Recent Results from the KEDR Detector

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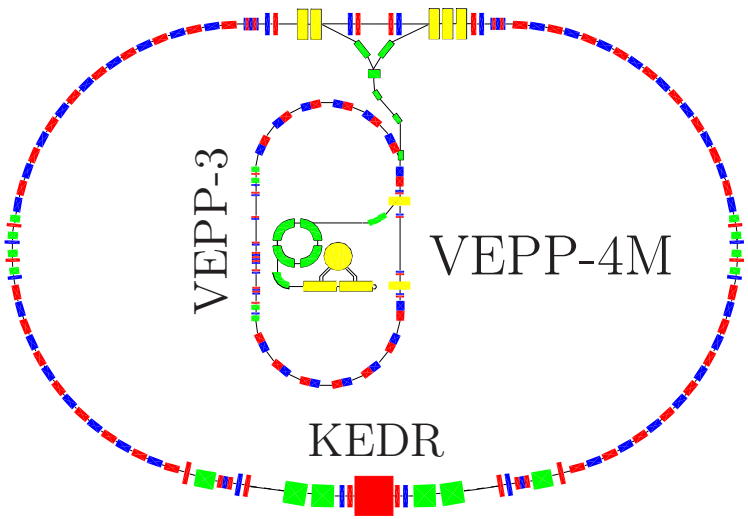
Outline

1. J/ψ and $\psi(2S)$ masses
2. R Measurement from 3.12 to 3.72 GeV
3. R Measurement from 1.84 to 3.05 GeV
4. $\Gamma_{ee}\mathcal{B}_{\rm h}$ and Γ_{ee} of the J/ψ
5. Conclusions

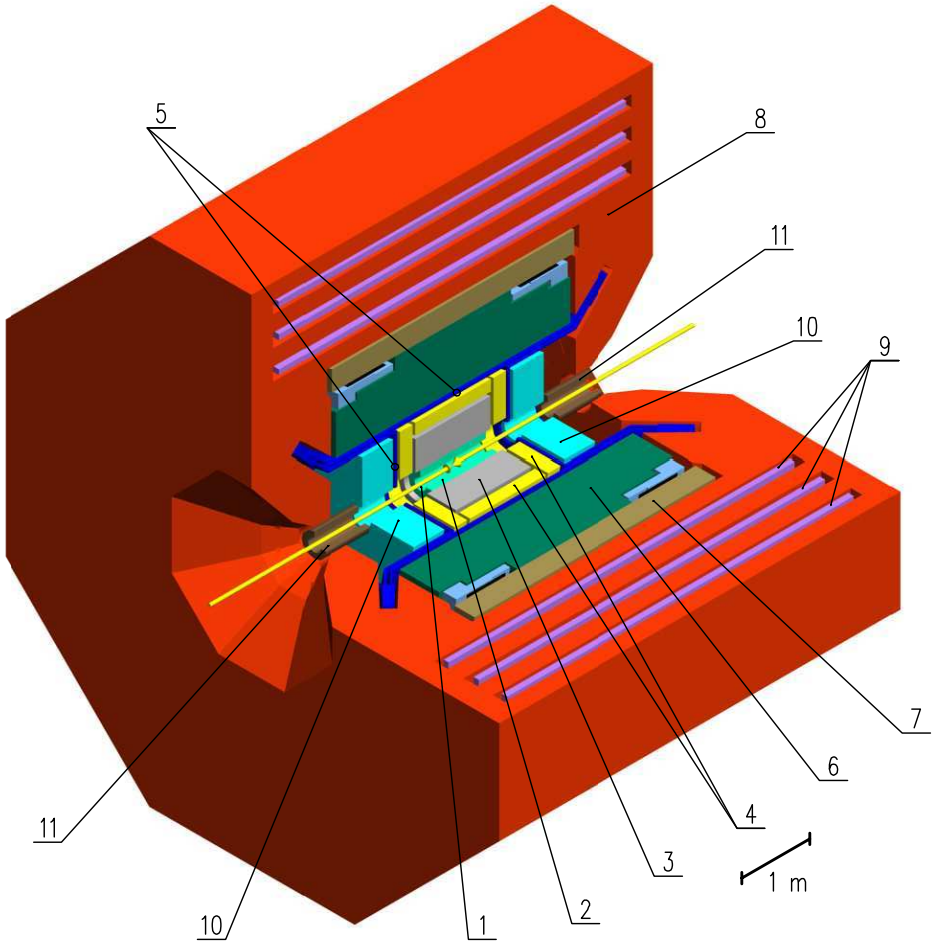
VEPP–4M collider



Circumference	366 m
Beam energy	$1 \div 5$ GeV
Number of bunches	2×2
Luminosity, $E = 1.5$ GeV	2×10^{30} cm^{-2}s^{-1}
Luminosity, $E = 5.0$ GeV	2×10^{31} cm^{-2}s^{-1}

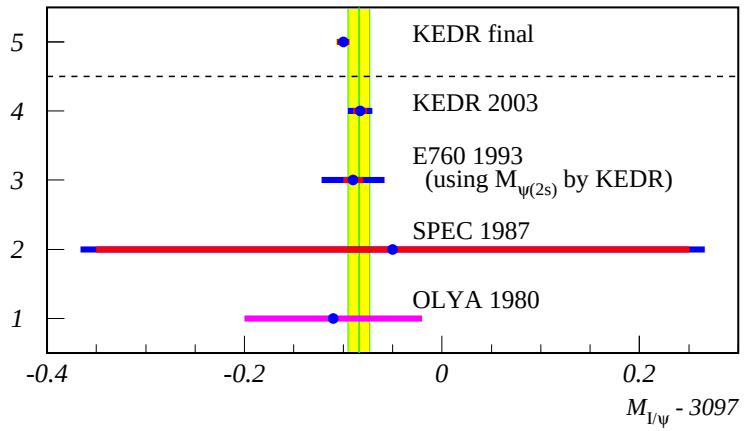
- Resonant depolarization technique:
  - Instantaneous measurement accuracy $\simeq 1 \times 10^{-6}$
  - Energy interpolation accuracy $(5 \div 15) \times 10^{-6}$ $(10 \div 30$ keV$)$
- Infrared light Compton backscattering:
  - Statistical accuracy $\simeq 5 \times 10^{-5}$ / 30 minutes
  - Systematic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

