Measurement of Λ_B Lifetime in the Decay Channel $\Lambda_B \to J/\psi\Lambda$

Text for the blessed web page – CDF note 6393

The CDF Collaboration

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Abstract

We present a measurement of the Λ_B lifetime in the exclusive decay mode $\Lambda_B \to J/\psi\Lambda$. A measurement in this channel complements that in the higher statistics semileptonic channel. Since the Λ_B is fully reconstructed, there is no uncertainty on the boost factor, $\beta\gamma$, due to the undetectable neutrino. In addition, this mode is more free of long-lived background from other heavy baryons. We reconstruct 246 ± 16 B^0 decays and 46 ± 9 Λ_B decays We obtain the result:

$$c\tau(\Lambda_B) = 374 \pm 78(stat.) \pm 29(syst.)\mu\mathrm{m}$$

$$\tau(\Lambda_B) = 1.25 \pm 0.26(stat.) \pm 0.10(syst.)ps$$

This represents the first Λ_B lifetime measurement in a fully reconstructed mode.

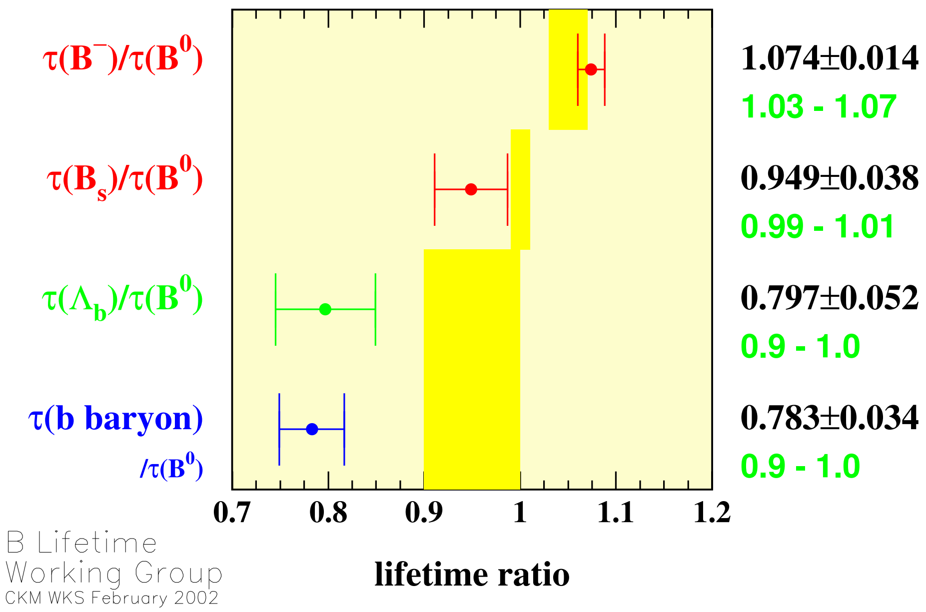

Figure 1: Theory predictions (yellow) and world averages for B lifetime ratios.

We present a measurement of the lifetime of the b-baryon Λ_B in the fully reconstructed decay mode $\Lambda_B \to J/\psi\Lambda$, where $J/\psi \to \mu^+\mu^-$, $\Lambda \to p^+\pi^-$. Measuring the lifetime in this mode is particularly interesting, since no measurement yet exists in a fully reconstructed mode. Many semileptonic measurements can claim only to be a measurement of the average b-baryon lifetime.

More importantly, measurements thus far have shown a marked disagreement with the theoretical predictions for $\tau(\Lambda_B)/\tau(B^0)$; the experimental world average is 0.797 ± 0.052, while theory predicts the value to be between 0.9 and 1.0 (see Figure **??**). Various theorists have constructed hypotheses in an attempt to explain the disagreement but the issue is ultimately unresolved.

Yet another interesting point about the Λ_B is that the only currently operating machine at which they are produced is the Tevatron. The Λ_B, like B_s^0, is not produced at the B-Factories. CDF has measured the Λ_B lifetime in Run I, in the semileptonic mode $\Lambda_B \to \Lambda_c l\nu$, with $\Lambda_c \to pK^+\pi^-$. The result was $1.33 \pm 0.15 \pm 0.07$ps [?]. This measurement will be the first of the Λ_B lifetime in a fully reconstructed mode.

