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THE MU-MESON POLARIZATION IN A STRONG MAGNETIC FIELD

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The muon polarization arising in the $\pi^+ - \mu^+$ decay is partially destroyed in emulsion by the presence of local magnetic fields. The application of a strong external field, however, decouples the muon from the local atomic fields, and the measured asymmetry coefficient of the $\mu^+ - e^+$ decay tends to approach that of the free muon.

In the magnetic field, the spin components parallel and antiparallel to the field have relative populations that depend on the angle of the polarization vector with respect to the field direction. If the muon is completely polarized in its direction of motion, we can calculate the polarization with respect to the field direction as a function of the angle between the initial direction of the muon track and the field vector.

Let a μ meson be emitted from a π meson at rest at an angle α to the direction of the magnetic field. Using the rotation transformation of a spinor, we find that the probability that the electron into which the μ meson decays will be emitted in the angular interval $d(\cos\phi)$ is

$$\frac{d(\cos\phi)}{2} \quad [\,1 + a \cos\alpha \cos\phi\,]. \qquad (1)$$

Here ϕ is measured with respect to the field direction and a is the "asymmetry coefficient", it is assumed that the probability of emission of an electron in an angular interval θ to $\theta + d\theta$ with respect to the direction of complete polarization has the form

$$\frac{1}{2}\,(1 + a \cos\theta) \sin\theta\, d\theta\,.$$

We have made an experimental study of the angular distribution predicted by Eq. (1). The measurements were carried out in 600- μ Ilford

G. 5 emulsion pellicles that had been exposed to π^+ mesons in a field of 14, 250 gausses. The muon and electron directions were measured relative to the field direction for about 3500 π-μ-e events associated with the stopping of π mesons in the emulsion. In less than 5% of the cases the electron track could not be found; the bias introduced was small, as we demonstrated by examining the angular distribution of the group of electron tracks found in a second intensive study of the events in which no electron was found initially. For comparison with Eq. (1), $|\cos\alpha|$ has been broken down into three intervals, and $\cos\phi$ (taken positive when it has the same sense as $\cos\alpha$) also in three intervals. The mean values, $\langle|\cos\alpha|\rangle$ and $\langle\cos\phi\rangle$, in these intervals have been calculated from the measured events. The probability distribution of Eq. 1 when plotted against $\cos\phi$ is a straight line. The slope, a', of the line determined by the events in a given interval of $|\cos\alpha|$ is an estimate of $a\langle|\cos\alpha|\rangle$. In Fig. 1, we show our results graphically for $\langle|\cos\alpha|\rangle = 0.86$, while in Fig. 2 we show the measurements of a' plotted against $\langle|\cos\alpha|\rangle$. The data have been used to evaluate the quantity a, and we obtain

$$a = -0.23 \pm 0.05 .$$

In addition to measuring the asymmetry the experimental results confirm the linearity of Eq. (1), both in $\cos\alpha$ and $\cos\theta$, thus providing additional evidence that the muon behavior is described by a simple spinor.

Since completing our work we have received a preprint by J. Heughebaert, M. Rene, J. Sancton, and G. Vanderhaeghe which reports preliminary data from a similar experiment with a field of 50 to 100 gauss. They obtain $a = -0.22 \pm 0.12$. We understand also that J. Orear is studying the polarization of the muon in a magnetic field, and have seen his calculation of the depolarization expected in muonium formation, which suggests that our field of 14, 250 gausses is ample to produce the complete Paschen-Back effect.

Figure Captions

Fig. 1. The number of decay electrons observed as a function of cos ϕ for $\langle | \cos \alpha | \rangle = 0.86$. Standard deviations are indicated. The slope a' of the least-squares straight line determined by the points is -0.207 ± 0.048.

Fig. 2. The measured value of a' for three intervals of $|\cos \alpha|$.

