FLAVOR THEORY SUMMARY

Gudrun Hiller, Dortmund

Generational structure & mixing is feature of SM and many BSM d.o.f.'s; VIRTUES:

i) high sensitivity to BSM in flavor violation;
FCNCs $b \to s\ell\ell, \mu \to e\gamma, h \to \tau\mu, ...$
we may discover BSM in flavor physics (even first)

ii) flavorful processes are intrinsically linked to "flavor puzzle"
Y_{SM} hierachies from where?
with BSM-signal, we may be able to progress here

iii) plenty of modes $s \to d$, $c \to u$, $b \to s, d$, $t \to c, u$, $\mu \to e$, $\tau \to \mu, e$
plus charged ones; plenty of ongoing & future experiments, too.
we may identify $\mathcal{L}_{BSM}$; complementary to direct searches

-SM precision: Higher order, hadronic matrix elements, lattice QCD

- bottom-up model-building/simplified models (Z', extra Higgses, leptoquarks..) ”data-driven”

- multi-observable fits to couplings ”Wilson coefficients” $C_{7,9,10}$ of standardized $|\Delta B| = |\Delta S| = 1$ effective hamiltonian; few groups, dedicated effort, exploit correlations, precision test of the SM

- design/use clean observables; related to (approximate) symmetries of the SM: lepton-nonuniversality, CP, helicity, LFV .. ”null tests”

- Higgs physics: $hf\bar{f}$ and $hf\bar{f}'$ – are couplings SM-like?

- quarks together with leptons: hint of lepton-nonuniversality in B-decays; searches for LFV

Points of interest 2015

Current flavor anomalies

- CMS [1502.07400]: 2.4σ lepton flavor violation:

$$\mathrm{BR}(h \to \mu\tau) = \left(0.84^{+0.39}_{-0.37}\right)\%\,.$$

- LHCb [1406.6482]: 2.6σ lepton non-universality:

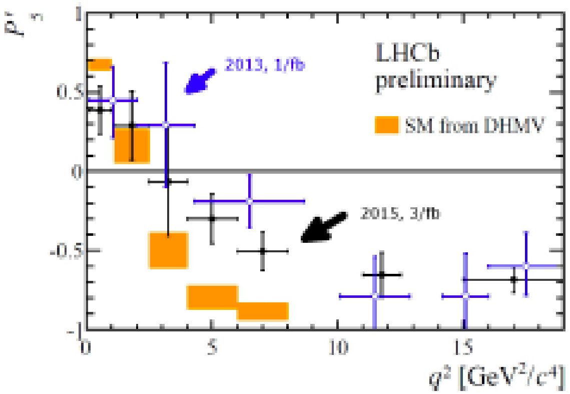
$$R(K) \equiv \frac{B \to K\mu\mu}{B \to Kee} = 0.745^{+0.090}_{-0.074} \pm 0.036,$$

SM prediction $R(K) = 1 \pm \mathcal{O}(10^{-4})$ [Bobeth, Hiller, Piranishvili, 0709.4174].

- LHCb [LHCb-CONF-2015-002]: 3.7σ deviation in angular observable P_5' of

$$B \to K^*\mu\mu \to K^+\pi^-\mu\mu\,,$$

confirming 1/fb analysis [1308.1707].
Might be QCD, charm-loop...



Exciting new physics or boring statistics?

HIGGS Flavor

Avital Dery, Erik Schumacher, Matthias König, Avelino Vicente

Best fit to B(H→μτ), %

Expected limit: $\mathrm{BR}(h \to \tau\mu) < 0.75\%$

Observed limit: $\mathbf{BR}(h \to \tau\mu) < 1.51\%$

Best fit value:

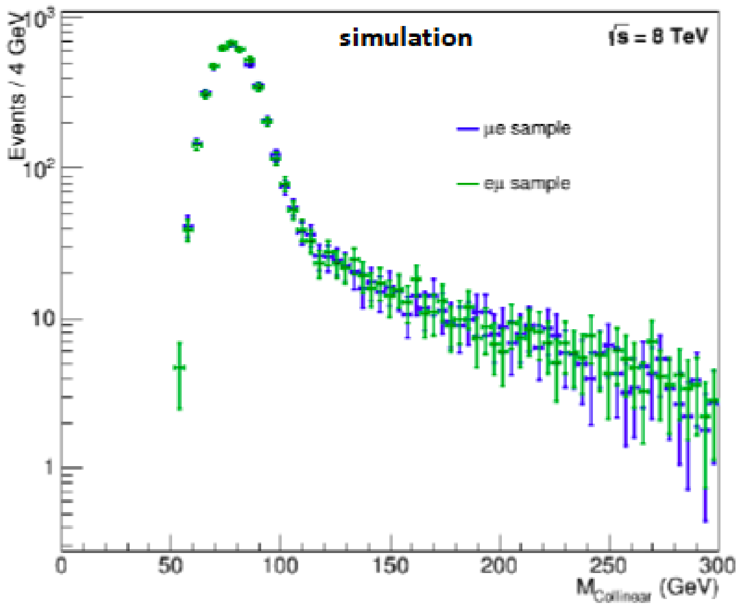
$\mathbf{BR}(h \to \tau\mu) = (0.84^{+0.39}_{-0.37})\%$

2.4σ from zero

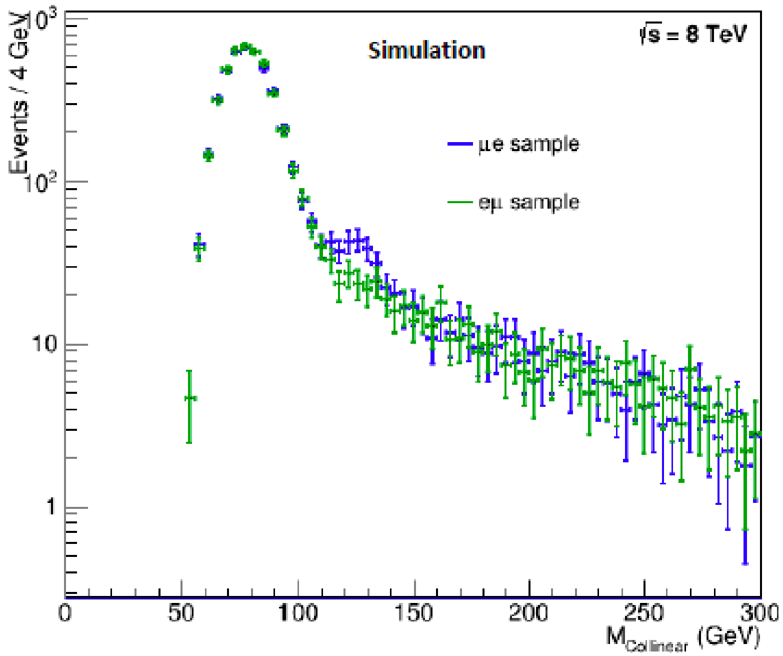
Avital Dery, Multi Higgs Models, 2/9/14 4

