Measuring $\Delta\Gamma_d$ with Run 3 LHCb data

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For neutral B mesons, flavour and mass eigenstates do not align. Instead the B^0 and $\bar{B}^0$ mesons are both linear combinations of the mass eigenstates $B^0_{L/H}$. These states are predicted to have slightly different lifetimes, with the difference of their inverse lifetimes being $\Delta\Gamma_d$. Due to its predicted smallness, $\Delta\Gamma_d/\Gamma_d(SM) = (4.2 \pm 0.8) \times 10^{-3}$ [1], a measurement of this parameter is expected to be sensitive to new physics [2] [3]. Further, $\Delta\Gamma_d$ provides the leading systematic uncertainty when determining $\sin(2\beta)$, an angle of the CKM-triangle.
For a precise measurement of $\Delta\Gamma_d$ two decay channels are required. The natural candidates for this are $B^0 \to J/\psi K^{*0}$ and $B^0 \to J/\psi K^0_S$, decays into a flavour-specific final state and a CP eigenstate, respectively. As additional benefit, measuring with two topological similar channels allows many systematic uncertainties to cancel, although care is still necessary to avoid introducing a mode dependent bias.
In this analysis, $\Delta\Gamma_d$ is measured using data recorded by the upgraded LHCb experiment during the LHC's Run 3. The data set of more than $25\,\mathrm{fb}^{-1}$ of proton-proton collisions promises a large increase in statistical power over previous measurements.

To find recorded signal-decay candidates, a displaced $J/\psi \to \mu^+\mu^-$ vertex is demanded on trigger-level. Then the hadronic part of the decay is reconstructed offline. Background is suppressed using a BDT-based multivariate classifier. To handle the remaining background contribution, the sWeight technique uses the signal and background shape extracted from a fit to the invariant four-body mass of the B^0 to infer their shape in the decay-time distribution.
The observed decay-time distribution is shaped by the detector time-acceptance, requiring it to be carefully described. This acceptance function is modelled per channel using cubic splines and calibrated using the control mode $B^+ \to J/\psi K^+$.

In the next step to be fully implemented, $\Delta\Gamma_d$ and the B^0 lifetime are extracted in a simultaneous fit to both signal-mode decay-time distributions. While the analysis treats different data-taking periods separately, in this final step the fit runs on the entire available data set at once.

At the moment the analysis aims to finish a first version of its principal structure. Once that is completed, the methodology will be further refined and systematic studies will commence. As the LHCb detector has been fully upgraded before Run 3, there is still much to understand about its data set, such as the rate and impact of primary-vertex misassociation or the consistency of detector performance over time.

References

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[2] T. Gershon *$\Delta\Gamma_d$: A Forgotten Null Test of the Standard Model*, arXiv:1007.5135.

[3] C. Bobeth, U. Haisch, A. Lenz, B. Pecjak, G. Tetlalmatzi-Xolocotzi *On new Physics in $\Delta\Gamma_d$*, arXiv:1404.2531.