B Hadron Lifetimes and Rare Decays

Nirmalya Parua
(for the CDF and D0 Collaboration)
Indiana University
Bloomington

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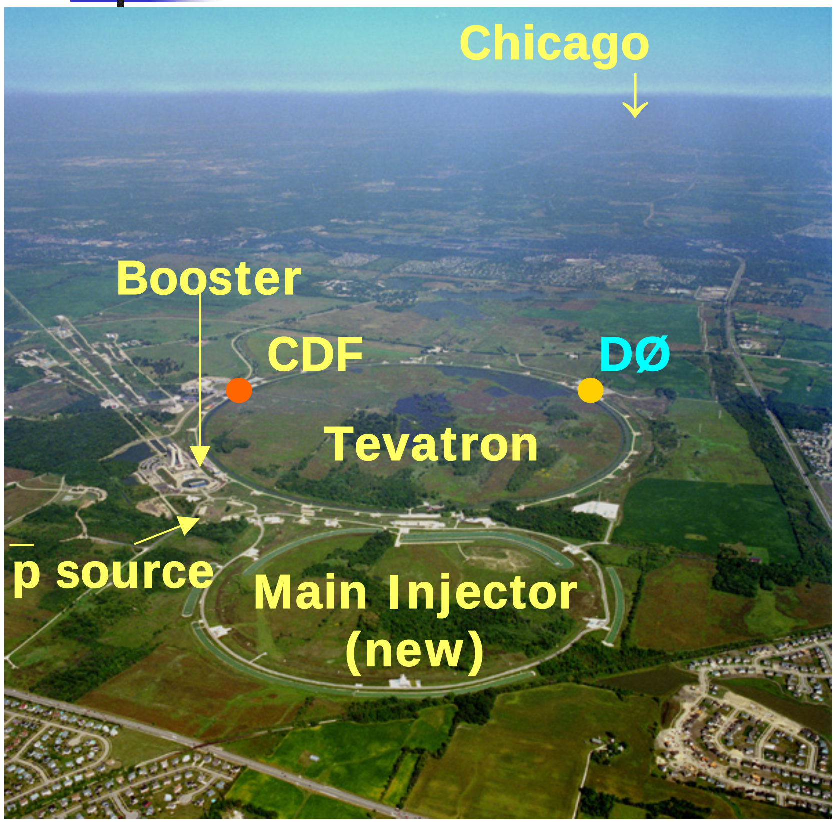
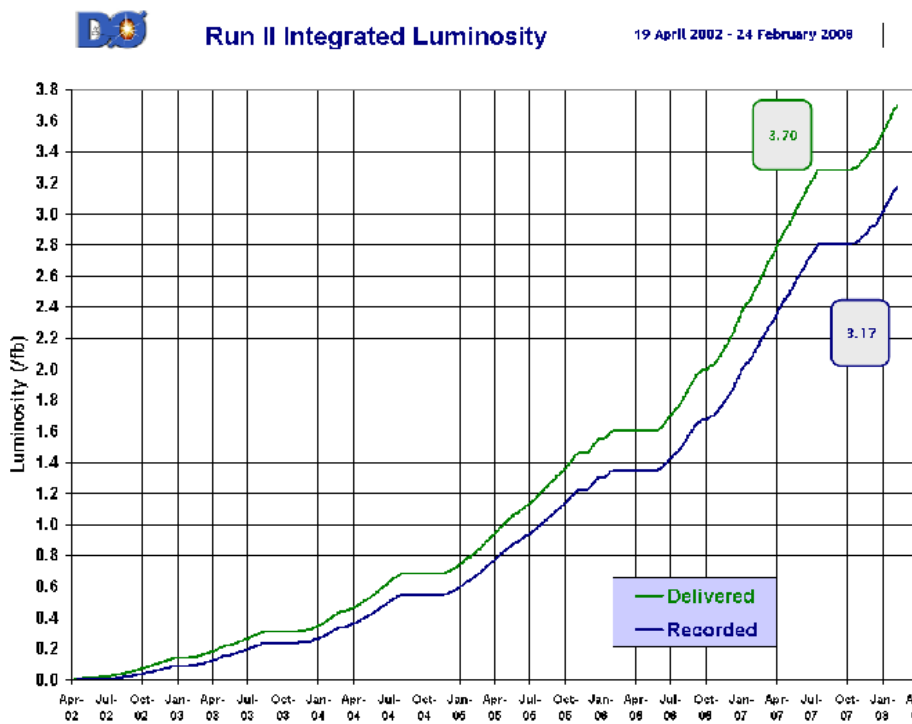
Outline

