Measurement of L$_b$ Branching Ratios in Modes Containing a L$_c$

University of Pennsylvania
Shin-Shan Yu, Nigel Lockyer

Fermilab
Rick Tesarek

Johns Hopkins University
Yi Le, Bruce Barnett,
Petar Maksimovic, Matthew Martin

Why are the L$_b$ branching fractions interesting?

- Little is known about the properties of b-baryons.
- Measurement of Λ_b branching fractions provides a way to test Heavy Quark Theory.
- Currently the b-baryons are only produced at the Tevatron.

Tevatron luminosity increase + Silicon Vertex Trigger = large Λ_b sample

Why measure the ratio of branching fractions?

- We measure the ratios of branching fractions in kinematically similar decay modes.
- Same triggers are used both for the signal and normalization modes.

Systematic errors from the acceptance, trigger and reconstruction efficiency cancel.

What ratios do we measure?

$f_{baryon} \times BR(?_b \to ?_c^+ p^-) / f_d \times BR(B^0 \to D^- p^+)$ and $BR(?_b \to ?_c^+ \mu^- ?) / BR(?_b \to ?_c^+ p^-)$

Both data are collected from the two-track trigger.

Two-track trigger: a trigger that requires a pair of opposite-charged tracks with 120 µm ≤ impact parameters ≤ 1 mm, transverse momentum ≥ 2GeV/c, scalar sum of the transverse momenta ≥ 5.5GeV/c, 2 ≤ angle between two tracks ≤ 90 degrees, the 2-D distance between the beam spot and the intersection point of two tracks ≥ 200 µm .

What do we know about L$_b$ decays?

2003 Particle Data Group

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$J/\psi(1S)\Lambda$	$(4.7\pm2.8)\times10^{-4}$	
Γ_2	$pD^0\pi^-$		
Γ_3	$\Lambda_c^+\pi^-$	seen	
Γ_4	$\Lambda_c^+ a_1(1260)^-$	seen	
Γ_5	$\Lambda_c^+\pi^+\pi^-\pi^-$		
Γ_6	$\Lambda K^0 2\pi^+ 2\pi^-$		
Γ_7	$\Lambda_c^+\ell^-\overline{\nu}_\ell$ anything	[a] (7.7 ± 1.8) %	
Γ_8	$p\pi^-$	$< 5.0 \times 10^{-5}$	90%
Γ_9	pK^-	$< 5.0 \times 10^{-5}$	90%
Γ_{10}	$\Lambda\gamma$	$< 1.3 \times 10^{-3}$	90%

[a] Not a pure measurement. See note at head of Λ_b^0 Decay Modes.

- σ_b : b-quark production cross section
- $f_{u,d,s,baryon}$: probability for the b-quark to hadronize to $B_{u,d,s,\ baryon}$
- ε : total reconstruction efficiency
- N_{signal} : measured event yield

How do we measure the branching fraction? Þ $\sigma_b \times f_{u,d,s,baryon} \times BR \times \varepsilon = N_{signal}$

$$\frac{f_{baryon} \times BR(?_b \to ?_c^+ p^-)}{f_d \times BR(B^0 \to D^- p^+)}$$

- L_c^+® p K$^-$ p$^+$ and D$^-$ ® K$^+$ p$^-$ p$^-$
- fully reconstruct decays
- We could extract ratio of production fractions if combined with other analysis
- large uncertainty from BR($\Lambda_c \to pK\pi$)

