DMWG Public Meeting
Overview of 1604.07975

CERN

Dec 15th 2016

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with Englert and Spannowsky

Summary

It seems there is a move towards more realistic scalar mediator models, especially as in 2HDM.

I think this is great!

Summary

This talk is sort of redundant after the previous talks today, and all the work folks have done this year!

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I think this is g

What is an EFT?

Scalar model proposed in white papers:

$$\mathcal{L} = \mathcal{L}_{SM} + g_\chi \phi \overline{\chi} \chi + g_t \phi \bar{t} t$$

Mediator is gauge singlet.

This is an EFT... Could arise from an operator such as

$$\frac{\phi}{\Lambda} g_t H \overline{Q}_3 U_3$$

Which is gauge-invariant but non-renormalizable.

What is an EFT?

Scalar model proposed in white papers:

$$\mathcal{L} = \mathcal{L}_{SM} + g_\chi \phi \bar{\chi} \chi + g_t \phi \bar{t} t$$

Mediator is gauge singlet.

This is an EFT... Could arise from singlet mixing

$$\phi |H|^2$$

But unless Higgs couplings are also modified this theory will break down at high energies.

What is an EFT?

Scalar model proposed in white papers:

$$\mathcal{L} = \mathcal{L}_{SM} + g_\chi \phi \overline{\chi} \chi + g_t \phi \bar{t} t$$

Mediator is gauge singlet.

This is an EFT... Could arise from a 2HDM

$$g_t H_2 \overline{Q}_3 U_3$$

But unless modified Higgs couplings and new pseudoscalar and charged scalar states are included, will break down somewhere.

What is an EFT?

Scalar model proposed in white papers:

$$\mathcal{L} = \mathcal{L}_{SM} + g_\chi \phi \bar{\chi} \chi + g_t \phi \bar{t} t$$

Mediator is gauge singlet.

Ok, so it is an EFT, but at least it is renormalizable?

Nope. This coupling breaks EW gauge invariance explicitly so, although the operator is dimension-4, theory cannot be renormalized with a finite number of counterterms.

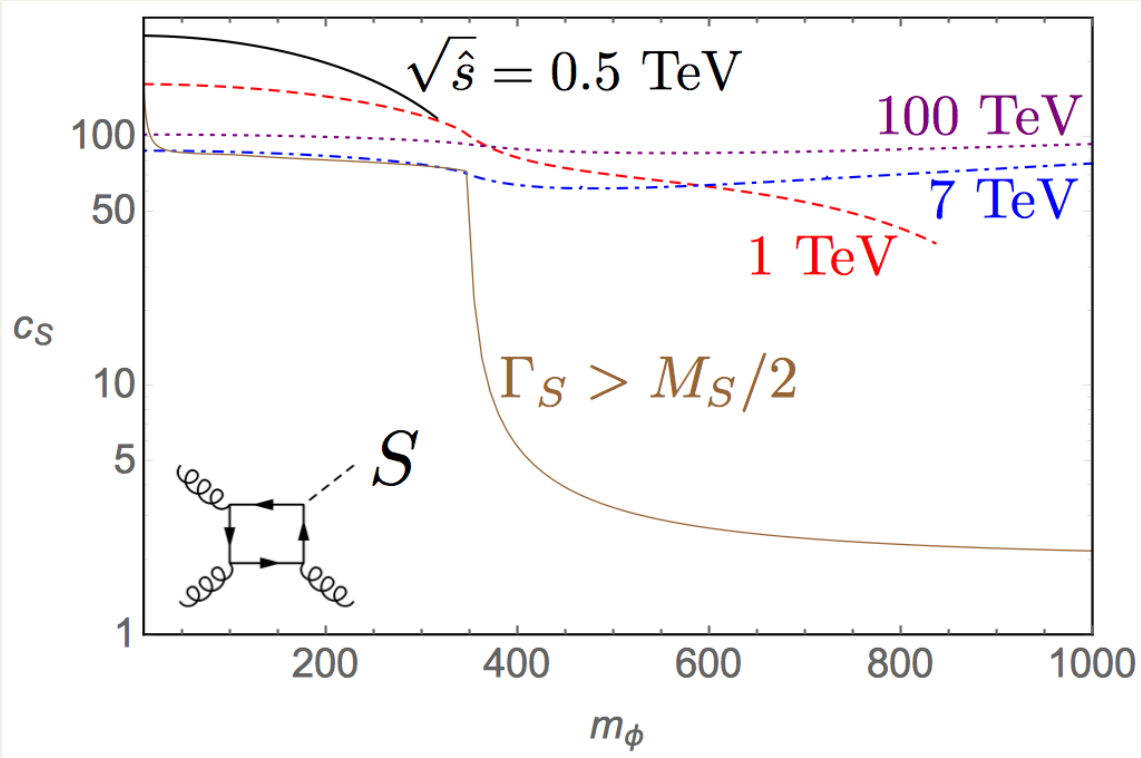
What is an EFT?

Manohar (and many others):

The basic premise of effective theories is that dynamics at low energies does not depend on the details of the dynamics at high energies. As a result, low energy physics can be described using an effective Lagrangian that contains only a few degrees of freedom, ignoring additional degrees of freedom present at higher energies.

Is it a good EFT?

For Simp Models, doesn't matter whether you call EFT vs not EFT, important point is that they model underlying process without breaking down at relevant energy scales...



Letting EFT Guide...

EFT perspective also tells us what we are missing. If we allow these couplings:

$$\mathcal{L} = \mathcal{L}_{SM} + g_\chi \phi \overline{\chi} \chi + g_t \phi \bar{t} t$$

Then why aren't these included?

$$\mathcal{L} = c_\phi \phi \left(\frac{M_W^2}{v} W^{+\mu} W^-_\mu + \frac{M_Z^2}{2v} Z^\mu Z_\mu \right) \quad ?$$

Letting EFT Guide...

