The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1951-12

Workshop on the original of P, CP and T Violation

2 - 5 July 2008

From NMSGUT to LHC

AULAKH Charanjit Singh
Panjab University
Department of Physics
160 014 Chandigarh
INDIA

Pinning NMSGUT at LHC

C. S. Aulakh

Panjab Univeristy & $\tilde{\text{I}}$ISER(Mohali)
Chandigarh,INDIA

SUMIT GARG ,

HEP-TH0807...

- MSGUTs basics and a brief History of Fits
- NMSGUT Formulae and their necessity
- Numerical searches for NMSGUT parameter based fits
- M_S Threshold corrections and Structure of Fits
- RRRR $\Delta B \neq 0$
- Outlook : Imminent Falsification or apotheosis?

VIRTUES OF SO(10) UNIFICATION

- $\{Q_L, L_L, u_L^c, d_L^c, l_L^c \oplus \nu_{\mathbf{L}}^{\mathbf{c}}\} \equiv 16$: Tight and complete !
- $SO(10) \ni CP \equiv DParity : f \Leftrightarrow f_L^c \Rightarrow$ BEST LOCUS FOR DEEP INSIGHT INTO CP VIOLATION !
- NATURAL HOME TO BOTH SEESAWS
  $\vec{\Delta}_R(1,3,-2), \vec{\Delta}_L(3,1,2) \subset \overline{126}$
- FM Higgs

$$16 \otimes 16 \quad = \quad 10 \oplus 120 \oplus 126 \Rightarrow 16 \cdot 16 \cdot (10 + 120 + \overline{126})$$

- SO(10) AM Higgs (R-PARITY PROTECTED! LSP STABLE):
  $\mathbf{45} \oplus \mathbf{54} \oplus \mathbf{126} \oplus \overline{\mathbf{126}}$ OR $\mathbf{210} \oplus \mathbf{126} \oplus \overline{\mathbf{126}} \Rightarrow MSGUT$

Guts OF MSGUT

- **AM Higgs** : $< \mathbf{210}(\Phi_{ijkl}),\ \ \overline{\mathbf{126}}(\overline{\mathbf{\Sigma}}_{ijklm})\ \ \mathbf{126} > \Rightarrow$
  $Susy\ SO(10) \longrightarrow MSSM$

- **Superpotential**

$$
\begin{aligned}
W &= m\ 210^2 + \lambda\ 210^3 + M\ 126 \cdot \overline{126} + \eta\ 210 \cdot 126 \cdot \overline{126} \\
&+ 10 \cdot 210(\gamma\ 126 + \bar{\gamma}\ \overline{126}) \\
&+ M_H\ 10^2 + h_{AB}\ 16_A \cdot 16_B + f'_{AB}\ 16_A 16_B
\end{aligned}
$$

Superpotential Parameters : (**25**) **Minimal** !! ABMSV(2003)

- **GUT scale VEVS** : $SO(10) \rightarrow MSSM$

$$
\begin{aligned}
\langle(15,1,1)\rangle_{210} &: a \qquad \langle(15,1,3)\rangle_{210} : \omega \\
\langle(1,1,1)\rangle_{210} &: p \\
\langle(10,1,3)\rangle_{\overline{126}} &: \bar{\sigma} \quad ; \quad \langle(\overline{10},1,3)\rangle_{126} : \sigma
\end{aligned}
$$

- D Terms : $|\sigma| = |\overline{\sigma}|$

- F Terms :SSB completely analyzable !!4 eqns $\Rightarrow$ **Cubic in** $x = -\lambda\omega/m : \xi = \frac{\lambda M}{\eta m}$. (ABMSV 2003)
  $8x^3 - 15x^2 + 14x - 3 = -\xi(1-x)^2$
- Units : $\frac{m}{\lambda}$
  $\tilde{a} = \frac{(x^2+2x-1)}{(1-x)} \quad ; \quad \tilde{p} = \frac{x(5x^2-1)}{(1-x)^2} \quad ; \quad \tilde{\sigma}\tilde{\overline{\sigma}} = \frac{2}{\eta}\frac{\lambda x(1-3x)(1+x^2)}{(1-x)^2}$
- Chiral GUT scale spectra : 52 MSSM multiplet sets, 26 MSSM types : 18 unmixed , 8 mixed : 504 Fields

  CSA, Girdhar(2003) ; Fukuyama, Ilakovac, Kikuchi, Mejanac, Okada (2004), BMSV (2004), CSA Girdhar(2004)

  Complete gauge, spinor couplings , Clebsches : CSA Girdhar (2002) (2004)
- Spectra$\Rightarrow$ RG including Threshold effects etc.CSA, Girdhar (2004), NMSGUT (WITH COMPLETE FERMION MASS,$d = 5, \Delta B \neq 0$ FORMULAE)!!!!!!!!!! CSA, Garg(2005/6)

