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Electromagnetic properties of neutrinos

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Abstract:

A review of theory and phenomenology of neutrino electromagnetic properties is presented. A massive neutrino even in the easiest generalization of the Standard Model inevitably has nonzero electromagnetic characteristics, at least nonzero magnetic moment. Although its value, determined by the neutrino mass, is very small, in other BSM theories much larger values of magnetic moments are predicted.

A short introduction to the derivation of the general structure of the electromagnetic interactions of Dirac and Majorana neutrinos is presented.

A thorough account of electromagnetic interactions of massive neutrinos in the theoretical formulation of low-energy elastic neutrino-electron scattering is discussed on the basis of our recently published paper. The formalism of neutrino charge, magnetic, electric, and anapole form factors defined as matrices in the mass basis with account for three-neutrino mixing is presented.

Then we discuss experimental constraints on neutrino magnetic and electric dipole moments, electric millicharge, charge radius and anapole moments from the terrestrial laboratory experiments. A special credit is done to bounds on neutrino electromagnetic characteristics (including magnetic and electric dipole moments, millicharge and charge radius) obtained by the reactor (MUNU, TEXONO and GEMMA) and solar Super-Kamiokande and the recent Borexino and COHERENT experiments.

The effects of neutrino electromagnetic interactions in astrophysical and cosmological environments are also reviewed. The main manifestation of neutrino electromagnetic interactions, such as: 1) the radiative decay in vacuum, in matter and in a magnetic field, 2) the Cherenkov radiation, 3) the plasmon decay, 4) spin light in matter, 5) spin and spin-flavour precession, 6) neutrino pair production in a strong magnetic field, and the related processes along with their astrophysical phenomenology are also considered.

The best world experimental bounds on neutrino electromagnetic properties are confronted with the predictions of theories beyond the Standard Model. It is shown that studies of neutrino electromagnetic properties provide a powerful tool to probe physics beyond the Standard Model.

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