Quark and Lepton mass textures: A model independent approach in the Kamland era

Marco Picariello[a]

Dipartimento di Fisica, Università di Milano
and INFN, Sezione di Milano

Works in collaboration with

P. Aliani (U L Bruxelles), V. Antonelli, F. Caravaglios, R. Ferrari (Milan), E. Torrente-Lujan (U A Madrid) [hep-ph 0207347, hep-ph 0212212]

[a] marco.picariello@mi.infn.it

Contents

Introduction

Standard Model (SM)

$\Updownarrow$

Experimental measurements

Free parameters in SM

quark mass matrices,

lepton mass matrices,

mixing angles and phases

$+$

Symmetries

$\Downarrow$

Model to be compared with experimental results

The Experimental constraints

used in this analysis

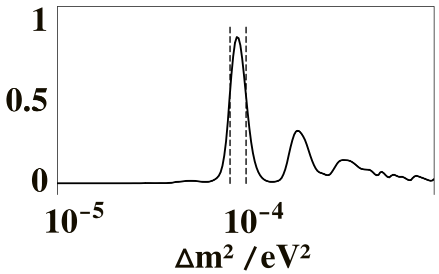
Quark flavor	Reference values GeV/c^2
top	$m_t^{pole} = 174.3 \pm 5.1$
bottom	$\overline{m}_b(\overline{m}_b) = 4.19 \pm 0.05$
charm	$\overline{m}_c(\overline{m}_c) = 1.304 \pm 0.027$
strange	$\overline{m}_s(m_\tau) = 0.125 \pm 0.030$
up and down quarks	**Reference values**
	$\frac{m_u}{m_d} = 0.46 \pm 0.09$ $Q^2 = \frac{4m_s^2-(m_u+m_d)^2}{4(m_d^2-m_u^2)} = 22.0 \pm 0.6$
CKM parameter	**Reference values**
λ	0.2237 ± 0.0033
$\lvert V_{cb} \rvert$	$(41.0 \pm 1.6) \times 10^{-3}$
ρ	0.225 ± 0.038
η	0.317 ± 0.041

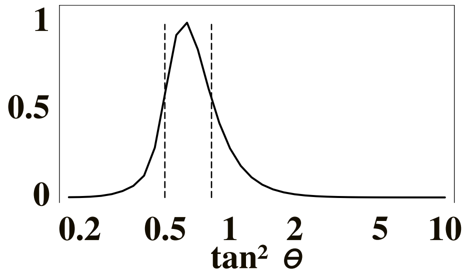
Table 1: *Values of quark masses and of the CKM matrix.*

The Experimental constraints

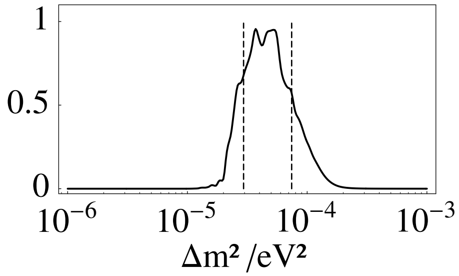
The solar neutrino problem:

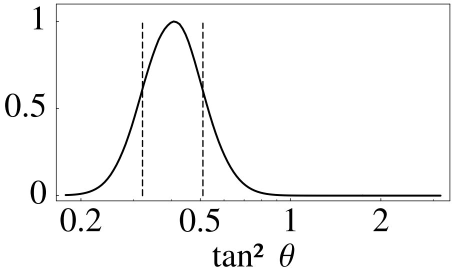
KamLAND





Post SNO





P. Aliani, V. Antonelli, R. Ferrari, M. P., E. Torrente-Lujan: hep-ph/0212212, hep-ph/0207348, hep-ph/0205053, Nucl.Phys.Proc.Suppl.110:361-363,2002, Nucl.Phys.B634:393-409,2002

The Experimental constraints

used in this analysis

Charged Lepton flavor	Reference values MeV/c^2
τ μ e	$m_\tau = 1777$ $m_\mu = 105.7$ $m_e = 0.511$
Neutral Leptons	**Reference values**
Atmospheric and CHOOZ	$\log\left(\frac{\delta m_2^2 - \delta m_3^2}{eV^2/c^4}\right) = -2.54 \pm 0.079$ $\log\left(\tan^2\theta_{23}\right) = 0 \pm 0.159$ $\log\left(\tan^2\theta_{13}\right) < -1.4$
Solar (post SNO-NC)	$\log\left(\frac{\delta m_1^2 - \delta m_2^2}{eV^2/c^4}\right) = -4.33 \pm 0.18$ $\log\left(\tan^2\theta_{12}\right) = -0.40 \pm 0.097$

Table 2: *Values of lepton masses and mixing angles.*

Theoretical prediction: a model

the charged lepton masses

$$L_{Yuk} = Y_l^{ij} H_d \bar{L}_i l_j + \text{h.c.} \quad \text{with} \quad Y_l^{ij} = \bar{\phi}^k / M^k$$

$U(2)$ horizontal symmetry:

$$U(2) \quad \stackrel{\phi_a, \Phi_{\{ab\}}}{\longrightarrow} \quad U(1) \quad \stackrel{A_{[ab]}}{\longrightarrow} \quad \emptyset$$

$$M_{L-R} \propto \begin{pmatrix} 0 & -v_3 & 0 \\ v_3 & v_2 & v_1 \\ 0 & v_1 & m \end{pmatrix} \equiv m \begin{pmatrix} 0 & -a_{12}\lambda^{v_{12}} & 0 \\ a_{12}\lambda^{v_{12}} & a_{22}\lambda^{v_{22}} & a_{23}\lambda^{v_{23}} \\ 0 & a_{23}\lambda^{v_{23}} & a_{33} \end{pmatrix}$$

where $|a_{ij}| = 1$ and are unpredictable.

A model independent parameterization

Parameterization for the neutrino matrix:

$$M_\nu = m_\nu \begin{pmatrix} a_{11}\lambda^{v_{11}} & a_{12}\lambda^{v_{12}} & a_{13}\lambda^{v_{13}} \\ a_{21}\lambda^{v_{21}} & a_{22}\lambda^{v_{22}} & a_{23}\lambda^{v_{23}} \\ a_{31}\lambda^{v_{31}} & a_{32}\lambda^{v_{32}} & a_{33}\lambda^{v_{33}} \end{pmatrix}$$

where $\lambda \approx 0.2$, and $|a_{ij}| = 1$ (are unpredictable).

