Search of a high mass neutral Higgs boson in fermion final states with the ATLAS detector.

Gaetano Αθανάσιος Barone

Brandeis University

On behalf of the ATLAS collaboration

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Introduction

- Heavy neutral Higgs bosons predicted by several Standard Model extensions, in particular
  - Minimal super symmetric Standard Model (MSSM)
  - Two Higgs doublet model (2HDM)
    - ✦ CP even neutral doublet (h, H) and CP odd pseudo scalar A and two scalars $H^{\pm}$
    - ✦ motivated also by dark matter axion models

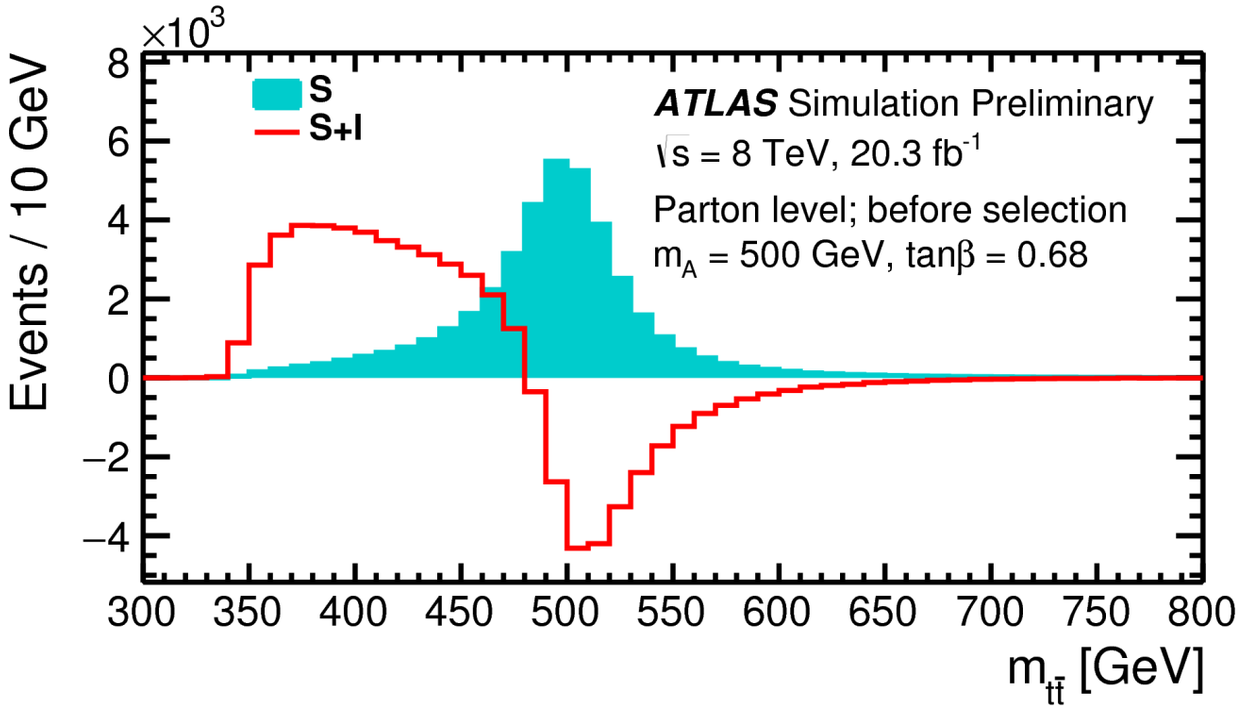
- Present recent searches for high mass neutral Higgs boson in fermion final states with the ATLAS detector

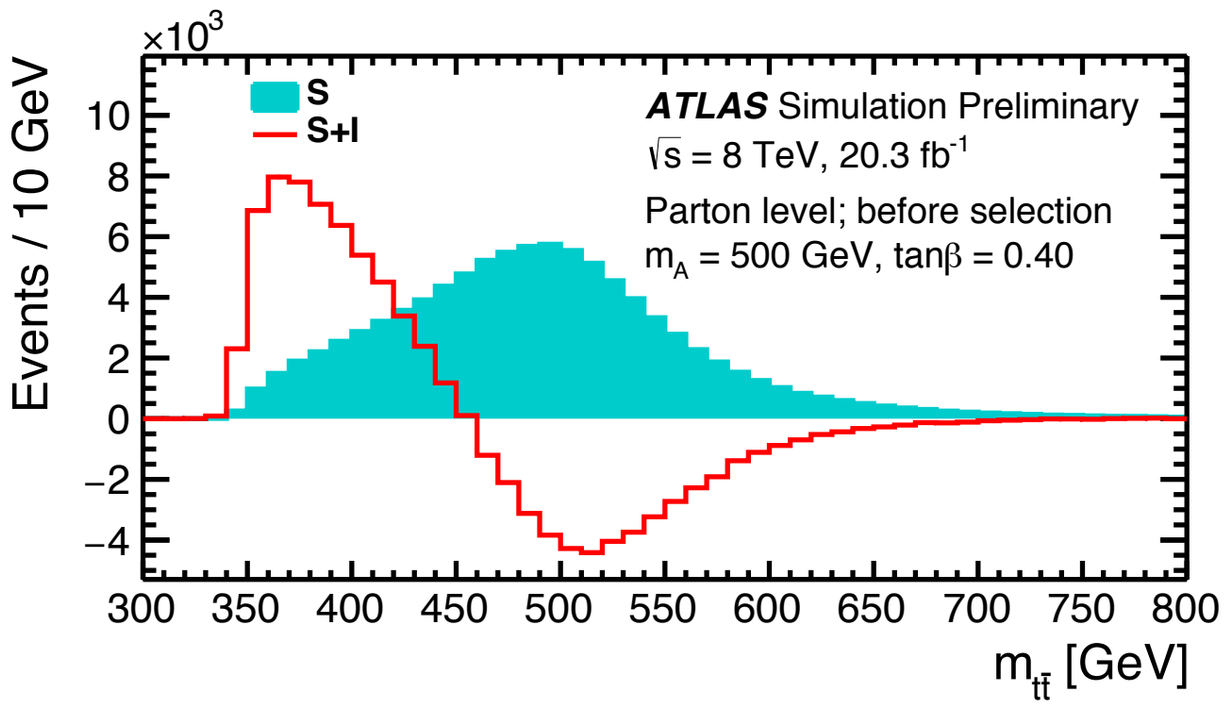
1. $A/H \to t\bar{t}$
2. $A/H \to \tau\bar{\tau}$

