$\chi_{cJ} \to K^*(892)\bar{K}$

decays within the effective theory framework

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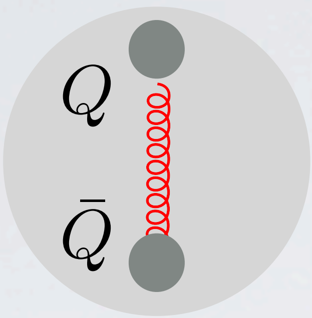
based on

N. Kivel, Eur. Phys. A 54, 2018

Motivation

Why $\chi_{cJ} \to K^*(892)\bar{K}$ decays ?

$\chi_{cJ}(1P)$



J=0 M=3.42 GeV

J=1 M=3.51 GeV

J=2 M=3.56 GeV

$$X_J(c\bar{c}) \leftrightarrow (n_r+1)^{(2S+1)}L_J$$

n_r "radial" quantum #

$\vec{J} = \vec{L} + \vec{S}$ ang. mom.

$\vec{S} = \vec{s}_c + \vec{s}_{\bar{c}}$ spin of $c\bar{c}$

$n_r = 0$

L=0 $^{2S+1}S_J$ $\eta_c(^1S_0)$ $J/\Psi(^3S_1)$

L=1 $^{2S+1}P_J$ $h_c(^1P_1)$ $\chi_{cJ}(^3P_J)$

Why $\chi_{cJ} \to K^*(892)\bar{K}$ decays ?

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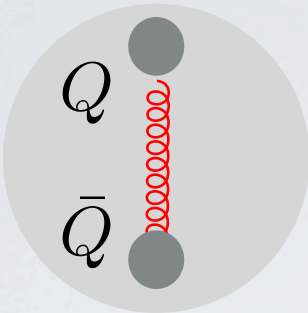


$J^{PC}= J^{++}$ J=1 M=3.51 GeV

final state

K(498) $J^P= 0^-$

K*(892) $J^P = 1^-$

amplitude $A[\chi_{cJ} \to K^* K] \sim m_s - m_q$ is sensitive to SU(3) breaking

3 amplitudes: $\chi_{c1} \to K K^*_{\|,\perp}$ $\chi_{c2} \to K K^*_{\perp}$

QCD: $$\frac{A[\chi_{cJ} \to K K^*_{\perp}]}{A[\chi_{c1} \to K K^*_{\|}]} \sim \frac{\Lambda}{m_c} \qquad m_c \gg \Lambda$$

Why $\chi_{cJ} \to K^*(892)\bar{K}$ decays ?

BESII, PRD 74, 2006

BESIII, PRD 96, 2017

Branching ratios in units of 10^{-4}

$\chi_{cJ} \to VP$	$K^*(892)^0\, \bar{K}^0$+c.c.	$K^*(892)^+\, \bar{K}^-$+c.c.
χ_{c1}	10 ± 4	15 ± 7
χ_{c2}	1.3 ± 0.28	1.5 ± 0.22

Theoretical description is based on the double expansion with respect to

- small velocity v of heavy quark ($m_Q \to \infty$): NRQCD & pNRQCD
- small ratio Λ/m_Q of heavy quark : collinear factorisation

There are many observed hadronic decay channels PP, PV, PT, VT

... and many theoretical challenges!

Very large effects beyond the leading order approximation!

Why $\chi_{cJ} \to K^*(892)\bar{K}$ decays ?

There are many observed hadronic decay channels PP, PV, PT, VT
... and many problems!

Very large effects beyond the leading order approximation!

charm mass is not large enough:
$$v_c^2 \simeq 0.3$$

- large relativistic corrections
- large hadronic corrections

Very special mechanism related with the color-octet component of quarkonia wave function:

$$\Psi = c_0|(Q\bar{Q})\rangle + c_8|(Q\bar{Q})g\rangle + \cdots$$

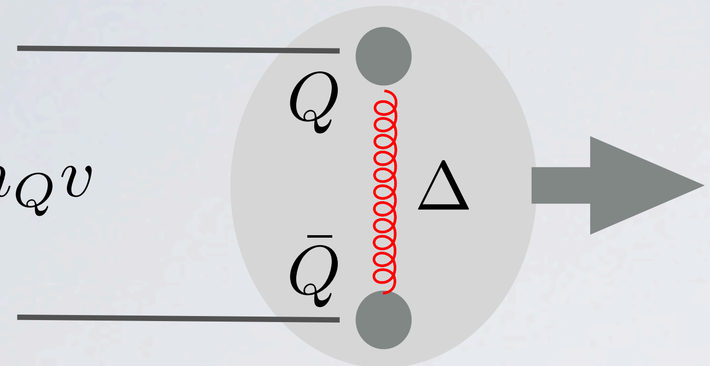
There are many speculations that octet component is especially important for the description of P-wave charmonia

however this mechanism has not been investigated within EFT framework ...

