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Durham University

$B \to K^* \mu^+ \mu^-$: SM and Beyond

Aoife Bharucha with W. Altmannshofer, Patricia Ball,
A.J. Buras, D. Straub and M. Wick (arXiv:0811.1214 [hep-ph])

IPPP/TU,Munich

XLIVth Rencontres de Moriond, 9th March 2009

Soon Launching Expedition to 14TeV

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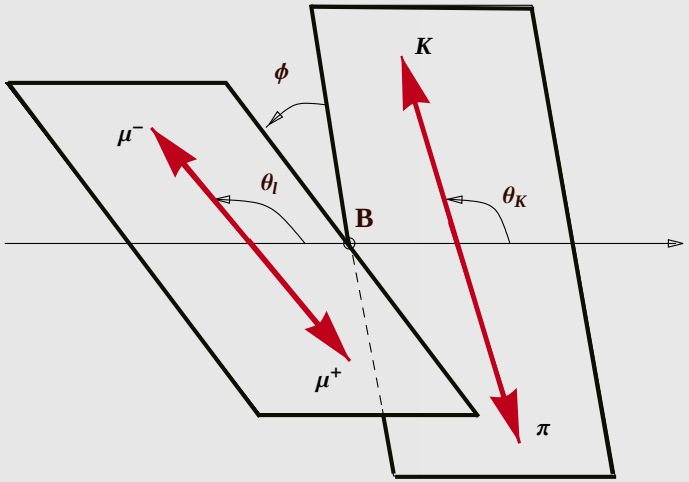
Some Structure

- Angular Observables via B Physics Tool Box
- Major Milestones and Recent Developments
- Effects of Different categories of NP models on Observables
- Some Concrete Examples

Angular Observables

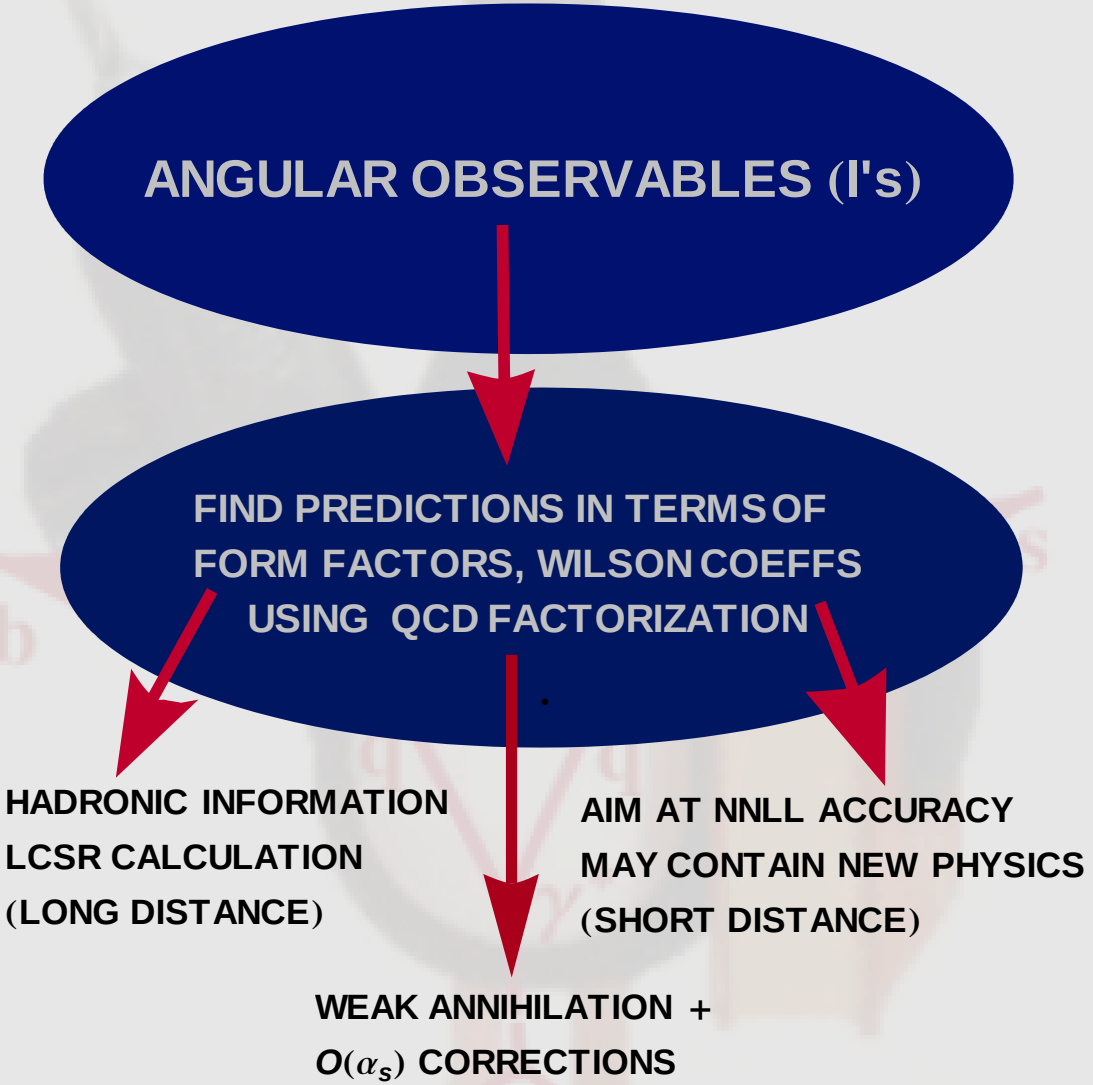
$$\frac{d^4\Gamma}{dq^2 d\Omega} = \frac{9}{32\pi} I(q^2, \theta_l, \theta_K, \phi)$$