Light Doublets and $m_{q,l}$

- Doublet Masses CSA, Girdhar (2003) : $\mathbf{10}, \overline{\mathbf{126}}, \mathbf{126}, \mathbf{210}$

$$\mathcal{H} = \begin{pmatrix} -M_H & +\bar{\gamma}\sqrt{3}(\omega - a) & -\gamma\sqrt{3}(\omega + a) & -\bar{\gamma}\bar{\sigma} \\ -\bar{\gamma}\sqrt{3}(\omega + a) & 0 & -(2M + 4\eta(a + \omega)) & 0 \\ \gamma\sqrt{3}(\omega - a) & -(2M + 4\eta(a - \omega)) & 0 & -2\eta\bar{\sigma}\sqrt{3} \\ -\sigma\gamma & -2\eta\sigma\sqrt{3} & 0 & -2m + 6\lambda(\omega - a) \end{pmatrix}$$

- $\overline{U}^T \mathcal{H} U = Dg(m_H^{(1)}, m_H^{(2)}, ..);\ h^{(i)} = U_{ij} H^{(j)} \quad ; \quad \bar{h}^{(i)} = \bar{U}_{ij} \bar{H}^{(j)}$
- Fine Tune $M_H \Leftarrow Det\mathcal{H} = 0 \Rightarrow$ Light Doublets $H^{(1)}, \overline{H}^{(1)}$

$$\begin{array}{lccccccc} E << M_X & : & h^{(i)} & \rightarrow & \alpha_i H^{(1)} & ; & \alpha_i = U_{i1} \\ & & \bar{h}^{(i)} & \rightarrow & \bar{\alpha}_i \bar{H}^{(1)} & ; & \bar{\alpha}_i = \bar{U}_{i1} \end{array}$$

- $\mathcal{H}\alpha = 0 \quad ; \quad \bar{\alpha}^T \mathcal{H} = 0 \quad \Rightarrow \alpha, \overline{\alpha}.$
  (ABMSV(2003), BMSV(2004),NMSGUT (6×6)
  CSA,Garg(2006))

FERMION MASSES IN SO(10)

- Data for GUT To Explain :
  Measured(17) : $m_{q,l}, \theta_i^{CKM}, \delta^{CKM}, \Delta m_\nu^2, \theta_{12,23}^{PMNS}$
  Bounded: $\theta_{13}^{PMNS} < .15$
- **Awaited (4) :** $M_\nu, \delta^{PMNS}, \alpha_{1,2}^{PMNS}$
- Yukawa couplings : $h = h^T, f = f^T, g = -g^T$
  $W = \mathbf{16}_A \times \mathbf{16}_B \cdot (h_{AB}\mathbf{10} + f_{AB}\overline{\mathbf{126}} + g_{AB}\mathbf{120})$
- MSGUT : only $\mathbf{10} + \overline{\mathbf{126}}$ Dirac masses at $M_X(\hat{h}, \hat{f}$ explict formulae need 16×16 clebsches CSA,GIRDHAR(2004,5), null eigenvectors of $\mathcal{H}$ CSA, BAJC, MELFO, SENJANOVIC,VISSANI ; CSA, GIRDHAR(2005)

$$
\begin{aligned}
m^u &= v(\hat{h} + \hat{f}) \\
m^\nu &= v(\hat{h} - 3\hat{f}) \\
m^d &= v(r_1\hat{h} + r_2\hat{f})
\end{aligned}
$$

$$m^l = v(r_1\hat{h} - 3r_2\hat{f})$$

- Seesaw masses :

$$\begin{aligned} M_\nu^I &= v r_4 \hat{n} \\ M_\nu^{II} &= 2v r_3 \hat{f} \\ \hat{n} &= (\hat{h} - 3\hat{f})\hat{f}^{-1}(\hat{h} - 3\hat{f}) \end{aligned}$$

- Babu and Mohapatra (1992): $\mathbf{10} \oplus \overline{\mathbf{126}} \Leftrightarrow \quad m_{q,l} \Rightarrow$ Predictive in the Neutrino Sector ?! : failure (1992,93,94..)
- Matsuda, Koide , Fukuyama, Nishiura (2002): Successful Type I , large θ^{PMNS} fit. Requires CP violation!

Type II: BM -BSV FITTING FRENZY

- Bajc, Senjanovic, Vissani (2003) Large PMNS mixing angle $b-\tau$ unification connection

$$M_\nu^{II} \sim f < \Delta_L > \sim (M_d - M_l) \sim m_\tau \begin{pmatrix} & \epsilon^2 & \epsilon^2 \\ \epsilon^2 & & \frac{(m_b - m_\tau)}{m_\tau} \end{pmatrix} \Rightarrow$$

MSSM : $m_b \simeq m_\tau(M_X) \quad \Rightarrow \theta_{23}^{PMNS} \simeq 1$

- Goh Mohapatra Ng : Type II : 3 generations , Real/Complex : Good Fits except $\delta^{CKM} > \frac{\Pi}{2}$.

