Forward dihadron correlations in the Gaussian approximation of JIMWLK

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ABSTRACT

We compute forward dihadron azimuthal angle correlations in deuteron-gold collisions using a Gaussian approximation for the quadrupole operator. We show that the double parton scattering contribution is included in our calculations, and obtain a good description of the azimuthal-angle dependent experimental data and a relatively good estimate for the pedestal contribution.

1 Introduction

Recent measurements of dihadron correlations at forward rapidity in deuteron-gold collisions display a strong suppression of the away side peak compared to midrapidity or proton-proton collisions. This phenomenon can be naturally described using the Color Glass Condensate (CGC) theory.

Dihadron correlations allow us to study multigluon correlations included in the JIMWLK evolution. The Gaussian approximation relates higher point Wilson line correlators to the two-point function obtained by solving the BK equation.

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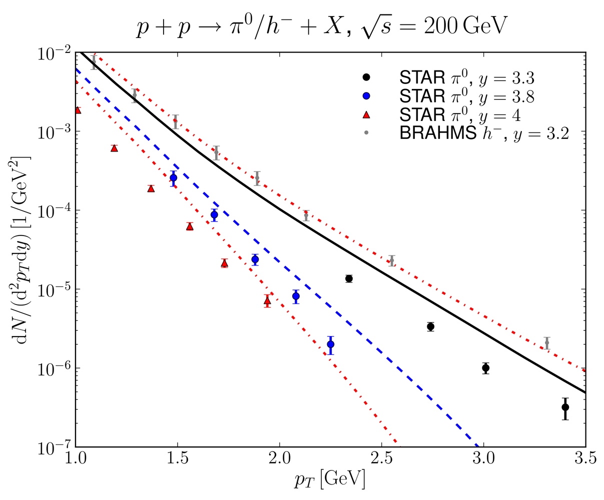
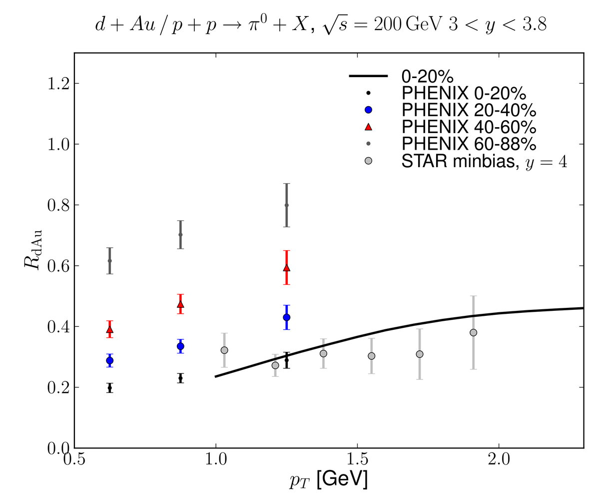
2 Single inclusive hadron production

$$\frac{\mathrm{d}N^{hA\to q/g+X}}{\mathrm{d}y\,\mathrm{d}\mathbf{q}_T} = \frac{1}{(2\pi)^2} x f(x) S(\mathbf{q}_T),$$

where S is the Fourier-transform of the dipole operator $\langle \hat{D} \rangle$. We obtain the dipole operator by solving the rcBK equation with an MV model initial condition. For the proton we use $Q_{s0}^2 = 0.2\ \mathrm{GeV}^2$ and for the gold nucleus $Q_{s0}^2 = 0.72\ \mathrm{GeV}^2$ which fits the most central PHENIX R_{dAu} data.

