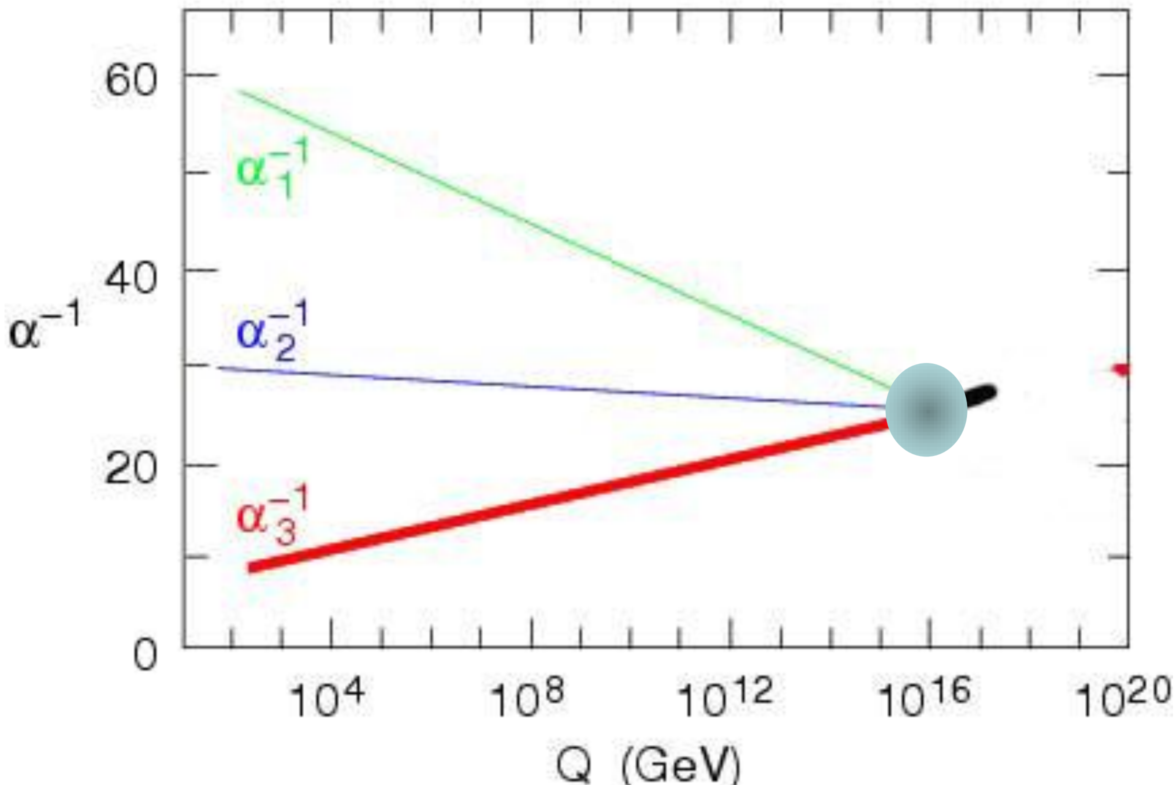
Testing SUSY GUTs + Family Symmetry

Stuart Raby

Bethe Forum
University of Bonn
November 7, 2011

THE OHIO STATE UNIVERSITY DEPARTMENT OF PHYSICS

MSSM



Threshold corrections at GUT scale depend on sparticle masses (i.e. via threshold corrections at M_Z)

$$\varepsilon_3 \equiv \frac{\alpha_3(M_G) - \alpha_G}{\alpha_G} \quad , \quad \alpha_G \equiv \alpha_1(M_G) = \alpha_2(M_G)$$

R parity violating operators

$$\kappa_i L_i H_u + \lambda^{(0)}_{ijk} L_i L_j \bar{E}_k + \lambda^{(1)}_{ijk} L_i Q_j \bar{D}_k + \lambda^{(2)}_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

$$10\ \bar{5}\ \bar{5} \supset L\ L\ \bar{E} + L\ Q\ \bar{D} + \bar{U}\ \bar{D}\ \bar{D}$$

But $\tau\left(p \to e^+ \pi^0\right) > 10^{34}$ years

$$\lambda^{(1)} \lambda^{(2)} \leq 10^{-27}$$

Dim 5 B & L violating operators

$$\kappa^{(1)}_{ijk\ell} Q_i Q_j Q_k L_\ell + \kappa^{(2)}_{ijk\ell} \bar{U}_i \bar{U}_j \bar{D}_k \bar{E}_\ell$$

$$\tau\left(p \to K^+ \overline{\nu}\right) > 2.3\times 10^{33} \text{ years}$$

$$\kappa^{(1,2)} \equiv \frac{1}{\Lambda} \leq 10^{-27} \text{ GeV}^{-1}$$

MSSM

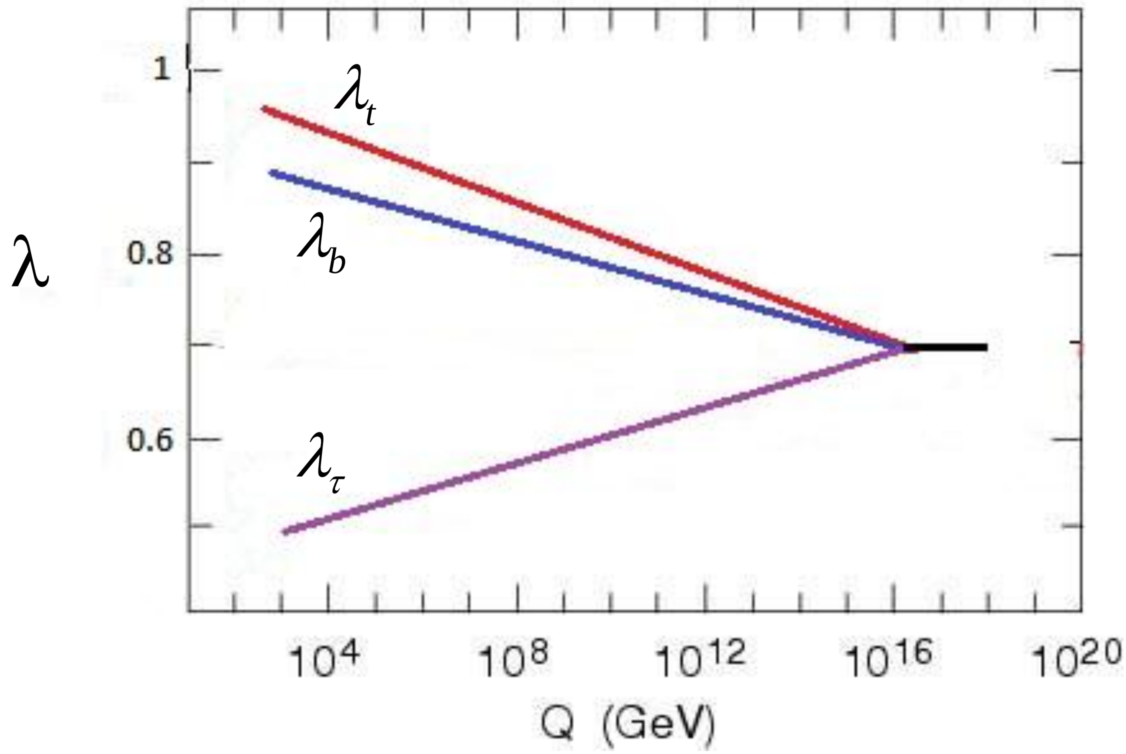
$$\mathcal{W} = Y_e^{ij} H_d L_i \bar{E}_j + Y_d^{ij} H_d Q_i \bar{D}_j + Y_u^{ij} H_u Q_i \bar{U}_j$$
$$+ \mu H_u H_d + \kappa_{ij}^{(0)} H_u L_i H_u L_j$$

μ term: Need $\mu \ll M_G$

$\kappa_{ij}^{(0)}$ term: Weinberg operator for neutrino mass

Michael Ratz - proton decay and mu

SO(10) Yukawa unification



$\tan\beta \sim 50$

Outline

- Testing SUSY GUTs - *by example*
- Minimal SO(10) SUSY Model
  - 3rd family only
  - consistent soft breaking
- SO(10) + Family Symmetry
  - 3 family model
- Conclusions

Yukawa Unification & Soft SUSY breaking

Blazek, Dermisek & Raby PRL 88, 111804 (2002)
PRD 65, 115004 (2002)

Baer & Ferrandis, PRL 87, 211803 (2001)

Auto, Baer, Balazs, Belyaev, Ferrandis & Tata
JHEP 0306:023 (2003)

Tobe & Wells **NPB 663, 123 (2003)**

Dermisek, Raby, Roszkowski & Ruiz de Austri
JHEP 0304:037 (2003)
JHEP 0509:029 (2005)

Baer, Kraml, Sekmen & Summy
JHEP 0803:056 (2008)
JHEP 0810:079 (2008)

Hierarchical SO(10) Yukawas

$$W \supset 16_3\, 10\, 16_3 \; + 16\; 10\; \frac{45}{M}\; 16 \; + \cdots$$

Albright, Anderson, Babu, Barr, Barbieri, Berezhiani, Blazek, Carena, Chang, Dermisek, Dimopoulos, Hall, Masiero, Murayama, Pati, Raby, Romanino, Rossi, Starkman, Wagner, Wilczek, Wiesenfeldt, Willenbrock

Effective higher dimension operators,

Small rep's + Many predictions !!

Possible UV completion to strings !!

$$\lambda \; 16_3 \, 10 \, 16_3$$

$$\lambda_t = \lambda_b = \lambda_\tau = \lambda_{\nu_\tau} \equiv \lambda$$

Note, CANNOT predict top mass due to large SUSY threshold corrections to bottom and tau mass

So instead use Yukawa unification to predict soft SUSY breaking masses !!

