



Higgs: Beyond the Standard Model

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On behalf of the ATLAS Experiment



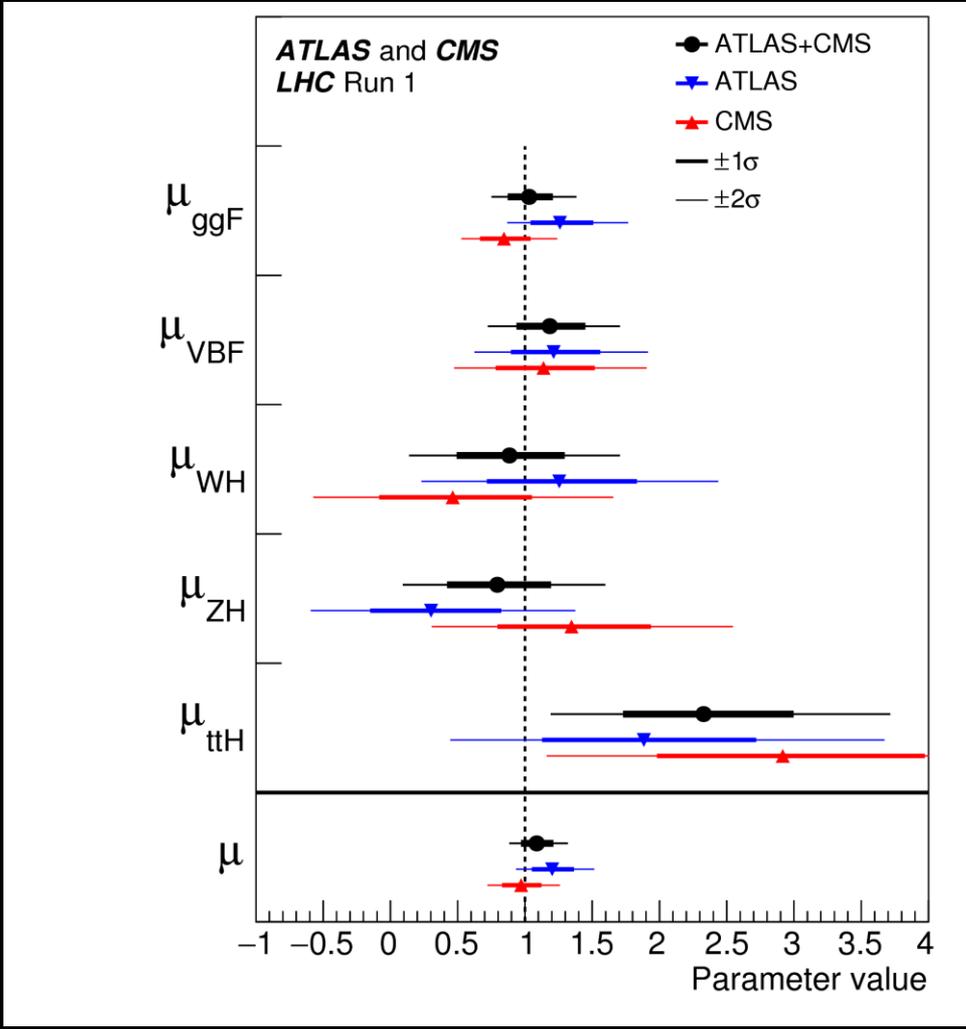
(B)SM Higgs

H(125) Looks very SM like so far

Many measurements on-going to search for new phenomena in the Higgs sector at ATLAS

- Deviations in SM measurements
- Lepton flavor violation in decays
- Invisible decays
- Charged Higgs bosons
- Heavy scalars
- Light scalars
- Heavy resonances
- Non-resonant signatures

Too much to cover in this talk!





Lepton Flavour Violation

LFV possible in many different models

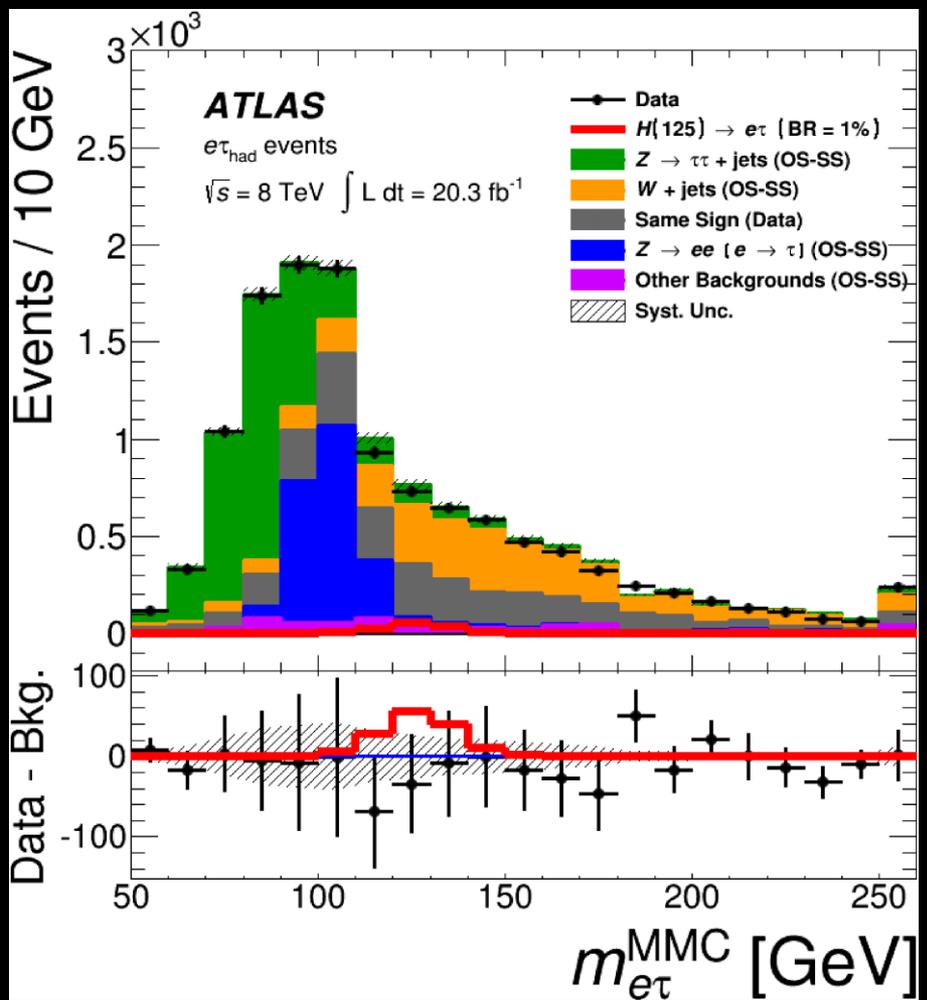
New publication of search for LFV in decays of H (and Z)

Two key (H) analyses:

