Search for Neutral MSSM Higgs Bosons H/A decaying to ττ with the ATLAS detector

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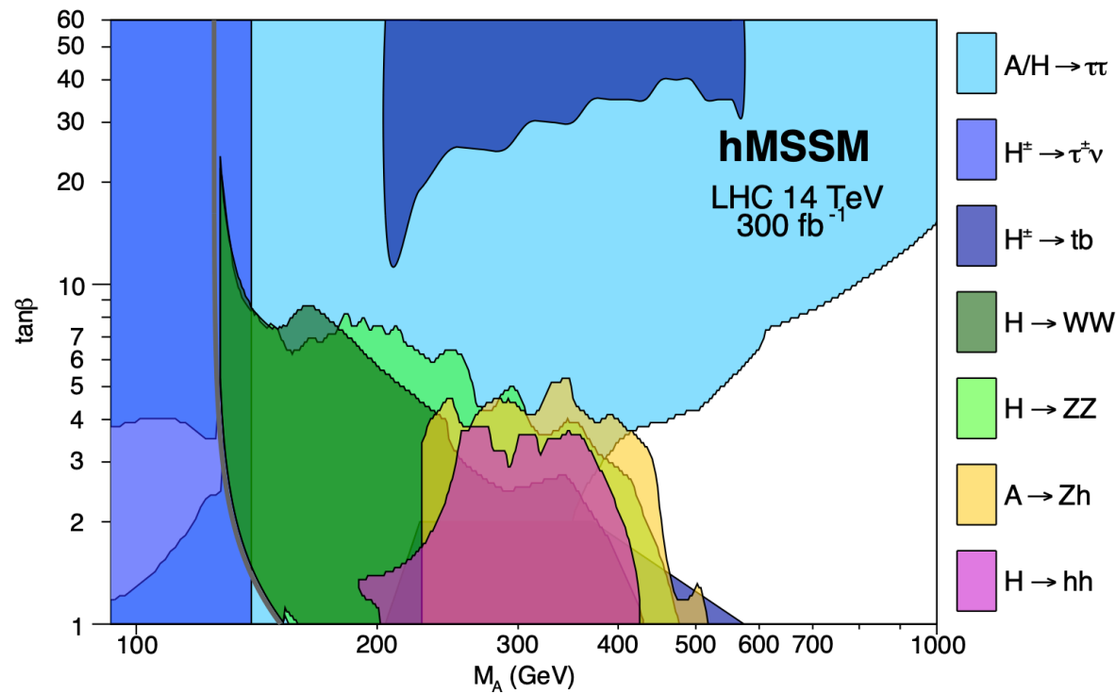
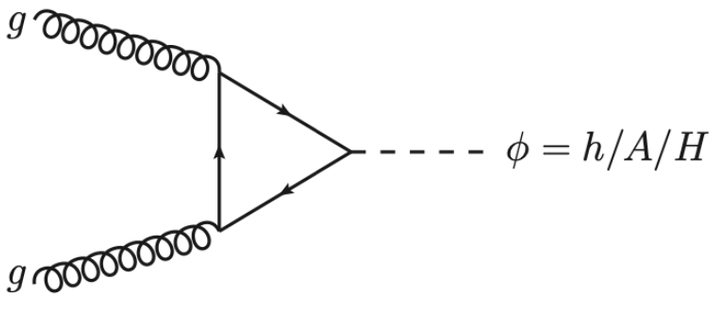
Introduction

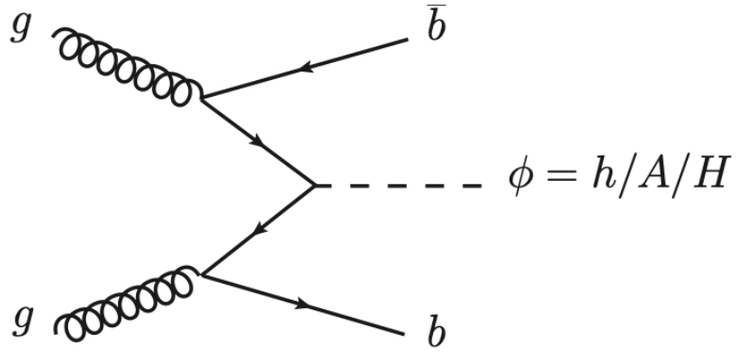
- MSSM: two Higgs doublets, five Higgs

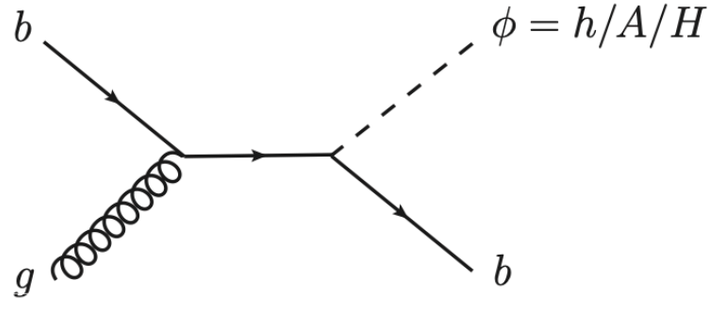
- At tree level, described by two parameters
  - m_A and tanβ
  - Enhanced couplings to τ for large tanβ
- Search H/A in $\tau\tau$ final state
  - dominant sensitivity at most of the of the parameter space
  - $\tau_{\text{lep}}\tau_{\text{had}}$ and $\tau_{\text{had}}\tau_{\text{had}}$
  - b-associated production and gluon fusion

Arxiv: 1502.05653



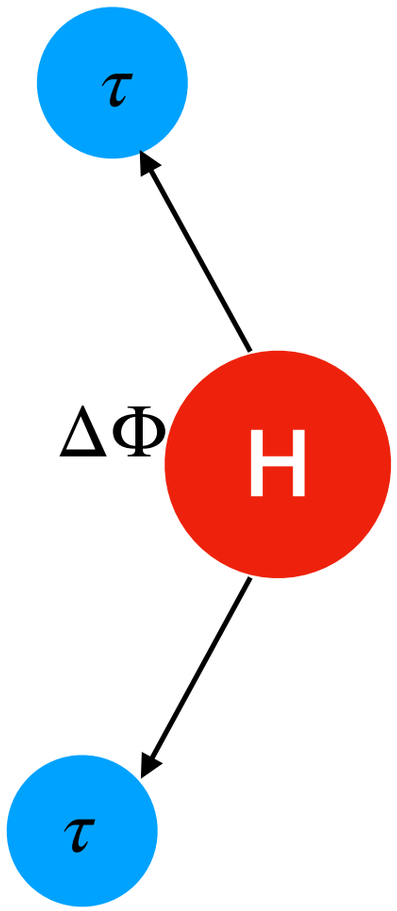






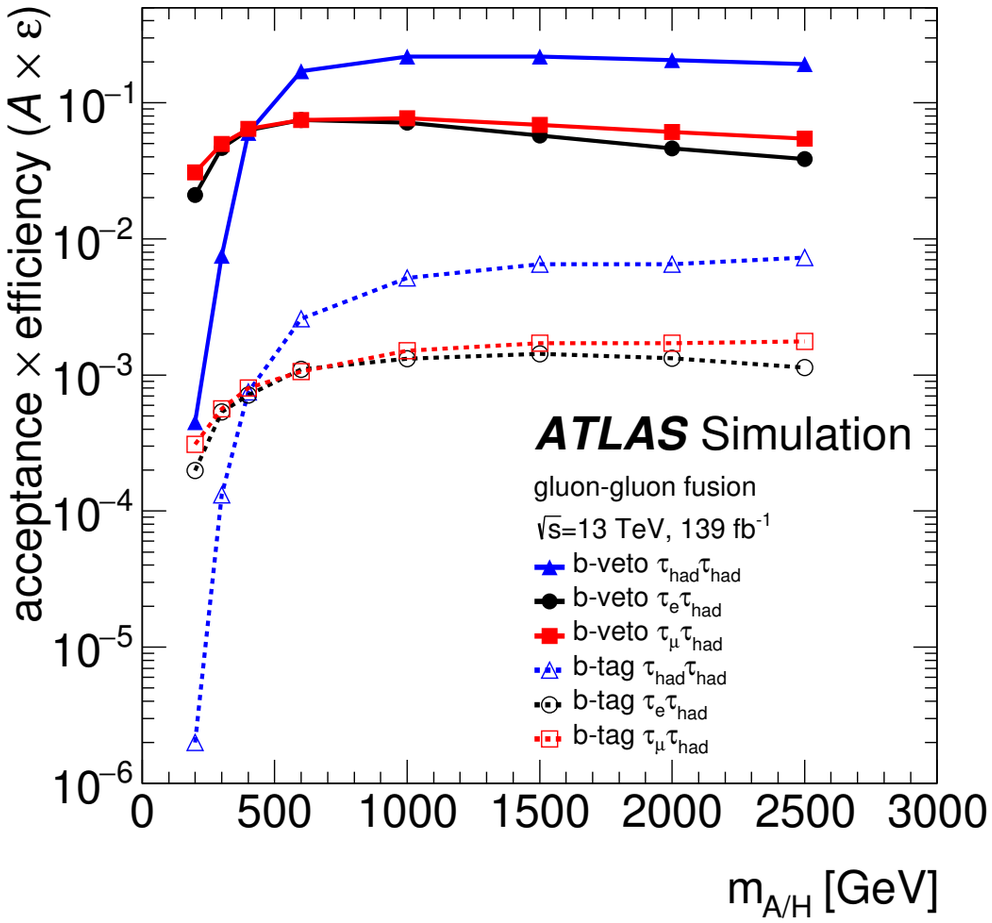
Event Selection

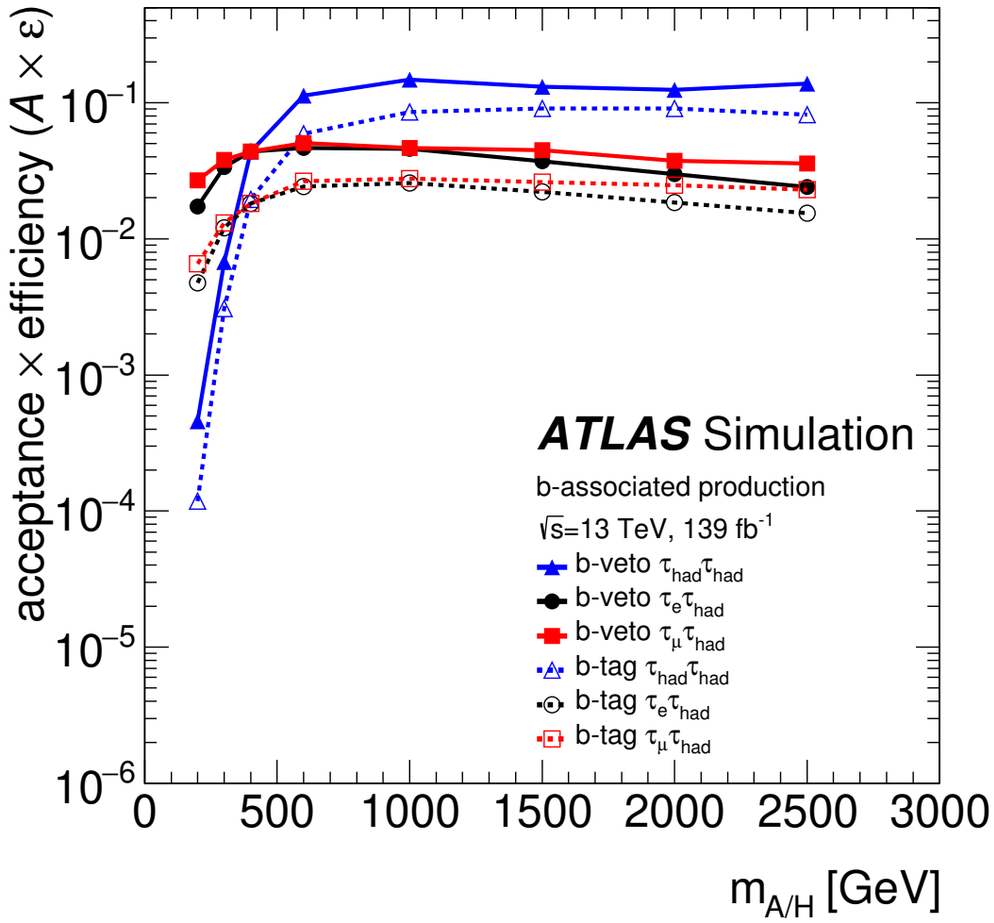
- $\tau_{\text{lep}}\tau_{\text{had}}$ (46%)
  - Single lepton trigger
  - $p_T^l > 30$ GeV, $p_T^{\tau_{\text{had}}} > 25$ GeV
  - At least one isolated lepton, and medium tauID WP (BDT)
  - Suppress W+jets: $m_{\text{T}}(\text{lep, MET}) \leq 40$ GeV
  - Suppress Zee:visible mass not in [80, 100] GeV
- $\tau_{\text{had}}\tau_{\text{had}}$ (42%)
  - Single τ_{had} trigger
  - $p_T^{\tau_{\text{had}}} > 85/130/165$ GeV, $p_T^{\tau_{\text{had}}} > 65$ GeV
  - Medium + Loose tauID WP (BDT)
  - Lepton veto
- Further selection: opposite sign, back-to-back
- Two categories: b-veto and b-tag



Final discriminating variable: $m_{\text{T}}^{\text{TOT}} = \sqrt{m_{\text{T}}^2(\tau_1, E_{\text{T}}^{\text{miss}}) + m_{\text{T}}^2(\tau_2, E_{\text{T}}^{\text{miss}}) + m_{\text{T}}^2(\tau_1, \tau_2)}$

Acceptance x Efficiency

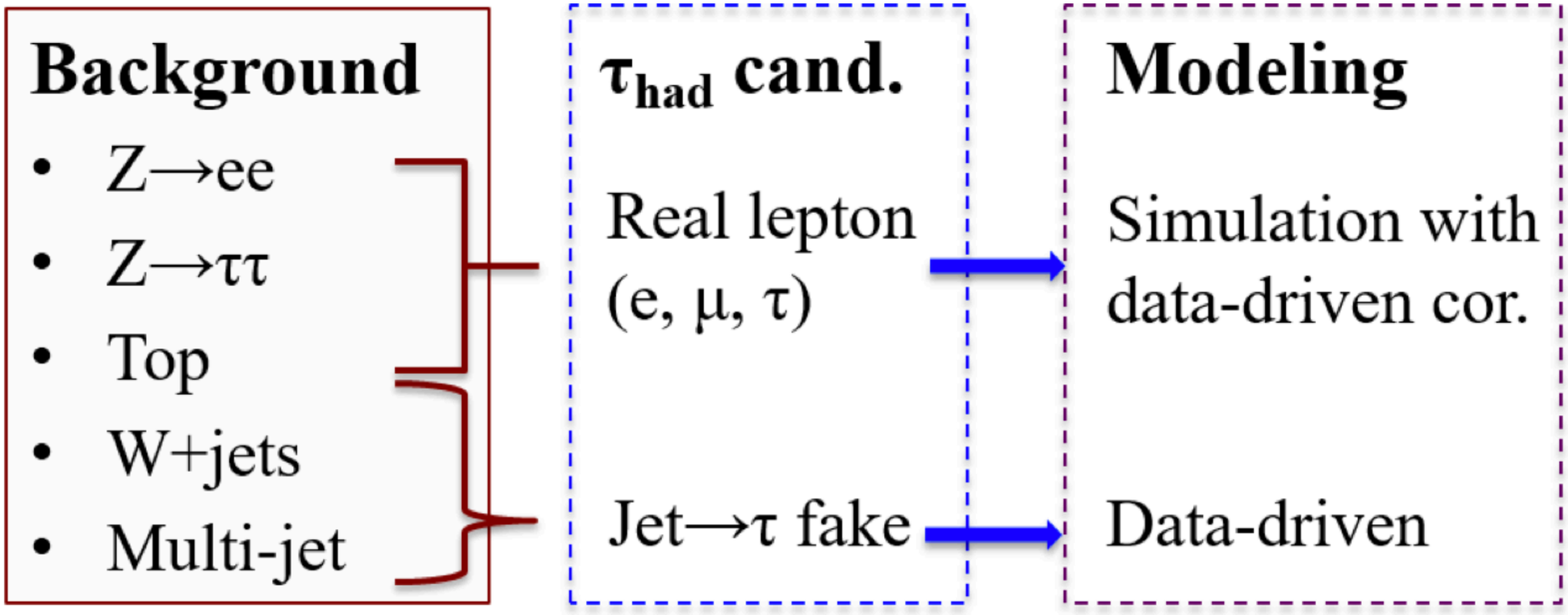




- $A\epsilon$ decreases rapidly in $\tau_{\mathrm{had}}\tau_{\mathrm{had}}$ for lower mass due to higher $p_T^{\tau_{\mathrm{had}}}$ threshold

→ $\tau_{\mathrm{lep}}\tau_{\mathrm{had}}$ **has better sensitivity in low mass**

