B Physics Results from the Tevatron: Lifetimes and Rare Decays

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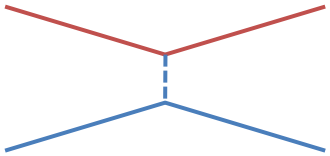
B Hadrons: A Window on New Physics

- System of one heavy and one light quark
  - Accessible from theory
    - Heavy Quark Effective Theory (HQET)
      - Light degrees of freedom decouple from heavy-quark processes
      - Can avoid stepping in the brown muck that binds hadrons
    - Spectator decays dominate
  - Predictions of lifetimes and decay rates
    - Shorter lifetimes indicate additional (non-SM?) decay processes
    - Higher rates than expected from SM in rare modes indicates new physics
      - No tree-level diagram in SM

Lifetime Expectations

- Spectator diagrams dominant

- Non-spectator contributions to B^0 and B_s
  - $\tau(B^+) = (1.06 \pm 0.02) \cdot \tau(B^0)$
  - $\tau(B_s) = (1.00 \pm 0.01) \cdot \tau(B^0)$



- Helicity suppression removed for baryons
  - $\tau(\Lambda_b) = (0.88 \pm 0.05) \cdot \tau(B^0)$

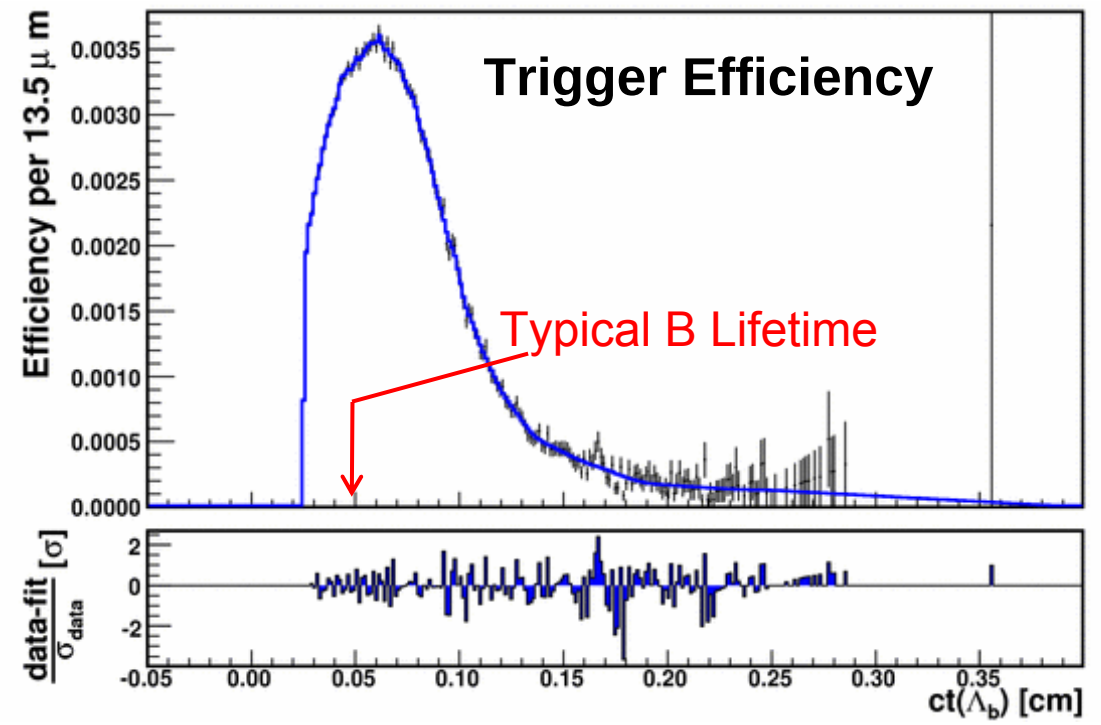
Values: C. Tarantino *et al.*, hep-ph/0310241

Measuring Lifetimes at the Tevatron

- Large signals, but large background
  - 50 mb hadronic cross section; 5 μb B cross section
- Trigger is key
  - Dimuon
    - Very clean but low yields (Product branching ratios ~10^{-5})
  - Single lepton
    - Large yield, but also large backgrounds
    - Precision suffers from missing neutrino
  - Displaced tracks (CDF's SVT)
    - Large yields and full reconstruction
    - Decay length distribution sculpted by trigger
- Focus on B_s, Λ_b, B_c -- Not accessible at e^+e^- factories

Λ_b Lifetime

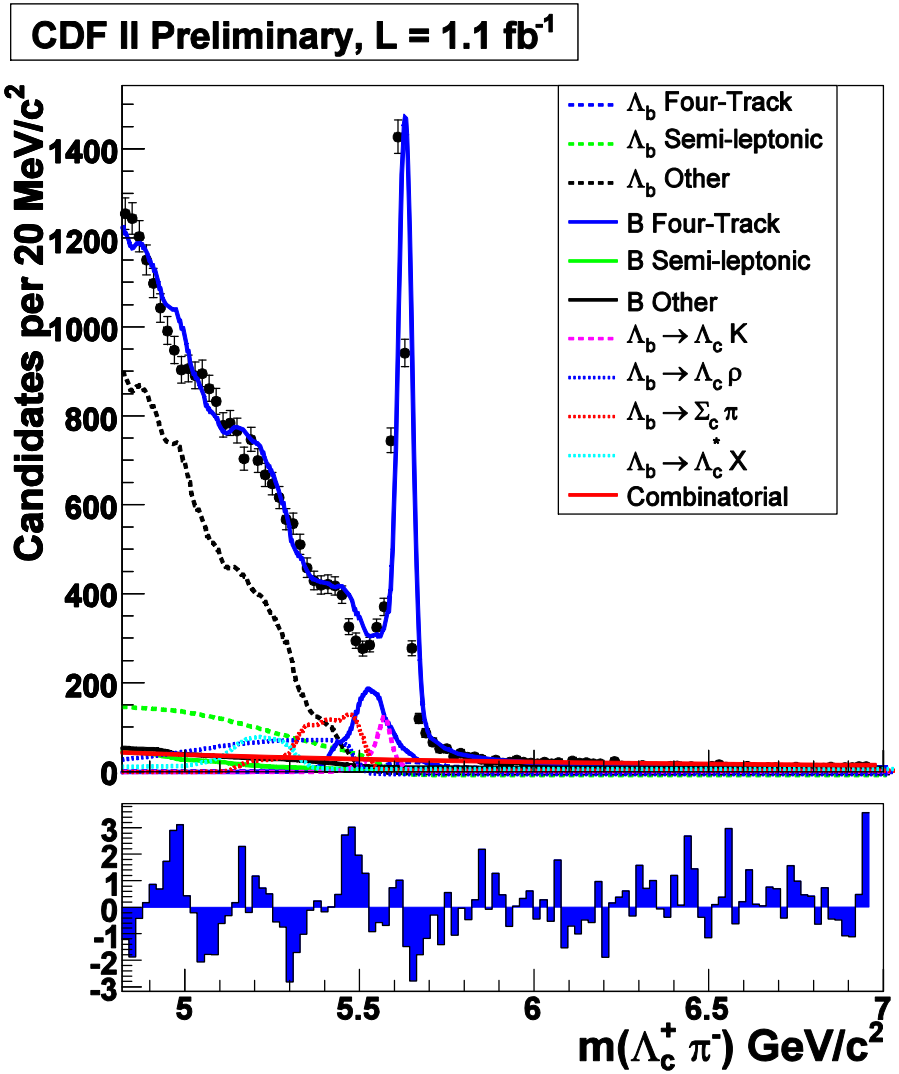
- Hadronic Decays
  - $\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^-$
  - $\Lambda_c^+ \rightarrow pK^-\pi^+$
- Two-track trigger
  - Two tracks $100\mu m < d_0 < 1mm$
  - $L_{xy} < 200\mu m$
  - $2^\circ < \Delta\phi < 90^\circ$
  - Kinematic cuts depend on running conditions



