FLAVOR PHYSICS: THEORY

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Generational structure & mixing is a feature of the SM and many BSM particles. 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 the "flavor puzzle":
masses, i.e., Y_{SM} do not appear to be random – from where?
with a 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 and $h \to f\bar{f}'$; ongoing & future experiments, too.
we may identify $\mathcal{L}_{BSM}$; complementary to direct searches

Flavor Themes 2015 (simplified)

crosstalk theory(SM/BSM)/pheno/experiment

new bottom-up New Physics benchmark models

leptons $\leftrightarrow$ quarks

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

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

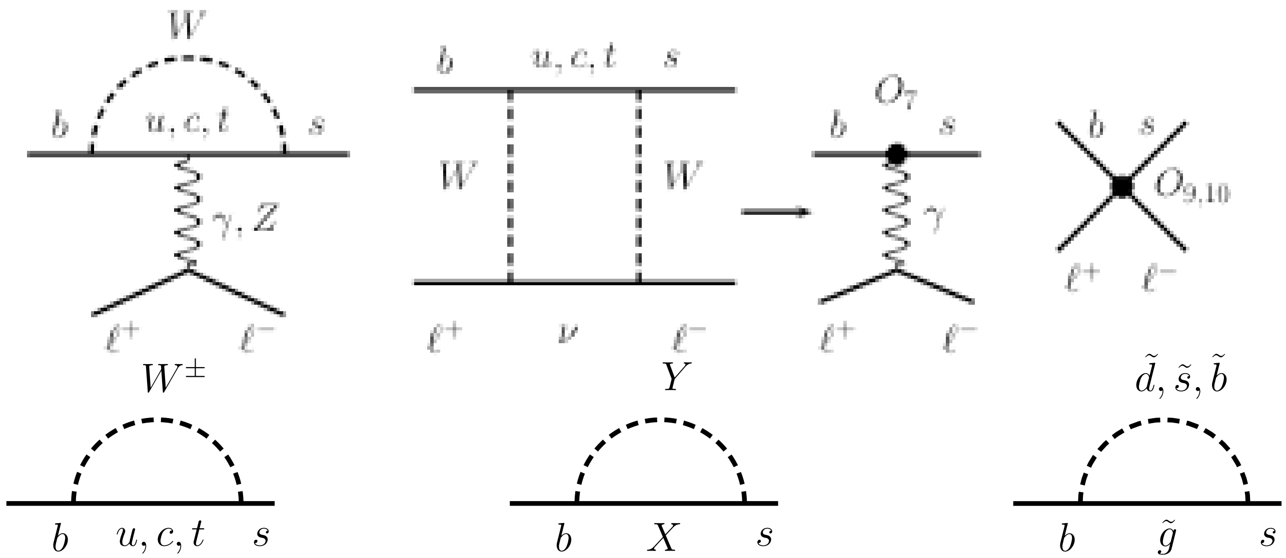
- design/use clean observables; related to (approximate) symmetries of the SM: lepton-nonuniversality, CP, helicity, LFV .. "null tests"

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

- 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

Precision tests of SM with $|\Delta B| = |\Delta S| = 1$ FCNCs



Construct EFT $\mathcal{H}_{\text{eff}} = -4\frac{G_F}{\sqrt{2}} V_{tb}V_{ts}^* \sum_i C_i(\mu)O_i(\mu)$ at dim 6

Perform multi-observable fits to Wilson coefficients $C = C^{SM} + C^{NP}$.
Few groups, dedicated effort, exploit correlations (TH input and exp), outcome depends on details of uncertainties and data set used.

Altmannshofer et al, Bobeth et al, Descotes-Genon et al

V,A operators $\mathcal{O}_9 = [\bar{s}\gamma_\mu P_L b]\,[\bar{\ell}\gamma^\mu \ell]\,, \quad \mathcal{O}'_9 = [\bar{s}\gamma_\mu P_R b]\,[\bar{\ell}\gamma^\mu \ell]$

$$\mathcal{O}_{10} = [\bar{s}\gamma_\mu P_L b]\,[\bar{\ell}\gamma^\mu \gamma_5 \ell]\,, \quad \mathcal{O}'_{10} = [\bar{s}\gamma_\mu P_R b]\,[\bar{\ell}\gamma^\mu \gamma_5 \ell]$$

S,P operators $\mathcal{O}_S = [\bar{s} P_R b]\,[\bar{\ell}\ell]\,, \quad \mathcal{O}'_S = [\bar{s} P_L b]\,[\bar{\ell}\ell]\,,$ ONLY O_9, O_{10} are SM, all other BSM

$$\mathcal{O}_P = [\bar{s} P_R b]\,[\bar{\ell}\gamma_5 \ell]\,, \quad \mathcal{O}'_P = [\bar{s} P_L b]\,[\bar{\ell}\gamma_5 \ell] \qquad C_9^{SM} \simeq -C_{10}^{SM} \simeq 4.2$$

and tensors $\mathcal{O}_T = [\bar{s}\sigma_{\mu\nu} b]\,[\bar{\ell}\sigma^{\mu\nu}\ell]\,, \quad \mathcal{O}_{T5} = [\bar{s}\sigma_{\mu\nu} b]\,[\bar{\ell}\sigma^{\mu\nu}\gamma_5 \ell]$

– 2 dof per Wilson coefficient with non-SM CP-violation

– lepton specific $C_i O_i \to C_i^\ell O_i^\ell$, $\ell = e, \mu, \tau$

– plus LFV operators

$\to$ proliferation of couplings; apply (model-driven/working) assumptions in fits.

