Consider the Lobster...

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INSS 2019 Student Presentations

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Equations!

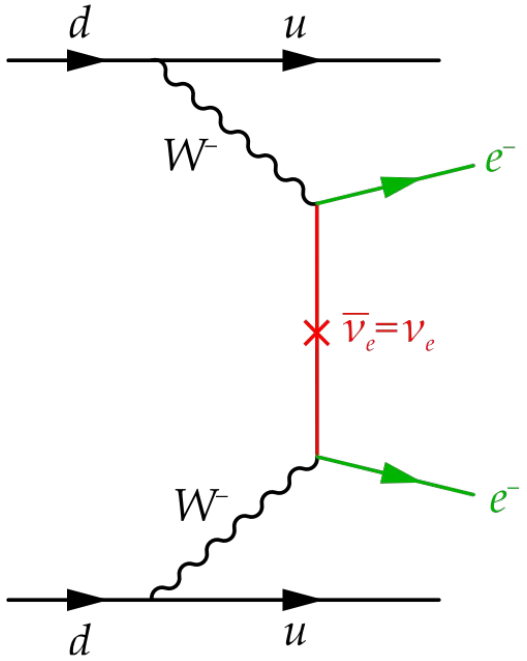
$$\mathcal{L}_{CC}^{\text{lepton}} = -\frac{g}{\sqrt{2}} \bar{l}'_i \gamma_\mu P_L W_\mu^+ \underbrace{(U_l^\dagger U_\nu)_{ij}}_{U_{\text{PMNS}}} \nu'_j + \text{h.c.}$$

$$\tilde{U}_{PMNS} = U_{PMNS}(\theta_{12}, \theta_{13}, \theta_{23}, \delta) \cdot \text{diag}(1, e^{i\alpha_1}, e^{i\alpha_2})$$

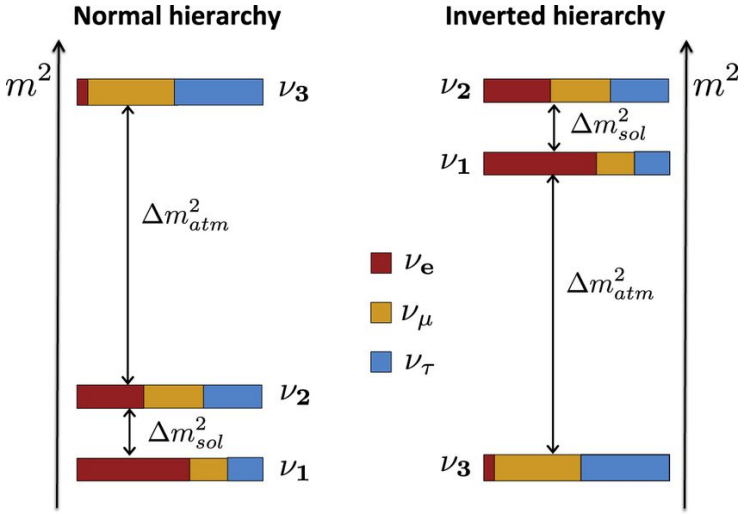
$$M_\nu = U_\nu^\dagger M_d U_\nu^*$$
$$\nu'_L = U_\nu \nu_L$$
$$l'_L = U_l l_L$$

