

Search for Flavor Changing Neutral Currents in Top Quark Decays

$$t \rightarrow q\gamma$$

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Table of Contents

Brief Background

Searching for Flavor Changing Neutral Current Signatures

Current Investigations

Top Quark Pair Production

- At $\sqrt{s} = 13\text{TeV}$ for $m_t = 172.5\text{GeV}$, $\sigma_{t\bar{t}} = 831.76\text{pb}$

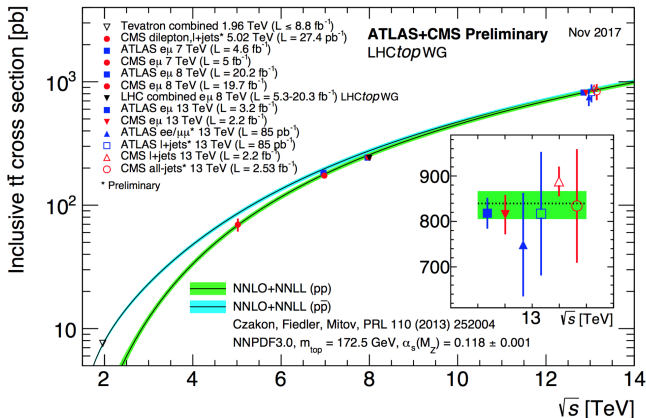


Figure: $t\bar{t}$ production cross section [TopWGSUMmaryPlots]

Top Quark Decays

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

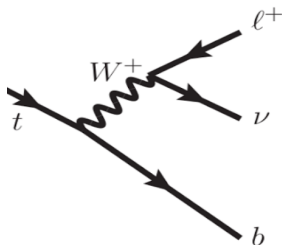


Figure: Leptonic final state diagram for a top decay

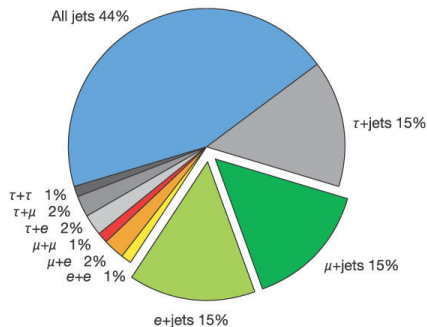
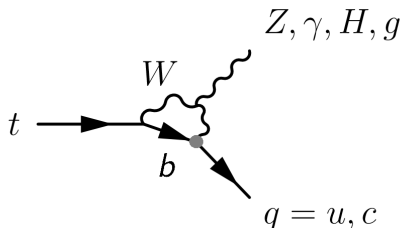
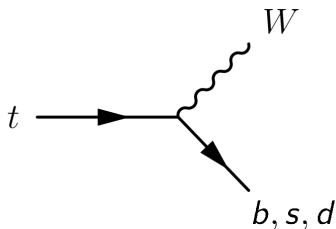


Figure: Top quark pair decay final states [Nature]

Top Quark Decays in the SM

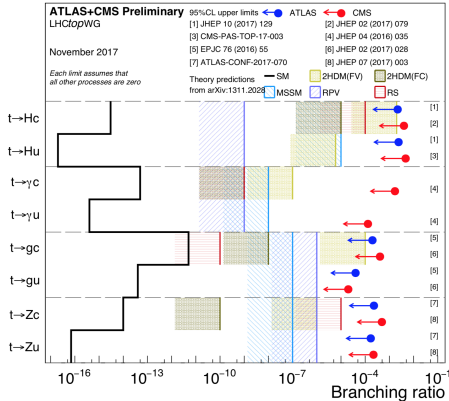


- ▶ $t \rightarrow bW \approx 99.83\%$
- ▶ $t \rightarrow sW \approx 0.16\%$
- ▶ $t \rightarrow dW \approx 0.01\%$

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

Top Flavor Changing Neutral Currents

► Current Limits on FCNC Decays

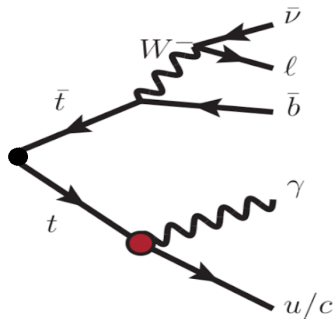


► Limits on $t \rightarrow \gamma q$ processes: [JHEP 04 (2016) 035]

