ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ СО АН СССР

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НОВОСИБИРСК

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Abstract

The preliminary results on the study of the reactions $ee \to ee+\mu\mu$ and $ee \to$ ee+hadrons are presented. The experiment was performed in 1983-84 at the storage ring VEPP-4 with the detector MD-1. The analysed integrated luminosity is 6.4 pb^{-1}. The reactions were studied in the double tag mode. The measured muon production cross-section is in agreement with QED. The total cross-section of two-photon hadron production was measured in the effective mass region 1-4 GeV.

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1. The experiment has been performed at the storage ring VEPP-4 with the detector MD-1 in 1983-84, at the energy $\sqrt{S} = 9.46$ GeV. The integrated luminosity of 10 pb^{-1} has been collected. At present the total integrated luminosity is equal to 30 pb^{-1}.

In this paper the preliminary results on the study of the reactions

$$e^+e^- \to e^+e^- + \mu^+\mu^- \qquad (1)$$

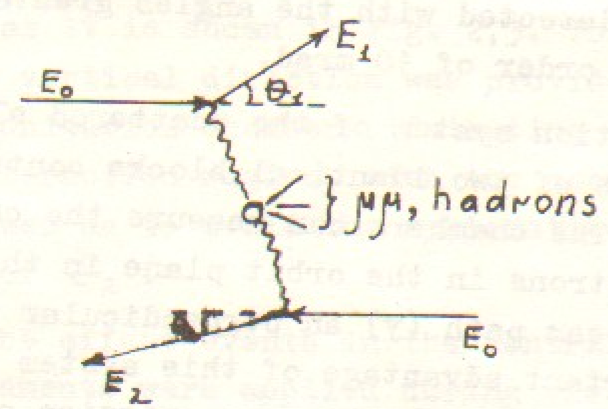
and

$$e^+e^- \to e^+e^- + hadrons \qquad (2)$$

in the double tag experiment are presented. The results were obtained in the analysis of 6.4 pb^{-1} integrated luminosity. The average luminosity during the experiment was $2.6 \cdot 10^{30}$ $cm^{-2} \cdot s^{-1}$, the total number of detector triggers was about $5 \cdot 10^6$.

2. The detailed analysis of theoretical questions, concerning two-photon reactions, was done in Ref. /1/. The problems of the extraction of the information about two-photon processes from the colliding beam experiments were discussed in Ref. /2/. The reaction (1) is described by QED and was used to check up apparatus operation and correctness of the detector description in the Monte Carlo programs. The reaction (2) is the source of the information about the mechanism of the hadron production in two-photon collisions; the exact theory of this process at present does not exist.

The kinematical scheme of both these reactions is shown in the following figure:



where E_0 is an energy of the initial electron (positron),
$E_{1(2)}$ - an energy of the scattered electron (positron),
$\theta_{1(2)}$ - an emission angle of the scattered electron (positron) in the lab. system,
$q_{1(2)} = (\omega_{1(2)}, \vec{q}_{1(2)})$ - 4-momenta of the virtual photon.

For the small emission angle of the scattered electrons the effective mass W of the produced system and the virtual photon (space-like) squared mass are given by the simple formulae:

$$W^2 \simeq 4\omega_1\omega_2 = 4(E_0 - E_1)(E_0 - E_2)$$

$$Q_{1,2}^2 = -q_{1,2}^2 = E_0 E_{1,2} \theta_{1,2}^2$$

Thus the measurement of the energy and the emission angle of the scattered electrons is sufficient to determine the transfered momenta Q_i^2 and the effective mass of the produced $\gamma\gamma$ - system.

3. The layout of the experimental region of the storage ring VEPP-4 with the detector MD-1 is shown in Fig. 1. The main distinction of the detector is the magnetic field, which direction is perpendicular to the orbit plane. This allows the detection of the two-photon events with low effective mass with simultaneous detection of the scattered electrons with Q^2 close to zero, unlike the standard situation when the scattered electrons are detected with the angles greater than some minimal one of the order of 10 mrad.

The detection system of the scattered electrons (tagging system) consists of two identical blocks containing 7 proportional chambers. The chambers can measure the coordinates of the scattered electrons in the orbit plane in the direction orthogonal to the beam path (y) an perpendicular to the orbit plane (z). The important advantage of this system is the possibility to detect electrons with the zero emission angle from the interaction point in the energy region E between 0.5 and 0.85 of the beam energy E_0 . The electrons with the energy $E = E_0$ are detected in the emission angle region 12-100 mrad.

The measurement of the coordinate (Y) and the angle (Y') of the electron in the detection system allows one to determine the energy (E) and the emission angle at the interaction point (θ). The energy and angle calibration of the system was performed with the help of processes of the single bremsstrahlung of the electron on the colliding beam and small angle Bhabha-scattering. The achieved energy resolution was $\sigma_E/E = 1.5\%$, the angular resolution for $\theta_y = 1$ mrad for $\theta_z = 0.5$ mrad.

The detailed description of the detector and the tagging system is given elsewhere /3/.

4. To select the events of the reactions (1) and (2) it was required to trigger both blocks of the tagging system, with this condition 10^6 events were obtained.

The main background in the tagging system comes from the single bremsstrahlung on the colliding beam (SB). The SB rate at the average luminosity of the experiment was about 200 kHz, the corresponding probability of the accidental coincidence of the SB electrons with the event in the central detector is very high (about 1/4). However, the angle distribution of the SB electron is much more narrow than one of the two-photon reactions. This allowed us to reject this background significantly with the acceptable loss of the efficiency by the selection of the events with the scattered electron in each block of the system detected at the distance from the orbit plane greater than 2 mm. The number of the remained events was $2.5 \cdot 10^4$.

