Odderon at the EIC from exclusive χ_c production

Sanjin Benić (University of Zagreb)

SB, Dumitru, Kaushik, Motyka, Stebel, 2402.19134

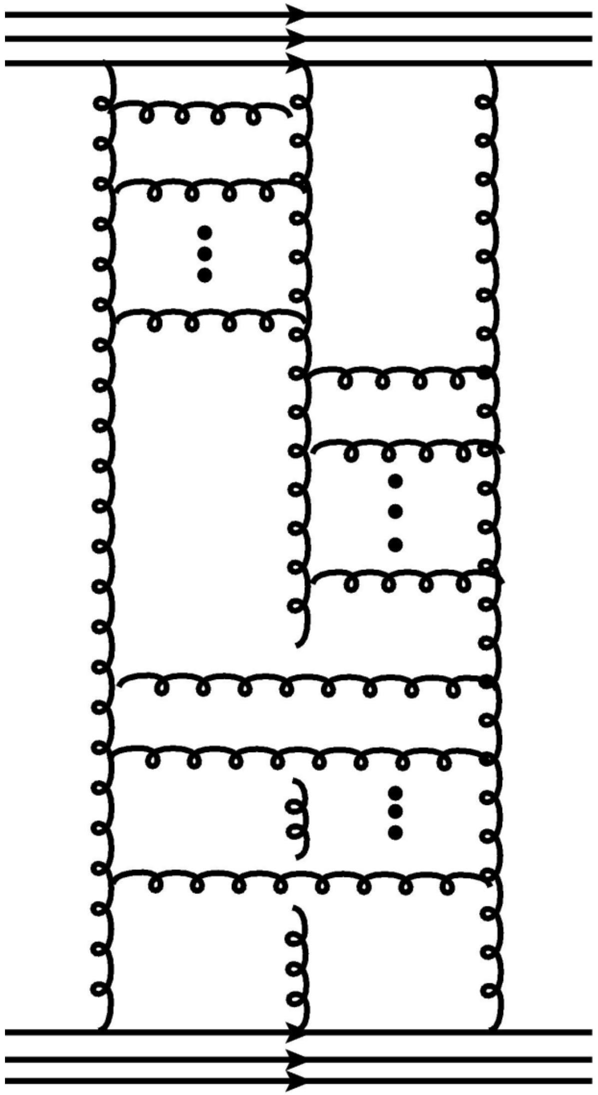
DIS 2024, Grenoble, France, April 9, 2024

Croatian Science Foundation

Odderon in QCD

. odderon is a state with vacuum quantum numbers which is **C-odd**

Lukaszuk, Nicolescu (1973)
Ewerz (2003)
McNulty, DIS24, Mon 14:00



-> In QCD at least three gluons contracted with d_{abc} color factor

. is pp and p$\bar{\text{p}}$ scattering same at high energy?

. Bartels-Jaroszewicz-Kwiecinski-Praszalowicz (BJKP) equation was constructed
-> pairwise BFKL ladders between three (reggeized) gluons

Bartels (1979)
Jaroszewicz (1980)
Kwiecinski, Praszalowicz (1980)

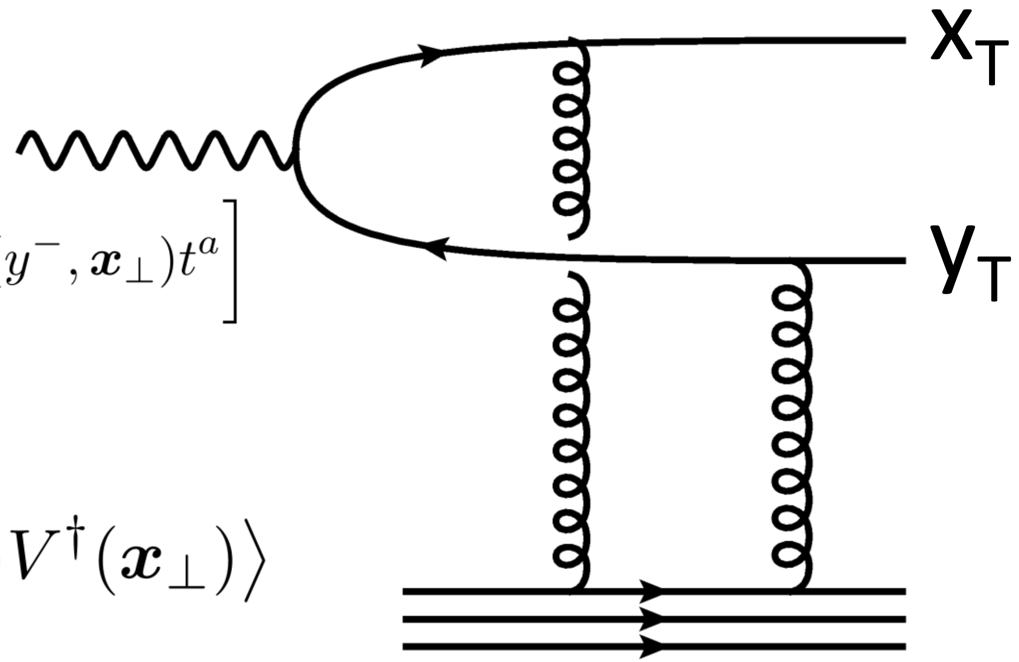
Odderon: a modern perspective

Kovchegov, Szymanowski, Wallon (2004)
Hatta, Iancu, Itakura, McLerran (2005)
Jeon, Venugopalan (2005)
Lappi, Ramnath, Rummukainen, Weigert (2016)

. dipole S-matrix

$$\mathcal{D}(\boldsymbol{x}_\perp,\boldsymbol{y}_\perp)=\frac{1}{N_c}\mathrm{tr}\left\langle V(\boldsymbol{x}_\perp)V^\dagger(\boldsymbol{y}_\perp)\right\rangle$$

$$V(\boldsymbol{x}_\perp)=\mathcal{P}\exp\left[-\mathrm{i}g\int \mathrm{d}y^- A^{+,a}(y^-,\boldsymbol{x}_\perp)t^a\right]$$



. odderon as the imaginary part

$$\mathcal{O}(\boldsymbol{x}_\perp,\boldsymbol{y}_\perp)=-\frac{1}{2\mathrm{i}N_c}\mathrm{tr}\left\langle V(\boldsymbol{x}_\perp)V^\dagger(\boldsymbol{y}_\perp)-V(\boldsymbol{y}_\perp)V^\dagger(\boldsymbol{x}_\perp)\right\rangle$$

. expand the Wilson line

$$\mathcal{O}(\boldsymbol{x}_\perp,\boldsymbol{y}_\perp)=-\frac{g^3}{24N_c}d^{abc}(\alpha^a(\boldsymbol{x}_\perp)-\alpha^a(\boldsymbol{y}_\perp))(\alpha^b(\boldsymbol{x}_\perp)-\alpha^b(\boldsymbol{y}_\perp))(\alpha^c(\boldsymbol{x}_\perp)-\alpha^c(\boldsymbol{y}_\perp))$$

. charge conjugation $\boldsymbol{x}_\perp \leftrightarrow \boldsymbol{y}_\perp$ ➡ odderon flips sign (C-odd)

Odderon: a modern perspective

$\boldsymbol{r}_\perp = \boldsymbol{x}_\perp - \boldsymbol{y}_\perp$ (dipole size) $\boldsymbol{b}_\perp = \frac{1}{2}(\boldsymbol{x}_\perp + \boldsymbol{y}_\perp)$ (impact parameter)

