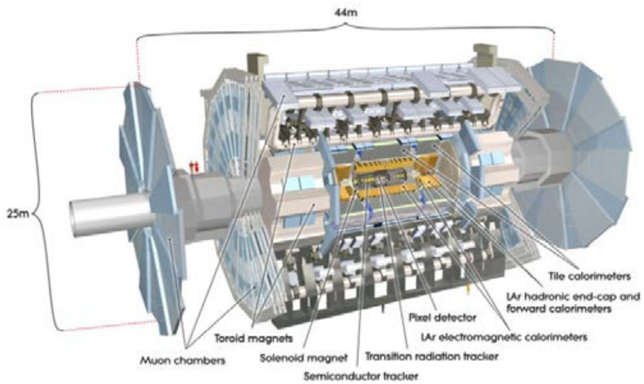
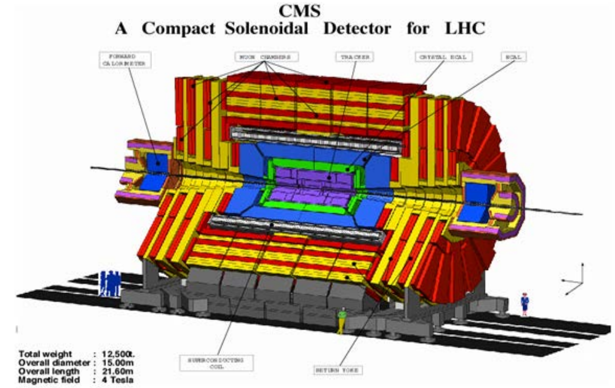
Simplified Higgs Models: Life Before 750





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1601.07208 8/5/16

Idea: Extend the Simplified Model approach from DM to Higgs

Dark Matter		Higgs
EFT= Higher dim operators	→	EFT= Higher dim operators
Simplified Models	→	?? Simplified Models ??
UV-complete Theories e.g., SUSY	→	UV-complete Theories e.g., E_6SSM

- EFT descriptions of NP, while useful, have limitations
- In the DM case, ATLAS & CMS have mostly moved from EFTs to Simplified Models: renormalizable, fewer validity issues & more useful for complementarity studies
- SMs for DM have only a few free parameters (masses + couplings) & are generally well-behaved in the UV. New particles (i.e., mediators) can also be produced & studied
- What's the analog of SMs in the case of Higgs physics?

$\rightarrow$ Introduce some new particles & couplings to allow for variation in Higgs properties w/ only a few parameters

$\rightarrow$ Add singlet Higgs, S, + isosinglet, Q=2/3, VLQ + mixings

These are 'mediators' of the Higgs coupling modifications that can also be produced & examined on-shell.

The Lagrangian parameters can all be traded for physical quantities:

$m_{h1,h2}$; $m_{t,T}$; $r = v_H / v_S$; s_θ (h-S); s_L (t-T) = 5 unknowns

(See 1601.07208 for details)

The T mass is generated by a Yukawa coupling to S which gets a vev

All observables can be expressed in terms of these quantities

Procedure – the power of SMs: Scan the parameter space & find regions preferred by precision EWK data + unitarity constraints + the ATLAS & CMS combined Higgs couplings results + searches for other Higgs states by employing HiggsBounds + HiggsSignals + the MultiNest algorithm

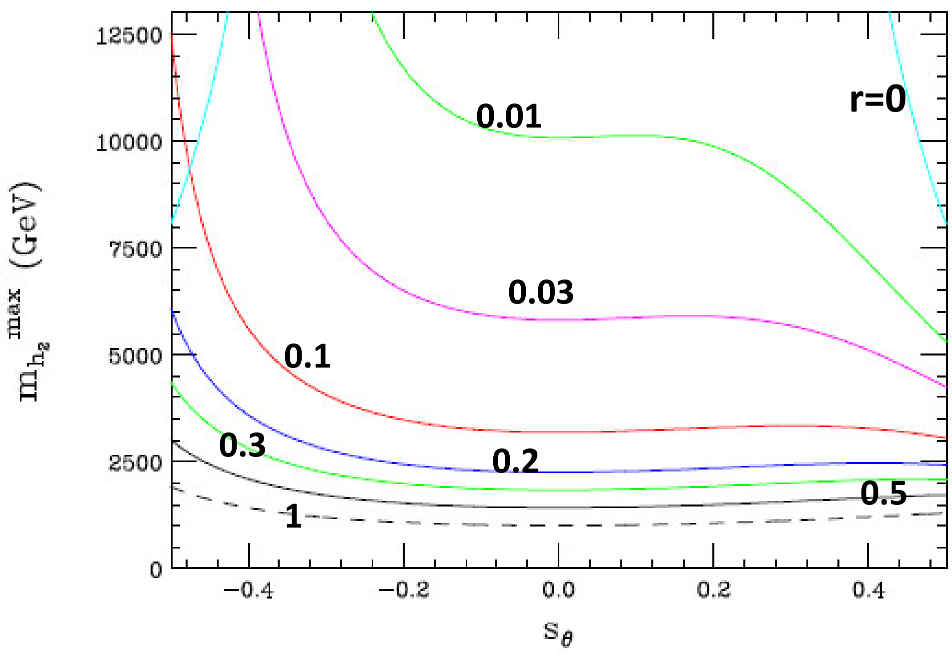
Some simple predictions:

$$\kappa_W = \kappa_Z = \kappa_b = \kappa_\tau = \cos\theta \qquad \kappa_t = c_L^2 c_\theta - s_L^2 s_\theta \frac{v_H}{v_S}$$

$$\kappa_g \approx c_\theta - s_\theta \frac{v_H}{v_S}. \qquad \kappa_\gamma \approx \frac{c_\theta A_1(\tau_W) + \frac{16}{9}\kappa_g}{A_1(\tau_W) + \frac{16}{9}}$$

