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EXPERIMENTS WITH NEUTRAL DETECTOR AT VEPP-2M IN THE ENERGY RANGE 1.0—1.4 GEV

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ABSTRACT

Results of experiments with the Neutral Detector in the energy range 1.0—1.4 GeV are presented. The cross section of the process $e^+e^- \to \pi^+\pi^-\pi^0$ was measured to be about 6 nb considerably exceeding the predictions of the vector dominance. The measured cross sections of the processes $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$, $\pi^+\pi^-\pi^+\pi^-$ increase with energy and are about 70 nb at the maximum energy $2E = 1.4$ GeV. An upper limit has been established for the product of the leptonic width and the branching ratio for the decay mode $\Phi\pi^0$ for a possible exotic state $C(1490)$ observed in Serpukhov:

$$\Gamma(C \to e^+e^-) \cdot B(C \to \Phi\pi^0) < 55 \text{ eV}.$$

A limit has been placed for the decay probability $\Phi \to a\gamma$ where a is a light shortliving particle decaying into a e^+e^--pair:

$$B(\Phi \to a\gamma) \cdot B(a \to e^+e^-) < 5 \cdot 10^{-5}.$$

This work presents results of the experiments performed with the Neutral Detector [1] at the VEPP-2M collider in the center of mass energy range $2E = 1.0-1.4$ GeV. The integrated luminosity was about 9 pb^{-1} near the Φ-meson resonance and about 4 pb^{-1} in a broad energy range from 1.04 to 1.40 GeV. The main bulk of the recorded information has already been processed and published [2—6], here we present results of the further analysis.

1. THE PROCESS $e^+e^- \to \pi^+\pi^-\pi^0$

The reaction

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

has earlier been studied near ω- and Φ-mesons at VEPP-2M and ACO [7, 8] and in the energy range $2E > 1.35$ GeV at the DCI collider [9, 10]. Our preliminary results for the energy range 1.05—1.40 GeV have been published in Ref. [3].

For analysis events were selected with two charged particles and two photons which met the requirement of the energy-momentum balance. The distributions in the mass of the photon pair $M_{\gamma\gamma}$ for detected events and Monte Carlo simulation are shown in Fig. 1. For further analysis we chose a band of masses from 100 to 160 MeV. The main sources of background events for the reaction (1) are the processes $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$ and $e^+e^- \to K_S K_L$. Assuming smooth dependence on $M_{\gamma\gamma}$ for the background processes we have determined the background level from the $M_{\gamma\gamma}$ regions 70—100 and 160—190 MeV.

The total number of events after background subtraction is about 900. The detection efficiency determined from the Monte Carlo simulation does not show energy dependence. Its absolute value was obtained by two methods: by simulation and from the data processing of the events from the Φ-meson region [4] using the same selection criteria and the table values of $\Gamma(\Phi\to e^+e^-)$ and $\Gamma(\Phi\to\pi^+\pi^-\pi^0)$ [11]. In further analysis the experimental value of the detection efficiency equal to $\varepsilon=(3.5\pm1.0)\%$ has been used. The uncertainty is systematic and was estimated from the difference in the detection efficiency values obtained by the two methods. Besides that a possible systematic error due to background subtraction was taken into account.

Fig. 2 shows the energy dependence of the cross section for the reaction (1). Radiative corrections were calculated by Monte Carlo simulation using Ref. [12], the correction did not exceed 5% at the energy higher than 1.1 GeV. The cross section value is about 6 nb. The error indicated is only statistical. In the vector dominance model (VDM) the cross section of the process (1) is determined in the energy range under study by the contributions of ω- and Φ-mesons: $e^+e^-\to\omega,\Phi\to\varrho\pi\to\pi^+\pi^-\pi^0$. If one takes into account the energy dependence of the ω- and Φ-mesons widths, its calculated value is 1 nb at $2E=1.05$ GeV and falls to 0.2 nb at 1.4 GeV. Thus the cross section measured is considerably higher than the VDM prediction, its value is in a good agreement with the results from DM1 [8] and deviates from those of DM2 [10] at 1.4 GeV (Fig. 2). The reasons of the discrepancy between VDM and our measurement are not clear. A contribution of the intermediate hadronic states is possible. The chiral model calculation taking into account the diagrams with intermediate nucleon-antinucleon states only [13] gives the cross section value of 0.1 nb, well below the measured one.

To determine the intermediate mechanism of 3π production we have studied the distribution over the recoil masses of π-mesons. In Fig. 3 the scatter plots are shown for detected events (Fig. 3,*a*) as well as for Monte Carlo events of the reaction (1) assuming pure Lorentz Invariant Phase Space (LIPS, Fig. 3,*b*) and ϱπ intermediate mechanism (Fig. 3,*c*). Approximation of the experimental distribution by a sum of these two contributions results in a value of the ϱπ contribution 75±10%.

The process under study gives a significant contribution to the isoscalar part of the total hadronic cross section at this energy. The quark model predicts for the ratio of the cross sections of the production of odd σ_- and even number of pions σ_+ far from resonances $K=\frac{\sigma_-}{\sigma_+}=\frac{|q_u+q_d|^2}{|q_u-q_d|^2}=1{:}9$. In Fig. 4 the energy dependence of K in our energy range is shown. To calculate K the following processes were taken into account: (1), $e^+e^-\to\pi^+\pi^-$ [14], $e^+e^-\to\pi^+\pi^-\pi^+\pi^-\pi^0$ [15] and $e^+e^-\to4\pi$ (Ch. 2 of this work). One can see that despite of ϱ′(1600) proximity and nonregular character of the energy dependence of K the average value of K is close to the expected one.

2. PROCESSES $e^+e^-\to4\pi$

At the energy $2E>1$ GeV the cross section of multihadronic production starts to grow. The following processes have the largest cross section at $2E<1.4$ GeV:

$$e^+e^-\to\pi^+\pi^-\pi^0\pi^0, \tag{2}$$

$$e^+e^-\to\pi^+\pi^-\pi^+\pi^-. \tag{3}$$

Earlier these processes were studied at VEPP-2M [15—17], ACO [18, 19], ADONE [20] and DCI [10, 21, 22]. Results of different experiments are consistent within a 20% accuracy, the cross section value is about 30—40 nb at the peak of the ϱ′(1600) resonance. In this work the cross sections of the processes (2) and (3) were measured with the statistics by a factor of 3 higher than the total statistics of all previous experiments in the energy range below 1.4 GeV.

In VDM the cross sections of the reactions (2) and (3) are described by the combined contribution of ϱ(770) and ϱ′(1600) [23, 24] decaying through quasi-two-particle intermediate states:

$$e^+e^-\to\omega\pi^0\to\pi^+\pi^-\pi^0\pi^0, \tag{4}$$

$$e^+e^-\to A_1\pi\to\pi^+\pi^-\pi^0\pi^0,\ \pi^+\pi^-\pi^+\pi^-, \tag{5}$$

$$e^+e^-\to\varrho\varepsilon,\ \varrho f\to\pi^+\pi^-\pi^0\pi^0,\ \pi^+\pi^-\pi^+\pi^-. \tag{6}$$

The channel (4) was first separated with our detector using the neutral decay mode of the ω-meson $\omega\to\pi^0\gamma$ [6]. Its cross section is about 15 nb which is a significant portion of the total cross section of the process (2) and is determined by contributions of ϱ(770) and ϱ′(1600). The channels (5) and (6) are badly distinguished since they have a common intermediate state ϱππ. Their separation is also hampered by the interference of (5) and (6) due to the large width of ϱ-, A_1-, ε- and *f*-mesons. One must also note that parameters of the A_1- and ε-mesons are determined with large errors. This makes reliable measurements of the cross sections of the processes (2) and (3) important independently of the knowledge of the intermediate mechanisms.

To study the reaction (2) 4734 events with two charged particles and two π^0-mesons have been selected which met a requirement of the energy-momentum balance. The detection efficiency determined from Monte Carlo for two intermediate states ($\omega\pi^0$ and LIPS) was $(4.80\pm0.25)\%$ and $(4.50\pm0.25)\%$ respectively. In the energy range under study the detection efficiency did not vary by more than 10%. In the further analysis it was assumed to be constant and equal to 4.6%. An additional uncertainty arising from this assumption was included in the total systematic error.