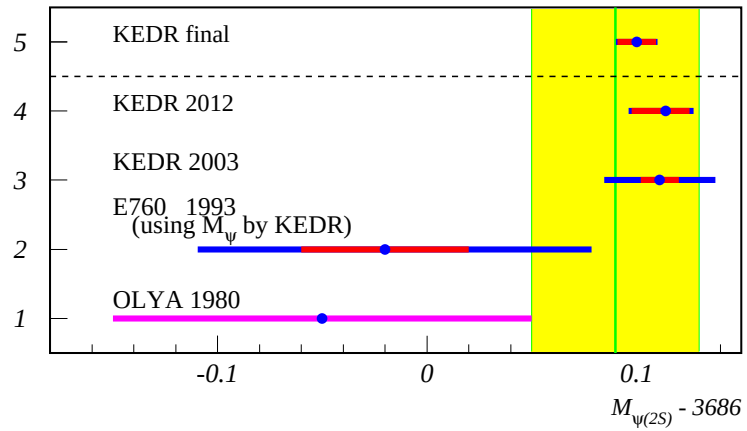
KEDR detector



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. Compensating s/c solenoid

J/ψ and $\psi(2S)$ Mass Measurement



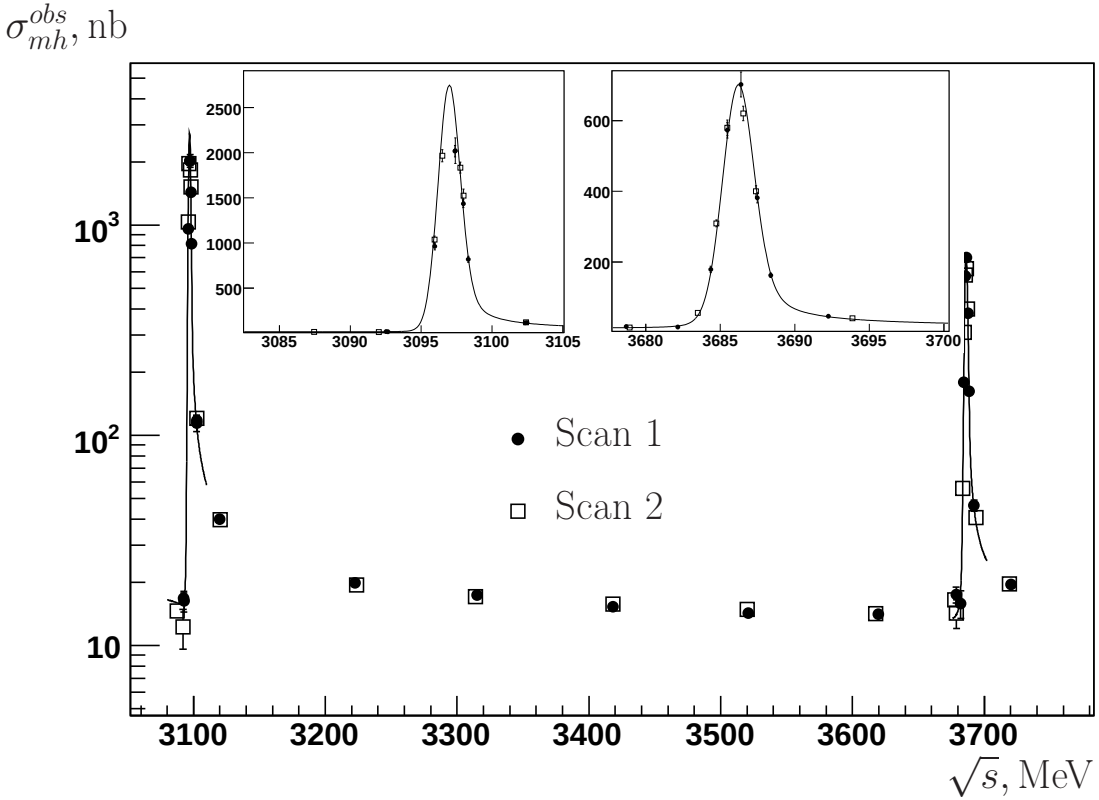


$$M_{J/\psi} = 3096.900 \pm 0.002 \pm 0.006 \text{ MeV}$$

$$M_{\psi(2S)} = 3686.099 \pm 0.004 \pm 0.009 \text{ MeV}$$

V.V. Anashin et al., Phys. Lett. B749, 50 (2015)