- Extensive tuning of Monte Carlo
  - Trigger performance
  - Match kinematics in data

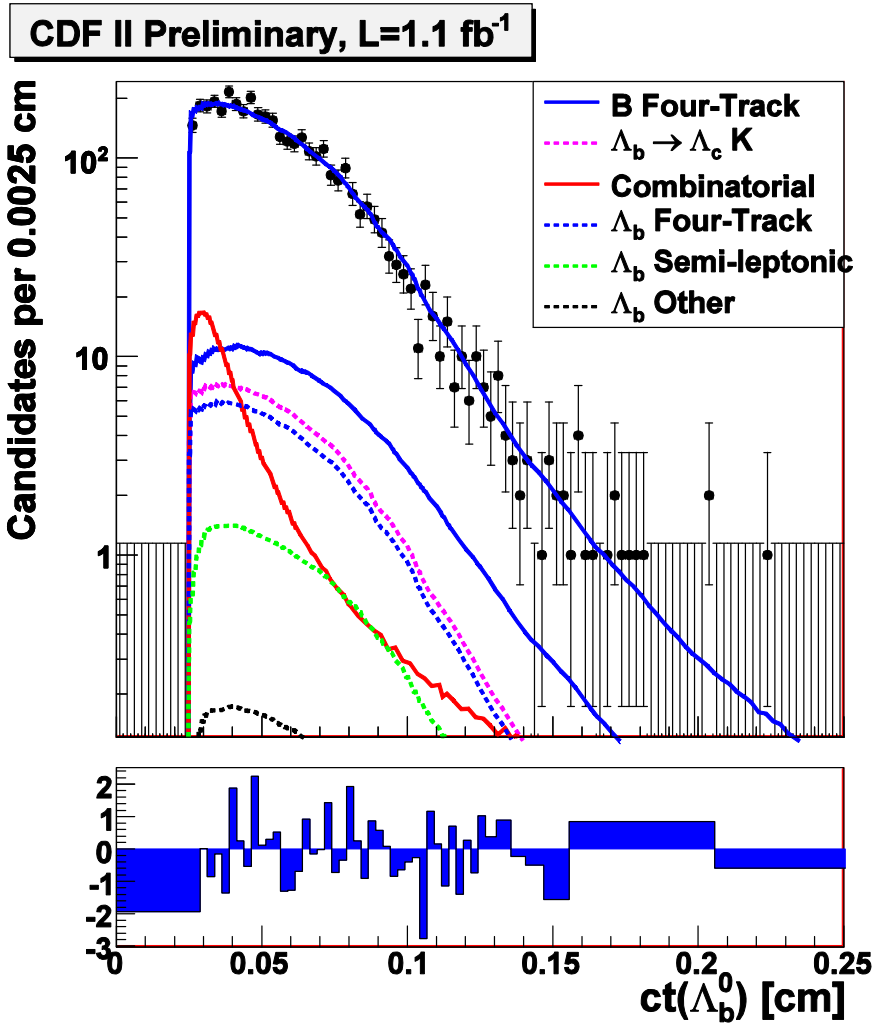
Λ_b Candidates

- Sample composition fixed from mass distribution
- Signal: 2927±58

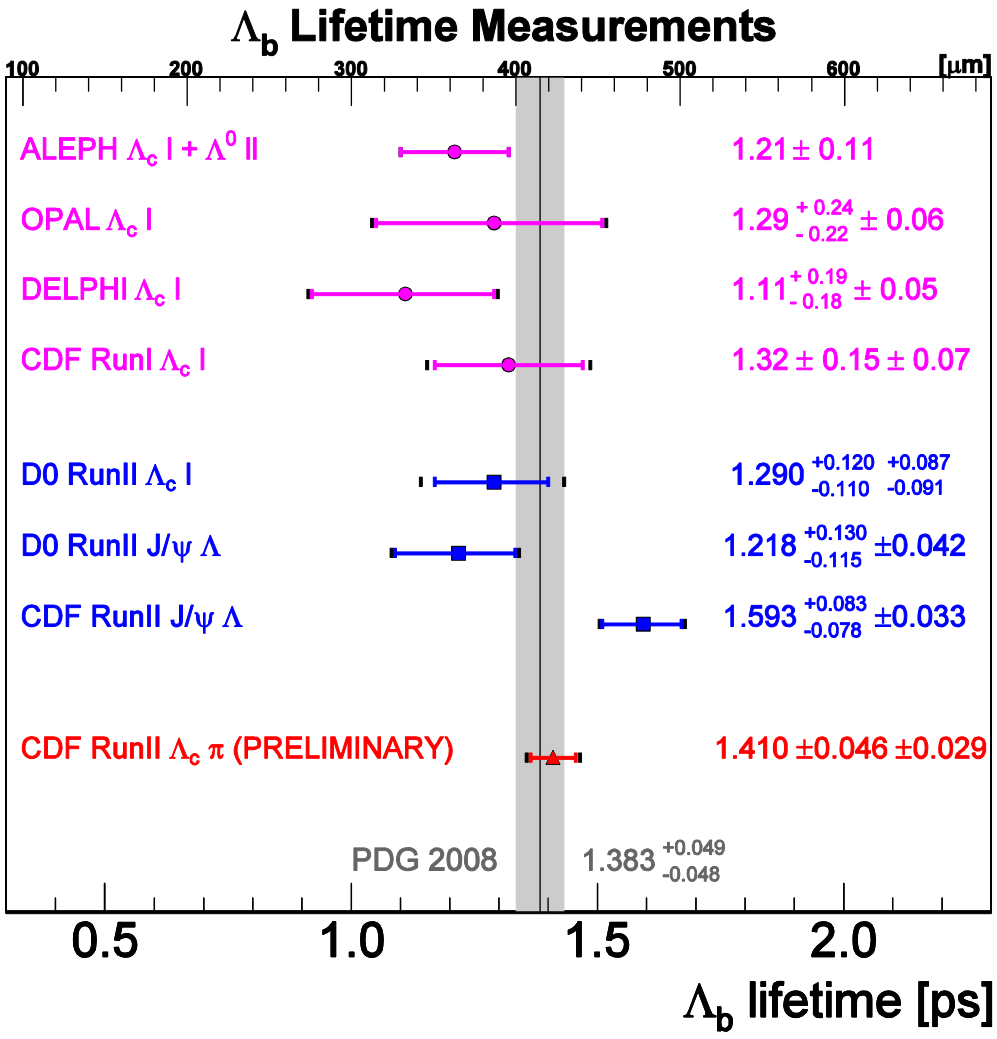


Lifetime Fit

- PDF is convolution of
  - Exponential
  - *ct* resolution PDF
  - Trigger efficiency
- Result
  - $c\tau = 422.8 \pm 13.3 \pm 8.8\ \mu m$
