tγq Round table

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EFT models

Two SMEFT models:

- SMEFTsim (2012.11343): only LO mode

  SMEFTsim_topU3l_MwScheme_UFO: A case with a $U(2)^3$ symmetry in the quark sector and a $U(3)^2$ symmetry in the lepton sector

  Wilson coefficients expressed in terms of their real and imaginary parts, rather than absolute values, correspond to CP conserving (violating)

  $\mathfrak{R}c_{t\gamma}$, $\mathfrak{R}c_{tW}$, $\mathfrak{R}c_{tb}$ are selected to do reweighting

- SMEFTatNLO:LO mode and NLO mode

  $c_{\phi Q3}$, $c_{\phi M}$, $c_{t\phi}$, c_{tZ}, c_{tW}, c_{tG} are selected to do reweighting

$\mathcal{O}^{(1)}_{\varphi Q}$	-	$i\left(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi\right)\left(\bar{Q}\,\gamma^\mu\, Q\right)$	$\mathcal{O}_{t\varphi}$	ctp	$\left(\varphi^\dagger\varphi - \frac{v^2}{2}\right)\bar{Q}\,t\,\tilde{\varphi} + \text{h.c.}$	$\mathcal{O}_{tW}$	-	$i\left(\bar{Q}\tau^{\mu\nu}\,\tau_I\,t\right)\tilde{\varphi}\,W^I_{\mu\nu} + \text{h.c.}$
$\mathcal{O}^{(3)}_{\varphi Q}$	-	$i\left(\varphi^\dagger \overleftrightarrow{D}_\mu \tau_I \varphi\right)\left(\bar{Q}\,\gamma^\mu\,\tau^I Q\right)$	$\mathcal{O}_{tG}$	ctG	$ig_S\left(\bar{Q}\tau^{\mu\nu}\,T_A\,t\right)\tilde{\varphi}\,G^A_{\mu\nu} + \text{h.c.}$	$\mathcal{O}_{tB}$	-	$i\left(\bar{Q}\tau^{\mu\nu}\,t\right)\tilde{\varphi}\,B_{\mu\nu} + \text{h.c.}$
-	cpQ3	$C^{(3)}_{\varphi Q}$				-	ctW	C_{tW}
-	cpQM	$C^{(1)}_{\varphi Q} - C^{(3)}_{\varphi Q}$				-	ctZ	$-\sin\theta_W C_{tB} + \cos\theta_W C_{tW}$

[1] https://feynrules.irmp.ucl.ac.be/wiki/SMEFT#no1
[2] https://feynrules.irmp.ucl.ac.be/wiki/SMEFTatNLO#no1

Workflow

Reweight sensitive/ interesting coefficients in MG reweighting card

Get reweighing model from MG5

Reweight NanoAOD events by branch LHEPart_*

An extra branch Reweights is added into NaNoAOD

SM, Linear, Quad parts

AnomalousCouplingEFTNegative

Get fit result!

$$\begin{cases} \omega_{\mathrm{Quad}} = 0.5 \cdot \left[\omega(k=1) + \omega(k=-1) - 2 \cdot \omega(k=0)\right] \\ \omega_{\mathrm{SM}} = \omega(k=0) \\ \omega_{\mathrm{Lin}} = 0.5 \cdot \left[\omega(k=1) - \omega(k=-1)\right] \end{cases}$$

$$\omega_{\mathrm{Mix}} = \omega(1,1) + \omega(0,0) - \omega(1,0) - \omega(0,1)$$

