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SEANCE DU VENDREDI APRES - MIDI.

President de séance : C.F. Powell.

RECAPITULATION ET DISCUSSION SUR LES MESONS LOURDS CHARGES.

Professor Powell opened the session by saying that the Congress had enabled workers from many laboratories all over the world to meet together and organise their work. He quoted the Clark Maxwell's comment on the world magnetic survey that "the scattered forces of science are converted into a regular army" and said that it applied equally well to the work of the Congress. In particular, he emphasied the value to be gained from discussiong together the results of experiments made with Wilson chambers and with the photographic emulsion.

He stated that the session would consider the following five topics :

1) Direct mass measurements of heavy charged mesons.
2) Evidence for the nature of the secondary decay products
3) The energy spectrum of the secondary particles from the decay of charged V-particles, S-particles and kappa-particles.
4) The nuclear capture of negative kappa-particles.
5) Tau-mesons.

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## I - DIRECT MASS MEASUREMENTS OF HEAVY CHARGED MESONS.

Powell introduced the subject by summarising the knowledge of the tau-and kappa-mesons. He considered that the experiments of Peters with stripped emulsions coupled with the analysis of events made in Rome by Amaldi made it certain that the mass of the tau-meson would soon be known to within ± I me apart from the uncertainty in the $\pi$-meson mass. He then summarised briefly the evidence that had been presented for the decay schemes of kappa and chi-mesons giving rise respectively to mu- and pi-meson secondaries.

Powell then stated that a central problem in the study of these mesons was the question whether or not the three decay schemes :

$$\tau^{\pm} \rightarrow \pi^{\pm} + \pi^{+} + \pi^{-}$$
$$\kappa^{\pm} \rightarrow \mu^{\pm} + \nu + \gamma$$
$$\chi^{\pm} \rightarrow \pi^{\pm} + ?$$

could be regarded as different modes of decay of a single particle. If this were so, the best value for the mass would be that obtained form the decay of tau-mesons, i.e. 970 me. If this hypothesis were correct the decays of kappa and chi- mesons would be limited by the conservation laws in the following way.

**TABLE I**

Assuming that $\tau = \kappa = \chi$ and that the mass is 970 $m_e$ we have the following possible decays. - 221 -

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| | | | |
|---|---|---|---|
| 1/ | $\tau^{\pm} \rightarrow \pi^{\pm} + \pi^{+} + \pi^{-}$ | $Q = 72$ Mev | $E_{\pi} = 0$ to $\sim 50$ Mev |
| 2/ | $\tau^{\pm} \rightarrow \pi^{\pm} + \pi^{0} + \pi^{0}$ | $Q \sim 72$ Mev | $E_{\pi} = 0$ to $\sim 50$ Mev |
| 3/ | $\kappa^{\pm} \equiv \tau^{\pm} \rightarrow \mu^{\pm} + (\nu + \gamma)$ | $Q \sim 380$ Mev | $E_{\mu}(max) \sim 150$ Mev<br>$p\beta_{\mu}(max) \sim 206$ Mev<br>$p_{\mu}(max) \sim 233$ Mev/c |
| 4/ | $\chi^{\pm} \equiv \tau^{\pm} \rightarrow \pi^{\pm} + (\gamma)$ | $Q \sim 350$ Mev | $E_{\pi} \sim 125$ Mev<br>$p\beta_{\pi} \sim 190$ Mev/c<br>$p_{\pi} \sim 224$ Mev/c |

a) Slow particles stopped in matter.

In presenting the mass measurements on the charged particles stopped in matter, Powell said that two developments in technique had increased the precision of the measurements. The first was the use of blocks of stripped emulsions with the consequent gain in track lengths available for measurement and the second was the use by the Ecole Polytechnique of two cloud chambers to measure the momenta and ranges of S-particles. Powell then reported that all the mass values of stopping kappa-mesons had be been collected together at the Congress. There were 32 examples with a range greater than I.5 mm in the emulsion. The mean mass value of all these particles was 990 $m_e$, 2I of the values were within one standard deviation of this mean and only one mass was more than two standard deviations removed in Table 2.