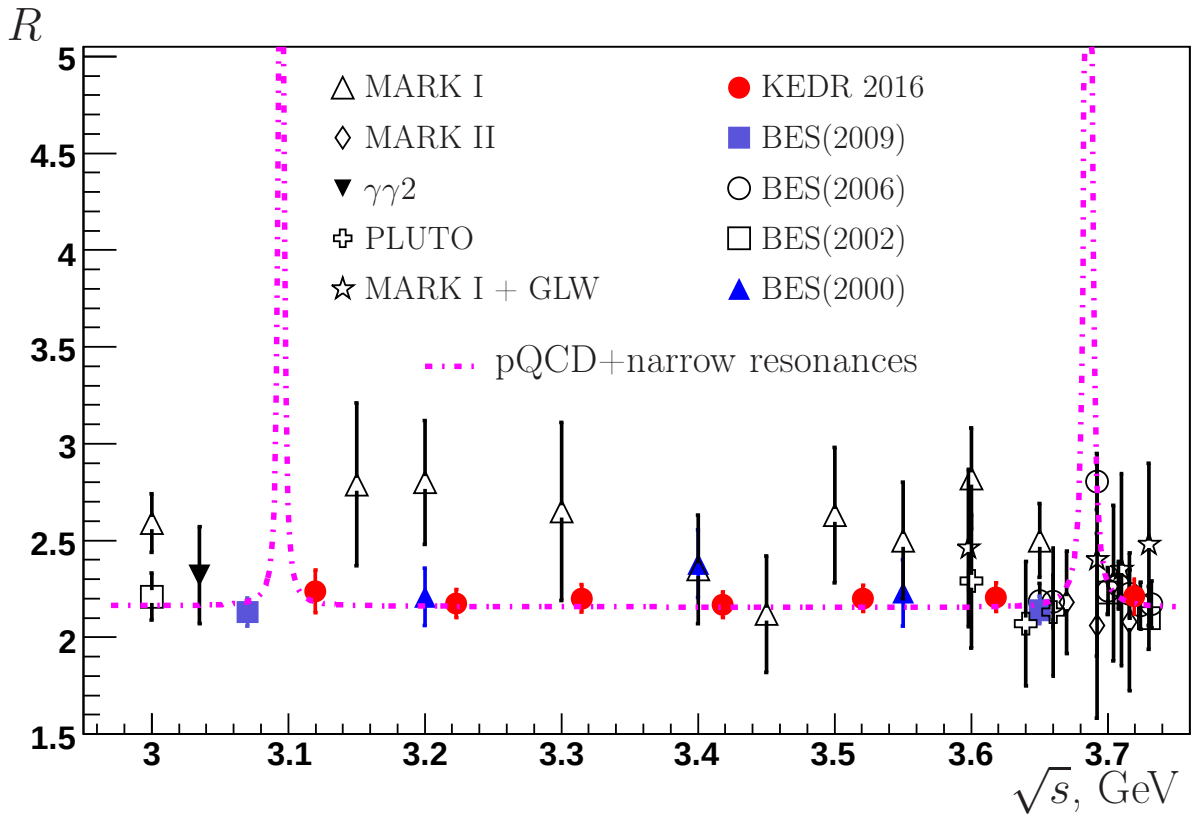
R Measurement between J/ψ and $\psi(2S)$ at KEDR – I



KEDR scanned $\sqrt{s}$ between J/ψ and $\psi(2S)$ with 1.4 pb^{-1} selecting $(2-3)\cdot 10^3$ m/h events per point, $\sim 18\cdot 10^3$ in total

V.V. Anashin et al., Phys. Lett. B753, 533 (2016)

R Measurement between J/ψ and $\psi(2S)$ at KEDR – II



R measured at 7 points between 3.12 and 3.72 GeV, syst. error 2.1%, total 3.3%

V.V. Anashin et al.,Phys. Lett. B753, 533 (2016)

R Measurement between 1.84 and J/ψ at KEDR – I

- The c.m. energy range between 1.84 and 3.05 GeV studied
- An integrated luminosity of 0.65 pb^{-1} collected at 13 equidistant points
- $\sim 10^3$ events per point $\Rightarrow \sim 13 \cdot 10^3$ events in total
- Simulation of the *uds* continuum based on the tuned LUARLW generator H.M. Hu and A. Tai, hep-ex/0106017
- JETSET 7.4 alternatively used at 2 points for a cross-check

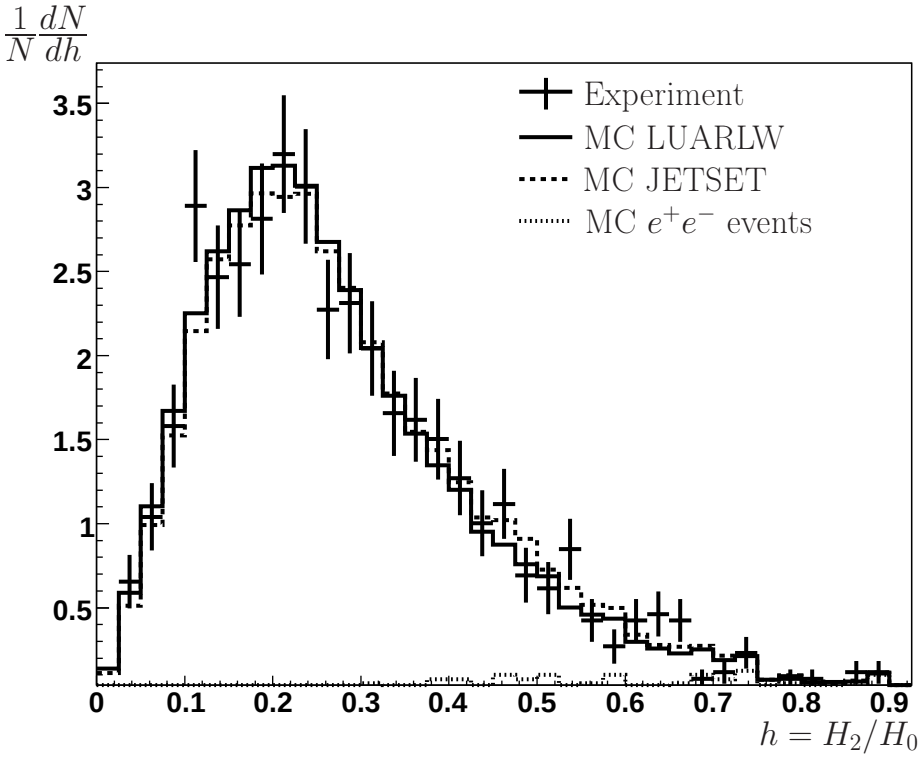
R Measurement between 1.84 and J/ψ at KEDR – II

