# Search for the Flavor Changing Neutral Current, $t \rightarrow q\gamma$ in Top Pair Events Using the ATLAS Detector

Jason Barkeloo

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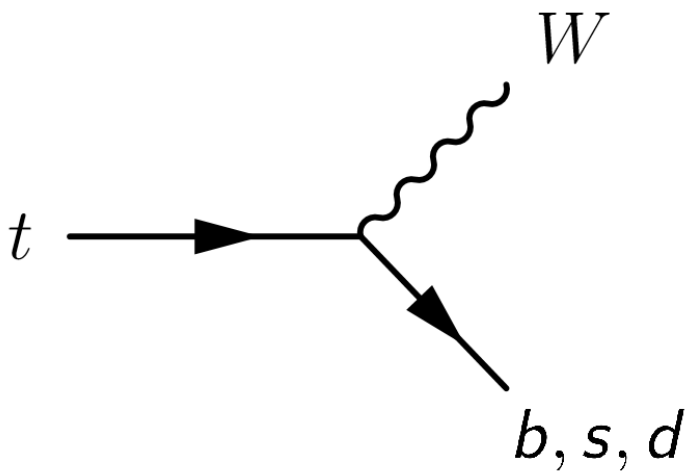
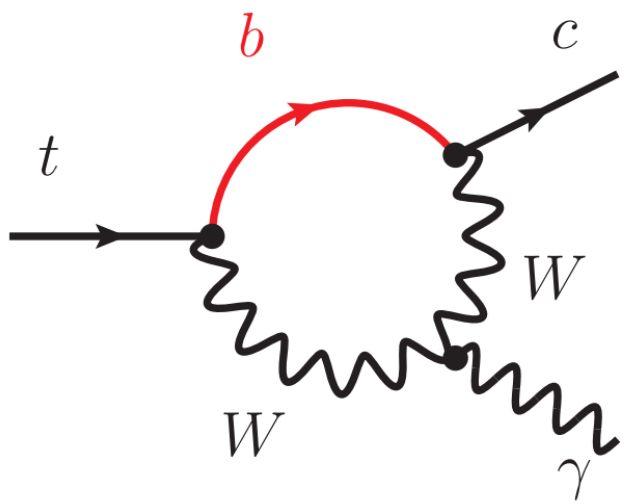
# Overview

# Top Quark Decays in the SM



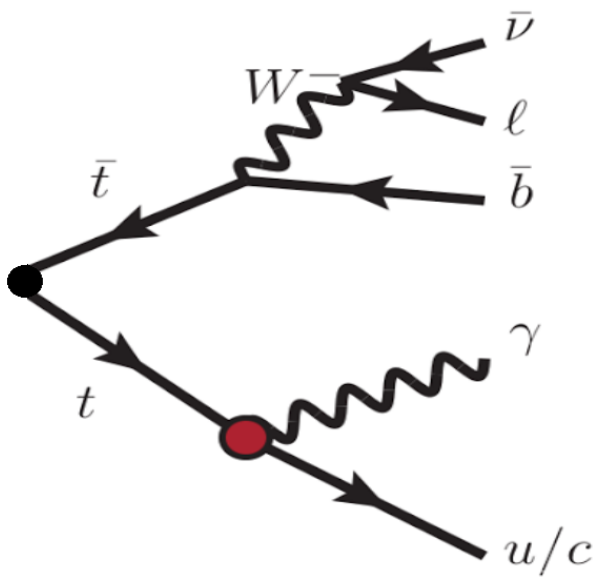

- $t \rightarrow bW \approx 99.83\%$
- $t \rightarrow sW \approx 0.16\%$
- $t \rightarrow dW \approx 0.01\%$

- $t \rightarrow q_{u,c}X \approx 10^{-17} - 10^{-12}$
- Limits on $t \rightarrow \gamma q$ processes: [JHEP 04 (2016) 035]
  - $t \rightarrow \gamma u < 1.3x10^{-4}$
  - $t \rightarrow \gamma c < 1.7x10^{-3}$

