The Compatibility of LHC Data with a New Heavy Scalar

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Observations
Most Run 1 results matched Standard Model predictions, there were a number of small excesses: Higgs $p_T$ spectrum, Di-Higgs rate:

[VV production ($V = W^\pm, Z$):

Top associated Higgs production:

The Model
These excesses can all explained by the existence of a Heavy Scalar, the Madala boson, produced through gluon fusion (arXiv:1506.00062, arXiv:1603.01208):

With the following decay modes:

- The intermediate scalar $S$ can explain a large $H \rightarrow h\chi\chi$ branching ratio
- Phenomenologically interesting in the range $m_h < m_S < m_H - m_h$
- $H$ can be identified as a part of a Two Higgs Doublet Model (2HDM)
- If $H$ is the CP-even component of a 2HDM, we would expect more particles: $A$ and $H^\pm$

Experimental Searches
- Tag the Higgs $h$ using any channel
- Tag the $Z$ boson by searching for di-lepton pairs
- Requirement on missing energy

There are two current experimental searches which do this:

- The $A \rightarrow Zh$ search channel: ATLAS and CMS search for $A$ using the $h \rightarrow bb$ decay channel. The mass of $Zh$ is used as a discriminant here.
- $Z \rightarrow E_T^{miss}$: the SUSY search, ATLAS and CMS searches for 2 same-flavour opposite-sign leptons, with missing energy.

Explaining the Excesses
- Heavy scalar decays to Higgs $\Longrightarrow$ distorted Higgs $p_T$ spectrum
- Di-Higgs production is enhanced through a resonance ($pp \rightarrow H \rightarrow hh$)
- Resonant production of $VV$ pairs ($pp \rightarrow \rightarrow H \rightarrow VV$)
- Small $H \rightarrow VV$ branching fraction $\Longrightarrow$ enhanced $pp \rightarrow tH$ cross section

A statistical combination is performed leaving the mass of this heavy scalar as a free parameter:

Illustrative Results