To check whether the measurement technique introduced a bias into the mass estimates or not the results obtained at Bristol had been separated from those found elsewhere. The mean masses for the two groups were :

| | |
|---|---|
| Bristol (I4 events) | I 060 $\pm$ 35 $m_e$ |
| Elsewhere (I8 events) | 965 $\pm$ 26 $m_e$ |

The mass measurements made on three S-particles observed by the Ecole Polytechnique group at the Pic du Midi gave a mean value of 922 $\pm$ 4I $m_e$. One S-particle, whose decay was consistent with that of a tau-meson where two of the secondaries were not observed, had been excluded from this mean.

## DISCUSSION

Leprince Ringuet : Are the mass values obtained for kappa-particles correlated with the lengths of their tracks ?

O'Ceallaigh : This has not been tested for the Bristol measurements. For all the other measurements the events have been split into two groups - those with tracks $\geq$ 3 mm long and < 3 mm long. The mean masses of the particles in the two groups are 960 $\pm$ 28 $m_e$ and 996 $\pm$ 72 $m_e$ respectively.

Peyrou : One should point our that the Ecôle Polytechnique S-particles are not slow particles in the sense that the kappa-particles seen in the emulsion are slow. The average initial momentum fo the three S-particles was about 400 Mev/c.

O'Ceallaigh : The scattering-range method of mass determination contains possoble systematic errors due to the uncertainty of our knowledge of the scattering constant and the energy-range relation. The situation would be improved if workers in

(45 events) **STOPPED "K" PARTICLES**

| | Primary | | | Secondary | | | |
|---|---|---|---|---|---|---|---|
| | Star | Length in mms | Mass me. | Length | p Mev/c | I/I$_0$ (9 ) | Mass me |
| Bombay | 20+5n* | I3.6 | 980±I50 | | 226±20 | | |
| | I4+2n* | I2.0 | 890±200 | | | ~0.98 | |
| | ? * | 52.0 | 970±I50 | | | ~I.0 | |
| | ? * | 3I.0 | I030±I70 | | | 0.93±0.07 | |
| Brussles | | I.4 | I030±260 | | | | |
| | | 2.0 | 750±I70 | | | | |
| | | 3.0 | 800±I60 | | | | |
| | | 20.0 | II00±I00 | 5.0 | 200±30 | I.09 | |
| Milan | | 2.0 | I270±290 | 3.44 | I50±27 | 0.94±0.03 | |
| | star | 5.26 | I030±I65 | 0.45 | | I.I5±0.I0 | |
| | star | I.88 | I350±2I0 | 2.08 | I08±I8 | I.I4±0.03 | I90±32 |
| | | I.47 | I360±340 | 2.50 | 200±33 | I.06±0.04 | 300±50 |
| | | 0.64 | I260±600 | 0.63 | > 80 | I.02±0.06 | |
| | | 3.40 | 970±I85 | 0.29 | | ~ I | |
| Cornell + Rochester | | ~3.0 | 970±I00 | | | | |
| | | ~3.0 | I030±I00 | | | | |
| | I4+3p | 4.5 | 870±I00 | | | | |
| Paris | | I.3 | I060±2I0 | 20.0 | I97±I3 | 0.97±0.03 | 220±25 |
| | I3+I8p | 4.95 | 890±75 | 0.I5 | | 0.85±0.20 | |
| | 9+2p | 6.04 | I030±80 | | | | |
| | 6+Ip | 9.0 | 900±60 | 0.85 | | I.0 ±0.I | |
| | | I.52 | 940±I70 | 0.20 | | ~I.0 | |
| | | I.40 | 900±I50 | 3.40 | 290 ±60 | 0.975±0.05 | |
| Bristol | | 4.I | I320±I70 | 2.2 | 235±35 | 0.97±0.04 | |
| | | 5.67 | II25±I40 | I.I | II±8 | | μ→e 2I0m$_e$ |
| | | 0.53 | I000±2000 | 5.9 | I44±I2 | 0.96±0.03 | I70±30 |
| | | 2.I0 | I370±320 | 0.I7 | | ~ I | |
| | | I.54 | I080±200 | 8.9 | 66±II | I.70±0.08 | 220±20 |
| | | 2.55 | I040±200 | 0.I0 | | ~ I | |
| | | 0.38 | ~ I000 | 2.5 | I70±30 | I.09±0.05 | 270±50 |
| | | 2.55 | II80±200 | 7.65 | I87±I7 | I.I4±0.03 | 330±30 |
| | | 0.63 | ~ I000 | I9.5 | I62±9 | I.094±0.0I6 | 265± I2 |
| | | I.38 | II00±330 | 0.27 | | ~ I | |
| | | I3.2 | I2I0±I50 | 0.I5 | | ~ I | |
| | | 0.96 | I080-450 | 0.20 | | ~ I | |
| | | 3.44 | 925±I90 | 0.5 | I20±44 | I.02±0.I0 | |
| | | 9.56 | II00±I70 | 4.I | I84±30 | I.03±0.03 | |
| | | I.7 | ~ I000 | 2.8 | I53±24 | I.03±0.05 | |
| | | 4.3 | I200±230 | 6.5 | I72±I7 | I.I5±0.03 | 295±25 |
| | | I.85 | ~ I500 | 4.0 | 3I5±70 | ~ I.0 | |
| | | 6.67 | 990±I50 | 0.I9 | | ~ I.0 | |
| | | 0.35 | I000-2000 | I8.0 | 205±I5 | 0.93±0.02 | μ ? |
| ? Ejected | I+0n)* I+0p)* | 28.0 | 780±90 | 6.0 | I70±20 | I.09±0.04 | 280±20 |
| | I9+3n * | 7.56 | 990±I50 | 0.5x6 | | | |
| | I0+0p * | 8.56 | I240±I00 | 3.0xI8 | II9±9 | I.2 to I.5 | 203±8 |

