Λ_b Physics at CDF

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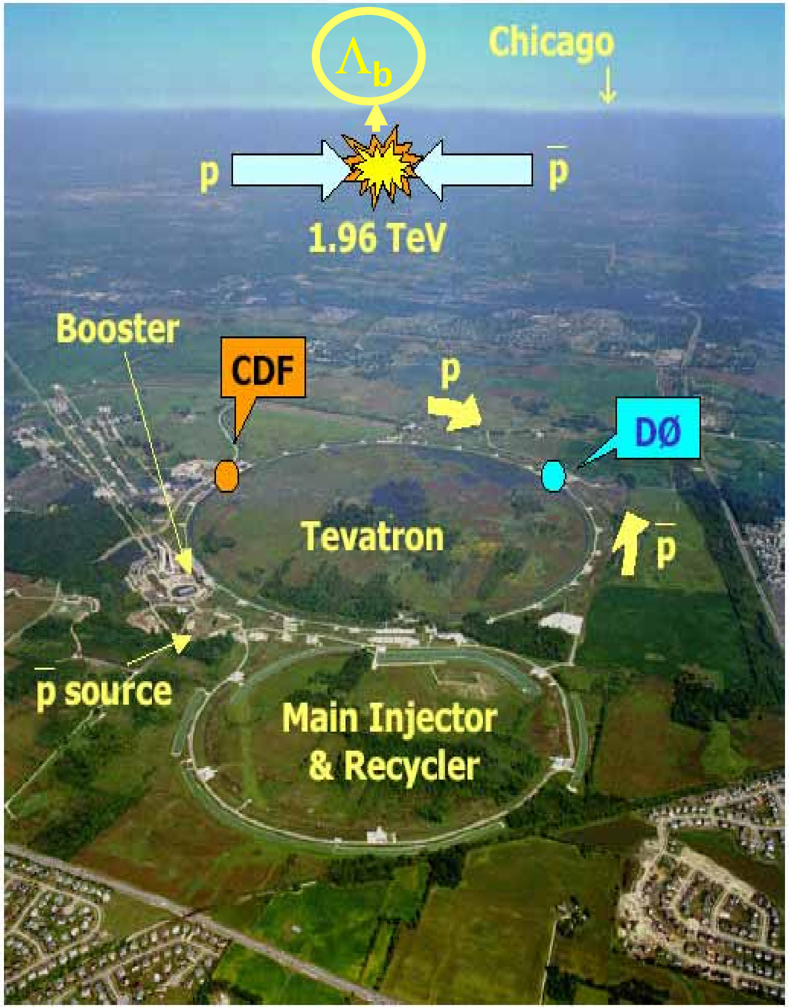
Outline

- Why Λ_b
- CDF Detector, Trigger
- Previous Λ_b Results
  - Lifetime and Mass:
    $\Lambda_b \to J/\psi\ \Lambda$
  - Branching Fractions:
    $\Lambda_b \to J/\psi\ \Lambda$, $\Lambda_b \to pK, p\pi$,
    $\Lambda_b \to \Lambda_c\ \pi$
- New Results
  - Branching Fractions:
    $\Lambda_b \to \Lambda_c\ \pi$, $\Lambda_b \to \Lambda_c\ \mu\nu$
  - First Observations:
    $\Lambda_b \to \Lambda_c^*\ \mu\nu$, $\Lambda_b \to \Sigma_c\ \pi\mu\nu$
    $\Lambda_b \to \Lambda_c\pi\pi\pi$
- Future



Big Picture : Why Λ_b baryon?

Λ_b^0 — u d b — $I(J^P) = 0(\frac{1}{2}^+)$

$I(J^P)$ not yet measured; $0(\frac{1}{2}^+)$ is the quark model prediction.

Mass $m = 5624 \pm 9$ MeV $(S = 1.8)$

Mean life $\tau = (1.229 \pm 0.080) \times 10^{-12}$ s

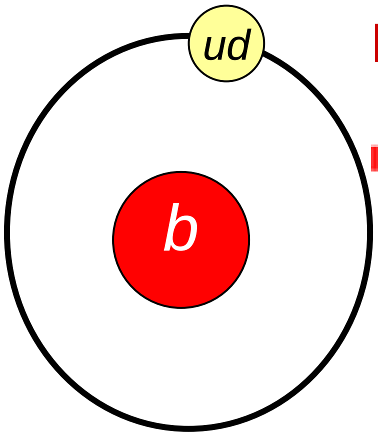
$c\tau = 368\ \mu$m

Λ_b^0 DECAY MODES		Fraction (Γ_i/Γ)
$J/\psi(1S)\Lambda$		$(4.7\pm2.8) \times 10^{-4}$
$\Lambda_c^+ \pi^-$		seen
$\Lambda_c^+ a_1(1260)^-$		seen
$\Lambda_c^+ \ell^- \overline{\nu}_\ell$ anything	[t]	(9.2 ± 2.1) %
$p\pi^-$		$< 5.0 \times 10^{-5}$
pK^-		$< 5.0 \times 10^{-5}$
$\Lambda\gamma$		$< 1.3 \times 10^{-3}$

This is all we know about Λ_b ...

Now, Fermilab Tevatron is the only facility that produces Λ_b and allows us to study Λ_b.

HQET and HQE



Heavy Quark Effective Theory and Heavy Quark Expansion

- HQET and HQE predict the b-hadron mass, branching fractions and lifetime
  - Assuming $m_b >> \Lambda_{QCD}$, the 3-body dynamics is reduced to 2-body heavy vs. light system.
  - The b quark can be treated the same way as the nucleus in the atom.
  - Little interaction between the heavy and light system.
  - Relate the b-hadrons of different flavors

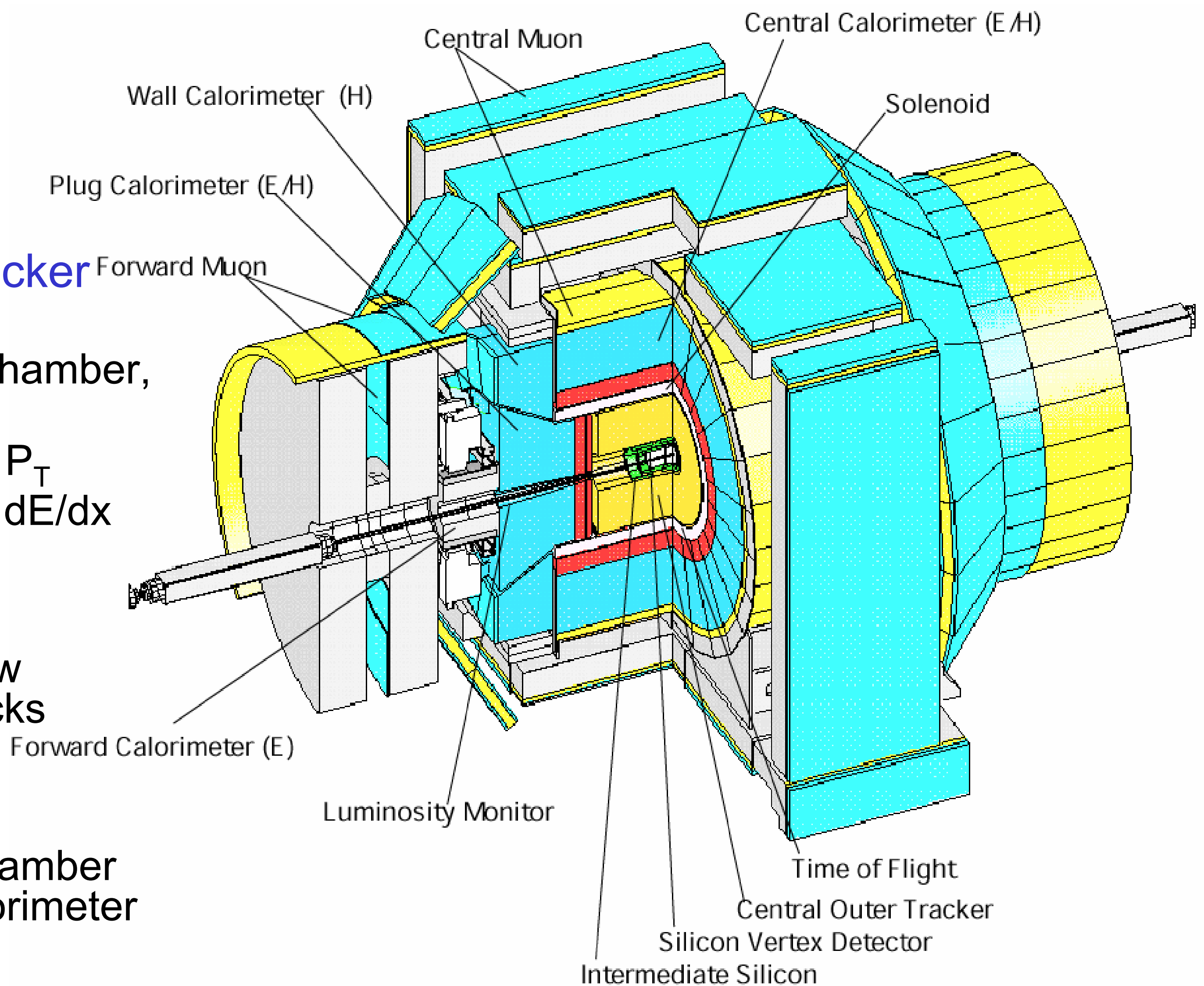
- Difference of b-hadrons are expressed in the power of $\frac{1}{m_b}$ and $\alpha_s(m_b)$
- Spin of di-quarks = 0, sub-leading order corrections are simpler than those of B mesons.

Measuring Λ_b mass, branching fractions, and lifetime tests HQET and HQE

independently from the B mesons.

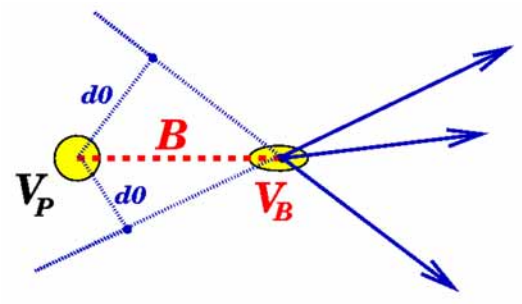
CDF Detector

- Solenoid
  - 1.4 Tesla
- Silicon Tracker
  - $|\eta| < 2$
  - $\sigma_{vertex} \sim 30\ \mu m$
- Central Outer Tracker (COT)
  - 96 layers drift chamber, up to $|\eta| \sim 1$
  - $\sigma_{P_T}/P_T \sim 0.15\%\ P_T$
  - Particle ID with dE/dx
- Time of Flight
  - Particle ID of low momentum tracks
- Muon chamber
  - 4 layers drift chamber outside the calorimeter
  - $|\eta| < 1$

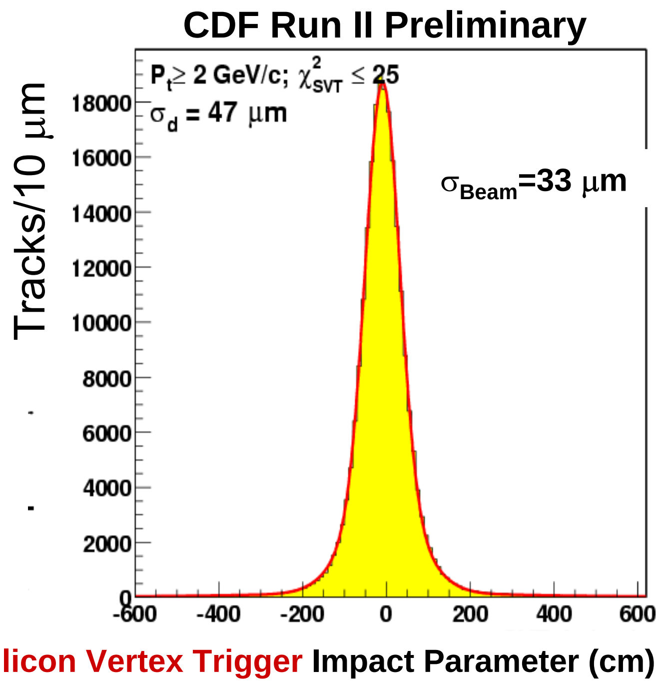


B Physics & *B* Triggers

- Huge production rates, 1000 times higher than at $e^+e^- \to \Upsilon(4S)$
  - $\sigma(pp \to bX, |y| < 0.6) = 17.6 \pm 0.4$ (stat.) ± 2.5 (syst.) μb PRD 71, 032001
- Heavy states produced
  - B^0, B^+, B_s, B_c, Λ_b, Ξ_b
- Backgrounds are also 3 orders of magnitude higher
  - Inelastic cross section ~100 mb
  - Challenge is to pick one *B* decay from ~10^3 QCD events



- Di-muon trigger (lifetime, mass, branching ratios)
  - $p_T(\mu) > 1.5$ GeV/c, within J/Ψ mass window
- Two displaced-tracks trigger (branching ratios)
  - $p_T > 2$ GeV/c, 120 μm $\le d_0 \le$ 1 mm, $L_{xy} > 200\ \mu$m, $\Sigma\, p_T > 5.5$ GeV/c
- Lepton + displaced-track trigger (lifetime, f_{baryon})
  - $p_T(\mu,e) > 4$ GeV/c, 120 μm $\le d_0 \le$ 1 mm, $p_T > 2$ GeV/c