Since the lb sample is not very large, we make use of a control sample of $B^0 \to J/\psi K_s^0$, where $K_s^0 \to \pi^+\pi^-$. This is useful as a guide for Λ_B selection, so we do not bias ourselves by using the Λ_B data itself. In addition, the higher statistics sample allows us validate our analysis methods. The cuts are summarized in table **??**.

The following is a brief summary of the analysis: We obtain a sample of Λ_B candidates from

Tracks	N (COT axial) ≥ 20 N (COT stereo) ≥ 16 ≥ 3 $r-\phi$ SVX hits on each μ
Muons	$\chi^2(\text{track}-\text{stub}) < 9$ (CMU only) $p_T(\mu) > 1.5\ GeV$
J/ψ	$Prob(\chi^2) > 0.1\%$ $3.01 \leq m_{\mu\mu}\ (GeV) \leq 3.17$
V_0	$Prob(\chi^2) > 0.1\%$ $0.477 \leq m_{\pi\pi}\ (GeV) \leq 0.517$ $1.104 \leq m_{p\pi}\ (GeV) \leq 1.128$ $L_{xy} > 0.25\ cm$ K_s^0 only: $p_T(\pi) > 400\ MeV$
Λ_B/B^0	$Prob(\chi^2) > 0.01\%$ $\theta_T > 0.9999$ $p_T > 4.5\ GeV$ Λ_B only: reject K_s^0's

Table 1: Cuts used in selecting Λ_B and B^0

the J/ψ trigger data sample, and consider both the signal and the sideband regions. For each event, we use the run-averaged beam position to determine the primary vertex. Employing the SVXII, we determine the position of the decay vertex of the J/ψ coming from the Λ_B. From the two quantities above, we calculate L_{xy}. This is the transverse distance between the primary vertex and the Λ_B decay vertex, projected onto the Λ_B transverse momentum direction. Then, using the Λ_B momentum, we transform to a proper decay time using $m/p_T(\Lambda_B) = L_{xy}/\beta\gamma = ct_{decay}$. Finally, we perform an unbinned maximum likelihood fit to the distribution of ct_{decay} in the signal and sideband regions, to extract our measurement of the lifetime, $c\tau$.

The signal region is assumed to have the form of an exponential convoluted with a gaussian which takes into account detector resolution. The background is a sum of a gaussian (for promptly decaying zero-lifetime particles, smeared by detector resolution) plus positive and negative going exponentials, which take into account the tails of detector resolution, and decays of other long-lived particles.

1 Blessed Numbers

This section summarizes the numbers which have been blessed for this analysis.

1.1 Fit results

Control sample fit lifetime, from $B^0 \to J/\psi K_s^0$ (statistical error only):

$$c\tau(B^0) = 415 \pm 31\mu\text{m}$$

$$\tau(B^0) = 1.38 \pm 0.10ps$$

1.2 Systematic errors

The systematic errors are enumerated in Table **??**.

Source	Value(μm)	From
Scale Factor	3	B^0
Alignment	5	B^+ [?]
Occupancy	11	B^0
V_0 Tracking	26	B^0
Total	29	

Table 2: Systematic errors in the Λ_B lifetime measurement

1.3 Final result

$$c\tau(\Lambda_B) = 374 \pm 78(stat) \pm 29(syst)\mu\text{m}$$

$$\tau(\Lambda_B) = 1.25 \pm 0.26(stat) \pm 0.10(syst)ps$$

For comparison, the 2002 Particle Data Group fit result is:

$$\tau(\Lambda_B) = 1.229 \pm 0.080ps$$

2 Blessed Figures

The following figures have been blessed for the mass difference measurement. More text can be found in CDF note 6393.

