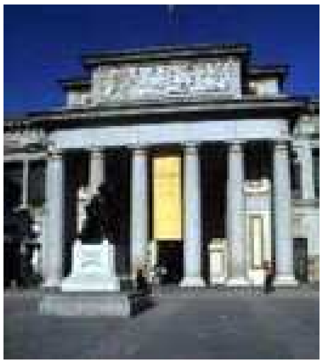
Quark and Lepton mass textures: A model independent approach in the post SNO-NC era

Marco Picariello[a]

Dipartimento di Fisica, Università di Milano via Celoria 16, 20133 Milano, Italy and INFN, Sezione di Milano



Works in collaboration with

P. Aliani, V. Antonelli, F. Caravaglios, R. Ferrari, E. Torrente-Lujan

[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 value 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
	$\frac{m_u}{m_d} = 0.46 \pm 0.09$ $Q^2 = \frac{4m_s^2-(m_u+m_d)^2}{4(m_d^2-m_u^2)} = 22.0 \pm 0.6$

Table 1: *Values of quark masses.*

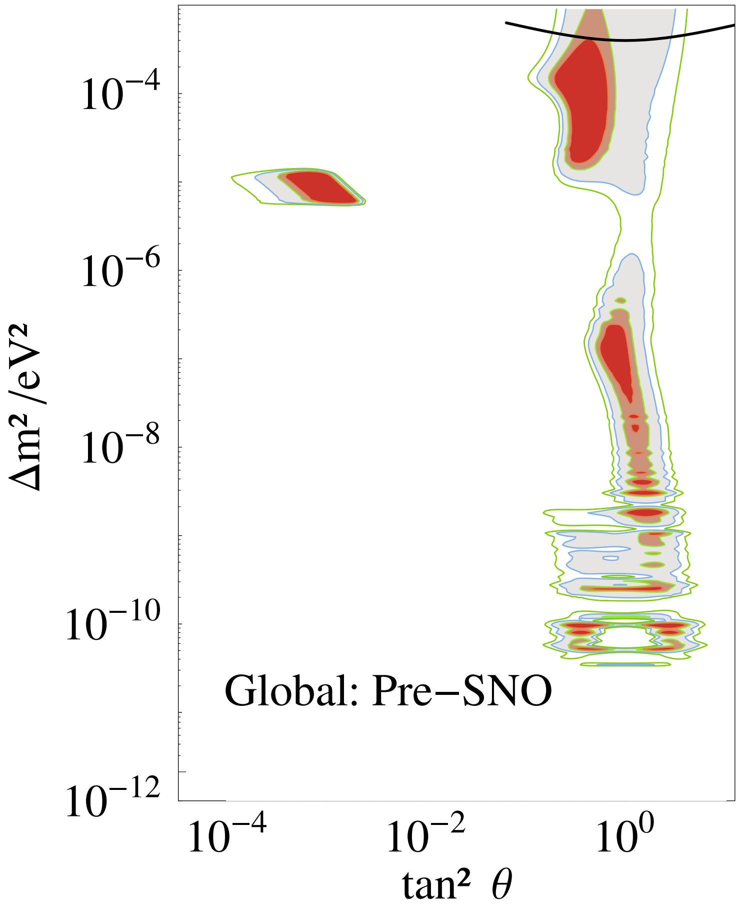
CKM parameter	Reference value
λ	0.2237 ± 0.0033
$\lvert V_{cb} \rvert$	$(41.0 \pm 1.6) \times 10^{-3}$
ρ	0.225 ± 0.038
η	0.317 ± 0.041

Table 2: *Values of the CKM matrix.*

The Experimental constraints

used in this analysis

The solar neutrino problem:



P. Aliani, V. Antonelli, R. Ferrari, M. P., E. Torrente-Lujan

hep-ph/0205061, hep-ph/0205053, hep-ph/0112101

[Nucl.Phys.Proc.Suppl.], hep-ph/0111418 [Nucl. Phys.]

The Experimental constraints

used in this analysis

Charged Lepton flavor	Reference value MeV/c^2
τ	$\mathrm{m}_\tau = 1777$
μ	$\mathrm{m}_\mu = 105.7$
e	$\mathrm{m}_e = 0.511$

Neutral Leptons	Reference value
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 3: *Values of lepton masses and mixing angles.*

A model independent parameterization

Parameterization for the neutrino matrix:

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

where $\lambda \approx 0.6$.

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

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

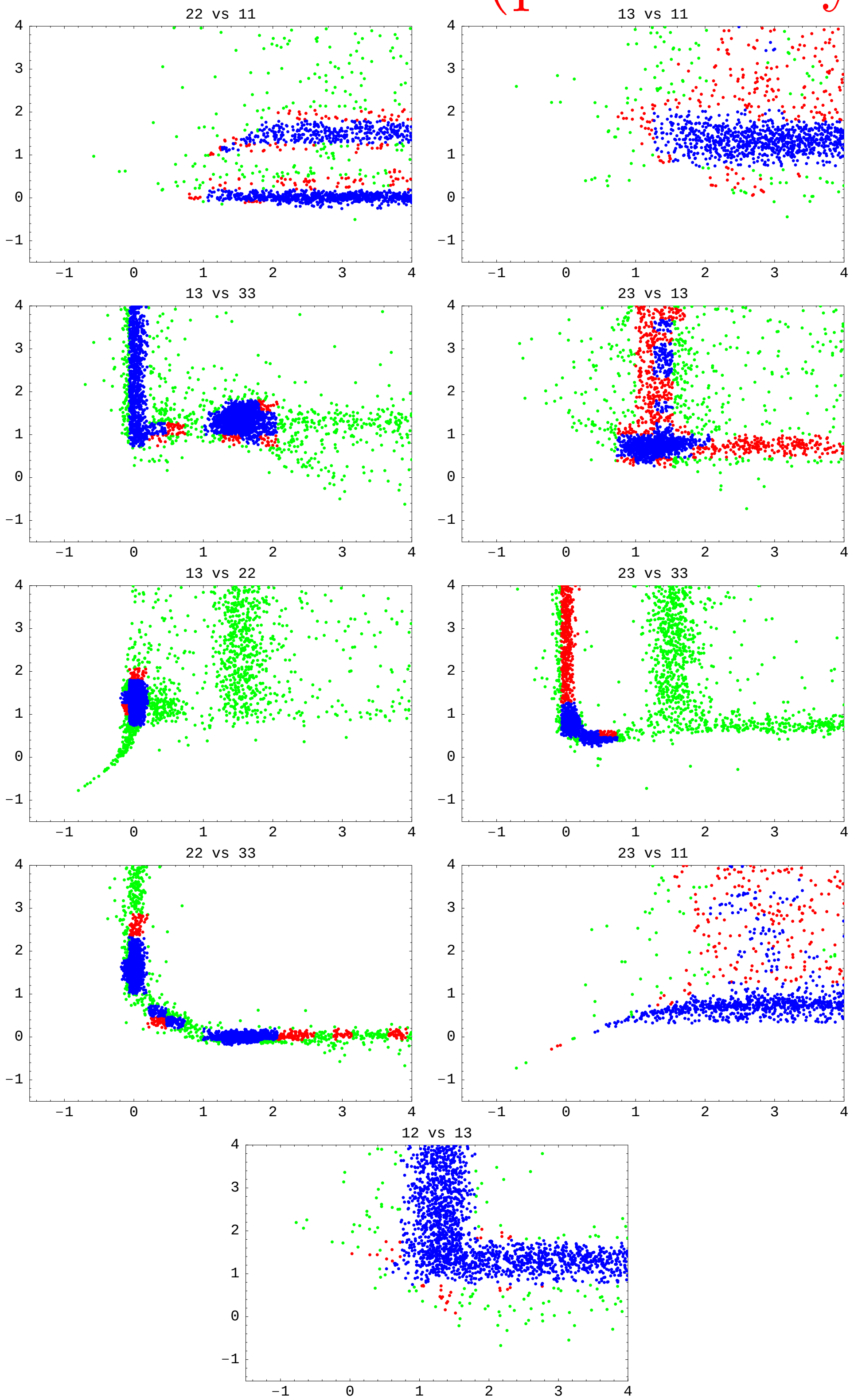
where $O_i^{\rm exp} \pm \sigma_i^{\rm exp}$ are the experimental inputs as shown in Tables 1, 2 and 3.

