Pair transverse momentum and rapidity correlations of heavy quarks at LHC

Umme Jamil†, Mohammed Younus‡, Dinesh K. Srivastava‡

†Saha Institute of Nuclear Physics, Kolkata 700 064, India
‡Variable Energy Cyclotron Center, Kolkata 700 064, India

Introduction

The advent of the ultrarelativistic nucleus nucleus collisions at higher and higher energies highlights heavy quarks as an excellent probe for the Quark-Gluon Plasma (QGP). Heavy quarks are produced in pairs \((Q\bar{Q})\) as the flavour is conserved in strong interaction. Again, as they are massive they would not change direction much during their passage through the QGP, which makes them a valuable probe for the properties of the plasma.

In this work we study the transverse momentum, and rapidity correlations of heavy quark-anti quark \((Q\bar{Q})\) pairs in \(pp\) collisions at Next-to-Leading Order (NLO).

Correlations of \(Q\overline{Q}\) pair in \(pp\) collisions

We study the correlations of heavy quarks produced in the initial fusion of gluons and quark-anti quark annihilation in proton-proton collision. The basic formulation which gives the correlation is given by:

\[
E_1E_2 \frac{d\sigma}{d^3p_1d^3p_2} = \frac{d\sigma}{dy_1dy_2d^2p_{T1}d^2p_{T2}} = C ,
\]

where \(y_1\) and \(y_2\) are the rapidities of heavy quark and anti-quark and \(p_{T1}\) and \(p_{T2}\) are their transverse momenta. We calculate the initial production of heavy quarks using the NLO pQCD treatment (NLO-MNR) developed by Mangano et al [1]. The structure function used is CTEQ5M. The mass of the charm quark is taken as \(m_c = 1.5\) GeV, and that for bottom quarks is \(m_b = 4.5\) GeV. The factorization and renormalization scales are taken as \(Q = 2m_T\) and \(Q = m_T\) for charm and bottom quarks respectively, where \(m_T\) is the transverse mass.

In Fig. 1 we show our results for the transverse momentum, and rapidity correlation of charm and bottom quark pairs produced in \(pp\) collisions at \(\sqrt{s}=2.76\) TeV. These results would lead to an interesting situation, where
we can consider a heavy-quark produced in LO pQCD in a nucleus-nucleus collision. As at LO, they will be produced back-to-back and are most likely to cover different lengths of the system before they fragment to a D-meson. Thus they would suffer different amount of energy loss and acquire a net-transverse momentum despite their zero initial net-transverse momentum.

**J/ψ production in pp collisions**

The J/ψ production in pp collisions is also important as the observed suppression of J/ψ in the nucleus nucleus collision carry the information of QGP formation.

Using the colour evaporation model, one can write:

\[
\frac{d\sigma_{J/\psi}}{dy} = F \int_{2m_c}^{2m_D} dM \frac{d\sigma_{J/\psi}}{dM} d\nu.
\]  

(2)

where \( M \) is the invariant mass of the pair, \( y \) is its rapidity, \( m_D \) is the mass of D-mesons, and \( F \) is the (constant) colour-evaporation factor. As discussed above, at LO pQCD the heavy quark are produced in pairs with pair-momentum identically equal to zero (though the NLO processes do provide them with a net-transverse momentum). This can be corrected if we consider the partons having an intrinsic \( k_T \) (see e.g. [2]) and in our calculation for J/ψ we impart an intrinsic \( k_T \) of 1.5 GeV/c to the partons.

In Fig. 2, we show our results for the transverse momentum and the rapidity distribution of J/ψ in pp collision at 7 TeV along with the experimental results. The transverse momentum distribution shows a very good description whereas we see a reasonable description of the rapidity distribution.

**Summary**

These results will act as a base-line for similar studies in the case of nucleus nucleus collisions at the corresponding centre of mass energies/nucleon, to determine the medium modifications.

A deviation of the observed correlations in nucleus nucleus collisions from the results shown in Fig. 1 and Fig. 2 is expected to give a measure of the medium modification. For a more detailed discussion of correlations please see ref. [3]

**Acknowledgments**

UJ and MY acknowledge the financial support from the Department of Atomic Energy, Government of India during the course of these studies.

**References**