- Lifetime Measurements
- Rare Decays
- Conclusions

The Run II Tevatron



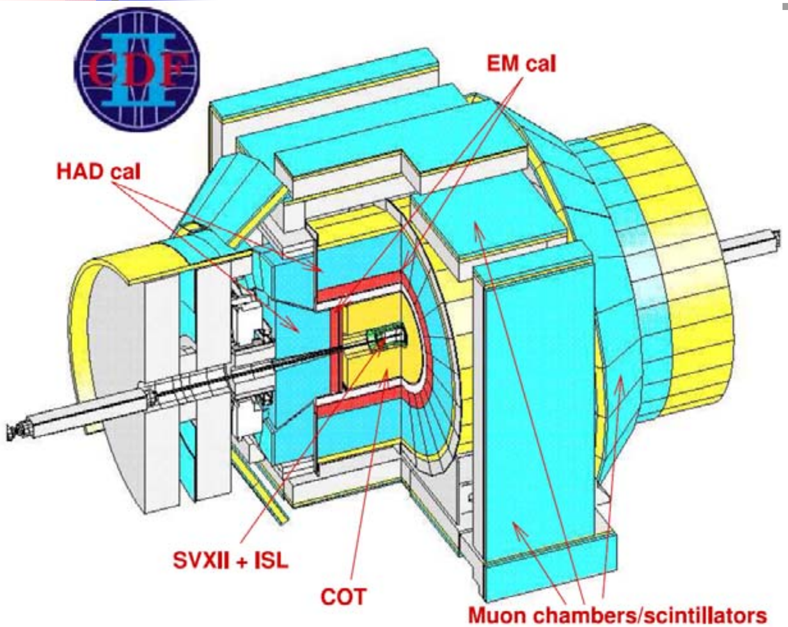
$p\bar{p}$ collisions at $\sqrt{s} = 1.96\ TeV$

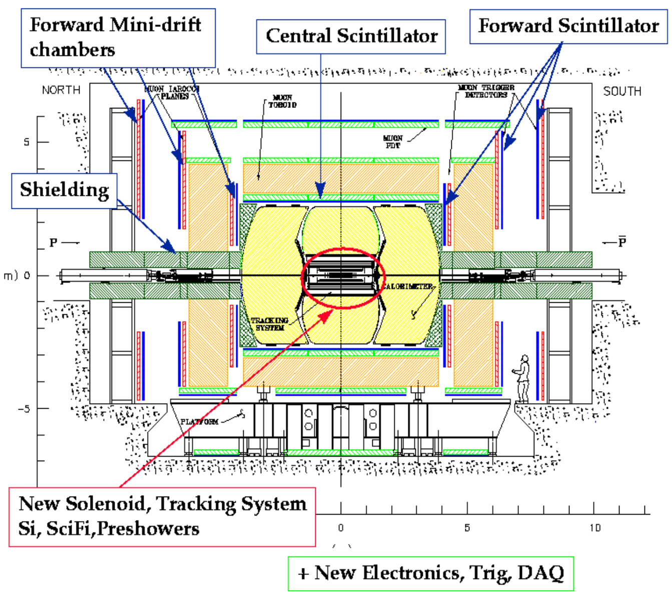


Analysis presented here uses up to 2.8 fb^{-1} of luminosity

More than 3 fb^{-1} of luminosity recorded

CDF and DØ Detectors





- **Central tracking with silicon vertex detector and drift chamber**
- **Excellent Mass resolution**
- **Excellent particle ID with dE/dX and TOF detector**
- **Good coverage for muon**

- **2 Tesla solenoid magnetic field for central tracking system with silicon and fiber tracker**
- **Excellent coverage for Muon detector in 1.8 Tesla toroid magnet**
- **Silicon Layer 0 installed in 2006**

B-hadron lifetimes

Accurate measurement of B-hadron lifetimes is a test of Heavy Quark Expansion theory.

At the lowest order all B-hadron lifetimes are same, higher order splittings are

$\propto (\Lambda_{qcd} / m_b)^2$

Prediction shows $\tau(B^+)/\tau(B^0)$ **: 1.04 – 1.08,**

$\tau(B_s^0)/\tau(B^0)$ **: 0.99 – 1.01 hep-ph/0310241, Phys Rev D70 094031**

$\tau(\Lambda_b)/\tau(B^0)$ **: 0.86 – 0.95**

$\tau(B_c)$ **: 0.48± 0.05 ps hep-ph/0308214**

D0 measurement of

$\tau(\Lambda_b)$ **in** $\Lambda_b \to J/\psi(\to \mu\mu)\Lambda$

$\tau(\Lambda_b)$ **in** $\Lambda_b \to \Lambda_c\, \mu\nu\, X$

$\tau(B_c)$ **in** $B_c \to J/\psi(\to\mu\mu)\mu\nu$

$\tau(B_s)$ **in** $B_s \to J/\psi(\to \mu\mu)\varphi$

CDF measurements of

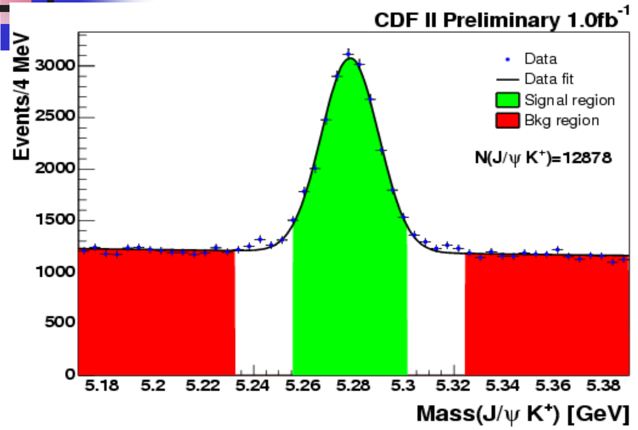
$\tau(B^+)$ **in** $B^+ \to J/\psi(\to \mu\mu)K^+$ **and**

