# Effective operators in t-channel single top production and decay

Nikhef

Eric Laenen, Eleni Vryondiou (*Theory*)
Marcel Vreeswijk, **Marc de Beurs** (*ATLAS*)

*arXiv:1807.03576*

18 September 2018

# Motivation

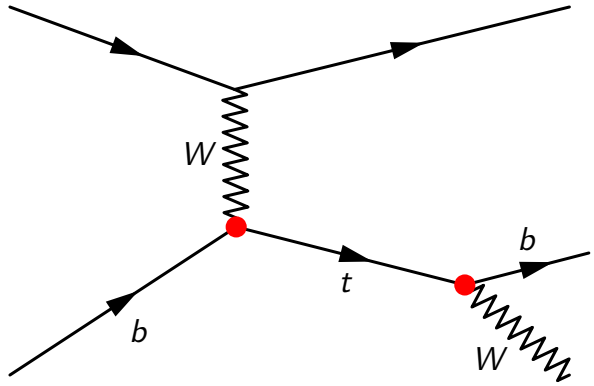
## Process

- Single top $\rightarrow$ only Wtb vertex
- t-channel $\rightarrow$ highest $\sigma$
- Polarized top
  - Polarization angles
  - W helicity angles

## Effective Field Theory (EFT)

- Precision era
- Indirect probe for NP
- Model independent
- Incorporates symmetries

- Pheno study
- MG5_aMC@NLO + Pythia8
- 5FS, Wbj production, W decay in MadSpin
- Multiple EFT insertions (production and/or decay)