Previous Λ_b Results

Lifetime, Mass, and Branching Fractions

- First measurement of $\tau(\Lambda_b)$ in a fully reconstructed mode $\Lambda_b \to J/\psi\, \Lambda$

  dimuon trigger data **τ = 1.25 ± 0.26 ± 0.10 ps**

  To be compared with the 2004 world average τ = 1.229 ± 0.080 ps

- Best single mass measurement $\Lambda_b \to J/\psi\, \Lambda$

  dimuon trigger data **M = 5619.7 ± 1.2 ± 1.2 MeV/c^2**

  To be compared with the 2004 world average M = 5624.0 ± 9.0 MeV/c^2

- Relative BR

  dimuon trigger data

$$\frac{\sigma_{\Lambda_b}}{\sigma_{B^0}} \times \frac{B(\Lambda_b \to J/\psi\, \Lambda)}{B(\overline{B}^0 \to J/\psi\, K_s^0)} = 0.43 \pm 0.12\,(\mathrm{stat}) \pm 0.08\,(syst)$$

  To be compared with the Run I result Ratio = 0.27 ± 0.12 (stat) ± 0.05 (syst)

- Best upper limit on Λ_b charmless decays

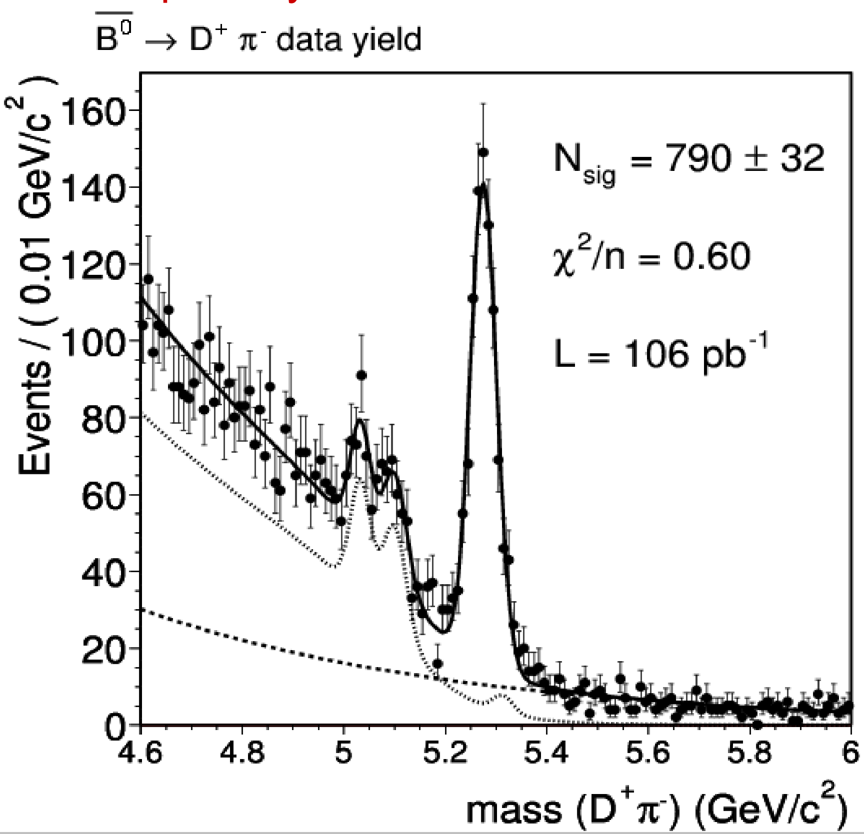
  two displaced track trigger data **$B(\Lambda_b \to pK+p\pi) < 2.2 \times 10^{-5}$ at 90% C.L**

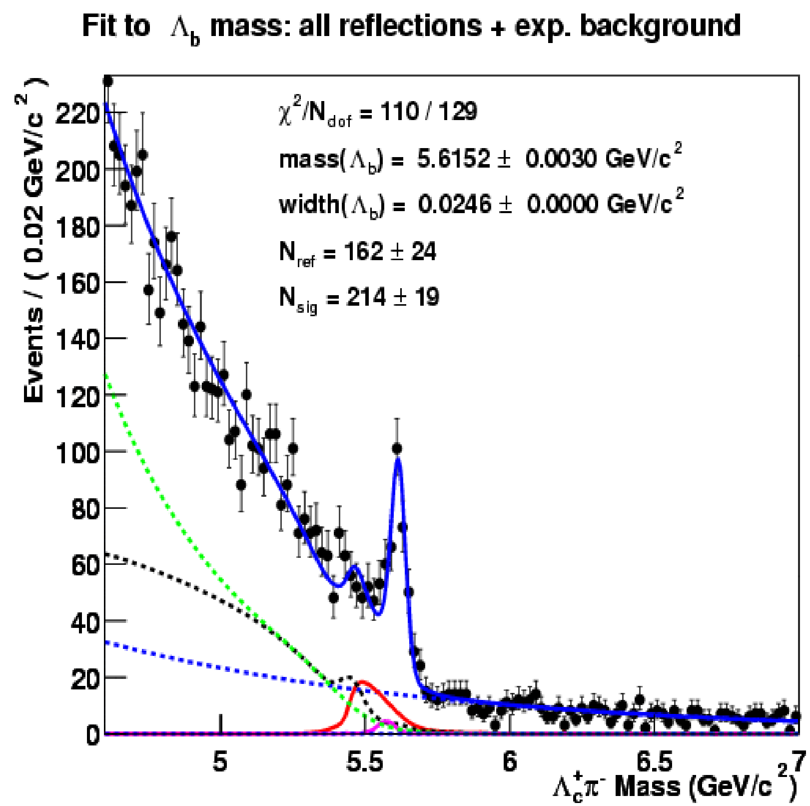
  To be compared with the 2004 world average $B(\Lambda_b \to pK+p\pi) < 5.0 \times 10^{-5}$ at 90% C.L

Branching Fraction $\Lambda_b \to \Lambda_c \pi$ $\Lambda_c \to p^+ K^- \pi^+$

- Data come from two displaced track trigger
- Background shapes obtained from Monte Carlo simulation:

  mis- or partially reconstructed b-hadron decays

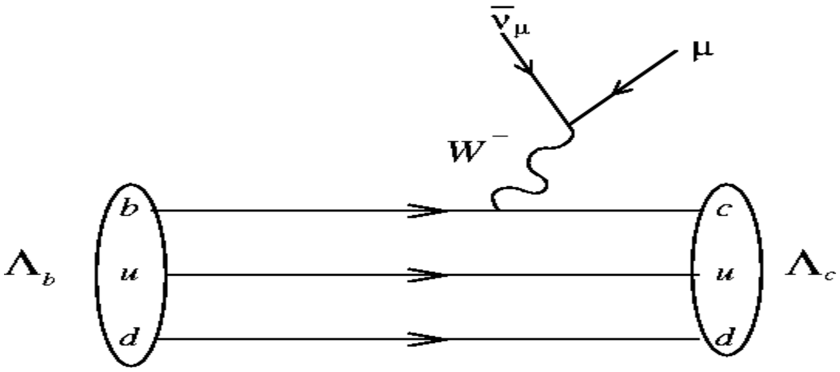


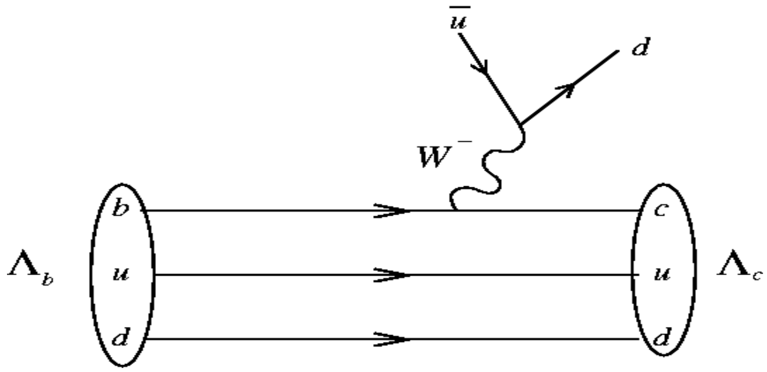


$$\frac{\sigma_{\Lambda_b}(P_T > 6 GeV/c)}{\sigma_{B^0}(P_T > 6 GeV/c)} \times \frac{B(\Lambda_b \to \Lambda_c^+ \pi^-)}{B(\overline{B}^0 \to D^- \pi^-)} = 0.82 \pm 0.08(\mathrm{stat}) \pm 0.11(syst) \pm 0.22\ (\Lambda_c\ \mathrm{BR})$$

New Results

Why $B(\Lambda_b \to \Lambda_c \mu \upsilon)/B(\Lambda_b \to \Lambda_c \pi)$?





- Similar Feynman diagrams. Theorists relate hadronic BR to easier and calculable semileptonic BR by factorization.
- Differential semileptonic decay width is related to 6 form factors, reduced to one in HQET

$$\frac{d\Gamma}{dq^2} \propto |M|^2 \propto |V_{cb}|^2 \cdot \left(\sum_i^6 F_i(q^2)\right)^2 \overset{HQET}{\Rightarrow} \zeta(w) = e^{-\rho^2(w-1)}, \text{ where } w = \frac{m_{\Lambda_b}^2 + m_{\Lambda c}^2 - q^2}{2 m_{\Lambda_b} m_{\Lambda c}}$$

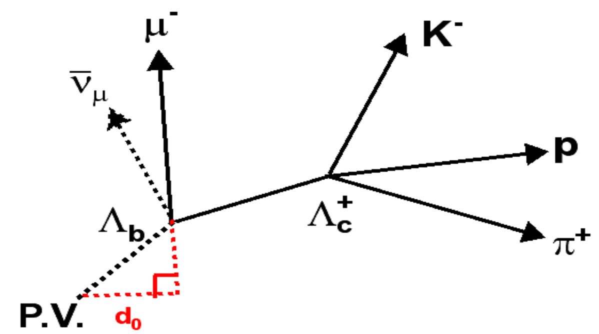
- Close form of $\zeta(w)$ can be obtained using Large Nc Limits, QCD Sum Rules, and etc.
- Predictions of Jenkins (***Nucl. Phys. B396, 38***), Huang, et al. (***hep-ph/0502004***) and Leibovich, Ligeti, Stewart, Wise (***Phys. Lett. B586, 337***) give a ratio of 15 with 10-30% error

$$\text{Predicted } B(\Lambda_b \to \Lambda_c^+ \mu^- \bar{\nu}) = 6.6\%, \quad B(\Lambda_b \to \Lambda_c^+ \pi^-) = 0.45\%$$

How $B(\Lambda_b \to \Lambda_c \mu \nu)/B(\Lambda_b \to \Lambda_c \pi)$?

- If hadronic BR is known, we can get V_{cb} from the semileptonic BR.
- Four charged tracks in the final state
- Control samples: similar decays in the B meson system

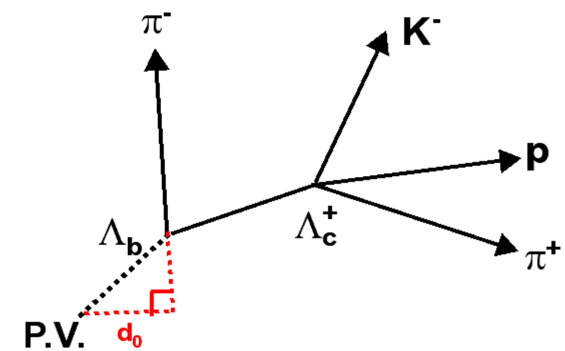
$$\frac{B(\overline{B}^0 \to D^+ \mu^- \overline{\nu})}{B(\overline{B}^0 \to D^+ \pi^-)}$$ and $$\frac{B(\overline{B}^0 \to D^{*+} \mu^- \overline{\nu})}{B(\overline{B}^0 \to D^{*+} \pi^-)}$$



$\Lambda_b \to \Lambda_c^+ \mu^- \overline{\nu}_\mu$
$\to pK^-\pi^+$

- Relative BR is the yield ratio corrected for the efficiency, e.g:

$$\frac{B(\Lambda_b \to \Lambda_c^+ \mu^- \overline{\nu})}{B(\Lambda_b \to \Lambda_c^+ \pi^-)} = \frac{N_{\Lambda_b \to \Lambda_c \mu \overline{\nu}} \times \varepsilon_{\Lambda_b \to \Lambda_c \pi}}{N_{\Lambda_b \to \Lambda_c \pi} \times \varepsilon_{\Lambda_b \to \Lambda_c \mu \overline{\nu}}}$$



