Motivation and Overview

In the high transverse momentum region, the recent RHIC data present a suppression of the charged hadron spectra in nucleus-nucleus processes. To explain this feature, different effects as the saturation in the initial nuclear wavefunctions and final state energy loss were proposed. Hadron-nucleus (d-Au) processes were studied to determine whether the suppression is an initial or final state effect. At mid-rapidity, the results suggest that this suppression is a final state effect, implying that the saturation effects are small. At higher rapidities, however, smaller parton momentum values are reached than in mid-rapidity, and saturation effects might be important. In this work, we investigate the hadron $q_T$ spectra in the forward rapidity region using perturbative QCD and the collinear factorization. We present our calculation for d-Au processes, including shadowing, whose nuclear modification is shown.

Factorization

When one assumes the factorization of the process, two kinds of effects could be considered:

- Initial state (IS) effects (present before the hard interaction)
- Final state (FS) effects (present after the hard interaction)

$\Rightarrow$ related to the nuclear medium formed in the collision $\Rightarrow$ Energy Loss.

Here, focus is given to d-Au processes, since FS effects are expected to be minimal in this interaction and it can provide important benchmarks for further measurements in Au-Au processes.

The Model

For jet production in a hadronic collision a pQCD based model is used in this work. The transverse momentum of the produced parton is $p_T$ and its rapidity, $y$,

$$\frac{d^3N}{dy p_T d^3q} = \int_{x_F} dxf \frac{N(x,f)}{2\pi y^2} \frac{e^{y E_{cm}/2}}{(1+e^{-y})^2}$$

$\Rightarrow y_T, y_T \rightarrow$ rapidities for partons j and i,

$\Rightarrow m_T = \sqrt{p_T^2 + p_0^2}, \quad z \rightarrow X = \frac{m_T}{m_T + p_0};$

Inclusive hadron production with transverse momentum $q_T$ and rapidity $y_0$ is given by

$$\frac{d^3N}{dy p_T d^3q} = a(q) \int_0^1 dx_g \int_0^1 dx_f$$

where $z$ is the light-cone fractional momentum of the hadron, related to its parent parton $i$.

To compute the nuclear modification factor due to the shadowing, defined by

$$R_{dAu}(x_f) = \frac{d^3N_{dAu}(x_f)}{d^3N_{pp}(x_f)}$$

the EKS parameterization is used. For the parton distributions, we use the CTEQ5 one.

Results for charged hadrons

A comparison between the results of this pQCD based model for charged hadron production at RHIC energies ($\sqrt{s}_{NN} = 200$ GeV) and the BRAHMS data is showed in the next figures for three different rapidities.

For mid-rapidity, the low $q_T$ spectra is underpredicted by the model. In order to correct the curvature of the hadron spectrum, an intrinsic $k_T$ for the colliding partons could be considered. Since this analysis concerns only to the modifications due to the nuclear shadowing, the intrinsic $k_T$ is not considered in this calculation, and so the Cronin effect.

Charmed meson production

Charmed mesons are a very important tool to study the properties of the strong interactions. The heavy quark mass are large enough to provides a scale that factorizes the dynamics and allows the use of pQCD for computing production processes. Charm mass is in the limit of applicability of pQCD. The application of this factorization is not so evident for the kinematical regime $m_c^2 < q_T^2$. The $v_1$ values reached by the nucleons can be lower enough to justify the calculation with the nucleus assumed as a saturated dense partonic system.

In this work, we assume the validity of the perturbative QCD and the collinear factorization for RHIC kinematical regime, and this treatment is considered as a baseline to explicitate the presence of new dynamical effects in charmed meson production.

The nuclear modification ratio, due only to modifications in the nuclear partonic distributions, is showed in the next figures. The EKS parameterization is used, providing a conservative estimate for the nuclear effects.

Investigating the medium

Due to their large mass, radiative energy loss for heavy quarks is expected to be lower than for light quarks. Different energy losses means that the ratio between hadrons with heavy quarks and with light quarks can provide a tool to investigate the medium formed in heavy ions collisions.

In the next figure, we present the predictions for RHIC and LHC energies for the ratio between D mesons and $x$, defined by

$$R_{D/A}(x_f)$$

RHIC $\Rightarrow$ enhancement in the region $q_T > 1$ GeV for the analyzed rapidities

$\Rightarrow$ EKS anti-shadowing;

LHC $\Rightarrow$ suppression in the region $q_T < 11$ GeV (region to be studied at LHC) $\Rightarrow$ EKS shadowing.

Conclusions

Hadron production at forward rapidities is studied using a perturbative approach. The model was tested for charged hadron production and a good agreement with the BRAHMS data was found.

This work applies the pQCD based model for D meson production and we present predictions for RHIC and LHC energies, at positive rapidities, and the mid-rapidity prediction is also shown for comparison. An enhancement due to nuclear anti-shadowing is found for large $q_T$ at RHIC. This enhancement is stronger for D meson than for pions. At LHC, the analysis predicts a suppression for positive rapidities due to the nuclear shadowing, in the region $q_T < 11$ GeV, even at mid-rapidity. This suppression is stronger for D mesons than for pions. It suggests that the shadowing predicted to D meson production at LHC is stronger than for pions, due to the quadratic dependence on the gluon distribution present in the charm production.

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References