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МАТЕРИАЛЫ, ПОСВЯЩЕННЫЕ ПАМЯТИ АКАДЕМИКА ЮРИЯ ДМИТРИЕВИЧА ПРОКОШКИНА

ЭКСПЕРИМЕНТ

OBSERVATION OF $\phi \longrightarrow \pi^0\pi^0\gamma$ AND $\phi \longrightarrow \pi^0\eta\gamma$ DECAYS IN SND EXPERIMENT AT VEPP-2M

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Preliminary results on the study of $e^+e^- \longrightarrow \phi(1020) \longrightarrow \pi^0\pi^0\gamma$, $\eta\pi^0\gamma$ processes from SND experiment at VEPP-2M collider in Novosibirsk are presented. Branching ratios of rare radiative $\phi \longrightarrow \pi^0\pi^0\gamma$ and $\phi \longrightarrow \pi^0\eta\gamma$ decays are measured: $B(\phi \longrightarrow \pi^0\pi^0\gamma) = (1.1 \pm 0.2) \times 10^{-4}$ ($M_{\pi\pi} > 800$ MeV), $B(\phi \longrightarrow \eta\pi^0\gamma) = (1.3 \pm 0.5) \times 10^{-4}$.

First upper limits of $\phi(1020) \longrightarrow \pi^0\pi^0\gamma$, $\eta\pi^0\gamma$ radiative decays were established in ND experiment [1] at VEPP-2M e^+e^- collider. Later it was shown by Achasov [2] that these decays can provide important information about quark structure of lightest scalar mesons $a_0(980)$ and $f_0(980)$. Further theoretical investigations [3–9] confirmed this idea. Similar decay $\omega(782) \longrightarrow \pi^0\pi^0\gamma$ have been observed in the GAMS experiment [10, 11].

In this work we present preliminary results of SND experiment [12, 13]. Main background for the decays under study is due to $\phi \longrightarrow \eta\gamma \longrightarrow 3\pi^0\gamma$ and $\phi \longrightarrow K_SK_L \longrightarrow \pi^0\pi^0K_L$ decays. To suppress it, events with 5 photons were selected, satisfying energy–momentum conservation. In addition a χ^2_γ parameter, quantitatively describing quality of photons [14], was used (Fig. 1). The spectrum of invariant masses of photon pairs in selected events (Fig. 2*a*) shows that most of them contain two π^0. The $\pi^0\gamma$ invariant mass distribution (Fig. 2*b*) was used to separate the decay under study from the remaining $e^+e^- \longrightarrow \omega\pi^0 \longrightarrow \pi^0\pi^0\gamma$ background (Table 1). The distributions in π^0-s polar angle with respect to recoil photon direction in the $\pi^0\pi^0$-pair rest frame are shown in Figs. 2*c*, 2*d*. Flat distribution of $f_0\gamma$-type events (Fig. 2*c*) is consistent with *S*-wave production mechanism, while distribution of $\omega\pi^0$-type events (Fig. 2*d*) clearly contradicts it.

The $\pi^0\pi^0$ invariant mass spectrum, corrected for detection efficiency dependence on $m_{\pi\pi}$ (Fig. 3), shows a visible peak close to f_0 mass. Its width (~60 MeV) and position (~950 MeV) do not contradict previous measurements [15]. The shape of the invariant mass spectrum is consistent with 4-quark model predictions [2, 9], which allows us to fit it using formulas of [2]. The results are the following:

$$m_{f_0} = 950 \pm 8\ \text{MeV}, g^2_{f\pi\pi}/4\pi = 0.4 \pm 0.1\ \text{GeV}^{-2},$$
$$B(\phi \longrightarrow f_0(980)\gamma) = (4.7 \pm 1.0) \times 10^{-4}.$$

Situation with $\phi \longrightarrow \eta\pi^0\gamma$ decay mode is less clear because there is no visible peak at η mass in the spec-

