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Λ_b Lifetime Using 1 fb^{-1} Data Taken With Two Displaced Track Triggers

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The CDF Collaboration
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We report a measurement of the lifetime of the Λ_b^0 baryon in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. Analyzing 1070 ± 60 pb^{-1} of data taken using the CDF two displaced track triggered dataset we have obtained a clean sample of $\sim 3,000$ fully reconstructed $\Lambda_b^0 \to \Lambda_c^+\pi^-$ decays (with Λ_c^+ subsequently decaying via $\Lambda_c^+ \to p^+K^-\pi^+$). We fit this sample for the lifetime of the Λ_b^0 baryon, and find;

$$c\tau(\Lambda_b^0) = 422.8 \pm 13.8\ \text{(stat)} \pm 8.8\ \text{(syst)}\ \mu\text{m}.$$

I. INTRODUCTION

The lifetime of Λ_b^0 baryons is a topic of considerable recent interest. In a simple quark spectator model, where the b-quark is approximated by a static object decaying with no interaction with the neighboring light degrees of freedom the lifetimes of all B hadrons are expected to be the same. However, because of significant non-spectator effects, the B hadron lifetimes follow a hierarchy; $\tau(B^+) \geq \tau(B^0) \sim \tau(B_s^0) > \tau(\Lambda_b^0) \gg \tau(B_c^+)$. This hierarchy is predicted by the Heavy Quark Expansion (HQE) technique [1], which expresses decay widths of heavy hadrons as an expansion in inverse powers of the heavy quark mass (*i.e.* $1/m_b$). In the second order of this expansion, Fermi motion of the b-quark and its spin interaction with the light quark pair in Λ_b^0 result in a shorter Λ_b^0 lifetime compared to the B mesons. In the third order of $1/m_b$, non-spectator effects modify the baryon and meson lifetimes differently and lead to their hierarchy.

The ratio $\tau(\Lambda_b^0)/\tau(B^0)$ has been the source of theoretical scrutiny since earlier calculations predicted a value larger than 0.90, almost 2-σ above the world average at that time. These predictions cluster around a most likely central value of 0.94[2]. Equation 1 lists the results of a recent calculation[3] of B hadron lifetime ratios.

$$\begin{aligned} \tau(B^+)/\tau(B^0) &= 1.06 \pm 0.02, \\ \tau(B_s^0)/\tau(B^0) &= 1.00 \pm 0.01, \\ \tau(\Lambda_b^0)/\tau(B^0) &= 0.88 \pm 0.05. \end{aligned} \tag{1}$$

The results listed in Equation 1 reflect a HQE calculation up to $O(1/m_b^4)$ which reduces the disagreement with the PDG $\tau(\Lambda_b^0/\tau(B^0)$ world average of 0.804 ± 0.049[4].

More recently CDF has reported two measurements of Λ_b^0 lifetime in the $\Lambda_b^0 \to J/\psi\Lambda$ channel, that differ by $\sim 2\sigma$ from the world average [5]. In contrast with earlier discrepancy, these measurements are significantly higher than the HQE prediction. Figure I summarizes several measurements of Λ_b^0 lifetime as well as the world average.

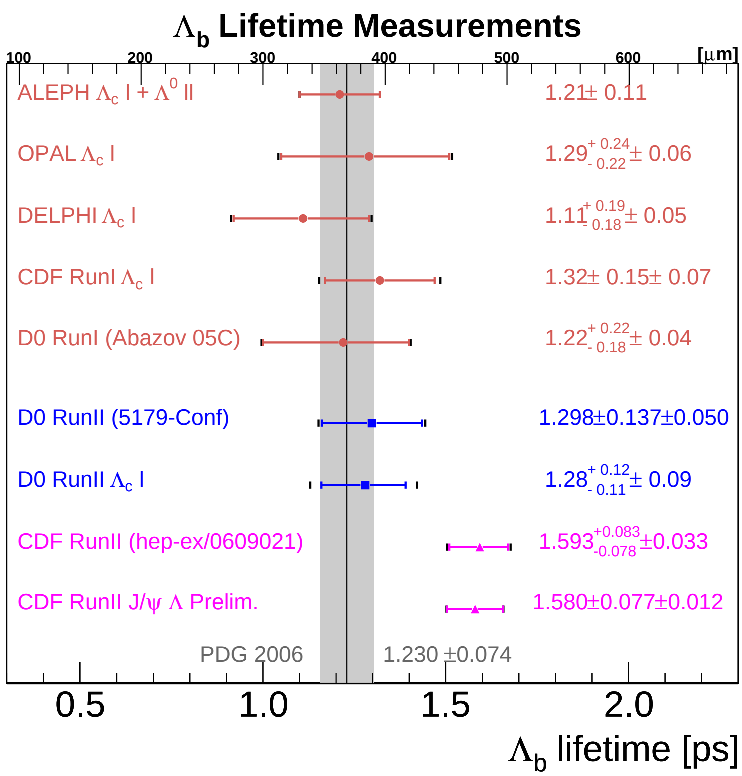

FIG. 1: A summary of recent Λ_b^0 measurements compared to the 2006 world average. Recent CDF measurements suggest a longer Λ_b^0 lifetime than has previously been measured.

Using a clean and high statistics sample of fully reconstructed $\Lambda_b^0 \to \Lambda_c^+\pi^-$ decays, this analysis hopes to shed light on the long standing discrepancy between the world average of Λ_b^0 lifetime and its HQE prediction. A sample of $\sim 3{,}000$ $\Lambda_b^0 \to \Lambda_c^+\pi^-$ decays are reconstructed from 1070 ± 60 pb^{-1} of data, collected using the CDF Two displaced Track Trigger (TTT). Because of the track displacement requirement at the trigger, the lifetime distribution is biased. We correct for the bias by employing a Monte Carlo based approach, already applied successfully to other CDF lifetime analyses [6].

