PARAMETERS OF CHARMONIUM STATES FROM KEDR

V. M. AULCHENKO^{*,†}, E. M. BALDIN^{*,†}, A. K. BARLADYAN^{*}, A. YU. BARNYAKOV^{*},
 M. YU. BARNYAKOV^{*}, S. E. BARU^{*,†}, I. YU. BASOK^{*}, A. M. BATRAKOV^{*}, A. E. BLINOV^{*},
 V. E. BLINOV^{*,†}, A. V. BOBROV^{*}, V. S. BOBROVNIKOV^{*}, A. V. BOGOMYAGKOV^{*,†},
 A. E. BONDAR^{*,†}, A. R. BUZYKAEV^{*}, S. I. EIDELMAN^{*,†}, D. N. GRIGORIEV^{*,†,‡},
 V. R. GROSHEV^{*}, YU. M. GLUKHOVCHENKO^{*}, V. V. GULEVICH^{*}, D. V. GUSEV^{*},
 S. E. KARNAEV^{*}, G. V. KARPOV^{*}, S. V. KARPOV^{*}, T. A. KHARLAMOVA^{*},
 V. A. KISELEV^{*}, V. V. KOLMOGOROV^{*}, S. A. KONONOV^{*,†}, K. YU. KOTOV^{*},
 E. A. KRAVCHENKO^{*,†}, V. N. KUDRYAVTSEV^{*}, V. F. KULIKOV^{*,†}, G. YA. KURKIN^{*,‡},
 E. A. KUPER^{*,†}, I. A. KUYANOV^{*}, E. B. LEVICHEV^{*,†}, D. A. MAKSIMOV^{*,†},
 V. M. MALYSHEV^{*}, A. L. MASLENNIKOV^{*}, O. I. MESHKOV^{*,†}, S. I. MISHNEV^{*},
 I. I. MOROZOV^{*,†}, N. YU. MUCHNOI^{*,†}, V. V. NEUFELD^{*}, S. A. NIKITIN^{*},
 I. B. NIKOLAEV^{*,†}, I. N. OKUNEV^{*}, A. P. ONUCHIN^{*,†}, S. B. ORESHKIN^{*}, I. O. ORLOV^{*,†},
 A. A. OSIPOV^{*}, I. V. OVTIN^{*}, S. V. PELEGANCHUK^{*}, S. G. PIVOVAROV^{*,†},
 P. A. PIMINOV^{*}, V. V. PETROV^{*}, A. O. POLUEKTOV^{*}, V. G. PRISEKIN^{*},
 O. L. REZANOVA^{*,†}, A. A. RUBAN^{*}, V. K. SANDYREV^{*}, G. A. SAVINOV^{*}, A. G. SHAMOV^{*},
 D. N. SHATILOV^{*}, B. A. SHWARTZ^{*,†}, E. A. SIMONOV^{*}, S. V. SINYATKIN^{*},
 A. N. SKRINSKY^{*}, A. V. SOKOLOV^{*,†}, A. M. SUKHAREV^{*}, E. V. STAROSTINA^{*,†},
 A. A. TALYSHEV^{*,†}, V. A. TAYURSKY^{*}, V. I. TELNOV^{*,†}, YU. A. TIKHONOV^{*},
 K. YU. TODYSHEV^{*,†}, G. M. TUMAIKIN^{*}, YU. V. USOV^{*}, A. I. VOROBIOV^{*},
 V. N. ZHILICH^{*}, V. V. ZHULANOV^{*,†}, A. N. ZHURAVLEV^{*,†}

^{*}*Budker Institute of Nuclear Physics, Novosibirsk, 630090, Russia*

[†]*Novosibirsk State University, 630090 Novosibirsk, Russia*

E.M.Baldin@inp.nsk.su

[‡]*Novosibirsk State Technical University, Novosibirsk, 630092, Russia*

Published 18 December 2014

We report results of experiments performed with the KEDR detector at the VEPP-4M e^+e^- collider. They include final results for the mass and other parameters of the J/ψ , $\psi(2S)$ and $\psi(3770)$ and $J/\psi \rightarrow \gamma\eta_c$ branching fraction determination.

Keywords: Detector; charmonium; collider.