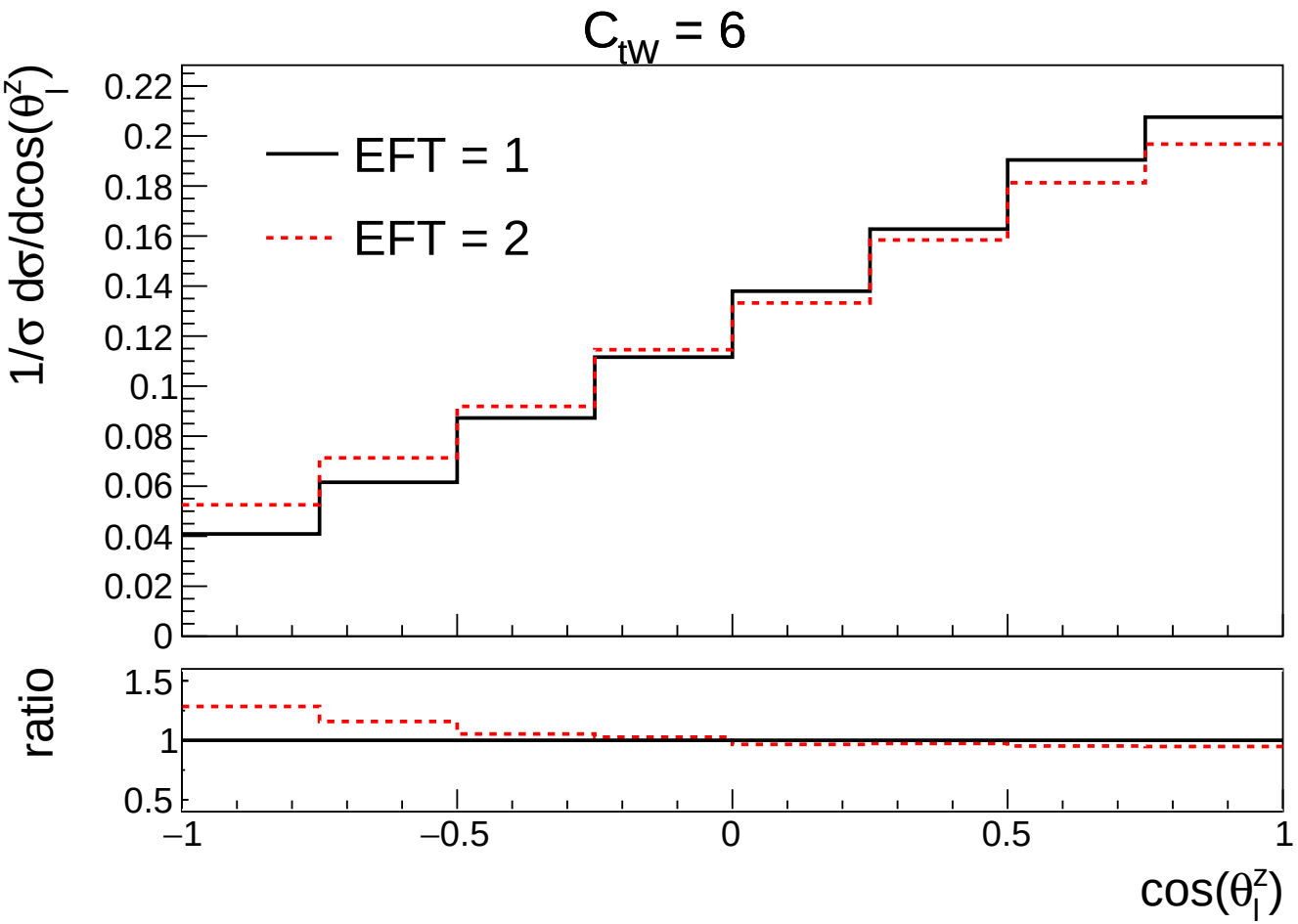

$$O_{\varphi Q}^{(3)} = i\frac{1}{2}y_t^2\left(\varphi^\dagger \overleftrightarrow{D}^I_\mu \varphi\right)(\bar{Q}\gamma^\mu\tau^I Q) \quad (1)$$

