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The width of the J/ψ resonance

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Measurements of the J/ψ total width and branching ratios for decays to lepton pairs and hadronic final states are reviewed. New values for the overall best fits are provided.

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A new measurement[1] of the branching ratio for the decay of J/ψ into lepton pairs has been recently published. While this measurement is based on the reconstruction of decay channels in a sample of identified J/ψ's, previous measurements[2–5] were obtained from the comparison of the processes:

$$e^+e^- \to J/\psi \to l^+l^- \tag{1}$$

$$e^+e^- \to J/\psi \to \text{hadrons} \tag{2}$$

where $l^\pm = e^\pm$ or $\mu^\pm$. The cross sections for processes (1) and (2), integrated across the resonance, are proportional to the expressions:

$$A_l = \Gamma(e^+e^-) \times \Gamma(l^+l^-)/\Gamma_{\text{total}} \tag{3}$$

$$A_h = \Gamma(e^+e^-) \times \Gamma(\text{hadrons})/\Gamma_{\text{total}} \tag{4}$$

respectively. Under the assumptions:

$$\Gamma(l^+l^-) \equiv \Gamma(e^+e^-) = \Gamma(\mu^+\mu^-) \tag{5}$$

$$\Gamma_{\text{total}} = 2 \times \Gamma(l^+l^-) + \Gamma(\text{hadrons}) \tag{6}$$

the branching ratio for lepton pairs ($\text{BR}(l^+l^-) \equiv \Gamma(l^+l^-)/\Gamma_{\text{total}}$) was extracted together with Γ_{total}. Therefore the new measurement requires a new combined fit of $\text{BR}(l^+l^-)$ together with Γ_{total}, or, equivalently, with one of the partial widths $\Gamma(l^+l^-)$, $\Gamma(\text{hadrons})$. We have performed a fit to the existing data and obtained new values for the overall best fits to the J/ψ total width and branching ratios for decays to the lepton pairs and hadronic final states.

Table I shows the values used in our fit. In particular, the authors of Ref. 2 provided values and experimental errors for the quantities A_l and A_h, and we have inferred the value of the correlation coefficient between them (ρ) from the quoted errors in $\Gamma_{\rm total}$ and Γ(hadrons). Ref. 3 quotes values of total width, partial widths and branching fractions, separating the e^+e^- and $\mu^+\mu^-$ final states. We have averaged the two lepton final states, extracting the value of the correlation coefficient from the quoted error in $\Gamma(\mu^+\mu^-)/\Gamma(e^+e^-)$. The remaining measurements and errors have been used to compute the values of the quantities A_l and A_h, and of the corresponding covariance matrix. Values of ρ in the range 0.25–0.4 are compatible with the published results, and we have chosen the lower limit, which is favored by the quoted $\pm3\%$ normalization error. The authors of Ref. 4 published results for line-shape integrals, separating the e^+e^- and $\mu^+\mu^-$ final states. We have averaged the leptonic cases with the same procedure applied to Ref. 3. Compatibility with the quoted errors requires the value of ρ to be in the range 0–0.2, and we have chosen the value 0.1. In Ref. 5 values of $\Gamma(l^+l^-)$ and $\Gamma_{\rm total}$ are quoted, and we have computed the corresponding values for the variables A_l and A_h. The value of ρ must be larger than 0.4 for compatibility with the published uncertainties, and we have set it to 0.6, as suggested by the quoted $\pm5\%$ normalization error.

All the values of the line-shape integrals were corrected for radiative effects in the initial state [2–5]. We have followed a recent revision of the radiative corrections[6], modifying the quantities A_l and A_h in Table I by factors in the range 0.0–4.5%.

In order to fit the data, a χ^2 minimization has been performed. Notice that in analogy with previous analyses [3, 5, 7], all the quoted errors are treated as Gaussian standard errors, and no distinctions between statistical and systematic contributions are made.

Table II shows the results of the fit. For completeness, the best fit values are given for three quantities, despite the fact that only two are independent. The results are highly correlated (correlation coefficients equal to -0.68 between $\Gamma_{\rm total}$ and BR(l^+l^-), and $+0.90$ between $\Gamma_{\rm total}$ and $\Gamma(l^+l^-)$). The minimum χ^2 is equal to 13.0 with 7 degrees of freedom. This suggests that some of the input errors may have been underestimated, or that the treatment of systematic errors may not be adequate. A safer error estimate[7] may be obtained by rescaling the errors by the factor $\sqrt{12.6/7} = 1.4$.

If the revision in the radiative corrections[6] is ignored, the best value of Γ_{total} is reduced by 2.0 keV.

Our results are scarcely affected by the uncertainty in the error assignment to the input data. Allowing the values of ρ for Ref. 3, 4, 5 to change within the ranges discussed above, the best fit to Γ_{total} varies by ± 0.6 keV at most. The reason for this stability is that the main experimental uncertainty in measuring line-shape integrals was in the detection efficiency for hadronic final states, affecting the quantity A_h only. A different choice of input variables would result in a larger sensitivity of our fit to uncertainties in the error assignment to the input data.

The mechanism by which the fit provides a value of Γ_{total} significantly larger than the previous one[7] can be understood intuitively. The new $\mathrm{BR}(l^+l^-)$ measurement[1] is significantly smaller, and more accurate than the other ones, so that the new average is $\simeq 10\%$ smaller than the previous accepted value[7]. Table I shows that the quantity A_l was measured better than A_h. Therefore the fit mostly corrects the value of the latter, maintaining the former. Since A_l is equivalent to $\Gamma(e^+e^-) \times \mathrm{BR}(e^+e^-) \equiv \Gamma_{\mathrm{total}} \times (\mathrm{BR}(e^+e^-))^2$, the correction to $\mathrm{BR}(e^+e^-)$ implies an approximately $+10\%$ correction to $\Gamma(e^+e^-)$ and $+20\%$ to Γ_{total}.

Finally, it should be noticed that changing the best value for $\Gamma(e^+e^-)$ will require updating the value of branching ratios other than $\mathrm{BR}(l^+l^-)$ and BR(hadrons). In fact the branching ratio to the exclusive final state f, different from l^+l^-, has been typically obtained[7] by comparing $\Gamma(e^+e^-)$ to the integral of the line-shape for the process $e^+e^- \to J/\psi \to f$, which is indeed proportional to $\Gamma(e^+e^-) \times \mathrm{BR}(f)$.

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TABLES

TABLE I. Experimental measurements used in the fit

Ref. 1	$BR(l^+l^-) = (5.91 \pm 0.23)\%$		
Ref.	$\Gamma(e^+e^-)\times\Gamma(l^+l^-)/\Gamma_{total}$	$\Gamma(e^+e^-)\times\Gamma(\text{hadrons})/\Gamma_{total}$	ρ
2	0.320 ± 0.070 keV	4.00 ± 0.80 keV	0.0
3	0.330 ± 0.035 keV	4.11 ± 0.62 keV	0.25
4	0.400 ± 0.037 keV	3.84 ± 0.79 keV	0.1
5	0.334 ± 0.031 keV	3.73 ± 0.56 keV	0.6

TABLE II. Results of the fit

Γ_{total}	$85.5^{+6.1}_{-5.8}$ keV
$BR(e^+e^-)$	$6.27^{+0.20}_{-0.19}$ %
$\Gamma(e^+e^-)$	$5.36^{+0.29}_{-0.28}$ keV