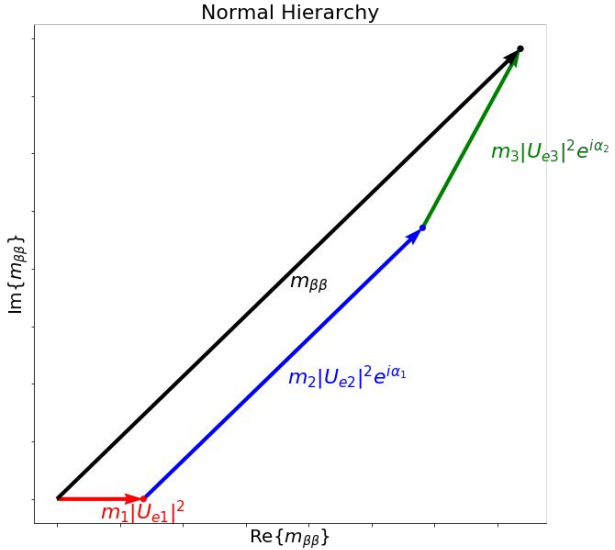
Probing the equations: 0νßß experiment

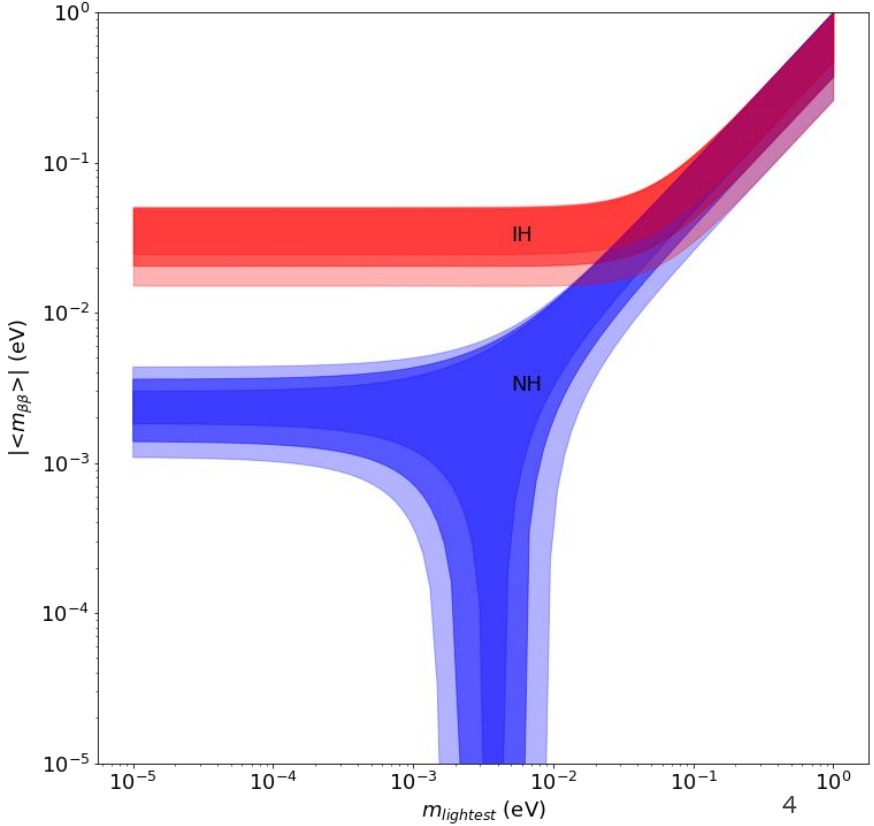
$$\frac{1}{T_{0\nu 2\beta}} \approx \underbrace{G^{0\nu}}_{\text{Phase-space}} \underbrace{\left|M^{0\nu}\right|^2}_{\text{Matrix element}} \left|m_{\beta\beta}\right|^2$$

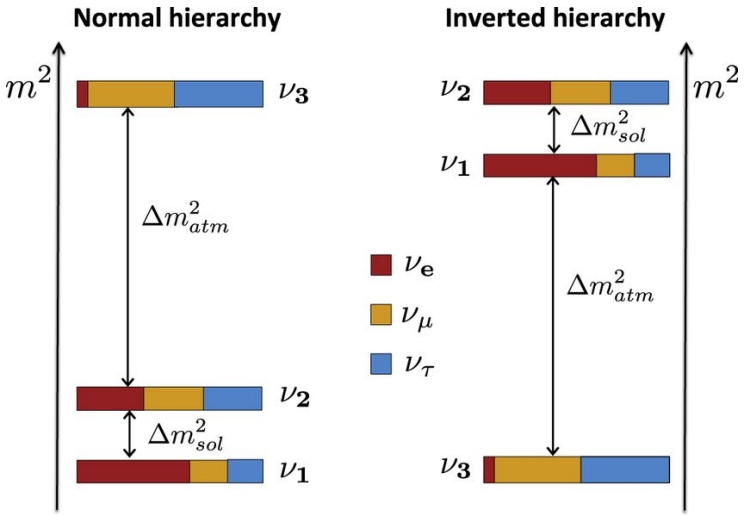


$$m_{\beta\beta} = \left| \sum_{i=1} |U_{ei}|^2 m_i e^{i\alpha_i} \right| = |U_{e1}|^2 m_1 + |U_{e2}|^2 m_2 e^{i\alpha_1} + |U_{e3}|^2 m_3 e^{i\alpha_2}$$