New exp method to search for $h \to \tau\mu$ with $h \to \tau_e\mu$; in prep. for ATLAS A.Dery

SM Background simulation
Pythia + Delphes ATLAS card



SM Background + BR($h \to \tau\mu$) = 2%
Pythia + Delphes ATLAS card



[S. Bressler, AD, A. Efrati, Phys. Rev. D 90 (2014) Editors Selection arXiv:1405.4545]

Explaining the CMS anomaly at face value is non-trivial (Dery, Vicente, Schumacher, Heeck):

Can do the trick: Multi-Higgs doublet models, $U(1)_{FN}$ w. holomorphic zeros, models with ”more LFV spurions e.g from seesaw

Strong constraints in general from radiative FCNCs $\tau \to \mu\gamma$ and other flavor violation. Succesful models generically are testable/predicitive!

S_4 flavor symmetry explaining higgs anomalies; E.Schumacher
”PMNS”-type model-building tools

The Model (charged leptons)

Objective: Build a model with LFV and Triality in S_4

Ingredients:

- $L = (L_e, L_\mu, L_\tau)\ :\ \mathbf{3}, \quad \tau_R\ :\ \mathbf{1}, \quad (e_R, \mu_R)\ :\ \mathbf{2}$
  required for LFT structure
- Three $SU(2)$ doublets to induce LFV $\phi = (\phi_1, \phi_2, \phi_3)\ :\ \mathbf{3}$
- VEV alignment $\frac{v}{\sqrt{3}}(1, 1, 1)$ of the ϕ_i breaks S_4 down to Z_3

Result:

$$M_l = \frac{v_{\text{SM}}}{\sqrt{6}} \begin{pmatrix} 1 & 1 & 1 \\ \omega^2 & \omega & 1 \\ \omega & \omega^2 & 1 \end{pmatrix} \text{diag}(y_e, y_\mu, y_\tau)$$

$\Rightarrow$ Charged lepton mass basis coincides with
Z_3 basis $(e,\ \mu,\ \tau) \sim (\omega,\ \omega^2,\ 1)$

Erik Schumacher, TU Dortmund — $h \to \mu\tau$ as an indication for S_4 flavor symmetry — Slide 6/18 predicts $h \to \tau e$ not far from $h \to \tau\mu$

Predictions

@1σ and $m_\eta = 200$ GeV

$$\begin{array}{ccccc} 0.002 & < & \theta & < & 0.090\,, \\ 126\ \text{GeV} & < & m_H & < & 204\,\text{GeV} \end{array}$$

- With these parameters we predict

$$\begin{array}{lll}
\text{Br}(\tau \to \mu\gamma) & \in (0.3 - 1.3) \times 10^{-8}, & \color{red}{< 4.4 \times 10^{-8}} \\
\text{Br}(\tau \to e\gamma) & \in (0.3 - 1.3) \times 10^{-8}, & \color{red}{< 1.2 \times 10^{-7} (?)} \\
\text{Br}(\tau \to 3\mu) & \in (1.9 - 8.1) \times 10^{-10}, & \color{red}{< 2.1 \times 10^{-8}} \\
\text{Br}(\tau \to 3e) & \in (0.9 - 4.1) \times 10^{-9}, & \color{red}{< 2.7 \times 10^{-8}} \\
\text{Br}(h \to e\tau) & \in (0.4 - 1.2) \times 10^{-2} & \\
\text{Br}(h \to e\mu) & \in (1.5 - 4.2) \times 10^{-5} &
\end{array}$$

- The LFV channels with τ lepton final states are closely related

$$\frac{\text{Br}(h \to \mu\tau)}{\text{Br}(h \to e\tau)} \approx \frac{|y_{\mu\tau}|^2}{|y_{e\tau}|^2} \approx 1 \quad \text{for small } \theta$$

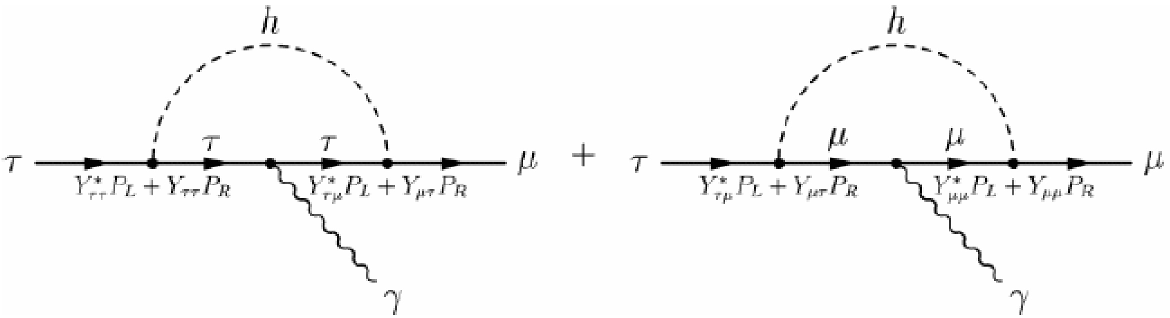
Therefore large LFV also expected in $h \to e\tau$ channel

Erik Schumacher, TU Dortmund — $h \to \mu\tau$ as an indication for S_4 flavor symmetry — Slide 16/18

A new hope: Type-III 2HDM

[Davidson, Grenier, 2010; Harnik et al, 2013; Kopp, Nardecchia, 2014]

$$\mathcal{L}_Y = m_i \bar{f}_L^i f_R^i - Y_{ij} (\bar{f}_L^i f_R^j + \text{h.c.})$$



[Figure from Harnik et al, arXiv:1209.1397]

A model!

