Properties of heavy-flavoured hadrons at CDF

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(for the CDF Collaboration)

Properties:

- Focus on masses , lifetimes (decays)

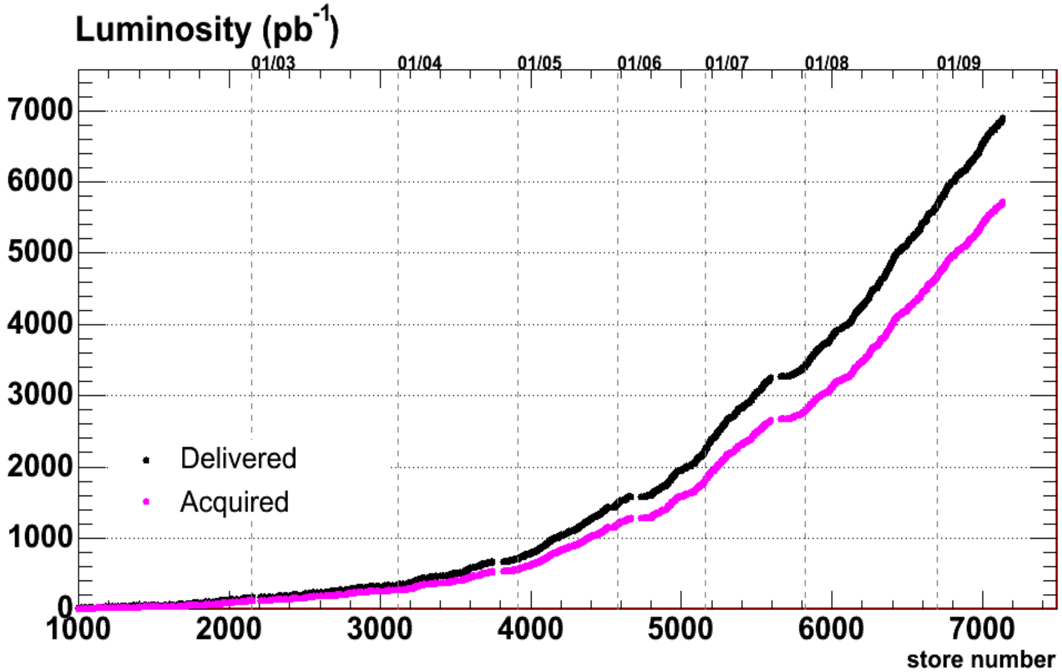
Why study B hadrons ?

- Heavy quark hadrons are the hydrogen atom of QCD => study of B hadron states = study of (non-perturbative) QCD
- Measurements of B hadron masses provide sensitive tests of potential models, HQET and all aspects of QCD including lattice gauge calculations

Why B Hadron Lifetimes ?

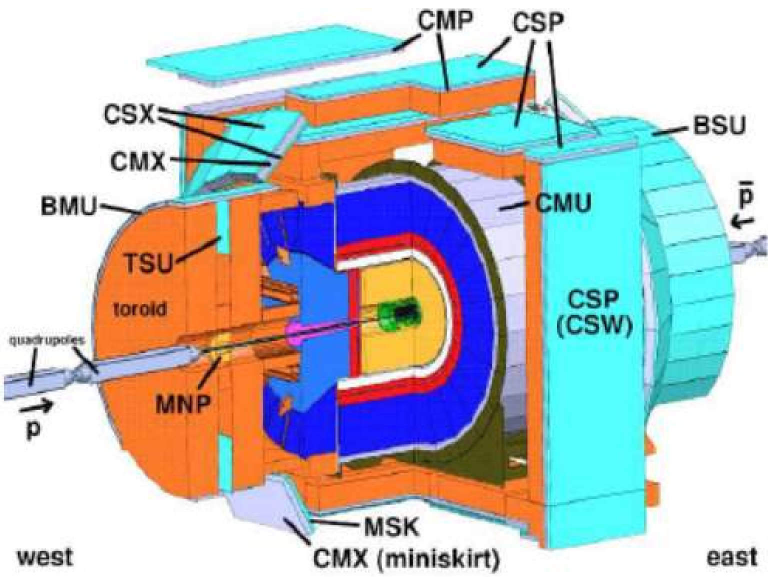
- Spectator model : b quark decays like free particle => all B hadron lifetimes are equal
- In reality QCD => lifetimes of B hadrons study the interplay between strong and weak interaction

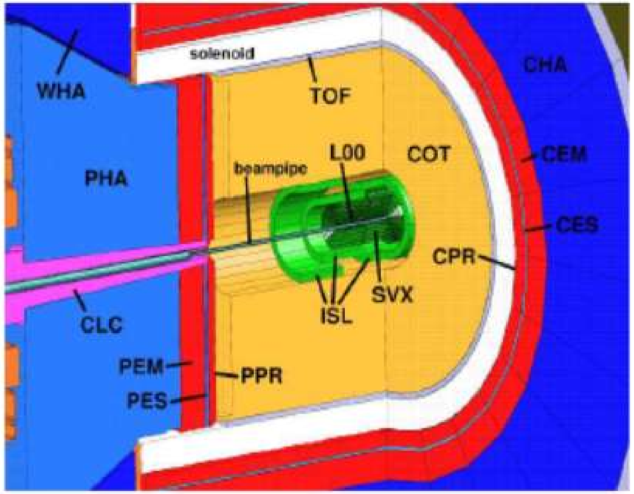
Introduction to the Tevatron



- ppbar collisions at 1.96 TeV
- Excellent performance of Tevatron accelerator
- Keep breaking record of peak Initial Luminosity after 8 years of running
- CDF and D0 have already ~ **6 fb^{-1}** on tape
- Expect 9 fb^{-1} by end 2010 (12 fb^{-1} by end 2011)
- The analyses presented in this talk span from 1 to 3.8 fb^{-1}

CDF detector





•Drift chamber (COT)

⇒ Good tracking resolution

$\sigma(p_T)/p_T \sim 0.1$ % GeV^{-1}

• Silicon vertex detector

⇒ Good vertex resolution

⇒ Important for triggering

(using a displaced track trigger, SVT)

