Search for Flavor Changing Neutral Currents in Top Quark Decays

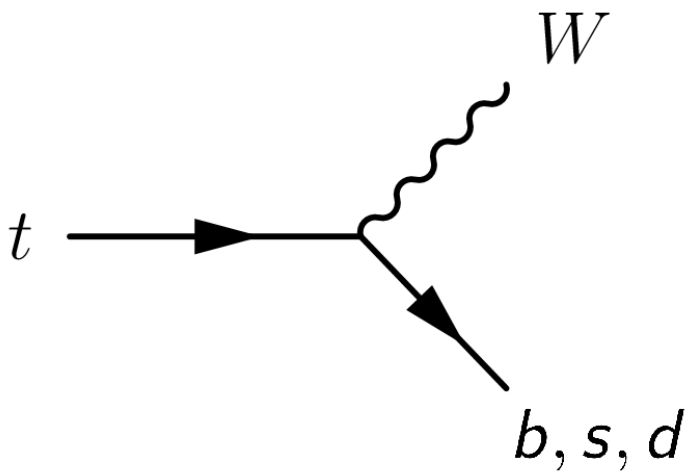
Fake Rates and Initial Asimov Fits

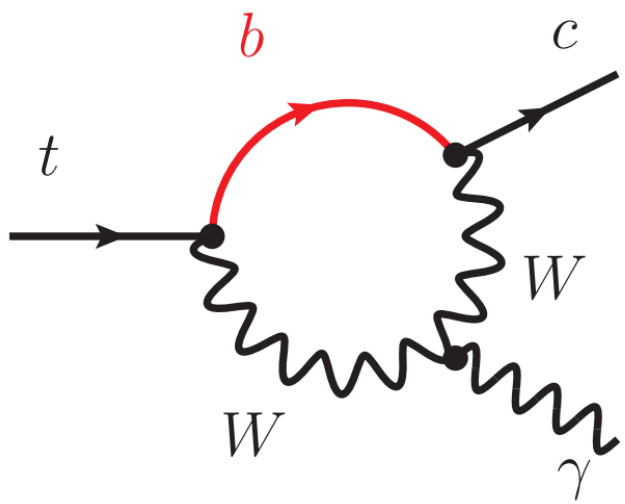
Jason Barkeloo

January 16, 2020

Overview

Top Quark Decays in the SM





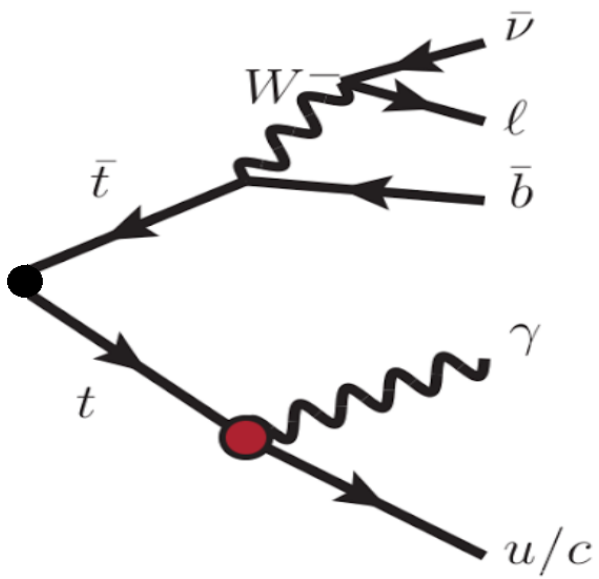
- $t \to bW \approx 99.83\%$
- $t \to sW \approx 0.16\%$
- $t \to dW \approx 0.01\%$

- $t \to q_{u,c}X \approx 10^{-17} - 10^{-12}$
- 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? $t\bar{t} \rightarrow W(\rightarrow l\nu)b + q\gamma$

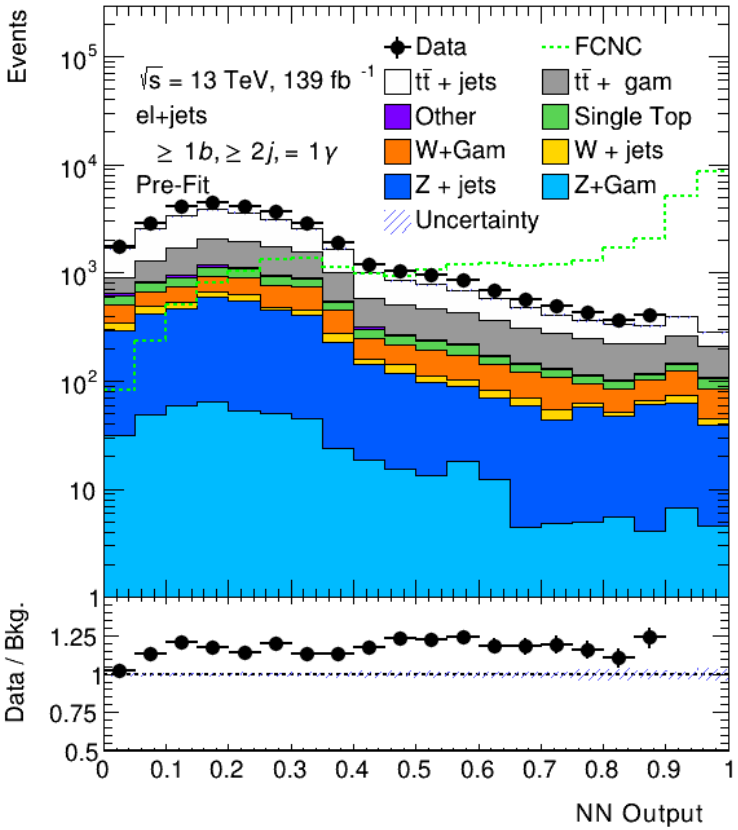
Will further investigate BJets here.