....where $I(q^2, \theta_l, \theta_K, \phi) =$

$$\begin{aligned}
&I_1^s \sin^2\theta_K + I_1^c \cos^2\theta_K + (I_2^s \sin^2\theta_K + I_2^c \cos^2\theta_K)\cos 2\theta_l \\
&+ I_3 \sin^2\theta_K \sin^2\theta_l \cos 2\phi + I_4 \sin 2\theta_K \sin 2\theta_l \cos\phi \\
&+ I_5 \sin 2\theta_K \sin\theta_l \cos\phi + (I_6^s \sin^2\theta_K + I_6^c \cos^2\theta_K)\cos\theta_l \\
&+ (I_7 \sin\theta_l + I_8 \sin 2\theta_l)\sin 2\theta_K \sin\phi + I_9 \sin^2\theta_K \sin^2\theta_l \sin 2\phi
\end{aligned}$$

Relating I's to New Physics



A B Physicists ToolBox

EFFECTIVE FIELD THEORIES

- Disentangle physics governed by different mass scales
- Write $\mathcal{L}$ in terms of **'Effective Operators'** and Effective Coupling Constants known as **'Wilson Coefficients'**

$$\mathcal{L} = \sum_i C_i O_i$$

For $B \to K^*(\to K^-\pi^+)\mu^+\mu^-$, important Operators are..

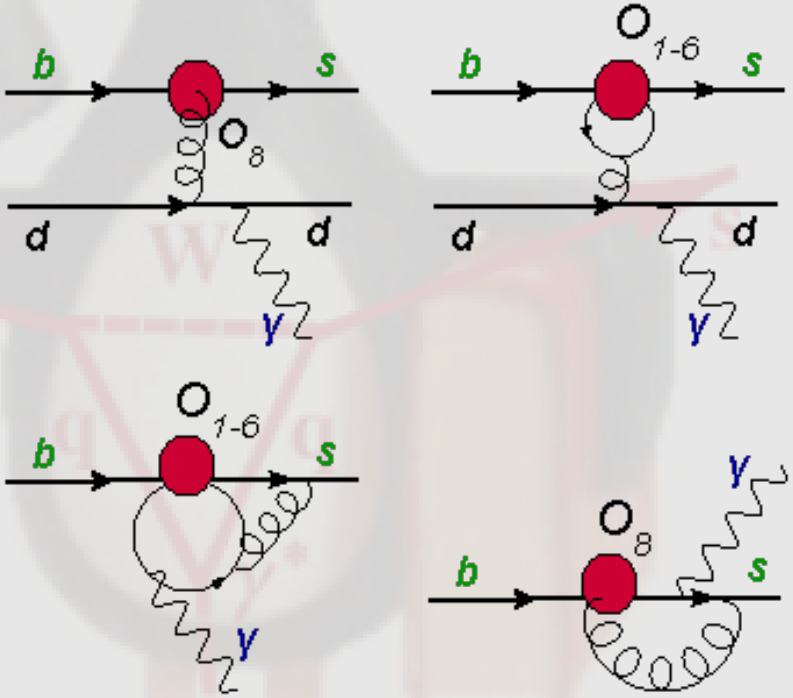
Electromagnetic Dipole O_7 Vector/Axial Current $O_{9(10)}$

A B Physicists ToolBox

HADRONIC MATRIX ELEMENTS

- eg. $\langle B|J|K^*\rangle$ described by Form Factors
- QCD Sum Rules on the Light Cone[1]/Lattice QCD

