Hadronic W Reconstruction in \(b'b'\rightarrow\text{lepton + jets}\)

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Outline

- Introduction

- Current Analysis

- Modified Hadronic W Reconstruction
  - Jet-type Selection
  - Cut justification
  - Effect Upon Analysis

- Conclusions
I. Introduction
Motivation

- Fourth generation of quarks natural extension to SM
- Could lead to additional CP symmetry violation
- Previous searches:
  - ATLAS: 1 fb-1 (lepton+jets) $m(b') > 480$ GeV (95% CL)
  - CMS: 4.8 fb-1 (SS + tri-leptons) $m(b') > 611$ GeV (95% CL)
Decay Channel

- $b'b' \to WtWt \to WWbWWb \to \text{lepton + jets}$
  - Each $W$: leptonic or hadronic decay
    - Leptonic decay helps distinguish from bkg, but low branching ratio
  - $WWtt$ very similar to $tt \to$ follow Top Group recommendations for selecting lepton-plus-jets final state
Sources of Background

• **ttbar**
  - Most significant background
  - From MC samples (Alpgen, AcerMC + Pythia, PowHeg + Herwig, PowHeg + Pythia)

• **W+jets**
  - Data-driven estimation; MC samples normalized with scaling factor measured from data

• **QCD** (in which a jet is misidentified as a lepton)
  - Data-driven estimation; matrix method

• **Z+jets** (when a lepton is missed)
  - From MC samples (Alpgen)

• **Diboson** (WW, WZ, ZZ)
  - From MC samples (Alpgen + Herwig)

• **Single top**
  - From MC @ NLO
The Challenge:

- Very difficult to distinguish signal from background

The Strategy:

Sort events into 9 bins based on:

- Jet multiplicity
  - numJets = 6, =7, >8
- # Hadronic Ws
  - NumHadW =0, =1, >2
II. Current Analysis
Object Definitions

- Electron:
  - Tight++, Author 1 or 3, |eta| < 2.47 & out of crack, 
    Pt > 25 GeV, OQ, Isolation (90Etcone20 & 90Ptcone30),

- Muon (MuidMuon)
  - Tight, author 12, |eta| < 2.5, et> 20 GeV, jet 
    isolation (no jet within dR = 0.4), isolation 
    (etcone20 < 4.0GeV, ptcone30 < 2.5GeV), hit 
    requirement

- Jet (AntiKt4TopoEMJet)
  - El removal, |eta| < 2.5, Pt > 25 GeV, |JVF| > 0.75
Event Selection

- GRL
- Trigger
- LAr clean
- Vertex cleaning
- Only 1 lepton
- Trigger matching for lepton
- Jet cleaning
- Muon el duplicate rejection
- Triangle cut
  - Echannel: met > 300 GeV, Mwt > 30 GeV
  - Mu channel: met > 20 GeV, met + Mwt > 60 GeV
- Ht cut
Previous Hadronic W Reconstruction

- From dijet pair
  - AntiKt jet with $R = 0.4$
  - $dR < 1.0$
  - Mass window 70-100 GeV

- Fine for previous limit of ~500 GeV, but now looking at higher b' masses, looking towards 8 TeV
III. Modified Hadronic W Reconstruction
   A. Jet-type Selection
Motivation

- 'Boosted' jets a known phenomenon
  - Jets from more massive source have higher pt
  - Leads to jet overlap, perhaps even completely

- Boosting can be observed in b' signal
  - Peak at low dR increases for higher masses of b'

Normalized to 1 to compare shapes
AntiKt4 Dijet Mass

Plots normalized to 100,000 events before selection
dR < 0.8

- Used for previous reconstruction
- Peak at ~80 GeV that survives high Pt cut → Hadronic W
- Peak increases with higher masses
- Peak definition improves with Pt cut
- Potentially better for overlapping jets: would include both
- Also displays Hadronic W peak that increases with mass
- Peak definition improves with Pt cut
AntiKt4 Jet Mass

Plots normalized to 100,000 events before selection

- For jets so highly boosted they completely overlap
- Also displays Hadronic W peak that increases with mass
- Peak definition improves with Pt cut
Jet-type Comparison

