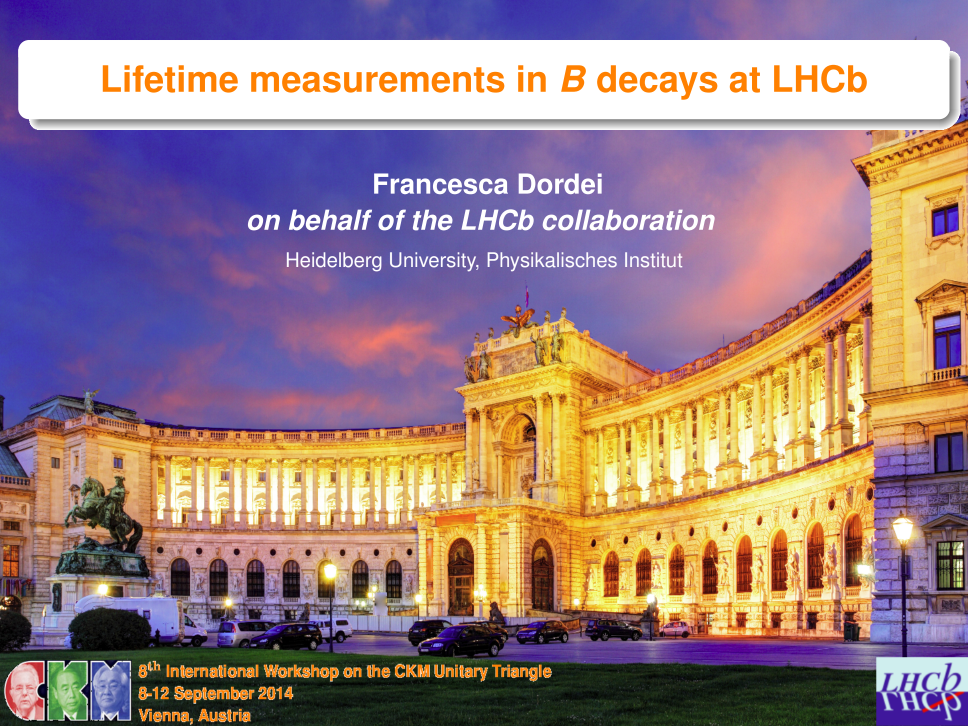
Lifetime measurements in *B* decays at LHCb



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8-12 September 2014
Vienna, Austria

Outline

① Motivation

- Probing QCD Predictions
- Probing *CP* violation

② Challenges of precision measurements

③ Recent Results

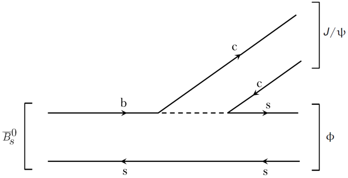
- $B_s^0 \to D_s^- \pi^+$ [arXiv:1407.5873]
- $B_s^0 \to K^+ K^-$ [arXiv:1406.7204]
- $\Lambda_b^0 \to J/\psi\ p\ K^-$ [Phys. Lett. B734 (2014) 122]
- $H_b \to J/\psi\ X$ family [JHEP 04 (2014) 114]
- Ξ_b^-, Ξ_b^0 and Ω_b^- baryons [Phys. Lett. B736 (2014) 154] and [Phys. Rev. Lett. 113 (2014) 032001]

Topics NOT covered by this talk:

$B_s^0 \to D_s^- D_s^+ X$ lifetime
Semileptonic $B_c^+ \to J/\psi \mu^+ \nu_\mu X$ lifetime

Theoretical status of *b*-flavoured hadron lifetimes

Lifetimes of heavy *b*-hadrons are dominated by the weak decay of the *b*-quark: spectator model.



Predictions made from series expansion

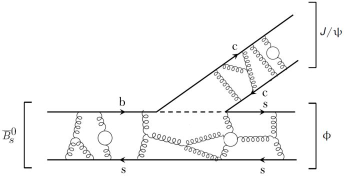
↪ **Heavy Quark Expansion (HQE)**

$$\Gamma = \Gamma_0 + \frac{\Lambda^2}{m_b^2}\Gamma_2 + \frac{\Lambda^3}{m_b^3}\Gamma_3 + \dots$$

- decay of a free heavy *b*-quark: $\tau_{B_d^0} \sim \tau_{B^+} \sim \tau_{B_s^0} \sim \tau_{\Lambda_b^0}$
- separation between mesons and baryons: $\tau_{B^+} \sim \tau_{B_d^0} \sim \tau_{B_s^0} > \tau_{\Lambda_b^0}$
- spectator quark/s involved: $\tau_{B^+} > \tau_{B_d^0} \sim \tau_{B_s^0} > \tau_{\Lambda_b^0}$

Theoretical status of *b*-flavoured hadron lifetimes

Different *b* species have distinct lifetimes $\Longrightarrow$ light quark(s) cannot be ignored.
Difficult interplay between weak and strong forces!



Predictions made from series expansion

$\hookrightarrow$ Heavy Quark Expansion (HQE)

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- spectator quark/s involved: $\tau_{B^+} > \tau_{B_d^0} \sim \tau_{B_s^0} > \tau_{\Lambda_b^0}$

Theoretical status of *b*-flavoured hadron lifetimes

- The study of the *b*-hadron lifetimes is a good probe of QCD predictions.

