DØ Note 5396-CONF

Updated Combination Results from Three Single Top Quark Cross Section Measurements using the BLUE Method

The DØ Collaboration
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We report results from combining three different measurements of the single top cross section from the decision trees (DT), matrix elements (ME) and Bayesian neural networks (BNN) analyses on 0.9 fb^{-1} of DØ data. We apply the Best Linear Unbiased Estimate (BLUE) method in exactly the same way as discussed in DØ Note 5342-CONF, the difference here being in the ME and BNN measurements used. The latter two are from significantly improved versions of the analyses described in the previous note. The new combined measurement is $\sigma\,(p\bar{p} \rightarrow tb + X,\ tqb + X) = 4.7 \pm 1.3$ pb. The probability to measure this value of the cross section or higher in the absence of signal is 0.014%, corresponding to a 3.6 standard deviation significance.

Preliminary Results for Spring 2007 Conferences

I. INTRODUCTION

This note presents the combination of three measurements of the single top quark production cross section obtained using different multivariate techniques, based on 0.9 fb^{-1} of DØ data [1]:

$$\begin{aligned}\sigma\,(p\bar{p} \rightarrow tb + X,\ tqb + X) &= 4.9^{+1.4}_{-1.4}\ \text{pb}\ \ \text{(Decision trees)}\\ &= 4.8^{+1.6}_{-1.4}\ \text{pb}\ \ \text{(Matrix elements)}\\ &= 4.4^{+1.6}_{-1.4}\ \text{pb}\ \ \text{(Bayesian neural networks).}\end{aligned}$$

We apply the Best Linear Unbiased Estimate (BLUE) method [2] in exactly the same way as discussed in DØ Note 5342-CONF, the difference here being in the ME and BNN results used. The latter two are from significantly improved versions of the analyses described in the previous note. In obtaining the combined result, we have assumed the Standard Model ratio between the s and t channel single top cross sections.

II. RESULTS USING THE BLUE METHOD

We use cross section measurements from the three analyses from the following two ensembles of pseudo-datasets:

- SM signal (2.9 pb) + background pseudo-datasets
- Background-only pseudo-datasets.

These ensembles of pseudo-datasets are the same as used for the previous combination result in DØ Note 5342-CONF. In order to take into account correlations between the different measurements (those arising from using the same set of observed events as well as those from the systematic uncertainties), we combine results from the same ensemble-entry of each analysis. There are about 1900 common entries between the three analyses in the SM signal+background pseudo-datasets, and about 72,000 entries in the background-only pseudo-datasets.

A. Weights, coverage probability, and combined measurement

We use the SM signal+background pseudo-datasets to determine the weights and to check the coverage probability of the confidence intervals. The cross section measurements from this ensemble are shown in Fig. 1 for the individual and combined analyses. The mean and square root of the variance obtained from these distributions are given in Table I. The weights w_i for each of the three analyses are:

- $w_{\text{DT}} = 0.127$
- $w_{\text{ME}} = 0.488$
- $w_{\text{BNN}} = 0.386$

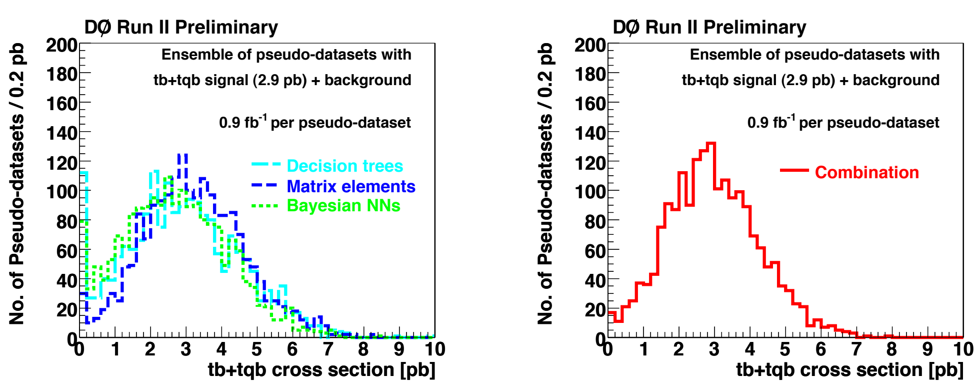

FIG. 1: Distributions of the measured cross sections from the individual analyses (left), and the combined analysis (right), using SM signal+background ensembles.

TABLE I: Mean and square root of variance from the SM signal (2.9 pb) + background ensembles for the different analyses.

Analysis	Mean σ [pb]	$\sqrt{\text{Var}}$ $\Delta\sigma$ [pb]	$\sigma/\Delta\sigma$
Decision trees (DT)	2.9	1.61	1.8
Matrix elements (ME)	3.2	1.42	2.3
Bayesian neural networks (BNN)	2.7	1.48	1.8
Combined	3.0	1.28	2.3

The correlation matrix is found to be:

$$\rho = \begin{pmatrix} \text{DT} & \text{ME} & \text{BNN} & \\ 1 & 0.64 & 0.66 & DT \\ 0.64 & 1 & 0.59 & ME \\ 0.66 & 0.59 & 1 & BNN \end{pmatrix},$$

and the one-standard-deviation coverage probability of the measurement is 0.67.

