CDF/PHYS/TOP/PUBLIC/9881
Draft 1.0
August 6, 2009

Lepton+jets and dilepton combined measurement of the top quark mass from the leptons' P_T using b-tagging at 2.8 fb^{-1}

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Abstract

A combination of the top mass results in the lepton+jets and the dilepton channels, using 2.8 fb^{-1} of data, is presented. Both measurements apply a b-tagged selection and use the information from the leptons' P_T. A combined top mass of $M_{top} = 172.8 \pm 7.2_{(stat)} \pm 2.3_{(syst)}$ GeV/c^2 is obtained.

1 Introduction

This note presents the combination of the top mass measurement in the lepton+jets and the dilepton channels from the leptons' P_T, using 2.8 fb^{-1} of data. The method of measuring the top quark mass from the lepton P_T was proposed in [1]. The results presented are obtained using data collected by the CDF detector in $\bar{p}p$ collisions at $\sqrt{s} = 1.96$ TeV with the CDF detector at the Fermilab Tevatron. The CDF detector is described in detail in [2].

The leptons' P_T is a variable that can be measured very well in the tracker and the calorimeter and can be accurately calibrated against Z→ dilepton decays. Jets have a minimal involvement in this analysis, i.e. only in the criteria used for the event selection. Therefore the top quark mass as extracted through this method, is associated with a low JES uncertainty. The leptons $P_T$is a simple variable that is common in the dilepton and the lepton+jets channels, a fact that that gives the opportunity to directly compare the results from the two channels and also combine them. Top mass measurements using the leptons P_T have been presented and approved by the CDF for both channels. It was first implemented for the lepton+jets channel at the low luminosity of 340 pb^{-1} [3] and again at 2.7 fb^{-1} [4] using b-tagging, and improving signicantly both the statistical and the systematic uncertainties to $M_{top} = 176.9 \pm 8.0_{(stat)} \pm 2.7_{(syst)}$ GeV/c^2. The first measurement in the dilepton channel used 1.8 fb^{-1} of data and no b-tagging [5]. This top mass measurement gave $M_{top} = 156.2 \pm 20 \pm 4.6$ GeV/c^2. The second top mass measurement in the dilepton channel used 2.8 fb^{-1} of data and b-tagging [6]. Both the statistical and systematic uncertainties improved significantly to $M_{top}^{dil} = 154.6 \pm 13.3_{(stat)} \pm 2.3_{(syst)}$ GeV/c^2. This note presents the combination of the most recent top mass measurements in the lepton+jets and dilepton channels that use 2.8 fb^{-1} of data and b-tagging.

The lepton+jets measurement is based on the identification of the lepton in the decay chain $t\bar{t} \rightarrow (W^+b)(W^-\bar{b}) \rightarrow l^{\pm}\nu q\bar{q}b\bar{b}$, where at least one jet is tagged. Therefore it selects decays with one high transverse energy leptons, high missing transverse energy ($\not\!\!E_T$) and at least four jets in the final state. The excess of the lepton+jets events selected in the data over the background expectation from the other known Standard Model sources is taken as a measurement of the production of $t\bar{t}$ events.

The dilepton measurement is based on the identification of both leptons in the decay chain $t\bar{t} \rightarrow (W^+b)(W^-\bar{b}) \rightarrow (l^+\bar{\nu}_l b)(l^-\nu_l\bar{b})$, where at least one jet is tagged. Therefore it selects decays with two high transverse energy leptons, high missing transverse energy ($\not\!\!E_T$) and at least two jets in the final state. The excess of the dilepton events selected in the data over the background expectation from the other known Standard Model sources is taken as a measurement of the production of $t\bar{t}$ events.

2 Top Mass Combination

The lepton+jets result was obtained from 2.7 fb^{-1} of data and is described in [4]. The top mass measurement is given in Equation 1 and the final fit to the lepton+jet data

events is illustrated in Figure 1.

$$M_{top}^{l+jets} = 176.9 \pm 8.0_{(stat)} \pm 2.7_{(syst)}\ GeV/c^2 \quad (1)$$

This is the result of the combination of the e+jets and μ+jets measurements:

$$M_{top}^{e+jets} = 192.4 \pm 11.3_{(stat)} \pm 4.1_{(syst)}\ GeV/c^2 \quad (2)$$

$$M_{top}^{\mu+jets} = 160.9 \pm 11.0_{(stat)} \pm 3.0_{(syst)}\ GeV/c^2 \quad (3)$$

