Spin effects in diffractive charmonia production

Roman Pasechnik

Uppsala University

In collaboration with:
Antoni Szczurek (IFJ, Krakow) and
Oleg Teryaev (JINR, Dubna)

MESON 2010, KRAKÓW, June 11th, 2010

Diffractive Higgs/meson production: motivation

Search for Higgs – primary task for LHC.

Diffractive production of Higgs – an alternative to inclusive production (background reduction).

QCD mechanism proposed by Kaidalov, Khoze, Martin and Ryskin (ref. as KKMR approach).

AS A SPIN-PARITY ANALYSER

V.A. Khoze, A.D. Martin and M.G. Ryskin, Phys. Lett. **B401** (1997) 330.
V.A. Khoze, A.D. Martin and M.G. Ryskin, Eur. Phys. J. **C23** (2002) 311.
A.B. Kaidalov, V.A. Khoze, A.D. Martin and M.G. Ryskin, Eur. Phys. J. C **31**, 387 (2003) [arXiv:hep-ph/0307064].
A.B. Kaidalov, V.A. Khoze, A.D. Martin and M.G. Ryskin, Eur. Phys. J. **C33** (2004) 261.

Still not possible to study Higgs at present.
Replace Higgs by a meson (scalar, pseudoscalar, vector, tensor, etc).

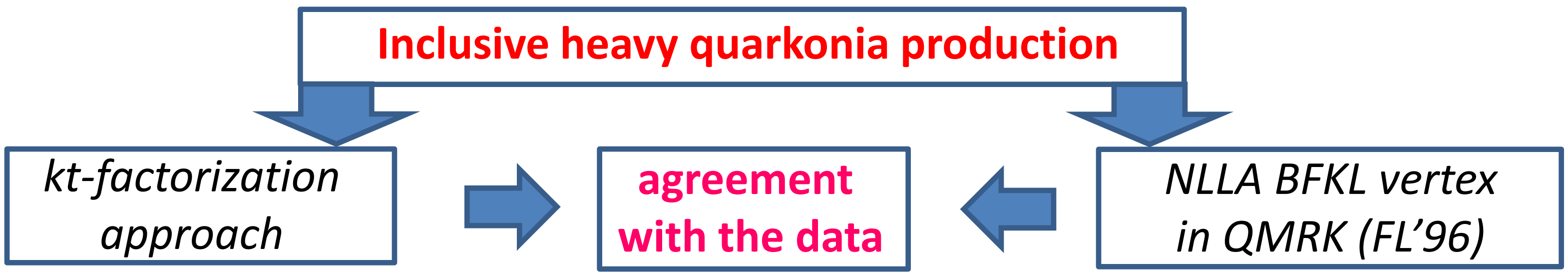
Diffractive χ_c production measured recently by CDF collaboration at Tevatron.

T. Aaltonen et al, Phys.Rev.Lett.102:242001,2009.

$$\left.\frac{d\sigma}{dy}\right|_{y=0}(\chi_c(0^+)) \simeq \frac{1}{\mathrm{BR}(\chi_c(0^+) \to J/\psi + \gamma)} \left.\frac{d\sigma}{dy}\right|_{y=0}(pp \to pp(J/\psi + \gamma)) = (76 \pm 14)\,\mathrm{nb}.$$

It is interesting to test KKMR approach for diffractive light mesons/heavy quarkonia production at high energies – a good probe of nonperturbative dynamics of partons described by UGDFs and related factorisation concepts.

Diffractive heavy quarkonia production: basic ideas



Based on inclusive production by:

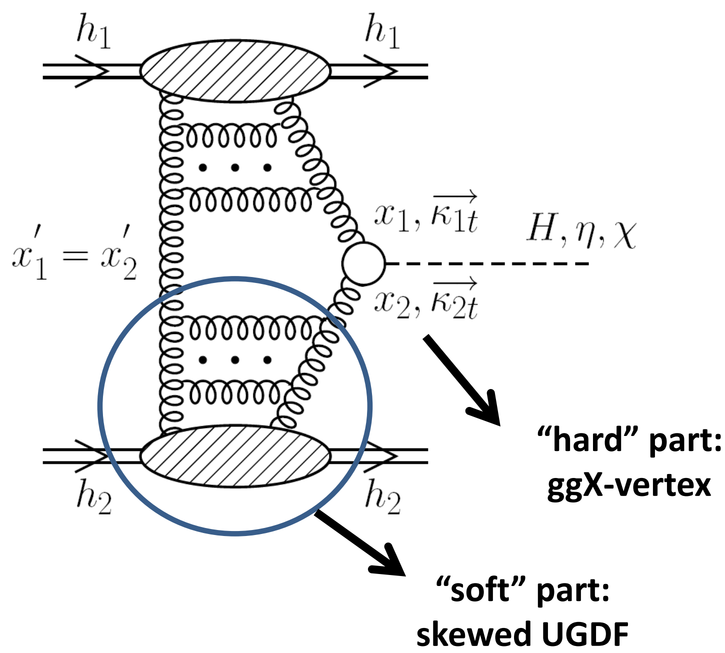
P. Hagler, R. Kirshner, A. Schafer, L. Szymanowski, O. Teryaev, '00, '01
A. Lipatov, V. Saleev, N. Zotov, '01, '03

Why don't we apply the same ideas for exclusive production processes?