$$A/H \rightarrow t\bar{t}$$

$A/H \rightarrow t\bar{t}$

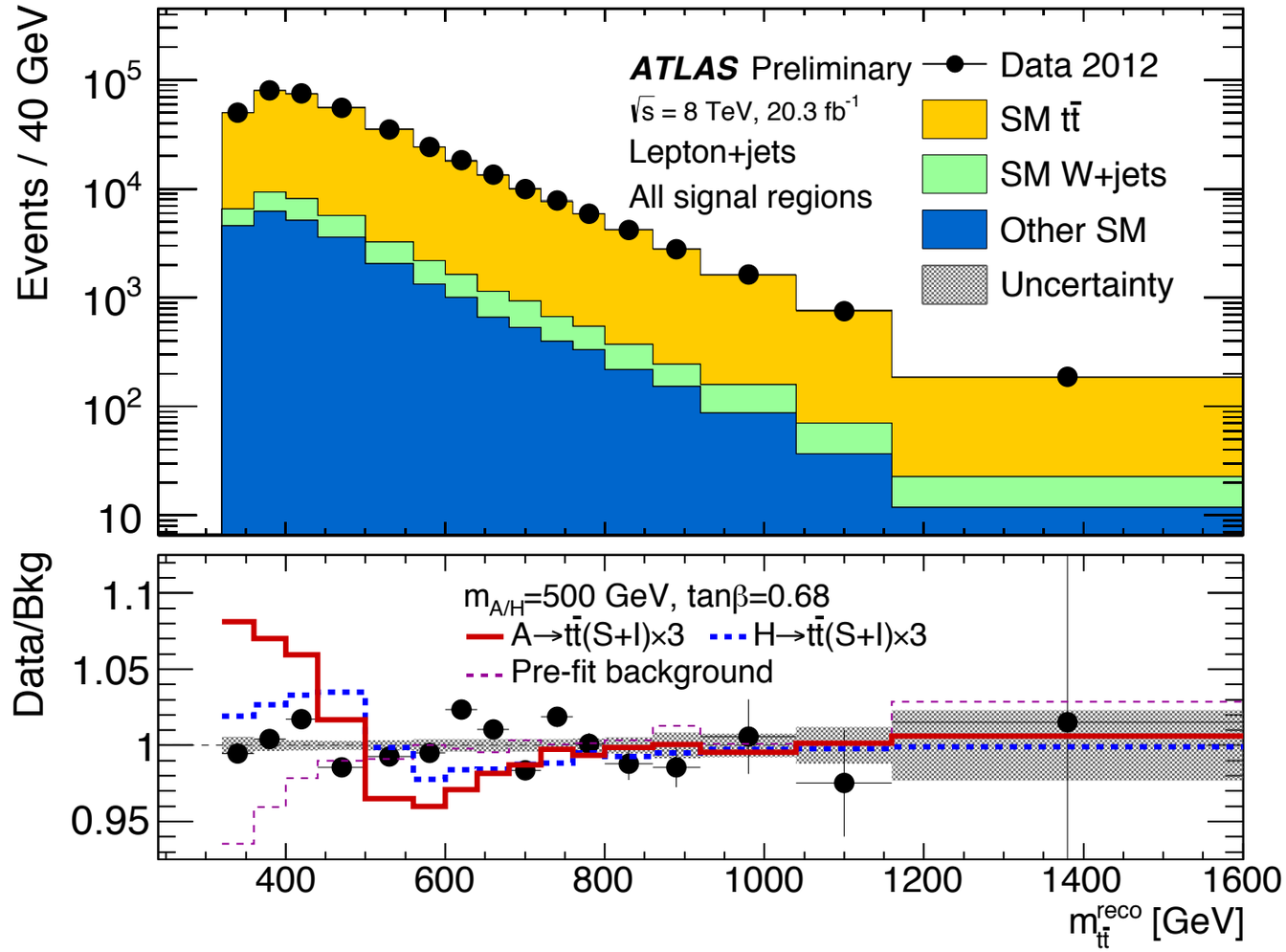
- Decays of A/H to $t\bar{t}$ enhanced for $\tan\beta<3$ and $m_{A/H}$ > 500 GeV.
  - Parameter region not probed by previous searches.





- Significant interference between $gg \rightarrow t\bar{t}$ production and $A/H \rightarrow t\bar{t}$
  - for $m_{A/H}$ above $t\bar{t}$ threshold, for LHC $t\bar{t}$ main production
  - Resonant shape distorted to a peak-dip structure.

- Analysis in the lepton (ℓ) plus jets (j) final state
  - One lepton (e or μ) with $p_T(\ell) > 25$ GeV.
  - At least four anti-$k_T(4)$ jets with $p_T(j) > 25$ GeV.
  - $E_T^{miss} > 20$ GeV and $E_T^{miss} + m_T^W > 60$ GeV.



- Considering only resolved kinematics
  - Most efficient strategy for $m_{A/H} < 800$ GeV
- Event classification into six categories
  - Kinematic χ^2 for jet association to W
- W+jets and Multijet contributions estimated from data.
- Leading uncertainties
  - Jet modelling ~6% on B and ~9% on $S+I$
  - $t\bar{t}$ modelling ~7% (m_t and pdf)

$A/H \to t\bar{t}$

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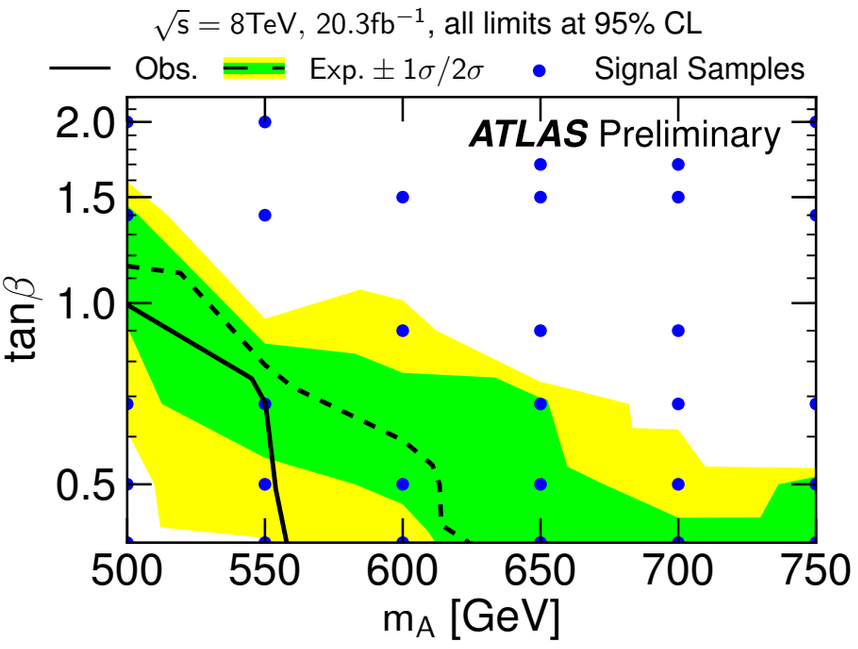
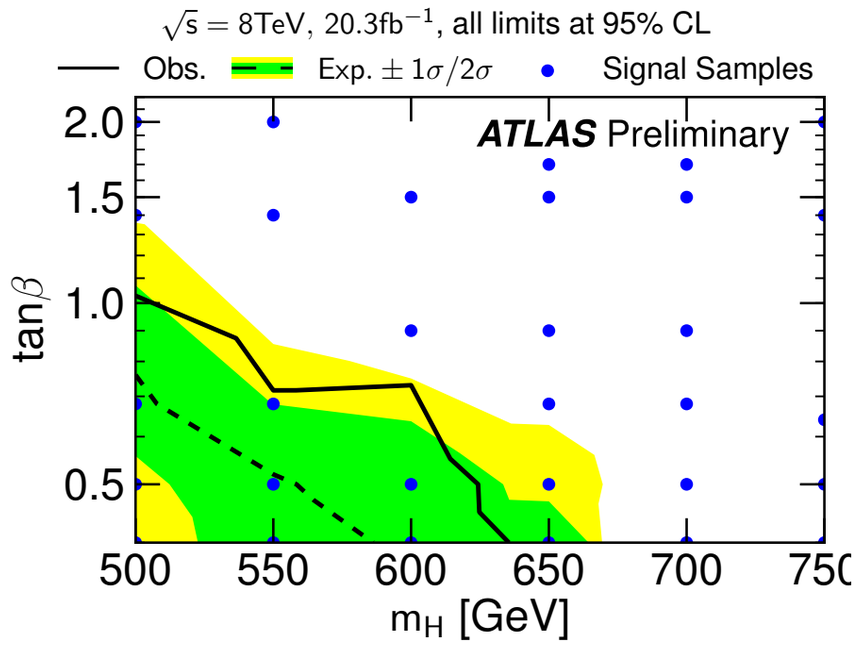
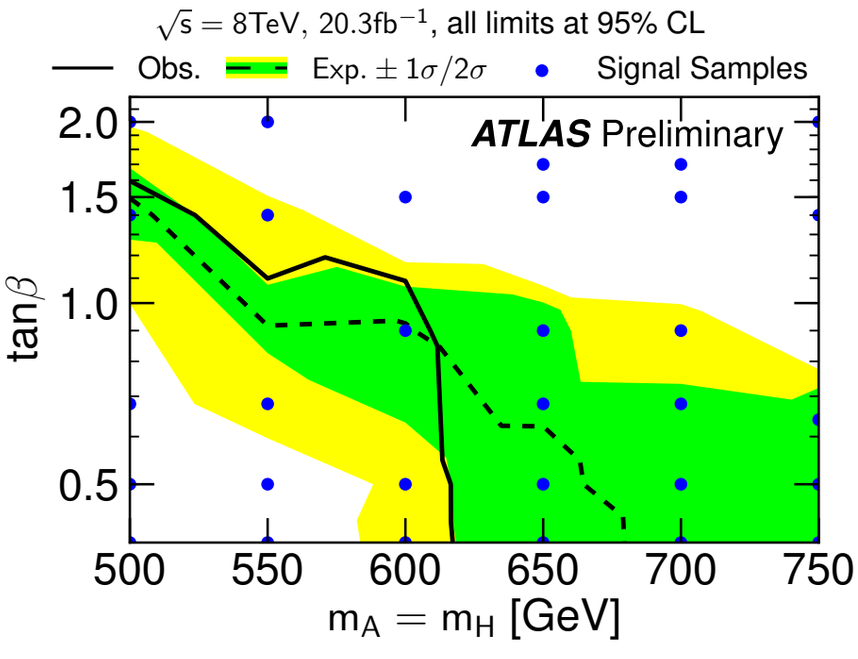