* Indicates stripped emulsion.

different laboratories were to use a standardised method of measurement.

Peters : It would be most valuable to have calibration measurements made on the tracks of artificially accelerated particles. This is now quite possible.

O'Ceallaigh : Vigneron (Journal de Physique) has calculated the energy-range and finds that it fits a power law. No calibration experiments have been made at energies greater than 40 Mev.

Professor Powell then asked to Professor Daudin to give his contributed paper to the session.

DAUDIN : Les varytrons et les nouvelles mesures de masse .

Comme on le sait, Alichanov et Alichanian avaient observé en Arménie à 3 200 m d'altitude un grand nombre de particules qu'ils appelaient varytrons. Ils utilisaient un aimant permanent et un hodoscope pour connaître le moment et le parcours des particules. Le nombre de leurs varytrons atteignait 8 % de la composante dure.

En 1950 a paru dans le Journal de Physique et le Radium une analyse de leurs travaux. On y attribuait les trajectoires de"varytrons" à des électrons, à des gerbes et au mauvais rendement de l'anticoïncidence.

En Septembre 1951, Vernov, Dobrotin et Zatsepin ont exprimé publiquement les critiques du Laboratoire du Professeur Skobettzyn. En ajoutant aux causes d'erreur mentionnées la diffusion (scattering) dans les pôles de l'aimant, le fond parasite s'élève encore davantage et atteint au moins 5 % de la composante dure. Vernov, Dobrotin et Zatsepin concluent qu'on n'a pas le droit de parler de la découverte de nouvelles particules de masses variées à propos de varytrons.

Alichanow et Alichanian défendent leur travail dans le même numéro du journal de physique soviétique. Nous n'examinerons pas leur défense. Il suffit qu'ils renoncent aujourd'hui aux varytrons plus lourds que les protons. En effet, si les trajectoires de grand moment étaient parasites, les trajectoires de moment plus faibles ressemblant à des mésons lourds pourraient l'être aussi.

Il arrive à chacun d'entre nous de se tromper. Une mauvaise expérience n'est pas une catastrophe ; sauf si elle bénéficie d'une autorité injustifiée. Je crois qu'il est heureux que les résultats d'Alichanian et d'Alichanow soient aujourd'hui contestés par leurs collègues soviétiques.

