Measurements of lepton & W charge asymmetry with the D0 detector

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**W asymmetry in p-pbar collisions**

- U-quark more momentum than d quark → $W^+$ boosted in p direction (corresponding for anti-particles)

- Yields information for valence-quarks for wide range of $x$ and high $Q^2$

- In corresponding LHC measurement
  - $W$ produced from sea quarks/gluons
    - Atlas: 1109.5141
    - CMS: 1103.3470, 1312.6283

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Björn Penning - 02/09/2015 - QCD@LHC
• **Traditional**: lepton rapidity

\[ A(\eta^e) = \frac{N^{e^+}(\eta^e) - N^{e^-}(\eta^e)}{N^{e^+}(\eta^e) + N^{e^-}(\eta^e)} \]

• **W boson asymmetry and V-A structure convoluted**

• **New**: W rapidity

\[ A(y_W) = \frac{d\sigma_{W^+}}{dy_W} - \frac{d\sigma_{W^-}}{dy_W} \]
\[ + \frac{d\sigma_{W^+}}{dy_W} + \frac{d\sigma_{W^-}}{dy_W} \]

• Requires some creativity due to missing \( p_z^\nu \)
General Selection

• Using full Run II dataset: 9.7fb\(^{-1}\)
• Require exactly one electron
  - One triggered, good electron in calorimeter
  - \(\eta(e) < |1.1|\) or \(|1.5| < \eta_e < |3.2|\)
  - \(25 < p_T(e) < 100\text{ GeV},\)
  - \(E_T^{\text{miss}} > 25\text{ GeV}\)
  - \(50 < m(W) < 130\text{ GeV}\)
• Additional selections include restrictions on the z vertex range, recoil and total calorimeter activity etc
• Backgrounds include QCD, \(W\rightarrow\tau\nu, Z\rightarrow ee, Z\rightarrow\tau\tau,\)
  - Largest background is QCD (4%), no charge asymmetry
• Efficiency corrections: charge mis-ID, electron energy scale, trigger, hadronic response, electron ID efficiency, etc.
Corrections

• **Charge mis-ID:**
  Tag and probe method with \( Z \rightarrow ee \)
  - Function of \( \eta \) and \( p_T(e) \)
  - Similar efficiency in data and MC (central)
  - If necessary correct MC to match data (forward)

• **Electron energy:**
  - Use \( Z \) events to perform ‘in situ’ calibration
  - Compare to LEP value and fit for correction parameters iteratively
  - Lepton \( \eta \), luminosity and calorimeter scalar \( E_T \) dependencies
Example Distributions

Reasonable Agreement
• If the $W^+$ and $W^-$ efficiencies and acceptances are similar, we can approximate

\[ A(\eta^e) = \frac{N^{e^+}(\eta^e) - N^{e^-}(\eta^e)}{N^{e^+}(\eta^e) + N^{e^-}(\eta^e)} \]

• Perform unfolding to remove detector effects and compare with generator level
  - considering electron selection efficiencies, luminosity, and event acceptance

• 5 bins, for electron $p_T$ and/or $E_T^{\text{miss}}$ thresholds of 25 and 35 GeV (symmetric and asymmetric bins)
Uncertainties

- **Variety of systematics considered:** 1-20% for increasing $\eta$ modeling, selection efficiencies, corrections, unfolding

<table>
<thead>
<tr>
<th>$\eta^e$</th>
<th>Gen</th>
<th>EMID</th>
<th>$K_{\text{eff}}^{q,p}$</th>
<th>Energy</th>
<th>Recoil</th>
<th>Model</th>
<th>Bkgs</th>
<th>$Q_{\text{mis}}$</th>
<th>Unfolding</th>
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- **Example:** symmetric selection $E_T^{\text{miss}} > 25$ GeV, $E_T > 25$ GeV
Results

- Results shown in detailed tables for each $\eta$-bin and selection

| $\langle|\eta^c|\rangle$ | $25 < E_T^c < 35$ GeV | $25 < E_T^c < 35$ GeV |
|----------------|------------------------|------------------------|
|                | $\langle \not{E}_T \rangle > 25$ GeV | $\langle \not{E}_T \rangle < 35$ GeV |
| Data | Prediction | Data | Prediction |
| 0.10 | $2.32 \pm 0.16 \pm 0.24$ | $2.47 \pm 0.21$ | $2.30 \pm 0.19 \pm 0.27$ | $2.07 \pm 0.24$ |
| 0.30 | $6.36 \pm 0.15 \pm 0.24$ | $7.18 \pm 0.38$ | $6.93 \pm 0.18 \pm 0.28$ | $6.04 \pm 0.51$ |
| 0.50 | $10.53 \pm 0.15 \pm 0.27$ | $11.26 \pm 0.60$ | $11.31 \pm 0.17 \pm 0.31$ | $9.00 \pm 0.78$ |
| 0.70 | $12.60 \pm 0.14 \pm 0.28$ | $14.73 \pm 0.73$ | $12.97 \pm 0.17 \pm 0.31$ | $11.55 \pm 0.98$ |
| 0.90 | $14.58 \pm 0.16 \pm 0.30$ | $17.10 \pm 0.80$ | $14.92 \pm 0.18 \pm 0.32$ | $12.44 \pm 1.02$ |
| 1.10 | $14.11 \pm 0.23 \pm 0.39$ | $17.36 \pm 0.87$ | $13.85 \pm 0.27 \pm 0.44$ | $10.98 \pm 1.14$ |
| 1.39 | $9.95 \pm 0.74 \pm 0.38$ | $13.74 \pm 0.87$ | $6.63 \pm 0.88 \pm 0.45$ | $3.78 \pm 1.17$ |
| 1.70 | $-1.40 \pm 0.44 \pm 0.34$ | $3.24 \pm 0.94$ | $-7.99 \pm 0.51 \pm 0.40$ | $-12.19 \pm 1.24$ |
| 1.90 | $-12.70 \pm 1.72 \pm 0.54$ | $-8.31 \pm 0.98$ | $-21.85 \pm 1.70 \pm 0.65$ | $-27.66 \pm 1.23$ |
| 2.10 | $-28.36 \pm 0.76 \pm 0.78$ | $-21.63 \pm 1.09$ | $-40.05 \pm 0.85 \pm 0.95$ | $-42.94 \pm 1.28$ |
| 2.30 | $-41.27 \pm 0.93 \pm 1.04$ | $-33.54 \pm 1.15$ | $-52.93 \pm 1.00 \pm 1.17$ | $-53.65 \pm 1.27$ |
| 2.54 | $-50.86 \pm 0.48 \pm 1.26$ | $-44.33 \pm 1.32$ | $-59.43 \pm 0.49 \pm 1.51$ | $-61.49 \pm 1.38$ |
| 2.92 | $-60.00 \pm 1.04 \pm 2.75$ | $-55.99 \pm 2.05$ | $-64.68 \pm 1.07 \pm 2.94$ | $-69.79 \pm 2.13$ |

