External masses effect to $Z\bar{b}s$ coupling

Shan Cheng

Hunan University

In collaboration with Qin Qin, and Hsiang-nan Li

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Overview

Background

$g_{Z\bar{b}s}$

- Mass effect

Conclusion

Background

- † Inami-Lim function is widely used to deal with B meson decays
- † large m_t, the limit of vanishing external momentum, $B_0, C_0, D_0, E_0, D_0', E_0'$
- † In B meson decay, the invariant mass of boson is much less than m_t, the limit is good

- † But in b production, ie., BK production in Z factory (CEPC), we should revisit C_0
- † At least the m_Z should considered, how well of the limit works

the first glance at $Z \to \bar{b}s$

- $g_{Z\bar{b}s} = \sum_i V_{is} V^*_{ib} \left[g_0 + m_i^2/m_W^2 \left(g_1 + g_2 \ln \frac{m_i^2}{m_W^2} \right) + \cdots \right]$
- Suppressed by the Glashow-Illiopoulous-Maini(GIM) mechani.
- do occur in electroweak interaction at one-loop penguin level

- Gauge condition: The t' Hooft-Feynman gauge ($\xi = 1$ in R_ξ)
  - † vector boson is proportional to $g_{\mu\nu}$, the simplest form
  - † the unphysical scalar boson has a pole at $p^2 = M^2$
  - † the negative-metric scalar-boson pole of the vector-boson propagator is cancelled by the unphysical-scalar-boson propagator
  - † the masses of unphysical scalars are took on their physical partner.
- Dimension regularization with the completely anticommunting γ_5 and the 't Hooft convention of γ_5

$Z \to \bar{b}s$

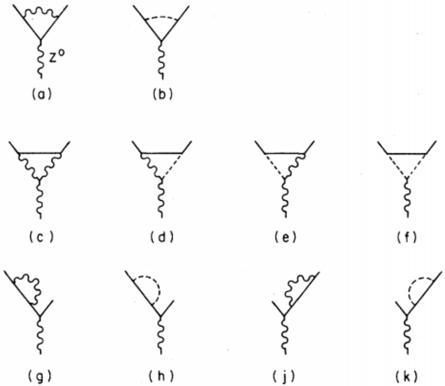


FIG. 1. Feynman diagrams contributing to $Z^0 \to q\bar{x}$ in the 't Hooft–Feynman gauge. The internal quarks must have weak isospin different from q and x. Wavy internal lines represent $W^{\pm}$; dashed internal lines represent the associated unphysical scalars.

looking at $Z \to \bar{b}s$

- no divergence appears in Fig1(d,e)
- Unitarity of the charged current mixing matrix, each divergence in Fig1(a,c,j,g) becomes finite
- divergences in Fig1(b,f,h,k) cancels for each internal flavour
- the couplings in Fig1(b,f,h,k) are proportional to $\mathcal{O}(m_i^2/m_W^2)$, zero power ($\propto 1$) in Fig1(a,c,j,g)
- the $\sin\theta_W$ dependence in individual diagram disppear finally

† $\sin\theta_W$ represents the coupling of photon to $\bar{b}\gamma_\mu(1-\gamma_5)s$
† the related $\phi\bar{b}s$ vertex does not have this dependence

Effects of the external momentum

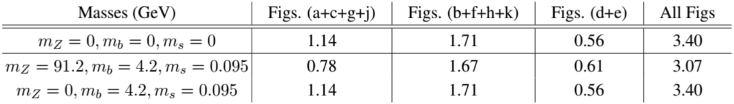
Taking Fig.1(b) for example, Preliminary

$$
\begin{aligned}
Z^\mu \bar{b}(k_1) g^{(b)}_{Z\bar{b}s} s(k_2) = Z^\mu \bar{b}\, \frac{g^3 V^*_{tb} V_{ts}}{4\, c_{\theta_W}} \frac{m_t^2}{m_W^2}\ \Big\{ \Big(\Big[(2-\epsilon) C_{g_{\mu\nu}}(\bar{k}'_2, -\bar{k}'_1) &+ (m_b^2 + m_s^2) C_{pp} \\
&-(m_Z^2 - m_b^2) C_{p_1 p_2} - 2 m_s^2 C_1 \Big] \left(-\frac{4}{3} s^2_{\theta_W} \right) \\
&- \left[m_t^2 C_0 - m_b^2 (C_0 - C_2) + m_s^2 (C_0 - C_1) \right] \left(1 - \frac{4}{3} s^2_{\theta_W} \right) \Big) \gamma_\mu L \\
&+ m_b m_s \left[2 C_2 \left(-\frac{4}{3} s^2_{\theta_W} \right) + (C_1 - C_2) \left(1 - \frac{4}{3} s^2_{\theta_W} \right) \right] \gamma_\mu R \\
&-2 m_b C_{pp} \left(-\frac{4}{3} s^2_{\theta_W} \right) k_{1,\mu} L \\
&-2 m_s \left[C_{p_1 p_2} \left(-\frac{4}{3} s^2_{\theta_W} \right) - C_2 \left(1 - \frac{4}{3} s^2_{\theta_W} \right) \right] k_{1,\mu} R \\
&+2 m_b \left[C_{p_1 p_2} \left(-\frac{4}{3} s^2_{\theta_W} \right) + C_1 \left(1 - \frac{4}{3} s^2_{\theta_W} \right) \right] k_{2,\mu} L \\
&-2 m_s \left[2 C_1 - C_{pp} \right] \left(-\frac{4}{3} s^2_{\theta_W} \right) k_{2,\mu} R \\
&- \frac{\epsilon}{4} B_0(-p'_s - p'_b) \left(1 - \frac{4}{3} s^2_{\theta_W} \right) \gamma_\mu L \Big\} s
\end{aligned}
$$

Effects of the external momentum

- † C_0; $C_\mu(k_1, k_2) = k_{1\mu} C_1 + k_{2\mu} C_2$;
  † $C_{\mu\nu}(k_1, k_2) = g_{\mu\nu} C_g + (k_{1\mu} k_{1\nu} + k_{2\mu} k_{2\nu}) C_{kk} + (k_{1\mu} k_{2\nu} + k_{1\nu} k_{2\mu}) C_{k_1 k_2}$
- C_g, B_1 are the leading power of $\mathcal{O}(m_t^2)$
- $m_W = 80.4\,\mathrm{GeV}$, $m_t = 173\,\mathrm{GeV}$

- Preliminary
  † Varying k_1^2, k_2^2 does not change B_1, C_g
  † $\gamma_\mu R$, k_μ terms are four and five order of magnitude smaller
  † The mass effect mainly come from the m_Z terms



Masses (GeV)	Figs. (a+c+g+j)	Figs. (b+f+h+k)	Figs. (d+e)	All Figs
$m_Z = 0, m_b = 0, m_s = 0$	1.14	1.71	0.56	3.40
$m_Z = 91.2, m_b = 4.2, m_s = 0.095$	0.78	1.67	0.61	3.07
$m_Z = 0, m_b = 4.2, m_s = 0.095$	1.14	1.71	0.56	3.40

Conclusion

湖南大学高能物理学科

- 理论物理硕士学位点（1985），物理学博士点；
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The End, Thanks.