Pseudo scalar



Scalar



Degenerate

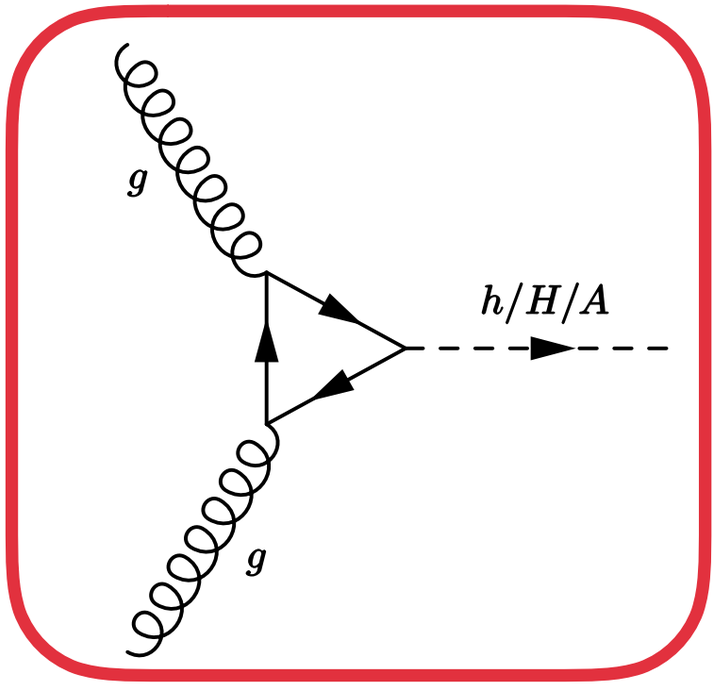
$$\mu \cdot S + \sqrt{\mu} \cdot I + B = \sqrt{\mu} \cdot (S + I) + (\mu - \sqrt{\mu}) \cdot S + B.$$

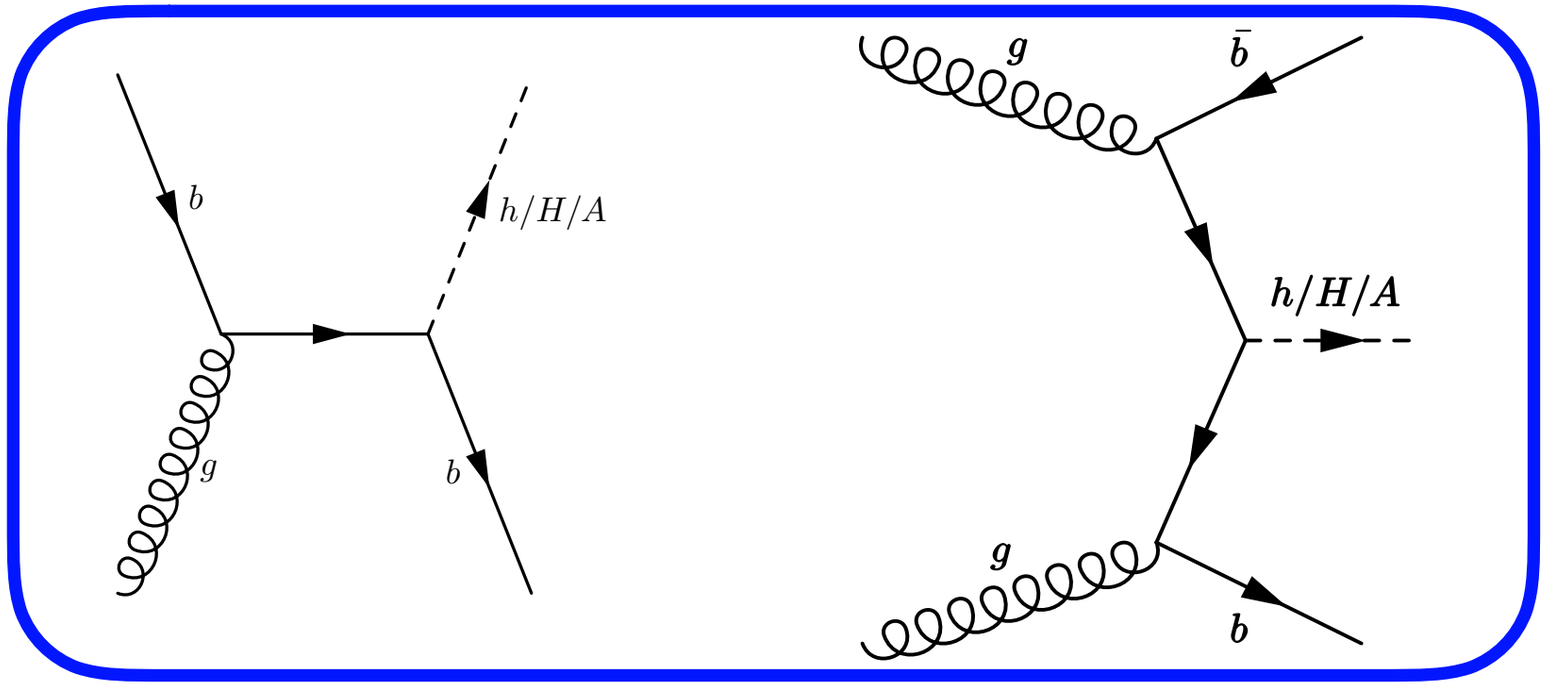
- CL_s limits taking into account signal (S), background (B) and interference (I)
  - $\tan\beta < 0.7$ for m_A=550 GeV and $\tan\beta$ < 0.72 for m_H=550 GeV
- First and strictest limits in this this parameter region

More details in Katharina Behr's poster and Saverio D'Auria's talk

$$A/H \rightarrow \tau\overline{\tau}$$

- For large tanβ A/H couplings to leptons and down quarks enhanced.
  - Increased branching fractions to τ-leptons
- Dominant production modes:
  - gluon gluon fusion for low tanβ,
  - b-associated production for high tanβ





- Events are split into two categories:
  - b-tag veto category: no b-jets in production.
  - $N(b\text{-jets}) > 0$ associated b-jet production.