II. ANALYSIS STRATEGY

In a detector with a perfect resolution and without a trigger bias, the distribution of the proper decay length, ct' of an unstable particle with true lifetime, τ, follows a simple exponential distribution, given by the probability density function (PDF)

$$P(ct') = \frac{1}{c\tau} e^{\frac{-ct'}{c\tau}}. \tag{2}$$

In a real detector, each measurement of ct' has an uncertainty σ_{ct} associated with it. This smearing of the true ct' which results in the measured value ct is accounted for by convolving the measured lifetime with a function to describe the detector resolution. The resolution function, $R(ct, \sigma_{ct}; ct')$, is the PDF of the measured ct and σ_{ct} given the true value of ct'. With this addition, the PDF for the measured proper decay length distribution becomes

$$P(ct|\sigma_{ct}) = \frac{1}{c\tau} e^{\frac{-ct'}{c\tau}} \otimes R(ct, \sigma_{ct}; ct'). \tag{3}$$

The PDF $P(ct|\sigma_{ct})$, is a one-dimensional conditional PDF that predicts the probability of observing this value of ct *given* the value of σ_{ct}. In order to obtain a proper two-dimensional PDF for both ct and σ_{ct} based on the conditional probability, the σ_{ct} distribution (PDF) must multiply $P(ct|\sigma_{ct})$. So the full two-dimensional ct-σ_{ct} PDF becomes;

$$\begin{aligned} P(ct, \sigma_{ct}) &= P(ct|\sigma_{ct}) \cdot P(\sigma_{ct}) \\ &= \frac{1}{c\tau} e^{\frac{-ct'}{c\tau}} \otimes R(ct, \sigma_{ct}; ct') \cdot P(\sigma_{ct}) \end{aligned} \tag{4}$$

where $P(\sigma_{ct})$ is the distribution of σ_{ct} observed in data. Figure 2 shows the signal and background σ_{ct} distributions obtained from the Λ_b^0 signal and upper sideband regions, respectively.

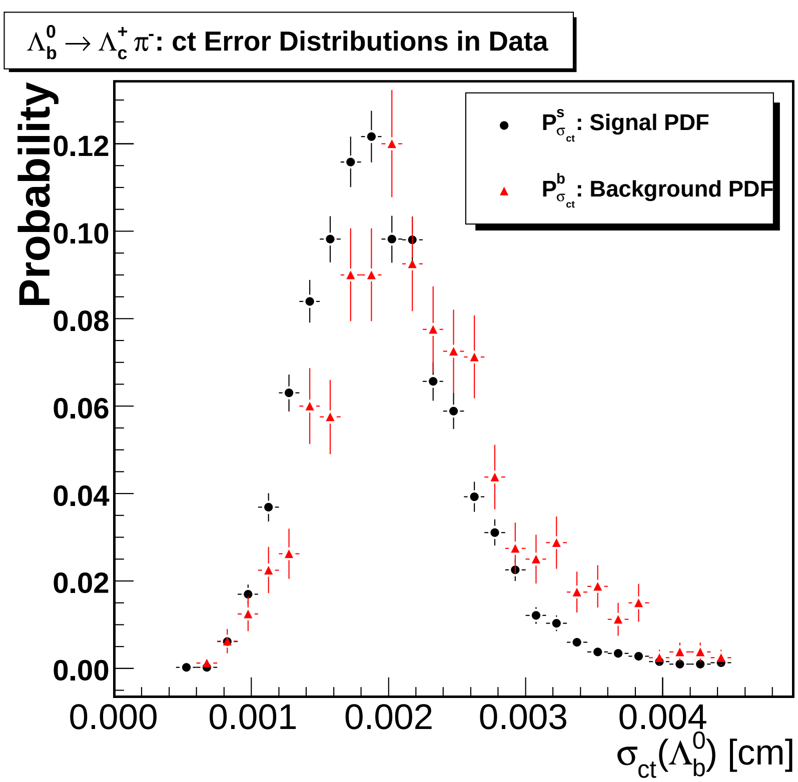

FIG. 2: The Λ_b^0 σ_{ct} distributions in data.

The value of σ_{ct}, obtained by a vertex-constrained kinematic fit is usually underestimated due to lack of knowledge of detector hit resolutions and track parameter errors due to wrong hit assignment. To account for these effects, σ_{ct} estimated by a vertex fit is multiplied by a scale factor S_{ct}. We estimate this scale factor by comparing the true ct' obtained from the MC truth information in the $\Lambda_b^0 \to \Lambda_c^+\pi^-$ signal Monte Carlo with the ct measured in the same event. A double-Gaussian resolution model is preferred by our data:

$$R(ct,\sigma_{ct}) = f \cdot Gauss(S_1 \cdot \sigma_{ct}) + (1-f) \cdot Gauss(S_2 \cdot \sigma_{ct});$$

Where the relative fraction, $f = 0.76$, and the scale factor widths, $S_1 = 1.107$ and $S_2 = 1.508$. Throughout this analysis, the same fraction and relative widths are used to model the resolution. In particular, when generating the trigger (SVT) efficiency and fitting the signal Monte Carlo sample.

When fitting data, it is impossible to measure the ct resolution directly as done for the Monte Carlo. A global scale factor, S_{ct}^{data}, is used instead to scale σ_{ct}. The value of the narrow Gaussian is set to S_{ct}^{data} while the broad Gaussian is scaled in order to maintain the same relative widths between S_1 and S_2 as measured in the Monte Carlo. The choice of S_{ct}^{data} is somewhat arbitrary and is treated as a source of systematic error.

In addition to the detector resolution, the Two Track Trigger (TTT) introduces a bias on the observed proper decay length. The TTT selects events with two displaced tracks which removes both the events with the short proper decay lengths, and those with very long ones. The resulting distribution is not an exponential any more, and this significantly complicates the extraction of the lifetime. An efficiency function, $\varepsilon_{TTT}(ct)$, is introduced to parameterize the trigger and offline selection effects and is computed using $\Lambda_b^0 \to \Lambda_c^+\pi^-$ signal Monte Carlo.

With the addition of the σ_{ct} scale factor S_{ct} and the efficiency function, $\varepsilon_{TTT}(ct)$, the joint two-dimensional $ct - \sigma_{ct}$ PDF becomes

$$P(ct,\sigma_{ct};S_{ct}) = P(ct|\sigma_{ct},S_{ct}) \cdot P(\sigma_{ct}) \cdot \varepsilon_{TTT}(ct). \tag{5}$$

A sample of pure signal Monte Carlo events are used to model the effect of the trigger and analysis cuts on measuring the lifetime. The efficiency function is of the form;

$$\varepsilon_{TTT}(ct) = \frac{Histo^{TTT}_{smoothed}(ct)}{\sum_i exp(ct^i, c\tau^{MC}) \otimes R(ct^i,\sigma^i_{ct})}. \tag{6}$$

The numerator is a smoothed histogram of the proper decay length for all Monte Carlo events that pass the trigger and analysis selection criteria. The denominator is the resolution-smeared lifetime, calculated analytically at every numerator bin and summed over all events (indexed by i) that pass the cuts required to fill the numerator. Figure 3 shows the resulting TTT efficiency histogram.

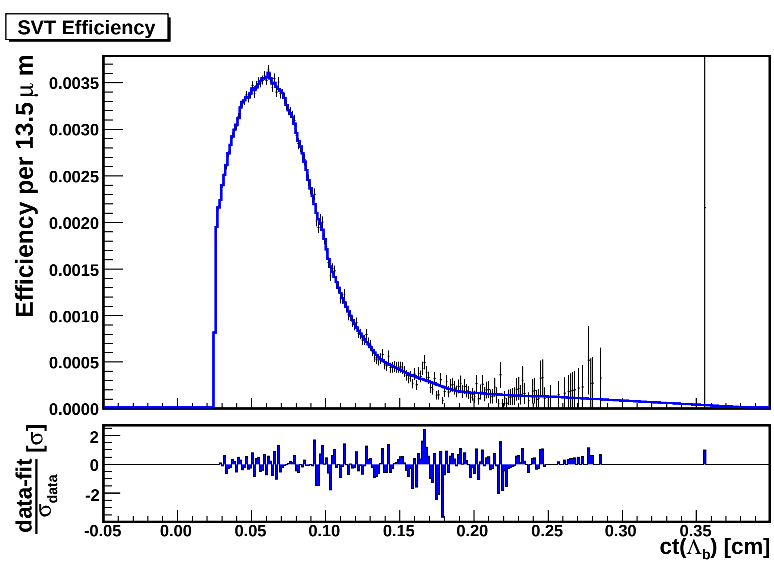

FIG. 3: The Λ_b^0 TTT efficiency distribution.

To obtain the lifetime of the Λ_b^0 baryon, we first determine the sample composition using a binned maximum likelihood fit of the invariant mass distribution of the $\Lambda_c^+\pi^-$ candidates. Second, the sample composition is fixed and an un-binned maximum-likelihood fit in ct and σ_{ct} is executed for the Λ_b^0 lifetime. In the second step, only events in the Λ_b^0 signal region are fit. The mass PDFs are integrated over the signal mass region, and multiplied by the corresponding normalizations to obtain the sample composition of the *signal* region. This yields $N^i_{\rm sig}$, the number of events of each component in the signal region.

The likelihood of one event is a sum over several fit components, j, of two-dimensional distribution functions;

$$\mathcal{L}(ct,\sigma_{ct}) = \sum_j N^j_{\rm sig} \cdot P^j_{ct}(ct|\sigma_{ct}) \cdot P^j_{\sigma_{ct}}(\sigma_{ct}). \tag{7}$$

Here P^j_{ct} is the probability distribution of ct – a product of the proper time of the Λ^0_b decay, t, and the speed of light c. $P^j_{\sigma_{ct}}$ is the probability distribution of the error on ct. In this fit, all values of $N^j_{\rm sig}$ are fixed, and the Λ^0_b lifetime is the sole parameter allowed to float. Moreover, several of the background components do not contribute to the signal region and are ignored in the lifetime fit.

III. DATA SAMPLES

We analyze events collected by the CDF detector from February 2002 through February 2006, with an integrated luminosity of $\mathcal{L} = 1070 \pm 60$ pb^{-1}, using CDF two displaced track trigger. We reconstruct a Λ^0_b candidate via its decay to a Λ^+_c and a pion, where Λ^+_c further decays to a proton, kaon and a pion. A Λ^+_c candidate is first reconstructed by requiring three tracks, with respectively proton, kaon and pion hypotheses, to have sufficient hits in tracking detectors and each track must have an impact parameter (d_0) from the primary vertex of less than 0.1 cm and a transverse momentum of more than 500 MeV/c. The proton candidate is additionally required to have a transverse momentum greater than the pion candidate, and greater than 2.0 GeV/c. A successful Λ^+_c candidate is required to satisfy the following cuts after a kinematic fit of the three tracks to a common vertex:

- $\chi^2_{xy} < 30$
- $p_{\rm T}(\Lambda^+_c) > 4.3$ GeV/c
- $2.269 < |{\rm M}(pK\pi)| < 2.301$ GeV/c^2.