- Bertolini, Malinsky (2004)(Type II, $\oplus$120) ; Babu Macesanu (2005)(Type I and II) **Good Angle and Ratio Fits. !!**

- Datta Mimura, Mohapatra(2004/5) **120**,$< CP >$,Type II: parameters reduced and generic fits excellent. $d = 5$ proton decay controllable by cancellations

MSGUT DOOM

- Type I ,Type II generic fits : freedom to choose r_1, r_2, r_3, r_4 *assumed.* M_ν scale, Relative strength of Type I / Type II *assumed.* NOT JUSTIFIED IN MSGUT ! In MSGUT magnitude and relative strength of seesaw masses fixed !! Fit fully specified : is it viable ??
- NO !! CSA (2005),CSA,Garg (2005)

  Seesaw masses $(v^2/M_X^0 = (1.7 \times 10^{-3} eV)\ )$

$$M_\nu^I = (1.7 \times 10^{-3} eV) \sin\beta\ F_I\ \hat{n}$$
$$M_\nu^{II} = (1.7 \times 10^{-3} eV) \sin\beta\ F_{II}\ \hat{f}$$

- $\hat{n}, \hat{f}, F_I >> F_{II}$ known and bounded so M_ν too small.

  CSA,CSA-Garg (May, December 2005)(utility of x emphasized by Bajc et al November 2005)
- **Checked**, Bertolini, Schwetz, Malinski(2006-April)

Re-Birthing MSGUTs

- NEW SCENARIO : CSA, GARG (2005); REASSIGNMENT OF ROLES !: $h \oplus g >>> f \quad \Rightarrow (m_{q,l}, \theta_q^i, \delta_c)$. $\overline{\mathbf{126}}$ IRRELEVANT TO CHARGED FERMION MASSES : CKM FROM G_{23} (GOOD AT ANGLES).
- $f << h, g \Rightarrow M_{\nu^c} << M_X \Rightarrow$ Type I BOOSTED $(\hat{n} \sim \hat{f}^{-1})$, Type II DEAD!!
- GRIMUS LAVOURA(2006)NO GO IN GENERIC CASE ! D QUARK TOO LIGHT EVEN WITHOUT CKM.
- GRIMUS KUHBOCK(2006) : ACCURATE GENERIC FITS , SMALL F, LARGE G, r_D ??
- CSA(2007) :GENERIC PARAMETERS CONSTRAINED IN NMSGUT; CONSTRAINT INSOLUBLE $\Rightarrow$ FRESH RE-SOLUTION IN TERMS OF NMSGUT PARAMETERS NECESSARY !

Guts of NMSGUT

- Decomposition **120**-plet w.r.t $SU(4) \times SU(2)_L \times SU(2)_R$

$$\begin{aligned} O_{ijk}(120) &= O^{(s)}_{\mu\nu}(10,1,1) + \overline{O}^{\mu\nu}_{(s)}(\overline{10},1,1) + O_{\nu\alpha\dot{\alpha}}{}^{\mu}(15,2,2) \\ &+ O^{(a)}_{\mu\nu\dot{\alpha}\dot{\beta}}(6,1,3) + O^{(a)}_{\mu\nu\ \alpha\beta}(6,3,1) + O_{\alpha\dot{\alpha}}(1,2,2) \end{aligned}$$

- AM SSB unmodified, 26 MSSM multiplet types same.

$$\begin{aligned} W_{120} &= M_O\ 120 \cdot 120 + k\ 10 \cdot 120 \cdot 210 + \rho\ 120 \cdot 120 \cdot 210 \\ &+\zeta\ 120 \cdot 126 \cdot 210 + \bar{\zeta}\ 120 \cdot \overline{126} \cdot 210 + g_{[AB]} 16_A \cdot 16_B \cdot 120 \end{aligned}$$

- Parameter Counting : Complex Case

$$M_O, k, \rho, \zeta, \bar{\zeta}, g_{AB} : (1+1+1+2+3) \times 2 - 1 = 15 \oplus 24\ \ (old) = 39$$

(Minimal No Longer ?)

- Too Hasty : Spontaneous CP violation only ? $\Rightarrow$ All Superpot couplings Real, phases from vevs ($\Rightarrow$ *Complex* x!!)

$$
\begin{aligned}
OLD \quad &: \quad m, M, M_H, \lambda, \eta, \gamma, \bar{\gamma}, h_{AB}, f_{AB} : 7 + 3 + 6 = 16 \\
NEW \quad &: \quad M_O, k, \rho, \zeta, \bar{\zeta}, g_{AB} : 5 + 3 = 8 \\
TOTAL \quad &: \quad 24 \;\; I.E \;\; one\ less \;\; than \;\; MSGUT!
\end{aligned}
$$

