Rencontres de Moriond, Electroweak Session, 20 March 2015

New physics implications of $b \to s$ measurements

Presented by David M. Straub

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Outline

1. Introduction
2. Model-independent analysis
   - Data vs. Standard Model
   - Data vs. new physics
   - New physics vs. hadronic effects
3. Implications for new physics models
4. Conclusions

$b \to s$ transitions in the LHC era

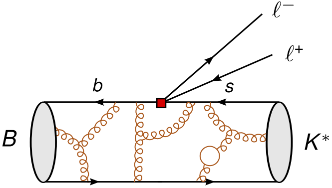
hadronic	$B \to \phi K$, $B \to \eta' K$, $B_s \to \phi\phi$, $B \to K\pi$, $B_s \to KK$, ...
radiative	$B \to X_s \gamma$, $B \to K^* \gamma$, $B_s \to \phi\gamma$, ...
semi-leptonic	$B \to X_s \ell\ell$, $B \to K\ell\ell$, $B \to K^*\ell\ell$, $B_s \to \phi\ell\ell$, ...
leptonic	$B_s \to \mu\mu$
neutrino	$B \to K\nu\bar{\nu}$, $B \to K^*\nu\bar{\nu}$

- Main players to constrain new physics in the LHC era: Leptonic, semi-leptonic & radiative exclusive decays
- Also inclusive decays still being updated by B factories

Theory callenges in exclusive semi-leptonic decays

Perturbative & parametric uncertainties are under control. Main issues:

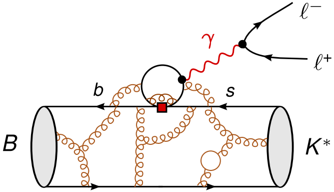
Form factors



- Systematic improvement possible: lattice, light-cone sum rules (LCSR); New results!
- Cross-check: heavy quark limit + corrections (not for BRs!)

(see previous talk)

Hadronic, non-FF corrections



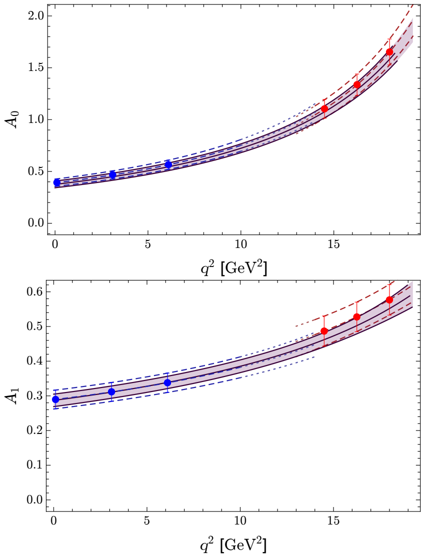
- In particular "charm loop" at low q^2 and broad $c\bar{c}$ resonances at high q^2: Dominant uncertainty and currently only educated guess

[Khodjamirian et al. 1006.4945, Jäger and Camalich 1212.2263, Lyon and Zwicky

New results on $B_{d,s} \to K^*, \rho, \phi, \omega$ form factors

[Bharucha et al. 1503.05534]

- Updated LCSR computation with increased precision
- Combined fit with recent lattice computation [Horgan et al. 1310.3722, Horgan et al. 1501.00367] to obtain predictions in full q^2 range and as consistency check



Red: lattice
Blue: LCSR
Purple: combined fit

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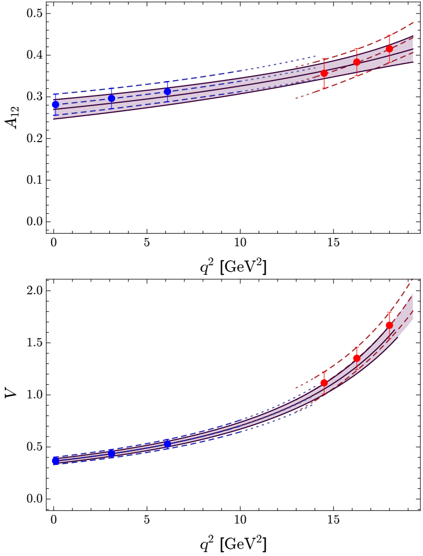

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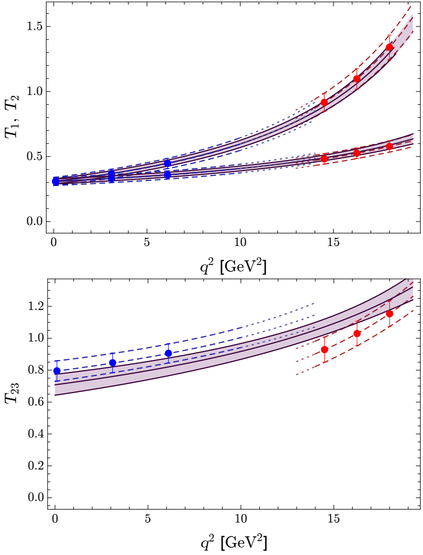
- Updated LCSR computation with increased precision
- Combined fit with recent lattice computation [Horgan et al. 1310.3722, Horgan et al. 1501.00367] to obtain predictions in full q^2 range and as consistency check
- Good agreement except T_{23} (irrelevant for $B \to K^* \mu\mu$ obs.!)

Red: lattice
Blue: LCSR
Purple: combined fit



Using the new form factor results

We provide all our form factors in terms of fit coefficients of a *z*-expansion that can be downloaded including full error correlations as arXiv ancillary files in JSON format.

arXiv.org > hep-ph > arXiv:1503.05534v1

Ancillary files for arXiv:1503.05534v1

There are 8 ancillary files associated with this article. You ma
entire source package as a gzipped tar file (.tar.gz). See ancil

- BKstar_LCSR-Lattice.json (31.0kB)
- BKstar_LCSR.json (30.9kB)
- Bomega_LCSR.json (31.0kB)
- Brho_LCSR.json (31.0kB)
- BsKstar_LCSR-Lattice.json (31.0kB)
- BsKstar_LCSR.json (30.9kB)
- Bsphi_LCSR-Lattice.json (31.0kB)
- Bsphi_LCSR.json (30.8kB)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1. Introduction
2. **Model-independent analysis**
   - Data vs. Standard Model
   - Data vs. new physics
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Global analysis of $b \to s$ transitions

Based on: [Altmannshofer and DS 1411.3161]

Observables included:

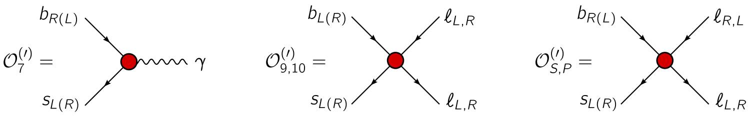
- Angular observables in $\bar{B}^0 \to \bar{K}^{*0}\mu^+\mu^-$
- (Differential) branching ratios of
  - $\bar{B}^0 \to \bar{K}^{*0}\mu^+\mu^-$, $B^- \to K^{*-}\mu^+\mu^-$, $\bar{B}^0 \to \bar{K}^{*0}\mu^+\mu^-$, $B^- \to K^-\mu^+\mu^-$, $B_s \to \phi\mu^+\mu^-$, $B_s \to \mu^+\mu^-$, $\bar{B}^0 \to \bar{K}^{*0}\gamma$, $B^- \to K^{*-}\gamma$, $B \to X_s\gamma$, $B \to X_s\mu^+\mu^-$,

  (NB: full LCSR, lattice form factors crucial for BR predictions)
- Including LHCb, ATLAS, CMS, BaBar, Belle, CDF (+ new LHCb result – thanks to the LHCb collaboration for sharing the data)
- In total, 88 measurements of 76 different observables

See also: [Descotes-Genon et al. 1307.5683, Beaujean et al. 1310.2478, Hurth and Mahmoudi 1312.5267, Hurth et al. 1410.4545]

Model-independent new physics analysis

- NP modifies coefficients of local non-renormalizable operators



$$\mathcal{O}_7^{(\prime)} \propto \frac{m_b}{e}(\bar{s}\sigma_{\mu\nu}P_{R(L)}b)F^{\mu\nu} \quad \mathcal{O}_9^{(\prime)} \propto (\bar{s}\gamma_\mu P_{L(R)}b)(\bar{\ell}\gamma^\mu\ell) \quad \mathcal{O}_{10}^{(\prime)} \propto (\bar{s}\gamma_\mu P_{L(R)}b)(\bar{\ell}\gamma^\mu\gamma_5\ell)$$

- Same Wilson coefficients enter many different processes

Decay	$C_7^{(\prime)}$	$C_9^{(\prime)}$	$C_{10}^{(\prime)}$	$C_{S,P}^{(\prime)}$
$B \to (X_s, K^*)\gamma$	X			
$B \to (X_s, K^{(*)})\ell^+\ell^-$	X	X	X	
$B_s \to \mu^+\mu^-$			X	X

Fit methodology

We construct a χ^2 containg 88 measurements of 76 different observables by 6 different experiments

$$\chi^2(\vec{C}^{\text{NP}}) = \left[\vec{O}_{\text{exp}} - \vec{O}_{\text{th}}(\vec{C}^{\text{NP}})\right]^T \left[\mathcal{C}_{\text{exp}} + \mathcal{C}_{\text{th}}\right]^{-1} \left[\vec{O}_{\text{exp}} - \vec{O}_{\text{th}}(\vec{C}^{\text{NP}})\right].$$

$$C_i = C_i^{\text{SM}} + C_i^{\text{NP}}$$

- Full dependence on Wilson coefficients contained in $\vec{O}_{\text{th}}$
- NP dependence neglected but all correlations retained in $\mathcal{C}_{\text{th}}$
- Theory correlations have an important impact

Fit result in the SM

- χ^2_{SM} =116.9 for 88 measurements (p value 2.14 %)

Including also $b \to s e^+ e^-$ processes:

- χ^2_{SM} =125.8 for 91 measurements (p value 0.92 %)

Biggest tensions: (careful, these observables are not independent! E.g. only P_5' or S_5 in fit)

Decay	obs.	q^2 bin	SM pred.	measurement		pull
$\bar{B}^0 \to \bar{K}^{*0}\mu^+\mu^-$	F_L	$[2, 4.3]$	0.81 ± 0.02	0.26 ± 0.19	ATLAS	$+2.9$
$\bar{B}^0 \to \bar{K}^{*0}\mu^+\mu^-$	F_L	$[4, 6]$	0.74 ± 0.04	0.61 ± 0.06	LHCb	$+1.9$
$\bar{B}^0 \to \bar{K}^{*0}\mu^+\mu^-$	S_5	$[4, 6]$	-0.33 ± 0.03	-0.15 ± 0.08	LHCb	-2.2
$\bar{B}^0 \to \bar{K}^{*0}\mu^+\mu^-$	P_5'	$[1.1, 6]$	-0.44 ± 0.08	-0.05 ± 0.11	LHCb	-2.9
$\bar{B}^0 \to \bar{K}^{*0}\mu^+\mu^-$	P_5'	$[4, 6]$	-0.77 ± 0.06	-0.30 ± 0.16	LHCb	-2.8
$B^- \to K^{*-}\mu^+\mu^-$	$10^7 \frac{dBR}{dq^2}$	$[4, 6]$	0.54 ± 0.08	0.26 ± 0.10	LHCb	$+2.1$
$\bar{B}^0 \to \bar{K}^0\mu^+\mu^-$	$10^8 \frac{dBR}{dq^2}$	$[0.1, 2]$	2.71 ± 0.50	1.26 ± 0.56	LHCb	$+1.9$
$\bar{B}^0 \to \bar{K}^0\mu^+\mu^-$	$10^8 \frac{dBR}{dq^2}$	$[16, 23]$	0.93 ± 0.12	0.37 ± 0.22	CDF	$+2.2$
$B_s \to \phi\mu^+\mu^-$	$10^7 \frac{dBR}{dq^2}$	$[1, 6]$	0.48 ± 0.06	0.23 ± 0.05	LHCb	$+3.1$

Best-fit values for NP in individual Wilson coefficients

Coeff.	best fit	1σ	2σ	$\sqrt{\chi^2_{\text{b.f.}} - \chi^2_{\text{SM}}}$	p [%]
C_7^{NP}	-0.04	$[-0.07, -0.01]$	$[-0.10, 0.02]$	1.42	2.4
C_7'	0.01	$[-0.04, 0.07]$	$[-0.10, 0.12]$	0.24	1.8
C_9^{NP}	-1.07	$[-1.32, -0.81]$	$[-1.54, -0.53]$	3.70	11.3
C_9'	0.21	$[-0.04, 0.46]$	$[-0.29, 0.70]$	0.84	2.0
C_{10}^{NP}	0.50	$[0.24, 0.78]$	$[-0.01, 1.08]$	1.97	3.2
C_{10}'	-0.16	$[-0.34, 0.02]$	$[-0.52, 0.21]$	0.87	2.0
$C_9^{\text{NP}} = C_{10}^{\text{NP}}$	-0.22	$[-0.44, 0.03]$	$[-0.64, 0.33]$	0.89	2.0
$C_9^{\text{NP}} = -C_{10}^{\text{NP}}$	-0.53	$[-0.71, -0.35]$	$[-0.91, -0.18]$	3.13	7.1
$C_9' = C_{10}'$	-0.10	$[-0.36, 0.17]$	$[-0.64, 0.43]$	0.36	1.8
$C_9' = -C_{10}'$	0.11	$[-0.01, 0.22]$	$[-0.12, 0.33]$	0.93	2.0