The Λ^+_c candidate is then paired with a pion which passes track quality cuts, an impact parameter < 0.1 cmand a transverse momentum ($p_{\rm T}$) of > 2.0 GeV/c. A successful Λ^0_b candidate is required to satisfy the following cuts after a kinematic fit of the Λ^+_c and pion candidates to common vertex, where the mass of the $pK\pi$ candidate is constrained to the Λ^+_c mass from the PDG [4]:

- $\chi^2_{xy} < 30$
- $4.8 < |{\rm M}(pK\pi\pi)| < 7.0$ GeV/c^2
- $p_{\rm T}(pK\pi\pi) > 6.0$ GeV/c
- $-0.007 < ct(\Lambda^+_c) < 0.028$ cm (w.r.t to Λ^0_b vertex)
- $ct(\Lambda^0_b) > 0.025$ cm.

These are the basic requirements to reconstruct a Λ^0_b candidate from the data sample. Table I lists a set of optimized cuts and Table II lists the cuts for offline confirmation of the two displaced track trigger, which are subsequently applied to the Λ^0_b candidate to obtain the final sample for our analysis. Using these cuts we obtain a $\Lambda^0_b \to \Lambda^+_c\pi^-$ yield of 2927 ± 58 candidates in the signal region m(Λ^0_b) $\in$ [5.565, 5.670] GeV/c^2, with the Λ^0_b mass plot shown in Figure 4.

As explained earlier, the two track trigger (TTT) efficiency, $\varepsilon_{TTT}(ct)$, is obtained from the Monte Carlo simulation. In order to ensure that this procedure is not influenced by fluctuations, the Monte Carlo sample of $\Lambda^0_b \to \Lambda^+_c\pi^-$ decays from which $\varepsilon_{TTT}(ct)$ is derived needs to be very large. A signal sample was produced using the CDF HeavyQuarkGenerator (HQGen) package, which directly produces B-hadrons following a known kinematic distribution measured from the data. The resulting Λ^0_b hadrons are decayed to the signal decay mode using the EvtGen package using $c\tau^{MC}(\Lambda^0_b) = 368.0$ μm. The events are then subjected to the realistic simulations of the CDF detector which uses a charge deposition model tuned on data, and includes dead channels and noisy channels. Including the dead regions from the SVXII detector is important, since the Silicon Vertex Trigger (SVT) track reconstruction algorithm requires hits on four out of five SVXII layers, and thus the position of dead SVX chips and ladders influences the SVT efficiency. The tracking detector data are then input into the trigger emulators, producing decisions bitwise identical to the algorithms implemented in the firmware of the trigger systems. It is important that the SVT behavior be modeled

Variable	Cut value
	B_CHARM_SCENA
$p_{\mathrm{T}}(\pi_b^-)$	> 2 GeV/c
$p_{\mathrm{T}}(p)$	> 2 GeV/c
$p_{\mathrm{T}}(p)$	$> \ p_{\mathrm{T}}(\pi^+)$
$p_{\mathrm{T}}(K^-)$	> 0.5 GeV/c
$p_{\mathrm{T}}(\pi^+)$	> 0.5 GeV/c
$ct(\Lambda_b^0)$	$> 250\ \mu$m
$ct(\Lambda_b^0)/\sigma_{ct}$	> 10
$\lvert d_0(\Lambda_b^0)\rvert$	$< 80\ \mu$m
$ct(\Lambda_c^+ \leftarrow \Lambda_b^0)$	$> -70\ \mu$m
$ct(\Lambda_c^+ \leftarrow \Lambda_b^0)$	$< 200\ \mu$m
$\lvert m(pK^-\pi^+) - m(\Lambda_c^+)_{PDG}\rvert$	< 16 MeV/c^2
$p_{\mathrm{T}}(\Lambda_b^0)$	> 6.0 GeV/c
$p_{\mathrm{T}}(\Lambda_c^+)$	> 4.5 GeV/c
Prob(χ^2_{3D}) of Λ_b^0 vertex fit	$> 0.1\%$

TABLE I: Analysis cuts determined for Λ_b reconstruction.

Quantity	Cut value
$Q(trk1) \times Q(trk2)$	< 0
$p_T(trk1) + p_T(trk2)$	> 5.5GeV/c
$p_T(trk1)$	> 2.0GeV/c
$p_T(trk2)$	> 2.0GeV/c
$\lvert z0(trk1) - z0(trk2)\rvert$	$< 5.0cm$
$\lvert D0_{SVT}(trk1)\rvert$	$[0.012, 0.1]cm$
$\lvert D0_{SVT}(trk2)\rvert$	$[0.012, 0.1]cm$
$p_{T(SVT)}(trk1)$	> 2.0GeV/c
$p_{T(SVT)}(trk2)$	> 2.0GeV/c
$\Delta\phi(trk1, trk2)$	$[2^\circ, 90^\circ]$

TABLE II: Cuts used for offline confirmation of the two displaced track trigger

as accurately as possible, since the SVT tracks in the Monte Carlo simulation are the basis for the TTT efficiency which is the crux of this measurement.

