MSSM Higgs search in ditau final state with the full ATLAS Run2 dataset

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October 26, 2019

Overview

Introduction

- 2HDM, e.g. in MSSM, introduces five Higgs bosons
  - h, H, A and $H^{\pm}$
- at tree level, described by:
  - m_A and $\tan\beta$
  - at large $\tan\beta$, coupling to τ enhanced
- search for H/A in ditau final state
  - down-type, 3rd generation fermion and heaviest lepton
  - better experimental accessibility w.r.t b quark
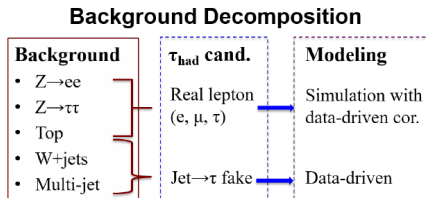 - $\tau\tau$ has dominant sensitivity at most of parameter space
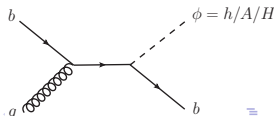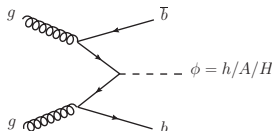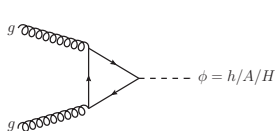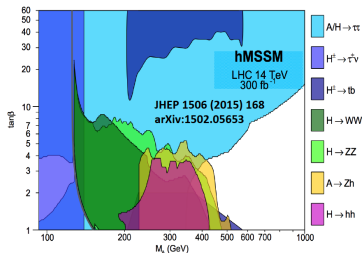
Event Selection

- $\tau_{lep}\tau_{had}(46\%)$:
  - single isolated ℓ + medium τ
  - $p_T^{\ell/\tau} > 30/25$ GeV,
    $m_T(\ell, E_T^{miss}) < 40$ GeV
- $\tau_{had}\tau_{had}(42\%)$:
  - medium τ_1 + loose τ_2
  - lepton veto
  - $p_T^{\tau_1} > 85/130/165$ GeV,
    $p_T^{\tau_2} > 65$ GeV
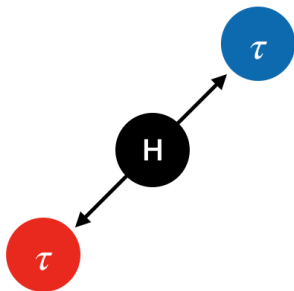
- further selection: opposite sign, back-to-back
- two categories: b-veto and b-tag categories
- final discriminant variable: m_T^{tot}

Background Estimation

- $\tau_{lep}\tau_{had}$:
    - data-driven: multi-jets, W+jets/$t\bar{t}$
    - MC simulation: $Z \to \tau\tau$, $Z \to \ell\ell$, diboson, top,

- $\tau_{had}\tau_{had}$:
    - data-driven: multi-jets
    - MC simulation: $Z \to \tau\tau$, W+jets, top, others
    - fake rate measurement: to improve modeling of MC(jets misidentified as τ_{had})

Background Decomposition

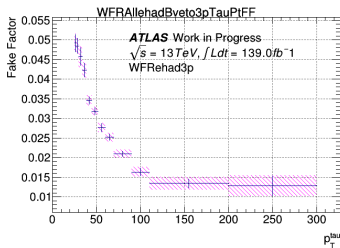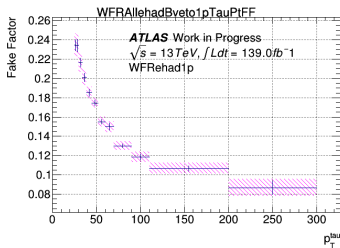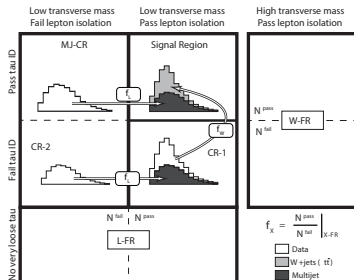| Background	τ_{had} cand.	Modeling
• Z→ee • Z→ττ • Top • W+jets • Multi-jet	Real lepton (e, μ, τ)	Simulation with data-driven cor.
	Jet→τ fake	Data-driven

Jets Misidentified as τ_{had}

- simulation not suitable
- fake factor method:
  $FF = N_{passID}/N_{failID}$
  - measured in multi-jets,
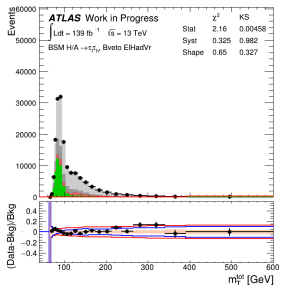   W+jets/$t\bar{t}$ enriched regions
  - application:
    $N_{bkg} = N_{X\_failID} \times FF$
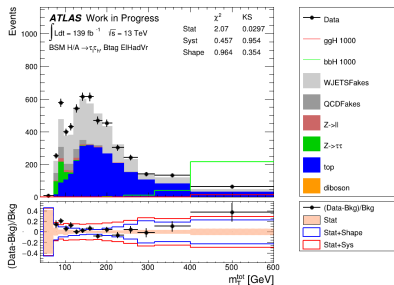
Background Modeling Check