Correlations among different experimental data are neglected.

Theoretical errors are not introduced.

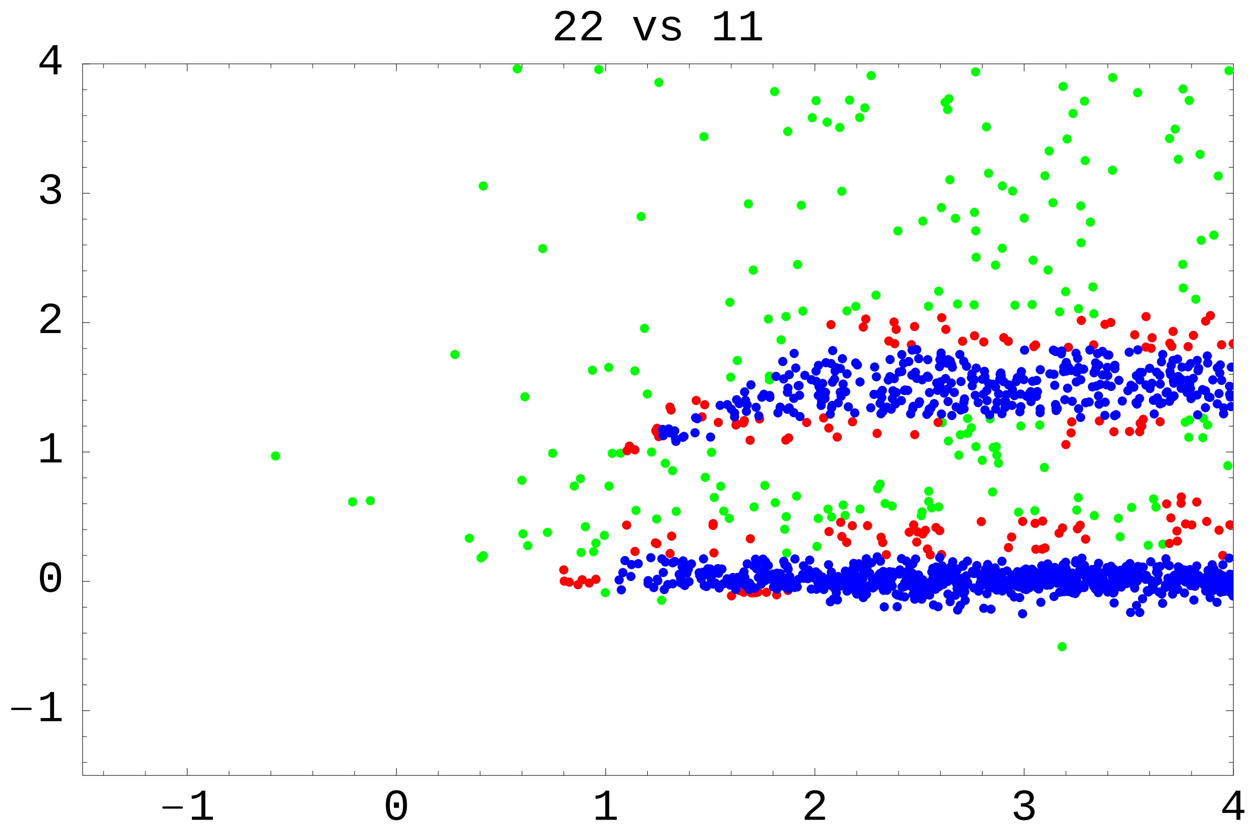
I.e. the constraints are imposed at low energy: renormalization flow has to be take into account for any specific model ($\in$ theoretical error).

Neutrino Results (preliminary)



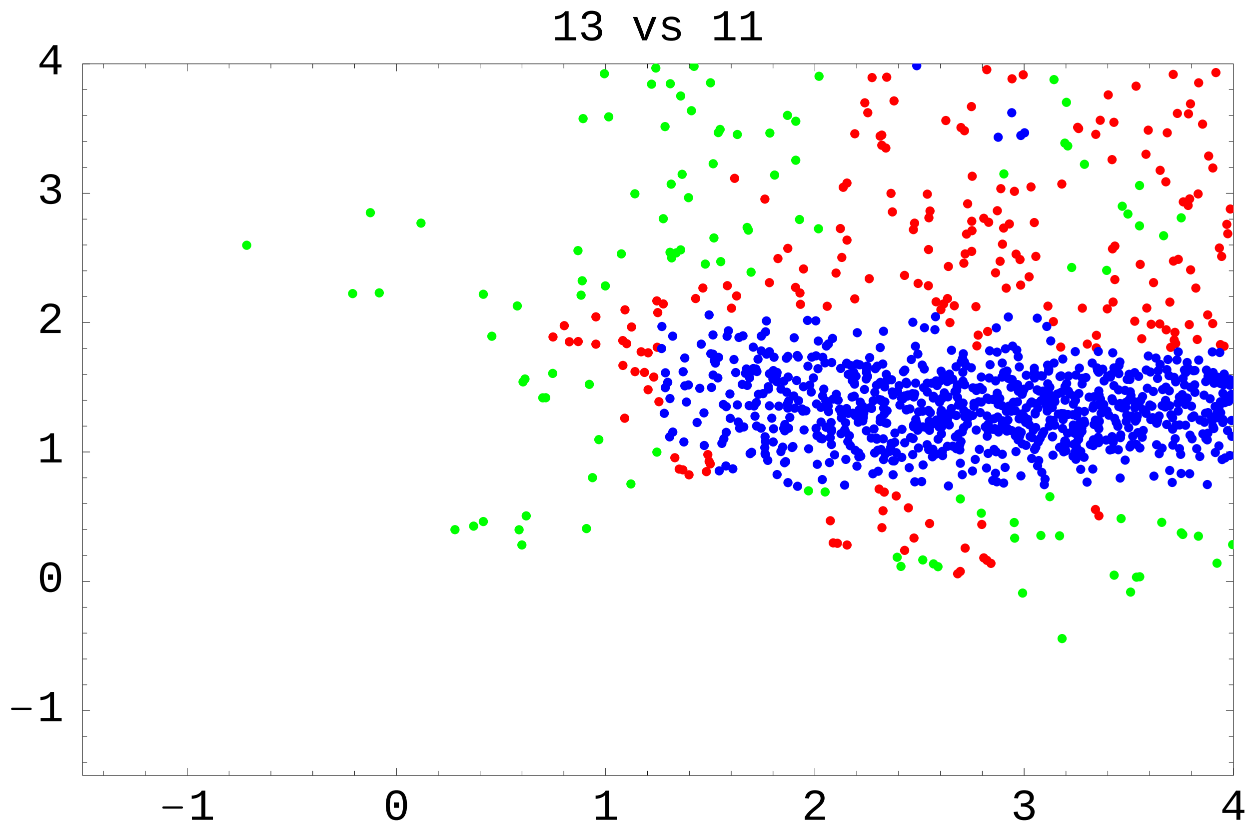
Neutrino Results (preliminary)