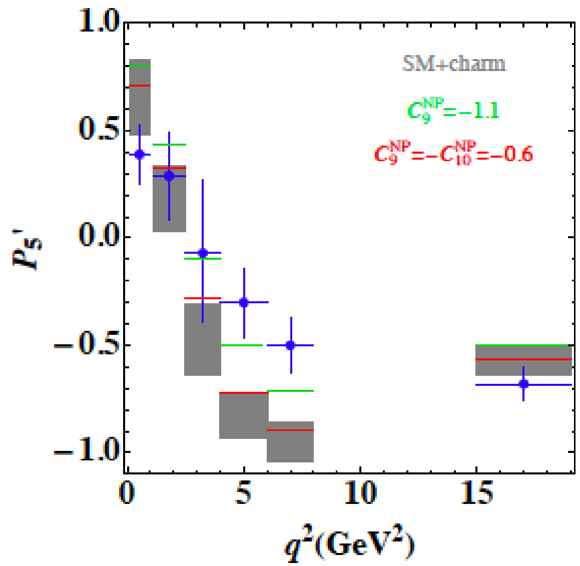
EOS flavor tool http://project.het.physik.tu-dortmund.de/eos/

Fitting dimuon observables globally; Descotes-Genon et al

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

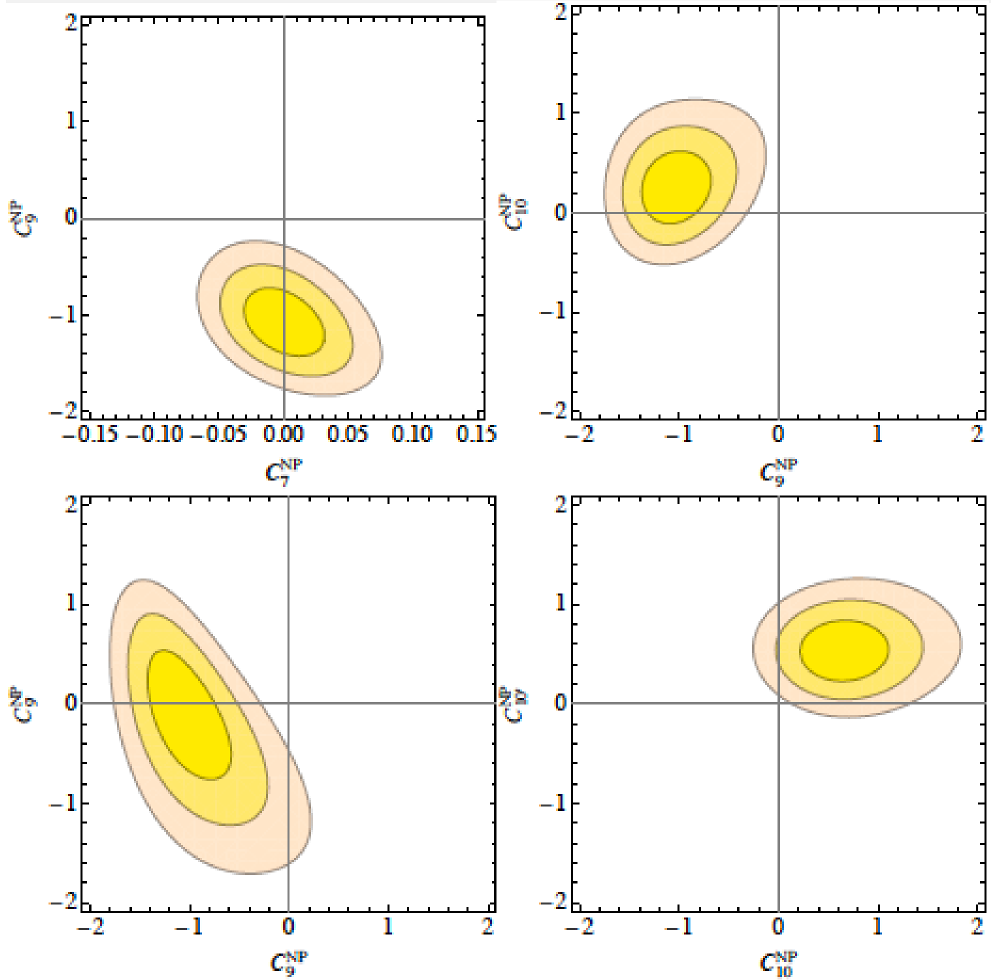


$C_9^{NP} < 0$ preferred, but alternatives with $C_9^{NP} = -C_{10}^{NP}$ and $C_9^{NP} = C_{9'}$

S. Descotes-Genon (LPT-Orsay) | $b \to s\ell\ell$ 2015 & NP | 12/06/15 | 17

Descotes-Genon et al

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 ?