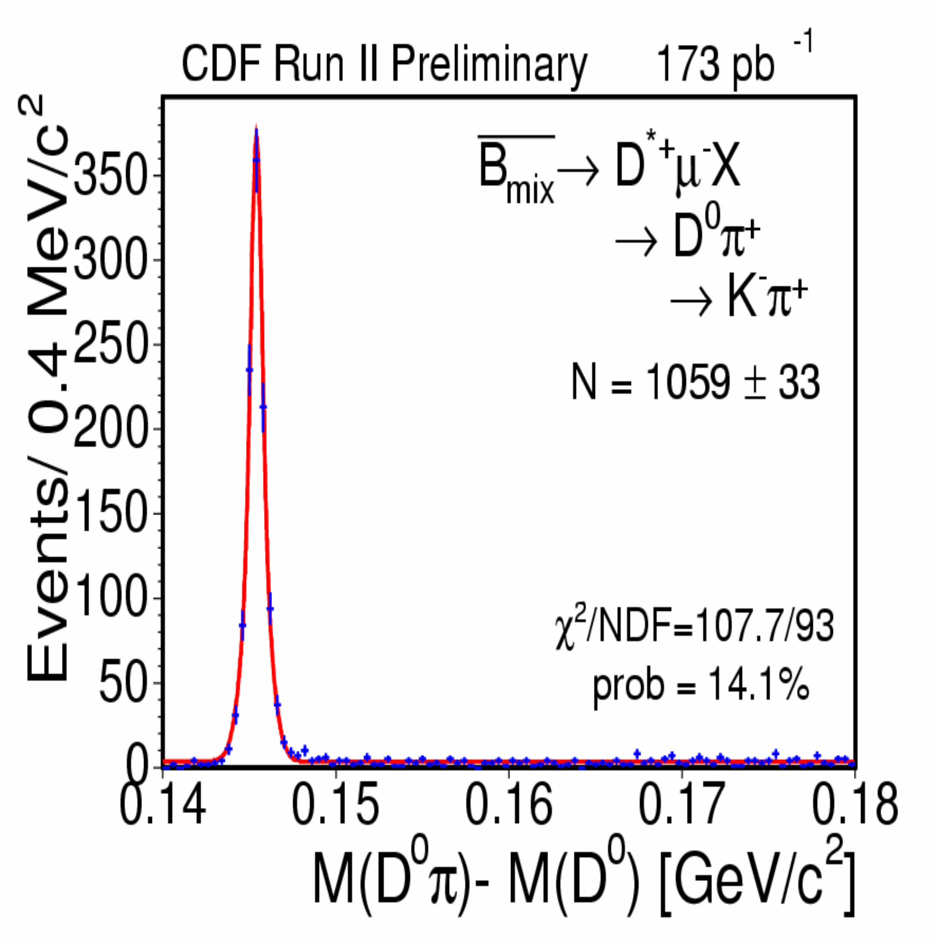
$\Lambda_b \to \Lambda_c^+ \pi^-$
$\to pK^-\pi^+$

But since we can not reconstruct neutrinos, several backgrounds can fake our semileptonic signals in the data ….

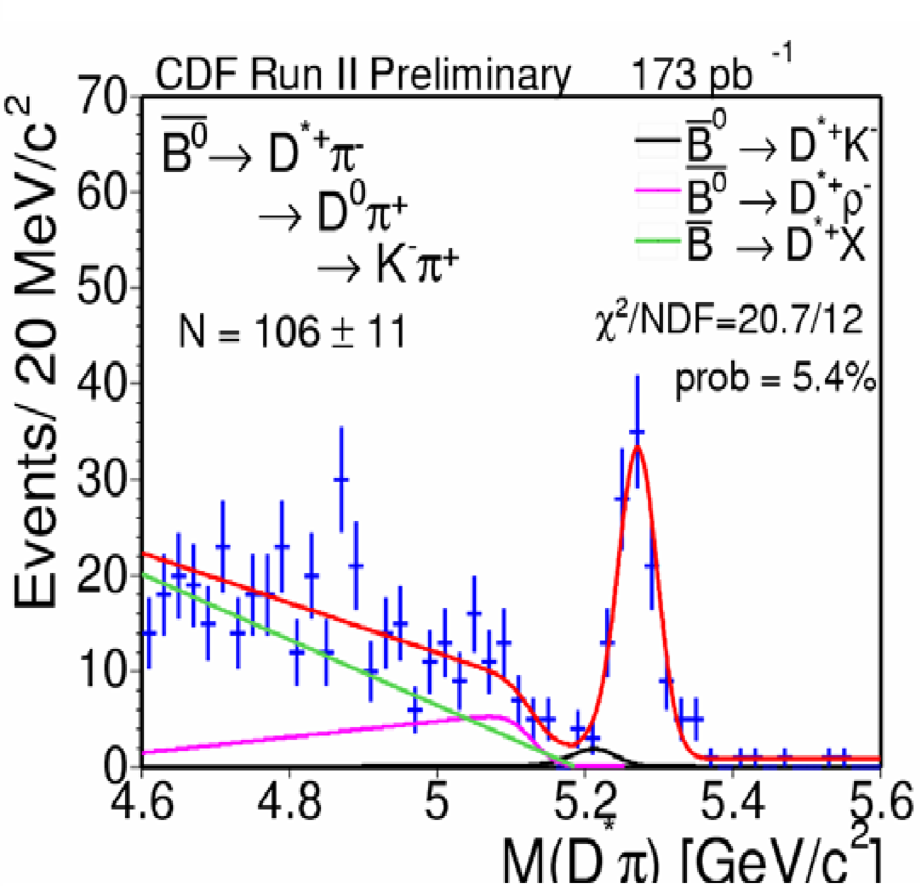
$$\frac{B(\Lambda_b \to \Lambda_c^+ \mu^- \overline{\nu})}{B(\Lambda_b \to \Lambda_c^+ \pi^-)} = \frac{(N_{B_{\text{mix}} \to \Lambda_c \mu X} - N_{\text{bg}}) \times \varepsilon_{\Lambda_b \to \Lambda_c \pi}}{N_{\Lambda_b \to \Lambda_c \pi} \times \varepsilon_{\Lambda_b \to \Lambda_c \mu \overline{\nu}}}$$

