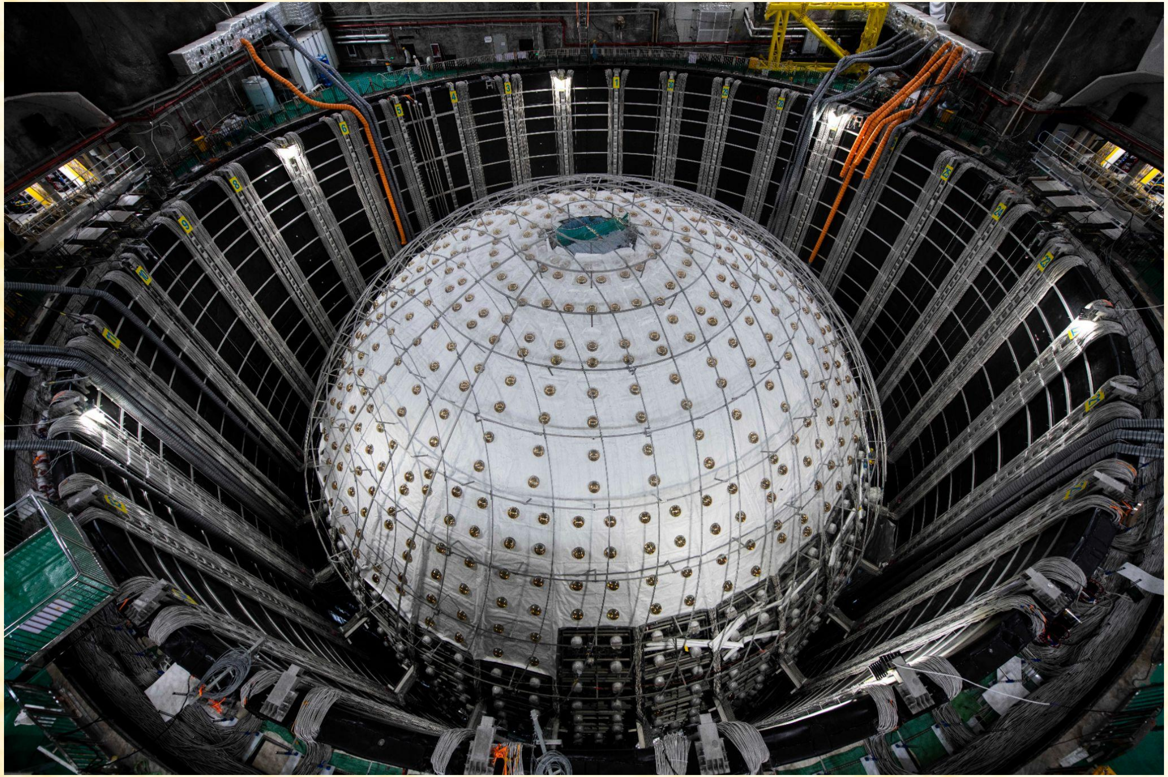

JUNO ***via Jin Liwang of the Xinhua News Agency***

https://english.news.cn/20260611/b488a9c1aa8c463bbd3a3056438d9285/c.html

Leptogenesis via Resonant Sequential Dominance and TBC3 Mixing in a Type-I Seesaw Model

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Outline

- Background
- Overview
- PMNS and TBC3
- Sequential Dominance and
  Resonant Sequential Dominance
- Searching for Simple Flavon VEVs
- Lagrangian
- Resonant Leptogenesis
- Conclusions

From my time as a DUNE member, underground at Sanford Lab
Left to right: Myself, Dr. Juergen Reichenbacher, Tyler Rath

Background: Neutrino Mixing and PMNS Matrix

- Neutrino mass leads to **flavour oscillations** described by **PMNS mixing matrix**
- Many of the parameters have already been measured to high precision
- **Non-zero reactor angle** and **$\sin^2\theta_{12}$ < ⅓ disfavors TBM mixing ansatz**
- **TBM** formerly achieved good agreement with data by extending the SM by small discrete symmetries (e.g. S_4, A_4)

TBM Mixing Ansatz

$$U_{\rm TBM} = \begin{pmatrix} \sqrt{\frac{2}{3}} & \sqrt{\frac{1}{3}} & 0 \\ -\sqrt{\frac{1}{6}} & \sqrt{\frac{1}{3}} & -\sqrt{\frac{1}{2}} \\ -\sqrt{\frac{1}{6}} & \sqrt{\frac{1}{3}} & \sqrt{\frac{1}{2}} \end{pmatrix}$$

JUNO 2025 Solar Angle Result

$$\sin^2\theta_{12,\,\rm JUNO} = 0.3092 \pm 0.0087$$

NuFIT 2025 Global Best Fits

$$\begin{aligned} s^2_{12} &= 0.3088^{+0.0067}_{-0.0066}\ (0.2893 \to 0.3295), \\ s^2_{23} &= 0.470^{+0.017}_{-0.014}\ (0.435 \to 0.584), \\ s^2_{13} &= 0.02248^{+0.00055}_{-0.00059}\ (0.02064 \to 0.02418), \\ \delta^{CP\circ} &= 212^{+26}_{-36}\ (125 \to 365), \\ \frac{\Delta m^2_{21}}{10^{-5}\,\mathrm{eV}^2} &= 7.537^{+0.094}_{-0.10}\ (7.236 \to 7.823), \\ \frac{\Delta m^2_{32}}{10^{-3}\,\mathrm{eV}^2} &= +2.511^{+0.021}_{-0.020}\ (+2.450 \to +2.576). \end{aligned}$$

Produced as flavour eigenstates

Different basis related through 3x3 PMNS rotation matrix

$$\begin{bmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{bmatrix} = \begin{bmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta_{CP}} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta_{CP}} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta_{CP}} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta_{CP}} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta_{CP}} & c_{23}c_{13} \end{bmatrix} \begin{bmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{bmatrix}$$

Must propagate as mass eigenstates

Background: Type-I Seesaw Mechanism + Leptogenesis

- Tiny neutrino masses naturally produced by adding several heavy **right-handed (RH) Majorana neutrinos** to Standard Model (SM)
- At energy scales below RH neutrino mass, leads to suppression of light neutrino masses via **Type-I seesaw mechanism**
- Decay of RH neutrinos in early universe generates **baryon asymmetry of the Universe (BAU)** (matter/antimatter asymmetry)
- **Leptogenesis mechanism** first produces lepton asymmetry, converted to baryon asymmetry via sphaleron process
- If some RH neutrino masses are nearly degenerate, certain CP violating RH neutrino decays resonantly enhanced - allows mass scale of RH neutrinos to be lowered to ~1 TeV scale
  - *This is known as **Resonant Leptogenesis***
- Many model building approaches assume **"Sequential Dominance" (SD)** where hierarchy of left-handed neutrino masses generated by hierarchy of RH neutrino masses

Heavy Right Handed Majorana Neutrino Mass Matrix

Type-I Seesaw Mechanism

$$\boxed{m_\nu = m_{\mathrm{D}} M_{\mathrm{R}}^{-1} m_{\mathrm{D}}^{T}}$$

Low-energy Neutrino Mass Matrix

Light Neutrino Dirac Mass Matrix

BAU Observed by Planck

$$\boxed{\eta_B = \frac{n_B - n_{\bar{B}}}{n_\gamma} = (6.12 \pm 0.04) \times 10^{-10}}$$

Baryon and Antibaryon Number Densities

Photon Number Density

Overview

- Explore **model building techniques assuming SD** with **degenerate RH neutrino masses**
- **Enables resonant leptogenesis** so we call it **Resonant Sequential Dominance (RSD)**
- We introduce **novel PMNS matrix ansatz - TBC3**
- We use indirect model building techniques from S.F. King assuming SD + our TBC3 ansatz to **search for viable simple Dirac mass matrix textures**
- We present an $A_4 x(Z_3)^4 x(Z_2)^2$-symmetric Lagrangian that can produce the mass matrix textures we discovered + admit resonant leptogenesis
- We find that the lightest Majorana neutrino mass
  - **M ∈ 0.13 TeV to 230 TeV**

Leptogenesis via Resonant Sequential Dominance and TBC3 Mixing in a Type-I Seesaw Model

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(Dated: April 2026)

We demonstrate how phenomenological model construction assuming Sequential Dominance can be extended to cases with degenerate right-handed neutrino masses. Because this framework accommodates resonant leptogenesis, we designate it as Resonant Sequential Dominance. We then investigate Dirac mass matrix textures compatible with current neutrino data within Resonant Sequential Dominance, utilizing a novel neutrino mixing matrix ansatz termed TBC3, proposed in this work. Additionally, we present an $A_4 \times (Z_3)^4 \times (Z_2)^2$-symmetric Lagrangian that is consistent with neutrino oscillation data and successfully drives resonant leptogenesis. Lastly, we find that accounting for the observed baryon asymmetry of the Universe requires the lightest right-handed neutrino mass to lie in the range $0.13\,\text{TeV} \leq m_{N_1} \leq 230\,\text{TeV}$.

Preprint: arXiv:2608.06983

TBC3 Mixing Matrix Ansatz

- We employ **King's expansion of the PMNS matrix** where it is expanded in terms of the solar (s), reactor (r), and atmospheric (a) deviations with the **zeroth order term being TBM**
- As done by others we define a,s, and r in terms of the **Cabibbo parameter λ**
- Our **TBC3** Cabibbo parameter ansatz achieves **1σ with 2025 NuFIT** and has the property of **equality of the solar and atmospheric deviations**
- ConfirmED **minimal deviation from unitarity** when taken to 2nd order

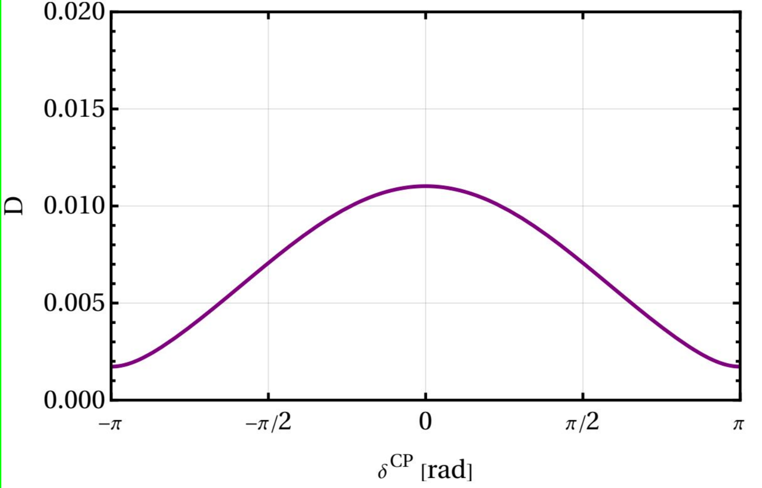
King PMNS Parameterization to 1st order in a,s,r

$$U \approx \begin{pmatrix} \sqrt{\frac{2}{3}}(1-\frac{1}{2}s) & \frac{1}{\sqrt{3}}(1+s) & \frac{1}{\sqrt{2}}re^{-i\delta} \\ -\frac{1}{\sqrt{6}}(1+s-a+re^{i\delta}) & \frac{1}{\sqrt{3}}(1-\frac{1}{2}s-a-\frac{1}{2}re^{i\delta}) & \frac{1}{\sqrt{2}}(1+a) \\ \frac{1}{\sqrt{6}}(1+s+a-re^{i\delta}) & -\frac{1}{\sqrt{3}}(1-\frac{1}{2}s+a+\frac{1}{2}re^{i\delta}) & \frac{1}{\sqrt{2}}(1-a) \end{pmatrix}$$

Novel TBC3 ansatz taken in this work

$$s = a = -\frac{1}{3\sqrt{3}}\lambda, \quad r = \frac{2}{3}\sqrt{2}\,\lambda$$

Deviation from Unitarity of TBC3 Ansats at 2nd Order



Frobenius Norm

$$\|A\|_F = \sqrt{\sum_i^m \sum_j^n |a_{ij}|^2}$$

Definition of Unitarity Deviation

$$D(\delta^{CP}) \equiv \|I_3 - U_{\text{TBC3}}U^\dagger_{\text{TBC3}}\|_F$$

Sequential Dominance & Resonant Sequential Dominance

- SD assumes that the **Dirac neutrino mass matrix** and effective **light neutrino mass Lagrangian** take the below forms so that the **mass eigenvalues** are determined primarily by each independent column and each heavy RH neutrino mass
- This way, a heavy RH neutrino mass ordering $M_1<M_2<M_3$ leads to Normal Ordering (NO) - *we do not consider IO*
- These columns arise from the **VEVs of flavon fields**

$$m_{\mathrm{D}} = \begin{pmatrix} m_{\mathrm{D},e,\mathrm{atm}} & m_{\mathrm{D},e,\mathrm{sol}} & [m_{\mathrm{D},e,\mathrm{dec}}] \\ m_{\mathrm{D},\mu,\mathrm{atm}} & m_{\mathrm{D},\mu,\mathrm{sol}} & [m_{\mathrm{D},\mu,\mathrm{dec}}] \\ m_{\mathrm{D},\tau,\mathrm{atm}} & m_{\mathrm{D},\tau,\mathrm{sol}} & [m_{\mathrm{D},\tau,\mathrm{dec}}] \end{pmatrix} \equiv \begin{pmatrix} m_{\mathrm{D,atm}} & m_{\mathrm{D,sol}} & [m_{\mathrm{D,dec}}] \end{pmatrix}.$$

$$M_{\mathrm{R}} = \begin{pmatrix} M_1 & 0 & 0 \\ 0 & M_2 & 0 \\ 0 & 0 & [M_3] \end{pmatrix}$$

$$m_\nu = m_{\mathrm{D}} M_{\mathrm{R}}^{-1} m_{\mathrm{D}}{}^T$$

$$\mathcal{L}^\nu_{eff} = \frac{(\overline{\nu}_L m_{\mathrm{D,atm}})(m^T_{\mathrm{D,atm}} \nu^c_L)}{M_{\mathrm{atm}}} + \frac{(\overline{\nu}_L m_{\mathrm{D,sol}})(m^T_{\mathrm{D,sol}} \nu^c_L)}{M_{\mathrm{sol}}} + \left[\frac{(\overline{\nu}_L m_{\mathrm{D,dec}})(m^T_{\mathrm{D,dec}} \nu^c_L)}{M_{\mathrm{dec}}} \right]. \qquad (24)$$

$$\frac{m_{\mathrm{D,atm}} m^T_{\mathrm{D,atm}}}{M_{\mathrm{atm}}} \gg \frac{m_{\mathrm{D,sol}} m^T_{\mathrm{D,sol}}}{M_{\mathrm{sol}}} \left[\gg \frac{m_{\mathrm{D,dec}} m^T_{\mathrm{D,dec}}}{M_{\mathrm{dec}}} \right]$$

$$m_3 \gg m_2 \ [\gg m_1\ ]$$

Sequential Dominance & Resonant Sequential Dominance (RSD)