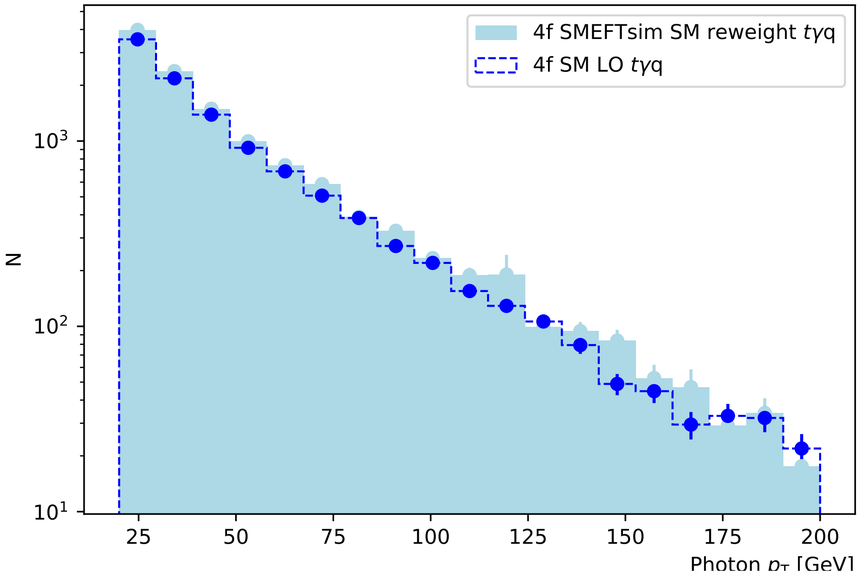
tγq/ttγ gridpacks

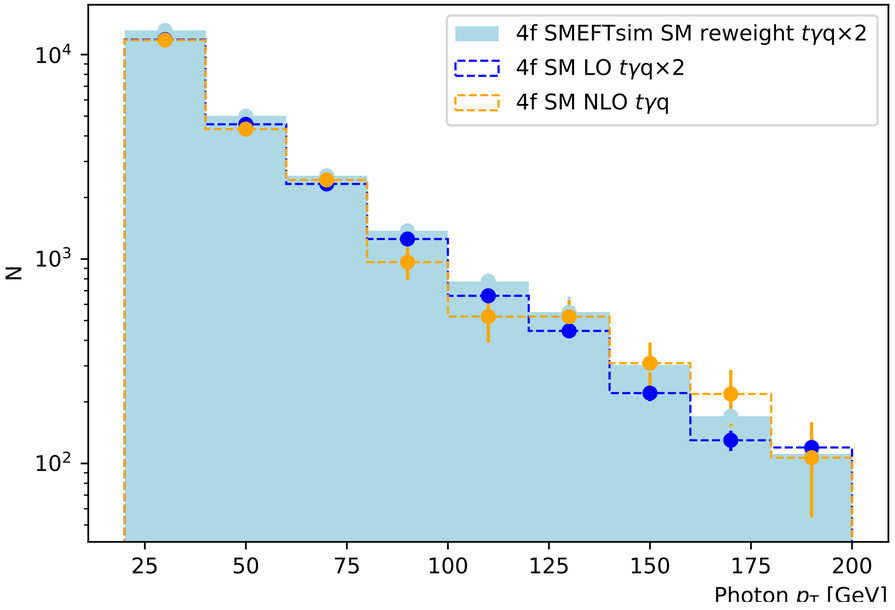
- ✳ Official SM NLO tγq production with 4f scheme (no FSR)
- ✳ Private SM LO tγq production with 4f scheme (no FSR)
- ✳ Private SMEFTsim LO tγq production with 4f scheme (no FSR)
- ✳ Private SMEFTatNLO LO tγq production with 5f scheme (no FSR)

- ✦ Official SM NLO $t\bar{t}\gamma$ production with 5f scheme (no FSR)
- ✦ Official SM LO $t\bar{t}\gamma$ production with 4f scheme
- ✦ Private SM LO $t\bar{t}\gamma$ production with 4f scheme (no FSR)
- ✦ Private SMEFTsim LO $t\bar{t}\gamma$ production with 4f scheme (no FSR)
- ✦ Private SMEFTatNLO LO $t\bar{t}\gamma$ production with 5f scheme (no FSR)

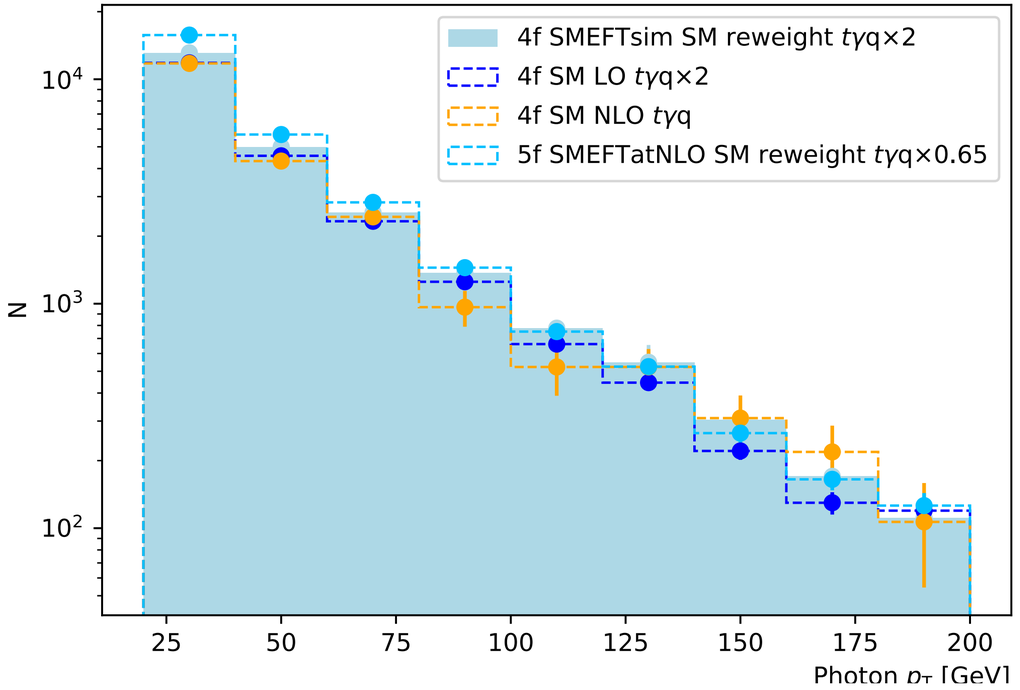
- The NLO EFT samples are still not working after many tests
  - Difficult to do tests due to the el9 migration, no solution from generator group yet
- Syntax details for these gripacks can be seen in the backup
- Tried to add extra j in the syntax, but it gave me dramatic cross sections and uncertainties…

Photon p_T distributions — LHE level





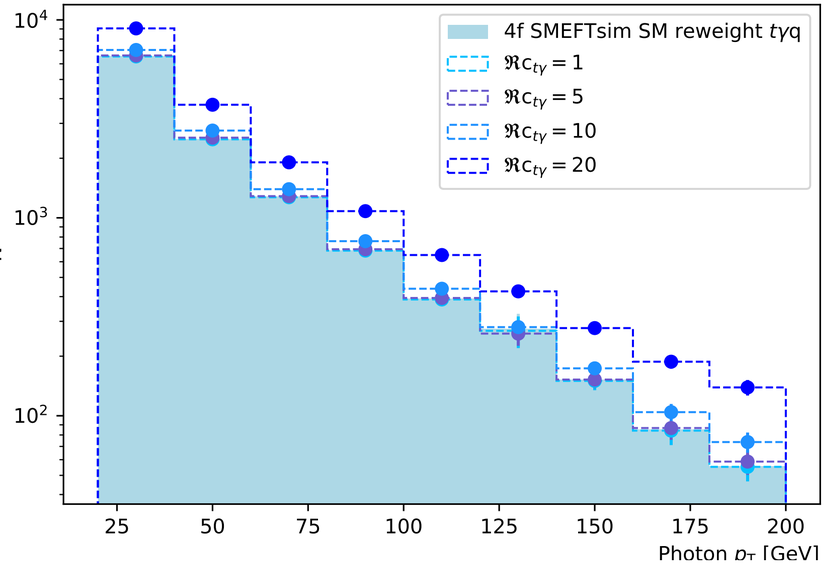
Selection: **N_ℓ=1, $N_\gamma \geq 1$, $N_j \geq 1$, $N_b \geq 1$**

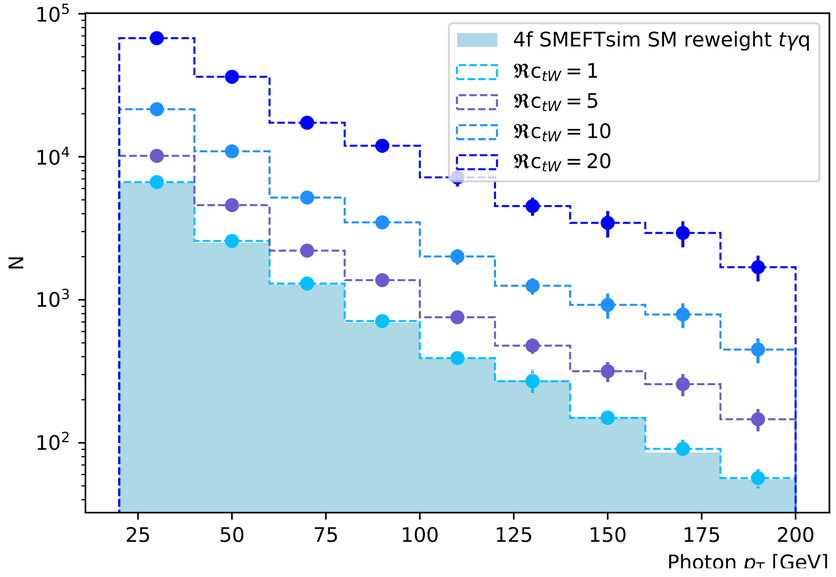


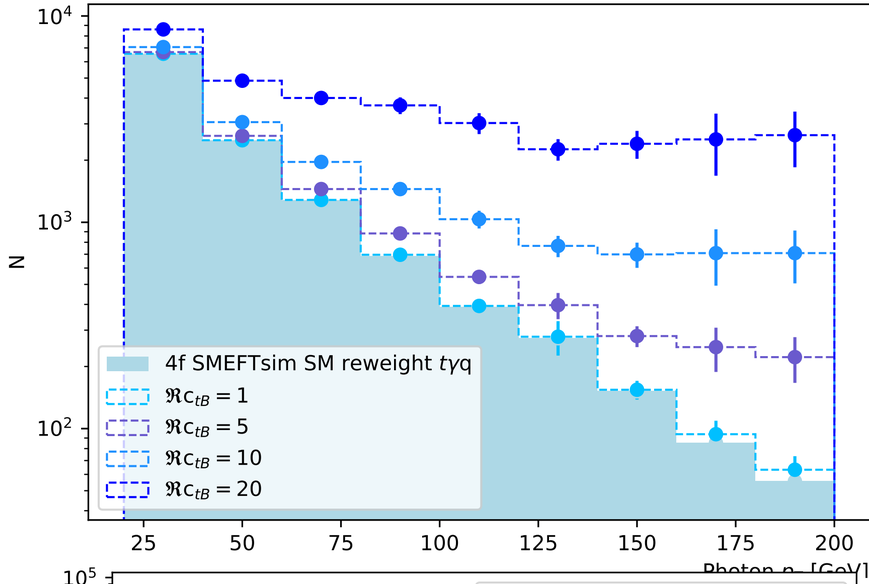
- With normalisation factor 2, the SMEFTsim with SM reweight has a good match to our official NLO sample
- The SMEFTatNLO one looks a little strange

