Recent Results on R Measurement from the KEDR Detector

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Outline

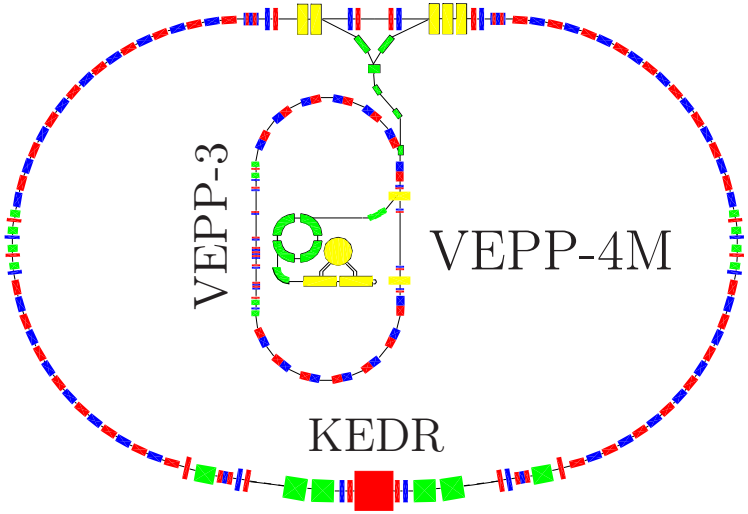
1. General
2. R measurement from 3.12 to 3.72 GeV
3. R measurement from 1.84 to 3.05 GeV
4. Conclusions

General

High precision determination of $R = \sigma(e^+e^- \to \text{ hadrons})/\sigma(e^+e^- \to \mu^+\mu^-)$ at low energies is important to determine various fundamental quantities:

- $(g_\mu - 2)/2$
- $\alpha(M_Z^2)$
- α_s
- Quark and gluon condensates from QCD sum rules
- Hadronic corrections to muonium properties

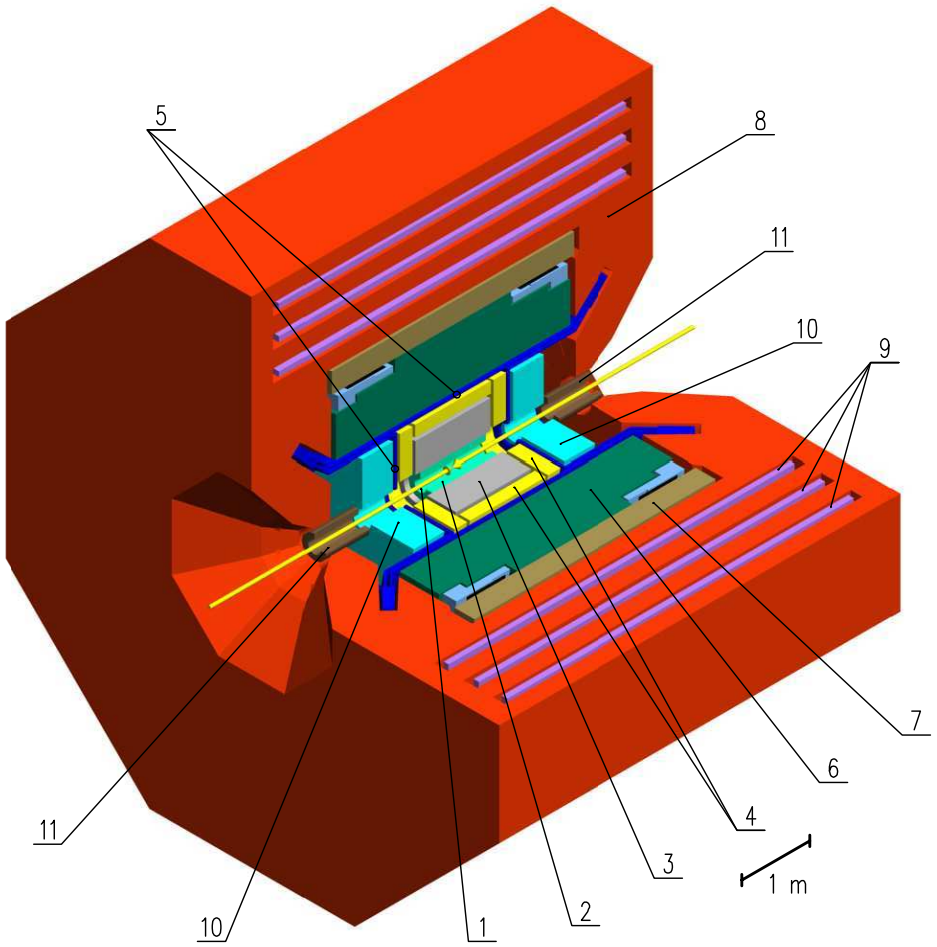
VEPP–4M collider



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}

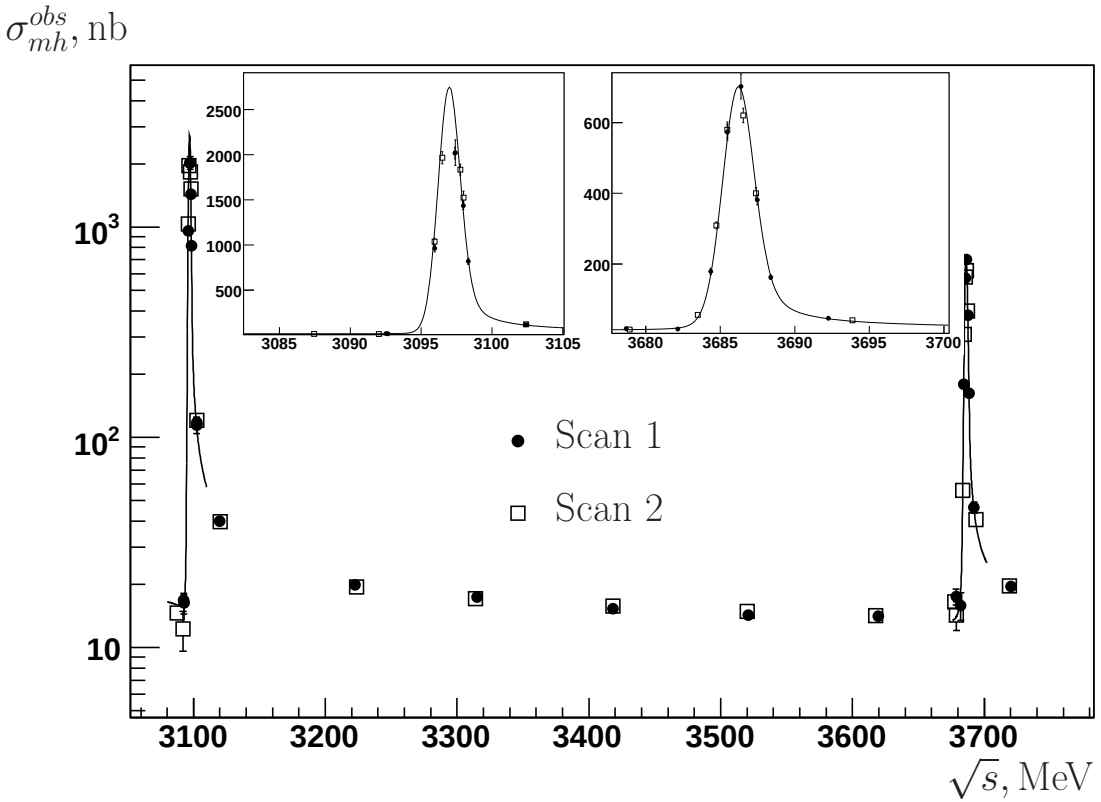
- Resonant depolarization technique:
  Instantaneous measurement accuracy $\simeq 1 \times 10^{-6}$
  Energy interpolation accuracy $(5 \div 15) \times 10^{-6}$ $(10 \div 30$ keV$)$
- Infrared light Compton backscattering:
  Statistical accuracy $\simeq 5 \times 10^{-5}$ / 30 minutes
  Systematic uncertainty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

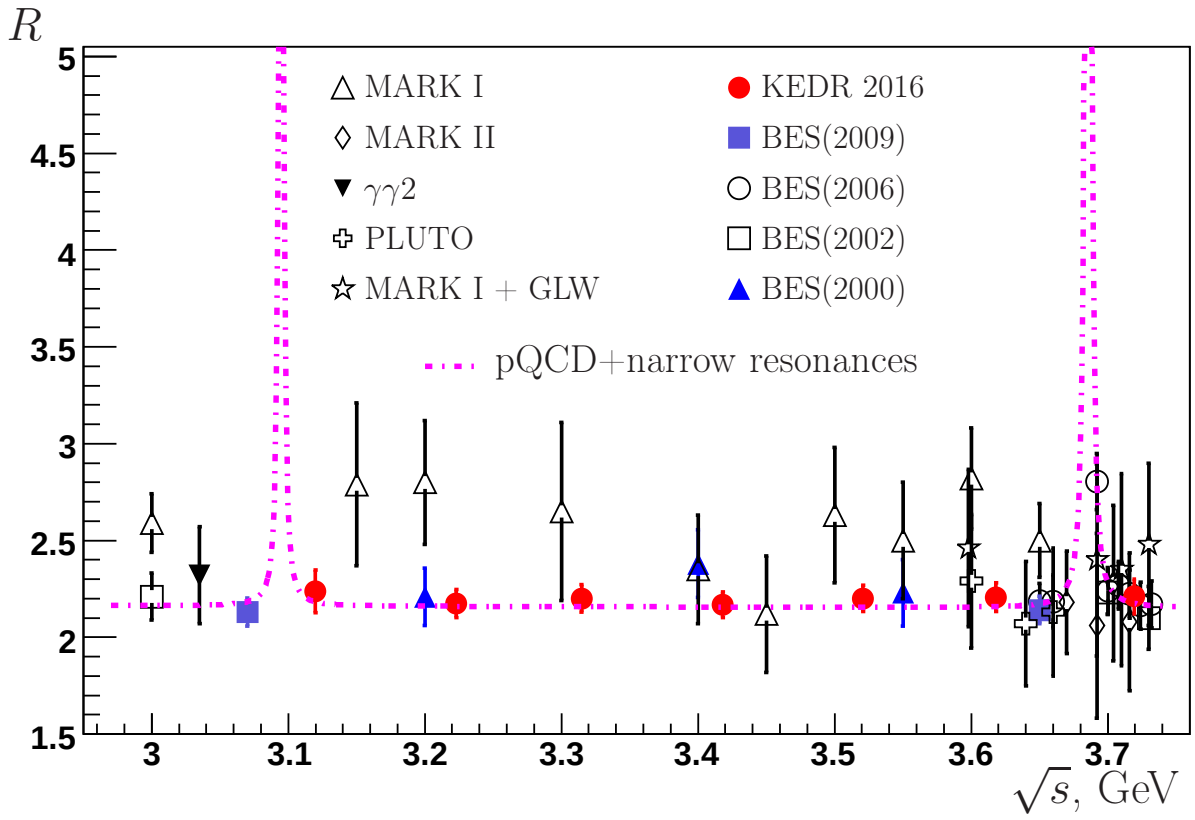
R Measurement between J/ψ and $\psi(2S)$ at KEDR – I



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 3.05 GeV at KEDR – I

- The c.m. energy range between 1.84 and 3.05 GeV studied
- An integrated luminosity of 0.66 pb^{-1} collected at 13 equidistant points with a step of $\sim$ 0.1 GeV: 1.841, 1.937, . . ., 3.048 GeV
- $\sim 10^3$ events per point $\Rightarrow \sim 15 \cdot 10^3$ 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 5 points for a cross-check
- MHG2000 used below 1.8 GeV, needed for radiative corrections, H. Czyż et al., arXiv:1312.0454, 1406.4639.

More on Monte Carlo Generators

For background estimation in VEPP-2000 experiments a data-driven Monte Carlo generator MHG2000 has been developed.

- MHG2000 uses a database of cross sections of $e^+e^- \to$ hadrons
- Currently about 35 final states are included, sometimes isospin relations are used for missing channels
- Each cross section is approximated by a curve, which is motivated by physics, e.g., a sum of relevant resonances with interference accounted for
- At each $\sqrt{s}$ $\sigma_{\rm tot} = \sum \sigma_i$ is calculated and the specific process is randomly chosen
- This very process is used to generate a random event (4-momenta), when available, underlying dynamics effects are taken into account
- Radiative effects (ISR) are also taken into account

Comparison of the KEDR generator with MHG2000 is underway at $1.8 < \sqrt{s} < 2.0$ GeV

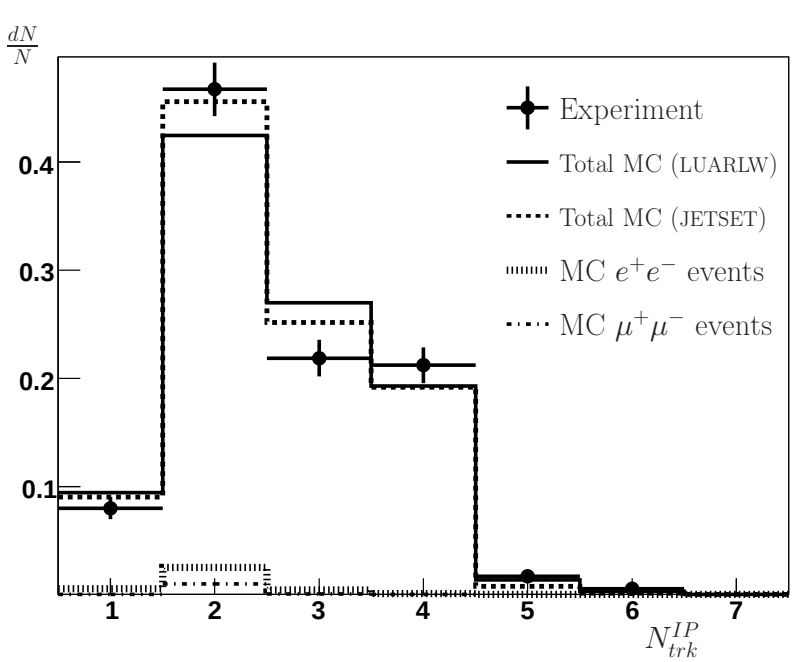
R Measurement between 1.84 and 3.05 GeV at KEDR – II

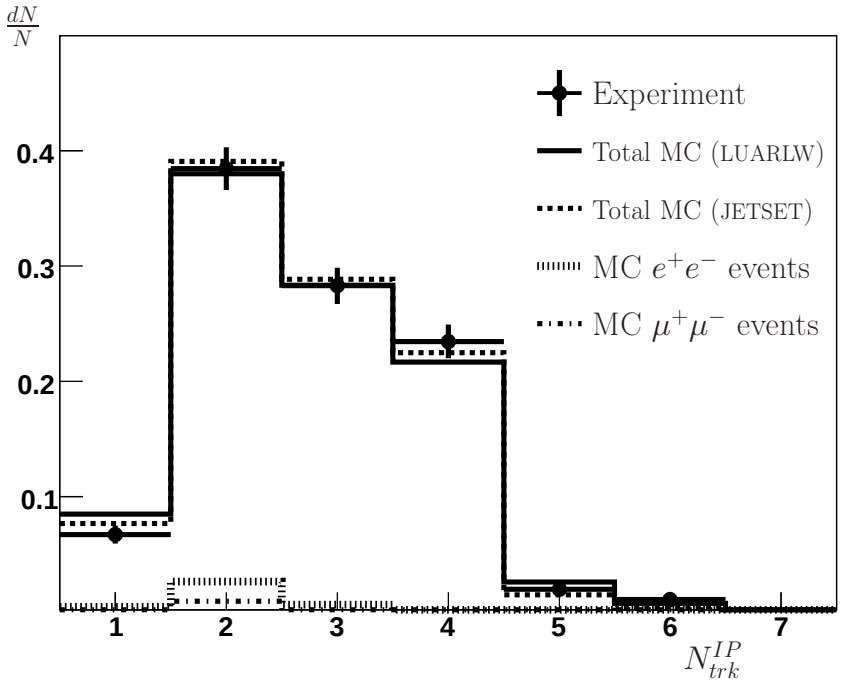
$$\sigma_{\rm obs}(s) = \frac{N_{\rm mh} - N_{\rm res.bg}}{\int \mathcal{L} dt}$$

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

- 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 (MC simulation): $e^+e^- \to e^+e^-$ - (3.3-6.1)%, $e^+e^- \to \mu^+\mu^-$ - (0.8-1.1)%, $e^+e^- \to e^+e^- X$ - (0.1-0.3)%
- Radiative corrections vary from 5.7% to 9.7% with $\sqrt{s}$ increase

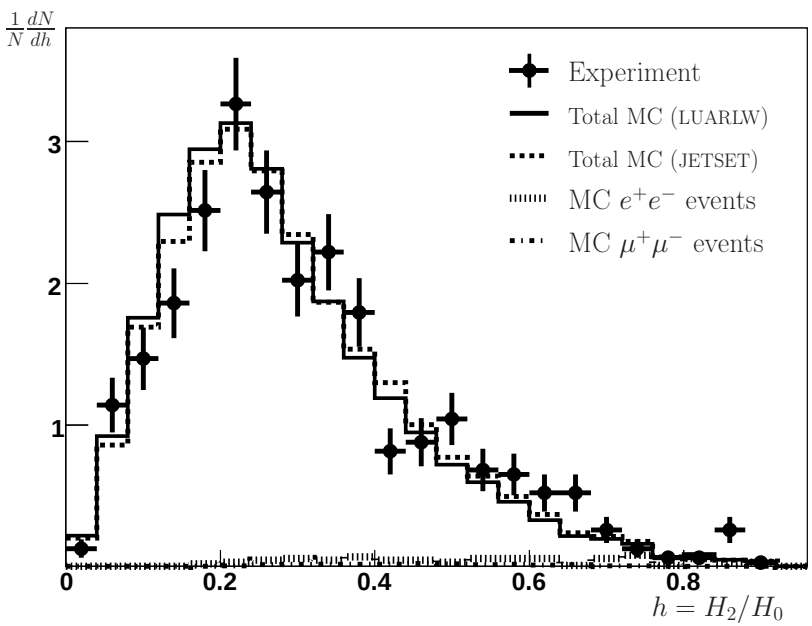
R Measurement between 1.84 and 3.05 GeV at KEDR – III

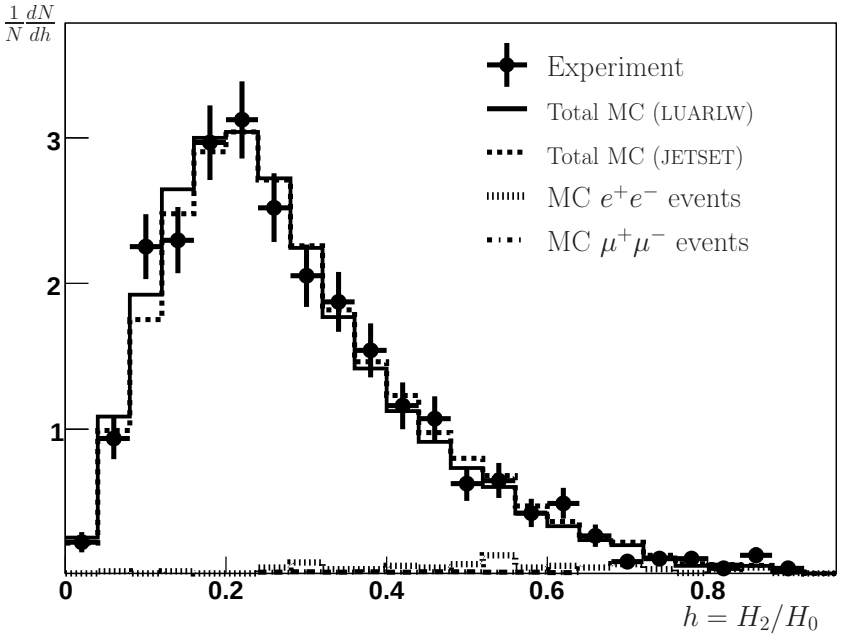




The number of tracks from the common vertex in the IP,
Fair agreement of simulation with data ($\sqrt{s}$ =1.94 and 2.14 GeV)

R Measurement between 1.84 and 3.05 GeV at KEDR – IV

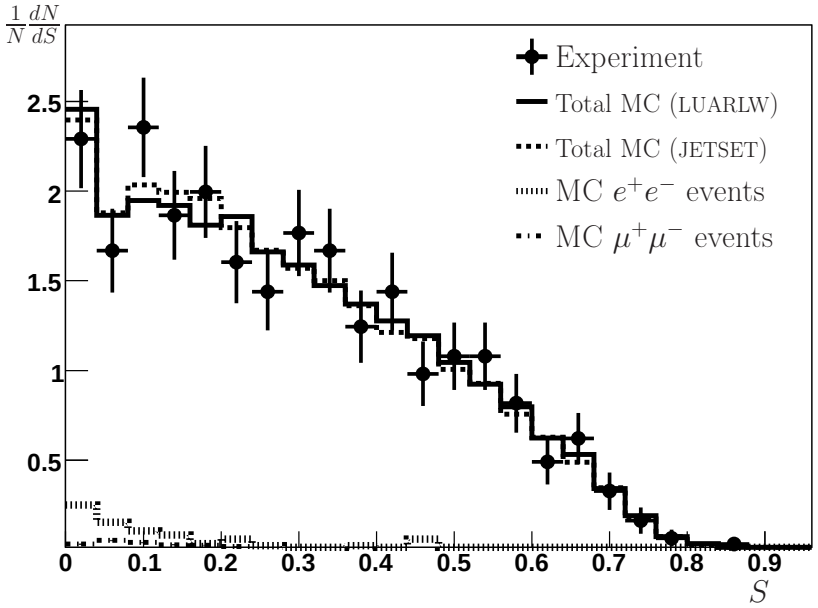


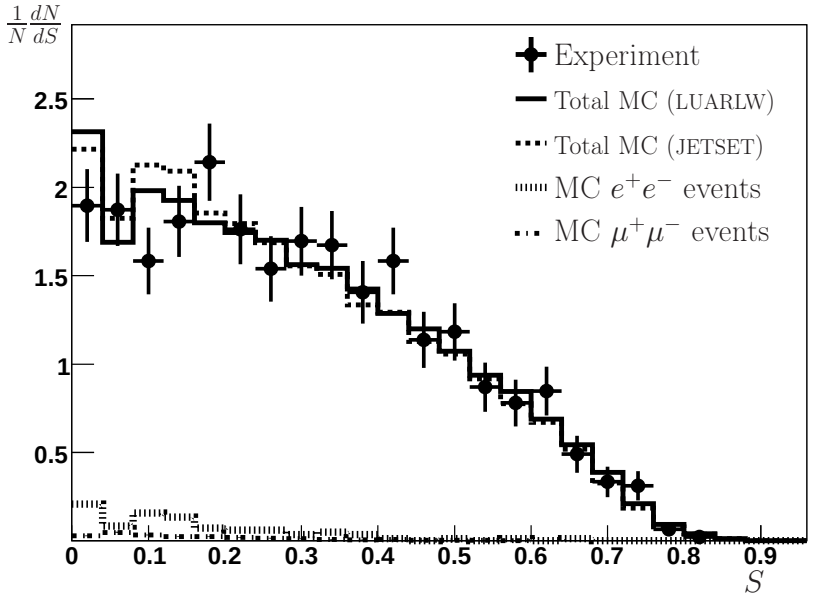


The ratio of Fox-Wolfram moments H_2/H_0,

Fair agreement of simulation with data ($\sqrt{s}$ =1.94 and 2.14 GeV)

R Measurement between 1.84 and 3.05 GeV at KEDR – V

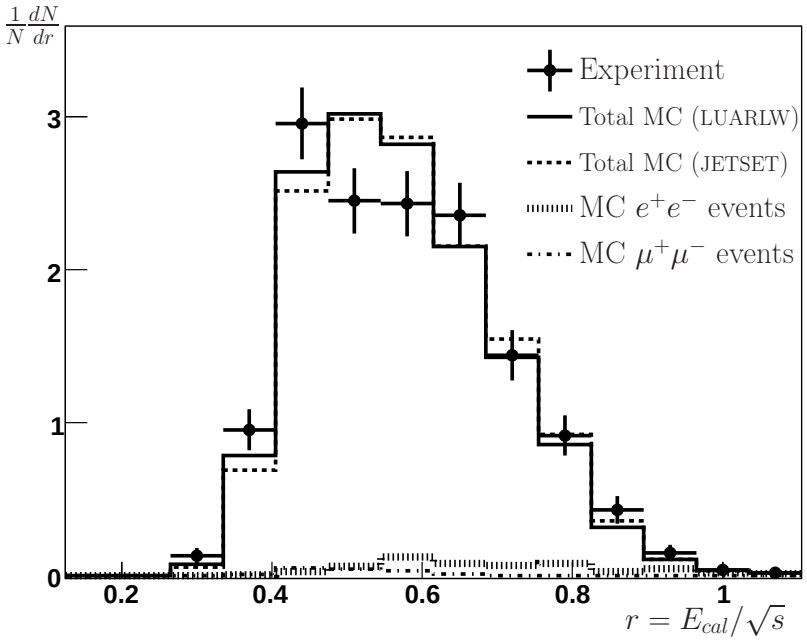


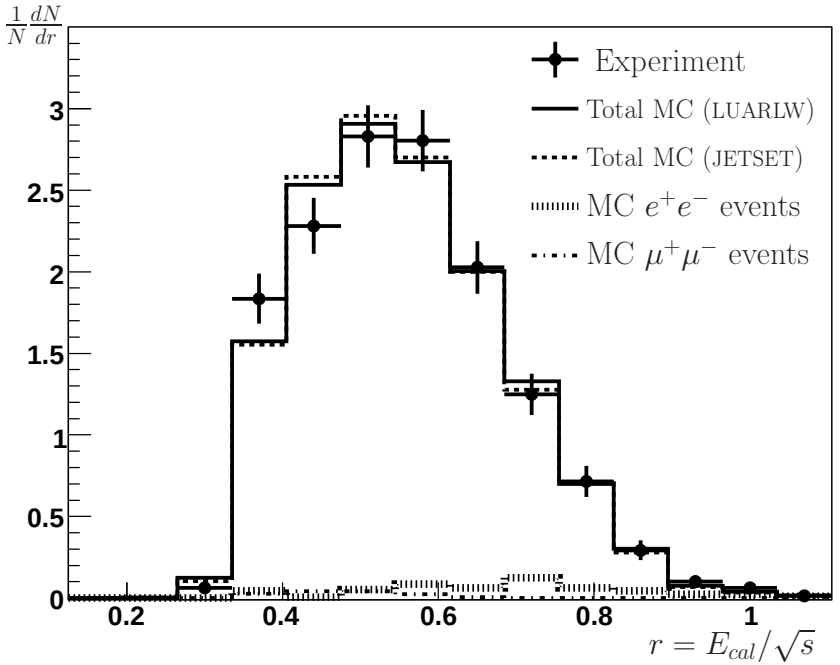


Sphericity of charged tracks,

Fair agreement of simulation with data ($\sqrt{s}$ =1.94 and 2.14 GeV)

R Measurement between 1.84 and 3.05 GeV at KEDR – VI





Energy deposited in the calorimeter,

Fair agreement of simulation with data ($\sqrt{s}$ =1.94 and 2.14 GeV)

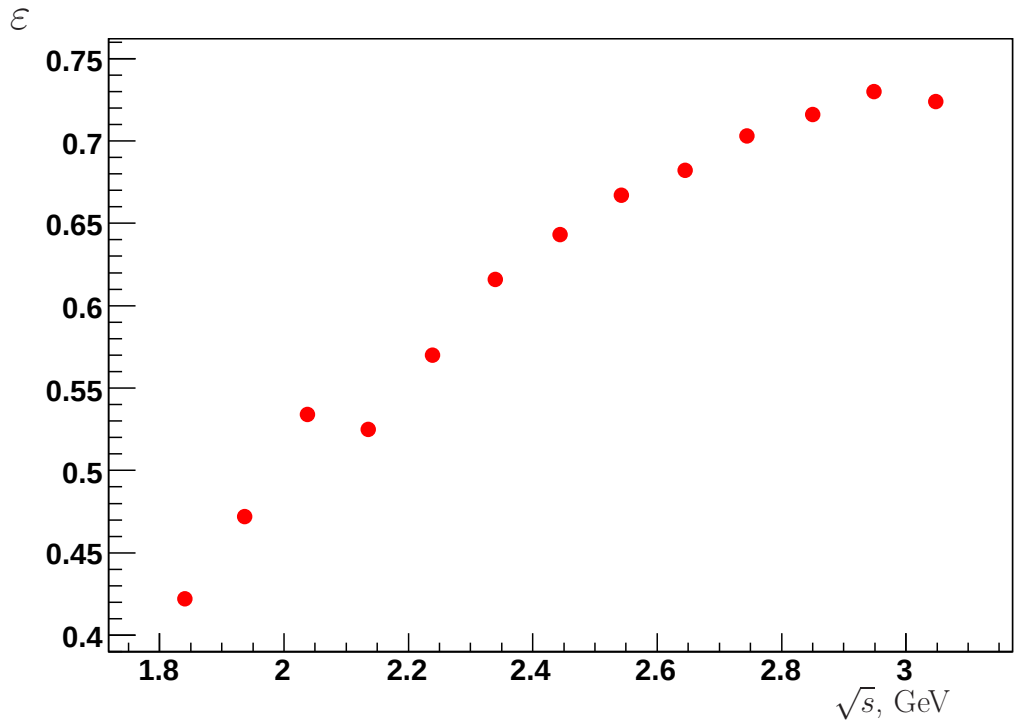
R Measurement between 1.84 and 3.05 GeV at KEDR – VII

Detection efficiency, comparison of two models

$\sqrt{s}$, MeV	$\varepsilon_{\text{LUARLW}}$,%	$\varepsilon_{\text{JETSET}}$,%	$\delta\varepsilon/\varepsilon$,%
1937	47.2 ± 0.1	46.0 ± 0.1	2.5 ± 0.2
2136	52.5 ± 0.1	51.3 ± 0.1	2.3 ± 0.2
2645	68.2 ± 0.1	68.0 ± 0.1	0.3 ± 0.2
2745	70.3 ± 0.1	70.6 ± 0.1	-0.4 ± 0.2
3048	72.4 ± 0.1	73.2 ± 0.1	-1.1 ± 0.2

R Measurement between 1.84 and 3.05 GeV at KEDR – VIII

Detection efficiency as a function of energy

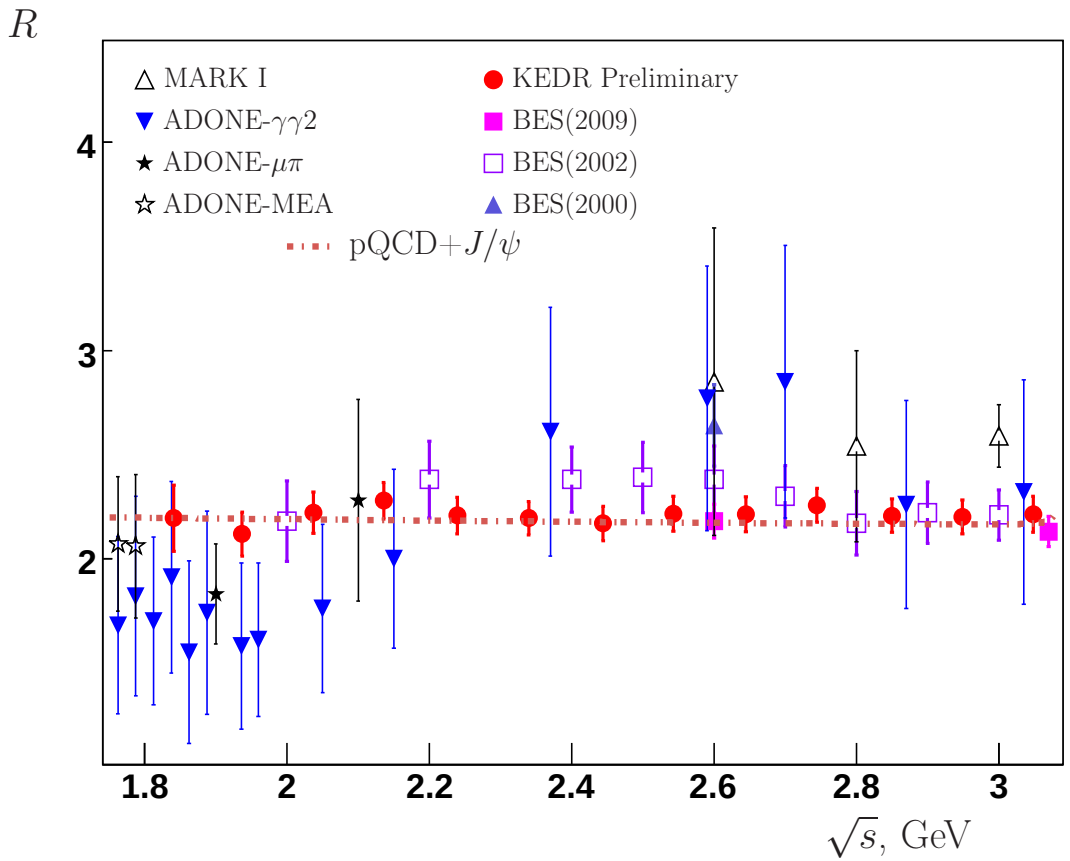


Selection criteria changed at point 4

R Measurement between 1.84 and 3.05 GeV at KEDR – IX

Source	Syst. error, %
Luminosity	1.2
Rad. corr.	2.0-0.5
uds simulation	2.6-1.3
l^+l^-	0.6-0.4
e^+e^-X	0.2
Trigger	0.3
Nucl. inter.	0.4
Cuts	0.7
Machine bg	0.4-0.9
Energy	0.1
Total	3.7-2.1

R Measurement between 1.84 and 3.05 GeV at KEDR – X



$\overline{R} = 2.209 \pm 0.020 \pm 0.046$ 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

Summary

- 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%
- Results between 1.8 and 2.0 GeV can be matched to those from CMD-3/SND (VEPP-2000) that sum exclusive cross sections
- We are discussing whether inclusive measurement is feasible between 1.5 and 2.0 GeV at CMD-3
- New precise measurement of $\Gamma_{ee}\mathcal{B}_h(J/\psi)$ and $\Gamma_{ee}\mathcal{B}_{\mu\mu}(J/\psi)$
- 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 3.05 GeV 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

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