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Studies of $\psi(2S)$ and $\psi(3770)$ at KEDR

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Precision measurements are presented of the main parameters of the $\psi(2S)$ and $\psi(3770)$ resonances. Experiment was performed with the KEDR detector at the VEPP-4M e^+e^- collider. Fitting the energy dependence of the multihadron cross section in the vicinity of the $\psi(2S)$ we obtained the mass value and the product of the electron partial width by the branching fraction into hadrons.

$$M = 3686.114 \pm 0.007 \pm 0.011\,^{+0.002}_{-0.012}\ \text{MeV}$$

$$\Gamma_{ee} \times \mathscr{B}_{hadrons} = 2.233 \pm 0.015 \pm 0.037 \pm 0.020\,\text{keV}.$$

These results are much more accurate than any of the previous experiments.
We present a measurement of the mass, total width and electron partial width of the $\psi(3770)$ meson. Interference of resonant and nonresonant $D\overline{D}$ production essential in the near-threshold region has been taken into account. We got two possible solutions for the $\psi(3770)$ electron partial width and the radiatively corrected nonresonant $D\overline{D}$ cross section at the mass of $\psi(3770)$.

$$M_{\psi(3770)} = 3779.2\,^{+1.8}_{-1.7}\,^{+0.5}_{-0.7}\,^{+0.3}_{-0.3}\ \text{MeV},$$
$$\Gamma_{\psi(3770)} = \ \ 24.9\,^{+4.6}_{-4.0}\,^{+0.5}_{-0.6}\,^{+0.2}_{-0.9}\ \text{MeV},$$

$$(1)\ \ \Gamma_{ee}^{\psi(3770)} = 154\,^{+79}_{-58}\,^{+17}_{-9}\,^{+13}_{-25}\,\text{eV},\ \ \sigma_{D\overline{D}}^{NR} = 1.4 \pm 0.7\,^{+0.1}_{-0.2}\,^{+0.3}_{-0.2}\,\text{nb},$$
$$(2)\ \ \Gamma_{ee}^{\psi(3770)} = 414\,^{+72}_{-80}\,^{+24}_{-26}\,^{+90}_{-10}\,\text{eV},\ \ \sigma_{D\overline{D}}^{NR} = 1.3 \pm 0.7\,^{+0.1}_{-0.2}\,^{+0.6}_{-0.2}\,\text{nb}.$$

The phase shifts of the $\psi(3770)$amplitude relative to the negative nonresonant amplitude are 171 ± 17 and 240 ± 9 degrees for solutions (1) and (2), respectively.

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1. Experiment description

In 2004–2006 three scans in the $\psi(2S)$ – $\psi(3770)$ energy region were carried out with an integrated luminosity of 2.6 pb^{-1}. The data acquisition scenario for $\psi(2S)$ is similar to that described in [1]. The observed cross section of $e^+e^- \to$ hadrons together with the results of the fits is shown in Fig. 1. At the points near the $\psi(3770)$ peak the energy calibrations using the resonant depolarization method (RDM) [2, 3] were performed before and after data taken. The RDM energy calibration was not required off the peak. Routine monitoring of the beam energy was performed using the Compton backscattering method [4]. The accuracy of the energy interpolation varies from 10 to 30 keV during the whole experiment.

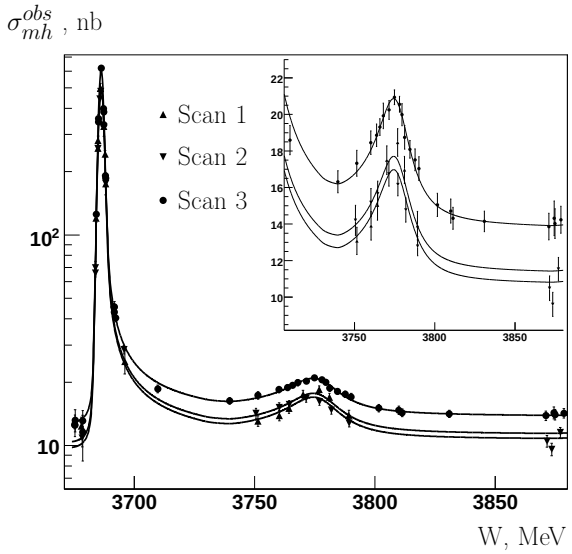

Figure 1: The visible multihadron cross section as a function of the c.m. energy for the three scans. The curves are the results of the vector dominance fit. The detection efficiencies and the energy spreads for the scans differ.

