Recent results from VEPP-4M and VEPP-2000 in Novosibirsk

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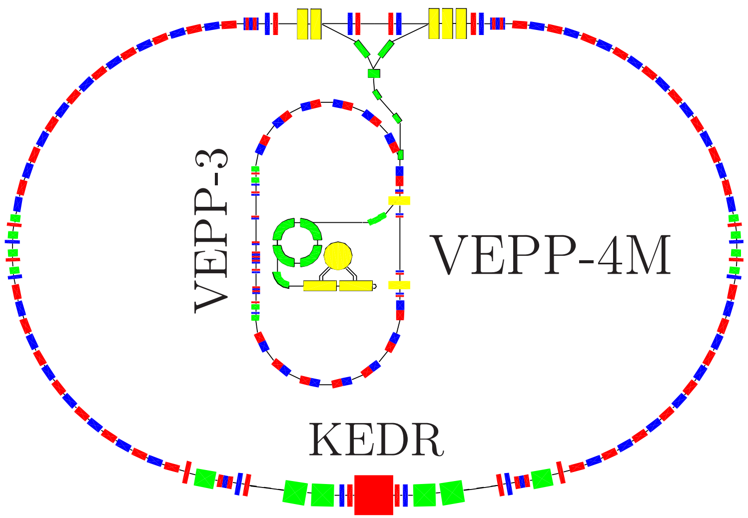
Outline

1. VEPP-4M
2. VEPP-2000
3. Super-tau-charm factory
4. Conclusions

Physics in the ψ family

- Despite more than 35 years of extensive studies many unclear issues and open questions still exist in the ψ family
- Even for the J/ψ a large fraction of hadronic decays is missing
- For the $\psi(2S)$ it is even worse: a strong $1D$ admixture, 15% puzzle
- For the $\psi(3770)$: exact structure?, shape anomaly, non-$D\bar{D}$ decays
- What is the decay pattern of the broad ψ's?
- Discovery of many possibly exotic charmonium-like states
- See a recent review: N. Brambilla et al., Eur. Phys. J. C71, 1534 (2011)
- KEDR at VEPP-4M made a focus on high-precision measurements of the mass and width for the narrow charmonia using scans and detailed analysis of systematic uncertainties

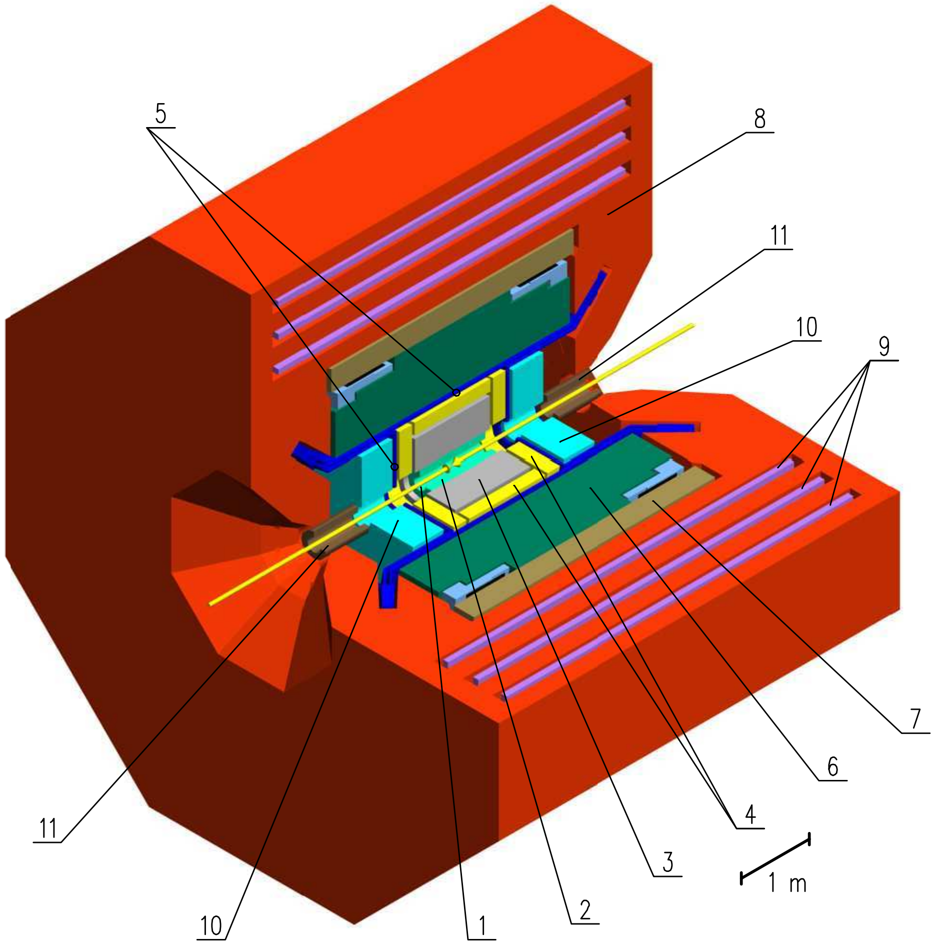
VEPP–4M collider



Circumference	366 m
Beam energy	1÷6 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}

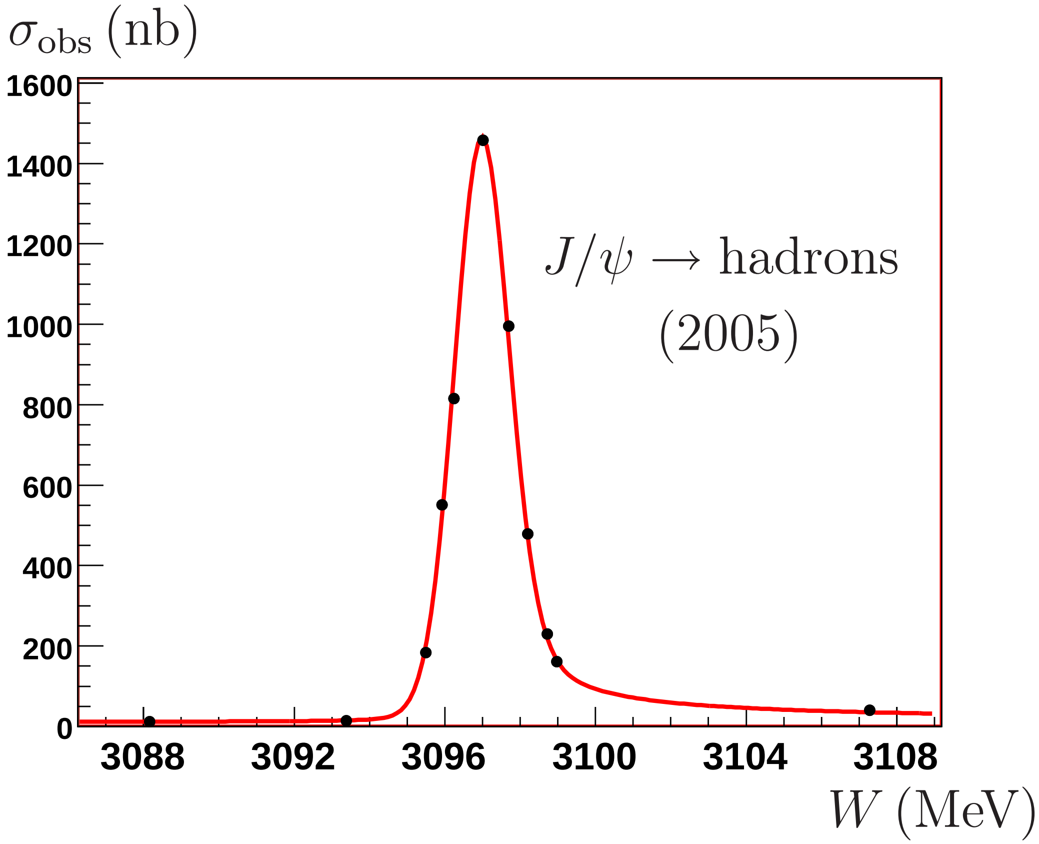
- Resonant depolarization technique:
  Instantaneous measurement accuracy $\simeq 1 \times 10^{-6}$
  Energy interpolation accuracy $(5 \div 15) \times 10^{-6}$ $(10 \div 30$ keV$)$
- Infrared light Compton backscattering:
  Statistical accuracy $\simeq 5 \times 10^{-5}$ / 30 minutes
  Systematic uncertainty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



A precise scan of the J/ψ ($\sim 2.5 \times 10^5$) can be used to measure leptonic widths or more precisely $\Gamma_{e^+e^-}\mathcal{B}_l$, a basis for $\Gamma_{e^+e^-}$ and $\mathcal{B}_{l^+l^-}$, $l = e,\ \mu$

V.V. Anashin et al., Phys. Lett. B 685, 134 (2010)

Theoretical basis for $\Gamma_{e^+e^-}\Gamma_{e^+e^-}/\Gamma$ at J/ψ

The cross section of $e^+e^- \to e^+e^-$ in the soft photon approximation

$$\left(\frac{d\sigma}{d\Omega}\right)_{th} = \frac{1}{M^2}\left\{\frac{9}{4}\frac{\Gamma_{ee}^2}{\Gamma M}\left(1+\frac{3}{4}\beta\right)\left(1+\cos^2\theta\right)\Im f \right.$$
$$\left. - \frac{3\alpha}{2}\frac{\Gamma_{ee}}{M}\left[\left(1+\cos^2\theta\right) - \frac{(1+\cos^2\theta)^2}{(1-\cos\theta)}\right]\Re f\right\} + \left(\frac{d\sigma}{d\Omega}\right)_{\rm QED},$$

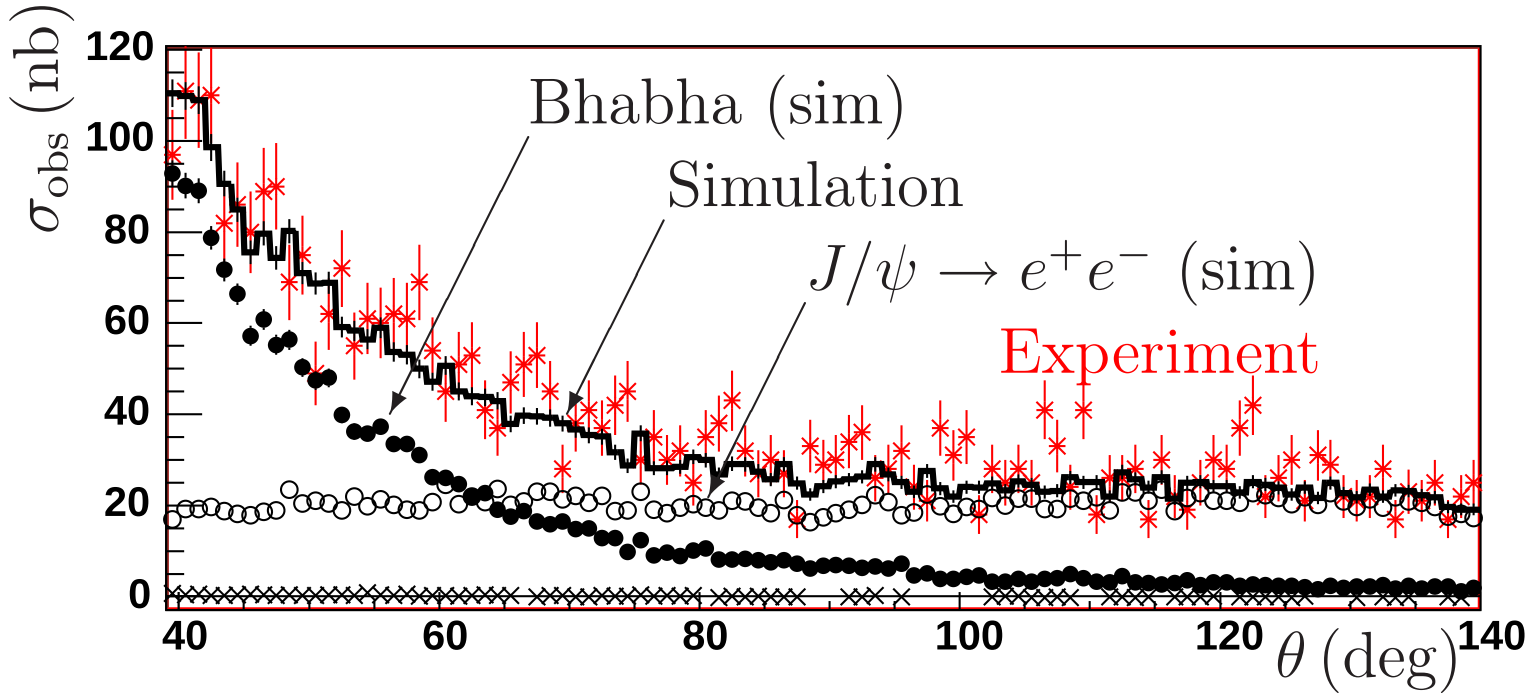
where $f = \left(\frac{\frac{M}{2}}{-W+M-\frac{i\Gamma}{2}}\right)^{1-\beta}, \quad \beta = \frac{4\alpha}{\pi}\left(\ln\frac{W}{m_e} - \frac{1}{2}\right) \simeq 0.077$

Ya. Azimov et al. JETP Lett. 21 (1975) 172

Taking into account the c.m.s. energy spread σ_W:

$$\sigma(W) = \frac{1}{\sqrt{2\pi}\sigma_W}\int \sigma_{th}(W')e^{\left\{-\frac{(W-W')^2}{2\sigma_W^2}\right\}}dW'$$

$d\sigma/d\Omega$ for $e^+e^- \to e^+e^-$ at J/ψ

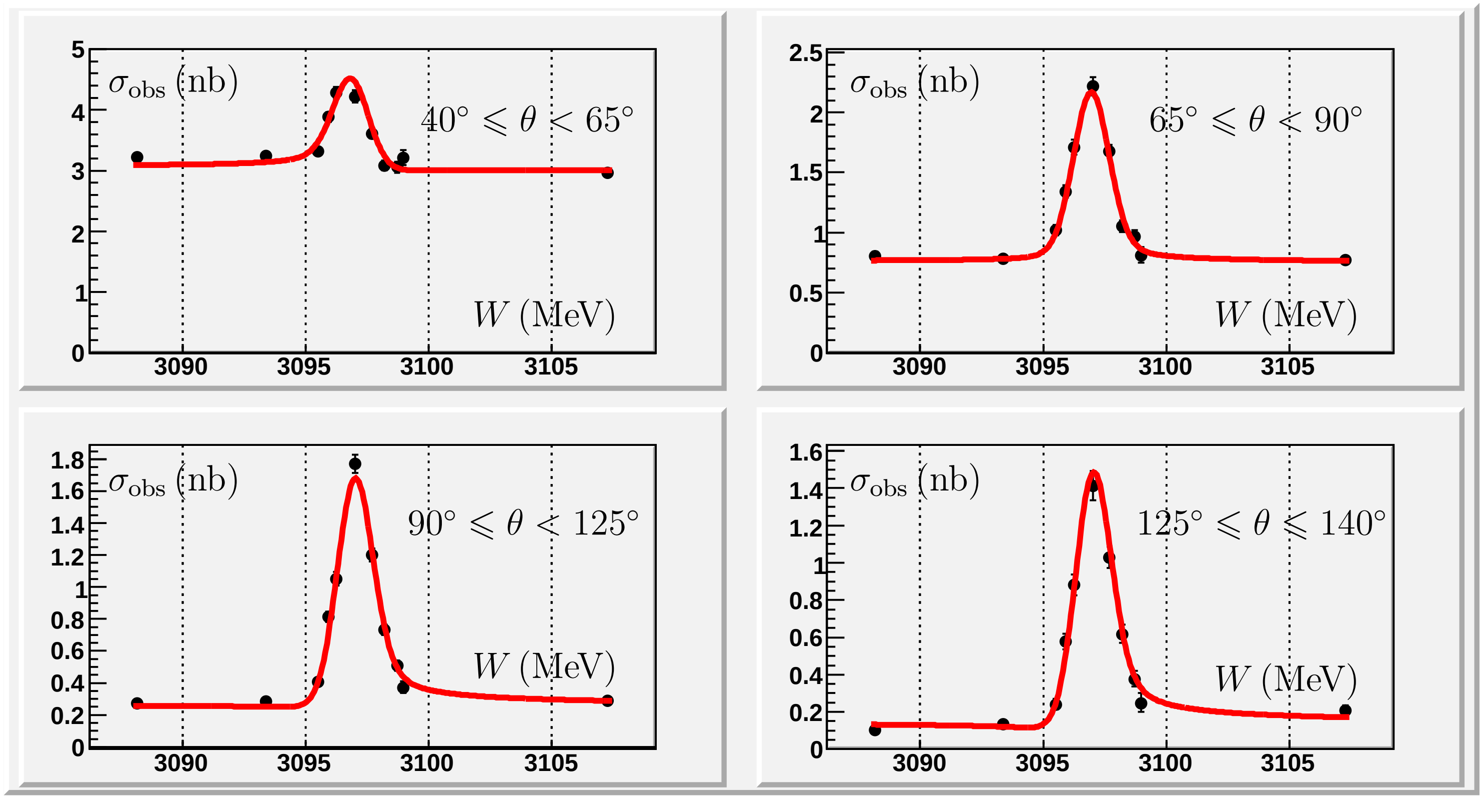


$$N_{\rm exp}(E_i,\theta) = \mathcal{R}_{\mathcal{L}} \times \mathcal{L}(E_i) \times \Big(\sigma^{\rm th}_{\rm peak}(E_i,\theta)\cdot\epsilon^{\rm sim}_{\rm peak}(E_i,\theta) +$$

$$+\sigma^{\rm th}_{\rm inter}(E_i,\theta)\cdot\epsilon^{\rm sim}_{\rm inter}(E_i,\theta) + \sigma^{\rm sim}_{\rm Bhabha}(E_i,\theta)\cdot\epsilon^{\rm sim}_{\rm Bhabha}(E_i,\theta)\Big),$$

where $\sigma^{\rm th}_{\rm peak}(E_i,\theta) \sim \Gamma_{ee} \times \Gamma_{ee}/\Gamma$

Cross Section of $e^+e^- \to e^+e^-$ at J/ψ



$$\Gamma_{ee} \times \Gamma_{ee}/\Gamma_{\rm total} = 0.3323 \pm 0.0064 \pm 0.0048\,{\rm keV}$$

Comparison of $\Gamma_{e^+e^-}\Gamma_{e^+e^-}/\Gamma$ Measurements at J/ψ

Group	Year	Γ^2_{ee}/Γ, keV
NaI/SLAC	1975	0.36 ± 0.10
MEA	1975	0.34 ± 0.09
$\gamma\gamma2$	1975	0.32 ± 0.07
DASP	1979	0.35 ± 0.02
KEDR	2009	$0.3323 \pm 0.0064 \pm 0.0048$

The precision of our $\Gamma_{e^+e^-}\Gamma_{e^+e^-}/\Gamma$ is 2.4%,
comparable to the world averages of $\Gamma_{e^+e^-}$ (2.6%) and $\Gamma_{e^+e^-}\Gamma_{\mu^+\mu^-}/\Gamma$ (2.1%)

It agrees well with $\Gamma_{e^+e^-}\Gamma_{e^+e^-}/\Gamma = 0.3291 \pm 0.0090$ keV
obtained using $\Gamma_{e^+e^-}$ and Γ from PDG-08

Theoretical basis for $\Gamma_{e^+e^-}\Gamma_{\mu^+\mu^-}/\Gamma$ at J/ψ

The cross section of $e^+e^- \to \mu^+\mu^-$ in the soft photon approximation

$$\left(\frac{d\sigma}{d\Omega}\right)^{ee\to\mu\mu} = \frac{3}{4M^2}\left(1+\cos^2\theta\right)\left\{\frac{3\Gamma_{e^+e^-}\Gamma_{\mu^+\mu^-}}{\Gamma M}\left(1+\frac{3}{4}\beta\right)\Im\mathcal{F} - \right.$$

$$\left. - \frac{2\alpha\sqrt{\Gamma_{e^+e^-}\Gamma_{\mu^+\mu^-}}}{M}\left(1+\frac{11}{12}\beta\right)\Re\mathcal{F}\right\} + \left(\frac{d\sigma}{d\Omega}\right)^{ee\to\mu\mu}_{\mathrm{QED}},$$