Significance of C_9^{NP} and $C_9^{\text{NP}} = -C_{10}^{\text{NP}}$ virtually unchanged! $C_9^{\text{NP}}|_{\text{b.f.}}$ slightly smaller

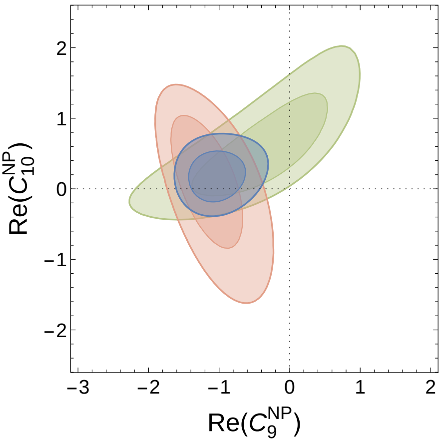
$\chi^2_{\text{SM}} = 116.9$ for 88 measurements ($p = 2.14$ %); $b \to s e^+ e^-$ not included

... including also $b \to s\, e^+ e^-$

Coeff.	best fit	1σ	2σ	$\sqrt{\chi^2_{\text{b.f.}} - \chi^2_{\text{SM}}}$	p [%]
C_7^{NP}	-0.04	$[-0.07, -0.02]$	$[-0.10, 0.01]$	1.52	1.1
C_7'	0.00	$[-0.05, 0.06]$	$[-0.11, 0.11]$	0.05	0.8
C_9^{NP}	-1.12	$[-1.34, -0.88]$	$[-1.55, -0.63]$	4.33	10.6
C_9'	-0.04	$[-0.26, 0.18]$	$[-0.49, 0.40]$	0.18	0.8
C_{10}^{NP}	0.65	$[0.40, 0.91]$	$[0.17, 1.19]$	2.75	2.5
C_{10}'	-0.01	$[-0.19, 0.16]$	$[-0.36, 0.33]$	0.09	0.8
$C_9^{\text{NP}} = C_{10}^{\text{NP}}$	-0.20	$[-0.41, 0.05]$	$[-0.60, 0.33]$	0.82	0.8
$C_9^{\text{NP}} = -C_{10}^{\text{NP}}$	-0.57	$[-0.73, -0.41]$	$[-0.90, -0.27]$	3.88	6.8
$C_9' = C_{10}'$	-0.08	$[-0.33, 0.17]$	$[-0.58, 0.41]$	0.32	0.8
$C_9' = -C_{10}'$	-0.00	$[-0.11, 0.10]$	$[-0.22, 0.20]$	0.03	0.8

χ^2_{SM} =125.8 for 91 measurements ($p = 0.92$ %)

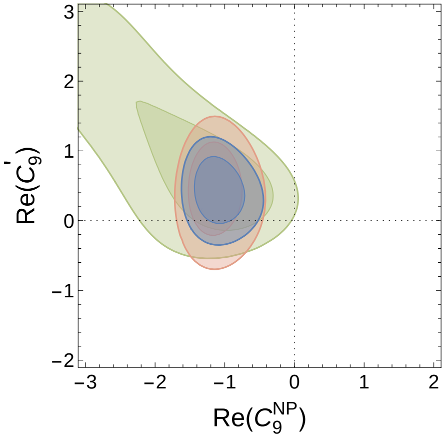
Allowed regions for 2 (real) Wilson coefficients



- Angular observables (new data) prefer $C_9^{\mathrm{NP}} < 0$, insensitive to C_{10}^{NP}
- Branching ratios are compatible with $C_9^{\mathrm{NP}} < 0$ as well as the SM

Green: all branching ratios | Red: $B \to K^* \mu^+ \mu^-$ angular observables | Blue: Global fit

Allowed regions for 2 (real) Wilson coefficients

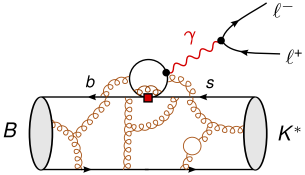


- Branching ratios pull slightly towards $C_9' > 0$

Green: all branching ratios | Red: $B \to K^* \mu^+ \mu^-$ angular observables | Blue: Global fit

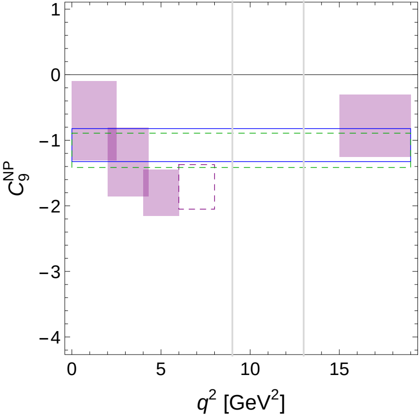
Physics beyond the SM or unexpected hadronic effect?

- Hadronic effects like charm loop are photon-mediated $\Rightarrow$ vector-like coupling to leptons just like C_9



- How to disentangle NP $\leftrightarrow$ QCD?
  - Hadronic effect can have different q^2 dependence
  - Hadronic effect is lepton flavour universal ($\longrightarrow R_K$!)

Important cross-check: q^2 dependence of C_9 best fit



- Fit to all $B \to K^* \mu\mu$ measurements from all experiments but split by q^2 bins

Blue: full global fit | Green: full $B \to K^* \mu\mu$ fit
NB: $[6, 8]$ bin not included in full fits

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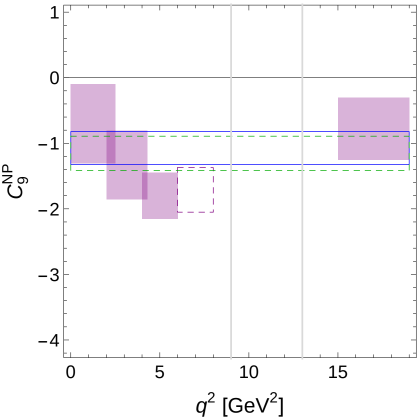

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- New physics interpretation: should be q^2-independent. Consistent at $\sim 1\sigma$.

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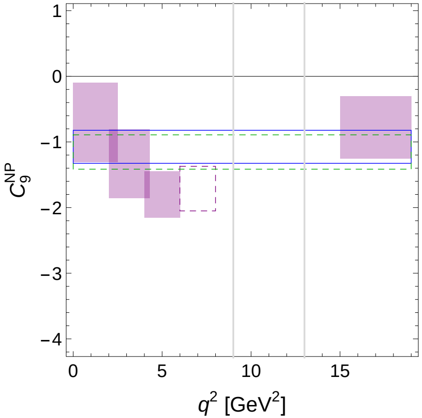

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- Form factor problem: expect to show up at ends of spectrum where one method (LCSR, lattice) dominates. Not the case!

