# Gluon Densities and Dihadron correlations

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- F. Dominguez, BX and F. Yuan, Phys.Rev.Lett.106:022301,2011.
- F. Dominguez, C. Marquet, BX and F. Yuan, arXiv:1101.0715[hep-ph].
- A. Stasto, BX and F. Yuan, in preparation.

Drell-Yan workshop at BNL, May, 2011

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# Outline



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# The effective $k_t$ factorization

For $pA$ (dilute-dense system) collisions, there is an effective $k_t$ factorization. The effective $k_t$ factorization for $pA$ (dilute-dense system) collisions for back-to-back dijets productions

$$\frac{d\sigma^{pA\to qfX}}{d^2k_{1\perp}d^2k_{2\perp}dy_1dy_2} = x_pq(x_p,\mu^2)xf(x,q_\perp^2)\frac{1}{\pi}\frac{\mathrm{d}\hat{\sigma}}{\mathrm{d}\hat{t}}.$$

Remarks:

- Penalty: $K_t$ dependent Parton distributions $xf(x,q_\perp^2)$ are not universal. $xf(x,q_\perp^2)$ here can be the quark or gluon distributions of the dense target.
- $x_pq(x_p,\mu^2)$ is the Feyman parton distribution of the dilute projectile.
- Thanks to the nuclear enhancement, soft gluon exchange from the dilute proton can be neglected.
- For pp, AA collisions, there is no such effective $k_t$ factorization[Rogers, Mulders; 10].
- Disclaimer: The calculation is only done in the leading order ($\alpha_s$ and $\frac{q_\perp^2}{P_\perp^2}$) for a dense target without small-x evolution (such as BFKL or Balitsky-Kovchegov or JIMWLK equations). ([Dominguez, Mueller, Munier, Xiao, in preparation]).
- Assuming small-x limit, namely, $s\to\infty$, fixed $Q^2$, $x\to 0$.

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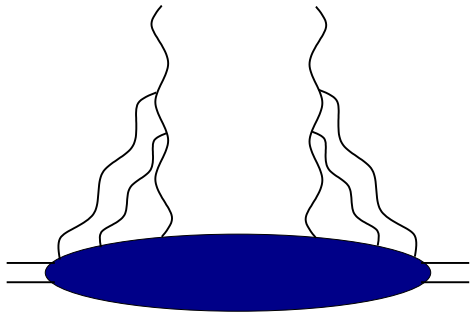
# A Tale of Two Gluon Distributions

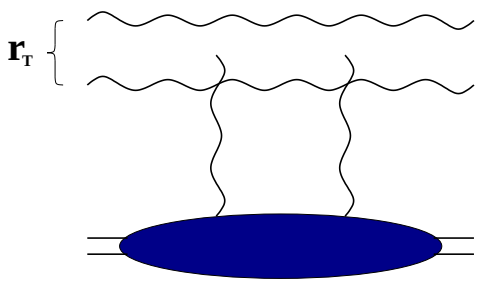
In small-x physics, two gluon distributions are widely used:
I. Weizsäcker Williams gluon distribution (MV model):

$$xG^{(1)} = \frac{S_\perp}{\pi^2\alpha_s}\frac{N_c^2-1}{N_c} \Leftarrow$$
$$\times \int \frac{d^2r_\perp}{(2\pi)^2}\frac{e^{-ik_\perp\cdot r_\perp}}{r_\perp^2}\left(1-e^{-\frac{r_\perp^2 Q_s^2}{2}}\right)$$



II. Color Dipole gluon distributions:

$$xG^{(2)} = \frac{S_\perp N_c}{2\pi^2\alpha_s} \Leftarrow$$
$$\times \int \frac{d^2r_\perp}{(2\pi)^2}e^{-ik_\perp\cdot r_\perp}\nabla_{r_\perp}^2 N(r_\perp)$$




Remarks:

- The WW gluon distribution simply counts the number of gluons.
- The Color Dipole gluon distribution often appears in calculations. $N(r_\perp)$ is the color dipole amplitude. It is now in fundamental representation. The adjoint representation form is similar and also widely used.
- Does this mean that gluon distributions are non-universal? Answer: Yes and No!
- These two distributions are used in $R_{pA}$ calculation. [Kharzeeve, Kovchegov, Tuchin; 03].

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# A Tale of Two Gluon Distributions

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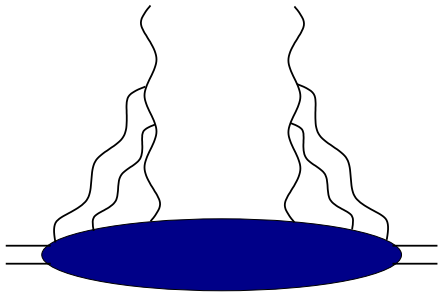

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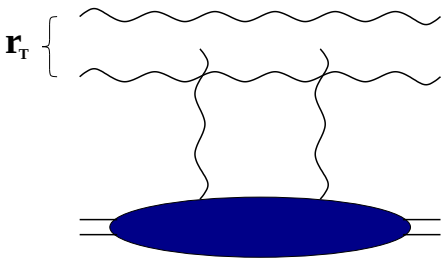


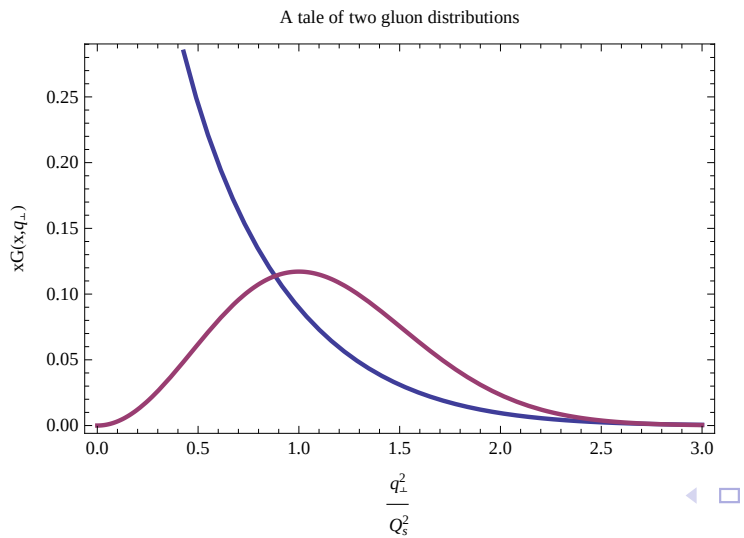


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# A Tale of Two Gluon Distributions

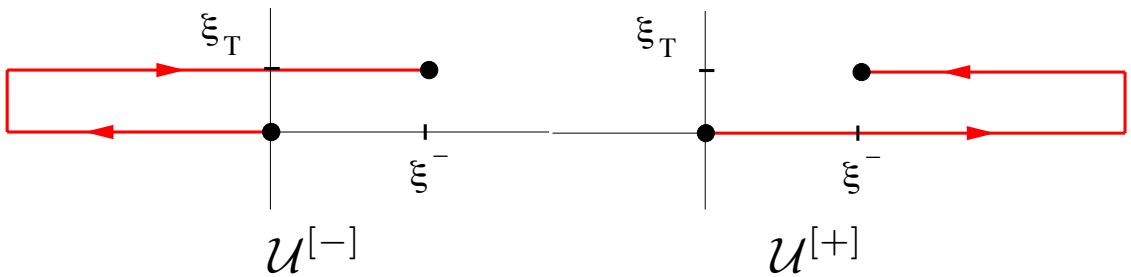
In terms of operators, we find these two gluon distributions can be defined as follows: [Bomhof, Mulders and Pijlman; 06],[F. Dominguez, BX and F. Yuan, 11]

I. Weizsäcker Williams gluon distribution:

$$xG^{(1)} = 2\int \frac{d\xi^- d\xi_\perp}{(2\pi)^3 P^+} e^{ixP^+\xi^- - ik_\perp\cdot\xi_\perp} \mathrm{Tr}\langle P|F^{+i}(\xi^-,\xi_\perp)\mathcal{U}^{[+]\dagger}F^{+i}(0)\mathcal{U}^{[+]}|P\rangle.$$

II. Color Dipole gluon distributions:

$$xG^{(2)} = 2\int \frac{d\xi^- d\xi_\perp}{(2\pi)^3 P^+} e^{ixP^+\xi^- - ik_\perp\cdot\xi_\perp} \mathrm{Tr}\langle P|F^{+i}(\xi^-,\xi_\perp)\mathcal{U}^{[-]\dagger}F^{+i}(0)\mathcal{U}^{[+]}|P\rangle.$$




Remarks:

- The WW gluon distribution is the conventional gluon distributions. In light-cone gauge, it is the gluon density. (Only final state interactions.)
- The dipole gluon distribution has no such interpretation. (Initial and final state interactions.)
- Both definitions are gauge invariant.
- Same after integrating over $q_\perp$.

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# A Tale of Two Gluon Distributions

In terms of operators, we find these two gluon distributions can be defined as follows: [Bomhof, Mulders and Pijlman; 06],[F. Dominguez, BX and F. Yuan, 11]

I. Weizsäcker Williams gluon distribution (Easy to evaluate in the MV model):

$$xG^{(1)} = 2\int \frac{d\xi^- d\xi_\perp}{(2\pi)^3 P^+} e^{ixP^+\xi^- - ik_\perp\cdot\xi_\perp} \mathrm{Tr}\langle P|F^{+i}(\xi^-,\xi_\perp)\mathcal{U}^{[+]\dagger}F^{+i}(0)\mathcal{U}^{[+]}|P\rangle.$$

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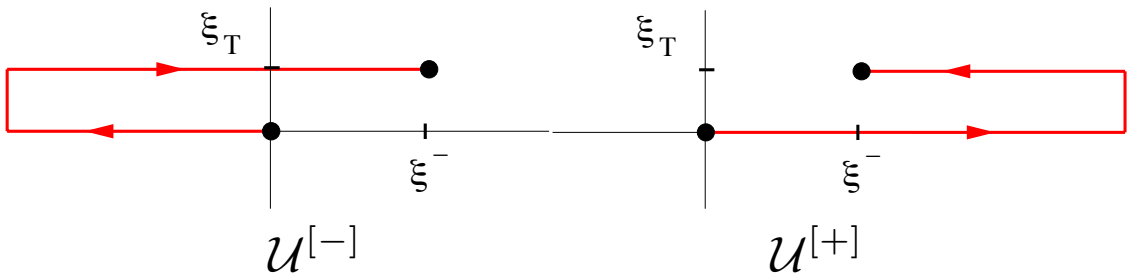
$$xG^{(2)} = 2\int \frac{d\xi^- d\xi_\perp}{(2\pi)^3 P^+} e^{ixP^+\xi^- - ik_\perp\cdot\xi_\perp} \mathrm{Tr}\langle P|F^{+i}(\xi^-,\xi_\perp)\mathcal{U}^{[-]\dagger}F^{+i}(0)\mathcal{U}^{[+]}|P\rangle.$$




Questions:

- Can we distinguish these two gluon distributions? Yes, We Can.
- How to measure $xG^{(1)}$ directly? DIS dijet.
- How to measure $xG^{(2)}$ directly? DY or Direct $\gamma$+Jet in $pA$ collisions. Maybe single-inclusive particle production in $pA$ (Subtle).
- What happens in gluon+jet production in $pA$ collisions? It's complicated!

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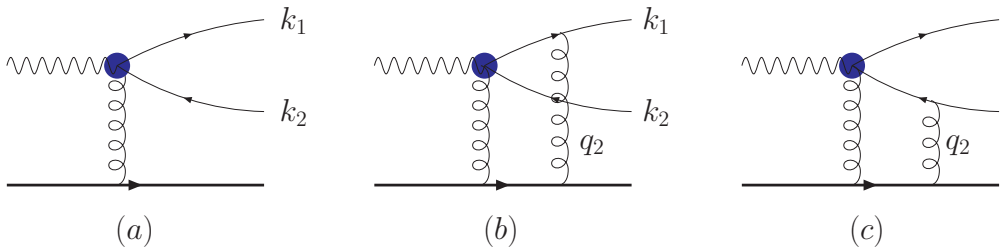
# DIS dijet




TMD factorization approach:

$$\frac{d\sigma^{\gamma_T^* A\to q\bar{q}+X}}{d\mathcal{P}.\mathcal{S}.} = \delta(x_{\gamma^*}-1)x_g G^{(1)}(x_g,q_\perp)H_{\gamma_T^* g\to q\bar{q}}, \quad \text{with} \quad d\mathcal{P}.\mathcal{S}. = dy_1 dy_2 d^2P_\perp d^2q_\perp .$$

Dipole model approach: $S^{(4)}_{x_g}(x,b;b',x') = \frac{1}{N_c}\left\langle \mathrm{Tr}U(x)U^\dagger(x')U(b')U^\dagger(b)\right\rangle_{x_g}$ Quadrupole

$$\begin{aligned}\frac{d\sigma^{\gamma_T^* A\to q\bar{q}+X}}{d\mathcal{P}.\mathcal{S}.} \propto\ & N_c\alpha_{em}e_q^2\int \frac{\mathrm{d}^2x}{(2\pi)^2}\frac{\mathrm{d}^2x'}{(2\pi)^2}\frac{\mathrm{d}^2b}{(2\pi)^2}\frac{\mathrm{d}^2b'}{(2\pi)^2}e^{-ik_{1\perp}\cdot(x-x')} \\ & \times e^{-ik_{2\perp}\cdot(b-b')}\sum\psi_T^*(x-b)\psi_T(x'-b') \\ & \left[1+S^{(4)}_{x_g}(x,b;b',x')-S^{(2)}_{x_g}(x,b)-S^{(2)}_{x_g}(b',x')\right],\end{aligned}$$

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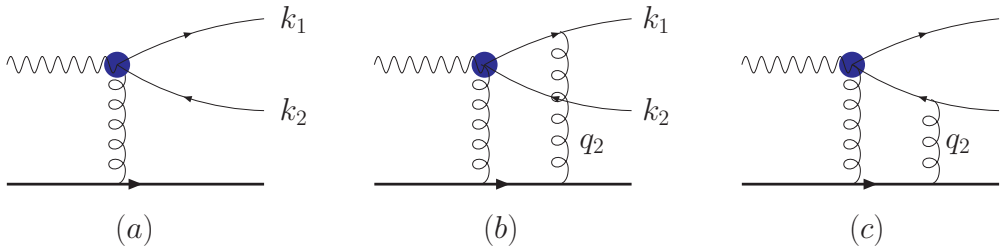
Two independent calculations agree perfectly in the correlation limit (Large $P_\perp$ and Small $q_\perp$).

# DIS dijet

The dijet production in DIS.




TMD factorization approach:

$$\frac{d\sigma^{\gamma_T^* A\to q\bar{q}+X}}{d\mathcal{P}.\mathcal{S}.} = \delta(x_{\gamma^*}-1)x_g G^{(1)}(x_g, q_\perp)H_{\gamma_T^* g\to q\bar{q}},$$

Remarks:

- Dijet in DIS is the only physical process which can measure Weizsäcker Williams gluon distributions.
- Golden measurement for the Weizsäcker Williams gluon distributions of nuclei at small-x. The cross section is directly related to the WW gluon distribution.
- EIC will provide us a perfect machine to study the strong gluon fields in nuclei.

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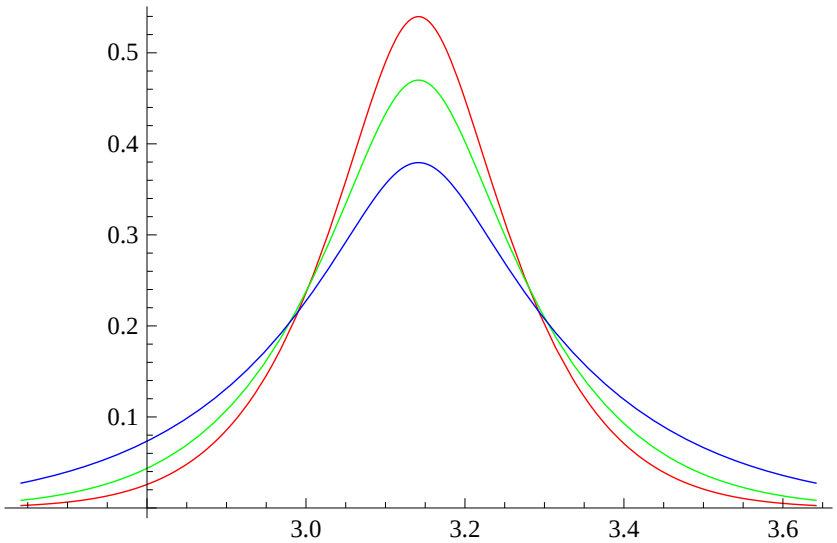
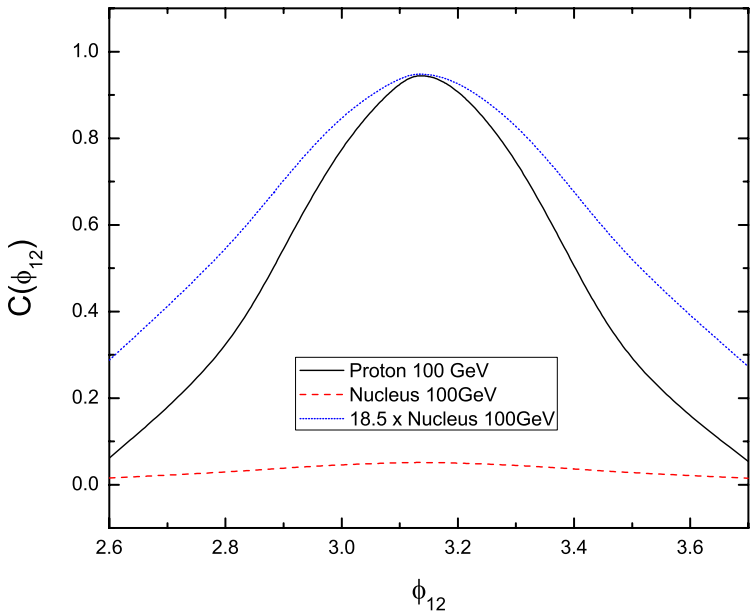
# DIS dijet correlation

Azimuthal angle correlation of dijet in DIS probes the WW gluon distributions




Remarks:

- $k_{1\perp} = 5.5$Gev, $k_{2\perp} = 5.0$Gev and $Q_s^2 = 1\,, 1.5\,, 3$GeV;
- Only away side peak is plotted due to the correlation limit.
- Suppression of away side peak and increase of width at large $Q_s^2$.
- Dramatic change between ep and eA collisions. $Q^2 = 4\text{GeV}^2$, $z_{h1} = z_{h2} = 0.3$, $2\text{GeV} < p_{1\perp} < 3\text{GeV}$ and $1\text{GeV} < p_{2\perp} < 2\text{GeV}$.
- No pedestal.

