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THE LEPTONIC WIDTH OF THE T''

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A B S T R A C T

Guided by semi-classical arguments we propose the formula $\psi_3(0) \simeq \psi_2(0) [\psi_2(0)/\psi_1(0)]^{1/2}$, where $\psi_n(0)$ is the wave function at the origin of the n^{th} $\ell=0$ state of a quark-antiquark system, and test it on usual potentials. Using the existing measurements of the leptonic widths of the T and τ' we get predictions on the leptonic width of the T'' . We also show that its total width is of the same order of magnitude as that of the T and τ' , by using production data in hadronic collisions.

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Since the observation of the particle T' at DORIS at an energy slightly lower than expected ¹⁾ the evidence for the existence of a third state T'' has been considerably increased by a re-analysis of the data of the Lederman group ²⁾. Up to now all data seem to be in agreement with the interpretation in which T, T', T'' are $\ell=0$ $b\bar{b}$ bound states inside a confining potential, where b is a coloured quark with charge $-1/3$ and mass $\geq 3.29 \text{ GeV} + m_c$, where m_c is the mass of the charmed quark ³⁾.

We want to present here a recipe which allows to get the leptonic width of the T'' from that of the T and of the T' . We shall use the Weisskopf-Van Royen formula ⁴⁾

$$\Gamma_e = \text{const} \times \frac{|\psi(0)|^2}{M^2} \quad (1)$$

Therefore the problem is reduced to finding a relation between the wave functions at the origin $\psi_1(0)$, $\psi_2(0)$, and $\psi_3(0)$, where the lower index is $1+$ the number of nodes of radial wave function. We shall be guided by semi-classical considerations and look first in the special case where the potential has a power behaviour $V(r) = r^\lambda$. Then, the WKB approximation leads, according to Quigg and Rosner ⁵⁾ to

$$\begin{aligned} |\psi_n(0)|^2 &\sim (n - 1/4)^{\frac{2(\lambda-1)}{2+\lambda}}, \quad \lambda > 0 \\ |\psi_n(0)|^2 &\sim (n - 1/4)^{\frac{\lambda-2}{2+\lambda}}, \quad \lambda \leq 0 \end{aligned} \quad (2)$$

One can eliminate the power λ of the potential by looking at the combination,

$$a = \log[\psi_3(0)/\psi_2(0)] / \log[\psi_2(0)/\psi_1(0)] \quad (3)$$

If (2) is valid we get

$$a = \log(11/7) / \log(7/3) \cong .533 \quad (4)$$

For all power potentials with $-1 \leq \lambda \leq +3$, and also $\lambda \rightarrow \infty$ we have calculated the exact a by solving numerically the Schrödinger equation and found $0.533 < a < 0.585$, where the upper limit is reached both for $\lambda \rightarrow -1$ and $\lambda \rightarrow +\infty$.

Encouraged by the remarkable insensitivity of a on λ we have also tried combinations of a short-range attraction and a long-range confining force and in particular the familiar mixture $\alpha r - (1-\alpha)r^{-1}$, used in most potential models of charmonium, but also $\alpha r - (1-\alpha)r^{-\frac{1}{2}}$ and $\alpha r^{-\frac{1}{2}} - (1-\alpha)r^{-1}$. There, not unexpectedly, one finds values of a which are lower, because the ratio ψ_2/ψ_1 is controlled by the inner part of the potential, while ψ_3/ψ_2 is controlled by the outside part of the potential. One gets $a \geq 0.306$ reached for $V = 0.02r - 0.98r^{-1}$. Notice in passing that a is positive for all values $0 \leq \alpha \leq 1$ ⁶⁾.

One may think that the spread in values of a is too large. However, for all potentials considered, which cover the class of what we believe to be realistic potentials, the equality

$$\psi_3(0) \simeq \psi_2(0) \times [\psi_2(0)/\psi_1(0)]^{1/2} \quad (5)$$

is valid with better than 12% accuracy.

Taking (5) for granted we can predict the leptonic width of the Υ'' using ¹⁾

$$\Gamma_e^{\Upsilon} = \begin{cases} 1.3 \pm .2 \text{ kev (DASP, PLUTO)} \\ 1.04 \pm .28 \text{ kev (DESY-HD2)} \end{cases} \quad \Gamma_e^{\Upsilon'} = \begin{cases} .35 \pm .14 \text{ kev (DASP2)} \\ .32 \pm .13 \text{ kev (DESY-HD2)} \end{cases} \quad (6)$$

and

$$M_{\Upsilon} = 9.46 \text{ Gev}, \quad M_{\Upsilon'} = 10.016 \text{ Gev}, \quad M_{\Upsilon''} = 10.38 \text{ Gev}. \quad (7)$$

We get, combining the measurements of the various groups

$$\Gamma_e^{\Upsilon''} = 0.17 \pm 0.10 \text{ kev} \quad (8)$$

The inaccuracy of the predictions is linked to the large experimental uncertainty on the T' leptonic width at the present time. More accurate predictions would be obtained from an over-all fit of the J/ψ and T families. However, the advantage of using only (5) is that one does not presuppose that the J/ψ and T potentials are the same.

Finally let us notice that, within the very limited accuracy of our prediction, we get, for the T'' the same puzzling situation which was noticed by Lederman²⁾ for the T' . In the Fermilab experiment²⁾ one has

$$B_e^{r'} \frac{d\sigma(r')}{dy} / B_e^r \frac{d\sigma(r)}{dy} = 0.30 \pm 0.03 \quad (9)$$

$$B_e^{r''} \frac{d\sigma(r'')}{dy} / B_e^r \frac{d\sigma(r)}{dy} = 0.155 \pm 0.016 \quad (10)$$

where the B 's are the leptonic branching ratios. If one assumes that the production cross-sections of T , T' , and T'' are approximately equal one deduces from (9) and from $\Gamma_e^{T'} \simeq 1/3 \Gamma_e^T$, that the total widths of the T and T' are about equal. Now we see also that (6), (8) and (10) are also compatible with the same total width for the T'' . More conservatively we can say that the total width of the T'' is of the same order of magnitude as that of the T . This constitutes a strong indication that the mass of the T'' is below the threshold for the production of visible "beauty", and that T'' is indeed one of these states which cannot decay without violating the OZI rule as first predicted by Eichten and Gottfried⁷⁾.

A more detailed account of this work will be published elsewhere in the future. We are grateful to Professor O. Brander for interesting conversations.

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