$$O_{tW} = y_t g_w(\bar{Q}\sigma^{\mu\nu}\tau^I t)\tilde{\varphi}W^I_{\mu\nu} \quad (2)$$

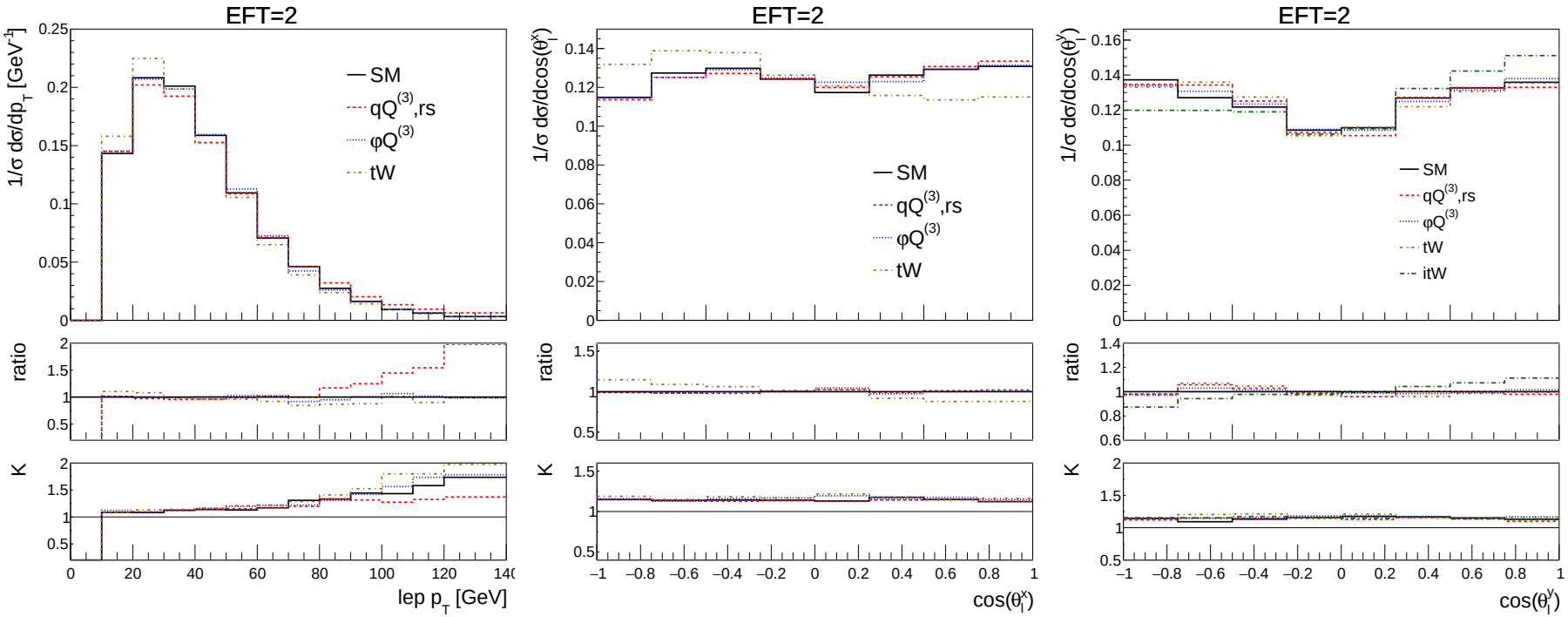
$$O_{qQ,rs}^{(3)} = \left(\bar{q}_r\gamma^\mu\tau^I q_s\right)\left(\bar{Q}\gamma_\mu\tau^I Q\right) \quad (3)$$