- $t \rightarrow \gamma u < 1.3 \times 10^{-4}$
- $t \rightarrow \gamma c < 1.7 \times 10^{-3}$

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



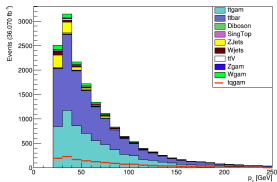
Object Preselection

- ▶ We preselect events with objects that look like our expected topology
- ▶ Require:
 - ▶ Exactly one lepton (e or μ) ≥ 28 GeV
 - ▶ Exactly one Good photon ≥ 25 GeV
 - ▶ Missing Transverse Energy ≥ 30 GeV
 - ▶ ≥ 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 $36.07 fb^{-1}$

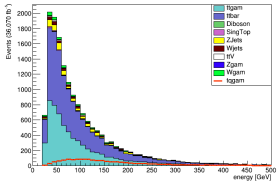
Preselection Objects

Electron Channel

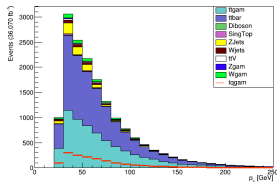
► Leading Jet p_T



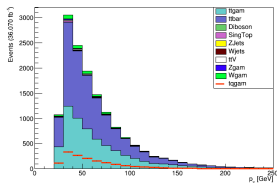
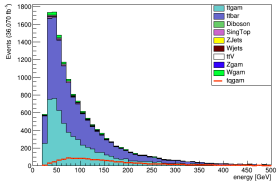
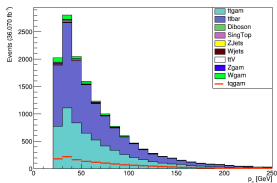
► Photons



► Leptons



Muon Channel



Where are the Tops?

- ▶ Must be 'reconstructed' from these objects as well as b-jets and E_T^{miss}
- ▶ E_T^{miss} is calculated to balance the event energy in the transverse plane of the detector
- ▶ The other particles are combined in the only way the signal topology would allow two top quark candidates
 - ▶ Standard model top candidate: b-jet + lepton + neutrino
 - ▶ FCNC Top: Photon + Light Jet

Neutrinos

- ▶ All missing energy in signal topology is from neutrino
- ▶ We have E_T^{miss} and its' direction
 - ▶ Can calculate E_{Tx}^{miss} and E_{Ty}^{miss} easily
 - ▶ Ambiguous direction along the z-axis
- ▶ A minimization of this χ^2 will allow us to determine the z momentum of the neutrino:
$$\chi^2 = \frac{(m_{b,l,\nu} - m_t)^2}{\sigma_{SMtop}^2} + \frac{(m_{l,\nu} - m_W)^2}{\sigma_W^2}$$

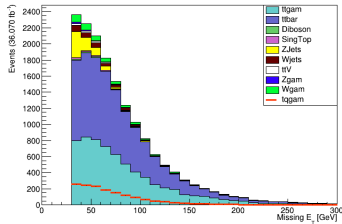


Figure: e-channel E_T^{miss} distribution

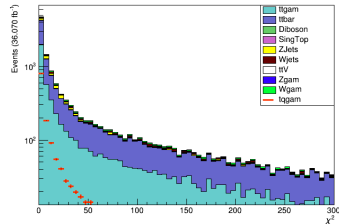


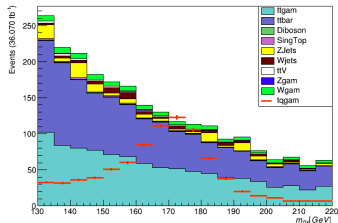
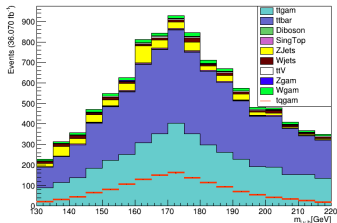
Figure: e-channel χ^2 distribution