- modeling checked in validation regions
  - $\tau_{lep}\tau_{had}$: same as SR except $40 < m_T(\ell, E_T^{miss}) < 60$ GeV
  - $\tau_{had}\tau_{had}$: same as SR except same sign

(a) b-veto

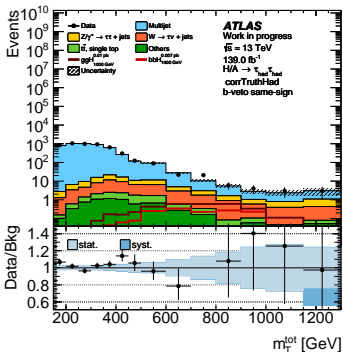(b) b-tag

Background Modeling Check

- modeling checked in validation regions
  - $\tau_{lep}\tau_{had}$: same as SR except $40 < m_T(\ell, E_T^{miss}) < 60$ GeV
  - $\tau_{had}\tau_{had}$: same as SR except same sign

(a) b-veto

(b) b-tag

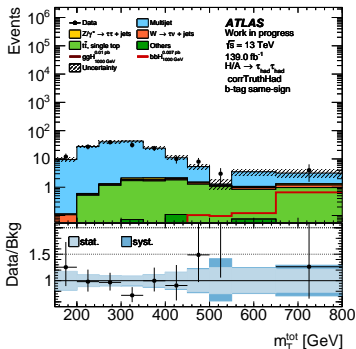# Blinded Signal Region

$\tau_{had}\tau_{had}$ SR

$\tau_{lep}\tau_{had}$ SR

Systematic Uncertainty

experimental systematic uncertainties

NP name	Description	Scheme (How many NPs)
"Lumi"	Integrated luminosity measurement	1
"TAU"	τ_{had} reconstruction, identification, electron-veto and energy scale	25
"MUON"	muon systematics, including trigger, reconstruction, isolation, identification and energy scale	15
"ELE or EG"	electron systematics, including trigger, reconstruction, isolation, identification and energy scale	12
"METSoft"	E_T^{miss} soft terms	3
"JER, JES, Jvt"	jet energy scale and resolution	17
"btag"	flavor-tagging	14
"PRW"	pile-up	1

Systematic Uncertainty

systematic uncertainties related to background modeling

| NP name	Description	Scheme (How many NPs)	Order
"LPX"	(Mainly on Z+jets) systematics on PDF choose, QCD scale, stronge interaction coefficient	12	-
"xsec_Diboson"	Cross section prediction uncertainty	1	10%
"xsec_top"	Cross section prediction uncertainty	1	6% [**topXsecSys**]
"TTBAR"	Top modeling sys (mainly shape sys)	4	-
"FakeFactor_Lep"	Lepton fake factor sys in τ_{lep} τ_{had} , $(e, \mu) \times$ (b-tag , b-veto)	4	-
"FakeFactor_QCDReweight"	QCD background reweight sys in $\tau_\mu \tau_{had}$ (b-tag , b-veto)	2	-
"FakeFactor_Wjets "	Wjets fake factor sys in τ_{lep} τ_{had} , (1p, 3p) $\times$ (b-tag , b-veto)	4	-
"FakeFactor_ExtraSysBveto "	Extrapolation systematic uncertainty of Wjets fake factor in b-veto category in τ_{lep} τ_{had} (1p, 3p)	2	-
"HHFAKERATE"	Fake rate sys in τ_{had} τ_{had}	2	-
"QCDFF_BINC "	Fake factor sys in τ_{had} τ_{had}	5	-

Statistical Analysis

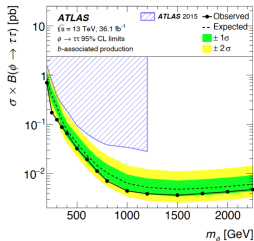- final discriminant variable: m_T^{tot}
- simultaneous fit in different regions(6 SR + 2 CR):
  - $\tau_{lep}\tau_{had}$: (btag, bveto)×(ehad, muhad) + Top CR(ehad, muhad)
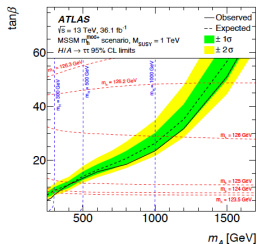 - $\tau_{had}\tau_{had}$: btag + bveto

