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V.E.Balakin, A.D.Bukin, L.M.Kurdadze, A.P.Onuchin,
E.V.Pakhtusova, S.I.Serednyakov, V.A.Sidorov,
A.G.Khabakhpashev

EVIDENCE FOR THE REACTION $e^+e^- \rightarrow e^+e^- + e^+e^-$ WITH THE COLLIDING BEAMS

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A b s t r a c t

The results of two experiments on the process $e^+e^- \rightarrow e^+e^- + e^+e^-$ are given. The work has been performed with the colliding beams of VEPP-2. The process cross-section has been measured for the large out-of-flight angles of produced particles.

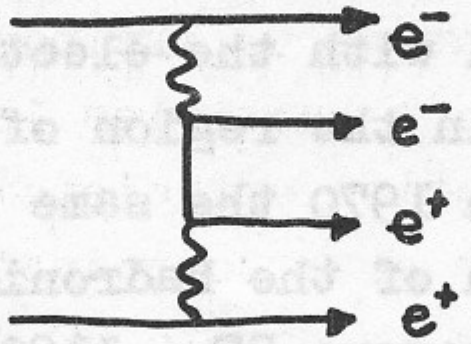
In 1969 the experiment on the Φ-meson resonance was performed with the electron-positron storage ring VEPP-2 in the region of the energy of $2E = 1020$ MeV /1/. In 1970 the same machine was used for the investigation of the hadronic form-factors at three values of energy: $2E = 1180$, 1260 and 1340 MeV /2/.

During the data handling of the Φ-meson resonance experiment about 100 two-body non-collinear events have been found that were not connected with the Φ-meson. Experimental data on the particle range and the multiple scattering angle showed that these particles could be identified as electrons. The preliminary results of this work have been reported at the Kiev conference and there an assumption was put forward that these events could be ascribed to the process of electron-positron pair electroproduction $e^+e^- \to e^+e^- + e^+e^-$ /3/. The further analysis confirmed this hypothesis /4/.

In this work the results of the joint data handling of two experiments are given. The presence of the Cerenkov counters in the 1970 experiment allows to perform a more rigid identification of the electron-positron pair events.

The main contribution to the cross-section of the reaction $e^+e^- \to e^+e^- + e^+e^-$ is given by

the following diagram (Landau diagram)



The total cross-section of this process in the three-logarithmic approximation has been obtained by Landau and Lifshitz in 1934 /5/. At the energy of our experiments this cross-section is about $5 \cdot 10^{-27} cm^2$ increasing logarithmically with the energy. Recently Baier and Fadin have obtained the total cross-section up to the one-logarithmic terms as well as the differential cross-section of the large angle particle production /6/.

Despite of the large value of the total cross-section of the electron-positron pair electroproduction this process has not been observed yet. It was not observed with the colliding beams due to two reasons. Firstly, the angular distribution of the produced particles has a sharp peaking in the direction of motion of initial particles but all the detection systems are placed at large angles. And in the second place the energy spectrum of produced particles is rather soft the detection cross-section being inversely proportional to the electron detection threshold squared. In the experiments

thick plates of matter are usually placed before the scintillation counters to exclude the large background from the soft particles leading to the negligibly small detection efficiencies for the electron-positron pair electroproduction. In our experiments the energy threshold of detection was sufficiently small.

The detection system used in the Φ -meson experiment was described in the work /1/. It consisted of two identical groups of the optical spark chambers covering a solid angle of 2x0.9 steradian near the vertical direction. Each group consisted of the coordinate, shower and range chambers. The spark chambers were triggered by four scintillation counters in coincidence. The detection threshold was 15 MeV for electrons and 35 MeV for π -mesons.

