Single Top Quark Measurements Combination and a Glance at Neural Networks

Jorge A. Benitez
On behalf of D0 Collaboration

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Outline

● Motivation
  ● Three Different measurements
    ● Matrix Element, Decision Trees, Bayesian Neural Networks

● Combination method (BLUE)

● Result

● Neural Networks (continuation of a previous analysis)
Motivation

- Have one number out of three measurements combined in the proper way of the $0.9 \ fb^{-1}$ of DØ Data, and gain from the combination.
- Combine three measurements (from the same data set):

$$\sigma(p\bar{p} \rightarrow tb + X, \ tqb + X)$$

\[\begin{align*}
\sigma_{DT} &= 4.9^{+1.4}_{-1.4} \ \text{pb} \\
\sigma_{ME} &= 4.6^{+1.8}_{-1.5} \ \text{pb} \\
\sigma_{BNN} &= 5.0^{+1.9}_{-1.9} \ \text{pb}
\end{align*}\]
Best Linear Unbiased Estimate (BLUE)

- Using a linear combination

\[ f(\hat{\sigma}, w) \equiv y = w_{DT} \sigma_{DT} + w_{ME} \sigma_{ME} + w_{BNN} \sigma_{BNN} \]

- Where the weights are determined by minimizing the variance

\[ \text{Var}(y) = \sum_i \sum_j w_i w_j \text{Cov}(\hat{\sigma}_i, \hat{\sigma}_j) \]

- bias negligible
Procedure

- Run the three analysis over the same pseudo-data sets from the SM + Background
- obtain weights
  \[ w_{DT} = 0.401 \quad w_{ME} = 0.452 \quad w_{BNN} = 0.146 \]
- calculate the correlation matrix
  \[
  \rho = \begin{pmatrix}
    DT & ME & BNN \\
    1 & 0.57 & 0.51 & DT \\
    0.57 & 1 & 0.45 & ME \\
    0.51 & 0.45 & 1 & BNN
  \end{pmatrix}
  \]
- and the uncertainty
  \[
  \delta_y = \sqrt{\sum_i \sum_j w_i w_j \rho_{i,j} \hat{\delta}_i \hat{\delta}_j} = 1.3 \text{ pb}
  \]
- Determine expected sensitivity and observed significance
Results

Cross section distribution for all three different analysis using SM signal + background ensembles

Cross section distribution for the combination, using SM signal + background ensembles
Results

\[ \sigma(p\bar{p} \rightarrow tb + X, \ tqb + X) = 4.8 \pm 1.3 \text{ pb} \text{ (DT + ME + BNN combined)} \]
**Significance**

### Analysis Table

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Measured Cross Section [pb]</th>
<th>Significance Expected [std. dev]</th>
<th>Significance Measured [std. dev]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DT</td>
<td>4.9</td>
<td>2.1</td>
<td>3.4</td>
</tr>
<tr>
<td>ME</td>
<td>4.6</td>
<td>1.8</td>
<td>2.9</td>
</tr>
<tr>
<td>BNN</td>
<td>5.0</td>
<td>1.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Combined</td>
<td>4.8</td>
<td>2.2</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Measured cross section, p-values, and significances for the individual and combined analyses.

**DØ Run II preliminary**

Ensemble of pseudo-datasets with background only (no signal) 0.9 fb⁻¹ per pseudo-dataset

Distribution of the measured cross section from the different analyses.
Layered Neural Networks

- Work in progress
- Established technique in the HEP community
- NNs were used in previous rounds of single top analyses
- The result of the Neural Network analysis would help compare new multivariable analyses with results from the previous round.
### Discriminants

#### S-Channel (tq)

<table>
<thead>
<tr>
<th>Measured Cross Section [pb]</th>
<th>Significance Expected [std. dev]</th>
<th>Significance Measured [std. dev]</th>
</tr>
</thead>
<tbody>
<tr>
<td>NNs</td>
<td>4.8</td>
<td>0.7</td>
</tr>
</tbody>
</table>

#### T-Channel (tqb)

Electron Neural Network output distributions for the s and t channel search

- **Data**
  - W+jets
  - ttbar
  - Fake lepton
  - Signal (x10)

Posterior Distribution for observed limits

- **Bayes Ratio:** 211.616000
- **Max Post:** 4.820000
Neural Network Result

DØ Run II

<table>
<thead>
<tr>
<th>Method</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layered NNs (WIP)</td>
<td>4.8 +2.1 -1.7 pb</td>
</tr>
<tr>
<td>Decision trees</td>
<td>4.9 +1.4 -1.4 pb</td>
</tr>
<tr>
<td>Matrix elements</td>
<td>4.6 +1.8 -1.5 pb</td>
</tr>
<tr>
<td>Bayesian NNs</td>
<td>5.0 +1.9 -1.9 pb</td>
</tr>
<tr>
<td>Combination</td>
<td>4.8 +1.3 -1.3 pb</td>
</tr>
</tbody>
</table>

N. Kidonakis, PRD 74, 114012 (2006), m_t = 175 GeV
Z. Sullivan, PRD 70, 114012 (2004), m_t = 175 GeV

σ(p̅p → tb+tqb) [pb]
Conclusion

- Three different multivariable analyses methods were combined using the **blue** method

\[ \sigma (p\bar{p} \rightarrow tb + X, tqb + X) = 4.8 \pm 1.3 \text{ pb} \ (\text{DT} + \text{ME} + \text{BNN combined}) \]

- Slight improvement in the significance for the combined result
  - Same data set is used, correlation expected in the results

- Analysis used previously (NNs), gives compatible results with current multivariable analyses.
Backup Slides
Training

- Training and testing errors from the first layer of the NN, for electrons and muons on the tb-wbb network
- Early Stopping is used in order to prevent over training