# 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



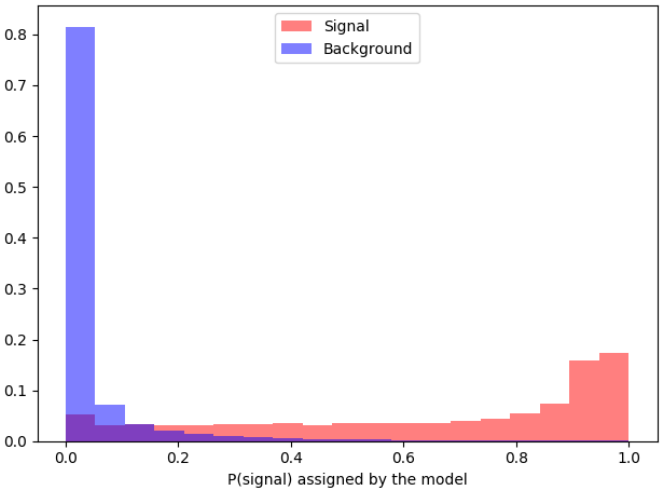
# B-tagging

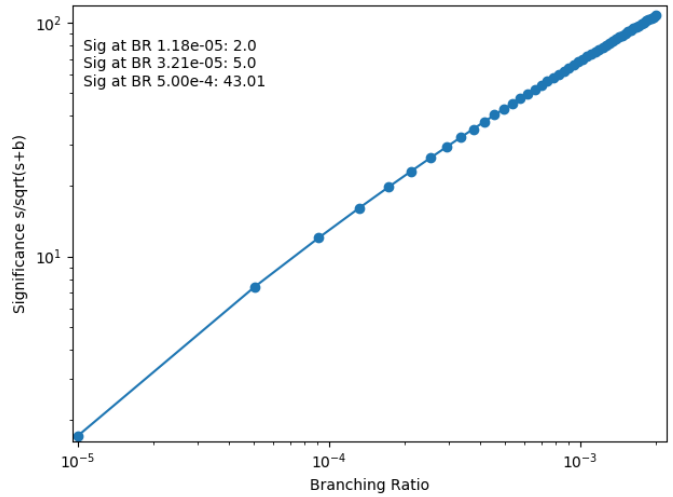
- B Hadrons travel a measureable distance before decay
- Tracks originate from outside of interaction point (Seconday Vertex)
- Backtracking tracks in displaced vertex gives an impact parameter
- Decay chain MVA attempts to reconstruct decay of the jet
- Outputs of these algorithms used in a BDT to determine if a Jet is from a b-quark

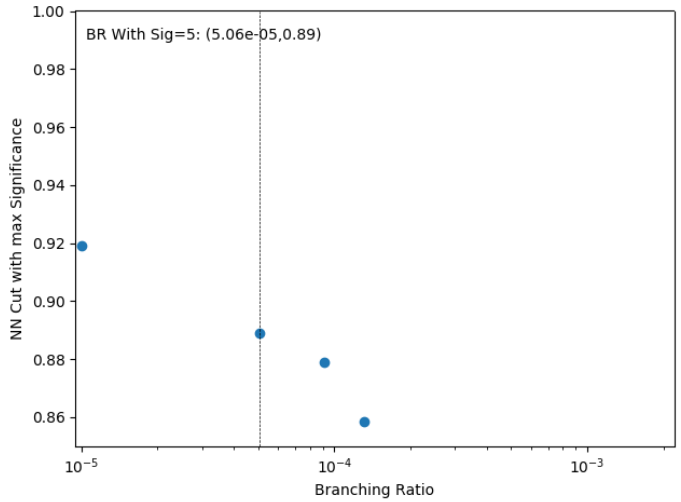
# Mv2c10

MV2c10 is used to tag b-jets. The c10 implies a 10% c-jet fraction in the background training sample. Can use various fixed-cut working points for b-jet identification.
Using a different working point can change which jets are identified as originating from b-quarks in the analysis.