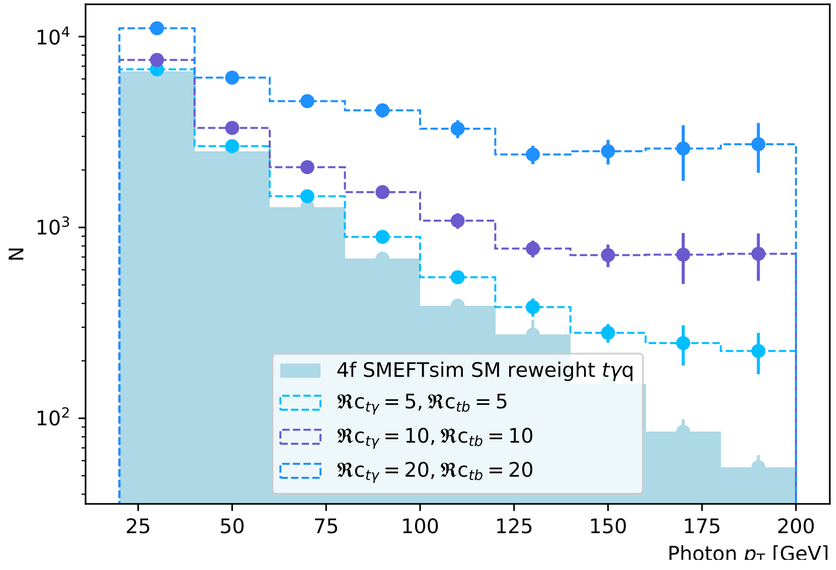
Photon p_T distributions — LHE level

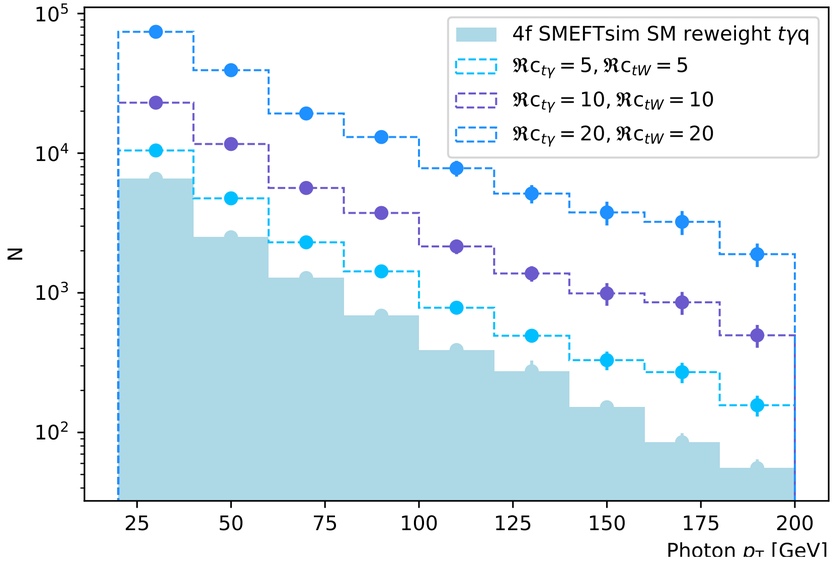
Selection: **N_ℓ=1, $N_\gamma \geq 1$, $N_j \geq 1$, $N_b \geq 1$**

