

Λ_b and heavy States at Tevatron

by
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On behalf of
CDF and D0 collaborations



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Outline:

- Tevatron & Detectors
- Λ_b quick overview
- Physics with the Λ_b
- Λ_b at Tevatron
 - Reconstruction
 - Semileptonic decays channels
 - Full reconstructed decays channels
 - Mass measurement
 - Lifetime measurement
 - Branching Fractions
- B^{**}
- B decays to narrow D^{**}

Overview on the Λ_b

- Lightest b baryon (udb)
- First observed by AU1 collaboration in 1991 in the decay channel $\Lambda_b \rightarrow J/\psi \Lambda$.
- First lifetime measurement from LEP experiments using semileptonic decays in 1992.
- Currently produced in high statistics only at Tevatron, (non produced in B factories)

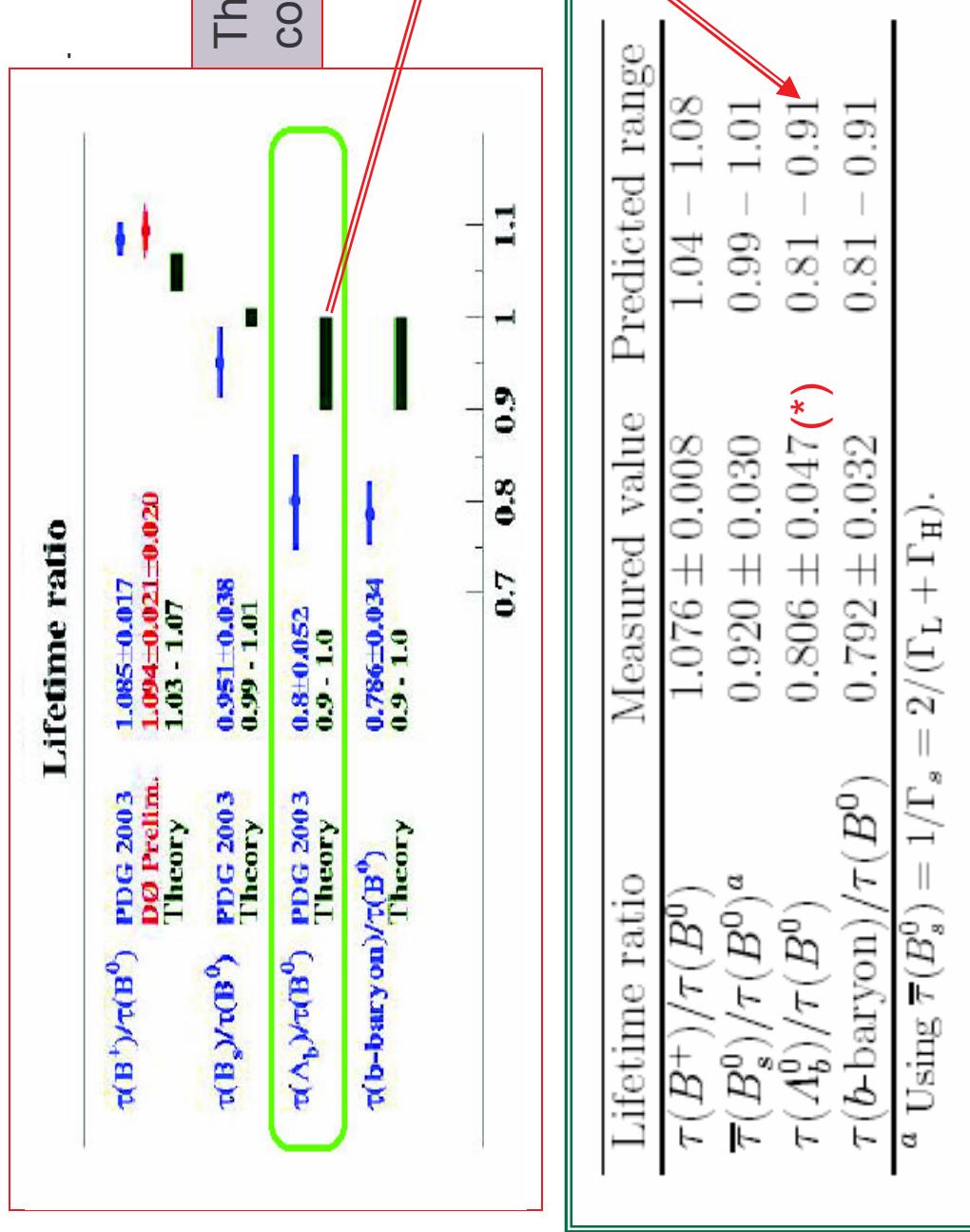
Rich physics program in the Λ_b

- Testing HQE theory in b baryons (lifetime)
- Spin role in heavy hyperons (polarization)
- CP violation
- T violation ($\Lambda_b \rightarrow \Lambda l^+ l^-$)
- New physics ($\Lambda_b \rightarrow \Lambda l^+ l^-$)

Experimental status

PDG'04	
Λ_b	Other b-baryons
<ul style="list-style-type: none">■ Mass ($\sigma_M \sim 0.16\%$)■ Lifetime ($\sigma_{ct} \sim 6.5\%$)■ Decay channels:<ul style="list-style-type: none"><input type="checkbox"/> $\Lambda_c^+ l^- \bar{\nu} X$ (BR, $\sigma_{BR} \sim 23\%$)<input type="checkbox"/> $J/\psi \Lambda$ (BR, $\sigma_{BR} \sim 60\%$)<input type="checkbox"/> $\Lambda_c^+ \pi^-$ (seen)<input type="checkbox"/> $\Lambda_c^+ a_1(1260)^-$ (seen)<input type="checkbox"/> $pK^-, p\pi^-, \Lambda\gamma$ upper limits	<ol style="list-style-type: none">1. Some indirect lifetime estimations2. Some “seen” decay channels

Example ...



This was just less of a couple of years ago.

A lot of theoretical work

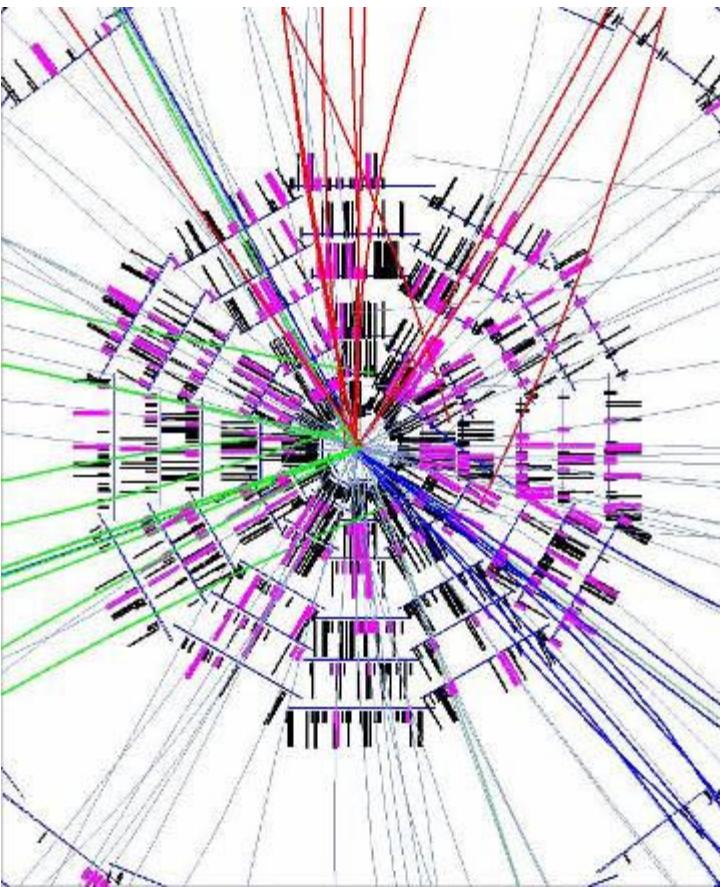
Just last month !!!
HFAG
hep-ex/0505100

(*) Includes D0 and CDF Run II measurements

Beauty 2005, Assisi (Perugia) Italy

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First step: "Reconstruction" Quite a challenge



For both detectors:

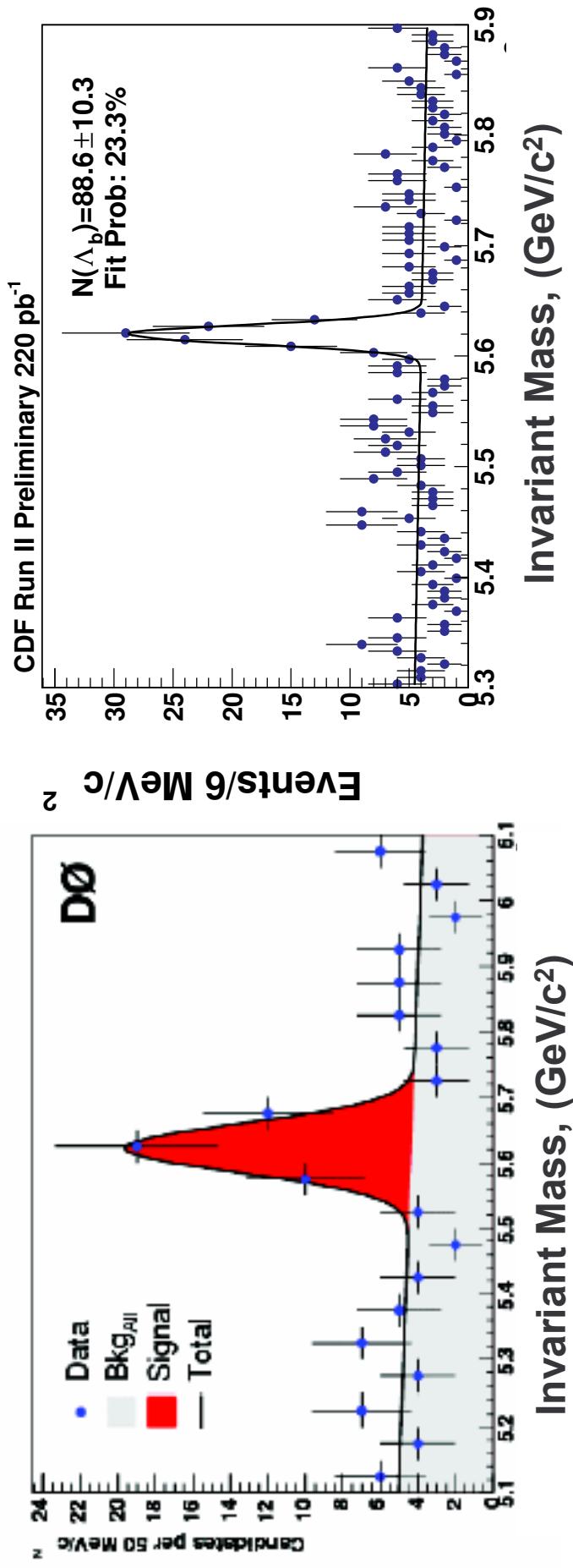
- Only charge particles reconstructed
- A lot of things going on in the silicon detector

Reconstruction of the Λ_b

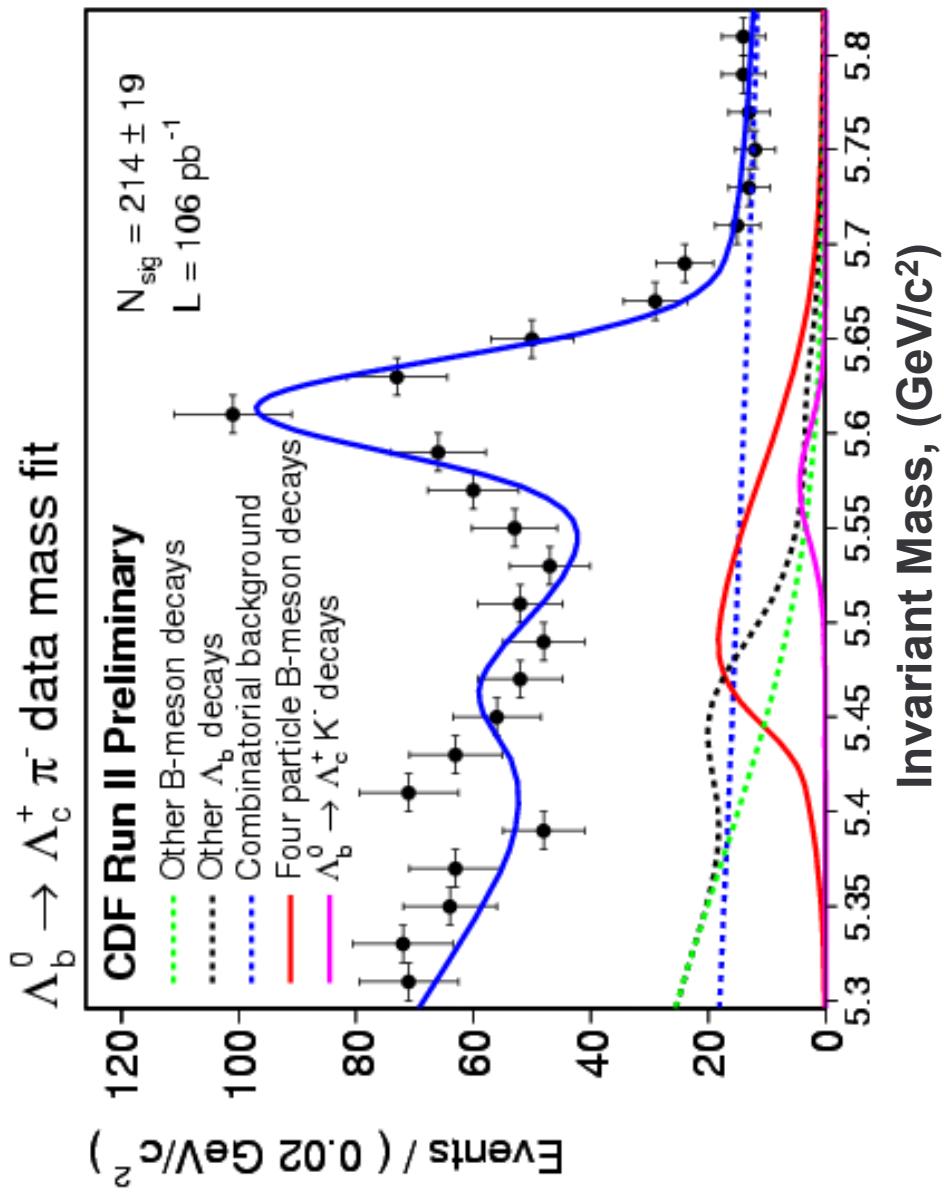
- Tevatron is like a B factory, but a dirty one
 - $\sigma(p\bar{p} \rightarrow bX) \approx 100 \mu b$
 $\mathcal{L}_{\text{inst}} \sim 100 \mu b^{-1} s^{-1} \rightarrow 10 \text{ kHz}$
 - Only ~5% reconstructable
 - Zoo of b hadrons: B^0 , B^+ , B_s , B_c , Λ_b , Ξ_b , B^{**}
 - But:
 - $\sigma(p\bar{p} \rightarrow X) \sim O(10^3)$ higher
 - Difficult to find other b
 - In b events, only $f_{\Lambda_b} \sim 10\%$ ($\Lambda_b \rightarrow X$)