# Neural Network Reminder

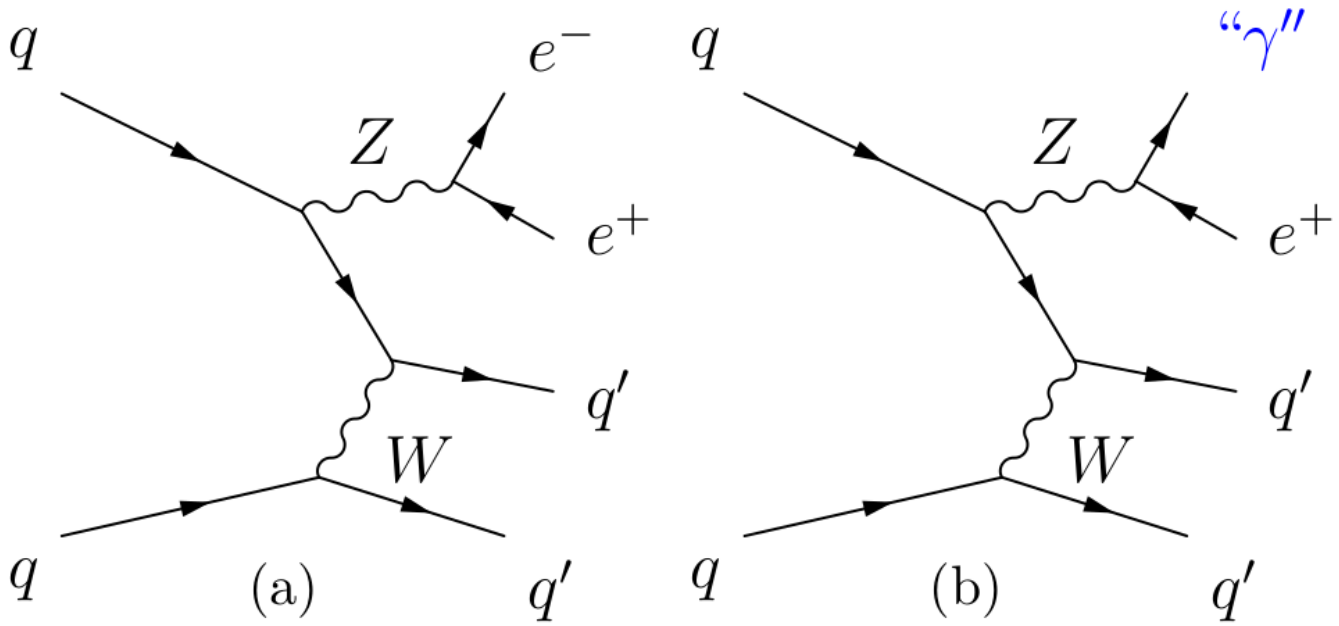



Branching ratio with Significance = 2: 1.18e-5

# Fake Rate Studies

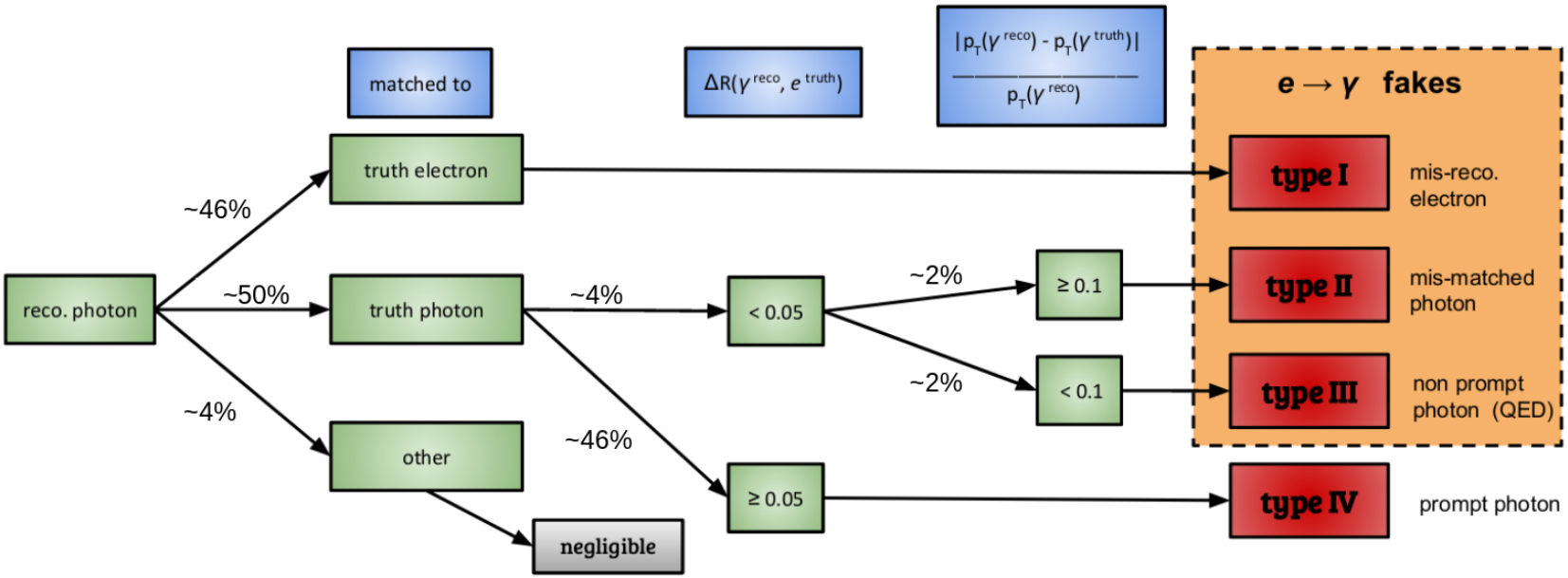



Want to be able to correct the number of fake photons predicted in MC to those present in Data

# 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

# Truth Study / Scale Factor



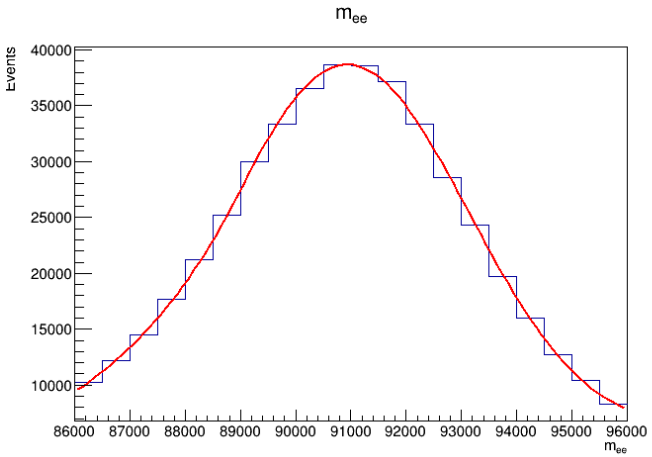

Catagories: Simple mis-match, mis-match to truth photon (Reco pt $\geq$10% higher than truth), non prompt photon, prompt photons

