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

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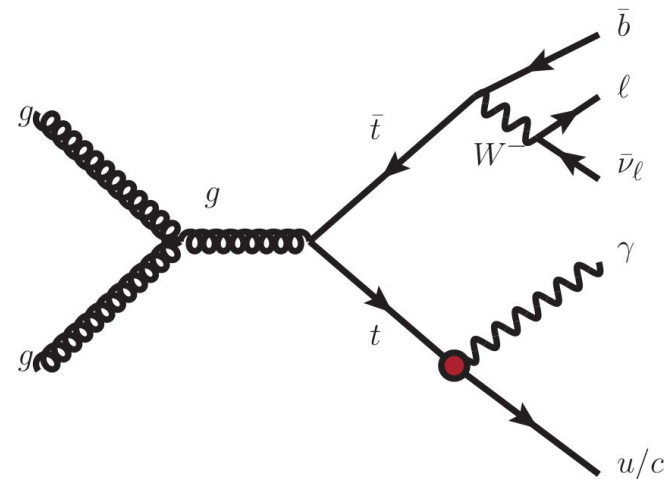October 13, 2016

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.D
AOD_TOPQ1.e4683_s2726_r7725_r7676_p2616
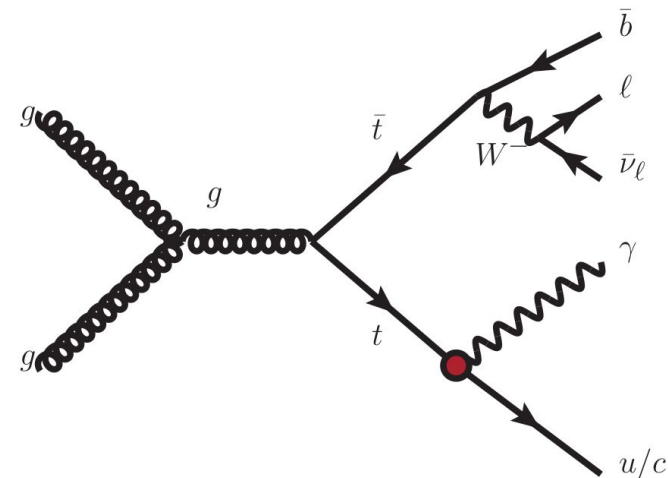
Set-up

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

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 large couplings→non-negligible top quark width increase that shouldn't matter in analysis

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
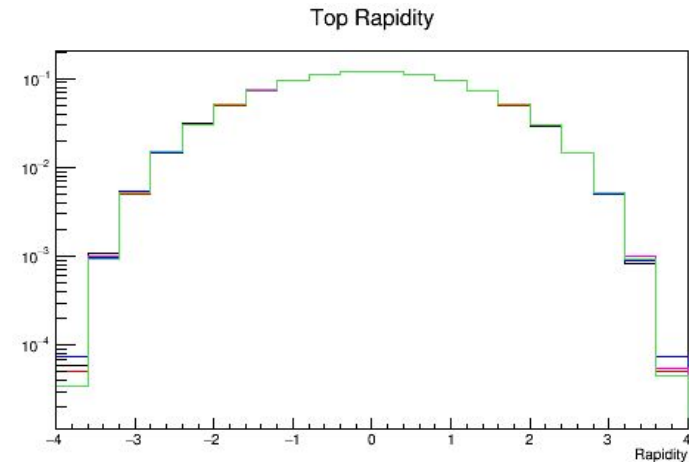
Definitions Used
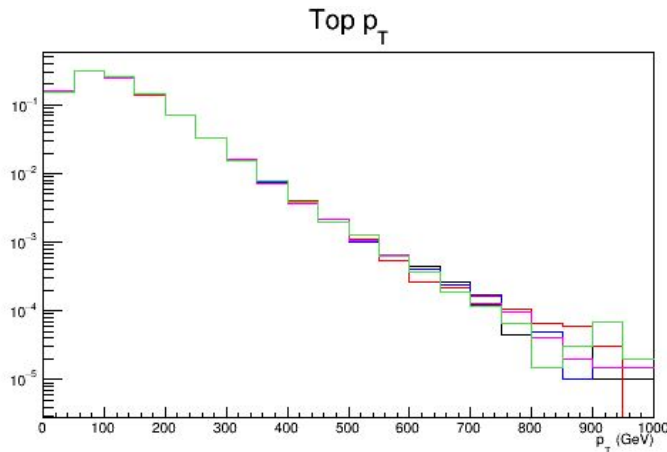
TRUTH1 Derivation used with no additional cuts