The geometrical lay-out of the apparatus used in the 1970 experiment is shown in Fig.1. From that in the Φ -meson experiment it differs in that the geometrical optical spark chambers have been replaced by the wire spark chambers and in addition the water Cerenkov counters have been placed between the scintillation counters. The presence of the Cerenkov counters led to reducing of the solid angle of the system by 10 % while the detection threshold has increased up to 25 MeV for electrons and 50 MeV for pions. From each side of the interaction point

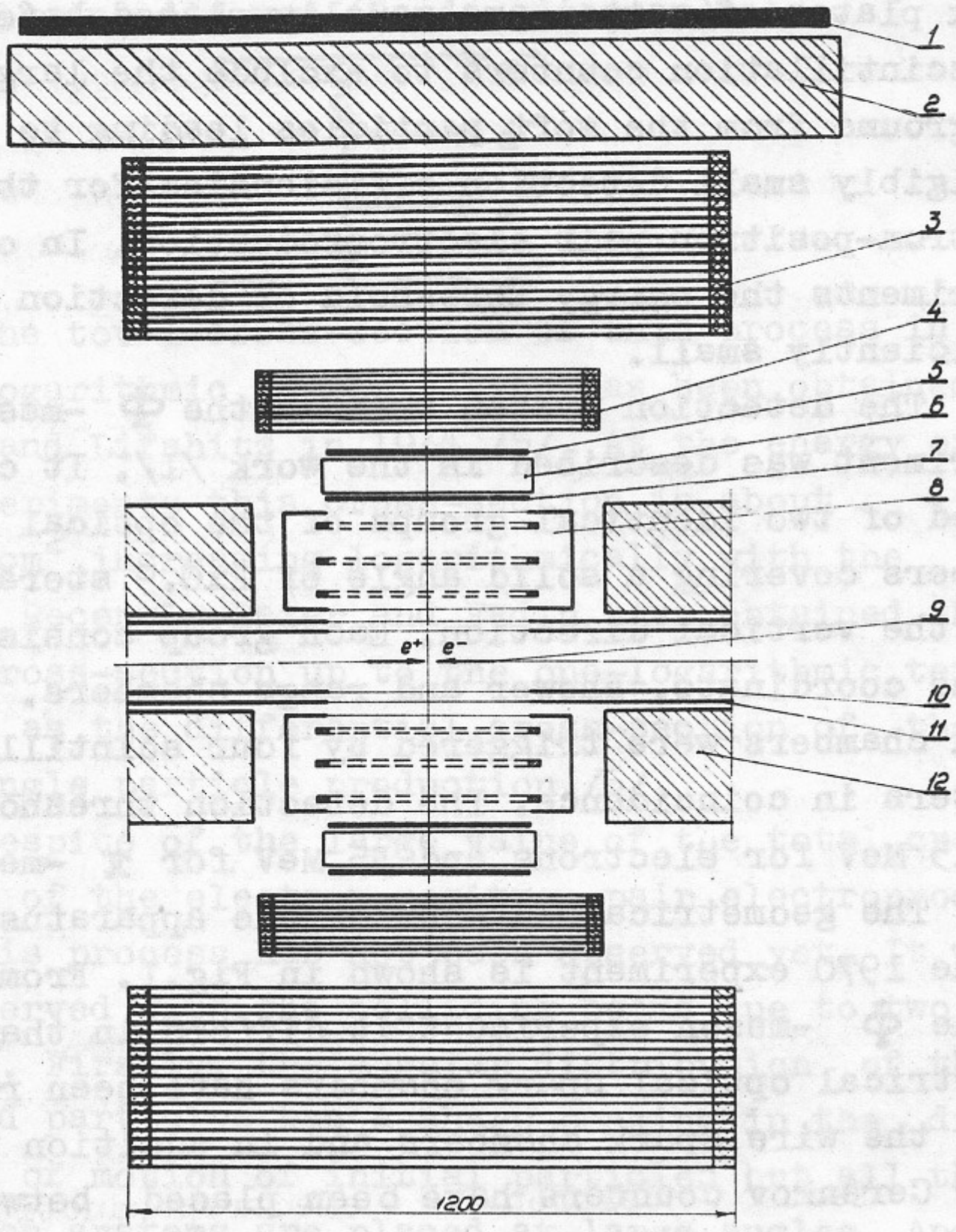


Fig.1. The geometrical lay-out of the experiment: 1-anticoincidence scintillation counter; 2-lead; 3-optical range spark chamber; 4-optical chower spark chamber; 5,7-scintillation counters; 6-water Cerenkov counter; 8-coordinate wire spark chambers; 9-interaction region; 10,11-internal and external vacuum chambers; 12-storage ring magnet.

three twocoordinate chambers with the ferrite cores were placed /7/. The wire chambers operated on-line with the computer, all the information being simultaneously recorded on the magnetic tape /8/. For events selected with the aid of the wire chambers the photographs from the shower and range spark chambers were scanned.

The Cerenkov counters had water radiators of the dimensions of 420 x 420 x 68 mm, the internal body of the counter was covered with the white diffuse paint. Each counter was scanned by four photomultipliers FEV-30 with two of them from the opposite small sides. These photomultiplier pairs operated with the separate discriminators. The information on the triggering of 4 discriminators was recorded for each event. During the analysis of the experimental data different requirements to the number of discriminators triggered were used depending on the selected events because it gave us the possibility to change the detection efficiency of the particles.

In both experiments the selection of the events of the electron-positron pair electroproduction was carried out by the particle range. In the first experiment the events were selected with both particles having a range from 6.4 up to 16 g/cm^2. In the second one the corresponding interval of the ranges was 10.5 - 20 g/cm^2.

In the second experiment the presence of a signal in four discriminators of the Cerenkov counters was also required. The detection efficiency for the electron pair measured by the elastic scattering events $e^+e^- \to e^+e^-$ was 72 %. The calculated value of the detection efficiency for the π -meson pair in the interval of the ranges mentioned was less than 1 %.

The fact that particles selected are electrons is confirmed by an agreement between the experimental and calculated values of the multiple scattering angle. In the first experiment the multiple scattering angle in foil (o.1 g/cm^2 of iron and 0.05 g/cm^2 of aluminum) was 5.5° and in the second one (0.5 g/cm^2 of iron) - 9°. Note that these angles for the π - mesons correspond to the energy of 8 MeV in the first experiment and to 13 MeV in the second one both values being much less than the detection threshold.

The summary results of both experiments are given in the Table 1.

The luminosity integral was determined by the elastic scattering process detected with the same apparatus.

About 30 % of the total time of the experiment was spent on the background measurements which were performed with two beams vertically displaced from each other by a distance of 2 mm.

Table 1

Energy 2E, MeV	1020		1180-1340
Luminosity integral, 10^{33} cm^2	8.5±0.4		13.2±0.6
Interval of the ranges, g/cm^2	6.4-16		10.5-20
Region of angles $\|\Delta\theta\|$	0°-40°	40°-90°	0°-90°
Effect	150	71	20
Background (normalized)	53	70	5
Admixture of the other processes investigated	13±5	0.2	<0.1
"Pure" effect	84±19	1±18	15±6
Calculation according to Baier and Fadin work /6/	65±13	22±5	15.4±3.2

Because of the small statistics for the second experiment only the combined results at three energies are given.

In the first experiment because of the different background conditions it proved convenient to consider

two regions of the non-collinearity angles $|\Delta\theta|$ between the tracks where θ was a polar angle in the spherical coordinate system with the polar axis along the beams motion direction.

Data from the Cerenkov counters in the second experiment allowed to make an admixture of the other many-body processes /2/ negligibly small. The calculation of the admixture in the first experiment has been carried out for the known modes of the ϕ -meson decay /1/.

The expected number of the events was calculated by the Monte-Carlo method with the account of the finite size of the interaction region, multiple scattering in the foil and the energy dependence of the electron detection efficiency. The detection efficiency has been also calculated by the Monte-Carlo method taking into account the generation of the showers. For electrons the ionization and bremsstrahlung losses as well as the multiple scattering were considered while for the γ -quanta the pair creation processes and Compton effect were considered. The correction was also made for the dependence of the effective thickness of the matter passed by a particle on the angles of its track with respect to the chamber plane.

In Fig.2 and Fig.3 the distribution of events with respect to the azimuth non-collinearity angle $\Delta\varphi$