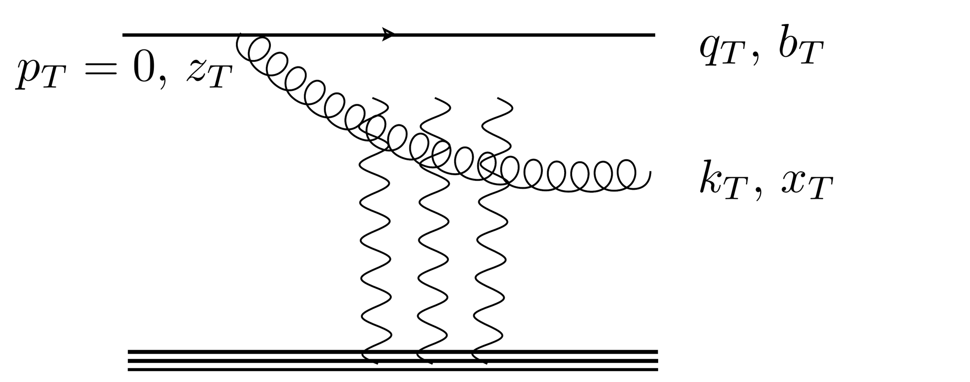




It seems generally difficult to describe simultaneously BRAHMS h^- and PHENIX and STAR π^0 data. We expect most of the overall normalization uncertainty to cancel when we compute dihadron correlation.

3 Dihadron production

Azimuthal-angle correlated production of quark with momentum $\mathbf{q}_T$ at $\mathbf{b}_T$ and gluon with momentum $\mathbf{k}_T$ at $\mathbf{x}_T$: large-x quark from the probe emits a gluon, and quark and gluon scatter off the target



The quark and gluon are initially back-to-back. When they interact with the nucleus the momentum transfer is of the order of Q_s, thus the back-to-back peak is suppressed if momenta are of the same order as the saturation scale.

4 Dihadron production in CGC

Dihadron production cross section in CGC, derived in Ref. [1]:

$$\frac{\mathrm{d}\sigma^{qA\to qgX}}{\mathrm{d}k^+\,\mathrm{d}^2\mathbf{k}_T\,\mathrm{d}q^+\,\mathrm{d}^2\mathbf{q}_T} \sim \alpha_s \int_{\mathbf{x}_T\mathbf{x}'_T\mathbf{b}_T\mathbf{b}'_T} e^{i\mathbf{k}_T\cdot(\mathbf{x}'_T-\mathbf{x}_T)} e^{i\mathbf{q}_T\cdot(\mathbf{b}'_T-\mathbf{b}_T)}$$
$$\times \mathcal{F}(\mathbf{x}_T,\mathbf{b}_T;\mathbf{x}'_T,\mathbf{b}'_T)\{S^{(4)}(\mathbf{b}_T,\mathbf{x}_T,\mathbf{b}'_T,\mathbf{x}'_T) - S^{(3)}(\mathbf{b}_T,\mathbf{x}_T,\mathbf{z}'_T)$$
$$- S^{(3)}(\mathbf{z}_T,\mathbf{x}'_T,\mathbf{b}'_T) + S^{(2)}(\mathbf{z}_T,\mathbf{z}'_T)\}. \quad (1)$$

$\mathcal{F}$ describes $q \to qg$ splitting. Evaluation of the dihadron cross section requires knowledge of higher-point functions:

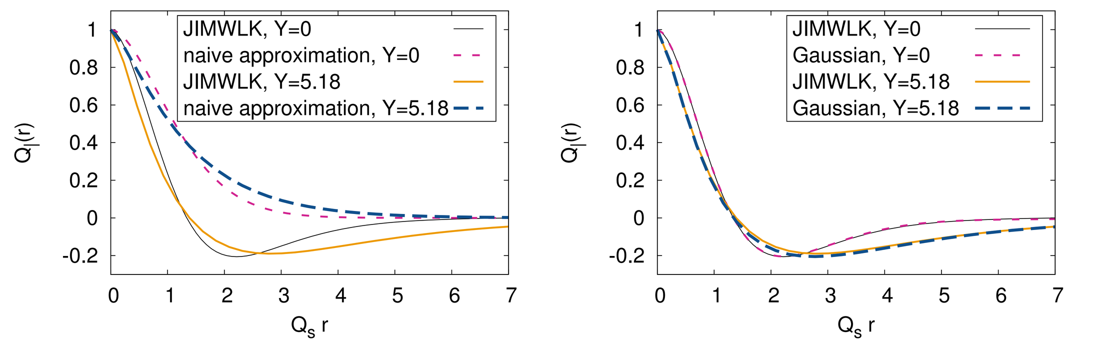
$$S^{(4)}(\mathbf{b}_T,\mathbf{b}'_T,\mathbf{x}_T,\mathbf{x}'_T) \sim \left\langle \hat{D}(\mathbf{x}_T,\mathbf{x}'_T)\hat{Q}(\mathbf{b}_T,\mathbf{b}'_T,\mathbf{x}_T,\mathbf{x}'_T)\right\rangle + \mathcal{O}(N_c^{-1})$$
$$S^{(3)}(\mathbf{b}_T,\mathbf{b}'_T,\mathbf{x}_T,\mathbf{x}'_T) \sim \left\langle \hat{D}(\mathbf{b}_T,\mathbf{x}_T)\hat{D}(\mathbf{x}_T,\mathbf{z}'_T)\right\rangle + \mathcal{O}(N_c^{-1})$$
$$S^{(2)}(\mathbf{x}_T,\mathbf{b}_T) = \langle \hat{D}(\mathbf{x}_T,\mathbf{b}_T)\rangle \sim \langle \mathrm{Tr}\, V(\mathbf{x}_T)V^\dagger(\mathbf{b}_T)\rangle$$
$$\hat{Q}(\mathbf{x}_T,\mathbf{y}_T,\mathbf{u}_T,\mathbf{v}_T) = \frac{1}{N_c}\mathrm{Tr}\, V(\mathbf{x}_T)V^\dagger(\mathbf{y}_T)V(\mathbf{u}_T)V^\dagger(\mathbf{v}_T)$$

In addition to the dipole operator (easy to obtain from BK) one needs to evaluate the quadrupole Q (correlator of 4 Wilson lines) which can, in principle, be obtained by solving the JIMWLK evolution equation.

5 Approximating the quadrupole

For practical phenomenology it would be convenient to be able to express these higher point correlators in terms of the dipole D. In previous phenomenological literature [1, 2] a "naive large N_c" approximation $Q \approx DD$ is used.

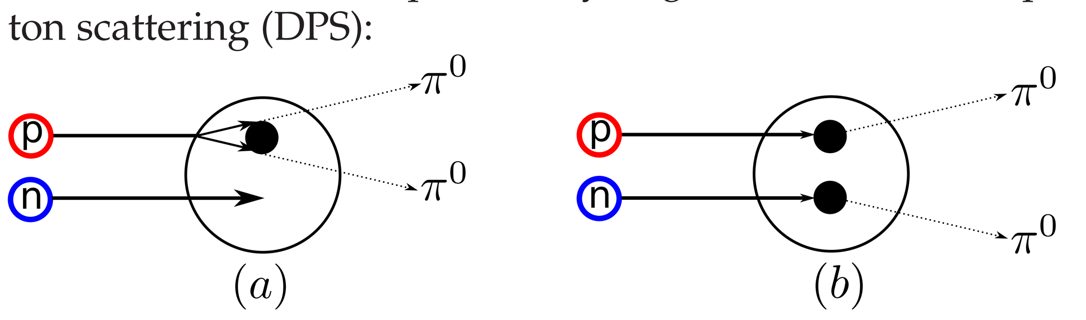
Instead of that we use the "Gaussian approximation" [3] which is numerically shown to be much more accurate [4].



Figures are from Ref. [4].