Radiative EWSB w/ large tanβ requires

$$\Delta m_H^2 \equiv \frac{\left(m_{H_d}^2 - m_{H_u}^2\right)}{2m_{10}^2} \approx 13\%$$

Roughly ½ comes from RG running from $M_G \rightarrow m_{\nu_\tau}$

Blazek, Dermisek & Raby "Just so" BCs

$$m_{16},\ m_{10},\ \Delta m_H^2,\ M_{1/2}\ ,\ A_0,\ \mu$$

1. Top - down vs. 2. Bottom - up analysis

1. Vary parameters at GUT scale and fit low energy data by minimizing χ^2
2. Fit central values of low energy data & run all parameters up to GUT scale & iterate until self-consistent

$$\boxed{\begin{array}{l}\text{Note : Varying } \; A_0, \; m_{10}, \; \Delta m_H^2 \\ \qquad \Rightarrow \; m_A \; \text{ arbitrary}\end{array}}$$

BUT this is difficult in bottom - up approach !!

Blazek, Dermisek & Raby
PRL 88, 111804 (2002)

Fit t,b,tau requires

$$A_0 \approx -2m_{16} \quad m_{10} \approx \sqrt{2}m_{16}$$

$$m_{16} > \textit{few}\ \mathrm{TeV} \qquad \mu, M_{1/2} << m_{16}$$

$$\tan\beta \approx 50$$

Baer, Kraml & Sekmen

arXiv:0908.0134

"DR3" BCs

$$m_i^2 = Q_X^i D_X + \left(m_i^0\right)^2$$

	Q	U	D	L	E	N	H_U	H_D
Q_X^i	1	1	-3	-3	1	5	-2	2
m_i^0			m_{16}					m_{10}

$$m_{16}^{(3)} \leq m_{16}^{(1,2)}$$

Badziak, Olechowski & Pokorski

arXiv:1107.2764

"gaugino splitting" BCs

$$m_i^2 = Q_X^i D_X + \left(m_i^0\right)^2$$

	Q	U	D	L	E	N	H_U	H_D
Q_X^i	1	1	-3	-3	1	5	-2	2
m_i^0	m_{16}						m_{10}	

$$M_1 : M_2 : M_3 = -1 : -3 : 2$$

$MSO_{10}SM^{\text{TM}}$

$\lambda\ 16_3\ 10\ 16_3$

- Gauge coupling unification
- Yukawa unification
- Inverted scalar mass hierarchy **

Bagger, Feng, Polonsky & Zhang
PLB473, 264 (2000)

- Suppresses flavor & CP violation
- Nucleon decay

** "just so" & "DR3"

$MSO_{10}SM^{TM}$

1. Extend to 3 family model in 4D

   (Dermisek & Raby PLB 622, 327 (2005).)

2. Extend to orbifold GUT in 5D

   (HD Kim, Schradin & Raby,
   JHEP 0301, 056 (2003) & JHEP 0505, 036 (2005))

3. Extend to heterotic string in 10D
   compactified on $Z_3 x Z_2$ orbifold

   (Kobayashi, Raby & Zhang,
   PLB 593, 262 (2004) & NPB 704, 3 (2005))

χ^2 analysis – 3rd family

Dermisek, Raby, Roszkowski and Ruiz de Austri
JHEP 09 (2005) 029

11 Parameters :

$$M_G \quad \alpha_G \quad \varepsilon_3 \quad \lambda$$

$$\mu \quad M_{1/2} \quad A_0 \quad \tan\beta \quad m_{16} \quad m_{10} \quad \Delta m_H$$

9 Observables (included in χ^2) :

$$\alpha_{EM} \quad G_\mu \quad \alpha_s \quad M_Z \quad M_W \quad \rho_{NEW}$$

$$M_t \quad m_b(m_b) \quad M_\tau$$

+ 14 add'l precision EW data

Results

1. Dark Matter & WMAP
2. $B_s \to \mu^+ \mu^-$
3. Light Higgs mass – m_h
4. Upper bound on m_A

$\Rightarrow$ Lower bound on $BR(B_s \to \mu^+ \mu^-)$

Dark Matter & WMAP

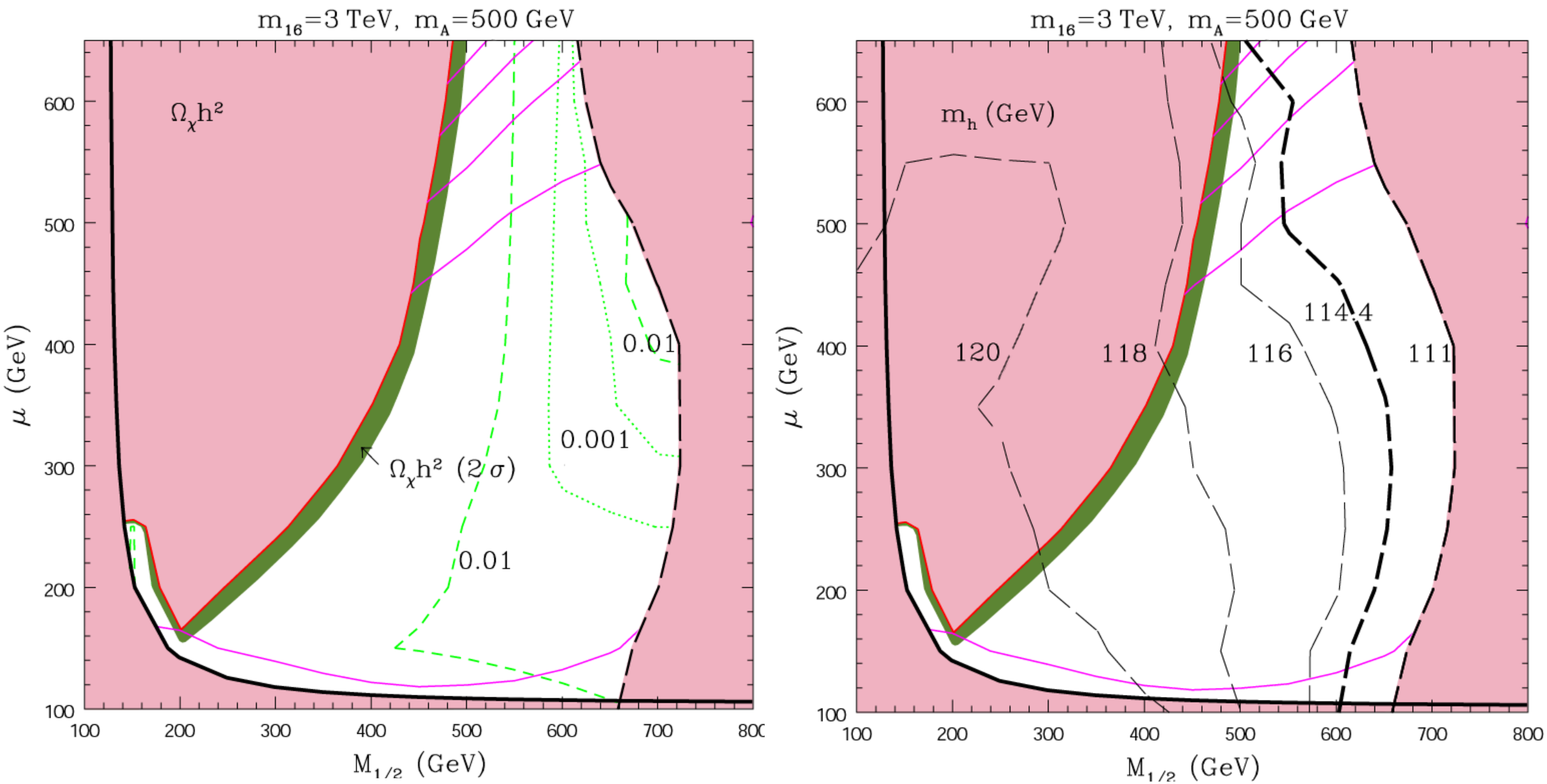
Neutralino LSP

$$\chi_1 \chi_1 \to A \to f\,\bar{f}$$

$$A b \bar{b} \propto \tan\beta$$

A : broad resonance, m_A arbitrary

Results - m_{16} & m_A fixed



Green band consistent with WMAP

Light Higgs mass contours

$Br(B_s \to \mu^+ \mu^-)$

SM : 3×10^{-9}

MSSM : $\sim (\tan\beta)^6 / m_A{}^4$

CDF = $1.8 + 1.1 / - 0.9 \times 10^{-8}$ (95% CL)

