Searches for diboson resonances with the ATLAS detector

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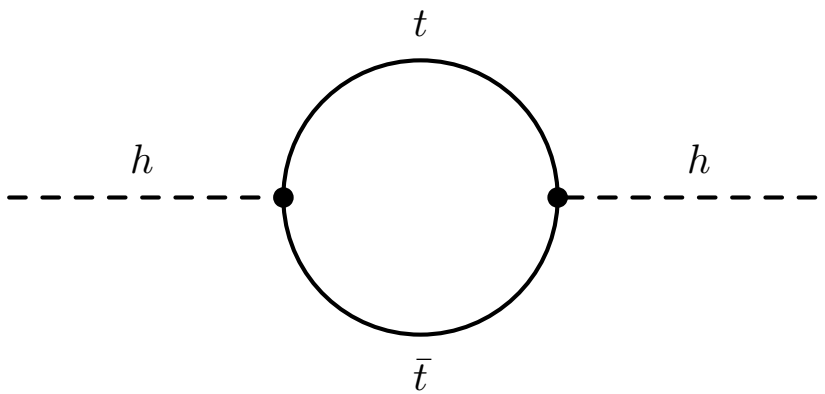
MAX-PLANCK-GESELLSCHAFT

Why the Standard Model has a problem

$$\delta m_h^2 \propto \mathcal{O}\left(\frac{\alpha}{\pi}\right)\Lambda^2$$



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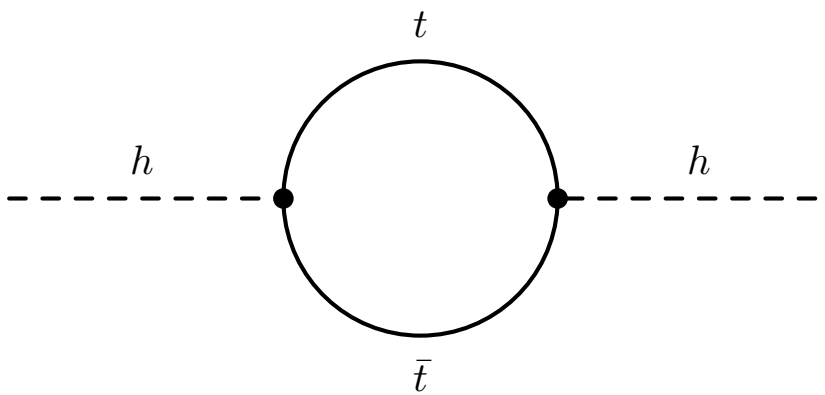

Also: ▷ Massive Neutrinos

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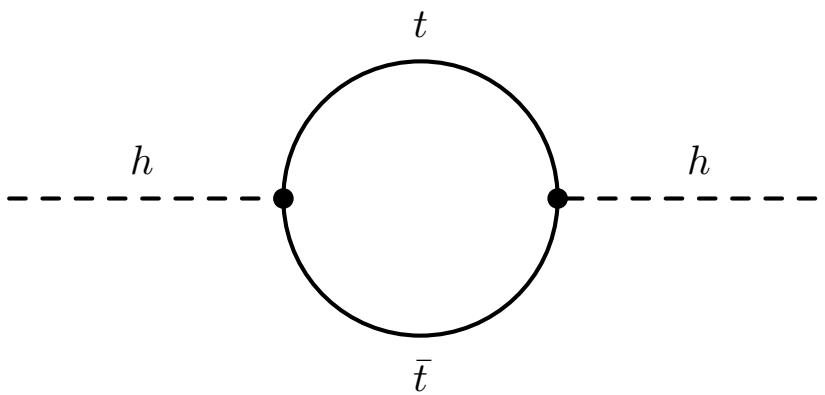

Also: ▷ Massive Neutrinos ▷ Dark Matter/Energy

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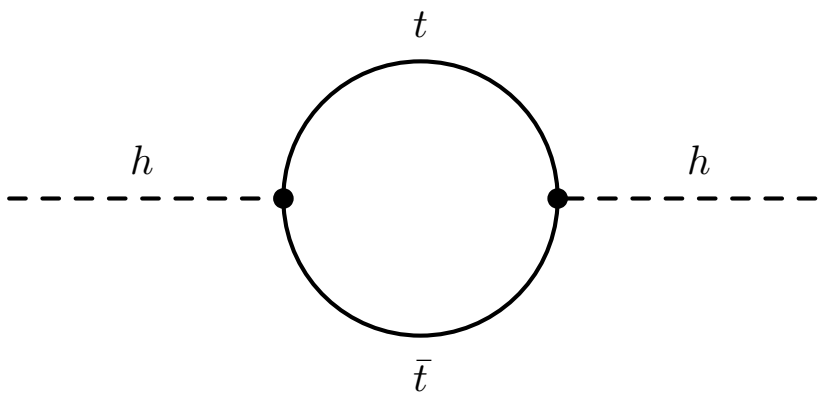