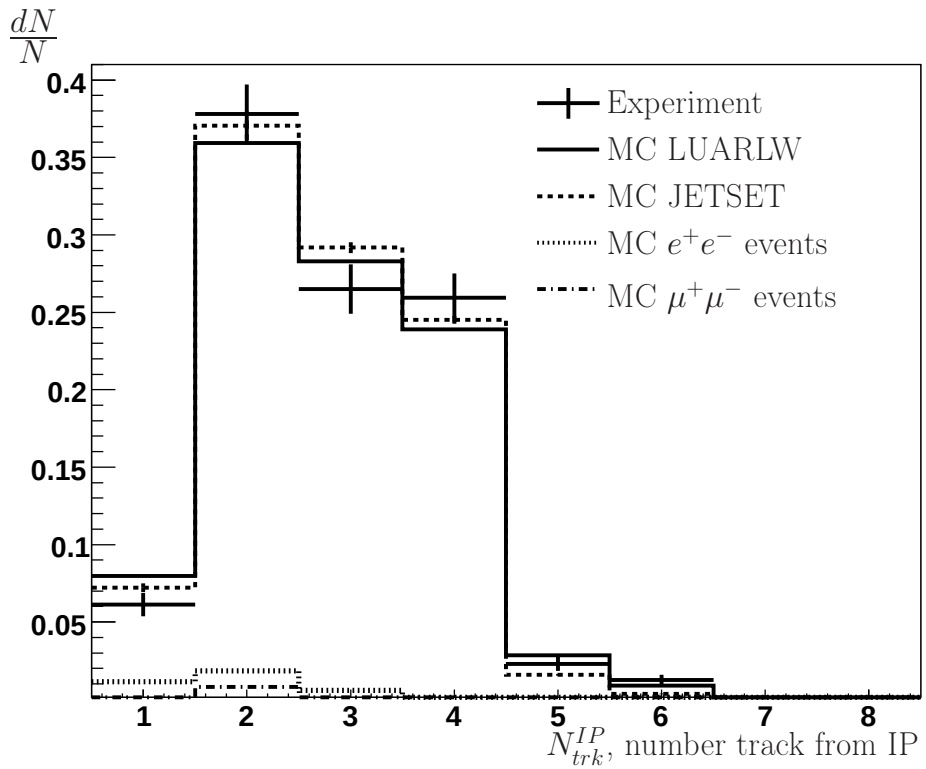
$$\sigma_{\rm obs}(s) = \frac{N_{\rm mh} - N_{\rm res.bg}}{\int \mathcal{L} dt}$$

$$R = \frac{\sigma_{\rm obs}(s) - \Sigma\varepsilon_{\rm bg}(s)\sigma_{\rm bg}(s)}{\varepsilon(s)(1+\delta(s))\sigma^0_{\mu\mu}(s)}$$

- The machine background is estimated from runs with separated e^+/e^- and is (1-2)% of $\sigma_{\rm obs}(s)$ depending on $I_{\rm beam}$ and $P_{\rm vac}$
- Physical background: $e^+e^- \to e^+e^-$ - (4-5)%, $e^+e^- \to \mu^+\mu^-$ - (1.1-0.4)%, $e^+e^- \to e^+e^-X$ - (0.1-0.2)%
- Radiative corrections vary from 2.6% to 8.8% with $\sqrt{s}$ increase

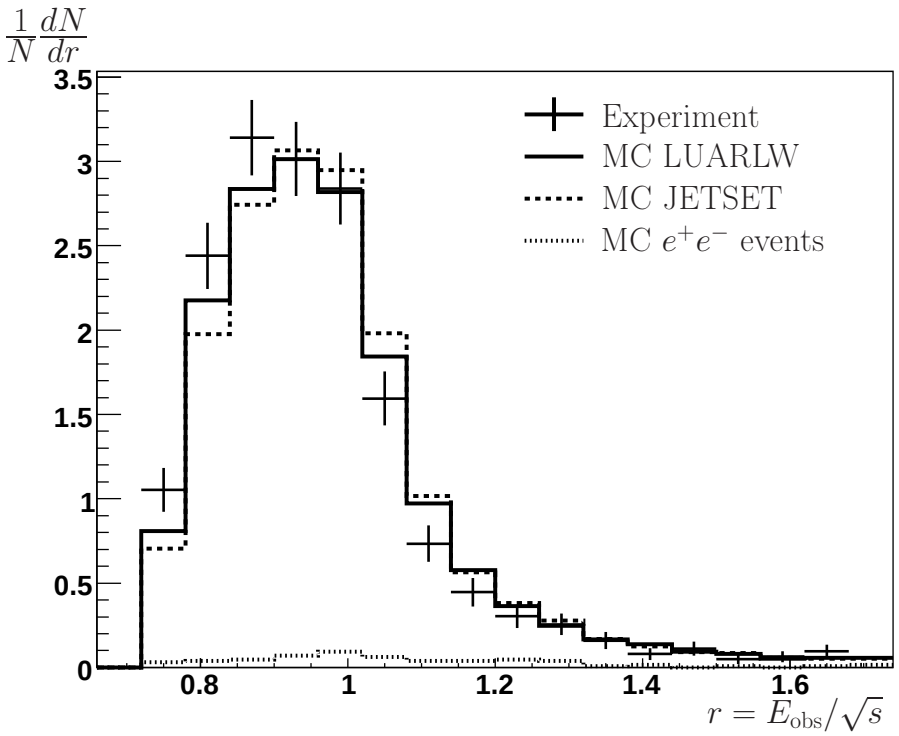
R Measurement between 1.84 and J/ψ at KEDR – III

