Recent Results from the KEDR detector at the VEPP-4M e^+e^--collider

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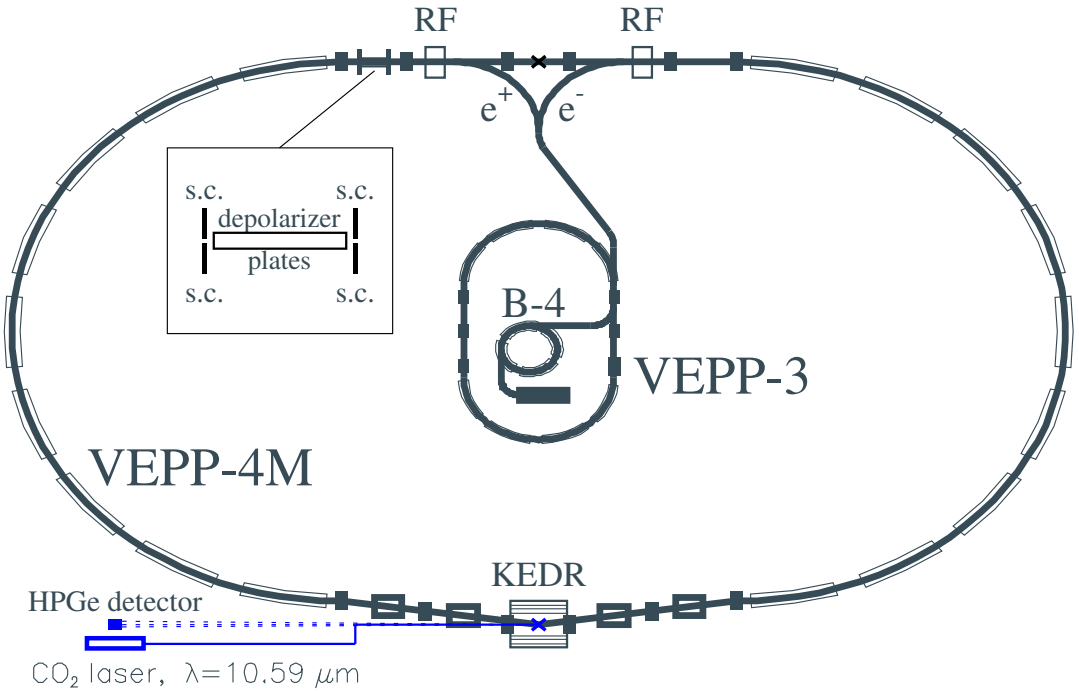
Outline