Reconstructed Tops

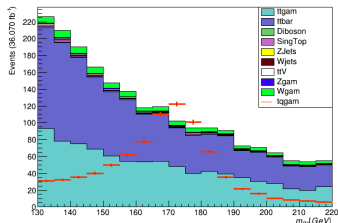
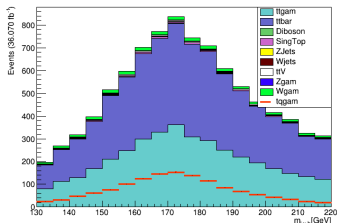
► SM Top

► FCNC Top

Electron Channel



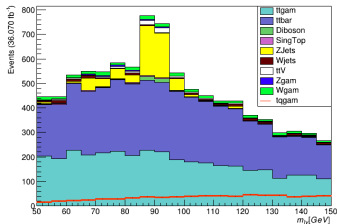
Muon Channel



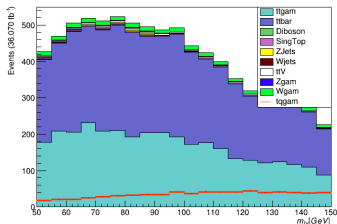
Thinning Out Backgrounds

► Reconstructing Z mass

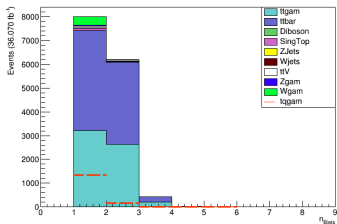
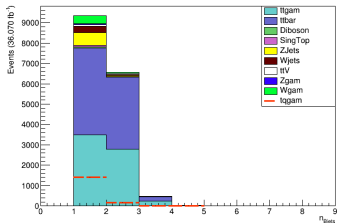
Electron Channel



Muon Channel



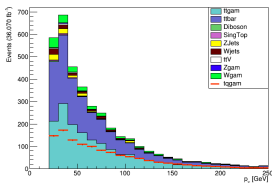
► Number of BJets



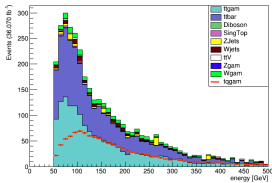
Thinning Out Backgrounds: Preselection Objects

Electron Channel

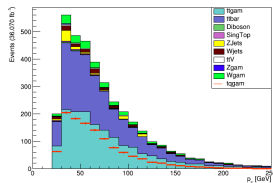
► Leading Jet p_T



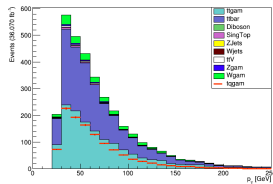
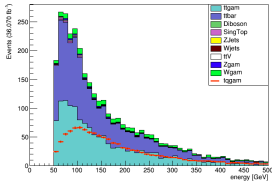
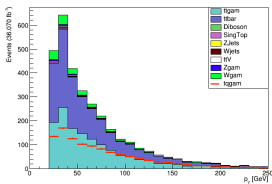
► Photons



► Leptons



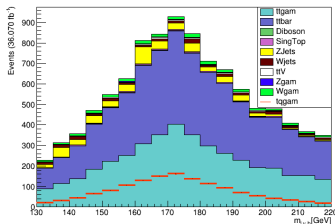
Muon Channel



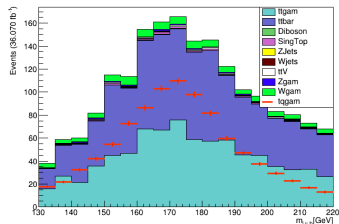
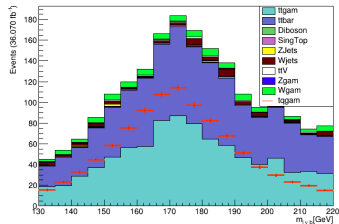
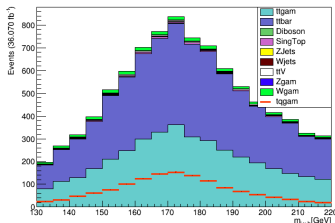
- Before Z-mass, Bjet cuts

