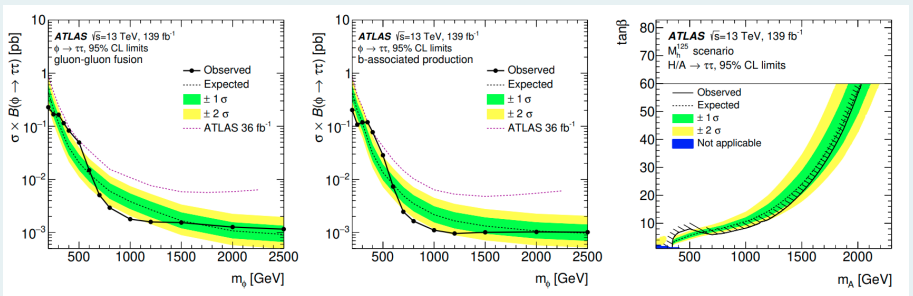
Searching for Neutral BSM Higgs Bosons in the $\tau\tau$ Decay Channel Using Full Run-2 Data from the ATLAS Detector

Analysis basics

- 140 fb^{-1} of data from $\sqrt{s}$ =13 TeV pp collisions
- searching for neutral MSSM Higgs bosons (CP-odd and -even)
- paper published in PRL: Phys. Rev. Lett. 125 (2020) 051801
- new limits:



Event selection

Had-had:

- leading τ_{had} matched to trigger, medium ID (BDT), p_{T} : +5 GeV over trigger
- subleading τ_{had} loose ID (BDT), p_{T} >65 GeV
- opposite charge, back to back ($\Delta\varphi > 2.7$)
- veto events with e, μ

Lep-had:

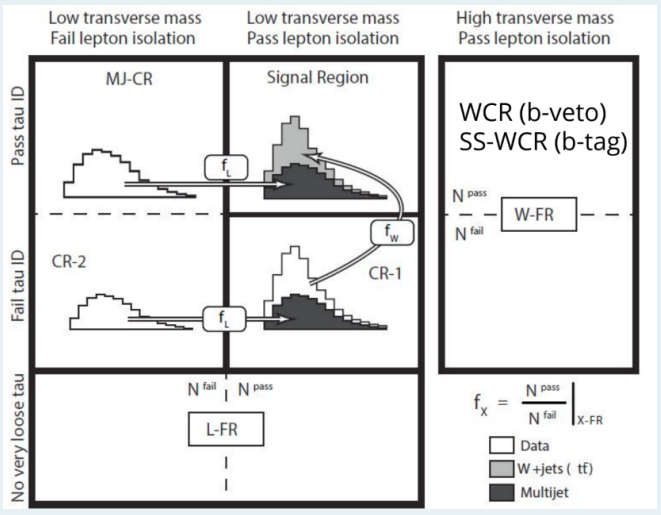
- τ_{lep} matched to trigger (p_{T} and isolation criteria)
- τ_{had} medium ID (BDT), p_{T} >25 GeV, $|\eta|$ <2.7 GeV
- opposite charge, back to back ($\Delta\varphi > 2.4$)
- $m_{\text{T}}(\text{lep}, E_{\text{T}}^{\text{miss}}) = \sqrt{2 p_{\text{T}}^{\text{lep}} E_{\text{T}}^{\text{miss}} [1 - \cos\Delta\phi(\text{lep}, E_{\text{T}}^{\text{miss}})]} < 40$ GeV
- exclude events with $80 < m(\tau\tau) < 110$ GeV (e-had)

Backgrounds

- MC: $W \to l(\tau)\nu$+jets, $Z/\gamma^* \to ll(\tau\tau)$, diboson, $t\bar{t}$ and single t
  - had-had MC uses data-driven jet$\to \tau$ fake rates
- data-driven fake factors: QCD in both had-had and lep-had, W+jets (b-veto) and $t\bar{t}$ (b-tag) in lephad