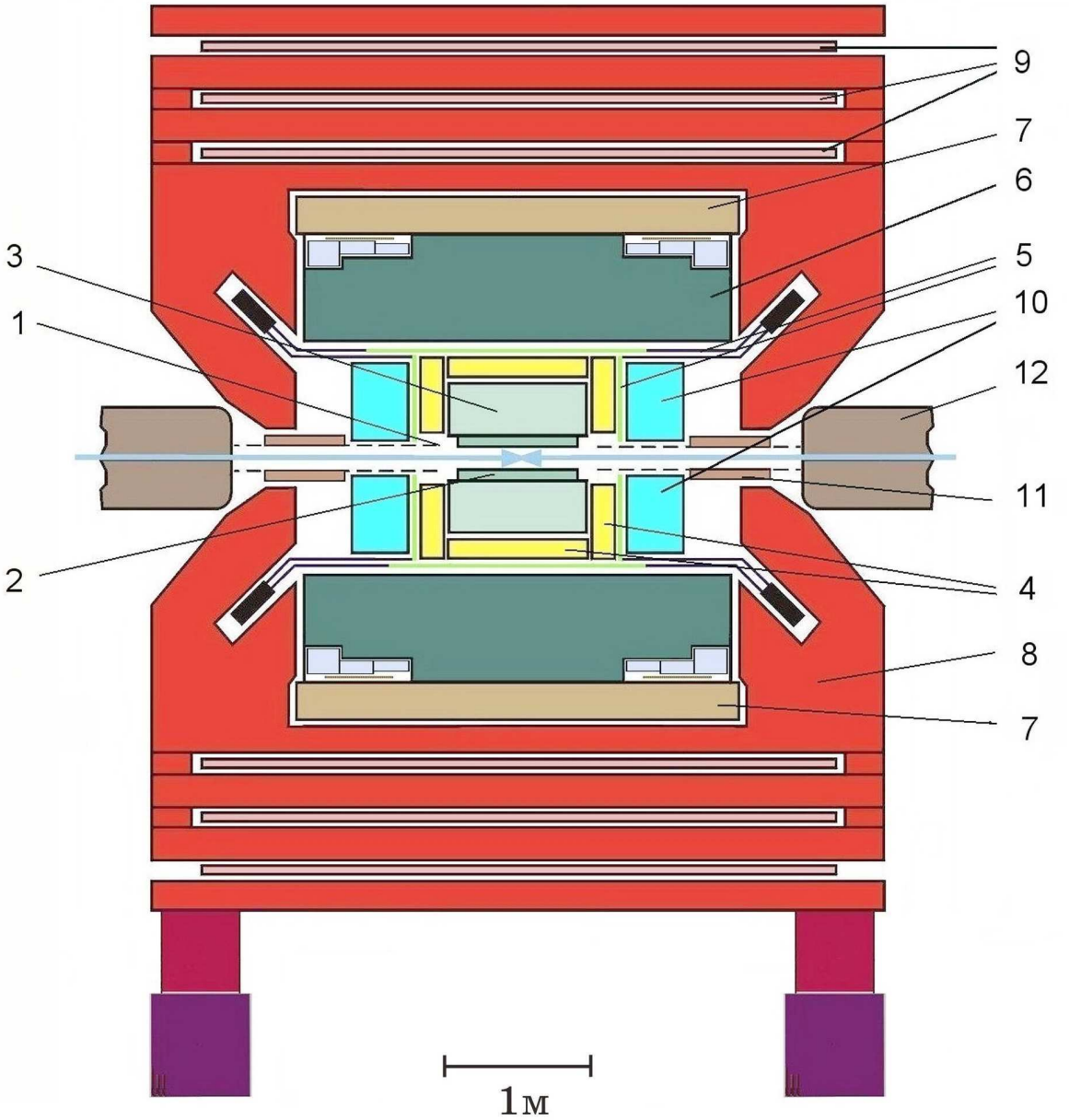
VEPP–4M collider



Circumference	366 m
Beam energy	$1 \div 6$ GeV
Number of bunches	2×2
Luminosity (1.5 GeV)	2×10^{30}
Luminosity (5.0 GeV)	2×10^{31}

- Resonant depolarization technique:
  - Instant measurement accuracy $\simeq 1 \times 10^{-6}$
  - Energy interpolation accuracy $(5 \div 15) \times 10^{-6}$ $(10 \div 30$ keV$)$
- Infra-red light Compton backscattering:
  - Statistical accuracy $\simeq 5 \times 10^{-5}$ / 30 minutes
  - Systematic uncertainty $\simeq 3 \times 10^{-5}$ $(50 \div 70$ keV$)$

KEDR detector



1. Vacuum chamber
2. Vertex detector
3. Drift chamber
4. Threshold aerogel counters
5. ToF–counters
6. Liquid krypton calorimeter
7. Superconducting coil
8. Magnet yoke
9. Muon tubes
10. CsI-calorimeter
11. Compensation solenoid
12. VEPP–4M quadrupole

Data and results

- In 2004 two scans of the $\psi(2S)$–$\psi(3770)$ energy region, 11 points, $\int \mathcal{L}\, dt \approx 0.7\,\text{pb}^{-1}$
- In 2006 the regions of $\psi(2S)$ and $\psi(3770)$ mesons, 23 points, $\int \mathcal{L}\, dt \approx 1.9\,\text{pb}^{-1}$

We present final results for $\psi(2S)$ and $\psi(3770)$ parameters.

- In 2005 scan of J/ψ meson, 11 points, $\int \mathcal{L}\, dt \approx 220\,\text{nb}^{-1}$

We present combined analysis of all 2002-2006 scans on J/ψ and $\psi(2S)$ masses.

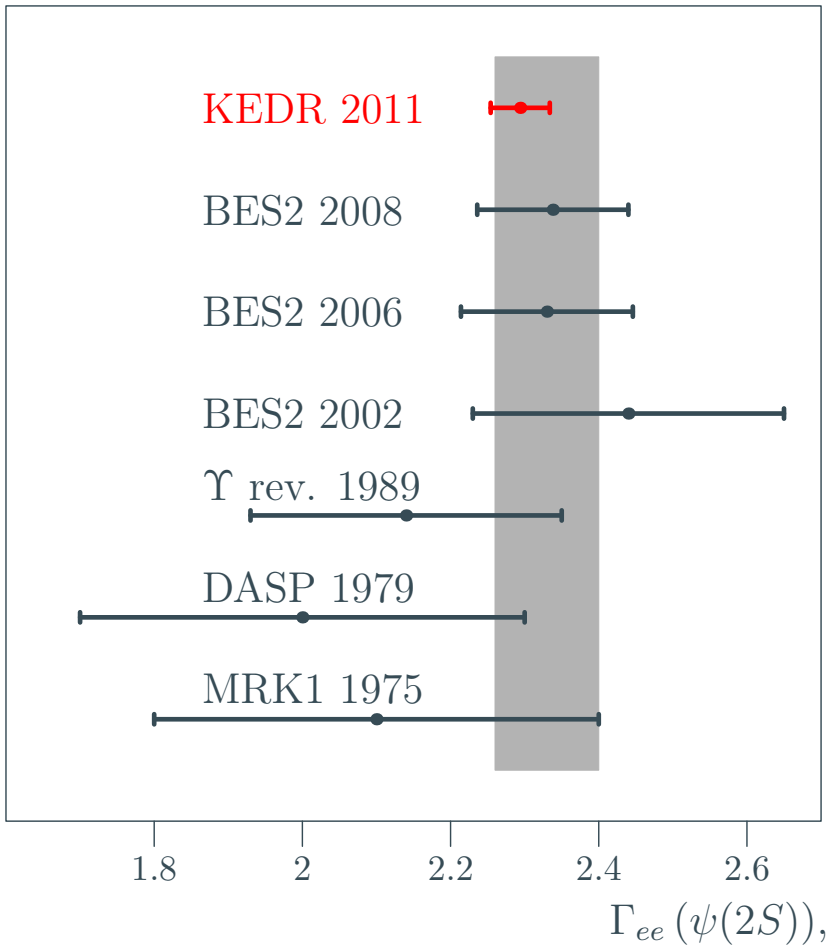
- In 2009 scan of $1.85 \div 3.1\,\text{GeV}$, $\int \mathcal{L}\, dt \approx 300\,\text{nb}^{-1}$, $\Delta W \approx 2\sigma_W$
- In 2010 scan of $1.85 \div 3.1\,\text{GeV}$, $\int \mathcal{L}\, dt \approx 1500\,\text{nb}^{-1}$, $\Delta W \approx 50\,\text{MeV}$

