

Azimuthal angle correlations in forward dihadron production in pA collisions

Hard Probes 2012

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In collaboration with T. Lappi

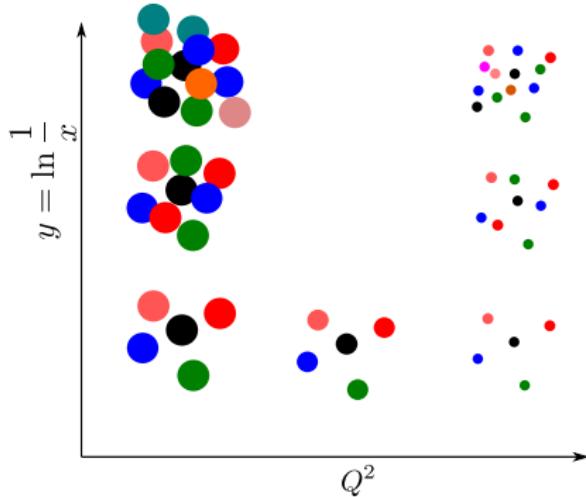
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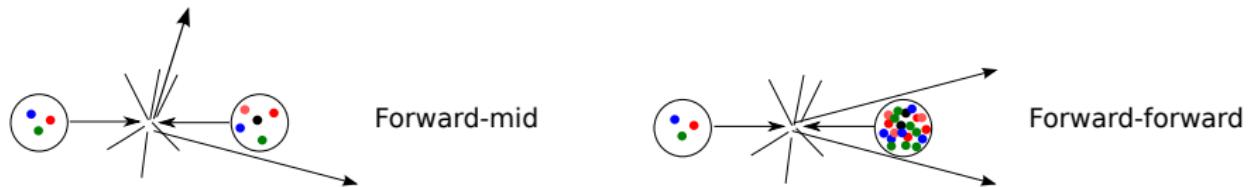
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- 3 Double parton scattering
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Introduction



- Hadron production in forward region probes small- x structure
- Saturation phenomena described by CGC
- Additional information to single inclusive spectrum: dihadron production in forward rapidities

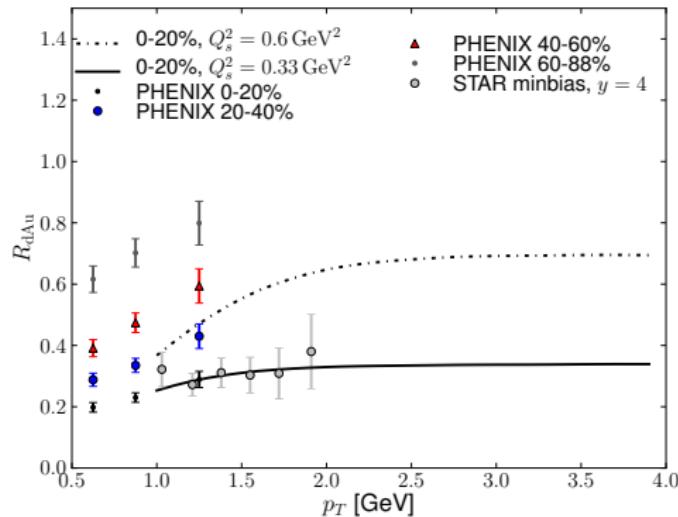


Single inclusive hadron production from CGC

$$dN \sim \int \frac{dz}{z^2} xf(x, Q^2) \tilde{S} \left(\frac{p_T}{z}, y \right) D(z, Q^2)$$

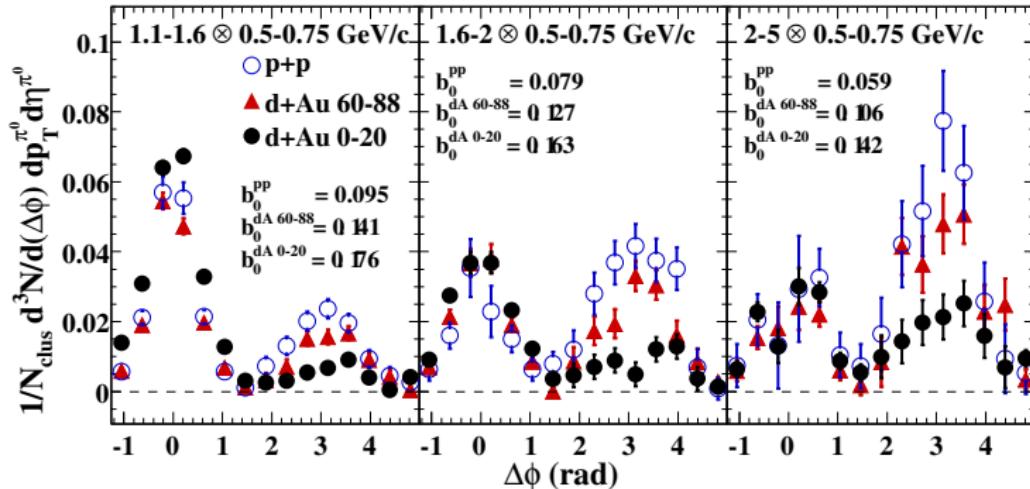
xf : PDF, \tilde{S} : FT of $1 - N$, N dipole amplitude, Vacuum FF (DSS)

$d + Au / p + p \rightarrow \pi^0 + X, \sqrt{s} = 200 \text{ GeV } 3 < y < 3.8$



- rcBK, IC: MV^γ
- Fit to HERA data (AAMS): describes $p + p$ yield w.o. K -factor, $Q_{s0}^2 = 0.15 \text{ GeV}^2$
- Very small Q_{s0}^2 required if $K = 1$, $R_{dAu} \not\rightarrow 1$
- STAR vs PHENIX
- Uncertainty to dihadron calculation

Azimuthal angle correlations

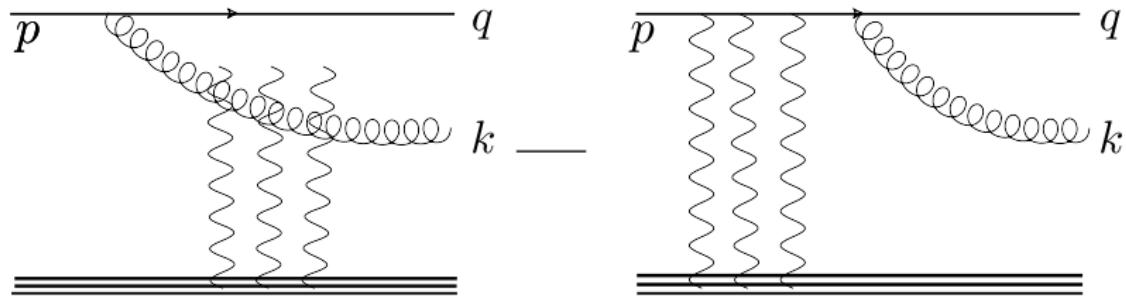


PHENIX data (1105.5112): away side peak disappears when moving from $p+p$ to central $d+Au$

Dihadron production from CGC

CGC description: quark emits a gluon and scatters off the target.

Momentum transfer $\sim Q_s \Rightarrow$ explains disappearance of the away side peak



$$Q_s^2 \approx A^{1/3} \left(\frac{x}{x_0} \right)^{-0.3} Q_{s0}^2$$

Quadrupole operator

CGC calculation by C. Marquet (Nucl.Phys. A796 (2007)):

$$\frac{d\sigma}{d^2k_T d^2q_T dy_q dy_k} \sim x q(x, \mu^2) \int \frac{d^2x}{(2\pi)^2} \frac{d^2x'}{(2\pi)^2} \frac{d^2b}{(2\pi)^2} \frac{d^2b'}{(2\pi)^2} e^{ik_T(x' - x)} e^{iq_T(b' - b)} \\ |\phi^{q \rightarrow qg}(x - b, x' - b')|^2 \left\{ S^{(6)} - S^{(3)} - S^{(3)} + S^{(2)} \right\}$$

