Top Quark Mass Measurement at DØ with the Matrix Element Method in the Lepton+Jets Channel

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The mass of the top quark is an important parameter of particle physics. In the Standard Model, it provides indirect contraints on the Higgs boson mass. The single most precise measurement by the DØ experiment is based on the matrix element method applied to the lepton+jets final state [1] corresponding to the reaction $p\bar{p} \to t\bar{t}X$ with $t\bar{t} \to b\bar{b}q\bar{q}\ell\nu$. This measurement is described here.

The technique described in [2] has been extended such that for each preselected event, the probability to be produced via the signal reaction is calculated not only as a function of assumed top quark mass, but also depending on the value of the global calorimeter energy scale ("jet energy scale", JES). The JES parameter enters the transfer function W that describes the probability for the detector to measure the actually observed event x as a result of an assumed partonic final state y. It is mainly constrained by information from the hadronic W decay in lepton+jets $t\bar{t}$ events. The signal probability for a measured event x is

$$P_{\rm sgn}(x;\, m_{\rm top}, JES) = \frac{1}{\sigma_{\rm obs}(p\bar{p} \to t\bar{t};\, m_{\rm top}, JES)} \times$$

$$\int_y \sum_{\rm flavours} f(q_1) f(q_2) {\rm d}\sigma(p\bar{p} \to t\bar{t} \to y,\, m_{\rm top}) W(x, y;\, JES) \ ,$$

where the integral is over all possible partonic final states y, f denotes the probability to find a quark of a given flavour inside the colliding proton or antiproton, dσ is the differential cross-section to produce a signal event y given the assumed top quark mass $m_{\rm top}$, and W is the above-mentioned transfer function that describes the detector resolution. The quantity is normalized with the total cross-section $\sigma_{\rm obs}$ for events that pass the trigger and acceptance cuts. This cross-section is shown in Figure 1 for both the e+jets and μ+jets channels.

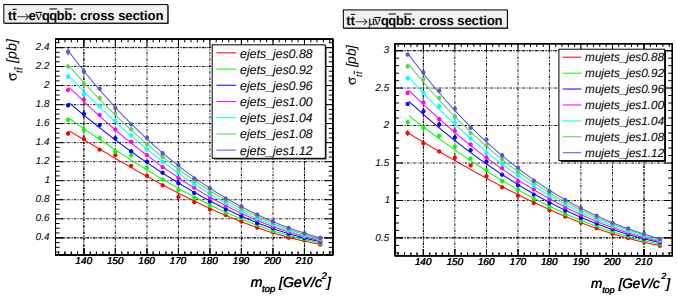

Fig. 1: $t\bar{t}$ cross-section for observed events in the e+jets (left) and μ+jets (right) channels, as a function of assumed top quark mass $m_{\rm top}$ and for various assumed JES values.

Similarly, a probability $P_{\rm bkg}$is calculated for each event to be produced via the main background process (W+jets), and an event probability is formed as

$$P_{\rm evt}(x; m_{\rm top}, JES, f_{\rm top}) = f_{\rm top}\, P_{\rm sgn}(x; m_{\rm top}, JES) + (1 - f_{\rm top})\, P_{\rm bkg}(x; JES) \ ,$$

where $f_{\rm top}$ denotes the $t\bar{t}$ fraction in the event sample.

Two analyses are then performed: In the first one, information from identified b quark jets is not used, while in the second one, events are classified into subsamples of different signal purity depending on the number of identified b jets; also, the additional information allows larger weights to be assigned on average to the correct assignment of final state quarks to measured jets.

In both analyses, the combined likelihood $\mathcal{L}(m_{\rm top}, JES, f_{\rm top})$ for the selected event sample is obtained from the individual $P_{\rm evt}$ values and projected onto the $m_{\rm top}$ and JES axes, taking the correlations into account. The central values and 68% confidence level intervals are determined from these projections, and the results are shown in Figure 2. The measurement technique is calibrated with ensemble tests as described in [2] using fully simulated DØ signal and background events.

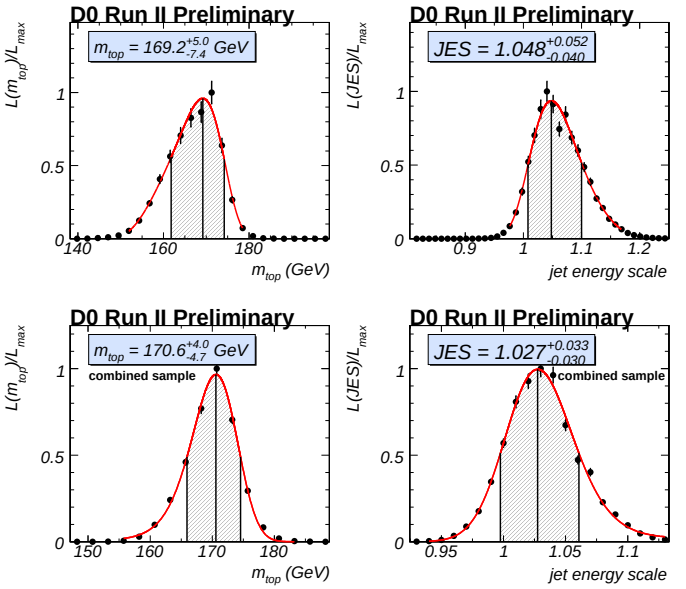

Fig. 2: Top quark mass (left column) and jet energy scale (right column) results in the topological (upper histograms) and b-tagging (lower histograms) analyses. The b tagging results from the individual subsamples have been combined. The points with error bars show relative probabilities for the individual $m_{\rm top}$ or JES assumptions, and the red curve is a fit to these points. The central measured values and the 68% confidence regions are indicated as well.

The top quark mass is determined to be

$$m_{\rm top}^{\rm topo} = 169.2^{+5.0}_{-7.4}\,({\rm stat.+JES})\,^{+1.5}_{-1.4}\,({\rm syst.})\ {\rm GeV \ and}$$
$$m_{\rm top}^{b-{\rm tag}} = 170.6^{+4.0}_{-4.7}\,({\rm stat.+JES})\ \pm 1.4\,({\rm syst.})\ {\rm GeV} \ .$$

The values measured for the jet energy scale indicate good consistency with the detector simulation.

References

[1] DØ Collaboration, *Top Quark Mass Measurement with the Matrix Element Method in the Lepton+Jets Final State at DØ Run II*, DØ note 5053.

[2] P. Schieferdecker *et al.*, *Top Mass Measurement at DØ Run II with the Matrix Element Method*, Annual report 2004, p. 40