Measurement of the Top Quark Mass in the Dilepton Channel with the Matrix Element Method at the DØ Experiment

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The mass of the top quark is an important parameter for testing and understanding the Standard Model of particle physics, and it provides an indirect constraint on the mass of the still undiscovered Higgs boson. The Matrix Element (ME) method has been used successfully at the DØ experiment during Run I [1] and Run II [2] of the Tevatron to measure the top mass in the final state with one charged lepton (lepton+jets channel). Compared to template based methods the measurement uncertainty could be reduced significantly. The dilepton channel is of interest to search for possible differences between measurements in different final states. In addition to that, as the measurements become dominated by systematic errors with increasing statistics the dilepton channel has the potential to contribute significantly to the world average.

The ME technique described in [2] can also be applied in the dilepton channel to calculate for each selected event the likelihood to be produced via the signal process $p\bar{p} \to t\bar{t} \to b\bar{b}l\nu l\nu$. This likelihood can depend both on the assumed top mass and the calorimeter energy scale for b-quark jets, $bJES$. So the signal likelihood $P_{\rm sgn}$ for each event is given by

$$\begin{aligned} P_{\rm sgn}(\vec{x}; m_{\rm top}, bJES) \;=\; & \frac{1}{\sigma_{\rm obs}(p\bar{p} \to t\bar{t}; m_{\rm top}, bJES)} \times \\ & \int_y \sum_{\rm flavors} f_{\rm PDF}(q_1) f_{\rm PDF}(q_2) \times \\ & {\rm d}\sigma(p\bar{p} \to t\bar{t} \to \vec{y}; m_{\rm top}) \times \\ & W(\vec{x}, \vec{y}; bJES) \end{aligned}$$

where the transfer function W describes the detector resolution, i.e., the probability to measure the observed event $\vec{x}$ as a result of an assumed partonic final state $\vec{y}$. The integral is over all possible partonic final states, f is the probability to find a quark of given flavor and momentum q inside the colliding proton or antiproton, and $\mathrm{d}\sigma$ is the differential cross-section to produce a signal event $\vec{y}$ given the assumed top quark mass m_{top}. The quantity is normalized with the total cross-section $\sigma_{\rm obs}$ for selected events.

Since this is the first time the method is applied at DØ in the dilepton channel an extended test has been carried out. In a first step around 10000 Monte Carlo simulated events in the electron-muon final state have been produced for seven different top pole masses between 150 and 200 GeV. A parameterization of the detector resolution has been used to smear jets and muons (it was shown in [3] that it is necessary to account for the resolution of highly energetic muons).

Events have been selected in which two isolated highly energetic leptons and a significant amount of missing transverse energy indicate the presence of the leptonically decaying W bosons. In addition, exactly 2 isolated jets with large transverse energy are required, corresponding to the 2 b quarks in the $t\bar{t}$ decay.

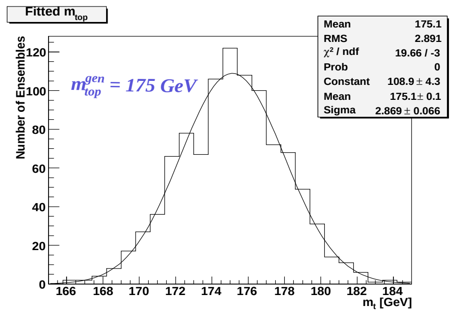

Fig. 1: Distribution of fitted top mass in pseudo-experiments.

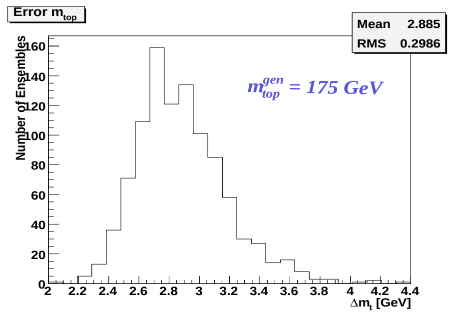

Fig. 2: Fitted statistical uncertainties in pseudo-experiments.

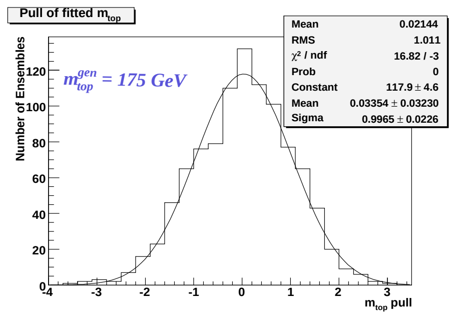

Fig. 3: Pull distribution in pseudo-experiments.

After calculating the signal probability for each event, 1000 pseudo-experiments, each based on an ensemble of 50 randomly chosen simulated $t\bar{t}$ events, have been performed. Figure 1 shows the resulting top quark mass for an input top mass of 175 GeV, Fig. 2 the statistical uncertainty on the mass, and Fig. 3 the pull (deviation of the fit result from the input mass, normalized by the fitted uncertainty) for each ensemble. This test shows that the method is unbiased and returns an accurate uncertainty estimate, also when applied to the dilepton channel.

In a next step pseudo-experiments including background and background probabilities will be considered. Once the method is fully tested, Monte Carlo events using the full DØ detector simulation will be used to calibrate the method. The method can then be applied to measure the top quark mass and promises to yield the most accurate measurement by DØ in the dilepton channel.

References

[1] V.M. Abazov *et al.*, Nature **429** (2004) 638-642

[2] V. M. Abazov *et al.*, [DØ Collaboration], Phys. Rev. **D74** (2006) 092005 see also F.Fiedler, p.32.

[3] F. Fiedler *et al.*, *Determination of the Muon Tranfer Fuction for Top Mass Measurements*, DØ note 4818 (2005).