Search for Flavor Changing Neutral Currents in Top Quark Decays

B-Tagging Working Point and $e \to \gamma$ Fakes

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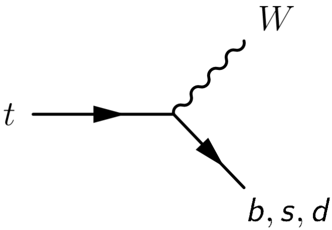
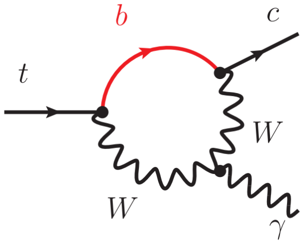
Overview

Top Quark Decays in the SM





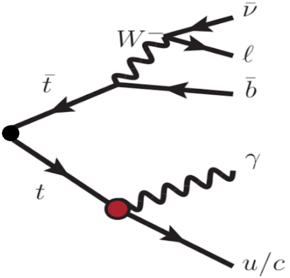
- $t \rightarrow bW \approx 99.83\%$
- $t \rightarrow sW \approx 0.16\%$
- $t \rightarrow dW \approx 0.01\%$

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

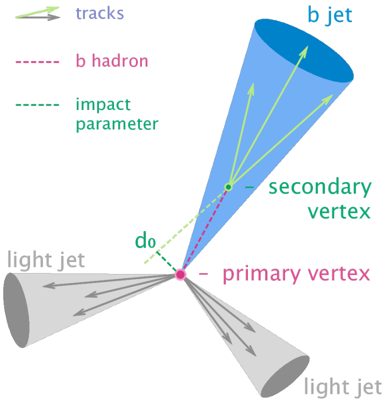
Will further investigate BJets here.

- 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

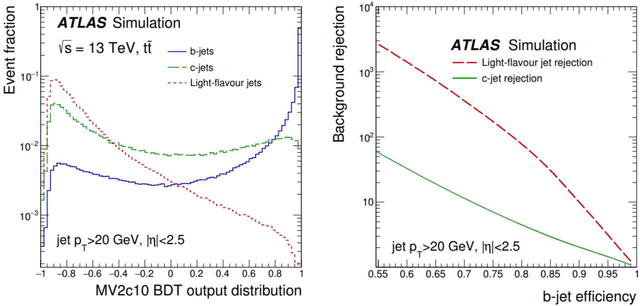
- B Hadrons travel a measureable distance before decay
- Tracks originate from outside of interaction point (Seconday Vertex)
- Backtracking tracks in displaced vertex gives an impact parameter
- Decay chain MVA attempts to reconstruct decay of the jet
- Outputs of these algorithms used in a BDT to determine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



(a) (b)

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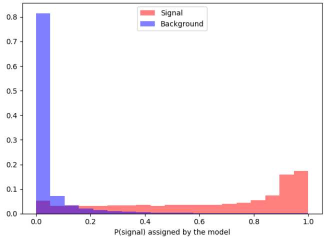
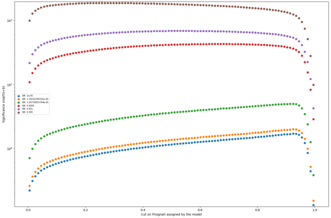
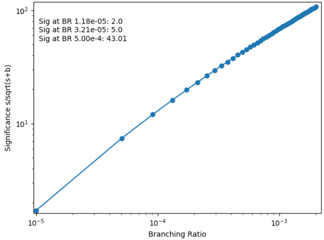
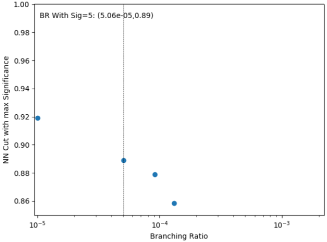
Neural Network Reminder