-> odderon linear in $\boldsymbol{r}_\perp$ -> need another vector: $\boldsymbol{r}_\perp \cdot \boldsymbol{b}_\perp$

-> odderon as an off-forward amplitude (GTMD)

-> vanishes at b_T=0

Kovchegov, Szymanowski, Wallon (2004)
Hatta, Iancu, Itakura, McLerran (2005)
Motyka (2006)

$$\mathcal{D}(\boldsymbol{r}_\perp, \boldsymbol{b}_\perp) = 1 - \mathcal{N}(\boldsymbol{r}_\perp, \boldsymbol{b}_\perp) + i\mathcal{O}(\boldsymbol{r}_\perp, \boldsymbol{b}_\perp)$$

. non-linear (Balitsky-Kovchegov) evolution equation (written here in local approx)

$$\frac{\partial \mathcal{O}(\boldsymbol{r}_\perp, \boldsymbol{b}_\perp)}{\partial Y} = \frac{\alpha_S N_c}{2\pi^2} \int_{\boldsymbol{r}_{1\perp}} \frac{\boldsymbol{r}_\perp^2}{\boldsymbol{r}_{1\perp}^2 \boldsymbol{r}_{2\perp}^2} \Big[\mathcal{O}(\boldsymbol{r}_{1\perp}, \boldsymbol{b}_\perp) + \mathcal{O}(\boldsymbol{r}_{2\perp}, \boldsymbol{b}_\perp) - \mathcal{O}(\boldsymbol{r}_\perp, \boldsymbol{b}_\perp)$$

$$- \mathcal{N}(\boldsymbol{r}_{1\perp}, \boldsymbol{b}_\perp)\mathcal{O}(\boldsymbol{r}_{2\perp}, \boldsymbol{b}_\perp) - \mathcal{O}(\boldsymbol{r}_{1\perp}, \boldsymbol{b}_\perp)\mathcal{N}(\boldsymbol{r}_{2\perp}, \boldsymbol{b}_\perp)\Big]$$

linear piece: equivalent to BJKP

saturation corrections: acts to suppress the odderon at high energy

$Y = \log(1/x)$

Odderon searches

. recently exciting news by the 5-sigma odderon discovery in $p\bar{p}$ vs pp

. interpretation in terms of a hard (p)QCD odderon?

➡ **how about discovering the odderon in DIS?**

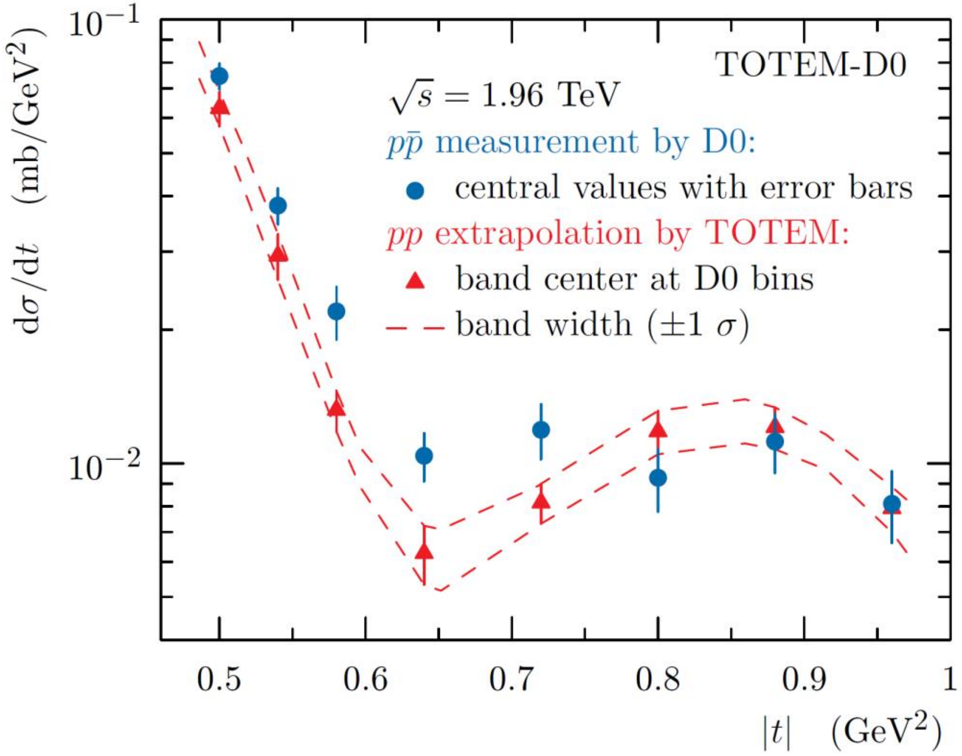
. exclusive reactions that tag onto the negative C-parity in the target

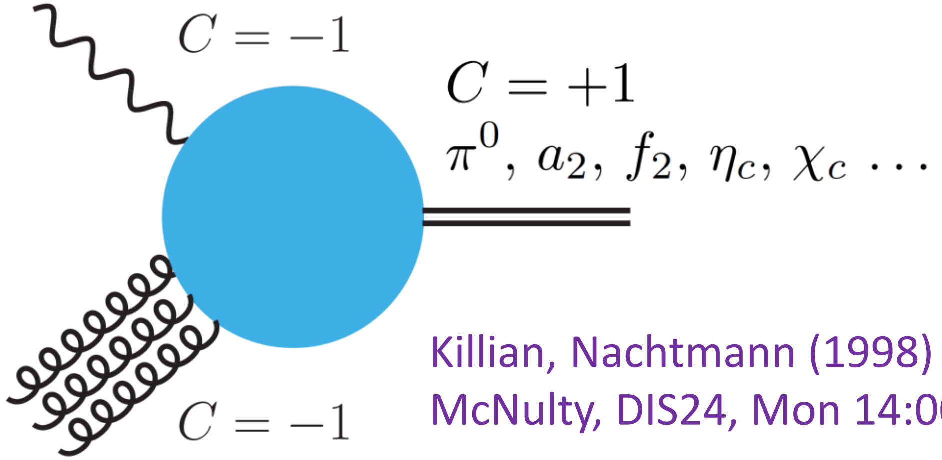
. in DIS C=+1 meson/quarkonia in the final state

. HERA: null result from H1 collaboration

$\sigma(\gamma^* p \to \pi^0 N^*) < 49$ nb (similar for a_2 and f_2)

TOTEM, D0 (2021)





Killian, Nachtmann (1998)

