Institut für Theoretische Teilchenphysik

Einführung in die Flavourphysik
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Sheet 10

Problem 15: Leptonic decay $B_s \to \ell^+\ell^-$

The relevant electroweak effective Lagrangian for the process $B_s \to \ell^+\ell^-$ is given by[1]

$$\mathcal{L} = N C_A(\mu_b) \left(\bar{b}\gamma_\alpha\gamma_5 s\right) \left(\bar{\mu}\gamma^\alpha\gamma_5\mu\right) + h.c. \,, \tag{1}$$

with the normalization $N = V_{tb}^* V_{ts} G_F^2 M_W^2/\pi^2$, the scale $\mu_b \sim m_b$ and Wilson coefficients $C_A(\mu_b)$. Latter are given at NLO EW and NNLO QCD as [1]

$$C_A(\mu_b = 5\,\text{GeV}) = 0.4690 R_t^{1.53} R_\alpha^{-0.09} \,, \tag{2}$$

with $R_\alpha = \alpha_s(M_Z)/0.1184$ and $R_t = M_t/(173.1\,\text{GeV})$. The decay $B_s \to \mu^+\mu^-$ has been observed in the experiments CMS and LHCb at CERN[2].

a) Draw the leading order diagrams (in the unitary gauge) for $B_s \to \ell^+\ell^-$.

b) Evaluate the numerical value for $\mathcal{B}(B_s \to \mu^+\mu^-)$. Use:

$$\langle 0|\bar{b}\gamma^\alpha\gamma_5 s|B_s(p)\rangle = i p^\alpha f_{B_s} \,. \tag{3}$$

The dependence of $\mathcal{B}(B_s \to \ell^+\ell^-)$ from $\overline{|\mathcal{M}|^2}$ is given through:

$$\mathcal{B}(B_s \to \ell^+\ell^-) = \frac{1}{16\pi M_{B_s}\Gamma_H^s}\sqrt{1 - \frac{4m_\ell^2}{M_{B_s}^2}}\,\overline{|\mathcal{M}|^2} \,. \tag{4}$$

You can find numerical values for the needed inputs in Ref. [3]. Test the standard model by comparing your result with the experimental value from Ref. [2].

Problem 16: Leptonic kaon decays

Consider leptonic $P^\pm \to \ell^\pm\nu$ decays (P_{l2}), with [4]

$$\Gamma^{\text{SM}}(P^\pm \to \ell^\pm\nu) = \frac{G_F^2 M_P M_\ell^2}{8\pi}\left(1 - \frac{M_l^2}{M_P^2}\right)^2 f_P^2 |V_{qq'}|^2 \,. \tag{5}$$

Let us introduce the ratio:

$$R_K \equiv \frac{\Gamma(K_{e2})}{\Gamma(K_{\mu 2})} \,. \tag{6}$$

What is the leading standard model expectation for this observable? Which special property does R_K have? The current values of inputs can be found in Ref. [3]. Now also use the result of the 2-loop calculation in chiral perturbation theory in Ref. [5], that evaluates QED-corrections, and then test the standard model by comparing to experimental value [4]

$$R_K^{\text{exp}} = (2.488 \pm 0.010) \times 10^{-5} \,. \tag{7}$$

References

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