6 Double parton scattering

Uncorrelated background (pedestal) to the experimentally measured coincidence probability originates from double parton scattering (DPS):



(a) Take two quarks from proton or neutron

(b) Take one quark from proton and another quark from neutron, dominates at forward rapidities

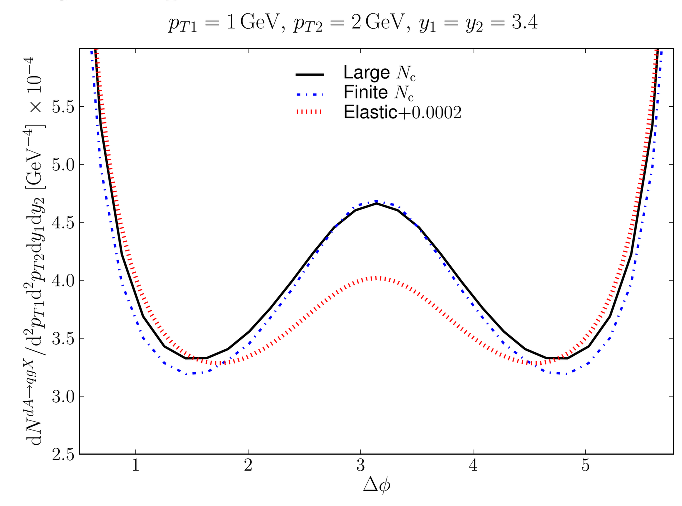
A DPS contribution is obtained from (1) when gluon is emitted far away from the quark: $|\mathbf{x}_T - \mathbf{b}_T| \gg 1/Q_s$. In this limit the only surviving contribution from $S^{(4)}$ is adjoint dipole of gluon times a fundamental representation dipole of quark:

$$S^{(4)}(\mathbf{b}_T,\mathbf{x}_T,\mathbf{b}'_T,\mathbf{x}'_T) \underset{\mathrm{DPS}}{\approx} S^{(4)}_{\mathrm{DPS}}(\mathbf{b}_T,\mathbf{x}_T,\mathbf{b}'_T,\mathbf{x}'_T)$$
$$= \frac{N_c^{\,2}}{N_c^{\,2}-1}\left\langle \hat{D}(\mathbf{b}_T,\mathbf{b}'_T)\right\rangle \left\langle \hat{D}^2(\mathbf{x}_T,\mathbf{x}'_T) - \frac{1}{N_c^{\,2}}\right\rangle,$$

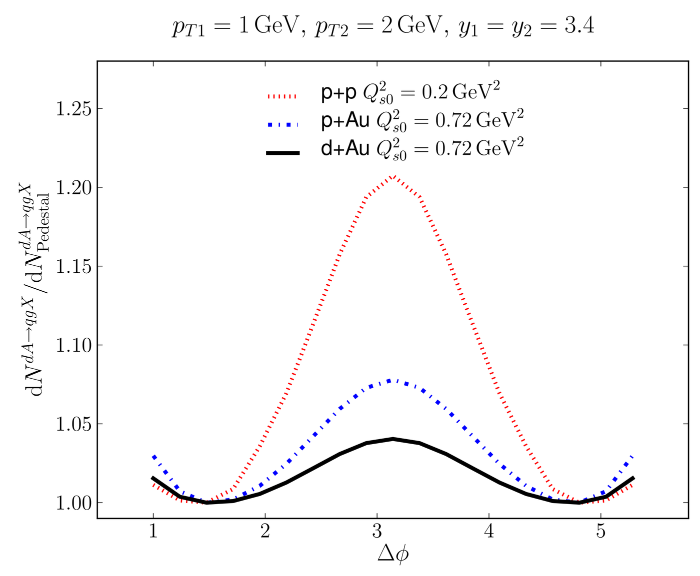
This gives a logarithmically divergent contribution to the dihadron cross section in the massless quark limit. This divergence must be regulated by confinement scale physics in the wavefunction of the projectile. We subtract the divergent DPS part from (1) and calculate it separately in the CGC framework. When calculating contribution (a) we model the double parton distribution function by implementing the constraint $x_1 + x_2 < 1$.