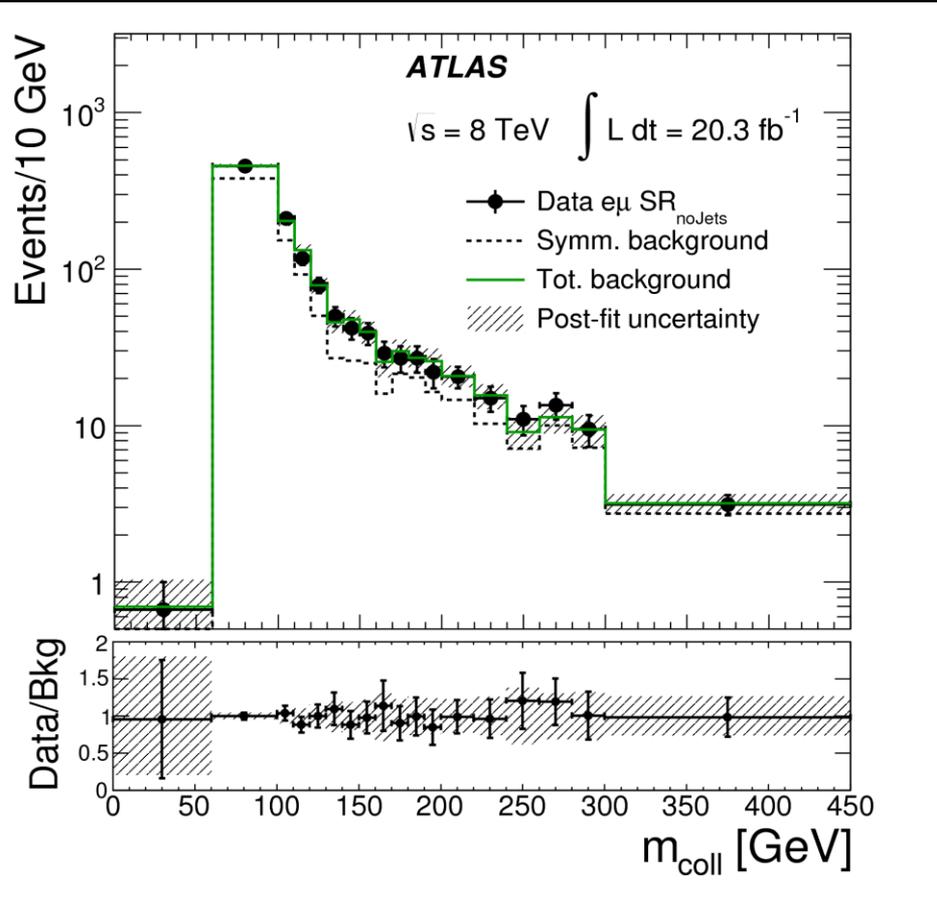
$$H \rightarrow e\tau_{had}$$

$$H \rightarrow l\tau_{lep} \quad (l = e, \mu)$$

And combination with previous $H \rightarrow \mu\tau_{had}$



Lepton Flavour Violation



$$H \rightarrow e\tau_{had}$$

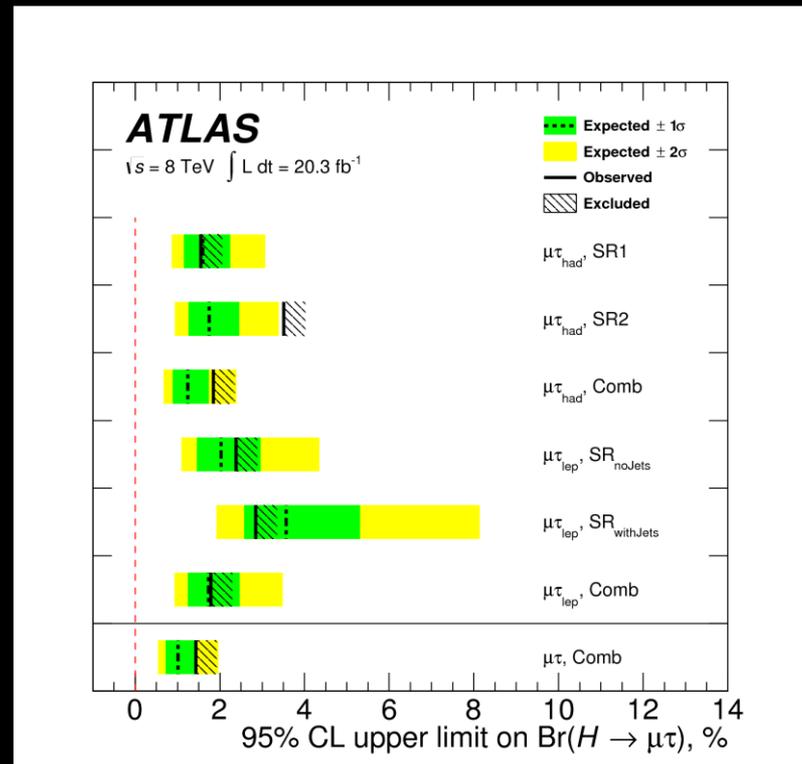
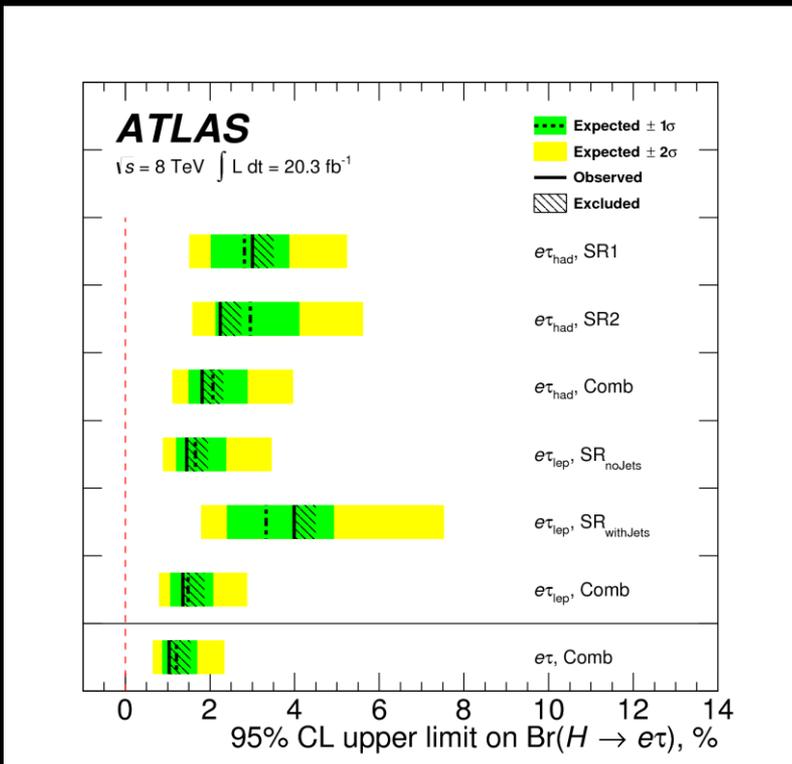
Fit for H(125) and set limits on BR(LFV) in two signal regions (W dominated and Z dominated backgrounds)

$$H \rightarrow l\tau_{lep} \quad (l = e, \mu)$$

Signature is OS $\mu e + MET$

Exploit symmetry in backgrounds under interchange of μ and e
 (split into categories with and w/o jet activity)

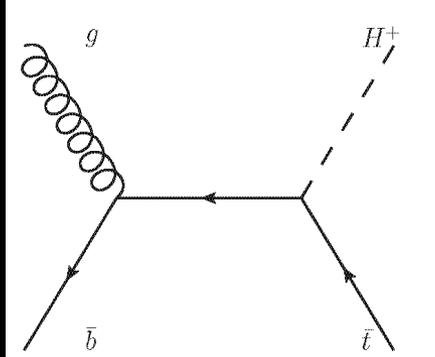
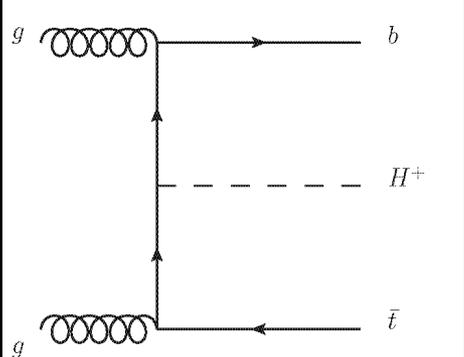
Lepton Flavour Violation



Limits assuming $BR(H \rightarrow \mu\tau) = 0$ or $BR(H \rightarrow e\tau) = 0$ respectively

Charged Higgs: $H^+ \rightarrow tb$

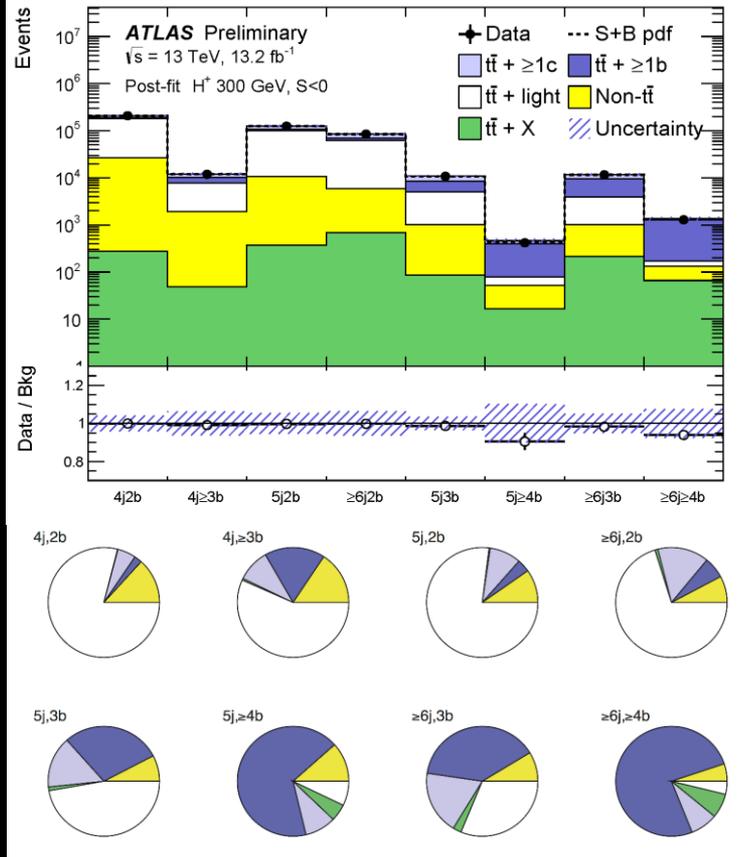
Many models predict charged Higgs boson
Including 2HDM, triplet models etc