The efficiencies for the detection of one ($\mathcal{E}_1$) and two ($\mathcal{E}_2$) scattered electrons depend on the effective mass of the produced system as it is shown in Fig. 2,3. The orbit plane stability in the vertical direction was provided by the feed--back from the ionization chambers, detecting synchrotron radiation from the interaction region, with the accuracy better than 0.1 mm. That allowed us to avoid the systematic uncertainty in the calculation of $\mathcal{E}_2$.

To select the effect events in the central detector the following requirements were applied during visual scanning: the candidates to the reaction (1) had to contain two and only two charged particles in the shower-range chambers with the narrow transverse spread of the hits along the tracks; for the reaction (2) more than two particles were required with at least one charged among them.

By these conditions candidates events of the reaction (1) and 289 of the reaction (2) were selected.

For further background suppression the following conditions were used:

a) one and only one particle had to be detected by each block of tagging system while for reaction (1) at least one of them with an emission angle $\theta_z > 5.6$ mrad;

b) the energy of each electron had to be in the region $2.7 < E/\mathrm{GeV} < 5.1$ for the reaction (1) and $2.4 < E/\mathrm{GeV} < 5.11$ for the reaction (2).

Finally, 221 and 176 events has been selected for the reactions (1) and (2) respectively. The remaining background is 7% for both reactions and was subtracted statistically. (Due to some inessential reasons only 5.3 pb^{-1} of the integrated luminosity has been used for the resulting selection of the reaction (1) events.

The detection efficiencies for each reaction were determined by the detailed Monte-Carlo (MC) simulation /4/.

5. The reaction $ee \to ee + \mu\mu$ was studied in the experiments DM1, PLUTO, TASSO, CELLO, MARK II, MARK-J. The good agreement with QED expectations was found in total cross-sections as well as in various differential distributions /2/.

As was mentioned before in our experiment this reaction was used to check up the apparatus and the M-C programs.

The distribution on the acoplanarity angle between the produced particles is shown in Fig. 4. The narrow distribution centred at zero is typical for two-photon production of the particle pairs and agrees well with the MC calculation. The visible cross-section of this reaction vs. the effective mass squared of the produced pair is presented in Fig. 5. Some excess in the experimental distribution at large W^2 is in qualitative agreement with the estimates of the radiative corrections due to the real photons emission.

The contribution of the main background process $ee \to ee + ee$ estimated by the MC-simulation does not exceed 10%. The contribution from the $ee \to ee + \pi\pi$ reaction was estimated to be also not more than 10%.

The total experimentally observed cross-section

$$\sigma_{exp} = (6.2 \pm 0.4) \cdot 10^{-2}\ nb$$

and simulated one

$$\sigma_{MC} = (4.7 \pm 0.8) \cdot 10^{-2}\ nb\ .$$

The difference does not exceed 1.5 standard deviations. To achieve the higher accuracy one has to increase the simulation statistics and to take into account the radiative corrections.

6. The first results for the measurement of two-photon hadron production were obtained by PLUTO /5/ and TASSO /6/ groups in 1979-80. Recently the new results of PLUTO /7/ and PEP4-TPC/ /PEP9-2 γ /8/ have been published. The discussion and the theoretical analysis of the last experiments is given in Ref. /9/.

The ee ee+hadr reaction study performed in present work was aimed to measure the total cross-section of the process $\gamma\gamma \to$ hadr in the region of effective mass $W < 5$ GeV for almost real photons ($Q^2 < 0.1$ GeV^2).

At present an exact theory of photon-hadron interactions does not exist. To describe the two-photon hadron production the vector dominance model (or generalized) VDM combined with the Regge model for hadron interactions is used. The predicted W-dependence, has the following form:

$$\sigma_{tot} = \sigma_0 + \sigma_1 / W$$

where σ_0 and σ_1 are calculated using the cross-sections of γN and NN reactions and are found to be: σ_0 = 240 nb, σ_1 = = 270 nb•GeV. More exact calculations taking into account the last experimental results on hadron collisions give slightly different values of these constants: $\sigma_0 = 250 \div 300$ nb, σ_1 = = 315 ± 55 nb•GeV /10/.

The contributions of the point-like photon-quark interaction proportional to W^{-2} is also discussed in the literature However the modern QCD technique does not allow to estimate its value /1,2/.

Let's mention the main problems in the information extraction about the $\gamma\gamma \to$ hadrons reaction from the colliding beam experiments:

a) In the no-tag and single tag experiments the effective mass of the produced system has to be reconstructed by the detected hadrons (W_{vis}) and due to the limited solid angle of the detector is always less than true value (W). The corrections cannot be made in a model independent way.

b) In the single tag and double tag typical situations the total cross-section extrapolation to $Q_i^2 = 0$ is also model dependent.

c) There are uncertainties in a description of the final state structure, necessary for the acceptance calculation.

In our case the problems a) and b) are absent due to double tagging with $Q_i^2 = 0$; problem c) is briefly discussed below.

7. To calculate the detection efficiency for the reaction (2) there was used a model of a hadron final state structure close to one obtained in Ref. /6/. The parameters of the model are presented in the table together with the parameters obtained in Ref. /7,8/.

Fig. 6,7 show the charged- and γ-quanta multiplicities. The inclusive transverse momenta of charged hadrons is shown in Fig. 8. The distributions on Q_1^2, Q_2^2 are statistically identical and are combined in Fig. 9.

All these distributions are in a good agreement with the MC-simulation that supports the used model.

The preliminary results of the total cross-section measurement are shown in Fig. 10 together with the results of last two experiments /7,8/. Error bars indicated for our experimental points are statistical only. One can see a good agreement of all three experiments in a common W-region.

