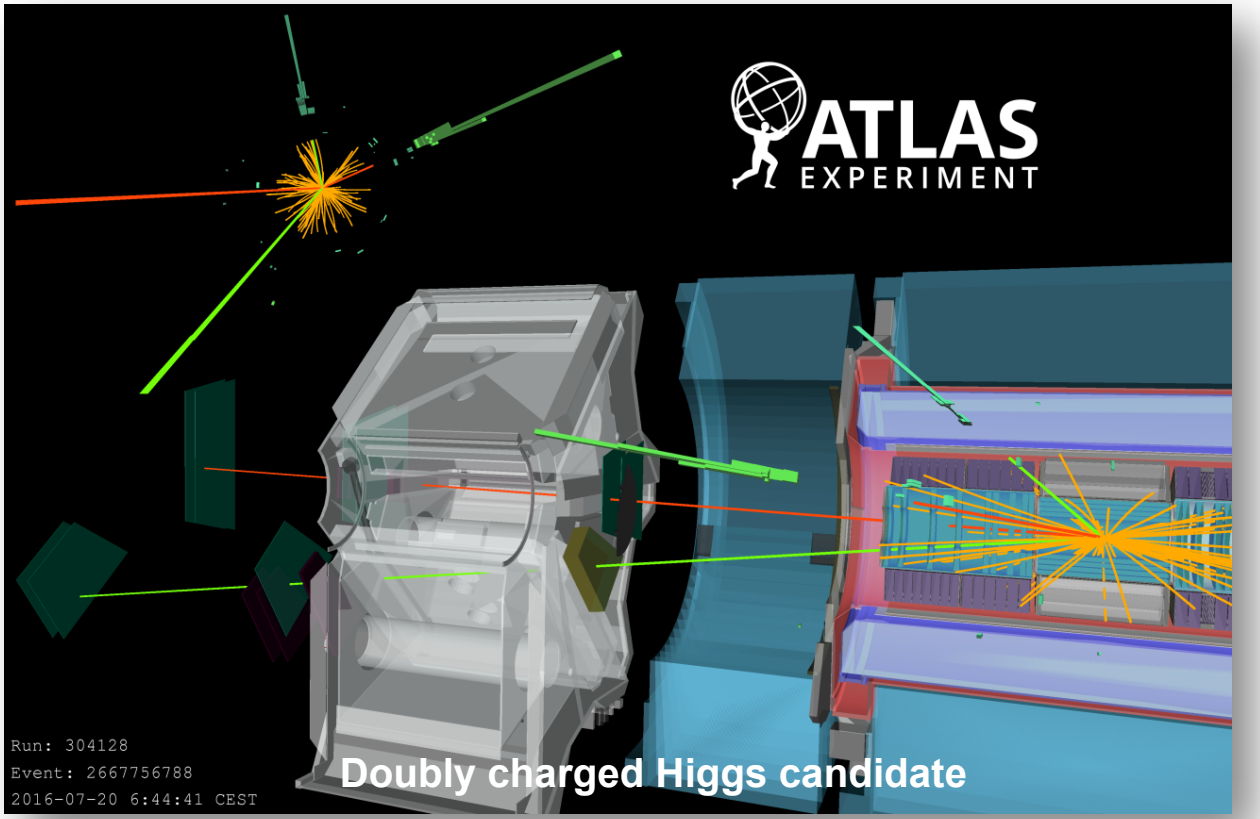
Searches for BSM Higgs bosons @ ATLAS



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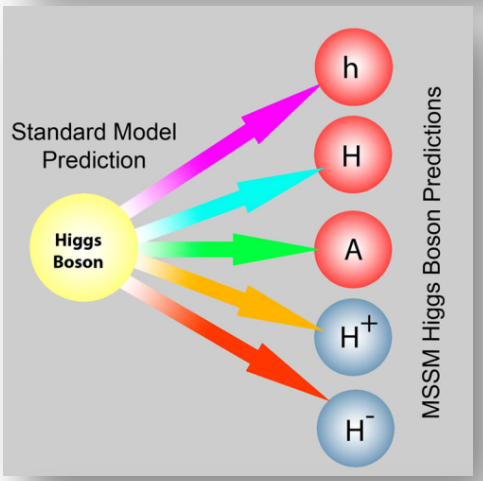
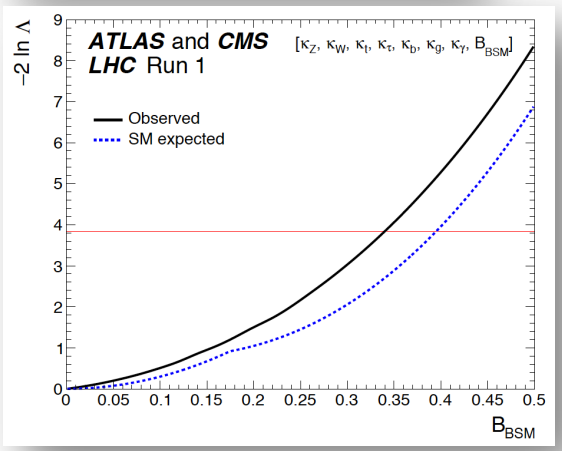
TeVPA 2017

Introduction

- **Higgs boson 2012-discovery completed the SM**
  - **h(125) looks very SM-like so far**
- **Still important phenomena are not included**
- **Several models beyond the SM (BSM) proposed as solutions to these issues which imply additional Higgs bosons**
  - **Neutral (CP-even *H*, CP-odd *A*)**
  - **Charged (singly $H^{\pm}$, doubly $H^{\pm\pm}$)**
- **Searches for BSM Higgs bosons performed by looking at:**
  - **Fermionic, bosonic, di-higgs decays**
  - **Deviations from SM in rare and invisible decays**



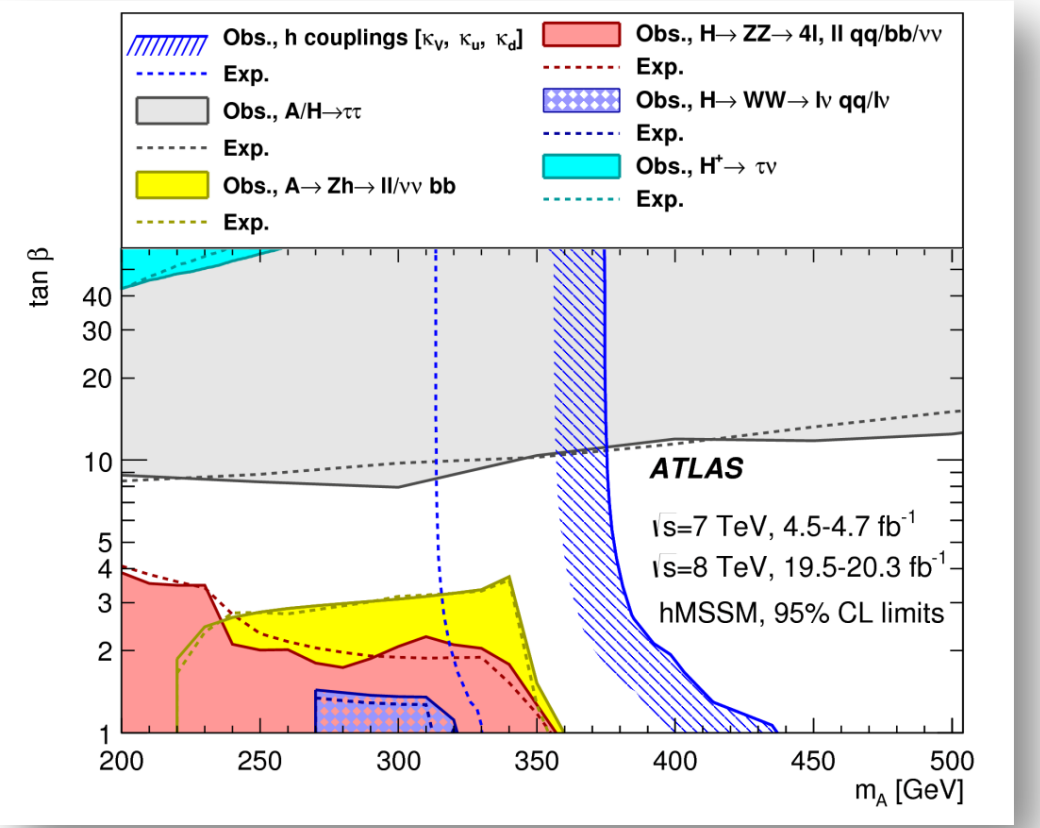


BR to BSM decays < 34% @ 95%CL

arXiv:1606.02266

BSM Higgs

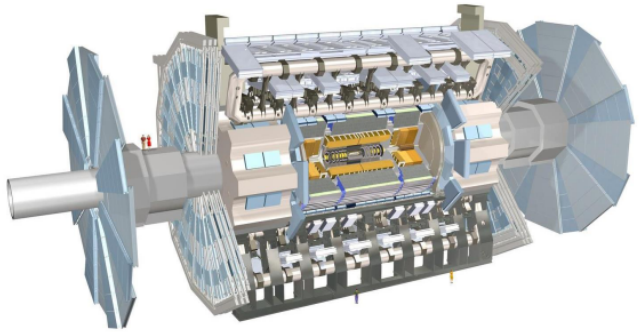
- **Electroweak Singlet**
  - Addition of real scalar singlet results in two bosons: *h* and *H*
- **Two Higgs Doublet Model (2HDM)**
  - 2 Higgs doublets ϕ_1 and ϕ_2
  - 5 Higgs bosons: *h, H, A,* $H^{\pm}$
  - Several types depending on the couplings
  - Many parameters: $tan\beta = v_1/v_2$, mixing angle α, masses
- **Minimal Supersymmetric SM (MSSM)**
  - SUSY in its minimal form
  - Type-II 2HDM with 5 Higgses *h, H, A,* $H^{\pm}$
  - 2 parameters at LO: $tan\beta$ and m_A
  - Phenomenological scenarios (*hMSSM,* m_h^{max}, $m_h^{mod\pm}$)
- **Higgs Triplet Model (HTM)**
  - ϕ^{++}, ϕ^{+}, ϕ^{0}
  - Includes $H^{\pm\pm}$



Run-1 exclusion limits for hMSSM

Phys. Rev. D 92, 092004 (2015)

Summary of results



- **Searches performed with the ATLAS detector**
  - **Run-2 data at $\sqrt{s}$ = 13 TeV: partial 2016 + full 2015 (~15fb^{-1}), full 2015 + 2016 (~36fb^{-1})**
  - **Results presented as:**
    - **Discovery!**
    - **limits on production cross section of new Higgs bosons**
    - **Constraints on BSM physics benchmark scenarios**