Normal hierarchy
Inverted hierarchy
m^2
ν_3
Δm^2_{atm}
ν_2
Δm^2_{sol}
ν_1
ν_e
ν_μ
ν_τ
ν_2
Δm^2_{sol}
ν_1
Δm^2_{atm}
ν_3
m^2


Normal Hierarchy
$m_{\beta\beta}$
$m_3|U_{e3}|^2 e^{i\alpha_2}$
$m_2|U_{e2}|^2 e^{i\alpha_1}$
$m_1|U_{e1}|^2$
Im{$m_{\beta\beta}$}
Re{$m_{\beta\beta}$}


IH
NH
$|<m_{\beta\beta}>|$ (eV)
$m_{lightest}$ (eV)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}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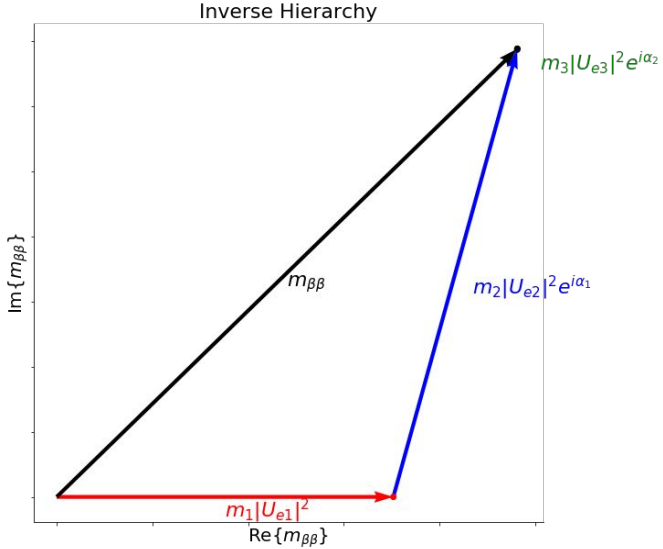
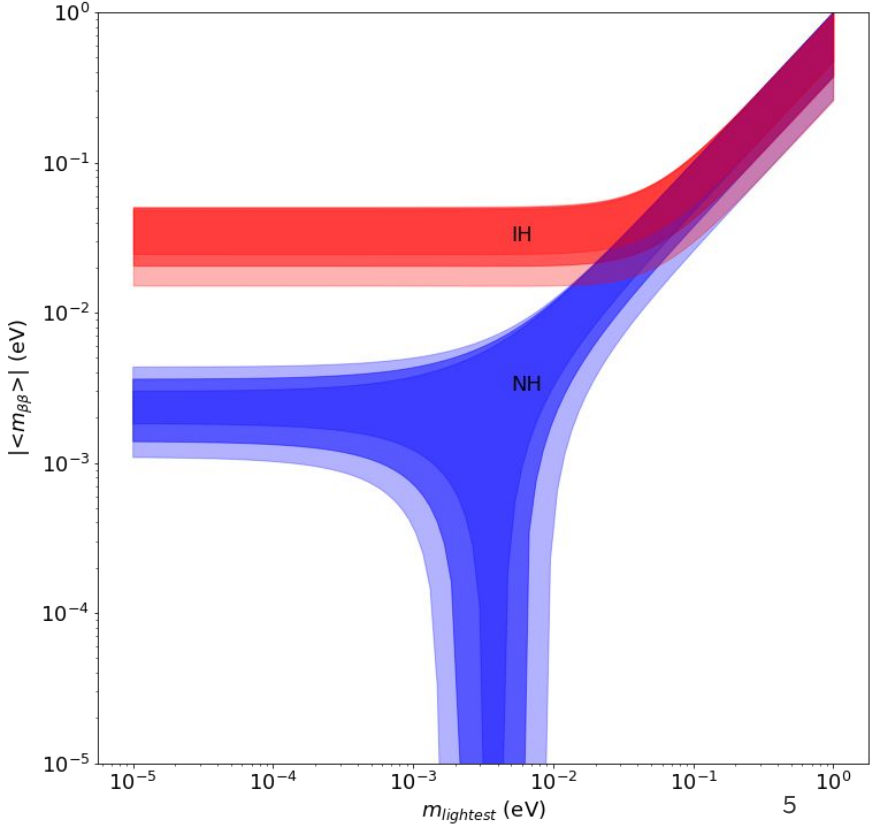
ν_τ


