Modeling of Single Top + Photon Process with Different Generators

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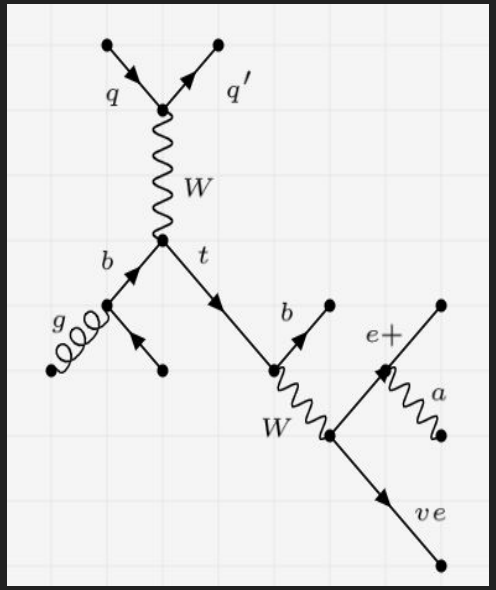
Single Top + Photon Process

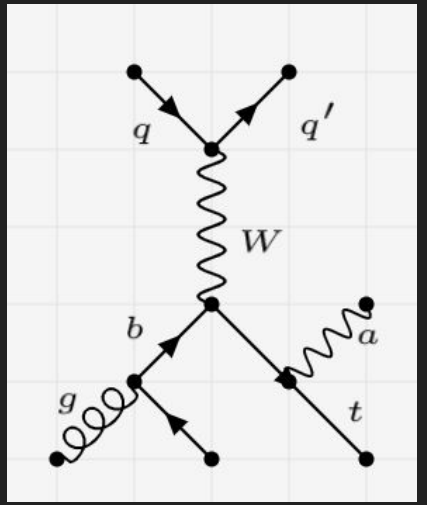
- Production of a single top quark in association with a photon (tqγ) is a rare process predicted in the Standard Model (SM)
- Measuring cross section of this process will test SM predictions about the top quark's charge and its interaction with photon and W boson
- This process has not been observed by any experiment yet
- CMS experiment found first evidence of events consistent with this process using partial Run-2 data at a luminosity of 35.9 fb^{-1}
    - Significance of 4.4 sigma
- Worked on the modeling of this process with different Monte Carlo generators

Classification of tqγ Events



tqγ events can be classified into two categories based on the photon origin:

- Radiative decay
  - events in which a photon is produced in the decay products of the top quark
- Radiative production
  - events in which a photon is produced along with a top quark



Modeling of the Process

- At Leading-order (LO), MadGraph5+Pythia8 can model both categories
- At Next-to-leading-order (NLO), MadGraph5 can produce only events of the radiative production category
- NLO generators cannot produce radiative decay events. This contribution can be approximated using NLO tq process, where a photon is added by Pythia8 during showering
- NLO problem is that the final state including the top quark decay products has too many particles
- Will present comparison of LO versus NLO modeling of this process
- All processes produced in 4-flavor scheme

LO tqγ

```
process = """
import model sm
define p = g u c d s u~ c~ d~ s~
define j = g u c d s u~ c~ d~ s~
define l+ = e+ mu+ ta+
define l- = e- mu- ta-
define vl = ve vm vt
define vl~ = ve~ vm~ vt~
generate p p > t b~ j a $$ w+, (t > l+ vl b)
add process p p > t b~ j $$ w+, (t > l+ vl b a)
add process p p > t~ b j a $$ w-, (t~ > l- vl~ b~)
add process p p > t~ b j $$ w-, (t~ > l- vl~ b~ a)
output -f
"""
```

- Following selection cuts were made at generator level:
  - γ p_T > 10 GeV
  - ΔR (γ, b) > 0.2
  - ΔR (γ, jet) > 0.2
  - ΔR (γ, lepton) > 0.2
  - lepton eta < 5
  - γ eta < 5
- 100,000 events generated

NLO tqγ

- Following cuts were made at generator level:
  - γ p_T > 10 GeV
  - ΔR (γ, b) > 0..2
  - ΔR (γ, jet) > 0.2
  - ΔR (γ, lepton) > 0.2
  - lepton eta < 5
  - γ eta < 5
- 100,000 events were generated

```
process = """
import model loop_sm
define p = g u c d s u~ c~ d~ s~
define j = g u c d s u~ c~ d~ s~
define l+ = e+ mu+ ta+
define l- = e- mu- ta-
define vl = ve vm vt
define vl~ = ve~ vm~ vt~
generate p p > t b~ j a $$ w+ w- [QCD]
add process p p > t~ b j a $$ w+ w- [QCD]
output -f
"""
```

