QCD Unitarirty Rules for Nuclear Collisions

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⋆1973: Abramovsky-Gribov-Kancheli unitarity rules for multipomeron amplitides

⋆ Unitarty: opening a new channel affects all previous inleastic channels & diffraction & elastic scattering

⋆ Nuclear targets: testing ground for multipomeron exchanges

(Bertocchi & Treleani & Capella &Kaidalov, 1976)

⋆ QCD: inelastic interaction = color flow from beam to target

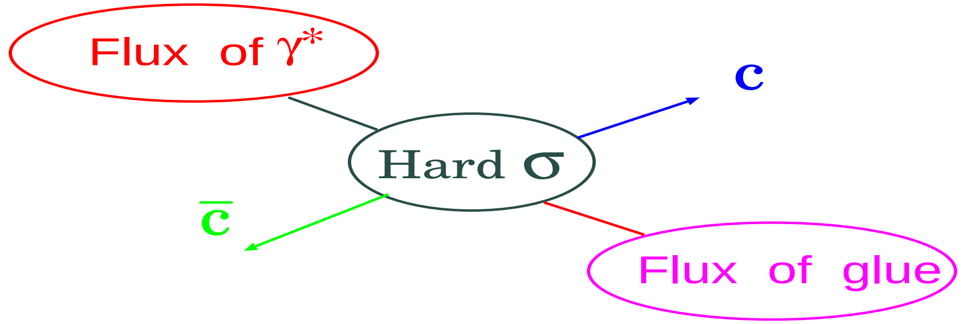
⋆ Classification of final states by color excitation of the target nucleus

⋆ Projectile parton and color flow-dependent nonlinear factorization for final states

⋆ Important QCD modifications of AGK-73

pQCD factorization theorems

Example: open charm in ep --> c $\bar{c}$ X



- Forward dijets: $x_\gamma = z_+ + z_- \approx 1$, jet-jet decorrelation momentum $\mathbf{\Delta} = \mathbf{p}_+ + \mathbf{p}_-$

$$\frac{d\sigma_N(\gamma^* \to c\bar{c})}{dz d^2\mathbf{p}_+ d^2\mathbf{\Delta}} = \frac{\alpha_S(\mathbf{p}^2)}{2(2\pi)^2} f(\mathbf{\Delta}) \left|\Psi(z,\mathbf{p}_+) - \Psi(z,\mathbf{p}_+ - \mathbf{\Delta})\right|^2 .$$

$$f(\boldsymbol{\kappa}) = \frac{4\pi}{N_c} \cdot \frac{1}{\kappa^4} \cdot \frac{\partial G_N(x,\boldsymbol{\kappa})}{\partial \log \kappa^2}$$

⋆ A linear functional of the unintegrated glue.

⋆ The dijet momentum $\mathbf{\Delta}$ probes the unintegrated gluon momentum.

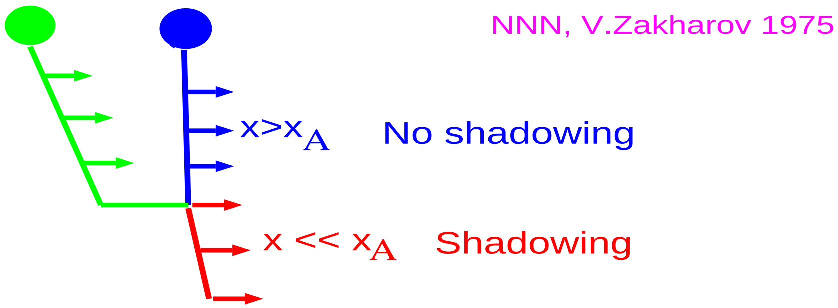
⋆ Back to 1973-74: Lorentz-contracted ultrarelativistic nucleus:

$$R_A \to R_A \frac{m_N}{p_N} < \lambda = \frac{1}{k_z} = \frac{1}{x p_N}\,.$$

⋆ Spatial overlap of partons from many nucleons if

$$x \lesssim x_A = 1/R_A m_N$$

parameter $\Longrightarrow$ FUSION & NUCLEAR SHADOWING.



⋆ Nuclear parton density (if it can be meaningfully defined!) is a nonlinear functional of the free nucleon parton density: the same sea is shared by many nucleons.

⋆ Must describe all nuclear observables!