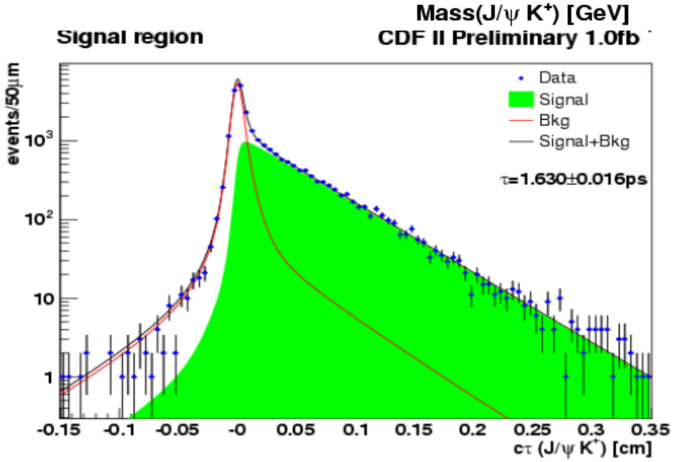
$\tau(B^0)$ **in** $B^0 \to J/\psi(\to \mu\mu)K^{*0}$ **,** $B^0 \to J/\psi(\to \mu\mu)K_s^0$

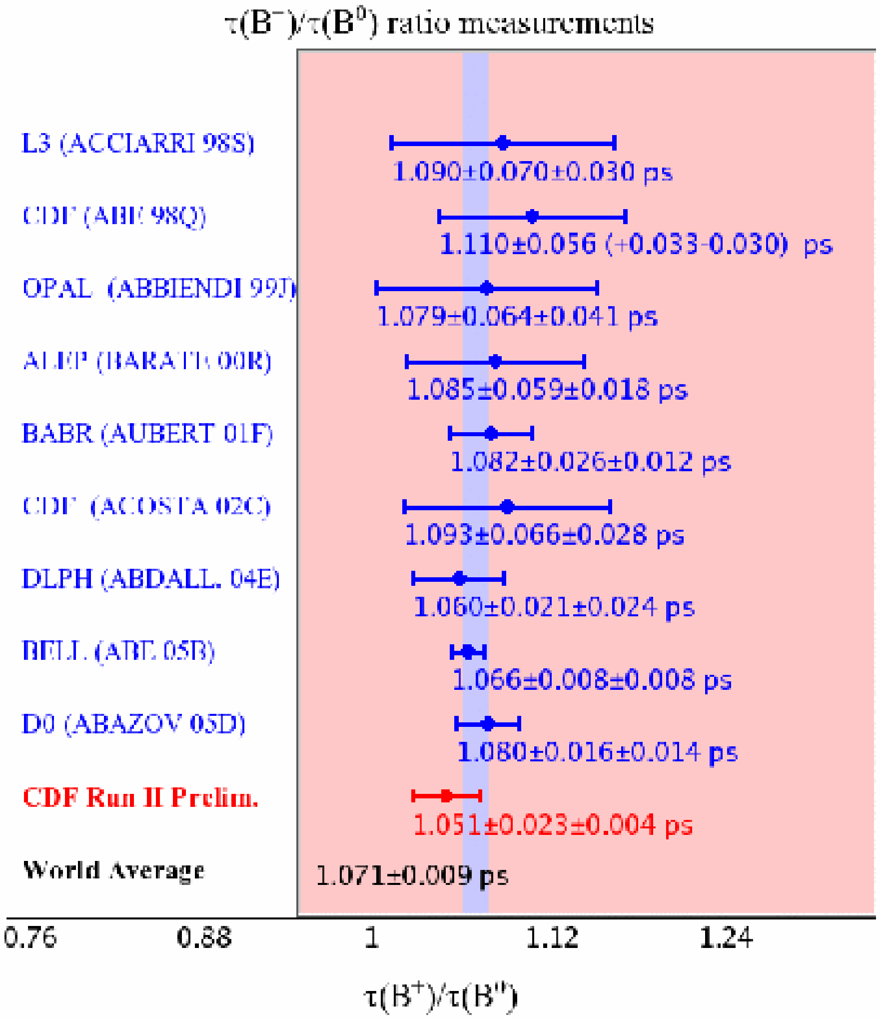
$\tau(\Lambda_b)$ **in** $\Lambda_b \to J/\psi(\to \mu\mu)\Lambda$

$\tau(B_s)$ **in** $B_s \to J/\psi(\to \mu\mu)\varphi$**, and in hadronic decays**