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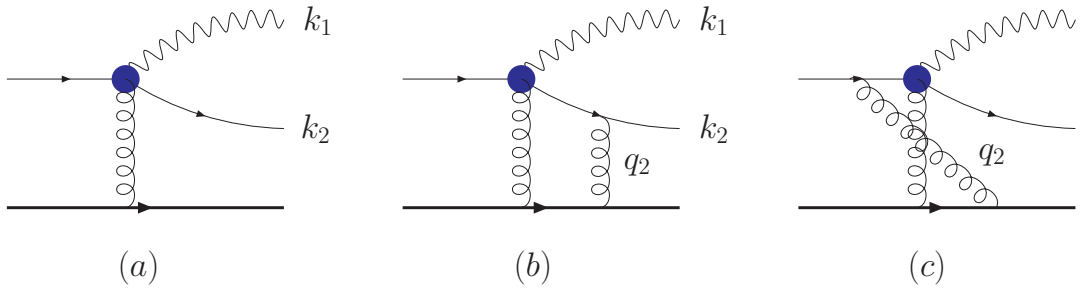
# $\gamma$+Jet in $pA$ collisions

The direct photon + jet production in $pA$ collisions. (Drell-Yan Process follows the same factorization.)




TMD factorization approach:

$$\frac{d\sigma^{(pA\to\gamma q+X)}}{d\mathcal{P}.\mathcal{S}.} = \sum_f x_1 q(x_1,\mu^2) x_g G^{(2)}(x_g, q_\perp) H_{qg\to\gamma q}.$$

Remarks:

- Independent CGC calculation gives the identical result in the correlation limit.
- This process can be calculated exactly for all range of azimuthal angles.
- Direct measurement of the Color Dipole gluon distribution.
- The RHIC and future LHC experiments shall provide us some information on this.

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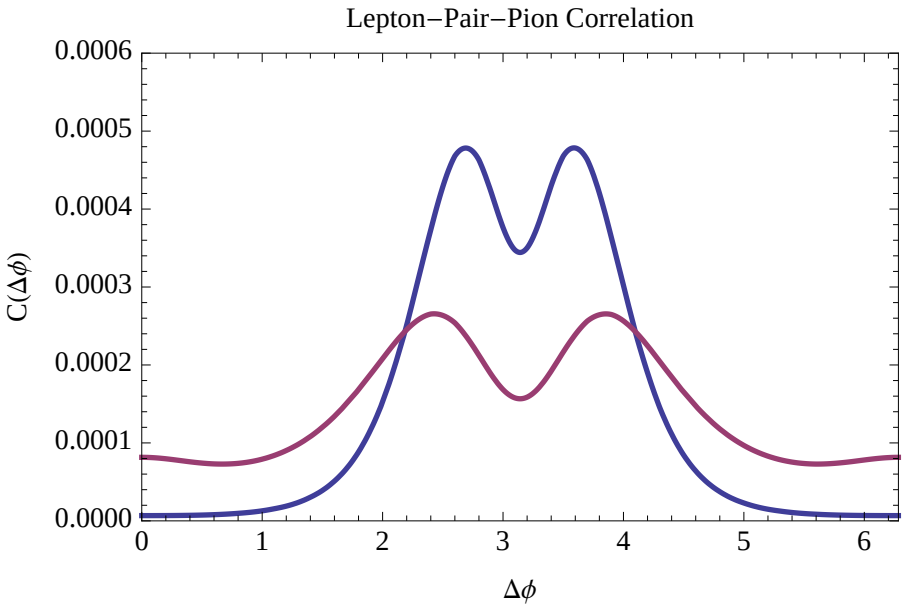
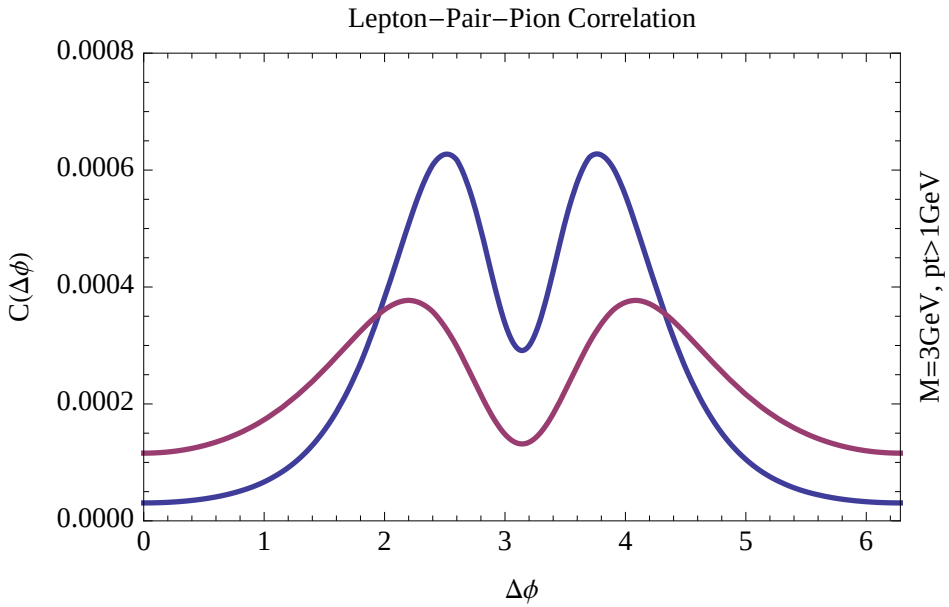
# Dilepton Pair + hadron correlation

[F. Dominguez, BX and F. Yuan, in preparation]

Azimuthal angle correlation of $\gamma^*+\pi^0$ at forward rapidity 3.2:




Remarks:

- $p_{1\perp} > 1.5$Gev, $p_{2\perp} > 1.5$Gev and $M^2 = 1\text{GeV}^2$;
- $p_{1\perp} > 1$Gev, $p_{2\perp} > 1$Gev and $M^2 = 9\text{GeV}^2$;
- Suppression of away side peak at central $dAu$ collisions.
- Double peak structure on the away side comes from the fact that $xG^{(2)} \propto q_\perp^2$ in the small $q_\perp$ limit.

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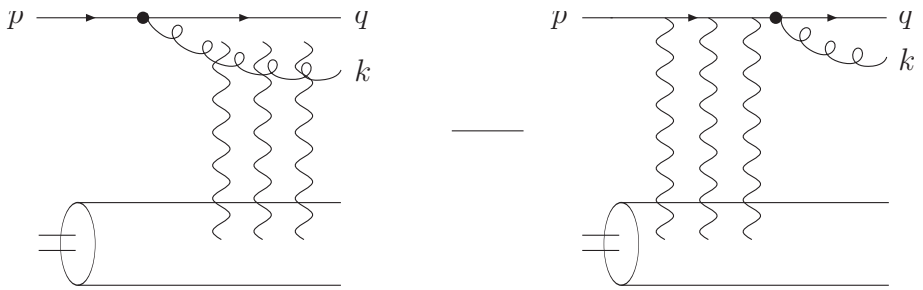
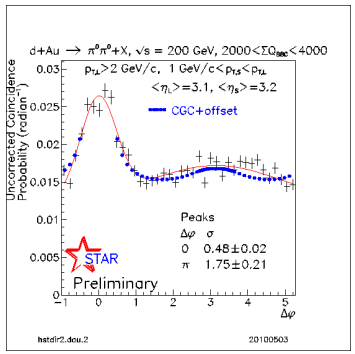
# Existing calculations on dijet production

Let us first look back, and re-examine the existing calculations on dijet productions.

I. Quark+Gluon channel [Marquet, 07] and [Albacete, Marquet, 10]




- Prediction of saturation physics.
- All the framework is correct, but over-simplified 4-point function.
- Improvement [F. Dominguez, C. Marquet, BX and F. Yuan, 11.]

$$S_{x_g}^{(4)}(x_1,x_2;x_2',x_1') \simeq e^{-\frac{C_F}{2}[\Gamma(x_1-x_2)+\Gamma(x_2'-x_1')]} - \frac{F(x_1,x_2;x_2',x_1')}{F(x_1,x_2';x_2,x_1')}\left(e^{-\frac{C_F}{2}[\Gamma(x_1-x_2)+\Gamma(x_2'-x_1')]} - e^{-\frac{C_F}{2}[\Gamma(x_1-x_1')+\Gamma(x_2'-x_2)]}\right)$$

II. Gluon+Gluon channel [Tuchin, 09]

- Fit the RHIC data amazingly well.
- Not correct, since the starting formula is $K_t$ factorization formula.