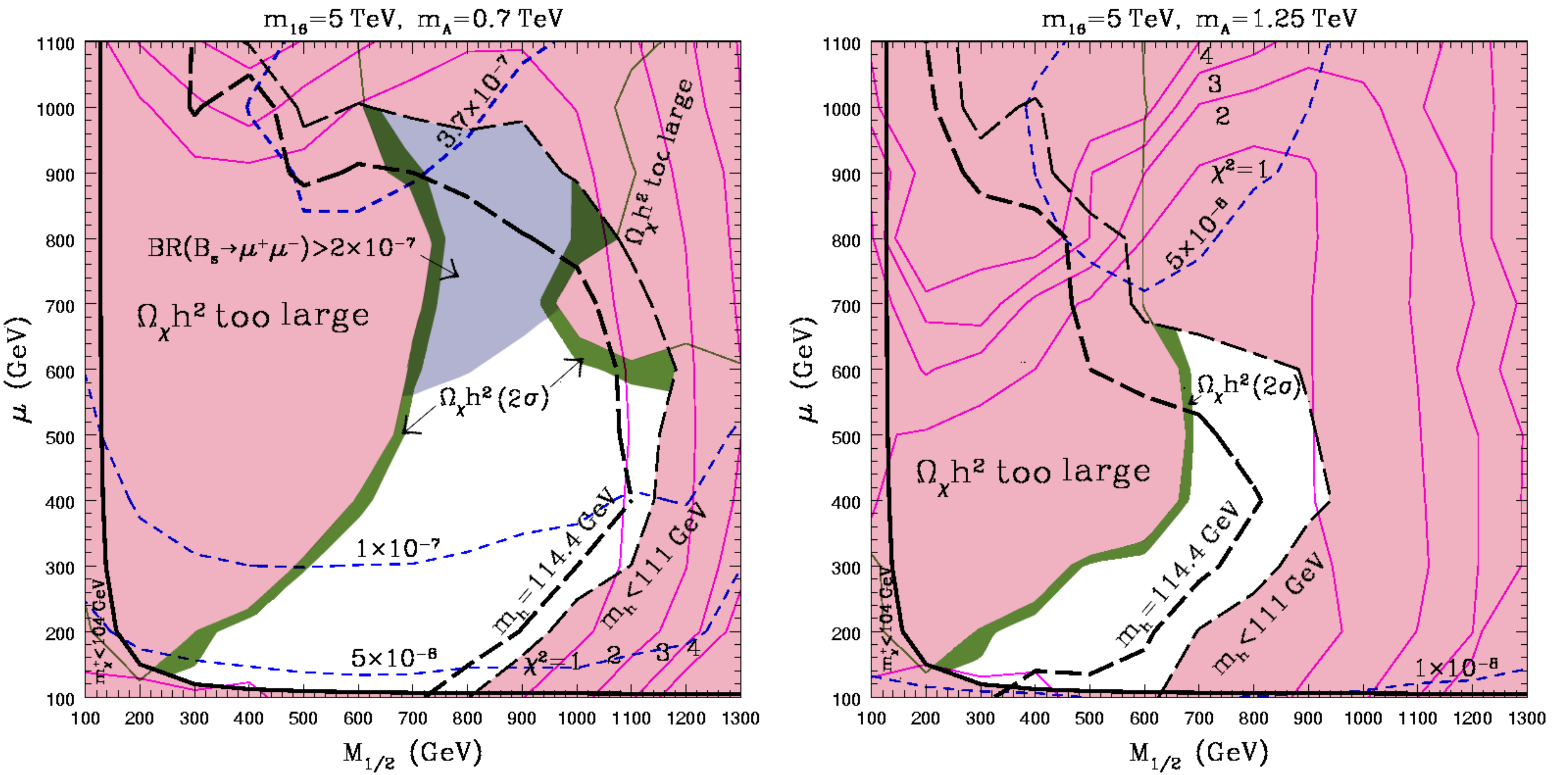
CDF bound < 4×10^{-8} (95% CL) w/ 7 fb^{-1}

LHCb < 1.5×10^{-8} (95% CL) w/ 300 pb^{-1} 2011

37 pb^{-1} 2010

LHCb + CMS < 1.1×10^{-8} (95% CL)

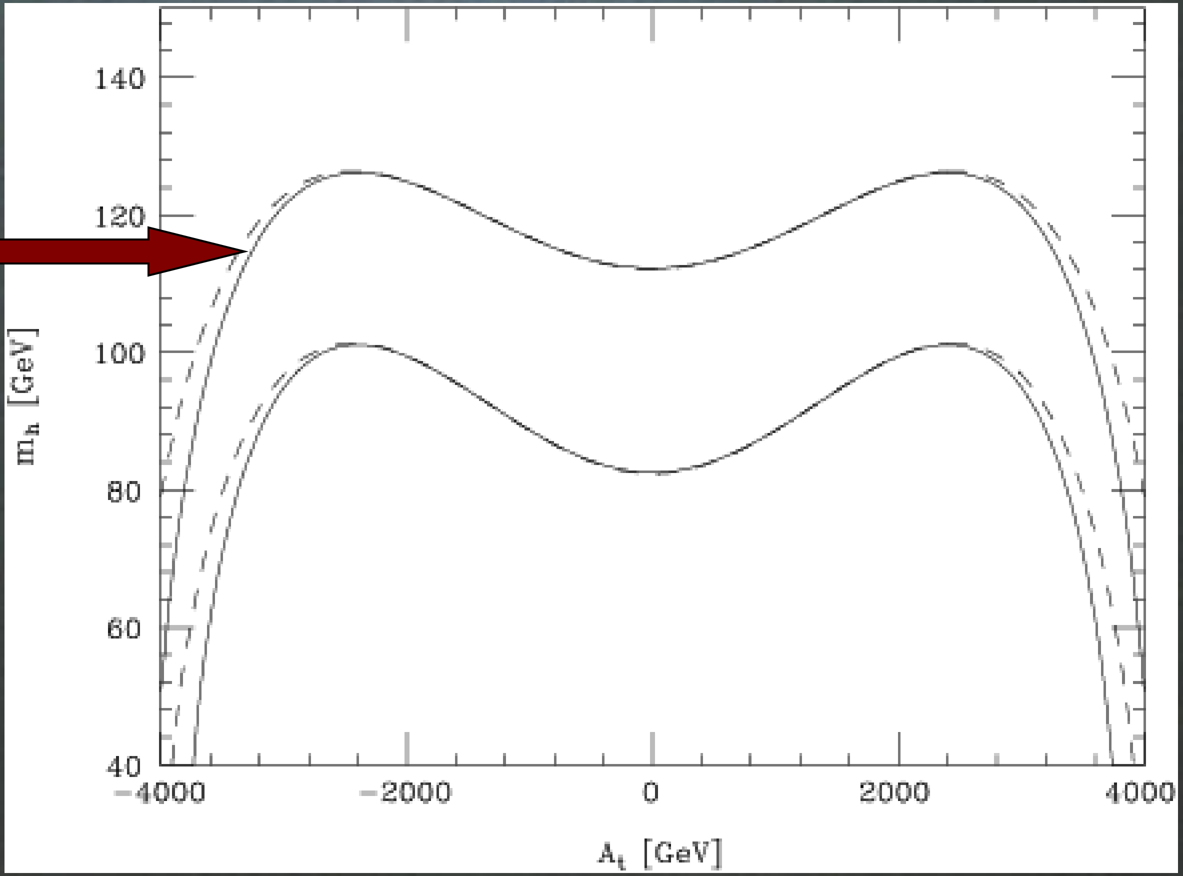
Results - m_{16} & m_A fixed



Constant χ^2 contours

Constant $B_s \rightarrow \mu^+ \mu^-$ contours

Light Higgs mass



Carena, Quiros & Wagner '95

$|A_t|$ increases → m_h decreases

Light Higgs mass

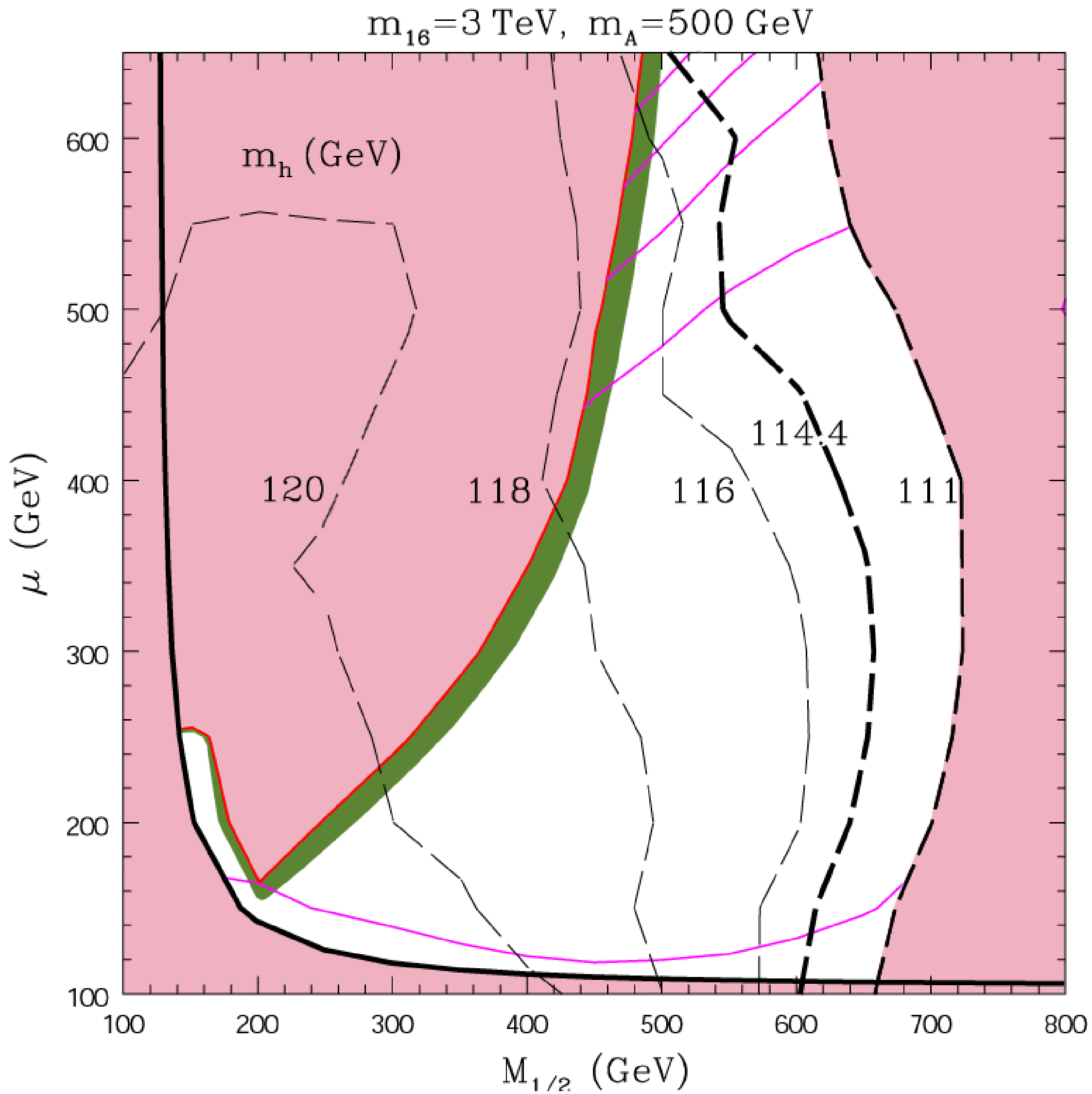
$$\delta m_b / m_b \propto \frac{\alpha_3 \mu M_{\tilde{g}} \tan\beta}{m_{\tilde{b}}^2} + \frac{\lambda_t^2 \mu A_t \tan\beta}{m_{\tilde{t}}^2} + \log corr.$$

