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ALPGEN

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The ALPGEN event generator, dedicated to the study of multiparton hard processes in hadronic collisions, is presented. The code performs, at the leading order, the calculation of the exact matrix elements for a large set of parton-level processes of interest in the study of the Tevatron and LHC data. Parton-level events are generated, providing full information on their colour and flavour structure, enabling the evolution of the partons into fully hadronised final states.

1 Introduction

The large energies available in current and forthcoming hadronic colliders make final states with several hard and well separated jets a rather common phenomenon.

Several examples of calculation of multijet cross-sections in hadronic collisions exist in the literature [1], often with the aid of packages for the authomaticac calculation of partonic matrix element [2].

In order to use these results in practical analyses of the experimental data, the calculations need to be completed with the treatment of the higher-order corrections leading to the development of partonic cascades, and with the subsequent transformation of the partons into observable hadrons [3]. The consistent combination of the parton-level calculations with the partonic evolution given by the shower MC programs is the subject of extensive work [4,5].

We discussed in [6] a theoretical framework for the evaluation and generation of events in such a way as to enable the subsequent perturbative evolution using a shower MC program. In [7] we presented a complete application to the case where a W boson is produced in association with a heavy quark pair, plus up to 4 additional light partons. In [8] we provide a detailed description of the library of MC codes for hadronic collissions `ALPGEN` toghether with numerical results for some benchmark processes. An interface to both `HERWIG` and `PYTHIA` is provided.

Independent work on the merging of parton-level calculations with shower MC's has been pursued by other groups [9].

The library containing all codes described in this work can be downloaded from the following URL: `http://mlm.home.cern.ch/mlm/alpgen` .

2 `ALPGEN`

`ALPGEN` is a collection of ready-to-use packages for the evaluation of several cross sections in hadronic collisions with up to eight hard partons in the final state.

The presently avaliable processes are;

1)$W^*Q\bar{Q}+n\text{-}jets$	2) $W^*+n\text{-}jets$	3) $Z^*/\gamma^*Q\bar{Q}+n\text{-}jets$
4)$Z^*/\gamma^*+n\text{-}jets$	5) $Q\bar{Q}+n\text{-}jets$	6) $Q\bar{Q}Q\bar{Q}+n\text{-}jets$
7)$Q\bar{Q}+H+n\text{-}jets$	8) $n\text{-}jets$	9) $n_W+n_Z+n_H+n\text{-}jets$
10) $n\text{-}jetsm\text{-}\gamma$	1)$W^*c\bar{c}+n\text{-}jets$	

and, in progress

1) Single Top, 2) $H+n\text{-}jets$ (gluon fusion, $m_t \to \infty$ limit)

where Q denotes an heavy quark ($Q=t,b$), W^*, Z^* denote a lepton pair and by $n\text{-}jets$ we mean n light jets.

The cross sections are evaluated at leading order using the *exact* matrix element as provided by ALPHA [10]. All relevant mass effects are accounted for. We also provide a description of vector bosons and top quark decay with spin correlation taken fully into account into the infinitely narrow width approximation.

The code is runned in two steps. In the first step the user inputs his choice for beam energy, pdf set, event generation cuts (any other kinematical cut can be applied into an appropriate subroutine), factorization scale, EW scheme, ... At this stage the partonic cross section is computed and *weighted events* are dumped on disk. In the second step the code read the weighted events, performs the unweighting and provide the appropriate coulor flow [6] for the event which is now dumped on disk in a `HERWIG` or `PYTHIA` readable format.

3 Comparisons with the data

An extended series of comparisons among avaliable packages (AMEGICC++, ComHEP, HELAC/PHEGAS/JetI, MadEvent) has been performed in CERN MC_4 Workshop [11]. This provide us a stronger confidence in the code.

To compare prediction versus data it is crucial to provide the best possible merging of partonic event generator and the shower-MC. Our procedure [6] is accurate at LL. However some topologies will be counted twice since a final jet can arise either as originated from a parton or from the shower. This subleading effect is enhanced by large-logs. If an hard jet is emitted by the shower a parton might (depending on the imposed generation cuts) become 'soft' and/or collinear in the matrix-element calculation. Therefore the simulation is infrared and collinear sensitive to generation cuts.

An approach suitable to deal with final state with a large number of partons has been suggested in [5]. This approach has been shown to be accurate at the NLL level in e^+e^-. An extension to *pp* has been suggested but there is no proof that it provides better than LL accuracy.