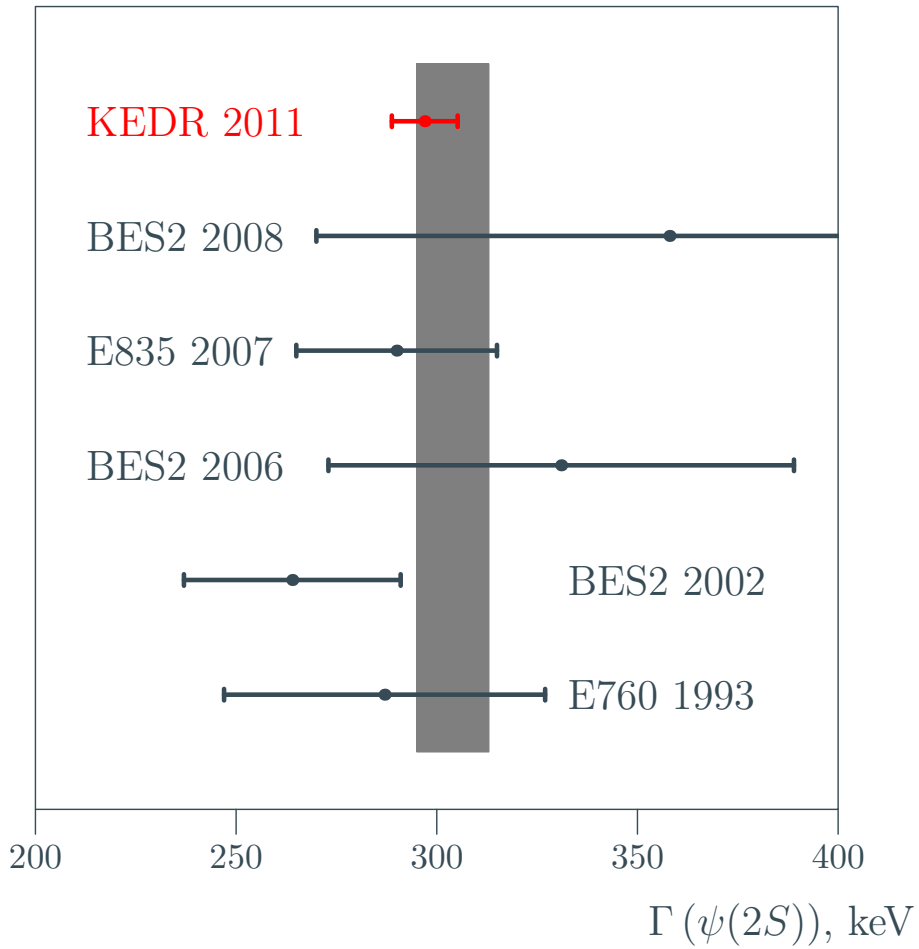
The R analysis is in progress, expected accuracy 5%.
Now we present the results of the narrow resonance search.

Parameters of $\psi(2S)$

$$\Gamma_{e^+e^-} \times \mathcal{B}(\psi(2S) \to \text{hadrons}) = (2.245 \pm 0.015 \pm 0.036)\,\text{keV}$$

We recalculate to Γ_{ee} and Γ using world average $\mathcal{B}(\psi(2S) \to \text{hadrons})$:



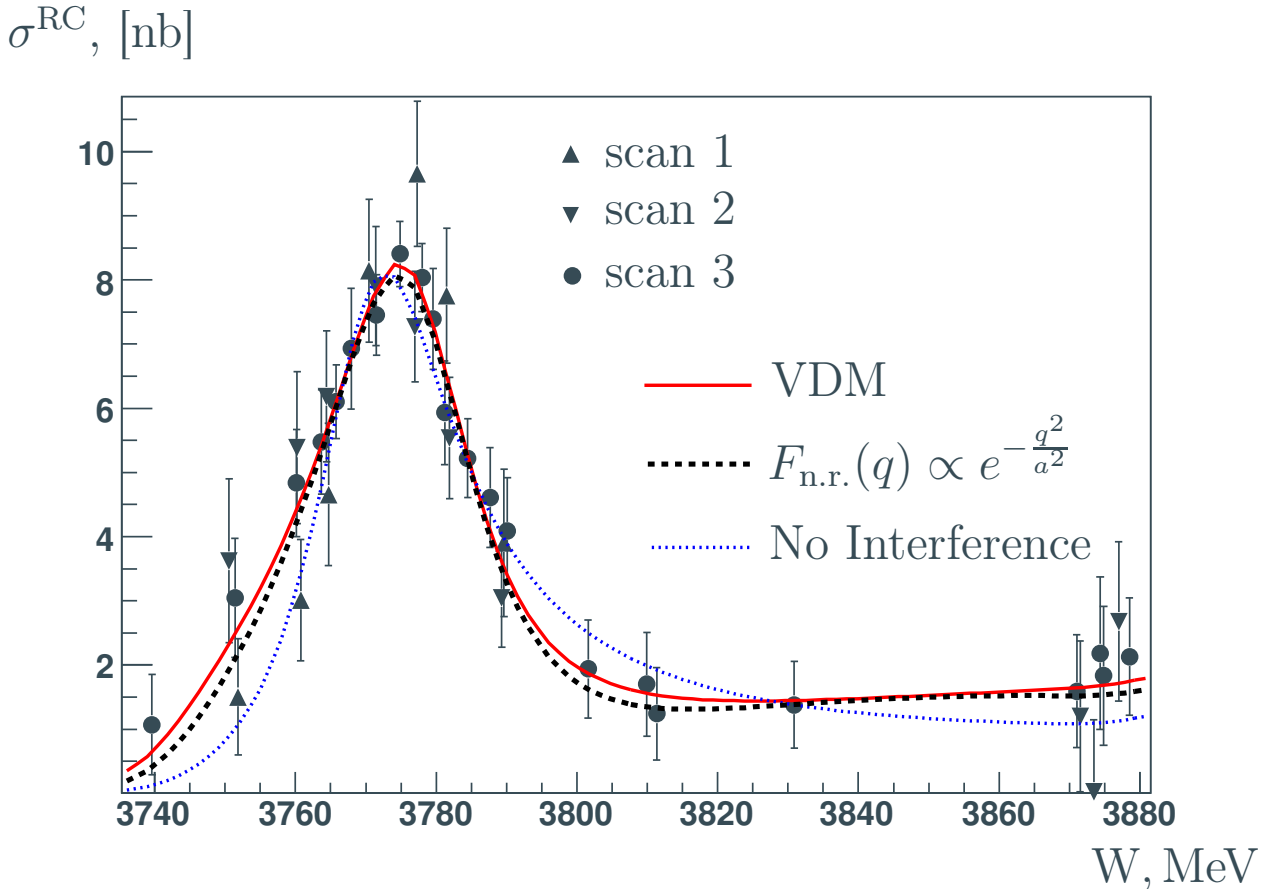


Parameters of $\psi(2S)$

- $\Gamma_{e^+e^-} \times \mathcal{B}(\psi(2S) \to \text{hadrons}) = (2.245 \pm 0.015 \pm 0.036)\,\text{keV}$,
  only old Mark I results were published in the same form
- Using the world-average value of $\mathcal{B}(\psi(2S) \to \text{hadrons})$
  $$\Gamma_{e^+e^-} = (2.294 \pm 0.015 \pm 0.037)\,\text{keV},$$
  about 3 times better than the best previous one.
- Using the world-average values of $\mathcal{B}(\psi(2S) \to \text{hadrons})$
  $$\Gamma = (297 \pm 2 \pm 8)\,\text{keV},$$
  again about 3 times better than the best previous one.

The mass result will be discussed later.

$\psi(3770)$ scans



$e^+e^- \to$ hadrons, light quarks contribution is subtracted

$$\sigma_{D\bar{D}} \propto |\mathrm{A}_{\psi(3770)}\, e^{i\phi} + \mathrm{F}_{\mathrm{n.r.}}|^2$$

$$\sigma_{D\bar{D}} \propto |\mathrm{A}_{\psi(3770)}\, e^{i\phi} + \mathrm{A}_{\psi(2S)} + \mathrm{B}|^2$$

Determination of $\psi(3770)$ parameters

Two solutions with close M, Γ and different (ϕ,Γ_{ee})

	solution 1	solution 2	No Interf.
M, MeV	3779.6 ± 1.8	3779.4 ± 1.8	3773.0 ± 0.5
Γ, MeV	24.7 ± 4.4	24.7 ± 4.1	24.0 ± 2.4
Γ_{ee}, eV	142 ± 79	508 ± 68	306 ± 29
ϕ, degrees	$155. \pm 35.$	$254. \pm 14.$	—
$P(\chi^2)$, %	18.8	19.1	1.8

The effect of the interference:

- $\Delta M = -6.5 \pm 1.8\,\text{MeV}$
- Γ_{ee} change is about 50% for both solutions though statistical uncertainty is large

Determination of $\psi(3770)$ parameters (Model, $F(q)$)

	$\frac{f}{1+aq^2+bq^4}$	$\frac{f}{1+a(W-2m_D)+b(W-2m_D)^2}$	$\frac{f}{1+aq^2+b(W-M_{\psi'})^2}$
M, MeV	3779.3 ± 1.7	3779.4 ± 1.7	3779.3 ± 1.7
Γ, MeV	25.1 ± 4.4	25.1 ± 5.2	26.1 ± 2.9
Solution 1 (smaller ϕ)			
ϕ, degrees	-10.3 ± 16.9	-10.1 ± 17.0	-7.4 ± 13.0
Γ_{ee}, eV	167 ± 81	167 ± 80	191 ± 32
$P(\chi^2)$, %	17.2	17.4	17.1
Solution 2 (large ϕ)			
ϕ, degrees	67.1 ± 8.8	67.2 ± 9.8	65.0 ± 7.1
Γ_{ee}, eV	555 ± 82	555 ± 82	549 ± 84
$P(\chi^2)$, %	17.3	17.1	17.0

