Top FCNC ($t\bar{t} \rightarrow bWq\gamma$) MC Validation Studies

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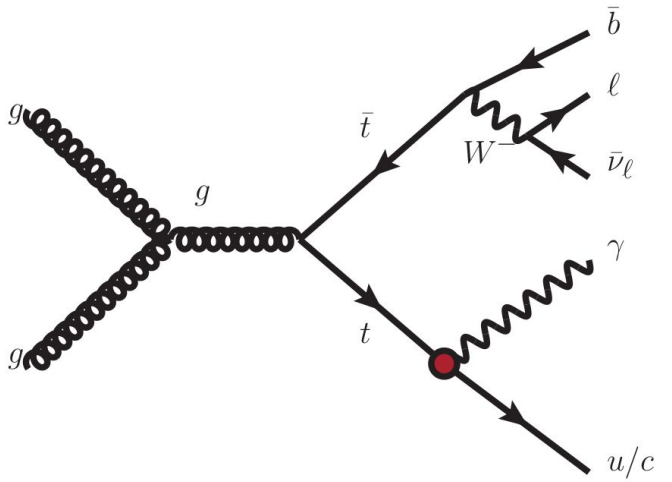
FCNC Monte Carlo

Top quarks decay via t→bW almost 100% of the time.

Flavor changing neutral currents are very suppressed in the Standard Model (SM), forbidden at tree level and suppressed at higher orders due to GIM mechanism.

SM branching ratio to FCNC decay ~10^{-16} for up type quarks and ~10^{-14} for charms.



Monte Carlo Samples

We are searching for FCNC in top quark decay

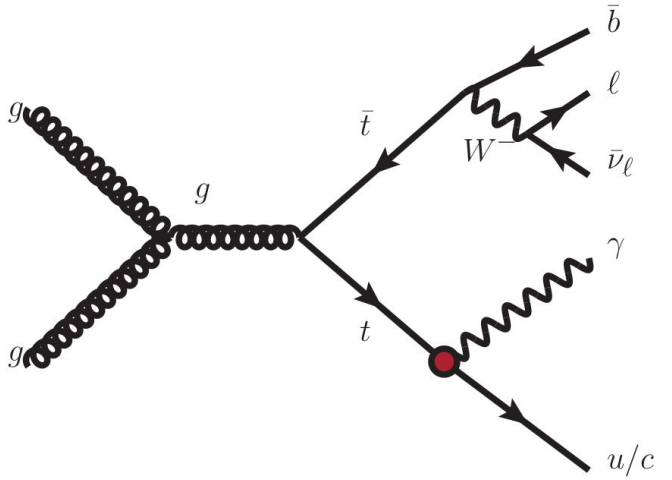
One top goes through SM process, the other to an up type quark and a photon

Following instructions at: TopPropertiesFCNCMCRunII

100k events of official ($t\bar{t} \rightarrow bW^{-}\bar{b}W^{+}$) production used for comparison

Official Sample used:
mc15_13TeV.410159.aMcAtNloPythia8EvtGen_A14_NNPDF23_NNPDF30ME_ttbar_nonallhad.merge.DAOD_TOPQ1.e4683_s2726_r7725_r7676_p2616