The systematic uncertainty in our measurement of the total

cross-section comes from the acceptance sensitivity to model parameters and requires an additional analysis. The preliminary estimations show that the main contribution is given by the charged multiplicity dependence on effective mass and is not greater than 30%.

In conclusion the authors express their sincere gratitude to the VEPP-4 and MD-1 staff for the help in the experimental work and to H.Kolanosky, E.A.Kuraev and V.G.Serbo for the useful discussions.

Table

The parameters of the final state structure model

	PLUTO	PEP4/9	MD-1
multiplicity	$2\sqrt{W}$	$1+0.52\cdot W$	$2+0.9\ln W$
	2/3	1/2	1/2
topology	IP for $W<3$ mixture IP and LP for $3<W<7$ LP for $W>7$	LP	LP
$f(P_{T_i})$	$-5\,P_{T_i}$	$-6{,}25\,P_{T_i}$	$-\sqrt{P_{T_i}^2+m_\pi^2}/0.35$

W - effective mass of the hadron system, GeV

P_{T_i} - transverse momenta of pions, GeV

f - function of the transverse momentum

IP - invariant phase space

LP - limited phase space, $LP = IP\cdot\prod_i \exp(f(P_{T_i}))$

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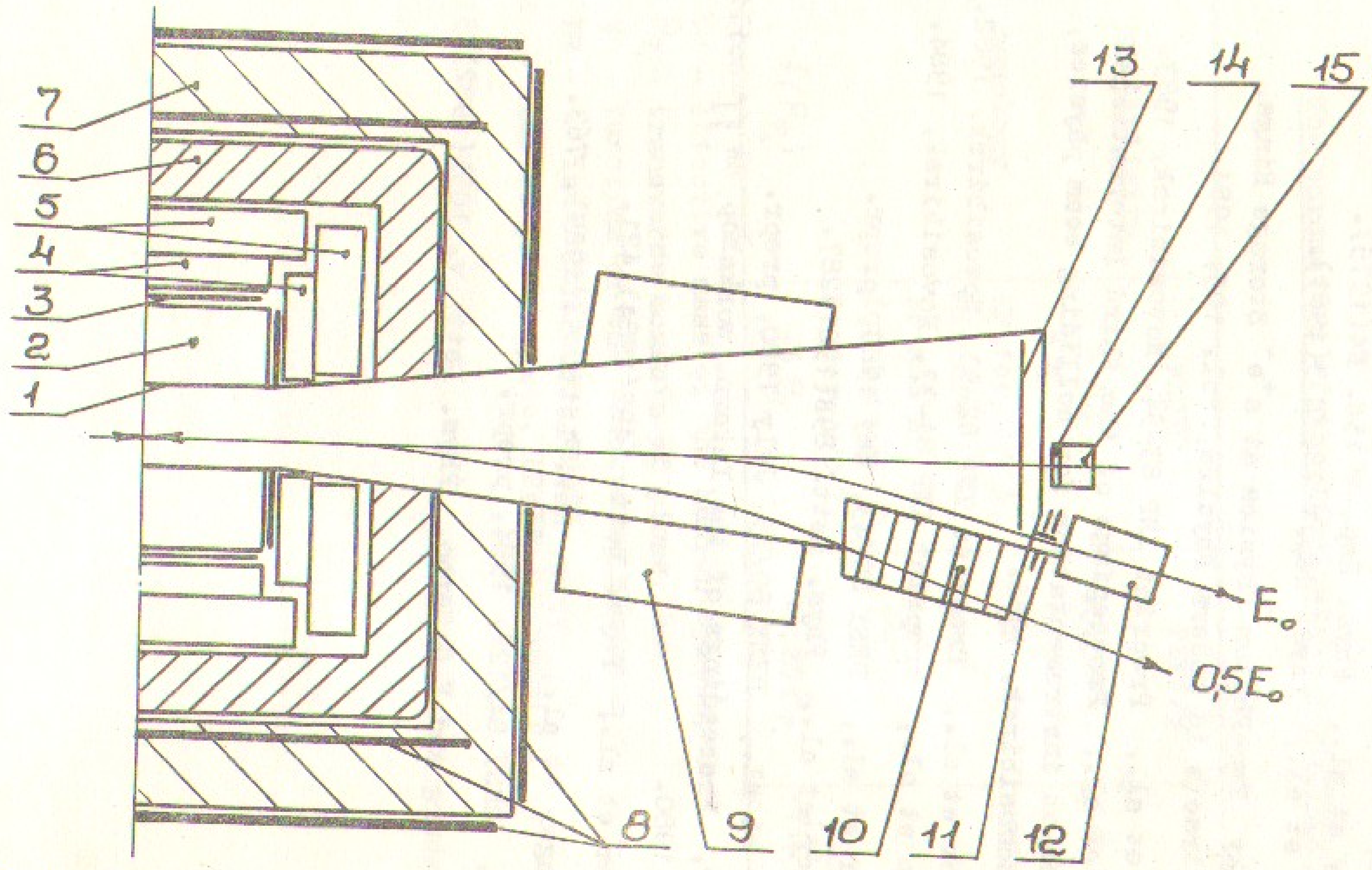

Fig. 1.

MD-1 detector. Section by the orbit plane. 1 - vacuum chamber; 2 - coordinate chambers; 3 - scintillation counters; 4 - C - counters, 5 - shower-range chambers; 6 - magnet winding; 7 - iron yoke, 8 - muon chambers, 9 - bending magnet; 10 - system of the scattered electrons detection, 11 - luminosity monitor, 12 - lense, 13 - SR-receiver; 14 - ionization chamber for orbit stabilization; 15 - γ-quanta detector.