Dihadron production cross section depends on six-point function

$$S^{(6)}(b, x, x', b') = Q(b, b', x', x) S(x, x') + \mathcal{O}\left(\frac{1}{N_c^2}\right),$$

where Q is a correlator of 4 Wilson lines

$$Q(b, b', x', x) = \frac{1}{N_c^2} \langle \text{Tr } U(b) U^\dagger(b') U(x') U^\dagger(x) \rangle$$

Quadrupole operator

$$Q = N_c^{-1} \langle \text{Tr } U(b) U^\dagger(b') U(x') U^\dagger(x) \rangle, S = S^{(2)} = N_c^{-1} \langle \text{Tr } U(x) U^\dagger(x') \rangle$$

Motivation for approximations

Dipole amplitude S is easy to obtain from BK \Rightarrow approximation depending only on dipole amplitude is much easier for practical work

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Approximating the quadrupole Q

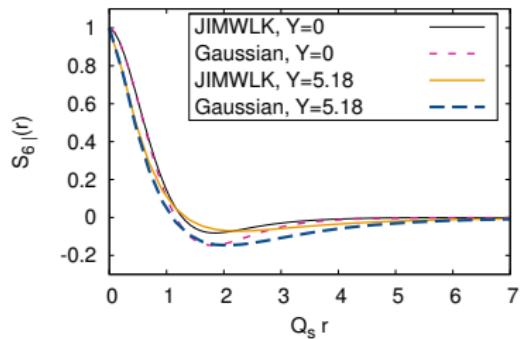
- Naive Large- N_c $Q(b, b', x', x) = \frac{1}{2}[S(x, b)S(x', b') + S(x, x')S(b, b')]$
previous phenomenological studies: without inelastic contribution
 $S(x, x')S(b, b')$
- Gaussian approximation (and large- N_c limit)

Gaussian approximation: assume that the correlators of the color charges are Gaussian \Rightarrow depends only on two-point functions

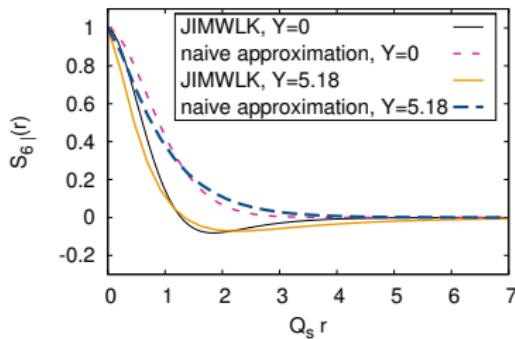
- We use the full Gaussian approximation which includes the inelastic contribution

Quadrupole operator

Comparison with full JIMWLK evolution (see talk by T. Lappi)



(a) Gaussian



(b) Naive

T. Lappi et al. 1108.4764

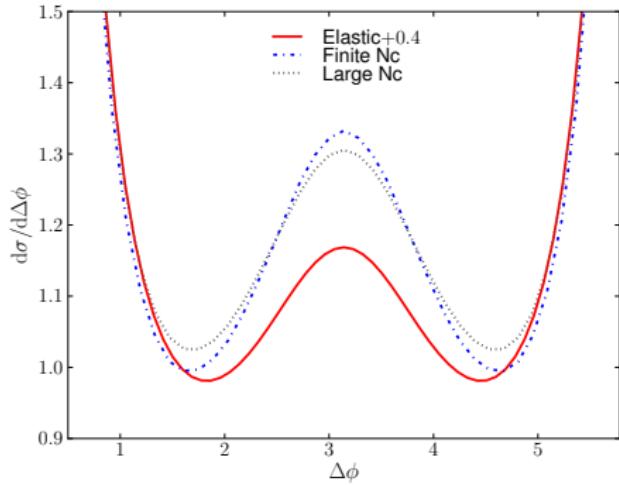
- Gaussian approximation is accurate, Naive Large- N_c is not.