Most precise predictions in lifetime ratios:

$$\frac{\tau_1}{\tau_2} = 1 + \frac{\Lambda^2}{m_b^2}\Gamma_2' + \frac{\Lambda^3}{m_b^3}\Gamma_3' + \ldots$$

Predicted range for different lifetime ratios

$$\frac{\tau_{B^+}}{\tau_{B_d^0}} = 1.04^{+0.07}_{-0.03} \quad \frac{\tau_{B_s^0}}{\tau_{B_d^0}} = 1.001 \pm 0.002 \quad \frac{\tau_{\Lambda_b^0}}{\tau_{B_d^0}} = 0.935 \pm 0.054 \quad \frac{\tau_{\Xi_b^0}}{\tau_{\Xi_b^+}} = 0.95 \pm 0.06$$

Theoretical predictions from: A. Lenz, arXiv:1405.3601 (2014). Find more in: Beneke NPB639 (2002), Tarantino EPJC33 (2004), Gabbiani *et al* PRD68 (2003) and PRD70 (2004).

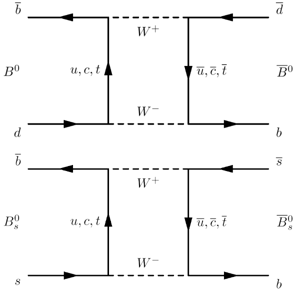
HQE is used to extract values of $|V_{cb}|$ and $|V_{ub}|$. Important to test its predictions for *b*-hadron lifetimes!

Effective lifetime

- *b*-baryons and charged *b*-mesons ⇒ decay is purely exponential.
- Neutral *B* mesons ⇒ mixing can occur.

$B^0_{(s)}$ and $\overline{B}^0_{(s)}$ superposition of mass eigenstates, B_H and B_L:

- with **separate masses**: m_H, m_L
  $\boxed{\Delta m_{d,s} = m_H - m_L}$ and $m_{d,s} = (m_H + m_L)/2$
- and **different lifetimes**: $\tau_H = 1/\Gamma_H$, $\tau_L = 1/\Gamma_L$
  $\boxed{\Delta\Gamma_{d,s} = \Gamma_L - \Gamma_H}$ and $\Gamma_{d,s} = (\Gamma_L + \Gamma_H)/2$



Effective lifetime: measured using a single exponential to model the proper time distribution

$$\Gamma(t) \propto A_H\, e^{-t/\tau_H} + A_L\, e^{-t/\tau_L} \to A_{eff}\, e^{-t/\tau_{eff}}$$

→ ignoring the decay-time difference between the two mass-eigenstates ($\Delta\Gamma_d \approx 0$, $\Delta\Gamma_s$ sizeable)

Effective lifetime in CP eigenstates

Fleischer, Kneijens [arXiv:1109.5115]

- In CP eigenstates, **effective lifetime is sensitive to $\Delta\Gamma_s$** and ϕ_s (mixing induced $\not{CP}$ phase).

Considering a $B_s^0(\overline{B}_s^0) \to f$ transition the untagged decay time distribution is:

$$\Gamma(t) \propto (1 - \mathcal{A}_{\Delta\Gamma_s})e^{-(\Gamma_L t)} + (1 + \mathcal{A}_{\Delta\Gamma_s})e^{-(\Gamma_H t)}$$

with $\mathcal{A}_{\Delta\Gamma_s}$ is a function of ϕ_s.
If we assume no $\not{CP}$ then for the CP eigenstates $\mathcal{A}_{\Delta\Gamma_s} = \pm 1$:

CP even: e.g. $B_s^0 \to K^+K^- \Rightarrow \Gamma_L$

CP odd: e.g. $B_s^0 \to J/\psi f_0(980) \Rightarrow \Gamma_H$

Expanding the effective lifetime in $y_s = \Delta\Gamma_s/2\Gamma_s$ and using $\tau_{B_s^0} = 2/(\Gamma_L + \Gamma_H) = \Gamma_s^{-1}$:

$$\frac{\tau_{eff}^f}{\tau_{B_s^0}} = 1 + \mathcal{A}_{\Delta\Gamma_s} y_s + [2 - (\mathcal{A}_{\Delta\Gamma_s})^2]y_s^2 + \mathcal{O}(y_s^3)$$

Alternative way to extract ϕ_s and $\Delta\Gamma_s$: $\begin{cases} \textit{complementary to e.g. } B_s^0 \to J/\psi\phi \\ \textit{No flavour tagging needed} \end{cases}$

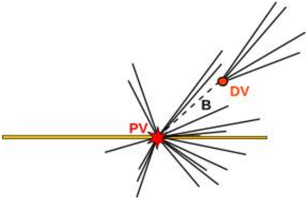
How to experimentally measure lifetimes

CHALLENGE: biased proper time distributions

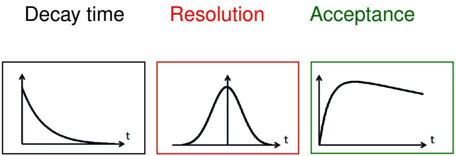
- *B* hadron candidates often selected using decay time biasing quantities (e.g. decay products significantly displaced from the PV)
- Implicit biases, e.g. geometrical and reconstruction acceptances

Absolute measurement

- Include the acceptance to correct the decay time distribution.
- **PROs**: no other input needed.
- **CONSs**: good understanding of acceptance needed. Data driven methods to obtain greater precision.



