AZIMUTHAL CORRELATION IN DIHADRON PRODUCTION

Alberto GUFFANTI
Università di Parma and INFN, Sezione di Milano, Gruppo Collegato di Parma, Italy
LPTHE Jussieu, Paris, France

We study the azimuthal correlation of hadron pairs produced in hadron-hadron collisions in the framework of perturbative QCD. We concentrate our attention on the ‘almost back-to-back’ region where resummation of large logarithms due to soft and/or collinear radiation are shown to play an important role. Our aim is to perform perturbative resummation at single logarithmic accuracy.

1 Introduction

To our knowledge the azimuthal correlation of a pair of hadrons identified among those produced in hadron-hadron collisions has been first proposed as a sensible observable to be studied in the framework of perturbative QCD (pQCD) at the end of the 70’s. Notably the observable studied was

\[ \Sigma \equiv \frac{d\sigma}{dp_{c\perp}dy_{c}dp_{d\perp}dy_{d}d\chi}, \] (1)

where \( p_{(c,d)\perp} \) and \( y_{(c,d)} \) are, respectively, the transverse momenta and the rapidities of the outgoing hadrons and \( \chi \) is the azimuthal angle, as defined in figure 1.

Moreover a complete QCD study has been recently carried out for the corresponding observable in DIS processes.

From an experimental point of view, the azimuthal correlation in pion-pair production in hadronic collision was one of the observables measured by the fixed target E706 experiment at the Fermilab Tevatron.

\[ ^a \text{Talk presented at the XXXVIIIth Rencontres de Moriond ‘QCD and Hadronic Interactions’, Les Arcs, France, 22-29 March 2002.} \]
Recently the results of the E706 experiment have been compared to next-to-leading-order (NLO) theoretical predictions. As is clearly shown by figure 2, the fixed order prediction fails to properly describe the data in the region $\chi \to 0$ (which corresponds to $\phi \to \pi$ in figure 2).

The reason of this failure is to be ascribed to the fact that for the observable under study what we call NLO prediction, i.e. one gluon emission, is, in fact, the first non trivial level of approximation. The $2 \to 2$ scattering being a planar process, the LO prediction for such an observable is simply proportional to $\delta(\chi)$.

The failure of the NLO prediction in describing the data in the $\chi \to 0$ region can be seen as an evidence that this region of phase space is dominated by soft and collinear multiple emission. In order to obtain a sensible answer we are thus forced to resum logarithmic contributions of infrared origin to all orders in perturbation theory.

### 3 Resummation

Up to now the resummation procedure has been carried out only to double logarithmic (DL) accuracy, i.e. taking care of logarithmic contributions of the form $\alpha_s^n \ln^{n+1} \chi$ in $\ln \Sigma$, due to gluons which are both soft and collinear. This approximation is known to be too crude and
largely insufficient to describe the data. Anyway this calculation showed the large impact of considering multigluon emission for our observable when studying the azimuthal correlation in the $\chi \rightarrow 0$ limit.

Our aim is to reach, in the case of this 4-jets\(^b\) observable, the same accuracy attained in 2- and 3-jets ones. This includes resummation of logarithmically enhanced terms to single logarithmic (SL) level, which means having under control all terms of the form $\alpha_s^n \ln^{n+1} \chi$ and $\alpha_s^n \ln^n \chi$ in $\ln \Sigma$, performing the matching with the exact NLO prediction and evaluate the leading power corrections.

Resummation to SL accuracy implies taking care of hard collinear emissions and soft large angle ones. The former contribute to set the scale of parton distribution functions (PDF) and fragmentation functions (FF) and the hard scales entering the process. The latter is related to the color structure of the underlying event.

Techniques to deal with soft large angle radiation from 4 hard emitters have been developed in the last decade\(^6\) and imply the refactorization of the partonic cross section into a hard ($H$) and a soft ($S$) function, and the use of the corresponding renormalization group equation to resum logarithmic contributions to SL level.

The resummation procedure is performed in the impact parameter space ($b$), which is the Fourier transform of the out-of-scattering-plane momentum, in order to properly take care of momentum conservation\(^7\)

\[
\hat{\Sigma} = \sum f \int \frac{p_{\perp} \, db}{\pi} e^{ip_{\perp} \chi} \prod_{a=1}^2 \int_0^1 dX_a P_a(X_a, b^{-1}) \prod_{b=3}^4 \int_0^1 dZ_b D_b(Z_b, b^{-1}) 
\delta \left( \frac{2e + 4d}{2} - Y \right) \delta \left( \frac{p_{\perp} - Z_3}{p_{\perp}} - Z_4 \right) \frac{1}{16 \pi s^2} \text{Tr} \left\{ H_f^{(1)} e^{-\mathcal{R}_f} S_f^{(0)} e^{-\mathcal{R}_f} \right\}
\]

where $P_a(X_a, b^{-1})$ and $D_b(Z_b, b^{-1})$ are, respectively, the PDFs and FFs of incoming and outgoing partons into corresponding hadrons evaluated at the scale $b^{-1}$. The sum is over all the partonic subprocesses, $f$, $H_f^{(1)}$, $S_f^{(0)}$, the hard and soft function, are matrices in color space and depend on the specific partonic subprocess $f$ and the radiator $\mathcal{R}_f$ also a matrix in color space, resums all logarithmic contributions up to Single Logarithmic (SL) accuracy.

4 Conclusions & Outlook

In this talk I reported on an ongoing work\(^8\) about the study of azimuthal correlation of hadron pairs produced in hadronic collision. Such an observable has great interest both from an experimental and a theoretical point of view.

Preliminary analytical and numerical results indicate that we should expect, for our observable in the region of small $\chi$, a behavior similar to what has been obtained for a similar observable analyzed in DIS environment\(^2\) (see Figure 3, for a graph showing the behavior of azimuthal correlation in DIS).

If this indeed was the case our prediction would, at least qualitatively, describe the behavior of the data in the region of ‘almost back-to-back’ production where present fixed order calculation have been shown to be inapplicable.

Acknowledgments

I would like to thank the organizers of the Moriond conference for offering me the opportunity of giving this talk. It is also a pleasure to thank Andrea Banfi for fruitful collaboration on the subject and Yuri Dokshitzer and Gavin Salam for helpful discussions.

\(^{b}\)We use the term jets in a loose acceptation, really meaning hard partons
References

1. Yu. L. Dokshitzer, D. Dyakonov and S. I. Troyan, *Phys. Rept.* **58**, (1980) 269
2. A. Banfi, G. Marchesini and G.E. Smye, *J. High Energy Phys.* **04**, (2002) 024 [hep-ph/0203150]
3. E706 Collaboration, L Apanasevich et al., *Phys. Rev. Lett.* **81**, (1998) 2642
   M. Begel, *Production of high mass pairs of direct photons and neutral mesons in a Tevatron fixed target experiment*, Ph.D. Thesis, Rochester University, 1999 [hep-ex/9711017]
4. T. Binoth, J.Ph. Guillet, E. Pilon, M. Werlen, *Eur. Phys. J. C* **24**, (2002) 245
5. J.F. Owens, *Phys. Rev.* **D 65**, (2002) 034011 [hep-ph/0110036]
6. J. Botts and G. Sterman, *Nucl. Phys. B* **325**, (1989) 62
   N. Kidonakis, G. Oderda and G. Sterman, *Nucl. Phys. B* **531**, (1998) 365
7. G. Parisi and R. Petronzio, *Nucl. Phys. B* **154**, (1979) 427
8. A. Banfi and A. Guffanti, in preparation