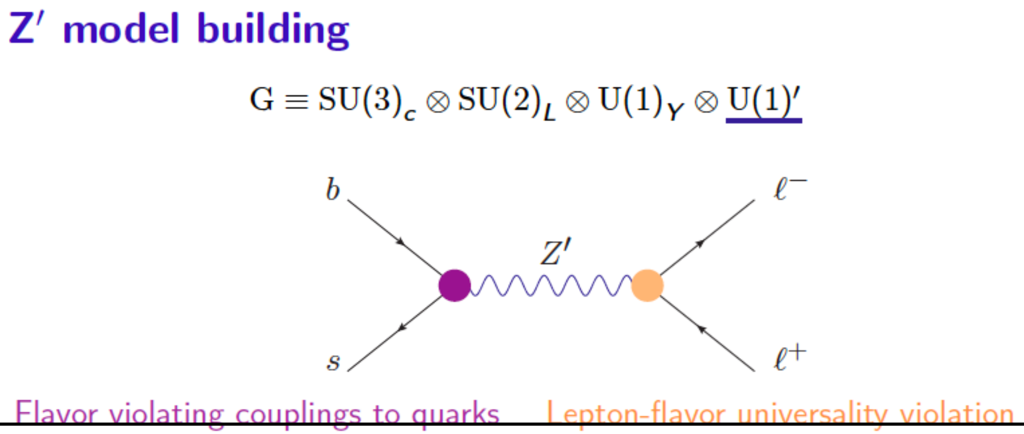
- Z' boson
- Leptoquarks
- Composite models
- Difficult with susy (?)

[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

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

$|C_9^{NP}| \geq |C_{10}^{NP}|$ requires model building different from RS,MSSM etc because Z couplings therein imply $C_9/C_{10} \sim 1 - 4\sin^2\Theta_W \ll 1$. Models who can do this: Z' models Goertz, Haisch, Buras, Girrbach, Heeck, Fuentes, Jung, Crivellin, Vicente,.. et al and leptoquarks Fajfer, Kosnik, Griapios, Nardecchia, Renner, GH Schmaltz, et al Fig from J.Fuentes WIN15



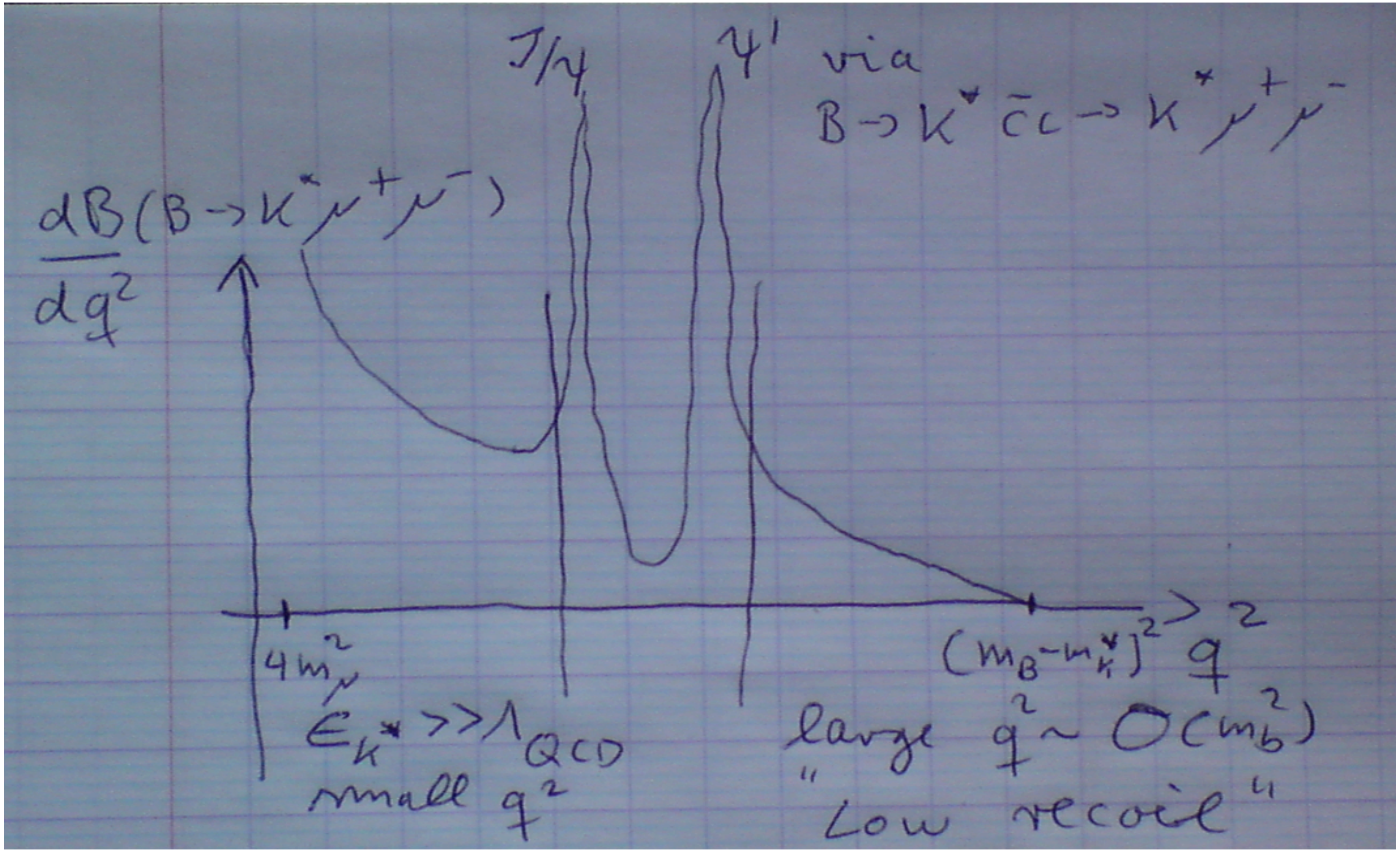
To access the significance of the anomaly requires understanding of hadronic uncertainties. Things are complicated because $O_9 \sim \bar{s}_L \gamma_\mu b_L \ell \gamma^\mu \ell$ gets EM-contributions and resonance contributions such as $B \to K^* \bar{c}c \to K^* \ell\ell$.