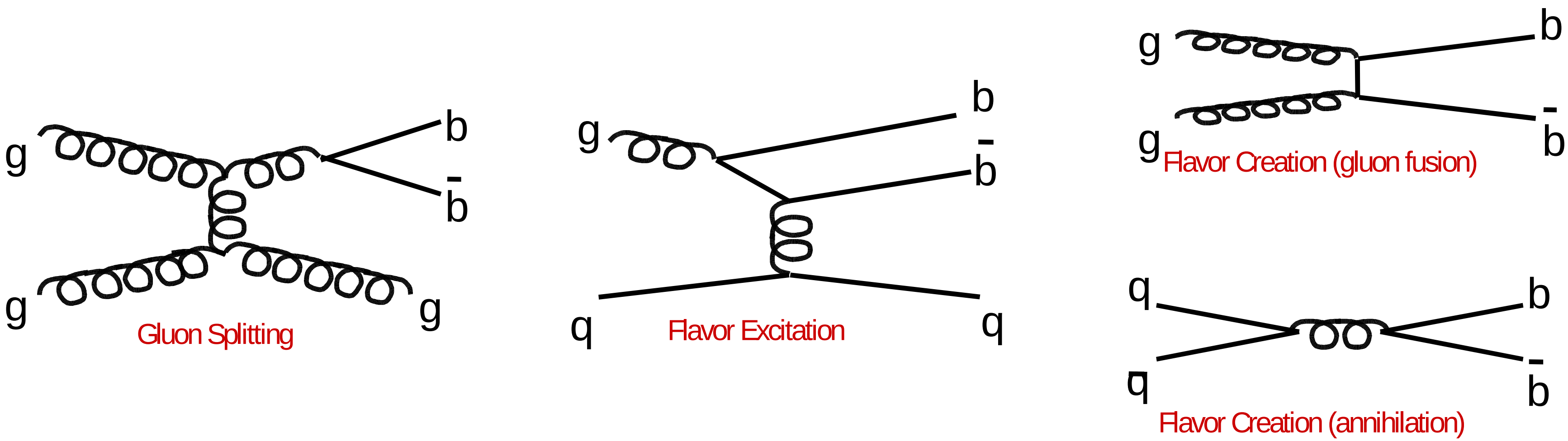
• TOF detector and dE/dx from COT

⇒ Good particle identification

• Muon System up to $|\eta| < 1.5$

⇒ Important for triggering

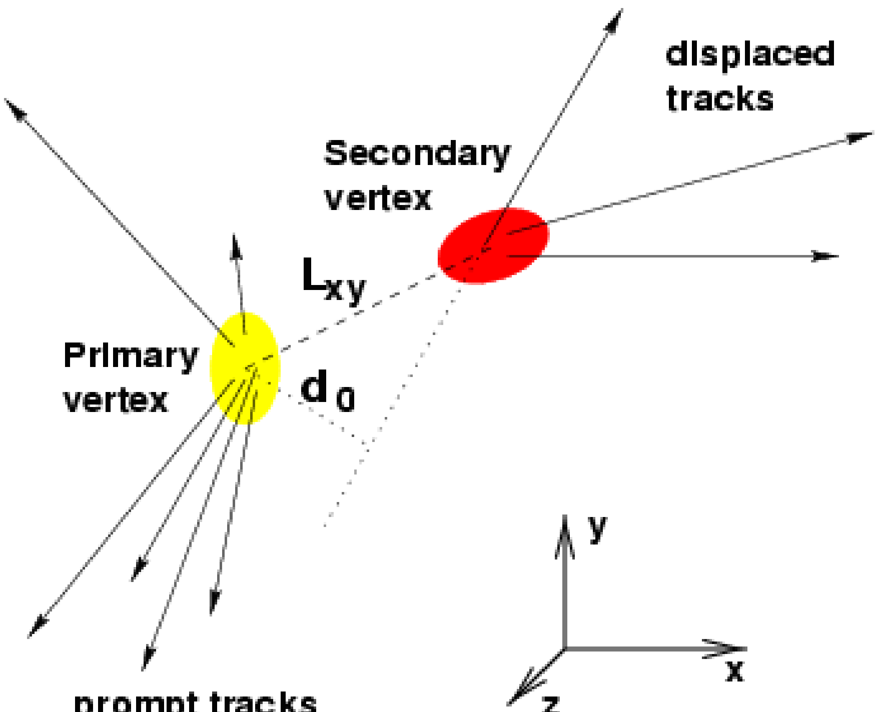
Basics of B Physics at the Tevatron

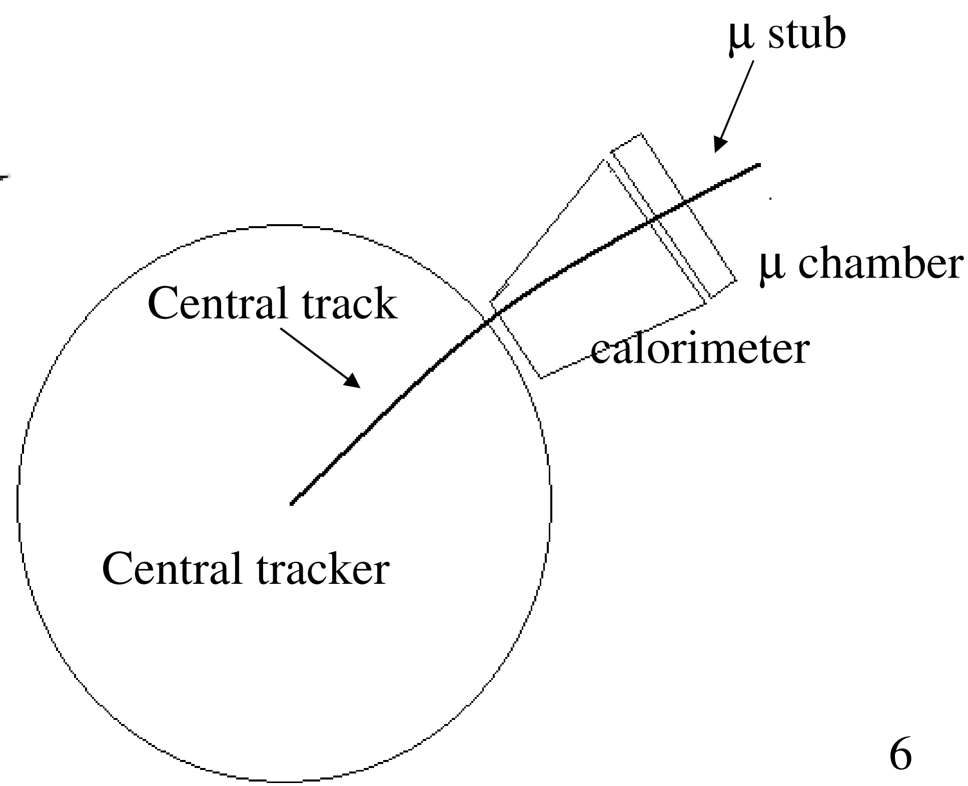


- High cross section σ ($\mathbf{p\bar{p} \rightarrow b\bar{b}}$) ~ 40 μb at $\sqrt{s}$ = 2 TeV
- Quarks fragment into hadrons: B_c^- ($b\bar{c}$), Λ_b(bdu), Ω_b(bss), Σ_b^+ (buu), Σ_b^- (bdd) [Tevatron exclusive], B_s^0 ($b\bar{s}$), B_0($b\bar{d}$), B^-(bu), also B*, B**, etc
- $\rightarrow$ Tevatron can be considered as a B factory

