The Lepton Sector and U(2)^5 Flavour Symmetry

Joel Jones-Pérez
Universitat de València - IFIC

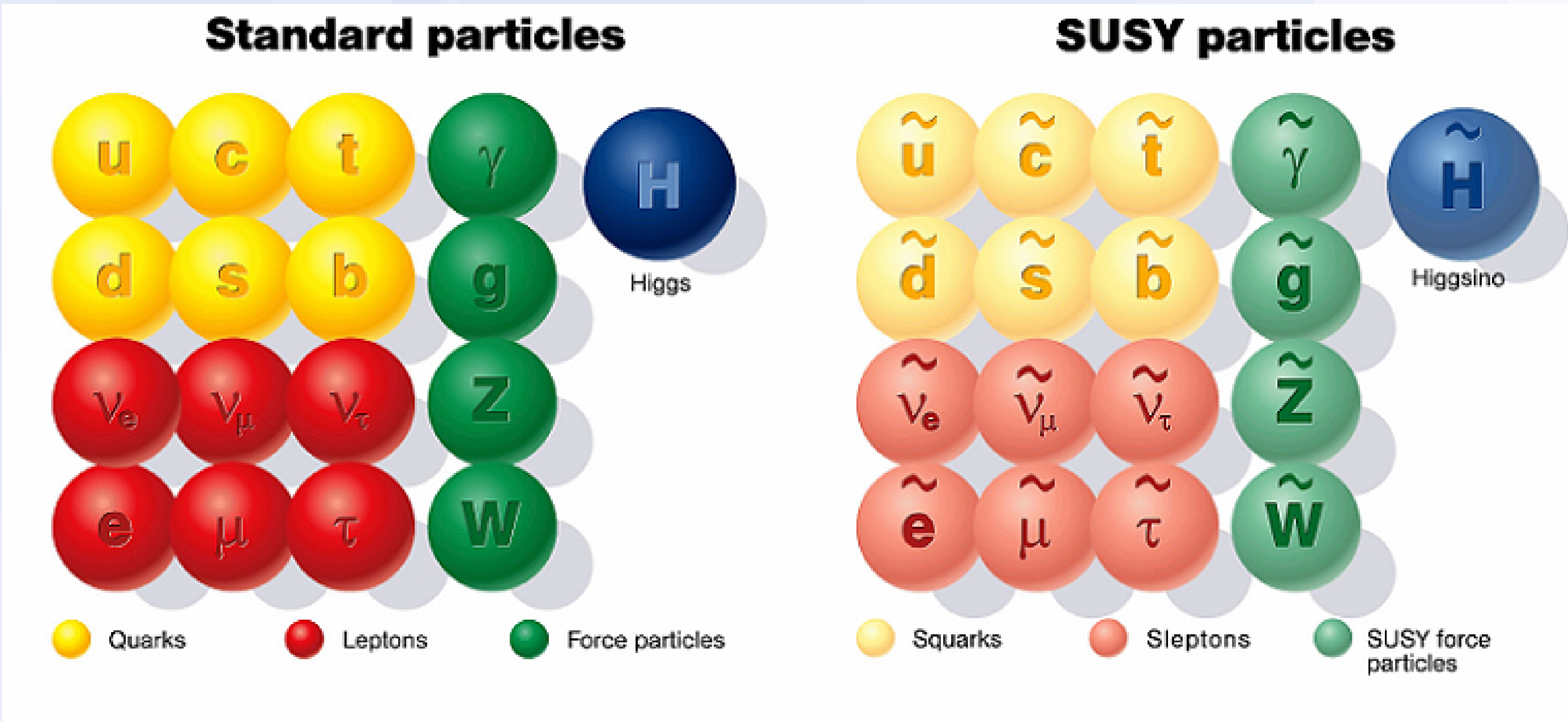
In Collaboration with

R. Barbieri, G. Isidori, P. Lodone, D. Straub (arXiv:1105.2296 [hep-ph])

G. Isidori, G. Blankenburg (arXiv: 1204.0688 [hep-ph])

BeNe, Trieste, 21/09/2012

Supersymmetry



Main reason why we still stick with SUSY: the hierarchy problem.

Natural SUSY = Effective SUSY?

- Light neutralinos
- Light third generation sfermions
- Not too heavy gluinos
- First two generation squarks: over 2 TeV.
- Everything else: ???

Papucci, Ruderman, Weiler (1110.6926)

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What about flavour?

Papucci, Ruderman, Weiler (1110.6926)

MFV Framework

- $U(3)^5$ framework built in order to suppress New Physics contributions to flavoured processes.
- SUSY masses are forced to be nearly degenerate.
- Flavour off-diagonal contributions are related to CKM and mass hierarchies: y_t, y_b.

D'Ambrosio, Giudice, Isidori, Strumia (hep-ph/0207036)

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- SUSY masses are forced to be nearly degenerate.
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Not so suitable for natural SUSY...

D'Ambrosio, Giudice, Isidori, Strumia (hep-ph/0207036)

$U(2)^5$ framework in quark/squarks

arXiv:1105.2296 [hep-ph]

U(2)^3 Framework

$$U(2)_Q \otimes U(2)_u \otimes U(2)_d$$

$$\begin{aligned} Q^{(2)} &= (Q_1, \quad Q_2) && \sim \quad (\bar{2}, 1, 1) \\ u_R^{c(2)} &= (u_{R,1}^c, \quad u_{R,2}^c)^T && \sim \quad (1, 2, 1) \\ d_R^{c(2)} &= (d_{R,1}^c, \quad d_{R,2}^c)^T && \sim \quad (1, 1, 2) \end{aligned}$$

$U(2)^3$ Framework

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$$W_q = y_t\, Q_3\, t_R^c\, H_u + y_b\, Q_3\, b_R^c\, H_d$$

$U(2)^3$ Spurions

$$\begin{aligned} \Delta Y_u &\sim (2, \bar{2}, 1) \\ \Delta Y_d &\sim (2, 1, \bar{2}) \end{aligned}$$

$$Y_u = \left(\begin{array}{c|c} \Delta Y_u & 0 \\ \hline 0 & 1 \end{array} \right) y_t \qquad Y_d = \left(\begin{array}{c|c} \Delta Y_d & 0 \\ \hline 0 & 1 \end{array} \right) y_b$$

Hierarchy between y_{f2} and y_{f3} should be related to suppression in ΔY_f.

$U(2)^3$ Spurions

$$\begin{aligned} \Delta Y_u &\sim (2, \bar{2}, 1) \\ \Delta Y_d &\sim (2, 1, \bar{2}) \\ V &\sim (2, 1, 1) \end{aligned}$$

$$Y_u = \left(\begin{array}{c:c} \Delta Y_u & x_t V \\ \hdashline 0 & 1 \end{array} \right) y_t \qquad Y_d = \left(\begin{array}{c:c} \Delta Y_d & x_b V \\ \hdashline 0 & 1 \end{array} \right) y_b$$

Hierarchy between V_{cb} and V_{tb} should be related to suppression in V.

Explicit Parametrization

$$Y_u = \begin{pmatrix} \Delta Y_u & x_t\, V \\ 0 & 1 \end{pmatrix} y_t \qquad\qquad Y_d = \begin{pmatrix} \Delta Y_d & x_b\, V \\ 0 & 1 \end{pmatrix} y_b$$

$$V = \epsilon \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

$$\Delta Y_f = \begin{pmatrix} c_f & s_f\, e^{i\alpha_f} \\ -s_f\, e^{-i\alpha_f} & c_f \end{pmatrix} \Delta Y_f^{\mathrm{diag}}$$

CKM Matrix

$$V_{\mathrm{CKM}} = (U_{uL}^{\dagger} \cdot U_{dL})$$

$$\begin{pmatrix} c_u c_d + s_u s_d\, e^{i(\alpha_d - \alpha_u)} & -c_u s_d\, e^{-i\alpha_d} + s_u c_d\, e^{-i\alpha_u} & s_u s e^{-i(\alpha_u - \xi)} \\ c_u s_d\, e^{i\alpha_d} - s_u c_d\, e^{i\alpha_u} & c_u c_d + s_u s_d\, e^{i(\alpha_u - \alpha_d)} & c_u s e^{i\xi} \\ -s_d s\, e^{i(\alpha_d - \xi)} & -s c_d e^{-i\xi} & 1 \end{pmatrix}$$

$$\begin{aligned} |s| &= 0.0410 \pm 0.0004 \\ s_u &= 0.0916 \pm 0.005 \\ s_d &= -0.22 \pm 0.02 \\ \cos(\alpha_u - \alpha_d) &= -0.13 \pm 0.2 \end{aligned}$$

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What about SUSY?

Soft Masses: Unbroken Limit:

$$m_{\tilde{f}}^2 = \begin{pmatrix} m_{f_h}^2 & 0 & 0 \\ 0 & m_{f_h}^2 & 0 \\ 0 & 0 & m_{f_l}^2 \end{pmatrix}$$

Same spurions that generated the Yukawa structure shall generate the soft mass structure.

Soft Masses

$$m^2_{\tilde{Q}} = m^2_{Q_h} \left(\begin{array}{c:c} 1 + V^* V^T + \Delta Y_u^* \Delta Y_u^T + \Delta Y_d^* \Delta Y_d^T & x_Q^* V^* \\ \hdashline x_Q V^T & m^2_{Q_l}/m^2_{Q_h} \end{array} \right)$$

$$m^2_{\tilde{u}} = m^2_{u_h} \left(\begin{array}{c:c} 1 + \Delta Y_u^T \Delta Y_u^* & x_u^* \Delta Y_u^T V^* \\ \hdashline x_u V^T \Delta Y_u^* & m^2_{u_l}/m^2_{u_h} \end{array} \right)$$

$U(2)^5$ framework in leptons/sleptons

arXiv: 1204.0688 [hep-ph]

$U(2)^5$ and Neutrinos

Keep same spurion structure.

$$V_e \sim V \qquad \Delta Y_e \sim \Delta Y_d$$

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$$\epsilon_e = \epsilon \qquad s_e = s_d$$

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Keep same spurion structure.

$$V_e \sim V \qquad \Delta Y_e \sim \Delta Y_d$$

$$\epsilon_e = \epsilon \qquad s_e = s_d$$

Does not work!!!

