Searching for light scalars in B-decays into six muons

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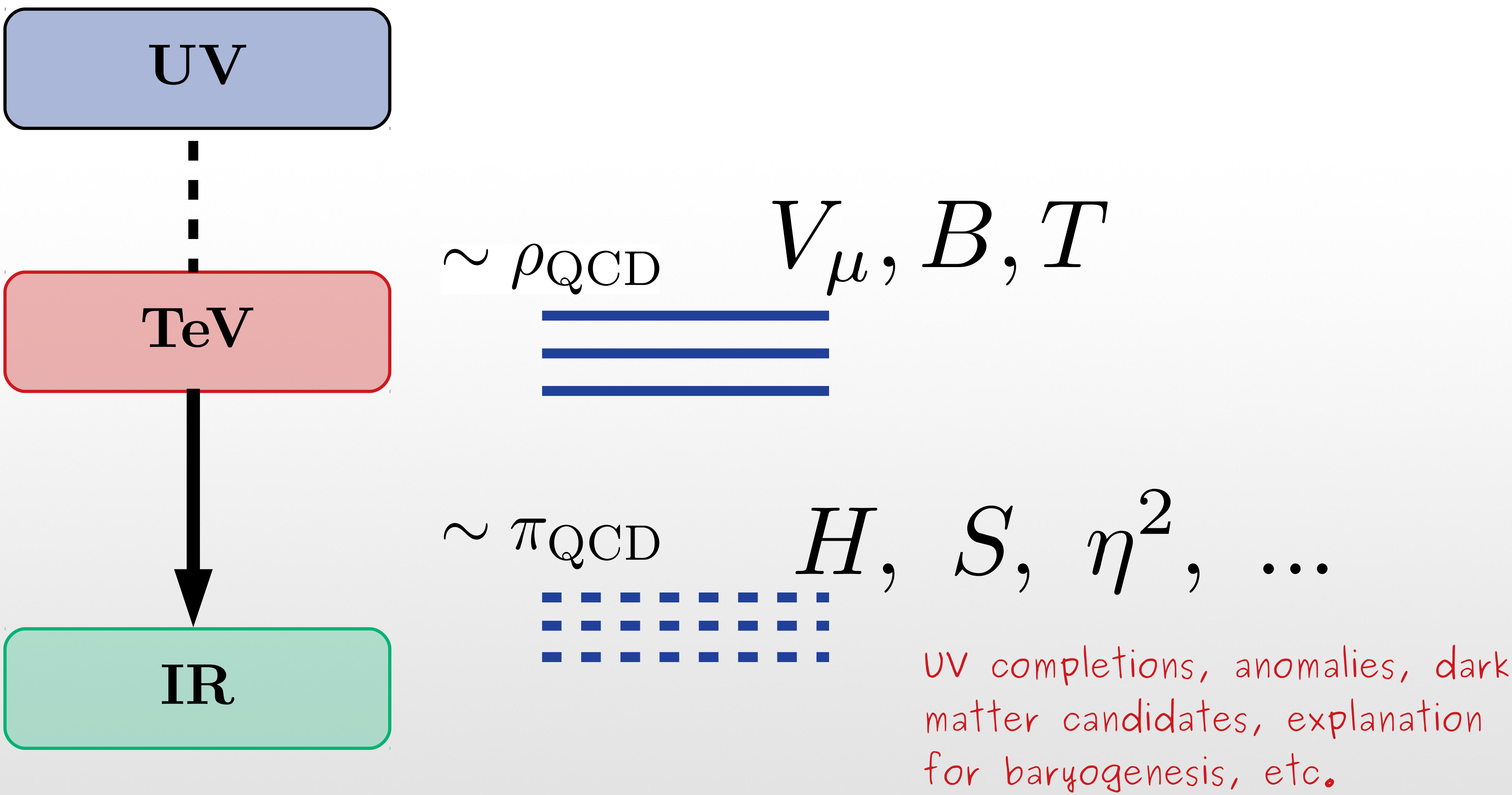
Where is new physics?