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

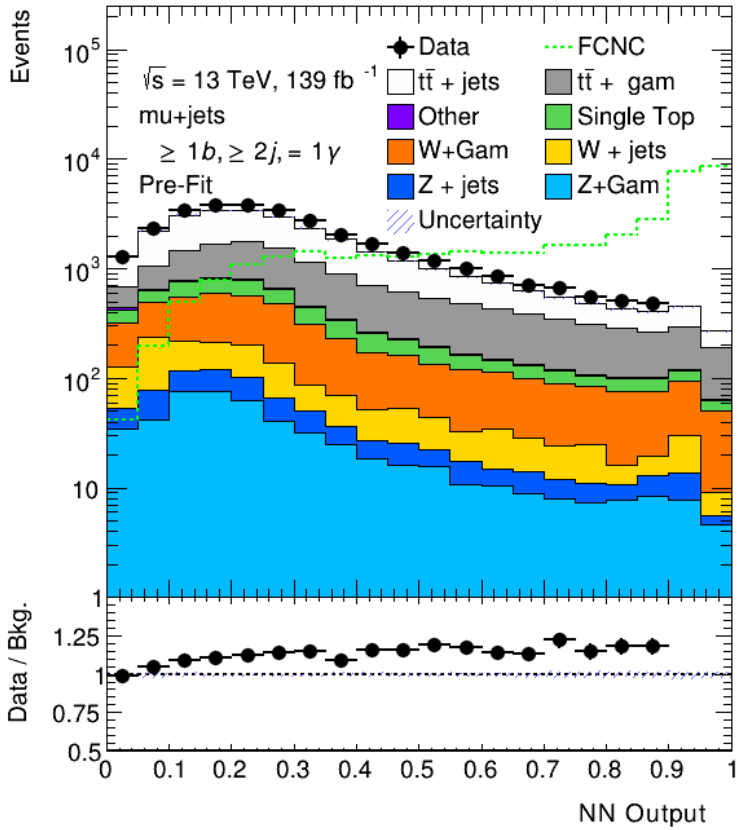


Preselection NN Outputs

- e+jets



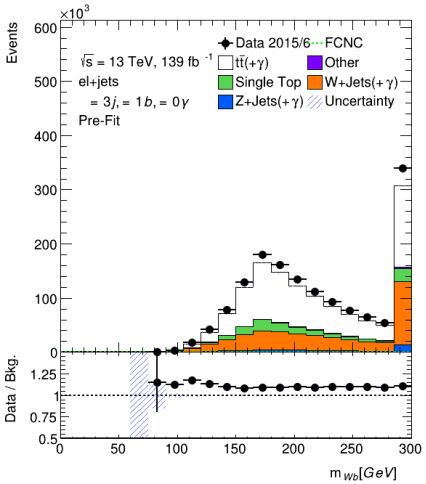
- μ+jets

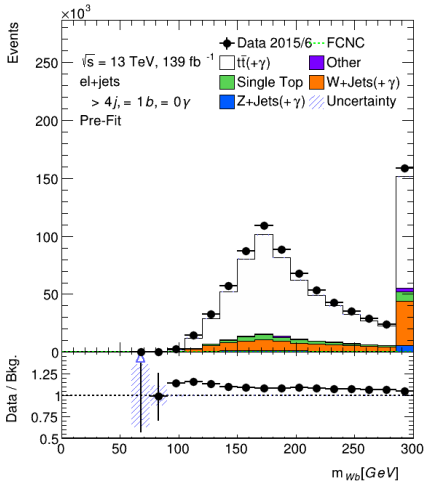


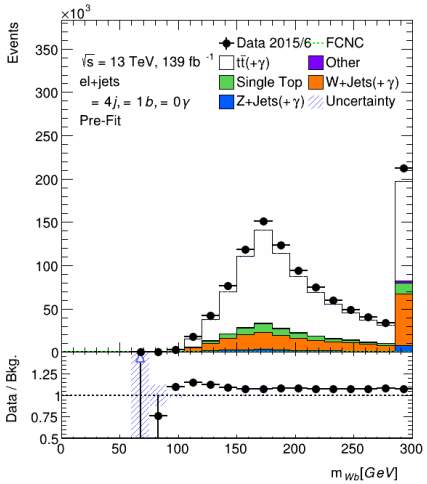
No Photon Scale Factors

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

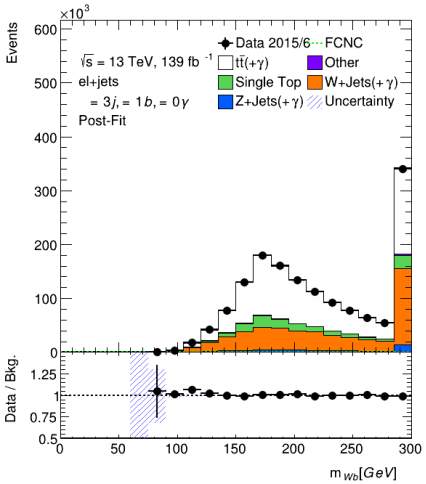
Before SF

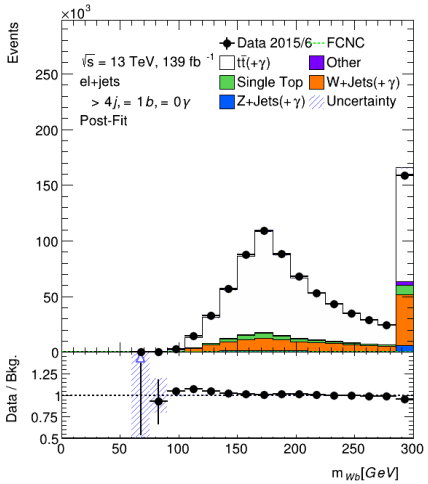


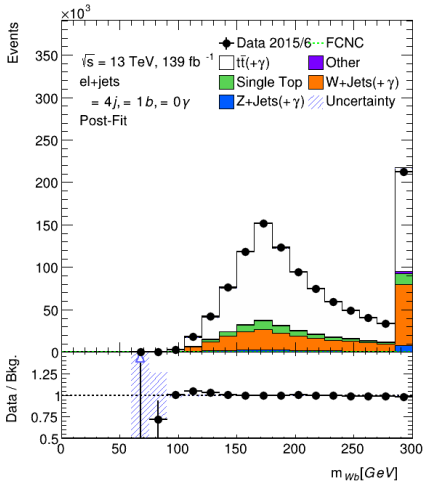




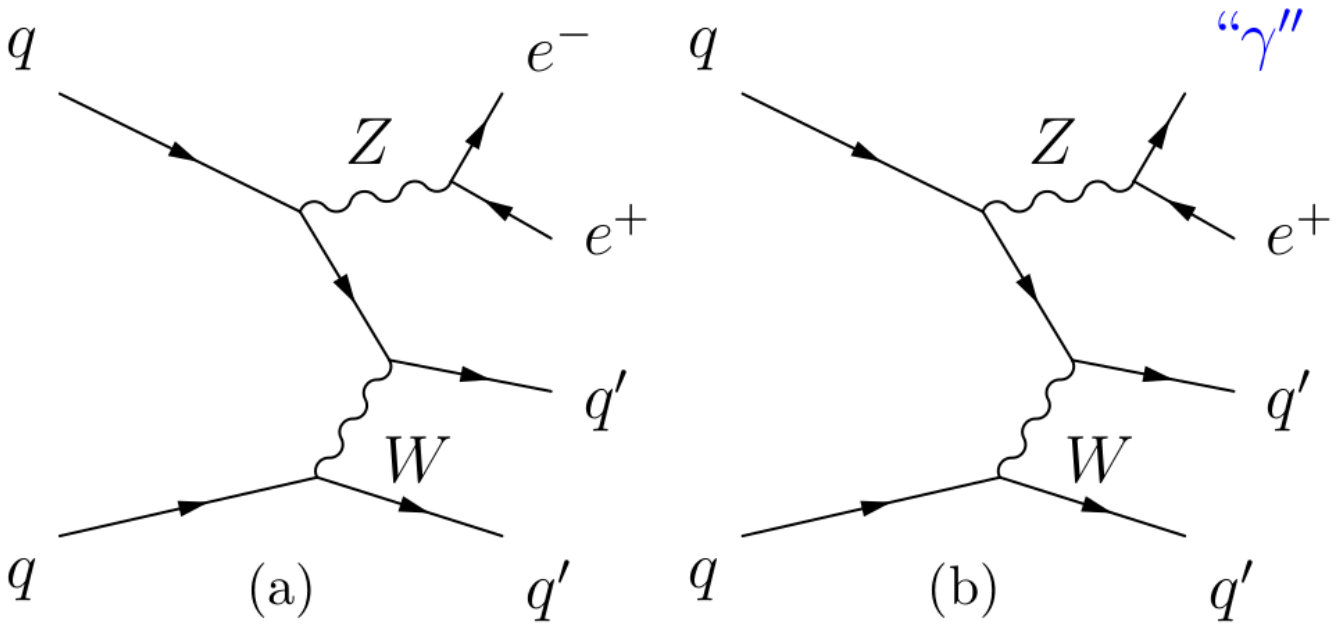
SF Applied