Online B selection process

- Huge background to the process σ ($p\bar{p} \rightarrow b\bar{b}$) in Tevatron: O(0.05 b)!
- B hadrons are filtered online using selective triggers based on clear signatures that overcome the QCD background :
  - events selected by a $J/\psi \rightarrow \mu\mu$ oriented dimuon trigger
  - events selected by an impact parameter based trigger (SVT)





Results :

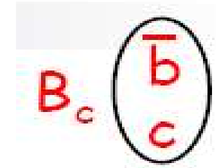
B_c mass, lifetime and cross section

Λ_b lifetime in $\Lambda_b \rightarrow \Lambda_c \pi$

B_s lifetime

Σ_b Baryon mass

B_c lifetime

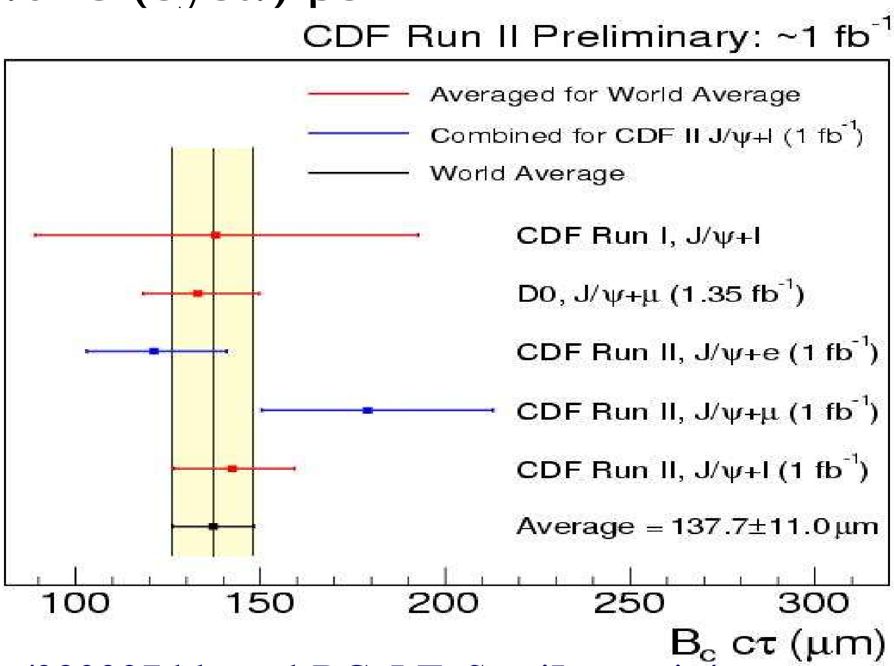


- B_c contains two heavy quarks: bottom and anti-charm
- Produced only at the Tevatron → unique testing ground for QCD
- Lifetime measurement in semileptonic decays $B_c \rightarrow J/\Psi + l + X$

$$\tau c\,(B_c) = 142.5\,^{+15.8}_{-14.8}(\text{stat.}) \pm 5.5\,(\text{syst.})\ \mu\text{m}$$

$$\tau = 0.475\,^{+0.053}_{-0.049}(\text{stat.}) \pm 0.018\,(\text{syst.})\ \text{ps}$$

Theoretical predictions:
0.47-0.59 ps



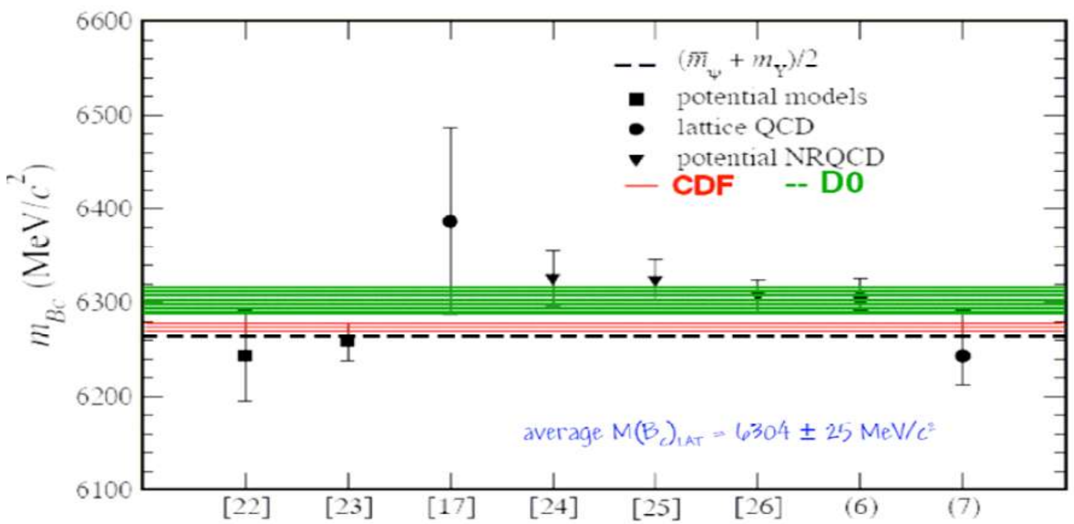
http://www-cdf.fnal.gov/physics/new/bottom/080327.blessed-BC_LT_SemiLeptonic/

