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FORM FACTORS IN $K^+_{\mu 3}$ DECAY

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July 2, 1964

FORM FACTORS IN $K^+_{\mu 3}$ DECAY*

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July 2, 1964

In an exposure of the Lawrence Radiation Laboratory's 30-inch heavy-liquid chamber, filled with C_3F_8, to stopping K^+ from the Bevatron, we have found about 12 000 examples of the decay mode $K^+_{\mu 3}$ in which the muon stops in the chamber. For about 800 of these events both photons from the π^0 decay convert in the chamber, giving a sample of kinematically over-determined (two-constraint) events. We report here preliminary results of an analysis of events from these classes.

In the universal (V - A) Fermi interaction, $K_{\ell 3}$ decay modes have a matrix element of the current-current form

$$\langle \pi | J_V | K \rangle \langle \nu | \gamma_\mu (1 + \gamma_5) | \ell \rangle .$$

The leading term, which contains all of the strong-interaction effects, may be expanded in the form[1]

$$f^+(q_K + q_\pi) + f^-(q_K - q_\pi) ,$$

where f^+ and f^- should be constant or slowly varying functions of the four-momentum transfer $q^2 = M_K^2 + M_\pi^2 - 2M_K E_\pi$. Terms in f^- are of the order

of the square of the lepton mass and thus are negligible in K_{e3} decay, but important in $K_{\mu 3}$. With the exception of the absolute decay rate, all observable quantities are uniquely determined by the ratio $\xi = f^-/f^+$. Since the event is completely determined by two kinematic quantities plus the components of the muon polarization in the decay plane, four independent measurements of ξ are possible, and their agreement constitutes a test of the theory. In addition, the relative $K_{\mu 3}$-K_{e3} branching ratio is a function of ξ, and agreement with values obtained from this ratio tests μ-e universality.

The longitudinal polarization was measured over the range $38 < T_\mu < 96$ MeV. To permit a substantial component of the polarization to be parallel to the magnetic field, we used 2988 events in which the muon stopped in the chamber and the dip of the muon track was greater than 12 deg. We obtained an average polarization

$$\langle \underset{\sim}{P}_\mu \rangle = 0.74 \pm 0.16 \qquad (38 < T_\mu < 96 \text{ MeV}) .$$

The energy dependence of the polarization, along with predictions for various values of ξ, is shown in Fig. 1. The measured polarization is consistent with values in the vicinity of $\xi = 0$ or $\xi = -4$, with the former somewhat favored; the ambiguity is a consequence of the energy region covered and the statistical accuracy of the experiment. To use the data most efficiently we made a direct likelihood fit for ξ; the results appear in Fig. 2, and show the ambiguity. The central values obtained are

$$\xi = -0.15 \pm 0.90 \quad \text{or} \quad -4.05 \pm 0.75.$$

The ambiguity does not overlap that of branching ratio experiments,[2] and thus it can be stated with some confidence that the $\xi = -0.15$ solution is the physically meaningful one. Further details of this experiment will be reported elsewhere.[3]

We have also analyzed 178 of the events in which conversion pairs are seen. In these events the π^0 momentum is determined to about 5% accuracy from kinematic fitting, and the muon momentum is known to about 2% from its range. Thus the events are well determined kinematically, and any convenient set of kinematic variables may be chosen to represent the event. We have chosen the kinetic energies of the muon and π^0. A Dalitz plot of the events, corrected for detection efficiency, is shown in Fig. 3.

The principal difficulty in analyzing these events lies in evaluating the detection efficiency as a function of T_μ and T_π. For the muon, this involves a potential path-length calculation, which may be carried out by Monte Carlo techniques. The π^0 detection efficiency is easily evaluated by using the known pair-production cross section, and does not vary rapidly with π^0 energy. The difficulty lies in the correlation of these detection efficiencies for a complete event, because events with a high-energy muon are not uniformly distributed in the chamber, and the π^0 and μ directions are correlated, the correlation itself being a function of ξ. Thus we have restricted this preliminary analysis to the region $15 < T_\mu < 85$ MeV, in which the correlation is not expected to be significant. This region contains 138 events.

Backgrounds in this experiment are not expected to be significant. $K_{\pi 2}$ events, because of their colinear structure, are confined to a small region of the Dalitz plot, which lies outside the range used in the analysis (see Fig. 3). From the number of $K_{\pi 2}$ events found in the sample we estimate that the μ of a π-μ-e decay chain is missed about 10% of the time. Using this figure, and the fact that 50% of a known sample of K_τ events give an unacceptable χ^2 for the $K_{\mu 3}$ hypothesis, we estimate the K_τ background to be less than 5%, which is not significant in this experiment.