Will be requesting FullSim MC



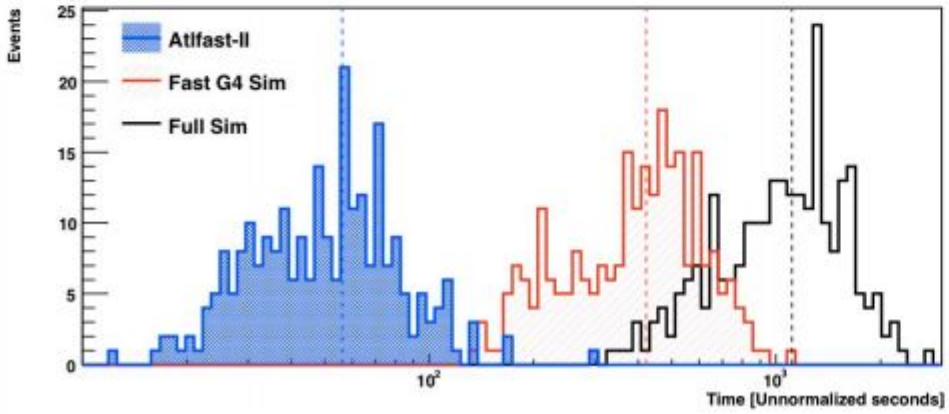
Full Sim vs Fast Sim

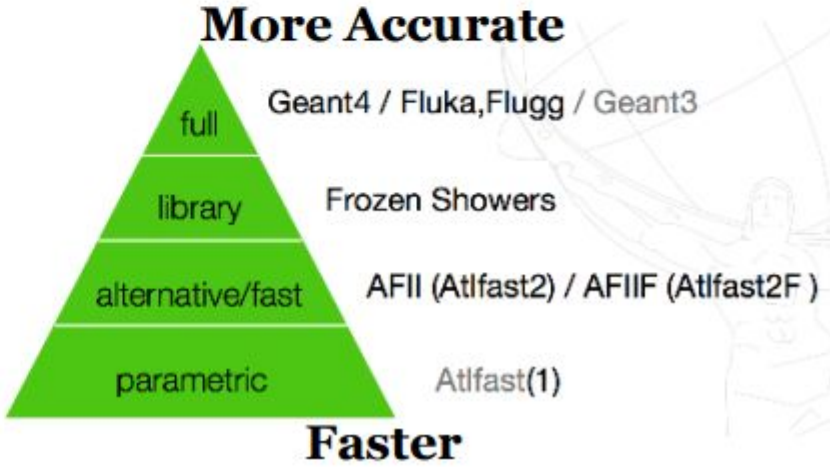
Full simulation does everything for every event. This process is slow; and for the amount of simulated events needed unwise

Most time in simulation is moving low energy particles around through calorimeters (especially electrons/photons < 1MeV)

Next most time from moving other particles through calorimeters.

- Frozen Showers
  - "Shower library" (pre-simulated showers) for low energy (<1 GeV) electrons and photons.
- ATLFAST-II aka FastCaloSim
  - Parameterization of calorimeter showers – histograms for e/γ/h, deposits in the readout structure (faster than using the detailed geometry).
- ATLFAST-IIF aka FATRAS+FastCaloSim
  - Adds a fast simulation of tracking in the ID and muon system with simplified geometry.
- ATLFAST-I
  - Mostly abandoned. Simple EVNT input to four-vector output with parameterized smearing.





Taken from Zach Marshall (LBNL) for ATLAS

Set-up

Event generation using MadGraph5_aMC@NLO

MadGraph Model: TopFCNC-onlyGam (TopFCNC with restrict file)

NLO Matrix Element generation using MadGraph

Top/W decays with MadSpin, preserves spin correlation effects

b decays and parton showering with Pythia8

A14 Tune

FCNC production following: C. Degrande, F. Maltoni, J. Wang and C. Zhang, Phys. Rev. D 91, 034024 (2015)

FCNC Monte Carlo

Since last update:

All of our hacked versions now in official production, can use official releases (MadSpin, MadGraphModels) to validate!

- Still requires fiddling to make hadronic W decays work (restrict_onlyGam.dat)
  - Need to get this file in official SVN release
- Requires larger couplings→non-negligible top quark width increase that shouldn't matter in analysis

MadSpin bug fixes for dealing with jets (and other multiparticles)

Samples (re)Produced

Produced 50k FCNC events for each Data Set ID (DSID)

DSIDs set aside for these processes: 410876-410883 (produced)

410884-410891 (similar final states)

$$t\bar{t} \rightarrow bWq\gamma$$

DSIDs correspond to combinations of final states

- Decays of t or tbar via FCNC
- Up or charm quark final state
- Leptonic or Hadronic W decay products
- Left or Right handed coupling of FCNC vertex to top, not varying