- If instead we assume two nearly **degenerate RH neutrino masses** we can instead achieve all the necessary features of Sequential Dominance via only the **Yukawa couplings**
- Type-I Seesaw mechanism still gives small neutrino masses
- Under the correct choice of Yukawas this still **preserves the mass hierarchy**
- This way resonant leptogenesis is admitted and thus we refer to it as **Resonant Sequential Dominance**
- The Yukawa hierarchy can be explained by, for example, the Froggatt-Nielsen mechanism - though we do not go into further detail in this work

$$\boxed{M_1 \approx M_2 \ll M_3}$$

$$\boxed{m_3 \gg m_2 \;[\gg m_1\,]}$$

King Master Formula and Simple VEV Search Procedure

- In our **RSD** framework we then employ the **Master Formula of King** for relating the light neutrino mass matrix elements to the PMNS matrix elements
- We work under the additional assumptions that the third RH neutrino is ultra-heavy (GUT scale) and decouples entirely, and that there is a **texture zero** in m_D - which is closely related to the nonzero reactor angle

$$m_{\mathrm{D}} = \begin{pmatrix} 0 & |a|e^{i\phi_a} \\ |e|e^{i\phi_e} & |b|e^{i\phi_b} \\ |f|e^{i\phi_f} & |c|e^{i\phi_c} \end{pmatrix}$$

$$\tilde{a} \equiv \frac{ie^{i\phi_e}a}{\sqrt{M}}, \quad \tilde{b} \equiv \frac{ie^{i\phi_\mu}b}{\sqrt{M}}, \quad \tilde{c} \equiv \frac{ie^{i\phi_\tau}c}{\sqrt{M}}$$

$$\tilde{e} \equiv \frac{ie^{i\phi_\mu}e}{\sqrt{M}}, \quad \tilde{f} \equiv \frac{ie^{i\phi_\tau}f}{\sqrt{M}}.$$

Quantities of interest

$$m_\nu = m_a\left(AA^T + \epsilon_\nu BB^T\right)$$

$$m_\nu = \begin{pmatrix} \tilde{a}^2 & \tilde{a}\tilde{b} & \tilde{a}\tilde{c} \\ \tilde{a}\tilde{b} & \tilde{e}^2+\tilde{b}^2 & \tilde{e}\tilde{f}+\tilde{b}\tilde{c} \\ \tilde{a}\tilde{c} & \tilde{e}\tilde{f}+\tilde{b}\tilde{c} & \tilde{f}^2+\tilde{c}^2 \end{pmatrix}_{\alpha\beta}$$
$$= e^{i\beta}m_2U_{\alpha2}U_{\beta2} + m_3U_{\alpha3}U_{\beta3},$$

Only two phases after rephasing

$$\eta_2 = \phi_b - \phi_e = \arg\tilde{b} - \arg\tilde{e}, \quad \eta_3 = \phi_c - \phi_f = \arg\tilde{c} - \arg\tilde{f}. \qquad (36)$$

$$Z_1 \equiv \frac{\tilde{e}}{\tilde{f}} = \pm\frac{U_{23}U_{12} - U_{13}U_{22}}{U_{33}U_{12} - U_{13}U_{32}},$$
$$Z_2 \equiv \frac{\tilde{b}}{\tilde{a}} = \frac{e^{i\beta}m_2U_{12}U_{22} + m_3U_{13}U_{23}}{e^{i\beta}m_2U_{12}^2 + m_3U_{13}^2},$$
$$Z_3 \equiv \frac{\tilde{c}}{\tilde{a}} = \frac{e^{i\beta}m_2U_{12}U_{32} + m_3U_{13}U_{33}}{e^{i\beta}m_2U_{12}^2 + m_3U_{13}^2},$$

Application of King Master Formula With TBC3 / 2025 NuFIT

$$m_{\mathrm{D}} = \begin{pmatrix} 0 & |a|e^{i\phi_a} \\ |e|e^{i\phi_e} & |b|e^{i\phi_b} \\ |f|e^{i\phi_f} & |c|e^{i\phi_c} \end{pmatrix}$$

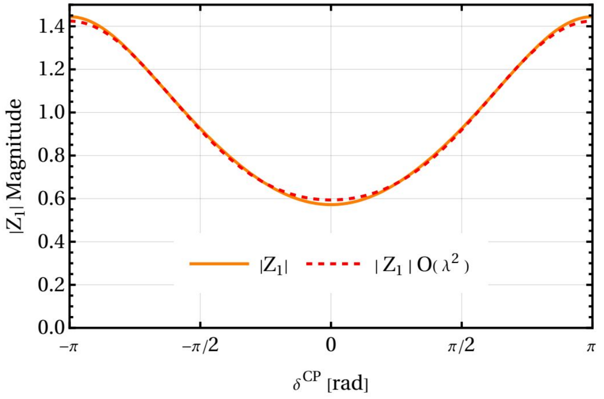


FIG. 3. $|Z_1| = |\tilde{e}|/|\tilde{f}|$ as a function of δ^{CP}.