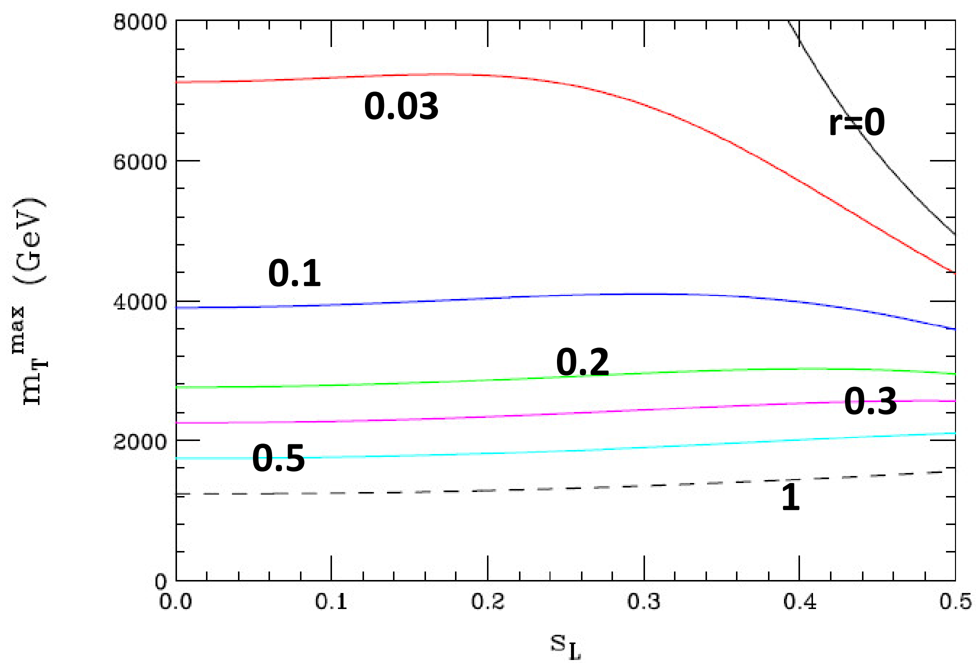
$$\kappa_{3h_1} \approx c_\theta^3 - \frac{v_H}{v_S} s_\theta^3$$