Definitions Used

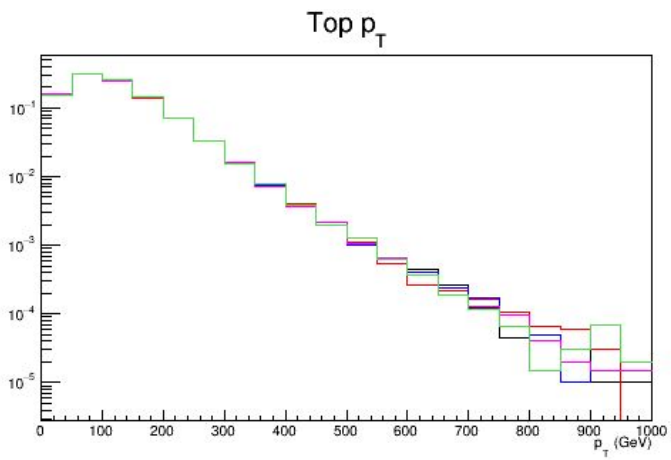
TRUTH1 Derivation used with no additional cuts

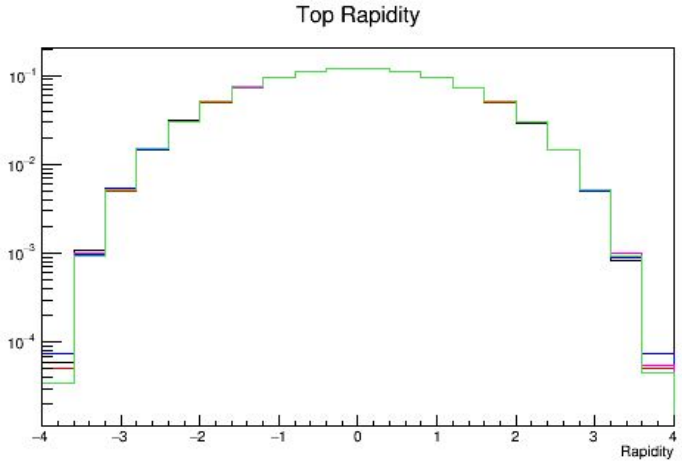
Using Pythia status codes

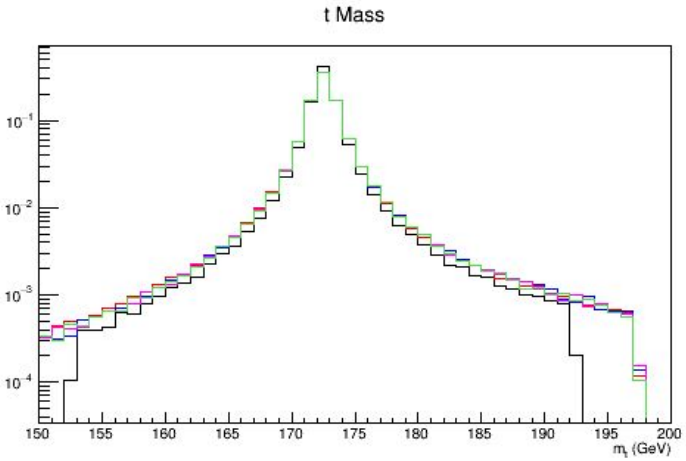
- 22: for tops, intended to preserve mass/from the hardest subprocesses
- 23: for outgoing particles (Leptons, bs, FCNC produced Quarks)