The mass spectrum of the pairs of charged pions is smooth (Fig. 5) and does not show the ρ-meson. This indicates that the reaction $e^+e^-\to\rho^0\pi^0\pi^0$ does not dominate. In Fig. 6 mass spectra of the system $\pi^+\pi^-\pi^0$ are presented. A peak near the ω-meson mass is seen corresponding to the channel $\omega\pi^0$. Also shown are the spectra for Monte Carlo events for a sum of two considered states $\omega\pi^0$ and LIPS. It can be seen that the observed spectrum is qualitatively well described by such a sum.

The total cross section of the process (2) σ_t was determined from the formula $\sigma_{vis}=\varepsilon\sigma_t\beta$, where σ_{vis} is the detection cross section, ε is the detection efficiency, β is a factor taking into account the radiative corrections [12] which varies from 0.90 to 0.95. The cross section obtained in our experiment (Fig. 7) is consistent with the most accurate previous measurement in this energy range performed with the OLYA detector [17]. The contribution of the channel $\omega\pi^0$ to the cross section of (2) estimated from the decay $\omega\to\pi^+\pi^-\pi^0$ (Fig. 6) coincides with our previous measurement using the decay mode $\omega\to\pi^0\gamma$ [6]. The channels $A_1\pi$ and $\rho\pi\pi$ were not separated.

To study the process (3) 6212 events with four charged particles have been selected with energy-momentum balance. The detection efficiency determined from Monte Carlo grows from 15% at $2E=1.0$ GeV to 19% at $2E=1.4$ GeV and is the same for two intermediate mechanisms considered (LIPS and $\rho\pi\pi$).

The energy of each pion was reconstructed using the values of its angles measured in the detector. The spectrum of pion pair masses is smooth, no ρ-meson is seen. The results of the previous experiments, however, gave evidence for the presence of the ρ-meson in

the final state [15]. This contradiction can be accounted for the fact that a sign of π-mesons is not distinguished in our detector resulting in a worse peak resolution.

The total cross section of (3) after applying radiative corrections is shown in Table 1 and in Fig. 8 with the most accurate

Table 1

Total Cross Sections of the Reaction $e^+e^-\to4\pi$

$2E$, MeV	$\sigma_{\pi^+\pi^-\pi^+\pi^-}$, nb	$\sigma_{\pi^+\pi^-\pi^0\pi^0}$, nb	r	$\sigma_{4\pi}$, nb
1000—1010	1.9±0.3	9.0±1.1	.86± .48	10.9±1.1
1010—1030	—	—	—	—
1030—1050	2.2±0.2	11.4±1.0	.88± .41	13.6±1.0
1050—1070	2.4±0.5	11.9±1.8	1.14± .87	14.3±1.9
1070—1090	2.2±0.5	16.8±2.2	.35± .14	19.0±2.3
1090—1110	4.2 +- 0.7	22.3 +- 2.8	.38± .11	26.5±2.9
1110—1130	4.4±0.7	21.6±2.9	.45± .15	26.0±3.0
1130—1150	4.1±0.6	21.5±2.6	.44± .14	25.6±2.7
1150—1170	6.7±0.7	28.4±2.8	.43± .09	35.1±2.9
1170—1190	7.8±0.8	27.4±3.0	.54± .13	35.2±3.1
1190—1210	9.0±0.6	25.5±2.1	.74± .14	34.5±2.2
1210—1230	12.4±0.7	30.8±2.2	.72± .10	43.2±2.3
1230—1250	15.5±0.7	33.9±3.1	.78± .13	49.4±3.2
1250—1270	16.1±1.1	28.5±2.8	1.12± .24	44.6±3.1
1270—1290	17.1±0.7	36.0±2.3	.80± .09	63.1±2.4
1290—1310	17.2±0.6	37.2±1.9	.77± .07	54.4±2.1
1310—1330	20.2±0.7	40.3±2.2	.80± .05	60.5±2.3
1330—1350	22.5±0.8	41.4±2.3	.86± .08	63.9±2.4
1350—1370	23.3±0.7	41.1±1.9	.91± .07	64.4±2.0
1370—1390	25.4±0.8	42.3±2.1	.96± .08	67.7±2.2
1390—1400	25.5±1.2	44.9±3.2	.89± .11	70.4±3.4

results of other experiments. The $\varrho'(1600)$ clearly dominates. In the energy range 1.0—1.2 GeV different experiments are in satisfactory agreement with each other, whereas for $1.2<2E<1.4$ GeV our results are close to those from CMD and are by 20% higher than at OLYA [17].

The total cross section of the reaction $e^+e^-\to4\pi$, i. e. a sum of the cross sections (2) and (3) is presented in Fig. 9 and in Table 1. In the energy range 1.0—1.4 GeV it linearly grows with energy.

The systematic error in the total cross sections (2) and (3) was estimated to be 10%. It was mainly due to the simulation accuracy and uncertainty of the intermediate mechanism. In Table 1 and Figs 7—10 only statistical errors are shown.

One can deduce information about the intermediate mechanism from the ratio r of the cross sections (2) and (3) (after subtraction of the contribution of the channel (4)). Isotopic invariance and approximation of narrow resonances predict $r=1$ for $A_1\pi$ and $r=2$ for $\varrho\varepsilon$ and ϱf. However, as shown in Ref. [27], the interference of diagrams differing by permutations of identical pions can notably change the value of r near the threshold of production. From [27] and our data (Fig. 10) one can conclude that neither one of the channels (4—6) is able to explain the observed behaviour. For further clarification of this problem one must also calculate the interference of different channels.

3. SEARCH FOR A POSSIBLE EXOTIC STATE $C(1490)$

Results obtained during the investigation of the process (2) can be used in a search for a possible exotic state $C(1490)$ discovered in Serpukhov in the reaction $\pi^-p\to C+n$ and decaying into $\Phi\pi^0$ [26]. This state can also be produced in electron-positron collisions in a one-photon channel if its quantum numbers coincide with those of a photon $J^{PC}=1^{--}$. Although its mass is higher than the maximum energy of the VEPP-2M collider (1.4 GeV), its left slope can be observed due to a large width of $\Gamma_C=165$ MeV. We have performed a search for $C(1490)$ in two reactions.

The first one is

$$e^+e^-\to C(1490)\to\Phi\pi^0\to\pi^+\pi^-\pi^0\pi^0. \qquad (7)$$

The mass spectrum of a $\pi^+\pi^-\pi^0$ system is shown in Fig. 6,*b* for the

energy region 1.35—1.40 GeV. A clear peak at the mass of the ω-meson is seen due to the reaction (4), whereas no signal is observed at the Φ-meson mass. Therefore only an upper limit for the product of the branching ratio of the decay mode $\Phi\pi^0$ and its leptonic width is obtained:

$$B(C\to\Phi\pi^0)\cdot\Gamma(C\to e^+e^-)<1.1\ \text{keV} \quad 90\%\ \text{c.l.}$$

A search for the resonance $C(1490)$ has also been performed using its purely neutral decay mode

$$e^+e^-\to C\to\Phi\pi^0\to K_SK_L\pi^0\to K_L\pi^0\pi^0\pi^0. \qquad (8)$$

A multiphoton final state is even more convenient for a search $C(1490)$ for the decay mode $\Phi\to K_SK_L$ since the total cross section of neutral particle production is small in the energy range under study and is mainly determined by a well-known process

$$e^+e^-\to\omega\pi^0\to\pi^0\pi^0\gamma. \qquad (9)$$

For a search for $C(1490)$ in the energy range 1.1—1.4 GeV events with five and more detected photons were used. To suppress the background due to cosmic particles and beam-gas interactions we required a total transverse momentum in an event to be less than 200 MeV. Since some of the photons of the reaction (8) escape detection, and the K_L meson produces rather small energy deposition in the detector, only those events were selected in which the energy deposition in the calorimeter was in the range $0.5E-1.4E$. The main characteristic feature of the process (8) is a monochromatic π^0-meson. A spectrum of π^0-meson recoil masses obtained by Monte Carlo simulation of the reaction (8) shows a peak at the mass of the Φ-meson (Fig. 11,*a*). A similar spectrum for experimental events (Fig. 11,*b*) does not have such a peak. In Fig. 12 we plot the energy dependence of the detection cross section for the events with a π^0-meson recoil mass in the region of the Φ-meson. At the maximum energy the detection efficiency for the process $e^+e^-\to\Phi\pi^0$ was 0.5%. The approximation of this energy dependence by a constant background and a Breit-Wigner curve with $M_C=1490$ MeV, $\Gamma_C=165$ MeV gives an upper limit for the cross section of $C(1490)$ production in the peak $\sigma_C<3.7$ nb, whence

$$B(C\to\Phi\pi^0)\cdot\Gamma(C\to e^+e^-)<85\ \text{eV} \quad 90\%\ \text{c.l.} \qquad (10)$$

Earlier search for the reaction $e^+e^- \to \Phi\pi^0$ was also performed at the energy 1.348 GeV by the CMD detector at VEPP-2M [15] and in the energy range 1.5—2.2 GeV by the DM1 detector at DCI [28]. In both experiments a decay mode $\Phi \to K^+K^-$ was used and no events were observed. Using the upper limits from these papers combined with our results on the decay mode $\Phi \to K_S K_L$ one can improve the upper limit above:

$$B(C \to \Phi\pi^0) \cdot \Gamma(C \to e^+e^-) < 55 \text{ eV} \quad 90\% \text{ c.l.} \qquad (11)$$

Vector mesons in this energy range — $\varrho(770)$, $\omega(783)$, $\Phi(1020)$ and $\varrho'(1600)$ are in the generally accepted classification two-quark states and have leptonic widths about 1 keV. An estimated value of the $C(1490)$ leptonic width is also about 0.5 keV [27].

