RECENT RESULTS FROM SND DETECTOR AT VEPP-2M

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The current status of experiments with SND detector at VEPP-2M e^+e^- collider in the energy range $2E_0 = 0.4 - 1.4$ GeV is given. The new results of analysis of ϕ decay into $\pi^0\pi^0\gamma$, $\eta\pi^0\gamma$ are based on the full SND statistics corresponding 20 million of ϕ decay. New measurement of $\omega \to \pi^0\pi^0\gamma$ decay and a first observation of $\rho \to \pi^0\pi^0\gamma$ are presented. The accuracy of many other rare decays of light vector mesons was improved. In the energy range $2E_0 = 1.0 \div 1.4$ GeV the cross sections of the processes $e^+e^- \to \omega\pi^0$ and $e^+e^- \to \pi^+\pi^-\pi^0$ were measured. The results of the fitting of data are discussed.

Introduction

VEPP-2M is the e^+e^--collider [1], operating since 1974 in the energy range 2E=0.4–1.4 GeV (ρ, ω, ϕ-mesons region). Its maximum luminosity is about $5 \cdot 10^{30}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ at E=510 MeV. Two detectors SND and CMD-2 carry out experiments at VEPP-2M now.

SND was described in detail in [2]. Its main part is the three layer spherical electromagnetic calorimeter consisting of 1620 NaI(Tl) crystals with a total mass of 3.6 tones. The solid angle coverage of the calorimeter is 90% of 4π steradian. The energy resolution for photons can be approximated as $\sigma_E(E)/E = 4.2\%/E(\mathrm{GeV})^{1/4}$, angular resolution is about 1.5°. The angles of charged particles are measured by two cylindrical drift chambers covering 98% of 4π solid angle.

Since 1996 the SND detector collected 32 pb^{-1} of integrated luminosity in three energy regions:

- 360–970 MeV, 9 pb^{-1} corresponding to $\sim 7\times10^6$ produced ρ mesons and $\sim 4\times10^6$ ω mesons;
- 980–1060 MeV, 13 pb^{-1} corresponding to $\sim 2\times10^7$ ϕ meson decays;
- 1050–1380 MeV, 9 pb^{-1}.

In this report we present results based on analysis of total statistics from last two energy regions and 3.6 pb^{-1} from ρ, ω region.

1. Search for ρ, ω, ϕ electric dipole radiative decays

The decays of the vector mesons into a scalar and a photon are well known for higher quarkonia, but there are very little data about such decays of light mesons ρ, ω, ϕ. The scalar candidates for their decays are $f_0(980)$, $a_0(980)$ and not well established broad object $\sigma(400-1200)$.

The decays $\phi \to \pi^0\pi^0\gamma, \eta\pi^0\gamma$. The first evidence of the electric dipole decays of ϕ meson was reported by SND detector in 1997 [3]. These decays were searched for in the reactions:

$$e^+e^- \to \phi \to \pi^0\pi^0\gamma, \tag{1}$$

$$e^+e^- \to \phi \to \eta\pi^0\gamma. \tag{2}$$

On the base of the analysis of full SND data sample collected in the ϕ meson energy region the following branching ratios were obtained from the study of the reactions (1), (2) [4, 5]:

$$B(\phi \to \pi^0\pi^0\gamma) = (1.22 \pm 0.12) \cdot 10^{-4}, \tag{3}$$

$$B(\phi \to \eta\pi^0\gamma) = (0.88 \pm 17) \cdot 10^{-4}. \tag{4}$$

Corresponding numbers of selected events were 419 ± 31 for the process (1) and 36 ± 6 for the process (2). The angular distributions of these events were found to be in agreement with expected for scalar intermediate $\pi^0\pi^0$ and $\eta\pi^0$ states. The $\pi^0\pi^0$ and $\eta\pi^0$ mass spectra after background subtraction and applying the detection efficiency corrections are shown in Figs. 1, 2.

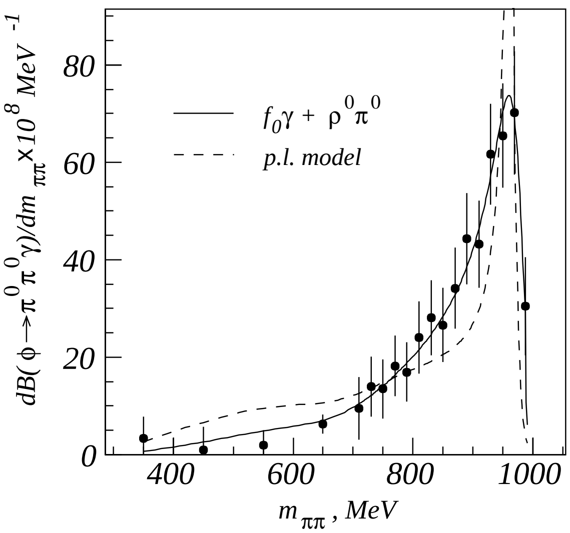

Figure 1: The $\pi^0\pi^0$ mass in the decay $\phi \to \pi^0\pi^0\gamma$.

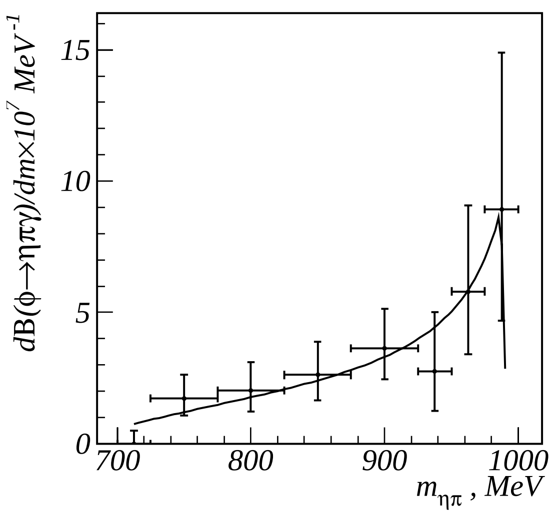

Figure 2: The $\eta\pi^0$ mass in the decay $\phi \to \eta\pi^0\gamma$.