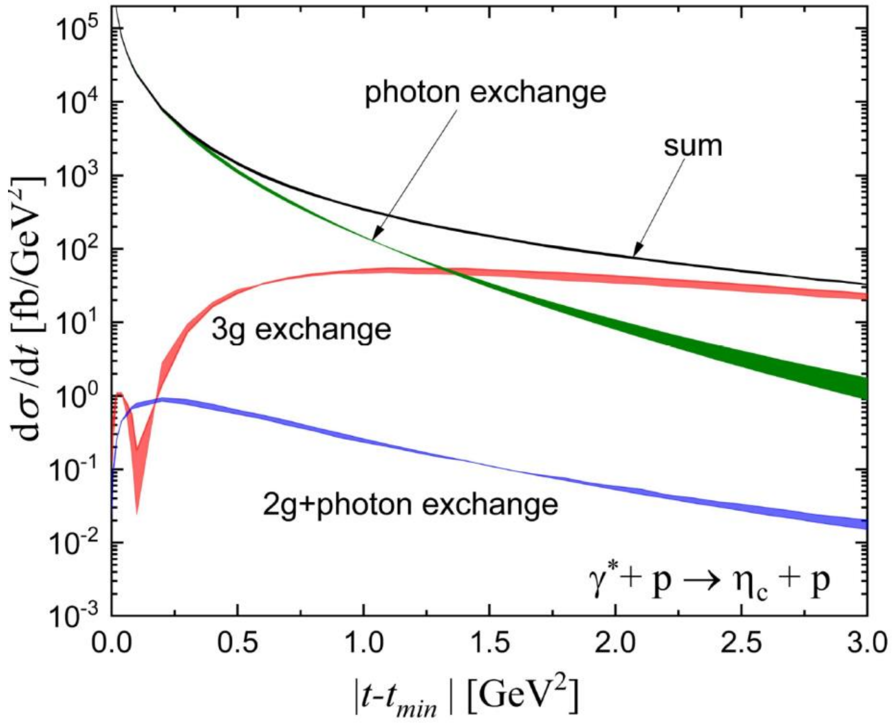
McNulty, DIS24, Mon 14:00

Motivations for this work

. from late 90's theorists explore exclusive η_c

. **no experimental detection so far**

Czyzewski, Kwiecinski, Motyka, Sadzikowski (1997)
Bartels, Braun, Colferai, Vacca (2001)
Dumitru, Stebel (2019)
SB, Horvatić, Kaushik, Vivoda (2023)



1. issues with η_c detection (small branching ratios to hadronic channels)

-> consider other C=+1 quarkonia: χ_{cJ} (J = 0, 1, 2) family

. χ_c is a P-wave so it is above J/ψ -> main decay mode χ_{cJ}->J/ψ γ (BR ~ 30% for χ_{c1}!)

. about 56 χ_{c1}'s and ~12 χ_{c2}'s detected (!) near threshold with GlueX   Pentchev, DIS2023, GHP 2023

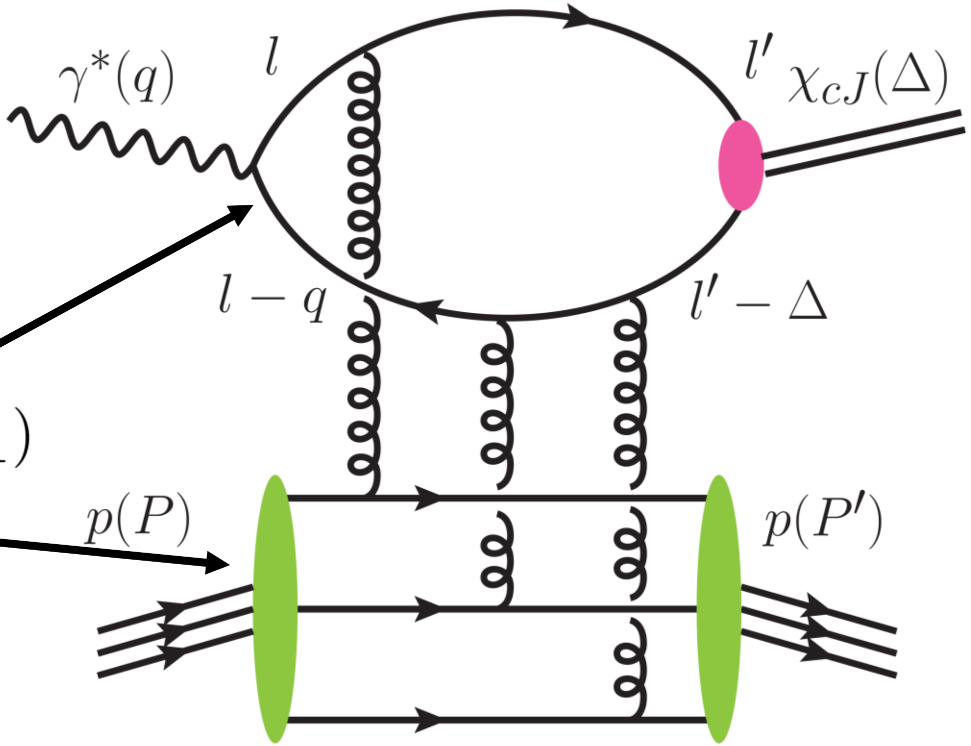
2. odderon cross sections in general small but EIC luminosity is high

-> discovery at the EIC?

Amplitude

$$\gamma^*(q)p(P) \to \mathcal{H}(\Delta)p(P')$$

$$\langle \mathcal{M}_{\lambda\bar{\lambda}} \rangle = 2q^- N_c \int_{\boldsymbol{r}_\perp \boldsymbol{b}_\perp} \mathrm{e}^{-\mathrm{i}\boldsymbol{\Delta}_\perp \cdot \boldsymbol{b}_\perp} \mathrm{i}\mathcal{O}(\boldsymbol{r}_\perp, \boldsymbol{b}_\perp) \mathcal{A}_{\lambda\bar{\lambda}}(\boldsymbol{r}_\perp, \boldsymbol{\Delta}_\perp)$$



. reduced amplitude

$$\mathcal{A}_{\lambda\bar{\lambda}}(\boldsymbol{r}_\perp, \boldsymbol{\Delta}_\perp) = \int_z \int_{\boldsymbol{l}_\perp \boldsymbol{l}'_\perp} \sum_{h\bar{h}} \Psi^{\gamma}_{\lambda,h\bar{h}}(\boldsymbol{l}_\perp, z) \Psi^{\mathcal{H}*}_{\bar{\lambda},h\bar{h}}(\boldsymbol{l}'_\perp - z\boldsymbol{\Delta}_\perp, z) \mathrm{e}^{\mathrm{i}(\boldsymbol{l}_\perp - \boldsymbol{l}'_\perp + \frac{1}{2}\boldsymbol{\Delta}_\perp)\cdot \boldsymbol{r}_\perp}$$

. perturbative photon wave function $\Psi^{\gamma}_{\lambda,h\bar{h}}(\boldsymbol{k}_\perp, z) \equiv \sqrt{z\bar{z}} \dfrac{\bar{u}_h(k) e q_c \not{\epsilon}(\lambda, q) v_{\bar{h}}(q-k)}{\boldsymbol{k}_\perp^2 + \varepsilon^2}$

$$\varepsilon \equiv \sqrt{m_c^2 + z\bar{z}Q^2} \qquad z = \frac{k^-}{q^-} \qquad \bar{z} \equiv 1 - z$$

C-even charmonia wave functions

scalar function: boosted Gaussian ansatz

$$\Psi^{\mathcal{H}}_{\bar\lambda,h\bar h}(\boldsymbol{k}_\perp, z) \equiv \frac{1}{\sqrt{z\bar z}} \underbrace{\bar u_h(k)\Gamma^{\mathcal{H}}_{\bar\lambda}(k,k')v_{\bar h}(k')}_{\text{spin structure}} \phi_{\mathcal{H}}(\boldsymbol{k}_\perp, z)$$

Forshaw, Sandapen, Shaw (2004)
Kowalski, Motyka, Watt (2006)

. covariant ansatz

polarization vector fo spin 1

$$\Gamma^{\mathcal{H}}_{\bar\lambda}(k,k') = \begin{cases} 1\ , & \mathcal{H} = \mathcal{S} \\ \mathrm{i}\gamma_5 \not{E}(\bar\lambda, \Delta_0)\ , & \mathcal{H} = \mathcal{A} \\ \frac{1}{4}\left(\gamma_\mu(k_\nu - k'_\nu) + \gamma_\nu(k_\mu - k'_\mu)\right) E^{\mu\nu}(\bar\lambda, \Delta_0)\ , & \mathcal{H} = \mathcal{T} \end{cases} \quad \chi_{cJ}$$

spin 2 -> coupling to the energy momentum tensor

spin 2 polarization tensor: in terms of $E^\mu(\bar\lambda, \Delta_0)$ via Clebsch-Gordans

