Radiative decays of light vector mesons.

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The new data on ρ, ω, ϕ radiative decays into $\pi^0\gamma, \eta\gamma, \eta'\gamma$ from SND experiment at VEPP-2M e^+e^- collider are presented.

1. INTRODUCTION

Radiative decays of ρ, ω and ϕ mesons were studied in the SND experiment at the VEPP-2M e^+e^- collider [1]. Approximately 20×10^6 ϕ, 2×10^6 ρ and 1×10^6 ω mesons were collected. The results for ϕ-meson decays were obtained mainly from the part of the data collected during 1996, when approximately 8×10^6 of ϕ mesons were produced with appropriate integrated luminosity 4.3 pb^{-1}.

The SND detector [2] provides good possibility to study the radiative decays of light vector mesons $e^+e^- \rightarrow \mathrm{V} \rightarrow \pi^0\gamma, \eta\gamma, \eta'\gamma$, where $\mathrm{V} = \rho, \omega, \phi$. In particular, large calorimeter solid angle, about 90% of 4π, allows to select the multi-photon final states with high efficiency.

2. DECAYS $\phi \rightarrow \eta\gamma, \pi^0\gamma$

The decay $\phi \rightarrow \eta\gamma$ was studied in the main final states of η: $3\gamma, 3\pi^0\gamma, \pi^+\pi^-\pi^0\gamma$, which cover about 94% of all decays of η meson. The study of 3γ final state allows to measure the probability of the decay $\phi \rightarrow \pi^0\gamma$ also.

2.1. 3γ final state [4].

In this final state two radiative decays of ϕ meson were studied: $e^+e^- \rightarrow \eta\gamma \rightarrow \gamma\gamma\gamma$ and $e^+e^- \rightarrow \pi^0\gamma \rightarrow \gamma\gamma\gamma$ with the main background coming from non-resonant QED three-quanta annihilation $e^+e^- \rightarrow \gamma\gamma\gamma$ (QED).

Preliminary selection included presence of three or four reconstructed photons; cut on the total energy deposition in the calorimeter: $0.7 \cdot 2E_{beam} < E_{tot} < 1.2 \cdot 2E_{beam}$; cut on the sum of the photon momenta: $\sum P_i < 0.2E_{tot}/c$; cut on the minimal energy of the photons at the level of 50 MeV. To suppress spurious signals in the calorimeter, which appear mainly in the crystals closest to the beam, additional restrictions were imposed on the energies and angles of the reconstructed photons: polar angle for the photons with energies 50–100 MeV was in the range $45^\circ < \theta < 135^\circ$, while for the photons with the energies higher than 100 MeV it was in the range $27^\circ < \theta < 153^\circ$.

To distinguish between the processes $\eta\gamma \to 3\gamma$, $\pi^0\gamma \to 3\gamma$ and $e^+e^- \to 3\gamma$ (QED) the kinematic fit was used. About 18000 events were selected for the process $\eta\gamma \to 3\gamma$ and about 1700 events for the process $\pi^0\gamma \to 3\gamma$ with corresponding efficiencies 44% and 14%.

2.2. 7γ final state [5]

In this final state main background comes from the process $\phi \to K_S K_L \to 2\pi^0 + X$. The selection criteria included presence of 6–8 reconstructed photons, cuts on the total energy deposition and the momentum balance. The most energetic photon in the event is the recoil photon with energy about 360 MeV. Therefore the restriction on the energy of the most energetic photon was imposed.

The selection efficiency of this final state was about 32%. Approximately 10000 events were selected with the background lower than 1%.

2.3. $\pi^+\pi^-\pi^0\gamma$ final state [6]

Main background for this final state comes from the decay $\phi \to \pi^+\pi^-\pi^0$ with spurious hits in calorimeter.

At first the events with 2 charged particles and 3 or more photons were selected. Then the cuts on distances between charged tracks and beam axis and on space angle between charged tracks (to reject the events of the process $\phi \to K_S K_L \to \pi^+\pi^- + X$) were applied. To suppress the background the kinematic fit was used.

The selection efficiency of this final state was about 18%. Approximately 20×10^6 events of ϕ-meson decays were processed.

