The ATLAS Monte Carlo tuning system

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DOI: http://dx.doi.org/10.3204/DESY-PROC-2012-03/95

The ATLAS experiment moved the tuning of the underlying event and minimum bias event shape modeling, previously done in a manual fashion, to the automated Professor tuning tool, employed in connection with the Rivet analysis framework, when the first corresponding experimental analysis from LHC became available. The tuning effort for the Pythia 8 generator, which includes improved models for diffraction, has been started in this automated way in ATLAS , with the aim of getting a good description of the pile-up generated by multiple minimum bias interactions. The first results for these Pythia 8 tunes, as well as PYTHIA 6 shower tunes are presented, including a study of tunes for various PDFs.

1 Introduction

Monte Carlo event generators are extensively used in high-energy particle physics, allowing the simulation of scattering processes and the generation of the outgoing particle spectra. The description of low energy QCD interactions in the generation processes necessitates the introduction of phenomenological models due to the increase of the strong coupling constant. Processes which are effected by the phenomenological description are for example: multiple parton interactions (MPI), initial- and final state radiation (which, together with the MPI, are the main contributions to the underlying event) and fragmentation processes. These models introduce additional parameters, which need to be fitted to measurements in order to provide a good Monte Carlo prediction for various other analyses. The ATLAS tuning effort for the PYTHIA 6 and Pythia 8 Monte Carlo generator and the tuning framework are presented in the following.

2 Tuning procedure

The baseline for the tuning procedure is the selection of N tuning parameters p_i and their considered ranges $[p_{\min}, p_{\max}]$. Event samples are generated for random points of the previous definite N-dimensional parameter hypercube, where the number of different points is depending on the number of input parameters to ensure a well converging behavior of the final tune. Each generated event is directly piped to the Rivet [1] framework, to perform specific analyses for each parameter variation. This allows the calculation of observables for each parameter point, which builds the input for the actual tuning process. The obtained distributions of observables for each parameter variation are the starting point for the tune, which is performed using

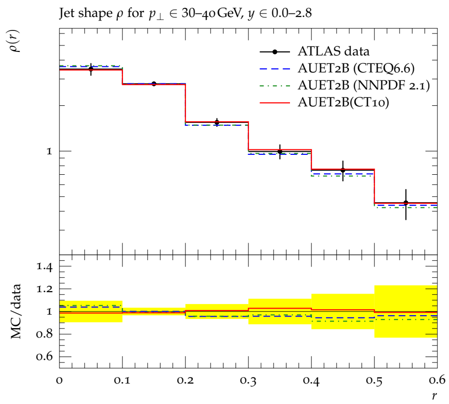

Figure 1: Comparing the PYTHIA 6 shower tune with ATLAS jet shape measurements at 7 TeV, for different next-to-leading order PDFs. Results are taken from [4].

the Professor framework [2]. Professor performs a parametrization of the generator response as a function of the parameter points and finds the set of parameters, which fits best to the given measurements of the considered observables. The user is able to influence the tuning by applying a weight for each observable, which specifies the impact of the variable for the tuning process. The whole tuning process is performed for different center-of-mass energies to obtain the energy dependence of some model parameters and for different parton density functions (PDF's), which are an extra input in the event generation step.

3 PYTHIA 6 tune

Based on the AMBT2B and AUET2B tune [3] for PYTHIA 6 a new MPI and a full shower tune were performed, using next-to-leading order PDF's and a p_T ordered shower model. The effective cutoff for space-like parton showers, the multiplier for the parton shower evolution scale and the final state radiation[1] were tuned to ATLAS measurements including jet shape studies, di-jet decorrelations and track-jet measurements. The final tune shows an excellent agreement between measurement and Monte Carlo prediction within the systematic uncertainties. Figure 1 shows the AUET2B predictions for the jet shape measurement, compared to measurements from the ATLAS experiment. All result are taken from [4].

4 Pythia 8 MPI tune

The Pythia 8 MPI tune was performed for leading order, modified leading order and next-to-leading order PDFs. The tune was accomplished using ATLAS minimum bias measurements, as well as ATLAS underlying event data based on tracks and clusters. A x dependent matter distribution was used and no rapidity order for spacelike showers was applied. The following parameters were varied for the tuning: the cutoff for MPI, the power of the energy rescaling for the min. p_T cutoff, color reconnection, and the width of the Gaussian matter function.

[1] The corresponding parameter are PARP(62), PARP(64) and PARP(72) respectively.

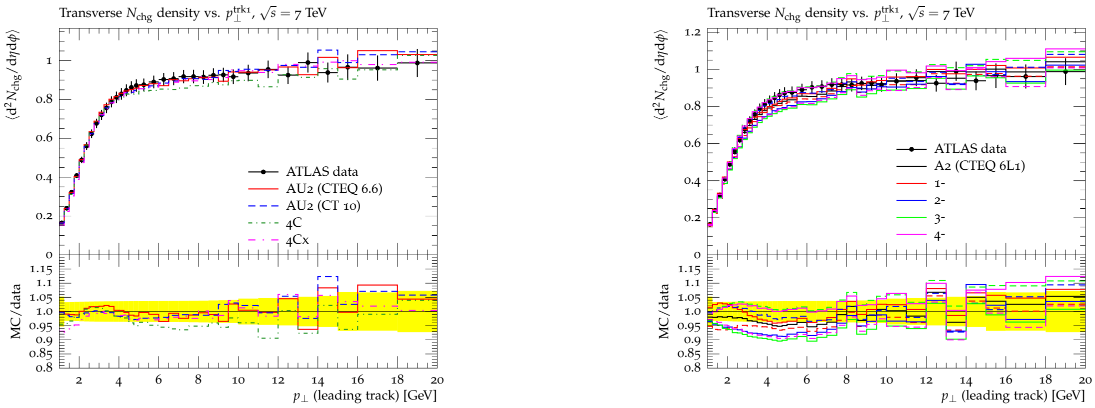

Figure 2: The average charged track number density ($p_T > 500$ MeV) as a function of the leading track p_T is compared between prediction of Pythia 8 MPI tunes and ATLAS underlying event data, for next-to-leading order PDF's (left) and with the considerations for the eigentunes (right). Results are taken from [4].

The tunes focus mainly on distributions with $p_T > 500$ MeV and a center-of-mass energy of 7 TeV. To estimate the systematic error on the Monte Carlo prediction, the "eigentune" method (see [3] for details) was used, as provided by the Professor framework. The uncertainty estimation is based on variations of the parameters around the best fit value, corresponding to one standard deviation. Figure 2 shows the final tune compared to the ATLAS underlying event measurements and the corresponding eigentunes. All results are taken from [4].

5 Conclusions

The wide use of predictions from Monte Carlo generators in high energy physics makes is necessary to provide tunes to actual measurements. The ATLAS tuning framework allows a coherent and efficient setup to tune the Monte Carlo prediction to ATLAS measurements. The new AMBT2B and AUET2B tunes for PYTHIA 6 and Pythia 8 shows a good description of the measurements.

References

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