Exploring Excited B Mesons at the LHCb Experiment

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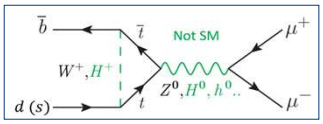
Abstract

The Large Hadron Collider beauty (LHCb)[1] experiment is a detector experiment collecting proton-proton collision data at the LHC. It is designed to study precisely the properties of particles containing bottom (b) and charm (c) quarks, with the aim of searching for possible deviations from predictions of theory. In particular, we look for extremely rare decays whose observation could provide hints of physics beyond the Standard Model (SM). The aim of my project is to search for the decay of excited $B^{*0}_{(s)}$ mesons into two muons.

Introduction



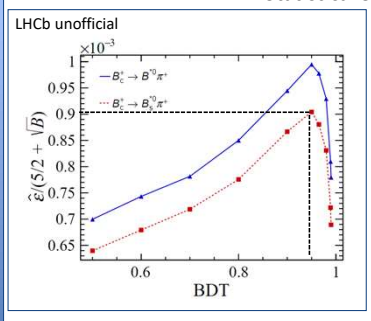
The SM successfully describes all known elementary particles and their interactions, but it fails to describe cosmological observations and explain features of its framework. Looking for deviations from the SM predictions is today the primary goal of experimental particle physics, for example by searching for rare decays expected to occur at rates as tiny as one in a trillion. We search for the $B^{*0}_{(s)} \to \mu^+\mu^-$ decays occurring via the B_c^+ decay chain shown. The method is to look for signal peaks in the two-dimensional distribution of the reconstructed B_c^+ and dimuon mass.
To maximise the sensitivity, we optimise a multivariate selection to suppress background.

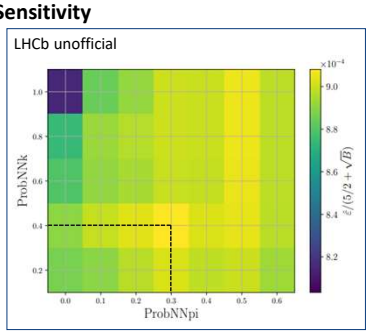
$$B_c^+ \to B^{*0}_{(s)}\pi^+, \quad B^{*0}_{(s)} \to \mu^+\mu^-$$

Optimisation

A multivariate algorithm (MVA) is used to discriminate between the signals and the background, caused by random combinations of particles. The algorithm exploits topological and kinematical information. We optimise a selection based on the output of this algorithm and particle identification information. We scan over a grid of possible combinations of selection criteria and choose the one that maximises the statistical sensitivity[2].

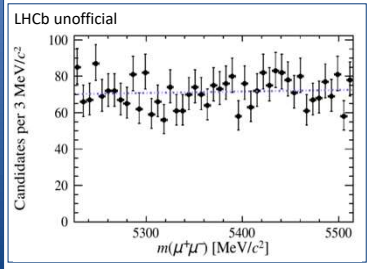
Statistical Sensitivity



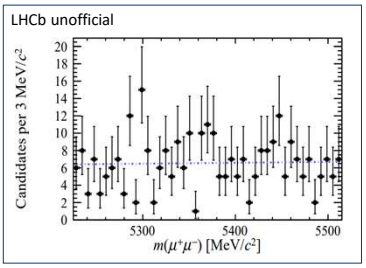


Optimal Selection Criteria

Background distribution in data



Unoptimised Selection Criteria

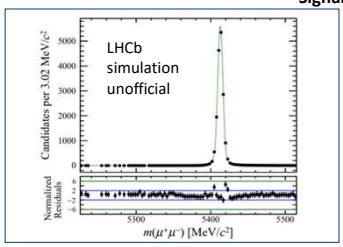


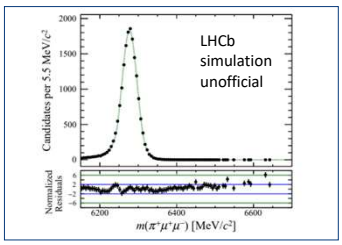
Optimal Selection Criteria

Invariant Mass Fits

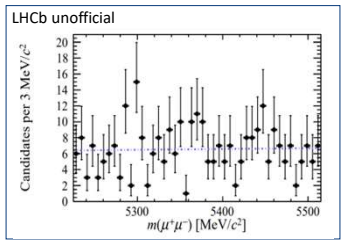
We describe the distributions of the signals and the background using empirical analytical functions validated in simulation and collision data. We then search for signals by performing fits of sample composition to the data.

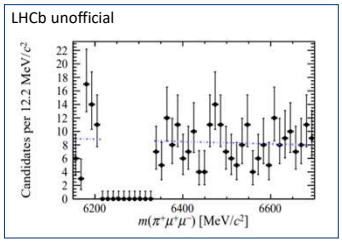
Signal simulation





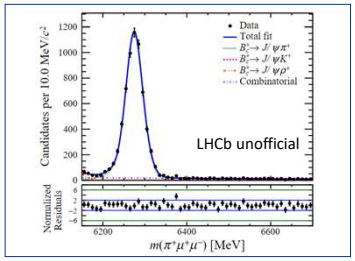
Background data

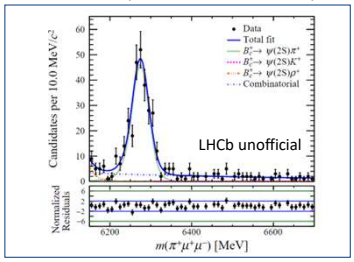




Validation

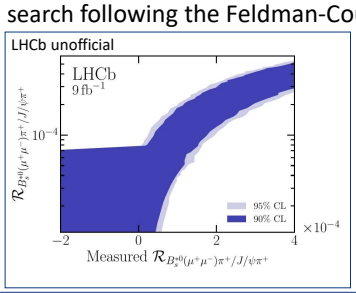
We validate our analysis procedure by measuring the ratio between the decay rates of the resonant modes $B_c^+ \to J/\psi\pi^+$ and $B_c^+ \to \psi(2S)\pi^+$ and checking that the measured value of the ratio (0.0366 ± 0.0030) agrees with the known value (0.0337 ± 0.0028)[2].

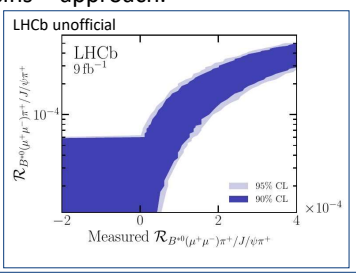




Results

We estimate the rate, $R_{B^{*0}_{(s)}(\mu^+\mu^-)\pi^+/J/\psi\pi^+}$, between the efficiency-corrected yields for the signal modes and the $B_c^+ \to J/\psi\pi^+$ mode. Based on pseudoexperiments we estimate the sensitivity of the search following the Feldman-Cousins[4] approach.





References

1. http://lhcb.web.cern.ch/
2. G. Punzi, eConf C030908 1326 (2003) MODT002, https://arxiv.org/abs/physics/0308063
3. LHCB-PAPER-2023-037 (https://cds.cern.ch/record/2873623)
4. G. J. Feldman and R. D. Cousins, Phys. Rev. D57 (1998) 3873, https://arxiv.org/abs/physics/9711021