

Observables in $B \rightarrow K^* \mu^+ \mu^-$ and New Physics Effects

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IOP HEPP: Beauty Physics in the UK

Lancaster, 12th November

Some Structure

- Categorising the NP Contribution
- Model Independent Analysis
- Specific NP Models:
 - Minimal Flavour Violation
 - Flavour Blind MSSM
 - General MSSM
 - Littlest Higgs with T Parity
- Distinguishing features of NP models

How will we find NP?

FOCUS ON..

- New **Operators**
- Additional **CP violating** phases
- Modified **Flavour** Structure

Keeping in Mind..

- Strict bounds on C_7 and C_7' from $B \rightarrow X_s \gamma$
- Bounds on $C_{9/10}^{(\prime)}$, C_S and C_P from $B \rightarrow X_s \mu^+ \mu^- / B_s \rightarrow \mu^+ \mu^-$
- EDM's, CP Asymmetries....
- (Possible B_s Mixing Phase at CDF/D0)

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What kind of New Operators?

Operators (O's) that aren't important in the SM

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

SM

Normal Dipoles O_7

$$\bar{s}\sigma_{\mu\nu}q^\nu\gamma_L b$$

NP

Spin Flipped Dipoles O'_7

$$\bar{s}\sigma_{\mu\nu}q^\nu\gamma_R b$$

Vector/Axial Currents $C_{9(10)}$

$$(\bar{s}\gamma_\mu\gamma_L b)(\bar{l}\gamma^\mu(\gamma_5)l)$$

Scalar/Pseudoscalar $C_{S(P)}$

$$(\bar{s}\gamma_L b)(\bar{l}(\gamma_5)l)$$

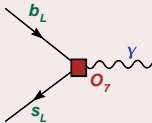
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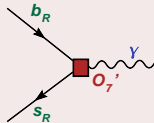
SM

Normal Dipoles O_7

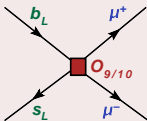


NP

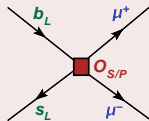
Spin Flipped Dipoles O_7'



Vector/Axial Currents $C_{9(10)}$



Scalar/Pseudoscalar $C_{S(P)}$



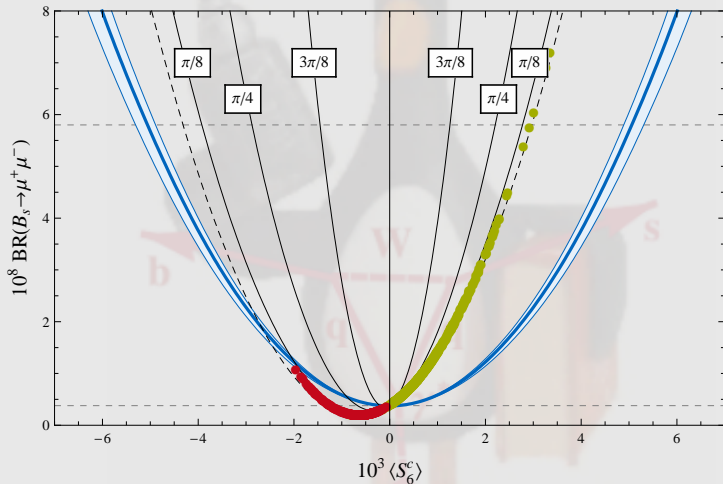
Model Independent Analysis

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

Model Independent Analysis

Observable	Most affected by
$S_1^s, S_1^c, S_2^s, S_2^c$	$C_7, C_7', C_9, C_9', C_{10}, C_{10}'$
S_3	C_7', C_9', C_{10}'
S_4	$C_7, C_7', C_{10}, C_{10}'$
S_5	C_7, C_7', C_9, C_{10}'
S_6^s	C_7, C_9
A_7	$C_7, C_7', C_{10}, C_{10}'$
A_8	$C_7, C_7', C_9, C_9', C_{10}'$
A_9	C_7', C_9', C_{10}'
S_6^c	$C_S - C_S'$