- **Neutral *H* to bosons**

$$H \to \gamma\gamma$$
$$H \to WW \to l\nu qq'$$
$$H \to ZZ \to 4l/2l2\nu$$

- **Neutral *H* to fermions**

$$A/H \to \tau\tau$$

- **Neutral *H* to SM di-higgs**

$$H \to hh \to WW\gamma\gamma$$

- **Charged Higgs**

$$H^{\pm} \to \tau^{\pm}\nu$$
$$H^{\pm} \to tb$$
$$H^{\pm\pm} \to 4l$$

- **Invisible and rare decays**

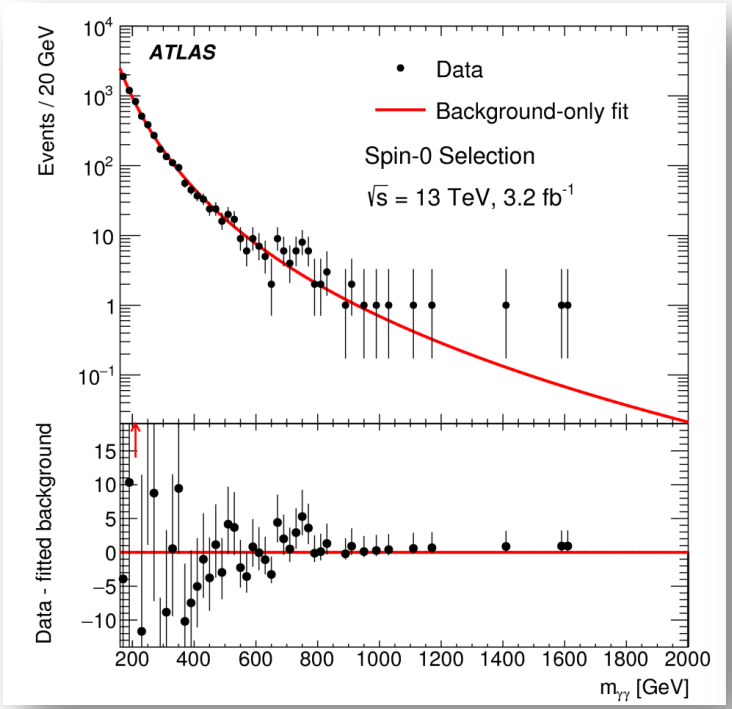
$$H \to inv \quad (ZH \to ll + E_T^{miss})$$
$$H \to Z\gamma$$
$$H \to \phi\gamma/H \to \rho\gamma$$

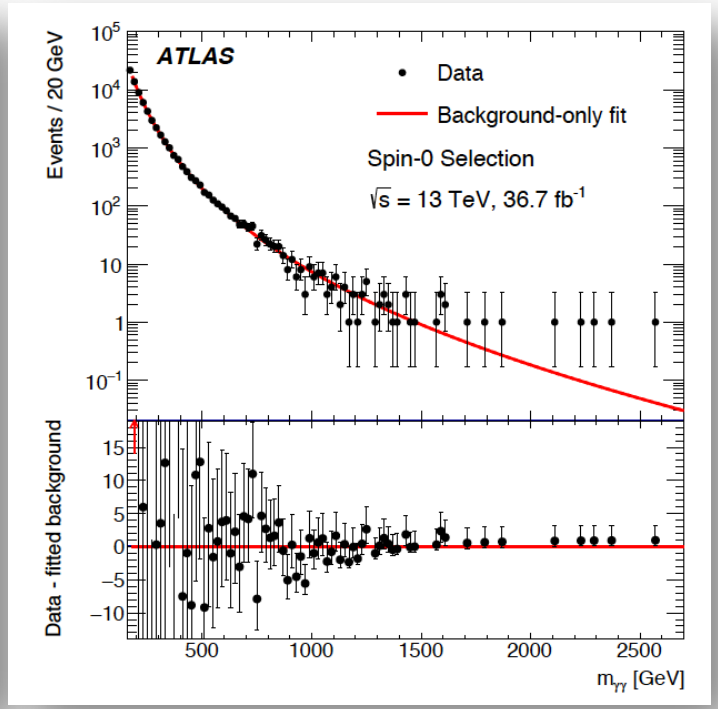
Neutral Higgs Boson to Bosonic final states

$H \rightarrow \gamma\gamma$

arXiv:1707.04147

- Two high-p_T photon final state
- In 2015 ATLAS and CMS reported ~3σ excess around 750 GeV with 3.2 fb^{-1}
- Latest result with 11 times that data shows no excess within 1σ
- Spin-0 and spin-2 (RS-model and KK-graviton) resonances search

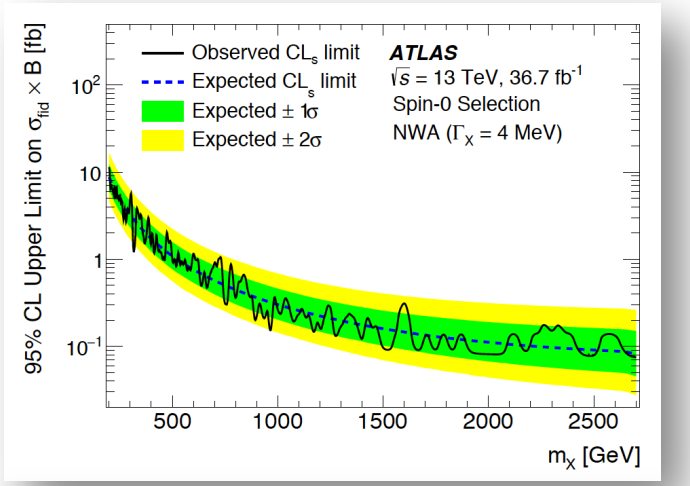


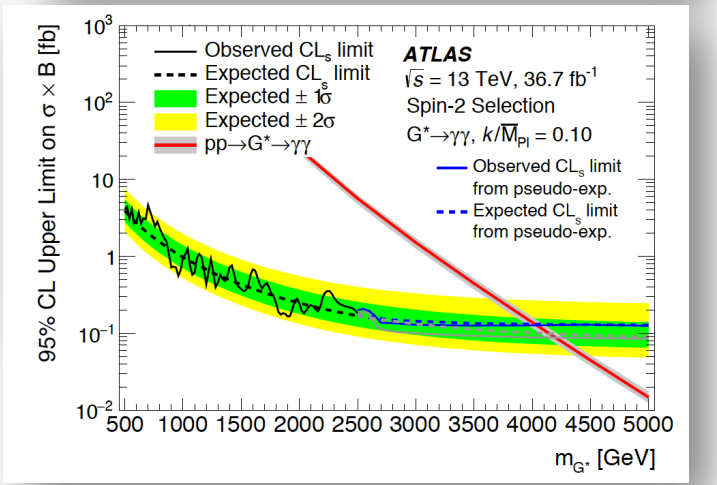


2015

2017

@750GeV: 3.0σ_{local}, 0.8σ_{global}

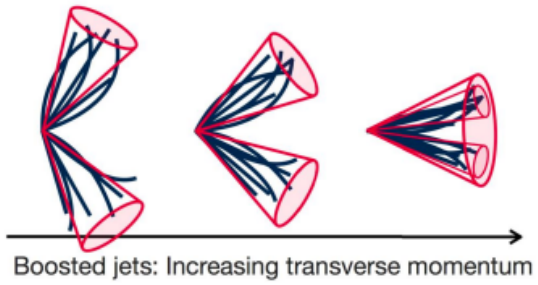


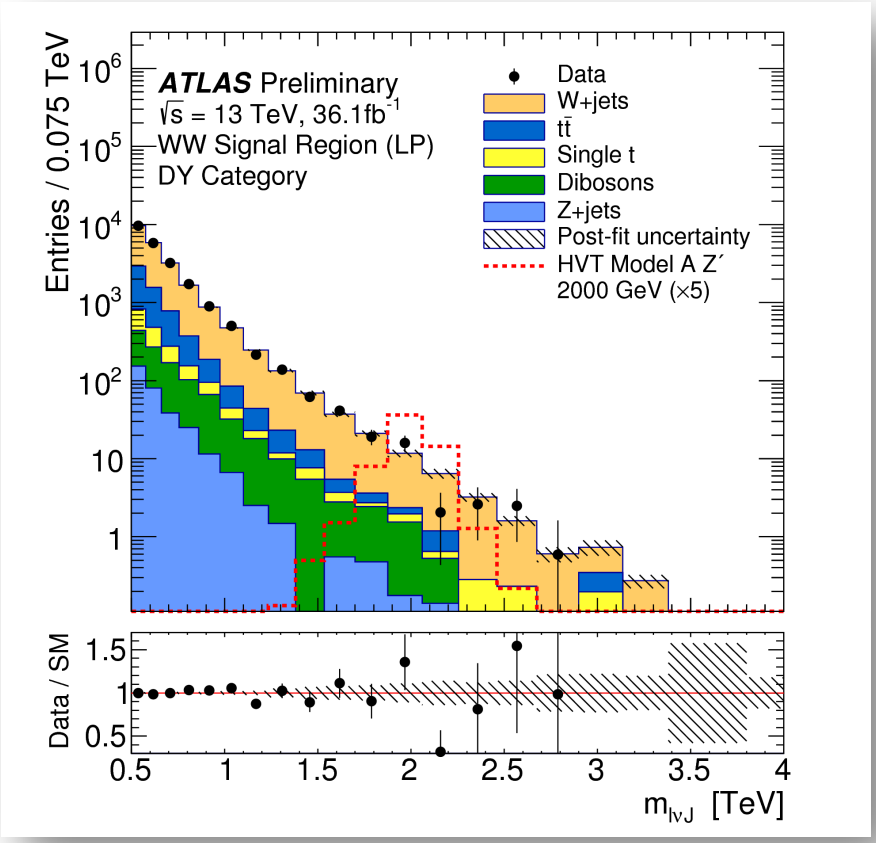


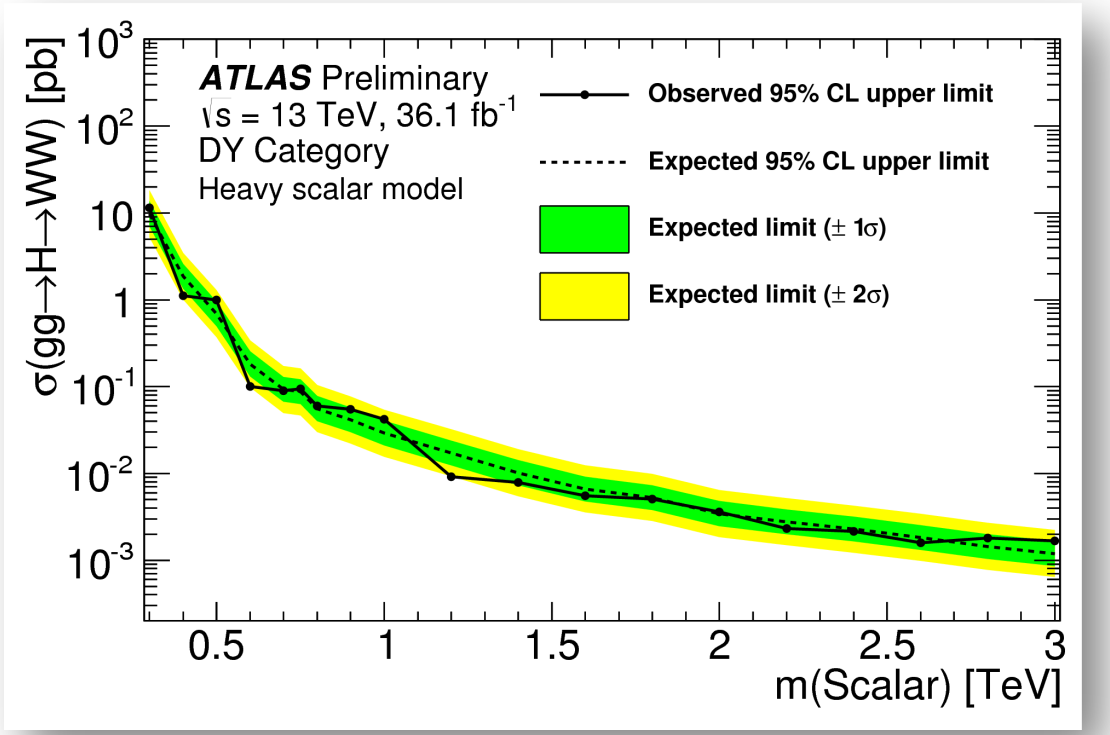
H → WW/WZ → *lνqq'*

ATLAS-CONF-2017-051

- **WW/WZ resonance search in the NWA (4 GeV)**
- **One W decays leptonically and the other boson to hadrons**
  - **Boosted boson tagging**
- **2 production modes considered: VBF and ggF**
- **Three signal hypothesis considered:**
  - **HVT, RS graviton, NW heavy scalar**



