Azimuthal angle correlations in forward dihadron production in pA collisions

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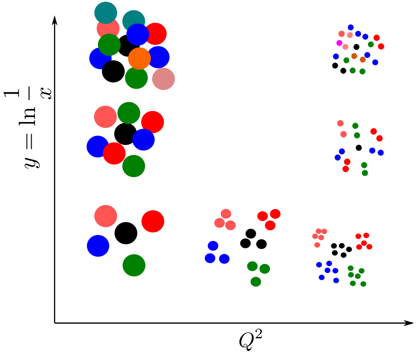
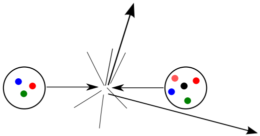
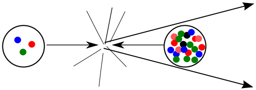
Content

Introduction



- Hadron production in forward region probes small-x structure
- Saturation phenomena described by CGC
- Evolution in x: BK equation
- Saturation scale Q_s = characteristic momentum scale
- Additional information to single inclusive spectrum: dihadron production in forward rapidities





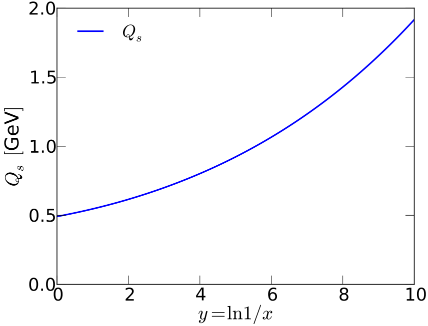
BK equation

Evolution equation in x for dipole-target scattering amplitude $N(r)$

$$\frac{\partial N(r)}{\partial y} = \frac{\alpha_s N_\mathrm{c}}{2\pi} \int \mathrm{d}^2 r' \mathcal{K}(r, r')[N(r') + N(r - r') - N(r) - N(r')N(r - r')]$$

r: dipole size.

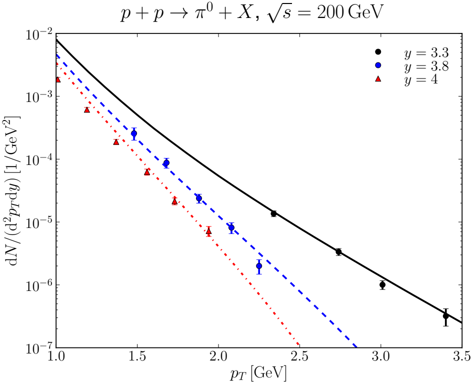
- Large-N_c result, can also be used to calculate x evolution of unintegrated parton distribution function



Single inclusive hadron production from CGC

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

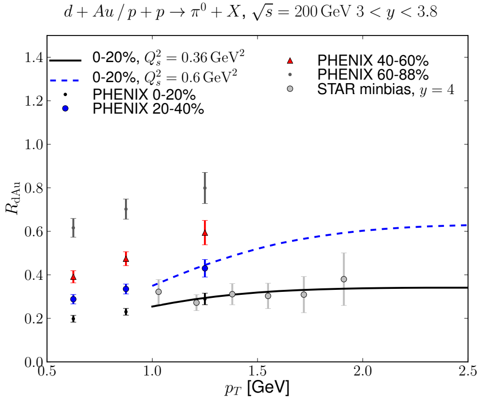
xf: PDF, $\tilde{S}$: FT of $1 - N$, N dipole amplitude, Vacuum FF (DSS)



Data: STAR, nucl-ex/0602011

- Dilute-dense collision
- x-evolution: rcBK, requires IC.
- Fit to HERA data (AAMQS): parameter-free description of STAR $p + p \to \pi^0 + X$ data
- Nuclear target: larger Q_{s0}^2 (only free parameter).