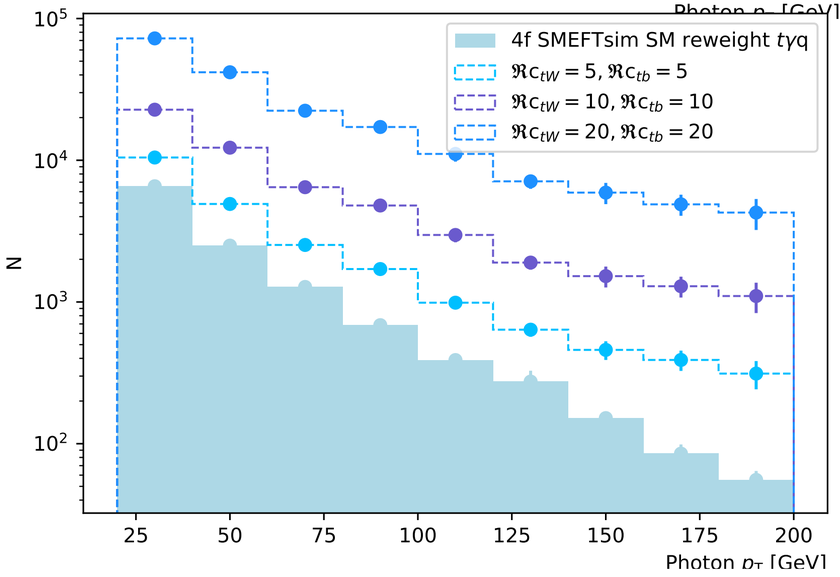






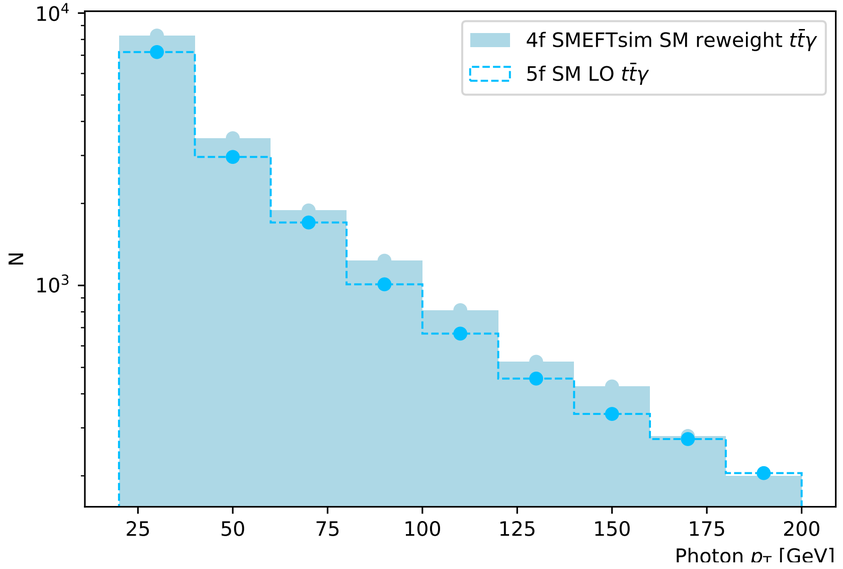


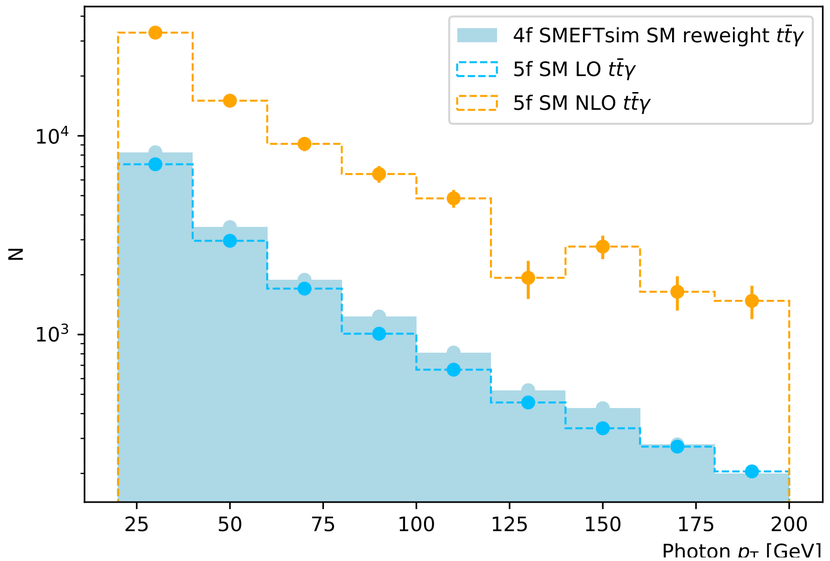


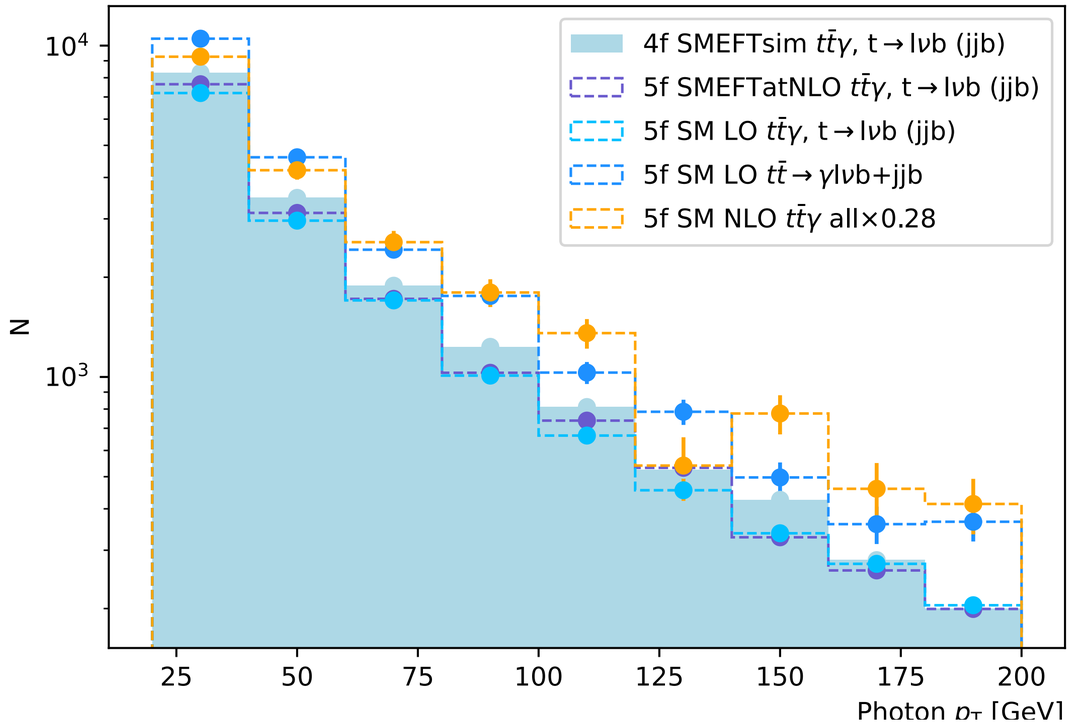


Photon p_T distributions — LHE level

Selection: **N_ℓ=1, $N_\gamma \geq 1$, $N_j \geq 1$, $N_b \geq 1$**



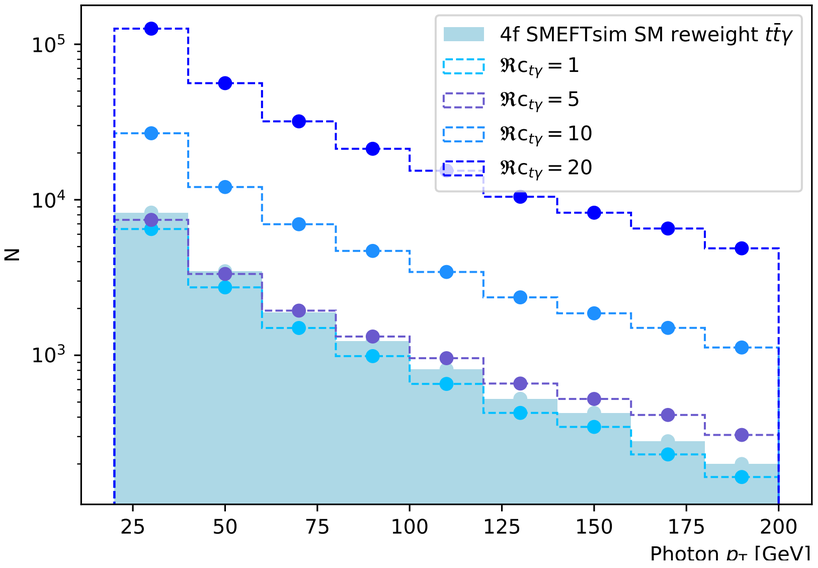