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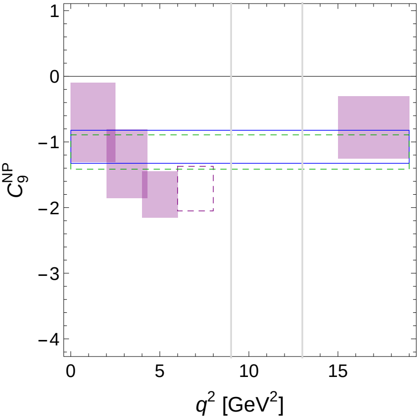

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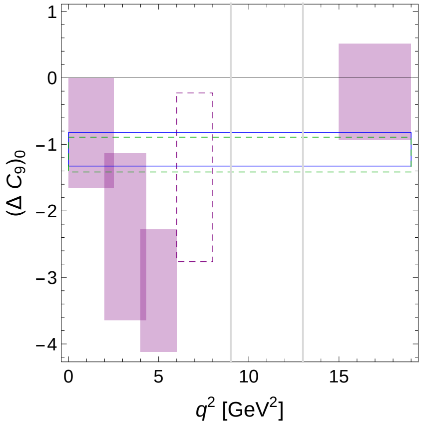
- Fit to all $B \to K^* \mu\mu$ measurements from all experiments but split by q^2 bins
- New physics interpretation: should be q^2-independent. Consistent at $\sim 1\sigma$.
- Form factor problem: expect to show up at ends of spectrum where one method (LCSR, lattice) dominates. Not the case!
- Charm loop: expect to dominate at low q^2 and grow towards the J/ψ. Possible interpretation.

Helicity dependence of shift in C_9



- Charm effect corresponds to q^2-dependent shift of C_9, possibly different in H_0 and H_- helicity amplitudes
- Shift in individual amplitudes requires huge (crazy) values

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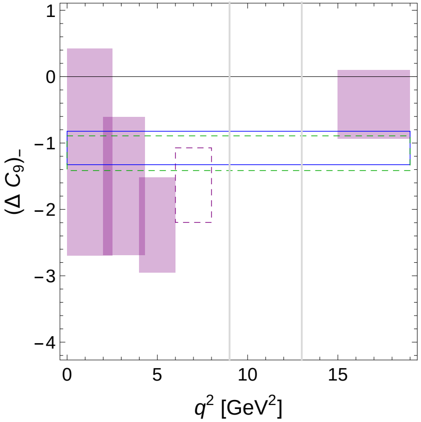

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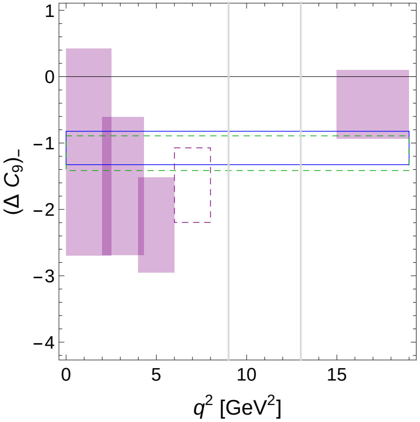

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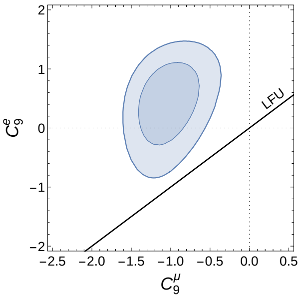
- Charm effect corresponds to q^2-dependent shift of C_9, possibly different in H_0 and H_- helicity amplitudes
- Shift in individual amplitudes requires huge (crazy) values
- If it is a charm effect, it has to enter in H_0 and H_- with the same sign and roughly same size (just like C_9^{NP} would)

Interesting hint or cruel coincidence?

Violation of lepton flavour universality?

$$R_K = \frac{\text{BR}(B \to K\mu^+\mu^-)_{[1,6]}}{\text{BR}(B \to Ke^+e^-)_{[1,6]}} = 0.745^{+0.090}_{-0.074} \pm 0.036\,, \quad R_K^{\text{SM}} \simeq 1.00$$

- Impossible to explain by hadronic effect!
- Just what one would expect if $B \to K^*\mu^+\mu^-$ tensions are due to NP involving only muons



Global fit of $b \to s\mu\mu$ and $b \to see$

(cf. [Ghosh et al. 1408.4097, Hurth et al. 1410.4545])

Violation of lepton flavour universality?

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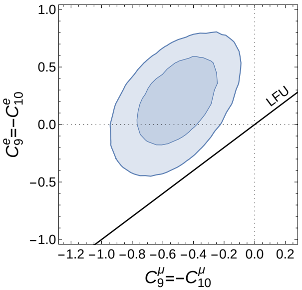

Global fit of $b \to s\mu\mu$ and $b \to see$

(cf. [Ghosh et al. 1408.4097, Hurth et al. 1410.4545])

Future tests of LFU

Spectacular deviations in $B \to K^* \mu^+ \mu^-$ vs. $B \to K^* e^+ e^-$ angular observables and others can distinguish between different scenarios!

Observable	Ratio of muon vs. electron mode			
	$C_9^{NP} = -1.5$	-1.5	-0.7	-1.3
	$C_9' = 0$	0.8	0	0
	$C_{10}^{NP} = 0$	0	0.7	0.3
$10^7 \frac{dBR}{dq^2}(\bar{B}^0 \to \bar{K}^{*0} \ell^+ \ell^-)_{[1,6]}$	0.83	0.77	0.79	0.81
$10^7 \frac{dBR}{dq^2}(\bar{B}^0 \to \bar{K}^{*0} \ell^+ \ell^-)_{[15,22]}$	0.76	**0.69**	0.76	0.75
$A_{FB}(\bar{B}^0 \to \bar{K}^{*0} \ell^+ \ell^-)_{[4,6]}$	**0.18**	**0.10**	0.75	**0.27**
$S_5(\bar{B}^0 \to \bar{K}^{*0} \ell^+ \ell^-)_{[4,6]}$	**0.66**	**0.66**	0.93	0.71
$10^8 \frac{dBR}{dq^2}(B^+ \to K^+ \ell^+ \ell^-)_{[1,6]}$	0.75	0.82	0.77	0.74
$10^8 \frac{dBR}{dq^2}(B^+ \to K^+ \ell^+ \ell^-)_{[15,19]}$	0.75	0.83	0.77	0.75

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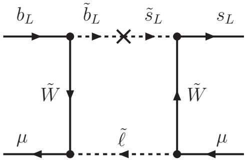
If the tensions are due to new physics . . .

