Measurement of $d\sigma(Z/\gamma^*\to e^+e^-)/dy$
at DØ

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**Z/γ* Production at Tevatron**

- Measure at high Q\(^2\), large and small x
  - At 1.96 TeV, \( Y_{\text{max}} \sim 3.0, \ x \sim 10^{-3} \)
  - \( Q^2 \sim M_Z^2 \)
  - Cover some area not covered by jets
  - Different systematics than jets
  - Reach larger \( x_{\text{f}} = x_1 - x_2 \) than fixed target experiment

\[
\sqrt{s} = 1960 \text{ GeV}
\]

\[
x = M_Z e^{-y} S^{-1/2}
\]

\[
x = M_Z e^y S^{-1/2}
\]

\[
x_1 + x_2 = M_Z^2 e^y S^{-1/2}
\]
NNLO Theoretical Calculation

• Help us better understand parton distribution functions
• Provide a method to test NNLO theoretical calculation
• Test PDF at high $Q^2$ ($\sim 91^2$) and higher $x_F$

*Calculation based on Anastasiou, Phys Rev D 69 094008(2004)*
Measurement Strategies

Differential cross section:

\[
\frac{d\sigma(Z/\gamma^* \rightarrow e^+ e^-)}{dy} = \frac{N_i - B_i}{\Delta_i (\varepsilon A)_i \mathcal{L}}
\]

A: boson acceptance  
\(\varepsilon\): boson efficiency  
\(\mathcal{L}\): Integrated luminosity  
N: Total events  
B: Background  
i : boson rapidity bin

Strategies:

• Look for di-electron events  
• Determine number of Z and Drell-Yan events from electrons  
• Estimate background  
• Determine Z and Drell-Yan selection efficiency from single electron cut efficiencies  
• Determine acceptance using Monte Carlo simulation
$Z/\gamma^* \rightarrow e^- e^+$ Events Selection

- Total integrated luminosity: $337\text{pb}^{-1}$
- Look for events with two good high $P_T$ electrons:
  - $P_{e1}^T > 15 \text{ GeV}$, $P_{e2}^T > 25 \text{ GeV}$
  - With two track matching in central and at least one track matching in forward
- $Z/\gamma^*$ invariant mass window $71 < M_{ee} < 111 \text{ GeV}$
- Bin events in boson rapidity bins:
  - $Y_{Z/\gamma^*} = \frac{1}{2} \ln \frac{E + P_Z}{E - P_Z}$
Background Distribution

• Main background sources:
  • Di-jets, jet fakes electron
  • W+jets, jet fakes electron
  • Determine background ratio within mass window from fitting
**Single Electron Cut Efficiencies**

Use $Z \rightarrow e^+ e^-$ events:

- Tag electron: passes all quality cuts
- Probe electron: apply the cut to be measured

Pass or fail cut?

\[
\varepsilon = \frac{N_{pass}}{N_{pass} + N_{fail}}
\]

- Single electron selection efficiencies
  - Electron ID efficiency (electron shower shape, ID, etc)
  - Trigger efficiency
  - Track matching efficiency

![Track matching Efficiency](image)
Use single electron efficiencies to determine Boson efficiency:

- Generate $Z/\gamma^* \rightarrow e^+e^-$ events using Pythia and CTEQ6M PDFs
- Smear electron energy and angular distribution with fast detector simulation code
- Determining smeared electron to PASS or FAIL single electron efficiencies by a flat random number generator
- Count how many $Z/\gamma^*$ events passed

Total 10M events generated:

$$\varepsilon A = \frac{\text{Number of } Z/\gamma^* \text{ passed}}{\text{Number of } Z/\gamma^* \text{ generated}}$$

- Central-Central: $(10.640 \pm 0.035)\%$
- Central-forward: $(11.315 \pm 0.036)\%$
- forward-forward: $(2.191 \pm 0.017)\%$
Data and Monte Carlo Comparison

- Verify the boson efficiency $\times$ acceptance is correct by comparing output distribution from Monte Carlo with data.

![Electrons w/ Track Match](image1)

- MC
  - Data

![Electrons in CC Region](image2)

- MC
  - Data

electron detector $\eta$ distribution

electron Pt distribution
Sources of Systematic Uncertainties

Five major sources:

- Single Electron efficiencies measurement
  - from single electron efficiencies measurement
  - from background subtraction method
- EM Energy Scale
  - from calorimeter EM energy scale calibration
- PDFs
  - from choice of different PDF sets
- Z boson $P_T$ and vertex uncertainty
  - difference between Monte Carlo and the data
Estimate Systematics: from Efficiencies

- From single electron efficiencies measurement: (statistical and correlated):
  - repeat boson $\varepsilon \times A$ calculation with single electron efficiencies varied randomly within their statistical error distributions
Estimate Systematics: from PDFs

- We use CTEQ6M PDF to determine acceptance
  - CTEQ6M is determined by 20 parameters,
  - Shift each parameter by ±1σ, total 40 PDFs
  - Use 40 PDFs in Monte Carlo generator, total 6M events generated
  - Use difference on ε×A as systematics
Total Systematics

- PDFs: $\sim 1.5\%$ ($|Y| \sim 0$) $\sim 10\%$ ($|Y| > 2$)
- Efficiencies $\sim 1.2\%$ ($|Y| \sim 0$) $\sim 20\%$ ($|Y| > 2$)
Differential Cross Section

* NNLO calculation based on Anastasiou Phys ReV D 69, 094008(2004) with latest PDF sets
Conclusion

Z/γ* rapidity distribution measurement at DØ

• Provide rapidity distribution over almost entire kinematic region at center of mass energy of 1.96 TeV

• Test with differential cross section from NNLO with latest MRST, CTEQ and Alekhin PDF sets

• Data agrees with NNLO calculation

• Approved as a preliminary result in Spring '05

• Currently updating the result to
  → Include Summer '04 data
  → Switch from Pythia to resbos for acceptance determination