SMEFT vs UV-completion

BSM-effects in the Tails of Distributions

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JMU Würzburg

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Outline of the Talk

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- Some Background on *Effective Field Theories* (EFTs)

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- Work in Progress & Outlook

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Figure 1: Shows an aerial view of CERN. Credit: Maximilien Brice (CERN), Wikimedia Commons

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Hence, we need stronger magnetic fields or larger radii for the colliders. Reaching higher COM energies might take a while...

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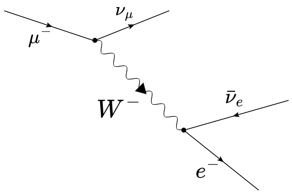
Historical Example: The Fermi-4 Theory



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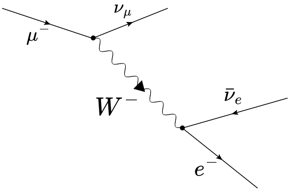

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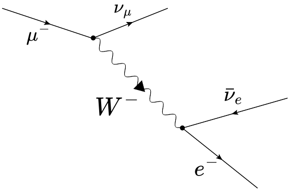

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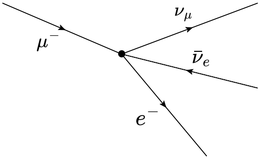

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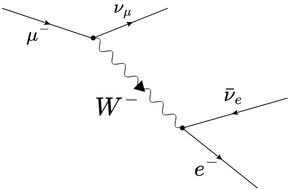

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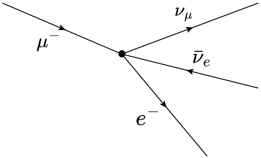

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Question: Can this be justified for arbitrary orders in perturbation theory?

Effective Field Theories

Answer: Yes! The framework to do this is called *Effective Field Theory*.

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Consider the propagator for scalar with the heavy mass m.

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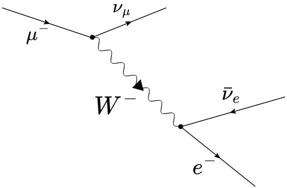

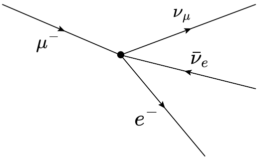

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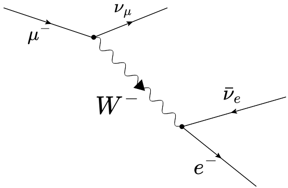

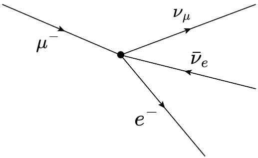

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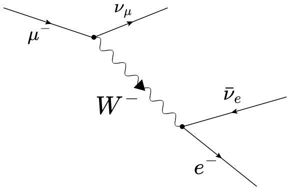
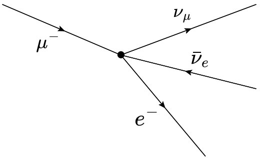


Next Question: Can one establish an equality of correlation functions at the level the Lagrangians between a UV Lagrangian and a non-renormalizable EFT Lagrangian?



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Power Counting

Practical calculations require a truncation in the infinite tower of operators. Figuring out which ones to truncate is called *power counting*.

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Example: The *Warsaw Basis* for the Standard Model's dimension ≤ 6 terms.

[B. Grzadkowski et. al. *Dimension-Six Terms in the Standard Model Lagrangian*, arXiv:1008.4884]

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Studying Observables requires event generation, accounting for hadronization and making appropriate cuts to get a signal out.

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Topic of my Work

The topic of my work is to study how well an EFT can reproduce the high energy tails of distributions of observables.

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Mathematica Packages for Performing the Matching

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`MatchMakerEFT` matches diagrammatically while `Matchete` uses another technique called *covariant derivative expansion* (CDE).

I have been working mainly with `Matchete`.

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Computer Programmes for Transferring EFT Information

- The WCxf file-format is made for storing information about EFTs and their associated Wilson-coefficients' numerical values. [J. Aebischer et. al, arXiv:1712.05298]

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- It is embedded inside the Python-package *Wilson*, which is capable of translating between different bases. [J. Aebischer et. al, arXiv:1804.05033]

SMEFTsim3

SMEFTsim3 contains Universal Feynman Output-files (UFO-files) for the Standard Model as an Effective Field Theory (SMEFT) (at dimension 6) which may be used with Madgraph. [I. Brivio et. al, arXiv:1709.06492]

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The Workflow:

Going from a UV-model to Madgraph

Matchete $\rightarrow$ Python Scripts $\rightarrow$ WCxf/Wilson $\rightarrow$
A SMEFTsim3 Parameter Card $\rightarrow$ Madgraph

A Coloured Scalar Sextet

We introduce a colored scalar sextet π_6.

$$\mathcal{L} = \mathcal{L}_{\mathrm{SM}} + [(\partial_\mu - igG^a_\mu T^a_{ij})\pi_{6\,j}][(\partial^\mu - igG^{a\,\mu}T^a_{jk})\pi_{6\,k}]^\dagger \\ + \left(y \cdot 2\sqrt{2}(\bar{K}_6)^{ij}_a \pi^a_6 \bar{t}_i P_L t^c_j + \text{ h.c}\right) \tag{6}$$

$\bar{K}_6$ is a Clebsch-Gordan Coefficient.

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The Studied Process: Four-Top Production

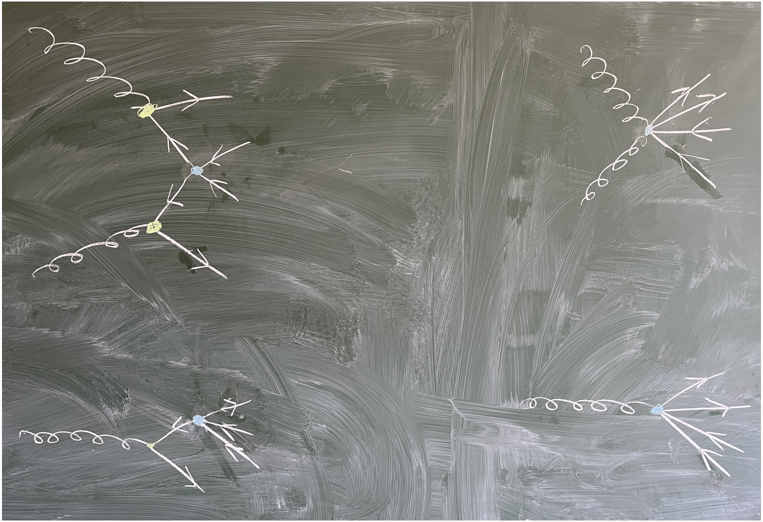
I am studying $p\,p \to t\,\bar{t}\,t\,\bar{t}$.

Colored Scalar Sextet - Feynman Diagrams

New Feynman diagrams which are not present in the Standard Model.

Colored Scalar Sextet - Feynman Diagrams

The Corresponding Diagrams in the SMEFT.



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- There are also restrictions on jet separations and lepton-jet isolation requirements.

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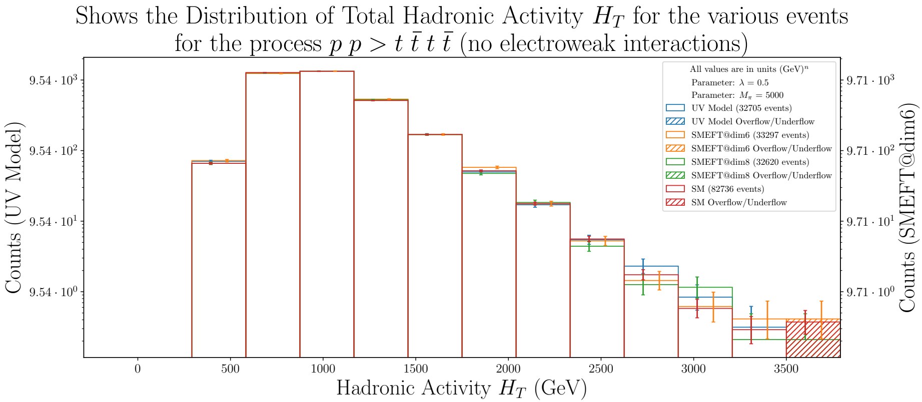

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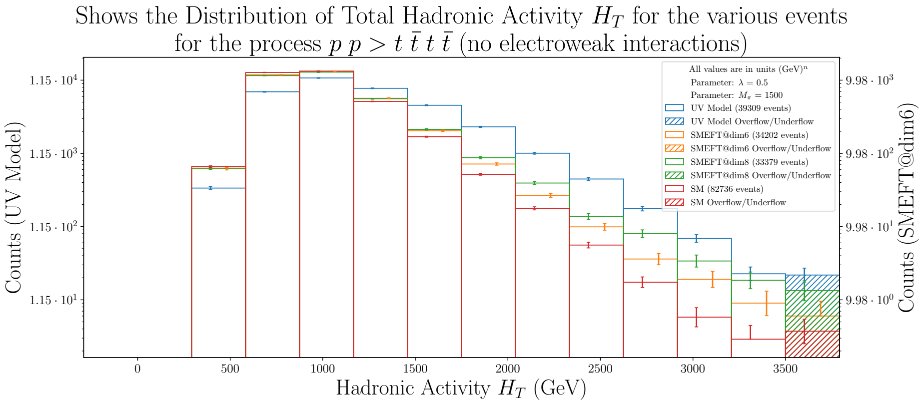
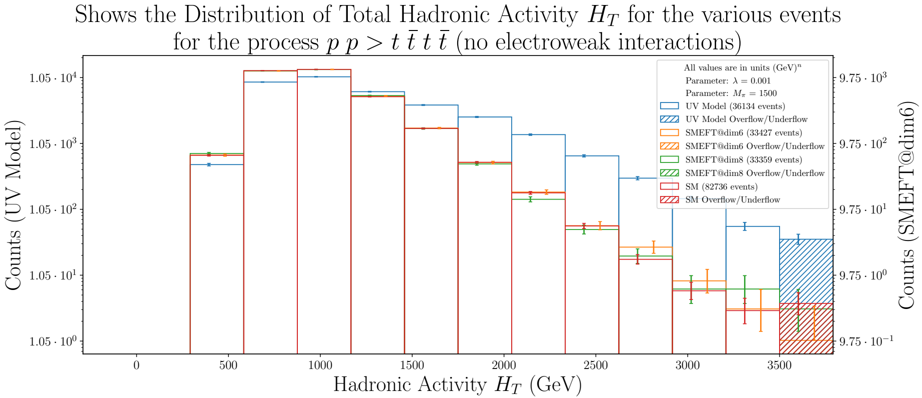
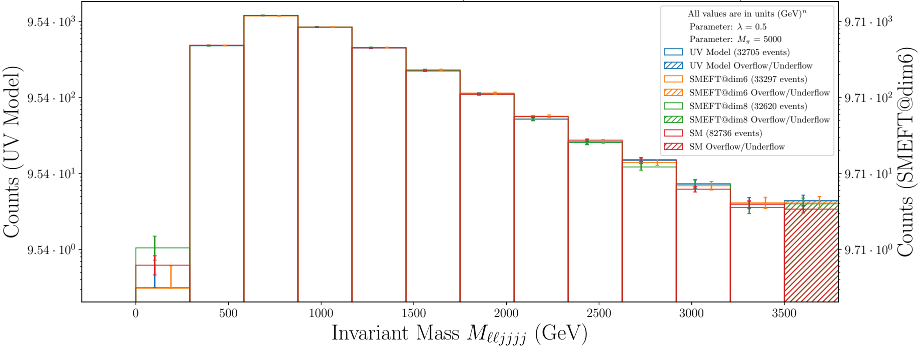


