LIMITS ON WILSON COEFFICIENTS OF SMEFT OPERATORS FROM PROCESSES OF 3 AND 4 TOP QUARK PRODUCTION

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OUTLINE OF THE TALK

- A few words about SMEFT
- Description of processes
- Simulation setup
- Results
- Summary

INTRODUCTION

SMEFT

Standard Model Effective Field Theory is a convenient framework for searching for New Physics effects in interactions of SM particles.

As such, SMEFT provides a model-independent way to discover, constrain and parametrise potential deviations from the Standard Model.

SMEFT

By following SMEFT approach, one extends the Standard Model with additional higher-dimensional operators. In general, the SMEFT Lagrangian reads:

$$L = L_{SM} + \sum \frac{c_i}{\Lambda} O_i^{d=5} + \sum \frac{c_i}{\Lambda^2} O_i^{d=6} + \sum \frac{c_i}{\Lambda^3} O_i^{d=7} + ..., \quad (1)$$

where L_{SM} is the SM lagrangian, $O_i^{d=n}$ - composite operators of mass dimension n in some particular basis, c_i - dimensionless Wilson coefficients.

IMPACT ON OBSERVABLES

The effects of SMEFT operators of dimension 6 on observables, such as cross-sections or differential distributions, can be written:

$$\sigma = \sigma_{SM} + \sum_{k} \frac{c_i}{\Lambda^2}\sigma_k^{(1)} + \sum_{j<=i} \frac{c_i c_j}{\Lambda^4}\sigma_{i,j}^{(2)}, \tag{2}$$

where σ_{SM} is the SM prediction, c_i - Wilson coefficients of i-th operator, Λ - hypothetical scale of the New Physics, $\sigma^{(1)}$ and $\sigma^{(2)}$ - coefficients, representing linear and quadratic (in terms of EFT coupling) contributions to the total amplitude.

EFT OPERATORS

There are a total of 11 four-quark EFT operators of dimension 6. Among them, only the following four operators will contribute to both processes of four and three top quark production:

$$
\begin{aligned}
O^1_{tt} &= (\bar{t}_R \gamma^\mu t_R)(\bar{t}_R \gamma_\mu t_R), \\
O^1_{QQ} &= (\bar{Q}_L \gamma^\mu Q_L)(\bar{Q}_L \gamma_\mu Q_L), \\
O^1_{Qt} &= (\bar{Q}_L \gamma^\mu Q_L)(\bar{t}_R \gamma_\mu t_R), \\
O^8_{Qt} &= (\bar{Q}_L \gamma^\mu T^A Q_L)(\bar{t}_R \gamma_\mu T^A t_R),
\end{aligned}
$$

where Q_L is the left-handed third generation quark doublet, t_R - the right-handed top quark singlet, T^A - halves of Gell-Mann matrices $T^A \equiv \lambda^A/2$.

- Many models of physics beyond the standard model (BSM) predict enhanced or modified couplings of top quarks to other particles.
- The process of the production of four top quarks is potentially sensitive to a possible contribution from the New Physics.

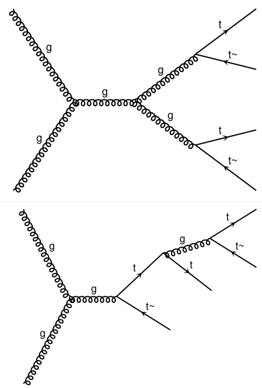

Figure 1: Representative diagrams of four top quark hadroproduction

FOUR TOP QUARK SMEFT PRODUCTION

Extension of the SM lagrangian with EFT operators introduce new vertices, which modifies SM observables.

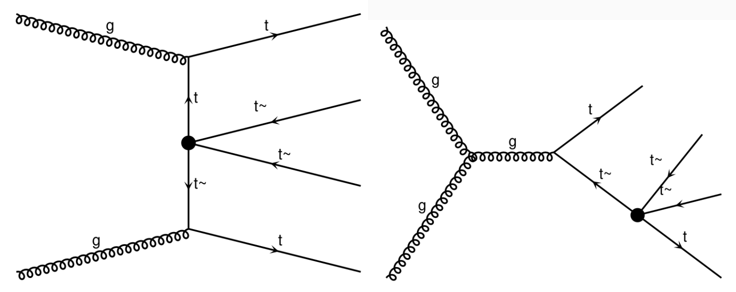

Figure 2: Examples of modified vertices in four top quark hadroproduction

TRIPLE TOP QUARK SM PRODUCTION

Another potentially powerful source of possible BSM effects is the production of three top quarks.
This process is also has rather low SM cross-section and also has not been yet observed.

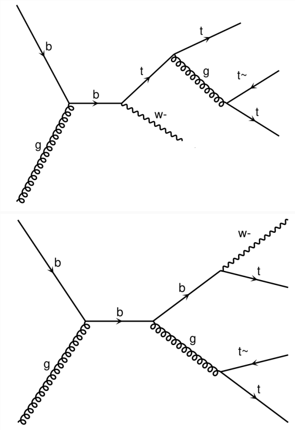

Figure 3: Representative diagrams of three top quark hadroproduction

Extension of the SM lagrangian with EFT operators introduce new vertices, which modifies SM observables.

