Using b Identification for an Improved Top Mass Measurement with the Matrix Element Method at DØ

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Over the last years, the Matrix Element (ME) Method has proven to be the most precise method for top mass measurements in the semi-leptonic decay channel $t\bar{t} \rightarrow W^{\pm}W^{\mp}b\bar{b} \rightarrow q\bar{q}b\bar{b}l\nu$. This report will give a short overview how identification of b quarks (the so-called b tagging) improves the measurement of the top quark mass with this method.

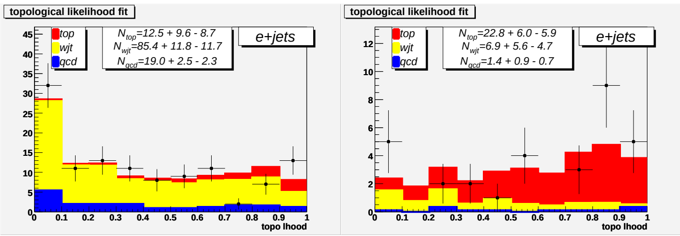

Fig. 1: Distributions of the topological likelihood discriminant for e+jets events with no b tagged jet (left) and exactly one b tagged jet (right). Points with error bars correspond to data. The colored histograms give the fitted contributions of $t\bar{t}$, W+jets and multijet MC events.

The achievement of b tagging is twofold as both statistical and systematic uncertainties can be addressed. The statistical uncertainty is reduced by giving higher weights to more pure b tagged samples. As the top quark decays to nearly 100% into a W boson and a b quark, b tagging helps to separate signal from background hardly containing any b quarks (see Fig. 1). Additionally, the ME method considers all possible jet-parton combinations to extract the maximum top mass information out of each event. In the semi-leptonic decay channel there are 24 possible ones (see Fig. 2). With the information from b tagging the most likely combinations are weighted higher than less likely ones.

The world average of the top mass is limited by systematic uncertainties already today. Thus, methods to decrease these uncertainties even at the cost of a larger statistical error need to be studied in detail. While using b tagged samples decreases the systematic uncertainty of background modelling due to higher purity, the dominant systematic error that needs to be addressed at high integrated luminosities is the unknown jet energy scale (JES) for b jets. A possible method how a reduction can be achieved will be described at the end.

For our top mass measurement we use data taken with the DØ detector between 2002 and 2006 (Run IIa) at the proton-antiproton collider Tevatron with a center-of-mass energy of 1.96 TeV. DØ has developed a neural network tagger that makes use of several inputs like secondary vertex tagging, soft lepton tagging and kinematic variables to separate b jets from c jets and light jets (u, d, s). The Tag Rate Functions (TRFs) give the probability for a quark of a given flavor, energy and pseudorapidity region to be tagged. Several operating points differ in the cut value on the neural network output. In previous analyses only one operating point with boolean tagging information was considered for each jet [1,2]. This study shows how the probability information from all operating points can be used to extract the maximal information out of b tagging.

First, each jet is classified by the highest operating point (0-11) of the neural network tagger that gives a tag (-1 if no tag). This information together with kinematic variables and the flavor of the assigned parton is used to lookup the TRFs and obtain the tagging probability for each individual jet. Multiplying the probabilities of all four jets then leads to a total probability for a certain permutation. Let's assume an event where two jets are classified by high operating points (e.g. 6 and 11) and the other two fall into the no tag bin (-1). Permutation 0 in Fig. 2, where the first two jets are assigned to light quarks and the second two to b quarks, would have a very low probability in this case as it is very unlikely that light quarks fall into high operating point bins. The other way round (e.g. permutation 10) would have a probability that can be orders of magnitudes larger as it is very likely for jets from b quarks to fall into high operating point bins and for light quarks not to show any tag. This would lead to a high weight of permutation 10 whereas permutation 0 is negligible for that specific event.

As stated above an important issue for top mass measurements is the reduction of b JES uncertainty. So far, only a general JES is derived at DØ and effects of different quark masses and particle composition in b and light jets are not considered. As each $t\bar{t}$ decay contains two b quarks this is a large source of uncertainty in precision measurements. Therefore, the next analysis will make use of a trick that was already applied to reduce the general JES error. Besides the assumptions of different top masses in the ME probability calculation assumptions of additional JES and b JES scale factors are made. A three dimensional likelihood fit is then performed to extract the most likely top mass, JES and b JES factor at once. While the general JES factor is constrained by the W mass given in the matrix element, the b JES factor will be constrained by the helicity angle distribution in the top rest frame.

Perm	q_{up}	q_{dn}	b_{had}	b_{lep}
0	jet0	jet1	jet2	jet3
1	jet0	jet1	jet3	jet2
2	jet0	jet2	jet1	jet3
3	jet0	jet2	jet3	jet1
4	jet0	jet3	jet1	jet2
5	jet0	jet3	jet2	jet1
6	jet1	jet2	jet0	jet3
7	jet1	jet2	jet3	jet0
8	jet1	jet3	jet0	jet2
9	jet1	jet3	jet2	jet0
10	jet2	jet3	jet0	jet1
11	jet2	jet3	jet1	jet0
12	jet1	jet0	jet2	jet3
13	jet1	jet0	jet3	jet2
14	jet2	jet0	jet1	jet3
15	jet2	jet0	jet3	jet1
16	jet3	jet0	jet1	jet2
17	jet3	jet0	jet2	jet1
18	jet2	jet1	jet0	jet3
19	jet2	jet1	jet3	jet0
20	jet3	jet1	jet0	jet2
21	jet3	jet1	jet2	jet0
22	jet3	jet2	jet0	jet1
23	jet3	jet2	jet1	jet0

Fig. 2: Permutations for the assignment of four jets to the quarks of a semi-leptonic $t\bar{t}$ decay.

References

[1] V.M. Abazov *et al.*, [DØ Collaboration] Phys.Rev. **D74** (2006) 092005

[2] DØ Collaboration, DØ note 5362 (2007)