R_{dAu}



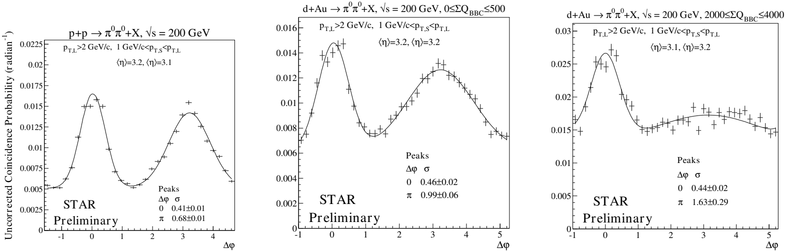
- Here: choose initial saturation scale such that it fits PHENIX most central R_{dAu} data
- Quite small $Q_{s0}^2 \sim 2Q_{s0,p}^2$ required
- STAR minbias $\approx$ central PHENIX, but slightly different rapidities
- Uncertainty to dihadron calculation

In forward rapidities $R_{dAu} \not\to 1$ (validity: $p_T \lesssim \mathcal{O}(10\text{ GeV})$). LHC pA run?

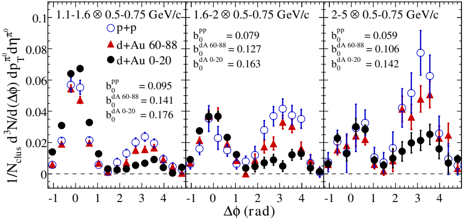
Azimuthal angle correlations

Two particle collision vs. $\Delta\phi$: away side peak goes away

p+p peripheral d+Au central d+Au



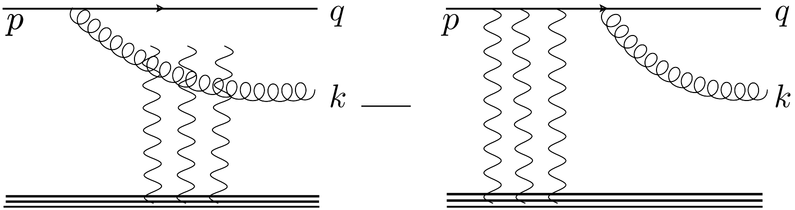
STAR, 1102.0931



PHENIX, 1105.5112

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



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

Dihadron production from CGC

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

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

Dependence on n-point functions $S^{(n)}$ ($n=2$: dipole amplitude), especially $S^{(6)}$

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

where Q is a correlator of 4 Wilson lines

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

$n > 2$: BK evolution equation $\rightarrow$ JIMWLK (=difficult!)

Quadrupole operator

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

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

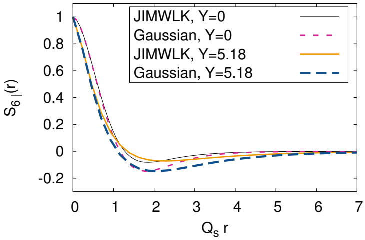
- Naive Large-N_c $Q(b,b',x',x) = \frac{1}{2}[S(x,b)S(x',b') + S(x,x')S(b,b')]$ previous phenomenology: w.o. inelastic contribution $S(x,x')S(b,b')$
- Gaussian approximation (and large-N_c limit)

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

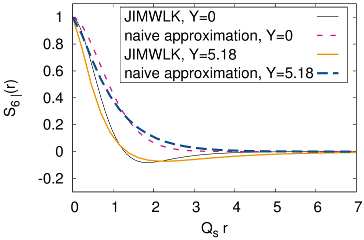
- We use the full Gaussian approximation which includes the inelastic contribution