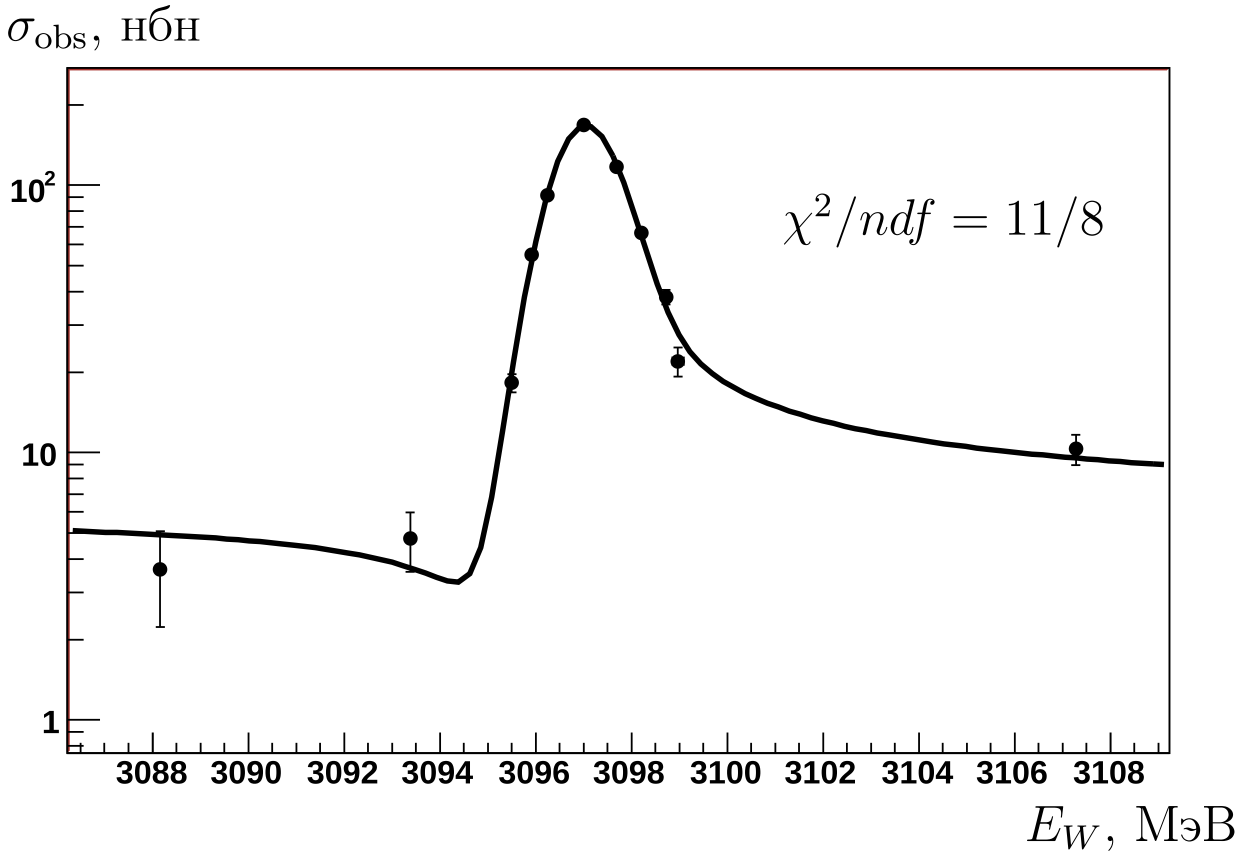
where $f = \left(\frac{\frac{M}{2}}{-W+M-\frac{i\Gamma}{2}}\right)^{1-\beta}$, $\beta = \frac{4\alpha}{\pi}\left(\ln\frac{W}{m_e}-\frac{1}{2}\right) \simeq 0.077$

Ya. Azimov et al. JETP Lett. 21 (1975) 172

Taking into account the c.m.s. energy spread σ_W:

$$\sigma(W) = \frac{1}{\sqrt{2\pi}\sigma_W}\int \sigma_{th}(W')e^{\left\{-\frac{(W-W')^2}{2\sigma_W^2}\right\}}dW'$$

Cross Section of $e^+e^- \to \mu^+\mu^-$ at J/ψ



$$\Gamma_{e^+e^-} \times \Gamma_{\mu^+\mu^-} / \Gamma = 0.3318 \pm 0.0052 \pm 0.0063 \text{ keV}$$

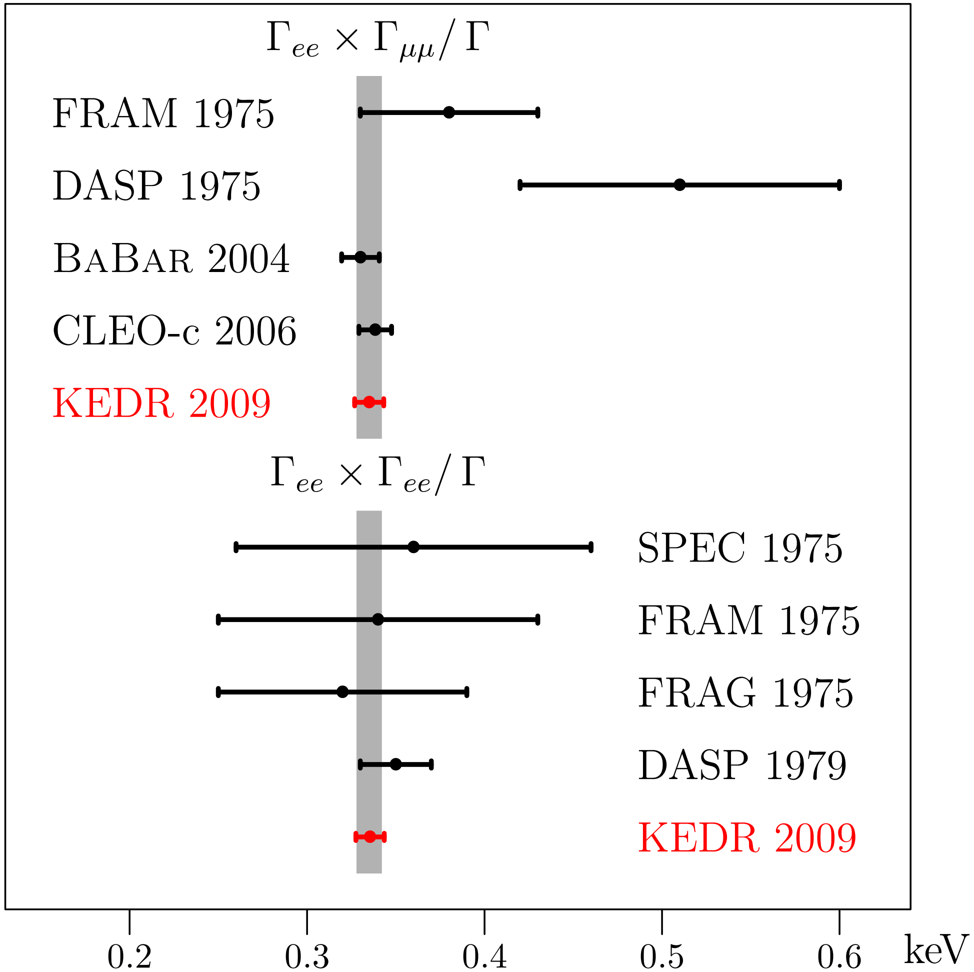
Comparison of $\Gamma_{e^+e^-}\Gamma_{\mu^+\mu^-}/\Gamma$ Measurements at J/ψ

Group	Year	$\Gamma_{ee}\Gamma_{\mu\mu}/\Gamma$, keV
FRAM	1975	0.36 ± 0.05
DASP	1975	0.51 ± 0.09
BaBar	2004	$0.3301 \pm 0.0077 \pm 0.0073$
CLEO	2006	$0.3384 \pm 0.0058 \pm 0.0071$
KEDR	2009	$0.3318 \pm 0.0052 \pm 0.0063$

The precision of our $\Gamma_{e^+e^-}\Gamma_{\mu^+\mu^-}/\Gamma$ is 2.5%,
comparable to the world average of 2.1%

It agrees well with 0.335 ± 0.007 keV from PDG-08

Comparison of $\Gamma_{e^+e^-}\Gamma_{e^+e^-}/\Gamma$ and $\Gamma_{e^+e^-}\Gamma_{\mu^+\mu^-}/\Gamma$ at J/ψ



Γ_{ll} and Γ for J/ψ from $\Gamma_{e^+e^-}\Gamma_{e^+e^-}/\Gamma$ and $\Gamma_{e^+e^-}\Gamma_{\mu^+\mu^-}/\Gamma$

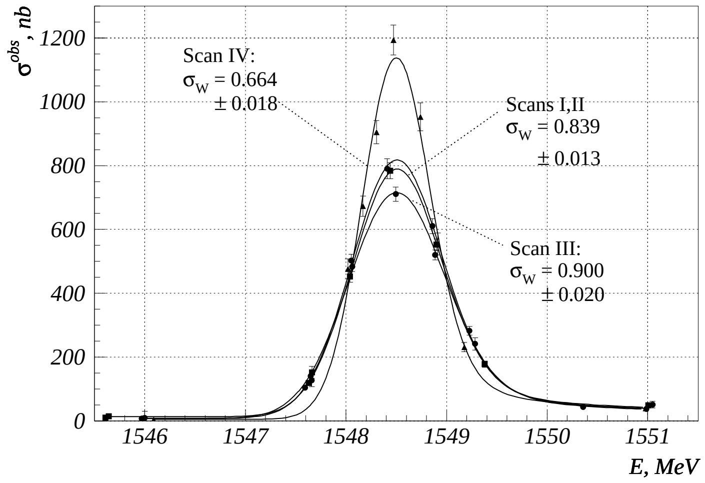
Test of lepton universality:

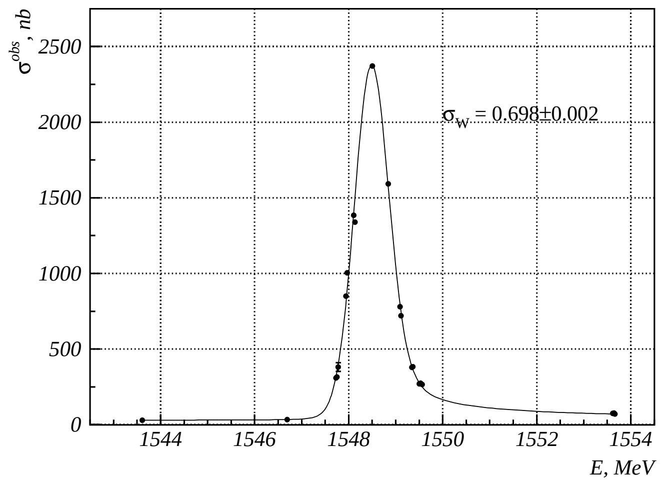
$$\Gamma_{e^+e^-}/\Gamma_{\mu^+\mu^-} = 1.021 \pm 0.021 \pm 0.013$$

Source	Γ_{ll}, keV	Γ, keV
KEDR, 2010	5.59 ± 0.12	94.1 ± 2.7
PDG, 2008	5.55 ± 0.14	93.2 ± 2.1

J/ψ Mass Measurement

4 scans in 2002 and 1 scan in 2005





$$M^{2002}_{J/\psi} = (3096.924 \pm 0.010 \pm 0.008)\ \text{MeV}$$

$$M^{2005}_{J/\psi} = (3096.905 \pm 0.002 \pm 0.008)\ \text{MeV}$$

The combined result is $M^{KEDR}_{J/\psi} = 3096.911 \pm 0.004 \pm 0.009$ MeV
(differs by -6 keV from the value published in PL B573 (2003) 63)

$\psi(2S)$ Mass Measurement

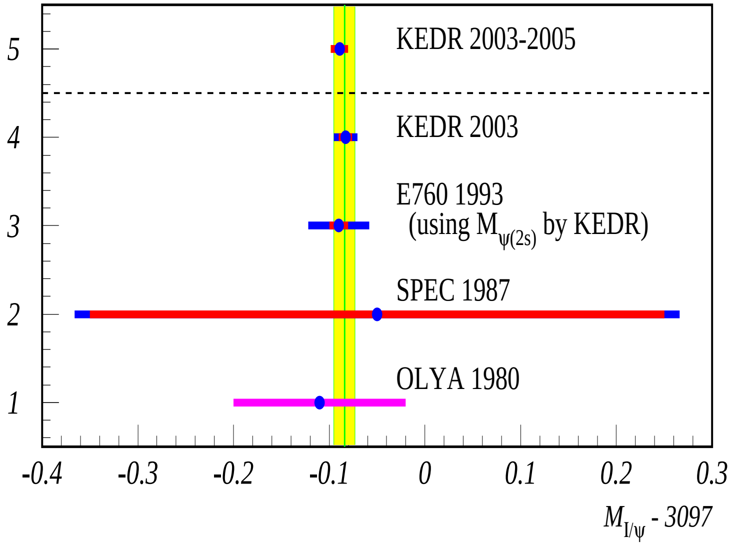
3 scans in 2002, 2 scans in 2004 and 1 scan in 2006

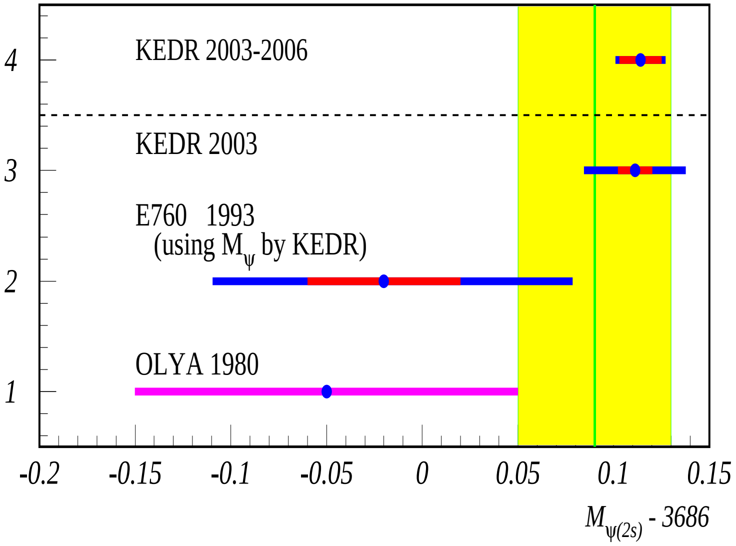
Mass values to be averaged (in MeV):

$$M^{2002}_{\psi(2S)} = 3686.094 \pm 0.025 \pm 0.013$$
$$M^{2004}_{\psi(2S)} = 3686.122 \pm 0.011 \pm 0.011$$
$$M^{2006}_{\psi(2S)} = 3686.110 \pm 0.010 \pm 0.012$$

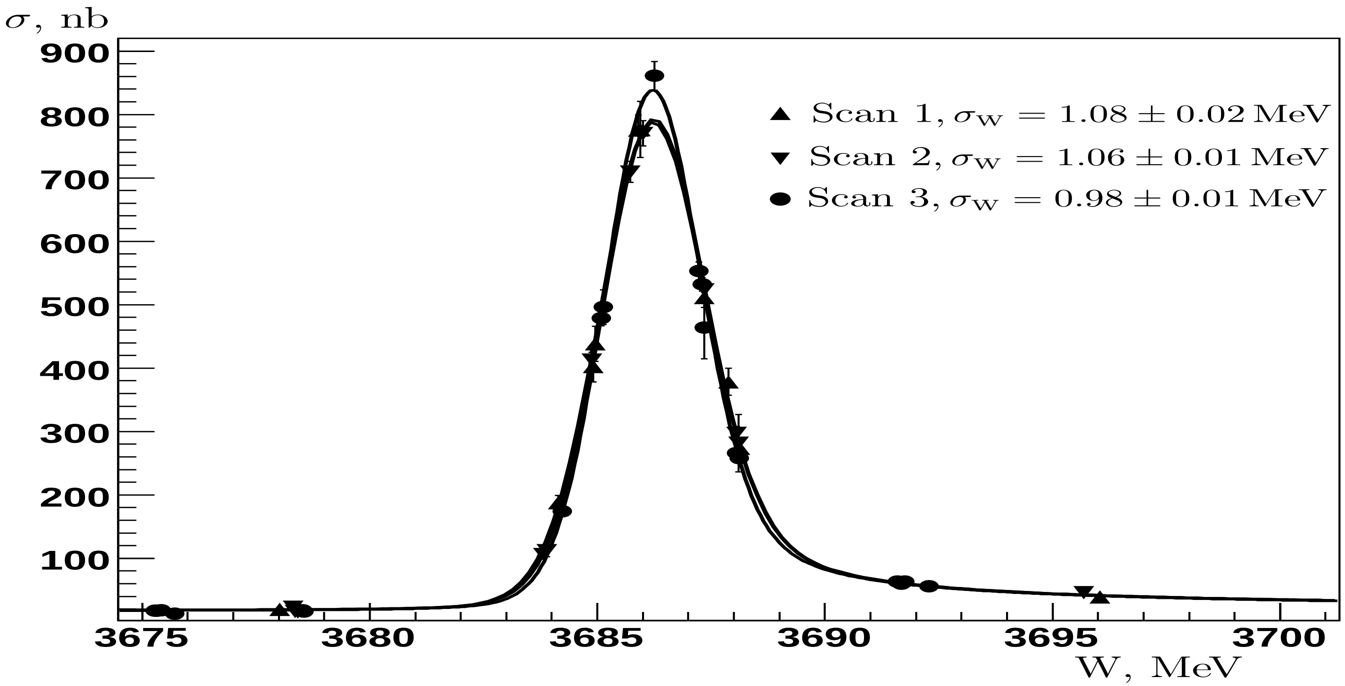
The combined result is $M^{KEDR}_{\psi(2S)} = 3686.114 \pm 0.007 \pm 0.011$ MeV
(differs by +3 keV from the value published in PL B573 (2003) 63)