Inverse Hierarchy
$m_3|U_{e3}|^2e^{i\alpha_2}$
$m_{\beta\beta}$
$m_2|U_{e2}|^2e^{i\alpha_1}$
$m_1|U_{e1}|^2$
Im{$m_{\beta\beta}$}
Re{$m_{\beta\beta}$}


IH
NH
$|<m_{\beta\beta}>|$ (eV)
$m_{lightest}$ (eV)

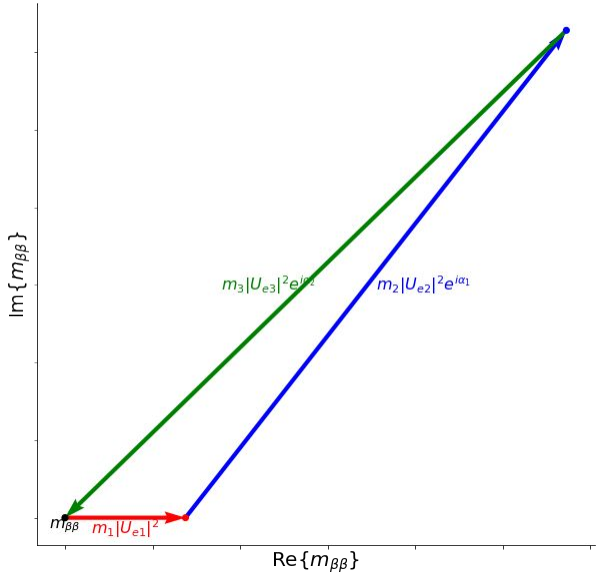
The doom case scenario

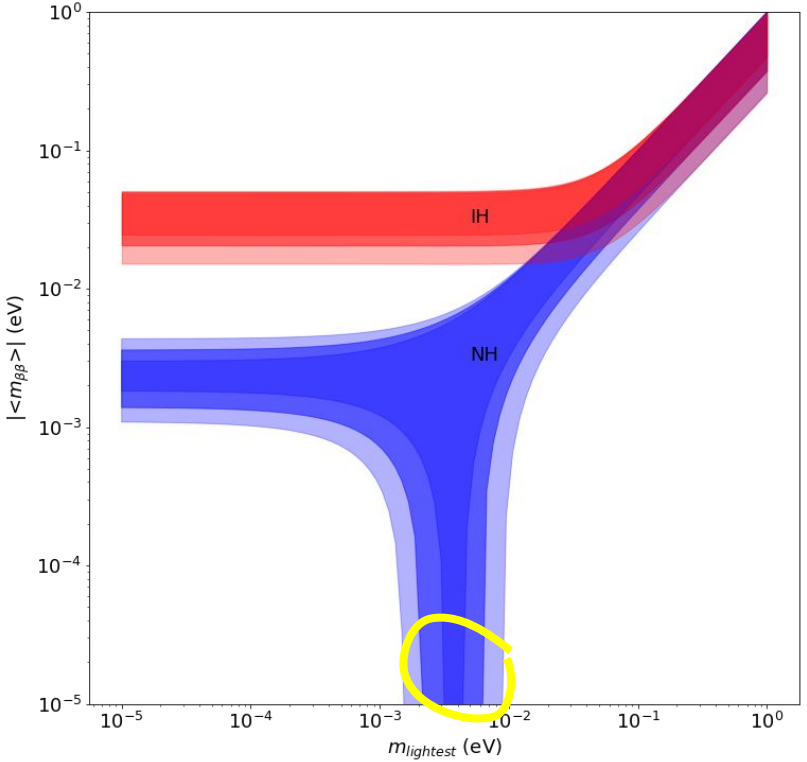
$$m_{\beta\beta} = \left| \sum_{i=1} |U_{ei}|^2 m_i e^{i\alpha_i} \right| = 0$$

$$\tan \alpha_1 = \frac{|U_{e3}|^2 m_3 \sin \alpha_2}{|U_{e1}|^2 m_1 + |U_{e3}|^2 m_3 \cos \alpha_2}$$