Our goals:

- to apply KKMR QCD mechanism to heavy quarkonia production
- to calculate the off-shell production matrix element
- to explore related uncertainties as indirect check of QCD factorisation principles
- to probe nonperturbative gluon dynamics at small qt by using different models for UGDFs → **spin effects!**

The QCD mechanism: amplitude



diffractive amplitude

$$\mathcal{M}_{J,\lambda} = const \cdot \delta_{c_1 c_2} \Im \int d^2 q_{0,t} V_{J,\lambda}^{c_1 c_2}(q_1, q_2, P) \frac{f_{g,1}^{\rm off}(x_1, x_1', q_{0,t}^2, q_{1,t}^2, t_1) f_{g,2}^{\rm off}(x_2, x_2', q_{0,t}^2, q_{2,t}^2, t_2)}{q_{0,t}^2 \, q_{1,t}^2 \, q_{2,t}^2}$$

$f^{off}(\ldots)$ – off-diagonal gluon unintegrated distributions

gauge invariance

production vertex

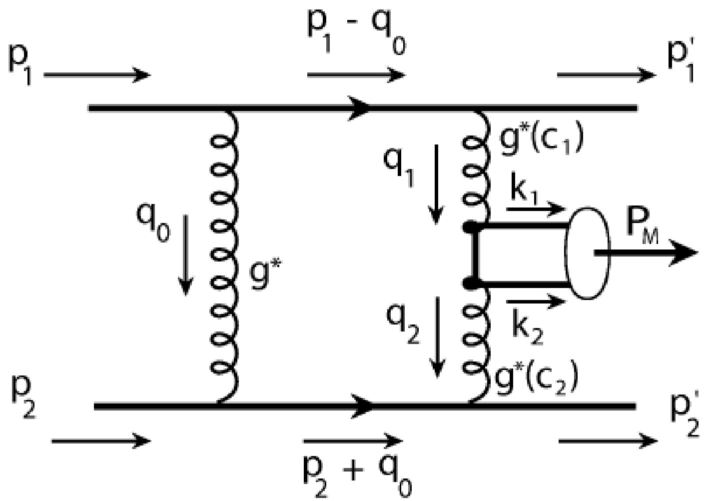
$$V_J^{c_1 c_2}(q_1, q_2) = n_\mu^+ n_\nu^- V_{J,\mu\nu}^{c_1 c_2}(q_1, q_2) = \frac{4}{s} \frac{q_{1,t}^\nu}{x_1} \frac{q_{2,t}^\mu}{x_2} V_{J,\mu\nu}^{c_1 c_2}(q_1, q_2)$$

Gribov's trick

unit light-cone vectors $\quad n^+ = p_2/E_{cms}, \;\; n^- = p_1/E_{cms}$

The QCD mechanism: kinematics

$pp \longrightarrow pp\chi_{cJ}$



$$q_{1,2} = x_{1,2}p_{1,2} + q_{1/2,t}, \quad x'_{1,2} \sim \frac{q_{0,t}}{\sqrt{s}} \ll x_{1,2}$$

- ***We goes beyond the forward limit***

$$\mathrm{p}'^{\,2}_{1/2,\mathrm{t}} \simeq -(1-\mathrm{x}_{1,2})\mathrm{t}_{1,2}, \quad |\mathrm{t}_{1,2}| \leq 1\,\mathrm{GeV}^2$$

- ***Original KKMR approach does not account for x' dependence, just the limit x'<<x; It is hard to do → kinematics of double diffraction does not predict the exact value of x'!***

- ***We probe x' to be small enough w.r.t. x but finite setting up naively:***

In terms of the meson rapidity

$$x_{1,2} = \frac{M_\perp^2}{\sqrt{s}} \exp(\pm y)$$

Due to x'<<x we have: $q_{0,t} \ll M_\perp, \quad \text{for} \quad \xi \sim 1$

$$x' = \xi \frac{q_{0,t}}{\sqrt{s}}, \quad 0.1 < \xi < 2$$

Thus, the reliability of KKMR approach is justified if:

1) The most contribution to the diffractive amplitude comes from nonperturbative q0t < 1 GeV!

2) The results change very slowly when ξ → 0! If it is strong, then unknown x' may produce extra theoretical uncertainties in the KKMR approach.

KMR UGDF: role of nonperturbative transverse momenta

two gluons are replaced by one "effective" gluon with Qt=min(q0t,q1/2t) and x:

"hard" scale

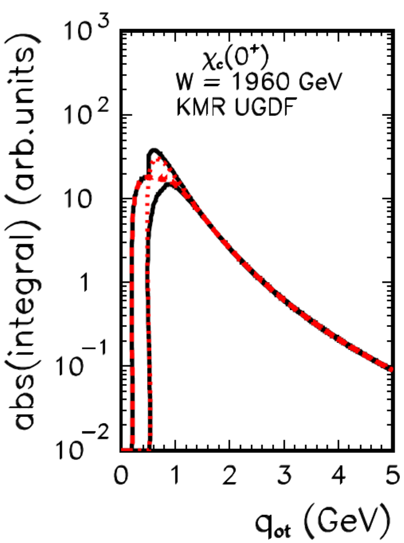
$$f_g^{KMR}(x,x',Q_t^2,\mu^2) = R_g \frac{\partial}{\partial \ln Q_t^2}\left[\sqrt{T(Q_t^2,\mu^2)}\,xg(x,Q_t^2)\right]$$

$$\mu = M_\chi/2$$

- ***depends on only one "effective" gluon transverse momentum***
- ***accounts for off-diagonal effect***
- ***Sudakov f.f. (ensures the purity of rapidity gaps)***
- ***Integrated density, defined at $Q_t > Q_0$***

$$|I(q_{0t};t_1 = -0.1\ \mathrm{GeV}^2,\ t_2 = -0.1\ \mathrm{GeV}^2,\ \phi=\pi)|$$

$$\mathcal{M}(y,t_1,t_2,\phi) = \int dq_{0,t}\ I(q_{0,t};y,t_1,t_2,\phi)$$



main contribution to the amplitude comes from very small gluon transverse momenta q0t