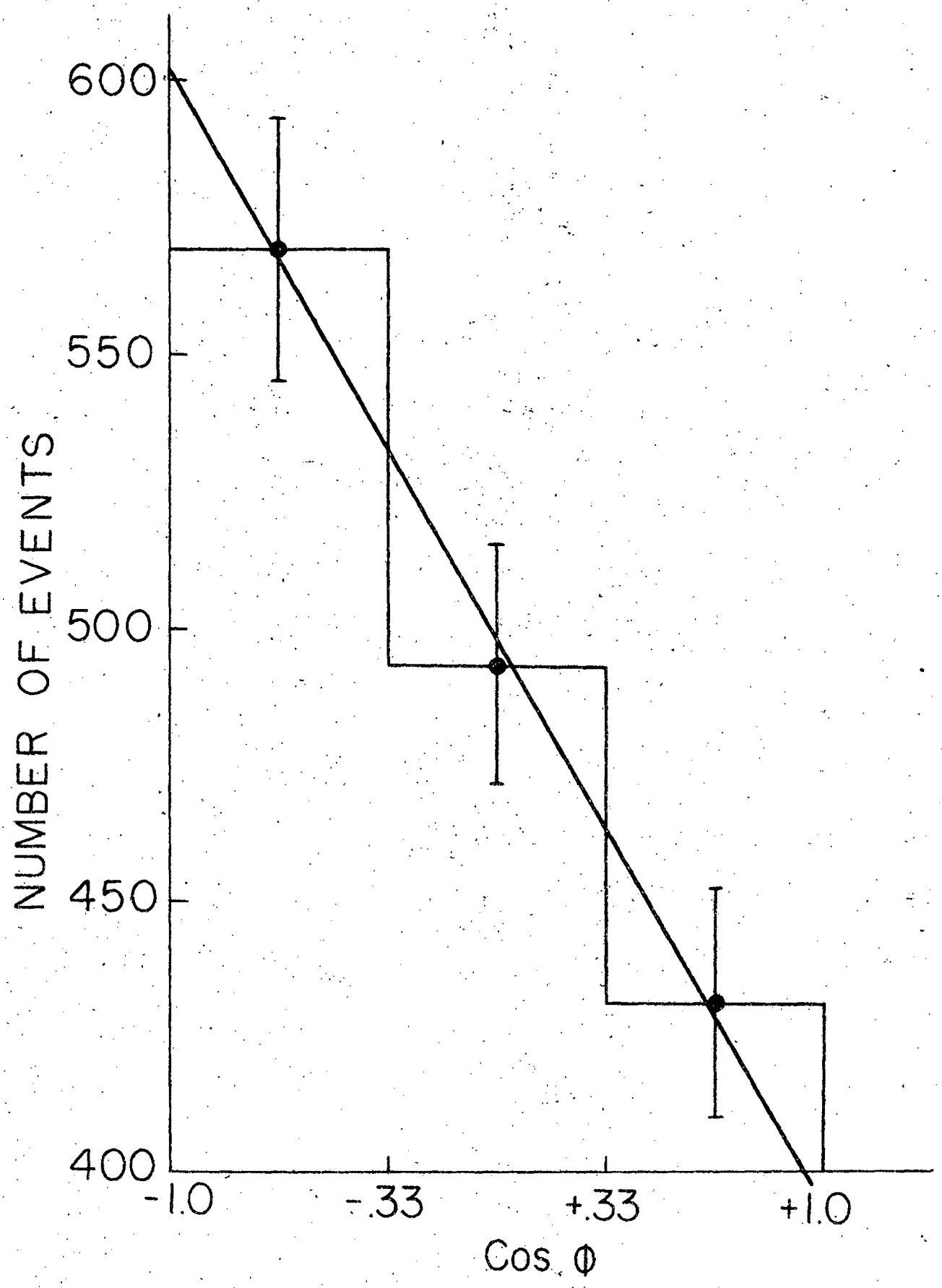

Fig. 1