Figure 4 gives χ^2 for the Dalitz plot (10 degrees of freedom) as a function of ξ; again we find an ambiguity, an accident of the choice of muon energies and the low statistical accuracy. This ambiguity should resolve itself when the analysis is completed, extending the energy region covered and improving the statistics. If we add to the statistical error an allowance for uncertainty in the detection-efficiency calculations, the two solutions are

$$\xi = +1.3 \pm 0.9 \quad \text{and} \quad -5.2 \pm 0.7 .$$

A weighted mean with the polarization data gives

$$\xi = +0.6 \pm 0.7 \quad \text{and} \quad -4.7 \pm 0.6 .$$

The first solution is favored, since it is consistent with the value obtained in recent branching-ratio and muon-spectrum experiments.[2,4] Thus, to the present level of statistical accuracy, a universal V - A theory with μ-e universality seems adequate to explain K^+_{β} decay. Statistical accuracy is not yet sufficient to serve as a test of energy dependence of the form factors or of detailed models of the interaction.[5] The negative solution does not have the value required by a recent theory of Schwinger.[6]

The muon spectrum is being measured by using 4000 events in which the muon stops in the chamber.

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*This work was done under the auspices of the U.S. Atomic Energy Commission.

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FIGURE LEGENDS

Fig. 1. Muon longitudinal polarization as a function of kinetic energy, compared with predictions for various values of ξ.

Fig. 2. Likelihood function for ξ in polarization measurement.

Fig. 3. Diagram of Dalitz plot, giving observed numbers of events (integers) and prediction for $\xi = +1.3$, corrected for detection efficiency.

Fig. 4. χ^2 for Dalitz plot in Fig. 3, with nine degrees of freedom, as a function of ξ.