E.g., Unitarity Constraints



$h_2h_2 \rightarrow h_2h_2$ & $T\bar{T} \rightarrow T\bar{T}$

scattering lead to constraints on the 5-d model parameter space

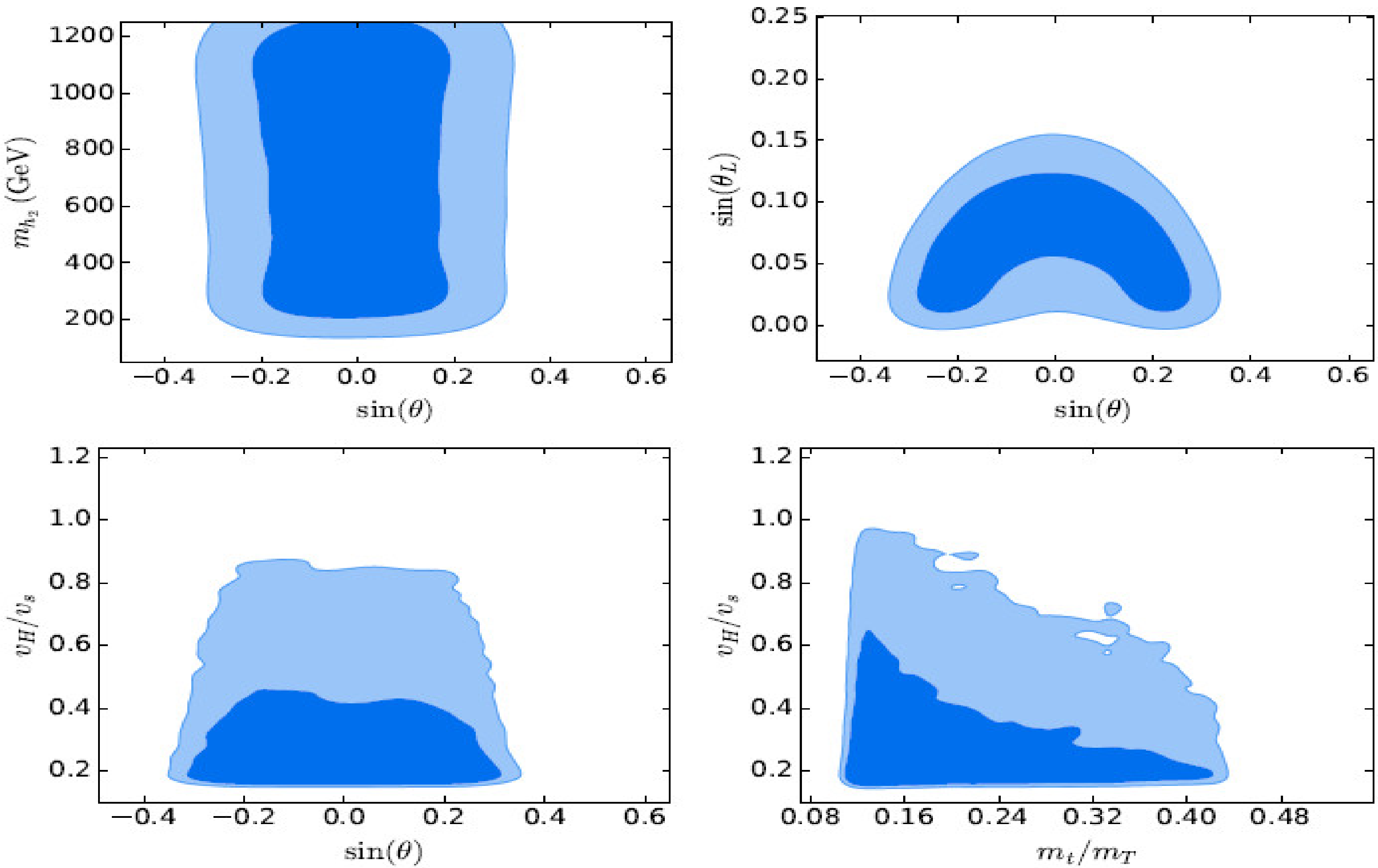


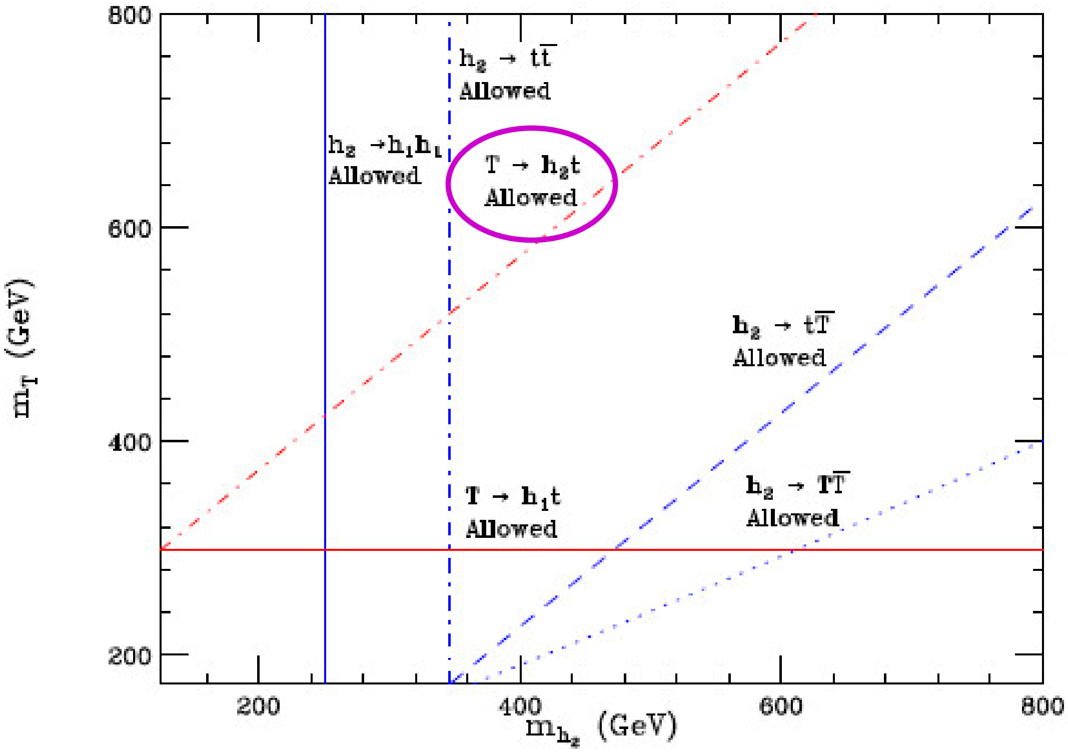
These provide upper limits on the T&h_2 masses as functions of the vev ratio, r, and the relevant mixing angles

For r>0.2 , T should be visible at the HL-LHC (or before)

Parameter Scan Results

Parameter	Range	Best fit value
θ	$(-\pi/2, \pi/2)$	-0.16
v_S (GeV)	$(250.0, 1500.0)$	250 GeV
m_T (GeV)	$(250.0, 1500.0)$	400 GeV
θ_L	$(0, \pi/2)$	0.11
m_{h2} (GeV)	$(150.0, 1250.0)$	1230 GeV