Je voudrais dire quelques mots des nouvelles expériences des mêmes auteurs, utilisant la même technique mais perfectionnée. L'hodoscope comprend 200 compteurs définissant 5 points de la trajectoire (IO Coordonnées) et 5 intervalles de parcours.

En outre, au niveau de la mer, ils enregistrent les coïncidences retardées de 2 µs,5. On arrive à séparer ainsi I/4 de mésons pi+ ($N(\pi^+)/N(\mu) \sim 0,2$). La masse moyenne des mésons µ est 2I8 ± 2 $m_e$. Il n'y a que I5 traces dans l'intervalle 400 - I 800 $m_e$ soit 3,4 % des mésons µ et pi. Là dessus il y a un certain nombre de mésons pi arrêtés par absorption nucléaire ; une particule de masse ~ I.I00 a donné lieu à une coïncidence retardée de 2 à 2,5 µ sec. Il s'agit sans doute d'un méson kappa.

En altitude, l'aimant permanent a été remplacé par un électroaimant de 76 tonnes donnant I 900 gauss. Des renseignements supplémentaires ont été fournis par des compteurs proportionnels indiquants l'ionisation à 50 % près et calibrés sur les protons.

Naturellement ils distinguent les mu des pi, la masse individuelle étant donnée à I0 % près environ. Les courbures parasites par scattering ont été mesurées avec champ nul.

Les particules intermédiaires sont très rares et groupées autour des valeurs 600 et 920 $m_e$. Les trajectoires groupées autour de la valeur 600 $m_e$ ont plus de chances d'être des pi-mesons arrêtés par absorption nucléaire. Leurs masses sont dispersées et les ionisations aussi.

Les particules groupées autour de la masse 920 sont au nombre de I3, le pouvoir ionisant est correct et de l'ordre de 2 fois le minimum. Les masses ont les valeurs : 940, 900, 880, 900, 920, I 090, 930, 930, 850; 900, et 900. Les valeurs ont une dispersion correcte comparable à celle des protons. Deux particules ont des masses I I00 mais sont très ionisantes.

La valeur moyenne des II premières masses est de 920 En y ajoutant les deux dernières la moyenne monte à 950. L'erreur déduite de la cohérence interne des mesures parait-être ± 40 environ.

Ces valeurs sont cohérentes avec celles trouvées dans les émulsions et la chambre de Wilson. Il n'y a pas de masse supérieure à I I00 $m_e$.

Le travail a été publié au printemps I952 et fait dans l'été I95I.

## DISCUSSION

Rossi : How were the values of ionisation measured ?
Daudin : By proportionnal counters calibrated with protons.

Leprince-Ringuet : One would like to know how many proportional counters were used. The work at the Aiguille du Midi by the Ecole Polytechnique and at Harwell has shown that it is very difficult, even with four proportional counters, to make accurate mass measurements of particles.
Lagarrigue : Where were the particles recorded by Alikhanian and Alichanov produced ? Were they isolated particles or did they come from showers ?
Daudin : The recorded particles come from a block of lead installed over apparatus.

This concluded the discussion on Alichavov and Alikhanian.

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b) Fast particles .

Powell recalled the results presented by Perkins giving evidence for heavy charged mesons coming from showers. The mass spectrum of the particles shows a peak et the proton mass with a "tail" extending to lower values. The significance of this tail had been proved by carrying out a calibration experiment with accelerated protons. The positions of the pi-meson and proton peaks were firm "anchors" and made it difficult to understand any large bias in the mass values of the heavy mesons. Nevertheless, only one particle with a mass less than that of the tau-meson had been observed. Shapiro's results also agree with those of Perkins and 4 or 5 particles of similar mass have been observed at Oslo. The question is : can these mass values be forced down to values obtained for particles stopping in the emulsion and in cloud chambers?