Slow cooking the lobster

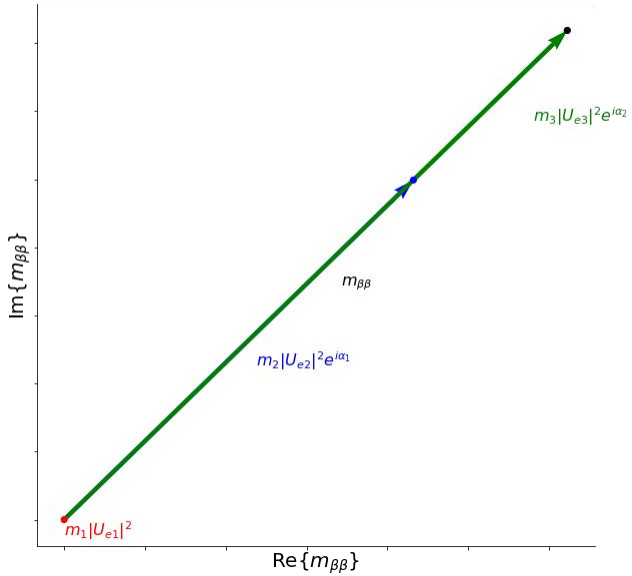
$$\tan\alpha_1 = \frac{|U_{e3}|^2 m_3 \sin\alpha_2}{|U_{e1}|^2 m_1 + |U_{e3}|^2 m_3 \cos\alpha_2}$$