- 6×6 DOUBLET MASS MATRIX CSA TIWANA; CSA,GARG(2005,6)

$$
\begin{pmatrix}
-M_H & \bar{\gamma}\sqrt{3}(\omega - a) & -\gamma\sqrt{3}(\omega + a) & -\bar{\gamma}\bar{\sigma} & kp & -\sqrt{3}ik\omega \\
-\bar{\gamma}\sqrt{3}(\omega + a) & 0 & -(2M + 4\eta(a + \omega)) & 0 & -\sqrt{3}\bar{\zeta}\omega & i(p + 2\omega)\bar{\zeta} \\
\gamma\sqrt{3}(\omega - a) & -(2M + 4\eta(a - \omega)) & 0 & -2\eta\bar{\sigma}\sqrt{3} & \sqrt{3}\zeta\omega & -i(p - 2\omega)\zeta \\
-\sigma\gamma & -2\eta\sigma\sqrt{3} & 0 & -2m + 6\lambda(\omega - a) & \zeta\sigma & \sqrt{3}i\zeta\sigma \\
pk & \sqrt{3}\bar{\zeta}\omega & -\sqrt{3}\omega\zeta & \bar{\zeta}\bar{\sigma} & -m_o & \frac{\rho}{\sqrt{3}}i\omega \\
\sqrt{3}ik\omega & i(p - 2\omega)\bar{\zeta} & -i(p + 2\omega)\zeta & -\sqrt{3}i\bar{\zeta}\bar{\sigma} & -\frac{\rho}{\sqrt{3}}i\omega & -m_0 - \frac{2\rho}{3}a
\end{pmatrix}
$$

- DIAGONALIZE $\mathcal{H}$ after $Det\mathcal{H} = 0 \Rightarrow, H, \bar{H} \Rightarrow M_H FIXED$!! LIGHT. RIGHT AND LEFT EIGENVECTORS DETERMINE $\alpha_i, \bar{\alpha}_i$
- YUKAWA COUPLINGS (CSA,GIRDHAR(2004),CSA,GARG(2006))

$$
\begin{aligned}
\hat{y}^u &= (\check{h} + \check{f} + \check{g}) \quad ; \quad r_1 = \frac{\bar{\alpha}_1}{\alpha_1} \quad ; \quad r_2 = \frac{\bar{\alpha}_2}{\alpha_2} \\
\hat{y}^\nu &= (\check{h} - 3\check{f} + (r_5 - 3)\check{g}) \quad ; \quad r_5 = \frac{4i\sqrt{3}\alpha_5}{\alpha_6 + i\sqrt{3}\alpha_5} \\
\hat{y}^d &= (r_1\check{h} + r_2\check{f} + r_6\check{g}); \quad r_6 = \frac{\bar{\alpha}_6 + i\sqrt{3}\bar{\alpha}_5}{\alpha_6 + i\sqrt{3}\alpha_5} \\
\hat{y}^l &= (r_1\check{h} - 3r_2\check{f} + (\bar{r}_5 - 3r_6)\check{g}); \quad \bar{r}_5 = \frac{4i\sqrt{3}\bar{\alpha}_5}{\alpha_6 + i\sqrt{3}\alpha_5} \\
\check{g} &= 2ig\sqrt{\frac{2}{3}}(\alpha_6 + i\sqrt{3}\alpha_5) \quad ; \quad \check{h} = 2\sqrt{2}h\alpha_1 \quad ; \quad \check{f} = -4\sqrt{\frac{2}{3}}if\alpha_2
\end{aligned}
$$

- New Baryon Decay Channels : P$[3, 3, \pm\frac{2}{3}]$, K$([3, 1, \pm\frac{8}{3}] \subset 120$

NUMERICAL SEARCH FOR COMPLETE GUT PARAMETERS

PRECISION DATA AT $m_t(m_t)$: Xing,Zhang,Zhou(2008)

2 loop SM $\Downarrow$RG FLOW

$\Downarrow$

M_S : THRESHOLD CORRECTIONS AMPLIFY UNCERTAINTIES

$\Downarrow$

2 loop MSSM $\Downarrow$ FLOW

$M_X = 10^{16.3}$ GeV,DOWNHILL SIMPLEX,ANTUSCH ERRORS

2 loop MSSM $\Downarrow$ RG FLOW

$\Downarrow$

LARGE $\tan\beta$ CORRECTIONS $\Rightarrow$ ACCURATE FITS ACROSS

M_S TO SM PRECISION DATA DETERMINE SOFT SUSY

$\Downarrow$

2 loop MSSM $\oplus$ SOFT $\Downarrow$ RG FLOW

$\Downarrow$

SOFT STRUCTURE AT M_X

SEARCH FEATURES

- ALL COUPLINGS PERTURBATIVE
- 10^6 ITERATIONS EACH RANDOM START UNLESS STUCK
- χ^2 NEVER WENT BELOW 4.0, SOLUTIONS FOUND EVERY 20 ITERATIONS OR SO.
- ACCURATE FITS TO $\Delta m_\nu^2, \theta^{PMNS}$
- VALUES OF $\overline{126}$ COUPLINGS TINY $\Rightarrow M_{\bar\nu}$ SPAN $\sim 10^8 - 10^{13} GeV$ CSA,GARG(2006)
- BULK(OVER 85%) OF χ^2 from D,S QUARK REST BOTTOM,TAU.
- $M_{B-L} \sim 10^{15}$ GeV SUPPRESSES THE NEUTRINO MASSES $\Rightarrow$ TINY $\overline{\mathbf{126}}$ YUKAWAS ALWAYS !

