Nov.4, 2020

D0 top mass determination in the lepton + jets channel

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A recent preprint [1] discussing the D0 top mass determination [2, 3] using the full Run II 9.7 fb^{-1} lepton+jets sample at the Fermilab Tevatron p-pbar collider makes the obvious point that a recalibration of jet energies would shift the measured top mass. Ref. [1] then goes on to say that there is "the need to revise the top mass measurement performed by D0", based on the findings of Ref. [4] which claims that the calibration of the jet energy scale by the D0 Collaboration [5] is incorrect. Reference [4] relies heavily upon internal documents [6,7] that were provided by D0 [8]. Such internal notes typically give a more detailed account of the data sets, analysis procedures and cross checks than can be found in the journal publications, but are not subject to rigorous review. The publication [5] on the D0 jet energy scale is however quite detailed and was carefully reviewed, and thus should be taken as the primary reference. There were no interactions between the authors of Refs. [1, 4] and the primary D0 authors concerning the details in the internal notes.

We have re-examined the analyses reported in Refs. [5, 6, 7] in the light of the arguments in Refs. [1,4]]. We summarize our main conclusions here (the appendix gives some added detail of our review of the D0 jet energy scale correction documentation):

1. There are instances where the event selection criteria, the choice of kinematic regions, or the detailed application of corrections in Ref. [4] differ from those in the D0 determination of the jet energy scale. Such differences would lead to changes in the jet energy scale and hence the top mass value. For example, a calibration of the entire calorimeter, $|\eta| < 2.5$, is necessary to measure the top mass, while Ref. [4] considered only $|\eta| < 0.4$.

2. Some specific selections used in the D0 analysis were not reported in the internal notes, but were simply taken as the defaults in the D0 analysis code packages. Although we would have been willing to provide these details, such discussions did not occur, and thus would not have been used in Ref. [4]. We believe that such discussions would have been more consistent with good scientific practice.

3. A few plots in the D0 internal notes used in Ref. [4] could be misleading. Their intent was to visualize the uncertainty band on the jet energy scale, but they were based on different sets of MC events. The published top mass [2,3] values were unaffected by the jet energy scale values shown in these illustrative plots.

4. We do not confirm the conclusions of Ref. [4], and hence Ref. [1], and stand by the correctness of the published D0 determination of the jet energy scale and top quark mass.

Appendix: Single particle corrections to the jet energy scale

The baseline jet energy calibration was developed using γ+jet events to correct the detected jet energies to the particle level, averaging differences due to the specific flavor of the parton that initiated the jet. Samples of jets of different composition than in γ+jet may require additional corrections to the jet energy scale (JES). The single-particle response (SPR) calibration, applied to individual particles within a MC jet, allows one to account for the dependence of the calorimeter response on the jet parton flavor and its kinematics and thus correct for the MC-data difference.

For this purpose, as explained in Section 14.1 (see Eqs. 49, 50 and text around them) of the JES publication [5], we first derive a correction factor *F* for the jet response to make the jet response simulated in MC be as close as possible to that observed in data. As we showed in Fig. 33 of [5], as well as in Figs. 13-36 of Ref. [7], we managed to derive SPRs to reproduce the jet response observed in data for any luminosity, jet p_T scale, η, and event sample composition, by looking at γ+jet and dijet events. The particle content of jets differs significantly over such a wide variation of kinematics and event samples. The observed good MC/data agreement in all those variations allows us to conclude that our data-driven SPR parameterizations were accurate within quoted uncertainties. In addition, since the baseline JES calibration is done in data using γ+jet events, we derive a relative correction factor F_{corr} (see Eq. 50 of Ref. [5]), which allows us to obtain a data-like jet response for individual jets with any particle composition (e.g. jets initiated by a b-quark). The multiplicative correction factor F_{corr} is hence dependent on the single particle composition of individual jets and is independent of other multiplicative JES MC corrections by construction.

The systematic uncertainties for F_{corr} derived using the tuned MC SPR are illustrated in Fig. 34 of Ref. [5] for the central jets, and in Figs. 40-42 of Ref. [7] for various jet rapidities and luminosities for a MC sample selected to ensure good statistical coverage over the p_T range of interest. The authors of Refs. [1] and [4] advertised an inconsistency in D0 corrections similar to what one would see if data points from Figs. 37-39 of Ref. [7] were overlaid on the parameterizations with the functional form of Figs 40-42. The visual differences in F_{corr} observed in Figs. 37-39 and Figs. 40-42 of Ref. [7] could be caused either by a difference in jet p_T scale (uncorrected in Figs. 37-39 vs. corrected in Figs. 40-42), or difference in event topologies (e.g. photon selections, requirements on $\Delta\phi(\gamma,\mathrm{jet})$ or on number of jets). A difference in event topologies would affect the jet sample composition (see e.g. Figs. 7-10 of [7]) and thus the averaged jet SPR that is shown in Figs 37-42. It is hard to identify an exact reason after so many years. However, it is important to realize that the average SPR parameterizations shown in both Figs. 37-39 and Figs. 40-42 are given for demonstration purposes only, and were not applied anywhere in our analyses. Instead, the actual SPR parameterizations, carefully validated in the way described above, were applied jet-by-jet in all data analyses.

References

[1] Hannu Siikonen, “Top Mass Shift Caused by the Recalibration of Flavor-Dependent Jet Energy Corrections in the D0 Lepton+Jets Top Mass Measurement”, arXiv.2002.06073 (2020).

[2] V.M. Abazov et al., “Precision measurement of the top quark mass in lepton+jets final states at D0”, Phys. Rev. Lett. 113, 032002 (2014).

[3] V.M. Abazov et al., “Precision measurement of the top-quark mass in lepton+jets final states”, Phys. Rev. D 91, 112003 (2015).

[4] T. Mäkelä, ”Flavour-dependent jet energy corrections and top quark mass,“ Masters Thesis, Aalto University Document Server https://aaltodoc.aalto.fi/handle/123456789/39024 (2019).

[5] V.M. Abazov et al., “Jet Energy Scale Determination in the D0 Experiment”, Nucl. Instrum. Meth. A 763, 442 (2014).

[6] D0 internal note 6143 “Correction for the MC-Data Difference in the Jet Response at D0”, available from https://www-d0.fnal.gov/Run2Physics/WWW/results/final/TOP/T15A/

[7] D0 internal note 6368 “Correction for the MC-Data Difference in the Jet Response at D0 for Run IIB”, available from https://www-d0.fnal.gov/Run2Physics/WWW/results/final/TOP/T15A/

[8] D0 has adopted the policy of making its internal notes stored on INSPIRE publicly available five years after their creation if their authors agree; however, for technical reasons beyond D0’s control this was not implemented. D0 did make these notes available to the authors of Refs. [1,4] upon request. We now make these notes more widely available through the links given in Refs. [6,7].