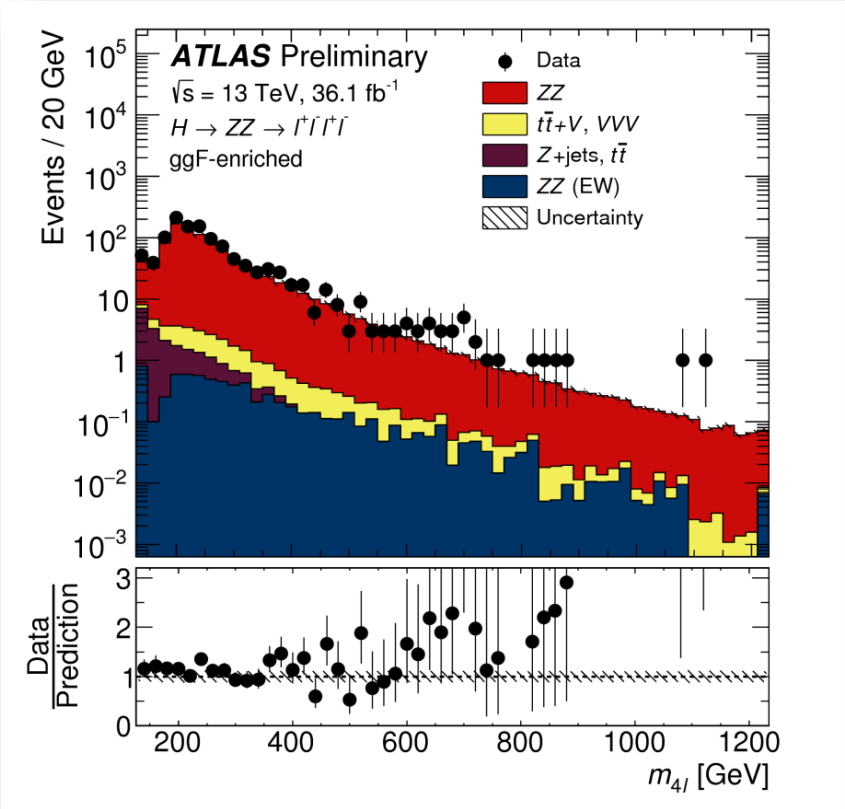




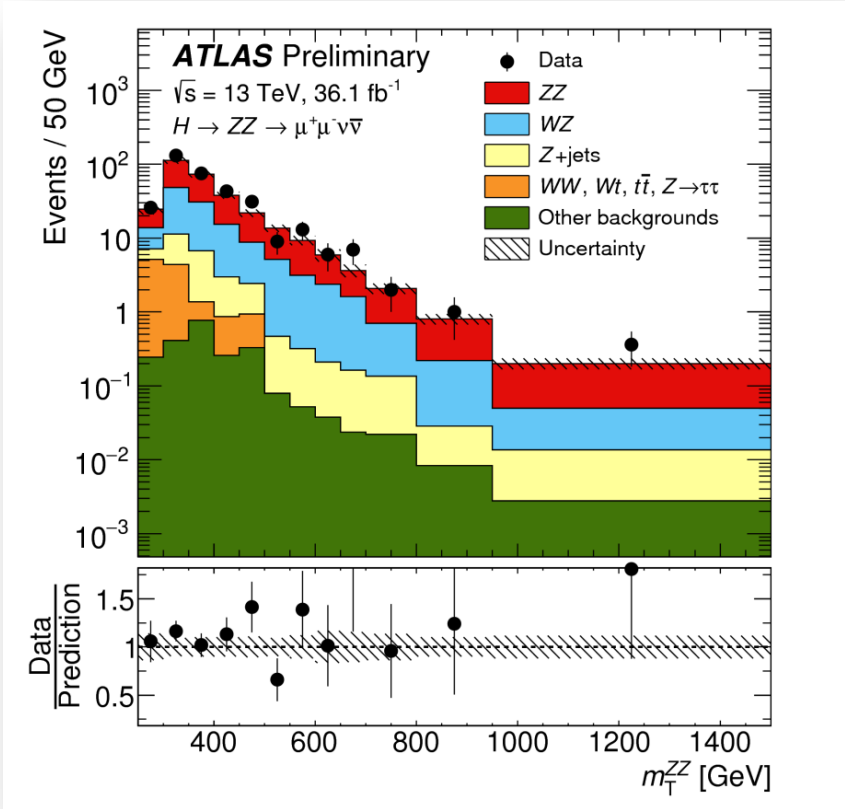
$H \rightarrow ZZ \rightarrow 4$ leptons

ATLAS-CONF-2017-058

- **Resonance search in the $4l$ and $2l2\nu$ final states using m_{4l} and m_T, respectively**
  - **Fully reconstructed pair of Zs decaying to 4 leptons**
- **Heavy higgs (H) in ggF and VBF modes decaying to ZZ in a NWA**
  - **Events with 2 separated jets with high dijet mass: VBF, ggF otherwise**
- **Also LWA considered**
- **Interpretation for bulk Randall-Sundrum Graviton Model and Heavy Scalar**