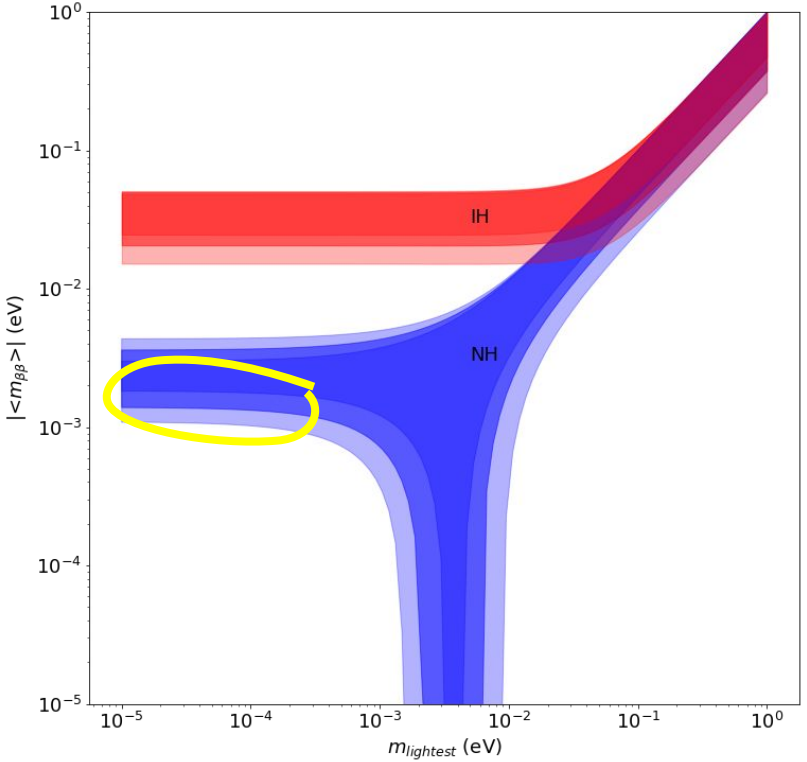




Slow cooking the lobster

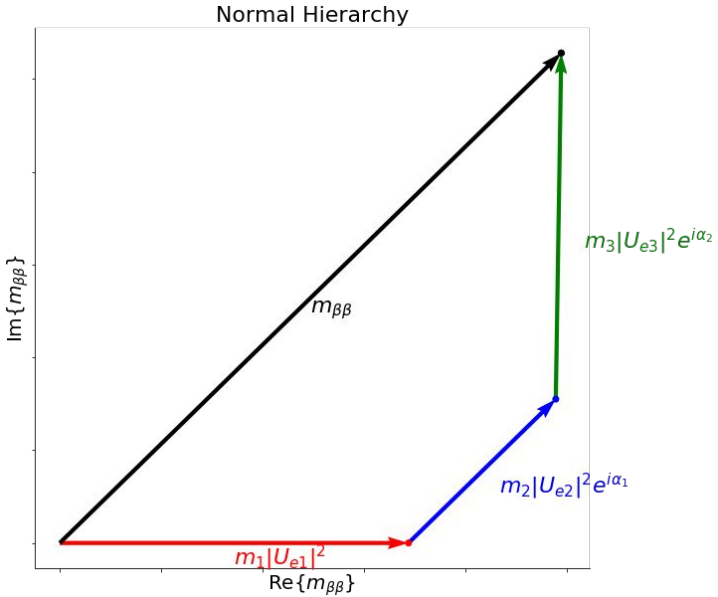
$$\tan\alpha_1 = \frac{|U_{e3}|^2 m_3 \sin\alpha_2}{|U_{e1}|^2 m_1 + |U_{e3}|^2 m_3 \cos\alpha_2} \approx \tan\alpha_2$$

