Effect of initial state beam parton energy loss in Drell Yan production for proton-nucleus collisons

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Introduction

In high energy nuclear collisions, the Drell-Yan (DY) process consists of the production of lepton pairs by quark-antiquark annihilation to produce a virtual photon (γ^*), or a Z boson, which subsequently decays into the lepton pair. The produced lepton pair does not interact with the surrounding nuclear medium, therefore the DY production is not affected by final-state effects and should exclusively reflect nuclear effects present in the initial stage which include the nuclear modification of parton distribution functions (PDF) and the possible energy loss by the quarks (and gluons) before the hard partonic interaction to produce the lepton pair. In this work, we aim to evaluate the initial state parton energy loss by analyzing the DY data in proton-nucleus ($p + A$) collisions.

The Formalism

The calaculation of double differential DY cross section in terms of pair mass M and x_F has been done with a phenomenological K-factor to account for the higher order corrections. We have employed MSTW 2008 [1] parton density distribution and recently proposed EPPS16 [2] nuclear patron density distribution for free protons and bound nucleons respectively. To simulate the nuclear effects on DY production, in addition to nuclear parton densities, the effect of initial state quark energy loss inside the target nucleus is also taken into account following the prescription proposed in [3]. It is based on the idea that inside target nucleus, the beam parton loses a constant fraction $\epsilon_{q,g}$ of its initial momentum each time it encounters a nucleon, until it undergoes the hard scattering where the DY di-muon is created. For a beam quark carrying a momentum fraction x_1, the parton distribution is evaluated for that x_1 while the partonic cross section is evaluated at

$$x_1^{'} = x_1(1 - \epsilon_q)^{N_{coll}-1} \quad (1)$$

where N_{coll} denotes the number of sub collisions that the quark suffers in the nuclear target [4].

Results and Discussions

Our investigated data sets resemble those reported in [3]. However the employed parton densities are different as mentioned above. Before going to the DY production in $p + A$ collisions which provides measurements of nuclear effects, we would like to validate our calculation for elementary proton-proton ($p + p$) collisions. In this regard, we have analyzed the data of E866 experiment [5] at Fermilab in 800 GeV $p+p$ collisions. The central set of MSTW 2008 NLO free proton pdfs are used for this purpose. The data can be nicely described with a global K factor of $K_{DY} = 1.13 \pm 0.009$, independent of x_F [FIG.1].

NA3 experiment [6] measured the DY double-differential production cross section in $p + Pt$ collisions at $E_{lab} = 400$ GeV, in different dimuon mass bins and covering a x_F region $0.0 < x_F < 0.65$. We have calculated the double-differential DY cross section for $p + Pt$ collisions at $E_{lab} = 400$ GeV using EPPS16 nPDF, without[FIG.2] and with[FIG.3] imposing the initial-state parton energy loss model as mentioned above. Inclusion of a small amount of initial-state parton energy loss [FIG.3] gives the best fit ($\chi^2/ndf = 0.78$) of the experimental data as compared to the case of no initial-state parton energy loss [FIG.2].

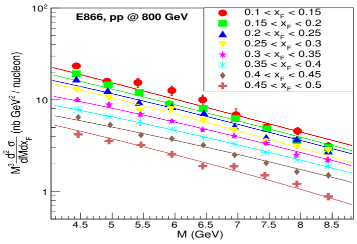

FIG. 1: DY production cross section vs. dimuon mass in different dimuon x_F ranges, as measured by the E866 experiment in $p + p$ collisions at 800 GeV and as calculated at NLO, using MSTW 2008 PDF.

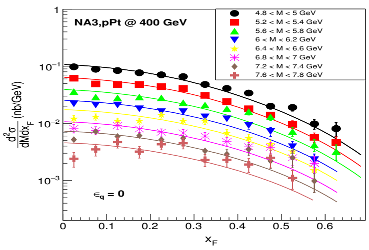

FIG. 2: DY production cross section as a function of dimuon x_F in different dimuon mass ranges, as measured by the NA3 experiment in $p + Pt$ collisions at 400 GeV and as calculated at NLO, using EPPS16 nPDFs ($\epsilon_q = 0$).

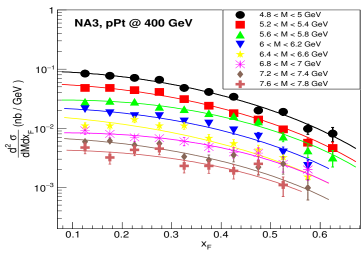

FIG. 3: DY production cross section as a function of dimuon x_F in different dimuon mass ranges, as measured by the NA3 experiment in $p + Pt$ collisions at 400 GeV and as calculated at NLO, using EPPS16 nPDFs ($\epsilon_q \neq 0$).

The E772 experiment [7] measured the integrated DY cross section, using deuterons as the light target and Fe as heavy target. In FIG.4, we have calculated the yeild ratio (Fe/H^2) and compared with E772 measurement to investigate the effect of initial state quark energy loss in this data corpus. Due to the large error bars of the data points, both the theoretical curves with $\epsilon_q = 0$ and $\epsilon_q = 0.006$ can match the data and thus refrain us to choose one scenario over the other. Unfortunately there is no data available from RHIC to probe the situation further. DY measurements in $p + Pb$ collisions at LHC if and when available, might help to have a deeper insight into this issue.

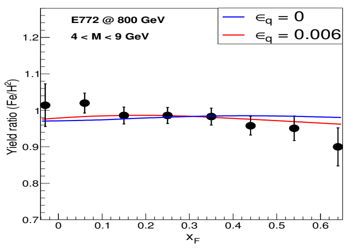

FIG. 4: Yield ratio of DY dimuon as a function of dimuon x_F, as measured by the E772 experiment at 800 GeV and as calculated at NLO, using EPPS16 nPDFs.

Acknowledgments

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