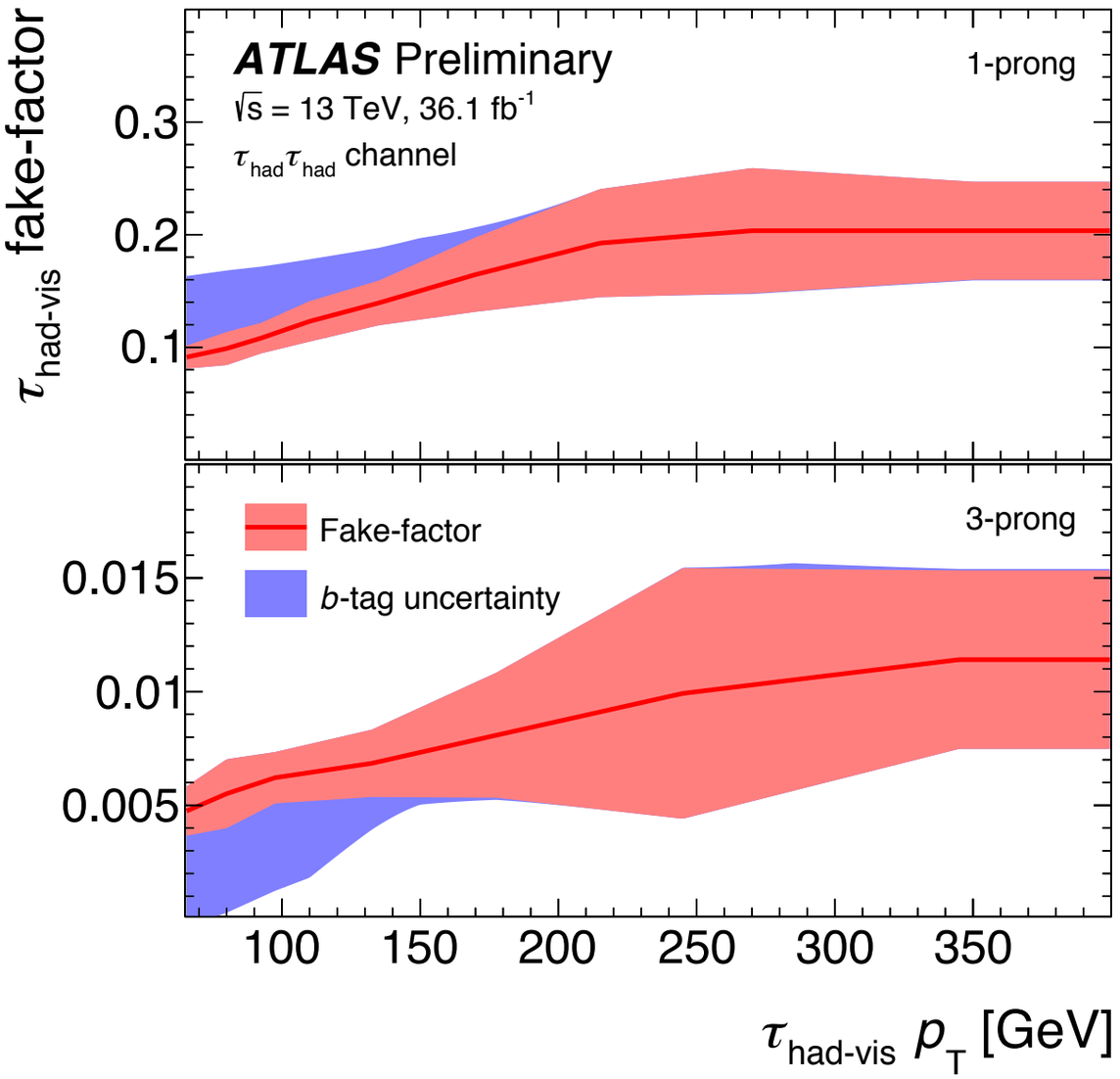
- τ reconstruction and event selection
  - Two τ decay modes are considered:
    - ✦ All hadronic final state ($\tau_{had}\tau_{had}$).
    - ✦ Semileptonic final state ($\tau_{lep}\tau_{had}$).

$\tau_{lep}\tau_{had}$	$\tau_{had}\tau_{had}$
One τ_{had} with p_T >25 GeV $\lvert\Delta\varphi(\ell,\ \tau_{had})\rvert > 2.4$ rad $m_T(\ell, E_T^{miss}) < 40$ GeV	At least two τ_{had} with p_T >65 GeV $\lvert\Delta\varphi(\tau_{had},\ \tau_{had})\rvert > 2.7$ rad

- Dominant backgrounds estimated from data
  - Estimate rates of jets faking taus by inverting identification criteria

$$f(\mathbf{x}) \equiv \frac{N_{\text{data}}^{\text{pass}}(\mathbf{x}) - N_{\text{bkg}}^{\text{pass}}(\mathbf{x})}{N_{\text{data}}^{\text{fail}}(\mathbf{x}) - N_{\text{bkg}}^{\text{fail}}(\mathbf{x})}$$

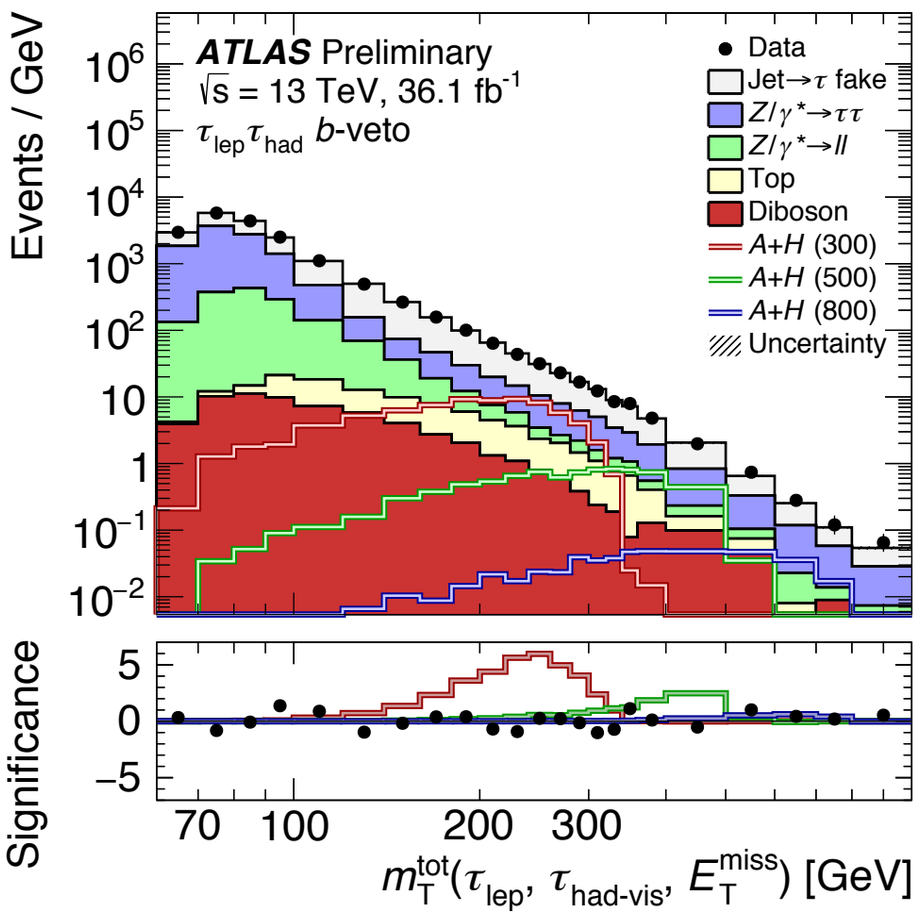
  - from regions in data enhancing the Mulitjet background, $t\bar{t}$ and W+jets