2.4. Analysis

For the description of the cross section of processes $e^+e^- \to P\gamma$, where P is a pseudoscalar meson, the following dependence was used:

$$\sigma(s) = \frac{F(s)}{s^{3/2}} \left| \sum_{V=\rho,\omega,\phi} \sqrt{\sigma_{VP\gamma} \frac{m_V^3}{F(m_V^2)}} \frac{m_V \Gamma_V e^{i\varphi_V}}{m_V^2 - s - i\sqrt{s}\Gamma_V(s)} \right|^2 , \tag{1}$$

where $\sigma_{VP\gamma} = 12\pi B(V \to e^+e^-)B(V \to P\gamma)/m_V^2$ is the cross section of the process $e^+e^- \to V \to P\gamma$ at the maximum of vector resonance V. $F(s) = [(s - m_P^2)/2\sqrt{s}]^3$ is the phase space factor for the process $e^+e^- \to P\gamma$. The relative phases of vector mesons were taken to be $\varphi_\rho = \varphi_\omega = 0$, $\varphi_\phi = 180^\circ$ for $\eta\gamma$ decay, $\varphi_\phi = (158 \pm 11)^\circ$ for $\pi^0\gamma$ decay.

The fit gave the following results for the decay $\phi \to \eta\gamma$ in the different final states:

$$3\gamma \; : \; \mathrm{BR}(\phi \to \eta\gamma) = (1.338 \pm 0.012 \pm 0.052)\% \tag{2}$$

$$7\gamma \; : \; \mathrm{BR}(\phi \to \eta\gamma) = (1.296 \pm 0.024 \pm 0.057)\% \tag{3}$$

$$\pi^+\pi^-\pi^0 \; : \; \mathrm{BR}(\phi \to \eta\gamma) = (1.259 \pm 0.030 \pm 0.059)\% \tag{4}$$

Main sources of systematic errors were luminosity measurement (2.5%), error in BR($\phi \to e^+e^-$) (3%), MC efficiency determination (1–2%), the error in the branching ratios of the decays of η meson (1–2%) and model dependence (1.5%).

If we combine the branching ratios (2), (3) and (4) some systematic errors will cancel and we will obtain BR($\phi \to \eta\gamma$) = $(1.304 \pm 0.049)\%$. This result agrees with the world average BR($\phi \to \eta\gamma$) = $(1.26 \pm 0.06)\%$ [3] and has smaller error. The systematic error comes mainly from the error in the branching ratio BR($\phi \to e^+e^-$).

For the decay $\phi \to \pi^0\gamma$ the following result was obtained: BR($\phi \to \pi^0\gamma$) = $(1.226 \pm 0.036^{+0.096}_{-0.089}) \times 10^{-3}$. The uncertainty in phase φ_ϕ for the process $\phi \to \pi^0\gamma$ gave about 6% systematic error for the decay $\phi \to \pi^0\gamma$.

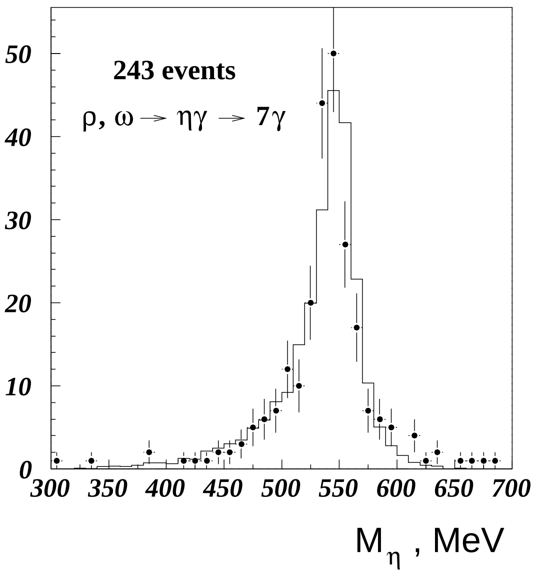

Figure 1. Recoil mass of the most energetic photon in an event of the process $e^+e^- \to \eta\gamma \to 7\gamma$. The histogram — MC; the points — experiment.