Understanding Neutrinos

Neutrino oscillation data:

$$s^2_{12} = 0.30 \pm 0.013 \qquad s^2_{23} = 0.41 \pm 0.03$$

$$s^2_{13} = 0.023 \pm 0.0023 \qquad \oplus\, 0.59 \pm 0.02$$

$$\delta_P = 240^\circ{}^{+102^\circ}_{-74^\circ}$$

$$\begin{aligned} \Delta m^2_{\rm sol} &= (7.50 \pm 0.185) \times 10^{-5}\ \mathrm{eV}^2 \\ |\Delta m^2_{\rm atm}| &= (2.47 \pm 0.07) \times 10^{-3}\ \mathrm{eV}^2 \end{aligned}$$

http://www.nu-fit.org

Understanding Neutrinos

Neutrino mass matrix:

$$\mathcal{L}^{\nu} = (m_{\nu})_{ij}\, \bar{\nu}_L^{ci} \nu_L^j$$

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$$M_{\nu}^2 \approx m_{\mathrm{light}}^2 \cdot I + \Delta m_{\mathrm{atm}}^2 \cdot \eta$$

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$$\eta_{[\mathrm{n.h.}]} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & s_{23}^2 & s_{23}c_{23} \\ 0 & s_{23}c_{23} & c_{23}^2 \end{pmatrix} \qquad \eta_{[\mathrm{i.h.}]} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23}^2 & -s_{23}c_{23} \\ 0 & -s_{23}c_{23} & s_{23}^2 \end{pmatrix}$$

Going back to MFV

$$U(3)^5$$

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$$U(2)^5$$

$$Y_u, Y_d, Y_e$$

Going back to MFV

$$U(3)^5$$

$$U(2)^5$$

$$Y_u, Y_d, Y_e$$

$$O(3)_L$$

$$m_\nu$$

U(3)^5 -> U(2)^5 Spurions

$$Y_e^{(0)} \sim (1,1,1,3,\bar{3})$$

$$Y_e^{(0)} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix} y_\tau^{(0)}$$

$$\mathbf{L}_L Y_e^{(0)} \mathbf{e}_R^c \rightarrow y_\tau^{(0)} L_3 e_3^c \ .$$

U(3)^5 -> U(2)^5 Spurions

$$Y_e^{(0)} \sim (1,1,1,3,\bar{3})$$
$$X \sim (1,1,1,8,1)$$

$$X = \left(\begin{array}{c|c} \Delta_L & V \\ \hline V^\dagger & x \end{array}\right)$$

$$Y_e^{(1)} = (1+X)Y_e^{(0)} \to \left(\begin{array}{c|c} 0 & V \\ \hline 0 & 1 \end{array}\right) y_\tau$$

$U(3)^5$ -> $U(2)^5$ Spurions

$$Y_e^{(0)} \sim (1,1,1,3,\bar{3})$$

$$X \sim (1,1,1,8,1)$$

$$\Delta\hat{Y}_e \sim (1,1,1,3,\bar{3})$$

$$\Delta\hat{Y}_e = \left(\begin{array}{c|c} \Delta Y_e & 0 \\ \hline 0 & 0 \end{array}\right)$$

(Big Assumption 1)

$$Y_e = (1+X)(Y_e^{(0)} + \Delta\hat{Y}_e) \to \left(\begin{array}{c|c} \Delta Y_e & V \\ \hline 0 & 1 \end{array}\right) y_\tau$$

$U(3)_L$ -> $O(3)_L$ Spurion

We shall break $U(3)_L$ -> $O(3)_L$ in neutrino sector.

One more spurion:

$$m_\nu^{(0)} \sim (1, 1, 1, 6, 1)$$

$$m_\nu^{(0)} \propto \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

(Big Assumption 2)

U(3)$_L$ -> O(3)$_L$ Spurion

We shall break U(3)$_L$ -> O(3)$_L$ in neutrino sector.

One more spurion:

$$m_\nu^{(0)} \sim (1,1,1,6,1)$$

$$m_\nu = m_\nu^{(0)} + X m_\nu^{(0)} + m_\nu^{(0)} X^T$$

$$m_\nu = \bar{m}_{\nu_1} \left[I + e^{i\phi_\nu} \begin{pmatrix} -\sigma\epsilon & \gamma\epsilon^2 & 0 \\ \gamma\epsilon^2 & -\delta\epsilon & r\epsilon \\ 0 & r\epsilon & 0 \end{pmatrix} \right]$$

U(3)$_L$ -> O(3)$_L$ Spurion

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(Big Assumption 3?)

U(3)$_L$ -> O(3)$_L$ Spurion

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Rotation to basis where Y_e is diagonal:

$$M_\nu^2 = \bar{m}_{\nu_1}^2 \begin{pmatrix} 1-2\epsilon\sigma & & \\ -2s_e\epsilon(\sigma-\delta)\, e^{i\alpha_e} & 1-2\epsilon\delta & \\ -2\epsilon\, s_e r\, e^{i\alpha_e} & 2\epsilon r & 1 \end{pmatrix} + O(\epsilon^2, s_e^2\epsilon)$$

U(2)^5 framework in leptons/sleptons

Phenomenology

arXiv: 1204.0688 [hep-ph]

Neutrino Parameters: Δm²

Mass Differences:

$$\Delta m^2_{\mathrm{atm}} = \tilde{m}^2_{\nu_1}\left(2\sigma - \delta + [\delta^2 + 4r^2]^{1/2}\right)\epsilon$$

Neutrino Parameters: Δm^2

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ε determines scale of neutrino masses

Neutrino Parameters: Δm^2

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$$\Delta m^2_{\mathrm{atm}} = \tilde{m}^2_{\nu_1} \left(2\sigma - \delta + [\delta^2 + 4r^2]^{1/2} \right) \epsilon$$

$$\zeta^2 = \frac{\Delta m^2_{\mathrm{sol}}}{\Delta m^2_{\mathrm{atm}}} = \frac{2\sigma - \delta - [\delta^2 + 4r^2]^{1/2}}{2\sigma - \delta + [\delta^2 + 4r^2]^{1/2}}$$

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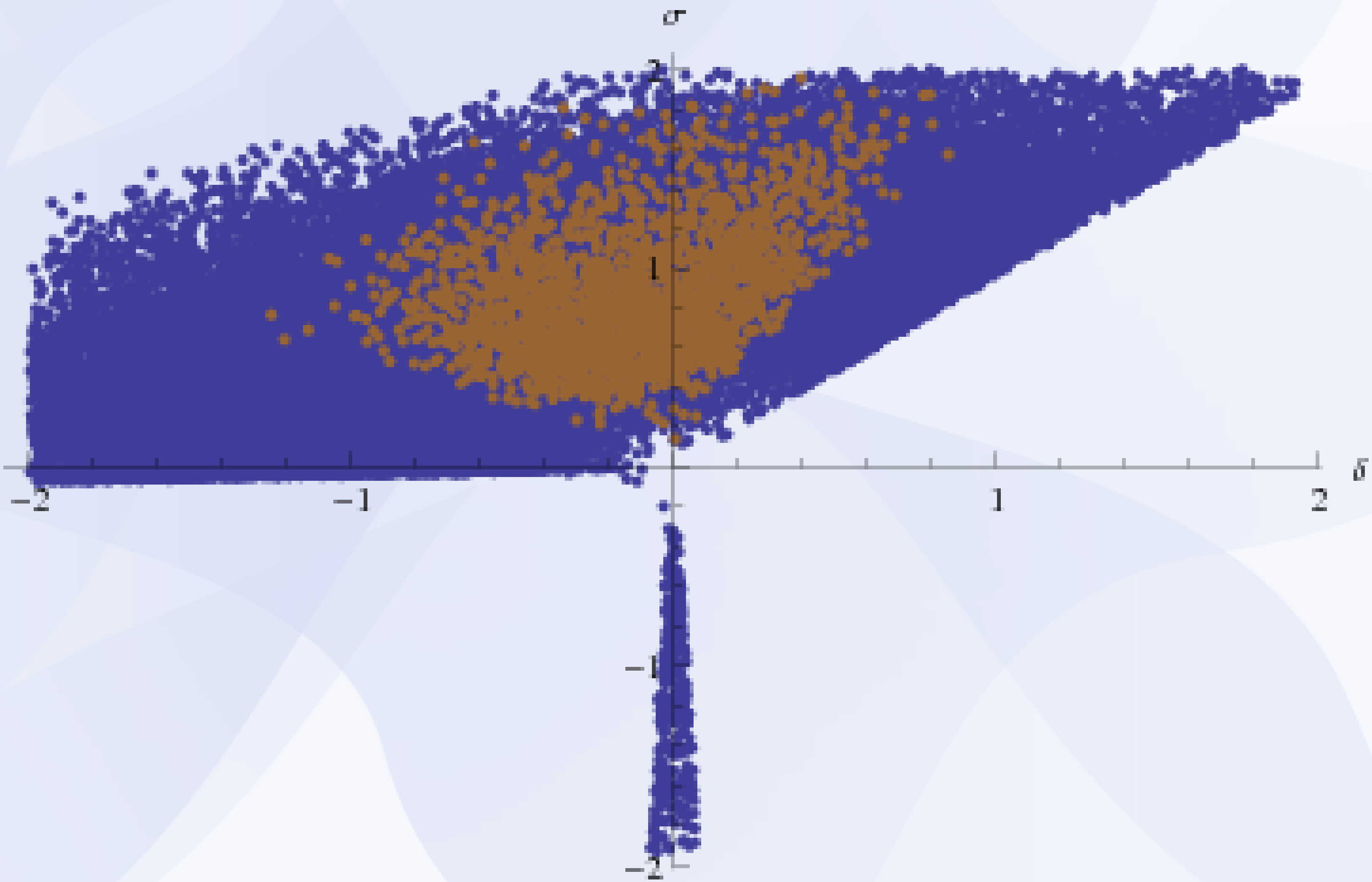
$$2\sigma - \delta - [\delta^2 + 4r^2]^{1/2} \sim \epsilon$$

