Measurement of $\Gamma_{ee}\cdot B_h$ (J/ψ) with KEDR detector at the VEPP-4M collider

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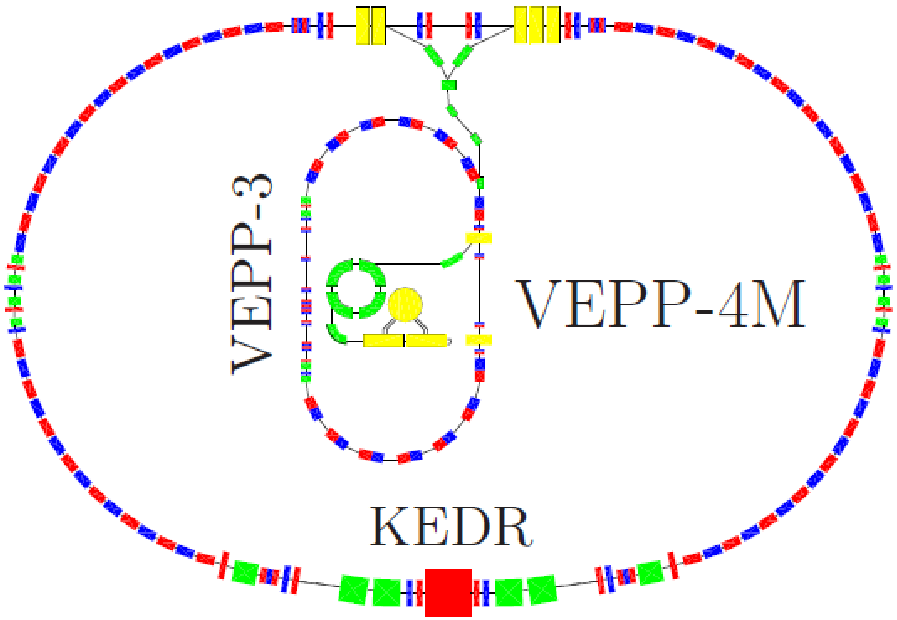
Outline:

1. VEPP-4M collider and KEDR detector
2. Motivation
3. Selection criteria
4. Fit procedure
5. Systematic uncertainties
6. Results and summary

23.08.2016

VEPP-4M collider



Beam energy 1÷6 GeV
Number of bunches 2 × 2

For E=1.5 GeV:
Beam current 1.5 mA
Luminosity 2×10^{30} $cm^{-2}s^{-1}$

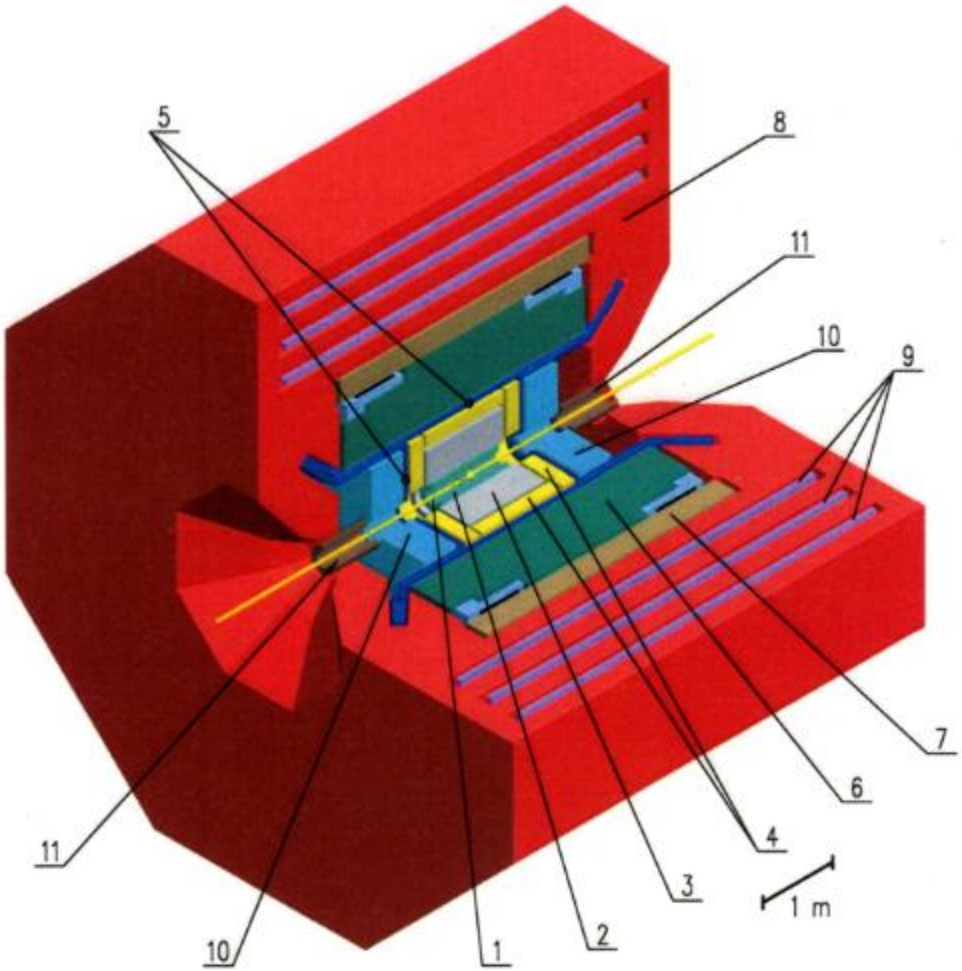
- Resonant depolarization :

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)