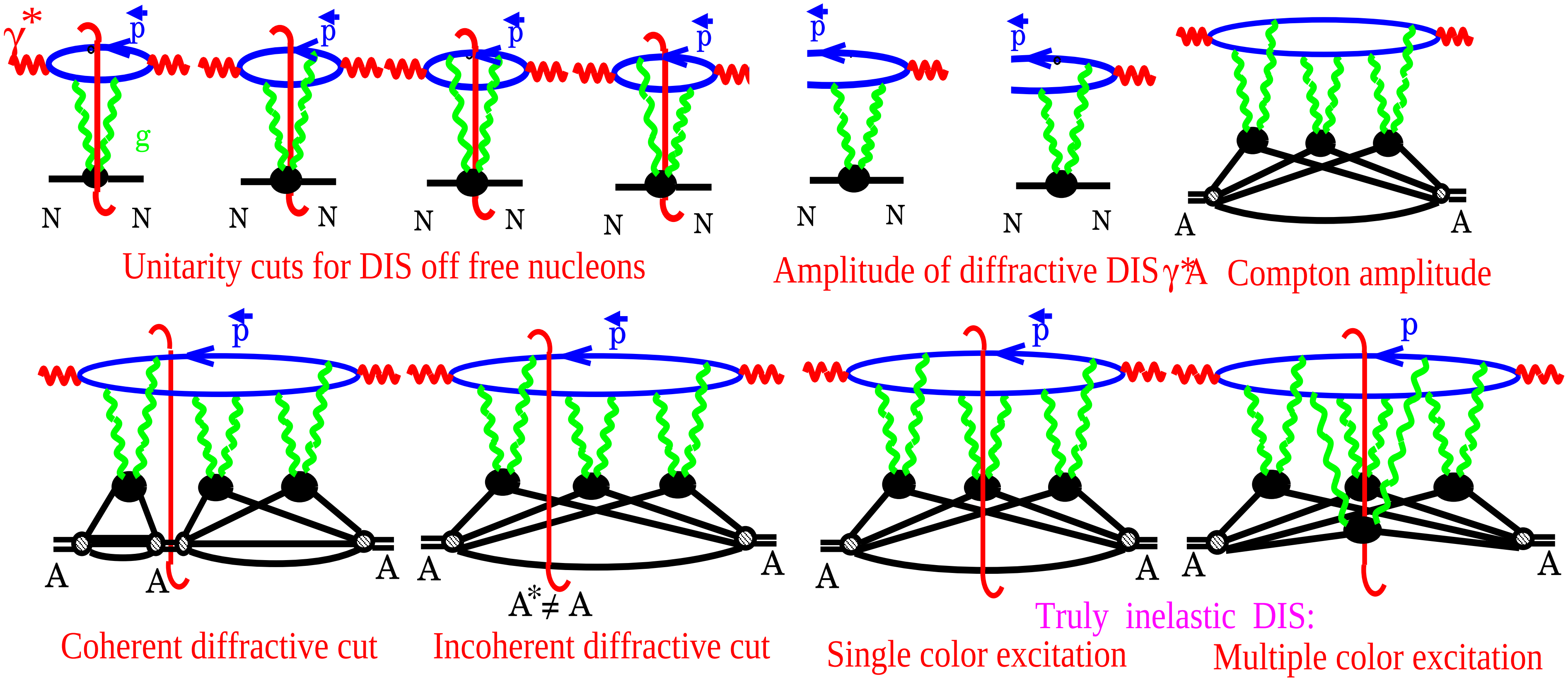
⋆ Major strategy of this talk: shadowing from unitarity for dipole amplitudes.

Coherent diffractive and truly inelastic DIS

Color dipole is coherent over whole nucleus for $x \lesssim x_A$: $\Longrightarrow$ Glauber–Gribov formalism (NNN, Zakharov (91)):

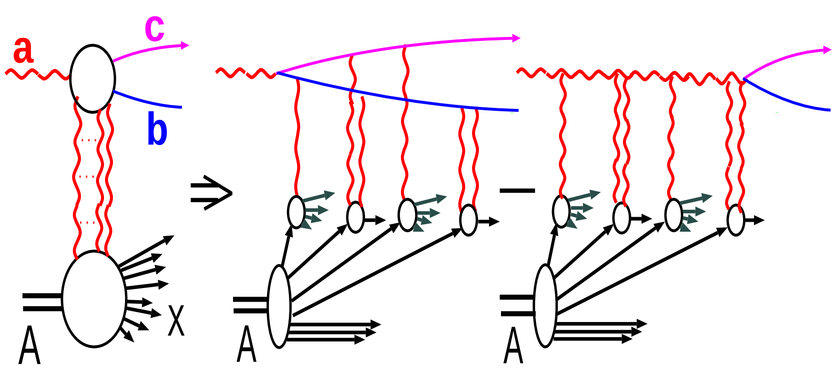
$$\sigma_A(\mathbf{r}) = 2\int d^2\mathbf{b}\Gamma_A(\mathbf{b},\mathbf{r}) = 2\int d^2\mathbf{b}[1-\exp(-\frac{1}{2}\sigma(\mathbf{r})T(\mathbf{b}))]$$

