Search for Flavor Changing Neutral Currents in Top Quark Decays

$t \to q\gamma$

Jason Barkeloo

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The Standard Model

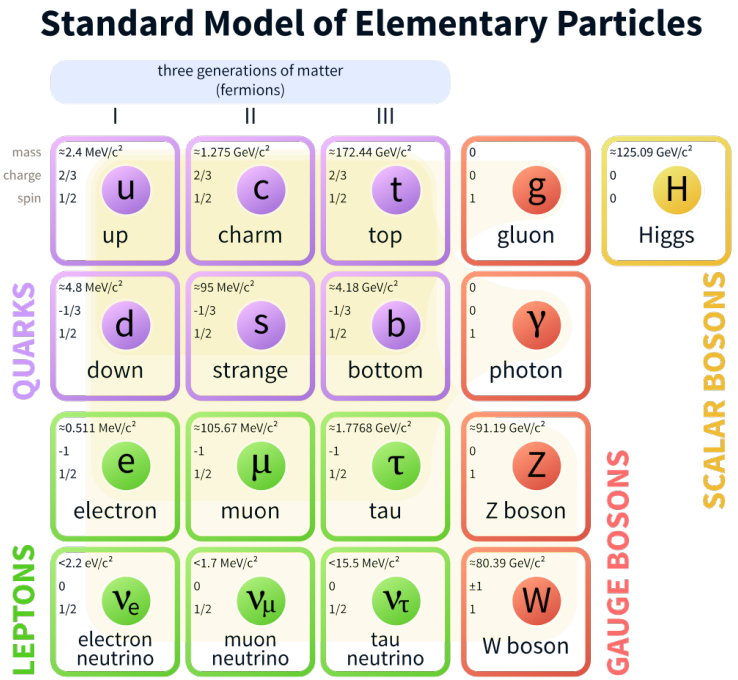


Figure: List of standard model particles

- Our current theory that attempts to explain everything
  - Experimentally precise and well behaved
  - Very few exceptions (i.e. Neutrino Mass, Matter-Antimatter Asymmetry, Dark Matter Abundance)

The Top Quark

- Heaviest fundamental particle, $172.5 GeV$
- Lifetime $5x10^{-25}s$, decays before hadronization
  - Allows us to study the decay of a single quark

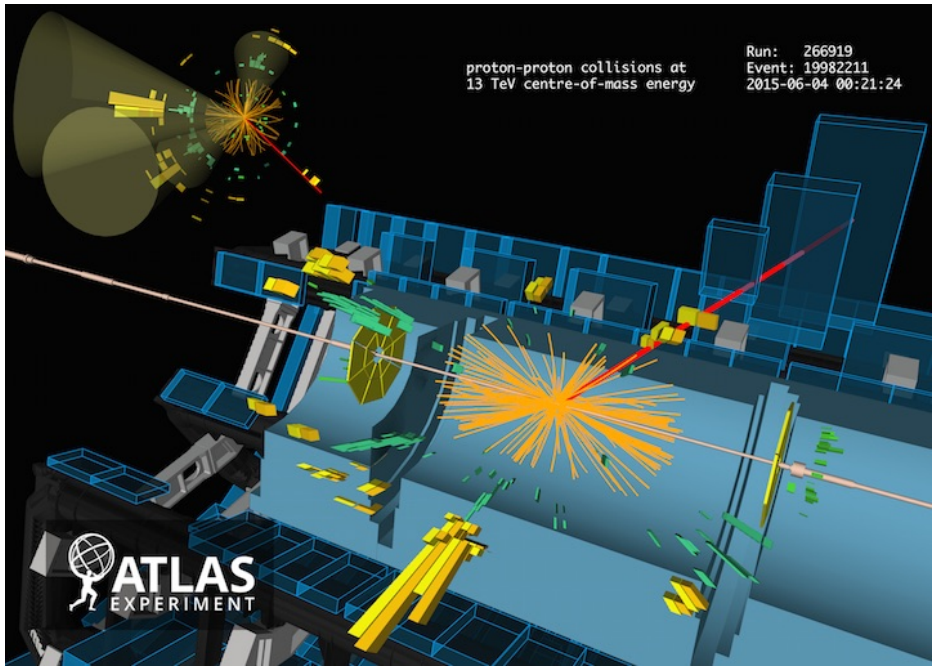


Figure: $t\bar{t}$ event in the ATLAS detector

Top Quark Pair Production

- Leading order processes for top quark production
  - Quark-antiquark annihilation $\approx 10\%$
  - Gluon-gluon fusion $\approx 90\%$