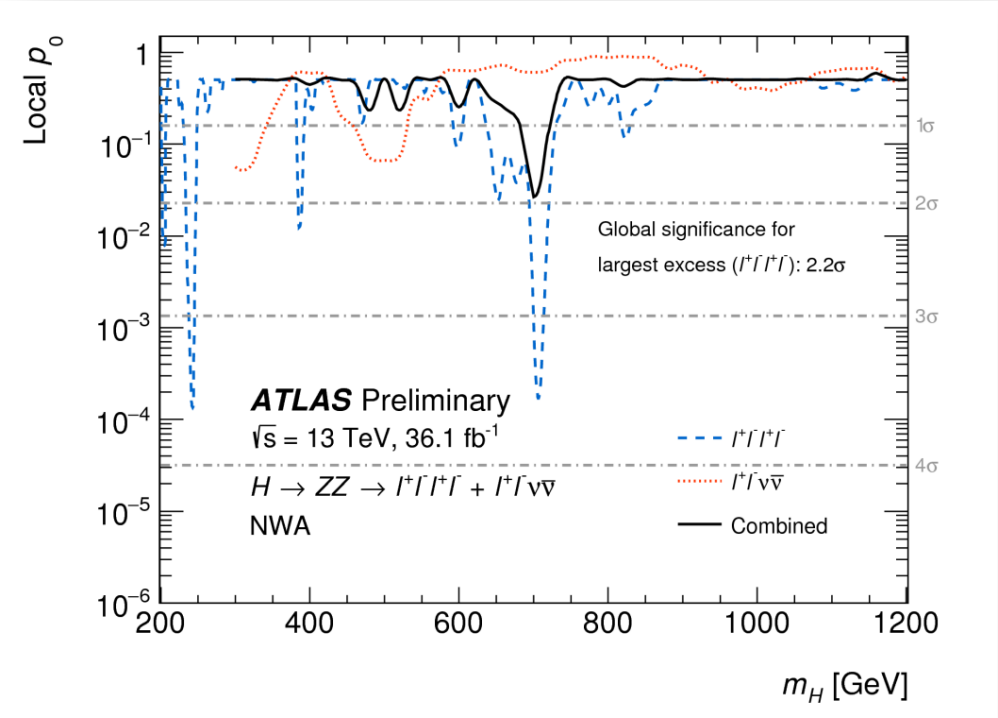
$4l$ – ggF-enriched

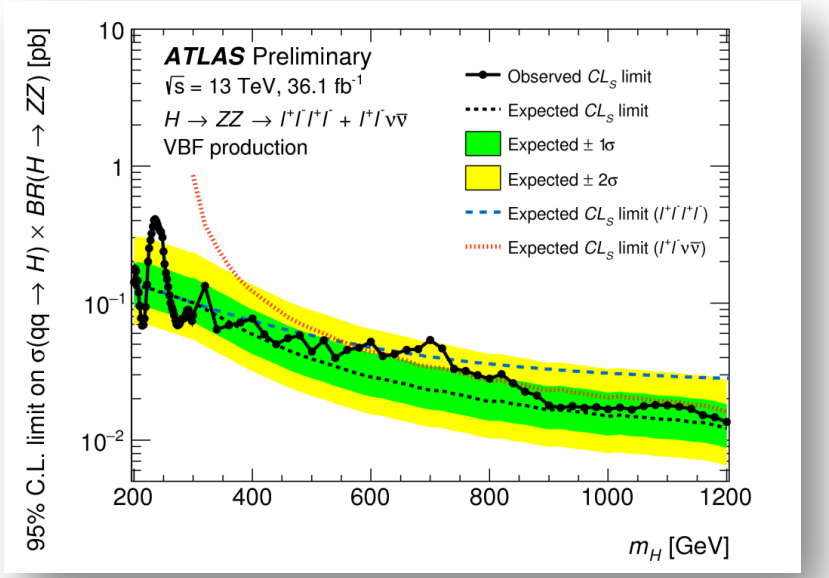


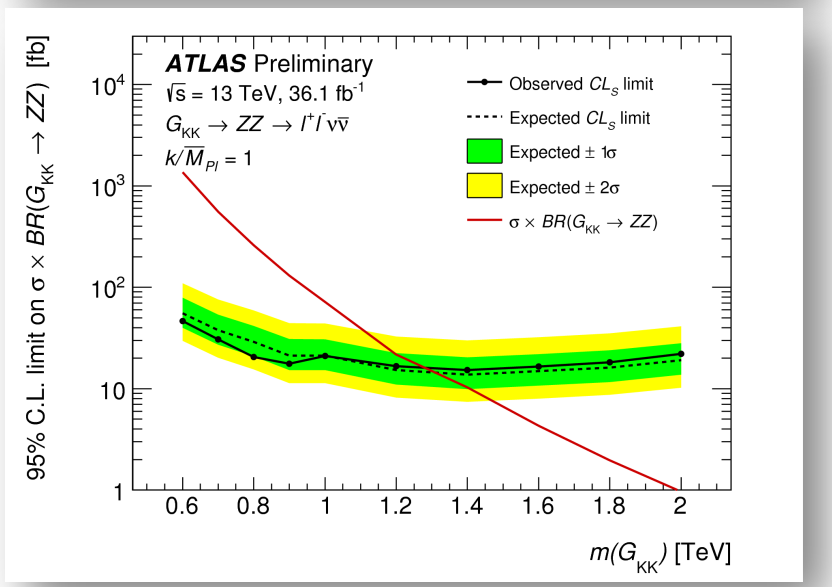
$2l2\nu$ – VBF-enriched

H → ZZ → 4 leptons

ATLAS-CONF-2017-058







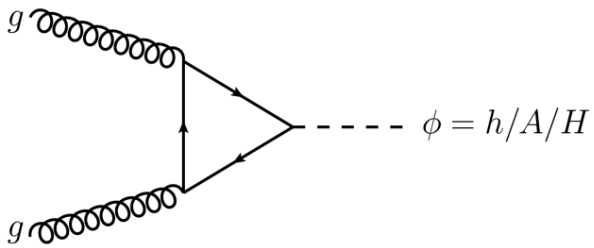
- **Data excess in NWA at 240 and 700 GeV predominantly in ggF 4*l* categories**
  - **3.6σ (local), 2.2σ (global)**
- **Also exclusion limits in 2HDM, RS graviton and LWA**

Neutral Higgs Boson to Fermionic final states

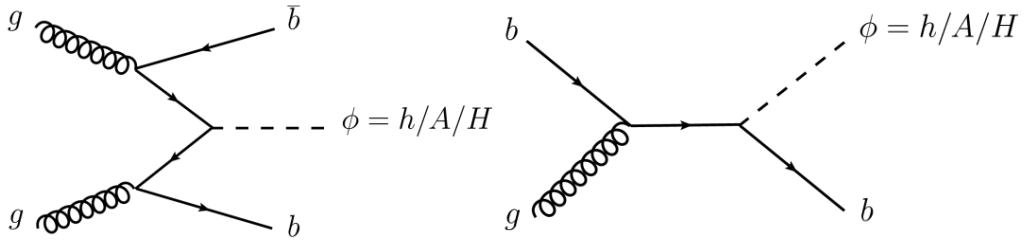
A / H → ττ

ATLAS-CONF-2017-050

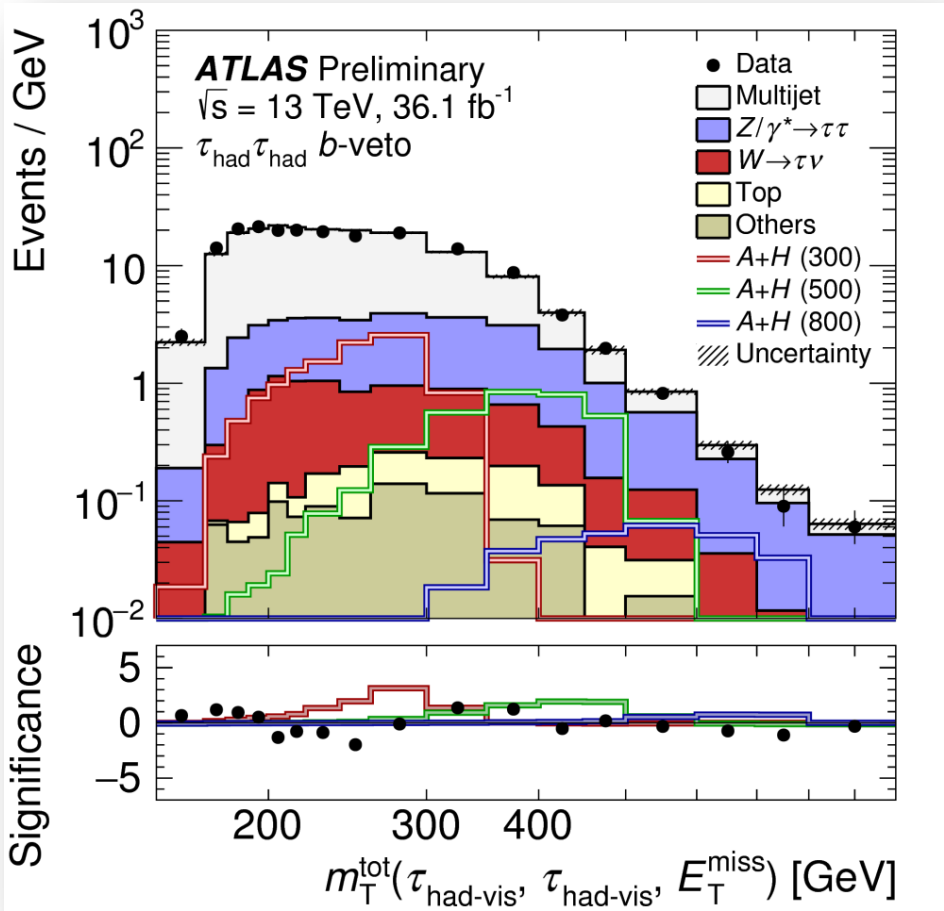
- Heavy resonance search in di-tau events
  - Two final states: semileptonic tau decays and fully hadronic
- Promising search for high tanβ
- Two main categories: b-tagged (bbH) and b-veto (ggF)
- Results interpreted in many MSSM scenarios
  - Large *tan*(β) enhances H coupling to down fermions (tau, b)



ggF



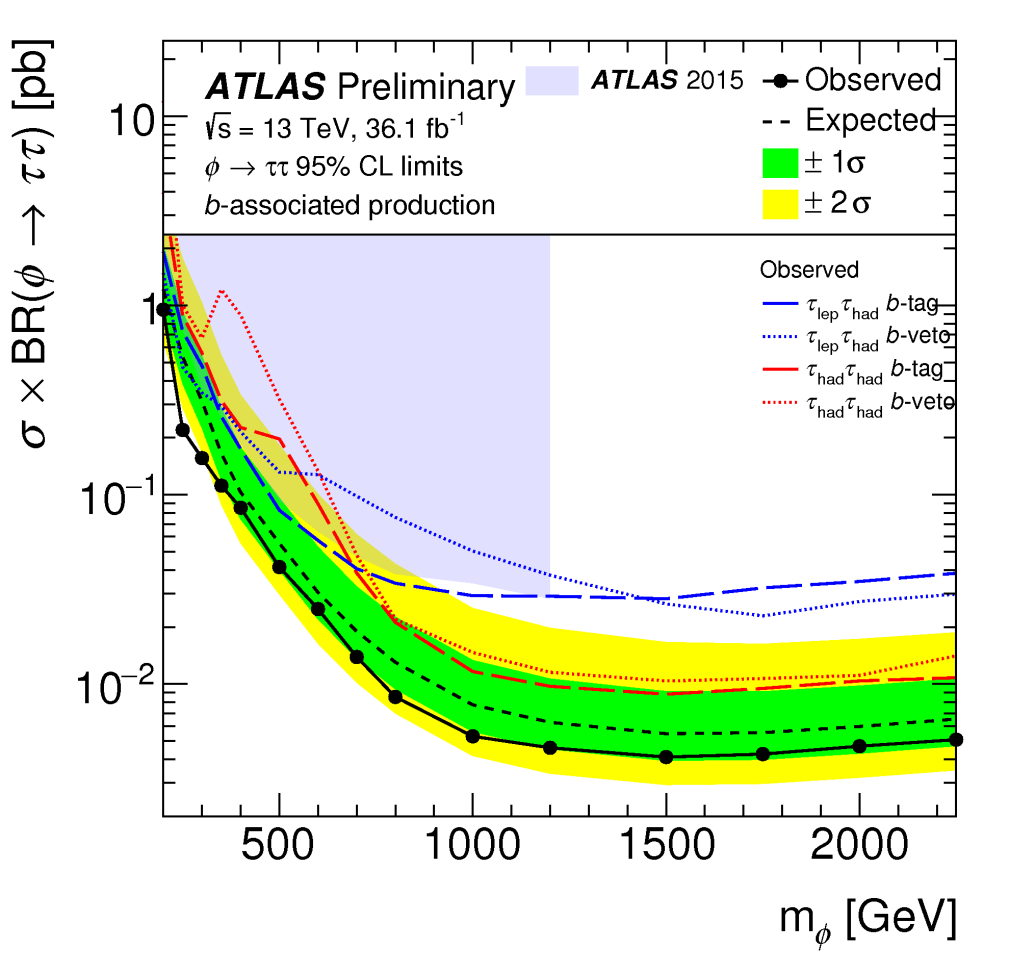
b-associated

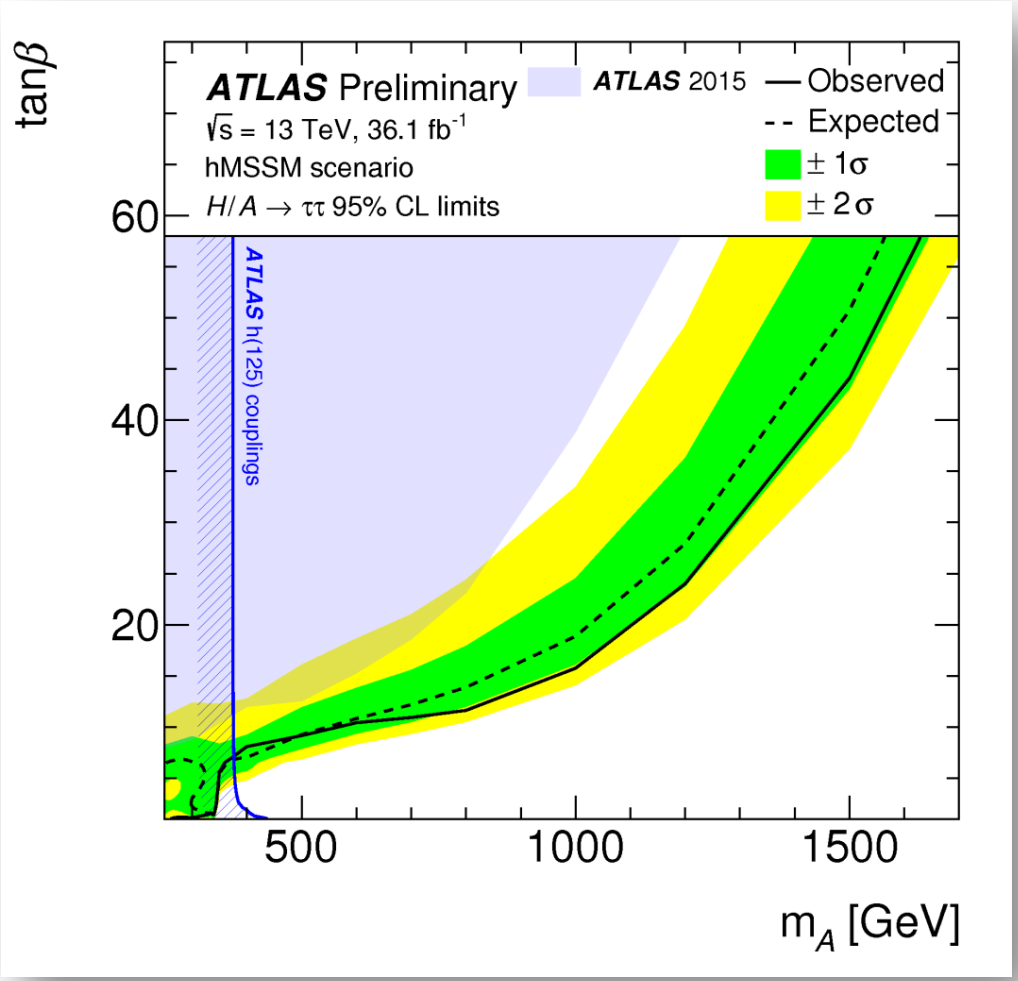


A / H → ττ

ATLAS-CONF-2017-050

- **Excusion limits on σ *x BR* for model independent (ggF, bbH) and model dependent (m_h^{mod+}, hMSSM)**



