Detector Resolution Studies

ALCWS 2018

Jason Barkeloo

J. Brau, A. Steinhebel, E. Meyer, J. Carlson

June 1, 2018

Table of Contents

Top Quark Decays

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

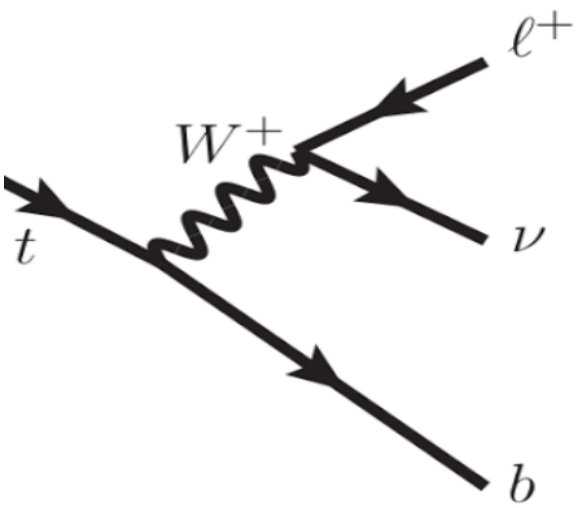


Figure: Leptonic final state diagram for a top decay

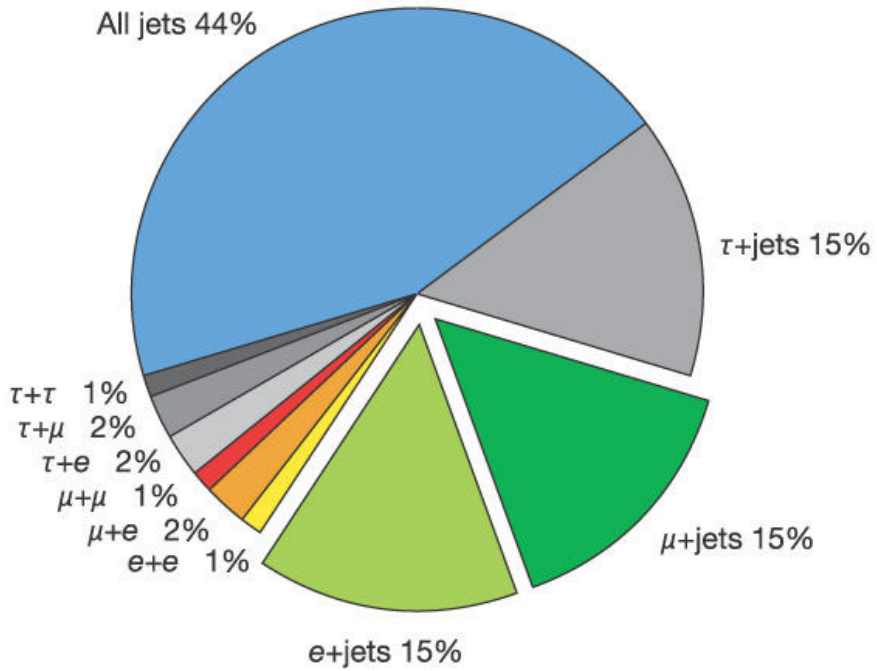
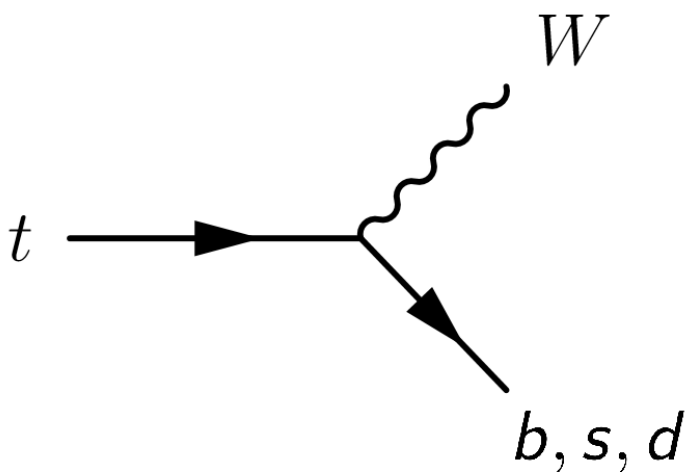
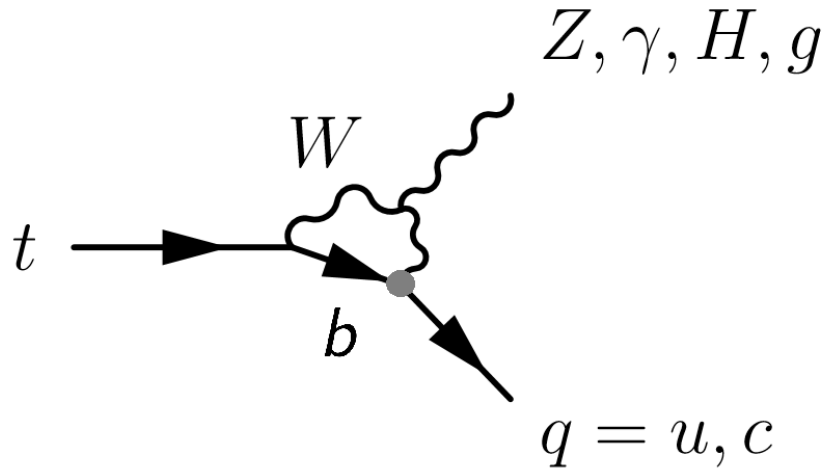


Figure: Top quark pair decay final states [Nature]

