Measurement of $\Delta\Gamma_s$ using the B_s decays to the final states $J/\psi\eta'$ and $J/\psi f_0$

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$B^0_{(d,s)}$ mixing

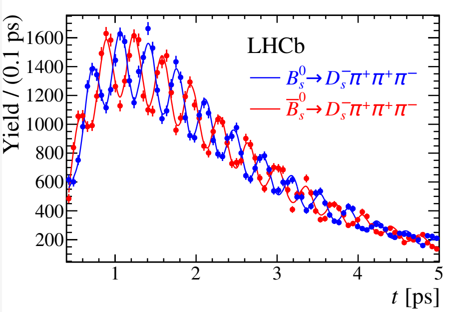
- In the Standard Model (SM) $B^0_{(d,s)}$ oscillation comes from the weak interaction.
- Mixing can be described by the effective Hamiltonian

$$\mathcal{H} = \mathcal{M} + \frac{i}{2}\Gamma$$

- Two possible eigenvalues called heavy (H) and light (L).

$$\Downarrow$$

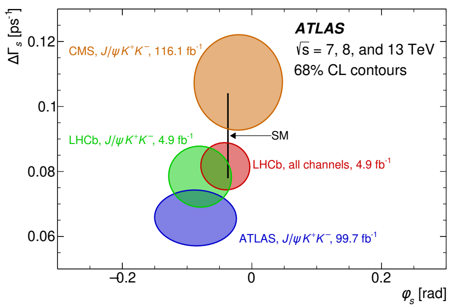
$$(1/\tau_L - 1/\tau_H) \equiv (\Gamma_L - \Gamma_H) \equiv \Delta\Gamma_{(d,s)}$$



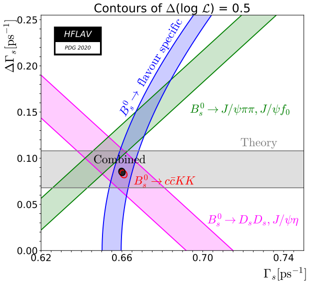
B_s^0 oscillation (10.1007/JHEP03(2021)137)

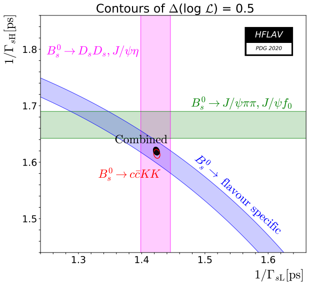
$\Delta\Gamma_s$, τ_L and τ_H measurements - overview

Some tension between ATLAS and CMS $\Delta\Gamma_s$ measurements $\Rightarrow$ a new measurement of $\Delta\Gamma_s$ can provide input resolving this tension.



Overview of ATLAS, CMS and LHCb measurements of $\Delta\Gamma_s$ (arXiv:2001.07115)





$\Delta\Gamma_s$ vs Γ_s (left) and τ_L vs τ_H (right) measurements (HFLAV)

Goals

- Measuring the lifetime difference between the two CP eigenstates of the B_s meson.
- $B_s \to J/\psi\eta'$ gives access to the CP-even eigenstate (τ_L).
- $B_s \to J/\psi f_0$ gives access to the CP-odd eigenstate (τ_H).
- Aiming at 0.01 ps^{-1} precision.

Data set

- Full run 1 and run 2 data corresponding to 9 fb^{-1}.
- Using the $\eta' \to \left(\rho^0 \to \pi^+\pi^-\right)\gamma$ decay mode due to its high yields and low background.
- Using the $f_0 \to \pi^+\pi^-$ decay as control mode: very similar decay with 4 tracks.
- In both decays $J/\psi \to \mu^+\mu^-$.

Assuming pure CP odd/even states and no direct CP violation, the number of events in a given lifetime interval can be written as:

$$N_H = \int_{t_1}^{t_2} e^{-\Gamma_s t}\left(\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) + \sinh\left(\frac{\Delta\Gamma_s t}{2}\right)\right) dt$$

$$N_L = \int_{t_1}^{t_2} e^{-\Gamma_s t}\left(\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) - \sinh\left(\frac{\Delta\Gamma_s t}{2}\right)\right) dt$$

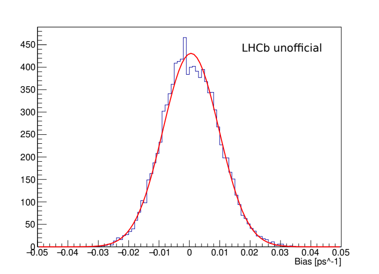
$$\Downarrow$$

$$\frac{N_L}{N_H} = \left[\frac{e^{t\left(\frac{-\Delta\Gamma_s}{2} - \Gamma_s\right)}}{e^{t\left(\frac{\Delta\Gamma_s}{2} - \Gamma_s\right)}}\right]_{t_1}^{t_2} \frac{\Gamma_s - \frac{\Delta\Gamma_s}{2}}{\Gamma_s + \frac{\Delta\Gamma_s}{2}}$$