http://home.thep.lu.se/~torbjorn/pythia81html/ParticleProperties.html

Single Tops







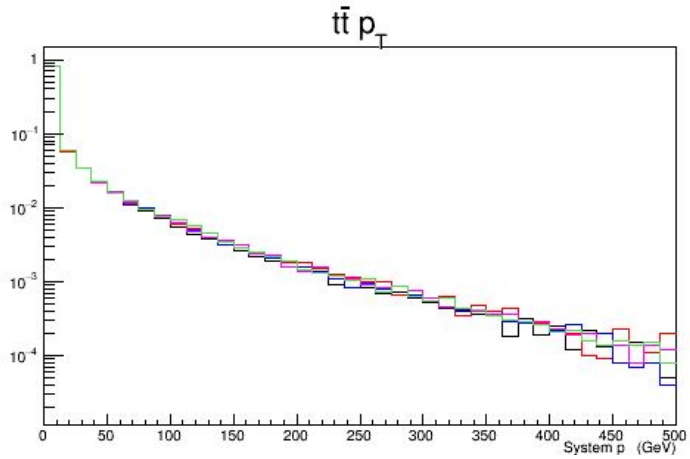
<p_T> = 121.1GeV

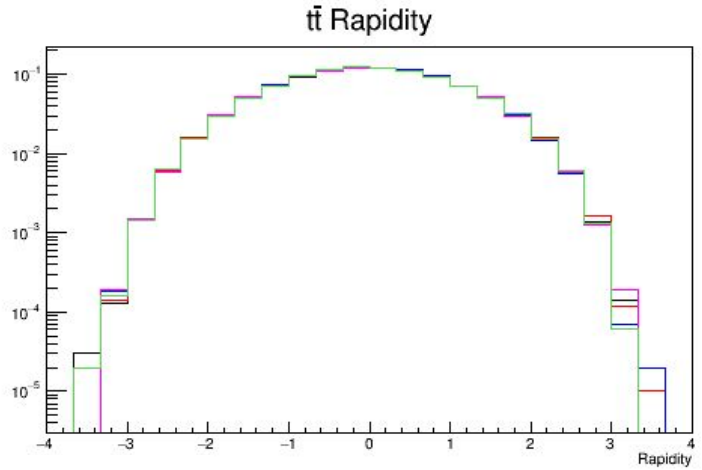
<m_t> =172.7
official **σ**= 2.79
FCNC **σ**= 3.46

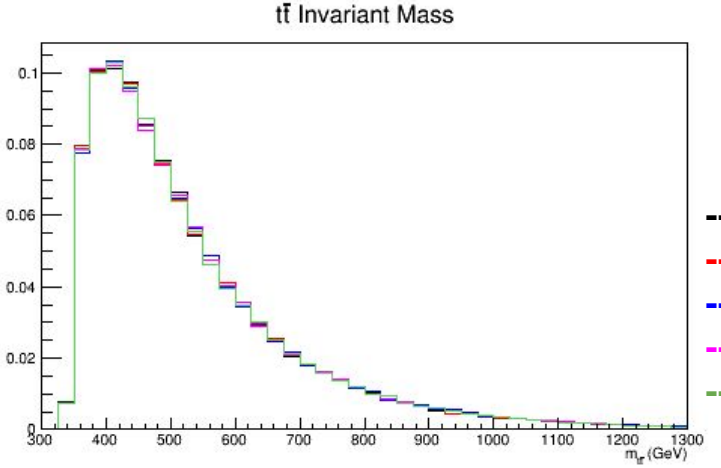
Consistent to official production
Difference in top mass width obvious, not large

-----: Official MC Production
-----: $t\bar{t} \to bW(\to l\nu)c\gamma$
-----: $t\bar{t} \to bW(\to jj)c\gamma$
-----: $t\bar{t} \to bW(\to l\nu)u\gamma$
-----: $t\bar{t} \to bW(\to jj)u\gamma$