Chosen CP Phase: $\delta = -\pi$

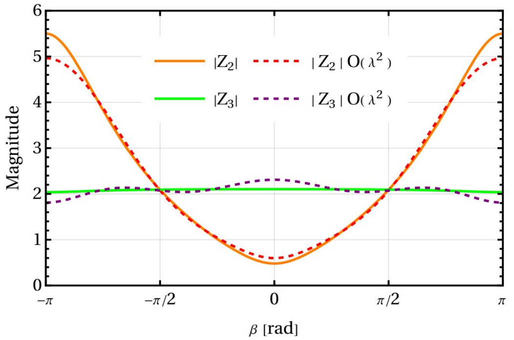


FIG. 4. $\delta^{CP} = -\pi$ rad, $|Z_2| = |\tilde{b}|/|\tilde{a}|$, $|Z_3| = |\tilde{c}|/|\tilde{a}|$ as functions of the Majorana phase β.

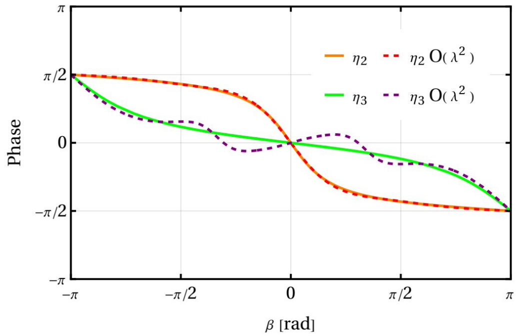


FIG. 6. $\delta^{CP} = -\pi$ rad, η_2, η_3 as functions of the Majorana phase β.

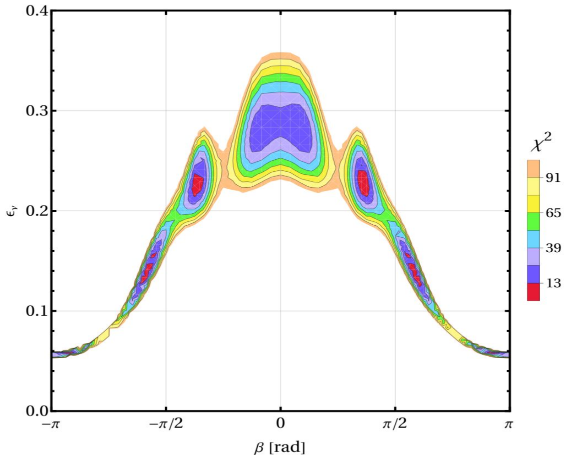


FIG. 8. $\delta^{CP} = -\pi$ rad, reduced 3 degrees of freedom χ^2 of θ_{ij}, δ^{CP}, m_2/m_3 as a function of both ϵ_ν and the Majorana phase β. The unshaded region represents $\chi^2 > 105$.

$$m_\nu = m_a\left(AA^T + \epsilon_\nu BB^T\right)$$

Application of King Master Formula With TBC3 / 2025 NuFIT

$$m_{\mathrm{D}} = \begin{pmatrix} 0 & |a|e^{i\phi_a} \\ |e|e^{i\phi_e} & |b|e^{i\phi_b} \\ |f|e^{i\phi_f} & |c|e^{i\phi_c} \end{pmatrix}$$

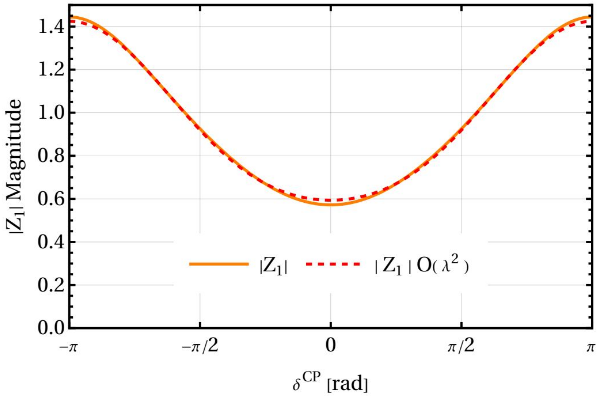


FIG. 3. $|Z_1| = |\tilde{e}|/|\tilde{f}|$ as a function of δ^{CP}.

Chosen CP Phase: $\delta = -5\pi/6$

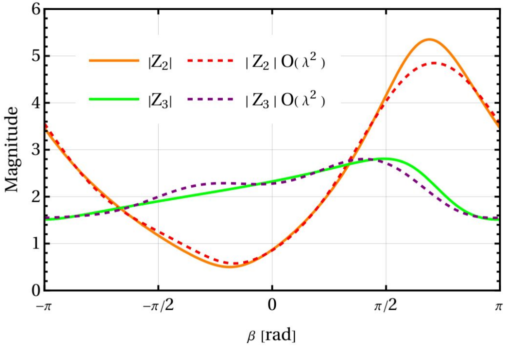


FIG. 5. $\delta^{CP} = -5\pi/6\,\mathrm{rad}$, $|Z_2| = |\tilde{b}|/|\tilde{a}|$, $|Z_3| = |\tilde{c}|/|\tilde{a}|$ as functions of the Majorana phase β.