$$t = \frac{(\mathrm{DV}-\mathrm{PV})}{\beta\gamma} = \frac{(\mathrm{DV}-\mathrm{PV})\cdot Mass_B}{p}$$


Decay time | Resolution | Acceptance

$$\text{Distribution} = \left[e^{\frac{-t}{\tau}} \otimes \mathrm{Res}(t,t')\right] \cdot \mathrm{Acc}(t')$$

How to experimentally measure lifetimes

CHALLENGE: biased proper time distributions

- *B* hadron candidates often selected using decay time biasing quantities (e.g. decay products significantly displaced from the PV)
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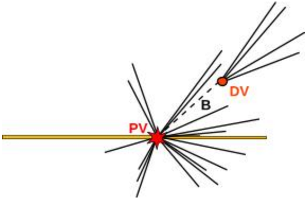


$$\boxed{t = \frac{(\mathrm{DV}-\mathrm{PV})}{\beta\gamma} = \frac{(\mathrm{DV}-\mathrm{PV})\cdot Mass_B}{p}}$$

Relative measurement

- Measure lifetime *X* relative to control mode (*CM*) with well known lifetime and similar topology
- **PROs**: systematic uncertainties due to acceptance cancel in the ratio
- **CONSs**: irreducible systematic from input lifetime

$$R(t) = \frac{A_X(t) \times [e^{-\frac{t}{\tau_X}} \otimes G(t, \sigma_X)]}{A_{CM}(t) \times [e^{-\frac{t}{\tau_{CM}}} \otimes G(t, \sigma_{CM})]}$$

Assuming acceptance *A* is the same and resolution effects cancel:

$$R(t) = R_0 \cdot e^{-t(\tau_X^{-1} - \tau_{CM}^{-1})}$$

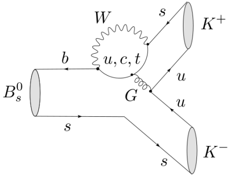
$B_s^0 \to K^+K^-$ with $\mathcal{L} = 1\,\mathrm{fb}^{-1}$

[arXiv:1406.7204]

The final state K^+K^- is a *CP*-even eigenstate:

→ $\boxed{\tau_{KK} \equiv \tau_L}$ with the assumption $\mathcal{A}_{\Delta\Gamma}$ = -1

- ~ completely *CP*-even eigenstate
- $\mathcal{A}_{\Delta\Gamma}^{SM} = -0.972 \pm 0.012$
  Fleischer, Kneijens [Eur.Phys.J.C71:1532,2011]

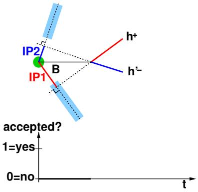


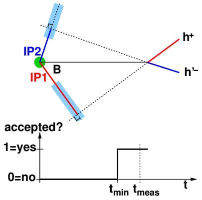
Re-analysis of the 2011 dataset using a data-driven method ⇒ Absolute measurement.

Strategy used: "Swimming" - per-event acceptance extracted from data

Re-run selection and trigger for all hypothetical lifetimes:

- Move the DV along the *B* momentum vector
- Evaluate if the candidate would be selected with this lifetime
- Use the per-event acceptance function in the fit

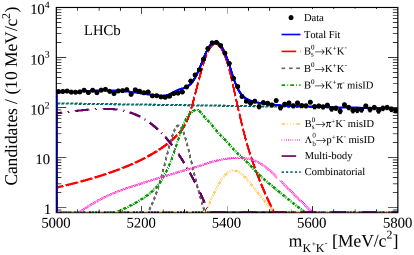


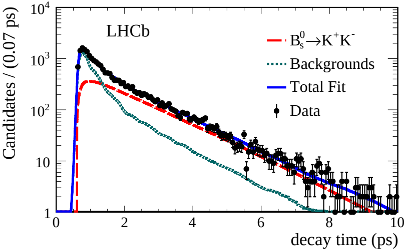


$B_s^0 \to K^+K^-$ with $\mathcal{L} = 1\,\mathrm{fb}^{-1}$

[arXiv:1406.7204]

Available statistics: 10471 ± 121 B_s^0 signal events after full selection.





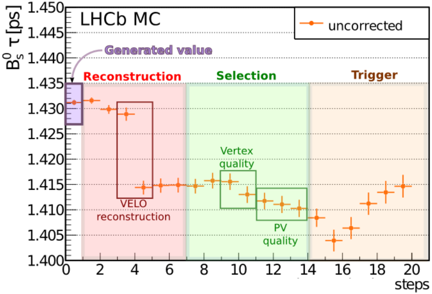
$$\boxed{\tau_{KK} = 1.407 \pm 0.016\,(\text{stat}) \pm 0.007\,(\text{syst})\ \text{ps}}$$

- Main systematic contribution: misidentified $B_s^0 \to h^+h^-$ backgrounds (5 fs)
- Used to extract $\mathcal{A}_{\Delta\Gamma} = -0.87 \pm 0.17 \pm 0.13$ (compatible with SM)
- Consistent with the previous independent measurement from LHCb

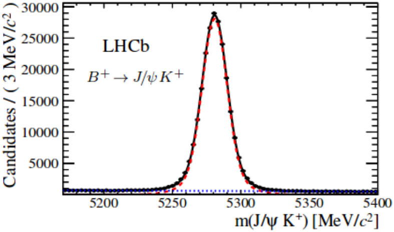
$H_b \to J/\psi\, X$ family with $\mathcal{L} = 1\ \mathrm{fb}^{-1}$