the first consideration for $B \to \chi_{cJ} K$ Beneke, Vernazza, NP B 2009

Heavy quark-antiquark states: brief introduction

$r \sim 1/m_Q v$



$P = M\omega$

rest frame $\omega = (1, \vec{0})$

relative momentum $\Delta = m_Q v$

$m_Q \gg \Lambda_{QCD}$ $m_Q \to \infty$ $v \ll c$

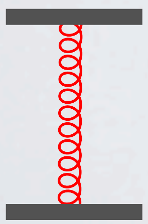
non-relativistic limit

kin. energy of heavy quark $E_{kin} = \vec{p}_Q^{\,2}/2m_Q \sim m_Q v^2$

virtuality $p_Q^2 - m_Q^2 \sim (m_Q v)^2$

Coulomb limit $m_Q \to \infty$ $m_Q v^2 \gg \Lambda_{QCD}$

Coulomb binding energies

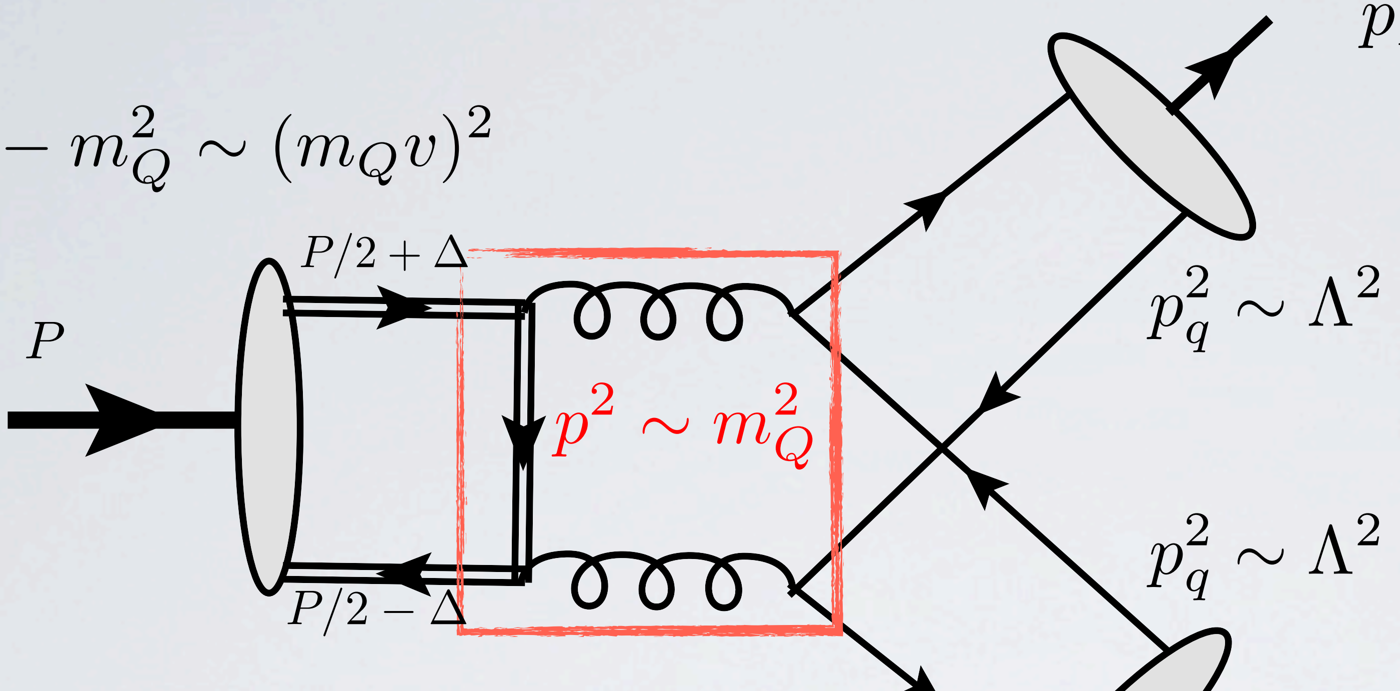


$$V_S = -\frac{4}{3}\frac{\alpha_s(mv)}{r}$$

$$\alpha_s(mv) \sim v$$

$$E_n = -\frac{4}{9}\frac{1}{n^2} m_Q \alpha_s^2 \sim m_Q v^2$$

$p_Q^2 - m_Q^2 \sim (m_Q v)^2$



$\Delta = m_Q v$

$p_{K^*} = (E_{K^*}, 0, 0, -p)$

$E_K + E_{K^*} = M_\chi$

$p \sim E_K \sim m_Q$

$p_K = (E_K, 0, 0, p)$

$$A[\chi_{cJ} \to K_\parallel^* K] = \int d^3\Delta \Psi_P^{(J)}(\vec{\Delta})\, T[c(\vec{\Delta})\bar{c}(\vec{\Delta}) \to K_\parallel^* K]$$

$$\sim \int \underline{d^3\Delta \Psi_P^{(J)}(\vec{\Delta})\vec{\Delta}}\, T'[c(0)\bar{c}(0) \to K_\parallel^* K]$$

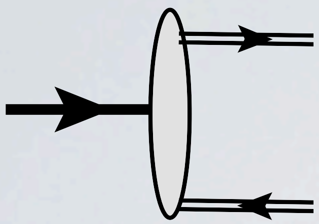
$$\sim R_{21}'(0)\, T'[c(0)\bar{c}(0) \to K_\parallel^* K]$$

$$\Delta\Psi_P^{(J)}(\vec{\Delta}) \sim \sum_m \tilde{R}_{21}(|\vec{\Delta}|) Y_{1m}(\Omega)$$

$$\int d^3\Delta \Psi_P^{(J)}(\vec{\Delta}) = 0$$

Effective field theory: NRQCD + soft QCD

NRQCD (small v)



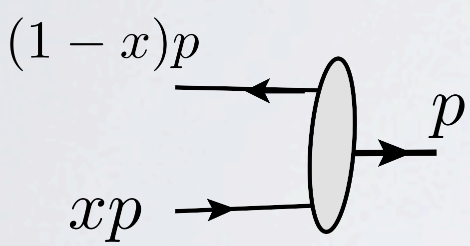
$$\langle 0|\,\mathcal{O}(^3P_J)\,|\chi_{cJ}\rangle \sim \sqrt{M_\chi}R'_{21}(0)$$

Heavy Quark Spin Symmetry:

The matrix elements are not independent (up to v^2) corr's

soft QCD (Λ/m_Q)

DA can be related with the BS wave function



$$\phi_{K,K^*}(x,\mu) = \int_{|k_\perp|<\mu} d^2k_\perp \Psi_{BS}(x,k_\perp)$$

$$f_K\phi_K(x) = \int d\lambda e^{i\lambda x(pn)}\langle K(p)|\bar{\psi}(\lambda n)\,\Gamma\,\psi(0)|0\rangle \qquad n^2 = 0$$ light-like vector

DA describes the momentum-fraction distribution of partons at zero transverse separation in a 2-particle Fock state

Decay amplitude $A[\chi_{c1} \to K^*_{\|} K]$

amplitude $A[\chi_{cJ} \to K^* K] \sim m_s - m_q$

QCD:

$$\frac{A[\chi_{cJ} \to K K^*_{\perp}]}{A[\chi_{c1} \to K K^*_{\|}]} \sim \frac{\Lambda}{m_c}$$

3 amplitudes: $\chi_{c1} \to K K^*_{\|,\perp}$ $\chi_{c2} \to K K^*_{\perp}$

$$A[\chi_{c1} \to K^*_{\|} K] \sim \frac{R'_{21}(0)}{m_c^{5/2}} \frac{f_V^{\|} f_P}{m_c^2} \alpha_s^2 \int_0^1 dx \, \frac{\phi_{K^*_{\|}}(x)}{x(1-x)} \int_0^1 dy \, \frac{\phi_K(y)}{y(1-x)} \frac{y-x}{xy + (1-x)(1-y)}.$$

$x \to 1 - x$: $\phi(x) \to \phi(1-x)$ $\Leftrightarrow$ $q \to \bar{q}$

$\pi(q\bar{q})$ $\phi(x) = \phi(1-x)$

$K(q\bar{s})$ $\phi(x) \neq \phi(1-x)$ $\phi(x) - \phi(1-x) \sim m_s - m_q$

Power counting in EFT:

$R'_{21}(0) \sim v^4$ $\frac{f_V^{\|} f_P}{m_c^2} \sim \frac{\Lambda^2}{m_c^2}$ $A[\chi_{c1} \to K^*_{\|} K] \sim v^4 (\Lambda/m_c)^2$

Branching ratio $Br[\chi_{c1} \to K^*_{\parallel} K]$

amplitude $A[\chi_{cJ} \to K^* K] \sim m_s - m_q$

$$A[\chi_{c1} \to K^*_{\parallel} K] \sim \frac{R'_{21}(0)}{m_c^{5/2}} \frac{f_V^{\parallel} f_P}{m_c^2} \alpha_s^2 \int_0^1 dx \, \frac{\phi_{K^*_{\parallel}}(x)}{x(1-x)} \int_0^1 dy \, \frac{\phi_K(y)}{y(1-x)} \frac{y-x}{xy+(1-x)(1-y)}.$$

Estimates: $Br[\chi_{c1} \to K^*_{\parallel} K] \simeq (0.2\text{–}0.6) \times 10^{-4}$

experiment $Br[\chi_{c1} \to K^*_{\parallel} K] \simeq (10 \pm 4/15 \pm 7) \times 10^{-4}$

This calculation strongly underestimates the data.

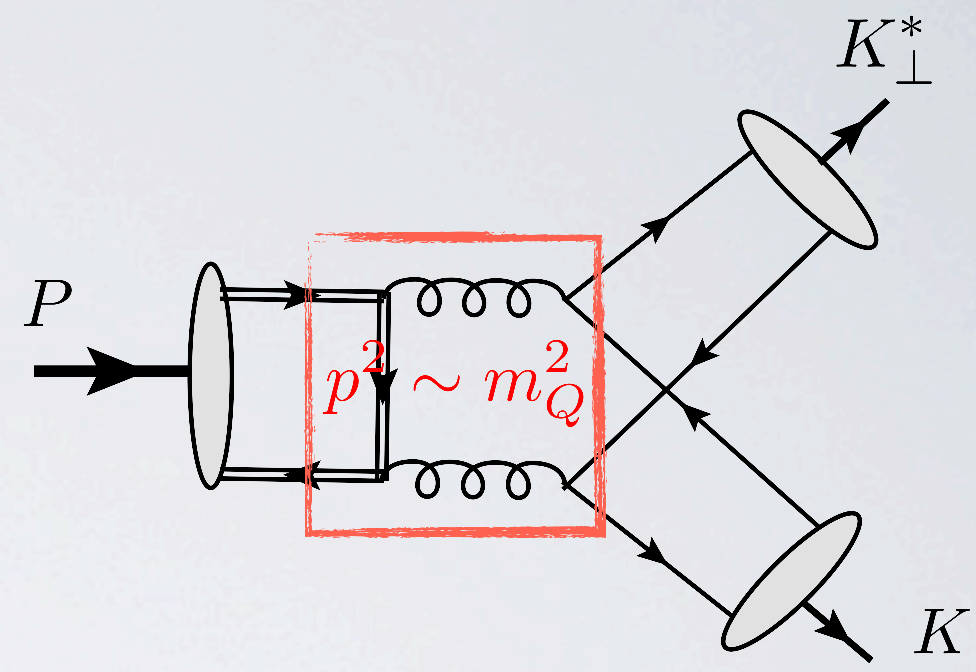
Large effect from $\chi_{c1} \to K K^*_{\perp}$ notice that

$$Br[\chi_{c2} \to K^*_{\perp} K] \simeq (1.3 \pm 0.3/1.5 \pm 0.2) \times 10^{-4}$$