After simulating the detector sculpting by SVT, the events are reconstructed using the standard production executable. The decay $\Lambda_b^0 \to \Lambda_c^+\pi^-$ is reconstructed from this sample using the same analysis cuts and trigger confirmation as the data. To mimic in Monte Carlo the run conditions and calibrations in the data, our Monte Carlo employs luminosity weighted run lists matched to data. After the trigger and offline reconstruction selection cuts, there are approximately *one million* events.

Kinematic agreement between Monte Carlo and data is critical to correctly measuring the lifetime of Λ_b^0. We re-weight Monte Carlo in the Λ_c^+ Dalitz fractions, Λ_b^0 polarization, pairs of stable tracks that satisfy the TTT requirements, and $p_T(\Lambda_b^0)$ to match the distributions observed in the data. After re-weighting, a sample of about 270,000 signal Monte Carlo events remain. Figure 5 compares data and re-weighted Monte Carlo distributions of track pairs that satisfy TTT requirements.

IV. RESULTS

Based on the result of the Λ_b^0 mass fit (shown in Figure 4), we define our signal region to be $5.565 < m(\Lambda_c^+\pi^-) < 5.67\text{GeV}/c^2$ with normalizations listed in Table III. Only the signal region is used when fitting for the lifetime. In some lifetime fits, the upper sideband is included explicitly, and the parametric shape of the combinatorial background is allowed to float in a combined signal plus sideband region fit. We chose not to follow this approach in favor of a less complicated, faster fit. We have studied changes to the shape of the combinatorial background along the *ct* axis. Since the ratio of the Λ_b^0 signal to combinatorial background in the signal region is about 30 : 1, the shape of the combinatorial background lifetime has sub-micron influence on the final lifetime fit (*i.e.*, on the order of $0.2 - 0.3\ \mu$m), and is therefore negligible.

The result of the un-binned, maximum likelihood, Λ_b^0 lifetime fit on data is

$$c\tau(\Lambda_b^0) = 422.8 \pm 13.8\ \mu\text{m} \tag{8}$$

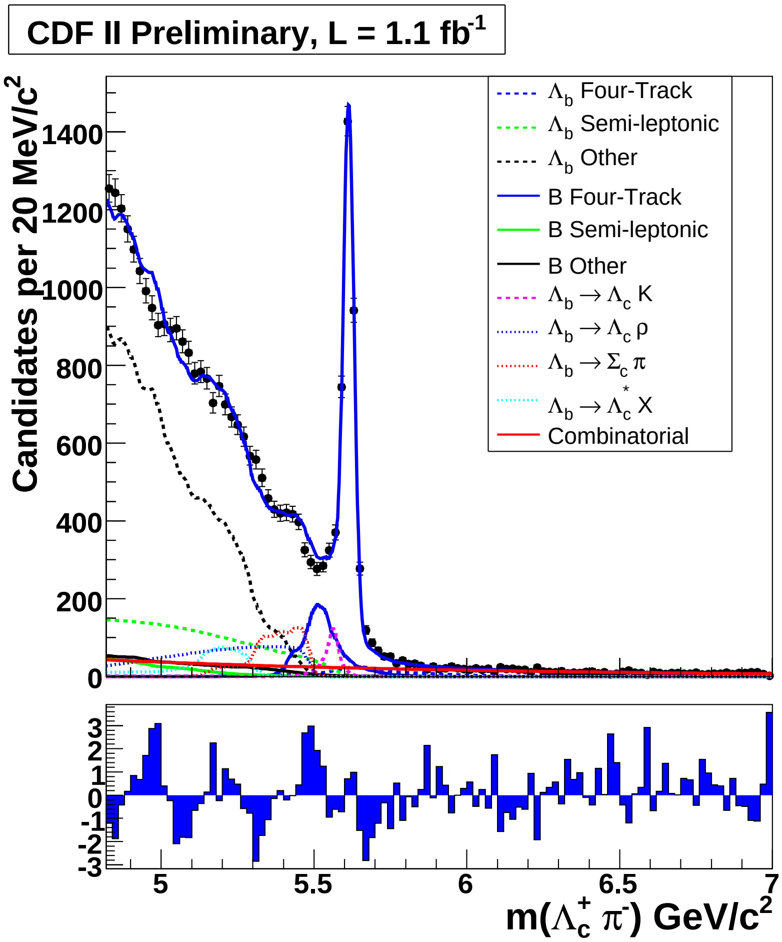

FIG. 4: Λ_b^0 mass fit. The solid blue line is the total fit. The primary background components are listed in the legend.

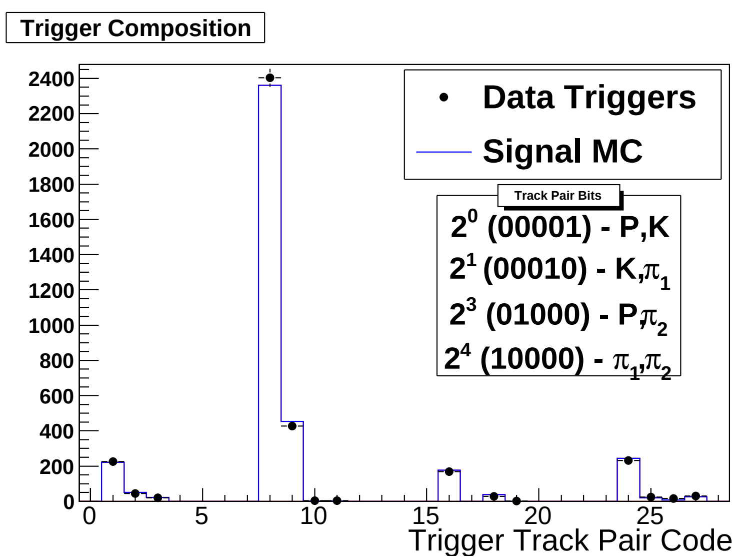

FIG. 5: Comparison of data and re-weighted Monte Carlo distributions of track pairs that satisfy TTT requirements.