Normalization Mode

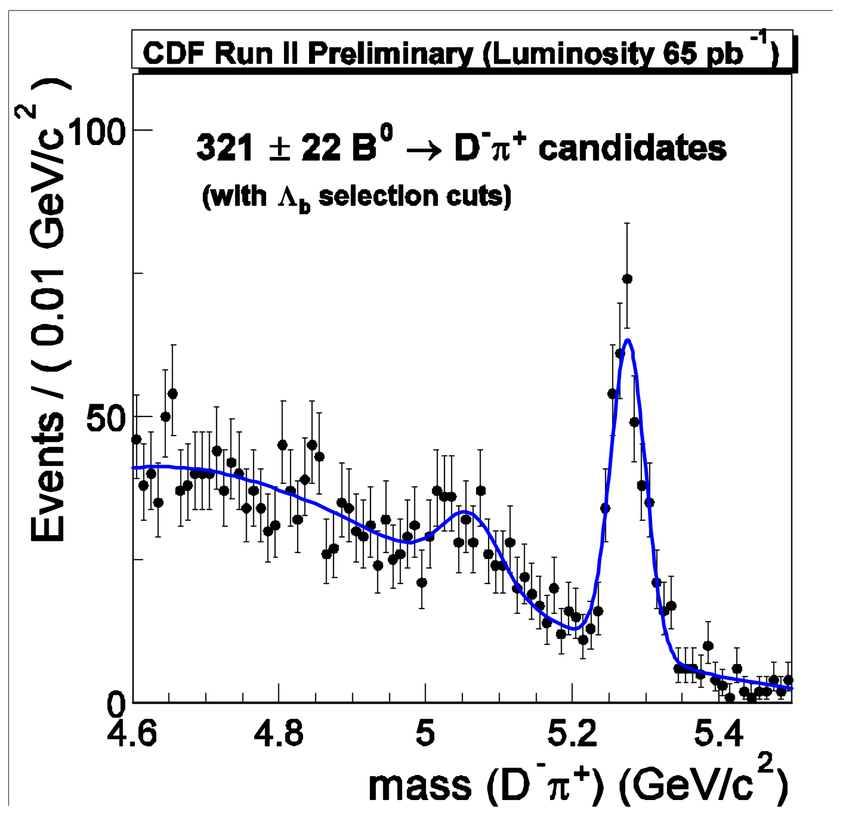

Figure 1: Reconstructed $B^0 \to D^-\pi^+$, $D^- \to K^+\pi^-\pi^-$. The data are fitted with a signal Gaussian, a satellite Gaussian and a broad Gaussian (background). χ^2/N=0.92

Signal Mode

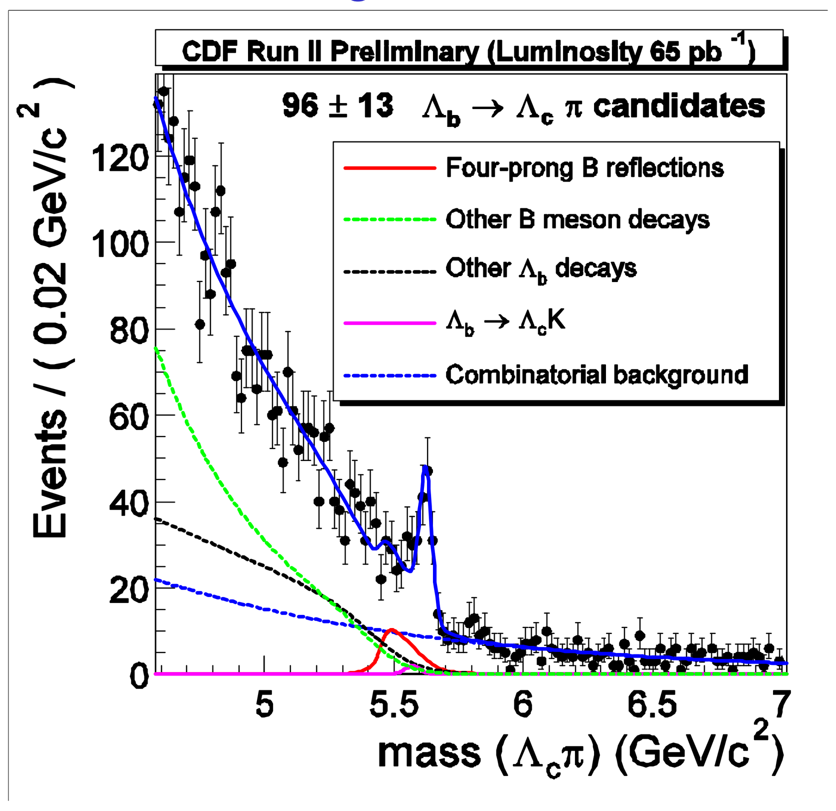

Figure 2: Reconstructed $\Lambda_b \to \Lambda_c\pi$, $\Lambda_c \to pK\pi$. The data are fitted with a Gaussian (signal). The background shape is obtained from the Monte Carlo. χ^2/N=167/116
There are two sources of backgrounds:
1. combinatorial 2. reflections. See below.

