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

A. Grohsjean, F. Fiedler, O. Biebel, P. Calfayan, P. Haefner, T. Nunnemann, M.P. Sanders, D. Schaile, R. Ströhmer, and B. Tiller

The top quark, discovered in 1995 by the CDF and DØ experiments at the Fermilab Tevatron Collider, is the heaviest of all known fundamental particles. The precise knowledge of its mass yields important constraints on the mass of the yet-unobserved Higgs boson and allows to probe for physics beyond the Standard Model.

The following summarizes the first measurement of the top quark mass in the dilepton channel with the Matrix Element method at the DØ experiment.

The Matrix Element method is based on the likelihood $L_{\mathrm{evt}}\ (m)$ to observe a given event under the assumption that the quantity to be measured has a specific value m [1]. Assuming one signal and one background process, the event likelihood can be written as

$$L_{\mathrm{evt}}(x; m_{\mathrm{top}}) = f_{\mathrm{top}} \cdot L_{\mathrm{sgn}}(x; m_{\mathrm{top}}) + (1 - f_{\mathrm{top}}) \cdot L_{\mathrm{bkg}}(x)\,, \tag{1}$$

where f_{top} denotes the signal fraction in the sample, and L_{sgn} (L_{bkg}) the signal (background) likelihood. In the dilepton channel, $Z+$jets events are the dominant source of background. Only small contributions from diboson production and events where a hadronic jet is misreconstructed as a lepton remain after the signal selection. Thus, these processes are not included in the background likelihood L_{bkg} . In order to extract the top quark mass from a set of n events with measurements $x_1, .., x_n$, an overall likelihood function is built from the event likelihoods and evaluated for different hypotheses of m_{top} . The top quark mass is then determined by minimizing the negative logarithm of the likelihood function for the event sample

$$-\ln L(x_1, .., x_n; m_{\mathrm{top}}) = -\sum_{i=1}^{n} \ln(L_{\mathrm{evt}}(x_i; m_{\mathrm{top}})) \tag{2}$$

w.r.t. m_{top} .
Since this is the first time the Matrix Element method is applied in the dilepton channel at the DØ experiment, an extended set of partonlevel tests was carried out [2].
For the final measurement, two different calibration curves are derived using fully simulated Monte Carlo events. This is necessary as the resolution of the DØ detector changed significantly with the upgrade in spring of 2006. As an example, the measured top quark mass as a function of the generated top quark mass for the pre-upgrade Monte Carlo samples is shown in the left plot of Figure 1. The offset is negligibly small; The slope is about 90% as the event likelihood does not account for diboson events. The corresponding pull width, i.e. the deviation of the measured top mass from the nominal value in units of the statistical uncertainty, is shown in the right figure. Due to an improved handling of events with more than two jets, the pull width is only 1.15 [3].

While only events with exactly one electron and one muon are taken into account so far, the measurement makes use of the full Run II data set recorded between April 2002 and May 2008. To reduce the fraction of background events and achieve a good agreement between simulated and measured events, a kinematic selection is applied, leaving 107 data events.

The left (right) plot in Figure 2 shows the measured top quark mass for the data events recorded before (after) the detector upgrade.

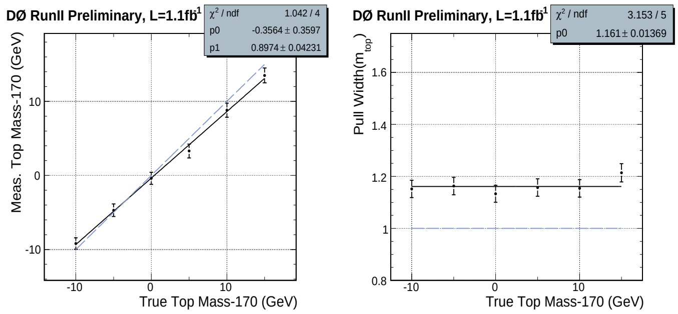

Fig. 1: Left: Measured top quark mass with respect to the generated mass for pre-upgrade electron+muon Monte Carlo events. Right: Corresponding pull width distribution.

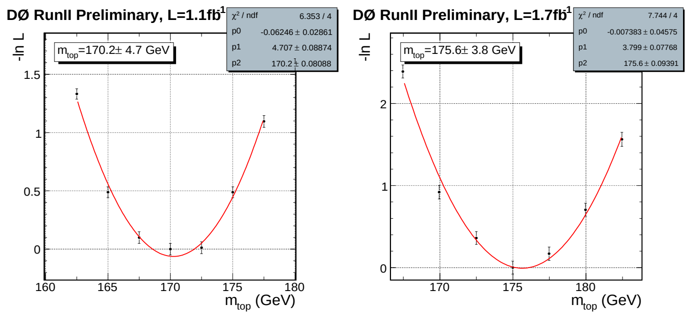

Fig. 2: Application of the matrix element method to the $2.8\mathrm{fb}^{-1}$ DØ Run II dataset. The plot shows the uncalibrated results for the pre- and post-upgrade data samples.

Taking the calibration curves into account the top quark mass is measured to be

$$m_{\mathrm{top}}^{comb} = 172.9 \pm 3.6\,(\mathrm{stat.}) \pm 2.3\,(\mathrm{syst.})\quad \mathrm{GeV} \tag{3}$$

in the combined Run II electron+muon data sample. With a statistical uncertainty of 3.6 GeV, this measurement has the smallest statistical uncertainty of all top mass measurements performed in the dilepton channel at DØ experiment. The dominant sources of systematic uncertainties are jet uncertainties, such as their energy scale and resolution.

A detailed description of the analysis can be found in Ref. [4].

References

[1] V.M. Abazov *et al.*, [DØ Collaboration], Phys.Rev. **D74** (2006) 092005
[2] A. Grohsjean *et al.*, Annual report 2006, p. 30
[3] A. Grohsjean *et al.*, DØ note-conf 5743.
[4] A. Grohsjean, Ph.D. thesis, LMU München, 2009 *Measurement of the Top Quark Mass in the Dilepton Final State using the Matrix Element Method*,