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1. SU(5) MFV

Here we adopt a modified minimal flavor violation, where the flavor group of our model is $\mathcal{G}_f = SU(3)_{10} \times SU(3)_{\bar{5}}$. Under this group the standard model particles and yukawas transform as follows:

$$u^c, q, e^c(3,1) \tag{1}$$
$$d^c, l(1,3) \tag{2}$$
$$Y_u(\bar{6},1) \tag{3}$$
$$Y_d, Y_e^T(\bar{3},\bar{3}) \tag{4}$$
$$\tag{5}$$

In the MFV spirit all higher dimensional standard model operators should be written with insertions of yukawa matrices to make these operators invariant under $\mathcal{G}_f$. The four dimension 6 baryon number violating operators can be made invariant to second order in the yukawas with the following wilson coefficients (each term individual term should appear with a coefficient c_i).

1. $C_{qqql}^{ijkl} = Y_u^{ij} Y_d^{kl} + Y_u^{ik} Y_d^{jl} + Y_u^{jk} Y_d^{il}$
2. $C_{duql}^{ijkl} = \delta^{il}\delta^{jk} + (Y_d^\dagger)^{ij} Y_u^{kl}$
3. $C_{qque}^{ijkl} = \delta^{ik}\delta^{jl} + \delta^{jk}\delta^{il} + Y_u^{ij}(Y_u^\dagger)^{kl}$
4. $C_{duue}^{ijkl} = (Y_d^\dagger)^{ij}(Y_u^\dagger)^{kl} + (Y_d^\dagger)^{ik}(Y_u^\dagger)^{jl}$

Note that $\mathcal{O}_{duql}$ and $\mathcal{O}_{qque}$ can be made into flavor singlets with no yukawa insertions. We choose a basis for the yukawas such that $Y_u = \text{diag}(\lambda_u, \lambda_c, \lambda_t)$ and $Y_d = V_{\text{CKM}}\text{diag}(\lambda_d, \lambda_s, \lambda_b)$. Only $\mathcal{O}_{qqql}$ and $\mathcal{O}_{duql}$ can contribute to $p \to K^+\bar{\nu}$. Inserting our choice for the yukawa basis, expanding out the flavor indices, and working to lowest order these two operators contribute to $p \to K^+\bar{\nu}$ as:

1. $\mathcal{O}_{duql}|_{p\to K^+\bar{\nu}} = -(\bar{s}_R^c u_R)(\bar{d}_L^c \nu_{\mu L})$
2. $$\begin{aligned}\mathcal{O}_{qqql}|_{p\to K^+\bar{\nu}} =& V^{2l}\lambda_u\lambda_s(\bar{s}_L^c d_L)(\bar{u}_L^c \nu_{lL}) - V^{2l}\lambda_u\lambda_s(\bar{s}_L^c u_L)(\bar{d}_L^c \nu_{lL}) + \\ & V^{2l}\lambda_u\lambda_s(\bar{d}_L^c s_L)(\bar{u}_L^c \nu_{lL} - V^{2l}\lambda_u\lambda_s(\bar{d}_L^c u_L)(\bar{s}_L^c \nu_{lL})\end{aligned}$$

where for $\mathcal{O}_{qqql}$ the neutrino flavor is summed over. We see that $\mathcal{O}_{duql}$ is unsuppressed by the small quark yukawas and CKM angles and will thus dominate over $\mathcal{O}_{qqql}$. With the above, we can compute the $p \to K^+\bar{\nu}$ lifetime by running each of the wilson coefficients for each operator and the yukawa terms down to $\mu = 2\text{GeV}$. There are 5 arbitrary wilson coefficients, and each operator is suppressed by a mass scale $\frac{1}{\Lambda^2}$ (Λ can be interpreted as the geometric mean of the SUSY breaking scale and the GUT scale). We write the lifetime as a function of these wilson coefficients at $\mu = M_z$ and multiply them by the appropriate long range renormalization factors. We extract the fermion masses at $\mu = 2\text{GeV}$ from [1] and set $\lambda_i(2\text{GeV}) = \frac{m_i(2\text{GeV})}{2^{1/2}v}$, where v is the Higgs vev.