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



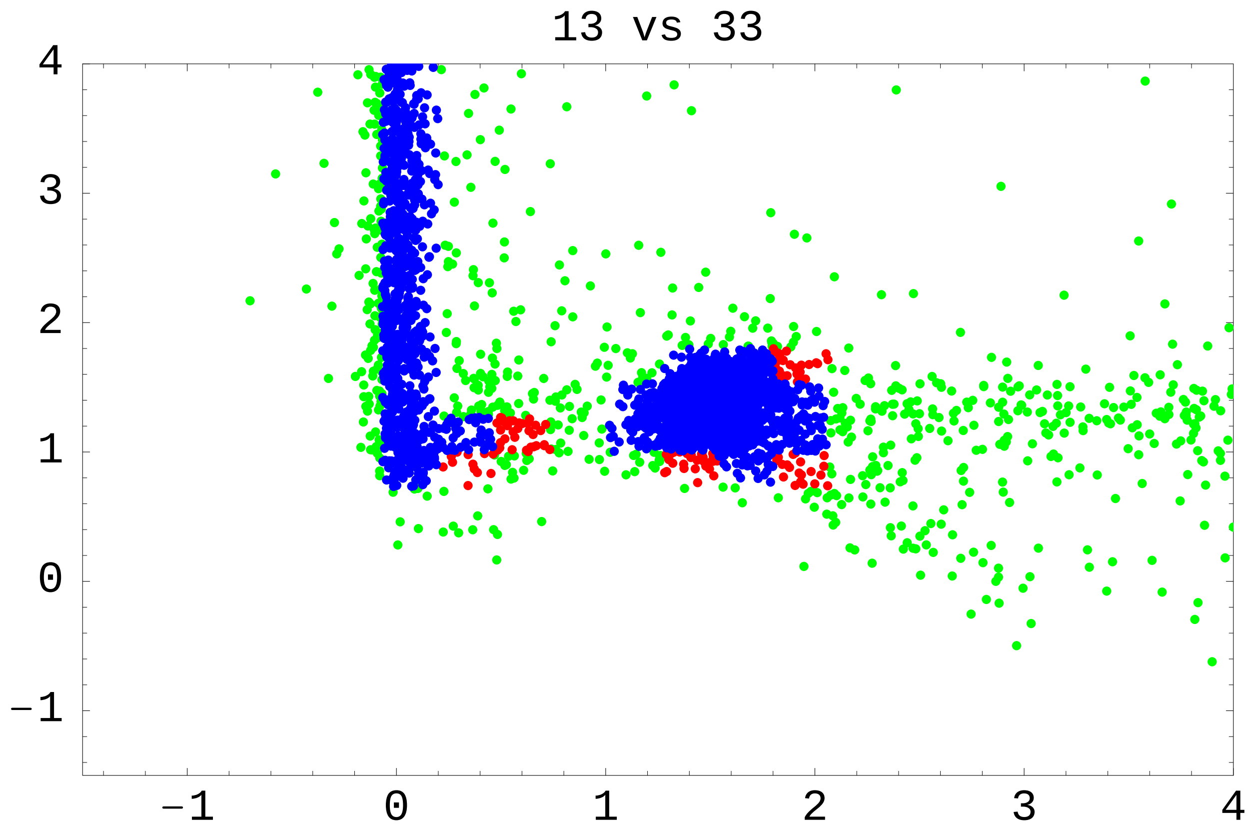
Neutrino Results (preliminary)

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



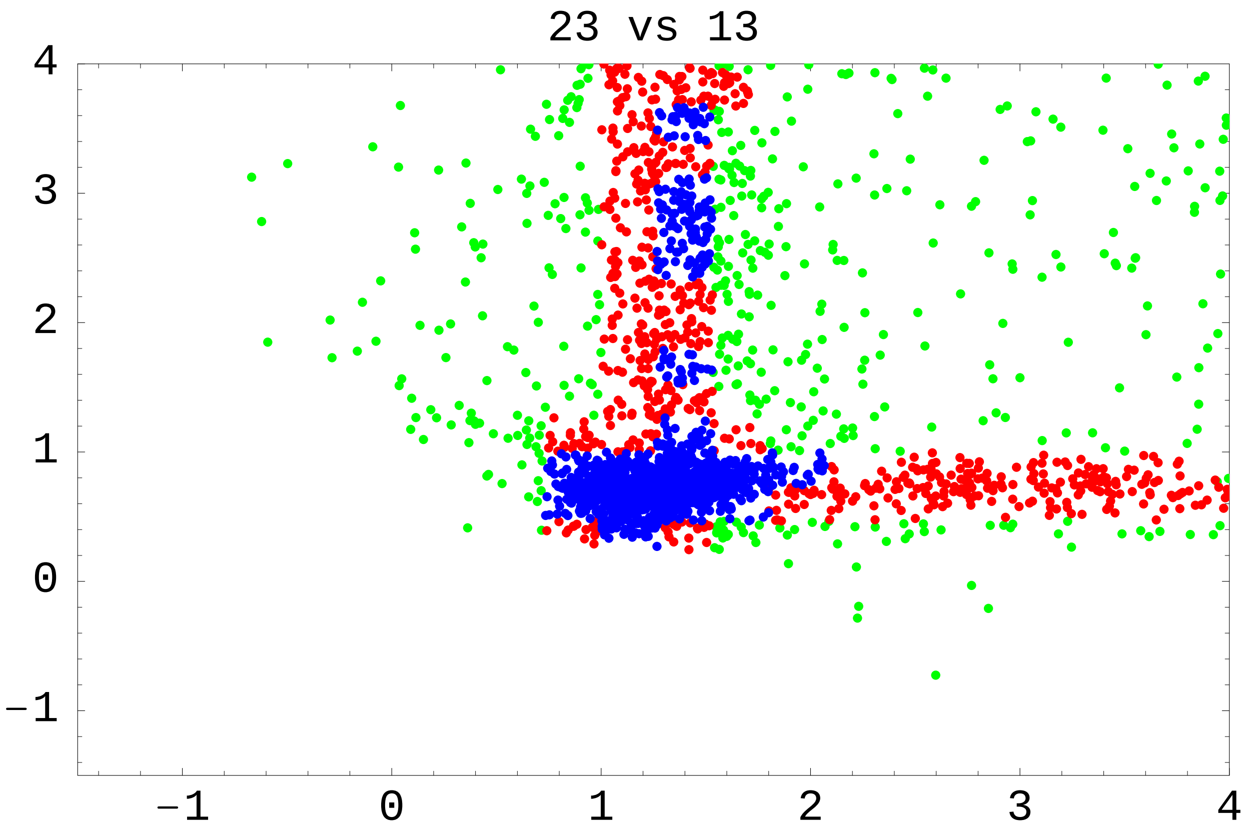
Neutrino Results (preliminary)