. transversality condition

$$\Delta_0 \cdot E(\bar\lambda, \Delta_0) = 0 \qquad \Delta_0 = k + k'$$

Berger, Donnachie, Dosch, Nachtmann (2000)
SB, Dumitru, Kaushik, Motyka, Stebel (2024)

Final amplitudes: scalar charmonia

SB, Dumitru, Kaushik, Motyka, Stebel (2024)

. reduced amplitudes

off-forward phase $\boldsymbol{\delta}_\perp = \frac{1}{2}(z-\bar{z})\boldsymbol{\Delta}_\perp$

$$\mathcal{A}_0(\boldsymbol{r}_\perp, \boldsymbol{\Delta}_\perp) = eq_c \int_z \mathrm{e}^{-\mathrm{i}\boldsymbol{\delta}_\perp\cdot\boldsymbol{r}_\perp} \mathcal{A}_L(r_\perp)$$

$$\mathcal{A}_{\lambda=\pm1}(\boldsymbol{r}_\perp, \boldsymbol{\Delta}_\perp) = eq_c \lambda \mathrm{e}^{\mathrm{i}\lambda\phi_r} \int_z \mathrm{e}^{-\mathrm{i}\boldsymbol{\delta}_\perp\cdot\boldsymbol{r}_\perp} \mathcal{A}_T(r_\perp)$$

$$\mathcal{A}_L(r_\perp) \equiv -\frac{2}{\pi} m_c Q(z-\bar{z}) K_0(\varepsilon r_\perp)\phi_S(r_\perp, z)$$

$$\mathcal{A}_T(r_\perp) \equiv \frac{\mathrm{i}\sqrt{2}}{2\pi}\frac{m_c}{z\bar{z}}\left[(z-\bar{z})^2 \varepsilon K_1(\varepsilon r_\perp)\phi_S(r_\perp, z) - K_0(\varepsilon r_\perp)\frac{\partial \phi_S}{\partial r_\perp}\right]$$

. numerics-ready full amplitudes (after removing overall phase)

odderon harmonics
(we keep only k=0 mode)

$$\widetilde{\mathcal{M}}_L = 8\pi N_c e q_c \sum_{k=0}^{\infty} (-1)^k \int_z \int_0^\infty r_\perp \mathrm{d}r_\perp \mathcal{O}_{2k+1}(r_\perp, \Delta_\perp) \mathcal{A}_L(r_\perp) \,\mathrm{sgn}(z-\bar{z}) J_{2k+1}(r_\perp \delta_\perp)$$

$$\widetilde{\mathcal{M}}_T = 4\pi \mathrm{i} N_c e q_c \sum_{k=0}^{\infty} (-1)^k \int_z \int_0^\infty r_\perp \mathrm{d}r_\perp \mathcal{O}_{2k+1}(r_\perp, \Delta_\perp) \mathcal{A}_T(r_\perp) \left[J_{2k}(r_\perp \delta_\perp) - J_{2k+2}(r_\perp \delta_\perp)\right]$$

Final amplitudes: axial vector charmonia

$$\mathcal{A}_{LL}(r_\perp) = 0$$

no contribution when photon and axial charmonia are longitudinally polarized

$$\mathcal{A}_{LT}(r_\perp) \equiv \frac{\sqrt{2}}{\pi} Q K_0(\varepsilon r_\perp) \frac{\partial \phi_{\mathcal{A},T}}{\partial r_\perp}$$

$$\mathcal{A}_{TL}(r_\perp) \equiv \frac{\sqrt{2}}{\pi} \frac{1}{z\bar{z}} \frac{1}{M_{\mathcal{A}}} \left[-m_c^2 K_0(\varepsilon r_\perp) \frac{\partial \phi_{\mathcal{A},L}}{\partial r_\perp} + \varepsilon K_1(\varepsilon r_\perp) \boldsymbol{\nabla}_\perp^2 \phi_{\mathcal{A},L} \right]$$

$$\mathcal{A}_{TT}(r_\perp) \equiv -\frac{\mathrm{i}}{\pi} \frac{z-\bar{z}}{z\bar{z}} \left[\frac{\partial \phi_{\mathcal{A},T}}{\partial r_\perp} \varepsilon K_1(\varepsilon r_\perp) - m_c^2 K_0(\varepsilon r_\perp) \phi_{\mathcal{A},T} \right]$$

only polarization preserving transition

$$\widetilde{\mathcal{M}}_B = 4\pi \mathrm{i} N_c e q_c \sum_{k=0}^{\infty} (-1)^k \int_z \int_0^\infty r_\perp \mathrm{d}r_\perp \mathcal{O}_{2k+1}(r_\perp, \Delta_\perp) \mathcal{A}_B(r_\perp) \left[J_{2k}(r_\perp \delta_\perp) - J_{2k+2}(r_\perp \delta_\perp) \right], \qquad B = TL, LT$$

$$\widetilde{\mathcal{M}}_{TT} = 8\pi N_c e q_c \sum_{k=0}^{\infty} (-1)^k \int_z \int_0^\infty r_\perp \mathrm{d}r_\perp \mathcal{O}_{2k+1}(r_\perp, \Delta_\perp) \mathcal{A}_{TT}(r_\perp)\, \mathrm{sgn}(z-\bar{z}) J_{2k+1}(r_\perp \delta_\perp),$$

SB, Dumitru, Kaushik, Motyka, Stebel (2024)

Final amplitudes: tensor charmonia

$$\widetilde{\mathcal{M}}_B = -4\pi N_c e q_c \sum_{k=0}^{\infty} (-1)^k \int_z \int_0^{\infty} r_\perp \mathrm{d}r_\perp \mathcal{O}_{2k+1}(r_\perp, \Delta_\perp) \mathcal{A}_B(r_\perp) \times \mathrm{sgn}(z-\bar{z}) \left[J_{2k+3}(r_\perp \delta_\perp) + J_{2k-1}(r_\perp \delta_\perp) \right] , \quad B = LT2, TTf ,$$

$$\widetilde{\mathcal{M}}_B = 4\pi \mathrm{i} N_c e q_c \sum_{k=0}^{\infty} (-1)^k \int_z \int_0^{\infty} r_\perp \mathrm{d}r_\perp \mathcal{O}_{2k+1}(r_\perp, \Delta_\perp) \mathcal{A}_B(r_\perp) \times \left[J_{2k}(r_\perp \delta_\perp) - J_{2k+2}(r_\perp \delta_\perp) \right] , \quad B = TT2p, LT, TL ,$$

$$\widetilde{\mathcal{M}}_B = 8\pi N_c e q_c \sum_{k=0}^{\infty} (-1)^k \int_z \int_0^{\infty} r_\perp \mathrm{d}r_\perp \mathcal{O}_{2k+1}(r_\perp, \Delta_\perp) \mathcal{A}_B(r_\perp) \mathrm{sgn}(z-\bar{z}) J_{2k+1}(r_\perp \delta_\perp) , \quad B = TTp, LL ,$$