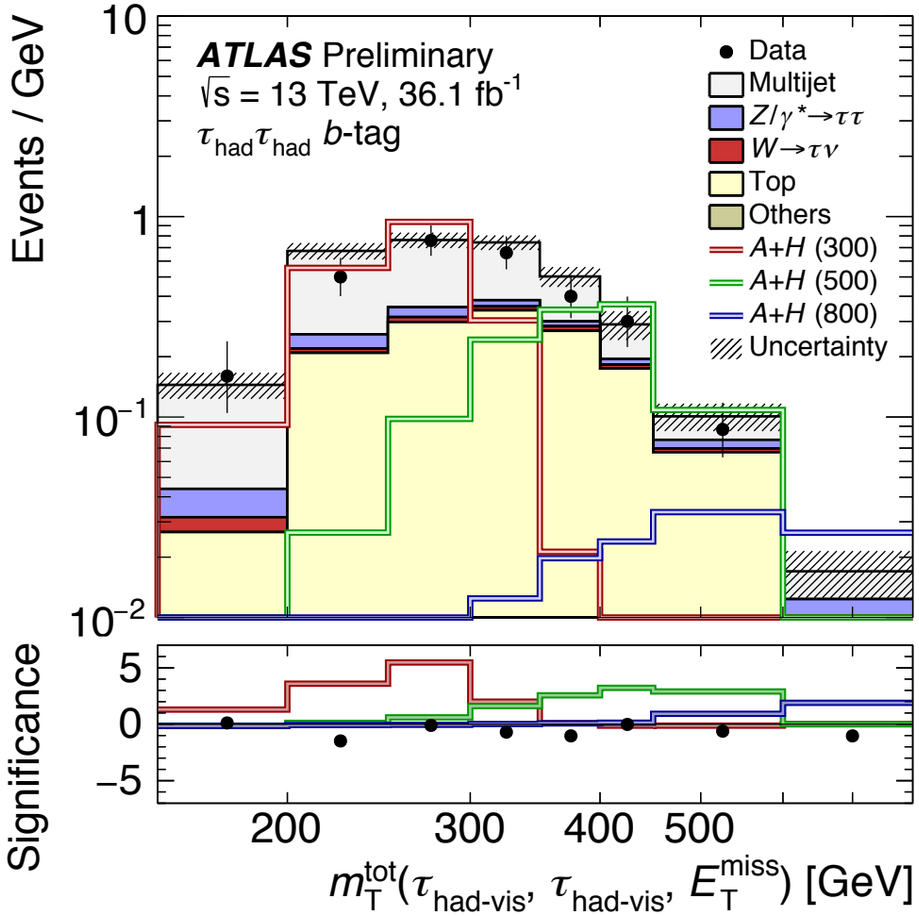


- Reconstruction of $\tau\bar{\tau}$ final states.
  - Two τ decay modes are considered:
    - ✦ All hadronic final state ($\tau_{had}\tau_{had}$) both τ decay hadronically.
    - ✦ Semileptonic final state ($\tau_{lep}\tau_{had}$) one τ decays hadronically and one leptonically.
- Discriminant is total transverse mass:

$$m_{\mathrm{T}}^{\mathrm{tot}} \equiv \sqrt{(\mathrm{p}_{\mathrm{T}}^{\tau_1} + p_{\mathrm{T}}^{\tau_2} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - (\mathbf{p}_{\mathrm{T}}^{\tau_1} + \mathbf{p}_{\mathrm{T}}^{\tau_2} + \mathbf{E}_{\mathrm{T}}^{\mathrm{miss}})^2}$$

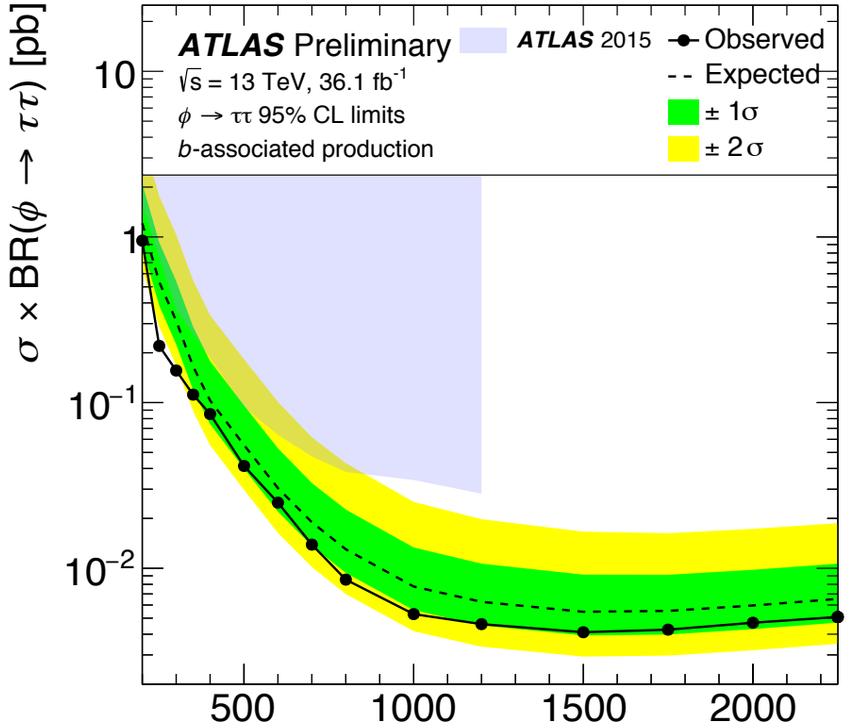
  - Missing energy challenges $m_{\tau\tau}$.
  - Backgrounds larger component in longitudinal axis.