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



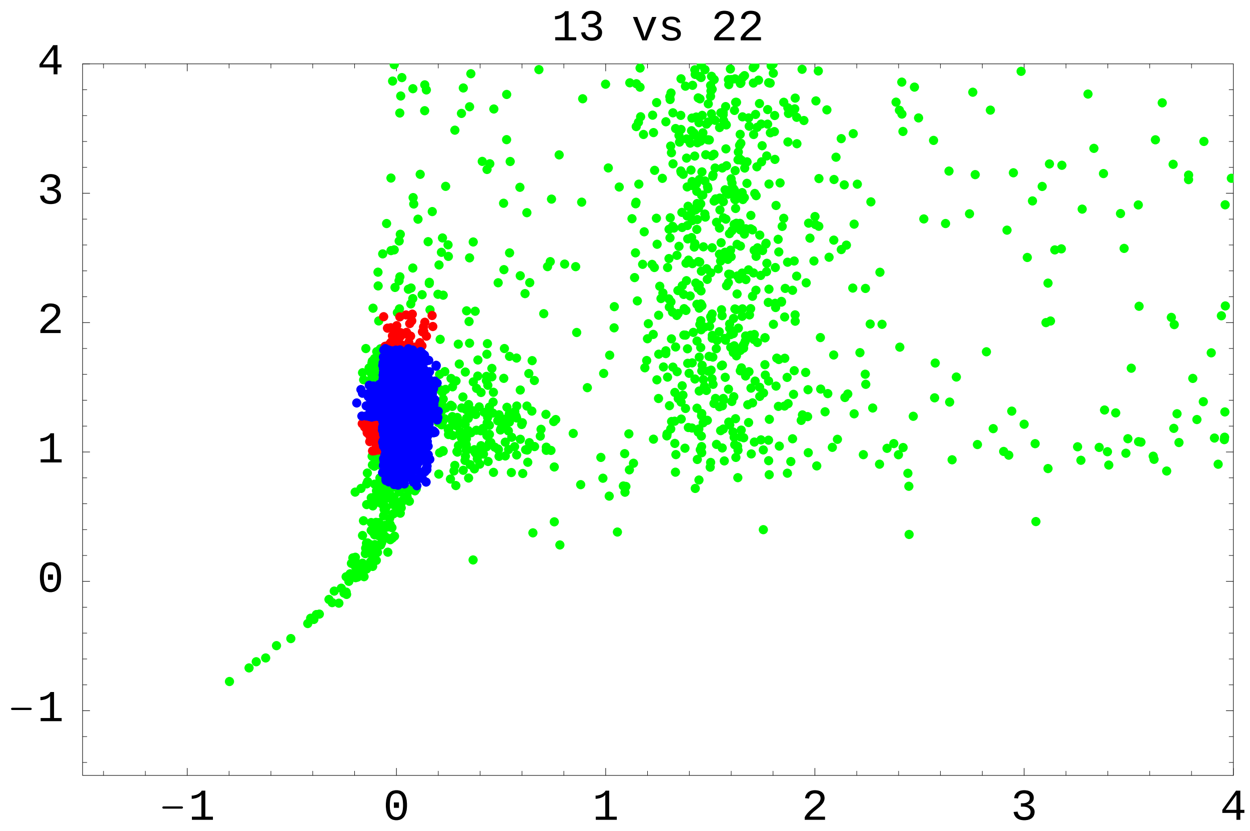
Neutrino Results (preliminary)

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



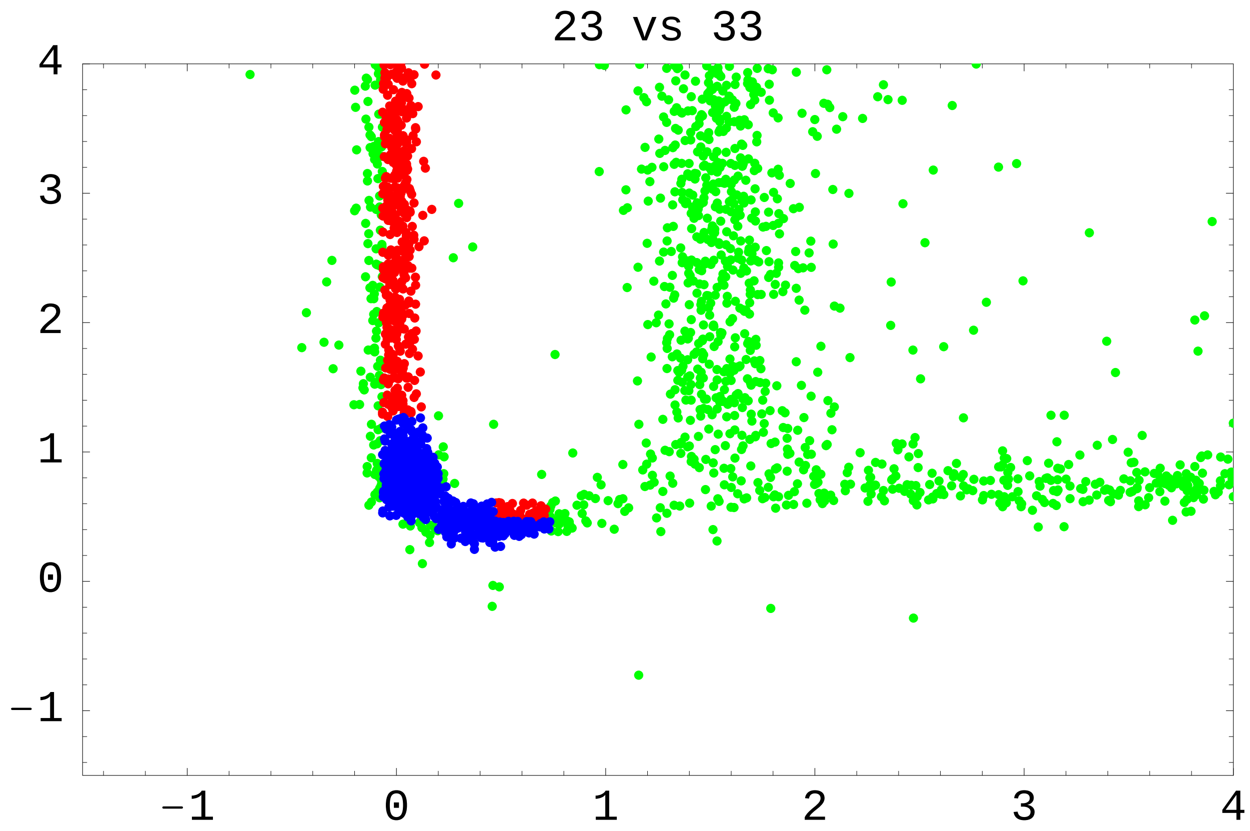
Neutrino Results (preliminary)