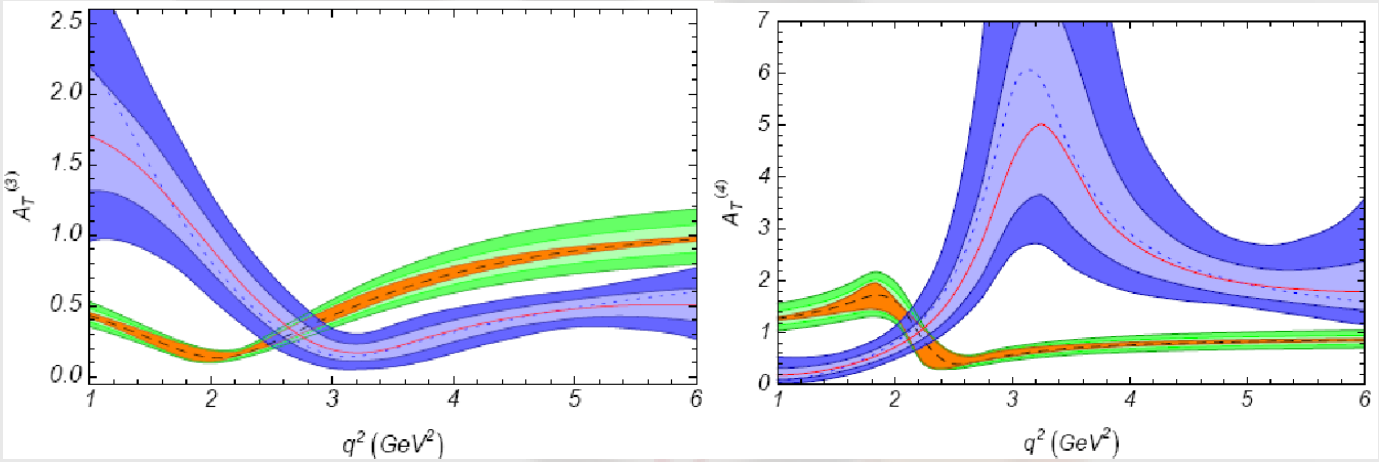
HARD SPECTACTOR EFFECTS- QCD factorization/ SCET/ HQET...



[1] Ball/Zwicky 04, Ball 08

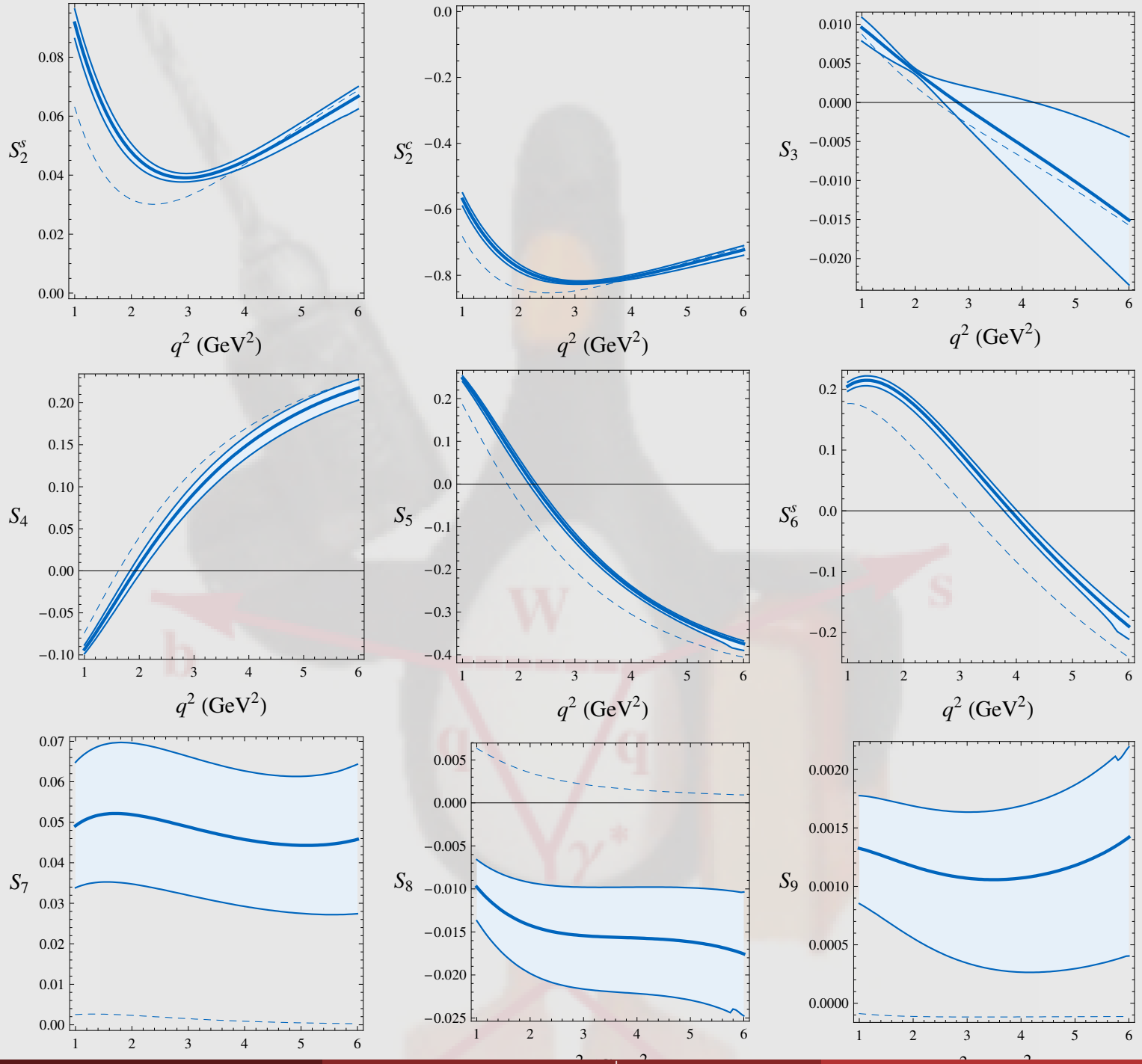
Major Milestones and Recent Developments

