Search for long-living scalars in $B^+ \to \chi(\to \mu^+\mu^-) + K^+$ decays at LHCb

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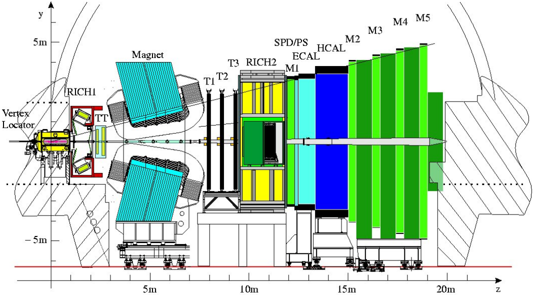
Introduction

1. LHCb is a forward spectrometer placed at **LHC**

Introduction: the detector

1. LHCb is a **forward** spectrometer placed at LHC
   - Pseudorapidity range: $2 < \eta < 4$
   - focused on the study of b and c decays
   - 3 fb^{-1} of data collected in 2011 and 2012

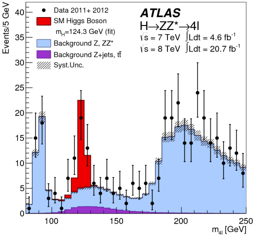


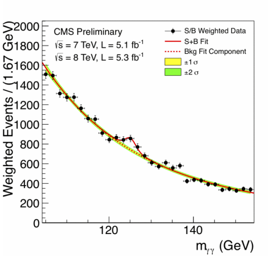
Introduction: LHCb physics

2. LHCb results:
   - many of the most up-to-date SM measurements ($B_s \to \mu\mu$, $B \to K^*\mu\mu$, CP violation, lepton universality, ect.)
   - also able to set limits on new physics (LFV, very rare B decay, ect.)

Theoretical motivation

- A Higgs-like Boson has been discovered!





- It is the first fundamental scalar particle in nature
- **Is there still room for fundamental scalars?**

Theoretical motivation

- Some models proposed the existance of a new scalar that mix with the SM Higgs:
  - M. Winkler et al., *Constraints on light mediators: confronting dark matter searches with B physics*, arXiv:1310.6752;
  - J. Clarke et al., *Phenomenology of a very light scalar mixing with the SM Higgs*, arXiv:1310.8042
  - F. Bezrukov et al., *Light inflaton after LHC8 and WMAP9 results*arXiv:1303.4395v1

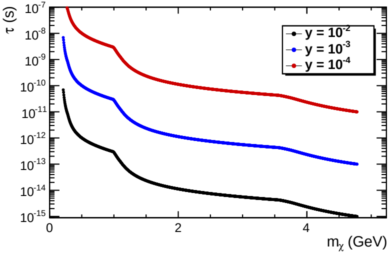
- The new scalar (χ) could have $m_\chi < 5$ GeV

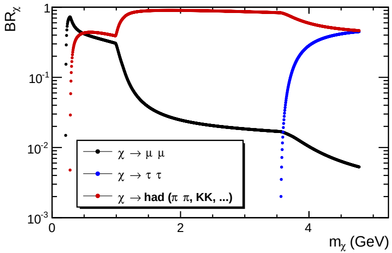
$$\begin{pmatrix} H \\ \chi \end{pmatrix} = \begin{pmatrix} \cos\rho & -\sin\rho \\ \sin\rho & \cos\rho \end{pmatrix} \begin{pmatrix} \phi_0' \\ S' \end{pmatrix}$$

$\mathbf{y = \sin\rho}$ is the coupling parameter to the Higgs

Properties of the new scalar χ

- All the coupling to the SM particles are proportional to y^2
  - production cross section
  - partial width
- The branching fractions do not depend on y^2
- The lifetime is inversely proportional to y^2



