$B^0 \to D_s^{(*)} D_s^{(*)}$ and outlook of $B^0 \to D^{(*)} D$ at LHCb

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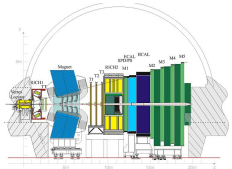


Introduction

The time evolution for B^0 and $\bar{B}^0$ mesons can be written as

$$\left|B^0_{(s)}(t)\right\rangle = g_+(t)\left|B^0_{(s)}\right\rangle + \frac{q}{p} g_-(t)\left|\bar{B}^0_{(s)}\right\rangle \qquad \left|\bar{B}^0_{(s)}(t)\right\rangle = g_+(t)\left|\bar{B}^0_{(s)}\right\rangle + \frac{p}{q} g_-(t)\left|B^0_{(s)}\right\rangle$$

where $g_\pm(t) = \frac{1}{2}(e^{-im_H t - \frac{1}{2}\Gamma_H t} \pm e^{-im_L t - \frac{1}{2}\Gamma_L t})$, L and H denote the light and heavy mass eigenstates, $\Delta m = m_H - m_L$ and $\Delta\Gamma = \Gamma_H - \Gamma_L$ are related to CKM matrix elements

Inclusive Branching Fraction in $B_s^0 \to D_s^{(*)} D_s^{(*)}$

- $B_s^0 \to D_s^{(*)+} D_s^{(*)-}$ branching fraction contributes to the determination of $\Delta\Gamma_s/\Gamma_s$ [1] [2], a key parameter of the SM
- It is one of the dominant contributions to the total inclusive $b \to c\bar{c}s$ branching fraction

What we measure is the branching fraction of $B_s^0 \to D_s^{(*)+} D_s^{(*)-}$ relative to $B^0 \to D_s^+ D^-$

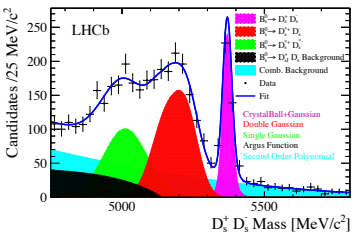
$$\frac{B(B_s^0 \to D_s^{(*)+} D_s^{(*)-})}{B(B^0 \to D_s^+ D^-)} = \frac{f_d}{f_s} \cdot \frac{\epsilon^{B^0}}{\epsilon^{B_s^0}} \cdot \frac{B(D^- \to K^+\pi^-\pi^-)}{B(D_s^+ \to K^- K^+ \pi^+)} \cdot \frac{N_{B_s^0}}{N_{B^0}}$$

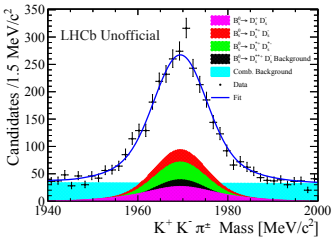
Data sample and Event selection

- The data set analysed corresponds to an integrated luminosity of 1fb^{-1}
- D_s^* decays as $D_s^* \to D_s\gamma(93.5\%)$ and $D_s^* \to D_s\pi^0(5.8\%)$
- Neither of the neutral particles is reconstructed in the decay chain

Mass Fit

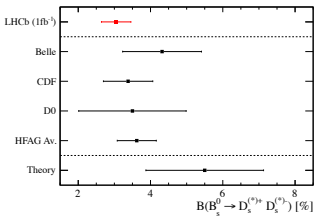
- B_s^0 and B^0 yields are extracted by a three-dimensional fit on $(m_{B_s^0}, m_{D_s^{(*)}}, m_{D_s^{(*)}})$





- Fixed shape parameters are taken from MC samples

Results [3]



$$\mathcal{B}(B_s^0 \to D_s^{(*)+} D_s^{(*)-}) = (3.05 \pm 0.10 \pm 0.20 \pm 0.34)\%,$$
$$\mathcal{B}(B_s^0 \to D_s^{*\pm} D_s^{\mp}) = (1.35 \pm 0.06 \pm 0.09 \pm 0.15)\%,$$
$$\mathcal{B}(B_s^0 \to D_s^{*+} D_s^{*-}) = (1.27 \pm 0.08 \pm 0.10 \pm 0.14)\%,$$

- The uncertainties are statistical, systematic and due to the normalisation channel
- The LHCb result is the most precise determination to date