- 1999: Ali et al. Naive Factorization hep-ph/9910221
- 2001/4: Beneke et al. full QCDF calculations hep-ph/0412400
- 2008: Bobeth et al. CP Asymmetries arXiv:0805.2525[hep-ph]
- 2008: Egede et al. New Observables arXiv:0807.2589[hep-ph]



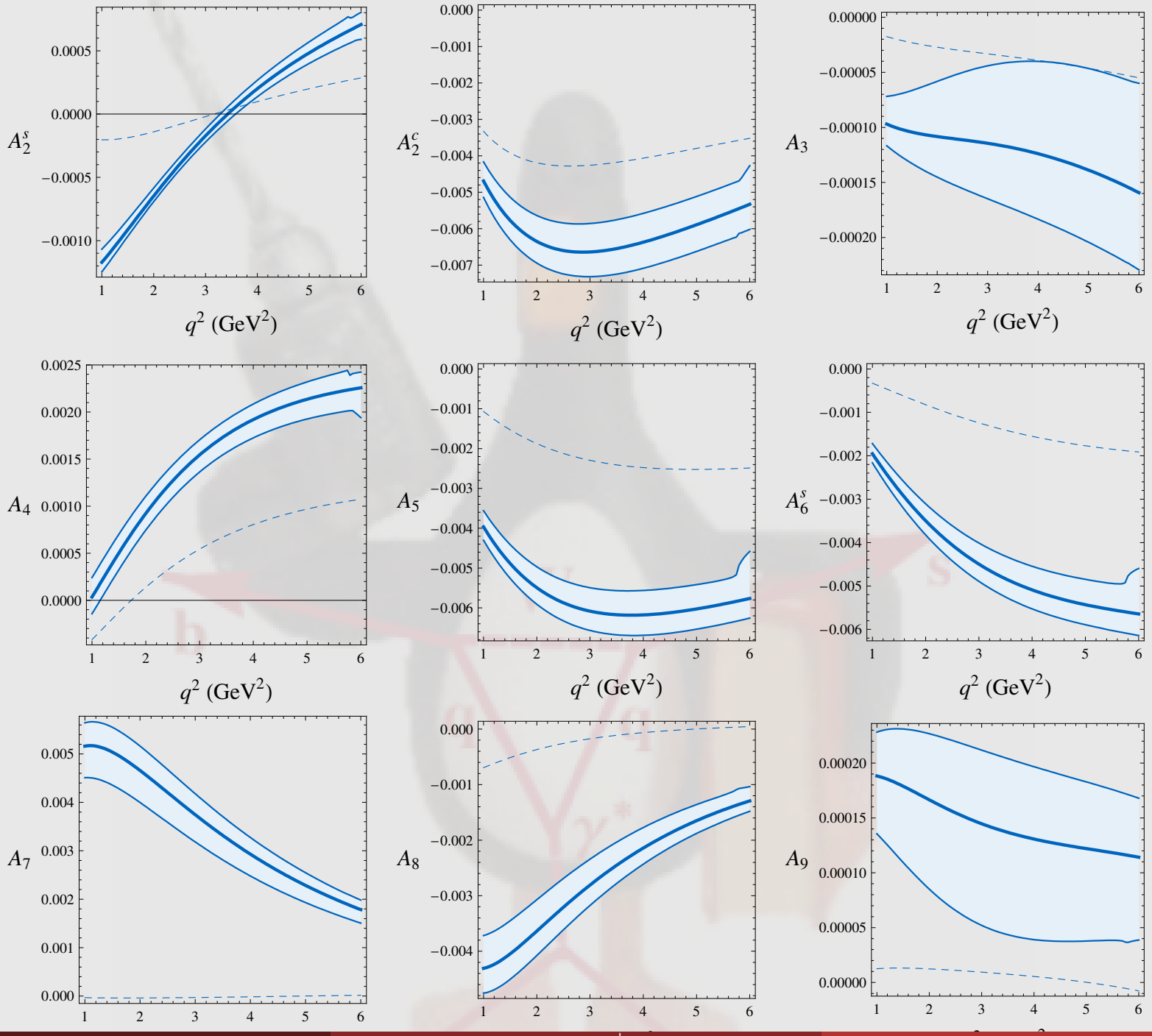
Emphasize CP Conserving Effects

$$S_i^{(a)} = \frac{I_i^{(a)} + \bar{I}_i^{(a)}}{d(\Gamma + \bar{\Gamma})/dq^2}$$


S_2^s
S_2^c
S_3
S_4
S_5
S_6^s
S_7
S_8
S_9
q^2 (GeV^2)

Emphasize CP Violating Effects

$$A_i^{(a)} = \frac{I_i^{(a)} - \bar{I}_i^{(a)}}{d(\Gamma + \bar{\Gamma})/dq^2}$$


A_2^s
A_2^c
A_3
A_4
A_5
A_6^s
A_7
A_8
A_9
q^2 (GeV^2)

What will the Flavour Telescope see?

