B_s Mixing and B Hadron Lifetimes at CDF

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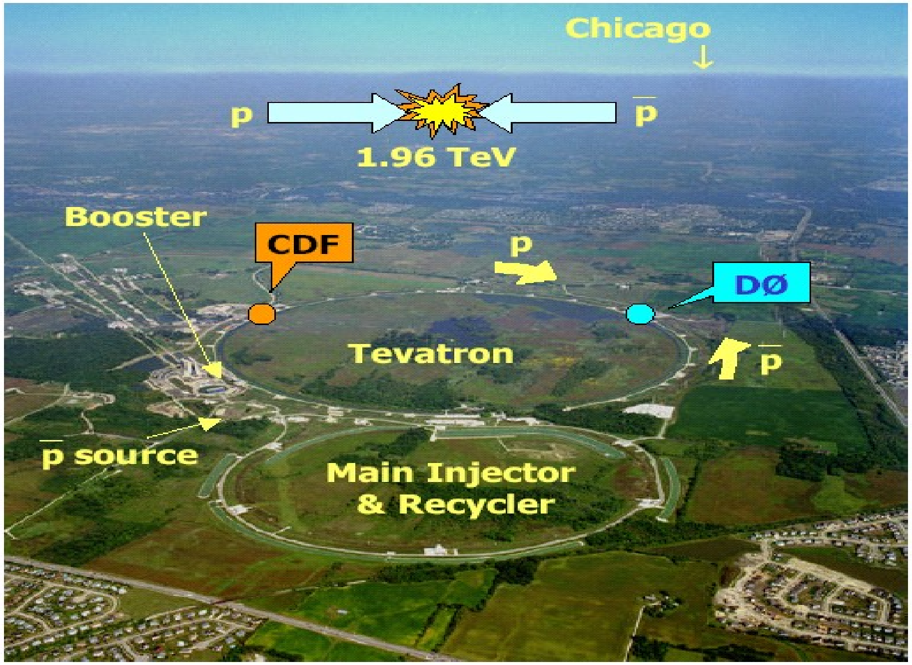
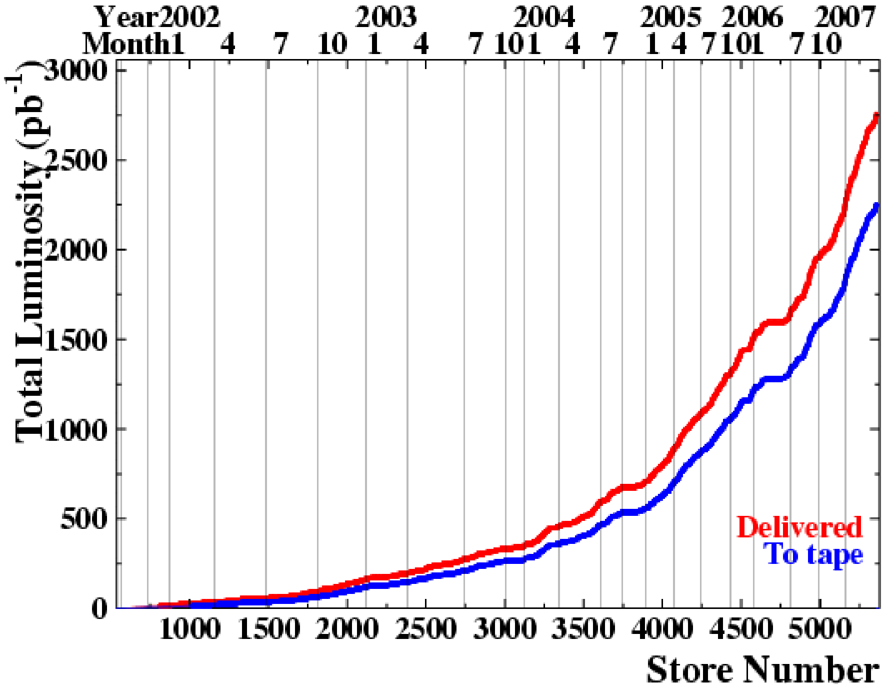
20. July 2007
HEP 2007 Manchester

Tevatron & Lumi

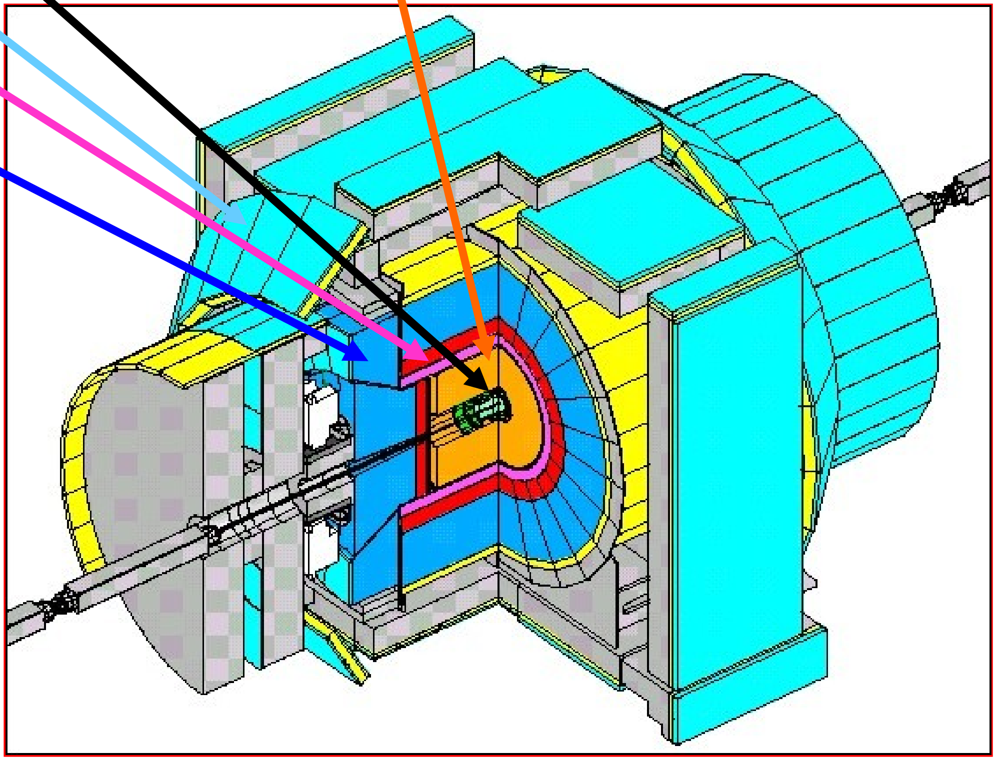




- Proton-antiproton Synchrotron
- Run II :
  - $\sqrt{s}$ = 1.96 TeV
  - Both experiments have now > 2.5 fb^{-1} on tape.
  - Aim for 6-8 fb^{-1} by 2009