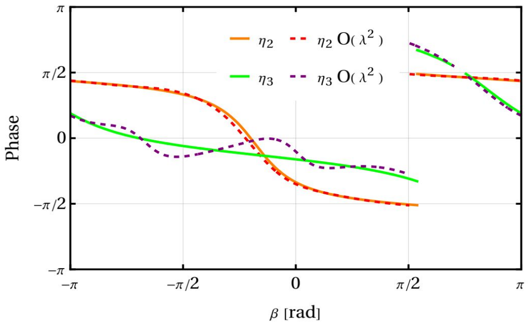


FIG. 7. $\delta^{CP} = -5\pi/6\,\mathrm{rad}$, η_2, η_3 as functions of the Majorana phase β.

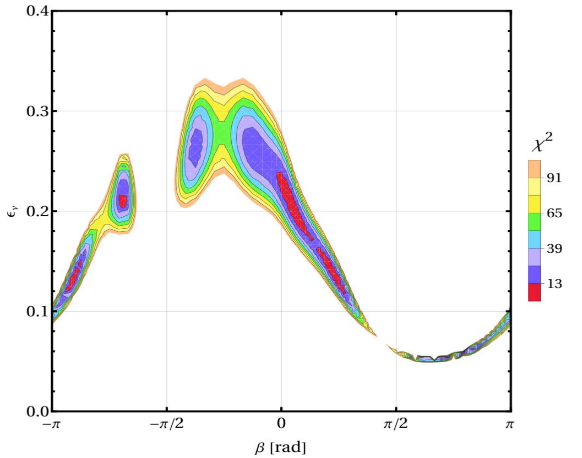


FIG. 9. $\delta^{CP} = -5\pi/6\,\mathrm{rad}$, reduced 3 degrees of freedom χ^2 of θ_{ij}, δ^{CP}, m_2/m_3 as a function of both ϵ_ν and the Majorana phase β. The unshaded region represents $\chi^2 > 105$.

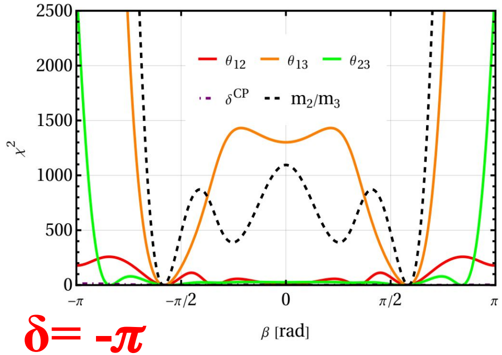
$$m_\nu = m_a\left(AA^T + \epsilon_\nu BB^T\right)$$

Some Simple Dirac Mass Matrix Elements

- Table shows some of the **simple Dirac mass matrix elements** that we determined using a combination of the plots generated from King's Master Formula and χ^2
- Outputs computed using **Mixing Parameters Tools (MPT) Mathematica package**
- The χ^2 **best fit points** corresponding to δ= -π and δ= -5π/6, are boxed in **green**
- The **best value set with the lowest χ^2** is boxed in red, we refer to this as the **Simple (√2,1:1,2) Alignment** - achieves **1σ agreement** w/ ***all mixing angles, mass squared differences, and Dirac CP violating phase***

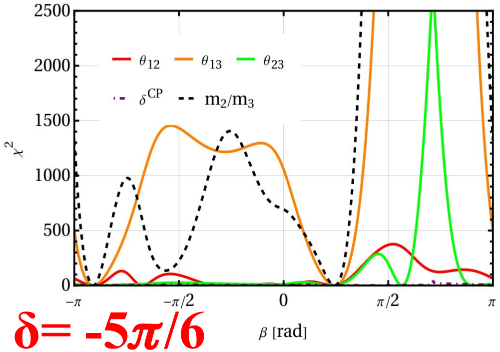
TABLE I. Inputs: Flavon alignments/VEVs, phases, and corresponding minima of ϵ_ν derived from the Master Formula calculations and χ^2 analysis under the TBC3 ansatz. Outputs: Low-energy observables computed via Mixing Parameters Tools [47] using the Dirac mass matrix constructed from the alignments given in "Inputs" and corresponding reduced χ^2 value. Bold rows indicate reduced $\chi^2(\delta^{CP}, \epsilon_\nu, \beta)$ best-fit points. The best alignment has its χ^2 value, 0.632, marked with stars.

Inputs (δ^{CP}, η_i) [rad]						Outputs $(\theta_{ij}, \delta^{CP})[°]$					
δ^{CP}	$A=(0,e,f)^T$	$B=(1,b,c)^T$	η_2	η_3	ϵ_ν	δ^{CP}	θ_{12}	θ_{13}	θ_{23}	m_2/m_3	Reduced χ^2
-π	**1.424, 1**	**2.614, 2.118**	**-1.403**	**-0.483**	**0.1393**	**180.5**	**33.61**	**8.64**	**42.18**	**0.172**	**0.997**
-π	$\sqrt{2}, 1$	$\frac{3}{2}\sqrt{3}, \frac{3}{2}\sqrt{2}$	-11π/24	-π/6	0.1451	174.6	33.78	8.42	42.44	0.175	2.513
-π	$\sqrt{2}, 1$	1, 2	-π/3	0	0.2758	192.2	33.95	8.57	42.55	0.174	* 0.632 *
-5π/6	**1.346, 1**	**2.928, 1.568**	**1.33**	**0.376**	**0.1317**	**150.0**	**33.69**	**8.63**	**42.44**	**0.173**	**1.677**
-5π/6	$\sqrt{2}, 1$	$2\sqrt{2}, \sqrt{3}$	7π/16	π/8	0.1369	163.3	33.68	8.47	42.80	0.175	1.910
-5π/6	4/3, 1	3, 3/2	5π/12	π/8	0.1303	144.61	33.95	8.77	42.77	0.171	3.131



