An explanation and some experiments for Solving the neutron lifetime puzzle via non standard neutrino interactions.

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Abstract

The neutron lifetime puzzle, characterized by a discrepancy between beam (887 seconds) and magnetic bottle (879 seconds) measurements, remains unsolved. This manuscript proposes an innovative explanation involving non-standard neutrino interactions and the inverse quantum Zeno effect. These interactions could reduce the neutron lifetime in magnetic bottle experiments to the observed value. To test this hypothesis, we suggest some experiments using isotopically varied materials and ultra-cold neutron sources. If validated, this work could deepen our understanding of fundamental forces, with significant implications for cosmology, dark matter, and particle physics.

Keywords

Neutron Decay, Quantum Zeno Effect, Neutrino Background

Introduction

Serveral neutron decay experiments recently have pinned the neutron lifetime down, but instead of one lifetime, two different lifetimes are observed depending on whether the neutron was observed to decay in a beam or in an ultracold state in a magnetic bottle. For example see [1], where beam has a lifetime of around 887 seconds, while bottles have a lifetime of around 877 seconds. Understanding neutron interaction is very importantly in cosmology and the production of elements in the early universe [18].

In 2021 we finally published our theory of a new neutrino interaction [3], an axial charge that reverses its spin if the neutrino spin is reversed, which also predicts a neutrino background new ordinary matter that is needed to screen out excess charges from Baryons in the new interaction. In general, we may place a charge $+1$ on an electron neutrino, and an interaction strength of α_a, we would assume that no new charge would be found on an electron as the electron interactions are very well described by the electromagnetic interaction. If the new charge is to be conserved in weak interactions, the neutron must have a charge 1 more than proton $n \to p + e^- + \nu$ then $Q(n) = Q(p) + 1$. Although our previous work assumes a new force or Axial force charge, is the same for neutrons with opposite spin, we do not need to assume that here, and it could be either reverse or stay the same under spin flip.

Giacosa and Pragiara [13] showed that the inverse quantum Zeno effect could increase the decay rate of the neutron if some new interaction, interacts with neutrons in a bottle with a rate of about a billion times per second. This would have to be new physics as existing interactions would not cause such interactions.

In general, if an interaction is to increase the neutron decay rate, it needs to be an interaction which can effectively measure that a neutron is a neutron and some decay products are its decay products, the vast difference in mass /charge ratio of a neutron to a neutrino would do that here.

It would be noted that Axion like particles in a background to an experiment would also increase the neutron decay rate we must be careful however that such particles do not convert to photons (as regular Axions might) on contact with the neutron, as electromagnetic signal would have been observed.

Inverse Quantum Zeno Effect

The quantum Zeno effect was rigorously described by Degasperis, Luciano Fonda, and Giancarlo Ghirardi, [9], and later by Misra, B. and Sudarshan [**?**]. It shows that when a reacting quantum state is repeatedly measured or interacted with, the act of measuring reduces the speed of the reaction. The quantum Zeno effect was first measured experimentally by Wineland et al [23] in 1989, and has been confirmed many times since.

Related to the quantum Zeno effect there is also the watchdog effect by K.Kruss [24]. In general, depending on the Hamiltonian the slowing of a decay can sometimes be an increase the decay rate [14] When this happens the effect is known as the inverse quantum Zeno effect. It is the Inverse Zeno effect that is needed here. According to Giacosa [13] if the neutron is interacted with around a billion times per second in a bottle, it produces an inverse zero effect of the correct magnitude to explain the neutron decay lifetime puzzle.

Neutrinophilic forces and our axial force

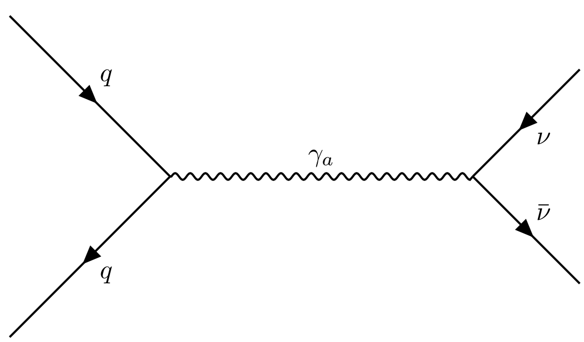
Neutrios are well studied and important to physics and cosmology [6] but there are still large regions of parameter space that allow non standard model interactions [5].

In 2005 we started investigating whether neutrinos might interact with an in additional force and our paper on the subject was finally published in 2021 [3]. We found a possible neutrino wave equation with additional right-handed neutrinos in the keV or MeV mass range. We found an earlier paper by L.M. Slad [7], that showed that an axial force completes the possible Poincare invariant forces for a particle. We also showed that have a neutrino axial force and an electron vector force (electromagnetism) simultaneously leaves left and right-handed weak forces completely separate due to charge conversation, indicating why the known weak force is purely left-handed.

