PROCEEDINGS OF SCIENCE

Experiments at the VEPP-2000 e+e- Collider

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Beginning from 2011, experiments are carrying out at the low energy e^+e^- collider VEPP-2000 in the energy range 0.3÷2.0 GeV. New results on $e^+e^- \to$ *hadrons* cross sections are presented, including $e^+e^- \to \pi^+\pi^-, K^+K^-, \pi^+\pi^-\pi^0, \eta K^+K^-, p\bar{p}, n\bar{n}$ etc ... Applications of the obtained results are discussed.

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Experiments. The collider VEPP-2000 [1] (Fig.1) is intended for e^+e^- experiments in the center of mass (c.m.) energy range $E = 0.3 - 2.0$ GeV. In comparison with its predecessor VEPP-2M [2] it has higher energy and higher luminosity up to $10^{31}\text{cm}^{-2}\text{sec}^{-1}$ at 2 GeV. Two detectors

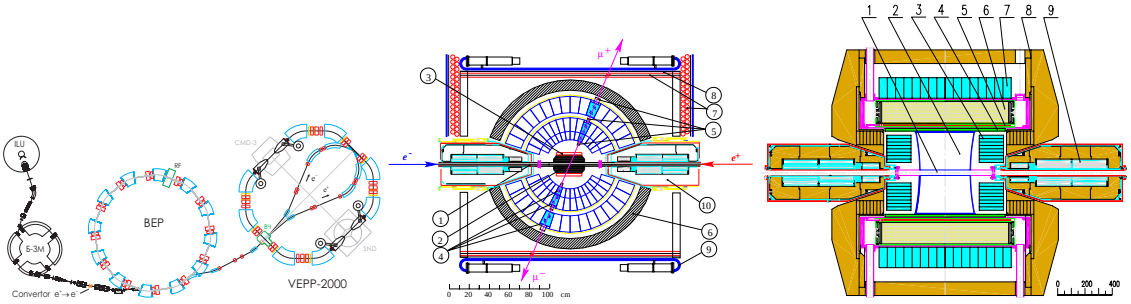

Figure 1: Left: VEPP-2000 collider. ILU - 3 MeV linear accelerator, B-3M - 200 Mev electron synchrotron, BEP - booster for electrons and positrons. **Middle**: SND detector. 1 - beam pipe, 2 - tracker, 3 - aerogel Cherenkov counter, 4 - NaI(Tl) EMC, 5 - photodetectors, 6 - iron, 7-9 - muon detector, 10 - SC solenoides. **Right**: CMD3 layout. 1 - beam pipe, 2 - tracker, 3 - BGO EMC, 4 - Z-chamber, 5 - magnet coil, 6 - LXE EMC, 7 - CsI(Tl) EMC, 8 - yoke, 9 - collider solenoid. μ-system is not shown.

SND [3] and CMD-3 [4], shown in Fig.1, perform experiments at VEPP-2000.

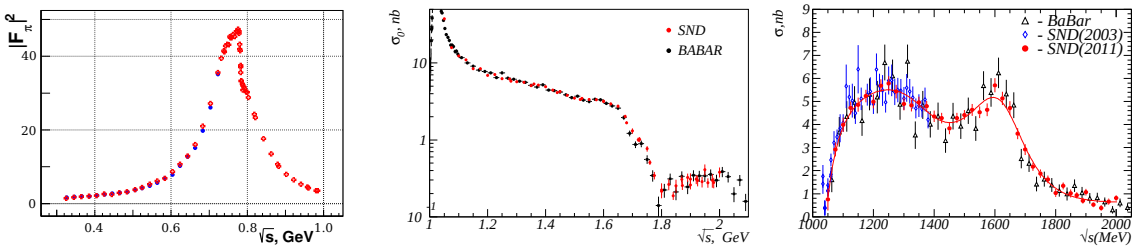

Figure 2: Left: The pion electromagnetic form factor, measured by CMD-3 [12]. **Middle**: The cross section of the $e^+e^- \to K^+K^-$ process, measured by SND. **Right**: The cross section of the $e^+e^- \to \pi^+\pi^-\pi^0$ process from SND.

The physical program for VEPP-2000 includes precise measurements of all major channels of e^+e^- annihilation to hadrons and hence the value R=$\sigma(e^+e^- \to hadrons)/\sigma(e^+e^- \to \mu^+\mu^-)$ used in calculation of the muon anomaly $(g-2)_\mu$ and the fine structure constant at Z-mass $\alpha_{em}(s = M_Z^2)$. Other items of the program are: the comparison of the $e^+e^- \to hadrons$ isovector cross sections with the τ decay spectra; study of the production and decays of the excited vector states $\rho\prime_s, \omega\prime_s, \phi\prime_s$; study of the nucleons production at the threshold.