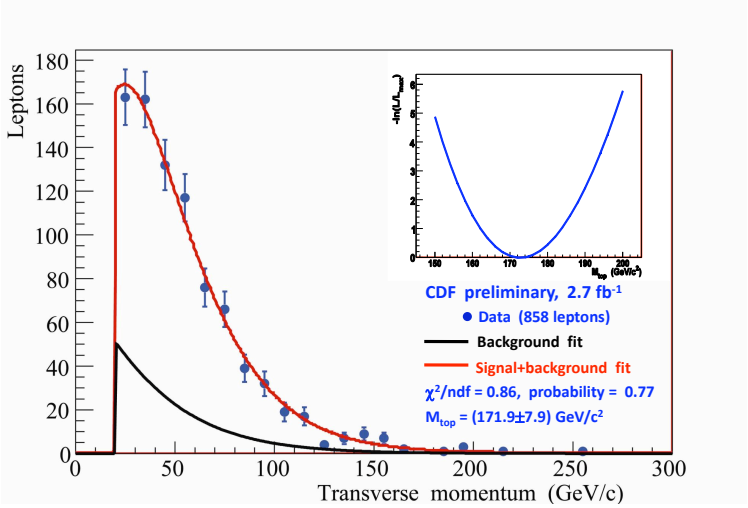

Figure 1: Fit to the 2.8 fb^{-1} b-tagged lepton+jets data. The top mass measurement in the fit is before any corrections are applied [4]

The lepton+jets result is combined with the one from the dilepton channel, described in [6]. The dilepton top mass measurement is given in Equation 4 and the final fit to the dilepton data events is illustrated in Figure 2:

$$M_{top}^{dil} = 154.6 \pm 13.3_{(stat)} \pm 2.3_{(syst)}\ GeV/c^2 \quad (4)$$

The statistical uncertainties in the two channels are not correlated, and therefore the combined statistical error $e_{comb,stat}$ is:

$$e_{comb,stat} = 7.2\ GeV/c^2 \quad (5)$$

The combined systematic uncertainty $e_{comb,syst}$ is derived using the Iterative Best Linear Unbiased Estimator "BLUE" [7], taking into account the dependence of the statistical error on the top mass. It has also been taken into account the correlation

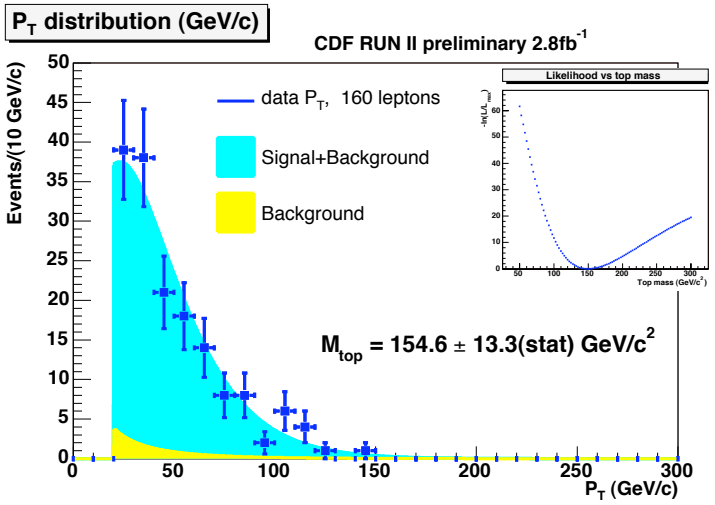

Figure 2: Fit to the 2.8 fb^{-1} b-tagged dilepton data. The top mass measurement in the fit is after any corrections are applied [6]

of the partial systematics between the e+jets and μ+jets decay modes of the lepton+jets channel and then between the lepton+jets and the dilepton decay channel. It is noted here that for the combination the e+jets and μ+jets decay modes of the lepton+jets channel are considered as separate measurements as they have different statistical significance and therefore different weight on the total combination [4]. Table 1 summarizes the partial systematic uncertainties for the two channels, as well as their combination.

