The 3.95-MeV state also seems to decay predominantly through the 1.95-MeV state and is isotropic within experimental error. The fact that no other strong $l=1$ states are observed in Ca^{41} makes the assignment of $1/2^-$ extremely likely.

This result, then, is contrary to what one might have expected naively on the basis of a mainly qualitative analogy with heavier nuclei. The source of the 2.47-MeV state remains somewhat of a mystery, since it is difficult to see how two $3/2^-$ states could occur at such a low excitation energy.[8] This state might be suspected of being the 3/2 state formed by an $f_{7/2}$ neutron coupled to the 2^+ excited state (at 3.90 MeV) of the Ca^{40} core. This possibility seems to be ruled out, however, by the fact that the ground-state transition from this state is very weak, less than 3% of the transition to the 1.95-MeV state. This $E2$ strength is not as strong as one might expect from a state whose parentage is in a 2^+ state. Alternatively, one might expect this to be a $p_{3/2}$ neutron coupled to the 0^+ first excited state of Ca^{40} at 3.35 MeV. The problem would then be to explain why such a state should occur at such a low excitation energy.

It is hoped that this additional information will encourage some theoretical calculations of the structure of these nuclei.

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THREE EXAMPLES OF THE $K^+ \to \pi^+ + \pi^- + e^+ + \nu$ DECAY MODE*

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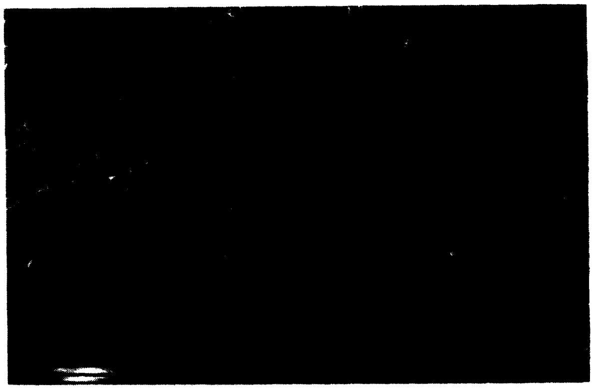
To study K^+ decay modes, we took 30 000 pictures of the CERN slow K^+ beam, stopping in the Ecole Polytechnique 80-cm liquid hydrogen bubble chamber. In the first scan we have found 3 decays consistent with scheme $K^+ \to \pi^+ + \pi^- + e^+ + \nu$. Another example of this decay mode in emulsion has already been reported.[1]

The characteristics of the three events are given in Table I and reproductions in Fig. 1.

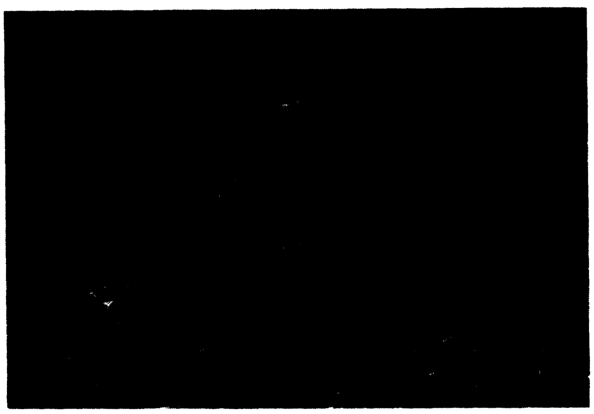
In the table, P is the momentum, θ and ϕ are the azimuthal and dip angle in the chamber system, and R is the visible track length. For dip-angle error, we give $\Delta\sin\phi$ which is more nearly linear in the larger Z measurement error than $\Delta\phi$.

Table I. Track parameters.

Event No.	Ident.	R (cm)	P (MeV/c)	$\Delta P/P$	θ	$\Delta\theta$	ϕ	$\Delta\sin\phi$
1	π^+	17.41	81	···	337.6	0.6	-28.4	0.019
	π^-	0.38	27	0.04	13.5	2.4	59.5	0.100
	e^+	25.70	68	0.04	265.5	0.0	3.5	0.011
2	π^+	13.80	92	0.09	190.8	0.6	44.5	0.0175
	π^-	15.18	78	···	342.8	0.6	48.9	0.0188
	e^+	10.16	88	0.07	312.0	0.6	-63.9	0.0096
3	π^+	7.85	112	0.06	196.4	0.6	-13.1	0.013
	π^-	3.8	72	0.10	5.5	0.9	6.3	0.029
	e^+	26.8	81	0.06	325.6	0.6	38.3	0.020



(a)



(b)

(c)

FIG. 1. Reproductions of the events with particle identities indicated. Parts (a), (b), and (c) show events Nos. 1, 2, and 3, respectively.

