STATUS OF THEORETICAL $\bar{B} \to X_S\gamma$ AND $\bar{B} \to X_S L^+ L^-$ ANALYSES

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Status of the theoretical $\bar{B} \to X_s\gamma$ and $\bar{B} \to X_s l^+ l^-$ analyses is reviewed. Recently completed perturbative calculations are mentioned. The level at which non-perturbative effects are controlled is discussed.

The present talk will be devoted to discussion of the SM predictions only. Let us begin with $\bar{B} \to X_s\gamma$. Since the completion of NLO QCD calculations[1] 4 years ago, many new analyses have been performed. They include evaluation of non-perturbative Λ^2/m_c^2 corrections[2] and the leading electroweak corrections.[3,4] None of these results exceeds half of the overall $\sim 10\%$ uncertainty, and there are cancellations among them. In consequence, the prediction for $BR[\bar{B} \to X_s\gamma]$ remains almost unchanged: $(3.29 \pm 0.33) \times 10^{-4}$. This prediction agrees very well with the measurements of CLEO[5], ALEPH[6] and BELLE[7], whose combined result is $(3.21 \pm 0.40) \times 10^{-4}$.

The dominant contribution to the perturbative $b \to s\gamma$ amplitude originates from charm-quark loops. After including QCD corrections, the top-quark contribution is less than half of the charm-quark one, and it comes with an opposite sign. This fact should be remembered when one attempts to extract $|V_{ts}|$ from $b \to s\gamma$. The u-quark contribution is suppressed with respect to the charm one by $|V_{ub}V_{us}|/|V_{cb}V_{cs}| \simeq 2\%$.

The results of CLEO, ALEPH and BELLE have to be understood as the ones with subtracted intermediate ψ background, i.e. the background from $\bar{B} \to \psi X_s$ followed by $\psi \to X'\gamma$. This background gives more than 4×10^{-4} in the "total" BR, but gets suppressed when only high-energy photons are counted. A rough estimate[8] of the effect of the photon energy cutoff on this background can be made when X_s in $\bar{B} \to \psi X_s$ is assumed to be massless, and the non-zero spin of ψ is ignored. Then,[a] the intermediate ψ background is less than 5%, for the present experimental cutoff $E_\gamma > 2.1$ GeV in the $\bar{B}$-meson rest frame.[b] However, the background grows fast when the cutoff goes down.

The photon energy cutoff *will* have to go down by at least 200 or 300 MeV in the future. With the present one, non-perturbative effects related to the unknown $\bar{B}$-meson shape function[4] considerably weaken the power of $b \to s\gamma$ for testing new physics. For the same reason, future measurements of $\bar{B} \to X_s\gamma$ should rely as little as possible on theoretical predictions for the precise shape of the photon spectrum above $E_\gamma \sim 2$ GeV.

A systematic analysis of non--perturbative effects in $\bar{B} \to X_s\gamma$ at order $\mathcal{O}(\alpha_s(m_b))$ is missing. There is no straightforward method to perform such an analysis, because there is no obvious operator product expansion for the matrix elements of the 4-quark operators, in the presence of one or more hard gluons (i.e. the gluons with momenta of order m_b). At present, we have only intuitive arguments to convince ourselves that such non-perturbative effects are probably significantly smaller than the overall $\sim 10\%$ theoretical uncertainty in $BR[\bar{B} \to X_s\gamma]$, when the energy cutoff is between 1 and 2 GeV, and when the intermediate $\psi^{(\prime)}$ contribution(s) are subtracted.

[a] The $\psi \to X\gamma$ spectrum is available from the ancient MARK II data[9]. New results are expected soon from the BES experiment in Beijing.

[b] A further suppression (to less than 1%) is found when X_s is not treated as massless but the measured[10] mass spectrum is used.

As far as the decay $\bar{B} \to X_s l^+ l^-$ is concerned (for $l = e$ or μ), the best control over non-perturbative effects can be achieved in the region of low dilepton invariant mass ($\hat{s} \equiv m^2_{l^+l^-}/m_b^2 \in [0.05,\ 0.25]$). The present prediction[11] for the branching ratio integrated over this domain is $(1.46 \pm 0.19) \times 10^{-6}$. The quoted uncertainty is only the perturbative one. The non-perturbative Λ^2/m_c^2 and Λ^2/m_b^2 contributions[12] have been included in the central value. They are around 2% and 5%, respectively.

A calculation of $\mathcal{O}(\alpha_s)$ terms in all the relevant Wilson coefficients $C_i(m_b)$ has been recently completed[11], up to small effects originating from 3-loop RGE evolution of C_9. However, the perturbative uncertainty in the above-mentioned prediction remains close to $\sim$13%, because 2-loop matrix elements of the 4-quark operators are unknown.

The low-$\hat{s}$ branching ratio is as sensitive to new physics as the forward-backward or energy asymmetries, i.e. $\sim$100% effects are observed when $C_7(m_b)$ changes sign.

The background from $\bar{B} \to \psi X_s$ followed by $\psi \to l^+ l^-$ is removed by the cutoff $\hat{s} < 0.25$. Analogous contributions from virtual $c\bar{c}$ states are, in principle, included in the calculated Λ^2/m_c^2 correction. An independent verification of this fact can be performed with help of dispersion relations and the factorization approximation.[13] Indeed, for $\hat{s} < 0.25$, the difference between results obtained with help of the two methods is quite small, and can be attributed to higher-order perturbative effects.

On the other hand, the background from $\bar{B} \to \psi X_s$ followed by $\psi \to X' l^+ l^-$ has never been studied. Most probably, for $\hat{s} < 0.25$, it is less important than the analogous background in the case of $\bar{B} \to X_s \gamma$. Experiment-based calculations of these backgrounds are awaited, because they are essential for performing theoretical estimates of similar non-perturbative contributions from other $c\bar{c}$ states.

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