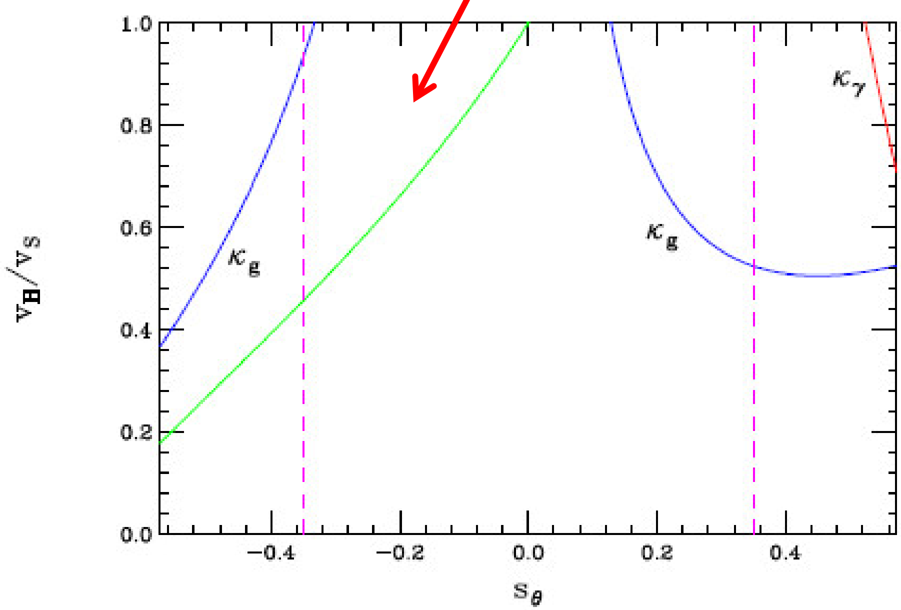




Particle decay & search pheno depends on your 'location' in the $m_{h2,T}$ plane

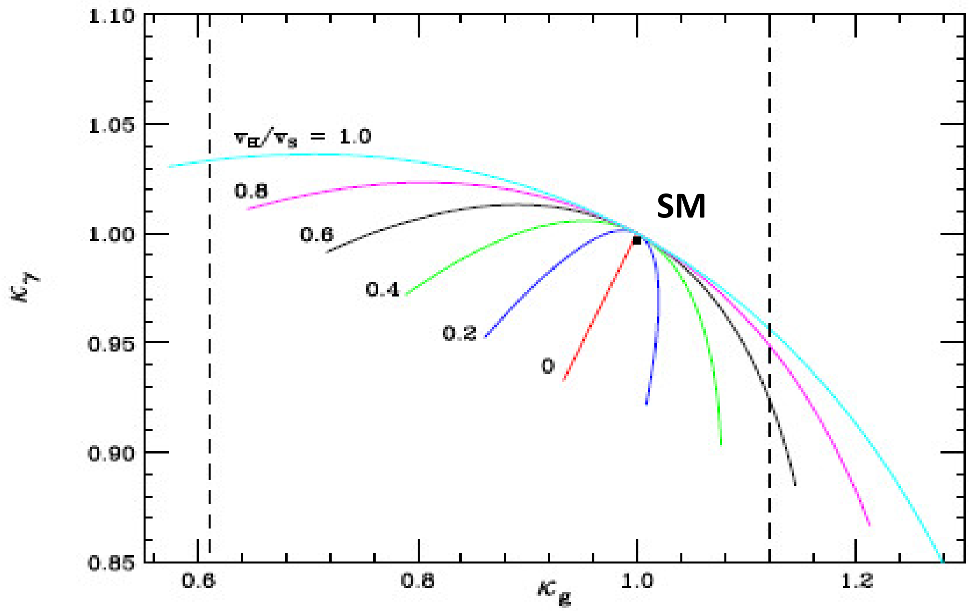
Significant $T \to th_2$ may have important impact on LHC VLQ searches which happens when

$$\frac{g^2_{h_2 Tt}}{g^2_{h_1 Tt}} = \left(\frac{s_\theta - r c_\theta}{c_\theta + r s_\theta}\right)^2 > 1\,,$$



Significant BFs for this mode are possible but not 'likely' in 'best fit' regions of the parameter space

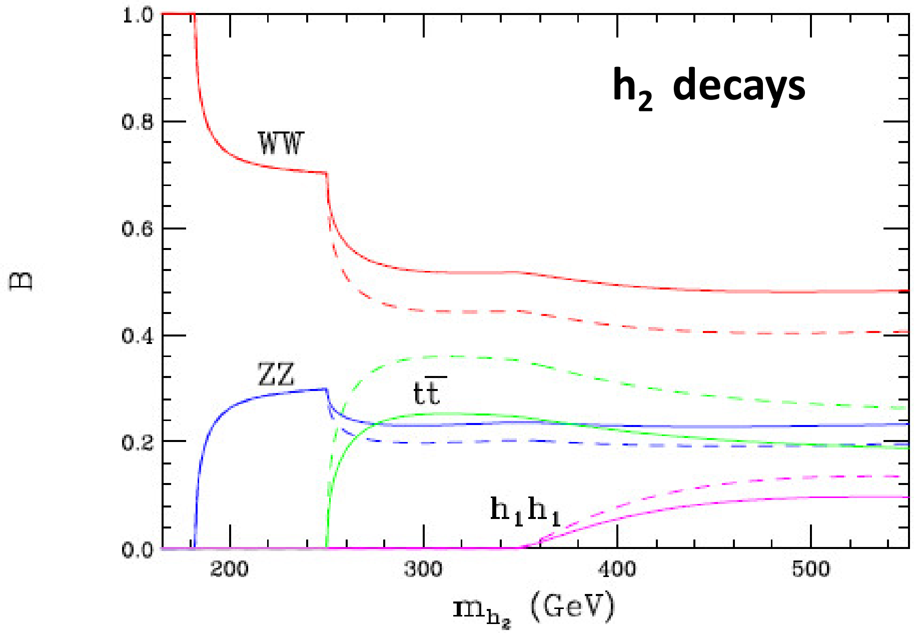
But they remain interesting & warrant further study !