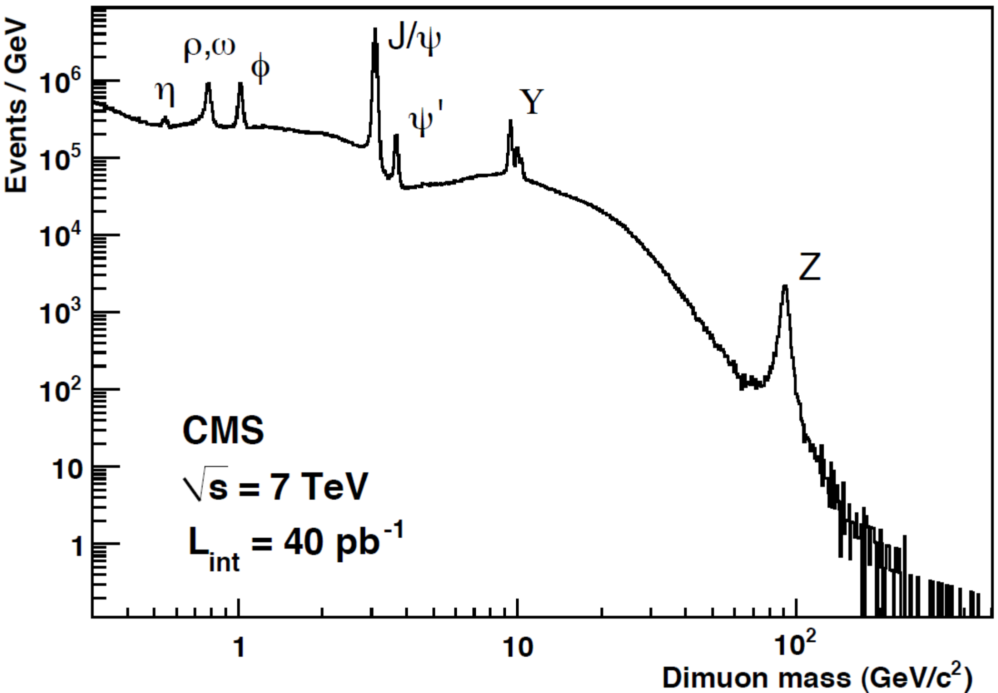
KEDR detector



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

Motivation

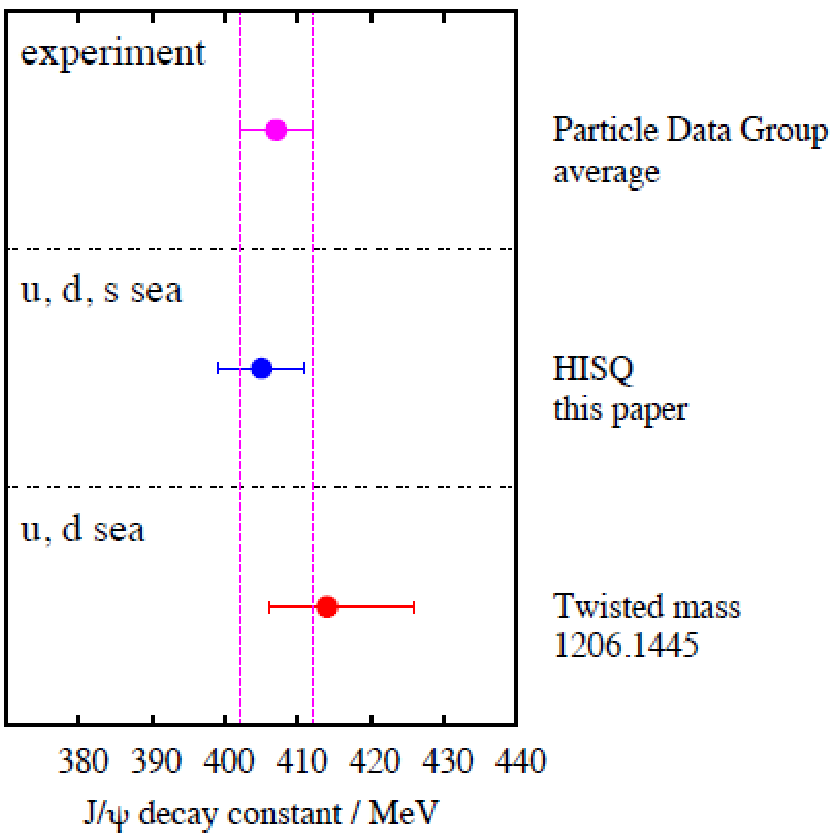
- Full and lepton *J/ψ*-meson widths are defined by fundamental properties of strong and electromagnetic c-quark interactions
- High precision in its experimental measurement is of importance for charmonium potential models, providing good opportunity to increase their prediction ability for more complicated quark states.
- In modern hadrons experiments, such as ALICE, ATLAS, CMS, LHCb:
  - tests of QCD models predictions,
  - methodological part of measuring efficiencies and detector calibration.

