The production of additional bosons and the impact on Higgs boson physics #95

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Introduction

In order to study a number of features in the Run I data, an effective Lagrangian was used. The effective Lagrangian includes a heavy scalar and a Dark Matter candidate with a number of interactions. This entails couplings to weak bosons, effective coupling to gluons, yukawa coupling to the top quark, trilinear and quartic interactions. The heavy boson is produced predominantly via gluon-gluon fusion.

$$\mathscr{L}_H = -\frac{1}{4}\beta_g \kappa_{hgg}^{SM} G_{\mu\nu}G^{\mu\nu}H + \beta_V \kappa_{hVV}^{SM} V_\mu V^\mu H,$$

$$\mathscr{L}_Y = -\frac{1}{\sqrt{2}}\left[y_{ttH}\bar{t}tH + y_{bbH}\bar{b}bH\right],$$

$$\mathscr{L}_T = -\frac{1}{2}v\left[\lambda_{Hhh}Hhh + \lambda_{h\chi\chi}h\chi\chi + \lambda_{H\chi\chi}H\chi\chi\right],$$

$$\mathscr{L}_Q = -\frac{1}{2}\boxed{\lambda_{Hh\chi\chi}Hh\chi\chi} - \frac{1}{4}\lambda_{HHhh}HHhh - \frac{1}{4}\lambda_{hh\chi\chi}hh\chi\chi - \frac{1}{4}\lambda_{HH\chi\chi}HH\chi\chi,$$

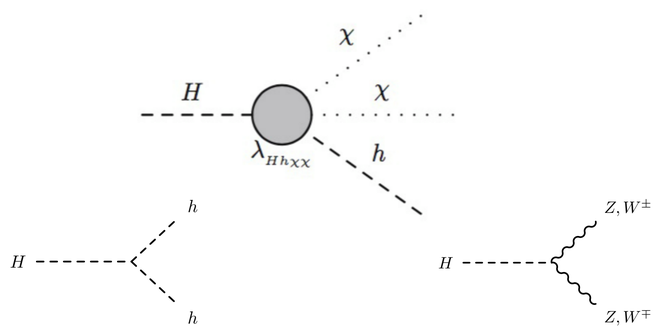

Figure 1. The different decay modes of H boson. Here h denotes the SM Higgs and χ for the scalar dark matter boson.

Statistical analysis

The BSM prediction constructed using the proposed model was fit against four classes of constraints. The constraints considered are the differential Higgs boson pT spectra, the limits on di-Higgs boson production through a resonance, various limits and measurements on top associated Higgs boson production, and the limits on a heavy scalar decaying to vector bosons. For each class of constraints, results from both ATLAS and CMS were used. Finally, it is found that the best fit mass is at around 270 GeV for the H boson.

Figure 2. A scan over m_H of the test statistic $\chi^2_{SM} - \chi^2_{BSM}$ employed for quantifying the significance of the effect of the BSM model.

The hypothesis

1. The starting point of the hypothesis is the existence of a boson, H, which contains Higgs-like interactions, with a mass in the range 250-295 GeV.
2. In order to avoid large quartic couplings and incorporate a mediator with Dark Matter, a real scalar, S, is introduced. This mediator also couples to SM particles, leading to jets and leptons.

$$\mathscr{L}_{HhS} = -\frac{1}{2}v\left[\lambda_{hhS}hhS + \lambda_{hSS}hSS + \lambda_{HHS}HHS + \lambda_{HSS}HSS + \boxed{\lambda_{HhS}HhS}\right],$$

$$H \to WW, ZZ, q\bar{q}, gg, Z\gamma, \gamma\gamma, \chi\chi$$

Dominant decays ⇨ + $H \to SS, Sh, hh$

Some predictions

If H is embedded into a 2HDM, the Hypothesis leads to rich phenomenology. One unique signature of the hypothesis is 4 isolated leptons coming from production of 4W, which has low backgrounds. One can also search for H boson via 3 same-signed leptons , which comes from production of 6W.