$$\widetilde{\mathcal{M}}_{TT2f} = 4\pi \mathrm{i} N_c e q_c \sum_{k=0}^{\infty} (-1)^k \int_z \int_0^{\infty} r_\perp \mathrm{d}r_\perp \mathcal{O}_{2k+1}(r_\perp, \Delta_\perp) \mathcal{A}_{TT2f}(r_\perp) \left[J_{2k+4}(r_\perp \delta_\perp) - J_{2k-2}(r_\perp \delta_\perp) \right] ,$$

$$\mathcal{A}_{LT2}(r_\perp) \equiv \frac{1}{\pi}(z-\bar{z}) Q K_0(\varepsilon r_\perp) \left(\frac{\partial^2 \phi_{\mathcal{T},T2}}{\partial r_\perp^2} - \frac{1}{r_\perp} \frac{\partial \phi_{\mathcal{T},T2}}{\partial r_\perp} \right) ,$$

$$\mathcal{A}_{TT2,p}(r_\perp) \equiv -\frac{\mathrm{i}}{\sqrt{2}\pi} \frac{1}{z\bar{z}} \left((z^2+\bar{z}^2) \varepsilon K_1(\varepsilon r_\perp) \left(\frac{\partial^2 \phi_{\mathcal{T},T2}}{\partial r_\perp^2} - \frac{1}{r_\perp} \frac{\partial \phi_{\mathcal{T},T2}}{\partial r_\perp} \right) + m_c^2 K_0(\varepsilon r_\perp) \frac{\partial \phi_{\mathcal{T},T2}}{\partial r_\perp} \right) ,$$

$$\mathcal{A}_{TT2,f}(r_\perp) \equiv \frac{\mathrm{i}\sqrt{2}}{\pi} \varepsilon K_1(\varepsilon r_\perp) \left(\frac{\partial^2 \phi_{\mathcal{T},T2}}{\partial r_\perp^2} - \frac{1}{r_\perp} \frac{\partial \phi_{\mathcal{T},T2}}{\partial r_\perp} \right) ,$$

$$\mathcal{A}_{LT}(r_\perp) \equiv -\frac{\mathrm{i}}{2\pi} Q M_{\mathcal{T}} \left(3 - 4(z^2+\bar{z}^2) \right) K_0(\varepsilon r_\perp) \frac{\partial \phi_{\mathcal{T},T}}{\partial r_\perp} ,$$

$$\mathcal{A}_{TT,p}(r_\perp) = -\frac{\sqrt{2} M_{\mathcal{T}}}{4\pi} \frac{z-\bar{z}}{z\bar{z}} \left[m_c^2 K_0(\varepsilon r_\perp) \phi_{\mathcal{T},T}(r_\perp, z) - (z-\bar{z})^2 \varepsilon K_1(\varepsilon r_\perp) \frac{\partial \phi_{\mathcal{T},T}}{\partial r_\perp} \right] ,$$

$$\mathcal{A}_{TT,f}(r_\perp) = -\frac{\sqrt{2} M_{\mathcal{T}}}{\pi} (z-\bar{z}) \varepsilon K_1(\varepsilon r_\perp) \frac{\partial \phi_{\mathcal{T},T}}{\partial r_\perp} ,$$

$$\mathcal{A}_{LL}(r_\perp) = -\frac{\sqrt{2} Q}{\sqrt{3}\pi} (z-\bar{z}) K_0(\varepsilon r_\perp) \left(3\boldsymbol{\nabla}_\perp^2 - 2m_c^2 \right) \phi_{\mathcal{T},L}(r_\perp, z) ,$$

$$\mathcal{A}_{TL}(r_\perp) = \frac{\mathrm{i}}{2\pi\sqrt{3}} \frac{1}{z\bar{z}} \left[\varepsilon K_1(\varepsilon r_\perp)(z-\bar{z})^2 \left(3\boldsymbol{\nabla}_\perp^2 - 2m_c^2 \right) \phi_{\mathcal{T},L} - m_c^2 K_0(\varepsilon r_\perp) \frac{\partial \phi_{\mathcal{T},L}}{\partial r_\perp} \right] .$$

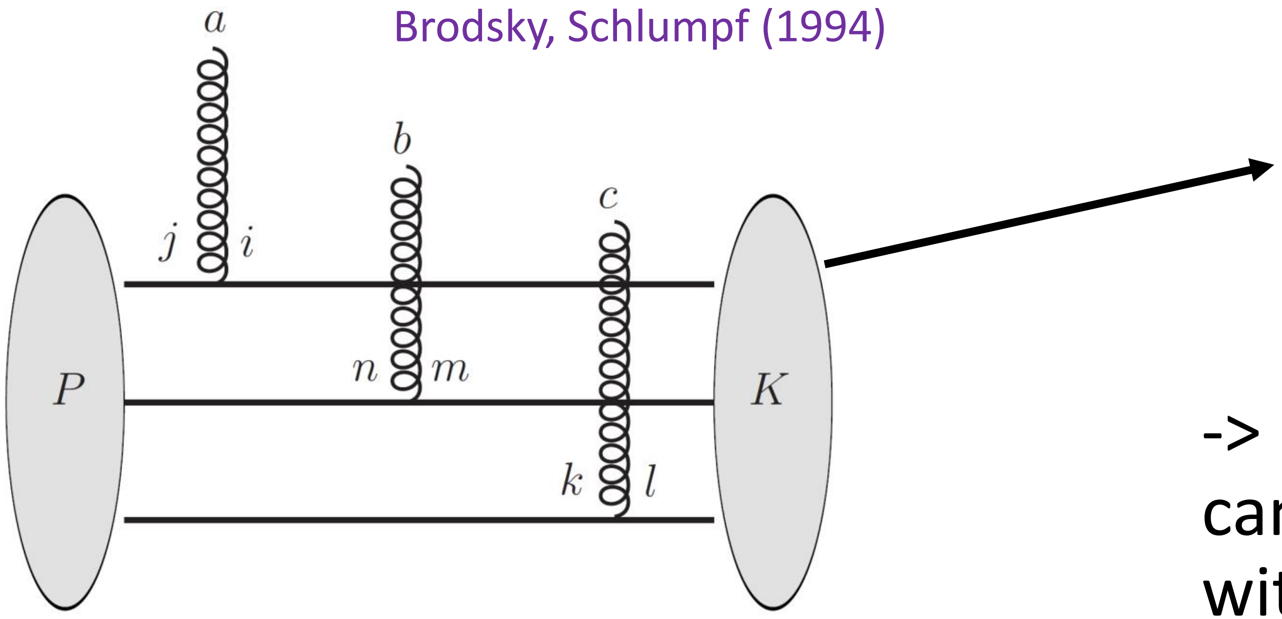
all overlaps calculated, all amplitudes found

SB, Dumitru, Kaushik, Motyka, Stebel (2024)

Odderon initial condition

. a microscopic quark model of the proton

Dumitru, Miller, Venugopalan (2018)
Brodsky, Schlumpf (1994)



an example of a 3-body contribution that becomes relevant at high-t

-> Landshoff mechanism: gluons can give a high-t kick to the proton without breaking it

Landshoff (1974)