FOCUS ON ADDITIONAL..

- **Operators** eg. Scalar
- **CP Violation**
- **Flavour** structure

Keeping in Mind Bounds from..

- $B_s \to \mu^+\mu^-$
- EDM's, CP Asymmetries....
- $B \to X_s\gamma$, $B \to X_s\mu^+\mu^-$

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Keeping in Mind Bounds from..

- $B_s \to \mu^+\mu^-$
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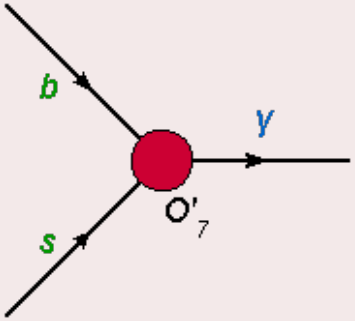
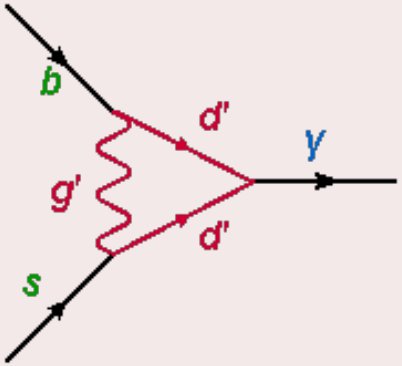
What kind of New Operators?

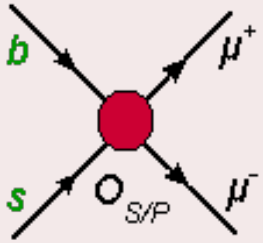
For $B \to K^*(\to K^-\pi^+)\mu^+\mu^-$, important NP O's are..

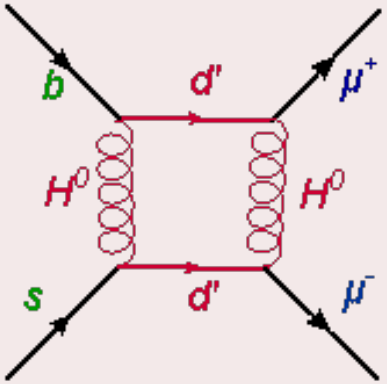
Spin-Flipped EM Dipole O_7'





Scalar/Pseudoscalar Current $O_{S(P)}$

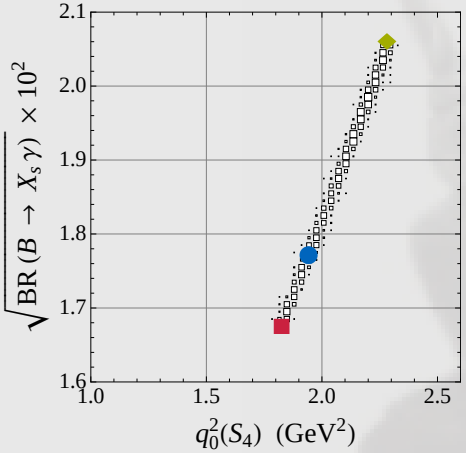


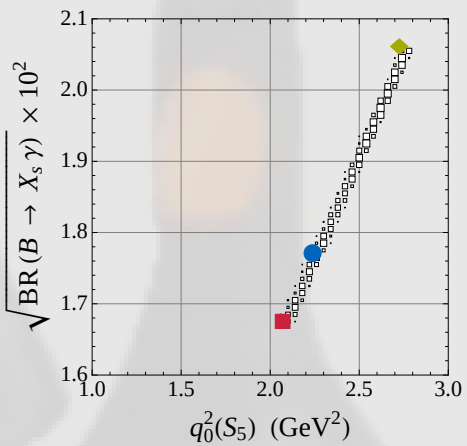


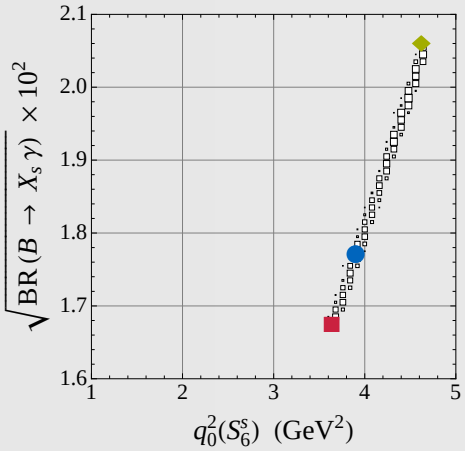
New Physics via Wilson Coefficients

Model	Additional Operators	CP/Flavour Violation
Constrained MFV	No	No
MFV MSSM	O_S, O_P	No
Flavour Blind MSSM	O_S, O_P	Yes/No
General MSSM	O_S, O_P, O_7'	Yes
Littlest Higgs +T Parity	No	Yes

