Verification of Forward Jet Production in Deep Inelastic Scattering at HERA

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Abstract

The inclusive forward jet cross-section in deep inelastic e+p scattering has been measured in the region of x–Bjorken, 4.5×10^{-4} to 4.5×10^{-2}, with the cut $0.5 < E_T^2, jet/Q^2 < 2$, where the results are the most sensitive to BFKL-effect. This measurement is motivated by the search for effects of BFKL–like parton shower evolution. The cross-section at hadron level as a function of x is compared to that predicted by Monte Carlo models (RAPGAP and ARIADNE). An excess of forward jet production at small x is observed compared with ARIADNE generated events. RAPGAP, a model based mainly on DGLAP parton shower evolution, has the lowest cross-section. This shows that the Colour Dipole model describes the data reasonably well. BFKL–like parton shower evolution effect is thus observed.

Contents

1 Introduction

Multiple approaches have been made to predict the behavior of proton structure F_2(x,Q^2), which changes dramatically at small x-Bjorken. In one approach, DGLAP evolution equation was used, which includes a leading term ln(Q^2). Another approach would be BFKL evolution equation, which has a leading term $ln(\frac{1}{x})$. In the paper 'Forward Jet Production in Deep Inelastic Scattering at HERA', they have produced some plots using ARIADNE, LEPTO and HERACLES for results simulation in Monte Carlo. In this paper, RAPGAP and ARIADNE are used to reproduce the plots and re-verify the Colour Dipole model and thus BFKL–like parton shower evolution. The paper consists of five sections, with theoretical background followed by Method and Results, and the last section is the Conclusion.

2 Theoretical Background

BFKL equation predicts a strong ordering of the longitudinal momenta(x), whereas DGLAP equation predicts a strong ordering of parton transverse momenta(k_T) (Table 1). Thus, for BFKL equation, partons with large transverse and longitudinal momenta will provide additional contributions to hadronic final state. These partons are experimentally resolved as jets.

Thus, one way to detect BFKL effect would be to investigate jets' cross-section at low x-Bjorken and compare it with Monte-Carlo generated data. In this case, RAPGAP and ARIADNE was used. RAPGAP is a generator which mostly has the components from DGLAP, while ARIADNE has some BFKL terms contribution towards it. It can be expected that the experimental data would have a higher cross-section comparing to Monte-Carlo simulated data, and ARIADNE generated data fits better with the HERA data in comparison to RAPGAP. In this way, the BFKL-effect at low x-Bjorken could be proved.

3 Methods

The HERA experimental data is acquired at HERA by operating with 174 colliding bunches of Ep=820GeV protons and Ee=27.5GeV positrons, the integrated luminosity used in this analysis was $6.36pb^{-1}$. Among all, about 7×10^6 events survived.

The Monte-Carlo data was produced using a DESY virtual machine[3]. Firstly, C++ was used to setup and fill the histograms and to select events with specific cuts (Table2). The chosen phase space ensures only forward jets which are most sensitive to BFKL effect were selected. The C++ file along with the plot file were then uploaded onto the DESY virtual machine, on which one can setup all necessary inputs for Pythia in steer-ep which are then used to generate events. In this case vast majority of the parameters were default parameters. Only Ep, Ee, IFPS was modified as required. The rapgap.sub file was then setup to run the program to generate events and input all events data into the yoda file. This is again downloaded and plotted using rivet-mkhtml command to show the final plot on a web-page.

4 Results

First, an appropriate range of $E_T^2, jet/Q^2$ for investigating BFKL effect is determined(Figure 1). For $E_T^2, jet/Q^2 \ll 1$, RAPGAP and ARIADNE generated data both fit rather well with the HERA data, showing DGLAP equation dominates over this region. For $E_T^2, jet/Q^2 \approx 1$, BFKL fits well, as a small number of excess jets were observed compared to both sets of MC generated data, showing that this region is where the results are the most sensitive to BFKL effect. At high $E_T^2, jet/Q^2$, neither equation fits well within this range, as it is already in the photo-production range, due to the low Q value. Hereby, we conclude that to show the most BFKL effect, phase space $0.5 < E_T^2, jet/Q^2 < 2$ should be applied.