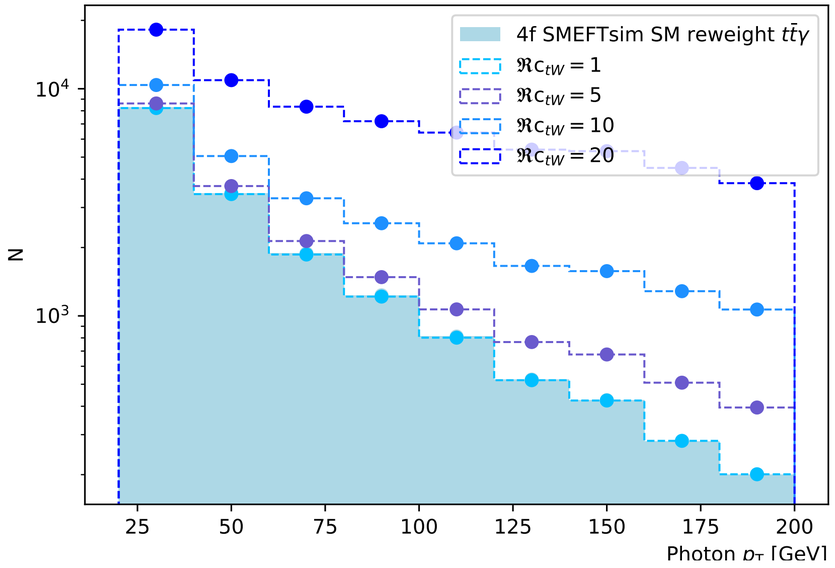


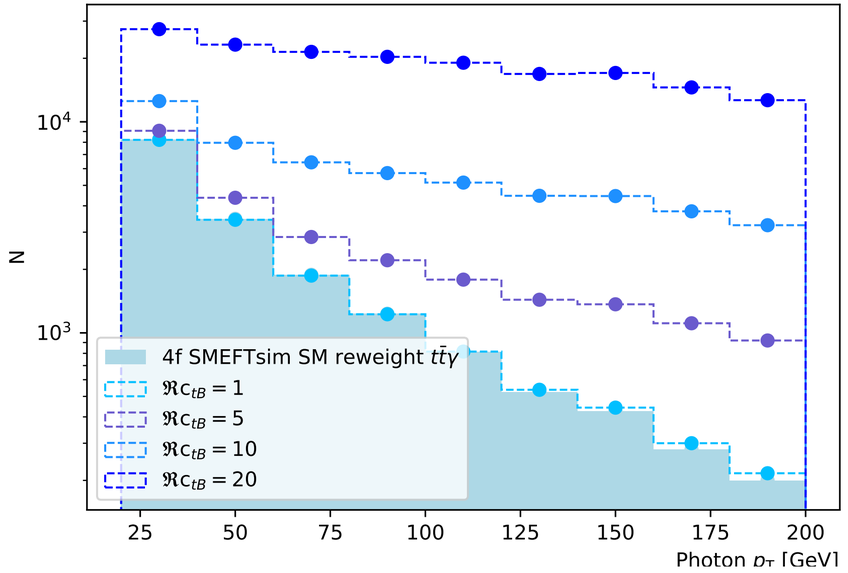
- The LO ones don't have large differences even for different flavour schemes and EFT models
- The LO ones are only one third of the official NLO samples
- Since the SMEFTatNLO is not ideal in tγq case, we'd better use SMEFTsim for both tγq and ttγ