$$\delta m_b / m_b \leq -2\%$$

Needed to fit data

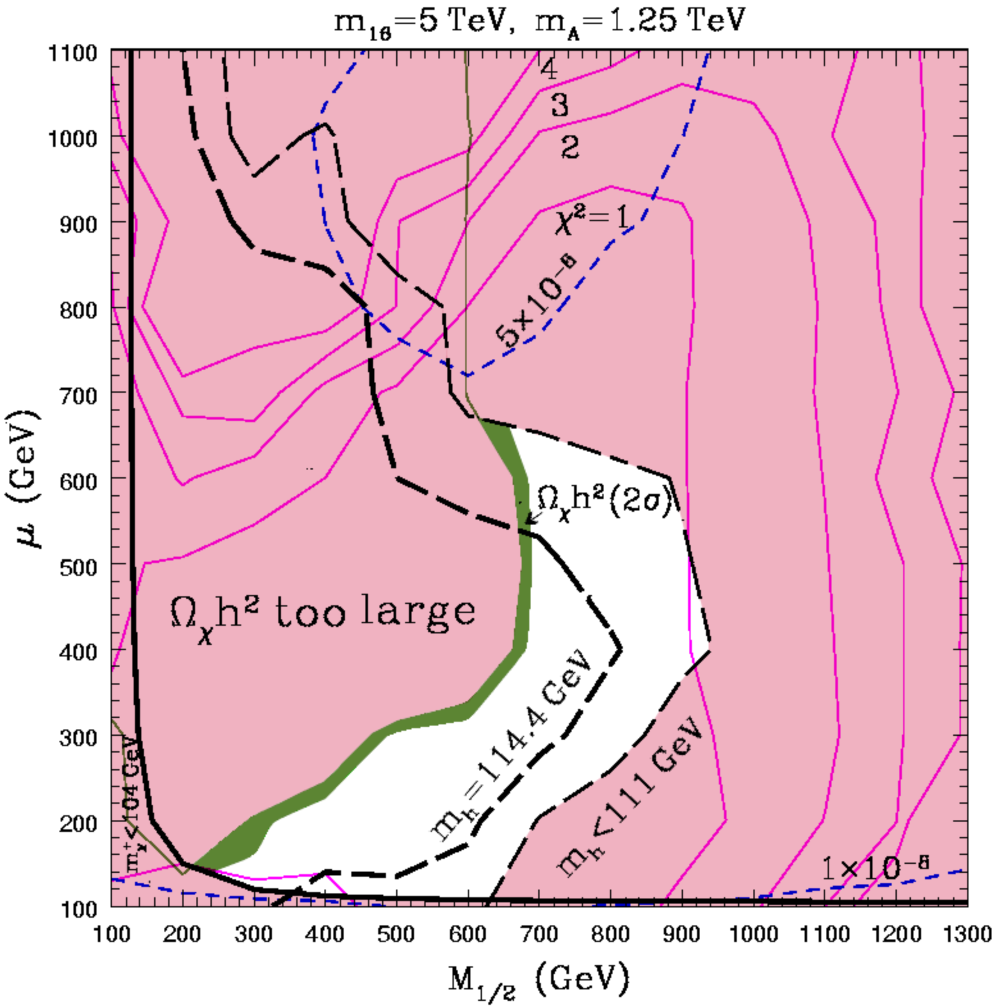
$M_{1/2}$ increases → $-A_t$ increases

→ m_h decreases



Light Higgs mass contours

m_A(max) ⟶ Br(B_s -> $\mu^+ \mu^-$)(min)



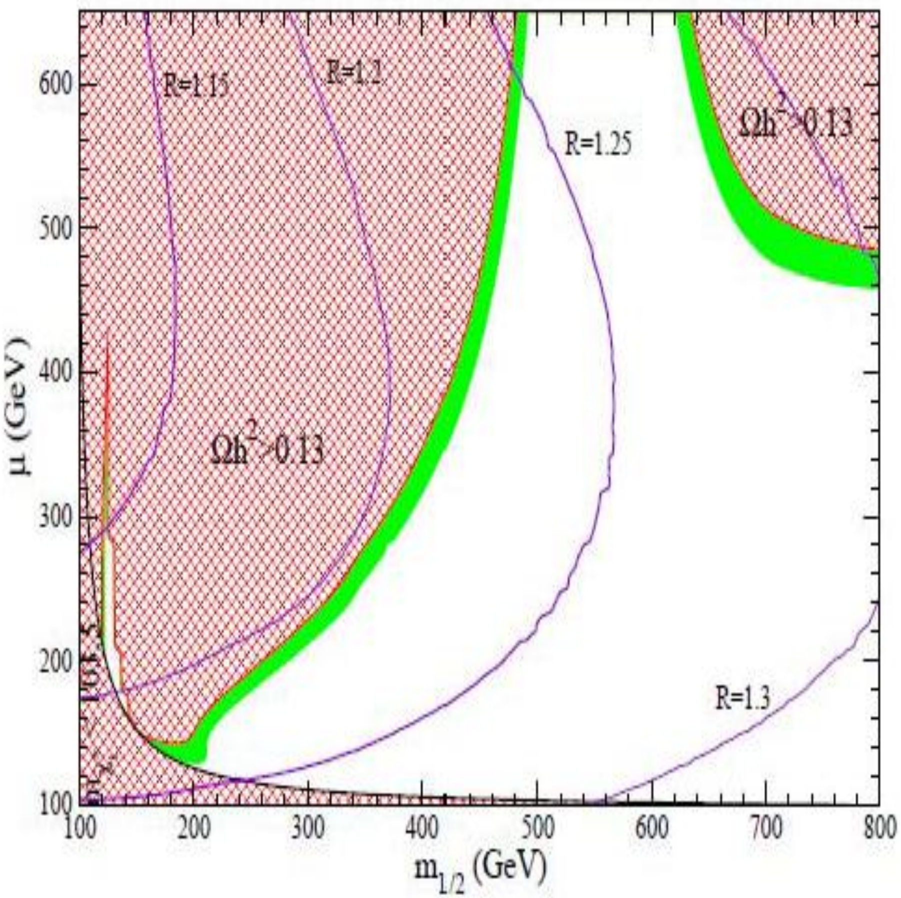
$$m_A \le 1.3 \text{ TeV}$$

$$\text{Br}(\, B_s \to \mu^+ \mu^- \,) \ge 10^{-8}$$

LHC ??

Baer, Kraml, Sekmen and Summy
JHEP 03 (2008) 056

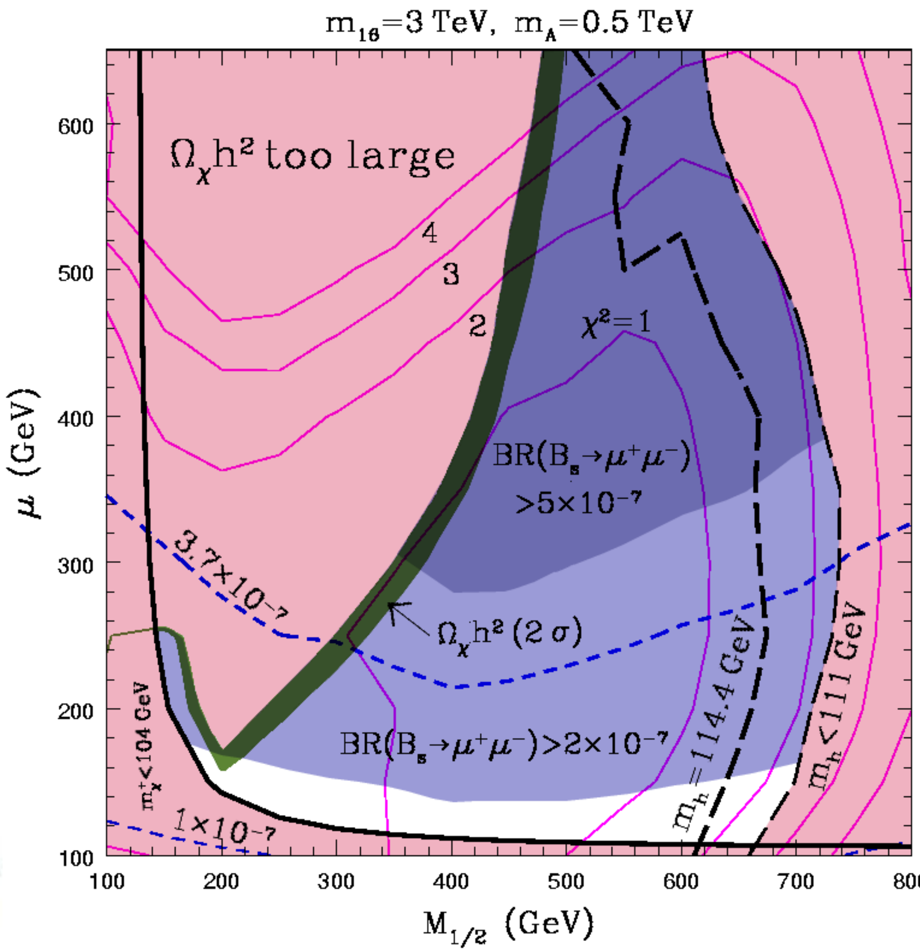
Bottom - Up and Down and Up ...



$$R = \frac{\max(f_t, f_b, f_\tau)}{\min(f_t, f_b, f_\tau)}$$

Dermisek, Raby, Roszkowski and Ruiz de Austri JHEP 09 (2005) 029

Top - Down



$$\chi^2$$

Summary - $MSO_{10}SM^{TM}$

1. Gauge & Yukawa unification
2. Suppresses flavor & CP viol. & N decay **
3. Dark Matter consistent w/WMAP
4. $114 < m_h < 121$ GeV
5. $m_A < 1.3$ TeV

   $BR(B_s \to \mu^+\mu^-) > 10^{-8}$

Discuss sparticle and higgs masses later

3 Family SO(10) + family symmetry

Dermisek & Raby PLB 622:327 (2005)

Dermisek, Harada & Raby PRD74, 035011 (2006)

Albrecht, Altmannshofer, Buras, Guadagnoli & Straub JHEP 0710:055 (2007)

3 family SO_{10} SUSY Model

- $D_3 \times U(1)$ Family Symmetry
- Superpotential
- Yukawa couplings
- χ^2 analysis
- Charged fermion masses & mixing
- Neutrino masses & mixing

Superpotential for charged fermion Yukawa couplings

$$W_{ch.\,fermions} = 16_3 10 16_3 + 16_a 10 \chi_a$$

$$+\overline{\chi_a}\left(M_\chi \chi_a + 45\frac{\phi_a}{M}16_3 + 45\frac{\phi_a}{M}16_a + A16_a \right)$$

$$\langle \phi \rangle = \begin{pmatrix} \phi_1 \\ \phi_2 \end{pmatrix} \qquad \langle \phi \rangle = \begin{pmatrix} 0 \\ \phi_2 \end{pmatrix} \qquad \langle 45 \rangle = (B-L) M_G$$

Familon VEVs assumed

SO(10) x (D_3 x U(1) family sym.)
Yukawa Unification for 3rd Family

7 real para's

+ 4 phases

+ 3 real Majorana Neutrino masses

Dermisek & Raby
PLB 622:327 (2005).

