W and Z boson production (D0)

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Outline

• Introduction
• Electron charge asymmetry $W \rightarrow e\nu$
• A study of the $Z \rightarrow ee$ and $Z \rightarrow \mu\mu$ events at low $p_T$ using a novel technique
• Forward Backward asymmetry ($A_{FB}$) measurement
Introduction

- W and Z production at Tevatron
  \[ p \rightarrow q, \bar{q}' \rightarrow W^\pm, q \rightarrow l^\pm, q \]
  \[ \bar{p} \rightarrow \nu, q' \rightarrow l^+, \bar{q} \]

- Constrain Parton Distribution Functions (PDFs)
  - W charge asymmetry

- Test higher order QCD and QED corrections
  - Z boson A_{FB} measurement and Z$_{pt}$ measurement
D0 detector

- Important components for these analyses
  - Silicon tracker (SMT) and fiber tracker (CFT): measure tracks of decay leptons
  - Calorimeter
    - Identify and measure $E_T$ of electrons.
    - Measure the overall $E_T$ of the event and calculate MET
  - Muon system
    - Identify muons
• **Z**: two high $P_T$ charged lepton
• **W**: one high $P_T$ charged lepton and one high $P_T$ neutrino
• **Neutrino can not be detected**: Missing $E_T$ used to estimate $P_T^\nu$
W asymmetry

- On average u quark carries more momentum than d quark, which causes asymmetry in $W^+$ and $W^-$ distributions.
- Rapidity $\eta = -\ln[\tan(\theta/2)]$, $\theta$ is azimuthal angle.
- Use $W$s to probe proton structure.
- $W \rightarrow e\nu \Rightarrow$ W asymmetry hard to measure as we don’t know longitudinal momentum of neutrino.
- $W$ asymmetry $\rightarrow$ electron asymmetry.
- Electron asymmetry: $A(y) \otimes (V-A)$

$$A(y_e) = \frac{N_{e^+}(y) - N_{e^-}(y)}{N_{e^+}(y) + N_{e^-}(y)}$$
Asymmetry

- The result corrected for the detector smearing effects
- Due to CP invariance, $A(y) = -A(-y)$. The asymmetry “folded” to increase statistics.

Major collaborations that use experimental data to derive PDFs are **CTEQ** and **MRST**

- **CTEQ 6.6 NLO PDFs**

- **MRST2004**
$E_T$ bins

- Splitting analysis in $E_T$ bins allows finer probe of PDFs
- Plot below - MC simulation.

Uncertainties smaller than PDF uncertainties:
Inclusion of our results will further constrain future PDF fits and improve predictions
Low $Z_P T$ analysis using novel method

- The $Z_P T$ distribution is interesting
- Test QCD
- Understand the production of inclusive vector bosons.
- Perturbative QCD insufficient.
- NP effects absorbed into universal form factor, e.g. BLNY.
- At the tevatron the $Z_P T$ is very sensitive to the $g_2$ parameter.

\[
\frac{d\sigma}{dy dq_T^2} = \frac{\sigma_0}{S} \int \frac{d^2 b}{(2\pi)^2} e^{-i\vec{q}_T \cdot \vec{b}} \tilde{W}_{\text{PERT}} e^{-S_{\text{NP}} b^2} + Y
\]

\[
S_{\text{BLNY}}^{\text{NP}}(b, Q^2) = -g_1 - g_2 \ln \left( \frac{Q^2}{Q_0} \right) - g_1 g_3 \ln(100 x_A x_B)
\]

G.A.Ladinsky, C.P.Yuan, Phys. Rev. 50 4239 (1994);
**a_t and a_L**

- Previous measurement of the dσ/dp_T have been dominated by systematics

- “unfolding” for the lepton p_T resolution

- Correcting for the Z p_T dependence of the event selection efficiency

- Decomposing Z p_T into a_t and a_L largely fixes the problem.
Results

- Consistent measurement in di-muon and di-electron channels.
- Experimental uncertainty comparable to the world average.
- Theoretical PDF uncertainty is dominant.
**$Z/\gamma^*$ Forward-Backward asymmetry**

- $p\bar{p} \rightarrow l^+l^- :$ mediated by $\gamma^*$, $Z$, $Z/\gamma^*$

\[ A_{FB} = \frac{(\sigma_F - \sigma_B)}{(\sigma_F + \sigma_B)} = \frac{(N_F - N_B)}{(N_F + N_B)} \]
Motivation

- New resonance can interfere with Z and $\gamma^*$
- $A_{FB}$ is sensitive to $\sin^2\theta_W$

Rosner, PRD 54, 1078 (1996)
Results

- Result corrected for the detector smearing effects.
- $\sin^2 \theta_W = 0.2327 \pm 0.0018\text{(stat)} \pm 0.0006\text{(syst)}$
- $A_{FB}$ result agrees with the SM prediction.
- $\sin^2 \theta_W$ result agrees with the global EW fit

DØ 1.1 fb$^{-1}$

$\chi^2$/d.o.f. = 10.6/14

arXiv 0804.3220

50 events
Conclusions

• Many exciting W and Z results at D0

• Many in the pipeline

• W charge asymmetry - 0.75 fb\(^{-1}\), \(A_{FB}\) -1 fb\(^{-1}\), Z pT analysis - 2 fb\(^{-1}\). Now more than 6 fb\(^{-1}\) data recorded

Bright future ahead
Thank you!
g2 measurement

- Start with 15 MC samples for different values of g2.
- Data vs MC $\chi^2$ is calculated for each of the 15.
- 2nd order polynomial is fitted to the results.

![Graphs of Data vs MC $\chi^2$ for different samples.](attachment:graphs.png)
Asymmetry calculation

- Remove SM background using Monte Carlo simulated data.
- Calculate charge misidentification rate (g) and correct for it.
- Estimate QCD background using samples that pass loose and tight shower shape conditions.

\[
N_L = N_e + N_{QCD}
\]

\[
N_T = \varepsilon N_e + f N_{QCD}
\]

- \(\varepsilon\) probability for real electron to pass tight cut, given it passed loose cut.
- \(f\) same thing for fake electron.

- Calculate \(\varepsilon\), \(f\) and \(g\) first and then calculate asymmetry.