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Estimation of the jet energy scale corrections using top quark events

P. Van Mulders

Abstract

A least-square kinematic fit using Lagrange multipliers is applied to enforce the W boson and top quark mass constraints in the reconstructed $pp \to t\bar{t} \to q\bar{q}b\mu\nu_\mu\bar{b}$ events. Residual corrections are estimated on the energy scale of the jets arising from both the light quarks in the W boson decay and the heavier bottom quark in the top quark decay. Utilizing the first integrated luminosity of 100 pb^{-1} of proton collisions at 14 TeV detected by the CMS detector, an uncertainty smaller than 1% can be obtained on the jet energy scale for both light and heavy jets.

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Estimation of the jet energy corrections using top quark events

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Summary. — We report a method for an estimation of the jet energy scale corrections. A least-square kinematic fit using Lagrange multipliers is applied to enforce the W boson and top quark mass constraints in the reconstructed $pp \rightarrow t\bar{t} \rightarrow q\bar{q}b\mu\nu_\mu\bar{b}$ events. Residual corrections are estimated on the energy scale of the jets arising from both the light quarks in the W boson decay and the heavier bottom quark in the top quark decay. Utilizing the first integrated luminosity of 100 pb^{-1} of proton collisions at 14 TeV detected by the CMS detector, an uncertainty smaller than 1% can be obtained on the jet energy scale for both light and heavy quark jets.

The AlpGen generator has been utilized to simulate the physics processes of interest in this paper, being $t\bar{t} + jets$ (NLO cross section) and $W/Z + jets$ (LO cross section). The QCD multi-jet background has been simulated with PYTHIA. A GEANT based simulation program is applied to simulate the CMS detector response. Alignment and calibration correction factors are used as they would have been estimated from a data sample with an integrated luminosity of 10 pb^{-1}. The reconstruction and selection of the events is the same as described in [1].

To avoid difficulties in the interpretation of the result, the jets are required not to overlap. To choose the correct jet combination among all possibilities a combined likelihood ratio is constructed as described in [2]. The jet combination in the event with the highest combined likelihood ratio is taken as the correct combination. To increase the number of correct jet combinations in the event sample, a cut on the logarithm of the combined likelihood ratio is applied at 0. We apply a general non-linear least square fit using Lagrange Multipliers constraining the reconstructed W boson and top quark masses in the hadronic top quark decay ($t \rightarrow bW \rightarrow q\bar{q}b$) to the world average values. The energies of the jets in the hadronic top decay are shifted in steps of 2.5% between -50% and +50%. From the probabilities returned by the kinematic fit a probability distribution $P_{fit} = P_{fit}(\Delta E_b, \Delta E_q, \Delta E_{\bar{q}})$ is constructed. The procedure was simplified by reducing the fit dimensions from 3 to 2 by requiring that the two light jet energy corrections be equal, $\Delta E_q = \Delta E_{\bar{q}}$. The fit probability before applying additional shifts on the jet energy scale is required to exceed 0.01, to help remove mis-reconstructed events. Events are only taken into account in the method if they have in the scanned range of corrections a maximal fit probability exceeding 0.98. The distribution of these two selection variables is shown in figure 1.

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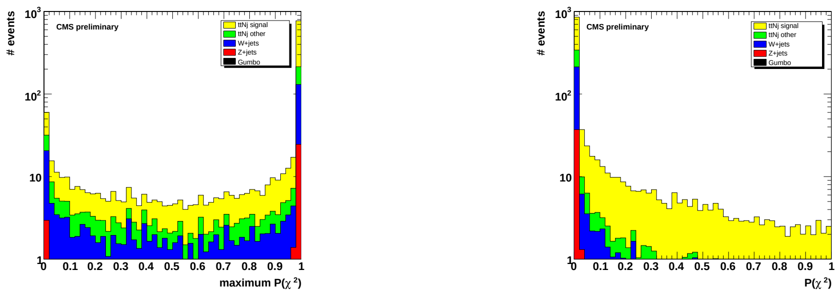

Fig. 1. – The maximum fit probability P_{fit}^{max} in the 2D range for each event (left) and the fit probability when no corrections are applied (right).

Events with best estimates for the jet energy scale corrections, corresponding to the energy corrections when the fit probability is maximal, are removed if they deviate more than 20% w.r.t the initial estimate. The method for obtaining the initial estimate is described in [2]. The best values of the residual corrections are obtained when the combined $\Delta\chi^2(\Delta E_b, \Delta E_q = \Delta E_{\overline{q}})$ distribution is minimized. The estimate of the corrections is obtained by projecting this distribution into each dimension separately. The resulting 1D $\Delta\chi^2$ distributions are then fitted with a parabola to obtain the estimates of the jet energy scale corrections resulting in uncertainties of 0.9% with a dataset of 100 pb^{-1} of integrated luminosity.

The uncertainties are corrected to obtain a unity width of the pull distribution determined via resampling techniques. It has been checked that the method is linear. Several systematic effects can influence the method described. The main effect is expected to be the contribution of pile-up collisions although this could be considered as part of the residual jet energy scale correction to be estimated. The sensitivity to both the jet combinatorial and the process background is estimated and found to be negligible. An extra smearing on the measured jet energies is applied prior to the analysis increasing the Gaussian width of the residual distribution with a factor of 2, but without a significant effect on the estimated jet energy scale corrections. From data itself it will be possible to estimate the sensitivity of the results with respect to different kind of backgrounds by changing the selection cuts in the analysis. For example the combined likelihood variable and the maximum fit probability cut to estimate the sensitivity to respectively the combinatorial and process background. Given the small sensitivity to systematic uncertainties, the jet energy scale can potentially be estimated from top quark events with a precision of about 1% using the first 100 pb^{-1} of data.

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