QCD: $\frac{A[\chi_{cJ}\to KK^*_\perp]}{A[\chi_{c1}\to KK^*_\parallel]}\sim\frac{\Lambda}{m_c}$

Decay amplitude $A[\chi_{c1}\to K^*_\parallel K]$

$$f_K\phi_K(x)=\int d\lambda e^{i\lambda x(pn)}\langle K(p)|\bar\psi(\lambda n)\,\Gamma\,\psi(0)|0\rangle$$



$$A[\chi_{cJ}\to KK^*_\perp]\sim\ \mathrm{Tr}[\Gamma_{K^*_\perp}\gamma\,\Gamma_K\,\gamma]$$

$$\Gamma_{K^*_\perp}\otimes\Gamma_K$$

tw2 x tw2 $\sigma^{+\perp}\gamma_5\otimes\gamma^-\gamma_5$ vanishes

tw2 x tw3 $\sigma^{+\perp}\gamma_5\otimes\sigma^{+-}\gamma_5$

tw2 x tw3 $\sigma^{+\perp}\gamma_5\otimes\gamma_5$

$\langle K(p)|\bar\psi(\lambda n)\,\Gamma\,\psi(0)|0\rangle\sim f_K m_K^2/(m_s+m_q)$

chiral enhanced corrections

tw3 x tw2 $\gamma^\perp(\gamma_5)\otimes\gamma^-\gamma_5$ $f_K m_K$

Decay amplitude $A[\chi_{cJ} \to K^*_\perp K]$

$$A[\chi_{cJ} \to K K^*_\perp] \sim \frac{R'_{21}(0)}{m_c^{5/2}} \frac{f_V^\perp f_P \mu_P}{m_c^3} \alpha_s^2 \int_0^1 dx \frac{\phi_{K^*_\perp}(x)}{x\bar{x}} \int_0^1 dy\, F(x,y)$$

$$R'_{21}(0) \sim v^4 \qquad \frac{f_V^\perp f_P \mu_P}{m_c^3} \sim \frac{\Lambda^3}{m_c^3} \qquad \underline{A[\chi_{cJ} \to K^*_\perp K] \sim v^4 (\Lambda/m_c)^3}$$

$$\mu_P = m_K^2/(m_s + m_q)$$

endpoint region $x \to 1,\, y \to 0$

$$\mu_P \int_{1-\delta}^1 dx \frac{\phi_{K^*_\perp}(x)}{x\bar{x}} \int_0^\delta dy\, F(x,y) \sim (m_s - m_q)\phi'_{K^*_\perp}(1) \int_{1-\delta}^1 dx \int_0^\delta dy\, \frac{1+\ln y}{[y+(1-x)]^2}$$

$$\sim (m_s - m_q)\phi'_{K^*_\perp}(1) \int_0^\delta dy\, \frac{\ln y}{y}$$

! $\delta \to 1$

same for region $x \to 0,\, y \to 1$

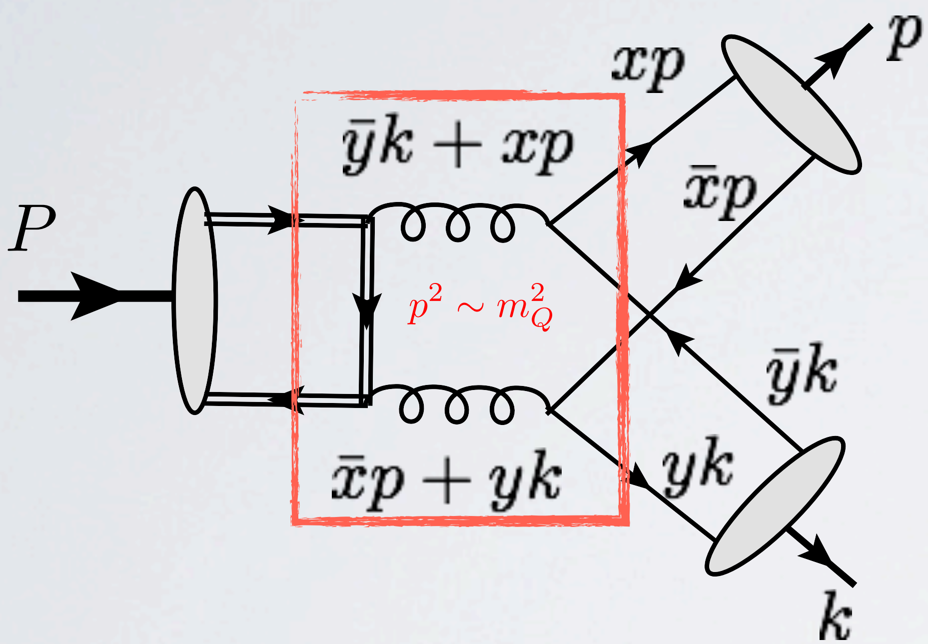
the integral is singular $\Rightarrow$ the factorisation scheme is not well defined!