CDF-Detector

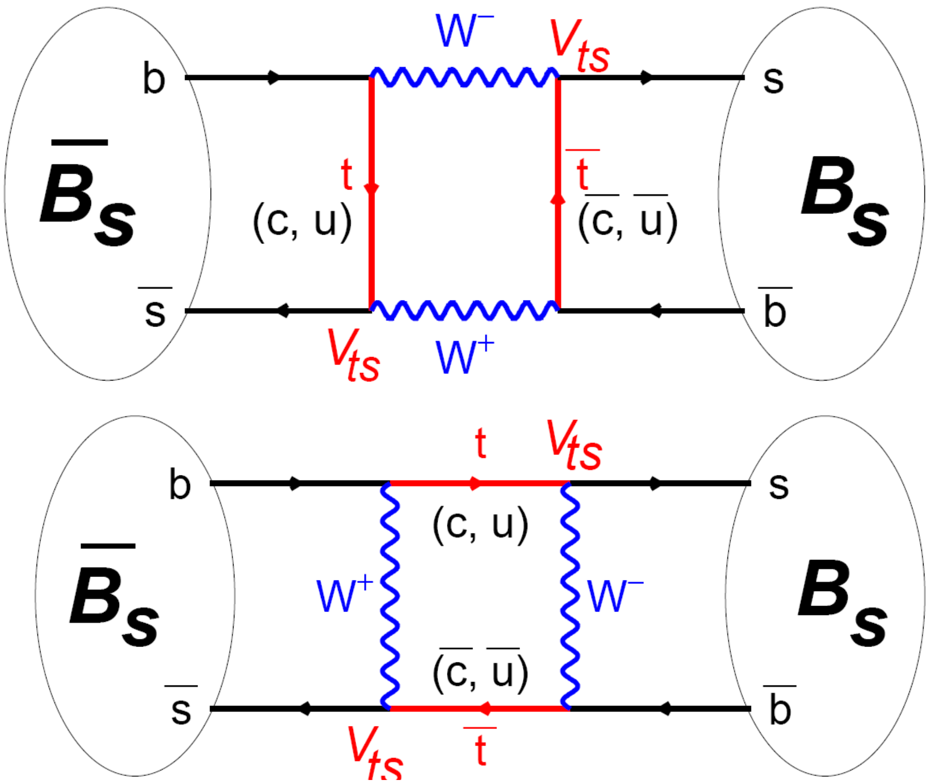
- Tracking: Silicon Detector + Drift Chamber (COT)
- PID: Muon chambers
  ToF,
  dEdx (COT)
  Calorimeter
- Huge background: soft QCD 1000x larger $\rightarrow$ trigger to find secondary vertex
  - 2-track trigger (TTT):
    - Pt(trk)>2GeV/c
    - IP(trk)>100 μ m
- Di-Muon Trigger



Mixing Introduction

- flavoured neutral mesons can turn into their antiparticle via box diagrams
  - measuring oscillation frequency
  - measure $|V_{ts}|$
- Δm ratio $\rightarrow$ measure one side of unitarity triangle (many theoretical uncertainties cancel in ratio)
- new physics can influence oscillation frequency

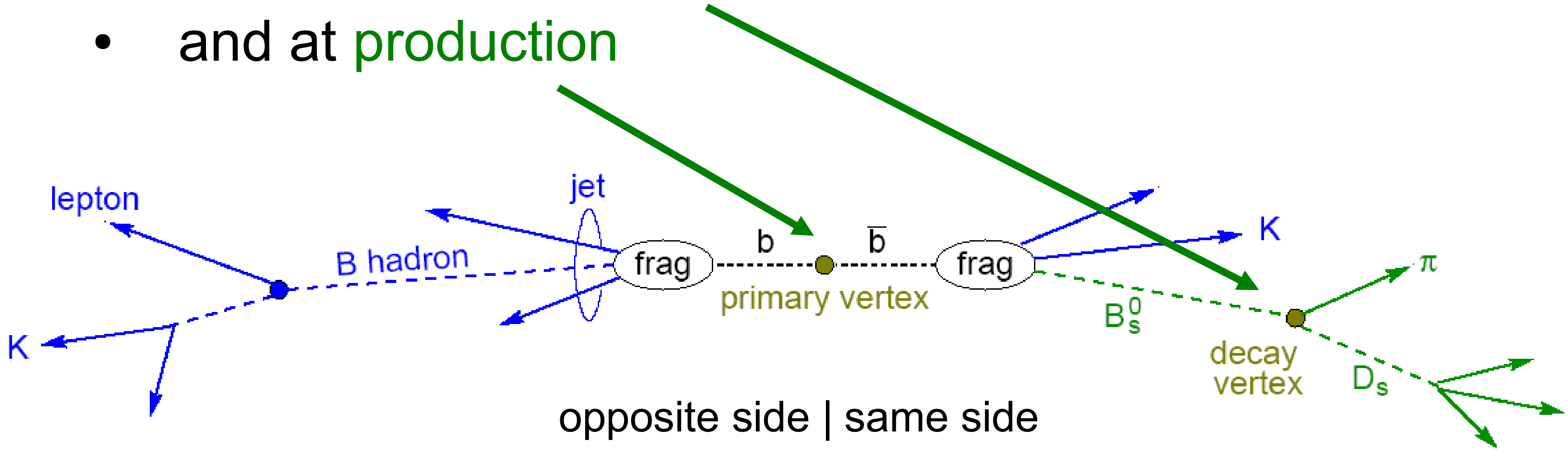
$\rightarrow$ test of Standard Model



$$\frac{\Delta m_s}{\Delta m_d} = \frac{m_{B_s}}{m_{B_d}} \xi^2 \frac{|V_{ts}|^2}{|V_{td}|^2}$$