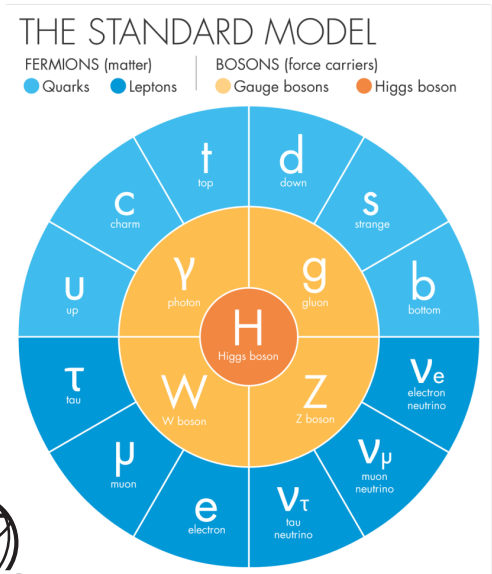
Also: ▷ Massive Neutrinos ▷ Dark Matter/Energy ▷ Gravity??

The Standard Model is not enough

Many theoretical models tackle the problems the Standard Model cannot solve.

Little Higgs	MSSM
Composite Higgs	Axion Model
Minimal Walking Technicolor	Baryogenesis Model

They generally predict **new, heavy particles**.



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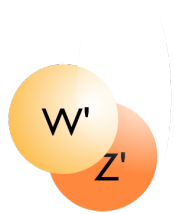

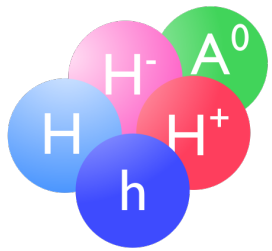

Physics beyond the standard model

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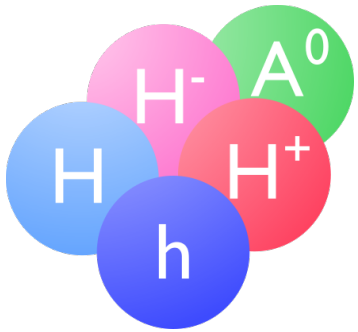
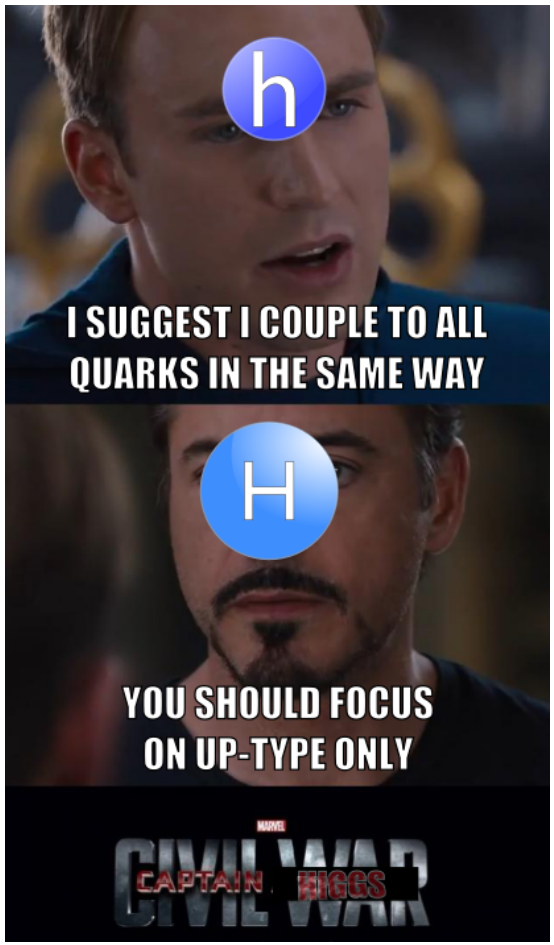
The answer to all questions?*