J/ψ and $\psi(2S)$ Mass Measurement in PDG





Measurement of $\Gamma_{ee} \cdot \mathcal{B}(\psi(2S) \to hadrons)$ – I

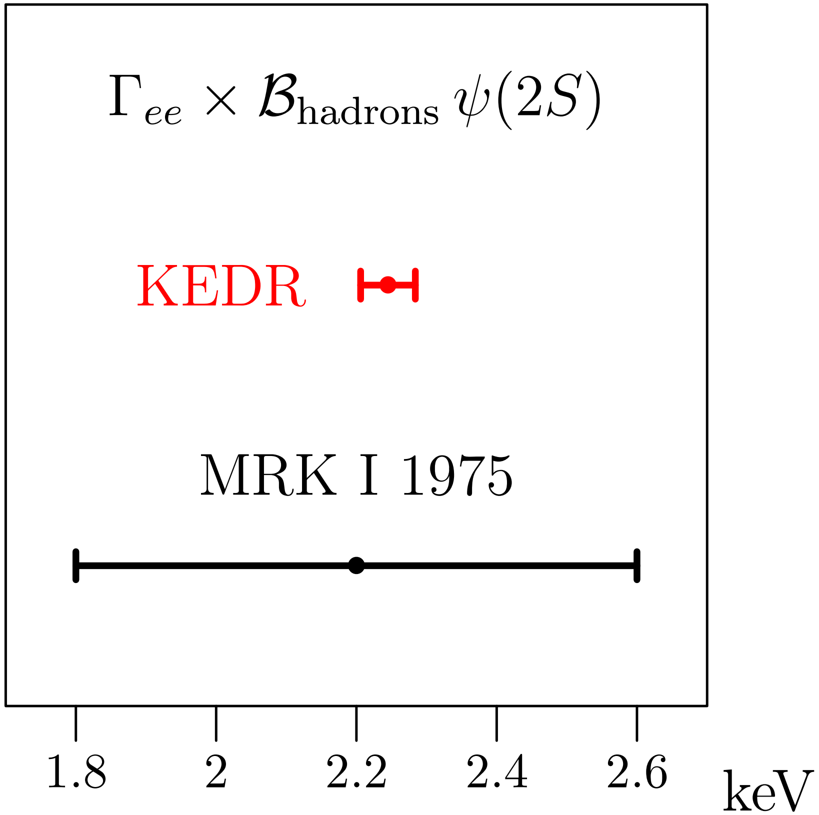


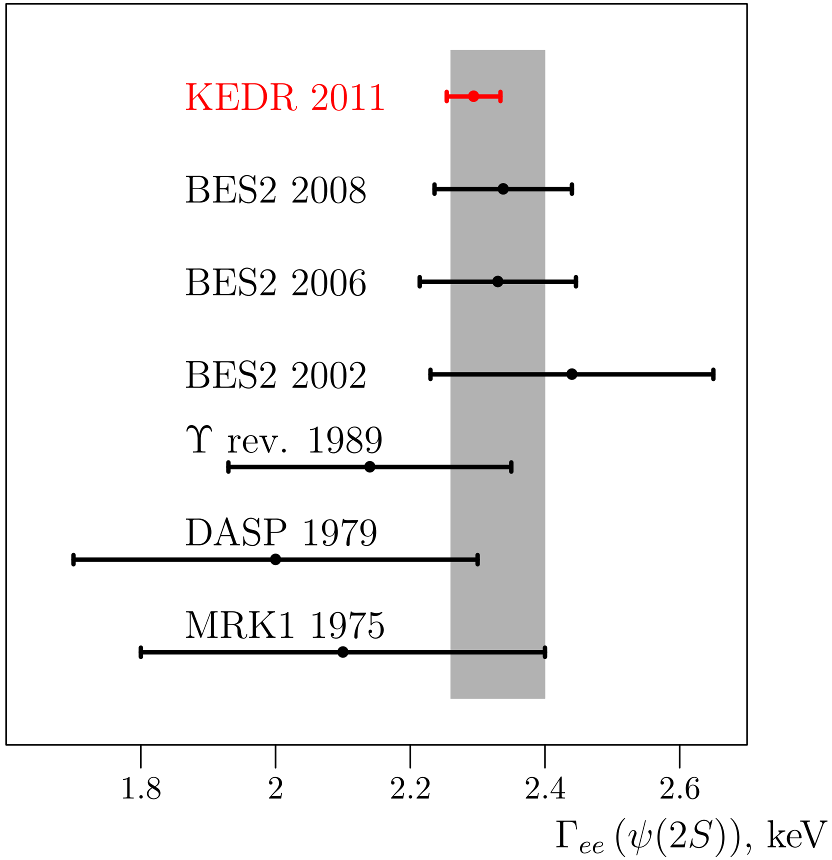
V.V. Anashin et al., arXiv:1109.4215

Measurement of $\Gamma_{ee} \cdot \mathcal{B}(\psi(2S) \to hadrons)$ – II

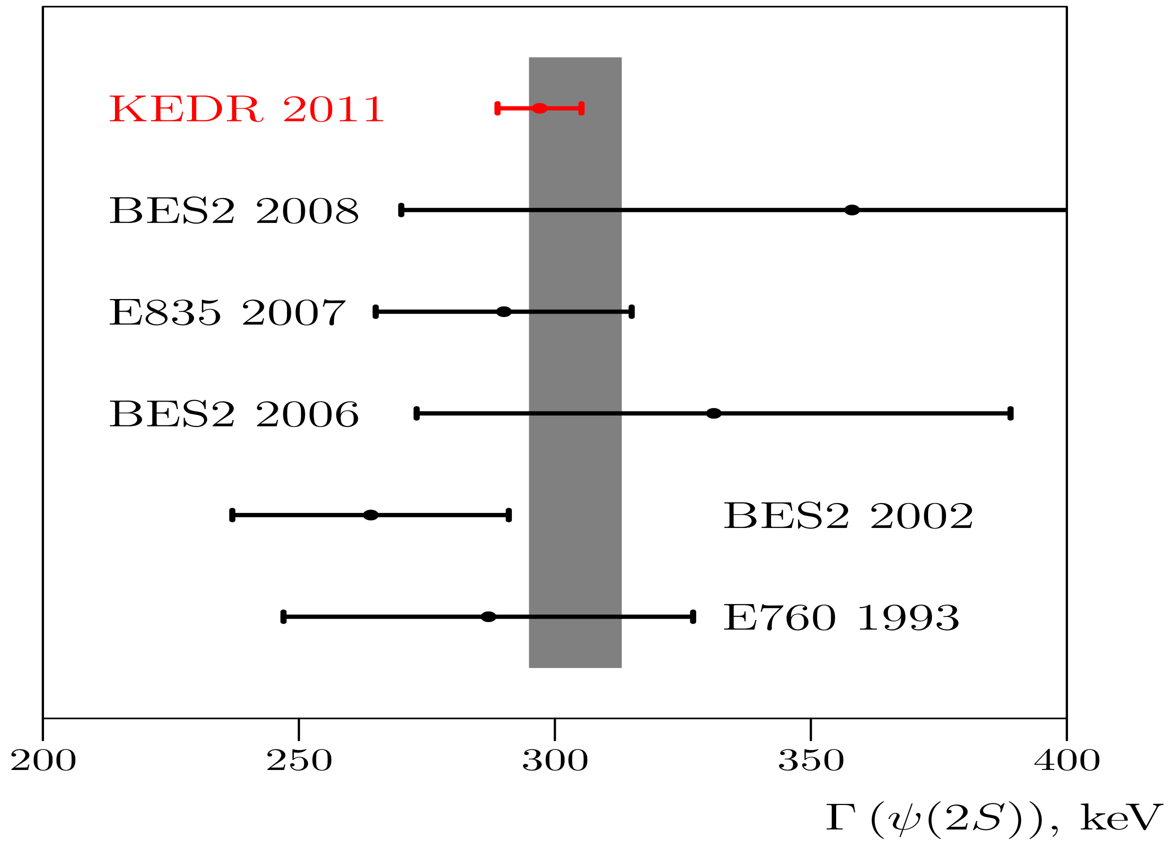
- $\Gamma_{e^+e^-} \cdot \mathcal{B}(\psi(2S) \to h) = (2.233 \pm 0.015 \pm 0.036)$ keV,
  much more precise than the only previous direct measurement
- Using the world-average value of $\mathcal{B}_h$
  $\Gamma_{e^+e^-} = (2.282 \pm 0.015 \pm 0.037)$ keV,
  more than 2 times better than the best previous one.
- Using the world-average values of $\Gamma_{e^+e^-}$ and $\mathcal{B}_h$
  $\Gamma = (296 \pm 2 \pm 8)$ keV,
  again more than 2 times better than the best previous one.

Measurement of $\Gamma_{ee} \cdot \mathcal{B}(\psi(2S) \to hadrons)$ – III





Measurement of $\Gamma_{ee} \cdot \mathcal{B}(\psi(2S) \to hadrons)$ – IV



Cross section of $e^+e^- \to \psi(3770) \to D\bar{D}$ – I

$$\sigma^{\rm obs}_{mh} = \epsilon_{\psi(2S)}\,\sigma^{RC}_{\psi(2S)} + \epsilon_{D^+D^-}\,\sigma^{RC}_{D^+D^-} + \epsilon_{D^0\bar{D}^0}\,\sigma^{RC}_{D^0\bar{D}^0} + \epsilon_{\tau\tau}\,\sigma^{RC}_{\tau\tau} + \sigma^{obs}_{1/s} + \sigma^{obs}_{D\bar{D}\pi} + \epsilon_{c\bar{c}\to LH}\,\sigma^{RC}_{c\bar{c}\to LH}. \qquad (1)$$

$$\sigma^{RC}_{D\bar{D}}(W) = \int z_{D\bar{D}}\left(W'\sqrt{1-x}\right)\sigma_{D\bar{D}}\left(W'\sqrt{1-x}\right) \times \mathcal{F}(x, W'^2)\, G(W, W')\, dW' dx, \qquad (2)$$

$$z_{D^+D^-} = \frac{\pi\alpha/\beta_{D^+}}{1-\exp\left(-\pi\alpha/\beta_{D^+}\right)} \times \theta(W - 2m_{D^+}). \qquad (3)$$

Cross section of $e^+e^- \to \psi(3770) \to D\bar{D}$ – II

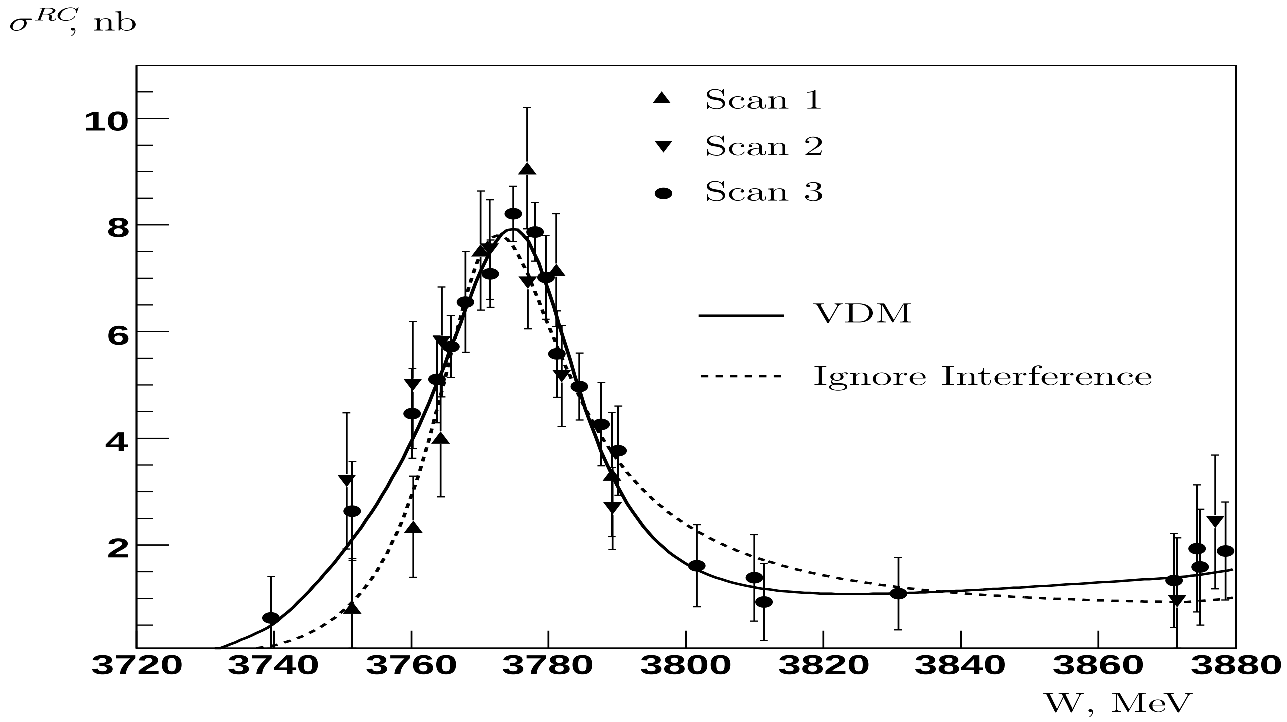
$$\sigma_{D\bar{D}}(W) = \frac{\pi\alpha^2}{3W^2}\,\beta_D^3\,\left|F_D(W)\right|^2, \quad \beta_D = \sqrt{1 - 4m_D^2/W^2} \tag{4}$$

Resonance amplitudes above the $D\bar{D}$ threshold should be separated in F_D:

$$F_D(W) = \sum_i F_D^{R_i}(W)\,e^{i\phi_i} + F_D^{NR}(W), \tag{5}$$

We assume the $\psi(2S)$ dominance:
$F_D^{NR}(W) = F_D^{\psi(2S)}(W) + c$
and check the model dependence with some empirical form factors

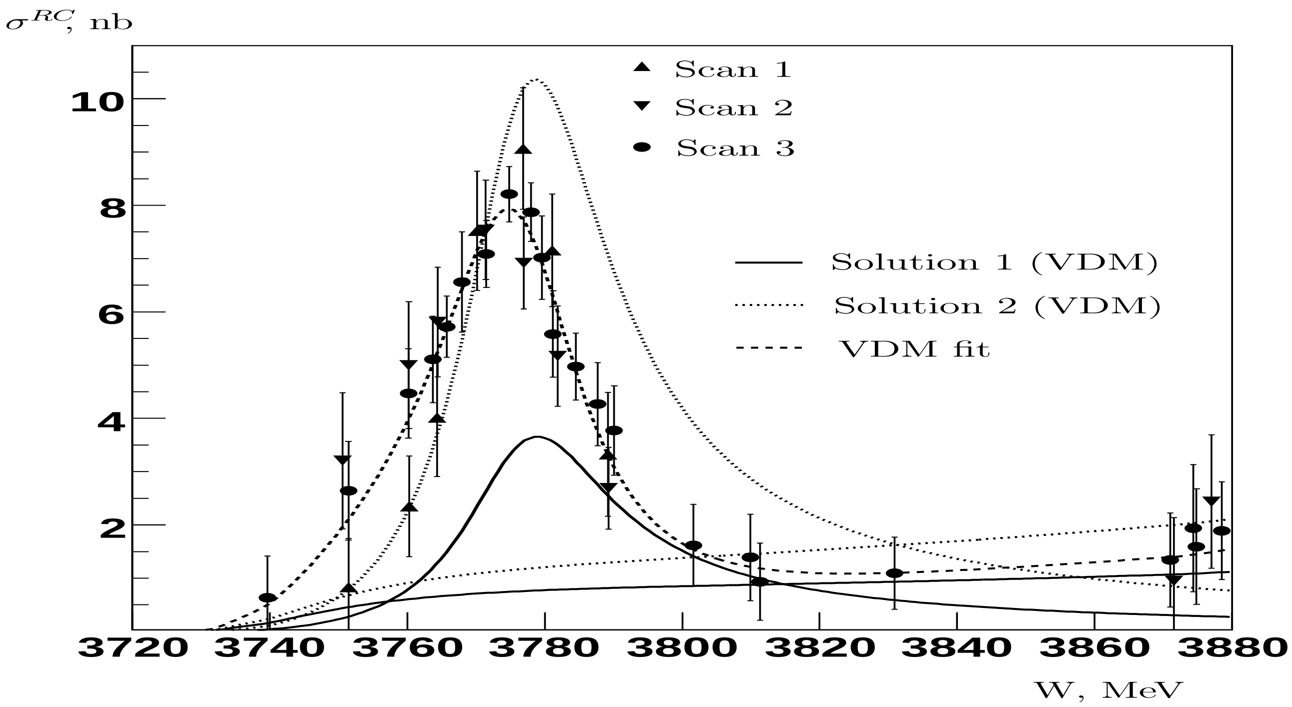
Determination of $\psi(3770)$ Parameters – I



Note that the energy spread affects the shape!

V.V. Anashin et al., arXiv:1109.4205

Determination of $\psi(3770)$ Parameters – II



Two different resonant and non-resonant parts add to the same curve because of two solutions corresponding to different interference phases!

2 solutions (fit for the $\psi(2S)$ dominance)

Solution	Mass, MeV	Γ, MeV	Γ_{ee}, eV
1	$3779.28^{+1.79}_{-1.69}$	$25.3^{+4.6}_{-4.1}$	147^{+97}_{-62}
2	$3778.97^{+1.82}_{-1.72}$	$25.0^{+4.4}_{-3.8}$	415^{+59}_{-58}
i.i.	3773.3 ± 0.5	$23.4^{+2.5}_{-2.2}$	250^{+25}_{-23}

Solution	φ, deg	$\Gamma^{\psi(2S)}_{D\bar{D}}$	$P(\chi^2)$, %
1	198.7 ± 42.4	$14.3^{+21.0}_{-14.0}$	35.4
2	257.4 ± 17.2	$20.1^{+11.3}_{-10.7}$	35.9

The ambiguity is principal!

Final results for $\psi(3770)$

Under the assumption of the $\psi(2S)$ dominance

and averaging over 2 solutions

KEDR: $M = (3779.1^{+1.8}_{-1.7} \pm 0.6^{+0.2}_{-0.3})$ MeV, $\Gamma = (25.2^{+4.6}_{-4.1} \pm 0.5^{+0.5}_{-0.2})$ MeV

PDG: $M = (3772.92 \pm 0.35)$ MeV, $\Gamma = (27.3 \pm 1.0)$ MeV

For the leptonic width we can't choose between 2 solutions:

KEDR (1): $\Gamma_{ee} = 147^{+97}_{-62} \pm 13^{+11}_{-10}$ eV,

KEDR (2): $\Gamma_{ee} = 415^{+59}_{-58} \pm 38^{+160}_{-10}$ eV,

PDG: $\Gamma_{ee} = 265 \pm 18$ eV

Most of the potential models support the first solution,

but barely tolerate the second one!