q is the CMS momentum of the D-meson

Determination of $\psi(3770)$ parameters

Source	M [MeV]	Γ [MeV]	Γ_{ee} [%]
Theoretical uncertainties and external data precision			
$\Gamma_{nD\overline{D}}/\Gamma$	0.3	0.1	8.0
$\Gamma_{D\overline{D}}(W)$	0.3	0.3	2.0
$\Gamma_{D^0\overline{D}^0}/\Gamma_{D^+D^-}$	0.1	0.1	0.01
$D, \overline{D}$ masses	0.06	0.04	0.01
$D\overline{D}\pi$ cross section	0.15	0.05	1.0
Detector and accelerator related uncertainties			
Event selection	0.3	0.3	3
Luminosity measurement	0.1	0.1	2
Beam energy	0.03	–	–

$$M = 3779.5 \pm 1.8 \pm 0.6\,^{+0.2}_{-0.3}\ \text{MeV},$$

$$\Gamma = 24.7 \pm 4.4 \pm 0.3\,^{+1.5}_{-0.1}\ \text{MeV}.$$

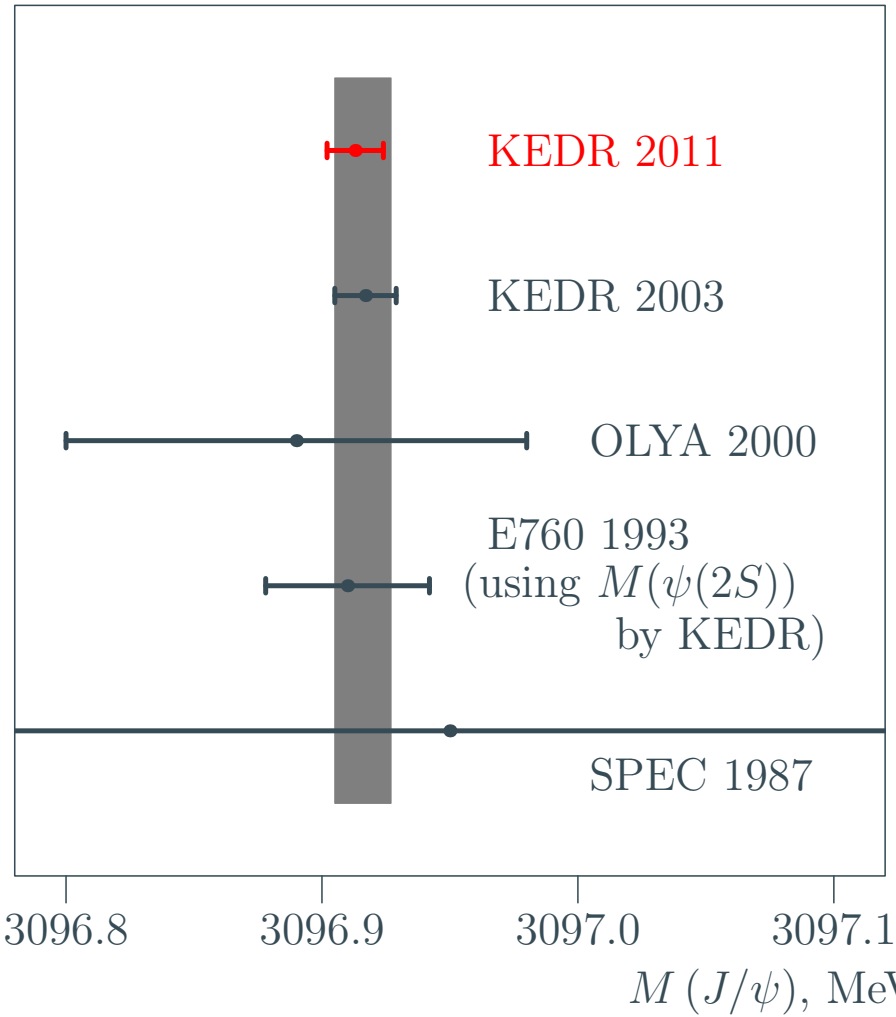
$$(1)\ \Gamma_{ee} = 142 \pm 79 \pm 13\,^{+50}_{-10}\ \text{eV},$$