For $M_{H^+} > M_{top}$ associated production with t dominates

Categories events based on jet and b-jet multiplicities define CR and SR

BDT used to discriminate in SR

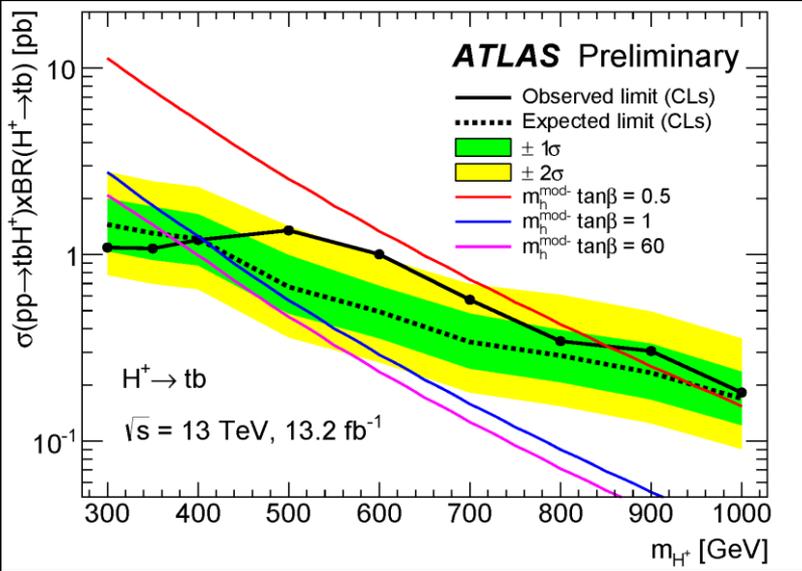
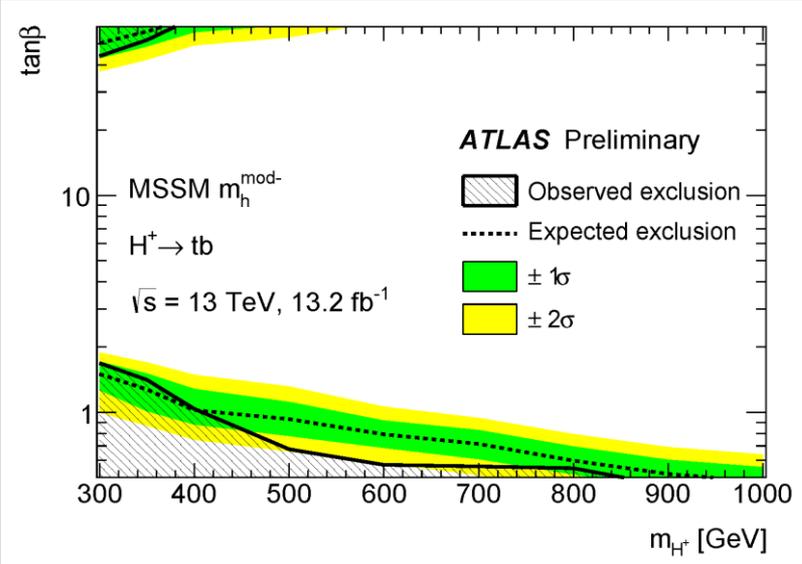




Charged Higgs: $H^+ \rightarrow tb$

Many models predict charged Higgs boson
Including 2HDM, triplet models etc

$t\bar{t} + \geq 1$ b-jet modelling and flavour
tagging systematics are dominant



No significant excess observed



Charged Higgs: $H^+ \rightarrow \tau\nu$

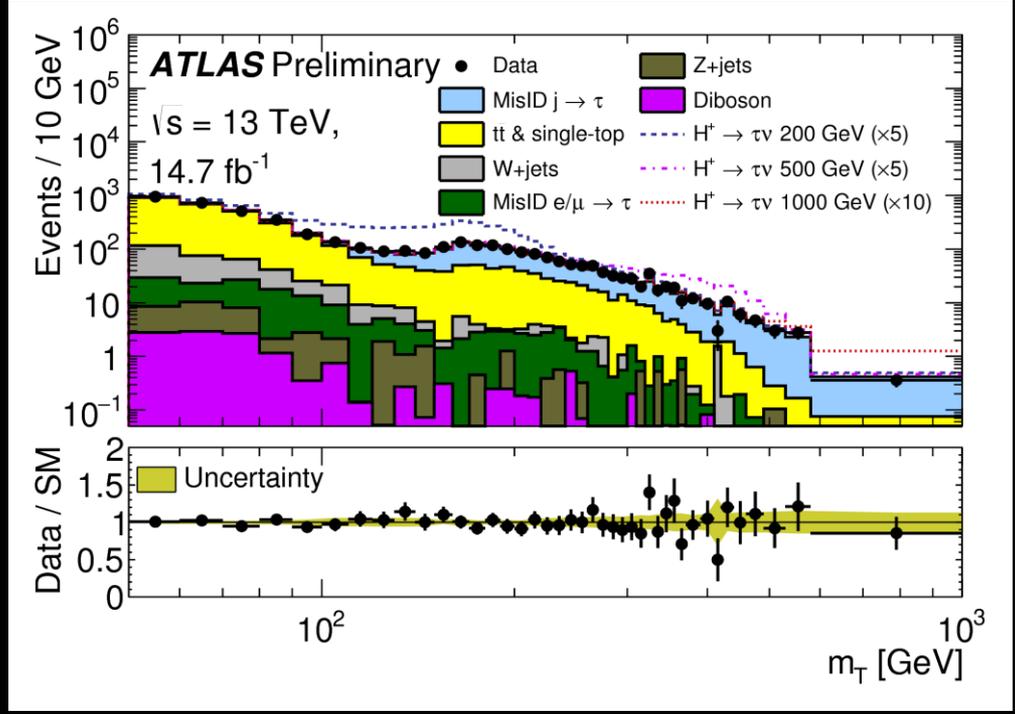
Many models predict charged Higgs boson
Including 2HDM, triplet models etc

Search for $H^+ t \rightarrow \tau\nu$ in hadronic
final states:

$\tau_{had} + 3jets (>=1 \text{ b-tagged})$

Low mass region dominated by
top backgrounds.

