Issues on NLO pQCD Programs

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Abstract. This paper summarizes a talk presented at the Durham HERA '98 Workshop. We compare the features that are available in NLO pQCD programs and demonstrate that understanding where in phase space NLO calculations are accurate is vital for extracting information from measurements at the HERA experiments.

A major task of the HERA experiments is to test pQCD features and the extraction of the proton structure functions[1]. In the process of comparing corrected data to theory, the calculation of quantities in next-to-leading order is needed[2, 3].

Several programs allow predictions up to next-to-leading order for a large set of variables. These programs and their features are compared in section 1. In addition to restrictions given by those programs, it is also important to check the applicability of NLO pQCD calculations for specific observables and the selected phase space. Besides well known properties, like infrared safety[4] or factorizability, it has become clear lately that special care is needed when using jet cuts[5]. One interesting topic in this region will be pointed out in section 2.

1. Features of NLO pQCD Programs

During the last few years four multi-purpose pQCD calculation programs for the HERA DIS processes have become available, Mepjet[6], Disent[7], Disaster++[8], and JETVIP[9]. Their main features are given in table 1. The most important difference is the method used to handle cancelations of singularities in real and virtual corrections. On the one hand, the phase space slicing method integrates analytically in regions of invariant masses lower than an extremly small cut-off parameter $s_{\min}$[10]. On the other hand, the subtraction method uses the "plus" prescription to calculate a counter term, that is subtracted from the divergent distributions[11]. For several features, e.g. mass treatment and the contribution of resolved and electroweak processes, only one program is available; therefore cross checks of results, where these corrections get important, are impossible.

2. Comment on DiJet cuts

Using dijet measurements several QCD tests and parameter extractions have been performed by the HERA experiments[2, 3]. NLO pQCD programs are important tools needed for this task, but the measurements nowadays tend to enter regions where pQCD alone is not able to describe the data, e.g. in the transition region from

photoproduction to DIS, where resolved processes become important. In those regions it is all the more important to have reliable NLO predictions.

An important restriction for cuts on dijet photoproduction calculations was pointed out some time ago by Frixione and Ridolfi[12].

The same arguments also hold for DIS processes. In figure 1a) the NLO prediction of the double differential cross section in transverse momenta of both jets in the Breit frame is shown. The jets were found using the longitudinal boost invariant k_t algorithm[13]. For the LO contributions the jet p_t are balanced. The same is true for the virtual corrections and this leads to large corrections on the diagonal, which are known to be negative. The real corrections, canceling the virtual divergences, introduce differences in the jet p_t. After imposing a cut of $p_{t,\mathrm{lower}} > 5\mathrm{GeV}$ for both jets, figure 1b) shows the integrated cross section as a function of the highest jet p_t. This plot clearly shows, that the NLO prediction breaks down at a $p_{t,\mathrm{higher}}$ cut of approximately 6GeV, since lowering the p_t cuts and thus enlarging the allowed phase space leads to a reduced NLO prediction.

A possible solution is to introduce an asymmetric cut, where the difference of the cut values ensures, that the NLO prediction is on the falling edge of the distribution of figure 1b). A different Ansatz is to make a symmetric cut and an additional cut on the sum of the jet p_t values, e.g. $\sum_{1,2} p_{t,i} > 17\mathrm{GeV}$. This cut removes the main negative contribution in the lower left corner of figure 1a) and ensures, that the cancelation of singularities takes place[5].

3. Conclusions

An overview of features currently available in NLO pQCD programs for HERA deep inelastic scattering processes has been given. In addition a special issue on jet cuts for dijet production has been pointed out demonstrating, that asking for a symmetric minimal p_t on both jets leads to unreliable NLO predictions. Two alternative scenarios are given, that produce reasonable results.

	MEPJET	DISENT	DISASTER++	JETVIP
version	2.2	0.1	1.0.1	1.1
method	PS slicing	subtraction	subtraction	PS slicing
1+1,2+1	NLO	NLO	NLO	NLO
3+1	LO	LO	LO	LO
4+1	LO	—	—	—
jet shapes	LO	LO	LO	LO
full event record	✓	✓	✓	(✓)
scales	all	factorisation: Q^2, fixed, renormalisation: all	all	all
flavour dependence	switch	switch	full	switch
quark masses	LO	—	—	—
resolved contribution	—	—	—	NLO
electroweak contribution	LO	—	—	—
polarized x-section	NLO	—	—	—

Table 1. Comparison of the different features of NLO pQCD programs.

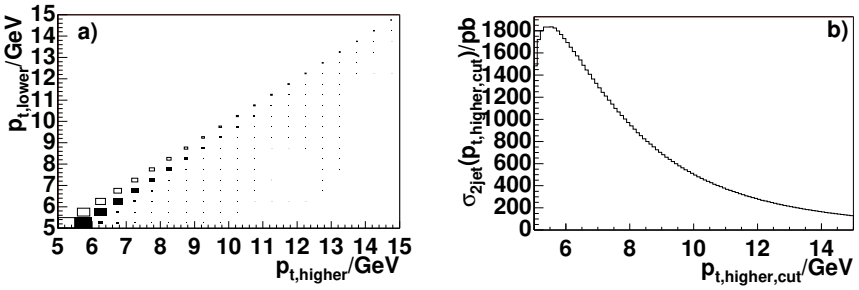

Figure 1. a) Distribution in bins of the transverse jet momenta of each jet. The size of the box corresponds to the dijet cross section in that bin. Hollow boxes denote negative values, full positive. The calculation was done using Disent. b) Integrated dijet cross section as a function of the highest jet transverse momentum after imposing a cut of $p_{t,\mathrm{lower}} > 5\mathrm{GeV}$.

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