# Color Octet Scalars at the LHC

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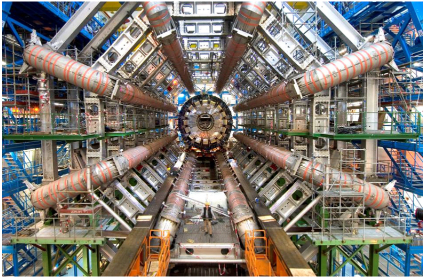
# Outline



Based on work with M. Gerbush, T. J. Khoo, A. Pierce, and D. Tucker-Smith [arXiv:0710.3133]

# LHC From a Color Perspective

1. *pp* machine with 14 TeV Center of Mass energy
2. Gluon-gluon scattering will be the dominant process.
3. There is a preferential coupling to states with $SU(3)$ quantum numbers.



# Color Octets and Minimal Flavor Violation

- Look at possible scalars you may add to the Standard Model with renormalizable couplings.
- Only one scalar is consistent with Minimal Flavor Violation [Manohar, Wise]
- Given the approximate $U(3)^5$ family symmetry is only broken by Higgs couplings, the new scalar addition should have couplings proportional to the Yukawa matrices.

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- Look at possible scalars you may add to the Standard Model with renormalizable couplings.
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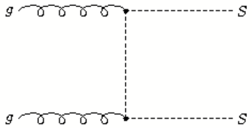
- Color adjoint Higgs doublet $(8, 2)_{1/2}$

$$\mathcal{L} \supset \eta_U \bar{Q}_L \mathbf{y_u} u_R S + \eta_D \bar{Q}_L \mathbf{y_d} d_R S + h.c.$$

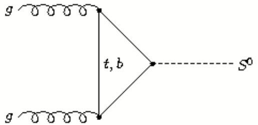
- Preferential decay to heavy quarks

# Production Modes at the LHC

1. The dominant process for pair production, set by gauge coupling:




2. Result is four top quarks. We are going to look for ways to reconstruct a resonance in this environment.
3. The dominant process for single production, set by Yukawas:



# Reconstruction method

Given we are going to look for four top final states, we need to find top quarks. We will attempt to find them as "fat" jets.

1. The top decays $t \to bW^+$
2. $W^+ \to jj$ or $W^+ \to l^+\nu$
3. For top quarks that are boosted $\gamma \gtrsim 3$, we can adjust the jet finding algorithm to try and catch all jets in a single large jet.
4. If there is just one lepton and missing energy, we can combine these into a $W$.

We will use a two step method for reconstructing top jets.

# The kT-jet Algorithm

We would like an infrared safe method for finding jets. It would merge soft collinear tracks together, and repeat until some cutoff.

1. Define some distance between jets $d_{ij} = min(E_{Ti}^2, E_{Tj}^2)\frac{\Delta R_{ij}}{\Delta R_{k_T}}$.
   - $\Delta R_{ij} = \sqrt{\Delta\eta_{ij}^2 + \Delta\phi_{ij}^2}$.
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3. If $d_{ij} < d_{ii}$, merge those two tracks together.
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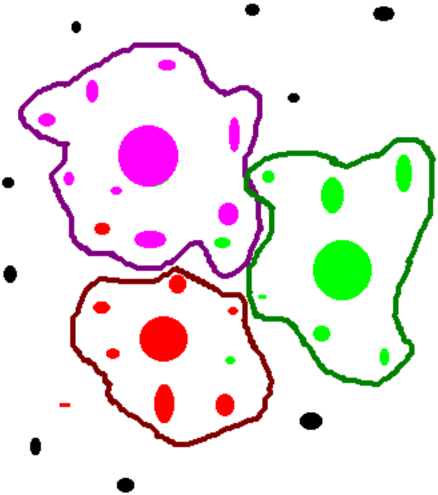
5. Repeat until all jets are a minimum distance $\Delta R_{k_T}$ apart.

