Search for a possible exotic state $C(1480)$ at the VEPP-2M storage ring

V. M. Aul'chenko, V. B. Golubev, S. I. Dolinskiĭ, V. P. Druzhinin, M. S. Dubrovin, P. M. Ivanov, V. N. Ivanchenko, E. V. Pakhtusova, A. N. Peryshkin, S. I. Serednyakov, V. A. Sidorov, Yu. M. Shatunov, and S. I. Éĭdel'man

Institute of Nuclear Physics, Siberian Branch, Academy of Sciences of the USSR

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An experiment has been carried out with the Neutral Detector at the VEPP-2M electron-positron storage ring to search for a possible exotic C state with a mass of about 1.5 GeV. An upper limit has been established on the product of the electron width $\Gamma(C\to e^+e^-)$ and the probability for decay by the $\varphi\pi_0$ channel for the C state: $\Gamma(C\to e^+e^-)B(C\to\varphi\pi_0)<70$ eV (90% confidence level).

A resonance in the $\pi^-p\to\varphi\pi_0 n$ system with a mass of about 1.5 GeV and with the quantum numbers $J^{PC}=1^{--}$, the "C-resonance," was recently discovered[1,2] in the reaction $\varphi\pi_0$ in the Lepton apparatus at Serpakhov. The absence of a decay to $\omega\pi_0$ with a significant width $\Gamma_c=130$ MeV is evidence that this state has an exotic structure. Achasov,[3] for example, has suggested that the C-resonance is a four-quark meson.

This state can also be observed in electron-positron collisions if its electron width $\Gamma(C\to e^+e^-)$ is large enough. We have carried out a search for the C-state in the reaction

$$e^+e^-\to C(1480)\to\varphi\pi_0\to K_SK_L\pi_0\to K_L\pi_0\pi_0\pi_0 \qquad (1)$$

The experiments[4] were carried out at the VÉPP-2M electron-positron storage ring. Although the mass of the C-state is higher than the maximum energy of the VÉPP-2M ($2E=1.4$ GeV), the left-hand slope of the resonance can be observed experimentally because of its large width. The measurements were carried out with the Neutral Detector (ND), which consists of 168 counters with NaI(Tl) crystals with a total weight of 2.6 metric tons (Ref. 5). The Neutral Detector can measure the energies and emission angles of γ rays in a solid angle of 0.65 of 4π steradians.

The events that were selected in the search for reaction (1) had five or more detected γ rays in the energy interval $2E=1.28$–1.40 GeV, in which at least two π_0 mesons were found. A further requirement was that the resultant transverse momentum of the particles in the event be less than 200 MeV and that the total energy evolved in the calorimeter lie between $0.5E$ and $1.4E$. These conditions significantly suppressed the background from cosmic rays, particles ejected from the beam, and events of the basic neutral process in this energy range, $e^+e^-\to\omega\pi_0\to\pi_0\pi_0\gamma$ (Ref. 6).

The basic distinctive feature of reaction (1) is a peak in the recoil mass spectrum

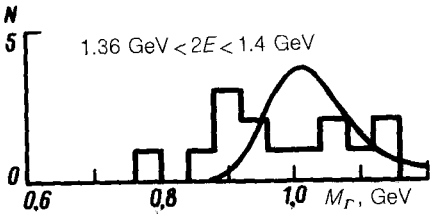

FIG. 1. Recoil mass spectrum of π_0 mesons in multiple-γ events, selected on the basis of the criteria given in the text proper. Curve—Monte Carlo calculations for the reaction $e^+e^- \to \varphi\pi_0$; histogram—experimental.

of the π_0 meson. For the events that were selected, however, this peak was not observed (Fig. 1). If we approximate the observed spectrum by the sum of a linear function and a curve found from a model for the reaction being sought, we can find upper limits on the cross section for the reaction $e^+e^- \to \varphi\pi_0$ in this energy range (Table I). The efficiency of the detection of this reaction for the selection criteria listed above was about 0.6%.