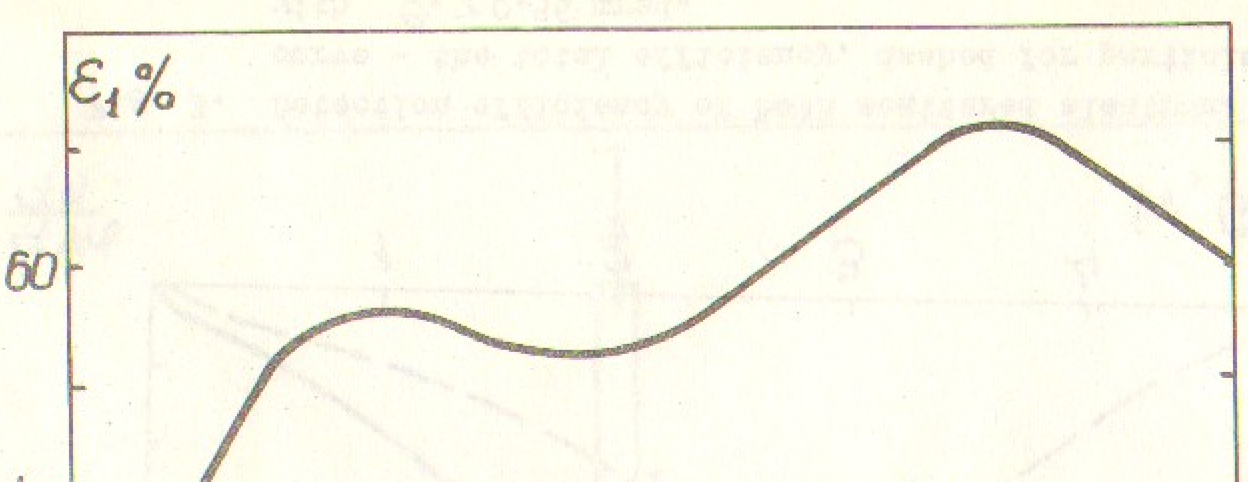

Fig. 2. Detection efficiency of one scattered electron. Full curve - the total efficiency, dashed for particles with $\theta_2 > 0.56$ mrad.

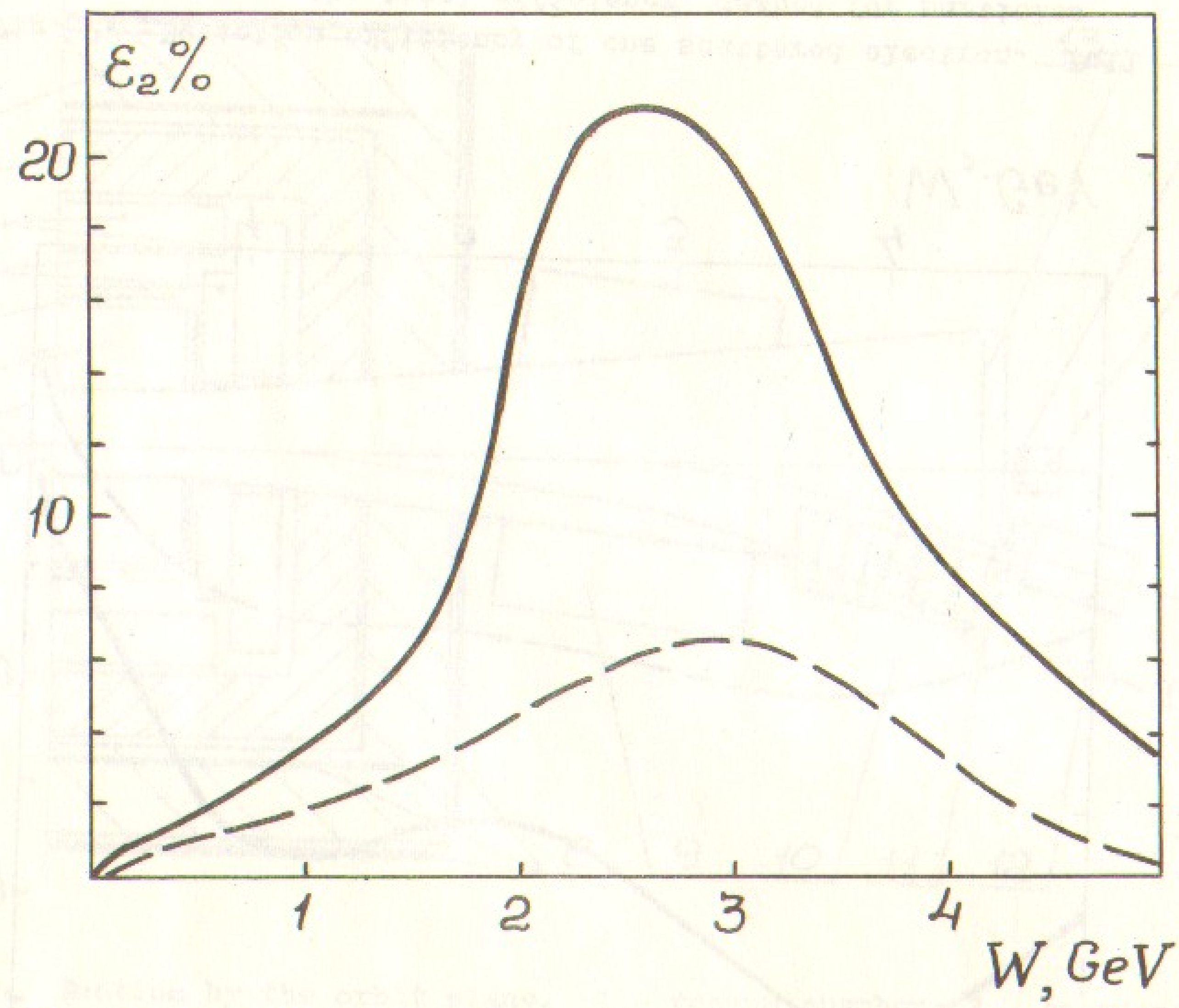

Fig. 3. Detection efficiency of both scattered electron. Full curve - the total efficiency, dashed for particles with $\theta_2 > 0.56$ mrad.