2HDM type III

In *principle*... it is possible to account for the CMS excess!

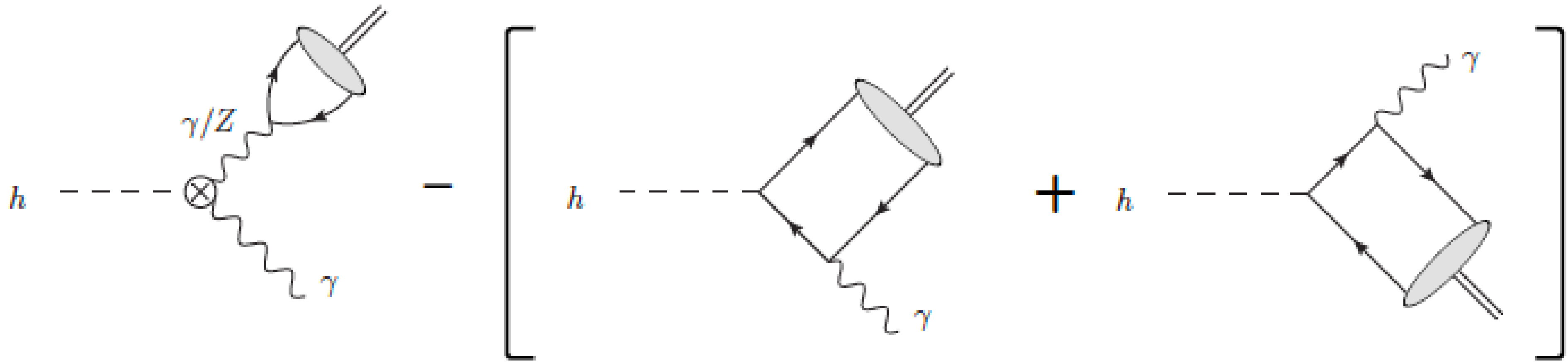
Higgs LFV couplings and other LFV processes: [Celis et al, 2014]

See also some recipes for model builders: [Dery et al, 2014]

A.Vicente

Probing light quark yukawas with exclusve higgs decays; M.König

Several different diagram topologies:



$$\frac{\Gamma(h \to V\gamma)}{\Gamma(h \to \gamma\gamma)} = \frac{8\pi\alpha^2(m_V)}{\alpha} \frac{Q_V^2 f_V^2}{m_V^2} \left(1 - \frac{m_V^2}{m_h^2}\right)^2 |1 - \kappa_q \Delta_V - \delta_V|^2$$

SM predictions

Nummerical results

JG|U

Assuming SM couplings of all particles, we find:

$$\mathrm{BR}(h \to \rho^0\gamma) = (1.68 \pm 0.02_f \pm 0.08_{h\to\gamma\gamma}) \cdot 10^{-5}$$

$$\mathrm{BR}(h \to \omega\gamma) = (1.48 \pm 0.03_f \pm 0.07_{h\to\gamma\gamma}) \cdot 10^{-6}$$

$$\mathrm{BR}(h \to \phi\gamma) = (2.31 \pm 0.03_f \pm 0.11_{h\to\gamma\gamma}) \cdot 10^{-6}$$

$$\mathrm{BR}(h \to J/\psi\gamma) = (2.95 \pm 0.07_f \pm 0.06_{\mathrm{direct}} \pm 0.14_{h\to\gamma\gamma}) \cdot 10^{-6}$$

$$\mathrm{BR}(h \to \Upsilon(1S)\gamma) = \left(4.61 \pm 0.06_f {}^{+1.75}_{-1.21}{}_{\mathrm{direct}} \pm 0.22_{h\to\gamma\gamma}\right) \cdot 10^{-9}$$

$$\mathrm{BR}(h \to \Upsilon(2S)\gamma) = \left(2.34 \pm 0.04_f {}^{+0.75}_{-0.99}{}_{\mathrm{direct}} \pm 0.11_{h\to\gamma\gamma}\right) \cdot 10^{-9}$$

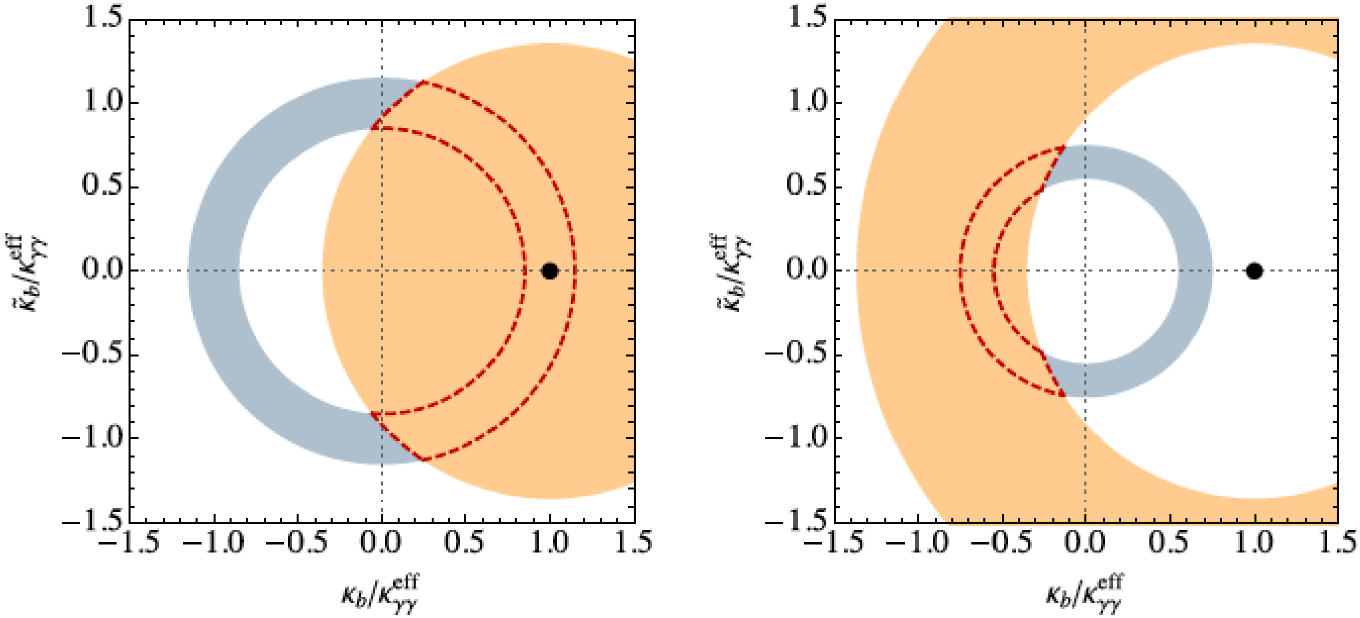
$$\mathrm{BR}(h \to \Upsilon(3S)\gamma) = \left(2.13 \pm 0.04_f {}^{+0.75}_{-1.12}{}_{\mathrm{direct}} \pm 0.10_{h\to\gamma\gamma}\right) \cdot 10^{-9}$$