► After Cuts

Electron Channel



Muon Channel

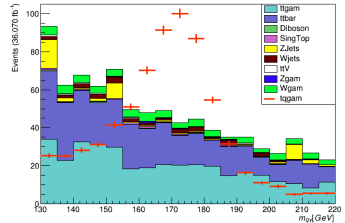
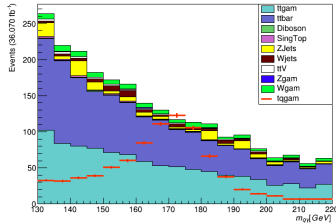


Thinning Out Backgrounds: FCNC Top ($m_{q\gamma}$)

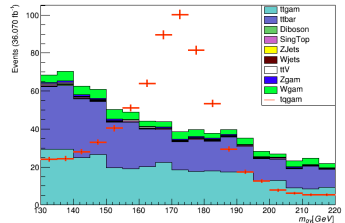
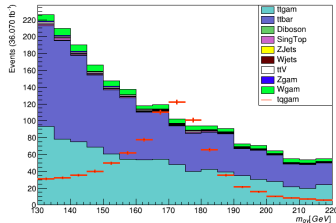
► Before Z-mass, Bjet cuts

► After Cuts

Electron Channel



Muon Channel



Current Investigation: χ^2

- Can χ^2 be used as a discriminating variable?
- $$\chi^2 = \frac{(m_{b,l,\nu} - m_t)^2}{\sigma_{SMtop}^2} + \frac{(m_{l,\nu} - m_W)^2}{\sigma_W^2}$$

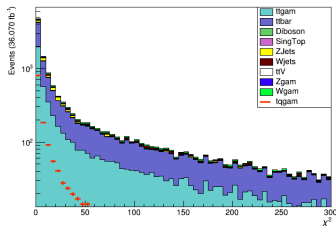


Figure: e-channel χ^2 before cuts

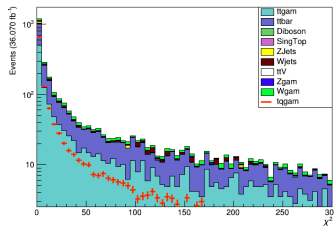


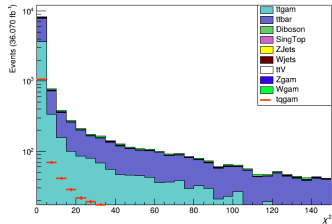
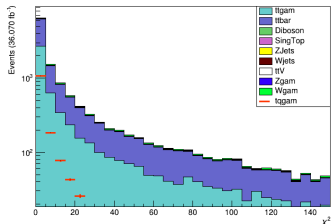
Figure: e-channel χ^2 after Z, Bjet cuts

Current Investigation: χ^2 μ -Channel

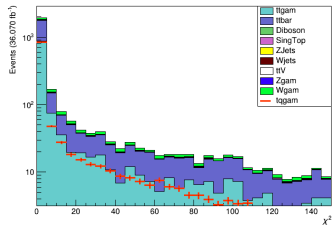
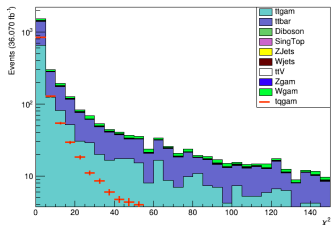
►
$$\frac{(m_{b,l,\nu} - m_t)^2}{\sigma_{SMtop}^2}$$

►
$$\frac{(m_{l,\nu} - m_W)^2}{\sigma_W^2}$$

Before Cuts



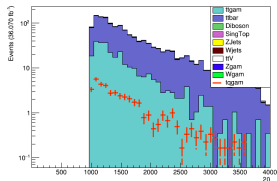
After Cuts



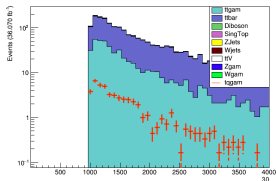
Current Investigation: Photon Isolation: μ -Channel

