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ANGULAR DISTRIBUTION IN $\pi \rightarrow \mu + \nu$ DECAY

by

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ANGULAR DISTRIBUTION IN $\pi \rightarrow \mu + \nu$ DECAY *,**

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In 1957 Lattes and Freier [1] studied the angular distribution of μ mesons resulting from the decay of π mesons at rest in nuclear emulsions. A beam of π^+ mesons entered a nuclear emulsion stack parallel to one of the edges. Being θ the angle between the initial direction of the μ meson projected on the plane of the emulsion and the direction of beam the distribution function $\frac{dN}{d\theta}$ was measured. Instead of an isotropic distribution which should be expected for a decaying particle of spin zero a

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back-forward asymmetry was obtained. The referred authors attributed this asymmetry to an instrumental error rather than to a real property of the pions.

After that work, many others papers appeared in most of which an anisotropy of the same nature was also observed; the origin of the asymmetry has not been settled, however. Also, most of these works suffered of the lack of sufficient statistics.

The purpose of this paper is to report the result of the analysis of that asymmetry in plates where a very large effect had been found in previous study by Ausländer et al [2] (to be referred from now on as A) with good statistics (7.526 $\pi \rightarrow \mu$ decays).

Using a new method of scanning which should reduce bias against small angles no back-forward asymmetry was found within statistical error.

<u>$\pi \rightarrow \mu$ vertex scanning</u> - In A as in previous works the method of area scanning was used to find the points of $\pi \rightarrow \mu$ decays. Fig. 1 shows the results of A both for μ's and e's (positrons). The histograms suggest angular distributions relative to the incoming beam of the form

$$\frac{dN}{d\theta} = C\,(1 + a_1 \cos\theta + a_2 \cos 2\theta + a_3 \cos 3\theta) \qquad (1)$$

Indeed the values of a_1, a_2 and a_3 obtained by the minimum square method gave a good fit of the experimental distributions by equation (1). These values are given in Table 1 together with the usual forward-backward asymmetry coefficient

$$b = 2\,(F - B)\big/(F + B)$$

TABLE I

Particle	a_1	a_2	a_3	b
μ	-0.107 ± 0.016	-0.210 ± 0.018	-0.050 ± 0.022	-0.115 ± 0.023
e	$+0.036 \pm 0.016$	-0.090 ± 0.016	$+0.020 \pm 0.021$	$+0.037 \pm 0.023$

Using the same method of scanning we obtained, for 2.594 cases in one plate, the following coefficients for the μ distributions:

$a_1 = -0.037 \pm 0.029$; $a_2 = -0.141 \pm 0.031$; $a_3 = -0.018 \pm 0.037$ and

$$b = -0.040 \pm 0.039 \ .$$

They are compatible with those of Table I within two standard deviations.

As to the origin of the observed anisotropy we considered then the possibilities:

a) That the asymmetry is due only to distortion. This is already excluded by the data of Table I as then μ's and e's should have the same distribution. The coefficients for μ and e are indeed incompatible. Of course the existence of some distortion effect is not excluded.

b) Existence of observational bias resulting from the fact that some $\pi \longrightarrow \mu$ events might be lost due to small decay angles. In order to examine this possibility we divised another method of scanning which minimises this effect if it is significant (μ-end scanning):

Instead of finding directly the points of $\pi \rightarrow \mu$ decay we looked for μ mesons stopping in the emulsion. The μ track was then followed back to find the $\pi \rightarrow \mu$ vertex within the expected range of μ's.

<u>μ-end scanning</u> - The same scanners who did the previous scanning were instructed to look for all black tracks ending in the emulsion (area scanning). These tracks were followed back to see whether they corresponded to a μ resulting from a $\pi \longrightarrow \mu$ decay at rest. All such black tracks with more than $400\,\mu$ (projection) in the emulsion which were not considered as a μ from a $\pi \longrightarrow \mu$ decay by these scanners were registered. All these cases and the $\pi \longrightarrow \mu$ decays were then revised by other scanner and, in case of disagreement, by all scanners. For 4.132 $\pi \longrightarrow \mu$ final cases 5 were discarded for being obvious mistakes and 13 new cases were found.