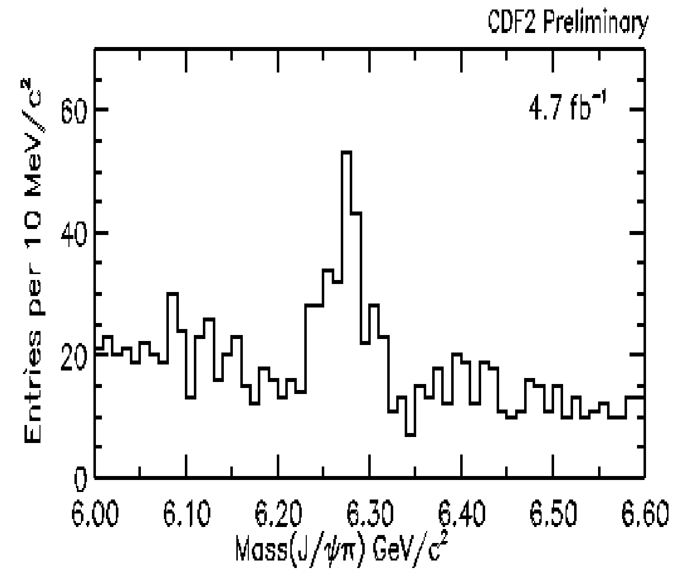
B_c mass

- Best mass measurement from CDF in $B_c \rightarrow J/\Psi\pi$ decays (2.4 fb^{-1})

  $m(B_c) = 6275.6 \pm 2.9 \pm 2.5$ MeV/c (PRL 100:182002,2008)

good agreement with theory (6304 ± 12+18-0) Phys. Rev. Lett. 94, 172001 (2005)





Horizontal axis corresponds to different theory predictions

Experimental measurements with small uncertainties start to challenge theoretical models and lattice techniques

- Recent update (4.7 fb^{-1})
  - analysis framework is unchanged from PRL
  - uses improved track parameter uncertainties

B_c cross section

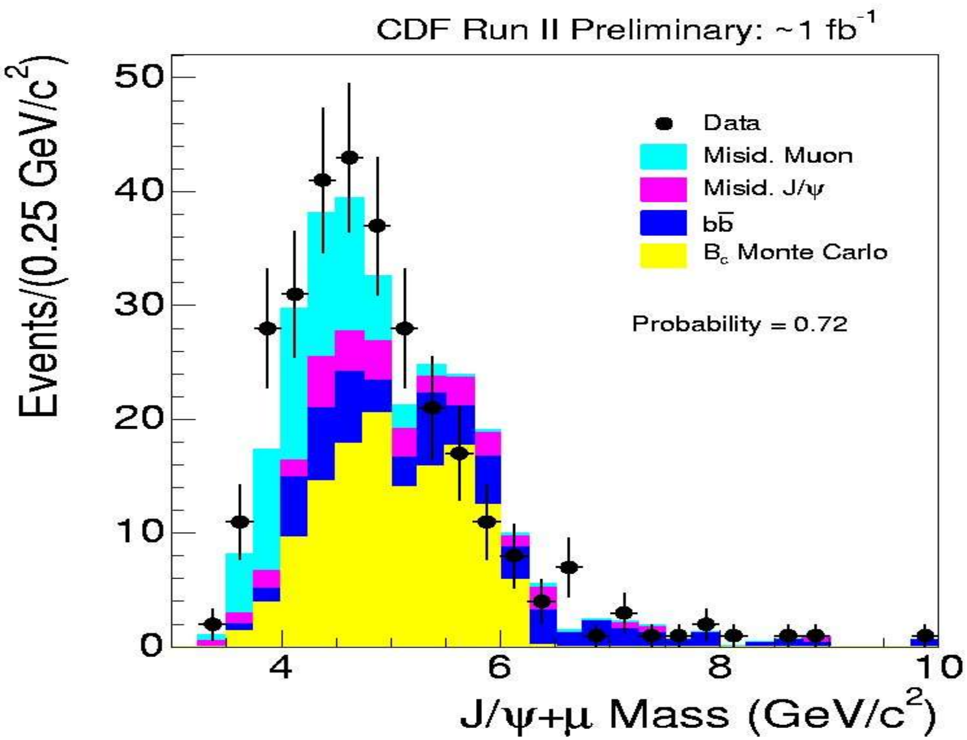
- Ratio of the production cross section times branching fraction of $B_c^+ \rightarrow J/\Psi\ \mu\ \nu$ relative to $B^+ \rightarrow J/\Psi K^+$ for two $p_T(B)$ cuts with 1 fb^{-1} .

- Select sample of 229(214) events with 3rd muon for $p_T(B_c)$>4GeV/c (6)

- Estimate background contributions using data and PYTHIA samples

  - misidentified J/Ψ & μ
  - bb background
  - Total : 111 ± 8

  (107 ± 8) events



- Select $B^+ \rightarrow J/\Psi K^+$

http://www-cdf.fnal.gov/physics/new/bottom/090305.blessed-bc-slXsec/

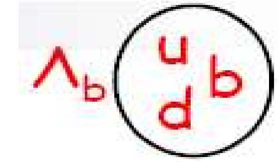
B_c cross section

$$\frac{\sigma(B_c^+)\cdot BR(B_c^+ \to J/\psi + \mu^+ + \nu)}{\sigma(B^+)\cdot BR(B^+ \to J/\psi + K^+)} = \frac{N_{B_c^+}}{N_{B^+}} \times \epsilon_{rel}$$

- ε_{rel} , relative efficiency : $\varepsilon_{rel} = \varepsilon_{B+} / \varepsilon_{Bc}$.

	Pt (B) > 4 GeV/c	Pt(B) > 6 GeV/c
$N(B_c^+)$	$117.6 \pm 17.2_{-6.4}^{+8.3}$	$107.1 \pm 16.7_{-6.1}^{+7.9}$
$N(B^+)$	2333 ± 55	2299 ± 53
ε_{rel}	5.867 ± 0.068	4.873 ± 0.060
	${}_{-0.450}^{+0.554} \pm 0.720$	${}_{-0.278}^{+0.420} \pm 0.298$
$\frac{N(B_c^+)}{N(B^+)} \times \varepsilon_{rel}$	0.295 ± 0.040 (stat) ${}_{-0.026}^{+0.033}$(sys) ± 0.036(spectrum)	0.227 ± 0.033 (stat) ${}_{-0.017}^{+0.024}$(sys)± 0.014