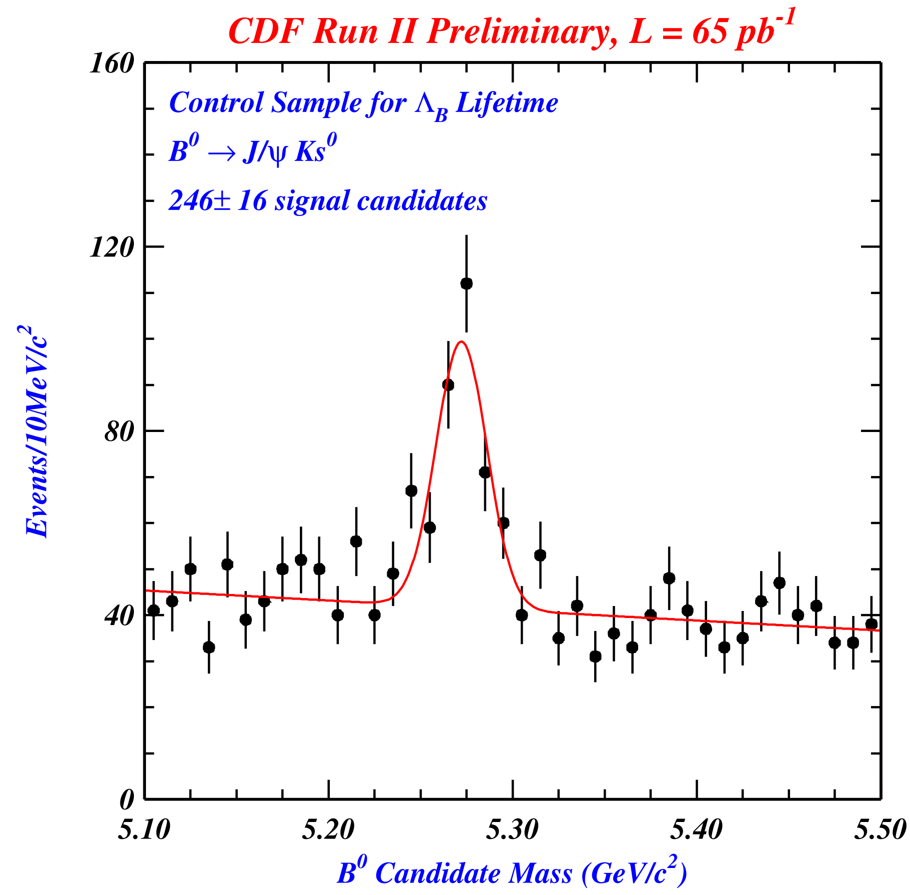

Figure 2: Candidates in B^0 control sample.

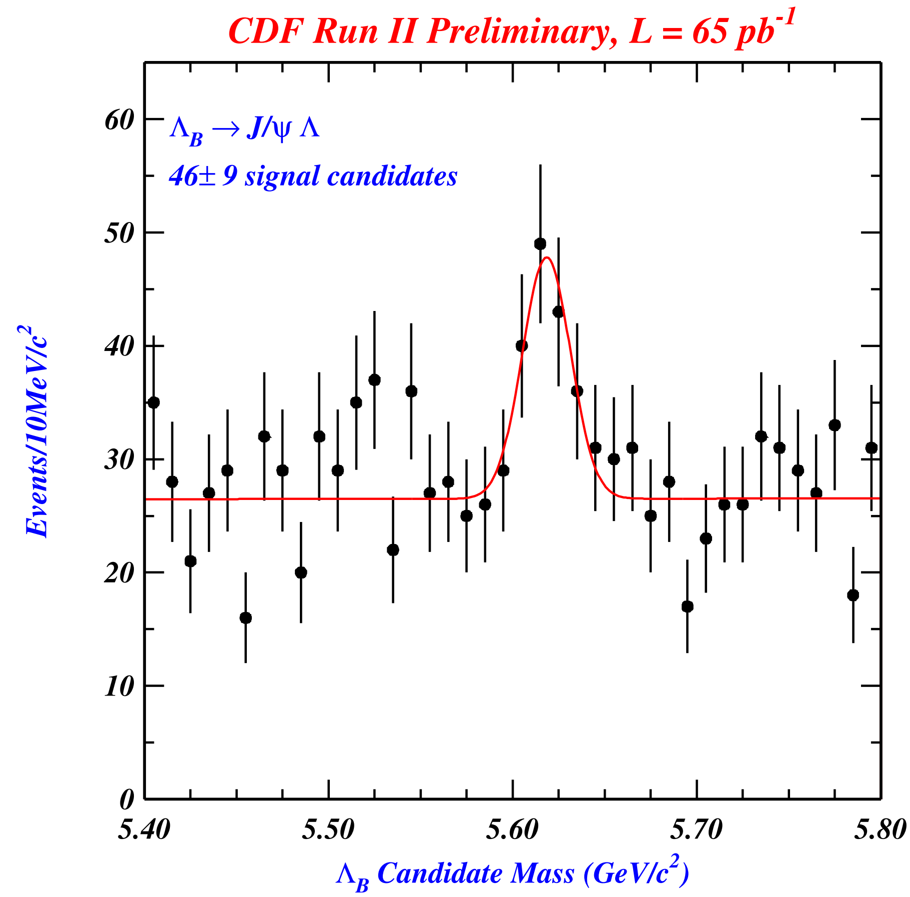

Figure 3: Λ_B candidates.