B^+, B^0 Meson lifetimes at CDF





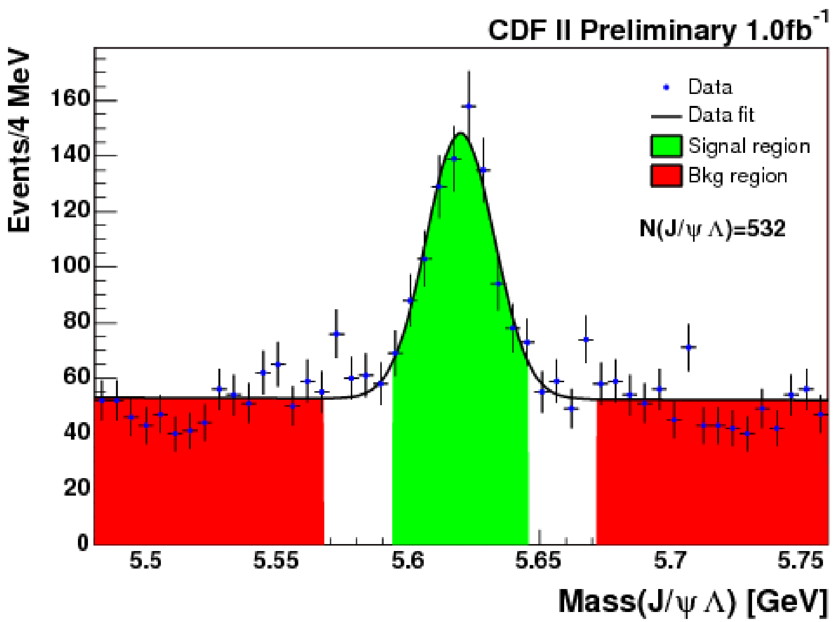


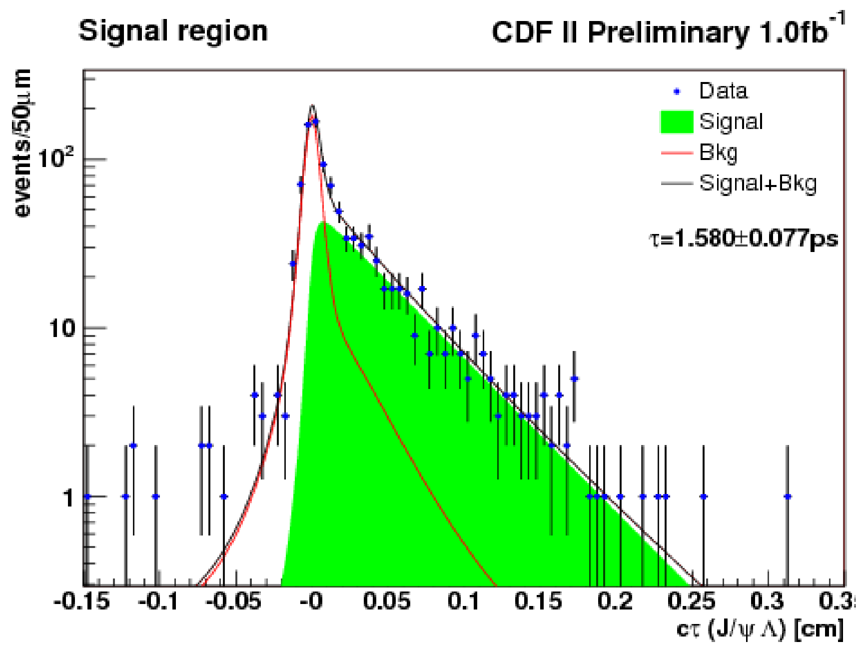
τ_{B^+} = 1.630 ± 0.016(stat.) ± 0.011 (syst.) ps

τ_{B^0} = 1.551 ± 0.019(stat.) ± 0.011 (syst.) ps

τ_{B^+} / τ_{B^0} = 1.051 ± 0.023(stat) ± 0.004(syst)

Λ_b Lifetime at CDF



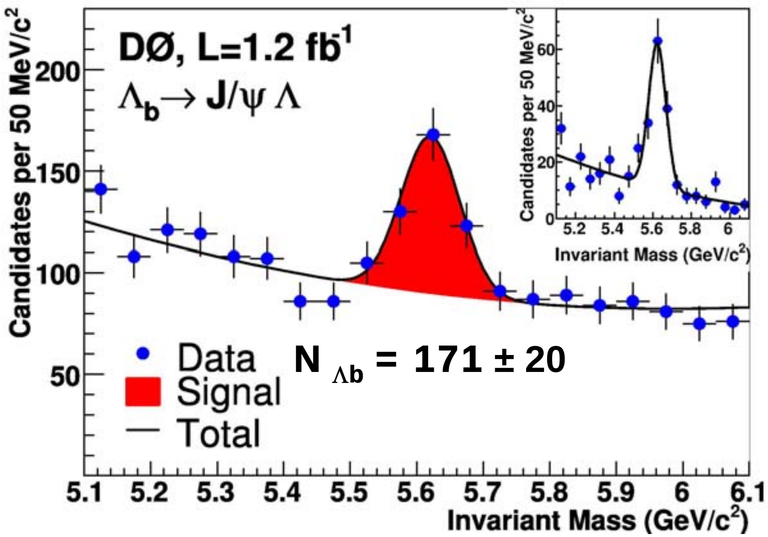


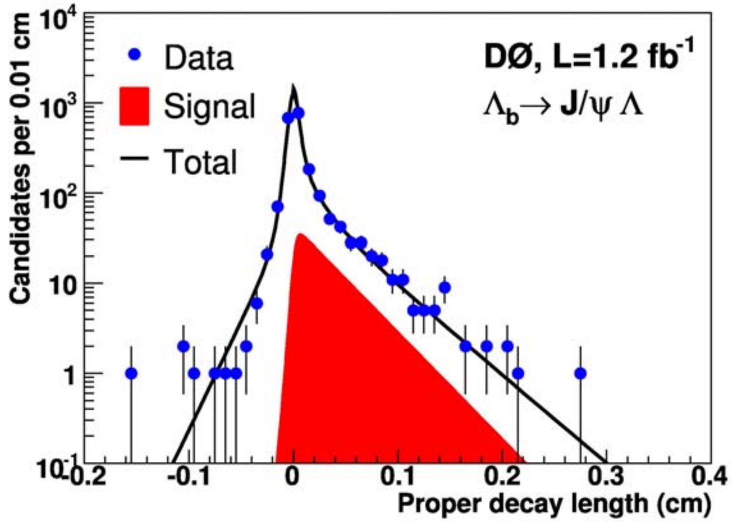
τ_{Λ_b} = 1.580 ± 0.077(stat.) ± 0.012 (syst.) ps
$\tau_{\Lambda_b} / \tau_{B^0}$ = 1.018 ± 0.062(stat)± 0.007(syst)