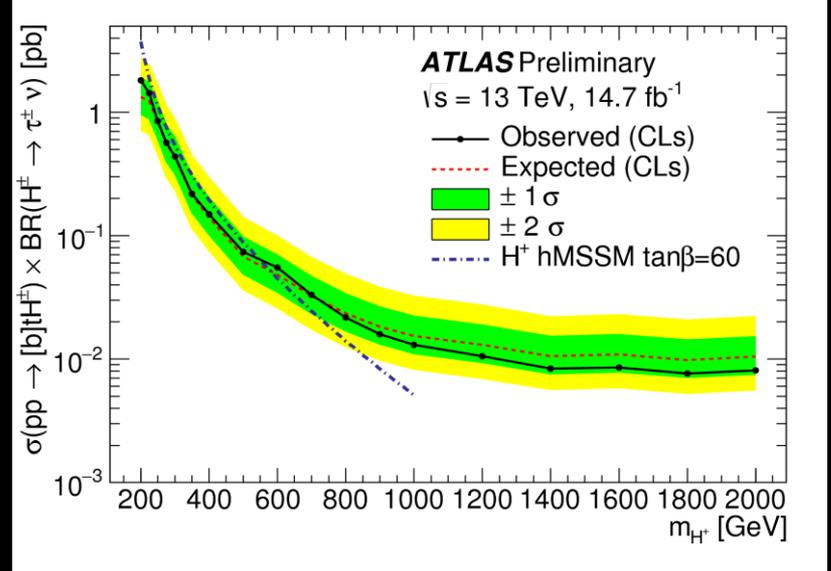
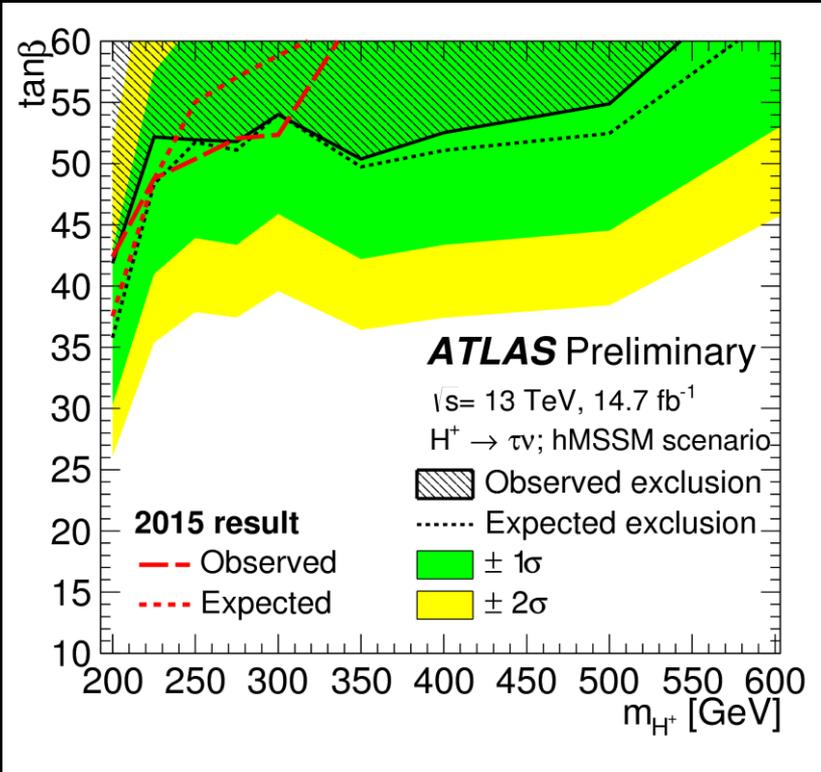
High mass region dominated by
multi-jet backgrounds with fake-
taus





Charged Higgs: $H^+ \rightarrow \tau\nu$

Many models predict charged Higgs boson
Including 2HDM, triplet models etc

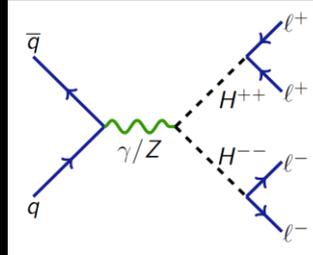


Uncertainties on fake-rates and top backgrounds dominate systematics

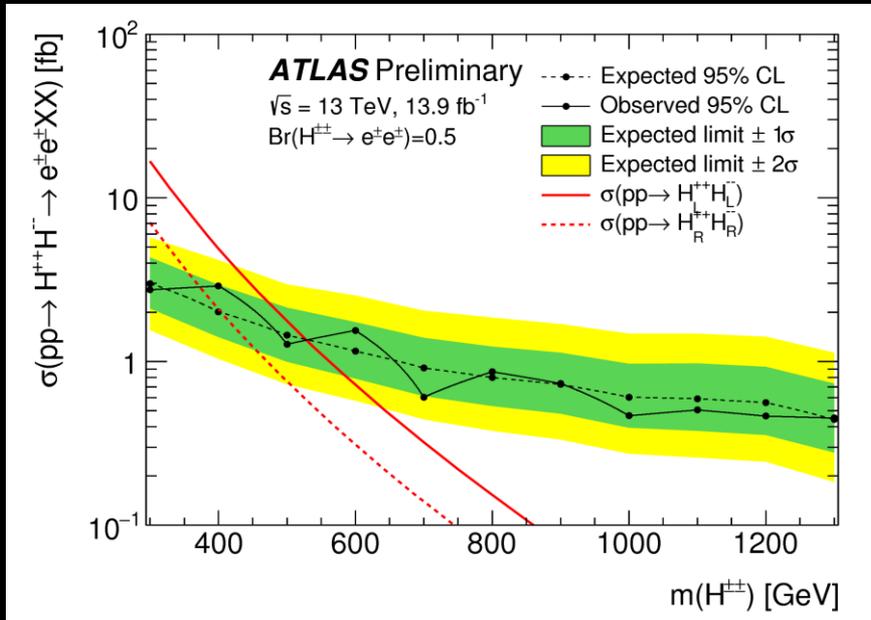
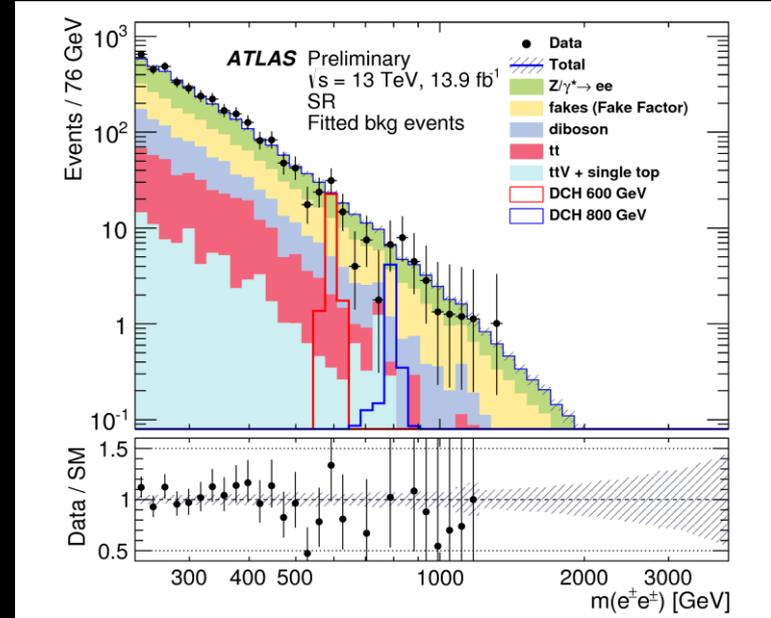
Limits set using M_T as discr. Variable interpreted in various scenarios (hMSSM shown)

Doubly charged Higgs

Run 2 search for $H^{++} \rightarrow e^{\pm}e^{\pm}$
 Run1 : JHEP 03 (2015) 041



Main background from charge-misid $Z \rightarrow ee$
 Next biggest from “fake” and non-prompt electron backgrounds