In the series of runs in 2010-2013 each detector accumulated about 70 pb^{-1} of data. Some physical results are published already [5, 6, 7, 8, 9, 10, 11]. In this talk recent SND and CMD-3 results are presented.

Productions of mesons. The $e^+e^- \to \pi^+\pi^-$ cross section is measured by CMD-3 (Fig.2) using $\sim 10^7$ events. The systematic accuracy is limited mainly by $e/\pi/\mu$ separation, fiducial volume determination, beam energy measurement and radiative correction calculation. Its total value is expected to be $\sim 0.3\%$ [12]. The process $e^+e^- \to K^+K^-$ is studied by SND (Fig.2). Charged kaons are identified by the aerogel Cherenkov counter [13] and dE/dx measurements in

drift chamber. The complex cross section energy dependence in Fig.2 is due to the contribution of $\rho\prime, \rho\prime\prime, \omega\prime, \omega\prime\prime, \phi\prime$ resonances and their interference. Our data agree with previuos Babar results [14]. The systematics uncertainty is estimated to be 2-3%. The isocalar process $e^+e^- \to \pi^+\pi^-\pi^0$ has been studied by SND above 1.05 GeV [15]. The cross section (Fig.2) is entirely described by two excited ω-like states: $\omega(1420)$ and $\omega(1650)$. The $e^+e^- \to \eta K^+K^-$ cross section, measured by CMD-3 [12] (Fig.3), agrees well with earlier measurements. The $e^+e^- \to \eta\pi^+\pi^-\pi^0$ cross section, measured by SND for the first time, is shown in Fig.3. The $\omega(1680)$ and $\phi(1650)$ states give the major contribution in this process.

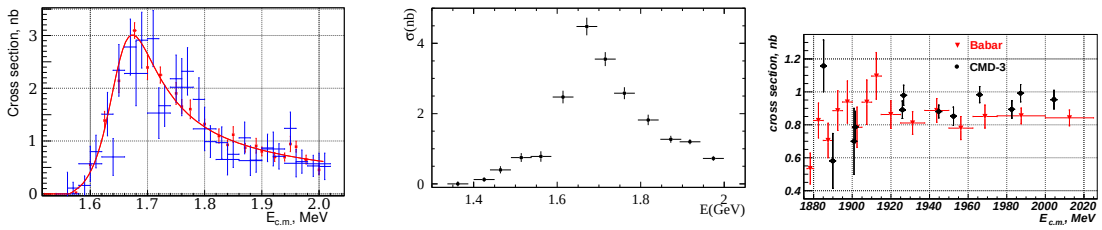

Figure 3: Left: The cross section of the $e^+e^- \to \eta K^+K^-$ process, measured by CMD-3. **Middle**: The cross section of the $e^+e^- \to \eta\pi^+\pi^-\pi^0$ process from SND. **Right**: The cross section of the $e^+e^- \to p\bar{p}$ process, measured by CMD-3.

Production of nucleon-antinucleon pairs. The $e^+e^- \to p\bar{p}$ process was studied in many experiments, most accurate is of Babar [16]. SND and CMD-3 preliminary data agree well with Babar [17] (Fig.3). Regarding the proton $|G_E/G_M|$ ratio, CMD-3 definitely confirms the Babar result that $|G_E/G_M| > 1$ (Fig.4). The $e^+e^- \to n\bar{n}$ cross section measured by SND [8] does slowly varies in the threshold region (Fig.4), and its value is close to that for $e^+e^- \to p\bar{p}$. SND cross section agrees with the FENICE measurement [18] but more precise.