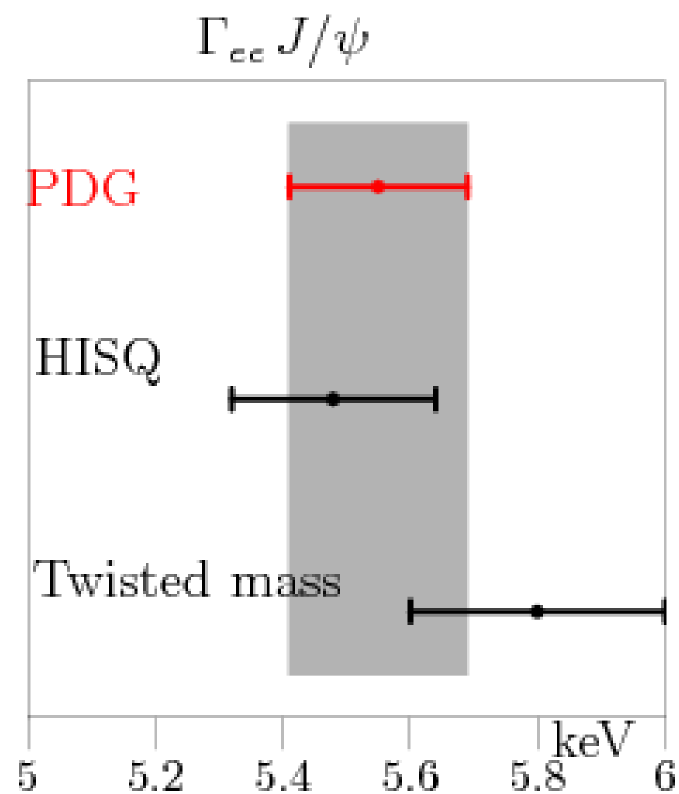


Precision test of J/ψ from full lattice QCD

f_v – vector meson decay constant

$$\langle 0|\overline{\psi}\gamma^i\psi|v\rangle = f_v m_v \epsilon^i \qquad \Gamma(v_h \to e^+e^-) = \frac{4\pi}{3}\alpha_{QED}^2 e_h^2 \frac{f_v^2}{m_v}$$





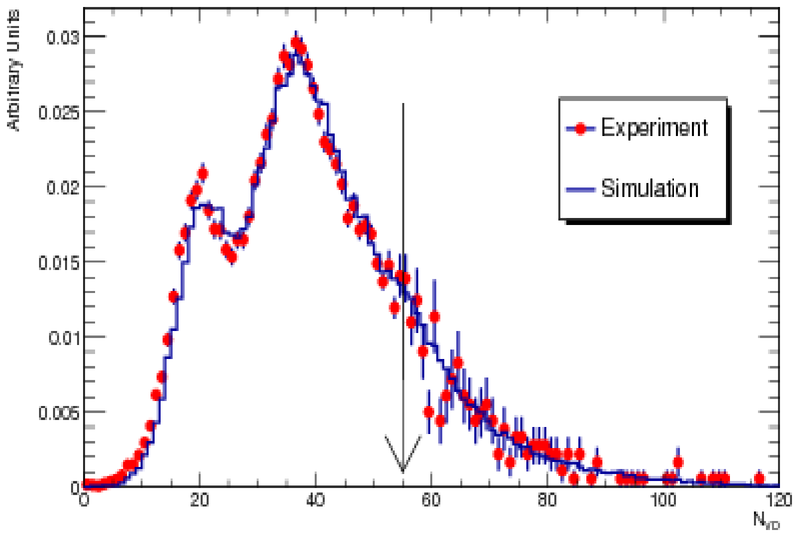
Selection criteria

- Primary trigger:
  - two or more non-collinear scintillation counters
  - veto from closest to the beam line CsI calorimeter crystals
- Secondary trigger:
  - at least two particles in the detector using information from drift chamber, calorimeter and scintillation

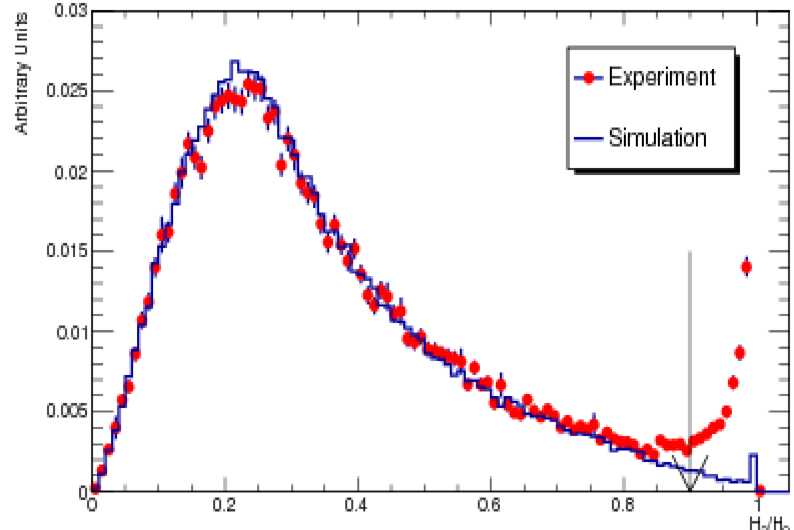
- **Hadrons selections:**
  - total energy deposition in the calorimeter $700<E_{emc}<2500$ MeV;
  - ≥ 1 track coming from beam spot ($\rho < 1.5$ cm, $|z_0| < 13$ cm, $P_t > 100$MeV);
  - ≥ 1 photon (calorimeter cluster, not associated with any track) with minimum energy $E_\gamma / E_{run} > 0.05$;
  - Fox-Wolfram moments $H_2/H_0 < 0.9$;
  - number of vertex detector hits < 55

