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СО АН СССР

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A b s t r a c t

Pion form factor has been measured by $e^+e^- \rightarrow \pi^+\pi^-$ reaction in the interval 2E from 1.06 to 1.4 GeV. Experimental values of the pion form factor exceed considerably the predictions of the Vector Dominance Model with one $\rho(770)$-meson.

Submitted to the International Symposium on Lepton and Photon Interactions, Batavia, USA, 1979.

The results presented in the paper are obtained at the new measurement of the pion formfactor with "OLYA"-detector at the storage ring VEPP-2M. A brief description of the detector is presented elsewhere /1/. The detector view is shown at Fig. 1.

After our previous experiment on the pion form factor measurement in a time-like region /2/ the average luminosity of the VEPP-2M increased considerably. During this period the detector "OLYA" was fully equipped with shower and range chamber allowing separation of muons and pions. All this enabled us to increase considerably the accuracy of the pion form factor measurement in comparison with the previous work.

The experiment was carried out in the energy interval 2E = 0.64 - 1.4 GeV. The total integrated luminosity is about 1.5 pb^{-1}. Data were taken in a scanning of the energy interval with a step equal to the c.m.s. energy spread. The luminosity in each energy point was about 1.5 nb^{-1}. This paper presents preliminary results of data processing in the energy region 1.06 - 1.4 GeV, corresponding approximately to $^1/2$ of the whole statistics.

Special runs without beams as well with beams colliding in another interaction region were performed to study background.

The considerable suppression of a cosmic ray background was achieved by the measurement of particle time-of-flight between counters C3 in opposite quadrants and also by a standard trigger-beam bunch timing.

During data processing events were selected with two tracks in coordinate chambers coming out of the interaction region and collinear

$$|\Delta\theta| < 5^\circ \quad \sigma_{\Delta\theta} = 1.2^\circ$$

$$|\Delta\varphi| < 3^\circ \quad \sigma_{\Delta\varphi} = 0.8^\circ$$

These criteria are met by the events of the processes

$$e^+e^- \to e^+e^-,\ \mu^+\mu^-,\ \pi^+\pi^-,\ K^+K^-$$

The [illegible]ged kaon may trigger the system at the energy 2E [illegible].12 GeV. We not interested in this process at the present work. Therefore K^+K^- - events were rejected at the early stage of analysis. For suppression of $e^+e^- \to K^+K^-$ - background we used a method applied in a work /3/ concerning charged kaon form factor measurement. The selection of K^+K^- events in [illegible] was done by the parameters representing the ratio of the two likehood functions for the pulse heights in the three first scintillation counters. One of these likehood functions was calculated by the kaon amplitude spectra and the other by those due to the minimum ionizing particles. Using the restrictions on these parameters values we were able to diminish K^+K^- contamination into $e^+e^- \to \pi^+\pi^-$ to the value less than 1% over all energy region.

Events thus selected were divided into three classes. The events with both tracks traversing all shower and spark chambers (180 g/cm^2) were included in the first class named "long-range" one (N_ℓ). The second class - "short-range" - consisted of events in which both particles did not reach the end of the range system (N_s). All other events were included in the third "mixed" class (N_M). The number of events in each of three classes is presented in Table 1.

The probabilities for e^+e^- , $\mu^+\mu^-$ and $\pi^+\pi^-$-events to come into each of these classes are at the energy 1.2 GeV shown in Table 2. The muon probabilities were obtained by Monte-Carlo simulation /5/. The probabilities presented for $\pi^+\pi^-$ and e^+e^- were calculated as a result of a data processing, but the choice of the selection procedure described below was based on the estimations made by Monte-Carlo simulation before the experiment.