δ= -π

FIG. 11. $\delta^{CP} = -\pi$ rad, individual χ^2 for each of the 5 low-energy observables for the minimizing value $\epsilon_\nu = 0.1393$.



δ= -5π/6

FIG. 13. $\delta^{CP} = -5\pi/6$ rad, individual χ^2 for each of the 5 low-energy observables for the minimizing value $\epsilon_\nu = 0.1317$.

Lagrangian

- A_4 chosen as starting point since it naturally yields **TM2** PMNS mixing ansatz which was in good agreement with data until recently
- Neutral lepton sector has its **symmetry badly broken by the VEVs of the flavons** ϕ_i - shaping symmetries ensure that their **VEVs each independently determine the columns of the Dirac mass matrix**
- Shaping symmetries further ensure **diagonality of Majorana mass matrix** and that the **required structure for RSD is preserved**

Lepton Mass Lagrangian

$$
\begin{aligned}
-\mathscr{L} \supset & \frac{y_e}{\Lambda}(\bar{L}_l H \varphi)_1 e_R + \frac{y_\mu}{\Lambda}(\bar{L}_l H \varphi)_{1''} \mu_R + \frac{y_\tau}{\Lambda}(\bar{L}_l H \varphi)_{1'} \tau_R \\
& + \frac{y_{D_1}}{\Lambda}(\bar{L}_l \tilde{H} \phi_1)_1 N_1 + \frac{y_{D_2}}{\Lambda}(\bar{L}_l \tilde{H} \phi_2)_1 N_2 \qquad (53) \\
& + \frac{y_{D_3}}{\Lambda}(\bar{L}_l \tilde{H} \phi_3)_{1''} N_3 \\
& + \frac{1}{2}\sum_{i=1}^{3}(\bar{N}_i^c N_i)\left[z_{i,1}\chi_i^* + z_{i,2}\frac{\chi_i \chi_i}{\Lambda}\right] + \text{h.c.},
\end{aligned}
$$

The shaping symmetries furthermore ensure that these are the only allowed mass terms up to dimension-5 in the Lepton sector

TABLE II. $A_4 \times (Z_3)^4 \times (Z_2)^2$-symmetric Lagrangian field contents and representations under A_4 and the auxiliary Z_3^X and Z_2^X shaping symmetries. Here ω is the cubic root of unity, $\omega = e^{2i\pi/3}$.

	L_l	H	φ	e_R	μ_R	τ_R	N_1	N_2	N_3	ϕ_1	ϕ_2	ϕ_3	χ_1	χ_2	χ_3
A_4	**3**	**1**	**3**	**1**	**1′**	**1″**	**1**	**1**	**1′**	**3**	**3**	**3**	**1**	**1**	**1″**
$Z_3^{N_1}$	1	1	1	1	1	1	ω	1	1	ω^2	1	1	ω^2	1	1
$Z_3^{N_2}$	1	1	1	1	1	1	1	ω	1	1	ω^2	1	1	ω^2	1
$Z_3^{N_3}$	1	1	1	1	1	1	1	1	ω	1	1	ω^2	1	1	ω^2
$Z_3^{\phi/\chi}$	ω^2	1	1	ω^2	ω^2	ω^2	ω	ω	ω	ω	ω	ω	ω^2	ω^2	ω^2
$Z_2^{N_1}$	1	1	1	1	1	1	-1	1	1	-1	1	1	1	1	1
$Z_2^{N_2}$	1	1	1	1	1	1	1	-1	1	1	-1	1	1	1	1

Resonant Leptogenesis

- First, connect **Master Formula terms** to **Lagrangian terms**
- Examine how constraints on Yukawa couplings, sphaleron freeze out temperatures, and cutoff scale Λ translate into **constraints on RH neutrino mass**
- Using **Simple (√2,1:1,2) Alignment** and our allowed range of Yukawa couplings, Λ, and RH neutrino masses, we find the range of mass splittings that can yield sufficient lepton asymmetry (and in turn produce the observed BAU)

$$m_{N_1} = M - \Delta, \quad m_{N_2} = M + \Delta = m_{N_1}(1 + x_\Delta)$$

$$z_{\rm crit} = \frac{m_{N_i}}{T_{\rm sph}} \approx \frac{m_{N_i}}{131\ \text{GeV}}$$

$$\begin{aligned} 0.1 \leq\ & y_{\rm D_1} \leq 1, \\ 100\ \text{TeV} \leq\ & \Lambda \leq 419\ \text{TeV}, \\ 2.45\times10^{-9}\ \text{GeV} \leq\ & x_{\Delta,\rm min} \leq 4.31\times10^{-6}\ \text{GeV} \end{aligned}$$

