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Measurement of the Top Quark Mass in the Dilepton channel at CDF and DØ

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Abstract. We present recent analyses of the top quark mass measurement in dileptonic channel. The measurements use 200-360 pb^{-1} of data collected by CDF and DØ experiments. The future prospects are discussed as well.

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INTRODUCTION

The top quark mass is a fundamental parameter of the Standard Model (SM), and it plays an important role in the precise prediction of electroweak observables like the Higgs boson mass. The Tevatron collider provides $p\bar{p}$ collisions at a center-of-mass energy $\sqrt{s}$=1.96 TeV. At this energy, the main production mechanism for the top quark is the pair production via quark annihilation ($q\bar{q} \to t\bar{t}$) or gluon fusion ($gg \to t\bar{t}$). The top quark decays into a b quark and a W boson with branching ratio nearly 100%.

In dileptonic channel, the two resulting W bosons decay leptonically. Such events have small statistics (5% branching ratio) and two neutrinos escaping the detector, but they also have little background contamination and only two possible parton-jet assignments. The measurement of the top quark mass in dileptonic channel is an important and direct confirmation that events in excess over background are due to the top quark as described by the Standard Model. If the measurement is consistent with that in other channels, it can be combined to yield greater precision; a significant discrepancy from measurements in other channels could indicate contributions from non-SM sources.

The dileptonic event selections include identification of two leptons with high transverse momentum (p_T), large trasverse missing energy ($\not{E}_T$) due to the undetected neutrinos from W decays, and at least two high-p_T jets. The reconstruction of the top mass from dilepton events poses a particular challenge as kinematic information is carried away undetected by the two neutrinos.

METHODS

The mass measurement techniques can be divided into two categories: template methods and matrix element methods. The template methods in dileptonic channel [1, 2, 3] scan over a chosen kinematic variable(s) to compensate under-constraint system. The most

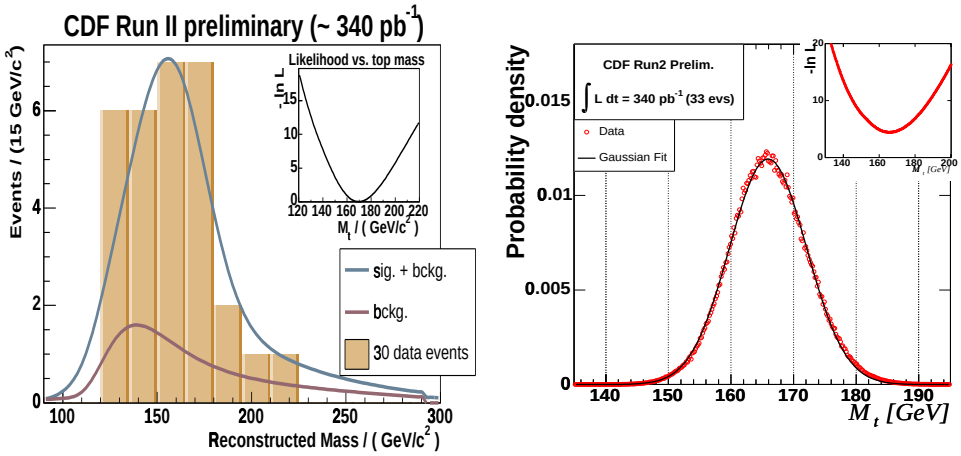

FIGURE 1. LEFT: Reconstructed top quark mass for the data events, with normalized background and signal+background parametrisation functions. The inset is the likelihood function. (CDF $P_z(t\bar{t})$) **RIGHT:** Final posterior probability density for the dilepton candidate events in data. (CDF Matrix Element)

probable m_{reco} is calculated in event by event basis. In this way, mass templates can be constructed for $t\bar{t}$ signal Monte Carlo with different m_{top} values, as well as for the modelled background processes. By comparing the observed m_{reco} distribution from data to the parametrized templates, the top mass can be extracted.

The CDF Collaboration uses three template methods to measure the top mass. The measurements use different scanning variables: longitudinal momentum of the $t\bar{t}$ system ($P_z(t\bar{t})$), two η angles of the two neutrinos (η of ν), or two azimuthal angles of the two neutrinos (ϕ of ν).

The matrix element methods [4, 5] use the leading-order model of the production process and a parametrized description of hadronization and reconstruction of jets. After integrating over all unknown quantities, one obtains per-event probabilities as a function of top mass. The final posterior probability is obtained by multiplying the per-event probabilities.