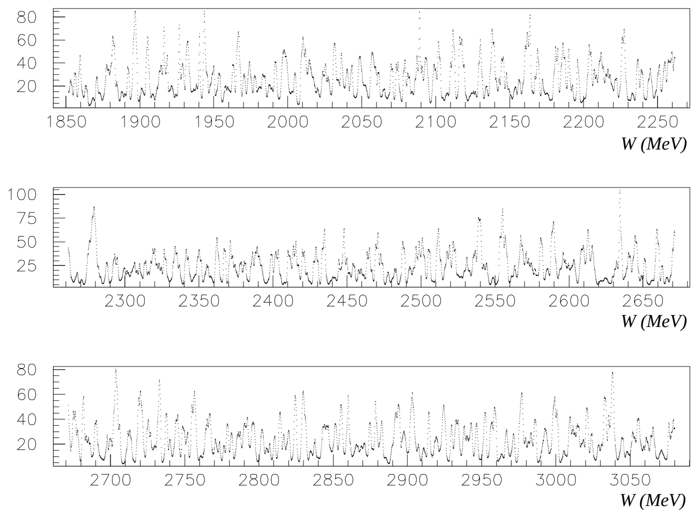
Determination of $\psi(3770)$ Parameters – III

A few general conclusions:

- Mass is higher than in previous measurements, 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
- Absolutely mandatory to take into account interference:
- There are usually two solutions with the same mass, width and likelihood, but strongly differing (a factor of up to 3) leptonic width
- While the current world-average value is $\Gamma_{e^+e^-} = 265 \pm 18$ eV, with interference effects included it can vary in the (100-500) eV range $\Rightarrow$ direct averaging of results in different groups is impossible

Search for Narrow Resonances – I

KEDR scanned the c.m.energy range from 1.85 to 3.1 GeV searching for narrow resonances

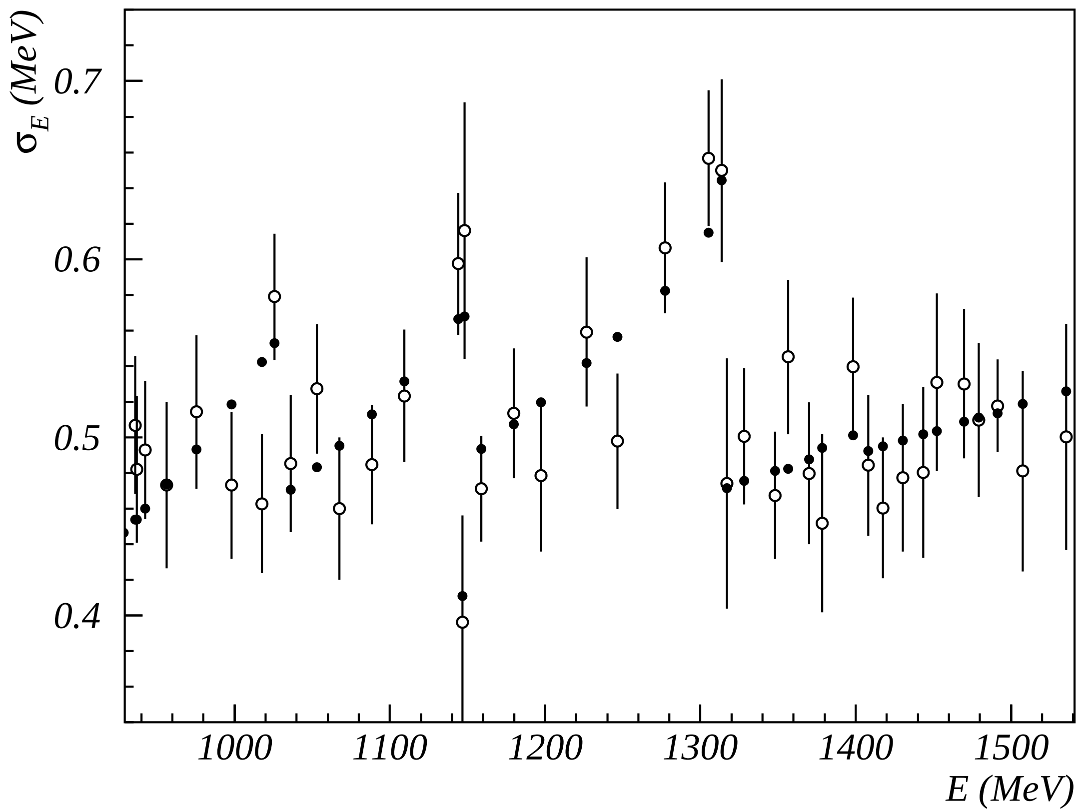


V.V. Anashin et al., Phys. Lett. B703, 543 (2011)

Search for Narrow Resonances – II

$\int \mathcal{L}dt \approx 300\ \mathrm{nb}^{-1}$ was collected

in a scan with a step $\approx\ 2\sigma_W$ (1.4-1.9 MeV)



Search for Narrow Resonances – III

- The model: a resonance with M_R, Γ_{ee}^R on top of a flat BG
- The fits use the range $M_R \pm 13$ MeV
- M_R is varied in 0.1 MeV steps
- A systematic error of $\sim 50\%$ conservatively
- $\Gamma_{ee}^R \cdot \mathcal{B}(R \to hadrons) < 120$ eV,
  4-5 times more stringent than at ADONE in 1975-1978:
  $\gamma\gamma 2$, $B\bar{B}$ and BOSON groups scanned 1.42-3.1 GeV
- KEDR hopes to measure R in this W range to 5%

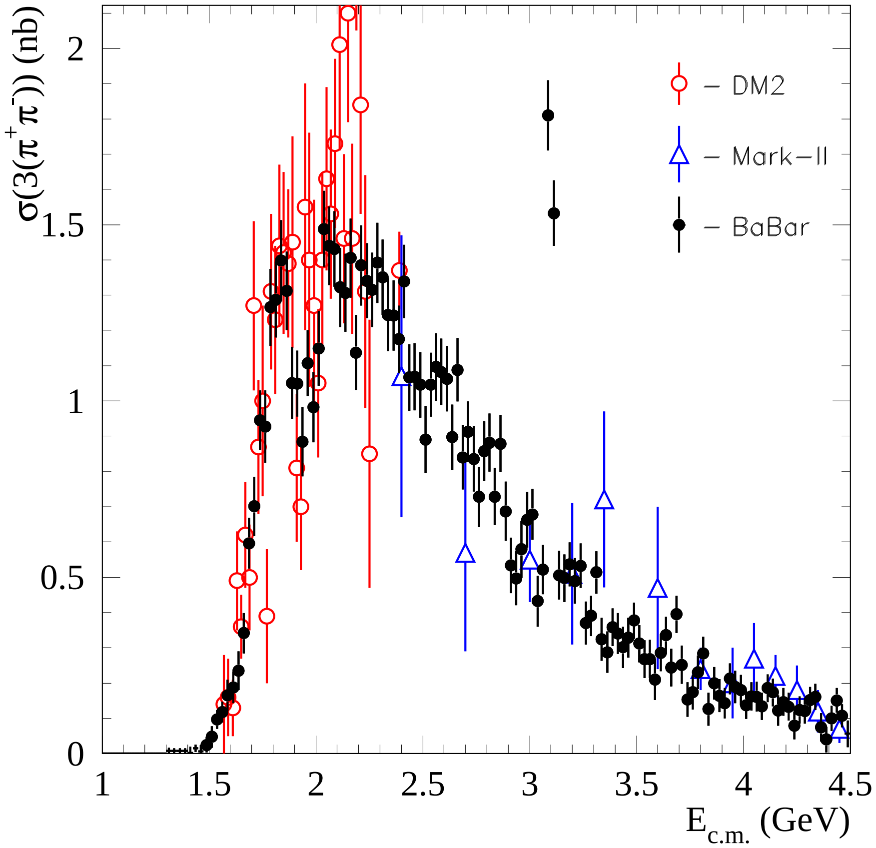
Conclusions on the results from VEPP-4M

- New precise values of $\Gamma_{e^+e^-} \cdot \mathcal{B}(e^+e^-, \mu^+\mu^-)$ significantly improve the values of both leptonic and total width for J/ψ
- Masses of J/ψ and $\psi(2S)$ measured. The accuracy reaches $(3-5) \cdot 10^{-6}$ setting an important mass calibration scale $(D^{\pm},\ D^0,\ D_s)$
- New precise value of $\Gamma_{e^+e^-} \cdot \mathcal{B}(\psi(2S))$ significantly improves the values of both leptonic and total width for $\psi(2S)$
- Interference effects are important for M and Γ of $\psi(3770)$
- Multiple solutions make difficult $\Gamma_{e^+e^-}$ determination for $\psi(3770)$
- No narrow states found between 1.85 GeV and J/ψ
- New R measurements are planned between 2 and 11 GeV

Physics at VEPP-2000 – I

- VEPP-2000 – e^+e^- collider in Novosibirsk, $\sqrt{s}$ from threshold to 2 GeV
- Total and exclusive cross sections of $e^+e^- \to$ hadrons:
  1. Interactions of light quarks
  2. Spectroscopy of light vector mesons – ρ', ω', ϕ'
  3. Study of mesons with other J^{PC}
  4. F/f measurement in various two-body channels
  5. $p\bar{p}$, $n\bar{n}$ production near threshold
  6. Search for various exotics

$e^+e^- \to 3\pi^+3\pi^-$



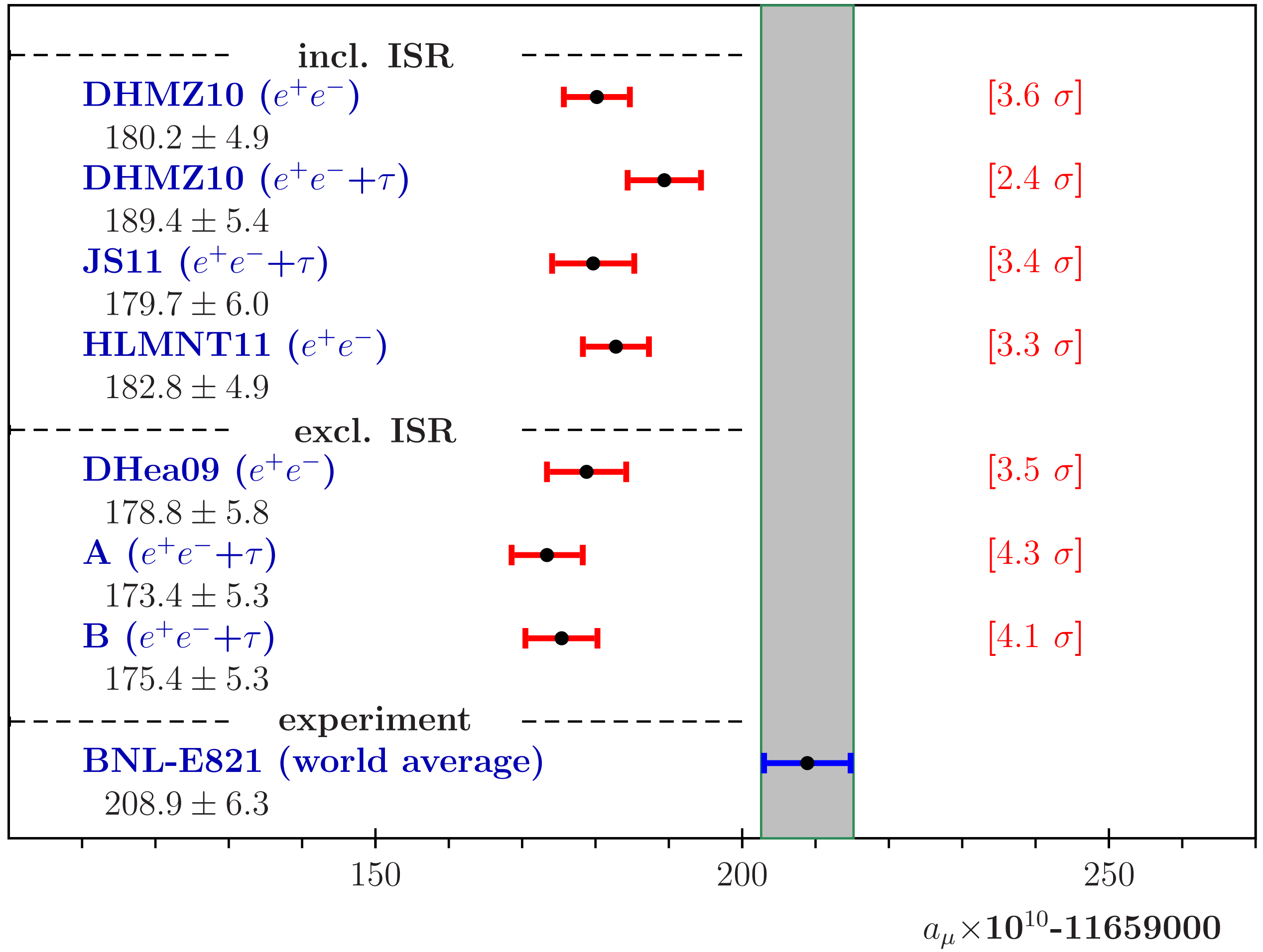
A new dip structure around 1.9 GeV – baryonium or $\rho(1900)$?

Physics at VEPP-2000 – II

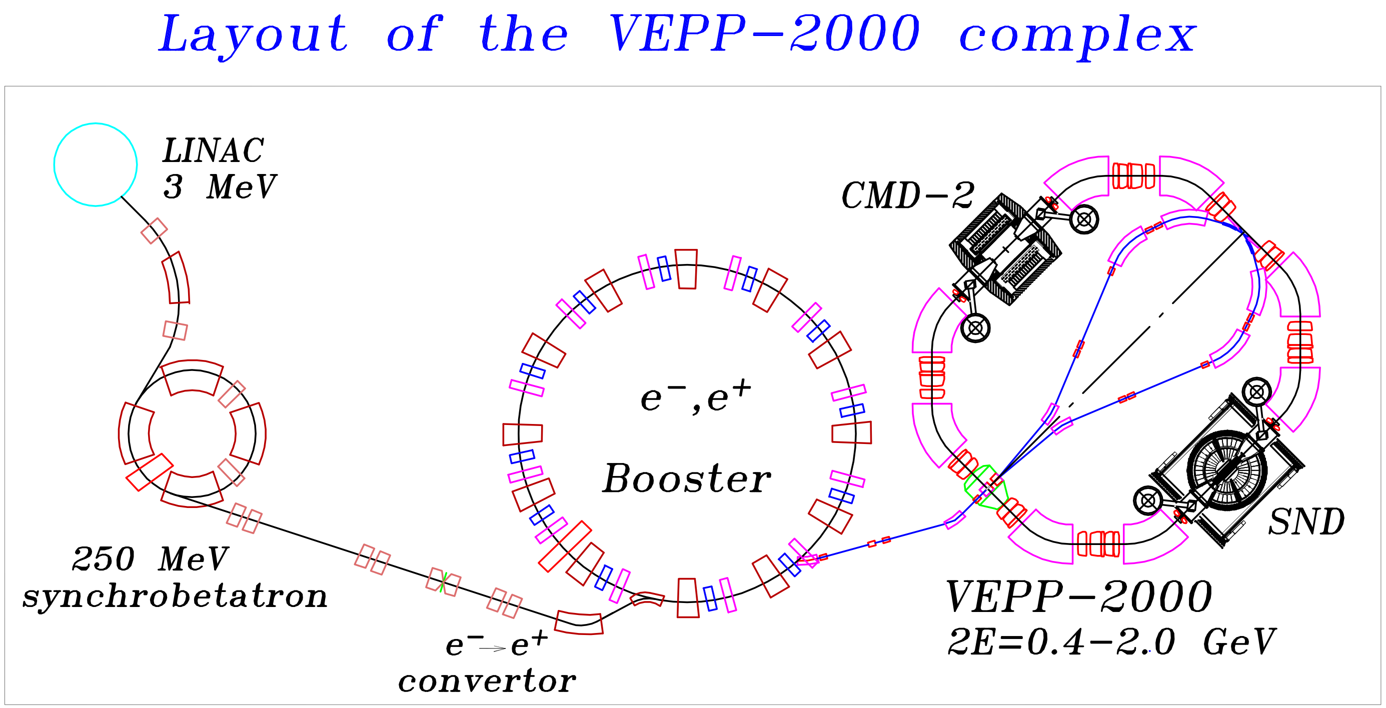
Implications of low energy cross sections for various fundamental quantities:

- Muon anomalous magnetic moment, a_μ, where a more than 3.5σ deviation is observed from the SM prediction
- 92% of $a_\mu^{\mathrm{had,LO}}$ is saturated by $\sqrt{s}$ from threshold to 2 GeV
- 73% of $a_\mu^{\mathrm{had,LO}}$ is saturated by $e^+e^- \to \pi^+\pi^-$ at $\sqrt{s} < 2$ GeV
- $\gamma\gamma \to \pi^0,\ \eta,\ \eta'$ is important for $a_\mu^{\mathrm{had,LBL}}$
- Hadronic contributions to running α
- $m_{u(d)}$ and quark /gluon condensates from QCD sum rules
- Test of CVC by comparing e^+e^- and τ

Status of the muon anomaly

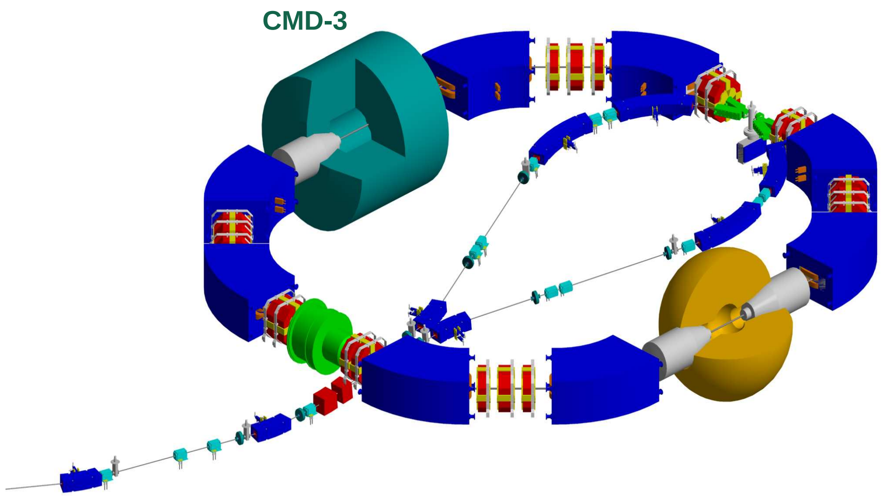


VEPP-2000 Accelerator Complex



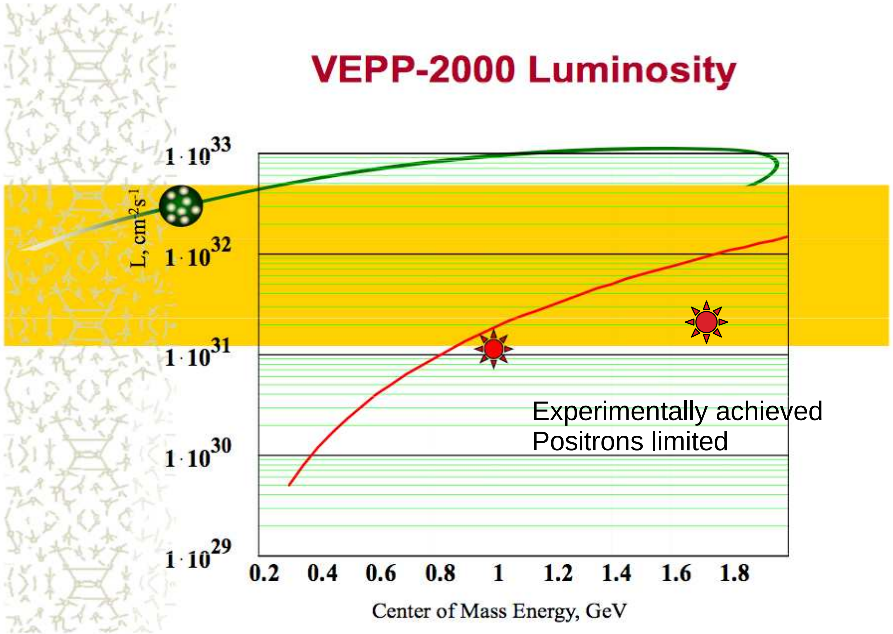
Machine	Physics	$\sqrt{s}$, MeV	$\mathcal{L}_{\max}$, $10^{30}\text{cm}^{-2}\text{s}^{-1}$	$\int \mathcal{L}\, dt$, pb^{-1}
VEPP-2M	1975 – 2000	360–1400	3	~ 60
VEPP-2000	2010 – 2020	300–2000	100	~ 3000

VEPP-2000 Collider



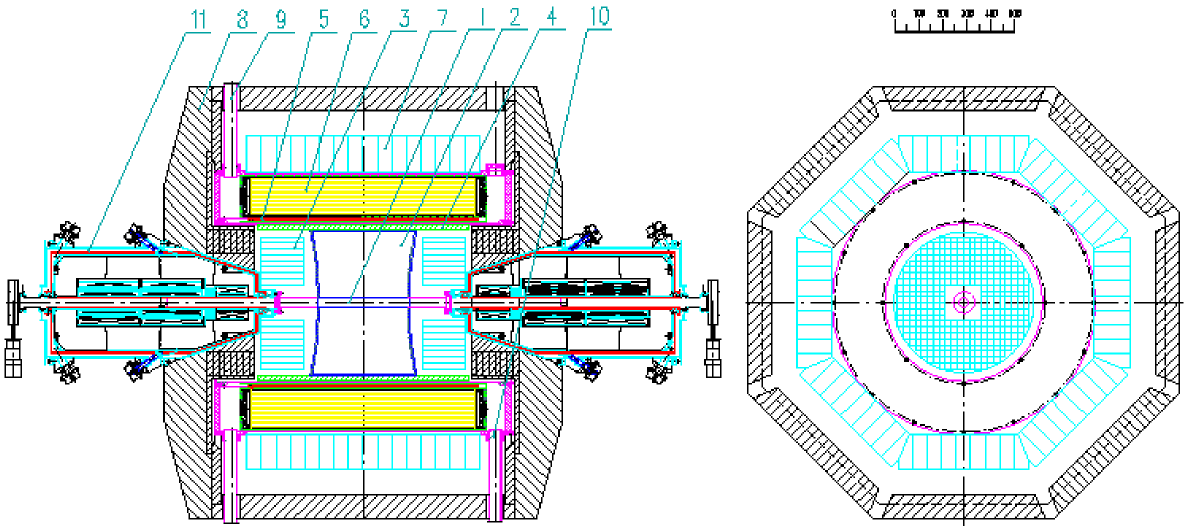
Round beams: 1×1 bunch, $\epsilon_x = \epsilon_y$, $\sigma_x^* = \sigma_y^*$, $\nu_x = \nu_y$