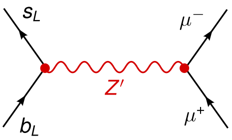
- . . . they are unlikely to be induced by a loop effect (SM $C_{9,10}$ are not chirality suppressed, CKM suppression weak)
- Example: MSSM [Altmannshofer and DS 1308.1501, Altmannshofer and DS 1411.3161]



  - Loop-induced Z-penguin can give a non-negligible contribution, but lepton flavour universal and with $C_9 \ll C_{10}$

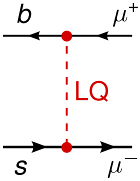
Tree-level new physics in $b \to s\mu^+\mu^-$

s-channel: Z' boson



[Altmannshofer and DS 1308.1501, Gauld et al. 1308.1959, Buras and Girrbach 1309.2466, Gauld et al. 1310.1082, Buras et al. 1311.6729, Altmannshofer et al. 1403.1269, Buras et al. 1409.4557, Glashow et al. 1411.0565, Crivellin et al. 1501.00993, Altmannshofer and DS 1411.3161, Crivellin et al. 1503.03477]

t-channel: scalar or vector leptoquark



[Hiller and Schmaltz 1408.1627, Biswas et al. 1409.0882, Buras et al. 1409.4557, Sahoo and Mohanta 1501.05193, Hiller and Schmaltz 1411.4773]

Z' models

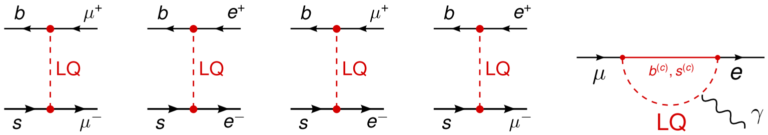
- Stringent constraints on couplings: bsZ' from B_s mixing, eeZ' from LEP, uuZ', ddZ' from LHC

Selection of interesting models/limiting cases:

- Coupling to $L_\mu - L_\tau$
  [Altmannshofer et al. 1403.1269, Crivellin et al. 1501.00993, Crivellin et al. 1503.03477]
  - Effect in C_9 only, violation of LFU
- Composite Higgs with partially composite muons [Niehoff et al. 1503.03865]
  - $C_9^{\rm NP} = -C_{10}^{\rm NP}$, violation of LFU
- Coupling to 3rd generation leptons in the flavour basis
  [Glashow et al. 1411.0565]
  - $C_9^{\rm NP} = -C_{10}^{\rm NP}$, violation of LFU, lepton flavour violation

Leptoquark models

- Can be spin 0 or 1, different representations possible
- Single leptoquark leads to $C_9^{\text{NP}} = \pm C_{10}^{\text{NP}}$
- Cannot be lepton flavour universal and conserving at the same time! (see e.g. [Buras et al. 1409.4557, Varzielas and Hiller 1503.01084])



- measurements of $R_{K^{(*)}}$ and searches for $b \to s\, e^\pm \mu^\mp$ and $\mu \to e\gamma$ should be able to test these models with zero hadronic uncertainties! (Barring more contrived cases with cancellations . . .)

Conclusions & Outlook

- **The $B \to K^* \mu^+ \mu^-$ anomaly persists.** Solution with new physics in C_9 preferred globally over SM by 3.7σ, including R_K by 4.3σ
- q^2 dependence indicates that (unexpectedly) huge charm effect mimicking $C_9^{\text{NP}} < 0$ at intermediate q^2 could solve the tensions as well

Conclusions & Outlook

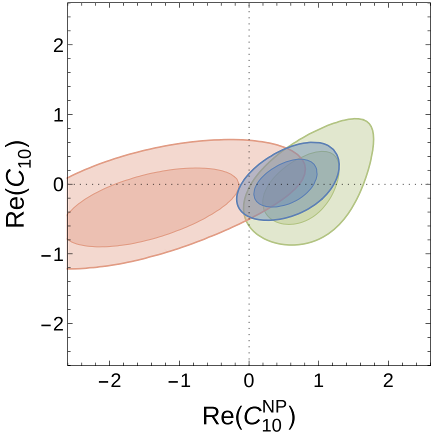
- **The $B \to K^* \mu^+ \mu^-$ anomaly persists.** Solution with new physics in C_9 preferred globally over SM by 3.7σ, including R_K by 4.3σ
- q^2 dependence indicates that (unexpectedly) huge charm effect mimicking $C_9^{\text{NP}} < 0$ at intermediate q^2 could solve the tensions as well

Shopping list to solve this puzzle

- Measure R_{K^*} and ratio of $B \to K^* \ell^+ \ell^-$ $(\ell = e, \mu)$ angular observables
- Search for $B \to K^{(*)} e^\pm \mu^\mp$ and similar LFV decays
- Improve precision on BR($B_s \to \mu^+ \mu^-$) (to pin down C_{10})
- Theory:
  - Fit the "charm loop" from data assuming the SM and discuss if such a huge effect is conceivable
  - More reliable estimates including strong phase

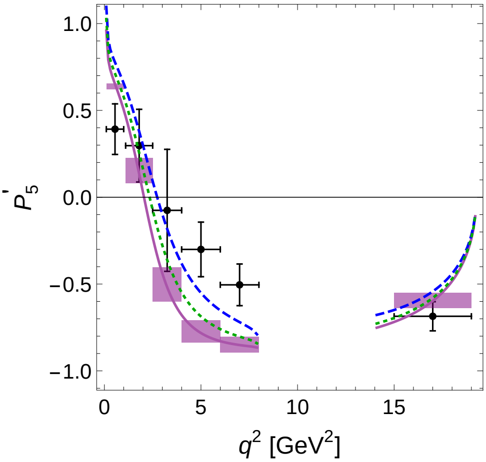
Bonus material

C_{10}^{NP} vs. C'_{10}



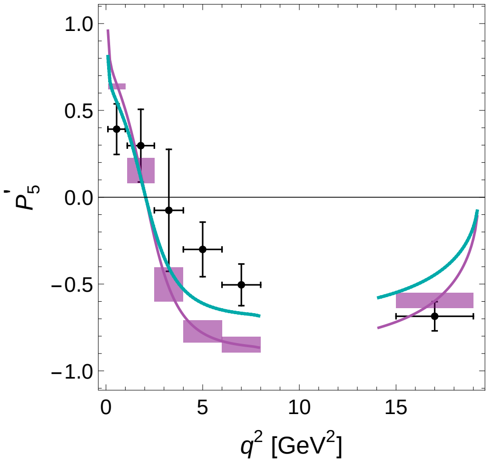
Green: all branching ratios | Red: $B \to K^* \mu^+ \mu^-$ angular observables | Blue: Global fit

Comparing new physics predictions for P_5'