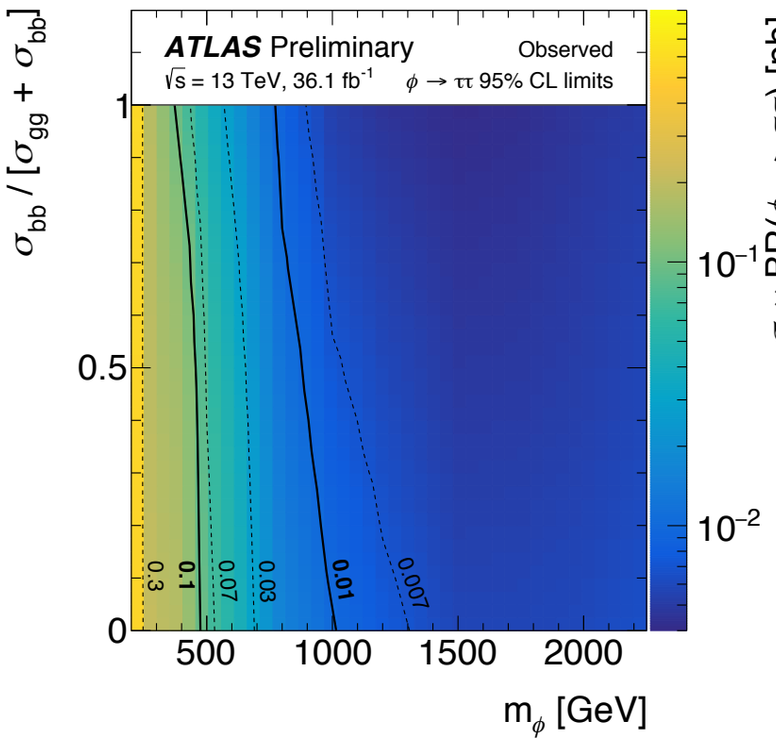


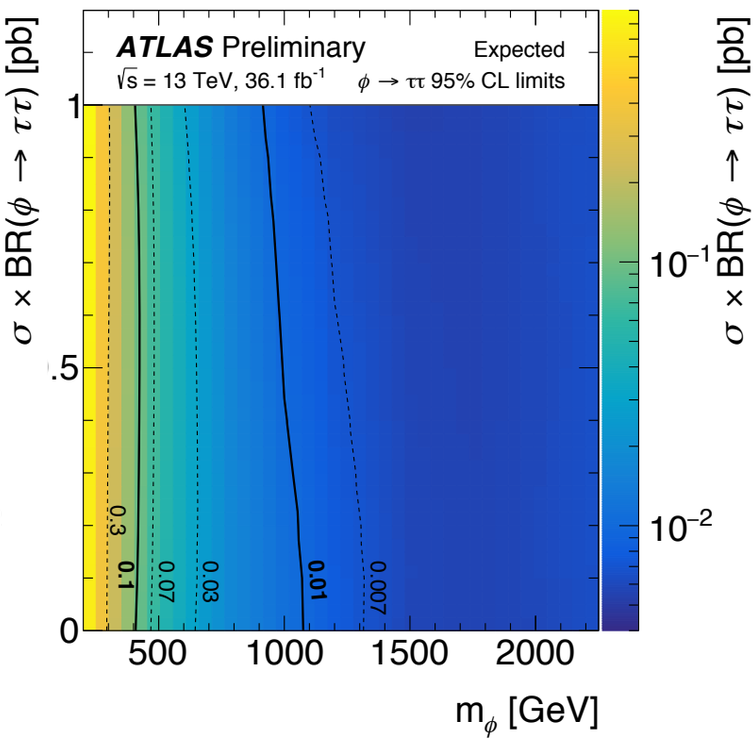


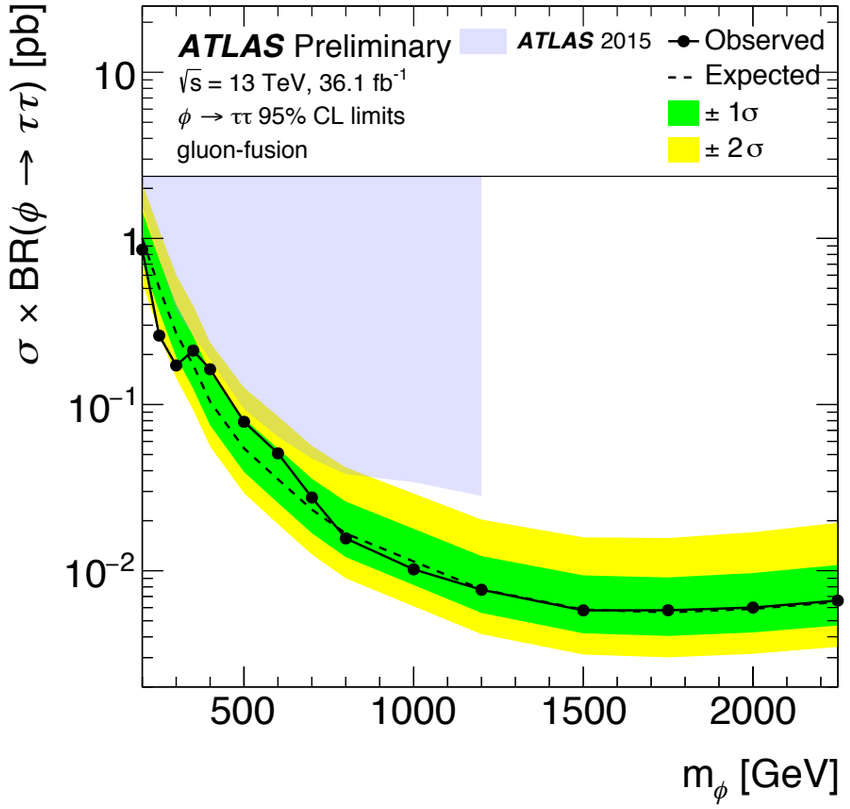
$A/H \to \tau\bar{\tau}$

- Results from profile likelihood fit on transverse mass m_T^{tot}
- Model independent limits on $\sigma \times BR$ (H/A) production
  - Separately for ggF production and b-associated production.
  - Limits from 200 GeV to > 2.0 TeV on m_ϕ
  - Narrow-width assumption of ϕ