Before Cuts

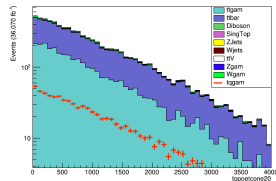
► ptvarcone20



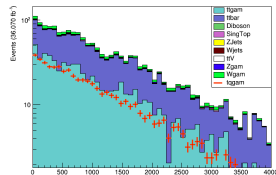
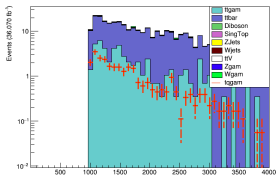
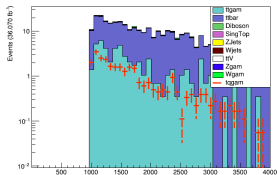
► ptvarcone30



► topoetcone20



After Cuts

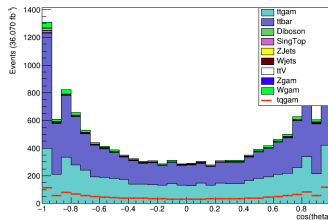
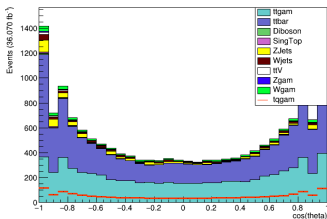


Current Investigation: γ Geometry

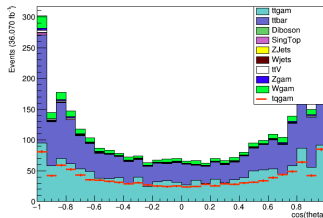
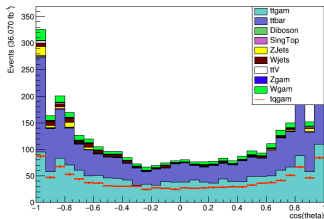
► e-channel

► μ -channel

Before Cuts



After Cuts

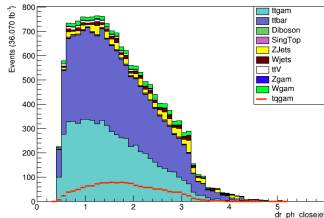
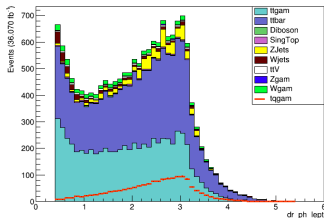


Current Investigation: Geometry ΔR to γ : e-channel

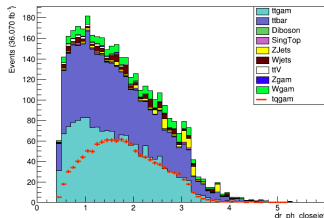
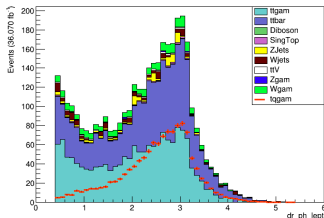
► $\Delta R_{\gamma l}$

► $\Delta R_{\gamma \text{closejet}}$

Before Cuts



After Cuts

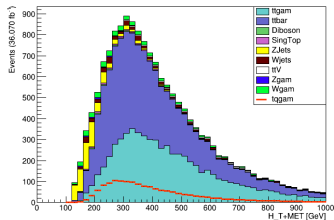
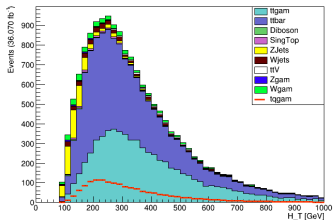


Current Investigation: H_T and $H_T + \text{MET}$ e-channel

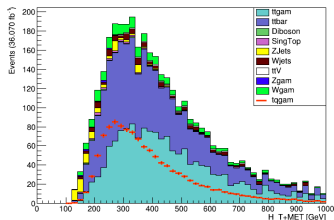
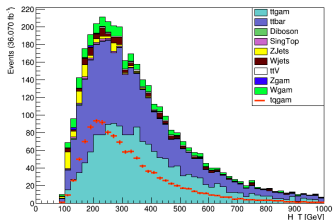
► H_T