Using Pythia status codes

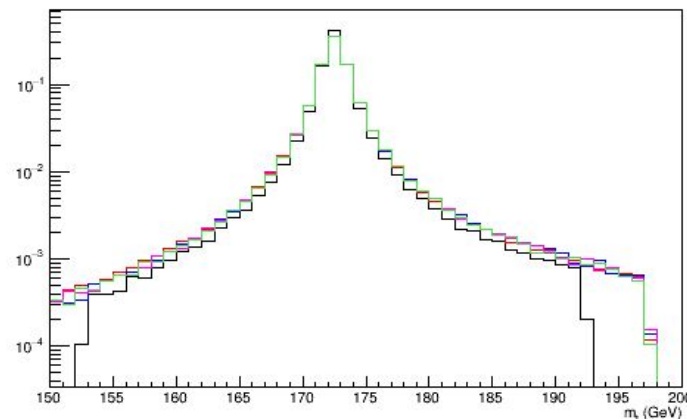> 22: for tops, intended to preserve mass/from the hardest subprocesses

> 23: for outgoing particles (Leptons, bs, FCNC produced Quarks, photons)

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

Single Tops

Top p_T

Top Rapidity

<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
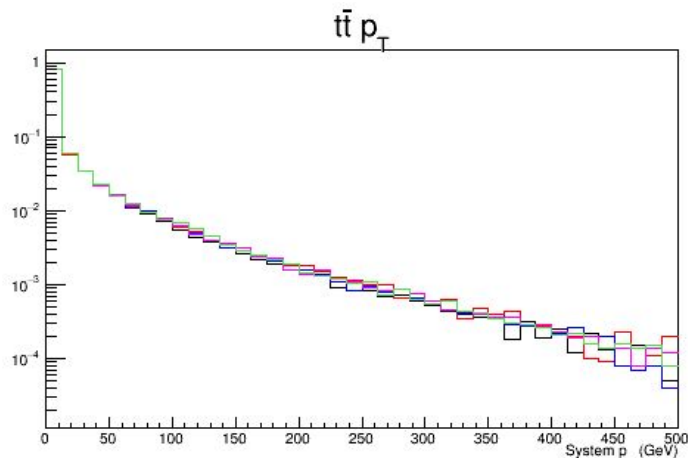

t Mass

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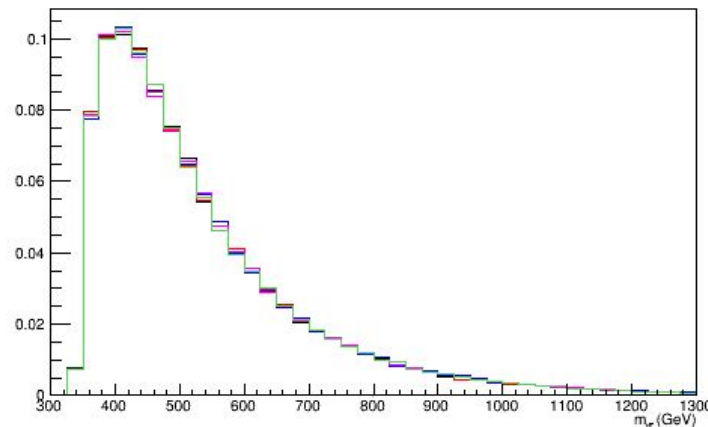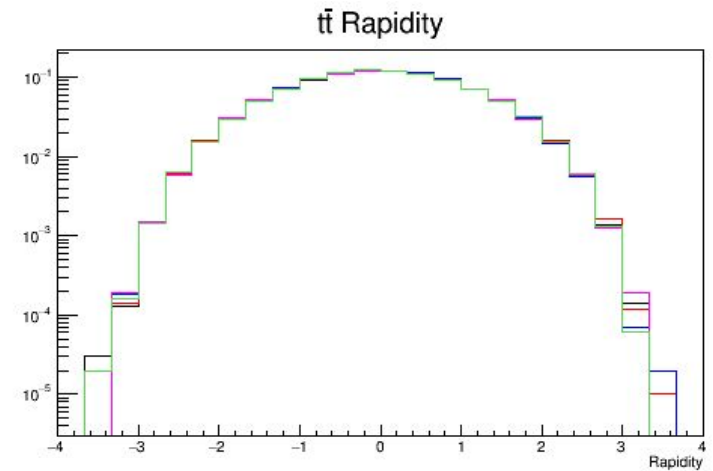**-----**: $t\bar{t} \rightarrow bW(\rightarrow jj)u\gamma$