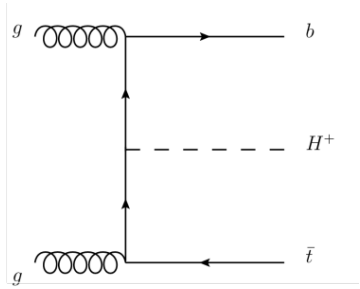


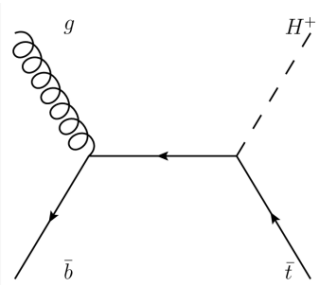
Charged Higgs Boson

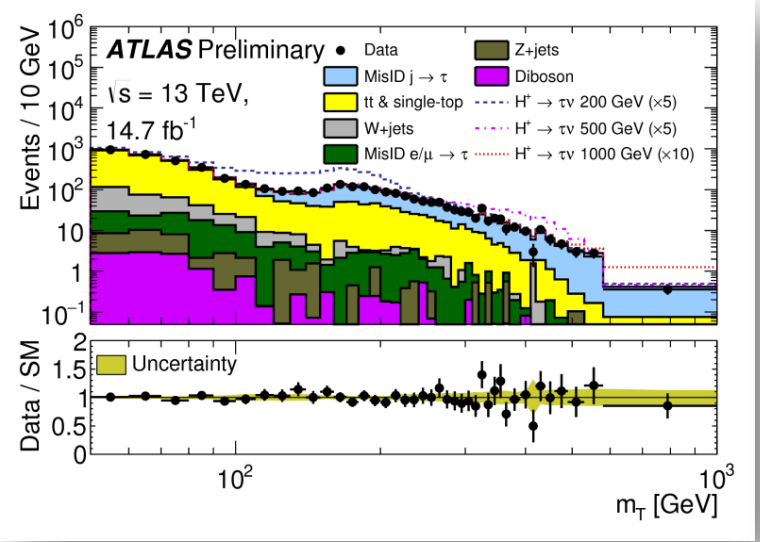
$H^{\pm} \rightarrow \tau^{\pm}\nu$

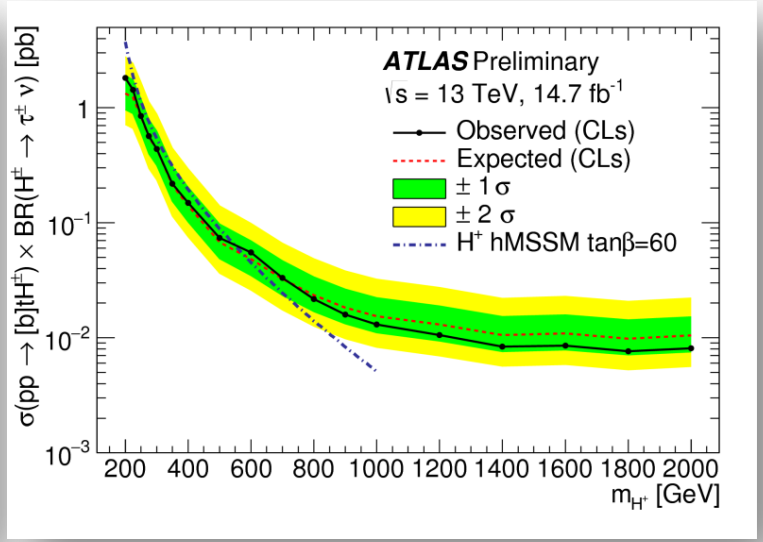
ATLAS-CONF-2016-088

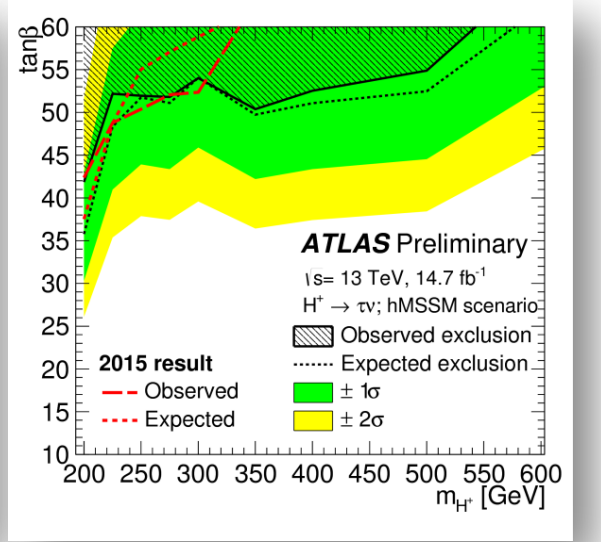
- **Final state: τ, E_T^{miss} and a top quark**
  - **Fully hadronic τ decays**
- **Limits on production cross section and parameter values**
- **Results interpreted in various scenarios**
  - **MSSM shown**
- **No significant excess**







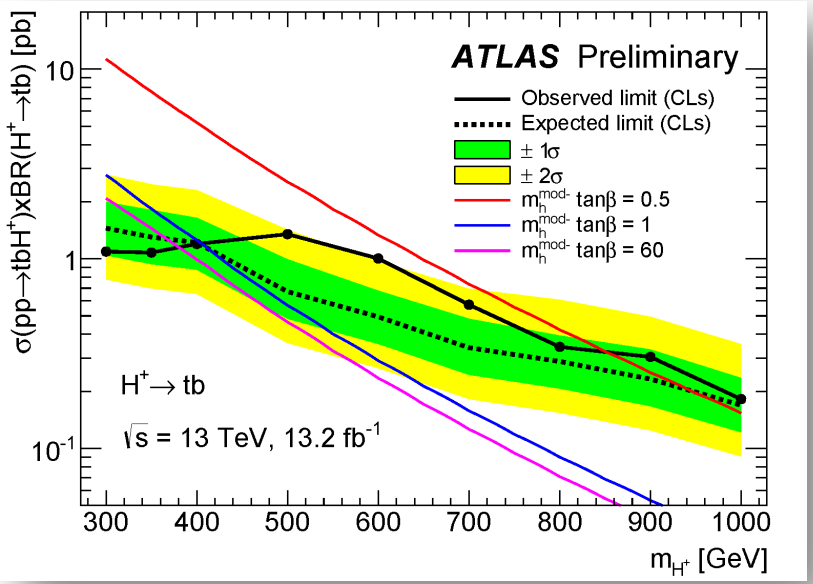


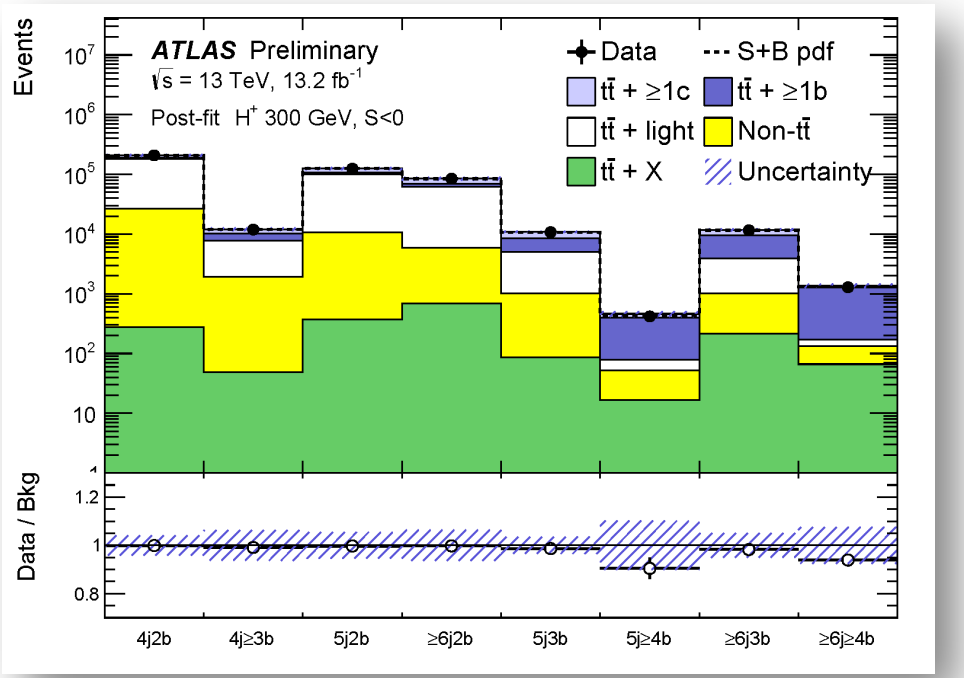


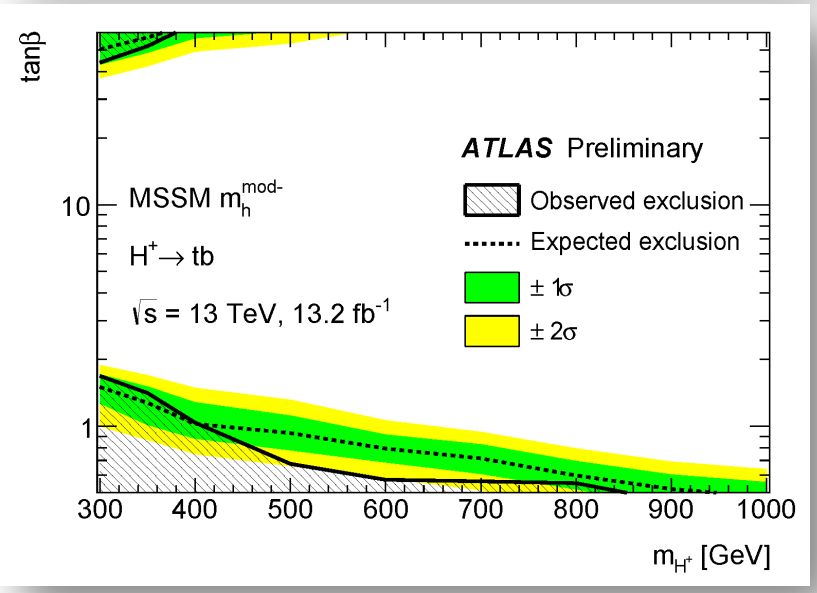
$H^{\pm} \rightarrow tb$

ATLAS-CONF-2016-089

- Same production mode as in previous result
- Final state: 1lepton, E_T^{miss} + jets (some b-jets)
- Events categorized in different signal/control regions
  - Use MVA technique for final discriminant
  - Simultaneous fit in all regions
- Result interpreted in m_h^{mod-} scenario of MSSM