Our force introduces one new particle, the axi-photon is a spin-1 gauge force particle of low or zero mass, and one vertix where a quark or neutrino (right-handed as well as left) emits or absorbs an axi-photon. They will be a force constant on the charge, α_a and scattering between quarks and neutrinos may be represented as in our diagram.

In order for the combined summing of the charges on protons and neutrons charges in matter, not to overwhelm the mechanical stability of matter under the electronic magnetic force, we find we needed a background of neutrinos. Due to the Fermi energy of the neutrinos many of the background particles would need to be right-handed neutrinos with keV energies. It is this background interacting with our axial force and then neutrons that we find here might be the cause of the neutron decay anomaly.

There are other, existing, models of the Neutron Decay Anomaly. Tan [10] model of a neutron oscillating to a mirror neutron, using Roberts Foots [11] hardly interaction copy of the standard model. Another model is an excited Neutron state decaying by an invisible particle, but particle mass ruled within a narrow mass range near twice the electron mass [12]



Possible models of the neutron decay anomaly

We already have that $Q(n)-Q(p) = 1$ and we must assume the force has a range of a least several nanometres and is conserved at least over intermediate time periods. If when the neutron spin is reversed the new charge reverses, then any net charge of our new force only occurs when many neutrons are polarised in a magnetic field. If on the other hand, all neutrons have the same charge, then any material that the charge density is $q = N_nQ_n + N_pQ_p + X$ where X is any the charge on any other near by particles, which we assume are a background of neutrinos. Total neutrality is needed over on average the range of the force. As there is a neutrino plasma expected, unless force screened by its own mass, it will also Debye screened by the plasma. So that beyond the screened range net neutrality is no longer needed.

Given a cross-section for interaction of σ and n neutrinos per unit area travelling near light speed as they have low mass, we have the interaction rate I per neutron per second, as

$$I = \rho_\nu r^2 \sigma c$$

which we need to be about a billion times per second according to Giacosa et al [13]

In our paper [3], we needed for neutrality a neutrino background of around 10ˆ17 neutrinos per cubic meter given a Debye screening distance of 5 nm, for air. This produces an interaction rate of one third of a billion, already near the right amount for explaining the neutron decay rate. Since high-speed neutrons are observed to have a slower decay rate, we need them to have a much lower interaction rate with neutrinos, asymptotic screening at high energies which we did observe in our interaction rate on paper, in section 12.2 on neutrino scattering we found the rate declines approximately as the neutrino energy [3].

Experiments

In order to see if it is a neutrino background that screens out a new force on neutrinos and neutrons that is causing the neutron lifetime puzzle, we need to compare the decay rate in the cases of the presence of three kinds of matter, a material with high proton to neutron ratio, a material with equal protons and neutrons numbers and finally a material that with high amounts of extra neutrons. Plotting the excess proton and neutron density of the nearby material, against the neutron decay rate, we would see different rates depending on the isotopic ratios of protons to neutrons in the material. In [3] our first NSI paper we assumed for simplicity that neutrons had a new (axial) charge of +1/2 and protons -1/2, in such a case they would be no neutrino background for say carbon-12 or oxygen-16 backgrounds, a positive result would be a return of the decay rate to the neutron beam decay rate for such materials. A negative result would be the same decay rate for all isotopic types of nearby material. In short, we need to try the neutron bottle experiment in magnetic bottles, with isotopically different materials.

The Recent UCN (ultra-cold neutron)experiments [19], seem to have used aluminium _13 Al 27 coated with a high fluorine Flobium Oil, such materials have a high neutron excess, and since a magnetic bottle is used, a high magnetic field (there 5 Telsa) is present near the experiment potential polarizing nuclei in the material (but at a low amount at room temperature). Since polarisation increases when temperatures are low, we might see an increased neutron decay rate (in the case where only net spins on neutrons introduce the new force) at much lower temperatures. Polarisation only matters for the case where opposite spin Baryons have opposite charges under our new force.

To use equal amounts of protons and neutrons in the near by material we suggest replace the material with carbon 12 graphite. While water ice would be (at low temperature) the ideal material for a high amount of excess protons.

The Size of the experiment may be a factor. At some distance inside trap material in larger bottles, the background neutrinos might diminish in density to the background air density (we estimated 10^{-17} in [3], while in smaller traps more neutrons are nearer material walls, and might interact with high levels of neutrino background at the similar to the density of excess neutrons inside the material, e.g. 10^{21} calculated for Pyrex in 2. Interestingly, Tan Wang [10] states that "All the smaller magnetic traps, such as the Ioffe-type NIST trap [19] HOPE [20], and tSPECT [21] [22], have produced very low values for neutron storage lifetime, sometimes more than 100 s lower than "accepted" lifetime values.

The experimental cost of such materials is not large, the researchers would of course need access to an ultra cold neutron source.

Conclusions

We observed that our new axial force described in [2] might explain the neutron lifetime puzzle, in the preserve of the standard quantum theory of the inverse quantum Zeno effect. We suggested a lab experiment which could in the time scale of a few years at most determine if our force was truly responsible for neutrons change in lifetime depending on the type of experiment measuring it.

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