

$HS\chi$ model

A generic tool for $h + E_{\text{T}}^{\text{miss}}$ searches

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Introduction

Introducing H , S and χ

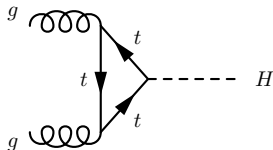
The theory behind the model is found in [EPJC76 \(2016\) no.10, 580](#)

- The model introduces several new particles
 - H (the SM Higgs is h !): a heavy scalar with mass between 250 GeV ($2m_h$) and 350 GeV ($2m_t$). It may be the heavy CP even component of a 2HDM.
 - S : a Higgs-like scalar with mass between 125 GeV (m_h) and at most 225 GeV ($m_H - m_h$). This could have theoretical origins in a Higgs singlet.
 - χ : a scalar dark matter (DM) candidate, which has a mass around $m_h/2$, and interacts only with S .
- The simplified model presented here could be embedded into more precise theories, such as Higgs portal models, extended 2HDMs, etc.

Phenomenology

Producing H and S

- H is produced dominantly through gluon fusion (ggF)



- S couples more weakly to SM particles, so direct production is suppressed
- S is dominantly produced through $H \rightarrow SS$, Sh
 - The admixture is controlled by the free parameter:

$$a_1 = \frac{\text{BR}(H \rightarrow Sh)}{\text{BR}(H \rightarrow SS)}$$

Plausibility

Is this within current limits?

- From EPJC76 (2016) no.10, 580, using the most liberal choice of $\sigma \times \text{BR}$

Channel/region (GeV)	Prediction (fb)	Experimental limit (fb)
<i>Monojet with $gg \rightarrow H \rightarrow SS \rightarrow 4\chi$ at $\sqrt{s} = 8$ TeV</i>		
$E_T^{\text{miss}} > 250$	15.1 ± 0.18	229
>300	8.90 ± 0.063	98.5
>350	5.42 ± 0.023	48.8
>400	3.42 ± 0.0093	20.2
>450	2.24 ± 0.0040	7.82
>500	1.48 ± 0.0017	6.09
>550	1.00 ± 0.00080	7.21
<i>$b\bar{b} + E_T^{\text{miss}}$ with $gg \rightarrow H \rightarrow Sh \rightarrow b\bar{b}\chi\chi$ at $\sqrt{s} = 13$ TeV</i>		
Signal region	0.10 ± 0.03	1.38
<i>$\gamma\gamma + E_T^{\text{miss}}$ with $gg \rightarrow H \rightarrow Sh \rightarrow \gamma\gamma\chi\chi$ at $\sqrt{s} = 13$ TeV</i>		
High $S_{E_T^{\text{miss}}}$, high $p_T^{\gamma\gamma}$	0.265 ± 0.009	12.1
High $S_{E_T^{\text{miss}}}$, low $p_T^{\gamma\gamma}$	0.675 ± 0.014	12.1
Intermediate $S_{E_T^{\text{miss}}}$	3.17 ± 0.03	12.1
Rest	2.80 ± 0.03	12.1

Interpretation

Using the *simplified* model

Scanning the parameter space (only four relevant parameters):

- m_H : varied between $2m_h$ and $2m_t$
- m_S : varied between 130 GeV and 200 GeV
 - Since S is the portal to the DM interactions, m_χ is irrelevant for this search
- $\text{BR}(S \rightarrow \chi\chi)$: varied between 0 and 1
 - One could argue that m_χ is related to this
- β_g : “signal strength”, varies the $gg \rightarrow H$ cross section.
 - 0 = no signal,
 - 1 = SM-like $gg \rightarrow H$ cross section

For more generic searches, the mass bounds can be relaxed

Event generation

How can we simulate the processes?

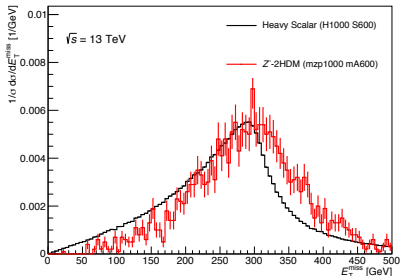
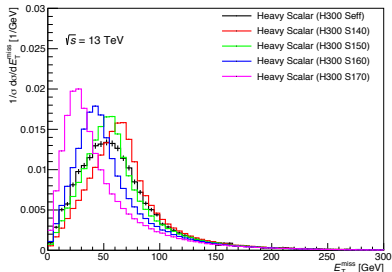
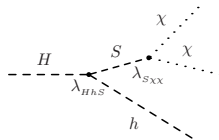
- Since we only add scalars \implies Pythia 8 can be used easily
 - I have a large variety of Pythia cards for generating various processes
- A UFO model does exist (not yet validated)
 - However, the simplified model approach is more useful when using Pythia

If there is any interest in generating/validating,
please email me!

Kinematics

E_T^{miss} at various parameter points

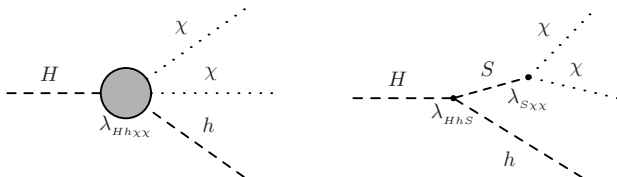
Selection of parameter points can produce E_T^{miss} in various regions of the phase space.



Search prospects

Higgs + E_T^{miss} – what has been done so far?

This model can be used to describe Higgs + E_T^{miss} processes:



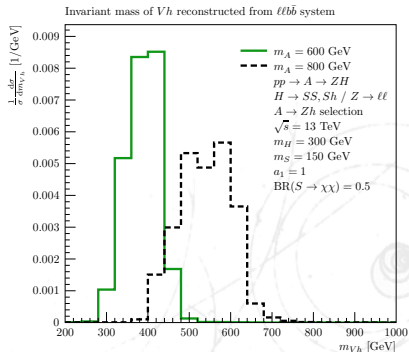
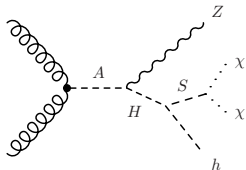
- The effective vertex (left) has already been studied under $h \rightarrow \gamma\gamma$ in ATLAS ([ICHEP Note](#))
- $\text{BR}(S \rightarrow \chi\chi)$ is a free parameter of the theory, so $\gamma\gamma + E_T^{\text{miss}}$ has set limits on it

Search prospects

Using the 2HDM embedding – what searches could be done?

Case study: $A \rightarrow ZH + E_{\text{T}}^{\text{miss}}$

- This was studied in the theory paper (EPJC76 (2016) no.10, 580)
- The model can motivate a large $A \rightarrow ZH$ (not h) BR
- Thereafter, $H \rightarrow Sh$, $S \rightarrow \chi\chi$



Conclusions

A model for generic $h + E_{\text{T}}^{\text{miss}}$ searches has been presented:

- Minimally, three new particles are introduced, H and S , both Higgs-like, and χ
- S is produced through the decay of H
 - $H \rightarrow SS$
 - $H \rightarrow Sh$
- A 2HDM could also be introduced
 - This expands the possible search channels
 - $A \rightarrow ZH$ has been used as a case study
 - A list of final states of the $HS\chi$ model using a 2HDM can be found in Table 2 of [EPJC76 \(2016\) no.10, 580](#)

Thank you

Backup

Search prospects

Branching ratios of S

- What channels can we study for potential S production?

