Beauty Baryons @ Tevatron

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Outline

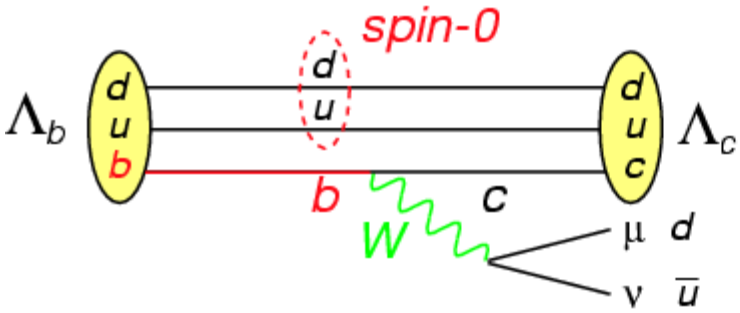
- DØ and CDF Detectors
- Lifetimes in the decay $\Lambda_b \rightarrow J/\psi\ \Lambda$
- Relative Branching ratios of

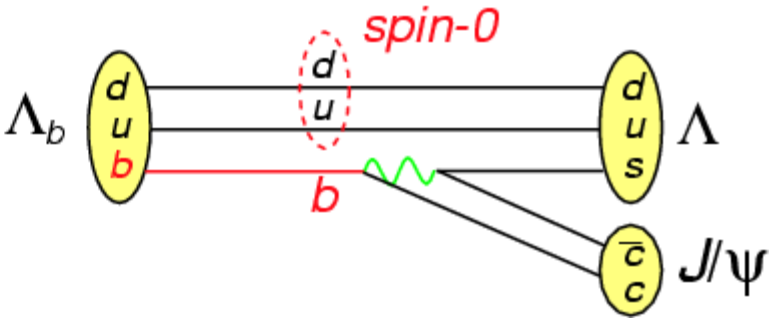
  $B(\Lambda_b \rightarrow \Lambda_c\ \mu\ \nu)/B(\Lambda_b \rightarrow \Lambda_c \pi)$
- Measurement of $\sigma_{\Lambda b} \times B(\Lambda_b \rightarrow \Lambda\pi)/\sigma_B{}^0 \times B(B0 \rightarrow D^+\pi^-)$
- Limits on charmless decays $\Lambda_b \rightarrow p\pi$, $\Lambda_b \rightarrow pK$
- Form factor in semileptonic decays of Λ_b
- Relative hadronization fractions $f_{\Lambda b}/(f_u + f_d)$
- Summary, Conclusions, and Coming soon..

Motivation

- The Tevatron is currently the only running machine producing beauty baryons
- Why study beauty baryons?
  - Understand the lifetime hierarchy

    $\forall\ \tau(\Lambda_b)<\tau(B_s)\sim\tau(B^0)<\tau(B^+)$
  - Great system to test Heavy Quark Effective Theory and non-perturbative QCD





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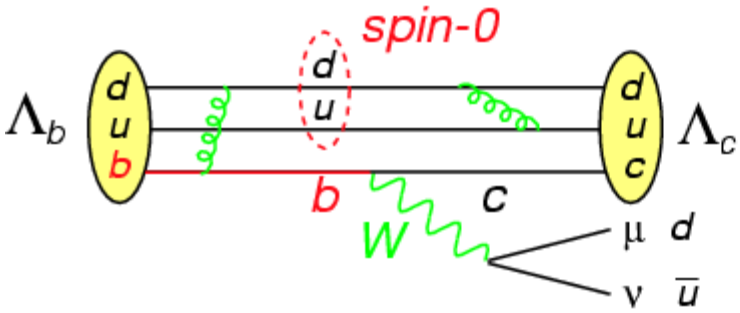

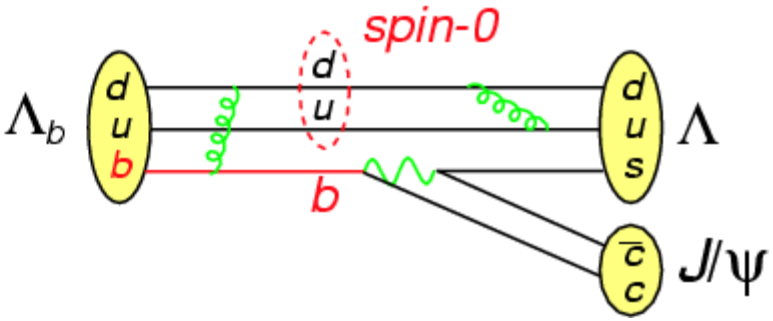

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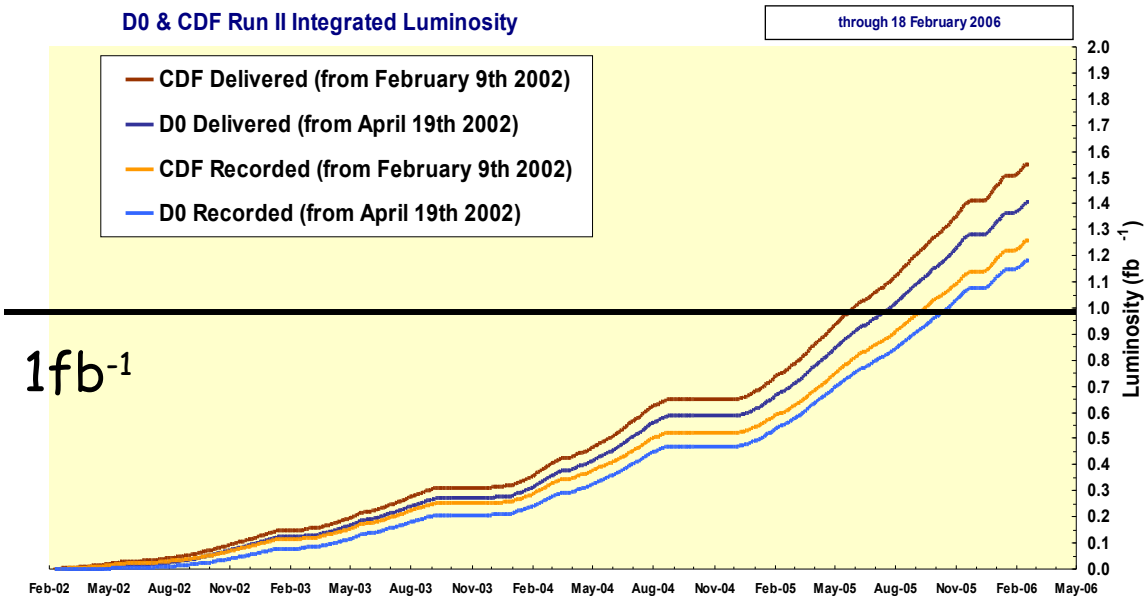
  - Great system to test Heavy Quark Effective Theory and non-perturbative QCD
    - HQET predictions are much more accurate for the b-baryon systems than B mesons.
    - Form factor study in semileptonic decays gives us insights in non-perturbative QCD
  - Probe decays with possible large CP violation, e.g.