CANDIDATE SET FILTRATION

- SCALES FROM WEINBERG OPERATOR κ_{ab} AND UNIFICATION MUST COINCIDE (1-5)(OUROBOUROS !)
- $-.0017 < \alpha_S(M_S) < -.004, \Delta(LogM_X) \geq 0$
- ACCURATE FITS TO $\Delta m_\nu^2, \theta^{PMNS}$
- VALUES OF $\overline{126}$ COUPLINGS TINY $\Rightarrow M_{\bar{\nu}}$ SPAN $\sim 10^8 - 10^{13} GeV$ CSA,GARG(2006)
- BULK(OVER 85%) OF χ^2 from D,S QUARK REST BOTTOM,TAU.
- $M_{B-L} \sim 10^{15}$ GeV SUPPRESSES THE NEUTRINO MASSES $\Rightarrow$ TINY $\overline{\mathbf{126}}$ YUKAWAS ALWAYS !

- 95% OF CANDIDATES KILLED ! RESIDUAL ALL INFECTED ds-b LOW DISEASE. EXTRAPOLATE TO M_S MATCH TO DATA USING

$$\frac{y^{SM}(M_S)}{y_f^{GUT}(M_S)} = \cos\beta(1+\epsilon_f(m_{\tilde{F}_i}, m_{\tilde{d}_i,\tilde{l}_i,\tilde{t}}, M_1, M_2, M_3, \mu, A_t, \alpha_1, \alpha_2, \alpha_3)\tan\beta)$$

- DOWNHILL SIMPLEX IN SOFT SUSY PARAMETER SPACE (EXCEPT $m_{\tilde{u},\tilde{c}}, B, M^2_{H,\bar{H}}$)

- GUT INSPIRED CONSTRAINTS (TO 10%):
1-2 DEGENERATE ; $M_1 : M_2 : M_3 :: 1 : 2 : 6$,
$|m_{\tilde{l},\tilde{L}}/M_1| \geq 0.9$; $|m_{\tilde{q},\tilde{Q}}/M_3| \geq 0.75$(TO 10%)

- AT LEAST ONE OF THIRD GEN SFERMIONS HEAVIER THAN 1-2 GEN; A_t, μ ARE OF OPPOSITE SIGN AND LARGE.

Parameter	$SOLN-1$	$SOLN-2$
h_{11}	8.95176×10^{-7}	2.69589×10^{-6}
h_{22}	0.000547776	0.00053838
h_{33}	0.196286	0.19651
f_{11}	-2.06673×10^{-7}	9.89865×10^{-8}
f_{12}	-2.37214×10^{-6}	2.02625×10^{-7}
f_{13}	-6.34652×10^{-6}	5.56002×10^{-6}
f_{22}	-0.0000237101	-5.28297×10^{-6}
f_{23}	-0.0000887439	0.0000439064
f_{33}	-0.000158592	0.00011407
g_{12}	-0.00592746	-0.0258934
g_{13}	0.0392534	0.0678888
g_{23}	0.428519	1.81457

Parameter	$SOLN-1$	$SOLN-2$
λ	2.1294	0.247415
η	-0.590395	-0.619743
ρ	-0.0325812	0.0682899
k	-0.000170967	-0.000055478
$\tilde{m}_O$	-0.0287934	0.338748
$\{m_{fit}/(10^{16}GeV)\}$	0.517858	0.347328
γ	-0.00131809	-0.0003681
$\bar{\gamma}$	0.0421822	0.04502453
ζ	-0.134801	-0.057408642
$\bar{\zeta}$	0.291861	-1.53557
ξ	0.848938	0.596808
$\{m_{RG}/(10^{16})\}GeV$	2.897	.304376
χ^2	5.71427	6.79112

Parameter	$SOLN-1$	$SOLN-2$
Δ_X	1.07903	1.60956
α_G^{-1}	14.7551	1.06413
$\Delta\alpha_3(M_Z)$	-1.33×10^{-3}	-0.015
$\{M^{\nu^c}/(10^{12})\}GeV$	$\{39.59, 3.97, 1.22\times10^{-3}\}$	$\{48.48, 7.46, 1.046\times10^{-3}\}$
$\{M_{II}^{\nu}/(10^{-12})\}eV$	$\{29.72, 2.98, 9.19\times10^{-4}\}$	$\{0.046, 7.\times10^{-3}, 9.99\times10^{-7}\}$
$M_{Drc}^{\nu}(GeV)$	$\{82.0, 6.49, .01606\}$	$\{82.26, 6.65, .016\}$
$M_\nu(meV)$	$33.93, 6.15, 1.82$	$33.75, 5.96, 1.0$
$\{Ev[f]\}/(10^{-5})$	$-20.28, 2.03, -6.2\times10^{-4}$	$12.87, -1.98, -2.78\times10^{-4}$