As follows from Table 2 at our statistics the "long-range" class contains $\mu\mu$ and $\pi\pi$ events only. The "short-range" and "mixed" events were divided into e^+e^- elastic scattering events - $N_s(ee)$, $N_M(ee)$ and the events e^+e^- annihilation into two mesons ($\mu\mu + \pi\pi$) $N_s(\mu\mu+\pi\pi)$, $N_M(\mu\mu+\pi\pi)$. This separation was performed by the correlation matrix method

/4/. The ratio of likelihood functions for sandwich pulse heights (one of them calculated in the assumption of e^+e^- and another of $\pi^+\pi^-$- event) was chosen as a separation parameter to form the correlation matrix. Using p_μ - muon probability to reach the end of the range system and $N_s(\mu\mu+\pi\pi)$, $N_M(\mu\mu+\pi\pi)$, $N_\ell(\mu\mu+\pi\pi)$, it is possible to calculate the total number of $N_t(\mu)$ and $N_t(\pi\pi)$by the following formulae

$$N_t(\mu\mu) = \frac{N_s(\mu\mu+\pi\pi)\,N_\ell - [N_M(\mu\mu+\pi\pi)]^2/4}{N_s(1-p_\mu)^2 - N_M p_\mu (1-p_\mu) + N_\ell p_\mu^2}$$

$$N_t(\pi\pi) = N_s(\mu\mu+\pi\pi) + N_\ell(\mu\mu+\pi\pi) + N_M(\mu\mu+\pi\pi) - N_t(\mu\mu)$$

The probability p_μ was obtained by the Monte-Carlo simulation of our experiment /5/. Its value changes with energy from $(5.4\pm.4)\%$ at 2E = 1.06 GeV to $(1.7\pm.4)\%$ at 2E = 1.4 GeV.

The total number of the e^+e^- events was calculated as a sum

$$N_t(ee) = N_s(ee) + N_M(ee)$$

As followed from the analysis of the background runs only cosmic ray particles could contribute to collinear events in our experiment. More than 90% of such background events came into the "long-range" class. Their fraction in "long-range" events was about 0.5% and subtracted during the data processing.

Detection efficiencies for the processes $e^+e^- \to \mu^+\mu^-, \pi^+\pi^-$ and detection cross-section for $e^+e^- \to e^+e^-$ were calculated by the Monte-Carlo simulation /5/. Note, that the detection efficiencies for $e^+e^- \to \pi^+\pi^-$ may contain a systematic error (not more than 10%) connected with an incomplete simulation of pion-nuclei interactions in the detector material.

Radiative corrections for the processes $e^+e^- \to e^+e^-, \mu^+\mu^-, \pi^+\pi^-$ were calculated in accordance with /6/. Table 3 contains the number of e^+e^-, $\mu^+\mu^-$ and $\pi^+\pi^-$ events versus energy. It presents also absolute value of the pion formfactor squared. The total ratio of muon number to that of electrons divided by the same value calculated according to QED was:

$$\frac{[N_t(\mu\mu)/N_t(ee)]_{exp.}}{[N_t(\mu\mu)/N_t(ee)]_{theor.}} = \frac{(6.128 \pm 0.060)\cdot 10^{-2}}{(5.99 \pm 0.21)\cdot 10^{-2}} = 1.035 \pm 0.038$$

Fig. 2 shows the energy dependence of this ratio. χ^2 was equal to 22.7 at 17 d.f., corresponding to 16% C.L. The good agreement between the data and QED confirms the correctness of the chosen treatment procedure.

At Fig. 3,4 the results obtained in previous works /7,8,9,2, 10,11/ and this experiment are presented. The curve corresponds to the ρ - meson tail calculated by the Gounaris-Sakurai formula /12/ with ρ-ω interference taken into account. Experimental values for the pion formfactor are considerably above the theoretical curve, the maximum deviation being in the region of 1.2 GeV.

At the first sight this circumstance supports the existence of a long-time discussed $\rho'(1250)$ with the main decay mode $\rho' \to \pi^+\pi^-$. But this interpretation seems to be not sufficiently well founded. Experimental data /13/ show the rapid increase of multihadron cross-sections in this energy region. This effect has to contribute to the pion formfactor as well. The model independent calculations made in the work /14/ demonstrated this effect to be able to explain the observed excess. But as was shown in /15/ the account of the inelastic channels contribution in the vector dominance model with one $\rho(770)$ could only <u>decrease</u> the pion formfactor. Constructive interference appears it one assumes, as was done in /16/, the existence of $\rho'(1250)$ with a peak cross-section $\sim$ 30 nb and the dominant decay mode $\rho'(1250) \to \pi\omega$. The pion formfactor calculations made in this work are in qualitative agreement with our results.

