A possible laboratory test for the axions

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Introduction

The axion is a hypothetical light boson with spin zero which was introduced [1, 2] theoretically more than 3 decades ago, following the Peccei-Quinn solution [3] to the strong CP problem. The axion is one amongst the candidates for dark matter [4] along with neutrinos, WIMPS, SIMPS, CHAMPS and Super heavy particles which could possibly be detected by neutrino facilities like IceCube. Through scalar (g_s) and pseudo scalar (g_p) couplings with ordinary matter, the axion could generate a P and T violating force [5] at macroscopic distances, of the order of cm, if its mass is sufficiently small of the order $10^{-5}eV$. As such considerable interest has been evinced in measuring the force in laboratory experiments [6]. In the KSVZ model [7], the axion interacts only with quarks but not with leptons, whereas the axion in the DFSZ model [8] interacts with leptons as well as quarks. Photoproduction of axions, its inverse process, bremstrahlung, decay of axions into two photons, axion production in NN collisions and in electromagnetic fields have all been considered theoretically [9]. The CERN Axion Solar Telescope (CAST) is designed to study such processes taking place in the Sun. The study of axion electrodynamics [10] has motivated the development of topological insulators [11]. Axion search through QED vacuum birefringence [12] and recent solar axion studies [13] may also be cited.
The purpose of the present contribution is to suggest a laboratory test for the existance of axions.

Theoretical Calculation

Let us consider that the electron is energised by the absorption of a photon with four momentum q_1 as in the case of Compton effect [14]. Using the same notations as in [14], this could lead to the emission of a photon with four momentum q_2 such that $p_1 + q_1 = p_2 + q_2$ where p_1 and p_2 denote the initial and final four momenta of the electron. If axions exist, the possibility of the emission of an axion with four momentum k such that $p_1 + q_1 = p_2 + k$ cannot be ruled out. Therefore, if an experiment is designed to observe the recoil electrons at a given angle ϕ as shown in fig 1,

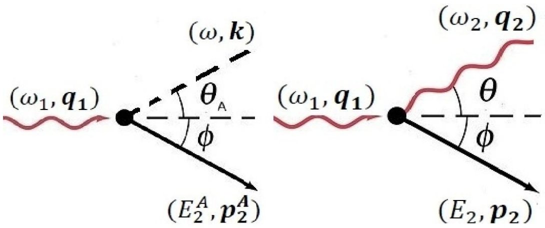

FIG. 1: Left: Axion Production, Right: Compton Scattering.

the energy $E_2 > m$ of the recoil electron in the laboratory is readily obtained using relativistic kinematics both in the cases of Axion production and Compton effect. If the axion is sufficiently heavy, the recoil electron energy resolution at a given angle ϕ would right away reveal the existence of axions. If the energy resolution is not sufficiently fine in view of the smallness of the axion mass $m_A \approx 10^{-5}eV$, we propose measuring the spin polarization of the recoil electron. The Feynman diagrams R

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and S for Compton scattering and R_A, S_A for axion production are shown in fig 2.

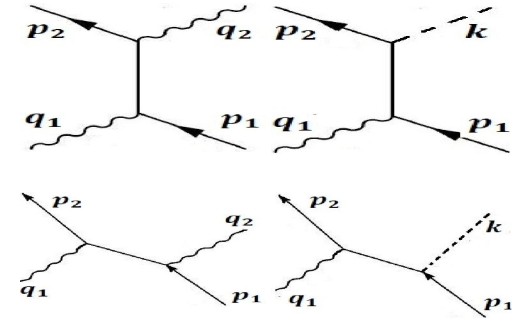

FIG. 2: Clockwise from top left Feynman R, R_A, S_A and S diagrams.

Working in the transverse frame employed in [14], the interference between the matrix elements M for the Compton effect and M_A for the axion production leads to a spin density matrix for the recoil electron with polarization in the $\mathbf{q_1} - \mathbf{p_2}$ plane, which is absent if R_A and S_A do not exist. It is important to note that the polarization of the electron in the scattering plane contains terms proportional to the weak coupling constant, whereas the macroscopic force [5] generated by axion exchange is proportional to $g_s\, g_p$. Numerical estimates for the recoil electron polarization at different ϕ and for different values of m_A and the weak coupling constant will be presented.

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