Search for Flavor Changing Neutral Currents in Top Quark Decays

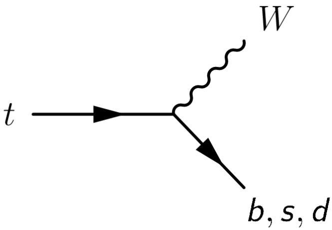
Fake Rates and Initial Asimov Fits

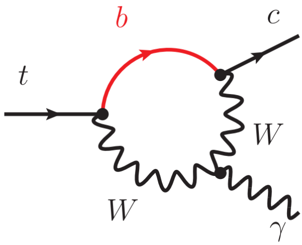
Jason Barkeloo

February 20, 2020

Overview

Top Quark Decays in the SM





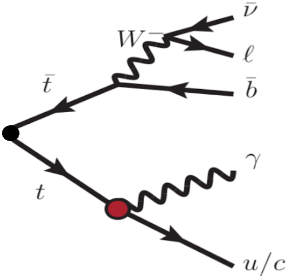
- $t \to bW \approx 99.83\%$
- $t \to sW \approx 0.16\%$
- $t \to dW \approx 0.01\%$

- $t \to q_{u,c}X \approx 10^{-17} - 10^{-12}$
- Limits on $t \to \gamma q$ processes: [Phys.Lett. B800 135082]
  - $t \to \gamma u < 2.8x10^{-5}$
  - $t \to \gamma c < 18x10^{-5}$

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

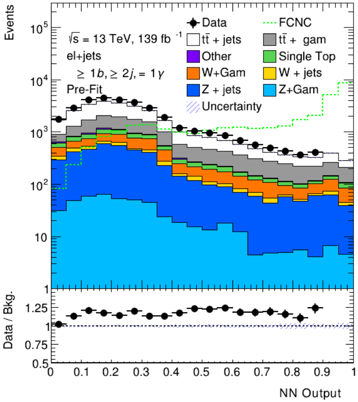
Will further investigate BJets here.

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

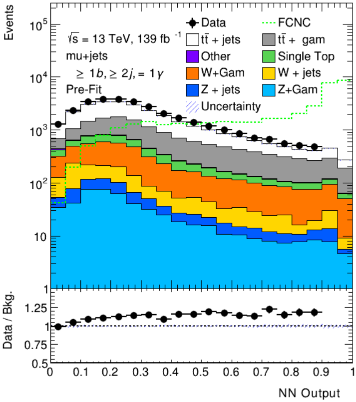


Preselection NN Outputs

- e+jets



- μ+jets



Fake Rate Object Selection

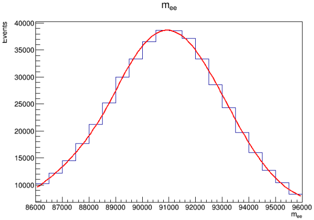
- Want to calculate fake rate in events which could enter the signal region.
- Create 2 control regions: $Z \rightarrow ee$ and $Z \rightarrow e\gamma$
- Require:
  - Common Object Selection (MET,Jets,Triggers, etc.)
  - Exactly 1Bjet
  - $Z \rightarrow ee$: 2 Opposite Sign Electrons, 86.1 GeV $< m_{e^+e^-} <$96.1 GeV
  - $Z \rightarrow e\gamma$:1 Electron, $\geq$1 Photon, 86.1 GeV $< m_{e\gamma} <$96.1 GeV
- Tag and Probe Method used
- Systematic determined by varying tail size and other parameters

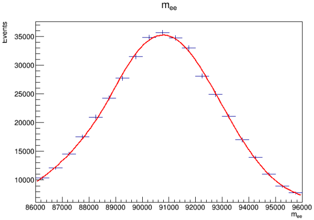
m_{ee}, $m_{e\gamma}$

Data and MC

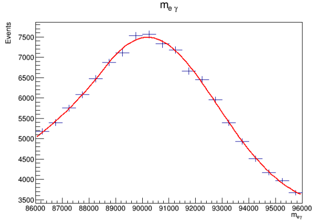
- Data
- Monte Carlo

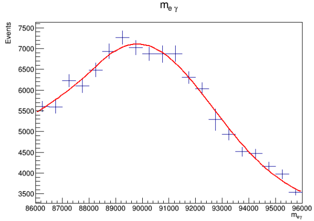
m_{ee}





$m_{e\gamma}$





Scale Factor

$$\mathrm{FR}^{\text{e-fake}} = \frac{N_{e,\gamma}}{N_{e,e}}$$

$$\mathrm{SF}_{\mathrm{FR}}^{\text{e-fake}} = \frac{\mathrm{FR}_{\text{data}}^{\text{e-fake}}}{\mathrm{FR}_{\text{MC}}^{\text{e-fake}}}$$