Theory is different for the two kinematic regions of interest:

1) Energetic recoiling K^*: QCDF applies BBNS, Beneke, Feldmann, Seidel'01,04

2) Slow K^*: "low recoil" OPE in $1/m_b$ applies Grinstein,Pirjol '04, Beylich, Buchalla,Feldmann'11

Dilepton Mass Spectra in $B \to K^* \mu^+ \mu^-$



Different regions =different uncertainties & systematics

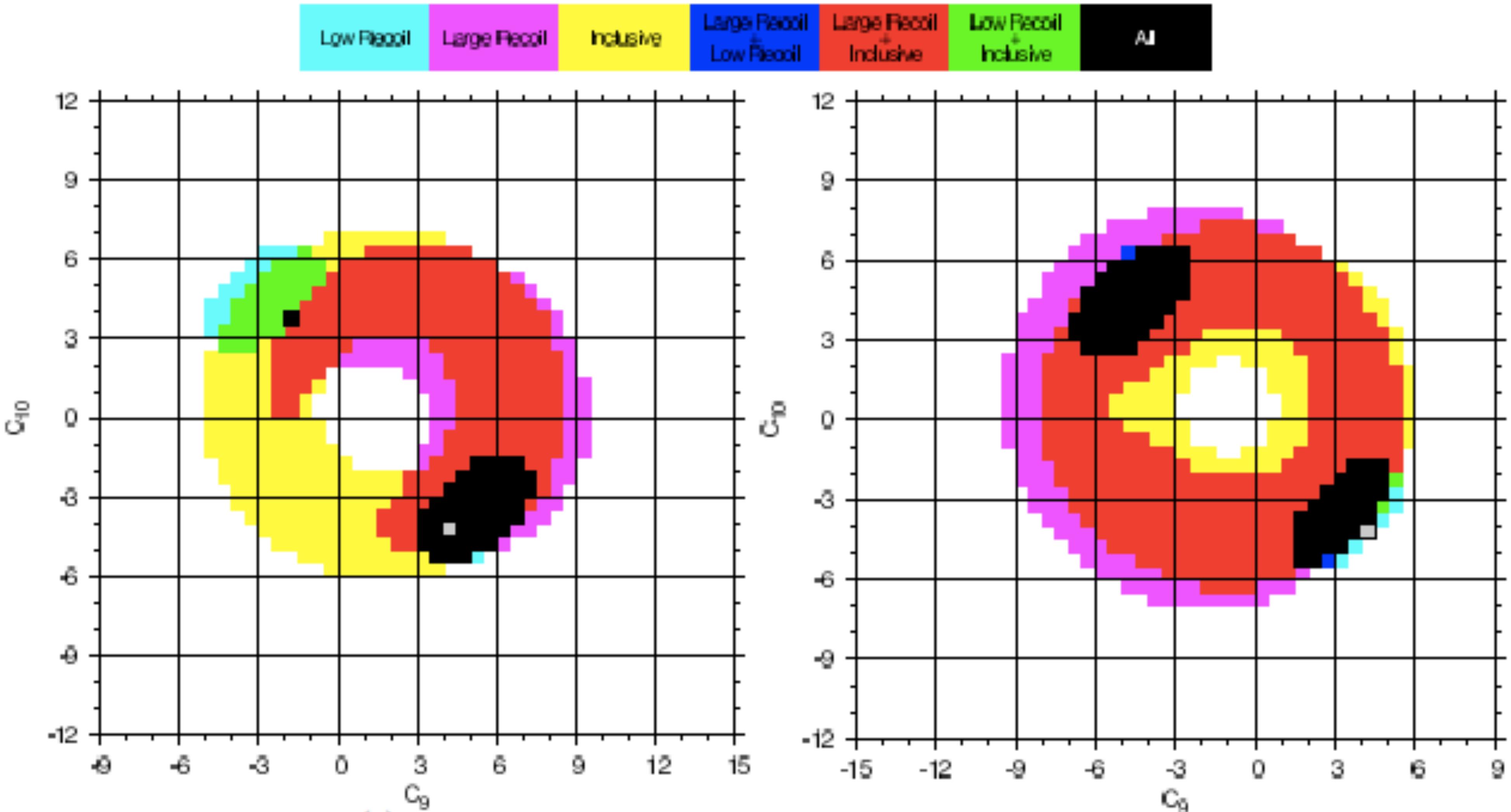


Fig from 1006.5013 Fit to individual sectors and check if results agree.