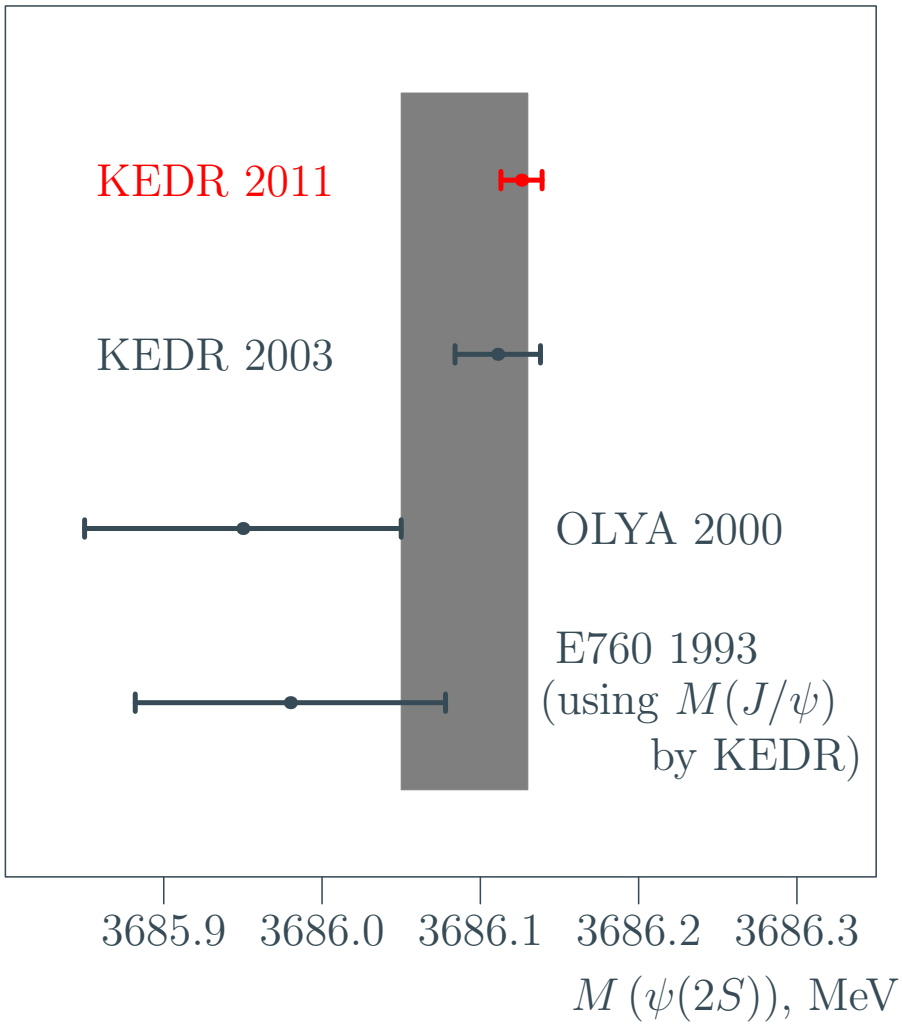
$$(2)\ \Gamma_{ee} = 508 \pm 68 \pm 46\,^{+200}_{-10}\ \text{eV}.$$

Determination of $\psi(3770)$ parameters

- Accounting of the resonance-continuum interference is essential for near-threshold region
- Mass is higher than in previous measurements ignoring the interference, but agrees with BaBar that also took into account interference
- Width is in reasonable agreement with previous measurements
- With our data sample we do not observe any shape anomaly
- While the current world-average value is $\Gamma_{e^+e^-} = 259 \pm 16$ eV, with interference effects included it is lower (≈ 140 eV) or higher ≈ 500 eV. The lower value would be greatly appreciated by many potential models.

J/ψ and $\psi(2S)$ masses





$$M\,(J/\psi) = (3096.913 \pm 0.006 \pm 0.009)\,\text{MeV}$$

$$M\,(\psi(2S)) = (3686.126 \pm 0.007 \pm 0.011)\,\text{MeV}$$

J/ψ and $\psi(2S)$ masses

- The precise measurement of the J/ψ and $\psi(2S)$ meson masses set the mass scale in the range around 3 GeV
- Systematic errors in mass measurements are the main issue
- More than 20 different effects considered: Energy spread, energy assignment, energy difference of e^+ and e^-, beam misalignment, luminosity etc.
- No significant improvement for the J/ψ because the additional scan had bigger systematics
- New mass measurements (KEDR 2011) will replace the old results (KEDR 2003)