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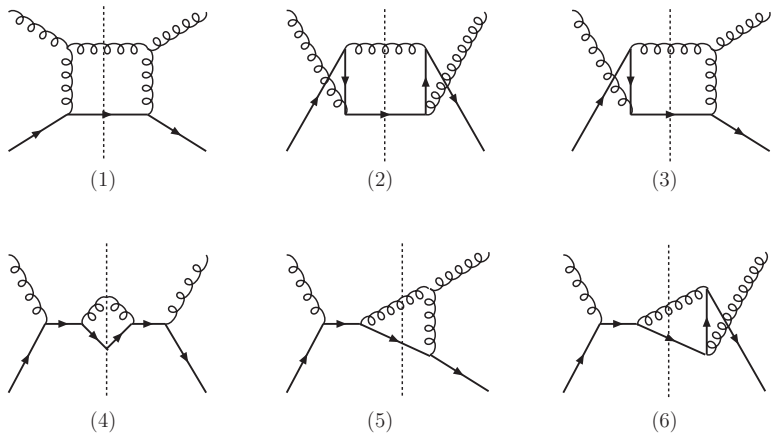
# Gluon+Jet in $pA$ collisions

Gluon+Jet in $pA$ collisions is the dominant channel for dijet production. For quark+gluon channel in the TMD approach, we have the following hard cross sections:




Hard cross sections and Color factors:

| (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|
| $-\frac{4(\hat{t}^2-\hat{s}\hat{u})^2}{\hat{t}^2\hat{s}\hat{u}}$ | $-\frac{2(\hat{u}^2+\hat{t}^2)}{\hat{s}\hat{u}}$ | $\frac{2(\hat{t}^2-\hat{s}\hat{u})(\hat{u}-\hat{t})}{\hat{s}\hat{t}\hat{u}}$ | $-\frac{2(\hat{s}^2+\hat{t}^2)}{\hat{s}\hat{u}}$ | $-\frac{2(\hat{t}^2-\hat{s}\hat{u})(\hat{s}-\hat{t})}{\hat{s}\hat{t}\hat{u}}$ | $\frac{2\hat{t}^2}{\hat{s}\hat{u}}$ |
| $\frac{1}{2}$ | $\frac{C_F}{2N_c}$ | $-\frac{1}{4}$ | $\frac{C_F}{2N_c}$ | $\frac{1}{4}$ | $-\frac{1}{4N_c^2}$ |

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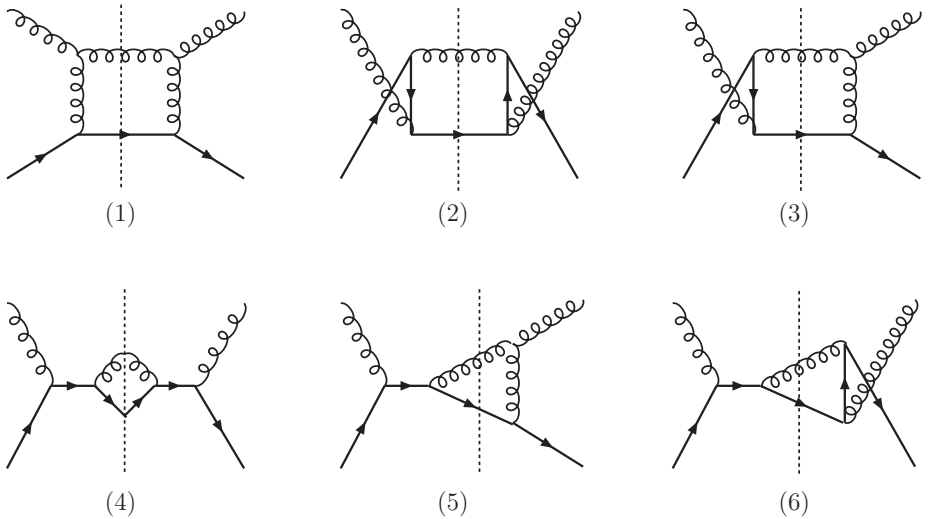
# Gluon+Jet in $pA$ collisions

For quark+gluon channel in the TMD approach, different graph corresponds to different gluon distributions:[Bomhof, Mulders and Pijlman; 06]




$$\Phi_g^{(1)} = \left\langle \mathrm{Tr}\left[ F(\xi) \left\{ \frac{1}{2} \frac{\mathrm{Tr}\left[\mathcal{U}^{[\square]}\right]}{N_c} \mathcal{U}^{[+]\dagger} + \frac{1}{2} \mathcal{U}^{[-]\dagger} \right\} F(0)\, \mathcal{U}^{[+]} \right] \right\rangle ,$$

$$\Phi_g^{(2)} = \left\langle \mathrm{Tr}\left[ F(\xi) \left\{ \frac{N_c^2}{N_c^2-1} \frac{\mathrm{Tr}\left[\mathcal{U}^{[\square]}\right]}{N_c} \mathcal{U}^{[+]\dagger} - \frac{1}{N_c^2-1} \mathcal{U}^{[-]\dagger} \right\} F(0)\, \mathcal{U}^{[+]} \right] \right\rangle ,$$

$$\Phi_g^{(3)} = \left\langle \mathrm{Tr}\left[ F(\xi) \frac{\mathrm{Tr}\left[\mathcal{U}^{[\square]}\right]}{N_c} \mathcal{U}^{[+]\dagger} F(0)\, \mathcal{U}^{[+]} \right] \right\rangle ,$$

$$\Phi_g^{(4),(5),(6)} = \left\langle \mathrm{Tr}\left[ F(\xi)\, \mathcal{U}^{[-]\dagger} F(0)\, \mathcal{U}^{[+]} \right] \right\rangle .$$

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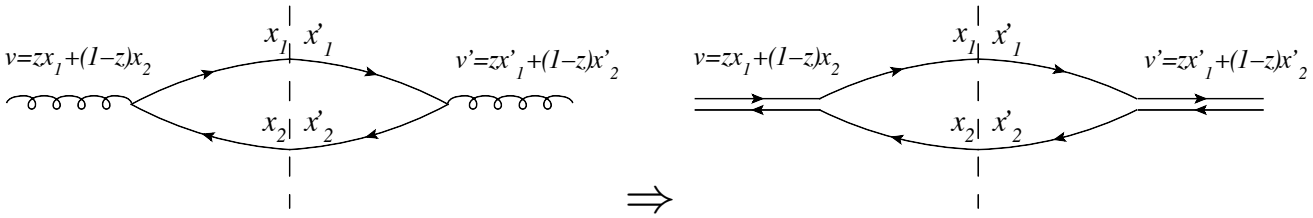
# Large $N_c$ limit

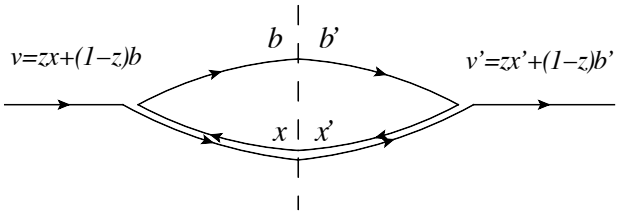
Graphical representation of dijet processes in the large $N_c$ limit

$g \to q\bar{q}$:

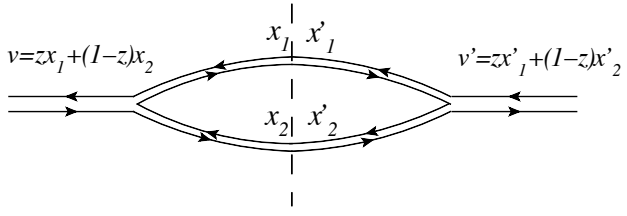



$\Rightarrow$

$q \to qg$




$g \to gg$




Two fundamental building blocks.

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# Gluon+quark jets correlation

Including all the $qg \to qg$, $gg \to gg$ and $gg \to q\bar{q}$ channels, a lengthy calculation gives

$$\begin{aligned}\frac{d\sigma^{(pA\to\text{Dijet}+X)}}{d\mathcal{P}.\mathcal{S}.} &= \sum_q x_1 q(x_1,\mu^2)\frac{\alpha_s^2}{\hat{s}^2}\left[\mathcal{F}_{qg}^{(1)}H_{qg}^{(1)}+\mathcal{F}_{qg}^{(2)}H_{qg}^{(2)}\right]\\ &+x_1 g(x_1,\mu^2)\frac{\alpha_s^2}{\hat{s}^2}\left[\mathcal{F}_{gg}^{(1)}\left(H_{gg\to q\bar{q}}^{(1)}+\frac{1}{2}H_{gg\to gg}^{(1)}\right)\right.\\ &\left.+\mathcal{F}_{gg}^{(2)}\left(H_{gg\to q\bar{q}}^{(2)}+\frac{1}{2}H_{gg\to gg}^{(2)}\right)+\mathcal{F}_{gg}^{(3)}\frac{1}{2}H_{gg\to gg}^{(3)}\right],\end{aligned}$$

with the various gluon distributions defined as

$$\begin{aligned}\mathcal{F}_{qg}^{(1)} &= xG^{(2)}(x,q_\perp),\quad \mathcal{F}_{qg}^{(2)}=\int xG^{(1)}\otimes F\,,\\ \mathcal{F}_{gg}^{(1)} &= \int xG^{(2)}\otimes F,\quad \mathcal{F}_{gg}^{(2)}=-\int\frac{q_{1\perp}\cdot q_{2\perp}}{q_{1\perp}^2}xG^{(2)}\otimes F\,,\\ \mathcal{F}_{gg}^{(3)} &= \int xG^{(1)}(q_1)\otimes F\otimes F\,,\end{aligned}$$

where $F=\int\frac{d^2r_\perp}{(2\pi)^2}e^{-iq_\perp\cdot r_\perp}\frac{1}{N_c}\left\langle \text{Tr}U(r_\perp)U^\dagger(0)\right\rangle_{x_g}$.