Photon p_T distributions — LHE level

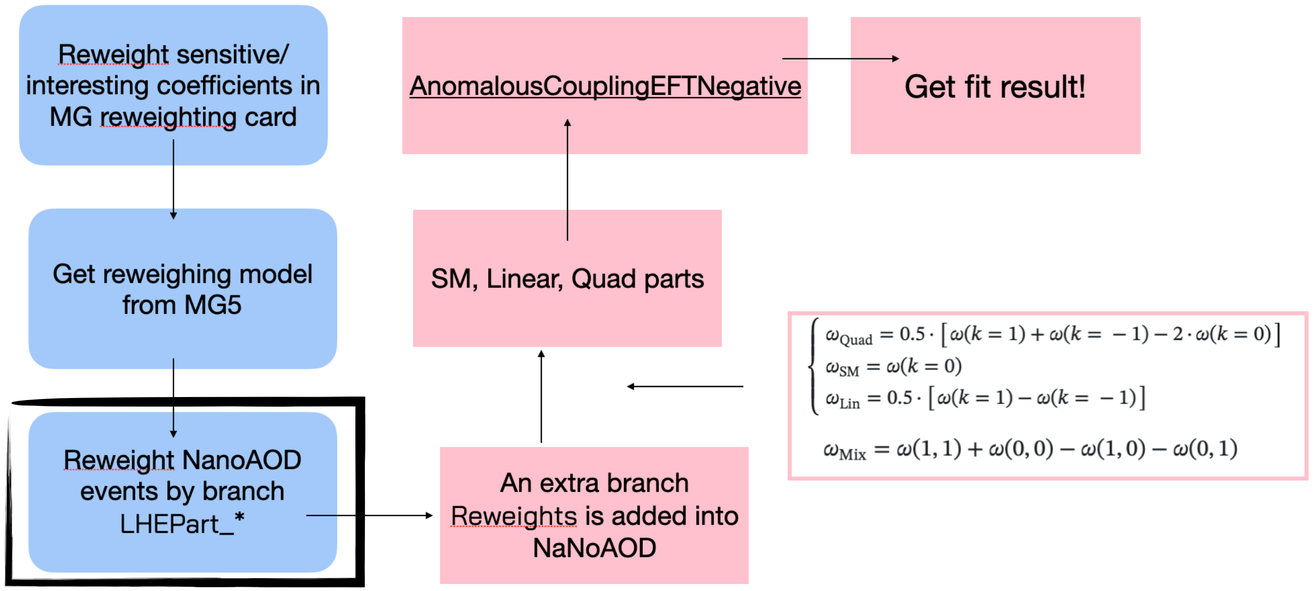
Selection: **N_ℓ=1, $N_\gamma \geq 1$, $N_j \geq 1$, $N_b \geq 1$**







Potential issue



It’s doing a mapping from a PDG list got from MG5 production to NanoAOD LHEPart

If the NanoAOD LHE events are not matched to the PDG list, the Reweights are just same as the generator weight

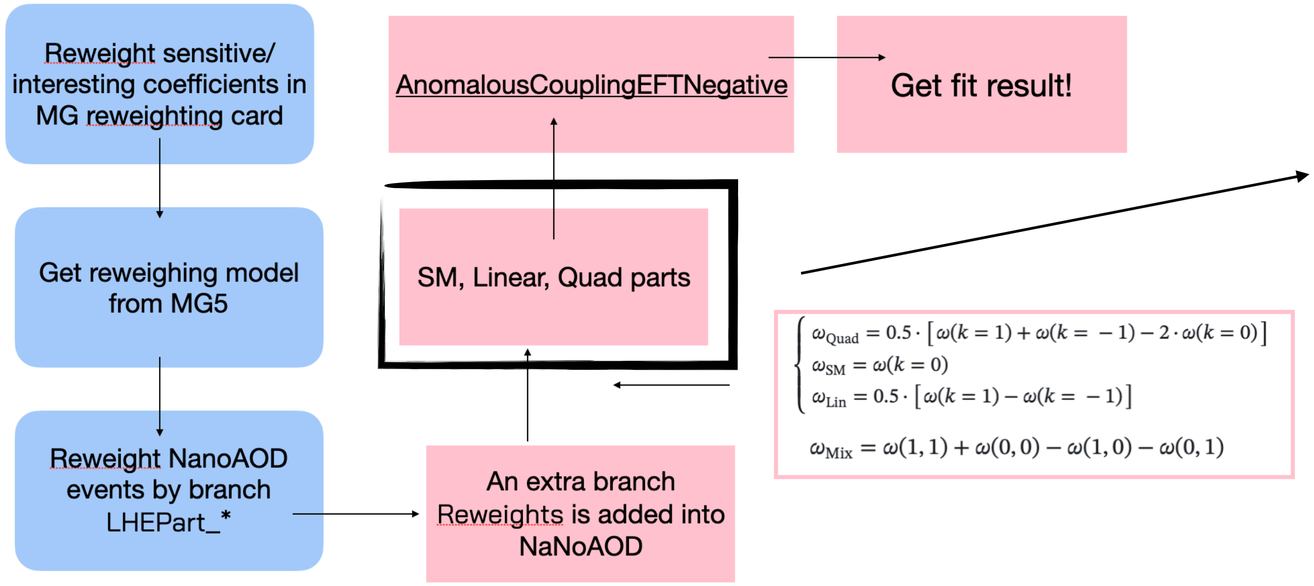
The potential issue is that some NLO events can’t be mapped to the LO PDG list, so the reweighs unchanged