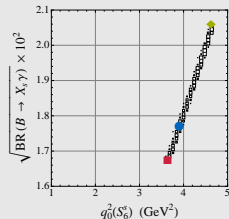
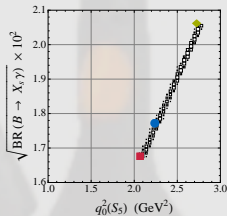
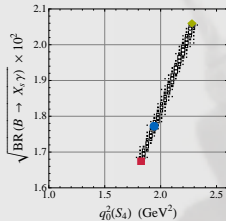
Model Independent Analysis



New Physics via Wilson Coefficients

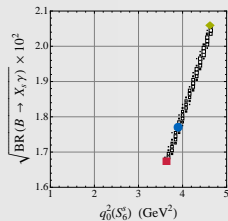
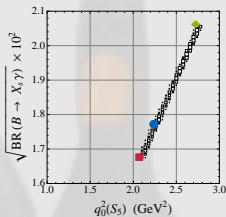
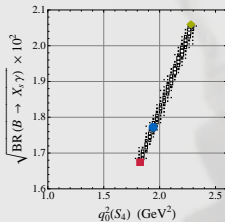
Model	Additional Operators	CP Violation	Flavour Violation
Constrained MFV	No	No	No
MFV MSSM	O_S, O_P	No	No
Flavour Blind MSSM	O_S, O_P	Yes	No
General MSSM	O_S, O_P, O'_7	Yes	Yes
Littlest Higgs +T Parity	No	Yes	Yes

MFV

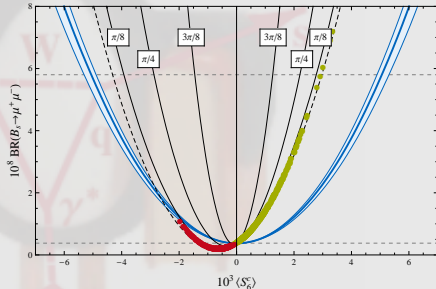


- Effects for CMFV at most 50%
- Correlate zeros of S_4 , S_5 , S_6^s with $B(b \rightarrow s\gamma)$
- In MSSM with MFV Scalar Operators affect S_6^c

MFV



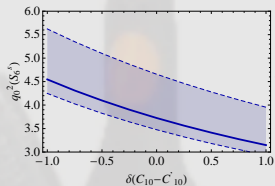
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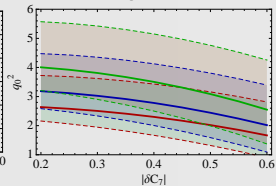
Model Independent Correlation

