Long-standing challenges and latest developments in the generation of SMEFT predictions within the Top Sector

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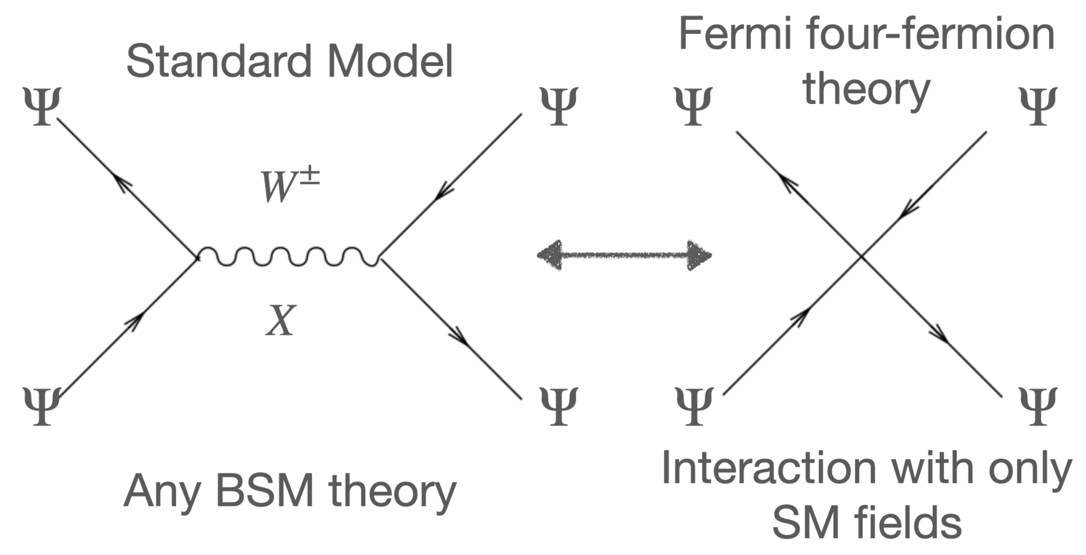
Why SMEFT?

SMEFT is a powerful tool to study **effects from BSM phase space not directly accessible** by LHC.



The SMEFT Lagrangian

This is possible by extending the SM with a set of **higher dimension and symmetry preserving operators**:

$$\mathscr{L}_{SMEFT} = \mathscr{L}^{(4)}_{SM} + \sum_{a=1}^{M(d)} \frac{\theta_a \mathcal{O}^{a}_{(d)}}{\Lambda^{d-4}}$$

- Wilson coefficients
- Higher dimension operators
- Dimensionful normalisation scale

From theory to measurement

$$\sigma \propto \left|\mathscr{M}_{BSM}\right|^2 = \left|\mathscr{M}_{SM} + \frac{1}{\Lambda^2}\sum_{a=1}^{M}\mathscr{M}^{a}_{EFT}\right|^2$$

Event yields in the "**separate simulation**":

$$\lambda(\theta) = \sum_{i=1}^{N} w_{i,0} + \sum_{a=1}^{M}\theta_a \sum_{i}^{N} w_{i,a} + \sum_{a,b=1}^{M}\theta_a\theta_b\sum_{i}^{N} w_{i,ab}$$

Event yields in the "**reweighted simulation**":

$$\lambda(\theta) = \sum_{i=1}^{N}\left(w_{i,0} + \sum_{a=1}^{M}\theta_a w_{i,a} + \sum_{a,b=1}^{M}\theta_a\theta_b w_{i,ab}\right)$$