Table 1: A sample set of NMSGUT couplings which pass the criteria of Section 2. Note how the strong hierarchy of M^{ν^c} weakens the strong hierarchy of $(M_{Drc}^{\nu})^2$ to reproduce the weak observed light neutrino hierarchy via the Type I seesaw mechanism.

Parameter	$Target$	$Uncert.$	$SOLN1$	$SOLN2$
$m_t(GeV)$	76.6	3.06	75.69	75.96
$m_c(MeV)$	194.97	32.2	207.31	193.477
m_u	.4	.15	.41	0.39
m_b	1186.8	616.0	1621.31	1626.01
m_s	17.82	8.4	4.47	4.92
m_d	.931	.54	.24	0.25
m_τ	1493.37	283.74	1693.83	1698.87
m_μ	74.989	11.248	75.01	76.65
m_e	0.355	0.0533	.35	0.35
$\sin\theta^q_{12}$	0.22098	0.0016	0.221004	0.220974
$\sin\theta^q_{23}$	0.0349	.0013	0.0347803	0.0349877
$\sin\theta^q_{13}$	.00297	.0005	0.00294978	0.00305354

Parameter	$Target$	$Uncert.$	$SOLN1$	$SOLN2$
δ_{CP}	60.026	14.0	52.0769	64.53
$\sin^2\theta_{12}^P$	.30029	.06	0.298219	0.288079
$\sin^2\theta_{23}^P$	.465	.14	0.467765	0.326723
$\sin^2\theta_{13}^P$	.0053	.03	.0108116	0.0292243
$m_{12}^2(\times 10^{-5}eV^2)$	3.46	.37	3.44621	3.4533
$m_{23}^2(\times 10^{-3}eV^2)$	1.11	0.22	1.11379	1.10343
χ^2	0	18.0	5.71427	6.79112
χ_d^2	0	1	1.58	1.536
χ_s^2	0	1	2.51	2.351
χ_b^2	0	1	0.49	0.508
χ_{DOWN}^2	0	1	4.58	4.395

Table 2: Values of the fermion data at M_X achieved by

Parameter	$SOLN1 - Set1$	$S2$	$S3$	$SOLN2 - S1$	$S2$	$S3$
M_1	0.18	0.17	$-.18$	0.17	0.18	0.16
M_2	0.33	0.33	$-.37$	0.3	0.34	0.32
M_3	1.0	1.0	1.0	1.0	1.	1.0
A_t	-6.8	-27.1	-18.95	-7.352	-18.08	-5.43
μ	22.66	17.9	16.5	22.2	9.66	8.57
$\tilde{m}_{Q_1}$	3.7	2.21	1.16	2.43	1.35	1.26
$\tilde{m}_{Q_2}$	3.5	2.17	1.22	2.27	1.14	1.3
$\tilde{m}_{Q_3}$	5.3	18.0	5.21	3.39	.30	14.41

Table 3: Values (TeV) in of the soft susy parameters found by the threshold fitting at M_S scale

Parameter	$SOLN1-Set1$	$S2$	$S3$	$SOLN2-S1$	$S2$	$S3$
$\tilde{m}_{L_1}$	0.80	0.63	2.03	0.99	1.00	0.52
$\tilde{m}_{L_2}$	0.76	0.64	2.1	0.81	0.97	0.47
$\tilde{m}_{L_3}$	0.30	0.45	1.22	5.97	0.31	1.08
$\tilde{m}_d$	0.9	1.68	2.68	1.99	1.26	1.082
$\tilde{m}_s$	0.98	1.59	2.47	2.00	1.36	0.90
$\tilde{m}_b$	27.69	1.70	7.24	19.35	2.91	11.23
$\tilde{m}_t$	0.79	0.37	1.55	0.41	0.33	1.05
$\tilde{m}_e$	1.45	1.31	4.65	1.05	0.55	0.37
$\tilde{m}_\mu$	1.51	1.31	4.35	1.24	0.58	0.42
$\tilde{m}_\tau$	7.31	6.13	0.6736	0.50	14.03	0.30
$tan(\beta)$	50.36	50.1	45.72	51.03	48.83	54.97