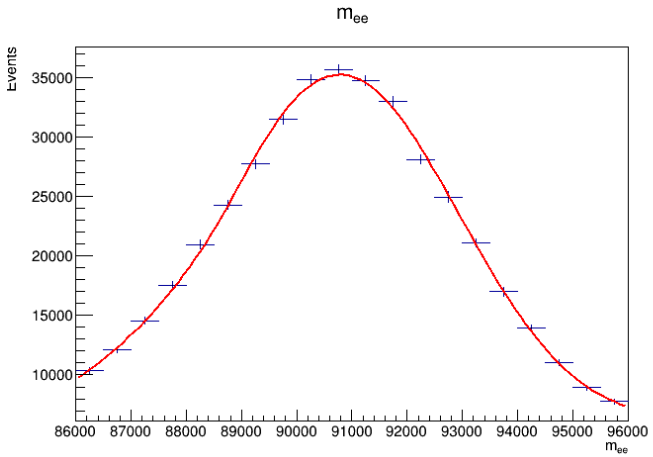
# $m_{ee}$, $m_{e\gamma}$

## Data and MC

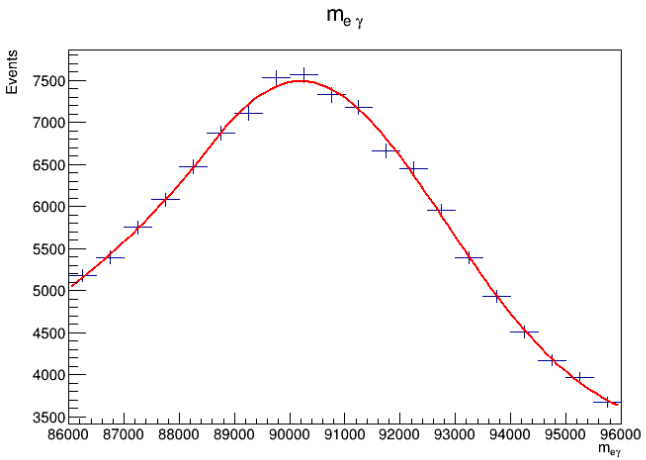
- Data
- Monte Carlo

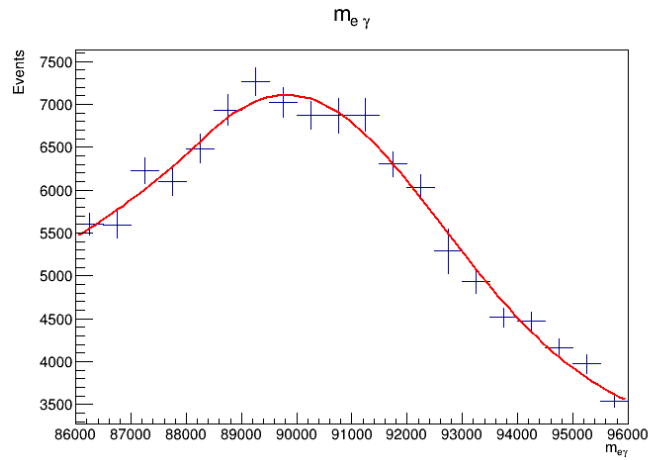
$m_{ee}$




$m_{e\gamma}$



# Scale Factor

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

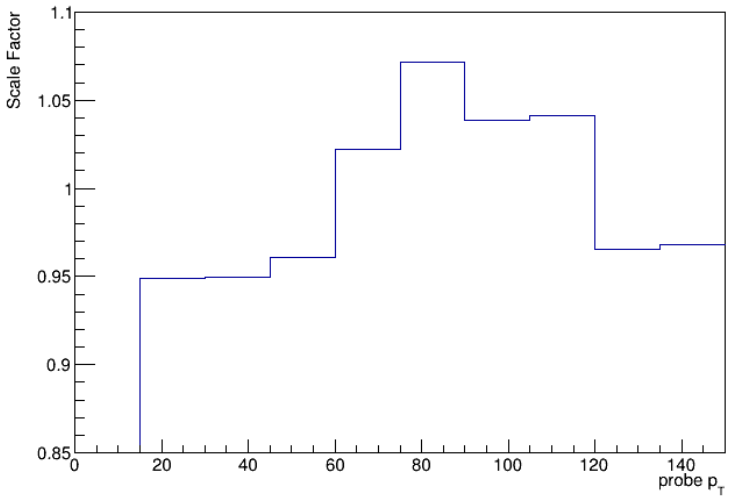
$$\mathrm{SF}^{\text{e-fake}}_{\mathrm{FR}} = \frac{\mathrm{FR}^{\text{e-fake}}_{\text{data}}}{\mathrm{FR}^{\text{e-fake}}_{\mathrm{MC}}}$$

Basic Scale Factor can be calculated for the entire spectrum:

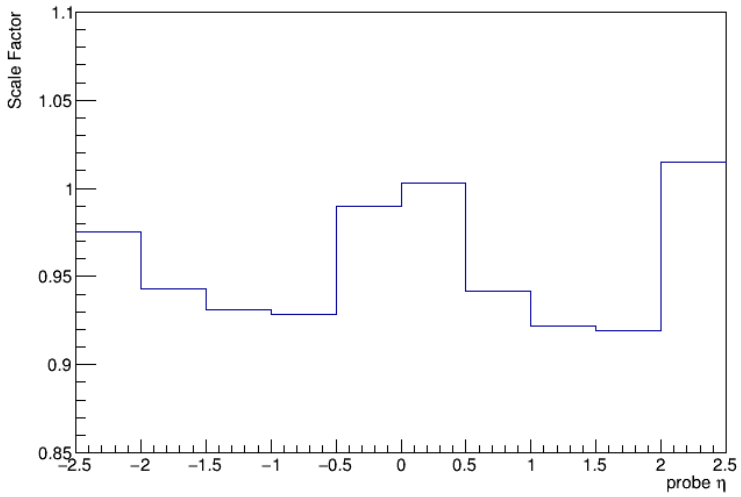
$\mathrm{FR}^{\text{e-fake}}_{\text{data}} = 0.201$
$\mathrm{FR}^{\text{e-fake}}_{\mathrm{MC}} = 0.212$
$\mathrm{SF}^{\text{e-fake}}_{\mathrm{FR}} = 0.953$