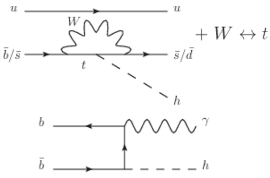


The case with $\sin\rho = 1$ corresponds to a SM Higgs with mass m_χ

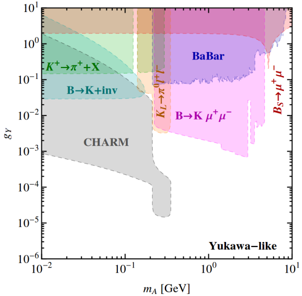
Production mechanism and current limit

Produced at LHC through meson decays (if kinematically allowed):

- $K \to \chi\, \pi$
- $\mathbf{B \to \chi\, K^{(*)}}$
- $\Upsilon \to \chi\, \gamma$

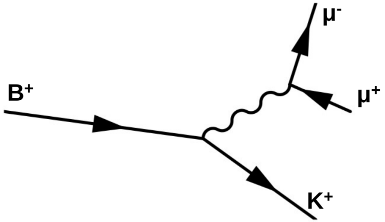


The current limit on the parameters space $(m_\chi,\, y)$ is:



Strategy of the analysis

- Long living particle
  - from B decay
  - di-muon displaced vertex
  - single track associated to the B-decay

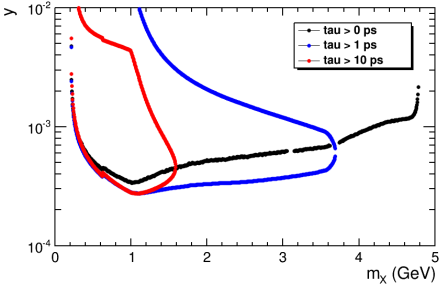


How much displaced?

Sensitivity preliminary study

We may want to cut on the lifetime of the reconstructed χ candidate

- LHCb acceptance:
- decay inside the VELO
  - $L_{min} = 0, L_{max} = 50$ cm
- 3 $fb^{-1} \sim 10^{10}$ B mesons
- efficiencies studied with MC
- combinatorial background extrapolated from the sideband
- SM $B \to K\mu\mu$ (affects only $\tau_{cut} = 0$)

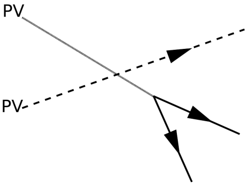


Not a simple choise due to the restriction of the parameter space

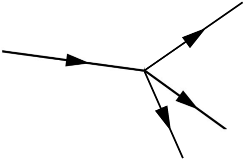
Background

Different sources of background:

1. Combinatorial background
   - does not peak in the signal region [B window]



2. Background from B decay:
   - $B^+ \to K^+ J/\psi$, [...]
   - SM $B^+ \to K^+\mu^+\mu^-$

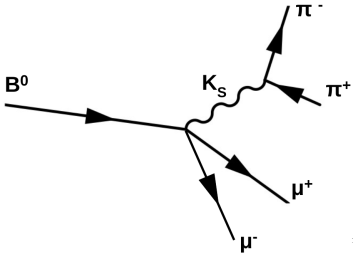


Signal VS background main difference: displaced di-muon vertex!
All the most discriminant variables are combined by a BDT algorithm.

Normalization channel: $B^0 \to J/\psi K_S$

As usual in LHCb analysis, we require a control channel to normalize the signal yield:

- Same topology (displaced vertex) except for the final number of tracks
- well known branching ratio: $\mathrm{BR}(B^0 \to (J/\psi \to \mu\mu)(K_S^0 \to \pi\pi)) = 1.8 \cdot 10^{-5}$
- $\sim 28.5 \cdot 10^3$ events observed at LHCb



Data-driven correction of the MC efficiency:

$$\varepsilon^{sig} = \varepsilon^{sig}_{MC} \frac{\varepsilon^{norm}_{DATA}}{\varepsilon^{norm}_{MC}}$$

Summary

- This has been the work for my first 6 months of PhD

- There's still a long way to go...
  - This is a blind analysis
  - τ_{cut} and BDT selection still to be optimized
  - proper background evaluation

- Conclusions
  - We expect to reduce the limit from B-factories of one order of magnitude
  - The analysis covers all the parameter space predicted by the inflaton model