ttbar system

$t\bar{t}\ p_T$

$t\bar{t}$ Rapidity

$t\bar{t}$ Invariant Mass

<p_T> = 13.2GeV

<m_tt> = 530 GeV
official σ= 162

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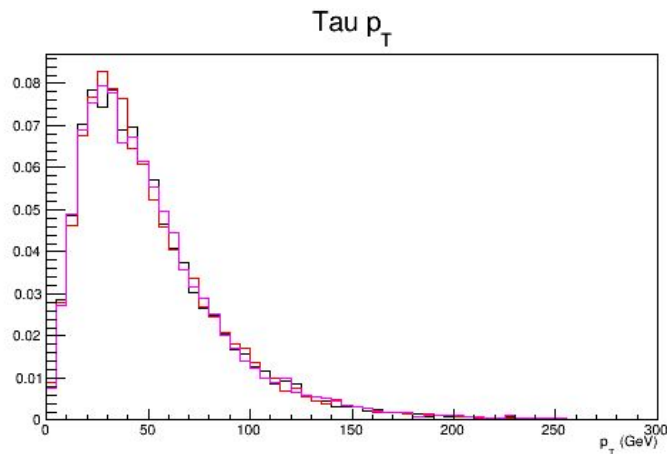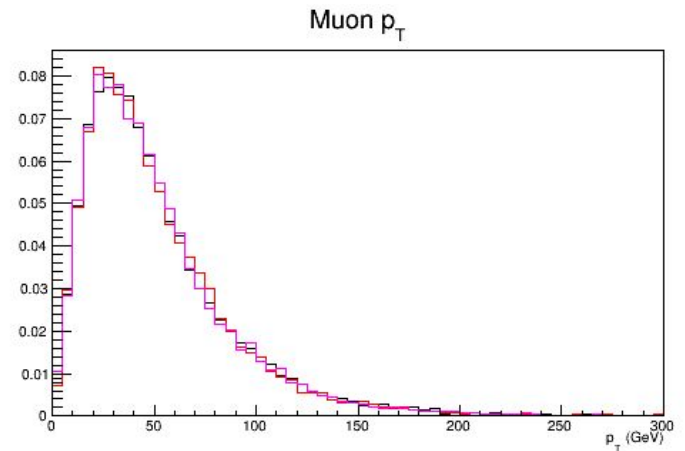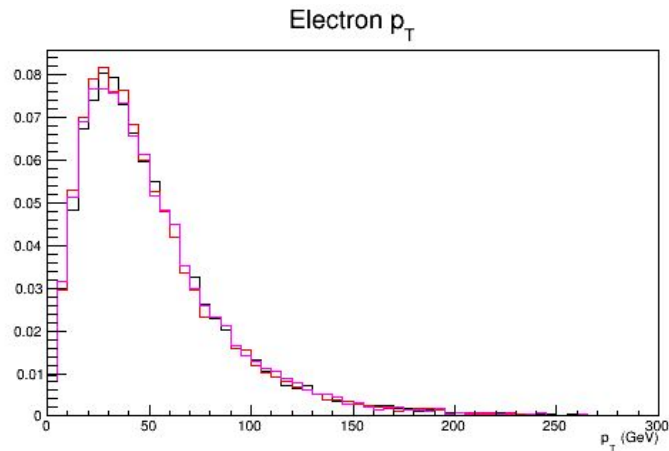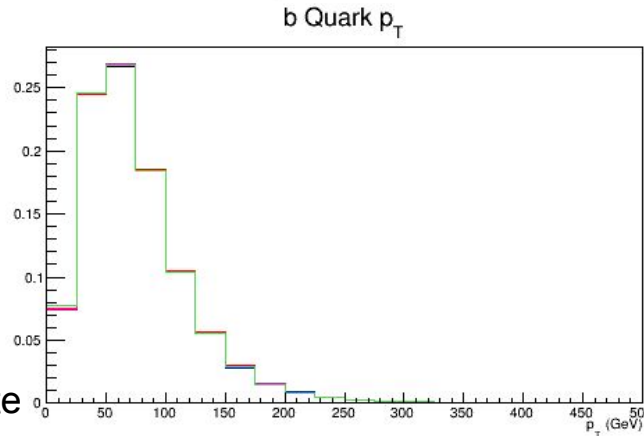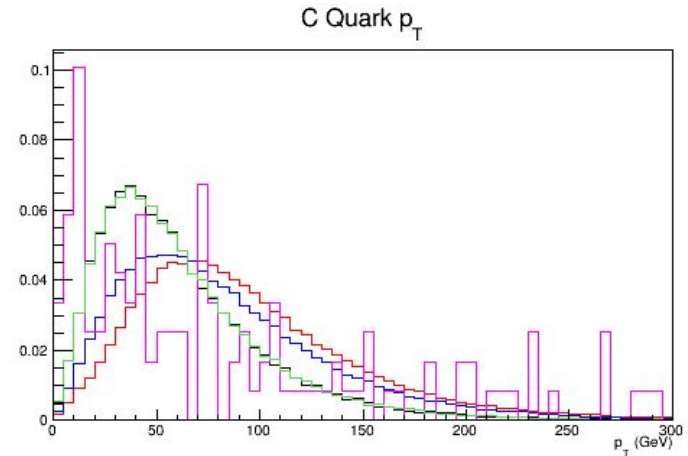-----: $t\bar{t} \rightarrow bW(\rightarrow l\nu)c\gamma$
-----: $t\bar{t} \rightarrow bW(\rightarrow jj)c\gamma$
-----: $t\bar{t} \rightarrow bW(\rightarrow l\nu)u\gamma$
-----: $t\bar{t} \rightarrow bW(\rightarrow jj)u\gamma$