Endpoint contribution

collinear region

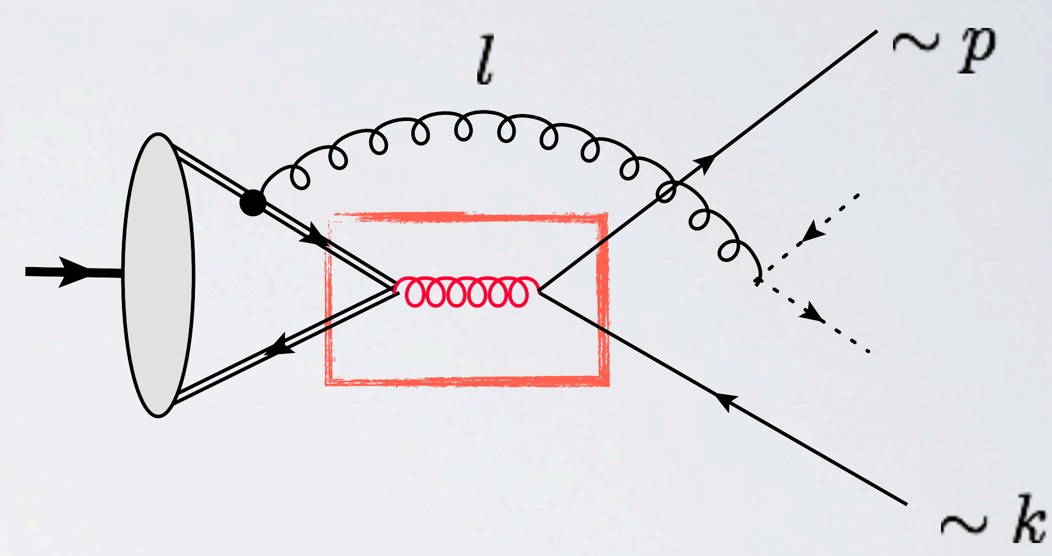
$0 \ll x \ll 1, 0 \ll y \ll 1$

$\bar{x} \equiv 1 - x$



v and Λ are well separated scales

endpoint region $x \to 1,\, y \to 0$
$x \to 0,\, y \to 1$



long distance exchange between 2 sectros:
NRQCD & soft QCD

NRQCD $l \sim m_Q v^2$

soft QCD $l \sim \Lambda$

$v^2 \sim \Lambda / m_Q$

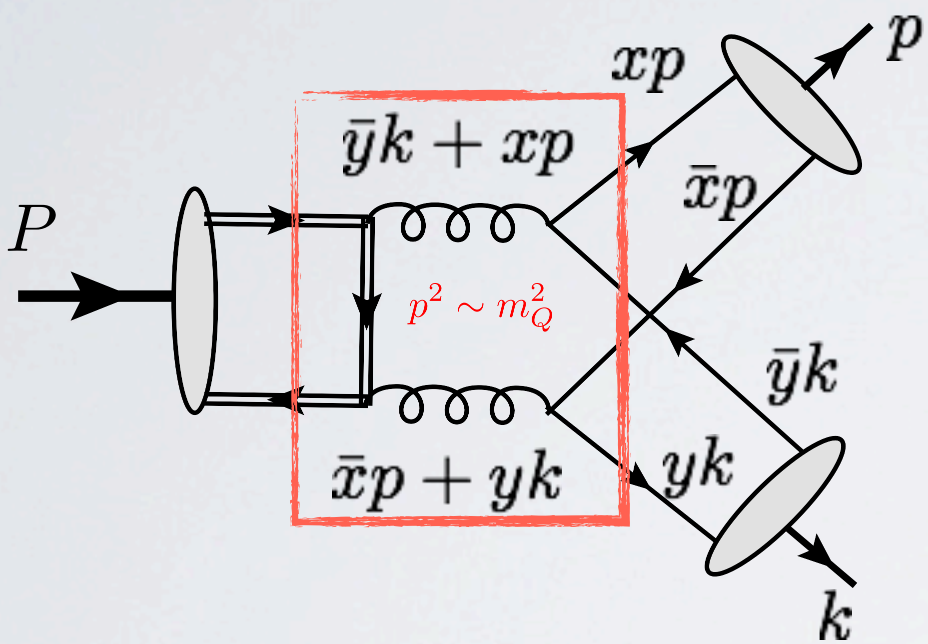
$v_c^2 \simeq 0.3$

Endpoint contribution

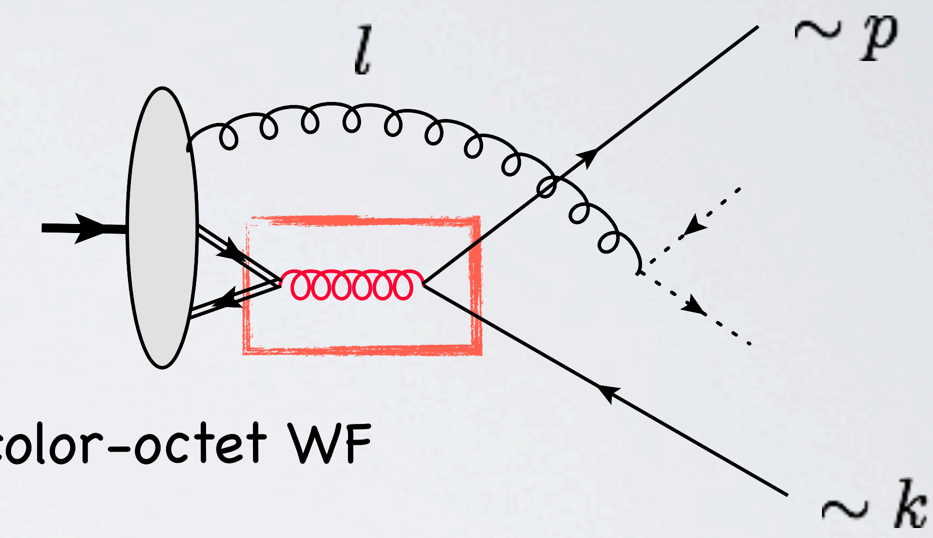
collinear region

$0 \ll x \ll 1, 0 \ll y \ll 1$

$\bar{x} \equiv 1 - x$



endpoint region $x \to 1, y \to 0$ / $x \to 0, y \to 1$



long distance exchange between 2 sectros:
NRQCD & soft QCD

v and Λ are well separated scales

NRQCD $\quad l \sim m_Q v^2$

soft QCD $\quad l \sim \Lambda$

$v^2 \sim \Lambda/m_Q$

$v_c^2 \simeq 0.3$

Decay amplitude $A[\chi_{cJ} \to K^*_\perp K]$

$$A[\chi_{cJ} \to K^*_\perp K] = \langle 0 | \mathcal{O}(^3P_J) | \chi_{cJ} \rangle \ \phi^\perp_{K^*} * \alpha_s^2 T_h * \phi_K$$

$$+ \ \langle K^*_\perp K | \alpha_s C_h (\bar{Q}Q)_8 (\bar{q}q)_8 | \chi_{cJ} \rangle$$

The soft-overlap contribution can be sufficiently large:

- it is less suppressed by α_s
- many indications from quarkonium phenomenology
- QCD sum rules estimates ...

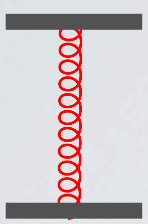
The IR-singularities in the "factorisable" contribution must be absorbed into renormalization of the "nonfactorisable" term.

Heavy Quark Spin Symmetry: does it works for the soft-overlap matrix elements?

Soft-overlap matrix element in the Coulomb limit

Coulomb limit $m_Q \to \infty \qquad m_Q v^2 \gg \Lambda_{QCD}$

Coulomb binding energies



$$V_0 = -\frac{4}{3}\frac{\alpha_s(mv)}{r}$$

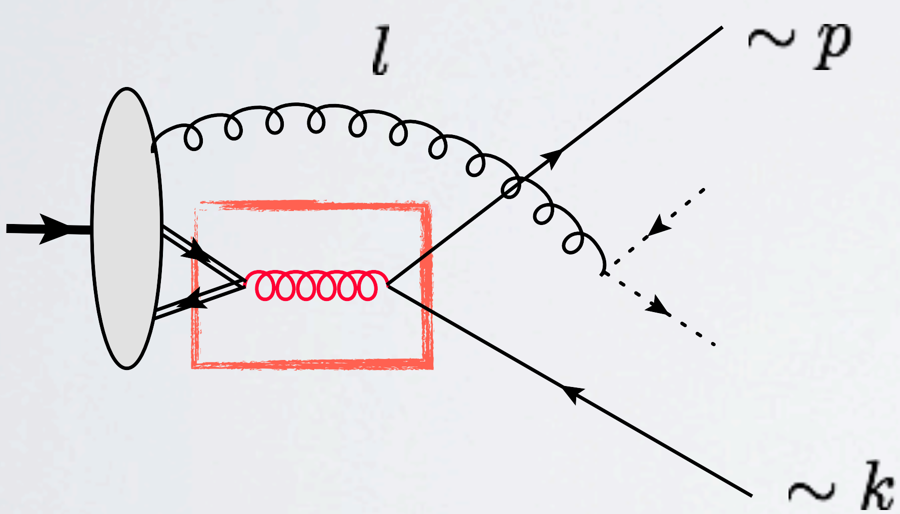
$$V_8 = \frac{1}{6}\frac{\alpha_s(mv)}{r}$$

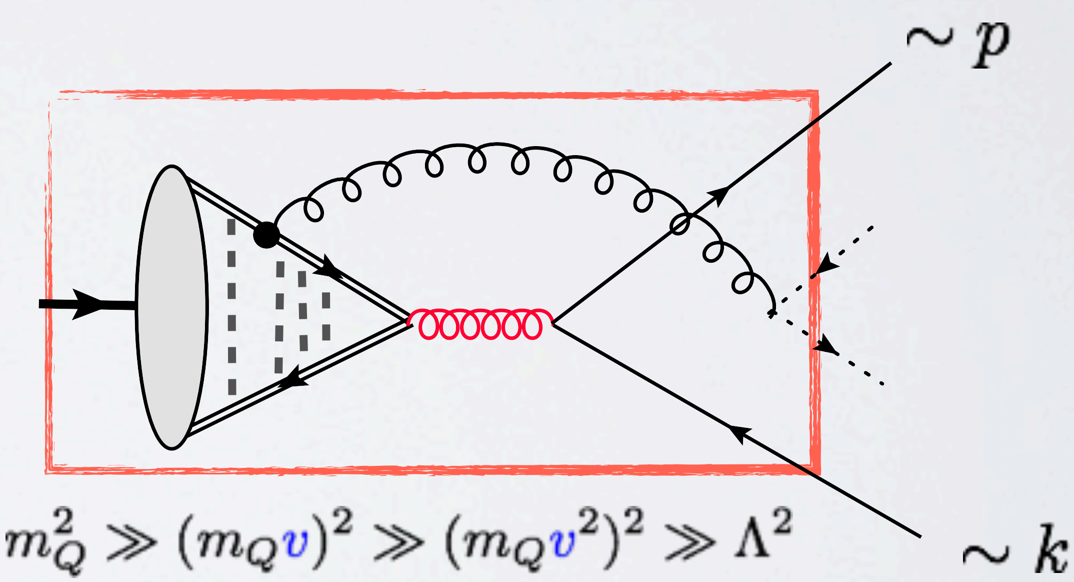
$$\alpha_s(mv) \sim v$$

$$E_n = -\frac{4}{9}\frac{1}{n^2} m_Q \alpha_s^2 \sim m_Q v^2$$

$v^2 \sim \Lambda/m_Q$

Coulomb: $v^2 \gg \Lambda/m_Q$





$m_Q^2 \gg (m_Q v)^2 \gg (m_Q v^2)^2 \gg \Lambda^2$

$\langle K_\perp^* K|\,\alpha_s C_h (\bar{Q}Q)_8 (\bar{q}q)_8\,|\chi_{cJ}\rangle$

