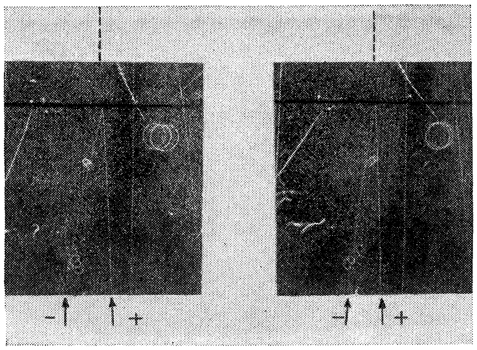

FIG. 2. Stereoscopic photograph of V^0 decay "B." Its apex is just below the horizontal bar across the picture, which is a sweeping field electrode suspended above the sensitive layer of the cloud chamber. The apex of the V^0 particle is vertically separated from the sweeping field electrode by about 5 cm in depth. The dashed line at the top of the picture points toward the part of the shield struck by the neutron beam. Information concerning the V^0 is given in Table I.

The details of the events are given in Table I. For both cases the given momenta and ionization densities show that the negative particles are light particles, most probably π-mesons.[1] The identification of the positive particles is not definite, although in both cases their ionization densities appear to be somewhat larger than minimum. If this were certain, these particles could be identified as protons, and V_1^0 particles ($V_1^0 \rightarrow p+\pi^-+Q_1$) would

TABLE I. Data on V^0 particles.

		Event A	Event B
Positive particle	Momentum, P_+	910 ± 230 Mev/c	1200 ± 180 Mev/c
	Estimated density of ionization	>1 (?), $<2\times$minimum	>1 (?), $<2\times$minimum
Negative particle	Momentum, P_-	72 ± 3 Mev/c	270 ± 30 Mev/c
	Estimated density of ionization	$3\times$minimum	$1\times$minimum
Angle between tracks		$61.5\pm1°$	$26\pm1°$
V^0 momentum, P_0		940 ± 240 Mev/c	1450 ± 210 Mev/c
Manchester parameter, $\alpha=(P_+^2-P_-^2)/P_0^2$		0.92	0.65
If V_1^0	Q value	39 ± 16 Mev	37 ± 8 Mev
	Lifetime (10^{-10} sec)	>8, <12	>5, <8
	Range for possible values of α	0.40 to 0.98	0.45 to 0.93
If V_2^0	Q value	236 ± 55 Mev	157 ± 30 Mev
	Lifetime (10^{-10} sec)	>3, <5	>2, <3
	Range for possible values of α	-0.90 to $+0.90$	-0.85 to $+0.85$

be involved. The Q values calculated for this assumption are given in Table I. They agree with the generally accepted $Q_1=35$ to 40 Mev. Assuming that these particles were produced in the lead or possibly in the steel wall of the chamber, lower and upper limits for their lifetimes are also given. These lifetimes are high compared to the lifetime of the V_1^0 of 3×10^{-10} sec given in the literature.[1] The parameter $\alpha=(P_+^2-P_-^2)/P_0^2$ may have any value between the limits given with equal probability. Both computed values for α fall within these ranges.

If one assumes that V_2^0 particles ($V_2^0\rightarrow\pi^++\pi^-+Q_2$) are involved, the calculated Q values are also consistent with the value of $Q_2=190$ Mev given in the literature.[1] The lifetimes are again higher than the mean lifetime of 10^{-10} sec for V_2^0. Here both of the computed values for α lie at the upper end of the possible ranges for α. This fact, the particularly good agreement of the calculated Q values with Q_1, and the apparently somewhat higher-than-minimum ionization density of the positive decay products, make it more probable that the observed particles are V_1^0 rather than V_2^0.

Assuming that the V^0 is produced in a collision of an incident neutron of maximum energy of 2.2 Bev with a nucleon in a nucleus, which may have itself an energy of 20 Mev, the maximum energy available in the center-of-mass system of the two nucleons is 1.11 Bev, which would be just sufficient to produce the total mass of a V_1^0. But then the kinetic energy of the V_1^0 in the laboratory system could be at most 400 Mev. The actual kinetic energies observed (assuming V_1^0) are 349 ± 140 and 714 ± 150 Mev for events A and B, respectively. The high kinetic energy observed for B, if not in error, rules out this possibility experimentally. Production of V_1^0 from pre-existing nucleons, singly or in pairs,[2] or of (V_1^0, V_2^0) pairs, would still be consistent with the present observations. The possibility of single V_1^0 production by 230-Mev π^- mesons has already been indicated by Schein.[3]

* Work performed under the auspices of the U. S. Atomic Energy Commission.