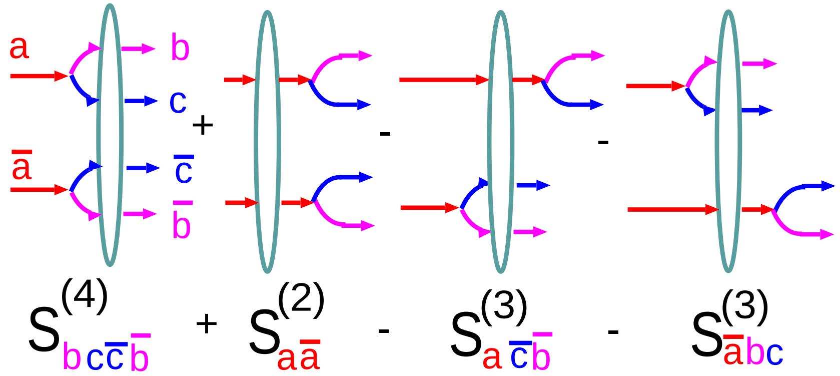
⋆ The unitarity content of DIS



Production processes as excitation of beam Fock states $a \longrightarrow bc$

Zakharov (87), NNN, Zakharov, Piller (95), NNN, Schäfer, Zakharov, Zoller (03)





⋆ Interactions after and before the virtual decay interfere destructively.

⋆ Apply closure over the nucleon & nucleus excitations

⋆ Hermitian conjugated S-matrix $=$ S-matrix for an antiparticle!

$$S_a S_b^\dagger = S_{a\bar{b}}$$

⋆ Partial cross sections with color-excitation of ν nucleons (ν cut pomerons in the Abramovsky-Gribov-Kancheli language)

⋆ Requires evaluation of specific intermediate states in $S^{(n)}$: well developed technique is available (NNN, Schafer, Zakharov (05))

Non-Abelian evolution and master formula for non-diffractive dijets

NNN, Zakharov, Piller (95), NNN, Schäfer, Zakharov, Zoller (03)

$$\frac{d\sigma(a^* \to bc)}{dz_b d^2\mathbf{p}_b d^2\mathbf{p}_c} = \frac{1}{(2\pi)^4} \int d^2\mathbf{b}_b d^2\mathbf{b}_c d^2\mathbf{b}'_b d^2\mathbf{b}'_c \times \exp[-i\mathbf{p}_b(\mathbf{b}_b - \mathbf{b}'_b) - i\mathbf{p}_c(\mathbf{b}_c - \mathbf{b}'_c)]$$
$$\Psi(z_b, \mathbf{b}_b - \mathbf{b}_c) \times \Psi^*(z_b, \mathbf{b}'_b - \mathbf{b}'_c)$$
$$\{S^{(4)}_{\bar{b}\bar{c}cb}(\mathbf{b}'_b, \mathbf{b}'_c, \mathbf{b}_b, \mathbf{b}_c) + S^{(2)}_{\bar{a}a}(\mathbf{b}', \mathbf{b}) - S^{(3)}_{\bar{b}\bar{c}a}(\mathbf{b}, \mathbf{b}'_b, \mathbf{b}'_c) - S^{(3)}_{\bar{a}bc}(\mathbf{b}', \mathbf{b}_b, \mathbf{b}_c)\}\,.$$

⋆ Coupled-channel non-Abelian evolution:

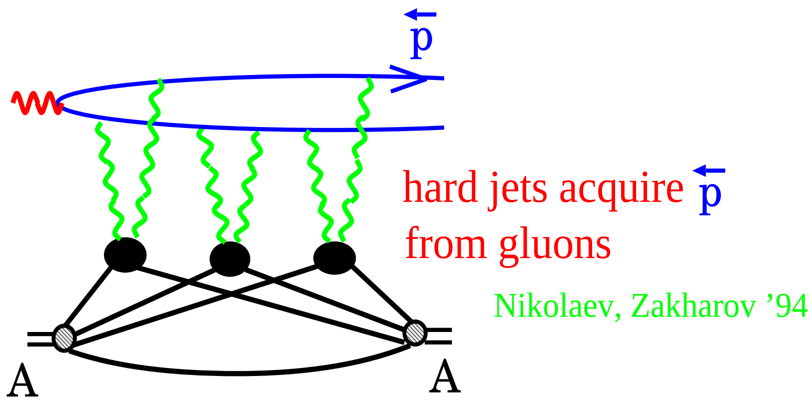
- DIS: $\gamma^* \to q\bar{q}$: $\quad\Longrightarrow\quad \underbrace{1}_{1} + \underbrace{8}_{N_c^2}$

- Open charm: $g \to c\bar{c}$: $\quad\Longrightarrow\quad \underbrace{1}_{1\ (N_c\ suppressed)} + \underbrace{8}_{N_c^2}$

- Forward dijets: $q \to qg$: $\quad\Longrightarrow\quad \underbrace{3}_{N_c} + \underbrace{6 + 15}_{N_c \times N_c^2}$