Large N_c vs finite- N_c

Preliminary numerical results

Parton level

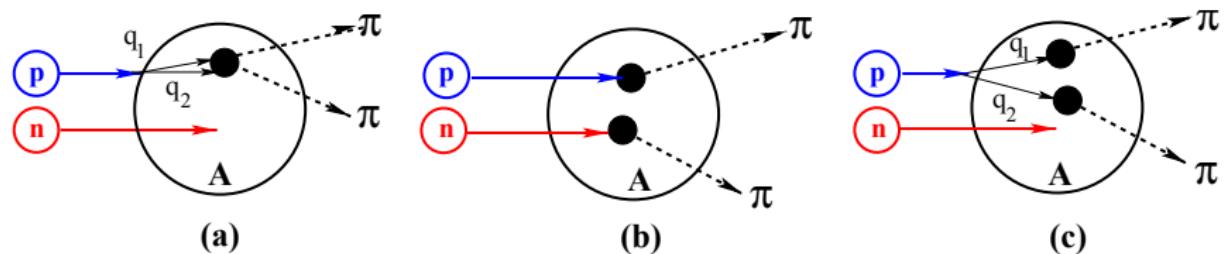
$p_{T1} = 0.5 \text{ GeV}$, $p_{T2} = 1.1 \text{ GeV}$, $y_1 = y_2 = 3.4$, $Q_s^2 = 0.33 \text{ GeV}^2$



- Finite- $N_c \approx$ Gaussian Large- N_c
- Naive Large- N_c : narrower and smaller back-to-back peak
- Different pedestal

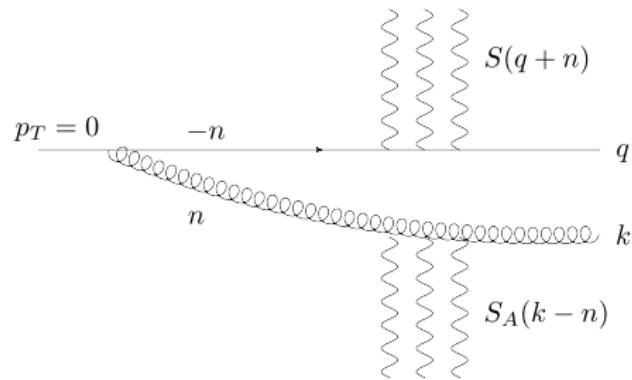
Double parton scattering

Background (pedestal) contribution to coincidence probability: two hadrons are produced independently



Strikman, Vogelsang, 1009.6123

Double parton scattering



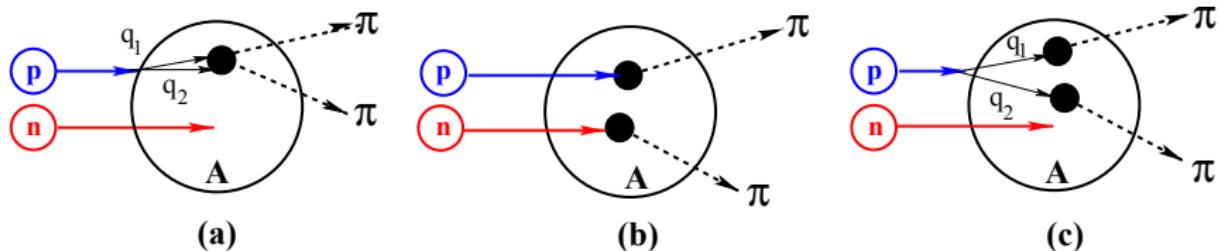
DPS in CGC framework: $S^{(6)}$ contains IR divergent contribution
(gluon emitted far away from the quark)

$$\sim xf(x) \left[\int^\Lambda d^2 n |\psi(n)|^2 \right] \tilde{S}_A(k) \tilde{S}(q),$$

for $\Lambda \ll k, q$, ψ is the splitting function $q \rightarrow qg$. \tilde{S} : FT of S .

