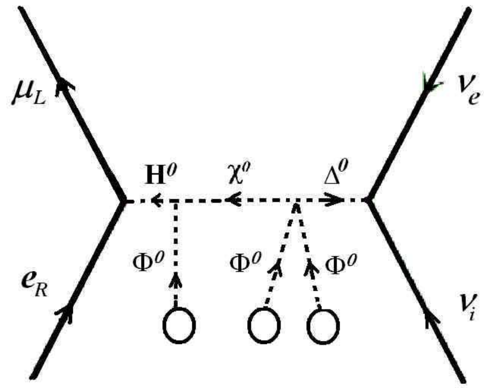

Figure 1: Scalar exchange inducing lepton number violating decay $\mu^+ \to e^+ + \overline{\nu}_e + \overline{\nu}_i$ through operator $\mathcal{O}_1$.

unitarity of K and the fact that $(\mathcal{M}^2)_{13} = 0$, we can write down the branching ratio to be

$$Br(\mu^+ \to e^+ \overline{\nu}_e \overline{\nu}_i) = \frac{|h_{\mu e} f_{ei}|^2 |K_{12} K_{32}^*|^2}{32 M_1^4 G_F^2} \left(1 - \frac{M_1^2}{M_2^2}\right)^2 \left(1 - \frac{M_2^2}{M_3^2}\right)^2 . \tag{7}$$

Noting that $|K_{12} K_{32}^*| \leq 1/2$, and demanding that Br is in the range $(0.0015 - 0.002)$, we obtain an upper limit on the lightest neutral scalar mass M_1: $M_1 \leq (442 - 412)$ GeV. If $|K_{12} K_{32}^*|$ is less than 1/2, M_1 will have to be even lighter. The heavier masses M_2 and M_3 cannot be very much larger, or else the mixing angle $|K_{12} K_{32}^*|$ will be suppressed. We estimate $M_{2,3}$ to be not larger than M_1 by about a factor of 2. While these limits hold for the neutral scalars, their charged partners should also have comparable masses. Any splitting between the masses of the neutral and charged scalars will be $SU(2)_L$–breaking, and is limited by the electroweak ρ parameter.

Ψ_i in Eq. (5) can be Ψ_e, Ψ_μ or Ψ_τ. Consider the case when $\Psi_i = \Psi_e$. In this case, the Lagrangian of Eq. (5) conserves two combinations of leptons numbers, viz., $(L_e + 3L_\mu)$ and L_τ. A Z_3 subgroup of electron number is also preserved. It is not required that these symmetries be broken, so they may be used to prevent rare processes at undesirable rates.[2]

If $\Psi_i = \Psi_\mu$ in Eq. (5), then muon and tau lepton numbers are unbroken. Also unbroken is a Z_2 subgroup of electron number. If $\Psi_i = \Psi_\tau$, then $(L_e + 2L_\mu)$ and $(L_\mu + L_\tau)$ are unbroken, as is Z_2 subgroup of L_e. These symmetries guarantee that potentially dangerous lepton number violating processes remain small.

The scalar fields Δ, χ and H carry lepton number symmetries (or a discrete subgroup of these symmetries), so that they do not acquire VEVs. This can be ascertained by choosing the mass–squared of these scalars to be positive. The lepton number symmetries

[2]We have in mind a scenario where the solar and the atmospheric neutrino oscillations arise from neutrino masses and mixings induced by the seesaw mechanism. Lepton flavor violation that arises from the seesaw mechanism is too tiny to be observable in any processes other than neutrino oscillations themselves.