Interpretation of measurements – Problems

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1 $B_q \to \ell^+\ell^-$

1. Discuss the physical origin of the factor of m_μ^2 in the branching ratio of $B_s \to \mu^+\mu^-$.
2. Compute the branching ratio $\overline{\text{BR}}(B_s \to \tau^+\tau^-)$ in the Standard Model. Discuss the prospects of measuring this decay in the near future.
3. Compute the branching ratio $\text{BR}(B_d \to \mu^+\mu^-)$ and compare it to the measurement by LHCb and CMS

$$\text{BR}(B_d \to \mu^+\mu^-) = (3.9^{+1.6}_{-1.4}) \times 10^{-9}.$$

   Try to interpret this measurement.

For the numerics, you can make use of the following resources.

- PDG http://pdg.lbl.gov/
- HFAG http://www.slac.stanford.edu/xorg/hfag/
- FLAG http://itpwiki.unibe.ch/flag
- CKMfitter or UTfit http://ckmfitter.in2p3.fr/, http://utfit.org/

2 Indirect bounds on modified top couplings

Assume that there is a new physics model that generates contributions to the Wilson coefficient $(C_{Hq}^{(1)})_{ij}$ at the electroweak scale. Find the maximum allowed branching ratio of the decay $t \to cZ$ using the following constraints.

1. The partial Z width to b quarks

$$R_b = \frac{\Gamma(Z \to \bar{b}b)}{\Gamma(Z \to \text{hadrons})}$$

can be written at leading order as

$$R_b = \frac{|g^L_{Zbb}|^2 + |g^R_{Zbb}|^2}{\sum_{q=u,d,s,c,b}\left(|g^L_{Zqq}|^2 + |g^R_{Zqq}|^2\right)}$$

In the SM, $g^L_{Zqq} \approx 0.577$ and $g^R_{Zqq} \approx 0.077$.

The measurement and SM prediction read

$$R_b^{\rm exp} = 0.21629(66) \qquad\qquad R_b^{\rm SM} = 0.21583(4)$$

2. The Wilson coefficient C_{10}, which is constrained by the measurement of $B_s \to \mu^+\mu^-$ is modified as

$$\frac{C_{10}}{C_{10}^{\rm SM}} = 1 + \frac{2\pi}{\alpha V_{tb}V_{ts}^* Y(x_t)}\delta g^L_{Zbb}$$

where $Y(x_t) \approx 0.98$.