DISECTING SPECIMENS

- KILL SINGLY OR IN GROUPS : UNCOVER ROLES
- TINY $\overline{126}$ YUKAWA f_{AB} HAS NO EFFECT AT ALL ON CHARGED FERMION MASSES. LIMIT $f \to 0$ SINGULAR (CHANGES EFFECTIVE THEORY). LOWERS $m_{\bar\nu} \Rightarrow$ RAISES m_ν THO $m_{B-L} \sim M_X$.
- LYNCH PIN h_{33} ALONE FITS 3 GEN TO 5%.
- (LARGEST) g_{23} RESTORES m_μ, θ^{23} to within 0.1% . $h_{22,h_1 1}$ RESTORE $m_{c,s}$ to 5%.
- $g_{12}, g13 \Rightarrow m_{u,d,e,c,s}, \theta^q_{12,13}$.
- STRONG HIERARCHY IN $f_{AB}, m_{\bar\nu}$ EIGENVALUES : $(10^2 : 10^1 : 10^{-3})$ COMPENSATES STRONG HIERARCHY IN $(M^\nu_{Dirac})^2$ TO GIVE WEAK LIGHT NEUTRINO HIERARCHY (15:3:1)

- GRIMUS KUHBOCK GENERIC $r_D \sim 10^4$ BOOST TOTALLY DIFFERENT : UN-ACHIEVABLE IN NMSGUT $(r_D < 300)$
- 2-3 CORE OF THE FERMION MASS HIERARCHY : PERTURB AROUND $h_{33}, g_{23} \sim O(1)$, rest $\sim O(\epsilon^n), n \geq 2$ CSA 2006: hep-ph/0607252, hep-ph/0602132 SEMI-SUCCESS : NOW DO-ABLE ds-b-TOO-LOW DISEASE IS THE CURE !

$d = 5$ NUCLEON DECAY

- FAMILIAR $\bar{t}[\bar{3}, 1, -\frac{2}{3}] \oplus t[3, 1, \frac{2}{3}] \oplus$ NOVEL $P[3, 3, \pm\frac{2}{3}], K[3, 1, \pm\frac{8}{3}]$ MULTIPLET TYPES CONTRIBUTE TO BARYON VIOLATION IN SO(10)
  BABU,PATI,WILCZEK(2000);CSA,GIRDHAR,GARG(2004,2006)

$$W_{eff}^{\Delta B \neq 0} = -\hat{L}_{ABCD}(\frac{1}{2}\epsilon \hat{Q}_A \hat{Q}_B \hat{Q}_C \hat{L}_D) - \hat{R}_{ABCD}(\epsilon \bar{\hat{e}}_A \bar{\hat{u}}_B \bar{\hat{u}}_C \bar{\hat{d}}_D)$$

where the coefficients are

$$\begin{aligned}
\hat{L}_{ABCD} &= \mathcal{S}_1{}^1 \tilde{h}_{AB} \tilde{h}_{CD} + \mathcal{S}_1{}^2 \tilde{h}_{AB} \tilde{f}_{CD} + \mathcal{S}_2{}^1 \tilde{f}_{AB} \tilde{h}_{CD} + \mathcal{S}_2{}^2 \tilde{f}_{AB} \tilde{f}_{CD} \\
&- \mathcal{S}_1{}^6 \tilde{h}_{AB} \tilde{g}_{CD} - \mathcal{S}_2{}^6 \tilde{f}_{AB} \tilde{g}_{CD} + \sqrt{2} (\mathcal{P}^{-1})_2{}^1 \tilde{g}_{AC} \tilde{f}_{BD} \\
&- (\mathcal{P}^{-1})_2{}^2 \tilde{g}_{AC} \tilde{g}_{BD}
\end{aligned}$$

and

$$\begin{aligned}
\hat{R}_{ABCD} &= \mathcal{S}_1{}^1\tilde{h}_{AB}\tilde{h}_{CD} - \mathcal{S}_1{}^2\tilde{h}_{AB}\tilde{f}_{CD} - \mathcal{S}_2{}^1\tilde{f}_{AB}\tilde{h}_{CD} + \mathcal{S}_2{}^2\tilde{f}_{AB}\tilde{f}_{CD} \\
&- i\sqrt{2}\mathcal{S}_4{}^1\tilde{f}_{AB}\tilde{h}_{CD} + i\sqrt{2}\mathcal{S}_4{}^2\tilde{f}_{AB}\tilde{f}_{CD} \\
&+ \mathcal{S}_6{}^1\tilde{g}_{AB}\tilde{h}_{CD} - i\mathcal{S}_7{}^1\tilde{g}_{AB}\tilde{h}_{CD} - \mathcal{S}_6{}^2\tilde{g}_{AB}\tilde{\tilde{f}}_{CD} + i\mathcal{S}_7{}^2\tilde{g}_{AB}\tilde{\tilde{f}}_{CD} \\
&+ i\mathcal{S}_1{}^7\tilde{h}_{AB}\tilde{g}_{CD} - i\mathcal{S}_2{}^7\tilde{\tilde{f}}_{AB}\tilde{g}_{CD} + \sqrt{2}\mathcal{S}_4{}^7\tilde{\tilde{f}}_{AB}\tilde{g}_{CD} \\
&+ i\mathcal{S}_6{}^7\tilde{g}_{AB}\tilde{g}_{CD} + \mathcal{S}_7{}^7\tilde{g}_{AB}\tilde{g}_{CD} - \sqrt{2}(\mathcal{K}^{-1})_1{}^2\tilde{\tilde{f}}_{AD}\tilde{g}_{BC} \\
&- (\mathcal{K}^{-1})_2{}^2\tilde{g}_{AD}\tilde{g}_{BC}
\end{aligned}$$