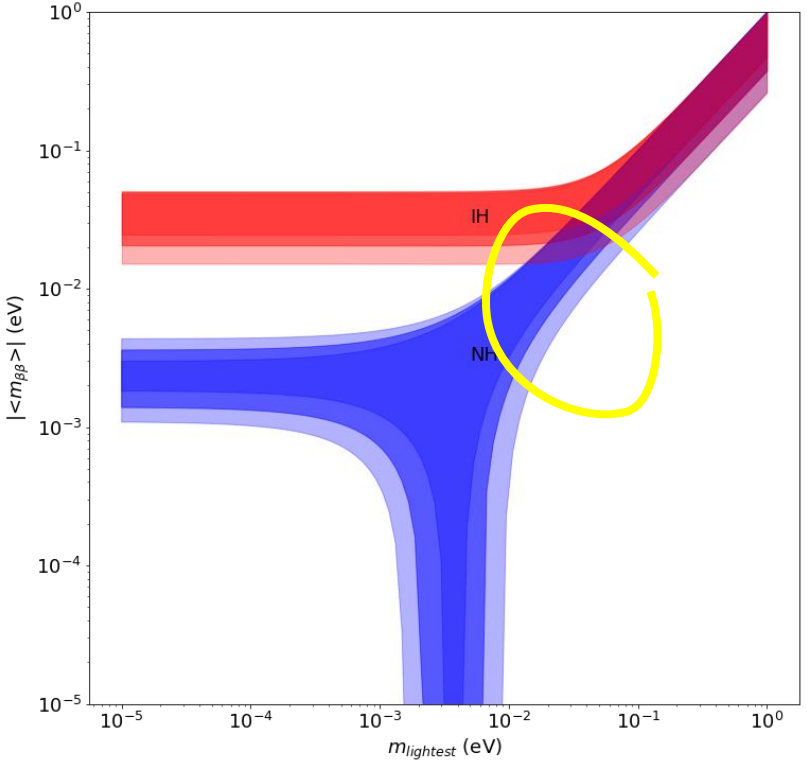




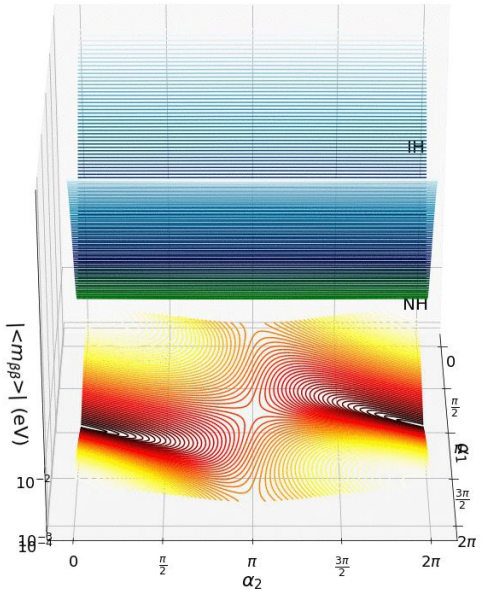
Slow cooking the lobster

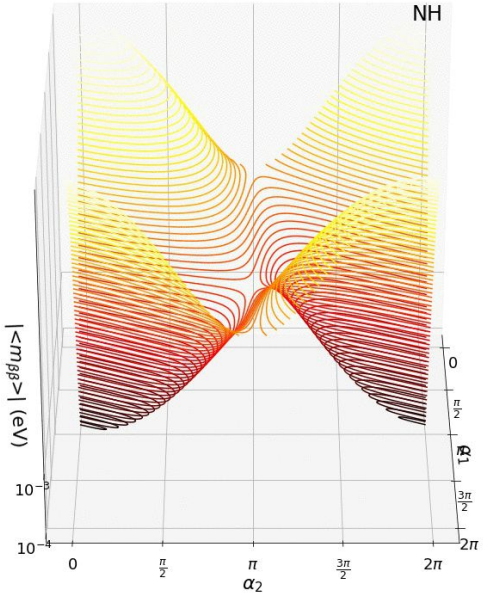
$$\tan\alpha_1 = \frac{|U_{e3}|^2 m_3 \sin\alpha_2}{|\mathbf{U_{e1}}|^2\mathbf{m_1} + |U_{e3}|^2 m_3 \cos\alpha_2}$$



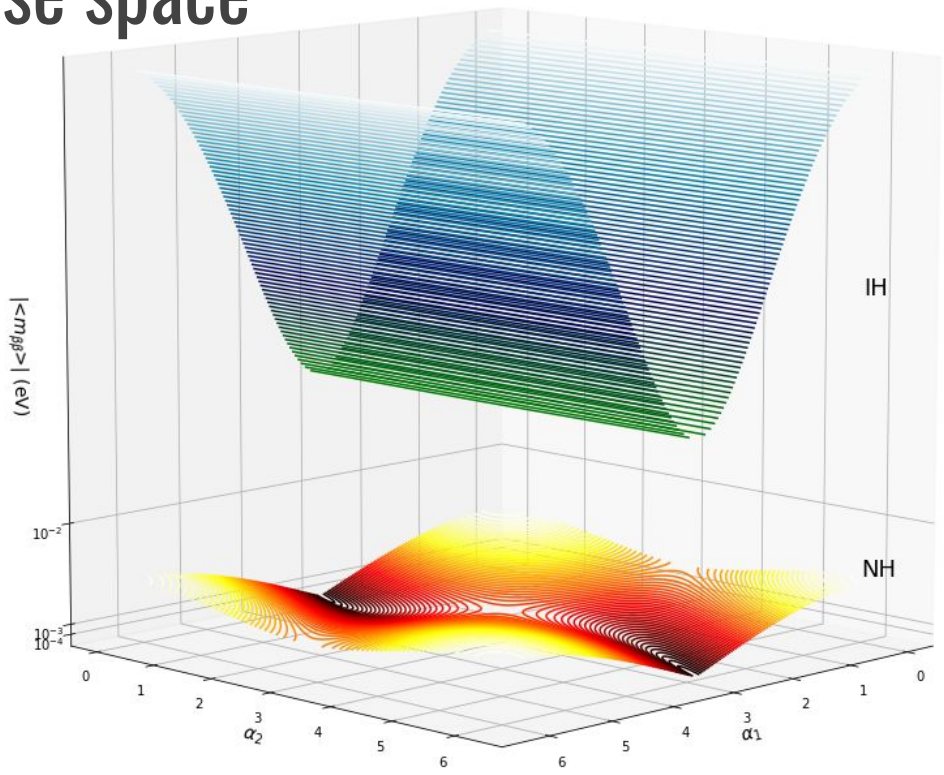


Majorana phase space





Majorana phase space



Conclusions/summary

- Got a better understanding of
  - Lobster plot's shape
  - Origin of mßß and majorana phases
- In the IH, m_3 barely contributes mßß
  - Mßß can't be cancelled
  - Only one majorana phase matters
- In the NH, both phases contribute and can conspire to cancel mßß
- Coding and "nullnubibi" experiments are fun!