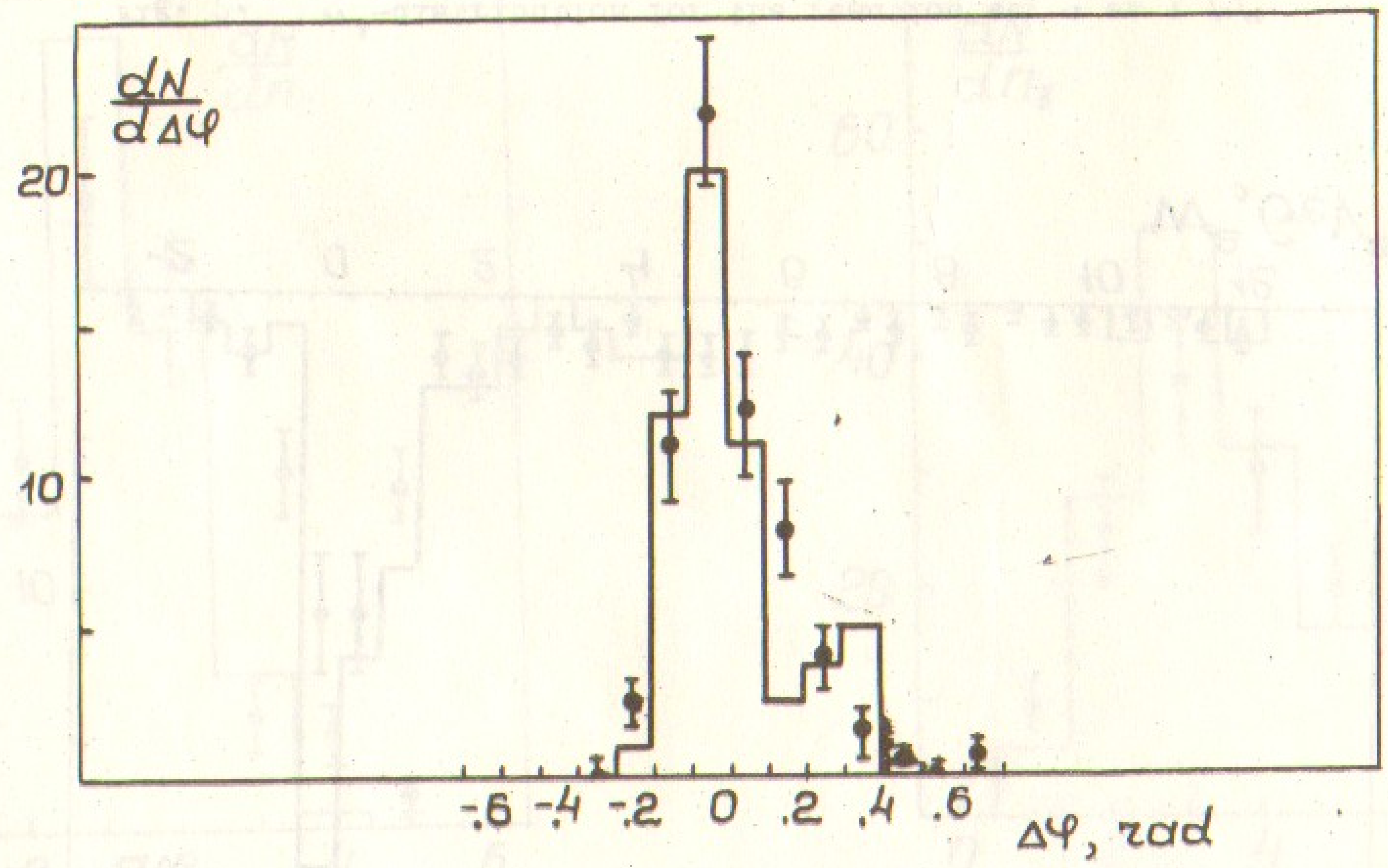

Fig. 4. Acoplanarity angle of produced muons, (points-data, hystogram - MC).