*most likely ≠ 42

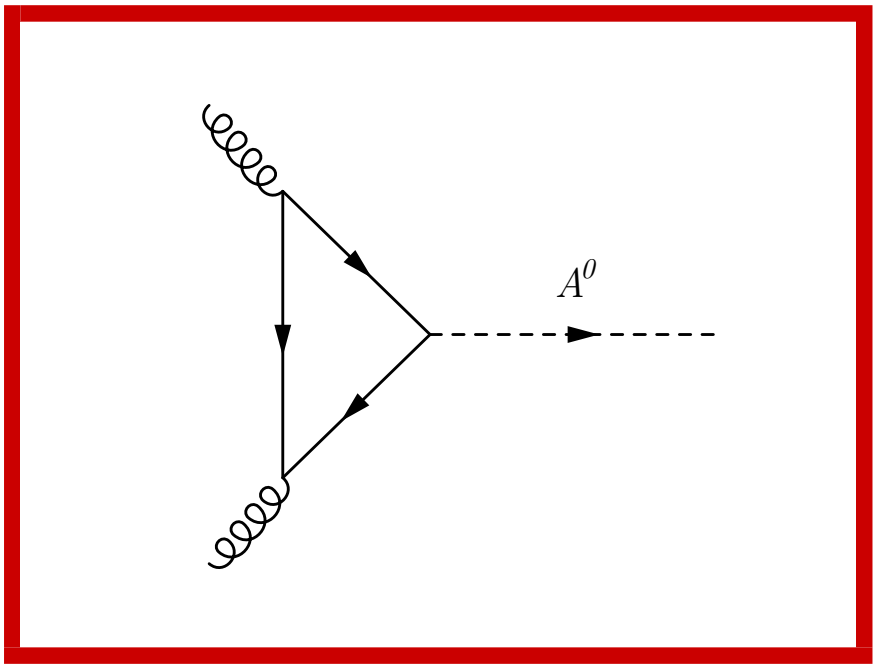
The two Higgs doublet model

- Two Higgs doublets: Φ_1, Φ_2
- After EWSB: 5 Higgs bosons
  - neutral, CP-even: h, H
  - neutral CP-odd: A^0
  - charged CP-even: H^+, H^-
- **Unknowns:**
  - **Ratio of vevs**: $\tan\beta = v_2/v_1$
  - h, H **mixing angle** α
  - **Masses** of H, $H^\pm$, A^0 [h is 125 GeV SM Higgs]
  - Couplings to SM particles

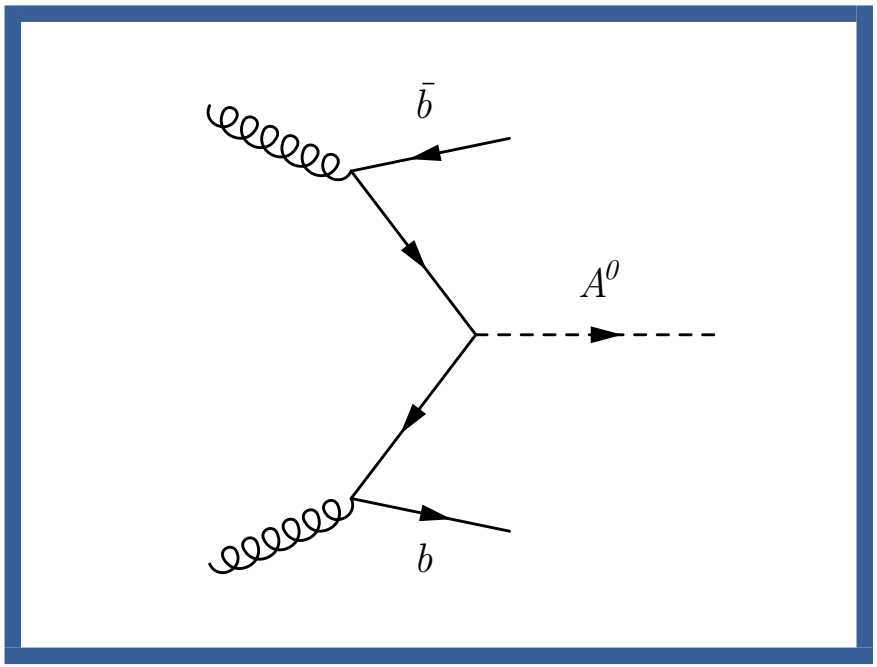




A^0 production



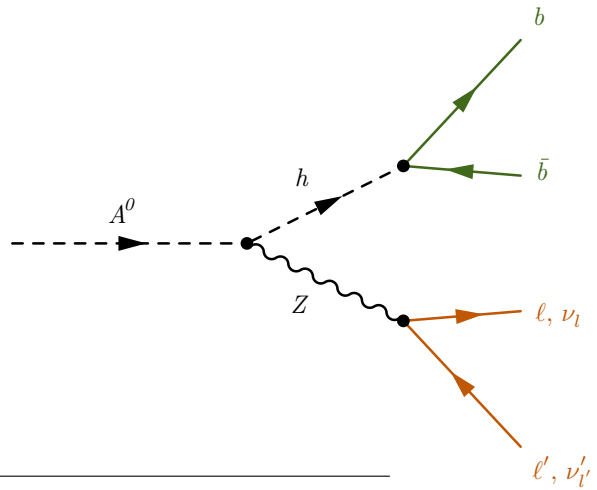
gluon-gluon fusion

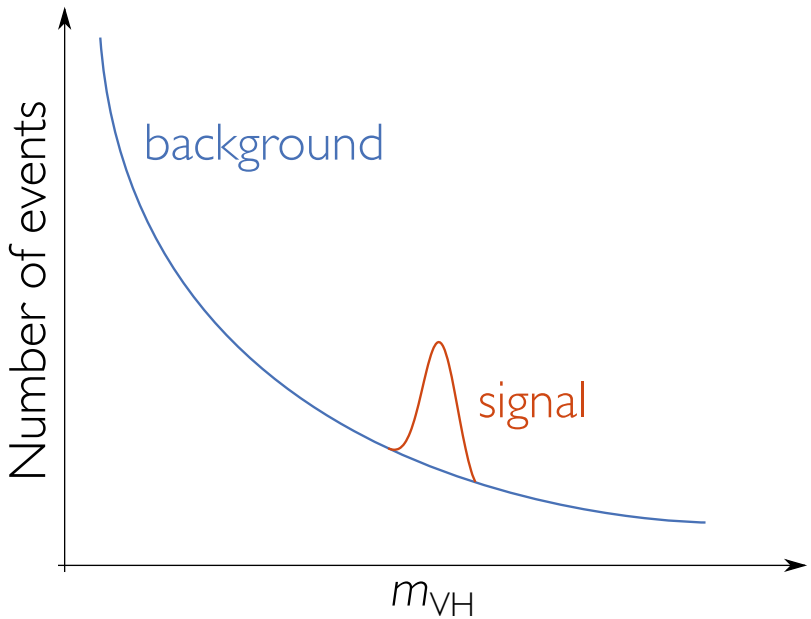


b-associated production

A^0 decay / Bump hunting

- Multiple decays modes possible
- Focus on
  - $h \to b\bar{b}$
  - $Z \to \ell\ell, \nu\nu$ $(\ell = e^-, \mu^-)$