Using same notation as *Zhang 2016*

# Multiple EFT insertions



# Sensitivity to NP




- Distinguish between different operators
- Sensitive to imaginary part of tW (CPV?)
- NLO over LO (K-factor) shows shape effects (not just normalization)

## Conclusions

- Multiple EFT insertions is important $\rightarrow$ decayed top
- NLO effects not just normalization
- Sensitive to NP including CPV

## Future

- Measurement in ATLAS
- Fit in multiple parameter space (Morphing)

# Backup

# Discussion

- Truth distributions
- Only scale + PDF uncertainties
- Background is SM t-channel only
- Selection cuts:
  - leptons: $p_T^l > 10$ GeV and $|\eta^l| < 2.47$
  - jets: $p_T^j > 20$ GeV and $|\eta^j| < 4.5$

# Coupling values

| Operator | Coupling value | LO | | NLO | |
|---|---|---|---|---|---|
| | | $\sigma$ $\pm$scale $\pm$pdf [pb] | $\Gamma_{\text{top}}$ [GeV] | $\sigma$ $\pm$scale $\pm$pdf [pb] | $\Gamma_{\text{top}}$ [GeV] |
| SM | - | $123\ ^{+9.3\%}_{-11.4\%}\ ^{+8.9\%}_{-8.9\%}$ | 1.49 | $137\ ^{+2.7\%}_{-2.6\%}\ ^{+1.2\%}_{-1.2\%}$ | 1.36 |
| $O^{(3)}_{\varphi Q}$ | 1 | $137\ ^{+9.3\%}_{-11.4\%}\ ^{+8.9\%}_{-8.9\%}$ | 1.67 | $154\ ^{+2.3\%}_{-2.3\%}\ ^{+1.2\%}_{-1.2\%}$ | 1.52 |
| $O^{(3)}_{qQ,rs}$ | -0.4 | $172\ ^{+8.7\%}_{-10.8\%}\ ^{+8.9\%}_{-8.9\%}$ | 1.49 | $190\ ^{+2.4\%}_{-1.8\%}\ ^{+1.1\%}_{-1.1\%}$ | 1.35 |
| $\mathrm{Re}\,(O_{tW})$ | 2 | $132\ ^{+9.3\%}_{-11.4\%}\ ^{+8.8\%}_{-8.8\%}$ | 1.83 | $148\ ^{+2.3\%}_{-2.5\%}\ ^{+1.2\%}_{-1.2\%}$ | 1.68 |
| $\mathrm{Im}\,(O_{tW})$ | 1.75 | $125\ ^{+9.2\%}_{-11.4\%}\ ^{+8.9\%}_{-8.9\%}$ | 1.51 | $140\ ^{+2.3\%}_{-2.5\%}\ ^{+1.2\%}_{-1.2\%}$ | 1.38 |