Luminosity at VEPP-2000



Design luminosity should be achieved after
the new injection complex is commissioned in 2012

CMD-3 Detector



1 Beam pipe

2 Drift chamber

3 BGO calorimeter

4 Z chamber

5 SC solenoid

6 LXe calorimeter

7 CsI calorimeter

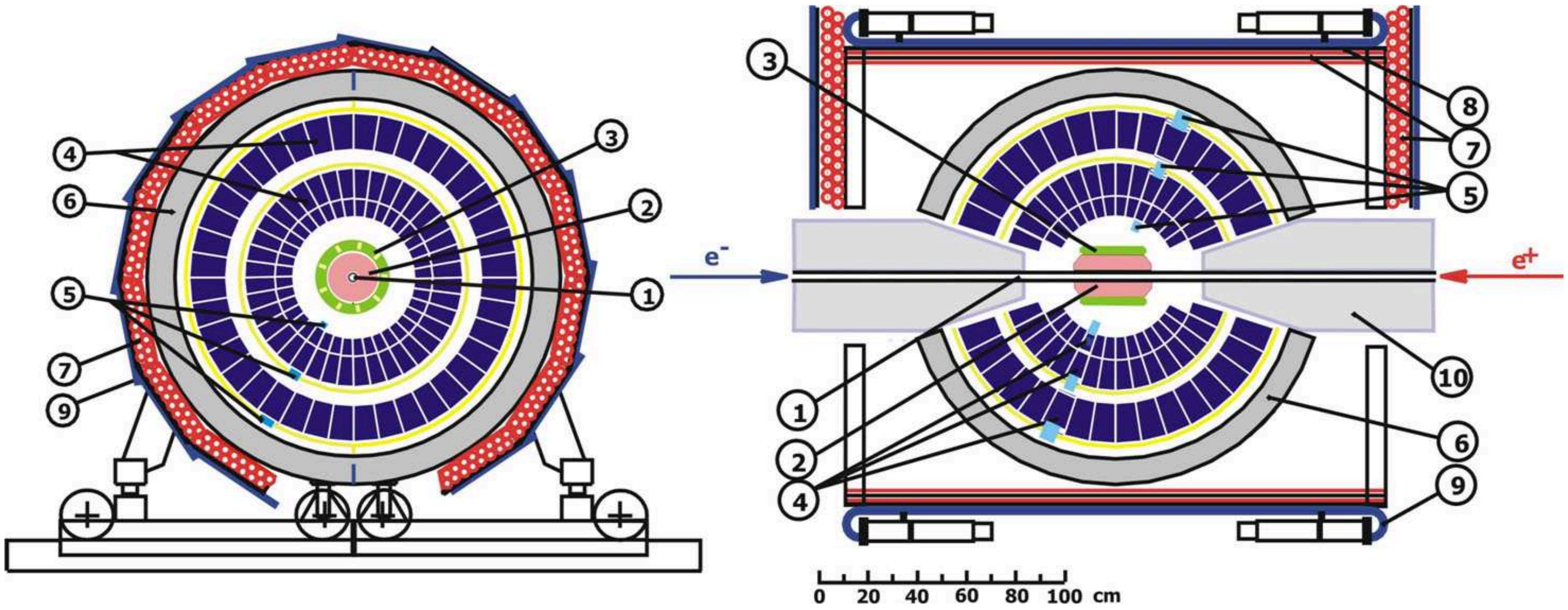
8 Flux return

9 LHe supply

10 Vacuum pumpdown

11 SC focusing solenoids

SND Detector

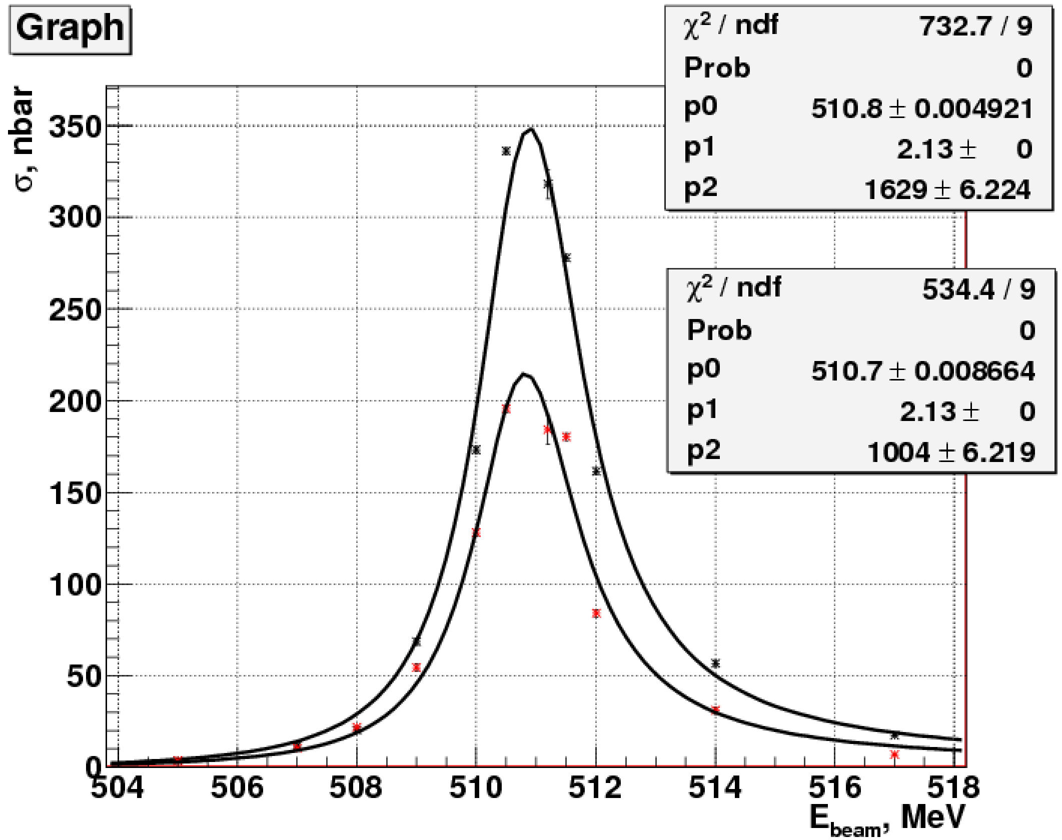


1 Beam pipe, 2 Tracking (drift and proportional chamber), 3 Aerogel Cherenkov counters, 4 NaI calorimeter, 5 Vacuum phototriodes, 6 Absorber, 7 Streamer tubes, 8 Iron filter, 9 Scintillation counters, 10 SC focusing solenoids

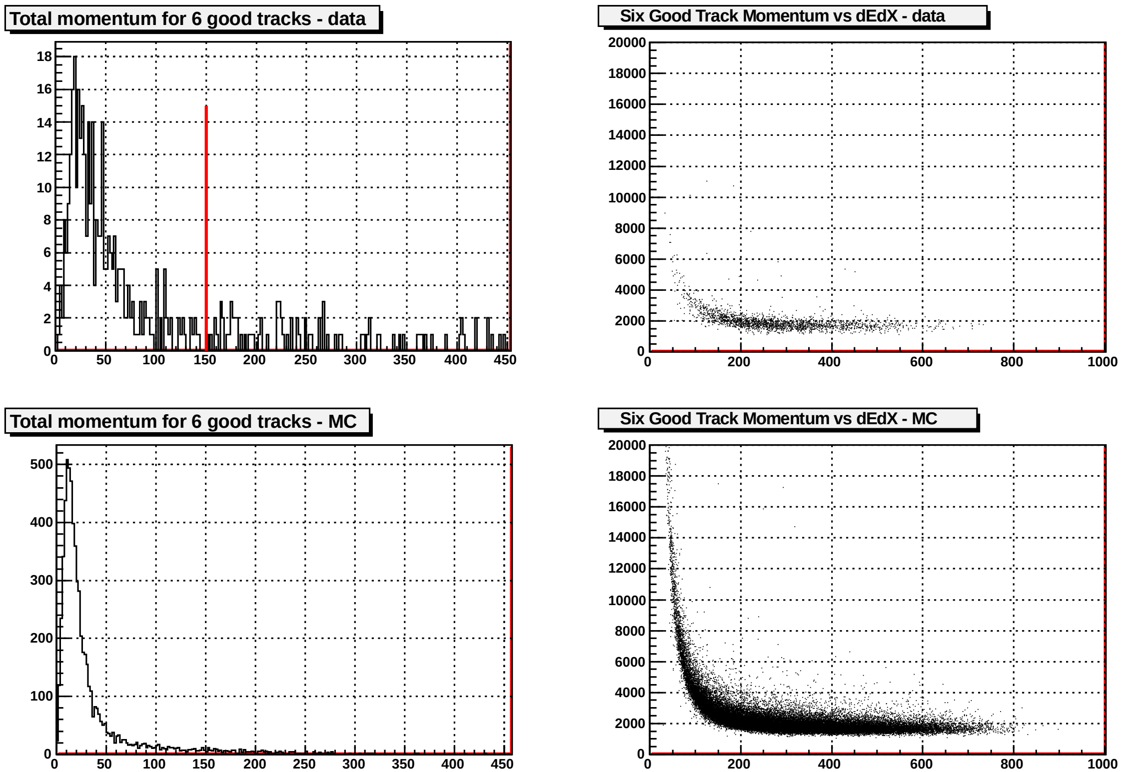
Data Taking

- In 2010 a scan was performed from the ϕ meson to 2 GeV with a step of 100 MeV and $\sim 5\ \text{pb}^{-1}$ in total
- In 2011 two scans (up and down) were performed from the ϕ meson to 2 GeV with a step of 25 MeV and $\sim 500\ \text{nb}^{-1}$ per point
- A step was smaller near the $p\bar{p}$ threshold
- ϕ meson, 1050, 1075, 1100, 1125, . . ., 1800, 1825, 1850, 1870, 1890, 1900, 1925, 1950, 1975, 2000
- 56 points $\Rightarrow \sim 22\ \text{pb}^{-1}$
- 15 points at the ϕ meson from 1010 to 1034 MeV, 1.9 pb^{-1} in total for detector studies and software tests

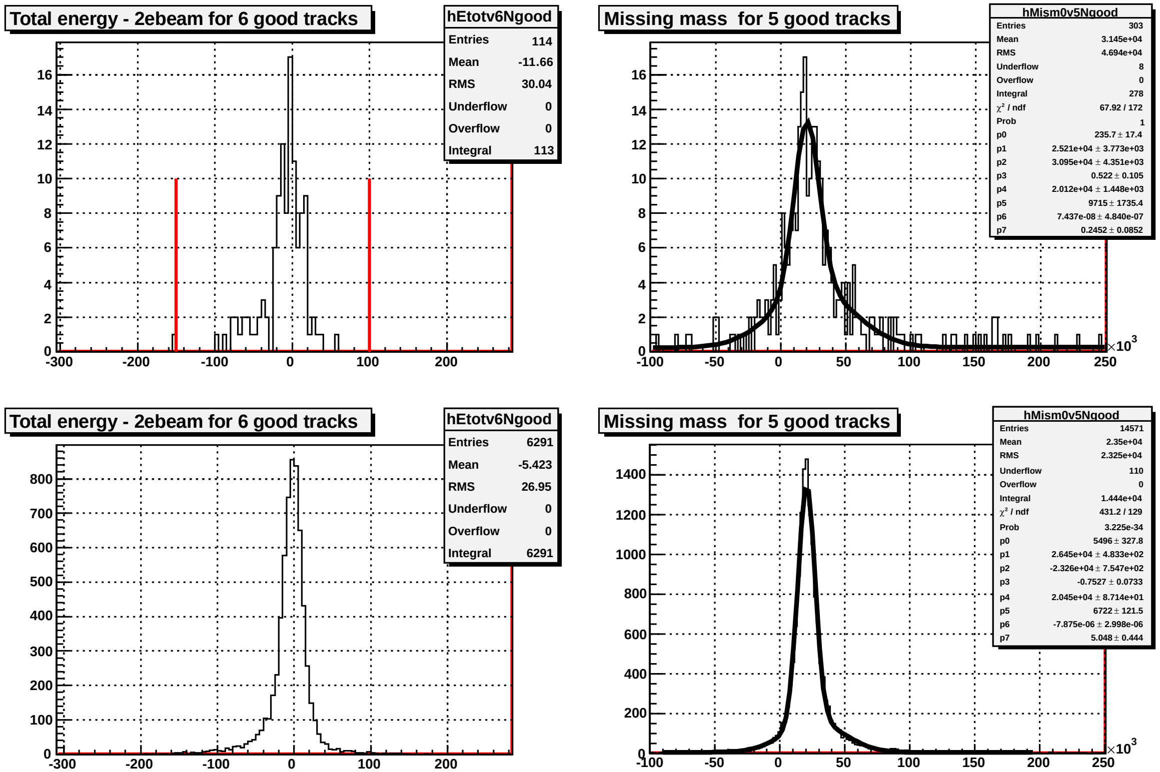
$\phi \to K^+K^-,\ K_S K_L$ at CMD-3



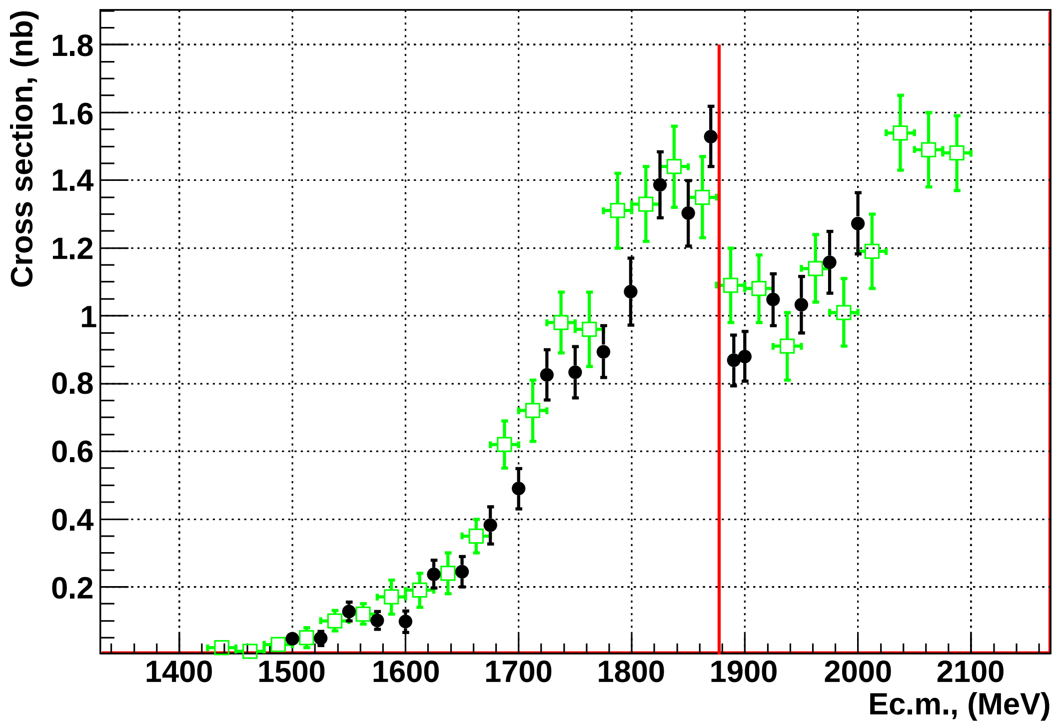
Selection of $3\pi^+3\pi^-$ Events at CMD-3 – I



Selection of $3\pi^+3\pi^-$ Events at CMD-3 – II

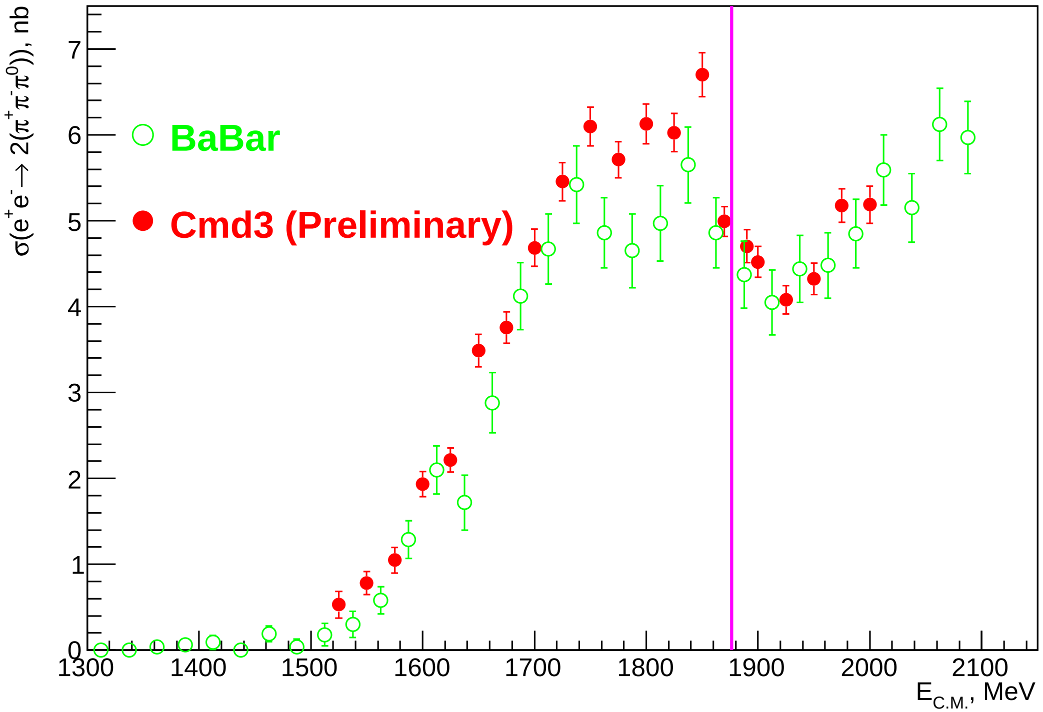


Cross section of $e^+e^- \to 3\pi^+3\pi^-$ at CMD-3



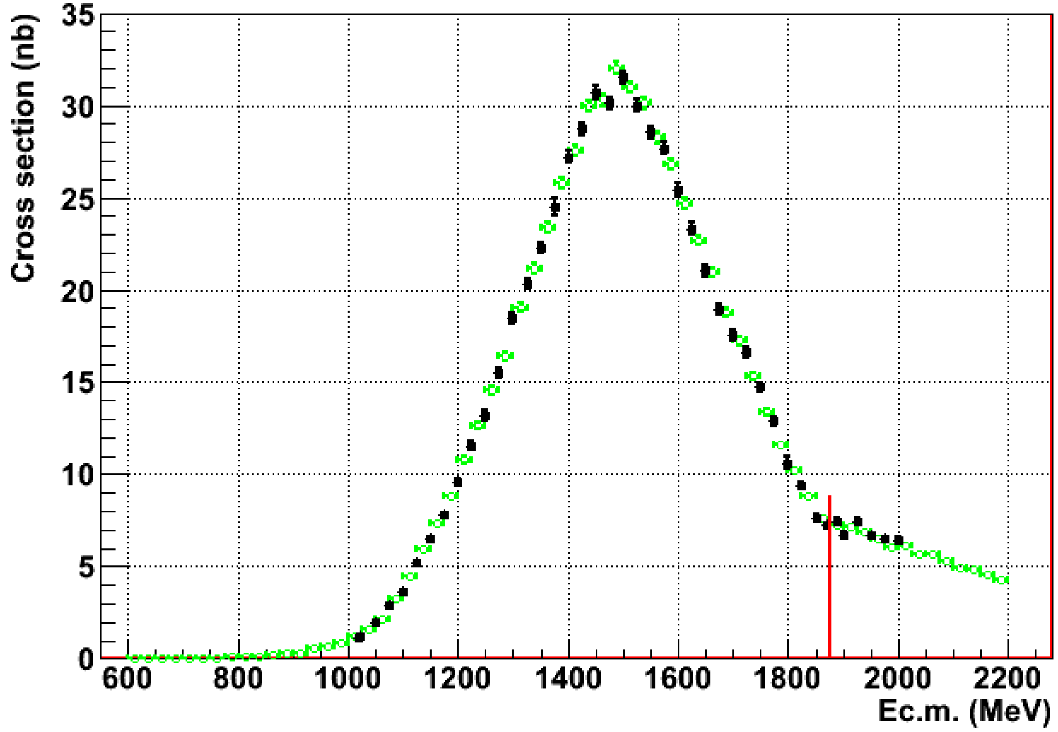
Good agreement and comparable precision to BaBaR, a dip at 1900 MeV confirmed, baryonium or $\rho(1900)$?

