Z+Jets Measurements with the DØ Detector

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Tevatron Collider in Run II

- Colliding protons and antiprotons at $\sqrt{s} = 1.96$ TeV
- 36 x 36 proton and antiproton bunches with 396 ns bunch crossing time
- Peak instantaneous luminosity during Run Ila
  $2 \times 10^{32} \text{cm}^{-2}\text{s}^{-1}$
- High luminosity Run IIb about to start
The DØ Detector

- Silicon and Fiber Trackers in 2T Solenoidal Magnetic Field
  - Additional layer of silicon added
- Liquid-Argon/Uranium Calorimeter
- Muon System in 1.8T Toroidal Magnetic Field
- DAQ & Trigger Systems
  - Upgraded L1 and L2 trigger systems
DØ Data Taking

Run II Integrated Luminosity

Delivered = 1.41 fb$^{-1}$
On tape = 1.18 fb$^{-1}$

- Run I = 130pb$^{-1}$ recorded
- Results presented are based on 343 & 950 pb$^{-1}$ of data
Z + Jets Measurements

- Associated production of vector bosons with jets provides a clean event signature

\[ \text{LO } Z+1 \text{ parton diagrams} \]

- Important background for particle searches
Z + Jets Measurements

- Test of QCD at hadron colliders
- Comparing data to MC samples that match matrix element calculations with parton shower simulations:
  - Over the past years these new 'matched' MC samples started to emerge
  - Generate $2\rightarrow N$ tree-level matrix element processes: hard jets
  - Use parton shower (+ hadronization) simulation to populate the rest of phase space: soft/collinear jets
  - Match the two domains consistently (CKKW*)

* Catani, Krauss, Kuhn, Webber: hep-ph/0109213
Z + n Jets: Data vs MC

- How well can we model jet production in Z/γ* events?
- Using CKKW-matched MC sample: SHERPA
- PYTHIA as reference
- Data to MC comparison:
  - \( L_{\text{int}} = 950 \text{ pb}^{-1} \)
  - Electrons: 2 high \( p_T \) electrons (\( p_T > 25 \text{ GeV} \))
  - Z Bosons: 70 GeV < \( M_{ee} < 100 \text{ GeV} \)
  - Jets (Run II Midpoint 0.5 Cone Alg.): \( p_T > 15 \text{ GeV} \)
$Z + n$ Jets: $p_T(Z)$

$p_T$ distribution of the di-electron system ($Z$)

- too few $Z$ bosons with large $p_T$
- lack of hard jets

- spectrum too hard at very large $p_T$
Z + n Jets: Jet Multiplicities

- MC normalized w.r.t. total number of events observed in data
- \( MC \) range stat: central value \( \pm 1 \sigma_{\text{stat}} \) for MC
- \( MC \) range stat & sys: central value \( \pm \) stat and sys
- Main data error due to jet energy scale uncertainties

- too few multijet events
Z + n Jets: Jet $p_T$

**Z + n Jets: Jet $p_T$**

**DO RunII Preliminary**

**Nr. of Events**

**Pt $1^{st}$ jet [GeV]**

**Pt $2^{nd}$ jet [GeV]**

**Pt $3^{rd}$ jet [GeV]**

**Pythia**

**Sherpa**

Marc Buehler, UVa

SUSY 06, UC Irvine
$Z + n$ Jets Cross Sections

- $Z/\gamma^* (\rightarrow e^+e^-) + \geq n$ Jets cross section measurement:
  - $L_{\text{int}} = 343$ pb$^{-1}$
  - Electrons: 2 high $p_T$ “central” electrons ($p_T > 25$ GeV)
  - $Z$ Bosons: $75$ GeV $< M_{ee} < 105$ GeV
  - Jets ($Run$ $II$ $Midpoint$ $0.5$ $Cone$ $Algorithm$): $p_T > 20$ GeV

Event Statistics

<table>
<thead>
<tr>
<th>Sample</th>
<th>N</th>
<th>Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z/\gamma^* + 0$ jets</td>
<td>12,247</td>
<td>0.8815</td>
</tr>
<tr>
<td>$Z/\gamma^* + 1$ jets</td>
<td>1,427</td>
<td>0.1027</td>
</tr>
<tr>
<td>$Z/\gamma^* + 2$ jets</td>
<td>189</td>
<td>0.0136</td>
</tr>
<tr>
<td>$Z/\gamma^* + 3$ jets</td>
<td>25</td>
<td>0.0018</td>
</tr>
<tr>
<td>$Z/\gamma^* + 4$ jets</td>
<td>3</td>
<td>0.0002</td>
</tr>
<tr>
<td>$Z/\gamma^* + 5$ jets</td>
<td>2</td>
<td>0.0001</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>13,893</td>
<td>1.0000</td>
</tr>
</tbody>
</table>
Data vs MC: Electrons and Zs

- $Z/\gamma^* (\rightarrow e^+e^-) + \geq 1$ Jets
- $\sim 1.6k$ events in data
- Compared to ALPGEN+PYTHIA MC

Mass = 91.40 GeV
Width = 4.09 GeV

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Data vs MC: Electrons and Zs

- $Z/\gamma^* (\rightarrow e^+e^-) + \geq 2$ Jets
- ~200 events in data
- Compared to ALPGEN+PYTHIA MC

Mass = 91.47 GeV
Width = 3.72 GeV
Data vs MC: Jets

Jet $p_T$ data to theory (ME-PS) comparison for

![Graph showing comparison between data and MC for jet $p_T$. The graph plots jet $p_T$ against number of events, showing three categories: 3rd jet $p_T$ in events with $n \geq 3$ jets, 2nd jet $p_T$ in events with $n \geq 2$ jets, and leading jet $p_T$ in events with $n \geq 1$ jets.]}
Z + n Jets Cross Sections

- $Z/\gamma^* (\to e^+e^-) + \geq n$ Jets cross sections are normalized w.r.t. inclusive $Z/\gamma^* \to e^+e^-$ cross section
- Results are corrected for jet energy resolution effects (unsmeared)
- Comparing data to:
  - NLO calculation (MCFM)
  - Matched sample (ME-PS)
  - Pythia
- Main systematics:
  - Jet Energy Scale
  - Jet reco/ID

![Graph showing Z + n Jets Cross Sections comparison]
Summary and Outlook

- Z+Jet cross section measurements and comparisons using ME-PS *matched* samples have been presented
- Run IIb with improved DØ detector and much higher luminosity is around the corner
- Entering the realm of fb⁻¹ datasets
- Exciting discoveries coming up next ...