Data and MC comparisons

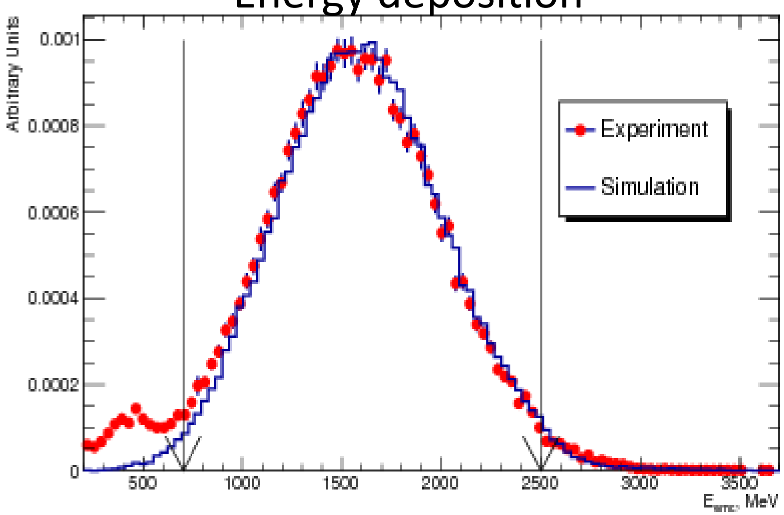
Number of VD hits



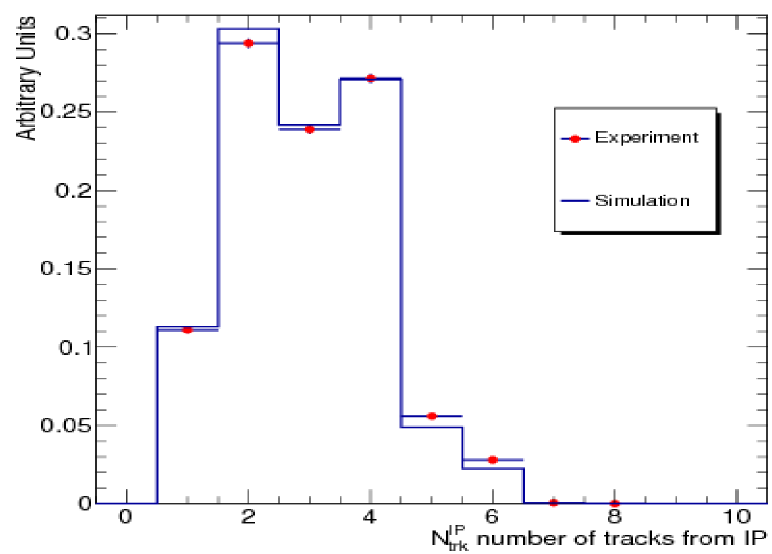
Fox-Wolfram moments



Energy deposition

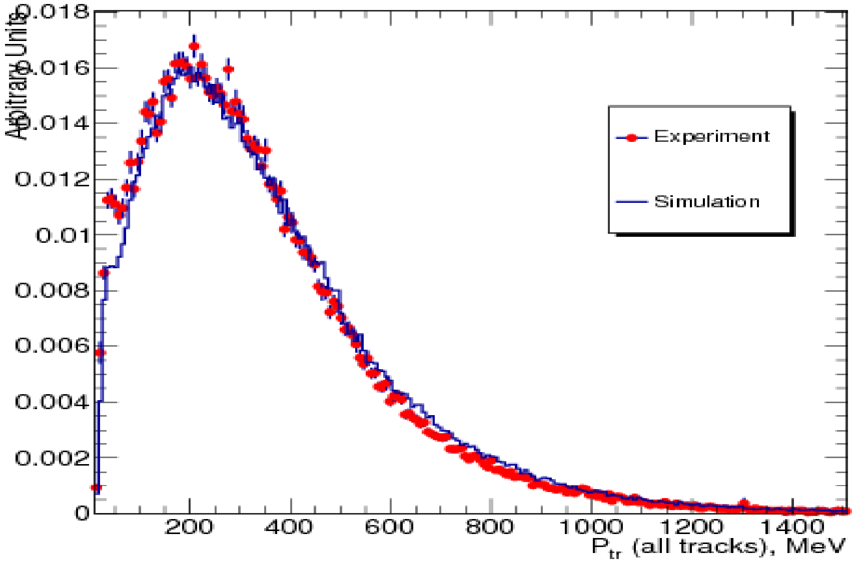


Number of tracks from IP

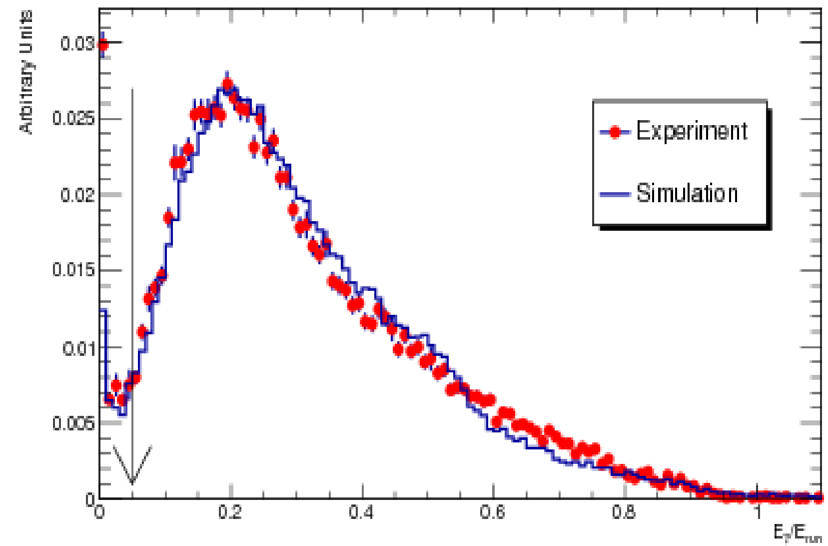


Data and MC comparisons

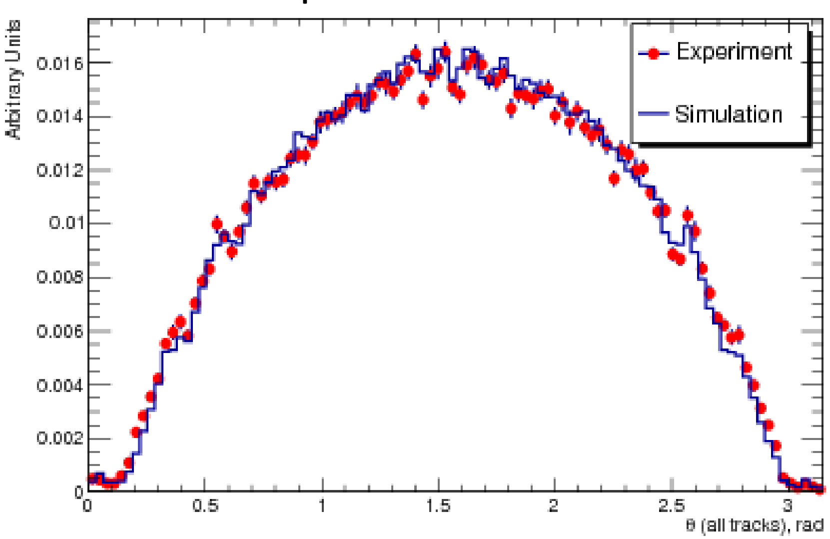
P_t spectrum for all tracks



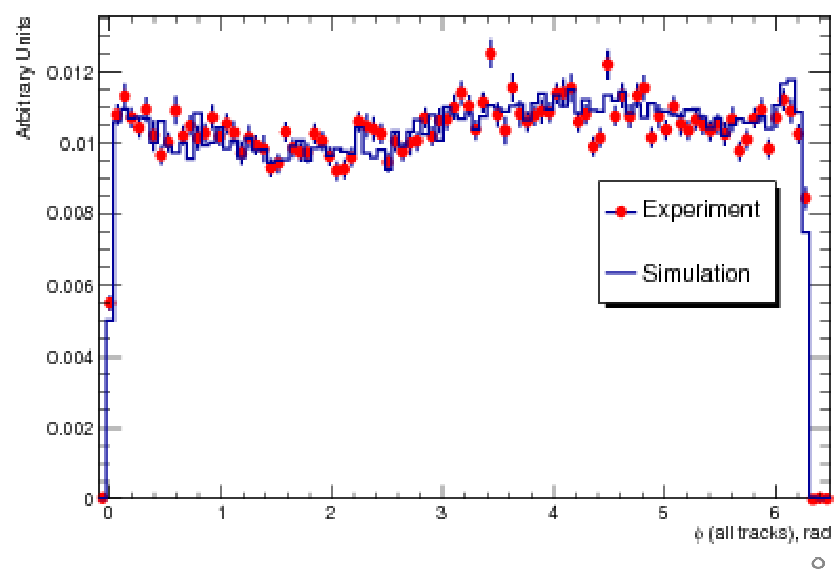
Maximum photon energy



θ spectrum for all tracks



φ spectrum for all tracks



Luminosity determination

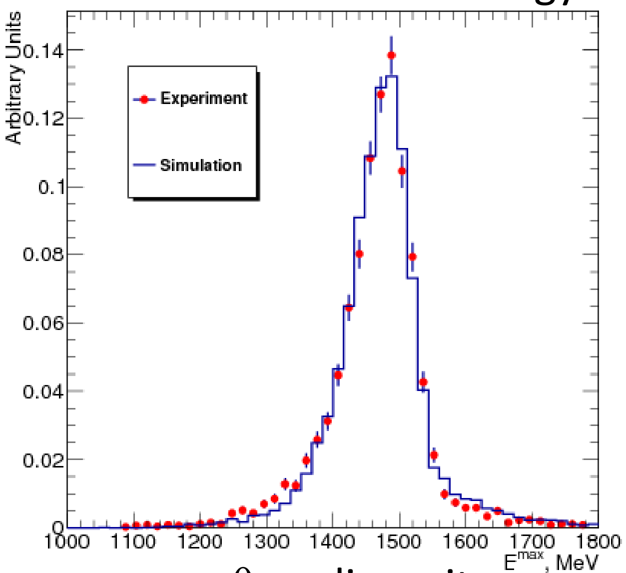