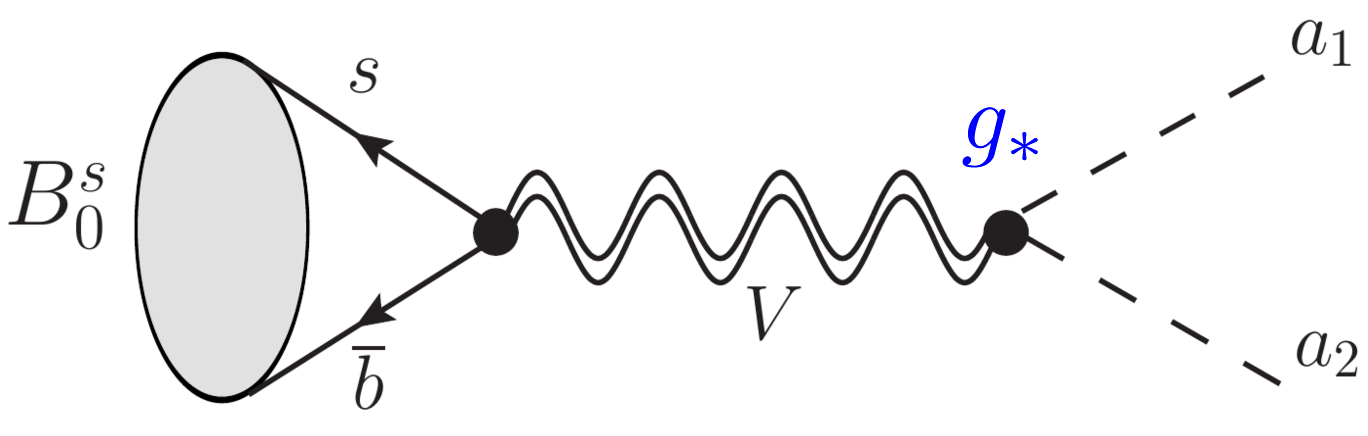
- It has not showed up in "standard candle" final states
- Minimal models are getting strongly constrained

Look for radically **new** and **unexplored** regions of signal

Non-minimal composite phenomenology

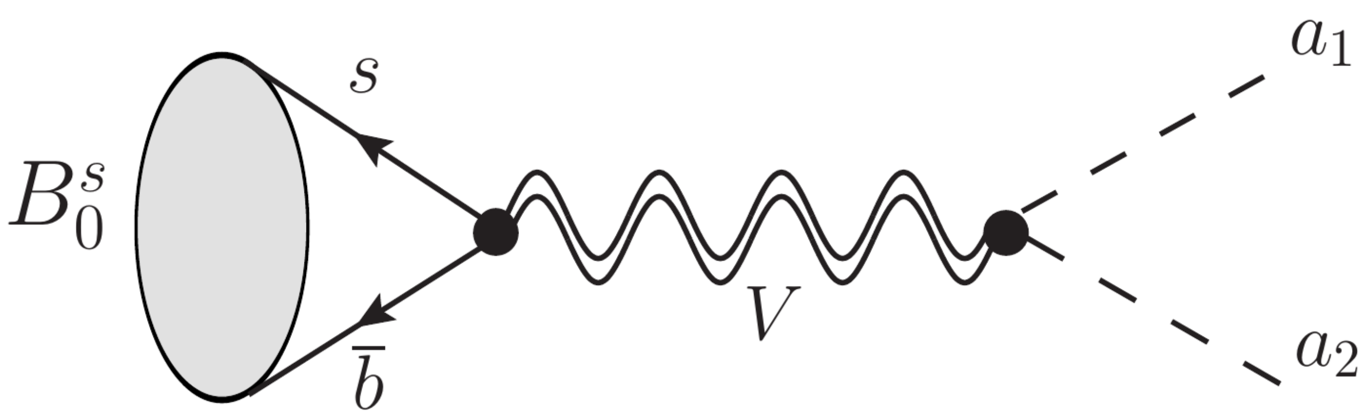


B-decay signatures of light scalars



Weaker bounds for composite decays
M.Chala, M. Spannowsky (1803.02364)