Neutrino Parameters: Δm^2



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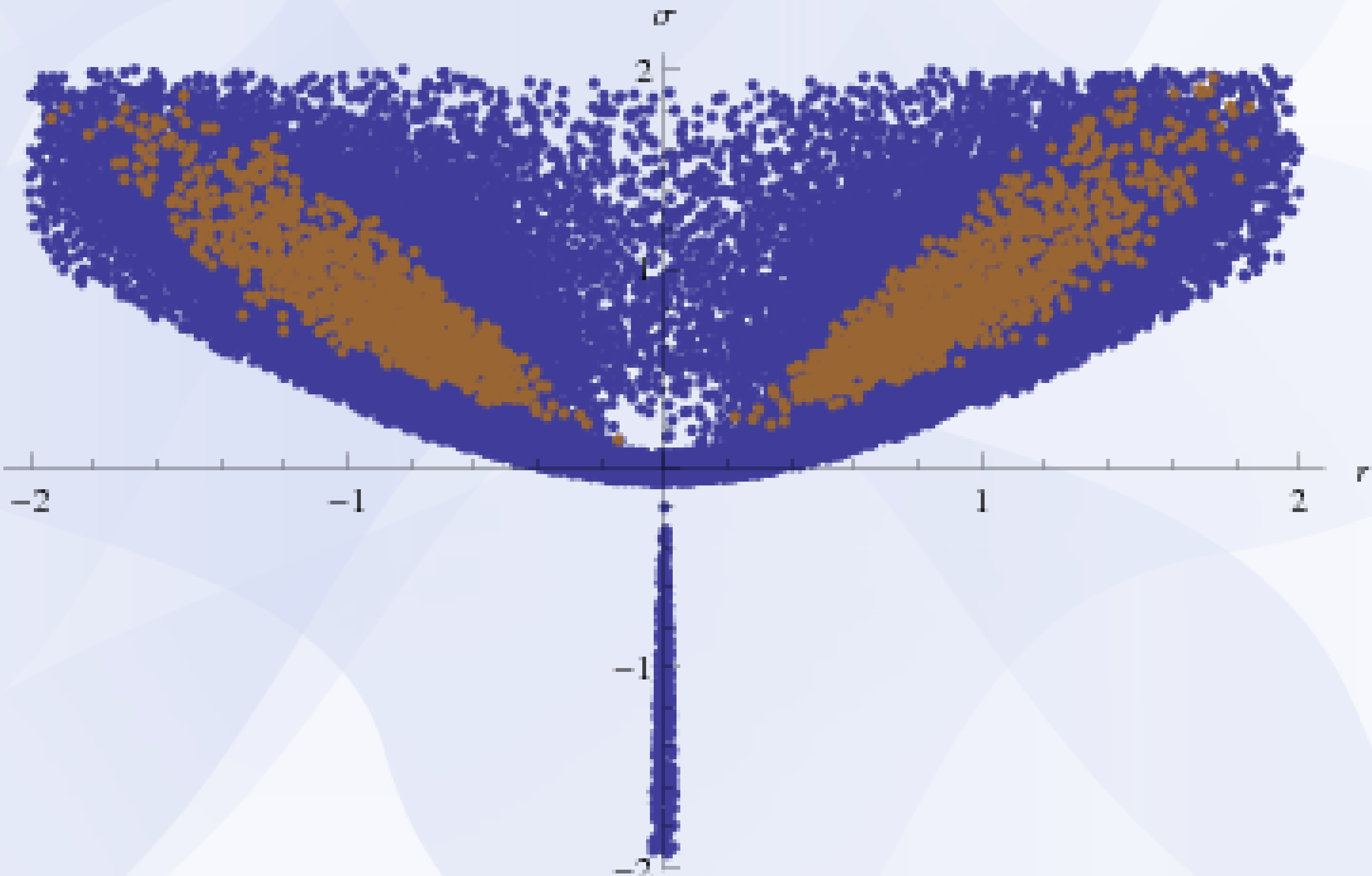

Neutrino Mixing: θ_{23}

Charged lepton mass basis:

$$M_\nu^2 = \bar{m}_{\nu_1}^2 \begin{pmatrix} 1-2\epsilon\sigma & & \\ -2s_e\epsilon(\sigma-\delta)\, e^{i\alpha_e} & 1-2\epsilon\delta & \\ -2\epsilon\, s_e r\, e^{i\alpha_e} & 2\epsilon r & 1 \end{pmatrix} + O(\epsilon^2, s_e^2\epsilon)$$

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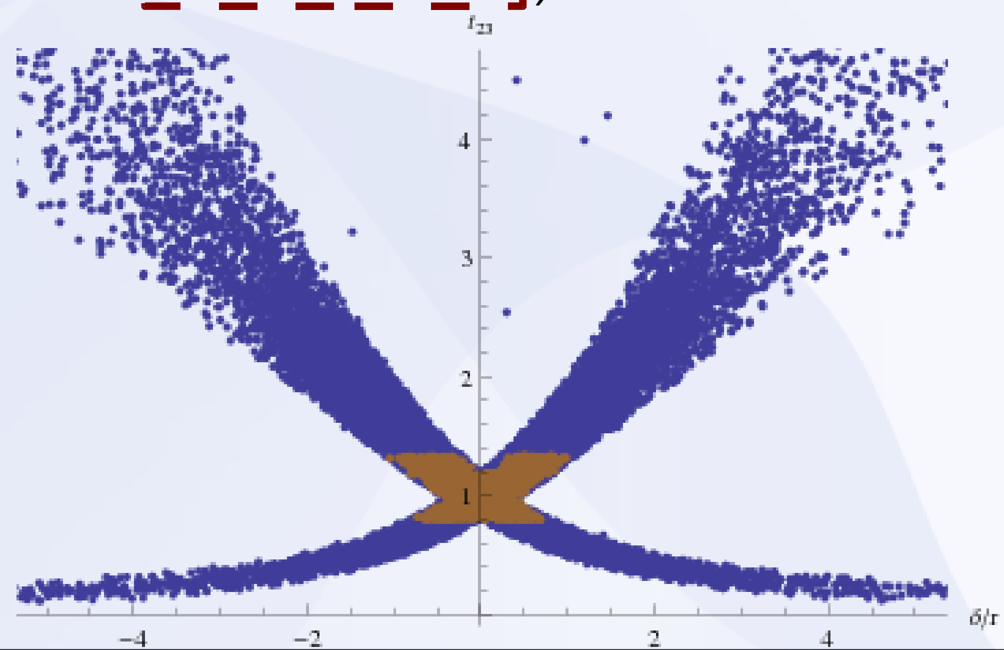
$$\frac{s_{23}}{c_{23}} \approx \frac{\delta \pm [\delta^2+4r^2]^{1/2}}{2r}$$



Neutrino Mixing: θ_{13}

Charged lepton mass basis:

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$$\frac{(M_\nu^2)_{31}}{(M_\nu^2)_{32}} = \frac{s_{13}}{c_{13}} \frac{1}{s_{23}} e^{i\delta_P}$$

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$$s_{13} e^{i\delta_P} = s_e s_{23} e^{\alpha_e + \pi}$$

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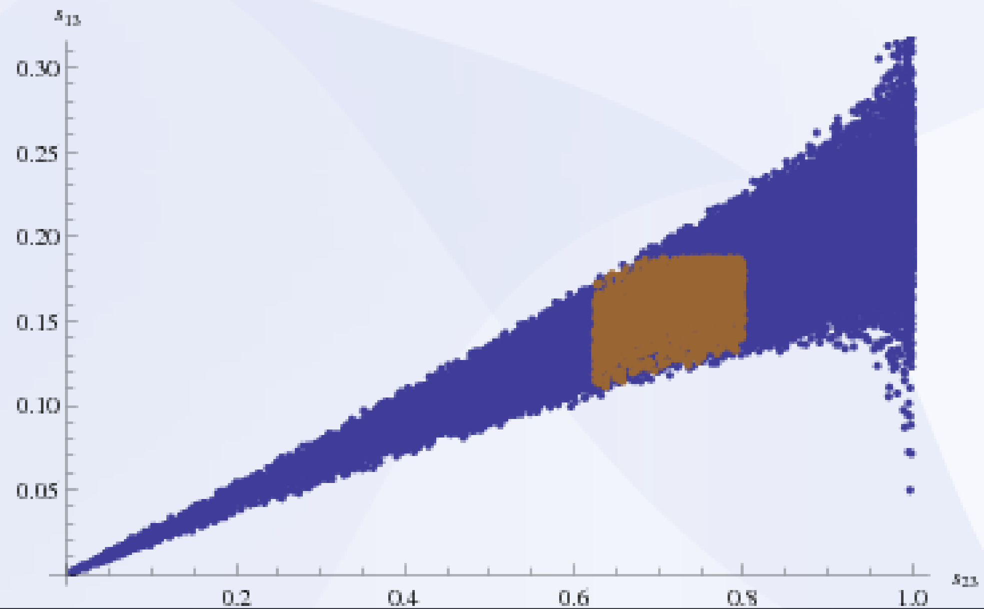
$$\begin{aligned} s_{13}e^{i\delta_P} &= s_e s_{23} e^{\alpha_e+\pi} \\ s_e &= s_d \\ \Rightarrow s_{13} &= 0.16 \pm 0.02 \\ s_{13}^{\text{fit}} &\approx 0.15 \pm 0.01 \end{aligned}$$



Neutrino Mixing: θ_{12}

Is θ_{12} unpredictable?

$$M_\nu^2 = m_\nu^\dagger m_\nu = U_{\rm PMNS}(m_\nu^2)^{\rm diag} U_{\rm PMNS}^\dagger$$

Expand on s_{13} and ζ^2...

Neutrino Mixing: θ$_{12}$

Is θ_{12} unpredictable?

$$
\begin{aligned}
(M_\nu^2)_{21} &= \Delta m^2_{\rm atm}\left[s_{13}c_{13}s_{23}e^{i\delta} + c_{13}c_{23}s_{12}c_{12}\zeta^2 - \mathcal{O}(s_{13}\zeta^2)\right] \\
(M_\nu^2)_{31} &= \Delta m^2_{\rm atm}\left[s_{13}c_{13}c_{23}e^{i\delta} - c_{13}s_{23}s_{12}c_{12}\zeta^2 - \mathcal{O}(s_{13}\zeta^2)\right] \\
(M_\nu^2)_{32} &= \Delta m^2_{\rm atm}\left[c_{13}^2 s_{23}c_{23} - s_{23}c_{23}c_{12}^2\zeta^2 + \mathcal{O}(s_{13}\zeta^2)\right]
\end{aligned}
$$

Neutrino Mixing: θ_{12}

Is θ_{12} unpredictable?