Process $e^+e^- \longrightarrow e^+e^-$

Leptons event selection:

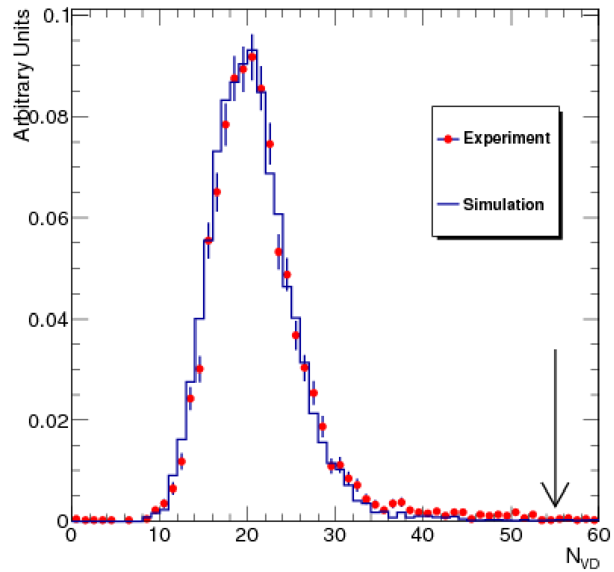
- two clusters within theta range $41 < \theta < 139^\circ$ and energy $E > 450$ MeV each;
- total energy of those two clusters > 2 GeV;
- energy deposition not from those two clusters < 20% of beams energy;
- θ and ϕ acolinearity are less than 7° and 10° respectively;
- event sphericity calculated with charged particles $S_{ch} < 0.05$;
- ≤ 3 additional clusters with energy > 40 MeV;
- ≤ 2 additional clusters with energy > 80 MeV