Remarks: Only the term in NavyBlue color was known before.

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# Illustration of gluon distributions

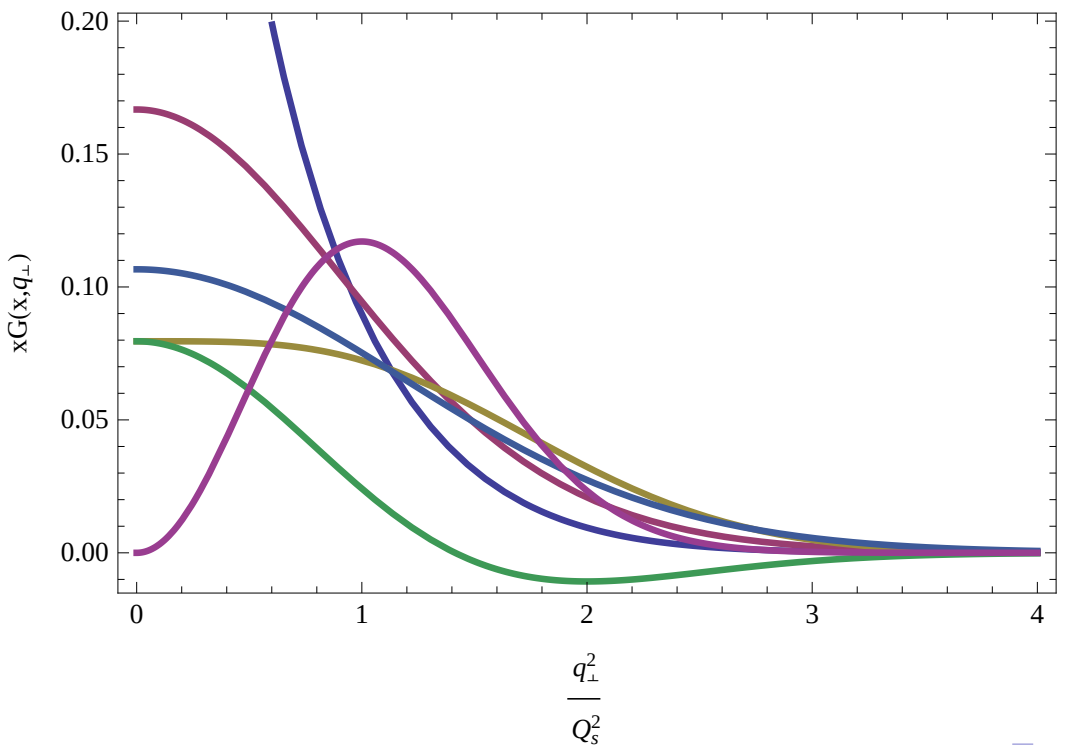
The various gluon distributions:

$$xG^{(1)}_{\rm WW}(x,q_\perp),\quad \mathcal{F}^{(1)}_{qg} = xG^{(2)}(x,q_\perp),$$

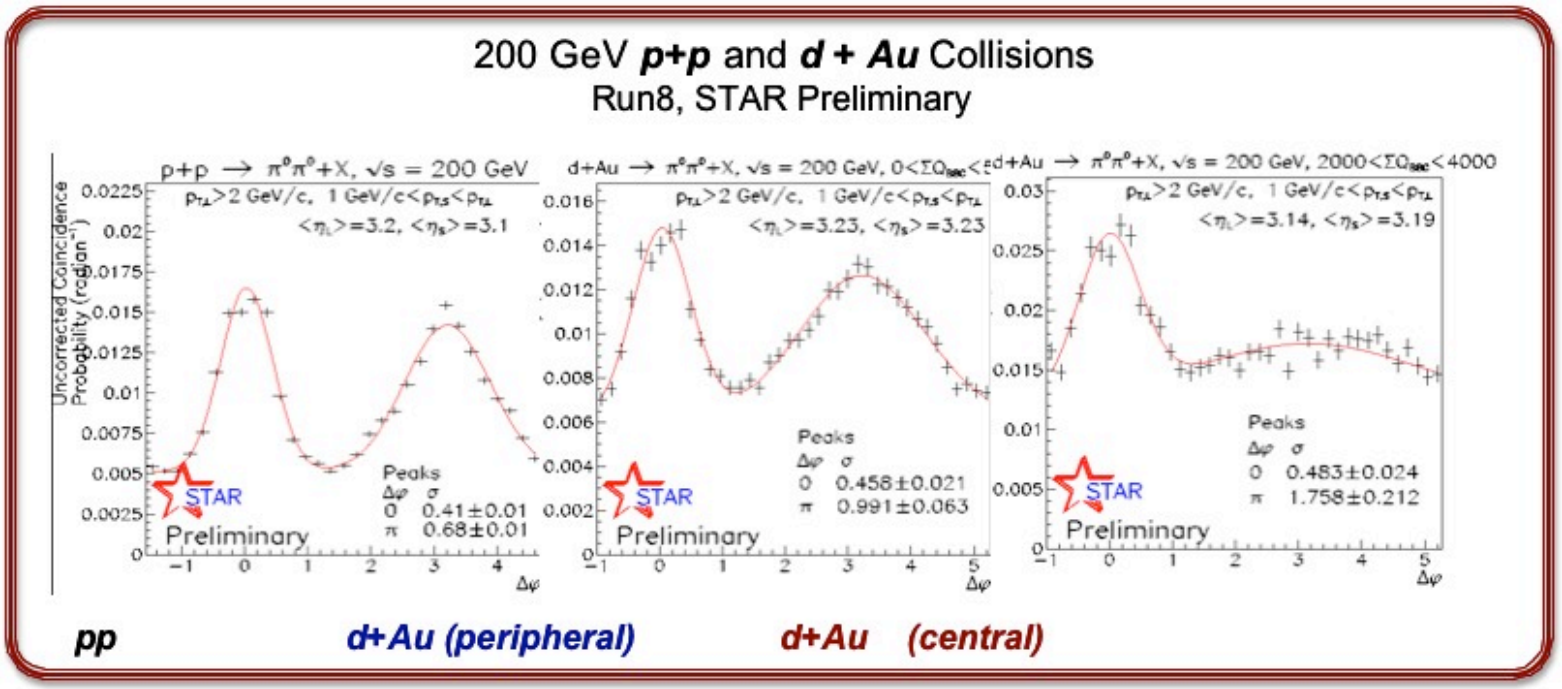
$$\mathcal{F}^{(1)}_{gg} = \int xG^{(2)} \otimes F,\quad \mathcal{F}^{(2)}_{gg} = -\int \frac{q_{1\perp}\cdot q_{2\perp}}{q^2_{1\perp}} xG^{(2)} \otimes F\,,$$

$$\mathcal{F}^{(3)}_{gg} = \int xG^{(1)}(q_1) \otimes F \otimes F\,,\quad \mathcal{F}^{(2)}_{qg} = \int xG^{(1)} \otimes F$$

6 different gluon distributions



# STAR measurement on di-hadron correlation in *dA* collisions




- There is no sign of suppression in the $p + p$ and $d + Au$ peripheral data.
- The suppression and broadening of the away side jet in $d + Au$ central collisions is due to the multiple interactions between partons and dense nuclear matter (CGC).
- Dissect the data into three features:
  Width $\sigma$ of peaks, Pedestal $P$ and Peak suppression.
- Near side peak: maybe due to 2-hadron fragmentation.

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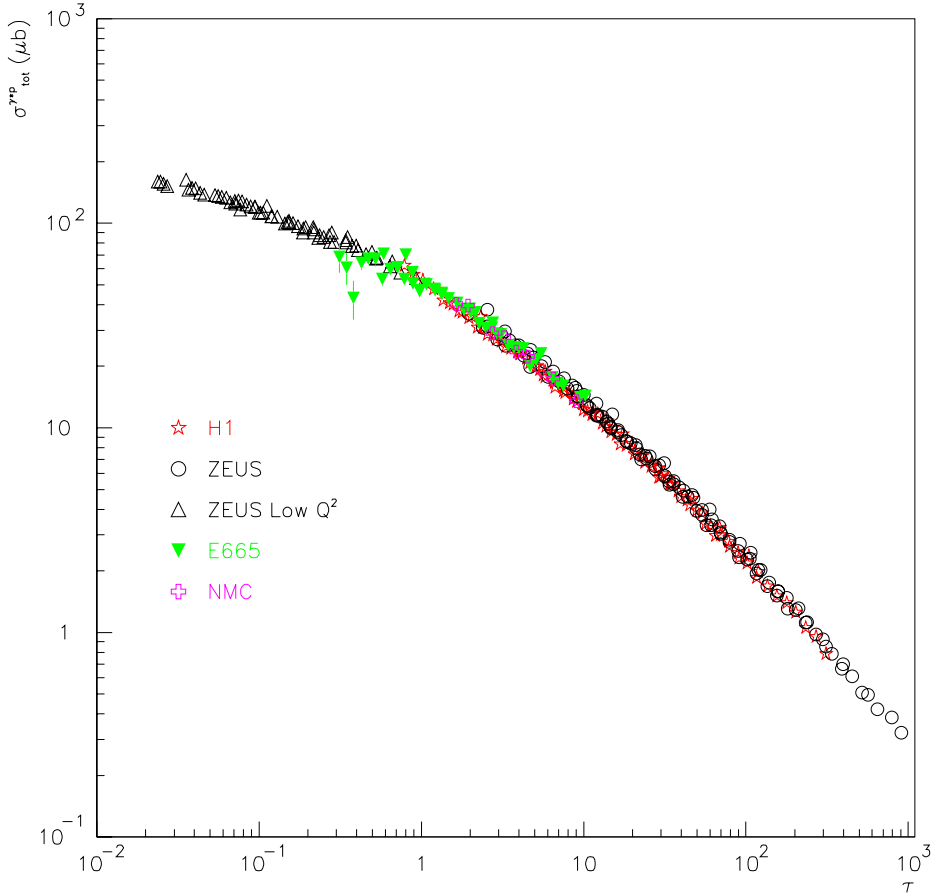
# Golec-Biernat Wusthoff model and Geometrical Scaling