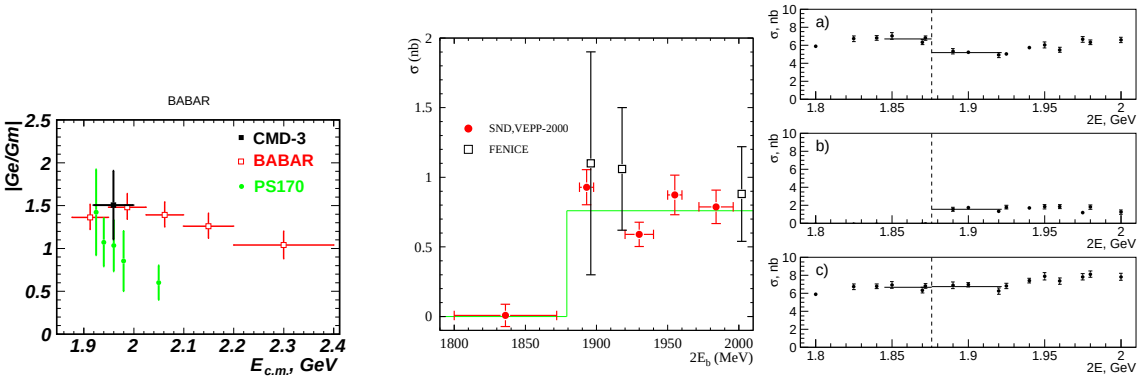

Figure 4: Left: The ratio $|G_E/G_M|$ for proton measured by CMD-3 in comparison with earlier data. **Middle**: The cross section of the $e^+e^- \to n\bar{n}$ process [8] measured by SND. **Right**: The cross sections near the nucleon-antinucleon threshold. (a) process $e^+e^- \to 6\pi$, (b) processes $e^+e^- \to p\bar{p}, n\bar{n}$, (c) sum of a) and b).

The sum cross section of $e^+e^- \to p\bar{p}$ and $e^+e^- \to n\bar{n}$ has the step-like shape with step height of about 1.7 nb (Fig.4,right). One can expect that such a step in the nucleon-antinucleon cross section must be compensating by a similar negative step in the meson production cross section. It turns out that such 1.7 nb negative step is observed in the $e^+e^- \to 6\pi$ channel [6], while the

full cross section (sum of $e^+e^- \to 6\pi$ and $e^+e^- \to p\bar{p}, n\bar{n}$) has no structure (Fig.4). Now there is no explanation, why only $e^+e^- \to 6\pi$ channel is sufficient to compensate the nucleon-antinucleon step.

Conclusions The e^+e^- coliider VEPP-2000, operating in the energy range 0.3÷2.0 GeV, and two detectors CMD-3 and SND, are shortly described. The results of analysis of processes $e^+e^- \to \pi^+\pi^-, K^+K^-, \pi^+\pi^-\pi^0, \eta K^+K^-, \eta\pi^+\pi^-\pi^0, p\bar{p}, n\bar{n}$ are presented. The physical program and significance of new data are discussed.

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References

[1] Yu. M. Shatunov *et al.*, in *Proceedings of the 7th European Particle Accelerator Conference, Vienna, 2000* (EPS, Geneva, 2000), p. 439.
[http://accelconf.web.cern.ch/AccelConf/e00/PAPERS/MOP4A08.pdf].

[2] I.A.Koop et al., Publised in: Physics and detectors for DAPHNE, Frascati (1999) 393-404.

[3] M. N. Achasov *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **449**, 125 (2000).

[4] B. I. Khazin, Nucl. Phys. B. Proc. Suppl. **181-183**, 376 (2008)

[5] M. N. Achasov *et al.*, Phys. Rev. D, **88**, 054013 (2013)

[6] A. E. Obrazovsky, S. I. Serednyakov, JETP. Lett. **99**, 363 (2014)

[7] M. N. Achasov *et al.*, Phys. Rev. D, **90**, 032002 (2014)

[8] M. N. Achasov *et al.*, Phys. Rev. D, **90**, 112007 (2014)

[9] V. M. Aulchenko *et al.*, Phys. Rev. D, **91**, 052013 (2015)

[10] R. R. Akhmetshin *et al.*, Phys. Lett., **B723**, 82 (2013)

[11] R. R. Akhmetshin *et al.*, Phys. Lett., **B740**, 273 (2015)

[12] V. F. Kazanin, Talk given at PHOTON-2015 Conference, 15-19 June 2015, Novosibirsk

[13] A. Yu. Barnyakov et al. Nucl. Instr. Meth. **A732**, 330 (2013)

[14] J. P. Lees et al. (Babar Collaboration), Phys. Rev. D **88**, 032013 (2013)

[15] V. M. Aulchenko et al. JETP, **121**, No.1, 27-34 (2015)

[16] J. P. Lees et al. (Babar Collaboration), Phys. Rev. D **87**, 092005 (2013)

[17] R. R. Akhmetshin, arXiv:1507.08013 [hep-ex]

[18] A. Antonelli et al., (FENICE Collaboration), Nucl.Phys. **B517**, 3 (1998)