The resulting likelihood projected onto the *ct*-axis is shown in Figure 6.
To gain confidence in the results various cross-checks have been performed. Figure 7 shows results of lifetime fits performed

Normalization	Value
$N_{\Lambda_b^0\to\Lambda_c^+\pi^-}$	2904.9 ± 57.9 (82%)
$N_{BFour-Track}$	250.5 ± 15.4 (7%)
$N_{\Lambda_b^0\to\Lambda_c^+K^-}$	138.6 ± 15.9 (4%)
$N_{Combinatorial}$	116.2 ± 5.0 (3%)
$N_{\Lambda_b^0 Four-Track}$	113.7 ± 15.9 (3%)
$N_{\Lambda_b^0\to\ell\bar{\nu}_\ell X}$	27.0 ± 7.8 ($<1\%$)
$N_{\Lambda_b^0 \text{`}Other'}$	7.2 ± 6.8 ($<1\%$)
$N_{B\text{`}Other'}$	3.5 ± 0.3
$N_{\Lambda_b^0\to\Sigma_c^+\pi^-}$	0.763917 ± 0.112236
$N_{B\to\ell\bar{\nu}_\ell X}$	0.643348 ± 0.27741
$N_{\Lambda_b^0\to\Lambda_c^{+*}X}$	0.097919 ± 0.0217996
$N_{\Lambda_b^0\to\Lambda_c^+\rho^-}$	0.0265047 ± 0.00408758

TABLE III: Normalizations for all backgrounds in the Λ_b^0 signal window $m(\Lambda_c^+\pi^-)\in[5.565, 5.670]\mathrm{GeV}/c^2$. Only the first seven components are included in the lifetime fit.

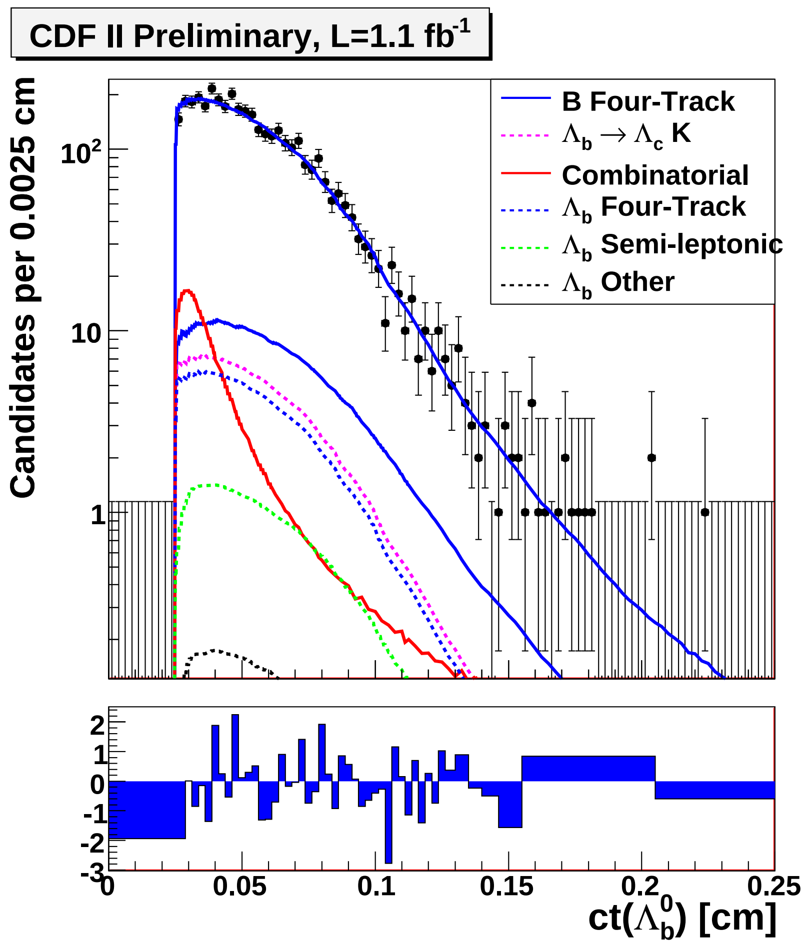

FIG. 6: Λ_b^0 lifetime fit on data. The projection of the 3-dimensional likelihood of the fit for $\tau(\Lambda_b^0)$ on the ct axis.

on Monte Carlo samples generated with Λ_b^0 lifetimes, 325μm, 368μm and 500μm. The fitter returns correct result over a significant range of input lifetimes. We have used our fitter framework to measure B^0 lifetime in the $B^0\to D^{*-}\pi^+$ decay mode, which is in agreement with the world average. We have confirmed that the Λ_b^0 lifetime result doesn't change appreciably due to moving up the lower edge of the mass window by 15 MeV$/c^2$ or by splitting the signal region into two halves. Finally we have split the data into 3 significant data taking periods and have found them compatible within statistical errors.