M.König

Correlations with $h \to b\bar{b}$

Phenomenology

Possible future scenarios:



Blue circles: direct measurements of $h \to q\bar{q}$ constrain $\kappa_q^2 + \tilde{\kappa}_q^2$

Red circles: measurements of $h \to \Upsilon\gamma$ constrain $(1 - \kappa_q)^2 + \tilde{\kappa}_q^2$

M.König

Precision Tests in $b \to s\ell\ell, \gamma$

Sebastien Descotes-Genon, Morimitsu Tanimoto

$H_{eff} = -4G_F/\sqrt{2} V_{tb} V_{ts}^* \frac{\alpha_e}{4\pi} \sum C_i O_i$

$O_9 = \bar{s}\gamma_\mu P_L b \bar{\ell}\gamma^\mu \ell$, $O_{10} = \bar{s}\gamma_\mu P_L b \bar{\ell}\gamma^\mu \gamma_5 \ell$ $\quad$ O' from O with $P_L \leftrightarrow P_R$.

$C_9^{SM} = 4.2$, $C_{10}^{SM} = -4.2$, $\quad$ $C'^{SM} \simeq 0$.

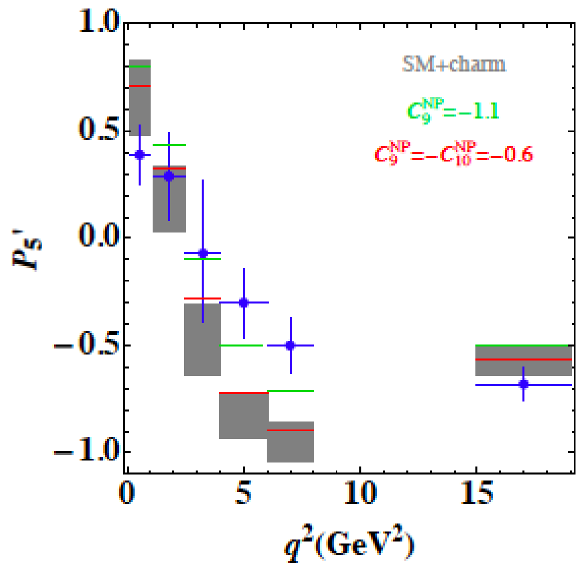
Model-independent fits: $C = C^{SM} + C^{BSM}$.

Fitting dimuon observables globally; S. Descotes-Genon

Global fits: 1D hypotheses

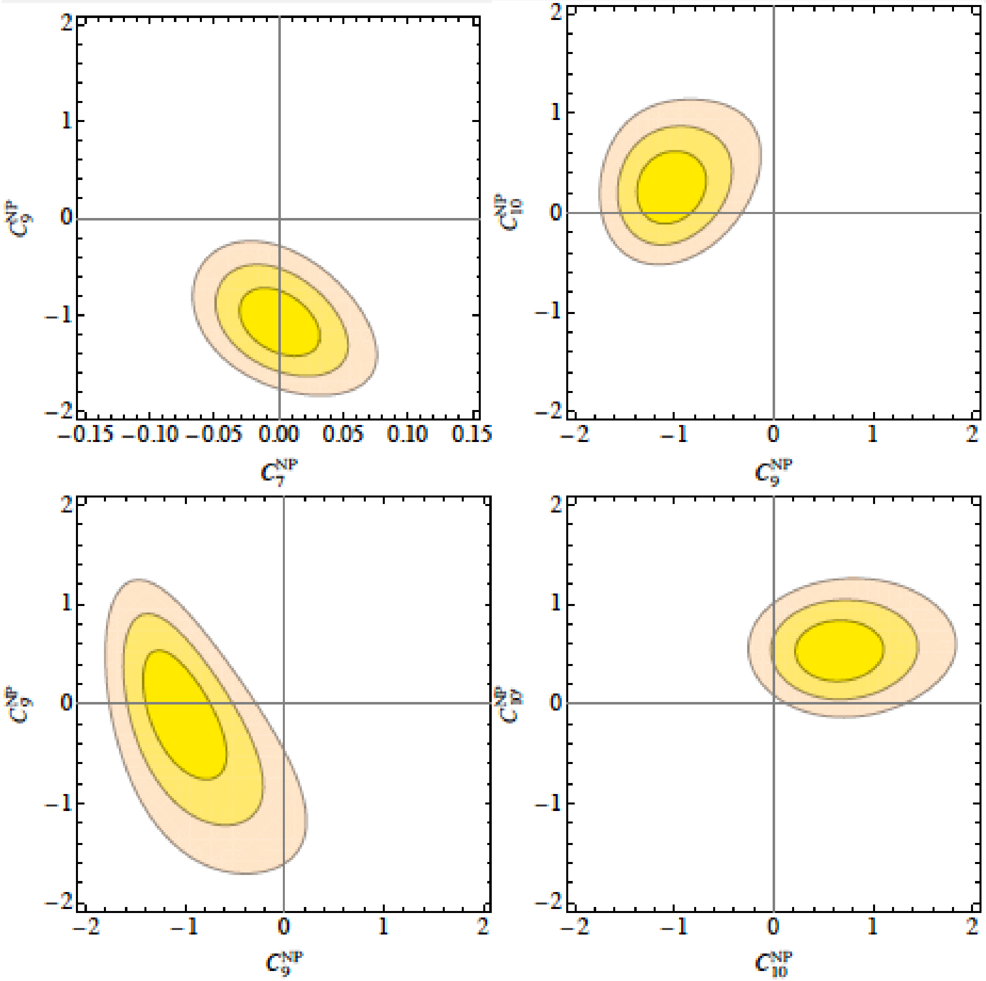
- χ^2 frequentist analysis to determine $C_i(\mu_{ref}) = C_i^{SM} + C_i^{NP}$
- $B \to K^*\mu\mu$ ($P_{1,2}$, $P'_{4,5,6,8}$, F_L: 5 large-recoil + 1 low-recoil bins), $B^+ \to K^+\mu\mu$, $B^0 \to K^0\mu\mu$, $B \to X_s\gamma$, $B \to X_s\mu\mu$, $B_s \to \mu\mu$ (Br), $B \to K^*\gamma$ (A_I and $S_{K^*\gamma}$) [Moriond 15, no correlations]