Top Quark Decays in the SM



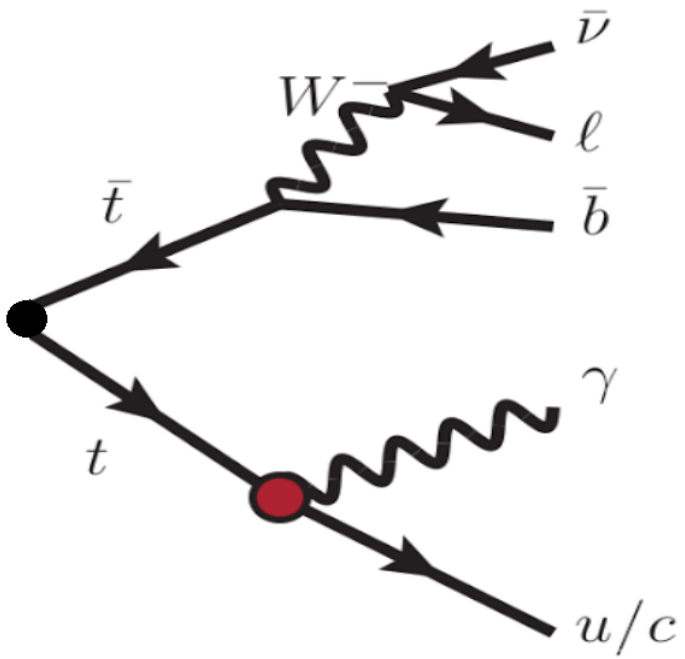


- $t \to bW \approx 99.83\%$
- $t \to sW \approx 0.16\%$
- $t \to dW \approx 0.01\%$

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

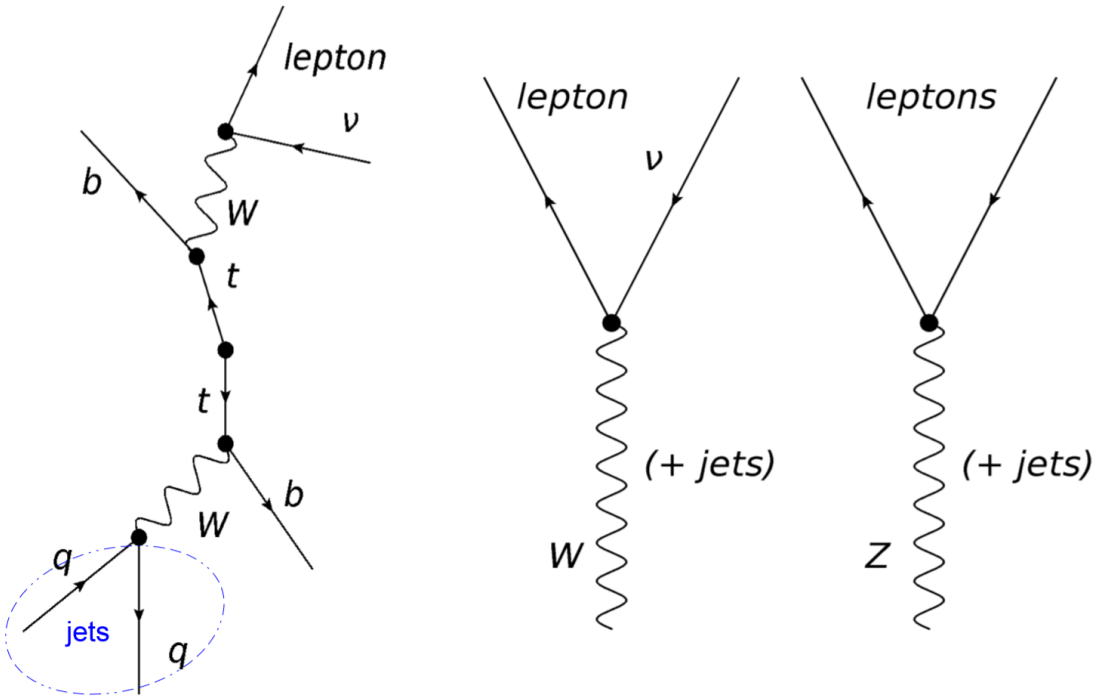
FCNC: What are we looking for? $t\bar{t} \rightarrow W(\rightarrow l\nu)b + q\gamma$

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



Background Processes

- Due to all of the processes at hadron colliders it is important to model similar event topologies well.
- Major backgrounds include $t\bar{t}$, W+Jets, Z+Jets, + processes with an associated photon



Monte Carlo Generation

- All of our MC data is put through a showering algorithm for propagation from final decay states
- Various showering algorithms are used at ATLAS - Pythia, Herwigg, etc.
- All of these will add radiative photons
- These events can be contained in other samples with explicit photons originating from the hard interaction
- Need to remove these events or risk double counting events

Photon Overlap Removal

- Truth matching procedure is used to identify origin and type of truth particle corresponding to reconstructed photon
  - If reco photon is associated with a truth electron or within R=0.2 we can consider this $e \rightarrow \gamma$ fake
  - If origination from boson or lepton with a corresponding truth hadron: hadron fake
  - Otherwise the photon is considered coming from the hard interaction
  - The procedure rejects less than 1% of events in $t\bar{t} + \gamma$ and $V + \gamma$ samples (except $Z + \gamma$ in e+jets channel because of fake rates)

Photon Overlap Removal

- For $t\bar{t}$ and $V + jets$ samples, the prompt photon contribution is subject to large statistical uncertainty and its modelling is less trusted, it is why the $t\bar{t} + \gamma$ and $V + \gamma$ samples are used.
- For this to work phase spaces of events must be close to identical otherwise the overlap removal will take out too much

