$\eta_b \to J/\Psi J/\Psi$ decay within light cone formalism

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Hard exclusive processes

Exclusive processes:

1. Decays: $\eta_b \to J/\Psi J/\Psi, \ldots$
2. Annihilation: $e^+e^- \to J/\Psi J/\Psi, \ldots$
3. Different formfactors: $F_\pi(Q^2), \ldots$

General property:

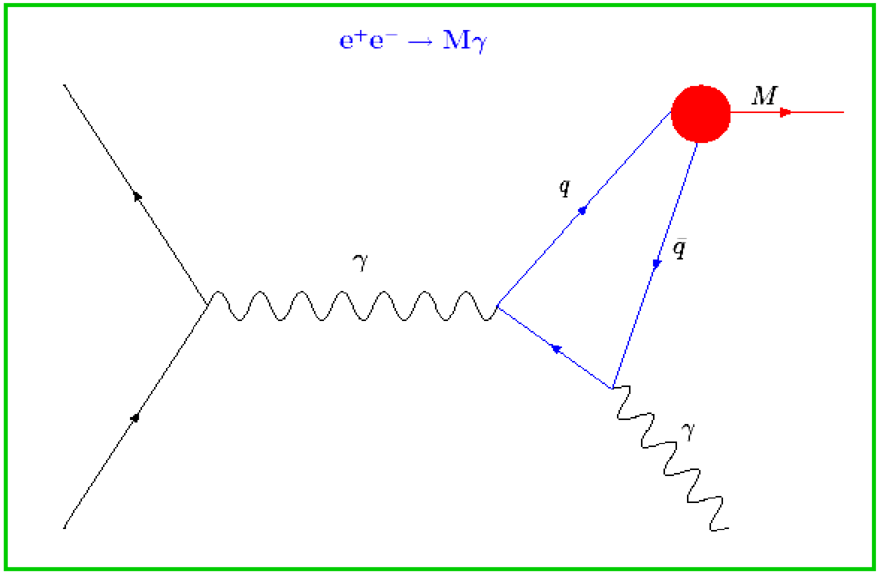
$$E_h >> \Lambda_{QCD}, M_h$$

$$\text{Expansion parameter}: \sim \frac{M^2_{J/\Psi}}{M^2_{\eta_b}} \sim \frac{1}{10}$$

$$\sigma = \frac{a_n(E_h = \infty)}{E_h^n} + \frac{a_{n+1}(E_h = \infty)}{E_h^{n+1}} + \ldots$$

Light cone expansion formalism

Factorization



Factorization formula :

$$T = \sum_n \overbrace{C_n}^{Short\ Dist.} \times \underbrace{< M \mid O_n(0) \mid 0 >}_{Large\ Dist.}$$

Different Contributions:

1. Short distance contribution : C_n (perturbative QCD)
2. Large distance contribution : $< M \mid O_n \mid 0 >$ (nonperturbative effects)

The leading twist distribution amplitude

Operators that contribute at the leading order approximation:

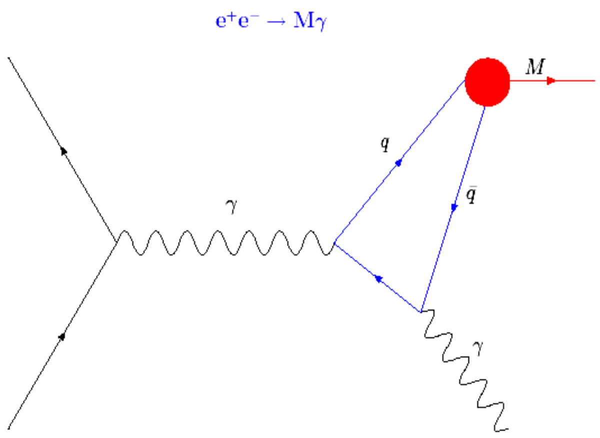
$$< \mathrm{M(p)}|\bar{\mathrm{q}}\, \gamma_\mu \gamma_5\, \mathrm{D}_{\mu_1} \ldots \mathrm{D}_{\mu_n} \mathrm{q}|0> \; \mathrm{z}^{\mu} \mathrm{z}^{\mu_1} \ldots \mathrm{z}^{\mu_n} \sim (\mathrm{pz})^{\mathrm{n}+1} \int_{-1}^{1} d\xi \; \xi^{\mathrm{n}} \varphi(\xi), \quad \mathrm{z}^2 = 0, \quad \xi = x_1 - x_2$$

Distribution amplitude $\varphi(\xi)$ can be considered as a meson wave function.

Distribution amplitudes

- Resume infinite series of operators
- Resume leading logarithmic radiative corrections

$$T = \int_{-1}^{1} d\xi \; \mathrm{H}(\xi, \mu)\, \varphi(\xi, \mu), \qquad \mu \sim \mathrm{E}_{\mathrm{hard}}$$



$\eta_b \to J/\Psi J/\Psi$ decay

The amplitude of the process

$$T = F\, e_{\mu\nu\rho\sigma}\, p_1^{\mu} \varepsilon_1^{\nu}\, p_2^{\mu} \varepsilon_2^{\nu}$$

F is the only formfactor of the process

- Helicity conservation + angular momentum conservation => $\Lambda_{J/\psi}=0$
- Helicity flip in gluon-quark-quark vertex leads to the suppression of the amplitude