M. Mangano has suggested [12] an alternative approach and we will show results based on this strategy. The major steps are as follows: 1) perform the parton level calculation with arbitrary generation cuts (rapidity, minimal parton energy and jet-jet separation) [a] 2) perform the unweighting and shower the event (**don't perform the adronization**) 3) use some jet algorithm to produce cluster of par-

[a] ideally the final sample should be independent from generation cuts, in practice the goal is to stabilize the prediction within the accuracy of the calculation for a wide range of cuts.

ticles (**this has nothing to do with the experimental anlaysis, particles are clustered if they are within some cone in phase space and a cluster can be a good one even if it is outside detector acceptance**) 4) you now search for 'matching' among clusters and partons (those generated at step 1). A parton matches a cluster if it's separation ΔR from the cluster is smaller than the ΔR_{mx} used to define the cluster 5) you now reject all events where more than one parton match the same jet 6) if you want an *exclusive* sample you also reject events with more clusters than initial partons 7) finally you build the event sample adding toghether *exclusive* samples with different jet multiplicities (actually the sample with the highest multiplicity is an *inclusive one*).

The accuracy is still at the LL level however one expects a strong reduction to double-counting effects (essentially because the phase space volume where it occurs is substantially shrinked) and therefore a good stability of the prediction over a wide range of generation cuts. This is shown in fig. 1 where difference among the prediction for the inclusive spectra of the W transverse momentum p_{TW} in the process $pp \to W + jets$ for four different sects of generation cuts

PT10	$p_{Tjet} > 10$ GeV, $\Delta R_{jj'} > 0.4$
PT20	$p_{Tjet} > 20$ GeV, $\Delta R_{jj'} > 0.4$
PT30	$p_{Tjet} > 30$ GeV, $\Delta R_{jj'} > 0.4$
PT10R07	$p_{Tjet} > 10$ GeV, $\Delta R_{jj'} > 0.7$

The prediction of `HERWIG` standalone is also shown

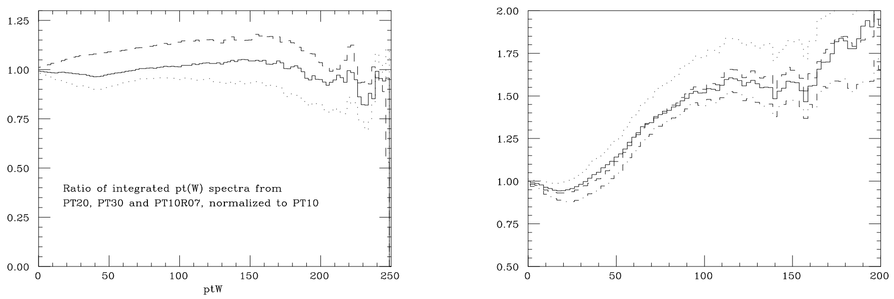

Figure 1. Effect of different generation cuts on the integrated $p_{T,W}$ spectrum. The right panel shows the ratios of the samples generated with PT20, PT30 and PT10R07, divided by PT10. The right panel shows all four samples divided by a plain (no ME correction) HERWIG W sample.

In fig. 2 we show the comparison of Tevatron CDF data versus the event sample (normalized to the data) built with the prescription described above.

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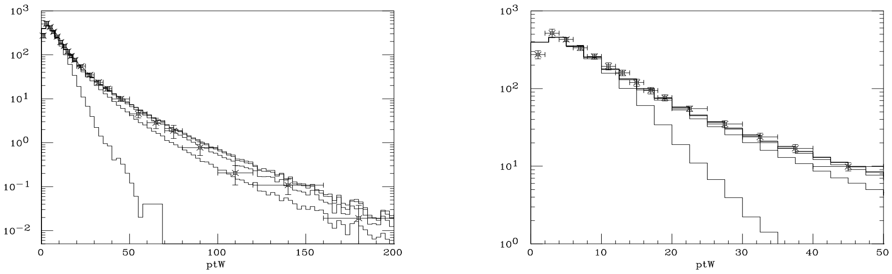

Figure 2. $p_{T,W}$ spectrum. The points represent run I CDF data. The curves correspond to the subsequent inclusion of samples with higher multiplicity, form the $W+0$ jet, up to the $W+4$ jets case. The right plot is the same as the left one, with an enhanced low-p_T scale.

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