Control Sample $B^0 \to D^*X$, $D^{*+} \to D^0 \pi^+$, $D^0 \to K^-\pi^+$

Inclusive Semileptonic Signal



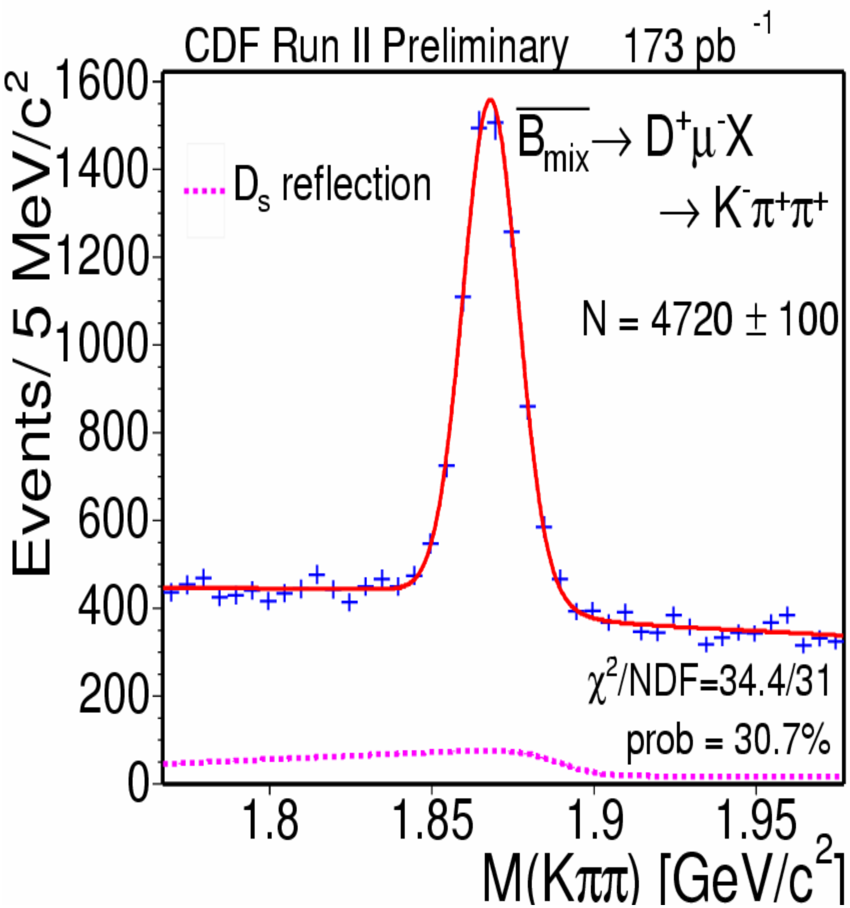
Hadronic Signal

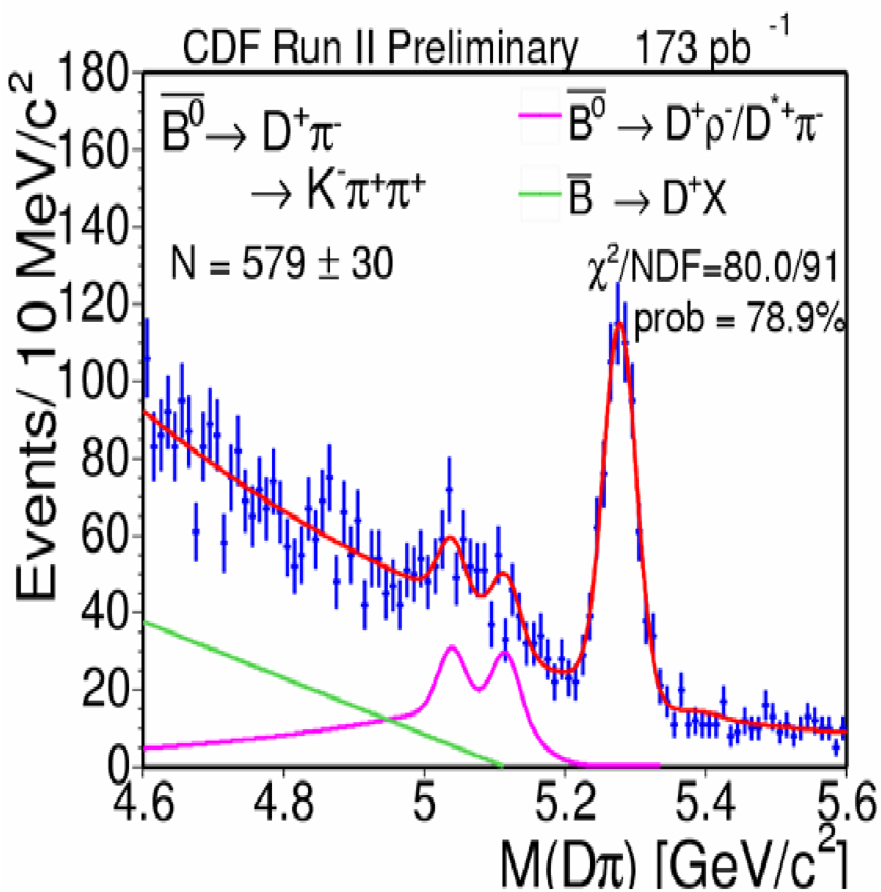


Control Sample $B^0 \rightarrow DX$, $D^+ \rightarrow K^-\pi^+\pi^+$

Inclusive Semileptonic Signal

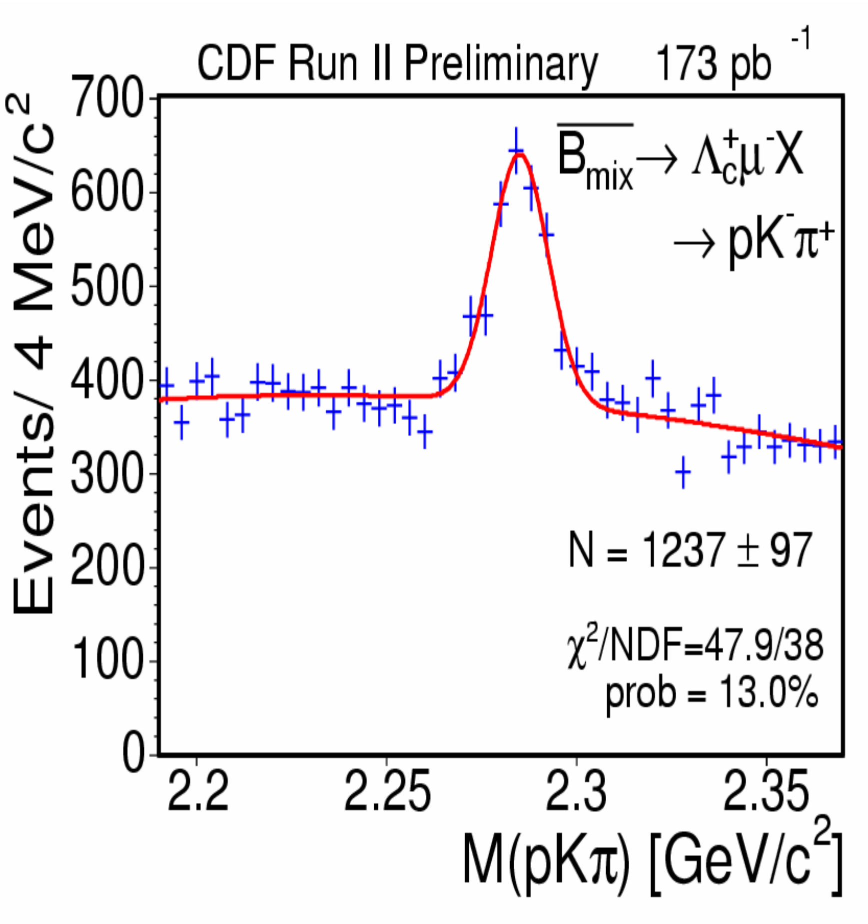
Hadronic Signal



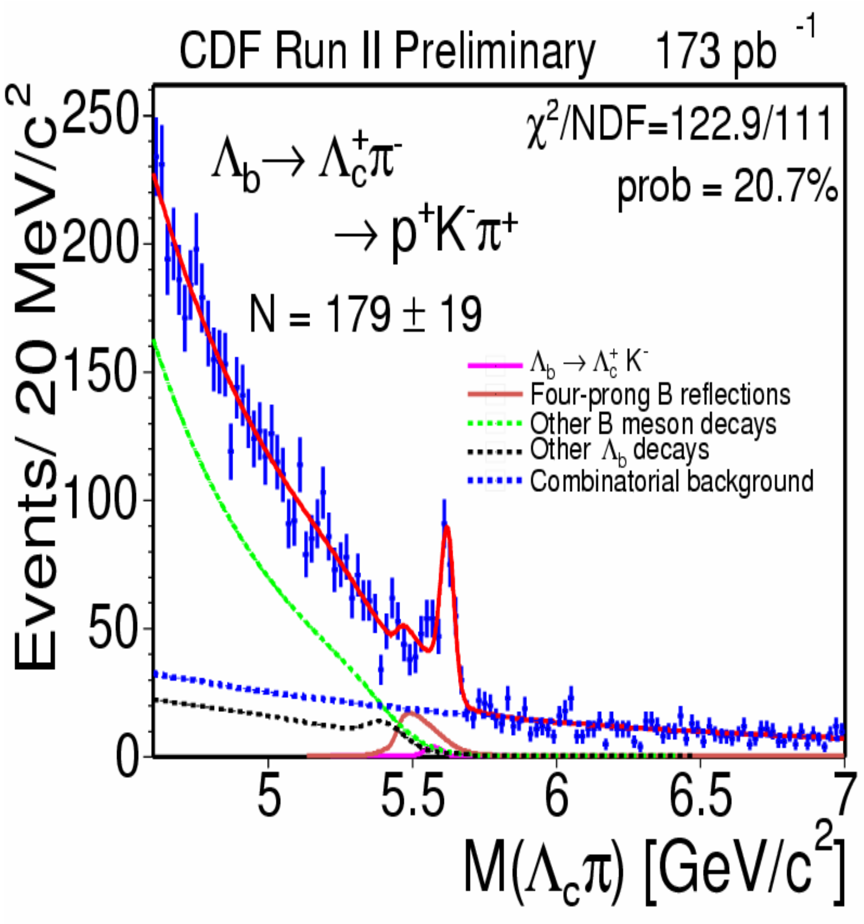


Signal Sample $\Lambda_b \to \Lambda_c X$ $\Lambda_c \to p^+ K^- \pi^+$

Inclusive Semileptonic Signal

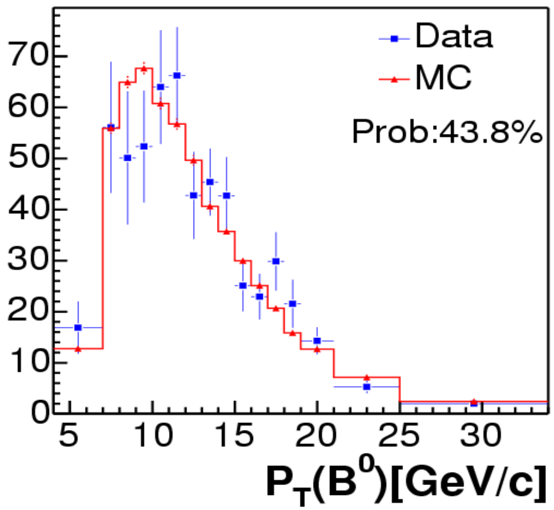


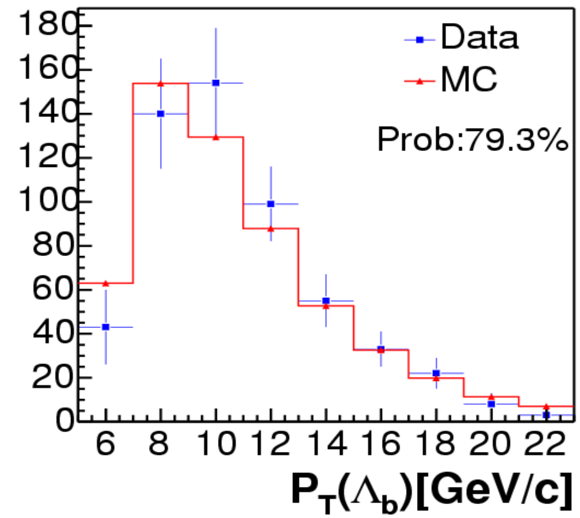
Hadronic Signal

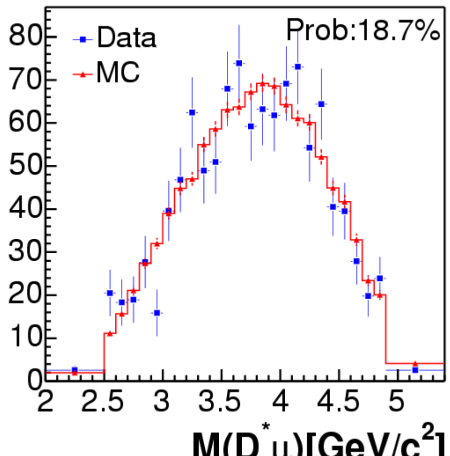


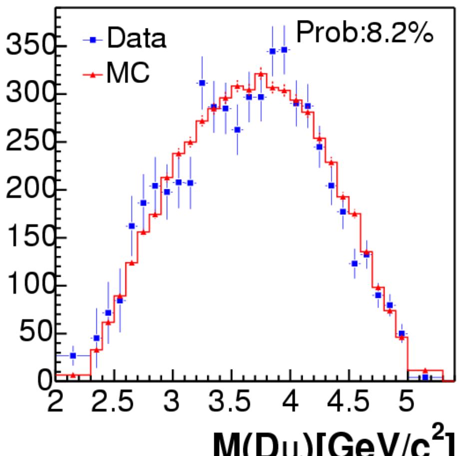
MC and Data Comparison

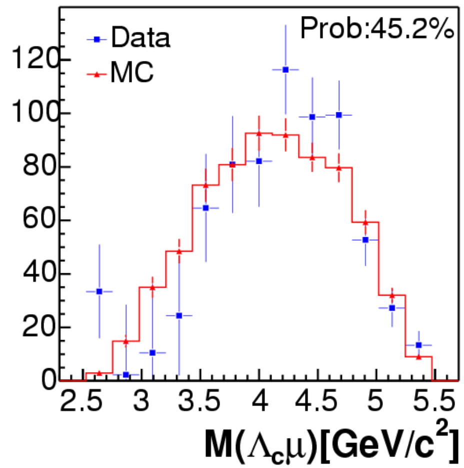
- We used MC to obtain relative efficiencies of signals and backgrounds.
- Compare MC and background subtracted signal distribution in the data.
- Tune our MC if MC and data disagree, e.g: pT of b-hadron, $M(\Lambda_c\mu)$











Where Are the Semileptonic Backgrounds From?

- Background signature: a (charm, muon) in the final state and passes our selection cuts
  - Physics Background
  - Muon Fakes
  - QCD $b\overline{b}, c\overline{c}$

Physics Background

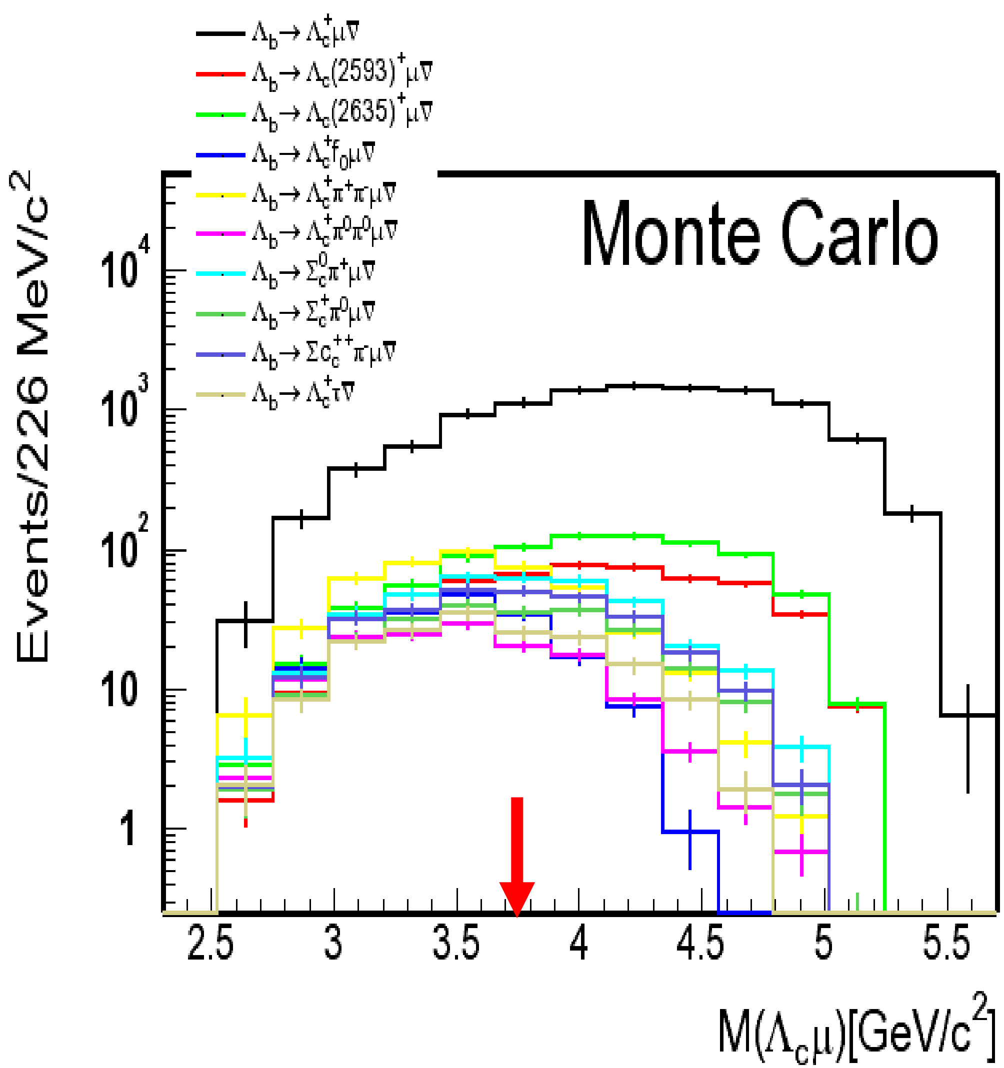
- Physics Background
  - b-hadron decays into a charm, a μ and additional particles, e.g:

$$\Lambda_b \rightarrow \Lambda_c^+(2593)\mu\bar{\nu}$$
$$\rightarrow \Lambda_c^+\pi^+\pi^-$$

  - Reduced by the $M(\Lambda_c\mu)$ cut
  - Normalize the amount to the measured hadronic signal

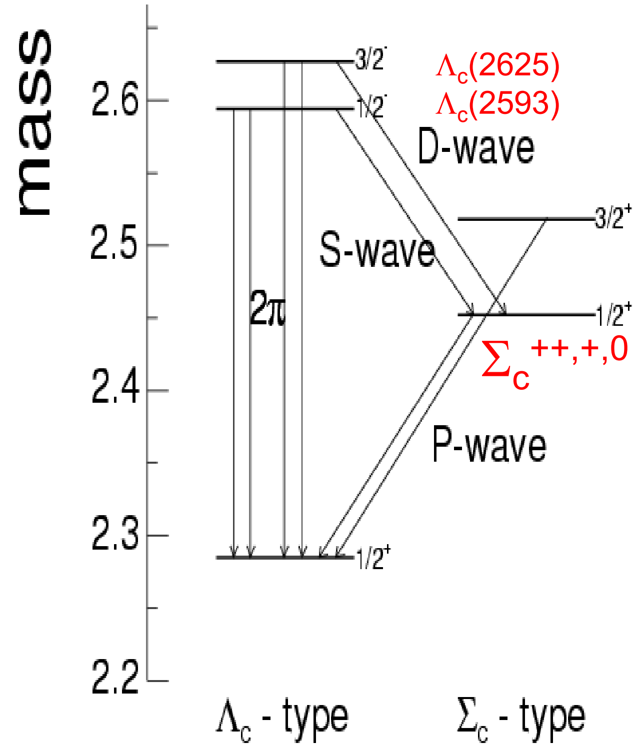
$$\frac{N_{\text{physics}}}{N_{\text{hadronic}}} = \frac{\sum_i B_{\text{physics}} \times \varepsilon_{\text{physics}}}{B_{\text{hadronic}} \times \varepsilon_{\text{hadronic}}}$$