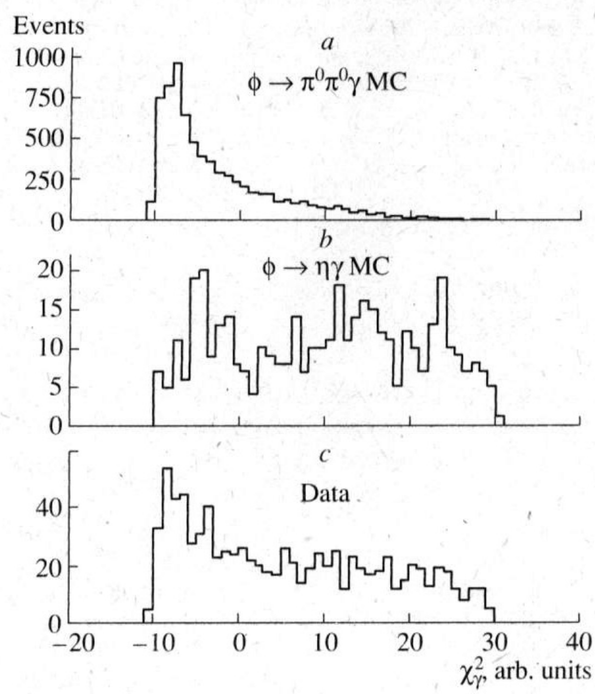

Fig. 1. The logarithmic likelihood function (χ^2_γ) of the photon shower transverse energy profile in the calorimeter for Monte Carlo (*a*, *b*) and for the data (*c*).

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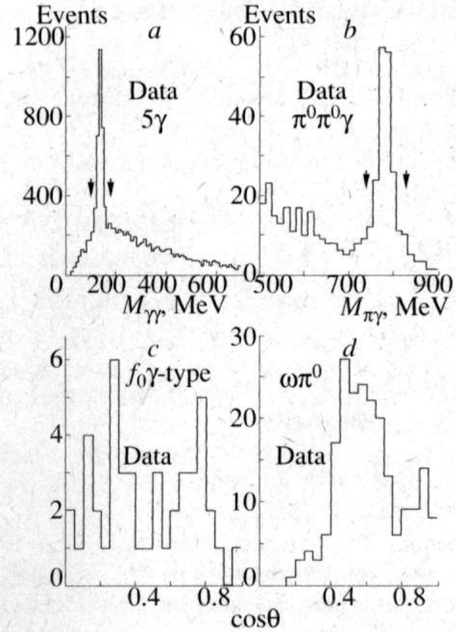

Fig. 2. Selection of $\pi^0\pi^0\gamma$ events: the invariant mass of photon pair (*a*); the invariant mass of $\pi^0\gamma$(*b*); the cosine of π^0 polar angle with respect to recoil photon direction in the $\pi^0\pi^0$-pair rest frame for $f_0\gamma$ events (*c*); the same for $\omega\pi^0$ events (*d*).

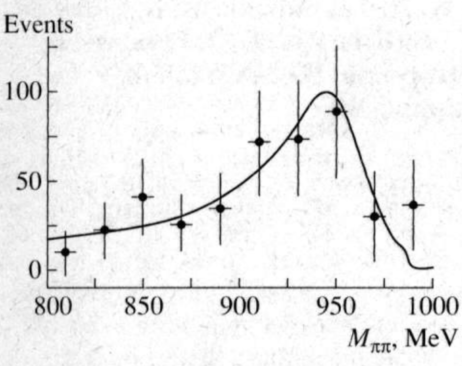

Fig. 3. The $\pi^0\pi^0$ invariant mass spectrum, the approximation with 4-quark model.

trum in Fig. 2*a*. But the number of selected $\eta\pi^0\gamma$ candidate events significantly exceeds estimated background (Figs. 4*a*, 4*b*). To check consistency of our analysis, 3 sets of selection criteria were used (Table 2). Ob-

Table 1. Number of the selected $\pi^0\pi^0\gamma$ events with $m_{\pi^0\pi^0} >$ > 800 MeV and estimated background

$\phi \longrightarrow \pi^0\pi^0\gamma$, exp.	45
$\phi \longrightarrow \eta\gamma$, sim.	5
$\phi \longrightarrow K_SK_L$, sim.	<6
$\phi \longrightarrow \rho\pi^0, \omega\pi^0 \longrightarrow \pi^0\pi^0\gamma$, sim.	1.4
$B(\phi \longrightarrow \pi^0\pi^0\gamma)$	$(1.1 \pm 0.2) \times 10^{-4}$