Sources of reflections in L$_b$ ® L$_c$p

- Four-prong B meson decays and all the other B meson decays
- $\Lambda_b \to \Lambda_c K$ and other Λ_b decays
- Normalized the reflections with the measured $B^0 \to D^-\pi^+$ yield in the Λ_b mass window, production fractions and relative BR of four-prong to other B decays

Efficiency ratio e(L$_b$)/e(B^0)

Table 1: Efficiency Ratio

	$\epsilon_{B^0\to D^-\pi^+}/\epsilon_{\Lambda_b\to\Lambda_c^-\pi^+}$
$\epsilon_{Trigger}$	1.30 ± 0.01
ϵ_{Reco}	0.96 ± 0.01
ϵ_{Ana}	0.96 ± 0.01
ϵ_{Tot}	1.20± 0.02

Systematic uncertainties

Table 2: Summary of Systematics

	central value	variation	(%) change
B^0 lifetime (μm)	462	457–467	±0
Λ_b lifetime (μm)	369	345–393	$^{+4}_{-5}$
Λ_c Dalitz structure	non-resonant		+1
MC P_T spectrum			+1
Λ_b polarization	0	±1	±7
XFT	2 miss	1 miss	+3
ϕ efficiency			+3
subtotal			±9
Fit model (B^0)			±6
Fit model (Λ_b)			±8
$BR(\Lambda_c^+ \to pK^-\pi^+)$			±27
$BR(D^- \to K^+\pi^-\pi^-)$			±27

We measure

$$\frac{f_{baryon}\times BR(?_b \to ?_c^+ p^-)}{f_d \times BR(B^0 \to D^- p^+)} = 0.66 \pm 0.11(stat) \pm 0.09(syst) \pm 0.18(BR)$$

$$\frac{BR(?_b \to ?_c^+ \mu^- ?)}{BR(?_b \to ?_c^+ p^-)} \rightarrow \frac{BR(B^0 \to D^{*-}\mu^+ ?)}{BR(B^0 \to D^{*-} p^+)}$$

- There are backgrounds from the feed-down of excited charm, other B-hadrons and fake muons. A slightly different formula : $R_{BR} = R_\varepsilon \times (R_{yield} - R_{physics} - R_{fake\mu})$
- We choose one control sample: $B^0 \to D^*\pi$ and $B^0 \to D^*\mu\nu$ to understand the backgrounds and systematic uncertainties.

Normalization Mode

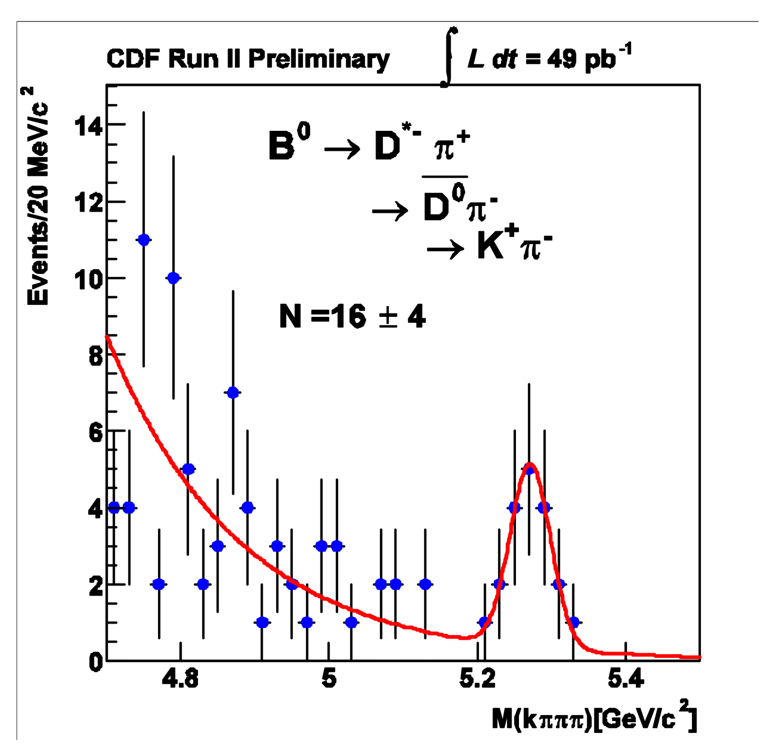

Figure 3: Reconstructed $B^0 \to D^*\pi$, Data are fitted with a single Gaussian (signal) and a exponential background. χ^2/N=29.26/22