Λ_b in full reconstructed channels

- Both experiments have clear signal of $\Lambda_b \rightarrow J/\psi \Lambda$



Λ_b in full reconstructed channels

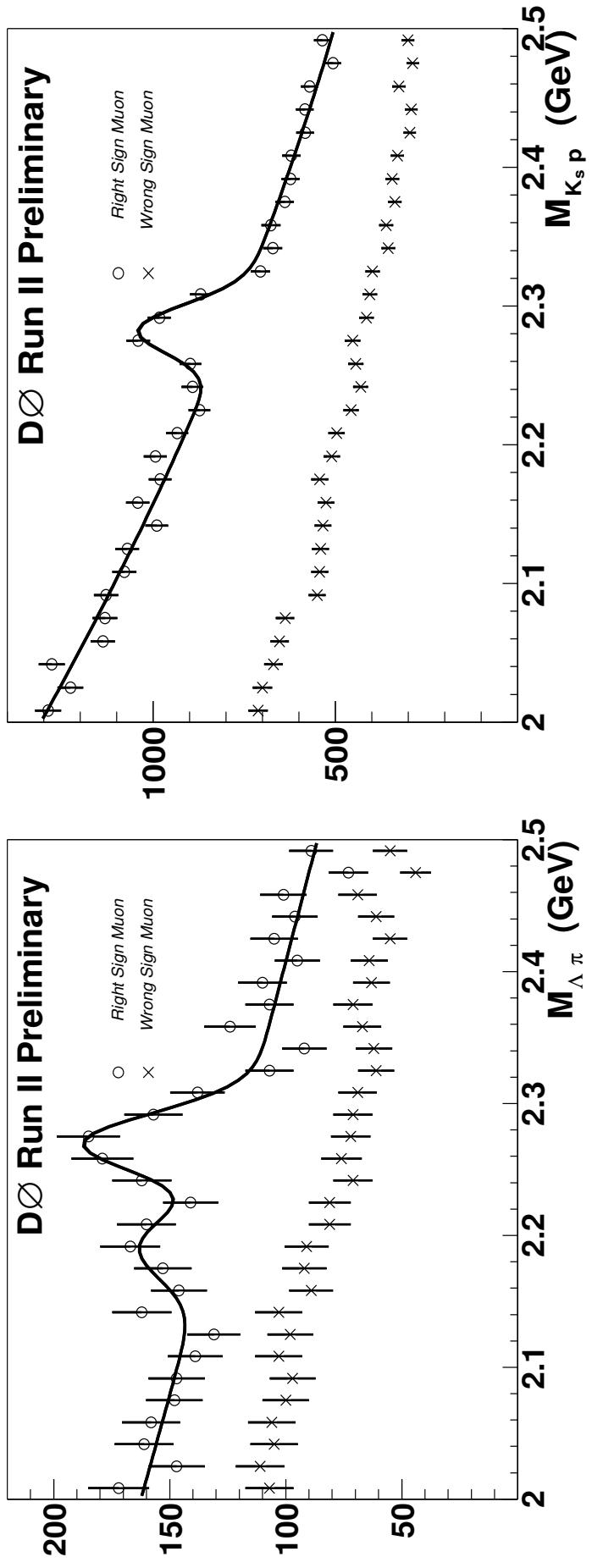
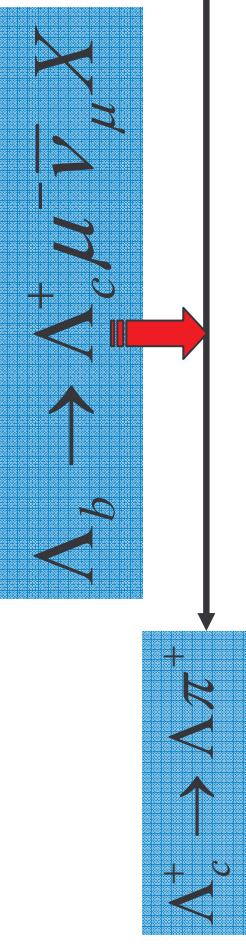


PDG'04 : Seen!

Now:

clear evidence
 $\Lambda_b \rightarrow \Lambda_c^+ \pi^- \sim 11\sigma$

Λ_b in semileptonic decays



Toward the direct measurement of $\tau(\Lambda_b)/\tau(B_d^0)$, similar to $\tau(B^+)/\tau(B_d^0)$

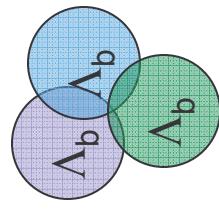
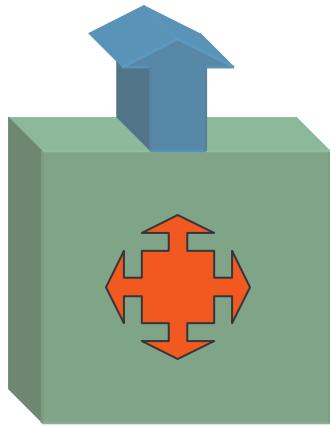
[PRL 94, 182001 (2005)]