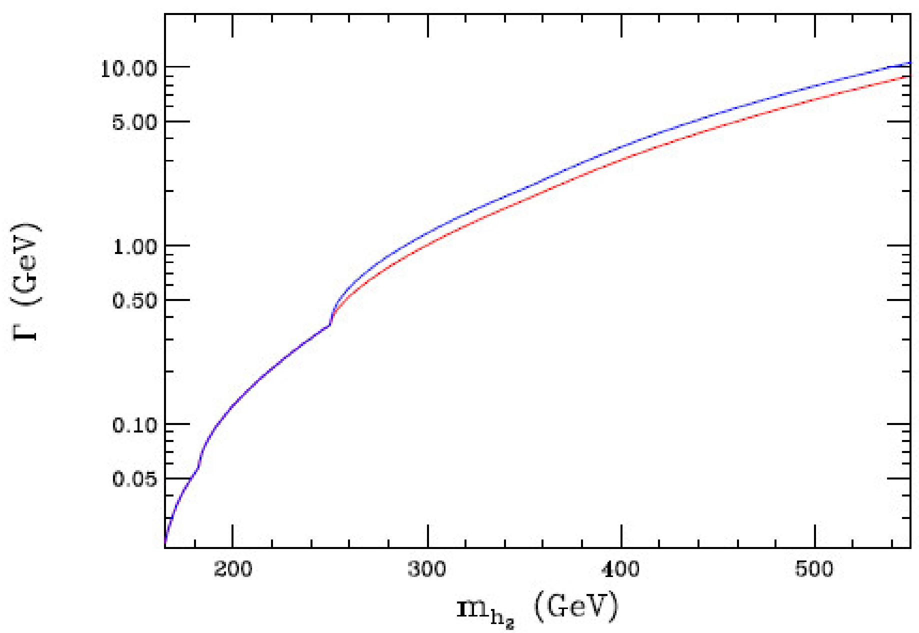


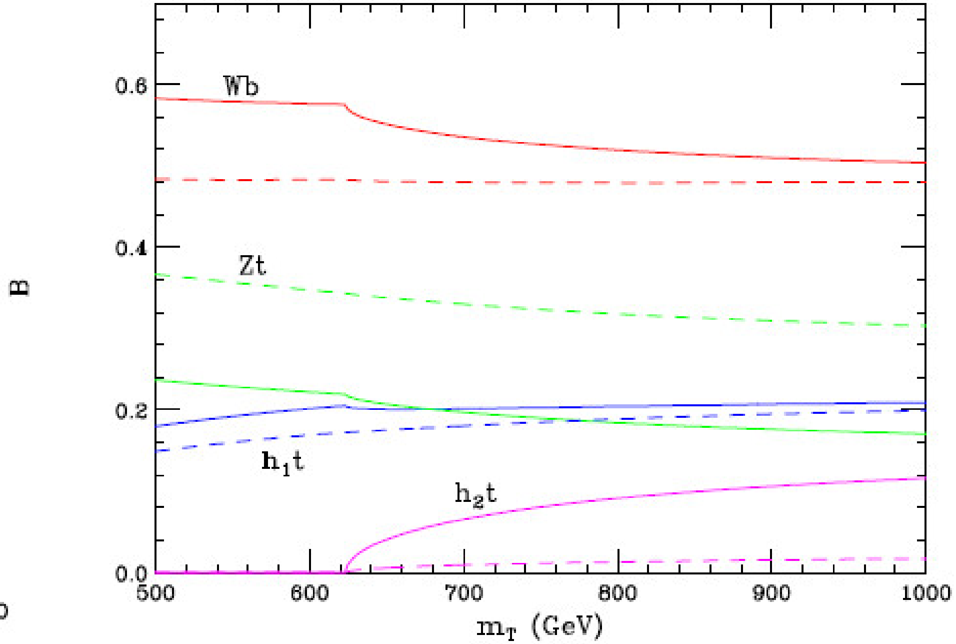
Mixing + T loops contribute to shifts in both $\kappa_{\gamma,g}$

← 'Reachable' & correlated regions in the κ_γ - κ_g parameter space. Values measured outside range will exclude this model