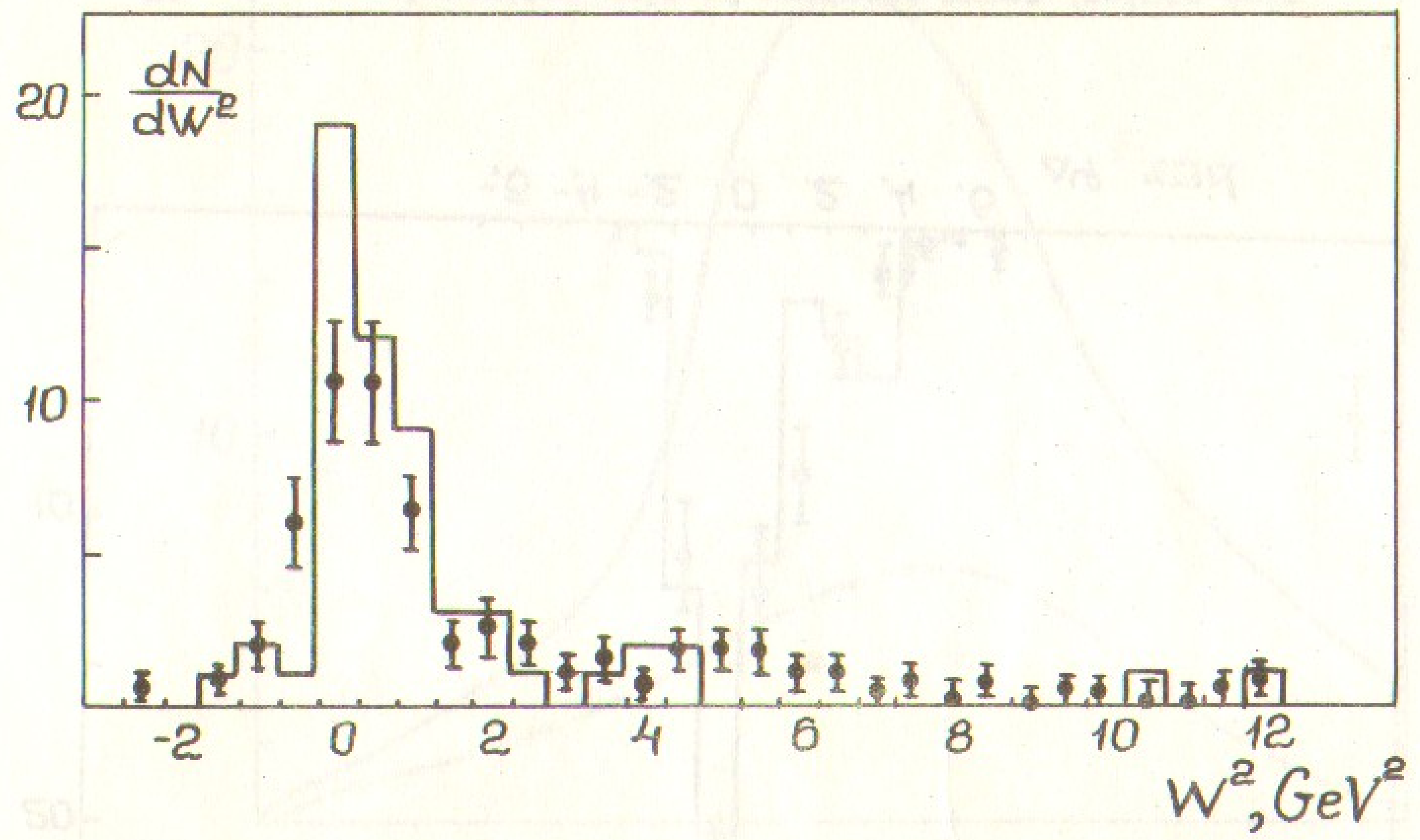

Fig. 5. W^2-distribution for the reaction ee → ee + $\mu\mu$ (points-data, hystogram - MC.)

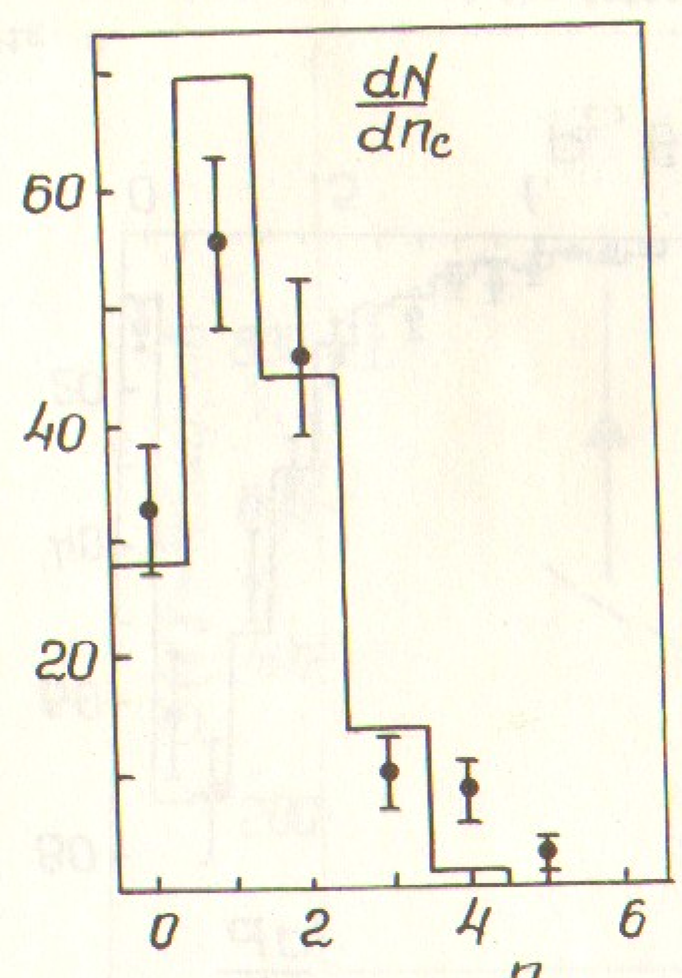

Fig. 6.

Charged multiplicity of the detected hadrons (points-data, hystogram - MC.)

