NOTAS DE FÍSICA

VOLUME V

N° 14

ON THE OBSERVATION OF π-MESONS EMITTED IN THE INTERACTION IN EMULSION OF K^-- MESONS

European Collaboration

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RIO DE JANEIRO

1959

Notas de Física - Volume V - Nº 14

ON THE OBSERVATION OF π-MESONS EMITTED IN THE INTERACTION IN EMULSION OF K^-- MESONS*

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1. Introduction.

In continuation of the work of the European Collaboration on K^- interactions at rest, a second stack has been exposed to a filtered K^- beam. This stack is of the Ilford K-5 emulsion, and presents certain advantages over the previous one for the study of fast

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* Previously published in Il Nuovo Cimento, Vol. XII, N. 1, April 1959.

** On leave of absence from Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, D.F., with a fellowship from Conselho Nacional de Pesquisas, Brazil.

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particles, having larger dimensions, a slightly higher grain density and lower background fog.

In a preliminary survey of the material the percentage of lightly ionizing tracks observed in the K^- stars at rest appeared to be higher than in the previous work [1]. This point was of immediate interest, since in the previous work two difficulties were encountered which could be resolved if there had been a larger scanning loss of π-mesons than was estimated. These difficulties were:

1) The difficulty of attribution of about 400 out of 3024 events to either K^--N or K^--2N interactions.

2) The lack of very high energy π-mesons ($E \geqslant 100$ MeV) associated with direct production of Λ^o hyperons in the reaction $(K^-N, \pi^-\Lambda^o)$.

Four groups (Bari, Bruxelles, Milan, London) have therefore examined the question and this letter contains their preliminary results.

2. Experimental method.

Grey tracks in the beam direction were picked up at about 1 cm from the entrance edge of the stack, and followed to their end. Those track endings falling within 50 μm of either surface of the emulsion were discarded from the statistics.

Measurements of ionization and range were made on tracks with ρ endings to separate K_ρ's from protons.

1148 K^- interactions at rest were thus selected.

The search for π-mesons emitted in the K^- interaction was

1. G. Alexander et al. (European Collaboration): Nuovo Cimento, in press.

TABLE I

(a)	Dip of π-meson	$0 \div 14.5^{\circ}$	$14.5 \div 30^{\circ}$	$30 \div 48.6^{\circ}$	$48.6 \div 60^{\circ}$
	No. of events	117	104	123	58

(b)	Depth above glass of K^--stars containing a π-meson	(50 - 100) μm	(100 - 200) μm	(200 - 300) μm	(300 - 400) μm	(400 - 500) μm	(500 - 550) μm
	No. of events	36	79	76	88	72	50