Data and MC comparisons for e^+e^- events

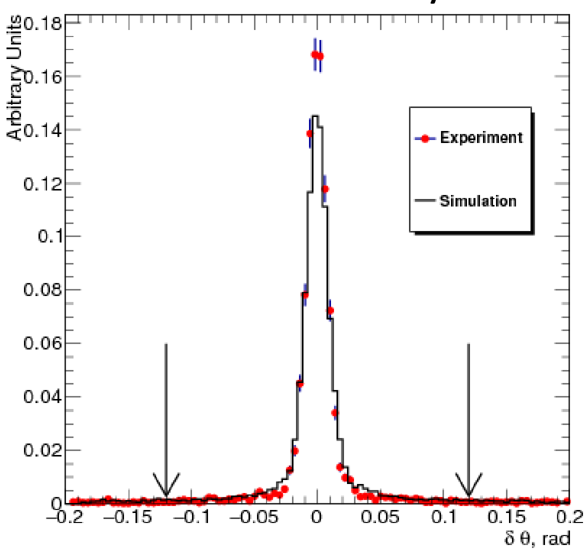
Maximum cluster energy



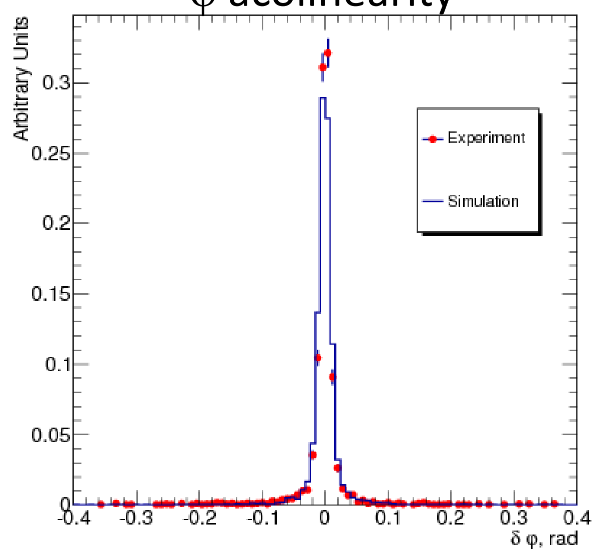
Number of VD hits



θ acolinearity



φ acolinearity



Fit procedure

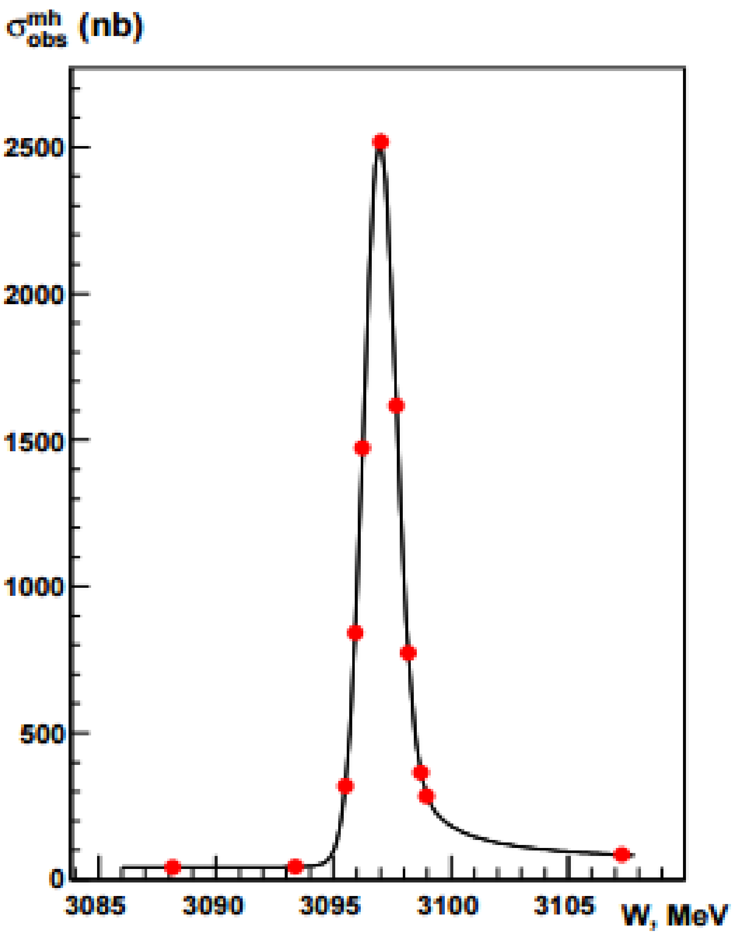
- $\Gamma_{ee} \cdot B_h$ (J/ψ) is extracted from combined fit of hadrons and e^+e^- production in the energy range of J/ψ resonance
- The numbers of hadrons (N_i) and e^+e^- (n_i) events observed at each energy point were fitted simultaneously as a function of collision energy with minimizing χ^2 functions:

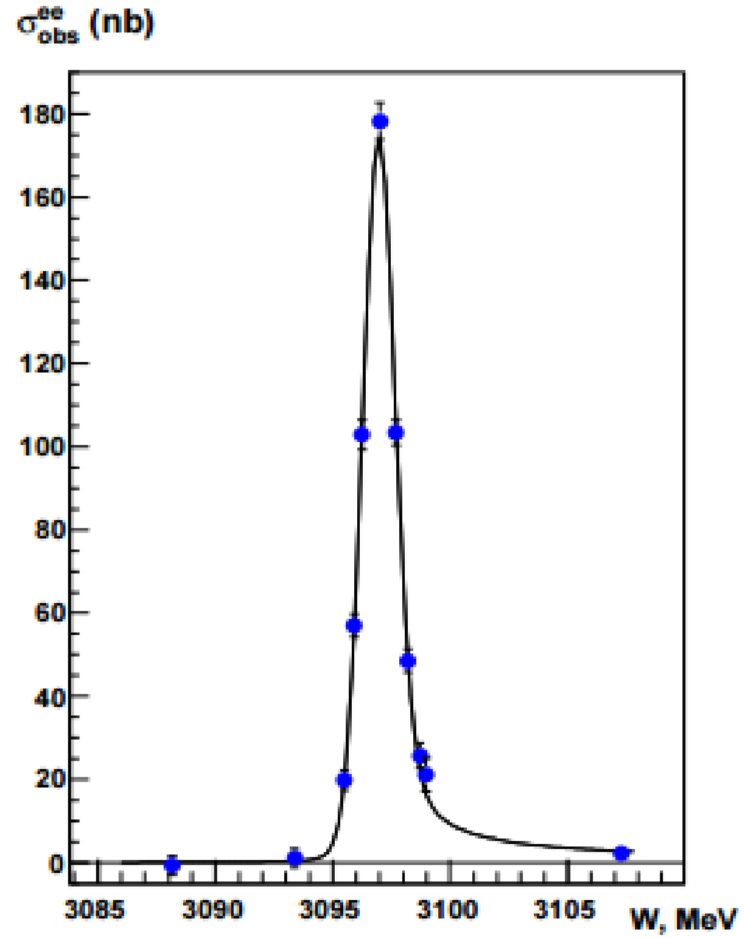
$$\chi^2 = \sum_i \frac{(N_i^{data} - N_i^{teor})^2}{N_i^{data}} + \frac{(n_i^{data} - n_i^{teor})^2}{n_i^{data}}$$

- Luminosity at each energy point is defined from likelihood function as well.
- Fit parameters: $\Gamma_{ee} \cdot B_h$ (J/ψ) value, mass shift, beam energy spread, and backgrounds contribution

Fit results

L = 0.23 pb $^{-1}$, σ_W = 0.697±0.014 MeV, ~250K J/ψ mesons



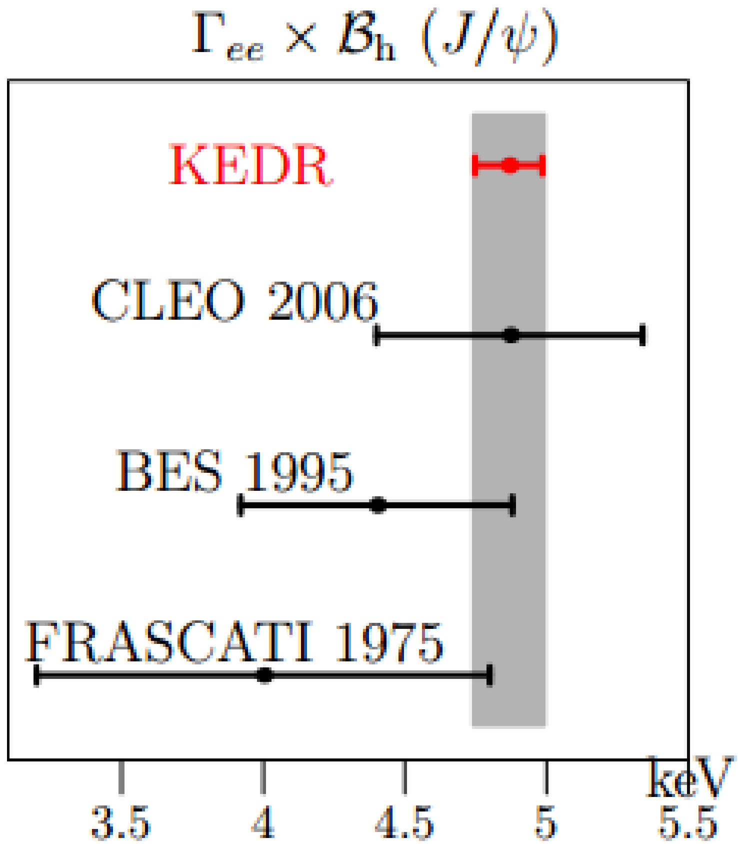


$$\chi^2 = \chi^2_{hadr} + \chi^2_{ee} = (2.7 + 7.7)/(22\text{-}4\text{-}1) = 10.4/17$$

Systematic uncertainties

Source:	Syst.error, %
Detector response -ABG thresholds, VD crosstalk, description of nuclear interaction, selection criteria	1.5
Luminosity determination - Uncertainties of absolute luminosity determination	1.3
Simulation of J/ψ decay -J/ψ→hadrons generator tuning, track reconstruction efficiency	1.0
Energy determination - energy determination at each point (<25 keV)	0.5
Other - Accuracy of resonance term calculation, interference parameter	0.3
Total	2.3