- Central dijets: $g \to gg$: $\quad\Longrightarrow\quad \underbrace{1}_{1\ (N_c\ suppressed)} + \underbrace{8_A + 8_S}_{N_c^2} + \underbrace{10 + \overline{10} + 27 + R_7}_{N_c^2 \times N_c^2}$

⋆ Universality classes depending on color excitation



Diffractive DIS off nuclei defines collective nuclear glue

⋆ Diffractive hard dijets from pions: $\pi N \longrightarrow Jet_1 + Jet_2, \qquad \mathbf{p}_{Jet_2} = -\mathbf{p}_{Jet_1} \gg \frac{1}{R_N}$:

$$M_{diff,N}(\mathbf{p}) \propto \int d^2\mathbf{r}\sigma(\mathbf{r})\exp(i\mathbf{p}\cdot\mathbf{r}) = -f(\mathbf{p})$$

⋆ Diffraction off nuclei (NNN,Shäfer,Schwiete'01):

$$M_{diff,A}(\mathbf{p}) \propto \int d^2\mathbf{r}\Gamma_A(\mathbf{b},\mathbf{r})\exp(i\mathbf{p}\cdot\mathbf{r})$$

⋆ Nuclear profile function (partial amplitude)

$$\Gamma_A(\mathbf{b},\mathbf{r}) = 1 - S_A(\mathbf{b},\mathbf{r}) = \int d^2\boldsymbol{\kappa}\phi(\mathbf{b},\boldsymbol{\kappa})\{1-\exp[i\boldsymbol{\kappa}\mathbf{r}]\}$$

⋆ Optical thickness $T(\mathbf{b}) = \int dz n_A(\mathbf{b},z)$ - a new large dimensional scale.

Collective glue of overlapping nucleons

- Nuclear S-matrix for the dipole: $S_A(\mathbf{b},\mathbf{r}) = \exp[-\frac{1}{2}\sigma(\mathbf{r})T(\mathbf{b})]$

$$\Phi(\mathbf{b},\boldsymbol{\kappa}) = \frac{1}{(2\pi)^2}\int d^2\mathbf{r} S_A(\mathbf{b},\mathbf{r})\exp(-i\mathbf{r}\boldsymbol{\kappa}) = \phi(\mathbf{b},\boldsymbol{\kappa}) + w_0(\mathbf{b})\delta(\boldsymbol{\kappa})$$

- Nuclear glue per unit area in the impact parameter space: unitarity interpretation as an expansion quasielastic qA scattering in in ν-fold quasilestic νN scattering

$$\phi(\mathbf{b},\boldsymbol{\kappa}) = \sum_{j=1}^{\infty} w_j(\mathbf{b}) f^{(j)}(\boldsymbol{\kappa})$$

- Probability to find j overlapping nucleons: boundary condition for evolution

$$w_j(\mathbf{b}) = \frac{\nu_A^j(\mathbf{b})}{j!}\exp\left[-\nu_A(\mathbf{b})\right], \quad \nu_A(\mathbf{b}) = \frac{1}{2}\sigma_0 T(\mathbf{b})$$

- Collective glue of j overlapping nucleons:

$$f^{(j)}(\boldsymbol{\kappa}) = \int \prod_i^j d^2\boldsymbol{\kappa}_i f(\boldsymbol{\kappa}_i)\delta(\boldsymbol{\kappa} - \sum_i^j \boldsymbol{\kappa}_i), \quad f^{(0)}(\boldsymbol{\kappa}) \equiv \delta(\boldsymbol{\kappa})$$

- Antishadowing of hard, $\boldsymbol{\kappa}^2 \gtrsim Q_A^2$, glue per bound nucleon (NNN,Schäfer, Schwiete '00):

$$f_A(\mathbf{b}, x, \boldsymbol{\kappa}) = \frac{\phi(\mathbf{b}, \boldsymbol{\kappa})}{\nu_A(\mathbf{b})}$$
$$= f(x, \boldsymbol{\kappa}) \left[1 + \frac{\gamma^2}{2} \cdot \frac{\alpha_S(\boldsymbol{\kappa}^2) G(x, \boldsymbol{\kappa}^2)}{\alpha_S(Q_A^2) G(x, Q_A^2)} \cdot \frac{Q_A^2(\mathbf{b})}{\boldsymbol{\kappa}^2} \right] .$$

- $\gamma =$ exponent of the large–$\boldsymbol{\kappa}^2$ tail

$$f(\boldsymbol{\kappa}) \sim \alpha_S(\boldsymbol{\kappa}^2)/(\boldsymbol{\kappa}^2)^\gamma$$