Absolute measurement

- $B^+ \to J/\psi K^+$: $N_{\mathrm{sig}} = 229\,434 \pm 503$
- $B^0 \to J/\psi K^*(892)^0$: $N_{\mathrm{sig}} = 70\,534 \pm 312$
- $B^0 \to J/\psi K^0_S$: $N_{\mathrm{sig}} = 17\,045 \pm 175$
- $B^0_s \to J/\psi \phi$: $N_{\mathrm{sig}} = 18\,662 \pm 152$
- $\Lambda_b \to J/\psi \Lambda$: $N_{\mathrm{sig}} = 3\,960 \pm 89$



[JHEP 04 (2014) 114]



Bias of $\boxed{\Delta\tau \sim 20\ \mathrm{fs}}$

- Several effects bias the measured lifetime already in the simulation!
- Data-driven method to remove the bias.

$H_b \to J/\psi\, X$ family with $\mathcal{L} = 1\ \mathrm{fb}^{-1}$

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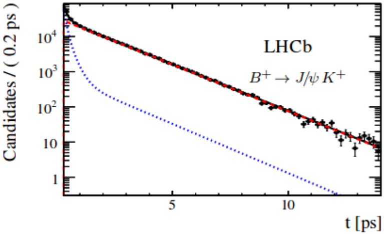
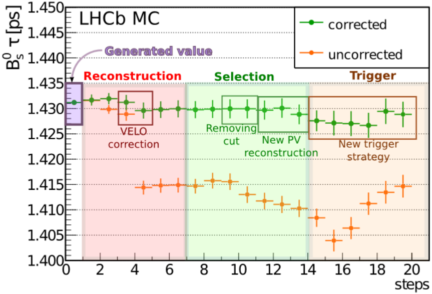
[JHEP 04 (2014) 114]





- Remaining bias no longer statistically significant.
- The same strategy can be applied on data without using simulated data.
- Unbinned fit in mass and decay time to extract lifetime.

$H_b \to J/\psi\, X$ family with $\mathcal{L} = 1\ \mathrm{fb}^{-1}$

Lifetime	Value [ps]	World average 2013 [ps]
$\tau_{B^+ \to J/\psi K^+}$	$1.637 \pm 0.004 \pm 0.003$	1.641 ± 0.008
$\tau_{B^0 \to J/\psi K^*(892)^0}$	$1.524 \pm 0.006 \pm 0.004$	1.519 ± 0.007
$\tau_{B^0 \to J/\psi K^0_S}$	$1.499 \pm 0.013 \pm 0.005$	1.519 ± 0.007
$\tau_{\Lambda^0_b \to J/\psi \Lambda}$	$1.415 \pm 0.027 \pm 0.006$	1.429 ± 0.024
$\tau_{B^0_s \to J/\psi \phi}$	$1.480 \pm 0.011 \pm 0.005$	1.429 ± 0.088

- From a theoretical point of view lifetime ratios are robust quantities ⇒ **test of HQE**.

Ratio	Value
$\tau_{B^+}/\tau_{B^0 \to J/\psi K^{*0}}$	$1.074 \pm 0.005 \pm 0.003$
$\tau_{B^0_s \to J/\psi \phi}/\tau_{B^0 \to J/\psi K^{*0}}$	$0.971 \pm 0.008 \pm 0.004$
$\tau_{\Lambda^0_b}/\tau_{B^0 \to J/\psi K^{*0}}$	$0.929 \pm 0.018 \pm 0.004$

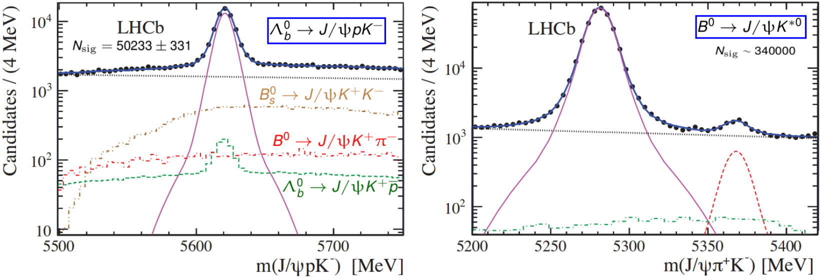
- Particle and antiparticle lifetimes ratio ⇒ **test of CPT**

τ_{B^+}/τ_{B^-}	$1.002 \pm 0.004 \pm 0.002$
$\tau_{\Lambda^0_b}/\tau_{\overline{\Lambda}^0_b}$	$0.940 \pm 0.035 \pm 0.005$
$\tau_{B^0 \to J/\psi K^{*0}}/\tau_{\overline{B}^0 \to J/\psi \overline{K}^{*0}}$	$1.000 \pm 0.008 \pm 0.003$

$\boxed{\Delta\Gamma_d/\Gamma_d = -0.044 \pm 0.025 \pm 0.011}$ compatible with $|\Delta\Gamma_d/\Gamma_d|^{\mathrm{SM}} = (3 \pm 1.2)\cdot 10^{-3}$ [arXiv:0412007]

$\Lambda_b^0 \to J/\psi p K^-$ lifetime - $\mathcal{L} = 3\,\mathrm{fb}^{-1}$

[Phys. Lett. B734 (2014) 122]



- $\Lambda_b^0 \to J/\psi p K^-$ previously unobserved decay mode.
- Relative measurement wrt B^0 lifetime.
- Most precise measurement to date!

$$\boxed{\frac{\tau_{\Lambda_b^0}}{\tau_{B^0}} = 0.974 \pm 0.006 \pm 0.004}$$

Main systematic: decay-time acceptance.

$$\tau_{\Lambda_b^0 \to J/\psi p K^-} = 1.479 \pm 0.009 \pm 0.010 \text{ ps}$$

Main systematic: B^0 lifetime uncertainty.