Uncertainties: Form factors

(Transversity) amplitudes, generically

$$\mathcal{A}_k = \underbrace{f_k}_{\text{hadronic form factor}} \times \underbrace{C_k}_{\text{SM/BSM coefficient}} + \text{non-fact}$$

Form factors $\langle K^*|\bar{s}\Gamma b|B\rangle$ required in whole region; At low recoil from lattice$\rightarrow$ Talk by Ruth van de Water, at low q^2 from light cone sum rules Ball,Braun, Zwicky, Khodjamirian, Mannel, Wang, Pivovarov

Form factor ratios can also be extracted from data at low recoil

Hambrock,GH

Branching ratios $\propto \sum_k |A_k|^2$ large uncertainties; "optimized" observables $=$ ratios of bilinears where form factors drop out at LO in $1/m_b \rightarrow$ more clean $(A_T^{(2)}, P_x', H_T^{(y)})$ Kruger, Matias, Descotes-Genon, Virto,Egede, Bobeth,GH,vanDyk

Uncertainties: power corrections

Non-fact. Λ/m_b corrections pose main theory limitation at low q^2– hence affect interpretation of "P_5' anomaly' – ongoing discussion. At low recoil, power corrections parametrically suppressed by α_s or C_7/C_9 to be below few percent.

Such corrections are

– seen in the data (1 fb^{-1}) assuming SM, at nominal size Beaujean et al

– complex-valued and non-universal functions of q^2; complicate fits

– do not break hierarchies of helicity amplitudes $\mathcal{A}_+ \ll \mathcal{A}_{0,-}$ Camalich, Jager

– absent at zero recoil: no genuine non-factorizable contributions ($1/m_b$, resonances,..) at zero recoil. GH, Zwicky

Uncertainties: charmonia

Higher charmonia $> \Psi'$ pose main theory issue at low recoil;

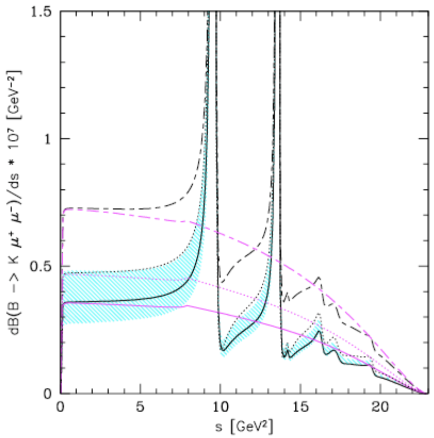


Fig from 9910221, solid: SM, dotted and dot-dashed: susy; local spectrum modeled with $c\bar{c}$ via $e^+e^- \to hadrons$ Kruger, Sehgal

OPE expected to capture this after sufficient binning (size/location).

$\to$ larger bins generically cleaner

no genuine non-factorizable contributions ($1/m_b$, resonances,..) at zero recoil. $\to$ end point bins generically cleaner

Status Low recoil $B \to K^*(\to K\pi)\mu\mu$ –largest bin

observable	LHCb[15,19][a,b]	SM$[15, 19]^d$
F_L	0.344 ± 0.031	$0.351(0.342) \pm 0.010 \pm 0.003$
$A_{\rm FB}$	-0.355 ± 0.029	$-0.391(-0.396) \pm 0.016 \pm 0.005$
S_3	-0.122 ± 0.026	$-0.129(-0.131) \pm 0.009 \pm 0.007$
S_4	0.214 ± 0.029	$0.215(0.218) \pm 0.005 \pm 0.002$
S_5	-0.244 ± 0.029	$-0.230(-0.233) \pm 0.009 \pm 0.006$

[a]Uncertainties added in quadrature and symmetrized. [b]Values adopted to common theory definitions.

LHCb (3 fb^{-1}): LHCb-CONF-2015-002, CERN-LHCb-CONF-2015-002

[d]OPE with $K\pi$ background; central values in parenthesis S-wave subtracted; second uncertainty due to interference (unknown strong phase) Das,GH,Jung

Status Low recoil $B \to K^*(\to K\pi)\mu\mu$ –endpoint bin

observable	LHCb$[17,19]^{a,b}$	SM$[17,19]^{d}$	endpoint
F_L	0.354 ± 0.054	$0.338(0.333) \pm 0.006 \pm 0.002$	$1/3$
$A_{\rm FB}$	-0.306 ± 0.049	$-0.349(-0.351) \pm 0.015 \pm 0.007$	0^c
S_3	-0.145 ± 0.062	$-0.167(-0.169) \pm 0.007 \pm 0.005$	$-1/4$
S_4	0.202 ± 0.052	$0.226(0.227) \pm 0.003 \pm 0.002$	$+1/4$
S_5	-0.245 ± 0.050	$-0.191(-0.193) \pm 0.008 \pm 0.006$	0^c

[a]Uncertainties added in quadrature and symmetrized. [b]Values adopted to common theory definitions.