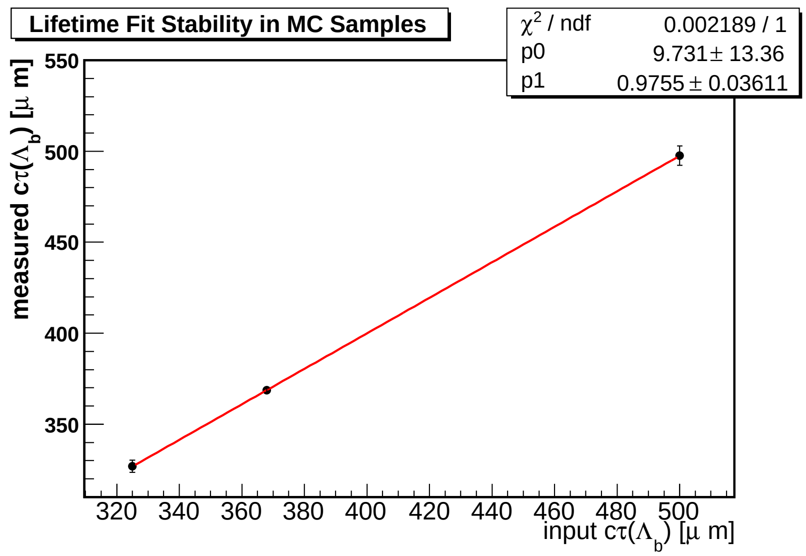

FIG. 7: Λ_b^0 lifetime fit results from Monte Carlo samples generated with 325μm, 368μm and 500μm lifetimes.

Description	**Value** [μm]
Alignment	2.0
SVT-SVX d0 correlation	1.0
Background Normalizations	1.0
Mass Template Shapes	negligible
SVT Model	6.3
Data-MC Agreement: Λ_c^+ Dalitz structure	3.7
Combinatorial *ct* Template	2.9
Data-MC Agreement: TrigCode re-weighting	2.0
Data-MC Agreement: Λ_b^0 polarization	1.4
Data-MC Agreement: Primary Vertex Position	1.2
B^0 Efficiency	1.0
B^0 Lifetime	1.0
Data-MC Agreement: $pt(\Lambda_b^0)$ spectrum	negligible
σ_{ct} Scale Factor	negligible
Fitter Bias	negligible
σ_{ct} Binning	negligible
Λ_c^+ Lifetime	negligible
Data-MC Agreement: Primary Vertex Error	negligible
Total Systematic Uncertainty	8.8

TABLE IV: Summary of the systematic uncertainties. The first group listed in the table are non-SVT-biased sources of systematic error. The total systematic uncertainty is obtained by adding the result of all systematics in quadrature.

A. Systematics

According to their effect on calculating the SVT efficiency, we consider two broad groups of systematic errors: those that bias the SVT efficiency, and those that do not. Most of the sources of systematic error fall in the latter category and are evaluated using a modified Toy Monte Carlo technique. For the parameters associated with an individual systematic, we generate Toy Monte Carlo samples where these parameters are varied. The sample is fit with both the default fit and the fit with varied parameters. We take the difference between the values of Λ_b^0 lifetime in the 'varied' (a.k.a. 'rigged') fit and the 'default' fit. This difference, caused by the systematic variation, constitutes the associated systematic error. After generating and fitting 1000 Toy Monte Carlo samples, the resulting distribution is fit with a Gaussian, and the mean is taken as the systematic shift due to that particular systematic.

The sources of systematic uncertainty are listed in Table IV. The total systematic uncertainty is computed by adding all sources of systematic error in quadrature. Our total systematic error, thus obtained, is 8.8 μm. The leading sources of systematic error are due to lack of knowledge of the SVT modeling in Monte Carlo, Λ_c^+ decay Dalitz structure and combinatorial *ct* template.

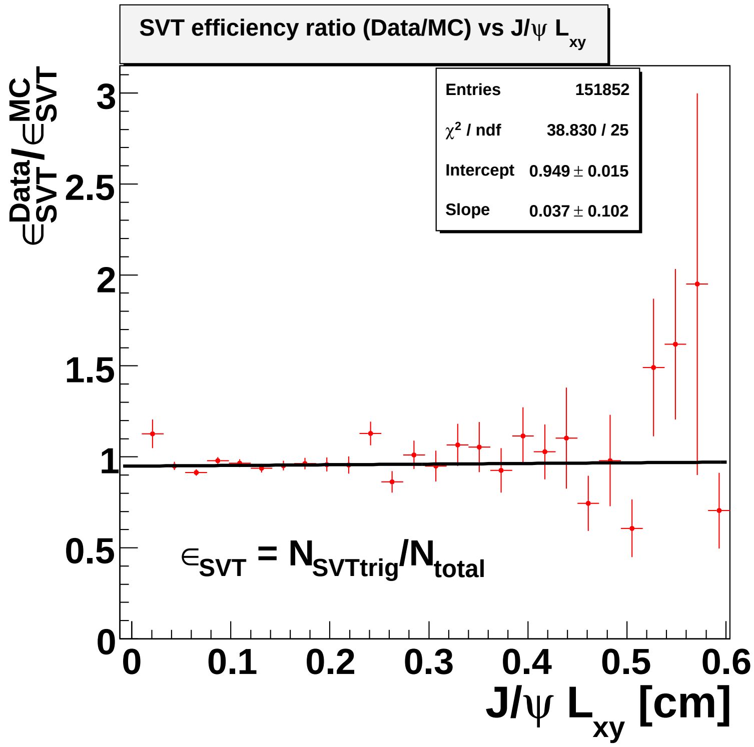

FIG. 8: Ratio of data and Monte Carlo SVT efficiencies fitted to a first order polynomial.