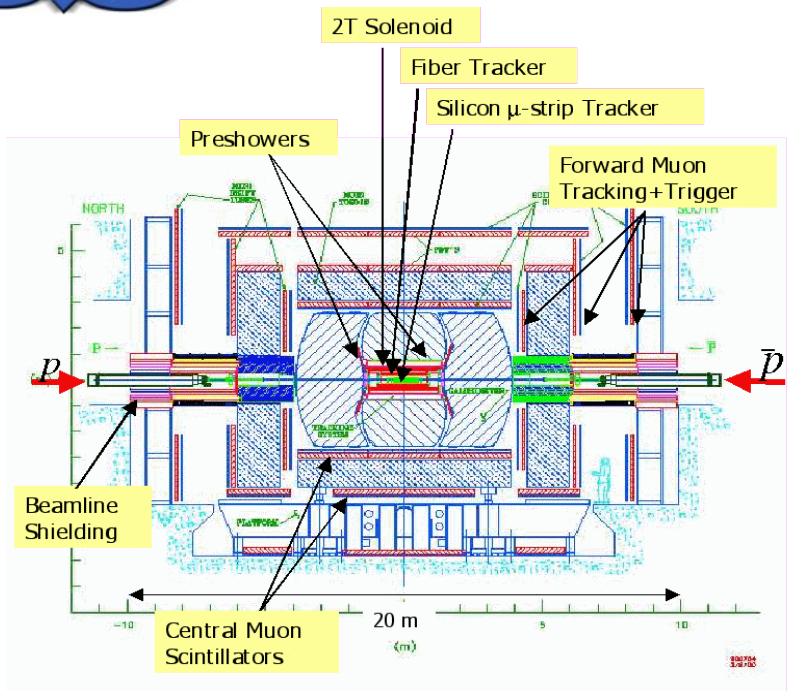
    $\forall\ \Lambda_b \to p\ K;\ \Lambda_b \to p\ \pi$

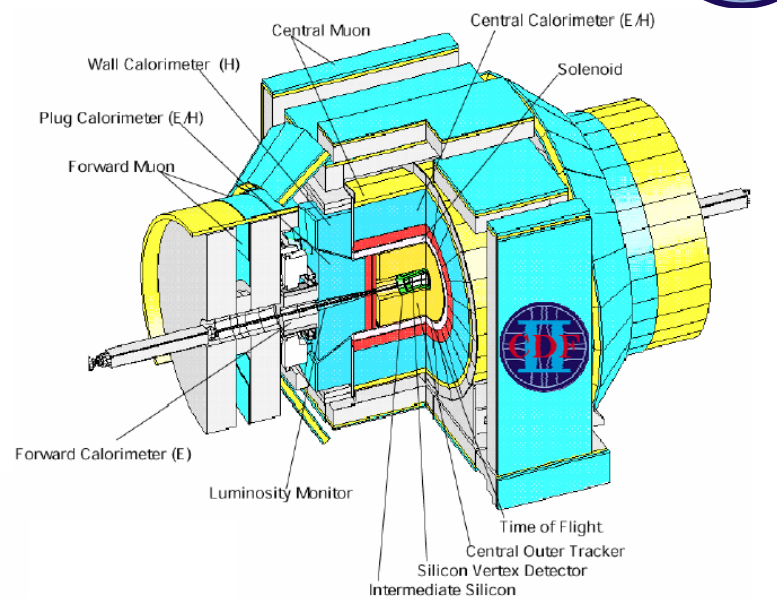
Tevatron Performance

- Excellent performance of Tevatron in 2004 and 2005
- Delivered more than 1.5 fb^{-1}
- recorded (DØ/CDF)
  - 1.2 fb^{-1} / 1.4 fb^{-1}
  - high data taking efficiency ~85%
- Current datasets analyzed
  - Up to 1 fb^{-1} analyzed
  - The analysis shown vary in range of integrated luminosities



DØ and CDF Detectors





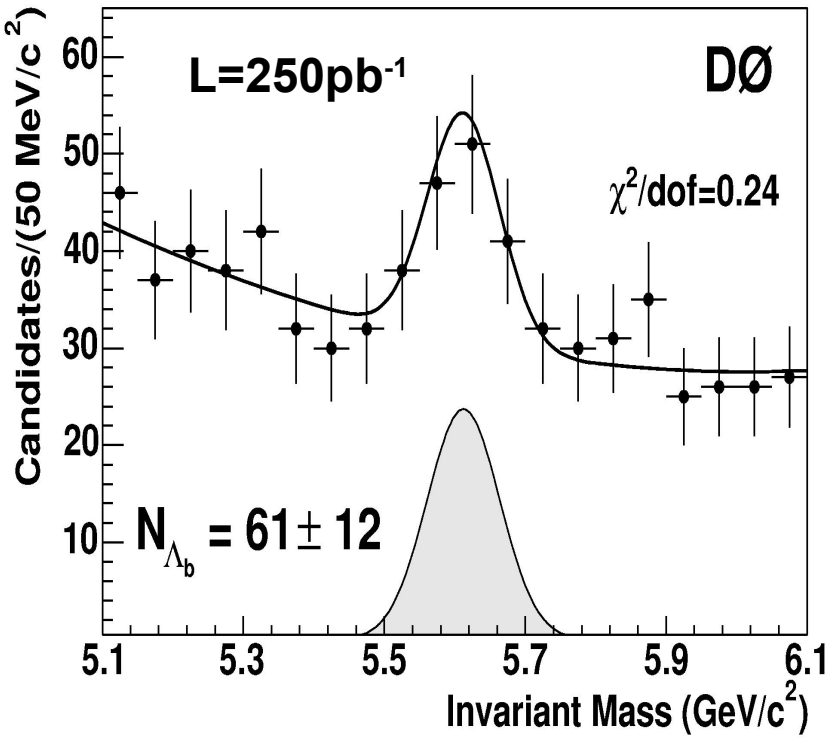
Component	DØ	CDF
Trigger	1 and 2 muons	muons + 2 TRK@ L1 + SVT@L2
Tracking	$\sigma(p)/p \sim 0.2\%$	$\sigma(p)/p \sim 0.1\%$
Lepton coverage	μ:$\lvert\eta\rvert<2$	μ:$\lvert\eta\rvert<1$ (1.6)
Particle ID	--	dE/dx, TOF

