ARMENTEROS-No, I doubt it. It is true that the events missing have in general angles greater than about 70°, but this should not affect their detection. Firstly, the proton - being emitted forward in the C.M. -would follow fairly closely the direction of the shower and thus, on the average, a good track length would be available for its identification. Secondly, over a wide band of the region in which events are missing the meson would, like the proton, be heavily ionizing and this should help in the detection of these V -tracks.

THOMPSON -Our most probable Q-value is 37 Mev. Is your value a weighted mean ?

ARMENTEROS-In plotting the Q-value distribution we have taken account of the errors in the individual Q-values by considering them to be distributed with equal probability between a lower limit obtained by decreasing the central value by one standard error and an upper limit obtained by increasing the central value by one standard error.

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9 - OBSERVATIONS ON THE NEW UNSTABLE PARTICLES WITH A MULTIPLATE CLOUD CHAMBER. EXPERIMENTAL METHOD. RESULTS CONCERNING NEUTRAL PARTICLES.

H. Bridge, B. Rossi -(Cambridge - Mass.)

INTRODUCTION - For the past few years the MIT group has been operating a multiplate cloud chamber at an elevation of 3250 meters. I would like to discuss some of the general results of this work and discribe some of the methods used for analysis. I also wish to recall briefly the results for the V1-particle. While these results are not new, they have provided important evidence concerning the uniqueness of the Q-value and the coplanarity of the V_1^0-event. For completeness I will summarize again our conclusions concerning these questions and the life-time.

A fairly large number of people have contributed to these results and to the results on the S-particles which will be discussed later in the program by Prof. Rossi. Those most directly concerned have been : Annis, Bridge, Courant, Dayton, De Staebler, Olbert, Peyrou, Rossi, Safford, and Willard.

Experimental Arrangement - Practically all of our result have been **obtained by triggering the chamber** expansion with a detector of high **energy nuclear interactions placed** just above the chamber. During the **past two years, two different arrangements** have been used and a total **of about 60.000 pictures have been taken.**

The general features of the experimental arrangement are as follows:

The cloud chamber itself is rectangular, approximately 50 cm square, and the illuminated region is 18 cm deep. For most of the recent work the chamber contained 11 lead plates 7.1 g cm^{-2} thick (0.64 cm) faced with thin glass mirrors to improve the illumination. Two photographs are taken at 5° to the chamber axis and two more at 30° to the axis. (The mean magnification is about 1/15 and the photographs are taken at f. 16.).

With this arrangement we have observed the decay of several unstable heavy particles and we have classified these decays as neutral V-events, charged V-events and S-events.

A. V°-events - The neutral V-events are divided into 3 groups. Those which can be identified as belonging to the decay scheme $P+\pi+Q$ are classified as V_1°. Those which cannot fit this decay scheme are called V_2° and all unidentified cases are included in a third group.

B. $V^{\pm}$ events - Any charged particle which appears to decay in flight and which cannot be a pi- or a mu- or a tau-meson is called a charged V. Obviously charged V-particles cannot always be distinguished with certainty from neutral V-particles.

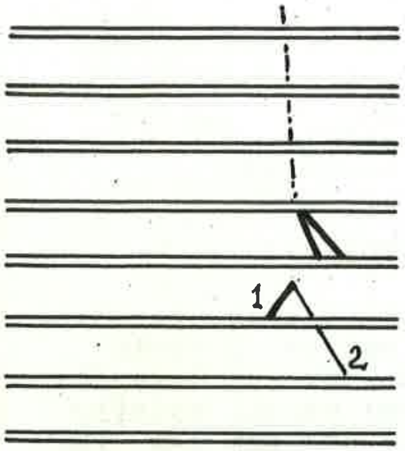

Figure 1.

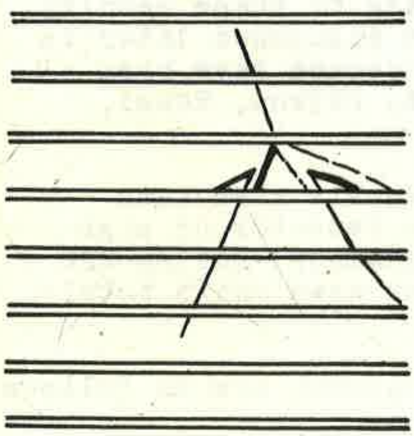

Figure 2.