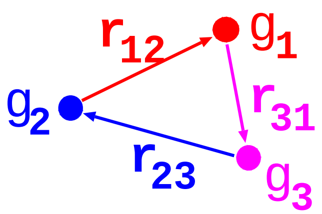
- Antishadowing $\Longrightarrow$ the Cronin effect.
- Plateau for softer collective glue

$$\phi(\mathbf{b}, \boldsymbol{\kappa}) \approx \frac{1}{\pi} \frac{Q_A^2(\mathbf{b})}{(\boldsymbol{\kappa}^2 + Q_A^2(\mathbf{b}))^2} ,$$

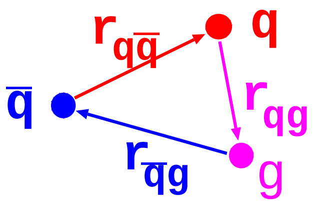
- Width of the plateau (saturation & higher twist scale, independent of auxiliary soft $\sigma_0(x)$)

$$Q_A^2(\mathbf{b}, x) \approx \frac{4\pi^2}{N_c} \alpha_S(Q_A^2) G(x, Q_A^2) T(\mathbf{b}) .$$

The origin, and inevitability of the nonlinear $k_\perp$-factorization



$$\sigma^{(3)} = \frac{C_A}{2C_F}\left(\sigma(\mathbf{r}_{31}) + \sigma(\mathbf{r}_{23}) + \sigma(\mathbf{r}_{12})\right)$$



$$\sigma^{(3)} = \frac{C_A}{2C_F}\left(\sigma(\mathbf{r}_{qg}) + \sigma(\mathbf{r}_{\bar{q}g}) - \sigma(\mathbf{r}_{q\bar{q}})\right) + \sigma(\mathbf{r}_{q\bar{q}})$$

⋆ Glauber-Gribov multiple scattering theory for the dilute-gas nucleus:

$$S_i(\mathbf{b}_c', \mathbf{b}_b', \mathbf{b}_c, \mathbf{b}_b) = \exp\{-\frac{1}{2}\Sigma_i(\mathbf{b}_c', \mathbf{b}_b', \mathbf{b}_c, \mathbf{b}_b)T(\mathbf{b})\}$$

⋆

$$\begin{aligned} S_{123} &= \exp\{-\frac{C_A}{4C_F}\sigma(r_{12})T(\mathbf{b})\}\exp\{-\frac{C_A}{4C_F}\sigma(r_{13})T(\mathbf{b})\}\exp\{-\frac{C_A}{4C_F}\sigma(r_{23})T(\mathbf{b})\} \\ &= \int d^2\boldsymbol{\kappa}_1 d^2\boldsymbol{\kappa}_2 d^2\boldsymbol{\kappa}_3 \Phi(\mathbf{b},\boldsymbol{\kappa}_1)\Phi(\mathbf{b},\boldsymbol{\kappa}_1)\Phi(\mathbf{b},\boldsymbol{\kappa}_1)\exp(i\boldsymbol{\kappa}_1 r_{12} + i\boldsymbol{\kappa}_2 r_{13} + i\boldsymbol{\kappa}_3 r_{23}) \end{aligned}$$

⋆ The multiparton S-matrix is a nonlinear functional of the collective nuclear glue!

Dijets: Universality class of coherent diffraction

⋆ Coherent distortion of dipole WF in slice $[0,\beta]$ of the nucleus:

$$\Psi(\beta; z, \mathbf{p}) = \int d^2\boldsymbol{\kappa}\Phi(\beta; \mathbf{b}, x, \boldsymbol{\kappa})\Psi(z, \mathbf{p}+\boldsymbol{\kappa})$$

$$\exp\left[-\frac{1}{2}\beta\sigma(x,\mathbf{r})T(\mathbf{b})\right] = \int d^2\boldsymbol{\kappa}\Phi(\beta; \mathbf{b}, x, \boldsymbol{\kappa})\exp(i\boldsymbol{\kappa}\mathbf{r})$$

⋆ Diffractive DIS:

$$\frac{(2\pi)^2 d\sigma_A(\gamma^* \to Q\overline{Q})}{d^2\mathbf{b}dzd^2\mathbf{p}d^2\boldsymbol{\Delta}} = \delta^{(2)}(\boldsymbol{\Delta})\left|\Psi(1; z_g, \mathbf{p}) - \Psi(z_g, \mathbf{p})\right|^2,$$

⋆ Exactly back-to-back dijets

⋆ $q \to qg$: net color charge of the incident parton

$$\frac{(2\pi)^2 d\sigma_A(q^* \to qg)}{d^2\mathbf{b}dzd^2\mathbf{p}_g d^2\boldsymbol{\Delta}} = \delta^{(2)}(\boldsymbol{\Delta})S_{abs}(2\nu_A(\mathbf{b}))\left|\Psi(1; z_g, \mathbf{p}_g) - \Psi(z_g, \mathbf{p}_g)\right|^2.$$