ttbar system





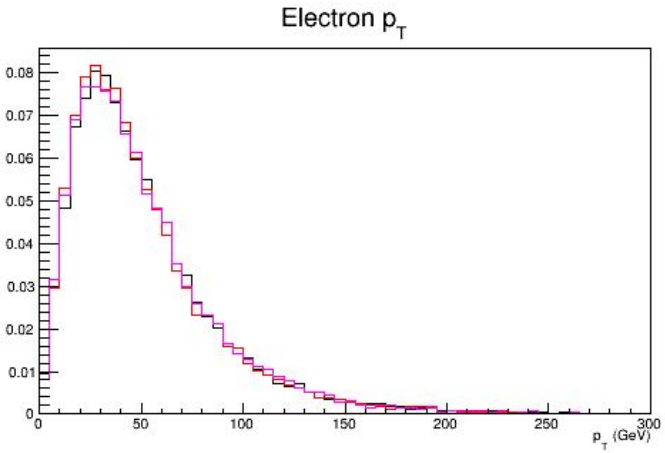


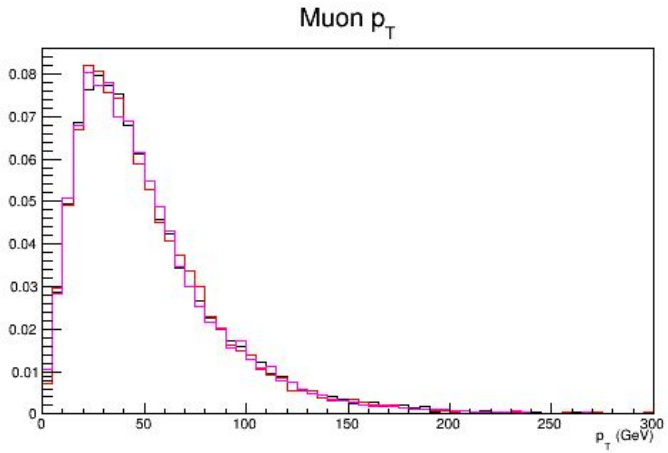
<p_T> = 13.2GeV

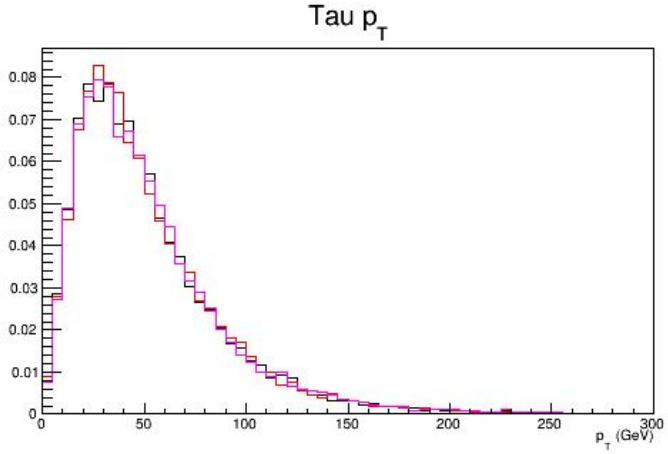
<m_tt> = 530 GeV
official **σ**= 162

-----: Official MC Production
-----: $t\bar{t} \to bW(\to l\nu)c\gamma$
-----: $t\bar{t} \to bW(\to jj)c\gamma$
-----: $t\bar{t} \to bW(\to l\nu)u\gamma$
-----: $t\bar{t} \to bW(\to jj)u\gamma$

Leptons







-----: Official MC Production

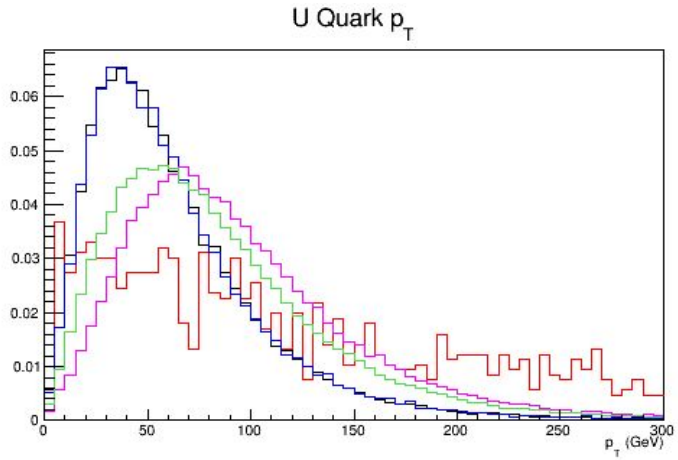
-----: $t\bar{t} \rightarrow bW(\rightarrow l\nu)c\gamma$

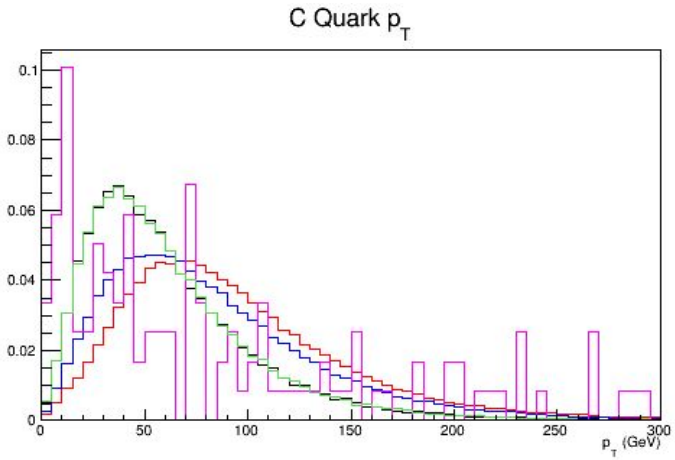
-----: $t\bar{t} \rightarrow bW(\rightarrow jj)c\gamma$

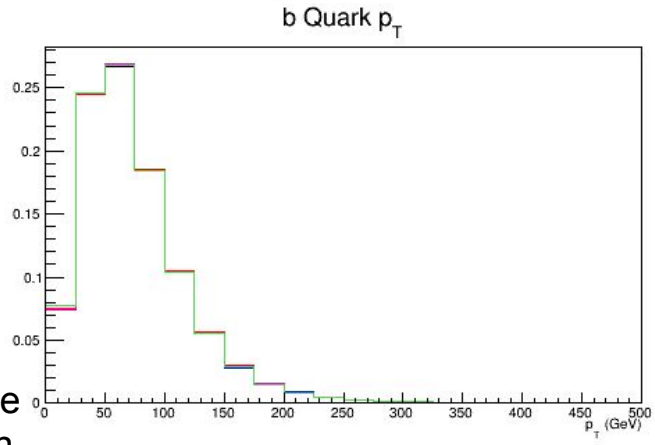
-----: $t\bar{t} \rightarrow bW(\rightarrow l\nu)u\gamma$

-----: $t\bar{t} \rightarrow bW(\rightarrow jj)u\gamma$

Quarks







Misplaced quarks from NLO processes, W decays
Expect jj processes with opposite quark to mirror official production