"nonfactorisable"

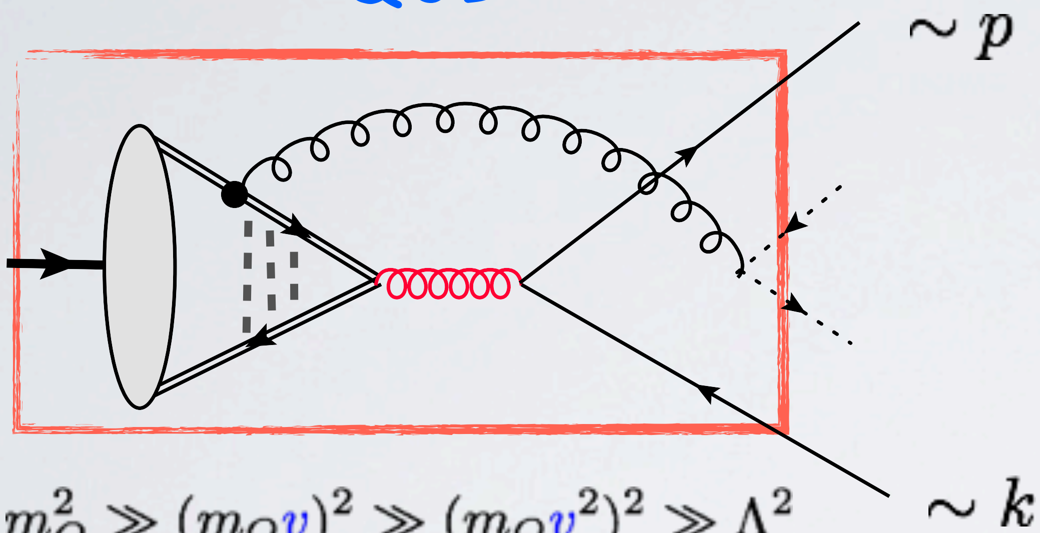
$\langle K_\perp^* K|\,\alpha_s C_h (\bar{Q}Q)_8 (\bar{q}q)_8\,|\chi_{cJ}\rangle$

"factorisable"

Soft-overlap matrix element in the Coulomb limit

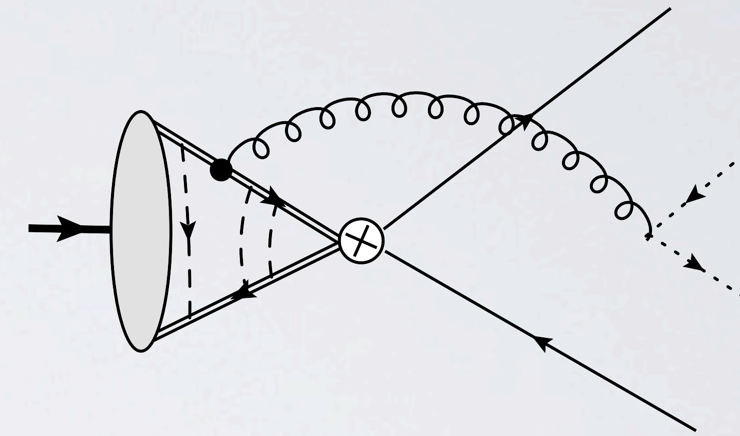
Coulomb: $v^2 \gg \Lambda/m_Q$ $\qquad \langle K_\perp^* K |\, \alpha_s C_h (\bar{Q}Q)_8 (\bar{q}q)_8 \,| \chi_{cJ} \rangle \;\sim v^4 (\Lambda/m_Q)^3$

QCD



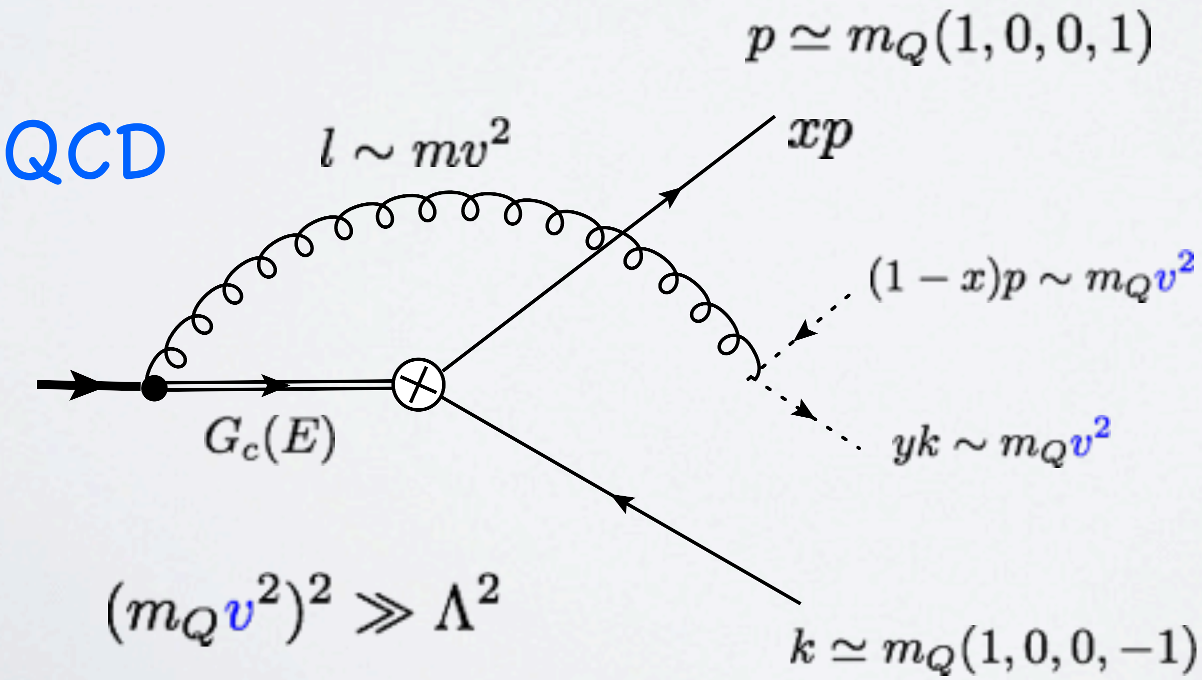
$m_Q^2 \gg (m_Q v)^2 \gg (m_Q v^2)^2 \gg \Lambda^2$