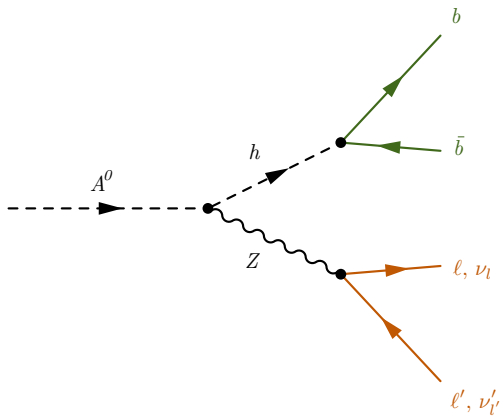


- Investigate mass of diboson system m_{Vh}
- 0-lepton: $m_{T,Vh}$

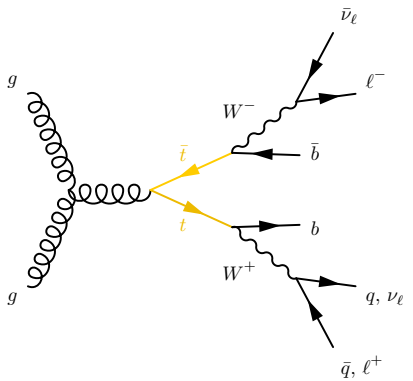
$$m_{T,Vh} = \sqrt{(p_T^h + E_T^{miss})^2 - (\vec{p}_T^{\,h} + \vec{E}_{T^{miss}})^2}$$

- Background is smoothly falling
- Sharp peak at resonance mass expected

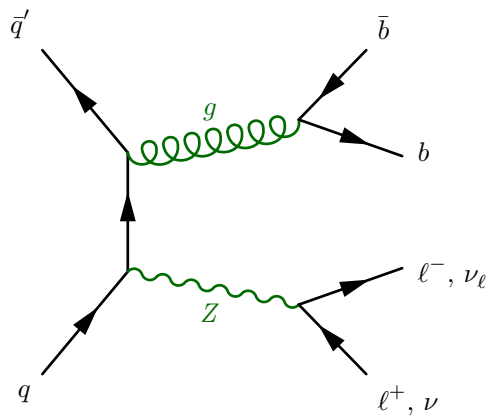
Some backgrounds (representative diagrams)



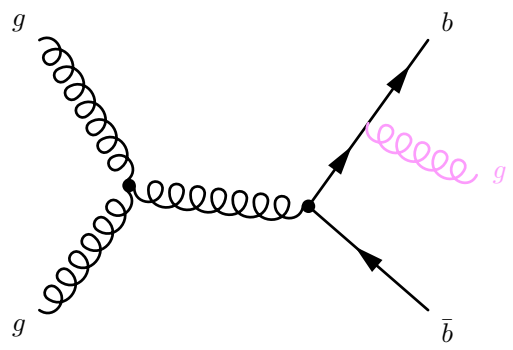
Signal Process



ttbar



Z+jets



Multijet

Background suppression / Event selection

Backgrounds are suppressed by **imposing cuts**.

Background	Example for a good cut variable
ttbar	Mass of di-lepton system (2-lepton channel)
Z+jets	Transverse momentum of di-lepton system (2-lepton channel)
Multijet	Missing transverse energy

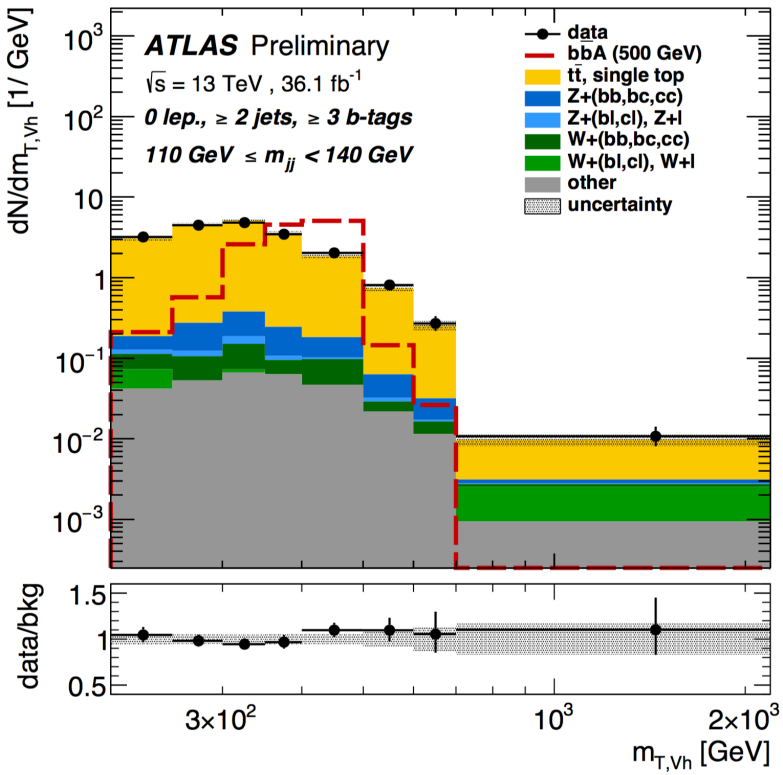
- Cut values are optimized in dedicated studies
  - Can depend on m_{Vh}