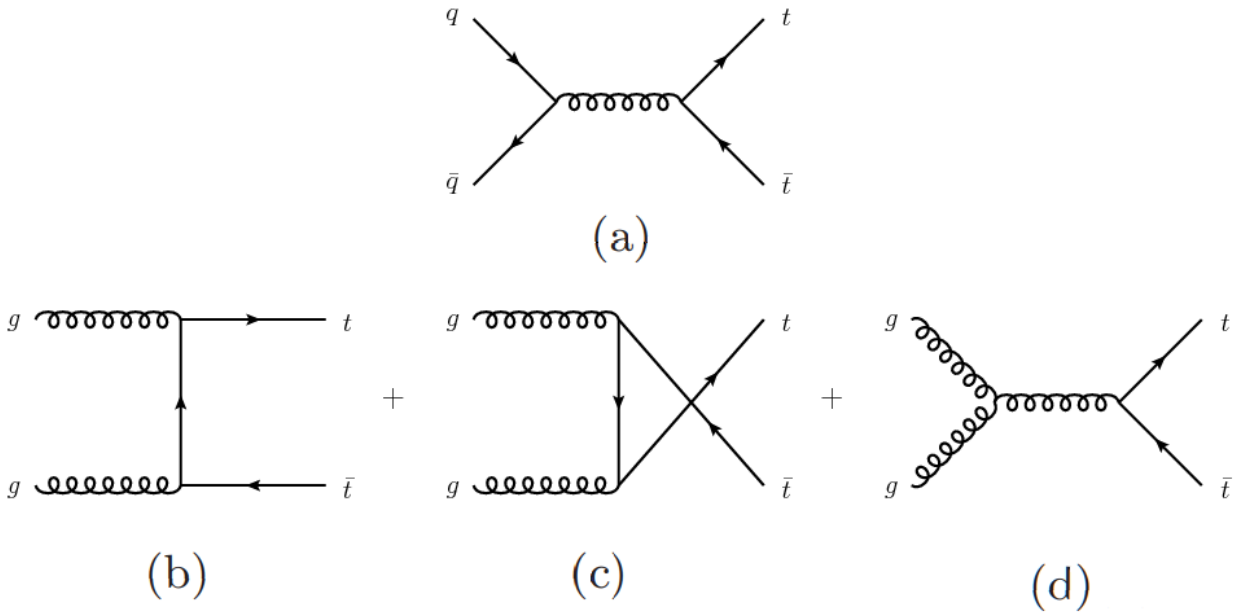


Figure: Leading order $t\bar{t}$ diagrams

Top Quark Pair Production

- At $\sqrt{s} = 13\,TeV$ for $m_t = 172.5\,GeV$, $\sigma_{t\bar{t}} = 831.76\,pb$

