Probing Neutrino-Scalar Couplings*

P. S. Pasquini†

Instituto de Física Gleb Wataghin - UNICAMP,

13083-859, Campinas SP, Brazil and

AHEP Group, Institut de Física Corpuscular – C.S.I.C./Universitat de València. C/Catedratico José Beltrán, 2 E-46980 Paterna (València) - SPAIN

O. L. G. Peres

Instituto de Física Gleb Wataghin - UNICAMP,

13083-859, Campinas SP, Brazil and

The Abdus Salam International Centre for Theoretical Physics,

Strada Costiera 11, 34014 Trieste, Italy.

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Abstract

Motivated by discovery of scalar particles at the LHC, we revisit the bounds from Yukawa couplings of scalar particles with neutrinos. Using data from meson decays and including for the first time the spectrum from meson decays we manage to put the following constraints for massless scalars: $|g_e|^2 < 1.9 \times 10^{-6}$, $|g_\mu|^2 < 1.9 \times 10^{-7}$ at 90%C.L. and we get bounds on massive scalars up to 100 MeV.

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INTRODUCTION

Neutrino masses may imply new interactions to scalar particles with several mass scales. One should ask how strong can be those interactions to be accommodate into currently data. Thus, we probe phenomenologically motivated neutrino Yukawa Couplings of the form,

$$-\mathcal{L}_{\rm int} = \frac{1}{2} g_{\alpha\beta} \overline{\nu}_\alpha \nu_\beta \chi_1 + \frac{i}{2} h_{\alpha\beta} \overline{\nu}_\alpha \gamma_5 \nu_\beta \chi_2 \tag{1}$$

$\chi_1(\chi_2)$ is a (pseudo-) scalar particle. This interactions can change meson decay,

$$P^- \to l + \overline{\nu}, \tag{2}$$

by adding a new possible reaction that also emits a scalar particle χ,

$$P^- \to l + \overline{\nu}_m + \chi \tag{3}$$

that is experimentally indistinguishable from Eq. (2). Notice that now in ν_m, $m = e, \mu, \tau$ not only $m = l$. This new contribution was calculated by [1] and can be parametrized as,

$$\Gamma(P \to l + \text{Anything}) = \Gamma_{\rm SM} + |\mathrm{g_l}|^2 \Gamma' \tag{4}$$

where $\Gamma' = \Gamma'(m_l, m_\nu, m_\chi, m_P)$ changes the usual two-body decay due to this new interaction and

$$|g_l|^2 = \sum_m |g_{lm}|^2 + |h_{lm}|^2 \tag{5}$$

ANALYSIS AND RESULTS

We used recent data from [2–5] of leptonic decay rates of π, K, D, D_s and B meson considered the standard model prediction of Γ, this was possible only because of recent calculations of f_p in lattice QCD [6]. By taking a χ^2 of the form,

$$\chi^2 = \sum_i \frac{\left(\Gamma^{(i)}_{\text{exp}} - \Gamma^{(i)}_{\text{teo}}\right)^2}{\sigma_i^2} \tag{6}$$

we extracted new limits for masses ranging from zero to 300 MeV, the full description of the analysis can be found in [7], results for zero scalar mass are presented in Table I and for non-zero masses in Figure 1

Constants	Ref. [8]	Ref. [9]	Our Results
$\|g_e\|^2$	$< 4.4 \times 10^{-5}$	$< (0.8 - 1.6) \times 10^{-5}$	< 4.4 (4.4) $\times 10^{-5}$
$\|g_\mu\|^2$	$< 3.6 \times 10^{-4}$		< 4.5 (3.6) $\times 10^{-6}$
$\|g_\tau\|^2$	$< 2.2 \times 10^{-1}$		< 40 (8)

TABLE I: Comparison between previous bounds [8, 9] with our results with $m_\chi = 0$, using the rates of the meson decay at 90% C.L. In Black the bounds marginalizing V_{CKM} in Red, taking the central value of uncorrelated measurements.