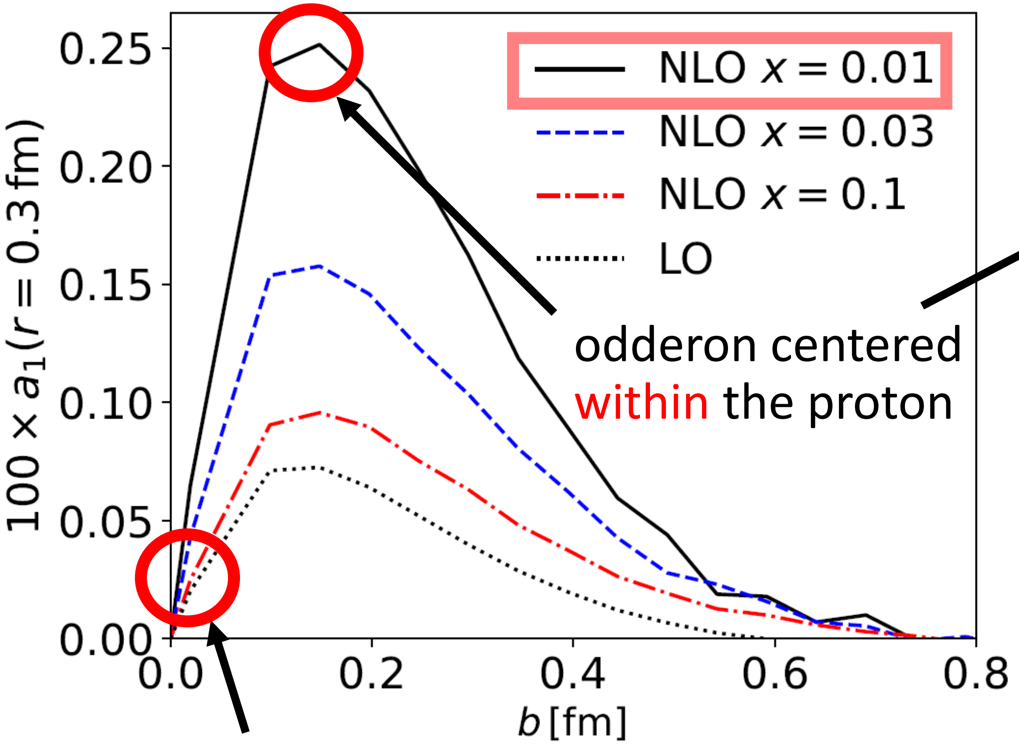
. model computation fixes the overall sign of the odderon

. evolution linear in O -> odderon sign not changed by evolution

Odderon evolved

. In the numerical approach the proton is described by |qqq>+|qqqg> Fock state computation by Dumitru, Mantysaari and Paatelainen

we take $\alpha_s(2m_c)$~0.25



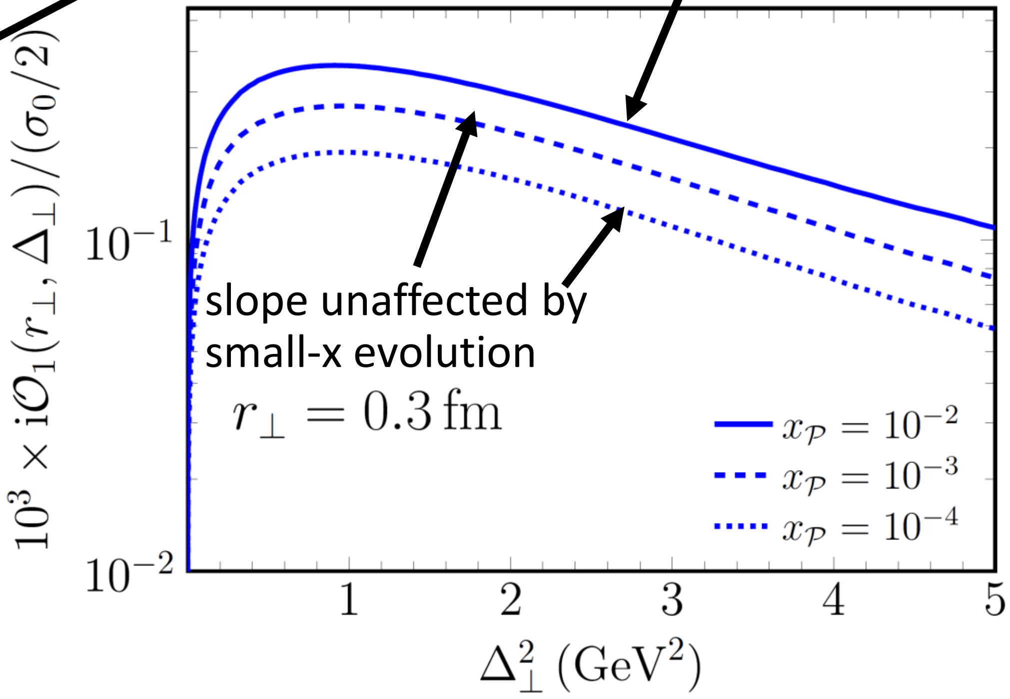
odderon centered within the proton

vanishes at the origin

Dumitru, Mantysaari, Paatelainen (2022)
Dumitru, Mantysaari, Paatelainen (2023)

Fourier transform

Landshoff mechanism



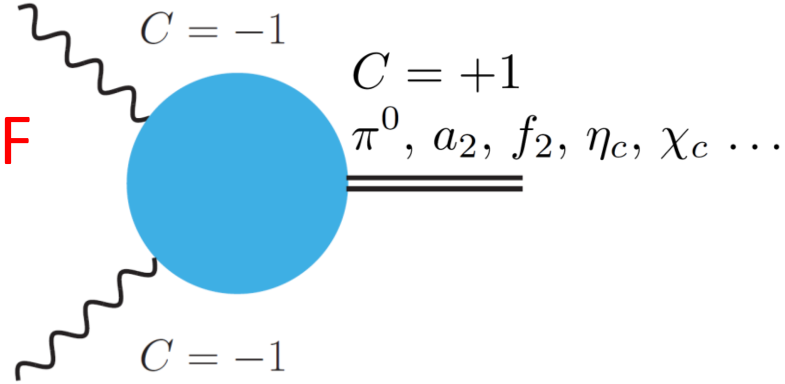
slope unaffected by small-x evolution

SB, Horvatic, Kaushik, Vivoda (2023)
SB, Dumitru, Kaushik, Motyka, Stebel (2024)

The Primakoff process

. usually we do not care about QED contributions to QCD process
. but in case of odderon QCD cross section is small (~α_S^6)
-> Primakoff process is a serious background to the odderon searches

. replace odderon with photon exchange



$$\gamma^*(q)\gamma^*(\ell) \to \mathcal{H}(\Delta)$$

QED charge FF

$$\mathcal{O}(\boldsymbol{r}_\perp, \boldsymbol{\Delta}_\perp) \to 8\pi i q_c \alpha \sin\left(\frac{\boldsymbol{\Delta}_\perp \cdot \boldsymbol{r}_\perp}{2}\right) \frac{F_1(\Delta_\perp)}{\boldsymbol{\Delta}_\perp^2}$$

