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

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With the current world average [1] of

$$m_t = 170.9 \pm 1.1(\text{stat.}) \pm 1.5(\text{syst.})\text{GeV}$$

the top quark is the heaviest of the observed fundamental particles. The mass of the top quark corresponds to a top Yukawa coupling of around one, which suggests that it may play a unique role in electroweak symmetry breaking. Precise measurements of the top mass also constrain the mass of the yet unobserved Higgs boson through radiative corrections to the W boson mass.

The key concept of the Matrix Element (ME) method [2] is to determine an event probability function which depends on the kinematic observables x and the quantities α_i to be measured e.g. $\alpha_1 = m_{\text{top}}$. Assuming one signal and one background process the event probability can be written as

$$P_{evt}(x, \alpha_i) \quad = \quad f_{\text{top}} \cdot P_{\text{sgn}}(x; \alpha_i) + (1 - f_{\text{top}}) \cdot P_{\text{bkg}}(x)$$

where f_{top} denotes the signal fraction in the sample, $P_{\text{sgn}}(P_{\text{bkg}})$ the signal (background) probability. $Z+$jets events are considered to be 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 the matrix element for these processes are not included in the event probability. In order to extract the top quark mass from a set of n events with measurements $x_1, .., x_n$ a likelihood function is built from the event probabilities 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

$$-\ln L(x_1, .., x_n; m_{\text{top}}) \quad = \quad -\sum_{i=1}^{n} \ln(P_{evt}(x_i; m_{\text{top}}))$$

w.r.t. m_{top} .

Since this is the first time the ME method is applied in the dilepton channel at DØ an extended set of tests were carried out [3].

The reference scale of the fitting procedure is derived from fully simulated Monte Carlo events. $t\bar{t}$ samples generated with 5 different top quark masses (160, 165,170, 175, 180 GeV) are used. The event selections applied in this analysis are consistent with the event selections used for the cross section measurements. Since the selection in the dimuon channel is not yet finalized only electron+muon and dielectron events are taken into account so far. The left plot in Figure 1 shows the measured top quark mass for the combination of the electron+muon and the dielectron channel as a function of the generated top quark mass. The right plot shows the corresponding pull width. The small offset of 1.2 GeV is mainly caused by the non vanishing transverse momentum of the top quark pair. When integrating over the final state phase space it is assumed that the top pair system is almost at rest, what is no longer valid for events with an additional jet from initial state radiation. This leads to the observed pull width of 1.37.

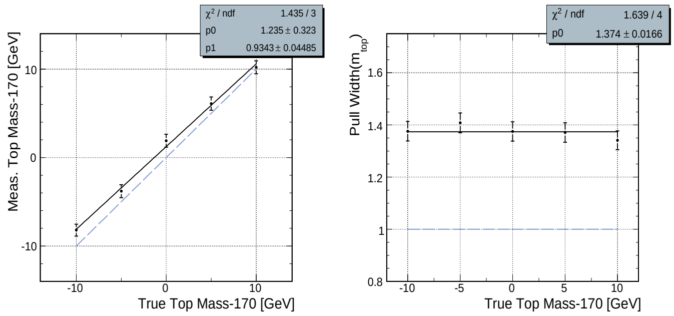

Fig. 1: Measured top quark mass with respect to the generated top quark mass using a combination of the electron+muon and dielectron channel (left) and the correspond pull width distribution (right).

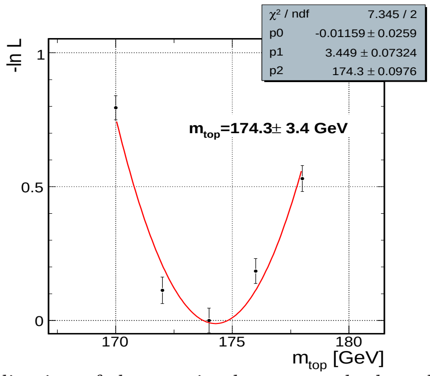

Fig. 2: Application of the matrix element method to the 1fb^{-1} DØ Run II dataset. The plot shows the uncalibrated result for the combination of the electron+muon and the dielectron channel.

Taking the calibration into account this analysis obtains

$$m_{\text{top}}^{comb} \quad = \quad 173.4 \pm 5.0\,(\text{stat.})\text{ GeV} \qquad (1)$$

in the combined electron+muon and dielectron channel, where the statistical error is corrected for the pull width and the slope. With an expected statistical uncertainty of 4.8 GeV derived from fully simulated Monte Carlo events the achieved uncertainty is about 25% smaller compared to template based measurements. The main systematic uncertainty in this measurement is the uncertainty due to the precision of the jet energy scale. It is measuered to be $+2\text{GeV}/-1.8\text{GeV}$. The additional uncertainty originating from the energy scale of b quark jets is expected to be of the same size.

References

[1] The Tevatron Electroweak Working Group for the CDF and DØ Collaborations, hep-ex/0703034.

[2] V. M. Abazov *et al.*, [DØ Collaboration], Phys. Rev. D **74** (2006) 092005.

[3] A. Grohsjean *et al.*, MLL-Annual Report 2006, p.30.