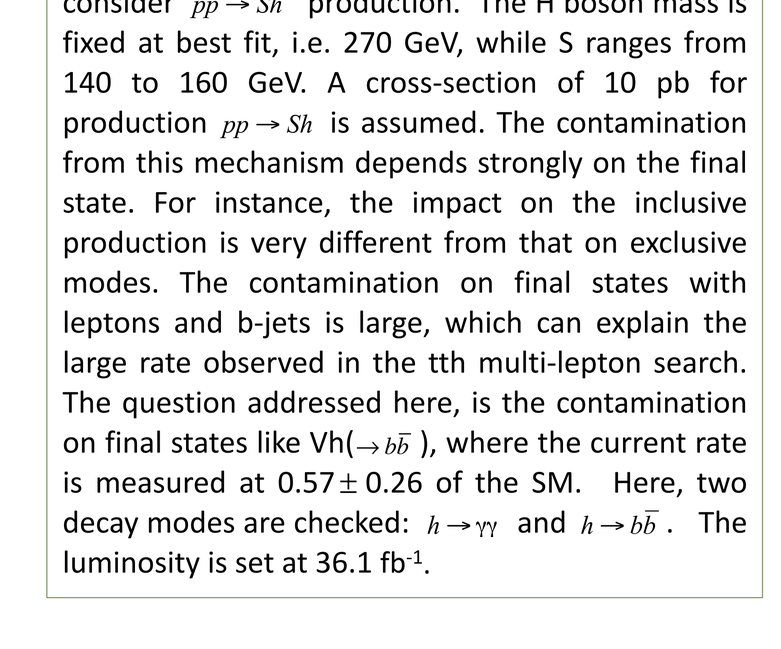

Figure 3. Predicted multi-lepton signatures

The impact on SM Higgs measurements

Here we evaluate the BSM contamination in yield measurements pertaining to SM Higgs boson production. To check the contamination, we consider $pp \to Sh$ production. The H boson mass is fixed at best fit, i.e. 270 GeV, while S ranges from 140 to 160 GeV. A cross-section of 10 pb for production $pp \to Sh$ is assumed. The contamination from this mechanism depends strongly on the final state. For instance, the impact on the inclusive production is very different from that on exclusive modes. The contamination on final states with leptons and b-jets is large, which can explain the large rate observed in the tth multi-lepton search. The question addressed here, is the contamination on final states like Vh($\to b\bar{b}$), where the current rate is measured at 0.57 ± 0.26 of the SM. Here, two decay modes are checked: $h \to \gamma\gamma$ and $h \to b\bar{b}$. The luminosity is set at 36.1 fb^{-1}.

Samples	VBF	VH hadronic
mS=140 GeV	2.86±0.069	0.16±0.016
mS=150 GeV	1.94±0.06	1.14±0.04
mS=160 GeV	2.89±0.07	1.97±0.06
Wh	0.22±0.01	1.90±0.03
Zh	0.14±0.007	1.31±0.02
tth	0.09±0.004	0.22±0.007
VBF	25.81±0.20	0.30±0.02

Table 1. The number of BSM contamination events in $h \to \gamma\gamma$ search

Samples	0 lepton	1 lepton	2 lepton, high pT(V)
mS=140 GeV	<0.10	0.21±0.15	<0.10
mS=150 GeV	0.52±0.23	2.39±0.50	<0.10
mS=160 GeV	<0.10	0.31±0.18	<0.10
Wh	21.10±1.00	100.76±2.20	<0.05
Z($\to ll$)h	0.35±0.06	2.40±0.15	18.84±0.41
Z($\to \nu\nu$)h	62.40±1.07	<0.02	<0.02
tth	0.11±0.02	0.56±0.05	0.04±0.01
VBF	<0.79	<0.79	<0.79

Table 2. The number of BSM contamination events in $h \to b\bar{b}$ search

Conclusions

We propose a Higgs boson production mode, which arises from the decay of a new heavy scalar. It is originally motivated by a number of features in the in the Run I data. A statistical study is done with various experimental constraints, and it is found the best fit mass of the heavy boson is around 270 GeV. If the heavy scalar is embedded into a 2HDM yields rich phenomenology follows. The contamination of the decay of the H boson in the inclusive rate can be about 35%. However, the contamination in the search for Vh($\to b\bar{b}$) is very small. This statement does not depend on assumptions on the decay of the mediator S. This is consistent with the smallness of the rate of Vh($\to b\bar{b}$)=0.57 ± 0.26, while explaining the tendency to overmeasure the tth production mechanism with the leptonic final state. The observation of the Vh($\to b\bar{b}$) mode with Run II data is critical for the verification of the SM.

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