[Golec-Biernat, Wusthoff,; 98], [Golec-Biernat, Stasto, Kwiecinski; 01]




- Use Golec-Biernat Wusthoff model for the saturation momentum, $Q_s^2(x) = Q_{s0}^2(x/x_0)^{-\lambda}$ with $Q_{s0} = 1\text{GeV}$, $x = 3.04 \times 10^{-3}$ and $\lambda = 0.288$.
- All data of $\sigma_{tot}^{\gamma^* p}$ when $x \leq 0.01$ and $Q^2 \leq 450 GeV^2$ plotting as function of $\tau = Q^2/Q_s^2$ falls on a curve.

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# The forward dihadron correlations in dAu collisions at RHIC

Measuement: For the process $dAu \to h_1 h_2 X$ at $\sqrt{s} = 200\text{GeV}$, both STAR and PHENIX measure the coincidence probability ($x_g = x_1 e^{-y_1} + x_2 e^{-y_2}$ and $x_d = x_1 e^{y_1} + x_2 e^{y_2}$)

$$C(\Delta\phi) = \frac{N_{\text{pair}}(\Delta\phi)}{N_{\text{trig}}}$$

where $N_{\text{pair}}(\Delta\phi)$ is the yield of two forward $\pi^0$ which includes a trigger particle with a transverse momentum $p_{1\perp}^{\text{trig}} > 2\text{GeV}$ and an associate particle with $p_{1\perp}^{\text{trig}} > p_{2\perp}^{\text{assc}} > 1\text{GeV}$.
Calculation: In terms of theory, this coincidence probability can be calculated via

$$C(\Delta\phi) = \frac{\int_{|p_{1\perp}|,|p_{2\perp}|} \frac{d\sigma_{\text{Correlated}}}{dy_1 dy_2 d^2p_{1\perp} d^2p_{2\perp}} + \int_{|p_{1\perp}|,|p_{2\perp}|} \frac{d\sigma_{\text{Uncorrelated}}}{dy_1 dy_2 d^2p_{1\perp} d^2p_{2\perp}}}{\int_{|p_{1\perp}|} \frac{d\sigma_{\text{Single Incusive}}}{dy_1 d^2p_{1\perp}}}$$

Remarks:

- $\sigma_{\text{Correlated}}$ gives the peaks.
- $\sigma_{\text{Uncorrelated}}$ gives the pedestal (offset). $\Leftarrow$ two (or more) independent single scatterings. [Strikman, Vogelsang; 11]
- $\sigma_{\text{Single Incusive}}$ matches the single inclusive cross section in forward $dAu$ collisions.
- Data Dissection: Width $\sigma$ of peaks, Pedestal $P$ and peak suppression.
- Width $\sigma$ of peaks and Pedestal $P$ $\uparrow$, while peak $\downarrow$ with $Q_s$ $\uparrow$. Why?

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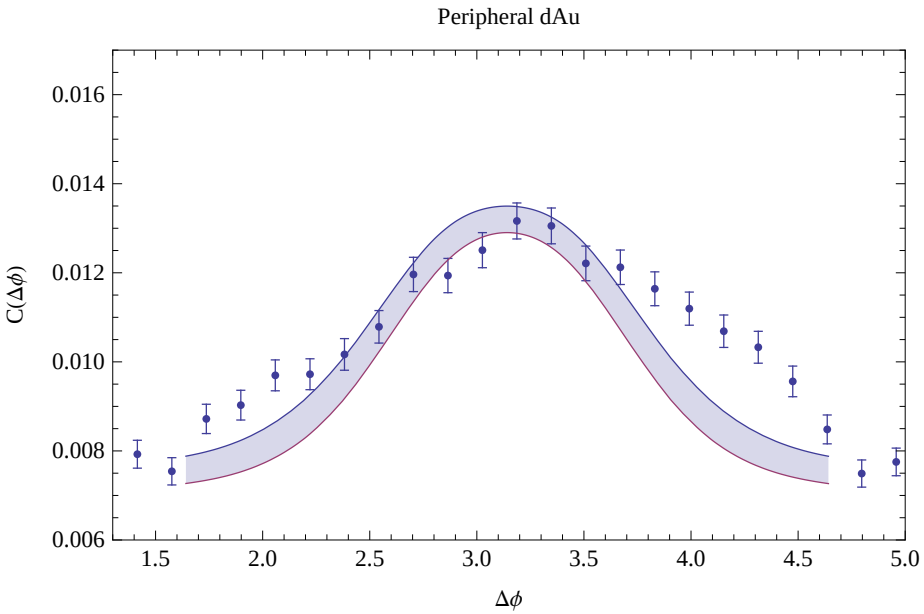
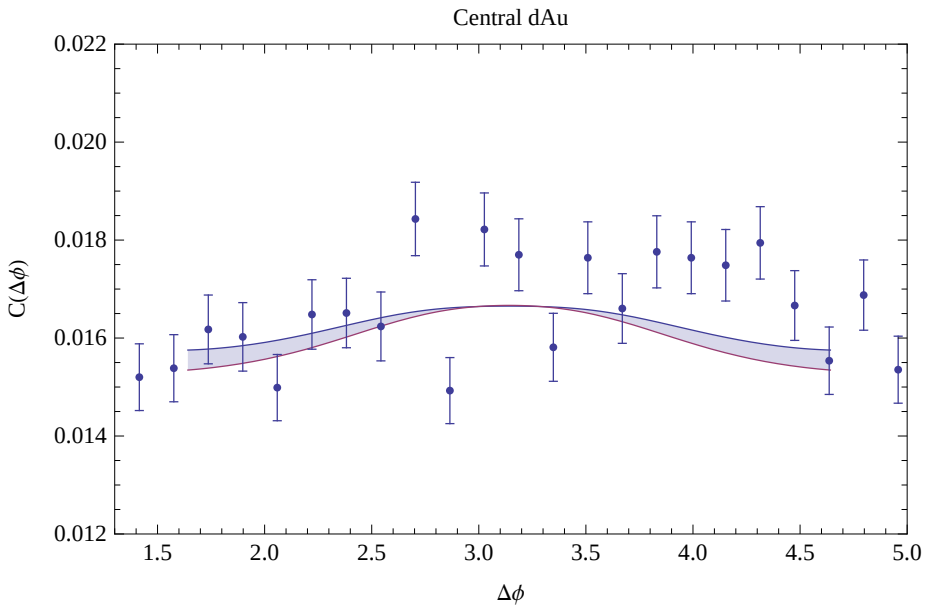
# Comparing to STAR data

[A. Stasto, BX, F. Yuan, in preparation]

For away side peak in both peripheral and central $dAu$ collisions in $q + g$ channel:




- The framework does not work for pp since the saturation scale $Q_s$ is too low at $\sqrt{s} = 200\text{GeV}$.
- Use Golec-Biernat Wusthoff model for the saturation momentum, $Q_s^2(x) = Q_{s0}^2(x/x_0)^\lambda$; Adding the nuclear and impact factor dependence: $Q_{sA}^2 = c(b)A^{1/3}Q_s^2(x)$ with $c(b) \propto \sqrt{1 - b^2/R^2}$.
- Peripheral $b = 6.8 \pm 1.7\text{fm}$ with $c(b) = 0.45$ and width $\sigma \simeq 0.99$;
- Central $b = 2.7 \pm 1.3\text{fm}$ with $c(b) = 0.85$ and width $\sigma \simeq 1.6$.