$$
\begin{aligned}
(M_\nu^2)_{21} &= \Delta m_{\rm atm}^2\left[s_{13}c_{13}s_{23}e^{i\delta} + c_{13}c_{23}s_{12}c_{12}\zeta^2 - \mathcal{O}(s_{13}\zeta^2)\right]\\
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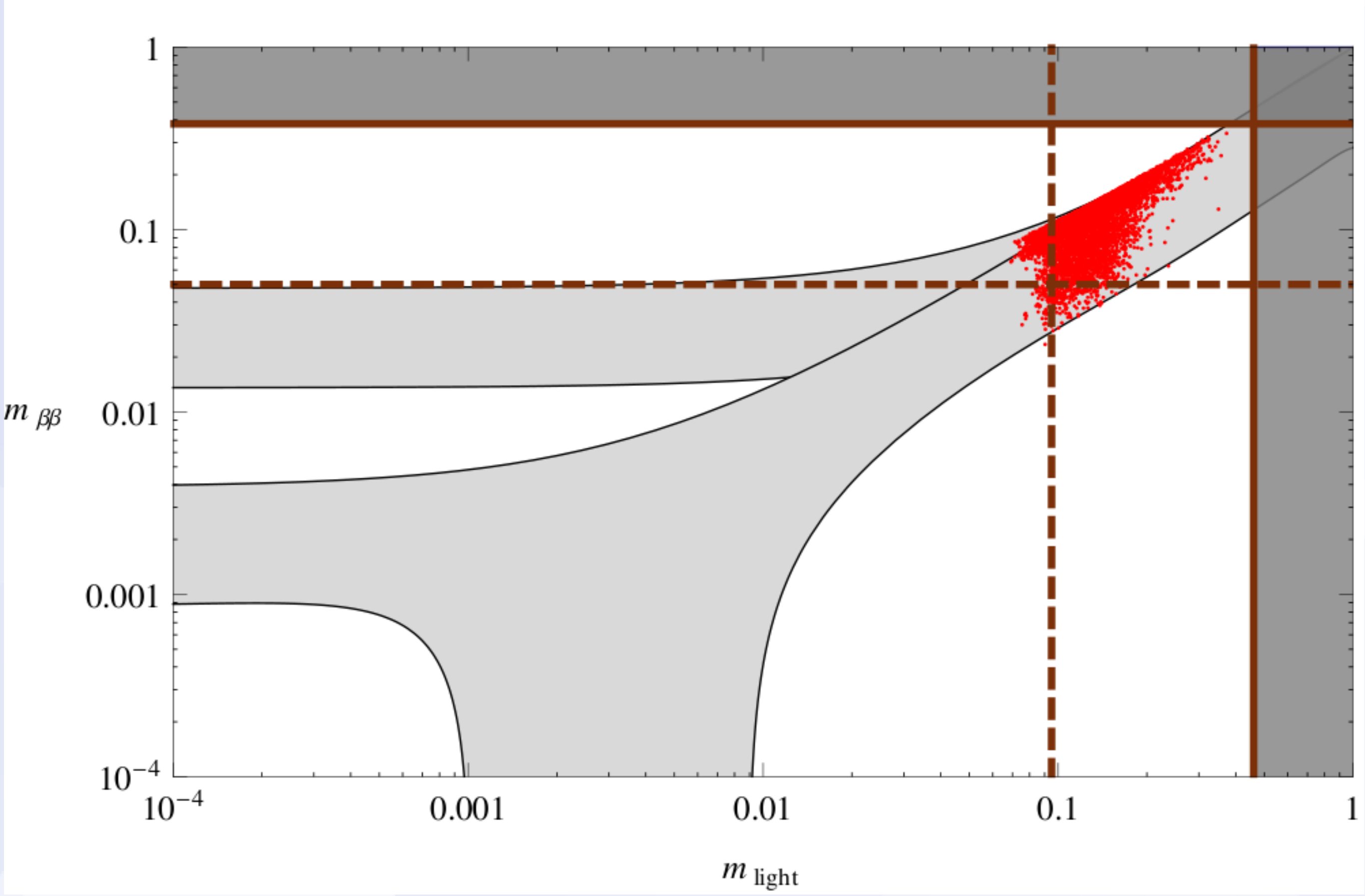
\end{aligned}
$$

$$
\begin{aligned}
(M_\nu^2)_{11} &= m_{\nu_1}^2 + \Delta m_{\rm atm}^2\left(s_{13}^2 + c_{13}^2s_{12}^2\zeta^2\right)\\
(M_\nu^2)_{22} &= m_{\nu_1}^2 + \Delta m_{\rm atm}^2\left(c_{13}^2s_{23}^2 + c_{23}^2c_{12}^2\zeta^2 - \mathcal{O}(s_{13}\zeta^2)\right)\\
(M_\nu^2)_{33} &= m_{\nu_1}^2 + \Delta m_{\rm atm}^2\left(c_{13}^2c_{23}^2 + s_{23}^2c_{12}^2\zeta^2 + \mathcal{O}(s_{13}\zeta^2)\right)
\end{aligned}
$$

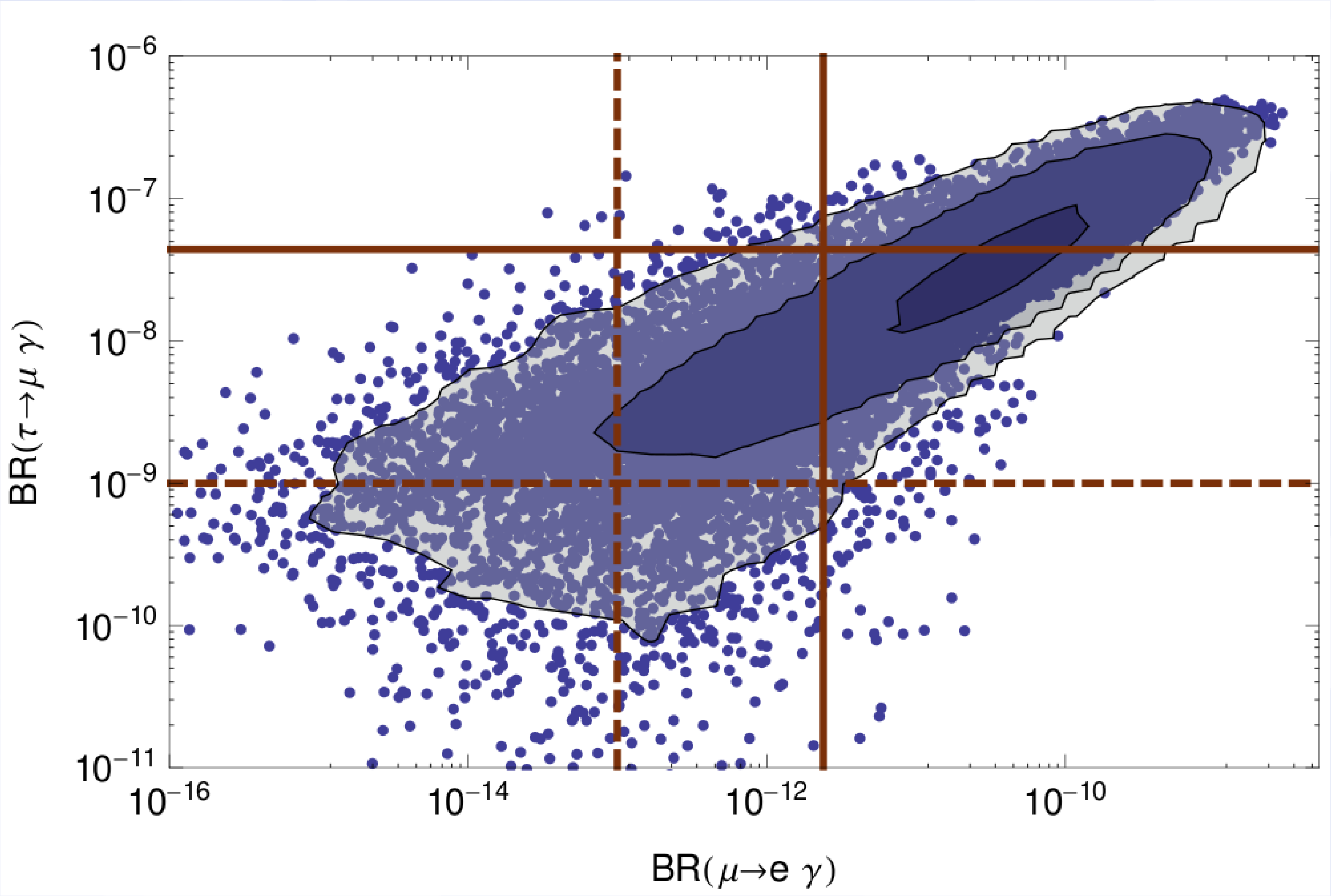
One would expect it to be generic, O(1)...

Neutrinoless Double Beta Decay

Large values for m_{light} and $m_{\beta\beta}$



Lepton Flavour Violation



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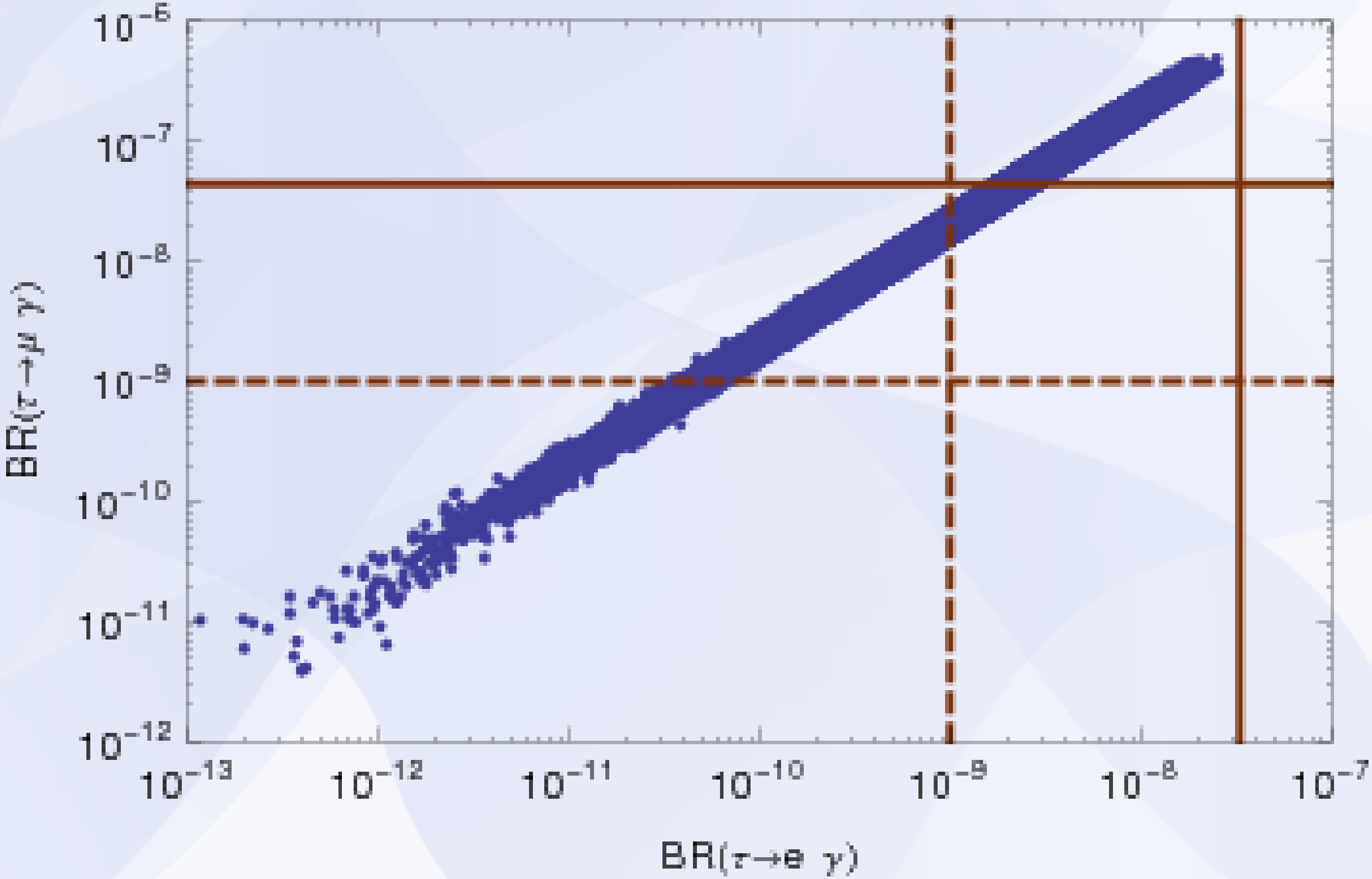