An upper limit from the decay mode $\Phi \to K_S K_L$ is by an order of magnitude better than that from the decay mode $\Phi \to \pi^+\pi^-\pi^0$ and is considerably lower than a theoretical estimate above. If the quantum numbers of the $C(1490)$ meson are really $J^{PC} = 1^{--}$ and the decay mode $C \to \Phi\pi^0$ has a large branching fraction, then our upper limit indicates to the exotic nature of its quark contents.

4. SEARCH FOR THE DECAY OF THE Φ-MESON INTO A PHOTON AND A LIGHT NEUTRAL PARTICLE DECAYING INTO A e^+e^--PAIR

Recently narrow peaks have been observed in spectra of positrons produced in collisions of heavy nuclei [29, 30]. As a possible explanation of this effect a hypothesis of a light neutral particle decaying into a e^+e^--pair is discussed [30, 31]. Further confirmation of this idea came from the observation of similar peaks in the spectra of electrons emitted simultaneously with positrons in the collisions of heavy nuclei [32]. From the width and position of the observed peaks restrictions for the a parameters were placed in Ref. [30]: the mass is about 1.8 MeV and the lifetime is more than 10^{-19} sec. Theoretical analysis [31] showed that this particle can be interpreted as a standard axion — a light pseudoscalar particle earlier suggested for explanation of the CP-invariance of strong interactions [33]. These results gave a new impetus to the searches for axion in e^+e^--collisions in the decay of heavy quarkonia. The corresponding limits for the decay mode $\Upsilon \to a\gamma$ were recently placed by CUSB and CLEO detectors [34]:

$$B(\Upsilon \to a\gamma) \cdot B(a \to e^+e^-) < 5 \cdot 10^{-3}.$$

This result excludes completely a standard axion. Also of interest is a search for the radiative decay of light vector mesons $V \to a\gamma$ where $V = \varrho$, ω, Φ, although the standard axion model predicts extremely low branching fractions for these decay modes. Earlier we have performed at the Neutral Detector a search for the decay $\Phi \to a\gamma$ assuming that the lifetime of a is large and it is not detected. An upper limit $B(\Phi \to a\gamma) < 0.7 \cdot 10^{-5}$ [4] was placed. Here we are looking for the decay

$$\Phi \to a\gamma, \quad a \to e^+e^- \qquad (12)$$

assuming that a is a light (mass is about several MeV) shortliving particle with the lifetime less than 10^{-11} sec. In our detector such decay will have the following signature: two collinear showers each having the energy of the beam. Note that a shower due to the e^+e^--pair can not be distinguished from that due to a single electron, since the angle between the particles of the pair is small ($\sim m_a/E$). To perform this search we have used the data recorded in the Φ-meson experiment in which the integrated luminosity of about 2.7 pb^{-1} was collected in the C. M. energy range 1000—1048 MeV.

For analysis events have been selected which had one charged particle and one photon with an acollinearity angle less than 10° and the energy deposition more than 0.65 E for each of the particles. These criteria suppressed completely the background due to the hadronic decays of the Φ-meson. The remaining background comes mainly from the two-photon annihilation with the conversion of one of the photons in the material in front of the coordinate chambers as well as from the process $e^+e^- \to e^+e^-\gamma$, the cross section of which has a sharp peak at small invariant masses of the pair (a kind of the photon internal conversion). The detection cross section of background is sufficiently high, but in contrast to the cross section of the process under study does not show resonance energy dependence.

In Fig. 13 the energy dependence of the detection cross section is presented for $1.1 \cdot 10^4$ selected events. No peak is observed in the Φ-meson region. To determine the upper limit for the detection cross section of the process (12) we have approximated it by a sum of the nonresonant background ($1/E^2$) and the radiatively corrected

Breit-Wigner. Results of the fit are presented in Fig. 13. The value of the observed background cross section in the Φ-meson peak is 3.33±0.04 nb (error statistical) in good agreement with the Monte Carlo simulation of the processes $e^+e^-\to\gamma\gamma$ and $e^+e^-\to e^+e^-\gamma$: 3.6±0.4 nb. The upper limit for the resonant cross section is 0.1 nb at the 90% confidence level. From Monte Carlo the detection efficiency for (12) is 45%, whence the upper limit for the branching ratio is

$$B(\Phi\to a\gamma)\cdot B(a\to e^+e^-)<5\cdot 10^{-5}.$$

The corresponding limitations for the case when the lifetime or the mass of a are greater than those in Refs 30, 32 are shown in Fig. 14. Also taken into account were the results of our previous work [4]. Our limits for the decay probability $B(\Phi\to a\gamma)$ are valid for any light exotic particles decaying into the e^+e^--pair, rather than axion only.

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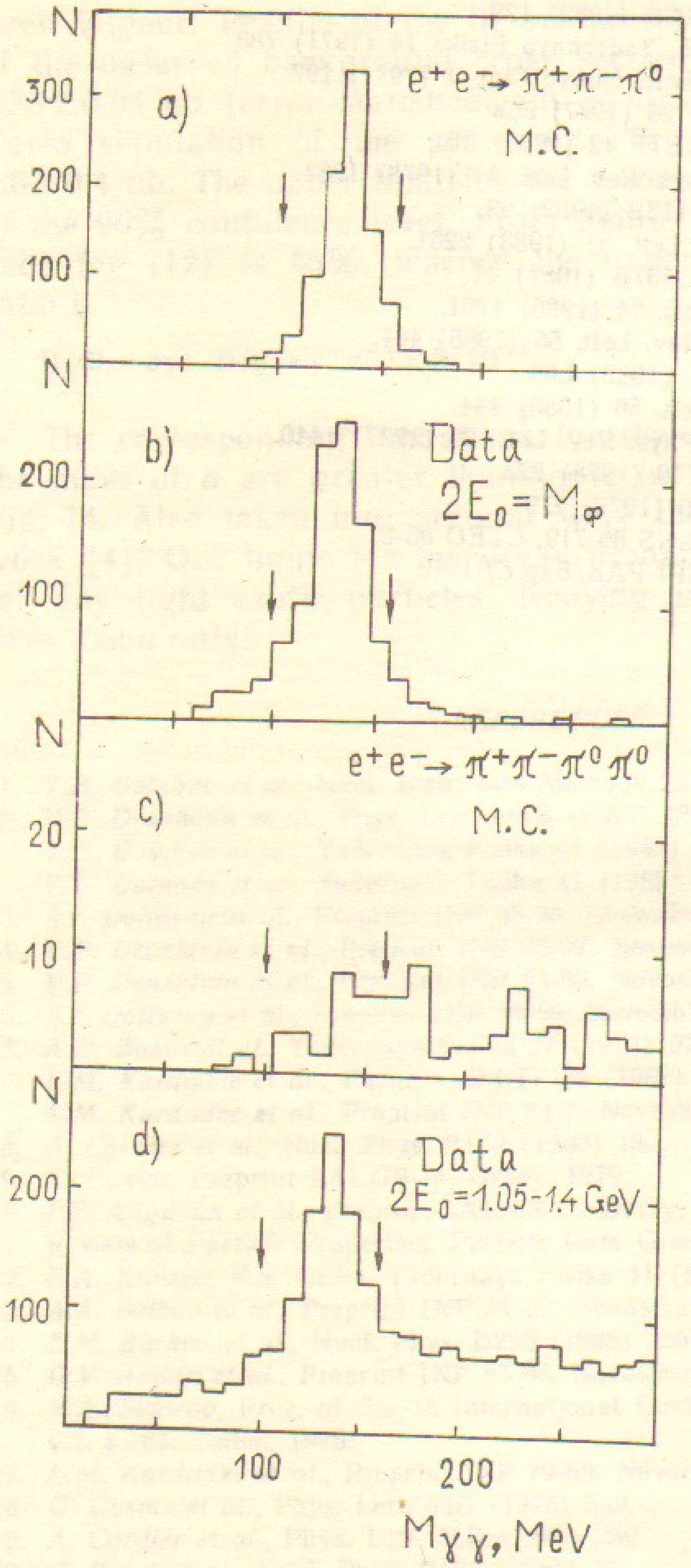


Fig. 1. Two-photon invariant mass $M_{\gamma\gamma}$:

a—simulation of the reaction (1); *b*—experimental data ($2E = M_\Phi$); *c*—simulation of the background reaction $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$; *d*—experimental data ($2E = 1.05-1.40$ GeV).

