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Energy-peak based method to measure top quark mass via B-hadron decay lengths

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We develop a method for the determination of the top quark mass using the distribution of the decay length of the B-hadrons originating from its decay. This technique is based on our earlier observation regarding the location of the peak of the b quark energy distribution. Such "energy-peak" methods enjoy a greater degree of model-independence with respect to the kinematics of top quark production compared to earlier proposals. The CMS experiment has implemented the energy-peak method using associated b-jet energy as an approximation for b quark energy. The new method uses B-hadron decay lengths, which are related to b quark energies by convolution. The advantage of the new decay length method is that it can be applied in a way that evades jet-energy scale (JES) uncertainties. Indeed, CMS has measured the top quark mass using B-hadron decay lengths, but they did not incorporate the energy-peak method. Therefore, mismodeling of top quark transverse momentum remains a large uncertainty in their result. We demonstrate that, using energy-peak methods, this systematic uncertainty can become negligible. We show that with the current LHC data set, a sub-GeV statistical uncertainty on the top quark mass can be attained with this method. To achieve a comparable systematic uncertainty as is true for many methods based on exclusive or semi-inclusive observables using hadrons, we find that the quark-hadron transition needs to be described significantly better than is the case with current fragmentation functions and hadronization models.

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