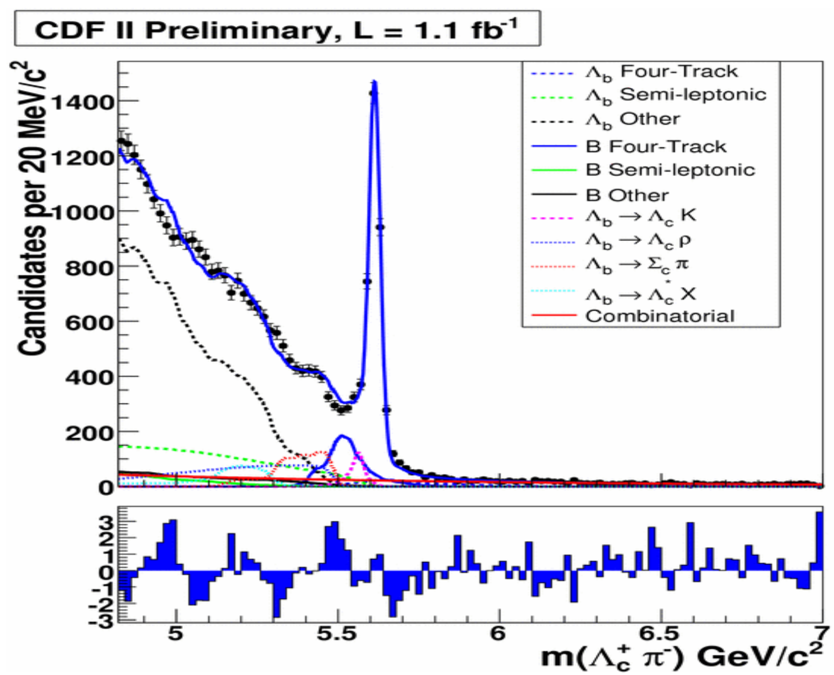
Λ_b lifetime in $\Lambda_b \rightarrow \Lambda_c\pi$



- Important test of models that describe interaction between heavy and light quarks within bound states
- Precise theoretical predictions difficult due to QCD effects.

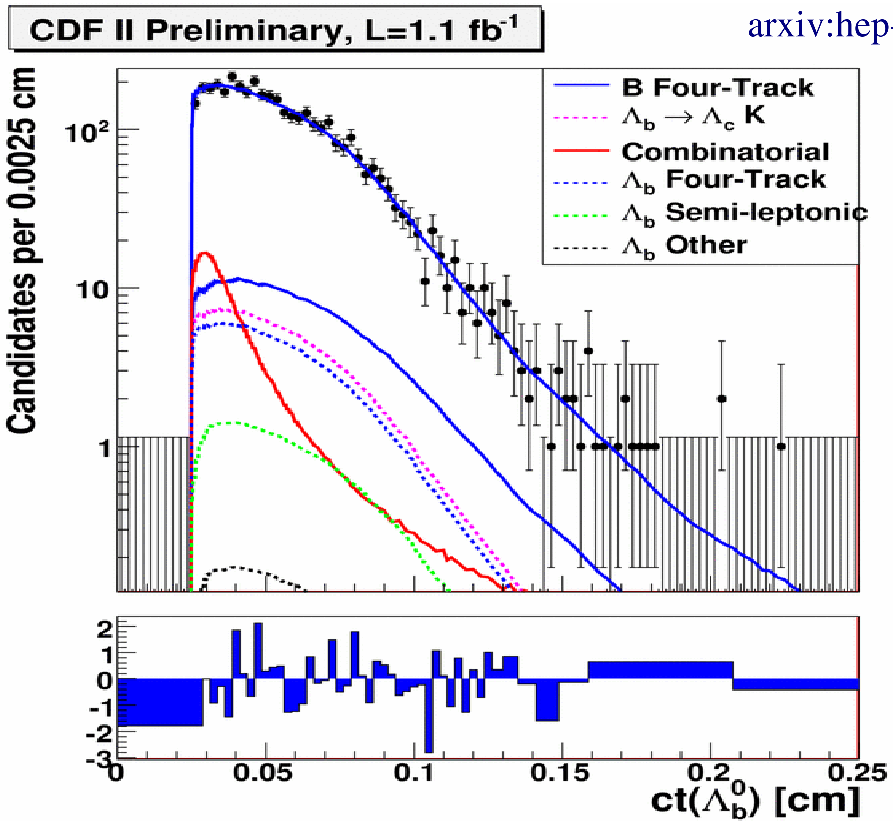
OPE/HQET predicts lifetime hierarchy of the b-hadrons

- CDF analysis with large sample of ~3000 signal events in 1.1 fb^{-1}
- Displaced track trigger requirements : 120 μm< IP < 1 mm
- Trigger bias corrected using simulation
- Sample composition obtained from mass distribution

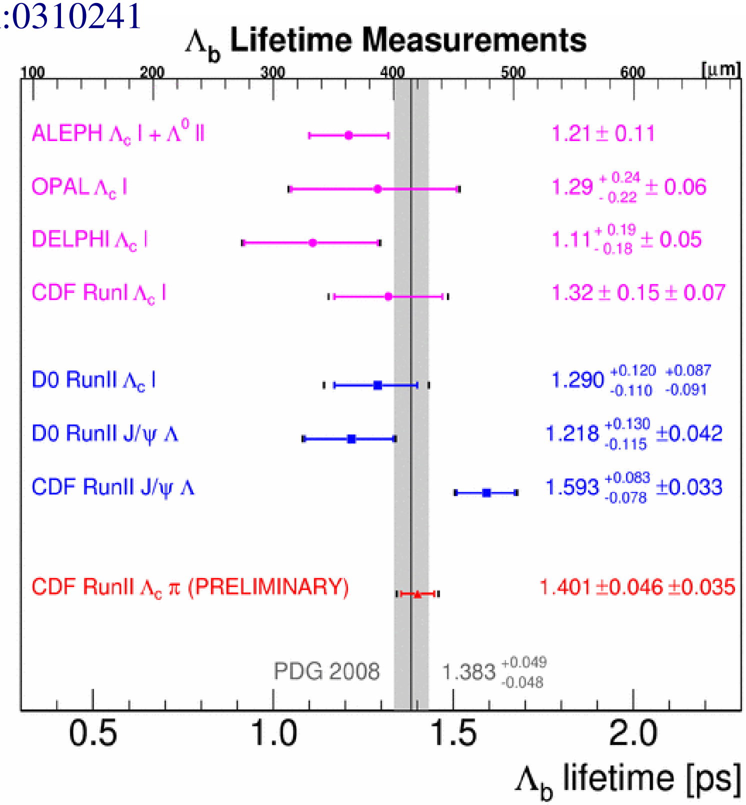


Λ_b lifetime results

- PDF is convolution of : exponential , cτ resolution PDF, trigger eff.
- Most precise measurement: $\tau c(\Lambda_b) = 420.1 \pm 13.7(\text{stat.}) \pm 10.6\ (\text{syst.})\ \mu m$
- $\tau(\Lambda_b)/\tau(B_0) = 0.916 \pm 0.038$
- Good agreement with theory (0.88 ± 0.05) and previous world average



