W / Z + jet production at CDF
1. Introduction
2. Inclusive measurements
3. Heavy flavour measurements
4. Conclusions

CDF
Motivation
Measurements

CDF

p \bar{p} collisions at \sqrt{s} = 1.96 \text{ TeV}

Up to 2.5 fb\(^{-1}\) used in reported analyses
QCD tests:

- Test of perturbative QCD ($W, Z$ ensures high $Q^2$)
- $W, Z + b$ jet production potentially sensitive to $b$ content of proton

**Background process:**

- Standard Model (eg. top)
- New physics (Higgs, SUSY)
Inclusive measurements:
- $W + \text{jets}$
- $Z + \text{jets}$

Heavy flavour measurements:
- $Z^+ \text{ b jets}$
- $W^+ \text{ b jets}$

Not included:
- $W + \text{c jets}$
- Inclusive $W, Z$
**Trigger** on high $E_T$ central electron

**Identify $W$:**
$E_T^e > 20$ GeV, $|\eta^e| < 1.1$
Missing $E_T > 30$ GeV
$m_T > 20$ GeV/$c^2$

**Identify jets:** Jetclu cone $0.4$ jet with $E_T>20$ GeV, $|\eta|<2.0$
$\Delta R^{e-jet} > 0.52$

Measure $\sigma$ at hadron level as function of $E_T^{jet}$ cf. LO, NLO predictions

**Backgrounds** $\sim 10\text{-}40\% \rightarrow 90\%$ depending on $E_T^{jet}$

**Systematics:** $\sim 20\% \rightarrow 50\text{-}80\%$

• jet energy scale (background) at low (high) $E_T^{jet}$
NLO: MCFM (W + 1 and 2 jet available)

LO: ME+PS + nonpQCD correction:


Agreement with NLO good.

LO low.
Trigger on high $E_T$ central electron

Identify $Z$:
- $E_T^e > 25$ GeV,
- $|\eta_1^e| < 1.0$, $|\eta_2^e| < 1.0$ OR $1.2 < |\eta_2^e| < 2.8$,
- $66 < M_{ee} < 116$ GeV/$c^2$

Identify jet; midpoint cone 0.7 jet, $R_{sep} 1.3$, with $p_T > 30$ GeV, $|y| < 2.1$

Measure $\sigma$ at hadron level as function of $p_T^{jet}$, cf. NLO predictions.

Backgrounds low (~12% for ≥1 jet)

Good agreement with NLO (MCFM + CTEQ6M, corrected for UE, fragmentation)

Corrections largest at low $E_T$
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Systematics dominated by:
- scale dependance (th.)
- jet energy scale (exp.).
1. Introduction

2. Inclusive measurements

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NLO describes data well
LO low by factor 1.4
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2 fb⁻¹

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Trigger on $Z \rightarrow e^+e^- (|\eta|<2.5)$, $\mu^+\mu^- (|\eta|<1.5)$

Identify b jet; Jetclu cone 0.7 jet with $E_T > 20$ GeV, $|\eta| < 1.5$, secondary vertex tag.

Estimate b fraction by secondary vertex tag, fit sec. vertex mass to MC templates to obtain b fraction.

Measure $\sigma$ at hadron level, compare to LO, NLO

### Table

<table>
<thead>
<tr>
<th></th>
<th>data</th>
<th>Alpgen</th>
<th>Pythia</th>
<th>MCFM ($Q^2 = m_Z^2 + p_{Tj}^2$)</th>
<th>MCFM ($Q^2 = &lt;p_{Tj}&gt;^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma(Z + b)$ / $\sigma(Z)$</td>
<td>$(3.32 \pm 0.53 \pm 0.42) \times 10^{-3}$</td>
<td>$2.1 \times 10^{-3}$</td>
<td>$3.5 \times 10^{-3}$</td>
<td>$2.3 \times 10^{-3}$</td>
<td>$2.8 \times 10^{-3}$</td>
</tr>
<tr>
<td>$\sigma(Z + b)$ / $\sigma(Z + j)$</td>
<td>$(2.08 \pm 0.33 \pm 0.34)$ %</td>
<td>$1.5$ %</td>
<td>$2.2$ %</td>
<td>$1.8$ %</td>
<td>$2.2$ %</td>
</tr>
</tbody>
</table>
NLO, LO at low scale describe data well.

NLO, LO at high scale are low.
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NLO, LO at low scale describe data well.
NLO, LO at high scale are low.
Trigger on high $E_T$ central electron or muon

Identify $W$:
- $e$: $E_T > 20$ GeV, $|\eta| < 1.1$
- $\mu$: $p_T > 20$ GeV/c, $|\eta| < 1.0$
- $\nu$: Missing $E_T > 25$ GeV

Identify $b$ jet: Jetclu cone 0.4 jet with $E_T > 20$ GeV, $|\eta| < 2.0$, sec. vertex.

Compare inclusive cross-section to LO: ALPGEN + CTEQ5L

Yield: ~ 496 signal events, ~180 background (70% $t\bar{t}$ or single $t$)
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Results:
in events with a $p_T > 20$ GeV/c, $|\eta| < 1.1$ electron or muon, a $p_T > 25$ GeV/c neutrino, and 1 or 2 $E_T > 20$ GeV, $|\eta| < 2.0$ jets regardless of species.

**Data:** $\sigma_{bjets}(W + b jets) \times BR(W \rightarrow l\nu) = 2.74 \pm 0.27 \pm 0.42 \text{ pb}$

**LO:** ALPGEN: $\sigma \cdot BR = 0.78 \text{ pb}$

**LO factor 3 low** (nb. high scale)
- awaiting NLO comparison.
W/Z + jet production measured at CDF on datasets up to 2.5 fb\(^{-1}\)

Inclusive measurements:

- LO estimates low
- NLO estimates show good agreement
- correction for U.E. and fragmentation needed at low \(E_{T}^{\text{jet}}\)

Heavy flavour measurements:

- NLO, LO estimates at high scales low.
- NLO, LO estimates at lower scales agree with data.
Backup
Systematic dominated by scale dependance (th.), jet energy scale (exp.).

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Identifying b jets

**Tagging algorithm:**
Consider tracks in \(\eta-\phi\) 0.4 cone around jet axis
Find secondary vertex from displaced tracks
Large transverse displacement = b tagged.

**Purity:** fit invariant mass to template shapes (MC or data), 45-70%

**Efficiency:** 20-40% dependent on operating point.