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Comments on the DØ Limit of M (top) > 131 GeV

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In a recent paper the D0 collaboration has published a limit on the mass of the top quark of m(top) > 131 GeV with 95%c.l. [1]. D0 does this by determining which expectation value for the number of top events in the data sample is excluded by their experiment. Assuming a top production cross section as function of m(top), one can then exclude a certain top mass, in principle. For this procedure it is necessary to know the probability that a top event, once produced, will pass all analysis cuts and show up in the data sample. This probability, or efficiency, is obtained from Montecarlo simulations. D0 makes use of the Isajet Montecarlo [2]. The ability of the Isajet Montecarlo to provide the correct top efficiency is not discussed in the D0 paper. We would like to remark in the following that Isajet may overestimate the probability that a top event will enter the D0 data sample. If this is true, then the number of top events which D0 can exclude, would translate to a lower limit on the top mass than claimed in [1].

D0 obtaines the top limit by searching for di-lepton + (at least) one jet events and for single lepton + (at least) four jet events, where in the single lepton channel an additional cut on the aplanarity of the events is applied. At low top masses the limit is mostly based on the expected events in the di-lepton channel, at higher top masses the single lepton channel provides most of the information. The cut on Et(jet) is 15 GeV, where the jets are corrected for various detector effects and for gluon radiation out of the jet reconstruction cone. Reference [1] states that systematic uncertainies on the expected number of top events are mainly due to the detector performance, the total error being from 20% to 30%.

In its standard version Isajet produces gluon radiation in addition to the hard 2→2 $t\bar{t}$ production process. It is doing this in a phenomenological way, not based on first principles. Isajet, like other shower Montecarlos, in the end needs to be provided with input parameters which come from experimental data.

It was suggested[3] that one way to obtain systematic errors on this theoretical uncertainty might be to compare various different top Montecarlos. However, most top simulators like for example Herwig or Pythia are working in a similar way as Isajet does. As a result most of their predictions are similar. Even with respect to variables which should most stronlgy distinguish these Montecarlos from each other, one needs high statistics data samples and sophisticated analysis methods to find significant differences [4].

As a matter of fact, in previous studies which derived limits on the top mass, based on the Isajet Montecarlo, the uncertainty in the Isajet gluon radiation was taken into account, as part of the analysis. In reference[5], [6] top searches are discussed which are based on a sample of W+2 jet events. The authors report that " The isajet monte carlo generator includes radiation of gluons from the initial and final state partons. Emission of these gluons increases the jet multiplicity and therefore increases the efficiency of the number-of-jets requirement.... We find that disabling gluon radidation in Isajet ... decreases the efficiency of the jet mulitplicity requirement by 15%... The uncertainty due to the monte carlo model of gluon radiation is taken to be one-half of this change...' [6]. The analysis quoted there was studying top in the mass range of up to about 90 GeV. As explained in[5], only the initial state radiation in Isajet has been disabled. At these low top masses the hadronic part of the (leptonic) W + jets final state consists only of one low pt W and two low pt beauty quarks, and so the final state radiation indeed could play a minor role. At higher top masses, where the final state is characterised by 4 high pt quarks, final state gluon radiation could become more important. We also note that in reference[5],[6] a search for W+2 jet events was done (two jets with an uncorrected Et(jet) of 10 GeV are required, which corresponds to a corrected Et(jet) of 15 GeV about). When looking for W+4 jet events instead, the effects of gluon radiation might become more important, since one can imagine that gluon radiation is affecting the leading jets less, and more the jets at low Et(jet).

We tried to estimate how important the effects of Isajet gluon radiation in a W+4 jet analysis might possibly be :

We produced 10.000 Isajet top events with and without gluon radiation [1]. We put the events through a copy of the CDF detector simulation. In figure 1 we compare the Et(jet) spectra for jet2 and for jet4 [2]. Figure 1(a) shows the Et(jet2) spectrum for events with (solid line) and without (broken line) gluon radiation. For both spectra the full jet energy corrections are applied, including the correction for out of cone radiation. Applying the out of cone corrections to events which have no gluon radiation will overestimate the jet energies. So we show in figure (c) Et(jet2) for events without gluon radiation, when applying (solid line) or not applying (broken line) the out of cone jet energy corrections. The corresponding distributions for Et(jet4) are shown in figures (b) and (d).
We observe that jet2 is little affected by the gluon radiation, while most fourth jets disappear when switching off the gluon radiation.
The number of W events with at least two jets with a corrected Et(jet) greater than 15 GeV gets reduced by 3% if we switch off the gluon radiation, but still apply out of cone corrections. If we also switch off the out of cone corrections, the number of W+2 jet events decreased by 13% instead. That agrees reasonably well with the reduction of 15% which is reported in[5],[6].
The number of jets with Et(jet4) > 15 GeV gets reduced by a factor of 2.6 when switching off gluon radiation, and by a total of a factor of 4.2 when also not applying the out of cone correction. It seems reasonable to assume that even with the gluon radiation switched off,

[1] Gluon radiation is supressed by setting the parameter 'cutjet' to 900 GeV.
[2] Jets are ordered in Et(jet). Jet1 is the jet with the highest Et(jet).

some energy still might be found outside the jet reconstruction cone, and in this sense the factor of 4.2 can be considered an overestimate of the effect under consideration, while the factor of 2.6 presents an underestimate. A W+4 jet analysis is therefore much more sensitive to gluon radiation and the uncertainties in simulating the gluon radiation, compared to a W+2 jet analysis.