Add an extra j in the production syntax to simulate an NLO process → doesn’t work

Apply normalisation factor → prefer to this way, we can add uncertainty in the fit, it’s fine for a limit measurement

Do some hard-coding to map these events manually (difficult)

Next to do



We are in the step of extracting histograms from different parts by pepper

- Check these histograms from GenPart and Reco objects

Next to perform the fit, need to take care of things:

- Apply normalisation factor to the inputs for SM and linear parts only
- Correlation between tγq and ttγ

Backup

tγq SM process

Official NLO tγq production

In 4-flavour scheme:

Process card

import model loop_sm-ckm
generate p p > t b~ j a $$ w+ w- [QCD] @0
add process p p > t~ b j a $$ w+ w- [QCD] @1

Madspind card

decay t > w+ b, w+ > ell+ vl
decay t~ > w- b~, w- > ell- vl~

Cross section: 2.909 +- 0.013e pb (without decay)
0.992 pb (considering ℓ branching ratio)

Private LO tγq production

In 4-flavour scheme:

Process card

import model sm-ckm
generate p p > t b~ j a $$ w+ w- , (t > w+ b, w+ > l+ vl) @0
add process p p > t~ b j a $$ w+ w- , (t~ > w- b~, w- > l- vl~) @1

Cross section: 0.7209 +- 0.002831 pb

tγq EFT process with reweight

tγq **LO production with 4-flavour scheme:**

Process card

```
import model SMEFTsim_topU3l_MwScheme_UFO-massless
generate p p > t b~ j a $$ w+ w- NP=1, (t > w+ b NP=0, w+ > l+ vl NP=0) @0 SMHLOOP=0
add process p p > t~ b j a $$ w+ w- NP=1, (t~ > w- b~ NP=0, w- > l- vl~ NP=0) @1 SMHLOOP=0
```

Cross section with SM weight: 0.82 +- 0.096 pb (1.26 pb with $c_{t\gamma} = 25$)

tγq **LO production with 5-flavour scheme:**

Process card

```
import model SMEFTatNLO-LO
generate p p > t b~ j a $$ w+ w- NP=2, (t > w+ b NP=0, w+ > l+ vl NP=0) @0
add process p p > t~ b j a $$ w+ w- NP=2, (t~ > w- b~ NP=0, w- > l- vl~ NP=0) @1
```

Cross section with SM weight: 1.53 +- 0.69 pb (5.92 pb with $c_{tZ} = c_{tW} = c_{t\gamma} = 7.5$)

ttγ SM process

Official $t\bar{t}\gamma$ (NLO or LO) production

NLO production with 5-flavour scheme:

Process card

```
import model loop_sm-ckm_no_b_mass
generate p p > t t~ a [QCD] @0
add process p p > t t~ a j [QCD] @1
```

Cross section: 6.052 +- 0.014 pb (All decays)

~2.58 pb for semi-leptonic decay

LO production with 5-flavour scheme:

Process card

```
import model sm-ckm_no_b_mass
generate p p > t t~ > l+ vl b ds uc~ b~ a
add process p p > t t~ > uc ds~ b l- vl~ b~ a
```

Cross section: 5.121 +- 0.003712 pb

Private LO $t\bar{t}\gamma$ production

LO production with 5-flavour scheme:

Process card

```
import model sm-ckm_no_b_mass
generate p p > t t~ a, (t > w+ b, w+ > l+ vl), (t~ > w- b~, w- > uc~ ds) @0
add process p p > t t~ a, (t > w+ b, w+ > uc ds~), (t~ > w- b~, w- > l- vl~) @1
```

Cross section: 0.6145 +- 0.00173 pb

ttγ EFT process with reweight

$t\bar{t}\gamma$ LO production with 4-flavour scheme:

Process card

```
import model SMEFTsim_topU3l_MwScheme_UFO-massless
generate p p > t t~ a NP=1, (t > w+ b NP=0, w+ > l+ vl NP=0), (t~ > w- b~ NP=0, w- > uc~ ds NP=0) @0 SMHLOOP=0
add process p p > t t~ a NP=1, (t > w+ b NP=0, w+ > uc ds~ NP=0), (t~ > w- b~ NP=0, w- > l- vl~ NP=0) @1 SMHLOOP=0
```

Cross section with SM weight: 0.73 +- 0.078 pb (16.8 pb with $c_{t\gamma} = 25$)

$t\bar{t}\gamma$ LO production with 5-flavour scheme:

Process card

```
import model SMEFTatNLO-LO
generate p p > t t~ a NP=2, (t > w+ b NP=0, w+ > l+ vl NP=0), (t~ > w- b~ NP=0, w- > uc~ ds NP=0) @0
add process p p > t t~ a NP=2, (t > w+ b NP=0, w+ > uc ds~ NP=0), (t~ > w- b~ NP=0, w- > l- vl~ NP=0) @1
```

Cross section with SM weight: 0.66 +- 0.029 pb (4.34 pb with $c_{tZ} = c_{tW} = c_{t\gamma} = 7.5$)