This measurement is about 3σ higher than the prediction and world average

Λ_b Lifetime at D0

- D0 measurement is based on 1.2 fb^{-1} of data, and uses $\Lambda_b \to J/\psi(\mu^+\mu^-)\Lambda(p\pi^-)$
- Fully exclusive decay, no missing neutrino
- In same run range lifetime of $B^0 \to J/\psi\ (\mu^+\mu^-)K_s(\pi^+\pi^-)$ is measured





$$\tau(\Lambda_b) = 1.218^{+0.130}_{-0.115}(stat) \pm 0.042(syst)\,ps$$

$$\tau(B^0) = 1.501^{+0.078}_{-0.074}(stat) \pm 0.050(syst)\,ps$$

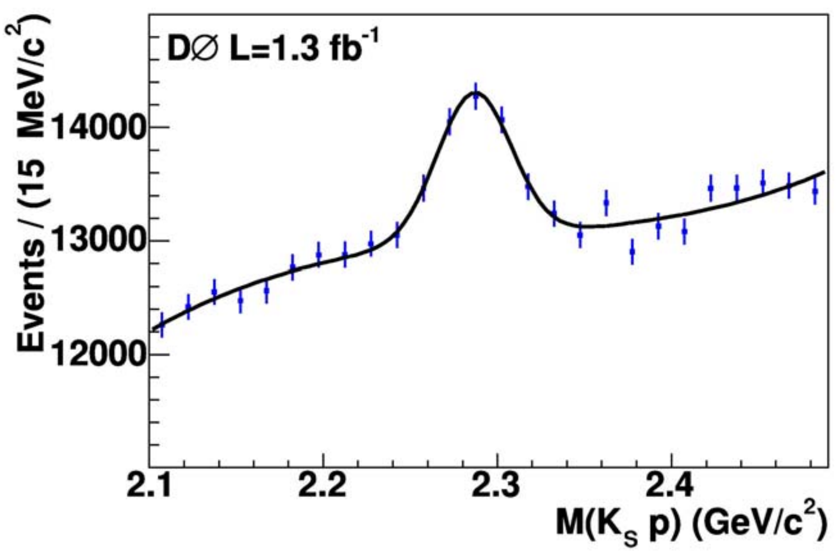
$$\frac{\tau(\Lambda_b)}{\tau(B^0)} = 0.811^{+0.096}_{-0.087}(stat) \pm 0.034(syst)$$

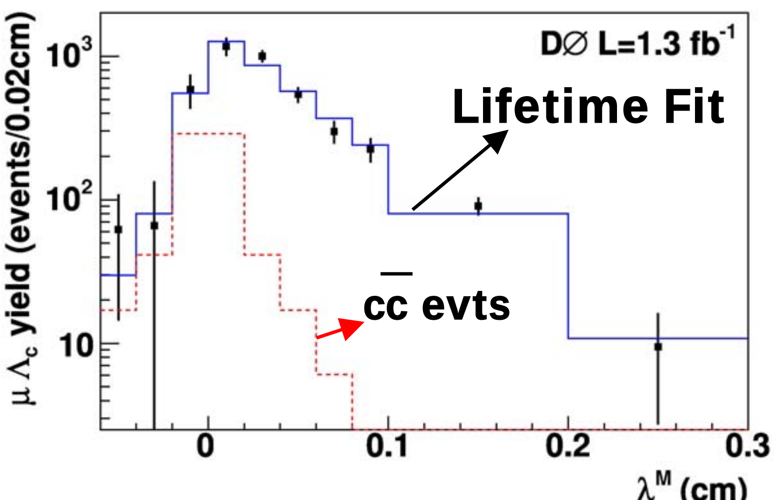
PRL 99, 142001 (2007)

Λ_b Lifetimes at D0 (semileptonic)

PRL 99, 182001(2007)