# Scale Factors As Functions of Probe pt and eta

Probe $p_T$




Probe $\eta$

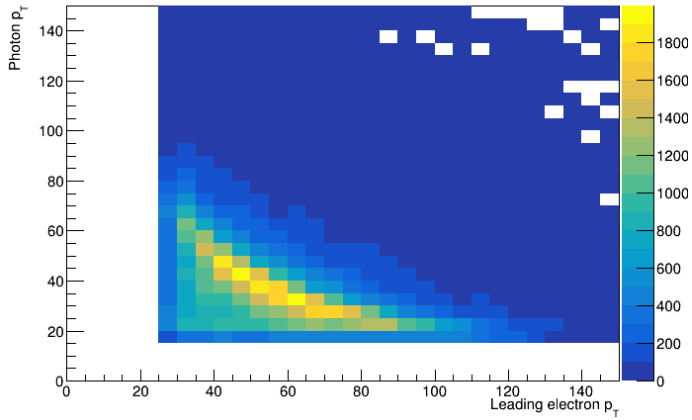


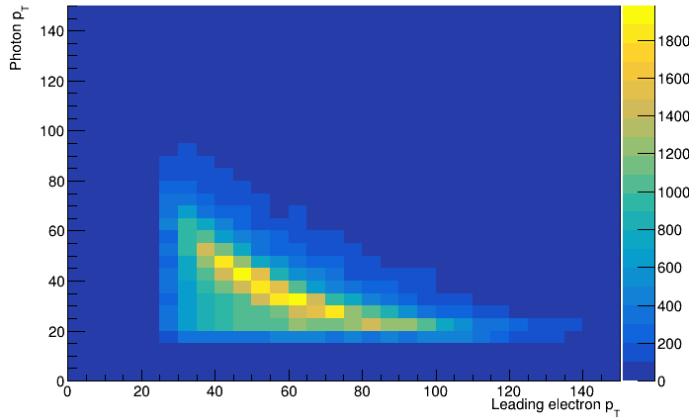

Good to check but in practice these are done using 2D Scale Factors

# Data and MC Distributions

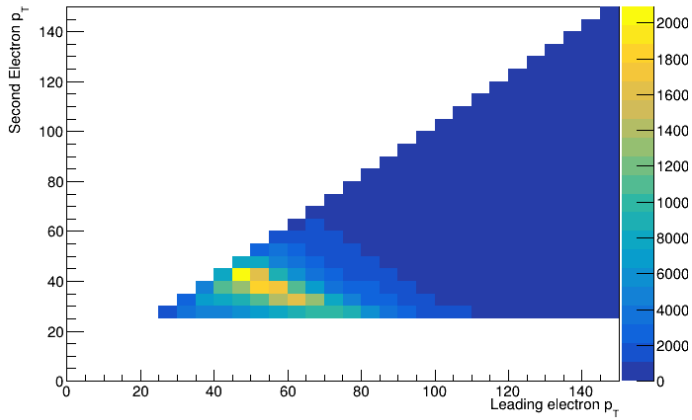
- Data
- Monte Carlo

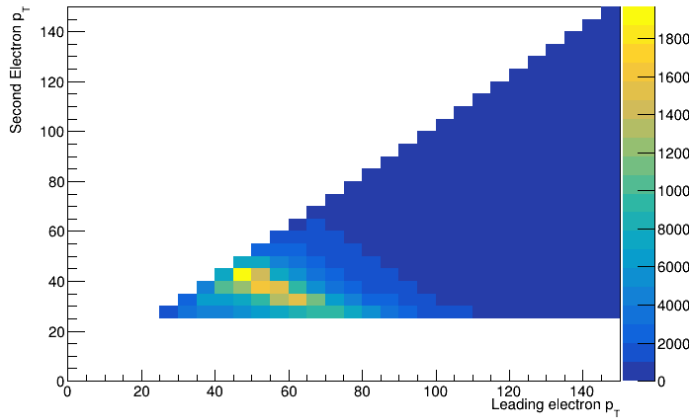
$e\gamma$ region



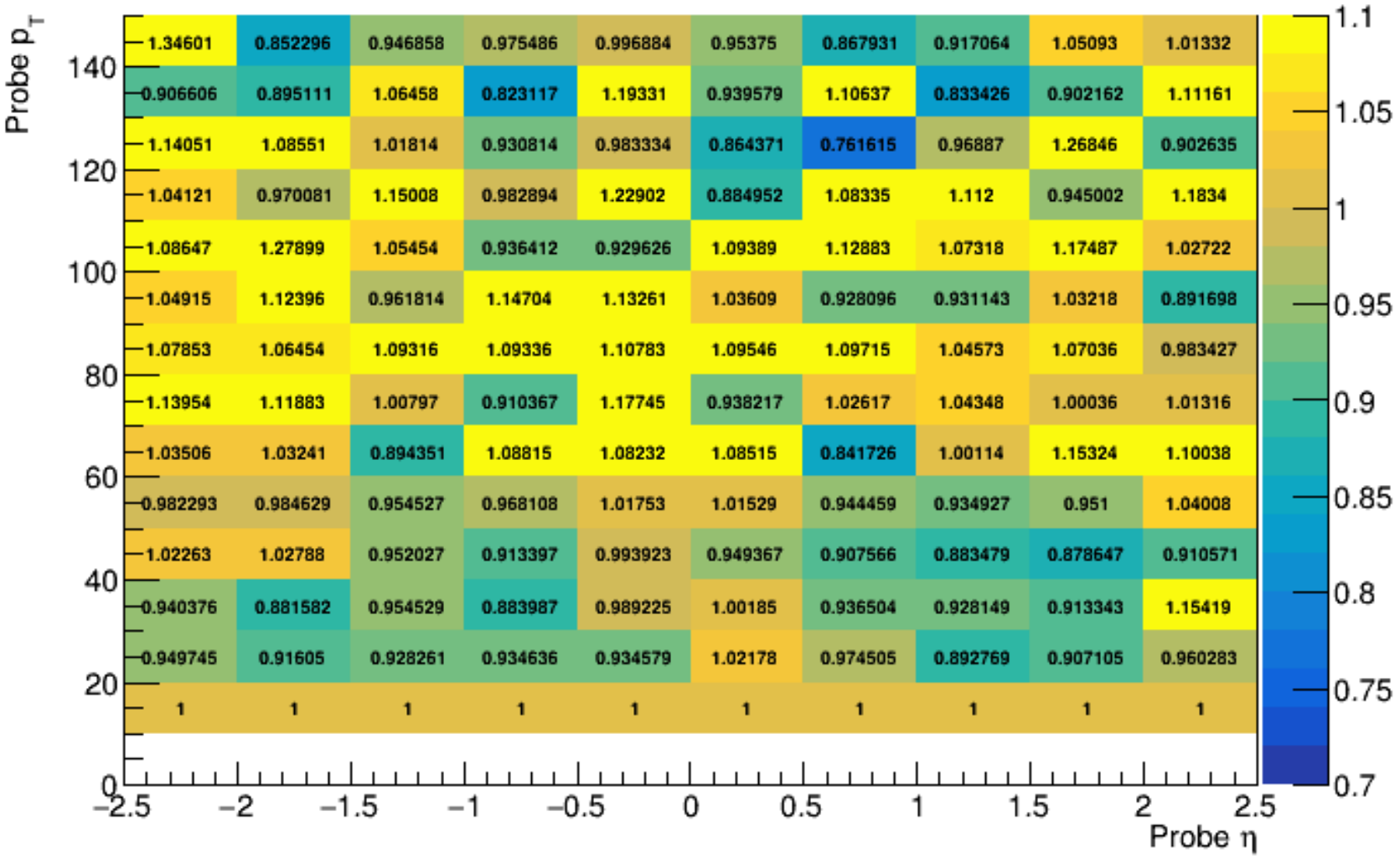




ee region