Below we plot the proton lifetime in this channel for $\mathcal{O}(1)$ wilson coefficients at $\mu = M_z$ vs Λ, and also as a function of the wilson coefficeints at several different values of Λ.

[1] Zhi-zhong Xing et al., "Impacts of the Higgs mass on vacuum stability, running fermion masses, and two-body Higgs decays", Phys. Rev. D 86, 013013 (2012).

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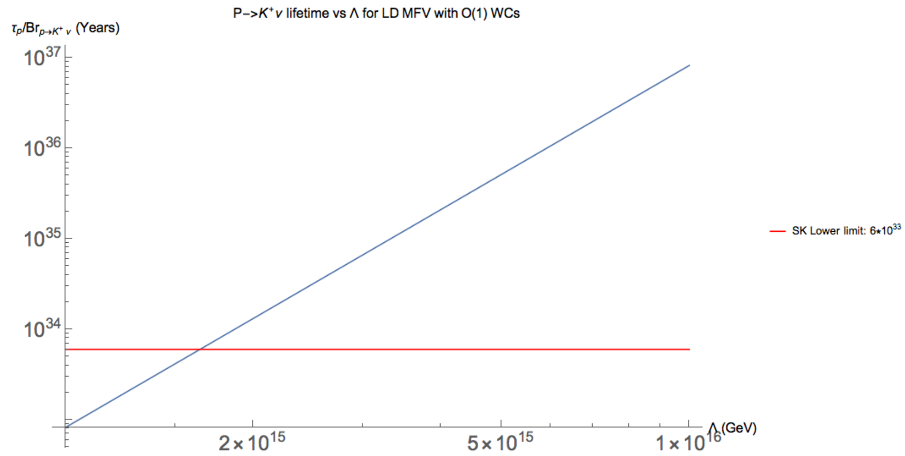

Figure 1: $\tau_{p\to K^+\bar{\nu}}$/years for $\mathcal{O}(1)$ wilson coefficients at $\mu = M_z$ vs Λ/GeV. The current lower limit on the lifetime of this channel is 6×10^{33} years, set by SuperK as of 2014.

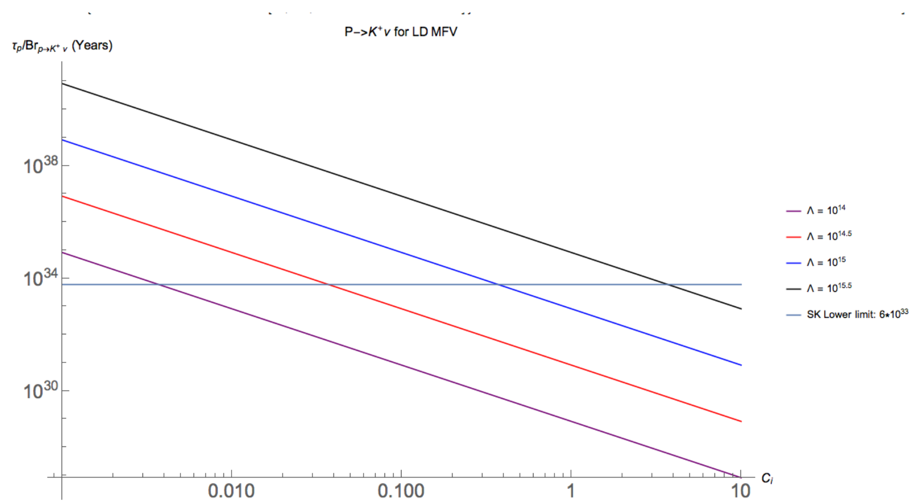

Figure 2: $\tau_{p\to K^+\bar{\nu}}$/years for $\Lambda = 10^{14}, 10^{14.5}, 10^{15}, 10^{15.5} GeV$ vs wilson coefficients at $\mu = M_z$. The current lower limit on the lifetime of this channel is 6×10^{33} years, set by SuperK as of 2014.