W and Anomalous Single Top Production

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- Introduction
- Isolated Leptons with High $P_{T,\text{miss}}$
- Cross Section Determination
- Measurement of $W$ Polarisation Fractions
- Anomalous Single Top Production
- Conclusions

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Isolated Leptons With Large Missing Transverse Momentum

Observation of events with isolated lepton & large missing $P_T$

Main SM contribution: real $W$ production
- hadronic system of typically low $P_T^{X}$

Interpreted in 3 ways here:
- generic analysis of this event topology
- in context of $W$ production
- anomalous single top production (at high $P_T^{X}$)

Two small SM contributions to signal topology

CC $W$ prod. $\sim 7\%$

Cabibo-Parisi $Z^{0}$ production $\sim 3\%$ (e channel only)
Quick reminder of event selection in both channels

\[ 5^\circ < \theta_{\text{lep}} < 140^\circ \]
\[ P_{T,e/\mu} > 10 \text{ GeV} \]
\[ P_{T,\text{miss}} > 12 \text{ GeV} \]
lepton-jet distance > 1 unit in \( \eta-\Phi \)

Further selections applied for background rejection (see previous talk)

Use complete HERA I+II data set 478 pb\(^{-1}\)
(e\(^+\)p & e\(^-\)p scattering data sets)

combine electron & muon samples

Backgrounds:
Neutral Current events with fake missing \( P_T \)
Charged Current events with isolated hadron misidentified as lepton
Lepton pair production (\( \gamma\gamma \) process) with fake missing \( P_T \) and one lost lepton
Photoproduction with fake missing \( P_T \) and misidentified hadron
Sample dominated by W production (signal contribution > 70%)

Overall excellent agreement

Use this to extract cross sections

Excess visible for $P_T^X > 25$ GeV
will look at possible interpretation later...

SM uncertainty (green band)
± 15% W production
± 30% remaining SM b/g

### Table: 

<table>
<thead>
<tr>
<th>H1 $e^\pm p$ data HERA I+II (478 pb$^{-1}$)</th>
<th>e channel obs. / exp. (signal)</th>
<th>$\mu$ channel obs. / exp. (signal)</th>
<th>e and $\mu$ channels obs. / exp. (signal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full sample</td>
<td>$42 / 46.7 \pm 6.5$ (69%)</td>
<td>$17 / 12.2 \pm 1.8$ (82%)</td>
<td>$59 / 58.9 \pm 8.2$ (72%)</td>
</tr>
<tr>
<td>$P_T^X &gt; 25$ GeV</td>
<td>$14 / 8.5 \pm 1.5$ (68%)</td>
<td>$10 / 7.3 \pm 1.2$ (79%)</td>
<td>$24 / 15.8 \pm 2.3$ (73%)</td>
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</table>
Isolated Lepton and W Production Cross Sections

Use this sample to extract cross section for Isolated e/μ & Large $P_{T,\text{miss}}$: $\sigma_{\ell+P_T}$

Defined purely in terms of event topology
Includes all processes with real isolated e/μ and genuine $P_{T,\text{miss}}$:

$$\sigma = \frac{N_{\text{data}} - N_{\text{bkd}}}{L} \cdot A$$
with

$$A = \frac{N_{\text{MC}}^{\text{rec}}}{N_{\text{MC}}^{\text{gen}}}$$

smeared detector acceptance
from reconstructed & generated
SM / signal MC events

Good SM description and large W production contribution allows
cross section for single $W^{\pm}$ production ($W \rightarrow e/\mu + X$): $\sigma_W$

Differ in definition of 'signal' processes e.g. $Z^0$ production is signal for
$\sigma_{\ell+P_T}$ only

Include Branching ratio = 0.24 for $W \rightarrow e/\mu + X$

Both cross sections based on identical event selection
Excellent agreement with SM prediction

Selection gives ~35 events - study angular decay properties...
**W Polarisation Fractions**

**W polarisation fraction defined in \( \cos(\theta^*) \) variable:**
angle between decay lepton in W rest frame & W momentum in lab frame

For \( W^+ \) decays the angular distribution is given by:

\[
\frac{d\sigma_W}{d \cos \theta^*} \propto (1 - F_- - F_0) \cdot \frac{3}{8} (1 + \cos \theta^*)^2 \\
+ F_0 \cdot \frac{3}{4} (1 - \cos^2 \theta^*) \\
+ F_- \cdot \frac{3}{8} (1 - \cos \theta^*)^2.
\]

with \( F_+ \equiv 1 - F_- - F_0 \).