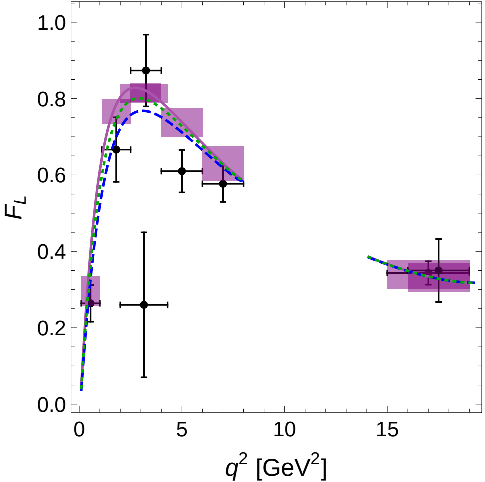
- Blue dashed: $C_9^{\text{NP}} = -1.1$ fits best at intermediate q^2
- Green dotted: $C_9^{\text{NP}} = -C_{10}^{\text{NP}} = -0.55$ fits slightly better in first and last bin

Comparing new physics predictions for P_5'



- Blue dashed: $C_9^{NP} = -1.1$ fits best at intermediate q^2
- Green dotted: $C_9^{NP} = -C_{10}^{NP} = -0.55$ fits slightly better in first and last bin
- Cyan: Negative C_9' (here -1.5) is the only way (with 1 coefficient) to suppress $|P_5'|$ in 1st and 4th bin

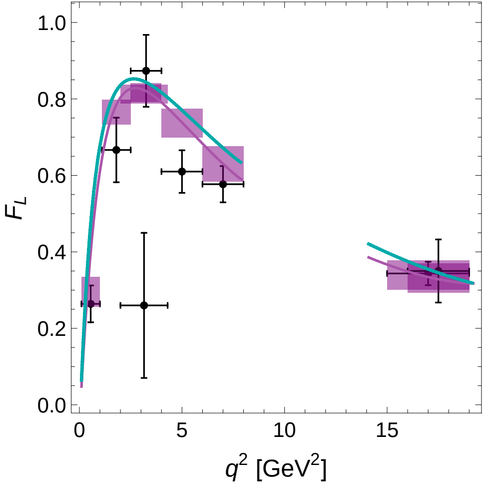
Comparing new physics predictions for F_L



(Low [2, 4.3] data point from ATLAS for comparison)

- $C_9^{\text{NP}} < 0$ and $C_9^{\text{NP}} = -C_{10}^{\text{NP}} < 0$ scenarios predict suppression of F_L

Comparing new physics predictions for F_L



(Low [2, 4.3] data point from ATLAS for comparison)

- $C_9^{\text{NP}} < 0$ and $C_9^{\text{NP}} = -C_{10}^{\text{NP}} < 0$ scenarios predict suppression of F_L
- $C_9' < 0$ predicts enhancement of F_L – not supported by the data

Fits with increased uncertainties

1. Nominal fit

Coeff.	best fit	1σ	2σ	$\sqrt{\chi^2_{\text{b.f.}} - \chi^2_{\text{SM}}}$	p [%]
C_7^{NP}	-0.04	$[-0.07, -0.01]$	$[-0.10, 0.02]$	1.42	2.4
C_7'	0.01	$[-0.04, 0.07]$	$[-0.10, 0.12]$	0.24	1.8
C_9^{NP}	-1.07	$[-1.32, -0.81]$	$[-1.54, -0.53]$	3.70	11.3
C_9'	0.21	$[-0.04, 0.46]$	$[-0.29, 0.70]$	0.84	2.0
C_{10}^{NP}	0.50	$[0.24, 0.78]$	$[-0.01, 1.08]$	1.97	3.2
C_{10}'	-0.16	$[-0.34, 0.02]$	$[-0.52, 0.21]$	0.87	2.0
$C_9^{\text{NP}} = C_{10}^{\text{NP}}$	-0.22	$[-0.44, 0.03]$	$[-0.64, 0.33]$	0.89	2.0
$C_9^{\text{NP}} = -C_{10}^{\text{NP}}$	-0.53	$[-0.71, -0.35]$	$[-0.91, -0.18]$	3.13	7.1
$C_9' = C_{10}'$	-0.10	$[-0.36, 0.17]$	$[-0.64, 0.43]$	0.36	1.8
$C_9' = -C_{10}'$	0.11	$[-0.01, 0.22]$	$[-0.12, 0.33]$	0.93	2.0

Fits with increased uncertainties

2. Doubled form factor uncertainties

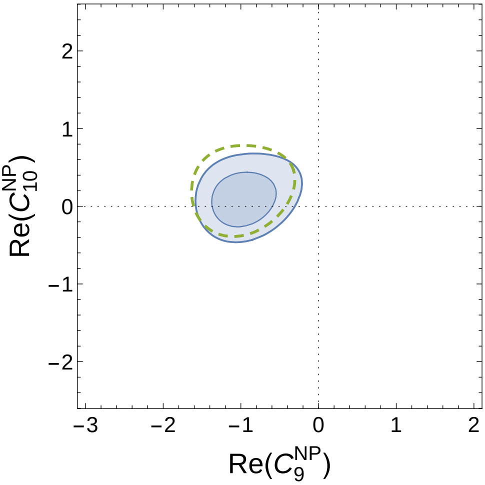
Coeff.	best fit	1σ	2σ	$\sqrt{\chi^2_{\text{b.f.}} - \chi^2_{\text{SM}}}$	p [%]
C_7^{NP}	-0.04	$[-0.07, -0.01]$	$[-0.10, 0.03]$	1.22	5.6
C_7'	0.01	$[-0.05, 0.06]$	$[-0.11, 0.11]$	0.12	4.6
C_9^{NP}	-1.25	$[-1.51, -0.96]$	$[-1.74, -0.63]$	3.62	21.1
C_9'	0.16	$[-0.21, 0.53]$	$[-0.57, 0.91]$	0.43	4.7
C_{10}^{NP}	0.41	$[0.11, 0.73]$	$[-0.17, 1.09]$	1.39	6.
C_{10}'	-0.13	$[-0.36, 0.11]$	$[-0.60, 0.34]$	0.55	4.8
$C_9^{\text{NP}} = C_{10}^{\text{NP}}$	-0.26	$[-0.49, 0.00]$	$[-0.69, 0.33]$	0.99	5.2
$C_9^{\text{NP}} = -C_{10}^{\text{NP}}$	-0.65	$[-0.91, -0.41]$	$[-1.18, -0.18]$	2.83	12.4
$C_9' = C_{10}'$	-0.10	$[-0.39, 0.19]$	$[-0.70, 0.47]$	0.35	4.7
$C_9' = -C_{10}'$	0.09	$[-0.07, 0.25]$	$[-0.23, 0.40]$	0.56	4.8