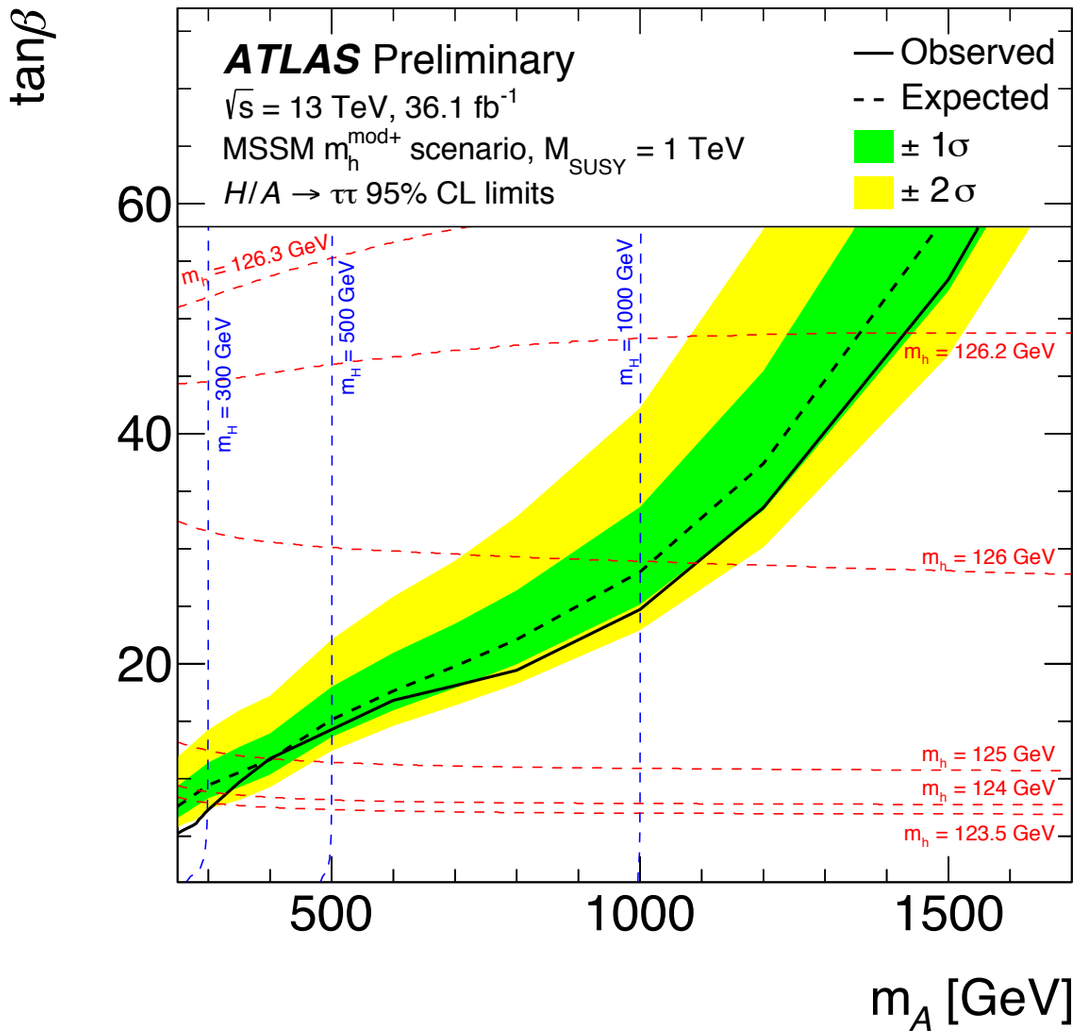


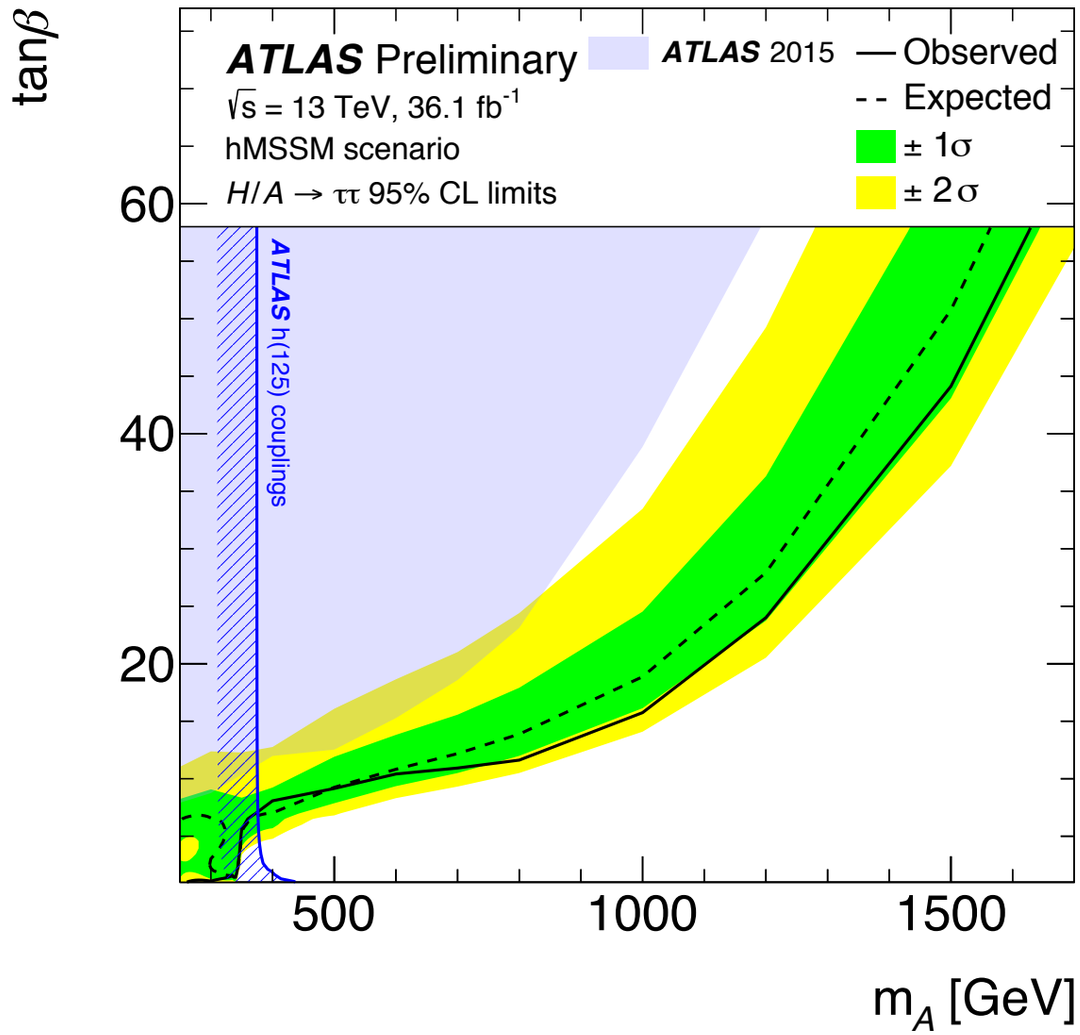






- Results interpreted as limits on MSSM and hMSSM models
  - For hMSSM $\tan\beta$ > 1.0 for m_A=0.25 TeV and $\tan\beta$ > 45 for m_A=1 TeV excluded.
  - For $m_h^{\text{mod+}}$ $\tan\beta$ > 5.3 for m_A=0.25 TeV and $\tan\beta$ > 54 for m_A=1 TeV excluded
    - ✦ Presence of low mass neutralinos decrease $A/H\to\tau\tau$ branching fraction





More details of the $Z'\to\tau\overline{\tau}$ limits in Giacomo Artoni's talk

Conclusions

Conclusion

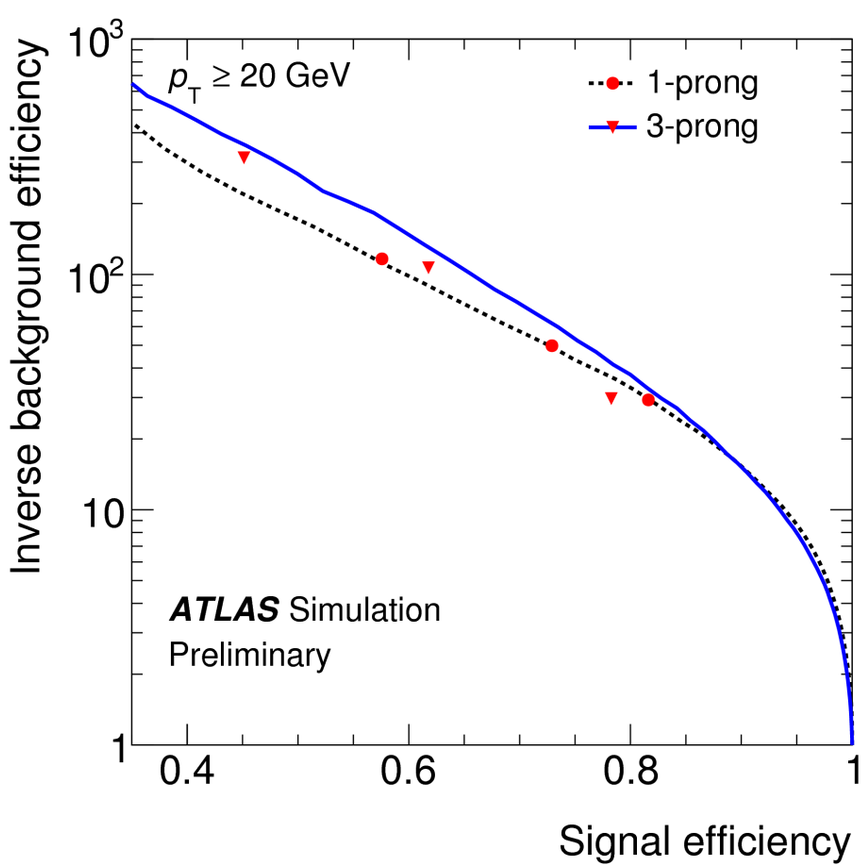
- ATLAS has good sensitivity to standard models extensions
- Searches for new phenomena a involving heavy neutral scalar production
  - Decaying into quarks (*t*) and leptons (τ)
- Carried novel experimental techniques to constrain the background.
  - Multivariate τ identification, background suppression.
- Model independent limits
  - Interpretations on MSSM limits also given.

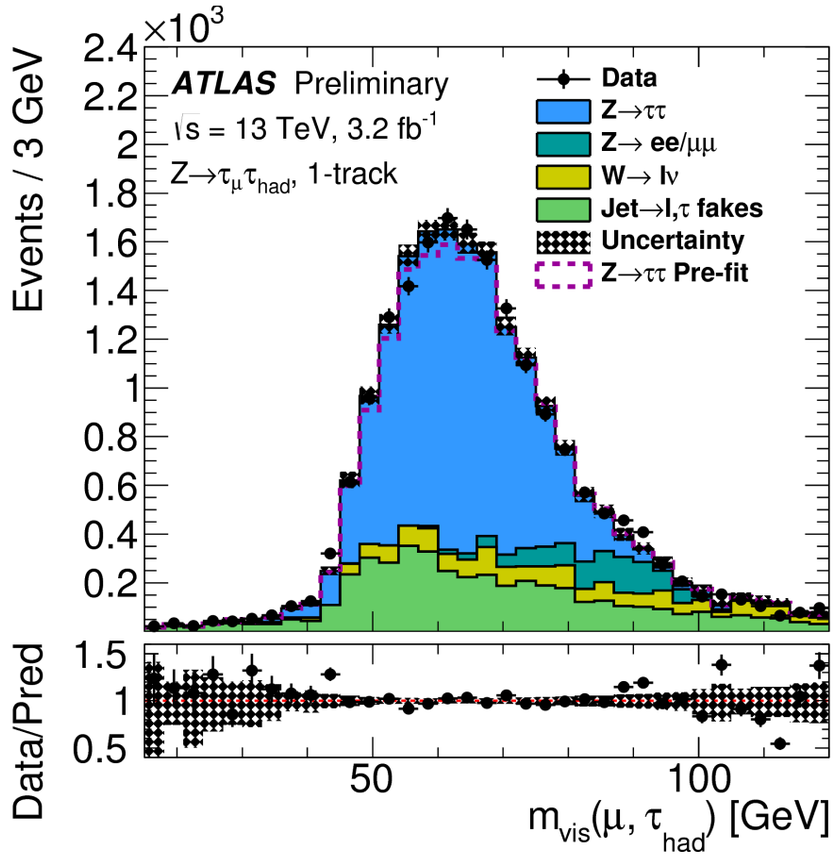
Additional material

- τ reconstruction and event selection

$\tau_{lep}\tau_{had}$	$\tau_{had}\tau_{had}$
One τ_{had} with p_T >25 GeV $\lvert\Delta\varphi(\ell, \tau_{had})\rvert > 2.4$ rad $m_T(\ell, E_T^{miss}) < 40$ GeV	At least two τ_{had} with p_T >65 GeV $\lvert\Delta\varphi(\tau_{had}, \tau_{had})\rvert > 2.7$ rad