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



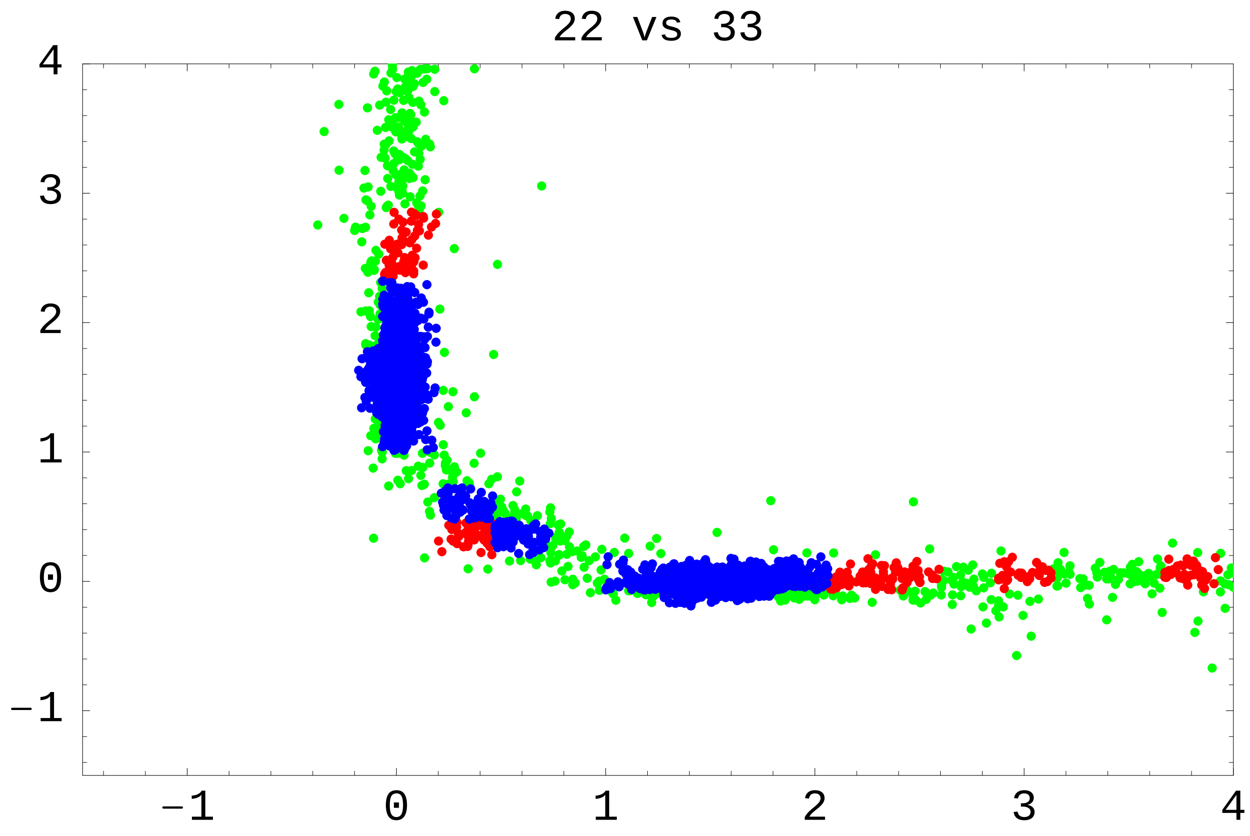
Neutrino Results (preliminary)

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



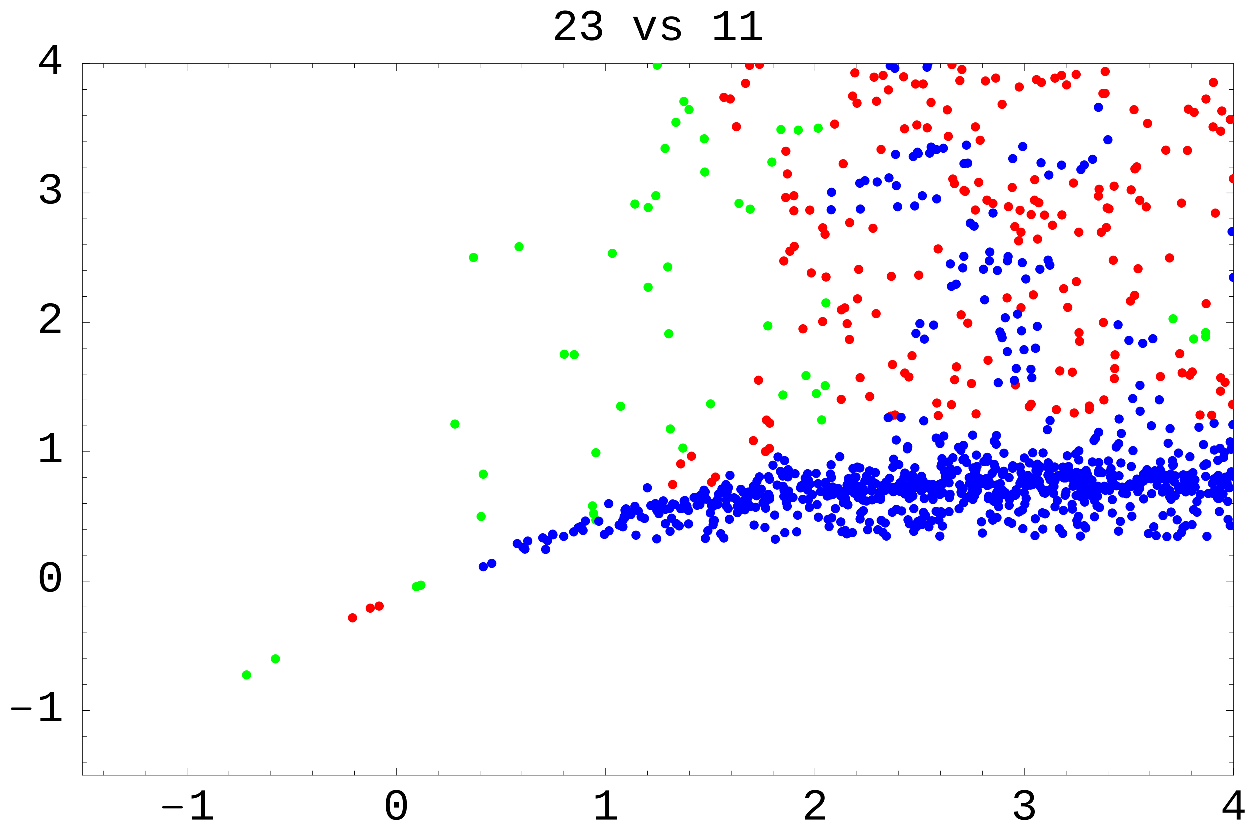
Neutrino Results (preliminary)