    - Systematic dominated by trigger modeling



Comparisons

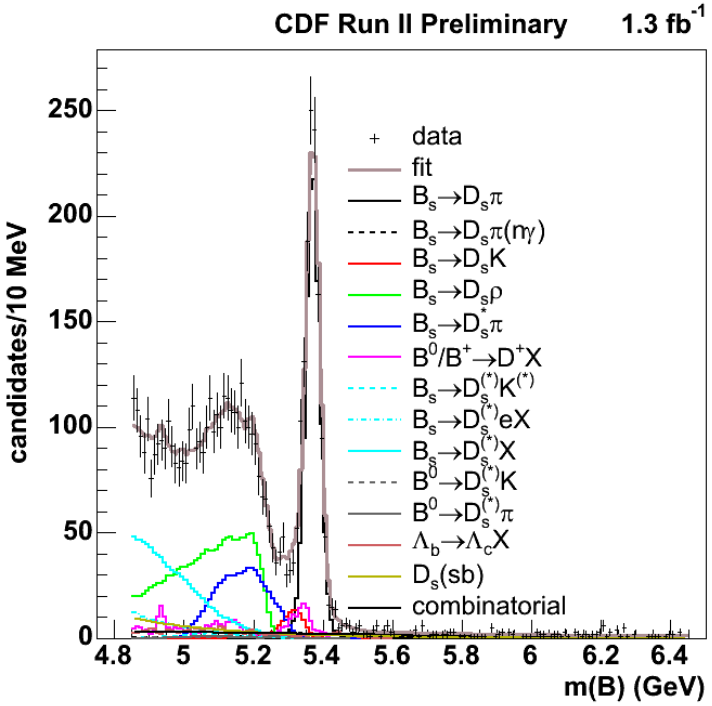


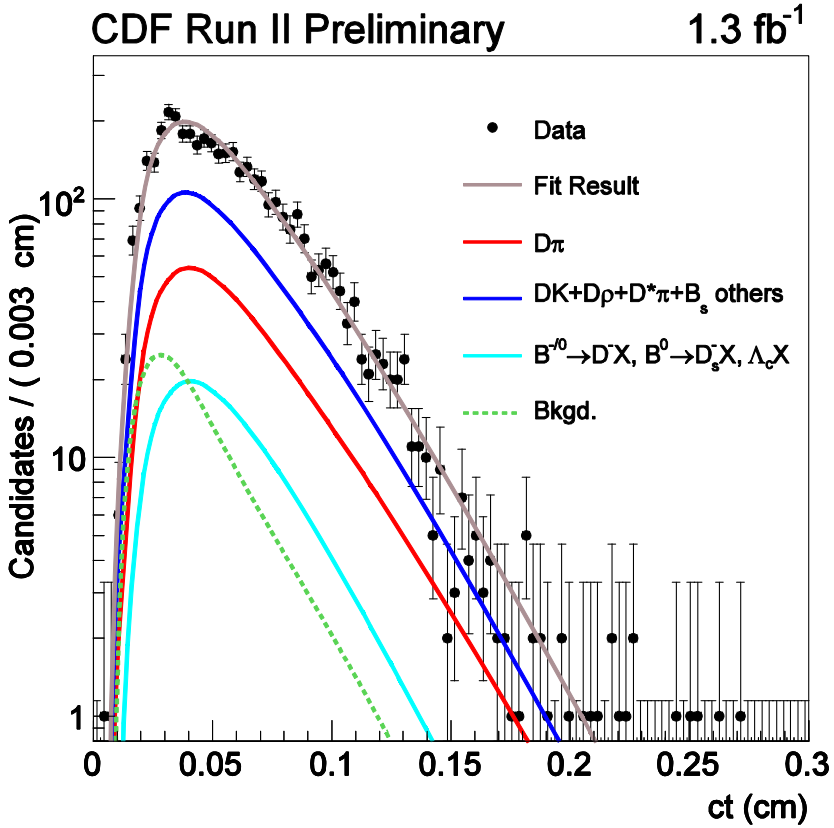
Measurement as good as prior world average

- Discrepancy between CDF's prior measurement and earlier results remains
- New result consistent with both and expectation

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

B_s Lifetime (CDF)