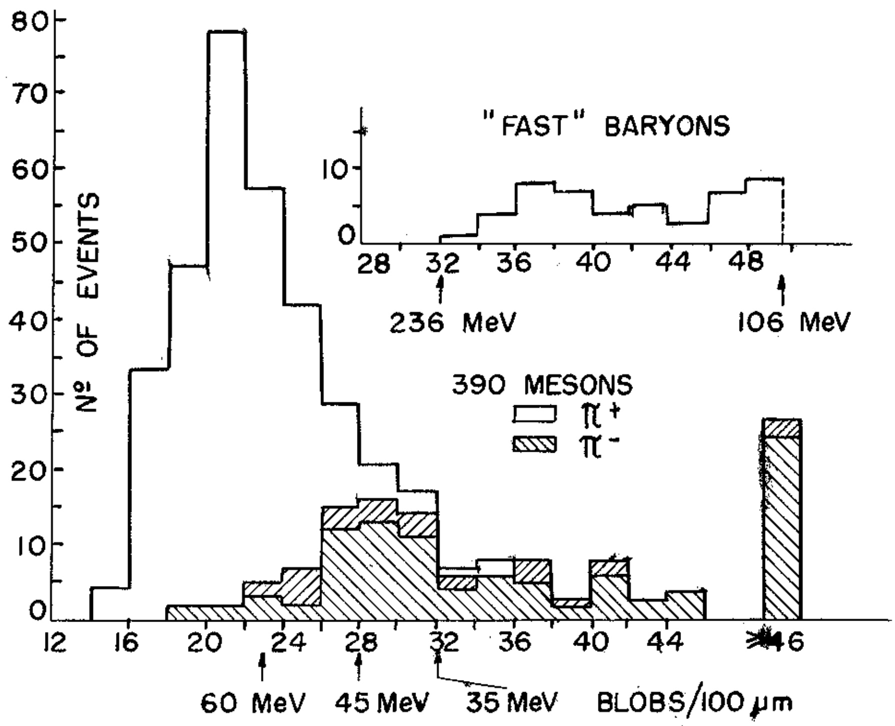

Fig. 1. Distribution in blob density of π-mesons and "fast" baryons. All the tracks with blob density ≥ 28 blobs/100 μm were followed to such an extent as to identify the particle as either a π-meson or a baryon. No baryon with density $\not< 32$ blobs/100 μm was observed.

carried out in two steps. First all black and "grey" tracks were followed to rest, and their nature and energy so determined. Then a careful search was made for "light" tracks. This care involved a scrutiny of the K^- endings by as many as 4 independent observers at different times. During the final scrutiny which lasted up to 20 min for each K^- ending the field of view was rotated slowly through 360° by rotation either of the stage or of the microscope head, or the eyepiece cross wire was similarly rotated.

In the analysis of the tracks emitted in the K^- stars, those tracks emitted at an angle of more than 60° to the plane of the emulsions were discarded, in order to avoid ambiguity in the separation of fast baryons from π-mesons. A correction for solid angle was then applied to the resulting π/K ratio.

The distribution in dip and depth of the π-meson tracks at their origin is given in Table I.

On all tracks which were not followed to rest, between 500 and 1000 blobs were counted on at least three different plates, in the central 400 μm of emulsion. It was necessary to count in more than one or two plates since, due either to processing or to fluctuations in sensitivity in these new fine grain emulsions, important differences in blob density were found in certain zones of the plates.

When the blob-density of the track was equal to or greater than that corresponding to a proton of the maximum expected energy of 300 MeV (π-meson of 45 MeV), the track was followed to its end or to the point at which, if a π-meson, it would have come to rest already, and a second blob count made. No baryon with blob density lower than that corresponding to 230 MeV was observed.

Fig. 1 shows the distribution in blob density of all π-mesons and of the "fast baryons with energy $> \sim$ 100 MeV.

For particles which interacted in flight or left the stack after a few mm, the value of $p\beta$ was determined by scattering in order to assure the separation of π - mesons from protons. Where the available track length was too short to allow scattering determination, the track was listed as doubtful. Owing to the difficulties of following close to the beam direction, some tracks had to be abandoned after a short distance. There were 3 instances of this, and these are also shown as doubtful events in Tables II and III.

TABLE II

Authors	No. of K^- at rest	No. of π-mesons observed	π/K^- ratio (%)
Bacchella *et al.*[2]	391	118	30
Chadwick *et al.*[3]	815	230	28.2
Eisenberg *et al.*[4]	548	175	32
European Collaboration[1]	3024	892	29.6(33.2) (*)
Present Work	1148	390+(12) (**)	39.2+(1.3)(**)

* Corrected for scanning losses. ** Bracketed figures refer to doubtful mesons.

2. G. L. Bacchella, A. Berthelot, A. Bonetti, O. Goussu, F. Levy, M. René, D. Revel, J. Sacton, L. Scarsi, G. Tabliaferri and G. Vanderhaeghe: Nuovo Cimento **8**, 215 (1958).

3. G. B. Chadwick, S. A. Durroni, P. B. Jones, J. W. G. Wignall and D. H. Wilkinson: Phil. Mag. **3**, 1193 (1958).

4. Y. Eisenberg, W. Koch, M. Nicolić, M. Schneeberger and H. Winzeler: Nuovo Cimento, 11, 315 (1959).

TABLE III

Class	Present Work				Previous Work [1]		
	Nº of K^--mesons	% of total K^-	Nº of mesons (angle of dip≤60°)	Ratio π/K^- in the class (corrected to total solid angle (%)	Ratio π/K^- in the class (%)	Mean Kin. Energy of π's in the class (MeV)	% Loss of π mesons deduced from present wrk.
K_ρ	112	9.8	---	---	---	---	---
K_{σ_1}	214	18.6	66+(5)	36 + (3)	27	79	33
K_{σ_2}	333	29.0	164+(4)	57 + (1)	51.5	52.5	10.7
K_{σ_3}	207	18.0	64+(2)	36 + (1)	32.8	51	9.8
K_{σ_4}	141	12.3	40+(1)	33 + (1)	22.4	}	}
K_{σ_5}	102	8.9	44	50	32.5	} 50	} 52
$K_{\sigma_{\geq 6}}$	39	3.4	12	35	25.0	}	}
Total	1148	--	390+(12)	39.2+(1.3)±2	29.6±1.1	-	32.5 + +(4.5±2.3