- Part of “inelastic contribution” (neglected by Albacete&Marquet)

Double parton scattering



Strikman, Vogelsang, 1009.6123

How to calculate DPS in CGC?

- Remove IR divergent contribution from $S^{(6)}$ (\Rightarrow dependence on cutoff $\Lambda \sim \Lambda_{\text{QCD}}$)
- (a) and (c): assume DPDF $f(x_1, x_2) \sim f(x_1)f(x_2)$ with kinematical constraint $x_1 + x_2 < 1$
- (b): $(\text{single inclusive})^2$, dominates in forward rapidities

Results: DPS

Preliminary numerical results

Comparison with PHENIX pedestal height

- $1.1 \text{ GeV} < p_{T,\text{trig}} < 1.6 \text{ GeV}$: 0.11 (exp. 0.18)
- $1.6 \text{ GeV} < p_{T,\text{trig}} < 2 \text{ GeV}$: 0.086 (exp. 0.16)

Correct systematics and order of magnitude.

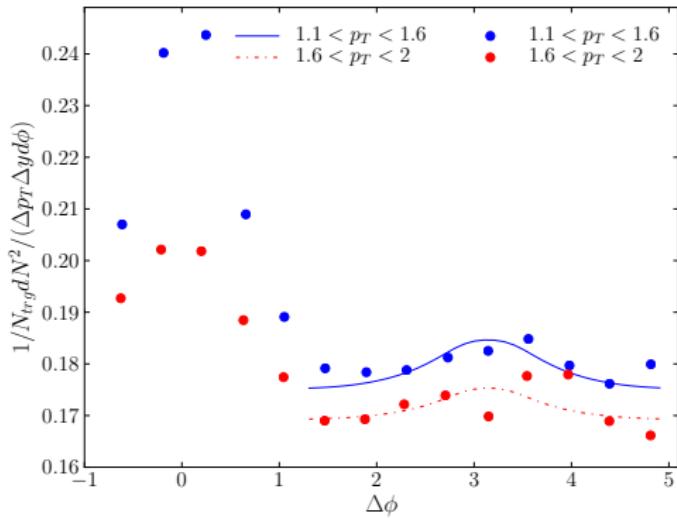
Theoretical uncertainties

- Dependence on cutoff in correlated dihadron production
- $Q_{s0}^2 = ?$
- K -factors?

Results: Coincidence probability

Preliminary numerical results

central d + Au, $\langle y_1, y_2 \rangle = 3.4$, $0.5 \text{ GeV} < p_{asc} < 0.75 \text{ GeV}$



- Good description of central PHENIX data (pedestal from exp. data)
- Gaussian large- N_c approximation

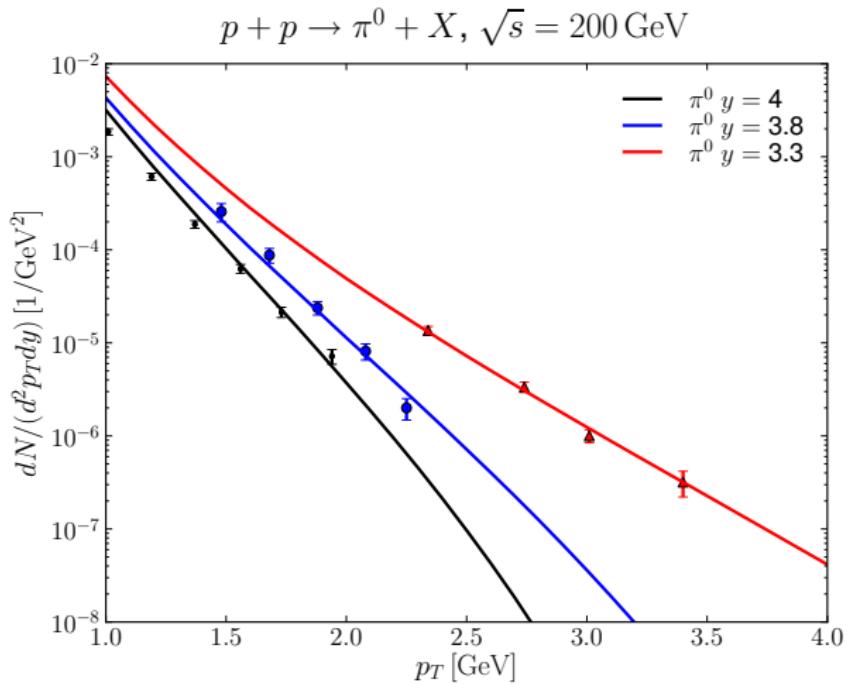
IC: MV^γ , $Q_s^2 = 0.33 \text{ GeV}^2$, data: PHENIX [1105.5112]