# Next Steps - 2D Fake Rate

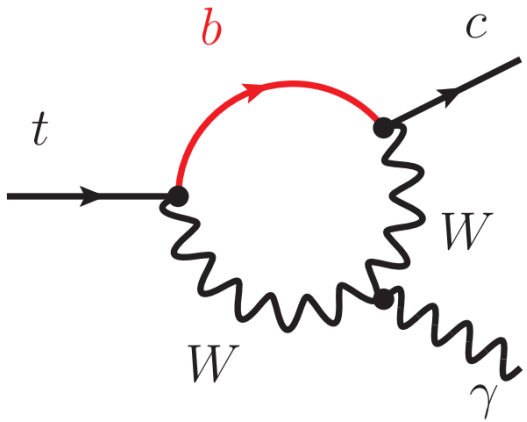


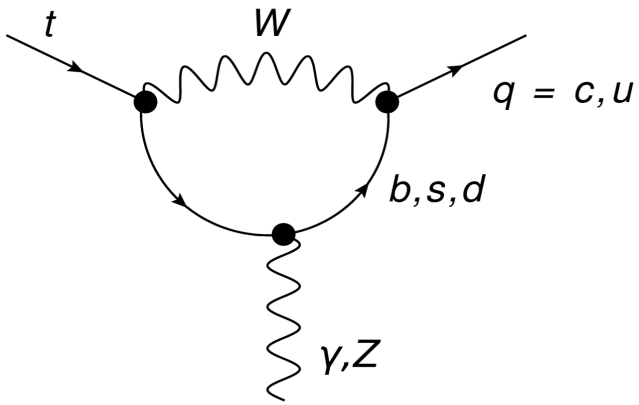
# Outlook

- As always, still lots to be done
- Fake Rate: $e \rightarrow \gamma$ has been investigated, further systematic investigations will continue
- Fake Rate: $j \rightarrow \gamma$ to be investigated soon
- Was able to squeak an extra factor of 2 out of Neural Network since I had to redo it for working points anyway
- Questions?