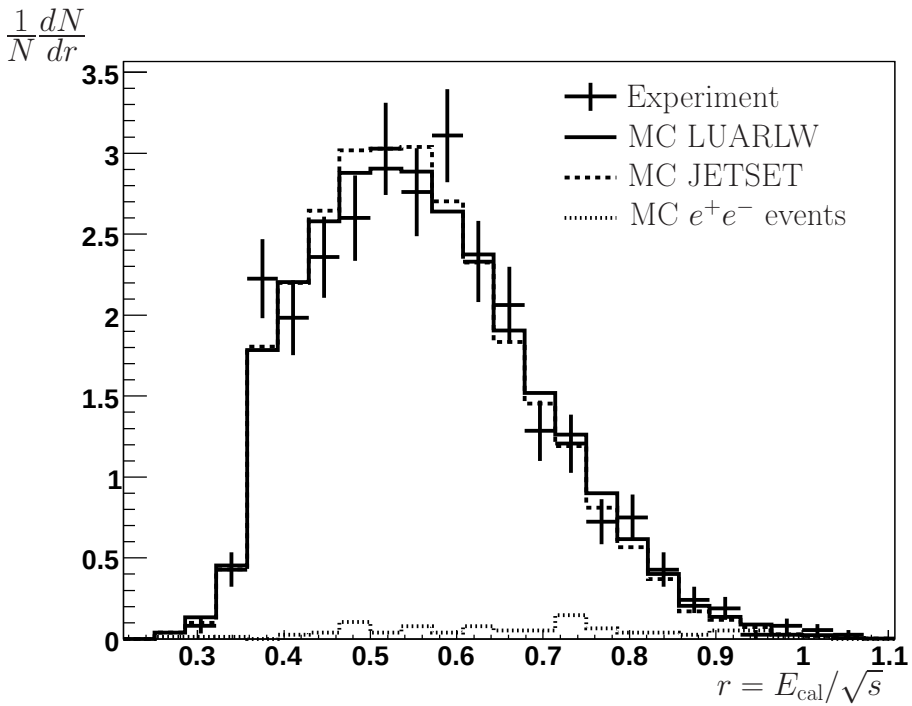




Fair agreement of simulation with data ($\sqrt{s} = 2.14$ GeV):
Ratio of Fox-Wolfram moments (H_2/H_0), number of tracks

R Measurement between 1.84 and J/ψ at KEDR – IV



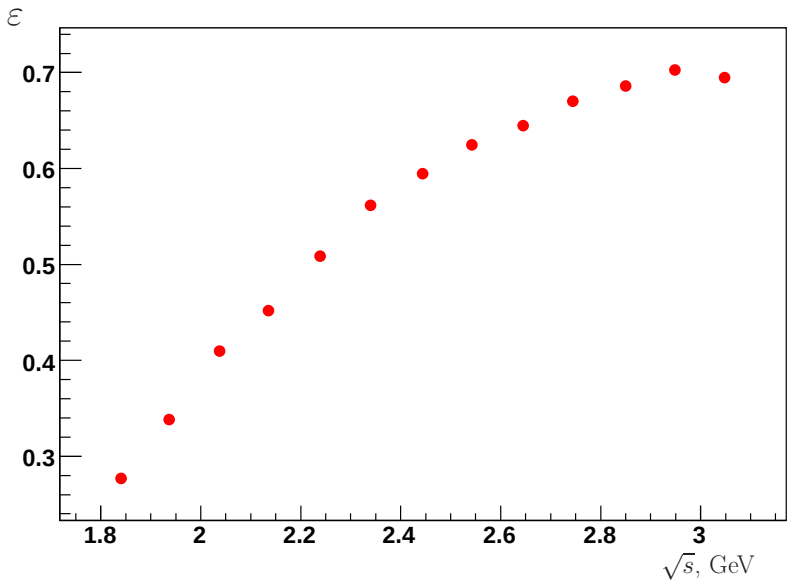


Fair agreement of simulation with data ($\sqrt{s} = 2.14$ GeV):