$\eta_b \to J/\Psi J/\Psi$ is a next-to-next-to-leading twist process

Distribution amplitudes of J/Ψ up to twist-4

$$\begin{aligned}
\langle J/\psi(p,\epsilon)|\bar{c}(x)\gamma_\rho[x,-x]c(-x)|0\rangle &= f_V M_V\left[\frac{(\epsilon x)}{(px)}p_\rho\int_{-1}^{1}d\xi e^{i\xi(px)}\left(\varphi_1(\xi,\mu)+\frac{M_V^2x^2}{4}\varphi_2(\xi,\mu)\right)\right.\\
&+ \left(\epsilon_\rho - p_\rho\frac{(\epsilon x)}{(px)}\right)\int_{-1}^{1}d\xi e^{i\xi(px)}\varphi_3(\xi,\mu)\\
&- \left.\frac{1}{2}x_\rho\frac{(\epsilon x)}{(px)^2}M_V^2\int_{-1}^{1}d\xi e^{i\xi(px)}\varphi_4(\xi,\mu)\right],\\
\langle J/\psi(p,\epsilon)|\bar{c}(x)\sigma_{\rho\lambda}[x,-x]c(-x)|0\rangle &= f_T(\mu)\left[(\epsilon_\rho p_\lambda - \epsilon_\lambda p_\rho)\int_{-1}^{1}d\xi e^{i\xi(px)}\left(\chi_1(\xi,\mu)+\frac{M_V^2x^2}{4}\chi_2(\xi,\mu)\right)\right.\\
&+ (p_\rho x_\lambda - p_\lambda x_\rho)\frac{(\epsilon x)}{(px)^2}M_V^2\int_{-1}^{1}d\xi e^{i\xi(px)}\chi_3(\xi,\mu)\\
&+ \left.\frac{1}{2}(\epsilon_\rho x_\lambda - \epsilon_\lambda x_\rho)\frac{M_V^2}{(px)}\int_{-1}^{1}d\xi e^{i\xi(px)}\chi_4(\xi,\mu)\right],\\
\langle J/\psi(p,\epsilon)|\bar{c}(x)\gamma_\rho\gamma_5[x,-x]c(-x)|0\rangle &= f_A(\mu)e_{\rho\lambda\alpha\beta}\epsilon^\lambda p^\alpha x^\beta\int_{-1}^{1}d\xi e^{i\xi(px)}\Phi_1(\xi,\mu),\\
\langle J/\psi(p,\epsilon)|\bar{c}(x)[x,-x]c(-x)|0\rangle &= -if_S(\mu)(\epsilon x)\int_{-1}^{1}d\xi e^{i\xi(px)}\Phi_2(\xi,\mu),
\end{aligned}$$

There are 10 distribution amplitudes needed in the calculation

The result of the calculation

$$F = \int d\xi_1 d\xi_2 H(\xi_1,\xi_2,\mu)\Big(f_V f_A(\mu) M_{J/\psi}\varphi_1(\xi_1,\mu)\Phi_1(\xi_2,\mu) + f_V f_A(\mu) M_{J/\psi}\varphi_1(\xi_2,\mu)\Phi_1(\xi_1,\mu)$$

$$+ f_S(\mu) f_T(\mu)\chi_1(\xi_2,\mu)\Phi_2(\xi_1,\mu) + f_S(\mu) f_T(\mu)\chi_1(\xi_1,\mu)\Phi_2(\xi_2,\mu)\Big).$$

$$H(\xi_1,\xi_2,\mu) = \frac{1024\pi^2\alpha_s^2(\mu)}{27} f_{\eta_b}\frac{1}{M_{\eta_b}^6}\frac{1}{(1-\xi_1^2)(1-\xi_2^2)(1+\xi_1\xi_2)},$$

$$\langle J/\psi(p,\epsilon)|\bar{c}(0)\gamma_\mu c(0)|0\rangle = f_V M_{J/\psi}\epsilon_\mu, \quad \langle J/\psi(p,\epsilon)|\bar{c}(0)\sigma_{\mu\nu} c(0)|0\rangle = f_T(\mu)\left(\epsilon_\mu p_\nu - \epsilon_\nu p_\mu\right)$$

$$f_A(\mu) = \frac{1}{2}\left(f_V - f_T(\mu)\frac{2m_c(\mu)}{M_{J/\psi}}\right)M_{J/\psi}, \quad f_S(\mu) = \left(f_T(\mu) - f_V\frac{2m_c(\mu)}{M_{J/\psi}}\right)M_{J/\psi}^2$$

Fine tuning between parameters at the leading order approximation in NRQCD

$$\frac{f_T}{f_V} = 1 - \frac{\langle v^2\rangle_{J/\psi}}{3}, \quad \frac{M_{J/\psi}}{2m_c} = 1 + \frac{\langle v^2\rangle_{J/\psi}}{2}, \quad \langle v^2\rangle_{J/\psi} \sim 0.2$$

$$F = \frac{256\pi^2\alpha_s^2}{81}\frac{1}{m_b^6} f_{\eta_b} f_V^2 m_c^2 \langle v^2\rangle$$

Fine tuning is broken due to relativistic and radiative corrections what leads to the dramatic enhancement of the branching ratio

Numerical results

$$
\begin{aligned}
Br(\eta_b \to J/\psi J/\psi) &= (6.2 \pm 3.5) \times 10^{-7}, \\
Br(\eta_b \to J/\psi \psi') &= (10 \pm 6) \times 10^{-7}, \\
Br(\eta_b \to \psi' \psi') &= (3.7 \pm 2.8) \times 10^{-7}.
\end{aligned}
$$

Approximately 100 events of the $\eta_b \to J/\Psi J/\Psi$ decay at LHC per year

Thank you