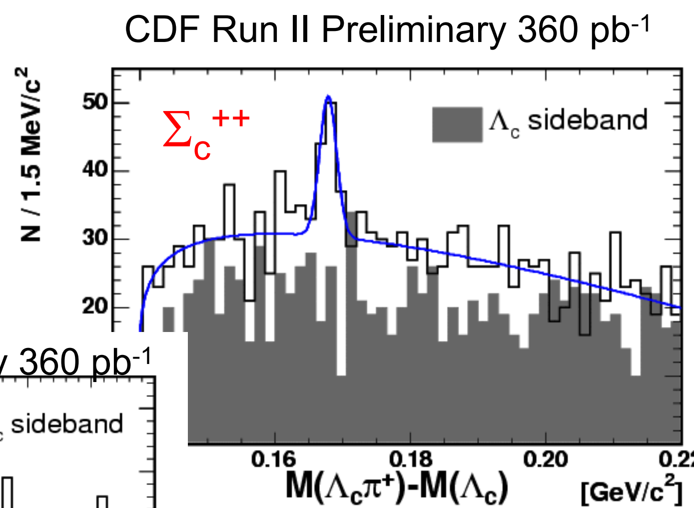
    - BRs come from PDG, theoretical estimate and preliminary measurements
  - 10~40% contribution

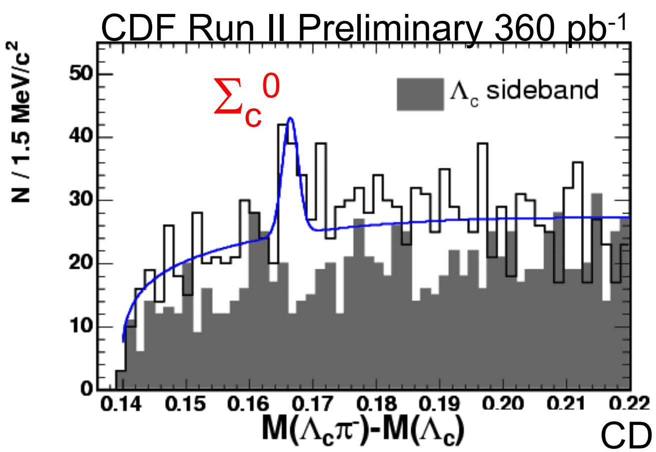


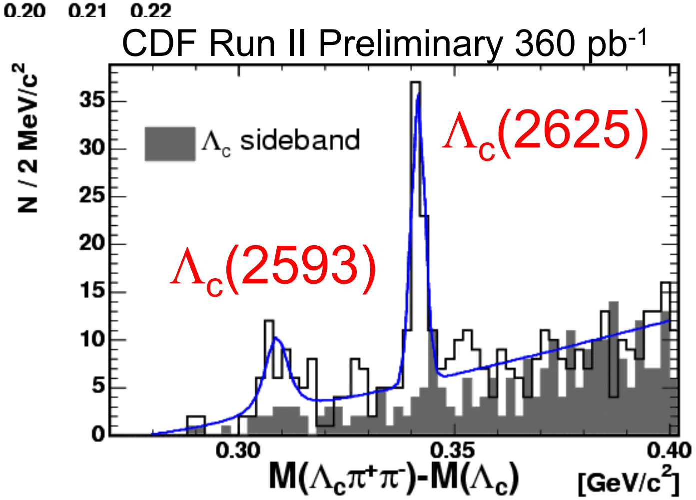
First Observation of $\Lambda_b \rightarrow \Lambda_c^* \mu\nu$, $\Lambda_b \rightarrow \Sigma_c \pi \mu\nu$

- First observation of several Λ_b semileptonic decays that can fake the signal $\Lambda_b \rightarrow \Lambda_c^+ \mu \bar{\nu}$
  - Estimate the BR based on the observation









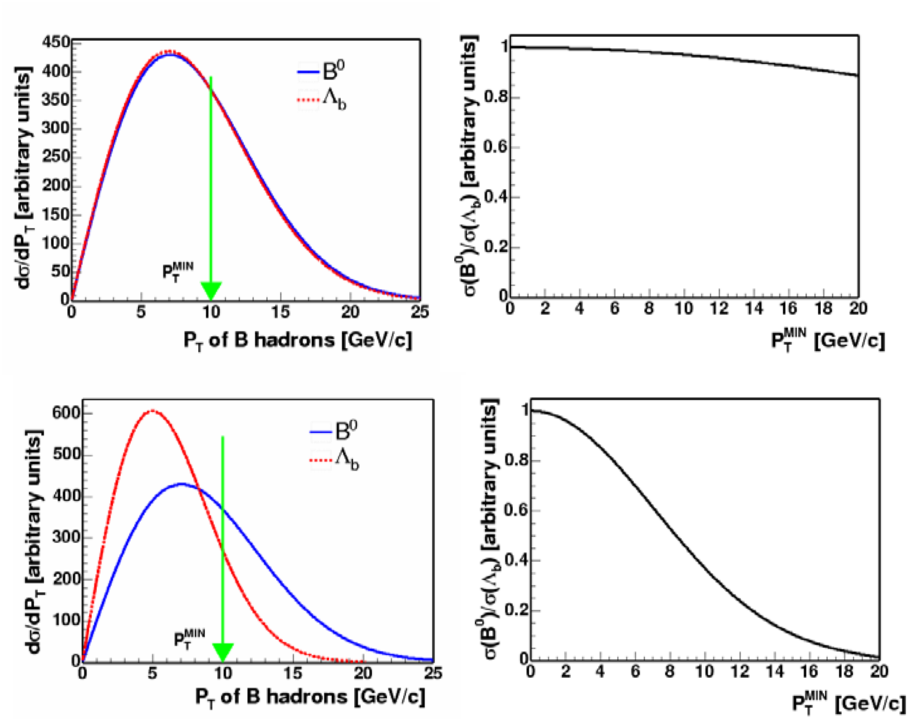
How to Obtain $B(\Lambda_b \to \Lambda_c \pi)$?

- Make use of previous CDF measurements

$$\frac{\sigma_{\Lambda_b}(P_T > 6\,GeV/c)}{\sigma_{B^0}(P_T > 6\,GeV/c)} \times \frac{B(\Lambda_b \to \Lambda_c^+ \pi^-)}{B(\bar{B}^0 \to D^- \pi^-)} = 0.82 \pm 0.08(\text{stat}) \pm 0.11(syst) \pm 0.22\ (\Lambda_c\ \text{BR})$$

$$\textbf{CDF Run I}\ \frac{f_{\text{baryon}}}{f_d} = 0.236 \pm 0.084$$

- However, a Λ_b MC P_T spectrum using fully reconstructed decay was not available for CDF I
  - Correct the CDF I f_{baryon}/f_d using measured P_T spectrum
    - Acceptance correction
    - Different P_T thresholds affect the ratio: 10 GeV/c vs. 6 GeV/c



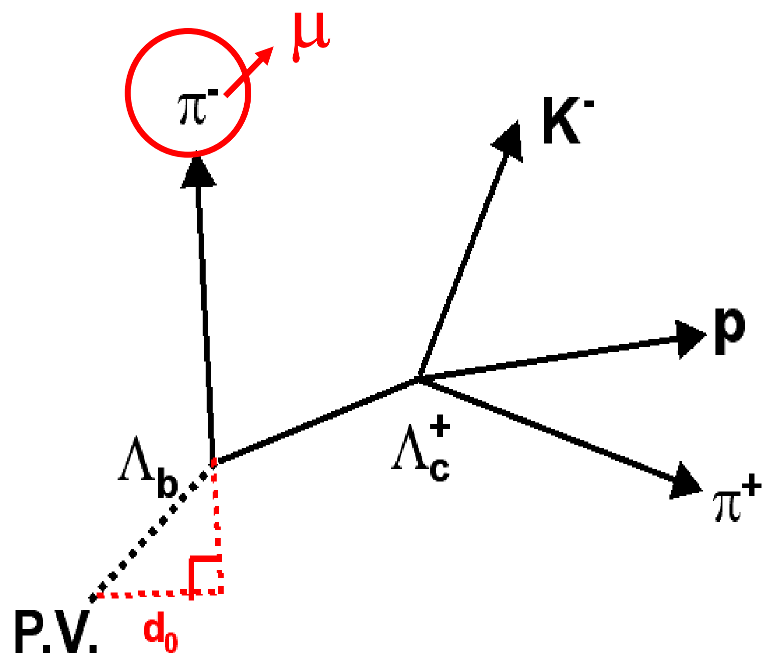
$$\frac{\sigma_{\Lambda_b}(P_T > 6\,\text{GeV}/c)}{\sigma_{B^0}(P_T > 6\,\text{GeV}/c)} = 0.63 \pm 0.23(\text{stat}+syst)\,{}^{+0.24}_{-0.14}\,(pT)$$

$$B(\Lambda_b \to \Lambda_c^+ \pi^-) = \left(0.41 \pm 0.19(\text{stat}+syst)\,{}^{+0.06}_{-0.08}\,(pT)\right)\%$$

*Consistent with the prediction 0.45% (**Phys. Lett. B586, 337**)*

Muon Fakes

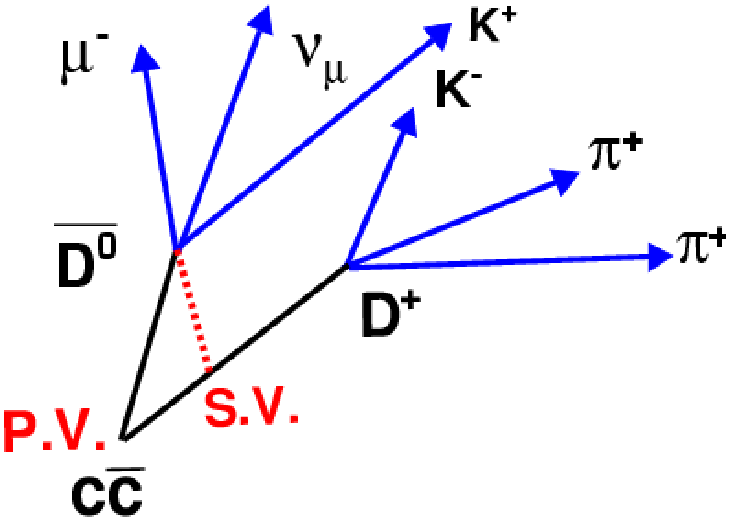
- Muon fakes
  - p, K, π fake muons
  - $c\tau$ and muon d_0 cuts suppress fakes from the primary vertex
  - Our fakes mostly come from b decays.
  - Weight "charm+$TRK_{fail\mu}$" events with muon fake prob.
  - Fit the weighted mass
  - ~5% contribution

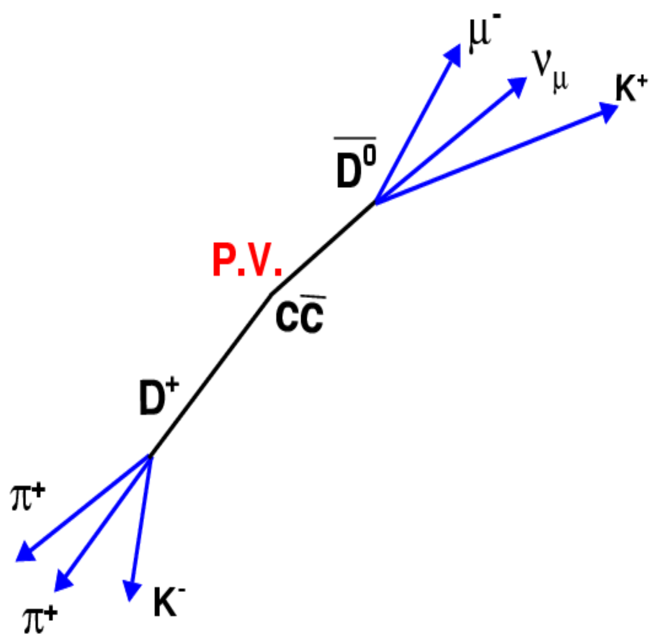


$$\Lambda_b \to \Lambda_c^+ \pi^-$$
$$\to pK^-\pi^+$$

QCD Pair Production

- QCD: $b\bar{b}, c\bar{c}$
  - charm and μ come from different b- or charmed hadrons
  - b, c quarks are pair produced and fragmented into two hadrons
  - Suppressed due to the $c\tau$ and $P_T(\mu)$ cuts
  - Rely on Pythia MC
  - Most sensitive to gluon splitting
  - Compare data and MC single hadron production -> 10~40% difference
  - 1~2% contribution





Semileptonic Background Summary

	$N_{bg}/N_{inclusive}$ (%)		
	$\Lambda_c\ \mu$	$D\ \mu$	$D^*\ \mu$
Physics	9.8	40.0	15.0
Fakes	3.2	4.9	4.3
$b\bar{b}, c\bar{c}$	0.2	1.2	0.9
Total	13.2	46.1	20.2