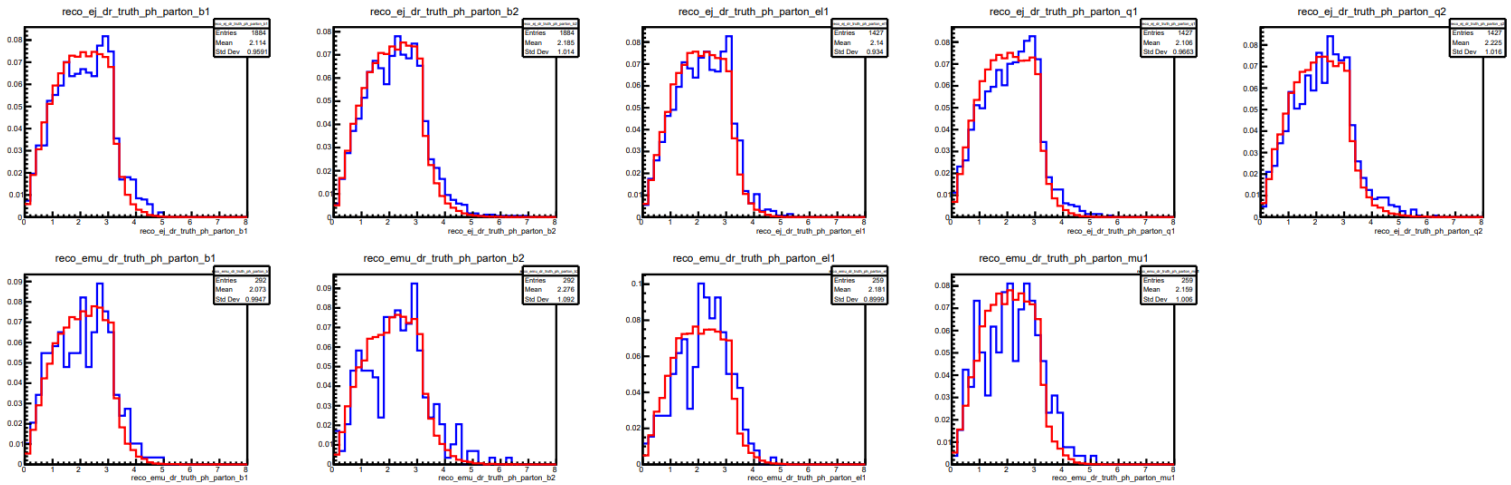


Figure: Overlaping Phase Space Regions of the photon and various objects [Y.Li] Red: $t\bar{t} + \gamma$ Blue: $t\bar{t}$

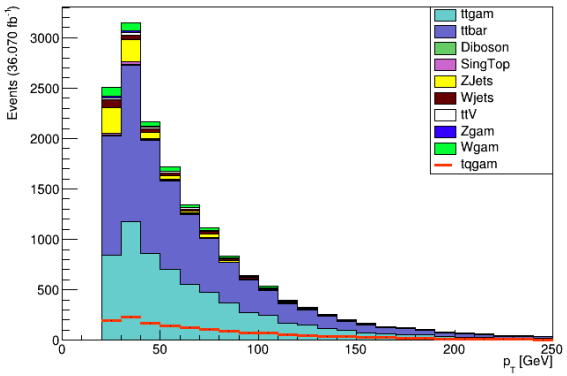
Object Preselection

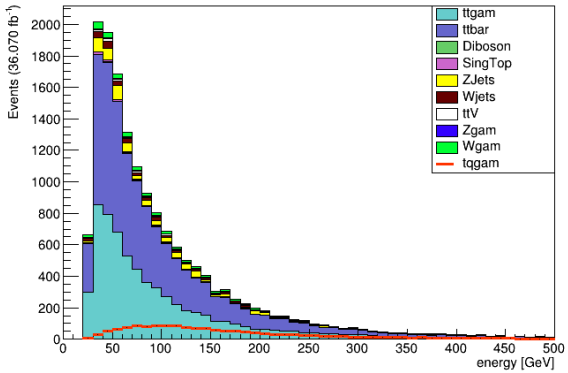
- We preselect events with objects that look like our expected topology
- Reminder that I require:
  - Exactly one lepton (e or μ) $\geq$ 28 GeV
  - Exactly one Good photon $\geq$ 25GeV
  - Missing Transverse Energy $\geq$ 30GeV
  - $\geq$ 2 Jets (at least one being b-tagged)
- All following plots will have signal scaled to 0.2% of nonallhadronic $\sigma_{t\bar{t}}$, MC scaled to $36.07 fb^{-1}$
- Only electron channel shown. Similar results for the muon channel are seen.