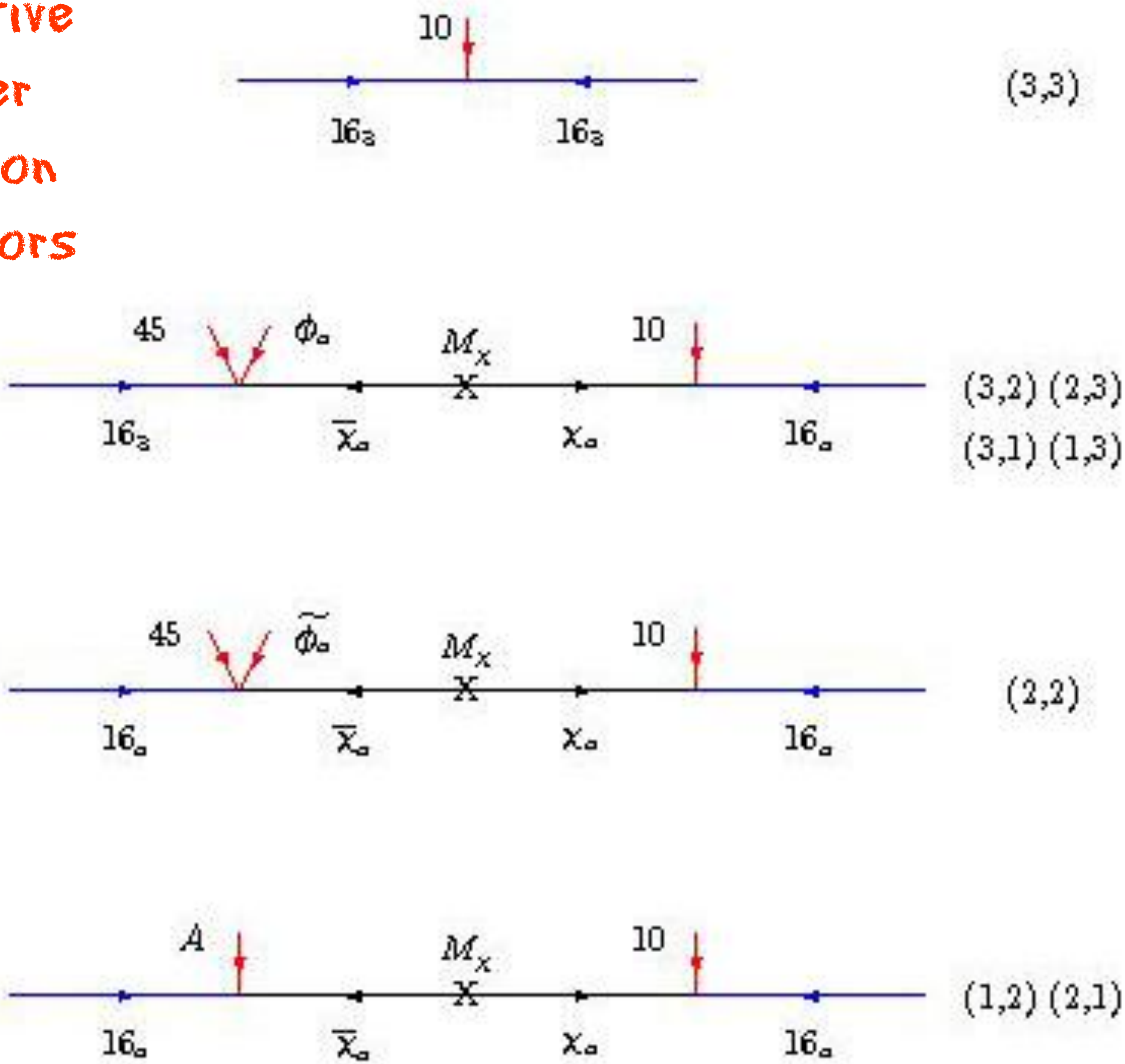
$$Y_u = \begin{pmatrix} 0 & \epsilon' \rho & -\epsilon \xi \\ -\epsilon' \rho & \tilde{\epsilon} \rho & -\epsilon \\ \epsilon \xi & \epsilon & 1 \end{pmatrix} \lambda$$

$$Y_d = \begin{pmatrix} 0 & \epsilon' & -\epsilon \xi \sigma \\ -\epsilon' & \tilde{\epsilon} & -\epsilon \sigma \\ \epsilon \xi & \epsilon & 1 \end{pmatrix} \lambda$$

$$Y_e = \begin{pmatrix} 0 & -\epsilon' & 3 \epsilon \xi \\ \epsilon' & 3 \tilde{\epsilon} & 3 \epsilon \\ -3 \epsilon \xi \sigma & -3 \epsilon \sigma & 1 \end{pmatrix} \lambda$$

$$Y_\nu = \begin{pmatrix} 0 & -\epsilon' \omega & \frac{3}{2} \epsilon \xi \omega \\ \epsilon' \omega & 3 \tilde{\epsilon} \omega & \frac{3}{2} \epsilon \omega \\ -3 \epsilon \xi \sigma & -3 \epsilon \sigma & 1 \end{pmatrix} \lambda$$

Effective higher dimension operators



Extend to neutrino sector

$$W_{neutrino} = \overline{16}\left(\lambda_2 N_a 16_a + \lambda_3 N_3 16_3\right) + \tfrac{1}{2}\left(S_a N_a N_a + S_3 N_3 N_3\right)$$

$$\langle S_a \rangle = M_a \qquad \langle S_3 \rangle = M_3 \qquad \langle \overline{16} \rangle = v_{16}$$

Assume 3 new real para's

$$W_{neutrino} = \nu m_\nu \bar{\nu} + \bar{\nu} V N + \tfrac{1}{2} N M_N N$$

$$Y_\upsilon = \begin{pmatrix} 0 & -\varepsilon'\omega & \tfrac{3}{2}\varepsilon\xi\omega \\ \varepsilon'\omega & 3\varepsilon\omega & \tfrac{3}{2}\varepsilon\omega \\ -3\varepsilon\xi\sigma & -3\varepsilon\sigma & 1 \end{pmatrix}\lambda$$

$$\omega = 2\sigma / (2\sigma - 1)$$

$$m_\nu = Y_\nu \frac{v}{\sqrt{2}} \sin\beta$$

$$V = v_{16} \begin{pmatrix} 0 & \lambda_2 & 0 \\ \lambda_2 & 0 & 0 \\ 0 & 0 & \lambda_3 \end{pmatrix}$$

$$M_N = diag\begin{pmatrix} M_1 & M_2 & M_3 \end{pmatrix}$$

$$M_\nu = U_e^T \left(m_\nu \left(V^T\right)^{-1} M_N V^{-1} m_\nu^T \right) U_e$$

Using χ^2 analysis, fit

15 charged fermion & 4 neutrino low energy observables with

11 arbitrary Yukawa & 3 Majorana mass parameters

4 & 1 d. o. f. or 5 predictions

Global χ^2 analysis

Sector	#	Parameters
gauge	3	$\alpha_G,\ M_G,\ \epsilon_3,$
SUSY (GUT scale)	5	$m_{16},\ M_{1/2},\ A_0,\ m_{H_u},\ m_{H_d},$
textures	11	$\epsilon,\ \epsilon',\ \lambda,\ \rho,\ \sigma,\ \tilde{\epsilon},\ \xi,$
neutrino	3	$M_{R_1},\ M_{R_2},\ M_{R_3},$
SUSY (EW scale)	2	$\tan\beta,\ \mu$

24 parameters at GUT scale

compared to SM - 27 parameters

CMSSM - 32 parameters

Global χ^2 analysis - good fits to

- charged fermion masses & mixing angles
- neutrino masses & mixing angles
- naturally satisfies Lepton Flavor Violation and electron electric dipole moment bounds