Fake Rate Studies



Want to be able to correct the number of fake photons predicted in MC to those present in Data

Fake Rate Object Selection

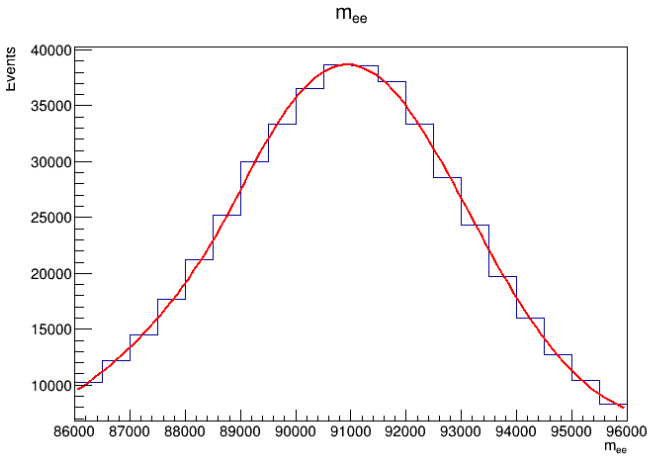
- Want to calculate fake rate in events which could enter the signal region.
- Create 2 control regions: $Z \rightarrow ee$ and $Z \rightarrow e\gamma$
- Require:
  - Common Object Selection (MET,Jets,Triggers, etc.)
  - Exactly 1Bjet
  - $Z \rightarrow ee$: 2 Opposite Sign Electrons, 86.1 GeV $< m_{e^+e^-} <$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