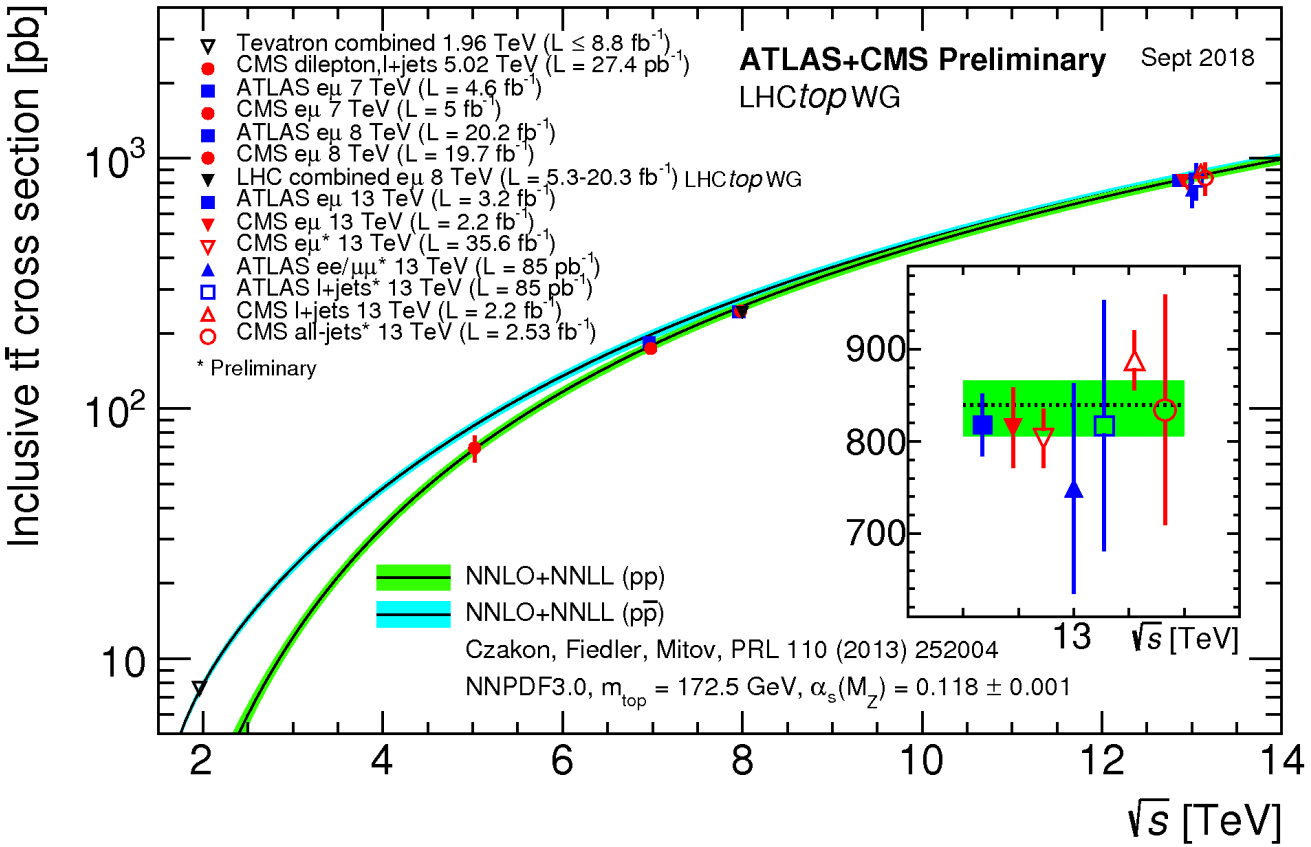


Figure: $t\bar{t}$ production cross section [TopWGSummaryPlots]