Colored Scalar Sextet - Distributions

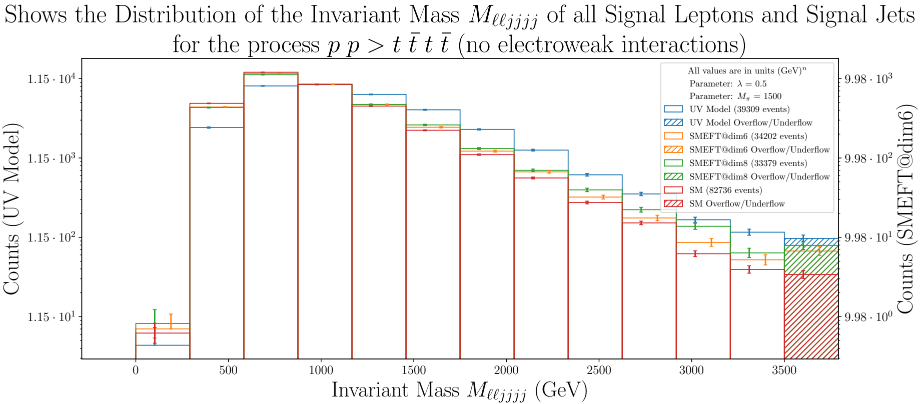


Colored Scalar Sextet - Distributions

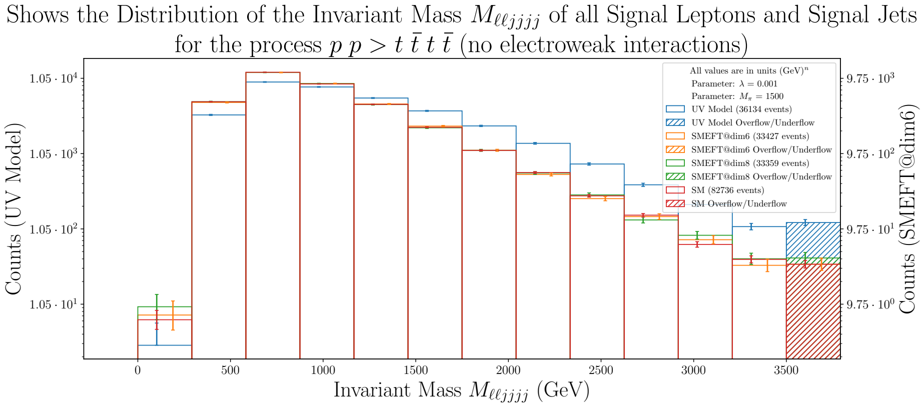
Shows the Distribution of the Invariant Mass $M_{\ell\ell jjjj}$ of all Signal Leptons and Signal Jets for the process $p\,p > t\,\bar{t}\,t\,\bar{t}$ (no electroweak interactions)



Colored Scalar Sextet - Distributions



Colored Scalar Sextet - Distributions

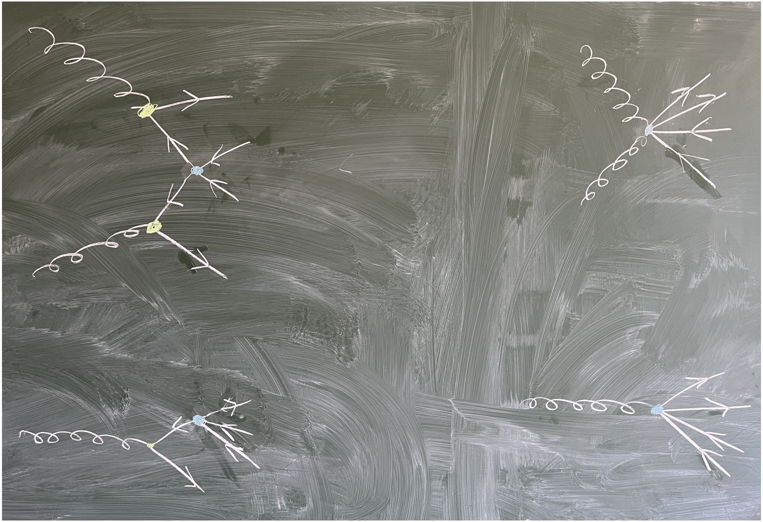


Colored Scalar Sextet - Feynman Diagrams

New Feynman diagrams which are not present in the Standard Model.

Colored Scalar Sextet - Feynman Diagrams

The Corresponding Diagrams in the SMEFT.



Outlook: Statistical Tests

Work-in-Progress:

Outlook: Statistical Tests

Work-in-Progress:

Test Statistics & Probing the Tails

Outlook: Statistical Tests

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- The χ^2-test.

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- A two-sided Poisson log-likelihood test.

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These may be studied both for/as

- Goodness-of-Fit Quantities.

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These may be studied both for/as

- Goodness-of-Fit Quantities.
- P-values under the null hypothesis that the histograms come from the same distribution.

Thank you for listening!

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