C. S-particles - Any charged particles which stops in the chamber and emits a lightly ionizing particle from the point of stopping is carefully examined to see whether the behaviour of the primary and secondary particles is consistent with that expected for a $\pi \rightarrow \mu \rightarrow e$ or a $\mu \rightarrow e$-decay or a tau-meson. If it is not, the particle is called an S-particle. The following figures show some examples of the events observed. Figure 1 shows a typical identified V_1°-decay. The V is coplanar with the origin to 1°. Particle # 2 stops in the well illuminated region of the cloud chamber and cannot be a proton because it ionizes too little for its range. Assuming that it is a pi-meson and that the heavily ionizing particle #1 is a proton, the momenta of the proton and meson can be computed from the transverse momentum balance. The Q-value for this case is 31-43 Mev. The uncertainty is due to the uncertainty in the range of the meson. Figure 2 shows an event in which a pair of V°-particles are produced. The V° on the right appears to be a V_1°, that on the left cannot be a V_1° and is therefore, classified as V_2°. Figure 3 shows a case in which the S-particle originated in a nuclear interaction inside the cloud chamber.

For part of the data we have made a rather complete statistical analysis. From this we conclude that in the range interval considered in this experiment there are between 30 and 100 stopped pi-mesons per S-particle. One also conclude that most V_1°-particles are produced by pi-mesons.

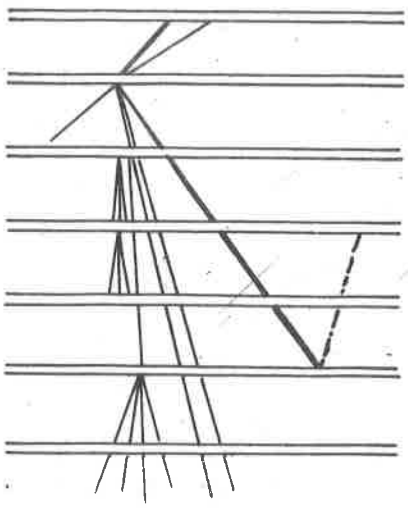

Figure 3.

MEASUREMENTS - The most significant measurements which can be made in the multiplate chamber are those on particles which stop inside the chamber. In this case the range, R, of the particle can be determined precisely and in addition the scattering and specific ionization can be measured as a function of the residual range of the particle. Since R/M is a function of the relative specific ionization, a measurement of the ionization vs. range determines the mass. However, we feel that our ionization measurements are only reliable to within a factor of two and hence this method is not very useful.

A more applicable method is based on the theory of multiple coulomb scattering and is similar to methods used by those working with photographic emulsions. To make use of the scattering in this way, one uses an approximate functional relation between $p\beta$ and R :

$$\frac{R}{Mc^2} = C_z \left(p\beta c / Mc^2 \right)^{1/\alpha} \quad ; \quad 0.05 < \frac{p\beta}{Mc} < 3 \quad ; \alpha = 0.55$$

Here, α is a constant and R is the residual range of the particle at the midpoint of a plate where the projected angle of scattering is φ. One can then define a variable S_2 which is independant of range and is a function only of the scattering material and the mass of the scattered particle. S_2 is defined as the r.m.s. value of $\varphi R^{\alpha} \sqrt{\cos\theta}$ where R and α have the meaning just given and θ is the angle the track makes with the perpendicular to the plate surface. The expected value of S_2 for 7.3 g cm^{-2} lead plates is given by :

$$\langle S_2 \rangle_{Av} = 657/(M/m_e)^{1-\alpha} .$$

Expected values of S_2 for several masses and for 7.3 g cm^{-2} thick lead plates are given in Table I.

Table I

	2300 me	1000 me	π-meson
$\langle S_2 \rangle_{Av}$	20.3	29.6	52.8

Since the cloud chamber contains only 11 plates the statistical accuracy in determining S_2 is poor for the case of a single stopped particle and mass determinations are correspondingly of limited accuracy. However, if some other method can be used to group particles of the same kind, the experimental value of S_2 obtained from the entire data can be used to compute the mass with moderate accuracy; a check on the correctness of this grouping can be obtained by plotting the distribution of the values of S_2 for each particle used and comparing this with the theoretical distribution. This method has been used extensively in our analysis of the results on S-particles.

NEUTRAL V-PARTICLES - The most important results for the V_1^o are based on 22 events in which the origin of the V° was a nuclear interaction visible inside the cloud chamber. When these events are analysed under the assumption that the only decay products are a proton and a pi-meson, one obtains Q-values which are not characterized by the usual statistical errors inherent in momentum measurements derived from a curvature in a magnetic field. Instead, one obtains the Q-values by using the range of one of the decay products and since in general the range must lie within well defined limits, the limits in Q must be correspondingly well defined. In 13 cases Q is determined to 15 Mev or better.