Set	$y_{\rm D_1}$	Λ [TeV]	m_{N_1} [TeV]	$z_{\rm crit}$	$x_{\Delta,\rm min}$ [GeV]
1	0.1	419	0.13	1	2.45×10^{-9}
2	0.1	100	2.3	17.56	4.31×10^{-8}
3	1	419	2.3	100	2.45×10^{-7}
4	1	100	230	1756	4.31×10^{-6}

TABLE III. The four extreme points of the parameters $(y_{\rm D_1}, \Lambda)$ and their corresponding m_{N_1}, $z_{\rm crit}$, and $x_{\Delta,\rm min}$.

$$0.13\ \text{TeV} \leq m_{N_1} \leq 230\ \text{TeV}$$

$$\begin{aligned} m_\nu &= m_{\rm D} M_{\rm R}^{-1} m_{\rm D}^T \\ &= \frac{v^2}{2M\Lambda^2}\left(y_{\rm D_1}^2 \langle\phi_1\rangle\langle\phi_1\rangle^T + y_{\rm D_2}^2 \langle\phi_2\rangle\langle\phi_2\rangle^T\right) \end{aligned}$$

$$m_\nu = m_a\left(AA^T + \epsilon_\nu BB^T\right)$$

$$m_a = \frac{v^2 y_{\rm D_1}^2}{2M\Lambda^2}, \quad \epsilon_\nu = \frac{y_{\rm D_2}^2}{y_{\rm D_1}^2}$$

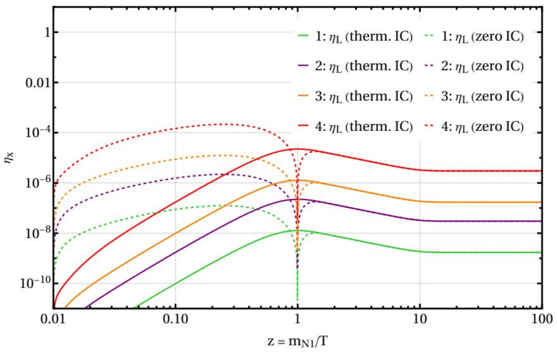


FIG. 17. η_L for $x_\Delta = 2.45\times10^{-9}$ GeV for the following extreme point sets: $1(y_{\rm D_1} = 0.1, \Lambda = 419\ \text{TeV})$, $2(y_{\rm D_1} = 0.1, \Lambda = 100\ \text{TeV})$, $3(y_{\rm D_1} = 1, \Lambda = 419\ \text{TeV})$, $4(y_{\rm D_1} = 1, \Lambda = 100\ \text{TeV})$

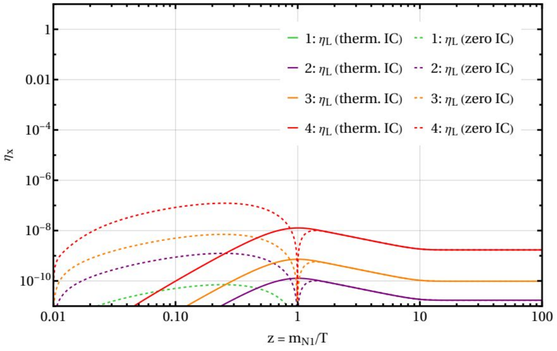


FIG. 18. η_L for $x_\Delta = 4.36\times10^{-6}$ GeV for the following extreme point sets: $1(y_{\rm D_1} = 0.1, \Lambda = 419\ \text{TeV})$, $2(y_{\rm D_1} = 0.1, \Lambda = 100\ \text{TeV})$, $3(y_{\rm D_1} = 1, \Lambda = 419\ \text{TeV})$, $4(y_{\rm D_1} = 1, \Lambda = 100\ \text{TeV})$

Summary

Preprint: arXiv:2608.06983

- Suggested **TBC3 PMNS matrix ansatz** that:
  - Achieves **1σ agreement with data** using only **simple ratios of Cabibbo parameter**
  - Minimizes parameters by setting **solar and atmospheric angle deviations equal**
- Showed that in **RSD**, SD can still be achieved with degenerate RH neutrino masses via Yukawa couplings alone
- Using **TBC3 ansatz** + **SD based model building techniques**, searched for **simple Dirac matrix textures** compatible with mixing data
- Found **Simple (√2,1:1,2) Alignment** : ***achieves 1σ agreement with all mixing angles, Dirac CP phase and mass squared differences***
- Created **$A_4 x(Z_3)^4 x(Z_2)^2$-symmetric Lagrangian** that admits our **Simple (√2,1:1,2) Alignment**, and **resonant leptogenesis**
- **Determined viable parameter space** of RH neutrino mass splitting, Yukawa couplings, cutoff scale Λ, and RH neutrino mass which **produce sufficient lepton asymmetry** and in turn can **match the observed BAU**

ご清聴ありがとうございました！