Mixing: Overview

- For mixing you need 3 ingredients:
  - Get flavour at decay
  - and at production



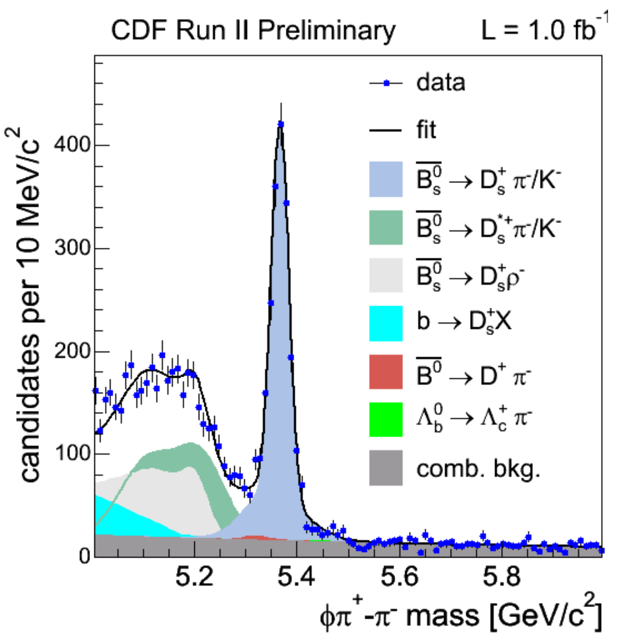
  - good proper time resolution for decay vertex reconstruction → mixed or not mixed after a specific time

Oscillation Amplitude (simplified B Meson case)

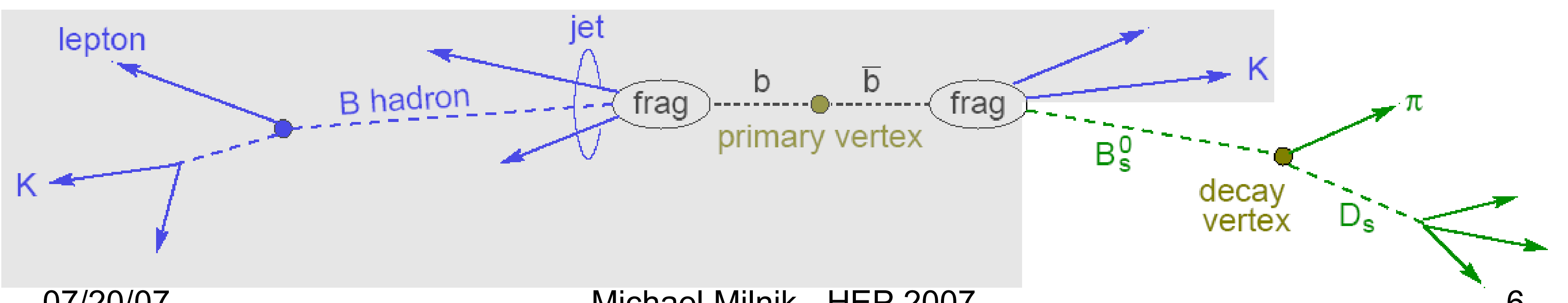
Decay Flavour and Channels

$B_s \rightarrow D_s \, \pi$
$B_s \rightarrow D_s \, 3\pi$
$B_s \rightarrow D_s \, l^+X$