B-decay signatures of light scalars



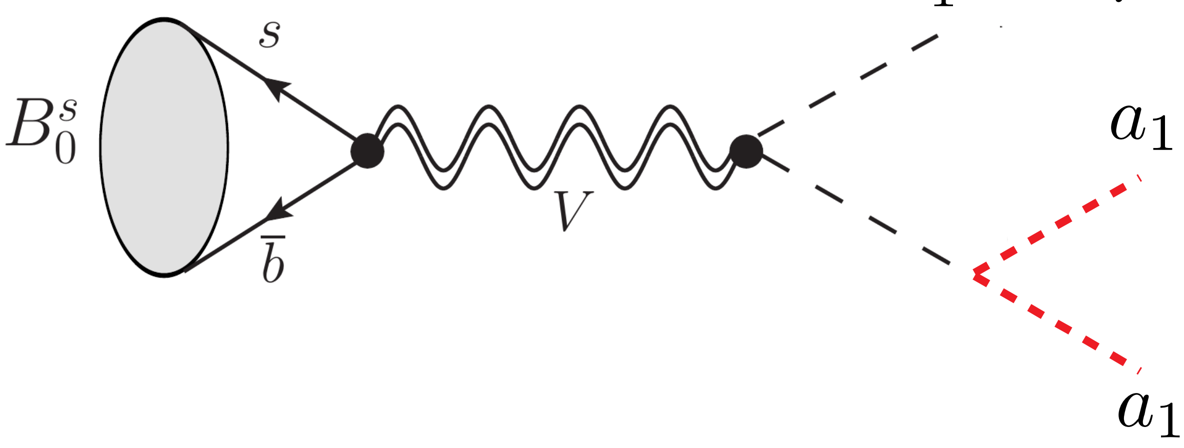
LHCb(2017) @8TeV with 3fb^{-1} data:

$$\mathcal{B}\left(B_s^0 \to \mu^+\mu^-\mu^+\mu^-\right) < 2.5 \times 10^{-9}$$

Motivation for alternative decays

#1 $\Gamma\left(a_2 \to \ell^+\ell^-\right) \ll \Gamma\left(a_2 \to a_1 a_1\right)$