NRQCD



$(m_Q v)^2 \gg (m_Q v^2)^2 \gg \Lambda^2$

pNRQCD



$(m_Q v^2)^2 \gg \Lambda^2$

endpoint region

$y \sim v^2$

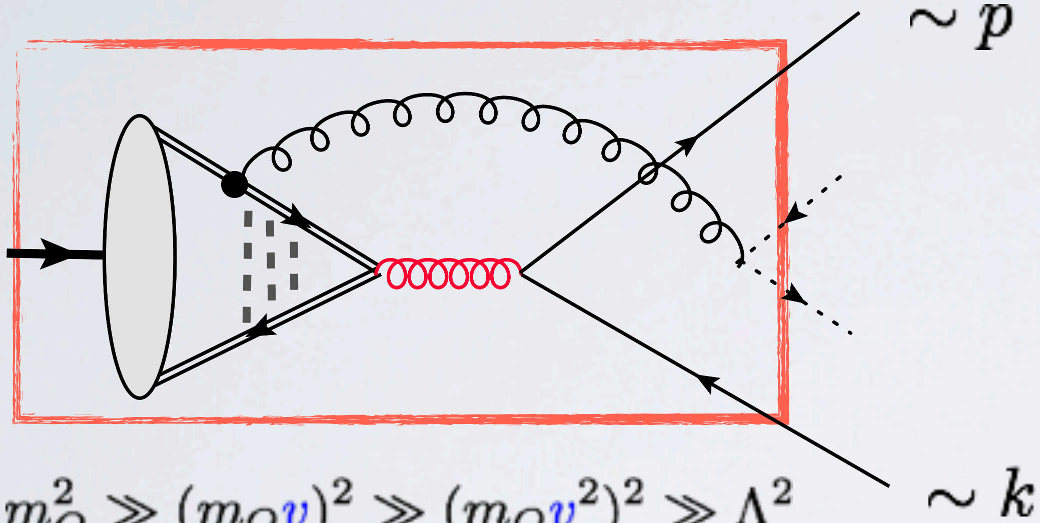
$1 - x \sim v^2$

soft QCD can be described by DAs

Soft-overlap matrix element in the Coulomb limit

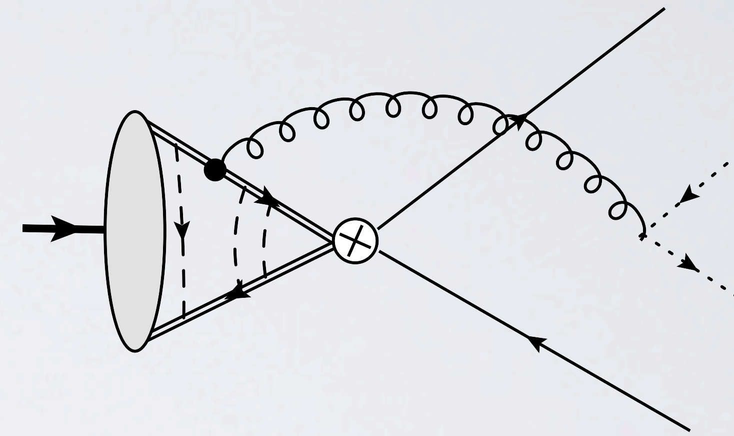
Coulomb: $v^2 \gg \Lambda/m_Q$ $\quad\quad \langle K_\perp^* K|\,\alpha_s C_h(\bar{Q}Q)_8(\bar{q}q)_8\,|\chi_{cJ}\rangle \;\sim v^4(\Lambda/m_Q)^3$

QCD



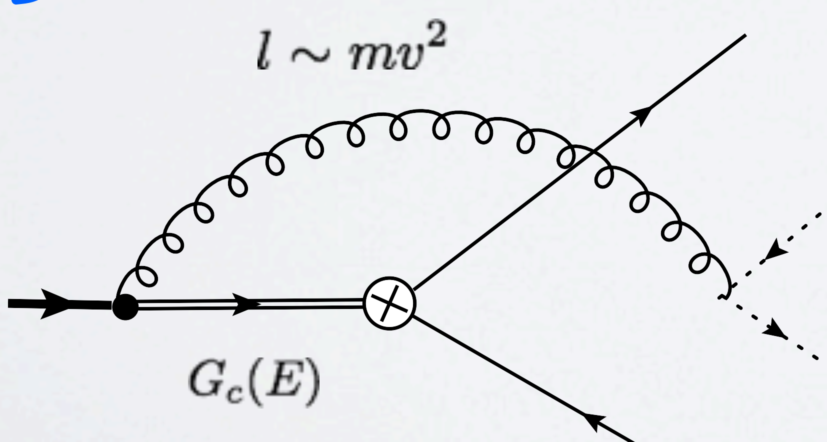
$m_Q^2 \gg (m_Q v)^2 \gg (m_Q v^2)^2 \gg \Lambda^2$

NRQCD



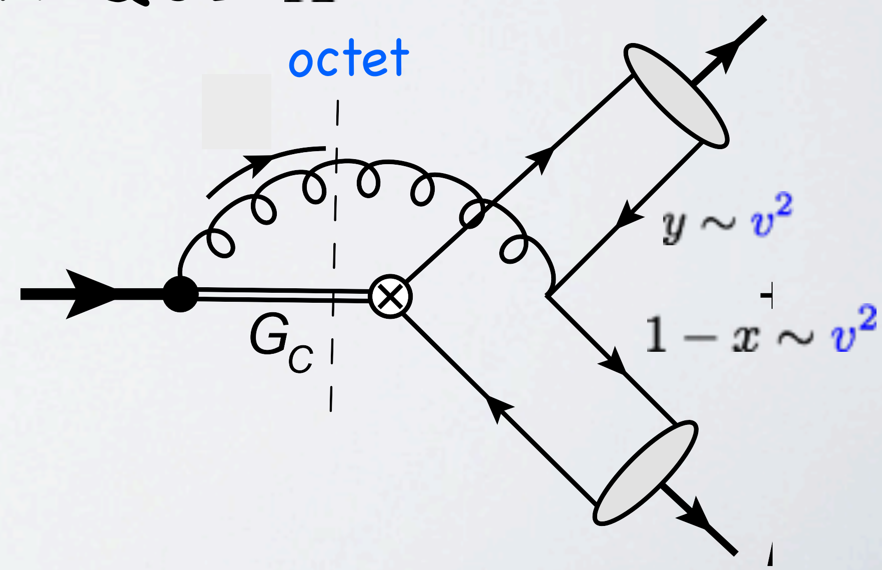
$(m_Q v)^2 \gg (m_Q v^2)^2 \gg \Lambda^2$

pNRQCD



$(m_Q v^2)^2 \gg \Lambda^2$

soft QCD Λ^2

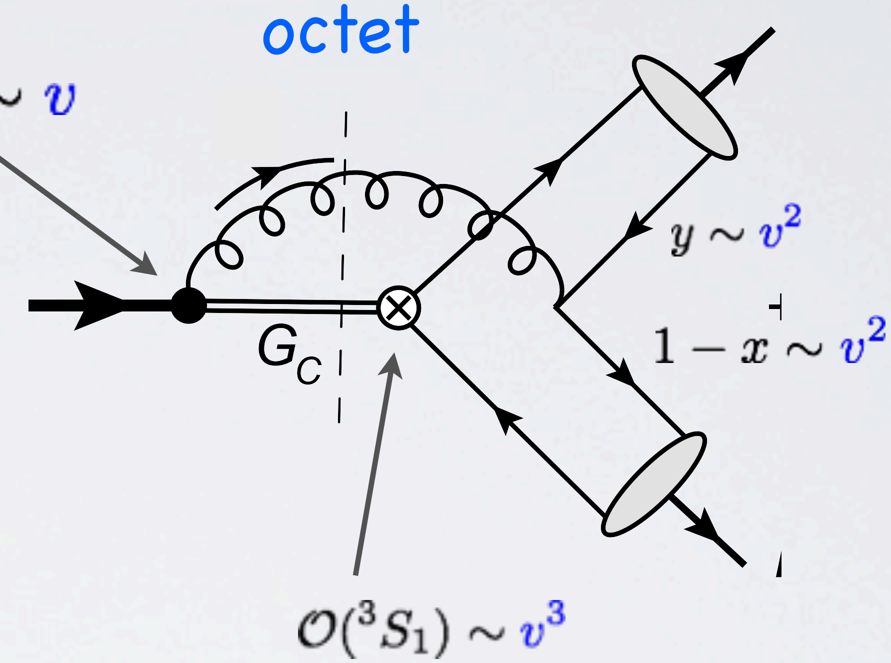


Soft-overlap matrix element in the Coulomb limit

$$\langle K_\perp^* K| \alpha_s C_h (\bar{Q}Q)_8 (\bar{q}q)_8 |\chi_{cJ}\rangle \quad \sim v^4 (\Lambda/m_Q)^3$$

$$\mathcal{L}_{int}(x) = -\psi_\omega^\dagger(x)\vec{x}\cdot g\vec{E}(t)\psi_\omega(x) \quad \sim v$$

does not depend on HQ spin!