The combined result and its uncertainty for the single top quark cross section is

$$\sigma\left(p\bar{p} \rightarrow tb + X,\ tqb + X\right) \ = 4.7 \pm 1.3 \text{ pb} \ \ (\text{DT} + \text{ME} + \text{BNN combined}),$$

using the measurements listed in Sec. I. Fig. 2 summarizes the measurements from the individual analyses as well as the combination.

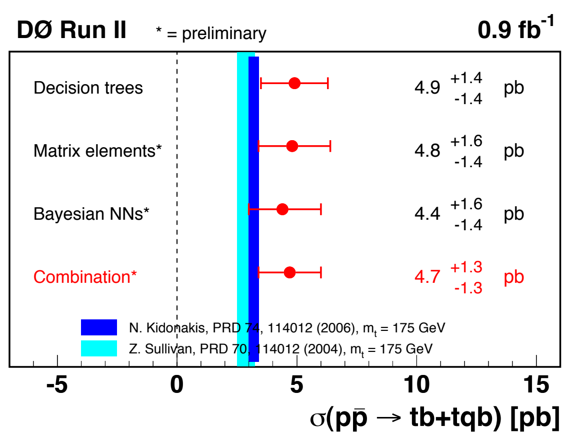

FIG. 2: The single top cross section measurements using real data, from the individual analyses and the combination.

B. Significance

We use the background-only ensemble to determine the expected and observed significance of the combined cross section. Distributions of the results from all the analyses are shown in Fig. 3.

The expected p-value (and the associated significance in Gaussian-like standard deviations) is obtained by counting how many background-only pseudo-datasets result in a measured cross section above the expected SM value of 2.9 pb. These are shown in Table II for the different analyses.

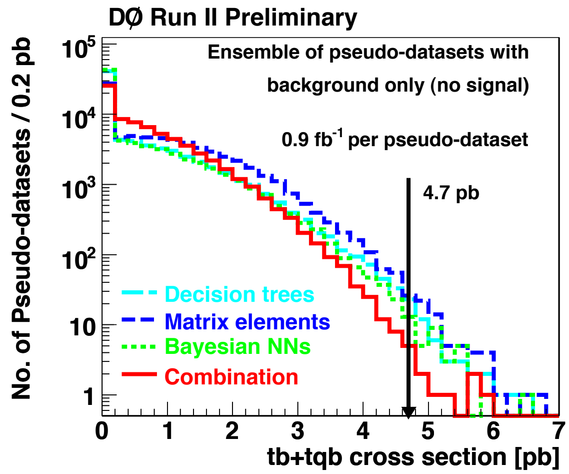

FIG. 3: Distributions of the measured cross sections from the different analyses, using background-only ensemble. The arrow shows the combined cross section measurement (4.7 pb) using real data.

TABLE II: The expected p-values and significances for the individual and the combined analyses, using the SM value of 2.9 pb for signal cross section as the reference point in Fig. 3.

Analysis	Expected p-value	Expected significance [std. dev.]
Decision trees (DT)	0.0177	2.1
Matrix elements (ME)	0.0307	1.9
Bayesian neural networks (BNN)	0.0155	2.2
Combined	0.0105	2.3

TABLE III: The measured cross sections, p-values, and significances for the individual and combined analyses, the latter two obtained using the background-only ensemble.

Analysis	Measured cross section [pb]	p-value	Significance [std. dev.]
Decision trees (DT)	4.9	0.00037	3.4
Matrix elements (ME)	4.8	0.00082	3.2
Bayesian neural networks (BNN)	4.4	0.00083	3.1
Combined	4.7	0.00014	3.6

The observed p-value is similarly calculated by counting how many background-only pseudo-datasets result in a measured cross section above the observed value of 4.7 pb. The result is 0.014% or 3.6 standard deviations. The observed cross sections, p-values, and significances from all the analyses are summarized in Table III.

Finally, using the SM signal+background pseudo-datasets, we obtain the compatibility with the SM expectation by counting how many pseudo-datasets result in a cross section with the observed value or higher for each of the analyses. The probabilities for the different analyses are 10% for the DT, 13% for the ME, 13% for the BNN, and 10% for the combined analyses.

III. CONCLUSIONS

To conclude, the measured single top quark production cross section, based on 0.9 fb^{-1} of DØ data and after combining results from the DT, ME and BNN analyses, is 4.7 ± 1.3 pb with a significance of 3.6 standard deviations.

[1] V. M. Abazov *et al.* [D0 Collaboration], "Evidence for production of single top quarks and first direct measurement of |V(tb)|," submitted to Phys. Rev. Lett., arXiv:hep-ex/0612052.

[2] L. Lyons, D. Gibaut, and P. Clifford, Nucl. Instrum. Methods **A 270**, 110 (1988); R. J. Barlow, *Statistics: A Guide To The Use Of Statistical Methods In The Physical Sciences*, The Manchester Physics Series, John Wiley and Sons, New York (1989); G. Cowan, *Statistical Data Analysis*, Oxford (1998).