Latest Public Result
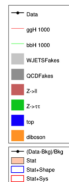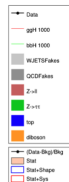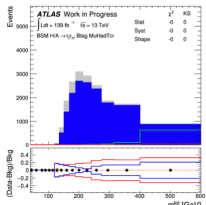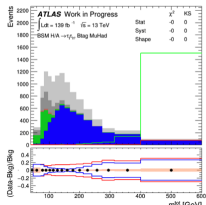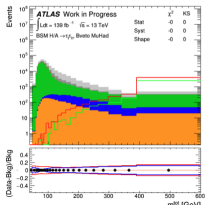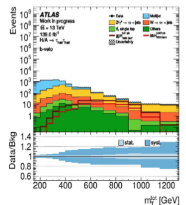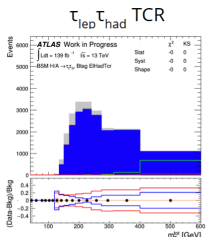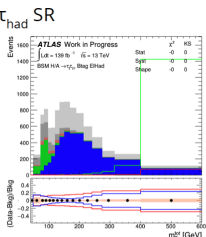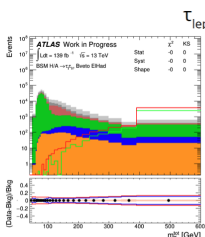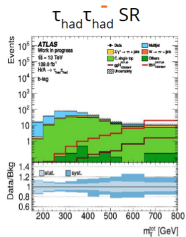
JHEP 01 (2018) 055
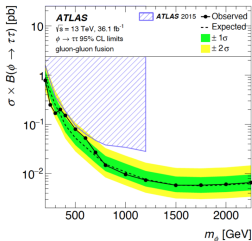
(a) $\phi \to \tau\tau$ (gluon–gluon fusion production)

(b) $\phi \to \tau\tau$ (b-associated production)

(a) m_h^{mod+} scenario
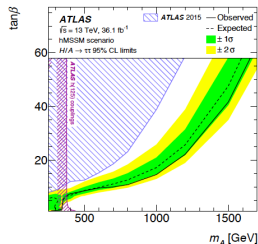
(b) hMSSM scenario

Summary

- motivation to do MSSM Higgs search in ditau final state
- analysis startegy for MSSM Higgs search in ditau final state with full ATLAS Run2 dataset
- latest public result(JHEP 01 (2018) 055), cited by 161 records on INSPIRE
- expected to see the new result with 139 fb^{-1}

| Information | References (150) | Citations (161) | Files | Plots | Data |

Search for additional heavy neutral Higgs and gauge bosons in the ditau final state produced in 36 fb^{-1} of pp collisions at $\sqrt{s} = 13$ **TeV with the ATLAS detector** - ATLAS Collaboration (Aaboud, Morad *et al.*) JHEP 1801 (2018) 055 arXiv:1709.07242 [hep-ex] CERN-EP-2017-199

Thanks for Listening

Backup

Definition of Regions: $\tau_{lep}\tau_{had}$

Region	Selection
SR	ℓ (trigger, isolated), τ_1 (medium), $q(\ell) \times q(\tau_1) < 0$, $\lvert\Delta\phi(\ell, \tau_1)\rvert > 2.4$, $m_T(\ell, E_T^{miss}) < 40\,\text{GeV}$, veto $80 < m(\ell, \tau_1) < 110\,\text{GeV}$ (ehad channel only)
CR-1	Pass SR except: τ_1 (very-loose, fail medium)
CR-2	Pass SR except: τ_1 (very-loose, fail medium), ℓ (fail isolation)
W-CR	Pass SR except: $60 < m_T(\ell, E_T^{miss}) < 150\,\text{GeV}$ in ehad (muhad) channel for b-veto
	Pass SR except: $60 < m_T(\ell, E_T^{miss}) < 110\,\text{GeV}$ in ehad (muhad) channel for b-tag
T-CR	Pass SR except: $m_T(\ell, E_T^{miss}) > 110\,\text{GeV}$ in the ehad (muhad) channel, b-tag category only
L-FR	ℓ (trigger, selected), jet (selected), no loose $\tau_{had\text{-vis}}$, $m_T(\ell, E_T^{miss}) < 30\,\text{GeV}$

Region	Selection
SR	τ_1 (trigger, medium), τ_2 (loose), $q(\tau_1) \times q(\tau_2) < 0$, $|\Delta\phi(\tau_1, \tau_2)| > 2.7$
CR-1	Pass SR except: τ_2 (fail loose)
DJ-FR	jet trigger, $\tau_1 + \tau_2$ (no identification), $q(\tau_1) \times q(\tau_2) < 0$, $|\Delta\phi(\tau_1, \tau_2)| > 2.7$, $p_T^{\tau_2}/p_T^{\tau_1} > 0.3$
W-FR	μ (trigger, isolated), τ_1 (no identification), $|\Delta\phi(\mu, \tau_1)| > 2.4$, $m_T(\mu, E_T^{miss}) > 40\,\text{GeV}$
	b-veto category only
T-FR	Pass W-FR except: b-tag category only