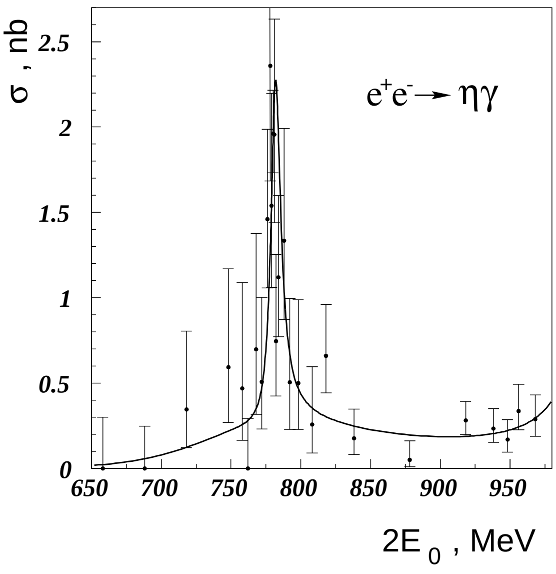

Figure 2. Born cross section of the process $e^+e^- \to \eta\gamma$.

3. DECAY $\phi \to \eta'\gamma$ [7]

The first observation of this decay was done at VEPP-2M in CMD-2 experiment [8]. The measurement of this decay at SND was performed with η' decaying into $\pi^+\pi^-\eta$ and η into two γ's. The background for this final state comes from the processes $e^+e^- \to \eta\gamma \to \pi^+\pi^-\pi^0\gamma$, $e^+e^- \to \pi^+\pi^-\pi^0$ and $e^+e^- \to \omega\pi^0 \to \pi^+\pi^-\pi^0\pi^0$. For the analysis events with two charged tracks and three photons were selected. To suppress the background a complex selection algorithm was developed based on the kinematics of all these processes. It was described in details in the ref. [7]. Due to the strict cuts the selection efficiency of the final state $\pi^+\pi^-3\gamma$ for the events of the process under study was 5.5%.

There were found $5.2^{+2.6}_{-2.2}$ events, which correspond to the branching ratio $BR(\phi \to \eta'\gamma) = (6.7^{+3.4}_{-2.9}) \times 10^{-5}$. The systematic error, not included in the above errors, is about 15% and determined mainly by the error in the efficiency estimation.

4. PRELIMINARY RESULTS ON DECAYS $\rho, \omega \to \eta\gamma$

To study the decays $\rho, \omega \to \eta\gamma$ the final state $\eta \to 3\pi^0 \to 6\gamma$ was chosen because of physical background in the energy region of ρ meson is absent for this final state. The analysis of these decays is similar to the analysis of the decay $\phi \to \eta\gamma \to 3\pi^0\gamma \to 7\gamma$. The spectrum of recoil mass of the most energetic photon in the event of the process under study is shown in Fig. 1. The Born cross section of the process $e^+e^- \to \eta\gamma$ in the energy region of ρ meson is presented in Fig. 2. The fit was done by the formula (1) with fixed phases $\varphi_\rho = \varphi_\omega = 0$, $\varphi_\phi = 180°$. The resulting branching ratios are following: $BR(\omega \to \eta\gamma) = (5.9 \pm 1.0) \times 10^{-4}$, $BR(\rho \to \eta\gamma) = (2.0 \pm 0.4) \times 10^{-4}$. These results agree with the table values $BR(\omega \to \eta\gamma) = (6.5 \pm 1.0) \times 10^{-4}$ and $BR(\rho \to \eta\gamma) = (2.4^{+0.8}_{-0.9}) \times 10^{-4}$ [3]. The result on the decay $\rho \to \eta\gamma$ has smaller error.

5. SUMMARY ON THE RESULTS

The results presented in this work are summarized in the table:

Decay	BR(SND)	BR(PDG) [3]
$\phi \to \eta\gamma$	$(1.304 \pm 0.049)\%$	$(1.26 \pm 0.06)\%$
$\phi \to \pi^0\gamma$	$(1.226 \pm 0.036^{+0.096}_{-0.089}) \times 10^{-3}$	$(1.31 \pm 0.13) \times 10^{-3}$
$\phi \to \eta'\gamma$	$(6.7^{+3.4}_{-2.9}) \times 10^{-5}$	$(12^{+7}_{-5}) \times 10^{-5}$
$\omega \to \eta\gamma$	$(5.9 \pm 1.0) \times 10^{-4}$	$(6.5 \pm 1.0) \times 10^{-4}$
$\rho \to \eta\gamma$	$(2.0 \pm 0.4) \times 10^{-4}$	$(2.4^{+0.8}_{-0.9}) \times 10^{-4}$

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