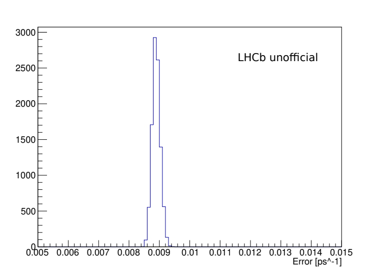
We would split the data set in multiple lifetime bins, compute the yields of the two modes, construct a χ^2, minimize it and extract $\Delta\Gamma_s$.

Preliminary toys

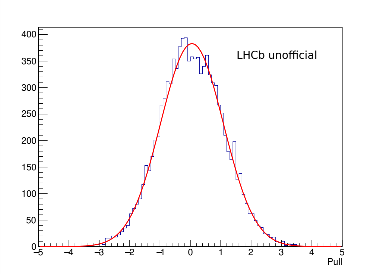
Generated 8000 toys to test the precision achievable taking into account the time acceptance introduced by the detector and with 7 bins of lifetime:



Bias



Error

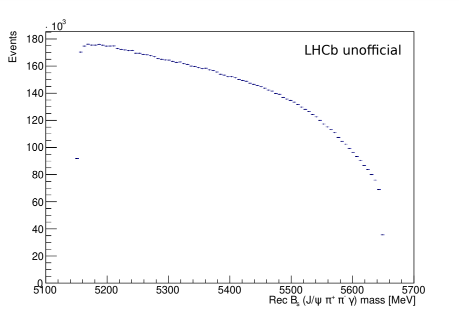


Pull

Selection cuts

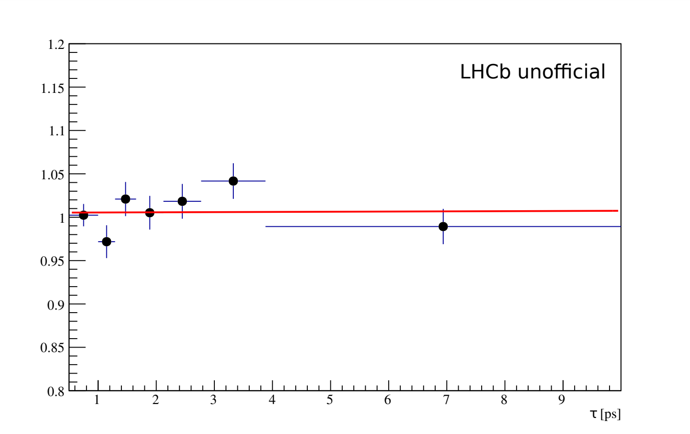
After selecting candidate events applying loose cuts (right plot), tighter cuts need to be applied in order to remove the background:

- $\tau_{B_s} > 0.5$ ps.
- Good quality B_s candidate selection.
- J/ψ selection at trigger level.
- Neural networks used for pions and muons PID and to classify muons' tracks.



Reconstructed B_s^0 mass, with loose selection cuts 2016 data set.

Time acceptance checks



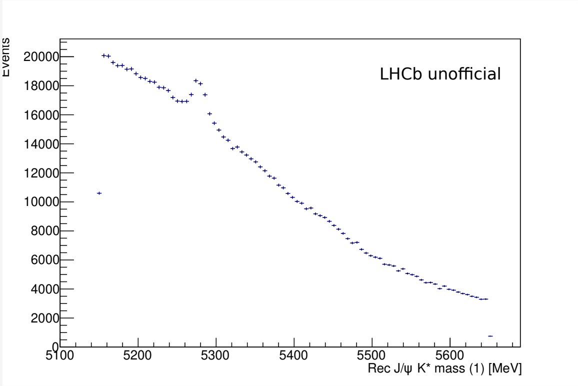
Time acceptance ratio between η' and f_0 channels - 2016 MC.

Peaking background

- Despite the selection cuts, a component of peaking background is still present.
- This type of background is generated by wrongly reconstructed particles (e.g. a pion reconstructed as a kaon).
- $\Rightarrow$ another decay is selected.
- This type of background can be vetoed by reconstructing the invariant mass with different mass hypothesis and applying tighter PID requirements.