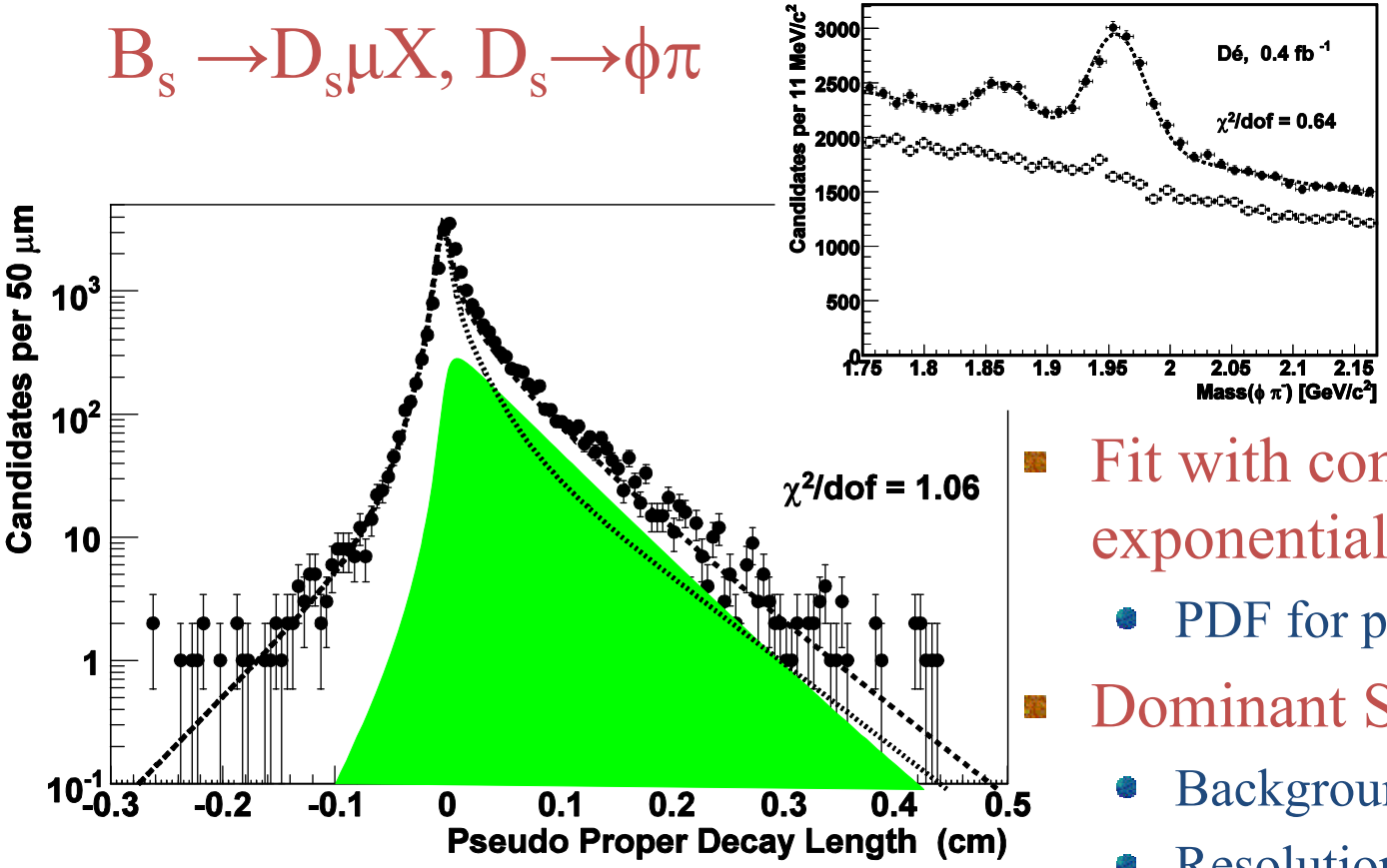


- $B_s \rightarrow D_s\pi$, $D_s \rightarrow \phi\pi$
  - 1100 events
- Add partially reconstructed events
  - $D_s^*\pi$ & $D_s\rho$
  - 2200 events

$c\tau = 455.0 \pm 12.2 \pm 8.2\ \mu m$

B_s Lifetime: Semileptonic (DØ)

$B_s \rightarrow D_s \mu X$, $D_s \rightarrow \phi\pi$



$c\tau = 419.1 \pm 13.2 \pm^{8.4}_{7.5}$ μm

- Fit with convolution of exponential with K-factor
  - PDF for $p_T(D_s\mu)/p_T(B_s)$
- Dominant Systematics
  - Background model
  - Resolution model
  - K factor

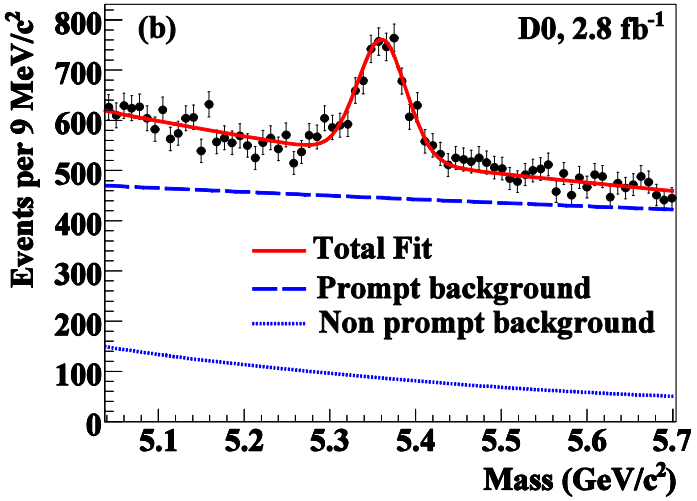
B_s Lifetime: $J/\psi\,\phi$

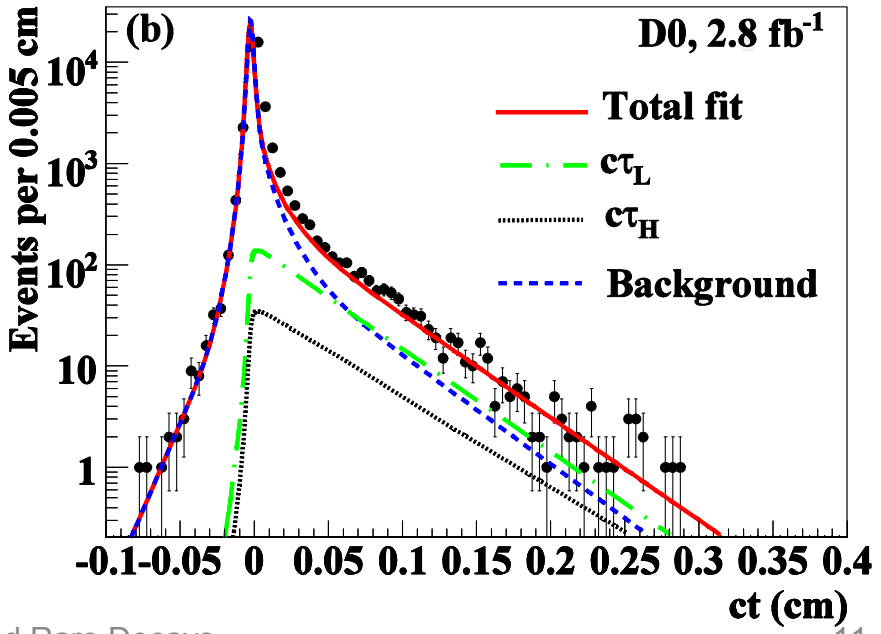
- Use angular information to measure three polarization amplitudes
- Extract lifetimes for CP-odd (heavy) and CP-even (light) eigenstates
- Mean lifetime:

  D0: $c\tau$=445.8±18.0±8.4 μm

  CDF: $c\tau$=459±12±3 μm

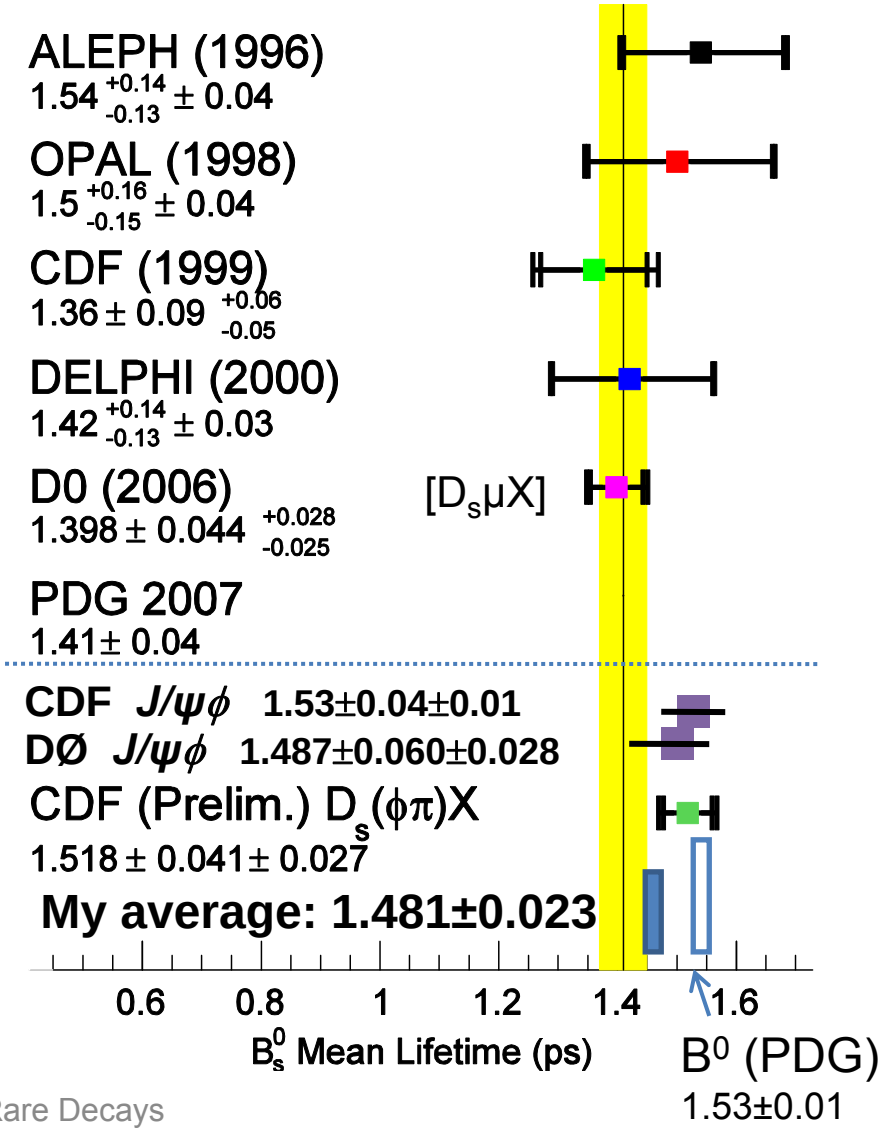
  - Results are mean of heavy and light states.
  - Difference from flavor specific measurement smaller than error given limits on Γ_s