7 Parton level results

Quark-gluon parton level azimuthal correlation:

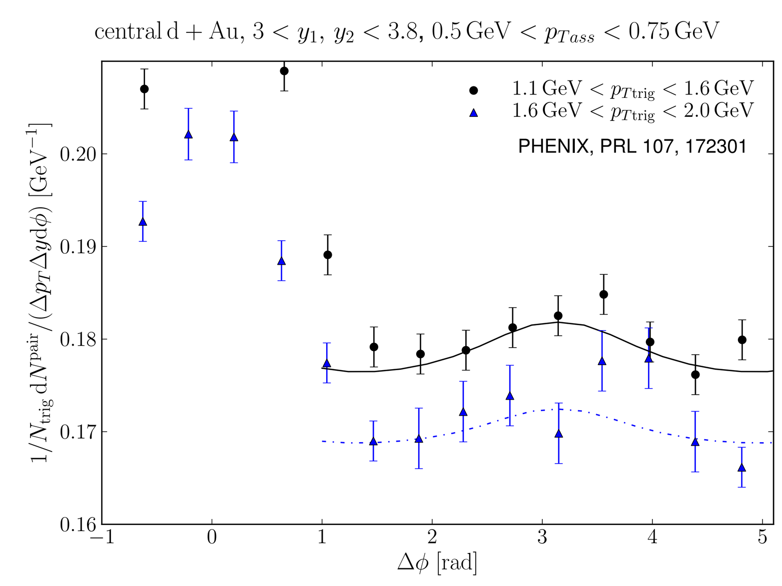


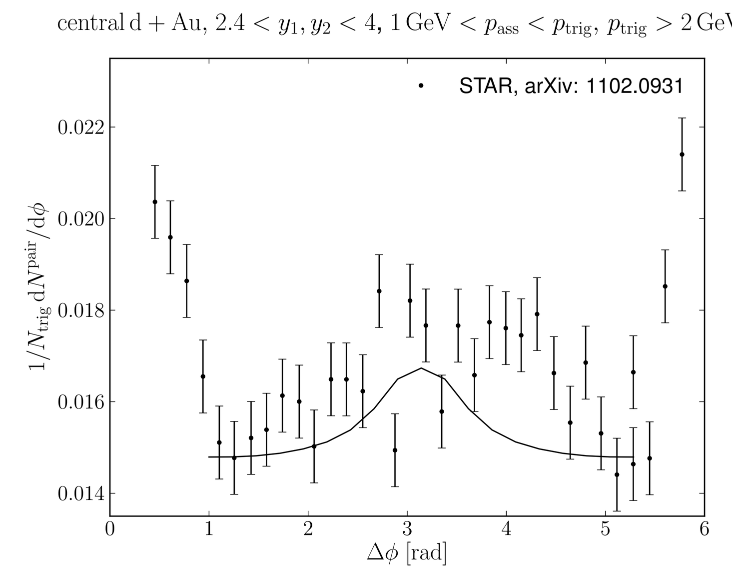
The width and especially the height of the back-to-back peak is modified when the more accurate Gaussian approximation is used compared to the previously used "naive large N_c" approximation (labeled as "elastic", used e.g. in [2]).



Total parton level dihadron yield normalized by pedestal. Note different peak/pedestal ratio in dAu and pAu.

8 Hadron level results





Pedestal is adjusted to fit the data.
Pedestal results (experimental value):
PHENIX: 1.1 GeV $< p_{T_{\mathrm{trig}}} <$ 1.6 GeV: 0.104 (0.176),
1.6 GeV $< p_{T_{\mathrm{trig}}} <$ 2.0 GeV: 0.081 (0.163) [GeV^{-1}]
STAR: 0.011 (0.0145).

References

[1] C. Marquet, Nucl. Phys. **A796**, 41 (2007), [arXiv:0708.0231 [hep-ph]].

[2] J. L. Albacete and C. Marquet, Phys.Rev.Lett. **105**, 162301 (2010), [arXiv:1005.4065 [hep-ph]].

[3] F. Dominguez, C. Marquet, B.-W. Xiao and F. Yuan, Phys.Rev. **D83**, 105005 (2011), [arXiv:1101.0715 [hep-ph]].

[4] A. Dumitru, J. Jalilian-Marian, T. Lappi, B. Schenke and R. Venugopalan, Phys.Lett. **B706**, 219 (2011), [arXiv:1108.4764 [hep-ph]].