Conclusions

- Calculation of dihadron production in forward rapidities requires knowledge of higher-point functions
- Naive Large- N_c approximation is not very accurate, Large- N_c Gaussian is, effect on away-side peak
- DPS contribution is not completely separated but included in six-point function
- We obtain reasonably good description of the $\Delta\phi$ dependence of the PHENIX data and order-of-magnitude result for the DPS
- Uncertainties in single inclusive baseline make it difficult to compute e.g. LHC predictions
- Work continues...

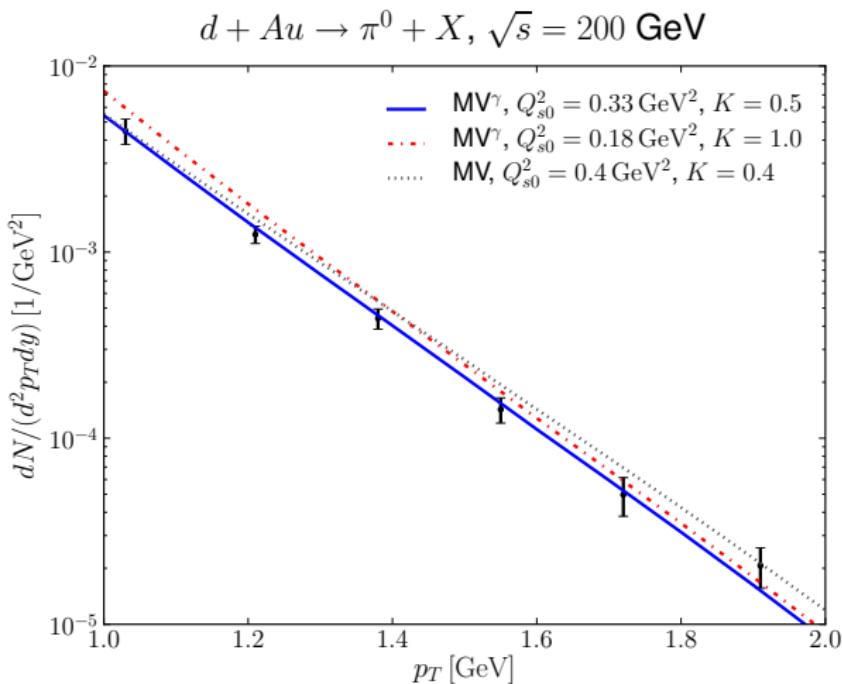
Backups

p+p yield and STAR data



IC: AAMS (MV^γ , $Q_s^2 = 0.15 \text{ GeV}^2$), data: STAR [nucl-ex/0602011]

d+Au yield and STAR data



MV $^\gamma$: $x_0 = 0.01$, p+p: $Q_s^2 = 0.15 \text{ GeV}^2$.

MV: $Q_s^2 = 0.4 \text{ GeV}^2$ at $x = 0.02$ (Albacete, Marquet), data: STAR minbias

[nucl-ex/0602011]