here $\mathcal{S} = \mathcal{T}^{-1}$ and $\mathcal{T}$ is the mass matrix for $[3, 1, \pm 2/3]$-sector triplets : $W = \bar{t}^i \mathcal{T}_i^j t_j + ...$, while

$$\tilde{h}_{AB} = 2\sqrt{2}h_{AB} \qquad \tilde{f}_{AB} = 4\sqrt{2}f_{AB} \qquad \tilde{g}_{AB} = 4g_{AB}$$

- CARETS DENOTE h_{AB} DIAGONAL BASIS UNITARILY RELATED TO MSSM $Y^{u,e}$-DIAGONAL Y^d

DIAGONAL-MODULO-CKM

$$\hat{Q}_A = \mathcal{Q}^*_{A'A} Q_{A'} \quad ; \quad \hat{L}_A = \mathcal{L}^*_{A'A} L_{A'} \quad ; \quad \hat{\bar{u}}_A = (V^u)^*_{A'A} \bar{u}_{A'}$$
$$\hat{\bar{d}}_A = (V^d)^*_{A'A} \bar{d}_{A'} \quad ; \quad \hat{\bar{e}}_A = V^{e*}_{A'A} \bar{e}_{A'}$$

.

- ALL UNITARY MATRICES DETERMINED BY FIT ! DETERMINATION RIGHT HANDED MIXING UNDERSCORES THE COMPLETENESS.
- TRANSLATE TO MSSM $Y^{u,e}$-DIAGONAL Y^d DIAGONAL-MODULO-CKM BASIS AND RG FLOW TO M_S (WORK IN PROGRESS)
- $L_{ABCD}, R_{ABCD}(M_X)$ GOOD ESTIMATORS FOR $L_{ABCD}, R_{ABCD}(M_S)$ USE WITH SFERMION FITS AND MIXING ASSUMPTIONS TO PARAMETRIZE DECAY RATE. e.g FOR SOLN1 WITH ALSO

$$m_{\tilde{u}} = .98, m_{\tilde{t}}, m_{\tilde{c}} = .99 m_{\tilde{t}}$$

$$\begin{aligned}
\tau_p &= 2.1 \times 10^{-29} yr - MeV \frac{(32\pi m_p^3 f_\pi^2)}{(m_p^2 - m_K^2)^2} |\alpha_p (R_{ext}(1 + m_p \frac{(3F + D)}{3m_B}) \\
&+ R_{int} \frac{2m_p D}{(23 m_B)} |^{-2} \\
&= 5.02565 \times 10^{18} \quad yrs \times (\cos^2\phi \cos\chi \sin\chi \\
&+ 1.00061(\cos\chi \sin\theta + \cos\theta \sin\phi \sin\chi)(\cos\theta \cos\chi \sin\phi - \sin\theta \sin\chi) \\
&- 1.00031(\cos\theta \sin\chi + \cos\chi \sin\phi \sin\theta)(\cos\theta \cos\chi - \sin\phi \sin\theta \sin\chi))^{-2} \\
&= 1.5 \times 10^{31} yrs (AT\{\phi \to 0.001, \theta \to 0.2, \chi \to 0.002\})
\end{aligned}$$

- STILL NON UNIQUE USE $D = 5$, GUT CONSTRAINTS TO FILTER AND FIX SFERMION SPECTRA. NON DIAGONAL COMPUTATION URGENTLY REQUIRED !

- LHC DISCOVERY OF SFERMION SPECTRA CAN FALSIFY NMSGUT : BETS ARE PLACED NOW !!!

Conclusions

- SO(10) NMSGUT IS COMPATIBLE WITH KNOWN FM DATA
- NMSGUT 23-DIM PARAMETER SETS BY DOWNHILL SIMPLEX SEARCHES
- M_S THRESHOLD CORRECTIONS VITAL CONSTRAIN SFERMION SPECTRA CANDIDATES
- SMALL $\overline{\mathbf{126}}$ COUPLINGS VITAL TO FIT : DOOR OPEN TO PERTURBATIVE UNDERSTANDING OF HIERARCHY
- D=5 NUCLEON DECAY, UNIFICATION CONSTRAINTS ON SFERMION SPECTRA WILL SIGNIFICANTLY CONSTRAIN AND MAP PARAMETER SPACE
- NMSGUT VULNERABLE TO FALSIFICATION AT LHSC (BUT PREPARING FOR APOTHEOSIS !)