Parameterization for the charged lepton matrix:

$$M_{L-R} = m \begin{pmatrix} 0 & {\epsilon_1}^{1-p} & 0 \\ {\epsilon_1}^{p} & \epsilon & \epsilon^{r} \\ 0 & \epsilon^{d} & 1 \end{pmatrix}$$

where m ($\approx m_\tau$), ϵ and ϵ_1 ($\approx \frac{m_e m_\mu}{m_\tau^2}$) are related to charged lepton masses.

Method applied for the analysis

$$\chi^2(O^{\rm th}) = \sum_i \left(\frac{O_i^{\rm th} - O_i^{\rm exp}}{\sigma_i^{\rm exp}} \right)^2 .$$

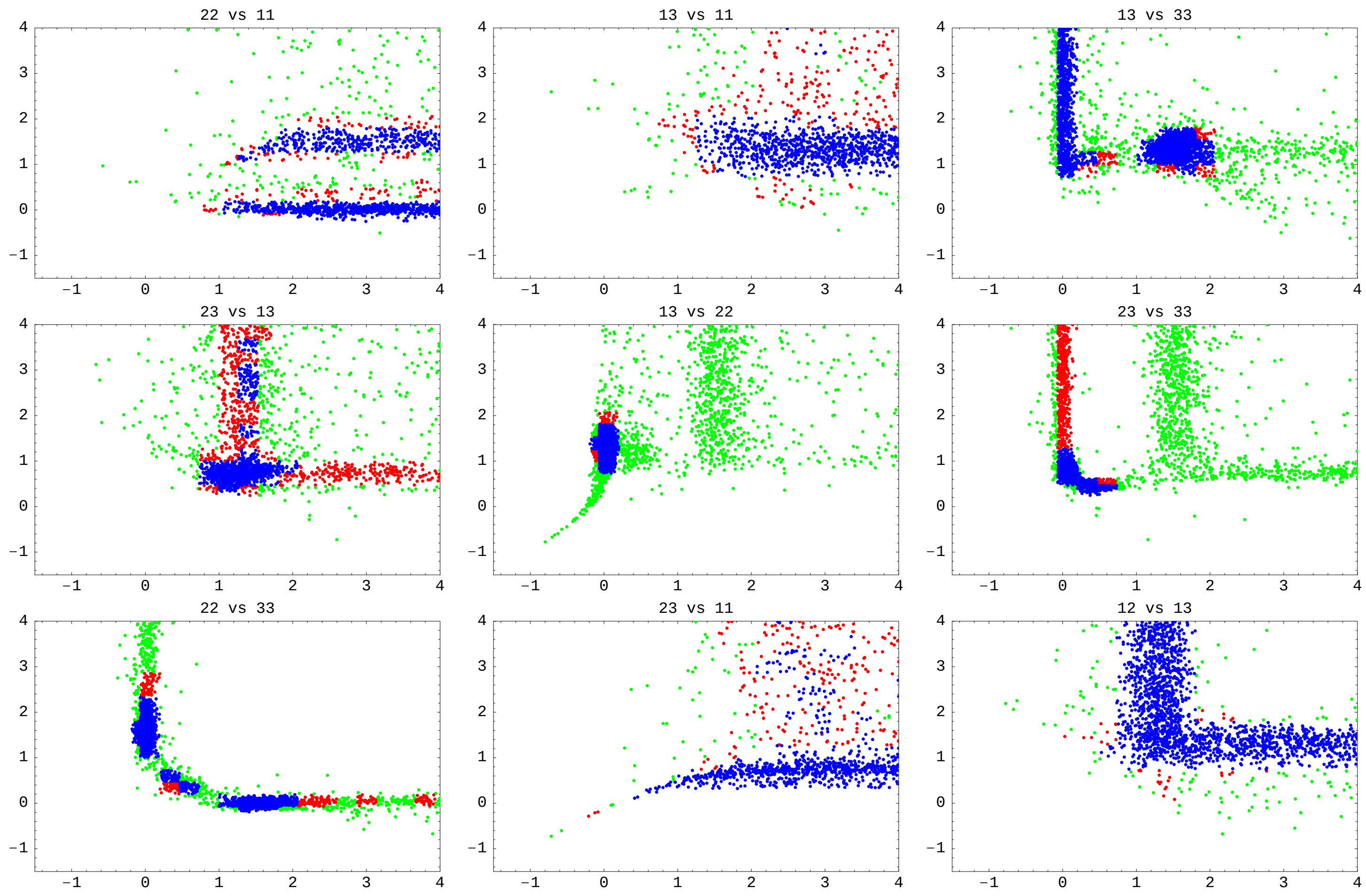
where $O_i^{\rm exp} \pm \sigma_i^{\rm exp}$ are the experimental inputs as shown in Tables 1, 2 and 3.

Correlations among different experimental data are neglected.

Theoretical errors are not introduced.

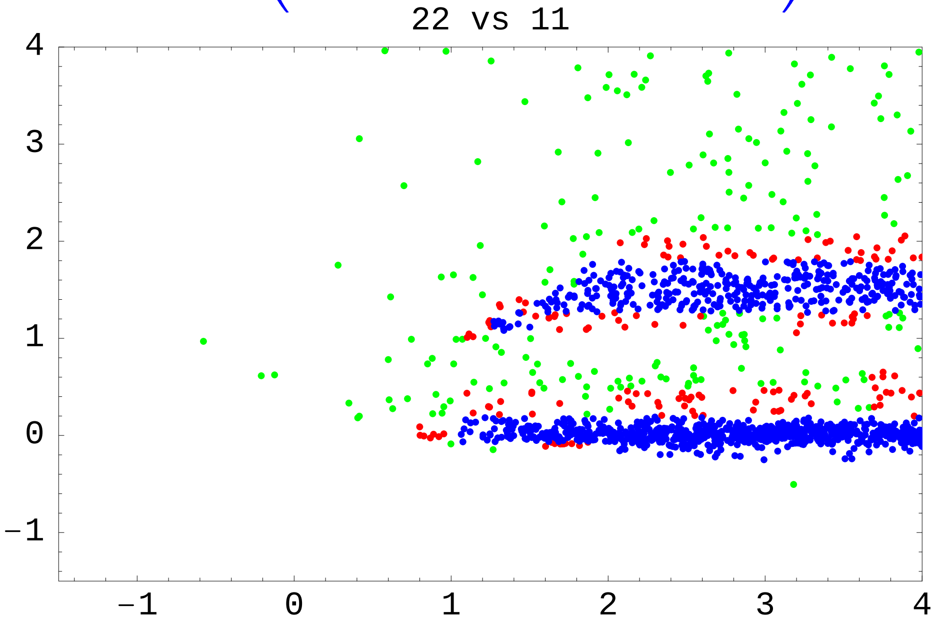
I.e. the constraints are imposed at low energy: renormalization flow has to be take into account for any specific model ($\in$ theoretical error).