Overview of Background Estimation

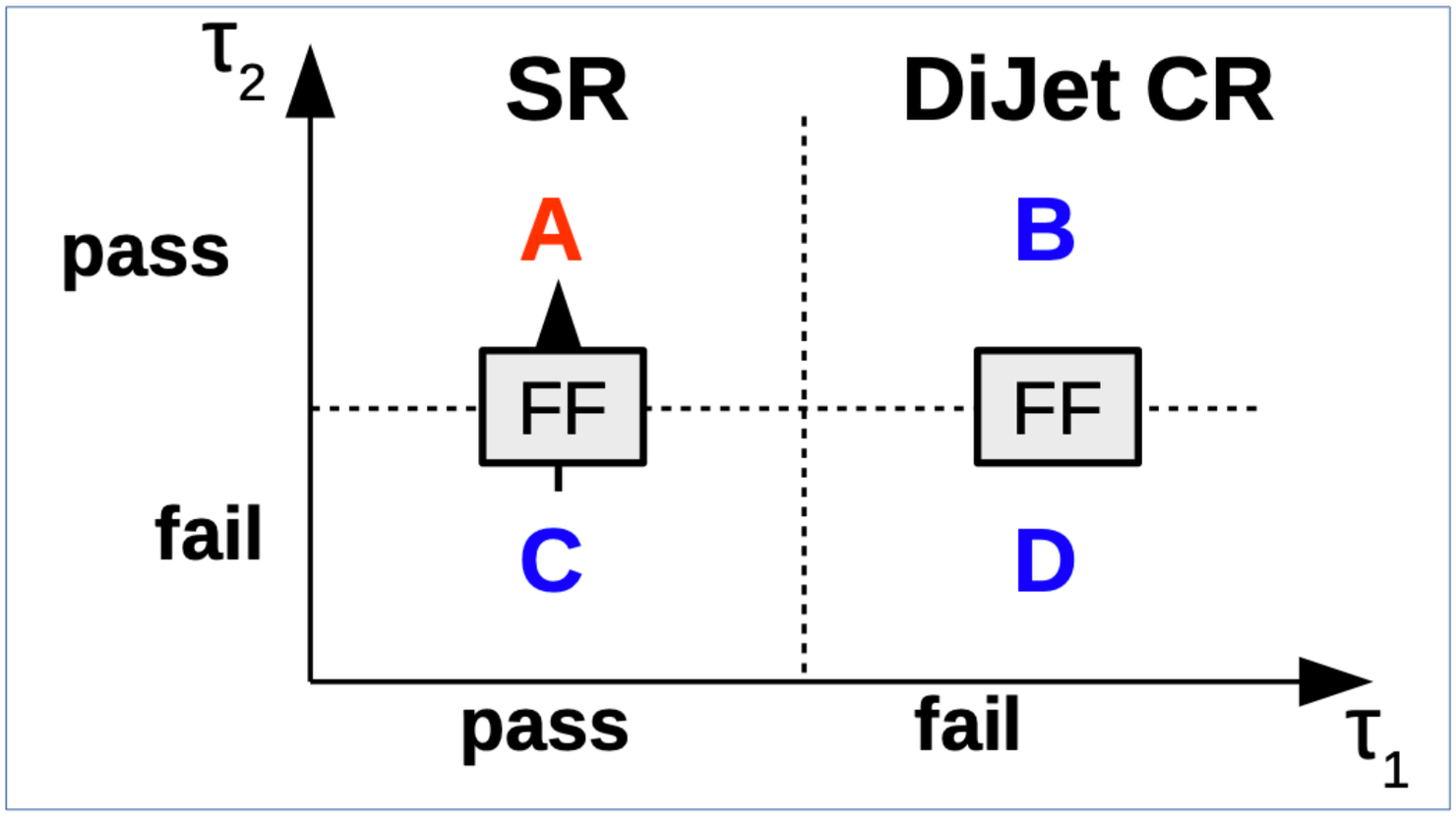


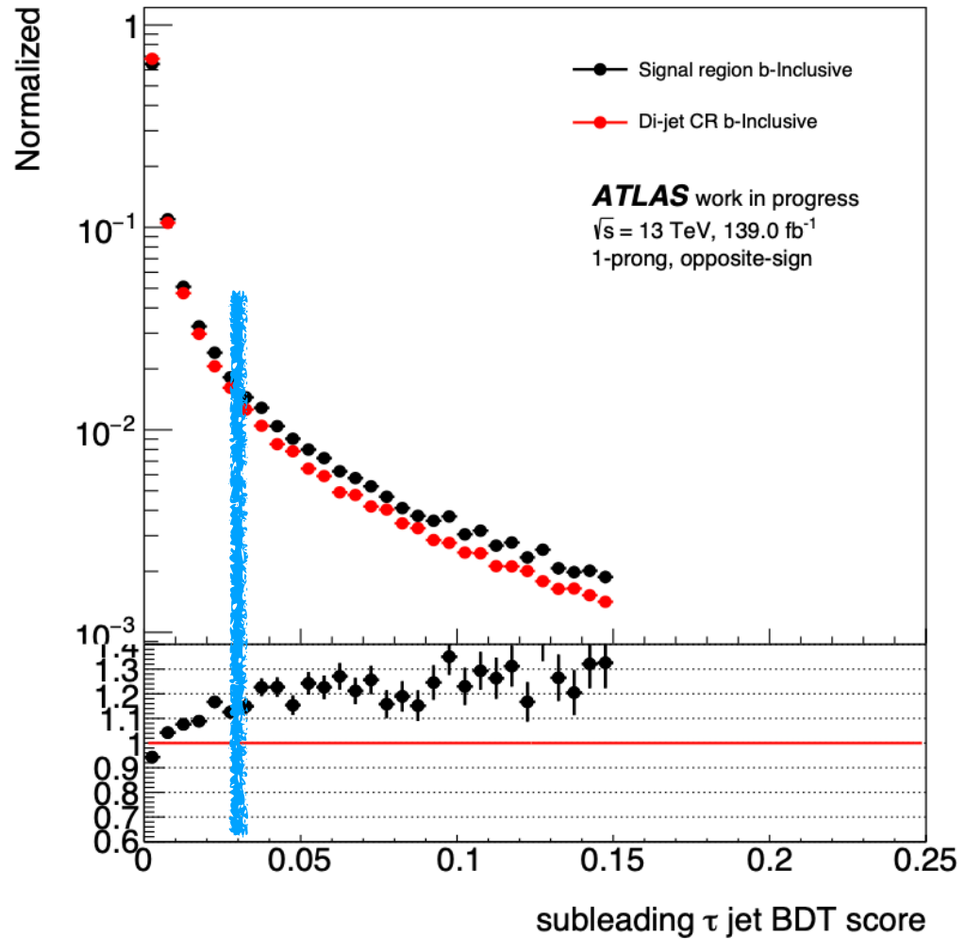
- $\tau_{\mathrm{had}}\tau_{\mathrm{had}}$ has more backgrounds from Multi-jet (mainly in low mass)
  - jets are more likely to fake τ_{had}
- More backgrounds from Top and W+jets in $\tau_{\mathrm{lep}}\tau_{\mathrm{had}}$
  - $\tau_{\mathrm{lep}}\tau_{\mathrm{had}}$: $W \to e\nu_e$, $W \to \tau(e\nu_e\bar{\nu}_\tau)\nu_\tau$
  - $\tau_{\mathrm{had}}\tau_{\mathrm{had}}$: $W \to \tau(\text{hadronic decay})\nu_\tau$

→ $\tau_{\mathrm{had}}\tau_{\mathrm{had}}$ **has better sensitivity in high mass**

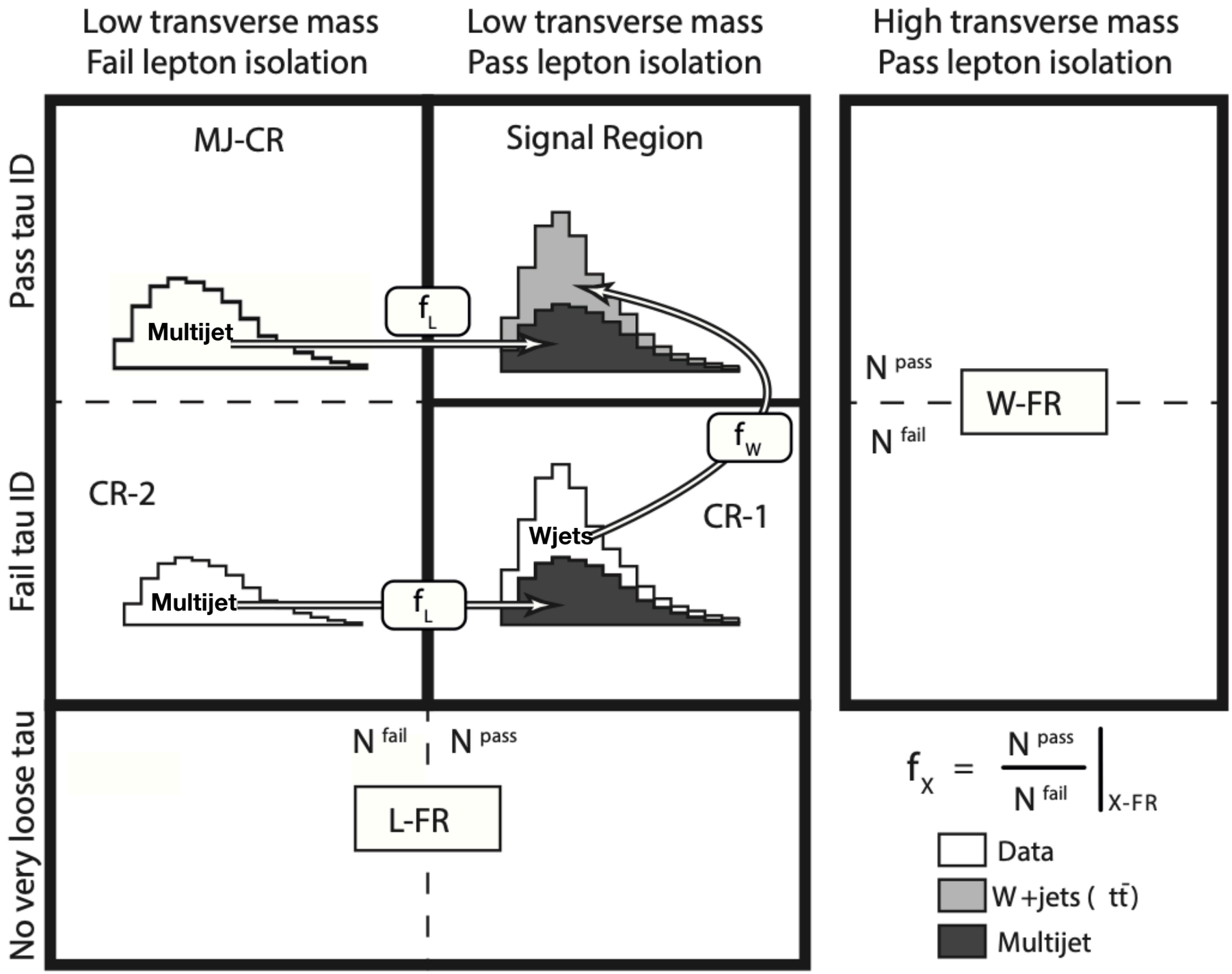
Fake Estimation in τ^1_{had} H τ^2_{had}

- Multi-jet fakes in SR (region A) is estimated from region C by applying a transfer factor, i.e. fake factor (**FF**)
  - defined as: $f_{\tau\text{-ID}}(p_{\mathrm{T}}, N_{\mathrm{track}}) \equiv \left.\frac{N^{\text{pass } \tau\text{-ID}}(p_{\mathrm{T}}, N_{\mathrm{track}})}{N^{\text{fail } \tau\text{-ID}}(p_{\mathrm{T}}, N_{\mathrm{track}})}\right|_{\text{di-jet}}$
  - calculated in a background enriched region (**DiJet CR**)
  - a cut of 0.03 to the BDT score is applied to make CR similar as SR