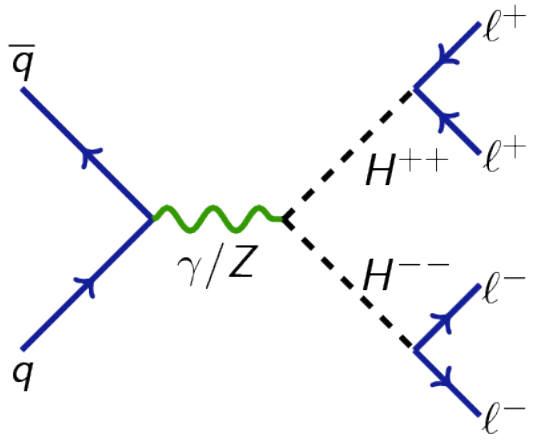


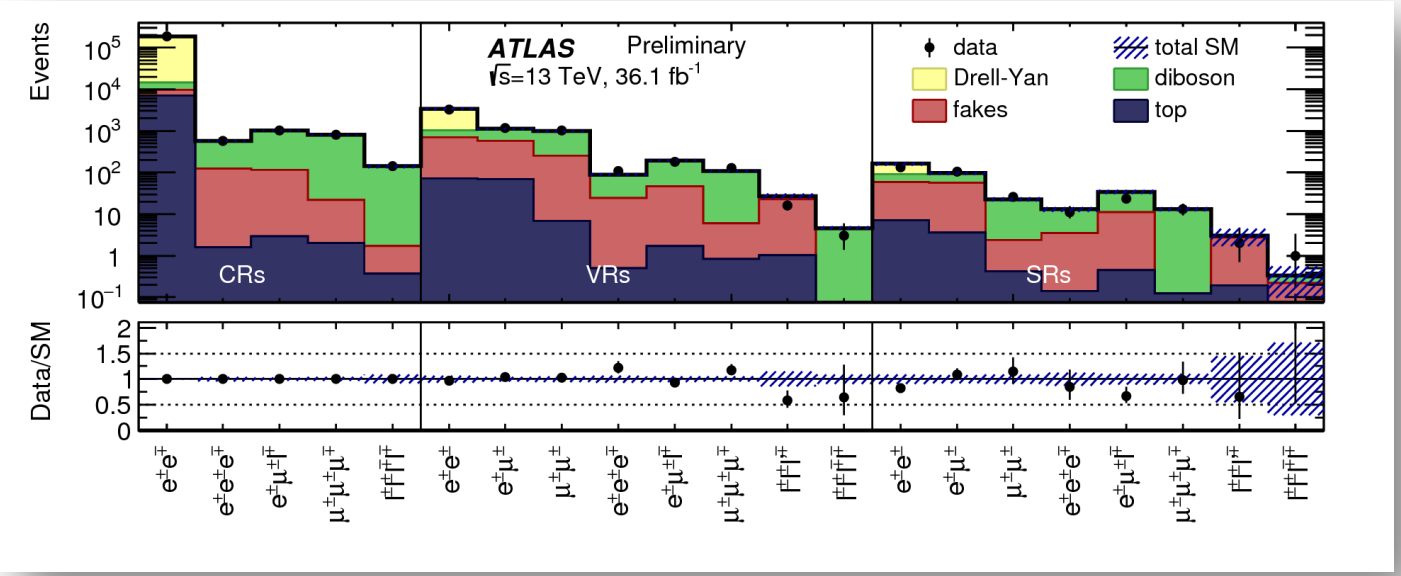


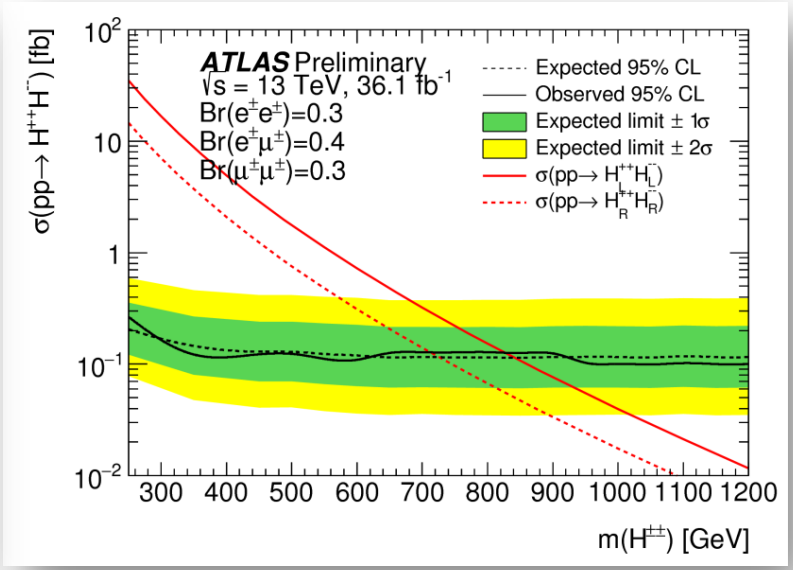
$H^{\pm\pm} \rightarrow$ 4 leptons

ATLAS-CONF-2017-053

- Doubly charged Higgs bosons from many BSM scenarios
- Pairs of high-p_T isolated SS leptons (e,μ)
  - Prompt leptons, fake leptons and charge-flip backgrounds
- Fit several control and signal regions
- Limits assuming different BRs





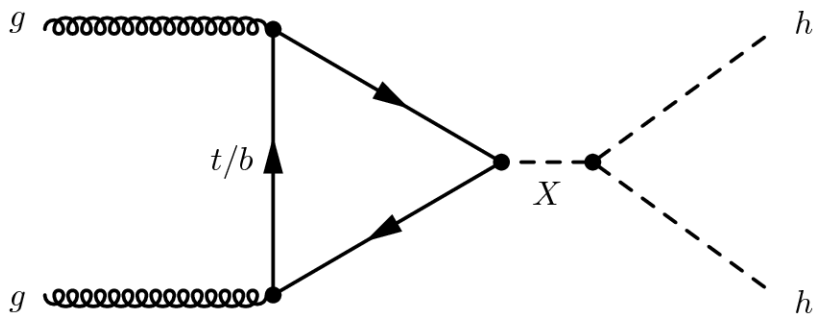


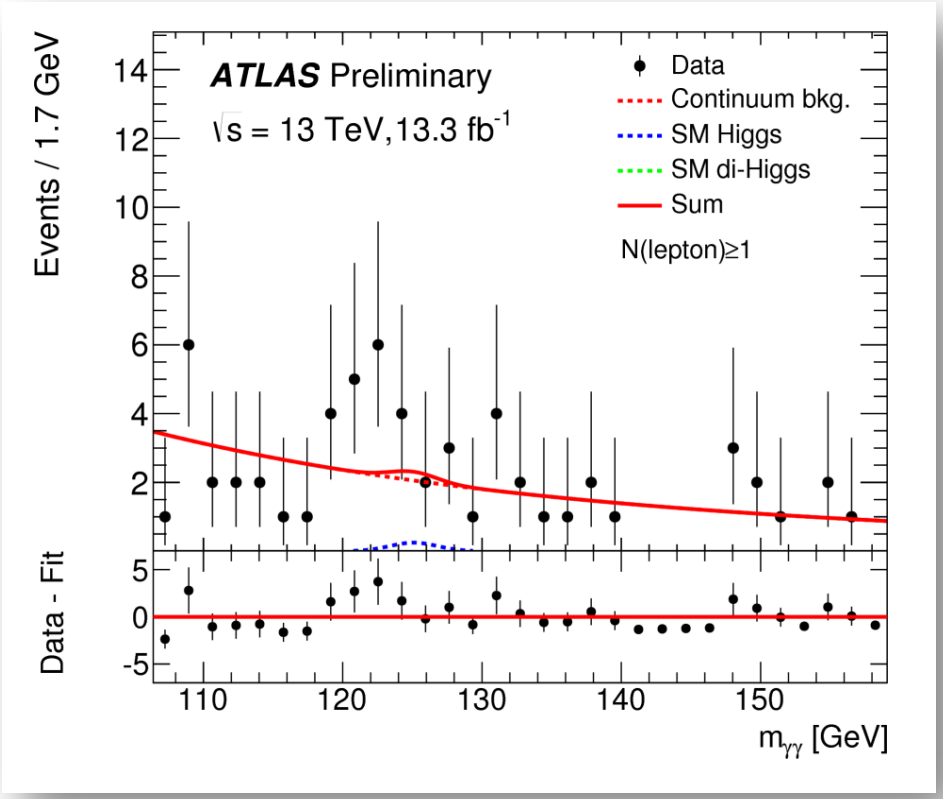
Di-Higgs production

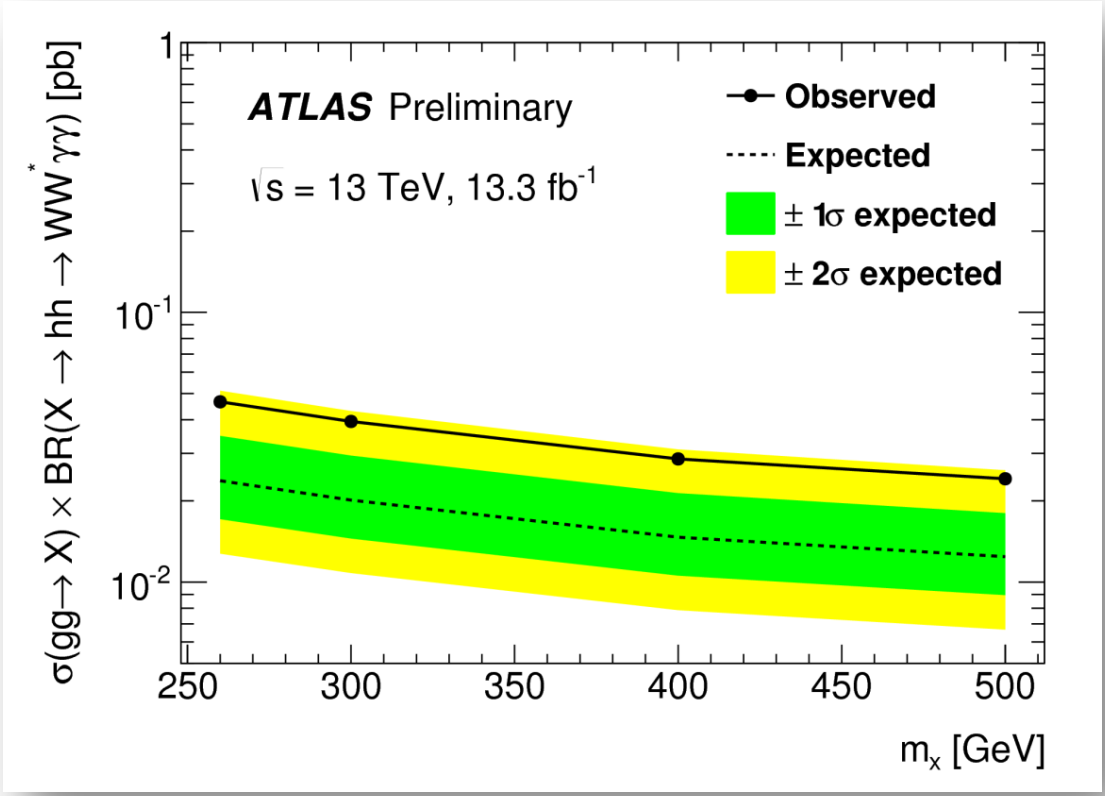
$H \rightarrow hh \rightarrow WW\gamma\gamma$