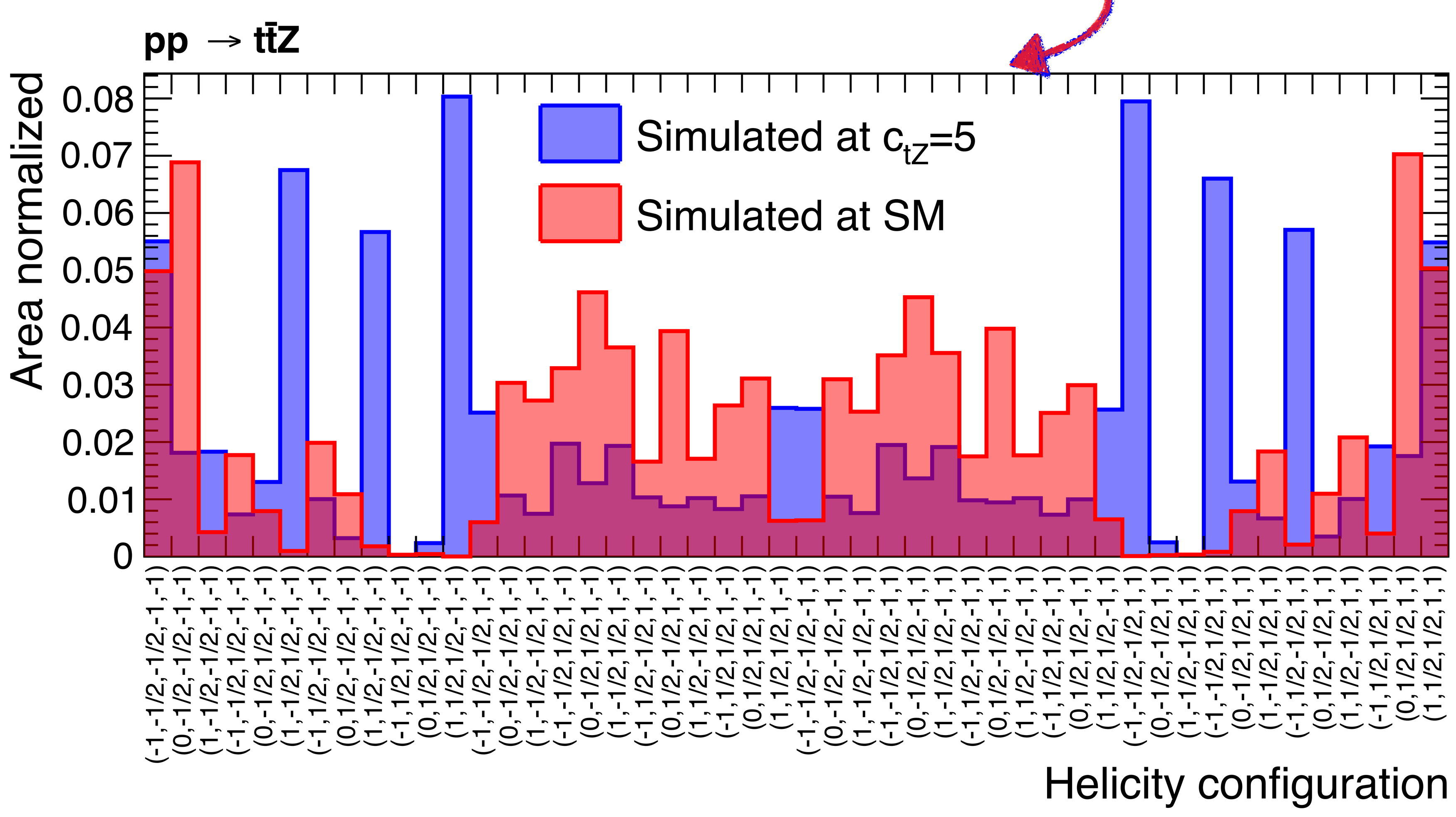
An interesting use case: SMEFT predictions for the ttZ process

The production of a top-antitop pair in association with a Z boson emission is sensitive to the $\mathcal{O}_{tZ}$ operator, which is defined as:

$$\mathcal{O}_{tZ} = -\,sin\theta_W(\bar{q}_p\sigma^{\mu\nu}u_r)\tilde{\phi}B_{\mu\nu} + cos\theta_W(\bar{q}_p\sigma^{\mu\nu}u_r)\tau^I\tilde{\phi}W^I_{\mu\nu}$$

The study of this process allows to test **differences** and **limitations** of the **separate** and **reweighted** simulation methods:

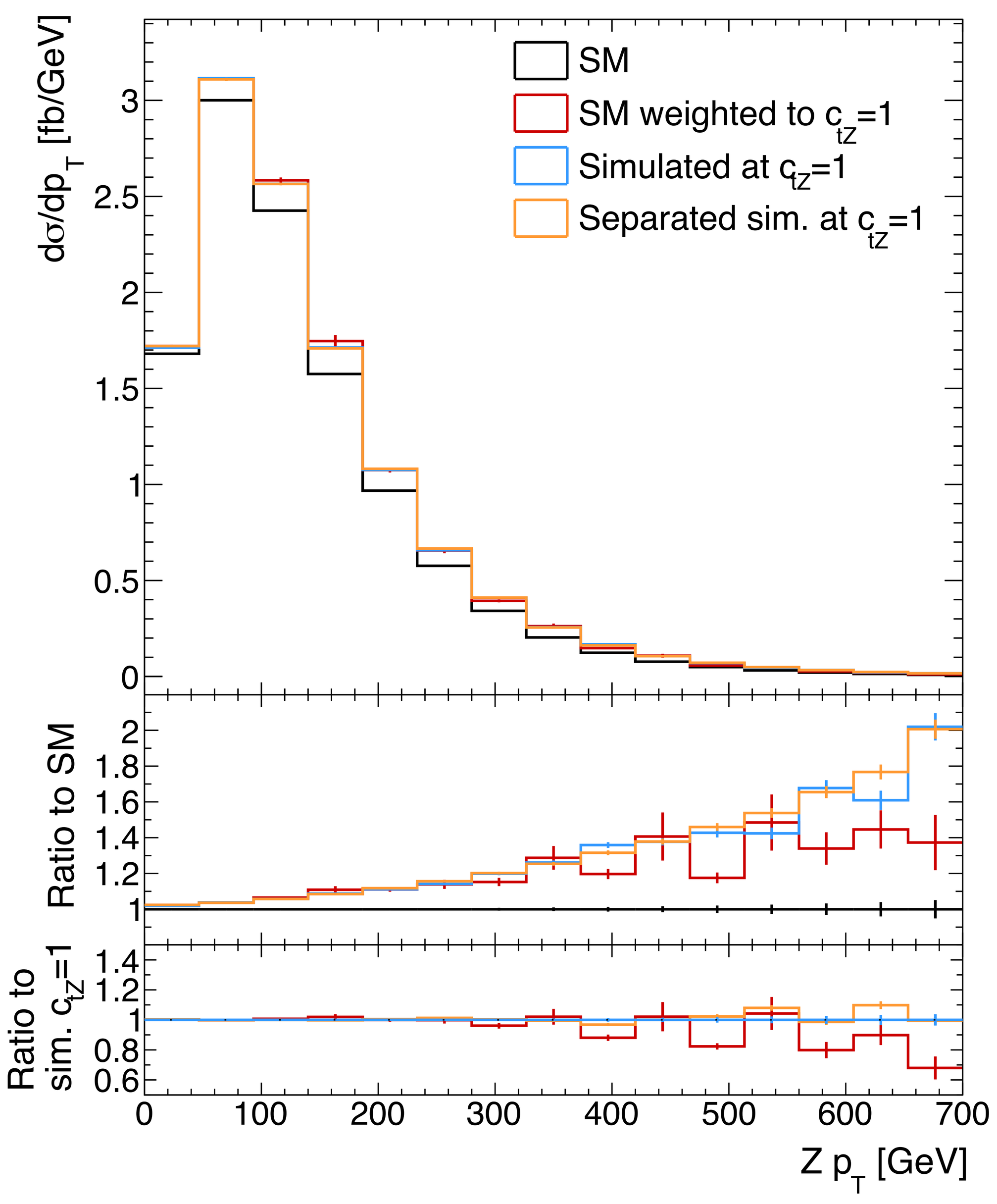
- Stochastic (in)dependence
- Reference point
- Scale choice
- Helicity configuration



