Underlying events in Herwig++[*]

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Abstract

In this contribution we describe the new model of multiple partonic interactions (MPI) that has been implemented in Herwig++. Tuning its two free parameters is enough to find a good description of CDF underlying event data. We show extrapolations to the LHC and compare them to results from other models.

1 Introduction

With the advent of the Large Hadron Collider (LHC) in the near future it will become increasingly important to gain a detailed understanding of all sources of hadronic activity in a high energy scattering event. An important source of additional soft jets will be the presence of the underlying event. From the experimental point of view, the underlying event contains all activity in a hadronic collision that is not related to the signal particles from the hard process, e.g. leptons or missing transverse energy. The additional particles may result from the initial state radiation of additional gluons or from additional hard (or soft) scatters that occur during the same hadron–hadron collision. Jet measurements are particularly sensitive to the underlying event because, although a jet's energy is dominated by the primary hard parton that initiated it, jet algorithms inevitably gather together all other energy deposits in its vicinity, giving an important correction to its energy and internal structure.

In this note, based on Ref. [1], we want to focus on the description of the hard component of the underlying event, which stems from additional hard scatters within the same proton. Not only does this model give us a simple unitarization of the hard cross section, it also allows to give a good description of the additional substructure of the underlying events. It turns out that most activity in the underlying event can be understood in terms of hard minijets. We therefore adopt this model, based on the model JIMMY [2], for our new event generator Herwig++ [3].

An extension to this model along the lines of [4], which also includes soft scatters is underway and will most probably be available for the next release of Herwig++. Covering the entire p_t range will also allow us to describe minimum bias interactions. We have examined the parameter space of such models at Tevatron and LHC energies in Ref. [5]. Existing measurements and the possible range of LHC measurements are used there to identify the maximally allowed parameter space.

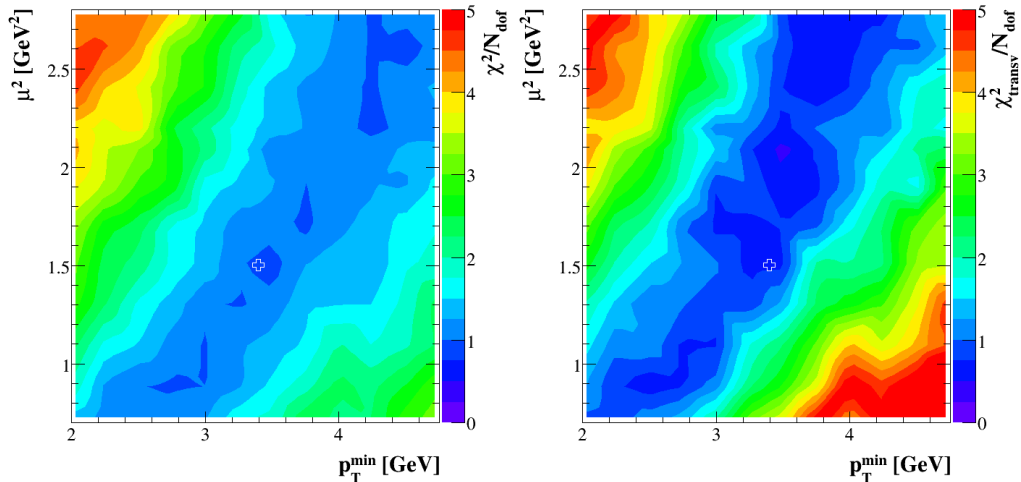[*] to appear in the proceedings of the HERA and the LHC workshop.

Fig. 1: Contour plots for the χ^2 per degree of freedom of all discussed observables (left) and only the ones from the transverse region (right). The cross indicates the location of our preferred tune.

2 Tevatron results

We have performed a tune of the model by calculating the total χ^2 against the jet data ($p_t^{\text{ljet}} > 20\,\text{GeV}$) from Ref. [6]. For this analysis each event is partitioned into three parts, the **towards, away** and **transverse** regions. These regions are equal in size in $\eta - \phi$ space and classify where particles are located in this space with respect to the hardest jet in the event. We compare our predictions to data for the average number of charged particles and for the scalar p_t sum in each of these regions.

The parameter space for this tune is two dimensional and consists of the p_t cutoff p_t^{min} and the inverse hadron radius squared, μ^2. In Fig. 2 we show the χ^2 contour for describing all six observables and especially those from the transverse region, which is particularly sensitive to the underlying event. For these, and all subsequent plots, we have used Herwig++ version 2.2.1 and the built-in MRST 2001 LO [7] PDFs. All parameters, apart from the ones we were tuning, were left at their default values.

The description of the Tevatron data is truly satisfactory for the entire range of considered values of p_t^{min}. For each point on the x-axis we can find a point on the y-axis to give a reasonable fit. Nevertheless an optimum can be found between $3 \dots 4\,\text{GeV}$. The strong and constant correlation between p_t^{min} and μ^2 is due to the fact that a smaller hadron radius will always balance against a larger p_t cutoff as far as the underlying event activity is concerned. As a default tune we use $p_t^{\text{min}} = 3.4\,\text{GeV}$ and $\mu^2 = 1.5\,\text{GeV}^2$, which results in an overall χ^2/N_{dof} of 1.3.

3 LHC extrapolation

We start the discussion of our predictions for the LHC with the plot in Fig. 2. The plot shows the mean charged multiplicity as a function of pseudorapidity, η. We show Herwig++ with and without MPI. We used QCD jet production with a minimal p_T of 20 GeV as signal process. The

MPI parameters were left at their default values, i.e. the fit to Tevatron CDF data. The effect of MPI is clearly visible, growing significantly from the Tevatron to the LHC.