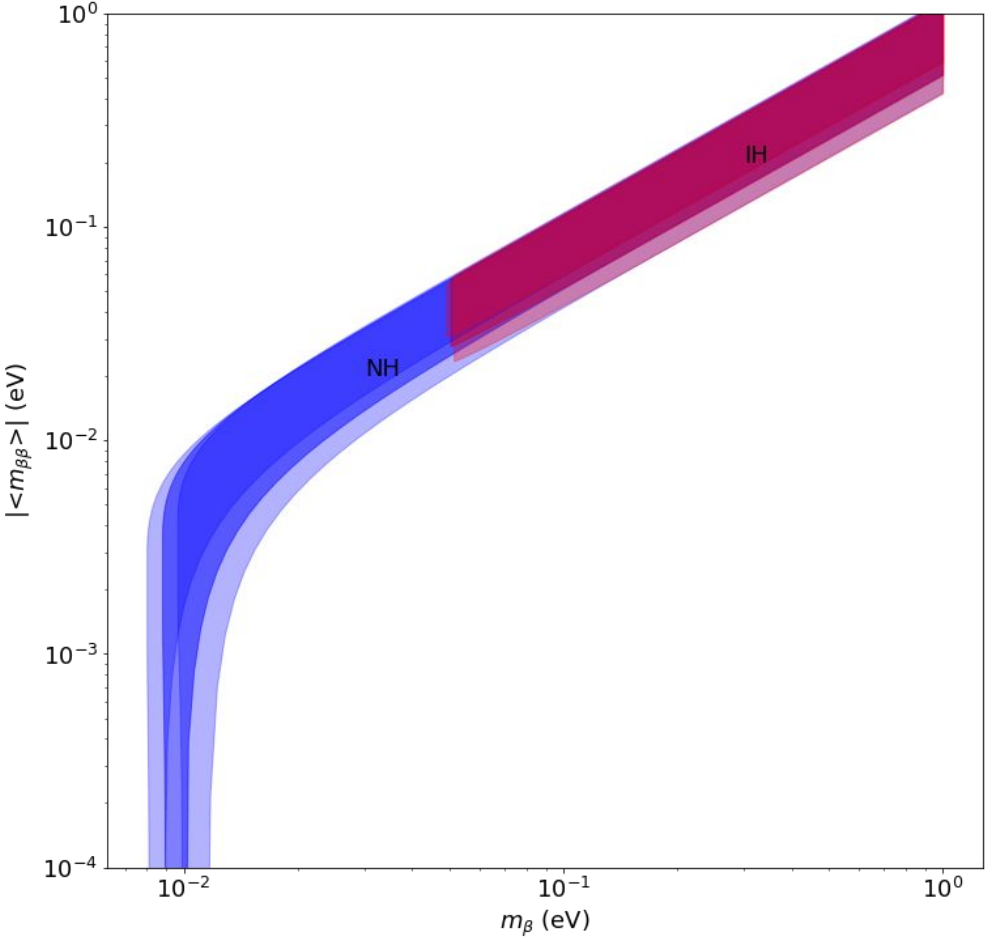
Backup

Neutrino mass scale: m_β

$$K(T) \equiv \left[\frac{\frac{\mathrm{d}\Gamma}{\mathrm{d}E}}{CF(E,Z)|\mathbf{p}|E} \right]^{1/2} \approx \sqrt{(Q-T)\sqrt{(Q-T)^2 - \sum_i |U_{ei}|^2 m_i^2}}$$

$$\text{assuming } m_i \ll Q - T \text{ and } \sum_i |U_{ei}|^2 = 1$$

$$m_\beta = \sqrt{\sum_i |U_{ei}|^2 m_i^2}$$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