Neutrino Results



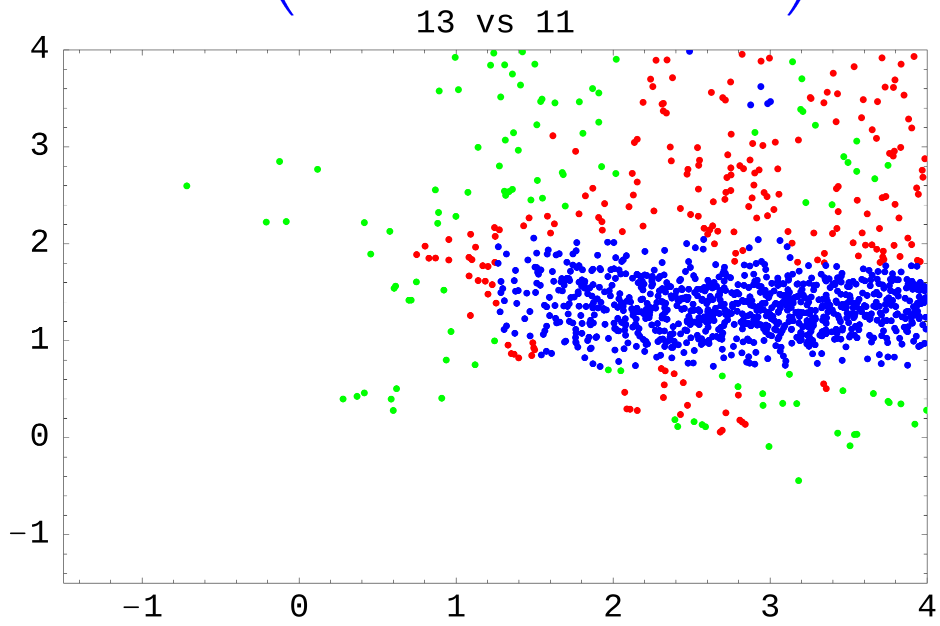
Neutrino Results

$$M_\nu = \begin{pmatrix} \lambda^{v_{11}} & \lambda^{v_{12}} & \lambda^{v_{13}} \\ \lambda^{v_{21}} & \lambda^{v_{22}} & \lambda^{v_{23}} \\ \lambda^{v_{31}} & \lambda^{v_{32}} & \lambda^{v_{33}} \end{pmatrix}$$



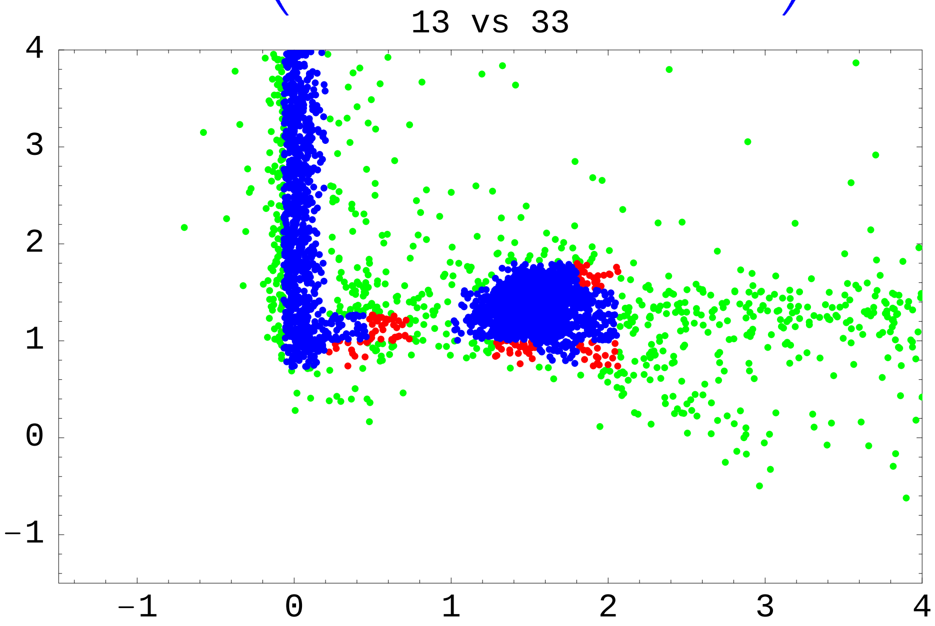
Neutrino Results

$$M_\nu = \begin{pmatrix} \lambda^{v_{11}} & \lambda^{v_{12}} & \lambda^{v_{13}} \\ \lambda^{v_{21}} & \lambda^{v_{22}} & \lambda^{v_{23}} \\ \lambda^{v_{31}} & \lambda^{v_{32}} & \lambda^{v_{33}} \end{pmatrix}$$