\( W^- \) decays the signs are swapped
So, study: \( q_l \cdot \cos(\theta^*) \)
\( q_l = \) lepton charge

Distribution for
left handed \( W^- = \) right handed \( W^+ \)
Require reliable lepton charge measurement: 
\[ \theta_l > 20^\circ \]

Charged track: curvature significance > 1

\[ \Rightarrow \text{charge misidentification} < 1\% \]

signal purity > 80%

Contains all \( W^+ \) and \( W^- \) data

Solid Blue line = 2 parameter fit to data for polarisation fractions
Perform simultaneous fit to $F_-$ and $F_+$

Results in agreement with SM

Polarisation fractions extracted in 1D fits constrained to SM for other parameter

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<th>H1</th>
<th>HERA I+II Data</th>
<th>SM</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_-$</td>
<td>$0.58 \pm 0.15 \text{ (stat)} \pm 0.12 \text{ (sys)}$</td>
<td>$0.61 \pm 0.01 \text{ (stat)}$</td>
</tr>
<tr>
<td>$F_0$</td>
<td>$0.15 \pm 0.21 \text{ (stat)} \pm 0.09 \text{ (sys)}$</td>
<td>$0.19 \pm 0.01 \text{ (stat)}$</td>
</tr>
</tbody>
</table>
Anomalous Single Top Production

- Charm contributions neglected
- Vector couplings to $Z^0$ neglected

Anomalous Single Top Production

- Excess unlikely to be $W$ production typical low $P_{T,X}$ process
- Topology is similar to top decay $t \rightarrow bW$
- Very small SM cross section < 1fb
- Possible cause: Anomalous single top production
  Flavour Changing Neutral Currents

$\kappa_{tuy}$ anomalous couplings of $\gamma/Z$
$\nu_{tuZ}$

Charm contributions neglected
Vector couplings to $Z^0$ neglected
Use 'standard' selection +
- good lepton charge determination
- good top quark reconstruction

4 vector reconstruction:
- $b$ quark = sum of all hadronic jets
- neutrino reconstructed as before
- top quark = lepton + $\nu + b$
  
  \[ 0 < M_{l\nu b} < 300 \text{ GeV} \]

Selected events:
- $e$: 24  \hspace{0.5cm} (SM: 26 \pm 4)
- $\mu$: 10 \hspace{0.5cm} (SM: 9.3 \pm 1.3)

Multivariate discriminator:
separate signal and $b/g$

$P_T^b, M_{l\nu b}$ and $\theta_W$

Anomalous single top MC used for signal training & W production for $b/g$
Few events are compatible with top - no large significance
• Use max. likelihood method to extract cross section limit for FCNC

• New H1 upper bound on cross section at 95% CL: $(ep \rightarrow etX) < 0.16$ pb

• Upper bound on the anomalous coupling $\kappa_{tu\gamma} < 0.14$

Recent updated CDF result on vector coupling
Conclusions

- H1 analysed complete HERA I+II 478 pb$^{-1}$
- Cross section measured for topology of: isolated leptons with large missing $P_T$
  - excellent SM agreement (excess at high $P_T$)
- Cross Section measurement extended to W production
- Polarisation fractions for W production have been determined in good agreement with SM
- High $P_T$ excess interpreted as anomalous single top production
- No significant anomalous coupling observed
  - limits set on $ep \rightarrow etX: < 0.16$ pb
  - $\kappa_{tu\gamma} < 0.14$ most stringent limit