$D_s \rightarrow \phi \, \pi$
$D_s \rightarrow K^*K$
$D_s \rightarrow 3\pi$

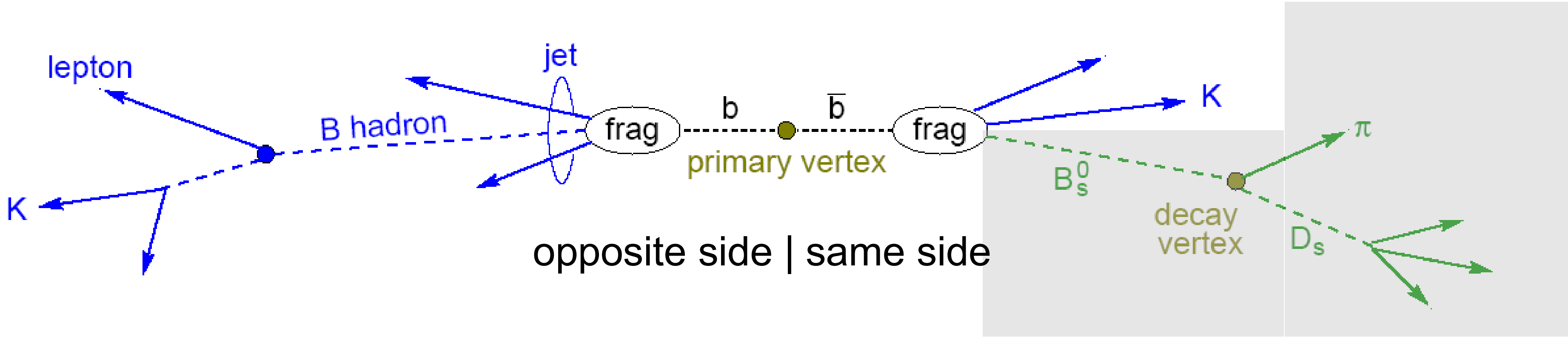


- Flavour specific modes, to get b flavour at decay



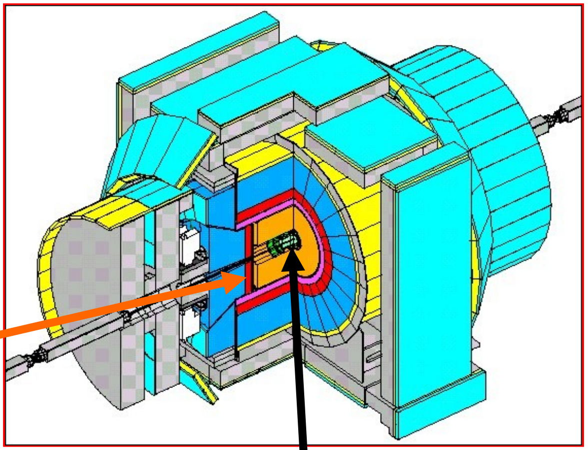
Production Flavour: Flavour Tagging

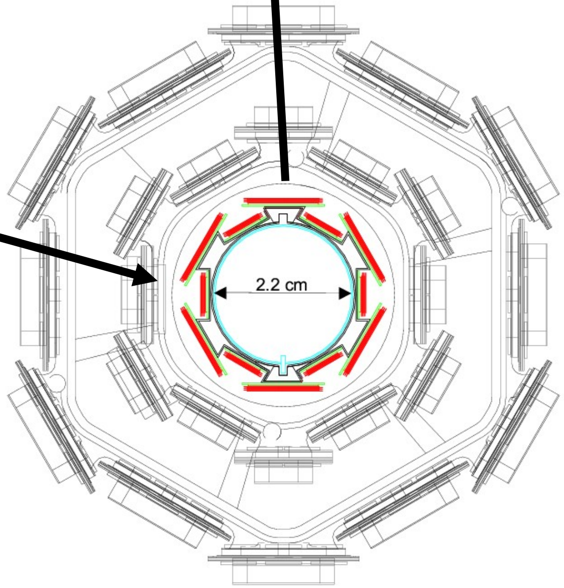
- Estimate flavour at production from the rest of the event
  - Opposite side - NN combination: εD^2=1.8%
    - Lepton identification: $b \rightarrow Xl^-$, but cascade: $b \rightarrow c \rightarrow Xl^+$
    - Jet-Charge: inclusive charge of fragmentation
    - Kaon identification: $b \rightarrow c \rightarrow XK^-$
  - Same side: → εD^2=3.5% (hadronic) – εD^2=4.8% (S.L.)
    - Kaon identification: the other s quark not in the B_s will create a K



Proper Time Resolution @ CDF

- Good proper time resolution requires excellent tracking as close as possible to the interaction point
  - Excellent tracking with large drift chamber (COT)
  - followed by the silicon detector with closest layer at about 1 cm from beam for good vertex resolution





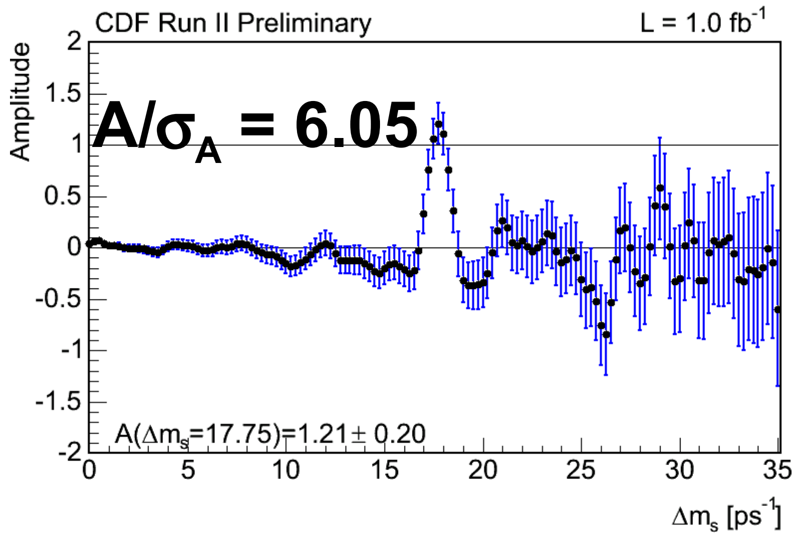
Mixing Results

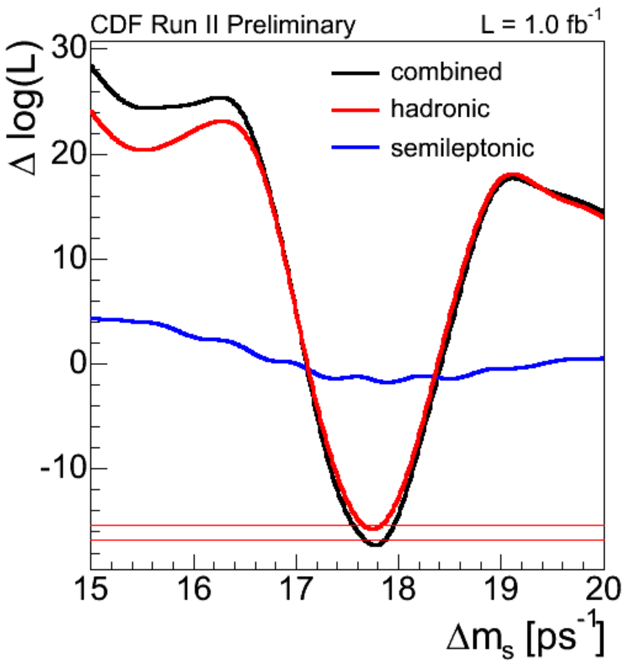
$$P_S(t,\xi,\sigma_t) \propto \frac{1+\xi AD\cos(\Delta m t)}{1+|\xi|}\frac{1}{\tau}e^{-t/\tau}$$

- fit only amplitude and fix frequency
- scan through frequencies

- Fourier Analysis which should have maximum at true oscillation frequency
- unbinned maximum likelihood fit >5σ significance :
  - $\Delta m_s = 17.77 \pm 0.10 \pm 0.07\ ps^{-1}$