Top Quark Decays

- Standard model top branching ratio to bW $\simeq 100\%$

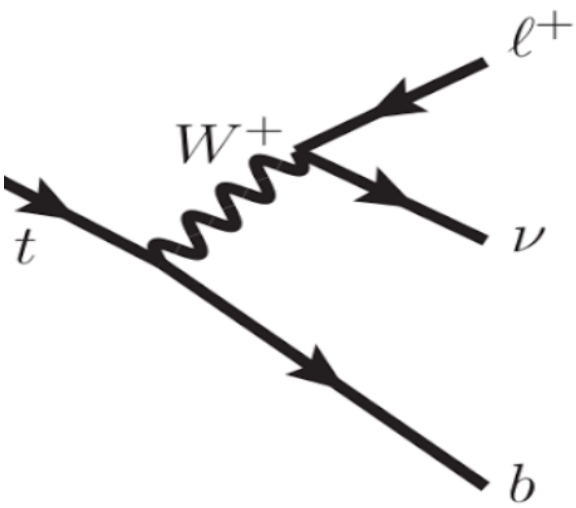


Figure: Leptonic final state diagram for a top decay

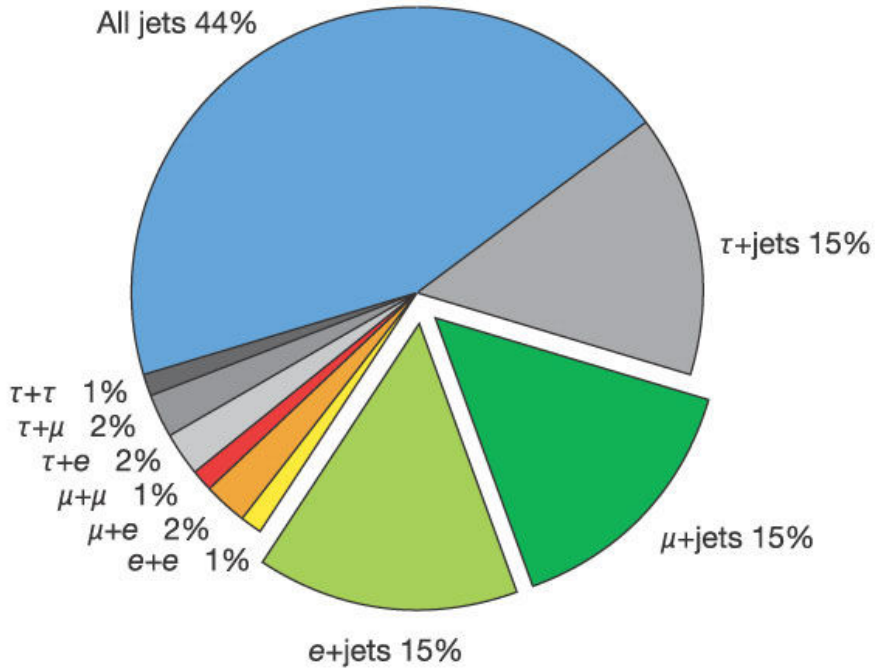
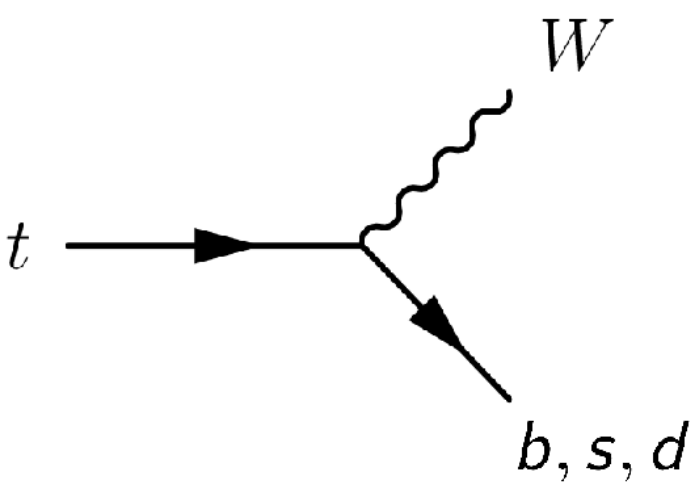
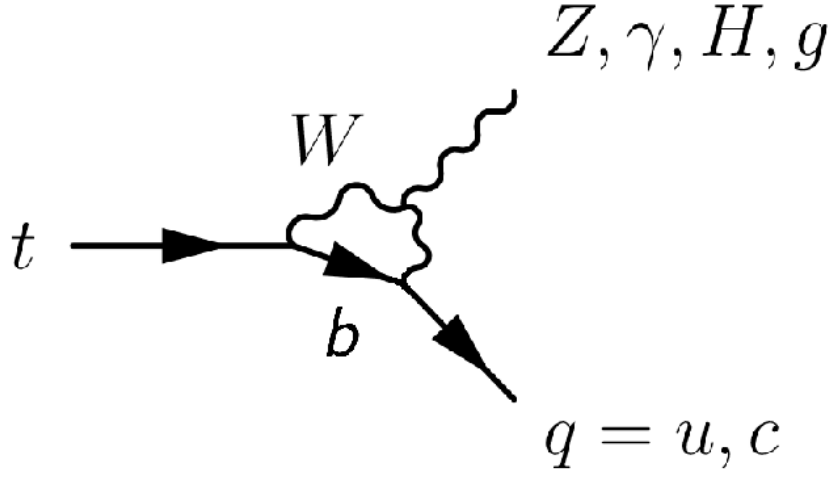