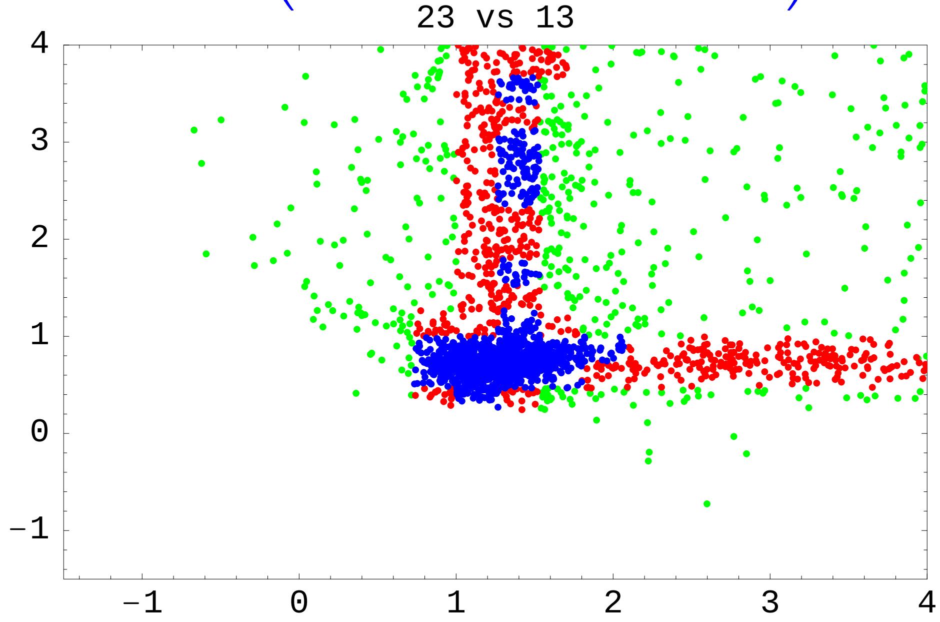
Neutrino Results

$$M_\nu = \begin{pmatrix} \lambda^{v_{11}} & \lambda^{v_{12}} & \lambda^{v_{13}} \\ \lambda^{v_{21}} & \lambda^{v_{22}} & \lambda^{v_{23}} \\ \lambda^{v_{31}} & \lambda^{v_{32}} & \lambda^{v_{33}} \end{pmatrix}$$



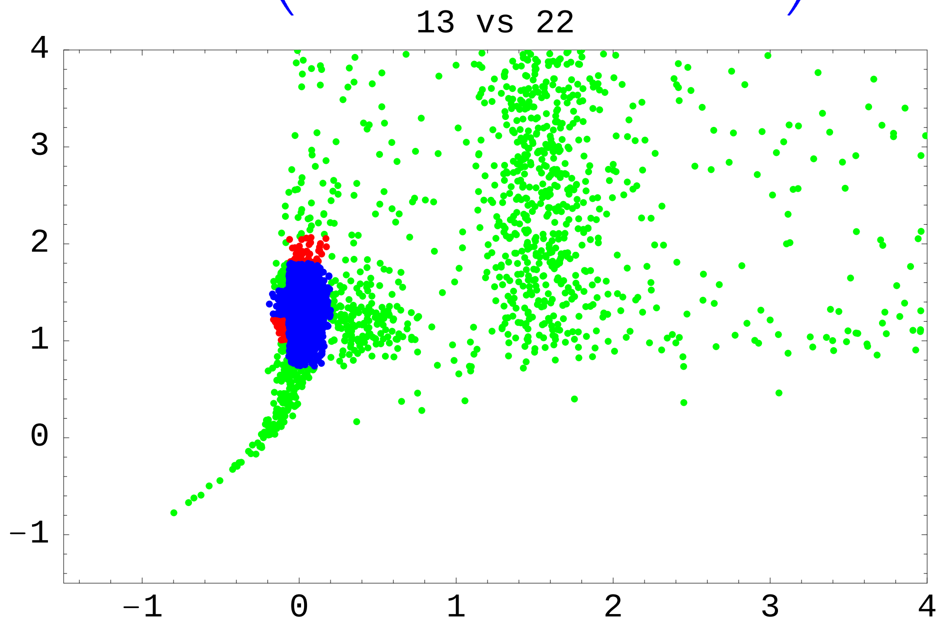
Neutrino Results

$$M_\nu = \begin{pmatrix} \lambda^{v_{11}} & \lambda^{v_{12}} & \lambda^{v_{13}} \\ \lambda^{v_{21}} & \lambda^{v_{22}} & \lambda^{v_{23}} \\ \lambda^{v_{31}} & \lambda^{v_{32}} & \lambda^{v_{33}} \end{pmatrix}$$



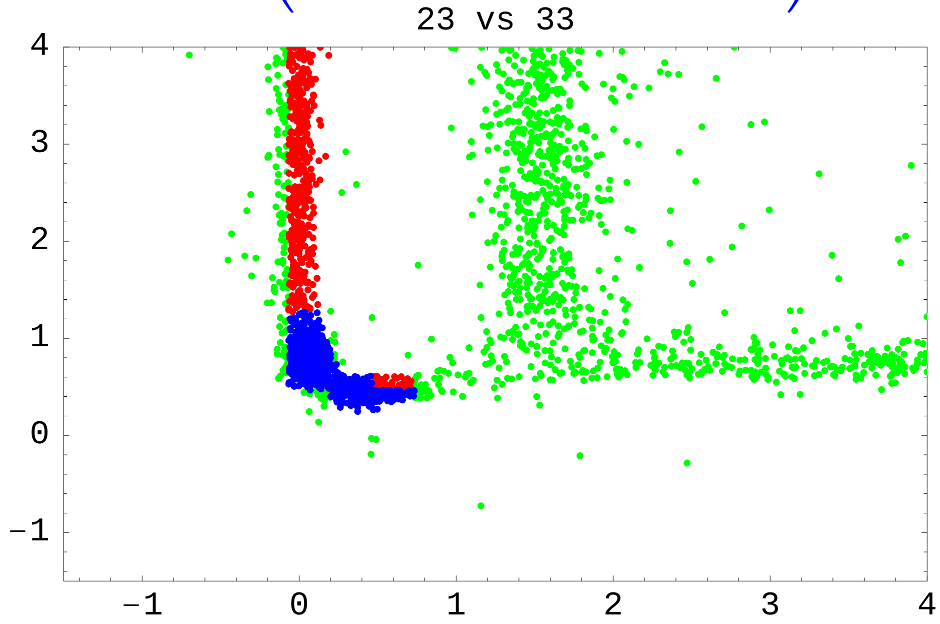
Neutrino Results

$$M_\nu = \begin{pmatrix} \lambda^{v_{11}} & \lambda^{v_{12}} & \lambda^{v_{13}} \\ \lambda^{v_{21}} & \lambda^{v_{22}} & \lambda^{v_{23}} \\ \lambda^{v_{31}} & \lambda^{v_{32}} & \lambda^{v_{33}} \end{pmatrix}$$