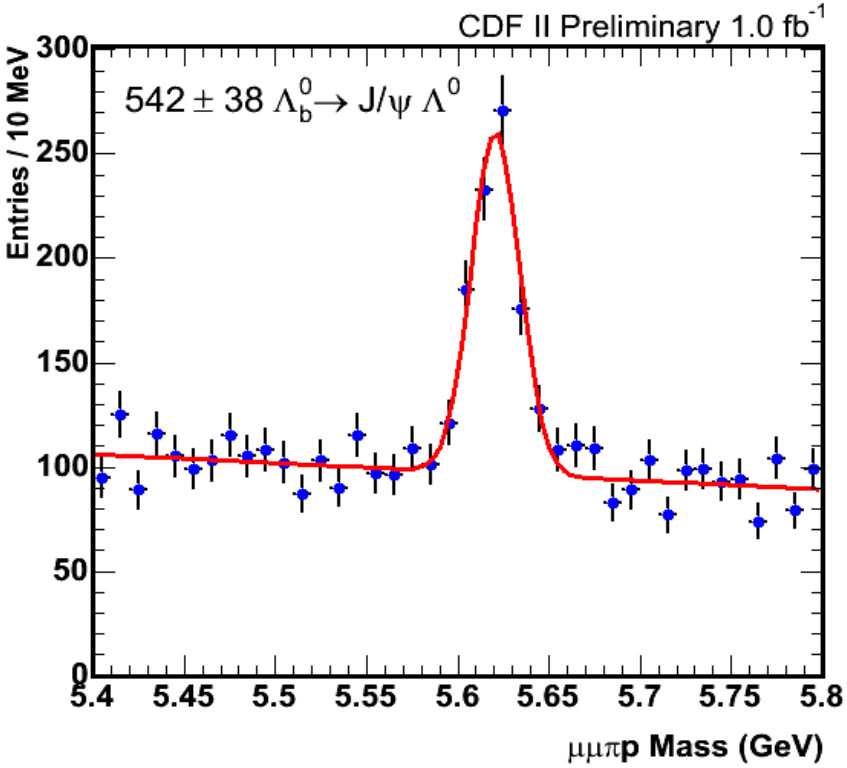
Λ_b Lifetime Fitting Approach

- Fit simultaneously for both mass and lifetime.
  - ***Mass (PDF)***
    - Gaussian function for the signal region.
    - First degree polynomial for the background.
  - ***Lifetime (PDF)***
    - **Signal;**
      - Exponential decay convoluted with a gaussian resolution function.
    - **Background**
      - Gaussian resolution function for zero lifetime components.
      - Exponential decay for the short lived physics background.
      - Exponential decay for long lived physics background.
      - A negative exponential decay for physics backgrounds, where Secondary Vertex is ahead of Primary Vertex.
- A likelihood function was formed combining both the mass and lifetime PDFs:

$$L = \prod_{j=1}^{N} [f_S S_M(M_j) S_L(\lambda_j, \sigma_j) + (1 - f_S) B_M(M_j) B_L(\lambda_j, \sigma_j)]$$

Λ_b Mass $\Lambda_b \rightarrow J/\psi\ \Lambda$





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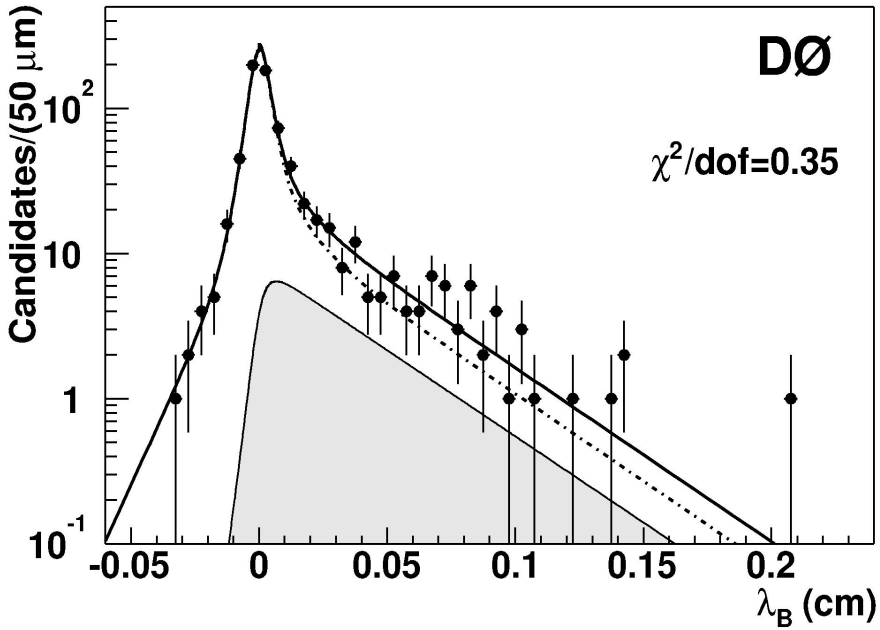
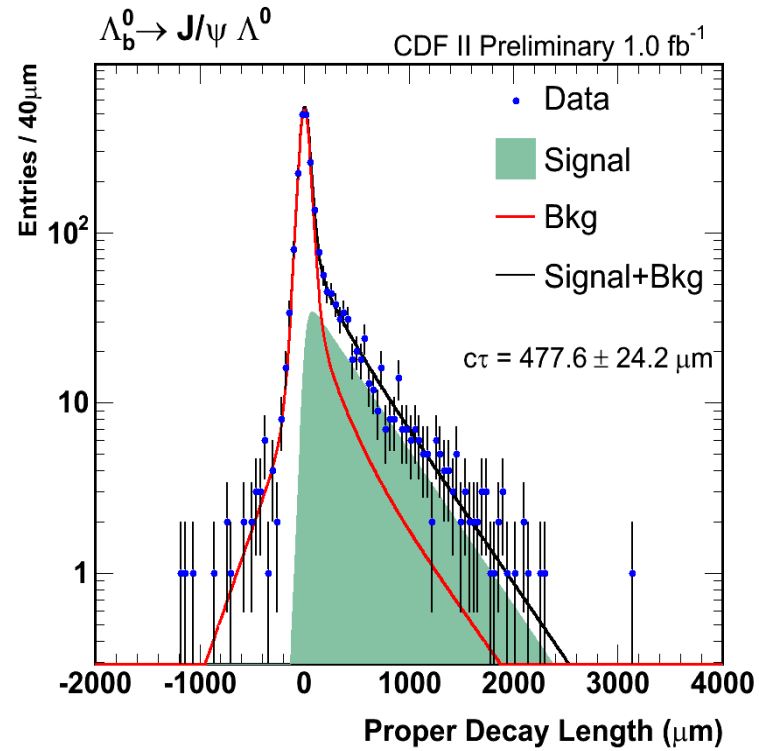
Λ_b Lifetime





$$\tau(\Lambda_b^0) = 1.22^{+0.22}_{-0.18}(\text{stat}) \pm 0.04\,(\text{syst})\ \text{ps}$$

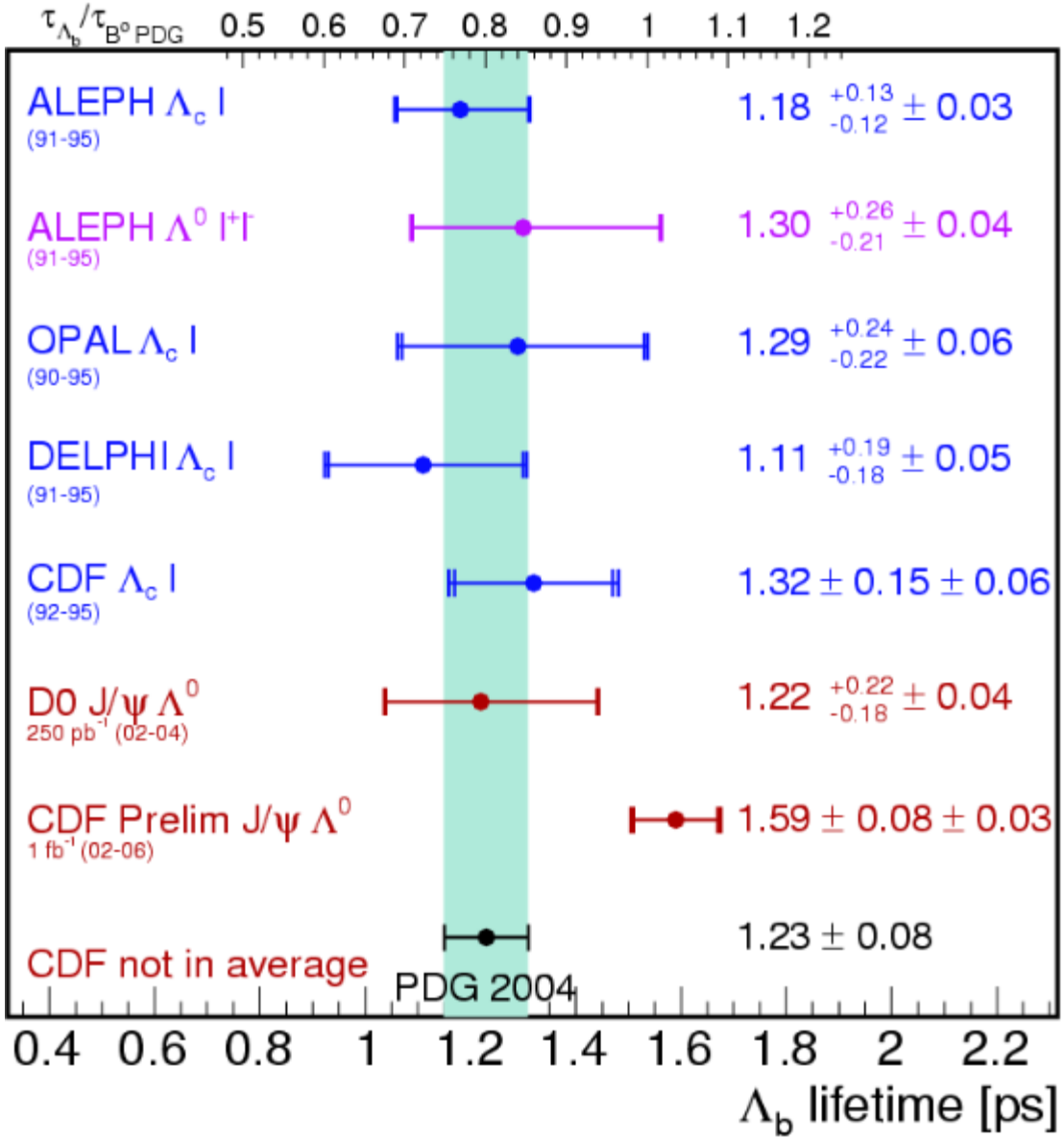
$$\frac{\tau(\Lambda_b)}{\tau(B^0)} = 0.87^{+0.17}_{-0.14}(\text{stat}) \pm 0.03(\text{syst})$$

$$1.593^{+0.083}_{-0.078}(\text{stat}) \pm 0.033\,(\text{syst})\ \text{ps}$$

$$\frac{\tau(\Lambda_b)}{\tau(B^0)} = 1.037 \pm 0.058(stat \oplus syst)$$

$B^0 \to J/\psi\ K_S$ is used as control sample

Λ_b Lifetime Measurements



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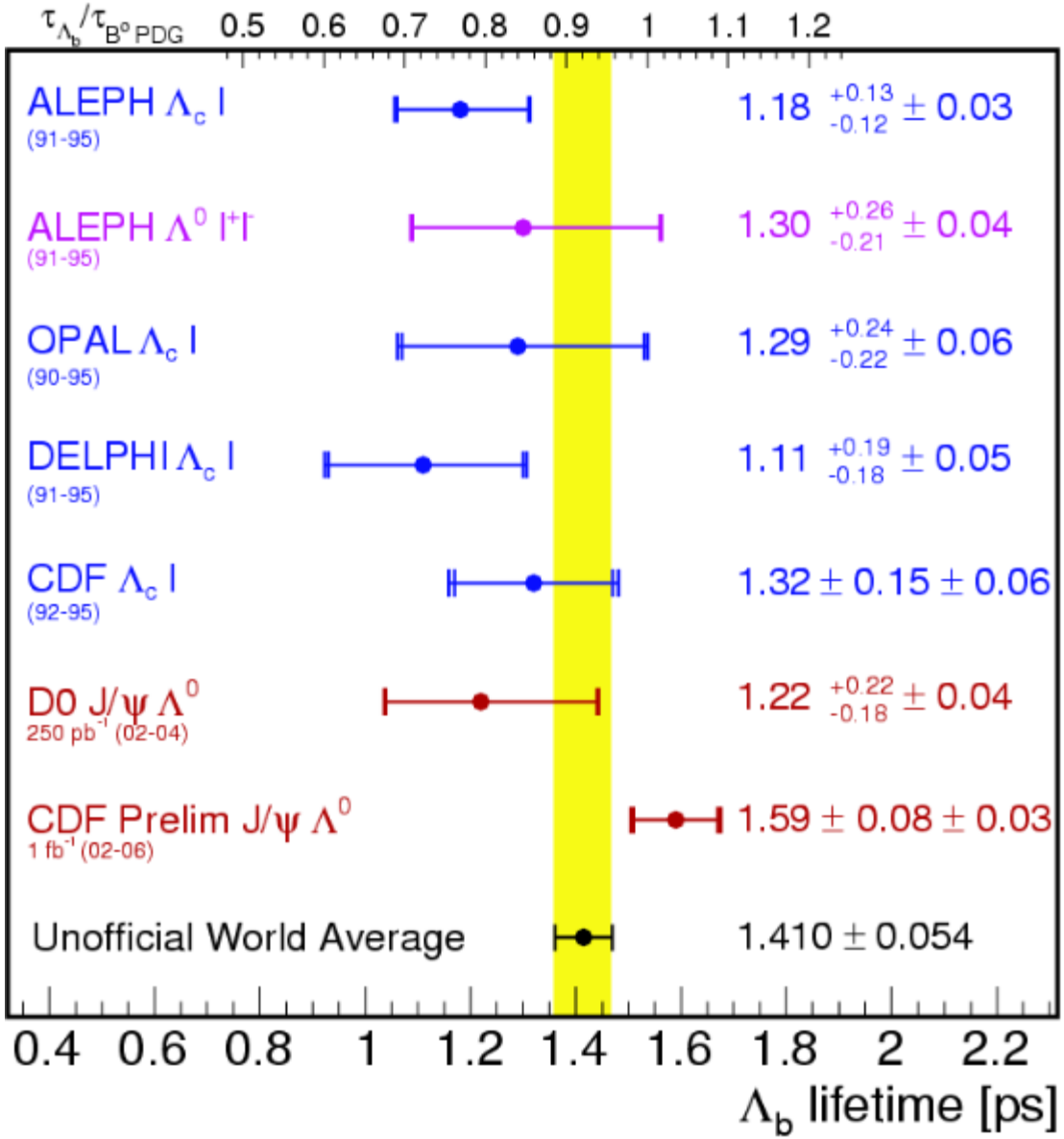

