94. Width Determinations of the Υ States

As is the case for the \( J/\psi(1S) \) and \( \psi(2S) \), the full widths of the \( b\bar{b} \) states \( \Upsilon(1S) \), \( \Upsilon(2S) \), and \( \Upsilon(3S) \) are not directly measurable, since they are much narrower than the energy resolution of the \( e^+e^- \) storage rings where these states are produced. The common indirect method to determine \( \Gamma \) starts from

\[
\Gamma = \Gamma_{\ell\ell}/B_{\ell\ell},
\]

(94.1)

where \( \Gamma_{\ell\ell} \) is one leptonic partial width and \( B_{\ell\ell} \) is the corresponding branching fraction (\( \ell = e, \mu, \) or \( \tau \)). One then assumes \( e-\mu-\tau \) universality and uses

\[
\Gamma_{\ell\ell} = \Gamma_{ee}
\]

\[
B_{\ell\ell} = \text{average of } B_{ee}, B_{\mu\mu}, \text{ and } B_{\tau\tau}.
\]

(94.2)

The electronic partial width \( \Gamma_{ee} \) is also not directly measurable at \( e^+e^- \) storage rings, only in the combination \( \Gamma_{ee}\Gamma_{\text{had}}/\Gamma \), where \( \Gamma_{\text{had}} \) is the hadronic partial width and

\[
\Gamma_{\text{had}} + 3\Gamma_{ee} = \Gamma.
\]

(94.3)

This combination is obtained experimentally from the energy-integrated hadronic cross section

\[
\int_{\text{resonance}} \sigma(e^+e^- \to \Upsilon \to \text{hadrons})dE
\]

\[
= \frac{6\pi^2 \Gamma_{ee}\Gamma_{\text{had}}}{M^2 \Gamma} C_r = \frac{6\pi^2 \Gamma_{ee}^{(0)}\Gamma_{\text{had}}}{M^2 \Gamma} C_r^{(0)},
\]

(94.4)

where \( M \) is the \( \Upsilon \) mass, and \( C_r \) and \( C_r^{(0)} \) are radiative correction factors. \( C_r \) is used for obtaining \( \Gamma_{ee} \) as defined in Eq. (94.1), and contains corrections from all orders of QED for describing \( (b\bar{b}) \to e^+e^- \). The lowest order QED value \( \Gamma_{ee}^{(0)} \), relevant for comparison with potential-model calculations, is defined by the lowest order QED graph (Born term) alone, and is about 7% lower than \( \Gamma_{ee} \).

The Listings give experimental results on \( B_{ee}, B_{\mu\mu}, B_{\tau\tau}, \) and \( \Gamma_{ee}\Gamma_{\text{had}}/\Gamma \). The entries of the last quantity have been re-evaluated consistently using the correction procedure of KURAEV 85 [1]. The partial width \( \Gamma_{ee} \) is obtained from the average values for \( \Gamma_{ee}\Gamma_{\text{had}}/\Gamma \) and \( B_{\ell\ell} \) using

\[
\Gamma_{ee} = \frac{\Gamma_{ee}\Gamma_{\text{had}}}{\Gamma(1-3B_{\ell\ell})}.
\]

(94.5)

The total width \( \Gamma \) is then obtained from Eq. (94.1). We do not list \( \Gamma_{ee} \) and \( \Gamma \) values of individual experiments. The \( \Gamma_{ee} \) values in the Meson Summary Table are also those defined in Eq. (94.1).

References: