Yield of leptonic $\mu^- e^+$ pairs in $\nu_\mu N$ interactions in the SKAT bubble chamber

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(Submitted 1 April 1980)
Pis'ma Zh. Eksp. Teor. Fiz. **31**, No. 12, 772–776 (20 June 1980)

The results of analyzing $\mu^- e^+$ pairs in $\nu_\mu N$ interactions at 4–30 GeV, which were recorded in the SKAT bubble chamber, are presented. The procedure for determining the background for $\mu^- e^+$ events is described. The yield of the $\mu^- e^+$ pairs at $E_{e^+} > 400$ Mev is obtained: $N(\nu_\mu + N \to \mu^- + e^+ + ...)/N(\nu_\mu + N \to \mu^- + ...) = 0.35 \pm 0.14\%$.

PACS numbers: 13.15. + g

In this experiment, performed with use of the SKAT bubble chamber, we recorded in its effective volume ($V_{\rm eff} = 1.73$ m^3, filled with CF_3Br) ~ 2000 neutrino interactions at an energy $E_\nu \geqslant 2$ GeV proceeding via a weak, charged current (CC events), after a double scanning and physical verification of the statistical data.

Of these statistical data, we found 13 $\mu^- e^+$ events with a positron energy $E_{e^+} \geqslant 5$ MeV. The selection criteria of CC interactions, methods of reconstructing the energy of the events and the preliminary data obtained in the search of $\mu^- e^+$ events have been published elsewhere.[1–3] In searching for and analyzing the production of $\mu^- e^+$ events, we paid special attention in the experiment to identification of positrons and determination of the magnitude of the background produced by the possible processes that simulate such events.

The $98.8 \pm 0.9\%$ identification efficiency of the e^+ tracks, determined experimentally on the basis of analyzing the $e^+ e^-$ pairs produced as a result of γ-ray conver-

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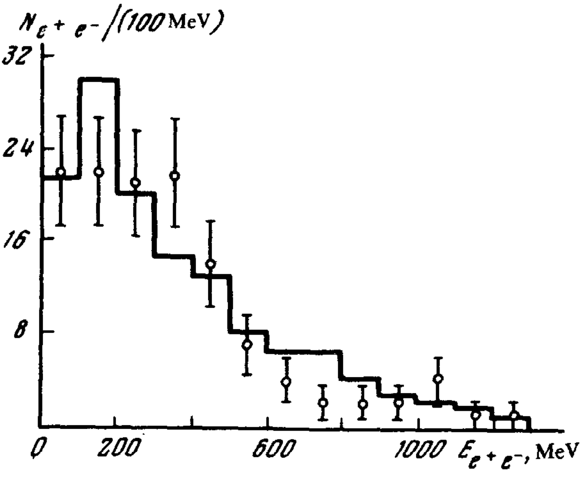

FIG. 1. Energy distribution of e^+e^- pairs in the $\mu^-e^+e^-$ events. The histogram represents the calculated distribution.

sion, turned out to be almost independent of the positron energy. To avoid confusion between the positron and the γ-ray quantum, it was stipulated that the positron must be without δ electrons 2 cm from the primary vertex.

The CC events containing an asymmetric e^+e^- pair produced by γ-ray conversion near the primary vertex or an asymmetric Dalitz pair with an electron energy $E_{e^-} \leqslant 5$ MeV, are the main background processes obtained in the search for μ^-e^+ pairs. The minimum distance at which a pair of e^+e^- tracks or a Compton electron can be uniquely classified as γ-ray quanta is 1 cm.

The background from these processes was determined from an analysis of the spectrum of γ-ray quanta observed experimentally in the effective volume of the bubble chamber, in which the following corrections were taken into account.

a) The bremsstrahlung γ-ray quanta. To identify these γ-ray quanta and to eliminate them from the spectrum, we used a method employed by Ammosov *et al.*[4] We eliminated from each pair of γ-ray quanta recorded in this event one γ-ray quantum with smaller energy, which was converted farther away from the primary vertex than the preceding quantum, if the angle $\theta_{\gamma\gamma}$ between the directions of escape of the γ-ray quanta was such that $\cos\theta_{\gamma\gamma} > 0.994$. The number of γ-ray quanta eliminated in this experiment amounted to 9.3%. In this case, 2.6% of the γ-ray quanta from π^0-meson decay was excluded from the spectrum and the impurity remained in 0.5% of the bremsstrahlung γ-ray quanta.

b) Allowance for the unrecorded γ-ray quanta with an energy $E_\gamma > 40$ MeV. A weight inversely proportional to its recording probability was assigned to each γ-ray quantum.

c) The examined recording efficiency of γ-ray quanta, determined on the basis of a double scanning of the larger fraction of statistical data, was $\epsilon_\gamma = 98 \pm 2\%$ for γ-ray quanta with an energy $E_\gamma \gtrsim 40$ MeV. Since the recording and identification efficiency

TABLE I.

number	Process	E_{ν}^{vis} (GeV)	p_{μ^-} (GeV/c)	p_{e^+} (GeV/c)	$\frac{p_{\mu^-}}{p_{e^+}}$	$\phi_{\mu^- e^+}$	$M_{\mu^- e^+}$ GeV/c^2	$M_{e^+\nu^0}$ GeV/c^2
1	$\nu_\mu p \to \mu^- e^+ 2\pi^0 p$	$7,4 \pm 0,5$	$3,8 \pm 0,2$	$0,75 \pm 0,19$	5,1	20°	0,37	–
2	$\nu_\mu N \to \mu^- e^+ \pi^+ \pi^0 n 3 p_s$	$6,6^{+0,5}_{-0,1}$	$4,8 \pm 0,1$	$0,60 \pm 0,06$	8,1	64°	0,27	–
3	$\nu_\mu N \to \mu^- e^+ \pi^- 2\pi^+ 3pn$	$6,6 \pm 0,3$	$4,3 \pm 0,2$	$0,43 \pm 0,12$	10,0	128°	0,42	–
4	$\nu_\mu N \to \mu^- e^+ \Lambda^0 p\pi^-$	$25,4 \pm 1,8$	$15,4 \pm 1,3$	$2,70 \pm 1,02$	5,7	105°	1,75	1,74
5	$\nu_\mu p \to \mu^- e^+ K_s^0 \pi^+ \pi^0 n$	$12,8 \pm 1,4$	$2,3 \pm 0,1$	$3,8 \pm 1,3$	0,6	85°	1,39	0,82
6	$\nu_\mu N \to \mu^- e^+ \pi^- 3\pi^+ 2\pi^0$	$29,9 \pm 1,5$	$18,2 \pm 1,1$	$2,3 \pm 0,7$	7,9	57°	1,02	–

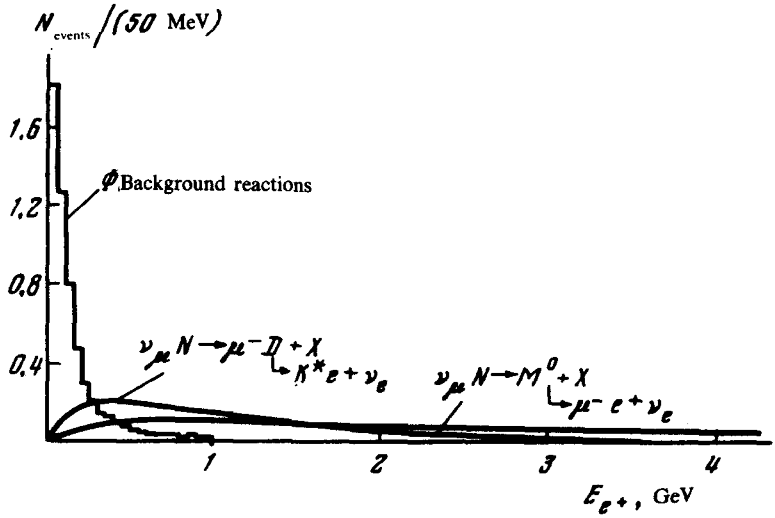

FIG. 2. Calculated energy distribution of positrons in the background $\mu^- e^+$ events and in the possible production reactions of new particles in the SKAT bubble chamber.