- Predictions from MC@NLO + NNPDF2.3
Results Symmetric Selections

(a) \( E_T^{\text{miss}} > 25 \text{ GeV} \)

(b) \( E_T^{\text{miss}} > 35 \text{ GeV} \)

DØ, 9.7 fb\(^{-1} \)

MC@NLO NNPDF2.3

NNPDF2.3 uncertainty

MC@NLO MSTW2008NLO

RESBOS CTEQ6.6

DØ A\(_e\), 7.3 fb\(^{-1} \)

DØ A\(_\mu\), 7.3 fb\(^{-1} \)

DØ A\(_e\), 9.7 fb\(^{-1} \)

DØ A\(_\mu\), 9.7 fb\(^{-1} \)

E\(_T^e\) > 25 GeV

\( \not{E}_T > 25 \text{ GeV} \)

E\(_T^e\) > 35 GeV

\( \not{E}_T > 35 \text{ GeV} \)
**Fig. 15:** (color online). The lepton charge asymmetry distribution after CP folding with symmetric kinematic cuts $<25\text{ GeV}$. (a) Comparison between the measured asymmetry and predictions using the NNPDF2.3 PDF set. The red dashed lines and cyan vertical bars show the total uncertainty. The green dot-dashed lines show the predicted central value from the total uncertainty. The red triangles show the published data and MC predictions and the predicted central value from the central PDF set, and the horizontal bars show statistical uncertainty and the vertical line showing the total uncertainty. The red dashed lines and cyan vertical bars show the total uncertainty. The green dot-dashed lines show the predicted central value from the total uncertainty. The red triangles show the published data and MC predictions and the predicted central value from the central PDF set, and the horizontal bars show statistical uncertainty and the vertical line showing the total uncertainty.

**Fig. 16:** (color online). The electron charge asymmetry distribution. The blue dotted lines show the prediction from the CTEQ6.6 central PDF set. The black dots show the measured electron charge asymmetry, with the horizontal bars showing statistical uncertainty and the vertical lines showing the total uncertainty. The red dashed lines and cyan vertical bars show the total uncertainty. The green dot-dashed lines show the predicted central value from the total uncertainty.
Results Asymmetric Selections

25 < E_{T^{(miss)}} < 35

25 < E_T < 35
E_T^{miss} > 25

E_T > 35
E_T^{miss} > 25
Results Asymmetric Selections

25 < \(E_T^{(\text{miss})}<35\)

No agreement with any predictions

25 < \(E_T<35\)

Agrees with RESBOS + CTEQ6.6

\(E_T^{(\text{miss}}>25\)

Agrees with RESBOS + CTEQ6.6

\(E_T>35\)

\(E_T^{(\text{miss}})>25\)
Comparison with CDF

- CDF, D0 agrees well
W Asymmetry Overview

- Asymmetry is difference in $W$ differential cross-sections (in rapidity) over total.

- Unknown neutrino $z$ value is an issue

- Well known $m(W)$, use to determine $z$ momentum within some two-fold ambiguity:

\[ y_W = \frac{1}{2} \ln \frac{E + p_z}{E - p_z} \]

\[ M_W^2 = (E_e + E_\nu)^2 - (\vec{P}_e + \vec{P}_\nu)^2 \]

- In case of complex $p_z(\nu)$ assume $E_T^{\text{miss}}$ is mis-reconstructed and scale accordingly

- Ambiguity resolved by assigning weights to the event, for each solution, related to $\cos\theta^*$, $W$ rapidity and $p_T(W)$
W Asym Results

Good agreement with predictions
Summary

• New $W$ charge asymmetry measurements using the full Run II dataset in $W\to e\nu$ decays

• Two separate methods to measure charge asymmetry:
  
  - Difference charged electron number (arXiv:1412.2862)
  - Reconstructing the $W$ using neutrino weighting (arXiv:1312.2895)

• Probe different phase space than LHC

• Measurements agree with previous Tevatron results

• Most precise measurements to date, and should be useful for PDF fits

• From recent CT14 paper (1506.07443):
  
  "....these new $A_{ch}$ data sets are perhaps the most challenging and valuable among all that were added in CT14"