From simple EFT perspective can see they arise at same dimension, with same symmetries

$$\frac{\phi}{\Lambda} g_t H \overline{Q}_3 U_3$$

And for gauge couplings

$$\mathcal{L} = \frac{\phi}{\Lambda} |D_\mu H|^2 \to \frac{\phi}{\Lambda} \left(M_W^2 W^{+\mu} W_\mu^- + \frac{1}{2} M_Z^2 Z^\mu Z_\mu \right)$$

This implies that in typical UV complete model you are not going to only have the quark couplings of the usual scalar simplified model.

Letting EFT Guide...

From simple EFT perspective can see they arise at same dimension, with same

$$\phi \qquad H\overline{Q}_3 U_3$$

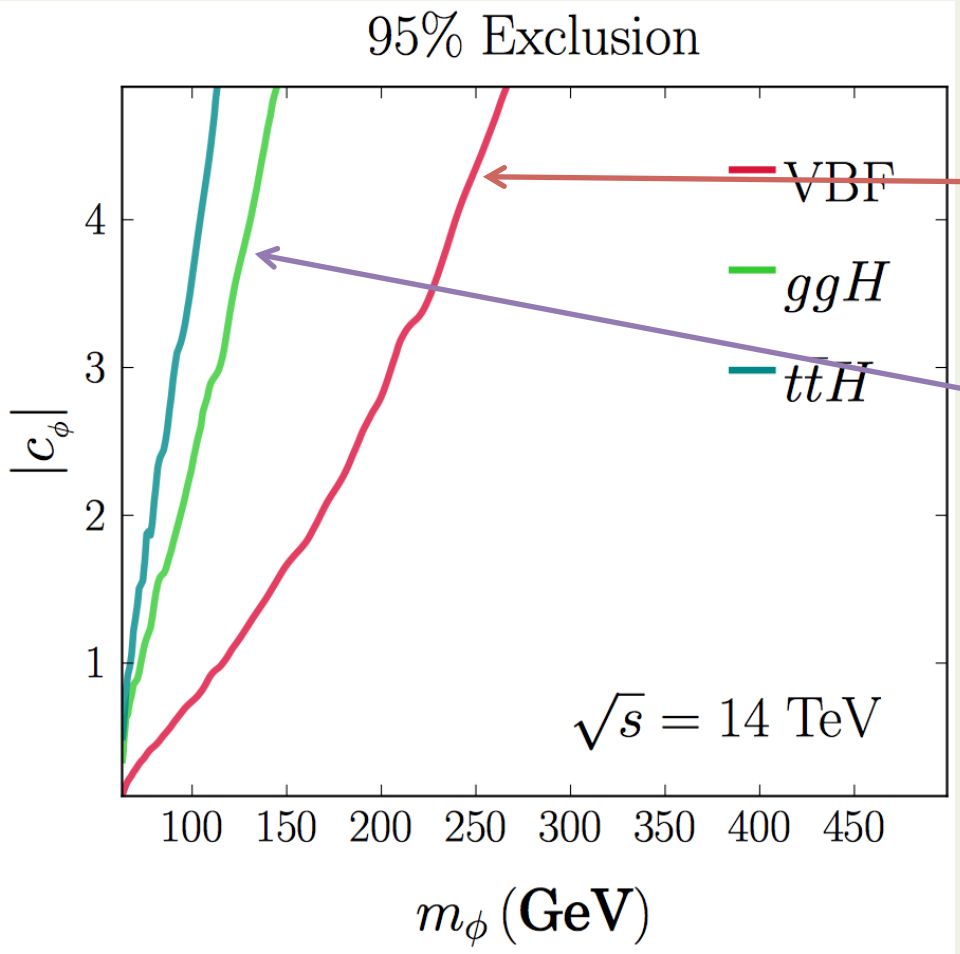
$$\mathcal{L} = \frac{\phi}{\Lambda}|D_\mu H|^2 \to \frac{}{\Lambda}\left(M_W \right.$$

Should be careful about imposing personal taste on where we believe these couplings can come from...

This implies that in typical UV complete model you are not going to only have the quark couplings of the usual scalar simplified model.

Which Channels?

Furthermore, the gauge boson couplings are far more constraining...



Gauge boson couplings.

Quark couplings.

Taken from 2 year old Study of Higgs portal DM:

1412.0258 (Craig, Lou, MM, Thalapillil.)

Models

So the coupling being left out could be the most important one... In other words:

With the usual scalar simplified model you may not be studying something corresponding to a description of well-motivated models...

E.g. Mixed singlet:

$$\mathcal{L} = \sin\theta\,\phi\left(\frac{m_q}{v}\bar{q}q + \frac{m_l}{v}\bar{l}l + 2\left(\frac{M_W^2}{v}W^{+\mu}W^-_\mu + \frac{M_Z^2}{2v}Z^\mu Z_\mu\right)\right) \quad .$$

This will be a story all about VBF...

Models

In a 2HDM the fermion and the gauge boson couplings may be varied independently. Higgs couplings go like:

$$c_{V,h} \propto 1 - \delta^2/2 \quad , \quad c_{t,h} \propto 1 - \delta \cot\beta$$

whereas if heavy scalar is the mediator then

$$c_{V,H} \propto \delta \quad , \quad c_{t,H} \propto -\cot\beta$$

So this is a nice UV-complete implementation that allows to explore richer scalar mediator phenomenology.

Comment

From talks this morning it seems there is a move towards more realistic scalar mediator models, especially as in 2HDM, which will cover these blind spots!