for γ-ray quanta with $E_\gamma \lesssim 40$ MeV was much lower, we used the logarithmic symmetry of the energy spectrum of γ-ray quanta produced as a result of π^0-meson decay, to determine the losses in this energy region.[5] This error amounted to $2.8 \pm 0.1\%$ of the total number of γ-ray quanta.

d) The contribution of Dalitz pairs from the $\pi^0 \to e^+ e^-$ decay was determined on the basis of the fact that the energy spectrum of Dalitz pairs is proportional to the spectrum of γ-ray quanta with a coefficient $(B/2)/(1 - B/2)$ (B is the relative width of the $\pi^0 \to e^+ e^- \gamma$ decay channel).

The foregoing corrections were verified by comparing the calculated number of $\mu^- e^+ e^-$ events with the recorded number. The recorded number of such events was $N_{\mu ee}^{\exp} = 139$ and the calculated number, based on the corrected spectrum of γ-ray quanta, was $N_{\mu ee}^{(c)} = 141 \pm 4$ events. The energy spectrum of $e^+ e^-$ pairs in $\mu^- e^+ e^-$ events (Fig. 1) is described fairly well by the calculated spectrum. This leads us to conclude that the energy spectrum of γ-ray quanta obtained after the introduction of corrections is close to the true one. By using this spectrum we can calculate both the number of positrons and their energy spectrum in the background $\mu^- \mu^+$ events. This spectrum is illustrated in Fig. 2 which also shows, for comparison, the predicted positron distributions in the production and decay processes of charmed D mesons or heavy M^0 leptons with a mass $m(D,M^0) = 2$ GeV, which were calculated in terms of the quark-parton model (the distributions were normalized arbitrarily).

We can see in Fig. 2 that if the $\mu^- e^+$ events with positron energies $E_{e^+} > 400$ MeV are analyzed, then an appreciable part of the background can be eliminated. In this experiment we recorded 7 $\mu^- e^+$ events with $E_{e^+} < 400$ MeV and 6 events[2)] with $E_{e^+} > 400$ MeV. The predicted background from the processes analyzed above is 5.1 ± 0.2 and 0.45 ± 0.02 events, respectively. The losses of the $\mu^- e^+$ events (E_{e^+}

>400 MeV) associated with the criteria for selection and identification of positron tracks amount to 0.49 ± 0.06 event.

An estimate of the background for $\mu^- e^+$ events from the process of $\tilde{\nu}eN$ interaction gives the value $N_{\tilde{\nu}e} \approx 0.04$ event.

The relative yield of the leptonic $\mu^- e^+$ pairs (taking into account the corrections for the background and for the loss of $\mu^- e^+$ events) at neutrino energies in the range $E_\nu = 4$–30 GeV and positron energy $E_{e^+} > 400$ MeV in this experiment is

$$R = \frac{N(\nu_\mu + N \rightarrow \mu^- e^+ + \ldots)}{N(\nu_\mu + N \rightarrow \mu^- + \ldots)} = 0{,}35 \pm 0{,}14\%.$$

The parameters of the $\mu^- e^+$ events with $E_{e^+} > 400$ MeV are given in Table I.

The authors take this opportunity to express their gratitude to L. D. Solov'ev, V. A. Yarbe, N. E. Tyurin, and S. P. Denisov for their abiding interest and support of the neutrino experiments using the SKAT bubble chamber. We thank the staff of the IHEP accelerator, of the neutrino beam, the SKAT bubble chamber, the photographic laboratory, and of the processing section for their help with the experiment.

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[2)]Two events were accompanied by the production of V^0 particles.

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