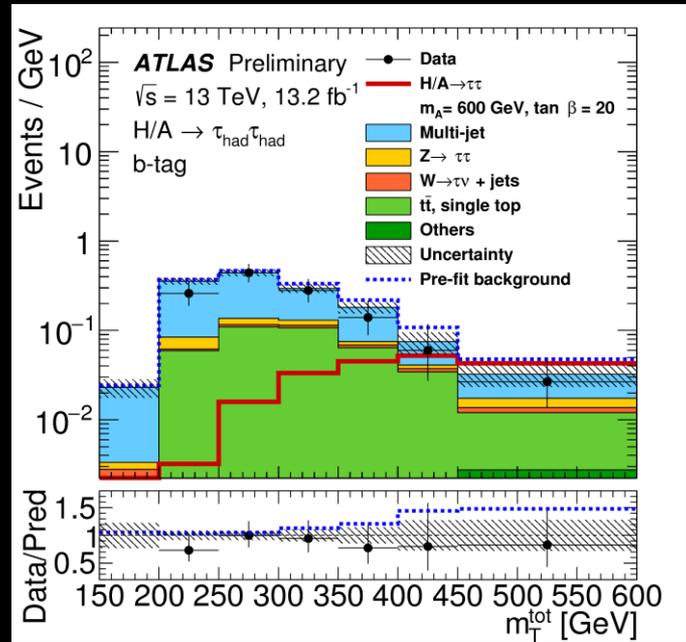
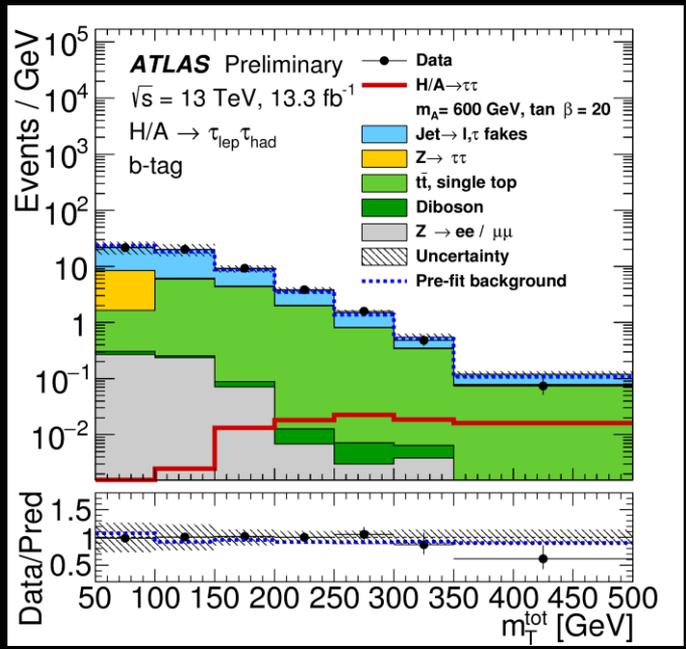
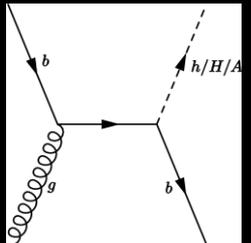
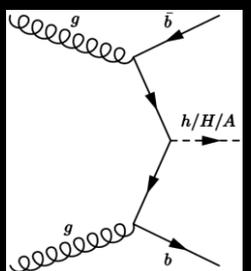
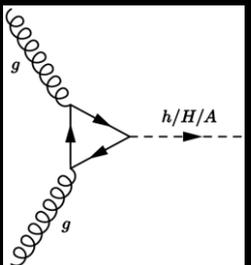
Discriminant variable M_{ee}

Limits set assuming $BR(ee)=50\%$
 (shown) and $BR(ee)=100\%$

Heavy Scalars: $H \rightarrow \tau\tau$

Search for final states with two taus with one or both decaying hadronically

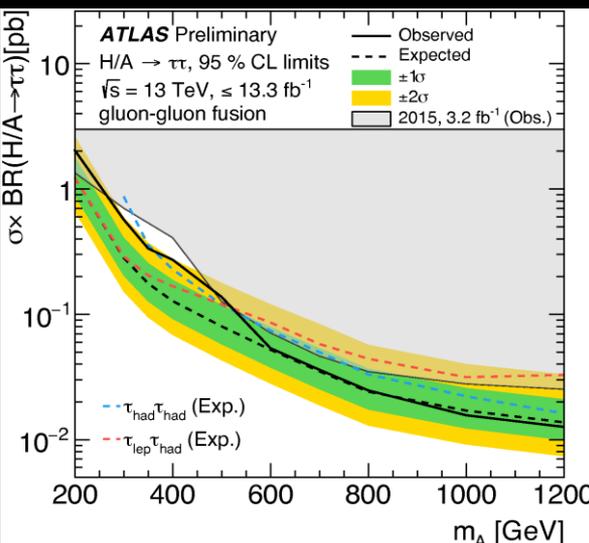
Events categorized according to b-tag multiplicity and the presence of high missing transverse energy



Total di-tau transverse mass used as discriminant variable

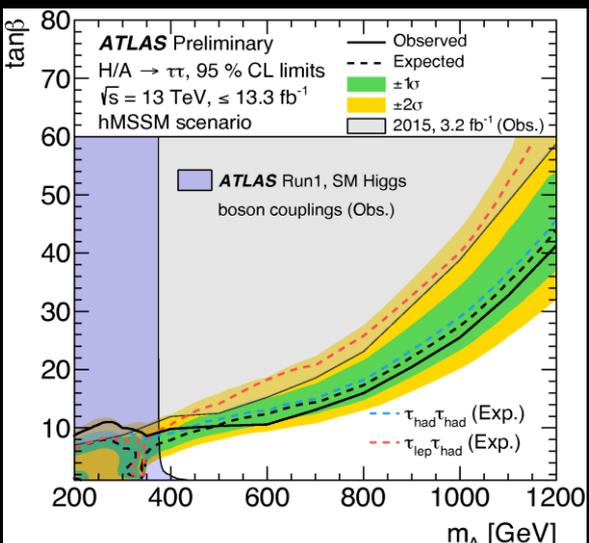


Heavy Scalars: $H \rightarrow \tau\tau$

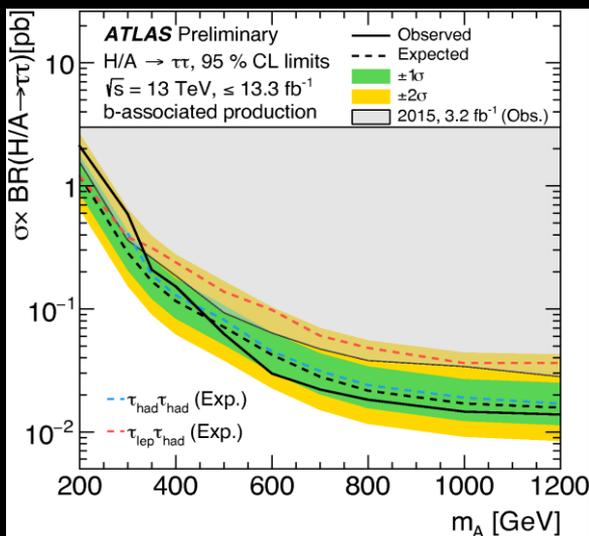


Cross section \times BR limits for gluon-gluon and b-associated production

And interpretation in m_h^{mod} and hMSSM (shown) benchmark scenarios



Important sources of uncertainties include: MET trigger modelling, fake tau modelling and fragmentation modelling in top-pair production



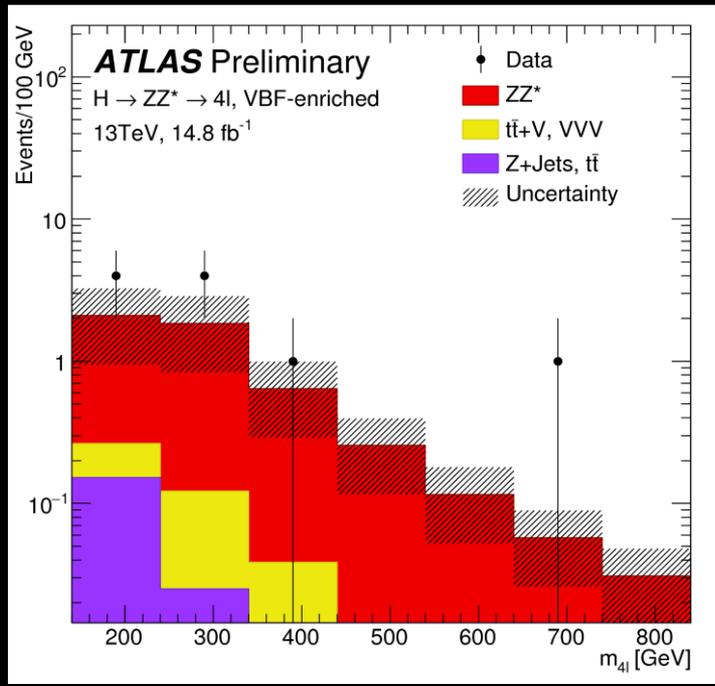
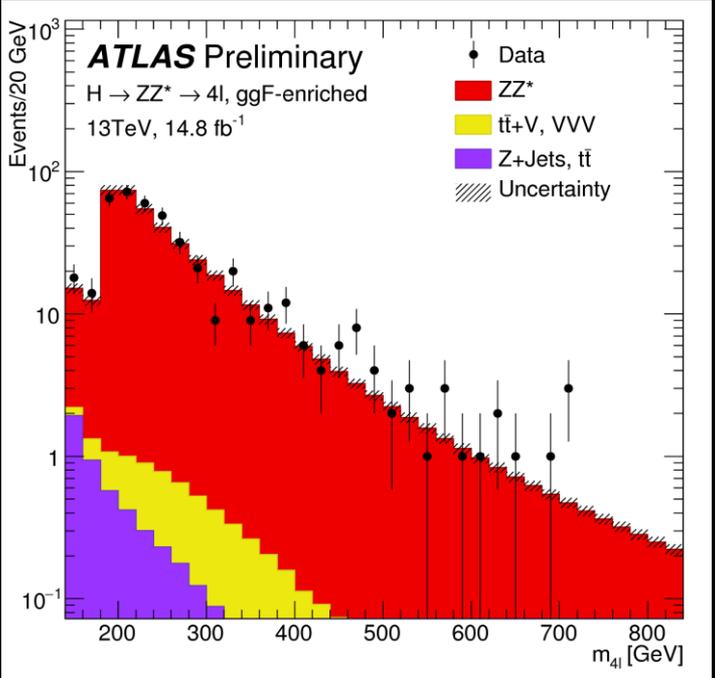
No significant excesses seen across the mass range searched