Dermisek, Harada & Raby

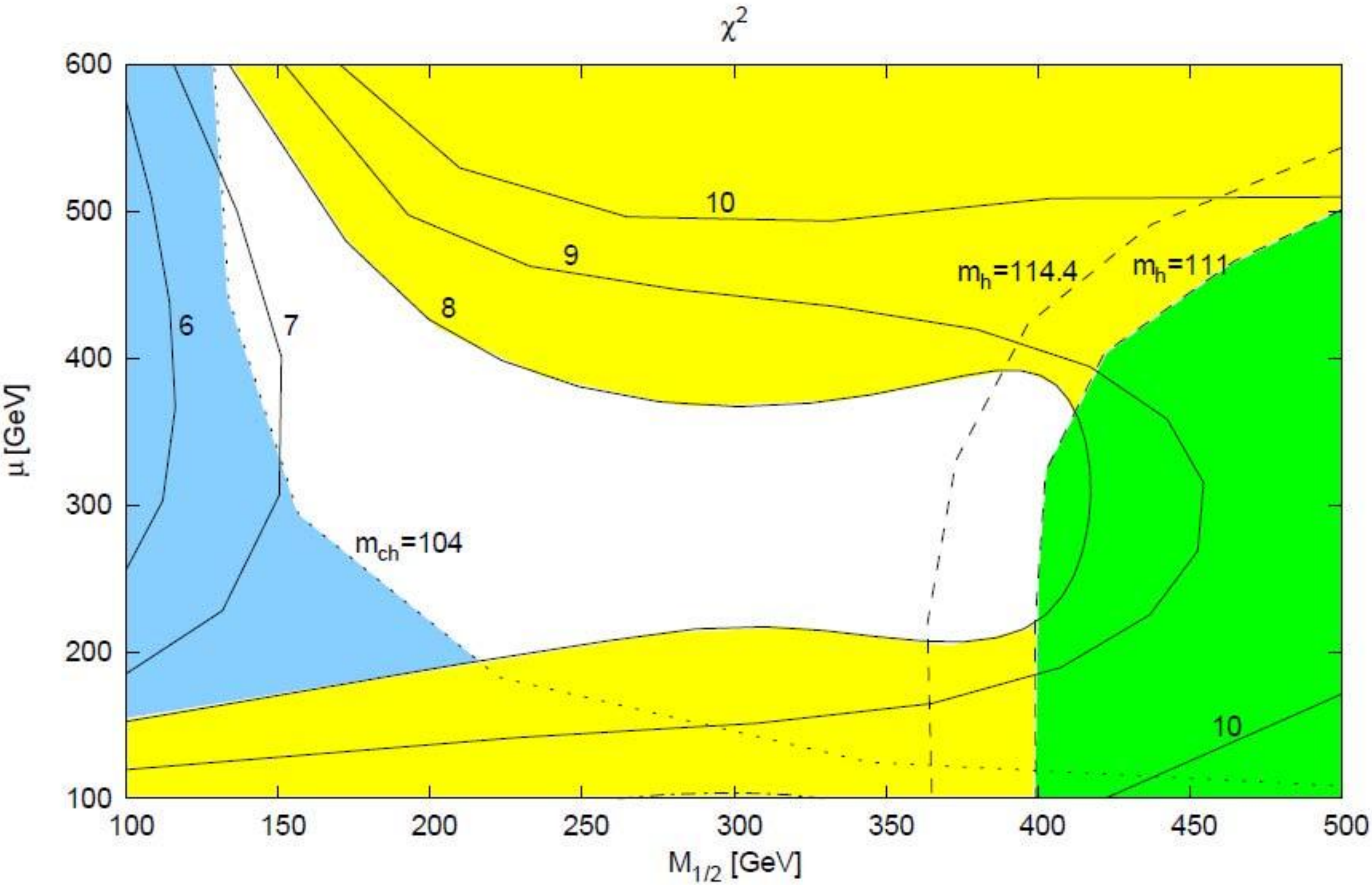
PRD74, 035011 (2006)

$m_{16} = 4$ TeV

$\mu = 300$ GeV

$M_{1/2} = 200$ GeV

Observable (masses in GeV)	Data (σ)	Theory	Pull
$G_\mu \times 10^5$	1.16637 (0.1%)	1.16638	< 0.01
α_{EM}^{-1}	137.036 (0.1%)	137.035	< 0.01
$\alpha_s(M_Z)$	0.1187 (0.002)	0.1174	0.37
M_t	172.7 (2.9)	173.11	0.02
$m_b(M_b)$	4.25 (0.25)	4.49	0.94
$M_b - M_c$	3.4 (0.2)	3.61	**1.16**
$m_c(m_c)$	1.2 (0.2)	1.16	0.03
m_s	0.105 (0.025)	0.107	0.01
m_d/m_s	0.0521 (0.0067)	0.0638	**3.09**
$Q^{-2} \times 10^3$	1.934 (0.334)	1.815	0.12
M_τ	1.777 (0.1%)	1.777	< 0.01
M_μ	0.10566 (0.1%)	0.10566	< 0.01
$M_e \times 10^3$	0.511 (0.1%)	0.511	< 0.01
V_{us}	0.22 (0.0026)	0.2193	0.06
V_{cb}	0.0413 (0.0015)	0.0410	0.03
V_{ub}	0.00367 (0.00047)	0.00316	**1.15**
V_{td}	0.0082 (0.00082)	0.00824	< 0.01
ϵ_K	0.00228 (0.000228)	0.00234	0.08
$\sin(2\beta)$	0.687 (0.064)	0.6435	0.46
$\Delta m^2_{31} \times 10^3$	2.3 (0.6)	2.382	0.01
$\Delta m^2_{21} \times 10^5$	7.9 (0.6)	7.880	< 0.01
$\sin^2\theta_{12}$	0.295 (0.045)	0.289	0.01
$\sin^2\theta_{23}$	0.51 (0.13)	0.532	0.03
TOTAL χ^2			**7.65**



χ^2
600
500
400
300
200
100
100
150
200
250
300
350
400
450
500
$M_{1/2}$ [GeV]
μ [GeV]
6
7
8
9
10
10
m_h=114.4
m_h=111
m_{ch}=104

Results for $7 < \chi^2 < 8$

$$m_{16} = 4\ \mathrm{TeV}$$

$$114 < \mathrm{m}_h < 129\ \mathrm{GeV}$$

$$0.010 < \sin^2 2\vartheta_{13} < 0.015$$

$$1 < \mathrm{BR}(\mu \to \mathrm{e}\gamma) \times 10^{14} < 7$$

$$2 < \mathrm{d}_e(e\ \mathrm{cm}) \times 10^{29} < 5$$

χ^2 analysis including B physics

Albrecht, Altmannshofer, Buras, Guadagnoli, & Straub

JHEP 0710:055 (2007)

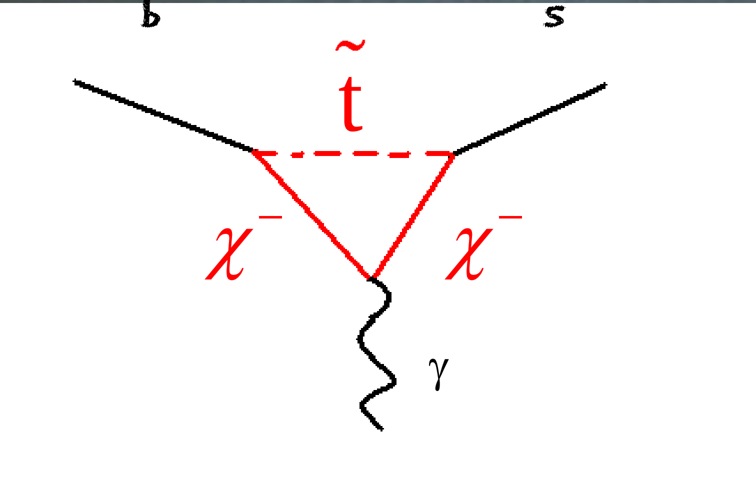
Find good fits to quark, charged lepton
& neutrino masses and mixing angles
& test flavor violation in b physics

some tension between $b \to s\gamma$ & $b \to s\, l^+ l^-$

$\Rightarrow$ $m_{16} \geq 10$ TeV

What is the tension ?

$$C_7^{\chi^+} \propto \mu A_t \tan\beta \times \mathrm{sign}\left(C_7^{\mathrm{SM}}\right) \approx -2C_7^{\mathrm{SM}}$$