The scanning and track following were made with obj. 25x and eyepieces 15x. Each track was also examined with obj. 100x and eyepieces 15x which were used to measure depths and angles. As in the first scanning only the cases where both π and μ ended more than $20\,\mu$ (developed) from the glass or emulsion surface were accepted. A map of the plate was made and the twice counted $\pi \longrightarrow \mu$ corrected. As the $\pi \longrightarrow \mu$ decays were not uniformly distributed in the emulsion, the cases with projected distance less than 700 μ from the border of the scanned area were rejected in order to avoid the introduction of a preferential direction.

The angular distribution of the μ mesons thus obtained is plotted in Fig. 2 together with the results of A for comparison. The line labeled μ in Table II gives the values of a_1, a_2, a_3 and b to be compared with those of A (Table I).

TABLE II

Particle	a_1	a_2	a_3	b
μ	-0.016 ± 0.022	-0.052 ± 0.024	-0.012 ± 0.028	-0.015 ± 0.031
e	$+0.005 \pm 0.022$	-0.030 ± 0.022	$+0.014 \pm 0.028$	0.000 ± 0.031
α	$+0.003 \pm 0.024$	-0.024 ± 0.026	$+0.012 \pm 0.030$	-0.001 ± 0.033
$\alpha+e+\mu$	-0.003 ± 0.013	-0.036 ± 0.014	$+0.004 \pm 0.017$	-0.005 ± 0.018

We see that the forward backward asymmetry (coefficients a_1, a_3, b) is consistent with zero. We conclude that this is a consequence of a strong reduction of bias in the present method of scanning. The fact that 11 of the 13 μ's lost by the first scanners had a $\pi \longrightarrow \mu$ angle smaller than 25° indicate that there is still some bias in our method against small values of θ.

<u>Possible distortion effects</u> - Although our results for

the μ angular distribution are compatible with isotropy the value of a_2 (responsible for the side peaking of the angular distribution) is larger than twice the statistical error. Thus we looked for eventual distortion effects by examining also the angular distribution of the electrons from μ-decay and 3.669 alpha particles from natural radioactive stars which had been determined simultaneously with the μ distribution. In Fig. 3 these distributions are compared. The 18 cases where the electron was not found correspond to μ's stopping near the surface or glass. The values of the coefficients of equation (1) are given in Table II also for α , e and the total distribution of α , e and μ together. The absence of back-forward asymmetry is confirmed. The a_2 values are found to be consistent with that for the μ distribution what would confirm the existence of distortion, but they are also consistent with isotropy. Improvement of the statistics is being done to find if the distortion effects exist. The value $a_2 = -0.090 \pm 0.016$ for electrons in A might be an indication that distortion effects exist and are larger in other plates of the stack.

We are thankful to Ausländer group for the permission for using three of their plates and to Professor Lattes who encouraged us to work on the $\pi \longrightarrow \mu$ decay angular distribution.

