PROCEEDINGS OF SCIENCE

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

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The products of the electron width of the J/ψ 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

$$\Gamma_{ee}\times\Gamma_{ee}/\Gamma = 0.3323\pm0.0064\,(\text{stat.})\pm0.0048\,(\text{syst.})\text{ keV},$$
$$\Gamma_{ee}\times\Gamma_{\mu\mu}/\Gamma = 0.3318\pm0.0052\,(\text{stat.})\pm0.0063\,(\text{syst.})\text{ keV}.$$

Their combinations

$$\Gamma_{ee}\times(\Gamma_{ee}+\Gamma_{\mu\mu})/\Gamma = 0.6641\pm0.0082\,(\text{stat.})\pm0.0100\,(\text{syst.})\,\text{keV},$$
$$\Gamma_{ee}/\Gamma_{\mu\mu} = 1.002\pm0.021\,(\text{stat.})\pm0.013\,(\text{syst.})$$

can be used to improve the accuracy of the leptonic and full widths of the J/ψ 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 $\Gamma_{\ell\ell}=5.59\pm0.12\,\text{keV}$ and total $\Gamma=94.1\pm2.7\,\text{keV}$ widths of the J/ψ meson. Details can be found in [1].

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1. Experiment description

A data sample used for this analysis comprises 230 nb^{-1} collected at 11 energy points in the J/ψ 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 [2]. With some up-today [3] modifications one obtains in the vicinity of a narrow resonance:

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

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

where a correction $\delta_{\rm sf}$ follows from the structure function approach of [4].

$$\mathscr{F}=\frac{\pi\beta}{\sin\pi\beta}\left(\frac{M/2}{-W+M-i\Gamma/2}\right)^{1-\beta},\quad\beta=\frac{4\alpha}{\pi}\left(\ln\frac{W}{m_e}-\frac{1}{2}\right)$$

Here W is the center-of-mass energy and Π_0 represents the vacuum polarization operator with the resonance contribution excluded. The terms proportional to $\mathrm{Im}\,\mathscr{F}$ and $\mathrm{Re}\,\mathscr{F}$ 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 θ_j, the expected number of $e^+e^-\to e^+e^-$ events was parameterized as

$$N_{\rm exp}(E_i,\theta_j)=\mathscr{R}_{\mathscr{L}}\times\mathscr{L}(E_i)\times\Big(\sigma^{\rm theor}_{\rm res}(E_i,\theta_j)\cdot\varepsilon^{\rm sim}_{\rm res}(E_i,\theta_j)+$$
$$\sigma^{\rm theor}_{\rm inter}(E_i,\theta_j)\cdot\varepsilon^{\rm sim}_{\rm inter}(E_i,\theta_j)+\sigma^{\rm sim}_{\rm Bhabha}(E_i,\theta_j)\cdot\varepsilon^{\rm sim}_{\rm Bhabha}(E_i,\theta_j)\Big).$$

where $\mathscr{L}(E_i)$ — the integrated luminosity measured by the luminosity monitor at the i-th energy point; $\sigma^{\rm theor}$ — the theoretical cross sections for resonance, interference and Bhabha contributions, $\varepsilon^{\rm sim}$ — 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 Γ_{ee}, which specifies the amplitude of the interference wave; the coefficient $\mathscr{R}_{\mathscr{L}}$, which provides the absolute calibration of

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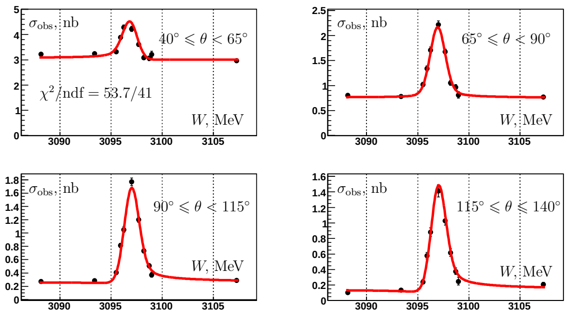

Figure 1: Fits to data for $e^+e^-\to e^+e^-$.

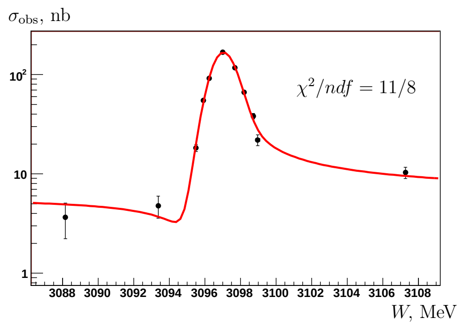

Figure 2: Fit to data for $e^+e^-\to\mu^+\mu^-$.

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 $e^+e^-\to\mu^+\mu^-$ events was parameterized in the form:

$$N_{\text{exp}}(E_i) = \mathscr{R}_{\mathscr{L}} \times \mathscr{L}(E_i) \times \Big(\sigma^{\text{theor}}_{\text{res}}(E_i)\cdot\varepsilon^{\text{sim}}_{\text{res}}(E_i) + \sigma^{\text{theor}}_{\text{inter}}(E_i)\cdot\varepsilon^{\text{sim}}_{\text{inter}}(E_i) + \sigma^{\text{theor}}_{\text{bg}}(E_i)\cdot\varepsilon^{\text{sim}}_{\text{bg}}(E_i)\Big) + F_{\text{cosmic}}\times T_i,$$

with the same meaning of $\mathscr{R}_{\mathscr{L}}$ and $\mathscr{L}(E_i)$ as for $e^+e^-\to e^+e^-$. $\mathscr{R}_{\mathscr{L}}$ was fixed from the $e^+e^-\to e^+e^-$ 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_{cosmic}, that passed the selection criteria for the $e^+e^-\to\mu^+\mu^-$ 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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