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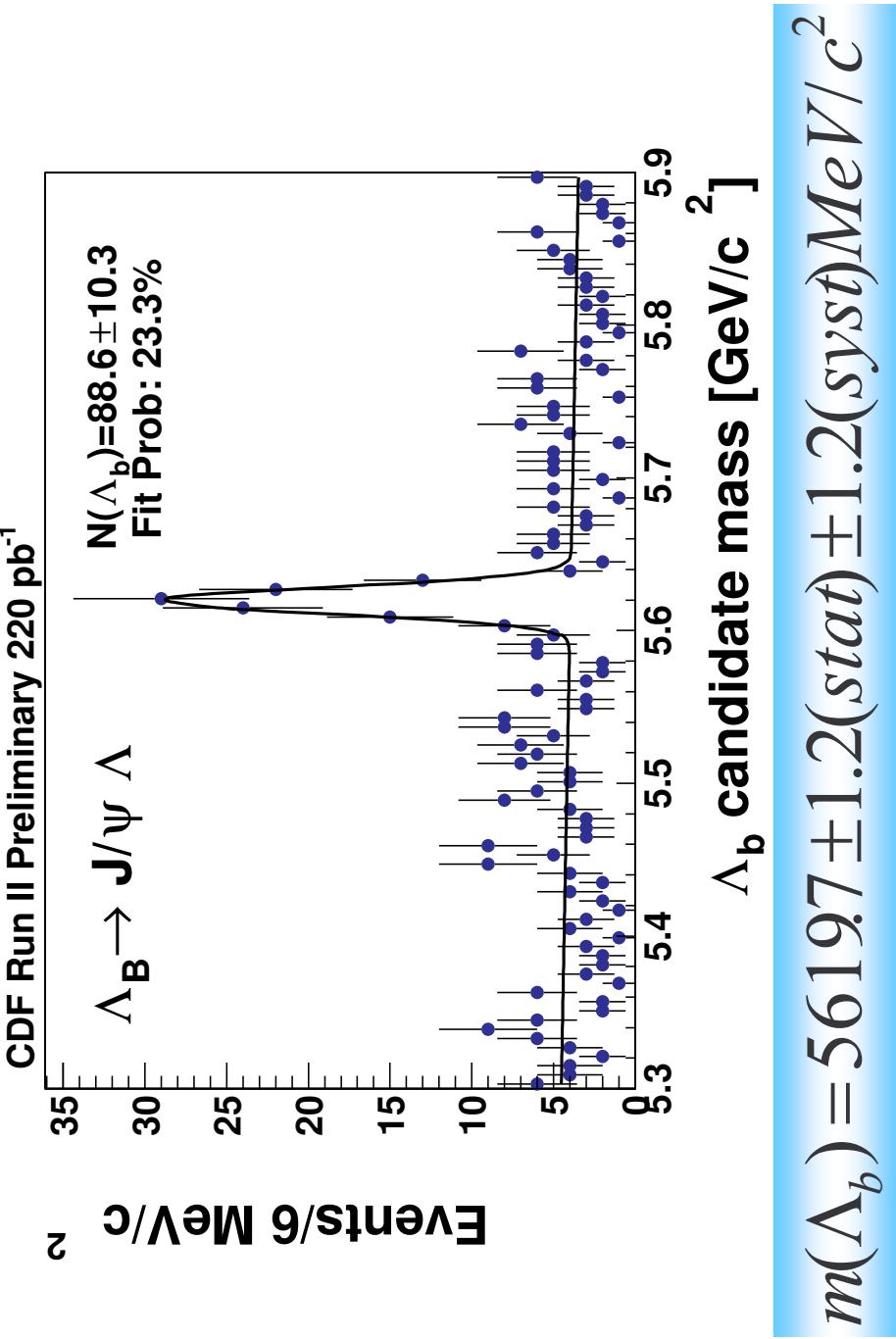
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After reconstruction ...

- Mass measurement
- Lifetime
- Branching fractions
- Etcetera ...



Λ_b mass measurement

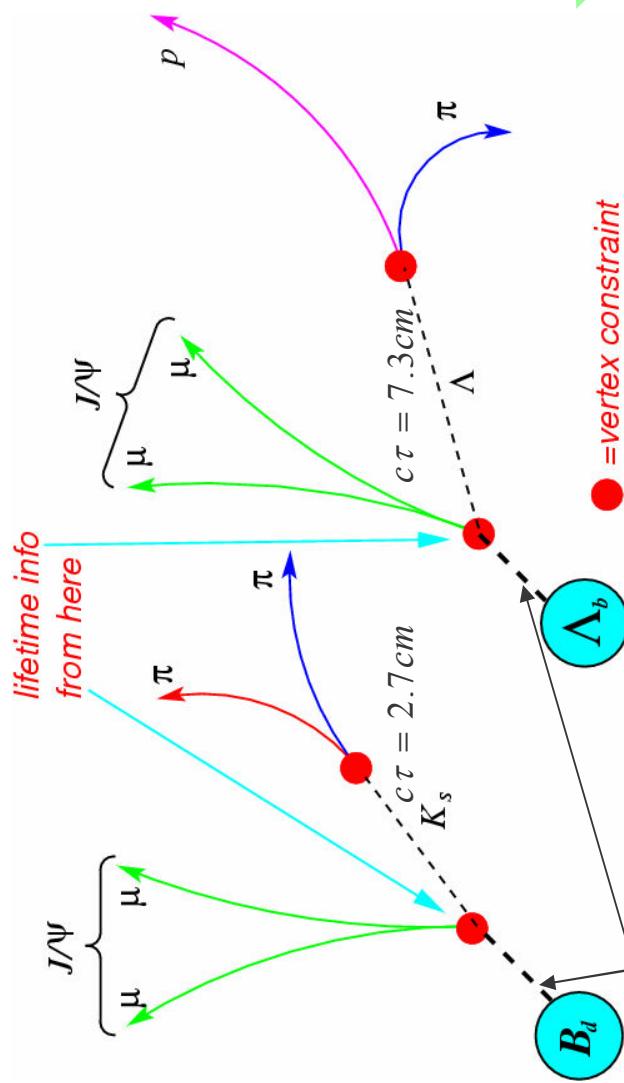


Most precise Λ_b mass measurement in the world !!!

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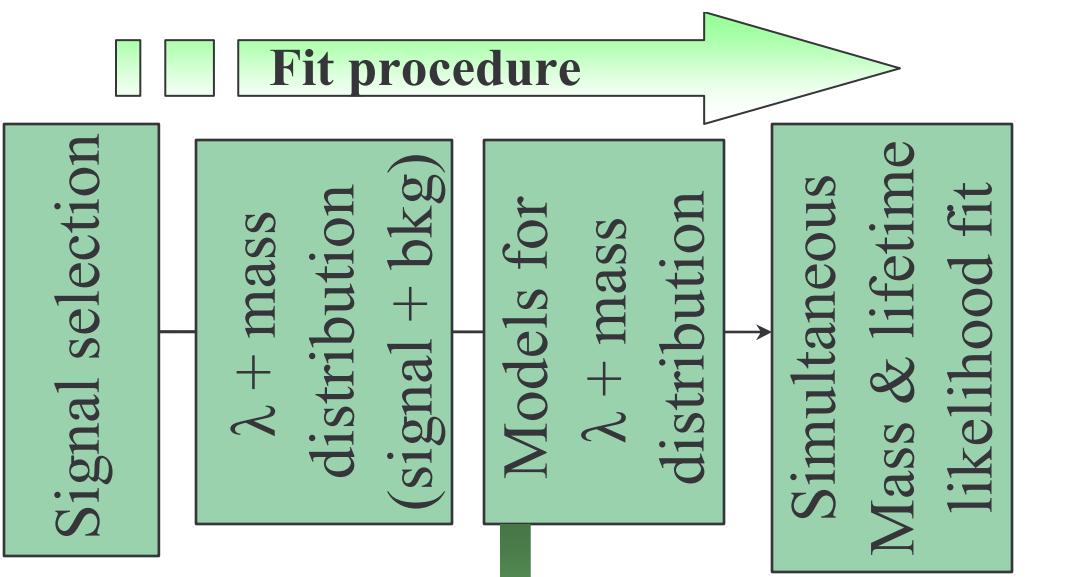
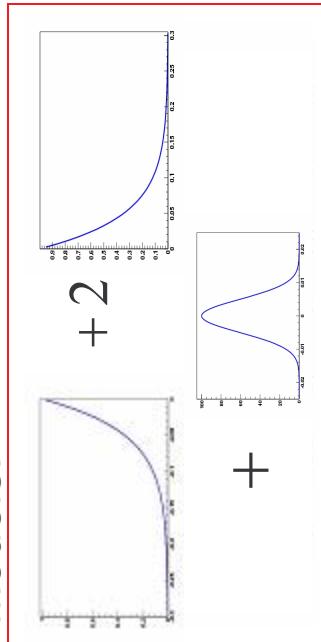
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Lifetime measurement