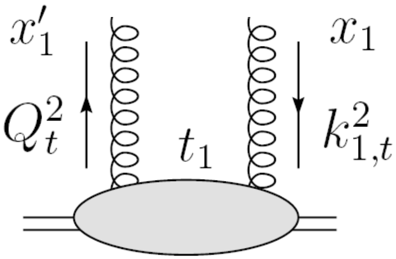
huge sensitivity to details in the nonperturbative domain $Q_t^2 < Q_0^2$

- ***scale effect***
- ***cut-off effect***
- ***Qt-prescription dependence***

KMR UGDF may not be reliable since it is not defined for $Q_t < Q_0$

Off-diagonal (skewed) UGDFs: general properties

Currently unknown; we model the skewedness effect using positivity constraints (Pire,Soffer,Teryaev'99) as



$$f_{g,1}^{\rm off}(x_1,x_1',k_{0,t}^2,k_{1,t}^2,t_1) \;=\; \sqrt{f_g^{(1)}(x_1',k_{0,t}^2,\mu_0^2)\cdot f_g^{(1)}(x_1,k_{1,t}^2,\mu^2)}\cdot F_1(t_1)$$

$$f_{g,2}^{\rm off}(x_2,x_2',k_{0,t}^2,k_{2,t}^2,t_2) \;=\; \sqrt{f_g^{(2)}(x_2',k_{0,t}^2,\mu_0^2)\cdot f_g^{(2)}(x_2,k_{2,t}^2,\mu^2)}\cdot F_1(t_2)$$

motivated by positivity of density matrix (saturation of Cauchy-Schwarz inequality)

factorisation scale **choice – three basic options:**

(1)	$\mu_0^2 = M^2,$	$\mu^2 = M^2,$	***(KKMR choice)***
(2)	$\mu_0^2 = Q_0^2,$	$\mu^2 = M^2,$	
(3)	$\mu_0^2 = q_{0,t}^2$ (+freezing at $q_{0,t}^2 < Q_0^2$),	$\mu^2 = M^2$	

non-perturbative input for QCD evolution: $Q_0^2 = 0.26\ {\rm GeV}^2$

Gluck,Reya,Vogt '95, '98

kt-dependence: $k_t^2 \to 0 \qquad f(x,k_t^2)\to 0\,,\quad \dfrac{f(x,k_t^2)}{k_t^2} = \mathcal{F}(x,k_t^2) \to const$

Production vertex: scalar charmonium

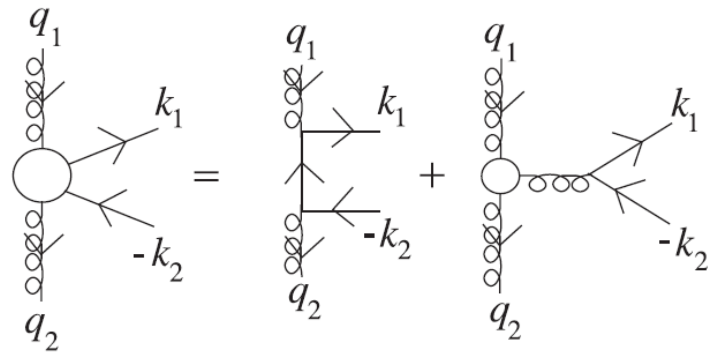
$gg \to \chi_c$ ***vertex***

$$V_J^{c_1 c_2} = \mathcal{P}(q\bar{q} \to \chi_{cJ}) \bullet \Psi_{ik}^{c_1 c_2}(k_1, k_2)$$

pNRQCD projector ***to color singlet bound state***

$gg \to q\bar{q}$

Fadin, Lipatov '96 (for mq=0)



when projecting to colour singlet state

$$\Psi(c_1, c_2; i, k; k_1, k_2) = -g^2(t_{ij}^{c_1} t_{jk}^{c_2} b(k_1, k_2) - t_{kj}^{c_2} t_{ji}^{c_1} \bar{b}(k_2, k_1)), \quad \alpha_s = \frac{g^2}{4\pi}$$

Feynman rules of QMRK

$$b(k_1, k_2) = \gamma^- \frac{\hat{q}_1 - \hat{k}_1 - m}{(q_1 - k_1)^2 - m^2} \gamma^+ - \frac{\gamma_\beta \Gamma^{+-\beta}(q_2, q_1)}{(k_1 + k_2)^2}$$

$$\bar{b}(k_1, k_2) = \gamma^+ \frac{\hat{q}_1 - \hat{k}_1 + m}{(q_1 - k_1)^2 - m^2} \gamma^- - \frac{\gamma_\beta \Gamma^{+-\beta}(q_2, q_1)}{(k_1 + k_2)^2}$$

turn to the standard Feynman rules for the colour singlet state (see, Kuhn et al Nucl.Phys'79 for $\gamma\gamma$-vertex)

Pasechnik, Szczurek, Teryaev, PRD'08

$$V_{J=0}^{c_1 c_2}(q_1, q_2) = 8ig^2 \frac{\delta^{c_1 c_2}}{M} \frac{\mathcal{R}'(0)}{\sqrt{\pi M N_c}} \frac{3M^2(q_{1,t}q_{2,t}) + 2q_{1,t}^2 q_{2,t}^2 - (q_{1,t}q_{2,t})(q_{1,t}^2 + q_{2,t}^2)}{(M^2 - q_{1,t}^2 - q_{2,t}^2)^2}$$

gluon virtualities are explicitly taken into account!