-----: Official MC Production
-----: $t\bar{t} \rightarrow bW(\rightarrow l\nu)c\gamma$
-----: $t\bar{t} \rightarrow bW(\rightarrow jj)c\gamma$
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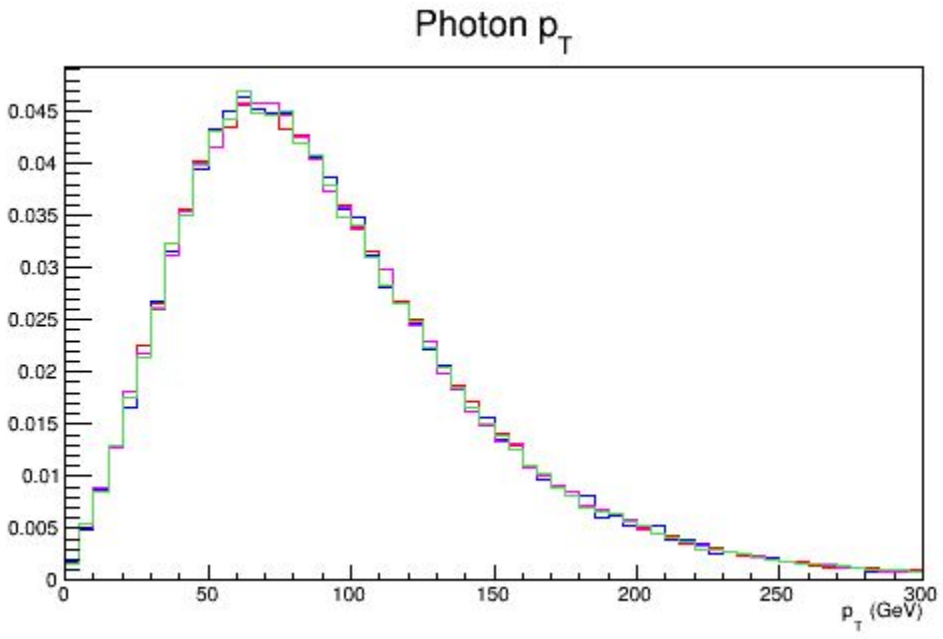
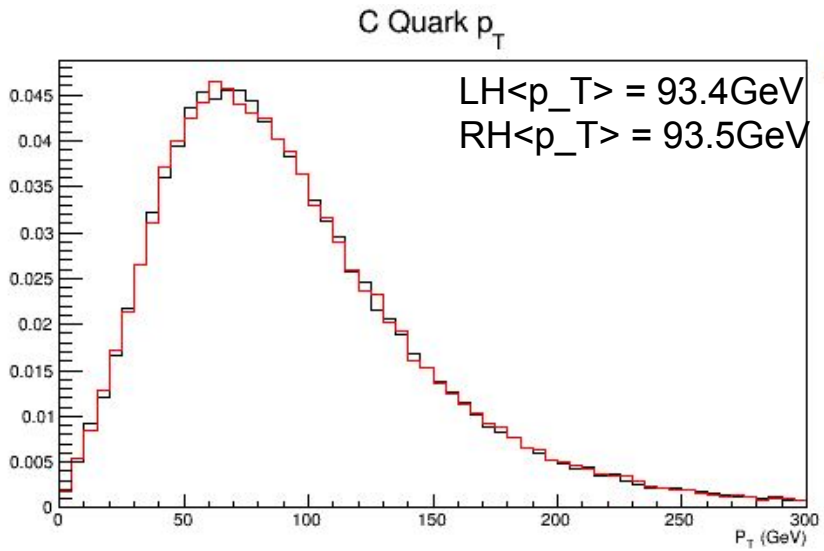
-----: $t\bar{t} \rightarrow bW(\rightarrow jj)u\gamma$

Photons

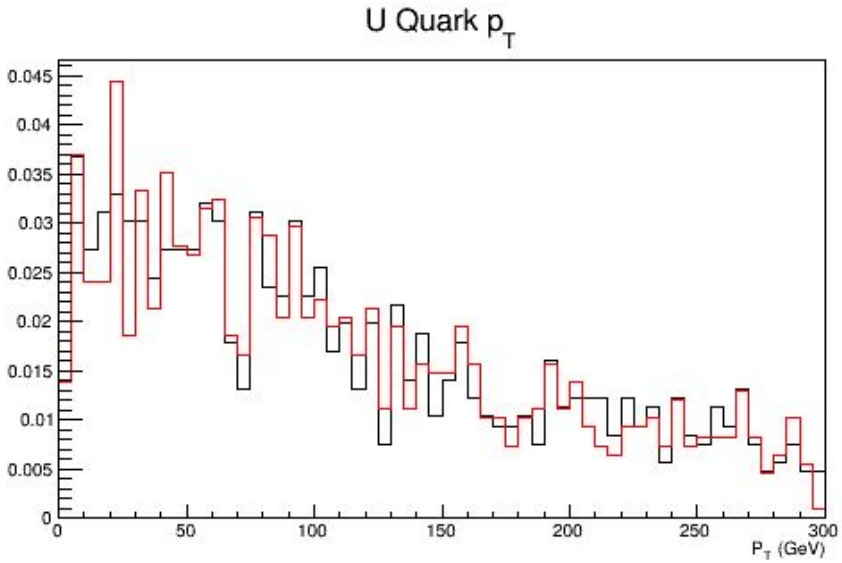


Nothing surprising here, no official production photons from initial decay, all others match.
<p_T> = 93.5 GeV