Future Analysis: $B^0 \to D^* D^{(*)}$

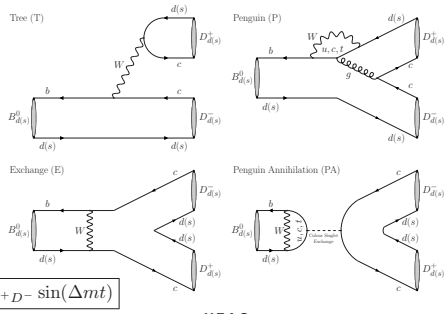
- $B^0 \to D^* D^{(*)}$ has the same underlying physics as $B^0 \to DD$
- The D^* is a vector particle and a full angular analysis will be required, the 3fb^{-1} taken in Run I would not be sufficient
- The channel $B^0 \to D^*(K\pi/K\pi\pi\pi)D(K\pi\pi)$ can be used to measure CP violation
- This analysis has started

References

1. C.-K. Chua, W.-S. Hou, and C.-H. Shen, *Long-distance contribution to $\Delta\Gamma_s/\Gamma_s$ of the $B_s^0 - \bar{B}_s^0$ system*, Phys. Rev. **D84** (2011) 074037, arXiv:1107.4325
2. A. Lenz, *Theoretical update of B-Mixing and Lifetimes*, arXiv:1205.1444
3. LHCb collaboration, *Measurement of the $B_s^0 \to D_s^{(*)+} D_s^{(*)-}$ branching fractions*, arXiv:1602.07543
4. BaBar collaboration, B. Aubert et al., *Measurements of time-dependent CP asymmetries in $B^0 \to D^{(*)+} D^{(*)-}$ decays*, Phys. Rev. **D79** (2009) 032002, arXiv:0808.1866
5. Belle collaboration, M. Rohrken et al., *Measurements of Branching Fractions and Time-dependent CP Violating Asymmetries in $B^0 \to D^{(*)\pm} D^{(*)\mp}$ Decays*, Phys. Rev. **D85** (2012) 091106, arXiv:1203.6647
6. Heavy Flavor Averaging Group, Y. Amhis et al., *Averages of b-hadron, c-hadron, and τ-lepton properties as of summer 2014*, arXiv:1412.7515
7. L. Bel et al., *Anatomy of $B \to DD$ decays*, JHEP **07** (2015) 108, arXiv:1505.01361

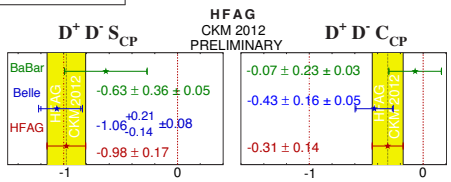
CP Violation Measurement in $B^0 \to D^+ D^-$

- Tree and penguin diagrams contribute to the decay amplitude [7]
- CP violation occurs in interference between decay and decay after mixing
- $\sin(2\beta_{\text{eff}})$ can be determined
- What we measure is the CP asymmetry



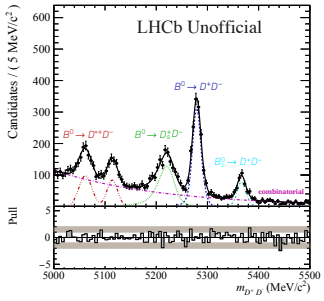
$$A_{CP}(t) = -C_{D^+D^-}\cos(\Delta m t) + S_{D^+D^-}\sin(\Delta m t)$$

- LHCb will provide its contribution in addition to the measurements by BaBar [4] and Belle [5]



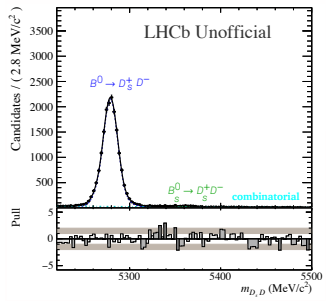
Data sample and Event selection

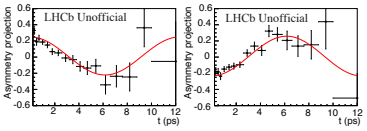
- The data sample analysed corresponds to an integrated luminosity of 3fb^{-1}
- D mesons are reconstructed through the decays $D \to K\pi\pi/KK\pi$ (the second mode is included for the first time)
- Mass fit is performed to disentangle signal from background



Flavour Tagging

- Flavour tagging calibration is performed using the flavour specific decay $B^0 \to D_s^+ D^-$
- D mesons are reconstructed through the decay $D(D_s) \to K\pi\pi(KK\pi)$
- OS tagger combination and a $SSp+SS\pi$ combination (see D. Fazzini's poster for details) are used to extract calibration parameters
- A fit of the $B^0/\bar{B}^0$ asymmetry is performed simultaneously for events tagged as B^0 and $\bar{B}^0$
- The Tagging Power obtained is $\epsilon_{\text{eff}} = (7.5 \pm 0.6)\%$





Data Fits and Conclusion

- A decay time fit is performed in order to extract CP parameters
- A per-event resolution is used, taken from simulation
- The acceptance is described using cubic splines
- This blinded analysis is ongoing
- LHCb sensitivity is expected to rival that of BaBar and Belle