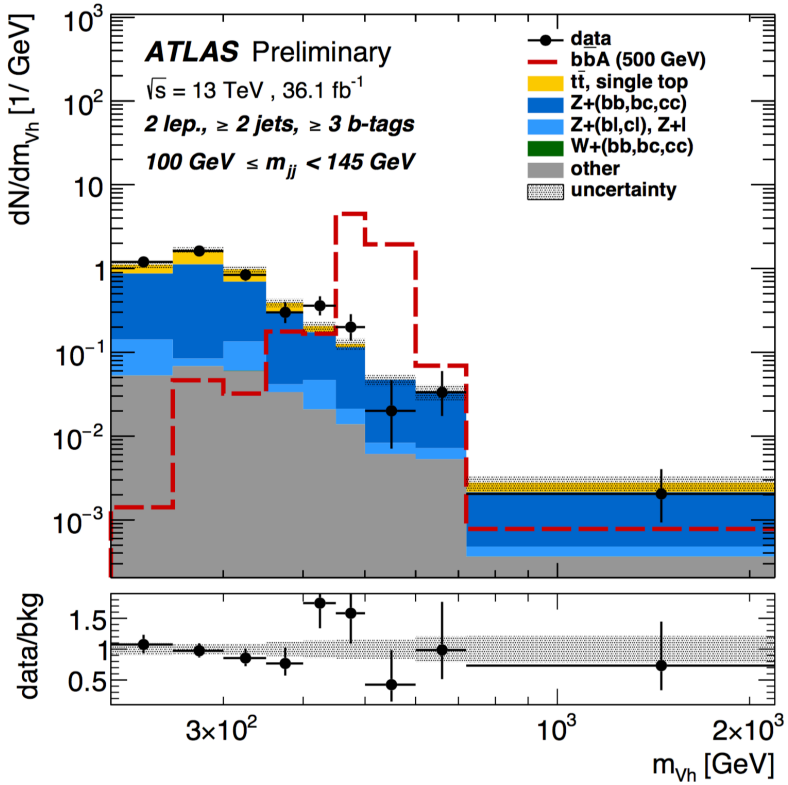
Events are then **categorised**.

Quantity	Effect
Number of b tags	Defines 1, 2, 3+ tag SR; 0 b-tag CR
Mass of di-quark system	Defines signal window & m_{bb} sidebands

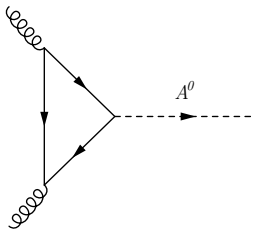
- Control regions can be used to investigate backgrounds
  - Some backgrounds have dedicated CRs