DISCUSSION

Bhabha : Where is the peak in Perkin's mass distribution ?
Powell : Near I 200 $m_e$ but the peak cannot be well defined as it is not resolved from the proton distribution. The evidence fot the higher mass value is the absence of a distribution around the tau-meson mass.
Perkins : The particles measured had momenta in the range from 330 Mev/c to 950 Mev/c.
Powell : This means that the particles are similar to the S-particles observed by the Ecole Polytechnique group except for their time of flight (they were observed for a total time of only $3 \times 10^{-10}$ sec). We must bear in mind that the range of times below $10^{-12}$ or $10^{-13}$ sec is obscure and there could be a transition with such a short mean lifetime.
Crussard : What is the proortion of protons to heavy mesons ?
Perkins : Tracks of I64 protons, I29 pi-mesons and 20 heavy mesons were measured.
Crussard : The proportion of heavy mesons is very much higher than among the stopping particles.
Powell : All these events came form stars with energies between 5 and 50 Bev.
Peters ; Can any apparent large angle scattering in the heavy meson tracks be interperted as decays with a very short

mean lifetime ?

Perkins : There is no indication of such decays.

Shapiro : The particles that I observed were of lower momentum than these of Perkins. The large tracks lengths gave reliable mass measurements in agreement with Perkin's results. All the tracks came from "fundamental" stars containing only thin or grey tracks.

Leprince-Ringuet : What is the statistical significance of the mass difference between Perkins's particles and the tau-meson ?

Perkins : On the average each mass value is about two standard deviations above the tau-meson mass.

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## 2 - EVIDENCE FOR THE NATURE OF THE SECONDARY DECAY PRODUCTS.

Powell opened the discussion by saying that evidence from both cloud chamber and emulsion experiments indicated the presence of a large number of mu-mesons among the charged secondaries produced in heavy meson decays.

In the multiplate experiments of the groups at M.I.T. and the Ecole Polytechnique S-particles secondaries had been observed to traverse 8 nuclear interaction lengths and only two possible (but not certain) interactions had been observed. The event recorded by Bridge and Annis could be interpreted as the decay of a superproton and there remained only the charged V-decay reported at the Congress by Butler where the secondary appeared to be scattered in the piston of the cloud chamber.

The emulsion experiments gave decisive evidence for the presence of a large number of mu-meson secondaries. First there was an event reported by O'Ceallaigh where a secondary decayed into an electron after coming ro rest in the emulsion. Second, mass measurements on three particles made by Menon using the grain density-scattering method gave masses of 208 $m_e$; 203 ± 8 $m_e$; and 220 ± 20 $m_e$. The absence of nuclear interactions of secondaries in the emulsion was not significant since the total length of track observed was less than 25 cm (one interaction length).

Powell then restated the evidence for the existence of pi-meson secondaries that had been presented by Menon and O'Ceallaigh. He quoted the values of the masses and p $\beta$ for the relevant particles from Table I.

Powell concluded by asking Rossi to explain the significance be attached to the M.I.T. observation of gamma-rays in from S-particle decay.

DISCUSSION

Rossi : There is definite evidence for the presence of gamma-rays in some S-particle decays. It is not possible that all S-particles decay into a single proton and a charged secondary particle. It is possible that all S-particles decay into three secondary particles one of which is a photon but if this is so, there must be a rather unlikely correlation between the directions of emission of the neutral secondary and the gamma-ray.

Crussard : What are the tracks lengths of the particles that are regarded as pi-meson secondaries ?

Powell gave the relevant figures from Table 2.

Powell : What are the energies with which the tau-mesons are emitted ?

Menon : II6.6 $\pm$ 6 Mev is the weighted mean value. This may be in error due to the uncertainty in our knowledge of the scattering constant and doubt about the cut-off procedure.

O'Ceallaigh : Event $K_{\circ I}$ gives the same mass value if the scattering is measured with and without a cut-off provided that the appropriate constant is used.

Rossi : Would systematic errors affect all the mass values and still give a unique value of p ?

Menon : The masses would not be affected as they are found by comparison but the values of $p\beta$ would be altered.

Rossi : If the mass values of Kappa-meson secondaries are all plotted on a histogram are two peaks apparent ?