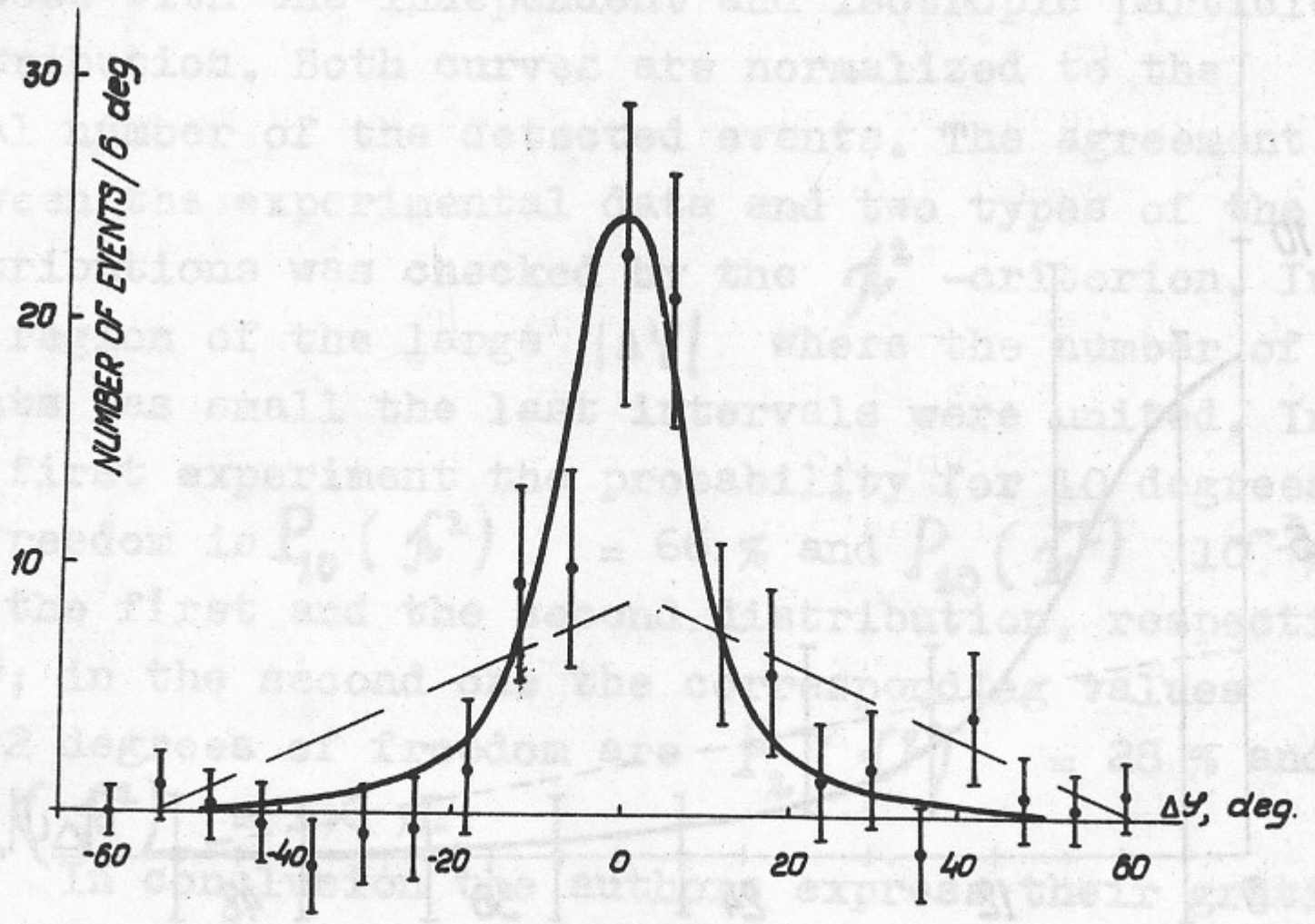


Fig.2. Distribution of events of the first experiment with respect to $\Delta\varphi$. The solid curve was obtained with the Baier and Fadin formulae, the dashed one was calculated for the process with independent isotropic particle distribution.