LHCb (3 fb^{-1}): LHCb-CONF-2015-002, CERN-LHCb-CONF-2015-002

[d]OPE with $K\pi$ background; central values in parenthesis S-wave subtracted; second uncertainty due to interference (unknown strong phase) Das,GH,Jung [c]goes to zero with non-negligible slope

More precise data bring in new backgrounds such as resonant and non-resonant $K\pi$ other than from K^*. S-wave Becirevic, Tayduganov, Blake, Egede, Shires, Matias, Meissner,Wang and higher waves Das, GH,Jung,Shires modify angular distribution. Interference with P-wave matters $\propto 1/(4\pi)$-effect, of lesser importance for narrower Φ. $K\pi$-interference in $B \to K^*\ell\ell$ at low recoil in Br: about $\sim 15\%$, but reduced in ratio-type observables.

The agreement with the SM at low recoil is good, within $(1-2)\sigma$.

Within uncertainties, and barring tuning, the OPE works. Data with finer binning could shed further light on this matter.

(Approximate) symmetries of the SM provide often clean null tests.

Very clean ones are those related to leptons:

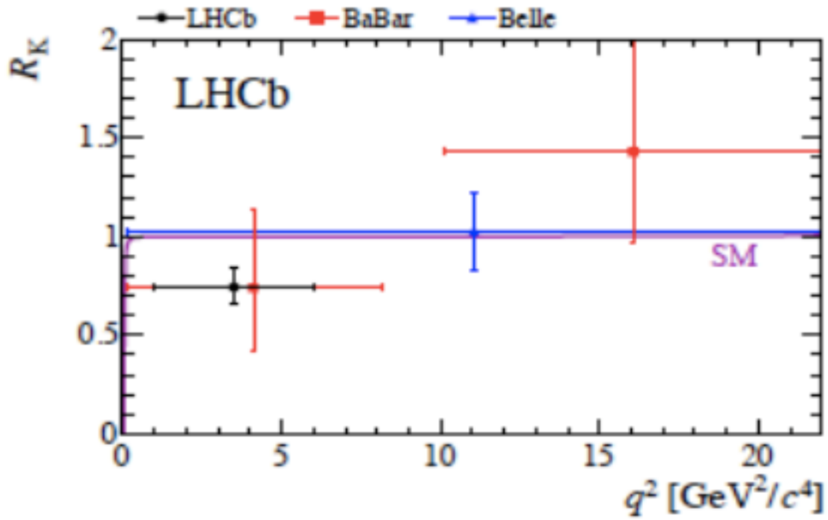
1) Lepton non-universality (LNU) (in SM by charged lepton masses)

2) Lepton flavor violation (LFV) (in SM by neutrino masses)

Such tests can be performed in hadron decays.

$$R_H = \frac{\mathcal{B}(\bar{B}\to\bar{H}\mu\mu)}{\mathcal{B}(\bar{B}\to\bar{H}ee)}, \quad H = K, K^*, X_s, \ldots$$

Lepton-universal models(SM): $R_H = 1+$tiny, GH, Kruger



LHCb 2014: $R_K = 0.745 \pm^{0.090}_{0.074} \pm 0.036 < 1$ at 2.6 σ

apriori too few muons, or too many electrons, or combination thereof.

Model-independent interpretations with V,A operators: Das et al

$$0.7 \lesssim \mathrm{Re}[X^e - X^\mu] \lesssim 1.5\,,$$
$$X^\ell = C_9^{\mathrm{NP}\ell} + C_9^{\prime\ell} - (C_{10}^{\mathrm{NP}\ell} + C_{10}^{\prime\ell})$$

Tensors and S,P muon operators are excluded as sole sources of R_K; S,P electronic operators allowed at 2 σ and require cancellations, testable with $\bar{B} \to \bar{K}ee$ angular distributions.

$X^e \simeq 0$ and $X^\mu \simeq C_9^{\mu NP} \simeq -1$ is consistent with global fit.

Why are muons different from electrons?

Splitting electrons from muons:

Z'- $U(1)_{\tau-\mu}$ (BSM in $b \to s\mu\mu$, not in $b \to see$).

