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Ernest O. Lawrence Radiation Laboratory

SEARCH FOR $K^- p \rightarrow \Lambda \mu^+ \mu^-$ OR $\Lambda e^+ e^-$ AT 2.45 AND 2.7 BeV/c INCIDENT K^-

Berkeley, California

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Paper to be presented at the 1964 International Conference on High Energy Physics, Dubna, U.S.S.R., August 5–15, 1964.

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SEARCH FOR $K^-p \to \Lambda\, \mu^+\mu^-$ OR Λe^+e^- AT 2.45 AND 2.7 BeV/c INCIDENT K^-

Angela Barbaro-Galtieri and Robert D. Tripp

(To be presented by Ronald R. Ross)

Lawrence Radiation Laboratory
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In the course of a general study of K^-p interactions at 2.4 and 2.7 BeV/c incident K^- momentum, in an experiment performed with the Lawrence Radiation Laboratory 72-inch hydrogen bubble chamber, we have investigated the reactions

$$K^-p \to \Lambda\mu^+\mu^- \qquad (1)$$

and

$$K^-p \to \Lambda e^+e^-. \qquad (2)$$

Approximately 18 000 events with the V 2-prong topology have been measured. In about 8000 events the V fitted a Λ, and 1250 events passed the criteria for fitting $K^-p \to \Lambda\pi^+\pi^-$. A cutoff in the four-constraint fit to this reaction has been set at $\chi^2 = 24$. The χ^2 distribution is reported in Fig. 1. Since the momentum distribution of muons and electrons is expected to be peaked above 200 MeV/c, we do not expect to separate muons and electrons from pions on the basis of ionization measurement. A sample of events has been selected with the following criteria: (a) events that did fit Λ for the V, but did not fit any of the usual reactions involving a Λ; (b) events that had a fit for $\Lambda\pi^+\pi^-$ but for which the χ^2 was larger than 5. In our sample 435 events are of type a and 487 of type b.

These selected 922 events have been fitted again with the assumption that the two tracks at the production vertex are muons or electrons. Table I summarizes the results of these fits.

Table I. Summary of the events fitted to $\Lambda\mu^+\mu^-$ and Λe^+e^-.

Events	Fitted reaction	Good fit	$CL > CL_{2\pi}$ (a)	$CL > 5CL_{2\pi}$
Type a, 435	$\Lambda\mu^+\mu^-$	13		13
	Λe^+e^-	9		9
Type b, 487	$\Lambda\mu^+\mu^-$	326	63	19
	Λe^+e^-	128	24	8

(a) CL = confidence level for the fit

Few events of type a have a good fit, because badly measured events fail in this category. The last two columns report the number of events whose fit is better for the μ and e hypothesis than for the π hypothesis. We consider as candidates for Reactions (1) and (2) only events for which $CL > 5\,CL_{2\pi}$.

In Fig. 1, we plot χ^2 for $\Lambda 2\pi$ fit versus χ^2 for $\Lambda 2\mu$ fit. The solid curves represent different ratios of confidence level (CL). Figure 2 represents a similar scatter diagram for the e^+e^- hypothesis. On each axis the histogram represents the χ^2 distribution for that hypothesis; the shaded area refers to events that did not fit the other hypothesis for the particle masses. Some of the events fit $\mu^+\mu^-$ as well as e^+e^-; in this case the hypothesis with the higher CL has been chosen. We are left with 22 candidates for $\mu^+\mu^-$ and 11 for e^+e^-.

In Fig. 3a we plot the invariant mass $M(\mu^+\mu^-)$ of the system $\mu^+\mu^-$ of Reaction (1), and in Fig. 3b, $M(e^+e^-)$. Neither distribution shows any peaking at any particular mass, but they are similar to a $\pi\pi$ mass spectrum for the reaction $K^-p \to \Lambda\pi^+\pi^-$. Of the known resonances, only the ω shows two possible candidates in the $\mu^+\mu^-$ system. In Fig. 3c we plot the p distribution of the secondary tracks of the 33 candidates. The total length of these tracks

tracks is $L = 24$ m. We observe three interactions along the tracks, while we expect none for muons or electrons. Were these tracks all π^+, or π^-, from the known cross sections at their momenta ($\sigma_{av} \approx 30$ mb) we would expect 2.7 interactions in this path length, which is consistent with what we observe.