► $H_T + \text{MET}$

Before Cuts



After Cuts



Outlook

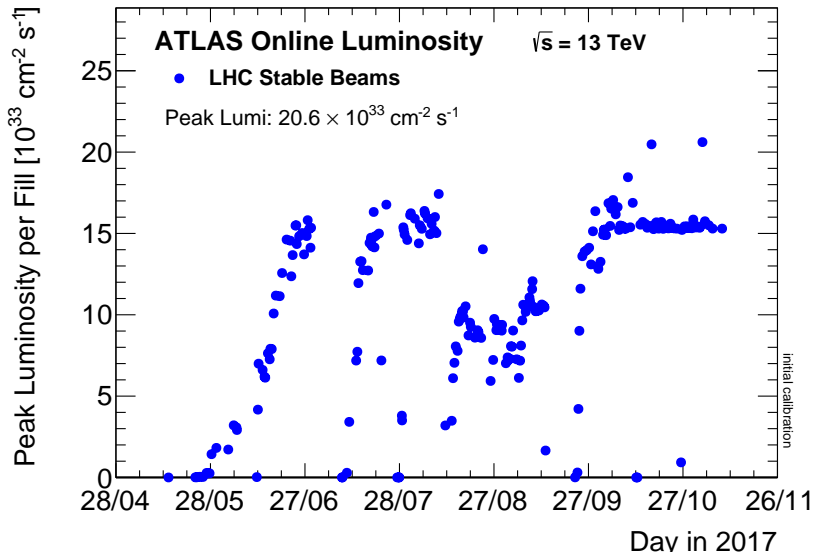
- ▶ Many improvements can be made to the analysis
 - ▶ Further investigation of χ^2 cuts
 - ▶ Inclusion of a new term in χ^2 to do with FCNC Top
 - ▶ Isolation cuts, Photon position don't seem too promising for background reduction
 - ▶ $\Delta R_{\gamma l}$ looks to be useful
- ▶ Many cuts being optimized currently

Conclusion

- ▶ Barring any excess: with $\approx 150\text{fb}^{-1}$ data at $\sqrt{s} = 13\text{TeV}$ setting an upper limit of $\text{BR}(t \rightarrow q\gamma) < 3 \times 10^{-5}$ is the goal, using a simple extrapolation from previous results.
- ▶ Orthogonal validation/control regions are in development
- ▶ Next grid run will include data to look at MC modeling in these orthogonal regions
- ▶ Need to request R21 version of MC

Backup

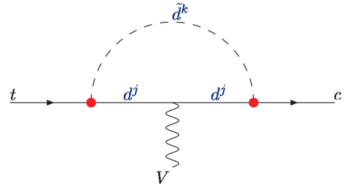
Integrated Luminosity



A Couple BSM Diagrams

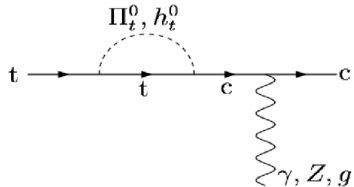
- R-parity-violating supersymmetric models

[arXiv:hep-ph/9705341]



- Top-color-assisted technicolor models

[arXiv:hep-ph/0303122]



Jets/AntiKT

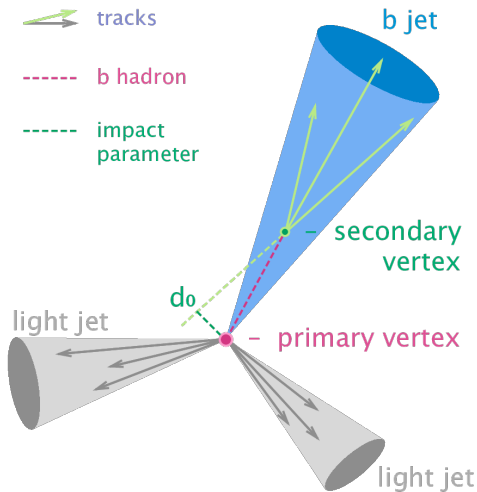
$$d_{ij} = \min\left(\frac{1}{p_{ti}^2}, \frac{1}{p_{tj}^2}\right) \frac{\Delta_{ij}^2}{R^2}$$

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

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

- ▶ 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



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