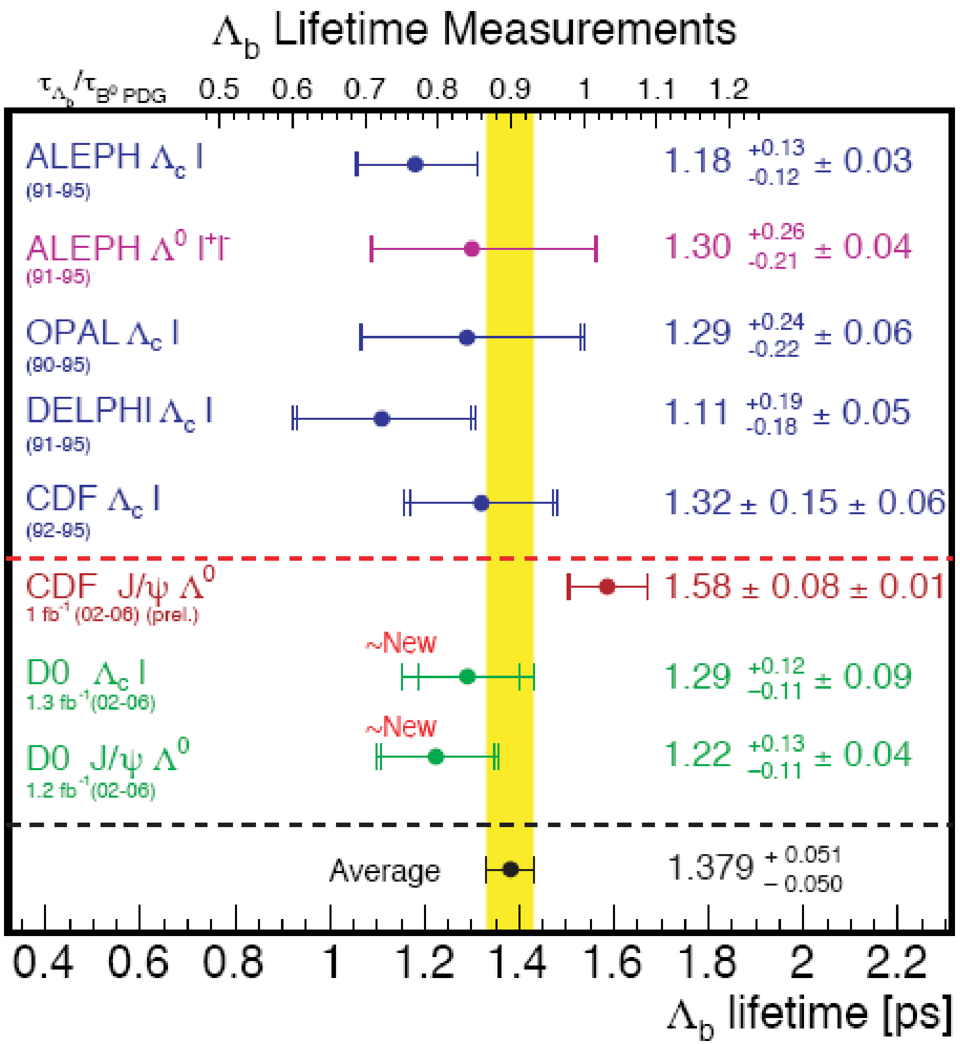
- $\Lambda_b \to \mu\nu\Lambda_c$ X; $\Lambda_c^+ \to K_s^0$ p
- First K_s^0 are constructed from two oppositely charged tracks that are assigned π mass.
- 4.4K Λ_c^+ events are reconstructed
- Define visible proper decay length $\lambda^M = mc(L_T.p_T(\mu\Lambda_c^+)) / |p_T(\mu\Lambda_c^+)|^2$
- $\mu\Lambda_c$ events are split into 10 λ^M bins





$$\tau(\Lambda_b) = 1.290^{+0.119}_{-0.110}(stat)^{+0.087}_{-0.091}\ ps$$

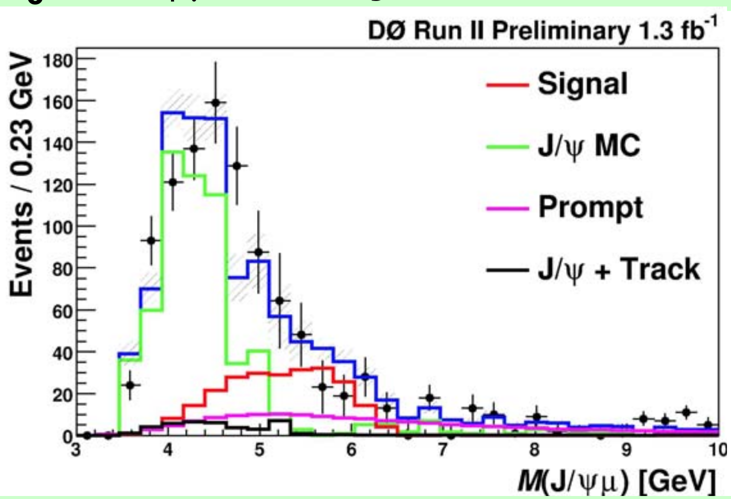
Summary of Λ_b Lifetimes

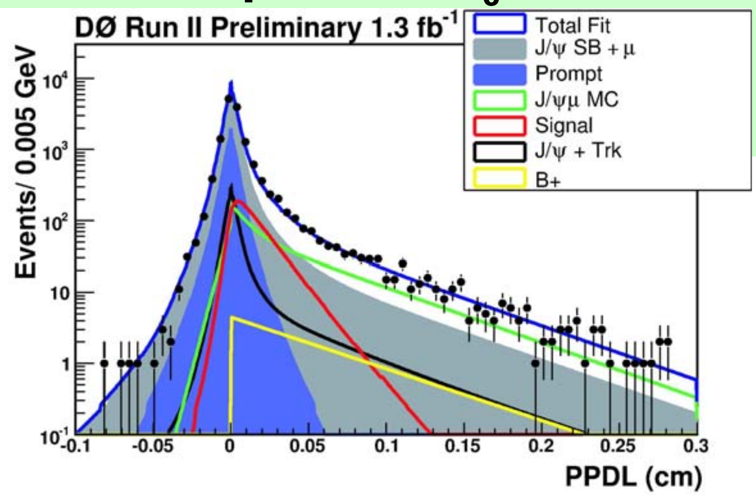


HFAG Plot

B_c Lifetime at D0

- B_c is an interesting hadron, composed of two different heavy quarks b and c
- Operator Product Expansion (OPE) calculation predicts B_c lifetime about 1/3 of other b-hadrons.
- $B_c \rightarrow J/\psi\mu\nu$ decay is considered





B_c mass signal following lifetime cut, demonstrating signal

Lifetime is determined from simultaneous fit to invariant mass and PPDL

$$\tau\left(B_c^{\pm}\right) = 0.444^{+0.039}_{-0.036}(stat)^{+0.039}_{-0.034}(syst)\,ps$$