Table 2 summarizes the correlation coefficients, where the sources that are partially or fully correlated are denoted with $\rho = 1$ and the ones that are uncorrelated with $\rho = 0$. The sources of systematic uncertainties that have been estimated from statistically independent samples or/and are using a different method or/and one of the errors to be combined is statistically dominated are considered uncorrelated. The correlation coefficient is therefore taken to be $\rho = 0$. The sources of systematic uncertainties that have been estimated from overlapping samples or come from the same origin are considered fully correlated. The correlation coefficient is therefore taken to be $\rho = 1$. In the case that the sources are partially correlated, we conservatively take the coefficient to be $\rho = 1$. In more detail, the correlation of the individual sources is justified as follows:

Global P_T scale The e+jets and μ+jets systematics are uncorrelated as the global P_T scale calibration comes from independent Z→ee and Z→ $\mu\mu$ samples. The dilepton systematic is partially correlated with the e/μ+jets ones as the dilepton events have both electrons and muons. The latter ones are conservatively taken to be fully correlated.

Local P_T scale The systematic uncertainties for all three channels are considered fully

correlated, as the local calibration of the electrons is based on the local calibration of the muons.

MC statistics The systematic uncertainties are uncorrelated as the MC e+jets, μ+jets and dilepton sub-samples are independent.

Generator The e+jets systematic uncertainty is statistically dominated and therefore its correlation with the μ+jets and dilepton ones is taken to be 0. Furthermore, as the dilepton uncertainty is also statistically dominated its $\rho^{e/\mu+jets-DIL}$ is taken to be 0.

IFSR As the μ+jets and dilepton systematics are statistically dominated all possible three correlations are taken to be 0.

PDF All systematic uncertainties are considered fully correlated as the shifts come from the same origin in all three channels.

Background shape As there is no μ+jets background shape (fakes) systematic error the correlation $\rho^{ejets-\mu jets}$=0. Furthermore $\rho^{ejets-DIL}$=0 as the e+jets systematic is estimated using the data sample (anti-electrons) while the dilepton one is based on MC.

Background constrain All sources are uncorrelated as there is no e/μ+jets systematic error from this source.

JES All systematic uncertainties are considered fully correlated as the shifts come from the same origin, the uncertainty on the jets energy, in all three channels.

Multiple Interactions All sources are considered uncorrelated, as the estimation of the e/μ+jets and dilepton systematic error was based on a different approach. The e/μ+jets systematic estimation is based on data while the dilepton one on the high - luminosity MC samples.

Q^2 The e+jets and μ+jets sources are of statistical origin and are therefore considered uncorrelated. This systematic does not exist in the dilepton channel.

Bias from the fit This source exists only in the dilepton channel and all correlation coefficients are taken to be 0.

The combined systematic uncertainty, as estimated from "BLUE", is $e_{comb,syst}$=2.3 GeV.

The "BLUE" algorithm estimates that the weight of the e+jets measurement is w^{e+jets}=0.42, of the μ+jets measurement is $w^{\mu+jets}$=0.40 and the corresponding dilepton one is w^{dil}=0.18. According to all of the above the combined lepton+jets and dilepton measurement at 2.8 fb^{-1} , using only the leptons' P_T is:

$$M_{top}^{comb} = 172.8 \pm 7.2_{(stat)} \pm 2.3_{(syst)} \text{ GeV/c}^2 \quad (6)$$

	δMass (GeV)				
source of systematic	e+jets	μ+jets	l+jets	DIL	combination
Global P_T scale	0.2	0.1	0.1	0.1	0.1
Local P_T scale	0.6	1.5	1.1	0.7	1.0
MC statistics	0.4	0.4	0.4	0.3	0.2
Generator	0.7	2.2	1.2	1.5	1.0
IFSR	1.5	0.7	0.8	1.3	0.7
PDF	0.6	0.6	0.6	0.7	0.6
Background shape*	3.6	0.0	1.8	0.4	1.4
Background constrain	0.0	0.0	0.0	0.3	0.1
JES	0.0	0.0	0.0	0.4	0.1
Multiple Interactions	0.1	0.1	0.1	0.2	0.1
Q^2	0.7	0.8	0.5	0.0	0.4
Bias from the fit	0.0	0.0	0.0	0.3	0.1
Total	4.1	3.0	2.7	2.3	2.3

Table 1: Partial and total systematic uncertainty on the top mass for the e+jets, μ+jets, the dilepton channel and their combination. *The "Background shape" systematic is called "Fakes" in the lepton+jets analysis [4]