In conclusion, in the sample examined, all events are consistent with being $\pi\pi$ productions, except for possibly two candidates for $\omega \to \mu^+\mu^-$. At this stage of the experiment, we can calculate only upper limits for electromagnetic decays of the ω and ϕ mesons, which we produce in other channels. Table II summarizes the results.

Table II. Branching ratios for electromagnetic decays of ω and ϕ.

	$\mu^+\mu^-$	e^+e^-	Total [a]	$2/3 \times$ total [b]	Branching ratios
ω	2?	0	540	360	$\frac{\omega \to \mu^+\mu^-}{\text{Total}} < 0.005$ $\frac{\omega \to e^+e^-}{\text{Total}} < 0.003$
ϕ	0	0	111	74	$\frac{\phi \to \mu^+\mu^-}{\text{Total}} < 0.013$ $\frac{\phi \to e^+e^-}{\text{Total}} < 0.013$

(a) Total number of ω and ϕ found in the same K path length examined here, corrected for neutral decays.

(b) This factor 2/3 takes into account the fact that we examine only events for which $CL_{2\mu}$ (or CL_{2e}) $> 5\, CL_{2\pi}$.

The upper limit for $\omega \to e^+e^-$ decay is not in disagreement with previously published results.[1]

The negative results of this experiment are of interest for the following reasons.

1. No evidence is found in strange-particle collisions for the production of any new meson resonances, up to a mass of 1200 MeV, whose dominant decay

mode might be into muon pairs. Heretofore no systematic search for short-lived states with this decay mode has been reported. For the known resonances ω and ϕ these decay modes show a very low rate. One of the tests for the validity of the ω mixing model[2] is to verify the ratio of electromagnetic decay rates by ω and ϕ. In fact according to this model,[3]

$$\frac{\Gamma(\omega \to e^+e^-)}{\Gamma(\phi \to e^+e^-)} = \tan^2 \theta, \qquad \text{and the same for} \qquad \mu^+\mu^-, \tag{3}$$

where θ is the mixing parameter. By use of the mass formula for the vector meson octet, $\tan \theta$ is found to be $\tan \theta = \pm 0.55$. This value predicts for the ratio (3) a value 1/3.3, which means

$$\frac{R_\omega \Gamma_\omega}{R_\phi \Gamma_\phi} = \frac{R_\omega}{R_\phi} \times \frac{9.0}{3.1} = \frac{1}{3.3}, \quad \text{i.e.,} \quad \frac{R_\omega}{R_\phi} \approx \frac{1}{10}.$$

With the present statistics we can set only upper limits for R_ω and R_ϕ, but our results are not in contradiction with the foregoing prediction.

2. In the past few years many experiments have been performed to check the validity of the quantum electrodynamic description of the muon propagator. No difference between muon and electron pair production has been observed up to now.[4] A different approach for checking electrodynamics over small distances consists in comparing the branching ratios of strongly interacting vector mesons (ω, ϕ) decaying into an e pair or a μ pair.[5] Any difference in the branching ratios would suggest an anomalous interaction for the muon. In the limit of statistics we do not see any such difference.

3. Finally, Ne'eman in a recent paper[6] suggested the existence of a fifth interaction, similar to electromagnetism but some ten times as strong, mediated by a vector meson coupled to the strangeness current. This interaction may be responsible for the muon mass. The $\phi(1020)$ meson may be this intermediate vector meson, and in this case $\phi(\mu^+\mu^-)/\phi(e^+e^-) \approx 10$.

The branching ratio $\phi \rightarrow \mu^+\mu^- / \phi \rightarrow K\bar{K}$ should be $\approx \frac{1}{37} \times 10 \times$ phase space factors. Beder et al.[7] estimate a width for $\phi \rightarrow \mu^+\mu^-$ of 30 MeV, i.e., this decay mode should be 10 times stronger than the $K\bar{K}$ decay, if Ne'eman's theory is correct. Our upper limit is in contradiction with this prediction. Ne'eman's theory can still hold, but the strong coupling of this interaction to the muons seems ruled out by our experiment.

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Figure Captions

Fig. 1. χ^2 for $\Lambda 2\pi$ fit ($\chi^2_{2\pi}$) versus χ^2 for $\Lambda 2\mu$ fit ($\chi^2_{2\mu}$). On the right is the χ^2 distribution for $\Lambda 2\pi$. On the X axes is reported the χ^2 distribution for only those events satisfying $CL_{2\mu} > 5\, CL_{2\pi}$. The solid lines represent different ratios of confidence level for $\Lambda 2\mu/\Lambda 2\pi$ hypotheses.

