Using Effective Field Theories To Search For New Physics Beyond the Standard Model

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Introduction

- The goal of this study is to use Effective Field Theories (EFT) to identify likely sources of new physics (NP).
- While the Standard Model (SM) of particle physics is well tested, there is little known about the newly discovered Higgs sector.
- A Higgs-like particle was discovered in 2012 at the Large Hadron Collider (LHC) at CERN independently by the CMS [1] and ATLAS [2] collaborations.
- EFT approaches provide a model-independent method of searching for NP.
- The study is general enough to include any source of new physics, i.e. particles or interactions not part of the SM.
- The motive is to test if the newly discovered particle is indeed the SM Higgs boson or something new.

Effective Field Theories

- The EFT approach lets us look for deviations in the SM Higgs sector that cannot be directly accessed by the LHC.
- The coupling of the Higgs to SM particles has been directly measured. Fig. [3], but there is still room for NP.
- New heavier particles may leave a trace in SM couplings at low energy.
- These effects can be captured by extending the SM Lagrangian using higher dimensional operators $O_i$ [7].

$$L = L_{SM} + \sum c_i \frac{1}{A} O_i + \ldots$$

Fig. 3: Measurement of Higgs couplings at the LHC [8].

- Since $L$ is of dimension 4 the coefficients of $O_i$ require inverse powers of mass $A$ and thus NP is suppressed by this energy scale.

Dimension-Six $\mathcal{C}_{WW}$ Operator

- Suppressed by two powers of the NP scale.
- Affects the Higgs couplings to gauge bosons.
- Vector Boson Fusion (VBF) given by $p + p \rightarrow H_{jj} \rightarrow WW_{jj} \rightarrow ll\nu\nu jj$ (shown in Fig. 4) at the 14 TeV LHC.

Figure 4: Schematic drawing of $p + p \rightarrow H_{jj} \rightarrow WW_{jj} \rightarrow ll\nu\nu jj$.

- We studied the invariant mass distribution of the final state leptons $m_{WW} = \sqrt{(p_t + p_j + p_{lj} + p_{k})^2}$.
- Experimental cuts from [9] were applied to enhance the signal over the background.
- Like sign W’s were used to enhance the signal.

Conclusion

- So far the Higgs particle looks like the SM Higgs Boson.
- More data is needed to find new physics in the Higgs sector at the next run of the LHC in 2015.
- If the Higgs boson that was discovered at the LHC at CERN deviates from the SM Higgs in its coupling to the W boson, we should be able to detect it or more strongly restrict NP at the next run.
- If the data collected for the process $p + p \rightarrow H_{jj} + d d j j$ resembles Figs. 6 or 7, then the EFT tells us to expect new physics in the W boson couplings to the Higgs boson. 
- This new physics could come in the form of, for example, a non-standard Higgs boson or unknown heavy particles entering through loops.

References

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