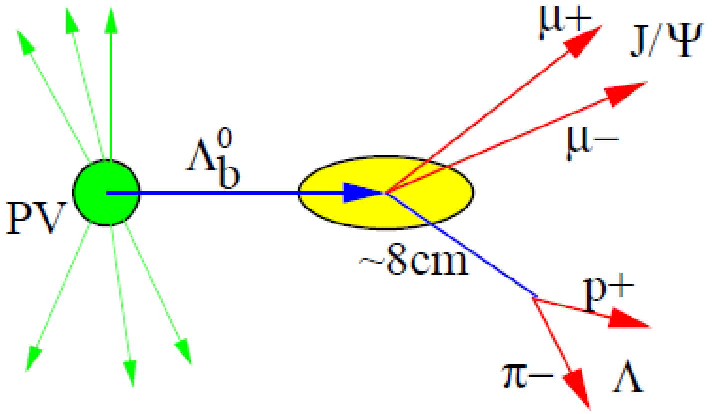
  $\rightarrow |V_{td}/V_{ts}| = 0.2060 \pm 0.0007$ (exp) $^{+0.0081}_{-0.0060}$ (theo.)

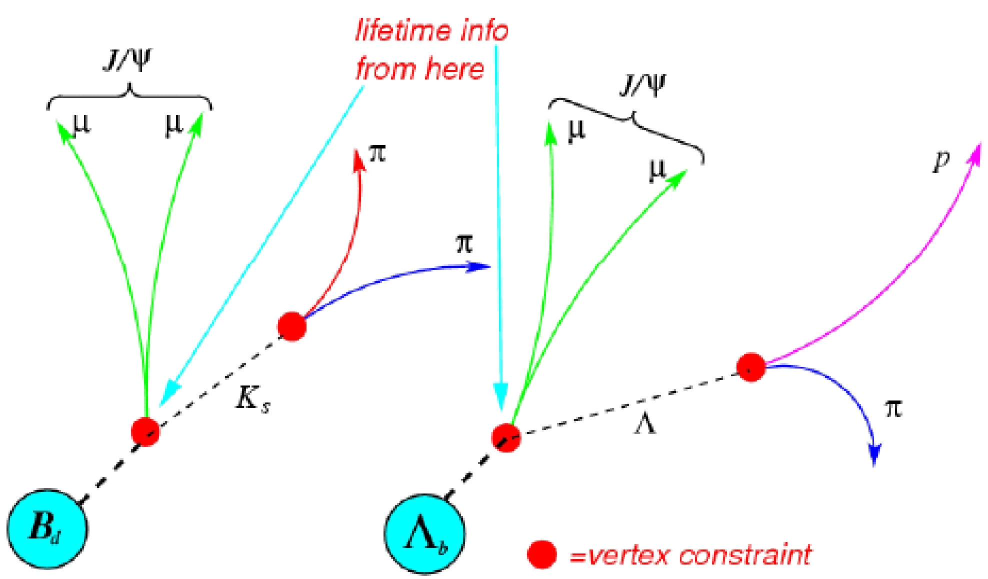




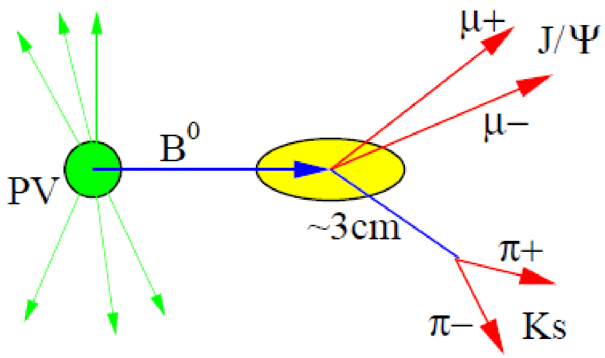
$\Lambda_b \to J/\psi\ \Lambda$

- Fully reconstructed decay channels
- Control channels with very similar topology:
  - $B^0 \to J/\psi\ K_s$
  - $B^0 \to J/\psi\ K^*$
  - $B^+ \to J/\psi\ K+$
  - $B^0_s \to J/\psi\ \phi$
- di-muon vertex used for lifetime measurement
- $J/\psi \to \mu\mu \to$ di-muon Trigger:
  - $2.7GeV/c^2 < M(\mu\mu) < 4GeV/c^2$
  - $Q(\mu_1)xQ(\mu_2) = -1$
  - $p_t(\mu)>1.5GeV/c$