Hypothesis	Best fit	Pull
$C_9^{\rm NP}$	-1.1	4.6
$C_{10}^{\rm NP}$	0.62	2.4
C'_9	-1.0	3.4
C'_{10}	0.61	3.3
$C_9^{\rm NP} = -C_{10}^{\rm NP}$	-0.62	4.0
$C_9^{\rm NP} = C_{10}^{\rm NP}$	-0.37	1.7
$C_{9'} = C_{10'}$	0.32	1.3
$C_9^{\rm NP} = C_{9'}$	-0.67	4.3
$C_{9'} = -C_{10'}$	-0.42	3.6



$C_9^{NP} < 0$ preferred, but alternatives with $C_9^{\rm NP} = -C_{10}^{\rm NP}$ and $C_9^{\rm NP} = C_{9'}$

Global fits: 2D hypotheses



Hyp.	Best-fit pt	Pull
(C_7^{NP}, C_9^{NP})	(0.0, -1.1)	4.2
(C_9^{NP}, C_{10}^{NP})	(-1.1, 0.2)	4.2
$(C_9^{NP}, C_{9'})$	(-1.0, -0.1)	4.2
$(C_{10}^{NP}, C_{10'})$	(0.5, 0.6)	3.4

$\to$ Main effect from C_9

Explanations ?

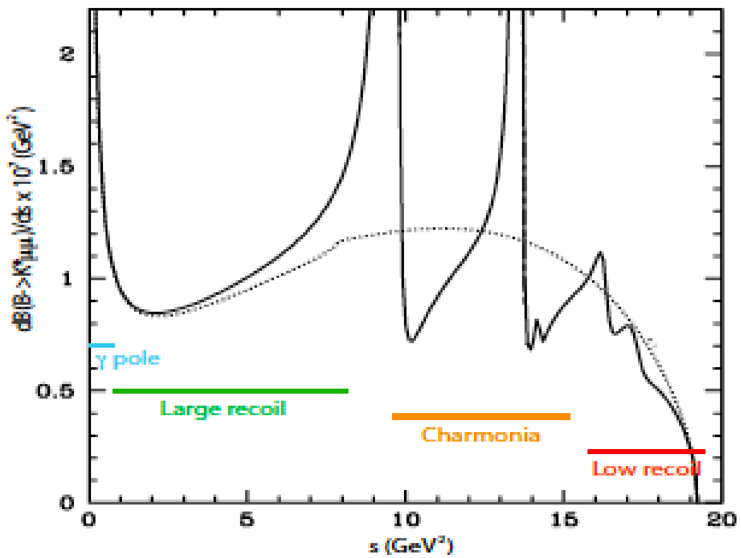
- Z' boson
- Leptoquarks
- Composite models
- Difficult with susy (?)

[Almannshoffer, Straub, Haisch, Gauld, Peczak, Buras, De Fazio, Girrbach, Hiller, Schmaltz, Varzielas, Crivellin. . .]

S. Descotes-Genon (LPT-Orsay) | $b \to s\ell\ell$ 2015 & NP | 12/06/15 | 18

The global fits indicate a hint for BSM in $C_9^{\mu BSM} \simeq -1$; other coefficients can be affected, but to a lesser degree, too. A good fit is obtained with the $SU(2)_L$ relation $C_9 = -C_{10} \simeq -0.6$.

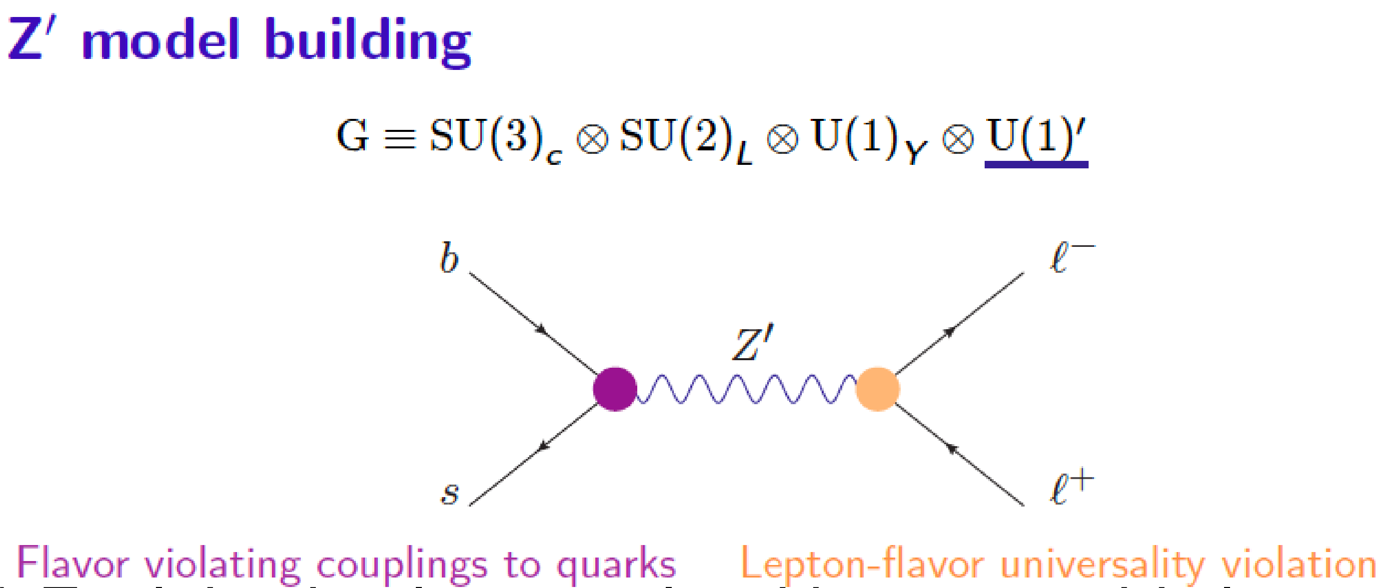
Main TH tasks: understand hadronic uncertainties: power corrections at low q^2, $c\bar{c}$ contributions and improved form factors