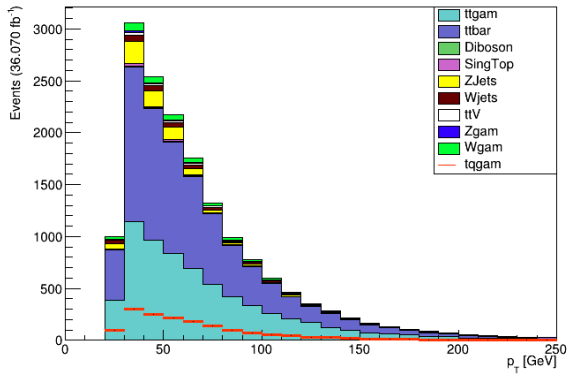
Preselection Objects

- Leading Jet p_T
- Photons
- Leptons

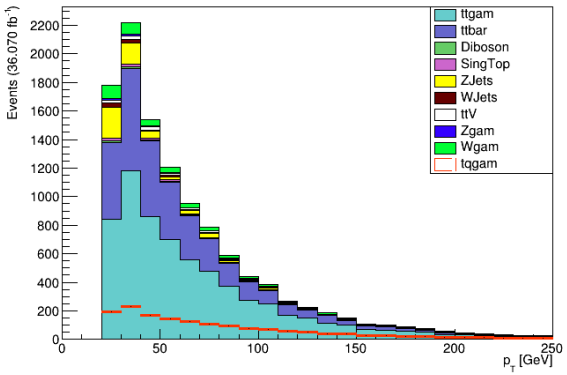
No OVR

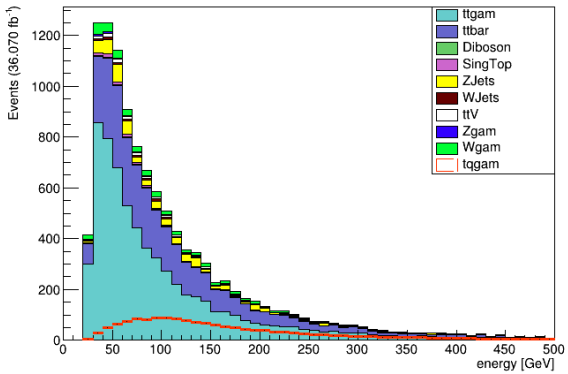


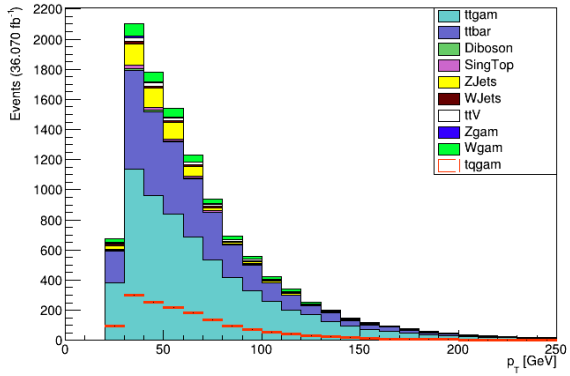




W/OVR







What does this mean?

- Previous presentations have dramatically overcounted $t\bar{t}$ events
- $40 - 50\%$ of the events in $t\bar{t}$ and $W + jets$ base samples are removed with this procedure
- The inclusion could have hidden some potential differences in ways to remove one or the other background processes

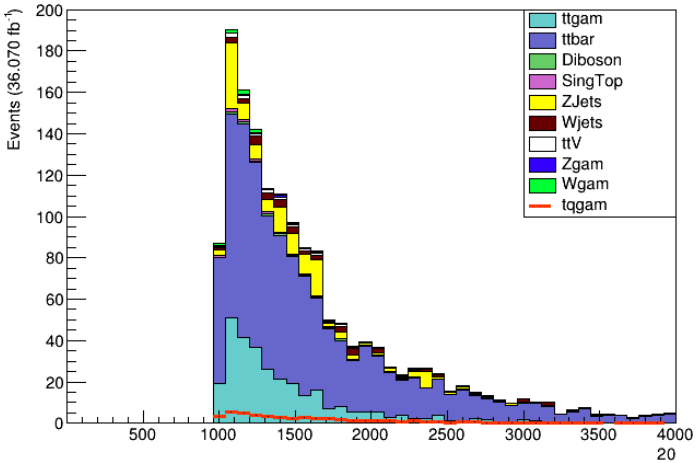


Figure: No OVR Photon ptcone20

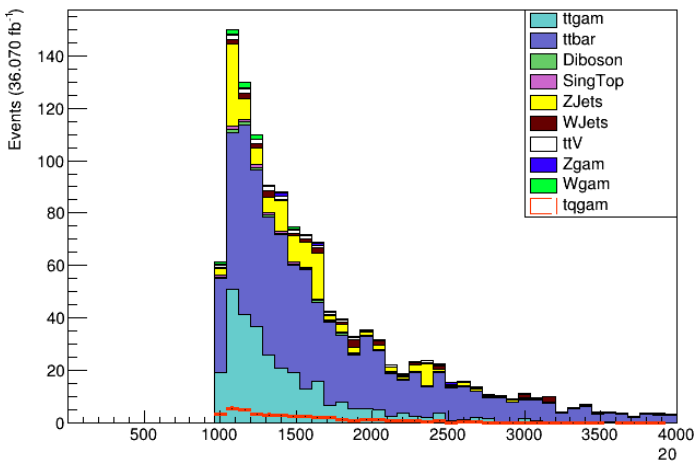
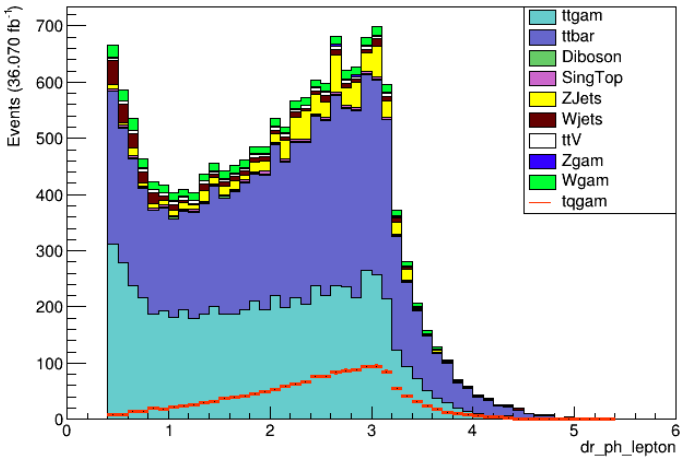


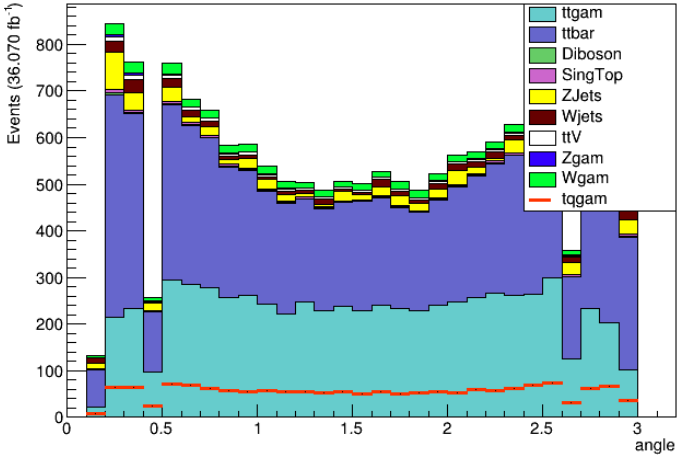
Figure: OVR Photon ptcone20

Other Variables

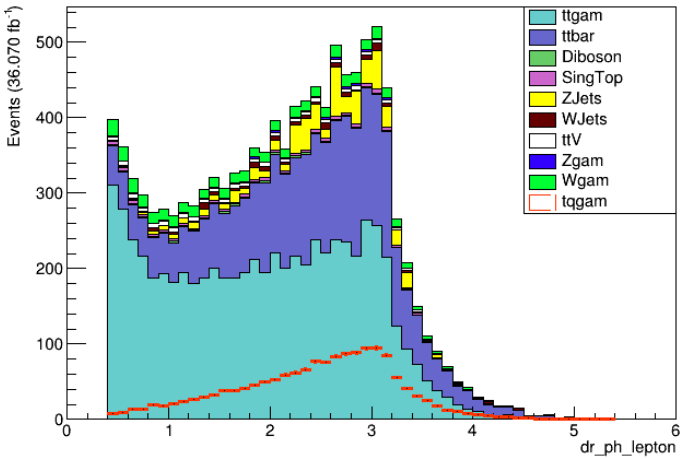
- $\Delta R_{\gamma l}$
- $\gamma\Theta$