PACS Numbers: 13.20.Gd, 13.66.De, 14.40.Gx

1. VEPP-4M collider

The VEPP-4M collider¹ with the KEDR detector² can operate in the wide range of beam energy from 1 to 6 GeV. The luminosity is quite modest, but VEPP-4M

This is an Open Access article published by World Scientific Publishing Company. It is distributed under the terms of the Creative Commons Attribution 3.0 (CC-BY) License. Further distribution of this work is permitted, provided the original work is properly cited.

Fig. 1. J/ψ mass comparison.

Fig. 2. $\psi(2S)$ mass comparison.

is equipped with two independent systems for precise energy determination:³ the resonant depolarization facility and infrared light Compton backscattering one.

2. J/ψ and $\psi(2S)$ mass measurement

The J/ψ and $\psi(2S)$ masses were measured using additional statistics. Systematic errors in mass measurements are the main issue. More than 20 different effects were considered: energy spread, energy assignment, energy difference of e^+ and e^- , beam misalignment, luminosity etc. New mass measurements will supersede the old results.⁴

The final mass values obtained are:

$$M(J/\psi) = (3096.900 \pm 0.002 \pm 0.006) \text{ MeV},$$

$$M(\psi(2S)) = (3686.100 \pm 0.004 \pm 0.009) \text{ MeV}.$$

A comparison with other measurements is presented in Figs. 1 and 2 for the J/ψ and $\psi(2S)$ masses, respectively. The position and width of the bar correspond to the PDG2012 fit.⁵

3. Comparison of the J/ψ leptonic widths

The ratio of the electron and muon widths of the J/ψ meson has been measured at the KEDR detector using direct J/ψ decays. The result

$$\Gamma_{e^+e^-}(J/\psi)/\Gamma_{\mu^+\mu^-}(J/\psi) = 1.0022 \pm 0.0044 \pm 0.0048 \text{ (0.65\%)}$$

is in good agreement with the lepton universality. The experience collected during this analysis will be used for a J/ψ lepton width determination with up to 1% accuracy.

Fig. 3. J/ψ $\Gamma_{ee}/\Gamma_{\mu\mu}$ comparison. Fig. 4. $\psi(2S)$ $\Gamma_{ee} \times \Gamma_{\mu\mu}/\Gamma$ comparison.

A comparison with other measurements is presented in Fig. 3. The position and width of the bar correspond to the PDG2012 fit.⁵ Currently the world average value of the J/ψ meson lepton width is completely dominated by the CLEO results obtained in 2005.⁶ Recently the BESIII collaboration announced the most precise measurement of the ratio of the electron and meson widths.⁷ For that analysis both experiments used the $\psi(2S) \rightarrow J/\psi \pi^+ \pi^-$, $J/\psi \rightarrow \ell^+ \ell^-$ decay chain ($\ell = e, \mu$).

4. Study of $\psi(2S) \rightarrow \mu^+ \mu^-$ decay

Since 2004 KEDR has been taking data at the VEPP-4M collider in the $\psi(2S)$ region and acquired a total luminosity of about 7 pb^{-1} , which corresponds to more than 3.5×10^6 $\psi(2S)$.

We report the preliminary value of

$$\Gamma_{ee}(\psi(2S)) \times \Gamma_{\mu\mu}(\psi(2S))/\Gamma(\psi(2S)) = (19.4 \pm 0.4 \pm 1.1) \text{ eV}.$$

No direct measurement of this quantity is listed in the PDG tables. For comparison (the position and width of the bar in Fig. 4) we use the product of the two world average values – Γ_{ee} and $\mathcal{B}_{\mu\mu}$.

5. The main parameters of the $\psi(3770)$

For the $\psi(3770)$ mass measurement the joint $\psi(2S)$ and $\psi(3770)$ scans were performed. Data analysis takes into account interference between the resonant and nonresonant $D\bar{D}$ production.

Fig. 5. The $\psi(3770)$ cross section with two fit solutions.

Fig. 6. The inclusive photon spectrum and the η_c observed cross section.