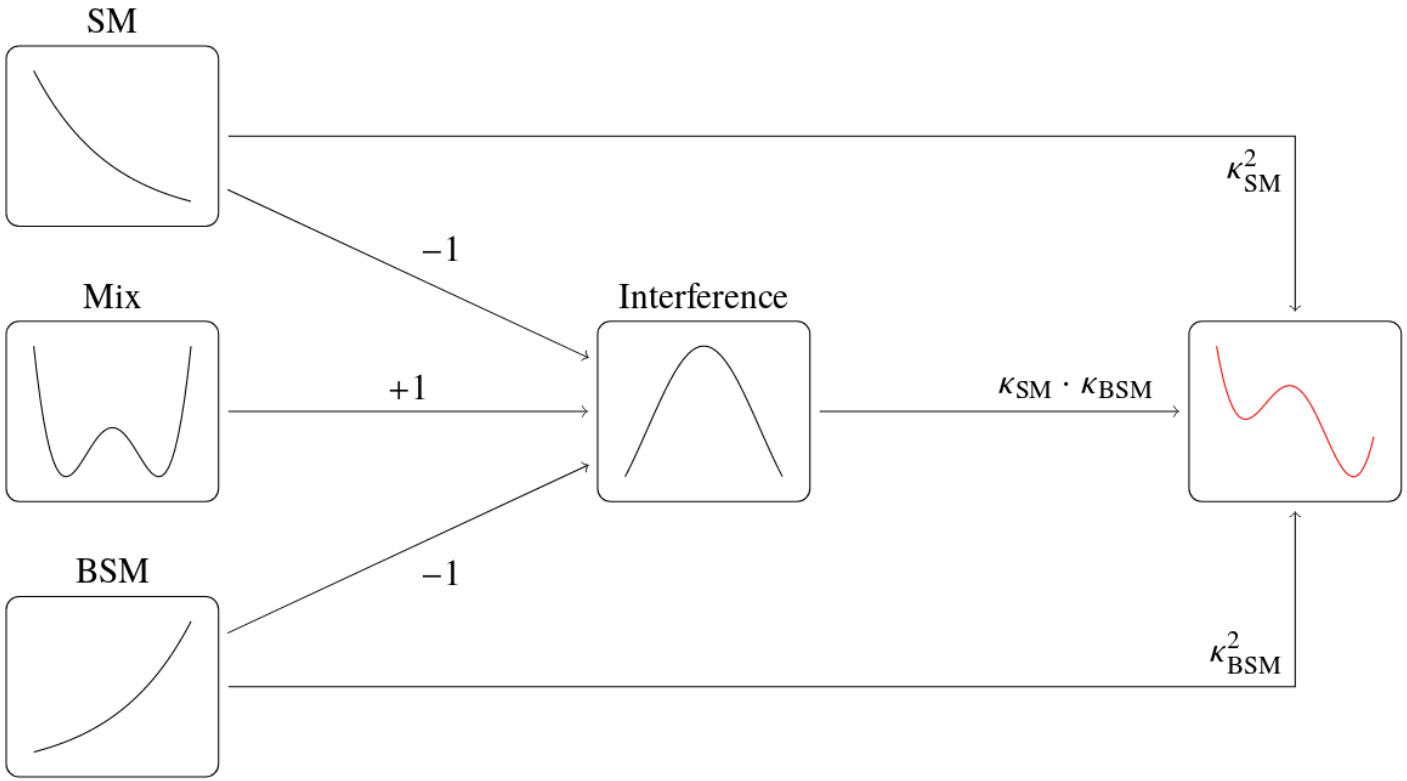
The deviations lie within the uncertainty of recent single top measurements

# Morphing

$$\mathcal{M}(g_{SM}, g_{BSM}) = g_{SM} \cdot O_{SM} + g_{BSM} \cdot O_{BSM}$$

$$|\mathcal{M}|^2 = SM^2 + BSM^2 + SM \cdot BSM$$

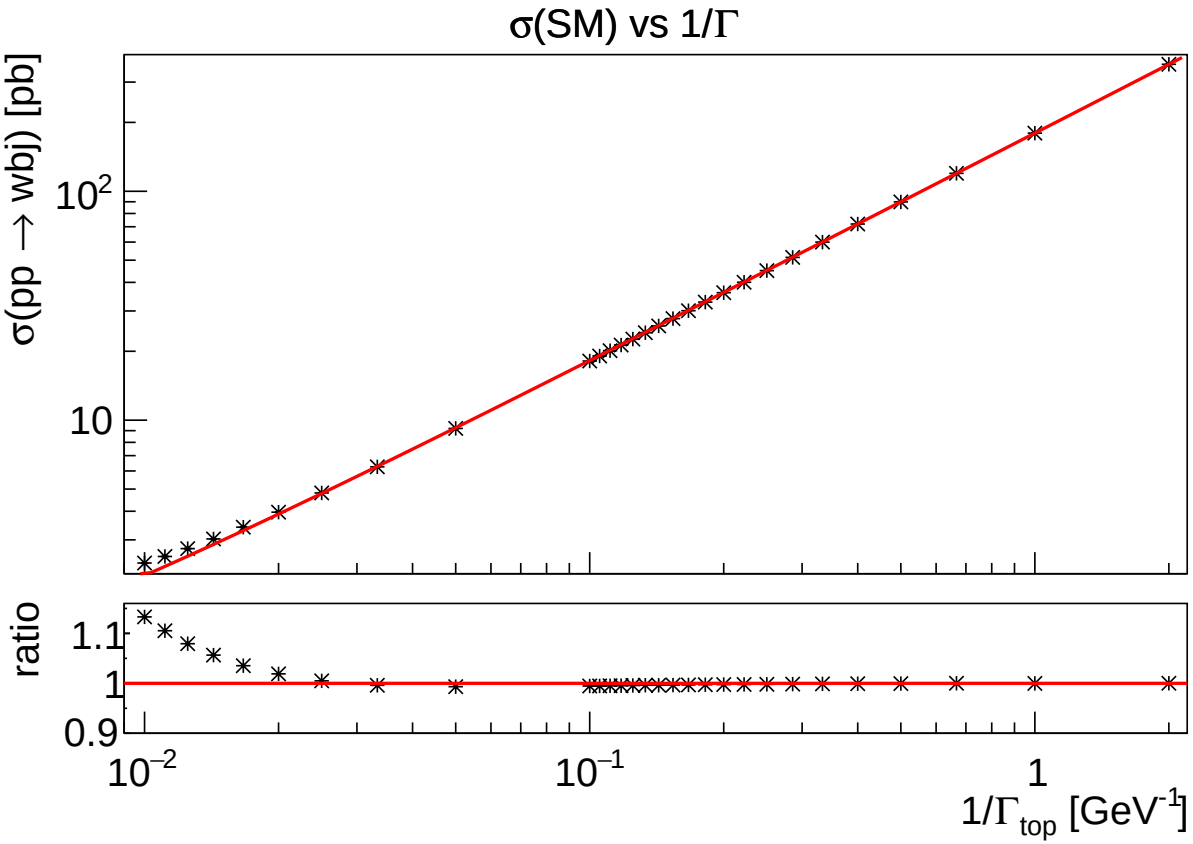
| $SM^2$ | $BSM^2$ | $SM \cdot BSM$ |
|---|---|---|
| 1 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 1 | 1 |