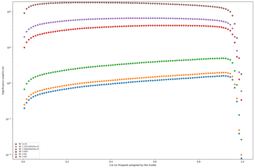


Branching ratio with Significance = 2: 1.18e-5

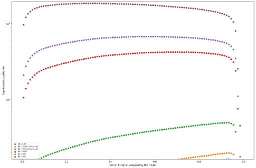
Neural Network Results

- 70% Working Point
- 77% Working Point
- 85% Working Point

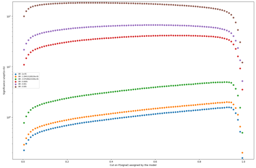
Electron Channel



BR with Sig=2: 1.25×10^{-5}

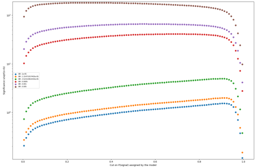


BR with Sig=2: 1.23×10^{-5}

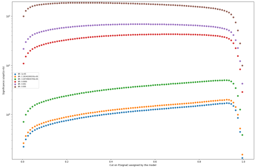


BR with Sig=2: 1.28×10^{-5}

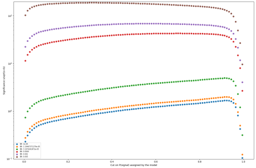
Muon Channel



BR with Sig=2: 1.31×10^{-5}

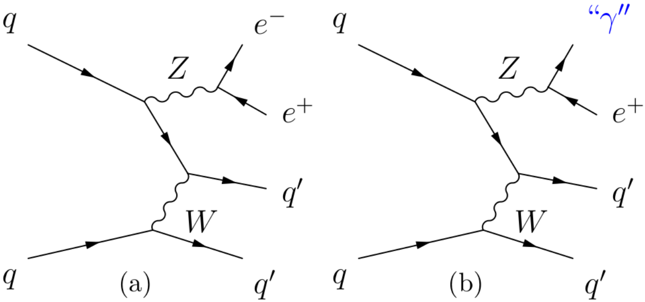


BR with Sig=2: 1.18×10^{-5}



BR with Sig=2: 1.19×10^{-5}

Fake Rate Studies

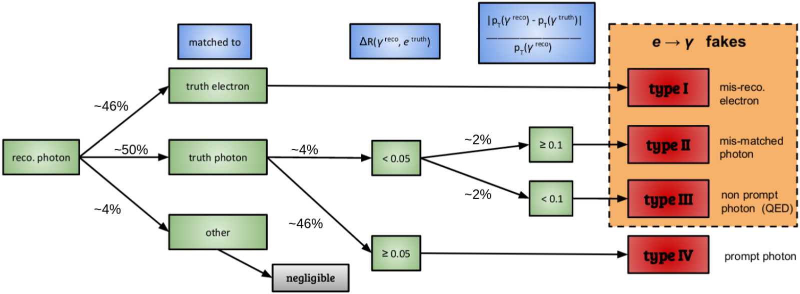


Want to be able to correct the number of fake photons predicted in MC to those present in Data

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

Truth Study / Scale Factor



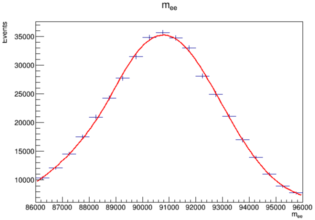
Catagories: Simple mis-match, mis-match to truth photon (Reco pt $\geq$10% higher than truth), non prompt photon, prompt photons

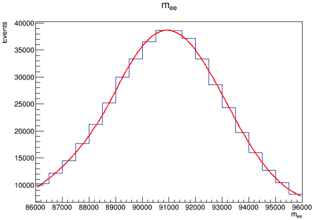
m_{ee}, $m_{e\gamma}$

Data and MC

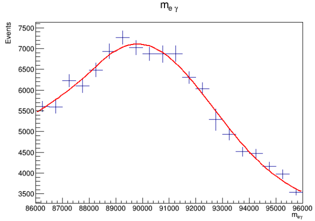
- Data
- Monte Carlo

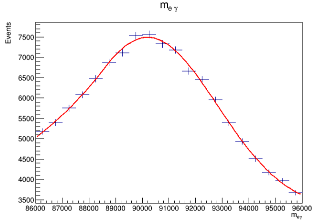
m_{ee}





$m_{e\gamma}$





Scale Factor

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

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

Basic Scale Factor can be calculated for the entire spectrum:
$\mathrm{FR}^{\text{e-fake}}_{\text{data}} = 0.201$
$\mathrm{FR}^{\text{e-fake}}_{\text{MC}} = 0.212$
$\mathrm{SF}^{\text{e-fake}}_{\mathrm{FR}} = 0.953$

