用微扰QCD方法研究$B_s \to PP$过程

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目录

- 目录
  - 研究背景
  - 研究方法
  - 工作进程

研究背景

- 理论和实验存在偏差，但并没有出现一些明显的超出标准模型的新物理信号，所以我们有必要更加精确的计算标准模型内的B介子衰变。

研究方法

- 低能有效哈密顿量

$$\mathcal{H}_{eff} = \frac{G_F}{\sqrt{2}} \sum_i V^i_{CKM} C_i(\mu) O_i(\mu)$$

- 衰变振幅

$$\begin{aligned} A(B \to M_1 M_2) &= \langle M_1 M_2 | \mathcal{H}_{eff} | B \rangle \\ &= \frac{G_F}{\sqrt{2}} \sum_i V_i C_i(\mu) \langle M_1 M_2 | O_i(\mu) | B \rangle \end{aligned}$$

简单因子化

- 忽略末态相互作用，把强子矩阵元拆成两个流算符的乘积。

$$\langle M_1 M_2 | O_i(\mu) | B \rangle \approx \langle M_2 | J_2^{\mu} | 0 \rangle \langle M_1 | J_{1\mu} | B \rangle$$

- 存在问题：
  (1)重整化标度的依赖性
  (2)忽略不可因子化的贡献
  (3)无法预言CP破坏

推广因子化

- 为了解决重整化标度的依赖性

$$C(\mu)\langle O(\mu)\rangle = C(\mu)g(\mu)\langle O\rangle_{tree} = C^{eff}\langle XY|O|B\rangle_{tree}$$

微扰QCD因子化

- 形状因子是以硬胶子交换为主，衰变振幅就可以为硬散射核与强子波函数的卷积。

$$
\begin{aligned}
\mathcal{A} \propto \quad & \int dx_1 dx_2 dx_3 b_1 db_1 b_2 db_2 b_3 db_3 \\
& \cdot \mathrm{Tr}[C_i(t)\ \Phi_{B_s}(x_1, b_1)\ \Phi_{P_2}(x_2, b_2)\ \Phi_{P_3}(x_3, b_3) \\
& H(x_i, b_i, t)\ S_t(x_i)\ e^{-S(t)}]
\end{aligned}
$$

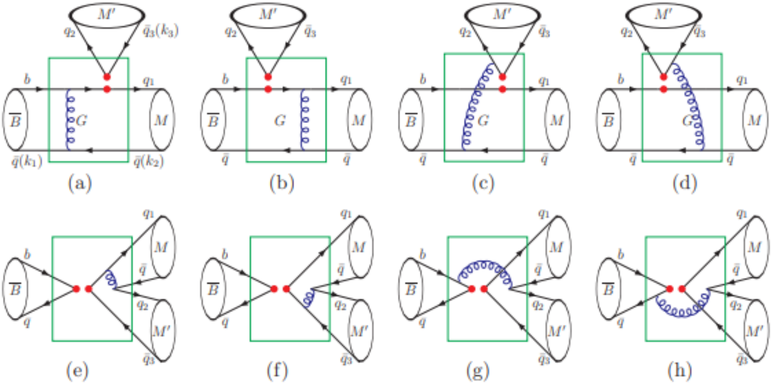
工作进程

- 低能有效哈密顿量，其中q=(d,s)

$$\mathcal{H}_{eff}=\frac{G_F}{\sqrt{2}}\{V_{ub}V_{uq}^{*}[C_1(\mu)O_1^u(\mu)+C_2(\mu)O_2^u(\mu)]$$
$$-V_{tb}V_{tq}^{*}[\sum_{i=3}^{10}C_i(\mu)O_i(\mu)]\}+\text{ h.c.}$$

工作进程

- 费曼图



微扰QCD因子化

- 下面我们以a图为例

$$
\begin{aligned}
\mathcal{A}_a^{LL} = \quad & C \int dx_1 dx_2 db_1 db_2 C_i\left(t_a\right) \alpha_s\left(t_a\right) S_t\left(x_2\right) H_{ab}\left(\alpha_g, \beta_a, b_1, b_2\right) \\
& \left\{\phi_{B1}\left[\phi_M^a\left(1+x_2\right)+\left(\phi_M^p+\phi_M^t\right)\left(\bar{x}_2-x_2\right)\right]\right. \\
& \left.-\phi_{B2}\left[\phi_M^a-\left(\phi_M^p+\phi_M^t\right) x_2\right]\right\}
\end{aligned}
$$

$$\mathcal{A}_a^{LR} = -\mathcal{A}_a^{LL}$$

微扰QCD因子化

$$\mathcal{A}_a^{SP} = 2r_{M'}\ C \int dx_1 dx_2 db_1 db_2 C_i(t_a)\alpha_s(t_a)S_t(x_2)$$
$$H_{ab}(\alpha_g, \beta_a, b_1, b_2)\{\phi_{B1}[\phi_M^a + \phi_M^p(2 + x_2) - \phi_M^t x_2]$$
$$-\phi_{B2}[\phi_M^a + \phi_M^p - \phi_M^t]\}$$

- 其中

$$C = i\frac{\pi C_F}{N_c} m_B^4 f_B f_M f_{M'}$$

微扰QCD因子化

- 下面我们以$\bar{B}_s^0 \to \pi^0 K^0$为例

$$
\begin{aligned}
&\mathcal{A}(\bar{B}_s^0 \to \pi^0 k^0) = \langle \pi^0 k^0 | \mathcal{H}_{eff} | \bar{B}_s^0 \rangle \\
&= \frac{G_F}{\sqrt{2}} \{ V_{ub} V_{ud}^* [a_2 A_{ab}^{LL}(k^0, \pi^0) + \frac{c_1}{N_c} A_{cd}^{LL}(k^0, \pi^0)] \\
&- V_{tb} V_{td}^* [(-a_4 + \frac{3a_9}{2} + \frac{a_{10}}{2}) A_{ab}^{LL}(k^0, \pi^0) + \frac{1}{N_c}(-c_3 + \frac{C_9}{2} + \frac{3C_{10}}{2}) A_{cd}^{LL}(k^0, \pi^0) \\
&+ \frac{3a_7}{2} A_{ab}^{LR}(k^0, \pi^0) + \frac{3c_8}{2N_c} A_{cd}^{LR}(k^0, \pi^0) + (-a_6 + \frac{a_8}{2}) A_{ab}^{SP}(k^0, \pi^0) \\
&+ \frac{1}{N_c}(-c_5 + \frac{C_7}{2}) A_{cd}^{SP}(k^0, \pi^0) + (-a_4 + \frac{a_{10}}{2}) A_{ef}^{LL}(\pi^0, k^0) + \frac{1}{N_c}(-c_3 + \frac{C_9}{2}) A_{gh}^{LL}(\pi^0, k^0) \\
&+ (-a_6 + \frac{a_8}{2}) A_{ef}^{SP}(\pi^0, k^0) + \frac{1}{N_c}(-c_5 + C_7) A_{gh}^{SP}(\pi^0, k^0)]\}
\end{aligned}
$$

微扰QCD因子化

- 分支比

$$\mathcal{B}r = \frac{\tau_B}{16\pi}\frac{p_{\rm cm}}{m_B^2}\left\{|\mathcal{A}(B \to f)|^2 + |\mathcal{A}(\bar{B} \to \bar{f})|^2\right\}$$

Table: $\bar{B}_s^0 \to \pi^0 K^0$ 衰变过程的分支比数值结果

	Φ_{B_1}	$\Phi_{B_1} + \Phi_{B_2}$	PQCD(Lu)
$\bar{B}_s^0 \to \pi^0 K^0$	$(0.146) \times 10^{-6}$	$(0.165) \times 10^{-6}$	$(0.16) \times 10^{-6}$

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