⋆ Intranuclear attenuation of the incident quark wave (Bj's gap survival):

$$S_{abs}(2\nu_A(\mathbf{b})) = \exp[-2\nu_A(\mathbf{b})]$$

Dijets: Universality class of dijet in higher color representation from partons in lower representation: black $q \to qg|_{6+15}$

$$
\left.\frac{d\sigma(q^* \to qg)}{d^2\mathbf{b}dzd^2\mathbf{\Delta}d^2\mathbf{p}}\right|_{6+15} = \frac{1}{(2\pi)^2}T(\mathbf{b})\int_0^1 d\beta
$$

$$
\times \int d^2\boldsymbol{\kappa}d^2\boldsymbol{\kappa}_1 d^2\boldsymbol{\kappa}_2 d^2\boldsymbol{\kappa}_3 \delta(\boldsymbol{\kappa}+\boldsymbol{\kappa}_1+\boldsymbol{\kappa}_2+\boldsymbol{\kappa}_3-\mathbf{\Delta})
$$

$$
\times \underbrace{\Phi(\beta;\mathbf{b},\boldsymbol{\kappa}_3)}_{Quark\quad ISI} \underbrace{f(\boldsymbol{\kappa})\left|\Psi(\beta;z,\mathbf{p}-\boldsymbol{\kappa}_1)-\Psi(\beta;z,\mathbf{p}-\boldsymbol{\kappa}_1-\boldsymbol{\kappa})\right|^2}_{Hard\quad Excitation}
$$

$$
\times \underbrace{\Phi(1-\beta;\mathbf{b},\boldsymbol{\kappa}_1)}_{Quark\quad FSI} \underbrace{\Phi(\frac{C_A}{C_F}(1-\beta);\mathbf{b},\boldsymbol{\kappa}_2)}_{Gluon\quad FSI}
$$

$\star\ \gamma^* \to q\bar{q}|_8$: the same as $q \to qg|_{6+15}$ modified for vanishing ISI

$\star\ g \to gg|_{10+\overline{10}+27+R_7}$: the same as $q \to qg$ subject to two modifications:

(i) Quark FSI/ISI $\Longrightarrow$ Gluon FSI/ISI

(ii) C_A/C_F: collective glue is a color matrix in color space.

Dijets: Universality class of dijets in the same lower color representation as the beam parton: $q \rightarrow qg|_3$

$$\left.\frac{d\sigma(q^*A \rightarrow qg)}{d^2\mathbf{b}dzd^2\mathbf{\Delta}d^2\mathbf{p}}\right|_3 = \frac{1}{(2\pi)^2}\phi(\mathbf{b},\mathbf{\Delta})\left|\Psi(1;z,\mathbf{p}-\mathbf{\Delta}) - \Psi(z,\mathbf{p}-z\mathbf{\Delta})\right|^2$$

$\star$ $\Psi(z,\mathbf{p}-z\mathbf{\Delta}) =$ probability amplitude for the qg state in a physical quark - driving term of quark jet fragmentation

$\star$ Color triplet dijets: nearly linear-factorizable fragmentation of the multiply-scattered quark subject to a coherently nuclear-distorted $\Psi(1;z,\mathbf{p}-\mathbf{\Delta})$:

$$|\underbrace{\Psi(z,\mathbf{p}-\mathbf{\Delta})}_{in-vacuum} - \Psi(z,\mathbf{p}-z\mathbf{\Delta})|^2 \Longrightarrow |\underbrace{\Psi(1;z,\mathbf{p}-\mathbf{\Delta})}_{in-nucleus\quad distorted} - \Psi(z,\mathbf{p}-z\mathbf{\Delta})|^2$$

Interpretation: nuclear modification of the fragmentation function

$\star$ WF distortions always by uncut pomerons

$\star$ More universality classes: $g \rightarrow q\bar{q}|_8$, $g \rightarrow gg|_{8_A+8_S}$, $g \rightarrow gg|_{8_S}$

Nonlinear evolution for collective glue in the dipole basis

⋆ Impact of the $a\bar{a}g$ Fock state on the $a\bar{a}$ scattering matrix, the 1st iteration:

$$\delta \mathsf{S}_{a\bar{a}}(x,\mathbf{b}_a,\mathbf{b}_{\bar{a}}) = \int_{x/x_0}^{1} dz_g \int d^2\boldsymbol{\rho}\Psi^*_{a\bar{a}g}\Psi_{a\bar{a}g}$$
$$\times[\mathsf{S}_a(x_0,\mathbf{b}_a)\mathsf{S}^\dagger_a(x_0,\mathbf{b}_{\bar{a}})\mathsf{S}_g(x_0,\mathbf{b}_g) - \mathsf{S}_{a\bar{a}}(x_0,\mathbf{b}_a,\mathbf{b}_{\bar{a}})]. \tag{1}$$