In spite of smaller recoil photon phase space and $\sim E_\gamma$ dependence of an amplitude for the decay into scalar and photon both observed mass spectra demonstrate enhancements in higher mass regions. These enhancements can be explained by only resonant contribution of $f_0(980)$, $a_0(980)$ mesons. The $\pi^0\pi^0$ mass spectrum was approximated by sum of contributions from $f_0(980)$ and σ mesons with a small addition of $\rho^0\pi^0$ mechanism calculated using VDM. The $f_0(980)$ shape was described by Flatte [6] type formula [7] taking into account the nearness of $K\bar{K}$ threshold. Results of the approximation in the two models are shown in Fig. 1. In contrast to the point-like model of $\phi \to f_0\gamma$ transition which can not give satisfactory description of the data ($P(\chi^2) = 28/14$), the model with the intermediate kaon loop [7] well reproduce the shape of experimental spectrum even without the additional contribution of σ meson ($P(\chi^2) = 3/14$). The similar model was applied to describe the $\eta\pi^0$ mass spectrum in Fig. 2. The fitting results demonstrate that $f_0\gamma$ and $a_0\gamma$ mechanisms dominate in the decays (1), (2). So, we can obtain from (3) and (4):

$$B(\phi \to f_0\gamma) = (3.5 \pm 0.3^{+1.3}_{-0.5}) \cdot 10^{-4}, \tag{5}$$

$$B(\phi \to a_0\gamma) = (0.88 \pm 0.17) \cdot 10^{-4}. \tag{6}$$

The result (5) was obtained assuming natural isotopic ratio $B(f_0 \to \pi^+\pi^-)/B(f_0 \to \pi^0\pi^0) = 2$.

It is hard to explain the relatively large values of $B(\phi \to f^0\gamma)$ and $B(\phi \to a^0\gamma)$ in the frame of a conventional two-quark description of f_0 and a_0 structure (see discussion in the work [8]). For example, the value of $B(\phi \to a^0\gamma)$ is close to $Br(\phi \to \eta'\gamma)$. So, the isovector a_0 should contain strange quarks like η'! The possible solution is proposed by the four-quark MIT bag model of a_0 and f_0 mesons which predictions are in a good agreement with our results [7, 8]. After observation of $\phi \to f_0\gamma, a_0\gamma$ decays many works on f_0 and a_0 nature appeared [9]. All these models are different from a conventional $q\bar{q}$ model and involve four-quark component either directly or as a result of strong S-wave meson-meson interaction.

Search for the decay $\rho, \omega \to \pi^0\pi^0\gamma$.

In VDM model these decays proceed through the $\rho \to \omega\pi^0 \to \pi^0\pi^0\gamma$ and $\omega \to \rho\pi^0 \to \pi^0\pi^0\gamma$ reactions with the relative probabilities $\sim 10^{-5}$. With additional contribution $\sim 10^{-5}$ from pion chiral loops to $\rho \to \pi^0\pi^0\gamma$ decay, the branching ratios $B(\rho \to \pi^0\pi^0\gamma) = 2.6 \cdot 10^{-5}$ and $B(\omega \to \pi^0\pi^0\gamma) = 2.8 \cdot 10^{-5}$ are predicted [10]. The only measurement of $\omega \to \pi^0\pi^0\gamma$ decay by GAMS [11] results value $(7.2 \pm 2.5) \cdot 10^{-5}$, which is about three times larger than the theoretical expectation.

About 150 pure events of the process $e^+e^- \to \pi^0\pi^0\gamma$ were selected in the energy region of ρ and ω resonances. The photon energy spectrum of events from the narrow energy range near ω are shown in Fig. 3. It is well described by $\sim E_\gamma^3$ dependence expected for S-wave state of $\pi^0\pi^0$ pair. But the problem is that in this energy range the S-wave contribution is dominant for all intermediate states including $\rho^0\pi^0$. So, we can not extract any information about $\omega \to \pi^0\pi^0\gamma$ decay mechanisms from the energy or angular distributions with our low statistics. The energy dependence of the $e^+e^- \to \pi^0\pi^0\gamma$ cross section is shown in Fig. 4.

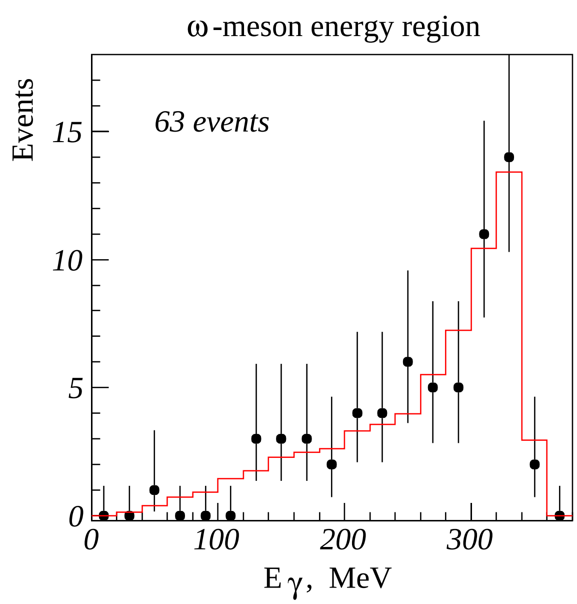

Figure 3: The photon energy spectrum in the reaction $e^+e^- \to \pi^0\pi^0\gamma$ in the energy range near ω meson mass.

