Report

Brief Report on Matter and Antimatter Asymmetry

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Abstract

The theoretically predicted difference between neutrinos and anti-neutrinos or more generally particles and anti-particles seem to be getting observational confirmation at the Daya Bay facility.

A long standing puzzle has been: Why do we encounter matter, rather than antimatter? The latter is negligible compared to the former. Given the symmetry between matter and anti-matter, this ought not to be the case. An answer has now come thanks to work at the Daya Bay Reactor Neutrino experiment. This is an international collaboration between China and the US, taking place in a Chinese nuclear reactor. What this experiment has found is the following: The hitherto unknown third mixing angle of neutrino oscillation is about eight degrees, the other two mixing angles being already known. This new result implies that neutrinos and anti neutrinos do not oscillate in the same way – there appears to be an asymmetry. This could well be the asymmetry between matter and anti matter.
In fact this result was anticipated in the author's work [1]. The starting point was the so called Snyder-Sidharth dispersion relation, which replaces the usual relation viz.,

$$E^2 = p^2 + m^2 \tag{0.1}$$

The new relation is

$$E^2 = p^2 + m^2 + \alpha l^2 p^4 \quad (c = 1 = \hbar;) \tag{0.2}$$

This is the result of a non-commutative spacetime [2].
We next observe that effectively

$$m^2 \to \vec{m}^2 = m^2 + \alpha\, l^2 p^4$$

So we can get as in the usual theory of the Dirac equation

$$\left(\gamma^0 p^0 + \Gamma + \bar{m}\right) \psi = 0 \tag{0.3}$$

where

$$\bar{m} \approx m + \frac{1}{2}\alpha l^2 p^4$$

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We can demonstrate this as follows. We first rewrite (0.3) using (0.2), as

$$\left(\frac{\partial}{\partial t} - \sum_{k=1}^{3} \alpha^k \frac{\partial}{\partial x^k} - \imath m\beta - \lambda l p^2 \right) \psi = 0 \tag{0.4}$$

where λ turns out to be a suitable matrix and α^k and β are matrices as in the usual theory. Let us now left multiply by

$$\left(\frac{\partial}{\partial t} + \sum \alpha^k \frac{\partial}{\partial x^k} + \imath m\beta + \lambda l p^2 \right)$$

to get

$$\left(D - \lambda^2 l^2 p^4 \right) \psi = 0$$

where D is the full Klein Gordon Hamiltonian and where we choose

$$\alpha^k \lambda + \lambda \alpha^k = 0, \quad \beta\lambda + \lambda\beta = 0$$

Going over to the usual γ matrices,

$$\gamma^0 = \beta, \quad \gamma^k = \beta\alpha^k = \gamma^0 \alpha^k,$$

we get, with

$$\Theta = \gamma^0 \lambda, \quad \Theta = \gamma^5$$

as can be easily verified.
Whence we get the modified Dirac equation

$$\left\{ \gamma^\circ p^\circ + \Gamma + \gamma^5 l p^2 \right\} \psi = 0 \tag{0.5}$$

There is a correction for the usual mass in (0.5), but which is a non-invariant under reflection due to the γ^5 factor.
This indicates a decay of the Fermion at ultra high energy – it is somewhat like ”splitting” of mass a la the Zeeman effect, as was discussed in earlier work.
If $m = 0$ to start with, (0.4) shows the origin of the neutrino mass. Earlier Chados and others inserted this term ad hoc and interpreted it as a superluminal neutrino. These ideas were subsequently dropped [3].
Let us analyse the ultra high energy Dirac equation (0.5) [4] further. This can be done best, as for the usual Dirac equation by considering a reduction to the Pauli equation as is usually done [5].
We get, with

$$\psi = e^{\frac{\imath}{\hbar} mc^2 t} \begin{pmatrix} \phi \\ \chi \end{pmatrix},$$

for the modified Dirac equation, this time

$$\phi = -\frac{\{c(\sigma \cdot \pi) + \omega\}}{2mc^2 + eV} \chi$$

with the Pauli-like equation for χ (instead of ϕ as in the usual theory), given by

$$\imath\hbar\dot{\chi} = [eV - \frac{\{c(\sigma \cdot \pi)\}^2 - \omega^2}{2mc^2 + eV}]\chi \tag{0.6}$$

where $\omega = \Theta l p^2$. For a magnetic field $\vec{B}$, this throws up the spin - magnetic field coupling, this time given by, remembering that we have

$$c(\sigma \cdot \pi)^2 = c^2\pi^2 - \frac{e\hbar c^2}{c}\vec{\sigma} \cdot \vec{B}$$

$$ec\hbar(\vec{\sigma} \cdot \vec{B} + \frac{\omega^2}{ec\hbar})$$

instead of $ec\hbar(\vec{\sigma} \cdot \vec{B})$ for the usual Dirac equation. We can see from (0.6) that we now have, additionally a spin half particle with charge $-e$, but the spin magnetic energy shifted due to the additional term involving ω. The other, positive energy solution ϕ of the usual theory, represents a spin half particle of charge e, but a different spin magnetic coupling energy with the opposite sign of ω^2. In any case this too differs from the usual Dirac theory due to the new effect of the ω term, that is due to the Hamiltonian (0.2).
The "splitting" can be seen because of the new ω term in (0.6). If ω were 0 we would be back to the usual theory.
This is true of any particle and anti-particle. In particular it is true of ν and $\bar{\nu}$. This result was also hinted at a few years ago in the MINOS experiment of Fermilab:
After recording firing of 7×10^{20} protons at the Fermilab target, researchers arrived at a result of $2.35 \times 10^{-3} eV^2$, which represents the square of the difference between the mass eigenstates (Δm^2) of the two different types of neutrino viz., muon and tau.
Later the MINOS team observed antineutrinos. The detector in the Soudan mine operates in the same way except muon antineutrinos produce positively-charged muons rather than their negative counter parts. Neutrino models suggest that antineutrinos should also oscillate between types, where Δm^2 should correspond to the same value as their neutrino counterparts.
The MINOS team surprisingly found a Δm^2 value of $3.35 \times 10^{-3} eV^2$ between muon antineutrinos and tau antineutrinos, which is larger than their neutrino result by approximately 40%! This startling discovery is not yet at the 3 sigma level and needs to be confirmed.
To conclude, the theoretically predicted difference between neutrinos and anti-neutrinos or more generally particles and anti-particles seem to be getting observational confirmation at the Daya Bay facility.

References

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