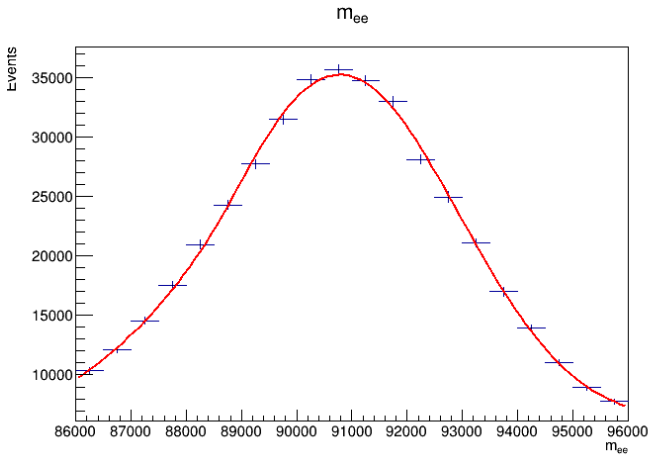
m_{ee}, $m_{e\gamma}$

Data and MC

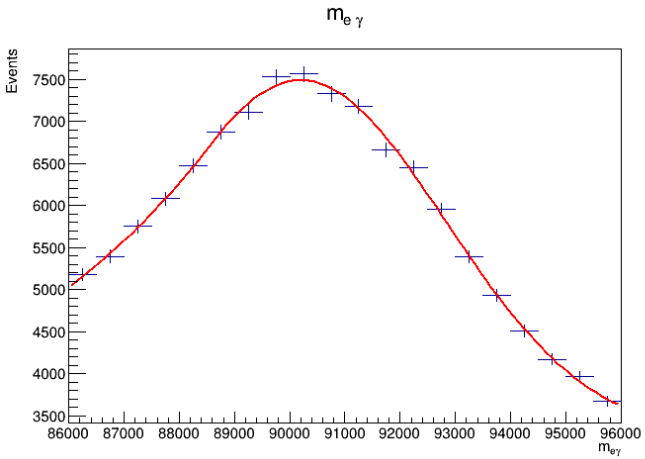
- Data
- Monte Carlo

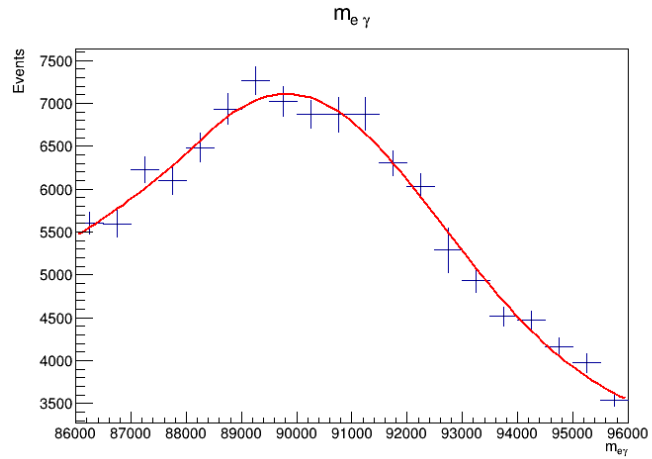
m_{ee}





$m_{e\gamma}$





Scale Factor

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

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

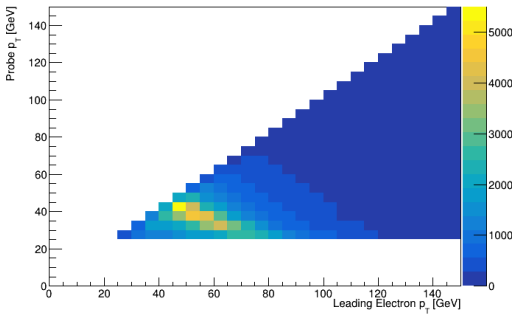
Basic Scale Factor can be calculated for the entire spectrum:
$\mathrm{SF}_{\mathrm{FR}}^{\text{e-fake}} = 0.97 \pm 0.01$
In practice this scale factor is calculated for converted and unconverted photons as well as in bins of η and ϕ

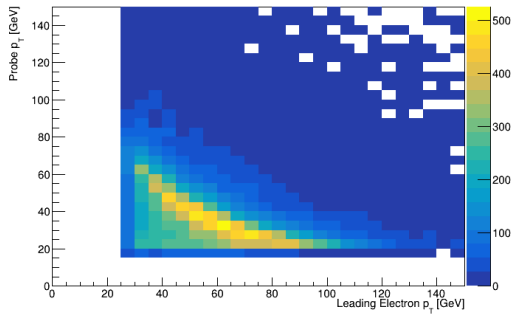
- Converted photons pair produce before the ECAL leaving tracks in the Inner Detector
- Unconverted photons only pair produce inside of the ECAL

