A Path to Higher Precision Top Mass Measurements with the Matrix Element Method in Semileptonic Top Pair Decays at D0

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

The top quark is special among the quarks due to its extremely high mass of about 172 GeV, its tiny lifetime evading hadronisation and its property to allow indirect constraints on the Higgs mass.

Top pair production with a semileptonic decay $t\bar{t} \to W^{\pm}W^{\mp}b\bar{b} \to q\bar{q}b\bar{b}l\nu$ is the "golden channel" for mass measurements, having a large branching fraction and low backgrounds compared to other channels. Top mass measurements based on this decay, performed with the Matrix Element (ME) Method have always been among the single best measurements in the world. In 2007, the uncertainty on the top mass world average reached the 1% level and it is no longer limited by statistical but by systematic uncertainties. Hence, more and more sophisticated improvements of the existing methods are needed to decrease the uncertainty further.

The approach shown here addresses the major source of systematic uncertainty at high integrated luminosities, the unknown jet energy scale (JES) for b-jets. So far, only a general JES is derived at D0 and effects of differences in b and light quark jets, e.g. particle composition, are not considered. As each $t\bar{t}$ event contains two b-quarks this is a large source of uncertainty. Therefore, this analysis employs a method, similar to the one that was applied to reduce the general JES error. In addition to a variation of the assumed top mass, the ME probability calculation includes assumptions on JES and b-JES scale factors (s_{jes}, s_{bjes}). A three-dimensional likelihood fit is performed to extract the most likely values of all three observables at once. In this method, s_{jes} is constrained by the W mass given in the matrix element. If the momenta of the two light quark jets of the W decay are wrongly estimated, the W mass will be mismeasured as well. Thus, s_{jes} can be derived as the average scale factor that needs to be applied to the jets to obtain the "correct" W mass. The other factor, s_{bjes}, is constrained by the transverse momentum balance of the top pair. As $t\bar{t}$ pairs are dominantly produced at rest in p_t and without hard gluon radiation at Tevatron energies, the top quarks' momenta need to be back-to-back in the transverse plane. A mismeasured b-JES breaks this balance. Hence, s_{bjes} can be obtained as the average scale factor needed to restore the balance of the reconstructed top quarks.

To test and calibrate the method, pseudoexperiments are performed. A pool of about 10^3 Monte-Carlo events is produced both for signal ($t\bar{t}$) and background (W+jets) processes. Other sources of background like QCD multijet production are not included explicitly as they have similar kinematic properties as W+jets. A pseudoexperiment utilizes an amount of events comparable to the one observed in data. In our case, we use about 10^2 events both in the e+jets and μ+jets channel. Events containing τ decays are not considered due to their difficult identification in the detector. The simulated events are analyzed in exactly the same way as data: signal and background likelihoods are calculated and top mass, JES and b-JES scale factors are determined. The measurement is repeated for 1000 pseudoexperiments to obtain mean values of the fit observables, the expected statistical uncertainties and the pull. The latter is defined as the difference between reconstructed and generated top mass (or one of the other input values) divided by the statistical uncertainty of the fit.

To obtain a calibration that can be used for data, the whole procedure is applied to pseudoexperiments with different input values of top mass, $s_{(b)jes}$ and background fraction to study their influence on the measurement. In Fig. 1 the calibration for the top mass is shown with only signal events included. Five different input top masses in the range 160-180 GeV are studied. The events are generated at parton level and smeared according to detector transfer functions [1]. The ratios of reconstructed to generated top mass, s_{jes} and s_{bjes} agree very well with unity for all top mass calibration points, thus, confirming the method. Calibration curves with different s_{jes} and s_{bjes} inputs and varying background fractions were studied as well, all of them revealing a flat ratio of one.

References

[1] P. Schieferdecker *et al.*, Annual report 2005, p. 36.

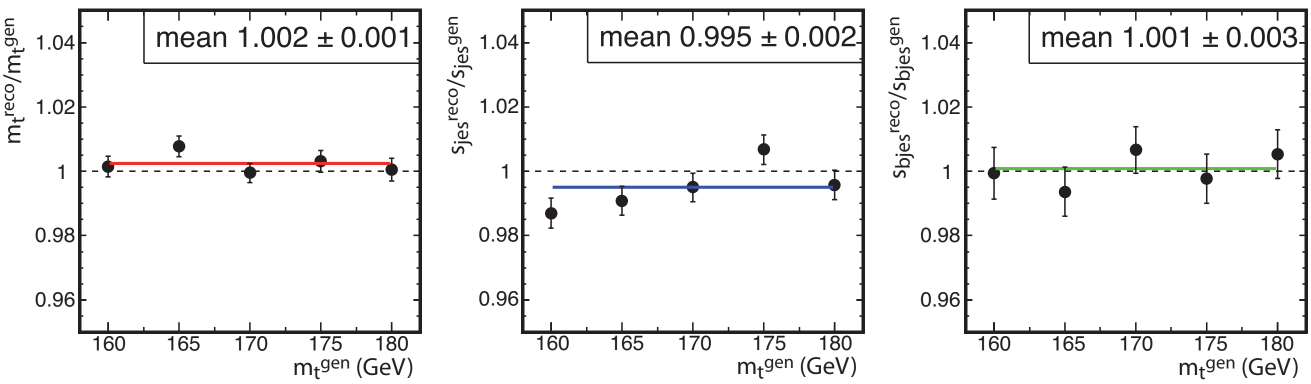

Fig. 1: Calibration of three-dimensional fit versus generated top mass. *Left:* Ratio of reconstructed and generated top mass, *Middle:* Ratio of reconstructed and generated JES scale factor, *Right:* Ratio of reconstructed and generated b-JES scale factor.