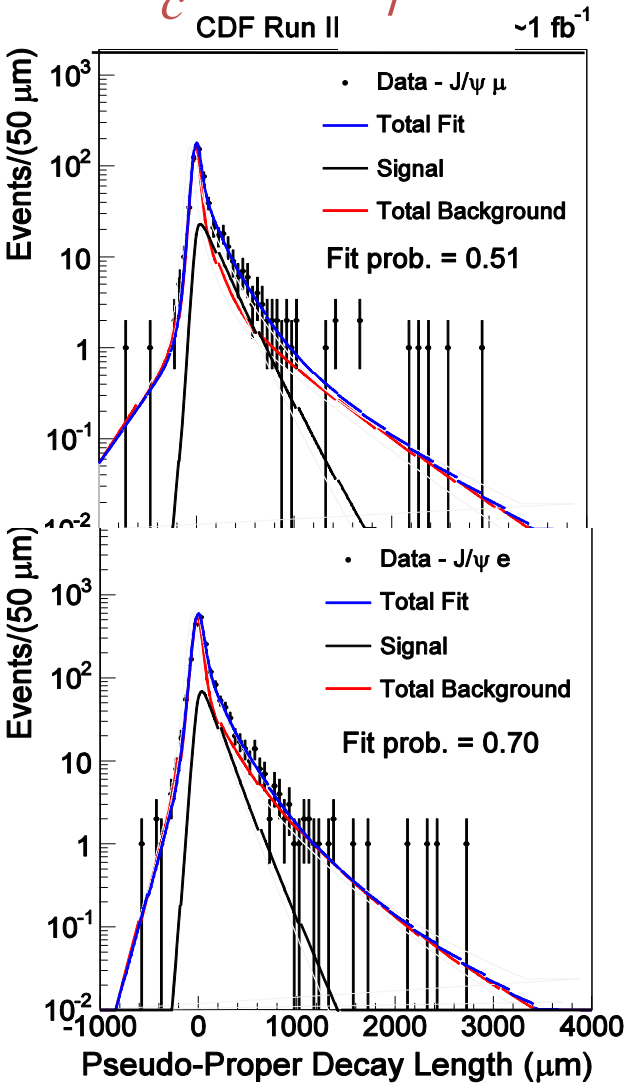
B_s Lifetime: Summary

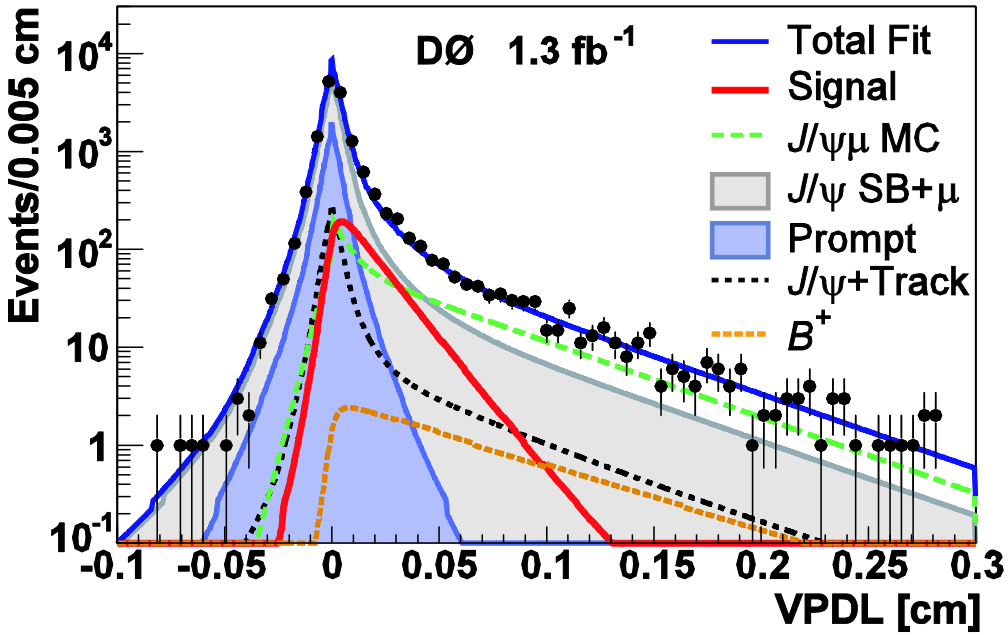
- Both newer measurements greater than earlier average
  - Strongly weighted by semileptonic channel from DØ
- Still have ~2σ discrepancy between data and expectation $\tau(B_s) \approx \tau(B^0)$



B_c

- $B_c \to J/\psi\, \ell\, X$





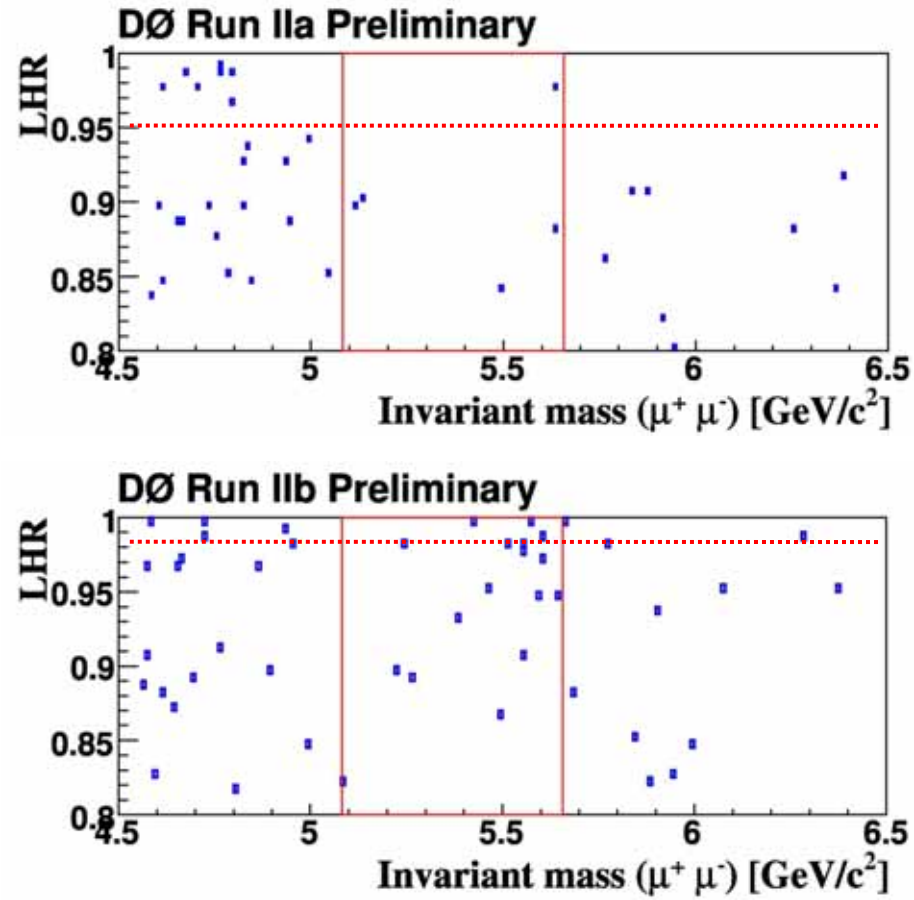
- CDF: $\tau(B_c) = 0.475^{+0.053}_{-0.049} \pm 0.018$ ps
- DØ: $0.448^{+0.038}_{-0.036} \pm 0.032$ ps
- Naïve mean: 0.460±0.036 ps
- Conforms to expectation
  - $\Gamma(B_c) \approx \Gamma_b + \Gamma_c$

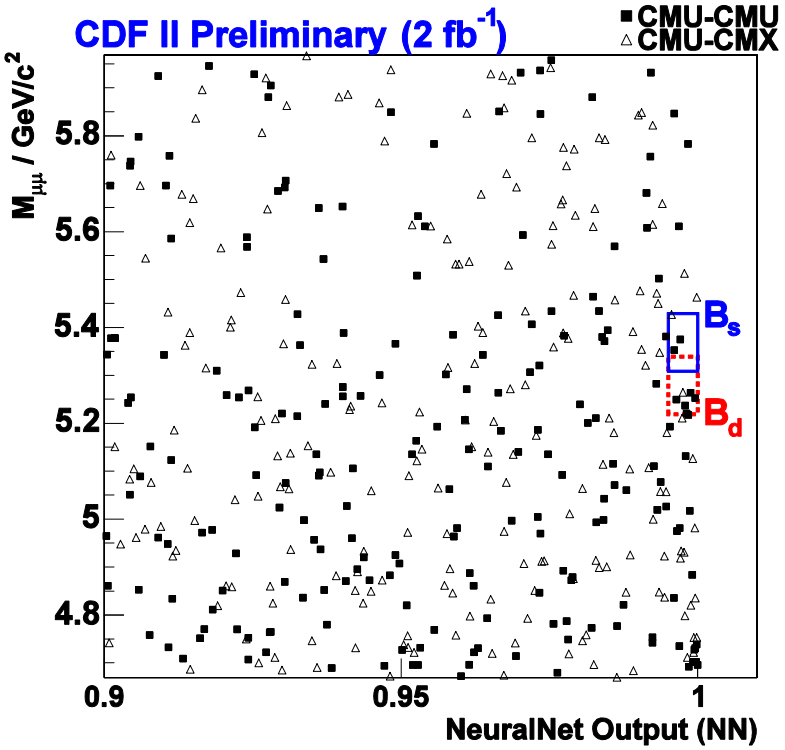
Rare Decays: $B_s \rightarrow \mu^+\mu^-$