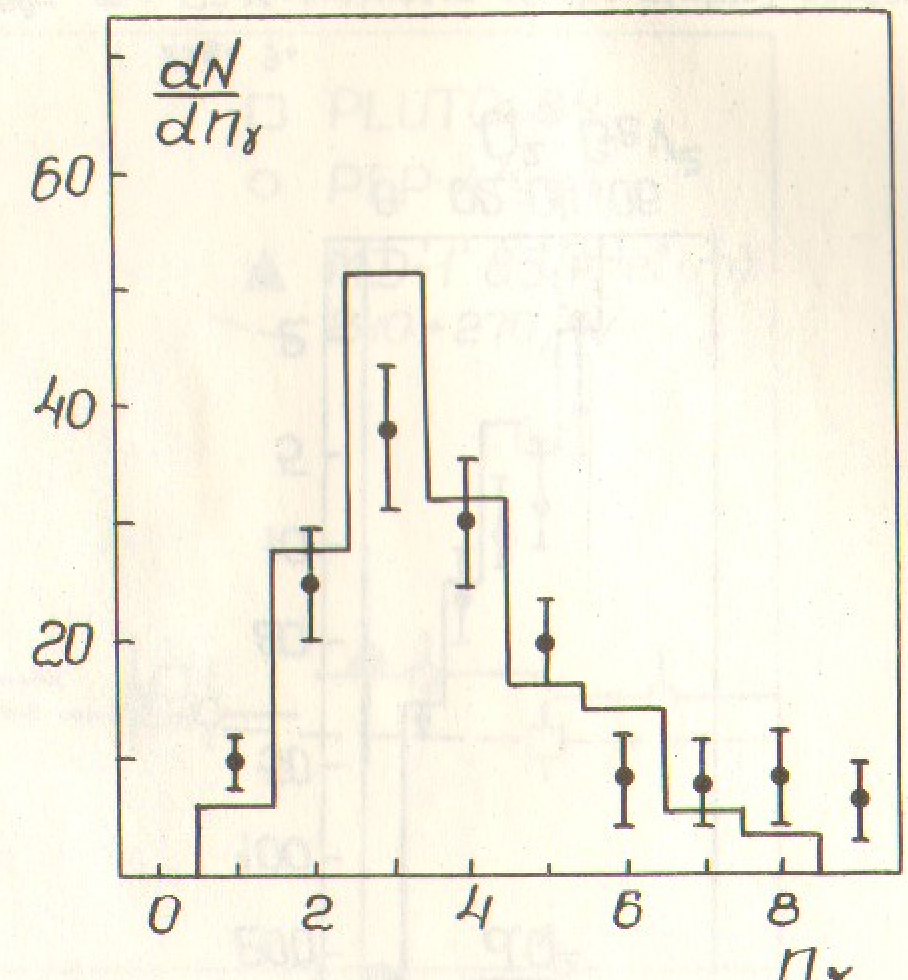

Fig. 7.

Multiplicity of the detected γ -quanta (points-data, hystogram - MC.)

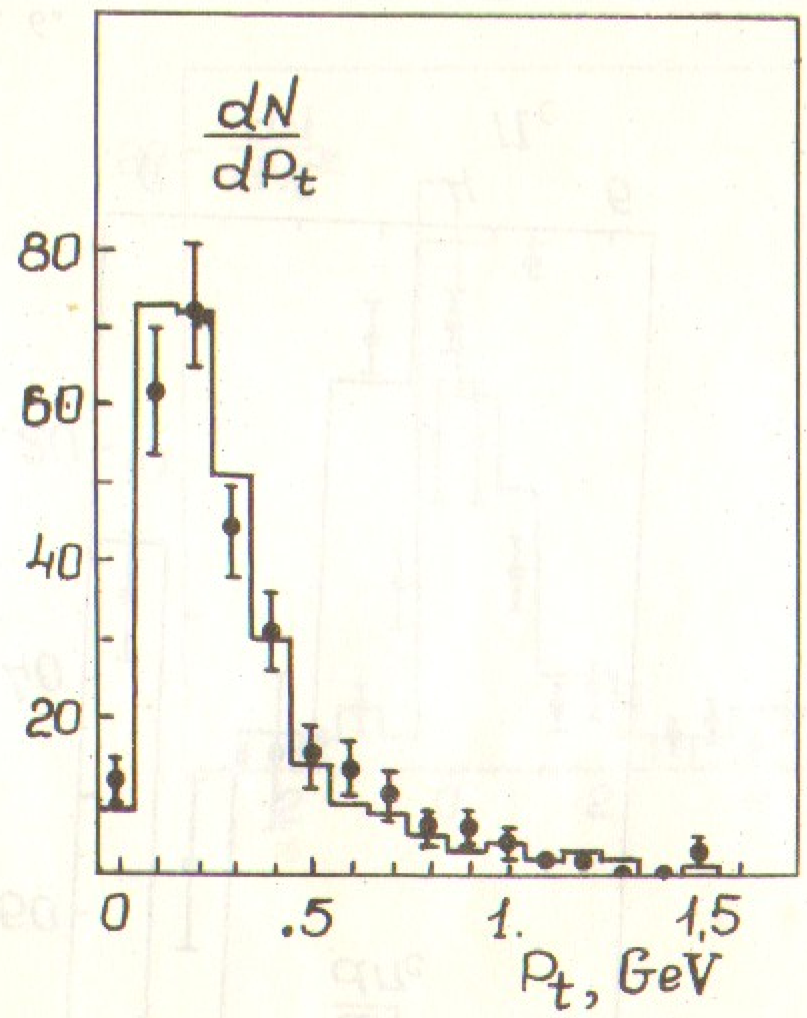

Fig. 8.

Inclusive distribution of the detected charged hadrons (points-data, hystogram - MC.)