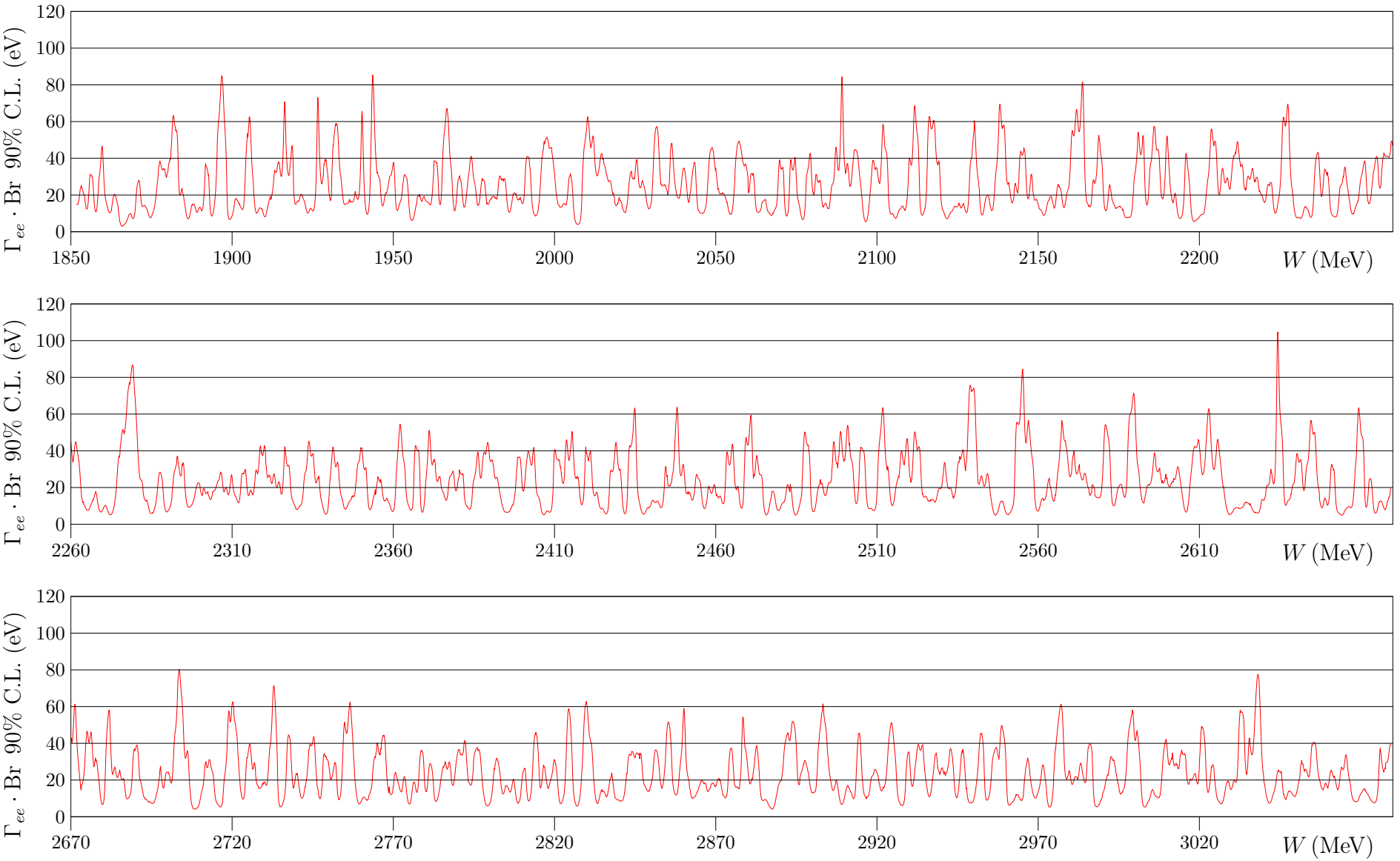
Search for narrow resonances

Searches in the energy range below J/ψ mass and down to 1.4 GeV were performed only in experiments at ADONE in 1975–1978 with upper limits of about 500 eV meanwhile for the 2.8–9.6 GeV region the limits of about 100 eV have been set.
$\int \mathcal{L}\, dt \approx 300\,\text{nb}^{-1}$ was collected in the center-of-mass (c.m.) energy range $1.85 \div 3.1$ GeV with a step $\approx 2\sigma_W$ $(1.4 \div 1.9\,\text{MeV})$

$$\Gamma^R_{ee} \times \mathcal{B}(R \to \text{hadrons}) < 120\,\text{eV}$$

- The model: a resonance with M_R, Γ^R_{ee} on top of a flat BG
- The fits use the range $M_R \pm 13\,\text{MeV}$
- M_R is varied in 0.1 MeV steps

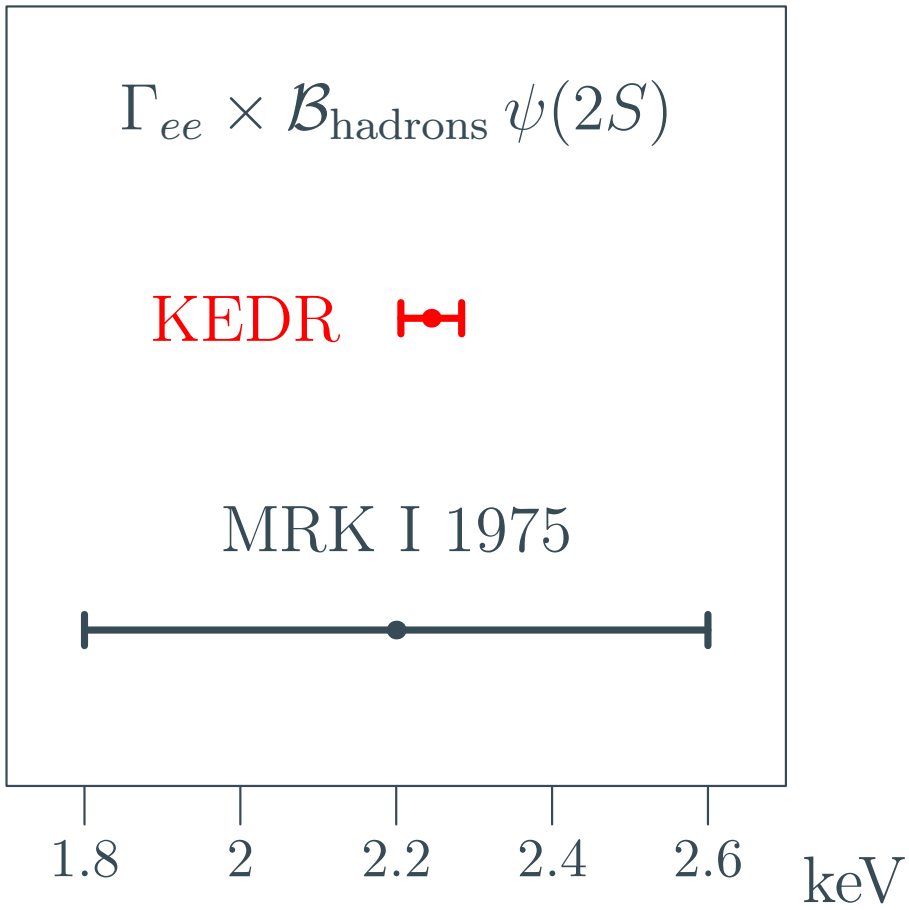
Search for narrow resonances



Conclusions

- New precise value of $\Gamma_{e^+e^-} \times \mathcal{B}\,(\psi(2S) \to \text{hadrons})$ significantly improves the values of both leptonic and total width for $\psi(2S)$
- Interference effects are of great importance for $\psi(3770)$ parameters determination
- Masses of J/ψ and $\psi(2S)$ measured. The accuracy reaches $(3 \div 5) \cdot 10^{-6}$
- No narrow states found between 1.85 GeV and J/ψ
- New R measurements are planned between 2 and 11 GeV

