HAL archives-ouvertes.fr

Review of $\Delta\Gamma\_B^0\_s$ measurements

S. Monteil

▶ **To cite this version:**

S. Monteil. Review of $\Delta\Gamma\_B^0\_s$ measurements. International Workshop on Heavy Quark Physics 5 HEP5, Apr 2000, Dubna, Russia. pp.1-5. in2p3-00010863

HAL Id: in2p3-00010863

http://hal.in2p3.fr/in2p3-00010863

Submitted on 27 Jul 2000

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Review of $\Delta\Gamma_{B_s^0}$ measurements

Stéphane Monteil

LPC Université Blaise Pascal - IN2P3/CNRS, 24, Avenue des Landais 63177 AUBIERE.
Email: Stephane.Monteil@in2p3.fr

ABSTRACT: A review of the $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ measurements performed up to the spring 2000 is presented. A combination of the LEP and CDF measurements yields $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0} = 0.17^{+0.09}_{-0.10}$.

1. Introduction

The mixing of flavour states B^0 and $\bar{B}^0$ results in the new states (mass eigenstates) B_L and B_H, which are the CP eigenstates in absence of CP violation [1]. The relevant parameters to characterize the $B_L - B_H$ system are the width and mass differences, denoted $\Delta\Gamma$ and Δm respectively. In the $K^0 - \bar{K}^0$ system, the large width difference comes from a dynamical accident : the very different phase space allowed for the two possible final states $\pi\pi$ (*CP*=+) and $\pi\pi\pi$ (*CP*=-). $\Delta\Gamma$ in the $B^0 - \bar{B}^0$ system is on the contrary expected to be very small. While it seems hopeless to measure $\Delta\Gamma$ in the $B_d^0 - \bar{B}_d^0$ system, the width difference in the $B_s^0 - \bar{B}_s^0$ may turn out to be sizeable because of the large branching ratio of the decay $B_s^0 \to D_s^{+(*)} D_s^{-(*)}$, predominantly *CP*=- [1]. Recent theoretical calculations predict $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0} = 0.16 \pm 0.05$ [2]-[3]. For notation convenience, the short-lived B_L (respectively long-lived B_H) component, corresponding to the *CP*=- (*CP*=+) eigenstate, will be referred to as B_s^{short} (B_s^{long})

The measurement of $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ serves essentially two purposes :

- $\Delta\Gamma_{B_s^0}$ and Δm_s are correlated, therefore allowing an indirect measurement of Δm_s to be performed; it is of special interest if the oscillation frequency is too high regarding to the sensitivity of the present direct measurements.
- In addition, a sizeable value of $\Delta\Gamma_{B_s^0}$ allows measurements of the CKM phases to be imagined from untagged B_s^0 samples in future experiments [4].

[1] CP violation effects are neglected throughout this document

2. Measurement strategies

$\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ measurements are performed by reconstructing the proper time distributions of enriched B_s^0 samples (but displaying a mixture of CP eigenstates) analysed with a double exponential lifetime fit. The analyses denoted *inclusive* are using this method and present a quadratic sensitivity to $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$. L3 and DELPHI analyses will be exposed in this review paper.

It has been shown [5] that the B_s^0 lifetime measurements neglecting the lifetime difference are still sensitive (quadratic sensistivity at lowest order) to the width difference, when compared to B_d^0 lifetime measurement. The LEP Heavy Flavour working group [6] played the game of reinterpretating all B_s^0 lifetime measurements to the light of this prescription.

In addition, provided that the decay width $\Gamma_{B_d^0}$ and $\Gamma_{B_s^0}$ are equal to the first order ($\Gamma_{B_d^0} = \Gamma_{B_s^0} = 1/\tau_{B_d^0}$) [7] and that the width difference $\Delta\Gamma_{B_d^0}$ can be neglected, a constraint on the allowed range of $\Gamma_{B_s^0}$ can be imposed, resulting in an improvement of the limit on the width difference.

The best sensitivity to $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ is obtained for B_s^0 samples enriched in one CP eigenstate. ALEPH and CDF performed such *exclusive* analyses by selecting the specific channels $B_s^0 \to J/\Psi\phi$ or $B_s^0 \to D_s^+(*) D_s^-(*)$.

3. Inclusive analyses

3.1 L3 measurement [8]

The measurement consists in reconstructing an image of the proper time distribution of b hadrons inclusively and fitting $|\Delta\Gamma_{B_s^0}|$, τ_{B^+} and $\tau_{B_d^0}$ to this distribution.

Secondary vertices are tagged by means of an impact parameter based algorithm; the event impact parameter distribution is defined as the error-weighted average of the individual impact parameters and forms the image of the proper time distribution. An estimator of the charge of the secondary vertex is used to enrich the sample in neutral B mesons.

The selected sample contains an unbiased mixture of B_s^{short} and B_s^{long}, with an overall B_s^0 purity of 11%.

Figure 1 displays the event impact parameter distribution of the subsequent sample in the data.

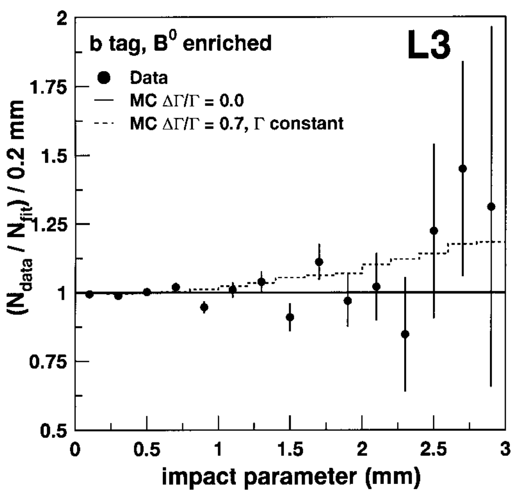

Figure 1: L3 - Event impact parameter distribution. The dashed line shows the expected Monte Carlo distribution for the value $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0} = 0.7$, where $\Gamma_{B_s^0}$ is fixed to the fitted value.

An upper limit with a 95% confidence level for $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ is derived :

$$|\Delta\Gamma_{B_s^0}|/\Gamma_{B_s^0} < 0.67$$

3.2 DELPHI measurements [9]

Two samples, based on the selection of the decay channel $B_s^0 \rightarrow l\nu D_s^+$ and $B_s^0 \rightarrow D_s^+ h$, ($h$ represents a hadron) are considered to measure $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$. The $B_s^0 \rightarrow l\nu D_s^+$ sample is composed of an unbiased mixture of CP eigenstates, while the latter presents an enhancement of the almost pure CP=- process, $B_s^0 \rightarrow D_s^{+(*)} D_s^{-(*)}$ (20 % of the sample), therefore displaying a slightly larger sensitivity to $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$.

D_s^+ is searched for in eight modes, two of which are semileptonic D_s decays. The inclusive $D_s h$ sample is limited to the channels $D_s^+ \rightarrow \phi\pi^+$, $\bar{K}^{*0}K^+$.

The two analyses are based on the same guidelines : the electric charge correlation between the reconstructed D_s^+ and the lepton (the most energetic hadron, in the $D_s h$ analysis) is used in order to remove fake contributions. DELPHI forms the vertex $D_s^+ l^-$ ($D_s^+ h^-$) and measures its decay length l and Lorentz boost $\beta\gamma$. The reconstructed proper time, defined as $t = l/\beta\gamma$, is governed basically by the two independent parameters $\tau_{B_s^0}$ and $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$.

A log likelihood fit of the quantities $\tau_{B_s^0}$ and $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ is performed to the proper time distribution, as underlined Figure 2.

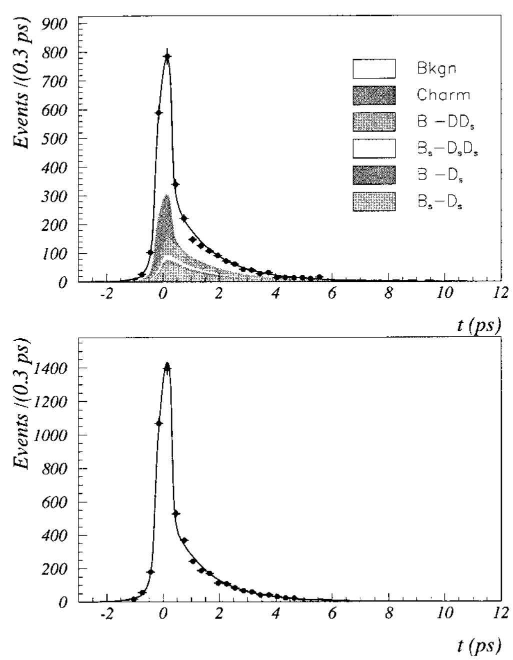

Figure 2: DELPHI - The upper plot represents the proper time distribution for ($D_s h$) candidates. The solid line shows the result of the fit. The lower plot displays the same distribution for background.

The following limits for $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ at the 95% confidence level are obtained :

$$\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0} < 0.46 \ ,$$

$$\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0} < 0.69 \ ,$$

for the semileptonic and the $D_s^+ h$ analyses respectively.

3.3 ACO [2] measurements à la Hartkorn-Moser

As underlined in section 2, the inclusive B_s^0 lifetime measurements [10] based on samples of semileptonically decaying B_s^0 and performed by neglecting the width difference keep the memory of $\Delta\Gamma_{B_s^0}$.

It can be shown [5] that $\tau_{B_s^0}$ is related to $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ in the following way, assuming the width difference to be small :

$$\tau_{B_s^{semi}} = \frac{1}{\Gamma_{B_s^0}}(1 + (\frac{\Delta\Gamma_{B_s^0}}{2\Gamma_{B_s^0}})^2)(1 - (\frac{\Delta\Gamma_{B_s^0}}{2\Gamma_{B_s^0}})^2)^{-1} \ .$$

Considering in addition the constraint $\Gamma_{B_s^0} = 1/\tau_{B_d^0}$, an upper limit of $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ can be derived.

The LEP Heavy Flavour working group played this game [6]. The average of the ACO B_s^0 lifetime measurements is found to be :

$$\tau_{B_s^0} = 1.46 \pm 0.07 \text{ ps} \ ,$$

yielding an upper limit on $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ with a 95 % confidence level of :

$$\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0} < 0.30 \ .$$

4. Exclusive analyses

Exclusive analyses consist in selecting samples with an enhanced specific CP eigenstate, i.e short-lived (long-lived) state, contribution. The lifetime of the selected CP eigenstate therefore depends linearly on $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$.

[2] ACO is the acronymous of ALEPH, CDF and OPAL experiments.

4.1 CDF measurement [11]-[12]

CDF selects B_s^0 from the decay channel $B_s^0 \to J/\Psi\phi$ reconstruction. The final state $J/\Psi\phi$ is thought to be predominantly *CP*=- [1]. This expectation is supported by the CDF measurement $f_{CP=-} = 79 \pm 19\%$.

J/Ψ is searched for in $\mu^+\mu^-$ and ψ is searched for in K^+K^-. Eventually, 58 ± 12 candidates are selected. The transverse decay length L_{xy} of the $J/\Psi\phi$ vertex is computed to derive the proper decay length ct, where $t = L_{xy}/\beta\gamma$ is the reconstructed proper time. This distribution is shown Figure 3.

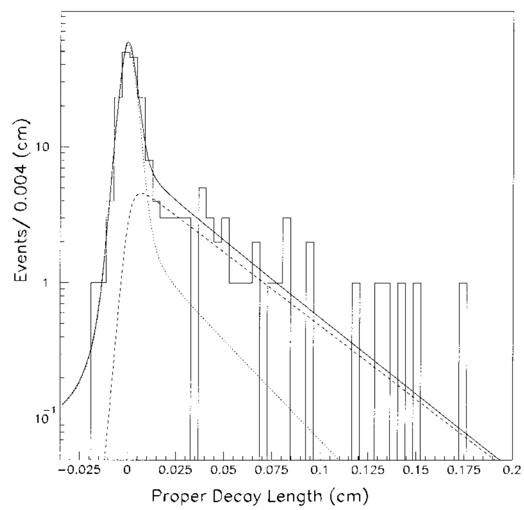

Figure 3: CDF - The proper decay length distribution of B_s^0 candidates. The results of the fit are shown : the dashed line is the signal, the dotted line is the background and the solid line is the sum of the two.

$\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ is fitted to the proper decay length distribution, assuming the measured value of $f_{CP=-}$, yielding

$$\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0} = 0.33^{+0.45}_{-0.42} \ .$$

The main systematic uncertainty is due to the background parametrization.

4.2 ALEPH measurements [13]

Predominantly *CP*=- (98 % pure) [1], the $B_s^0 \to D_s^{+(*)} D_s^{-(*)}$ decay mode offers a great opportunity to measure $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ with a good accuracy. ALEPH proposes in that respect two independent methods based respectively on the fit to the proper time distribution of the selected B_s^0 and on the measurement of the branching ratio $Br(B_s^0 \to D_s^{+(*)} D_s^{-(*)})$.

D_s is searched for in ϕX, where ϕ is searched for in K^+K^- and X represents the best hadron candidate matching the K^+K^- vertex. Figure 4 shows the event display of a $B_s^0 \to D_s^{+(*)} D_s^{-(*)}$ candidate. The two ϕ of the event are required to belong to the same hemisphere.