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x*x*x*x*x*x*x

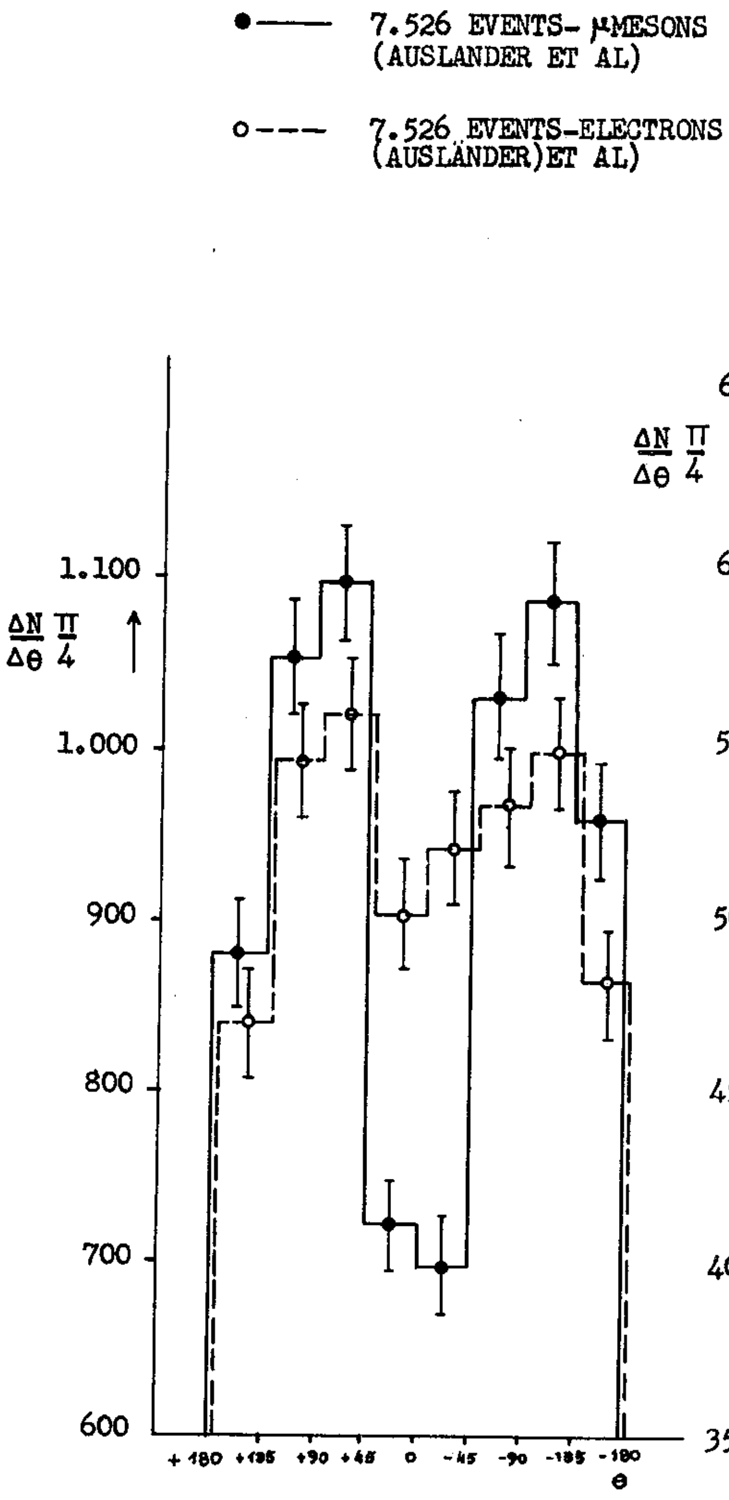
7.526 EVENTS- μMESONS (AUSLANDER ET AL)
7.526 EVENTS-ELECTRONS (AUSLÄNDER)ET AL)
1.100
1.000
900
800
700
600
$\frac{\Delta N}{\Delta\theta}\frac{\pi}{4}$
+180 +135 +90 +45 0 -45 -90 -135 -180
θ