MFV

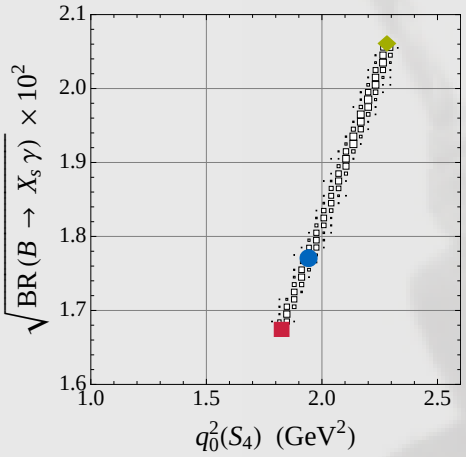


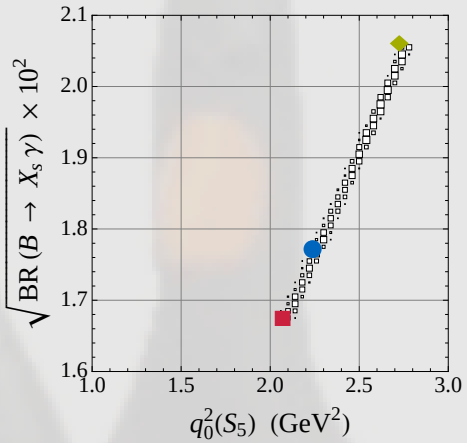


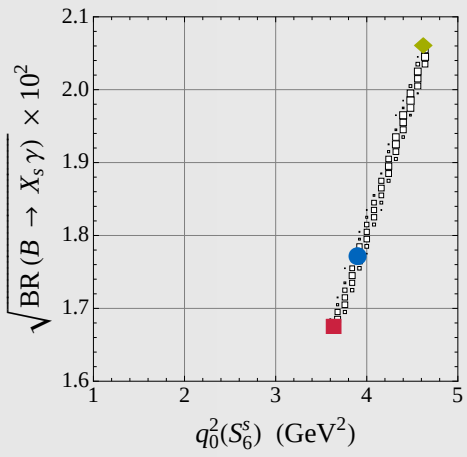


- Effects for CMFV at most 50%
- Correlate zeros of S_4, S_5, S_6^s with $B(b \to s\gamma)$
- In MSSSM with MFV Scalar Operators affect S_6^c

MFV







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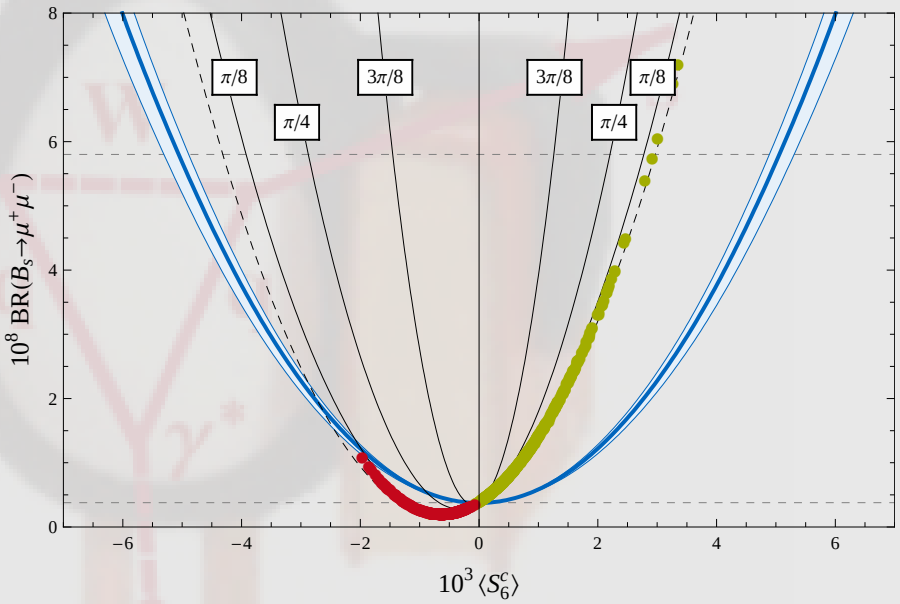
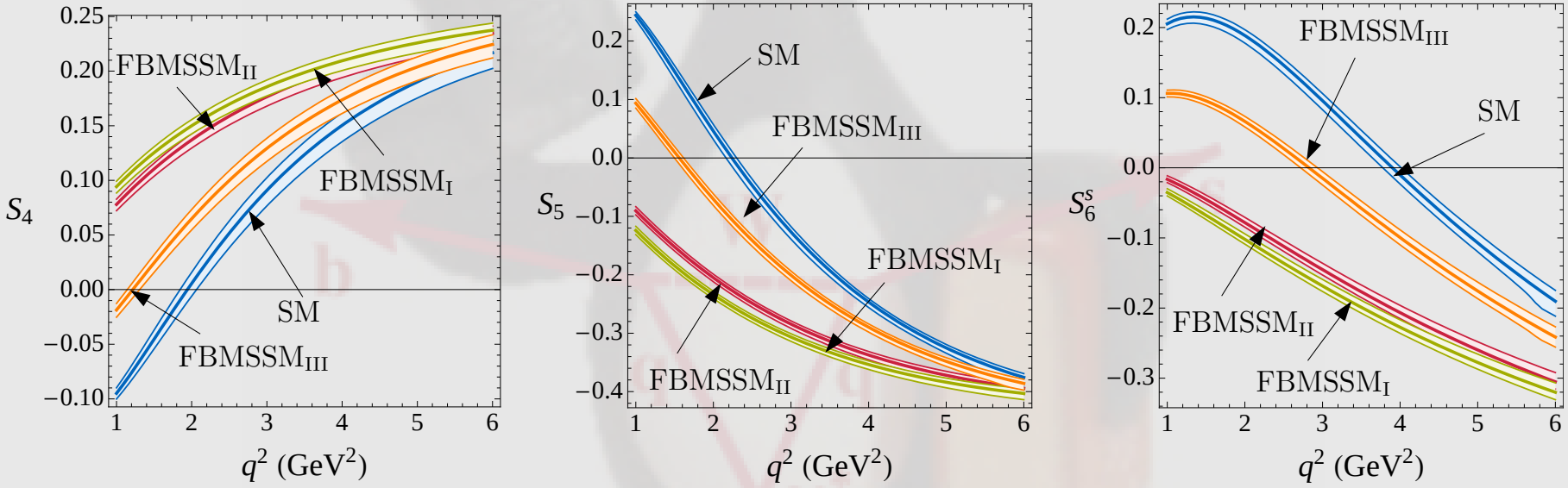


