HIGH PT SUPPRESSION WITHOUT JET QUENCHING IN AU+AU COLLISIONS IN NEXUS

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Problem of high $P_T$ suppression in RHIC data is generally associated to jet quenching in a dense medium. We recently proposed a new approach to high energy nuclear scattering, which treats the initial stage of heavy ion collisions in a sophisticated way, and whose numerical solution is the model neXus. Within this model, there is no jet quenching, but the explicit energy conservation leads to similar results. RHIC high $P_T$ ratio between AA and pp results can be reproduced for different centrality bins.

1 Introduction

High $P_T$ suppression in RHIC Au+Au data is one of the most exciting results of this experiment. Together with back-to-back high $P_T$ hadron correlations and new results for d+Au collisions, this suppression appears to be an effect of final state interactions. Indeed, jet quenching in association with Cronin effect and nuclear shadowing, can describe the data reasonably well. For a qualitative description it is enough, but for a precise quantitative description of high $P_T$ and all the other observables in ultra-relativistic heavy ion collisions, we have to take care about other effects. Those can lead to significant difference in the energy-loss parameter for instance.

Then it is important to have a proper description of the initial state of this kind of interaction. The most sophisticated approach to high energy hadronic interactions is the so-called Gribov-Regge theory. This is an effective field theory, which allows multiple interactions to happen “in parallel”, with phenomenological objects called Pomerons representing elementary interactions.

We recently presented a new approach for hadronic interactions and the initial stage of nuclear collisions, which is able to solve several of the problems of the Gribov-Regge theory, such as a consistent approach to include both soft and hard processes, and the energy
conservation both for cross section and particle production calculations. In both cases, energy is properly shared between the different interactions happening in parallel. This is the most important new aspect of our approach, which we consider a first necessary step to construct a consistent model for high energy nuclear scattering. And this leads to interesting results.

2 neXus

We will discuss the basic features of the new approach in a qualitative fashion. It is an effective theory based on effective elementary interactions. Multiple interactions happen in parallel in proton-proton and nucleus-nucleus collisions. An elementary interaction is referred to as a Pomeron, and can be either elastic (uncut Pomeron) or inelastic (cut Pomeron). The spectators of each proton form remnants, see Fig. 1a.

\[ \text{Figure 1: a) Multiple elementary interactions (Pomerons) in neXus. The energy of each proton (blob) is shared between elastic (full vertical line) and inelastic (dashed vertical line) elementary interactions. A Pomeron b) has soft (blob), hard (ladder) and semihard contributions. c) Enhanced diagrams are included and can give different inelastic contributions d).} \]

Since a Pomeron is finally identified with two strings, the Pomeron aspect (to obtain probabilities) and the string aspect (to obtain particles) are treated in a completely consistent way. In both cases energy sharing is considered in a rigorous way, and in both cases all Pomerons are identical. To share the energy of the nucleons, we made a strong and simple assumption that the partition function does not depend of the number of elementary interactions. We will discuss this important point in the followings.

This theory provides also a consistent treatment for hard and soft processes: each Pomeron can be expressed in terms of contributions of different types, soft, hard and semihard ones, cf. Fig. 1b. A hard Pomeron stands for a hard interaction between valence quarks of initial hadrons. A semihard one stands for an interaction between sea quarks or gluons but in which a perturbative process involves in the middle. The high $P_T$ particles come from this middle part of the semi-hard (or hard) Pomeron. No perturbative process occurs at all in soft Pomerons.

A Pomeron is an elementary interaction. But those Pomerons may interact with each other at high energy \[ \text{10} \] then they give another type of interaction called enhanced diagram. There are many types of enhanced diagrams depending on the number of Pomerons for each vertices and on the number of vertices. In our model, effective first order of triple-Pomeron vertices (Y diagrams see Fig. 1c) are enough to cure unitarity problem which occur at high energy without this kind of diagram \[ \text{15}. \] Indeed, Y-type diagrams are screening corrections which are negative contributions to the cross-section. The inelastic contributions (cut enhanced diagrams on Fig. 1d) of this diagrams contribute to the increase of the fluctuations in particle production, and in case of nuclear collision, this type of diagramms correspond to a kind of shadowing (modification of the structure function of the nucleons inside a nucleus).
The model neXus is designed to reproduce proton-proton interactions. The initial stage of nuclear interaction is obtained by a sophisticated extension of the formalism with some approximations for the numeric solution. As a consequence, there is neither Cronin Effect nor partonic or hadronic final state interaction as jet quenching, hydrodynamic or rescattering. Comparison with the data should then be done carefully.

3 Results

Since neXus results for AA are just an extrapolation of pp, but with a proper energy sharing scheme, we can compare the high $P_T$ production of Au+Au collisions at 200 Gev in neXus with the data, to see what is the effect of the energy-momentum conservation. As there is no hadronic final state interactions, the results for a $P_T < 3 – 4$ GeV should not be regarded as a realistic one. To quantify the medium effect, we use the nuclear modification factor $R_{AA}$ defined in eq. 1 or the ratio $R_{CP}$ of the central to the peripheral yield defined in eq. 2 where in both cases $< N_{coll} >$ is the mean number of binary collisions for a given centrality region in the Glauber model (which does not take into account the energy-momentum conservation).

$$R_{AA} = \frac{(1/N_{AA}^{evt}) d^2N_{AA}/dydp_T}{< N_{coll} > / \sigma_{pp}^{\text{cen}} \times d^2\sigma_{pp}/dy/dp_T}$$

$$R_{CP} = \frac{< N_{cent}^{\text{peri}} > \times d^2N_{cent}/dydp_T}{< N_{cent}^{\text{peri}} > \times d^2N_{cent}/dydp_T}$$

![Figure 2: Left-hand side, nuclear modification factor for $\pi^0$ at 200 GeV for two different centrality-selected spectra. Points are experimental data from Phoenix collaboration. Right-hand side, ratio of central to peripheral charged particles yield for two different peripheral centrality-selected spectra. Points are experimental data from STAR collaboration.](image)

In fig. 2 the experimental ratio $R_{AA}$ for $\pi^0$ is compared to neXus predictions for the 0-10% central events (top) and 70-80% peripheral events (bottom left-hand side), together with the $R_{CP}$ for charged hadrons ($(h^+ + h^-)/2$) where central means 0-5% central events and peripheral means 40-50% (top) or 60-80% peripheral events (bottom right-hand side).
We can see that in all cases, an energy-momentum conservation scheme at the level of the cross-section calculation (which fixes the number of binary collisions) can lead to a suppression of the high $P_T$ produced particles which is compatible with the data.

4 Discussion

Of course, we are not claiming that this kind of process explains the high $P_T$ suppression. The recent d+Au data do not show any particular suppression for high $P_T$, while in NeXus a suppression appear. A Cronin effect would explain a part of the difference, but surely not all. In fact in our scheme, the suppression due to the energy conservation mechanism is maximal because of our simple choice for the partition function. It has to be seen as a maximum limit of this effect. A better understanding of this part of our formalism, which can be done partially with pp data, should lead to a weaker suppression. Together with a strong Cronin effect, it could appear like a weak Cronin effect in d+Au reaction. For heavy ion reactions, this can change the value of the needed energy-loss. Thus we want to emphasize that for a quantitative description of heavy ion collision data, and for a real comprehension of the complex processes involved in this kind of reaction, it is important to take care about energy-momentum conservation. It can play a non-negligible role to fix the proportion of all the other processes like the Cronin effect or the jet quenching.

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