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Recent developments in SHERPA

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Some recent QCD-related developments in the SHERPA event generator are presented.

In the past decades, event generators such as PYTHIA [1, 2] and HERWIG [3, 4] have been central for nearly all physics analyses at particle physics experiments at the high-energy frontier. This will also hold true at the LHC, where a large number of interesting signals for new particles or new phenomena (the Higgs boson or any other manifestation of the mechanism behind electro-weak symmetry breaking, supersymmetry, extra dimensions etc.) is hampered by a plethora of severe, sometimes overwhelming backgrounds. Nearly all of them are largely influenced by QCD. Therefore it seems fair to say that the success of the LHC in finding new physics may very well depend on a deep and detailed understanding of old physics, like QCD. Examples for this include, among others, the central-jet veto for the vector boson fusion channel for Higgs production or topologies, where gauge bosons emerge in association with many jets, a background for many search channels.

In a reflection on increased needs by the experimental community, aiming at higher precision, incorporation of new physics models and so on, the work horses of old have undergone serious renovation efforts, resulting in new, improved versions of the respective codes, namely PYTHIA8 [5] and HERWIG++ [6]. In addition a completely new code, SHERPA [7], has been constructed and is in the process of maturing. The status of this code is the topic of this contribution.

SHERPA's hallmark property is the inclusion of higher-order tree-level QCD contributions, leading to an improved modelling of jet production. They are introduced through a full-fledged matrix element generator, AMEGIC++ [8], which is capable of generating matrix elements and corresponding phase space mappings for processes with multi-particle final states in various models, including the Standard Model, anomalous gauge triple and quadruple couplings according to [9, 10], the Minimal Supersymmetric Standard Model with Feynman rules from [11], the ADD-model of extra dimensions [12, 13], and a model with an extra $U(1)$ singlet coupling to the Higgs boson only [14]. The code has been thoroughly tested and validated [15]. This code, however, is limited, especially in the treatment of many (≥ 6) external QCD particles. Therefore, in the near future, SHERPA will incorporate another, new matrix element generator, COMIX, which is based on Berends-Giele recursion relations [16] and colour-dressing [17] rather than colour-ordering. In Tabs. 1 and 2 some example cross sections for $gg \to ng$ at fixed energies and $pp \to b\bar{b} + n$ jets obtained with this program are exhibited and compared to those from other programs.

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gg → ng	Cross section [pb]				
n	8	9	10	11	12
$\sqrt{s}$ [GeV]	1500	2000	2500	3500	5000
Comix	0.755(3)	0.305(2)	0.101(7)	0.057(5)	0.019(2)
Maltoni	0.70(4)	0.30(2)	0.097(6)		
Alpgen	0.719(19)				

Table 1: Cross sections for multi-gluon scattering $gg \to ng$ at different center of mass energies $\sqrt{s}$, using the phase space cuts specified in [18] , compared to literature results. In parentheses the statistical error is stated in units of the last digit of the cross section.

$b\bar{b} + n$jets	σ [μb]						
n	0	1	2	3	4	5	6
Comix	470.8(5)	8.83(2)	1.826(8)	0.459(2)	0.1500(8)	0.0544(6)	0.023(2)
ALPGEN	470.6(6)	8.83(1)	1.822(9)	0.459(2)	0.150(2)	0.053(1)	0.0215(8)
AMEGIC++	470.3(4)	8.84(2)	1.817(6)				

Table 2: Cross sections for $pp \to b\bar{b} + n$ jets at the LHC, with cuts and definitions according to those in the MC4LHC workshop, compared to literature results. In parentheses the statistical error is stated in units of the last digit of the cross section.

In addition, concerning the calculation of higher-order matrix elements and cross sections, there have been first steps towards an automation of such caluclations at truly next-to leading order accuracy. They manifest themselves in the implementation of a procedure [19] to fully automatically construct and evaluate Catani-Seymour dipole subtraction terms [20] for the real part of such NLO calculations.