The CDF Matrix element method calculates the posterior probablity using the theoretical description of the $t\bar{t}$ production process expressed with respect to a vector of measured event quantities, x:

$$P_s(x|M_t) = \frac{1}{\sigma(M_t)} \frac{d\sigma(M_t)}{dx}, \tag{1}$$

where $\frac{d\sigma}{dx}$ is the per-event differential cross-section and $\sigma(M_t)$ is the total cross section as a function of top mass. To evaluate the probability, one integrates over neutrino energies and transfer functions $W(p, j)$, which describe the probability of measuring jet energy j with given parton energy p. Because a fraction of candidate events are background events, the probability $P_{bg}(x)$ needs to be calculated for each background process. The generalized per-event probability is a sum of signal and background probabilities.

The results from the four described CDF methods are combined via determination of statistical correlations between the measurements [6]. The result is $m_t = 168.2 \pm$

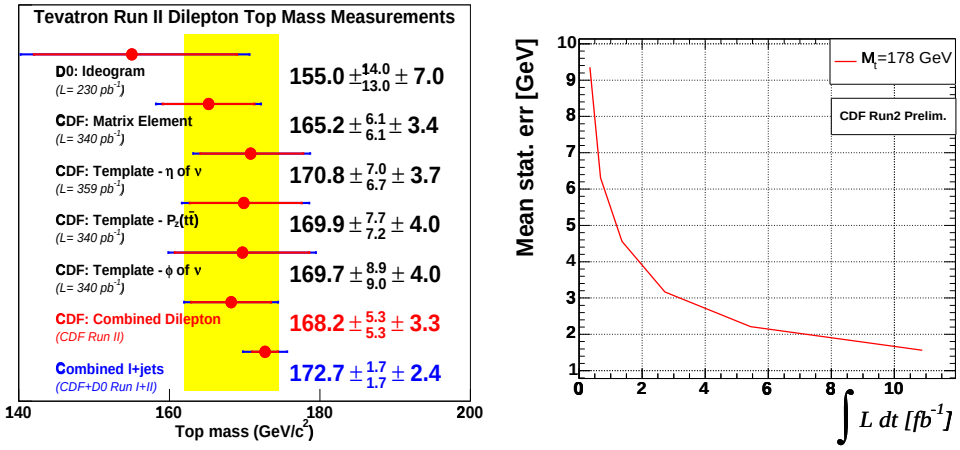

FIGURE 2. LEFT: The Tevatron Run II top mass measurements in dileptonic channel. The results are consistent within statistics between CDF and DØ , and between lepton+jets and dileptonic decay channels. **RIGHT**: Expected statistical uncertainty as a function of integrated luminosity. (CDF Matrix element method)

$5.3(\text{stat}) \pm 3.3(\text{syst})$ GeV/c^2. Each of the analysis use 340-360 pb^{-1} of data collected by CDF experiment.

The DØ top mass measurement in dileptonic channel is a combination of a template method and a matrix element method. The most probable event-by-event top mass is found with a matrix element calculation. Then the method follows the template method methology. The final top mass measurement for this method is $m_t = 155^{+14}_{-13}(\text{stat}) \pm 7(\text{syst})$ GeV/c^2, using 230 pb^{-1} of data collected by DØ experiment.

PROSPECTS

The top mass measurement in dileptonic channel has been statistically limited. The studies performed with the CDF Matrix element method show, that with 2.5 fb^{-1} of data, the statistical error is excepted to be of the same order as the current systematic uncertainty of the method. The most of the systematic uncertainties can be reduced with more data and with a smarter algorithm. For example, the b-jet energy scale can be checked with $Z \to b\bar{b}$ sample. The top mass measurement in dileptonic channel is becoming a precision measurement.

REFERENCES

1. J. Antos, *Acta Phys. Slov.* **49**, 127 (1999)
2. F. Abe et. al., The CDF Collaboration, *Phys. Rev. Lett.* **82**, 271 (1999)
3. B. Abbot, et. al., The DØ Collaboration, *Phys. Rev. Lett.* **80**, 2063 (1998)
4. K. Kondo, *J. Phys. Soc. Jpn.* **57**, 4126 (1988)
5. V. Abazov, et. al., The DØ Collaboration, *Nature* **429**, 638 (2004)
6. L. Lyons, D. Gibaut, and P. Cliord, *Nucl. Instrum. Meth.* **A270**, 110 (1998)