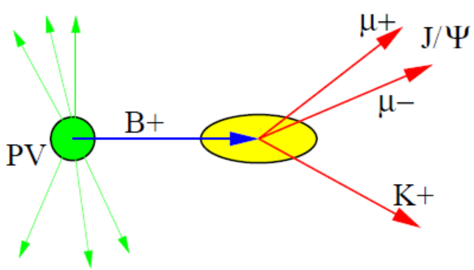
Control Channels

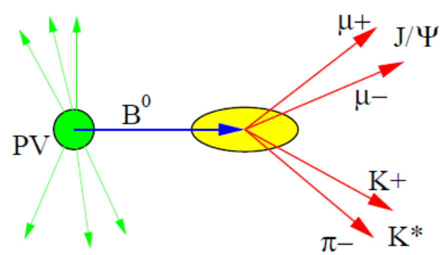


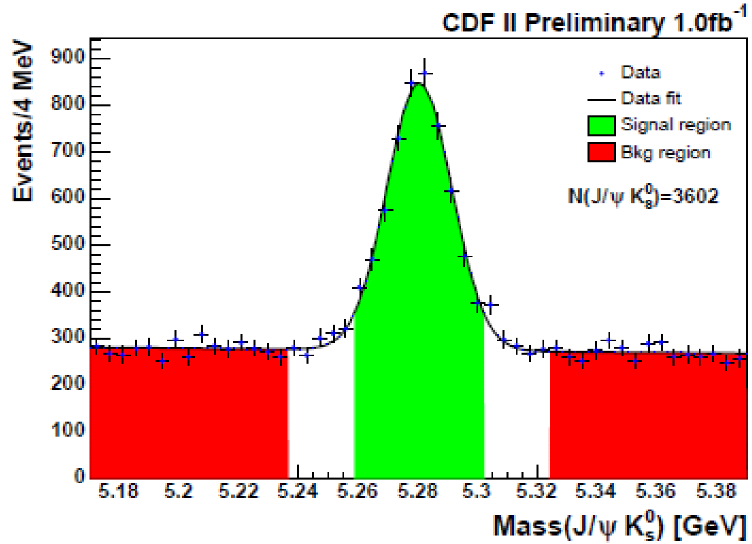
$$N(J/\psi K^{*0}) \sim 3600$$

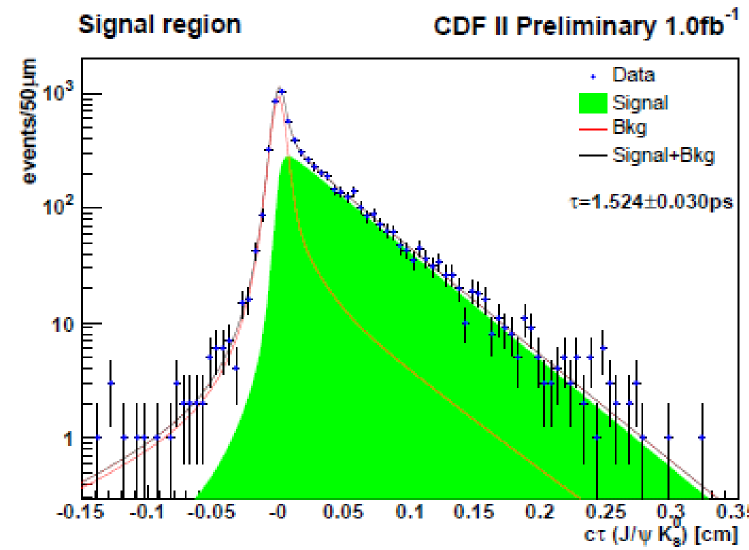
$$c\tau(B^0) = 457.1 \pm 8.8(stat) \pm 3.2(syst)\mu m$$