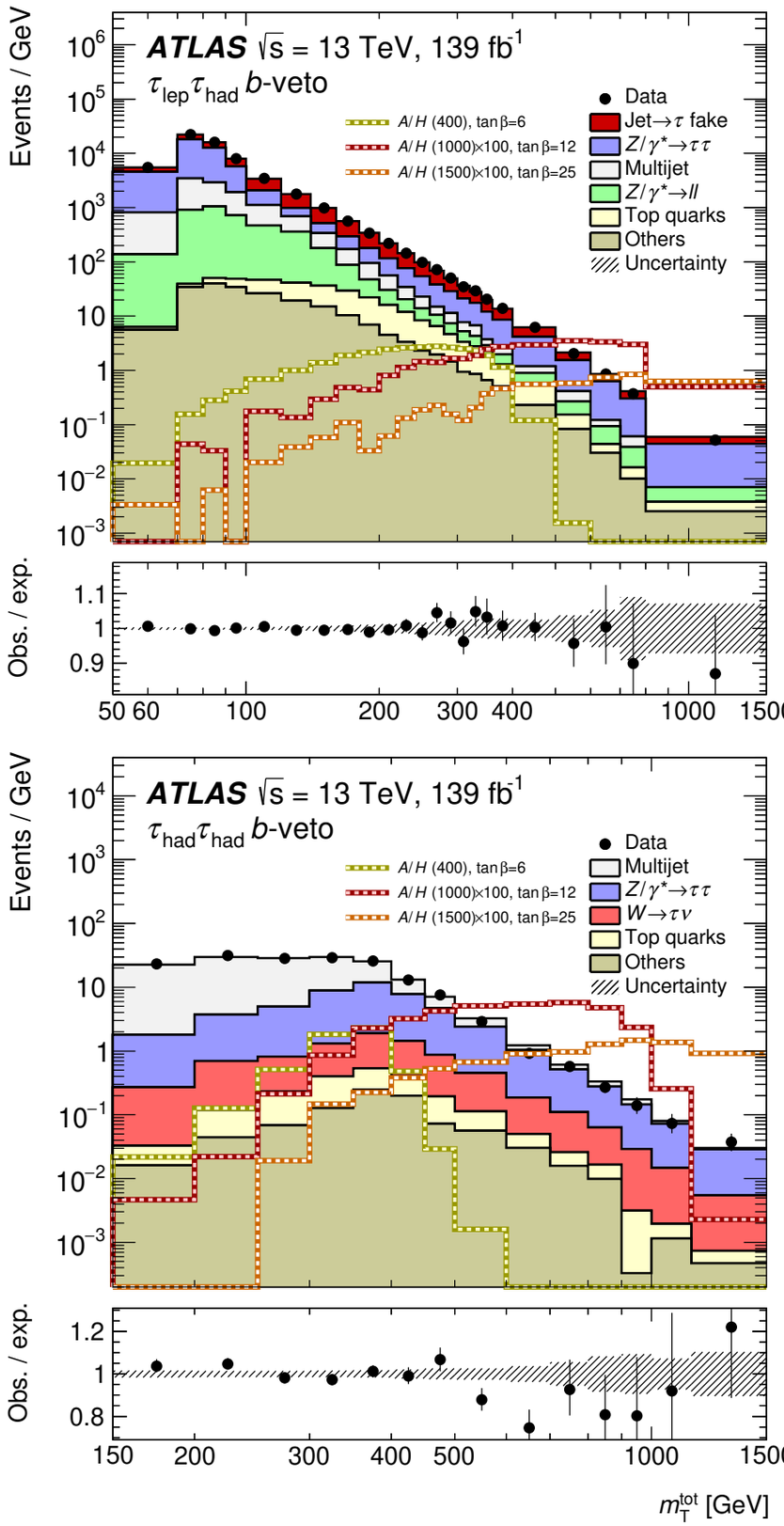


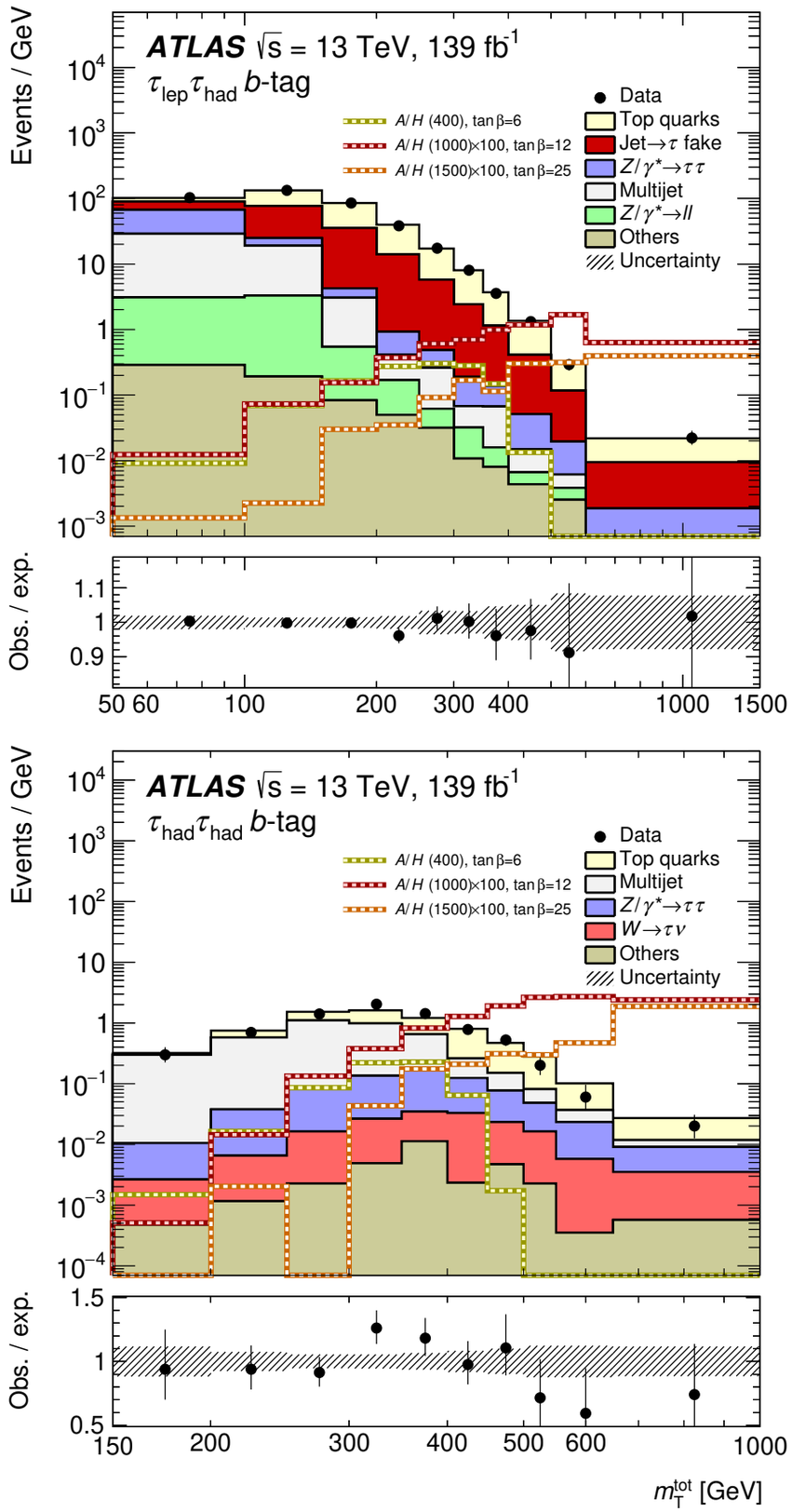


Fake Estimation in



Post-fit distribution



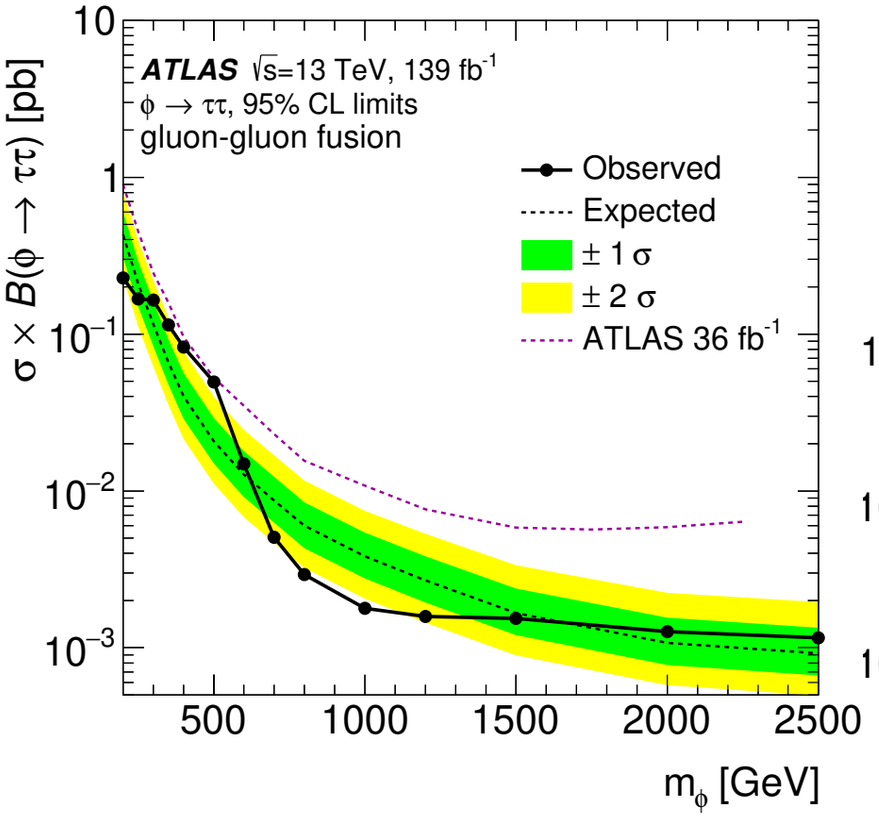


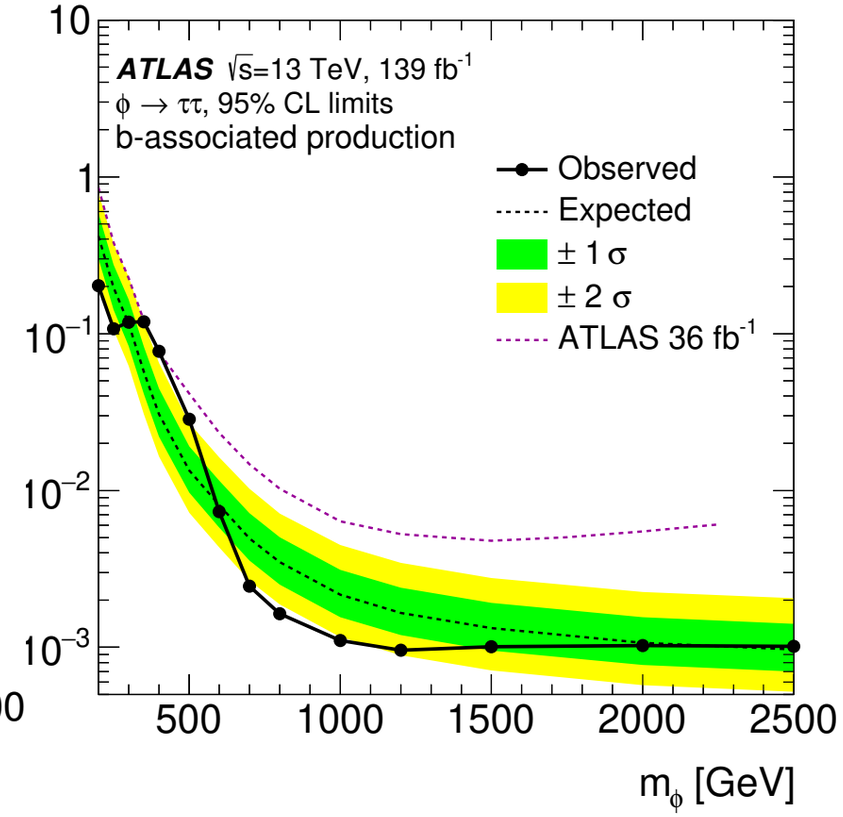
Systematic uncertainty

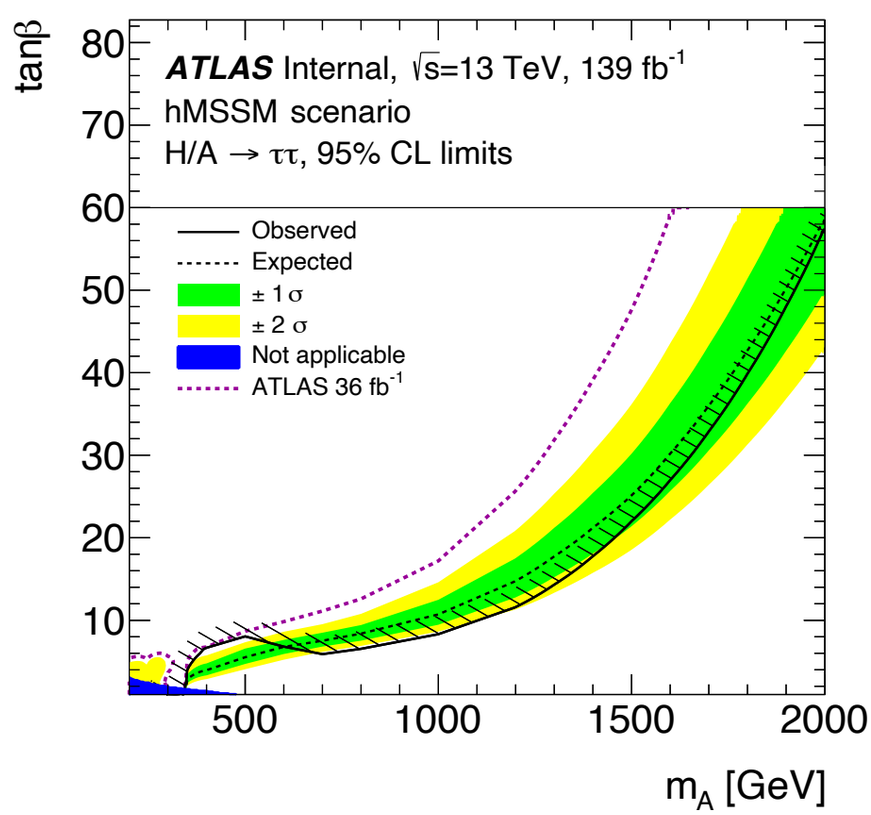
Source	ggF (400 GeV)	ggF (1 TeV)	bbH (400 GeV)	bbH (1 TeV)
Tau id. efficiency	0.14	0.16	0.12	0.08
Tau energy scale	0.33	0.09	0.22	0.03
Z+jets bkg. modeling	0.27	0.19	0.08	0.04
Mis-id. $\tau_{\text{had-vis}}$ bkg.	0.22	0.01	0.14	0.03
Others	0.09	0.04	0.11	0.02
Total	0.54	0.28	0.45	0.13

- Low mass
  - ggF, dominant background is **Z+jets**, and **fakes**
  - bbH: dominant background is $t\bar{t}$, and **fakes**
- High mass
  - ggF: some contribution from **Z+jets**, signal efficiency becomes more important
  - bbH: almost background free, signal efficiency is the most important

Upper Limit







- Compared to previous result, the limit is improved by a factor of **4-5** in the mass range 700-2500 GeV

Summary

- Search for A/H decaying into a pair of τ is performed using full Run2 data
- Data is consistent with background estimation in SM
- The upper limit is improved significantly

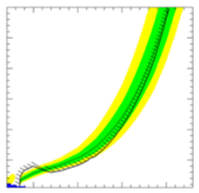
Editors' Suggestion

PDF HTML

Search for Heavy Higgs Bosons Decaying into Two Tau Leptons with the ATLAS Detector Using pp Collisions at $\sqrt{s} = 13\ \mathrm{TeV}$

G. Aad *et al.* (ATLAS Collaboration)