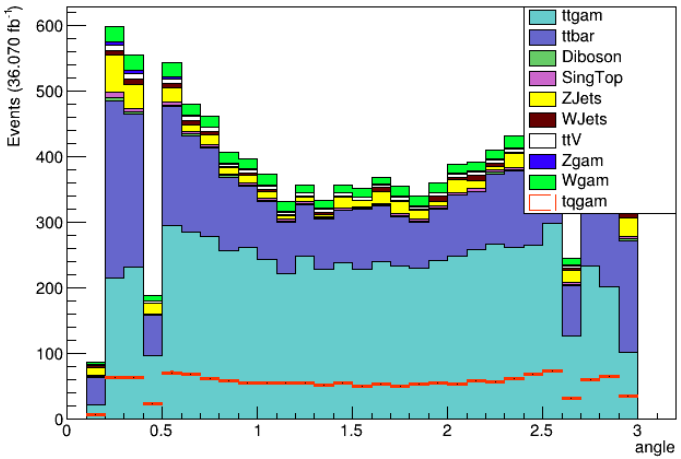
No OVR





W/OVR





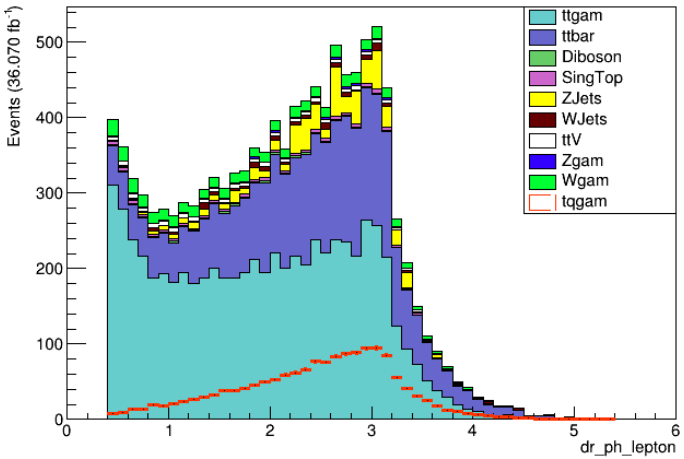
Signal Region

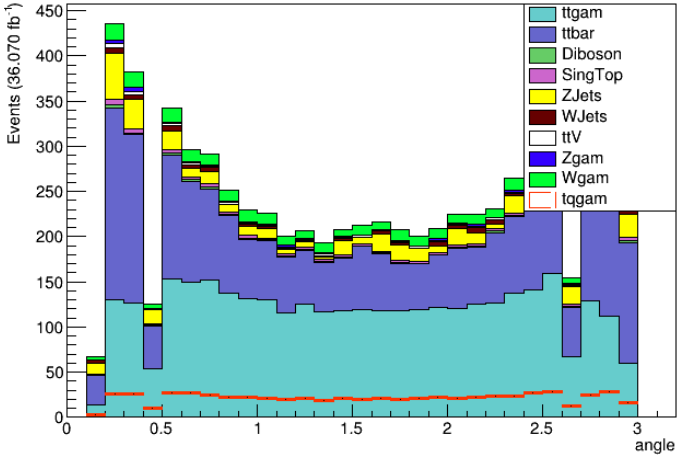
- Current Requirements:
  - Preselection Cuts
  - FCNC Top Mass: $m_{q\gamma}$ within 50GeV of m_t
  - SM Top Mass: $m_{bl\nu}$ within 50GeV of m_t
  - Z Mass: $m_{l\gamma} > 10 GeV$ from m_Z
  - Photon pt $> 50 GeV$
  - ==1 Bjet