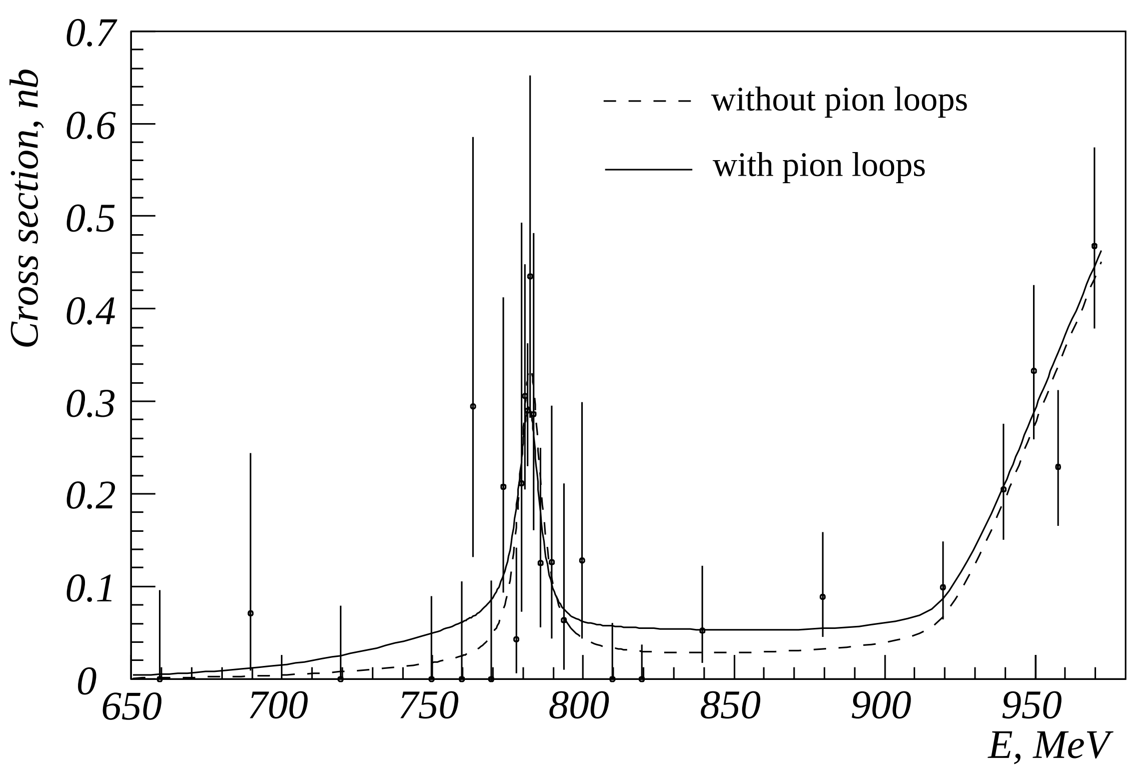

Figure 4: The cross section of the $e^+e^- \to \pi^+\pi^-\gamma$ reaction and the fitting curves for two models described in the text.

The fit of the cross section included $\rho, \rho' \to \omega\pi^0$ transition and $\omega, \rho \to \pi^0\pi^0\gamma$ decays in the different models: $\rho^0\pi^0$ and $S\gamma$. Here S is σ meson or S-wave $\pi^0\pi^0$ state in chiral pion loops mechanism. The strong difference in the energy dependences of the phase spaces for $\rho \to \omega\pi^0$ and $\rho \to S\gamma$ mechanisms allows to distinguish the different models. The model without $\rho \to S\gamma$ contribution gives $P(\chi^2) = 5\%$ and large value of $B(\omega \to \pi^0\pi^0\gamma) = (12.7 \pm 2.4) \times 10^{-5}$. Inclusion of the scalar mechanism to the fit improves $P(\chi^2)$ to 24%. The resulting $\rho \to S\gamma$ amplitude was found to be 2.5σ above zero.

The branching ratios obtained from fitting of the cross section are the following [12]:

$$B(\omega \to \pi^0\pi^0\gamma) = (7.8 \pm 3.3) \cdot 10^{-5},$$
$$B(\rho \to \pi^0\pi^0\gamma) = (4.8^{+3.4}_{-1.8}) \cdot 10^{-5}.$$

So, we have confirmed the value $B(\omega \to \pi^0\pi^0\gamma)$, obtained by GAMS. The decay $\rho \to \pi^0\pi^0\gamma$ was observed for the first time. For both decays, the measured values exceed the VDM predictions.

1.1. Magnetic dipole radiative decays

The magnetic dipole radiative decays $V \to P\gamma$ are traditional objects of the study in the light meson spectroscopy. Only two among the seven decays of this type, $\phi \to \eta\gamma$ and $\omega \to \pi^0\gamma$, are measured with relatively high accuracy. The decay $\phi \to \eta'\gamma$ was observed by CMD-2 not long ago, in 1997 [13].

ρ, ω, $\phi \to \eta\gamma$ decays. The reaction $e^+e^- \to 7\gamma$ is free of any physical background and the best channel for study of $\rho, \omega \to \eta\gamma$ decays. The cross section of the reaction $e^+e^- \to \eta\gamma$ measured in 7 photon final state is shown in Figs. 5, 6.

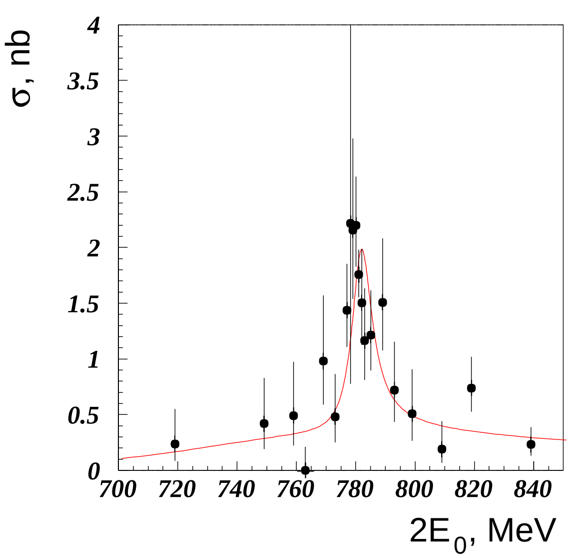

Figure 5: The cross section of the reaction $e^+e^- \to \eta\gamma$ in ρ and ω energy region.

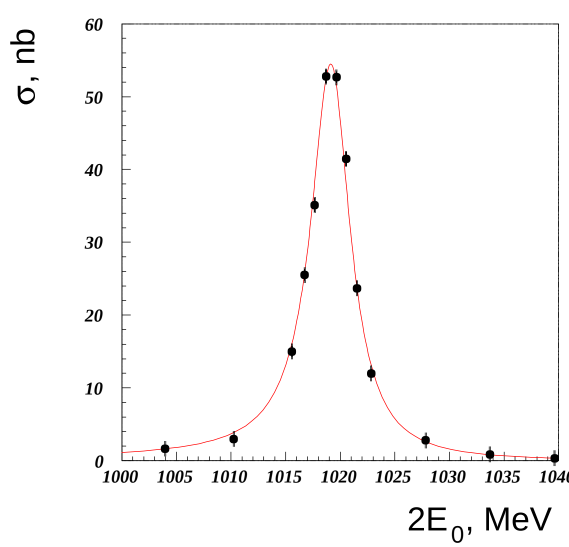

Figure 6: The cross section of the reaction $e^+e^- \to \eta\gamma$ in ϕ meson energy region.

The results of fitting of cross section by a sum of the contributions of ρ, ω, and ϕ mesons are listed in the following table [14]:

	SND (7γ final state)	PDG98
$\rho \to \eta\gamma$	$(2.73 \pm 0.31 \pm 0.15) \times 10^{-4}$	$(2.4 \pm 0.9) \times 10^{-4}$
$\omega \to \eta\gamma$	$(4.62 \pm 0.71 \pm 0.18) \times 10^{-4}$	$(6.5 \pm 1.0) \times 10^{-4}$
$\phi \to \eta\gamma$	$(1.353 \pm 0.011 \pm 0.052) \times 10^{-2}$	$(1.26 \pm 0.06) \times 10^{-2}$

All three results have accuracies comparable or better than world average ones. The experimental ratio of the partial widths $\Gamma_{\omega\eta\gamma} : \Gamma_{\rho\eta\gamma} : \Gamma_{\phi\eta\gamma} = 1 : (15.4 \pm 2.6) : (10.6 \pm 2.2)$ is in agreement with a prediction of the simple quark model: 1 : 12 : 8.

The probability of the decay $\phi \to \eta\gamma$ was measured by SND in two other decay modes of η meson with following results: $(1.259 \pm 0.030 \pm 0.059)\%$ for $\eta \to \pi^+\pi^-\pi^0$ [15] and $(1.338 \pm 0.012 \pm 0.052)\%$ for $\eta \to \gamma\gamma$ [16]. Combining the results for three different modes we can obtain the SND average

$$BR(\phi \to \eta\gamma) = (1.310 \pm 0.045)\%,$$

the most precise measurement of this value.

***ρ, ω → $\pi^0\gamma$* decays.** The cross section of 3 photon events selected as candidates for $e^+e^- \to \pi^0\gamma$ reaction is presented in Fig. 7.

The cross section was fitted by a sum of the contributions of $\omega \to \pi^0\gamma$ and $\rho \to \pi^0\gamma$ decays and the background from the process of e^+e^- annihilation to three photon. The preliminary results of the fit together with corresponding PDG values [17] and SND result for $\phi \to \pi^0\gamma$ decay [16] are listed in following table:

	SND	PDG-1998
$\rho \to \pi^0\gamma$	$(4.3 \pm 2.2 \pm 0.4) \times 10^{-4}$	$(6.8 \pm 1.7) \times 10^{-4}$
$\rho \to \pi^\pm\gamma$		$(4.5 \pm 0.5) \times 10^{-4}$
$\omega \to \pi^0\gamma$	$(8.5 \pm 0.2 \pm 0.4) \times 10^{-2}$	$(8.5 \pm 0.5) \times 10^{-2}$
$\phi \to \pi^0\gamma$	$(1.23 \pm 0.04 \pm 0.09) \times 10^{-3}$	$(1.31 \pm 0.13) \times 10^{-3}$

The $\rho, \omega \to \pi^0\gamma$ branching ratios are in a good agreement with both PDG values and a prediction of a simple quark model for $\rho \to \pi^0\gamma$ decay $\approx 5 \times 10^{-4}$ calculated from $\omega \to \pi^0\gamma$ branching ratio. The obtained accuracies are comparable with table ones. These results are based on a part of available statistics. For full data sample we expect about two-fold improvement of statistical accuracy of $\rho \to \pi^0\gamma$ branching ratio. We also hope that combined analysis of data from ϕ and ρ, ω energy regions could reduce the systematic error of $\phi \to \pi^0\gamma$ branching ratio caused by the model dependence of $\phi - \omega$ interference description.