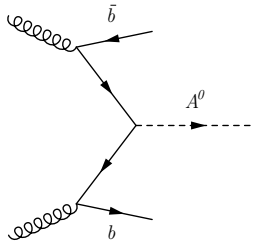
Post-fit distributions

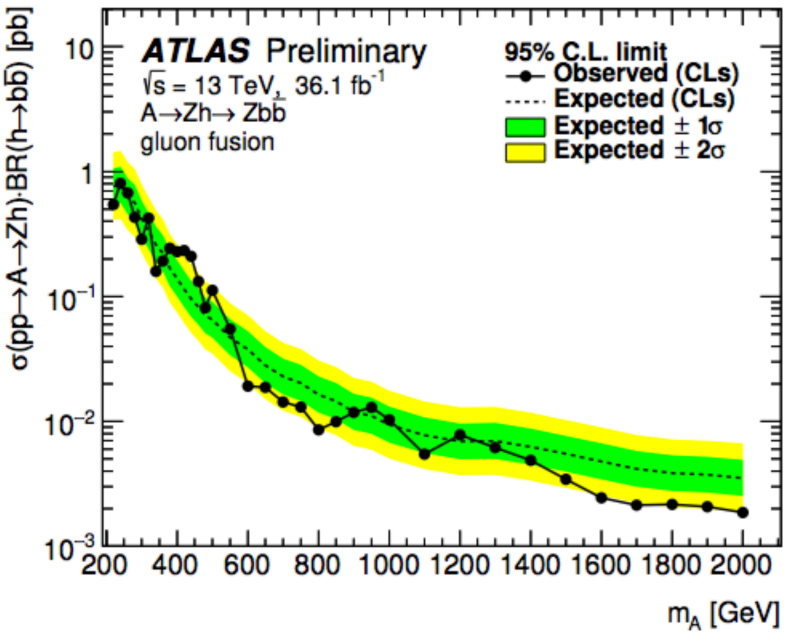


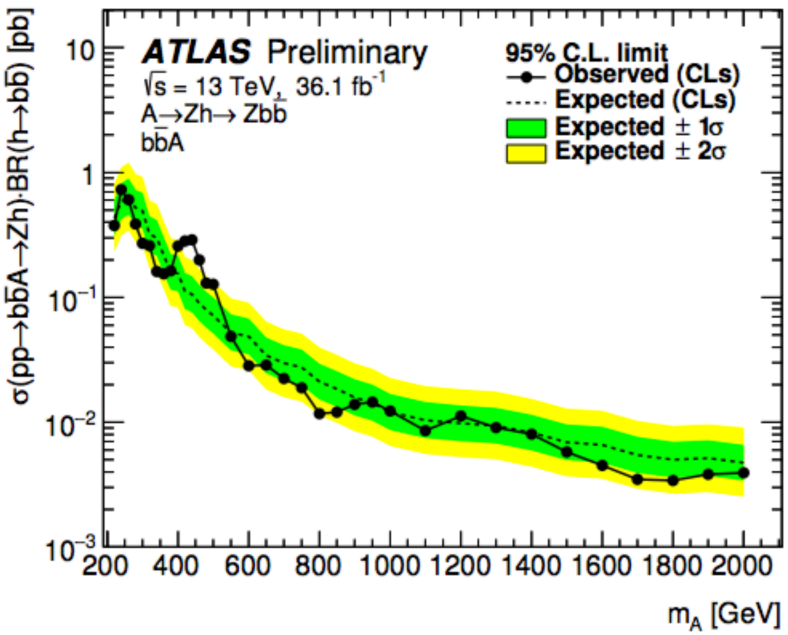


Cross section time branching ratio limits

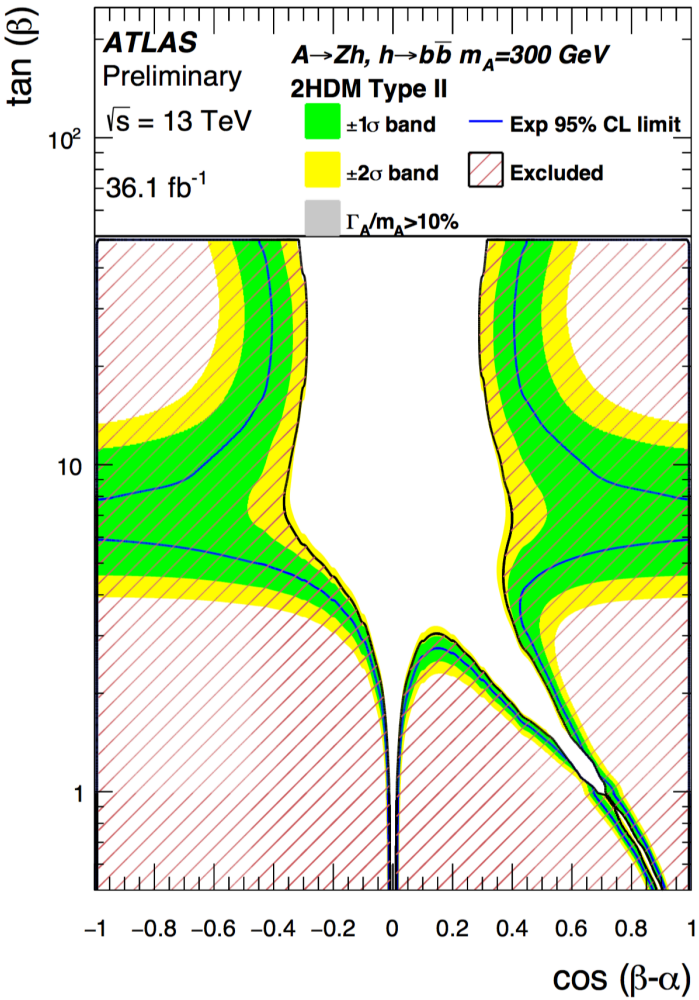








Model parameter limits I

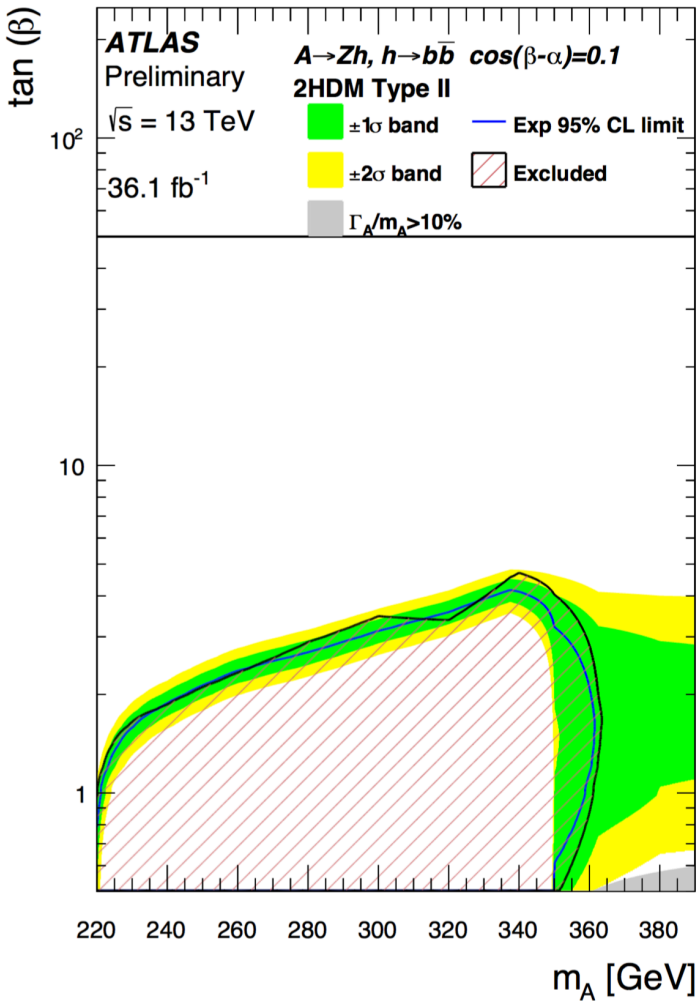


- Four models (Type I, Type II, Lepton Specific, Flipped) investigated
- Only Type II limit plot shown, others similar
- m_A assumed to be 300 GeV

Interesting areas:

- $\cos(\beta - \alpha) \to 0$ (aligment limit): $\mathrm{BR}(A^0 \to Zh)$ vanishes
- $\tan(\beta) \to 0$: $\mathrm{BR}(h \to b\bar{b})$ vanishes

Model Parameter Limits II



- Type II, close to aligment limit
  $\cos(\beta - \alpha) = 0.1$
- $m_A > 350\,\text{GeV}$: $A \to t\bar{t}$ becomes accessible & is dominant decay mode

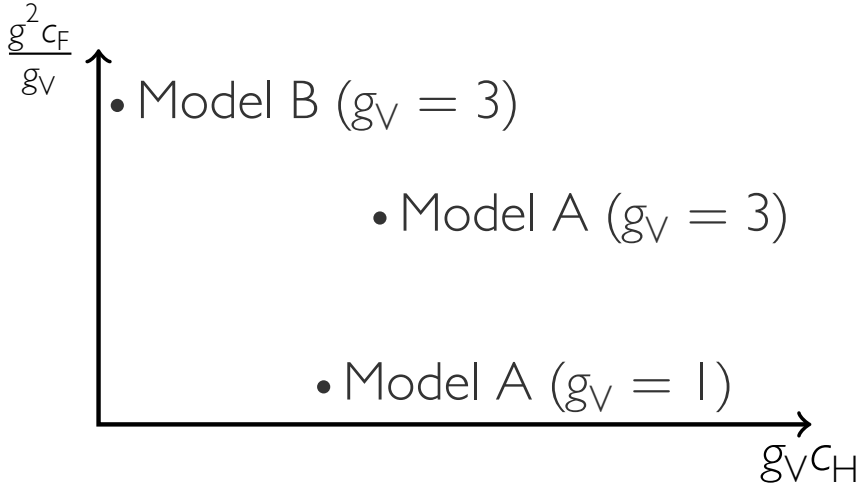
Summary

- Extensions of the Standard Model required