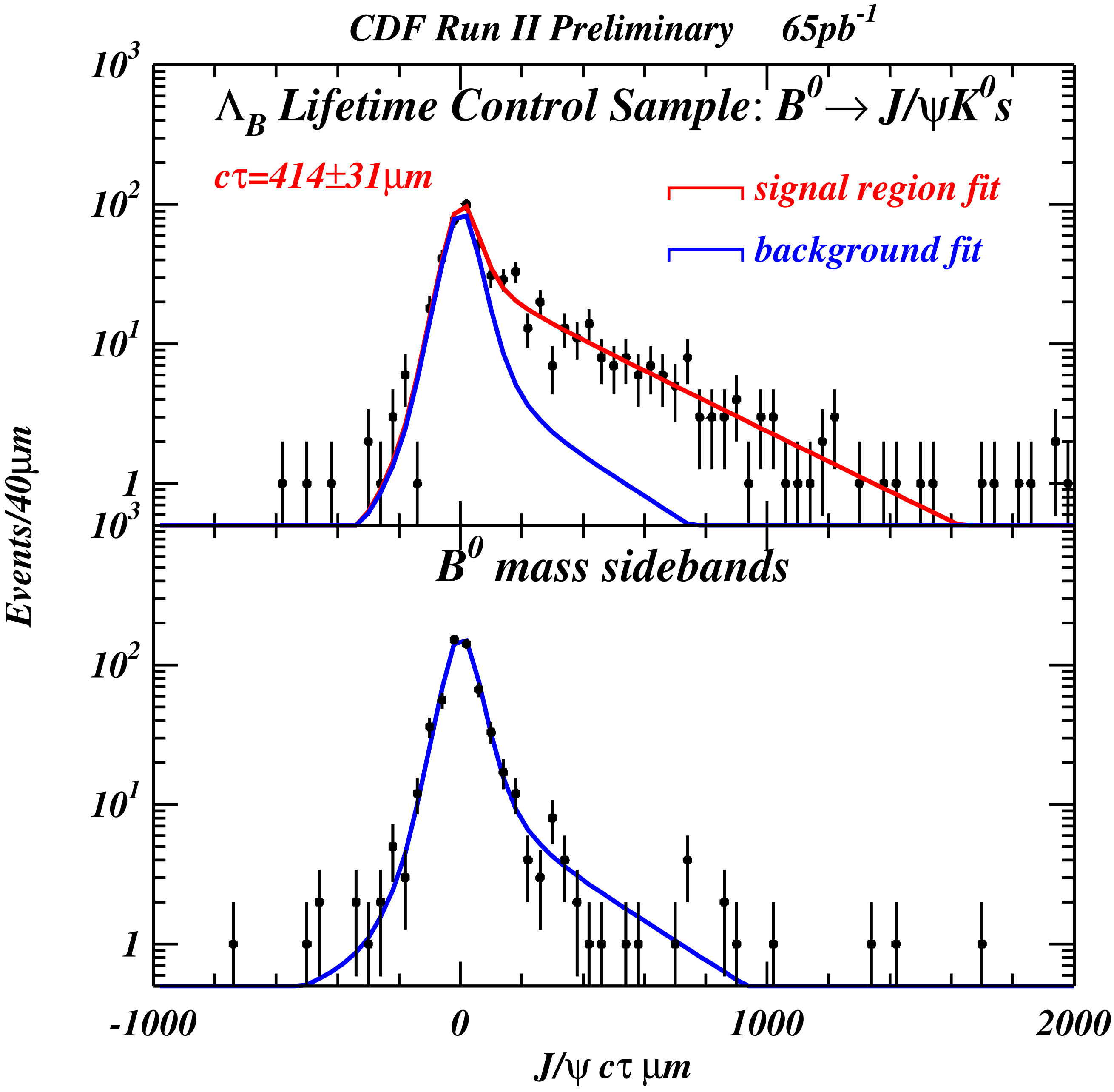

Figure 4: Results of control sample lifetime fit.