Heavy Scalars: ZZ (a selection)

Searches for “SM-like” 4-lepton as well as diboson-resonance $llqq$ and $\nu\nu qq$ with Heavy Higgs interpretation (amongst others)

4-lepton final state: $4\mu, 4e, 2e2\mu$
Fully reconstruct Z's – on shell



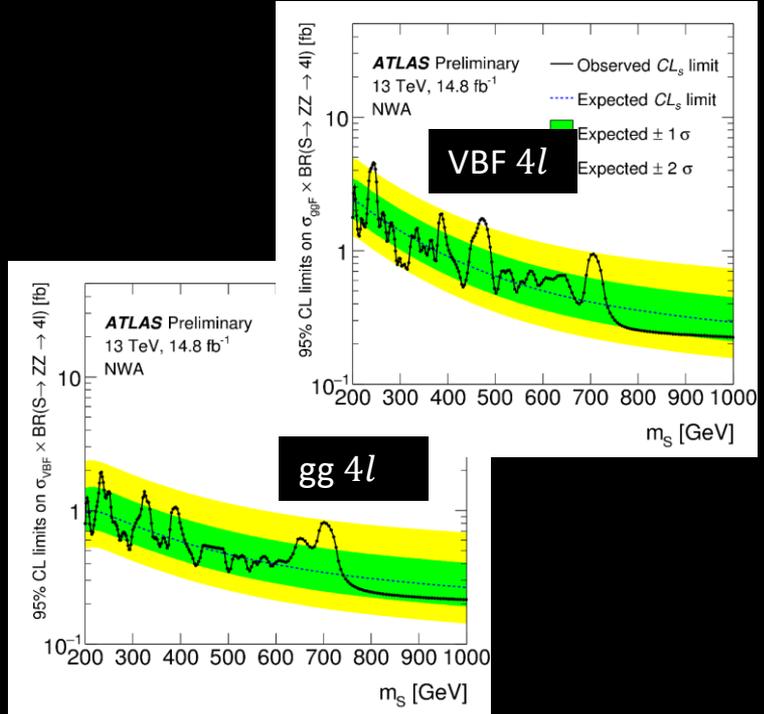
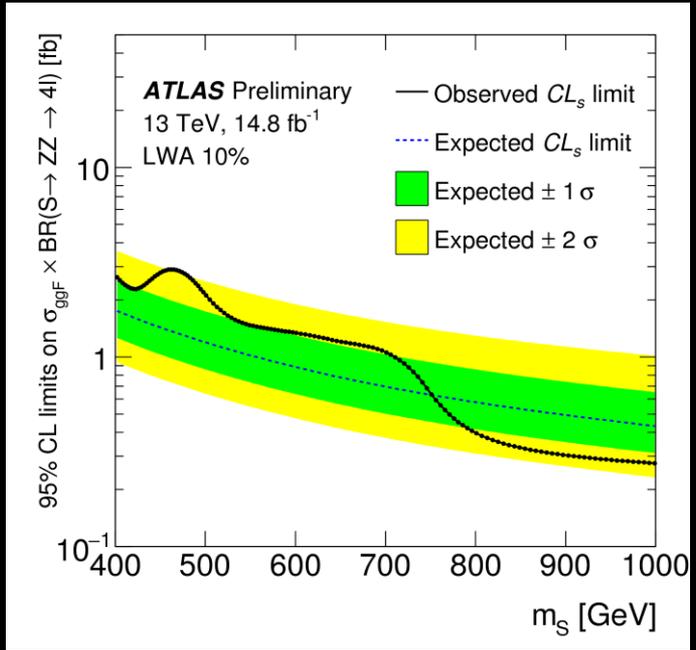
Events with two well-separated jets with high di-jet mass VBF category – otherwise gg category



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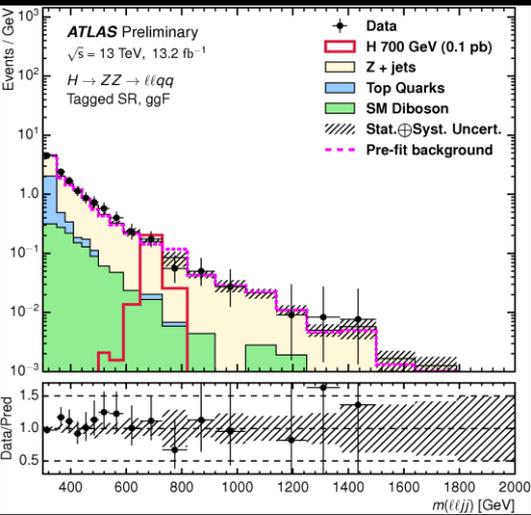
Set limits for both narrow width approx. and various large widths (10% shown)

No significant excess observed



Heavy Scalars: ZZ (a selection)

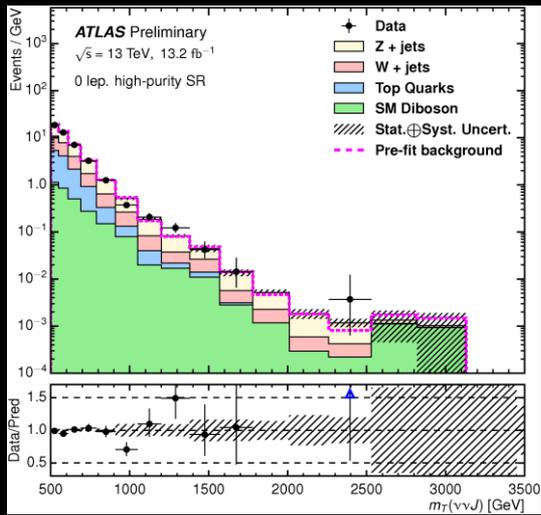
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Additional purity from b-jet tags

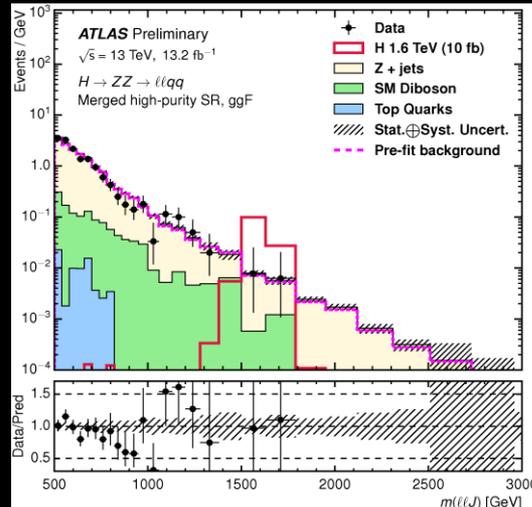
Dominant background Z+jet
lower b-jet content

VBF channel also used)



$llqq$ or llj where $l = e, \mu$

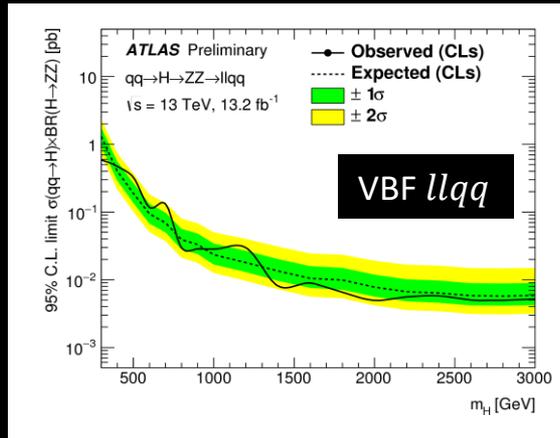
Merged and resolved jets
– either single large-R jet
or two distinct jets