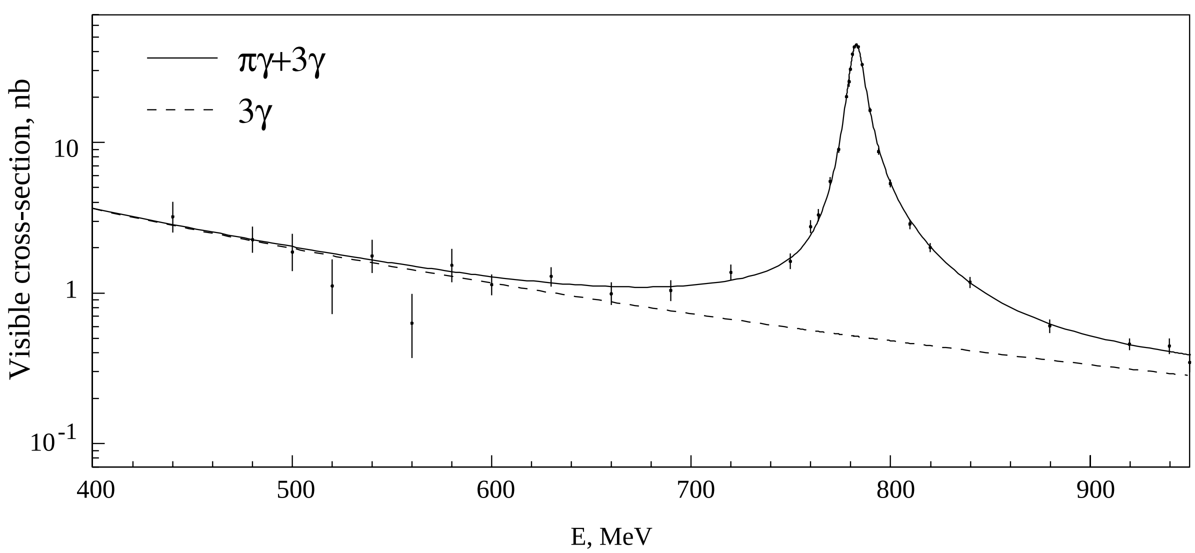

Figure 7: The cross section of 3 photon events selected as candidates for $e^+e^- \to \pi^0\gamma$ reaction.

2. Rare ϕ decays

OZI and G-parity suppressed ϕ decays. The decays $\phi \to \pi^+\pi^-$, $\phi \to \omega\pi^0$ and $\phi \to \pi^+\pi^-\pi^0\pi^0$ were observed at VEPP-2M by detectors OLYA [18], SND [19] and CMD-2 [20]. Here we will discuss the SND measurements of $\phi \to \pi^+\pi^-$, $\phi \to \omega\pi^0$ decays. These double suppressed by QZI rule and G-parity decays can be seen as interference patterns in the energy dependenceof the cross sections of $e^+e^- \to \omega\pi$ and $e^+e^- \to \pi^+\pi^-$ processes. The Born cross section with the interference term can be written as follows:

$$\sigma(E) = \sigma_0(E) \cdot \left|1 - Z\frac{m_\phi \Gamma_\phi}{D_\phi(E)}\right|^2,$$

where $\sigma_0(E)$ is nonresonant cross section, Z is complex interference amplitude, $D_\phi(E)$ is ϕ meson inverse propagator. One can extract from experimental data both real and imaginary parts of the decay amplitude. The corresponding decay branching ratio is proportional to $|Z|^2$ and $\sigma_0(m_\phi)$. The simplest and most natural mechanism for G-parity breaking is a single-photon transition $\phi - \gamma - \rho$ which contributes only to real part of the interference amplitude: $Re(Z)_\gamma = 3B(\phi \to e^+e^-)/\alpha = 0.123$. Other mechanisms are sensitive to the nature of $\rho - \omega - \phi$ mixing.

The cross-sections of selected events of $e^+e^- \to \omega\pi$ and $e^+e^- \to \pi^+\pi^-$ processes for 1998 data set are shown in Figs. 8,9. The interference patterns around ϕ meson mass are clearly seen in both reactions. The measured interference parameters and corresponding branching ratios are listed in the following table [21, 22]:

	Re(Z)	Im(Z)	$BR \times 10^5$
$\phi \to \omega\pi^0$	0.108 ± 0.16	-0.125 ± 0.020	$5.2^{+1.3}_{-1.1}$
$\phi \to \pi^+\pi^-$	0.061 ± 0.006	-0.041 ± 0.007	7.1 ± 1.4

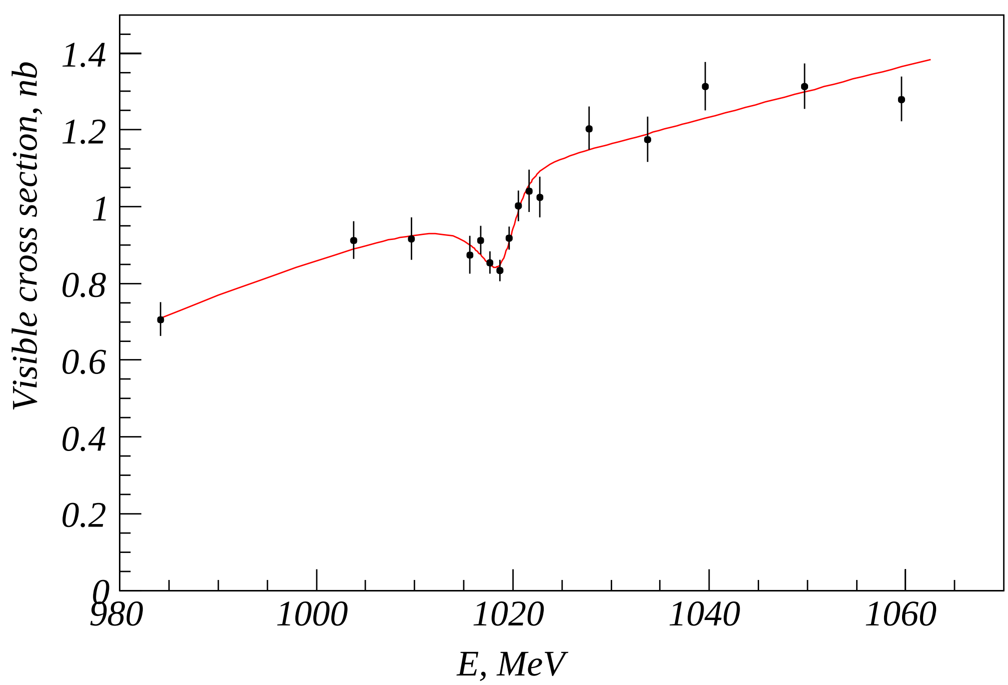

Figure 8: The visible cross section of $e^+e^- \to \omega\pi \to \pi^+\pi^-\pi^0\pi^0$ reaction near the ϕ peak.

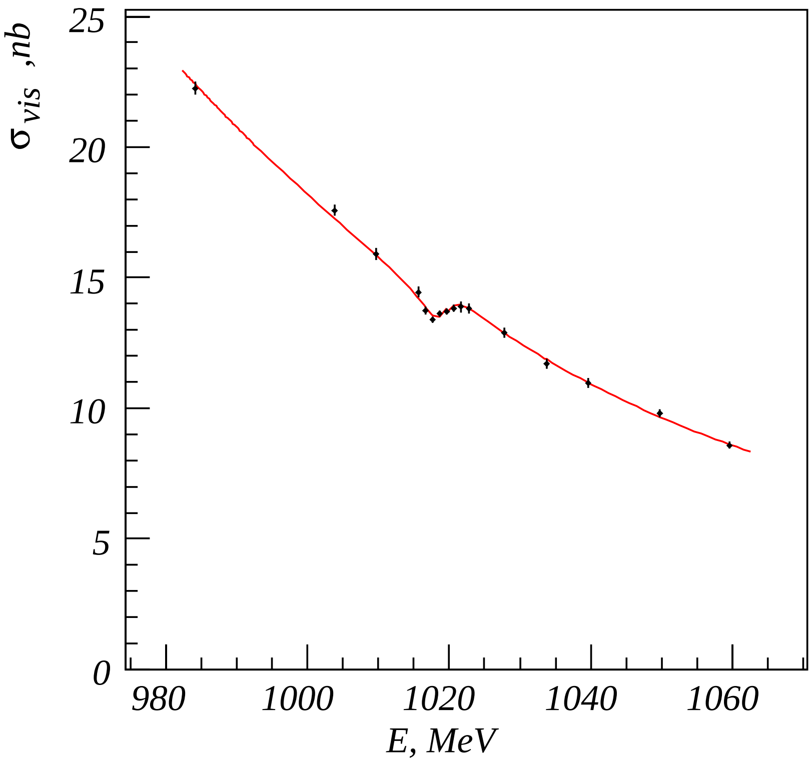

Figure 9: The visible cross section of $e^+e^- \to \pi^+\pi^-$ reaction near the ϕ peak.

The VDM model and standard $\omega-\phi$-mixing give considerably larger values of branching ratios: $BR(\phi \to \omega\pi^0) = (8 \div 9) \times 10^{-5}$ and $BR(\phi \to \pi^+\pi^-) = 34 \times 10^{-5}$. The reasons of the discrepancy between the experiment and these predictions are too low value of Re(Z), measured in both decays. A possible explanation are considered in [23, 24] and could be a nonstandard $\omega-\phi$-mixing and direct decays $\phi \to \pi\pi$, $\phi \to \omega\pi^0$.

The decay $\phi \to \omega\pi^0$ was observed by SND for the first time. The measured $\phi \to \pi^+\pi^-$ branching ratio agrees with PDG value [17]: $(8^{+5}_{-4}) \cdot 10^{-5}$ but is in contradiction with preliminary CMD-2 result $(18 \pm 3) \cdot 10^{-5}$ [25].

ϕ meson leptonic branching ratios. The usual and most precise method of the determination of ϕ meson leptonic branching ratio is an extraction of $B(\phi \to e^+e^-)$ from the value of the ϕ production cross section in e^+e^- collisions. This cross section is measured as a sum of all ϕ decay modes: $\phi \to K^+K^-$, K_SK_L, 3π, etc. The list of the branching ratios of the main ϕ decay modes measured by SND [26] is presented in the following table:

	SND	PDG98
$B(\phi \to K^+K^-), \%$	47.4 ± 1.6	49.1 ± 0.8
$B(\phi \to K_SK_L), \%$	35.4 ± 1.1	34.1 ± 0.6
$B(\phi \to 3\pi), \%$	15.9 ± 0.7	15.5 ± 0.7
$B(\phi \to e^+e^-) \times 10^4$	2.94 ± 0.14	2.99 ± 0.08

The last line of the table shows $B(\phi \to e^+e^-)$ value obtained by SND.

Another method of the determination of the leptonic width is measurement of the amplitude of interference pattern in the cross section of $e^+e^- \to \mu^+\mu^-$. This amplitude is equal to $\sim 12\%$ and proportional to $\sqrt{B(\phi \to e^+e^-)B(\phi \to \mu^+\mu^-)}$. Up to now an accuracy of this method was limited by experimental statistics. The Fig. 10 demonstrates the $e^+e^- \to \mu^+\mu^-$ cross section in ϕ meson energy region measured by SND detector. From the fit of experimental cross section we obtain the following value of ϕ meson leptonic branching ratio [27]:

$$\sqrt{B(\phi \to e^+e^-)B(\phi \to \mu^+\mu^-)} = (2.93 \pm 0.10 \pm 0.06) \cdot 10^{-4},$$

which is in a good agreement with $B(\phi \to e^+e^-)$ value and has comparable accuracy. Using table value of $B(\phi \to e^+e^-)$ we can obtain the probability of $\phi \to \mu^+\mu^-$ decay [27]:

$$B(\phi \to \mu^+\mu^-) = (2.87 \pm 0.20 \pm 0.14) \cdot 10^{-4}.$$

Our result is the most precise measurement of $B(\phi \to \mu^+\mu^-)$.

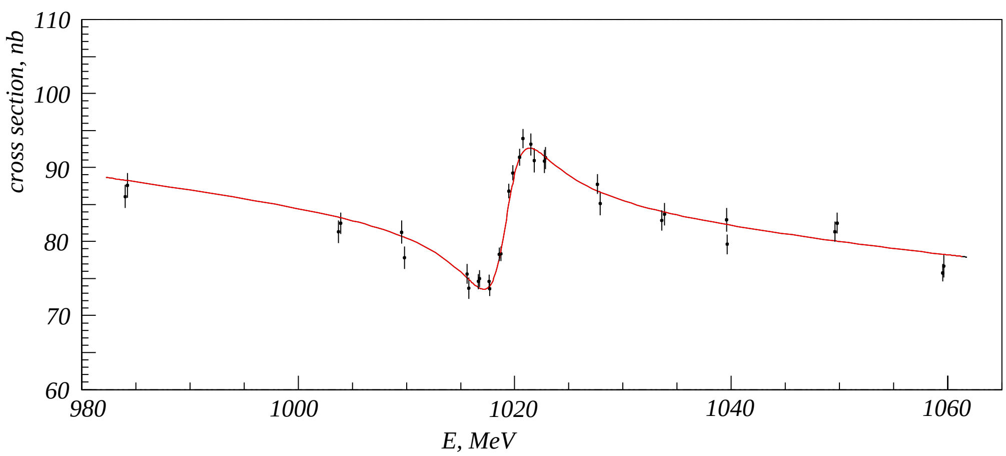

Figure 10: The visible cross section of $e^+e^- \to \mu^+\mu^-$ reaction near the ϕ peak.