arxiv:hep-ph:0310241

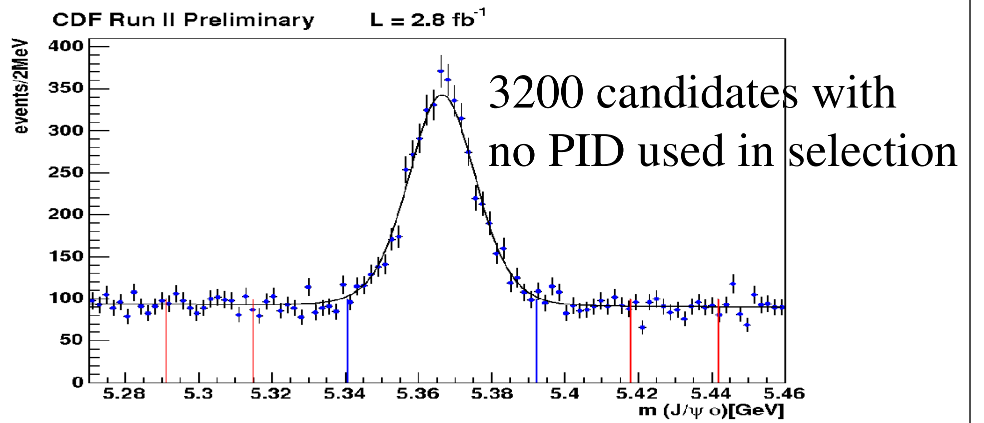


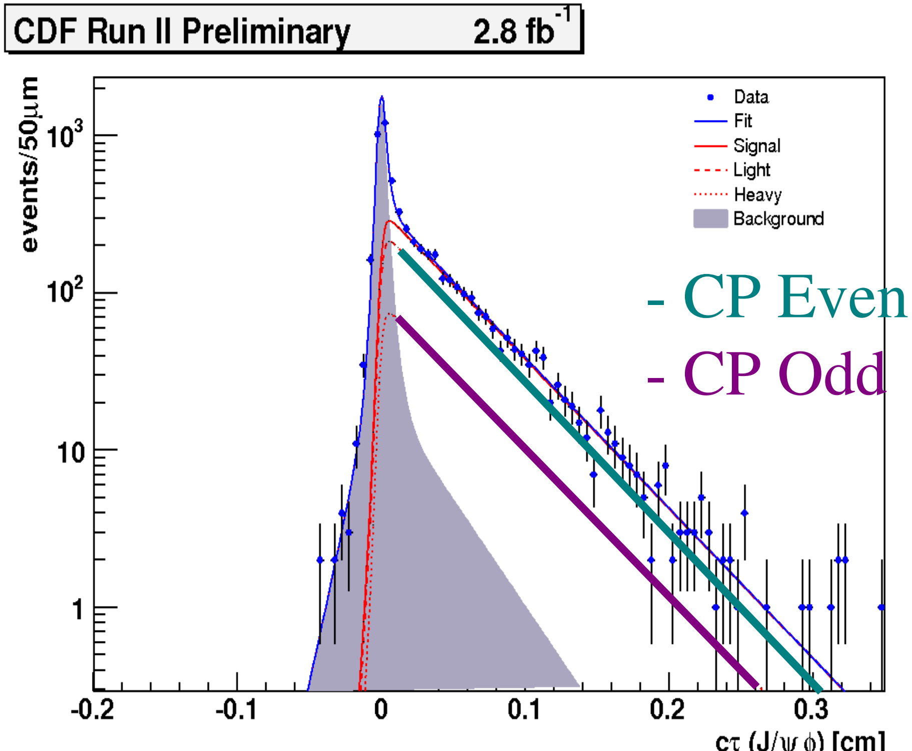
B_s lifetime in $B_s \to J/\Psi\phi$

- As part of angular analysis that together with three polarization amplitudes meaures $\Delta\Gamma$ and $\sin 2\beta_s$
- No bias from trigger
- Mean lifetime (assuming no CP violation, $\beta_s^{J/\Psi\phi} = 0$) :
  - τc (Bs)= $1/\Gamma_s$ = 459 ± 12 (stat.) ± 3 (syst.) μm

  Results are mean of heavy and light states

  No flavor specific measurement





http://www-cdf.fnal.gov/physics/new/bottom/080724.blessed-tagged_BsJPsiPhi_update_prelim/