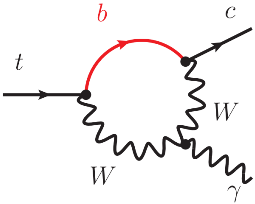
Next Steps - 2D Fake Rate

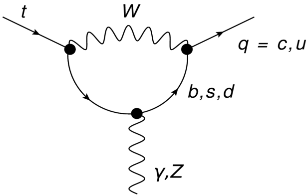
Outlook

- As always, still lots to be done
- Fake Rates $e \to \gamma$ and $j \to \gamma$ are being investigated, $e \to \gamma$ shown here, $j \to \gamma$ 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?

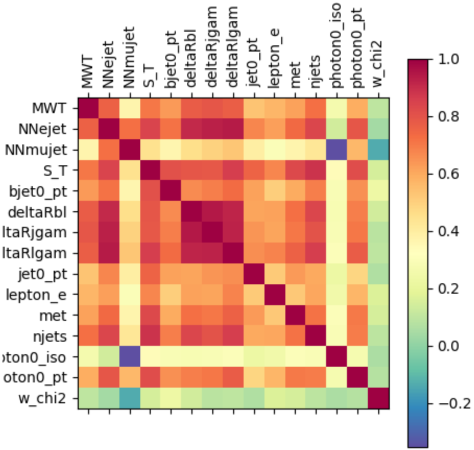
Backup

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

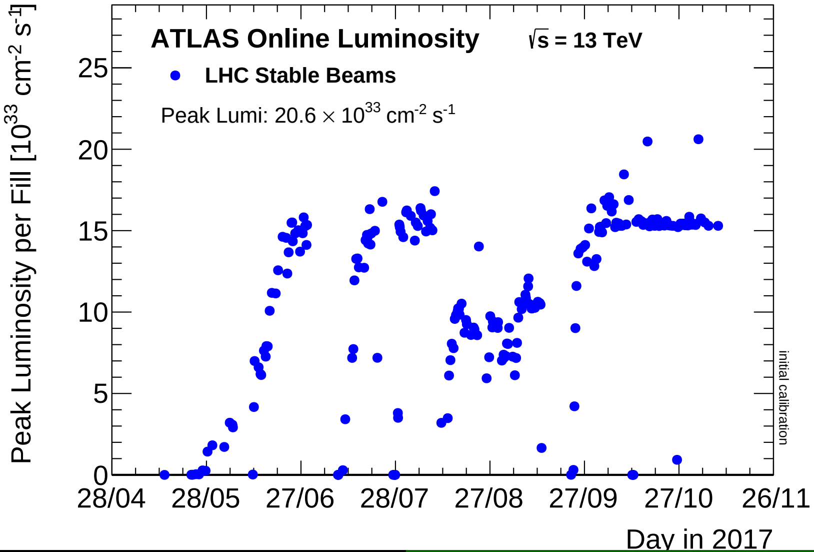
e+jets channel

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']

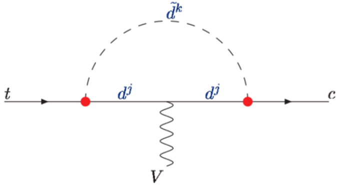
Integrated Luminosity



A Couple BSM Diagrams

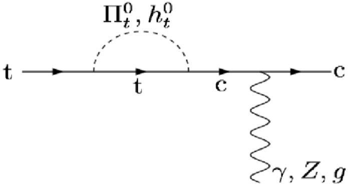
- R-parity-violating supersymmetric models

  [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 Δ_{ij} is greater than R

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