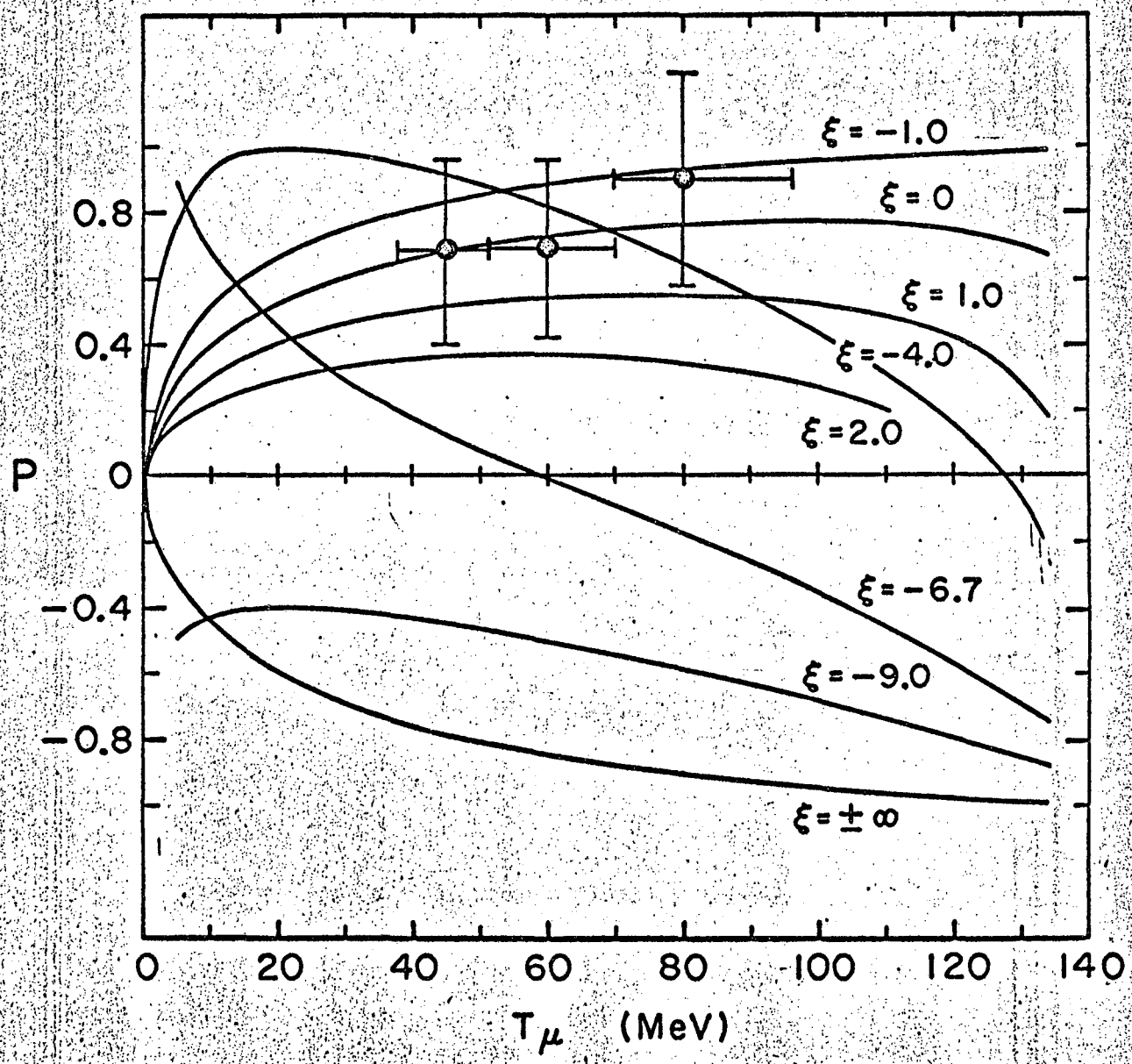

Fig. 1 MUB-2903

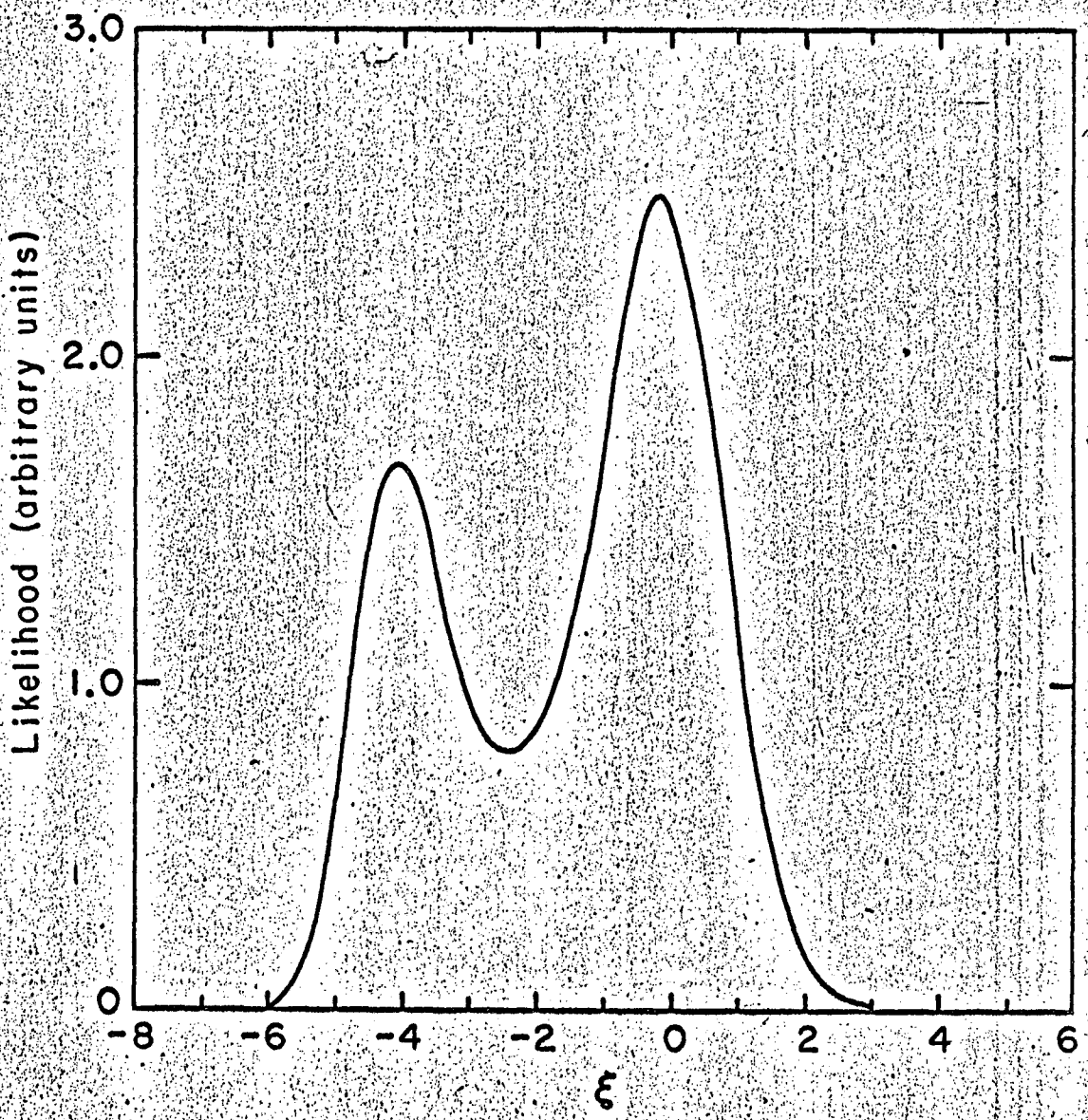