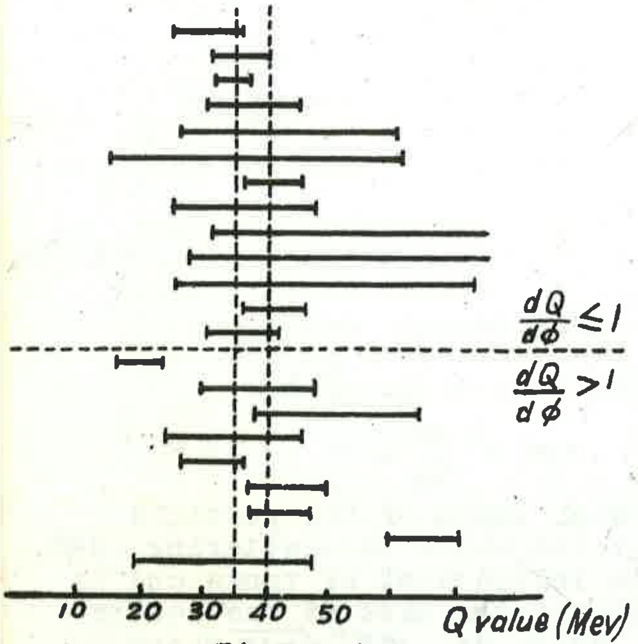

Figure 4.

If there is a unique Q-value and if the limits in range represented the only uncertainty in the measurements, all the measurements should overlap and therefore, all horizontal lines in the figure 4 should be cut by a single vertical line. As one can see from the figure, this condition is very nearly fulfilled at a Q = 37 Mev. One case gives a Q-value which seems (3872) (60-71) too high, and one case (43430) (17-24) seems definitely low. An occasional low value for the Q must be expected because a nuclear interaction can cause the range of the particle to be smaller than its true value; hence the Q-value will also be too low. We believe that the slight spread in the data results from random errors in angular measurements of the order of 1 to 2 degrees. A two degree error in 3872 would explain the high Q-value. We consider that the evidence for a unique Q-value at about 37 Mev is very strong, but that our results do not rule out the possibility that a small fraction of the V_1^o-events decay with a higher Q-value.

DISCUSSION. It may be well to recall the evidence that these events do not represent V°-decays into a heavy and light meson. This is mainly that no decay-product has been seen at the end of the track of the heavier particle, as would certainly be expected if one of the products were a K-particle or an S-particle. (5-6 cases)

COPLANARITY - For all the 22 events mentioned above, we measured the angle of uncoplanarity, δ , between the plane of the V and the assumed origin. 16 were 2° or less and 6 were 5° or less. It is, of course, possible that some of the identifications of origins are erroneous and if this were the case, the average value of δ might be increased considerably. To eliminate any bias of this sort, 16 events were selected in which there was a nuclear interaction in the plate just above, or just below the apex of the V. This interaction was assumed to be the origin of the V-particle. For one event selected in this manner, δ was $\sim$120 degrees. Obviously, this was not the origin of the V-particle. For the remaining 15 events the r.m.s.-value of δ was 2.5°.

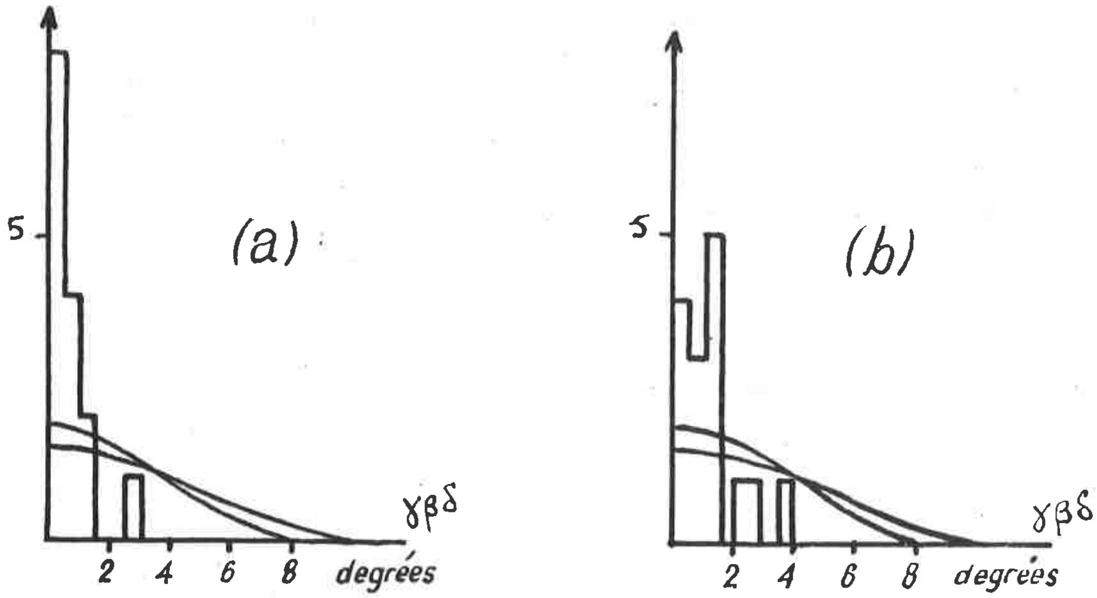

Figure 5.