LH vs RH Coupling Comparison

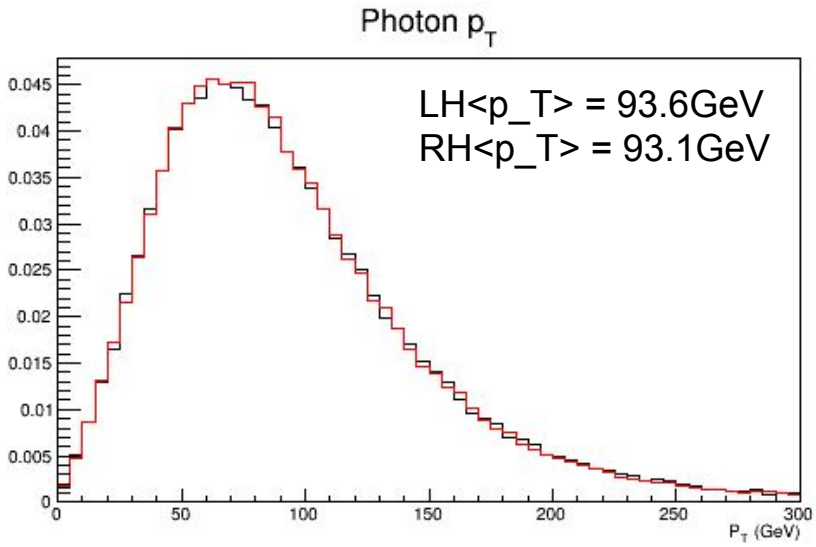


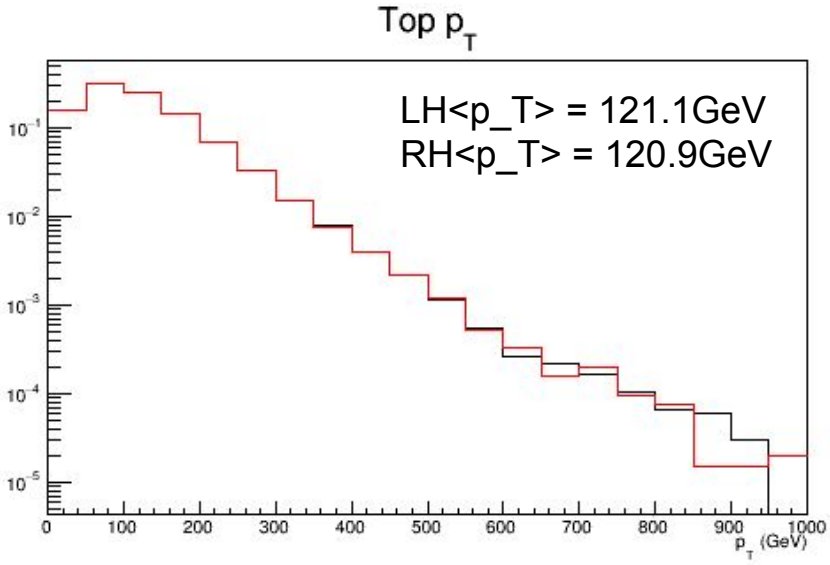
$$\mathcal{L}_{\gamma tc} = -e\bar{c}\,\frac{i\sigma^{\mu\nu}q_\nu}{m_t}\left(\lambda^L_{ct}P_L + \lambda^R_{ct}P_R\right)t\,A_\mu + \text{H.c.}$$



-----: LH Coupling
-----: RH Coupling

LH vs RH Coupling Comparison





-----: LH Coupling
-----: RH Coupling

Summary

- After many recreations of MC events we finally are ready to move forward with official production (Need to add restrict file to SVN)
- All initial processes and kinematic information appear to match very well with official production.
- Final state kinematics (leptons, quarks) behave as expected
- LH vs RH coupling investigated in leptonic $t \rightarrow c\gamma$ channel

- JIRA ticket has been started
  - FullSIM for all events, currently no usable uncertainties for photons in FastSIM