Fig. 2. χ^2 for $\Lambda 2e$ fit (χ^2_{2e}) versus χ^2 for $\Lambda 2\pi$ fit ($\chi^2_{2\mu}$). On the right is the $\chi^2_{\Lambda\pi^+\pi^-}$ distribution for $\Lambda\pi^+\pi^-$. On the X axis is reported the χ^2 distribution for only those events satisfying $CL_{2\mu} > 5\, CL_{2\pi}$. The solid lines represent different ratios of confidence levels for $\Lambda 2e/\Lambda 2\pi$ hypothesis.

Fig. 3(a). Invariant mass distribution of the $(\mu^+\mu^-)$ system for 22 events satisfying the criteria (see text) for fitting $K^-p \to \Lambda\mu^+\mu^-$. (b) Invariant mass distribution of the (e^+e^-) system for 11 events fitting $K^-p \to \Lambda e^+e^-$. (e) Momentum distribution of μ or e tracks of the above 33 events.

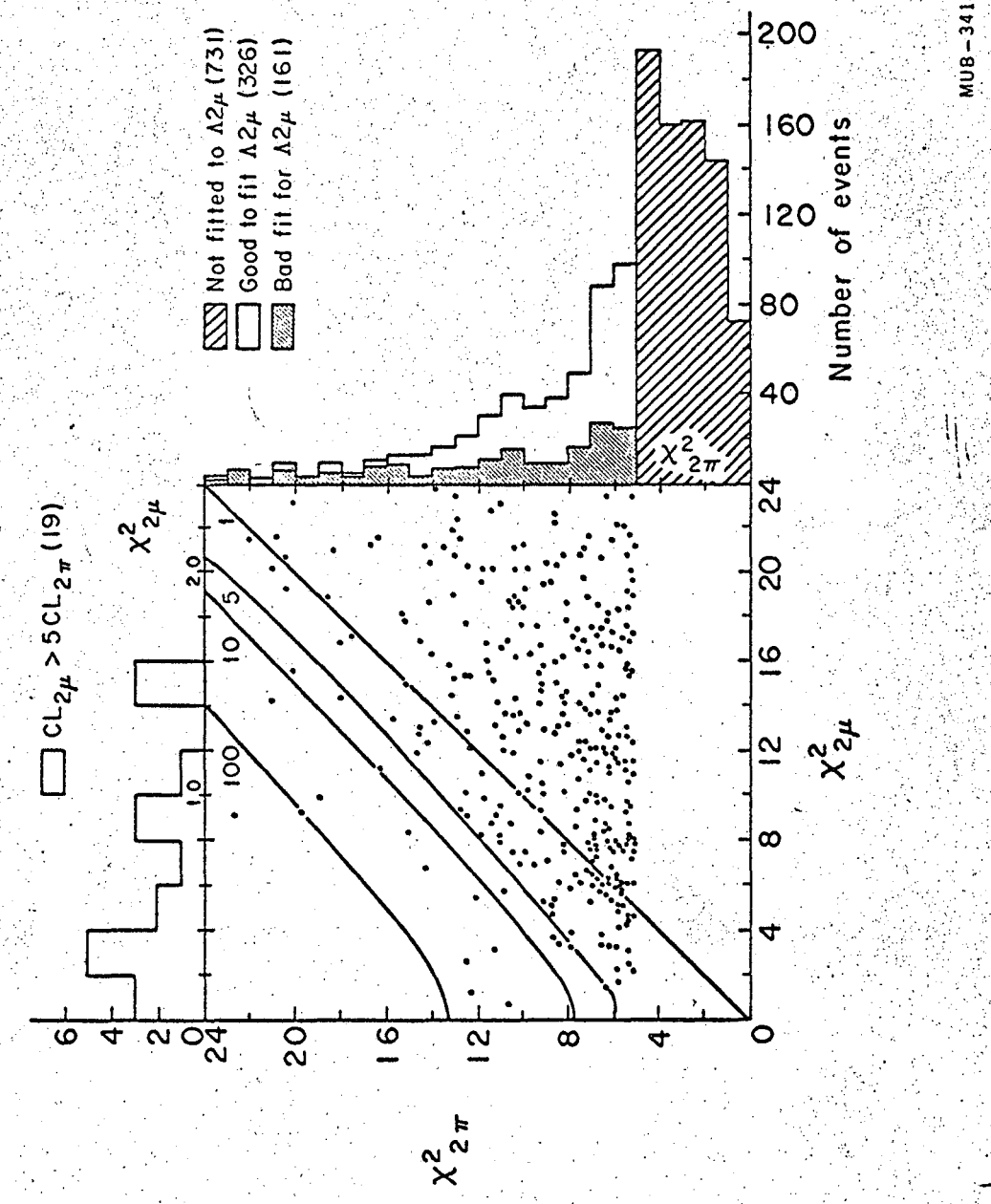
Not fitted to Λ2μ (731)
Good to fit Λ2μ (326)
Bad fit for Λ2μ (161)
Number of events
$\chi^2_{2\pi}$
$\chi^2_{2\mu}$
$CL_{2\mu} > 5CL_{2\pi}$ (19)
1
2.0
5
10
100
1.0
MUB-3418

