Inclusive $\Upsilon(1S) \to \eta^{(\prime)} + X$ Decays with Account of α_s Running in Effective $\eta^{(\prime)} g^* g$-Vertex

Ahmed Ali, Alexander Parkhomenko, and Alexander Rusov

Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany
P. G. Demidov Yaroslavl State University, Yaroslavl, Russia

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Introduction

- Quantitative description of rare decays with the η- and η'-meson production, such as $B \to \eta^{(\prime)} K^{(*)}$, $B \to \eta^{(\prime)} X_s$, $\Upsilon(1S) \to \eta^{(\prime)} X$, $\Upsilon(1S) \to \eta^{(\prime)}\gamma$, requires understanding of $\eta^{(\prime)} g^* g^{(*)}$ effective vertex function $F_{\eta^{(\prime)} g^* g^{(*)}}(q_1^2, q_2^2, m_{\eta^{(\prime)}}^2)$
- $\eta^{(\prime)}$-meson assumed to be energetic: collinear degrees of freedom are considered; transverse ones are neglected
- Fock-state decomposition of the η'-meson wave-function

$$|\eta'\rangle = \sin\phi\,|\eta'_q\rangle + \cos\phi\,|\eta'_s\rangle + |\eta'_g\rangle$$

with $|\eta'_q\rangle \sim |\bar{u}u + \bar{d}d\rangle/\sqrt{2}$, $\quad |\eta'_s\rangle \sim |\bar{s}s\rangle$, $\quad |\eta'_g\rangle \sim |gg\rangle$

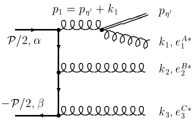
- Eigenfunction of the mixed $|\bar{q}q\rangle$ and $|gg\rangle$ state

$$\Psi = C \begin{pmatrix} \phi_{\eta'}^{(q)}(x, Q^2) \\ \phi_{\eta'}^{(g)}(x, Q^2) \end{pmatrix}, \quad C = \sqrt{2}\, f_q \sin\phi + f_s \cos\phi$$

- f_q and f_s are decay constants; ϕ is the $\eta - \eta'$ mixing angle
- Light-Cone Distribution Amplitudes (LCDAs) are introduced

$$\phi_{\eta'}^{(q)}(x, Q^2) = 6x\bar{x}\left[1 + 6(1 - 5x\bar{x})\, A_2(Q^2) + \ldots\right]$$
$$\phi_{\eta'}^{(g)}(x, Q^2) = 5x^2\bar{x}^2\,(x - \bar{x})\, B_2(Q^2) + \ldots$$

Perturbative QCD Analysis of $\Upsilon(1S) \to \eta' X$ Decay



- Typical Feynman diagram for $\Upsilon(1S) \to ggg^*(g^* \to \eta' g) \to \eta' X$ decay
- Static limit for the heavy quark and antiquark in $\Upsilon(1S)$-meson was used
- Definition of the η'-meson energy distribution function

$$\frac{dn}{dz} = \frac{1}{\Gamma_{3g}^{(0)}} \frac{d\Gamma_{\eta' X}(z)}{dz} = \frac{1}{\Gamma_{3g}^{(0)}} \frac{1}{3!} \frac{1}{(2\pi)^8} \frac{1}{2M} \int \frac{d\mathbf{k}_1}{2\omega_1} \frac{d\mathbf{k}_2}{2\omega_2} \frac{d\mathbf{k}_3}{2\omega_3} \frac{d\mathbf{p}_{\eta'}}{2E_{\eta'}}$$

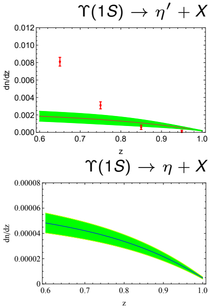
$$\times \delta^{(4)}(\mathcal{P} - k_1 - k_2 - k_3 - p_{\eta'})\, \delta(z - 2E_{\eta'}/M)\, \frac{1}{3} \sum \left| \mathcal{M}[\Upsilon \to \eta' ggg] \right|^2$$

- Normalized on the three-gluon decay width in the leading order

$$\Gamma_{3g}^{(0)} = \frac{16}{9} \left(\pi^2 - 9 \right) C_F\, B_F\, \alpha_s^3(\mu_\Upsilon^2)\, \frac{|\psi(0)|^2}{M^2}$$

- $C_F = (N_c^2 - 1)/(2N_c)$ and $B_F = (N_c^2 - 4)/(2N_c)$
- $\mu_\Upsilon \sim m_b$ is a typical hard scale of the process
- Explicit form of $\mathcal{M}[\Upsilon \to \eta' ggg]$ and analytical expression for the amplitude squared are presented in [A.Ali & AP, hep-ph/0304278]

- CLEO Collab. measured η'-meson energy spectrum in $\Upsilon(1S) \to \eta' X$ decay [hep-ex/0211029]
- Fits of $B_2^{(q)}(\mu_0^2)$ and $B_2^{(g)}(\mu_0^2)$ entering LCDAs based on the last three experimental bins with $z \geq 0.7$ gives $\chi^2_{\rm min} \simeq 2.4$ [hep-ph/0304278]
- Improved CLEO measurements using the 1.2 fb^{-1} of data [PRD74 (2006) 092006] result $\chi^2_{\rm min} \simeq 27$ for our approach.



- To improve a quality of a fit, modifications in existing theoretical calculations are under way, for example, in the EVF $F_{\eta^{(\prime)}g}(p^2)$
- In particular, $F_{\eta^{(\prime)}g}(p^2)$ is rederived under assumption that the strong coupling α_s is dependent on the energy of a parton in the meson; improved dn/dz will be presented in a forthcoming paper
- It could be also interesting if the BaBar and Belle Collaborations work out η- and η'-meson energy spectra based on their statistics of $\Upsilon(nS)$-mesons ($n = 1, 2, 3$) and compare results obtained with both CLEO data and theoretical predictions