The spin of the $\mu$ mesons

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We can determine the intrinsic angular momentum of the $\mu$ mesons from the sum of the angular momentum vectors of the lattice oscillations and the sum of the spin vectors of the neutrinos in the lattice and the spin vector of the electric charge which the $\mu$ mesons carry. We used this neutrino lattice before to calculate the rest mass of the $\mu$ mesons. Here we learn how the apparent discrepancy between the concept of a point particle and the finite size of a neutrino lattice is resolved. We also learn that the spin of the $\mu$ mesons originates exclusively from the spin of the electric charge of the $\mu^{\pm}$ mesons.

1 Introduction

We have shown earlier [1] that the spin of the “stable” mesons and baryons can be explained with the standing wave model [2]. In [3] we have determined the rest mass of the $\mu$ mesons with the concepts used in the standing wave model and explained why $m(\mu^{\pm})$ is $\approx 3/4 \cdot m(\pi^{\pm})$. According to [3] the $\mu^{\pm}$ mesons consist of a lattice of $\nu_\mu$ (respectively $\bar{\nu}_\mu$), $\nu_e$ and $\bar{\nu}_e$ neutrinos which remain from the cubic neutrino lattice of the $\pi^{\pm}$ mesons after their decay, plus an electric charge. It has been argued that our explanation of the mass of the $\mu$ mesons cannot be correct because in our model the $\mu$ meson lattice has a diameter of $0.88\cdot 10^{-13}$ cm, whereas the $\mu$ mesons are commonly said to be point particles. However, since in our model the $\mu$ mesons consist of neutrinos, but for the electric charge, and since neutrinos do not, in a first approximation, interact with electric charge or with mass, it will not be possible to establish the size of the $\mu$ meson lattice, i.e. of the $\mu$ mesons, through conventional scattering experiments. Therefore the $\mu$ mesons will appear to be point particles. We will now show that the neutrino lattice does not only determine the mass of the $\mu^{\pm}$ mesons but also provides an explanation of the spin of the $\mu$ mesons which has, so far, not been explained.
2 The spin of the $\mu^\pm$ mesons

The spin $s = 1/2$ or the intrinsic angular momentum $\hbar/2$ of the $\mu^\pm$ mesons can, theoretically, be the sum of the angular momentum vectors of all neutrino lattice oscillations of frequency $\nu_i$ in the $\mu$ mesons, plus the sum of all spin vectors of the $n_i$ neutrinos in the lattice, plus the spin vector of the electric charge which each $\mu$ meson carries. In a formula

$$j(\mu^\pm) = \sum_i j(\nu_i) + \sum_i j(n_i) + j(e^\pm) \quad 0 \leq i \leq N_\mu,$$

where $N_\mu$ is the number of all neutrinos in the $\mu$ meson lattice, $N_\mu = 2.14 \cdot 10^9$. This procedure is completely analogous to the way how the spin of the $\pi^\pm$ mesons is determined, only that then a cubic neutrino lattice is considered consisting of $\nu_\mu, \bar{\nu}_\mu, \nu_\tau$ and $\bar{\nu}_\tau$ neutrinos with $N = 2.854 \cdot 10^9$ neutrinos.

The lattice oscillations in the $\mu$ mesons are longitudinal and hence do not have an angular momentum because for each oscillation $\vec{r} \times \vec{p} = 0$. So the lattice oscillations do not contribute to the intrinsic angular momentum of the $\mu$ mesons, or $\sum_i j(\nu_i) = 0$. Each of the $\mathcal{O}(10^9)$ neutrinos in the $\mu$ meson lattice has, however, an angular momentum $\hbar/2$. The sum of the spin vectors of all neutrinos in the lattice of the $\mu$ mesons must be zero; otherwise the sum of the spin vectors of all neutrinos in the lattice plus the spin vector of the electric charge of a $\mu^\pm$ meson could not be $\hbar/2$, as it must be.

In order to show that the angular momentum vectors around a central axis of the lattice caused by the spin vectors of all neutrinos in the $\mu$ meson lattice is zero we have to consider this lattice in detail, Fig. 1. As we have learned in [3] the, say, $\mu^+$ meson lattice is obtained from the cubic neutrino lattice of the $\pi^+$ meson through the removal of all $\nu_\mu$ neutrinos. That means that in the $\mu^+$ meson lattice are then $N/4 = (2.854 \cdot 10^9)/4$ vacancies at the location where originally $\nu_\mu$ neutrinos were. Each vacancy is surrounded in the $xy$ plane by combinations of four electron neutrinos. In the $z$-direction there is on top as well as below each vacancy another electron neutrino. The same applies for the electron neutrinos around each antimuon neutrino, which are the centers of the cells of a $\mu^+$ meson lattice. The cells of the $\mu$ meson lattice are octahedrons, two pyramids joint at their square base. As can be seen on Fig. 1 each lattice point in the upper right quadrant has at the opposite position in the lower left quadrant the same type of neutrino. The same applies in the upper left and lower right quadrant.
As is well-known it appears that only left-handed neutrinos and right-handed antineutrinos exist, at least as long as the neutrinos are massless. Suppose this also holds in the case of neutrinos with a rest mass. The angular momentum vectors originating from the spin of the neutrinos would then not cancel on a diagonal through the center of the lattice. The spin vectors on either side of the same length on the diagonal are then from the same type of neutrino (Fig. 1) and therefore point in the same direction and do not cancel. However, the polarization vector of the spin of a neutrino depends on the direction of the velocity of the neutrino, because the helicity $H$ is given by

