Complementarity of muon charged lepton flavour violating processes in the MRSSM

Uladzimir Khasianevich
Wojciech Kotlarski, Dominik Stöckinger and Hyejung Stöckinger-Kim

Institut für Kern- und Teilchenphysik, TU Dresden

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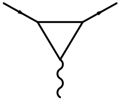
Motivation by ...

- New bounds / results

$(g-2)_\mu$
BNL + FNAL:
$(25.1 \pm 5.9) \cdot 10^{-10}$



$\mu \to e$ conversion COMETs: 3,4
$\mu \to 3e$ Mu3es: 2,4
$\mu \to e\gamma$ MEG-II: 1

They are connected! ... ?

Q: Do we need / How to use all of that?

- SUSY — Extension of Poincaré algebra | No quadratic divergences | ...
- MRSSM — Different SUSY realization | Absence of MSSM limit | R-symmetry
- Rich phenomenology — Electroweak precision observables | Higgs boson mass | Dark matter relic density | Coloured sector

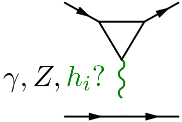
[Diessner, Kalinowski, Kotlarski, Stöckinger] '14-19

- Implementation — Model-independent implementation in spectrum-generator generator `FlexibleSUSY`

Well motivated!

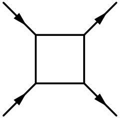
Q: What's the model contribution / parameter dependence?

Processes



$$\rightarrow m_\mu C_X^{\mathcal{D}} [\bar{e}\sigma^{\mu\nu} P_X \mu] F_{\mu\nu}$$

$$\rightarrow C_{XY,f}^{\Gamma} [\bar{e}\Gamma_X \mu][\bar{f}\Gamma_Y f] \leftarrow$$



Q: What's in the loop? | charginos, neutralinos, sfermions, squarks*

$$\Gamma_{\mu\to e\gamma} \propto |C_L^{\mathcal{D}}|^2 + |C_R^{\mathcal{D}}|^2$$

$$\Gamma_{\mu\to 3e}^{\text{[Hisano et al] '95}} \propto 0.006 \cdot \Gamma_{\mu\to e\gamma} + \sum_{L,R} \left(\mathrm{Re}\, C_{*,e}^{\mathcal{V}} C_*^{\mathcal{D}*} + |C_{*,e}^{\mathcal{S},\mathcal{V}}|^2 \right)$$

$$\omega_{\mu-e}^{\text{[Kitano et al] '02}} \propto \sum_{L,R} |D C_X^{\mathcal{D}} - \sum_{n,p} (S^{(N)} g_*^{\mathcal{S}} + V^{(N)} g_*^{\mathcal{V}})|^2$$

MRSSM?[Kribs, Poppitz, Weiner] '08

$U(1)_R$ symmetry: $\theta \to e^{i\alpha Q_\theta}\theta, \quad Q_\theta := +1$

Same superfield $\to$ related Q_*

Assertion	$Q_V = 0$	$Q(v_{d,u}) = 0$	Yukawas form	All previous
Result	**no** Majorana gauginos	**no** μ-term	Q_{SM} are* fixed	**no** L/R mixing **no** A-terms
Consequence	Dirac masses			sfermion masses*
$-\mathcal{L} \ni$	$M_B^D(\tilde{B}\tilde{S} - \sqrt{2}D_B S)$			$(m^2_{\tilde{l}})_{ij}\tilde{l}^*_i\tilde{l}_j$
		higgsino masses	usual Yukawas	new "Yukawas"
$W \ni$		$\mu_u R_u \cdot H_u$	$-Y^e_{ij}\ \bar{E}_i L_j \cdot H_d$	$\lambda_u S R_u \cdot H_u$

Parameters

Dirac masses	higgsino masses	sfermion masses*	new "Yukawas"
$M_B^D(\tilde{B}\tilde{S} - \sqrt{2}D_B S)$	$\mu_u R_u \cdot H_u$	$(m_{\tilde{l}}^2)_{ij}\tilde{l}_i^*\tilde{l}_j$	$\lambda_u S R_u \cdot H_u$

M_B^D or M_W^D should be light!

μ_d – dipole
μ_u – restricted

$$\delta_L = \frac{(m_{\tilde{l}}^2)_{12}}{(m_{\tilde{l}})_{11}(m_{\tilde{l}})_{22}}$$

and / or

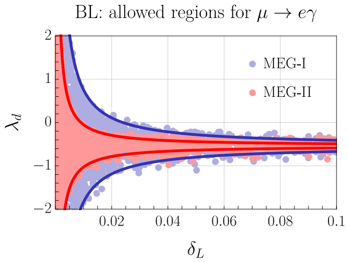
$$\delta_R = \frac{(m_{\tilde{e}}^2)_{12}}{(m_{\tilde{e}})_{11}(m_{\tilde{e}})_{22}}$$

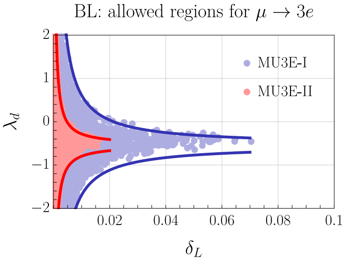
λ_d, λ_u, Λ_d, Λ_u – dependent

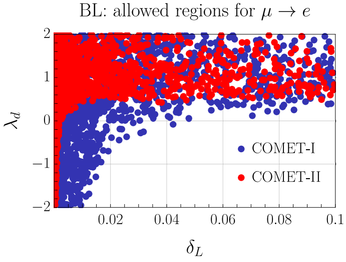
So many! **Q:** What to do?

Simplified scenarios: i.e. BHL

Scattering plots







expectation:

$$\mathrm{Br}_{\mu\to e\gamma} \propto \delta_L^2(\lambda_d + \Delta)^2$$

check!

expectation:

dipole dominance if

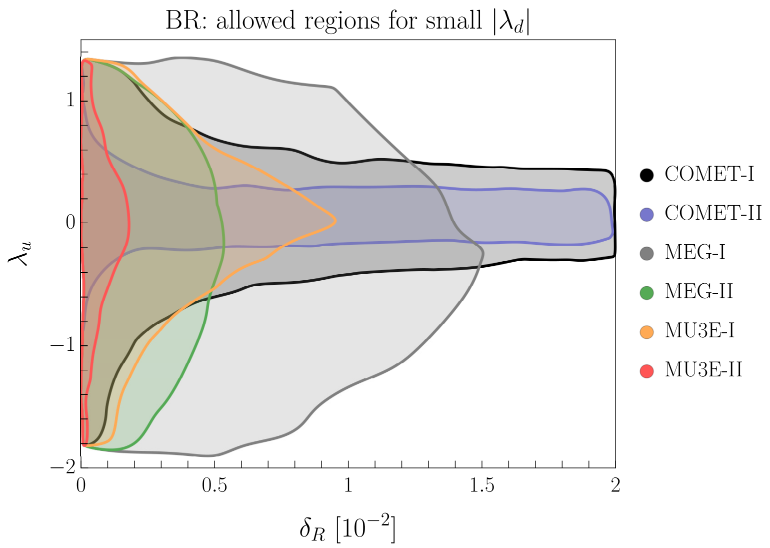
$\mathrm{Br}_{\mathsf{MEG}} \to \mathrm{Br}_{\mathsf{MU3E}}\, /0.006$

correlation?

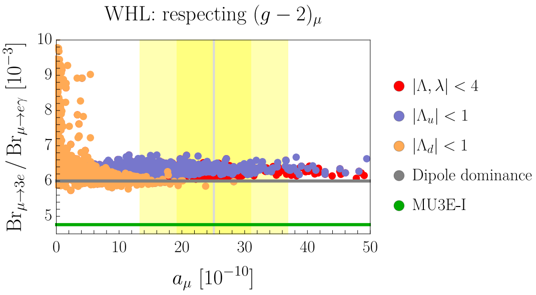
cancellations,

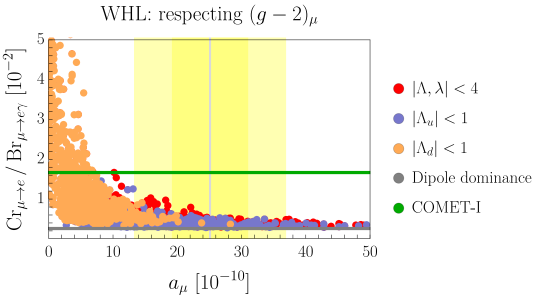
non-correlation!

Scattering plots



What if ... $(g-2)_\mu$?





$$\frac{\mathrm{Br}_{\mu\to 3e}}{\mathrm{Br}_{\mu\to e\gamma}} \approx 0.006$$

$$\frac{\mathrm{Cr}_{\mu\to e}}{\mathrm{Br}_{\mu\to e\gamma}} \approx 0.0026$$

Chirality flip *aka* $\sigma_{\mu\nu}$, **no** μ-term $\to \Lambda_d, \lambda_d$ enhancement.

FlexibleSUSY'15-?

Background

The C++ and Mathematica spectrum-generator generator:

- SARAH model file: masses, vertices, RGE, EWSB
  - FlexibleSUSY model file: boundary conditions, spectrum settings
    - output: pole masses, mixing matrices, ...

Fast, modular, extensions / tests

Q: Why to have NPointFunctions?

Relies on FeynArts, FormCalc and FlexibleSUSY C++ templates

- currently $l_i \to l_j l_k l_k^C$ and $l_i \to l_j$ conversions ($l_i \to l_j \gamma$ – differently)
  - different 1-loop libraries: LoopTools, COLLIER, softsusy, fflite
    - Wilson coefficients output

Conclusions

- MRSSM @ SUSY
  - Different realization of SUSY
  - No MSSM limit
  - Rich phenomenology
- cLFV @ MRSSM
  - Interplay between $(g-2)_\mu$, $\mu \to e\gamma$, $\mu \to 3e$, $\mu \to e$ conversion
  - Constructive region coverage by experiments
  - Interesting enhancement / interference patterns
- NPointFunctions @ FlexibleSUSY
  - Fast and customizable
  - Cross-check-able by design
  - Extendable / modular structure