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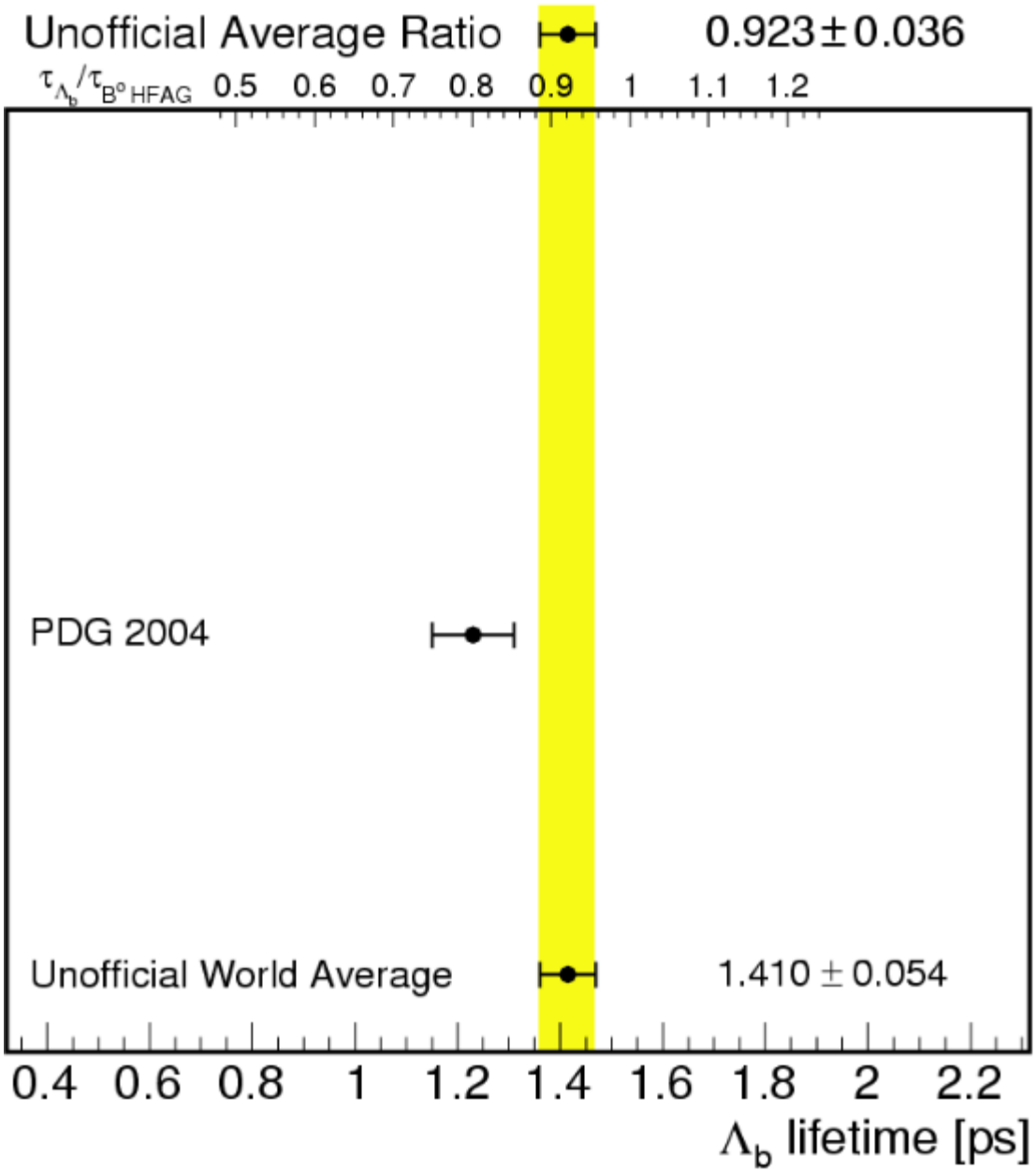

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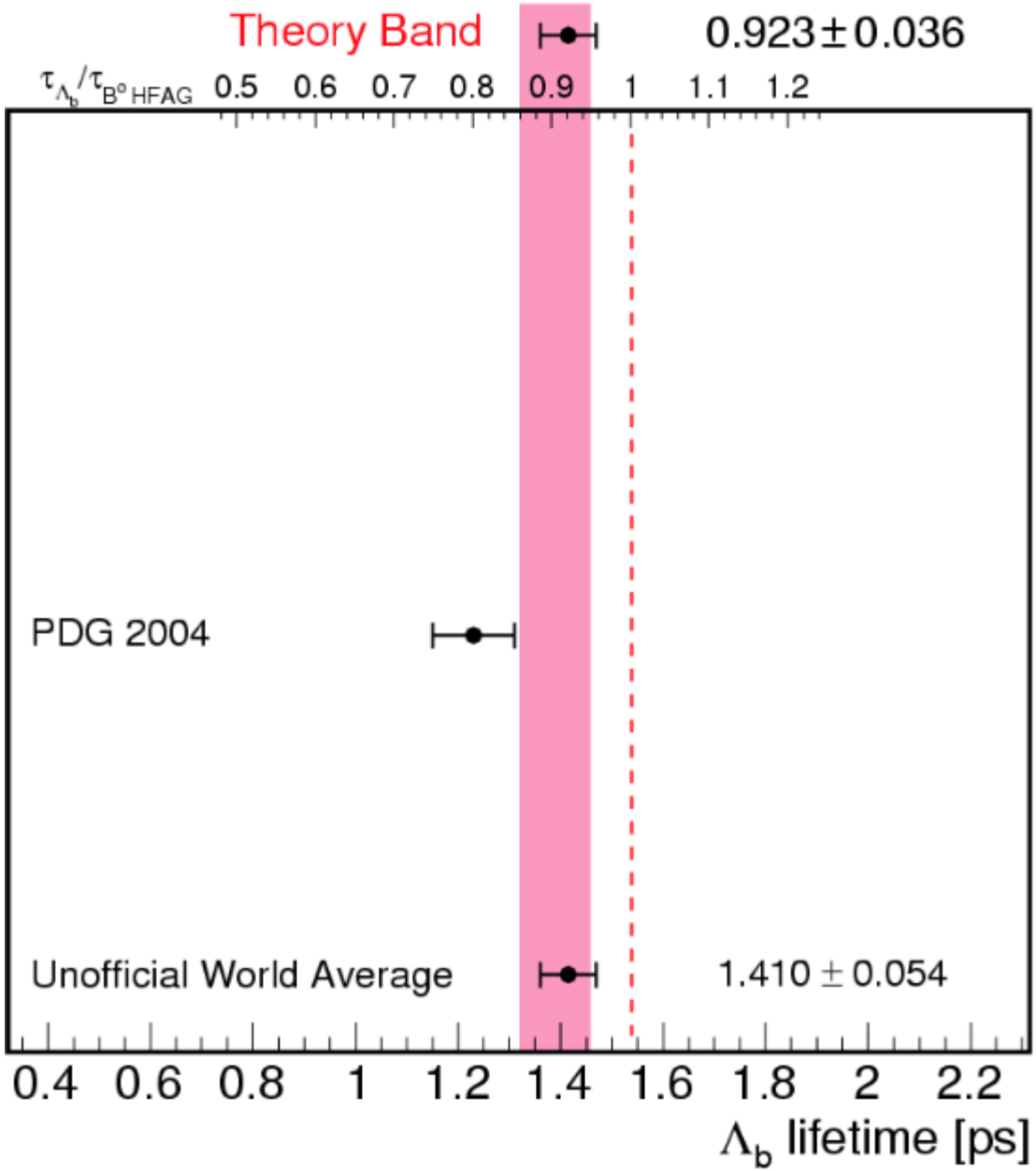