- Many theories predict an extended Higgs sector
- Direct search for CP-odd A performed at ATLAS
- Final states: $b\bar{b}\ell^+\ell^-, b\bar{b}\nu\nu$
- No significant excess found with combined 2015+2016 data set ($36\,\text{fb}^{-1}$)
- Exclusion limits in four different parameter spaces presented in paper
- ATLAS-CONF-2017-055

BACKUP

Content of HVT

- Additional heavy vector boson triplet
  - Z' ($q = 0$), W' ($q = \pm 1e$)
  - Neutral & charged final states possible
- $1\ \text{TeV} \lesssim M_0 \simeq M_\pm$
- Parameters: Masses, Couplings



g_V: new vector–boson coupling
g: $\mathrm{SU}(2)_L$ gauge coupling
c_H: $V' \leftrightarrow h$ correction of g_V
c_F: $V' \leftrightarrow$ fermion correction of g

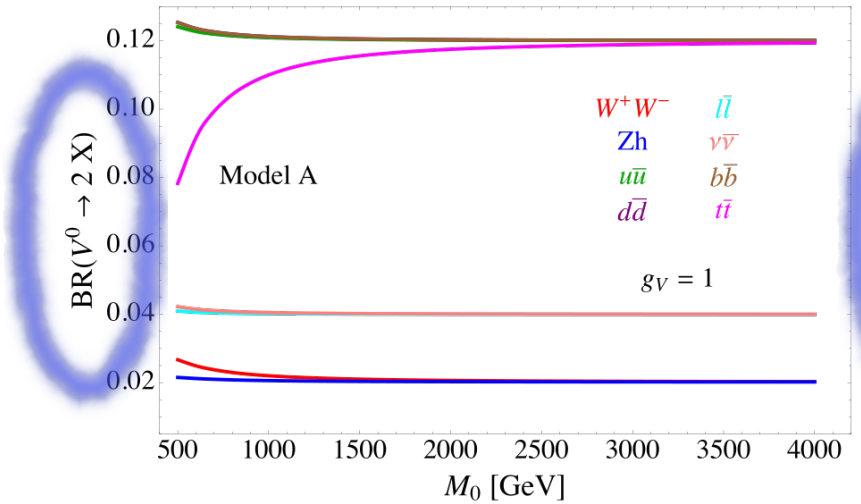
- Choice of Model A / Model B fixes how parameters depend on each other
- Pick a point in plane spanned by couplings and scan masses

