CHAPTER 12

SUMMARY

Using 138 fb^{-1} of pp collisions at $\sqrt{s}$ 13 TeV collected by the CMS experiment during 2016, 2017, and 2018, this thesis has presented a search for new physics in the top sector within the context of an EFT framework. The goal of the analysis is to extract limits for the WCs of 26 dimension-six EFT operators involving top quarks. Processes that are significantly impacted by these operators correspond to the signal for this analysis; these processes constitute $\mathrm{t\bar{t}H}$, $\mathrm{t\bar{t}l}\nu$, $\mathrm{t\bar{t}l\bar{l}}$, $\mathrm{tl\bar{l}q}$, tHq, and $\mathrm{t\bar{t}t\bar{t}}$.

This analysis focuses on multilepton signatures involving two same-sign leptons or three or more leptons. Additional jets and b-tagged jets are also required, resulting in 43 signal-region categories; to improve the sensitivity to the EFT effects, the events in each category are binned according to a differential kinematical distribution, resulting in 178 total bins. Any process that contributes to these multileptonic final-state signatures but is not significantly impacted by the 26 WCs is considered to be a background for the analysis. The largest background contributions arise from $\mathrm{t\bar{t}}$ events with misidentified leptons and from diboson processes.

Multiple signal processes impacted by various EFT effects may all contribute to the same final-state signature, making it important to analyze all EFT effects across all channels simultaneously. To this end, we obtain detector-level EFT predictions by parameterizing the weight of each simulated event as a 26-dimensional quadratic function in terms of the WCs. For any observable bin, we are consequently able to obtain the dependence of the predicted yield on the WCs by summing the quadratic parameterizations for each of the events passing the bin's selection criteria.

Each of the 178 bins is treated as an independent Poisson measurement with a mean corresponding to the predicted yield (where the yield is a function of the 26 WCs). The likelihood corresponds to the product over the 178 bins. A statistical analysis is performed to extract the confidence intervals for the WCs by numerically minimizing the negative log of the likelihood function; scanning over one WC at a time, the other WCs are profiled in the likelihood fit. The 2σ confidence intervals for all WCs are consistent with the SM prediction.

Although this analysis did not identify any indications of new physics, there are many ways in which it could be improved and expanded. Further optimization of the categorization, binning, and differential distributions would help to increase the sensitivity. It would also be beneficial to improve the EFT modeling (e.g. by generating the simulated samples at NLO), and the incorporation of an uncertainty to account for the neglected dimension-eight effects would lead to more accurate limits. To broaden the analysis, additional signal regions could be explored and more rare processes could be studied. Performing combinations with other analyses that target different EFT effects would further expand the sensitivity to potential new physics.

Looking ahead, a global combination of EFT analyses across all sectors would provide a powerful and comprehensive probe of heavy new physics at the LHC. However, before such a combination could be accomplished, many computational challenges will need to be overcome. The generation of EFT samples, the processing/histogramming of the data, and the statistical analysis of the data will all become increasingly expensive as additional data is collected and as additional processes, WCs, and categories are studied. Each step in the analysis workfow involves unique challenges that will require innovative solutions. As our field pushes towards global EFT combinations in the pursuit of new physics at the LHC, it will be important to not only continue exploring improvements in theoretical modeling and novel analysis techniques, but also to proactively confront the navigation of computational challenges.