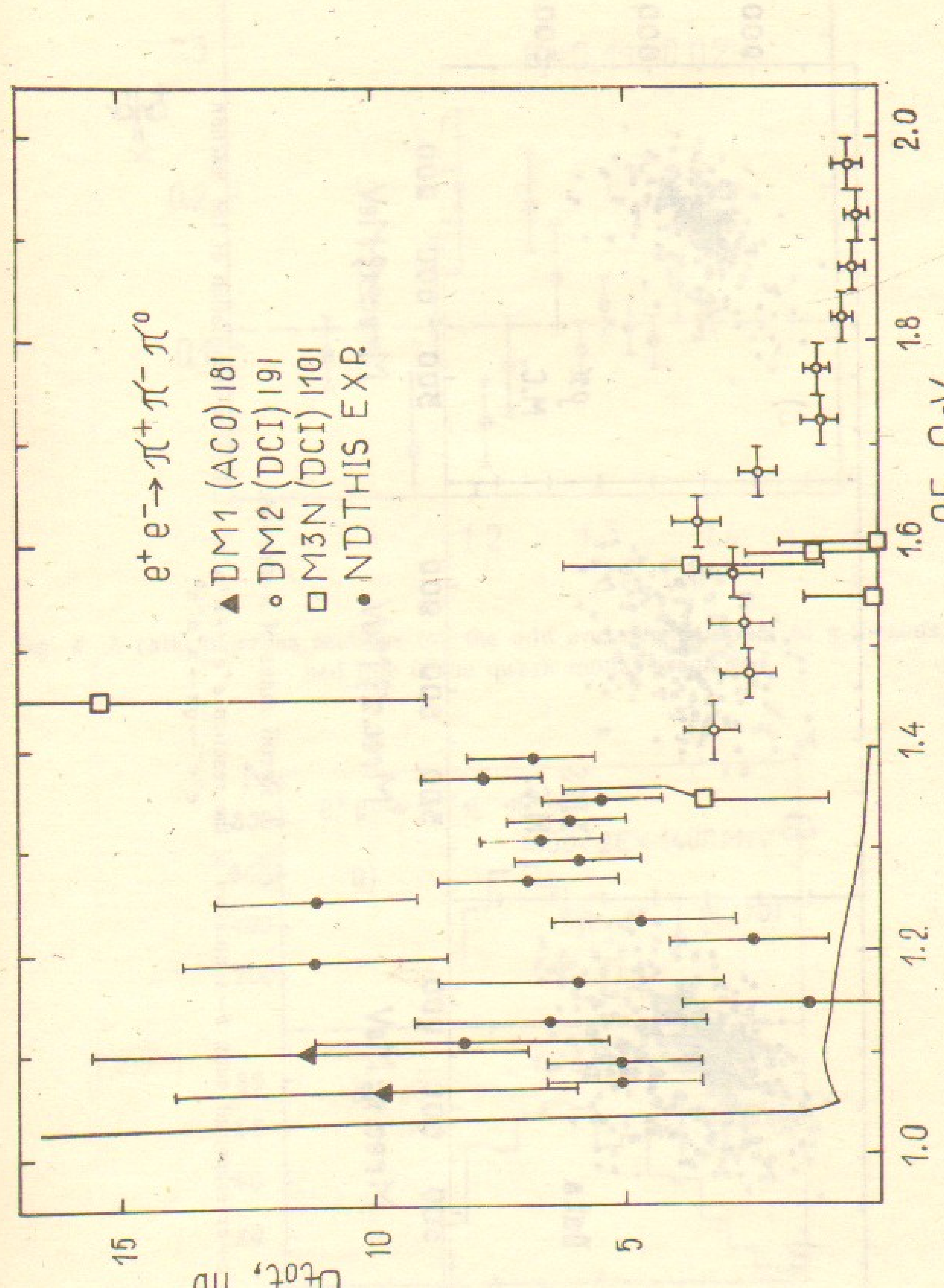


Fig. 2. Energy dependence of the total cross section of the reaction (1). the Solid line is a calculated cross section in the VDM.

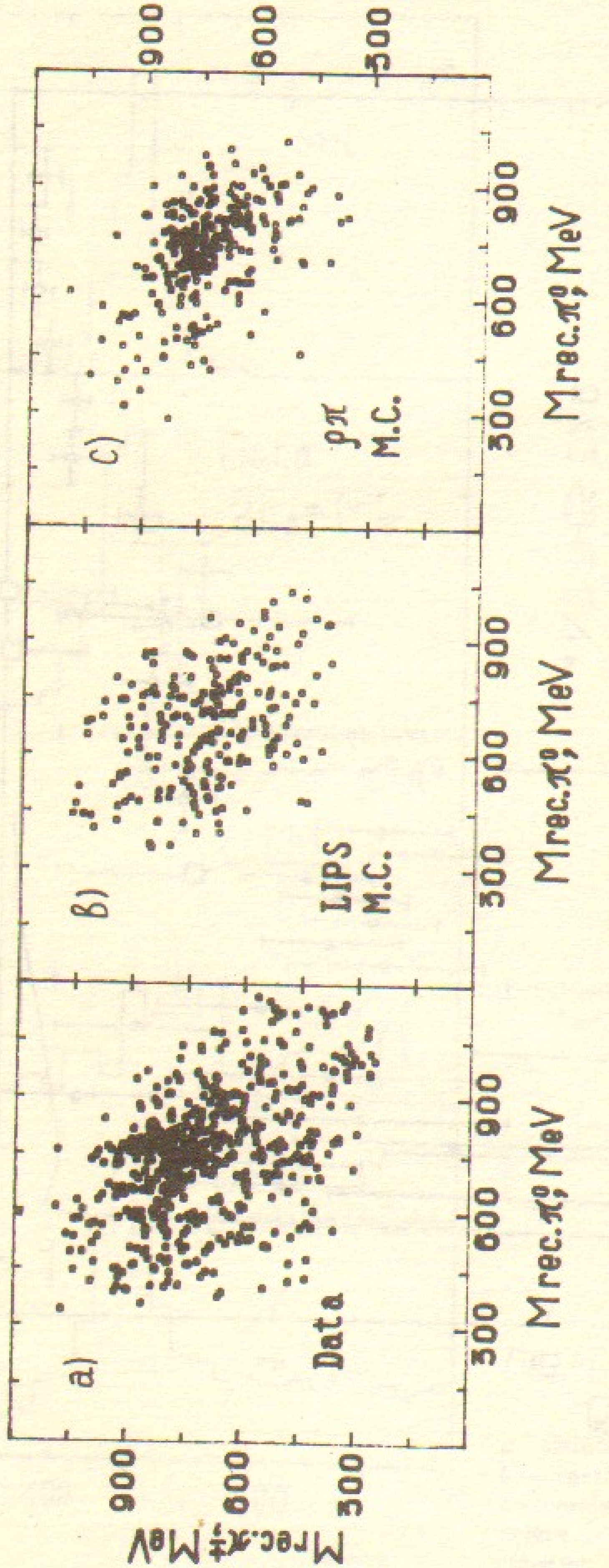


Fig. 3. Recoil mass of π-mesons:
a—experimental data; b—simulation of the reaction $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$ (LIPS); c—simulation of the reaction $e^+e^- \to \rho\pi \to \pi^+\pi^-\pi^0$.