Data-driven background estimation

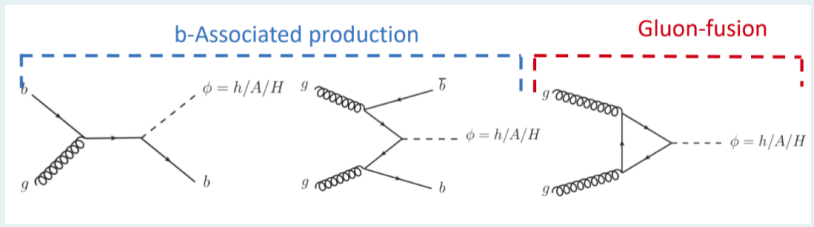
- Lep-had - QCD and W+jets/$t\bar{t}$:



- Had-had - QCD only, similar method

Production and decay

- Higgs b-associated production → b-tag category
- Higgs gluon-gluon fusion → b-veto category



- tau decay: hadronic mode 65% of the time, leptonic 35% of the time → analysis split into had-had and lep-had categories

Systematic uncertainties

MC:

- theoretical cross-section calculation
- luminosity, pile-up uncertainty
- efficiency of reco, ID, triggering algorithms
- energy scale and resolution of e, μ, τ, (b-)jets, $E_{\text{T}}^{\text{miss}}$

Data-driven background estimates:

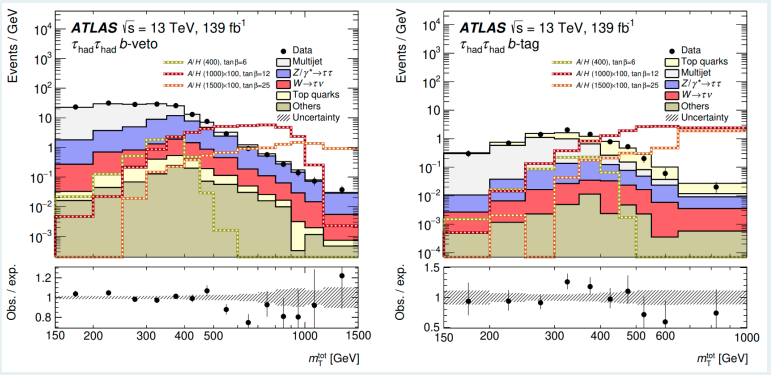
- fake factors (limited size of fake regions, background subtraction)

Fit model

- parameter of interest: signal strength $\mu = \frac{(\sigma \times BR)_{\text{observed}}}{(\sigma \times BR)_{\text{predicted}}}$
- discriminating variable:

$$m_{\text{T}}^{\text{tot}} = \sqrt{m_{\text{T}}^2(E_T^{miss}, \tau_1) + m_T^2(E_{\text{T}}^{\text{miss}}, \tau_2) + m_{\text{T}}^2(\tau_1, \tau_2)}$$

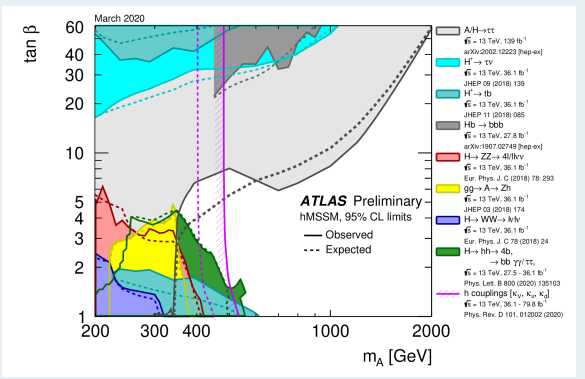
- fit function: likelihood function constructed as the product of Poisson probability terms (one for each bin in $m_{\text{T}}^{\text{tot}}$)



Model interpretations

hMSSM scenario:

- mass of lighter CP-even Higgs boson is 125 GeV
- masses of SUSY partners are heavy



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