3. e^+e^- annihilation into hadrons

The process of e^+e^- annihilation into hadrons in the 1–2 GeV energy region is an important source of information about excited states of light vector mesons ρ, ω and ϕ. The current PDG status [17] of these states based mainly on the analysis of e^+e^- annihilation cross sections and τ lepton hadronic decays by A.B.Clegg and A.Donnachie [28] are shown in the following table:

	ρ'	ρ''	ω'	ω''
Mass, MeV	1465 ± 25	1700 ± 20	1419 ± 31	1649 ± 24
Width, MeV	310 ± 60	240 ± 60	174 ± 60	220 ± 35

The key channels for ρ' and ω' states are $e^+e^- \to \pi^+\pi^-$, $\omega\pi$, $\pi^+\pi^-\pi^0$ reactions. Recently new data in this energy region became available from SND [29, 30], CMD-2 [31], CLEO [32, 33], ALEPH [34] experiments. We present the results of SND measurements of $e^+e^- \to \omega\pi$ [30] and $e^+e^- \to \pi^+\pi^-\pi^0$ [29] cross sections at the energy up to 1.4 GeV.

Process $e^+e^- \to \omega\pi \to \pi^0\pi^0\gamma$. The process $e^+e^- \to \omega\pi$ was studied in five photon $\pi^0\pi^0\gamma$ final state in which this intermediate state is dominant. Measured cross section in comparison with the most precise CMD-2 [31], CLEO [32], and DM2 [35] measurements are shown in Fig.11.

The CLEO results are in good agreement with ours while the CMD-2 measurements are about 10% lower, although the difference observed is smaller than the 15% systematic error quoted in [31]. There is a significant difference between the results of DM2 and CLEO. For the cross section fitting we used our data together with the data from CLEO. The energy dependence of the cross section was described by a sum of contributions of $\rho(770)$ and its excitations ρ' and ρ''. Two different approaches were considered to describe of ρ' and ρ'' shapes. One of them [28] assumes constant total width of excited states (Model 1). In another one [36] energy dependent width is used: $\Gamma_{\rho_i} \sim q^3/(1+(qR)^2)$, where q is momentum of ω meson in $\omega\pi$ final state, R is parameter restricting fast growth of the resonance width (Model 2 and 3). The fit parameters obtained in 3 models with R ranged from 0 to 2 GeV^{-1} are listed in following table:

	Model 1	Model 2	Model 3
$m_{\rho'}$, MeV	1460–1520	–	$\equiv$ 1400
$\Gamma_{\rho'}$, MeV	380–500	–	$\equiv$ 500
$m_{\rho''}$, MeV	–	1710–1580	1620–1550
$\Gamma_{\rho''}$, MeV	–	1040–490	580–350
χ^2/N_D	(52–48)/35	(47–48)/35	(43–44)/34