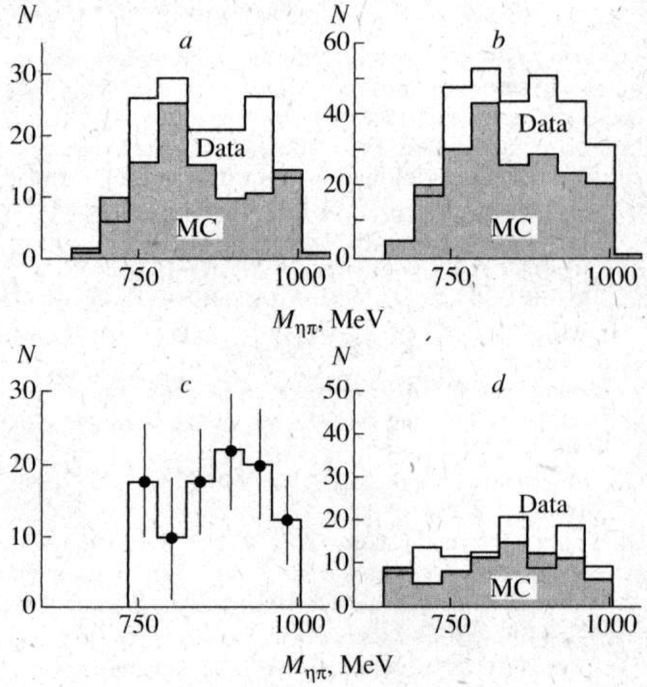

Fig. 4. Selection of $\eta\pi^0\gamma$ events. Invariant mass of $\eta\pi^0$: strong cuts (*a*); soft cuts (*b*); auto background subtraction (*c*); background (*d*).

served background in the kinematic region, where only small number of $\eta\pi^0\gamma$ events were expected, is well reproduced by Monte Carlo simulation (Fig. 4*d*), indicating that our estimations of background in the "effect" kinematic region are correct. Strong (Fig. 4*a*) and soft (Fig. 4*b*) cuts give practically the same mass spectra, final mass spectrum after background subtraction is shown in Fig. 4*c*.

In conclusion we would like to emphasize that SND measurement of $B(\phi \longrightarrow \eta\gamma)$ in 7γ final state (Table 9 in [13]) is in a good agreement with the PDG value [15] and upper limits, presented in the same table for several forbidden neutral decay modes, are established at levels significantly lower than branching ratios measured in this work:

$$B(\phi \longrightarrow \pi^0\pi^0\gamma) = (1.1 \pm 0.2) \times 10^{-4} \ (M_{\pi\pi} > 800 \text{ MeV}),$$

Table 2. Number of the selected $\eta\pi^0\gamma$ events and estimated background

χ^2_γ	<0 (Strong cuts)	<25 (Soft cuts)	25–50 (Background)
$e^+e^- \longrightarrow \eta\pi\gamma$, exp.	34	283	96
$e^+e^- \longrightarrow \eta\gamma$, sim.	4.2	109	50
$e^+e^- \longrightarrow K_SK_L$, sim.	<5.8	10	20
$e^+e^- \longrightarrow \omega\pi$, sim.	2.1	85	4
$B(\phi \longrightarrow \eta\pi^0\gamma)$	$(1.5 \pm 0.5) \times$ $\times 10^{-4}$	$(1.3 \pm 0.5) \times$ $\times 10^{-4}$	$(0.6 \pm 0.5) \times$ $\times 10^{-4}$

$$B(\phi \longrightarrow \eta\pi^0\gamma) = (1.3 \pm 0.5) \times 10^{-4}.$$

This analysis is virtually model independent and its results are more in favor of 4-quark model. Further theoretical studies are necessary to prove this conclusion as well as additional experimental data are needed to confirm our observation of $\phi \longrightarrow \pi^0\pi^0\gamma$ and $\phi \longrightarrow \eta\pi^0\gamma$ decays.

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НАБЛЮДЕНИЕ РАСПАДОВ $\phi \longrightarrow \pi^0\pi^0\gamma$ И $\phi \longrightarrow \pi^0\eta\gamma$ В ЭКСПЕРИМЕНТЕ СНД НА ВЭПП-2М

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Представлены предварительные результаты по изучению процессов $e^+e^- \longrightarrow \phi(1020) \longrightarrow \pi^0\pi^0\gamma$, $\eta\pi^0\gamma$ в эксперименте СНД на коллайдере ВЭПП-2М в Новосибирске. Измерены относительные вероятности редких радиационных распадов $\phi \longrightarrow \pi^0\pi^0\gamma$ и $\phi \longrightarrow \pi^0\eta\gamma$: $B(\phi \longrightarrow \pi^0\pi^0\gamma) = (1.1 \pm 0.2) \times 10^{-4}$ ($M_{\pi\pi} > 800$ МэВ), $B(\phi \longrightarrow \eta\pi^0\gamma) = (1.3 \pm 0.5) \times 10^{-4}$.