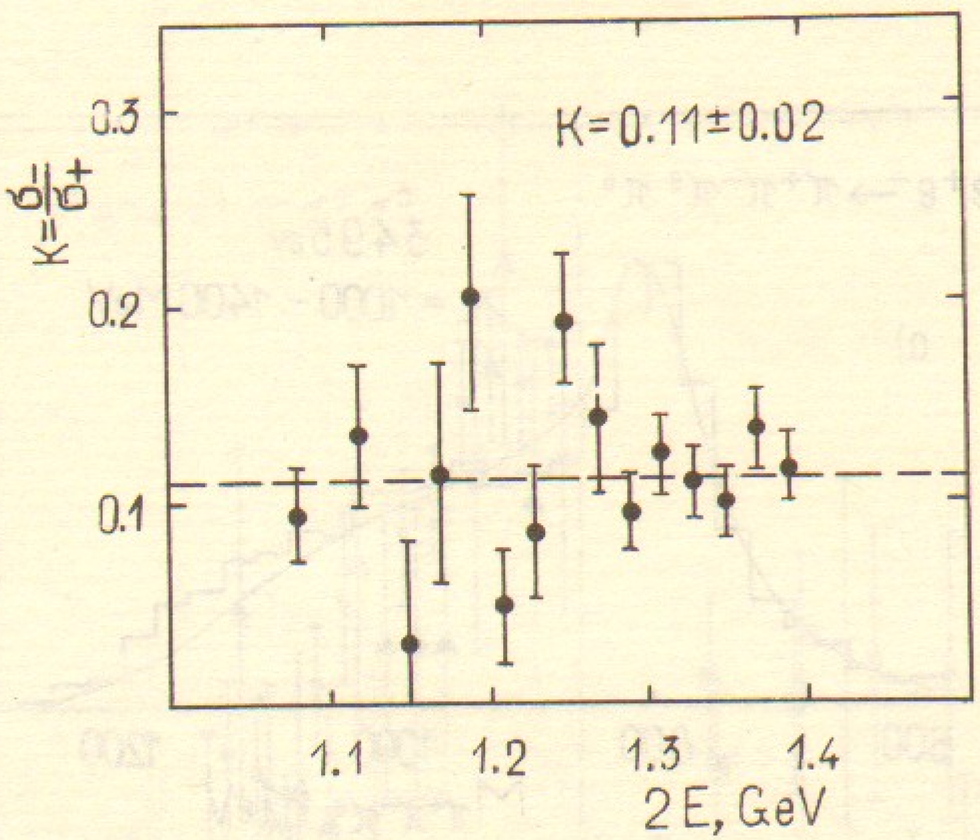


Fig. 4. A ratio of cross sections for the odd and even number of π-mesons. The dashed line is the quark model prediction.

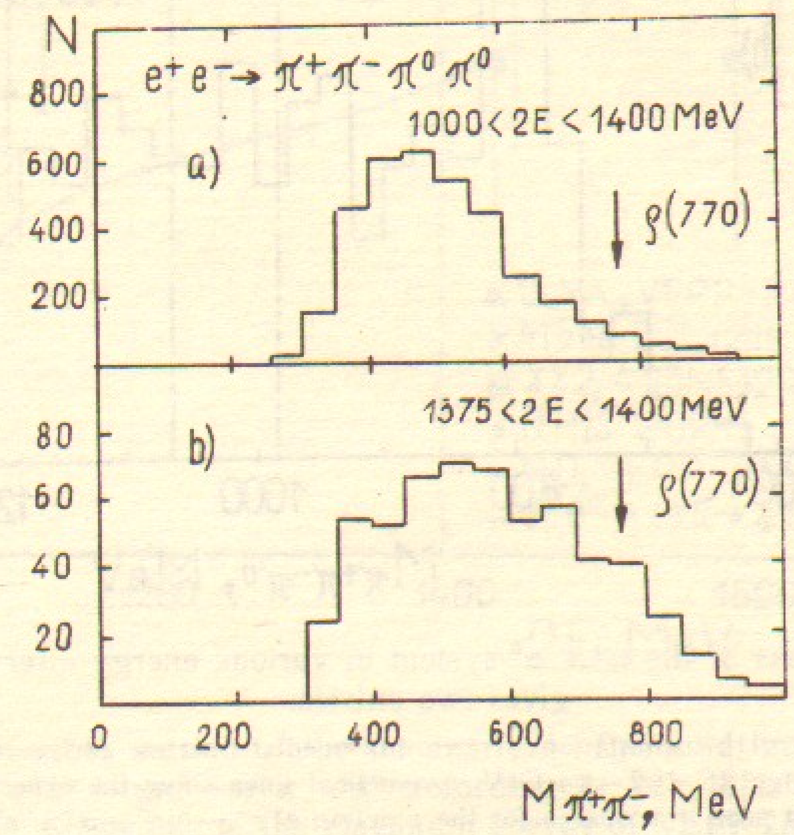


Fig. 5. Invariant mass of two charged π-mesons in the reaction (2).

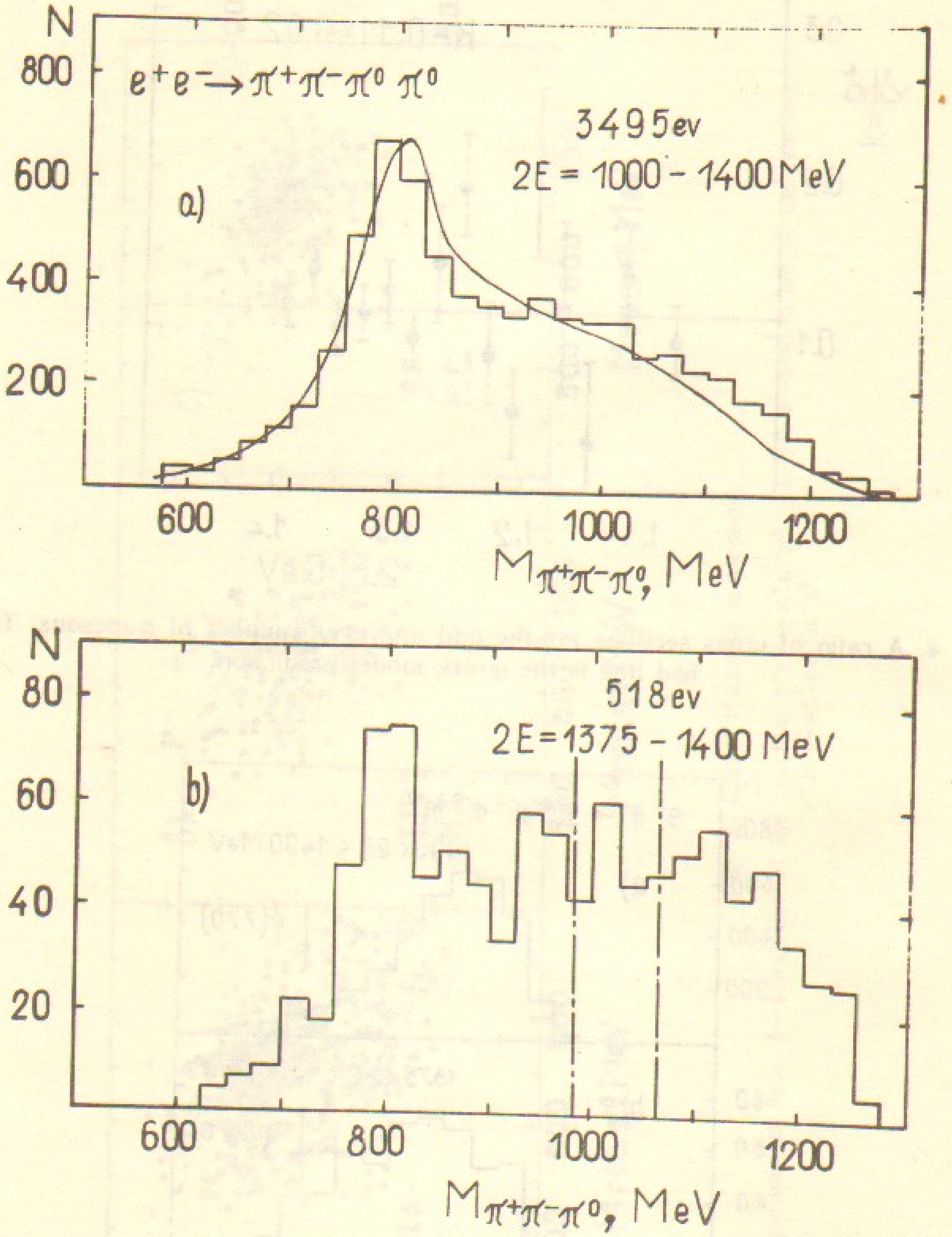


Fig. 6. Invariant mass of the $\pi^+\pi^-\pi^0$-system in various energy intervals. Each event gives two entries.

a—The solid line shows the simulation of two intermediate states: 50%-$\omega\pi^0$ and 50%-model LIPS in the energy range $2E=1.2-1.4$ GeV; *b*—vertical lines show the expected position of the Φ-meson peak in a search for the reaction $e^+e^- \to \Phi\pi^0 \to \pi^+\pi^-\pi^0\pi^0$.

