Abstract

We present a method developed at DØ for extracting information from data through a direct calculation of a probability for each event. A function of any parameter of interest is calculated by convoluting the differential cross section and resolution of the detector. The method is used to re-measure the mass of the top quark and to extract the fraction of background probability (signal-like events). The new method yields a top mass of $M_{\text{top}} = (174.2 \pm 0.9 \text{ (stat)} \pm 1.1 \text{ (syst)})$ GeV/c$^2$, which corresponds to a significant improvement over the previous measurement done at DØ. The new measurement is the first to be in the high precision region and set an uncertainty of 400 GeV/c$^2$.

Introduction

Top Quark Production

To present analysis results at Tevatron energies, top quarks are primarily produced in pairs, either via quark- or gluon-fusion. In the Tevatron, the main contributions to this process are from quark-antiquark annihilation into a top-antitop pair. This is justified by the fact that the parton distribution functions (PDF's) favor this channel (as mentioned in Ref. 1). In fact, about 90% of the top quarks are produced this way. The rest arise via the charm-anticharm channel, and according to the Standard Model is almost always expected to decay to $W+b$.

Top-Production and Decay

The top quark's decay products are used to detect the produced top quark. It decays via the weak interaction, and according to the Standard Model is almost always expected to decay to $W+b$. This is followed by the electroweak charged current, and a neutrino is left. In the case of the left-handed W, which is by far the more abundant, the electron-like neutrino is detected. However, for right-handed W, a quark (specifically a top quark) can decay to a left-handed W (negative helicity W) or a right-handed W (positive helicity W).

The Standard Model is the left-handed W, $W^-$, and represents the parton distribution functions (CTEQ4) for $u$ and $d$. The probability for each event being signal is calculated by convoluting the differential cross section with the resolution and acceptance of the detector. The method is used to re-measure the mass of the top quark and to extract the fraction of background probability (signal-like events). The new method yields a top mass of $M_{\text{top}} = (174.2 \pm 0.9 \text{ (stat)} \pm 1.1 \text{ (syst)})$ GeV/c$^2$, which corresponds to a significant improvement over the previous measurement done at DØ. The new measurement is the first to be in the high precision region and set an uncertainty of 400 GeV/c$^2$.

A precise measurement of the helicity of the W boson examines the nature of the decay vector $W^{-}$ and its effect on the $W+b$ final state track and jet properties in the Tevatron. To conserve angular momentum, the emitted quark is essentially massless, with its helicity fixed. Only a fraction of this angular momentum is conserved in the decay, so the emitted quark can decay to a left-handed W (negative helicity W) or a right-handed W (positive helicity W). The Standard Model requires the parton distribution functions (CTEQ4) for $d$ and $s$. The probability for each event being signal is calculated by convoluting the differential cross section with the resolution and acceptance of the detector. The method is used to re-measure the mass of the top quark and to extract the fraction of background probability (signal-like events). The new method yields a top mass of $M_{\text{top}} = (174.2 \pm 0.9 \text{ (stat)} \pm 1.1 \text{ (syst)})$ GeV/c$^2$, which corresponds to a significant improvement over the previous measurement done at DØ. The new measurement is the first to be in the high precision region and set an uncertainty of 400 GeV/c$^2$.

Although the value of parameter $M_{\text{top}}$ is a function of the systematics, the uncertainty on the systematics for this measurement is 400 GeV/c$^2$.

Matrix Element Method

The method calculates the probability of events being signal at a function of the systematics. The systematics that are being background is also calculated. The results are presented in one-beam for the likelihood function. The likelihood functions are calculated in the previous analysis, the data was composed with dimensional cross sections and the resolution and acceptance of the detector. The method is used to re-measure the mass of the top quark and to extract the fraction of background probability (signal-like events). The new method yields a top mass of $M_{\text{top}} = (174.2 \pm 0.9 \text{ (stat)} \pm 1.1 \text{ (syst)})$ GeV/c$^2$, which corresponds to a significant improvement over the previous measurement done at DØ. The new measurement is the first to be in the high precision region and set an uncertainty of 400 GeV/c$^2$.

Top Quark Mass

The top quark is detected indirectly via its decay products. It decays via the weak interaction, and according to the Standard Model is almost always expected to decay to $W+b$. In the case of the left-handed W, which is by far the more abundant, the electron-like neutrino is detected. However, for right-handed W, a quark (specifically a top quark) can decay to a left-handed W (negative helicity W) or a right-handed W (positive helicity W).

The Standard Model is the left-handed W, $W^-$, and represents the parton distribution functions (CTEQ4) for $u$ and $d$. The probability for each event being signal is calculated by convoluting the differential cross section with the resolution and acceptance of the detector. The method is used to re-measure the mass of the top quark and to extract the fraction of background probability (signal-like events). The new method yields a top mass of $M_{\text{top}} = (174.2 \pm 0.9 \text{ (stat)} \pm 1.1 \text{ (syst)})$ GeV/c$^2$, which corresponds to a significant improvement over the previous measurement done at DØ. The new measurement is the first to be in the high precision region and set an uncertainty of 400 GeV/c$^2$.

Background Probability $P_{\text{background}}$

It is defined to be in terms of the mass background (W-jets, BB, $P_{\text{background}}$), which proves to be an appropriate representation for the background. The background for each system is measured using MC simulations for the W-jets and BB. The probability for each event being signal is calculated by convoluting the differential cross section with the resolution and acceptance of the detector. The method is used to re-measure the mass of the top quark and to extract the fraction of background probability (signal-like events). The new method yields a top mass of $M_{\text{top}} = (174.2 \pm 0.9 \text{ (stat)} \pm 1.1 \text{ (syst)})$ GeV/c$^2$, which corresponds to a significant improvement over the previous measurement done at DØ. The new measurement is the first to be in the high precision region and set an uncertainty of 400 GeV/c$^2$.

Conclusions

Using a comprehensive and parameterized flavor, we calculated the event probabilities, and measured $p_{\text{top}}$ (proportion of 180°: 13.1 ± 2.9 (4.0) GeV/c$^2$) using MC simulations. Some important conclusions are:

- Significant improvement to our previous analysis, and is equivalent to having $\approx 400$ more data.
- $p_{\text{top}}$ (proportion of 180°: 0.51 ± 0.21 ± 0.04 (4.0) GeV/c$^2$) using MC simulations.
- First measurement obtained at DØ.

We have a method that allows us to optimize information to extract $p_{\text{top}}$ and $M_{\text{top}}$. The statistical power comes from:

- Correct permutation is always considered (along with the other eleven)
- Significant improvement in the statistics for $p_{\text{top}}$ and $M_{\text{top}}$
- More data from the CDF and DØ collaborations
- First measurement obtained at DØ.

For higher statistics, one clearly needs to improve the calculation of the likelihood function. To do this, we will track the events with the highest signal-to-background ratio. To conclude the future:

- More general method (other top properties, Higgs, electrons, etc.)

Optimal Use of Information to Measure Top Properties - F. Canelli, J. Estrada