MARDI APRES - MIDI

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D-1 CHARGED V-PARTICLES

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1.-Introduction - Remarkably little progress has been made in the elucidation of the properties of charged V-particles since their discovery in 1947. This is probably due to two difficulties -

(i) Only about 15 % of the decays of all V-particles are due to charged V-particles.

(ii) Up to the present, very few cases with accurately measured primary and secondary momenta have been obtained. (This difficulty is particularly true in the experiments of the Manchester group on the Pic-du-Midi using a chamber only 28 cm. in diameter).

I propose now to describe the main features of the work on charged V-particles by the Manchester groups working at the Pic-du-Midi and at the Jungfrau/Joch. The latter group directed by M. J.A. Newth. Both groups are indebted to Professor Blackett for his general direction and advice. Whenever possible, details of other published work is included.

2.-The masses of the primary particles.- Mass values for seven charged V-particles are given in Table I.

TABLE I THE MASSES OF SEVEN CHARGED V-PARTICLES

No.	Sign	Angle of decay (deg)	Primary Momentum (MeV/c)	Estimated Ionization	Estimated Primary Mass		
					Lower Limit	Mean (m_e)	Upper Limit
J2	-	95	230±50	2.5 - 5	600	1000	1500
J6	-	55	350±50	2 - 4	800	1300	1800
P38	+	145	130±24	5 -15	550	950	1500
P33	+	70	368±52	2 - 3	800	1100	1500
P11	+	20	590±74	< 2	-	-	1600
P22	+	63	420±42	< 2	-	-	1200
L1	-	100	185±20	6 -10	900	1200	1500

J: Jungfraujoch Group - P: Pic-du-Midi Group - L:Leighton et al. 1952

A single mass measurement has a very limited significance but we may conclude from all the data that :

(i) The average mass is about 1100 m_e, i.e. close to the average value for K-particles;

(ii) There is no evidence for particles heavier than the proton.

(iii) There is no evidence for particles with masses $>$1500 m_e.

3.- The charged secondary particles - Measurements on two slow secondary particles are consistent with their being either pi- or mu-mesons. Recently the Pic-du-Midi group obtained the event shown in Figure D-1, 1.

A slow charged V-particle, having a mass within the range (500 - 1500) m_e is emitted upwards; it decays close to the front edge of the illuminated region. The charged secondary product travels back accross the chamber and enters the piston. Close to the point of entry into the piston a slow meson enters the chamber with a momentum of 35 Mev/c. The most probable explanation is that the V-secondary is a pi-meson which suffers nuclear scattering in the piston with considerable loss of energy - very similar to the Bridge and Annis case but in ours we are sure that the primary is not a superproton.

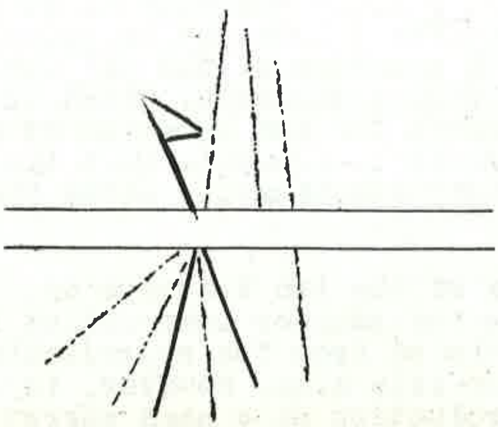

Figure D-1, 1

4.-The neutral secondary particles. The Pic-du-Midi and Jungfraujoch groups have not obtained any significant information bearing on the existence of pi°-particles; gamma-rays or neutrons among the neutral secondaries. Sometime ago, the Pic-du-Midi group obtained a remarkable photograph of a double decay phenomena which indicates that V°-particles may be produced by $V^{\pm}$ -particles. No doubt, most people have seen this picture, but, although it is still the only published example, its interpretation is very important.

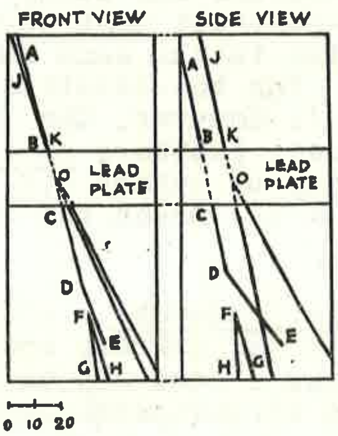

Figure D-1, 2

The negative primary has a momentum greater than 1 Bev/c. The momentum of the secondary is (178 $\pm$ 70) Mev/c. At a point 1.25 cm. from the decay there is a V°-track. The plane of the V°-track contains the point of the charged decay. These observations can be explained by the following scheme :

$$V^- \rightarrow V^\circ + \begin{pmatrix} \pi \\ \mu \\ e \end{pmatrix}^- \qquad 4.1$$

Most of the primary momentum is given to the V°-particle. Unfortunately, the type of V°-particle cannot be determined from the very inaccurate measurements on the secondary particles.

