Lepton flavor violation in the MSSM

JANUSZ ROSIEK

Yamagata, May 29, 2018

New Physics models come with extended flavor sector: SUSY, fermion mass models, neutrino seesaw models, dark flavor, ...

Usually:

- flavor transitions encoded in off-diagonal elements of mass matrices of heavy particles, so-called “Mass Insertions” (MI).
- heavy particle exchanges generate new effective flavor interactions of the SM fields.

Extended flavor sector often complicated - effective techniques of calculating transition amplitudes needed.

Two approaches to amplitude calculations:

- in "symmetry" basis, before the mass matrix diagonalization, MI's treated as new interaction vertices:
  - Pro: direct dependence on original symmetry-related parameters.
  - Con: tedious diagrammatic calculations, combinatorial complication grows quickly with MI order. Amplitude expressed as double infinite series, in loop order and MI order.

- in "mass eigenstates" basis, in terms of physical fields after mass matrix diagonalization.
  - Pro: compact expressions, exact formulae in terms of flavor changing parameters.
  - Con: complicated non-linear dependence on initial symmetry-related parameters, effects can be analyzed only numerically.

Dedes, Paraskevas, JR, Suxho, Tamvakis 2015: **Transition from mass basis to interaction basis amplitudes can be done using purely algebraic techniques!**

- No need for diagrammatic calculations with Mass Insertions, MI expansion derived directly from mass basis amplitude
- Method fully automatized in the symbolic *Mathematica* package *MassToMI* (JR 2016, `www.fuw.edu.pl/masstomi`)

Not only SUSY: technique applicable to any New Physics flavor model.

Application – review of LFV violation in the MSSM, without any constraints on SUSY spectrum (Crivellin, Fabisiewicz, Materkowska, Nierste, Pokorski, JR, arxiv:1802.06803).

Included processes:

$\mu \to e\gamma$, $\tau \to e\gamma$, $\tau \to \mu\gamma$
$\mu \to 3e$, $\tau \to 3e$, $\tau \to 3\mu$, $\tau \to \mu ee$, $\tau \to \mu\mu e$
$\mu \to e$ conversion in Nuclei
$h \to \mu e$, $h \to \tau e$, $h \to \tau\mu$

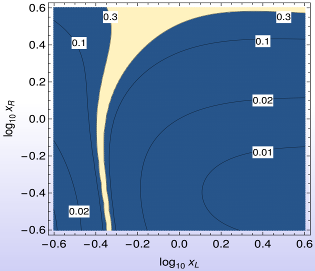
- full analytical results given for all processes, including consistently all terms scaling up to $1/M_{SUSY}^2$.
- updated upper bounds derived on dimensionless slepton mass insertions ($X = L, R$ - slepton "chiralities", $I, J = e, \mu, \tau$ - slepton flavors):

$$\Delta_{XY}^{IJ} = \frac{(M_{XY}^2)^{IJ}}{((M_{XX}^2)^{II}(M_{YY}^2)^{JJ})^{1/2}}$$

Current experimental accuracies: strongest bounds given by the radiative lepton decays $\mu \to e\gamma, \tau \to \mu\gamma, e\gamma$

"Blind spots" exists: for some SUSY mass spectra bounds from radiative decays may become weak or vanish entirely.

Plot: bounds on $\Delta_{RR}^{e\mu}$ vs. $x_{L(R)} = \frac{m_{\tilde{\mu}_{L(R)}}}{M_2}$, vanish for $m_{\tilde{e}_L} \approx m_{\tilde{\mu}_L} \sim 0.4 M_2$.



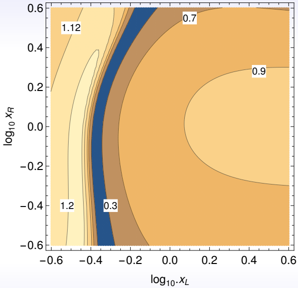
Complementary measurement: 3-body decays $l \to l' l'' l'''$

- current bounds 1-2 orders of magnitude weaker than from $l \to l'\gamma$
- usually closely correlated ("photon penguin domination scenario")

$$R_{\ell\ell'} = \frac{\alpha_{em}}{3\pi}\left(\log\frac{m_\ell^2}{m_{\ell'}^2} - \frac{11}{4}\right)\frac{\mathrm{Br}(\ell \to \ell'\gamma)}{\mathrm{Br}(\ell \to 3\ell')} \approx 1$$

$l \to 3l'$ decays does not exhibit "blind spots" (plot: $R_{\mu e}$ vs. $\frac{m_{\tilde{\mu}_L}}{M_2}, \frac{m_{\tilde{\mu}_R}}{M_2}$).

Constraining for any SUSY spectrum - important information for developing new LFV experiments.



Higgs LFV decays $h \to ll'$: some effects do not decouple with SUSY scale, for very heavy SUSY spectrum may become the most constraining observable!