- Very large K^*-recoil ($4m_\ell^2 < q^2 < 1$ GeV^2): γ almost real (C_7/q^2 divergence and light resonances)
- Large K^*-recoil ($q^2 < 9$ GeV^2): energetic K^* ($E_{K^*} \gg \Lambda_{QCD}$: form factors via light-cone sum rules LCSR)

If taken at face value, the fit outcome $|C_9^{BSM}| \geq |C_{10}^{BSM}|$requires non-standard model building. $Z \to \ell^+\ell^-$ in SM opposite hierarchy.

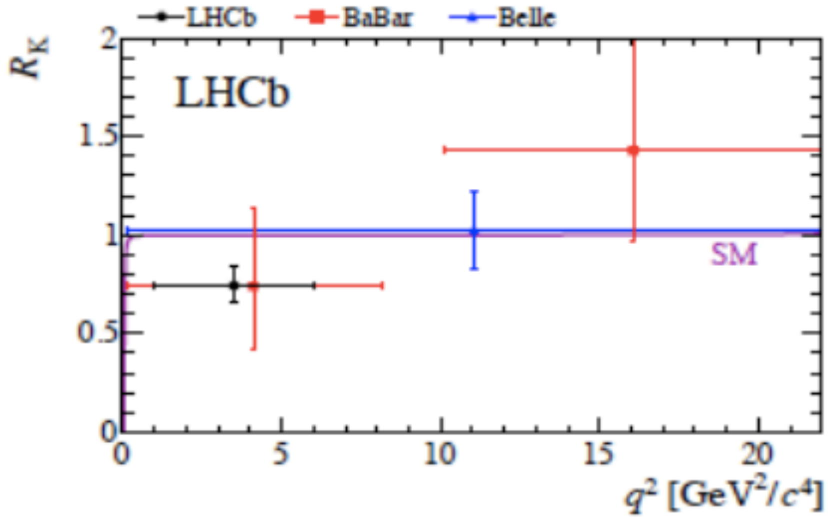
Current proposals: Z' models (Heeck, Fuentes, Vicente), Leptoquarks (de Medeiros Varzielas)



(J.Fuentes) Explain simultaneously with R_K– avoids large hadronic uncertaintes

LNU and LFV in $b \to s$

Ivo de Medeiros, Javier Fuentes, Avelino Vicente, Julian Heeck



$$R_K = \frac{\mathcal{B}(\bar{B}\to\bar{K}\mu\mu)}{\mathcal{B}(\bar{B}\to\bar{K}ee)}$$

Lepton-universal models(SM): $R_K \simeq 1$ very clean

LHCb: $R_K = 0.745 \pm^{0.090}_{0.074} \pm 0.036 < 1$

Activity counter; A.Vicente

Composite Higgs

Buras, Girrbach-Noe, Niehoff, Stangl, Straub

Other

Calibbi, Crivellin, Greljo, Isidori, Marzocca, Ota

Model building

Z' boson

Altmannshofer, Aristizabal Sierra, Buras, Celis, Crivellin, D' Ambrosio, Fuentes-Martín, Gauld, Girrbach-Noe, Goertz, Gori, Haisch, Heeck, Jung, Niehoff, Pospelov, Serôdio, Staub, Straub, Vicente, Yavin

Global fits

Alonso, Altmannshofer, Beaujean, Bobeth, Descotes-Genon, Egede, Ghosh, Grinstein, Hiller, Hurth, Mahmoudi, Martin Camalich, Matias, Nardecchia, Neshatpour, Patel, Petridis, Renner, Schmaltz, Straub, van Dyk, Virto

Leptoquarks

Alonso, Becirevic, Biswas, Chowdhuri, de Medeiros Varzielas, Fajfer, Grinstein, Gripaios, Han, Hiller, Kosnik, Lee, Martin Camalich, Mohanta, Nardecchia, Renner, Sahoo, Schmaltz

$b \to s$ anomalies

Implications - LFV -

Bhattacharya, Boucenna, Civellin, Datta, de Medeiros Varzielas, Glashow, Gripaios, Guadagnoli, Hiller, Hofer, Kane, Lee, London, Matias, Mohanta, Nardecchia, Nierste, Pokorski, Renner, Rosiek, Sahoo, Shivashankara, Tandean, Valle, Vicente

SM uncertainties

Altmannshofer, Bharucha, Descotes-Genon, Ghosh, Hiller, Hofer, Horgan, Hurth, Jaeger, Liu, Lyon, Martin Camalich, Matias, Meinel, Straub, Virto, Wingate, Zwicky

Explanations: Z'-models (BSM in $b \to s\mu\mu$, not in $b \to see$), leptoquarks (both $\mu\mu$ and ee possible), R-Parity violation

Vicente: dark $SM \times U(1)_X$ simultaenous expl of $b \to s$ anomalies and relic density

Fuentes: minimal input $SM \times U(1)$; uses anomaly conditions

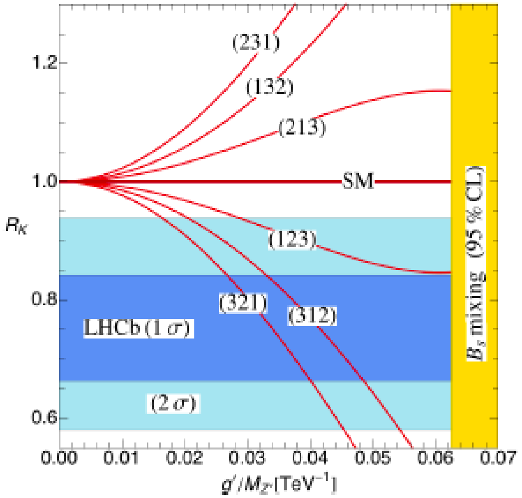
Heeck: gauged $SM \times U(1)_{\tau-\mu}$; amended by extra Higgs-dublet gives $h \to \tau\mu$

Varzielas: Leptoquarks with flavor symmetries, e.g. $U(1)_F$ (quarks) and $A_4 \times Z_3$ for letpons; relate leptoquark couplings to SM masses and mixings.