The systematic error due to defi ciency in SVT trigger modeling as well as silicon hit simulation in Monte Carlo is evaluated using a $J/\psi \rightarrow \mu\mu$ sample collected using the CDF di-muon trigger. Unlike the SVT triggered samples the J/ψ decay length distribution of this sample is not biased. We reconstruct J/ψ's in this sample and calculate SVT effi ciency as the ratio of J/ψ candidates passing the SVT cuts and the total number of J/ψ candidates in the sample in $L_{xy}(J/\psi)$ bins. To ensure maximum compatibility between data and Monte Carlo events, we generate fake events with the 3-momenta of the reconstructed data events and primary vertex positions. We pass them through CDF detector and SVT trigger simulations and calculate SVT effi ciency the same way as in data. Figure 8 shows the ratio of data and MC SVT effi ciencies fi tted to a fi rst order polynomial. We fluctuate the resulting slope within the fi t error to evaluate the systematic error using the Toy Monte Carlo method described above.

Our baseline Monte Carlo is generated with the Λ_c^+ Dalitz decay branching fractions set to the PDG [4] values. A comparison between data and Monte Carlo Λ_c^+ Dalitz distributions suggest the MC modeling to be largely inadequate to reproduce data. The systematic error, due to the Dalitz fractions, is therefore estimated very conservatively. Several random ensembles are generated; the value of each fraction is fluctuated, between $\pm 3\sigma$ of the PDG error, using a flat prior distribution. The systematic is computed using the usual Toy Monte Carlo method. The RMS of the resulting shifts from the baseline lifetime result is quoted as the systematic.

In the baseline fi t the combinatorial background ct is modeled with a Landau distribution obtained by fi tting candidates in the upper sideband of data. We obtain a rigged template by smoothing the same sideband candidate distribution rather than fi tting it. The systematic error is obtained using our modifi ed Toy Monte Carlo method as explained above.

V. SUMMARY

Analyzing a sample of $\sim$3000 fully reconstructed $\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-$ decays from 1070 $\pm$ 60 pb^{-1} of data, collected with two displaced track triggers, we measure the lifetime of the Λ_b^0 baryon to be:

$$c\tau(\Lambda_b^0) = 422.8 \pm 13.8 \text{ (stat)} \pm 8.8 \text{ (syst) } \mu\text{m}.$$

It is expressed in picoseconds as:

$$\tau(\Lambda_b^0) = 1.410 \pm 0.046 \text{ (stat)} \pm 0.029 \text{ (syst) ps}.$$

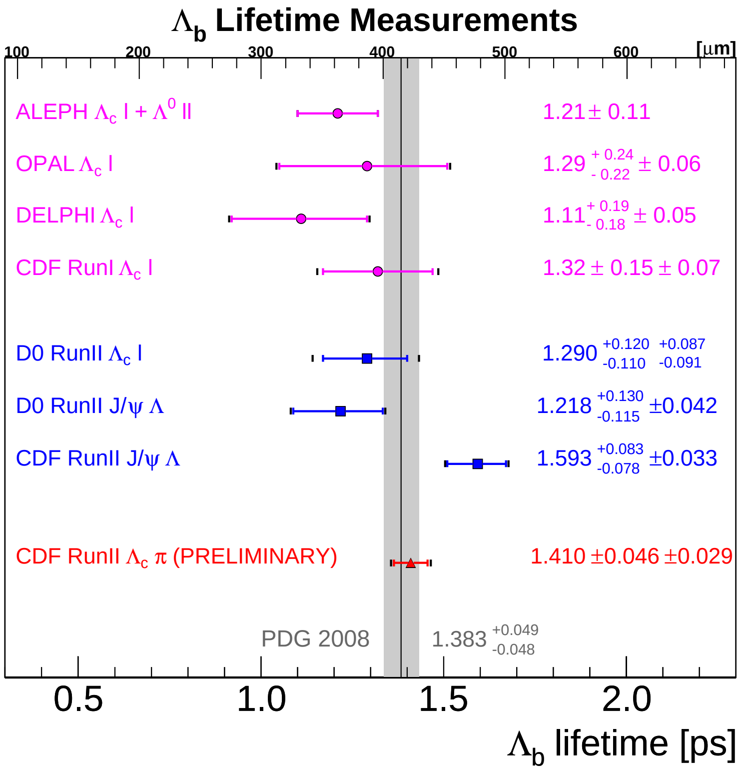

FIG. 9: Our Λ_b^0 lifetime measurement is compared with the current world average (HFAG 2008) and all measurements contributing to it.

Using the current world average for B_d^0 lifetime [7] we obtain:

$$\tau(\Lambda_b^0)/\tau(B^0) = 0.922 \pm 0.039.$$

In Figure 9 our result is compared with the current world average [8] for Λ_b^0 lifetime. It is currently world's single most precise measurement. Shown also are all the measurements that contribute to the world average, including the last CDF measurement in the $\Lambda_b^0 \to J/\psi\Lambda$ mode. We see an excellent agreement between our result and the current world average, which is dominated by the CDF $\Lambda_b^0 \to J/\psi\Lambda$ result. Also, our result lies at the upper end of the the current HQE prediction [3] of $\tau(\Lambda_b^0)/\tau(B^0)$ = 0.88 $\pm$ 0.05, and prefers its most probable value of 0.94. This measurement thus resolves the puzzle concerning the long standing disagreement between the Λ_b^0 lifetime ratio and its HQE prediction.

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