	Correlations		
source of systematic	$\rho^{\text{ejets}-\mu\text{jets}}$	$\rho^{\text{ejets}-\text{DIL}}$	$\rho^{\mu\text{jets}-\text{DIL}}$
Global P_T scale	0	1	1
Local P_T scale	1	1	1
MC statistics	0	0	0
Generator	0	0	0
IFSR	0	0	0
PDF	1	1	1
Background shape	0	0	0
Background constrain	0	0	0
JES	1	1	1
Multiple Interactions	0	0	0
Q^2	0	0	0
Bias from the fit	0	0	0

Table 2: Correlations of the partial systematic uncertainties. We denote as $\rho^{\text{ejets}-\mu\text{jets}}$ the correlation between the e+jets and μ+jets components in the lepton + jets channel. We denote as $\rho^{\text{ejets}-\text{DIL}}$ & $\rho^{\mu\text{jets}-\text{DIL}}$ the correlations between the e+jets/μ+jets and dileptons components respectively. For the sources that are considered fully or partially correlated it has been taken ρ=1 and for the uncorrelated ρ=0.

Figure 3 illustrates the statistical significance of the e+jets, μ+jets and dilepton top mass measurements in comparison to the combined top mass measurement.

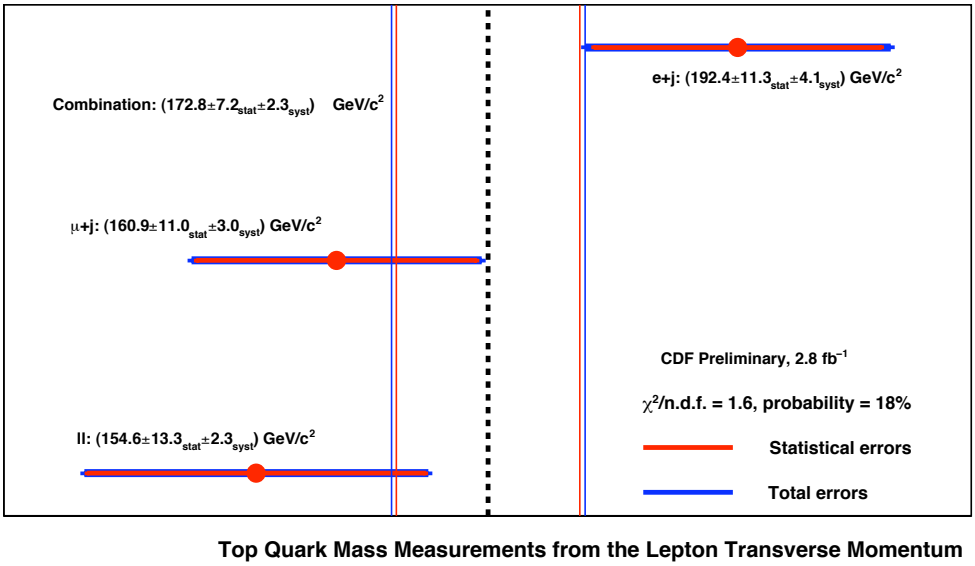

Figure 3: The statistical significance of the the e+jets, μ+jets and dilepton top mass measurements at 2.8 fb^{-1} using the leptons P_T in comparison to their "BLUE" combination (vertical band). The red color denotes the statistical uncertainties (dominant) and the blue color denotes the total uncertainties.

Acknowledgments

We thank the Fermilab staff and the technical staffs of the participating institutions for their vital contributions. This work was supported by the U.S. Department of Energy and National Science Foundation; the Italian Istituto Nazionale di Fisica Nucleare; the Ministry of Education, Culture, Sports, Science and Technology of Japan; the Natural Sciences and Engineering Research Council of Canada; the National Science Council of the Republic of China; the Swiss National Science Foundation; the A.P. Sloan Foundation; the Bundesministerium für Bildung und Forschung, Germany; the Korean Science and Engineering Foundation and the Korean Research Foundation; the Science and Technology Facilities Council and the Royal Society, UK; the Institut National de Physique Nucleaire et Physique des Particules/CNRS; the Russian Foundation for Basic Research; the Comisión Interministerial de Ciencia y Tecnología, Spain; the European Community's Human Potential Programme; the Slovak R&D Agency; and the Academy of Finland.

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