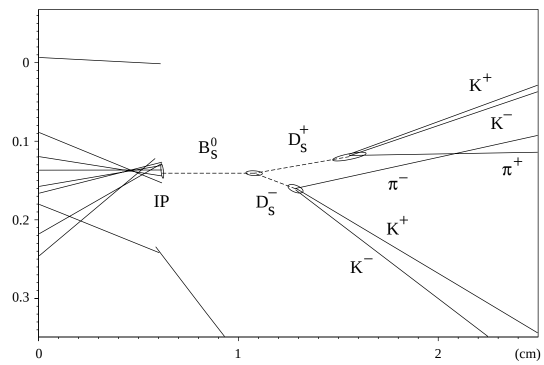

Figure 4: ALEPH - Event display of a $B_s^0 \to D_s^{+(*)} D_s^{-(*)}$ candidate. B_s^0 and D_s vertices are marked with their error ellipses.

Eventually, 18.5 ± 6.7 reconstructed B_s^0 are found.

4.2.1 Lifetime method

The B_s^0 boost $\beta\gamma$, measured from the $\phi\phi$ jet, and the B_s^0 decay length, measured from the $\phi\phi$ vertex, are used to reconstruct the proper time distribution of the B_s^0 candidates.

The B_s^{short} lifetime, $\tau_{B_s^{short}}$, is fitted with a maximum likelihood by a single exponential to this distribution, as stressed Figure 5.

$\tau_{B_s^{short}}$ is measured to be 1.27 ± 0.33(stat) $\pm$ 0.07 (syst).

$\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ is related to $\tau_{B_s^{short}}$ through the expression :

$$\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0} = 2(\frac{1}{\Gamma_{B_s^0}\tau_{B_s^{short}}} - 1) .$$

Constraining $\Gamma_{B_s^0}$ to its measured value from semileptonic B_s^0 decays yields :

$$\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0} = 0.22^{+0.38}_{-0.51}$$

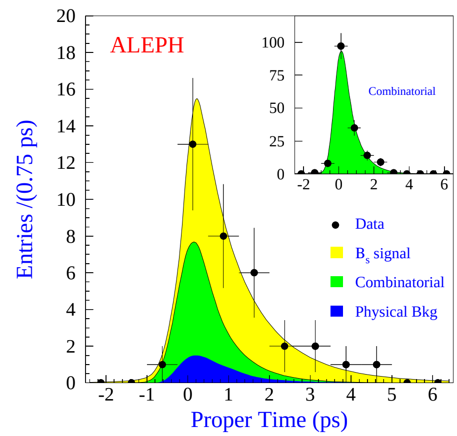

Figure 5: ALEPH - The proper time distribution of the B_s^0 candidates in the $\phi\phi$ sample. The solid line is the result of the maximum likelihood fit.

4.2.2 Counting method

If one assumes that only decays to defined CP eigenstates contribute to the width difference, $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0} = \Gamma(B_s^{short} \to D_s^{+(*)} D_s^{-(*)})$ to a first approximation. This is supported by the fact that the process $B_s^{short} \to D_s^{+(*)} D_s^{-(*)}$ constitutes 95% of the CP defined final states in the B_s^0 decay. It can be shown that $\Delta\Gamma_{B_s^0}/\Gamma_{B_s^0}$ is related to $Br(B_s^0 \to D_s^{+(*)} D_s^{-(*)})$ through :

$$Br(B_s^{short} \to D_s^{(*)+} D_s^{(*)-}) = \frac{\Delta\Gamma_{B_s^0}}{\Gamma_{B_s^0}(1 + \Delta\Gamma_{B_s^0}/2\Gamma_{B_s^0})} . \quad (1)$$

Experimentally,

$$Br(B_s^{short} \to D_s^{(*)+} D_s^{(*)-}) = \frac{N_{\phi\phi}[Br(\phi \to K^+K^-)]^{-2}}{\epsilon f_s R_b N_Z^h [Br(D_s^+ \to \phi X)]^2},$$

where $f_s = 10.5 \pm 1.8\%$ is the B_s^0 production fraction, $R_b = 21.7 \pm 0.1\%$ the fraction of hadronic Z decays in $b\bar{b}$ pair, $N_Z^h = 4.2 \times 10^6$ the total number of $Z \to q\bar{q}$, $Br(\phi \to K^+K^-) = 49.1 \pm 0.6\%$, and $\epsilon = 9.5 \pm 0.5\%$, the selection efficiency. The main part of the uncertainty is coming from the misknowledge of the branching ratio $Br(D_s^+ \to \phi X) = 17.0 \pm 4.4\%$ [3].

$Br(B_s^{short} \to D_s^{(*)+} D_s^{(*)-})$ is found to be 0.23 ± 0.10 (stat) $^{+0.19}_{-0.9}$ (syst).

[3] Its estimation is a key point of the analysis and is fully documented in [13]

From expression (1), $\Delta\Gamma_{B^0_s}/\Gamma_{B^0_s}$ is measured to be :

$$\Delta\Gamma_{B^0_s}/\Gamma_{B^0_s} = 0.26^{+0.30}_{-0.15} \; .$$

Combining with the previously exposed ALEPH measurement yields

$$\Delta\Gamma_{B^0_s}/\Gamma_{B^0_s} = 0.25^{+0.21}_{-0.14} \; .$$

5. Combination of the measurements

The combination described in these proceedings has been performed by the LEP Heavy Flavour Working Group [6]. Each analysis result [4] is converted into a two-dimensional log-likelihood in the $(1/\Gamma_{B^0_s}, \Delta\Gamma_{B^0_s}/\Gamma_{B^0_s})$ plane. All resulting distributions are summed and Figure 6 displays the variation of the resulting sum as a function of $\Delta\Gamma_{B^0_s}/\Gamma_{B^0_s}$.

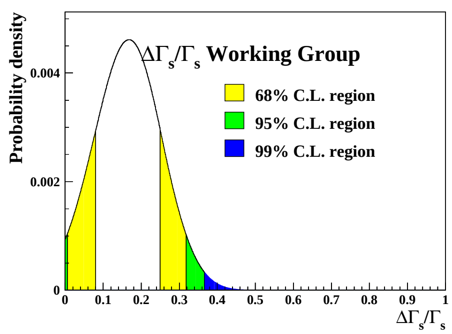

Figure 6: Probability density function for $\Delta\Gamma_{B^0_s}/\Gamma_{B^0_s}$ after applying the constraint $\tau_{B^0_d} = 1/\Gamma_{B^0_s}$ [6].

The value $\Delta\Gamma_{B^0_s}/\Gamma_{B^0_s} = 0.24^{+0.16}_{-0.12}$ is obtained.

The combination is further improved by applying the constraint $\tau_{B^0_d} = 1/\Gamma_{B^0_s}$, yielding :

$$\Delta\Gamma_{B^0_s}/\Gamma_{B^0_s} = 0.17^{+0.09}_{-0.10} \; .$$

6. Conclusion

This document reviewed the experimental constraint on the width difference $\Delta\Gamma_{B^0_s}/\Gamma_{B^0_s}$ in the $B^0_s - \bar{B}^0_s$ system.

A combination of the LEP and CDF measurements gives :

$$\Delta\Gamma_{B^0_s}/\Gamma_{B^0_s} = 0.17^{+0.09}_{-0.10} \; ,$$

in agreement with recent theoretical calculations [2]-[3].

The ratio $\Delta\Gamma_{B^0_s}/\Delta m_s$ is calculated to be $(6.5 \pm 2.2) \times 10^{-3}$ [14][15]. Let us notice that this result is based for a part on preliminary lattice calculations.

Although the systematic uncertainty estimation is still under question, it is extremely tempting to determine the corresponding constraint on Δm_s. The following value of Δm_s is obtained :

$$\Delta m_s = 15^{+12}_{-11} \; ps^{-1},$$

very close to the present experimental sensitivity of the direct measurement [16].

[4] apart the L3 measurement.

References

[1] R. Aleksan *et al.*, *Phys. Lett.* **B 316** (1993) 567.

[2] M. Beneke *et al.*, *Phys. Lett.* **B 459** (1999) 631.

[3] S. Hashimoto, Preprint `hep-lat/9909136` (October 1999).

[4] I. Dunietz, *Phys. Rev.* **D 52** (1995) 3048.

[5] K. Hartkorn, H.-G. Moser, *Eur. Phys. J.* **C 8** (1999) 381.

[6] ALEPH, CDF, DELPHI, L3, OPAL, SLD, LEPHFS note **99-02**.

[7] M. Beneke *et al.*, *Phys. Rev.* **D 54** (1996) 4419.

[8] The L3 Collaboration *Phys. Lett.* **B 438** (1998) 417.

[9] The DELPHI Collaboration, CONF **99-296**, Tampere (Finland).

[10] The ALEPH Collaboration, *Phys. Lett.* **B 377** (1996) 205, The OPAL Collaboration, *Phys. Lett.* **B 426** (1998) 161.

[11] The CDF Collaboration, *Phys. Rev.* **D 57** (1998) 5382.

[12] The CDF Collaboration, *Phys. Rev.* **D 59** (1999) 32004.

[13] The ALEPH Collaboration, Submitted to *Phys. Lett.* **B** (2000) , CERN-EP **(2000-036)**.

[14] M. Beneke, private communication.

[15] P. Spagnolo, private communication.

[16] O. Leroy, these proceedings.