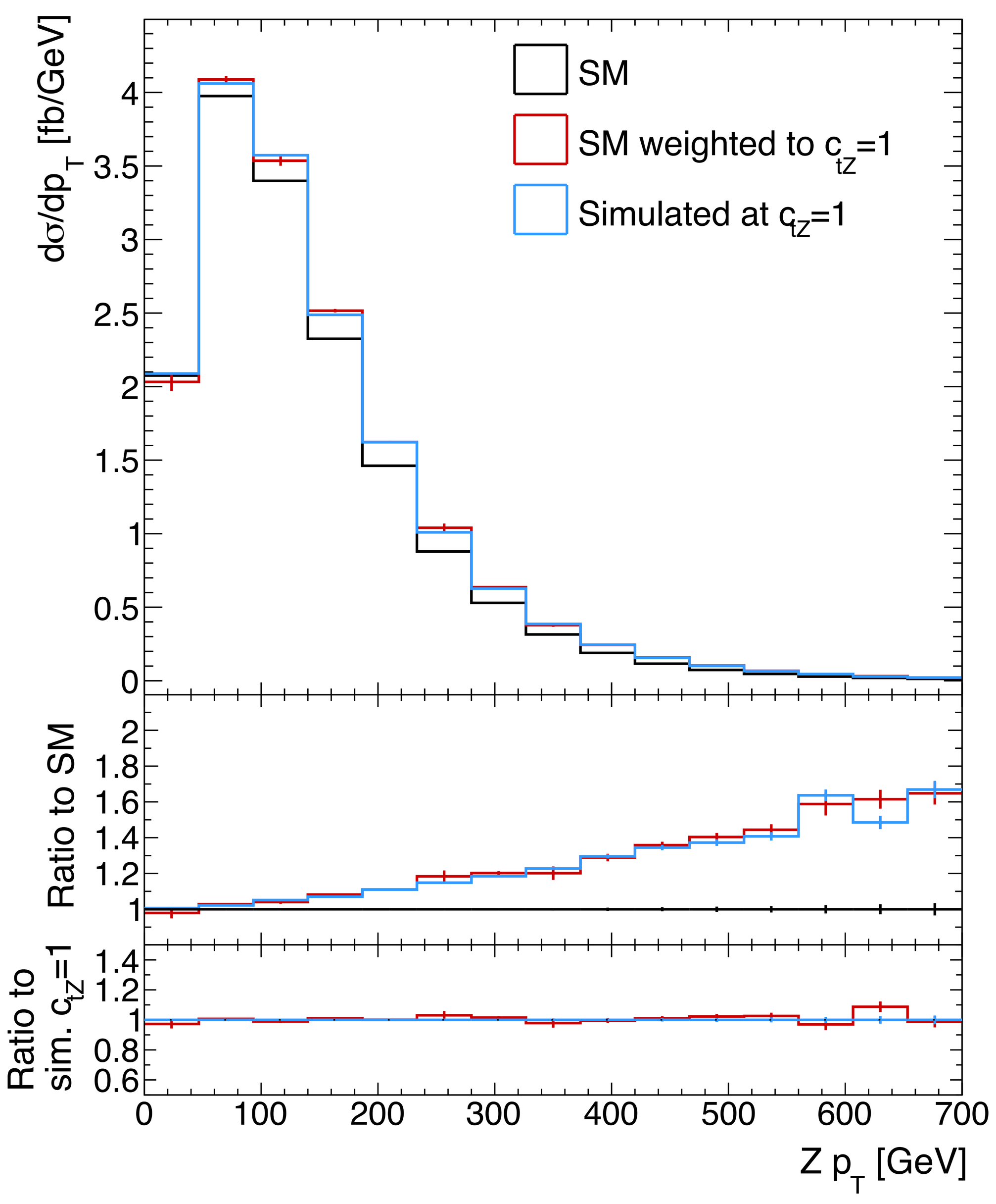
Different subtleties have to be taken into account when computing the **predictions at LO or NLO in QCD:**