Relative BR with Statistical Uncertainty

$$\frac{B(\overline{B}^0 \to D^+ \mu^- \overline{\nu})}{B(\overline{B}^0 \to D^+ \pi^-)} = 9.8 \pm 1.0\,(\text{stat})$$

$$\frac{B(\overline{B}^0 \to D^{*+} \mu^- \overline{\nu})}{B(\overline{B}^0 \to D^{*+} \pi^-)} = 17.7 \pm 2.3\,(\text{stat})$$

$$\frac{B(\Lambda_b \to \Lambda_c^+ \mu^- \overline{\nu})}{B(\Lambda_b \to \Lambda_c^+ \pi^-)} = 20.0 \pm 3.0\,(\text{stat})$$

Systematics

- Physics background and hadronic signal branching fractions
  - Measured: from PDG
  - Estimated or Unmeasured
    - 5% for charm decays
    - 100% for b-hadron decays
- Mass fitting model
  - Vary the constant parameters in the fit
  - Several background shapes come from inclusive MC
    - vary BR of the dominant decays
- Muon fake estimate
  - Data sample size for the measurement of muon fake probability
  - Uncertainty of the proton, kaon, pion fractions in the hadron tracks
- MC modeling of acceptance and efficiency
  - pT spectrum
  - muon reconstruction efficiency scaling
  - QCD process
  - detector material
  - Λ_c Dalitz structure, Λ_b lifetime, Λ_c and Λ_b polarizations
  - Λ_b semileptonic decay model

Uncertainty Summary

	fractional uncertainty (%)		
	$\frac{B(\Lambda_b \to \Lambda_c^+ \mu^- \bar{\nu})}{B(\Lambda_b \to \Lambda_c^+ \pi^-)}$	$\frac{B(\bar{B}^0 \to D^+ \mu^- \bar{\nu})}{B(\bar{B}^0 \to D^+ \pi^-)}$	$\frac{B(\bar{B}^0 \to D^{*+} \mu^- \bar{\nu})}{B(\bar{B}^0 \to D^{*+} \pi^-)}$
Measured BR	**+3.5 -10.5**	**± 8.2**	**± 2.3**
Estimated BR	**± 2.5**	**± 9.2**	**± 6.2**
CDF Internal			
Mass fitting	± 3.2	± 4.1	< ± 0.1
Pt spectrum	+1.4-2.5	± 3.2	± 2.2
Detector material	± 1.1	± 1.7	± 1.3
Muon fake	± 0.9	± 0.7	± 0.4
ε scaling	± 0.4	± 0.5	± 0.4
$b\bar{b}, c\bar{c}$	± 0.2	± 2.2	± 1.3
Λ_c Λ_b polarizations	± 1.9	--	--
Λ_c Dalitz	± 0.4	--	--
Λ_b lifetime	± 1.1	--	--
Λ_b decay model	± 2.9	--	--
	± 6.0	**± 6.1**	**± 3.4**
Statistical	**± 15.0**	**± 10.2**	**± 13.0**

Control Sample Result

$$\frac{B(\overline{B}^0 \rightarrow D^+ \mu^- \overline{\nu})}{B(\overline{B}^0 \rightarrow D^+ \pi^-)} = 9.8 \pm 1.0\,(\text{stat}) \pm 0.6\,(\text{syst}) \pm 0.8\,(\text{BR}) \pm 0.9\,(\text{UBR})$$

Consistent with the 2004 world average 7.8 ± 1.0 at the 1σ level

New world average ratio 8.3 ± 0.9

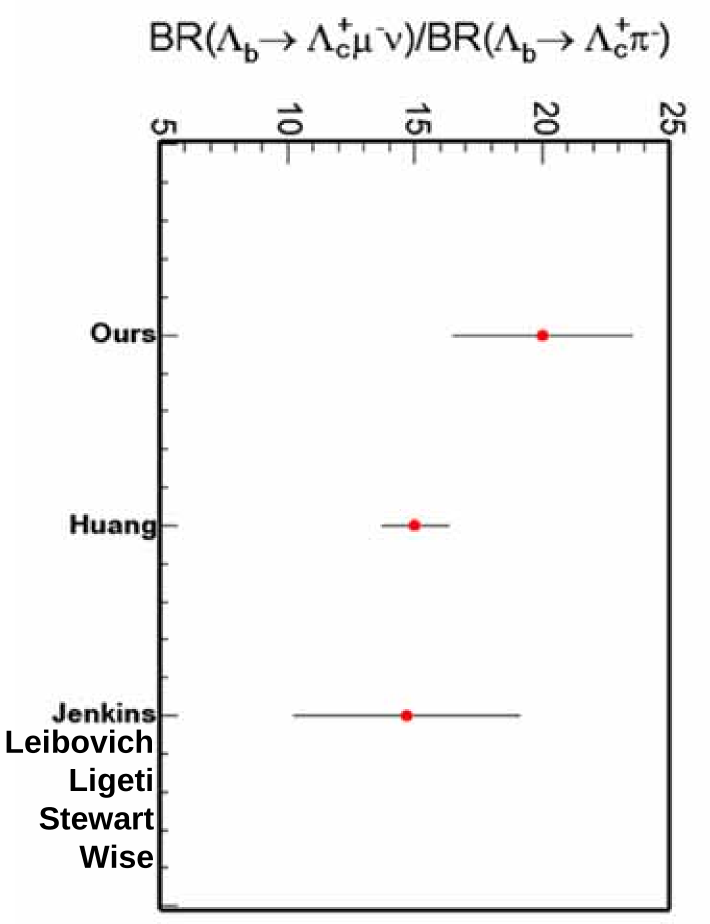
$$\frac{B(\overline{B}^0 \rightarrow D^{*+} \mu^- \overline{\nu})}{B(\overline{B}^0 \rightarrow D^{*+} \pi^-)} = 17.7 \pm 2.3\,(\text{stat}) \pm 0.6\,(\text{syst}) \pm 0.4\,(\text{BR}) \pm 1.1\,(\text{UBR})$$

Consistent with the 2004 world average 19.7 ± 1.7 at the 0.7σ level

New world average ratio 19.1 ± 1.4

Signal Sample Result

$$\frac{B(\Lambda_b \to \Lambda_c^+ \mu^- \overline{\nu})}{B(\Lambda_b \to \Lambda_c^+ \pi^-)} = 20.0 \pm 3.0\,(\text{stat}) \pm 1.2(syst)\,{}^{+0.7}_{-2.1}\,(\text{BR}) \pm 0.5\,(\text{UBR})$$



- Experimental Uncertainties dominated by:
  - Data sample size
  - Measured BR $B(\Lambda_b \to \Lambda_c \pi)$
    - Reminder: physics backgrounds are normalized to hadronic signal
    - Dominated by the uncertainties on the production cross-section and $B(\Lambda_c\text{->}pK\pi)$

$B(\Lambda_b \to \Lambda_c \mu\upsilon)$?

Combined the ratio of BR and $B(\Lambda_b \to \Lambda_c \pi)$, we have

$$B(\Lambda_b \to \Lambda_c^+ \mu^- \bar{\nu}) = \left(8.1 \pm 1.2\,(\mathrm{stat})\,{}^{+1.1}_{-1.6}\,(syst) \pm 4.3\ (B(\Lambda_b \to \Lambda_c^+ \pi^-)) \right)\%$$

Consistent with DELPHI result (Phys. Lett. B585, 63)

$$B(\Lambda_b \to \Lambda_c^+ \mu^- \bar{\nu})^{\mathrm{DELPHI}} = \left(5.0\,{}^{+1.1}_{-0.9}\,(\mathrm{stat})\,{}^{+1.6}_{-1.2}\,(syst) \right)\%$$

Weighted average

$$B(\Lambda_b \to \Lambda_c^+ \mu^- \bar{\nu})^{\mathrm{WORLD}} = \left(5.5 \pm 1.8 (stat + syst) \right)\%$$

Also in agreement with the theoretical prediction 6.6% ***(Phys. Lett. B586, 337)***

- $|V_{cb}|$ Exercise
  - Plug in the weighted average and the theoretical slope parameter of the ISGW function into the formula for $B\ (\Lambda_b \to \Lambda_c \mu\upsilon)$

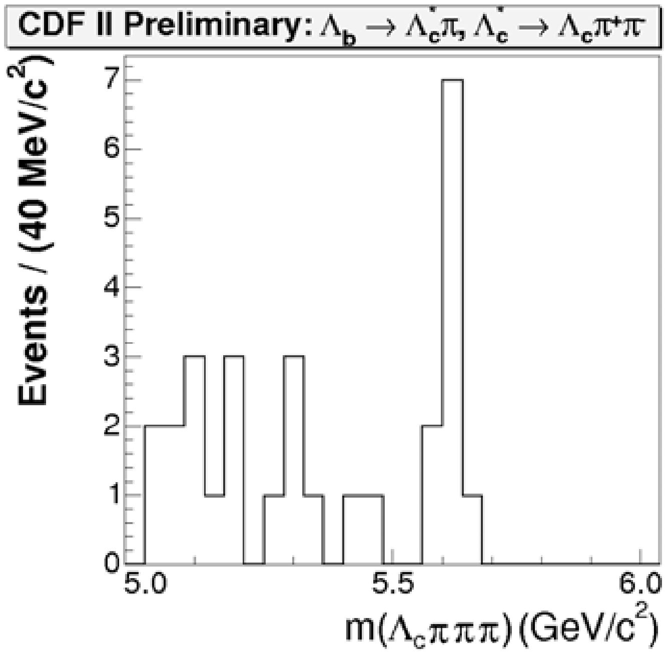
$$\Lambda_b \quad |V_{cb}| = 0.038 \pm 0.006\,(\exp) \pm (0.002 \sim 0.006)\,(\mathrm{theory})$$

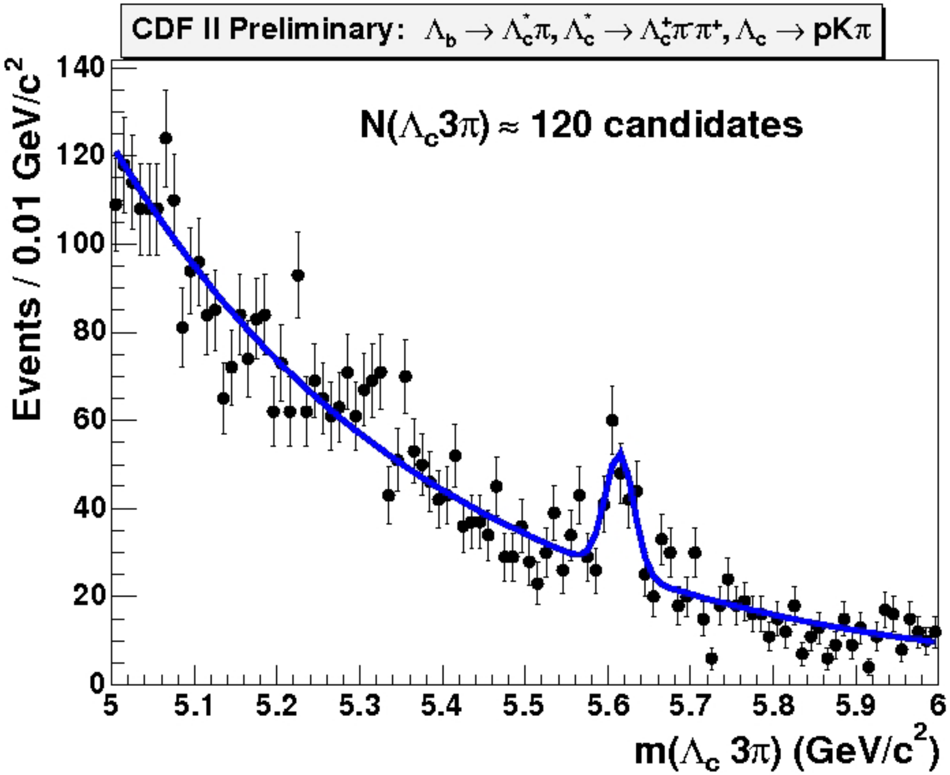
Consistent with the $|V_{cb}|$ from DELPHI measured with B->D*lυ decays ***(Eur. Phys. J C33, 213)***

$$B\ \mathrm{meson} \quad |V_{cb}| = 0.0414 \pm 0.0024\,(\exp) \pm (0.0018)\,(\mathrm{theory})$$

First Observation of $\Lambda_b \to \Lambda_c \pi \pi \pi$

- Data come from two displaced track trigger
- $\Lambda_c \pi \pi$ Dalitz structure study in progress





Conclusions

Previous Λ_b Results

- First time Λ_b lifetime is measured in a fully reconstructed decay
- Best single mass measurement
- Improved upper limit of $B(\Lambda_b \to ph)$ by more than a factor of 2
- First unambiguous signal of $\Lambda_b \to \Lambda_c\pi$
- First measurement of $$\frac{\sigma_{\Lambda_b}(P_T > 6\,GeV/c)}{\sigma_{B^0}(P_T > 6\,GeV/c)} \times \frac{B(\Lambda_b \to \Lambda_c^+\pi^-)}{B(\bar{B}^0 \to D^-\pi^-)}$$

New Results

- First measurement of $$\frac{B(\Lambda_b \to \Lambda_c^+\mu^-\bar{\nu})}{B(\Lambda_b \to \Lambda_c^+\pi^-)}$$
- Both ratio and absolute BRs are in agreement with the prediction
- First observation of $\Lambda_b \to \Lambda_c\pi\pi\pi$, $\Lambda_b \to \Lambda_c^{*}\mu\nu$, $\Lambda_b \to \Sigma_c\pi\mu\nu$

What Do We Know About Λ_b Now?