Figure: Top quark pair decay final states [Nature]

Top Quark Decays in the SM



(a)



(b)

- $t \to bW \approx 99.83\%$
- $t \to sW \approx 0.16\%$
- $t \to dW \approx 0.01\%$

- $t \to q_{u,c}X \approx 10^{-17} - 10^{-12}$

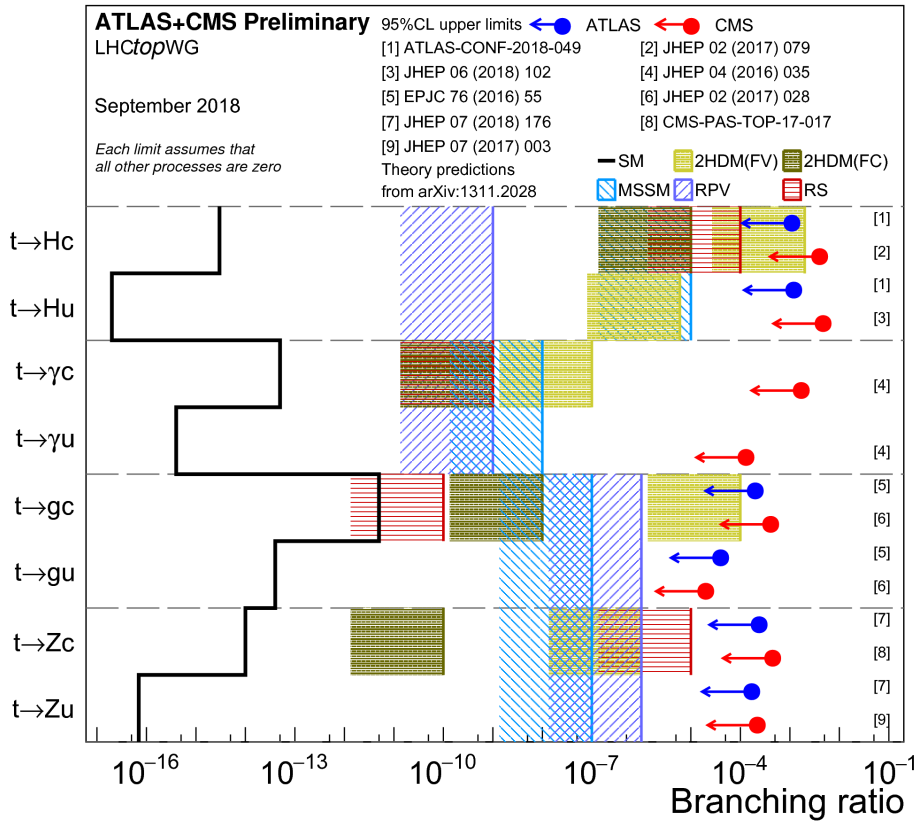
Top Flavor Changing Neutral Currents (FCNCs)

Process	SM	2HDM(FV)	2HDM(FC)	MSSM	RPV	RS
$t \to Zu$	7×10^{-17}	–	–	$\leq 10^{-7}$	$\leq 10^{-6}$	–
$t \to Zc$	1×10^{-14}	$\leq 10^{-6}$	$\leq 10^{-10}$	$\leq 10^{-7}$	$\leq 10^{-6}$	$\leq 10^{-5}$
$t \to gu$	4×10^{-14}	–	–	$\leq 10^{-7}$	$\leq 10^{-6}$	–
$t \to gc$	5×10^{-12}	$\leq 10^{-4}$	$\leq 10^{-8}$	$\leq 10^{-7}$	$\leq 10^{-6}$	$\leq 10^{-10}$
$t \to \gamma u$	4×10^{-16}	–	–	$\leq 10^{-8}$	$\leq 10^{-9}$	–
$t \to \gamma c$	5×10^{-14}	$\leq 10^{-7}$	$\leq 10^{-9}$	$\leq 10^{-8}$	$\leq 10^{-9}$	$\leq 10^{-9}$
$t \to hu$	2×10^{-17}	6×10^{-6}	–	$\leq 10^{-5}$	$\leq 10^{-9}$	–
$t \to hc$	3×10^{-15}	2×10^{-3}	$\leq 10^{-5}$	$\leq 10^{-5}$	$\leq 10^{-9}$	$\leq 10^{-4}$