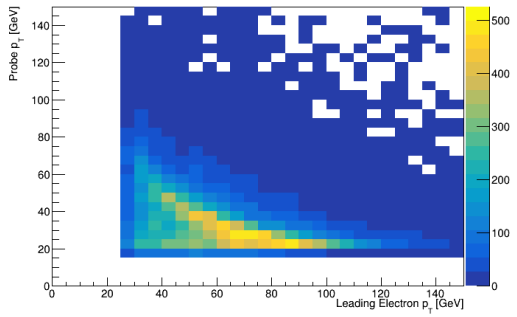
Data and MC Distributions

- Probe e
- Converted γ
- Unconverted γ

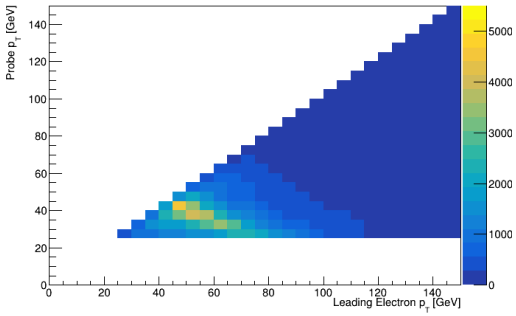
Data

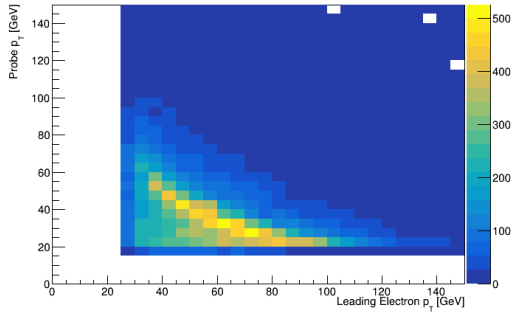


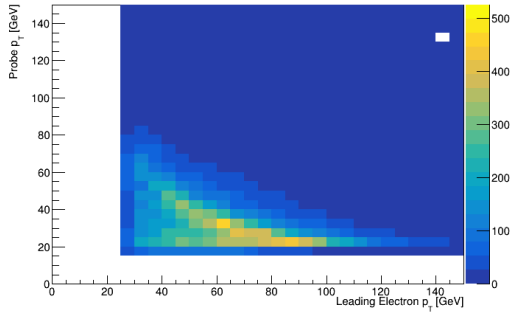




MC

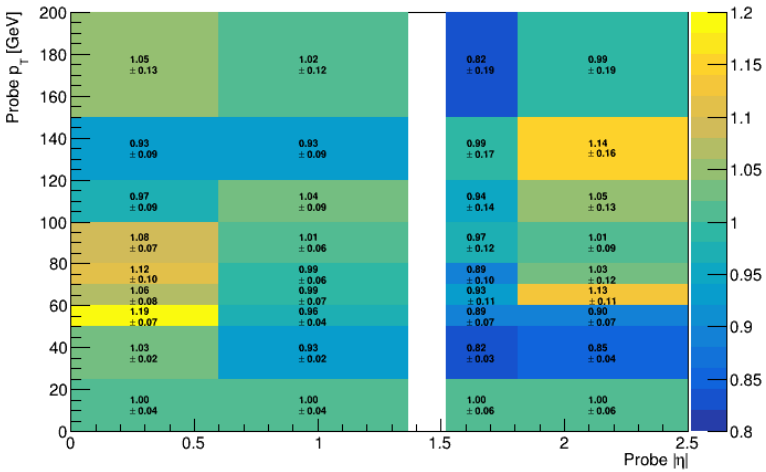




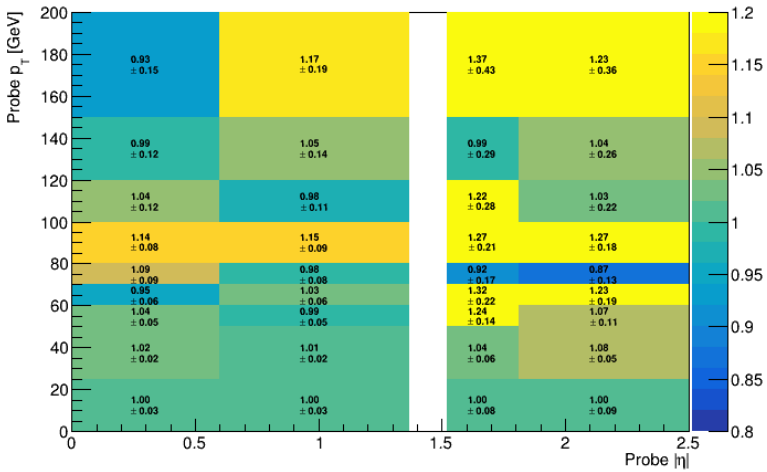


2D Fake Rates

- Converted γ

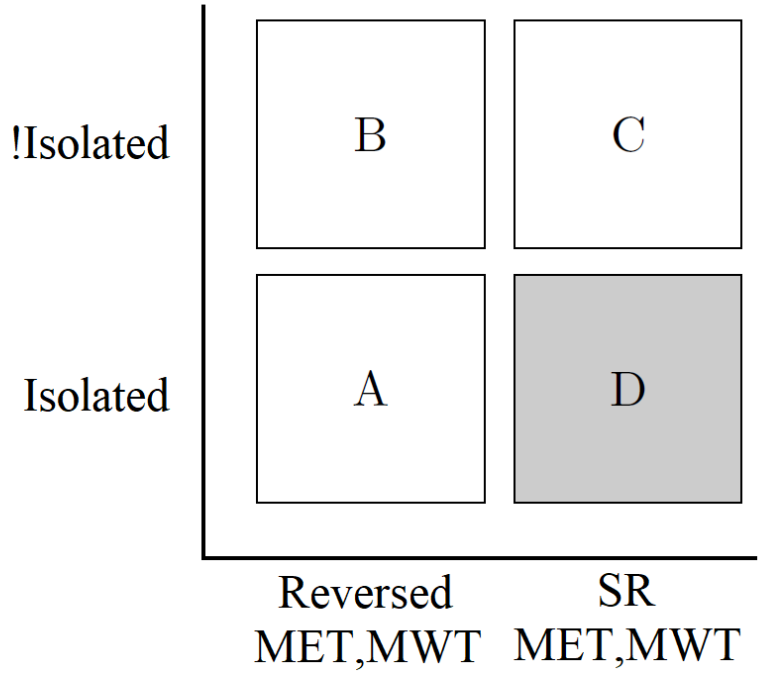


- Unconverted γ



$j \to \gamma$ Fake Rate Studies

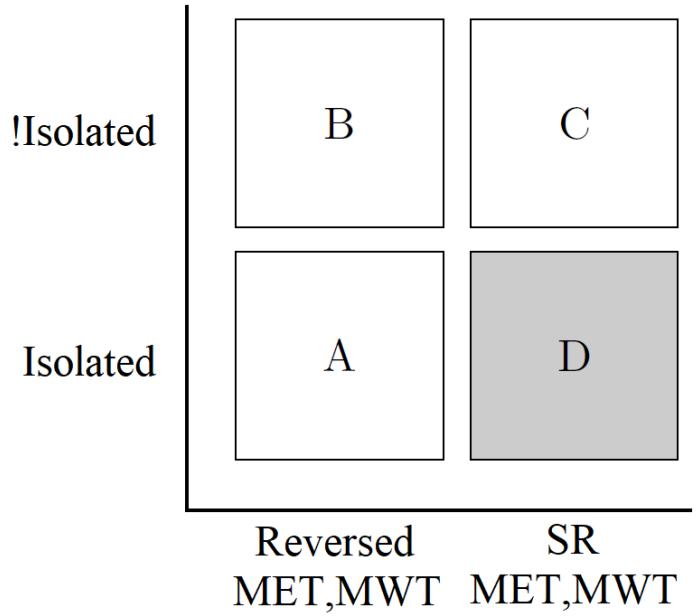
Majority of hadronic fake photons from from $t\bar{t}$ events where a final state jet radiates a non-prompt photon. Similarly radiated photons for W+jets and single top processes can enter the signal region through the radiation of a non-prompt photon.



