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Electromagnetic properties of neutrinos

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We start with an introduction to the theory of neutrino electromagnetic properties [1]. Then we consider the most recent experimental constraints on neutrino magnetic μ and electric d moments, millicharge q , charge radii r_{v2} and anapole a_v moments from the terrestrial experiments (the bounds from MUNU, TEXONO, GEMMA, Super-Kamiokande, Borexino, COHERENT, XENON1T, CONUS and the most recent bounds from XENONnT [2] and LUX-ZEPHELIN [3]) and also discuss results of the recent studies on possible manifestations of neutrino electromagnetic properties in astrophysics [4-7]. Then we focus on the main manifestation of neutrino electromagnetic interactions, such as: 1) the radiative decay in vacuum, in matter and in a magnetic field, 2) the neutrino Cherenkov radiation, 3) the plasmon decay to neutrino-antineutrino pair, 4) the neutrino spin light in matter, and 5) the neutrino spin and spin-flavour precession are discussed. Phenomenological consequences of neutrino electromagnetic interactions (including the spin light of neutrino) in astrophysical environments are also reviewed. The best bounds from laboratory experiments and astrophysical observations on neutrino electromagnetic properties are confronted with the predictions of theories beyond the Standard Model.

[1] C.Giunti, A.Studenikin, Neutrino electromagnetic interactions: A window to new physics, *Rev. Mod. Phys.* 87 (2015) 531. [2] A.Khan, Light new physics and neutrino electromagnetic interactions in XENONnT, *Phys. Lett. B* 837 (2023) 137650. [3] M.Atzori Corona et al., New constraint on neutrino magnetic moment from LZ dark matter search results, *Phys. Rev. D* 107 (2023) 053001. [4] C.Giunti, K.Kouzakov, Y.F.Li, A.Lokhov, A.Studenikin, S.Zhou, *Annalen Phys.* 528 (2016) 198. [5] K.Stankevich, A.Studenikin, Neutrino quantum decoherence engendered by neutrino radiative decay, *Phys. Rev. D* 101 (2020) 5, 056004. [6] A.Popov, A.Studenikin, Manifestations of nonzero Majorana CP-violating phases in oscillations of supernova neutrinos, *Phys. Rev. D* 103 (2021) 115027. [7] S.Jana and Y.Porto, Resonances of supernova neutrinos in twisting magnetic fields, *Phys. Rev. Lett.* 132 (2024) 101005.

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