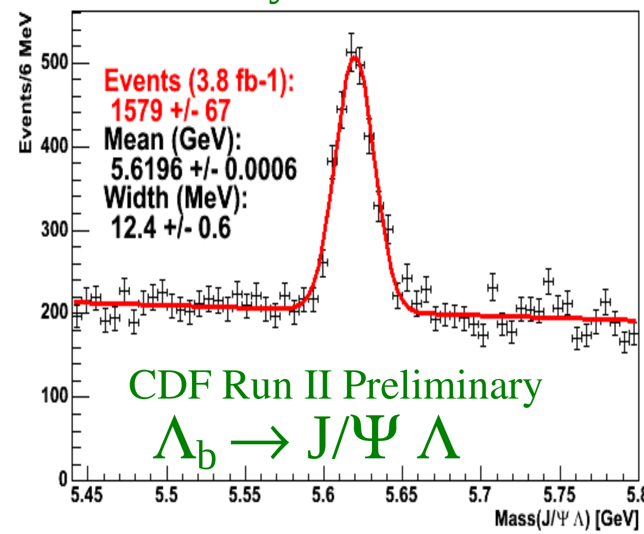
Σ_b , Σ_b^* Baryons

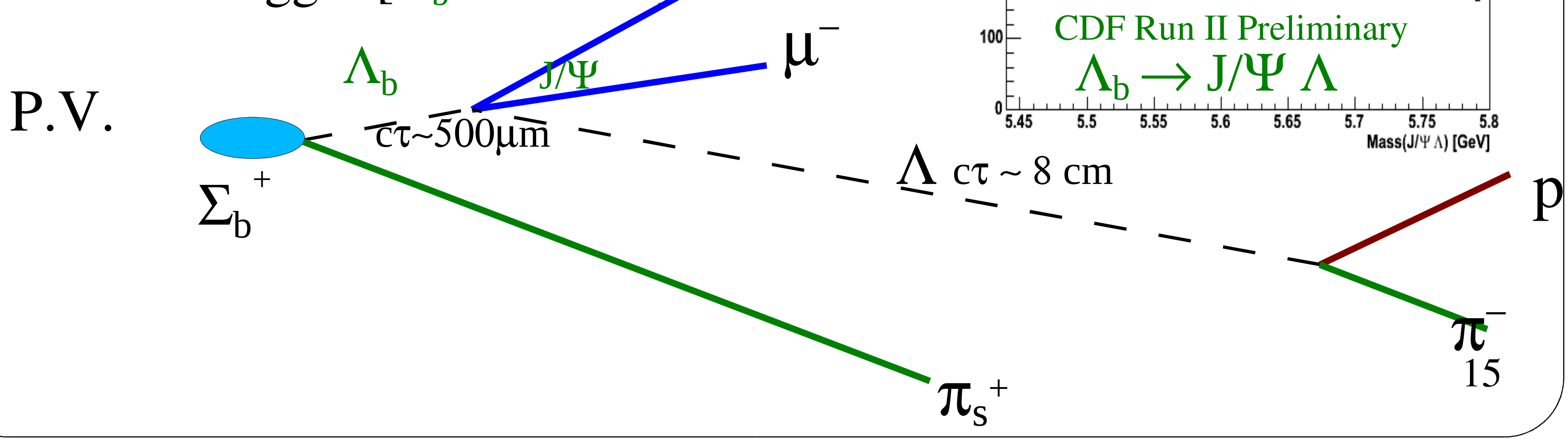
- Until 2006 Λ_b was only established B baryon

=> search for $\Sigma_b^+ = |buu\rangle$ $\Sigma_b^- = |bdd\rangle$

- $\Sigma_b^{*\pm}$ excited state of $\Sigma_b^\pm$ with s = 3/2
- Use two different triggers :
  - displaced track [PRL 99, 202001(2007); decay $\Lambda_b \rightarrow \Lambda_c^+\pi^-$ with $\Lambda_c^+ \rightarrow pK^-\pi^+$]
  - J/Ψ trigger [$\Lambda_b \rightarrow J/\Psi\ \Lambda$]:

Reconstruct ~ 1600 Λ_b in J/Ψ Λ decay with 3.8 fb^{-1} .