D0Note 5524-CONF

$$\tau\left(B_c^{\pm}\right) = 0.48 \pm 0.05\,ps$$

hep-ph/0308214

$$\tau\left(B_c^{\pm}\right) = 0.463^{+0.073}_{-0.065} \pm 0.036\,ps$$

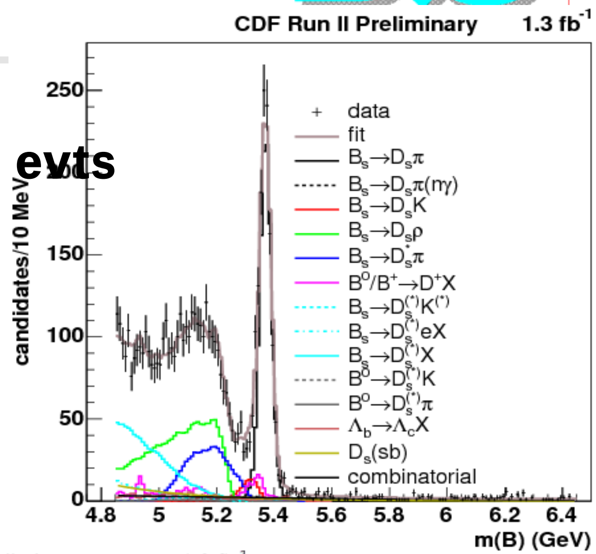
CDF Phys Rev Lett. 97, 012002 (2006)

B_s lifetimes (Flavour specific)

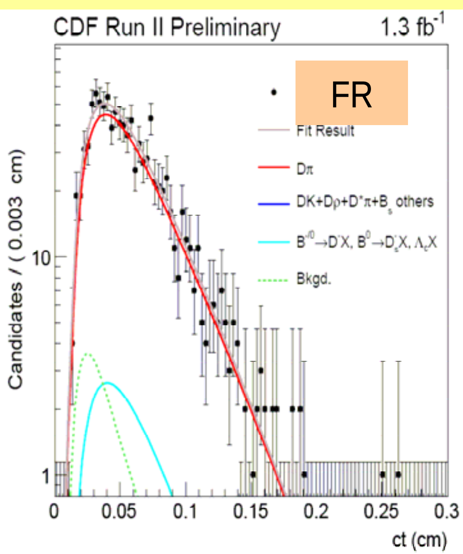
$B_s \rightarrow D_s^-(\phi\pi^-)\pi^+$ **:Fully Reconstructed (FR)**

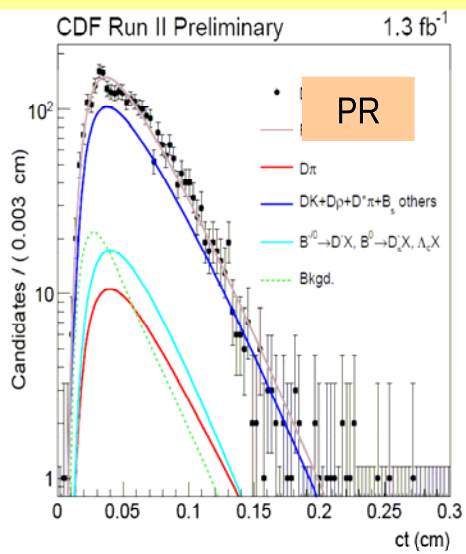
$B_s \rightarrow D_s^-\rho^+(\pi^+\pi^0)$ **:Partially reconstructed (PR)**

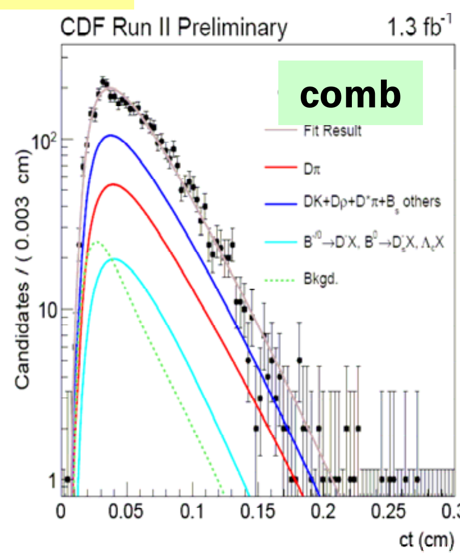
~1100 evts



- **Lifetime determined in two steps:**
  - **First fit mass to determine relative fraction in different modes**
  - **Fit the proper decay time of Bs candidates**
- **K-factor multiplied to correct for missing tracks or wrong mass assignment for partially reconstructed events**