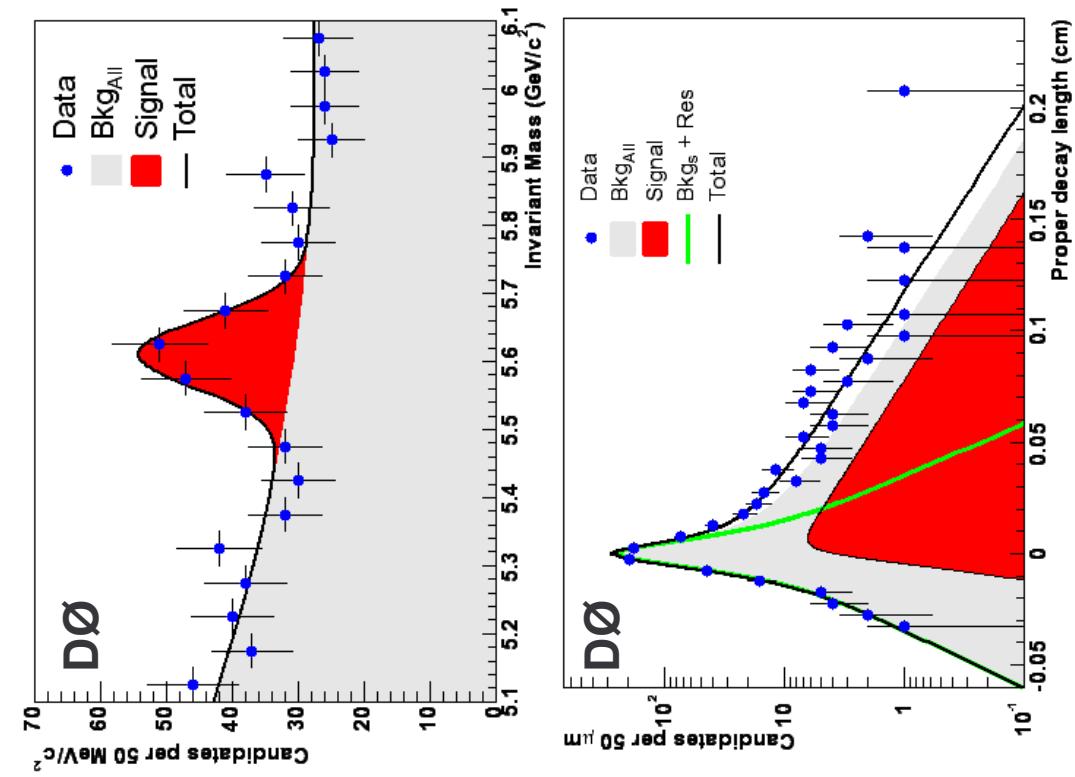


$$c\tau = \lambda = \vec{L} \cdot \hat{\vec{p}}_T \frac{M}{p_T}$$

Models: Background (λ)



Λ_b lifetime[1]



$$ct(\Lambda_b) = 366.0^{+65.2}_{-53.6} (stat) \pm 12.9 (syst)$$

Source	Λ_b^0 (μm)
Alignment	5.4
Model for Λ_B resolution	6.7
Model for Λ_B background	2.7
Model for signal mass	0.2
Model for background mass	2.5
Long-lived components	1.5
Contamination	8.8
Total	12.9

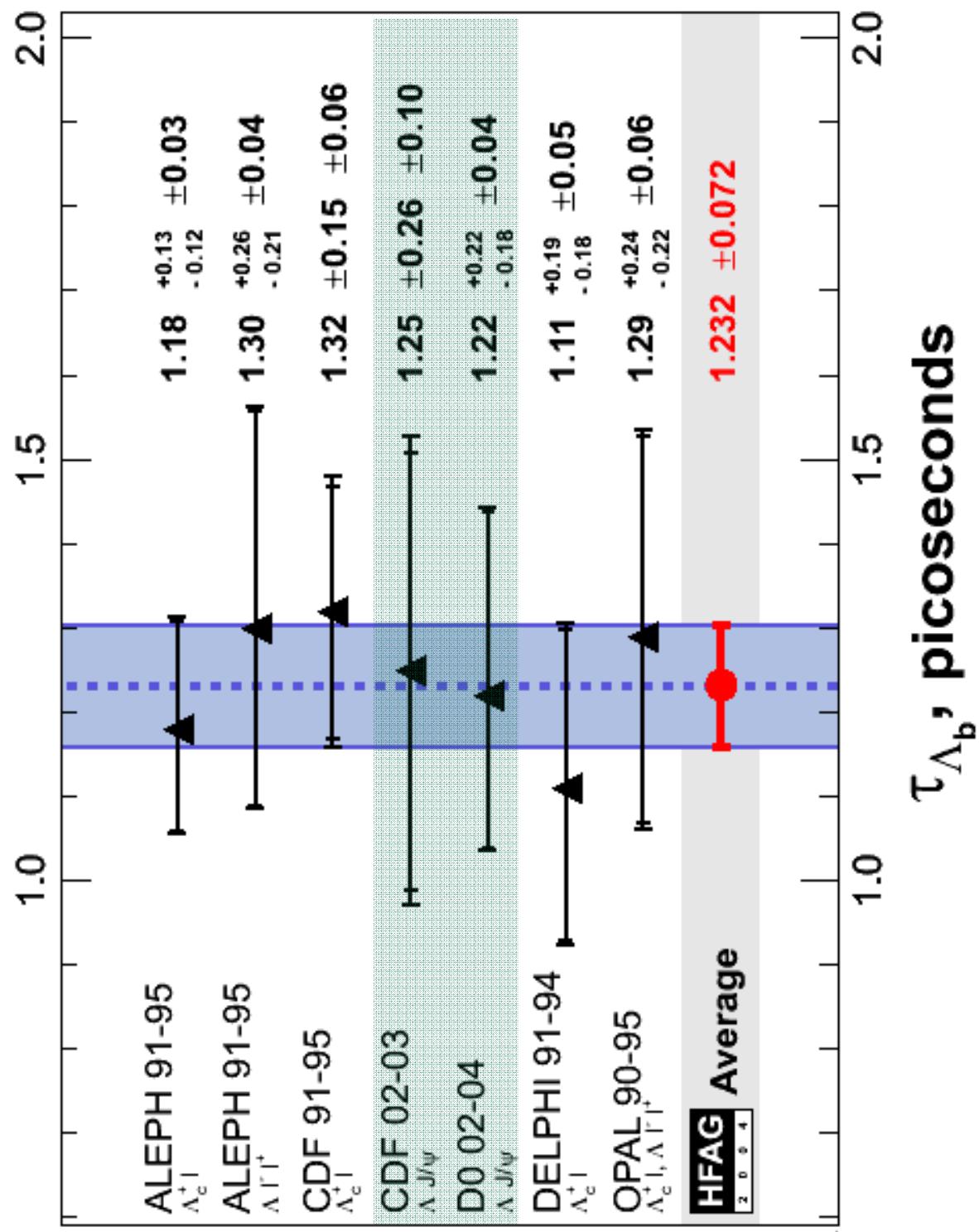
$$\tau = 1.22^{+0.22}_{-0.12} (stat) \pm 0.04 (syst) ps$$