Some SR Variables

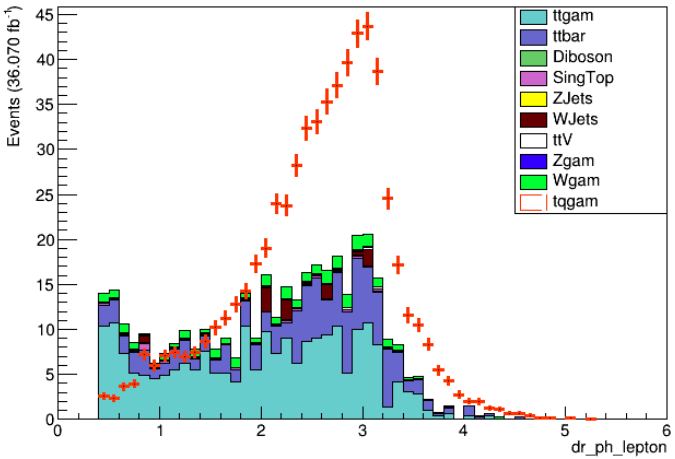
- $\Delta R_{l\gamma}$
- $\gamma\Theta$

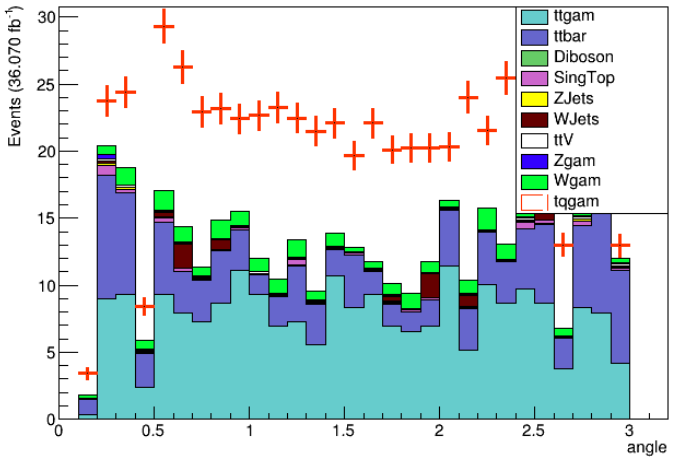
PreSelection





SR Cuts

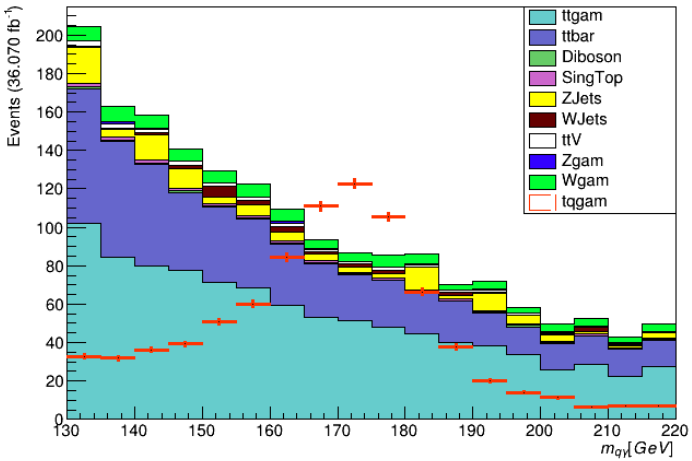


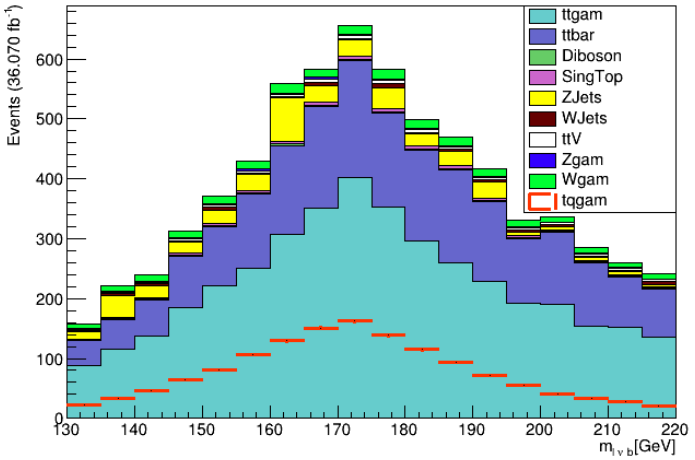


Some More SR Variables

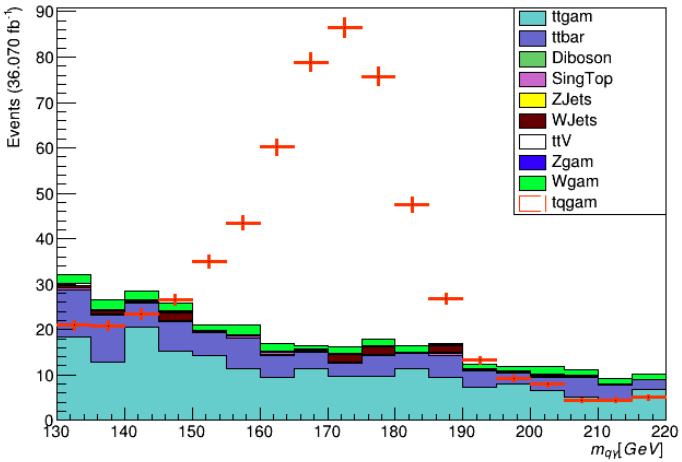
- $m_{q\gamma}$
- $m_{bl\nu}$

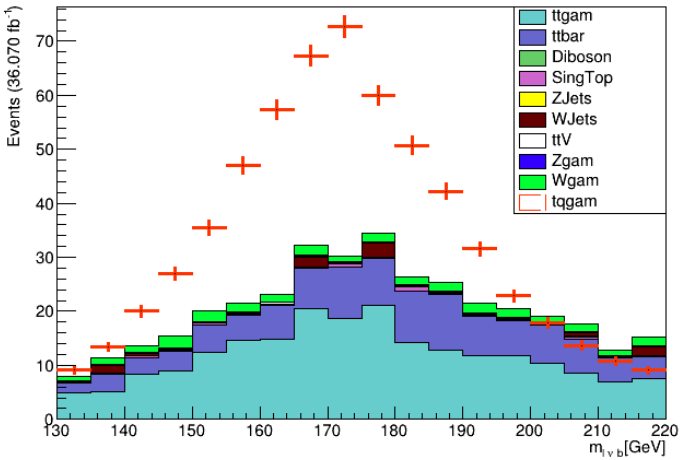
PreSelection





SR Cuts





$t\bar{t} + \gamma$ rich region

- Preselection Cuts
- FCNC Top Mass - Orthogonal to SR
- ≥ 4 Jets

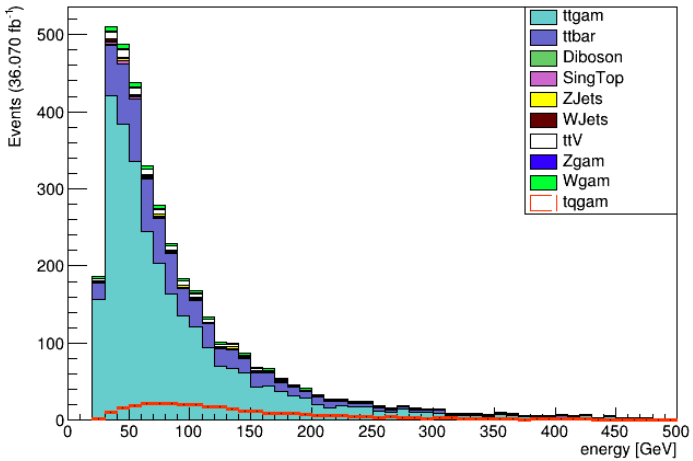


Figure: γ_e

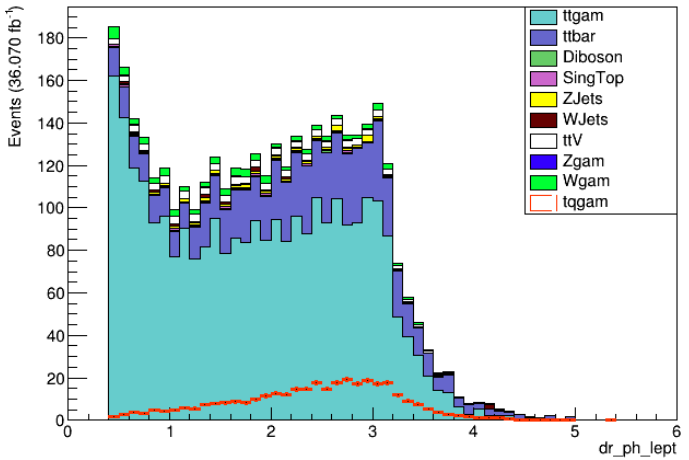


Figure: $\Delta R_{l\gamma}$

Other Regions

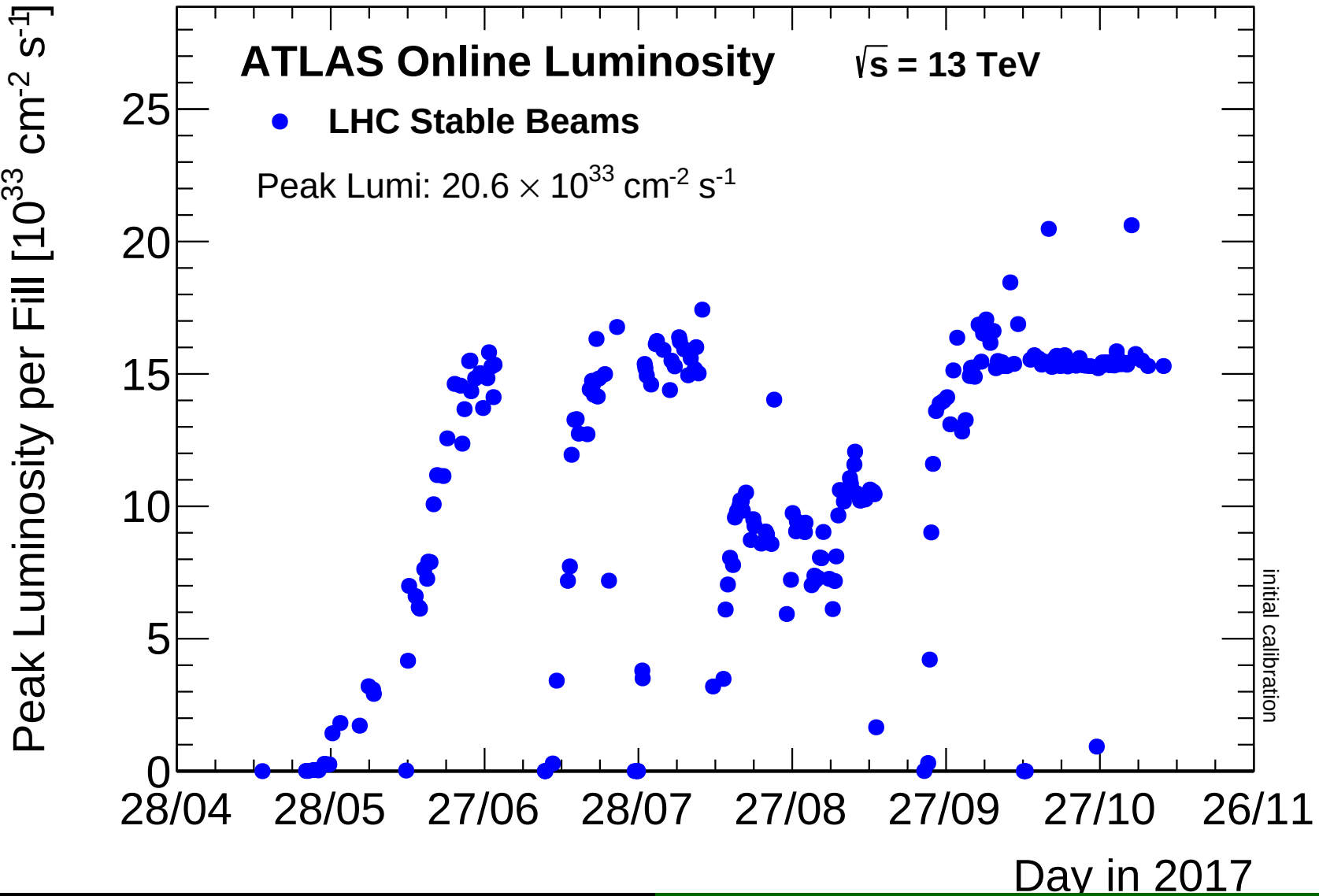
- Developing more region to test the performance of MC samples
- Regions are designed to isolate various physics processes using orthogonal selections
- $t\bar{t}(+\gamma)$ is of utmost important to model extremely well, especially with the increase in cross section at 13TeV

Conclusion, Outlook

- Orthogonal validation/control regions are in development
- Data grid run complete, need to incorporate into CR/VR plots
- Next grid run will include a couple of looser regions for CR/VRs
  - 0 Photon Samples for Backgrounds with no Real Photons
  - 0 BJet Samples - possibly for WJets region
- Top Group - Pushing for MVA, want to start investigations using these techniques