Altmannshofer, Crivellin, Fuentes, Vicente, .. et al

Links with $h \to \tau\mu$ with extras Higgses Cvrivellin et al, Heeck et al

new particle exchanged at tree level, including leptoquarks, MSSM with R-Parity violation amended with Froggatt-Nielsen flavor symmetry (both $\mu\mu$ and/or ee possible) Schmaltz, Gripaios, Varzielas, .. et al

This naturally provides a link for LFV decays Guadagnoli, Kane, Varzielas which however is not strict , Alonso et al, Fuentes et al.

pl see original refs for complete list of contributions to this effort

Leptoquark coupling matrix: $\lambda \equiv \begin{pmatrix} \lambda_{de} & \lambda_{d\mu} & \lambda_{d\tau} \\ \lambda_{se} & \lambda_{s\mu} & \lambda_{s\tau} \\ \lambda_{be} & \lambda_{b\mu} & \lambda_{b\tau} \end{pmatrix}$, $\mathcal{L} = \bar{D}_i \lambda_{ij} \varphi \ell_j$

$C_{10}^{\prime\ell} = -C_9^{\prime\ell} = -\frac{\lambda_{s\ell}\lambda_{b\ell}^*}{2M^2}(24\mathrm{TeV})^2$ $\quad M \lesssim 50$ TeV (B_s-mixing, R_K)

Use flavor symmetry to predict SM masses and leptoquark couplings, eg. $U(1)$-flavor-symmetry for quarks and non-abelian one e.g. A_4 for leptons and assume Higgs to be uncharged. Predicts generically hierarchies for quarks and ”zeros” and ”ones” for leptons.

$$\lambda \sim \lambda_0 \begin{pmatrix} \rho_d \kappa & \rho_d & \rho_d \\ \rho \kappa & \rho & \rho \\ \kappa & 1 & 1 \end{pmatrix}$$

constraints: $\rho_d \lesssim 0.02\,, \kappa \lesssim 0.5\,, 10^{-4} \lesssim \rho \lesssim 1\,, \kappa/\rho \lesssim 0.5\,, \rho_d/\rho \lesssim 1.6$

predictions in leptoquark model with flavor symmetries Varzielas

$$\mathcal{B}(B \to K \mu^\pm e^\mp) \simeq 3 \cdot 10^{-8}\, \kappa^2 \left(\frac{1-R_K}{0.23}\right)^2, \qquad < 3.8 \cdot 10^{-8} @90\% CL$$

$$\mathcal{B}(B \to K e^\pm \tau^\mp) \simeq 2 \cdot 10^{-8}\, \kappa^2 \left(\frac{1-R_K}{0.23}\right)^2, \qquad < 3.0 \cdot 10^{-5} @90\% CL$$

$$\mathcal{B}(B \to K \mu^\pm \tau^\mp) \simeq 2 \cdot 10^{-8} \left(\frac{1-R_K}{0.23}\right)^2, \qquad < 4.8 \cdot 10^{-5}\, @90\% CL.$$

$$\mathcal{B}(\mu \to e\gamma) \simeq 2 \cdot 10^{-12} \frac{\kappa^2}{\rho^2} \left(\frac{1 - R_K}{0.23} \right)^2 , \qquad < 5.7 \cdot 10^{-13} @ 90\% CL$$

$$\mathcal{B}(\tau \to e\gamma) \simeq 4 \cdot 10^{-14} \frac{\kappa^2}{\rho^2} \left(\frac{1 - R_K}{0.23} \right)^2 \qquad < 1.2 \cdot 10^{-7} @ 90\% CL,$$

$$\mathcal{B}(\tau \to \mu\gamma) \simeq 3 \cdot 10^{-14} \frac{1}{\rho^2} \left(\frac{1 - R_K}{0.23} \right)^2 , \qquad < 4.4 \cdot 10^{-8} @ 90\% CL$$

$$\mathcal{B}(\tau \to \mu\eta) \simeq 4 \cdot 10^{-11} \rho^2 \left(\frac{1 - R_K}{0.23} \right)^2 \qquad < 6.5 \cdot 10^{-8} @ 90\% CL.$$

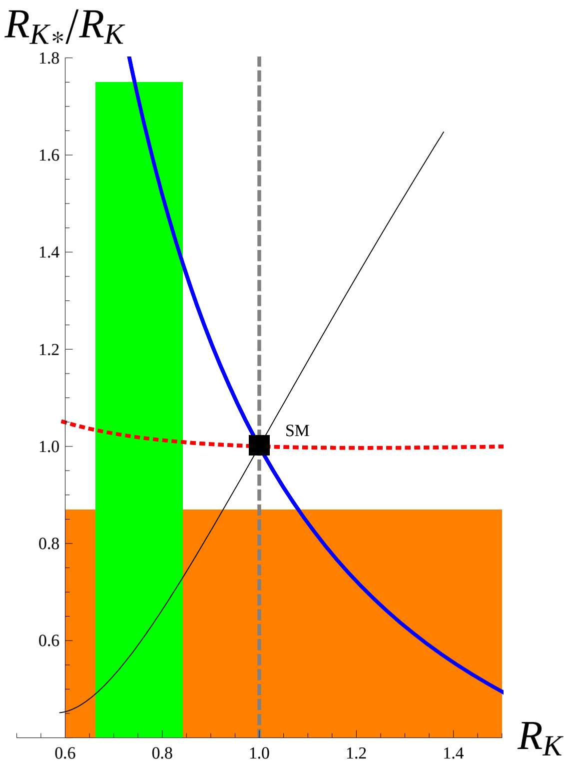
Different spin/parity final states are complementary/ probe right-handed currents; $p, p' \simeq O(1)$:

$$
\begin{aligned}
R_K &\simeq 1 + \Delta_+ \,, \\
R_{K_0(1430)} &\simeq 1 + \Delta_- \,, \\
R_{K^*} &\simeq 1 + p\,(\Delta_- - \Delta_+) + \Delta_+ \,, \\
R_{K_1} &\simeq 1 + p'\,(\Delta_+ - \Delta_-) + \Delta_- \,, \\
R_{X_s} &\simeq 1 + (\Delta_+ + \Delta_-)/2 \,, \\
\Delta_\pm &= \frac{2}{|C_9^{\rm SM}|^2 + |C_{10}^{\rm SM}|^2} \left[{\rm Re}\left(C_9^{\rm SM} (C_9^{{\rm NP}\mu} \pm C_9'^{\mu})^* \right) + {\rm Re}\left(C_{10}^{\rm SM} (C_{10}^{{\rm NP}\mu} \pm C_{10}'^{\mu})^* \right) - (\mu \to e) \right] .
\end{aligned}
$$

$p = \frac{g_0 + g_\parallel}{g_0 + g_\parallel + g_\perp}$ where $\mathcal{B}(\bar{B} \to \bar{K}^* \ell\ell) = \int_{q^2_{\rm min}}^{q^2_{\rm max}} dq^2 \, \frac{d\mathcal{B}}{dq^2} = (g_0 + g_\parallel)|C - C'|^2 + g_\perp |C + C'|^2$

predictions: $R_K = R_\eta \simeq R_{K_1}$, $R_{K^*} = R_\Phi$, and correlations betw. R_H.

Measure two R_H (with $C \pm C'$) and predict all of them !



Green band: R_K 1 sigma LHCb. Curves: different BSM scenarios. red dashed: pure C_{LL}. Black solid: $C_{LL} = -2C_{RL}$. Blue: C_{RL}. Orange band is prediction for R_{K^*} (not significantly measurend) based on R_K and $B \to X_s \ell\ell$: $R_{X_s}^{\mathrm{Belle}'09} = 0.42 \pm 0.25\,, \quad R_{X_s}^{\mathrm{BaBar}'13} = 0.58 \pm 0.19$.

– 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.

– Explanations imply correlations with other FCNC processes including LFV as well as predictions for direct searches, that can be tested in the future, e.g. $M \lesssim 50$ TeV (leptoquark).

– Fantastic prospects to progress in understanding flavor and BSM.

BACK-UP

asymmetric branching ratios:

$$\frac{\mathcal{B}(B_s \to \ell^+\ell'^-)}{\mathcal{B}(B_s \to \ell^-\ell'^+)} \simeq \frac{m_\ell^2}{m_{\ell'}^2} \,. \quad \text{Left-handed leptons only} \tag{1}$$

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

$$\frac{\mathcal{B}(B_s \to \tau^+ e^-)}{\mathcal{B}(B_s \to \mu^+\mu^-)_{\rm SM}} \simeq 4\,\kappa^2 \cdot \left(\frac{1-R_K}{0.23}\right)^2 , \tag{3}$$

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

situation for numerator $\mu\mu$ and denominator ee of R_K separately:

	LHCb[a]	SM[b]
$\mathcal{B}(B \to K\mu\mu)_{[1,6]}$	$(1.21 \pm 0.09 \pm 0.07) \cdot 10^{-7}$	$(1.75^{+0.60}_{-0.29}) \cdot 10^{-7}$
$\mathcal{B}(B \to Kee)_{[1,6]}$	$(1.56^{+0.19+0.06}_{-0.15-0.04}) \cdot 10^{-7}$	same
$R_K\vert_{[1,6]}$	$0.745 \pm^{0.090}_{0.074} \pm 0.036$	$\simeq 1$

[a] 1209.4284 (μ) and 1406.6482 (e) [b] Bobeth, GH, van Dyk '12, form factors from 1006.4945

Individual branching ratios make presently no case for new physics, although muons are a bit below SM. The ratio R_K is much cleaner. Lepton-universal effects – including hadronic ones – drop out in ratios of branching fractions GH,Krüger'03.

Comments:

–$R_K = 0.745 \pm^{0.090}_{0.074} \pm 0.036 < 1$ implies suppressed muons and/or enhanced electrons, that is, BSM in electrons, or muons, or both.

– $R_K \simeq 3/4$ is almost an order 1 effect. Yet, it is not excluded by other data essentially because R_K is so clean and the effect, lepton-nonuniversality in $b \to s$, is quite specific.

– Ongoing precision fits in $B \to K^{(*)}\ell\ell$ decays (Babar,Belle,CDF, ATLAS,CMS,LHCb) 1307.5683, 1308.1501, 1310.2478 dominated from hadron colliders hence give essentially lepton-specific constraints for $\ell = \mu$.

– Electrons much more difficult for LHCb than muons:
$B \to K\mu\mu$: ~ 1226 events, $B \to Kee$: $\sim O(200)$ events.