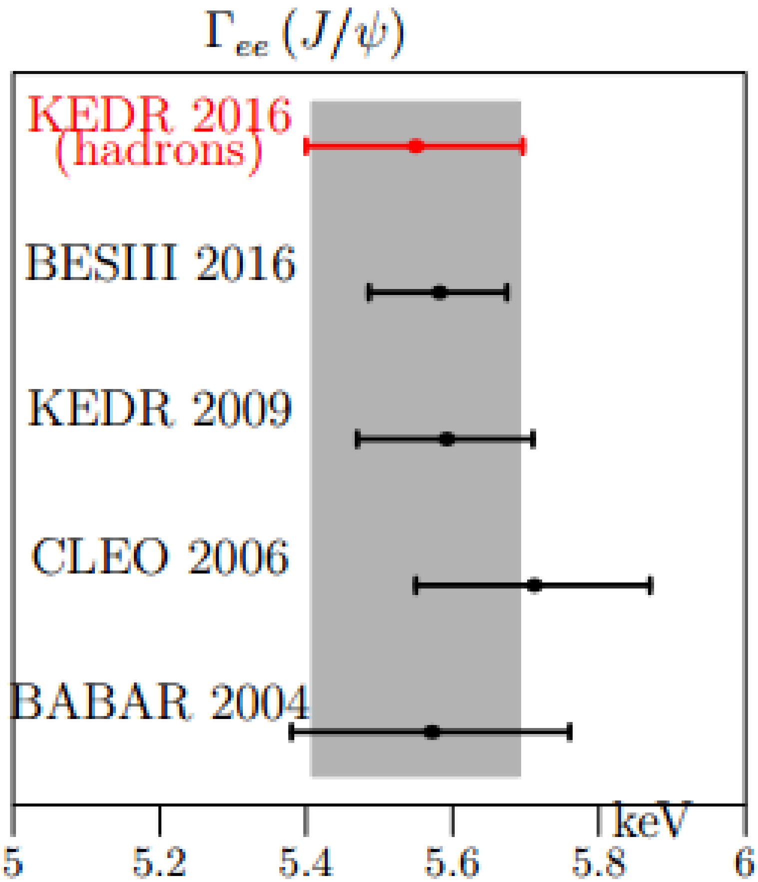
Results



$\Gamma_{ee} \cdot B_h\ (J/\psi) = 4.866 \pm 0.044(\mathrm{stat}) \pm 0.112(\mathrm{syst})\ \mathrm{keV}$

Grey band corresponds to PDG value

Results



Γ_{ee} (J/ψ) = 5.55 ± 0.05 ± 0.15 keV

Using $B_h(J/\psi)$ = (87.7 ± 0.5) from PDG

Summary

- New precise measurement of $\Gamma_{ee}B_h(J/\psi)$ and $\Gamma_{ee}(J/\psi)$ with the KEDR detector at the VEPP-4M e^+e^- collider was performed
- Experimental methods and techniques applied during this analysis can be then directly used within data treatment from super-charm-tau factory

Back ups

Fit procedure - 2

- Theoretical numbers of hadrons and e^+e^- events are defined as follows:

$$N_i^{teor}(hadr) = L_i \cdot \sigma_{hadr}^{obs}(W_i)$$

$$N_i^{teor}(ee) = L_i \cdot \left[\int \varepsilon(\theta) \frac{\mathrm{d}\sigma_{ee}^{obs}(W_i,\theta)}{\mathrm{d}\Omega} \mathrm{d}\Omega + \frac{N_{QED}^{MC}}{L_t} \right]$$

Resonance and interference terms

QED term calculated with MC

- Observed multihadron cross sections is parameterized with:

$$\sigma_{J/\psi}^{obs}(W) = \varepsilon_{J/\psi} \cdot \int \sigma_{J/\psi}^{RC}(W')\rho(W,W')\mathrm{d}W' + \sigma_{cont}$$

Narrow resonance form

Cross section for the process $e^+e^- \to J/\psi \to$ hadrons with $s=W^2$

$$\sigma^{RC}_{J/\psi}(s) = \int \frac{12\pi\Gamma_{ee}\Gamma_h}{(s(1-x)-M^2)^2+\Gamma^2 M^2}\mathcal{F}(x,s)dx$$

Γ, Γ_{ee}, Γ_h – full, lepton and hadron resonance width
M- resonance mass
$F(x,s)$ – taking into accoun radiation corrections

E.A. Kuraev, V.S. Fadin, Sov. J. Nucl. Phys. 41 (1985) 466

Interference and calculation with accuracy~1%

Y.I. Azimov, et al., JETP Lett. 21 (1975) 172

Increasing accuracy

K.Yu. Todyshev. arXiv.org:0902.4100

Systematic uncertainties - details

Simulation

Source	%
$J/\psi \to hadrons$ generator tuning	0.8
Selection of MC samples for tuning	0.3
MC statistics	0.3
Efficiency of track reconstruction	0.1
Reweighting	0.3 (0.2)
Sum in quadrature	1.2

Luminosity

Source	%
Calorimeter response calibration	0.2
Calorimeter alignment in respect to DC	0.2
Determination of J/ψ contrubution (θ angle)	0.3
Cross section calculation	0.4
MC statistics	0.15
Cuts variation	1.0
Sum in quadrature	1.3

Detector

Source	%
Calorimeter response	0.6
Nuclear interaction	0.2
Tracking P_t/θ resolutions	0.7
Trigger efficiency (ToF)	0.3
VD crosstalk	0.8
Cuts variation	0.8
Sum in quadrature	1.5

Collider

Source	%
Collider background	0.2
Energy collision asymmetry	0.2
Energy interpolation	0.3
Sum in quadrature	0.5

Other

Source	%
accuracy of the resonance term	0.1
accuracy of radiative correction calculations	0.1
interference parameter λ	0.3
Sum in quadrature	0.5