Menon showed the slide giving the required histogram (See figure E - I, 6.)

Menon : The probability of any single mu-meson giving a mass value > 240 $m_e$ is ~ 5 % and Bristol has 5 out of 8 mass-value greater than this.

Leighton : At California Cowan has found a charged V-particle decay where the secondary track shows a deflexion consistent with $\pi \rightarrow \mu$ decay. I cannot remember the sign of the particle.

Menon : What is the probability of a gamma-ray from S particle decay being observed ?

Rossi : The probability of seeing a gamma-ray of I50 Mev is about 80 %. Only in 4 cases out of 22 examples of S-decay have electrons form gamma-rays been observed. The gamma-ray energies were between ICO and 200 Mev. If the gamma-ray energy were much less than I50 Mev - (corresponding to 3-body decay) - the probability of observation would be smaller.

Reynolds: Is there any reason to think that a distribution in the energies of mu-mesons from kappa-decays would lead to a spurious distribution of mass valeus ?

Menon : I can see no reason for such an effect.

Peters ; Were all the measurements made in 600$\mu$ emulsions ?

Menon : Yes.

Peters : Then the correction for dip is large.

Perkins : The correction is only 2 % and an error of 20 % would be needed to move the measured masses as far as the mu-meson mass.

Goldschmidt-Clermont : Has a search been made fot electron pairs produced by gamma-rays arising from kappa-decays in the emulsion ?

Menon : For the chi-decays we have searched a distance of about 2.5 cm and have found nothing.

Powell and Bhabha then raised the question : Does the process $\tau = \pi^{\pm} + \pi^{o} + \pi^{o}$ exist or not ?

Powell : Part of the difficulty in answering this question arises from the different methods of searching thet are used in various laboratories

Menon : If such events occur in the emulsion they might be classified as I-prong sigma stars or as $\pi \to \mu$ decays or as 2-prong stars. In a volume of 60 cc. of emulsion 2 tau-mesons have been observed. 20 cc. of this emulsion has been scanned for the alternative mode of decay. No example was found. This is not conclusive evidence against the existence of decays, $\tau \to \pi + \pi^{o} + \pi^{o}$

Leprince-Ringuet : Could the possibility of kappa-decays being $\tau \to \pi + \pi^{o} + \pi^{o}$ be excluded in those cases where the secondary energy was small ?

Powell : There are only three events where the energy is sufficiantly low and in those three cases the secondary masses ate all determined to be close to the mu-meson mass. One is the event where the secondary is identified by $\mu \to e$ decay.

Peters : The fact that this mode of decay has not been observed does not mean that it does not exist. Only 20 % of kappa-decays give measurable secondary tracks in plates. Only I2 tau-decays have been found. Therefore, between 2 and 4 examples of the alternative mode might be expected to have been seen.

Powell : Peters method of searching by following back pi-mesons to their origin should give one example of $\tau^{\pm} \to \pi^{\pm} + \pi^{o} + \pi^{o}$ for every three normal tau-decays if the alternative mode of de decay occurs.

## 3 - THE ENERGY DISTRIBUTION OF THE SECONDARIES -

Powell asked Butler to summarise the evidence available from cloud chamber measurements on charged V-decays.

Butler pointed out that experimental bias prevented a true spectrum of the transverse momenta ($P_t$) in charged V-decays from being obtained by adding results from all laboratories. Only rarely could events with low values of $P_t$ be distinguished from scattering deflection. The available distribution of values could be consistent with that of the two-body decay of chi-mesons. The distribution of the mu-meson momentum ($P^x$) in the decay at rest of kappa-mesons was not known but if all charged V - particles were to be interpreted as kappa-mesons , then the values of $P^x$ must be near 200 Mev/c for most events. No definite conclusion sould be drawn from the cloud chamber measurements of $P_t$ .

## DISCUSSION

Rossi : Is it certain that there is a distribution of the secondary energies in the centre of mass system ?

Butler : Not certain. Only when both primary and secondary tracks are measurable is it possible to transform to the centre of mass system and evaluate $P^x$. There are two events (one from Manchester and one from the Ecole Polytechnique) where this transformation leads to values of $P^x$ near to 100 Mev/c.