Phys. Rev. Lett. **125**, 051801 (2020) – Published 27 July 2020



A search for heavy neutral Higgs bosons at the LHC agrees with the Standard Model and results in a significant reduction in parameter space for two-Higgs-doublet models.

A search for heavy neutral Higgs bosons is performed using the LHC Run 2 data, corresponding to an integrated luminosity of $139\ \mathrm{fb}^{-1}$ of proton-proton collisions at $\sqrt{s} = 13\ \mathrm{TeV}$ recorded with the ATLAS detector. The search for heavy resonances is performed over the mass range 0.2–2.5 TeV for the $\tau^+\ \tau^-$ decay with at least one τ-lepton decaying into final states with hadrons. The data are in good agreement with the background prediction of the standard model. In the M_h^{125} scenario of the minimal supersymmetric standard model, values of $\tan\beta > 8$ and $\tan\beta > 21$ are excluded at the 95% confidence level for neutral Higgs boson masses of 1.0 and 1.5 TeV, respectively, where $\tan\beta$ is the ratio of the vacuum expectation values of the two Higgs doublets.

PRL 125, 051801

The end, thanks you.

BACKUP

Overview of Background Estimation

Type I: real τ_h or lepton faking τ_h

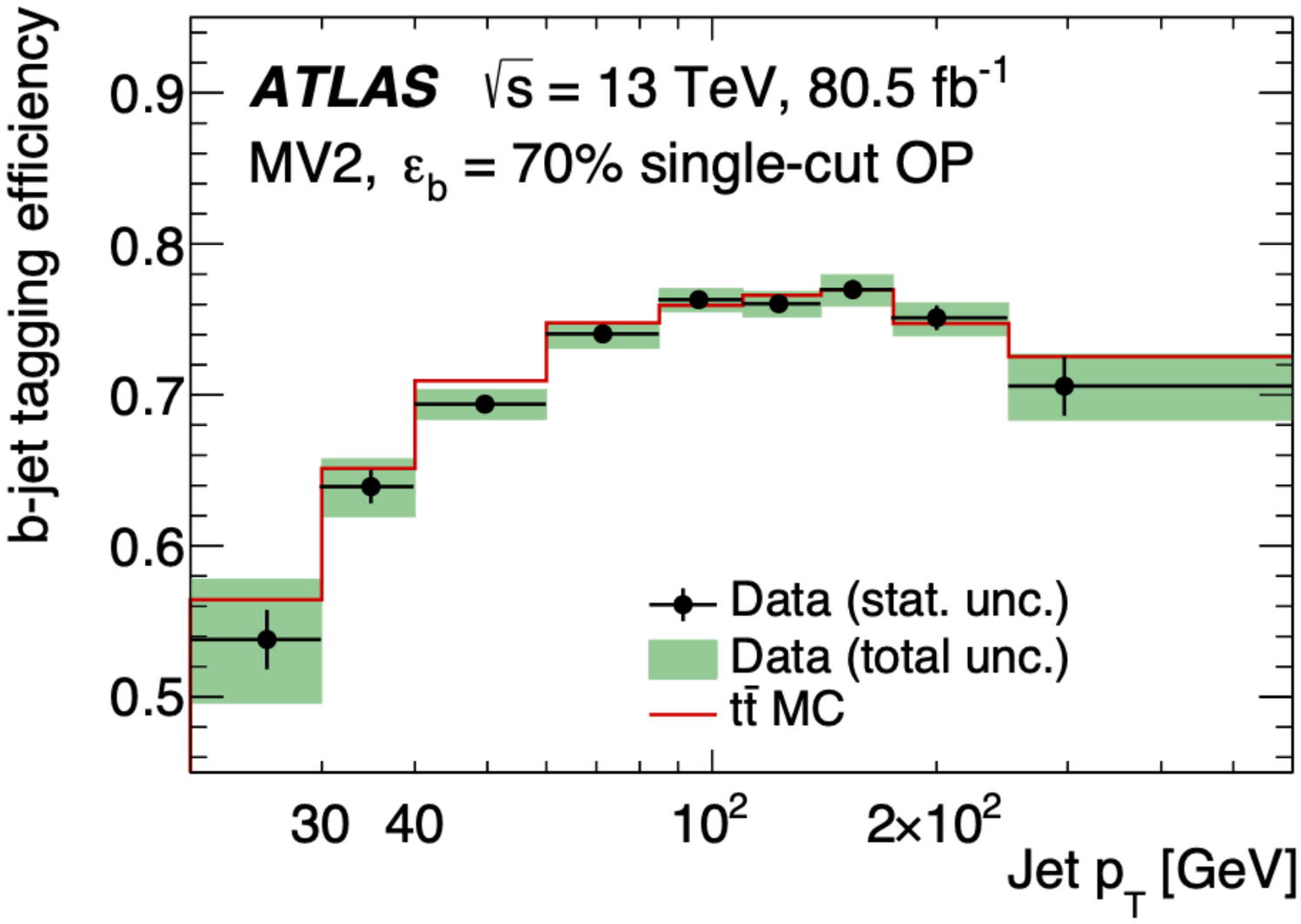
$Z/\gamma^* \to \tau\tau$ (b-veto) $t/t\bar{t}$ (b-tag) Diboson	real τ_h	MC simulation with data driven corr.
$Z/\gamma^* \to l^+l^-(\tau_{\text{lep}}\tau_{\text{had}})$	lepton faking τ_h	