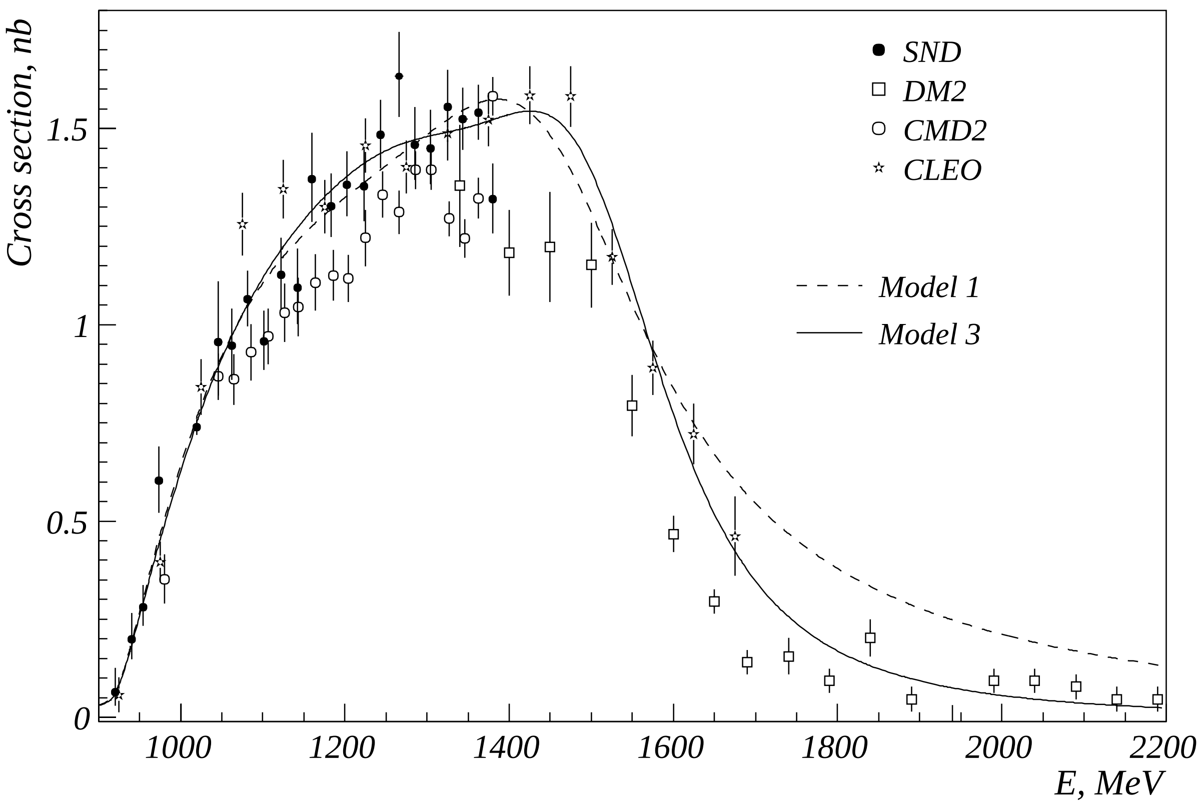

Figure 11: The cross section of the reaction $e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$. The results of the SND [30], DM2 [35], CMD [31], CLEO [32] experiments are shown. Curves are results of fitting to the data in model 1 and 3 with $R = 0$.

Both models 1 and 2 consider only one excited ρ state but give very different results. An inclusion of the energy dependent width in the model 2 leads to significant growth of resulting mass and width of the exited state. Only in model 1 with $R = 0$ the parameters ρ' meson are compatible with their PDG values, but this model yields a poorest χ^2 value: $P(\chi^2) = 3\%$. The satisfactory description of the experimental data was obtained in model 3 with two excited states. The mass and width of first one were fixed to 1400 and 500 MeV respectively. These parameters were taken from CLEO analysis of $\pi^+\pi^-$ channel [32]. However the large amplitude of ρ'' meson obtained in this case contradicts the theoretical expectations [37, 38] which predict larger contribution from the lowest excited state ρ'.

Process $e^+e^- \to \pi^+\pi^-\pi^0$. The result of SND measurements of $e^+e^- \to \pi^+\pi^-\pi^0$ is presented in Fig. 12. The measured cross section shows a broad maximum at $2E \simeq 1200$ MeV. The SND and DM2 [40] data (Fig. 13) were fitted by a sum of ϕ, ω, ω', ω'' amplitudes. Similar to $e^+e^- \to \omega\pi$ case the fit gives ω' parameters strongly dependent on the model used. For example, in the model with $\Gamma_{\omega'}$=constant we obtained $M_{\omega'} = 1170 \div 1250$ MeV, $\Gamma_{\omega'} = 190 \div 550$ MeV [39], while the model with strong width dependence on the energy gives ω' parameters $M_{\omega'} = 1430 \pm 100$ MeV, $\Gamma_{\omega'} \sim 900$ MeV [41] which are close to the PDG values.

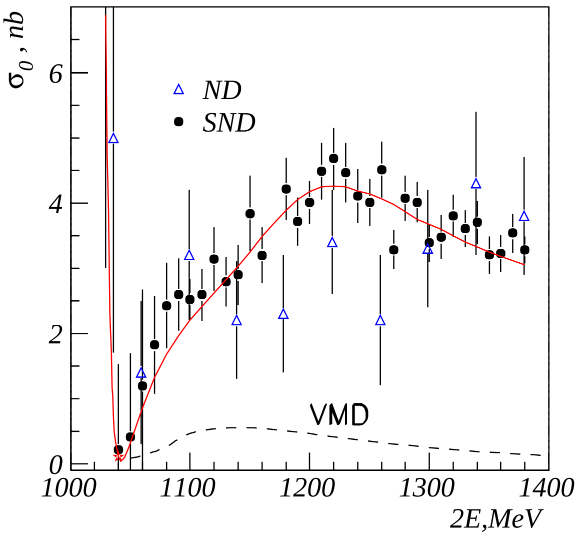

Figure 12: The cross section of the reaction $e^+e^- \to \pi^+\pi^-\pi^0$. The lower curve is a prediction of VDM with only $\omega(782)$ and $\phi(1020)$ contribution.

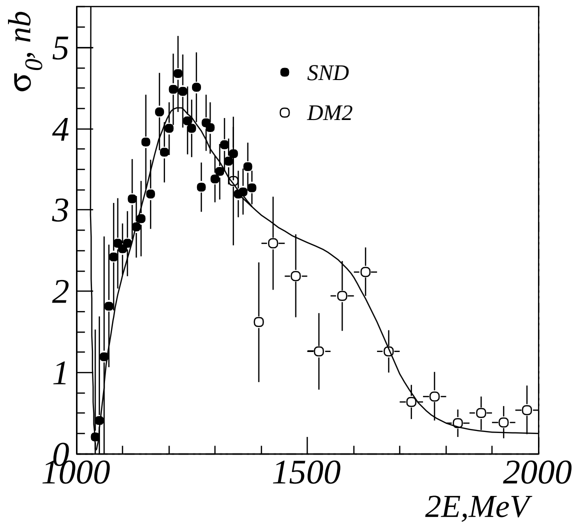

Figure 13: The cross section of the reaction $e^+e^- \to \pi^+\pi^-\pi^0$. The SND [39] and DM2 [40] data are shown. The curve is a fit result.

The conclusions from the analysis of the processes $e^+e^- \to \omega\pi^0$ and $e^+e^- \to \pi^+\pi^-\pi^0$ are the following. Fitting of the same experimental data by models with fixed and energy-dependent total widths of the excited states yields quite different parameters of these states. This is caused by strong energy dependence of the phase space for the main decay modes of ρ' and ω' mesons and this effect should be taken into account in the fitting of experimental data. To obtain more definite values of the parameters of ρ and ω exited states new experimental data at higher energies $2E = 1400 \div 2000$ MeV are needed. We hope that these data will be soon available from experiments at VEPP-2000 e^+e^- collider [42] which construction is to be started in 2000 in BINP, Novosibirsk. The two upgraded detectors SND and CMD-2 will take data at VEPP-2000 with $1 fb^{-1}$ of integrated luminosity. The physical program is aimed to detailed study of e^+e^- annihilation processes in the energy range $2E_0 = 1 \div 2$ GeV.

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