Model Independent
Analysis of Zero of
 $S_6^s \sim A_{fb}$

Real C_7



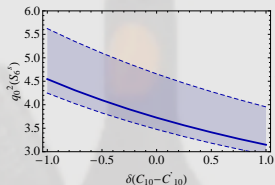
Complex C_7



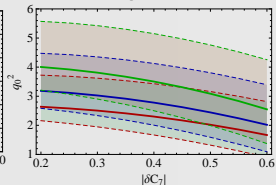
Flavour-Blind MSSM

Model Independent
Analysis of Zero of
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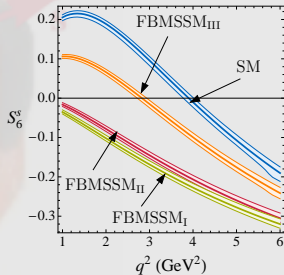
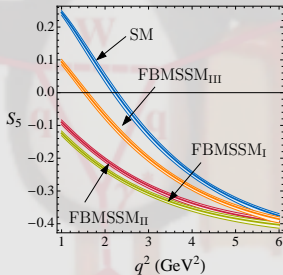
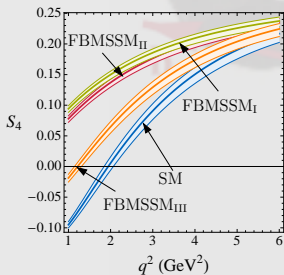
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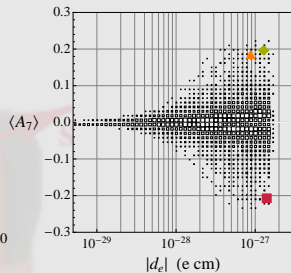
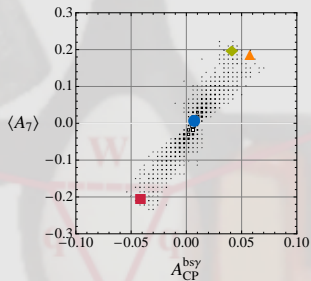
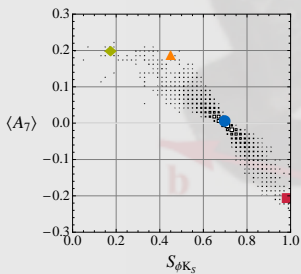
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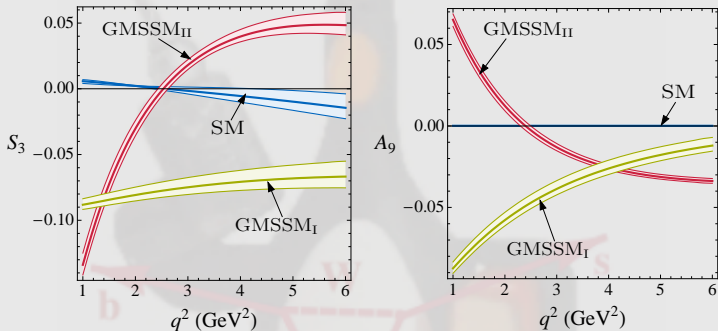
In this Model lots of complex phases possible..



Flavour-Blind MSSM



General MSSM



- Large no. of free parameters \Rightarrow Concentrate on complex C'_7
- Generate C'_7 via down squark gluino loops
- Sizeable effects in $S_{4/5/6}^{(i)}$, $A_{7/8}$, and uniquely in S_3/A_9

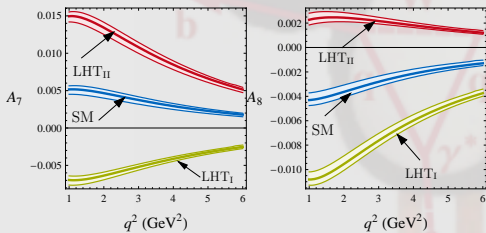
Quick Intro to the Little Higgs with T Parity

- Higgs protected from quadratic divergences by approximate global symmetries (SU(5))
- T parity imposed (like R parity), EW bounds less stringent

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

Quick Intro to the LHT with T Parity

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Summary

- $B \rightarrow \bar{K}^* \mu^+ \mu^-$ 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

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FBMSSM	C_7, C_7'	$S_1^s, S_1^c, S_2^s, S_2^c, S_3, S_4, S_5, S_6^s$	
GMSSM		A_7, A_8, A_9	Sensitive to C_7'
		$\text{BR}(B \rightarrow X_s \gamma), \text{BR}(B \rightarrow X_s \mu^+ \mu^-)$	
LHT	$C_9, C_9', C_{10}, C_{10}'$	$S_1^s, S_1^c, S_2^s, S_2^c, S_3, S_4, S_5, S_6^s$	Suppressed in the SM
		A_7, A_8, A_9	
		$\text{BR}(B \rightarrow X_s \mu^+ \mu^-)$	
MFVMSSM	$C_S - C_S'$	S_6^c	Zero in SM
		$\text{BR}(B_s \rightarrow \mu^+ \mu^-)$	
	$C_P - C_P'$	$S_1^c + S_2^c$	
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