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# Texture one zero Dirac neutrino mass matrix with vanishing determinant or trace condition

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**Abstract**

In the light of non-zero and relatively large value of rector mixing angle ($\theta_{13}$), we have performed a detailed analysis of texture one zero neutrino mass matrix $M_\nu$ in the scenario of vanishing determinant/trace conditions, assuming the Dirac nature of neutrinos. In both the scenarios, normal mass ordering is ruled out for all the six possibilities of $M_\nu$, however for inverted mass ordering, only two are found to be viable with the current neutrino oscillation data at $3\sigma$ confidence level. Numerical and some approximate analytical results are presented.


## 1. Introduction

The Double Chooz, Daya Bay and RENO Collaborations [1–7] have finally established the non-zero and relatively large reactor mixing angle $\theta_{13}$, therefore the number of precisely known neutrino oscillation parameters becomes five comprising two mass squared differences ($\delta m^2$, $\Delta m^2$) and three neutrino mixing angles ($\theta_{12}$, $\theta_{23}$, $\theta_{13}$). However, any general $3 \times 3$ neutrino mass matrix contains more parameters than can be measured in realistic experiments.

Several phenomenological schemes in particular, texture zeros [8–15] have been adopted in the literature in both flavor and non flavor basis, which not only allows to reduce the number of free parameters of $M_\nu$, but also helps to establish some interesting relations between flavor

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mixing angles and fermion mass ratios [9]. Specifically, in the flavor basis wherein the charged lepton mass matrix is considered to be diagonal, a particular attention has been paid to explore the viability of texture zero mass matrices for Dirac [13,14] as well as Majorana [8–12,15] neutrinos with the experimental data. In Refs. [8–15], most of the texture zero analyses have been carried out assuming the Majorana nature of neutrinos, because various see-saw mechanisms for neutrino mass generation lead to light Majorana neutrinos. However, considering the present ambiguity on neutrino mass, neutrinos could still be a Dirac particle. The highly-suppressed Yukawa couplings for Dirac neutrinos can naturally be achieved in the several models with extra spatial dimensions [16] or through radiative mechanisms [17] and also in supersymmetry models [18], supergravity models [19] of Dirac neutrino masses. Moreover, a common argument in favor of Majorana neutrinos is that the implied lepton number violation can be used to generate the baryon asymmetry of the universe via the leptogenesis mechanism [20]. However, similar argument can be made even for Dirac neutrinos [21,22].

Seeking the motivation for Dirac neutrinos from these theoretical grounds, Liu and Zhou [14] have carried out an analysis of texture zero mass matrices in the flavor basis, and found that all the six possibilities carrying one texture zero in the neutrino mass matrix are experimentally viable. This is not surprising as texture one zero makes available larger parametric space for viability with the data compared with texture two zero case. However, to impart predictability to texture one zero, additional constraints in the form of $\mathrm{Det}\, M_\nu = 0$ or $\mathrm{Tr}\, M_\nu = 0$ can be incorporated. The $\mathrm{Det}\, M_\nu = 0$ [23] condition can be motivated on various theoretical grounds [24,25]. The condition $\mathrm{Det}\, M_\nu = 0$ is equivalent to assuming one of the neutrinos to be massless. This is realized, for instance, in the Affleck–Dine scenario for leptogenesis [26] which requires the lightest neutrino to be practically massless ($m \simeq 10^{-10}$ eV) [27,28]. In Refs. [15,29], the implication for the same have been rigorously studied for texture one zero mass Majorana matrices. The motivation for $\mathrm{Tr}\, M_\nu = 0$ condition, was first put forward in [30] applying a three neutrino framework that simultaneously explains the anomalies of solar and atmospheric neutrino oscillation experiments as well as the LSND experiment. In [31], X. G. He and A. Zee have investigated the CP conserving traceless $M_\nu$ for the more realistic case of explaining only the solar neutrino atmospheric and deficits. Further motivation of traceless mass matrices can be provided by models wherein $M_\nu$ is constructed through a commutator of two matrices, as it happens in models of radiative mass generation [32]. H. A. Alhendi et al. [33] have incorporated the traceless condition with two $2 \times 2$ sub-matrices of Majorana mass matrix in the flavor basis and carried out a detailed numerical analysis at $3\sigma$ confidence level. Also the phenomenological implications of traceless $M_\nu$ on neutrino masses, CP violating phases and effective neutrino mass term is studied in Ref. [34], for both normal and inverted mass ordering and in case of CP conservation and violation.

Without loss of generality, we consider a neutrino mass matrix $M_\nu$ for Dirac neutrinos to be Hermitian by redefining the right-handed neutrino fields. As $M_\nu$ is Hermitian, three independent off-diagonal matrix elements are in general complex, while three independent diagonal ones are real. Following Ref. [14], the six possible texture one zero hermitian matrices are given in Table 1. The nomenclature is similar to texture one zero for Majorana neutrino except that here neutrino mass matrix is hermitian.

Textures $P_2$ and $P_4$ are related through permutation symmetry to $P_3$ and $P_5$, respectively [14]. This corresponds to permutation of the 2–3 rows and 2–3 columns of $M_\nu$. The corresponding permutation matrix is

$$P_{23} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}. \tag{1}$$