- Simulation of extra partons
- QED coupling order

LO prediction



NLO prediction



A new way to generate SMEFT prediction: post-generation reweighting

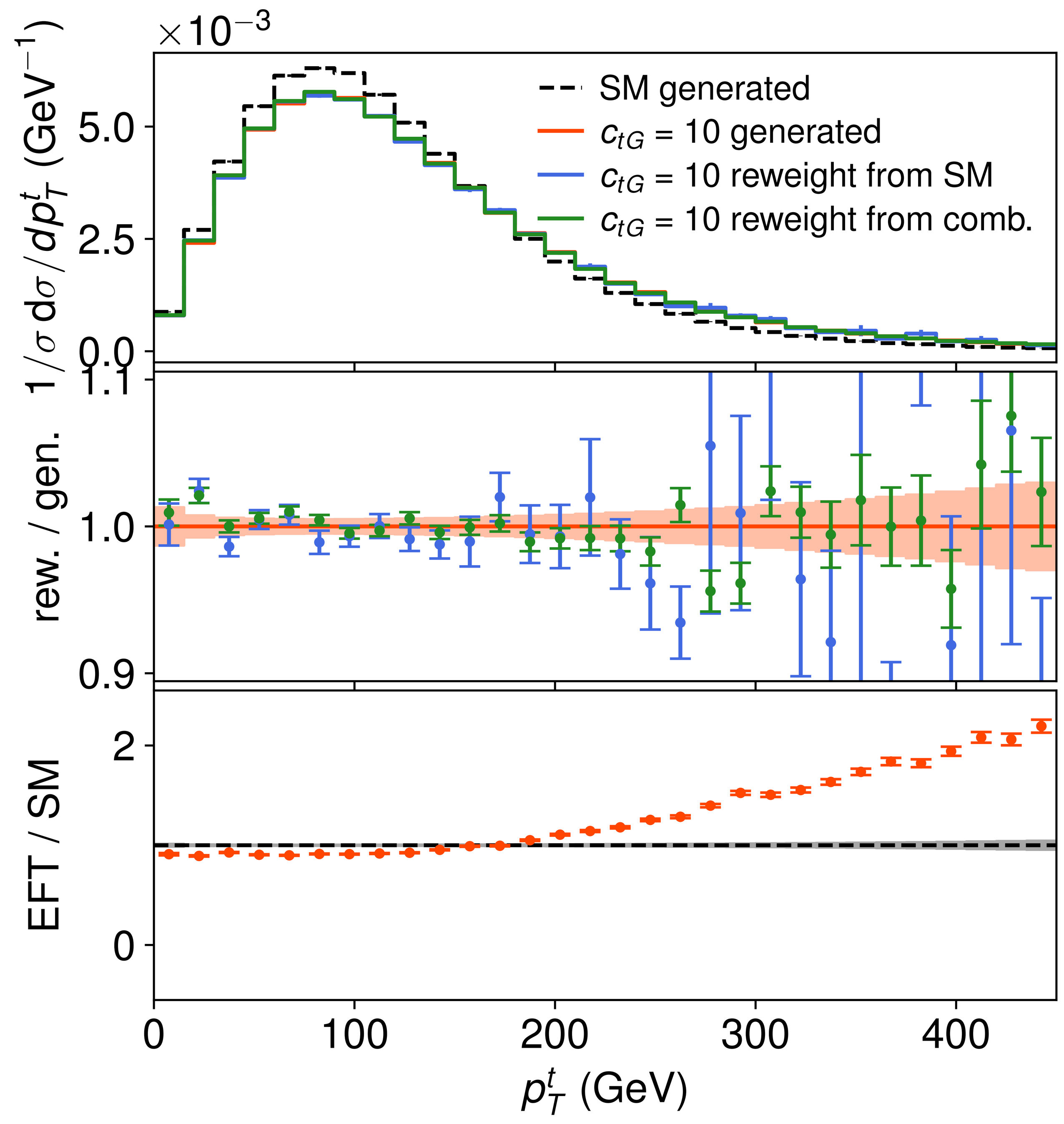
The post-generation reweighting allows to **add EFT weights to already generated samples** significantly reducing computing costs associated with regeneration.

Needs:

- Same initial and final states.
- Good phase space coverage.
- LHE-level information.

Advantages:

- Significant reduction of computing costs.
- Possible to add new UFO models.



CONCLUSIONS

The Standard Model Effective Field Theory is a powerful tool to look for BSM effects.

Producing correct and useful predictions involves many subtleties and pitfalls.

The recently published LHC EFT WG note[1] can be used as a guide to obtain state of the art SMEFT predictions since it highlights best practices and common pitfalls.

[1] arXiv:2406.14620 - Submitted to SciPost Community Reports