ANGULAR DISTRIBUTION OF μ MESONS FROM π-μ DECAY

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Submitted to JETP editor February 28, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) **41**, 106-108 (July, 1961)

It is shown that the angular distribution of μ mesons from the decay of π mesons produced in strong interactions is isotropic. The deviation from isotropy observed in some cases may be due to the omission of some of the π-μ decays when their density is very high. Emulsion and microscope distortions are shown to have no effect on the angular distribution.

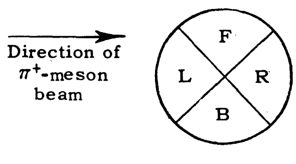
FOLLOWING the detection of asymmetry in the spatial distribution of electrons from the π-μ-e decay a number of experiments were performed in order to verify that the distribution of μ mesons from the π-μ decay is isotropic. Nearly all the authors who studied the π-μ decay[1-6] arrived at the conclusion that the distribution of interest was isotropic. The work of Hulubei et al[1] provides an exception: with a statistics of approximately 8000 π-μ decays the number of μ mesons emitted "forward" (relative to the direction of the π-meson beam) and "backwards" was found to be smaller by 20-25% than the number emitted "right" and "left." Another exception is the work of Garwin et al,[6] who studied the distribution of μ mesons from the decay of π mesons produced in the decay of τ mesons in emulsions. In this work the following data were obtained on the distribution of μ mesons relative to the direction of motion of the π meson at the instant of decay:

	$E_\pi < 12$ Mev	$E_\pi < 15$ Mev	All π mesons
Back/front ratio:	71/39 = 1.8	85/54 = 1.6	186/160 = 1.16

These data indicate the existence not only of a considerable "forward-backward" asymmetry but also the dependence of it on the energy of the π meson from the τ-meson decay.

The photoemulsion method makes it possible to identify errorlessly π-μ decays and to measure with exceptional accuracy the projection onto the plane of the emulsion of the angles between a given direction and the direction of emission of the μ meson. It therefore seemed to us important to understand how a method so well adapted to the observation of π-μ decays undistorted by systematic errors, could give rise to the results observed by Hulubei et al[1] and Garwin et al.[6]

We carried out measurements in one of the available to us emulsion chambers (NIKFI-R type emulsion), with layers $10 \times 10 \times 0.04$ cm, irradiated by a π^+-meson beam whose energy at the output of the collimator was equal to 150 Mev. These π^+ mesons were slowed down by additional filters and the density of the π-μ decays in the emulsion itself was close to 500 events per cm^2 at a distance of 2 cm from the incoming end of the emulsion layer, and close to 60 cm^{-2} at a distance of 2 — 3 cm from the opposite end.



Prior to the measurement of the distribution of μ mesons from the π-μ decay we performed for control purposes measurements of the angular distribution of α particles from thorium stars with 3 to 5 prongs. The measurements were performed with a 20×15 magnification in the following manner. Into the field of view of the microscope ocular was inserted a scale, marked as shown on the figure, and the observers recorded with the letters B, F, L and R the occurrence of an α particle from a thorium star in the corresponding quadrant of the scale. The results obtained by seven observers were in excellent agreement with each other and are given below:

Scale quadrant	B	F	L	R
Number of particles	1292	1344	1266	1253

This distribution is for practical purposes isotropic: thus for example an analysis according to the χ^2 test gives the magnitude $\chi^2 = 3.7$ for three degrees of freedom.

The second control experiment consisted of measurements of the angular distribution of electrons from the μ-e decay relative to the same direction of the collimator axis. It is obvious that this distribution too should be isotropic. We have selected, under 20×15 magnification, some 4100 π-μ-e decays wholly contained in the emulsion layer. The following angular distribution was found for the electrons:

Scale quadrant	B	F	L	R
Number of electrons	1027	1048	1002	1013

Just like the previous distribution these results indicate isotropy. On the basis of these observations we conclude that distortions of first order in the emulsion, as well as distortions that could be due to the microscope, have no noticeable effect on our measurements of angular distributions.

Let us pass now to the consideration of the data on the angular distribution of μ mesons from π-μ decay.

The microscope operator would find (at 20×10 magnification) a π-μ-decay event by its vertex. From all π-μ decays only those were selected for which the subsequent μ-e decay took place in the same emulsion layer. The decay was drawn in and its coordinates recorded. After the scanning was completed the same observers would repeat it using unchanged selection criteria and recording rules. This double scanning permits one to find events that were missed the first time and also determines the scanning efficiency for each observer. The first measurements were carried out in that region of the emulsion where the density of π-μ decays was small and amounted to approximately 60 cm^{-2}. The resultant angular distribution (from the data of seven observers) and average scanning efficiency of seven observers were as follows:

Scale quadrant:	F	B	L	R
Number of mesons:	504	540	508	487
Scanning efficiency:	0.86±0.03	0.85±0.03	0.87±0.03	0.82±0.03

An analysis according to the χ^2 test gives $\chi^2 \approx 3$ for three degrees of freedom which indicates the absence of statistically significant deviations from isotropy. Furthermore, it turned out that the scanning efficiency was practically the same in all four quadrants.

We shall now give the results obtained in the part of the chamber where the density of π-μ decays was high and approximately equal to 400 — 500 cm^{-2}. Here the data obtained by different observers were in strong disagreement. The measurements of one group of observers (whom we might denote as A, B, C, D) were, as before, in agreement with an isotropic distribution and with a scanning efficiency independent of the quadrant:

Scale quadrant:	F	B	L	R
Number of mesons:	389	405	375	360
Scanning efficiency:	0.80±0.05	0.73±0.05	0.73±0.05	0.76±0.05

A second group (E, F, G) showed an effect analogous to the one found by Hulubei et al.[1]

Scale quadrant:	F	B	L	R
Number of mesons:	593	647	560	479
Scanning efficiency:	0.77±0.03	0.72±0.03	0.66±0.03	0.63±0.03

This result points to a large anisotropy (the deviation from isotropy is characterized by a χ^2 of approximately 37 for three degrees of freedom), but the analysis indicates that it is due to weakening of scanning efficiency of operators E, F, and G in the quadrants L and R.

We conclude that the present data indicate that the angular distribution of μ mesons from the decay of π mesons produced in strong interactions is isotropic. The asymmmetry found by some of the observers is explained by scanning omissions. These omissions are apparently caused by psychological factors: they arise under conditions of high π-μ-decay density. If on the average several π-μ decays appear in the field of view of the microscope operator he will leave out those decays which require greater attention for their identification, i.e., the "backward" and "forward" decays (quadrants L and R). These considerations do not apply to π mesons produced in the τ decay, where the π meson can be traced from the point of its production, however the statistical accuracy of the data of Garwin et al.[6] is insufficient. The accumulation of large numbers of τ decays in emulsion and in bubble chambers will show whether one is dealing here with an exceptionally large fluctuation or an extraordinarily important physical phenomenon.

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Translated by A. M. Bincer
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