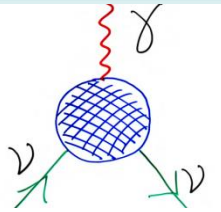
Electromagnetic Properties of ν

(effects of magnetic moments)

MSU Alexander Studenikin JINR

C.Giunti, A.Studenikin, "ν electromagnetic interactions: A window to new physics", Rev.Mod.Phys, 2015

Studenikin, "ν electromagnetic interactions: A window to new physics - II", arXiv: 1801.18887



matrices in ν mass eigenstates space

① νEP theory - ν vertex function

$$\Lambda^{if}_{\mu}(q) = f^{if}_{Q}(q^2)\gamma_\mu + f^{if}_{M}(q^2)i\sigma_{\mu\nu}q^\nu + f^{if}_{E}(q^2)\sigma_{\mu\nu}q^\nu\gamma_5 + f^{if}_{A}(q^2)(q^2\gamma_\mu - q_\mu \not{q})\gamma_5,$$

electric charge

magnetic moment

electric moment

anapole moment

form factors $f^{if}_{X}(q^2)$ at $q^2 = 0$ static EP of ν

Dirac ν Majorana

	Dirac ν	Majorana ν
q_{if}		$q_{if} = 0$
μ_{if}		$\mu_{if}(i \neq f)$
ε_{if}	$\neq 0$	$\varepsilon_{if}(i \neq f)$
a_{if}		a_{if}

CPT + charge concervation

Hermiticity and discrete symmetries of EM current put constraints on form factors

$$\langle \nu(p')|J^{EM}_{\mu}|\nu(p)\rangle = \bar{u}(p')\Lambda_\mu(q)u(p)$$

② $\mu^D_{jj} = \frac{3e_0 G_F m_j}{8\sqrt{2}\pi^2} \approx 3.2 \times 10^{-19}\mu_B \left(\frac{m_j}{1\ \text{eV}}\right)$

- much greater values are Beyond Minimally Extended SM
- transition moments $\mu_{i\neq f}$, $\varepsilon_{i\neq f}$ are GIM suppressed

reactor ν scattering

③ νEP experimental bounds

$\mu^{eff}_{\nu} < 2.8 \times 10^{-11}\mu_B$ (2.9 ~0.1)

GEMMA Coll. 2012

Borexino Coll. 2017

Astrophysics, Raffelt ea 1988

Arcoa Dias ea 2015

$q_{\nu_e} < \sim 10^{-12}$ AS '14, Chen ea '14

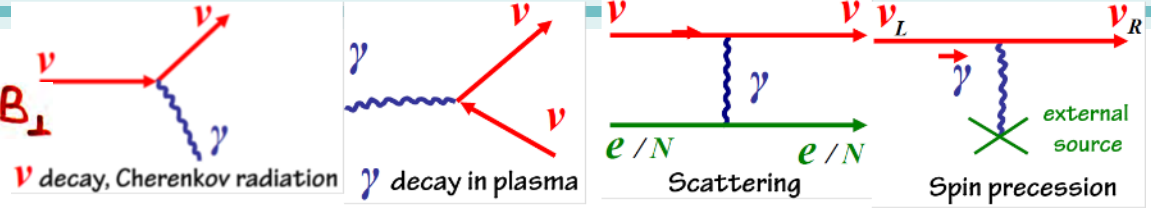
$\sim 10^{-19}$ AS '14 (astrophysics)

$\sim 10^{-21}$ neutrality of matter

e_0

Effects of ν magnetic moment:

- spin precession and oscillations in $B_\perp$



Cisneros, Okun, Voloshin, Vysotsky, Valle, Raffelt, Schechter, Petkov, Akhmedov, Lim, Marciano, Smirnov, Pulido, Dvornikov, Grigoriev, Lobanov, Lokhov, Kouzakov, Ternov, Studenikin et al

New effects reported at Neutrino 2018

1 Electromagnetic interactions and oscillations of ultrahigh-energy cosmic ν in interstellar space

Kouzakov & AS, poster # 174
PRD 96 (2017)

$$L_B = \pi/\mu_\nu B$$

$$P_{\nu^L \to \nu^R}(x) = \sin^2\left(\frac{\pi x}{L_B}\right)$$

$$P_{\nu_e^L \to \nu_\mu^L}(x) = [1 - P_{\nu^L \to \nu^R}(x)] \sin^2 2\theta \, \sin^2\left(\frac{\pi x}{L_{\rm vac}}\right)$$

amplitude of flavour oscillations is modulated by $\mu_\nu B$ frequency

2 ν flavour, spin and spin-flavour oscillations and consistent account for a constant magnetic field

Popov & AS, poster # 140 **arXiv: 1803.05766**
probability of spin oscillations depends on Δm^2

$$P_{\nu_e^L \to \nu_e^R} = \left\{ \sin(\mu_+ B_\perp t)\cos(\mu_- B_\perp t) + \cos 2\theta \sin(\mu_- B_\perp t)\cos(\mu_+ B_\perp t) \right\}^2 - \sin^2 2\theta \sin(\mu_1 B_\perp t)\sin(\mu_2 B_\perp t)\sin^2\frac{\Delta m^2}{4p}t$$

3 ν spin and spin-flavour oscillations engendered by transversal matter current

Pustoshny & AS, poster # 139 **arXiv: 1801.08911**
Studenikin 2004, 2017

- transversal matter currents $j_\perp$ do change ν helicity !

4 Spin-light of ν in Gamma-Ray Bursts

new mechanism of EM radiation by ν
JCAP 1711 (2017) no. 11, 024

Grigoriev, Lokhov, Studenikin, Ternov, poster # 167