Production vertex: axial-vector charmonium

Bose-symmetric w.r.t. interchange of gluon polarisation vectors and transverse momenta

In the Lorentz-covariant form

$$V^{c_1c_2}_{J=1} = 2g^2\delta^{c_1c_2}\sqrt{\frac{6}{M\pi N_c}}\frac{\mathcal{R}'(0)}{M^2(q_1q_2)^2}\,\varepsilon_{\sigma\rho\alpha\beta}\epsilon^{\beta}(J_z)\Big[q^{\sigma}_{1,t}q^{\rho}_{2,t}(x_1p^{\alpha}_1 - x_2p^{\alpha}_2)(q^2_{1,t}+q^2_{2,t}) -$$

$$\frac{2}{s}\,p^{\sigma}_1p^{\rho}_2\left(q^{\alpha}_{1,t}(2q^2_{2,t}(q_1q_2)-(q_{1,t}q_{2,t})(q^2_{1,t}+q^2_{2,t})) - q^{\alpha}_{2,t}(2q^2_{1,t}(q_1q_2)-(q_{1,t}q_{2,t})(q^2_{1,t}+q^2_{2,t}))\right)\Big]$$

meson polarisation vector with definite helicity

$$\lambda = 0, \pm 1$$

$$\epsilon^{\beta}(P,\lambda) = (1-|\lambda|)n^{\beta}_3 - \frac{1}{\sqrt{2}}(\lambda n^{\beta}_1 + i|\lambda|n^{\beta}_2),\quad n^{\mu}_0 = \frac{P_{\mu}}{M},\quad n^{\mu}_{\alpha}n^{\nu}_{\beta}g_{\mu\nu} = g_{\alpha\beta},\quad \epsilon^{\mu}(\lambda)\epsilon^{*}_{\mu}(\lambda') = -\delta^{\lambda\lambda'}$$

vertex in the c.m.s. in coordinates with z-axis collinear to meson momentum P

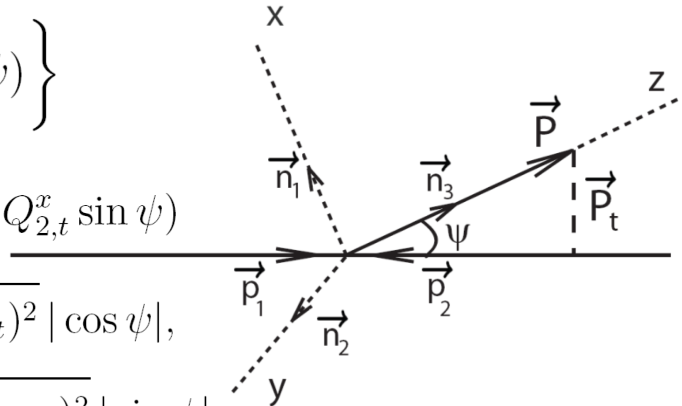
$$V^{c_1c_2}_{J=1,\lambda} = -8g^2\delta^{c_1c_2}\sqrt{\frac{6}{M\pi N_c}}\frac{\mathcal{R}'(0)}{|\mathbf{P}_t|(M^2-q^2_{1,t}-q^2_{2,t})^2}\Bigg\{\frac{1}{\sqrt{2}}\Big[i|\lambda|(q^2_{1,t}-q^2_{2,t})(q_{1,t}q_{2,t})\mathrm{sign}(\sin\psi) +$$

$$\lambda(q^2_{1,t}+q^2_{2,t})\,|[\mathbf{q}_{1,t}\times\mathbf{q}_{2,t}]\times\mathbf{n}_1|\,\mathrm{sign}(Q^y_t)\,\mathrm{sign}(\cos\psi)\Big] +$$

$$(1-|\lambda|)(q^2_{1,t}+q^2_{2,t})\,|[\mathbf{q}_{1,t}\times\mathbf{q}_{2,t}]\times\mathbf{n}_3|\,\mathrm{sign}(Q^y_t)\,\mathrm{sign}(\sin\psi)\Bigg\}$$

Pasechnik, Szczurek, Teryaev, PL'09

simplest form!



gluon transverse momenta in considered coordinates

$$q_{1,t} = (0,\ Q^x_{1,t}\cos\psi,\ Q^y_t,\ Q^x_{1,t}\sin\psi),\qquad q_{2,t} = (0,\ Q^x_{2,t}\cos\psi,\ -Q^y_t,\ Q^x_{2,t}\sin\psi)$$

Double vector products

$$|[\mathbf{q}_{1,t}\times\mathbf{q}_{2,t}]\times\mathbf{n}_1| = \sqrt{q^2_{1,t}q^2_{2,t}-(q_{1,t}q_{2,t})^2}\,|\cos\psi|,$$

$$|[\mathbf{q}_{1,t}\times\mathbf{q}_{2,t}]\times\mathbf{n}_3| = \frac{E}{M}\sqrt{q^2_{1,t}q^2_{2,t}-(q_{1,t}q_{2,t})^2}\,|\sin\psi|.$$

Production vertex: tensor charmonium

Pasechnik, Szczurek, Teryaev, PRD'10

$$V_{J=2}^{c_1c_2} = 2ig^2\sqrt{\frac{3}{M\pi N_c}}\frac{\delta^{c_1c_2}\mathcal{R}'(0)\epsilon^{(\lambda)}_{\rho\sigma}}{MM_\perp^2(q_1q_2)^2}\Big[(q_{1,t}q_{2,t})(q_1^\sigma - q_2^\sigma)\Big\{P^\rho(q_{1,t}^2 - q_{2,t}^2) + (x_1p_1^\rho - x_2p_2^\rho)M^2 -$$
$$(q_{1,t}^\rho - q_{2,t}^\rho)M^2\Big\} - 2(q_1q_2)\Big\{M^2(q_{1,t}^\rho q_{2,t}^\sigma + q_{1,t}^\sigma q_{2,t}^\rho) - q_{1,t}^2(q_{1,t}^\rho q_{2,t}^\sigma + q_{2,t}^\sigma q_{2,t}^\rho) -$$
$$q_{2,t}^2(q_{1,t}^\sigma q_{2,t}^\rho + q_{1,t}^\sigma q_{1,t}^\rho) + (x_1p_1^\sigma - x_2p_2^\sigma)(q_{1,t}^2 q_{2,t}^\rho - q_{2,t}^2 q_{1,t}^\rho) + (q_{1,t}q_{2,t})(x_1p_1^\rho - x_2p_2^\rho)(q_{1,t}^\sigma - q_{2,t}^\sigma) -$$
$$2q_{1,t}^2 x_1p_1^\rho q_{2,t}^\sigma - 2q_{2,t}^2 x_2p_2^\rho q_{1,t}^\sigma + 2(q_{1,t}q_{2,t})(x_1p_1^\sigma q_{2,t}^\rho + x_2p_2^\sigma q_{1,t}^\rho) + \frac{M_\perp^2}{s}(q_{1,t}q_{2,t})(p_1^\rho p_2^\sigma + p_2^\rho p_1^\sigma)\Big\}$$