If one defines the sytematic error by halfing the effect of gluon radiation, as suggested in[5], then one arrives at a systematic error due to possible uncertainties in the Isajet gluon radiation of approximately 30% to 50%.

The question of how much Isajet gluon radiation can be attributed to the final and how much to the initial state radiation process, as a function of m(top), comes to mind. A detailed discussion of this subject goes beyond the scope of this paper. Here we only want to mention that we did not find significant differences between the rapidity distributions of jet4 when comparing the samples with and without gluon radiation and with and without out of cone corrections. Since one would expect that initial state gluons prefer to be radiated into the forward direction, we take that as indication that Isajet gluon radiation in top events (for m(top) = 110 GeV) does not only come from the initial state.

Of course, the numbers found in this note cannot directly by applied to the D0 analysis, and they are not meant for that. For example, the D0 jet finding algorithm will be different, the characteristic properties of the D0 calorimeter need to be taken into account and the aplanarity cut might have some correlation with Et(je4). However, it is clear that a dependence of the D0 analysis on the Isajet gluon radiation must exist, and that it will contribute a considerable systematic error.

As a conclusion we find that the effects of gluon radiation in a W+4 jet analysis at moderately high top masses need to be taken into account, they might cause a systematic uncertainty in the top efficiency by as much as a factor of 2. In [1], the cross section which is excluded by experiment is never very much below the theoretical predicted one. The uncertainty from Isajet might change the limit given there considerably.

References

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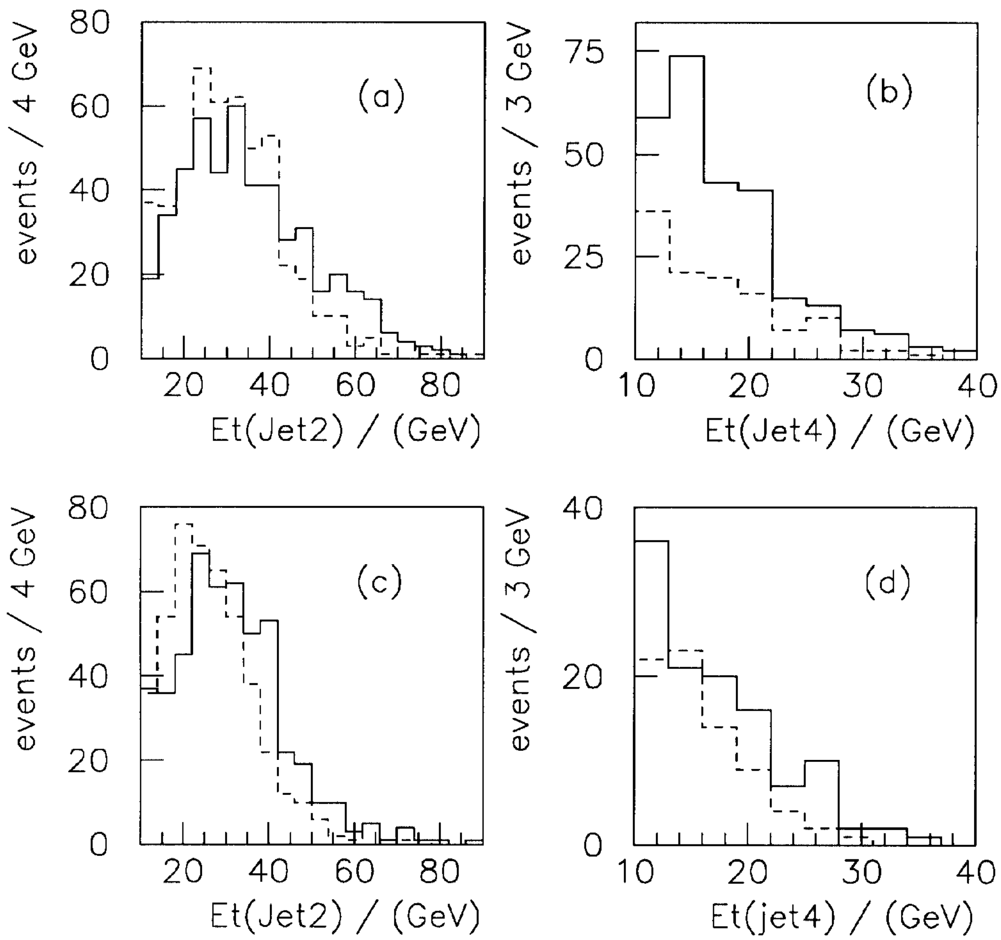

Figure 1: Et(jet) for jet2 and jet4. (a) and (b) show the distributions from events with (solid line) and without gluon radiation (broken line) in the standard Isajet version. In both samples out of cone jet energy corrections are applied. (c) and (d) show events without gluon radiation, the solid line is from events where again the out of cone correction is applied (identical to the broken lines in figures (a), (b)), the broken line shows the result of not applying out of cone corrections.