First measurement in a full reconstructed decay channel !!!

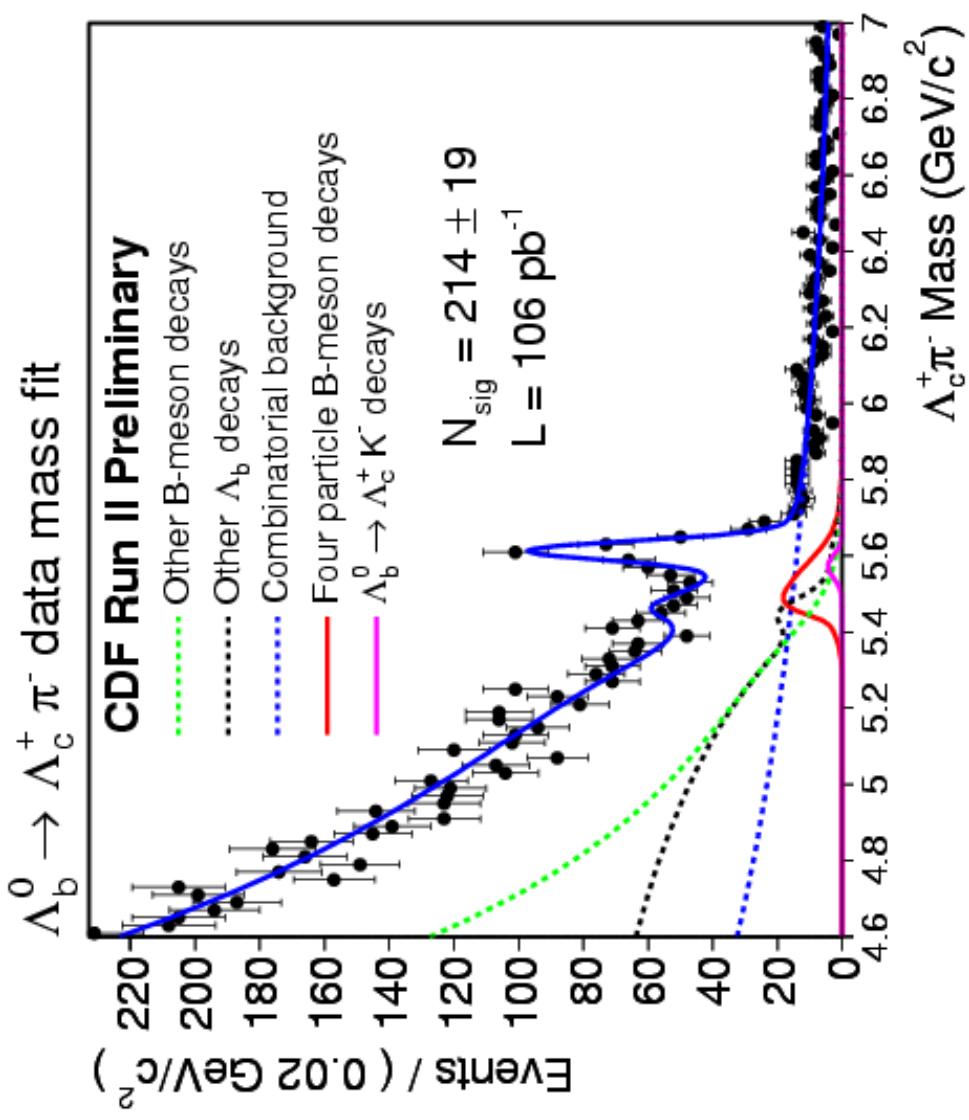
[1] V.M Abazov et al, PRL 94, 10201 (2005)

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Branching fractions:



Branching Fraction: $\Lambda_b \rightarrow \Lambda_c \pi$

$$\frac{\sigma_{\Lambda_b^0}(p_T > 6\text{GeV})}{\sigma_{\bar{B}^0}(p_T > 6\text{GeV})} \times \frac{BR(\Lambda_b \rightarrow \Lambda_c^+ \pi^-)}{BR(\bar{B}^0 \rightarrow D^+ \pi^-)} = \frac{BR(D^+ \rightarrow K\pi\pi)}{BR(\Lambda_c^+ \rightarrow pK\pi)} \times \frac{N_{\Lambda_b^0}}{N_{\bar{B}^0}} \times \frac{\mathcal{E}_{\bar{B}^0}}{\mathcal{E}_{\Lambda_b^0}}$$

From the fit:

$$N_{\Lambda b} = 214 \pm 19 (\text{stat})$$

$$N_{B0} = 790 \pm 32 (\text{stat})$$

From PDG:
1.84±0.493

From MC:
1.65±0.03

$$\frac{\sigma_{\Lambda_b^0}}{\sigma_{\bar{B}^0}} \times \frac{BR(\Lambda_b \rightarrow \Lambda_c^+ \pi^-)}{BR(\bar{B}^0 \rightarrow D^+ \pi^-)} = 0.82 \pm 0.08 (\text{stat}) \pm 0.11 (\text{syst}) \pm 0.22 (\text{BR})$$

Assuming: $\frac{\sigma_{\Lambda_b^0}(p_T > 6\text{GeV})}{\sigma_{\bar{B}^0}(p_T > 6\text{GeV})} \approx \frac{f_{\Lambda_b^0}}{f_{\bar{B}^0}} = 0.249 \pm 0.043$ (PDG '04)

$$\frac{BR(\Lambda_b \rightarrow \Lambda_c^+ \pi^-)}{BR(\bar{B}^0 \rightarrow D^+ \pi^-)} = 3.3 \pm 0.3 (\text{stat}) \pm 0.4 (\text{syst}) \pm 1.1 (\text{BR} + \text{FR})$$

