

Question

$$3 \times \begin{pmatrix} \nu \\ e_L \end{pmatrix} e_R \begin{pmatrix} u_{L,1} u_{L,2} u_{L,3} \\ d_{L,1} d_{L,2} d_{L,3} \end{pmatrix} (d_{R,1} d_{R,2} d_{R,3}) (u_{R,1} u_{R,2} u_{R,3})$$

$$3 \times \begin{pmatrix} d_{R,1}^c \\ d_{R,1}^c \\ d_{R,1}^c \\ e_L \\ -\nu \end{pmatrix} \begin{pmatrix} 0 & u_{R,3}^c & -u_{R,2}^c & u_{L,1} & d_{L,1} \\ -u_{R,3}^c & 0 & u_{R,1}^c & u_{L,2} & d_{L,2} \\ u_{R,2}^c & -u_{R,1}^c & 0 & u_{L,3} & d_{L,3} \\ -u_{L,1} & -u_{L,2} & -u_{L,3} & 0 & e_R^c \\ -d_{L,1} & -d_{L,2} & -d_{L,3} & -e_R^c & 0 \end{pmatrix}$$

Question

$$3 \times \begin{pmatrix} \nu \\ e_L \end{pmatrix} e_R \begin{pmatrix} u_{L,1} u_{L,2} u_{L,3} \\ d_{L,1} d_{L,2} d_{L,3} \end{pmatrix} (d_{R,1} d_{R,2} d_{R,3}) (u_{R,1} u_{R,2} u_{R,3})$$

What are the odds!?

$$3 \times \begin{pmatrix} d_{R,1}^c \\ d_{R,1}^c \\ d_{R,1}^c \\ e_L \\ -\nu \end{pmatrix} \begin{pmatrix} 0 & u_{R,3}^c & -u_{R,2}^c & u_{L,1} & d_{L,1} \\ -u_{R,3}^c & 0 & u_{R,1}^c & u_{L,2} & d_{L,2} \\ u_{R,2}^c & -u_{R,1}^c & 0 & u_{L,3} & d_{L,3} \\ -u_{L,1} & -u_{L,2} & -u_{L,3} & 0 & e_R^c \\ -d_{L,1} & -d_{L,2} & -d_{L,3} & -e_R^c & 0 \end{pmatrix}$$

How common are “unifiable” fermions among “Standard Model like” theories?

Assumptions

“Standard Model like”

We consider “Standard Model like” theories to be (generation by generation) a

- $D \leq 20$ dimensional representation of $SU(3) \times SU(2) \times U(1)$ (SM: 15)
- with integer $U(1)$ charges $|Q| \leq 10$ (SM: 6)
- that is not completely vector-like. (SM: fully chiral)

We require all forces to couple to some fermion. We count charge rescaled or conjugate reps only once.

We take charge quantisation for granted; it may possibly be established at low scales by Majorana nature of neutrinos.

“unifiable”

We consider a theory to be “*neatly* unifiable” as the SM is when

- the fermion representation unifies into that of a simple group
- without predicting additional fermions.

We do not consider gauge coupling unification (unclear in SM, depends on scalar sector).

> can use SuperFlocci or GroupMath codes to answer the question!

Result (teaser) see you at the poster!

first naive result:

$(D \leq 20, Q \leq 10)$

$$\frac{\text{\#neatly unifiable reps}}{\text{\#all SM-like reps}} = \frac{61}{4541567} \simeq 10^{-5}$$

most conservative result:

$(D \leq 15, Q \leq 6, S \leq 1)$

$$\frac{\text{\#neatly unifiable reps}}{\text{\#all SM-like reps}} = \frac{1}{76} \simeq 10^{-2}$$

\Rightarrow rare at “ 2σ ” level.