For calculating the LHC extrapolations we left the MPI parameters at their default values, i.e. the fit to Tevatron CDF data. In Ref. [8] a comparison of different predictions for an analysis modelled on the CDF one discussed earlier was presented. As a benchmark observable the charged particle multiplicity in the transverse region was used. We show this comparison in Fig. 3 together with our simulation. All expectations reached a plateau in this observable for $p_t^{\text{ljet}} > 10$ GeV. Our prediction for this observable also reached a roughly constant plateau within this region. The height of this plateau can be used for comparison. In Ref. [8] PYTHIA 6.214 [9] ATLAS tune reached a height of ~ 6.5, PYTHIA 6.214 CDF Tune A of ~ 5 and PHOJET 1.12 [10] of ~ 3. Our model reaches a height of ~ 5 and seems to be close to the PYTHIA 6.214 CDF tune, although our model parameters were kept constant at their values extracted from the fit to Tevatron data.

We have seen already in the previous section that our fit results in a flat valley of parameter points, which all give a very good description of the data. We will briefly estimate the spread of our LHC expectations, using only parameter sets from this valley. The range of predictions that we deduce will be the range that can be expected assuming no energy dependence on our main parameters. Therefore, early measurements could shed light on the potential energy dependence of the input parameters by simply comparing first data to these predictions. We extracted the average value of the two transverse observables for a given parameter set in the region $20\,\text{GeV} < p_t^{\text{ljet}} < 30\,\text{GeV}$. We did that for the best fit points at three different values for p_t^{min}, namely 2 GeV,
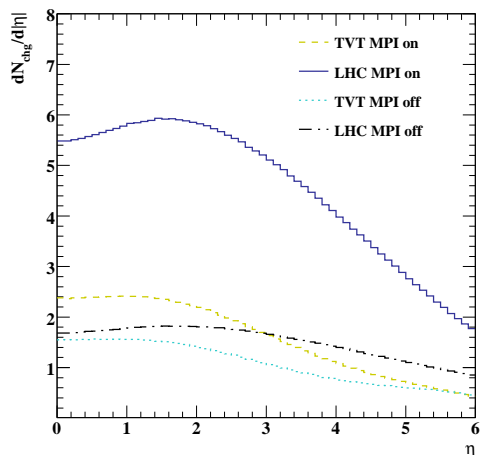

Fig. 2: Differential multiplicity distribution with respect to $|\eta|$. The different data sets are: Tevatron with MPI off, LHC with MPI off, Tevatron with MPI on and LHC with MPI on.

3.4 GeV and 4.5 GeV, and found an uncertainty of about 7 % for the multiplicity and 10 % for the sum of the transverse momentum.

LHC predictions	$\langle N_{\text{chg}} \rangle^{\text{transv}}$	$\langle p_t^{\text{sum}} \rangle^{\text{transv}}\,[\text{GeV}]$
TVT best fit	5.1 ± 0.3	5.0 ± 0.5

Table 1: LHC expectations for $\langle N_{\text{chg}} \rangle$ and $\langle p_t^{\text{sum}} \rangle$ in the transverse region. The uncertainties are obtained from varying p_t^{min} within the range we considered. For μ^2 we have taken the corresponding best fit (Tevatron) values.
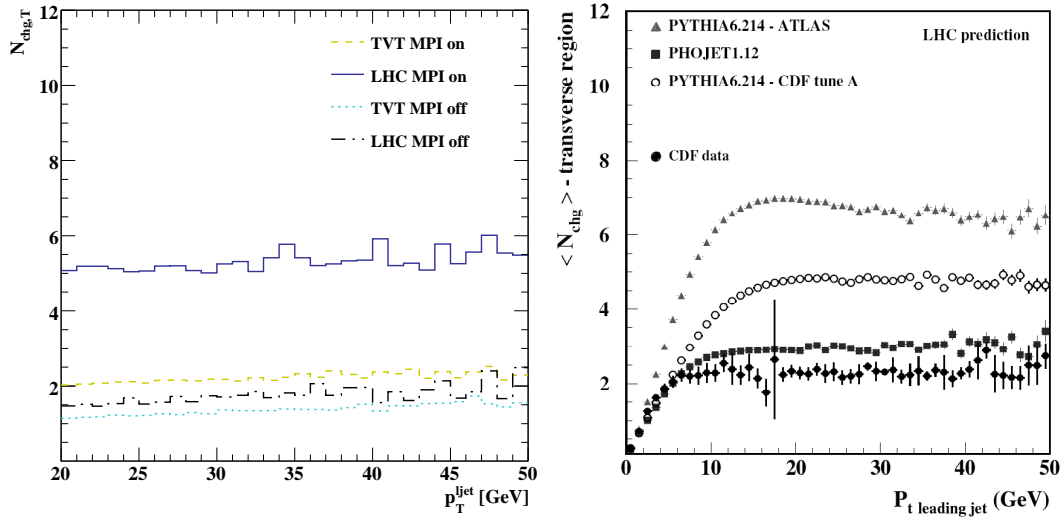
Fig. 3: Multiplicity in the transverse region for LHC runs with Herwig++ (left) and the same observable for several other generators (right), taken from Ref. [8]. The different data sets for the left plot are (from bottom to top): Tevatron with MPI off, LHC with MPI off, Tevatron with MPI on and LHC with MPI on.

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