Signal Mode

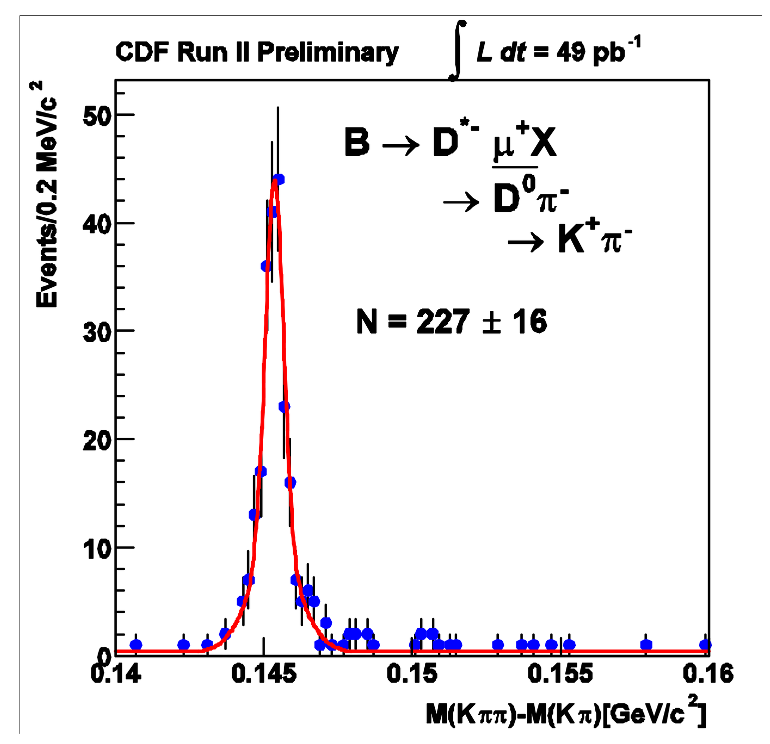

Figure 4: Reconstructed $B^0 \to D^*\mu\nu$, Data are fitted with double Gaussian (signal) and a constant background. χ^2/N=21.11/31

Physics backgrounds from the feed-down of excited D mesons

- Physics backgrounds are estimated from predicted branching ratios and the efficiencies from the Monte Carlo. Backgrounds contributing < 1% are not included.

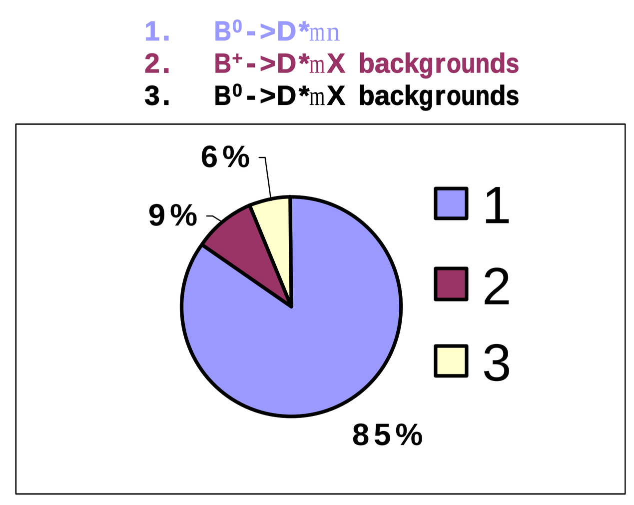

Table 3: Branching Ratio

Mode	BR (%)
$B^0 \to D^{*-}\mu^+\nu$	5.53±0.23
$B^+ \to \overline{D_1^0}\mu^+\nu$	0.56±0.16
$\hookrightarrow D^{*-}\pi^+$	66.67± ?
$B^+ \to \overline{D_1^{0\prime}}\mu^+\nu$	0.37± ?
$\hookrightarrow D^{*-}\pi^+$	66.67± ?
$B^+ \to D^{*-}\pi^+\mu^+\nu$	0.20±?
$B^0 \to D^{*-}\tau^+\nu$	1.60±?
$\hookrightarrow \mu^+\nu$	17.37±0.06
$B^0 \to D_1^-\mu^+\nu$	0.56±?
$\hookrightarrow D^{*-}\pi^0$	33.33±?
$B^0 \to D_1^{-\prime}\mu^+\nu$	0.37±?
$\hookrightarrow D^{*-}\pi^0$	33.33±?
$B^0 \to D^{*-}\pi^0\mu^+\nu$	0.100±?