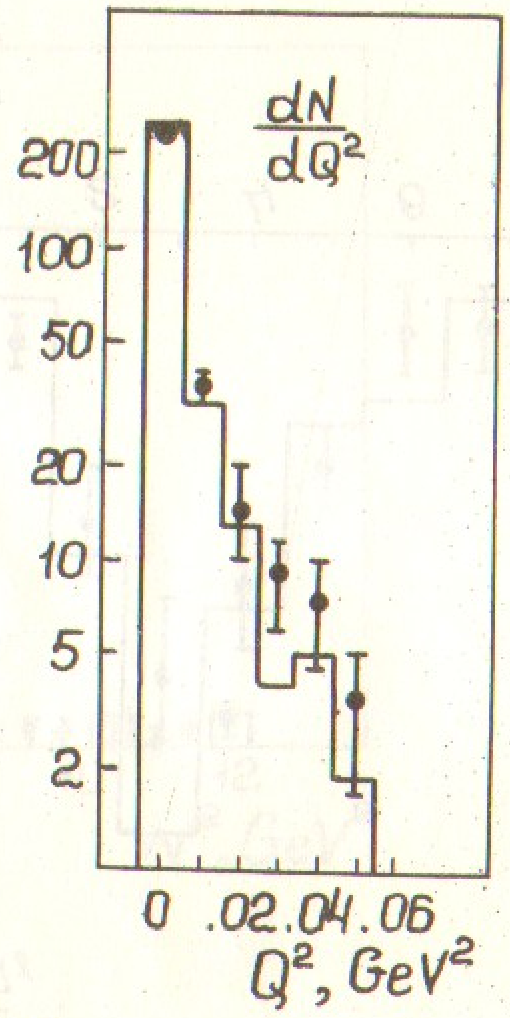

Fig. 9.

The Q^2 distribution of the virtual photons (points-data, hystogram - MC.)

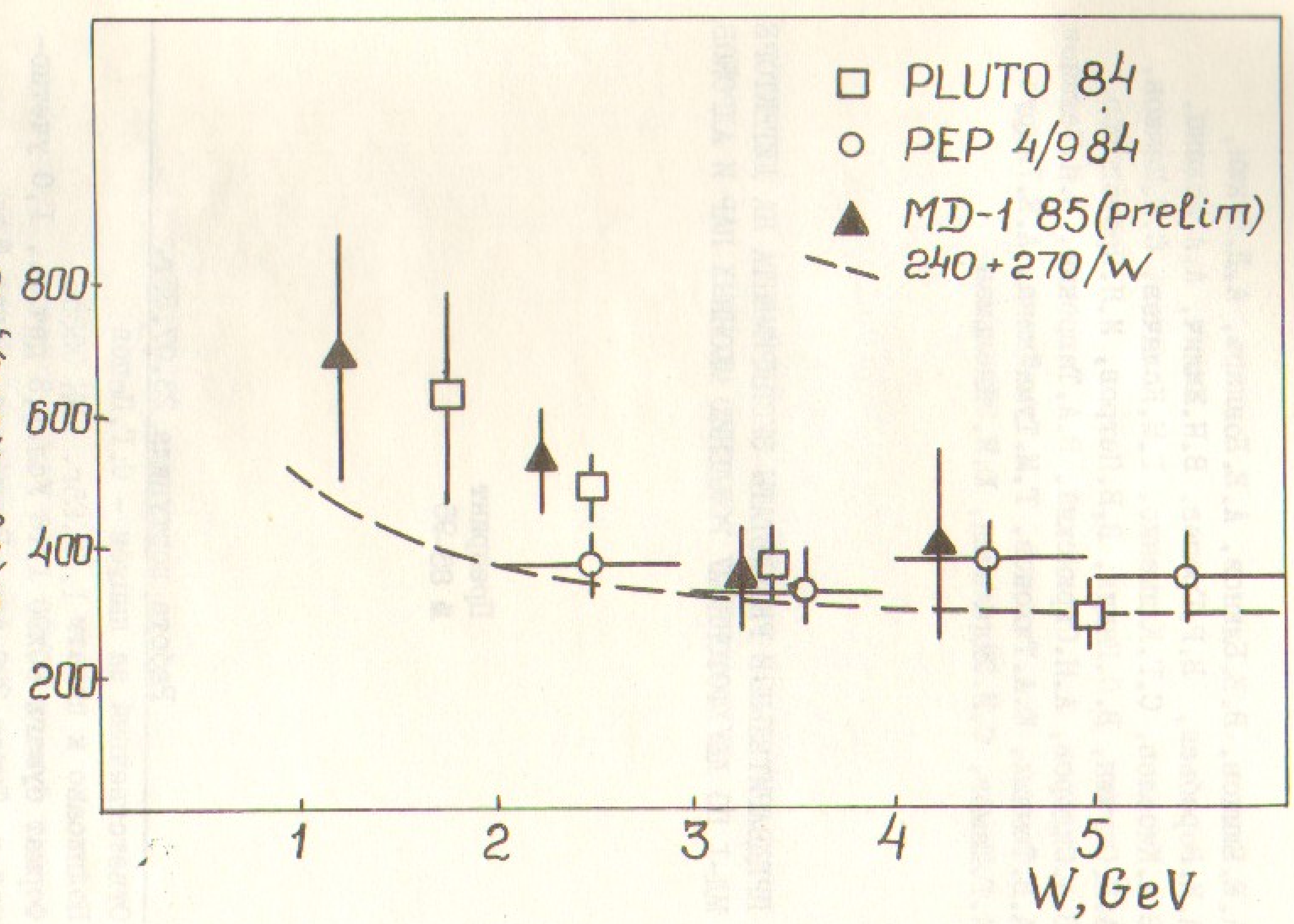

Fig.10. The total cross-section of the reaction $\gamma\gamma \to$ hadrons. (The error bars for MD-1 are statistical only).

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ПРЕДВАРИТЕЛЬНЫЕ РЕЗУЛЬТАТЫ ЭКСПЕРИМЕНТА НА ДЕТЕКТОРЕ МД-I ПО ДВУХФОТОННОМУ РОЖДЕНИЮ МЮОННЫХ ПАР И АДРОНОВ

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