Fig. 1

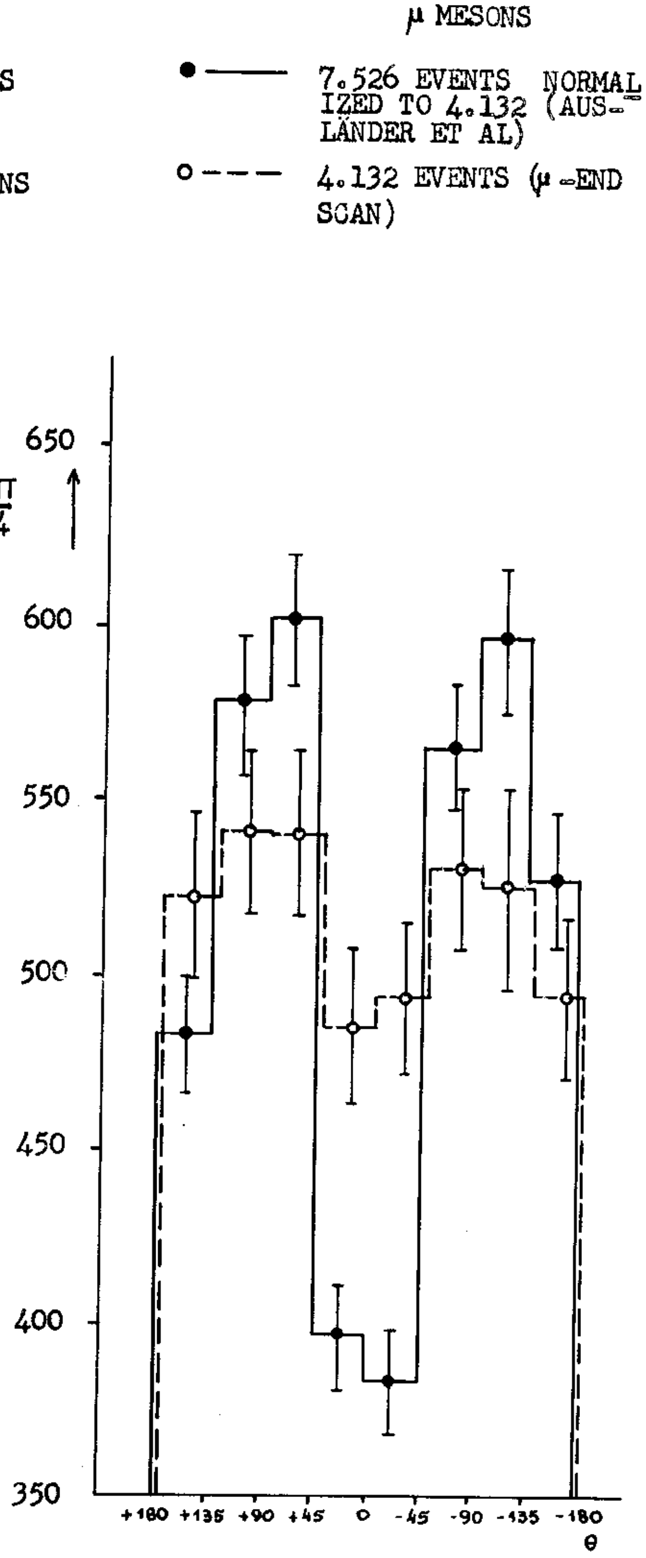
μ MESONS
7.526 EVENTS NORMALIZED TO 4.132 (AUSLÄNDER ET AL)
4.132 EVENTS (μ -END SCAN)
650
600
550
500
450
400
350
$\frac{\Delta N}{\Delta\theta}\frac{\pi}{4}$
+180 +135 +90 +45 0 -45 -90 -135 -180
θ

Fig. 2

o——— 3.669 EVENTS - α PARTICLES

⊙ --- 4.114 EVENTS NORMALIZED TO 3.669 - ELECTRONS

o—·— 4.132 EVENTS NORMALIZED TO 3.669 - μ MESONS

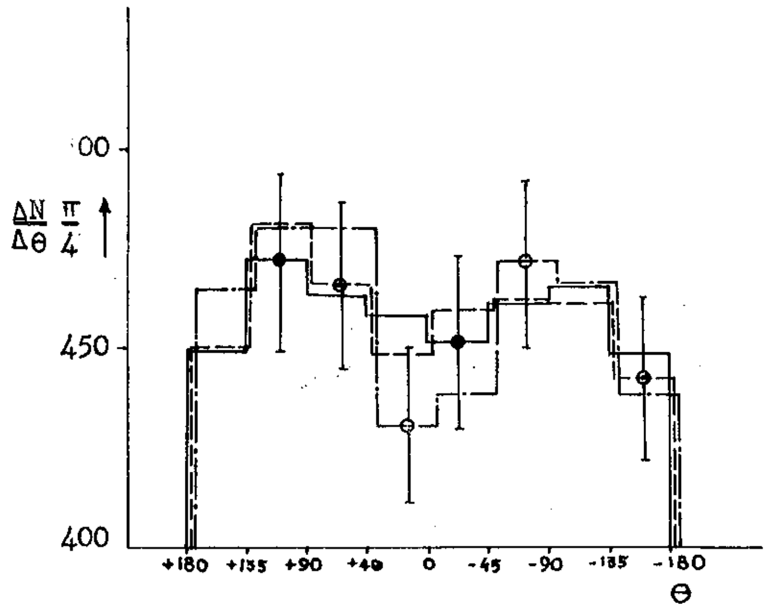

Fig. 3