Shapiro : We have observed an example of a decay in flight where the secondary energy is 20 Mev?

Fretter : What is the largest value of $P_t$ that has been observed ?

Butler : In Manchester we have one event which gives a value of $P_t$ just over 300 Mev/c but with a large error. It is consistent with a value of 230 Mev/c.

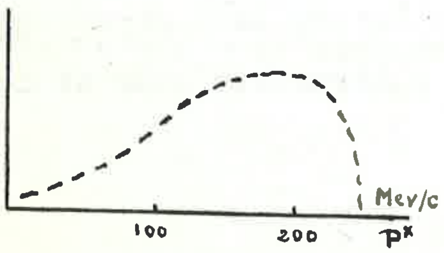
Leighton : All the C.I.T. values are consistent with a cut-off at 230 Mev/c except one event at 320 Mev/c with a large error.

Thomson : The events from Indiana have not been fully analysed but the largest value of $P_t$ is 225 ± 15 Mev/c.

Muller : All our events at the Pic du Midi are also consistent with a limit of 230 Mev/c.

Powell: To summarise, these seems to be no good evidence for values of $P^x$ greater than 230 Mev/c.

Rossi : The evidence from S-particle decays indicates no values of $P^x$ greater than 230 Mev/c. As with the charged V-particles the indication is that most values of $P^x$ are near 200 Mev/c. One should remember that S-particles are observed in the chamber for a much longer time than charged V-particles and the two groups of particles should be considered separatly.

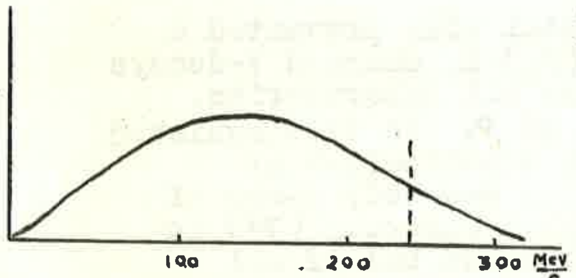



V and S particles

Powell then sketched the distribution of values of $P^x$ suggested by the charged V-particle and S-particle decays.

He then sketched also the distribution found from decays of $\kappa$-particles in the emulsion ans asked what was the weight of the high energy region of the spectrum.

The evidence from measurements of $\mu \to e$ decays was a "high energy tail" to the spectrum occurs chiefly as a result of fluctuations in the scattering of the particles.




K - particles

Menon and O'Ceallaigh then gave their reasons for considering the observed values of $p\beta$ for kappa-secondaries inconsistent with a cut-off at 206 Mev/c (which correspond to $p \sim 233$ Mev/c for a mu-meson). There are 24 events (Table 2) for which $p\beta$ has been measured for the secondary particle. 12 of the values lie within two standard deviations of 206 Mev/c while five of the best values lie above 206 Mev/c.

When the very low values of p$\beta$ are discarded as being impossible to reconcile with a p$\beta$ of 206 Mev/c one finds that the probability of obtaining the observed p$\beta$ distribution is less than I %.

Leighton : I am suspicious of the separation of secondary particles into pi and mu-mesons because of the magnitude of the errors in mass measurements.
Mabboux : What is the Primakoff correction for kappa-particles ?
Michel : For mu$^-$-mesons it is Z x E/I37 where E is the mu-meson energy. The correction might be about the same for kappa-particles.
Powell : To summarise, the cloud chamber evidence is consistent with an upper cut-off to $P^x$ at 230 Mev/c but the emulsion evidence does not conform with this conclusion. Further evidence on this point would be extremely important.
Bhabha : Can the chi-meson and the tau-meson be identical ?
Powell :- As far as the experimental evidence is concerned, the answer must be yes.