Fits with increased uncertainties

3. Doubled non-form factor hadronic uncertainties

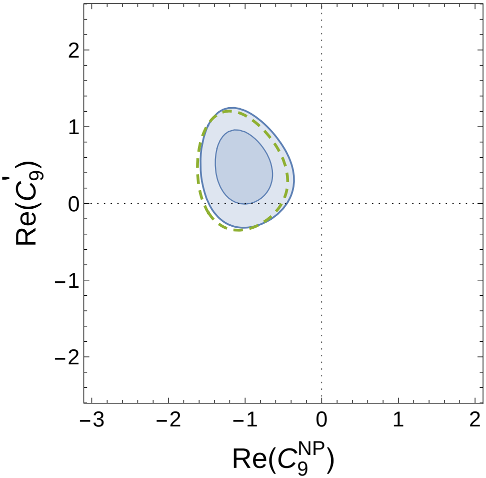
Coeff.	best fit	1σ	2σ	$\sqrt{\chi^2_{\text{b.f.}} - \chi^2_{\text{SM}}}$	p [%]
C_7^{NP}	-0.03	$[-0.06, 0.01]$	$[-0.09, 0.04]$	0.79	5.5
C_7'	0.02	$[-0.03, 0.07]$	$[-0.09, 0.12]$	0.38	5.1
C_9^{NP}	-1.21	$[-1.51, -0.87]$	$[-1.78, -0.51]$	3.31	18.3
C_9'	0.27	$[-0.03, 0.56]$	$[-0.33, 0.85]$	0.9	5.6
C_{10}^{NP}	0.44	$[0.18, 0.72]$	$[-0.06, 1.01]$	1.74	7.5
C_{10}'	-0.20	$[-0.40, 0.01]$	$[-0.61, 0.22]$	0.96	5.7
$C_9^{\text{NP}} = C_{10}^{\text{NP}}$	-0.10	$[-0.36, 0.19]$	$[-0.58, 0.52]$	0.37	5.1
$C_9^{\text{NP}} = -C_{10}^{\text{NP}}$	-0.48	$[-0.68, -0.29]$	$[-0.89, -0.11]$	2.66	12.
$C_9' = C_{10}'$	-0.13	$[-0.42, 0.15]$	$[-0.71, 0.42]$	0.46	5.2
$C_9' = -C_{10}'$	0.13	$[0.00, 0.26]$	$[-0.13, 0.39]$	1.02	5.8

Plots including also $b \to s\, e^+ e^-$



- Green dashed: nominal fit (only $b \to s\mu^+\mu^-$)
- Blue: Fit including also $b \to s\, e^+ e^-$

Plots including also $b \to s\, e^+ e^-$



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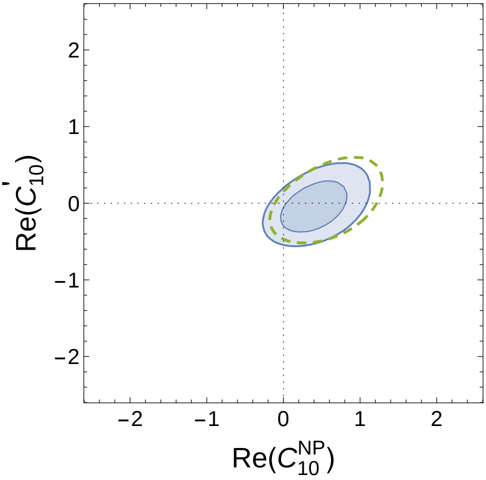
Plots including also $b \to s\, e^+ e^-$



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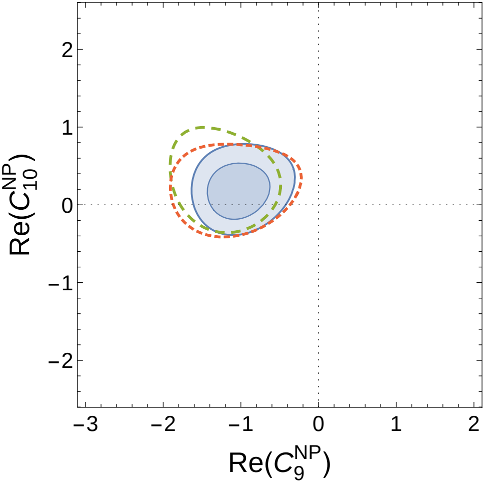
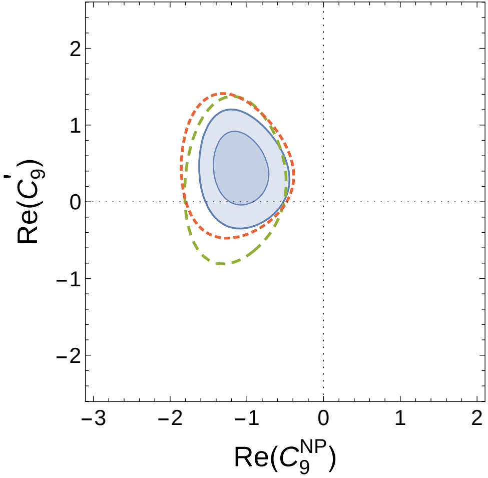
Plots with increased uncertainties



- Red: doubled form factor uncertainties
- Green: doubled non-form factor hadronic uncertainties

Plots with increased uncertainties



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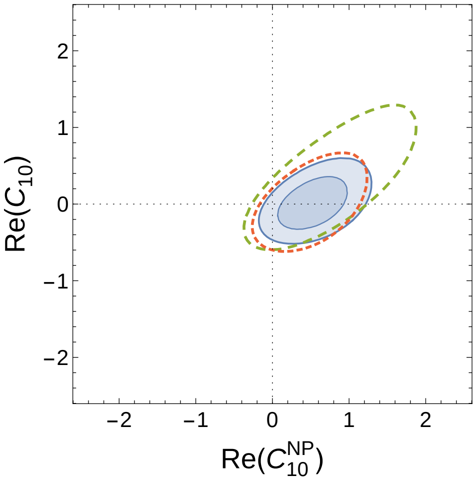
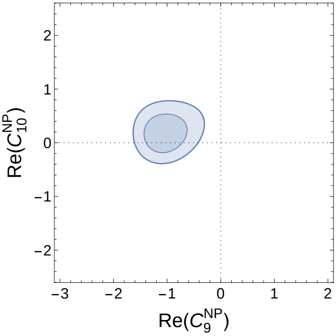


- Red: doubled form factor uncertainties
- Green: doubled non-form factor hadronic uncertainties

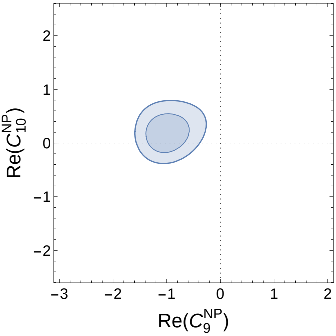
Showing basis independence

Taking into account all theoretical correlations and the experimental ones provided by LHCb, the fits are independent of the basis chosen for angular observables.