Table I also shows an upper limit on the product of the electron width and the relative probability for the decay $C \to \varphi\pi_0$, found with the help of a Breit-Wigner curve with a P-wave phase volume. These calculations allowed for the energy dependence of the width of the resonance and used the following parameter values for the resonance: $M_c = 1480 \pm 40$ MeV and $\Gamma_c = 130 \pm 60$ MeV (Ref. 2). This limit is determined by the cross section for the reaction $e^+e^- \to \varphi\pi_0$ at a maximum beam energy $2E = 1.4$ GeV.

Previous searches for the reaction $e^+e^- \to \varphi\pi_0$ have been carried out at 1.348 GeV with the KMD detector at the VÉPP-2M storage ring[7] and in the energy interval 1.5–2.2 GeV with the DM1 detector at Orsay.[8] In each of those experiments, a study was made of the decay mode $\varphi \to K^+K^-$. The upper limits established on the cross section in those previous studies are listed in Table I. Also shown here are upper limits on the

TABLE I. Upper limits on the cross section for the reaction $e^+e^- \to \varphi\pi_0$ and limits on the product $\Gamma(C \to e^+e^-)B(C \to \varphi\pi_0)$.

Experiment	$2E$(GeV)	σ_{tot} (nb)	$\Gamma(C \to e^+e^-)B(C \to \varphi\pi_0)$ (eV)
ND[2]	1.28 – 1.32	1.3	130
	1.32 – 1.36	4.1	
	1.36 – 1.40	2.3	
KMD[7]	1.348	0.5	90
DM1[8]	1.5 – 1.6	2.2	80
	1.6 – 1.7	0.8	
	1.7 – 1.8	0.5	

product of the lepton width of the resonance being sought and the probability for its decay by the $\varphi\pi_0$ channel, which we calculated by the method described above. Drawing from the results of all three experiments, we find the following upper limit:

$$\Gamma(C\to e^+e^-)B(C\to\varphi\pi_0)<70 \text{ eV (90\% confidence level)}. \quad (2)$$

It should be noted that the upper limit which has been found could have been lowered significantly if the parameters of the C-resonance had been determined more accurately.

According to the standard classification, the vector mesons in this mass range—$\rho(770)$, $\omega(783$, $\varphi(1020)$, and $\rho(1600)$—are two-quark states and have electron widths on the order of 1 keV. The limitation which we have found here, (2), is significantly smaller than this value. If the quantum numbers of the C-state are indeed $J^{PC}=1^{--}$, and if the decay $C\to\varphi\pi_0$ is the primary decay channel, then the limit found here is evidence that this state has an exotic quark composition. It is difficult to generate theoretical predictions of the electron width of the C-state under the assumption that it has a four-quark structure. An upper limit of about 0.5 keV has been estimated.[9]

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[1]S. I. Bityukov *et al.*, Pis'ma Zh. Eksp. Teor. Fiz. **42**, 310 (1985) [JETP Lett. **42**, 384 (1985)].
[2]S. I. Bityukov *et al.*, Preprint 86-110, Institute of High-Energy Physics, Serpukhov, 1986.
[3]N. N. Achasov, Pis'ma Zh. Eksp. Teor. Fiz. **43**, 410 (1986) [JETP Lett. **43**, 526 (1986)].
[4]V. P. Druzhinin *et al.*, Preprint INP 84-93, Novosibirsk, 1984; S. I. Dolinsky *et al.*, Preprint INP 85-98, Novosibirsk, 1985.
[5]V. B. Golubev *et al.*, Nucl. Instr. Meth. **227**, 467 (1984).
[6]S. I. Dolinsky *et al.*, Phys. Lett. **174**, 453 (1986).
[7]G. V. Anikin *et al.*, Preprint INP 83-85, Novosibirsk, 1983.
[8]B. Delcourt *et al.*, Phys. Lett. **113B**, 93 (1982).
[9]F. E. Close and H. J. Lipkin, Phys. Rev. Lett. **41**, 1263 (1978).

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