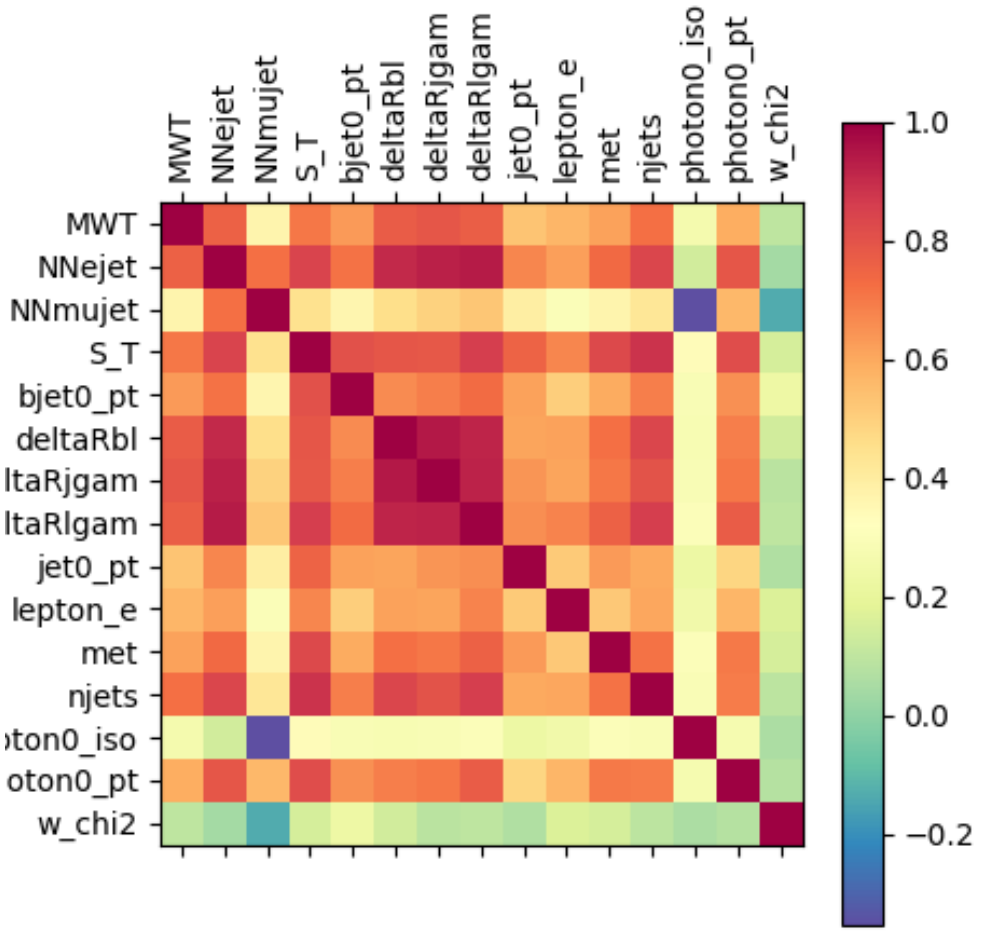
# Backup

# FCNC Diagrams



# NN Input Variable Correlations



# Neural Network Model Inputs

$$\text{Separation} = \sum_i^{bins} \frac{n_{si} - n_{bi}}{n_{si} + n_{bi}}$$

## mu+jets channel

| Variable | Separation |
|---|---|
| photon0iso | 41.18 |
| mqgam | 28.27 |
| photon0pt | 24.07 |
| mtSM | 11.60 |
| mlgam | 7.56 |
| deltaRjgam | 5.64 |
| deltaRbl | 4.42 |
| MWT | 3.34 |
| ST | 3.30 |
| nuchi2 | 3.12 |
| jet0pt | 2.81 |
| njets | 2.07 |
| smchi2 | 1.89 |
| wchi2 | 1.87 |
| jet0e | 1.52 |
| deltaRlgam | 1.17 |
| leptone | 0.87 |
| deltaRjb | 0.86 |
| met | 0.68 |
| bjet0pt | 0.52 |
| leptoniso | 0.27 |