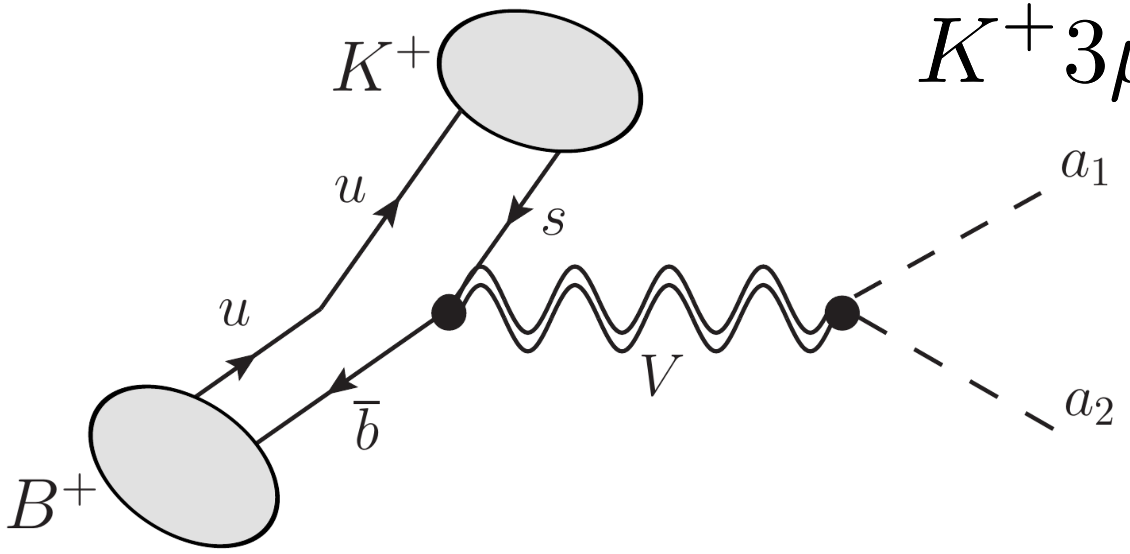
$3\mu^+3\mu^-$



Motivation for alternative decays

#2 $\Gamma\left(B_s^0 \to a_1 a_2\right) \propto \frac{|m_2^2 - m_1^2|}{m_B}$

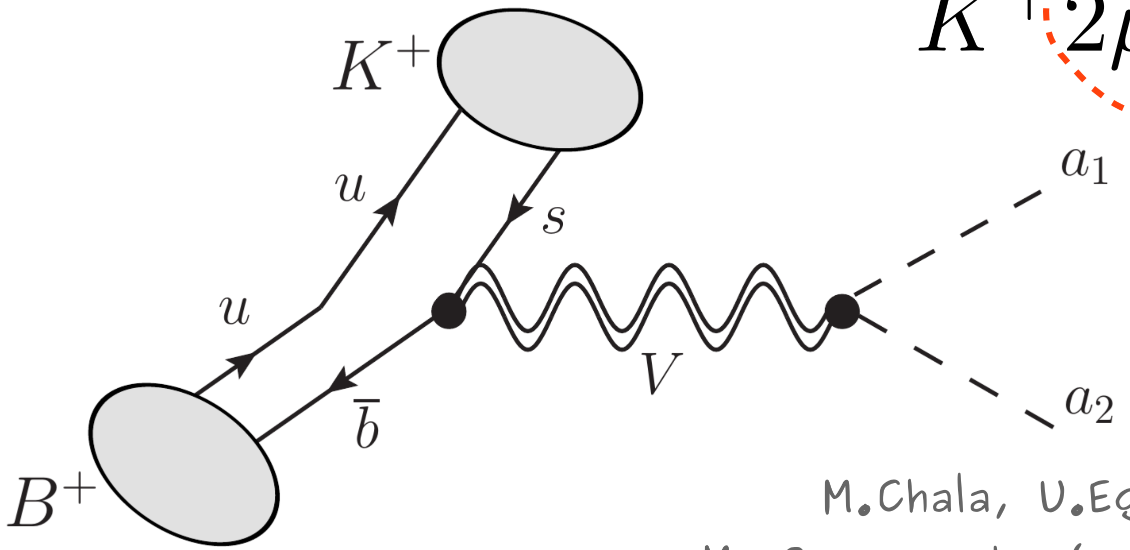
$K^+ 3\mu^+ 3\mu^-$



Motivation for alternative decays

#2' This was also not searched:

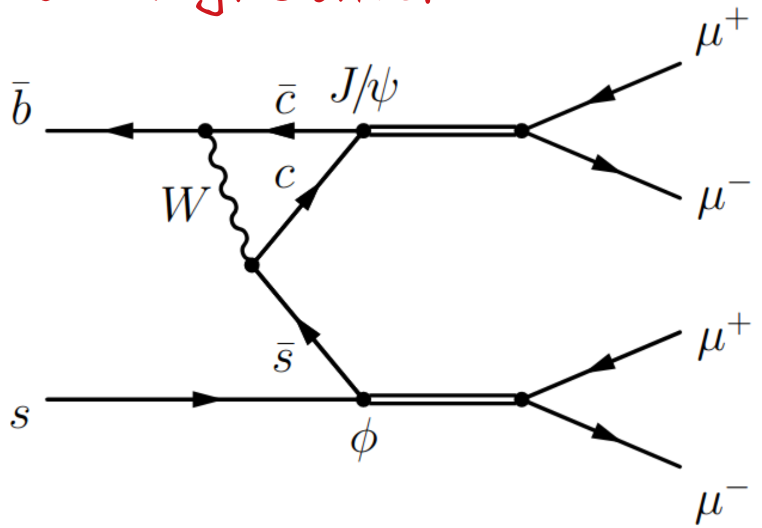
$K^+ 2\mu^+ 2\mu^-$



M.Chala, U.Egede, M. Spannowsky (1902.10156)

LHCb analysis for the new decays

Main background



$\mathcal{B} \sim 10^{-8}$

$$m_{\mu^+\mu^-} \notin [0.95, 1.09] \cup [3.0, 3.2]\ \text{GeV}$$

LHCb analysis for the new decays

6muons final state = "bkg free"

$$\mathcal{B}_{\rm max}^{3\mu^+3\mu^-} \simeq \frac{\mathcal{B}_{\rm max}^{2\mu^+2\mu^-} \times \varepsilon_{2\mu^+2\mu^-}}{1.8 \times \varepsilon_{3\mu^+3\mu^-}} \times \frac{\mathcal{L}}{\mathcal{L}'}$$