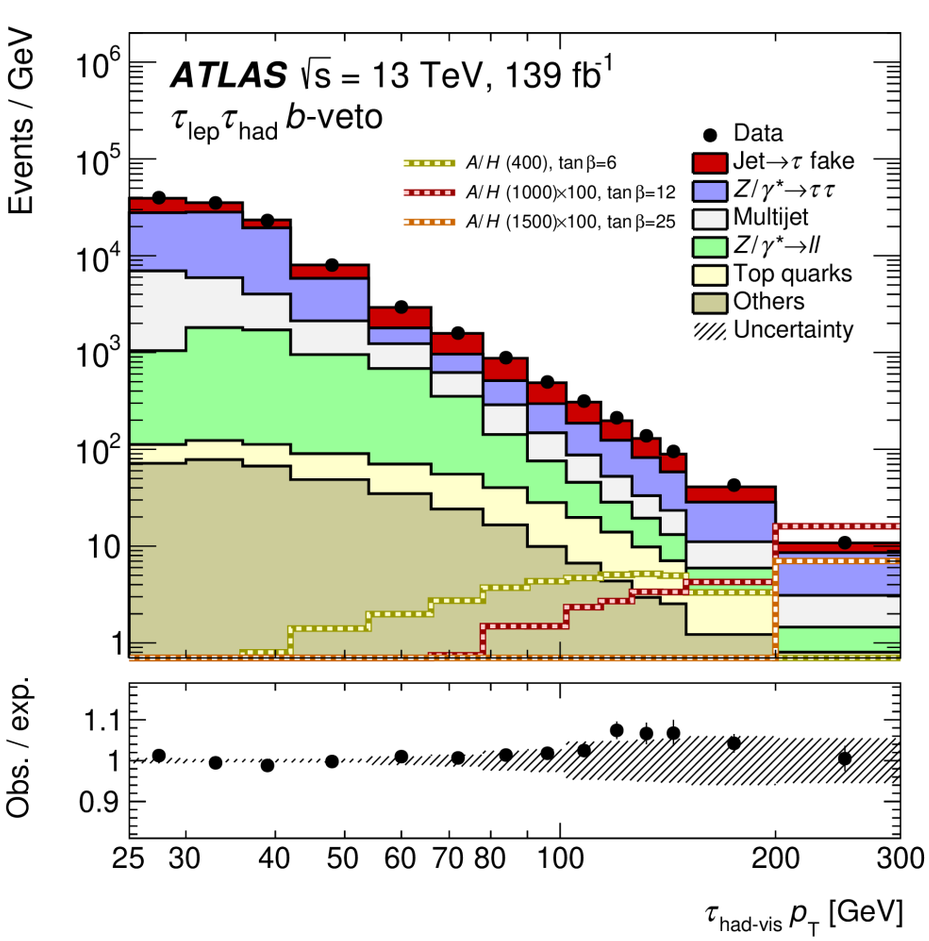
Type II: one jet faking τ_h

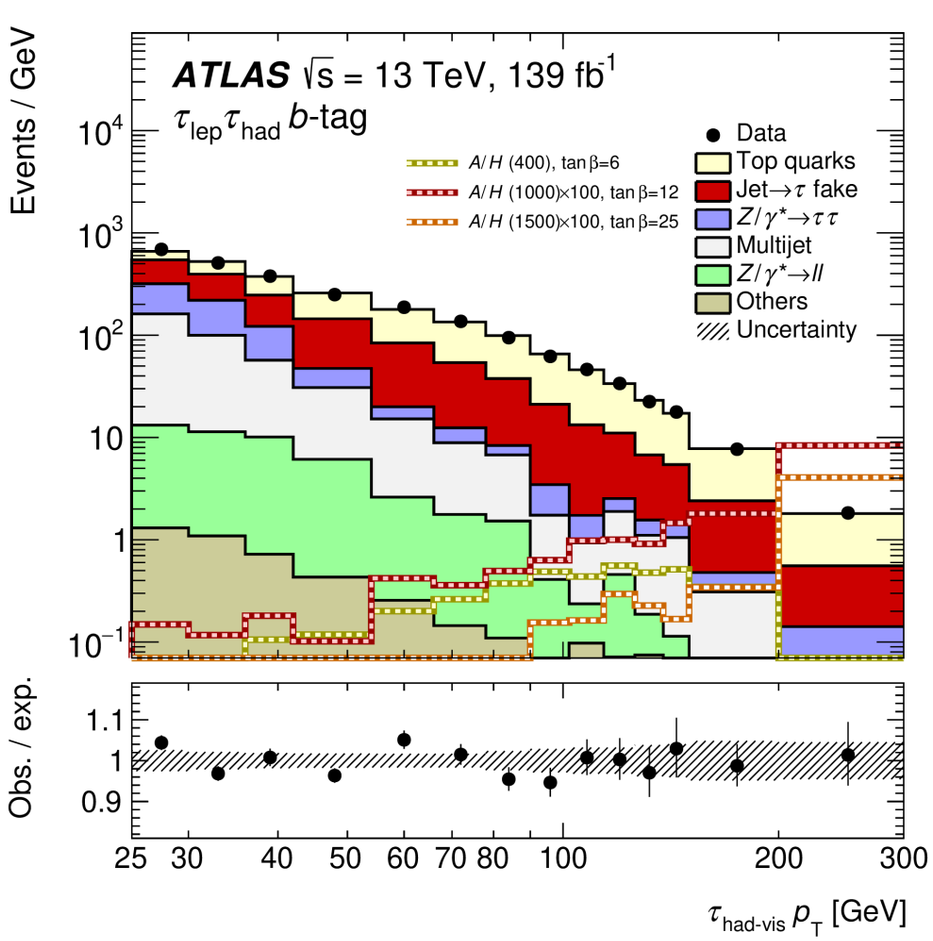
W+jets (b-veto) $t/t\bar{t}$ (b-tag)	jet faking τ_h	Data driven method (FF/FR)