We have not found any evidence for V^--particles with masses above 1500 me. If we regard this mass as an upper limit for the mass of the V^--particle then the V° is unlikely to be heavier than about 1000 m_e. It might be a V_2° -meson (mass 964 ± 40) m_e. i.e. the following scheme is possible :

$$V^- \rightarrow \pi^- + V_2^\circ$$
$$V_2^\circ \rightarrow \pi^+ + \pi^- \qquad 4.2$$

The momentum of the V_2° can be accurately calculated knowing only the angle (c;f. Butler 1952). The angle of (15 ± 1.5)° corresponds to a momentum of (3.2 ± 0.5) Bev/c. The mass of the V^- can now be calculated and is found to be (1600 ± 90) m_e. The momentum of the pi^- -particle and V_2° in the rest system is found to be (250 ± 30)Mev/c, which is consistent with the value of (216 ± 10) Mev/c for the momentum of the decay products of the chi-meson. Therefore it is possible that the V^- is a chi-meson but the mass is definitely considerably above the mean value for the K-mesons (1100 m_e).

It is possible that the associations of the two V-decays is fortuitous. The V° may have originated in the nuclear interaction in the plate. This possibility cannot be excluded from the reprojection measurements. An accidental association of this kind, however, is very remarkable, since it requires the production of a high energy V°-particle in such a position as to satisfy the geometrical requirements of two successive two-body decays. In addition, the momentum of the V-particle has to be well defined to satisfy the assumption that the V^- is a chi-meson (e.g. if the V° had a momentum of 1 Bev/c $p^+ \sim 120$ Mev/c and 1 Bev/c is about the average momentum of the V°-particles produced in the plate).

If all the charged V-particles are chi-mesons and decay according to scheme 4.2, then the lifetime of the V_2° -particle must be very long, probably about 5 x 10^{-9} sec. (This value is the same as the lower limit obtained by Bridge et al. (1953) for the lifetime of the neutral secondary produced by the S-particle). However, the mean lifetime of V_2° -particles is about 1.6 x 10^{-10} sec. (Astbury et al. 1952). Thus the fraction of $V^\pm$ -particles which decay by scheme 4.2 is very small. Alternatively the V°-particle is not a V_2° -meson but a longer lived particle.

5.-Examples with measured primary and secondary momenta - A few decays have reasonably accurate measurements on both the primary and secondary particles. Using the momenta measurements a test may be made to see if these decays could have been produced by chi-particles. By performing a Lorentz transformation, the longitudinal momentum component of each secondary particle is found in the rest system of the unstable particle. The velocity of the primary particle is determined from its ionization. Alternatively, it is possible to assume a mass for the chi-meson and to calculate the velocity from the momentum. The value of p^*, the momentum of the secondary in the rest system, is then obtained by combining the longitudinal component with the value of p_T. The final values of p^+ are shown in Table II (next page) for four Manchester examples, one by Leighton et al (1952) and two selected examples of Bridge et al. (1953). Five of the seven values of p^* are consistent with the value for the chi-meson. P33 is an exceptional case and cannot have been produced by a chi-meson. The secondary momentum of (107 ± 25) Mev/c would have to be increased by 90% in order to increase the p^* to the value of 216 Mev/c for the chi-meson. The increased momentum would be inconsistent with the ionization if the particle is a pi-meson. The example B2 is probably similar, since the upper limit of the pi-meson momentum in the centre of mass system is 187 Mev/c; this is probably significantly smaller than 215 Mev/c. We conclude, therefore, that some of the charged V and S-particles differ from the chi-meson; these examples may well be kappa-mesons.

6.- The transverse momentum distribution.- The main conclusion from the measurements described already is that the majority of the $V^{\pm}$-particles consist of a mixture of chi- and kappa-mesons. It is interesting to enquire if any information on the relative frequencies of the two types can be obtained from the distribution of the transverse momentum components. The experimental distribution for 25 cases is shown in figure D-1, 3; it is probably free from bias except for the region below 50 Mev/c.