In conclusion the authors want to express their sincere gratitude to the VEPP-2M staff that ensured the good machine performance during the experiment and to V.M.Budnev for his constant interest to this work and the fruitful discussions.

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Figure captions

Fig. 1. The detector "OLYA".

Fig. 2. Energy dependence of the ratio of the total $\mu^+\mu^-$ - events number to the total e^+e^- - events number normalized to the same value obtained in accordance with QED. Statistical error of Monte-Carlo simulation is shown by the corridor. $\chi^2 = 22.7$ at 17 d.f. that corresponds to 16% C.L.

Fig. 3. The values of the pion form factor squared versus energy. The curve corresponds to Gounaris-Sakurai formula with the account of ρ-ω - interference.

Fig. 4. $|F_\pi|^2$ energy dependence in the interval 2E from 0.4 to 1.4 GeV. Experimental values were obtained in the following works: ▼ - /7/, ▲ - /8/, ■ - /9/; ◆ - /10/; × - /2,11/; ● - this experiment. The curve is drawn according to Gounaris-Sakurai formula.

Table 1

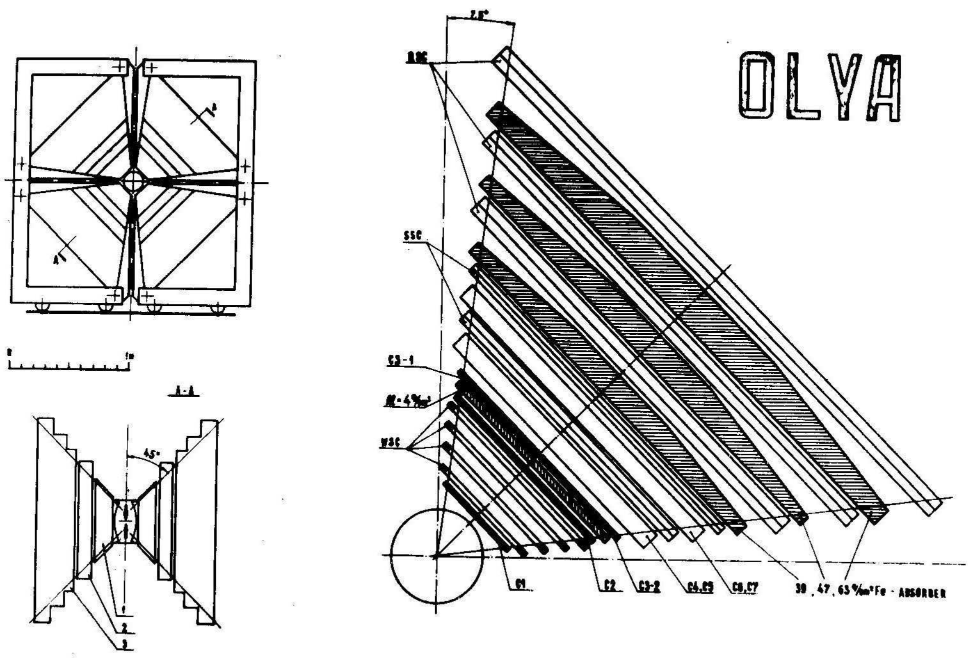
Measurement time	898000
Integrated luminosity nb^{-1}	646
Number of collinear events	203513
N_ℓ	11108
N_μ	2004
N_s	190401
$N_\pm (ee)$	188439±435
$N_\pm (\mu\mu)$	11679±114
$N_\pm (\pi\pi)$	3369±90
Number of background events normalized to the measurement time	27±13

Table 2

	$e^+e^- \to e^+e^-$	$e^+e^- \to \mu^+\mu^-$	$e^+e^- \to \pi^+\pi^-$
"short range"	(99.7±0.1)%	$(7.3\pm2.2)\cdot10^{-2}$%	(72.8±8.4)%
"mixed"	(0.3±0.1)%	(5.3±0.8)%	(25.1±6.9)%
"long-range"	$<5\cdot10^{-4}$%	(94.6±0.8)%	(2.2±1.4)%