# The Two-Step Reconstruction Method



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- Once this is completed, all jets with a jet mass between 125 GeV and 225 GeV will be reclassified as top jets.

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4. Limit top background by requiring large $M_{eff} \gtrsim 1500$ GeV, where $M_{eff}$ is the sum of $p_T$ of all tracks.
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5. Limit QCD multijet background by requiring four jets with $p_T > 100$ GeV.
6. Require two or more hard $b$-jets $p_T > 100$ GeV to ensure that tops are present.

To get our signal, we get the invariant mass of all combinations of top jets, then look for a peak.

# Generating Signals and Background

- Largest background will be from $t\bar{t} + n$ jets.
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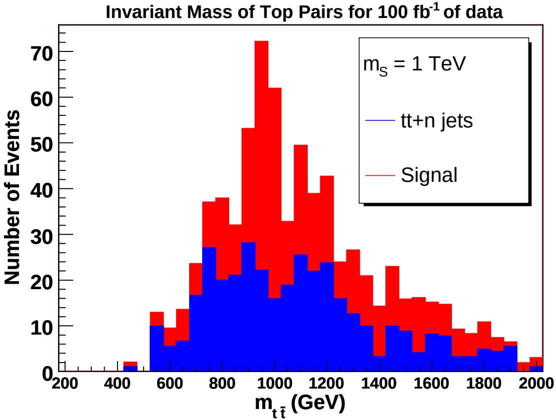
- Showered in PYTHIA.
- Used PGS detector simulation [Conway].

# Neutral Octet Pair Production - Four Top Quarks

- We do not reconstruct the leptonic tops in order to limit the $t\bar{t}$ background.

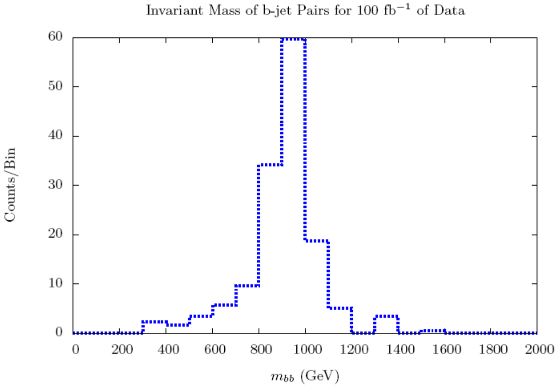


# Neutral Octet Pair Production - Four Bottom Quarks

- Can decay to *b*-quarks if the ratio $\eta_D/\eta_U \sim 40$.

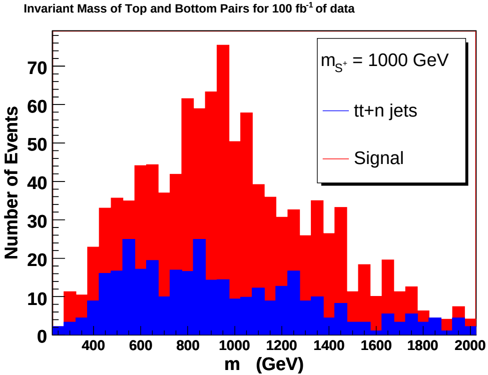
$$\mathcal{L} \supset \eta_U \bar{Q}_L \mathbf{y_u} u_R S + \eta_D \bar{Q}_L \mathbf{y_d} d_R S + h.c.$$

- No leptons, but can require four *b*-jets with $p_T > 200$ GeV.



# Charged Octet Pair Production - Top and Bottom Quarks

- Include leptonically reconstructed tops.
- Require more *b*-tags.
- Take invariant masses of all top-bottom pairs.



# Work Not Mentioned and Outlook

Not mentioned:

- Can get single production via gluon fusion with large $\eta$, but it is hurt by large backgrounds.
- Can look at couplings to Higgs via $S^+S^-h$ production, but need light scalars and stable charged octets.

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Further Areas:

- Look at reconstructing top jets by looking at $k_T$ substructure.
- Look at using muons from W-decays in a jet to identify the top jet.