$\mathcal{L} = 3\,\mathrm{fb}^{-1}$

$\mathcal{L}' = 300\,\mathrm{fb}^{-1}$ @upgradeII

LHCb (2017)

σ_{14}/σ_{8}

from simulation

Particle reconstruction

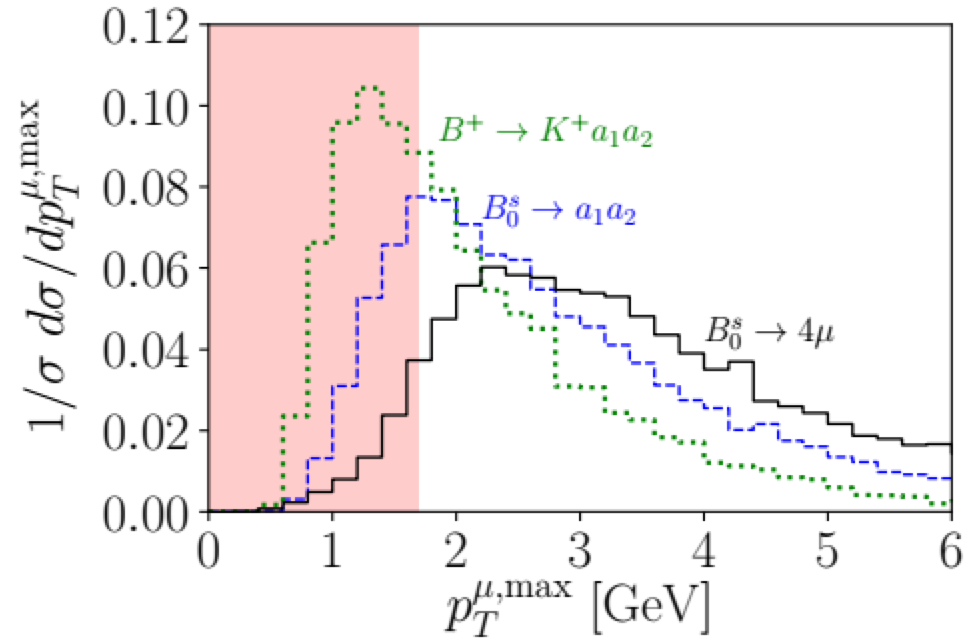
Basic cuts

$p_T > 0.5$ GeV

$2.5 < \eta < 5.0$

$p_{total} > 2.5$ GeV

$p_T^{\mu_1} > 1.7$ GeV



REMARK: We're assuming no changes to the trigger or tracking performance in the upgrades of LHCb.