Nominal fit



Fit including P_5' instead of S_5



* No, I didn't accidentaly put the same plot twice ;)

$B^0 \to K^{*0}\mu^+\mu^-$		
Observable	q^2 bin	SM prediction
$10^7 \frac{dBR}{dq^2}$	[0.1, 1]	$1.083 \pm 0.074 \pm 0.151 \pm 0.057$
	[1, 2]	$0.511 \pm 0.030 \pm 0.069 \pm 0.017$
	[2, 3]	$0.459 \pm 0.027 \pm 0.064 \pm 0.015$
	[3, 4]	$0.467 \pm 0.028 \pm 0.062 \pm 0.018$
	[4, 5]	$0.494 \pm 0.031 \pm 0.062 \pm 0.023$
	[5, 6]	$0.530 \pm 0.036 \pm 0.063 \pm 0.029$
	[1.1, 2.5]	$0.488 \pm 0.067 \pm 0.067 \pm 0.015$
	[2.5, 4]	$0.464 \pm 0.062 \pm 0.062 \pm 0.017$
	[4, 6]	$0.512 \pm 0.063 \pm 0.063 \pm 0.026$
A_{FB}	[0.1, 1]	$-0.088 \pm 0.001 \pm 0.009 \pm 0.001$
	[1, 2]	$-0.140 \pm 0.003 \pm 0.029 \pm 0.010$
	[2, 3]	$-0.078 \pm 0.003 \pm 0.018 \pm 0.019$
	[3, 4]	$0.002 \pm 0.003 \pm 0.009 \pm 0.025$
	[4, 5]	$0.077 \pm 0.004 \pm 0.018 \pm 0.028$
	[5, 6]	$0.144 \pm 0.006 \pm 0.026 \pm 0.030$
	[1.1, 2.5]	$-0.124 \pm 0.027 \pm 0.027 \pm 0.013$
	[2.5, 4]	$-0.018 \pm 0.009 \pm 0.009 \pm 0.023$
	[4, 6]	$0.112 \pm 0.022 \pm 0.022 \pm 0.029$
F_L	[0.1, 1]	$0.308 \pm 0.009 \pm 0.053 \pm 0.018$
	[1, 2]	$0.738 \pm 0.008 \pm 0.045 \pm 0.021$
	[2, 3]	$0.831 \pm 0.002 \pm 0.031 \pm 0.012$
	[3, 4]	$0.820 \pm 0.002 \pm 0.034 \pm 0.007$
	[4, 5]	$0.776 \pm 0.003 \pm 0.040 \pm 0.012$
	[5, 6]	$0.723 \pm 0.004 \pm 0.045 \pm 0.019$
	[1.1, 2.5]	$0.776 \pm 0.040 \pm 0.040 \pm 0.018$
	[2.5, 4]	$0.825 \pm 0.033 \pm 0.033 \pm 0.007$
	[4, 6]	$0.749 \pm 0.043 \pm 0.043 \pm 0.016$

$B^0 \to K^{*0}\mu^+\mu^-$		
Observable	q^2 bin	SM prediction
S_4	$[0.1, 1]$	$0.097 \pm 0.000 \pm 0.004 \pm 0.002$
	$[1, 2]$	$0.023 \pm 0.004 \pm 0.008 \pm 0.009$
	$[2, 3]$	$-0.081 \pm 0.004 \pm 0.013 \pm 0.013$
	$[3, 4]$	$-0.151 \pm 0.003 \pm 0.016 \pm 0.013$
	$[4, 5]$	$-0.198 \pm 0.002 \pm 0.016 \pm 0.013$
	$[5, 6]$	$-0.228 \pm 0.001 \pm 0.015 \pm 0.011$
	$[1.1, 2.5]$	$-0.009 \pm 0.009 \pm 0.009 \pm 0.011$
	$[2.5, 4]$	$-0.135 \pm 0.016 \pm 0.016 \pm 0.013$
	$[4, 6]$	$-0.213 \pm 0.016 \pm 0.016 \pm 0.012$
S_5	$[0.1, 1]$	$0.247 \pm 0.002 \pm 0.009 \pm 0.004$
	$[1, 2]$	$0.119 \pm 0.005 \pm 0.015 \pm 0.020$
	$[2, 3]$	$-0.077 \pm 0.005 \pm 0.015 \pm 0.027$
	$[3, 4]$	$-0.212 \pm 0.003 \pm 0.021 \pm 0.028$
	$[4, 5]$	$-0.300 \pm 0.005 \pm 0.023 \pm 0.025$
	$[5, 6]$	$-0.356 \pm 0.006 \pm 0.021 \pm 0.022$
	$[1.1, 2.5]$	$0.059 \pm 0.014 \pm 0.014 \pm 0.023$
	$[2.5, 4]$	$-0.182 \pm 0.020 \pm 0.020 \pm 0.028$
	$[4, 6]$	$-0.329 \pm 0.022 \pm 0.022 \pm 0.024$

$B^0 \to K^{*0}\mu^+\mu^-$		
Observable	q^2 bin	SM prediction
P_4'	$[0.1, 1]$	$0.252 \pm 0.003 \pm 0.006 \pm 0.006$
	$[1, 2]$	$0.058 \pm 0.010 \pm 0.019 \pm 0.022$
	$[2, 3]$	$-0.232 \pm 0.012 \pm 0.028 \pm 0.042$
	$[3, 4]$	$-0.413 \pm 0.006 \pm 0.022 \pm 0.035$
	$[4, 5]$	$-0.487 \pm 0.003 \pm 0.017 \pm 0.023$
	$[5, 6]$	$-0.518 \pm 0.002 \pm 0.015 \pm 0.016$
	$[1.1, 2.5]$	$-0.023 \pm 0.023 \pm 0.023 \pm 0.029$
	$[2.5, 4]$	$-0.375 \pm 0.024 \pm 0.024 \pm 0.038$
	$[4, 6]$	$-0.502 \pm 0.016 \pm 0.016 \pm 0.019$
P_5'	$[0.1, 1]$	$0.643 \pm 0.001 \pm 0.009 \pm 0.014$
	$[1, 2]$	$0.297 \pm 0.010 \pm 0.026 \pm 0.041$
	$[2, 3]$	$-0.223 \pm 0.015 \pm 0.041 \pm 0.084$
	$[3, 4]$	$-0.579 \pm 0.011 \pm 0.037 \pm 0.077$
	$[4, 5]$	$-0.738 \pm 0.014 \pm 0.033 \pm 0.057$
	$[5, 6]$	$-0.809 \pm 0.016 \pm 0.031 \pm 0.042$
	$[1.1, 2.5]$	$0.154 \pm 0.032 \pm 0.032 \pm 0.055$
	$[2.5, 4]$	$-0.504 \pm 0.038 \pm 0.038 \pm 0.081$
	$[4, 6]$	$-0.774 \pm 0.032 \pm 0.032 \pm 0.049$