Branching Fraction: B_{semi}/B_{had}

$$\frac{B_{semi}}{B_{had}} = \left(\frac{N_{inclusive-semi} - N_{background}}{N_{had}} \right) \times \frac{\mathcal{E}_{had}}{\mathcal{E}_{semi}}$$

Background Type	$D^* \mu$	$D\mu$	$\Lambda_c \mu$	$N_{bg}/N_{inc\ semi} (\%)$
Physics	15	40	9.8	
Muon fakes	4.3	4.9	3.2	
$b\bar{b}$ and $c\bar{c}$	0.9	1.2	0.2	
Total	20.2	46.1	13.2	

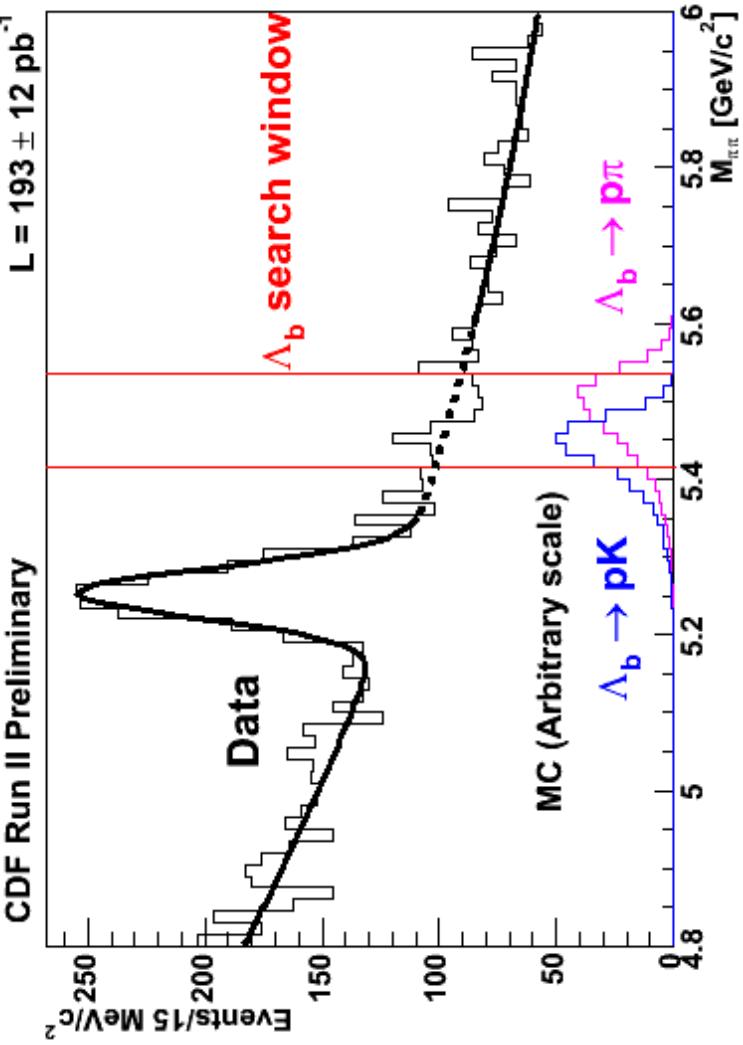
$$\frac{B(\Lambda_b \rightarrow \Lambda_c^+ \mu^- \bar{\nu}_\mu)}{B(\Lambda_b \rightarrow \Lambda_c^+ \pi^-)} = 20.0 \pm 3.0(stat) \pm 1.2(syst)_{-2.1}^{+0.7}(BR) \pm 0.5(UBR)$$

First measurement of this ratio !!

$$B(\Lambda_b \rightarrow \Lambda_c^+ \pi^-) = (0.41 \pm 0.19(stat \oplus syst)_{-0.08}^{+0.06}(P_T spectrum))\%$$

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

Search for $\Lambda_b \rightarrow hh$ decays

- Prediction[2]:
 - $\text{Br}(\Lambda_b \rightarrow pK) = (1.4 - 1.9) \times 10^{-6}$
 - $\text{Br}(\Lambda_b \rightarrow pp) = (0.8 - 1.2) \times 10^{-6}$
 - compare to
 $\text{Br}(B^0 \rightarrow Kp) = 18 \times 10^{-6}$
 - Large CP asymmetries
 $O(10\%)$ expected in b-baryons
 - Previous best limit from ALEPH
 - $\text{BR}(\Lambda_b \rightarrow pK) < 50 \times 10^{-6}$ @ 90%
 - $\text{BR}(\Lambda_b \rightarrow p\pi) < 50 \times 10^{-6}$ @ 90%
 - $\text{BR}(\Lambda_b \rightarrow hh) < 22 \times 10^{-6}$ (90% C.L.)
- 
- CDF Run II Preliminary
 $L = 193 \pm 12 \text{ pb}^{-1}$
- Λ_b search window
- Data
- MC (Arbitrary scale)
- $\Lambda_b \rightarrow pK$
- $\Lambda_b \rightarrow p\pi$
- $B(B^0 \rightarrow Kp) = 18 \times 10^{-6}$
- $B(\Lambda_b \rightarrow hh) < 22 \times 10^{-6}$ (90% C.L.)

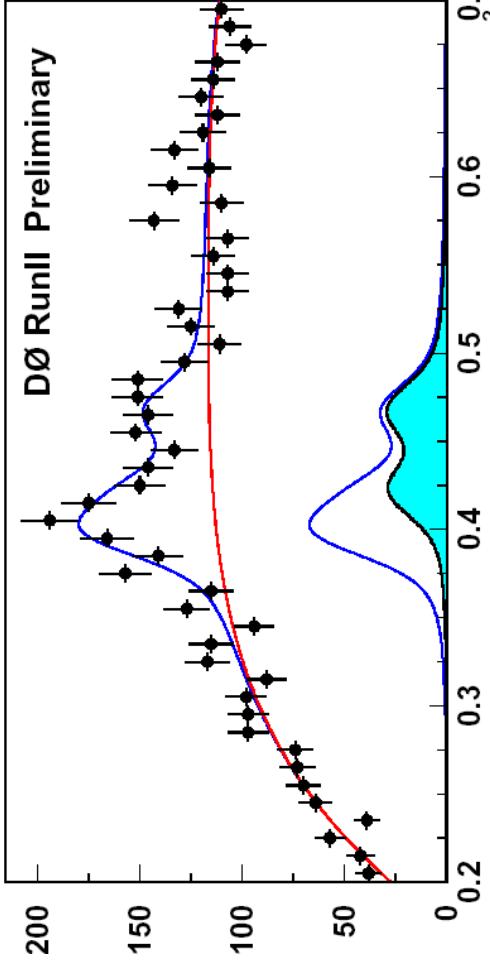
[2] Mohanta, Phys. Rev. D63:074001, 2001