First Observation of $\Lambda_b \to \Lambda_c \pi$

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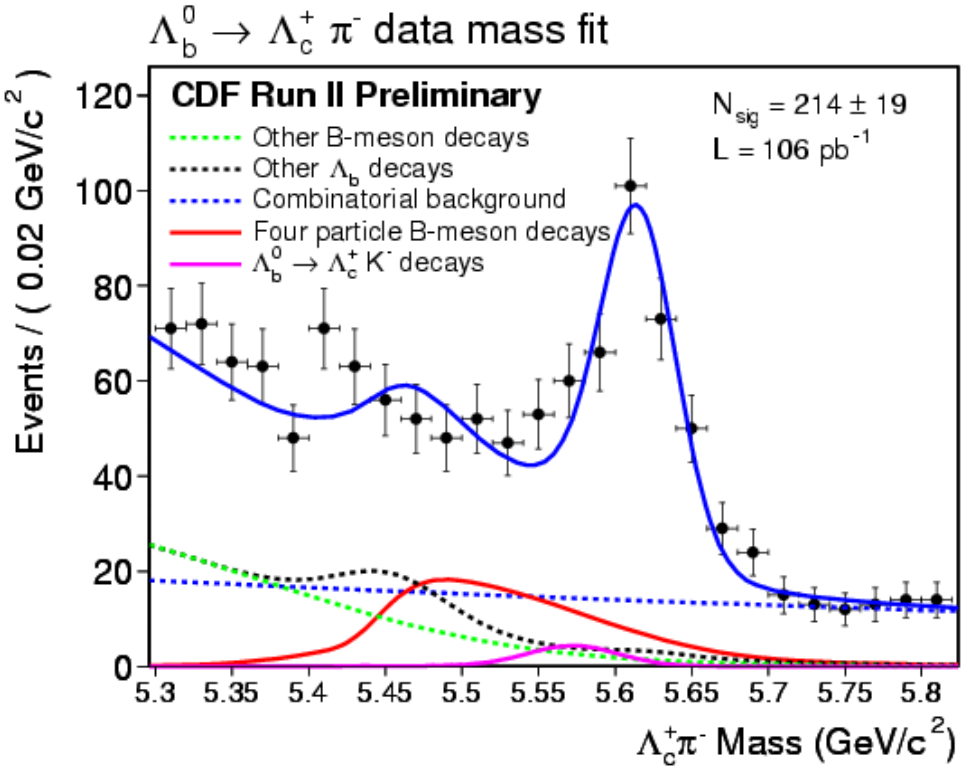


HQET predicts:

$$R_{BR} \equiv \frac{B(\Lambda^0{}_b \to \Lambda^+{}_c \pi^-)}{B(\overline{B}^0 \to D^+ \pi^-)} \approx 1.7$$

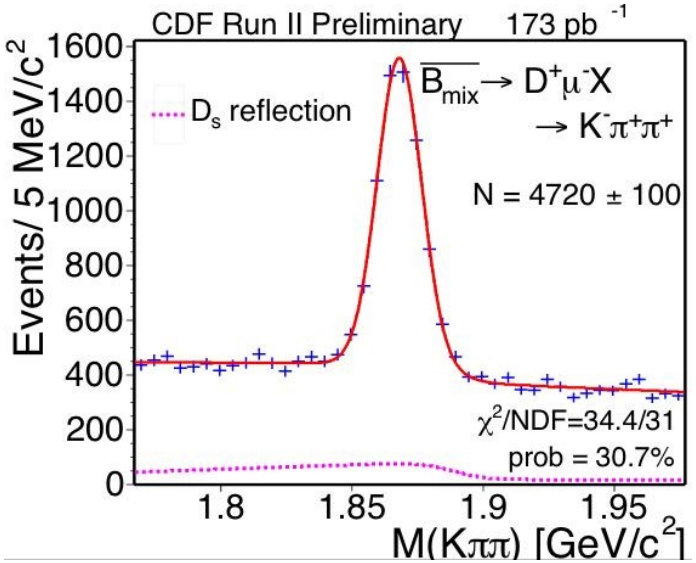
- Provide means of determining CKM matrix elements with different systematic uncertainties than *B* mesons
- Will use to determine the lifetime of Λ_b baryon

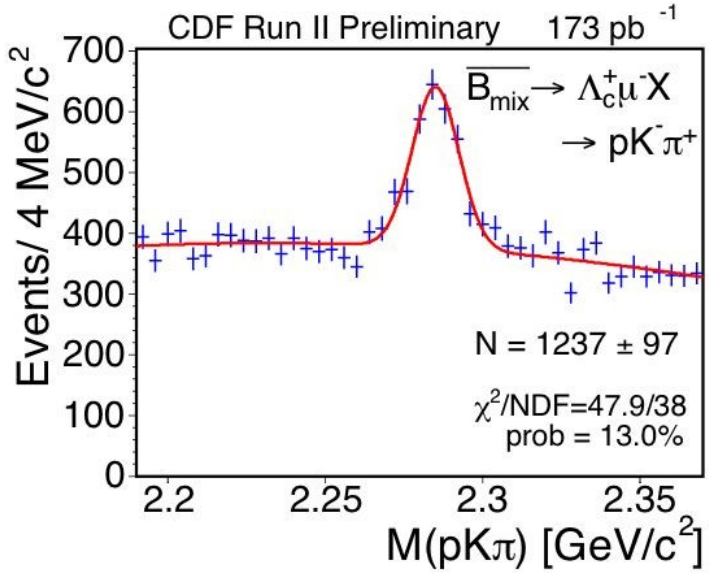
$$\frac{\sigma(p\overline{p} \to \Lambda_b X)}{\sigma(p\overline{p} \to \overline{B}^0 X)} \times R_{BR} = 0.82 \pm 0.08(stat) \pm 0.11(syst) \pm 0.22(B(\Lambda^+{}_c \to pK^-\pi^+))$$

Derived: → R_{BR}~3.3 +/- 1.2 consistent with 1.7 from theory

Branching Ratios
$B(\Lambda_b \to \Lambda_c \mu \nu)/B(\Lambda_b \to \Lambda_c \pi)$

$B(\Lambda_b \to \Lambda_c \mu \nu)/B(\Lambda_b \to \Lambda_c \pi)$~15 from HQET with 30% error





Measured:

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

Calculated with $f_{bbaryon}/f_d$=0.236:

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

Derived:

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

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

Theoretical predictions:

$BR(\Lambda_b \to p\pi) = (0.9\text{-}1.2) \times 10^{-6}$

$BR(\Lambda_b \to pK) = (0.9\text{-}1.2) \times 10^{-6}$

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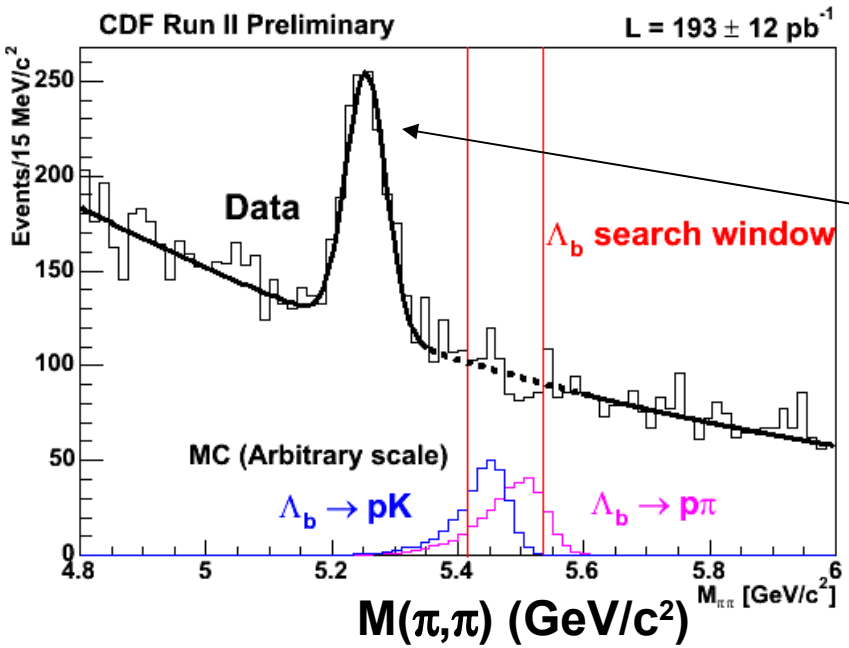
$BR(\Lambda_b \to hh) < 5 \times 10^{-5}$ @ 90%CL from LEP experiments