$$A_t < 0$$

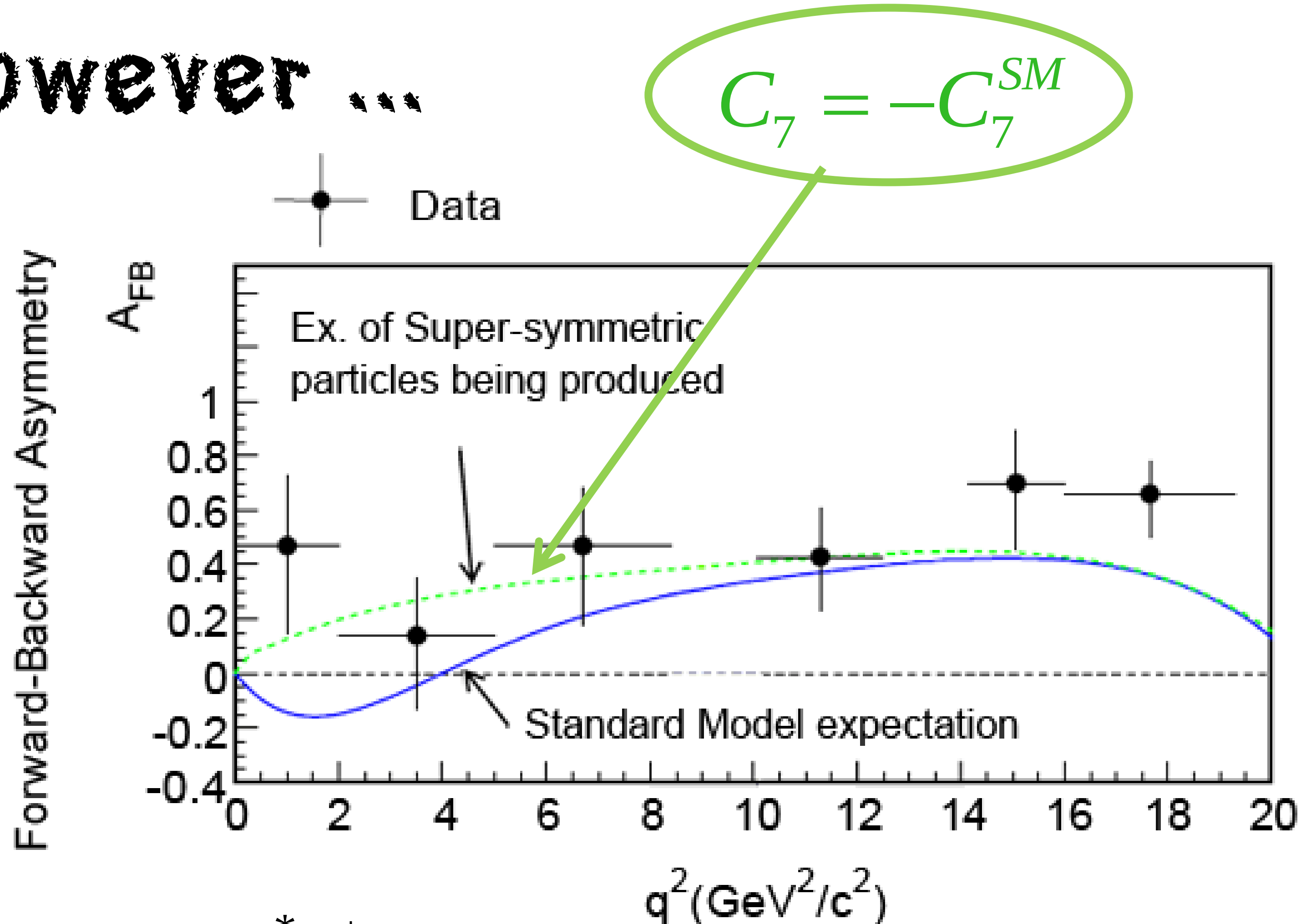
$$\Downarrow$$

$$C_7 = C_7^{\mathrm{SM}} + C_7^{\chi^+} \approx -C_7^{\mathrm{SM}}$$

$\mathrm{BR}(B \to X_s\, l^+\, l^-)$ favors $C_7 \approx +C_7^{\mathrm{SM}}$

at $\sim 2\sigma$

However ...

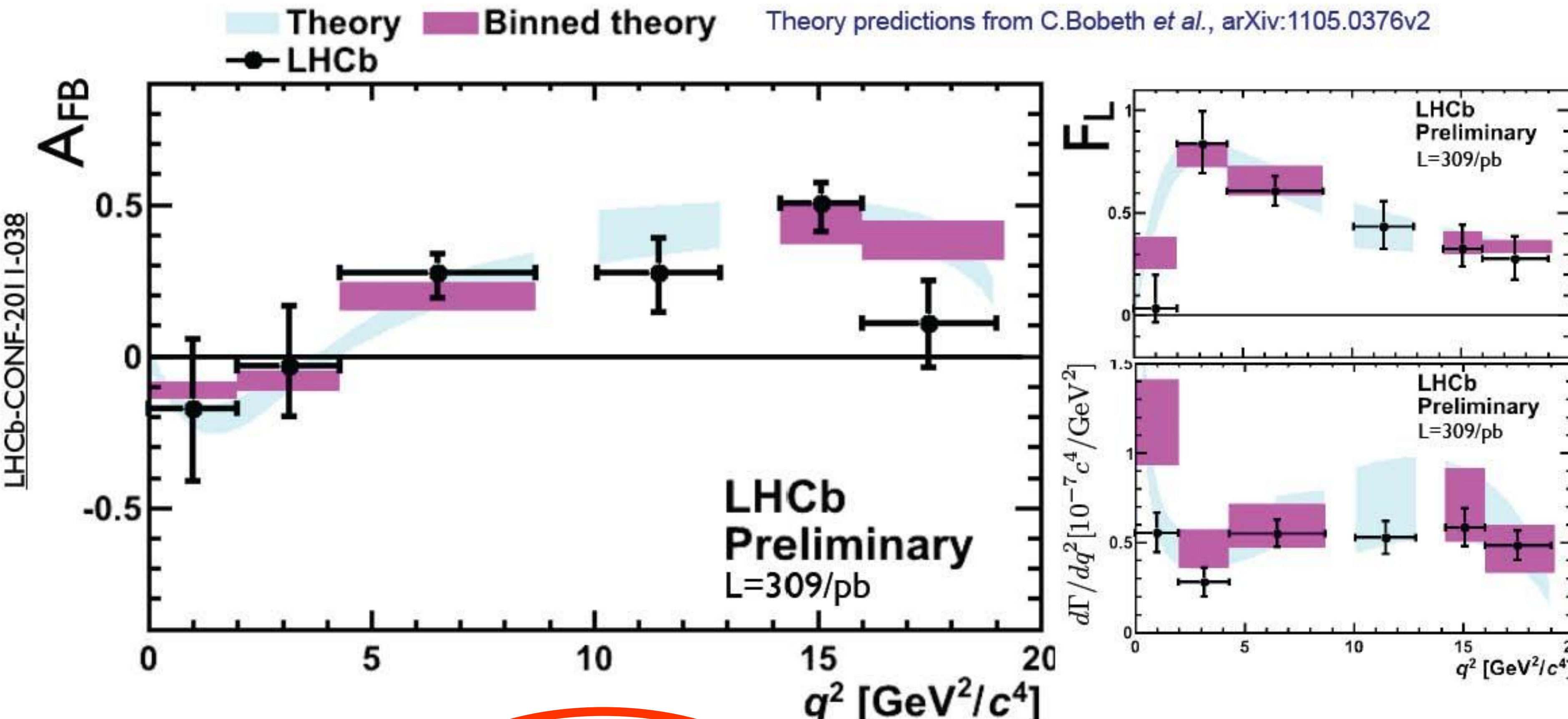


$B \to K^* l^+ l^-$

Invariant mass of lepton pair

Belle arXiv:0904.0770

Recently ...



$$C_7 \approx +C_7^{SM}$$

Where do we stand after

1 fb^{-1} LHC ??

LHC - NO significant signals beyond the Standard Model

However -

- slight excess for light higgs ?
- slight excess for multi-leptons ?
- if $m_{gluino} = m_{squark}$, then $m_{gluino} > 1$ TeV
- if 1st & 2nd family scalars much heavier than 3rd family ⇒ $m_{gluino} > O(500$ GeV$)$

Observable	Exp. value	Fit value	Pull (σ)
M_W	80.403	80.6	0.5
M_Z	91.1876	90.7	1.1
$G_F \times 10^5$	1.16637	1.16	0.3
$1/\alpha_{em}$	137.036	136.8	0.4
$\alpha_s(M_Z)$	0.1176	0.117	0.2
M_t	170.9	170.6	0.2
$m_b(m_b)$	4.2	4.22	0.3
$m_c(m_b)$	1.25	1.14	1.2
$m_s(2\,\mathrm{GeV})$	0.095	0.107	0.5
$m_d(2\,\mathrm{GeV})$	0.005	0.00741	1.2
$m_u(2\,\mathrm{GeV})$	0.00225	0.00461	**3.1**
M_τ	1.777	1.78	0.1
M_μ	0.10566	0.106	0.1
M_e	0.000511	0.000511	0.0
$\|V_{us}\|$	0.2258	0.225	0.6
$\|V_{ub}\| \times 10^3$	4.1	3.26	**2.1**
$\|V_{cb}\|$	0.0416	0.0416	0.1
$\sin 2\beta$	0.675	0.639	1.4
$\Delta m^2_{31} \times 10^{21}$	2.6	2.6	0.0
$\Delta m^2_{21} \times 10^{23}$	7.9	7.9	0.0
$\sin^2 2\theta_{12}$	0.852	0.852	0.0
$\sin^2 2\theta_{23}$	0.996	1.0	0.2
$\epsilon_K \times 10^3$	2.229	2.33	0.4
$\mathrm{BR}(B \to X_s\gamma) \times 10^4$	3.55	2.86	1.3
$\mathrm{BR}(B \to X_s\ell^+\ell^-) \times 10^6$	1.6	1.62	0.0
$\Delta M_s/\Delta M_d$	35.05	31.1	1.1
$\mathrm{BR}(B^+ \to \tau^+\nu) \times 10^4$	1.31	0.517	1.7
		total χ^2:	**27.4**

Albrecht et al.

JHEP 0710:055 (2007)

3 family analysis !!

m_{16}	4000	6000	10000
μ	378	953	1200
$\mathrm{BR}(B_s \to \mu^+\mu^-) \times 10^8$	8.6	7.7	2.1
$\hat{s}_0$	0.022	0.13	0.14
$\mathrm{BR}(\mu \to e\gamma) \times 10^{13}$	0.36	0.021	0.0026
$\delta a_\mu^{\mathrm{SUSY}} \times 10^{10}$	+5.8	+1.6	+0.52
M_{h_0}	126	129	129
M_A	507	559	842
$m_{\tilde{t}_1}$	640	1172	1903
$m_{\tilde{b}_1}$	895	1475	2366
$m_{\tilde{\tau}_1}$	1510	2419	3933
$m_{\tilde{\chi}^0_1}$	60	60	60
$m_{\tilde{\chi}^+_1}$	115	119	120
$m_{\tilde{g}}$	462	478	506

$\boxed{\text{Required } C_7 \approx +C_7^{SM}}$

Baer et al.

JHEP 0909,005 (2009)

3rd family only

"Just so" splitting

parameter	Pt. B [14]	DR3
$m_{16}(1,2)$	10000	11805.6
$m_{16}(3)$	10000	10840.1
m_{10}	12053.5	13903.3
M_D	3287.1	1850.6
$m_{1/2}$	43.9442	27.414
A_0	-19947.3	-22786.2
$\tan\beta$	50.398	50.002
R	1.025	1.027
μ	3132.6	2183.4
$m_{\tilde{g}}$	351.2	321.4
$m_{\tilde{u}_L}$	9972.1	11914.2
$m_{\tilde{t}_1}$	2756.5	2421.6
$m_{\tilde{b}_1}$	3377.1	1359.5
$m_{\tilde{e}_R}$	10094.7	11968.5
$m_{\tilde{\chi}_1^\pm}$	116.4	114.5
$m_{\tilde{\chi}_2^0}$	113.8	114.2
$m_{\tilde{\chi}_1^0}$	49.2	46.5
m_A	1825.9	668.3
m_h	127.8	128.6
θ_b (radians)	0.329	1.53

Table 2: Masses in GeV units and parameters for Yukawa-unified point B of Ref. [14] with just-so HS, and a point with the DR3 model using $M_N = 10^{13}$ GeV. We also give the b-squark mixing angle.

