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

$$\Gamma = \Gamma_{\ell\ell}/B_{\ell\ell},$$

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

$$\Gamma_{\ell\ell} = \Gamma_{ee}$$

$$B_{\ell\ell} = \text{average of } B_{ee}, B_{\mu\mu}, \text{ and } B_{\tau\tau}.$$  \hspace{1cm} (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

$$\Gamma_{\text{had}} + 3\Gamma_{ee} = \Gamma.$$ \hspace{1cm} (3)

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

$$\int_{\text{resonance}} \sigma(e^+e^- \rightarrow \Upsilon \rightarrow \text{hadrons})dE$$

$$= \frac{6\pi^2}{M^2} \frac{\Gamma_{ee}\Gamma_{\text{had}}}{\Gamma} C_r = \frac{6\pi^2}{M^2} \frac{\Gamma_{ee}^{(0)}\Gamma_{\text{had}}^{(0)}}{\Gamma} C_r^{(0)},$$ \hspace{1cm} (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. (1), and contains corrections from all orders of QED for describing $(b\bar{b}) \rightarrow e^+e^-$. 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

$$\Gamma_{ee} = \frac{\Gamma_{ee}\Gamma_{\text{had}}}{\Gamma(1 - 3B_{\ell\ell})}.$$ \hspace{1cm} (5)

The total width $\Gamma$ is then obtained from Eq. (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. (1).

References: