Status of Lepton Flavor Violation

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Implications of LHCb measurements and future prospects
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NP search strategies

- **High-energy frontier: A unique effort to determine the NP scale**

- **High-intensity frontier (flavor physics): A collective effort to determine the flavor structure of NP**

Where to look for New Physics at the low energy?

- **Processes very suppressed or even forbidden in the SM**
  - FCNC processes ($\mu \to e\gamma$, $\tau \to \mu\gamma$, $B^0_{s,d} \to \mu^+\mu^-$, $K \to \pi\nu\bar{\nu}$)
  - CPV effects in the electron/neutron EDMs, $d_{e,n}$...
  - FCNC & CPV in $B_{s,d}$ & D decay/mixing amplitudes

- **Processes predicted with high precision in the SM**
  - EWPO as $(g-2)_{\mu,e}$: $a_\mu^{exp} - a_\mu^{SM} \approx (3 \pm 1) \times 10^{-9}$, a discrepancy at 3σ!
  - LU in $R_M^{e/\mu} = \Gamma(M \to e\nu)/\Gamma(M \to \mu\nu)$ with $M = \pi, K$

Leptonic dipoles: LFV, $(g-2)_\ell$, EDMs

- **Neutrino Oscillation** $\Rightarrow m_{\nu_i} \neq m_{\nu_j} \Rightarrow$ **LFV**
- **see-saw**: $m_\nu = \frac{(m_\nu^D)^2}{M_R} \sim eV,\ M_R \sim 10^{14-16} \Rightarrow m_\nu^D \sim m_{top}$
- LFV transitions like $\mu \to e\gamma$ @ 1 loop with exchange of
  - W and ν in the SM framework (GIM) with $\Lambda_{NP} \equiv M_R$

$$Br(\mu \to e\gamma) \sim \frac{m_\nu^{D\,4}}{M_R^4} \leq 10^{-50}$$

  - $\tilde{W}$ and $\tilde{\nu}$ in the MSSM framework (SUPER-GIM) with $\Lambda_{NP} \equiv \tilde{m}$

$$Br(\mu \to e\gamma) \sim \frac{m_\nu^{D\,4}}{\tilde{m}^4}$$ [Borzumati & Masiero '86]

$$\Downarrow$$

- LFV signals are undetectable (detectable) in the SM (MSSM)

Experimental status

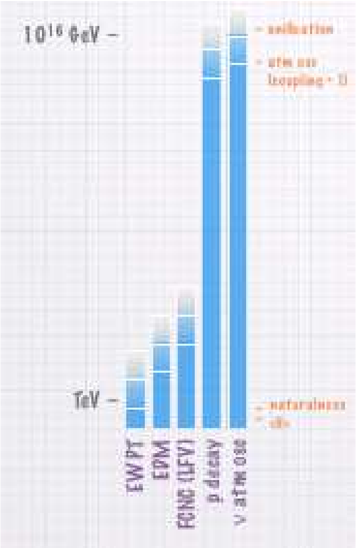
process	current exp.	future exp.
K^0 mixing	$\epsilon_K = (2.228 \pm 0.011) \times 10^{-3}$	—
D^0 mixing	$A_\Gamma = (-0.02 \pm 0.16)\%$	$\pm 0.007\%$ LHCb $\pm 0.06\%$ Belle II
B_d mixing	$\sin 2\beta = 0.68 \pm 0.02$	± 0.008 LHCb ± 0.012 Belle II
B_s mixing	$\phi_s = 0.01 \pm 0.07$	± 0.008 LHCb
d_{Hg}	$< 3.1 \times 10^{-29}$ $e$cm	–
d_{Ra}	–	$\lesssim 10^{-29}$ $e$cm
d_n	$< 2.9 \times 10^{-26}$ $e$cm	$\lesssim 10^{-28}$ $e$cm
d_p	–	$\lesssim 10^{-29}$ $e$cm
d_e	$< 1.05 \times 10^{-27}$ $e$cm YbF	$\lesssim 10^{-30}$ $e$cm YbF, Fr
$\mu \to e\gamma$	$< 5.4 \times 10^{-13}$ MEG	$\lesssim 6 \times 10^{-14}$ MEG upgrade
$\mu \to 3e$	$< 1.0 \times 10^{-12}$ SINDRUM I	$\lesssim 10^{-16}$ Mu3e
$\mu \to e$ in Au	$< 7.0 \times 10^{-13}$ SINDRUM II	–
$\mu \to e$ in Al	–	$\lesssim 6 \times 10^{-17}$ Mu2e

Table: Summary of current and selected future expected experimental limits on CP violation in meson mixing, EDMs and lepton flavor violating processes.

[Altmannshofer, Harnik, & Zupan, '13]

The NP “scale”

- **Gravity** $\Longrightarrow$ $\Lambda_{\text{Planck}} \sim 10^{18-19}\ \mathrm{GeV}$
- **Neutrino masses** $\Longrightarrow$ $\Lambda_{\text{see-saw}} \lesssim 10^{15}\ \mathrm{GeV}$
- **BAU**: evidence of CPV beyond SM
  - Electroweak Baryogenesis $\Longrightarrow$ $\Lambda_{NP} \lesssim \mathrm{TeV}$
  - Leptogenesis $\Longrightarrow$ $\Lambda_{\text{see-saw}} \lesssim 10^{15}\ \mathrm{GeV}$
- **Hierarchy problem**: $\Longrightarrow$ $\Lambda_{NP} \lesssim \mathrm{TeV}$
- **Dark Matter** $\Longrightarrow$ $\Lambda_{NP} \lesssim \mathrm{TeV}$



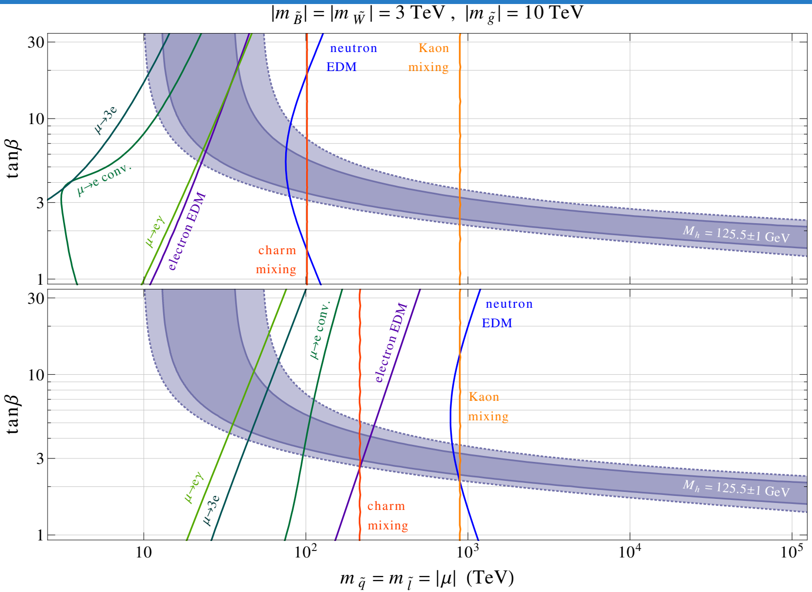
SM = effective theory at the EW scale

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \sum_{d\geq 5} \frac{c_{ij}^{(d)}}{\Lambda_{NP}^{d-4}}\, O_{ij}^{(d)}$$

- $\mathcal{L}_{\text{eff}}^{d=5} = \frac{y_{\nu}^{ij}}{\Lambda_{\text{see-saw}}} L_i L_j \phi\phi$,
- $\mathcal{L}_{\text{eff}}^{d=6}$ generates FCNC operators

$\mathrm{BR}(\ell_i \to \ell_j \gamma) \sim \frac{1}{\Lambda_{NP}^4}$

SUSY Flavour after the Higgs discovery



Low energy constraints fixing $(\delta_A)_{ij} = 0.3$. The upper (lower) plot gives the reach of current (projected future) experimental results [Altmannshofer, Harnik, & Zupan, '13]

On leptonic dipoles: $\ell \to \ell' \gamma$

- **NP effects are encoded in the effective Lagrangian**

$$\mathcal{L} = e\frac{m_\ell}{2}\left(\bar{\ell}_R \sigma_{\mu\nu} A_{\ell\ell'} \ell'_L + \bar{\ell}'_L \sigma_{\mu\nu} A^\star_{\ell\ell'} \ell_R\right) F^{\mu\nu} \qquad \ell, \ell' = e, \mu, \tau\,,$$

$$A_{\ell\ell'} = \frac{1}{(4\pi\,\Lambda_{\rm NP})^2}\left[\left(g^L_{\ell k}\, g^{L*}_{\ell' k} + g^R_{\ell k}\, g^{R*}_{\ell' k}\right) f_1(x_k) + \frac{v}{m_\ell}\left(g^L_{\ell k}\, g^{R*}_{\ell' k}\right) f_2(x_k)\right]\,,$$

  - **Δa_ℓ and leptonic EDMs are given by**

$$\Delta a_\ell = 2 m_\ell^2\, {\rm Re}(A_{\ell\ell}), \qquad \frac{d_\ell}{e} = m_\ell\, {\rm Im}(A_{\ell\ell})\,.$$

  - **The branching ratios of $\ell \to \ell'\gamma$ are given by**

$$\frac{{\rm BR}(\ell \to \ell'\gamma)}{{\rm BR}(\ell \to \ell'\nu_\ell \bar{\nu}_{\ell'})} = \frac{48\pi^3\alpha}{G_F^2}\left(|A_{\ell\ell'}|^2 + |A_{\ell'\ell}|^2\right)\,.$$

- **“Naive scaling”:**

$$\Delta a_{\ell_i}/\Delta a_{\ell_j} = m^2_{\ell_i}/m^2_{\ell_j}, \qquad d_{\ell_i}/d_{\ell_j} = m_{\ell_i}/m_{\ell_j}\,.$$

(for instance, if the new particles have an underlying SU(3) flavor symmetry in their mass spectrum and in their couplings to leptons, which is the case for gauge interactions).

[Giudice, P.P., & Passera, ’12]

Model-independent predictions

- $(g-2)_\ell$ **assuming "Naive scaling"** $\Delta a_{\ell_i}/\Delta a_{\ell_j} = m^2_{\ell_i}/m^2_{\ell_j}$

$$\Delta a_e = \left(\frac{\Delta a_\mu}{3\times 10^{-9}}\right) 0.7\times 10^{-13}\,, \qquad \Delta a_\tau = \left(\frac{\Delta a_\mu}{3\times 10^{-9}}\right) 0.8\times 10^{-6}.$$

- **EDMs assuming "Naive scaling"** $d_{\ell_i}/d_{\ell_j} = m_{\ell_i}/m_{\ell_j}$

$$d_e \simeq \left(\frac{\Delta a_e}{7\times 10^{-14}}\right) 10^{-24}\ \tan\phi_e\ \ e\,\mathrm{cm}\,,$$
$$d_\mu \simeq \left(\frac{\Delta a_\mu}{3\times 10^{-9}}\right) 2\times 10^{-22}\ \tan\phi_\mu\ \ e\,\mathrm{cm}\,,$$
$$d_\tau \simeq \left(\frac{\Delta a_\tau}{8\times 10^{-7}}\right) 4\times 10^{-21}\ \tan\phi_\tau\ \ e\,\mathrm{cm}\,,$$

- $\mathrm{BR}(\ell_i \to \ell_j\gamma)$ **vs.** $(g-2)_\mu$

$$\mathrm{BR}(\mu\to e\gamma) \approx 3\times 10^{-13}\left(\frac{\Delta a_\mu}{3\times 10^{-9}}\right)^2 \left(\frac{\theta_{e\mu}}{10^{-5}}\right)^2,$$
$$\mathrm{BR}(\tau\to \mu\gamma) \approx 4\times 10^{-8}\left(\frac{\Delta a_\mu}{3\times 10^{-9}}\right)^2 \left(\frac{\theta_{\ell\tau}}{10^{-2}}\right)^2.$$

[Giudice, P.P., & Passera, '12]

A concrete SUSY scenario: "Disoriented A-terms"

- **Challenge**: Large effects for $g-2$ keeping under control $\mu \to e\gamma$ and d_e
- **"Disoriented A-terms"** [Giudice, Isidori & P.P., '12]:

$$(\delta^{ij}_{LR})_f \sim \frac{A_f \theta^f_{ij} m_{f_j}}{m_{\tilde f}} \quad f = u, d, \ell \,,$$

  - Flavor and CP violation is restricted to the trilinear scalar terms.
  - Flavor bounds of the down-sector are naturally satisfied thanks to the smallness of down-type quark/lepton masses.
  - This ansatz arises in scenarios with partial compositeness (where a natural prediction is $\theta^\ell_{ij} \sim \sqrt{m_i/m_j}$ [Rattazzi et al.,'12]) or, as shown in [Calibbi, P.P. and Ziegler,'13], in Flavored Gauge Mediation models [Shadmi and collaborators].

- $\mu \to e\gamma$ and d_e are generated only by $U(1)$ interactions

$$\mathrm{BR}(\mu \to e\gamma) \sim \left(\frac{\alpha}{\cos^2\theta_W}\right)^2 \left|\delta^{\mu e}_{LR}\right|^2 , \qquad \frac{d_e}{e} \sim \frac{\alpha}{\cos^2\theta_W}\, \mathrm{Im}\delta^{ee}_{LR} \,.$$

- $(g-2)_\mu$ is generated by $SU(2)$ interactions and is $\tan\beta$ enhanced

$$\Delta a_\ell \sim \frac{\alpha}{\sin^2\theta_W} \tan\beta$$

- $(g-2)_\mu$ is enhanced by $\approx 100 \times (\tan\beta/30)$ w.r.t. $\mu \to e\gamma$ and d_e amplitudes

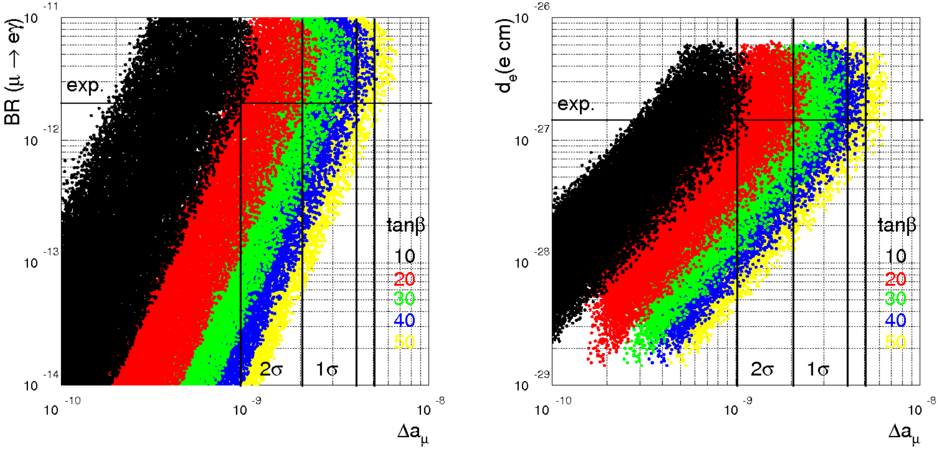
A concrete SUSY scenario: “Disoriented A-terms”

- **Numerical example**: $\tilde{m} = |A_e| = 1\ \mathrm{TeV}$, $\sin\phi_{A_e}$=1, $M_2 = \mu = 2M_1 = 0.2\ \mathrm{TeV}$, and $\tan\beta = 30$ [Giudice, P.P., & Passera, ’12]

$$
\begin{aligned}
\mathrm{BR}(\mu \to e\gamma) &\approx 6 \times 10^{-13} \left| \frac{A_\ell}{\mathrm{TeV}} \frac{\theta^\ell_{12}}{\sqrt{m_e/m_\mu}} \right|^2 \left(\frac{\mathrm{TeV}}{m_{\tilde{\ell}}} \right)^4 , \\
d_e &\approx 4 \times 10^{-28}\, \mathrm{Im} \left(\frac{A_\ell\, \theta^\ell_{11}}{\mathrm{TeV}} \right) \left(\frac{\mathrm{TeV}}{m_{\tilde{\ell}}} \right)^2 e\, \mathrm{cm} , \\
\Delta a_\mu &\approx 1 \times 10^{-9} \left(\frac{\mathrm{TeV}}{m_{\tilde{\ell}}} \right)^2 \left(\frac{\tan\beta}{30} \right) .
\end{aligned}
$$

  - Disoriented A-terms can account for $(g-2)_\mu$, satisfy the bounds on $\mu \to e\gamma$ and d_e, while giving predictions for $\mu \to e\gamma$ and d_e within experimental reach.
  - The electron $(g-2)$ follows “naive scaling”.
  - The Higgs boson mass $m_h \approx 126$ GeV is a natural prediction (even for stops at 1 TeV) thanks to the large A-terms [Giudice, Isidori, P.P., ’12].

A concrete SUSY scenario: “Disoriented A-terms”



Predictions for $\mu \to e\gamma$, Δa_μ and d_e in the disoriented A-term scenario with $\theta^\ell_{ij} = \sqrt{m_i/m_j}$. Left: $\mu \to e\gamma$ vs. Δa_μ. Right: d_e vs. Δa_μ [Giudice, P.P., & Passera, ’12]

- LFV processes with an undelying $\tau - \mu$ and $\tau - e$ are unobservable

Not only $\mu \to e\gamma$...

- LFV operators up to dimension-six

$$\mathcal{L}_{\rm eff} = \mathcal{L}_{\rm SM} + \frac{1}{\Lambda^2_{\rm LFV}}\,\mathcal{O}^{\rm dim-6} + \ldots\,.$$

$$\mathcal{O}^{\rm dim-6} \ni \;\; \bar{\mu}_R\,\sigma^{\mu\nu}\,H\,e_L\,F_{\mu\nu}\,, \;\; (\bar{\mu}_L\gamma^{\mu}e_L)\left(\bar{f}_L\gamma^{\mu}f_L\right)\,, \;\; (\bar{\mu}_R e_L)\left(\bar{f}_R f_L\right)\,, \; f = e,u,d$$

- the dipole-operator leads to $\ell \to \ell'\gamma$ while 4-fermion operators generate processes like $\ell_i \to \ell_j\bar{\ell}_k\ell_k$ and $\mu \to e$ conversion in Nuclei.
- When the dipole-operator is dominant:

$$\frac{\mathrm{BR}(\ell_i \to \ell_j\ell_k\bar{\ell}_k)}{\mathrm{BR}(\ell_i \to \ell_j\bar{\nu}_j\nu_i)} \simeq \frac{\alpha_{el}}{3\pi}\left(\log\frac{m^2_{\ell_i}}{m^2_{\ell_k}} - 3\right)\frac{\mathrm{BR}(\ell_i \to \ell_j\gamma)}{\mathrm{BR}(\ell_i \to \ell_j\bar{\nu}_j\nu_i)}\,,$$

$$\mathrm{CR}(\mu \to e \text{ in N}) \simeq \alpha_{\rm em} \times \mathrm{BR}(\mu \to e\gamma)\,.$$

- $\mathrm{BR}(\mu \to e\gamma) \sim 10^{-12}$ implies $\mathrm{BR}(\mu \to eee) \leq 0.5 \times 10^{-14}$ and $\mathrm{CR}(\mu \to e \text{ in N}) \leq 0.5 \times 10^{-14}$.
- A combined analysis of $\mu \to e$ conversion on different target nuclei can discriminate among the underlying operators since the sensitivity of different processes to these operators is not the same [Okada et al. 2004].
- For three body LFV decays as $\mu \to eee$, an angular analysis of the signal would be crucial to shed light on the operator which is at work.

Pattern of LFV in NP models

- **Ratios like $Br(\mu \to e\gamma)/Br(\tau \to \mu\gamma)$ probe the NP flavor structure**
- **Ratios like $Br(\mu \to e\gamma)/Br(\mu \to eee)$ probe the NP operator at work**

ratio	LHT	MSSM	SM4
$\frac{Br(\mu\to eee)}{Br(\mu\to e\gamma)}$	$0.02 \ldots 1$	$\sim 2\cdot 10^{-3}$	$0.06\ldots 2.2$
$\frac{Br(\tau\to eee)}{Br(\tau\to e\gamma)}$	$0.04 \ldots 0.4$	$\sim 1\cdot 10^{-2}$	$0.07\ldots 2.2$
$\frac{Br(\tau\to \mu\mu\mu)}{Br(\tau\to \mu\gamma)}$	$0.04 \ldots 0.4$	$\sim 2\cdot 10^{-3}$	$0.06\ldots 2.2$
$\frac{Br(\tau\to e\mu\mu)}{Br(\tau\to e\gamma)}$	$0.04 \ldots 0.3$	$\sim 2\cdot 10^{-3}$	$0.03\ldots 1.3$
$\frac{Br(\tau\to \mu ee)}{Br(\tau\to \mu\gamma)}$	$0.04 \ldots 0.3$	$\sim 1\cdot 10^{-2}$	$0.04\ldots 1.4$
$\frac{Br(\tau\to eee)}{Br(\tau\to e\mu\mu)}$	$0.8 \ldots 2$	~ 5	$1.5\ldots 2.3$
$\frac{Br(\tau\to \mu\mu\mu)}{Br(\tau\to \mu ee)}$	$0.7 \ldots 1.6$	~ 0.2	$1.4\ldots 1.7$
$\frac{\mathrm{R}(\mu\mathrm{Ti}\to e\mathrm{Ti})}{Br(\mu\to e\gamma)}$	$10^{-3} \ldots 10^{2}$	$\sim 5\cdot 10^{-3}$	$10^{-12}\ldots 26$

[Buras et al., '07, '10]

Testing new physics with the electron $g-2$

- **Longstanding muon $g-2$ anomaly**

$$\Delta a_\mu = a_\mu^{\rm EXP} - a_\mu^{\rm SM} = 2.90(90) \times 10^{-9}\,, \qquad \textbf{3.5}\boldsymbol{\sigma}\ \textbf{discrepancy}$$

- **NP effects are expected to be of order $a_\ell^{\rm NP} \sim a_\ell^{\rm EW}$**

$$a_\mu^{\rm EW} = \frac{m_\mu^2}{(4\pi v)^2}\left(1 - \frac{4}{3}\sin^2\theta_{\rm W} + \frac{8}{3}\sin^4\theta_{\rm W}\right) \approx 2 \times 10^{-9}.$$

- **Main question: how could we check if the a_μ discrepancy is due to NP?**
- **Answer: testing new-physics effects in a_e** [Giudice, P.P, & Passera, '12]
- **"Naive scaling":** $\Delta a_{\ell_i}/\Delta a_{\ell_j} = m_{\ell_i}^2/m_{\ell_j}^2$

$$\Delta a_e = \left(\frac{\Delta a_\mu}{3 \times 10^{-9}}\right) 0.7 \times 10^{-13}\,.$$

  - a_e has never played a role in testing beyond SM effects. From $a_e^{\rm SM}(\alpha) = a_e^{\rm EXP}$, we extract α which is is the most precise value of α available today!
  - The situation has now changed thanks to progresses both on the th. and exp. sides.

The Standard Model prediction of the electron $g-2$ [Giudice, P.P, & Passera, '12]

- **Using the second best determination of α from atomic physics $\alpha(^{87}\mathrm{Rb})$**

$$\Delta a_e = a_e^{\mathrm{EXP}} - a_e^{\mathrm{SM}} = -10.6\,(8.1) \times 10^{-13},$$

  - Beautiful test of QED at four-loop level!
  - $\delta\Delta a_e = 8.1 \times 10^{-13}$ is dominated by δa_e^{SM} through $\delta\alpha(^{87}\mathrm{Rb})$.

- **Future improvements in the determination of Δa_e**

$$\underbrace{(0.6)_{\mathrm{QED4}},\;\; (0.4)_{\mathrm{QED5}},\;\;\; (0.2)_{\mathrm{HAD}},}_{(0.7)_{\mathrm{TH}}}\;\; (7.6)_{\delta\alpha},\;\; (2.8)_{\delta a_e^{\mathrm{EXP}}}.$$

  - The first error, 0.6×10^{-13}, stems from numerical uncertainties in the four-loop QED. It can be reduced to 0.1×10^{-13} with a large scale numerical recalculation [Kinoshita]
  - The second error, from five-loop QED term may soon drop to 0.1×10^{-13}.
  - Experimental uncertainties 2.8×10^{-13} ($\delta a_e^{\mathrm{EXP}}$) and 7.6×10^{-13} ($\delta\alpha$) dominate. We expect a reduction of the former error to a part in 10^{-13} (or better) [Gabrielse]. Work is also in progress for a significant reduction of the latter error [Nez].

- **Δa_e at the 10^{-13} (or below) is not too far! This will bring a_e to play a pivotal role in probing new physics in the leptonic sector.**

Supersymmetry and a_e [Giudice, P.P, & Passera, '12]

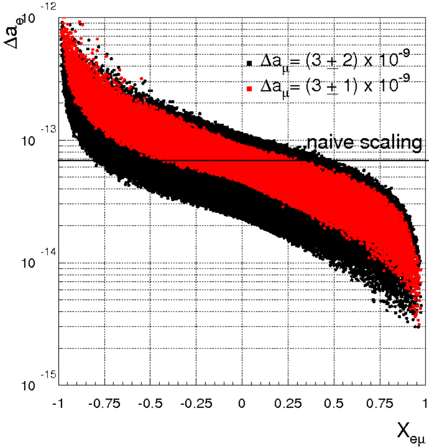
- SUSY contributions to a_ℓ comes from loops with exchange of chargino/sneutrino or neutralino/charged slepton.

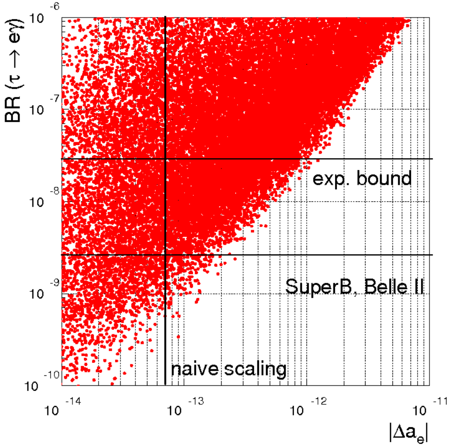
- **Violations of "naive scaling"** can arise through sources of non-universalities in the slepton mass matrices in two possible ways

  - **Lepton flavor conserving (LFC) case**. The charged slepton mass matrix violates the global non-abelian flavor symmetry, but preserves $U(1)^3$. This case is characterized by non-degenerate sleptons ($m_{\tilde{e}} \neq m_{\tilde{\mu}} \neq m_{\tilde{\tau}}$) but vanishing mixing angles because of an exact alignment.
    - Interesting interplay with collider physics: slepton mass splittings from kinematic edges [Allanach, Colon, Lester, '08, Buras, Calibbi, P.P., '09, see talk by Shadmi]

  - **Lepton flavor violating (LFV) case**. The slepton mass matrix fully breaks flavor symmetry up to U(1) lepton number, generating mixing angles that allow for flavor transitions. Lepton flavor violating processes, such as $\mu \to e\gamma$, provide stringent constraints on this case. However, because of flavor transitions, a_e and a_μ can receive new large contributions proportional to m_τ (from a chiral flip in the internal line of the loop diagram) [Girrbach, Nierste, '09], giving a new source of non-naive scaling.