- FCNC forbidden at tree level in Standard Model
  - Expect $3.5 \pm 0.5 \times 10^{-9}$
  - BR($B_d \rightarrow \mu^+\mu^-$) $\sim 10^{-10}$
    - Suppressed by $|V_{td}/V_{ts}|^2$
- Two experiments use similar methods
  - Multivariate selection
    - Kinematic, vertex and candidate isolation quantities
    - DØ likelihood ratio, CDF neural net
  - Normalize to $B^+ \rightarrow J/\psi\, K^+$

$B_s \rightarrow \mu^+\mu^-$: Results (2 fb^{-1})

DØ: <9.3×10^{-8} (95% CL) **CDF: <5.8×10^{-8} (95% CL)**

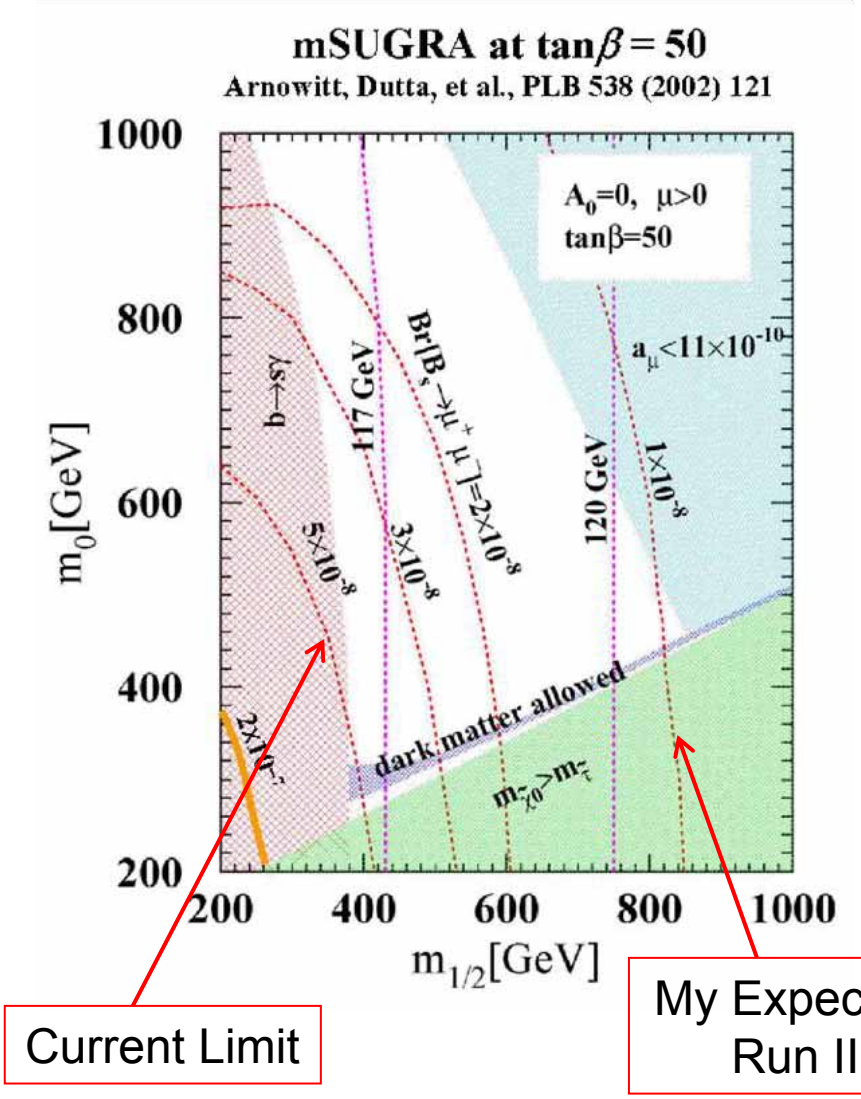




BR($B_d \rightarrow \mu^+\mu^-$) <$1.5\times10^{-8}$

- Also world's best

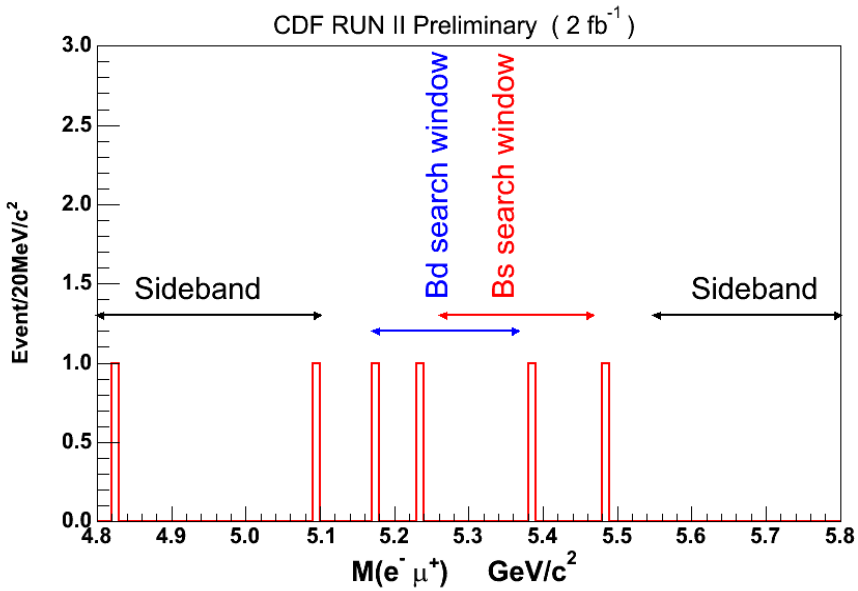
$B_s \rightarrow \mu^+\mu^-$: Significance & Outlook