$$H = \vec{P} \cdot \vec{v}/P_v,$$

where $\vec{P}$ is the polarization vector. If only left-handed neutrinos ($H = -\beta$) and right-handed antineutrinos ($H = +\beta$) exist, the direction of $\vec{P}$ must be reversed if the direction of motion of the neutrinos during their oscillation in the $\mu$ meson lattice is, in the lower left quadrant of Fig. 1, opposite to the direction of motion in the upper right quadrant. This change of the direction of motion follows from the equation of motion for the displacements $u_n$ of
the lattice points in Eq.(7) of [2]

\[ u_n = A e^{i(\omega t + n\phi)}, \]

from which follows that \( \dot{u}_n = v_n = i\omega u_n \). The frequencies are given by

\[ \nu_n = \nu_0 \phi_n, \]

as in Eq.(19) of [2]. Since \( n\phi = kx \), \( \phi_n \) is proportional to \( x \) with \( x = na \), where \( a \) is the lattice constant. It follows that the direction of motion of the neutrinos in the upper right quadrant (\( \phi > 0 \)) is opposite to the direction of motion of the neutrinos in the lower left (\( \phi < 0 \)) quadrant. Consequently the angular momentum vectors around the center of the lattice caused by the spin of the neutrinos in the \( \mu \) meson lattice are opposite and of the same magnitude, they cancel. The only point without an opposite is the point at the center of the lattice, at which there is no neutrino, so the center does not contribute a spin vector. The sum of the angular momentum vectors caused by the spin of all neutrinos in the \( \mu \) meson lattice is zero, \( \sum_i j(n_i) = 0 \). Together with \( \sum_i j(\nu_i) = 0 \), as shown above, we arrive from Eq.(1) at

\[ j(\mu^\pm) = j(e^\pm). \]

The spin \( s = 1/2 \) of the \( \mu^\pm \) mesons is caused exclusively by the spin of the electric charge that a \( \mu \) meson carries. Crucial for this point is the absence of a neutrino at the center of the \( \mu \) meson lattice.

The cubic lattice of the \( \pi^\pm \) mesons is easily recovered from the \( \mu \) meson lattice by filling all vacancies with either \( \nu_\mu \) (or \( \bar{\nu}_\mu \)) neutrinos. The \( \pi^\pm \) mesons do not have spin. As in the \( \mu \) meson lattice all neutrino spin vectors around the center of the cubic \( \pi^\pm \) lattice cancel, but for the angular momentum \( \hbar/2 \) of the center neutrino. This angular momentum is canceled by the spin of the electric charge which the \( \pi^\pm \) mesons carry, so \( s(\pi^\pm) = 0 \), as it must be. This explanation supercedes the explanation given in [1] for the spin of the particles of the neutrino branch which applies only for a static lattice.

3 Conclusions

If the \( \mu^\pm \) mesons consist of a lattice of \( \bar{\nu}_\mu \) (respectively \( \nu_\mu \)), \( \nu_e \) and \( \bar{\nu}_e \) neutrinos, as is suggested by the decay of the \( \pi^\pm \) mesons, then it can be shown [3]
that the theoretical mass of the $\mu^\pm$ mesons is, within 1%, equal to the measured mass of the $\mu^\pm$ mesons. Using the octahedronal lattice structure of the $\mu^\pm$ mesons suggested by the determination of the mass of the $\mu^\pm$ mesons it follows that the angular momentum vectors of all longitudinal lattice oscillations are zero and that the sum of the angular momentum vectors caused by the spin of the neutrinos of the lattice, taken around the center of the lattice, is also zero. The only contribution to the intrinsic angular momentum of the $\mu$ mesons comes from the spin of the electric charge which the $\mu^\pm$ mesons carry. Consequently the spin of the $\mu$ mesons is $s(\mu^\pm) = 1/2$, as it must be. We note that the spin of the $\mu$ mesons can be explained, without any additional assumption, from the structure of the $\mu$ mesons which we have used for the explanation of the mass of the $\mu$ mesons.

Both the $\pi^\pm$ mesons and the $\mu^\pm$ mesons carry an electric charge. The $\pi^\pm$ mesons do not have spin, whereas the $\mu^\pm$ mesons have spin 1/2. The presence or absence of a neutrino at the center of the lattice makes the difference. The spin of the electric charge in $\pi^\pm$ is canceled by the spin of the central neutrino, whereas the spin of the electric charge in $\mu^\pm$ remains because there is no central neutrino to cancel the spin of the electric charge.

REFERENCES

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