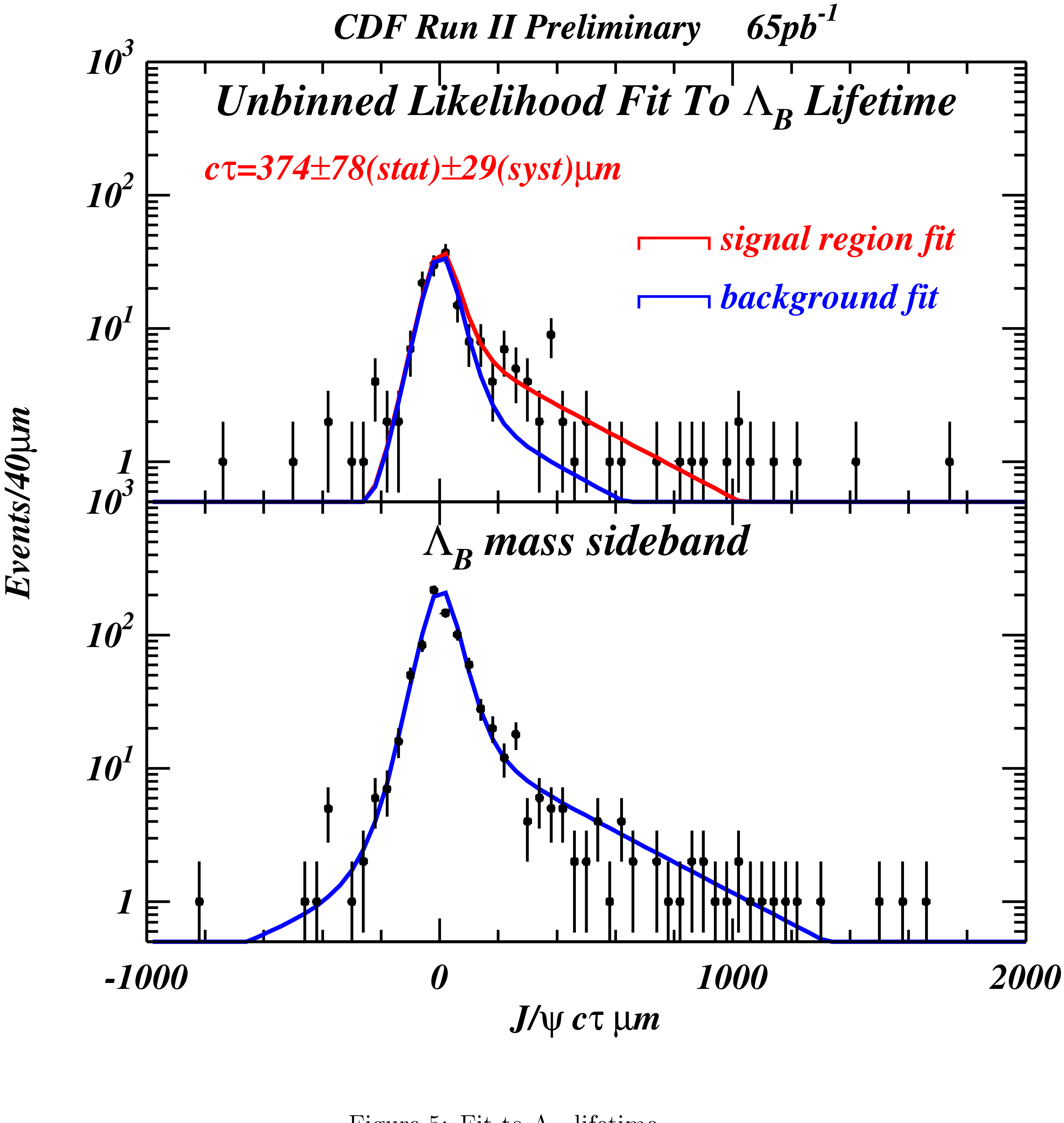

Figure 5: Fit to Λ_B lifetime

References

[1] F. Abe *et. al., Measurement of* Λ_b^0 *Lifetime Using* $\Lambda_b^0 \to \Lambda_c^+ l^- \bar{\nu}$,
Phys. Rev. Lett. 77, 1439 (1996).

[2] K. Anikeev *et al., B Meson Lifetime Measurements Using Exclusively Reconstructed Decays* $B \to JPsi\ X$, CDF Note 6266.