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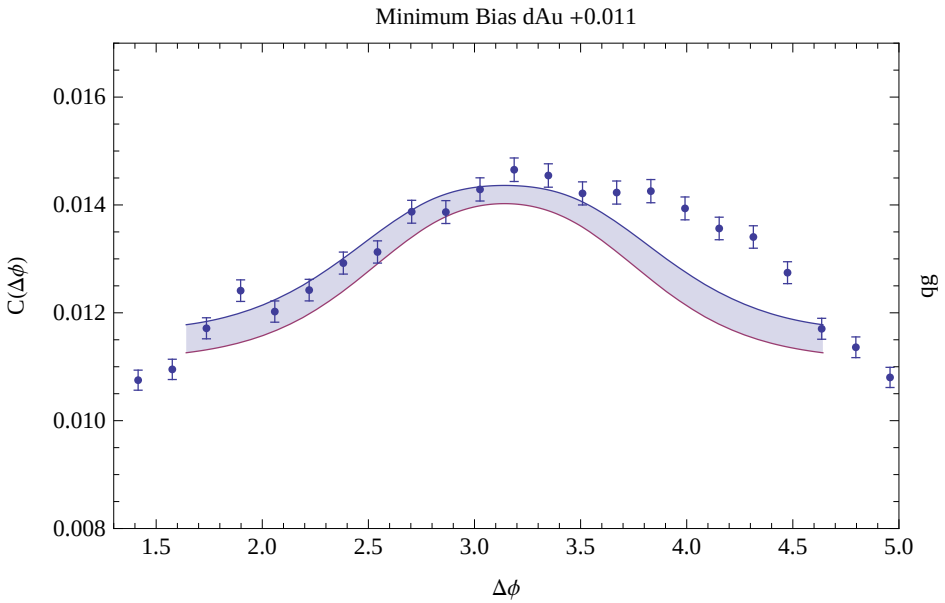
# Comparing to STAR data

[A. Stasto, BX, F. Yuan, in preparation]

For minimum bias away side peak in $dAu$ collisions in $q + g$ channel:




- Peripheral $b = 6.8 \pm 1.7$fm with $c(b) = 0.45$ and width $\sigma \simeq 0.99$;
- Central $b = 2.7 \pm 1.3$fm with $c(b) = 0.85$ and width $\sigma \simeq 1.6$;
- Minimum Bias $c(b) = 0.56 \Rightarrow \langle b \rangle = 6$fm and width $\sigma \simeq 1.2$.

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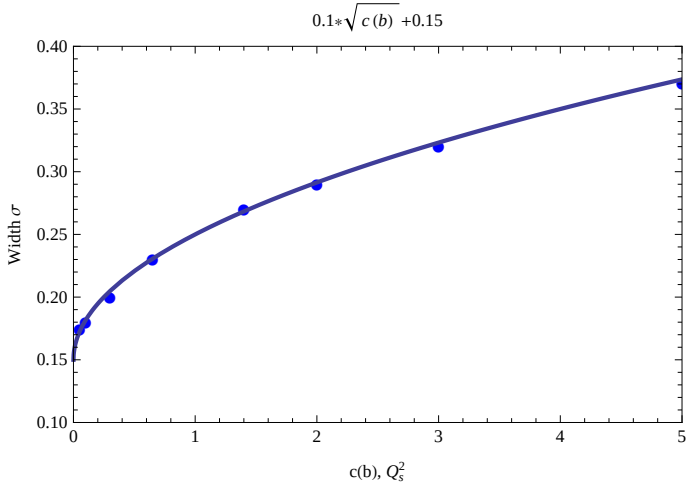
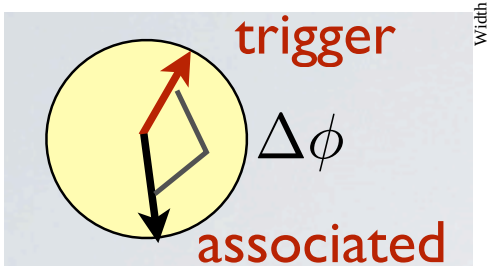
# The connection between the Width $\sigma$ of away side peaks and $Q_{sA}^2(b)$

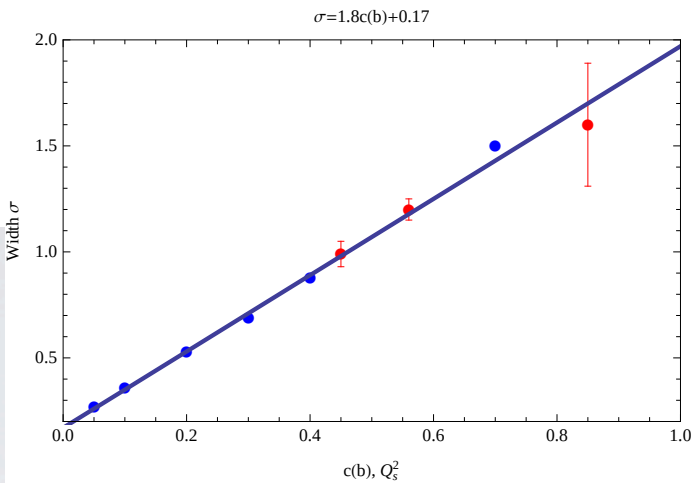
Let us do a simple exercise first. Assume the relevant gluon distribution has the form $\exp(-\frac{q_\perp^2}{Q_s^2(b)})$ with $q_\perp = k_{1\perp} + k_{2\perp}$, thus around the away side peaks

$$C(\Delta\phi) \propto \exp\left[-\frac{(|k_{1\perp}| - |k_{2\perp}|)^2 + 2|k_{1\perp}||k_{2\perp}|(1+\cos\Delta\phi)}{Q_{sA}^2(b)}\right]$$

$$\propto \exp\left[-\frac{|k_{1\perp}||k_{2\perp}|(\Delta\phi-\pi)^2}{Q_{sA}^2(b)}\right] \Rightarrow \sigma \propto \frac{Q_{sA}(b)}{\Lambda} \propto \sqrt{c(b)}$$




*eA* colllisions

*dAu* collisions

- However, we found $\sigma \propto c(b) \propto \frac{Q_{sA}^2(b)}{\Lambda^2}$ from dAu data. (No additional parameter!)
- $C(\Delta\phi) \propto C_1 + C_2 \int(\frac{q_\perp^2}{Q_s^2}) + C_3 \int(\frac{q_\perp^2}{Q_s^2})^2$ with $C_2 \simeq 0$

# Comparing to STAR data

[A. Stasto, BX, F. Yuan, in preparation]

Assume that the pedestal (offset) mostly comes from two independent single scatterings (double parton scattering[Strikman, Vogelsang; 11] ):

$$P = \frac{\int_{|p_{1\perp}|} \frac{dN_{\text{Single Inclusive}}}{dy_1 d^2p_{1\perp}} \times \int_{|p_{2\perp}|} \frac{dN_{\text{Single Inclusive}}}{dy_2 d^2p_{2\perp}}}{\int_{|p_{1\perp}|} \frac{dN_{\text{Single Incusive}}}{dy_1 d^2p_{1\perp}}}$$

with $\frac{dN_{\text{Single Inclusive}}}{dyd^2p_\perp} = \int dz x q(x_p) F_{x_g}(k_\perp) D(z)$

- The pedestal increase as the saturation momentum increases.
- Multiple parton interactions? Three?

| Offsets | Exp | Theory $q+g$ | Theory $q+g$ and $g+g$ |
|---|---|---|---|
| Peripheral | $0.007 \pm 0.001$ | 0.0065 | 0.016 |
| Central | $0.015 \pm 0.001$ | 0.011 | 0.018 |

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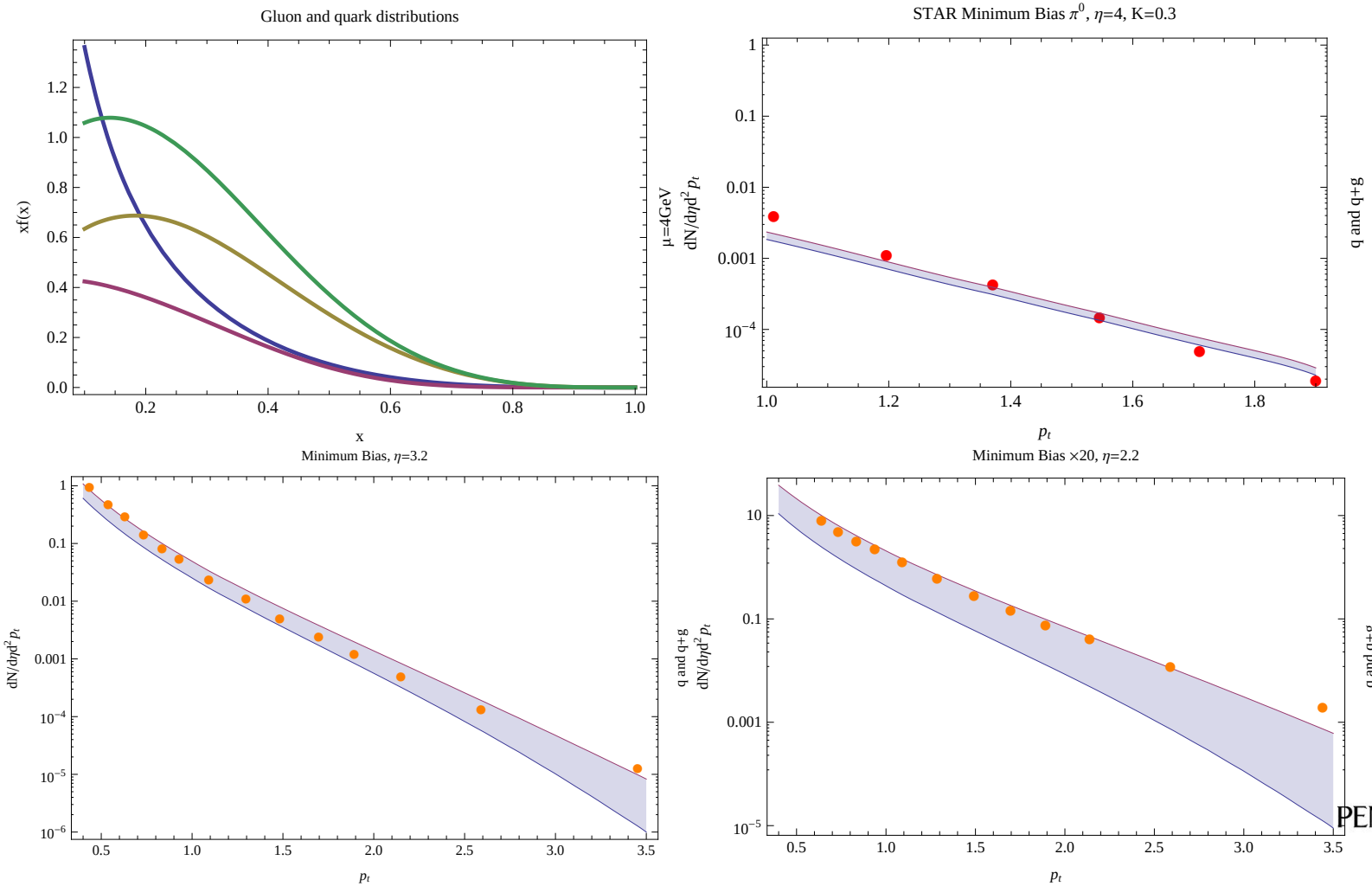
# $q + g$ channel as compared to $g + g$ channel