Basic Scale Factor can be calculated for the entire spectrum:
$\mathrm{SF}_{\mathrm{FR}}^{\text{e-fake}} = 0.97 \pm 0.01$
In practice this scale factor is calculated for converted and unconverted photons as well as in bins of η and ϕ

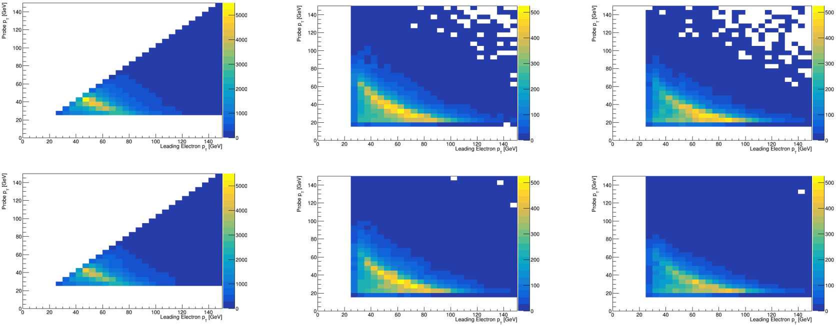
- Converted photons pair produce before the ECAL leaving tracks in the Inner Detector
- Unconverted photons only pair produce inside of the ECAL

Data and MC Distributions

- Probe e
- Converted γ
- Unconverted γ

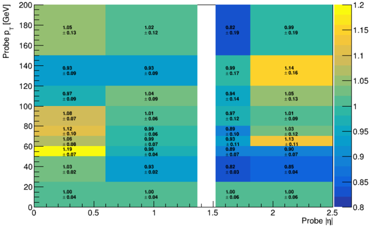
Data

MC

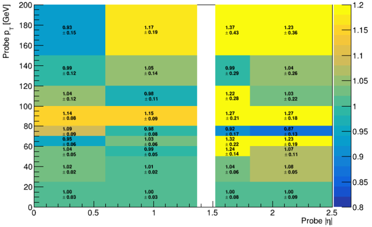


2D Fake Rates

- Converted γ

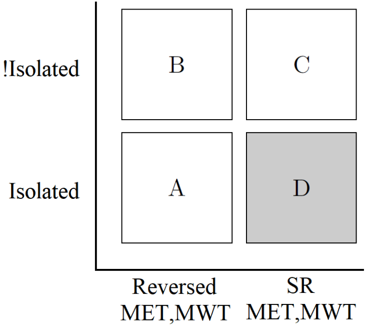


- Unconverted γ



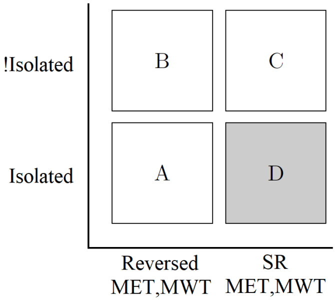
$j \to \gamma$ Fake Rate Studies

Majority of hadronic fake photons are from $t\bar{t}$ events where a final state jet radiates a non-prompt photon. Similarly radiated photons for W+jets and single top processes can enter the signal region through the radiation of a non-prompt photon.



ABCD Method

$$\frac{N_D^{\text{h-fake}}}{N_C^{\text{h-fake}}} = \frac{N_A^{\text{h-fake}}}{N_B^{\text{h-fake}}} \text{ and } \frac{N_D^{\text{h-fake}}}{N_A^{\text{h-fake}}} = \frac{N_C^{\text{h-fake}}}{N_B^{\text{h-fake}}}$$



Want uncorrelated variables, use a correction factor to account to ensure closure

$$\theta_{\text{MC}} = \frac{N_{\text{D,MC}}^{\text{h-fake}} / N_{\text{C,MC}}^{\text{h-fake}}}{N_{\text{A,MC}}^{\text{h-fake}} / N_{\text{B,MC}}^{\text{h-fake}}}$$