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



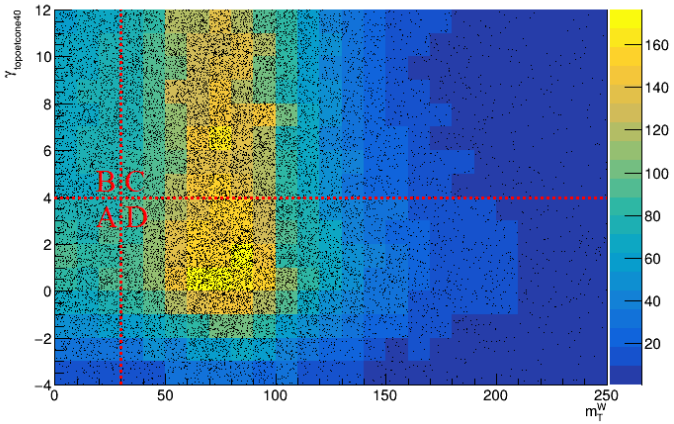
$$\theta_{\text{MC}} = \frac{N_{\text{D,MC}}^{\text{h-fake}} / N_{\text{C,MC}}^{\text{h-fake}}}{N_{\text{A,MC}}^{\text{h-fake}} / N_{\text{B,MC}}^{\text{h-fake}}}$$

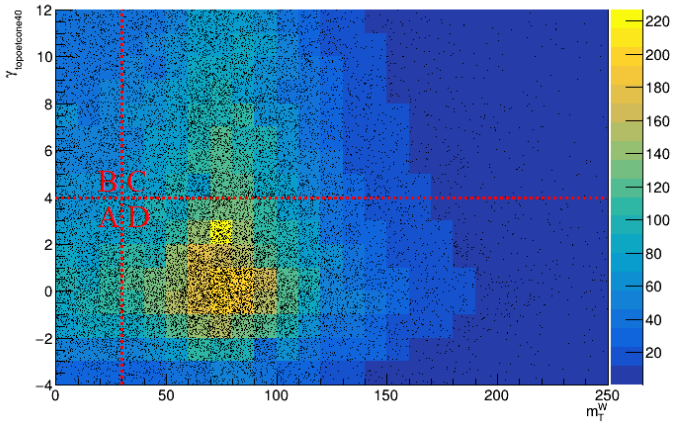
$$N_{\text{D,est.}}^{\text{h-fake}} = \frac{N_{\text{A,data}}^{\text{h-fake}} \times N_{\text{C,data}}^{\text{h-fake}}}{N_{\text{B,data}}^{\text{h-fake}}} \times \theta_{\text{MC}}$$

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

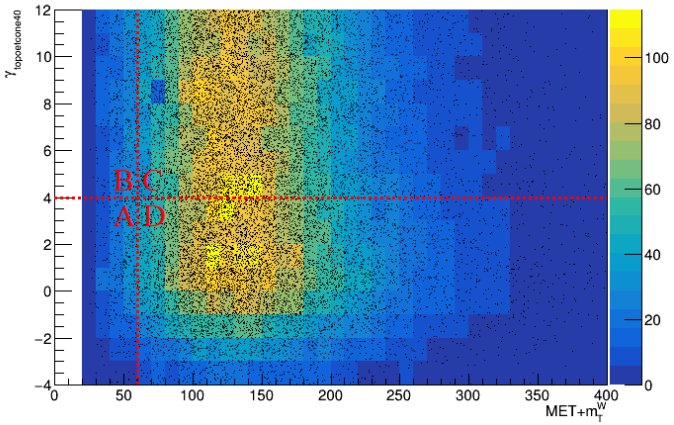
- Converted Photons
- Unconverted Photons