- Use $B_d \to K\pi$ as a normalization mode

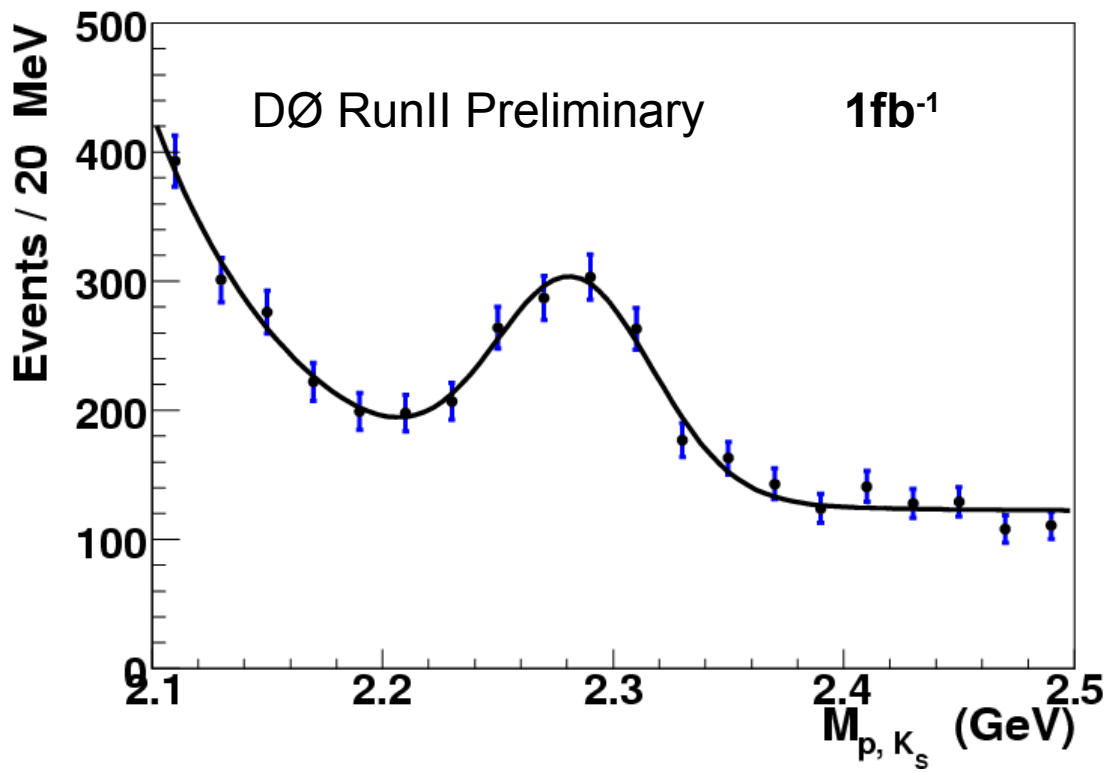
$B \to h^- h'^+$

where h, h' stand for π/K

Result:
$BR(\Lambda_b \to hh) < 2.3 \times 10^{-5}$ @ 90%CL

Improved Limit

Form Factor in Semileptonic Decays of $\Lambda_b \rightarrow \Lambda_c \mu \nu$



$\Lambda_b \rightarrow \Lambda_c \mu \nu$

$\Lambda_c \rightarrow p K_S$

Yield=702±72

M=2283±3 MeV

σ=34±3 MeV

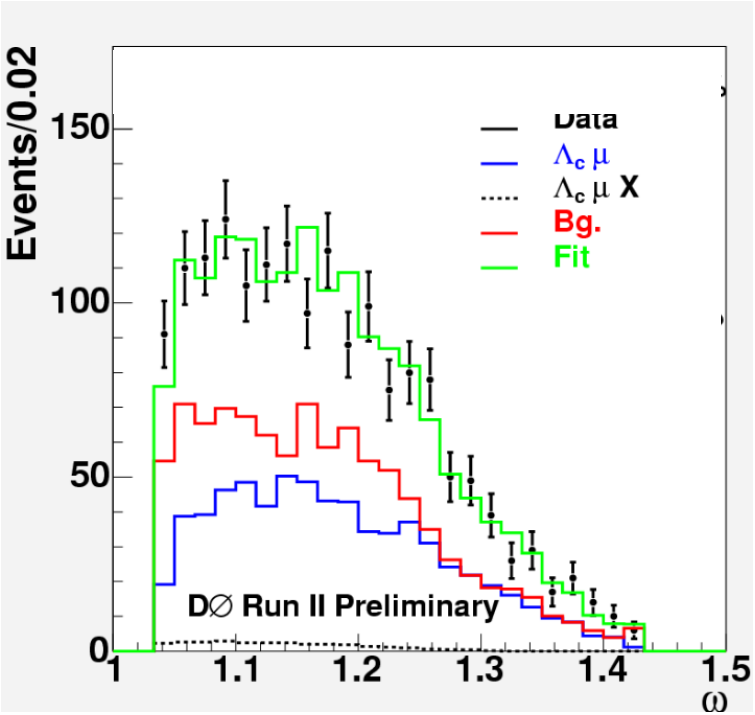
Fit for the form factor

Test non-perturbative QCD:

Theoretical prediction for the form factor varies over a large range

ω is the four velocity product between initial and final baryon

ω=1 corresonds to "zero recoil"; Λ_c is at rest in Λ_b rest frame, μ and ν are back to back



Decay rate:

$$\frac{d\Gamma}{d\omega} = GK(\omega)\xi_B^2(\omega)$$

Isgur Wise function is:

$$\xi_B(\omega) = \xi_B(1)e^{\left[-\rho^2(\omega-1)\right]}$$

DELPHI measured it:

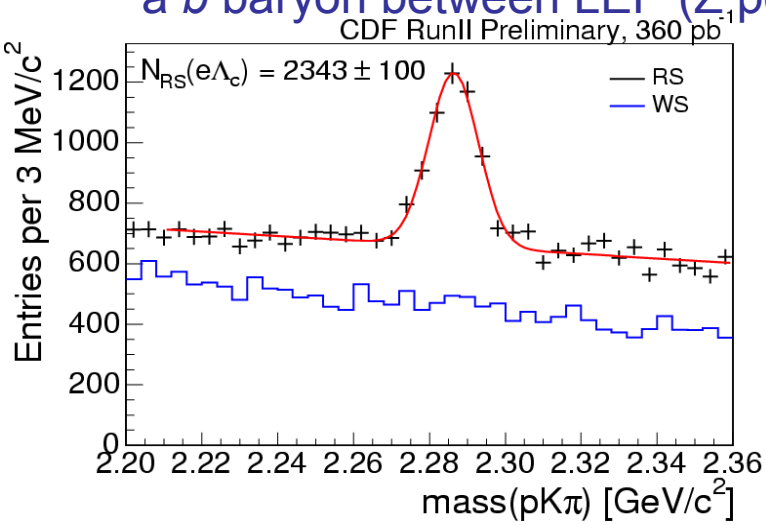
$$\rho^2 = 2.03 \pm 0.46(stat)^{+0.71}_{-1.00}(syst)$$