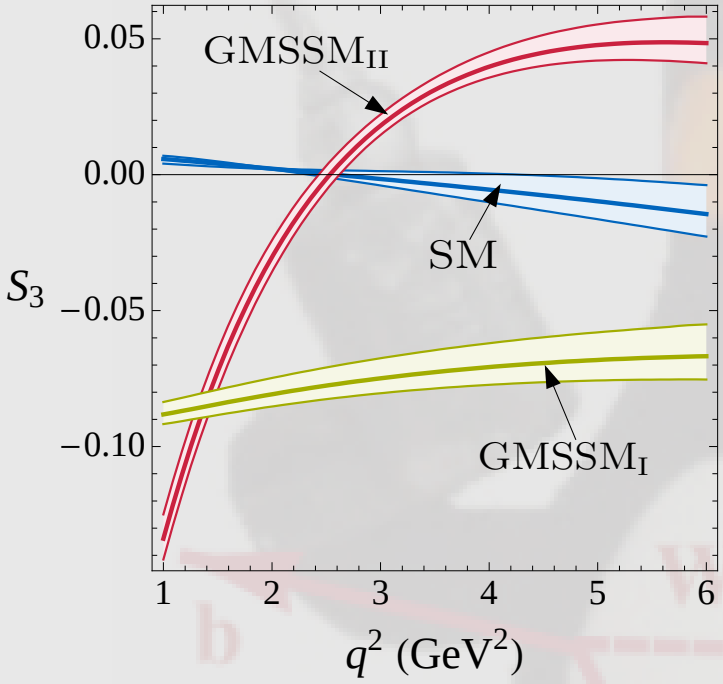
Model Independent Correlation

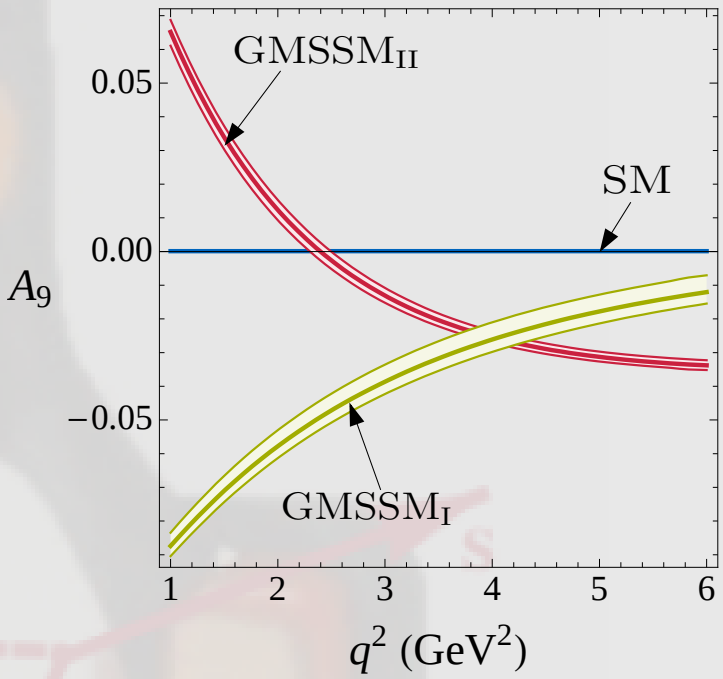
Flavour-Blind MSSM

Bound on C_7 from $b \to s\gamma$ weakened if complex FBMSSM has additional CP violating phases..



