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Measurement of the Top Quark Mass in the Lepton+Jets Channel using DØ Run II Data

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We present a measurement of the top quark mass, using lepton+jets events collected in $p\overline{p}$ collisions at $\sqrt{s} = 1.96$ TeV at the Fermilab Tevatron using the DØ detector. The dataset corresponds to an integrated luminosity of approximately 160 pb^{-1} collected between April 2002 and November 2003. We use a template method for measuring the top quark mass using a kinematic fitting technique. We measure the top quark mass to be:

$$m_{\mathrm{t}} = 170.0 \pm 6.5(\mathrm{stat})\,{}^{+10.5}_{-6.1}\,(\mathrm{syst})\ \mathrm{GeV}$$

Keywords: Top Quark; Electroweak Physics

1. Introduction

The measurement of the top quark mass is interesting because it is an important parameter in many predictions of the Standard Model. In particular, precise knowledge of the top quark mass, together with the W boson mass, constrain the mass of the Higgs boson in the framework of the Standard Model. Here we present the first measurement of the top quark mass from Run II data by DØ. The integrated luminosity used for this measurement is about 160 pb^{-1}. We present a measurement from the lepton+jets channel using a "Template" method that is very similar to the technique used for the first top quark mass measurement by DØ [3].

The top quark decays to a W boson and a b quark. The W boson can either decay to leptons (e+ν_e, μ+ν_μ, τ+ν_τ) or quarks (ud', cs'). The quarks will manifest themselves as jets in our detector. If the W boson from the top decays to $e\nu$ or $\mu\nu$ and the W boson from the antitop decays to quarks (or vice versa), the events contain one charged lepton and four jets (from the two b quarks and the W). We call this the lepton+jets channel. It is characterized by a sizeable branching fraction ($\approx 30\%$) and small backgrounds. Events of this type kinematically constrain the top quark mass.

2. Data Set and Selection

The data sample used is the same as for the topological cross section analysis in the lepton+jets channel. The first step is to identify events in which have a high p_T electron or a muon accompanied by substantial $\not\!\!E_T$('missing' transverse energy - taken by the neutrino), indicative of a W boson production in the final state. We require isolated electron (muon) candidates to have $p_T > 20$ GeV, be within the pseudorapidity range $|\eta| < 1.1$ ($|\eta| < 2.0$) and to satisfy tight quality requirements. The muon p_T is also required to not exceed 150 GeV. A minimum event $\not\!\!E_T$ of 20 GeV (17 GeV) is required for the e+jets (μ+jets) events. Next, we select events with at least 4 jets with transverse momentum $p_T > 15$ GeV, out of which the leading 3 jets are required to have a $p_T > 20$ GeV. The jets must all be in the pseudorapidity range $|\eta| < 2.5$.

The major sources of background are W + mulitple jets produced from gluon radiation and multijet events one jet is misidentified as an isolated lepton. To further reduce the background from mis-identified electrons in multijet events, we require that $E_T^W = \left|p_T^l\right| + |\not\!\!E_T| > 65$ GeV. We require the sum of the jet p_T (excluding the leading jet) to be larger then 90 GeV: reducing the background by $\approx 50\%$ but retaining 98% of the signal.

In order to get further discrimination between signal and background, we derive a discriminant (Low Bias Discriminant, LB) constructed from the topology of the events. Because of the large mass of the top quark, $t\bar{t}$ events have a unique topology. The discriminant is designed to be uncorrelated with the top quark mass. We developed this discriminant by closely following the work described in reference [3]. We require that the discriminant be larger then 0.4, optimized to minimize the expected statistical error of the measurement.

2.1. *Method for mass extraction*

The Template analysis is based on comparing the fitted mass from the kinematic fit on the collider data with the results obtained from fitting simulated Monte Carlo samples of known top masses. For each hypothetical top quark mass, we create templates and also construct a background template from the most prominent background to our decay channel: $W + 4$ jet production.

In order to extract the top quark mass from this comparison, we use a binned likelihood fit. We write the probability distribution function for the mass estimator in terms of the number of signal events n_s and the number of background events n_b in our sample. We constrain the fraction of background events to the expected number using a Poisson probability term.

For each hypothesized top quark mass, the likelihood is maximized as a function of the number of signal and background events. The mass with the largest likelihood, or equivalently the smallest negative log likelihood ($-\ln(L)$) is identified and a parabola is fit to the values of $-\ln(L)$ for all hypothesized top quark masses within $\pm$ 15 GeV of the mass with the largest likelihood.

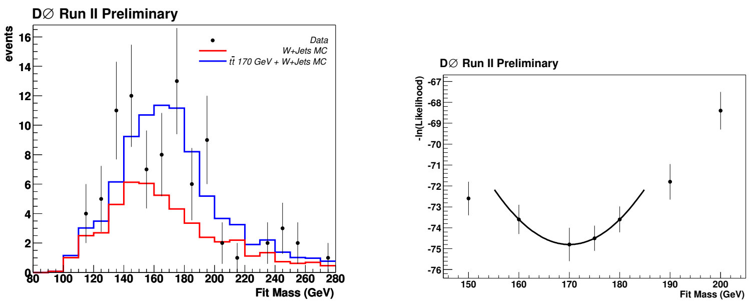

Fig. 1. The fit mass distribution of the final event selection (left).$-\ln(L)$ distribution as a function of the fit top quark mass. The background constrained fit (right) yields a top quark mass of 170.0 ± 6.5 GeV (statistical) in the lepton + jets data sample.

Source	Uncertainty
Jet Energy Scale	-4.0 $+9.0$ GeV
Jet Energy Resolution	± 2.3 GeV
Underlying Event and Multiple Interactions	$+3.0$ GeV
Limited MC Statistics	± 0.5 GeV
Trigger Uncertainty	± 1.0 GeV
Calibration Curve	± 0.5 GeV
$t\bar{t}$ Model	± 3.8 GeV
total	-6.1 $+10.5$ GeV

2.2. *Mass measurement from collider data*

After this final event selection we find 87 events in the lepton+jets channel. The fit mass distribution of the events and the fit for the top quark mass are shown in Fig. 1. The topological cross-section analysis, with the slight differences in event selection taken into account, predicts that 40 of the 87 events are background.

The systematic uncertainties are summarized in Table 1. After adding the uncertainties in quadrature we measure the top quark mass to be

$$m_{\mathrm{t}} = 170.0 \pm 6.5(\mathrm{stat})\,{}^{+10.5}_{-6.1}\,(\mathrm{syst})\ \mathrm{GeV}$$

References

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