Comparing AdS/QCD and Sum Rules predictions for $B \to K^{*}\nu\bar{\nu}$

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Introduction

The flavor changing neutral current (FCNC) $b \to s$ transition has been at the focus of extensive experimental and theoretical investigations. The rare decay $B \to K^{*}\nu\bar{\nu}$ has not yet been measured experimentally and it is challenging to do so, as both leptons are in detecting eluding neutrinos. Only the upper bounds on the branching ratio (BR) are known and the most ones are set by the Belle Collaboration\cite{1}:

$BR(B^{+} \to K^{*+}\nu\bar{\nu}) < 4.0 \times 10^{-6}$ (90% CL)

$BR(B^{0} \to K^{0}\nu\bar{\nu}) < 5.5 \times 10^{-6}$ (90% CL)

With the advent of Super-B facilities, the prospects of measuring these branching ratios in the near future are good. The Belle-II experiment, with an integrated luminosity 50 ab\textsuperscript{-1} that is expected to be collected by 2023, a measurement of the SM BRs with 30% precision is expected\cite{2}. Theoretically, the presence of only one operator in the effective Hamiltonian for the $b \to s\nu\bar{\nu}$ transition makes $B \to K^{*}\nu\bar{\nu}$ much less susceptible to hadronic uncertainty due to sensitivity to a minimal number of form factors. Moreover, this decay process does not suffer from additional uncertainties beyond the form factors, such as those that plague the $b \to s\ell\nu$ transitions due to the breaking of factorization caused by photon exchange.

A remarkable feature of the AdS/QCD correspondence is referred to as light-front holography\cite{3}. In light-front QCD, the holographic meson wavefunction is:

\[ \Psi_{x} (\zeta) = N \sqrt{a_{2} (1-x)^{-1}} \exp \left\{ \frac{\zeta}{2} \left( 1 - \frac{m_{0}^{2}}{2m_{s}} \right) \right\} \]

The variable $\zeta = 2a_{2}(1-x)r$ where $r$ is the transverse distance between the quark and antiquark forming the meson and $x$ is the fraction of the meson’s momentum carried by the quark. $\kappa$ is the fundamental confinement scale that emerges in light-front holography. Spectroscopic data indicate that $\kappa = 0.55$ GeV for light vector mesons. We shall fix the quark masses $m_{q/s}$ in order to fit the experimentally measured decay constant $f_{K}$\cite{4, 5}:

\[ f_{K} \approx N \int d^{3}p \left[ \frac{1}{x(1-x)} \Psi_{x} (\zeta, x) \left( \frac{m_{0}^{2}}{2m_{s}} \right) \right] \]

$m_{s} = (195 \pm 55)$ MeV and $m_{q} = (300 \pm 20)$ MeV lead to $f_{K} \sim 200$ MeV compared to the experimental value $205 \pm 6$ MeV from $F(\tau^- \to K^{*-}\nu_{\tau})$.

Distribution Amplitudes

The Distribution Amplitudes (DAs) of the meson are related to its light-front wavefunction. The two twist-2 DAs are predicted as:

\[ f_{K}(q^{2}) = \frac{N}{2m_{s}} \int d^{3}p \left[ \frac{1}{x(1-x)} \Psi_{x} (\zeta, x) \left( \frac{m_{0}^{2}}{2m_{s}} \right) \right] \]

$F(0) = 0.19$ GeV\textsuperscript{2} and $\Delta F(0) = 0.05$ GeV\textsuperscript{2}

The Gegenbauer coefficients are [6] $a_{0} = 0.06 \pm 0.04$, $a_{1} = 0.16 \pm 0.09$ for $\phi_{q}(x, \mu = 1$ GeV) and $a_{1} = 0.04 \pm 0.03, a_{2} = 0.10 \pm 0.08$ for $\phi_{q}(x, \mu = 1$ GeV)[6].

Results

$BR(B \to K^{*}\nu\bar{\nu})_{\text{ADs/QCD}} = (6.36^{+0.50}_{-0.39}) \times 10^{-6}$

$BR(B \to K^{*}\nu\bar{\nu})_{\text{SR}} = (8.14^{+0.16}_{-0.10}) \times 10^{-6}$

$BR(B \to K^{*}\nu\bar{\nu})_{\text{SM}} = 0.41 \pm 0.01$

Conclusion

Experimental observation of $B \to K^{*}\nu\bar{\nu}$ can provide an excellent test for the theoretical computation of the $B \to K^{*}$ transition form factors. The differential branching ratio for this decay shows the largest sensitivity to the form factors for low-to intermediate values of the momentum transfer.

Ongoing and Future Research

- AdS/QCD prediction for $B \to \phi\mu^{+}\mu^{-}$.
- Direct computation of the form factors using holographic meson wavefunctions.

References


Acknowledgements

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Table 1: AdS/QCD lattice prediction for the form factors. Lattice data is taken from [10]. The error bars are due to the variation of the quark masses as explained in the text.