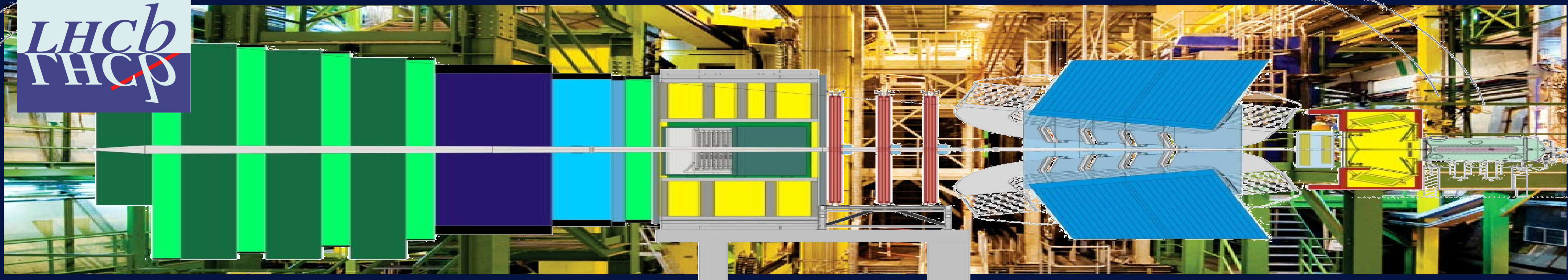

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Search for the rare decays $B^0_{(s)} \to \mu^+\mu^-$ with the LHCb Experiment

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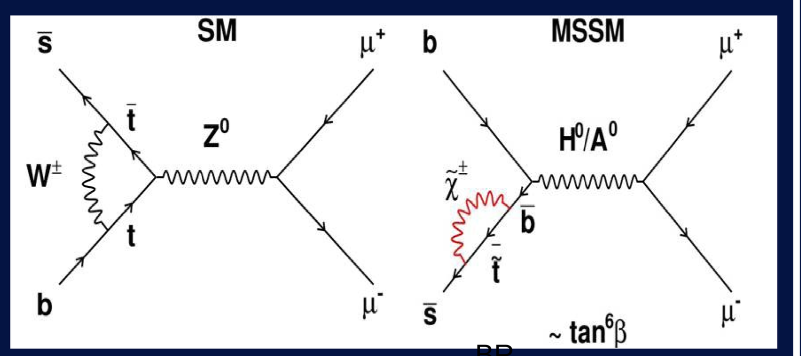
1. Introduction