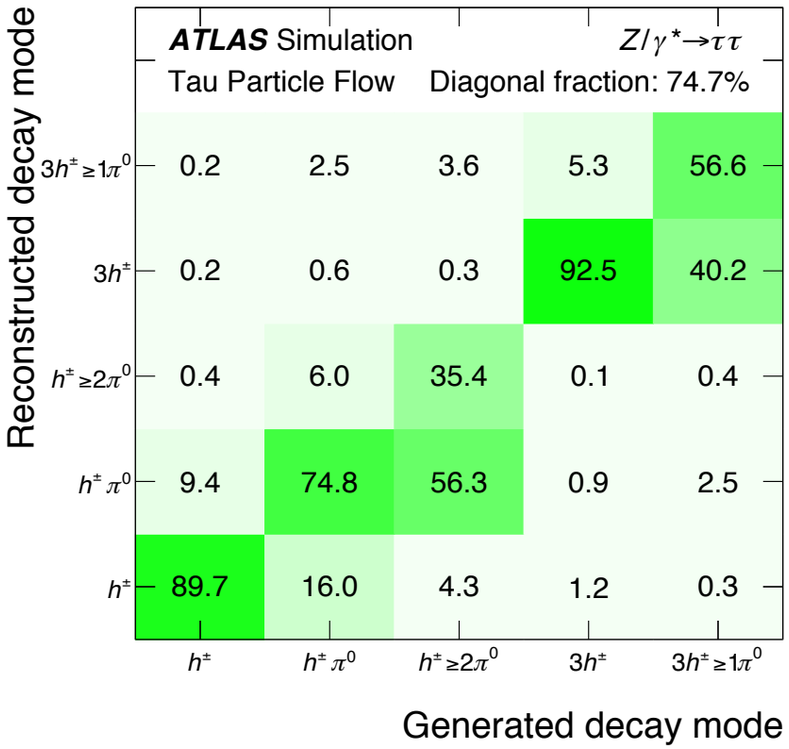
- Hadronic τ decays: one or more charged particles, a neutrino and π^0
- Visible decay products identification based on multivariate technique
- 50% to 60% identification efficiencies measured on $Z \to \tau\tau$

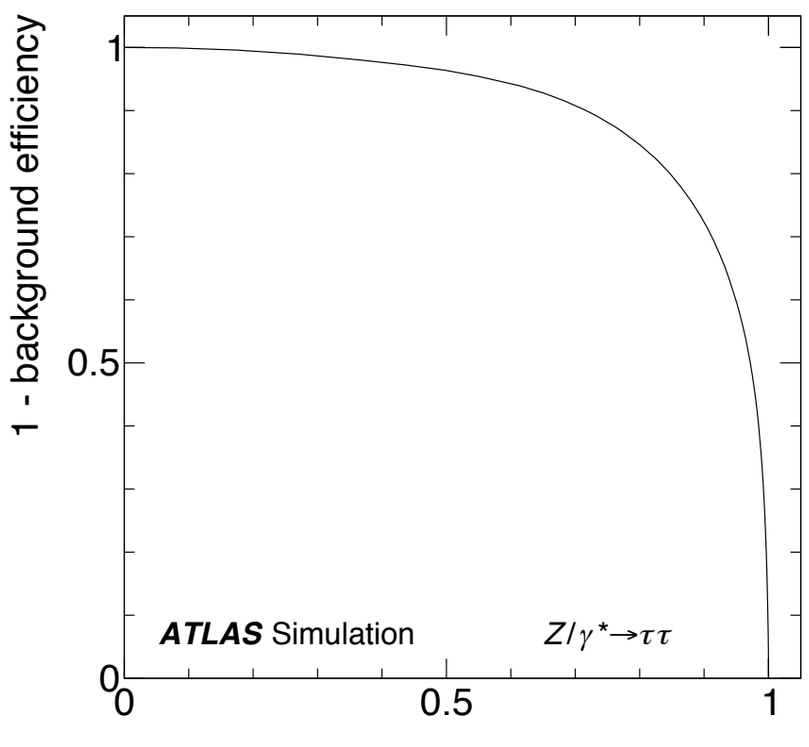


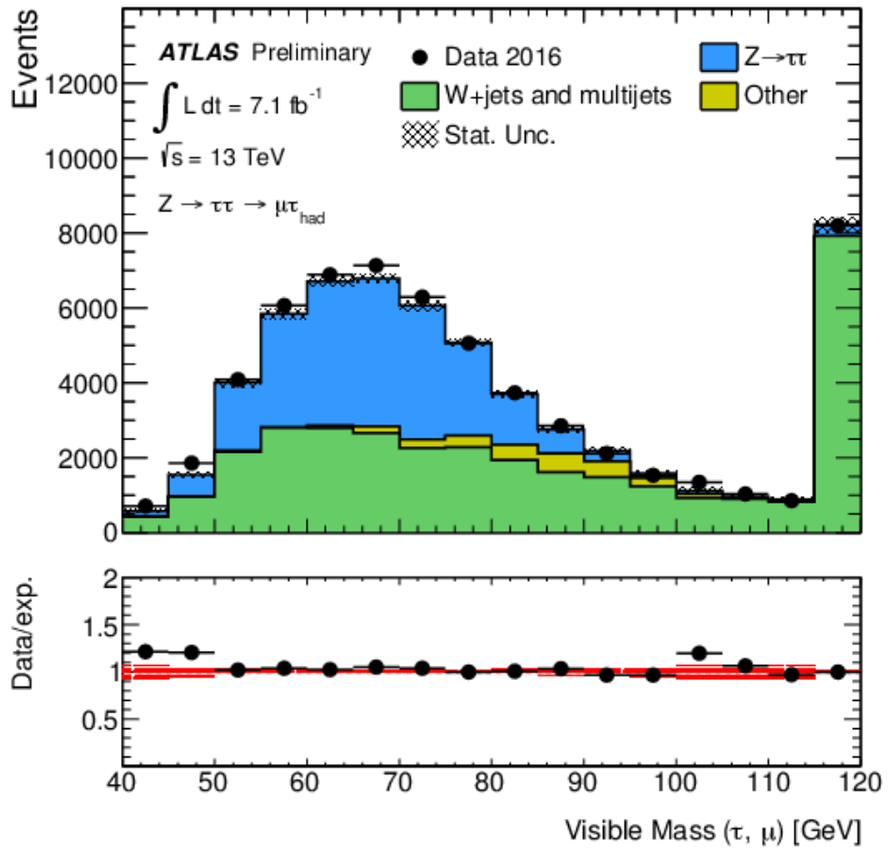


$H/A \to \tau\bar{\tau}$

- Hadronic tau decays: one or more charged particles, a neutrino and π^0
- Visible decay products ID based on multivariate technique
  - Rejection of jets faking a tau lepton.
    - ✦ Shower shapes and track multiplicities.
  - 50% to 60% identification efficiencies measured on $Z \to \tau\tau$







- In τ leptonic decays E_T^{miss} stringent requirements

- Results from profile likelihood fit on transverse mass m_T^{tot}