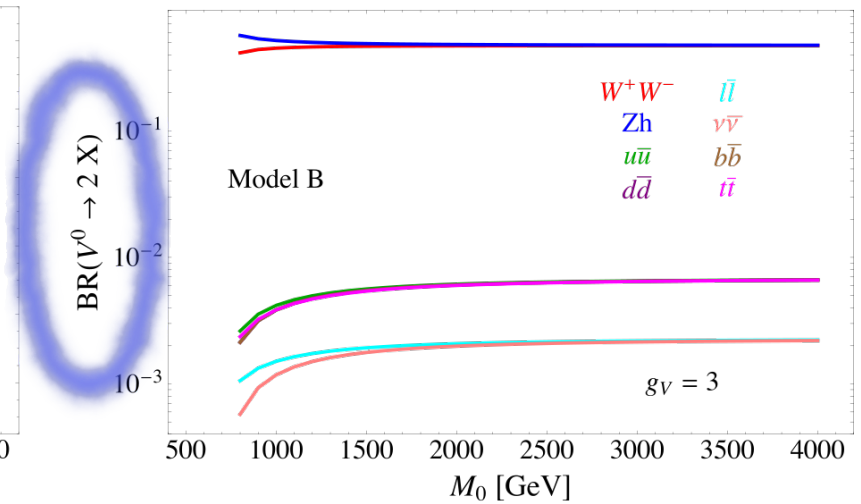
HVT Models A and B

Linear Scale
All BR similar in maginute

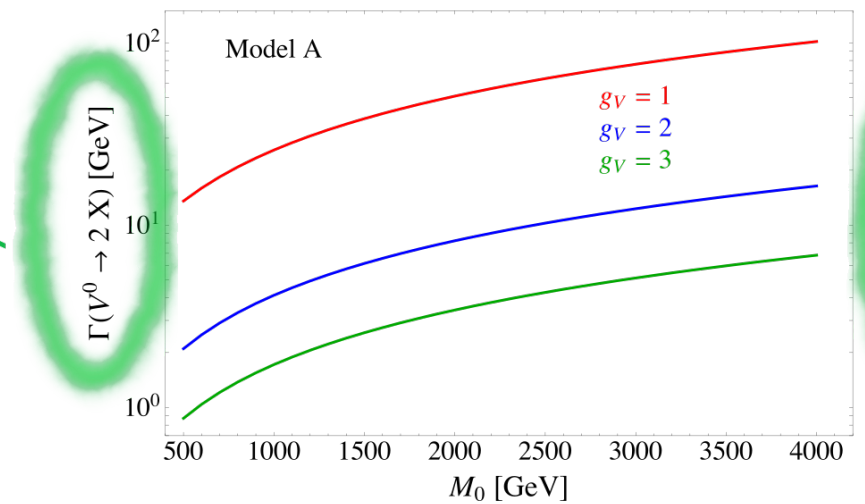
Log Scale
fermionic decays strongly disfavoured

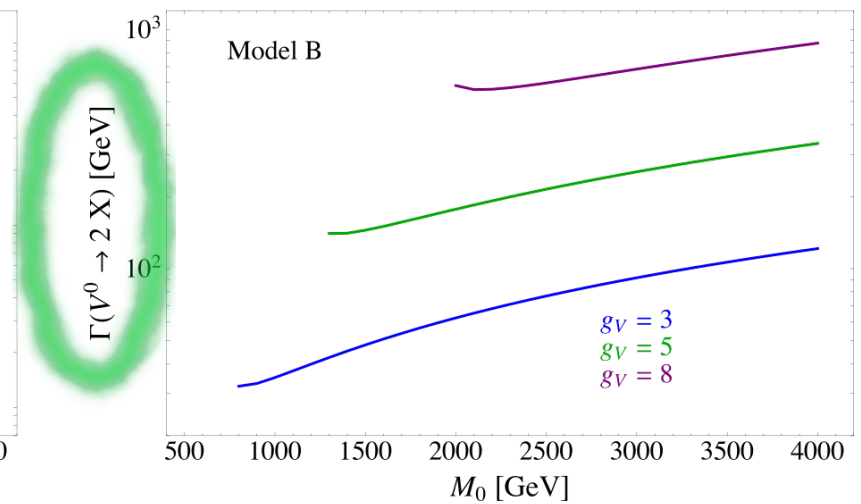
Branching Ratio





Decay Width





Model A / Model B

Model A:

$$g_V c_H \simeq \frac{g^2 c_F}{g_V} \simeq \frac{g^2}{g_V} \qquad (1)$$

Model B:

$$g_V c_H \simeq -g_V \qquad \frac{g^2 c_F}{g_V} \simeq \frac{g^2}{g_V} \qquad (2)$$