We also used heavy neutrino search [10, 11] to constraining even further the bounds. It was possible due to the fact that the virtual neutrino ν_x of the decay of Eq. (3) can acquire a virtual mass m_x that mimics a continuum spectrum of heavy neutrinos ν_H that was probed in those searches. Thus, setting $m_x = m_H$ into the differential decay rate of the decay $P \to l\overline{\nu}\chi$, we can translate point to point previous bounds of the mixing $|U_{lH}|$ of the heavy neutrino to the lepton into bounds to the Yukawa coupling between scalar and the SM neutrino, the allowed region of the parameter space can be found on Figure 1.

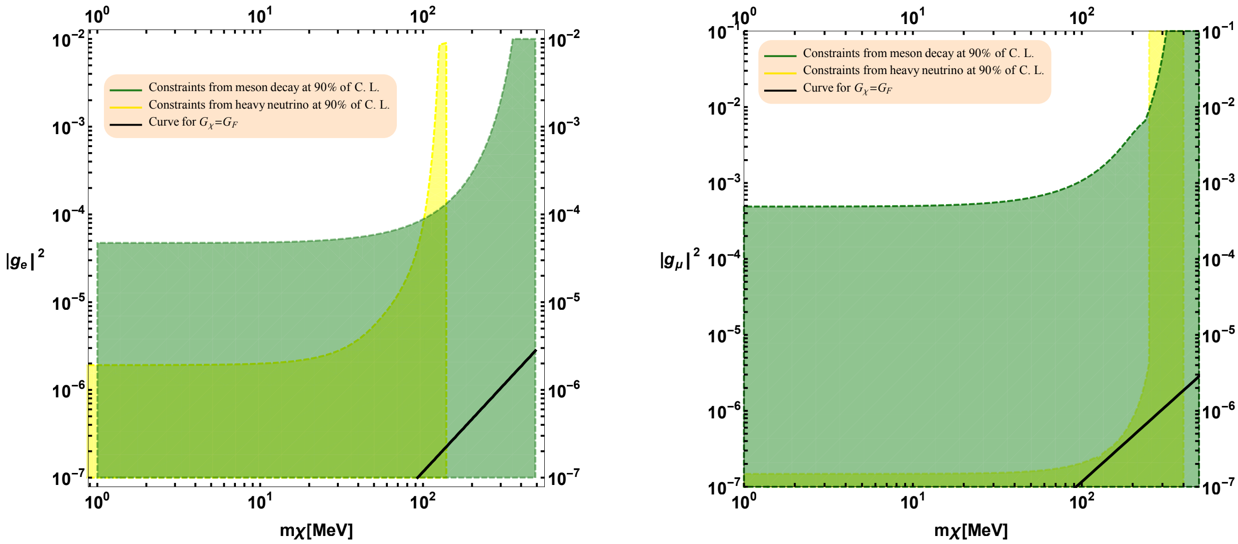

FIG. 1: Bounds on $|g_l|^2$ at 90% C.L. The Green part comes from meson decay and the Yellow part from heavy neutrino search. The black line are interactions weaker than the weak interaction.

CONCLUSION

We recalculated bounds for Yukawa interactions between Neutrinos and Hypothetical scalar particles χ using recent data and decay rates rather than branching fractions for two cases, (I) $m_\chi = 0$ and obtaining $|g_e|^2 < 1.9 \times 10^{-6}$ and $|g_\mu|^2 < 1.9 \times 10^{-7}$ at 90%C.L., which is an improvement on previous results in literature and (II) $m_\chi \neq 0$ showing that those bounds can be safely used up to 100 MeV scales and no bounds can be put for masses $m_\chi \gtrsim 300$ MeV.

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† Electronic address: `pasquini@ifi.unicamp.br;orlando@ifi.unicamp.br`

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