⋆ The linear approximation is the dipole form of the BFKL eqn. (NNN B.G.Zakharov (1993))

⋆ Recall the classic momentum space form

$$\frac{\partial f(x,\mathbf{p})}{\partial \log\frac{1}{x}} = \mathcal{K}_0 \int d^2\boldsymbol{\kappa}[2K(\underline{\mathbf{p}},\mathbf{p}-\boldsymbol{\kappa})f(x,\boldsymbol{\kappa}) - f(x,\mathbf{p})K(\boldsymbol{\kappa},\boldsymbol{\kappa}-\mathbf{p})] = (\mathcal{K}_{BFKL}\otimes f)(x,\mathbf{p})$$

⋆ The nonlinear case for the quark-antiquark dipole is the BK "equation" (Balitsky (1966), Kovchegov (1999)):

⋆ $K(\mathbf{p},\mathbf{p}+\mathbf{q}) = |\psi(\mathbf{p}) - \psi(\mathbf{p}+\mathbf{q})|^2$

⋆ Infrared regularization

$$\psi(\mathbf{p}) = \frac{\mathbf{p}}{\mathbf{p}^2+\mu^2}$$

The nonlinear case for the initial gg dipole (NNN, W.Schaefer (2006))

⋆ Large N_c: gluon-gluon dipole interacts as two uncorrelated overlapping quark-antiquark dipoles

$$\begin{aligned}\delta \mathsf{S}_{gg}(\mathbf{b}; x, \mathbf{r}) &= \int_x^1 dz_g \int d^2\boldsymbol{\rho} |\Psi_{ag}(z_g, \boldsymbol{\rho}) - \Psi_{ag}(z_g, \boldsymbol{\rho} + \mathbf{r})|^2 \\ &\times \{\mathsf{S}[\mathbf{b}; \sigma_{ggg}(x_0)] - \mathsf{S}[\mathbf{b}; \sigma_{gg}(x_0)]\} \\ &= \int_x^1 dz_g \int d^2\boldsymbol{\rho} |\Psi_{ag}(z_g, \boldsymbol{\rho}) - \Psi_{ag}(z_g, \boldsymbol{\rho} + \mathbf{r})|^2 \\ &\times \{\mathsf{S}[\mathbf{b}; \sigma_g(x_0, \boldsymbol{\rho})]\mathsf{S}[\mathbf{b}; \sigma_g(x_0, \boldsymbol{\rho} + \mathbf{r})]\mathsf{S}[\mathbf{b}; \sigma_g(x_0, \mathbf{r})] - \mathsf{S}[\mathbf{b}; \sigma_{gg}(x_0, \mathbf{r})]\}.\end{aligned}$$

⋆ Higher nonlinearity compared to the inititial quark-antiquark dipole
⋆ Not a closed form equation.
⋆ Only an approximation for small number of iterations $\lesssim \nu_A(\mathbf{b})$.
⋆ Inapplicable to the free-nucleon case.

Evolution of the collective glue in the momentum space

⋆ BK for quark-antiquark dipoles in the momentum space (NNN, W.Schaefer (1966))

$$\frac{\partial \phi(\mathbf{b},x,\mathbf{p})}{\partial \log(1/x)} = \mathcal{K}_{BFKL} \otimes \phi(\mathbf{b},x,\mathbf{p}) + \mathcal{Q}[\phi](\mathbf{b},x,\mathbf{p}) \,, \tag{2}$$

⋆ The nonlinear term: the real emission resembles coherent diffraction

$$\mathcal{Q}_{real}[\phi](\mathbf{b},x,\mathbf{p}) \;=\; -\mathcal{K}_0 \Big| \int d^2\mathbf{q} [\psi(\mathbf{p}) - \psi(\mathbf{p}+\mathbf{q})] \phi(\mathbf{b},x,\mathbf{q}) \Big|^2$$

It defines a triple pomeron vertex in the evolution eqn. Only undistorted $\psi's$ make it entirely different from the ones in incoherent dijet production!

⋆ The nonlinear term: the virtual emission

$$\mathcal{Q}_{virt}[\phi](\mathbf{b},x,\mathbf{p}) = \phi(\mathbf{b},x,\mathbf{p}) \int d^2\mathbf{q} \phi(\mathbf{b},x,\mathbf{q}) \left[\omega(\mathbf{p}) - \omega(\mathbf{p}+\mathbf{q})\right]$$

The nonlinear renormalization of the intercept of a collective glue

⋆ Glue for the gluon-gluon dipoles evolves as a convolution of the glue for quark-antiquark dipoles:

$$\Phi_{gg}(\mathbf{b},x,\mathbf{p}) = \big(\Phi \otimes \Phi\big)(\mathbf{b},x,\mathbf{p}). \tag{3}$$