Quadrupole operator

Comparison with full JIMWLK evolution



(a) Gaussian



(b) Naive

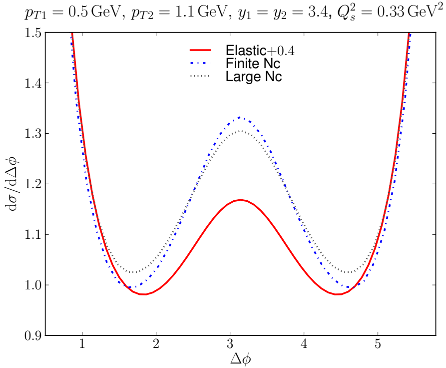
T. Lappi et al. 1108.4764

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

Large N_c vs finite-N_c

Preliminary numerical results

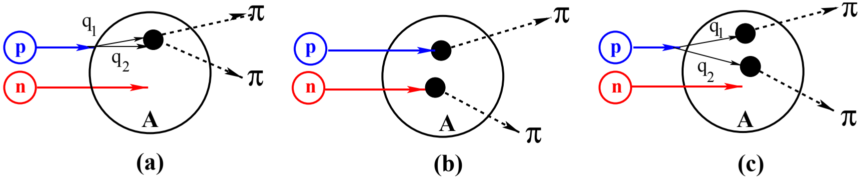
Parton level: $p + A \to q + g + X$



- Finite-N_c ≈ Gaussian Large-N_c
- Naive Large-N_c: narrower and smaller back-to-back peak
- Different pedestal

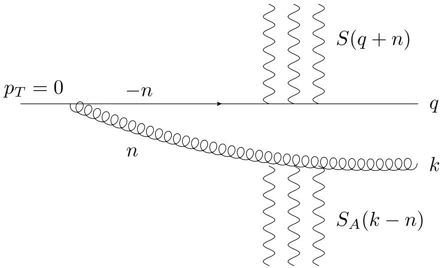
Double parton scattering

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



Strikman, Vogelsang, 1009.6123

Double parton scattering



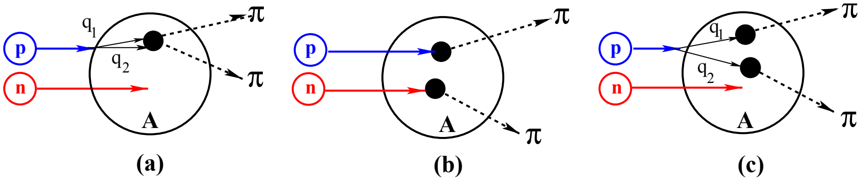
DPS in CGC framework: $S^{(6)}$ contains IR divergent contribution (gluon emitted far away from the quark), DPDF should cancel

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

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

- Part of "inelastic contribution" (neglected previously)

Double parton scattering



Strikman, Vogelsang, 1009.6123

How to calculate DPS in CGC?

- Remove IR divergent contribution from $S^{(6)}$ ($\Rightarrow$ dependence on cutoff $\Lambda \sim \Lambda_{\mathrm{QCD}}$)
- (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): (single inclusive)^2, dominates in forward rapidities

Results: DPS

Preliminary numerical results

Comparison with PHENIX pedestal height

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

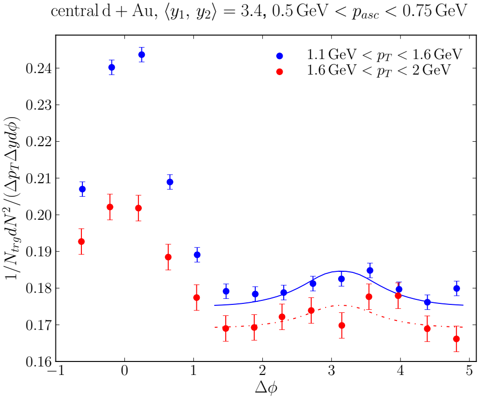
Correct systematics and order of magnitude.

Theoretical uncertainties

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

Results: Coincidence probability

Preliminary numerical results



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

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

Conclusions

- Dihadron production in forward rapidities: detailed study of small-x structure and saturation phenomena
- Previously used "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 good description of the $\Delta\phi$ dependence of the PHENIX data and order-of-magnitude result for the DPS
- LHC forward R_{pA} ja dihadron correlation results will be interesting
- Work continues...