$$\tau(B^0) = 1.524 \pm 0.030(stat) \pm 0.011(syst)ps$$

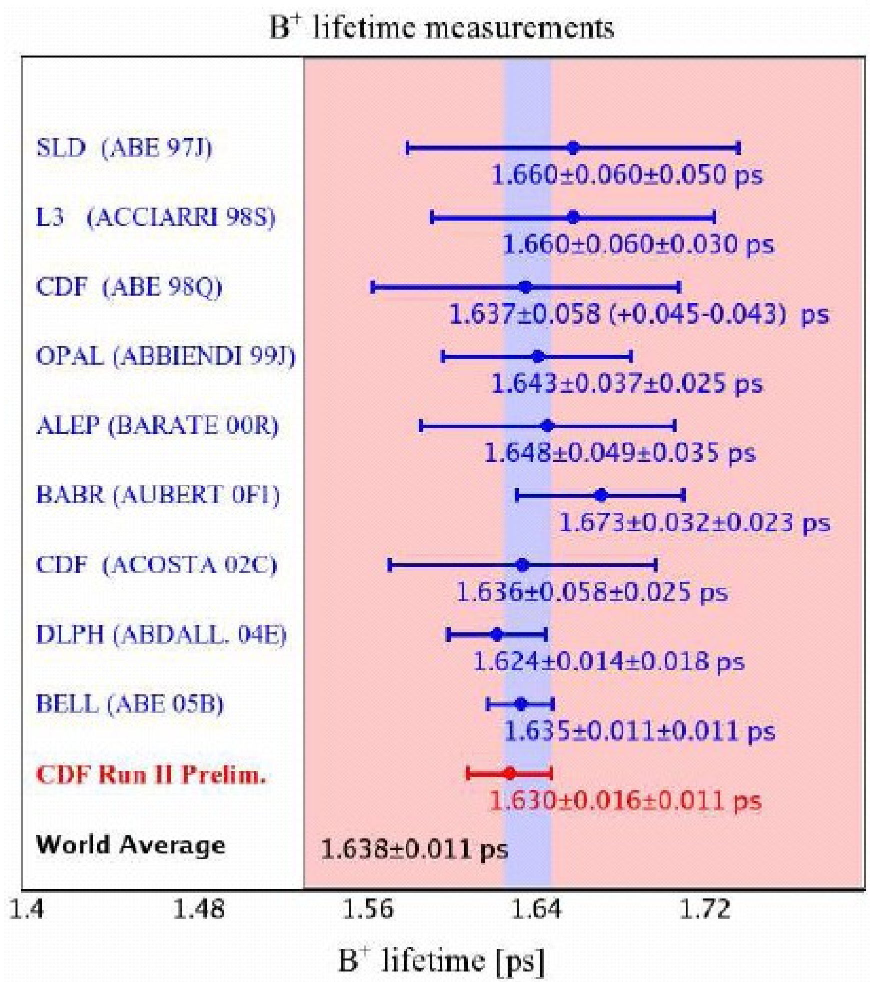


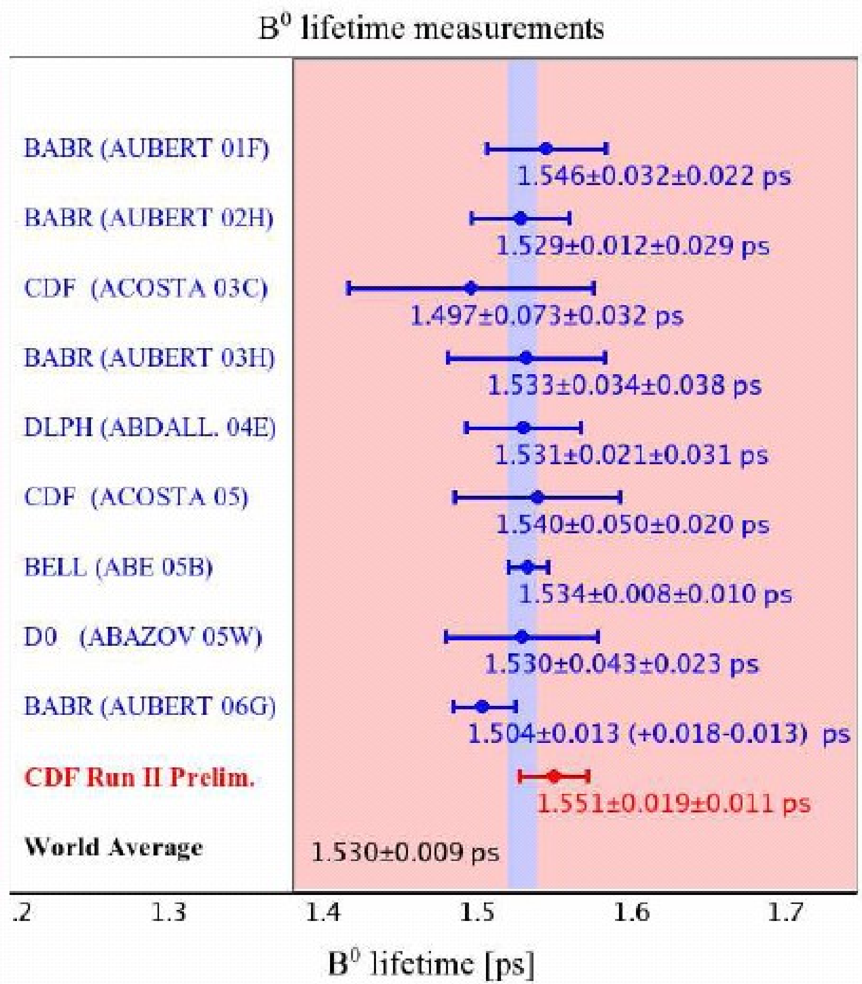




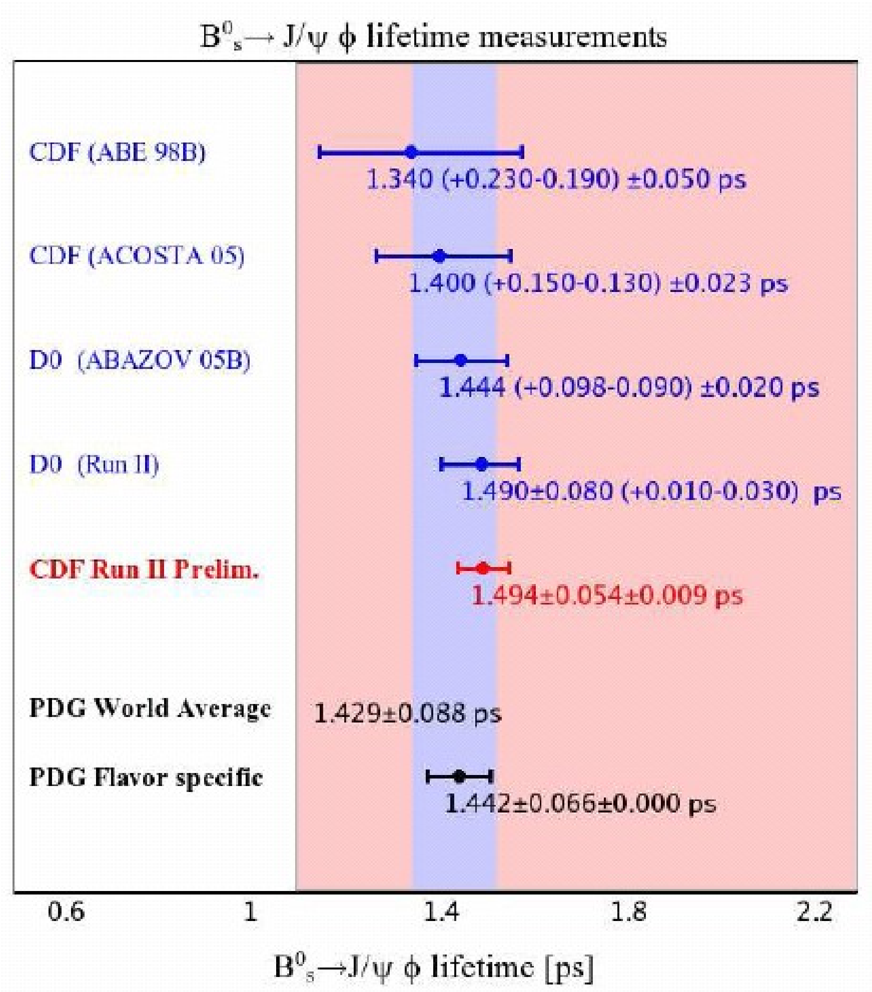


Control Channels

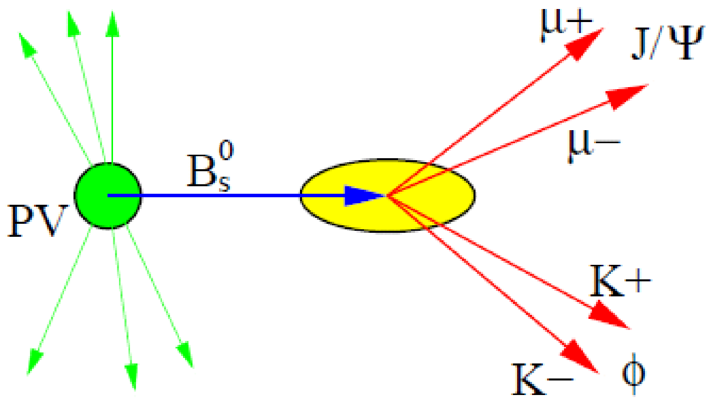




Control Channels



- All control channels provide excellent lifetime measurements
- Consistent with world average