Table 3

Energy interval	$\int L dt$, nb^{-1}	N_t (ee)	N_t ($\mu\mu$)	N_t ($\pi\pi$)	σ_π, nb	$\lvert F_\pi \rvert^2$
1.06-1.08	31±1.0	12147±111	727±30	418±29	37.4±3.0	2.20±0.17
1.08-1.10	31.8±1.1	11995±110	761±30	386±25	33.8±2.5	2.05±0.15
1.10-1.12	31.6±1.1	11496±107	726±28	314±24	27.7±2.4	1.73±0.15
1.12-1.142	34.3±1.2	12057±110	709±29	309±30	25.1±2.6	1.62±0.17
1.142-1.159	11.8±0.4	3988±64	266±17	101±12	23.9±3.0	1.60±0.20
1.159-1.18	29.5±1.0	9677±99	587±25	198±19	18.7±2.0	1.29±0.14
1.18-1.20	34.3±1.2	10852±105	698±28	222±21	18.1±1.8	1.28±0.13
1.20-1.22	35.0±1.2	10696±104	651±27	196±20	15.7±1.7	1.15±0.13
1.22-1.24	34.7±1.2	10277±101	645±26	178±18	14.3±1.6	1.08±0.12
1.24-1.26	36.3±1.2	10419±103	630±26	175±27	13.4±2.1	1.04±0.16
1.26-1.28	46.4±1.6	12897±114	778±29	138±16	8.3±1.0	0.66±0.08
1.28-1.30	42.5±1.4	11438±107	692±28	158±23	10.4±1.6	0.86±0.13
1.30-1.32	43.1±1.5	11245±106	765±28	150±22	9.8±1.4	0.83±0.12
1.32-1.34	43.2±1.5	10934±105	667±27	125±17	8.1±1.1	0.70±0.10
1.34-1.36	52.3±1.8	12838±113	795±30	121±25	6.5±1.3	0.58±0.12
1.36-1.38	50.0±1.7	11917±109	767±29	90±19	5.0±1.1	0.46±0.10
1.38-1.40	58.6±2.0	13566±117	815±30	90±18	4.30±0.85	0.41±0.08