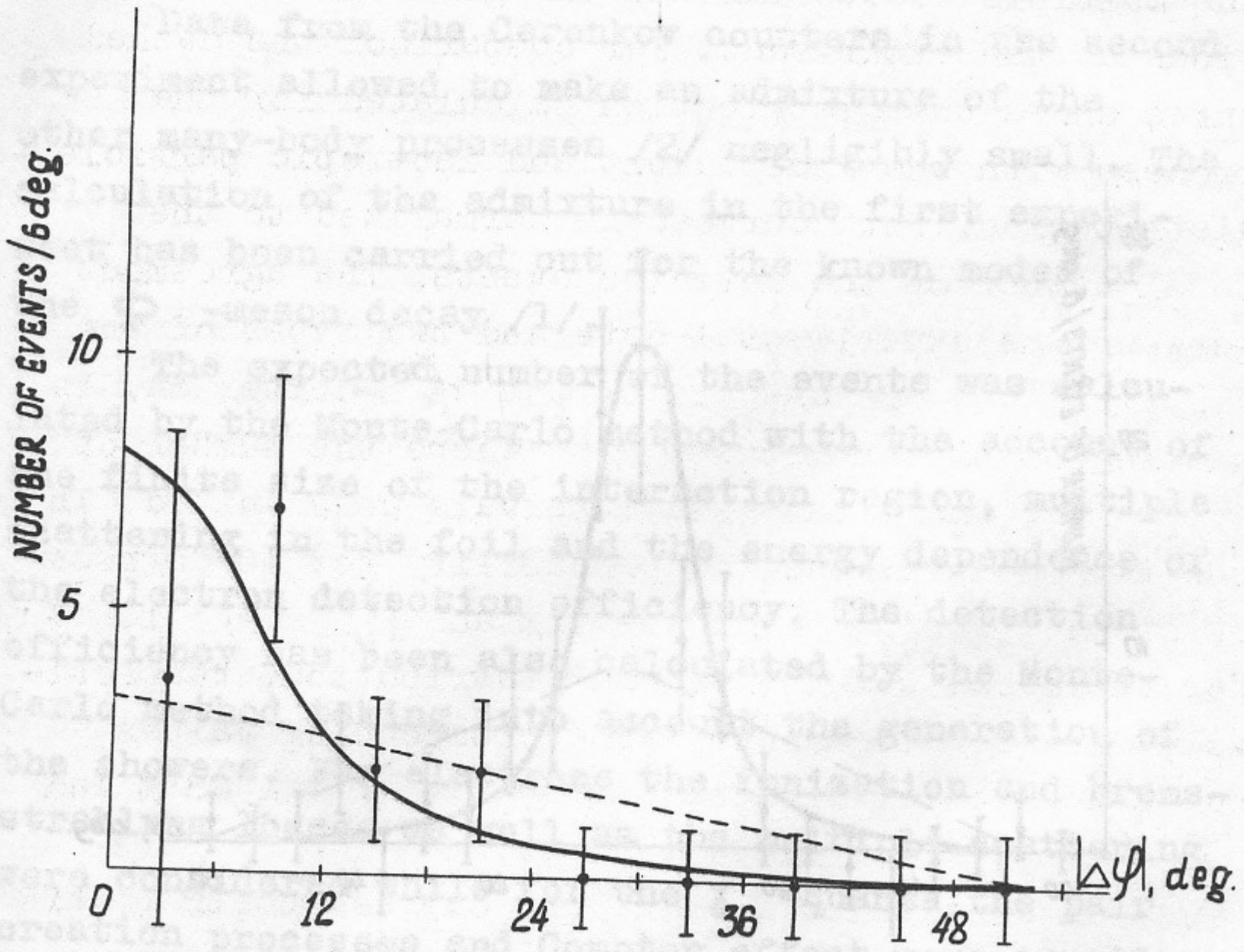


Fig.3. Distribution of events of the second experiment with respect to $\Delta\varphi$. The solid curve was obtained with the Baier and Fadin formulae, the dashed one was calculated for the process with independent isotropic particle distribution.

is shown for the first and the second experiments, respectively. A solid curve was obtained with the Baier and Fadin formulae /6/ with the account of the multiple scattering and the geometrical conditions of the experiment. For comparison the dashed curve shows the distribution calculated for the process with the independent and isotropic particle distribution. Both curves are normalized to the total number of the detected events. The agreement between the experimental data and two types of the distributions was checked by the χ^2 -criterion. In the region of the large $|\Delta\varphi|$ where the number of events was small the last intervals were united. In the first experiment the probability for 10 degrees of freedom is $P_{10}(\chi^2) = 66\ \%$ and $P_{10}(\chi^2)\ 10^{-3}\%$ for the first and the second distribution, respectively; in the second one the corresponding values for 2 degrees of freedom are $P_2(\chi^2) = 28\ \%$ and $P_2(\chi^2) = 1.6\ \%$.

In conclusion the authors express their gratitude to the co-workers who participated in data recording and data handling and to V.N.Baier and V.S.Fadin for discussions.

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