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



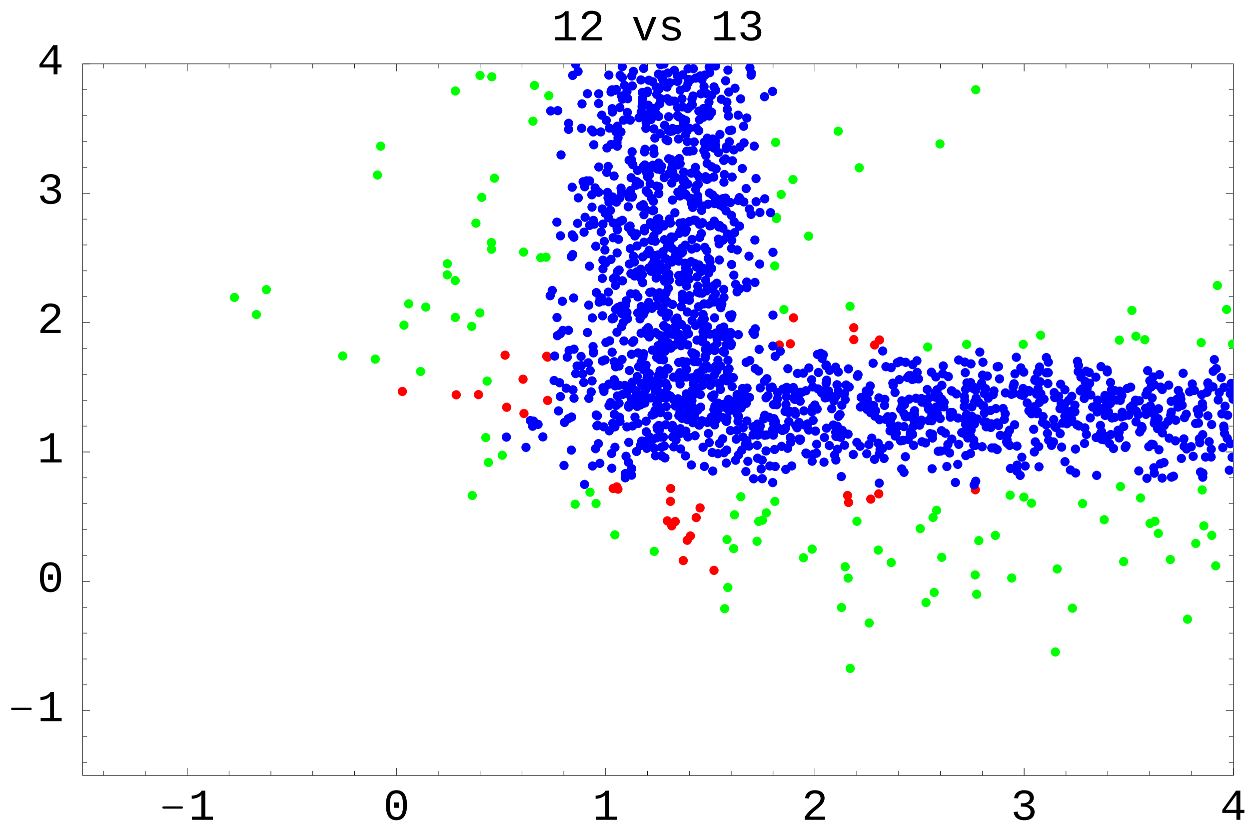
Neutrino Results (preliminary)

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



Neutrino Results (preliminary)

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



Neutrino Results (preliminary)

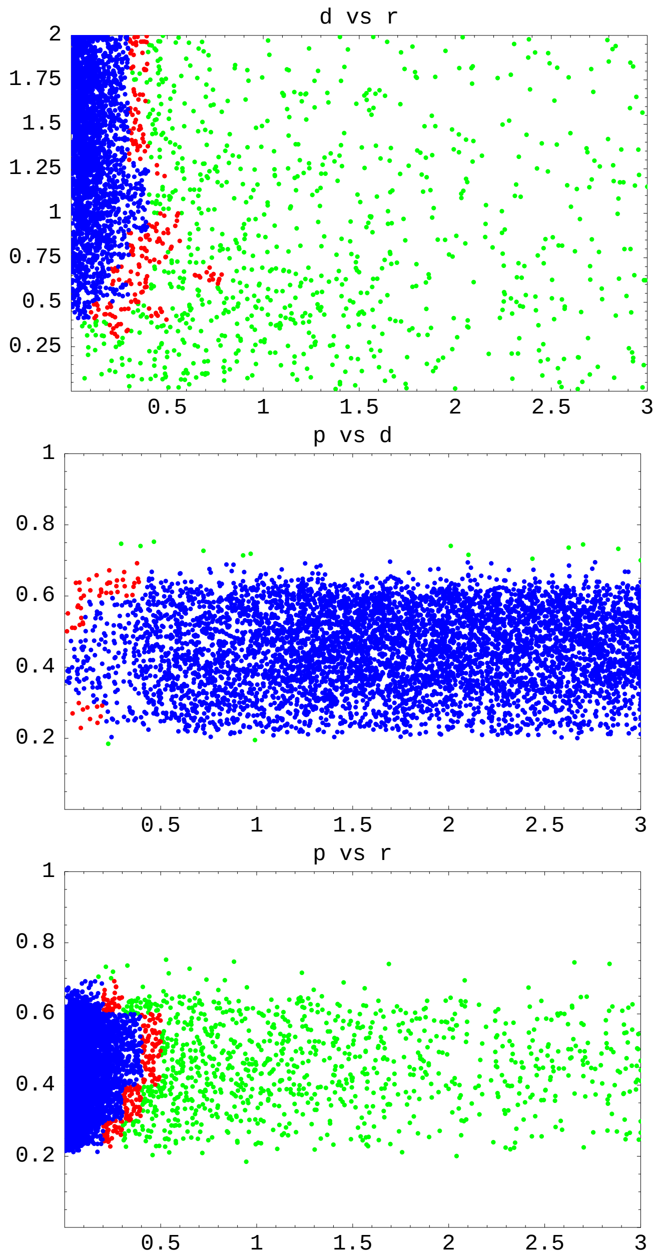
$$M_\nu = \begin{pmatrix} \lambda^{v_{11}} & \lambda^{v_{12}} & \lambda^{v_{13}} \\ \lambda^{v_{21}} & \lambda^{v_{22}} & \lambda^{v_{23}} \\ \lambda^{v_{31}} & \lambda^{v_{32}} & \lambda^{v_{33}} \end{pmatrix}$$

We find the following regions:

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

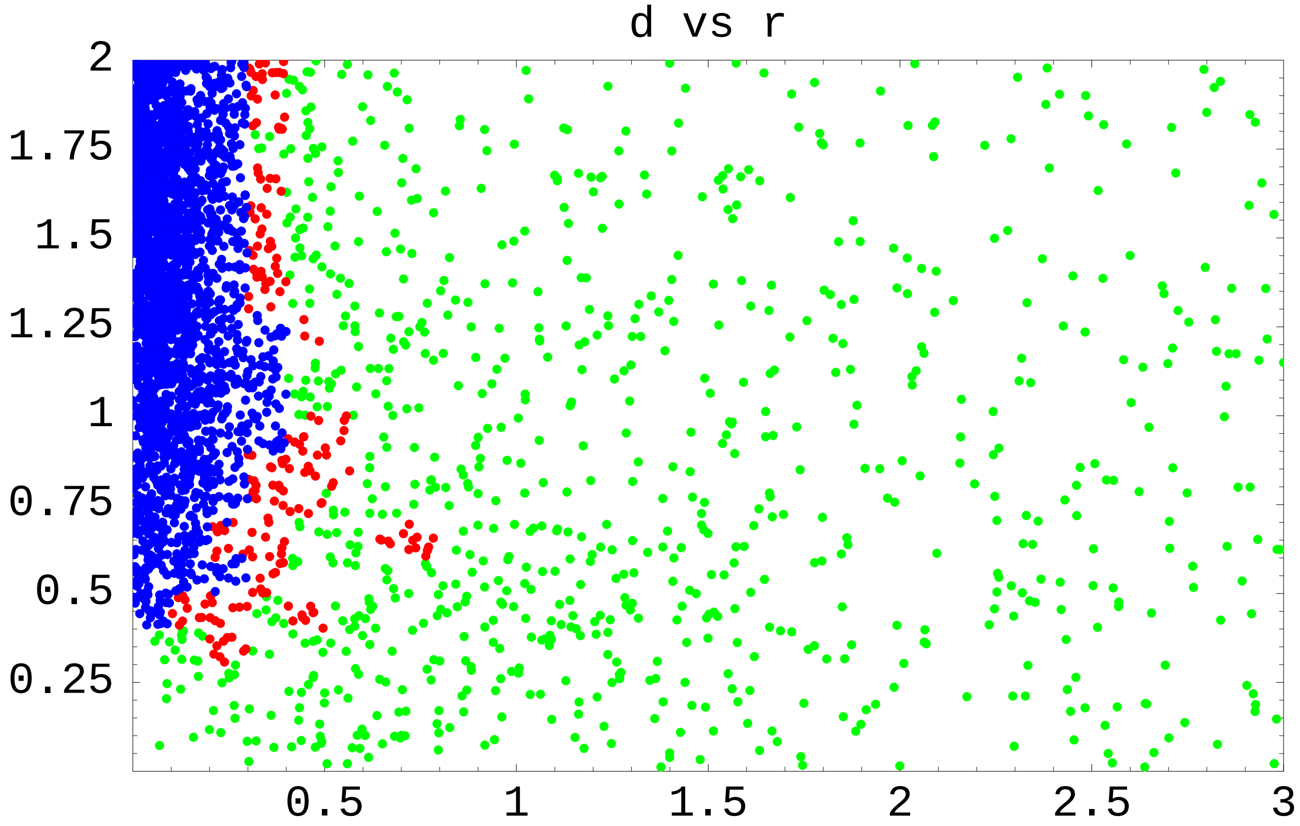
and symmetrization $2 \leftrightarrow 3$

Charged Lepton Results (preliminary)