Table: Branching ratio enhancements in various beyond the standard model theories [Snowmass Top Report]

Top Flavor Changing Neutral Currents

- Current Limits on FCNC Decays



- Limits on $t \to \gamma q$ processes: [JHEP 04 (2016) 035]
  - $t \to \gamma u < 1.3x10^{-4}$
  - $t \to \gamma c < 1.7x10^{-3}$

Monte Carlo Production of FCNC Signal Samples

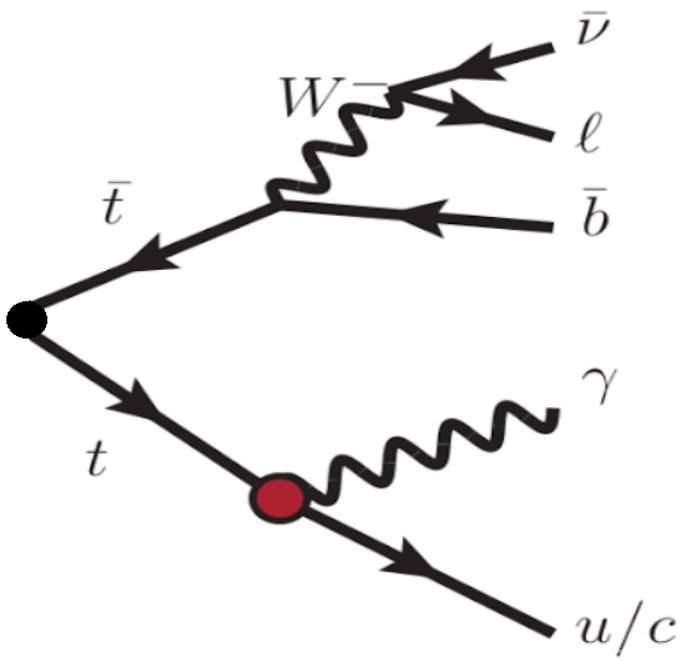
- Due to the low cross sections we must create our own Monte Carlo Samples for our Signal
- An effective field theory approach was taken in the creation of the model
- This model takes advantage of dimension-6 operators

$$\mathcal{L}_{SM} = \mathcal{L}_{SM}^{(4)} + \mathcal{L}^{eff} \text{ where } \mathcal{L}^{eff} = \frac{1}{\Lambda^2}\sum_k C_k^{(6)} Q_k^{(6)}$$

$$\mathcal{L}_{tq\gamma}^{eff} = C\sigma^{\mu\nu} q_\nu (\lambda_{ct}^L P_L + \lambda_{ct}^R P_R) t A_\mu + H.c.$$

FCNC: What are we looking for? $t\bar{t} \rightarrow W(\rightarrow l\nu)b + q\gamma$

- Final state topology
  - One Neutrino, from W
  - One Lepton, from W
  - One B-jet, SM top
  - One Photon, FCNC Top
  - One Jet, FCNC Top



Object Preselection

- We preselect events with objects that look like our expected topology
- Require:
  - Exactly one lepton (e or μ) $\geq$ 25 GeV
  - Exactly one Good photon $\geq$ 25GeV
  - Missing Transverse Energy $\geq$ 30GeV
  - $\geq$ 2 Jets (at least one being b-tagged)
- All following plots will have signal scaled to 1% of $\sigma_{t\bar{t}}$, MC scaled to $36.07 fb^{-1}$