Measurement of $\Gamma_{ee}(J/\psi) \cdot \mathcal{B}(J/\psi \to e^+e^-)$ and
$\Gamma_{ee}(J/\psi) \cdot \mathcal{B}(J/\psi \to \mu^+\mu^-)$

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The products of the electron width of the $J/\psi$ meson and the branching fraction of its decays to the lepton pairs were measured using data from the KEDR experiment at the VEPP-4M electron-positron collider. The results are

$$\Gamma_{ee} \times \Gamma_{ee}/\Gamma = 0.3323 \pm 0.0064 \text{ (stat.)} \pm 0.0048 \text{ (syst.) \, keV},$$
$$\Gamma_{ee} \times \Gamma_{\mu\mu}/\Gamma = 0.3318 \pm 0.0052 \text{ (stat.)} \pm 0.0063 \text{ (syst.) \, keV}.$$

Their combinations

$$\Gamma_{ee} \times (\Gamma_{ee} + \Gamma_{\mu\mu})/\Gamma = 0.6641 \pm 0.0082 \text{ (stat.)} \pm 0.0100 \text{ (syst.) \, keV},$$
$$\Gamma_{ee}/\Gamma_{\mu\mu} = 1.002 \pm 0.021 \text{ (stat.)} \pm 0.013 \text{ (syst.) \, keV}$$

can be used to improve the accuracy of the leptonic and full widths of the $J/\psi$ and test leptonic universality in its decays.

Assuming $e\mu$ universality and using the world average value of the lepton branching fraction, we also determine the leptonic $\Gamma_{\ell\ell} = 5.59 \pm 0.12 \text{ keV}$ and total $\Gamma = 94.1 \pm 2.7 \text{ keV}$ widths of the $J/\psi$ meson. Details can be found in [1].
1. Experiment description

A data sample used for this analysis comprises 230 nb$^{-1}$ collected at 11 energy points in the $J/\psi$ energy range during the KEDR experiment at the VEPP-4M electron-positron collider. This corresponds to approximately 15000 $J/\psi \to e^+e^-$ decays. During this scan, 26 calibrations of the beam energy have been done using resonant depolarization.

2. Theoretical $e^+e^-\to \ell^+\ell^-$ cross section

The analytical expressions for the cross section of the process $e^+e^-\to \ell^+\ell^-$ with radiative corrections taken into account in the soft photon approximation were first derived by \cite{2}. With some up-to-date \cite{3} modifications one obtains in the vicinity of a narrow resonance:

$$\frac{d\sigma}{d\Omega}^{ee\to ee} \approx \frac{1}{M^2} \left[ \frac{9\Gamma^2_{ee}}{4M} \left( 1 + \cos^2 \theta \right) \left( 1 + \delta_{ef} \right) \text{Im}\mathcal{F} - \frac{3\alpha \Gamma_{ee}}{2M} \left( 1 + \cos^2 \theta \right) - \frac{1 + \cos \theta}{1 - \cos \theta} \right] \text{Re}\mathcal{F} \right] + \left( \frac{d\sigma}{d\Omega} \right)^{ee}_{\text{QED}},$$

$$\frac{d\sigma}{d\Omega}^{ee\to \mu\mu} \approx \frac{3}{4M^2} \left( 1 + \delta_{ef} \right) \left( 1 + \cos^2 \theta \right) \times \frac{3\Gamma_{ee}\Gamma_{\mu\mu}}{M} \text{Im}\mathcal{F} - \frac{2\alpha \sqrt{\Gamma_{ee}\Gamma_{\mu\mu}}}{M} \text{Re} \frac{\mathcal{F}}{1 - \Pi_0} + \left( \frac{d\sigma}{d\Omega} \right)^{\mu\mu}_{\text{QED}},$$

where a correction $\delta_{ef}$ follows from the structure function approach of \cite{4}. Here $W$ is the center-of-mass energy and $\Pi_0$ represents the vacuum polarization operator with the resonance contribution excluded. The terms proportional to $\text{Im}\mathcal{F}$ and $\text{Re}\mathcal{F}$ describe the contribution of the resonance and the interference effect, respectively.

3. Data analysis

At the $i$-th energy point $E_i$ and the $j$-th angular interval $\theta_j$, the expected number of $e^+e^-\to e^+e^-$ events was parameterized as

$$N_{\text{exp}}(E_i, \theta_j) = \mathcal{R}_{\mathcal{F}} \times \mathcal{L}(E_i) \times \left( \sigma_{\text{res}}(E_i, \theta_j) \cdot \varepsilon_{\text{res}}^{\text{sim}}(E_i, \theta_j) + \sigma_{\text{inter}}(E_i, \theta_j) \cdot \varepsilon_{\text{inter}}^{\text{sim}}(E_i, \theta_j) + \sigma_{\text{Bhabha}}(E_i, \theta_j) \cdot \varepsilon_{\text{Bhabha}}^{\text{sim}}(E_i, \theta_j) \right).$$

where $\mathcal{L}(E_i)$ — the integrated luminosity measured by the luminosity monitor at the $i$-th energy point; $\sigma_{\text{theor}}$ — the theoretical cross sections for resonance, interference and Bhabha contributions, $\varepsilon_{\text{sim}}$ — the detector efficiencies obtained from simulation.

In this formula the following free parameters were used: the product $\Gamma_{ee} \times \Gamma_{ee}/\Gamma$, which determines the magnitude of the resonance signal; the electron width $\Gamma_{ee}$, which specifies the amplitude of the interference wave; the coefficient $\mathcal{R}_{\mathcal{F}}$, which provides the absolute calibration of
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**Figure 1:** Fits to data for $e^+e^- \rightarrow e^+e^-$. 

**Figure 2:** Fit to data for $e^+e^- \rightarrow \mu^+\mu^-$. 

the luminosity monitor. The dominant uncertainty of the $\Gamma_{ee} \times \Gamma_{ee}/\Gamma$ result is associated with the luminosity monitor instability.

The expected number of $e^+e^- \rightarrow \mu^+\mu^-$ events was parameterized in the form:

$$N_{\text{exp}}(E_i) = \mathcal{R}_L \times \mathcal{L}(E_i) \times \left( \sigma_{\text{res}}(E_i) \cdot \mathcal{E}_{\text{sim}}(E_i) + \sigma_{\text{inter}}(E_i) \cdot \mathcal{E}_{\text{sim}}(E_i) + \sigma_{\text{bg}}(E_i) \cdot \mathcal{E}_{\text{sim}}(E_i) \right) + F_{\text{cosmic}} \times T_i,$$

with the same meaning of $\mathcal{R}_L$ and $\mathcal{L}(E_i)$ as for $e^+e^- \rightarrow e^+e^-$. $R_L$ was fixed from the $e^+e^- \rightarrow e^+e^-$ fit and $T_i$ is the live data taking time.

The following free parameters were used: the product $\Gamma_{ee} \times \Gamma_{\mu\mu}/\Gamma$, which determines the magnitude of the resonance signal; the square root of electron and muon widths $\sqrt{\Gamma_{ee}\Gamma_{\mu\mu}}$, which specifies the amplitude of the interference wave; the rate of cosmic events, $F_{\text{cosmic}}$, that passed the selection criteria for the $e^+e^- \rightarrow \mu^+\mu^-$ events. The dominant uncertainty of the $\Gamma_{ee} \times \Gamma_{\mu\mu}/\Gamma$ result is associated with the absolute luminosity calibration done in the $e^+e^-$-channel.

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**References**