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K Mesons

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SIX K mesons[1] coming to rest in the emulsion have been observed in a series of 600 μ Ilford G5 plates exposed to the cosmic radiation at balloon altitude (140 cm^3 of emulsion$\times$hours of flight above 70 000 feet). Most of the plates were exposed under a copper absorber 3 cm thick. Among these K mesons, three are ejected from stars (see Fig. 1);[2] their ranges are sufficiently long (5000μ, 6000μ, and 9000μ) to allow accurate measurements of their masses. Two of the three remaining mesons are observed in favorable conditions to give some indication of the nature of the secondary particles.

(1) *Mass measurements of the K mesons emitted from stars.*—Scattering-range measurements have been carried out by several observers using different methods. One observer derives the scattering angle from measurements made with continously variable cell-lengths, as suggested by the Brussel group; while others employ the method indicated by the Bristol group.[3] All the measurements yield results in good agreement.

Ionization measurements have been made with a specially designed set-up to determine the opacity of the track by means of a photomultiplier associated to a microscope.[4,5] Appropriate corrections have been made to take into account the depth as well as the dip of the track. The results thus obtained are perfectly consistent, allowing good precision. This precision has been controlled by means of particles of known mass.

The measurements are listed in Table I. If we put together

TABLE I. Mass measurements for the three events.

	Star[a]	K meson[b] Length μ	Mass from scatt. range	Mass from ioniza. range	Secondary Length μ	Ionization[c]
K_{P_2}	$13+18p$	4950	850 ± 150	902 ± 80	155	0.85 ± 0.2
K_{P_3}	$9+2p$	6040	1065 ± 160	1015 ± 85	a few grains	
K_{P_4}	$6+1p$	9000	920 ± 130	910 ± 75	850	1.0 ± 0.1

a The notation $m+np$ is used to describe a star initiated by a singly charged primary: m indicates the number of heavy tracks (black and gray) and n that of minimum ionization.
b The masses are expressed in terms of electron rest-mass.
c The ionizations are relative to the plateau.

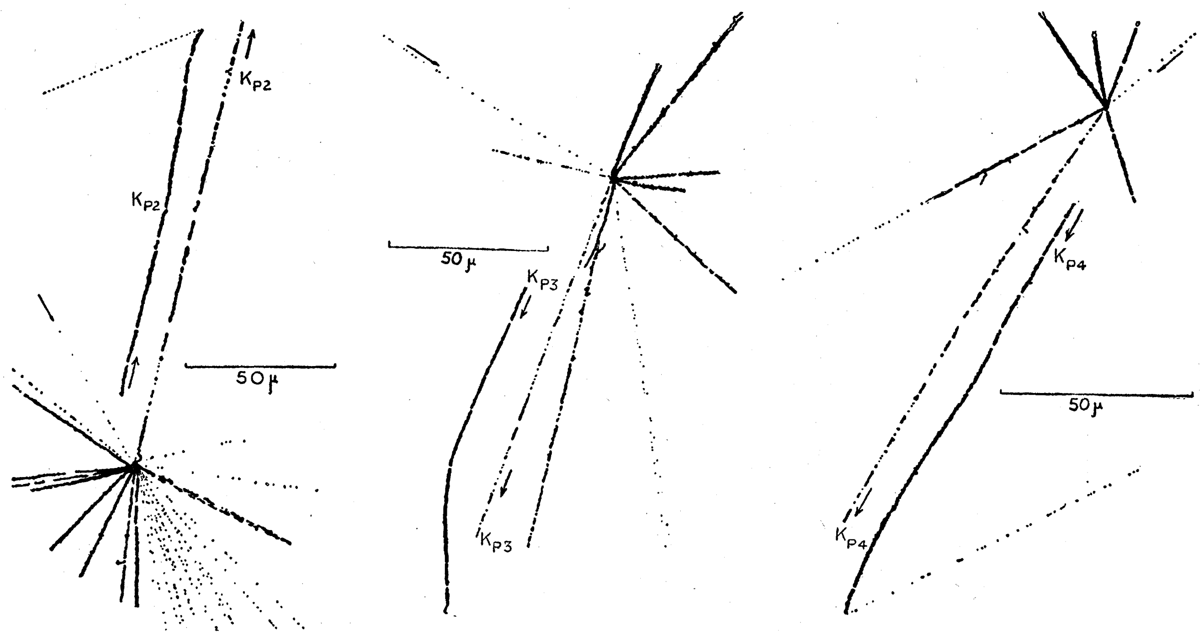

FIG. 1. Tracks of three K mesons emitted from stars. Since the K-meson tracks are very long, only the beginning and end are shown in each case.

the results of these six independent measurements of the mass of the K meson (three by scattering range, three by ionization range), we find

$$M_K = 940 \pm 40.$$

None of the mass measurements of K mesons made in other laboratories disagree with this value. The longest tracks, giving the best measurements, yield the following results:

$$\begin{array}{ll} K_{B2} & 1125\pm150(\ \ 5670\mu)^6 \\ K_{B12} & 870\pm100(13\,300\mu)^6 \\ K_{M2} & 1040\pm\ \ 90(\ \ 5260\mu)^7 \\ K_O & 950\pm\ \ 50(14\,000\mu)^8 \end{array}$$

We see that they are not significantly different from the value given above. Therefore, we will assume tentatively that all the K mesons hitherto observed in emulsions have the same mass, $M_K = 940 \pm 40$.