## 4 - THE NUCLEAR CAPTURE OF KAPPA-PARTICLES.

Powell : The results obtained by Peters suggest that negative kappa-particles appear with the same sort of frequency as tau-mesons. If only positive kappa-particles decay and the negative kappa-particles form stars and if there is a symmetrical charge distribution among kappa-particles, then kappa-stars should occur as frequently as kappa-decay. This is in apparent contradiction with the results of Friedlander who finds kappa-stars to be very rare compared with kappa-decays. In Bristol 60 kappa-decays have been found, 4 tau-decays and no kappa-stars.

Now, this difficulty is resolved if one can compare the number of heavy meson stars, not with the number of kappa-decays but with the number of tau-mesons : Dr. Peters observes about the same number (4 or 5) for both and we, in Bristol, observed 4 tau-mesons and no star. To compare these two results one should further notice that Dr. Peters would have missed two of his heavy meson stars, had he not worked with stripped emulsions (what at the time we did not).

Schein then reported two examples of kappa-stars, one produced by an upward moving heavy meson. The primary track in the second example was 200 µ long.

Michel : Perkins results on heavy mesons formed in stars makes it impossible to assume a small nuclear interaction for kappa-particles.
Peters : Nine cases of kappa-stars have been reported. The yield of these events in the Bombay experiemtns may have been higher than in the Bristol experiments because of the small thickness of material that was placed round our emulsion and the fact that this material was rather close. If the kappa-particles have rather a short life (and thus a possibility of decaying in flight) we should expect indeed a high yield inthese circumstances. Could Friedlander say how the Bristol plates were exposed ?
Friedland : Some were exposed at the Jungfraujoch and some in balloo

flights. They were selected for examination because kappa-decays had been found in them.

Blackett : If the tau-meson and the kappa-meson are the same particle with different mode of decay the ratio of the numbers of the two types ofddecay should be the same whether the particles decay in flight of are brought to rest. In cloud chamber experiments about IOO charged V-decays and 5 tau-decays have been observed giving a ratio of 20 to I for the two types of decay. The Bristol figures give a ratio of I5 to I for kappa-decays and tau-decays.

Powell : Perhaps positive tau-mesons decay while negative tau-meson are captured . The fact that the coplanarity of the three secondary particles is always good supports this view since a negative tau-meson would be caught in a Bohrorbit would probably be destroyed. Also, among the secondaries of his tau-decays Peters found 8 positive and 3 negative pi-mesons which again suggests that the tau-mesons were positive.

What, then, happens to negative kappa-particles ? It may be that negative kappa-particle interactions are difficult to observe.

Peters : We estimate that there must be about I5 tau-meson decays in our stripped emulsionsin Bombay. Four kappa-decays heve been found accidentally and many more must be present. The number of kappa-interactions found is nowhere near to equalling the estimated number of kappa-decays.

Blackett : It would be extremely unlikely for the kappa-particles and tau-mesons to have the same mean life. This is the only alternative way of explaining the constancy of the relative proportions of kappa- to tau-decays in flight and at rest. Otherwise the particles must be identical with two modes of decay.

Peters : If we accept the conclusion which seems to emerge that the kappa-mesons are much more frequent than the $\tau$ mesons and that what we have identified are negative tau-mesons, then we get immediately into difficulties if we try to identify the kappa-mesons with tau-mesons, as an alternative decay scheme, because, irrespective of the decay scheme, we would expect an equal number of negative particles of this type ( $\kappa - \tau$ ) and if they are not there then we have to drop the hypothesis with which we started working, namely that we could identify the kappa-mesons with the tau-mesons and simply say it may be a different decay scheme of the same particle.

Schein : I agree. If negative tau- produce stars and negative kappa do not, kappa and tau obviously cannot be identified.

Sard : Is there any reason why the kappa-decays should not be due to both negative and positive particles.

Powell : No reason.

Crussard :The three S-particles observed by the Ecole Polytechnique were positive.

Peters : It seems that we have the same situation as existed before the discovery of the pi-meson.A link must exist to give rise to the kappa-particles if they do not interact.

Perkins :The lifetime of the intermediate particles must be very short.

Schein : The experiments on the nuclear interaction of shower particles do suggest on the other hand that kappa-particles interact.

Fretter The Ecole Polytechnique cloud chambers may settle this point.