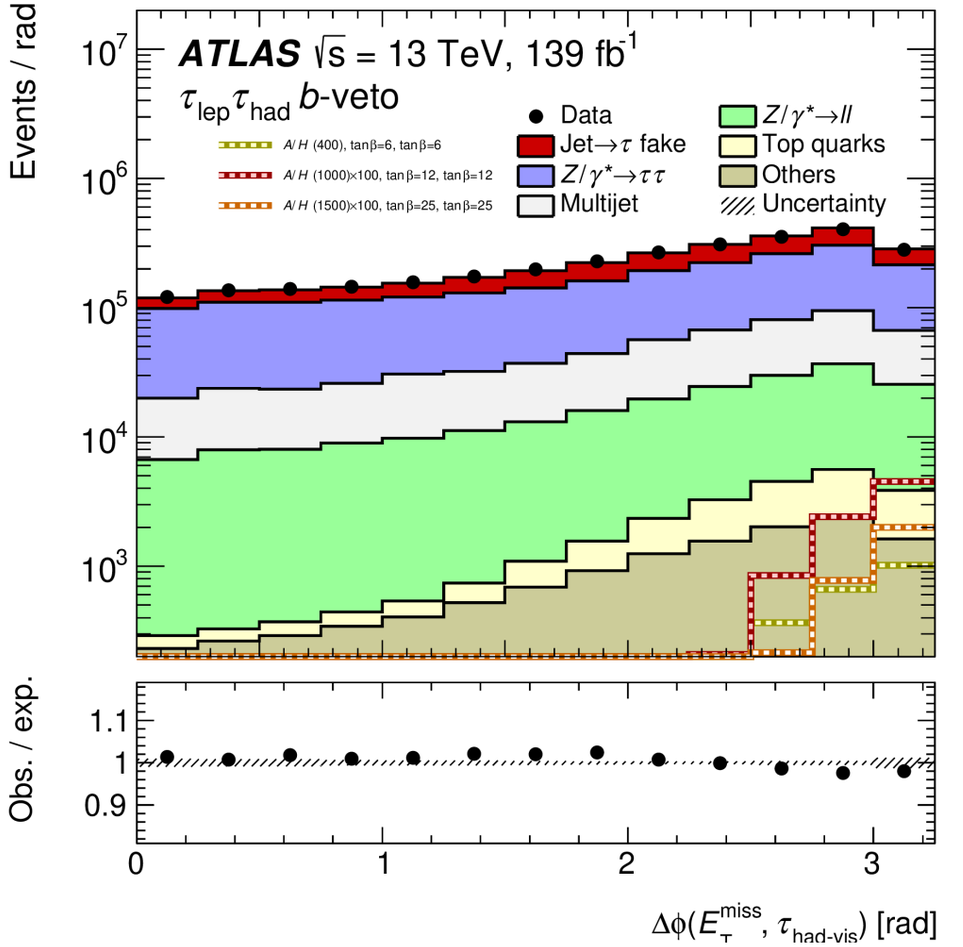
Type III: two jets faking l/τ_h

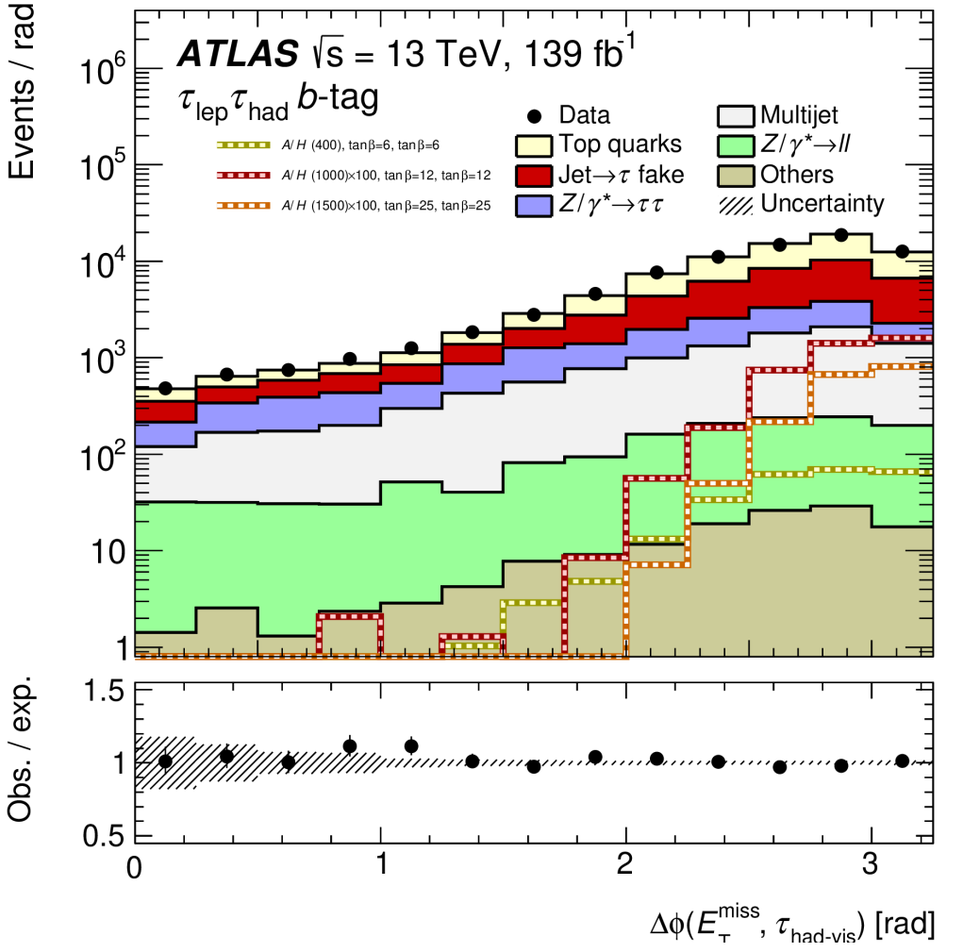
Multijet	jet faking l and τ_h	Data driven method (FF)

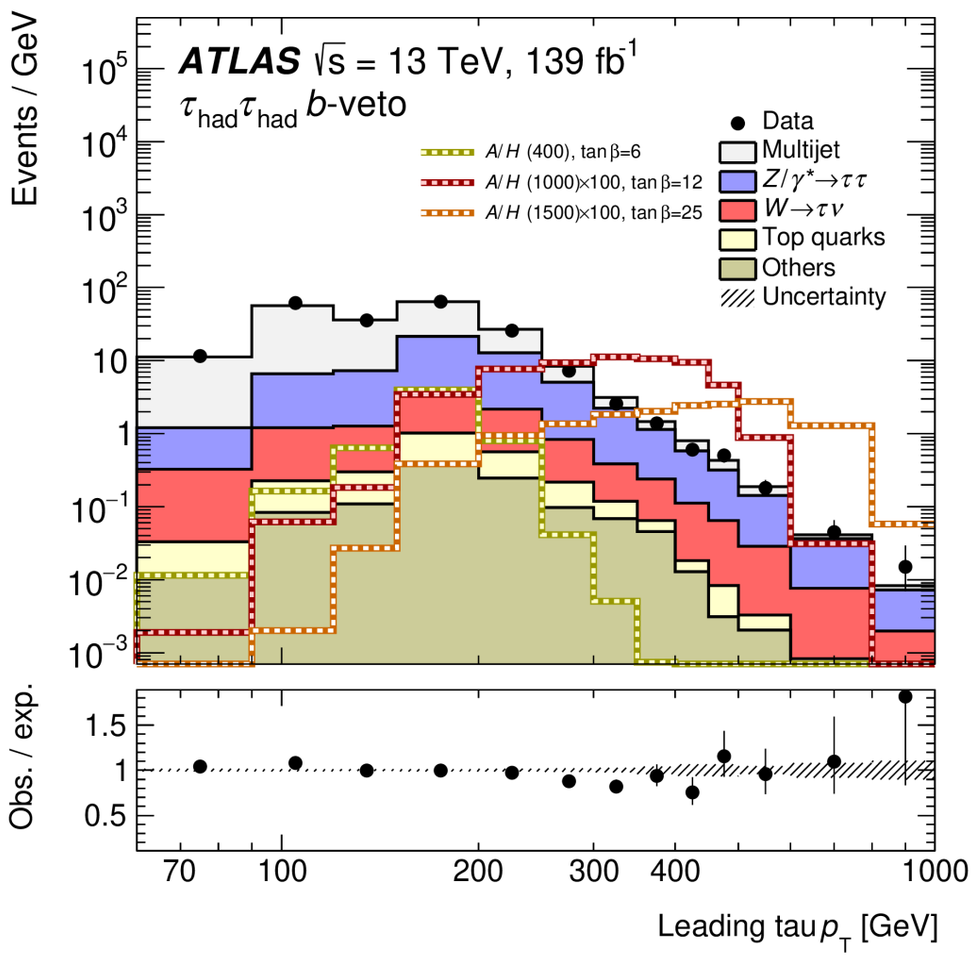

ATLAS √s = 13 TeV, 80.5 fb-1
MV2, εb = 70% single-cut OP
b-jet tagging efficiency
0.9
0.8
0.7
0.6
0.5
Data (stat. unc.)
Data (total unc.)
tt̄ MC
30
40
10²
2×10²
Jet pT [GeV]

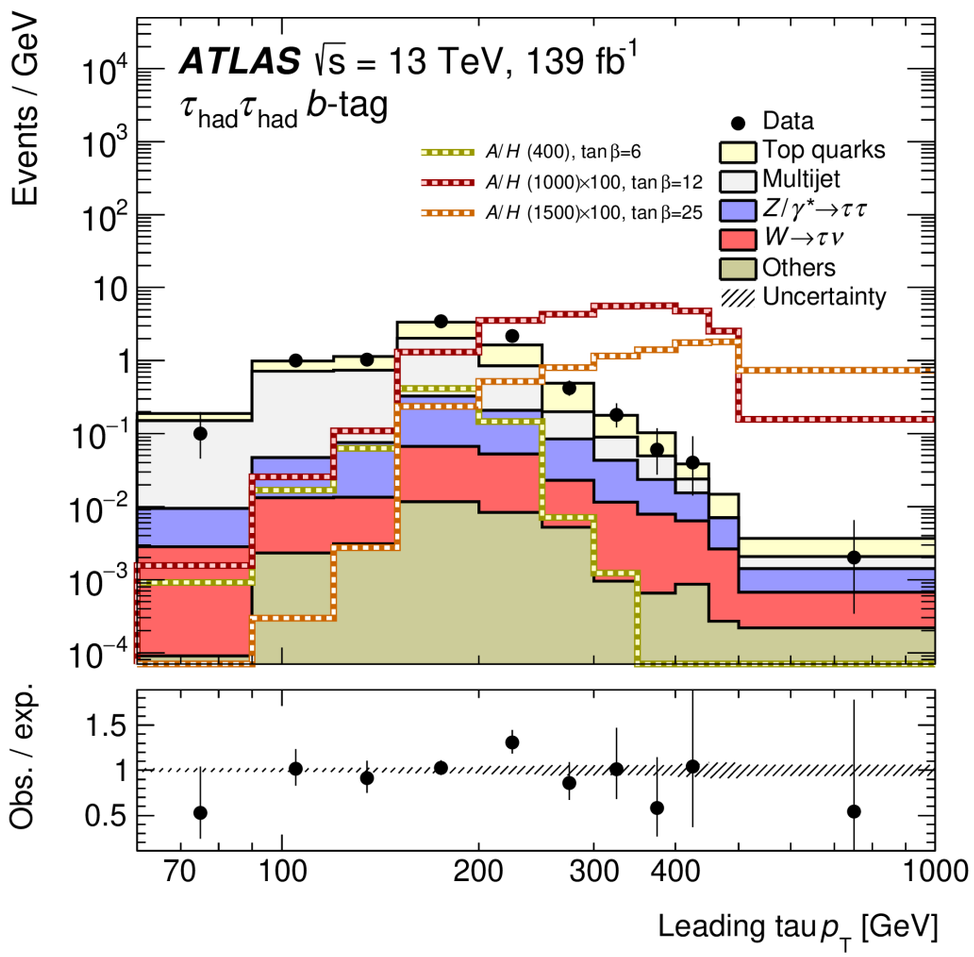

ATLAS √s = 13 TeV, 139 fb-1
τlepτhad b-veto
A/H (400), tanβ=6
A/H (1000)×100, tanβ=12
A/H (1500)×100, tanβ=25
Data
Jet→τ fake
Z/γ*→ττ
Multijet
Z/γ*→ll
Top quarks
Others
Uncertainty
Events / GeV
Obs. / exp.
τhad-vis pT [GeV]

