Search for $B^0_s \to \eta' \phi$ decays at LHCb

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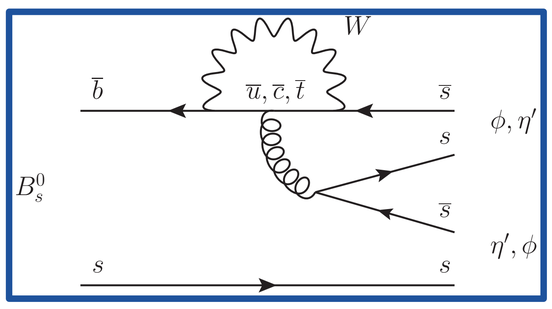
1. Motivation

The $B^0_s \to \eta' \phi$ decay has never been observed.

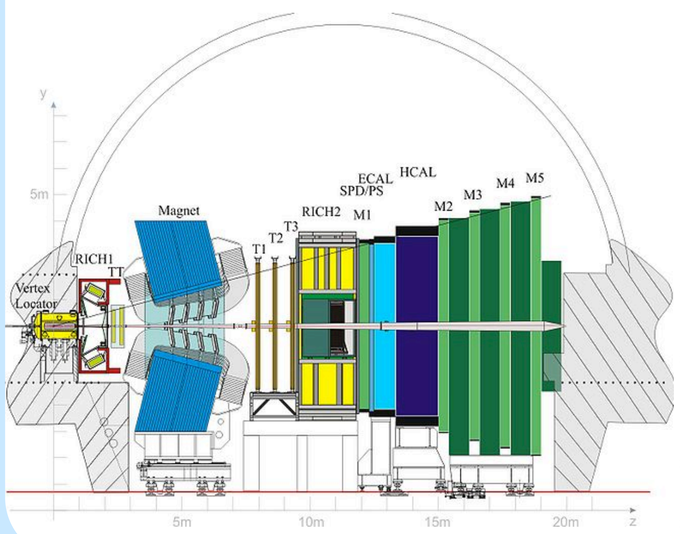
- It belongs to the family of $b \to s\bar{s}s$ transitions $B^0_s \to XX$ ($X = \eta^{(\prime)}, \phi$), useful to measure the B_s mixing-induced CP violation.
- Wide range of predictions in Standard Model.
  Poor knowledge of $B \to \phi$ form factor, $\omega - \phi$ mixing angle.
- Branching fraction prediction is small due to strong cancellation of PV and VP final states.

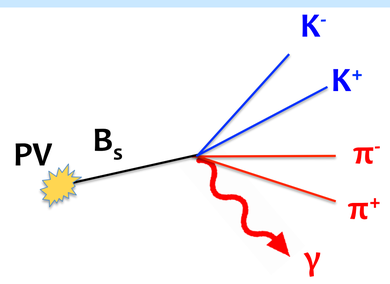


Predictions

Theory approach	$\mathcal{B}$ (10^{-6})
QCD factorisation	$0.05^{+1.18}_{-0.19}$
QCD factorisation	$2.2^{+9.4}_{-3.1}$
Perturbative QCD	$0.19^{+0.20}_{-0.13}$
Perturbative QCD	$20.0^{+16.3}_{-9.1}$
SCET	$4.3^{+5.2}_{-3.6}$
SU(3) flavour symmetry	5.5 ± 1.8
FAT	13.0 ± 1.6

2. LHCb detector





- High B^0_s production rate
- Good momentum resolution ($\Delta p/p \sim 0.4$-0.6%)
- Good B^0_s vertex reconstruction
- Good π/K identification

3. Strategy

The search is performed using Run1 dataset (3 fb^{-1}) and the $B^+ \to \eta' K^+$ decay as normalization channel in the determination of the branching fraction.

$$Br(B^0_s \to \eta' \phi) = \frac{Br(B^+ \to \eta' K^+)}{Br(\phi \to K^- K^+)} \times \frac{f_u}{f_s} \times \frac{N(B^0_s \to \eta' \phi)}{N(B^+ \to \eta' K^+)} \times \frac{\varepsilon(B^+ \to \eta' K^+)}{\varepsilon(B^0_s \to \eta' \phi)}$$

- Known branching fractions
- B^+/B_s production fractions
- Signal yields obtained from fit to data
- Selection efficiencies

4. Event selection

$B^0_s \to \eta' \phi$ candidate selection:

- Trigger: select inclusive B decays
- Loose pre-selection
- PID helpful in reducing physics backgrounds:
  - $B^0 \to \phi K^*$
  - Modes with resonances decaying to $K^+\pi^-\pi^0$
- Selection with Boosted Decision Tree:
  - Input: topological and kinematical variables
  - Most powerful: quality of B vertex and p_T of the photon
- Similar selection for normalization channel to reduce systematics

Total efficiency ratio

$$\frac{\varepsilon(B^+ \to \eta' K^+)}{\varepsilon(B^0_s \to \eta' \phi)} = 1.83 \pm 0.08$$