Total observed energy, sum of cluster energies

R Measurement between 1.84 and J/ψ at KEDR – V

Detection efficiency as a function of energy

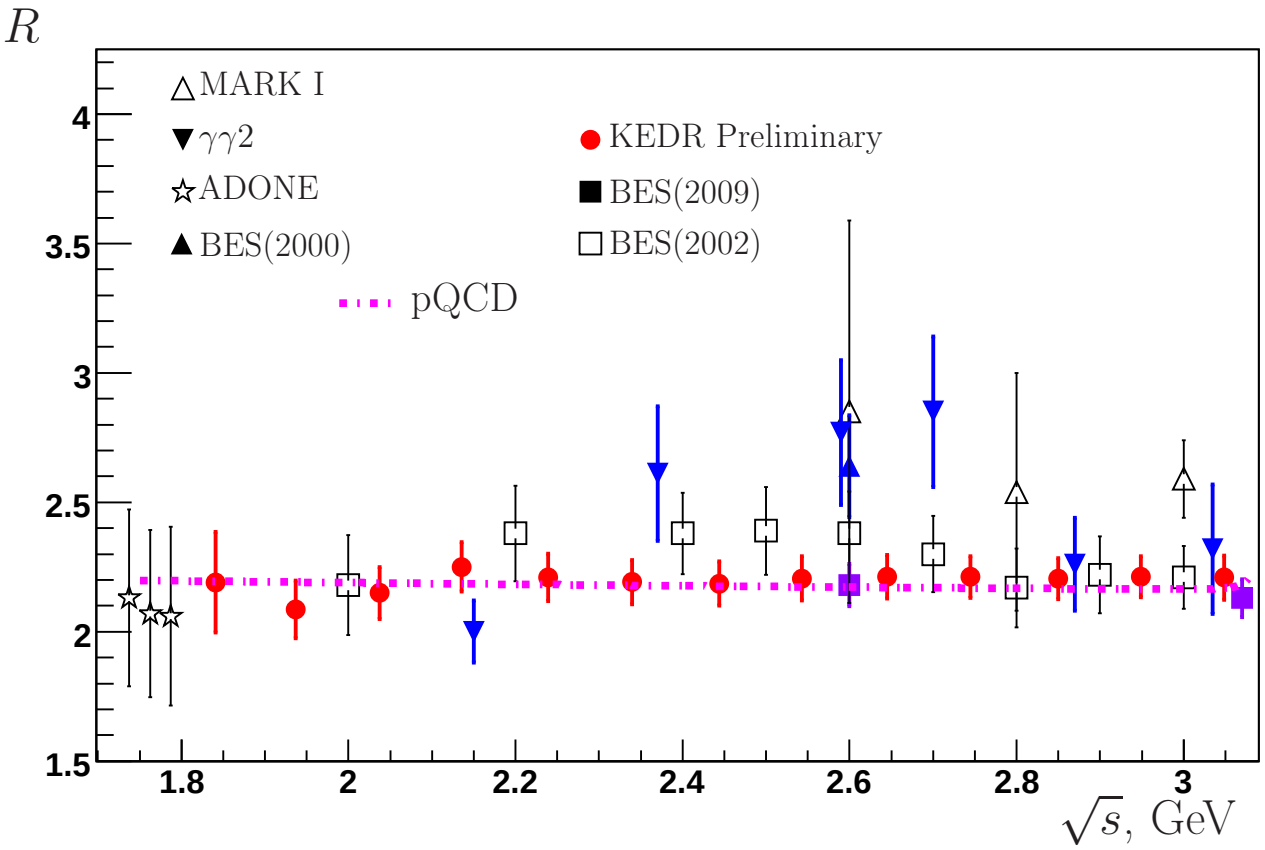


$\sqrt{s}$, MeV	$\varepsilon_{\text{LUARLW}}$,%	$\varepsilon_{\text{JETSET}}$,%	$\delta\varepsilon/\varepsilon$,%
2135.7	45.2 ± 0.1	44.9 ± 0.1	-0.7 ± 0.2
3048.1	69.5 ± 0.1	68.8 ± 0.1	-1.0 ± 0.2

R Measurement between 1.84 and J/ψ at KEDR – VI

Source	Syst. error, %
Luminosity	1.3
Rad. corr.	2.3-0.4
uds simulation	1.1
l^+l^-	0.4
e^+e^-X	0.1
Trigger	0.2
Nucl. inter.	0.4
Cuts	0.7
Machine bg	0.4
Energy	0.1
Total	3.2-2.0

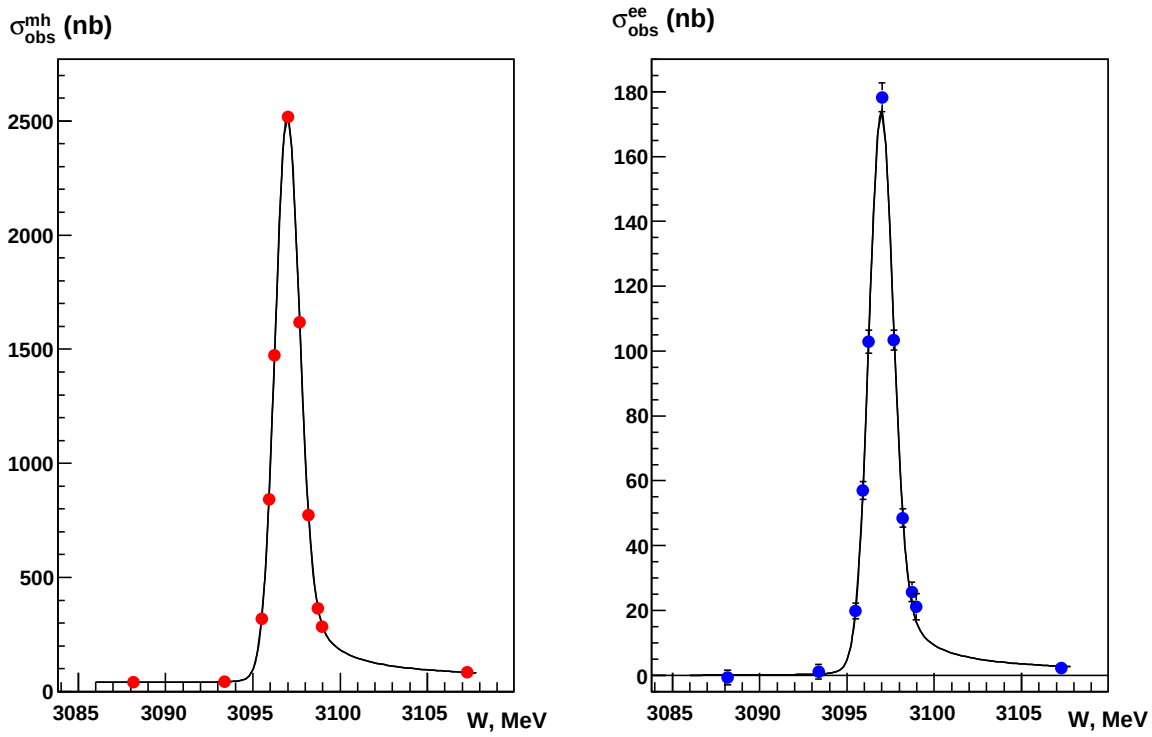
R Measurement between 1.84 and J/ψ at KEDR – VII



$\overline{R} = 2.198 \pm 0.025$ agrees with $R_{\rm pQCD} = 2.18 \pm 0.02$

based on $\alpha_s(m_\tau) = 0.333 \pm 0.013$ derived from hadronic τ decays

Measurement of $\Gamma_{ee}\mathcal{B}_h(J/\psi)$ and $\Gamma_{ee}(J/\psi)$ at KEDR – I



