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THE NEW MONTE CARLO EVENT GENERATOR Herwig++

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We present results obtained with the new Monte Carlo event generator Herwig++. In its first version (1.0), Herwig++ is capable of simulating e^+e^- Annihilation events. We compare results for different distributions with a vast amount of available data from e^+e^- annihilation.

1 Introduction

The advent of the future Large Hadron Collider (LHC) requires new tools for the Monte Carlo (MC) simulation of final states. As the well–established tools, e.g. PYTHIA [2] and HERWIG [1] have grown tremendously during the LEP era and are considered difficult to maintain and even more difficult to extend, it was decided to rewrite them in an object oriented language, in particular C++. Therefore, the old codes are presently being rewritten under the names Pythia7 [3] and Herwig++ [5]. Furthermore, a new project with the same goals, SHERPA [4], has been established. In this talk we consider our own project Herwig++. This program is available in version 1.0 and capable of simulating e^+e^- annihilation events, particularly at LEP energies. We compare our results to event shape data and exclusive particle spectra mainly taken at the LEP experiments but also by SLD and JADE.

2 Simulation

The main steps of the physical simulation of an e^+e^- annihilation consist of a hard subprocess, a parton shower evolution, cluster hadronization and hadronic decays. In Herwig++ 1.0 we have a basic $e^+e^- \to (\gamma, Z) \to q\bar{q}$ tree level matrix element (ME). In addition, we apply ME corrections of two different natures in order to be able to match up the phase space space accessible by the parton shower with that of the full matrix element at the lowest order for $q\bar{q}g$ production. For the hard ME correction [7], one additional gluon is emitted according to the full ME whenever a trial emission would hit the so-called dead region in the $q\bar{q}g$ phase space (cf. Fig. 1). For the soft ME correction we consider the parton shower emission from, say, the quark (cf. region Q in Fig. 1). Comparing the expression for one parton shower emission with that for the full $q\bar{q}g$ matrix element we can compute an additional weight or apply an extra veto in order to distribute parton shower emissions closer to the actual matrix element in this phase space. Applying the soft correction to the 'hardest emission so far' we continue the parton shower evolution until a lower cutoff scale is reached ($\sim \delta$ in Figs. 2, 3). We carry out the parton shower evolution in terms of a set of new evolution variables as described in [6].

These allow a smooth coverage of soft gluon phase space (cf. Fig. 1, $x, \bar{x} \to 1$) and a correct treatment of heavy quarks in the quasi collinear limit. Next, due to preconfinement, the low scale partons are paired up into colourless clusters which still carry the flavour information of their constituting quarks. In this way we will find a cluster mass spectrum which is invariant against variations of the initial cm energy of the e^+e^- annihilation. Clusters which still have a large invariant mass are fissioned and finally decayed into hadrons according to some phenomenological weights. Here, we have introduced a different interpretation of the diquark weight in order to have a more consistent baryon production mechanism [5], cf. also [8]. Finally, all unstable hadrons decay into stable ones, predominantly pions and hard photons.

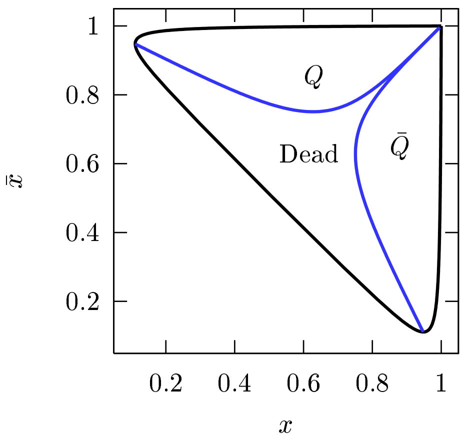

Figure 1. The phase space for $q\bar{q}g$ production in e^+e^- annihilation for heavy quarks. Using the new parton shower variables the regions Q and $\bar{Q}$ are populated by the first parton shower emission whereas the 'Dead' region is populated with the help of a hard matrix element correction.

3 Results for e^+e^- Annihilations

We used the program Herwig++ to simulate a large number of observables in e^+e^- collisions and compared the results to LEP [9] and SLD data as well as older data from PETRA [10]. We covered the available spectrum of data ranging from exclusive hadron multiplicities and momentum distributions over all kinds of event shape distribution to four jet angles. We wanted to give a reasonable overall description of the available data without emphasising any particular observable too much and came up with a 'recommended' parameter set for Herwig++ [5]. Here, we want to focus on a few examples. First, we adjusted the hadronization parameters to reasonable values in considering multiplicity data. In Fig. 2 (left) we consider the number of minijets in the $k_\perp$–algorithm at different collider energies and find a very good description of the data. Despite the fact that we apply matrix element corrections, the thrust distribution tends to overshoot for too spherical and too point–like events. Quite in contrast, we find that the distribution of transverse momentum in the thrust event plane is described very well. As we haven't attempted a detailed tuning of our generator, we assume that these minor contradictions will be properly adjusted in the future. Considering four jet events at $y_{\rm cut} = 0.08$ we find that our description of e.g. the Bengtsson–Zerwas angle distribution is very good. This is by no means guaranteed as we have not used any four–jet matrix element in our code. In addition, we have been able to give a very good description of the B–fragmentation function (for a figure, see [11]). This exemplifies the quality of our new parton shower for heavy quark physics as we can simply tune the parton shower accordingly, attributing heavy quark partonic effects to the perturbative domain as one might expect.