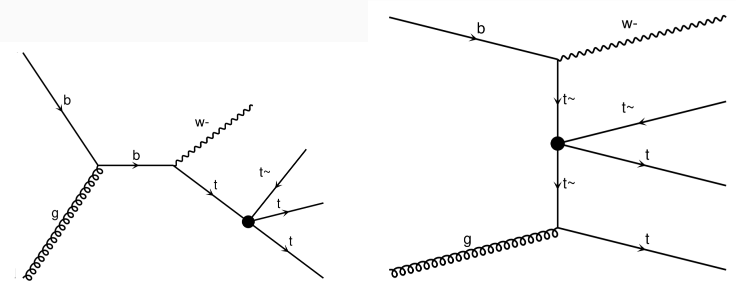

Figure 4: Examples of modified vertices in three top quark hadroproduction

GOALS OF THIS STUDY

- Obtain constraints on Wilson coefficients of certain dimension-6 EFT operators from processes of three and four quark hadroproduction.
- Compare the results obtained for both processes and assess them in terms of sensitivity to the possible contribution of NP.

NUMERICAL SIMULATIONS

SIMULATION SETUP

- MC events generator: *Madgraph5* (results validated with *CompHEP* package)
- PDF set: *NNPDF3.0*
- Factorization/renormalization scale: *172.5 GeV*
- FeynRules EFT model: *4topEFT*
- Statistical analysis tool: *EFTfitter*

SM CROSS-SECTIONS

C.o.m. energy, GeV	SM cros.-sect. σ_{SM}, fb	MC err.$\Delta\sigma_{SM}$, fb	scale uncert., %	PDF uncert., %
13	11.5	0.1	82.8	17.5
14	15.6	0.1	81.3	15.7
100	5000	30	70.0	7.66

Table 1: SM cross-sections for process $pp \to t\bar{t}t\bar{t}$

C.o.m. energy, GeV	SM cros.-sect. σ_{SM}, fb	MC err.$\Delta\sigma_{SM}$, fb	scale uncert., %	PDF uncert., %
13	1.26	0.04	40.7	18.1
14	1.65	0.04	40.1	17.7
100	440	4.0	45.3	8.14

Table 2: SM cross-sections for process $pp \to 3t + X$

EXTRACTED PARAMETERIZATION COEFFICIENTS

	$pp \to 4t$			$pp \to 3t + X$		
	13 TeV	14 TeV	100 TeV	13 TeV	14 TeV	100 TeV
$\sigma^{(1)}_{Q^1_{tt}}$	0.65	1.01	400	0.01	0	0
$\sigma^{(1)}_{Q^1_{QQ}}$	0.8	1	400	0.13	0.14	40
$\sigma^{(1)}_{Q^1_{Qt}}$	0.04	-0.15	100	0.02	0.01	20
$\sigma^{(1)}_{Q^8_{Qt}}$	0.44	0.53	200	0.05	0.05	-10
$\sigma^{(2)}_{Q^1_{tt}}$	5.65	7.72	14300	0.11	0.15	270
$\sigma^{(2)}_{Q^1_{QQ}}$	5.71	7.79	14200	0.9	1.3	3530
$\sigma^{(2)}_{Q^1_{Qt}}$	2	2.4	5000	0.22	0.31	820
$\sigma^{(2)}_{Q^8_{Qt}}$	0.6	0.57	1000	0.03	0.07	170

Table 3: Parameterization coefficients extracted from processes of 3 and 4 top quark production.

RESULTS

Operator	Extracted limits $C_k/\Lambda^2 (TeV^{-2})$ $pp \to 4t$	$pp \to 3t + X$	Comb. channels
Q^1_{tt}	[-1.90, 1.78]	[-3.34, 3.25]	[-1.86, 1.74]
Q^1_{QQ}	[-1.90, 1.76]	[-1.23, 1.08]	[-1.19, 1.04]
Q^1_{Qt}	[-3.10, 3.08]	[-2.38, 2.29]	[-2.21, 2.14]
Q^8_{Qt}	[-6.03, 5.29]	[-7.20, 5.53]	[-5.56, 4.46]

Table 4: Limits obtained from simulations at centre of mass energy of 13 TeV

RESULTS

	Extracted limits $C_k/\Lambda^2 (TeV^{-2})$		
Operator	$pp \to 4t$	$pp \to 3t + X$	Comb. channels
Q^1_{tt}	[-1.88, 1.75]	[-3.14, 3.14]	[-1.83, 1.71]
Q^1_{QQ}	[-1.87, 1.74]	[-1.12, 1.01]	[-1.09, 0.98]
Q^1_{Qt}	[-3.21, 3.29]	[-2.18, 2.18]	[-2.08, 2.09]
Q^8_{Qt}	[-6.93, 6.10]	[-4.97, 4.25]	[-4.73, 3.99]

Table 5: Limits obtained from simulations at centre of mass energy of 14 TeV

RESULTS

	Extracted limits $C_k/\Lambda^2(TeV^{-2})$		
Operator	$pp \to 4t$	$pp \to 3t + X$	Comb. channels
Q_{tt}^1	[-0.71, 0.68]	[-1.21, 1.21]	[-0.69, 0.67]
Q_{QQ}^1	[-0.71, 0.69]	[-0.34, 0.34]	[-0.33, 0.33]
Q_{Qt}^1	[-1.18, 1.17]	[-0.70, 0.70]	[-0.68, 0.68]
Q_{Qt}^8	[-2.71, 2.55]	[-1.50, 1.56]	[-1.47, 1.51]

Table 6: Limits obtained from simulations at centre of mass energy of 100 TeV

SUMMARY

SUMMARY

- Theoretical constraints on Wilson coefficients of several SMEFT operators was obtained from analysis of processes of three and four top quark hadroproduction.
- Results show that certain processes manifest better sensitivity to contributions of particular operators.

QUESTIONS?