Cross section of $e^+e^- \to 2(\pi^+\pi^-\pi^0)$ at CMD-3



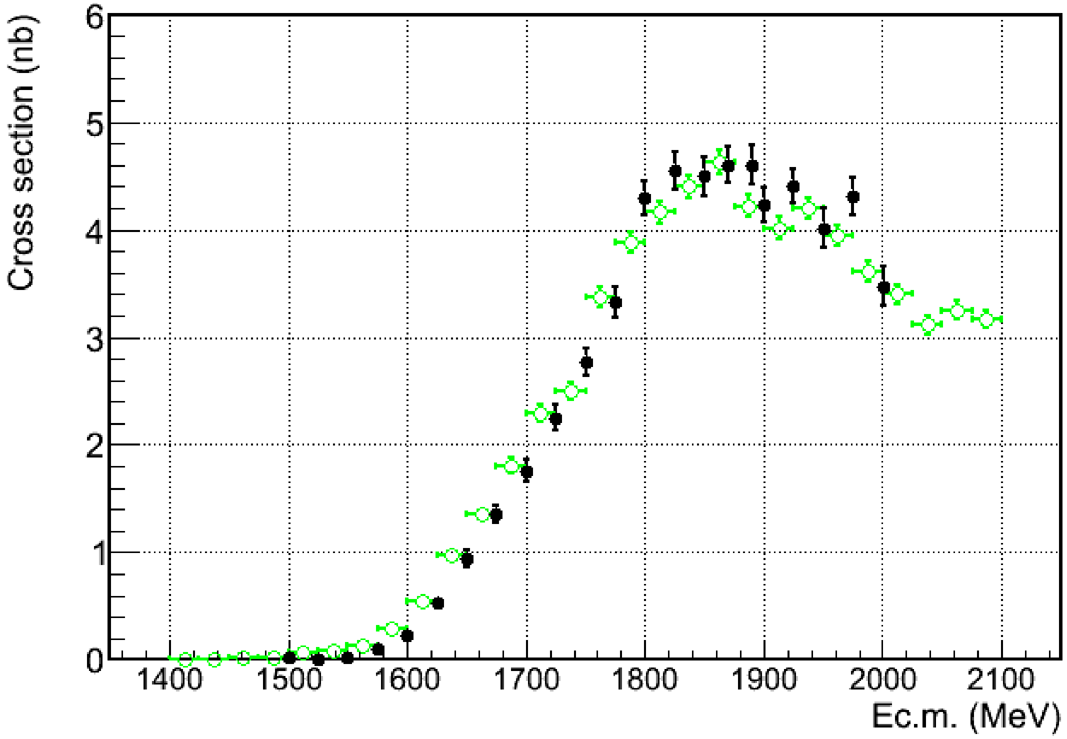
A dip at 1900 MeV confirmed in one more final state

Cross section of $e^+e^- \to 2(\pi^+\pi^-)$ at CMD-3



Good agreement and comparable precision to BaBaR, $\rho(1450)$ and $\rho(1700)$?

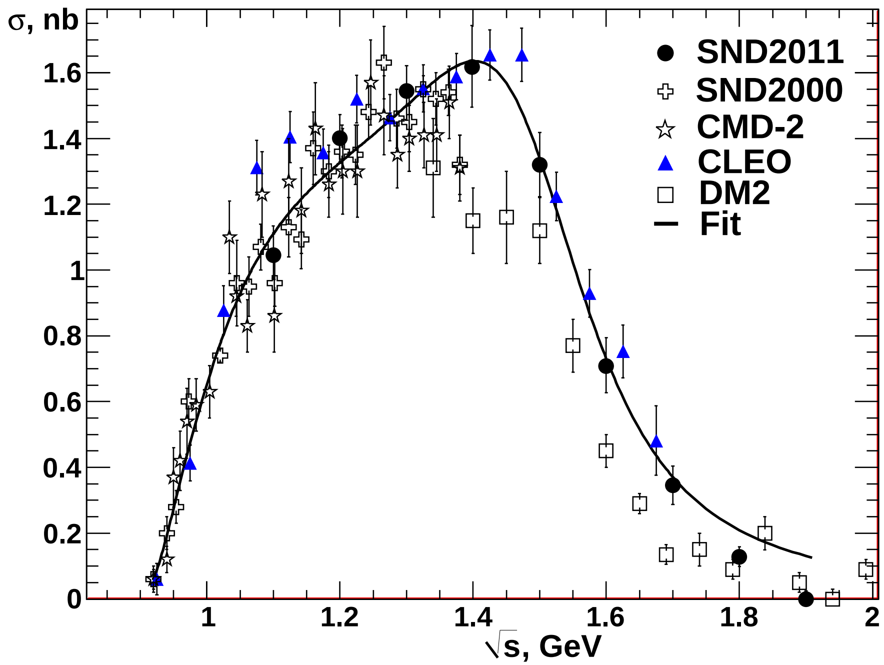
Cross section of $e^+e^- \to K^+K^-\pi^+\pi^-$ at CMD-3



Good agreement and comparable precision to BaBaR,

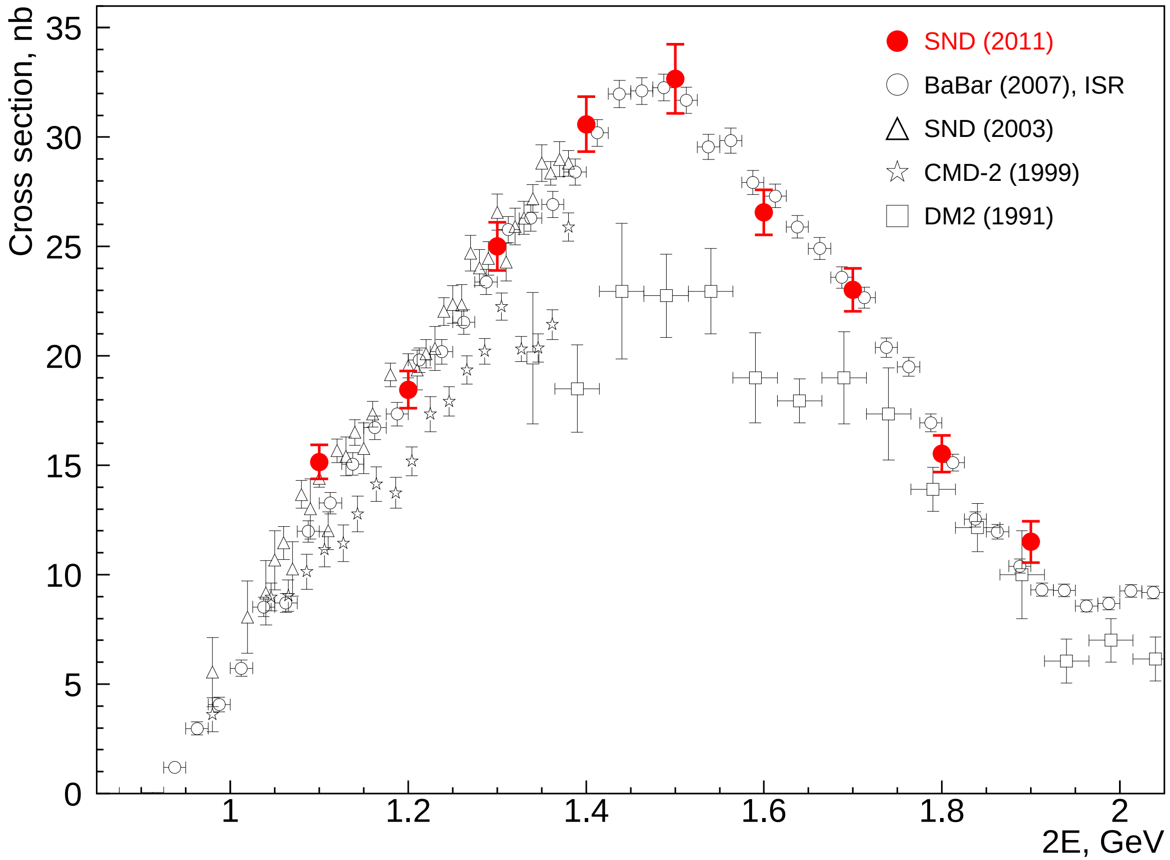
Is there a $\phi(1680)$?

Cross section of $e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$ at SND



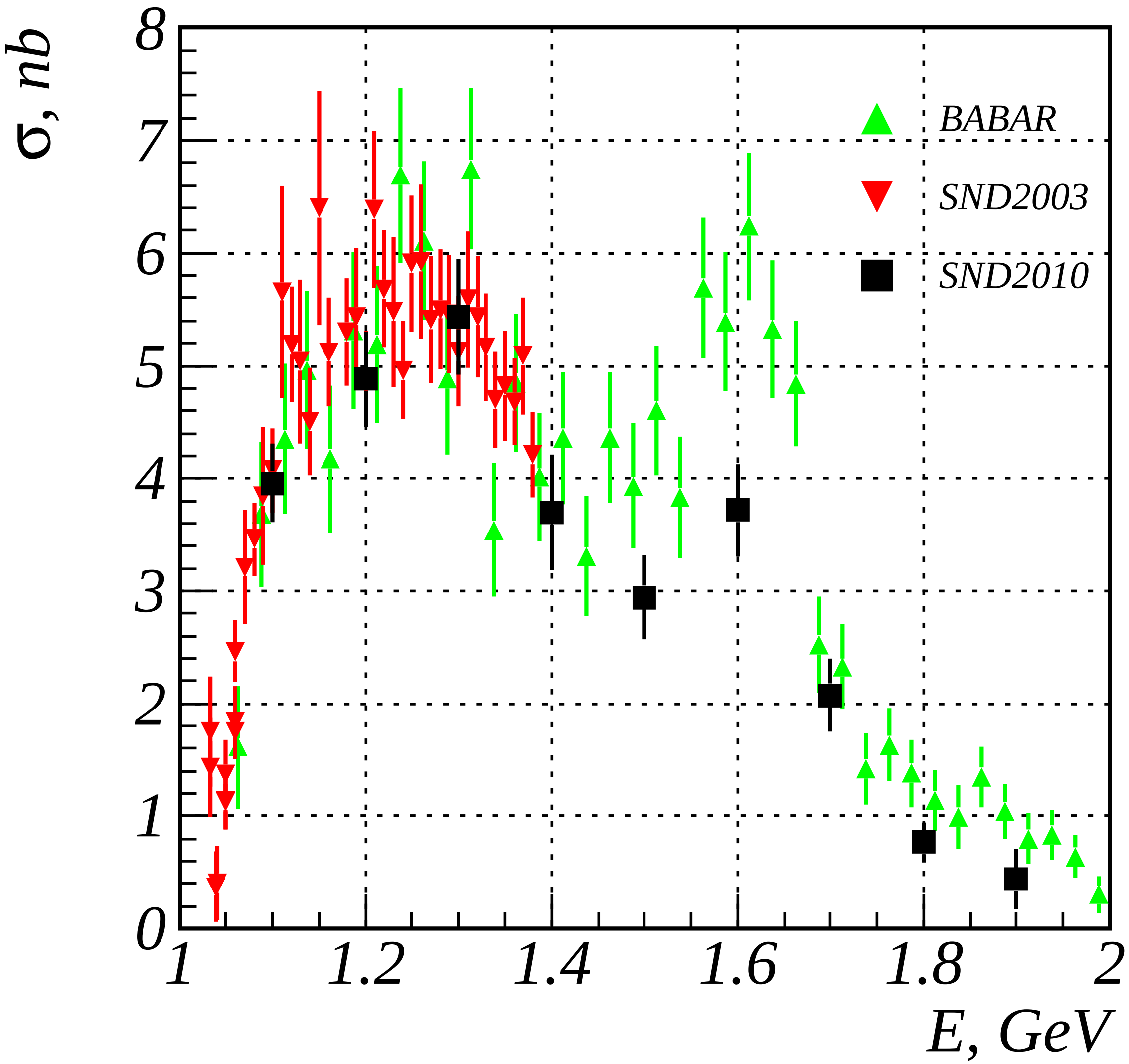
DM2 points are obviously lower

Cross section of $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$ at SND

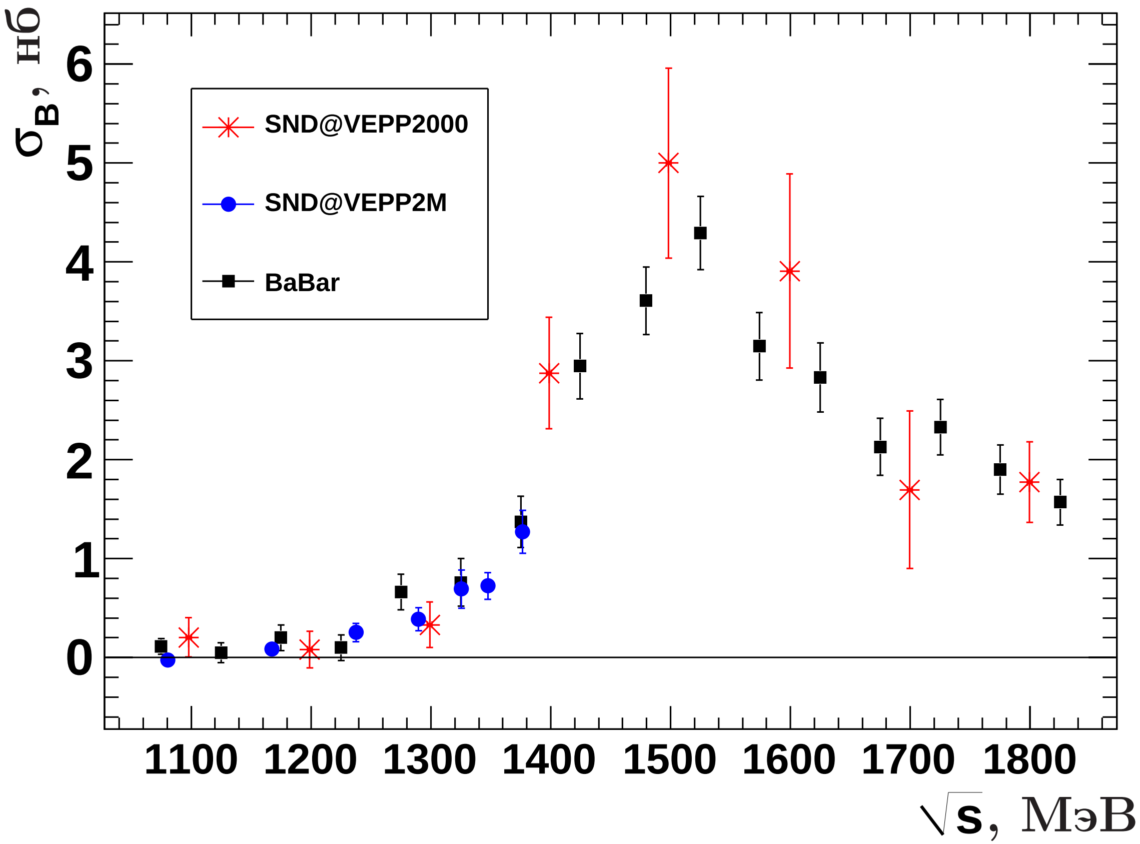


DM2 points are obviously lower

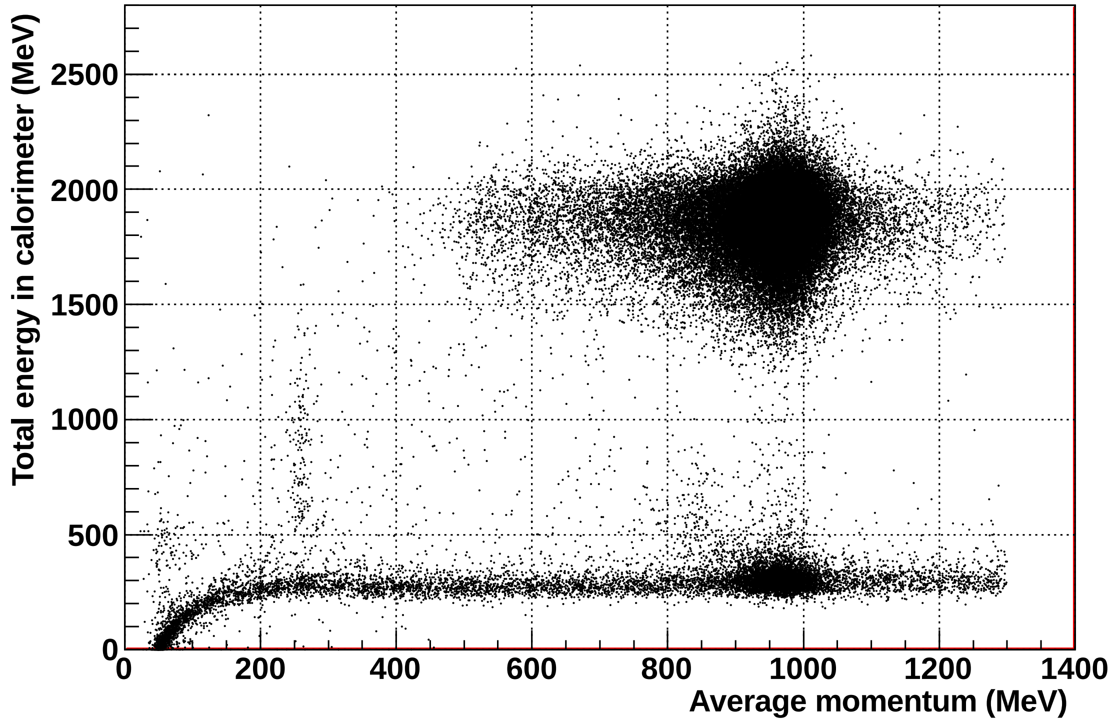
Cross section of $e^+e^- \to \pi^+\pi^-\pi^0$ at SND

