Independent Measurement of the Top Quark Mass and the Light- and Bottom-Jet Energy Scales at Hadron Colliders

F. Fiedler

At hadron-colliders, the measurement of the mass m_t of the top quark and the absolute energy scale S for calorimeter jets are closely linked. While the scale S_j for light jets can be calibrated with hadronic W decays in the same ℓ+jets $t\bar{t}$ events used to measure m_t, the main remaining systematic uncertainty on m_t is so far due to differences between S_j and the scale S_b for b jets [1]. A novel measurement technique has now been developed that allows a simultaneous determination of m_t, S_j, S_b, and the jet energy resolution R from ℓ+jets $t\bar{t}$ events [2].

It is assumed that the full calorimeter calibration up to constant scales S_j and S_b has been performed before this method is applied. Three *estimators*, $m_t^{\rm reco}$, $S_j^{\rm reco}$, and $S_b^{\rm reco}$, are calculated for each selected event. Functions are derived to describe the expected estimator distributions (*templates*) for any given set of assumed values of m_t, S_j, S_b, and R. A comparison of the measured estimator distributions in the data with these fitted templates then yields the m_t, S_j, S_b, and R values and their uncertainties.

The method has been tested using ℓ+jets $t\bar{t}$ events in 14 TeV pp collisions generated at parton level with ALPGEN [3]. The energies of the final-state quarks have been smeared according to a Gaussian resolution whose width is set to $\sigma(E) = R\sqrt{E}$ with constant R. All jet energies are multiplied by a factor S_j, and b-jet energies by another factor S_b. Tests have been performed with various (m_t, S_j, S_b, R) parameter sets.

Standard $t\bar{t}$ event selection criteria [2] are applied. In each event, assuming unambiguous b-jet identification, the estimator $S_j^{\rm reco} = \frac{m_W^{\rm raw}}{m_W}$ is calculated from the known W mass m_W and the mass $m_W^{\rm raw}$ reconstructed from the smeared light-jet energies. A scan over $S_b^{\rm reco}$ values is performed. Given an assumed value of $S_b^{\rm reco}$, the reconstructed b-quark jet energies and momenta are scaled accordingly, and the missing transverse momentum is adjusted and taken as transverse momentum of the neutrino from the leptonic W decay. The longitudinal neutrino momentum p_ν^z is then obtained from m_W, and the resulting top quark masses $m_{t,\,\rm lep}^{\rm reco}$ and $m_{t,\,\rm had}^{\rm reco}$ of the top quarks with the leptonic/hadronic W decay are computed. If one finds $m_{t,\,\rm lep}^{\rm reco} = m_{t,\,\rm had}^{\rm reco}$, then this top quark mass and the corresponding $S_b^{\rm reco}$ value are taken as estimator values for the event. Events are only retained if exactly one solution with $0.5 < S_b^{\rm reco} < 2.0$ and $150\,{\rm GeV} < m_t^{\rm reco} < 200\,{\rm GeV}$ is found.

After the preselection, events with a magnitude of the vector sum of b-quark jet transverse momenta of less than 50 GeV that yield poor independent information on the top quark mass and b-quark jet energy scale are rejected. Finally, the quantity $\Delta^{\rm reco} := \frac{\partial m_{t,\,\rm lep}^{\rm reco}}{\partial S_b^{\rm reco}} - \frac{\partial m_{t,\,\rm had}^{\rm reco}}{\partial S_b^{\rm reco}}$ is obtained during the scan of $S_b^{\rm reco}$ values. Events with $\Delta^{\rm reco} < 30\,{\rm GeV}$ have a degraded resolution and are rejected. The resulting $S_b^{\rm reco}$ estimator distributions for various choices of input parameters are shown in Figure 1 as an example.

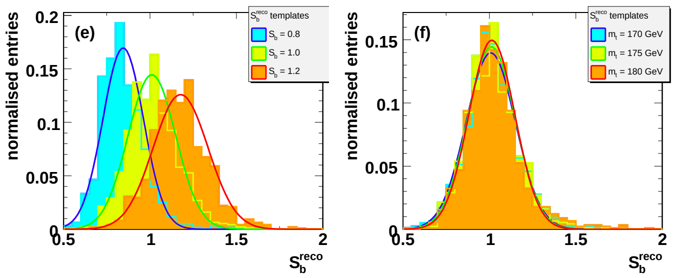

Fig. 1: $S_b^{\rm reco}$ template when varying (left plot) the input S_b value, and (right plot) the input m_t value. The template parameterizations are overlaid.

To test the method, pseudo-experiments are then performed using simulated events for various sets of input parameter values. Figure 2 shows results for the distributions of measured m_t, S_j, and S_b values. The correlation matrix between the four measured parameters is given by:

	S_j	S_b	R
m_t	-0.09	-0.50	-0.22
S_j		-0.38	-0.11
S_b			-0.14

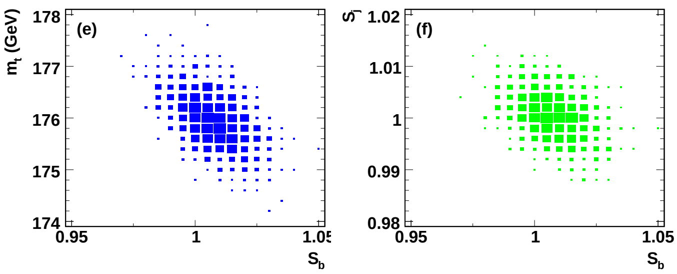

Fig. 2: Pseudo-experiments: The correlation between m_t and S_b results (left plot), and that between S_j and S_b (right plot).

The parton-level tests of the method have been published [2] as a proof of principle. In the future, the method will be applied to fully simulated ATLAS events, and systematic uncertainties will be investigated.

References

[1] F. Fiedler, "Precision Measurements of the Top Quark Mass", habilitation thesis, 2007, http://www.etp.physik.uni-muenchen.de/dokumente/thesis/habil_ffiedler.pdf

[2] F. Fiedler, Eur. Phys. J. **C 53** (2008) 41 [arXiv:0706.1640 [hep-ex]].

[3] M. L. Mangano *et al.*, JHEP **307** (2003) 1