$B^0_s \to \mu^+\mu^-$ Feynman diagrams

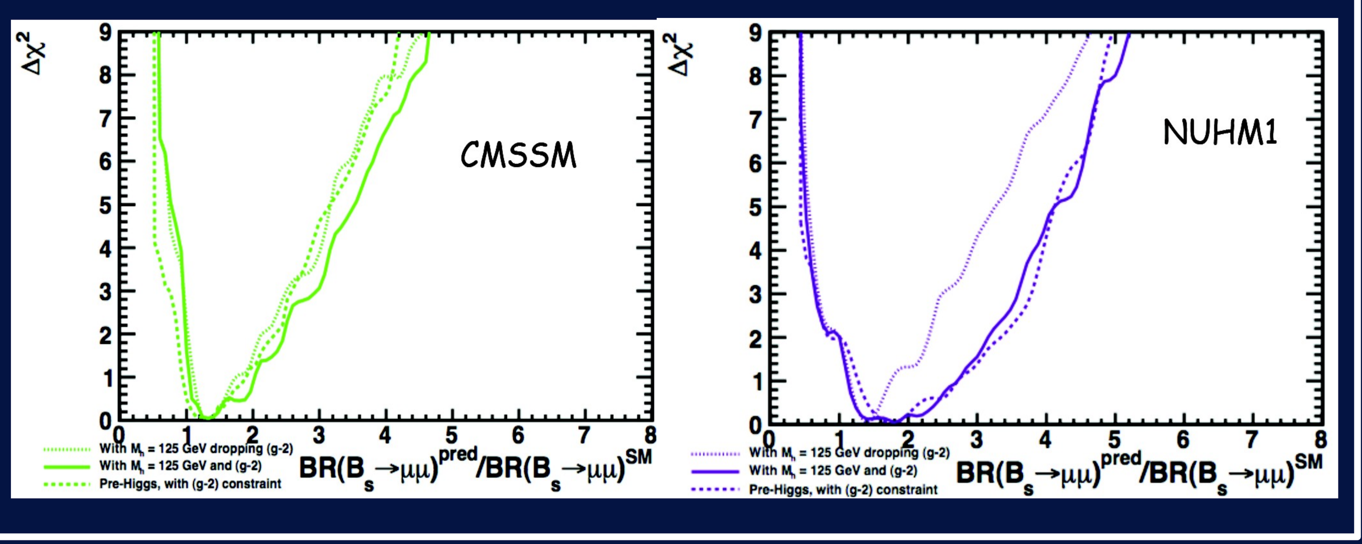


Within the Standard Model the $B^0_{(s)} \to \mu^+\mu^-$ decays are very rare (FCNC and helicity suppression) and precisely predicted [1]:

$\mathcal{B}(B^0_s \to \mu^+\mu^-) = (3.2 \pm 0.2) \times 10^{-9}$
$\mathcal{B}(B^0 \to \mu^+\mu^-) = (1.0 \pm 0.1) \times 10^{-10}$

In New Physics (NP) scenarios with large tan β the BR of these decays can be high. Therefore the measurement of these decays bring very stringent constraints on NP parameters.

Likelihoods of the ratios between the predicted BR($B^0_s \to \mu^+\mu^-$) in two MSSM models and the SM prediction. [2]



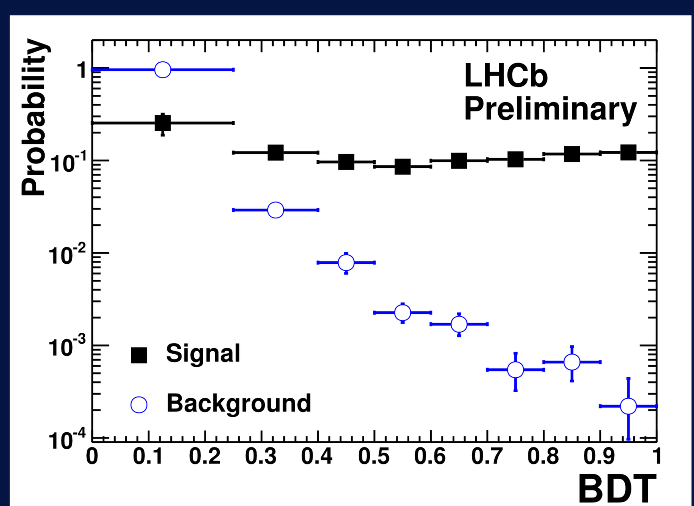
2. $B \to \mu\mu$ at LHCb

LHCb performances

- Large cross section: σ(pp → $b\bar{b}$X) ~ 300 μb at 7 TeV [3].
- Large acceptance for bb pairs produced mostly forward/backward: LHCb covers 2<η<5.
- Efficient trigger on low p_T muons.
- Large boost: the B meson decay vertex is displaced in average ~ 1 cm from the PV .
- Good mass resolution: σ($B^0_{(s)} \to \mu^+\mu^-$) = ~25 MeV/c^2.
- Good impact parameter resolution: σ(IP) ~25 μm (p_T = 2 GeV/c).
- MuonID performance: ε(μ→μ) ~ 97 % (p>10 GeV/c), ε(h→μ) < 1% (p>10 GeV/c).