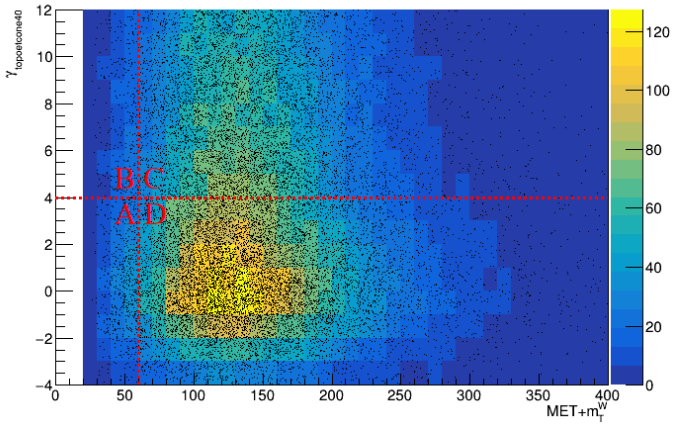
e channel





μ channel

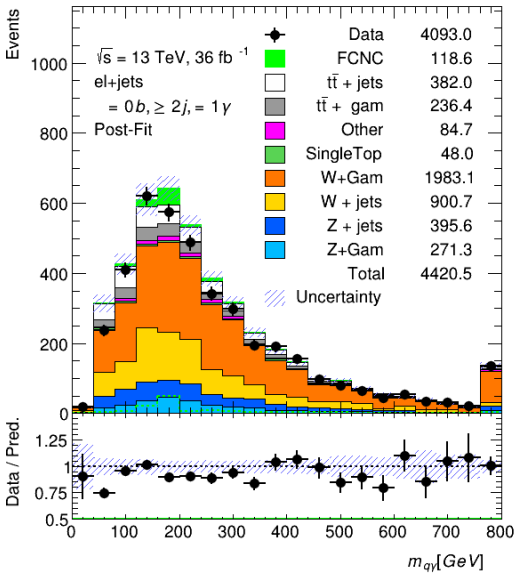


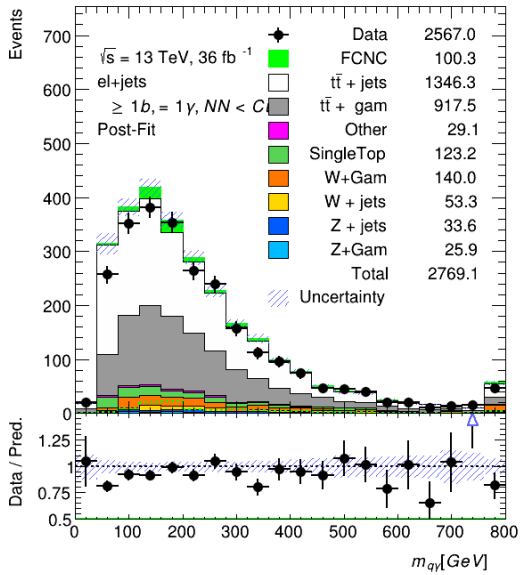


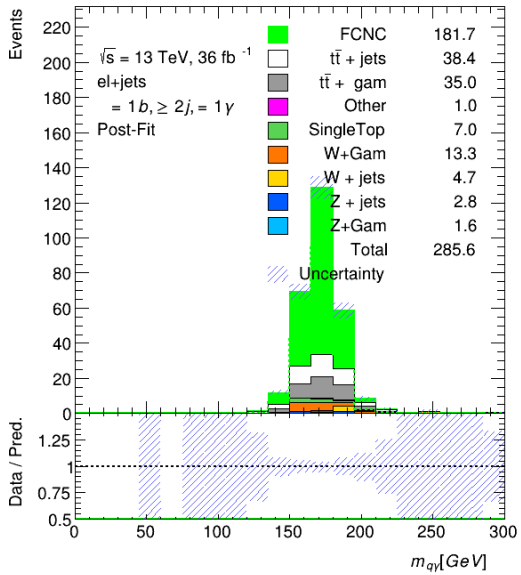
Channel:	Converted	Unconverted
Electron Channel	1.04 ± 0.14	2.27 ± 0.22
Muon Channel	1.64 ± 1.40	2.27 ± 0.41

Asimov Data Fit

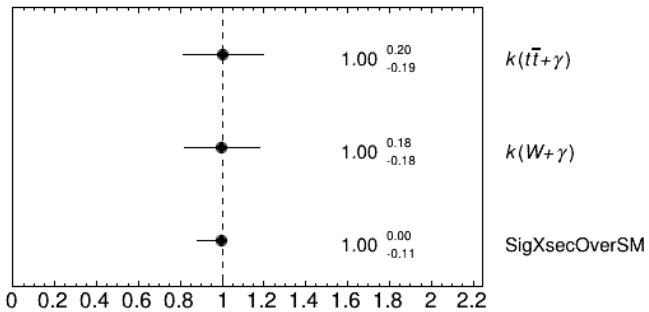
- VR1, W+γ
- VR2: $t\bar{t}+\gamma$
- Signal Region







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



Statistical Limit from Asimov Fit

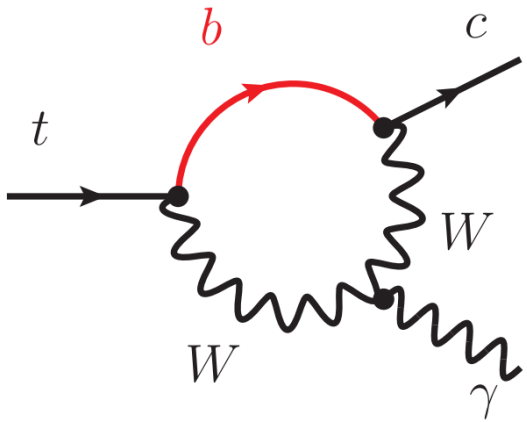
- Expected signal strength $\mu = 0.13^{+0.05}_{-0.04}$
- Corresponds to $\mathrm{BR}(t \to q\gamma) = 13 \times 10^{-5}$
- Extrapolation to full data set limit: $\mathrm{BR}(t \to q\gamma) \approx 4 \times 10^{-5}$

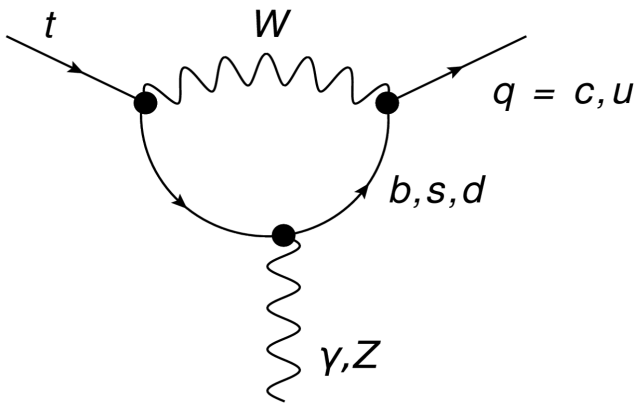
Outlook

- Fake rates have been calculated and applied
- Full systematics samples (slowly) running on the grid
- Fitting machinery mostly in place now, should be ready once samples finish
- Questions?