NLO tq

```
process ="""
import model loop_sm
define p = g u c d s u~ c~ d~ s~
define j = g u c d s u~ c~ d~ s~
define l+ = e+ mu+ ta+
define l- = e- mu- ta-
define vl = ve vm vt
define vl~ = ve~ vm~ vt~
generate p p > t b~ j $$ w+ w- [QCD]
add process p p > t~ b j $$ w+ w- [QCD]
output -f
"""
```

- Following selection cut was made at generator level:
  - lepton eta < 5
- Decaying top quark leptonically with madspin
- 600,000 events were generated to reduce statistical error

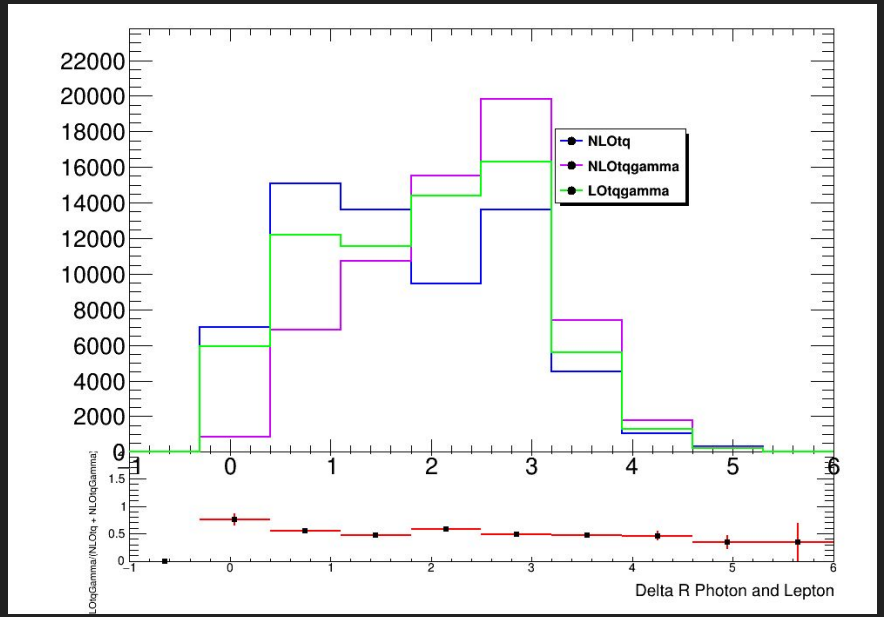
Cross Section Results

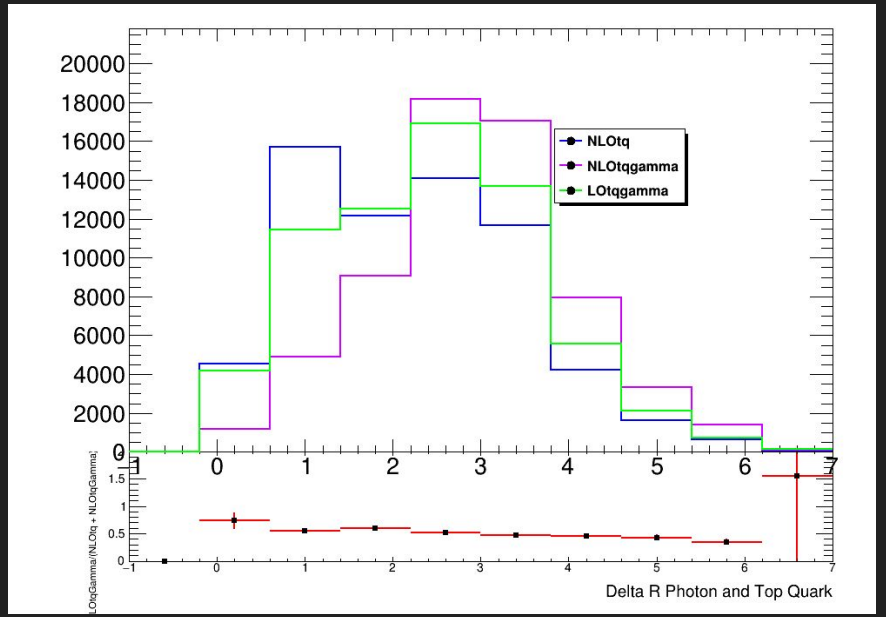
Process	Cross section [pb]
NLO tq	62.41
LO tqγ	1.412
NLO tqγ	1.1802