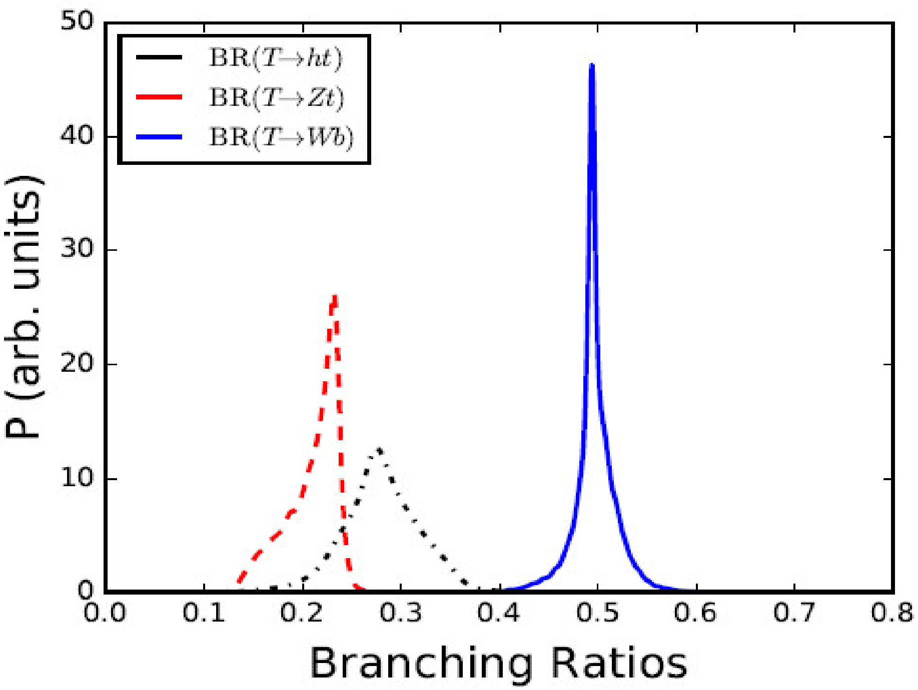
'Typical' h_2 branching fractions & total widths





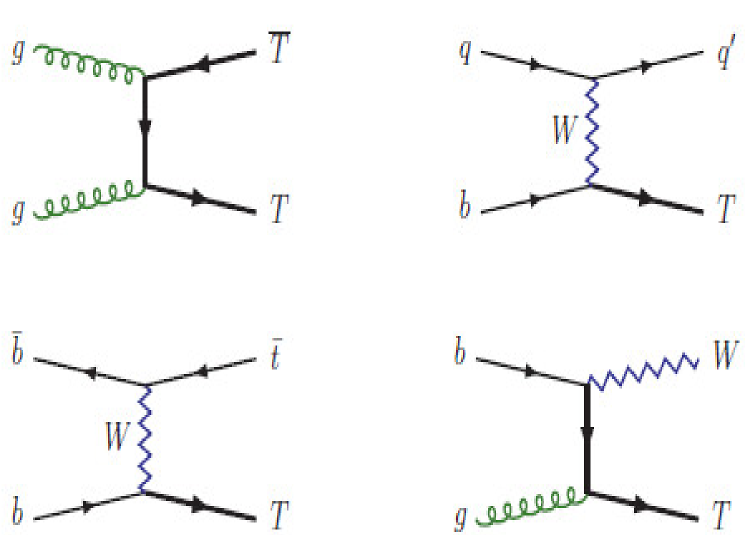


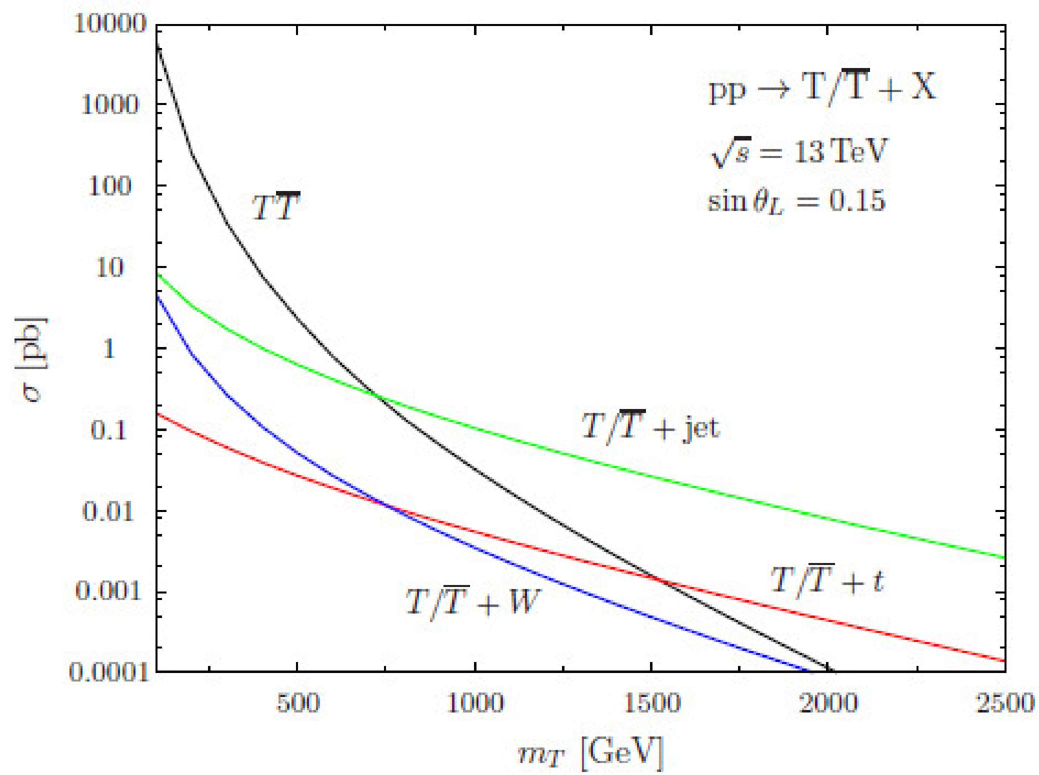
‘Typical’ T decay branching fractions for 2 parameter choices. The $T \to h_2 t$ mode BF is ‘usually’ small but can be more significant in corners of the space. If this BF is big LHC VLQ searches for T may be altered