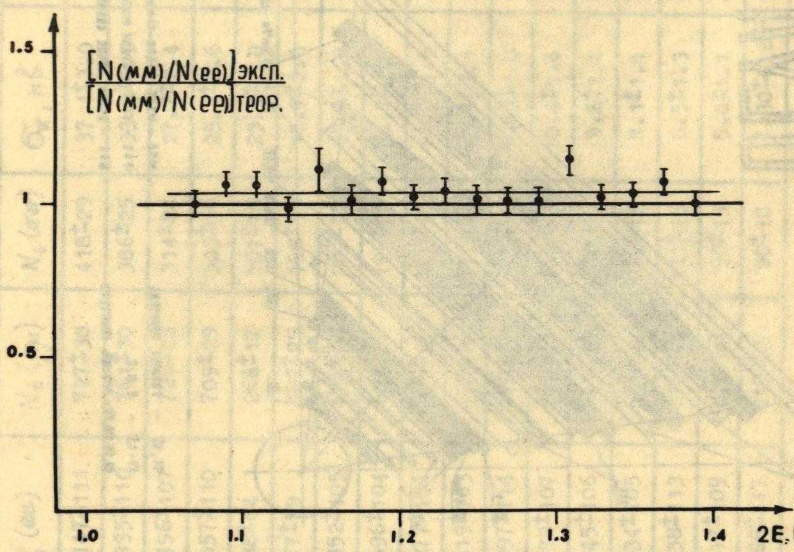


1 - COORDINATE CHAMBERS
2 - SHOWER DETECTOR
3 - RANGE SYSTEM

C1, C2 - TRIGGER COUNTERS
C3-1,2 - T.O.F.
C4,C5,C6,C7 - SHOWER COUNTERS

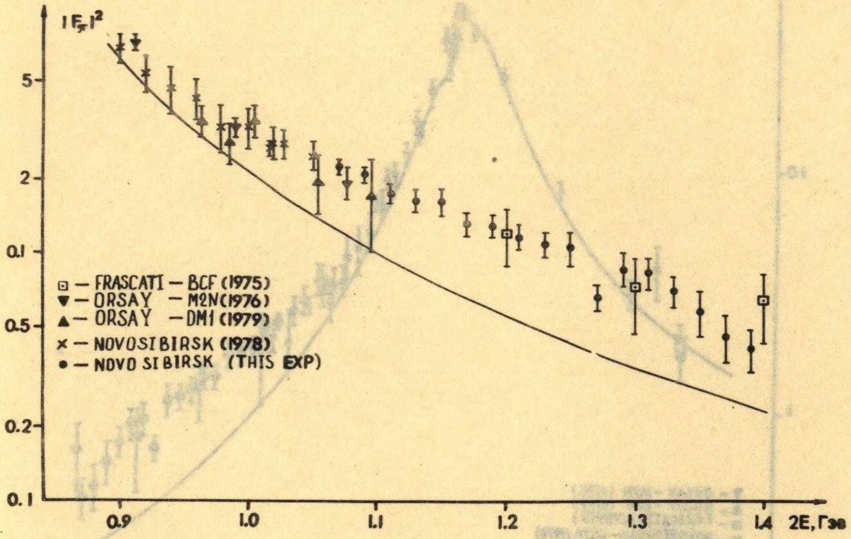
WSC - WIRE SPARK CHAMBERS
SSC - SHOWER SPARK CHAMBERS
RSC - RANGE SPARK CHAMBERS

Fig. 1



[N(мм)/N(ee)]эксп.
[N(мм)/N(ee)]теор.
1.5
1
0.5
1.0
1.1
1.2
1.3
1.4
2E,Г

Fig. 2



|Fπ|²
5
2
0.1
0.5
0.2
0.1
▫ – FRASCATI – BCF (1975)
▼ – ORSAY – M2N (1976)
▲ – ORSAY – DM1 (1979)
× – NOVOSIBIRSK (1978)
• – NOVOSIBIRSK (THIS EXP)
0.9
1.0
1.1
1.2
1.3
1.4
2E, Гэв

Fig. 3

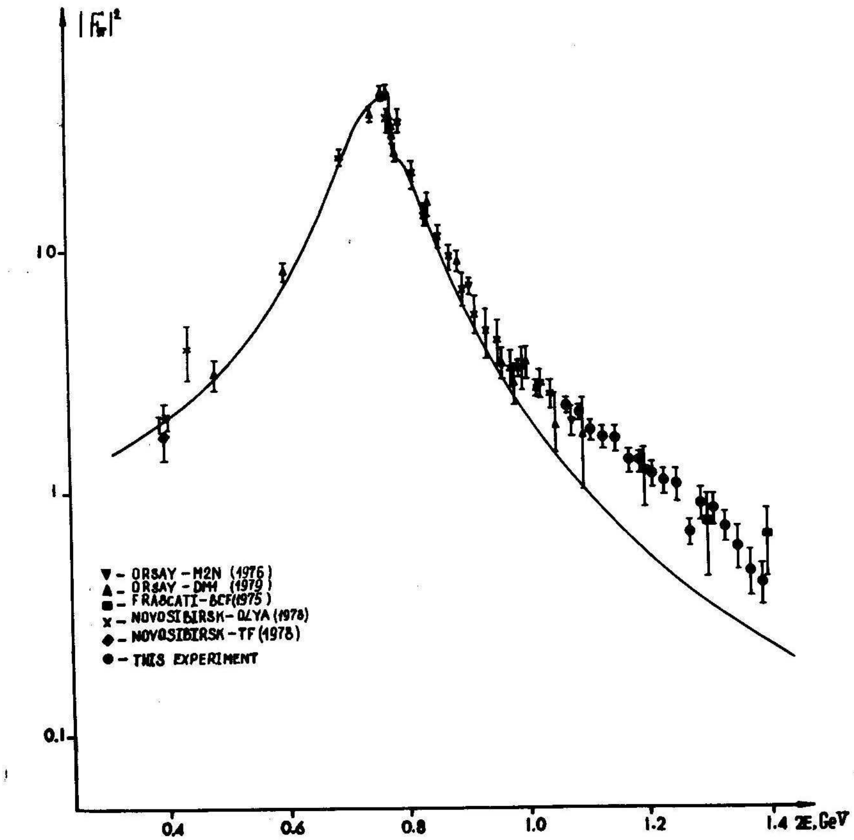


Fig. 4

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