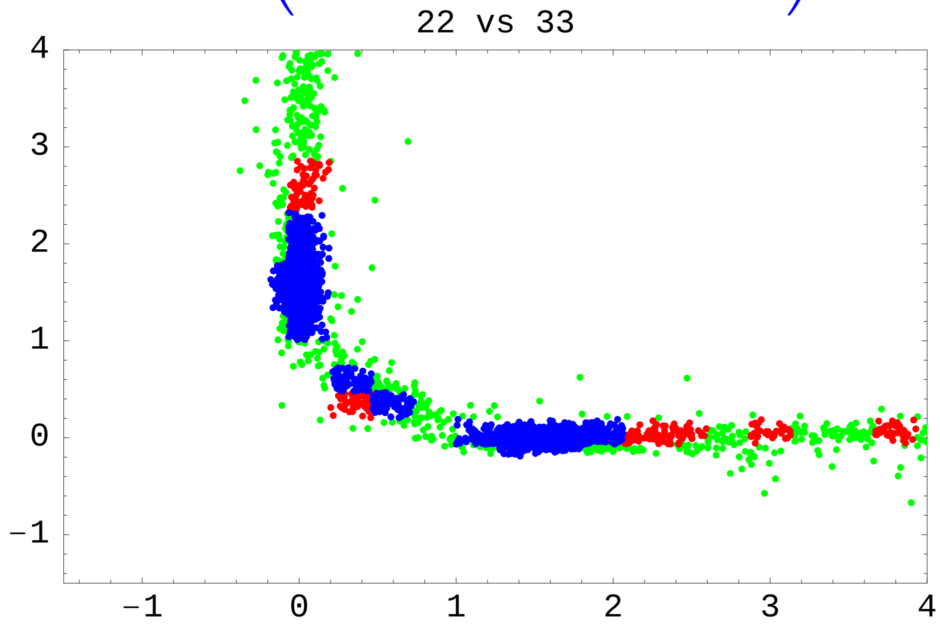
Neutrino Results

$$M_\nu = \begin{pmatrix} \lambda^{v_{11}} & \lambda^{v_{12}} & \lambda^{v_{13}} \\ \lambda^{v_{21}} & \lambda^{v_{22}} & \lambda^{v_{23}} \\ \lambda^{v_{31}} & \lambda^{v_{32}} & \lambda^{v_{33}} \end{pmatrix}$$



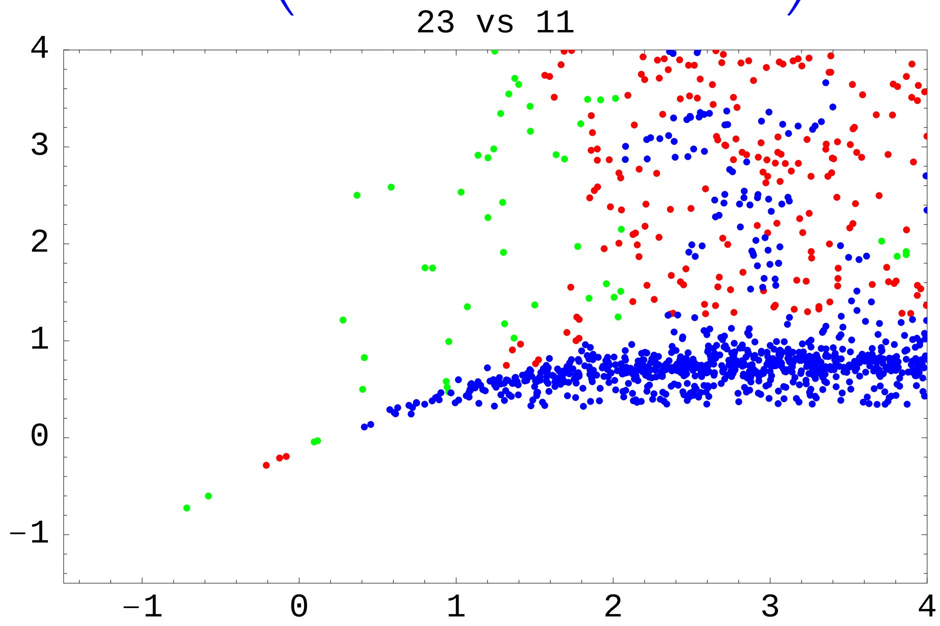
Neutrino Results

$$M_\nu = \begin{pmatrix} \lambda^{v_{11}} & \lambda^{v_{12}} & \lambda^{v_{13}} \\ \lambda^{v_{21}} & \lambda^{v_{22}} & \lambda^{v_{23}} \\ \lambda^{v_{31}} & \lambda^{v_{32}} & \lambda^{v_{33}} \end{pmatrix}$$



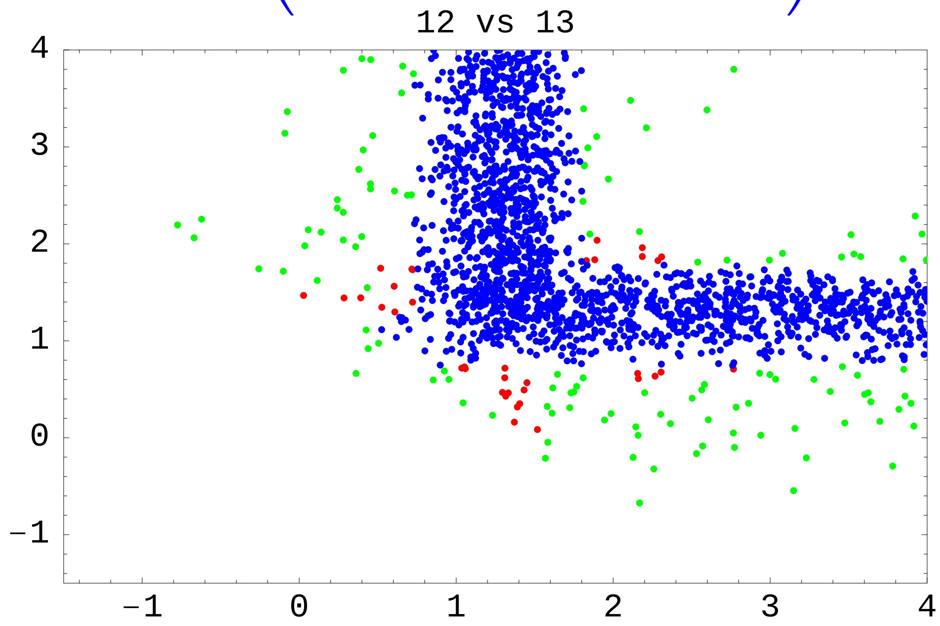
Neutrino Results

$$M_\nu = \begin{pmatrix} \lambda^{v_{11}} & \lambda^{v_{12}} & \lambda^{v_{13}} \\ \lambda^{v_{21}} & \lambda^{v_{22}} & \lambda^{v_{23}} \\ \lambda^{v_{31}} & \lambda^{v_{32}} & \lambda^{v_{33}} \end{pmatrix}$$



Neutrino Results

$$M_\nu = \begin{pmatrix} \lambda^{v_{11}} & \lambda^{v_{12}} & \lambda^{v_{13}} \\ \lambda^{v_{21}} & \lambda^{v_{22}} & \lambda^{v_{23}} \\ \lambda^{v_{31}} & \lambda^{v_{32}} & \lambda^{v_{33}} \end{pmatrix}$$



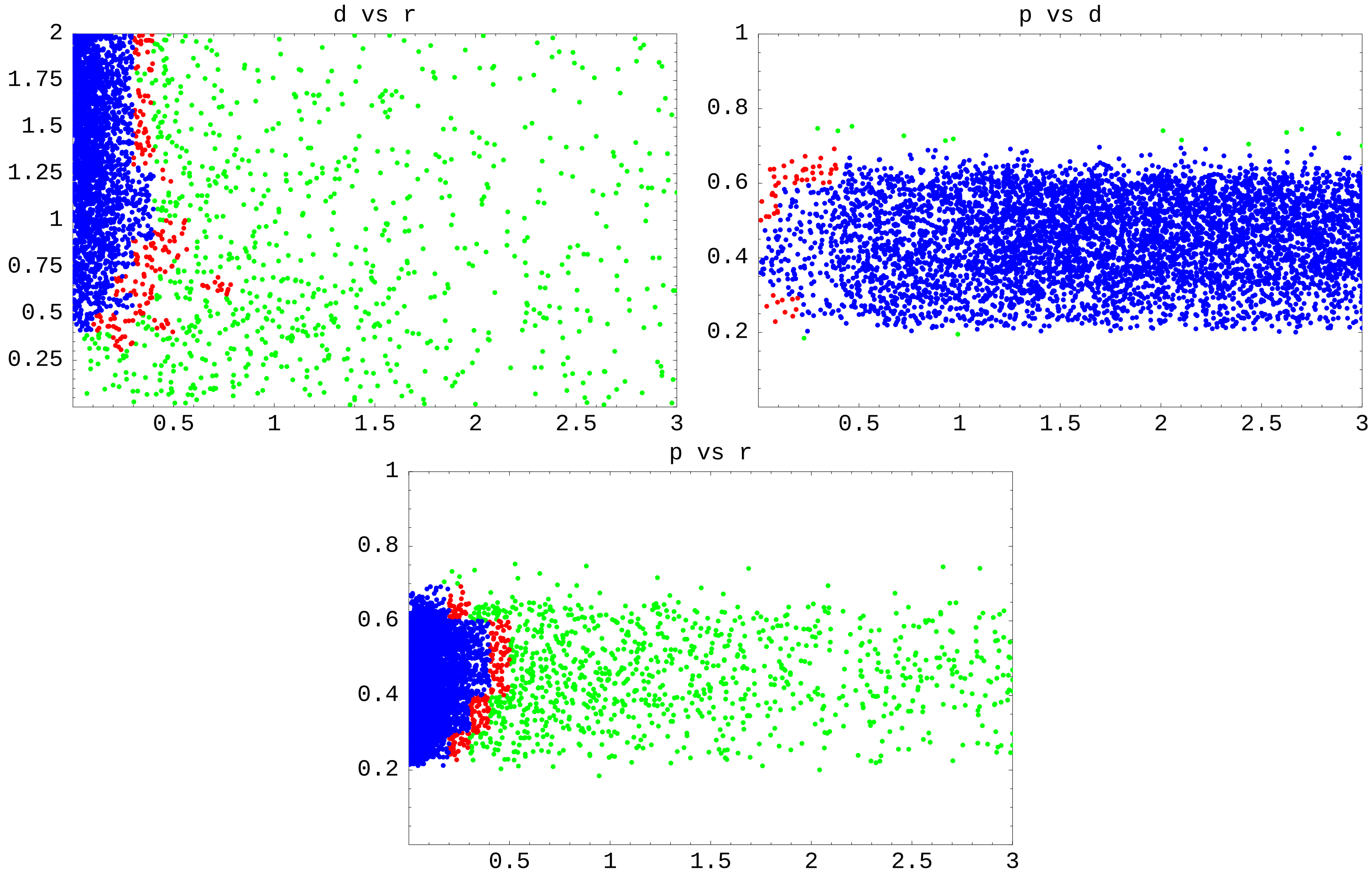
Neutrino Results

$$M_\nu = \begin{pmatrix} \lambda^{v_{11}} & \lambda^{v_{12}} & \lambda^{v_{13}} \\ \lambda^{v_{21}} & \lambda^{v_{22}} & \lambda^{v_{23}} \\ \lambda^{v_{31}} & \lambda^{v_{32}} & \lambda^{v_{33}} \end{pmatrix}$$

We find the following regions (and symmetrization $2 \leftrightarrow 3$):