meson polarisation tensor with definite helicity λ

$$\lambda = 0, \pm 1, \pm 2$$

$$\begin{aligned}\epsilon_{\mu\nu}(\lambda) \;=\; & \frac{\sqrt{6}}{12}(2-|\lambda|)(1-|\lambda|)\left[g_{\mu\nu} - \frac{P_\mu P_\nu}{M^2}\right] + \frac{\sqrt{6}}{4}(2-|\lambda|)(1-|\lambda|)n_3^\mu n_3^\nu + \\ & +\frac{1}{4}\lambda(1-|\lambda|)[n_1^\mu n_1^\nu - n_2^\mu n_2^\nu] + \frac{1}{4}i|\lambda|(1-|\lambda|)[n_1^\mu n_2^\nu + n_2^\mu n_1^\nu] + \\ & +\frac{1}{2}\lambda(2-|\lambda|)[n_1^\mu n_3^\nu + n_3^\mu n_1^\nu] + \frac{1}{2}i|\lambda|(2-|\lambda|)[n_2^\mu n_3^\nu + n_3^\mu n_2^\nu]\end{aligned}$$

finally, in the same coordinates as for axial-vector case

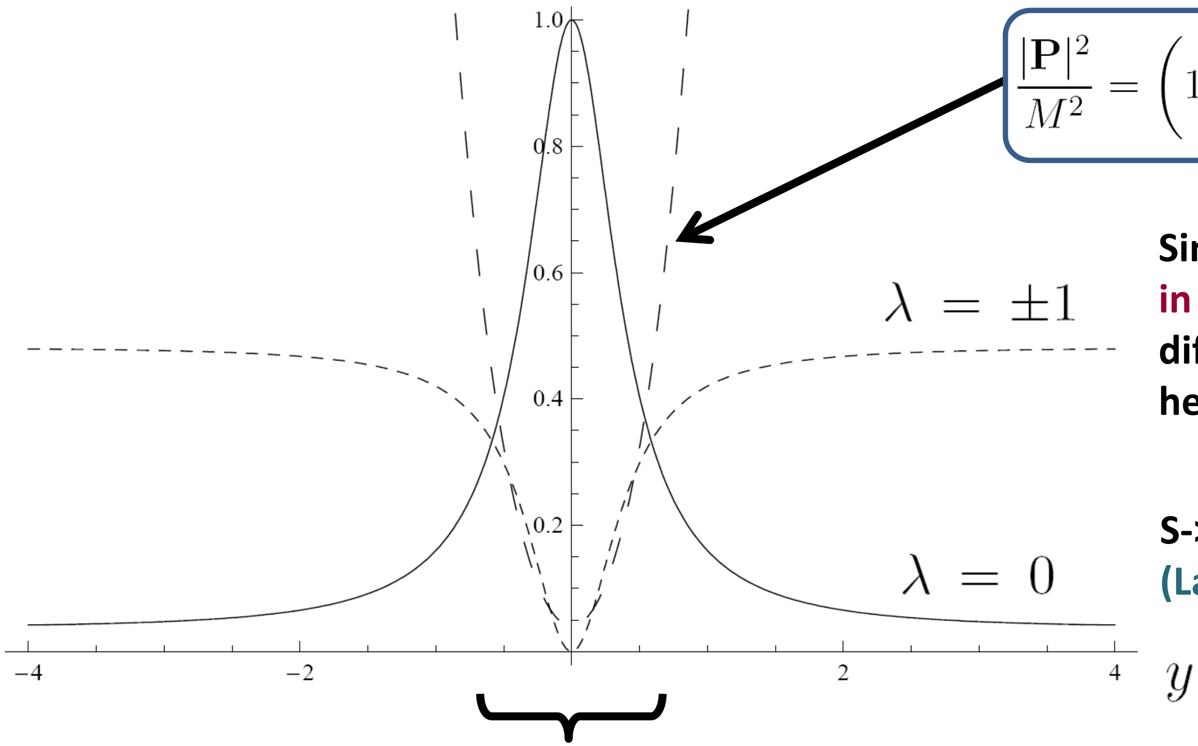
$$V_{J=2,\lambda}^{c_1c_2} = 2ig^2\delta^{c_1c_2}\sqrt{\frac{1}{3M\pi N_c}}\frac{\mathcal{R}'(0)}{M|\mathbf{P}_t|^2(M^2 - q_{1,t}^2 - q_{2,t}^2)^2}\times$$
$$\Big[6M^2\, i|\lambda|(q_{1,t}^2 - q_{2,t}^2)\,\mathrm{sign}(Q_t^y)\Big\{|[\mathbf{q}_{1,t}\times\mathbf{q}_{2,t}]\times\mathbf{n}_1|\,(1-|\lambda|)\,\mathrm{sign}(\sin\psi)\,\mathrm{sign}(\cos\psi) +$$
$$2|[\mathbf{q}_{1,t}\times\mathbf{q}_{2,t}]\times\mathbf{n}_3|\,(2-|\lambda|)\Big\} - \left[2q_{1,t}^2q_{2,t}^2 + (q_{1,t}^2 + q_{2,t}^2)(q_{1,t}q_{2,t})\right]\Big\{3M^2(\cos^2\psi + 1)\lambda(1-|\lambda|) +$$
$$6ME\sin(2\psi)\,\lambda(2-|\lambda|)\,\mathrm{sign}(\sin\psi)\,\mathrm{sign}(\cos\psi) + \sqrt{6}\,(M^2 + 2E^2)\sin^2\psi\,(1-|\lambda|)(2-|\lambda|)\Big\}\Big]$$