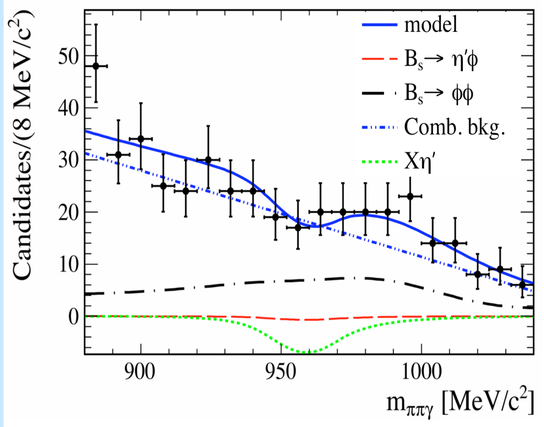
- Uncertainty dominated by BDT, trigger, and PID efficiency calibration

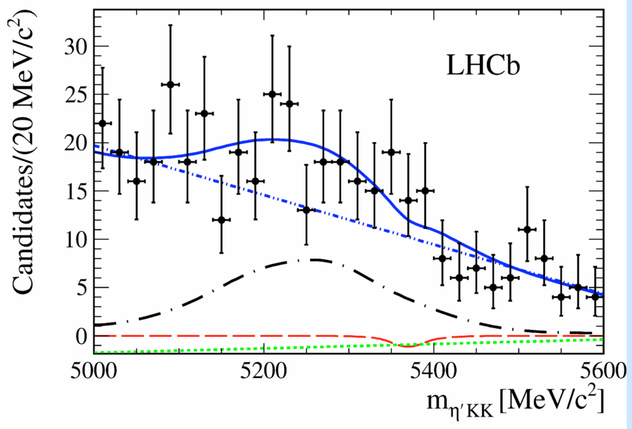
Efficiency uncertainty

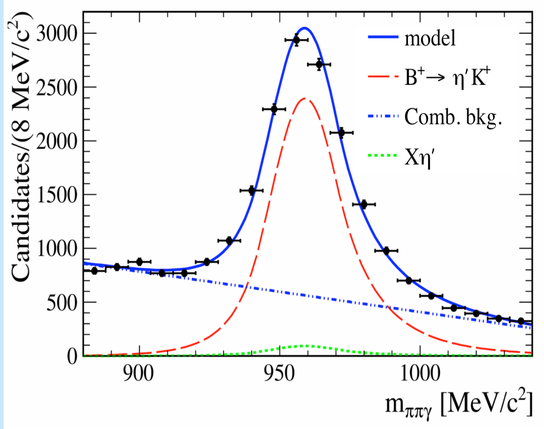
Source	Relative uncertainty [%]
BDT efficiency calibration	2.5
PID efficiency calibration	1.1
Trigger efficiency calibration	2.3
SPD multiplicity (mismodelling)	0.9
Track reconstruction	0.4
Photon reconstruction	0.1
Hadronic interactions	1.4
Simulation statistics	1.6
Total	4.3

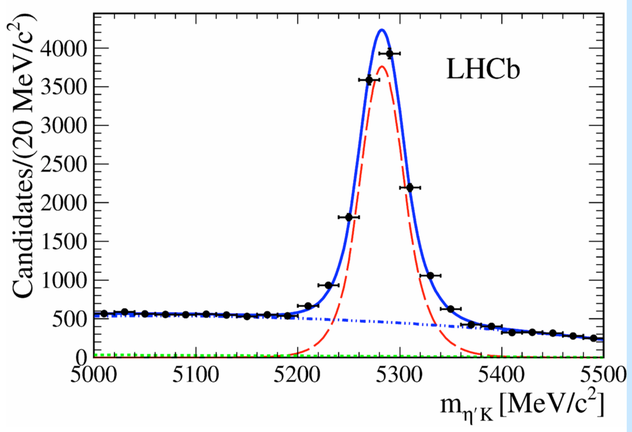
5. Signal yields

Yields obtained for signal and normalization channel from two-dimensional simultaneous unbinned maximum likelihood fit to the invariant mass distributions $\eta' K^+ K^-$ ($\eta' K^+$) and $\pi^+\pi^-\gamma$.









No signal is found. Fitted signal yield $N_{signal} = -3.2^{+5.0}_{-3.8}$

$$\frac{N(B^0_s \to \eta' \phi)}{N(B^+ \to \eta' K^+)} = (-1.7^{+4.5}_{-3.5} \pm 1.0) \times 10^{-4}$$

Systematic uncertainty

Source	σ_N (events)	σ_R (10^{-4})
Fit bias	0.7	0.7
Combinatorial background modelling	0.6	0.6
$B^0_s \to \phi\phi$ background modelling	0.4	0.3
Fixed parameters in the fit	0.3	0.3
Total	1.1	1.0

6. Results and conclusions

Upper limit calculated using Bayesian approach. Uniform prior assumed for the branching fraction:

$$Br(B^0_s \to \eta' \phi) < 0.82\ (1.01) \times 10^{-6} \text{ at } 90\%\ (95\%)\ \text{CL}$$

Result incompatible with the central values of many predictions, although the large uncertainties on these predictions do not exclude them.

Reference

[1] Roel Aaij et al. [LHCb collaboration], Search for the $B_s \to \eta' \phi$ decay, [hep-ex/1612.08110].