Distribution of T decay BFs from the 5-d parameter scan roughly peak near their ‘canonical’ numbers .. but $T \to h_1 t$ tends to be a bit larger than Zt

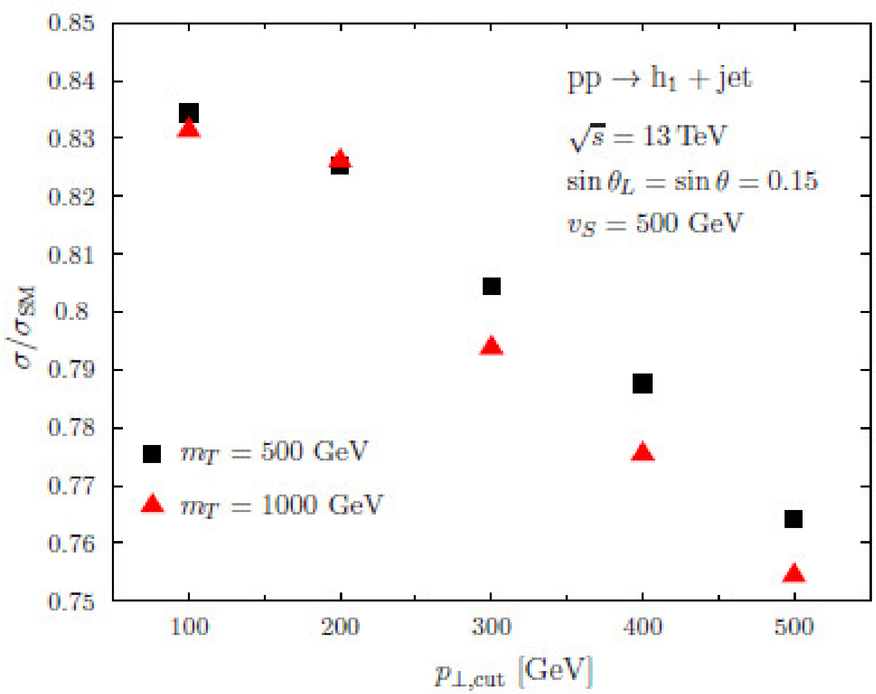
- Single T production via t/T mixing in various channels can be more important than T-pair production by QCD when the T masses > 700- 800 GeV. The details depend upon the specific values of the mixing angles that are assumed.

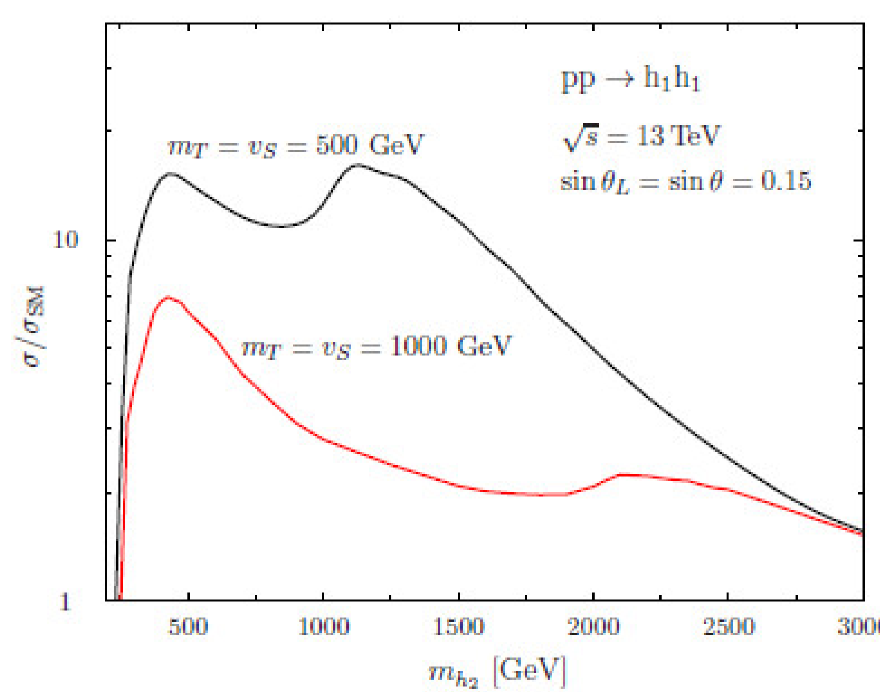




- The existence of **both** S & T + mixing with the SM fields can alter Higgs production distributions once (i) the t/T loop is ‘resolved’ and/or (ii) $h_2 \rightarrow h_1 h_1$ becomes relevant…

→ Here we see typical effects from both of these sources..