Triple-pomeron (?) regime of diffraction off nucleons

⋆ Forward diffraction into large-mass $q(\mathbf{p}), \bar{q}, g(\mathbf{q})$, $\beta = Q^2/(Q^2 + M^2_{q\bar{q}g})$

$$\frac{\partial}{\partial \log \frac{1}{\beta}} \frac{d\sigma_N^D}{dz d^2\mathbf{p} d^2\mathbf{q} dt}\Bigg|_{t=0} = \frac{1}{16\pi(2\pi)^4} \cdot \left(\frac{C_A}{2C_F}\right)^2 \cdot 4\alpha_S C_F P_{q\gamma}(z)$$
$$\left| \int d^2\boldsymbol{\kappa} f(x_{\mathbb{P}}, \boldsymbol{\kappa}) H^N_{ij}(\boldsymbol{\kappa}, \mathbf{q}, \mathbf{p}) \right|^2, \quad (4)$$

⋆ Try a triple-pomeron reinterpretation?

$$\begin{aligned} H^N_{ij}(\boldsymbol{\kappa}, \mathbf{q}, \mathbf{p}) &= \psi_i(\mu^2, \mathbf{q})\{[\psi_j(\varepsilon^2, \mathbf{p}+\mathbf{q}) - \psi_j(\varepsilon^2, \mathbf{p})] \\ &+ +[\psi_j(\varepsilon^2, \mathbf{p}-\boldsymbol{\kappa}+\mathbf{q}) - \psi_j(\varepsilon^2, \mathbf{p}-\boldsymbol{\kappa})]\} \\ &- \{\mathbf{q} \to \mathbf{q}+\boldsymbol{\kappa}\}, \end{aligned} \quad (5)$$

⋆ $\psi_j(\varepsilon^2, \mathbf{p})$ from the $\gamma^* \to q\bar{q}$, where $\varepsilon^2 = z(1-z)Q^2 = m_q^2$
⋆ $H^N_{ij}(\boldsymbol{\kappa}, \mathbf{q}, \mathbf{p})$ does not admit factorization into the photon impact factor and triple-pomeron vertex.

Triple-pomeron regime of diffraction off heavy nuclei

$$\frac{\partial}{\partial \log \frac{1}{\beta}} \frac{d\sigma_A^D}{dz d^2\mathbf{b} d^2\mathbf{p} d^2\mathbf{q}} = \frac{1}{(2\pi)^4} 4\alpha_S C_F P_{q\gamma}(z)$$

$$\times \left| \int d^2\boldsymbol{\kappa}_1 d^2\boldsymbol{\kappa}_2 \Phi(\mathbf{b}, x_{\mathbb{P}}, \boldsymbol{\kappa}_1) \Phi(\mathbf{b}, x_{\mathbb{P}}, \boldsymbol{\kappa}_2) H_{ij}^A(\boldsymbol{\kappa}_1, \boldsymbol{\kappa}_2, \mathbf{q}, \mathbf{p}) \right|^2,$$

$$\begin{aligned} H_{ij}^A(\boldsymbol{\kappa}_1, \boldsymbol{\kappa}_2, \mathbf{q}, \mathbf{p}) &= \psi_i(\mu^2, \mathbf{q})[\psi_j(\varepsilon^2, \mathbf{p} - \boldsymbol{\kappa}_1 + \mathbf{q}) - \psi_j(\varepsilon^2, \mathbf{p} - \boldsymbol{\kappa}_1)] \\ &- \{\mathbf{q} \to \mathbf{q} + \boldsymbol{\kappa}_1 + \boldsymbol{\kappa}_2\} \end{aligned} \quad (6)$$

⋆ Only undistorted $\psi's$, but

⋆ Diffraction neither off free-nucleons nor heavy nuclei admits a simple reinterpretation in terms of a diffractive pomeron: there is a strong entanglement of the photon impact factor and a triple-pomeron coupling

⋆ No semblance of the "diffractive triple vertex" in the evolution of the colective nuclear glue: still another breaking of the old AGK rules

⋆ Possible recovery of a triple-pomeron reinterpretation in the restricted LLQ^2 regime?

Summary and further applications:

- Nuclear collective glue is an observable defined by coherent diffraction
- Nonlinear $k_\perp$-factorization: explicit quadratures for all observables in terms of the collective
- Expansion of nuclear unintegrated glue in terms of *collective glue of overlapping nucleons and coherent nuclear gluons*.
- *A non-abelian* intranuclear evolution of color dipoles.
- Incoherent multiproduction off nuclei: the universality class-dependent AGK rules
- Coherent diffraction does not factorize into the photon impact factor and triple-pomeron vertex
- Distinct cut and uncut and evolution-defined mutipomeron vertices in QCD.
- Further complications with coherent distortions of multipomeron vertices.
- A beauty of AGK-73 is lost in nonabelian QCD