Z + jets results from DØ

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Outline

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  – Differential cross sections
  – Angular correlations
• Z+b-jets production
  – $\sigma(Z+b)/\sigma(Z+\text{jet})$ ratio
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Motivation

• Vector bosons production in association with jets can serve as an important test of perturbative QCD calculations

• As a background, they contribute to many other processes and searches, such as ttbar production, Higgs, SUSY signatures

• Measurements of events kinematic properties are important for tuning MC event generators applicable at the Tevatron and LHC
DØ has recorded more than 8 fb\(^{-1}\) of data

Current Z+jets results are based on 1 fb\(^{-1}\) and σ(Z+b)/σ(Z+jet) analysis – on 4.2 fb\(^{-1}\) of data
$Z/\gamma^* \rightarrow e^+e^-/\mu^+\mu^-$ candidates

- $Z/\gamma^* \rightarrow e^+e^-/\mu^+\mu^-$ decays are easily identified with little background

- $Z/\gamma^* \rightarrow \mu^+\mu^-$ typical selections:
  - Suite of single/dimuon triggers, ~90% efficient
  - $p_T > 10$ GeV, $|\eta| < 2$
  - $65$ GeV $< M_{\mu\mu} < 115$ GeV

- $Z/\gamma^* \rightarrow e^+e^-$ typical selections:
  - Suite of single/diEM triggers, ~100% efficient
  - $p_T > 15$ GeV, $|\eta| < 2.5$
  - $65$ GeV $< M_{ee} < 115$ GeV
Selection of jets

• Jets are identified with the DØ Run II midpoint cone algorithm
  – $R_{\text{cone}} = 0.5$, $p_T > 15$ GeV, $|y| < 2.8$

• Jets are corrected for the calorimeter response, instrumental out-of-cone showering and pile-up effects

• These jet energy scale corrections are determined in-situ using $\gamma$+jet, di-jet and minimum bias collider data

• Resulting calorimeter jets are corrected to the particle level jets using detailed simulations of the DØ detector

• These particle level jets then are unfolded for the detector resolution effects and compared to a model/theory predictions
pQCD calculations and MC event generators

• Z+2 jets (+3 jets) at NLO (LO) evaluated with MCFM v5.4
  - $\mu_r^2 = \mu_f^2 = p^2_{T,Z} + M^2_Z$

• Parton shower event generators
  - PYTHIA v6.420
    - Tune Perugia ($p_T$ ordered showers)
    - Tune QW ($Q^2$ ordered showers)
  - HERWIG v6.510 +JIMMY v4.31

• Matrix element generators matched with parton shower generators
  - ALPGEN v2.13+PYTHIA v6.420
  - ALPGEN v2.13+HERWIG v6.510
  - Sherpa 1.1.3
$Z/\gamma^* (\rightarrow \mu^+ \mu^-) + \text{jets production (1)}$

- Differential cross sections in $p_T$ and $y$ of the leading jet

- NLO pQCD better describes data
$Z/\gamma^*(\rightarrow \mu^+\mu^-) + \text{jets production (2)}$

- Differential cross sections in $p_T$ and $y$ of the Z boson

- NLO pQCD better describes data at large $p_T^Z$
$Z/\gamma^* (\rightarrow e^+e^-) + N \text{ jets production}$ (1)

- Normalized differential cross section in $p_T$ of the leading jet

- Data described well by NLO QCD
\( Z/\gamma^* (\rightarrow e^+e^-) + N \) jets production (2)

- Normalized differential cross section in \( p_T \) of the 2\(^{nd}\) jet

- Data described well by NLO QCD
$Z/\gamma^* (\rightarrow e^+e^-) + \text{N jets production}$ (3)

- Normalized differential cross section in $p_T$ of the 3rd jet

- MCFM LO and Sherpa are preferred. Uncertainties in data and predictions due to scale variations are large
$Z/\gamma^* (\rightarrow \mu^+\mu^-)$ + jets: angular correlations

- Normalized diff. cross section in $\Delta\phi(Z,\text{leading jet})$, $p_T^Z > 25$ GeV


- Sherpa is preferred by data
$Z/\gamma^*(\rightarrow \mu^+\mu^-) +\text{jets: rapidity correlations}$

- Normalized diff. cross section in $\Delta y(Z,\text{leading jet})$, $p_T^Z > 25$ GeV

- NLO pQCD is preferred by data
• Event Selection
  • Dilepton mass $70 \leq M \leq 110$ GeV
  • $\geq 1$ jet: $p_T > 20$ GeV, $|\eta| < 1.1$

• Inputs for NN tagging algorithm
  – Decay length significance of sec. vtx.
  – No. of tracks associated to sec. vtx.
  – Mass of the sec. vertex
  – (reduced) Jet Lifetime Probability, $rJLIP$: confidence level that all tracks in a jet originate from primary vertex
  – etc., 9 in total

Before tagging

\[ \sigma(Z+b)/\sigma(Z+\text{jet}) \] ratio measurement
Separation of light, c and b jets

- Apply Neural Network tagging algorithm on jets to enrich b content
- Use rJLIP variable to discriminate between light, c and b jets
- Light jet template is derived from “Negatively Tagged” (NT) data
  - Jets are formed from tracks that have negative values for some of the inputs for the NN algorithm
- Use Alpgen+Pythia for b and c jet templates
- Use log likelihood fit to extract Z+b fraction from the preselected sample
${\sigma(Z+b)}/{\sigma(Z+\text{jet})}$: preliminary results

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>$Z+b$ fraction</td>
<td>$0.191 \pm 0.030$</td>
</tr>
<tr>
<td>$Z+c$ fraction</td>
<td>$0.384 \pm 0.072$</td>
</tr>
<tr>
<td>$Z+$light jet fraction</td>
<td>$0.424 \pm 0.054$</td>
</tr>
<tr>
<td>$\sigma(Z+b)/\sigma(Z+\text{jet})_{\text{NLO/MCFM}}$</td>
<td>$0.0176 \pm 0.0024$ (stat) $\pm 0.0023$ (syst) $0.0184 \pm 0.0022$</td>
</tr>
</tbody>
</table>
· DØ has an active program to measure various properties of vector boson production in association with jets

· First measurement at hadron collider for: $\Delta \phi(Z, \text{jet}), \Delta y(Z, \text{jet})$

· Generally, NLO pQCD calculations using MCFM describe data well, while Sherpa and Alpgen require large scaling

· Preliminary result for $\sigma(Z+b)/\sigma(Z+\text{jet})$ agrees well with the theoretical prediction given by MCFM

· More results on vector boson production in association with (b/c) jets are expected soon