We conclude that we have succeeded in delivering the new Monte Carlo event generator Herwig++ which is perfectly capable of describing LEP physics in a similar or better quality as it was known from HERWIG. This is considered a first step towards a new generator that will be suitable for the description of hadronic events at HERA, the Tevatron and the LHC.

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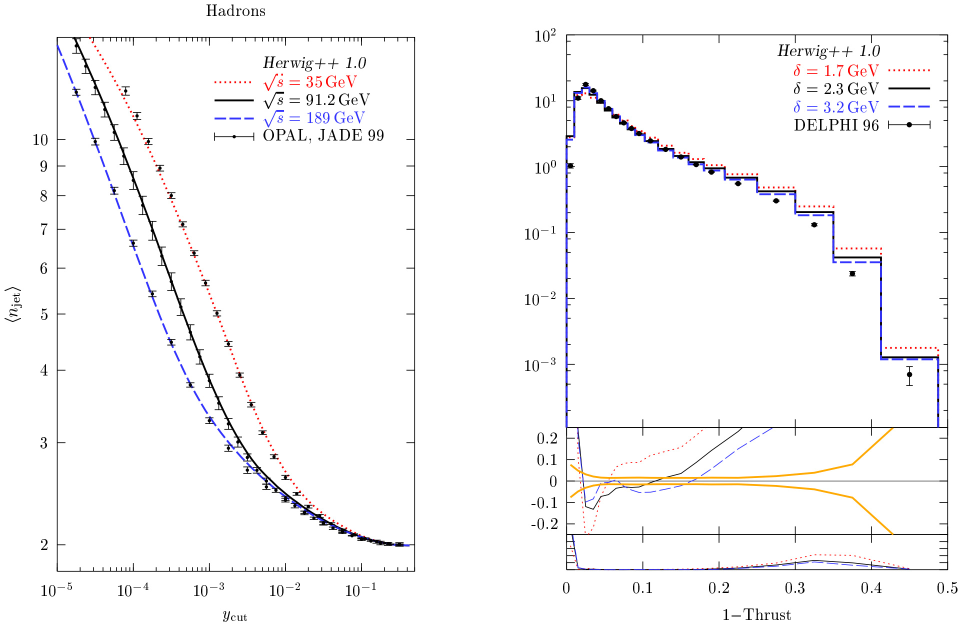

Figure 2. The multiplicity of minijets ($k_\perp$ algorithm) at PETRA, LEP and LEPII energies from Herwig++ in comparison with data (left). The thrust distribution compared to DELPHI data (right).

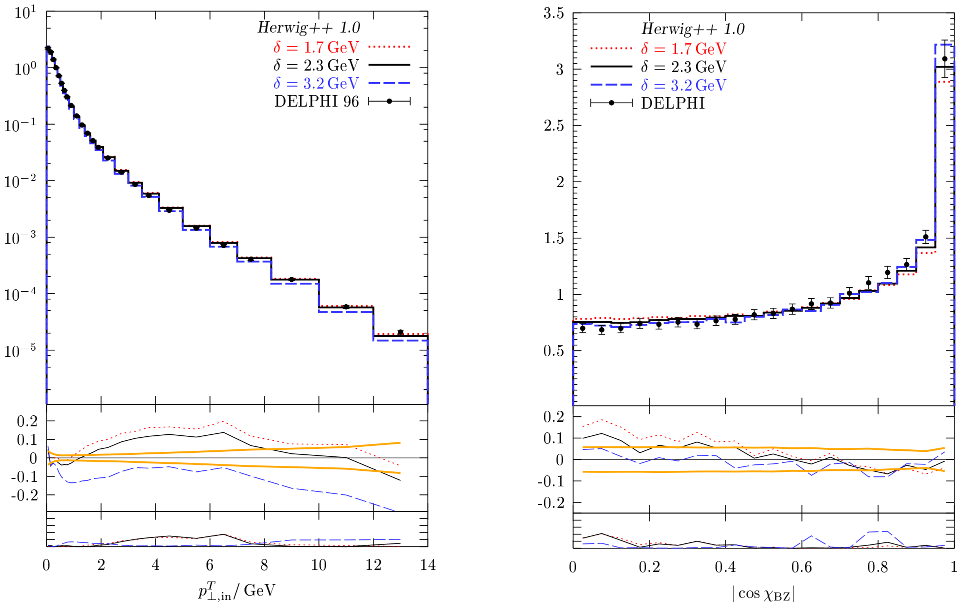

Figure 3. The distribution of transverse momentum in the event plane w.r.t. the thrust axis (left) and of the Bengtsson–Zerwas angle (right).