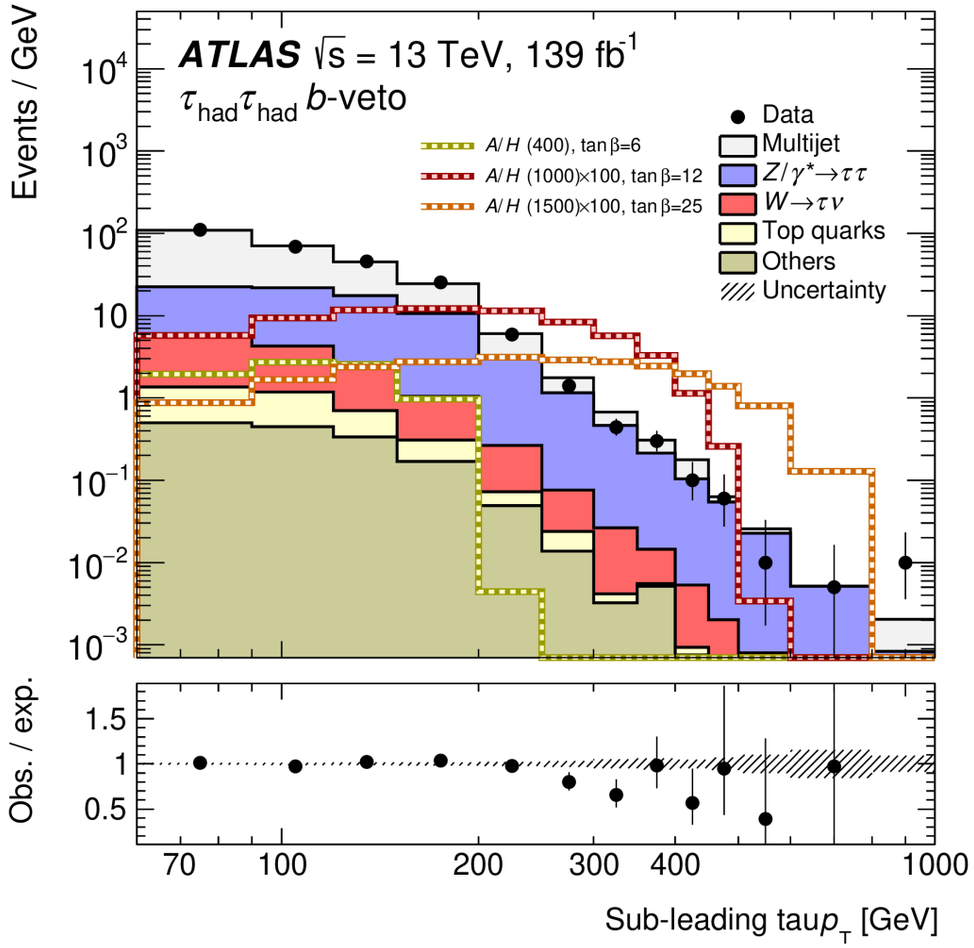

ATLAS √s = 13 TeV, 139 fb-1
τlepτhad b-tag
A/H (400), tanβ=6
A/H (1000)×100, tanβ=12
A/H (1500)×100, tanβ=25
Data
Top quarks
Jet→τ fake
Z/γ*→ττ
Multijet
Z/γ*→ll
Others
Uncertainty
Events / GeV
Obs. / exp.
τhad-vis pT [GeV]

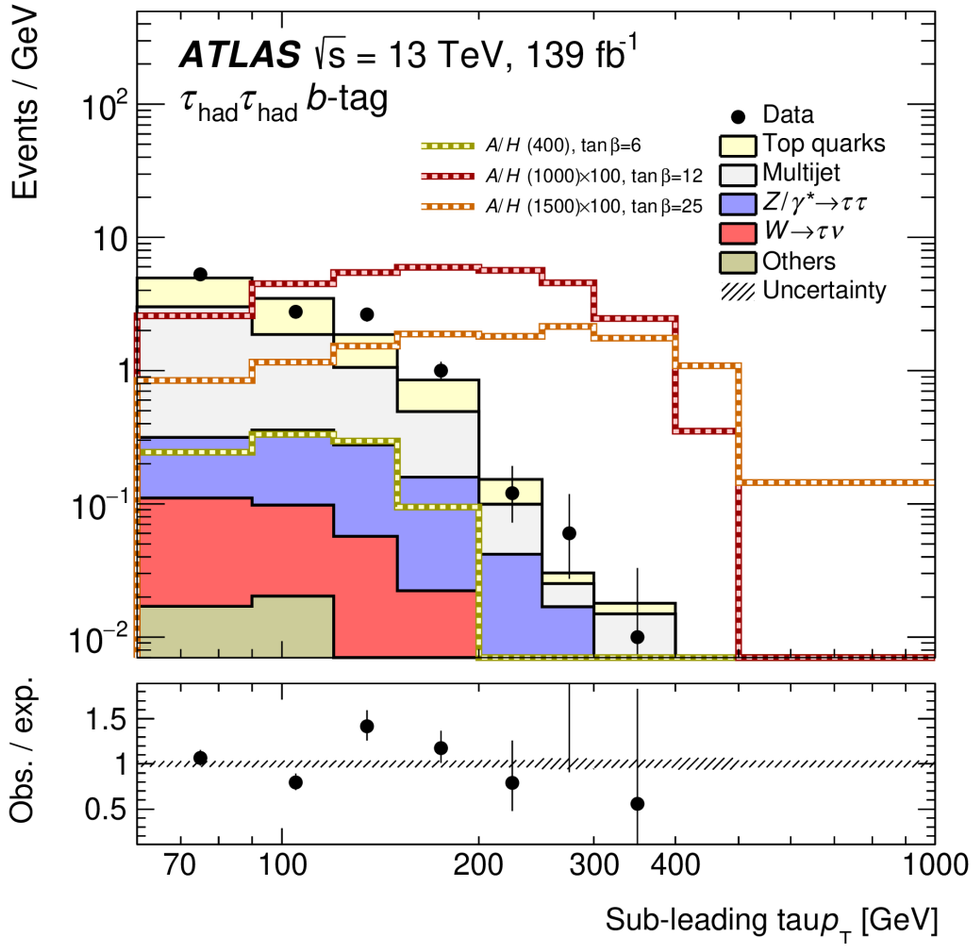

ATLAS √s = 13 TeV, 139 fb-1
τlepτhad b-veto
A/H (400), tanβ=6, tanβ=6
A/H (1000)×100, tanβ=12, tanβ=12
A/H (1500)×100, tanβ=25, tanβ=25
Data
Jet→τ fake
Z/γ*→ττ
Multijet
Z/γ*→ll
Top quarks
Others
Uncertainty
Events / rad
Obs. / exp.
Δφ(Emiss T, τhad-vis) [rad]


ATLAS √s = 13 TeV, 139 fb-1
τlepτhad b-tag
A/H (400), tanβ=6, tanβ=6
A/H (1000)×100, tanβ=12, tanβ=12
A/H (1500)×100, tanβ=25, tanβ=25
Data
Top quarks
Jet→τ fake
Z/γ*→ττ
Multijet
Z/γ*→ll
Others
Uncertainty
Events / rad
Obs. / exp.
Δφ(Emiss T, τhad-vis) [rad]


ATLAS √s = 13 TeV, 139 fb-1
τhadτhad b-veto
Data
Multijet
Z/γ*→ττ
W→τν
Top quarks
Others
Uncertainty
A/H (400), tanβ=6
A/H (1000)×100, tanβ=12
A/H (1500)×100, tanβ=25
Events / GeV
Obs. / exp.
Leading tau pT [GeV]


ATLAS √s = 13 TeV, 139 fb-1
τhadτhad b-tag
Data
Top quarks
Multijet
Z/γ*→ττ
W→τν
Others
Uncertainty
A/H (400), tanβ=6
A/H (1000)×100, tanβ=12
A/H (1500)×100, tanβ=25
Events / GeV
Obs. / exp.
Leading tau pT [GeV]


ATLAS √s = 13 TeV, 139 fb-1
τhadτhad b-veto
Data
Multijet
Z/γ*→ττ
W→τν
Top quarks
Others
Uncertainty
A/H (400), tanβ=6
A/H (1000)×100, tanβ=12
A/H (1500)×100, tanβ=25
Events / GeV
Obs. / exp.
Sub-leading tau pT [GeV]


ATLAS √s = 13 TeV, 139 fb-1
τhadτhad b-tag
Data
Top quarks
Multijet
Z/γ*→ττ
W→τν
Others
Uncertainty
A/H (400), tanβ=6
A/H (1000)×100, tanβ=12
A/H (1500)×100, tanβ=25
Events / GeV
Obs. / exp.
Sub-leading tau pT [GeV]