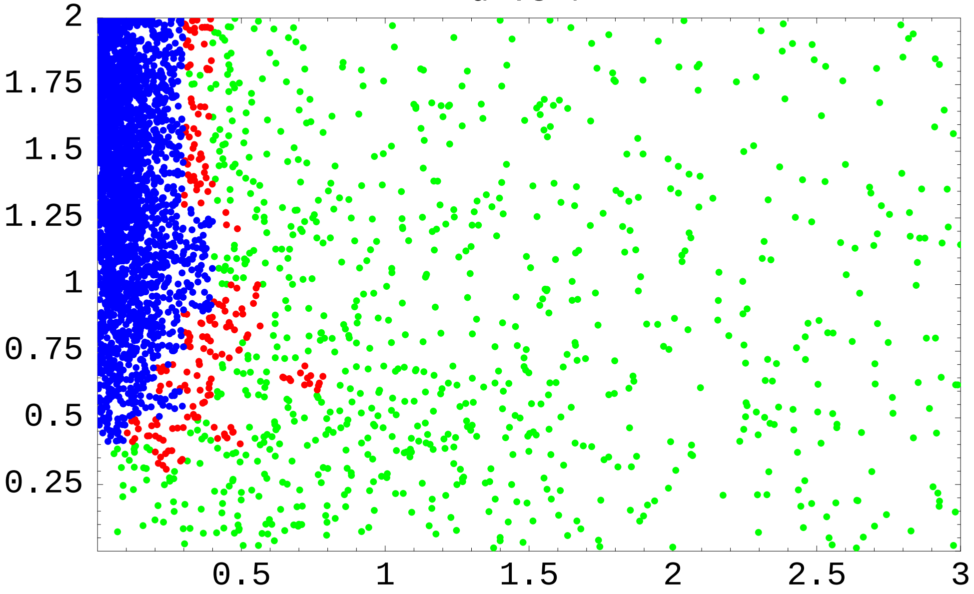
$2. < v_{13}$ $-0.125 < v_{33} < 0.125$	$2. < v_{23}$ $1 < v_{11}$	$0.7 < v_{12} < 1.8$ $1 < v_{22} < 2.$ $\rho = 41.26$
$0. < v_{13} < 2.$ $-0.125 < v_{33} < 0.125$	$2. < v_{23}$ $1 < v_{11}$	$0.6 < v_{12} < 2.$ $1 < v_{22} < 2.2$ $\rho = 14.14$
$2. < v_{13}$ $-0.15 < v_{33} < 0.2$	$0. < v_{23} < 2.$ $1 < v_{11}$	$0.6 < v_{12} < 2.$ $1 < v_{22} < 2.$ $\rho = 15.77$
$2. < v_{13}$ $-0.2 < v_{33} < 0.2$	$0.5 < v_{23} < 1.25$ $1 < v_{11}$	$0.5 < v_{12} < 2.$ $2 < v_{22}$ $\rho = 13.76$

Charged Lepton Results



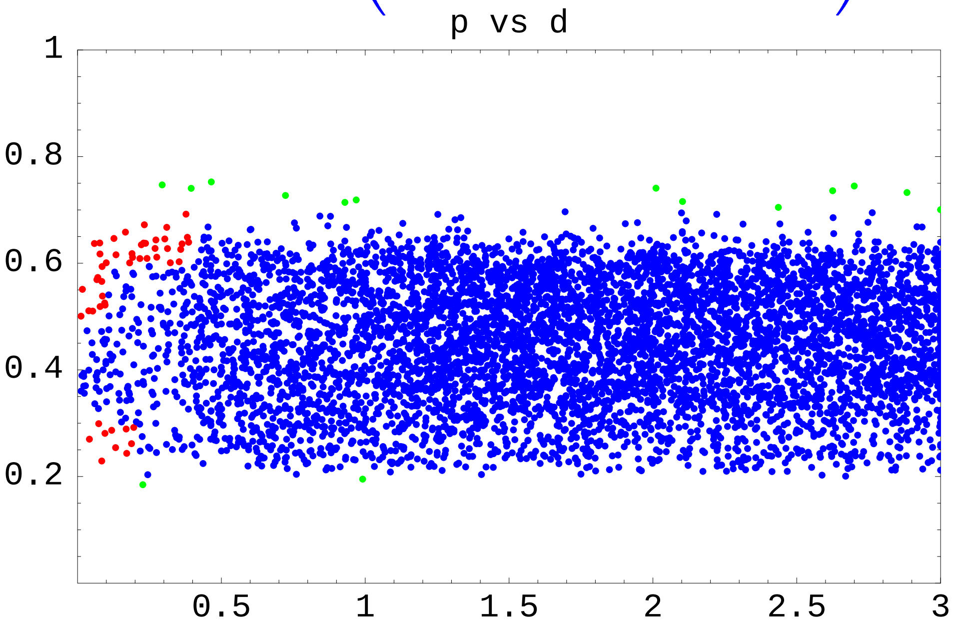
Charged Lepton Results

$$M_{L-R} = m \begin{pmatrix} 0 & {\epsilon_1}^{1-p} & 0 \\ {\epsilon_1}^{p} & \epsilon & \epsilon^{r} \\ 0 & \epsilon^{d} & 1 \end{pmatrix}$$



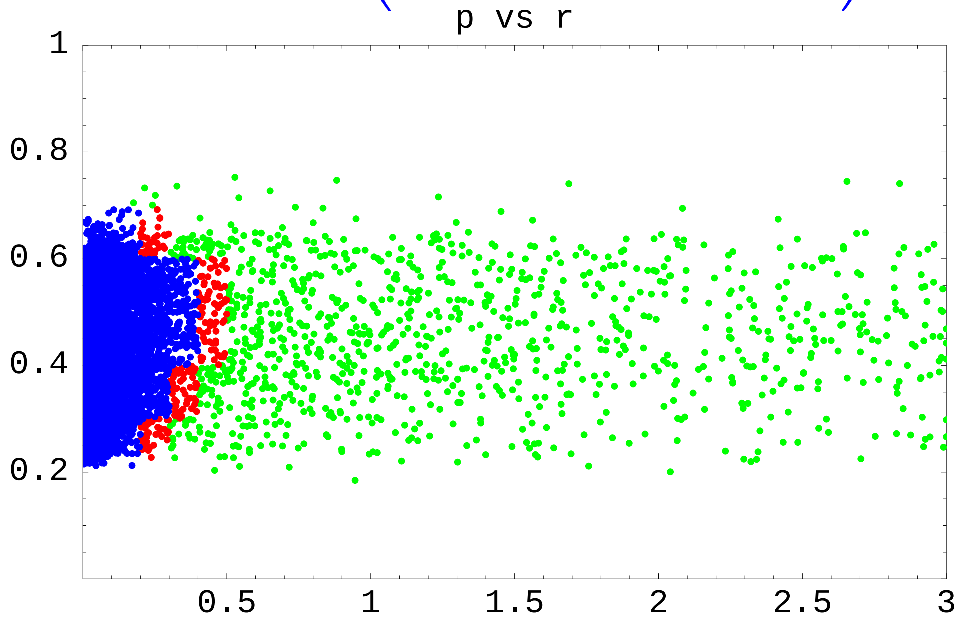
Charged Lepton Results

$$M_{L-R} = m \begin{pmatrix} 0 & {\epsilon_1}^{1-p} & 0 \\ {\epsilon_1}^p & \epsilon & \epsilon^r \\ 0 & \epsilon^d & 1 \end{pmatrix}$$



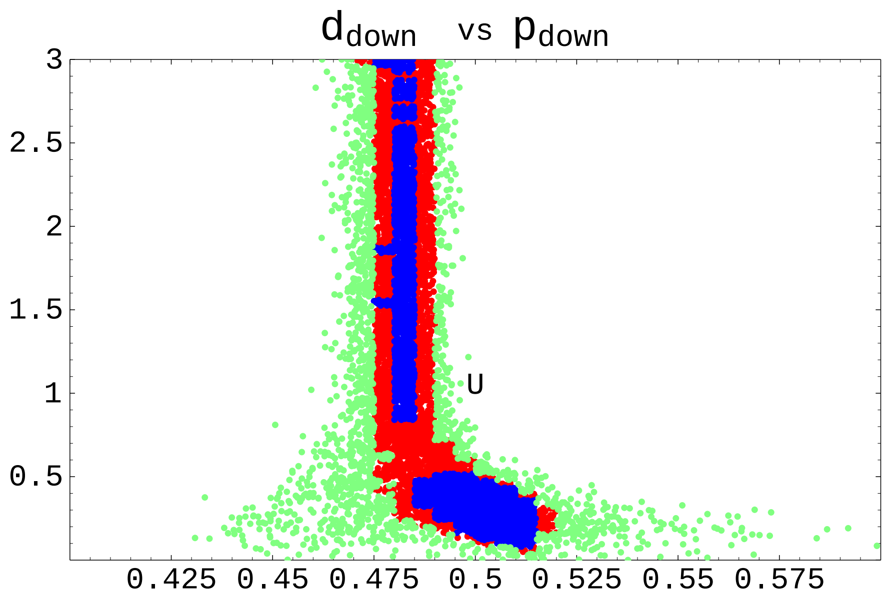
Charged Lepton Results

$$M_{L-R} = m \begin{pmatrix} 0 & {\epsilon_1}^{1-p} & 0 \\ {\epsilon_1}^{p} & \epsilon & \epsilon^{r} \\ 0 & \epsilon^{d} & 1 \end{pmatrix}$$



Quarks Results

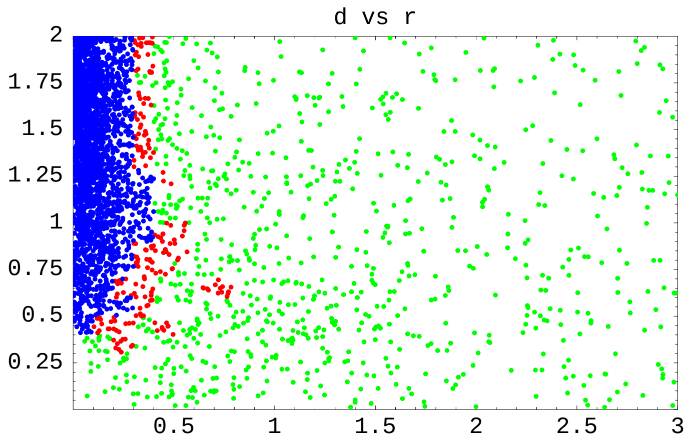
$$M^q_{L-R} = m \begin{pmatrix} 0 & {\epsilon_1}^{1-p} & 0 \\ {\epsilon_1}^p & \epsilon & \epsilon^r \\ 0 & \epsilon^d & 1 \end{pmatrix}$$

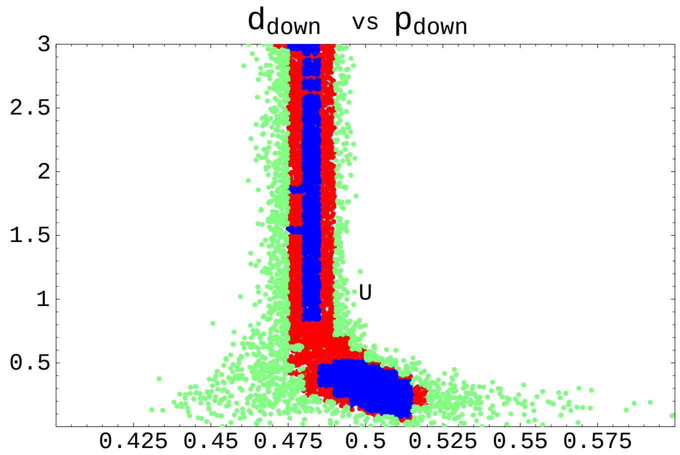


F. Caravaglios, P. Roudeau, A. Stocchi: Nucl.Phys. B633 (2002) 193-211

Unification

$$M^l = m \begin{pmatrix} 0 & {\epsilon_1}^{1-p} & 0 \\ {\epsilon_1}^{p} & \epsilon & \epsilon^r \\ 0 & \epsilon^d & 1 \end{pmatrix} \qquad M^q = m \begin{pmatrix} 0 & {\epsilon_1}^{1-p} & 0 \\ {\epsilon_1}^{p} & \epsilon & \epsilon^r \\ 0 & \epsilon^d & 1 \end{pmatrix}$$





$$5_2 \equiv (s_R, s_R, s_R, \nu_L, \mu_L) \qquad \bar{5}_2 10_3 \Rightarrow \bar{s}_R b_L + \bar{\mu}_L \tau_R$$

This is in agreement with b-τ mass unification!

Conclusions

- Standard Model and Experiments: KamLAND era
- A model independent parameterization
  - U(2) horizontal symmetry for quarks and charged leptons
  - No symmetry for neutrinos
- The method: Montecarlo simulation
- Mass matrices for neutral and charged leptons
- Allowed regions in the parameter space
- Another signal of unification!