Fig. 1.

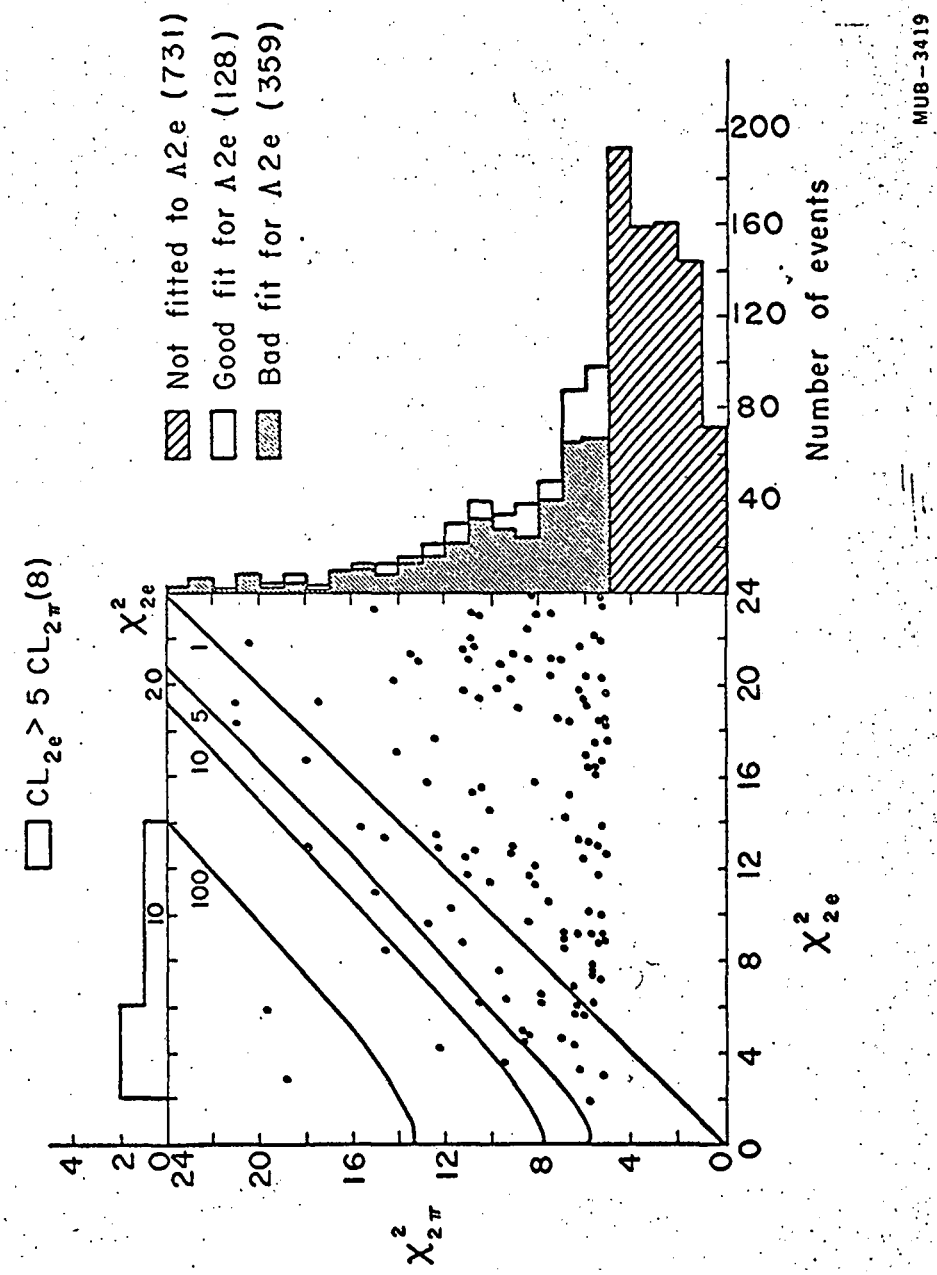
Not fitted to Λ2e (731)
Good fit for Λ2e (128)
Bad fit for Λ2e (359)
Number of events
MUB-3419
$CL_{2e} > 5\ CL_{2\pi}(8)$
χ^2_{2e}
$\chi^2_{2\pi}$
χ^2_{2e}
1
2.0
5
10
10
100

Fig. 2.