ATLAS-CONF-2016-071

- **Large BR of WW and clean signature of two photons and 1 lepton**
  - **Low BR of $\gamma\gamma$ limits sensitivity at high mass**





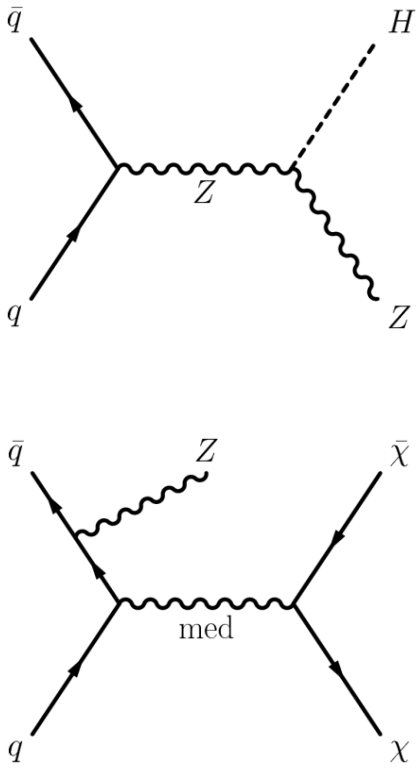


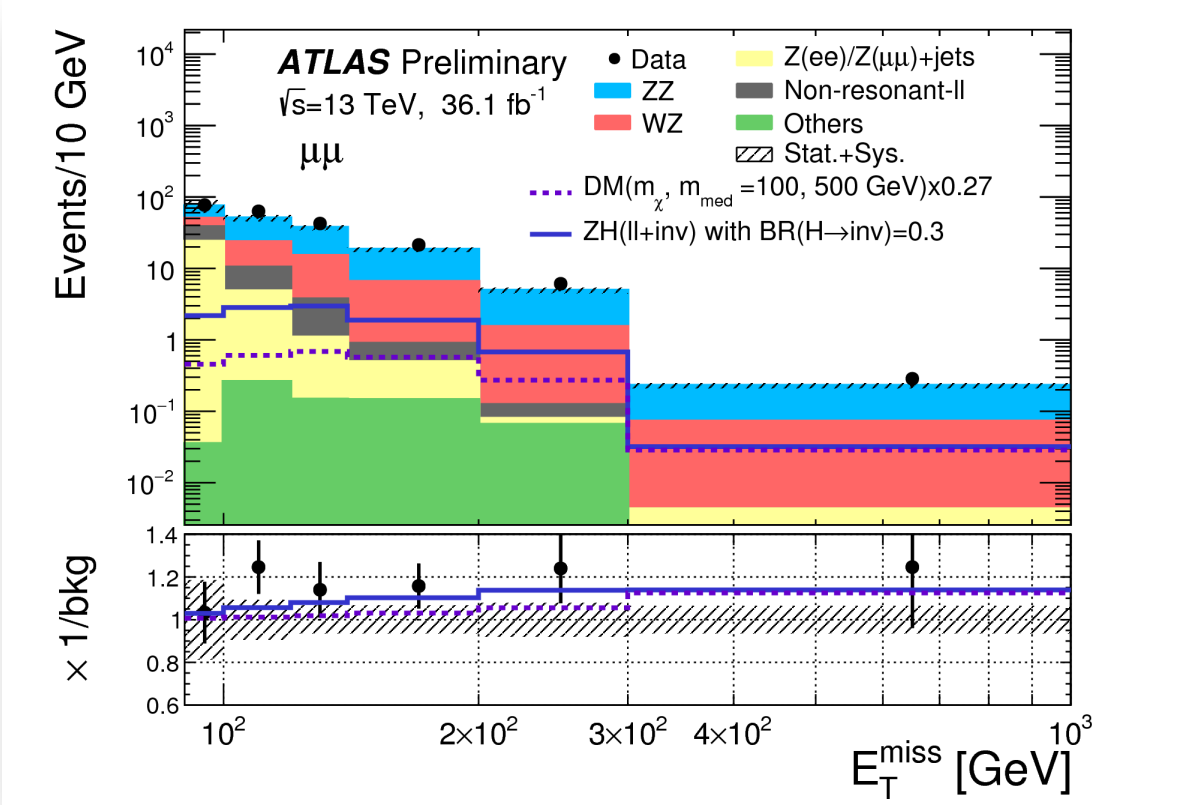
Higgs boson rare or invisible decays

H → invisible

ATLAS-CONF-2017-040

- Clear signature for ZH → *ll* + E_T^{miss}
  - The SM invisible decay (H→ZZ→ 4neutrinos) has *BR* ~ 10^{-3}
- Assume SM ZH production to place upper limit on *B*(H→inv)
- Interpret result in DM models with BSM vector mediator
- Small excess in μμ channel (2.2σ)

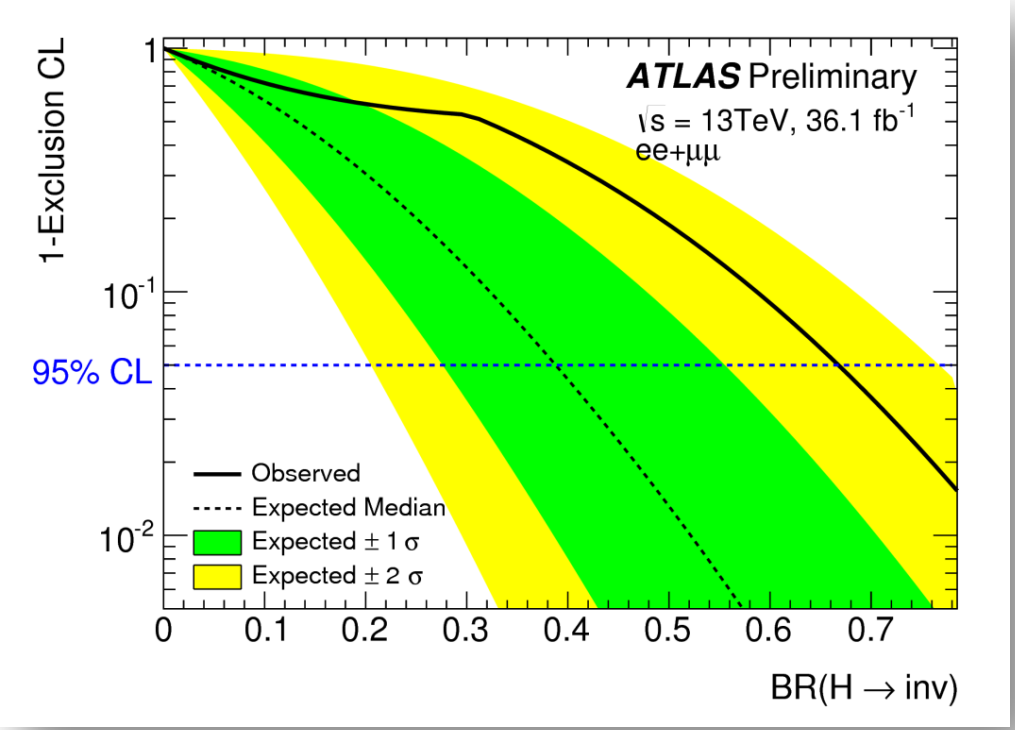


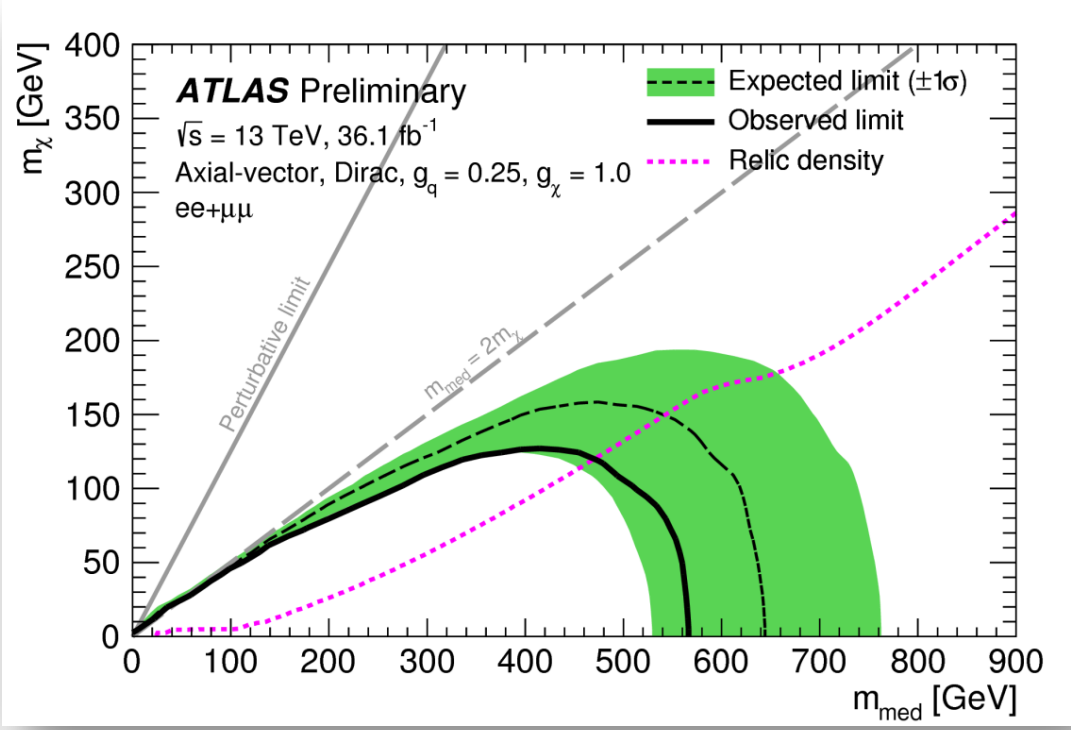


H → invisible

ATLAS-CONF-2017-040

- **Exclusion limit on *B*(H→inv) assuming SM ZH cross section: 67% (observed)**
- **95% exclusion limit in 2D m_χ and m_{med}**
  - **Mediator mass excluded up to 560 GeV**
  - **WIMP mass (m_χ) excluded up to 130 GeV**