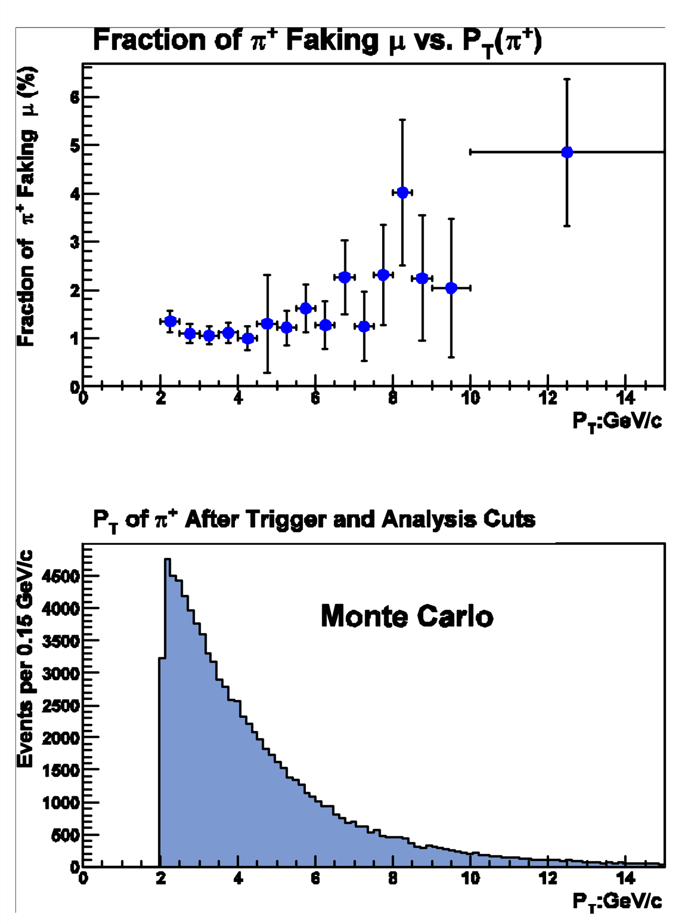

Figure 5: muon fake rate and π^+ Pt spectrum

Fake muons from the B hadronic decays

- Backgrounds from fake muons are estimated by weighting the K/π Pt spectra from $B_{mix} \to D^*X_{hadron}$ Monte Carlo by the measured muon fake rate. See Figure 5.

Systematic uncertainties

Note: The systematic error from the unmeasured BR is calculated by assigning 5% uncertainty to the charm decays and 100% uncertainty to the B decays.

Table 4: Summary of Systematics

CDF Internal Systematics: $\sigma_{R_{BR}}$	
Fake μ Rate	± 0.22
$P_T(B^0)$ Spectrum	$^{+1.23}_{-0.73}$
Total	$^{+1.25}_{-0.76}$
External Systematics from Measured BR: $\sigma_{R_{BR}}$	
$B_d \to D^{*-}\pi^+$	±0.31
$B^+ \to \overline{D_1^0}\mu^+\nu$	±0.29
$B_{mix} \to D^{*-}X$	±0.17
f_d	±0.03
Total	±0.46
External Systematics from Unmeasured BR: $\sigma_{R_{BR}}$	
	±1.09
Statistical Uncertainty: $\sigma_{R_{BR}}$	
	±7.12

Result agrees with 2003 PDG within 0.4s.
Þ proceed with L$_b$ analysis

We measure

$$\frac{BR(B^0 \to D^{*-}\mu^+ ?)}{BR(B^0 \to D^{*-} p^+)} = 22.9 \pm 7.1(stat)^{+1.3}_{-0.8}(internal\ sys.) \pm 0.5(measured\ BR) \pm 1.1(unmeasured\ BR)$$

Lepton/Photon 2003, Batavia, IL, USA August 11th – 16th

Shin-Shan Yu, University of Pennsylvania for the CDF Collaboration