Comparison of All 3 Processes

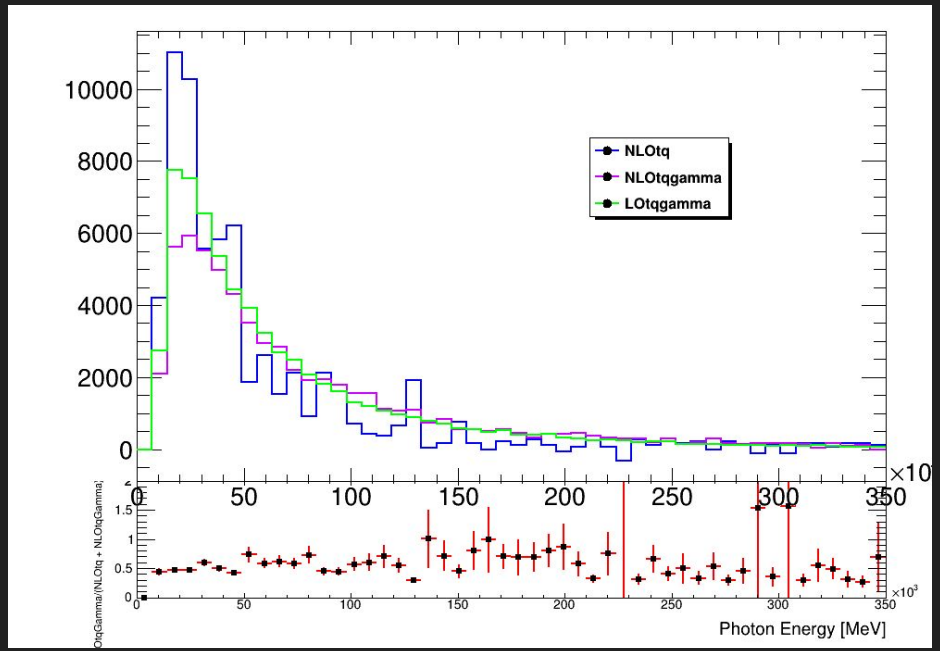
- Veto event if photon parent is a hadron
- Selection cuts applied:
  - abs(photon eta) < 2.5
  - abs(lepton eta) < 2.5
  - photon p_T > 10 GeV
  - lepton p_T > 27 GeV
- All plots normalized to luminosity of 139 fb^{-1}
- Ratio plots are LO tqγ/(NLO tq +NLO tqγ)

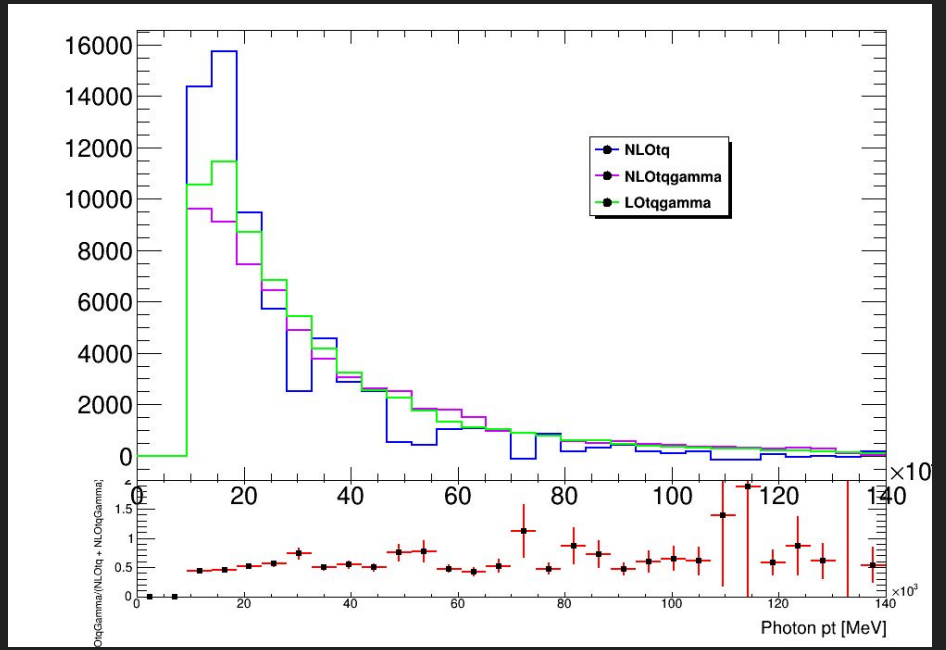
Delta R (photon, lepton) & Delta R (photon, top)





Photon Kinematics





Conclusions

- tqγ production is a rare process predicted in the SM
- Observing this process with ATLAS experiment data will test the SM predictions about the top quark charge and its coupling with the W boson and photon
- Comparison of this process with different MC generators is presented
- LO tqγ tends to lie between the two NLO samples