2. Observed cross section

In order to describe multihadron cross section the following function is fit to the data in the energy range from slightly below the $\psi(2S)$ peak to slightly above the $D\overline{D}\pi$ threshold:

$$\begin{aligned}\sigma^{\rm obs}_{mh} = {} & \varepsilon_{\psi(2S)}\,\sigma^{RC}_{\psi(2S)} + \varepsilon_{J/\psi}\,\sigma^{RC}_{J/\psi} + \varepsilon_{\tau\tau}\,\sigma^{RC}_{\tau\tau} + \sigma^{emp}_{uds} + \\ & \varepsilon_{D^+D^-}\,\sigma^{RC}_{D^+D^-} + \varepsilon_{D^0\overline{D}^0}\,\sigma^{RC}_{D^0\overline{D}^0} + \varepsilon_{nD\overline{D}}\,\mathscr{B}_{nD\overline{D}}\,\sigma^{RC}_{\psi(3770)} + \\ & \sigma^{emp}_{D\overline{D}\pi}\end{aligned} \tag{2.1}$$

where σ^{RC}'s are theoretical cross sections, ε's are corresponding detection efficiencies, and σ^{emp}'s are terms treated empirically. The *RC* superscript means that the cross section has been corrected

for initial state radiation (ISR) effects, $nD\overline{D}$ stands for the direct $\psi(3770)$ decay to light hadrons, the other (super/sub) scripts seem self-explanatory, $\mathscr{B}_{nD\overline{D}}$ is a branching fraction.

The details of analysis can be found in [5, 6]. The values of the $\psi(3770)$ resonance parameters were obtained using the vector dominance model. To evaluate the model dependence a few empirical parameterizations of nonresonant amplitude were employed, which do not assume vector dominance.

The excess of the multihadron cross section associated with $D\overline{D}$ production in the $\psi(3770)$ region is shown in Fig. 2. The vector dominance fit, ignored-interference fit and the fits with the anomalous line shapes from Ref. [7] are presented for comparison. The assumption of vector

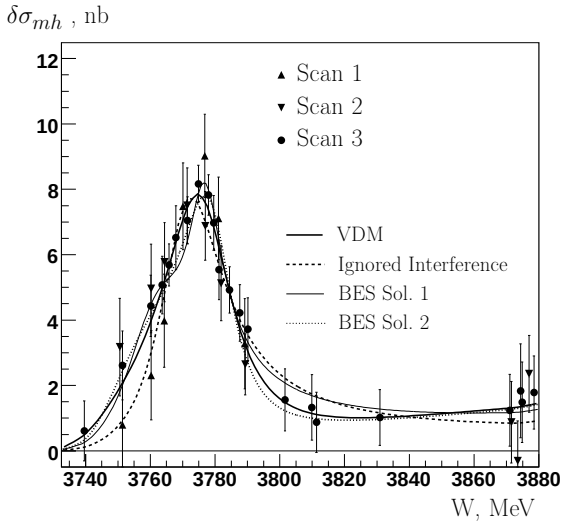

Figure 2: Excess of the multihadron cross section associated with $D\overline{D}$ production in the $\psi(3770)$ region. The curves show relevant parts of the fits. The error bars correspond to the uncertainty of the measured multihadron cross section. All data are corrected for the detection efficiency which is different in the three scans.

dominance gives the most reliable description of our data in $\psi(3770)$ energy region.

3. Summary

We presented results which were published recently [5, 6]. Using the data collected with the KEDR detector at the VEPP-4M e^+e^- collider in 2004 and 2006 we measured the product of the electron partial width by the branching fraction into hadrons of $\psi(2S)$ resonance and it's mass.

$$M = 3686.114 \pm 0.007 \pm 0.011\ ^{+0.002}_{-0.012}\ \text{MeV}$$

$$\Gamma_{ee} \times \mathscr{B}_{hadrons} = 2.233 \pm 0.015 \pm 0.037 \pm 0.020\,\text{keV}\,.$$

The first and second uncertainties are statistical and systematic, respectively. The third uncertainty quoted is evaluation of the model dependence of the result due to assumptions on the interference effects in the cross section of the single-photon e^+e^- annihilation to hadrons.

To measure the parameters of the $\psi(3770)$ meson the interference of resonant and nonresonant production essential in the near-threshold region has been taken into account. The results on the mass and width of $\psi(3770)$ are:

$$M_{\psi(3770)} = 3779.2\ ^{+1.8}_{-1.7}\ ^{+0.5}_{-0.7}\ ^{+0.3}_{-0.3}\ \text{MeV},$$
$$\Gamma_{\psi(3770)} = \ \ 24.9\ ^{+4.6}_{-4.0}\ ^{+0.5}_{-0.6}\ ^{+0.2}_{-0.9}\ \text{MeV}.$$

There are two possible solutions for the $\psi(3770)$ electron partial width and the radiatively corrected nonresonant $D\overline{D}$ cross section at the mass of $\psi(3770)$:

$$(1)\ \ \Gamma_{ee}^{\psi(3770)} = 154^{+79}_{-58}\ ^{+17}_{-9}\ ^{+13}_{-25}\,\text{eV},\ \ \sigma_{D\overline{D}}^{NR} = 1.4 \pm 0.7\ ^{+0.1}_{-0.2}\ ^{+0.3}_{-0.2}\,\text{nb},$$
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The quoted model errors do not include possible deviations of the resonance shape from the Breit-Wigner one with usual assumptions about the total width energy dependence.

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