$$\langle K_\perp^* K| \ldots |\chi_{cJ}\rangle \sim \quad \alpha_s(m_Q v^2)\alpha_s(m_Q) \int d^3\Delta\ \tilde{R}_{21}^c(\Delta)\,\mathrm{tr}\left[\mathcal{P}_J\gamma_\alpha\right] V_{us}(\Delta)$$

$$\times \int_{1-\delta}^{1} dx \int_0^\delta dy\, G_c(E-\Delta^2/m_Q, \bar{x}, y)[(1+\ln y)(m_s - m_q)\phi'_{K_\perp^*}(1)]$$

$$\delta \to \infty \qquad y \sim v^2 \qquad 1-x \sim v^2$$

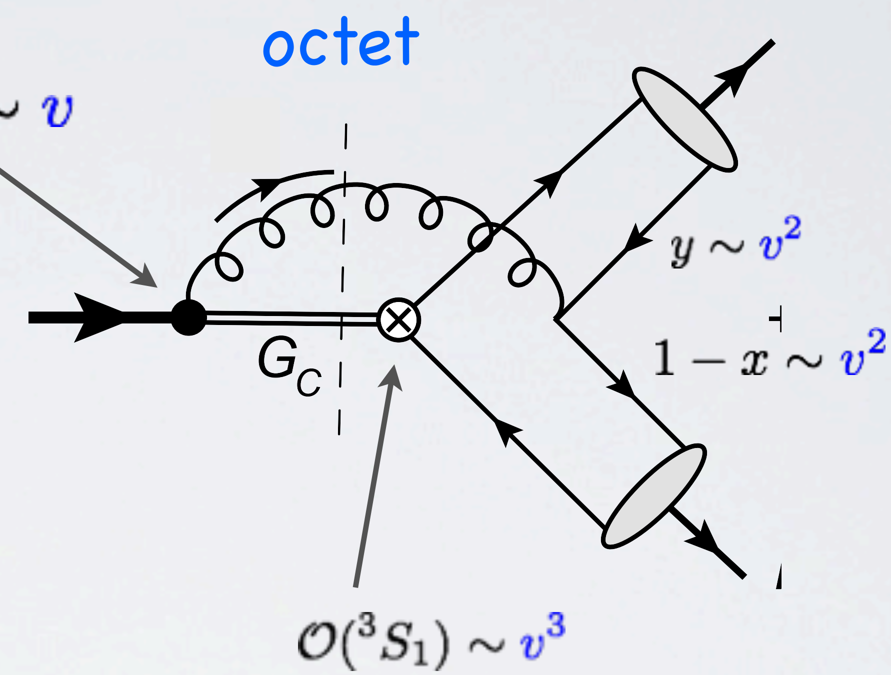
Soft-overlap matrix element in the Coulomb limit

$$\langle K_\perp^* K | \alpha_s C_h (\bar{Q}Q)_8 (\bar{q}q)_8 | \chi_{cJ} \rangle \sim v^4 (\Lambda/m_Q)^3$$

$$\mathcal{L}_{int}(x) = -\psi_\omega^\dagger(x)\vec{x}\cdot g\vec{E}(t)\psi_\omega(x) \quad \sim v$$

does not depend on HQ spin!

$\chi_{QJ}(^3P_1)$



$$\langle K_\perp^* K | \ldots | \chi_{cJ} \rangle \sim \alpha_s(m_Q v^2)\alpha_s(m_Q)\,\underline{(-1)^J 2^{J/2}} \int d^3\Delta\, \tilde{R}_{21}^c(\Delta)\,\Delta$$

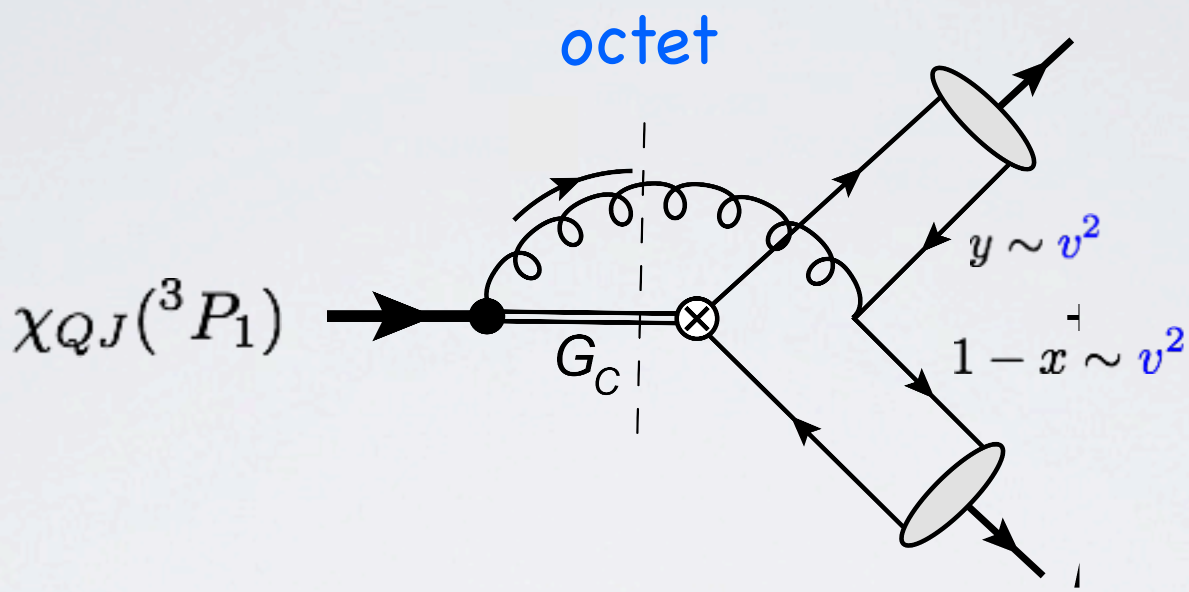
$$\times (m_s - m_q)\phi'_{K_\perp^*}(1) \int_{1-\delta}^1 dx \int_0^\delta dy \frac{(1+\ln y)}{[E - m_Q(y+\bar{x}) - \Delta^2/m_Q + i\varepsilon]^2}$$

$\delta \to \infty \qquad y \sim v^2 \qquad 1-x \sim v^2$

IR finite!

Soft-overlap matrix element in the Coulomb limit

$$\langle K_\perp^* K|\,\alpha_s C_h (\bar{Q}Q)_8 (\bar{q}q)_8\,|\chi_{cJ}\rangle \;\sim v^4 (\Lambda/m_Q)^3$$



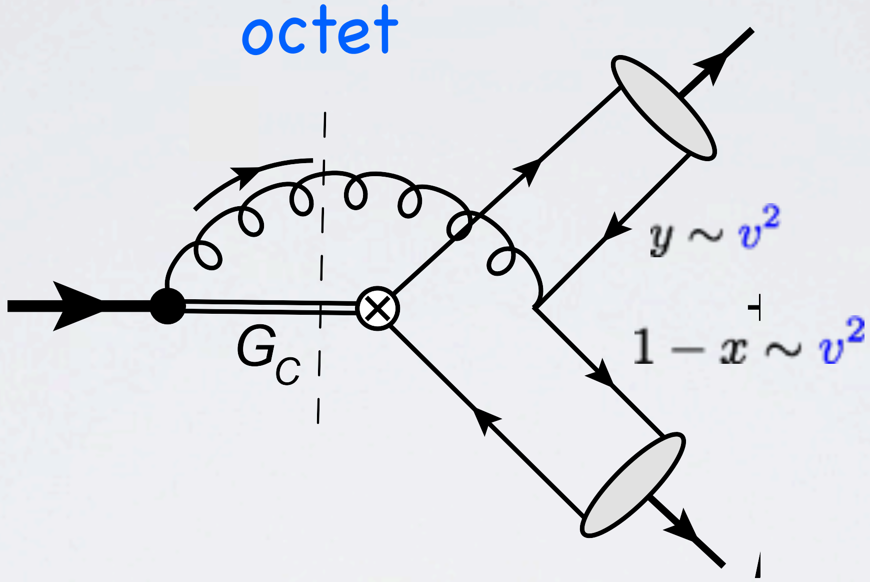
$$\langle K_\perp^* K|\,...\,|\chi_{cJ}\rangle \sim \;\alpha_s(m_Q v^2)\alpha_s(m_Q)\;(-1)^J 2^{J/2} \int d^3\Delta\; \tilde{R}^c_{21}(\Delta)\,\Delta$$

$$\times (m_s - m_q)\phi'_{K_\perp^*}(1) \int_0^\infty dx \int_0^\infty dy \,\frac{(1+\ln y)}{[E - m_Q(y+x) - \Delta^2/m_Q + i\varepsilon]^2}$$

$$y \sim v^2 \qquad 1-x \sim v^2$$

Soft-overlap matrix element in the Coulomb limit

$$\langle K_\perp^* K | \alpha_s C_h (\bar{Q}Q)_8 (\bar{q}q)_8 | \chi_{cJ}\rangle \sim v^4 (\Lambda/m_Q)^3$$