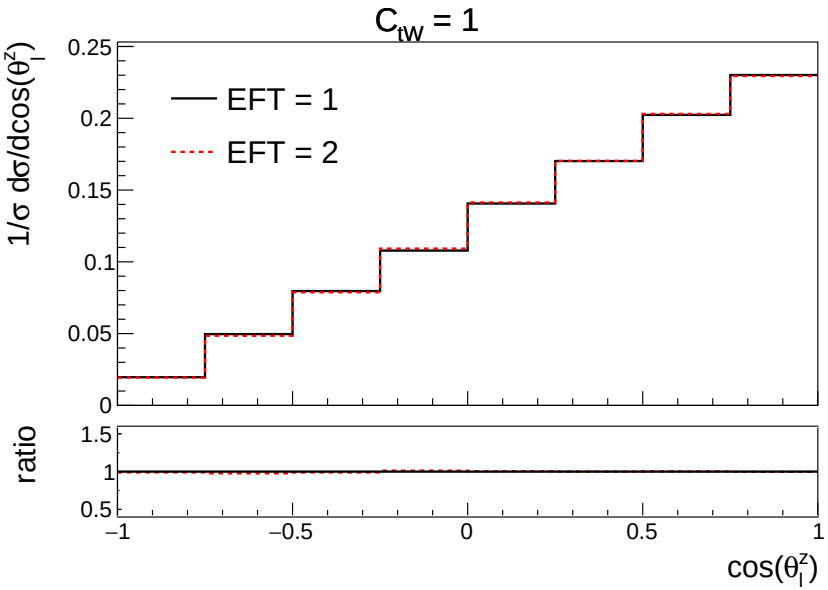

*ATL-PHYS-PUB-2015-047*

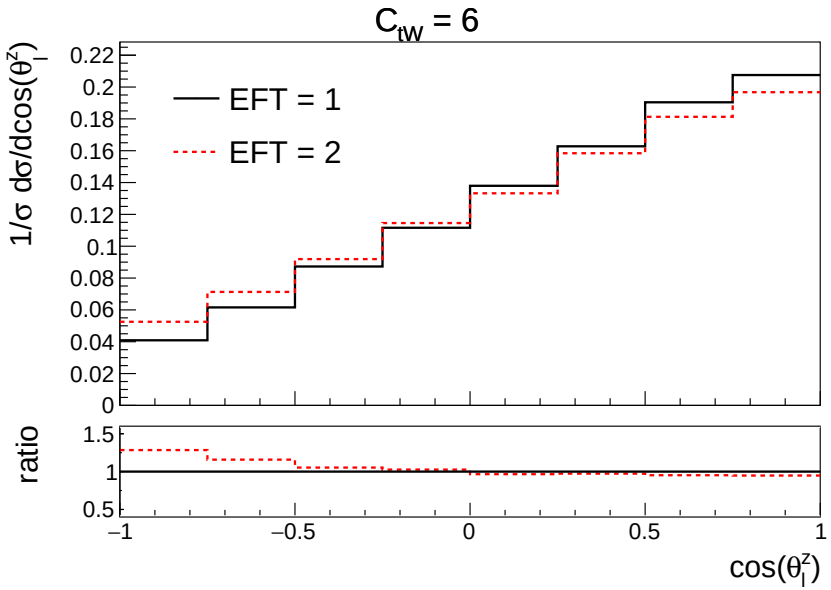
# Narrow width approximation

$$\frac{1}{(p^2 - M_{\text{top}}^2)^2 + M_{\text{top}}^2 \Gamma_{\text{top}}^2} \xrightarrow{(\Gamma_{\text{top}}/M_{\text{top}} \to 0)} \frac{\pi}{M_{\text{top}} \Gamma_{\text{top}}} \delta(p^2 - M_{\text{top}}^2) \qquad (4)$$



# Top width and multiple EFT insertions

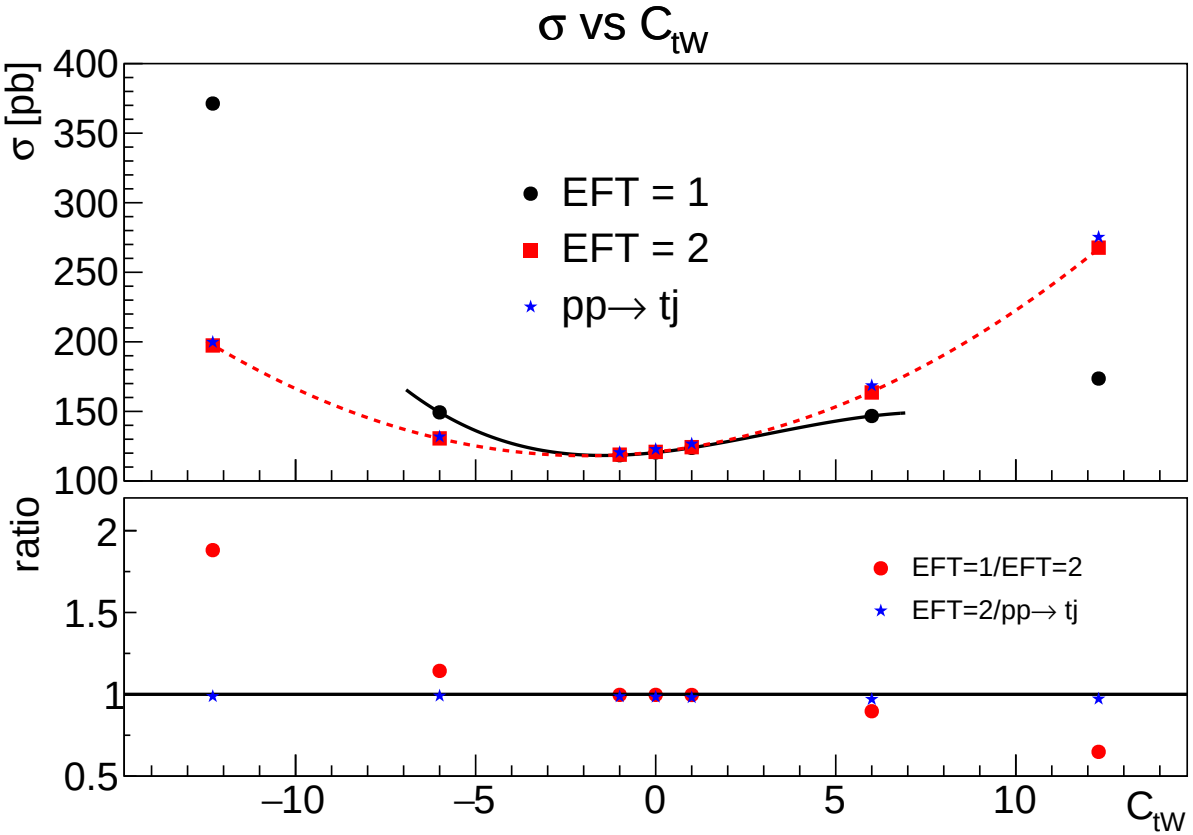



Also a shape effect
Noticeable for high C

# Top width and multiple EFT insertions

$$\sigma(pp \to Wbj) = \sigma(pp \to tj) \frac{\Gamma(t \to Wb)}{\Gamma_{\text{top}}} \tag{5}$$



# Sensitive to NP