3. Results.

Among 1148 K^- stars examined, 390 π-mesons were identified and 12 particles classed as "doubtful π-mesons". Applying the correction for the restriction of solid angle, this gives a π/K^- ratio of [39.2 + (1.3) ± 2]%, a value substantially higher than that found in previous experiments. (See Table II).

This value is subject to the following uncertainties:

1) Statistical fluctuations. These lead to the given error of ± 2%.

2) Errors in the solid angle correction, due to errors in measurement of the dip of the particle near the cut-off, fluctuations in thickness of the plates and uncertainty in the mean thickness of the

plates and uncertainty in the mean thickness of the plates of this stack. The first two are random errors, the total effect on the π/K^- ratio being negligible. The third effect leads to a systematic error. Measurements made in specimen plates indicate that the true mean thickness does not differ from the nominal value by more than 10%. With a deviation of 10 % from the nominal thickness, the π/K^- ratio would change by $\pm$ 1 %.

3) Further observational loss. It is most probable that there still remains a scanning loss of the faster π-mesons. A general scarcity of grains in the field of view, the existence of a large gap in the π-meson track at its origin, and, associated with either of these, a high distortion in the plate, will reduce the visibility of the track below observational level. Plates were exchanged between the collaborating groups, so that a part of each sample could be re-examined. One or two additional π-mesons were found in each case, which showed that while the efficiency of observation of all groups was comparable, it was always less than 100 %.

In Table III are given the numbers of π-mesons in the various types of K^- stars and for comparison, the values obtained in the previous work [1]. Table IV shows the percentages of π-mesons below and above 45 MeV, as well as those of "fast" baryons in the interval (60 $\div$ 300) MeV, together with the corresponding values from (1).

From these two tables, some idea can be got of the cause of loss of fast particles in the previous experiment:

1) The factor of loss is higher for multi-pronged, ([illegible] ≥ 4) stars than in stars of one, two or three prongs. This implies that the more complex was the event, the less carefully it was examined,

as might be expected.

2) Among the stars with fewest prongs, the greatest loss of π's was that among the $K\sigma_1$ events. This may be attributed to the higher mean energy of the mesons in this type of event. There is a corresponding reduction in the percentage of $K\rho$ events. That the higher energy π-mesons are those which escape observation appears from Table IV.

TABLE IV

Kinetic energy	% of π-mesons and fast baryons	
	present work	previous work [1]
π-mesons		
$0 < E \leqslant 45$ MeV	10.5 ± 1	10.0 ± 0.6
$E > 45$ MeV	28.7 ± 1.7	19.6 ± 0.8 $(23.2 \pm 1$ (*)
Baryons		
60 MeV $< E < 300$ MeV	14.7 ± 1.1	14.2 ± 0.7

(*) Corrected for scanning losses.

4. Conclusions

1) The value of the π/K^- ratio found in this work, $[39.2 + (1.3) \pm 2]\%$, is higher than was previously estimated.

2) A comparison with the previous work of this collaboration shows that the scanning loss there was chiefly among the higher energy π-mesons in $K\sigma_1$ stars and among the multi-pronged events.

3) This implies a larger proportion of hyperons produc-

ed directly in the interaction

$$K^- + N \longrightarrow \pi^- + \Lambda^\circ ,$$

and that the absorption of π-mesons is even smaller than previously estimated.

4) The importance of the loss of π-mesons in previous work requires a reassessment also in the study of Σ hyperons, of the branching ratio

$$\Sigma^+ \longrightarrow \pi^+ / \Sigma^+ \longrightarrow p ,$$

of the sign ratio, and possibly of the lifetime.

5) The estimation of the frequency of K^--2N interactions, if based on the number of events not associated with π-mesons, is likely to lead to an over-estimate.