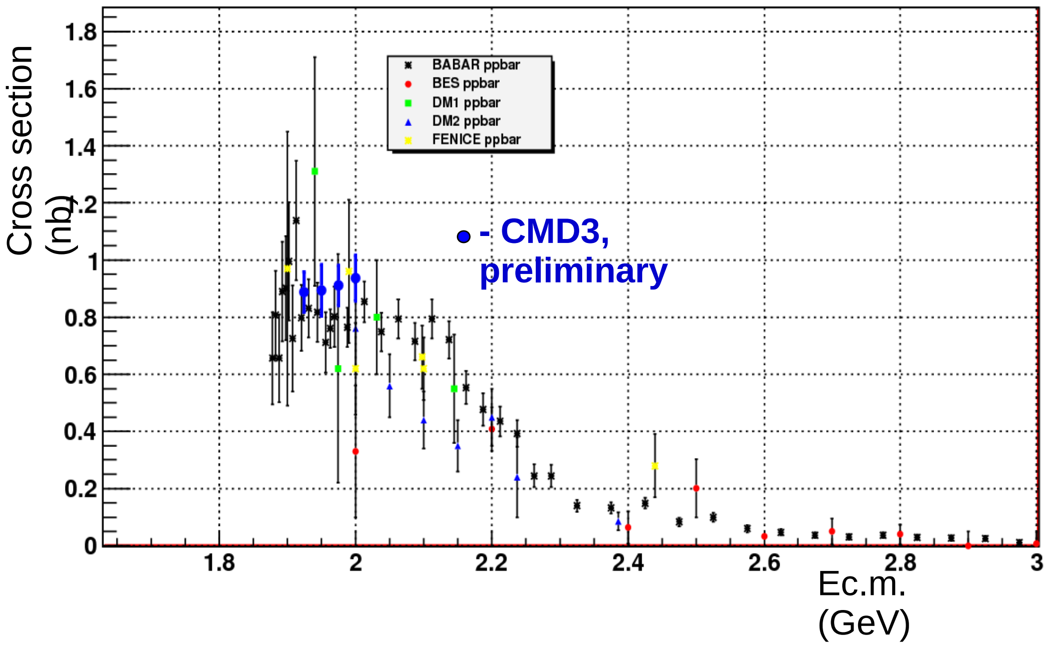


Cross section of $e^+e^- \to \eta\pi^+\pi^-$ at SND



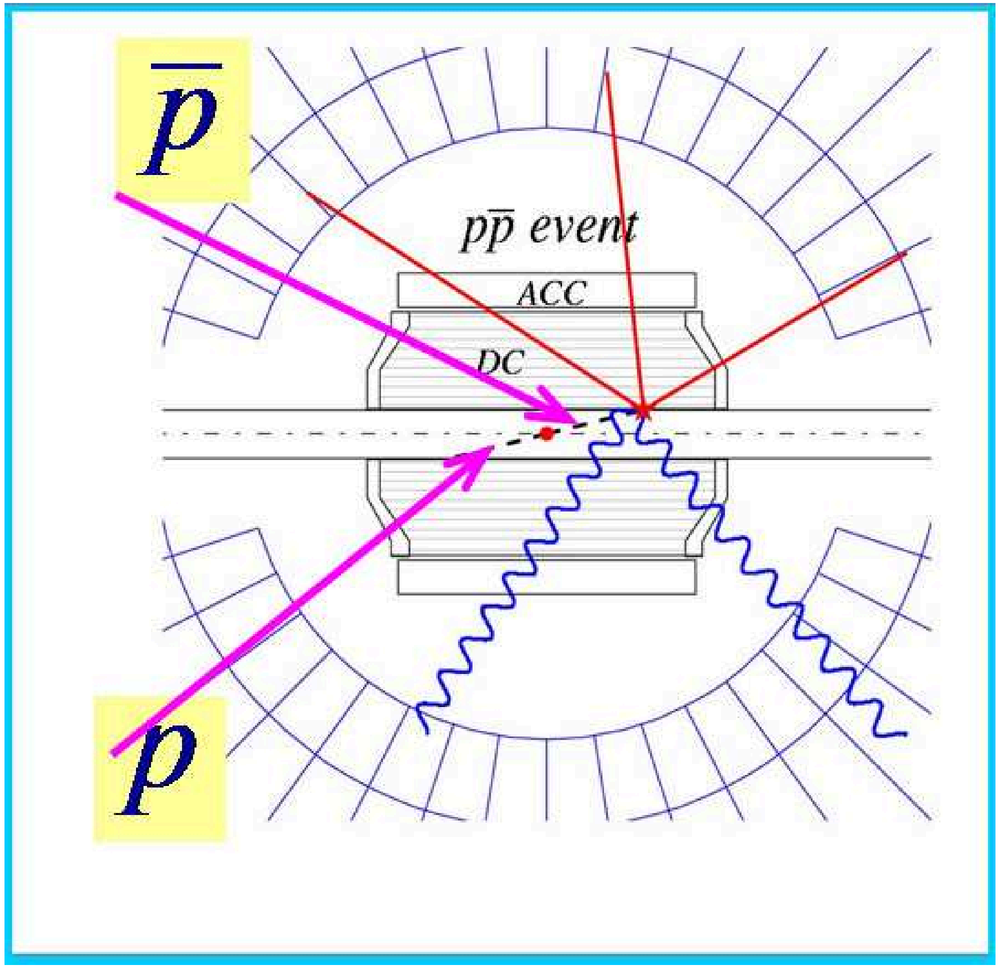
Selection of $e^+e^- \to p\bar{p}$ Events at CMD-3



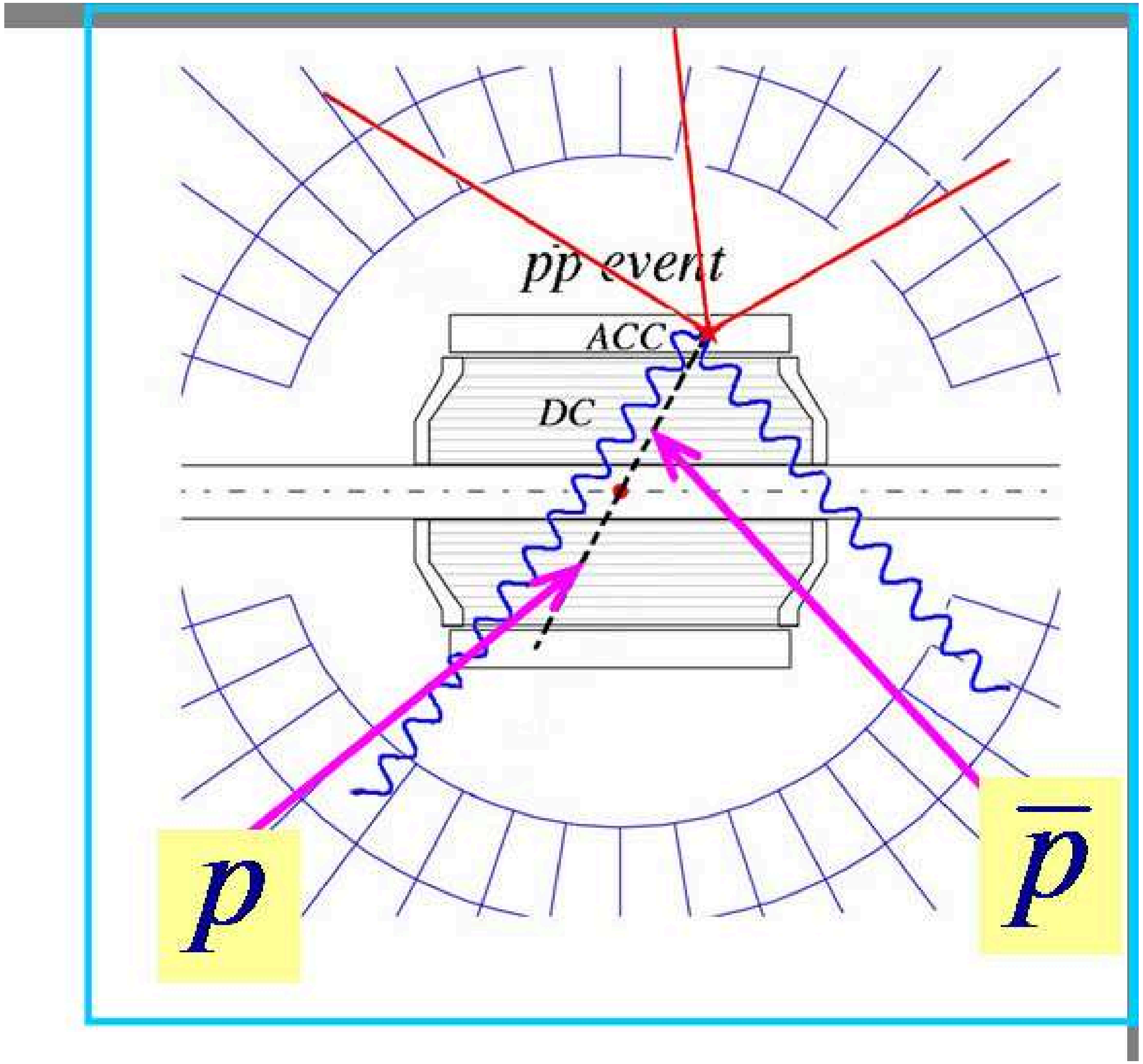


$\sigma(e^+e^- \to p\bar{p})$ is consistent with that of BaBaR and older measurements

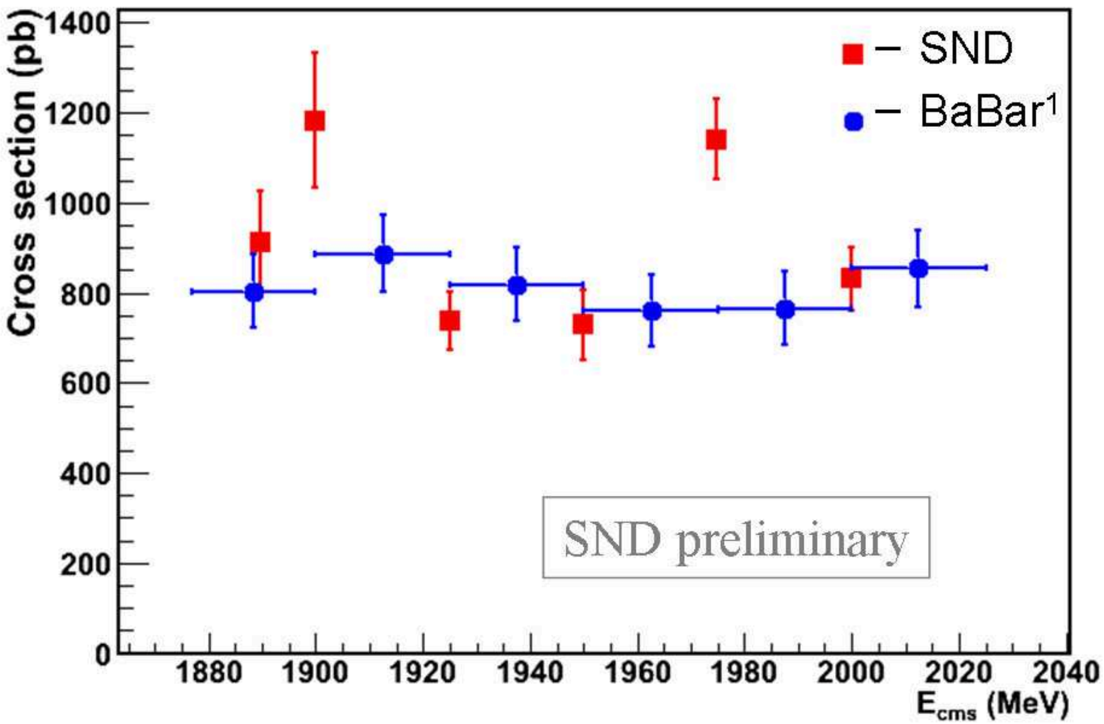
An $e^+e^- \rightarrow p\bar{p}$ event at SND - I



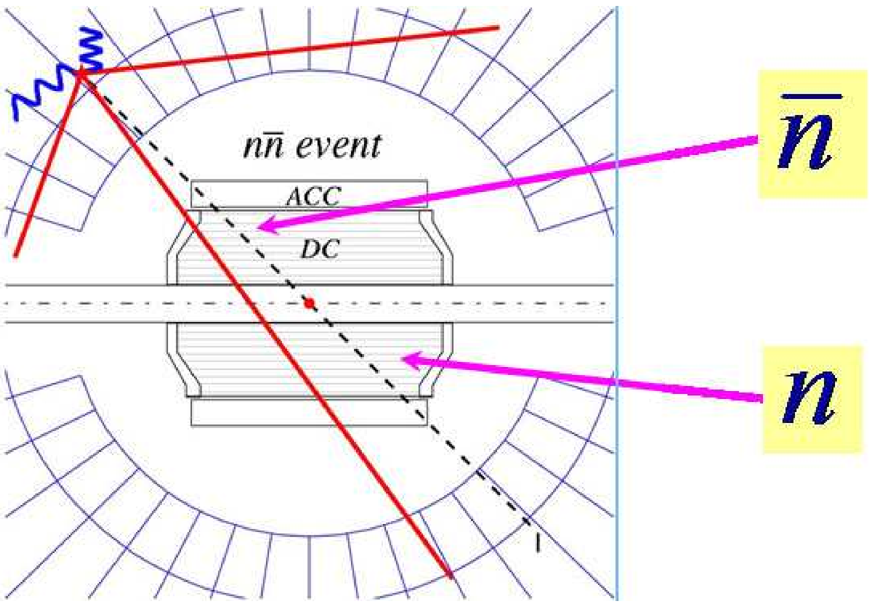
An $e^+e^- \to p\bar{p}$ event at SND - II



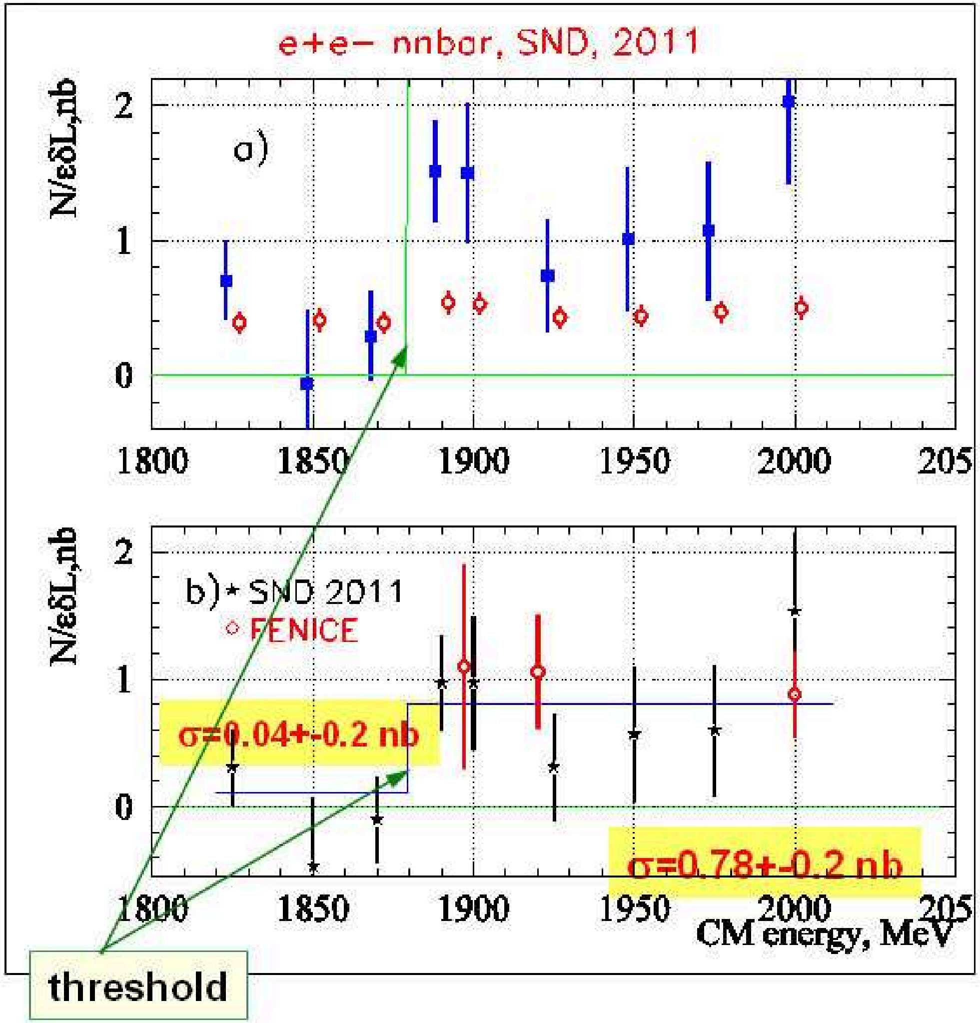
Cross section of $e^+e^- \to p\bar{p}$ at SND



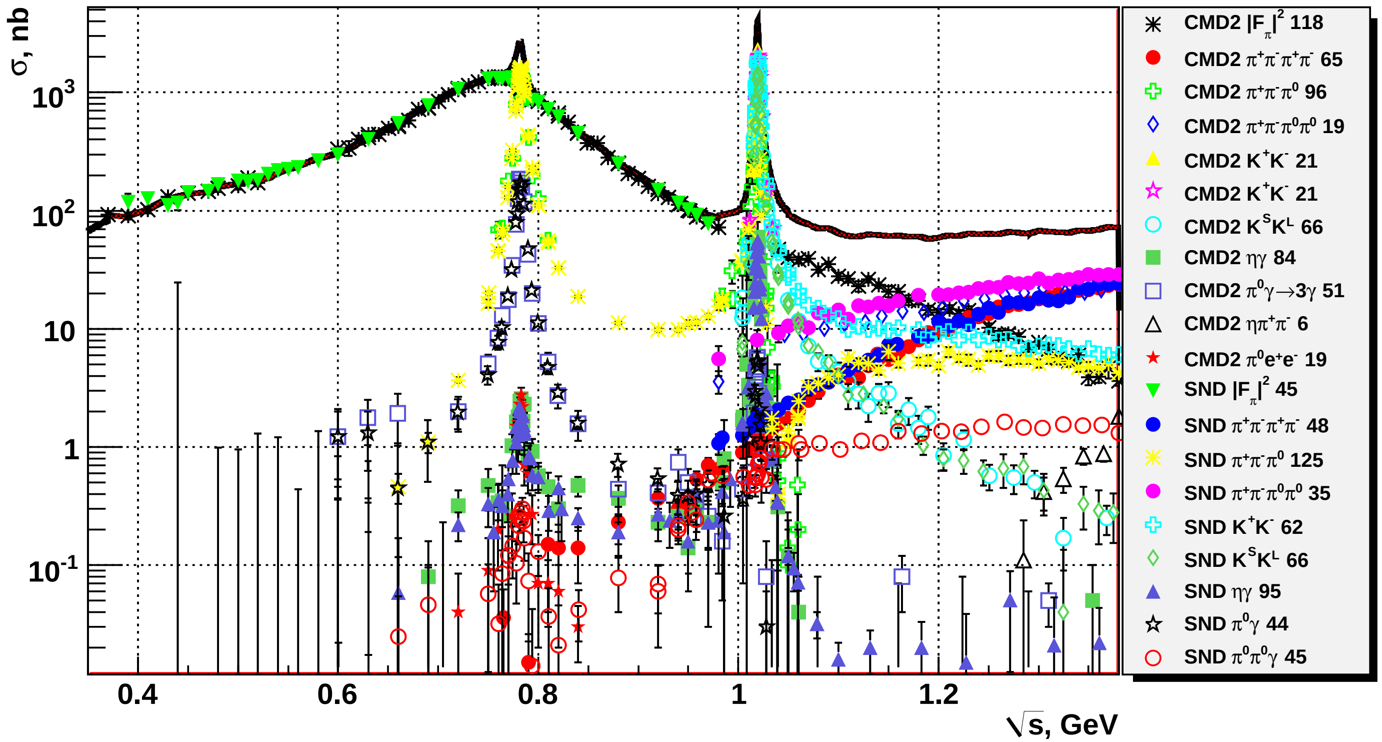
An $e^+e^- \to n\bar{n}$ event at SND



Cross section of $e^+e^- \to n\bar{n}$ at SND



All cross sections from VEPP-2M



Conclusions on VEPP-2000

- VEPP-2000 has been successfully commissioned with a luminosity of $2 \cdot 10^{31}$ cm^{-2}s^{-1} achieved
- Two detectors, SND and CMD-3, are taking data, we start understanding their performance
- The integrated luminosity collected between 1 and 2 GeV already exceeds the one previously achieved in direct scans with precision close to BABAR
- CMD-3 measures $\sigma(3\pi^+3\pi^-,\ 2\pi^+2\pi^-2\pi^0)$ and confirms a dip at 1900 MeV
- Hundreds of $e^+e^- \to p\bar{p},\ n\bar{n}$ events observed near threshold
- In a few years we hope to measure $\sigma(e^+e^- \to \text{hadrons})$ with high accuracy and significantly improve the precision of $a_\mu^{\text{had,LO}}$

