Low-energy Lepton Observables in the MRSSM

JHEP08(2019)082,Kotlarski,Stöckinger,Stöckinger-Kim [arXiv:1902.06650]

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DRESDEN concept

Low-energy lepton observables

$(g-2)_\mu$: $a_\mu^{\text{Exp. BNL(E821)}} - a_\mu^{\text{SM}} = (28.1 \pm 6.3^{\text{Exp.}} \pm 3.6^{\text{Th(KNT18)}}) \times 10^{-10}$

Keshavarzi,Nomura,Teubner'18;Jegerlehner'17:$\pm 4.4^{\text{Th}}$

New experiment at Fermilab(E969): ~ 0.14 ppm

$\mu \to e\gamma$: $B_{\mu^+ \to e^+ \gamma} = \frac{\Gamma(\mu \to e\gamma)}{\Gamma(\mu \to e \nu_\mu \bar{\nu}_e)} < 4.2 \times 10^{-13}$ MEG 2016

Future MEG-II: expect to improve sensitivity $\sim 5 \times 10^{-14}$

$\mu \to e$: $B_{\mu\text{Au} \to e\text{Au}} < 7 \times 10^{-13}$ SINDRUM 2006

Future COMET and Mu2E: expected 7.2×10^{-15}

- Parameter ranges? Correlation among them?
- LFV processes $\propto \delta_{12}^{\text{L/R}}$ (1. and 2. generation slepton mixing)

Outline

1. Model: MRSSM
2. $g-2$ and $\mu \to e\gamma$
3. $\mu \to e$
4. Correlation between the observables
5. Summary

Minimal R-Symmetric Supersym. SM

MSSM with a continuous unbrocken R-symmetry $U(1)_R$: R-charge

[Kribs, Poppitz, Weiner]

enlarged $\begin{cases} \text{Higgs sector: } \hat{R}_{u,d} \\ \text{Gauge sector: } \hat{O},\ \hat{T},\ \hat{S} \end{cases}$

Fields	Fermion		Boson	
Matter	$l,\ e_R^*$	0	$\tilde{l},\ \tilde{e}_R^*$	+1
	$q,\ d_R^*,\ u_R^*$	0	$\tilde{q},\ \tilde{d}_R^*,\ \tilde{u}_R^*$	+1
Gauge	$\tilde{g},\ \tilde{W},\ \tilde{B}$	+1	$g,\ W,\ B$	0
Adjoint chiral	$\tilde{O},\ \tilde{T},\ \tilde{S}$	-1	$O,\ T,\ S$	0
H-Higgs	$\tilde{H}_{u,d}$	-1	$H_{u,d}$	0
R-Higgs	$\tilde{R}_{u,d}$	+1	$R_{u,d}$	+2

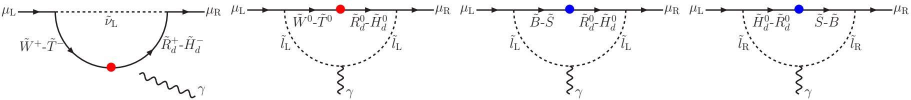
$\tilde{e}_R,\ \tilde{u}_R,\ \tilde{d}_R$: -1

MRSSM Superpotential and Interaction terms

$W^{\text{MRSSM}}_{\text{sup.pot.}} \ni \Lambda_d \hat{R}_d \cdot \hat{T}\hat{H}_d + \lambda_d \hat{S}\hat{R}_d \cdot \hat{H}_d + (d \to u)$ Yukawa-like sup.pot. parameters:

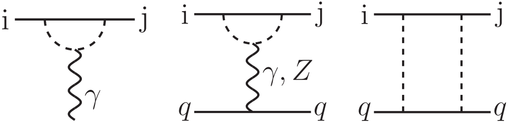
$$\mathcal{L}_{\text{int}} \ni \sum_{(f,\tilde{f}),g} \left(\overline{\tilde{\chi}^0_A}[n^{\mathsf{L}(f)}_{gA}\mathsf{P}_\mathsf{L} + n^{\mathsf{R}(f)}_{gA}\mathsf{P}_\mathsf{R}] f_g \tilde{f}^\dagger_\mathsf{R} + \overline{\tilde{\chi}^{0c}_A}[o^{\mathsf{L}(f)}_{gA}\mathsf{P}_\mathsf{L} + o^{\mathsf{R}(f)}_{gA}\mathsf{P}_\mathsf{R}] f_g \tilde{f}^\dagger_\mathsf{L} \right)$$
$$+ \sum_{(f',\tilde{f}),g} (\overline{\tilde{\chi}^-_A}[c^{\mathsf{L}(f')}_{gA}\mathsf{P}_\mathsf{L} + c^{\mathsf{R}(f')}_{gA}\mathsf{P}_\mathsf{R}] f'_g \tilde{f}^\dagger_\mathsf{L})$$

Gaugino interactions: n^R, o^L, c^L
Higgsino interactions: n^L, o^R, c^R $\leftarrow$ suppressed by small Yukawa couplings



MRSSM:Λ_d, λ_d , no $\tan\beta$-enhancement like MSSM .

Observables and diagrams



$A_1^{ji}{}_{[q^2\gamma^\mu]}$ $\quad A_Z \quad A_{\text{box}}$

$A_2^{ji}{}_{[\sigma^{\mu\nu}q_\nu]}$ $\quad A_1^{\bar{e}\mu},\ A_2^{\bar{e}\mu}$

$$(g-2)_\mu \propto A_2^{\bar{\mu}\mu}$$
$$\mu \to e\gamma \propto A_2^{\bar{e}\mu}$$
$$\mu \to e \propto A_1^{\bar{e}\mu}, A_2^{\bar{e}\mu}, A_Z, A_{\text{box}}$$

1. a_μ and $\mu \to e\gamma$ always correlated
2. correlation of a_μ and $\mu \to e$ $\uparrow$ when dipoleA_2 dominates
3. large λ_d or Λ_d
4. $\mu \to e\gamma$, $\mu \to e \propto \delta_{12}^{\mathsf{L,R}}$ slepton-generation-mixing

Survey of relevant parameters

M_B^D, M_W^D, μ_d, λ_d, Λ_d, $m_{\tilde{l},22}$, $m_{\tilde{e},22}$ $(m_{\tilde{e},11} = (1.5)m_{\tilde{e},22}$, $m_{\tilde{l},11} = (1.5)m_{\tilde{l},22})$

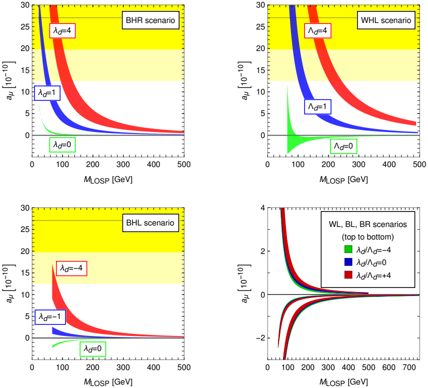
dimensionless LFV parameters: $\delta_{12}^{\mathsf{L}} \equiv \frac{(m_{\tilde{l}}^2)_{12}}{m_{\tilde{l},11} m_{\tilde{l},22}}$, $\delta_{12}^{\mathsf{R}} \equiv \frac{(m_{\tilde{e}}^2)_{12}}{m_{\tilde{e},11} m_{\tilde{e},22}}$

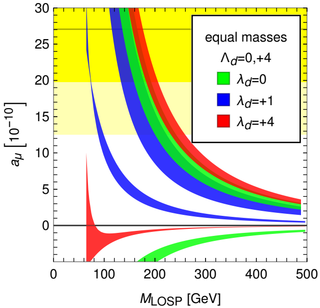
Scenario	light masses			
BHL	M_B^D, μ_d, $m_{\tilde{l}}$	$\delta_{12}^{\mathsf{R}} \neq 0$	BHR	BR
BHR	M_B^D, μ_d, $m_{\tilde{e}}$	$\delta_{12}^{\mathsf{L}} \neq 0$	BHL, WHL	BL, WL
WHL	M_W^D, μ_d, $m_{\tilde{l}}$			
Equal-mass	M_B^D, M_W^D, μ_d, $m_{\tilde{l}}$, $m_{\tilde{e}}$			

λ's, Λ's: perturbative ($|\lambda_i|$, $|\Lambda_i| < 4$)
$|\lambda_u|$, $|\Lambda_u| < 2$ from EW prec. T-parameter

LHC: small mass splitting between sparticles, $M_{\tilde{\chi}_1^\pm} > 92$ Gev, $m_{\tilde{\mu}_{\mathsf{R}}} > 94$ Gev

Numerical analysis of $g-2$





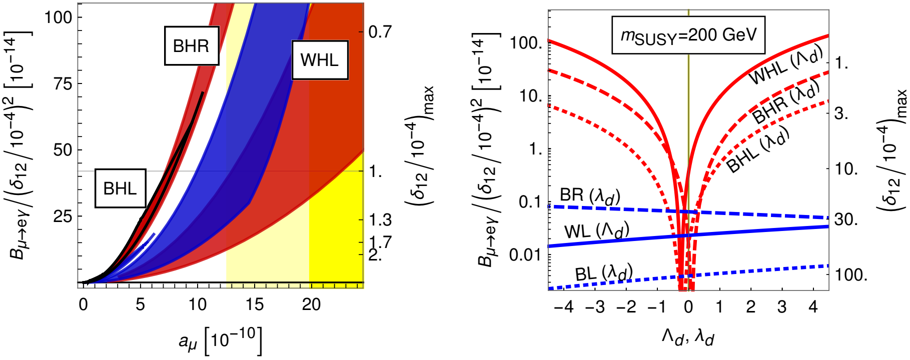
Smaller hyper-charge: BHL < BHR
WHL ← larger SU(2) gauge coupling
λ_d, Λ_d enhancement: WHR, BHR, BHL
BL, BR, WL: simple, mainly gauge couplings

Equal mass cases
upper 3 bands: $\Lambda_d = 4$
lower 3 bands: $\Lambda_d = 0$

a_μ and $\mu \to e\gamma$

$$a_\mu \propto A_2^{\bar{\mu}\mu\mathsf{L}} + A_2^{\bar{\mu}\mu\mathsf{R}}$$

$$B_{\mu\to e\gamma} \propto |A_{2\mathsf{red}}^{\bar{e}\mu\mathsf{L}}|^2 \times |\delta_{12}^{\mathsf{L}}|^2 + |A_{2\mathsf{red}}^{\bar{e}\mu\mathsf{R}}|^2 \times |\delta_{12}^{\mathsf{R}}|^2$$

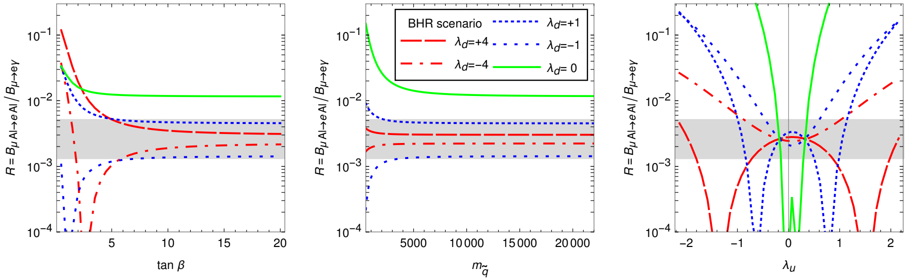


$\mu \to e$ with respect to $\tan\beta$, $m_{\tilde{q}}$, λ_u

Useful quantity: $R(N) \equiv \frac{B_{\mu N \to e N}}{B_{\mu \to e\gamma}}$; dependence on the δ's drops out

Especially for A_2 dominance:dipole A_2 form factor drops out; perfect correlation; only dependent on the element used in the experiment. [Kitano, Koike, Okada, 2002]

$$R^{\text{only dip.}}(Al) = 0.0026.$$

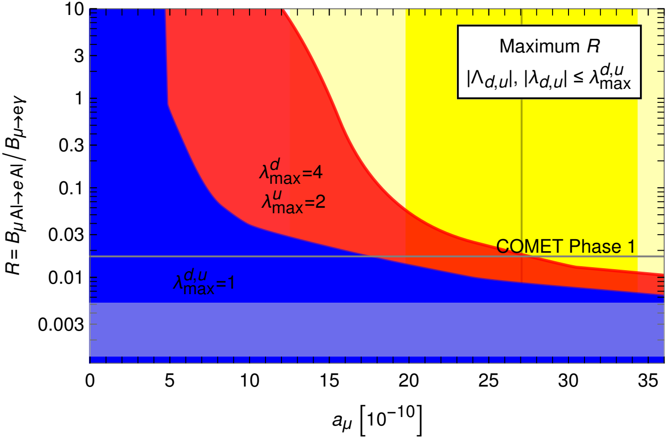


$\to$ MEG limit on $\mu \to e\gamma$ determines the maximum possible $\mu \to e$ conversion rate

Impace of the additional form factors A_1, A_Z, A_{box} $\to$ deviation

Large $\lambda_u \to A_Z$ dominance(Z-Higgsino coupling $\sim v_u\lambda_u(\Lambda_u)$ or $\sim v_d\lambda_d(\Lambda_d)$)

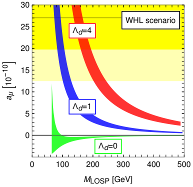
Correlation: $g-2$, $\mu \to e\gamma$, $\mu \to e$

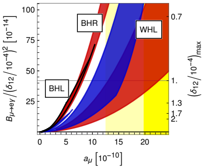


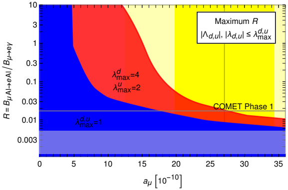
Dipole A_2 dominates, correlation strong, $g-2$ large

Summary

- MRSSM: enlarged Higgs and Gauge sector
- λ_d, Λ_d enhancement for $g-2$
- Correlation between $g-2$, $\mu \to e\gamma$ and $\mu \to e$







- Dipole A_2 dominance

$\to$ strong correlation between the low-energy lepton opservables

- Future experiment results:

$g-2$(fermilab), $\mu \to e\gamma$ (MEG-II), $\mu \to e$ (COMET, Mu2E)