Conclusions

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- $U(2)^5$ framework, compatible with Effective SUSY, has been built.
- In quark sector, flavour tensions can be eliminated

Conclusions

- $U(2)^5$ framework cannot reproduce neutrino data, need a $U(3)^5 \to U(2)^5$ breaking.
- We can predict value of s_{13} from that of s_{23}, and fit in quark sector.
- Main predictions: large neutrino masses, large neutrinoless double beta decay, LFV.

Backup

Supersymmetry

What do we need to solve the hierarchy problem?

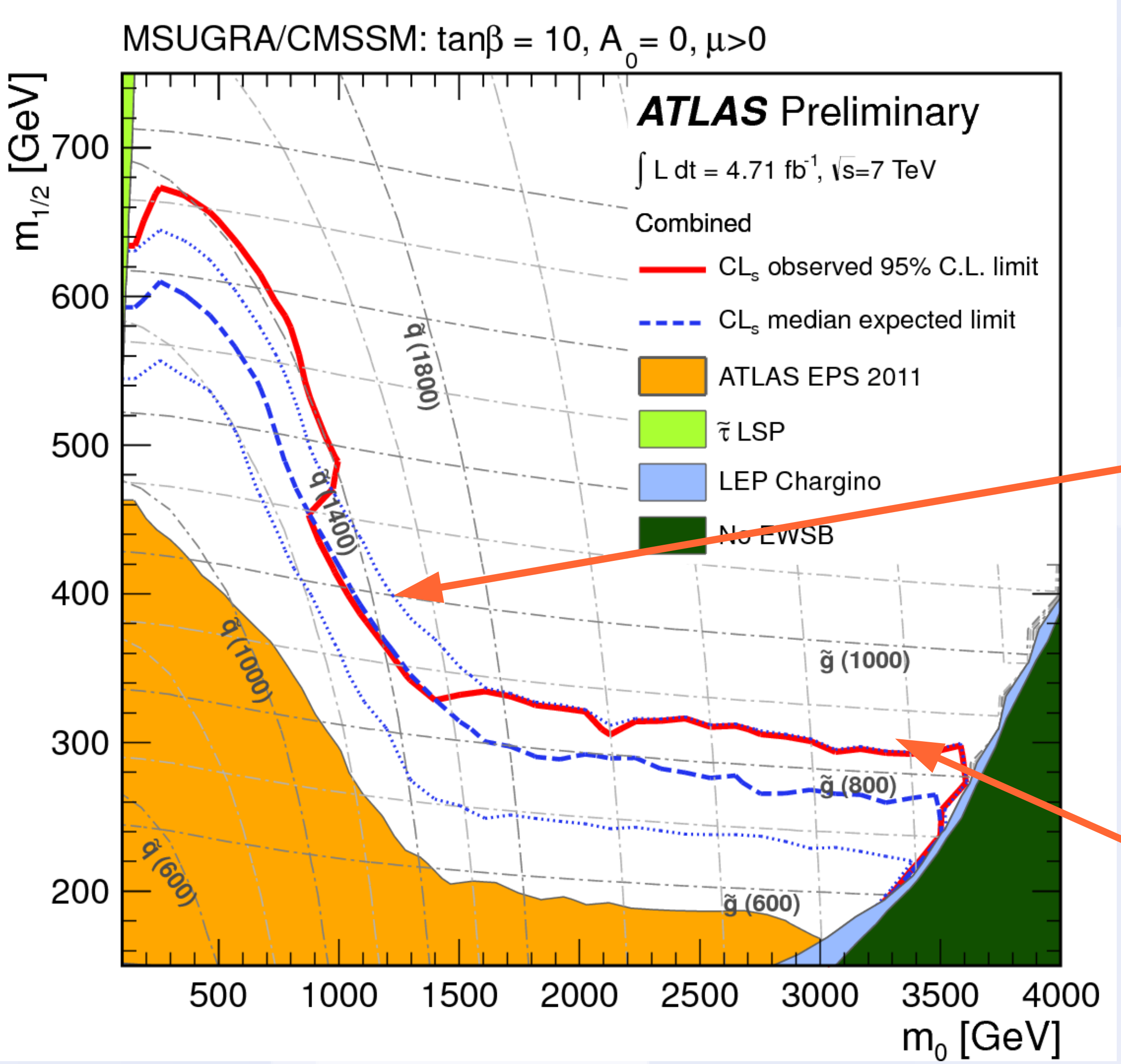
$$\mu \lesssim 210 \text{ GeV}$$

$$m_{\tilde{g}} \lesssim 950 \text{ GeV}$$

$$\sqrt{m_{\tilde{t}_1}^2 + m_{\tilde{t}_2}^2 + A_t^2} \lesssim 620 \text{ GeV}$$

Papucci, Ruderman, Weiler (1110.6926)

Supersymmetry



$$m_{\tilde{g}} = 1 \text{ TeV}$$

$$\Rightarrow m_{\tilde{t}_1} \approx 920 \text{ GeV}$$

$$\mu \approx 520 \text{ GeV}$$

$$m_{\tilde{g}} \gtrsim 850 \text{ GeV}$$

ATLAS-CONF-2012-033

$U(2)^3$ Framework for Small *tan*β

$$U(2)_Q \otimes U(2)_u \otimes U(2)_d \otimes U(1)_b$$

$$\begin{aligned} d_R^{c(2)} &\quad\longrightarrow\quad e^{i\beta}\, d_R^{c(2)} \\ b_R^c &\quad\longrightarrow\quad e^{i\beta}\, b_R^c \end{aligned}$$

$$y_b \longrightarrow e^{-i\beta}\, y_b$$

Small Spurion

Diagonalization Matrices

$$U_{fL} Y_f U_{fR}^\dagger = Y_f^{\mathrm{diag}}$$

$$U_{uR} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & -\lambda_{u2} s_t e^{i\phi_t} \\ 0 & \lambda_{u2} s_t e^{-i\phi_t} & 1 \end{pmatrix}$$

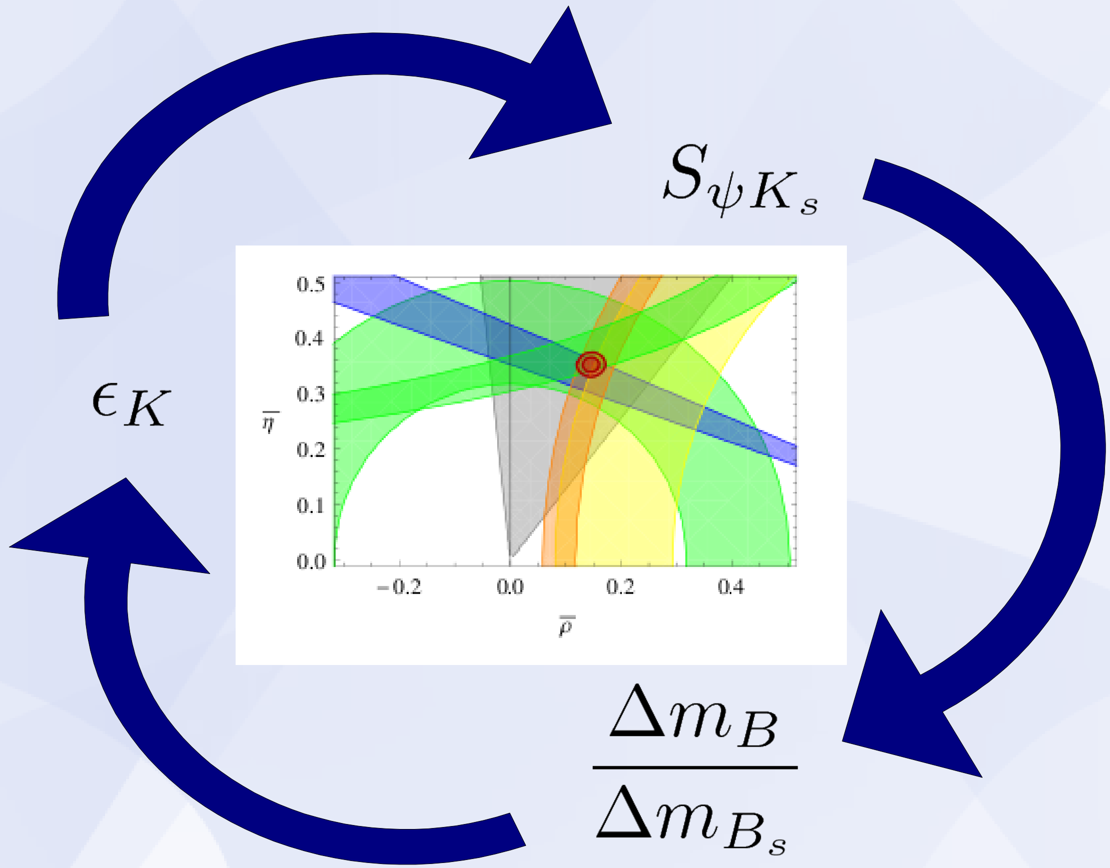
$$U_{uL} = \begin{pmatrix} c_u & s_u\, e^{i\alpha_u} & -s_u s_t e^{i(\alpha_u+\phi_t)} \\ -s_u\, e^{-i\alpha_u} & c_u c_t & -c_u s_t e^{i\phi_t} \\ 0 & s_t e^{-i\phi_t} & c_t \end{pmatrix}$$

$$s_t / c_t = x_t \epsilon$$

Input to CKM Fit

$\lvert V_{ud}\rvert$	$0.97425(22)$	f_K	(155.8 ± 1.7) MeV
$\lvert V_{us}\rvert$	$0.2254(13)$	$\hat{B}_K$	0.724 ± 0.030
$\lvert V_{cb}\rvert$	$(40.89 \pm 0.70) \times 10^{-3}$	κ_ϵ	0.94 ± 0.02
$\lvert V_{ub}\rvert$	$(3.97 \pm 0.45) \times 10^{-3}$	$f_{B_s}\sqrt{\hat{B}_s}$	(291 ± 16) MeV
γ_{CKM}	$(74 \pm 11)^\circ$	ξ	1.23 ± 0.04
$\lvert\epsilon_K\rvert$	$(2.229 \pm 0.010) \times 10^{-3}$		
$S_{\psi K_S}$	0.673 ± 0.023		
ΔM_d	$(0.507 \pm 0.004)\,\mathrm{ps}^{-1}$		
ΔM_s	$(17.77 \pm 0.12)\,\mathrm{ps}^{-1}$		