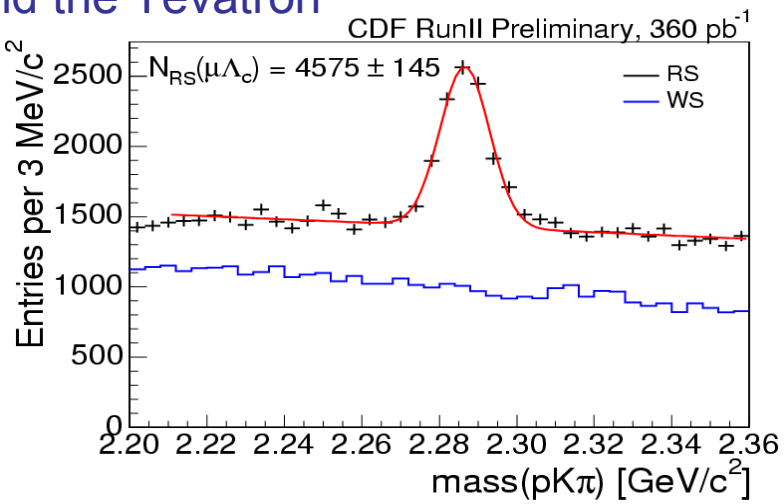
sensitivity:

ρ^2 to ±25%

Hadronization

- Test for difference of probability of hadronization of a *b* quark to a *b* baryon between LEP (Z_0 peak) and the Tevatron





$$\frac{f_{\Lambda_b}}{(f_u + f_d)} = 0.281 \pm 0.012(stat)^{+0.058}_{-0.056}(syst)^{+0.128}_{-0.086}(BR)$$

The average value measured from LEP is using HFAG05 inputs, A.K ratio: →

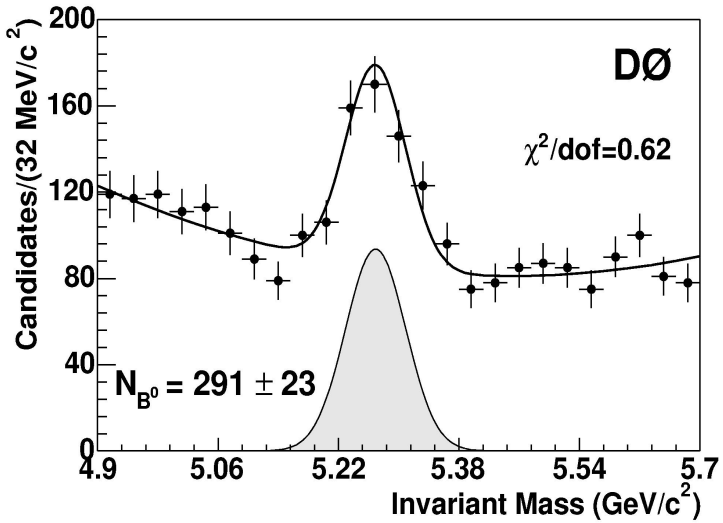
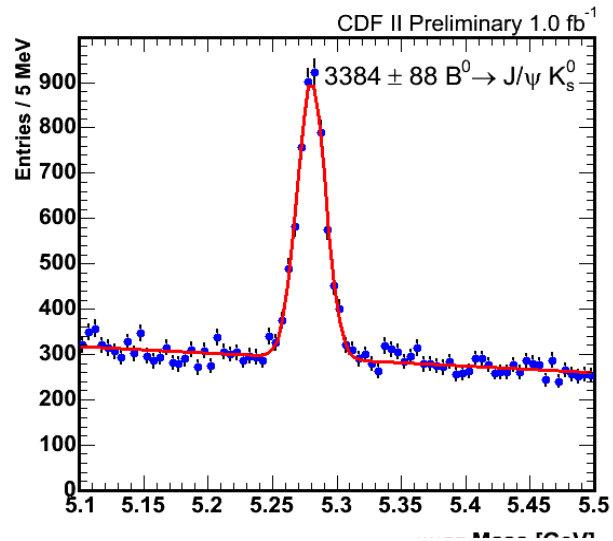
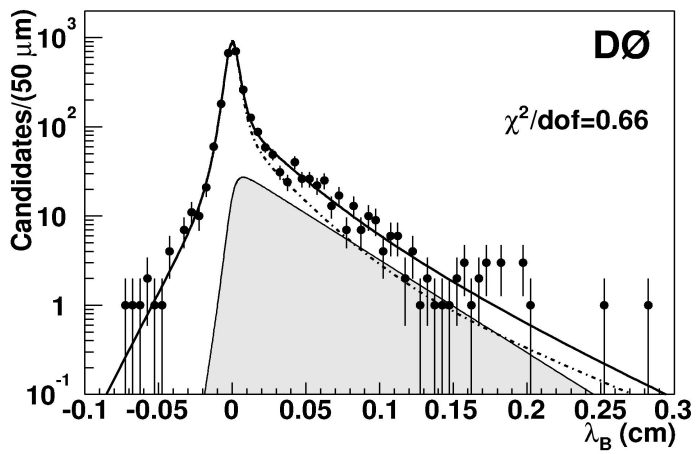
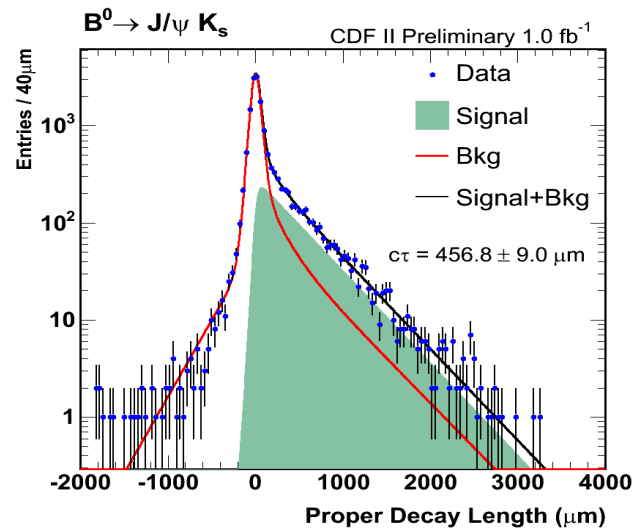
$$\frac{f_{\Lambda_b}}{(f_u + f_d)} = 0.124 \pm 0.021$$

Summary and Outlook

- Tevatron is currently the only running machine producing *b*-baryons
  - Improvements in the Λ_b Lifetime
  - First observation of $\Lambda_b \rightarrow \Lambda_c \pi$
  - First branching ratio measurement $B(\Lambda_b \rightarrow \Lambda_c \mu \nu)/B(\Lambda_b \rightarrow \Lambda_c \pi)$
  - Improvements on the branching fraction limits of charmless decays of Λ_b, probing states with large expected CP violation.
  - Extracting the form factor in semileptonic decays of Λ_b; thus understanding non-perturbative QCD better

- Tevatron will resume Run IIb ~ June 2006
  - DØ has added a Layer 0 silicon detector.
    - Provide much better vertex resolution. Hope to have a higher bandwidth for B physics
  - CDF improving silicon vertex trigger to allow increase of factor of 2 trigger rate. Improve tracking trigger and PC farm to increase purity and utilize higher b physics rate

Coming soon…

- More results will become available this summer
  - DØ
    - Form factor measurement in semileptonic decay of Λ_b
    - Updated $\Lambda_b \rightarrow J/\psi\Lambda$ Lifetime with 1 fb^{-1}
    - Measurement of Λ_b Lifetime in semileptonic decays using 1 fb^{-1}
  - CDF
    - Lifetime measurement in $\Lambda_b \rightarrow \Lambda_c\pi$
    - Updated search for $\Lambda_b \rightarrow pK$ and $\Lambda_b \rightarrow p\pi$ using 1 fb^{-1}
- Stay tuned for these exciting results from Tevatron

Control Sample, $B^0 \rightarrow J/\psi\ K_S$