$\nu\nu jj$ analysis signature: large missing E_T and merged jj in 1 large R-jet

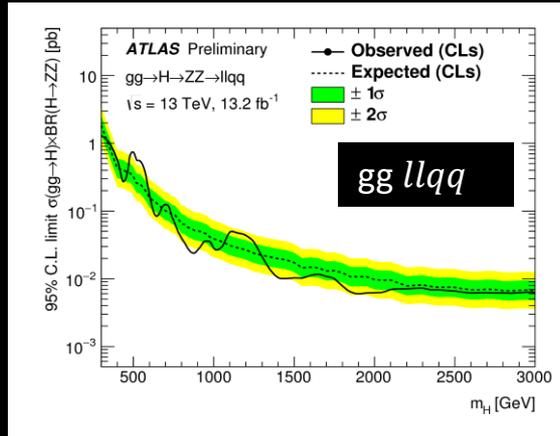
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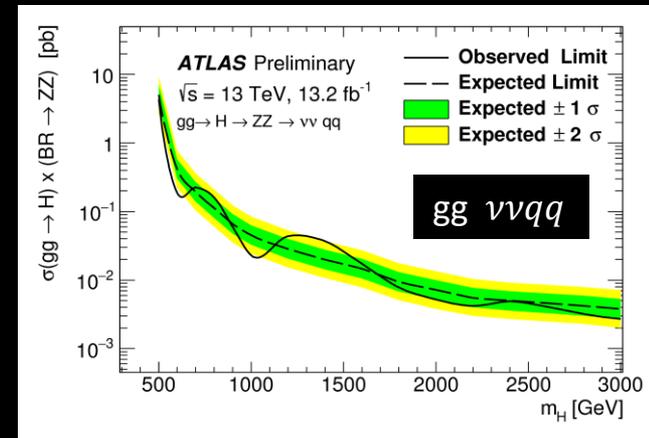


Final discriminants m_{llqq}, m_{llJ} and $m_T(\nu\nu J)$

Interpretation possible with multiple different signal models. Heavy Scalar shown here.



Some wiggles but no significant excess is observed

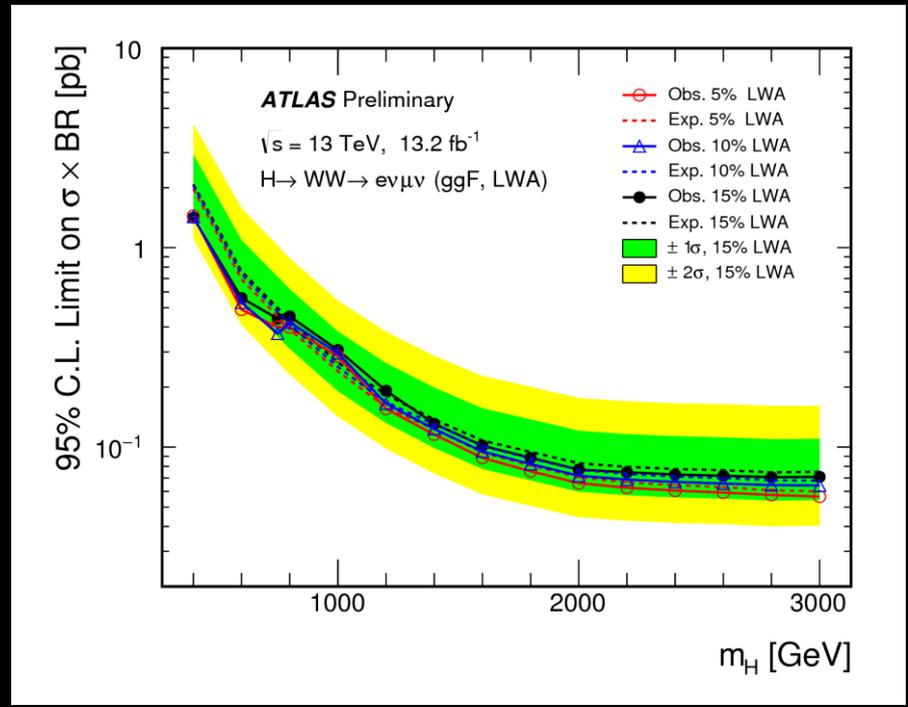
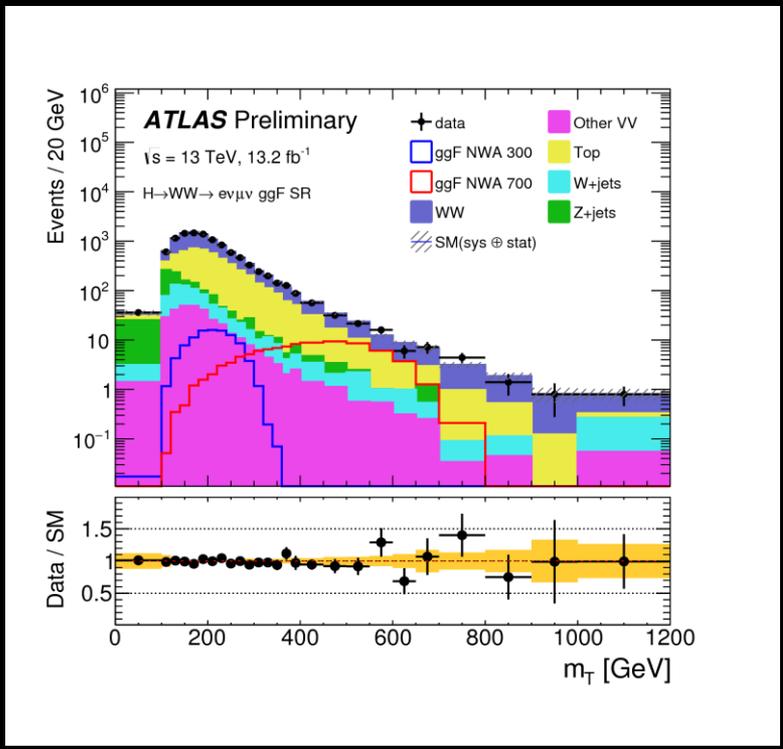




Heavy Scalars: WW

Search for heavy scalar $H \rightarrow WW \rightarrow e\nu\mu\nu$

Limits set using M_T as discriminant variable in NWA and various LWA scenarios



No significant excesses are observed

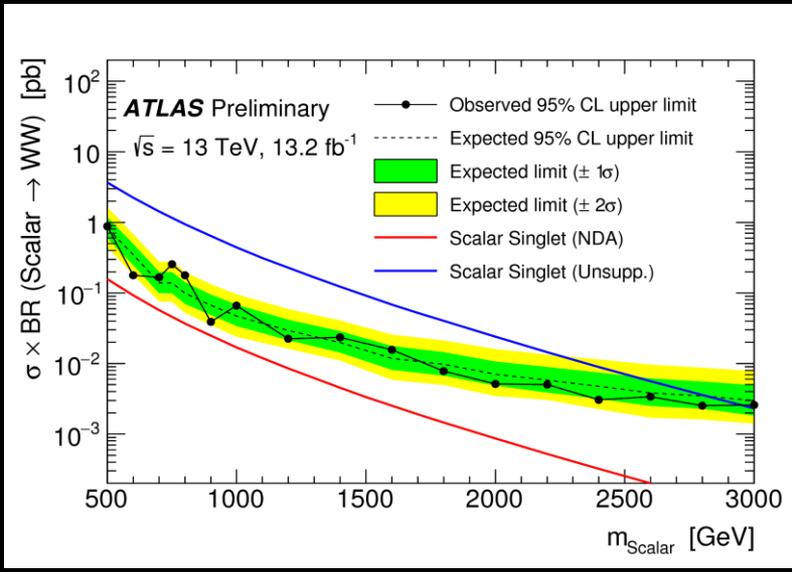
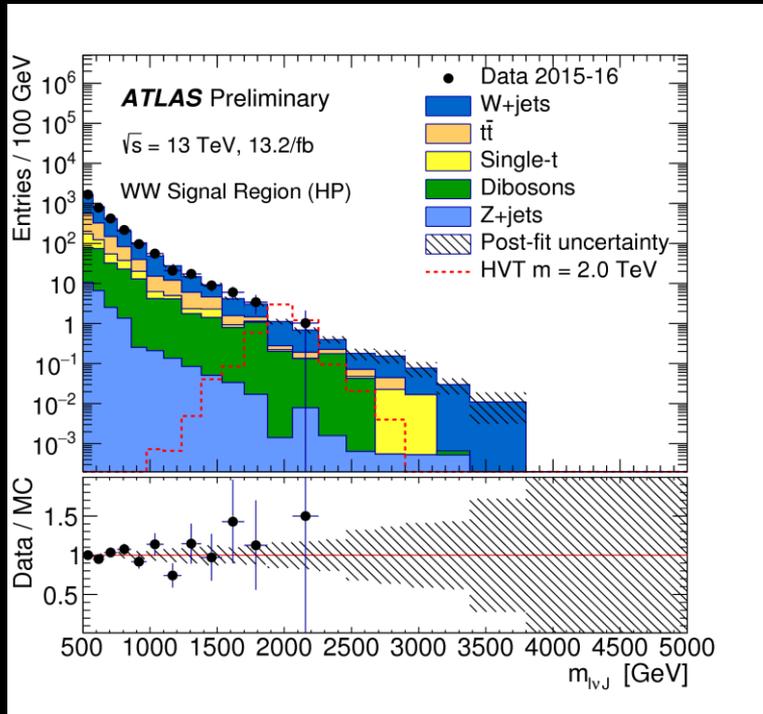
Dominant backgrounds from WW and top
 Three categories defined: gg, VBF1 (mix VBG and gg)
 VBF2 (high mass jet pair – dominated by VBF)