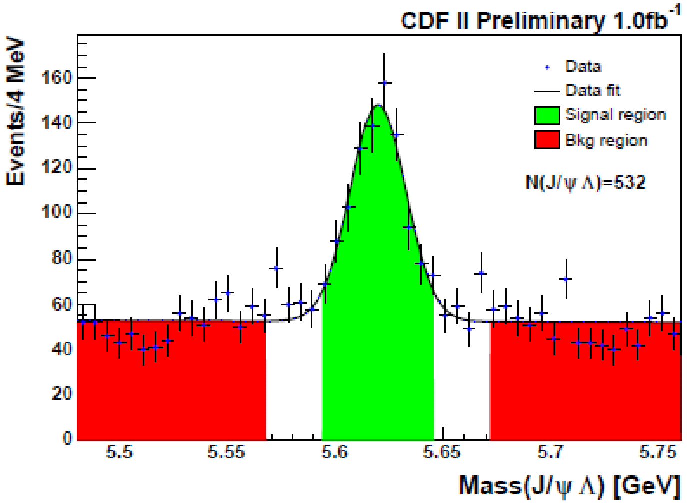


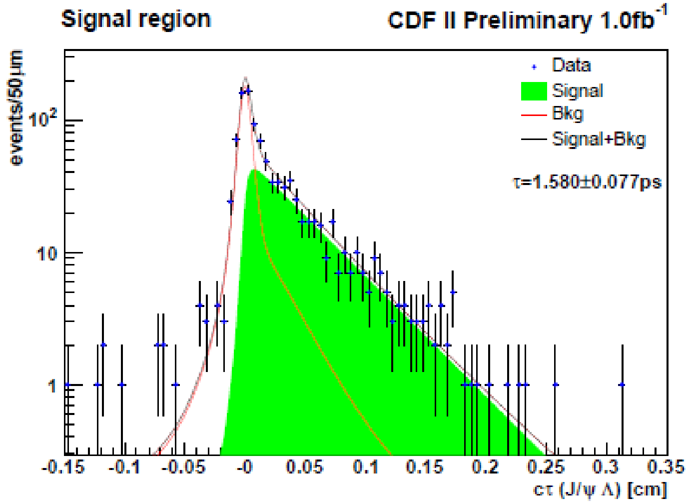
Λ_b Results

$$N(J/\psi\Lambda) = 532$$

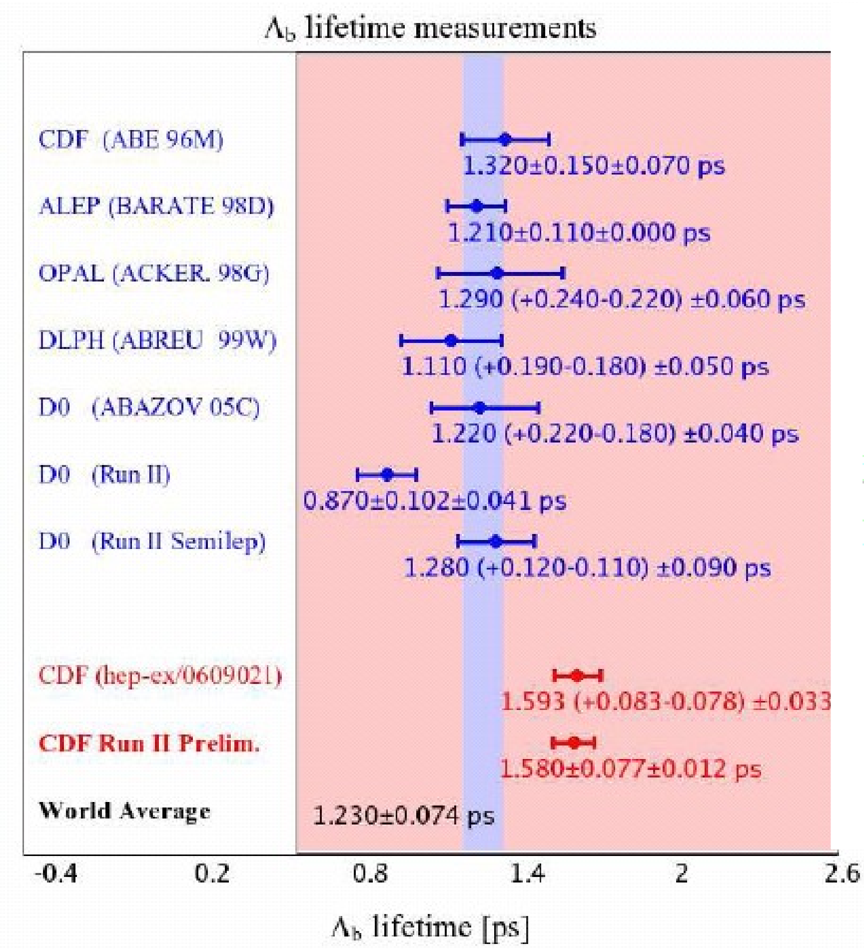
$$c\tau(\Lambda_b^0) = 473.8 \pm 23.1(stat) \pm 3.5(syst)\mu m$$

$$\tau(\Lambda_b^0) = 1.580 \pm 0.077(stat) \pm 0.012(syst)ps$$





Λ_b Comparison



- 3σ deviation from WA
- Lifetime ratio:

$$\frac{\tau(\Lambda_b^0)}{\tau(B^0)} = 1.018 \pm 0.062(stat) \pm 0.007(syst)$$

- Theory prediction:

$$\tau(\Lambda_b^0)/\tau(B^0) = 0.88 \pm 0.05$$

Summary

- First observation of B_s^0-$\overline{B}_s^0$ Oscillations >5σ
  - very precise Δm_s measurement
  - Published: Phys. Rev. Lett., 97, 242003 (2006)
- Most precise single Λ_b lifetime measurement
  - other b-hadron lifetimes agree with world average
  - Λ_b lifetime is 3σ above world average and at the upper side of theoretical prediction
  - $\Lambda_b \rightarrow \Lambda_c \pi$ lifetime measurement in progress
- More info @:

  http://www-cdf.fnal.gov/physics/new/bottom/bottom.html