Properties of helicity amplitudes: maximal helicity enhancement

***Helicity amplitudes squared** as functions of meson rapidity for $\phi=\pi/2$ (angle between gluon qt's)*

$$|V|^2_{\lambda=0} = S\frac{|\mathbf{P}_t|^2(\cosh y + 1)}{M^2(\cosh y - 1) + |\mathbf{P}_t|^2(\cosh y + 1)}, \quad |V|^2_{\lambda=\pm1} = \frac{S}{2}\frac{M^2(\cosh y - 1)}{M^2(\cosh y - 1) + |\mathbf{P}_t|^2(\cosh y + 1)}$$

Kinematical "maximal helicity enhancement" (similar effect observed by WA102 for f1(1285), f1(1420) –production; initially predicted by Boreskov'69 and revived in diffraction in KKMR'03)



$$\frac{|\mathbf{P}|^2}{M^2} = \left(1 + \frac{|\mathbf{P}_t|^2}{M^2}\right)\cosh^2 y - 1$$

Similar peaked structure observed in rapidity distributions of the diffractive cross section for different helicities

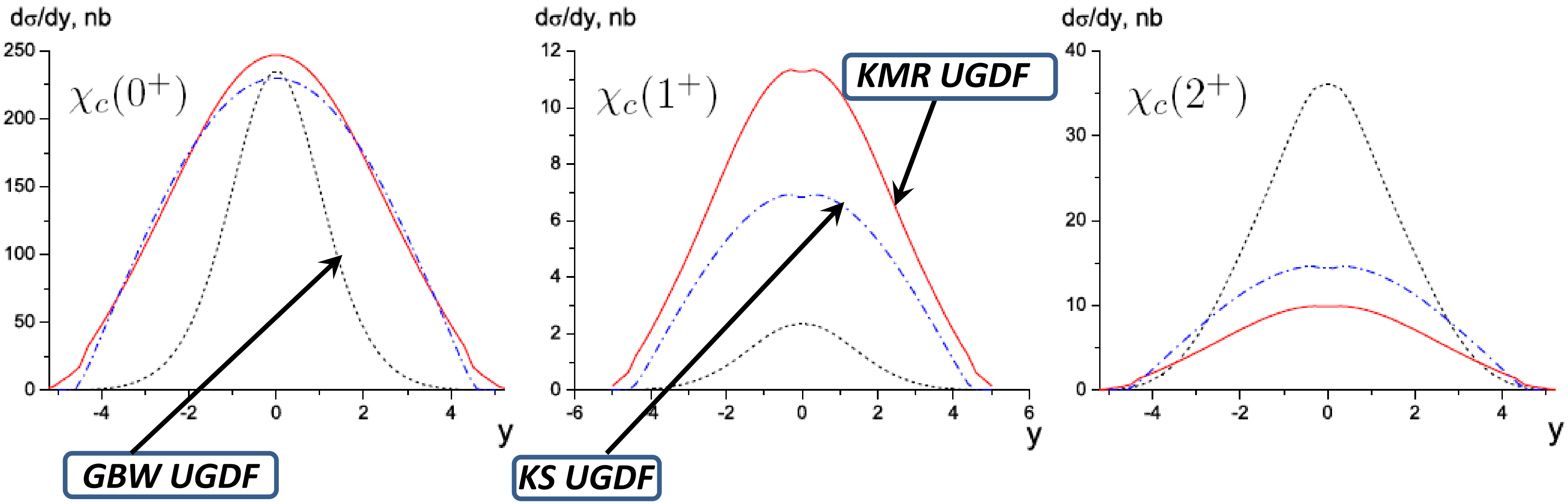
S->0 in the limit of on-shell gluons (Landau-Yang theorem)

Nonrelativistic (heavy) meson is dominated by $\lambda=0$ contribution.
relativistic (almost massless) meson → by maximal λ contribution.

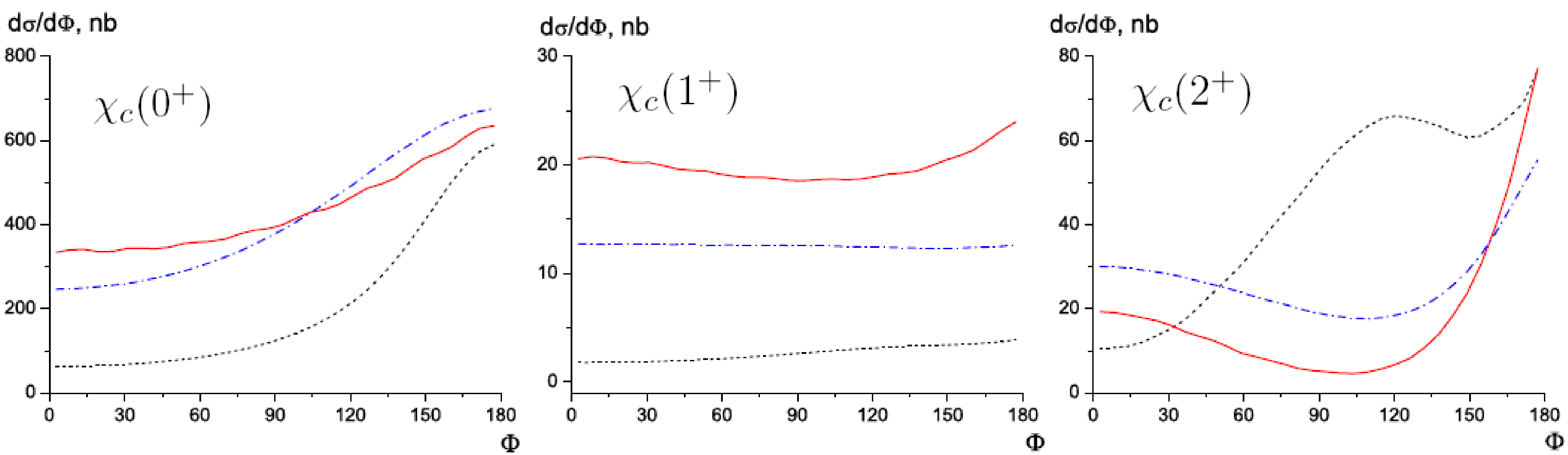
Results for different UGDFs: scalar, axial-vector and tensor charmonia

Rapidity distributions

t-dependences are similar!



Azimuthal angle correlations



Relative contributions of charmonium spin states

Absorbtion factors (KMR'09): $\langle S^2_{\rm eff}(\chi_c(0^+))\rangle \simeq 0.02$, $\langle S^2_{\rm eff}(\chi_c(1^+))\rangle \simeq 0.05$ and $\langle S^2_{\rm eff}(\chi_c(2^+))\rangle \simeq 0.05$.

skewed UGDF prescription	ξ	$\chi_c(0^+)$ $\frac{d\sigma_{\chi_c}}{dy}$	$\chi_c(0^+)$ $\frac{d\sigma_{J/\psi\gamma}}{dy}$	$\chi_c(1^+)$ $\frac{d\sigma_{\chi_c}}{dy}$	$\chi_c(1^+)$ $\frac{d\sigma_{J/\psi\gamma}}{dy}$	$\chi_c(2^+)$ $\frac{d\sigma_{\chi_c}}{dy}$	$\chi_c(2^+)$ $\frac{d\sigma_{J/\psi\gamma}}{dy}$	ratio $1^+/0^+$	ratio $2^+/0^+$	signal $\frac{d\sigma_{obs}}{dy}$
GBW [30], "R_g"	—	94.2	1.07	1.64	0.58	19.5	3.78	0.5	3.5	5.4
GBW [30], "sqrt"	1.0	13.2	0.15	0.13	0.04	2.07	0.39	0.3	2.6	0.6
	0.3	12.8	0.15	0.13	0.04	1.65	0.34	0.3	2.3	0.5
lin KS [31], "R_g"	**—**	**32.6**	**0.37**	**0.93**	**0.31**	**1.34**	**0.25**	**0.8**	**0.7**	**0.9**
lin KS [31], "sqrt"	1.0	17.2	0.19	0.44	0.16	0.98	0.19	0.8	1.0	0.5
nlin KS [31], "sqrt"	1.0	12.6	0.14	0.36	0.12	0.67	0.13	0.9	0.9	0.4
	0.3	20.6	0.23	0.58	0.20	1.04	0.20	0.9	0.9	0.6
	0.1	**29.6**	**0.34**	**0.84**	**0.29**	**1.4**	**0.27**	**0.9**	**0.8**	**0.9**
KMR [13], GRV94LO, $q_{0,t}^{cut} = 0.85$ GeV	—	48.8	0.56	1.94	0.66	1.61	0.31	1.2	0.6	1.5
KMR [13], GRV94HO, $q_{0,t}^{cut} = 0.85$ GeV	—	13.5	0.16	0.58	0.19	0.45	0.09	1.2	0.6	0.4
KMR [13], GRV94HO, $q_{0,t}^{cut} = 0.60$ GeV	**—**	**33.8**	**0.39**	**1.11**	**0.38**	**1.18**	**0.23**	**1.0**	**0.6**	**1.0**
HKRS result [10] $q_{0,t}^{cut} = 0.85$ GeV	—	27.1	0.31	0.72	0.25	0.95	0.19	0.8	0.6	0.7

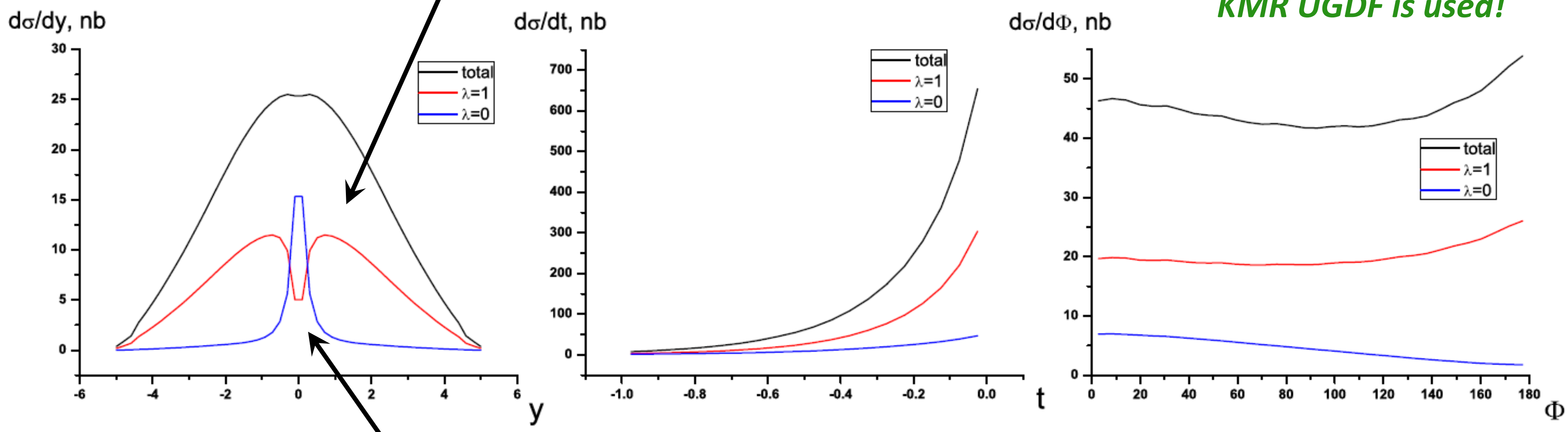
Measurement of spin-1 and spin-2 contributions separately would allow to put strict constraints on UGDF models