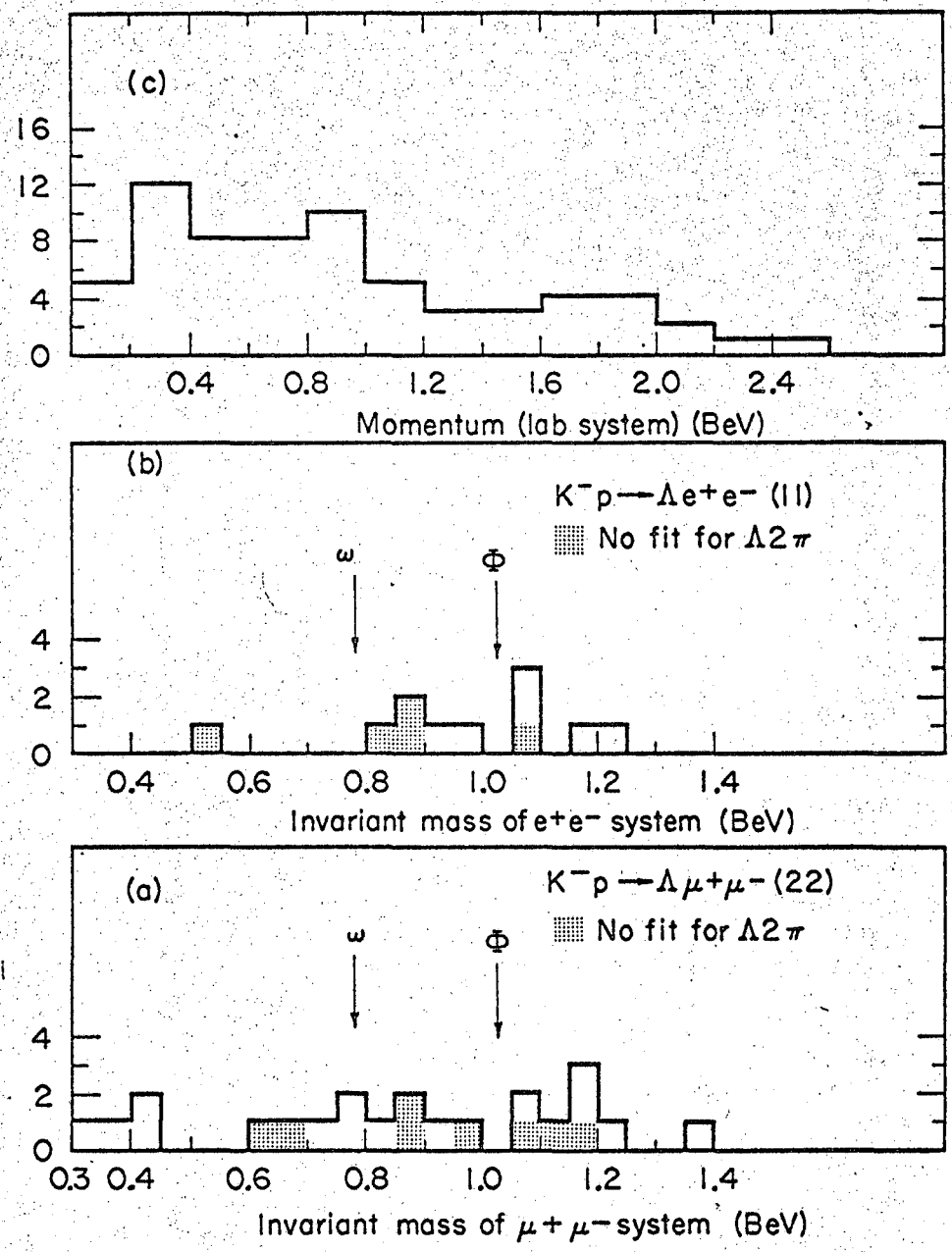

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Fig. 3(a), (b), and (c).