3. Analysis strategy

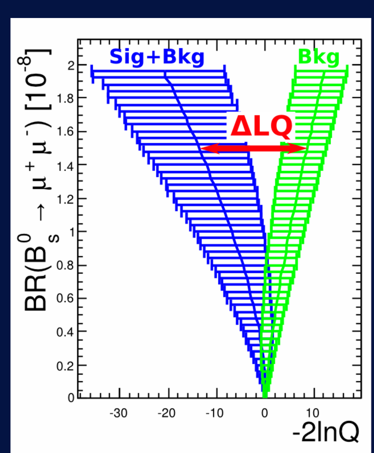
- **Multivariate selection** that reduces the size of the data sample and rejects most of the background.
- After the selection, a further **discrimination between signal and background** is achieved by combining variables* related with the geometry and the kinematics of the event into a single variable using a Boosted Decision Tree (BDT). This variable is defined to be flat for signal and peaked at zero for background.



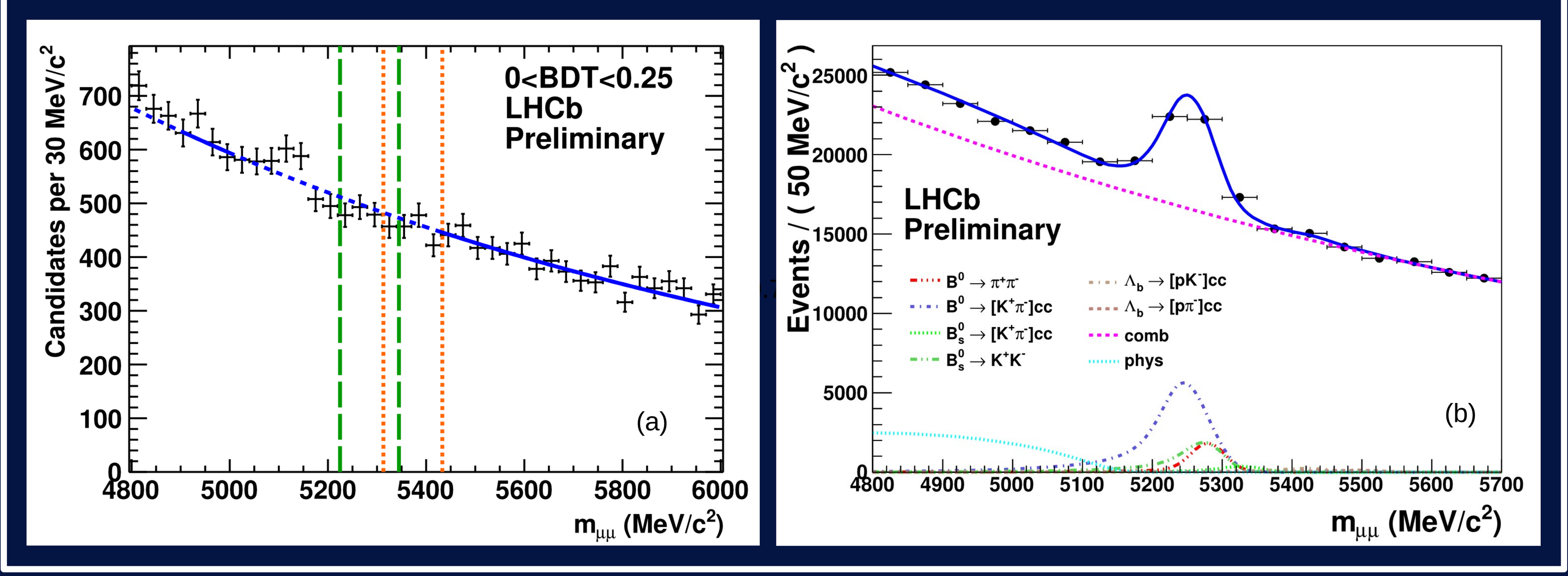
***List of the BDT variables:**

-the B lifetime
-the B impact parameter
-the B transverse momentum
-the isolation of the B
-the isolation of the muons
-the polarization angle
-the minimum transverse momentum
-the distance of closest approach
-the lowest impact parameter significance with respect to any reconstructed PV