MadGraph5aMC@NLO

Summary & Conclusions

- Simplified Models provide an alternative description of potential modifications to Higgs boson properties with only a few parameters.

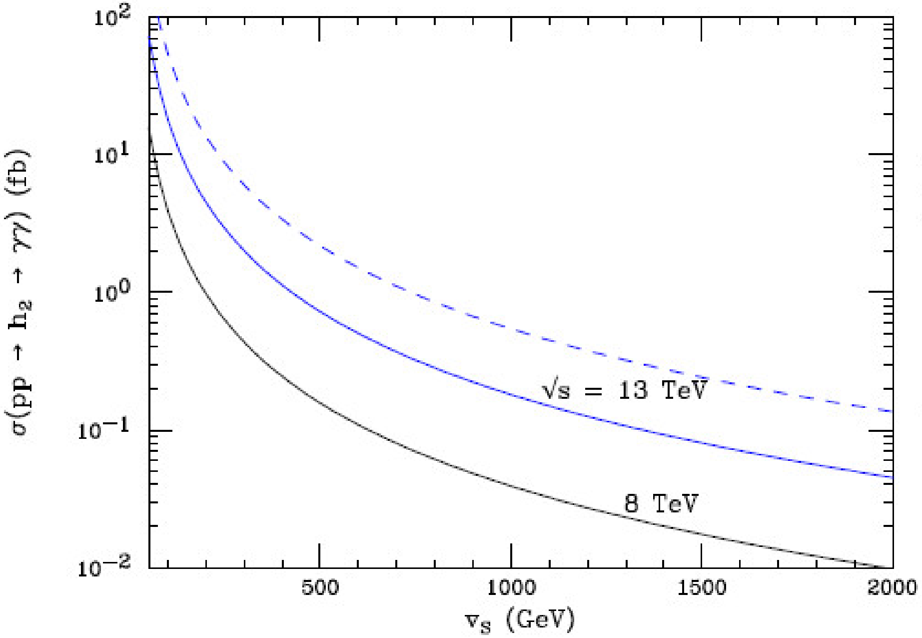
- Unlike EFTs, SMs are renormalizable & well-behaved in the UV.

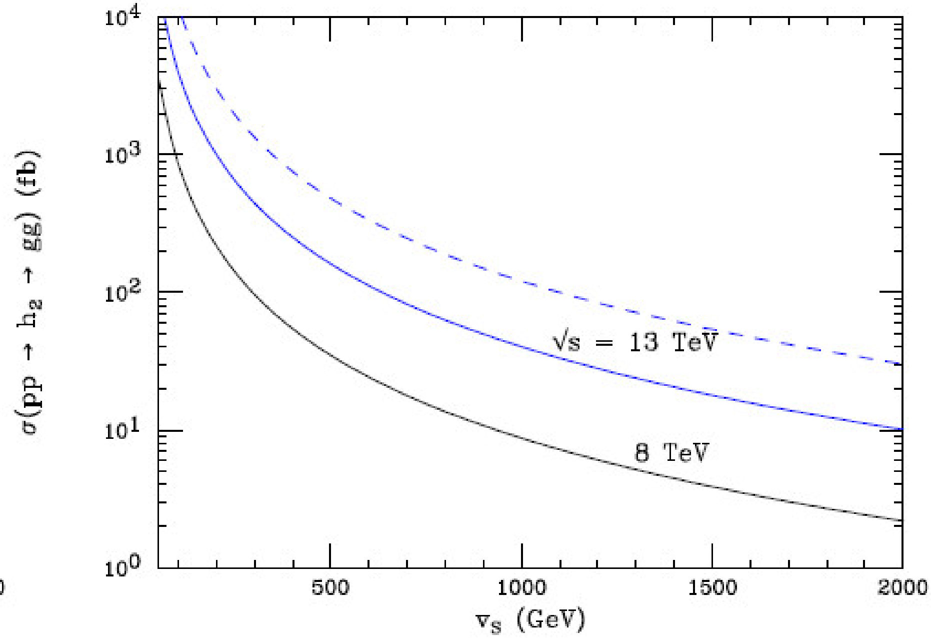
- The new (here, S & T) particles can be constrained & looked for at the LHC

- Here only one example of this class of models was studied but many alternatives are possible (as subsequent analyses of the 750 GeV excess have shown …)

Hopefully some new physics is just around the corner !

Backup


10^2
10^1
10^0
10^{-1}
10^{-2}
500
1000
1500
2000
$\sigma(pp \to h_2 \to \gamma\gamma)$ (fb)
v_S (GeV)
$\sqrt{s}$ = 13 TeV
8 TeV


10^4
10^3
10^2
10^1
10^0
500
1000
1500
2000
$\sigma(pp \to h_2 \to gg)$ (fb)
v_S (GeV)
$\sqrt{s}$ = 13 TeV
8 TeV