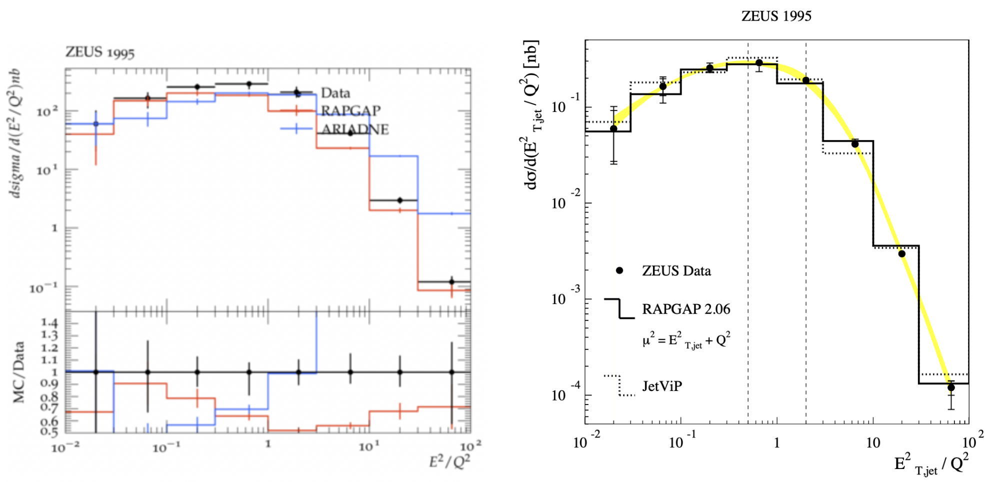

Figure 1: Comparison of results obtained from rivet and the corresponding ones in the paper 'Forward jet production in deep inelastic scattering at HERA'. (a) HERA experimental and MC generated data of the cross-section plotted with respect to $E_T^2, jet/Q^2$, ARIADNE generated data(blue), RAPGAP generated data(red).(b) Validation graph with results generated using RAPGAP.[1]

With all appropriate phase space, an excess of forward jets was observed compared to MC generated events using RAPGAP and ARIADNE in the small x-Bjorken region(Figure 2). Specifically, ARIADNE generated data fits better than RAPGAP generated data, which is what we expected. Both of which show that the BFKL-effect is observed at the small x-Bjorken region. At the high x-Bjorken region, the HERA data fits well with MC simulated events - this means that the DGLAP equation dominates over this region, which is what was expected from their equation format.

5 Conclusions

In conclusion, we have reproduced the graphs with RAPGAP and ARIADNE - RAPGAP has fewer BFKL characteristics than ARIADNE. It is proven that for $E_T^2, jet/Q^2 \approx 1$, jets in this range are more sensitive to BFKL-effect. Applying with appropriate phase space, where BFKL-effect is enhanced, the events' cross-section is plotted against x-Bjorken. It is proved that, at small x-Bjorken, the Colour Dipole model describes the data reasonably

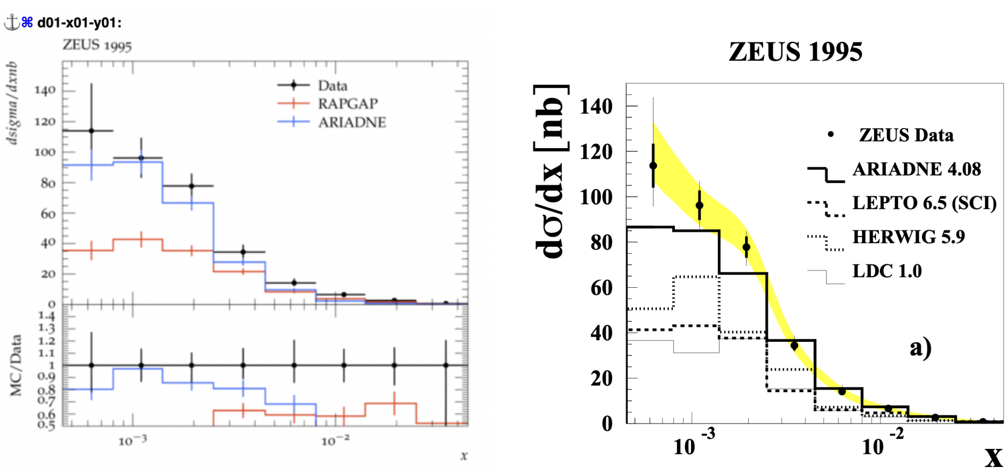

Figure 2: Comparison of results obtained from rivet and the corresponding ones in the paper 'Forward jet production in deep inelastic scattering at HERA'. (a) HERA experimental and MC generated data of the cross-section plotted with respect to $x{-}bj$, ARIADNE generated data(blue), RAPGAP generated data(red).(b) Validation graph with results generated using a few MC generators.[2]

well. BFKL–like parton shower evolution effect is observed. For further improvement, a larger number of events or different event generators can be used for comparison purposes.

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