The imaginary part is given by the region 0<Delta^2/m< E . Small Delta -- large distance between the HQ's. Hence the Im part is the 100% usoft effect.

$$\langle K_\perp^* K | \ldots | \chi_{cJ}\rangle \sim \alpha_s(m_Q v^2)\alpha_s(m_Q)\, (-1)^J 2^{J/2} \int d^3\Delta\, \tilde{R}^c_{21}(\Delta)\, \Delta$$

$$\times (m_s - m_q)\phi'_{K_\perp^*}(1) \left(\frac{1}{2} \ln^2 \left[\Delta^2/m_Q^2 - E/m_Q - i0\right] + \ln\left[\Delta^2/m_Q^2 - E/m_Q - i0\right] \right)$$

imaginary part!

$$\tilde{R}^c_{21}(\Delta) = R'_{21}(0) \frac{16\pi\gamma_B \Delta}{(\Delta^2 + \gamma_B^2/4)^3} \qquad \gamma_B = \frac{1}{2} m_Q \alpha_s C_F$$

Decay amplitude $A[\chi_{cJ} \to K_\perp^* K]$

$$A[\chi_{c1} \to K_\perp^* K] = R'_{21}(0)\ \phi_{K^*}^{\perp}(y) * \alpha_s^2 T_h^{J=1}(x,y) * \phi_K(y)$$

$$+\ \langle K_\perp^* K|\, \alpha_s C_h (\bar{Q}Q)_8 (\bar{q}q)_8\, |\chi_{c1}\rangle$$

$$A[\chi_{c2} \to K_\perp^* K] = R'_{21}(0)\ \phi_{K^*}^{\perp}(y) * \alpha_s^2 T_h^{J=2}(x,y) * \phi_K(y)$$

$$+\ \langle K_\perp^* K|\, \alpha_s C_h (\bar{Q}Q)_8 (\bar{q}q)_8\, |\chi_{c2}\rangle$$

HQ Spin Symmetry:

$$\langle K_\perp^* K|\, \alpha_s C_h (\bar{Q}Q)_8 (\bar{q}q)_8\, |\chi_{c1}\rangle = -\frac{1}{\sqrt{2}}\ \langle K_\perp^* K|\, \alpha_s C_h (\bar{Q}Q)_8 (\bar{q}q)_8\, |\chi_{c2}\rangle + \mathcal{O}(v^2)$$

$$A[\chi_{c1} \to K_\perp^* K] = -\frac{1}{\sqrt{2}}\ A[\chi_{c2} \to K_\perp^* K]$$

$$+\ R'_{21}(0)\, \phi_{K^*}^{\perp}(y) * \alpha_s^2 \left(T_h^{J=1} - \frac{1}{\sqrt{2}} T_h^{J=2}\right)(x,y) * \phi_K(y)$$

well defined Spin-symmetry breaking corr's

Phenomenology $\chi_{cJ} \to K^* K$

$$R_{\rm exp} = \frac{{\rm Br}[\chi_{c2} \to \bar{K}K^* + c.c.]}{{\rm Br}[\chi_{c1} \to \bar{K}K^* + c.c.]} \frac{\Gamma_{tot}[\chi_{c2}]}{\Gamma_{tot}[\chi_{c1}]} = 0.30 \pm 0.13,$$

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Assume that HQSS breaking is negligible

$$A[\chi_{c1} \to K^*_\perp K] \simeq -\frac{1}{\sqrt{2}} A[\chi_{c2} \to K^*_\perp K]$$

then

$$R_{th} = \frac{\Gamma[\chi_{c2} \to \bar{K}^0 K^{*0} + c.c.]}{\Gamma[\chi_{c1} \to \bar{K}^0 K^{*0} + c.c.]} \simeq 0.55$$

with HQSS breaking corrections:

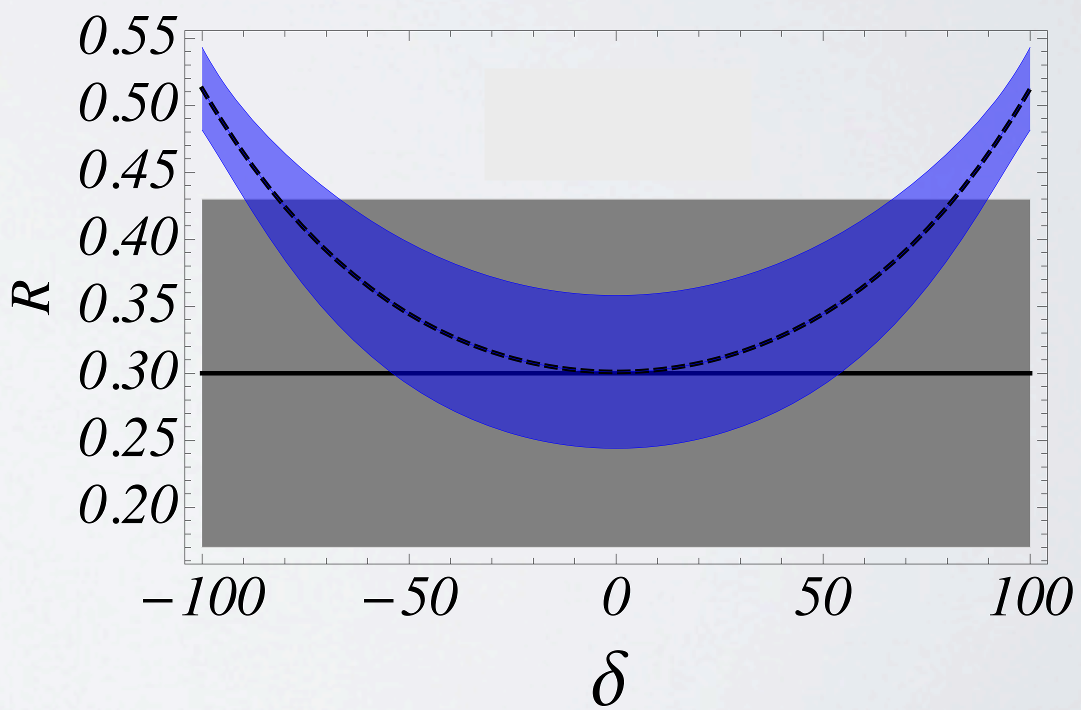
$$|\mathcal{A}_2^\perp| = (7.0 \pm 1.5) \times 10^{-3}$$

$$\Delta A = (-1.6 \pm 0.2) \times 10^{-3}$$

$$\mathcal{A}_2^\perp = |\mathcal{A}_2^\perp| \, e^{i\delta}$$ imaginary phase is unknown

$$R = \frac{6}{10} 0.91 \left(1 - 2\sqrt{2}\cos\delta \frac{\Delta A}{|A_2^\perp|} + 2\frac{|\Delta A|^2}{|A_2^\perp|^2}\right)^{-1}$$

$$+0.65\cos\delta \qquad +0.10$$



Color-octet mechanism provide dominant effect

Thank you!