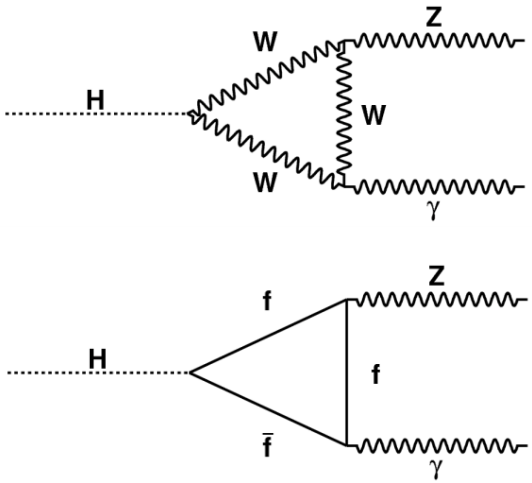


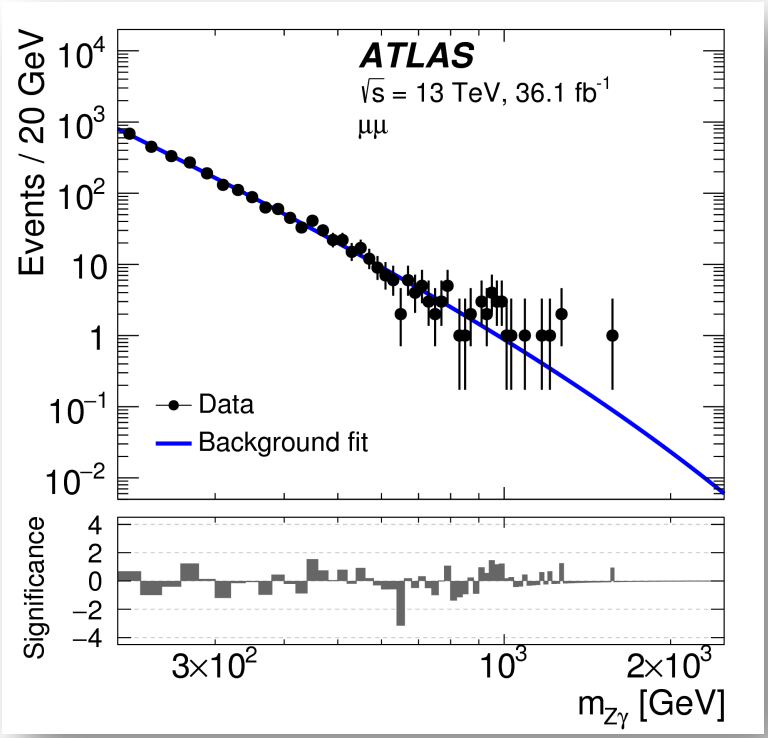


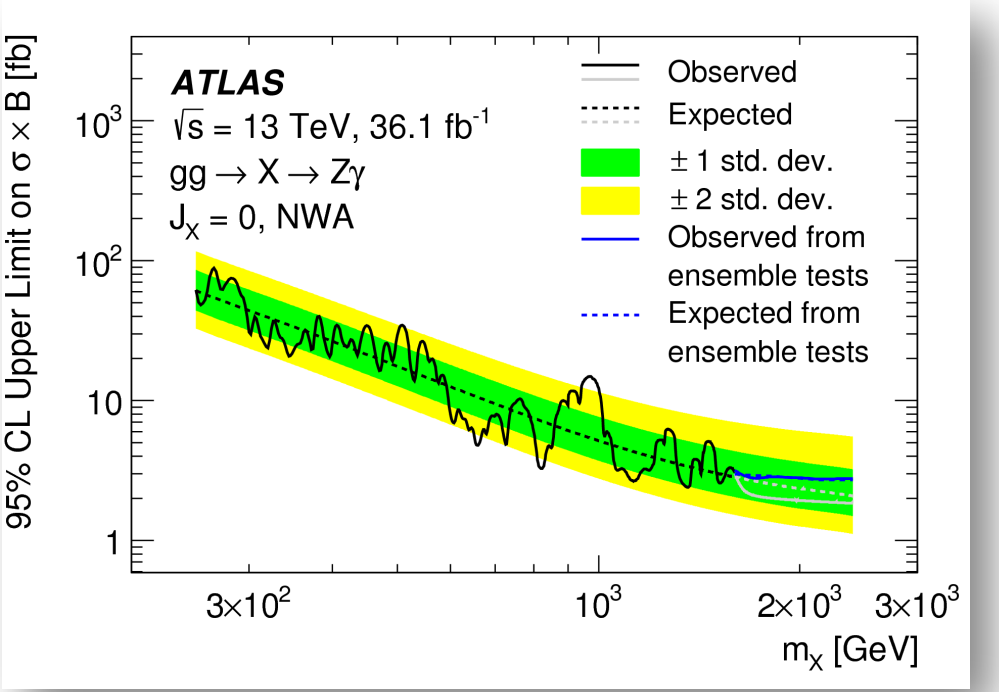
$H \rightarrow Z\gamma$

arXiv:1708.00212

- Final state coming from loop diagrams
- Possible differences from SM prediction
  - H is a different neutral scalar
  - H is composite
  - Additional particles in the loops
- Signal extracted from S+B fit to m(Zγ)
  - 6 categories and BDT discriminant
- No significant excess observed w.r.t SM
  - 2.7 σ^{local}, 0.8 σ^{global} @ 960 GeV







Conclusions

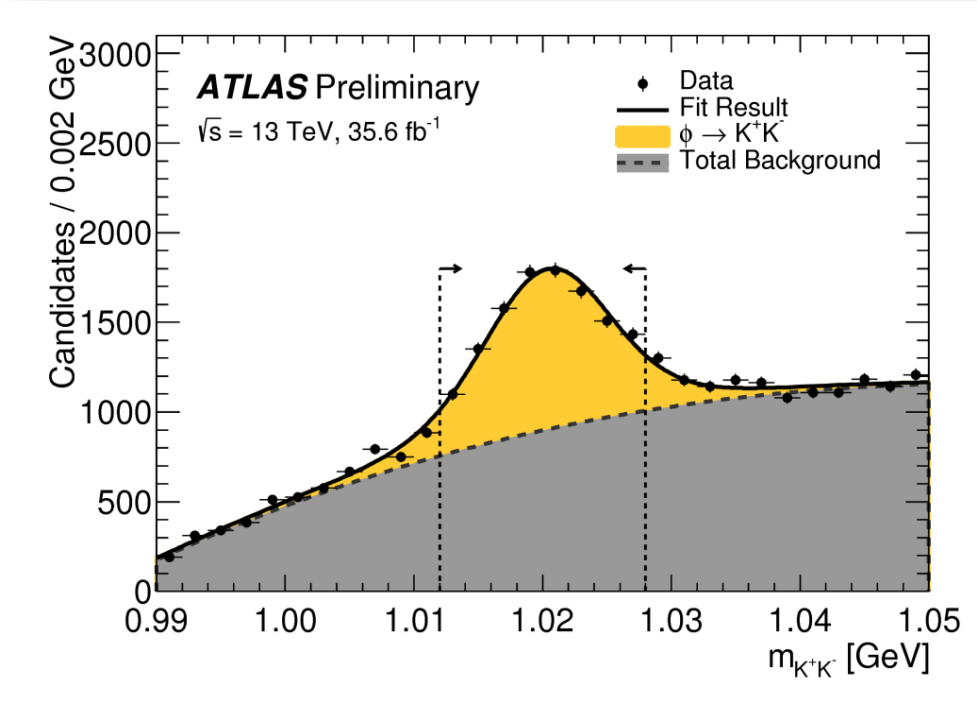
- **Very active ATLAS' search for BSM phenomena in the Higgs sector**
  - **Results with partial / full 2016 data presented**
- **Only a small fraction of results shown here**
  - **Checkout ATLAS public results at** https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults
- **No significant excesses over SM have been found so far**
  - **10 fb^{-1} of 2017 data being analyzed and x10 full 2016 statistics for full Run-2!**

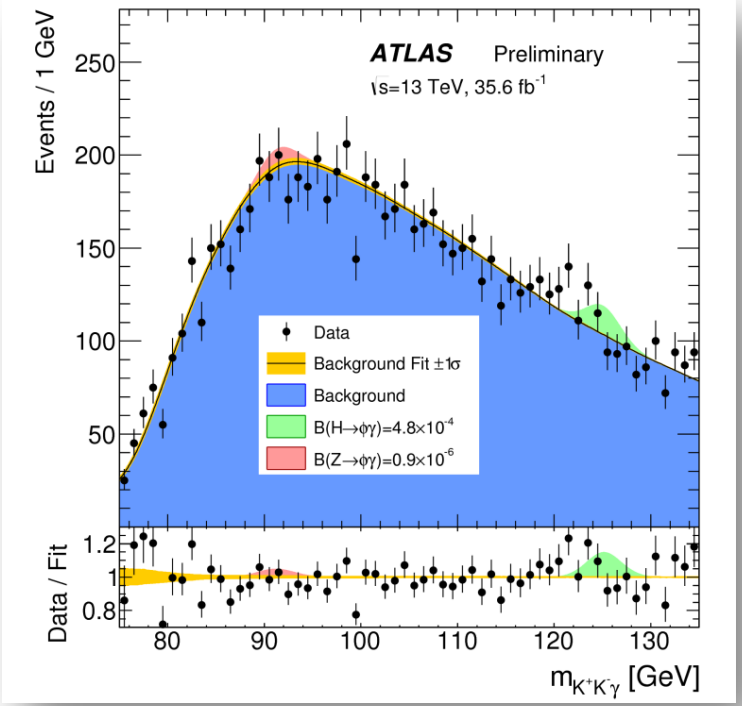
Back Up

$H \to \phi\gamma$, $H \to \rho\gamma$

ATLAS-CONF-2017-057

- **Processes sensitive to light quarks couplings to the Higgs**
- **SM expectation: $B(H \to \varphi\gamma) \sim 10^{-6}$ and $B(H \to \rho\gamma) \sim 10^{-5}$**
- **Final state reconstructed from two high-pT isolated tracks consistent with ϕ or ρ with a recoiling photon**





- **Observed 95% CL upper limits on branching fractions for $H \to \varphi\gamma$ ($H \to \rho\gamma$) decays are around 208 (52) the expected SM**