Leptons

Electron p_T

Muon p_T
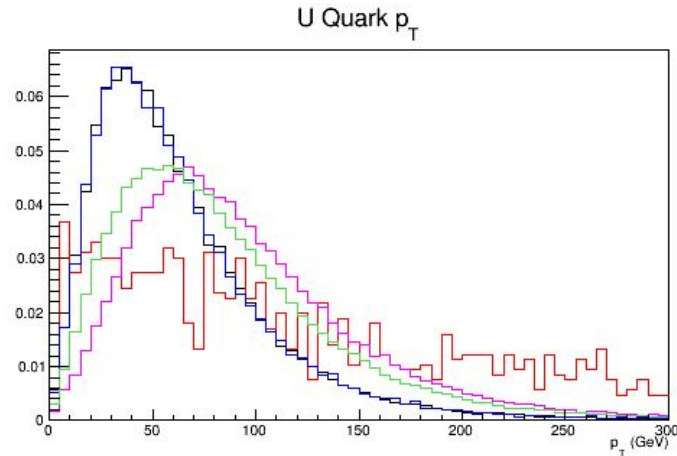
Tau p_T

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

Quarks

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

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

Photons

Photon p_T

Nothing surprising here, no official production photons from initial decay, all others match.

$<p\_T>$ = 93.5 GeV

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, photons) behave as expected

- Request: 150k FullSim (each sample)
  - Up for suggestions on actual number
    - 8TeV requested (I believe) 100k FullSim (for validation), 200k FastSim in unified file
  - t/tbar going through FCNC
  - u/c as quark from FCNC
  - At least Leptonic decay of W for now, expect more sensitivity in this channel (from 8TeV analysis)