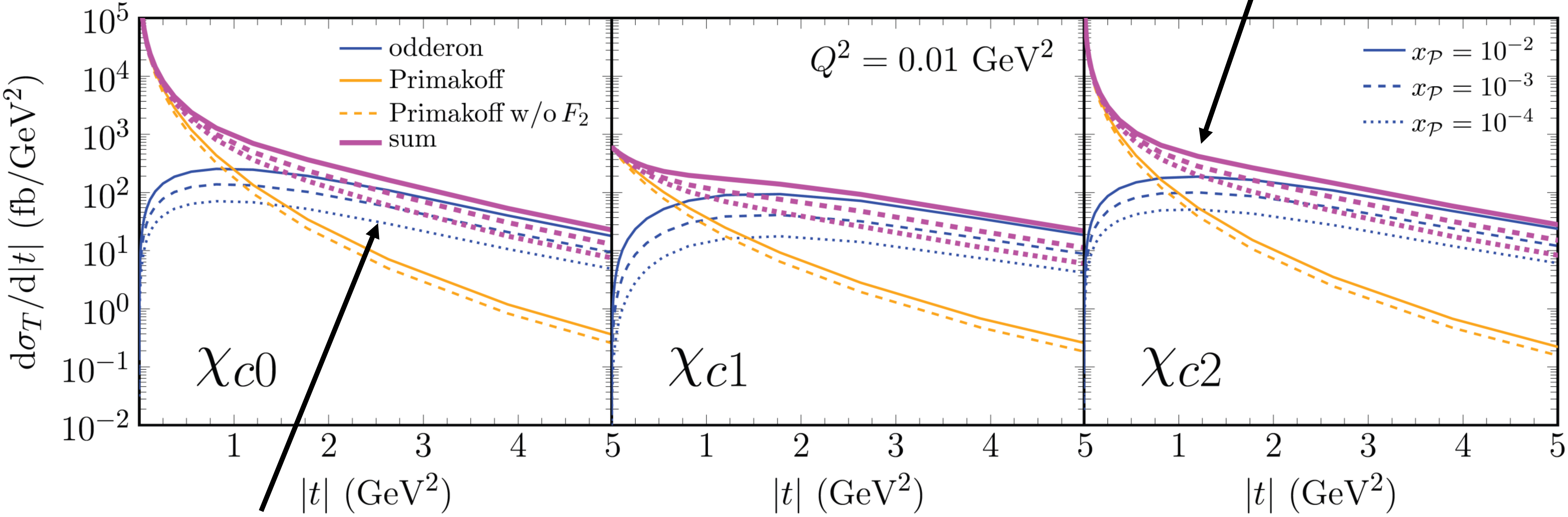
. In numerical computations we also take into account Pauli (spin-flip) FF (up to 50% correction at finite t)

$$\langle \mathcal{M}_{\lambda\bar\lambda}(\gamma^* p \to \mathcal{H}p)\rangle = -n_\mu \mathcal{M}^\mu_{\lambda\bar\lambda}(\gamma^*\gamma^* \to \mathcal{H})\left[\frac{eF_1(\ell_\perp)}{\boldsymbol{\ell}_\perp^2}\delta_{hh'} + \frac{eF_2(\ell_\perp)}{\boldsymbol{\ell}_\perp^2}\frac{\ell_\perp}{2m_N} h e^{ih\phi_\ell}\delta_{h,-h'}\right]$$

t-distributions

. odderon important after |t|~ 1 GeV^2, low t-region dominated by Primakoff

coherent sum of photon+odderon

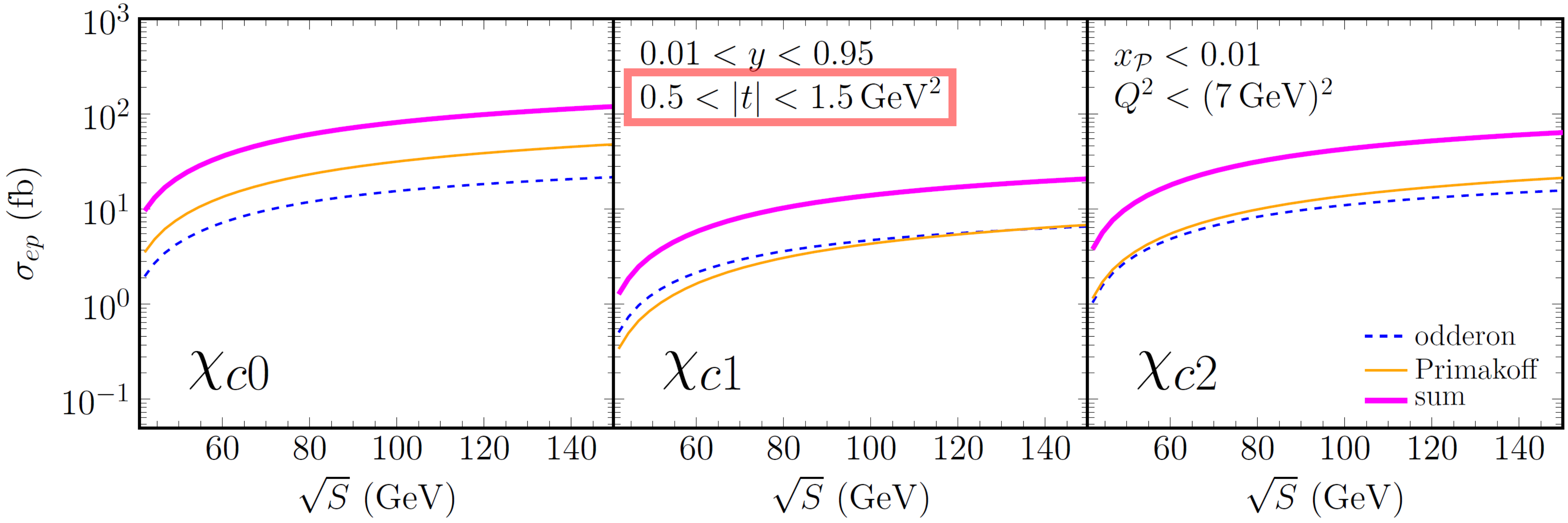


Landshoff mechanism

photon and odderon interfere **constructively**

SB, Dumitru, Kaushik, Motyka, Stebel (2024)

Total electroproduction cross section



SB, Dumitru, Kaushik, Motyka, Stebel (2024)

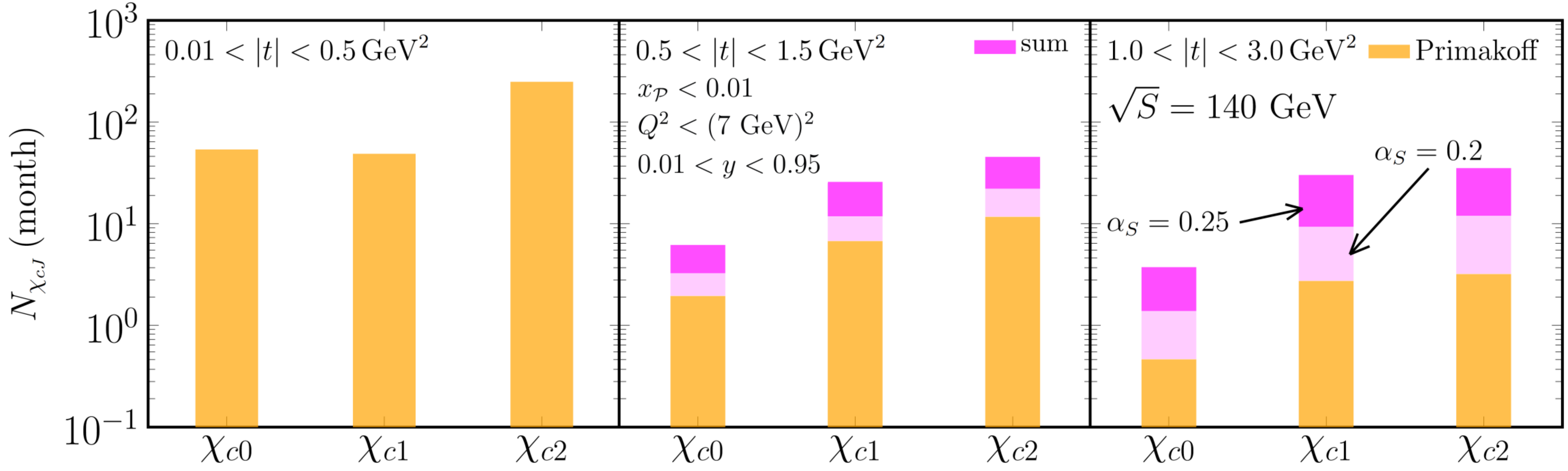
. note: at the EIC proton detection is up to p_T~1.3 GeV

EIC Yellow report
Van Hulse: DIS24, Mon, 14:30

Expected number of events at the EIC

. detection channel: χ_{cJ} -> $J/\psi\gamma$, J/ψ->l^+l^-

SB, Dumitru, Kaushik, Motyka, Stebel (2024)



. we predict **excess** in odderon events over Primakoff background

. for χ_{c1} (30% BR to $J/\psi + \gamma$): with EIC luminosity 10^{34} cm^{-2} s^{-1}
expect ~20 events/month (only Primakoff~5 events/month)

Concluding remarks

. can the **'hard' odderon (ggg exchange) be discovered** at the EIC?