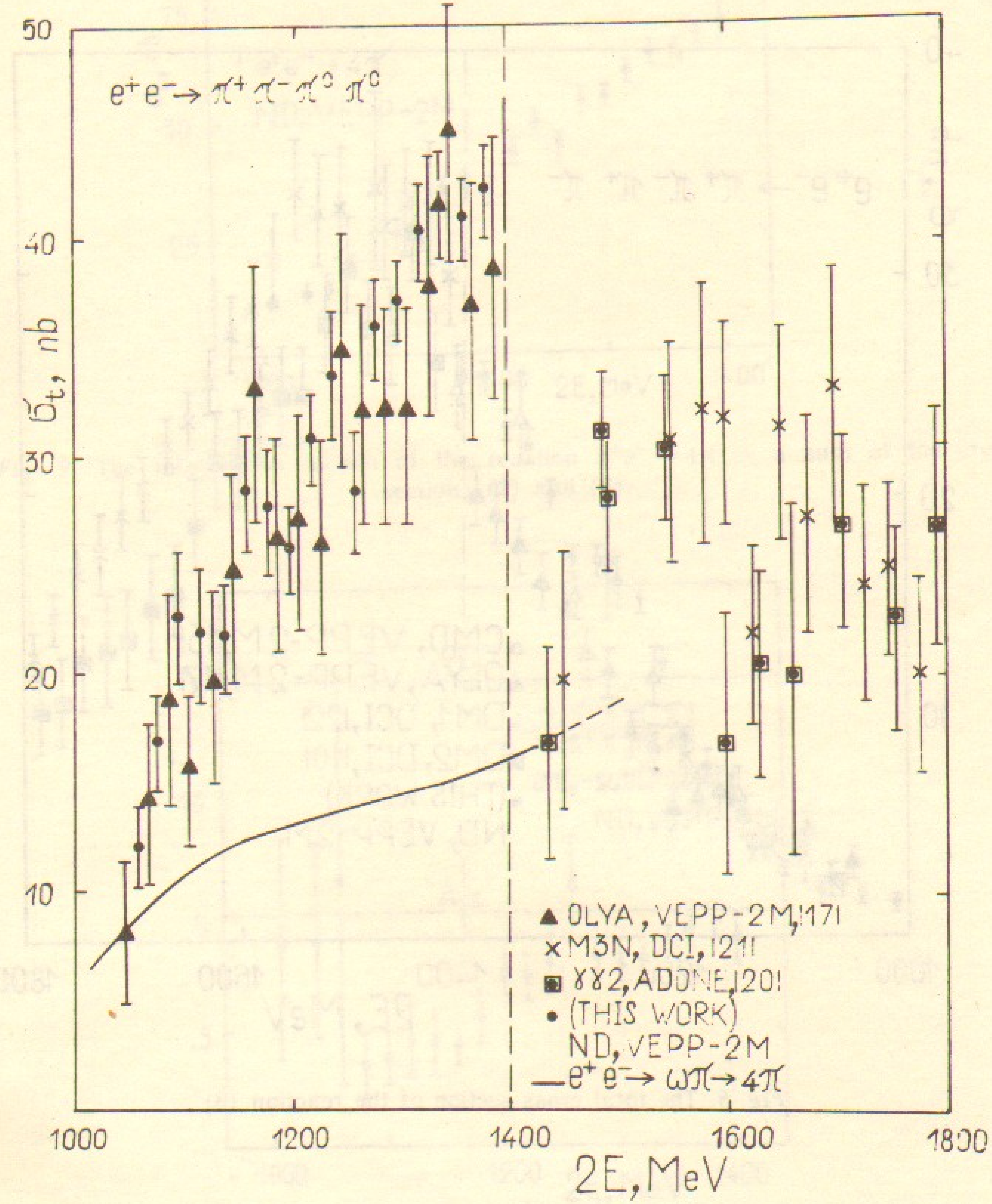


Fig. 7. The total cross section of the reaction (2). The solid line is the cross section of the reaction $e^+e^- \to \omega\pi^0 \to \pi^+\pi^-\pi^0\pi^0$ according to Ref. [6]. The vertical line corresponds to the maximum energy of VEPP-2M.

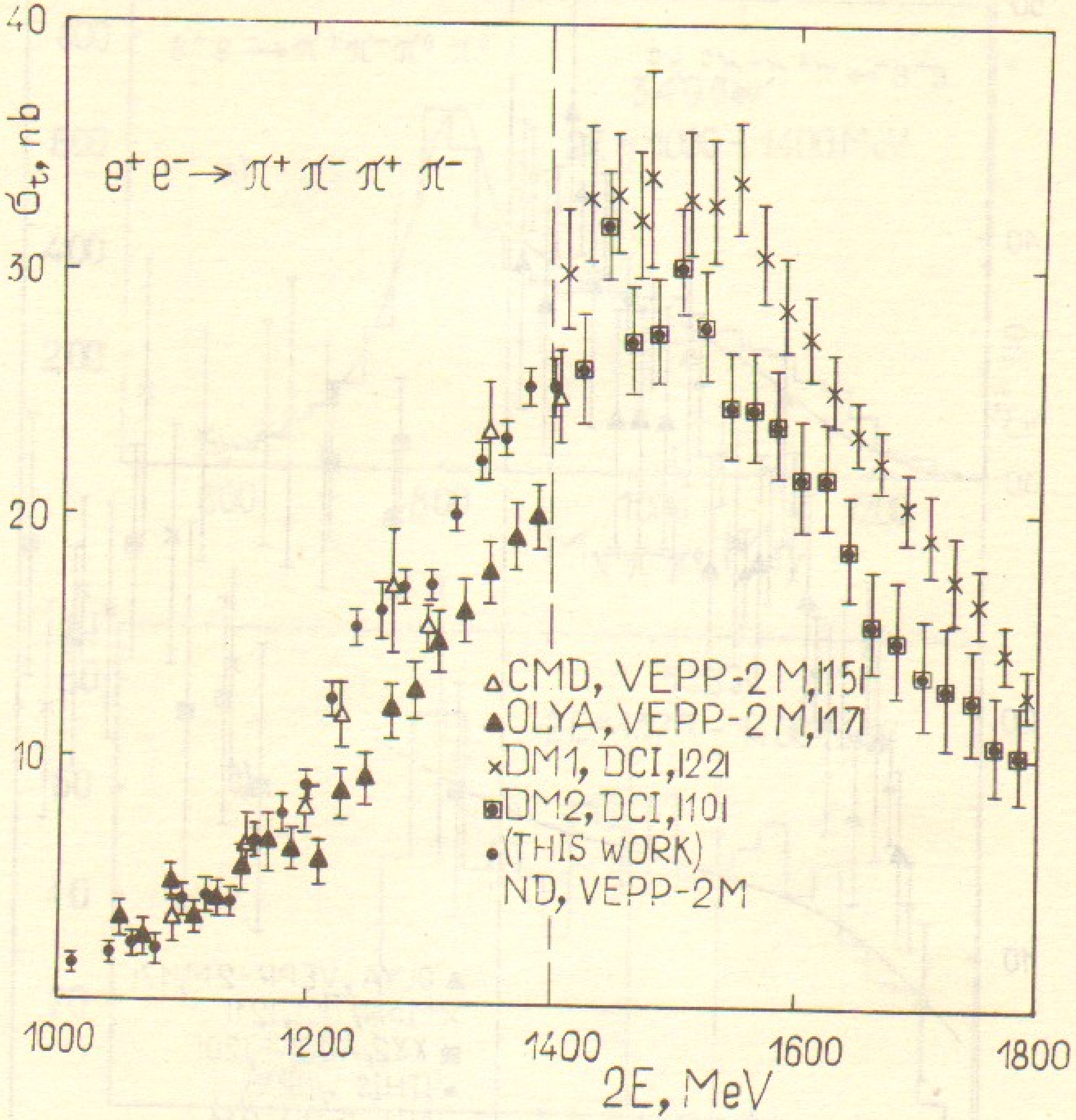


Fig. 8. The total cross section of the reaction (3).