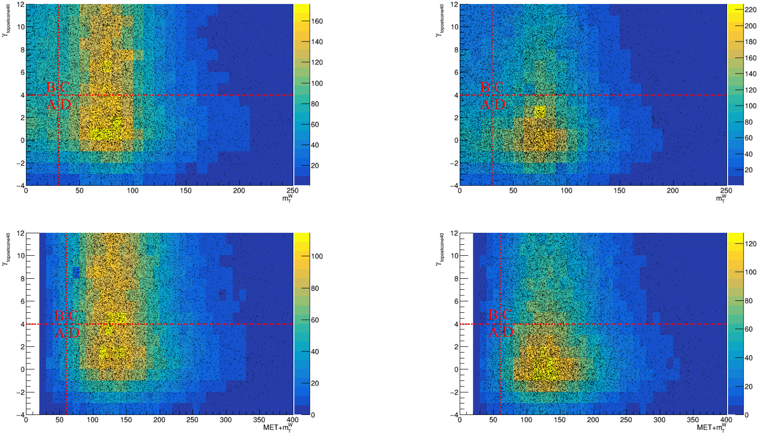
$$N_{\text{D,est.}}^{\text{h-fake}} = \frac{N_{\text{A,data}}^{\text{h-fake}} \times N_{\text{C,data}}^{\text{h-fake}}}{N_{\text{B,data}}^{\text{h-fake}}} \times \theta_{\text{MC}}$$

$$\text{SF}^{\text{h-fake}} = \frac{N_{\text{D,est.}}^{\text{h-fake}}}{N_{\text{D,MC}}^{\text{h-fake}}}$$

- Converted Photons
- Unconverted Photons

e channel

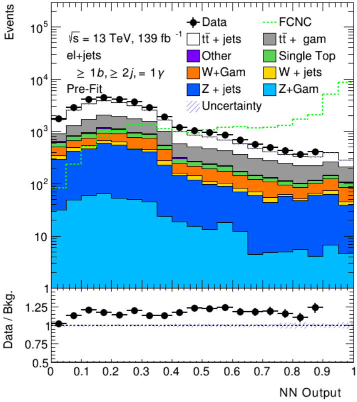
μ channel



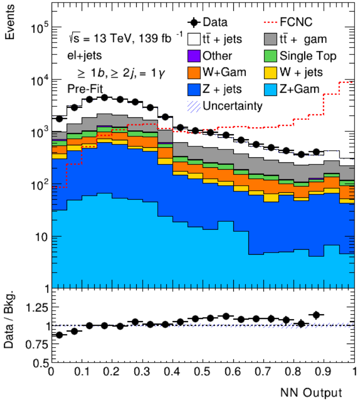
Channel:	Converted	Unconverted
Electron Channel	1.28 ± 0.34	1.99 ± 0.52
Muon Channel	1.23 ± 0.50	2.27 ± 0.92

Preselection NN Outputs

- Before Fake Rate SFs

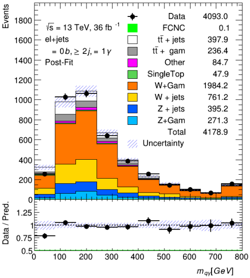


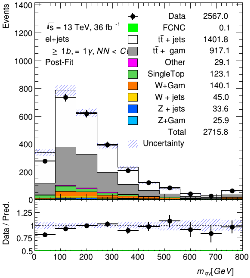
- With Fake Rate SFs

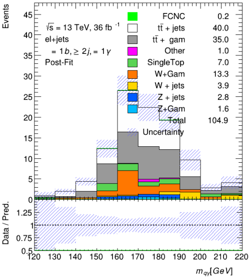


Asimov Data Post-Fit

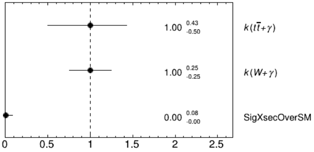
- VR1, W+γ
- VR2: $t\bar{t}+\gamma$
- Signal Region







Nominal signal strength $\mu = 1.0 \Rightarrow$ Branching Ratio $= 10^{-3}$



Statistical Limit from Asimov Fit

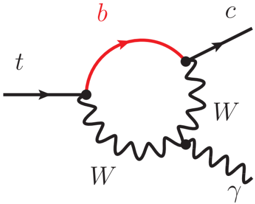
- Expected signal strength $\mu = 0.13^{+0.05}_{-0.04}$
- Corresponds to $\mathrm{BR}(t \rightarrow q\gamma) = 13 \times 10^{-5}$
- Extrapolation to full data set limit: $\mathrm{BR}(t \rightarrow q\gamma) \approx 4 \times 10^{-5}$