For these 15 events the distribution of $\gamma\beta\delta$ was compared with that predicted by Brueckner and Thompson, who give the expected distribution in the case of a three-body-decay into a proton and charged meson with either a pi°-meson or neutrino as the neutral product. The results are shown in Figure 5. The histograms represent the experimental data and the solid curves are those of Brueckner and Thompson normalized to the same area. One difficulty in the comparison is in the computation of the velocity of the neutral V-particle, . In curve (a) β was computed, assuming a two-body-decay and in curve (b) it was computed from the maximum momentum of the proton compatible with the experimental evidence. It can be shown that this is an upper limit for the three-body-decay, considered by Brueckner and Thompson.

We conclude that the true width of the distribution of $\gamma\beta\delta$ is intermediate between (a) and (b), and that it is not compatible with the three-body-decay considered by Brueckner and Thompson. The observed width is what we would expect from the expected errors in angular measurement.

LIFE-TIME - For each of the 22 events mentioned above, we assumed that the decay was a two-body-process with a Q of 40 Mev, and we calculated the time the particle lived in its rest system. Since the path-length of the V°-particle in the observation region is finite, the mean life calculated from this data must be corrected for the corresponding finite time of observation. In addition, the observation time is divided into available and unavailable regions by the plates of the chamber. Taking this into account, the mean-life is found to be :

$$\left(3.5\left\{{}^{+2.1}_{-1.0}\right.\right) \times 10^{-10} \text{ sec.}$$

The errors in this result have been revised from those originally quoted and are calculated according to the method suggested by the Manchester group. Essentially this assumes that the distribution in $1/\tau$ rather than the distribution in τ is normal. Since the question of the life-time is to be discussed this afternoon, I will omit any further details.

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We should like to and a strong word of caution about the interpretation of this result. V_2^o-events can be mistaken for charged V-particles, particularly in our experiment. We have recently found several cases where the interpretation is uncertain. If these cases were included in the data the life-time would be significantly longer. Another way to state the problem is to say that in our case, the identification of the event as a V_2^o- depends on finding an origin close by. If this is the case, the life-time may be grossly in error.

DISCUSSION

BLACKETT - Your life-time refers to only identified V_1^o ? Have you any information on V_2^o -lifetimes ?

BRIDGE - We have 7 cases, giving : $\tau = (0,9^{+1,0}_{-0,3}) \times 10^{-10}$ sec.

This could be misleading, since in order to have its life-time measured the V_2^o must be near its origin, thus biasing towards low times. If it is far away, one isn't certain of its origin or line of flight.

? - What on the relative numbers of V_1^o and V_2^o ?

BRIDGE - Half the cases are not identified: 27 V_1, 6 or 7 V_2^o.

POWELL - Can you say anything about the spectrum of V_1^o ? Are the corrections very big for the slow ones ?

REYNOLDS - I will mention this point this afternoon.

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10 - PRODUCTION OF V_1^o BY A ONE BEV NEGATIVE PRIMARY

W.B.Fretter, B.P.Gregory, R.Johnston, A.Lagarrigue, H.Meyer, F.Muller, C.Peyrou -(Ecole Polytechnique)

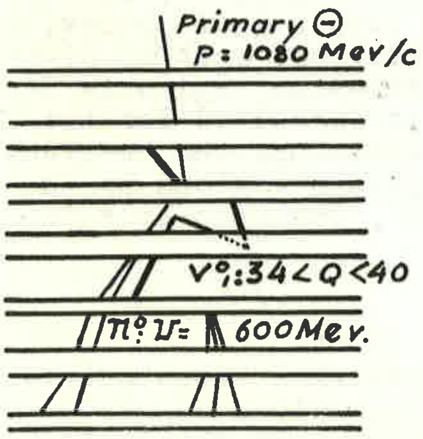

Figure 1.

The Pic-du-Midi installation of the Ecole Polytechnique consists of two chambers one above the other. The upper one is in a magnetic field, the lower one contains alternate carbon and lead plates. It will be described later.

Figure 1 shows in diagram form the event which I wish to describe.

A negative particle of momentum 1080 Mev/c is seen to enter the lower chamber having traversed the upper. It interacts in the second lead plate giving,