Fig. 2

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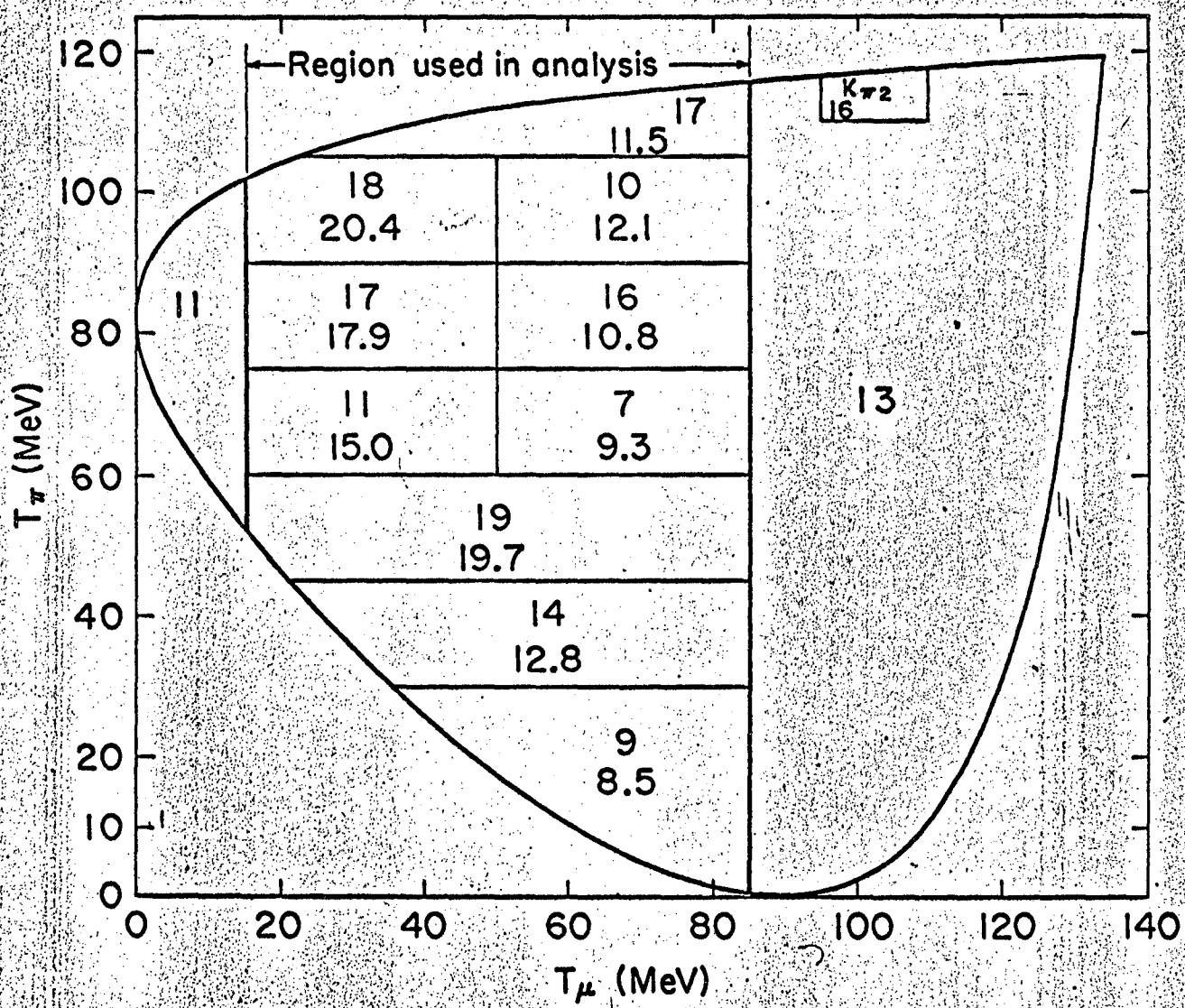