Mass m = 5619.9 ± 1.7 MeV/c^2

Mean life $\tau = (1.229 \pm 0.080) \times 10^{-12}$ s

$c\tau = 368\ \mu m$

Λ_b^0 DECAY MODES	Fraction (Γ_i/Γ)
$J/\psi(1S)\Lambda$	$(4.7 \pm 2.8) \times 10^{-4}$
$\Lambda_c^+ \pi^-$	$(4.1 \pm 2.0) \times 10^{-3}$
$\Lambda_c^+ a_1(1260)^-$	seen
$\Lambda_c l \upsilon$	(5.5 ± 1.8) %
pK + pπ	< 2.2×10^{-5}
$\Lambda_c^+ \pi^- \pi^- \pi^+$	seen
$\Lambda\gamma$	$< 1.3 \times 10^{-3}$
$\Lambda_c(2593)^+ / \upsilon$	seen
$\Lambda_c(2625)^+ / \upsilon$	seen
$\Sigma_c^{++} \pi^- / \upsilon$	seen
$\Sigma_c^0 \pi^+ / \upsilon$	seen

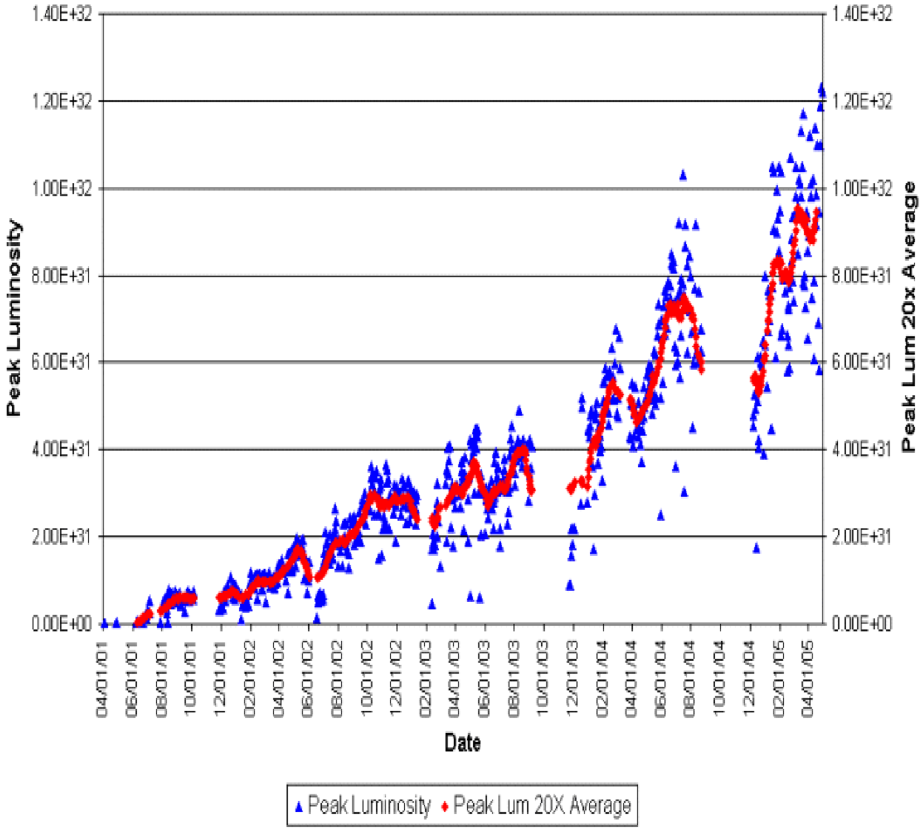
Future

- Most analyses are still statistically limited, more data in the future will improve the result
  - $\Lambda_b \rightarrow J/\psi\ \Lambda$ lifetime analysis with 5x data expected
- TOF+dE/dx combined PID will be used in the search for $\Lambda_b \rightarrow ph$
- f_{baryon}/f_d using the lepton+displaced track trigger data anticipated
- Lifetime and branching fraction measurement from $\Lambda_b \rightarrow \Lambda_c \pi \pi \pi$
- $\Lambda_b \rightarrow \Lambda_c \mu\nu$ form factor
- Λ_b polarizations

Back Up Slides

Collider Run II Peak Luminosity

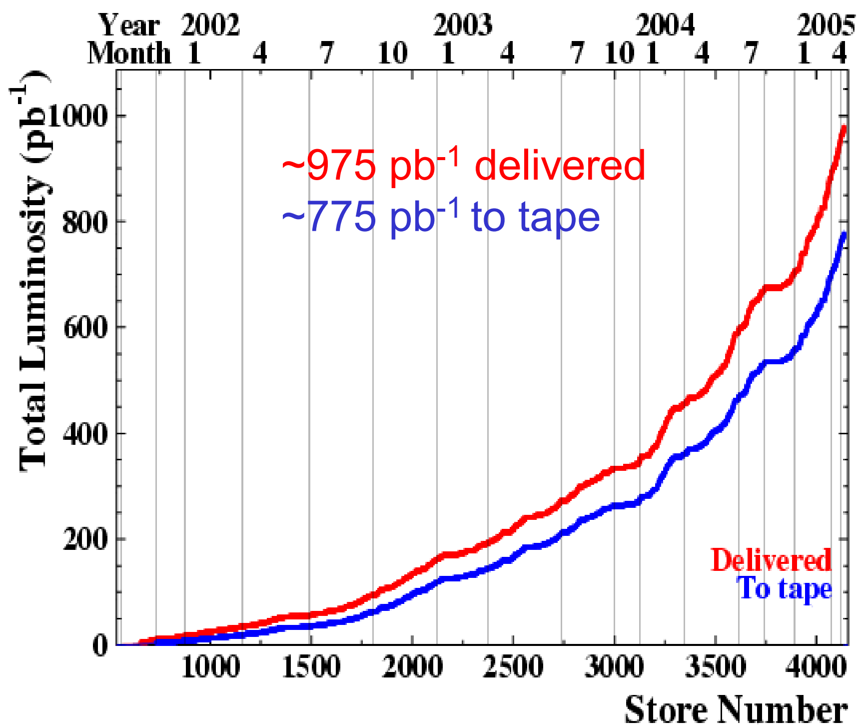
Year 2001 2002 2003 2004 2005
Month 4 7 10 1 4 7 10 1 4 7 10 1 4 7 10 1 4



- Record peak luminosity

  $1.27 \times 10^{32}\ sec^{-1}\ cm^{-2}$

  May 12, 2005

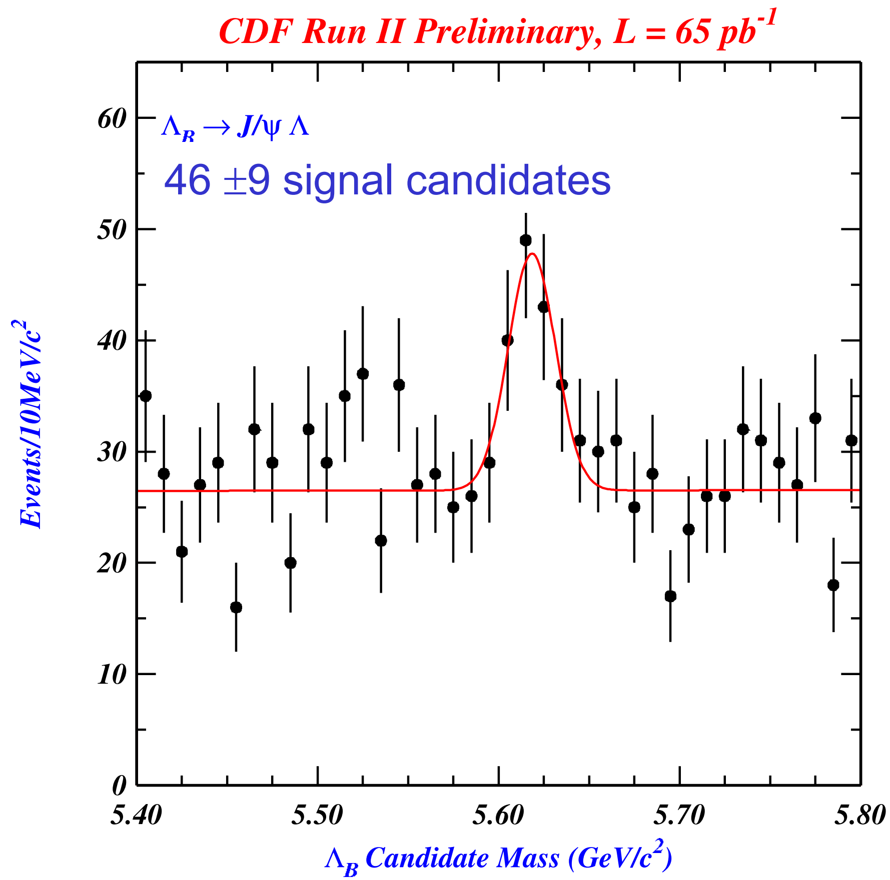


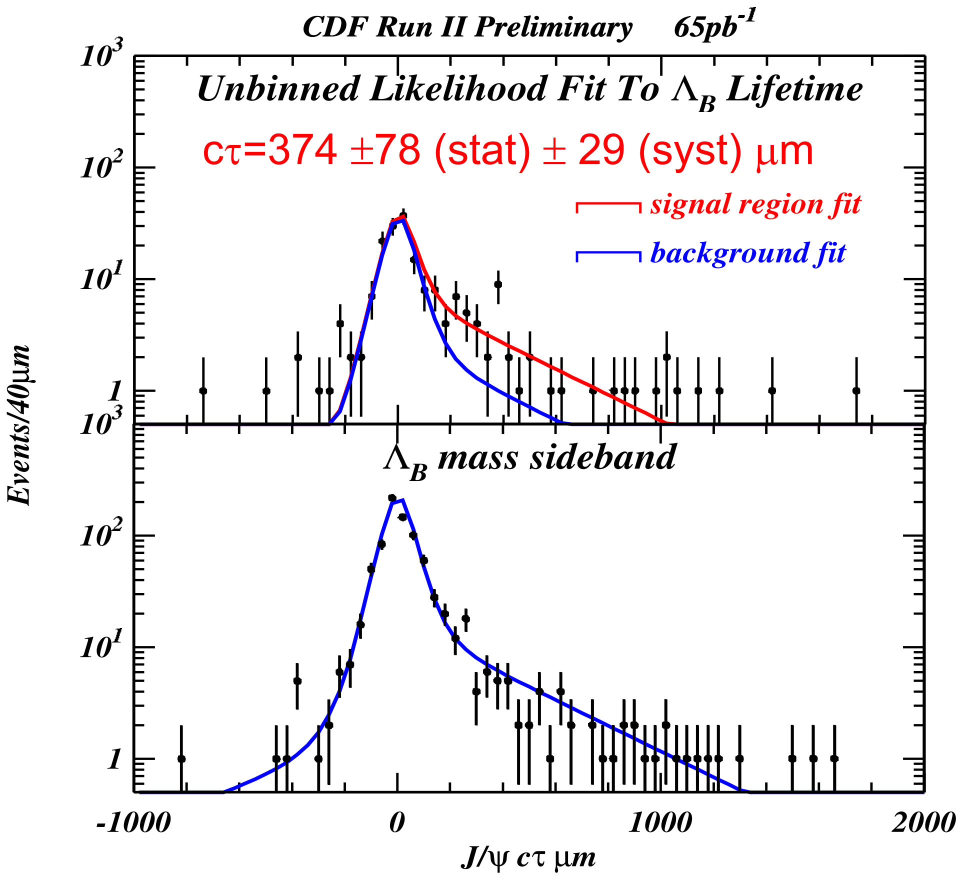
- ~775 pb^{-1} on tape (Run I ≈ 100 pb^{-1})
- ~400 M events from the displaced track trigger

Lifetime $\Lambda_b \to J/\psi\ \Lambda$ $J/\psi \to \mu^+ \mu^-$, $\Lambda \to p^+ \pi^-$

- First measurement of $\tau(\Lambda_b)$ in a fully reconstructed mode dimuon trigger data

CDF Run $\Lambda_b \to \Lambda_c l\nu$ ($\Lambda_c \to pK\pi$) τ = 1.33 ± 0.15 ± 0.07 ps