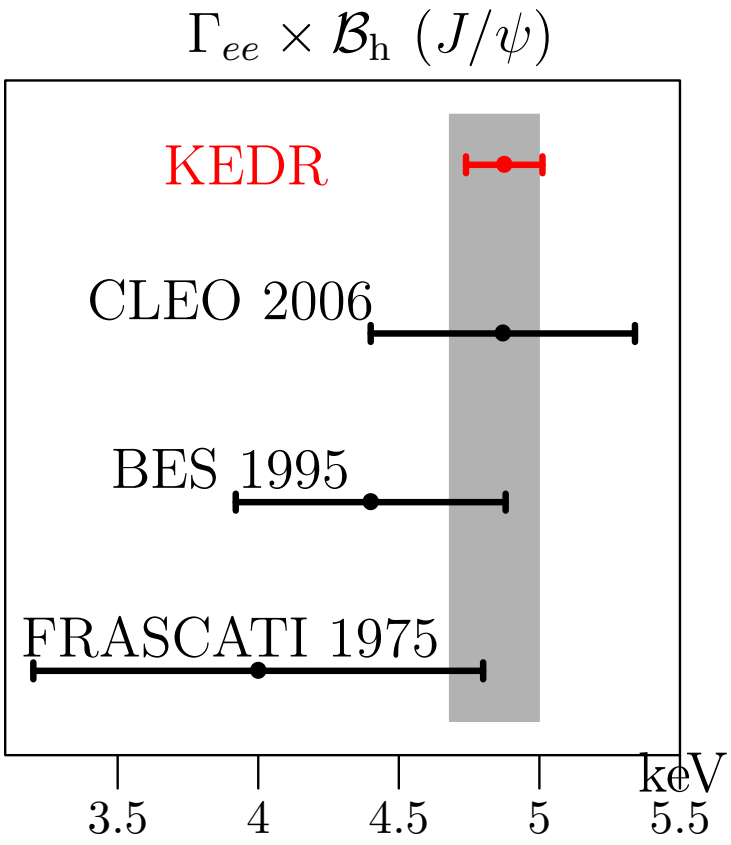
A combined fit of multihadronic and Bhabha events using 0.23 pb^{-1} $\Rightarrow \Gamma_{ee}\mathcal{B}_h(J/\psi)$

Measurement of $\Gamma_{ee}\mathcal{B}_h(J/\psi)$ and $\Gamma_{ee}(J/\psi)$ at KEDR – II

Source	Syst. error, %
Luminosity	1.5
Simulation	1.2
Detector and cuts	1.8
Energy determination	0.5
Other	0.5
Total	2.7

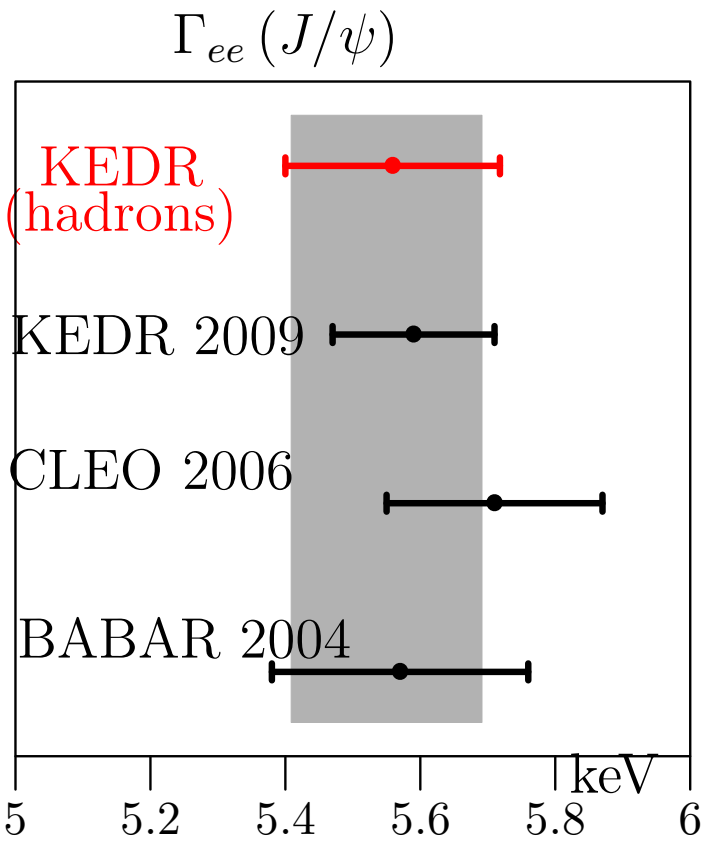
Systematic uncertainties

Measurement of $\Gamma_{ee}\mathcal{B}_h(J/\psi)$ and $\Gamma_{ee}(J/\psi)$ at KEDR – III



$$\Gamma_{ee}\mathcal{B}_h(J/\psi) = (4.875 \pm 0.040 \pm 0.132)\ \text{keV}$$

Measurement of $\Gamma_{ee}\mathcal{B}_h(J/\psi)$ and $\Gamma_{ee}(J/\psi)$ at KEDR – IV



Using $\mathcal{B}_h(J/\psi) = (87.7 \pm 0.5)\%$ from PDG

$\Gamma_{ee}(J/\psi) = (5.56 \pm 0.05 \pm 0.15)$ keV

Measurement of $\Gamma_{ee}\mathcal{B}_h(J/\psi)$ and $\Gamma_{ee}(J/\psi)$ at KEDR – V

- After this work was completed BES3 placed in arXiv 1604.01924
- They use 2.93 fb^{-1} at $\psi(3770)$ and apply ISR to study $e^+e^- \to J/\psi\gamma \to \mu^+\mu^-\gamma$ and measure $\mathcal{B}_{\mu\mu}\Gamma_{ee}(J/\psi) = (333.4 \pm 2.5 \pm 4.4)$ eV
- From the earlier BES3 measurement $\mathcal{B}_{\mu\mu}(J/\psi) = (5.973 \pm 0.007 \pm 0.037)\%$ $\Gamma_{ee}(J/\psi) = (5.58 \pm 0.05 \pm 0.08)$ keV – BES3
- $\Gamma_{ee}(J/\psi) = (5.56 \pm 0.05 \pm 0.15)$ keV – KEDR

Summary

- High-precision measurement of J/ψ and $\psi(2S)$ masses was performed setting an absolute calibration for measuring charm masses
- R measured at 7 points between 3.05 and 3.72 GeV to 3.3%
- R measured at 13 points between 1.84 and 3.05 GeV to 3.9%
- New precise measurement of $\Gamma_{ee}\mathcal{B}_h(J/\psi)$ and $\Gamma_{ee}(J/\psi)$
- Data taking: at J/ψ ($\mathcal{B}(\eta_c\gamma)$), around $\psi(3770)$ to improve D masses, then $\sqrt{s}$ increase to measure R and $\gamma\gamma \to$ hadrons ($4 < \sqrt{s} < 5$ GeV)

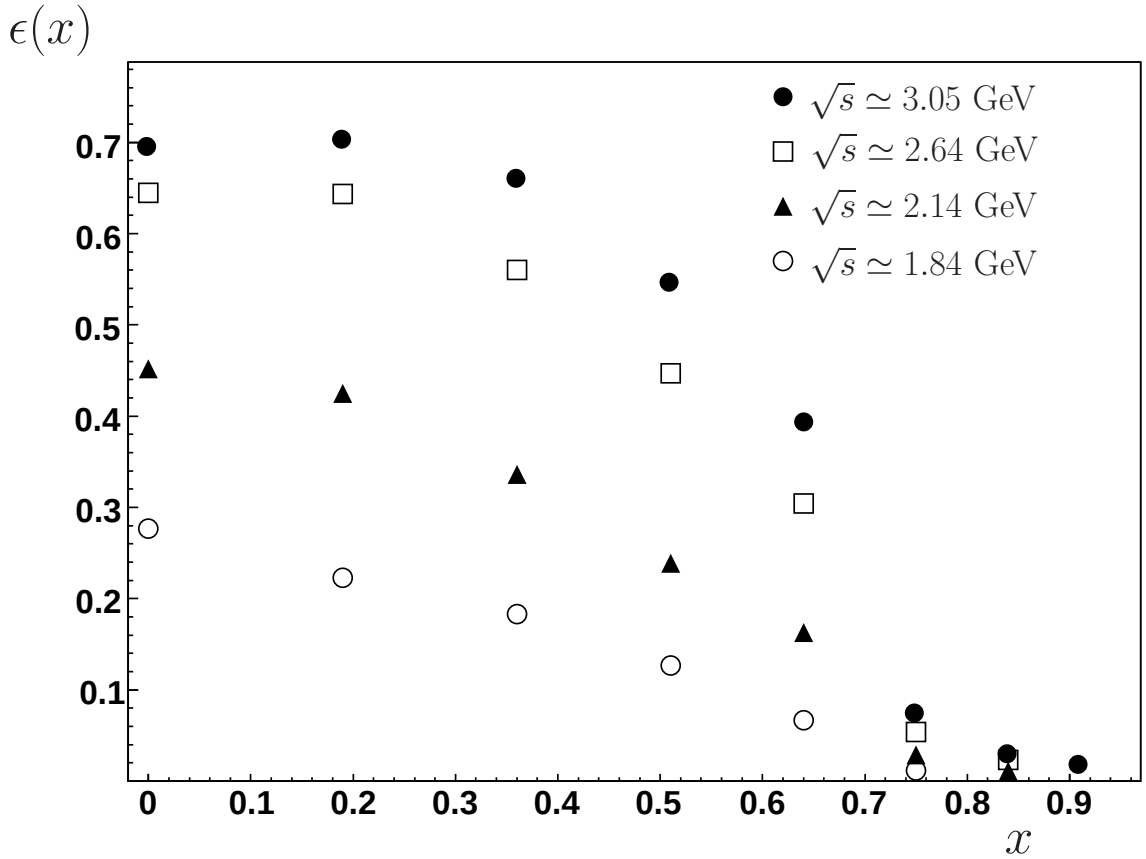
Backup Slides

R Measurement between 1.84 and J/ψ at KEDR – Selection

Variable	Range
$N_{\rm tr}^{\rm IP}$	≥ 1
$E_{\rm obs}$	> 1.6 GeV
$E_\gamma^{\rm max}/E_{\rm beam}$	< 0.7
$E_{\rm obs} - E_\gamma^{\rm max}$	> 1.3 GeV
$E_{\rm cal}^{\rm tot}$	> 0.55 GeV
H_2/H_0	< 0.9
$\lvert P_z^{\rm miss}/E_{\rm obs}\rvert$	< 0.6
$E_{\rm LKr}/E_{\rm cal}^{\rm tot}$	> 0.15
$\lvert Z_{\rm vert}\rvert$	< 15.0 cm

$$N_{\rm part} \geq 3 \text{ or } \tilde{N}_{\rm tr}^{\rm IP} \geq 2$$

Measurement of R_{uds} and R between 1.84 and J/ψ at KEDR – I



Measurement of R_{uds} and R between 1.84 and J/ψ at KEDR – V

$\sqrt{s}$, MeV	ϵ, %	$\sqrt{s}$, MeV	ϵ, %
1841.0	27.7	2444.1	59.5
1937.0	33.8	2542.6	62.4
2037.3	41.0	2644.8	64.5
2135.7	45.2	2744.6	67.0
2239.2	50.9	2849.7	68.6
2339.5	56.2	3048.1	69.5

Detection efficiency as a function of energy