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NEXT-TO-LEADING ORDER RESULTS IN JET PHYSICS

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ABSTRACT

Reliable predictions of jet and jet-associated quantities are important to understanding the backgrounds to new physics signals at hadron colliders; this requires the use of next-to-leading order calculations. We present, as an example, the use of a next-to-leading order calculation in improving the analysis of W+jet measurements.

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Next-to-leading order calculations in jet physics are important to providing reliable predictions of jet cross sections and distributions at colliders, since it is only at next-to-leading order that one can start to control spurious renormalization-scale dependence, and that one can start to see the correct dependence on various experimental resolution parameters, such as the jet cone size.

Reliable predictions of jet cross sections and distributions are in turn important to the discovery and identification of new physics. An important example of current interest is the search for the top quark in the channel where one of the top-antitop pair decays hadronically whilst the other decays semileptonically. This yields the typical signature of an isolated lepton accompanied by four jets and missing transverse energy. Such a signal can also arise from the ordinary process of W boson production accompanied by four jets arising from QCD radiation; the experimental challenge lies in separating the signal from this background.

In order to calculate the background, one must use a leading-order program, VECBOS.[1] Higher-order corrections to exclusive-jet distributions calculated with it may be large, and will in general depend on the jet algorithm employed in the analysis. While we cannot examine these corrections directly, we can explore them in a simpler context, that of W boson production accompanied by a lone jet, using a program built upon the framework described in refs. [2,3].

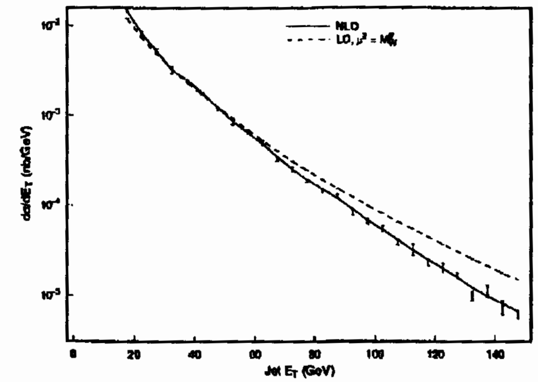

Figure 1. Jet spectrum in $W+1$ jet events with the standard jet algorithm.

There are two contributions to next-to-leading order corrections to n-jet cross-sections and distributions: the virtual corrections to the leading-order matrix elements; and the real radiative corrections, where configurations with an additional parton sufficiently soft or collinear to classify the event as an n-

jet one using the experimental jet algorithm. In the framework used here, one introduces a parameter (the 'parton resolution') to divide the $n+1$ parton integration region into two subregions, the first containing all the soft and collinear divergences. Upon performing these integrations analytically, one obtains a result which cancels the singularities present in the virtual matrix elements, but introduces a logarithmic dependence on the parton resolution parameter. The integral over the second subregion, performed numerically, then cancels this logarithmic dependence, yielding an answer which is both finite and free of dependence on such artificially-introduced parameters. This is similar to the method widely used in QED calculations.[4] The key point is the organization using color-ordered amplitudes, which yields a factorization of the soft singularities per ordering, and makes it possible to perform the integrals over the singular regions analytically. These integrals can be summarized in a universal set of functions, independent of the details of the hard process.

The virtual corrections to the basic process lessen the large spurious dependence present in leading-order calculations (where the only dependence is through the coupling constant); and the real-radiation corrections introduce the *leading* perturbative dependence on jet resolution parameters such as the jet cone size ΔR.

The corrections to the leading-order result from these two sources may be quite large, if the ratios of scales in the logarithms they introduce are large. In this case, we should be wary of relying on a perturbative calculation, as the logarithms may spoil the applicability of perturbation theory (unless one can resum them). Conversely, one may be able to modify the jet algorithm, and choose the renormalization scale, so as to minimize such logarithms; with the modified algorithm, the next-to-leading order result will be close to the leading-order one, and the latter will be reliable. One can then apply the same algorithm to more complicated processes where next-to-leading order calculations are not available, with increased confidence in the reliability of a leading-order prediction.

We illustrate this procedure with the calculation of the jet spectrum in events with a W and exactly one jet. Figure 1 shows the jet E_T spectrum in such events at Tevatron energies ($\sqrt{s} = 1.8$ TeV), with the standard CDF cone algorithm ($\Delta R = 0.7$) in the rapidity region $|\eta_J| < 2$, and with standard cuts on the daughter lepton ($p_{T\ell} > 20$ GeV, $|\eta_\ell| < 3$) and on missing transverse energy (> 20 GeV). At larger jet transverse energies, the corrections are large.

By changing the renormalization scale used at leading order from M_W to $\sqrt{M_W^2 + E_{TJ}^2}$, and by modifying the jet algorithm to require not only a minimum E_T, but also a minimum fraction of the hardest jet's E_T, we can make the next-to-leading order corrections small throughout the spectrum. This is shown in figure 2. We may also note that this change of renormalization scale has, as expected, little effect on the next-to-leading order prediction.

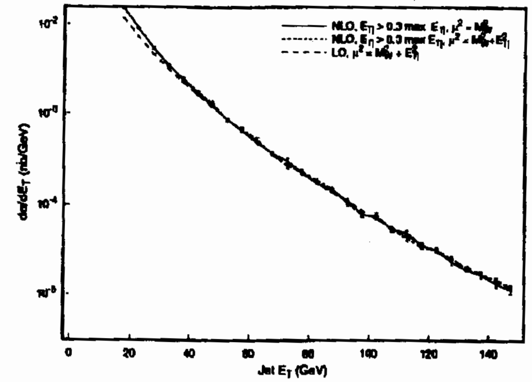

Figure 2. Jet spectrum in $W + 1$ jet events with the modified jet algorithm.

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