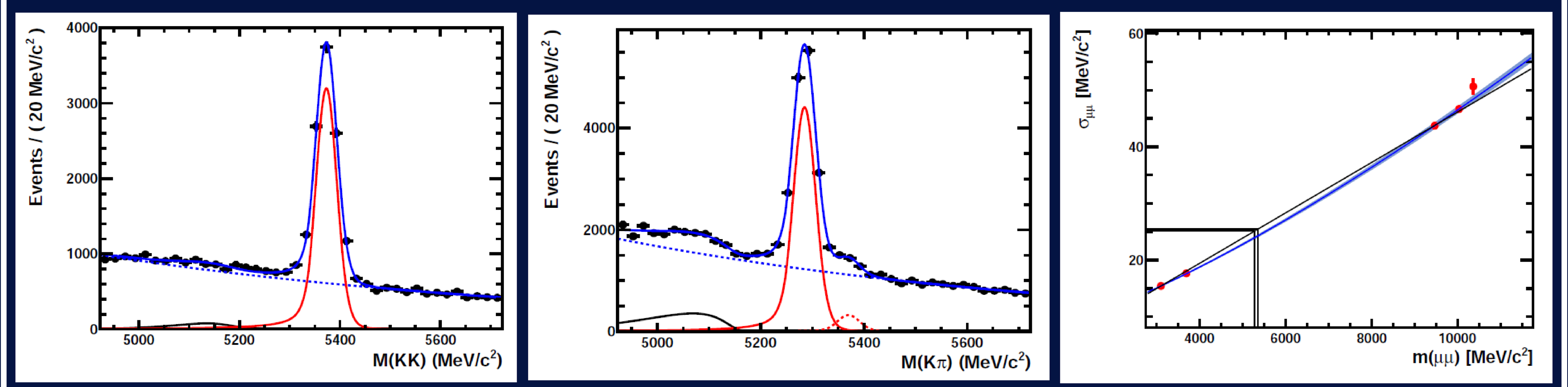
- Each event is given a probability to be signal or background in a two-dimensional space defined by the invariant mass and the BDT. This 2D space is **binned** in order to maximize the sensitivity (8 in the BDT and 9 in the invariant mass). The sensitivity is evaluated using the difference in test statistics between the two hypotheses background only and SM+background.
- The **expected number of background** events in each bin is obtained by interpolating from the mass sidebands (a).



- The **BDT line-hape for signal** is calibrated on data using a B → hh inclusive sample (b) and to define the **BDT for background** we use the events in the side-bands of the invariant mass distribution. **Invariant mass line-shape for signal:** mean determined from exclusive B→hh modes and width from interpolation between di-muon resonances (J/Ψ, Ψ(2S), Y(1S),Y(2S),Y(3S)).



B^0_s mass extraction / B^0 mass extraction / Resolution extraction



- The expected number of signal events in each bin is obtained by normalizing to a channel with well measured BR. In this way the knowledge of the absolute luminosity and the bb cross section are not needed:

$$\mathrm{BR} = \mathrm{BR}_{\mathrm{cal}} \times \boxed{\frac{\epsilon^{\mathrm{REC}}_{\mathrm{cal}}\,\epsilon^{\mathrm{SEL|REC}}_{\mathrm{cal}}\,\epsilon^{\mathrm{TRIG|SEL}}_{\mathrm{cal}}}{\epsilon^{\mathrm{REC}}_{\mathrm{sig}}\,\epsilon^{\mathrm{SEL|REC}}_{\mathrm{sig}}\,\epsilon^{\mathrm{TRIG|SEL}}_{\mathrm{sig}}}} \times \boxed{\frac{f_{\mathrm{cal}}}{f_{B^0_q}}} \times \frac{N_{B^0_s\to\mu^+\mu^-}}{N_{\mathrm{cal}}} = \underbrace{\boxed{\alpha}}_{\text{Normalization factor}} \times N_{B^0_s\to\mu^+\mu^-}$$