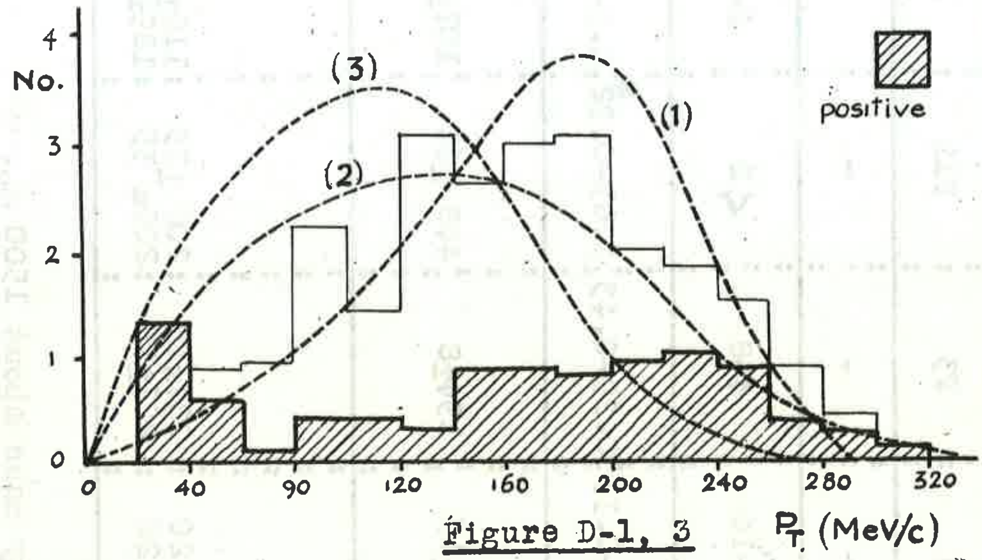

Figure D-1, 3

Curve (1) is the theoretical distribution for a 2-body decay with $p^* = 216$ Mev/c i.e. for the chi-meson. The theoretical distribution is modified by an average experimental error of 15 %. This curve does not fit the data very well but a statistical chi^2-test shows that we cannot regard the deviation of the experimental histogram as established statistically.

Curve (2) is a theoretical distribution for kappa-mesons calculated from a formula given by York (1952). The decay scheme assumed is :

$$\kappa^{\pm} \rightarrow \mu^{\pm} + \nu + \nu \qquad 5.1$$

and the mass of the κ is taken to be 1150 m_e. Again a chi^2-test shows that this curve is compatible with the experimental histogram so that

TABLE II. - PRIMARY AND SECONDARY MEASUREMENTS ON SEVEN CHARGED V-PARTICLES

No.	L1	P3	P12	P33	J6	B1	B 6
Sign	-	-	-	+	-	?	?
Ionization of Primary(I_{min})	6-10	4-8	< 2	2-3	2-4		
Primary Velocity	0.26-0.33	0.29-0.43	0.83-0.92*	0.5-0.62	0.43-0.62	0.37-0.62	0.4-0.6
Secondary Momentum in lab. system (Mev/c)	150 ±15	194±8	448 ±61	107±25	280±60	142-145	138-150 (π) 116-127 (μ)
Secondary momentum in C-system (Mev/c) (i) π-meson (ii) μ-meson	 175± 20 170± 20	 227±15 227±15	 208 ±35 206± 35	 118±30 129±35	 221±40 221±40	 172-225 -	 146-187 122-153

* Calculated primary mass about 1500 m_e.

a large fraction of the $V^{\pm}$ -particle could be kappa-mesons.

Curve 3 is similar to curve 2 but calculated from a mass of 1000 m_e. In this case the fit is not so good and all the $V^{\pm}$ -particles cannot be kappa-particles with this mass.

We conclude that owing to the overlap between the p_T distribution for the chi-meson and the distribution calculated by York for the kappa-meson we cannot hope to make a statistical separation between the two types, using a meagre amount of data.

7.- The charge symetry of charged V-particles. Leighton et al. (1953) have drawn attention to charge assymetries in their data on charged V-particles. These results are compared with those of the Pic-du-Midi and Jungfraujoch groups in Table III.

TABLE III. - THE CHARGE DISTRIBUTION OF CHARGED V-PARTICLES

Origin	Charge Positive N^+	Charge Negative N^-	$\frac{N^+}{N^-}$	10% fiducial limits
1. Above Chamber				
Cal. Tech.	8	18	0.45	0.23 - 0.83
Pic-du-Midi	9	17	0.53	0.28 - 0.96
Jungfraujoch	11	5	2.2	0.98 - 5.25
TOTAL	28	40	0.7	0.49 - 0.98
2. Inside Chamber				
Cal. Tech.	18	9	2.0	1.1 -- 3.7
Pic-du-Midi	1	3		
Jungfraujoch	1	1		
TOTAL	20	13	1.5	0.96 - 2.6
OVERALL TOTAL	48	53	0.9	0.65 - 1.25

The Cal. Tech. and Pic-du-Midi groups find a negative excess among the charged V-particles produced above their chambers. The 10 % fiducial limits, calculated using the tables of Fisher and Yates, are given in the last column of the table. In contrast, the Jungfraujoch group found an excess of positive particles. The overall value of N^+/N^- is 0.7 and there is a 10% probability that it is as high as 0.98. Thus there is no definite evidence that the negative particles predominate.

