Search for resonances decaying into top quark pairs with ATLAS

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*SUSY09: the 17th International Conference on Supersymmetry
and the Unification of Fundamental Interactions*

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BSM through $t\bar{t}$ resonances

- $t\bar{t}$ is one of the key channels for searching for the BSM physics.
- A BSM particle is predicted to be strongly coupled with top quark.
  - $\sigma\{\text{KKgluon}(1\text{TeV})\} = \mathcal{O}(10\text{pb})$
  - $\text{Br}\{\text{KKgluon} \rightarrow t\bar{t}\} = 92\%$
- If there is an anomaly in dijet channel, other decay channel is important to understand its characteristics.
- Tevatron experiments exclude part of the mass region for $t\bar{t}$ exotic particles.

$$pp \rightarrow X \rightarrow t\bar{t}$$

Topcolor Z' excluded for $M < 800\text{GeV}$

Background of $t\bar{t}b\bar{b}$ resonances

- Main background of $t\bar{t}b\bar{b}$ resonance is QCD multi-jet events.
  - and SM $t\bar{t}b\bar{b}$ events.

B. Lillie et. al
JHEP0709:074,2007

KK gluon invariant mass distribution of bulk RS model
in large QCD background.

1lepton channel to search for resonance

- Golden channel in terms of searching for $t\bar{t}$ resonance.

Standard reconstruction of $t\bar{t}$ resonances

- Event selection with:
  - One isolated electron or muon
  - At least 4jets
    - in which 2jets tagged as b-jets
  - $E_T^{\text{miss}} > 20\text{GeV}$
- Full reconstruction with a semi-leptonic decay top ($\rightarrow b\nu$) and a hadronic decay top ($\rightarrow bqq$).
  - Use W-mass constraint for W reconstruction

Expected sensitivity for $t\bar{t}$ resonance

- Benchmark based on narrow $Z' \rightarrow t\bar{t}$ resonance.

~7pb for M=1TeV

- Worse sensitivity at higher mass due to the decreasing of reconstruction efficiency of $t\bar{t}$ resonance with $M_{Z'}$.
  - Efficiency: 5% at $M_{Z'}=700\text{GeV}$, 1% at $M_{Z'}=1500\text{GeV}$
  - At high- $M_{Z'}$, overlapping jets would be more collimated.
- New techniques to reconstruct boosted high- p_T top is necessary to search for high mass BSM particles.

Difficulty to reconstruct ttbar from BSM resonances

- Due to the large mass of BSM particles, the pT of decay top is quite high.
- Hard to reconstruct such high-pT top with conventional invariant mass method.

pT of top is so high that particles end up reconstructed as one jet. (~75% within $dR < 0.4$ for 1TeV/c top)
Reconstructed as mono-jet.

Reconstruction of hadronic decay top jets

- Use of jet inv. mass
- kT algorithm is useful to see the jet substructure
  - $d_{ij} = \min(p_{Ti}^2, p_{Tj}^2) R_{ij}^2 / R^2$
  - get the kT distance (y-scale), where jets merge into $2 \rightarrow 1$ ($3 \rightarrow 2$) jet.
  - Phys.Rev.D65:096014,2002

Scale of sub-jet splitting for QCD jet (DGLAP-like) is logarithmically below the $\text{top} \rightarrow 3\text{jet}$ scale.

Invariant mass of high-pT top mono-jet

$Z'(m=2\text{TeV}) \rightarrow t\bar{t}$

QCD multi-jet

- Useful for rejection of QCD-BG, though much of QCD background is expected to remain.

kt splitting parameter of high- p_T top mono-jet

- Splitting value of 2jets $\rightarrow$ 3jets in kt jet reconstruction.

$Z'(m=2 \text{ (or 3) TeV}) \rightarrow t\bar{t}$

QCD multi-jet

Performance of high- p_T hadronic decay top reconstruction

- Cut with invariant mass and k_t splitting parameter of jets.
- In the case of $p_T=1\text{TeV}/c$, $\sim 50\%$ of top mono-jets and $\sim 5\%$ of QCD jets are identified as originated from top.

b-tagging for high- p_T top

$Z_H (m=2\text{TeV}) \rightarrow q\bar{q}$

- B-tagging for high- p_T top reconstruction has been studied.
- Light jet rejection power of ~ 6 for 60% efficient high- p_T top mono-jet identification.
  - $E_T=1\text{TeV}$ jet

Summary

- ATLAS estimated the expected 95% C.L. limits on signal production cross-section times branching ratio of $t\bar{t}$ resonances.
  - Standard reconstruction in 1lepton $t\bar{t}$ decay channel.
  - With 1fb^{-1} data, $\sigma \times \text{Br} \sim 7\text{pb}$ for $M=1\text{ TeV}$ Z' boson.
- ATLAS developed kinematic variables and selection criteria in order to reconstruct boosted top quarks with a high efficiency.
  - Jet mass, substructure.
  - b-tagging.