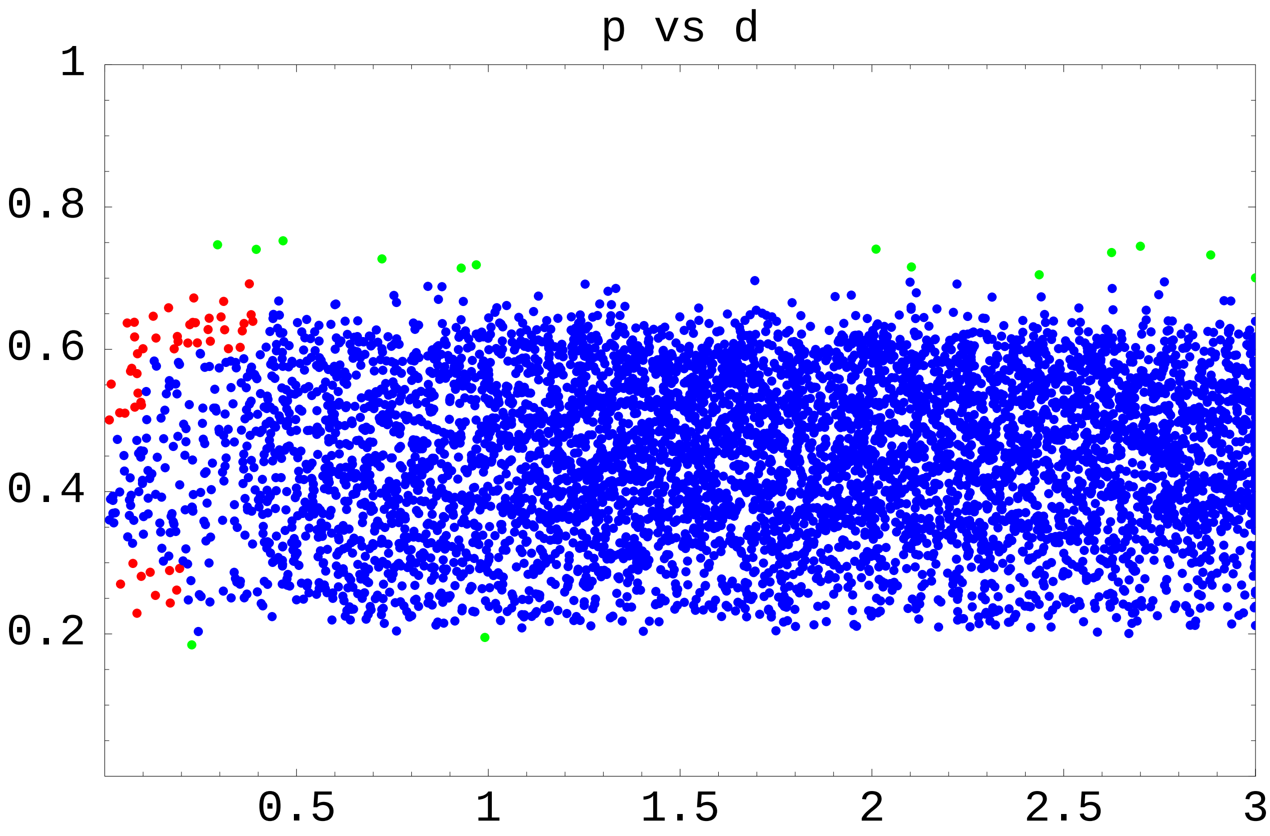
Charged Lepton Results

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



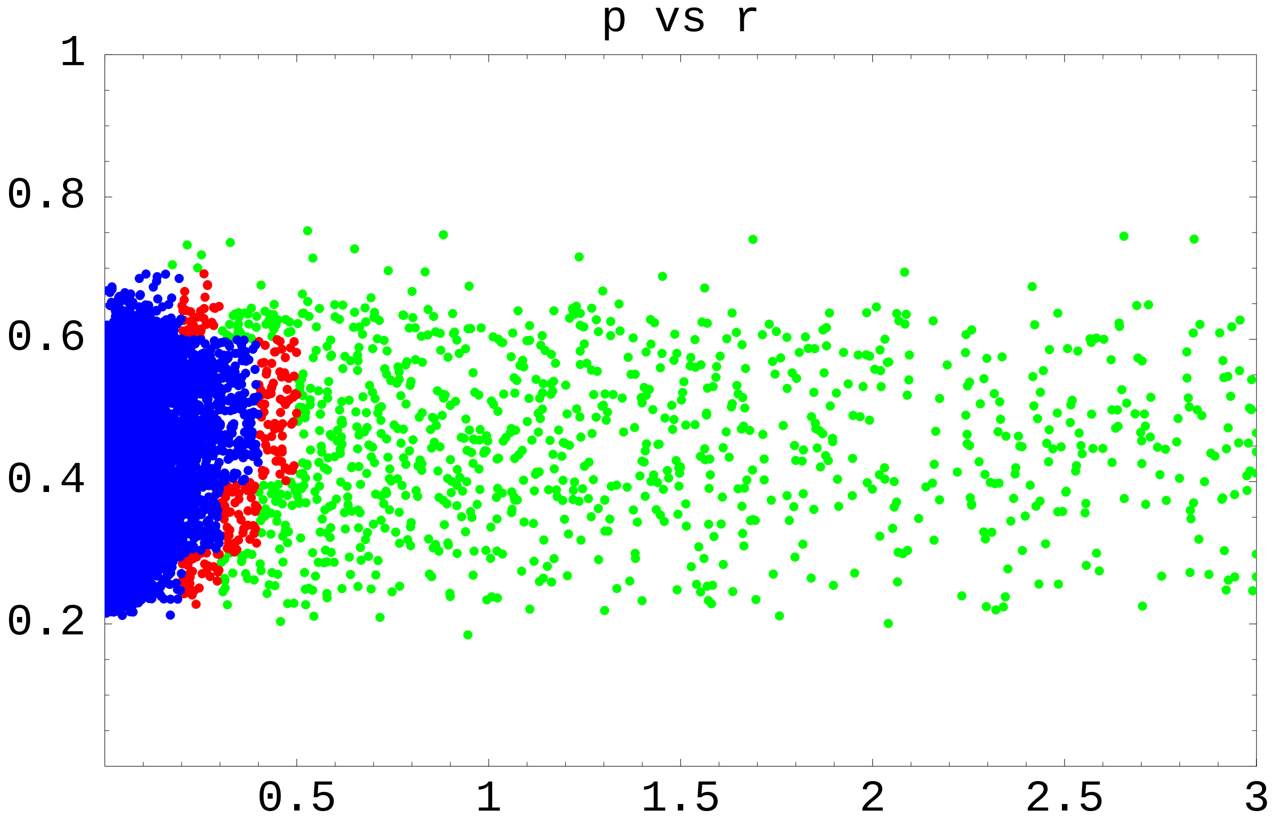
Charged Lepton Results

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



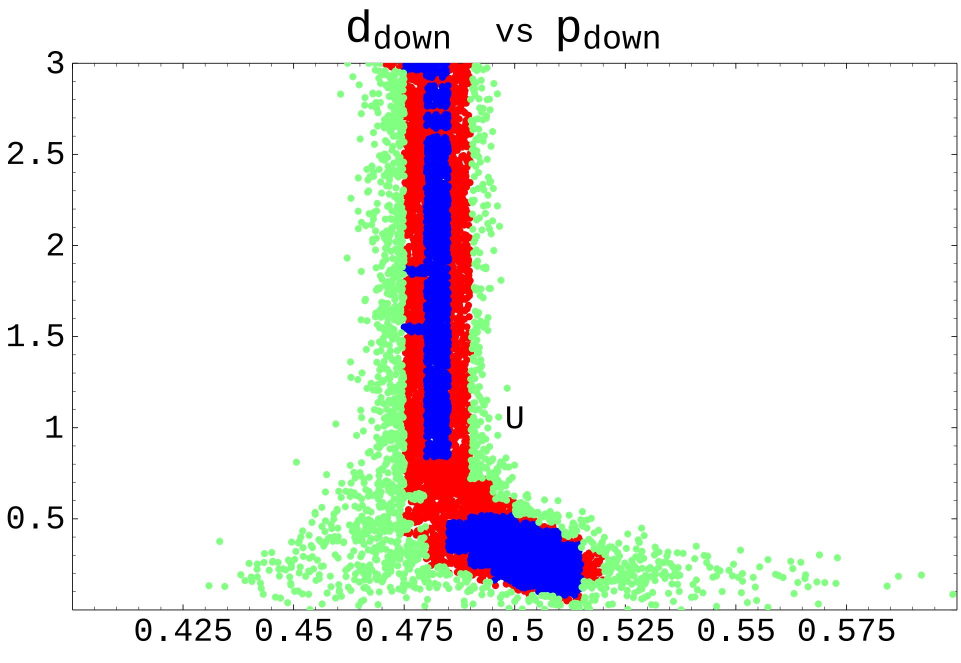
Charged Lepton Results

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



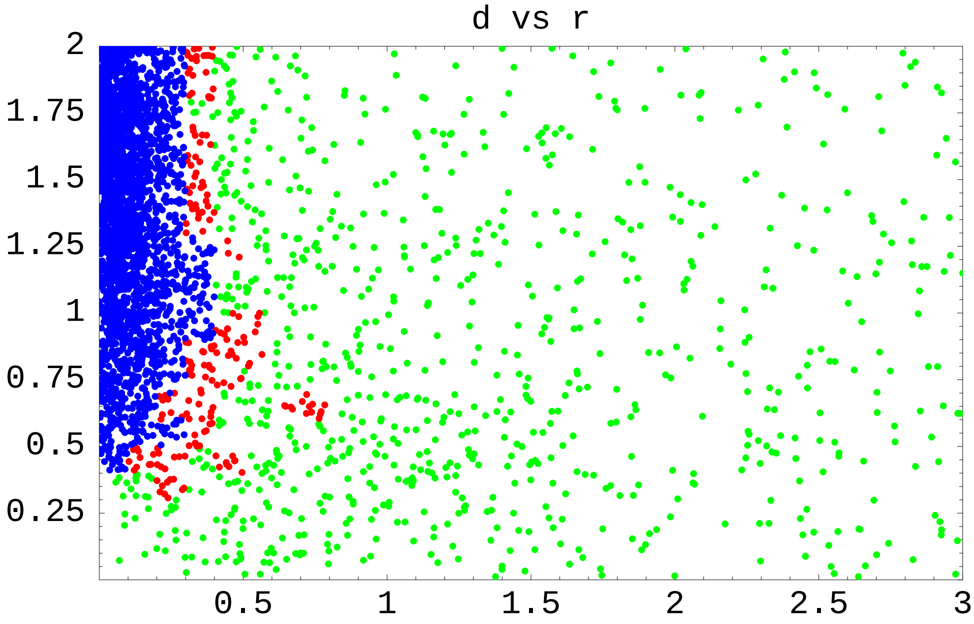
Quarks Results

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



Unification

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



$$5_2 \equiv (s_R, s_R, s_R, \nu_L, \mu_L)$$

$$\bar{5}_2 10_3 \Rightarrow \bar{s}_R b_L + \bar{\mu}_L \tau_R$$

This is in agreement with b-τ mass unification!

P. Aliani, V. Antonelli, F. Caravaglios, R. Ferrari, M. P

Conclusions

- Standard Model and Experiments: post SNO-NC 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!