$B_s^0 \to D_s^- \pi^+$ with $\mathcal{L} = 1\,\mathrm{fb}^{-1}$

[arXiv:1407.5873]

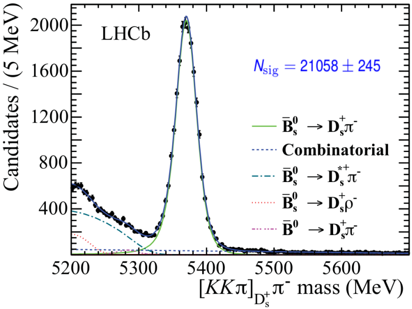
$D_s^- \pi^+$ is a **flavour-specific** final state, f_{fs}:

$$\begin{array}{lcl} B_s^0 \to f_{fs} & \text{or} & \overline{B}_s^0 \to B_s^0 \to f_{fs} \\ \overline{B}_s^0 \to \overline{f_{fs}} & \text{or} & B_s^0 \to \overline{B}_s^0 \to \overline{f_{fs}} \end{array} \quad \Rightarrow \quad \tau_{fs} \approx \frac{1}{\Gamma_s} \frac{1+\left(\frac{\Delta\Gamma_s}{2\Gamma_s}\right)^2}{1-\left(\frac{\Delta\Gamma_s}{2\Gamma_s}\right)^2}$$

Relative measurement

Between $B_s^0 \to D_s^- \pi^+$, $D_s^- \to K^- K^+ \pi^-$ and

- $B^0 \to D^- \pi^+$, $D^- \to K^+ \pi^- \pi^-$
  same number of tracks, very different D lifetimes
- $B^+ \to \overline{D}^0 \pi^+$, $\overline{D}^0 \to K^+ \pi^-$
  different number of tracks, similar D lifetimes
- $B^+ \to \overline{D}^0 \pi^+$, $\overline{D}^0 \to K^+ \pi^- \pi^+ \pi^-$
  different number of tracks, similar D lifetimes



$B_s^0 \to D_s^- \pi^+$ with $\mathcal{L} = 1\,\mathrm{fb}^{-1}$

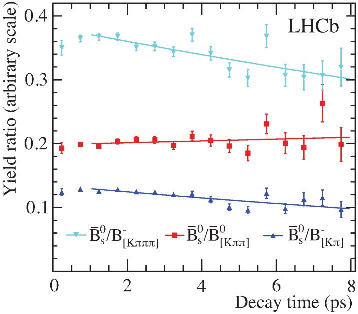
[arXiv:1407.5873]

Three consistent results fully correlated, the one with the smallest uncertainty is chosen

$$\frac{\tau_{fs}(\overline{B}_s^0)}{\tau(\overline{B}^0)} = 1.010 \pm 0.010 \pm 0.008$$

$$\Downarrow$$

$$\boxed{\tau_{fs}(\overline{B}_s^0) = \underbrace{1.535}_{} \pm \underbrace{0.015}_{\text{Stat}} \pm \underbrace{0.012}_{\text{Syst}} \pm \underbrace{0.007}_{\text{PDG}}\,\mathrm{ps}}$$



- Most precise measurement to date.
- Consistent with previous measurement and HQE predictions.
- Main systematic: lifetime acceptance.

Ξ_b^-, Ω_b^- and Ξ_b^0 lifetimes - $\mathcal{L} = 3\,\mathrm{fb}^{-1}$

[Phys. Lett. B736 (2014) 154]

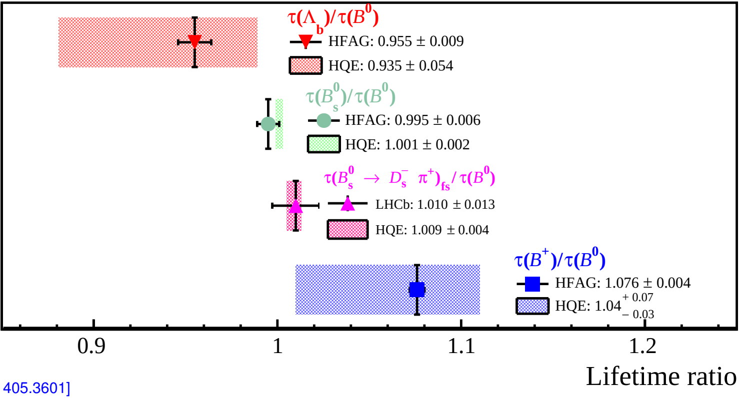
- Signal decays: $\Xi_b^- \to J/\psi\Xi^-$ and $\Omega_b^- \to J/\psi\Omega^-$.
- Absolute measurement: use similar methods to analysis of $H_b \to J/\psi X$.
- Decay-time acceptance taken from simulation.
- $\boxed{\tau_{\Xi_b^-} = 1.55^{+0.10}_{-0.09} \pm 0.03\text{ ps}}$ and $\boxed{\tau_{\Omega_b^-} = 1.54^{+0.26}_{-0.21} \pm 0.05\text{ ps}}$
- Main systematic: decay-time acceptance.
- Most precise measurement to date!

[Phys. Rev. Lett. 113 (2014) 032001]

- Signal decay: $\Xi_b^0 \to \Xi_c^+\pi^-$.
- Relative measurement wrt the $\Lambda_b^0 \to \Lambda_c^+\pi^-$ lifetime.
- $\boxed{\frac{\tau_{\Xi_b^0}}{\tau_{\Lambda_b^0}} = 1.006 \pm 0.018 \pm 0.010}$ $\Rightarrow$ $\boxed{\tau_{\Xi_b^0} = 1.477 \pm 0.026 \pm 0.014 \pm 0.013\ \mathrm{ps}}$
- Main systematic: simulated sample size.
- First measurement!

Conclusions

- Recent LHCb measurements give a consistent picture of *b*-hadron lifetimes.
- Good agreement with HQE predictions.
- Experimental ratios known to striking precision.

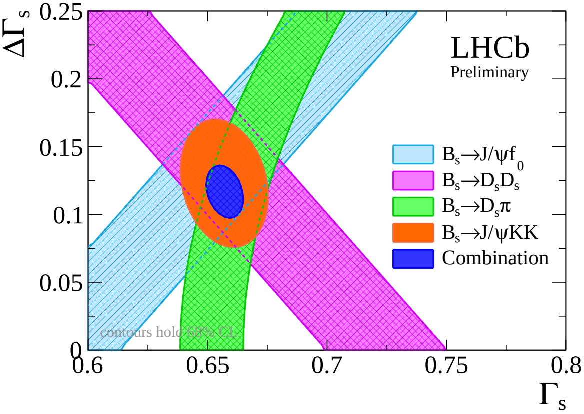


HQE: Lenz [arXiv:1405.3601]

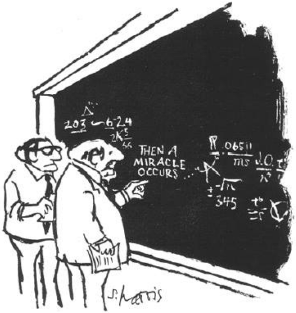
HFAG: Heavy Flavour Averaging Group [PDG 2014]

Conclusions

- Combination of all LHCb results shows very nice agreement!
- Consistent with SM prediction $\Delta\Gamma_s^{\mathrm{SM}} = 0.087 \pm 0.021\ \mathrm{ps}^{-1}$ [A. Lenz and U. Nierste, arXiv:1102.4274]



Thanks for your attention!



The theory of measurement

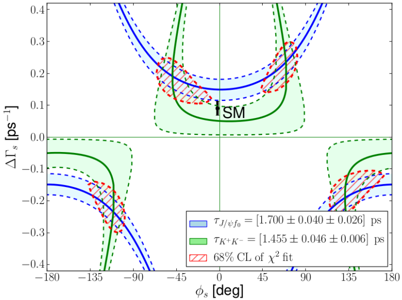
"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."

Backup Slides

Status at beginning of 2014

Kneijens [arXiv:1305.6834]

Using effective lifetime to constrain $\Delta\Gamma_s$ and ϕ_s



Using:

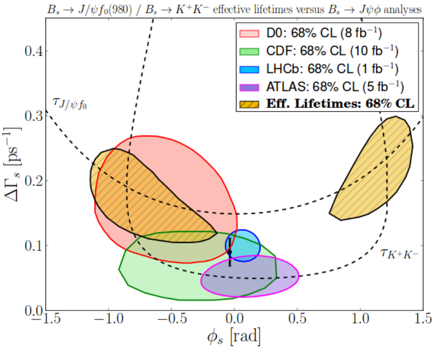
$\tau_{K^+K^-} = [1.455 \pm 0.046\ \text{(stat)} \pm 0.006\ \text{(syst)}]$ ps

[Phys. Lett. B716 (2012) 393-400]

$\tau_{J/\psi\, f_0} = [1.700 \pm 0.040\ \text{(stat)} \pm 0.026\ \text{(syst)}]$ ps

[Phys. Rev. Lett. 109 (2012) 152002]

Inluding direct measurement



$B_s^0 \to J/\psi\, f_0(980)$ with $\mathcal{L} = 1\ fb^{-1}$ - Introduction

[LHCb-PAPER-2012-017, arXiv: **1207.0878**]

The final state $J/\psi\, f_0(980)$ is a *CP*-odd eigenstate:

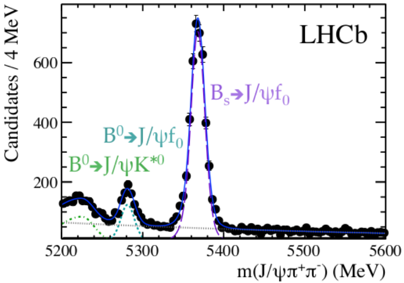
- Measured ϕ_s limits $cos\, \phi_s > 0.99$ @ 95% CL
  [LHCb-CONF-2012-002]
- Selection provides $> 99.4\%$ @ 95% CL *CP*-odd sample
  [Phys. Rev. D 86, 052006 (2012)]

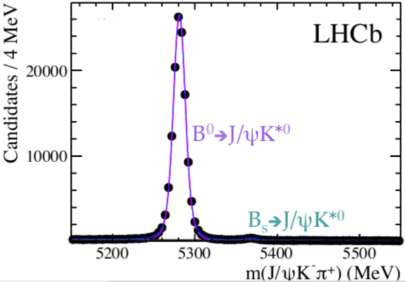
→ $\boxed{\tau_{J/\psi\, f_0} \equiv \tau_H}$ with the assumption $\mathcal{A}_{\Delta\Gamma}$=1

- pure CP-odd eigenstate
- no CP violation

Strategy used: Lifetime measured relative to $B^0 \to J/\psi K^{*0}$

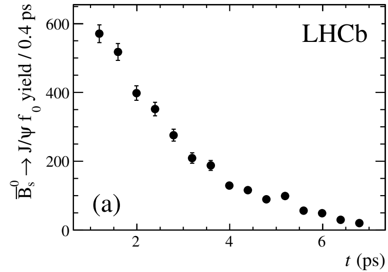
- Decays have very similar kinematics
- Compare signal yields in bins of decay time
- Fit for width difference: $\tau^{-1}_{J/\psi f_0} - \tau^{-1}_{J/\psi K^{*0}}$
- Use well known B^0 lifetime to extract B_s^0 lifetime

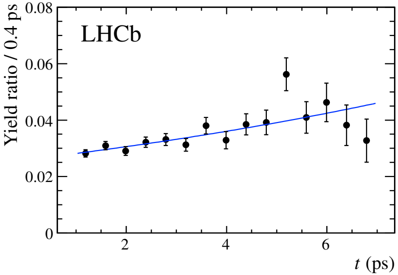


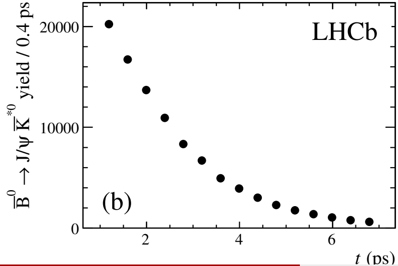


$B_s^0 \to J/\psi\, f_0(980)$ with $\mathcal{L} = 1\ fb^{-1}$ - Results

[LHCb-PAPER-2012-017, arXiv: **1207.0878**]







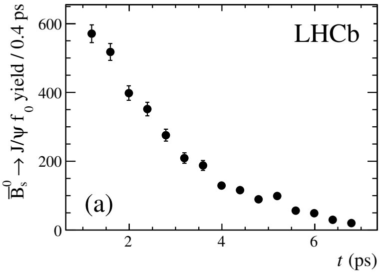
$$\boxed{\tau_{J/\psi f_0} = 1.700 \pm 0.040\ \text{(stat)} \pm 0.026\ \text{(syst) ps}}$$

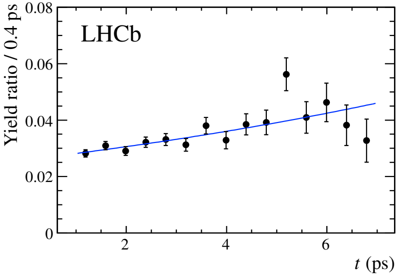
- Main systematic contributions: acceptance correction (18 fs), statistical bias (12 fs)

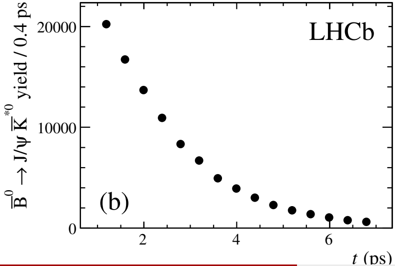
WORLD'S BEST!

$B_s^0 \to J/\psi\, f_0(980)$ with $\mathcal{L} = 1\ fb^{-1}$ - Results

[LHCb-PAPER-2012-017, arXiv: **1207.0878**]







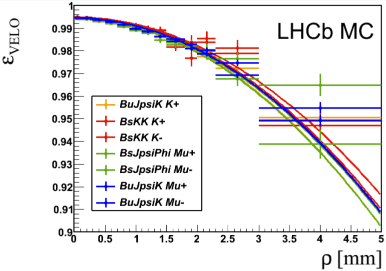
$$\tau_{J/\psi f_0} = 1.700 \pm 0.040\ (\text{stat}) \pm 0.026\ (\text{syst})\ \text{ps}$$

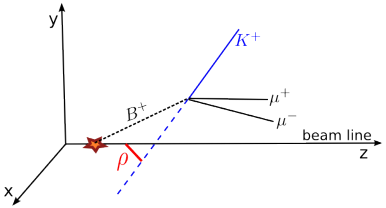
- Main systematic contributions: acceptance correction (18 fs), statistical bias (12 fs)
- Γ_H can be calculated adding an additional syst uncertainty due to a possible $\phi_s \neq 0$

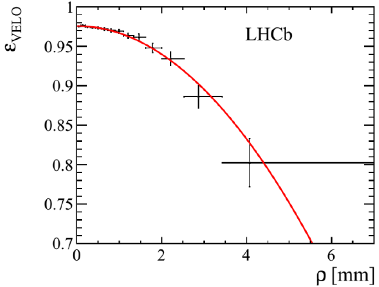
$$\Gamma_H = 0.588 \pm 0.014\ (\text{stat}) \pm 0.009\ (\text{syst})\ ps^{-1}$$

VELO reconstruction acceptance

- VELO reconstruction efficiency nearly identical for different decay products.
- Measure the efficiency on data using $B^+ \to J/\psi K^+$ control sample: ***Tag and Probe*** - technique.
- Correct data for the inefficiency weighting differently every event.