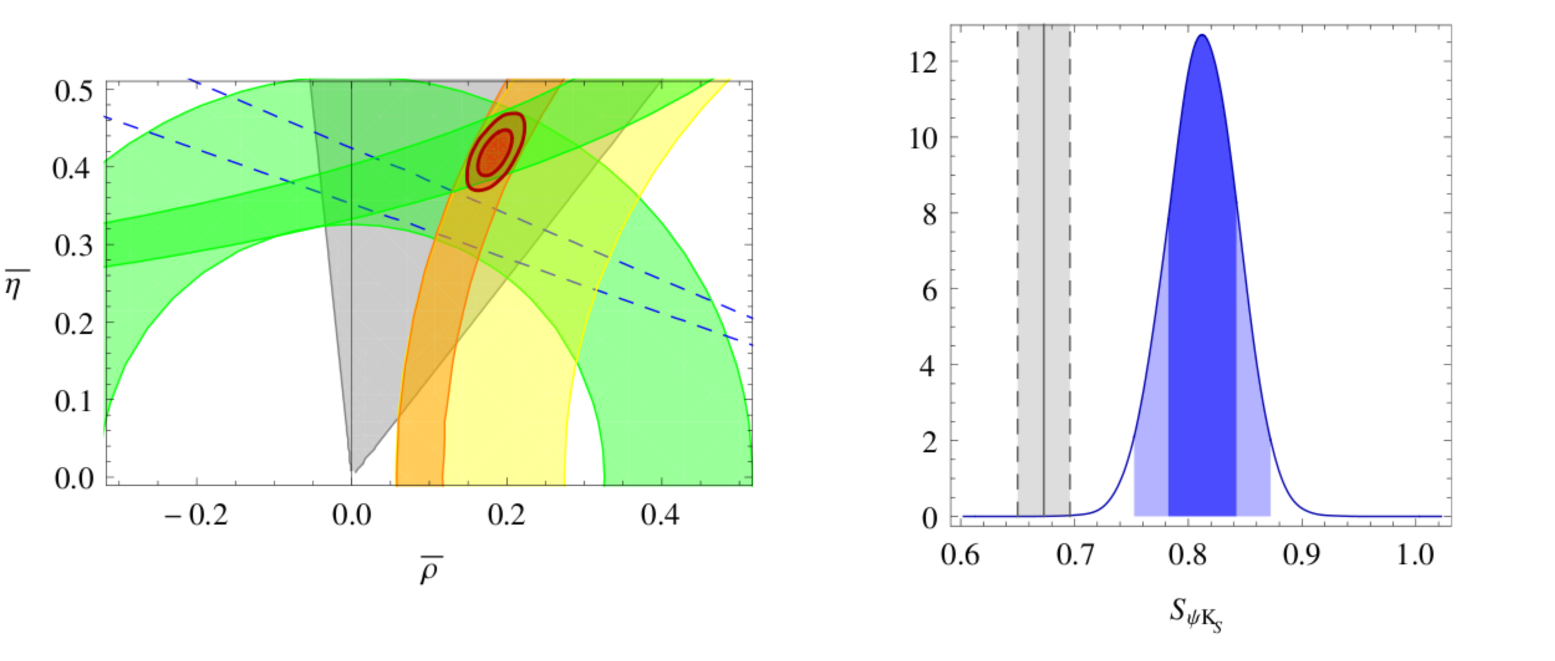
Flavour Tension in the SM



Buras, Guadagnoli (0901.2056 [hep-ph])
Altmannshofer *et al* (0909.1333 [hep-ph])

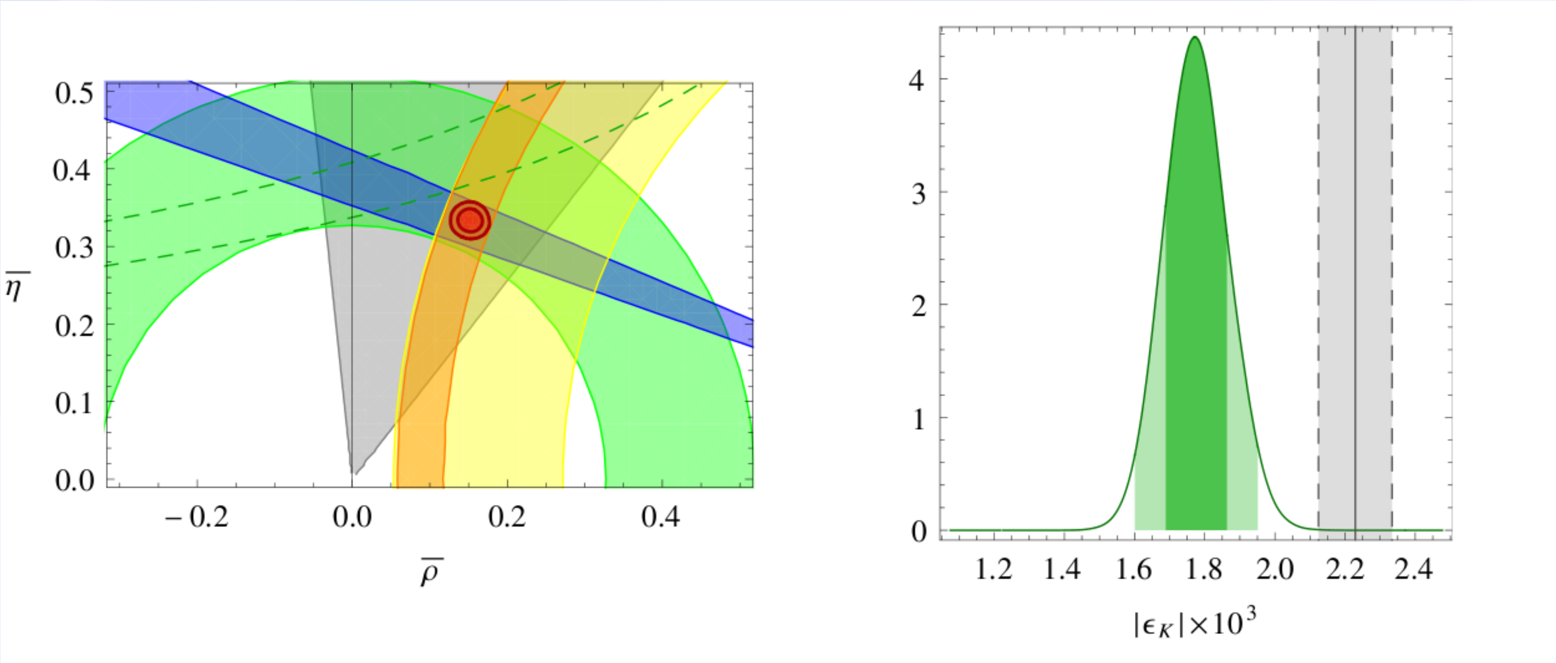
Flavour Tension in the SM

UT fit without $S_{\psi Ks}$:



Flavour Tension in the SM

UT fit without ε_K:



Squark Mixing Matrices

$$W_L^{d\dagger}\ m_{\tilde{Q}}^2\ W_L^d = (m_{\tilde{Q}}^2)^{\text{diag}}$$

$$W_L^d = \begin{pmatrix} c_d & \kappa^* & -\kappa^* s_L e^{i\gamma} \\ -\kappa & c_d & -c_d s_L e^{i\gamma} \\ 0 & s_L e^{-i\gamma} & 1 \end{pmatrix}$$

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$\kappa = c_d V_{td}/V_{ts}$

No new phases on the (1-2) sector

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$$s_L e^{-i\gamma} \quad = \quad \epsilon\, e^{i\xi}(x_b + x_Q)$$

New phase on the (1-3) and (2-3) sectors!

Squark Mixing Matrices

$$W_L^{d\dagger}\, m^2_{\tilde{Q}}\, W_L^d = (m^2_{\tilde{Q}})^{\rm diag}$$

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New CPV in (1-3) sector is connected to CPV in (2-3) sector!