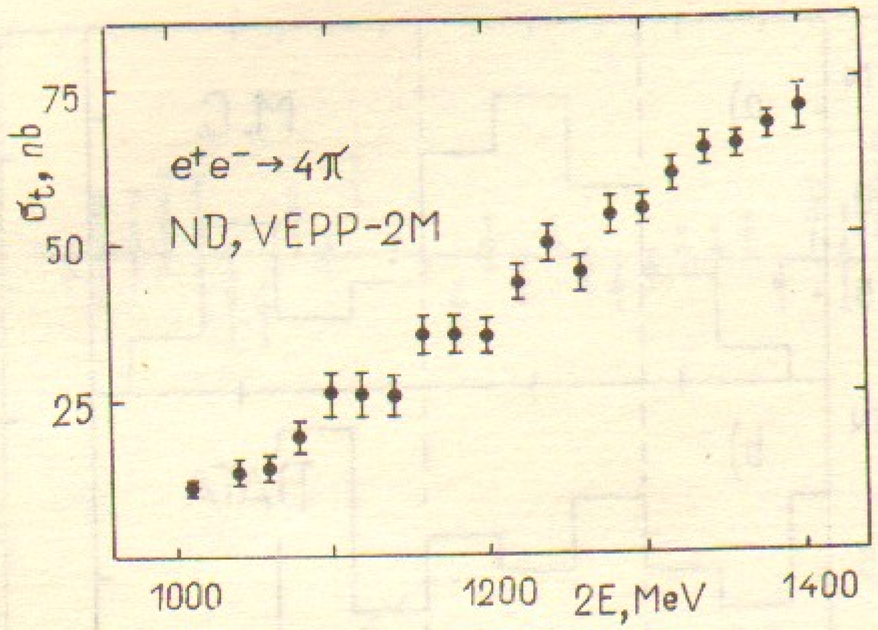


Fig. 9. The total cross section of the reaction $e^+e^- \to 4\pi$ — a sum of the cross sections (2) and (3).

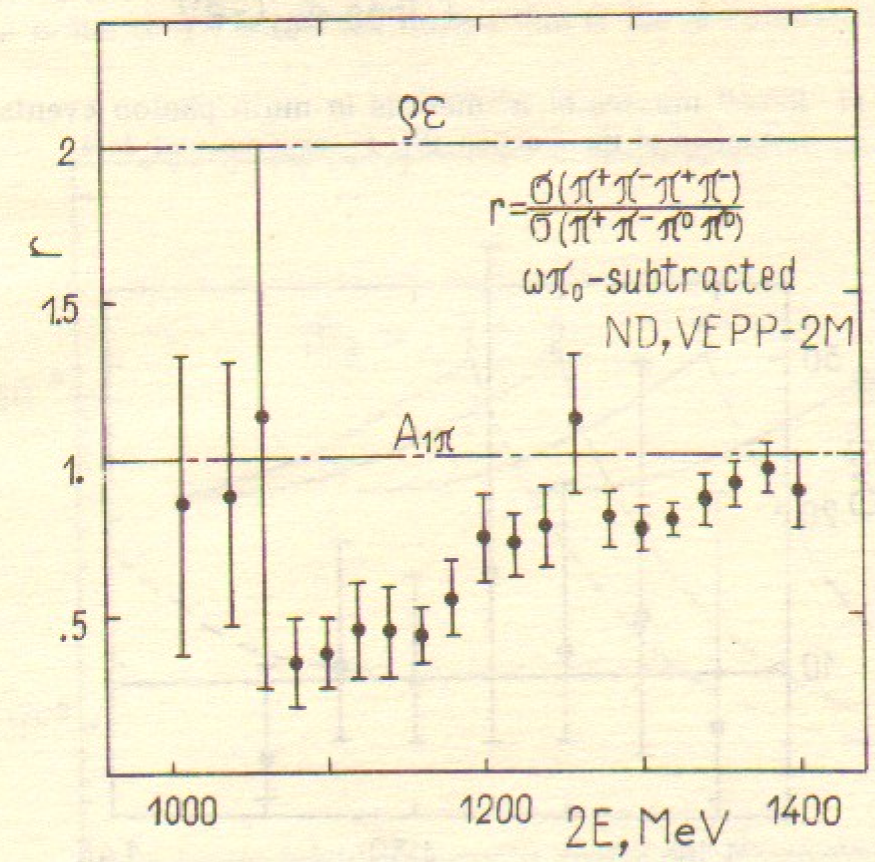


Fig. 10. A ratio of cross sections of the reactions (2) and (3), the process $e^+e^- \to \omega\pi^0$ was subtracted. Horizontal lines show the expected values of the ratio for the $A_1\pi$ and $\rho\varepsilon$ intermediate states in the approximation of narrow resonances.

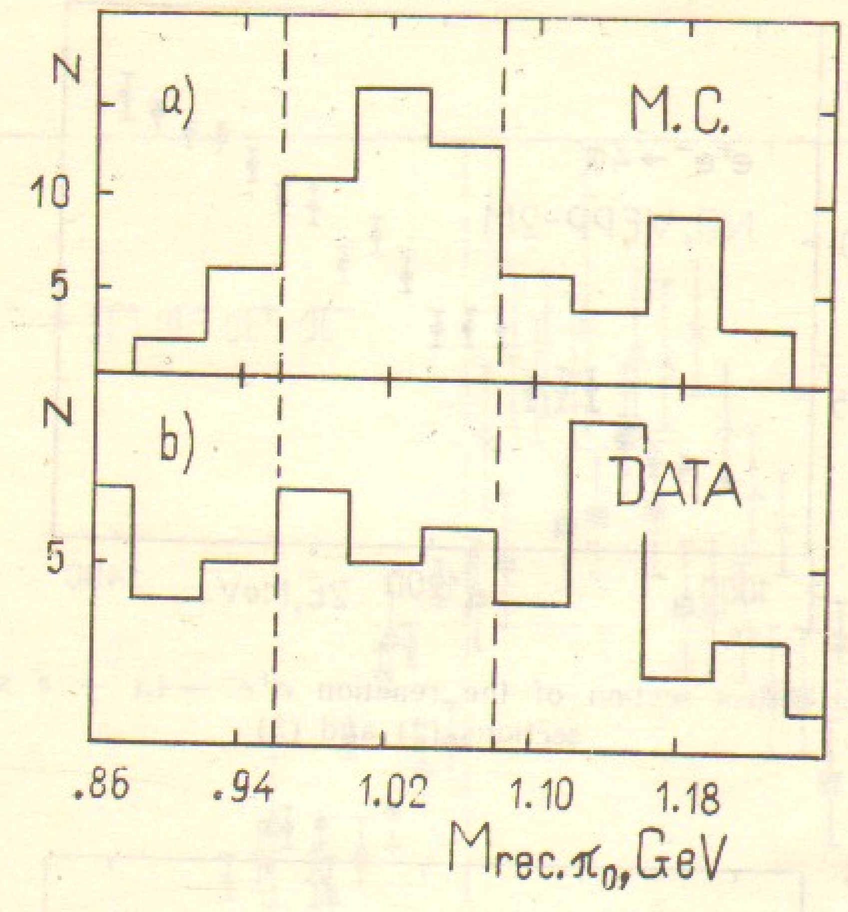
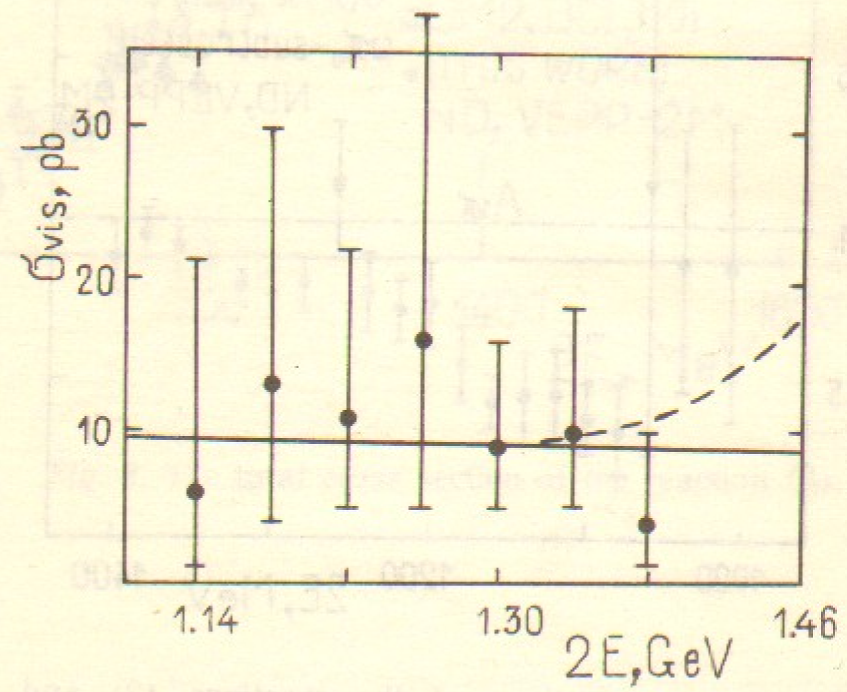