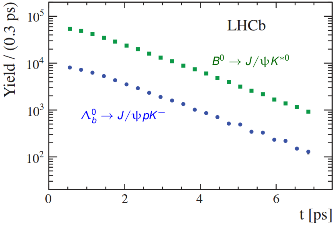




Λ_b^0 lifetime - $\mathcal{L} = 3\,\mathrm{fb}^{-1}$

[Physics Letters B **734**, arXiv:1402.6242 (2014)]

Yield as a function of decay-time



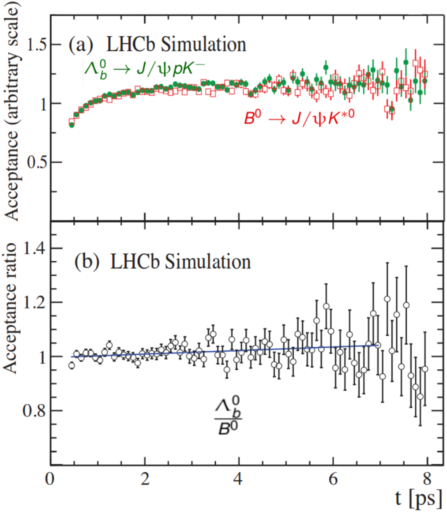
- Most precise measurement to date!

$$\boxed{\frac{\tau_{\Lambda_b^0}}{\tau_{B^0}} = 0.974 \pm 0.006 \pm 0.004}$$

Main syst: acceptance slope.

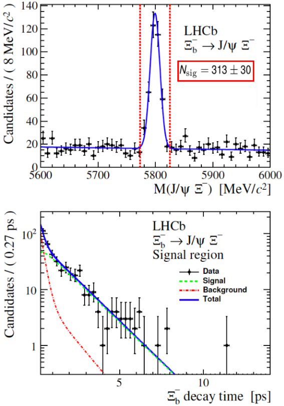
$$\tau_{\Lambda_b^0 \to J/\psi pK^-} = 1.479 \pm 0.009 \pm 0.010 \text{ ps}$$

Main syst: B^0 lifetime uncertainty.



Ξ_b^- and Ω_b^- lifetimes - $\mathcal{L} = 3\,\mathrm{fb}^{-1}$

[Physics Letters B **736**, arXiv:1405.1543 (2014)]



- $\boxed{\tau_{\Xi_b^-} = 1.55^{+0.10}_{-0.09} \pm 0.03\ \text{ps}}$ and $\boxed{\tau_{\Omega_b^-} = 1.54^{+0.26}_{-0.21} \pm 0.05\ \text{ps}}$
- Dominant systematic from upper decay time acceptance (“beta factor”) from MC;
- Λ_b^0 lifetime consistent with other LHCb measurements.

$\overline{B}_s^0 \to D_s^+ D_s^-$ effective lifetime - $\mathcal{L} = 3\,\mathrm{fb}^{-1}$

[arXiv:1312.1217 [hep-ex]]

- Final state is CP-even, ϕ_s is small $\implies \tau_{\mathrm{eff}} \approx 1/\Gamma_L$
- Measure lifetime relative to a similar final state topology decay, $B^- \to D^0 D_s^-$, with well-known lifetime:

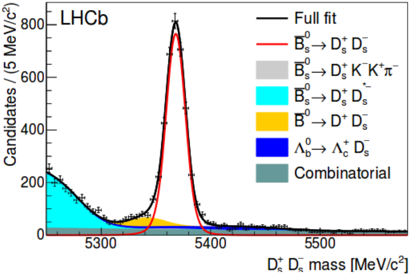
$$\tau_{B^-} = 1.641 \pm 0.008\ \mathrm{ps}$$

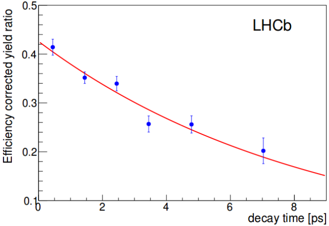
- The relative rate is given by:

$$\frac{\Gamma_{B_s^0(\overline{B}_s^0) \to D_s^+ D_s^-}(t)}{\Gamma_{B^-(B^+) \to D^0(\overline{D}^0) D_s^-(D_s^+)}(t)} \propto e^{-\alpha t}$$

where: $\alpha = 1/\tau_{\overline{B}_s^0 \to D_s^+ D_s^-} - 1/\tau_{B^-}$

- Main systematic is from acceptance.





$$\boxed{\tau^{\mathrm{eff}}_{\overline{B}_s^0 \to D_s^+ D_s^-} = 1.379 \pm 0.026 \pm 0.017\ \mathrm{ps} \qquad \Gamma_L = 0.725 \pm 0.014 \pm 0.009\ \mathrm{ps}^{-1}}$$

Λ_b^0 lifetime - The end of the puzzle

- Long-standing puzzle of the Λ_b^0 lifetime now solved!
- LHCb has the most precise single measurement.
- Last measurements consistent with the original predictions of the HQE.
- Ratio with the B^0 lifetime close to unity.

Plot from S. Stone presentation, FPCP Marseilles, May 2014.