$$\kappa = c_d V_{td}/V_{ts}$$

No new phases on the (1-2) sector

$$s_L e^{-i\gamma} \quad = \quad \epsilon\, e^{i\xi}(x_b + x_Q)$$

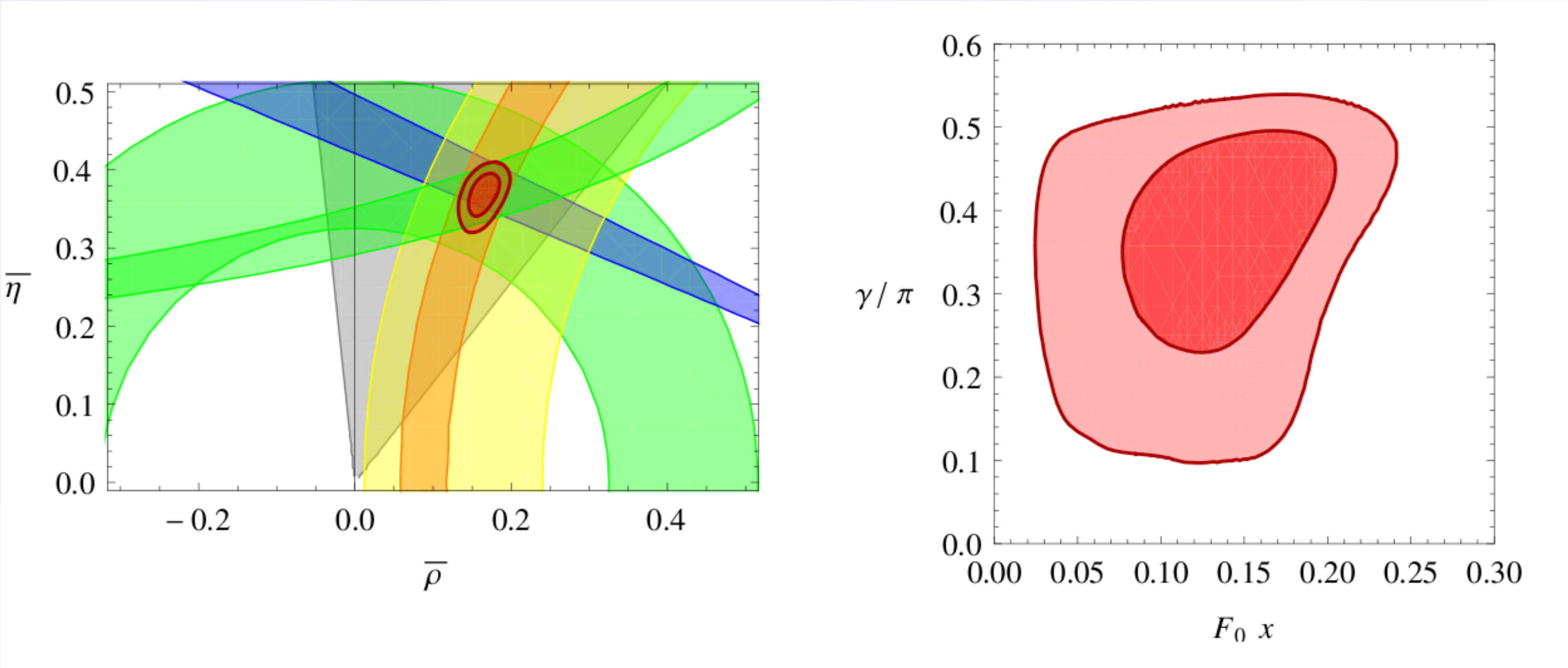
New phase on the (1-3) and (2-3) sectors!

New SUSY Contributions

$$\begin{aligned}
\epsilon_K &= \epsilon_K^{\mathrm{SM(tt)}} \times \left(1 + x^2 F_0\right) + \epsilon_K^{\mathrm{SM(tc+cc)}} \\
S_{\psi K_S} &= \sin\left(2\beta + \arg\left(1 + x F_0 e^{-2i\gamma}\right)\right) \\
\frac{\Delta M_d}{\Delta M_s} &= \frac{\Delta M_d^{\mathrm{SM}}}{\Delta M_s^{\mathrm{SM}}}
\end{aligned}$$

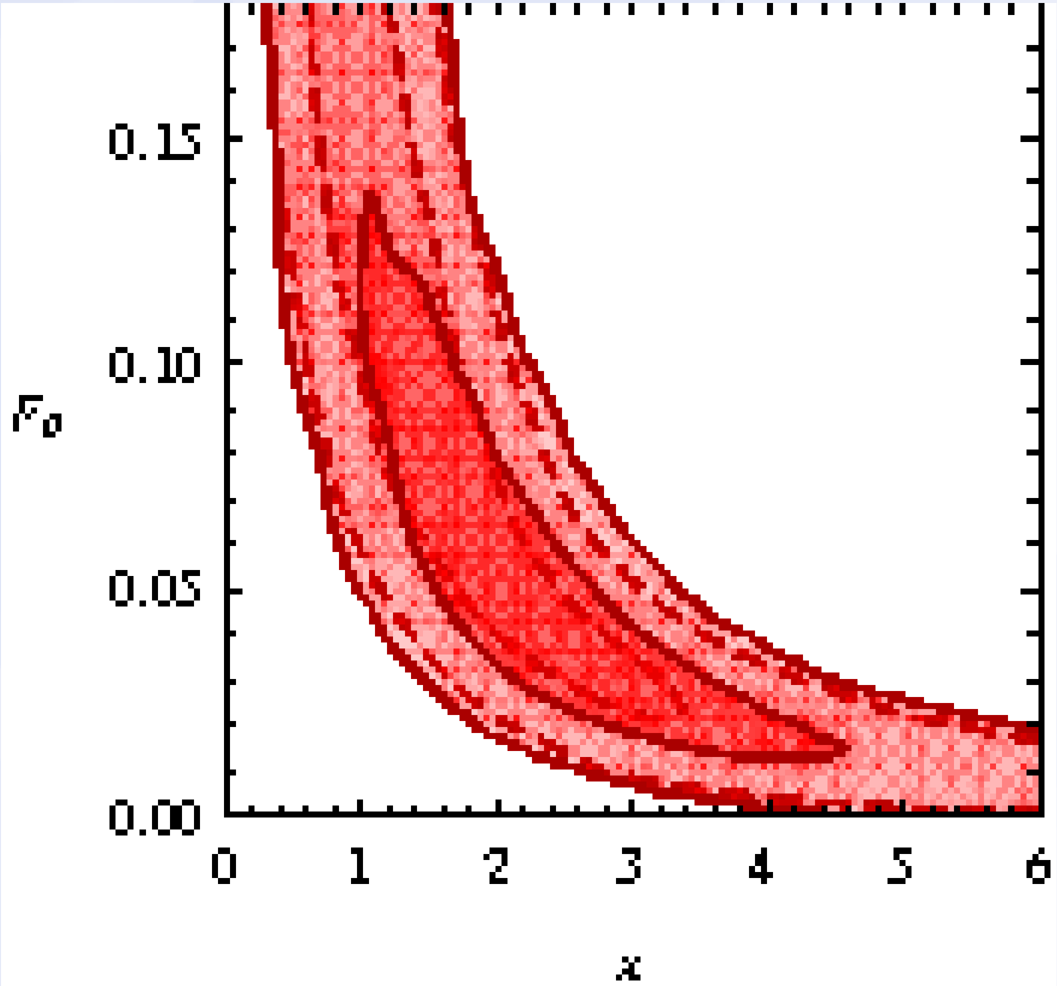
$$x = \frac{c_d^2 s_L^2}{|V_{ts}|^2}$$

Fit with SUSY Contribution

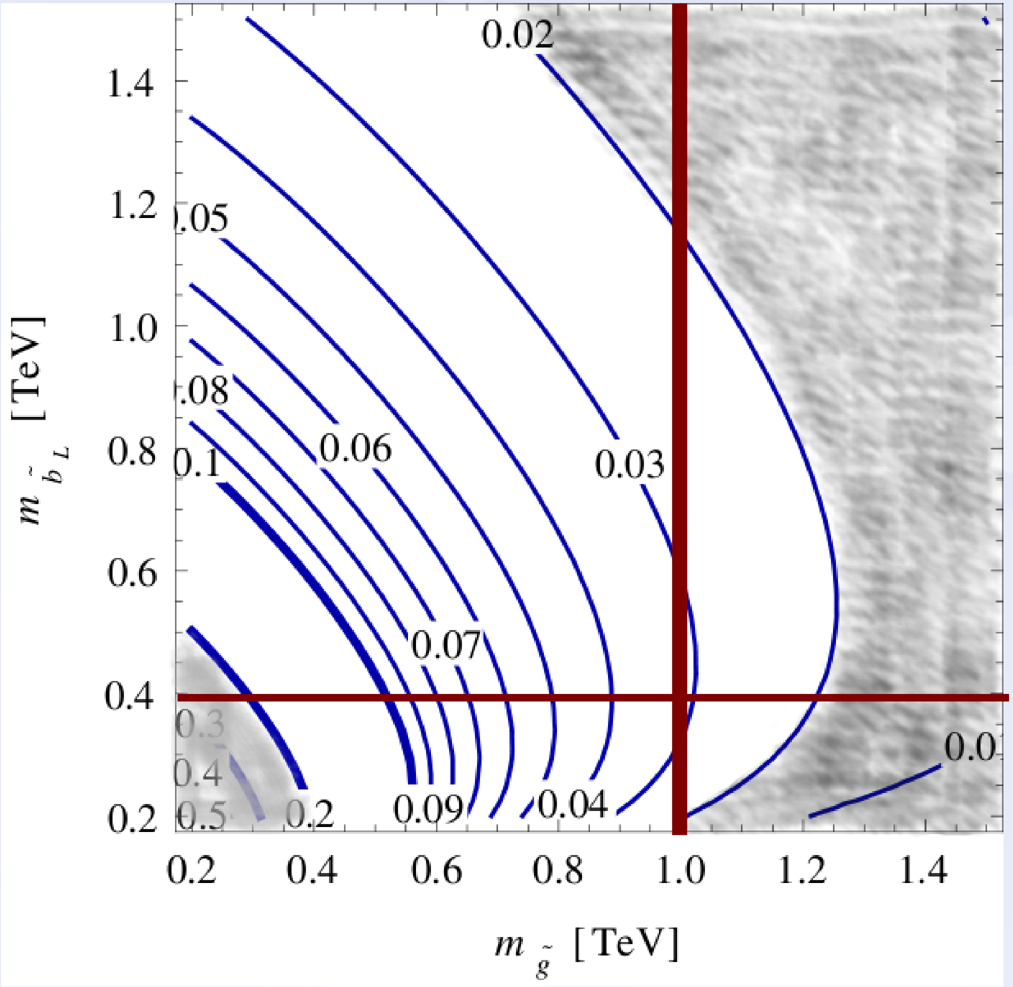


$(\chi^2/N_{\mathrm{d.o.f.}})_{\mathrm{SM}} = 9.8/5 \qquad (\chi^2/N_{\mathrm{d.o.f.}})_{\mathrm{SUSY}} = 0.7/2$