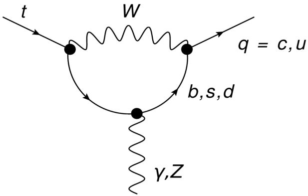
Outlook

- Fake rates calculated
- Full systematics samples almost done, one major sample being run locally
- Fitting machinery in place
- Internal note draft started, complete first draft expected by end of February
  - Will be hosted here: gitlab:fcnc-tqgam-decay-intnote
- New post-doc joining the project to help push toward publication either alone or in combination with production mode

Backup

FCNC Diagrams

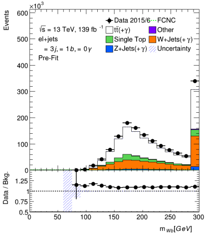


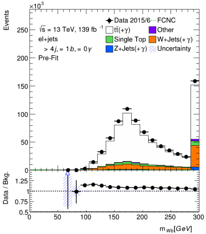


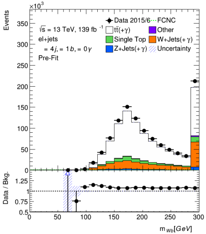
No Photon Scale Factors

- W+jets Rich
- $t\bar{t}$+jets Rich
- Validation Region

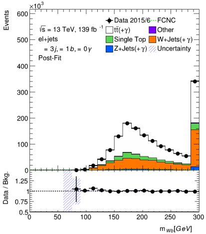
Before SF

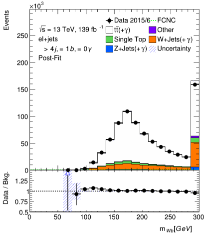


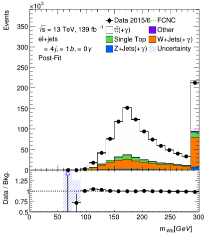




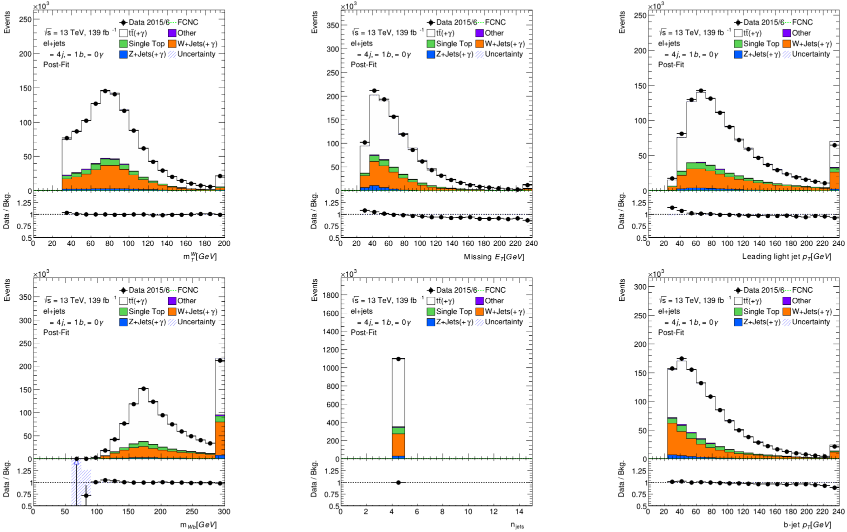
SF Applied





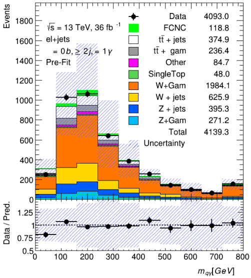


No Photon Region SF Applied in Val Region

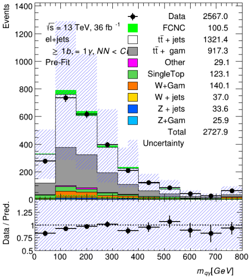


Asimov Data Pre-Fit

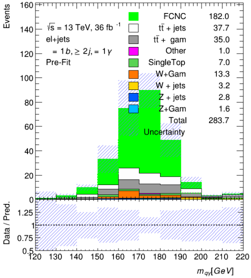
- VR1, W+γ



- VR2: $t\bar{t} + \gamma$



- Signal Region



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

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