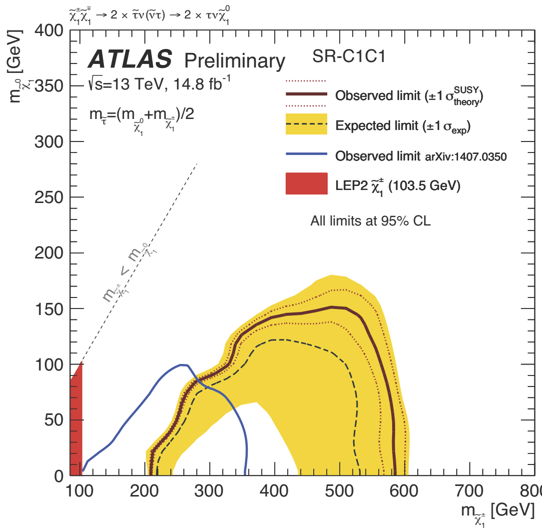

Figure 8: The expected and observed 95% CL limits in the scenario for the neutralino-chargino mass plane [15].

No significant excess is observed, and limits are set in chargino-chargino and neutralino-chargino mass planes (see Figure 8), significantly extending the previous limits shown from Run-1 [16].

6. Conclusion

ATLAS has set limits on heavy Higgs bosons and models of supersymmetry using events with tau lepton decays. Expect the results shown here to be updated with the more than 36 fb^{-1} of integrated luminosity in the complete 2015-2016 datasets.

References

[1] ATLAS Collaboration, The ATLAS experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003.

[2] ATLAS Collaboration, Evidence for the Higgs-boson Yukawa coupling to tau leptons with the ATLAS detector, JHEP 04 (2015) 117. arXiv:1501.04943.

[3] ATLAS Collaboration, Reconstruction of hadronic decay products of tau leptons with the ATLAS experiment, EPJC 76 (5) (2016) 295.

[4] ATLAS Collaboration, Identification and energy calibration of hadronically decaying tau leptons with the ATLAS experiment in pp collisions at $\sqrt{s} = 8$ TeV, EPJC 75 (7) (2015) 303.

[5] ATLAS Collaboration, Reconstruction, energy calibration, and identification of hadronically decaying tau leptons in the ATLAS experiment for Run-2 of the LHC, ATL-PHYS-PUB-2015-045 (2015).

[6] ATLAS Collaboration, Search for Minimal Supersymmetric Standard Model Higgs bosons H/A in the $\tau\tau$ final state in up to 13.3 fb^{-1} of pp collisions at $\sqrt{s}$= 13 TeV with the ATLAS detector, ATLAS-CONF-2016-085 (2016).

[7] A. L. Read, Presentation of search results: the CLs technique, Journal of Physics G: Nuclear and Particle Physics 28 (10) (2002) 2693.

[8] ATLAS Collaboration, Search for Minimal Supersymmetric Standard Model Higgs bosons H/A and for a Z' boson in the $\tau\tau$ final state produced in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS Detector, EPJC 76 (11) (2016) 585. arXiv:1608.00890.

[9] ATLAS Collaboration, Search for charged Higgs bosons in the τ+jets final state using 14.7 fb^{-1} of pp collision data recorded at $\sqrt{s} = 13$ TeV with the ATLAS experiment, ATLAS-CONF-2016-088 (2016).

[10] ATLAS Collaboration, Search for charged Higgs bosons produced in association with a top quark and decaying via $H^{\pm} \to \tau\nu$ using pp collision data recorded at $\sqrt{s} = 13$ TeV by the ATLAS detector, Phys. Lett. B759 (2016) 555–574. arXiv:1603.09203.

[11] ATLAS Collaboration, Search for top-squark pair production in final states with two tau leptons, jets, and missing transverse momentum in $\sqrt{s} = 13$ TeV pp collisions with the ATLAS detector, ATLAS-CONF-2016-048 (2016).

[12] ATLAS Collaboration, Search for squarks and gluinos in events with hadronically decaying tau leptons, jets and missing transverse momentum in proton-proton collisions at $\sqrt{s} = 13$ TeV recorded with the ATLAS detector, Submitted to EPJC (2016). arXiv:1607.05979.

[13] C. G. Lester, D. J. Summers, Measuring masses of semiinvisibly decaying particles pair produced at hadron colliders, Phys. Lett. B463 (1999) 99–103. arXiv:hep-ph/9906349.

[14] ATLAS Collaboration, Search for direct top squark pair production in final states with two tau leptons in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector, EPJC 76 (2) (2016) 81. arXiv:1509.04976.

[15] ATLAS Collaboration, Search for electroweak production of supersymmetric particles in final states with tau leptons in $\sqrt{s} =$ 13 TeV pp collisions with the ATLAS detector, ATLAS-CONF-2016-093 (2016).

[16] ATLAS Collaboration, Search for the direct production of charginos, neutralinos and staus in final states with at least two hadronically decaying taus and missing transverse momentum in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector, JHEP 10 (2014) 096. arXiv:1407.0350.