Backup

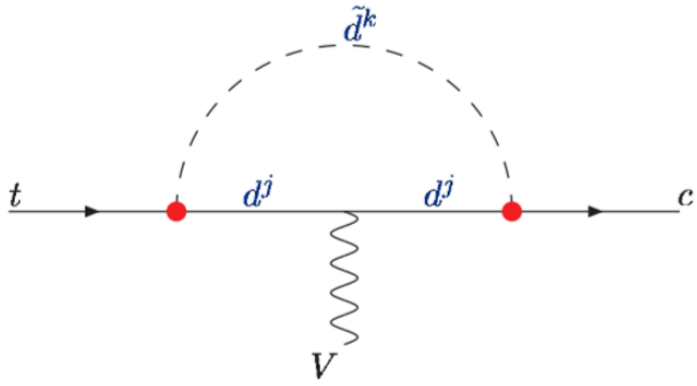
Integrated Luminosity



A Couple BSM Diagrams

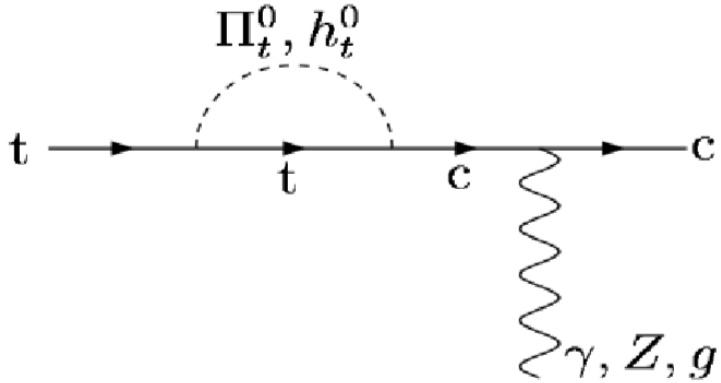
- R-parity-violating supersymmetric models

  [arXiv:hep-ph/9705341]



- Top-color-assisted technicolor models

  [arXiv:hep-ph/0303122]



Jets/AntiKT

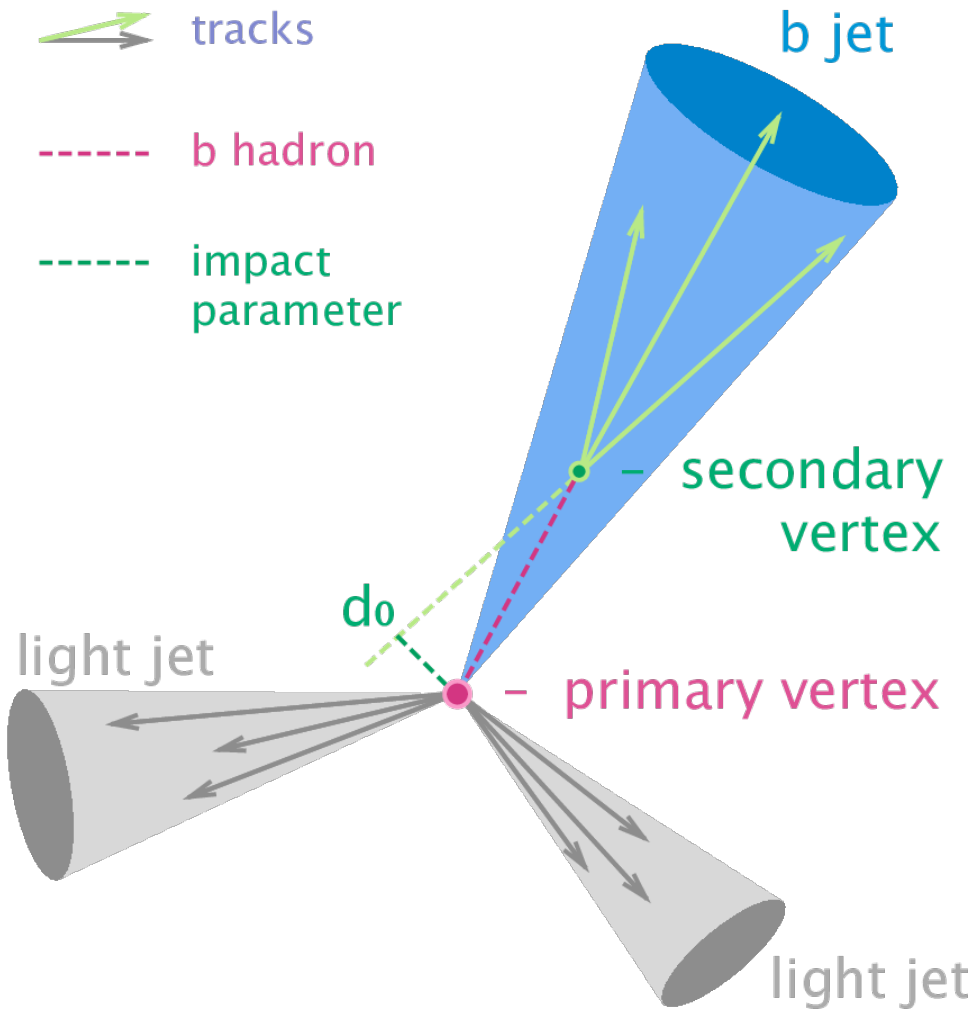
$$d_{ij} = min(\frac{1}{p_{ti}^2}, \frac{1}{p_{tj}^2})\frac{\Delta_{ij}^2}{R^2}$$

$$d_{iB} = \frac{1}{p_{ti}^2}$$

$$\Delta_{ij}^2 = (\eta_i - \eta_j)^2 + (\phi_i - \phi_j)^2$$

- Find minimum of entire set of $\{d_{ij}, d_{iB}\}$
- If d_{ij} is the minimum particles i,j are combined into one particle and removed from the list of particles
- If d_{iB} is the minimum i is labelled as a final jet and removed from the list of particles
- Repeat until all particles are part of a jet with distance between jet axes Δ_{ij} is greater than R

B-tagging


tracks
b hadron
impact parameter
b jet
secondary vertex
d0
light jet
primary vertex
light jet

$$\mathcal{L}^{eff}_{tq\gamma} = -e\bar{c}\frac{i\sigma^{\mu\nu}q_\nu}{m_t}(\lambda^L_{ct}P_L + \lambda^R_{ct}P_R)tA_\mu + H.c.$$