At ($\eta \simeq 4$), the quark distribution dominates the $\sigma_{\text{Single Incusive}}$. Not true, for $\eta \simeq 3.2$ or 2.2. STAR dAu $\pi^0$ data and BRAHMS $h^-$ data (80 percent of $h^-$ is $\pi^-$)

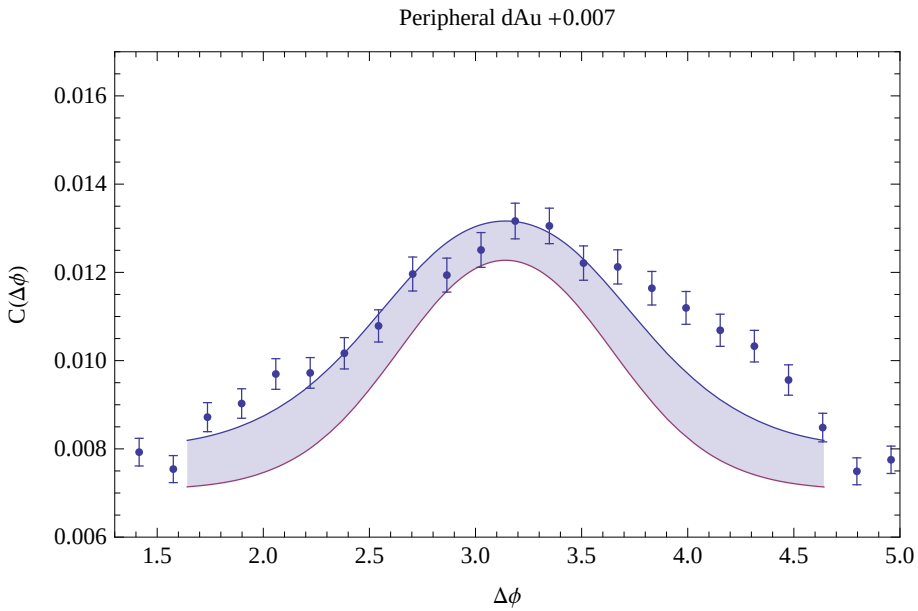


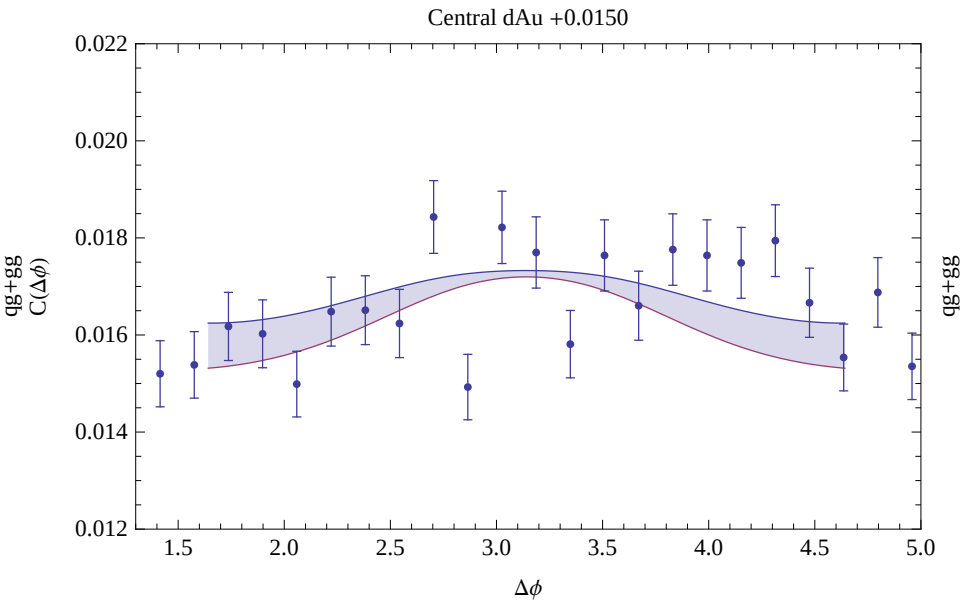

Comment: The height of away side peak is very sensitive to the value of total single inclusive cross section.

# Comparing to STAR data including both $q + g$ and $g + g$

[A. Stasto, BX, F. Yuan, in preparation]

For away side peak in both peripheral and central *dAu* collisions:




- Adding a $k-$factor of 2 to the ratio since the total single inclusive cross section is twice of the data at $\eta = 3.2$.
- Other parameters are kept the same.

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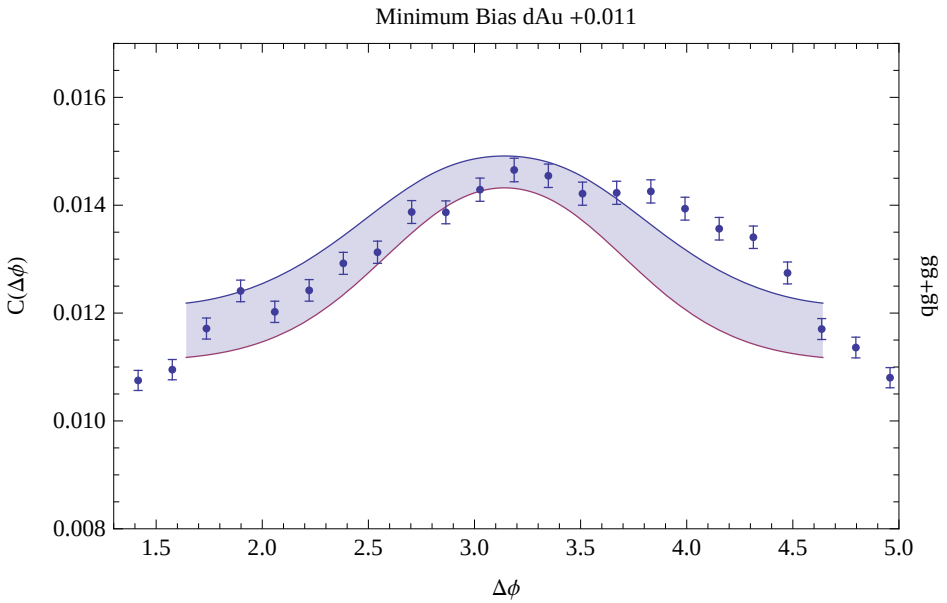
# Comparing to STAR data including both $q + g$ and $g + g$

[A. Stasto, BX, F. Yuan, in preparation]

For minimum bias away side peak in $dAu$ collisions in $q + g$ channel:




- Adding a $k-$factor of 2 to the ratio since the total single inclusive cross section is twice of the data at $\eta = 3.2$.
- Peripheral $b = 6.8 \pm 1.7$fm with $c(b) = 0.45$ and width $\sigma \simeq 0.99$;
- Central $b = 2.7 \pm 1.3$fm with $c(b) = 0.85$ and width $\sigma \simeq 1.6$;
- Minimum Bias $c(b) = 0.56 \Rightarrow \langle b \rangle = 6$fm and width $\sigma \simeq 1.2$.

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# Conclusion and Outlook

- The effect of the $k_t$ factorization violation is calculable and resummable. This eventually helps us to reach an effective factorization for the collisions between a dilute projectile and a dense target.
- DIS dijet provides direct information of the WW gluon distributions. Perfect for testing CGC, and ideal measurement for EIC.
- Parton distributions may not be exactly universal, but they are related.

| | Inclusive | Single Inc | DIS dijet | $\gamma$ +jet | g+jet |
|---|---|---|---|---|---|
| $xG^{(1)}$ | $\times$ | $\times$ | $\surd$ | $\times$ | $\surd$ |
| $xG^{(2)}$, F | $\surd$ | $\surd$ | $\times$ | $\surd$ | $\surd$ |

$\times \Rightarrow$ Do Not Appear. $\surd \Rightarrow$ Apppear.

- Two fundamental gluon distributions. Other gluon distributions are just different combinations and convolutions of these two.
- Dilepton-pair-hadron correlations probes the dipole gluon distribution.
- Dihadron correlation calculation and comparison with the STAR data.

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