The results from the matrix element calculations are merged with the subsequent parton shower through the formalism of [21, 22]. The results of its implementation in SHERPA [23] has recently been compared with other algorithms [24]. Although there remains some dispute about the theoretical equivalence of the different approaches, the overall results show satisfying agreement with each other, such that they can be used with confidence for data analysis.

Furthermore, two new parton shower algorithms have been implemented. One is based on the Catani-Seymour subtraction kernels [25], following a proposal in [26][a]. It can be anticipated that this shower, together with the automated subtraction terms for the real part of the NLO calculations, will allow for a greatly alleviated construction of simulation of QCD radiation including NLO accuracy, in the spirit of MC@NLO or POWHEG. This new shower has been extensively compared with various data; as an illustrative example consider the azimuthal decorrelation of the two leading jets in jet production at the Tevatron, cf. Fig. 1, where the results of the simulation are confronted with data from [28]. The other new parton shower, presented in [29], constitutes a further development of the dipole-based shower formulation encoded in ARIADNE [30]. In the new model, initial state radiation is treated truly perturbatively, and is not replaced – as in the original proposal – by final-state

[a]This algorithm has independently been also implemented in [27].

radiation involving the hadronic remnants and non-perturbative ideas to define their radiation properties. A first result underlining the power of this new formulation is shown in Fig. 2, where the $p_\perp$-distribution of the lepton pair in Drell-Yan processes at the Tevatron is confronted with data [31].

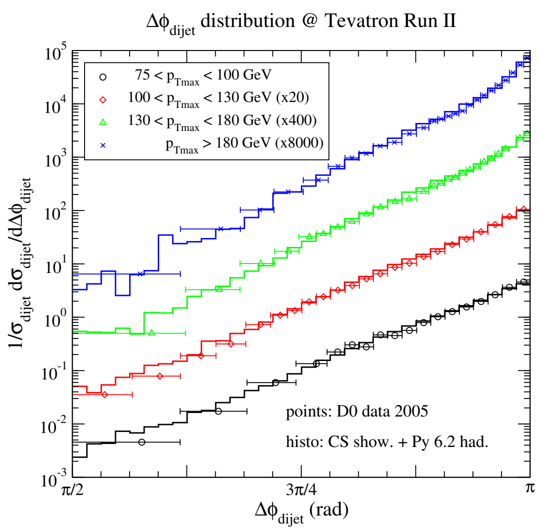

Figure 1: The azimuthal decorrelation of the two leading jets in pure QCD processes at the LHC, in different bins of the leading $E_\perp$. The new parton shower based on Catani-Seymour kernels is confronted with data from [28].

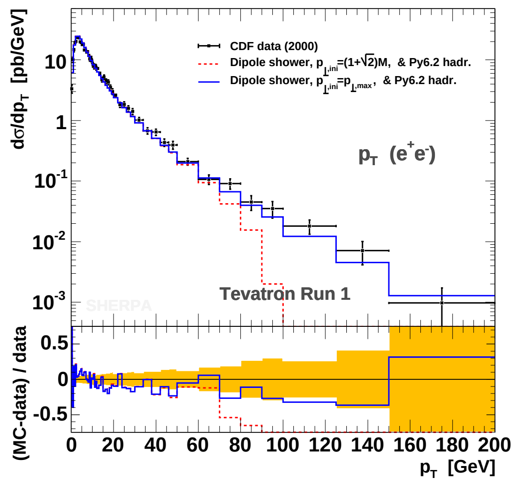

Figure 2: The $p_\perp$ distribution of the Z boson in Drell-Yan processes at the Tevatron. The new dipole shower is confronted with data from [31].

Finally, the implementation of a new cluster hadronization model following [32] has been finished and it is now the default hadronization module of SHERPA. It has been supplemented with new modules for the simluation of hadron decays and of QED final state radiation in these decays.

In this contribution the current status of the SHERPA project has been summarised, with special emphasis on perturbative QCD issues, and some of its forthcoming attractions have been briefly discussed.

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