In event No. 1, the π^+ and π^- are easily identified because they stop in the chamber. The other track is certainly an electron because a π or μ of the same momentum would have stopped. Also the ionization remains minimum.

In event No. 2, the π^- stops in the chamber while the π^+ and e^+ are identified from momentum and ionization.

In event No. 3, the π^- scatters and then stops in the chamber, and the electron identity is certain from ionization and because a π of the same energy would have stopped.

For a kinematic study of the events, it is important to know the residual momentum of the K^+ at the decay. In event No. 1 the K^+ scatters elastically 1.3 cm before decaying. An analysis of this interaction yields an outgoing K^+ momentum equal within the errors to its visible range. In events Nos. 2 and 3, the K^+ track length is 14 cm and 20 cm, respectively, enough to measure quite precisely its curvature. The comparison of measured momentum with the momentum from range of half the track length yields a zero residual momentum with an upper limit of 85 MeV/c in both cases. We believe all these K^+ to have decayed at rest and present the kinematical results below based upon this justifiable assumption. In any case these events decay in such a way that residual K^+ momentum would only increase the momentum unbalance.

The missing energy and momentum are, respectively,

(122 ± 3) MeV and (119 ± 7) MeV/c (event No. 1),

(72 ± 8) MeV and (79 ± 11) MeV/c (event No. 2),

(77 ± 7) MeV and (72 ± 10) MeV/c (event No. 3).

A possible interpretation is a τ decay in which a π^+ decays immediately into $e^+ + \nu$. However, the invariant mass between the e^+ and the single neutrino needed to balance energy and momentum is (168 ± 3) MeV, (102 ± 10) MeV, and (93 ± 8) MeV for events Nos. 1, 2, and 3, respectively.

Event No. 2, the only in which the electron is identified only by ionization, is incompatible with the alternative hypothesis of radiative τ decay.

Discussion:—In the same scan in which these three events were found, we have seen 15 000 τ decays. It is very difficult to evaluate the detection efficiency for a K_{e4}^+. There is a strong background of decays with three visible tracks due to τ decays and K^+ decays with a Dalitz pair. To suspect a K_{e4}, we look for an evident lack of momentum balance or identification of all three tracks. Because of the considerable background of decays in flight, the momentum unbalance must not be forward. Often track identification requires a track length comparable to the chamber dimensions ($80 \times 30 \times 30$ cm^3). A systematic rescan is under way to improve the efficiency. We estimate the efficiency of the first scan to be about 10% judging from the fraction of τ's with two stopping pions and assuming for K_{e4} decay a reasonable ν spectrum.[2] Thus at present we estimate the ratio K_{e4}/τ to be ~10^{-3} from this experiment alone.

This result agrees with the emulsion result[1] and several theoretical estimates.[2,3]

The invariant mass of the two pions is 298 MeV, 303 MeV, and 332 MeV. It would be very interesting to know the distribution of this quantity.[3] However, it is difficult experimentally because the detection efficiency for decays at rest depends upon the neutrino energy which depends strongly upon the relative energy between the pions. This decay mode is compatible with the $\Delta Q = \Delta S$ rule. In the same scan we have not found any clear example of the decay $K^+ \rightarrow \pi^+ + \pi^+ + e^- + \bar{\nu}$ which violates the $\Delta Q = \Delta S$ rule.[4]

To establish the latter mode we must identify unambiguously all three tracks, while for the present example the π^- identity alone removes the chief background, τ' decay with Dalitz pair. This factor reduces our efficiency somewhat for the negative electron mode.