. our suggestion: exclusive χ_c production

. odderon signal enhancement thanks to a constructive photon-odderon interference

-> event excess above the Primakoff background

. we predict about a few dozen events/month at the EIC (max energy, max luminosity)

. was not possible at HERA.. (luminosity ~ 10^{32} cm^{-2} s^{-1})

. need moderate to high |t| and low Q^2 (opposite from GPDs)

The Primakoff process in the t->0 limit

. Strong constraint on the Primakoff cross section at t->0 by the γγ width

For J≠1 (Landau-Yang theorem)

$$\lim_{|t|\to 0} |t| \frac{\mathrm{d}\sigma(\gamma p \to \mathcal{H} p)}{\mathrm{d}|t|} = \frac{8\pi\alpha(2J+1)\Gamma(\mathcal{H}\to\gamma\gamma)}{M_{\mathcal{H}}^3}$$

. Extracted γγ widths in accordance with the literature

Li, Li, Vary (2022)

. Charmonia model wave function -> boosted Gaussian

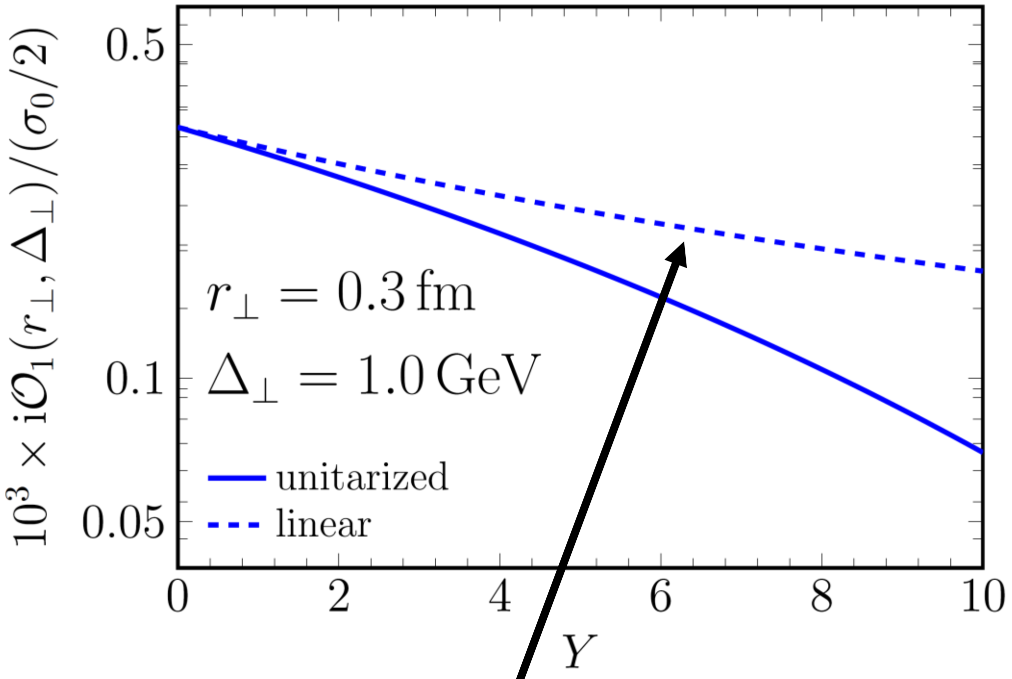
$$\phi_{\mathcal{H},B}(r_\perp, z) = \mathcal{N}_{\mathcal{H},B}\, z\bar{z} \exp\left(-\frac{m_c^2 \mathcal{R}_{\mathcal{H}}^2}{8z\bar{z}} - \frac{2z\bar{z}r_\perp^2}{\mathcal{R}_{\mathcal{H}}^2} + \frac{1}{2}m_c^2\mathcal{R}_{\mathcal{H}}^2\right)$$

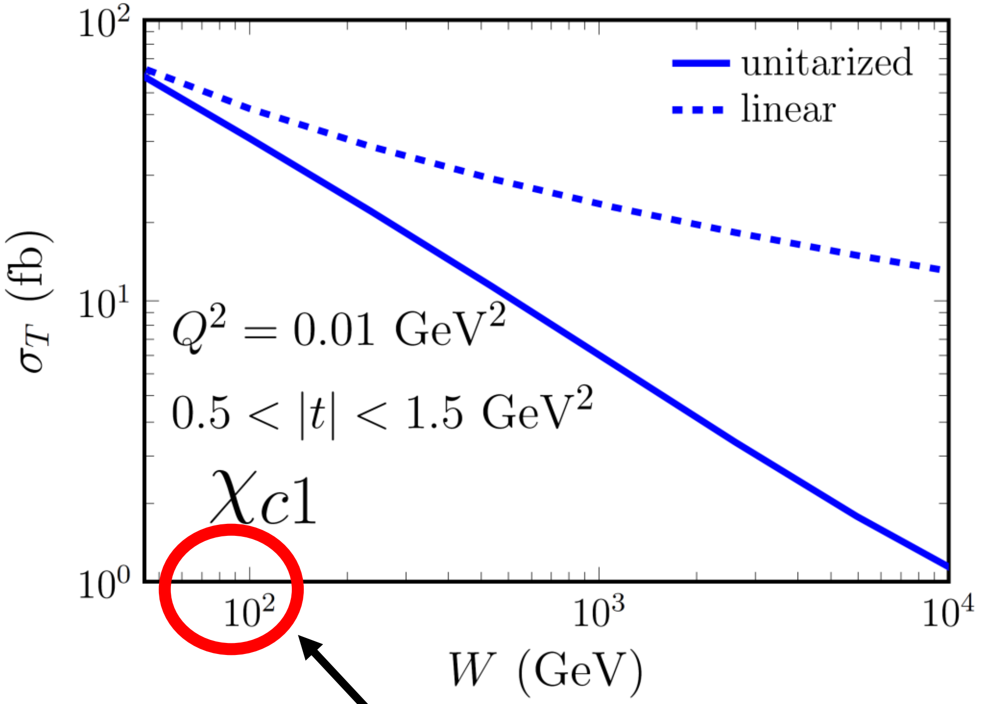
Forshaw, Sandapen, Shaw (2004)
Kowalski, Motyka, Watt (2006)

. We fit the radius and the normalization parameters to the γγ width and the WF normalization

SB, Dumitru, Kaushik, Motyka, Stebel (2024)

W distributions linear vs nonlinear evolution





Dropping the unitarity/saturation corrections Odderon evolution with Y much slower -> BLV asymptotics? (difficult to see numerically..)

May not matter much at the EIC..

SB, Dumitru, Kaushik, Motyka, Stebel (2024)