Heavy Scalars: WW (WZ)

Search for NP in final states with $lvjj$ in boosted topologies where two jets are reconstructed as single large-R jet.

Sensitive to multiple NP signals – RS graviton, HVT, heavy scalar (WW)



No significant excesses are observed

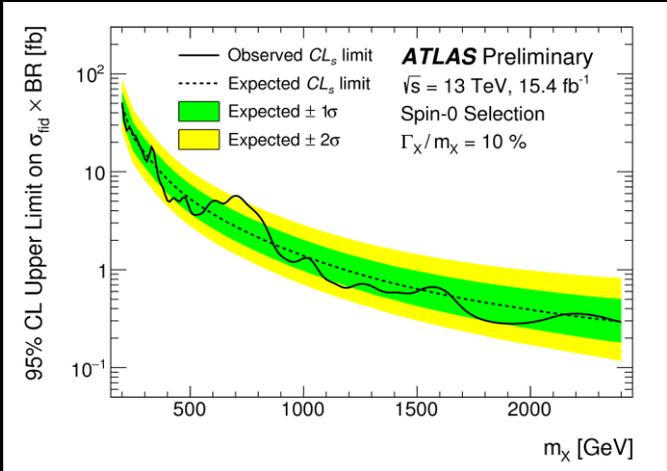
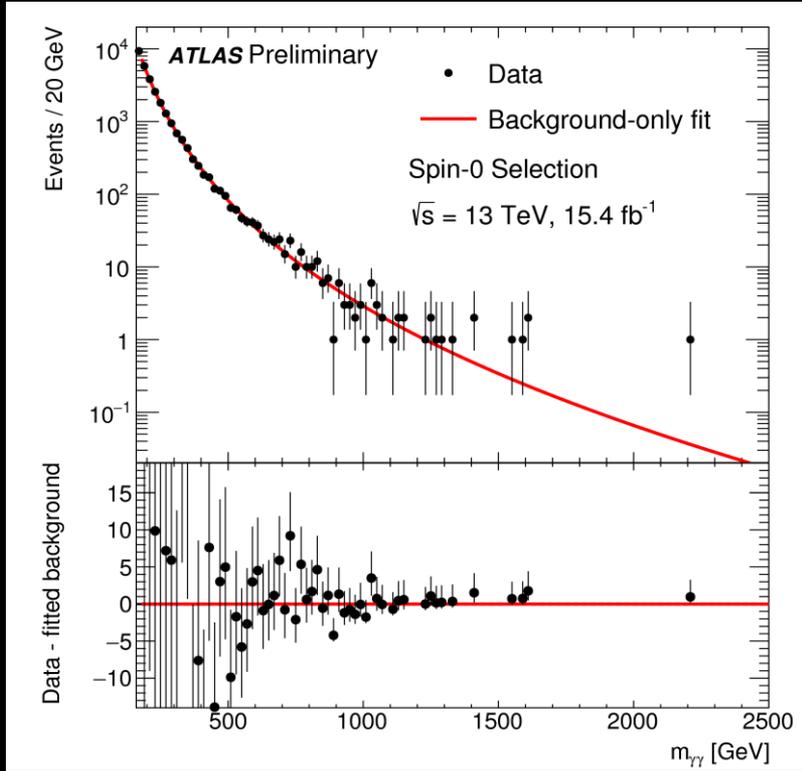


Heavy Scalars: $\gamma\gamma$

Diphoton resonance search

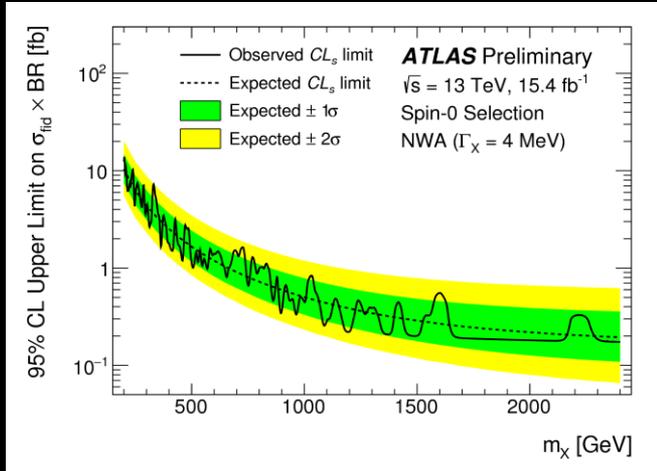
Created some excitement in 2015

Updated analysis see reduction in significance of previous excess



As with other diboson analyses – NWA and LWA interpretations

No significant excess observed



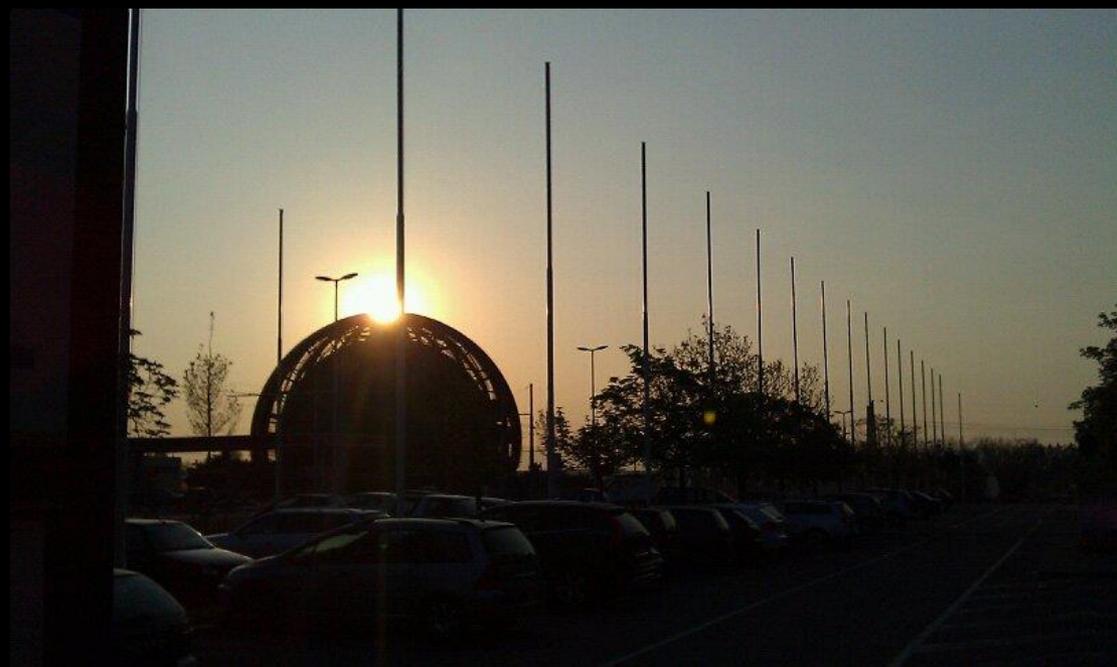


Conclusions

ATLAS is highly active in searching for BSM phenomena in the Higgs sector

Only a small fraction of results shown here – checkout ATLAS public results for more:

<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults>



Nothing significant has yet been observed

Lots more data to come!