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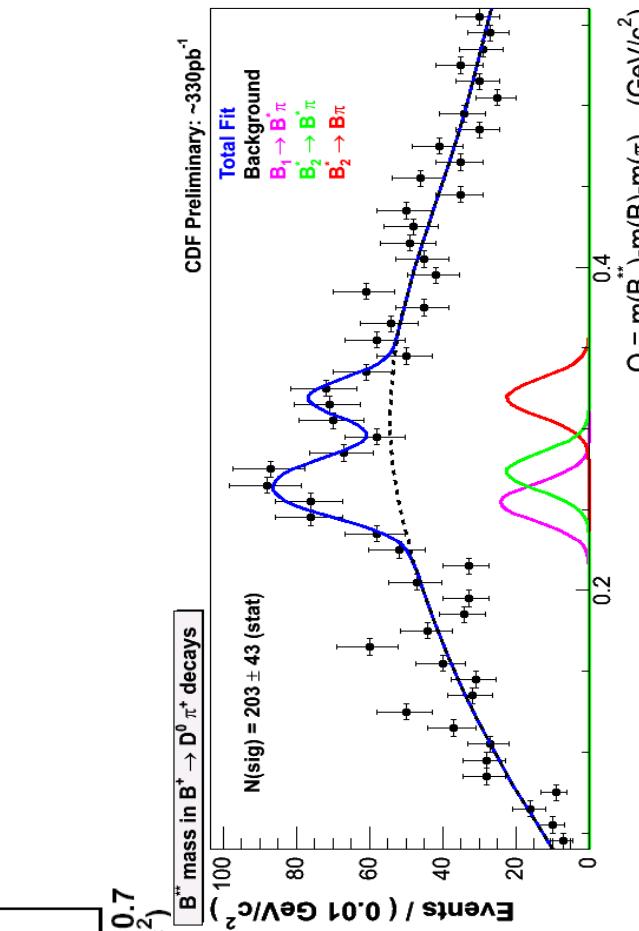
B^{**} resonances

- **B meson spectroscopy only well established for ground states B^+, B^0, B_s .**
- **Few models with precise predictions: mass/widths/BR**



$m_{B_1} = 5274 \pm 4 \pm 7 \text{ MeV}/c^2$

$\Delta m(B_2^* - B_1) = 23.6 \pm 7.7 \pm 3.9 \text{ MeV}/c^2$



**B_1 & B_2^* observed by first time
as separate states!!**

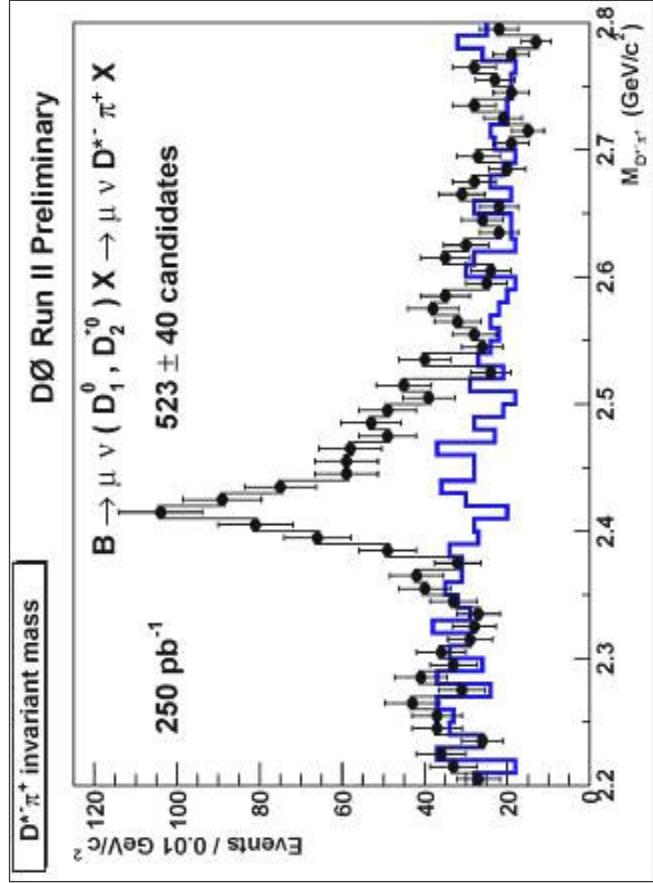
Semileptonic decays to excited states

$\blacksquare B \rightarrow D^{**} \mu\nu$

$$Br(B \rightarrow \mu\nu [D_1^0(2420), D_2^{*0}(2460)] X) \otimes$$

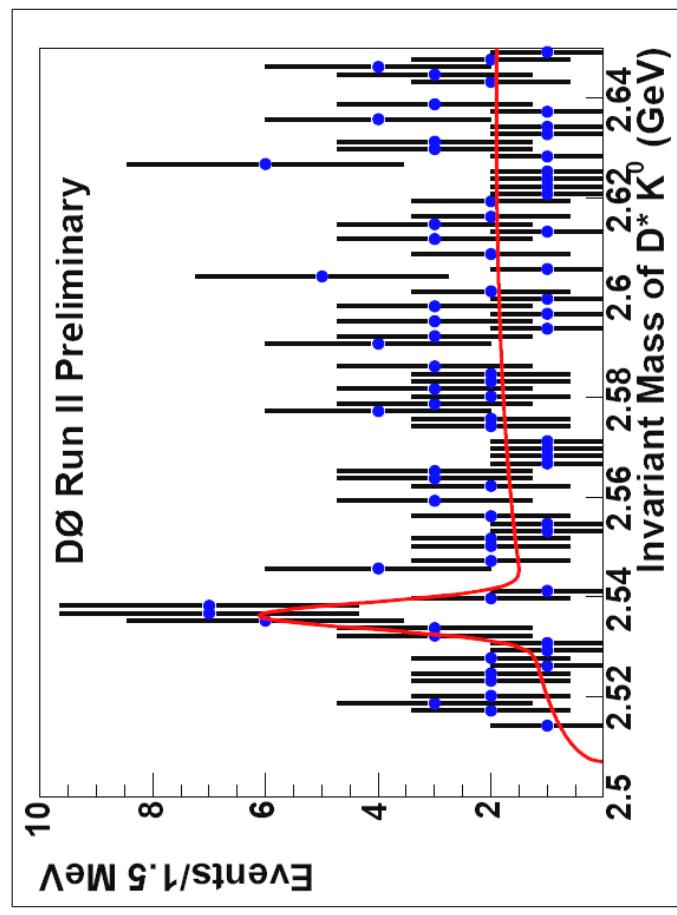
$$Br([D_1^0(2420), D_2^{*0}(2460)] \rightarrow D^{*+} \pi^-)$$

$$= (0.280 \pm 0.021 \pm 0.088)\%$$



$\blacksquare B_s \rightarrow D_s^{**} \mu\nu$
 $D_s^{**} \rightarrow D^* K_S$

Excess: $20.6 \pm 5.6 (3.7\sigma)$



Summary

- A lot of new results from Tevatron on the Λ_b baryon
 - Best mass measurement
 - First lifetime in full reconstructed channel
 - Branching fractions by first time measured
- More in preparation:
 - Direct lifetime ratio measurement $\tau(\Lambda_b)/\tau(B^0)$
 - Others b baryons and studies...
 - CDF and D0 are looking forward to contribute to a best knowledge of the b baryons.