Fig. 11. Recoil masses of π^0-mesons in multi-photon events: a—simulation of the reaction (8); b—experimental data.



g. *12.* Visible cross section for events having a recoil mass of the π-meson in the -meson region. The soli l line is the average cross section, the dotted line is the contribution of $C(1490)$ at the level of the established upper limit.

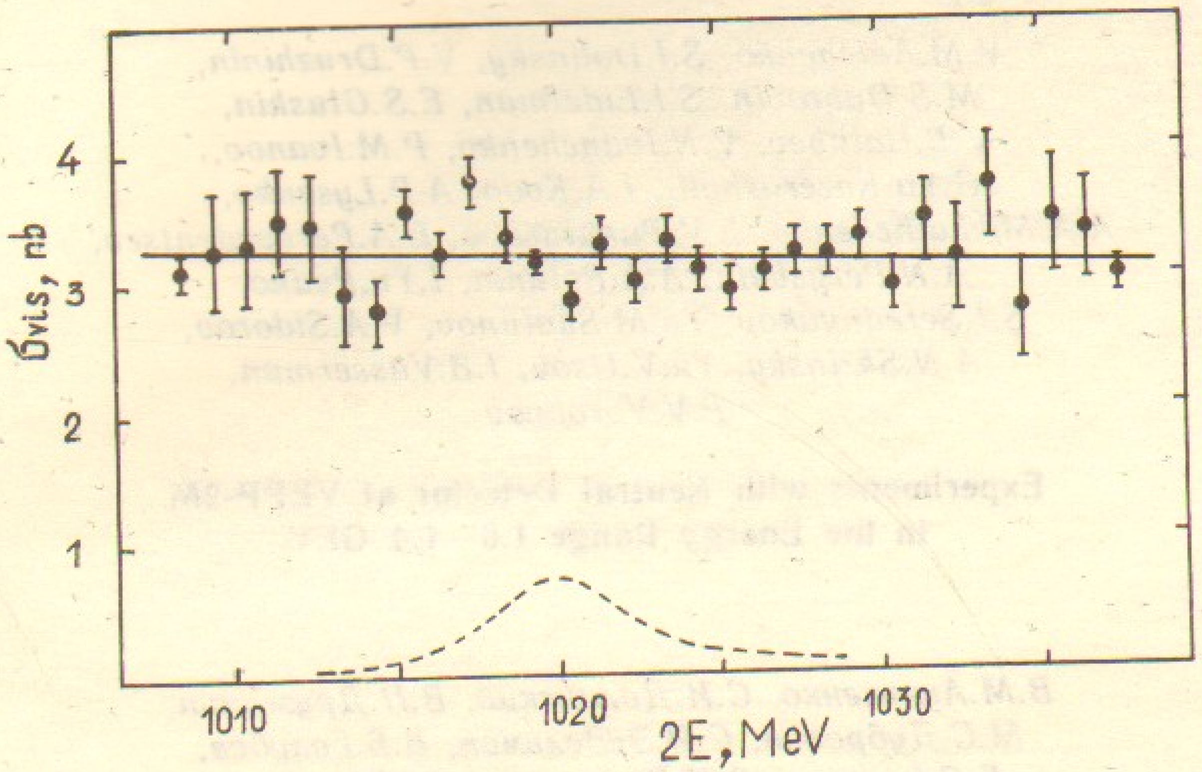


Fig. 13. Visible cross section for selected events with collinear electron and photon. The solid line is the result of the fit, dotted line is the Φ-resonance excitation curve.

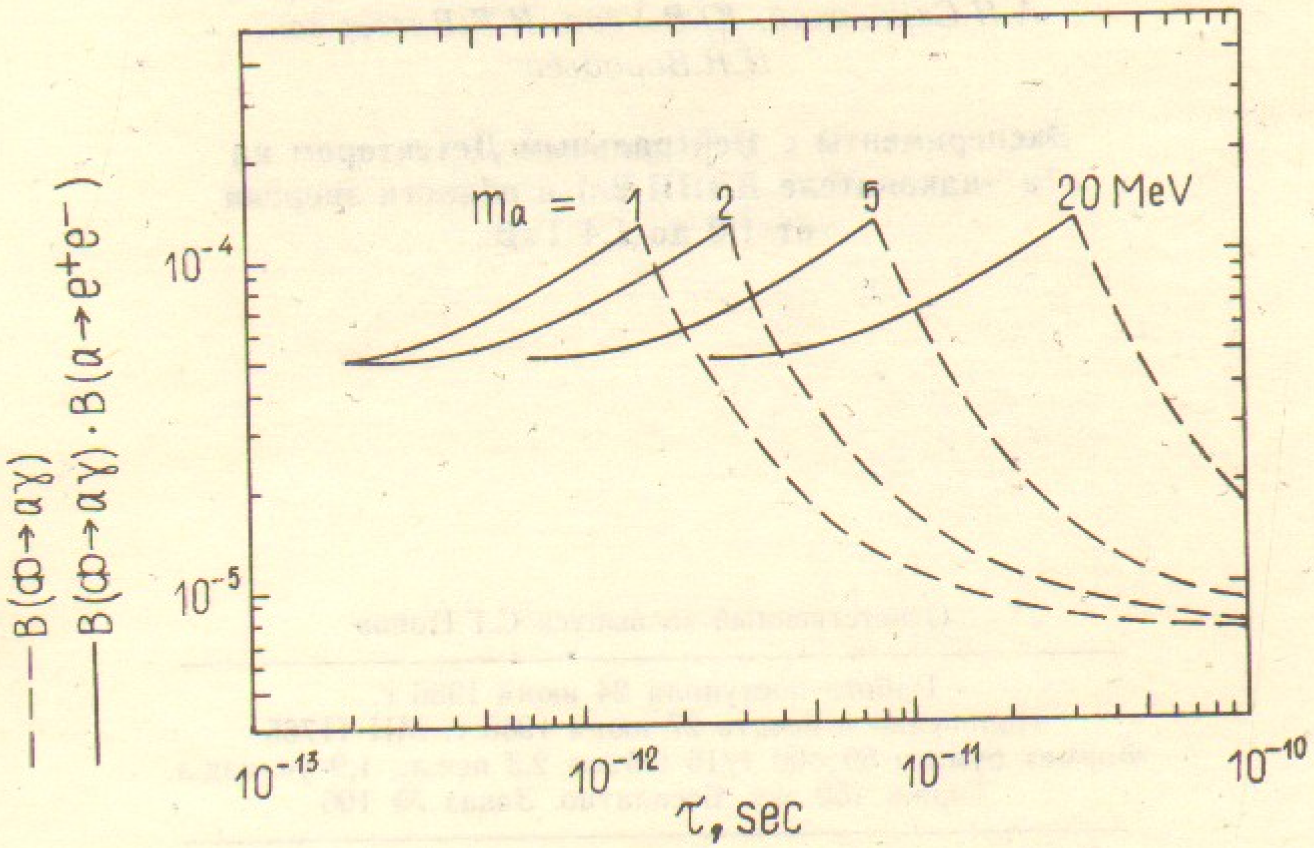


Fig. 14. The upper limit for the product of branching ratios $\Phi \to a\gamma$ and $a \to e^+e^-$ as a function of lifetime and mass of a.

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**Experiments with Neutral Detector at VEPP-2M
in the Energy Range 1.0—1.4 GEV**

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e^+e^--накопителе ВЭПП-2М в области энергии
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