EMBEDDING NLO CALCULATIONS IN SHOWER EVENT GENERATORS WITH POSITIVE WEIGHTS

P. NASON

INFN, Sez. di Milano Bicocca
Università di Milano-Bicocca, Dip. di Fisica "G. Occhialini"
Piazza della Scienza 3, 20126 Milano, Italy

I discuss a method for the implementation of Next-to-Leading corrections to hard processes in Shower Monte Carlo programs, that allows for positive weight event generation. A first implementation for the Z pair production process in hadronic collisions is discussed.

1. Introduction

Next-to-leading order (NLO) QCD calculations have by now become the standard for the study of processes relevant to collider physics. It is well known that the inclusion of NLO terms are important for a reliable estimate of cross sections. One finds corrections of the order of 30 to 100% for typical production processes. Until recently, the results of NLO computations were not included in shower Monte Carlo (SMC) models, since their inclusion is highly non trivial. In ref. [1] a method (referred to as MC@NLO) was proposed to include the results of NLO calculations in a parton shower Monte Carlo, and it was applied to several processes[a][2,3] in connection with the HERWIG implementation.[4] The MC@NLO method in general must be adapted to the SMC algorithm being used. Furthermore, the event generation is not strictly positive, i.e. negative weighted events are generated.

In ref. [5] a novel method was proposed, that overcomes these problems, and allows one to compute the generation of the hardest radiation (i.e. the radiation with the largest transverse momentum) independently of the SMC employed for the subsequent shower. It was found there that, in the

[a]For the full list of processes implemented in MC@NLO, see the MC@NLO web page `http://www.hep.phy.cam.ac.uk/theory/webber/MCatNLO/`.

framework of angular ordered SMC's, in order to preserve the correctness of the soft radiation spectrum, it is necessary to include the soft radiation coherently emitted from the partons produced in the hardest splitting. Such coherent radiation was named "truncated shower", since it is a shower that stops when the angular variable approaches the angle of the hardest emission. The need for a truncated shower should not however be overemphasized. It is relevant only to angular ordered SMC's that fully enforce soft coherence. At present, only the HERWIG program does this. Other SMC's implementations do not care to enforce coherence at the same level of accuracy.[b] Furthermore, it may be possible to perform the generation of the truncated shower independently of the chosen SMC.

The problem of interfacing NLO calculations to SMC's can thus be split into three independent issues:

(1) Generation of the hardest emission: one constructs an algorithm to generate the hardest emission with NLO accuracy. The resulting events can be put in a standard form, such as the "Les Houches Interface for User Processes" (LHI).[8]
(2) Generation of the truncated shower: given the hardest event, on the LHI, one can add the truncated shower and put the event back in the LHI. This step is only required if one wants to maintain the correct soft emission pattern, and is using an angular ordered SMC.
(3) Showering, hadronization, decays: any SMC that complies with the LHI requirements can now perform the rest of the showering, provided it also implements a p_{T} veto. Today's most popular SMC's satisfy these requirements.

Following the above strategy, the problem becomes more manageable, since it no longer requires to modify or rewrite a full SMC implementation. Furthermore, several independent solutions to each of the above points may be pursued by independent researchers.

In ref. [9], item 1 of the above list, in the specific case of Z boson pair production in hadronic collisions, was addressed. The chosen process is an important one for LHC physics, it involves initial state radiation, it is readily extended to the similar WZ and WW production processes, and should be easily generalizable to other important processes, like, for instance, single boson, Higgs and heavy flavour production. Its implementation does

[b]There are programs that generate soft radiation using dipole type formalisms,[6,7] but they do not treat initial state radiation consistently.

therefore prove the viability of the method proposed in ref. [5].

In ref. [9] the methods and the results of the calculation are presented in full details. Here I would like to describe few features of the results. First of all, we show a comparison of the calculation of ref. [9] (POWHEG from now on) interfaced to HERWIG, with the only other existing calculation that merges NLO results for ZZ production with a shower Monte Carlo, namely the MC@NLO result. We also show, for comparison, the result of a fixed

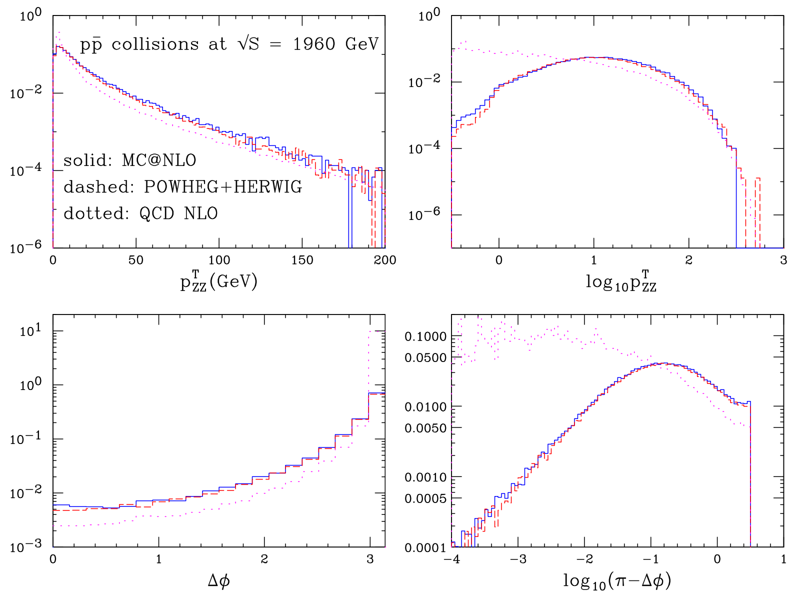

Figure 1. Comparison of four distributions computed according to MC@NLO, the POWHEG interfaced to HERWIG, and a fixed order calculation. On the vertical axes we report the cross sections in picobarns per bin. Energies are expressed in GeV.

order calculation of the same process.[10] As we expect, in the region of zero transverse momentum of the Z pair, the NLO calculation diverges, while the POWHEG result is nicely regularized by the Sudakov form factor. The POWHEG result agrees well with the MC@NLO. The agreement between the two methods in the region of large transverse momentum radiation is expected, since both methods are in good agreement with the fixed-order calculation in this region. The region of soft radiation in the MC@NLO implementation is controlled by the HERWIG shower. We therefore conclude that our treatment of the soft region is consistent with the HERWIG implementation. One of the main features of the POWHEG method is the possibility of interfacing its output to any shower Monte Carlo that implements the Les Houches interface for user-provided processes. This is possible with the popular Monte Carlo PYTHIA[11] since its version 6.3, which is based upon a p_{T}-ordered shower algorithm. In ref. [9] we thus also show results obtained interfacing the POWHEG calculation with PYTHIA.

2. Conclusions

The extension of the present work to WZ and WW pair production is straightforward. Furthermore, the choice of kinematic variables adopted here can be easily extended to processes of Drell-Yan type, like single W and Z production, and Higgs production. We also believe that the method can be applied without major modifications to the case of heavy flavour production, where final state soft radiation is also present. The treatment of collinear final state radiation with the method of ref. [5] presents no difficulties, being in fact easier than the initial state radiation case. A general formulation of the method for general processes is in preparation.[12]

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