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Fig. 3

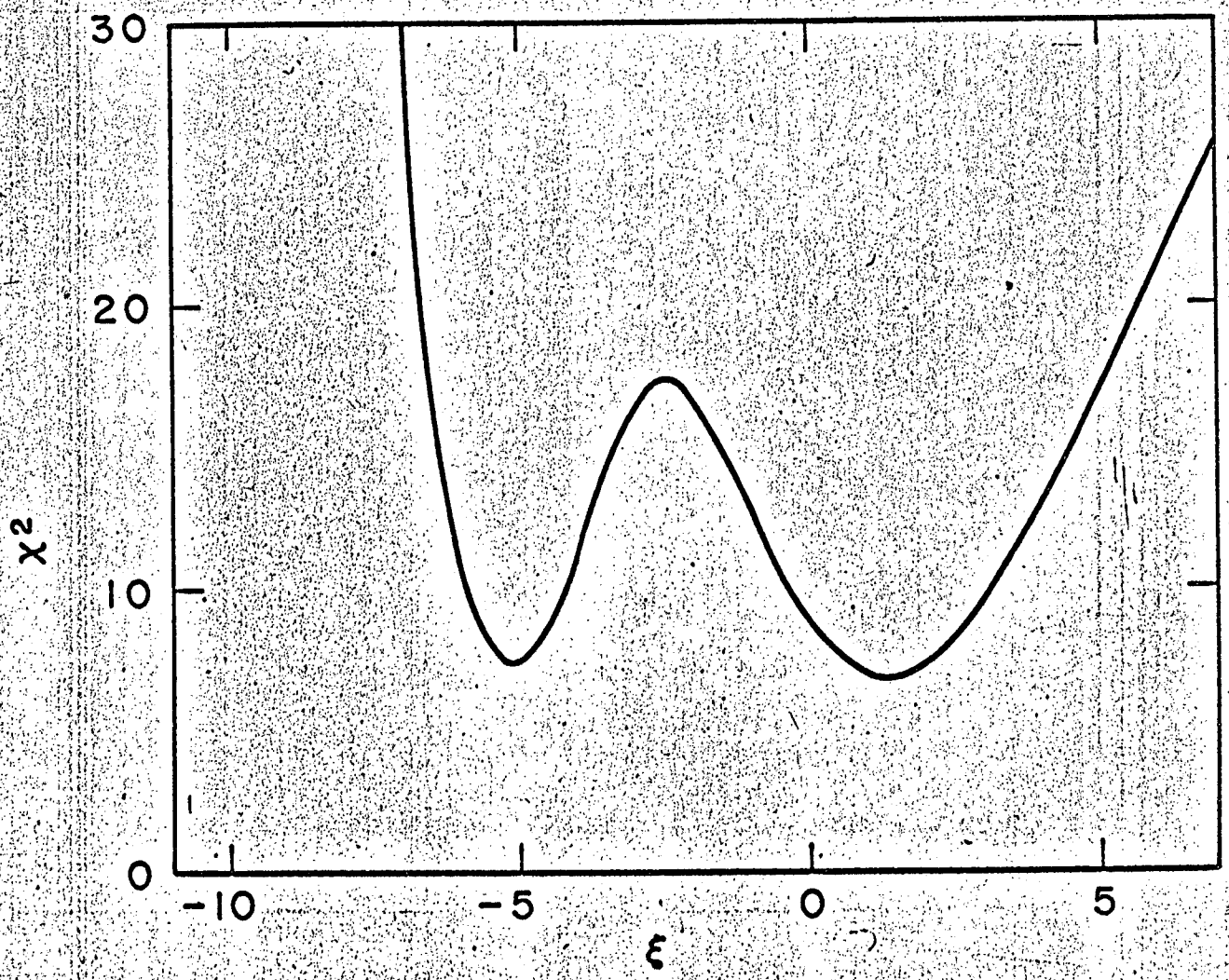

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Fig. 4

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