Upper limits on branching ratios

X = m_{Bs0} or $m_{B+} - m_{K+}$

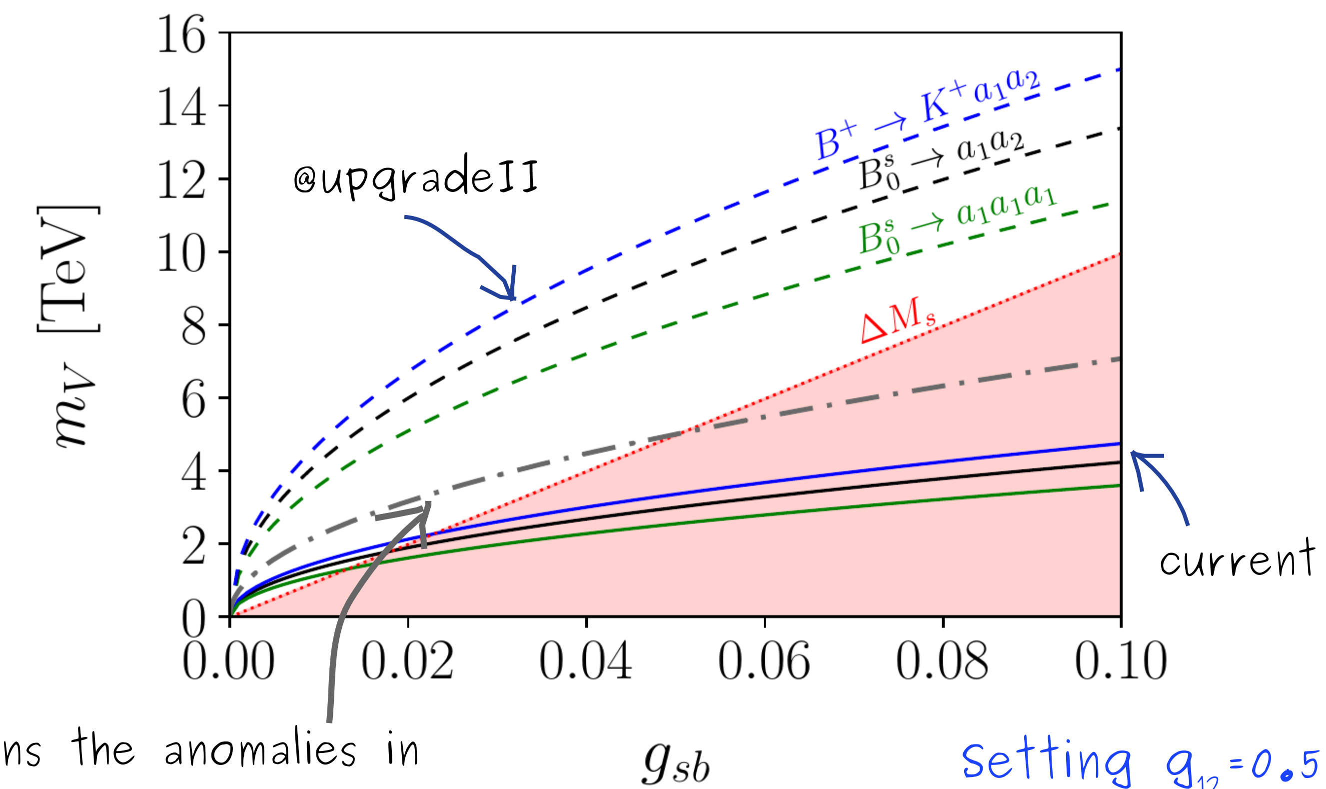
	$m_X \geq m_1 + m_2$		$m_X < m_1 + m_2$
	$m_2 \geq 2m_1$	$m_2 < 2m_1$	$m_X \geq 3m_1$
$B_s^0 \to 3\mu^+ 3\mu^-$	[0.02,0.03]	[0.01,0.02]	[0.02,0.03]
limit ($\times 10^{-9}$)	[6.7, 11.6]	[7.9, 18.2]	[6.0, 11.9]
$B^+ \to K^+ 3\mu^+ 3\mu^-$	[0.007,0.009]	[0.003,0.009]	four-body
limit ($\times 10^{-9}$)	[5.9, 8.0]	[6.0, 16.6]	four-body

stronger

$\sigma_{B+} = 3.7\, \sigma_{Bs}$

Further motivation to search for this final state

Maximum mass that can be tested



Explains the anomalies in R_K and R_{K*} at the 1σ level (1712.06572)

Setting $g_{12}=0.5$, $m_1(m_2)=1.2(2.0)$ GeV

Conclusions

- Heavy vector–light scalar couplings arise naturally in CHMs
- Since V is out of reach, this scenario triggers rare B-decays:

$$\overset{6.0}{B_s^0} \to 3\mu^+3\mu^- \quad \text{and} \quad \overset{5.9}{B^+} \to K^+3\mu^+3\mu^- \quad \times 10^{-9}$$

(B^0) 1.6 $\qquad (B_s^0 \to K^{*0})$ 18.

- None of these signals has been explored experimentally
- The *three-body decay* is a *key* signature
- If a signal is observed, the scalars could be reconstructed *backup
- Sensible probe of effective operators

Thank you very much for your attention!

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If a signal is observed:

Algorithm:

$(m_2 > 2m_1)$

- Minimize

  $|m_{11}^{rec} - m_{12}^{rec}| + |m_{12}^{rec} - m_{13}^{rec}|$

- Reconstruct a_2 from the two closest a_1^{rec}