ε^{REC} reconstruction efficiency, includes acceptance and particle identification;
$\varepsilon^{SEL|REC}$ selection efficiency on reconstructed events;
$\varepsilon^{TRIG|SEL}$ trigger efficiency on reconstructed events

f_x denotes the probability that a b-quark fragments into a B_x hadron

Two of the channels used have similar trigger efficiency and muon identification efficiency to the signal but a different number of particles in the final state. The third one has the same topology but is selected with different trigger. (BR values on table below).

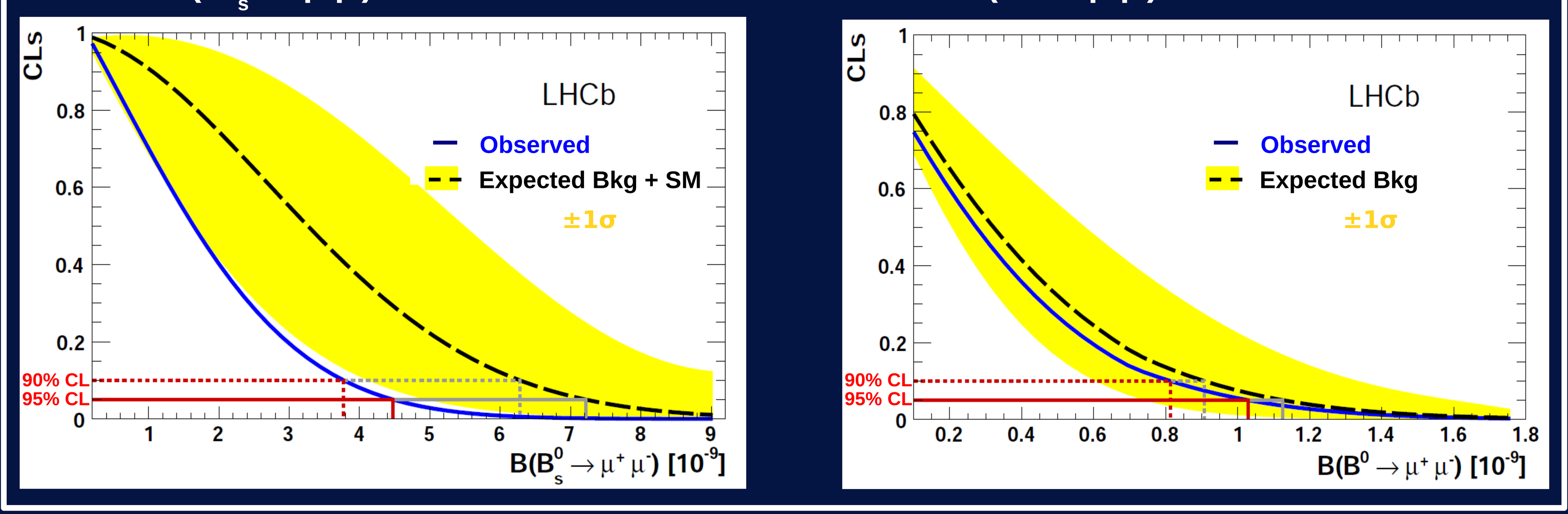
	$\mathcal{B}$ ($\times 10^{-5}$)	$\frac{\epsilon^{REC}_{cal}\epsilon^{SEL\|REC}_{cal}}{\epsilon^{REC}_{sig}\epsilon^{SEL\|REC}_{sig}}$	$\frac{\epsilon^{TRIG\|SEL}_{cal}}{\epsilon^{TRIG\|SEL}_{sig}}$	N_{cal}	$\alpha^{cal}_{B_d\to\mu^+\mu^-}$ ($\times 10^{-11}$)	$\alpha^{cal}_{B_s\to\mu^+\mu^-}$ ($\times 10^{-10}$)
$B^+ \to J/\psi K^+$	6.01 ± 0.21	0.502 ± 0.013	0.954 ± 0.022	$340\,129 \pm 4468$	8.464 ± 0.433	3.170 ± 0.297
$B^0_s \to J/\psi\phi$	3.4 ± 0.9	0.245 ± 0.011	0.954 ± 0.022	$19\,035 \pm 158$	11.13 ± 3.124	4.169 ± 1.123
$B^0 \to K^+\pi^-$	1.94 ± 0.06	0.857 ± 0.028	0.0469 ± 0.0034	$10\,124 \pm 916$	7.709 ± 0.957	2.887 ± 0.424