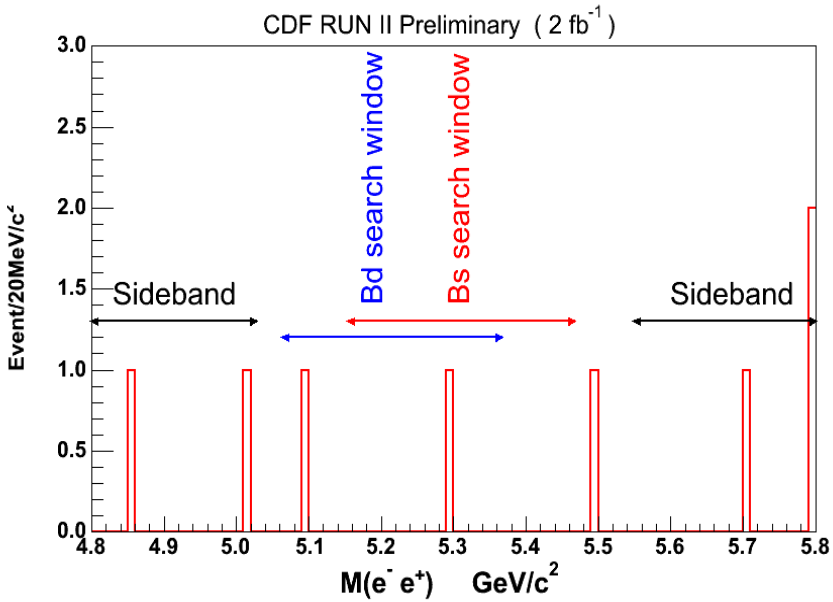


- Expect sensitivity to get better
  - DØ: detector and analysis improvements
  - CDF: tighter rejection possible with more data
- Expect combined limit $O(10^{-8})$ by end of Run II
  - Significant constraints on New Physics

CDF: $B_{d,s} \rightarrow e^+\mu^-$, e^+e^-

- $B_{d,s} \rightarrow e^+\mu^-$ essentially forbidden in SM
  - Possible with SUSY, ED, or lepto-quarks
- $BR(B \rightarrow e^+e^-) \sim 10^{-15}$ expected in SM
  - relative to $B \rightarrow K\pi$ in displaced track sample
  - 95% CL Limits





$BR(B_s \rightarrow e^+\mu^-) < 2.6 \times 10^{-7}$, $M_{LQ} > 44$TeV

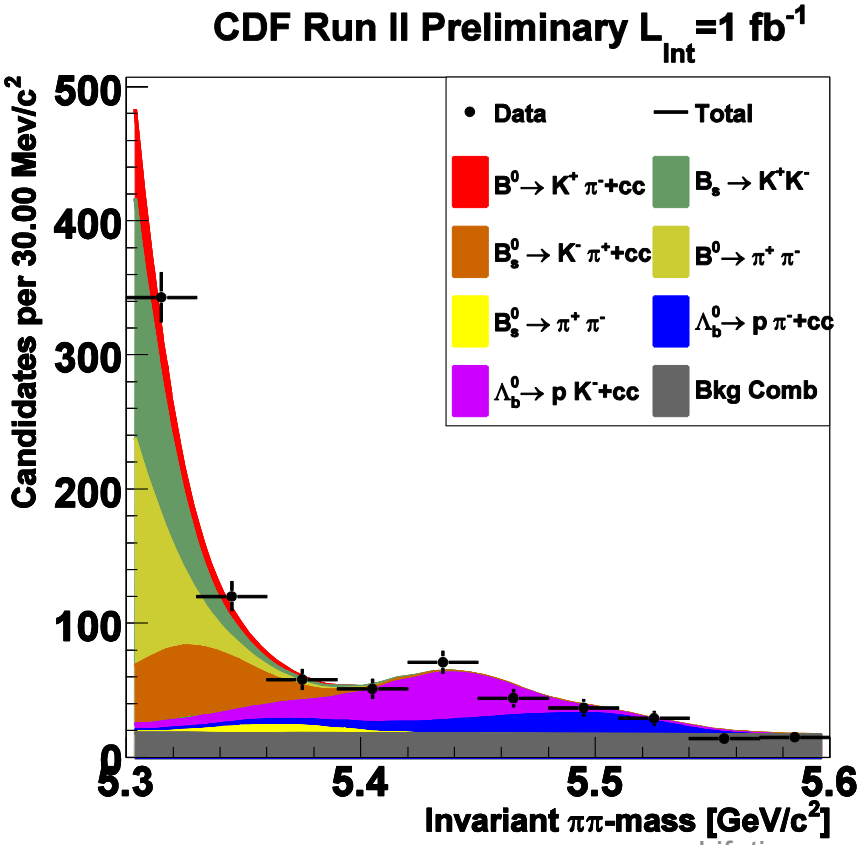
$BR(B_d \rightarrow e^+\mu^-) < 7.9 \times 10^{-8}$, $M_{LQ} > 55$TeV

$BR(B_s \rightarrow e^+e^-) < 3.7 \times 10^{-7}$

$BR(B_d \rightarrow e^+e^-) < 1.1 \times 10^{-7}$

$\Lambda_b^0 \to pK^-$,$p\pi^-$

- Displaced track sample
- Use mass and particle ID (dE/dx) in likelihood fit
- Normalize to $B^0 \to K\pi$
- Use $\pi\pi$ mass to for consistent treatment across modes



- $BR(\Lambda_b^0 \to pK^-) = 3.1 \pm 0.6 \pm 0.7 \times 10^{-6}$

  $BR(\Lambda_b^0 \to p\pi^-) = 5.0 \pm 0.7 \pm 1.0 \times 10^{-6}$
  - Factor 2 smaller with CDF value of f_Λ/f_b
  - Inconsistent with R-parity violating MSSM at $O(10^{-4})$
- $A_{CP}(\Lambda_b^0 \to pK^-) = 0.37 \pm 0.17 \pm 0.03$

  $A_{CP}(\Lambda_b^0 \to p\pi^-) = 0.03 \pm 0.17 \pm 0.05$
  - Consistent with SM expectation of ~0.3

Conclusions

- The study of bottom hadrons continues to put physics beyond the Standard Model in a box
- That box will get smaller soon
  - Today's results are 1-2 fb^{-1}
  - 5 fb^{-1} on tape and colleting ~50 pb^{-1}/week