Lepton flavor conserving case [Giudice, P.P, & Passera, '12]





Δa_e vs. $X_{e\mu} = (m^2_{\tilde{e}} - m^2_{\tilde{\mu}})/(m^2_{\tilde{e}} + m^2_{\tilde{\mu}})$

$\mathrm{BR}(\tau \to e\gamma)$ vs. $|\Delta a_e|$

Other important LFV searches

- **LFV Higgs decays** are interesting probes of LFV: $\mathrm{BR}(h \to \tau\mu) \lesssim 0.1$ is allowed by all low-energy constraints [see talks by Zupan, Harnik], "What if $\mathrm{BR}(h \to \mu\mu)/\mathrm{BR}(h \to \tau\tau) \neq m_\mu^2/m_\tau^2$?" [Nir and collaborators, '13]

- **How large can be $\mathrm{BR}(B_s \to \tau\mu)$? ** A crude estimate: assuming $\mathrm{BR}(B_s \to \mu\mu) \sim 3 \times 10^{-9}$ to be saturated by NP effect

$$\mathrm{BR}(B_s \to \tau\mu) \lesssim \mathrm{BR}(B_s \to \mu\mu) \times \left| \frac{Y_{\tau\mu}}{Y_{\mu\mu}} \right|^2$$

  - In the Cheng-Sher ansatz $Y_{\tau\mu}/Y_{\mu\mu} \sim \sqrt{m_\tau/m_\mu}$ and therefore $\mathrm{BR}(B_s \to \tau\mu) \lesssim 5 \times 10^{-8}$.

  - In SUSY $Y_{\tau\mu}$ is loop-induced by non-holomorphic Yukawa couplings $Y_{\tau\mu}/Y_{\mu\mu} \sim \epsilon \tan\beta \times (m_\tau/m_\mu) \times \delta_{\tau\mu}$. For $\epsilon \tan\beta \sim 0.2$ and $\delta_{\tau\mu} \sim 0.5$ $\mathrm{BR}(B_s \to \tau\mu) \lesssim 10^{-8}$.

- **τ-LFV channels @ Belle II & LHCb** and $B \to K(K^\star)\tau\mu$ **at LHCb** are interesting probes of LFV as they are complementary to $\mu \to e$ processes.

- LFV at collider: [see the talk by Shadmi]

Conclusions and future prospects

- **Important questions in view of ongoing/future experiments are** [Isidori, Nir & Perez, '10]:
  - What are the expected deviations from the SM predictions induced by TeV NP?
  - Which observables are not limited by theoretical uncertainties?
  - In which case we can expect a substantial improvement on the experimental side?
  - What will the measurements teach us if deviations from the SM are [not] seen?

- **Answers**:
  - The expected deviations from the SM predictions induced by NP at the TeV scale with generic flavor structure are already ruled out by many orders of magnitudes.
  - On general grounds, we can expect any size of deviation below the current bounds.
  - The cleanest th. observables are cLFV processes, leptonic EDMs, LFU observables, rare B and K decays (especially $B_{s,d} \to \mu^+\mu^-$, $K \to \pi\nu\bar{\nu}$), CPV in meson mixing
  - On the exp. side there are still excellent prospects of improvements in several clean channels: $\mu \to e\gamma$, $\mu N \to eN$, $\mu \to eee$, τ-LFV, EDMs, leptonic $(g-2)$, $B_{s,d} \to \mu^+\mu^-$, $K \to \pi\nu\bar{\nu}$, CPV in B_s and D systems, γ from $B \to DK$.
  - The the origin of the $(g-2)_\mu$ discrepancy can be understood testing new-physics effects in the electron $(g-2)_e$. This would require improved measurements of $(g-2)_e$ and more refined determinations of α in atomic-physics experiments.

Conclusions

Irrespectively of whether the LHC will discover or not new particles, flavor physics will continue to teach us a lot!