Our final results for mass and width are:⁸

$$M(\psi(3770)) = 3779.2^{+1.8}_{-1.7}{}^{+0.5}_{-0.7}{}^{+0.3}_{-0.3} \text{ MeV},$$

$$\Gamma(\psi(3770)) = 24.9^{+4.6}_{-4.0}{}^{+0.5}_{-0.6}{}^{+0.2}_{-0.9} \text{ MeV}.$$

When a resonance interferes with a variable continuum, the ambiguity appears. Figure 5 illustrates two solutions corresponding to VDM. The resulting cross sections, mass and width are almost indistinguishable, but for the lepton width and phase we have two solutions:

$$(1) \quad \Gamma_{ee}(\psi(3770)) = 154^{+79}_{-58}{}^{+17}_{-9}{}^{+13}_{-25} \text{ eV}, \quad \phi = (171 \pm 17)^\circ,$$

$$(2) \quad \Gamma_{ee}(\psi(3770)) = 414^{+72}_{-80}{}^{+24}_{-26}{}^{+90}_{-10} \text{ eV}, \quad \phi = (240 \pm 9)^\circ.$$

Recently the VDM approach was applied for the joint analysis of BABAR, BELLE, BES, CLEO and KEDR data on $D\bar{D}^-$ and inclusive hadronic cross sections:⁹

Solution	M (MeV)	Γ (MeV)	$\mathcal{B}_{nD\bar{D}}$	Γ_{ee} (eV)	ϕ (deg)
1	3779.3 ± 1.0	26.7 ± 1.4	0.19 ± 0.05	202 ± 18	185.6 ± 5.2
2	3779.5 ± 1.0	26.8 ± 1.4	0.11 ± 0.03	346 ± 19	228.6 ± 3.0

The results of KEDR were confirmed at the much better level of accuracy.

6. $\mathcal{B}(J/\psi \rightarrow \gamma\eta_c)$

The η_c mass, width and branching fraction of $J/\psi \rightarrow \gamma\eta_c$ decay have been measured in the inclusive photon spectrum of multihadron J/ψ decays (Fig. 6), using a sample of about 6 million J/ψ mesons.

$J/\psi \rightarrow \gamma\eta_c$ decay is an M1 transition between the 1S states of charmonium, so its rate can be easily calculated in potential models in the limit of a zero width of the resonance. For this decay, the resonance width to transition energy ratio is about 1/4, thus the photon line shape deviates from the Breit-Wigner. During the analysis the ω^3 factor near the η_c resonance and interference effects were taken into account.

Our final result for the branching fraction of $J/\psi \rightarrow \gamma\eta_c$ is:

$$\mathcal{B}(J/\psi \rightarrow \gamma\eta_c) = (3.58 \pm 0.38 \pm 0.20)\%$$

7. Summary

Most of the results are in good agreement with the world average values if they exist and have comparable or better accuracy.

The results of the KEDR detector on $\psi(3770)$ are confirmed by joint analysis of data published by 5 experiments at a better accuracy level.

This work is supported by the Ministry of Education and Science of the Russian Federation, the RFBR grants 12-02-00023, 11-02-00112, 11-02-00558, the Sci. School Nsh-5320.2012.2 grant and the DFG grant HA 1457/7-2.

References

1. V. Anashin *et al.*, *Stockholm 1998, EPAC 98**, 400 (1998), Prepared for 6th European Particle Accelerator Conference (EPAC 98), Stockholm, Sweden, 22–26 Jun 1998.
2. V. V. Anashin *et al.*, *Phys. Part. Nucl.* **44**, 657 (2013).
3. V. Blinov *et al.*, *Nucl. Instrum. Meth.* **A598**, 23 (2009).
4. V. M. Aulchenko *et al.*, *Phys. Lett. B* **573**, 63 (2003).
5. J. Beringer *et al.*, *Phys. Rev.* **D86**, p. 010001 (2012).
6. Z. Li *et al.*, *Phys. Rev.* **D71**, p. 111103 (2005).
7. M. Ablikim *et al.*, *Phys. Rev.* **D88**, p. 032007 (2013).
8. V. V. Anashin *et al.*, *Phys. Lett.* **B711**, 292 (2012).
9. A. G. Shamov, An attempt of a joint analysis of BABAR, BELLE, BES, CLEO and KEDR data for determination of $\psi(3777)$ parameters. PhiPsi 2013, International Workshop on e+e- collisions from Phi to Psi. September 9–12, 2013, Rome, Italy. Poster session.