Super-$\tau - c$ factory – basic features

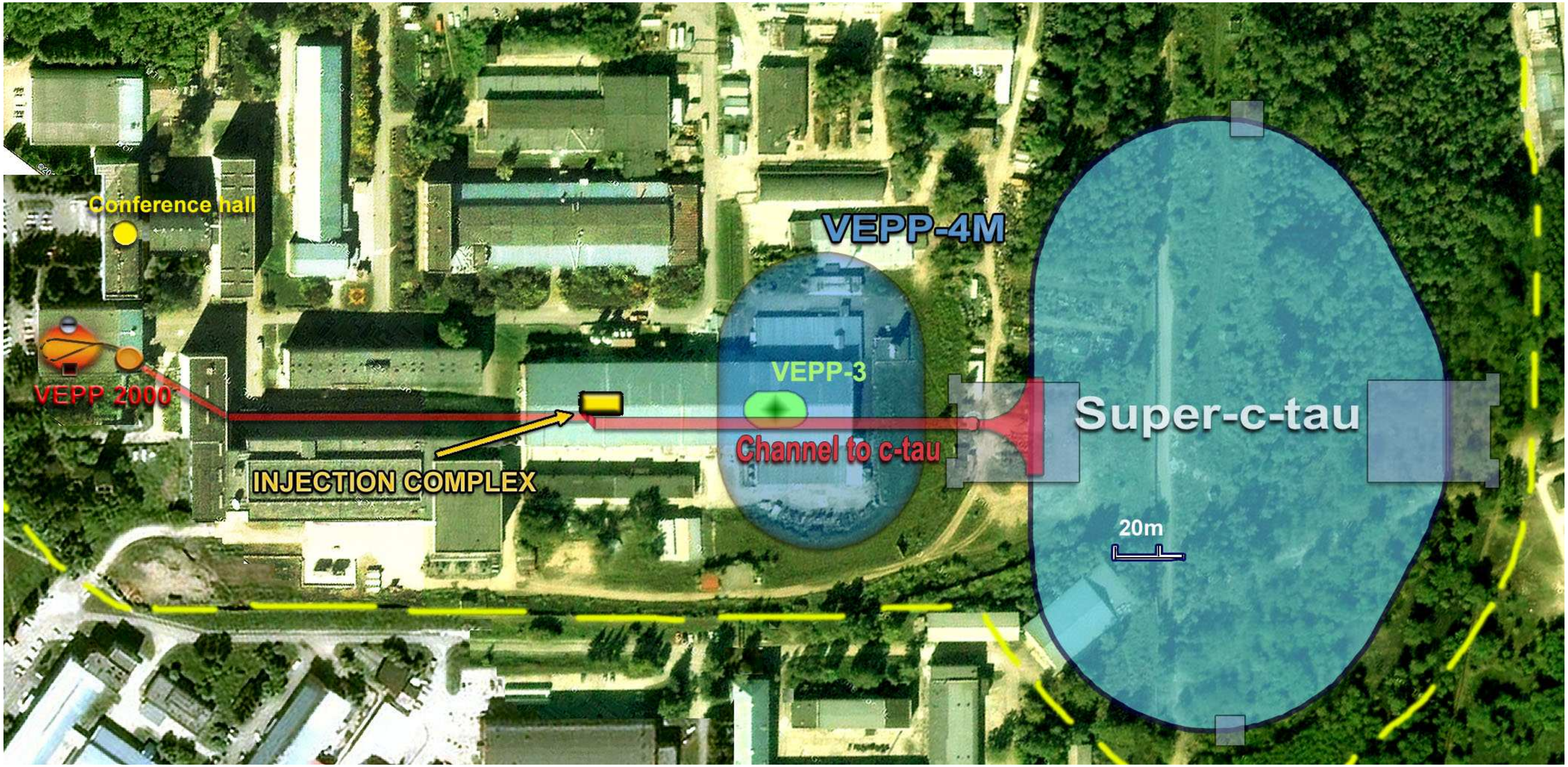
A new Crab Waist collision scheme successfully tested at DAFNE is a base for both Super-B factories and allows 10^{35} cm^{-2} s^{-1} to be reached $\Rightarrow$ unprecedented number of $c\bar{c}$ and $\tau^+\tau^-$ pairs produced with low background

- Center-of-mass energy W from 2 to 5 GeV
- Superconducting wigglers provide optimal luminosity at all W
- 5×10^{34} cm^{-2} s^{-1} at 2 GeV to 10^{35} cm^{-2} s^{-1} at the $\tau^+\tau^-$ production threshold
- Longitudinal polarization of the e^- beam
- The W calibration with $(5-10) \times 10^{-5}$ accuracy

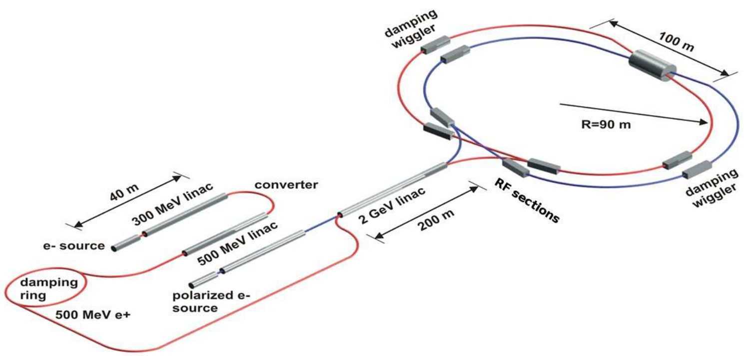
Super-$\tau - c$ factory – physics issues

- $D\bar{D}$ mixing
- Search for CPV in charm decays
- Rare and forbidden decays of the open charm mesons
- Study of standard charmonia and charmonium-like states
- Tests of SM in τ decays
- Search for CP/T and LF violation in τ decays
- Study of light mesons between 1 and 3 GeV, scan and ISR
- Production of polarized antinucleons
- A high chance to get funds from the budget,
  collaborators are very welcome!!!

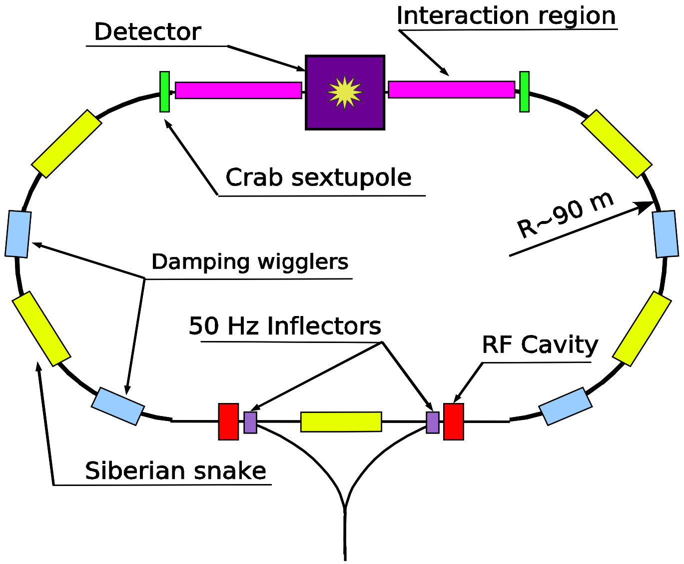
The general view of BINP



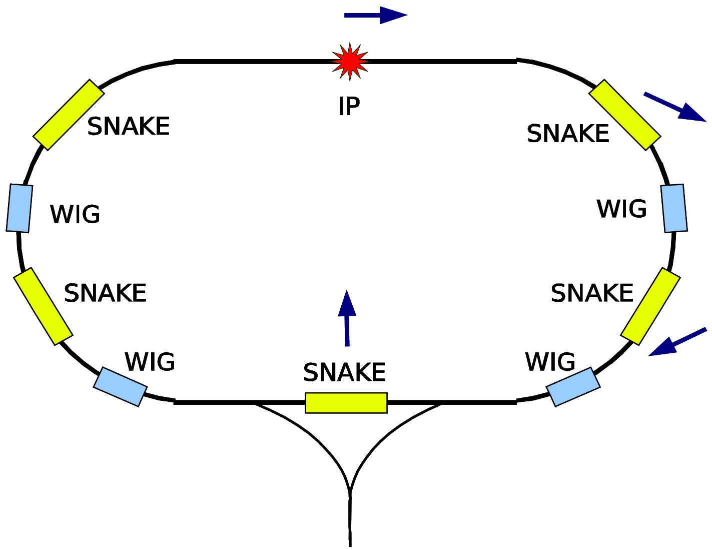
Scheme of the Super-tau-charm factory



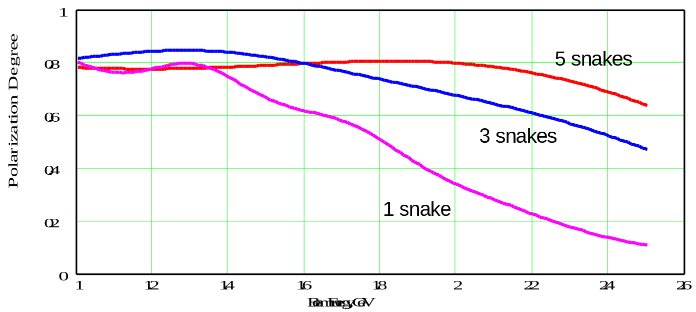
The new collider



Obtaining polarization – I



Obtaining polarization – II



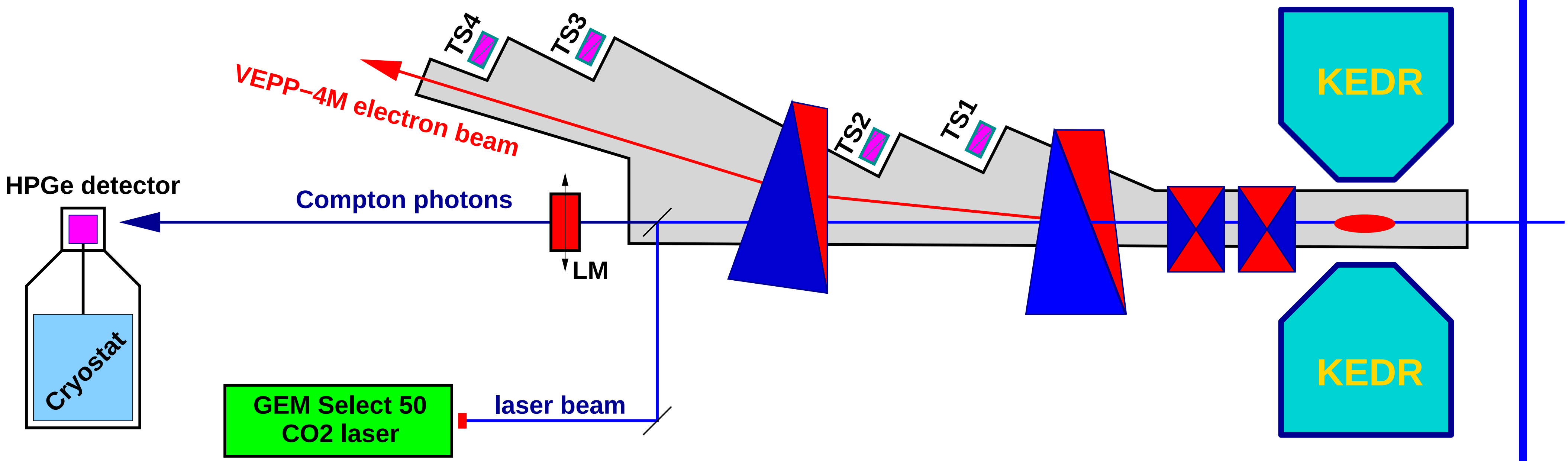
Conclusions

- The KEDR detector at VEPP-4M measured with high precision masses of J/ψ and $\psi(2S)$ as well as their total and leptonic widths; no narrow resonances were found between 1.85 GeV and J/ψ; interference effects are important for measurements of mass and width of $\psi(3770)$, there is principal ambiguity for its leptonic width
- The upgraded e^+e^- collider VEPP-2000 started running with two detectors (CMD-3 and SND) at a maximum W of 2 GeV and $\mathcal{L}$ of $2 \cdot 10^{31}$ cm^{-1}s^{-1}. Multihadronic cross sections have been measured with precision comparable to BaBar. Cross sections of $p\bar{p}$, $n\bar{n}$ have been determined near threshold
- An ambitious project of the Super-tau-charm factory with W between 2 and 5 GeV, $\mathcal{L}$ of 10^{35} cm^{-1}s^{-1} and longitudinal polarization of the e^- beam has been developed. There are good chances of its support by the Russian government.

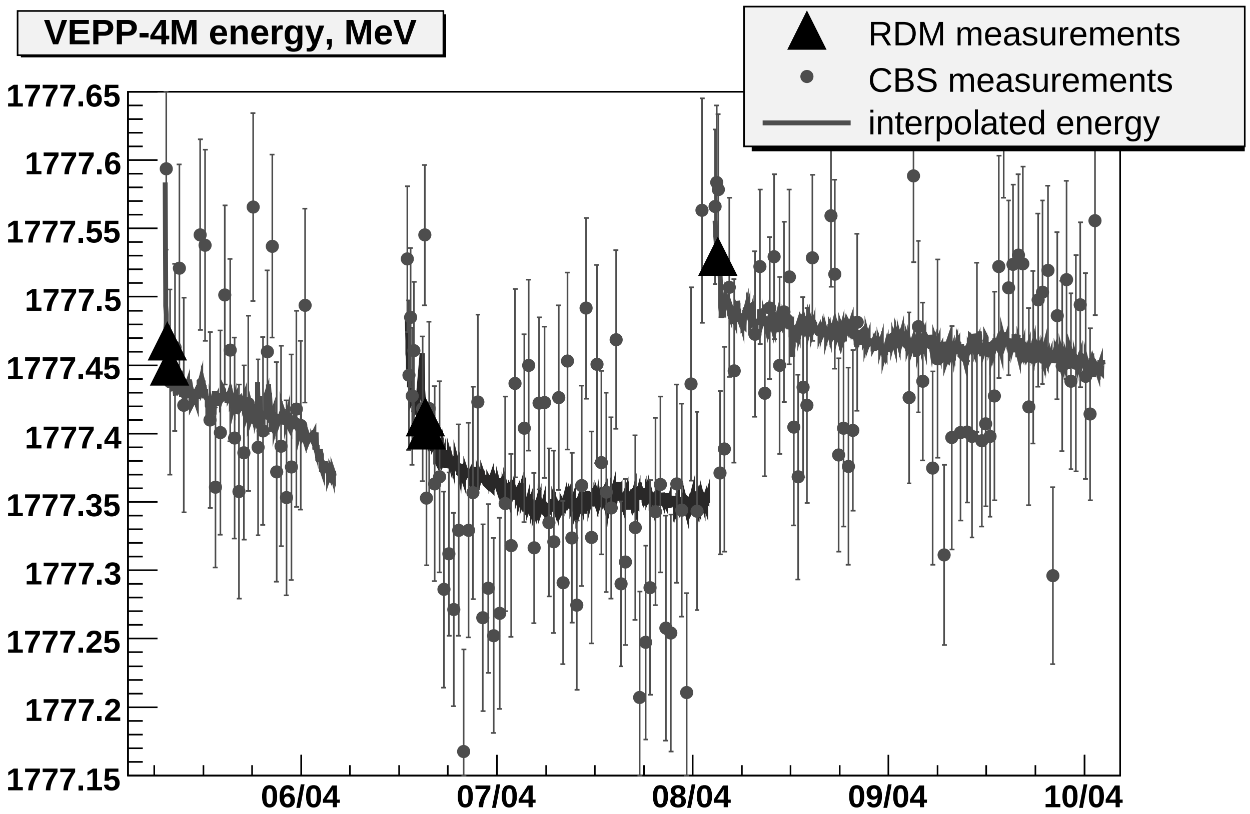
Backup slides

Compton Backscattering Monitor

Realized at BESSY-I in 1987



VEPP-4M Energy Behaviour



During the run, E measured by CBS and from interpolation

Systematic errors for $\Gamma_{e^+e^-}\Gamma_{e^+e^-}/\Gamma$ at J/ψ

Source	σ, %	Source	σ, %
Peak position	< 0.1	Angle θ	0.2
Energy spread	0.2	Interference	0.2
Energy per point	0.3	Bhabha MC	0.4
DC selection	0.7	PHOTOS	0.4
LKr selection	0.2	BG from $J/\psi \to$ hadrons	0.2
Luminosity	0.8	Fit	0.2
Trigger	0.5	Total	1.4

Systematic uncertainties for $\Gamma_{e^+e^-}\Gamma_{\mu^+\mu^-}/\Gamma$ at J/ψ

Source	$\sigma, \%$	Source	$\sigma, \%$
Energy spread	0.5	Angle θ	0.2
Energy per point	0.5	Bhabha MC	0.6
$\epsilon_{ee} \neq \epsilon_{\mu\mu}$	0.8	PHOTOS	0.5
L calibration (abs.)	0.7	BG (non-resonant)	0.1
L measurement (rel.)	0.8	BG from $J/\psi \to$ hadrons	0.6
Trigger	0.5	Total	1.9

Systematic uncertainties in the J/ψ mass (keV)

Uncertainty source	2002	2005	Common
Energy spread variation	3.4	1.0	1.0
Energy assignment	3.8	4.5	2.0
Beam misalignment in the I.P.	1.8	1.2	1.2
e^+-, e^--energy difference	< 2.0	5.5	2.0
Symmetric dL/dE shape distortion	< 1.3	< 1.5	1.0
Asymmetric dL/dE shape distortion	2.7	2.2	2.2
Beam potential	1.0	1.5	1.0
Single energy calibration	0.7	1.5	0.7
Vertical orbit disturbances	0.6	0.9	0.6
Detection efficiency instability	2.3	2.3	1.2
Luminosity measurements	2.3	4.0	0.5
Interference in the hadronic channel	1.7	1.5	1.5
Sum in quadrature	≈ 6.0	≈ 7.9	≈ 4.7

Systematic uncertainties in the $\psi(2S)$ mass (keV)

Error source	2002	2004	2006	Common
Energy spread variation	2.0	1.5	1.5	1.5
Energy assignment	4.3	4.0	6.0	4.0
Beam misalignment in the I.P.	5.1	4.0	4.0	4.0
e^+-, e^--energy difference	9.0	7.0	7.0	7.0
Symmetric dL/dE shape distortion	< 2.0	< 1.5	< 1.5	< 1.2
Asymmetric dL/dE shape distortion	3.5	4.2	4.2	3.5
Beam potential	1.0	1.5	1.5	1.0
Single energy calibration	0.8	0.6	0.6	0.6
Vertical orbit disturbances	0.5	0.6	0.6	0.6
Detection efficiency instability	2.0	2.0	1.0	1.0
Luminosity measurements	3.0	3.7	2.0	0.5
Interference in the hadronic channel	1.5	1.5	1.5	0.8
Sum in quadrature	≈ 12.8	≈ 11.2	≈ 11.6	≈ 10.1

Measurement of $\Gamma_{ee} \cdot \mathcal{B}(\psi(2S) \to hadrons)$ – II

Source	Scan 1	Scan 2	Scan 3	Common 1-2	Common
Lumin.	1.6	1.7	1.2	1.6	0.5
MC gener.	1.0	1.0	1.1	1.0	1.0
Trigger	0.2	0.2	0.2	0.2	0.2
Selection	0.5	0.3	0.6	0.3	0.3
MC nucl.	0.2	0.2	0.3	0.2	0.2
Energy	0.15	0.18	0.60	0.15	0.15
Fit	0.3	0.3	0.3	0.3	0.3
Total	2.0	2.1	1.9	2.0	1.2

Determination of $\psi(3770)$ Parameters – III

Source	Mass, MeV	Width, MeV	Γ_{ee}, %
$\mathcal{B}_{nD\bar{D}}$	0.3	0.1	8.0
R_0 variation	0.3	0.3	2.0
$\Gamma_{D^0\bar{D}^0}/\Gamma_{D^+\bar{D}^-}$	0.1	0.1	0.4
$D, \bar{D}$ mass	0.06	0.04	0.3
$\sigma_{D\bar{D}\pi}$	0.15	0.05	1.
Fit	0.05	0.1	0.5
Event selection	0.3	0.3	3.
Luminosity	0.1	0.1	2.
Energy assignment	0.03	–	–
Total	0.6	0.5	9.1