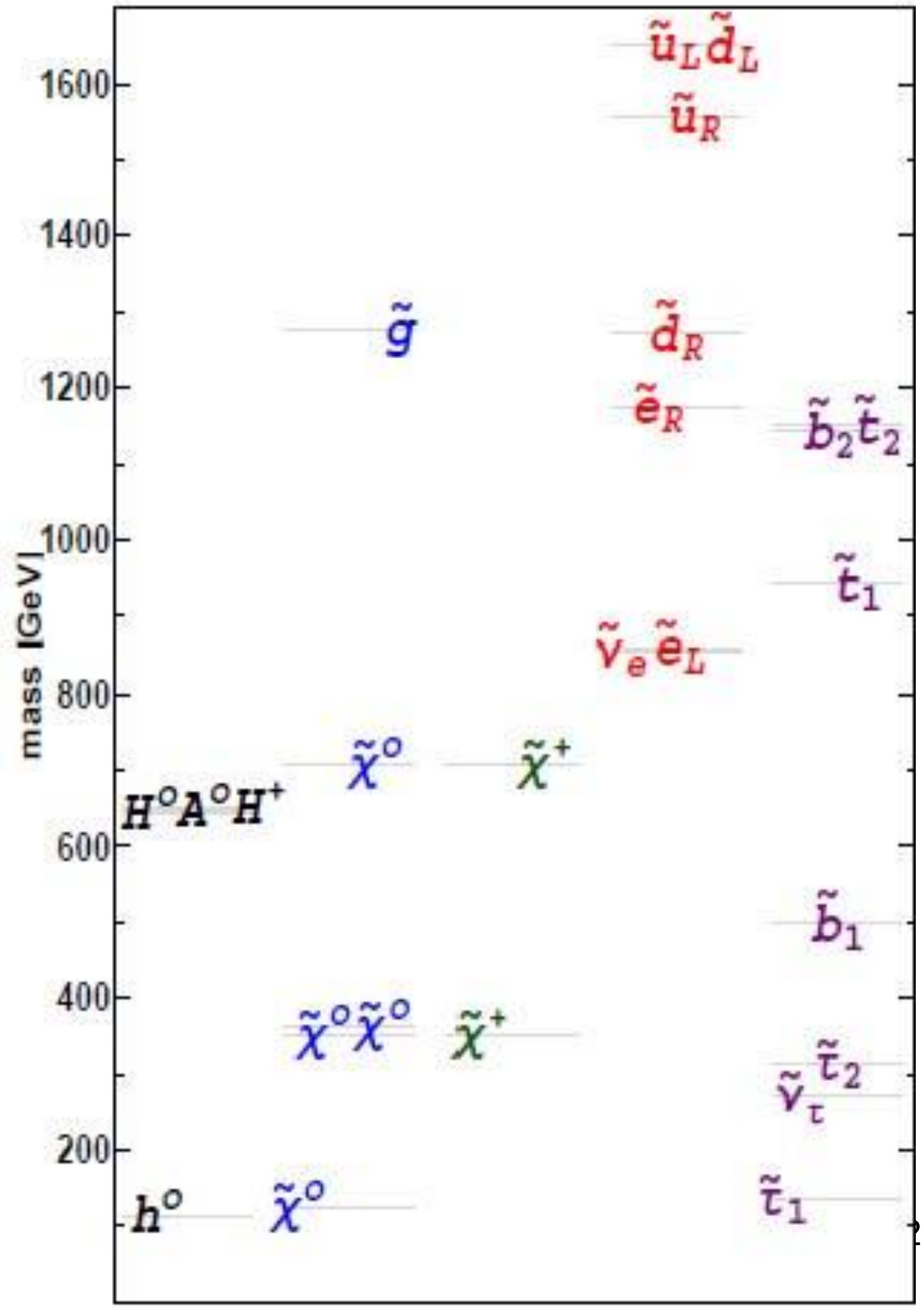
Badziak et al.

JHEP 1108,147 (2011)

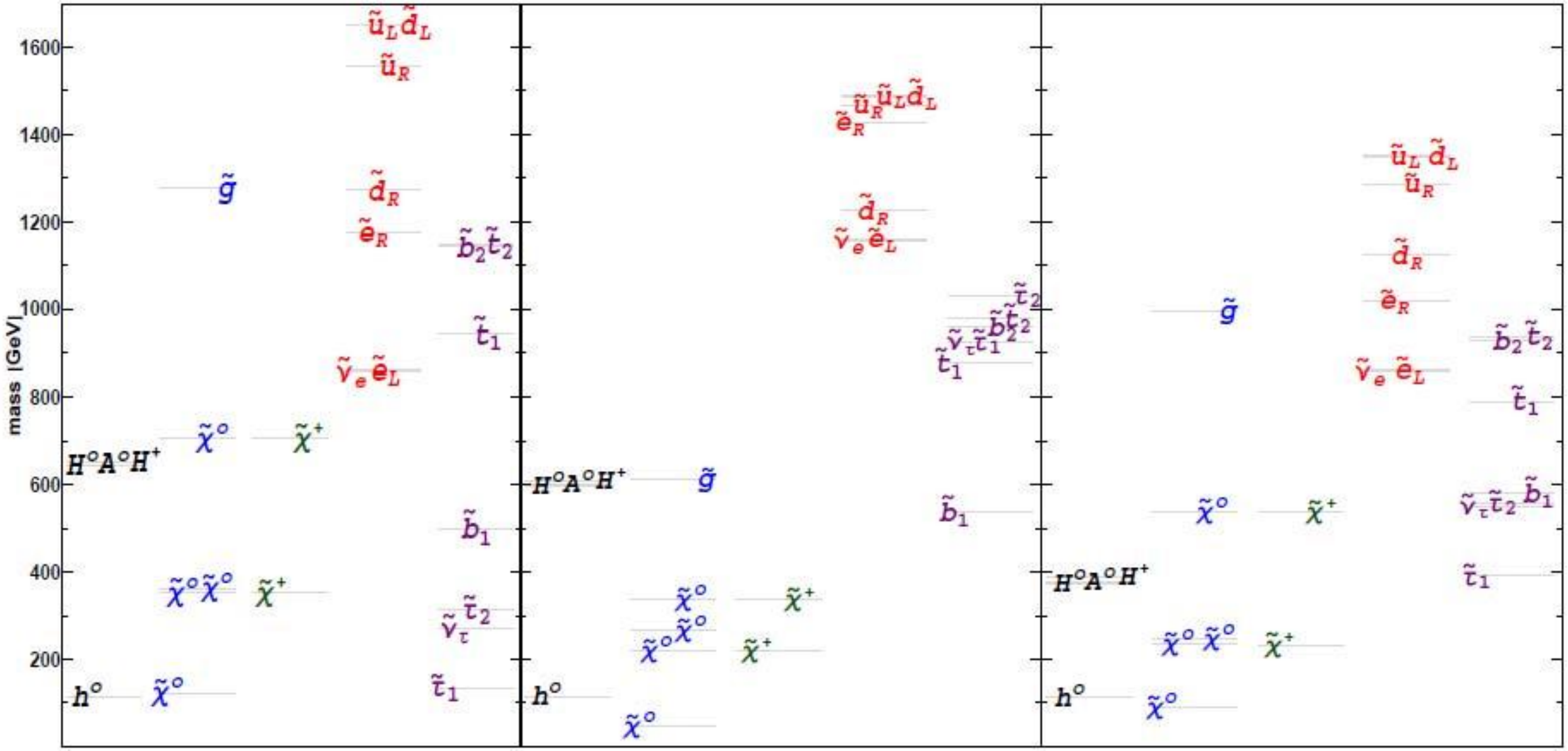
3rd family only

Completely distinct spectrum
just one example

m_{16}	1054
$M_{1/2}$	542.5
m_{10}/m_{16}	1.454
D/m_{16}^2	0.1907
A_0/m_{16}	2.312
$\tan\beta$	45.78
a_μ^{SUSY}	13.2×10^{-10}
$\mathrm{BR}(b \to s\gamma)$	3.83×10^{-4}
$\Omega_{\mathrm{DM}} h^2$	0.095
R	1.007



Badziak et al. JHEP 1108.147 (2011)



	left	centre	right
m_{16}	1054	1352	949.5
$M_{1/2}$	542.5	224.2	408.8
m_{10}/m_{16}	1.454	1.125	1.324
D/m_{16}^2	0.1907	0.0921	0.1154
A_0/m_{16}	2.312	-0.357	1.865
$\tan\beta$	45.78	48.47	47.72
a_μ^{SUSY}	13.2×10^{-10}	14.2×10^{-10}	17.4×10^{-10}
$\mathrm{BR}(b\to s\gamma)$	3.83×10^{-4}	4.11×10^{-4}	4.19×10^{-4}
$\Omega_{\mathrm{DM}}h^2$	0.095	0.111	0.125
R	1.007	1.016	1.005

$MSO_{10}SM$ & Large tan(β)

- Fits WMAP
- Predicts light Higgs
  with mass of order 120 – 130 GeV
- Predicts lighter 3rd and heavy 1st & 2nd gen.
  squarks and sleptons (inverted scalar mass hier.)
- LFV bounds satisfied
- Enhances $Br(B_s \longrightarrow \mu^+ \mu^-)$
- Suppresses $Br(B \longrightarrow \tau \nu)$ & ΔM_{B_s}
- $B \longrightarrow X_s \gamma$, $X_s\ l^+\ l^-$ tension ??

LHCb

after 1 fb^{-1} LHC

- light gluinos ~ 300 – 500 GeV XX
  heavier gluinos ⟶ $m_{16} > 10$ TeV ?
- multi-leptons ⟶ lighter charginos and neutralinos ?
- predicts heavy 1st & 2nd generations and lighter 3rd ⟶ multi-leptons + jets + $\not{E}_T$

$$\boxed{\text{Test GUTs via global } \chi^2 \text{ analysis}}$$