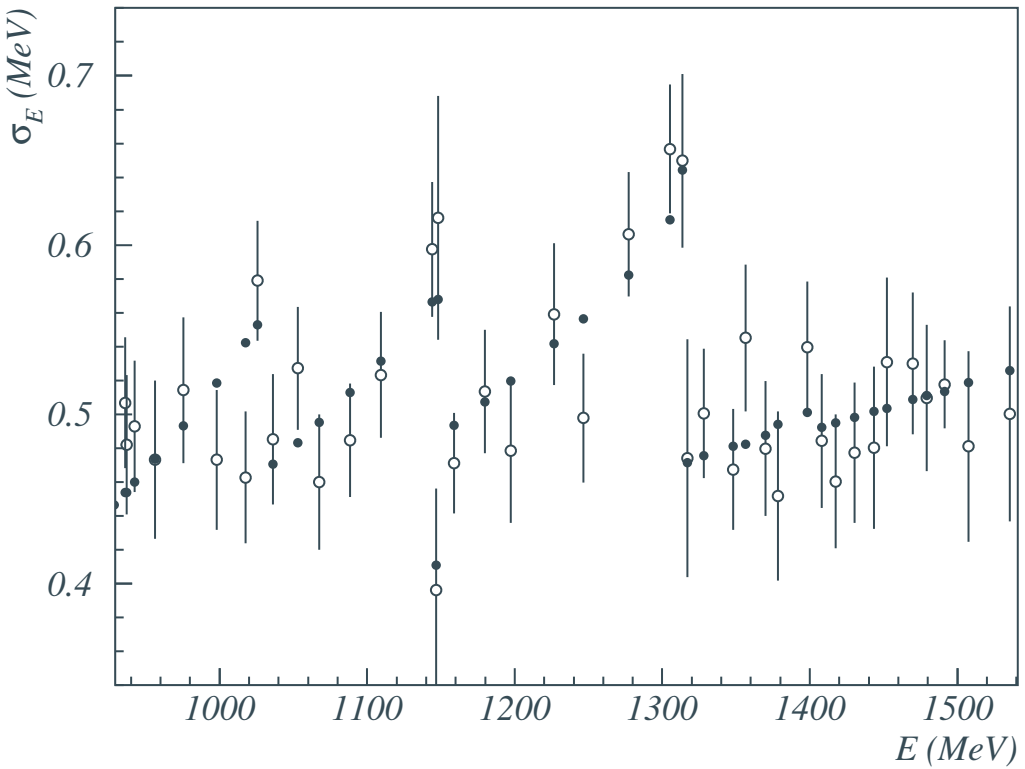
Measurement of $\Gamma_{ee} \times \mathcal{B}(\psi(2S) \to \text{hadrons})$



$$\Gamma_{e^+e^-} \times \mathcal{B}(\psi(2S) \to \text{hadrons}) = (2.245 \pm 0.015 \pm 0.036)\,\text{keV}$$

▸ Parameters of $\psi(2S)$

Search for narrow resonances



Why is Γ_{ee} splitting so large?

$$\sigma^{\text{obs}}(W) = \sigma_R(W) + 2\text{Im}\frac{\sqrt{\Gamma_{ee}\Gamma\sigma_0\sigma_{\text{n.r.}}}}{(W-M)+i\Gamma/2}\sin\phi + 2\text{Re}\frac{\sqrt{\Gamma_{ee}\Gamma\sigma_0\sigma_{\text{n.r.}}}}{(W-M)+i\Gamma/2}\cos\phi + \sigma_{\text{n.r.}}$$

$\Gamma_{ee} \propto \int \sigma\, dW$, neglecting small $\sigma_{\text{n.r.}}$ and integrating over W one obtains

$$\Gamma_{ee}^{\text{No Inter.}} \approx \Gamma_{ee}\left(1+\frac{\alpha}{3}\sqrt{\frac{R_{\text{n.r.}}(M)}{B_{ee}}}\sin\phi\right) + \frac{2\alpha\sqrt{B_{ee}}}{3\pi}M\cos\phi \times k\int\frac{(W-M)\sqrt{\Gamma(M)\Gamma(W)}\sqrt{R_{\text{n.r.}}(W)}}{(W-M)^2+\Gamma(W)^2/4}\frac{dW}{W}$$

Far from the threshold $\int \to 0$, for $\psi(3770)$ $\sim \sqrt{R_{\text{n.r.}}(M)} \approx 0.3$,
$2\alpha\sqrt{B_{ee}}M/3\pi \sim 18$ keV $\Rightarrow$ splitting of 350 eV is quite expectable!