Similarly there is a tendency for the charged V-particles produced inside the chamber to be predominantly positively charged but again the result is not really significant.

I would like to comment briefly on the interesting discovery of a positively charged V-particle with a secondary heavier than the pi-meson(York et al. (1953)). We have made accurate measurements on 25 $V^{\pm}$ -particles and have not found a similar example . The measurements on the primary particles are very incomplete, but there are five cases which could be heavier than the proton(i.e. have secondaries of protonic mass). Now York et al have suggested that their event may be an example of the decay of a V_1^+ -particle according to the scheme:

$$V^+ \rightarrow p^+ + \pi^o + Q \qquad 7.1$$

If the V_1^+ is the charged counterpart of the V_1^o -particle and if it has the same mass, then Q = 40 Mev and the maximum possible value of p_T = 110 Mev/c. However, all of the five positively charged V-particles which might be more massive than the proton have values of p_T greater than 110 Mev/c. Thus we consider that only a very small fraction of our events could be V_1^+ -particles (with Q = 40 Mev).

DISCUSSION

Peters - Apart from mass values only one event might distinguish a K and a chi - the one where the secondary suffers a large angle scatter in the piston - could this be coulomb scatter of a μ?

Butler - After scatter the meson has a momentum of 35 Mev/c, before scatter the momentum can't be measured but is probably ~150 Mev - at such a value coulomb scatter of the μ is unlikely.

Sard - Until the K decay spectrum is known the μ-e curve might be used to find the p_T distribution.

Butler - This is what York has done.

Michel - The theoretical spectrum is not unambiguous, there are other possible curves. In the case of 2 zero mass neutral particles the shape could be very different.

Newth - Event P33 (see figure) differs in its dynamics from the others - in view of the results of the Cal. Tech. who find 2 life times, could you say how long this V lived in the chamber ?

Butler - ~ 5×10^{-10}. It is of positive charge.

Peyrou - In a determination of the momentum in the rest mass system does the biggest error come from the ionization estimate on the secondary momentum?

Butler - Secondary momentum.

? - Can you say anything of the energy of the particles that creates the V ?

Butler - Few of our V^{+}_{-}'s come from the plate; of those that do, some are created by high energy particles, some by more moderate energied particles (few Bev.)

D - 2. RECENT MEASUREMENTS ON CHARGED V-PARTICLES AND HEAVY MESONS IN PASADENA

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Most of the observations have been made in 2 chambers separated by a Pb plate and surmounted by a Pb production layer.

Relative frequency of V^+ and V^- - It has been already reported (Phys. Rev.) that for charged V's produced in the production layer there is an excess of negative particles whilst the reverse is true for V's formed in the plate. The latest figures still indicate this. Below the total results to date are given, the brachetted figures being those already published :

	No of V^+	No of V^-
From production layer	14 (8)	25 (18)
From plate	22 (18)	12 (9)
Total	36 (26)	37 (27)

If all charged V-particles are the same, the probability of an asymmetry as great as the above is about 10^{-2}.

Life-Time - The possibility of there being 2 V-types with different positive to negative ratios is supported by the measured life times.

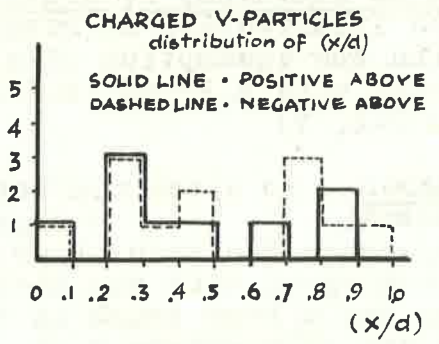

Figure D-2, 1

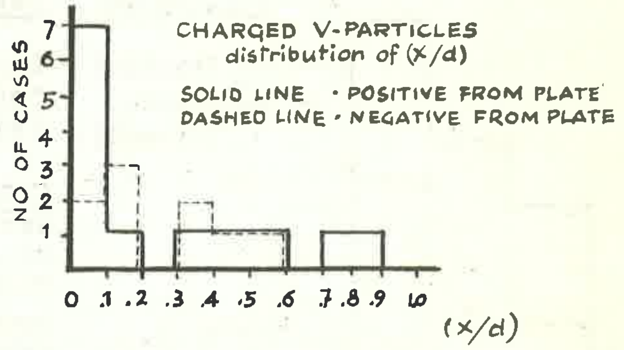

Figure D-2, 2

In the upper chamber the decay of both positive and negative particles is distributed uniformly. In the lower chamber, there is a high proportion of V^+'s decaying near the plate.(Figure D-2, 1 and 2).