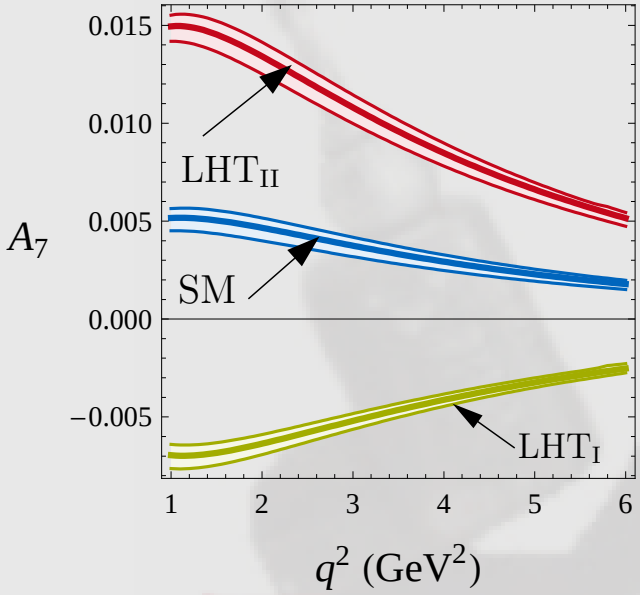
General MSSM

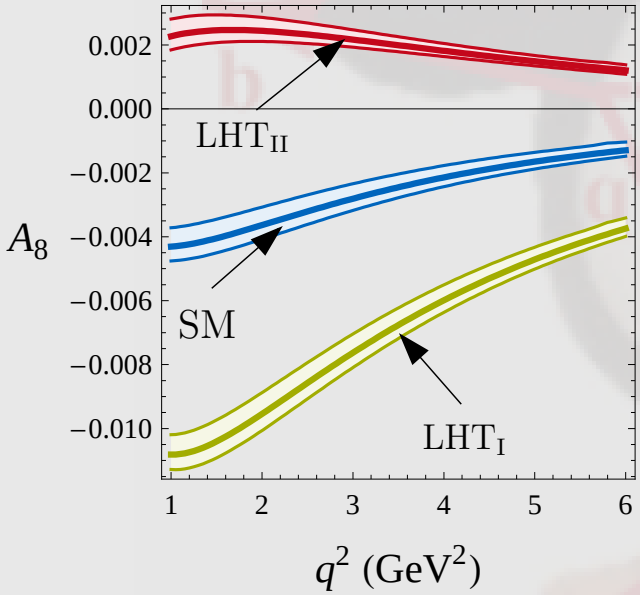




- Large no. of free parameters⇒Concentrate on complex C_7'
- Generate C_7' via down squark gluino loops
- Sizeable effects in $S^{(i)}_{4/5/6}$, $A_{7/8}$, and uniquely in S_3/A_9

LHT





- Smaller effects DESPITE complex phases
- $C_7^{\rm np}$ small, but large complex $C_9^{\rm np}$, $C_{10}^{\rm np}$
- Most sensitive: A_7 and A_8

Summary

- $\mathbf{B \to \bar{K}^* \mu^+ \mu^-}$ will provide a multitude of sensitive observables at the LHC

- **Visible effects at the LHC:** LHCb, ATLAS, CMS
  Full Angular Distribution will be measured, deviations from SM will be seen

Summary

- $\mathbf{B \to \bar{K}^* \mu^+ \mu^-}$ will provide a multitude of sensitive observables at the LHC

Wilson coefficients	Largest effect in
$C_7,\ C_7'$	$S_1^s,\ S_1^c,\ S_2^s,\ S_2^c,\ S_3,\ S_4,\ S_5,\ S_6^s,$ $A_7,\ A_8,\ A_9,$ $\mathrm{BR}(B \to X_s\gamma),\ \mathrm{BR}(B \to X_s\mu^+\mu^-)$
$C_9,\ C_9',\ C_{10},\ C_{10}'$	$S_1^s,\ S_1^c,\ S_2^s,\ S_2^c,\ S_3,\ S_4,\ S_5,\ S_6^s,$ $A_7,\ A_8,\ A_9,$ $\mathrm{BR}(B \to X_s\mu^+\mu^-)$
$C_S - C_S'$	$S_6^c,$ $\mathrm{BR}(B_s \to \mu^+\mu^-)$
$C_P - C_P'$	$S_1^c + S_2^c,$ $\mathrm{BR}(B_s \to \mu^+\mu^-)$

FBMSSM

GMSSM

LHT

MFVMSSM

Measure Zero

Sensitive to C7'

Suppressed in the SM

Zero in SM

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