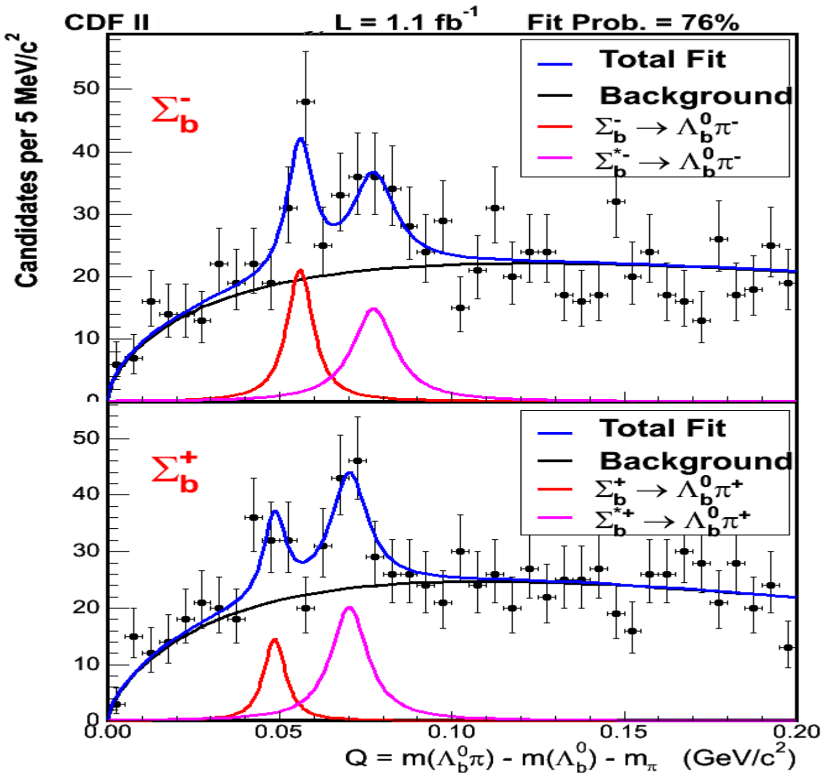


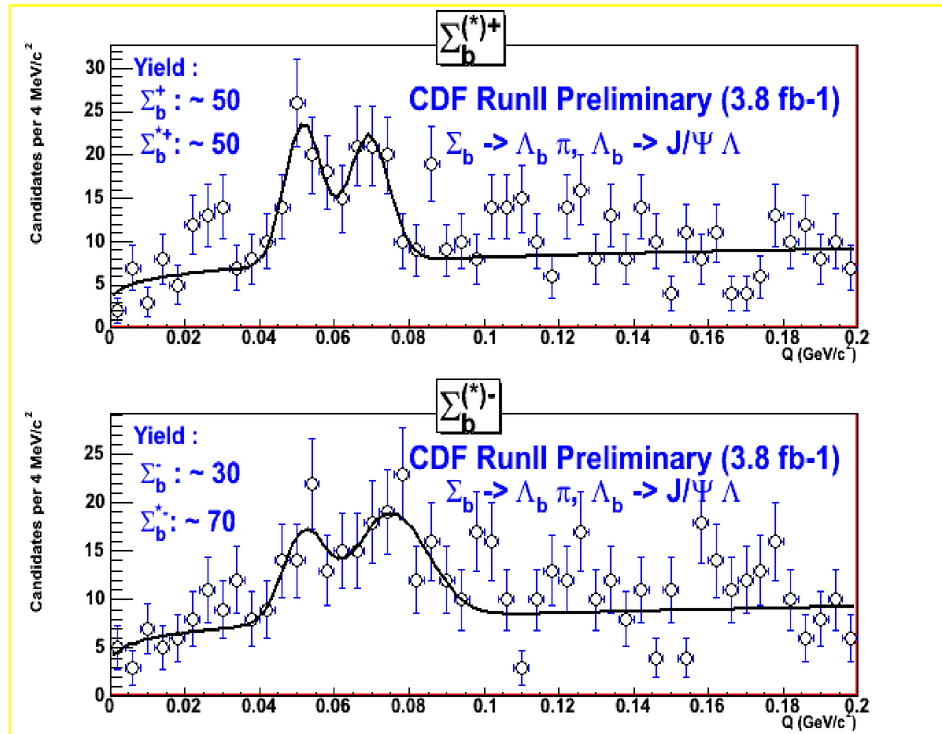


Σ_b , Σ_b^* Baryons

- Show results in terms of Q = $m(\Sigma_b) - m(\Lambda_b) - m(\pi)$

- Q for $\Lambda_b \rightarrow \Lambda_c \pi$ decay mode
- Q for $\Lambda_b \rightarrow J/\Psi\ \Lambda$ decay mode





- Observe peaks with > 5σ w.r.t no signal
- Data suggest that in $\Lambda_b \rightarrow J/\Psi\Lambda$ decay mode there are consistent peaks

Conclusions

Very rich heavy flavour program at CDF.

Many results on properties of heavy B hadrons :

- B_c lifetime, mass and cross section
- Λ_b lifetime
- B_s lifetime
- Σ_b, Σ_b^* mass
- Ω_b not covered here (see Pat Lukens' talk)

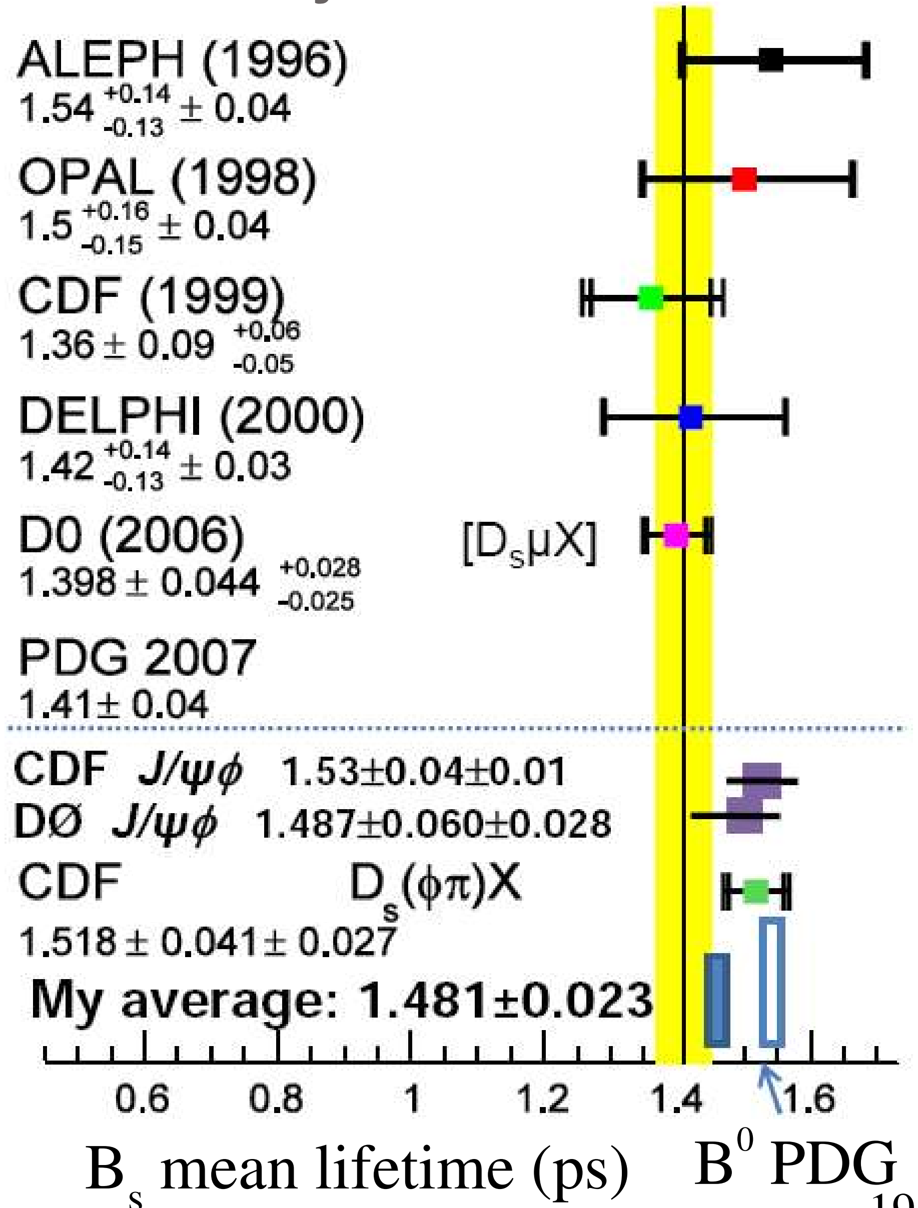
Great Tevatron performance. More data to come.

Good time for flavor physics at the Tevatron right now!

Back up

B_s lifetime summary

- New measurement greater than earlier average
  - Strongly weighted by semileptonic channel from D0
- New combination will reduce discrepancy between data and expectation $\tau(B_s) \approx \tau(B^0)$



Σ_b , Σ_b^* Baryons

State	Yield	Q or $\Delta_{\Sigma_b^*}$ (MeV/c^2)	Mass (MeV/c^2)
Σ_b^+	32^{+13+5}_{-12-3}	$Q_{\Sigma_b^+} = 48.5^{+2.0+0.2}_{-2.2-0.3}$	$5807.8^{+2.0}_{-2.2} \pm 1.7$
Σ_b^-	59^{+15+9}_{-14-4}	$Q_{\Sigma_b^-} = 55.9 \pm 1.0 \pm 0.2$	$5815.2 \pm 1.0 \pm 1.7$
Σ_b^{*+}	77^{+17+10}_{-16-6}	$\Delta_{\Sigma_b^*} = 21.2^{+2.0+0.4}_{-1.9-0.3}$	$5829.0^{+1.6+1.7}_{-1.8-1.8}$
Σ_b^{*-}	69^{+18+16}_{-17-5}		$5836.4 \pm 2.0^{+1.8}_{-1.7}$