### Picking which jets to use

- AntiKt10 peak larger, but less well-defined
- Combining antiKt10 jets with antiKt4 jets involves complicated overlap removal
- Combine
  - AntiKt4 single-reconstructed hadronic Ws (HadW_1j)
  - AntiKt4 dijet pair-reconstructed hadronic Ws (HadW_2j)
B. Cut Validation
Optimizing Cuts for HadW_1j

- Optimize Pt cut, mass window
- Use truth-jet matching
  - Take jets within $dR < 0.05$ and mass window 60-100 GeV of jets from truth Ws
  - Knowing what real Ws look like after being run though detector, can get range for cuts to isolate them
    - Look at $s/sqrt(b)$ within that range to decide upon final cut

- Pt cut in range 250-350 GeV

Normalized to 100,000 events before selection
Optimizing Cuts for HadW_1j

- Choose Pt cut 250 GeV
- Choose mass range 70-110 GeV

\[
\frac{s}{\sqrt{b}}: \\
\text{s = \# of signal event with \geq 1 single jet W after pre_selection} \\
\text{b = \# of bkg events with \geq 1 single jet W after pre_selection}
\]

- mWin0: 60-110GeV; mWin1: 65-105GeV; mWin2: 70-100GeV

600GeV b'  
700GeV b'  
800GeV b'

• Choose Pt cut 250 GeV
• Choose mass range 70-110 GeV
Optimizing Cuts for HadW_2j

- Optimizing Pt cut, dR cut, mass window
- Same process as for single-jet reconstructed hadronic Ws

- Choose no pt cut
- Choose mass range 70-110 GeV
- Choose dR < 0.8

Normalized to 100,000 events before selection
Proposed Hadronic $W$ Reconstruction

- Reconstruct $\text{HadW}_1 j$
  - AntiKt4 jets
  - $\text{Pt} > 250$
  - Mass 70-100 GeV

- From remaining jets, reconstruct $\text{HadW}_2 j$
  - AntiKt4 dijets
  - $\text{dR} < 0.8$
  - Mass 70-100 GeV
C. Effect Upon Analysis
Limit Setting Comparison

- No Systematics Included

![Graph showing the comparison between different reconstruction scenarios. The x-axis represents the mass of the b' particle (m_{b'} [GeV]) and the y-axis shows the cross section (σ B(b' \rightarrow tW) [pb]).]

**Previous HadW Reconstruction:**

- \( m(b') > 650 \) 
- \( m(b') > 690 \)

→ 40 GeV gain
27-bin Analysis

- Grouped by #Jets, #HadW_1j, #HadW_2j
- Significant differences between bins with more HadW_1j and HadW_2j
- Compare bins based on whether Ws are from single jet or dijets

- At high masses of $b'$ expect to look like figure above:
  - $s/\sqrt{b}$ higher for HadW_1j than HadW_2j
  - $s/\sqrt{b}$ lower for higher jet multiplicity
At low b' mass, do not observe expected trends
- Some bins value of infinity (no ttbar passed)
- See better ratios for more HadW_2j

Yet at higher masses, see trend towards expected high HadW_2j performance
Conclusion

- Improvement by using Hadronic Ws from antiKt4 single jets and dijets

- Adding HadW_1j potentially particularly helpful for 8 TeV

- Potential for further improvement in limit setting by using some recombination of 27 categories

- Worth investigating antiKt10 jets for 8 TeV
Back-up Slides
Cut optimization for HadW_2j

- $s/\sqrt{b}$:
  - $s$: number of signal events with $\geq 2$ W after pre_selection
  - $b$: number of ttbar bkg events with $\geq 1$ W after pre_selection

- $m_{\text{Win0}}$: 60-110GeV; $m_{\text{Win1}}$: 65-105GeV; $m_{\text{Win2}}$: 70-100GeV

- $dR_0=0.6$, $dR_1=0.7$, $dR_2=0.8$, $dR_3=0.9$, $dR_4=1.0$

- $p_{\text{t\_cut}}$(GeV): 0., 100., 110., 120., 130., 140., 150., 160., 170., 180., 190., 200
Cut optimization for HadW_2j

- mWin0: 60-110GeV
- mWin2: 65-105GeV
- mWin2: 70-100GeV

600GeV

700GeV

800GeV