(2) *Indications on two secondary particles.*—Table II summarizes the measurements of secondary particles having sufficient lengths, observed in this laboratory.

(a) If we analyze the measurements concerning the secondary of K_{P1} using the calibration and method established by the Bristol group,[9] the results strongly suggest a μ-meson, rather than a π-meson.

(b) The mass of K_{P6} (1400μ long) is found to be 900±160. The measurement, though not very accurate, agrees with the adopted value, 940±40. Assuming this mass, if we take into account: (1)—the upper limit of the energy of the secondary particle for a given value of the mass of the K, and (2)—the results of the measurement of $p\beta c$ and ionization of the secondary,

TABLE II.

	Length	$p\beta c$ Mev	Grain-density[a]
K_{P1}	20 000μ	197 ±14	0.97 ±0.03
K_{P6}	3400μ	290 ±60	0.975 ±0.05

[a] Grain density is relative to that of the plateau.

we arrive at the conclusion that for the secondary particle, a μ-meson is more probable than a π-meson.

(3) *Discussion.*—We mentioned above that all the measurements on K mesons agree with a unique mass of 940±40. This suggests the possibility of trying also a unique scheme of decay. In this case the secondary particle would have to be a μ-meson, and the decay would involve three particles, since the Bristol group has observed with certainty two events in which secondary μ-mesons are emitted with low energies.

The main objection to this assumption is the observation by the Bristol group of three or four secondaries identified by scattering-ionization measurement, most probably, as π-mesons having the same energy.[6] We know also that among the heavy charged particles observed in cloud chambers (charged V's), there is one which emits a π-meson secondary[10] (identified by nuclear scattering).

It may be interesting to investigate whether there is another objection raised by the energy of the secondary: is it possible that K mesons of such a small mass could give rise to energetic secondaries as observed? Assuming the decay scheme $K \rightarrow \mu + 2$ neutral particles of zero mass, we deduce from the conservation laws the limit of the energy spectrum of μ-mesons:

$$p\beta c = 200 \text{ Mev} \quad \text{for} \quad M_K = \ \ 940,$$
$$p\beta c = 220 \text{ Mev} \quad \text{for} \quad M_K = 1000.$$

Actually several secondaries have been found with a $p\beta c$ of the order of 250 Mev, greater than these limit values. However, if we consider only the published cases of secondaries longer than 2000μ, we have

$$K_{B1} = p\beta c = 250 \pm 35 \text{ (length: } 2200\mu),^6$$
$$K_{P6} = p\beta c = 290 \pm 60 \text{ (length: } 3400\mu).$$

The lower limit of these measures lies not far from the grouping observed around $p\beta c = 185$ Mev (K_{P1}: 197±14 Mev, K_{B7}: 174 ±29 Mev, K_{B8}: 192±18, K_{B9}: 179±18). There is therefore no real disagreement between the most energetic secondaries observed and the limit of the spectrum calculated above.

If another decay scheme is adopted, $K \rightarrow \pi^0 + \mu + v$, the limit of the spectrum turns out to be

$$p\beta c = 180 \text{ Mev} \quad \text{for} \quad M_K = 940,$$
$$p\beta c = 200 \text{ Mev} \quad \text{for} \quad M_K = 1000.$$

Agreement with the experimental results is still possible, though somewhat more difficult.

Hence the main argument against the hypothesis of a unique K meson arises from the observations mentioned above of the Bristol group.

One may note that any decay scheme involving a neutral particle heavier than π^0, such as $V_2{}^0$, is excluded on account of the small value of the mass of the parent particle.

To sum up, the great majority of K particles observed until now in photographic emulsions can be interpreted as due to the decay of a particle of 940±40 electron masses into at least three particles, one of which is a μ; the upper limit of the energy spectrum of the μ is about $p\beta c = 200$ Mev; among the neutral products, at most one could be a π^0, and none could be heavier than a π^0. We suggest the name "kappa" (first introduced by O'Ceallaigh and the Bristol group[11]) to designate the parent particle.