Fit to F_0 and x



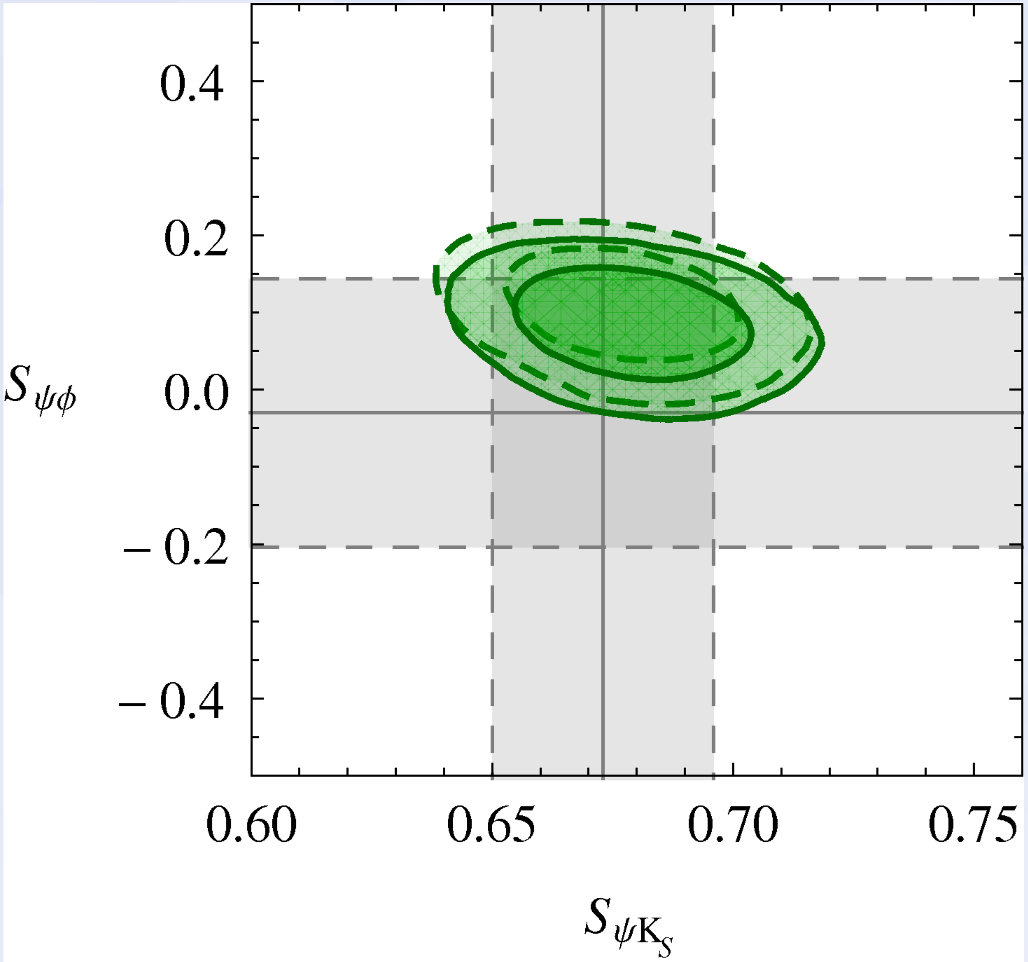
Predictions from Fit



$$0.02 < F_0 < 0.15$$

Light spectrum for third generation sfermions!

Predictions from Fit



Large $S_{\psi\phi}$!

Straub (1110.6391 [hep-ph])

Neutrinoless Double Beta Decay

Bounds	
Experiment	Bound (eV), C.L.
KamLAND-Zen (^{136}Xe)	$< 0.3 - 0.6$, 90%
CUORICINO (^{130}Te)	$< 0.19 - 0.68$, 90%
NEMO3 (^{100}Mo)	$< 0.7 - 2.8$, 90%
Heidelberg-Moscow (^{76}Ge)	0.32 ± 0.03, 68%

Prospects	
Experiment	Reach (eV)
KamLAND-Zen (^{136}Xe)	0.062
CUORE (^{130}Te)	0.062
NEXT (^{136}Xe)	0.071
EXO (^{136}Xe)	0.072

Slepton Mass Matrix

$$\tilde{m}^2_{LL} = \begin{pmatrix} 1 & c''_3\,\epsilon^2 & 0 \\ c''^*_3\,\epsilon^2 & 1 + c_3\,\epsilon & c'_3\,\epsilon \\ 0 & c'^*_3\,\epsilon & 1 + c_2|y_\tau|^2 \end{pmatrix} \tilde{m}^2_L$$

We need a cancellation

Slepton Mixing

$$\mathcal{R}_L^{\tilde{\nu}\dagger} = \left(\begin{array}{ccc} c_e & s_e e^{-i\alpha_e} & -s_e s_L^e e^{i\gamma} e^{-i\alpha_e} \\ -s_e e^{i\alpha_e} & c_e & -c_e s_L^e e^{i\gamma} \\ 0 & s_L^e e^{-i\gamma} & 1 \end{array} \right)$$

$$\begin{aligned} \mathcal{R}_{13}^{\tilde{\nu}} &= -s_e\, s_L^e\, e^{i(\gamma-\alpha_e)} \\ \mathcal{R}_{23}^{\tilde{\nu}} &= -c_e\, s_L^e\, e^{i\gamma} \\ \mathcal{R}_{33}^{\tilde{\nu}} &= 1 \end{aligned}$$

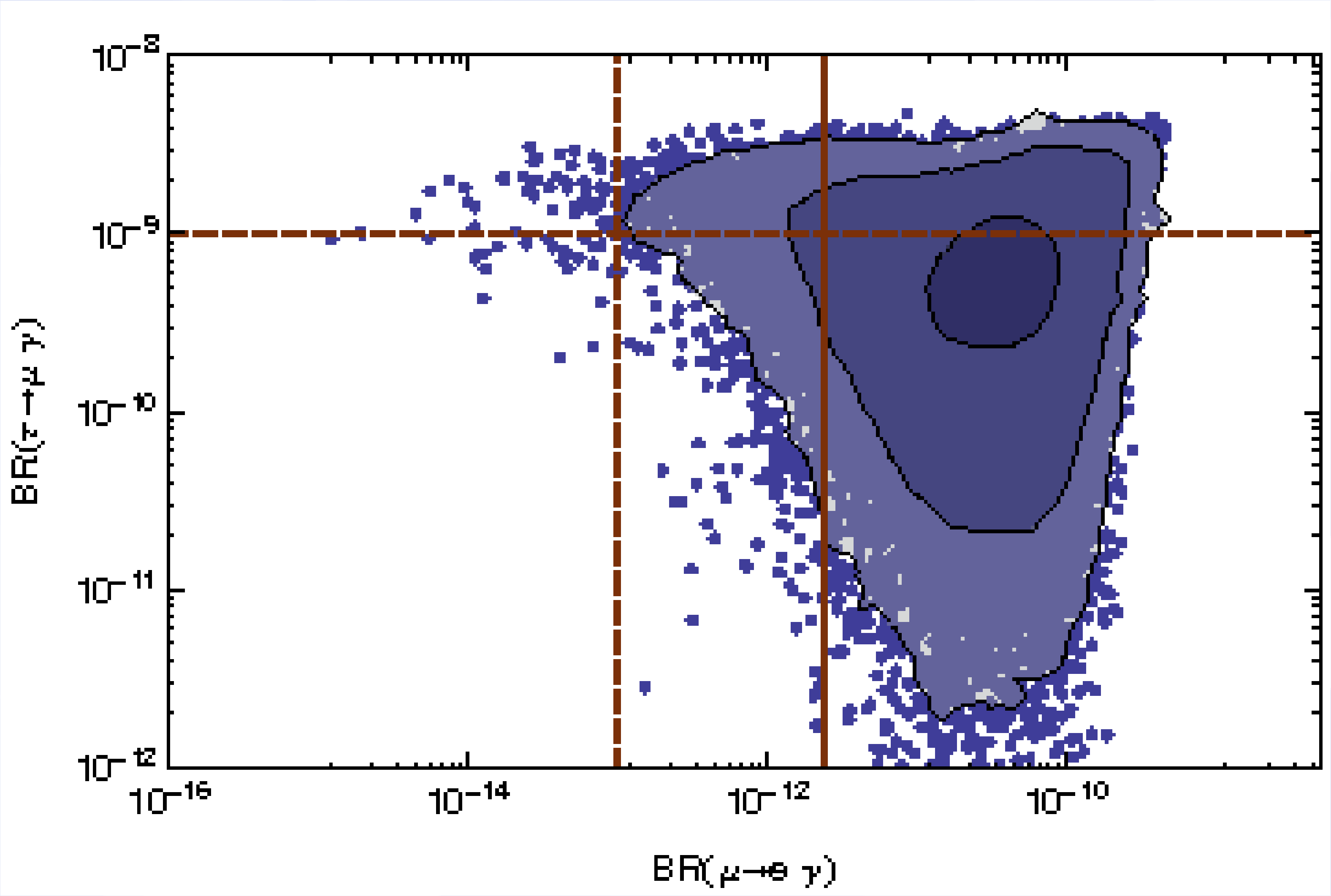
LFV

$$\left(\frac{\mathcal{B}(\mu \to e\gamma)}{\mathcal{B}(\tau \to \mu\gamma)}\right)^{\chi^\pm} \approx \left(\frac{m_\mu}{m_\tau}\right)^5 \frac{\Gamma_\tau}{\Gamma_\mu} \left|\frac{\mathcal{R}^{\tilde{\nu}}_{23}\mathcal{R}^{\tilde{\nu}*}_{13}}{\mathcal{R}^{\tilde{\nu}}_{33}\mathcal{R}^{\tilde{\nu}*}_{23}}\right|^2$$

$$\approx 5.1\, s_e^2\, {s_L^e}^2$$

$$\left(\frac{\mathcal{B}(\tau \to e\gamma)}{\mathcal{B}(\tau \to \mu\gamma)}\right)^{\chi^\pm} \approx \left|\frac{\mathcal{R}^{\tilde{\nu}}_{33}\mathcal{R}^{\tilde{\nu}*}_{13}}{\mathcal{R}^{\tilde{\nu}}_{33}\mathcal{R}^{\tilde{\nu}*}_{23}}\right|^2 \approx s_e^2$$

Lepton Flavour Violation



Dynamical Two-Site Model

$$G_1^{SM} \otimes G_2^{SM}$$

Third generation
Higgs

First + second generation

U(2) symmetry

Dynamical Two-Site Model

Chiral field	$G_1^{\rm SM}$	$G_2^{\rm SM}$
χ_h	$(3, 2, \frac{1}{6})$	$(\overline{3}, 2, -\frac{1}{6})$
$\tilde{\chi}_h$	$(\overline{3}, 2, -\frac{1}{6})$	$(3, 2, \frac{1}{6})$
χ_ℓ	$(1, 2, \frac{1}{2})$	$(1, 2, -\frac{1}{2})$
$\tilde{\chi}_\ell$	$(1, 2, -\frac{1}{2})$	$(1, 2, \frac{1}{2})$

$$Y_u,\, Y_d \sim \begin{pmatrix} \epsilon_\ell & \epsilon_\ell & \epsilon_h \\ \epsilon_\ell & \epsilon_\ell & \epsilon_h \\ \epsilon_\ell\epsilon_h & \epsilon_\ell\epsilon_h & 1 \end{pmatrix}$$