Axial-vector and tensor charmonia polarizations

Axial-vector case

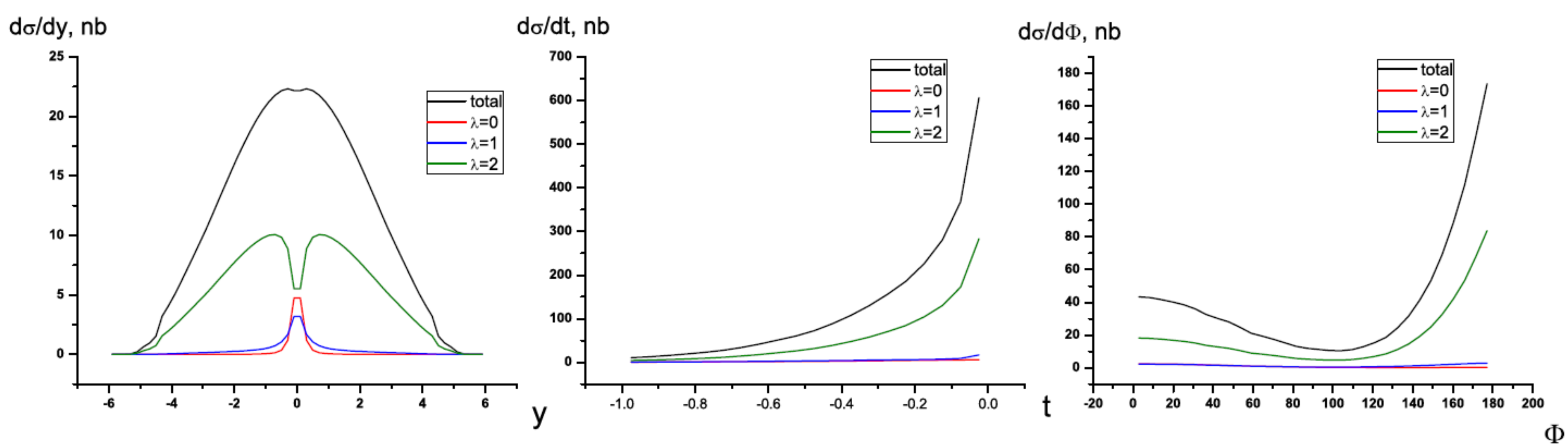
maximal helicity enhancement in integrated cross section!

KMR UGDF is used!



Tensor case

minimal helicity dominance in differential cross section at y=0!



Angular distribution of J/ψ mesons

$$pp \to pp(\chi_{cJ} \to J/\psi\gamma)$$

$$\frac{d\sigma^J_{J/\psi}}{d\Omega} = B_J(\chi_{cJ} \to J/\psi\gamma) \cdot W(\theta,\phi), \qquad W(\theta,\phi) = \sum_{\lambda,\lambda'=-J}^{J} \rho^J_{\lambda\lambda'} A^J_{\lambda\lambda'}(\theta,\phi),$$

Axial-vector case

$$W^{J=1}(\theta,\phi) = \frac{3}{4\pi}\Big\{\rho^1_{0,0}\left[r^1_0\cos^2\theta + \frac{r^1_1}{2}\sin^2\theta\right] + \rho^1_{1,1}\left[r^1_0\sin^2\theta + \frac{r^1_1}{2}(1+\cos^2\theta)\right] -$$
$$-\sqrt{2}\sin(2\theta)\left(r^1_0 - \frac{r^1_1}{2}\right)\left[\mathrm{Re}(\rho^1_{1,0})\cos\phi - \mathrm{Im}(\rho^1_{1,0})\sin\phi\right] -$$
$$-\sin^2\theta\left(r^1_0 - \frac{r^1_1}{2}\right)\left[\mathrm{Re}(\rho^1_{1,-1})\cos(2\phi) - \mathrm{Im}(\rho^1_{1,-1})\sin(2\phi)\right]\Big\},$$

--- Different functional dependence on polar angle at small and large meson rapidities;
--- Importance of non-diagonal elements of density matrix in azimuthal angular dependences;
--- Possibility for experimental separation of spin contributions → better constraints on QCD diffractive mechanism and UGDFs!

Conclusion and discussions

1 . ***Total and differential cross sections*** of exclusive diffractive production of heavy scalar, axial-vector and tensor charmonia are calculated. ***The maximal helicity*** dominance in the integrated cross-section is demonstrated.

2. ***Significant contribution*** to the diffractive cross section comes from ***non-perturbative Qt region*** (order of fraction of GeV), so we apply ***a sort of continuation*** of perturbative result to the region where its applicability ***cannot be rigorously proven***.

3. ***Measurements of polar/azimuthal angular distributions of J/ψ mesons would allow to separate different spin states and to put extra stronger constraints on QCD mechanism and non-perturbative gluon dynamics described by UGDFs.***