1 The term K meson is used to designate any unstable particle of unit charge which has a mass lying between those of π-meson and proton and emits a charged secondary particle at the end of its range. K_B, K_M, K_O, K_P = observations from Bristol, Milano, Oslo, Paris.

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Energy Levels of C^{12} from the $Be^9(\alpha,n)C^{12}$ Reaction

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ENERGY levels of C^{12} have been studied by examining the gamma-radiation from the reaction $Be^9(\alpha,n)C^{12}$. The α-particles were emitted from a thin polonium source (strength 80 mC) deposited on a 1-cm square of thin platinum foil. The foil was placed adjacent to a 1-cm square of beryllium foil (33 mg/cm²) and the whole enclosed in an evacuated copper box with sides 1 mm thick. The gamma-radiation was analyzed with a pair spectrometer similar to that described by Johansson[1] and the spectrum displayed on a 25-channel kicksorter.

Apart from the well-known energy level of C^{12} at 4.43±0.05 Mev (the mean value of a number of observations)[2-6] with $J=2^+$, the existence of a level at 7.5 Mev is indicated by the neutron spectrum from this reaction,[7] and also by the discovery of pair emission [energy (7.0±0.6) Mev] from this reaction.[8] This evidence, together with the absence of gamma-radiation of 7.5 Mev from such an excited level to the ground state of C^{12} ($J=0$), suggested that its spin is also zero. It is to be expected that the de-excitation of this level could also take place by a gamma-cascade via the 4.43-Mev level, resulting in the emission of a gamma-ray of energy about 3 Mev. Previous measurements do not exclude the existence of such a line and place an upper limit of 30 percent on its intensity.[9] (All intensities refer to the 4.43-Mev line as 100 percent.)

We have detected gamma-radiation of energy 3.16±0.05 Mev and intensity ~3 percent in addition to the 4.43-Mev line (see Fig. 1). Together with the evidence obtained from internal pairs,[8] this suggests the existence in C^{12} of a level with energy 7.59±0.07 Mev rather than a level at 3.16 Mev. To show that this radiation was not due to secondary effects caused by neutrons from the reaction (i.e., interaction of the neutrons with the copper of the source box or with the sodium and iodine nuclei of the central crystal of the spectrometer) the following two tests were made. First a run was made with ½ cm of extra copper surrounding the source box. The intensity of the line was not enhanced, thus eliminating the first possibility. Again if the radiation is due to secondary effects in the central crystal, then

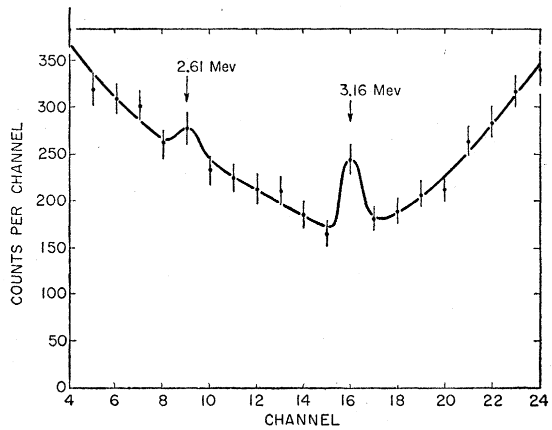

FIG. 1. 3.16-Mev line from $Be^9(\alpha,n)C^{12}$.

intensity (relative to the 4.43-Mev line) would vary as the linear dimensions of the crystal. Measurements made of the intensity with two crystals of different sizes (1 in. cube and 1.5 cm×1 cm ×1 cm) definitely exclude this possibility.

A very weak gamma-ray of energy 2.61±0.08 Mev and intensity ~1.5 percent was also detected but on repeating the copper test its intensity increased to ~7 percent. This line was therefore attributed to interaction of the neutrons with copper (probably inelastic scattering).

We have also examined the region in the neighborhood of 7.5 Mev but no evidence was found for radiation of this energy (upper limit of intensity 1 part in 2500). Previous measurements have placed an upper limit of 1 part in 500.[5]

We wish to thank Dr. W. B. Mims for his help and advice in constructing the spectrometer, Mr. D. Hicks for his help in the initial stages of this experiment, and Professor Lord Cherwell for extending to us the facilities of his laboratory.

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Proton-Proton Scattering at 32.0 Mev

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CALCULATIONS have been made[1] of the differential cross section for proton-proton scattering at 18.3 and 32 Mev. The pseudoscalar meson theory was analyzed and comparison was made with the 18.3-Mev data[2] and the 32-Mev data.[3-4]

The purpose of this letter is to point out that later data have been published[5] supplementing the earlier data.[3] These data are plotted in Fig. 1 transformed to 32.0 Mev assuming a $1/E$ de-