- For each 2D bin evaluate CL_s [4] to extract the limits.

4. Results

Observed upper limits at 95 % C.L. [5]:

$\mathcal{B}(B^0_s \to \mu^+\mu^-) < 4.5 \times 10^{-9}$ $\mathcal{B}(B^0 \to \mu^+\mu^-) < 1.0 \times 10^{-9}$



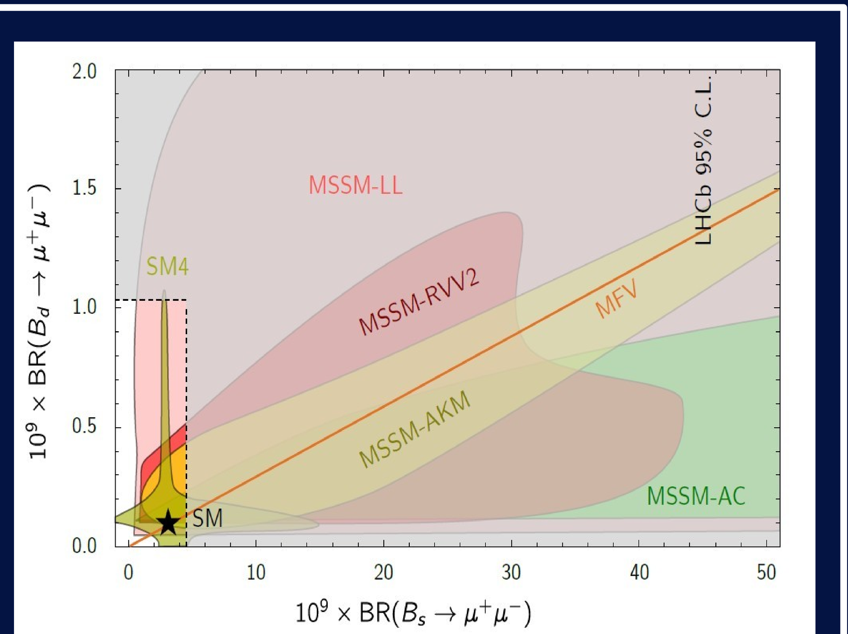
5. Conclusions

With 1 fb^{-1} at LHCb no significant excess of $B^0_{(s)} \to \mu^+\mu^-$ events has been observed and the world best limits on the decay branching fractions have been set at 95% CL:

$\mathcal{B}(B^0_s \to \mu^+\mu^-) < 4.5 \times 10^{-9}$
$\mathcal{B}(B^0 \to \mu^+\mu^-) < 1.0 \times 10^{-9}$

These limits constrain NP models →

The data expected during the 2012 will allow LHCb to explore the region of branching ratios ~SM.



(modified from [6])

[1] A.J. Buras. Acta Phys. Pol vol 41 (2010).
[2] O. Buchmueller et al., arXiv:1112.3564. (2012)
[3] The LHCb Collaboration, Phys. Lett. B 694 (2010) 209
[4] A.L. Read, J. Phys. G 28, 2693 (2002);
T. Junk, Nucl. Instrum. Meth. A 434, 435 (1999).
[5] The LHCb Collaboration, LHCb-PUB-2012-007.
[6] D.M. Straub. arXiv:1107.0266 (2011).

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