Electroweak precision measurements in supersymmetric models with a $U(1)_R$ lepton number

Hugues Beauchesne
Carleton University
Ottawa, Canada

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Work done in collaboration with Thomas Grégoire

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Model I

- Recent model
  - arXiv:1107.4634
  - arXiv:1210.0541
  - arXiv:1210.5257
  - arXiv:1402.5432
  - ...

Model II

- Supersymmetric model
- The usual R-parity is replaced by a $U(1)_R$ symmetry.
- The gauginos are Dirac (additional singlet, triplet and octet chiral superfields).
- One of the the sneutrinos acquires a vev and provides mass to the down type quarks and charged leptons

$$W_0 = y_u Q H_u U^c + y_d Q L_a D^c + y_{e_b} L_a L_b E^c_b + y_{e_c} L_a L_c E^c_c + \mu H_u R_d .$$

- Additional superpotential not prohibited by any symmetry

$$W_{adj} = \lambda_S S H_u R_d + \lambda_T H_u T R_d .$$

Goal

- The structure of the model affects strongly the electroweak sector
  - R-parity violation
  - Mixing of a generation of lepton with Higgsinos and gauginos
  - Etc
- As a consequence, there are strong limits that often outweight collider constraints.
- The goal is to use electroweak precision tests (EWPT) to put limits on the model.

Overview of the procedure

- We use and expand the work of Han and Skiba (hep-ph/0412166).
- Overview of the procedure
  - Calculating the coefficients of the effective operators in terms of the parameters of the theory
  - Calculating the correction to precision EWPT in term of these coefficients
  - Fitting and constraining the parameters

Calculation of the coefficients

- We code the new physics in terms of operators that respect the symmetries of the standard model
  - Oblique parameters
  - Lepton mixing
  - Scalar exchange
  - Other loop diagrams
- Note : Strong contribution to the T parameter due to a vev of the third component of the scalar part of T

Corrections to observables

- We use the obervables of Han and Skiba.
- We also add RPV observables.
- We expand their work by removing their $U(3)^5$ symmetry.
- Note : Leads to a two-sided bound on the vev of the sneutrino. v_a too big leads to too much mixing of the electron and v_a too small modifies the decay of heavy charged leptons too much.

Fitting of the parameters

- We set the masses.
- We constrain λ_S, λ_T and v_a.

Results 1

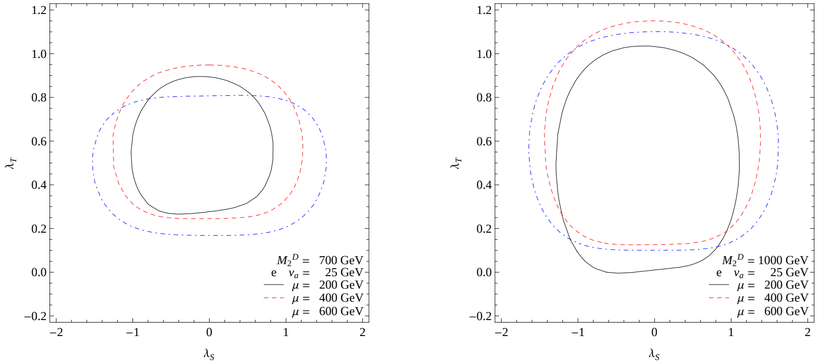

Figure 1 : Region of allowed phase space for the mass combinations of table [2] and for different values of μ. The solid, dashed and dotdashed lines correspond respectively to 200, 400 and 600 GeV. (a) is taken for $M_1^D = M_2^D = 700$ GeV and (b) for $M_1^D = M_2^D = 1000$ GeV. Both are taken at $v_a = 25$ GeV and lepton a is the electron. The contours correspond to 95.45% confidence level.

Results 2

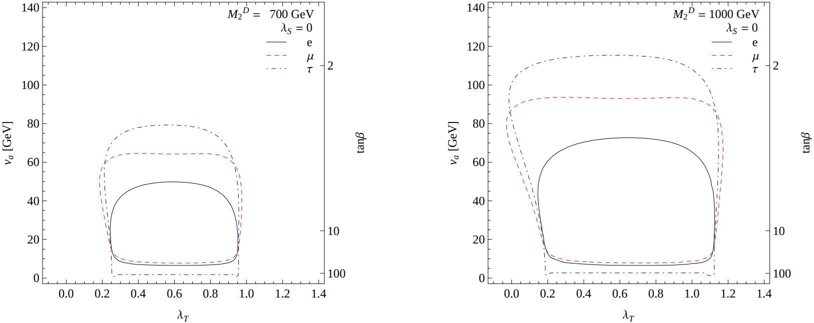

Figure 2 : Region of allowed phase space for the mass combinations of table [2] and for different choices of lepton (a) The solid, dashed and dotdashed lines correspond respectively to the electron, muon and tau. Both figures have $\lambda_S = 0$ and (a) has $M_1^D = M_2^D = 700$ GeV and (b) has $M_1^D = M_2^D = 1000$ GeV. The contours correspond to 95.45% confidence level.

Conclusion

- We use effective operators and EWPT to constrain $U(1)_R$ models.
- Strong constraints from the vev of the neutral component of the triplet, RPV observables and lepton mixing

Questions

Operators 1

$$O_{WB} = (h^\dagger \sigma^a h) W^a_{\mu\nu} B^{\mu\nu} \qquad\qquad O_h = |h^\dagger D_\mu h|^2.$$

Operators 2

$$O^s_{ll}[mn] = \frac{1}{2}(\bar{l}^m\gamma^\mu l^m)(\bar{l}^n\gamma_\mu l^n) \qquad O^t_{ll}[mn] = \frac{1}{2}(\bar{l}^m\sigma^a\gamma^\mu l^m)(\bar{l}^n\sigma^a\gamma_\mu l^n)$$

$$O^s_{lq}[m] = (\bar{l}^m\gamma^\mu l^m)(\bar{q}\gamma_\mu q) \qquad O^t_{lq}[m] = (\bar{l}^m\sigma^a\gamma^\mu l^m)(\bar{q}\sigma^a\gamma_\mu q)$$

$$O_{le}[mn] = (\bar{l}^m\gamma^\mu l^m)(\bar{e}^n\gamma_\mu e^n) \qquad O_{qe}[m] = (\bar{q}\gamma^\mu q)(\bar{e}^m\gamma_\mu e^m)$$

$$O_{lu}[m] = (\bar{l}^m\gamma^\mu l^m)(\bar{u}\gamma_\mu u) \qquad O_{ld}[m] = (\bar{l}^m\gamma^\mu l^m)(\bar{d}\gamma_\mu d)$$

$$O_{ee}[mn] = \frac{1}{2}(\bar{e}^m\gamma^\mu e^m)(\bar{e}^n\gamma_\mu e^n) \qquad O_{eu}[m] = (\bar{e}^m\gamma^\mu e^m)(\bar{u}\gamma_\mu u)$$

$$O_{ed}[m] = (\bar{e}^m\gamma^\mu e^m)(\bar{d}\gamma_\mu d).$$

Operators 3

$$O_{hl}^{s}[m] = i(h^\dagger D^\mu h)(\bar{l}^m \gamma_\mu l^m) + \text{h.c.} \qquad O_{hl}^{t}[m] = i(h^\dagger \sigma^a D^\mu h)(\bar{l}^m \sigma^a \gamma_\mu l^m) + \text{h.c.}$$

$$O_{hq}^{s} = i(h^\dagger D^\mu h)(\bar{q} \gamma_\mu q) + \text{h.c.} \qquad O_{hq}^{t} = i(h^\dagger \sigma^a D^\mu h)(\bar{q} \sigma^a \gamma_\mu q) + \text{h.c.}$$

$$O_{he}[m] = i(h^\dagger D^\mu h)(\bar{e}^m \gamma_\mu e^m) + \text{h.c.} \qquad O_{hu} = i(h^\dagger D^\mu h)(\bar{u} \gamma_\mu u) + \text{h.c.}$$

$$O_{hd} = i(h^\dagger D^\mu h)(\bar{d} \gamma_\mu d) + \text{h.c.}$$

Operators 3

$$O_{\hat{W}} = \epsilon^{abc} W_{\mu}^{a\nu} W_{\nu}^{b\lambda} W_{\lambda}^{c\mu}.$$

Observables

	Standard Notation	Measurement	Reference
Atomic parity violation	$Q_W(Cs)$	Weak charge in Cs	[37]
	$Q_W(Tl)$	Weak charge in Tl	[38,39]
DIS	g_L^2 , g_R^2	ν_μ-nucleon scattering from NuTeV	[40]
	R^ν	ν_μ-nucleon scattering from CDHS and CHARM	[41,42]
	κ	ν_μ-nucleon scattering from CCFR	[43]
	$g_V^{\nu e}$, $g_A^{\nu e}$	ν-e scattering from CHARM II	[44]
Z-pole	Γ_Z	Total Z width	[45]
	σ_h^0	e^+e^- hadronic cross section at Z pole	[45]
	$R_f^0(f = e, \mu, \tau, b, c)$	Ratios of decay rates	[45]
	$A_{FB}^{0,f}(f = e, \mu, \tau, b, c)$	Forward-backward asymmetries	[45]
	$A_f(f = e, \mu, \tau, b, c)$	Polarized asymmetries	[45]
Fermion pair production at LEP2	$\sigma_f(f = q, \mu, \tau)$	Total cross section for $e^+e^- \to f\bar{f}$	[45]
	$A_{FB}^f(f = e, \mu, \tau, b, c)$	Forward-backward asymmetries for $e^+e^- \to f\bar{f}$	[45]
	$d\sigma_e/d\cos\theta$	Differential cross section for $e^+e^- \to e^+e^-$	[46]
W pair	$d\sigma_W/d\cos\theta$	Differential cross section for $e^+e^- \to W^+W^-$	[47]
	M_W	W mass	[45,48]
Ratio of lepton decay rate	R_τ	Ratio of decay rate of τ to e on τ to μ	[36]
	$R_{\tau\mu}$	Ratio of decay rate of τ to μ on μ to e	[36]

Table: Relevant observables. Taken and expanded from [1].