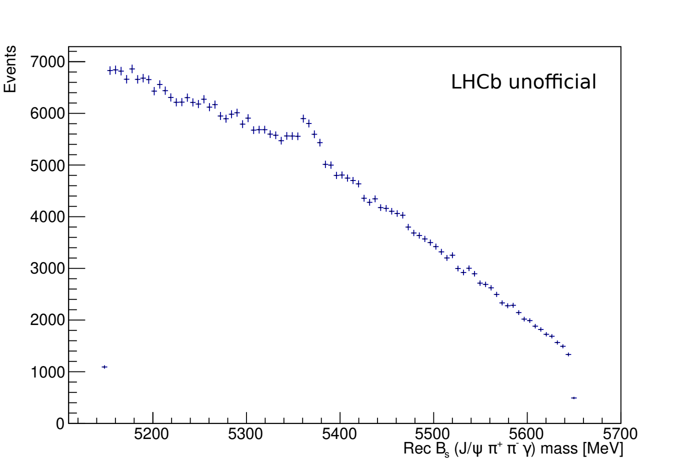
Peaking background

One of the contribution is $B_d \to J/\psi\left(K^{0*} \to K\pi\right)$ where a pion is wrongly reconstructed as kaon and the photon is not detected:



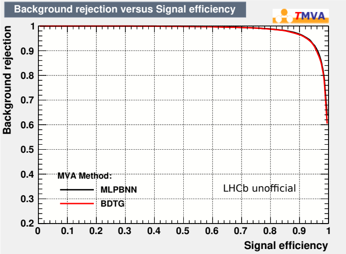
Reconstructed $J/\psi K^*$ mass - 2016 data set.

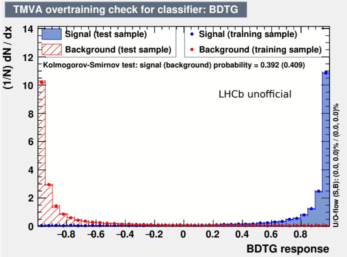
B_s^0 mass spectrum

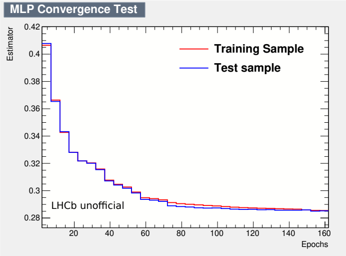


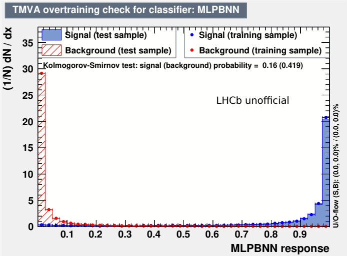
Reconstructed B_s^0 mass, selection cuts and peaking background veto applied - 2016 data set.

MVA performance - η'



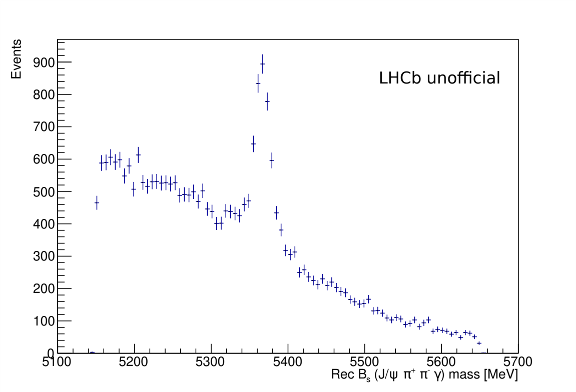






MVA on data

Preliminary $B_s^0 \to J/\psi\eta'$ mass plot corresponding to $\mathcal{O}(2500)$ events for the 2016 data set:



Reconstructed B_s^0 mass, MVA cuts applied - 2016 data set.

Conclusions

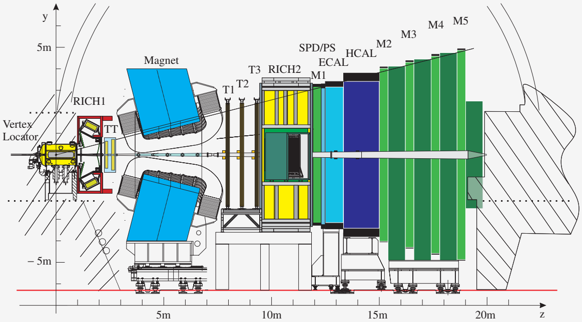
- The strategy to measure $\Delta\Gamma_s$ using the $B_s^0 \to J/\psi\eta'$ channel normalized to the $B_s^0 \to J/\psi f_0$ was presented.
- Time acceptance response is under control showing a flat response.
- Toy studies showed good performance.
- A solid veto of the peaking background components was put in place.
- MVA showed a very good response classifying signal and background.
- Working on the mass fit and the $\Delta\Gamma_s$ measure.

Thank you for your attention

Backups

LHCb experiment

The LHCb experiment studies CP violation and rare decays of beauty and charm hadrons to better understand matter/antimatter asymmetry in the Universe and to test standard model prediction.



LHCb detector.