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Rapid Communications

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Leptonic branching ratio of the $\Upsilon(2S)$

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Using the CLEO magnetic detector at the Cornell Electron Storage Ring, we find $B(\Upsilon(2S)\to\mu^+\mu^-)=0.018\pm0.008$ (statistical) ±0.005 (systematic) and $B(\Upsilon(2S)\to\tau^+\tau^-)=0.017\pm0.015\pm0.006$.

In this Rapid Communication, we present a new and more accurate measurement of $B(\Upsilon(2S)\to\mu^+\mu^-)$ and the first measurement of $B(\Upsilon(2S)\to\tau^+\tau^-)$. Combining these new measurements with previous results, we find an improved value for the total width of the $\Upsilon(2S)$.

The data were obtained with the CLEO magnetic detector operating at the Cornell Electron Storage Ring (CESR). An extensive description of the CLEO detector has been given elsewhere.[1] In addition the relevant features for the measurement of the leptonic branching fractions of the Υ resonances are described in our previous publications on this subject.[2,3]

The results are based on an accumulated luminosity of 22.2 pb^{-1} at the $\Upsilon(2S)$ resonance and 1.2 pb^{-1} in the nearby continuum. The corresponding numbers of observed hadronic events are 2×10^5 and 4×10^3, respectively. After subtracting the continuum contribution at the $\Upsilon(2S)$, $128\,000\pm1250$ hadronic events are observed. The acceptance for hadronic decays of the $\Upsilon(2S)$ is estimated by Monte Carlo to be 0.87 ± 0.06, yielding $147\,100\pm10\,250$ as the corrected number of hadronic $\Upsilon(2S)$ decays.

The selection criteria for muon-pair events is described in detail in Ref. 2. Briefly, events with two essentially collinear high-momentum tracks were classified as muon pairs if at least one track was positively identified as a muon by penetration through iron and if neither track was identified as an electron. Time-of-flight methods were used to reject cosmic-ray events. The number (N_{res}) of dimuon events at the $\Upsilon(2S)$ and the number (N_{con}) from the continuum are given in Table I.

TABLE I. The observed number of resonance events (N_{res}), continuum events (N_{con}), background events (N_{back}), and the detection efficiencies.

	$\mu^+\mu^-$	$\tau^+\tau^-$
N_{res}	6660	1503
N_{con}	315	68
N_{back}	114	100
ϵ_{res}	0.300 ± 0.020	0.054 ± 0.006
ϵ_{con}	0.250 ± 0.014	0.042 ± 0.006

We first find $\bar{B}_{\mu\mu} = \Gamma_{\mu\mu}/\Gamma_{had}$, where Γ_{had} is the decay width of the $\Upsilon(2S)$ into hadrons, from

$$\bar{B}_{\mu\mu} = \frac{(N_{res} - \epsilon_{con}\sigma_{QED}\mathscr{L}_{res} - N_{back})}{N_{2S}\epsilon_{res}} .$$

In the above, σ_{QED} is the QED muon-pair cross section [1.03 nb (Ref. 4)] at the $\Upsilon(2S)$, $\mathscr{L}_{res}$ is the accumulated luminosity at the resonance, N_{back} is a background contribution to the dimuon signal (see below), N_{2S} is the corrected number of hadronic decays of the $\Upsilon(2S)$, and ϵ_{res} (ϵ_{con}) is the dimuon acceptance for resonant (continuum) production. The value of ϵ_{con} can be obtained by comparing the observed number of dimuons on the continuum to the expected number or by a Monte Carlo simulation of the detector response. Both methods yield $\epsilon_{con} = 0.25$. The dimuon acceptance for resonance decays is greater by a factor of 1.19 ± 0.02 than for continuum production, as a result of the absence of initial-state radiation.

Background contributions arise from[5] $\Upsilon(2S) \to \pi\pi\Upsilon(1S)$, $\Upsilon(1S) \to \mu^+\mu^-$ decays, wherein the pions are not observed in the detector (27 events), from $\Upsilon(2S) \to \gamma\gamma\Upsilon(1S)$, $\Upsilon(1S) \to \mu^+\mu^-$ [70 events using[6] $B(\Upsilon(2S) \to \gamma\gamma\Upsilon(1S)) = 4\%$], and from $\Upsilon(2S) \to \tau^+\tau^-$, $\tau \to \mu\nu\nu$ (17 events). We note that a 50% uncertainty in the number of background events results in a 10% change in the branching ratio. Assuming lepton universality, then $B_{\mu\mu} = \bar{B}_{\mu\mu}/(1+3\bar{B}_{\mu\mu})$. Our final result is

$$B(\Upsilon(2S) \to \mu^+\mu^-) = 0.018 \pm 0.008 \pm 0.005 .$$

The selection methods for $\tau^+\tau^-$ events are described in Ref. 3 and only briefly discussed here. Events with a 1-vs-3 topology were selected, wherein one τ decayed to a single charged prong plus neutrals, and the other to three charged prongs plus neutrals. The fraction of $\tau^+\tau^-$ events yielding the 1-vs-3 topology is taken to be 0.25 ± 0.02.[7,8] The observed number of events is given in Table I. Backgrounds to the apparent $\tau^+\tau^-$ signal include low-multiplicity hadronic events in addition to the cascade decays to the $\Upsilon(1S)$ discussed above. Monte Carlo simulations of the various processes were used to estimate the number of background events, and the total number is given in Table I. The detector acceptance for $\tau^+\tau^-$ events was also evaluated by Monte Carlo methods for both continuum and resonance production. The results are given in Table I and include the factor of 0.25 for the decay into the 1-vs-3 topology. Combining the numbers and assuming lepton universality, we find

$$B(\Upsilon(2S) \to \tau^+\tau^-) = 0.017 \pm 0.015 \pm 0.006 .$$

TABLE II. A summary of measurements of the leptonic branching ratio of the $\Upsilon(2S)$. The first error given is the statistical error, and the second is the systematic error. Statistical and systematic errors have been added in quadrature to get the error given for the average branching ratio.

	Branching ratio (%)	Group	Reference
$\Upsilon(2S) \to \mu^+\mu^-$	$1.8 \pm 0.8 \pm 0.5$	CLEO	This expt.
	$1.9 \pm 1.3 \pm 0.5$	CLEO	2
	$1.9 \pm 0.3 \pm 0.5$	CUSB	10
$\Upsilon(2S) \to \tau^+\tau^-$	$1.7 \pm 1.5 \pm 0.6$	CLEO	This expt.
Average	1.9 ± 0.5		

In Table II, we summarize the existing measurements of the leptonic decays of the $\Upsilon(2S)$. Adding both statistical and systematic errors in quadrature and assuming lepton universality, the average value of $B(\Upsilon(2S) \to l^+l^-)$ is determined to be 0.019 ± 0.005. The leptonic width (Γ_{ee}) of the $\Upsilon(2S)$ has been measured by many groups, yielding an average value of 0.54 ± 0.03 keV.[9] From the relationship $\Gamma_{tot} = \Gamma_{ee}/B_{ee}$, one finds $\Gamma_{tot} = 28.4 \pm 7.6$ keV.

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