Correlations $B \to K$ with $B \to K^*$; J.Fuentes

Z′ contributions: ratios and double ratios

- $R_M \equiv \frac{\text{Br}(\bar{B} \to \bar{M}\mu^+\mu^-)}{\text{Br}(\bar{B} \to \bar{M}e^+e^-)}$ $M \in \{K, K^*, X_s, K_0(1430), \ldots\}$



Model	$C_9^{\text{NP}\mu}(1\sigma)$	$C_9^{\text{NP}\mu}(2\sigma)$
(1,2,3)	–	[−2.92, −0.61]
(3,1,2)	[−0.93, −0.43]	[−1.16, −0.17]
(3,2,1)	[−1.20, −0.53]	[−1.54, −0.20]

Good for $B \to K^*\mu^+\mu^-$ ✓

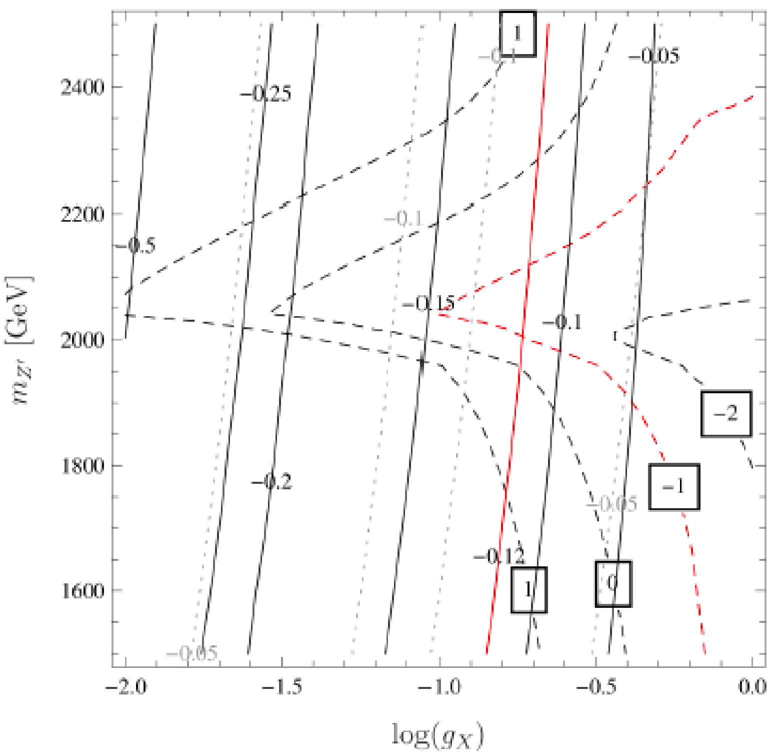
- $\widehat{R}_M \equiv \frac{R_M}{R_K} = 1$ Test of the flavor structure of the model!

[Hiller, Schmaltz '15]

$SM \times U(1)_X$: A.Vicente

Dark matter and LHCb anomalies

$C_9^{\rm NP}/C_9^{\rm SM}$ (full) $\quad \log\left(\Omega_{\rm DM} h^2\right)$ (dashed) $\quad C_9^{\rm NP}/C_9^{\rm SM}$ (tree) (dotted gray)



[DM RD Computed with **micrOMEGAs**]

Parameters:

$$\lambda_Q^b = \lambda_Q^s = 0.025$$

$$\lambda_L^\mu = 0.5$$

$$m_Q = m_L = 1\ \text{TeV}$$

$$m_\chi^2 = 1\ \text{TeV}^2$$

- Compatible with flavor constraints (small quark mixings)
- Resonance required to get the correct DM relic density
- Large loop effects for low g_X

$b \to s$ anomalies– correlations with direct searches: J.Heeck

LHC constraints

Z' couples to first-gen. quarks $\Rightarrow$ direct detection via $pp \to Z' \to \mu^+\mu^-$.

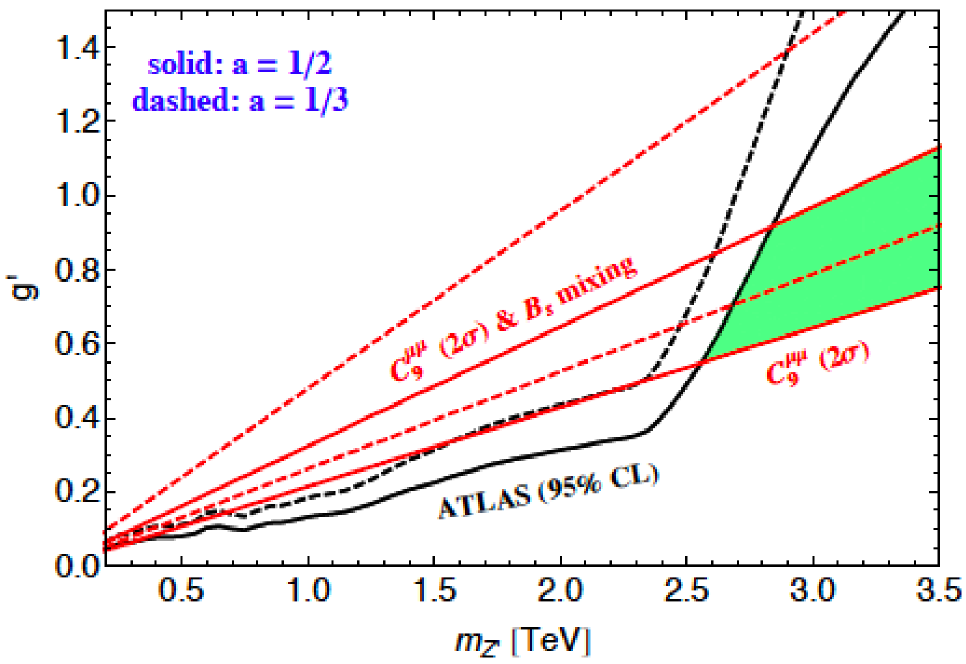
- For $m_t \ll m_{Z'} < 2m_{\nu_R}$:

  $$\mathrm{BR}(Z' \to \mu\mu) \simeq \frac{1}{3+4a^2},$$

  and

  $$ee : \mu\mu : \tau\tau : uu : dd : ss : cc : bb : tt$$
  $$= 0 : 1 : 1 : \frac{a^2}{3} : \frac{a^2}{3} : \frac{a^2}{3} : \frac{a^2}{3} : \frac{4a^2}{3} : \frac{4a^2}{3}.$$

- Can rescale $B-L$ limits from ATLAS [1405.4123].
- Flavor violating decays $Z' \to bs$ suppressed.



Look forward to new LHC run!

In models with LNU there is generically also LFV.

An exception is the minimal $U(1)$ extension by Fuentes.

LFV can show up in B-decays and Higgs decay (Heeck)

predictions in leptoquark model with flavor symmetries (Varzielas):
$M \lesssim 50$ TeV

$$\mathcal{B}(B \to K\mu^{\pm}e^{\mp}) \simeq 3 \cdot 10^{-8}\,\kappa^2 \left(\frac{1-R_K}{0.23}\right)^2 , \quad (1)$$

$$\mathcal{B}(B \to Ke^{\pm}\tau^{\mp}) \simeq 2 \cdot 10^{-8}\,\kappa^2 \left(\frac{1-R_K}{0.23}\right)^2 , \quad (2)$$

$$\mathcal{B}(B \to K\mu^{\pm}\tau^{\mp}) \simeq 2 \cdot 10^{-8} \left(\frac{1-R_K}{0.23}\right)^2 , \quad (3)$$

and

$$\mathcal{B}(\mu \to e\gamma) \simeq 2 \cdot 10^{-12} \, \frac{\kappa^2}{\rho^2} \left(\frac{1 - R_K}{0.23} \right)^2 \,, \tag{4}$$

$$\mathcal{B}(\tau \to e\gamma) \simeq 4 \cdot 10^{-14} \, \frac{\kappa^2}{\rho^2} \left(\frac{1 - R_K}{0.23} \right)^2 \,, \tag{5}$$

$$\mathcal{B}(\tau \to \mu\gamma) \simeq 3 \cdot 10^{-14} \, \frac{1}{\rho^2} \left(\frac{1 - R_K}{0.23} \right)^2 \,, \tag{6}$$

$$\mathcal{B}(\tau \to \mu\eta) \simeq 4 \cdot 10^{-11} \, \rho^2 \left(\frac{1 - R_K}{0.23} \right)^2 \,. \tag{7}$$

asymmetric branching ratios:

$$\frac{\mathcal{B}(B_s \to \ell^+\ell'^-)}{\mathcal{B}(B_s \to \ell^-\ell'^+)} \simeq \frac{m_\ell^2}{m_{\ell'}^2} \,. \quad \text{Left-handed leptons only} \tag{8}$$

$$\frac{\mathcal{B}(B_s \to \mu^+ e^-)}{\mathcal{B}(B_s \to \mu^+\mu^-)_{\rm SM}} \simeq 0.01\,\kappa^2 \cdot \left(\frac{1-R_K}{0.23}\right)^2 , \tag{9}$$

$$\frac{\mathcal{B}(B_s \to \tau^+ e^-)}{\mathcal{B}(B_s \to \mu^+\mu^-)_{\rm SM}} \simeq 4\,\kappa^2 \cdot \left(\frac{1-R_K}{0.23}\right)^2 , \tag{10}$$

$$\frac{\mathcal{B}(B_s \to \tau^+ \mu^-)}{\mathcal{B}(B_s \to \mu^+\mu^-)_{\rm SM}} \simeq 4 \cdot \left(\frac{1-R_K}{0.23}\right)^2 , \tag{11}$$

A.Vicente

Great experimental perspectives!

LFV Process	Present Bound	Future Sensitivity
$\mu \to e\gamma$	5.7×10^{-13}	6×10^{-14} (MEG)
$\tau \to e\gamma$	3.3×10^{-8}	$\sim 10^{-8} - 10^{-9}$ (B factories)
$\tau \to \mu\gamma$	4.4×10^{-8}	$\sim 10^{-8} - 10^{-9}$ (B factories)
$\mu \to 3e$	1.0×10^{-12}	$\sim 10^{-16}$ (Mu3e)
$\tau \to 3e$	2.7×10^{-8}	$\sim 10^{-9} - 10^{-10}$ (B factories)
$\tau \to 3\mu$	2.1×10^{-8}	$\sim 10^{-9} - 10^{-10}$ (B factories)
μ^-, Au $\to e^-$, Au	7.0×10^{-13}	—
μ^-, SiC $\to e^-$, SiC	—	2×10^{-14} (DeeMe)
μ^-, Al $\to e^-$, Al	—	$10^{-15} - 10^{-17}$ (COMET) $10^{-17} - 10^{-18}$ (Mu2e)
μ^-, Ti $\to e^-$, Ti	4.3×10^{-12}	$\sim 10^{-18}$ (PRISM/PRIME)

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Summary

– Anomalies in the flavor sector have inspired new types of bottom-up model-building.

– Leptons and quarks flavor links are becoming important – current $b \to s, c$-anomalies hint at non-SM lepton flavor.

– If LHCb's measurement of R_K substantiates it implies that there is more difference between a muon and an electron than their mass. Lepton-universality, a feature of the $SU(3)_C \times SU(2)_L \times U(1)_Y$ SM appears to be violated in $b \to s$ FCNC transitions.

– Fantastic prospects to progress in understanding of flavor and BSM.

We thank the organizers of WIN'15, all our speakers for great talks and our fantastic session chairs.