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ELECTRON-PROTON ELASTIC SCATTERING AT 1 AND 4 BeV†

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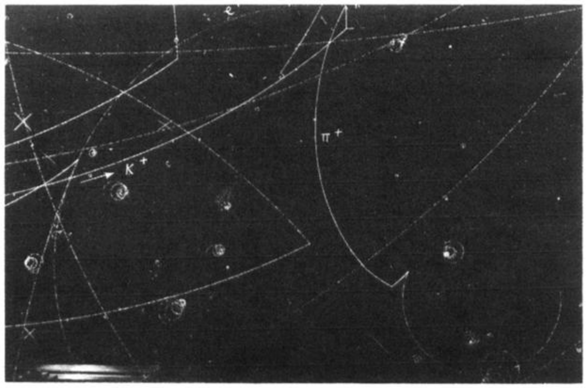
The elastic electron-proton scattering cross section has been measured at forward electron angles to detect possible deviations from the Rosenbluth formula. Data have been obtained at 4-BeV incident electron energy with $q^2 = 6$, 10, 14, and 18 F^{-2}, and at 1 BeV with $q^2 = 6$, 10, and 14 F^{-2}. The results are consistent with a photon Regge trajectory of zero slope. A core term is indicated in the values of the proton's charge form factor, G_{ep}, extracted from the 4-BeV data.

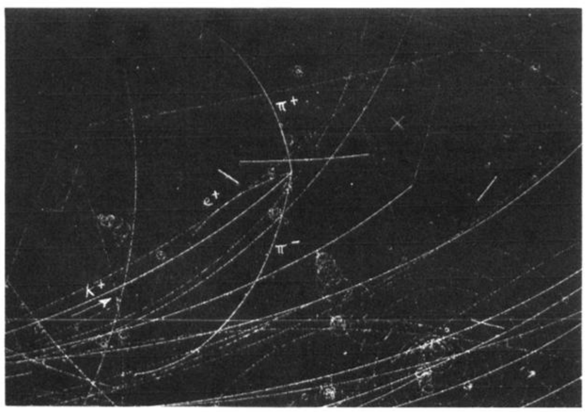
These measurements were undertaken using the apparatus shown in Fig. 1. The radio-frequency power was turned off and the internal beam of the Cambridge electron accelerator was allowed to spiral in to strike a CH_2 target of 0.009 radiation length thickness. Hydrogen counts were then obtained by a carbon subtraction procedure. The bremsstrahlung beam (typically 1.5×10^{10} equivalent quanta per second) was monitored by a thin, helium-filled ion chamber. To obtain absolute cross sections, the ion chamber was calibrated at reduced beam against a quantameter similar to that described by Wilson.[1] The recoil protons were momentum analyzed by a quadrupole magnet spectrometer 12 in. in diameter, employing scintillation counters C_1 and C_2 as detectors. The large dE/dX counter, C_3, was used to separate minimum ionizing particles from protons. The integral spectrum obtained with the 5% momentum bite used was 50% wider than the tails of the elastic peak in the worst case.

The raw hydrogen data were treated as outlined in Table I. The cross sections so obtained are listed in Table II. Only relative uncertainties are indicated. The estimated ±7% scale factor uncertainty is common to all measurements.

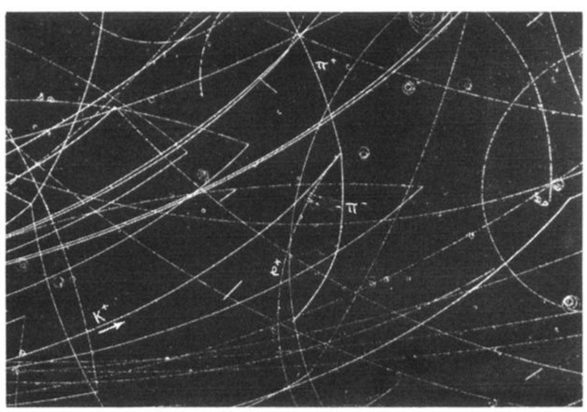
The data have been analyzed for possible Regge behavior. Following Blankenbecler, Cook, and Goldberger,[2] a factor Z^a, with $a = 2[\alpha(q^2) - 1]$, was assumed to multiply the Rosenbluth cross section. To test for a value of $\alpha(q^2)$ different



(a)



(b)



(c)

FIG. 1. Reproductions of the events with particle identities indicated. Parts (a), (b), and (c) show events Nos. 1, 2, and 3, respectively.