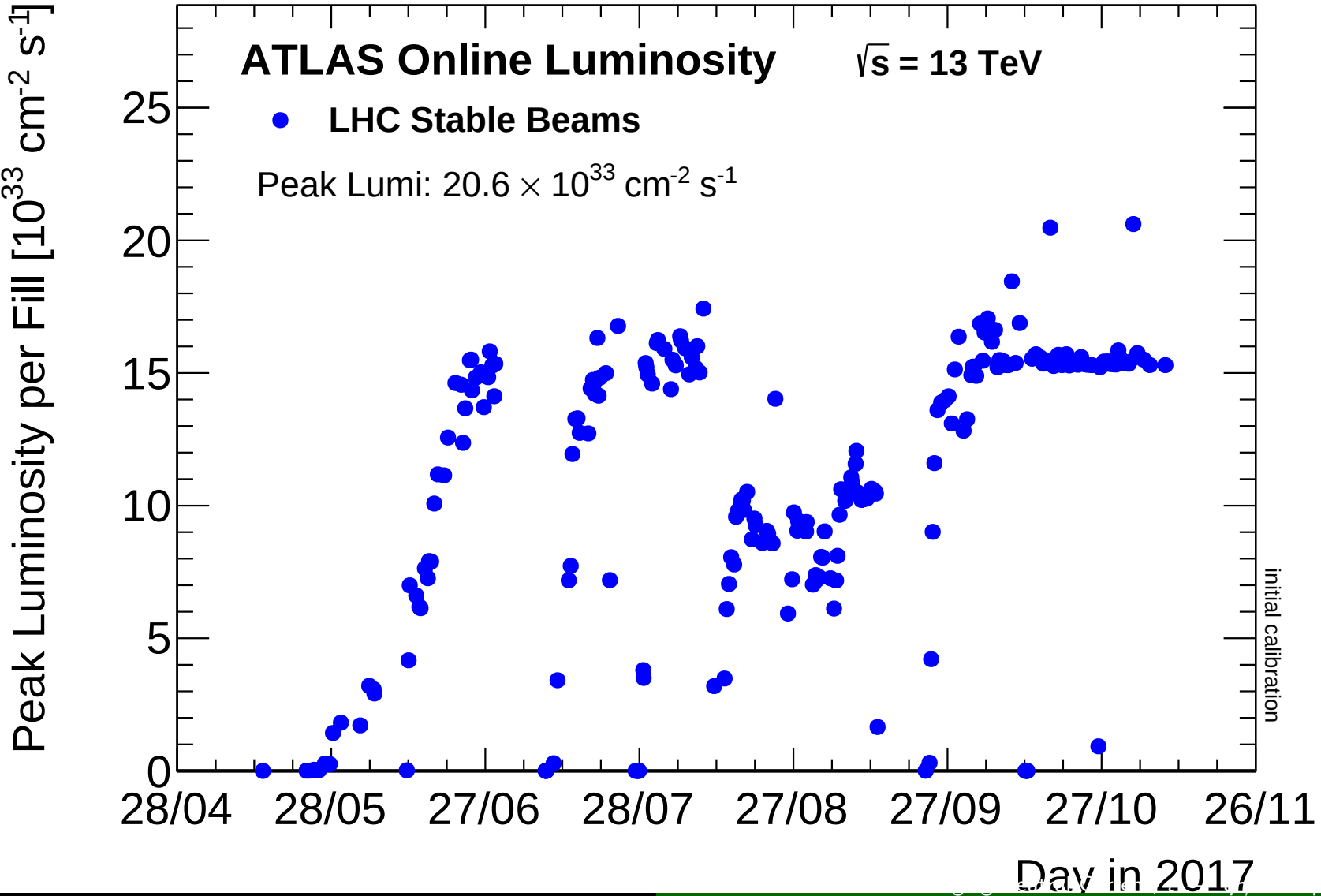
## e+jets channel

| Variable | Separation |
|---|---|
| photon0pt | 23.14 |
| mqgam | 22.73 |
| photon0iso | 18.70 |
| mtSM | 11.02 |
| mlgam | 9.53 |
| deltaRbl | 5.00 |
| deltaRjgam | 4.60 |
| ST | 3.83 |
| MWT | 3.16 |
| jet0pt | 2.47 |
| njets | 1.70 |
| nuchi2 | 1.59 |
| deltaRlgam | 1.40 |
| wchi2 | 1.33 |
| smchi2 | 1.09 |
| deltaRjb | 0.88 |
| leptone | 0.85 |
| leptoniso | 0.56 |
| bjet0pt | 0.50 |
| met | 0.47 |

# Input Variables

['photon0iso','photon0pt','mqgam','mlgam','mtSM','deltaRjgam','deltaRbl',
'MWT','ST','njets','wchi2','jet0pt','deltaRlgam','leptone','met','bjet0pt']

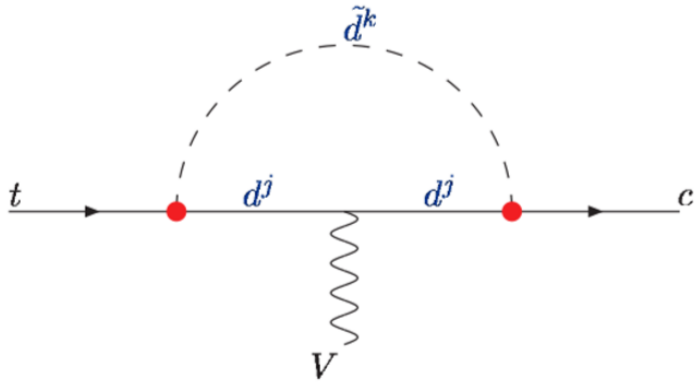
# Integrated Luminosity



# A Couple BSM Diagrams

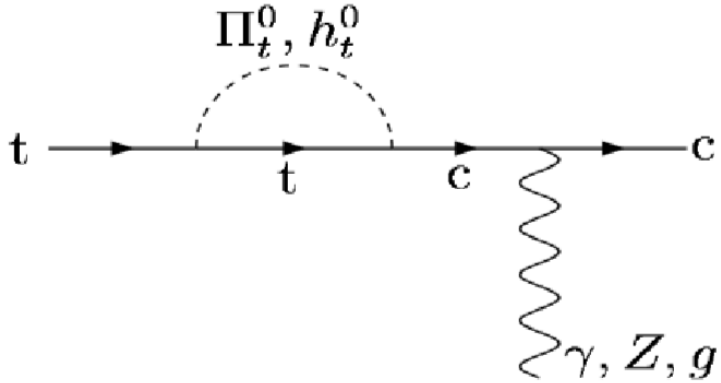
- R-parity-violating supersymmetric models

  [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 $\Delta_{ij}$ is greater than R

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