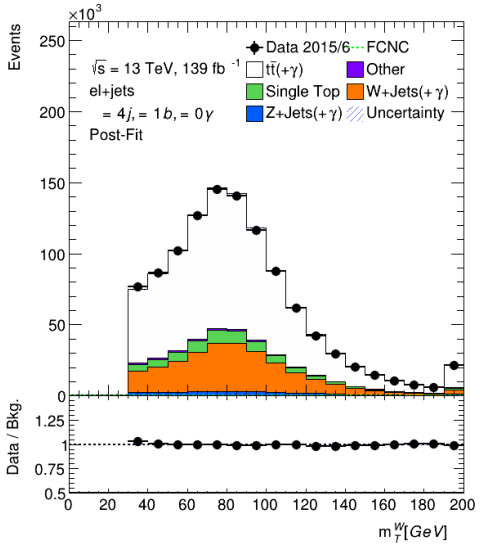
Backup

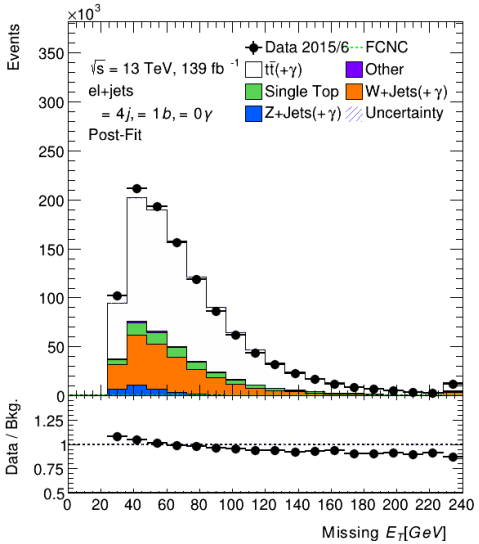
FCNC Diagrams

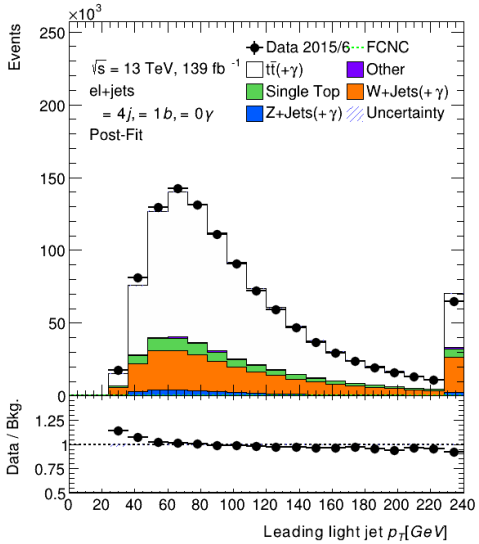


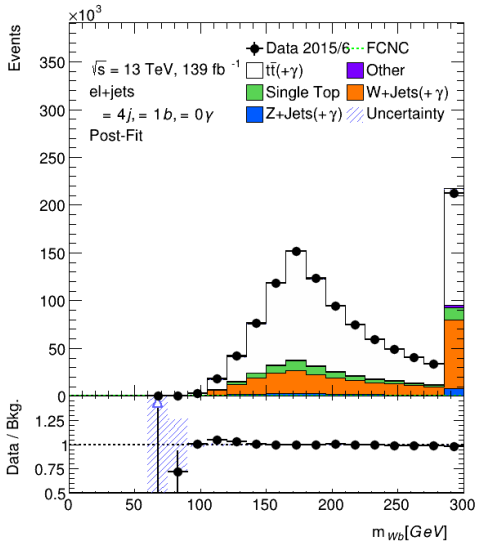


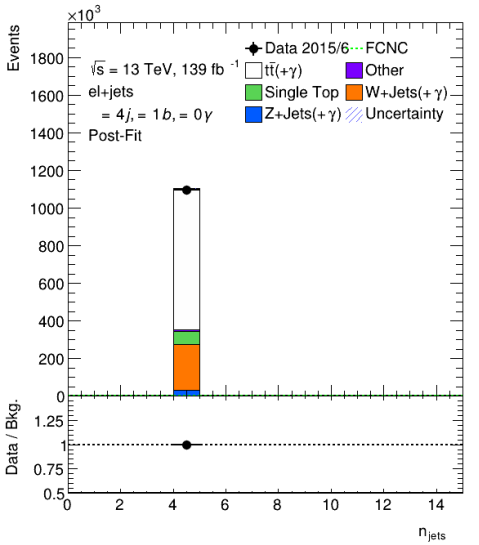
No Photon Region SF Applied in Val Region

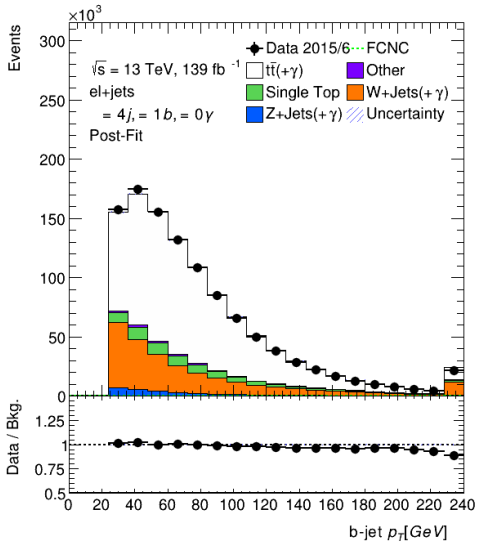












Jets/AntiKT

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

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

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

- 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

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