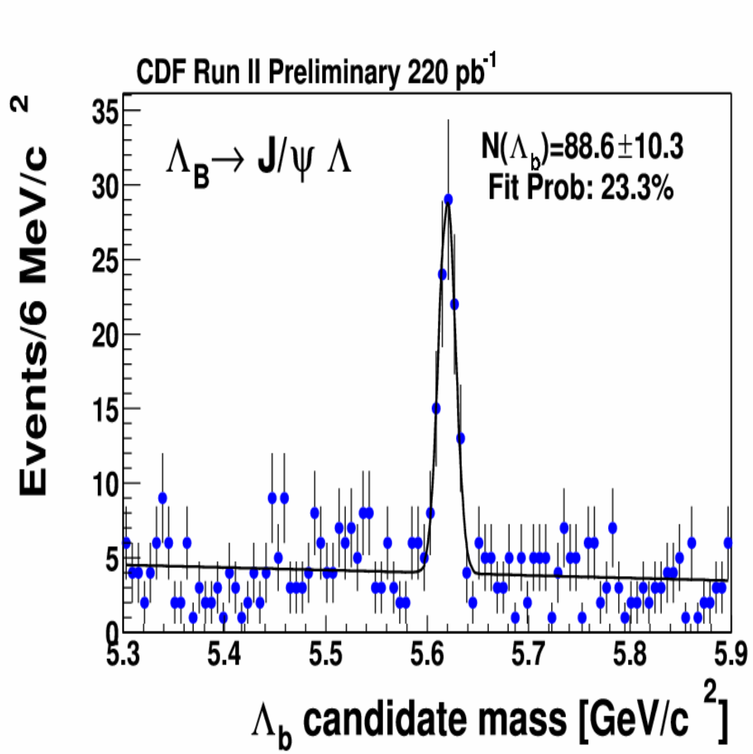
CDF II $\tau(\Lambda_b)$ = 1.25 ± 0.26 (stat.) ± 0.10 (syst.) ps

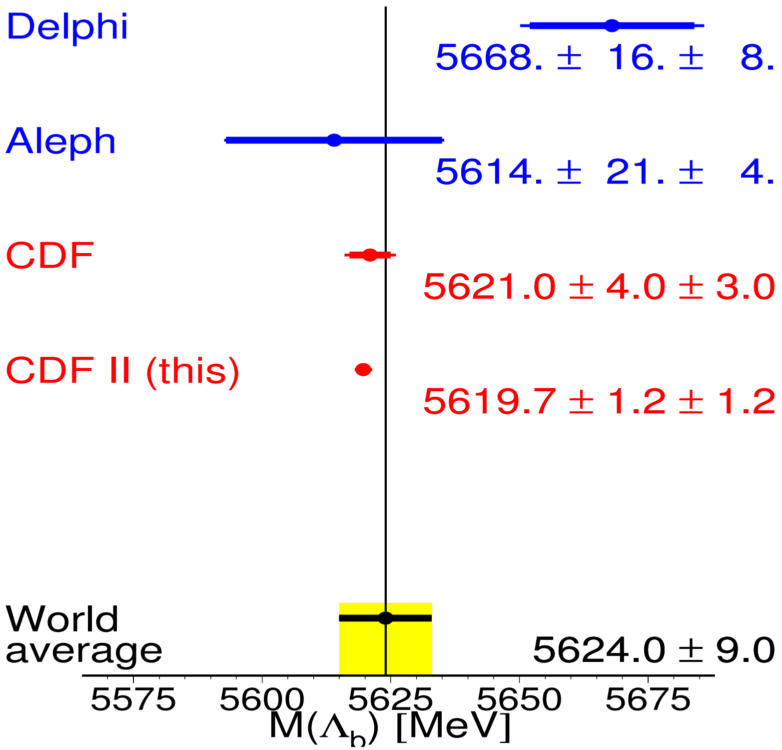
2004 World average $\tau(\Lambda_b)$ = 1.229 ± 0.080 ps

Mass $\Lambda_b \to J/\psi\ \Lambda$ $J/\psi \to \mu^+ \mu^-$, $\Lambda \to p^+ \pi^-$

- Best single mass measurement Data come rom the dimuon trigger
- Calibrate mass with the J/Ψ sample

CDF Run Λ_b **mass = 5621.0 ± 4.0 ± 3.0 MeV/c²**





CDF II $M(\Lambda_b)$ **= 5619.7 ± 1.2 (stat.) ± 1.2 (syst.) MeV/c²**

2004 World average $M(\Lambda_b)$ = 5624.0 ± 9.0 MeV/c²

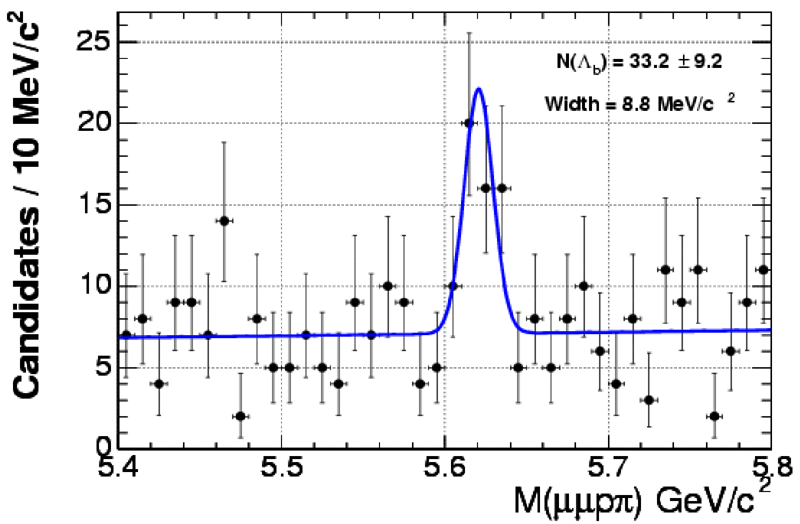
Branching Fraction $\Lambda_b \to J/\psi\ \Lambda$ $J/\psi \to \mu^+ \mu^-$, $\Lambda \to p^+ \pi^-$

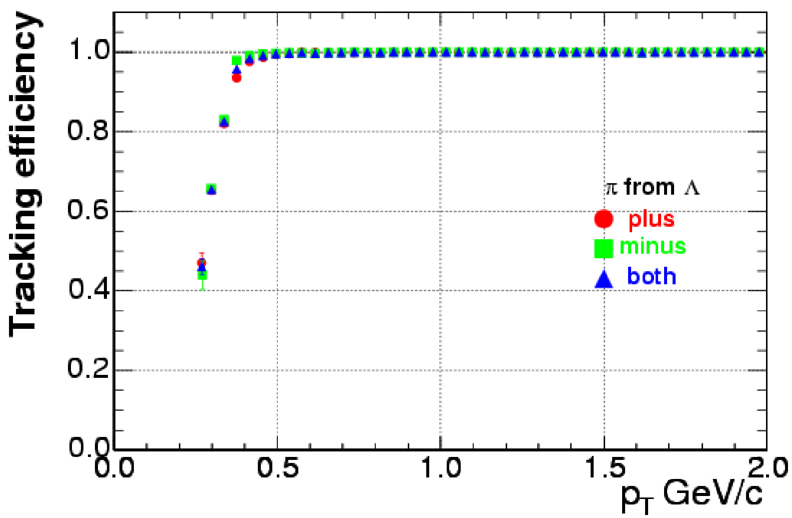
- Data come from the dimuon trigger

CDF Run

$$\frac{\sigma_{\Lambda_b}}{\sigma_{B^0}} \times \frac{B(\Lambda_b \to J/\psi\ \Lambda)}{B(\overline{B}^0 \to J/\psi\ K_s^0)} = 0.27 \pm 0.12(stat) \pm 0.05(syst)$$

- Pion from the Λ is soft, can not rely on the MC to get the tracking efficiency for pT < 0.5 GeV/c.
  - studied by embedding simulated signal hits in the J/ψ data.

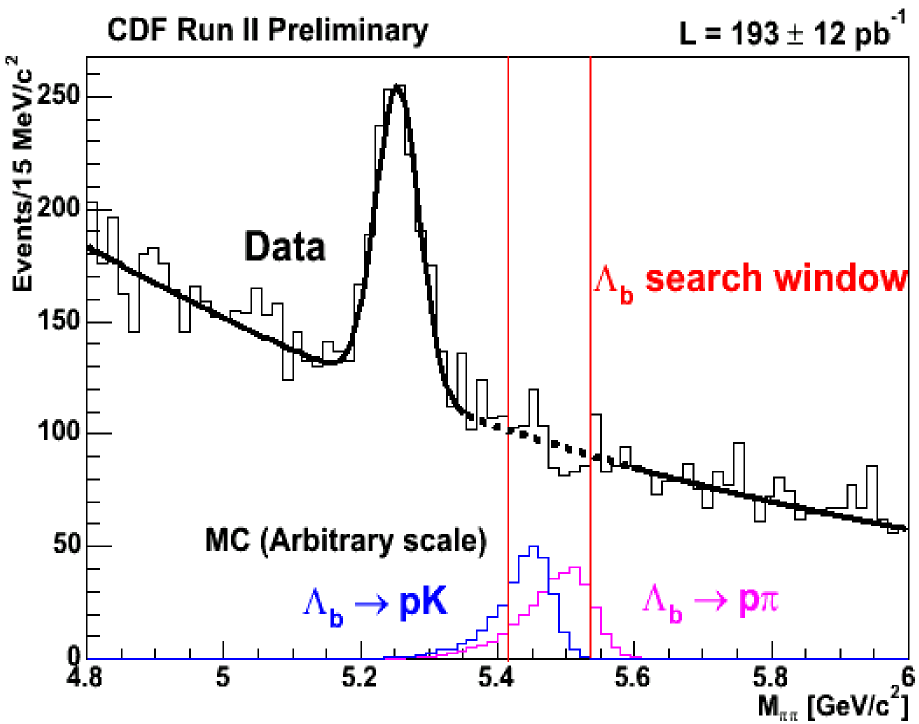




$$\frac{\sigma_{\Lambda_b}}{\sigma_{B^0}} \times \frac{B(\Lambda_b \to J/\psi\ \Lambda)}{B(\overline{B}^0 \to J/\psi\ K_s^0)} = 0.43 \pm 0.12\,(\mathrm{stat}) \pm 0.08\,(syst)$$

Search for $\Lambda_b \rightarrow pK, p\pi$

- Data come from two displaced track trigger
- Mohanta, Phys. Rev. D63:074001,2001 Prediction:
  - $B(\Lambda_b \rightarrow pK) = (1.4 \sim 1.9) \times 10^{-6}$
  - $B(\Lambda_b \rightarrow p\pi) = (0.8 \sim 1.2) \times 10^{-6}$
  - *compare to*
    $B(B0 \rightarrow K\pi) = (18.5 \pm 1.1) \times 10^{-6}$
- Normalized to $B(B0 \rightarrow K\pi)$
- Assigned π mass to both tracks to maximize the separation from $B \rightarrow hh$
- Large CP assymetry O(10%) expected
- Improved previous upper limit



CDF II $B(\Lambda_b \rightarrow pK + p\pi) < 22 \times 10^{-6}$ **at 90% C.L**

PDG 2004 $B(\Lambda_b \rightarrow pK) < 50 \times 10^{-6}$ **at 90% C.L**

PDG 2004 $B(\Lambda_b \rightarrow p\pi) < 50 \times 10^{-6}$ **at 90% C.L**

Control Sample Analysis Requirements

D^0

- $\chi^2_{r\phi} < 16$
- $c\tau > -70\ \mu m$
- p_T (D^*)> 5.0 GeV/c
- $|M-M_{PDG}| < 3\ \sigma$

π_B and μ_B

- $p_T > 2.0$ GeV/c
- $120\ \mu m \leq d_0 \leq 1$ mm
- $|\eta| < 0.6$, fiducial to central muon chamber

Four tracks

- $\chi^2_{r\phi} < 17$
- $c\tau > 200\ \mu m$
- $p_T > 6.0$ GeV/c

Semileptonic

- Muon matching $\chi^2_{r\phi} < 9$
- 3.0 < Four track mass < 5.3 GeV/c^2
- N = 1059 ± **33**

Hadronic

- $|D^*-D^0 - 0.1455| < 3\ \sigma$
- N = 106 ± **11**

D^+

- $\chi^2_{r\phi} < 14$
- $c\tau > -30\ \mu m$
- $p_T > 5.0$ GeV/c

π_B and μ_B

- $p_T > 2.0$ GeV/c
- $120\ \mu m \leq d_0 \leq 1$ mm
- $|\eta| < 0.6$, fiducial to central muon chamber

Four tracks

- $\chi^2_{r\phi} < 15$
- $c\tau > 200\ \mu m$
- $p_T > 6.0$ GeV/c

Semileptonic

- Muon matching $\chi^2_{r\phi} < 9$
- 3.0 < Four track mass < 5.3 GeV/c^2
- N = 4720 ± **100**

Hadronic

- $|M_D-M_{PDG}| < 3\ \sigma$
- N = 579 ± **30**

Signal Sample Analysis Requirements

Λ_c^+

- $\chi^2_{r\phi} < 14$
- $c\tau > -70\ \mu m$
- $p_T > 5.0$ GeV/c

π_B and μ_B

- $p_T > 2.0$ GeV/c
- $120\ \mu m \leq d_0 \leq 1$ mm
- $|\eta| < 0.6$, fiducial to central muon chamber

Four tracks

- $\chi^2_{r\phi} < 15$
- $c\tau > 250\ \mu m$
- $p_T > 6.0$ GeV/c

Semileptonic

- Muon matching $\chi^2_{r\phi} < 9$
- 3.7 < Four track mass < 5.64 GeV/c^2
- N = 1237 ± **97**

Hadronic

- $|M_{Lc} - M_{PDG}| < 3\ \sigma$
- N = 179 ± **19**

Consistency Check