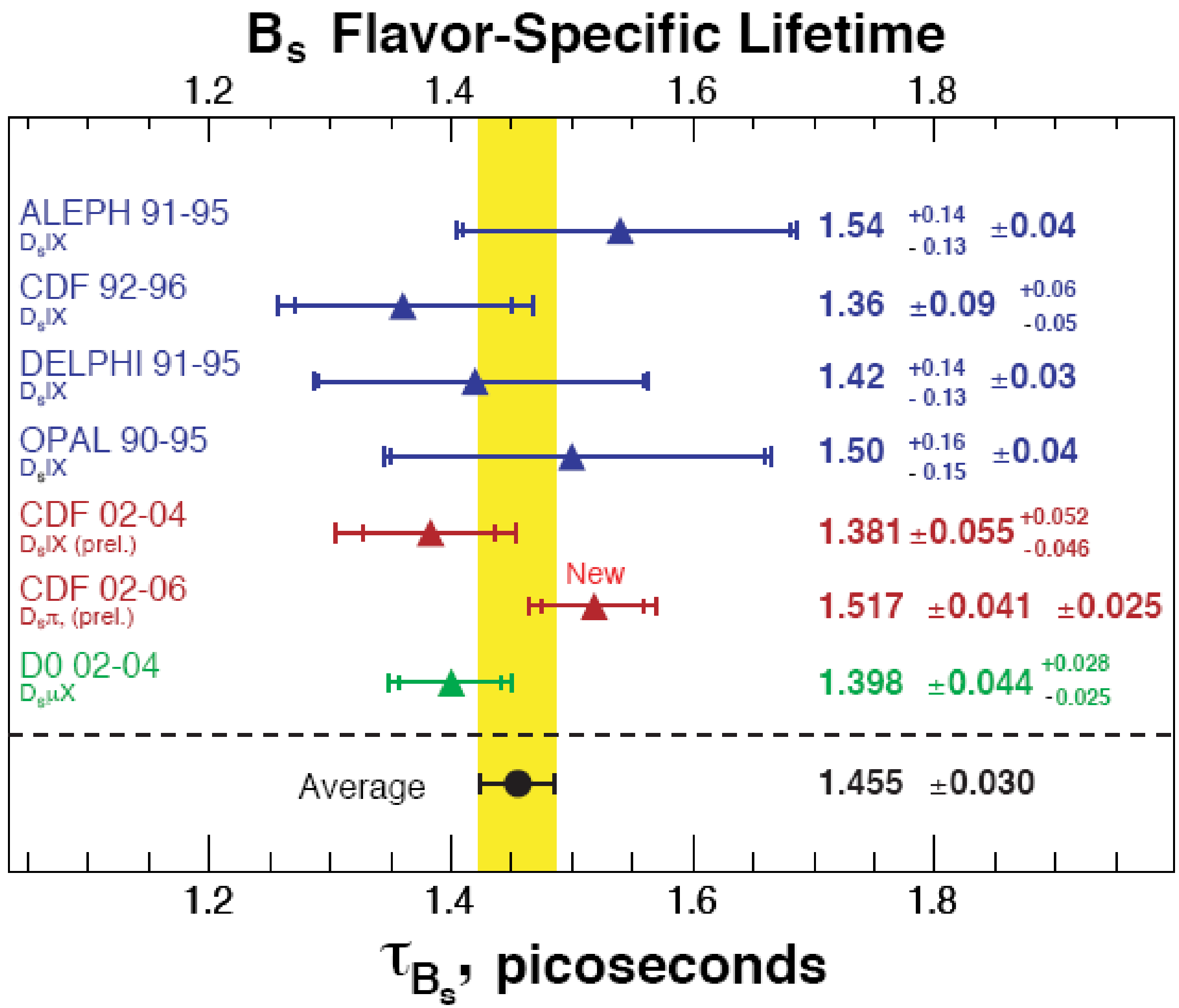






$\tau(B_s)$ = 1.456±0.0 67ps **$\tau(B_s)$ = 1.545±0.051 ps** **$\tau(B_s)$ = 1.518±0.041±0.025 ps**

B_s lifetimes summary

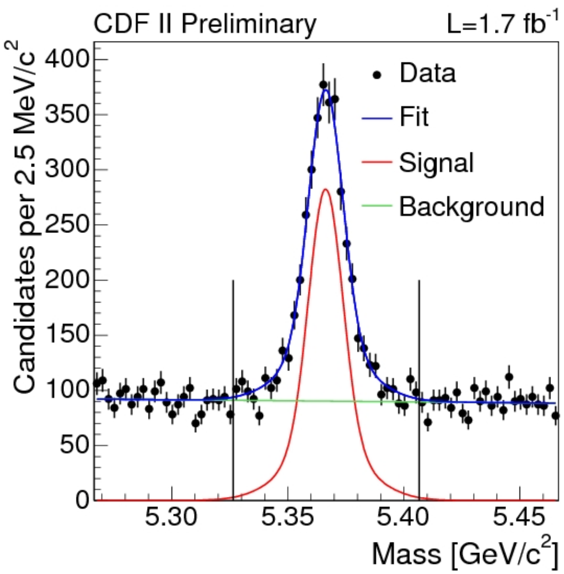


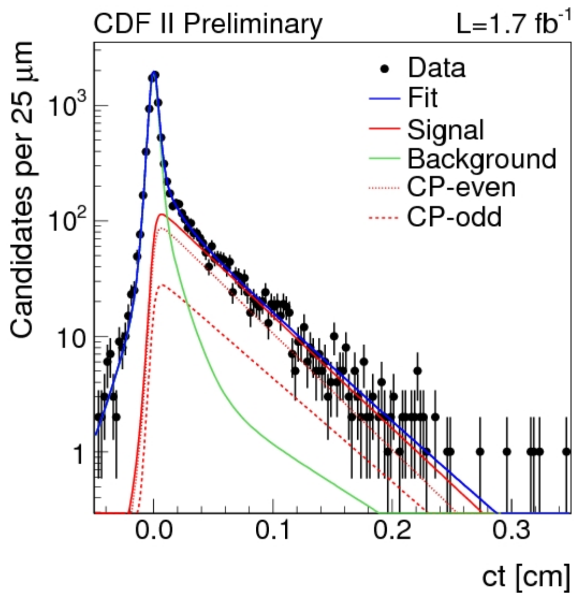
HFAG

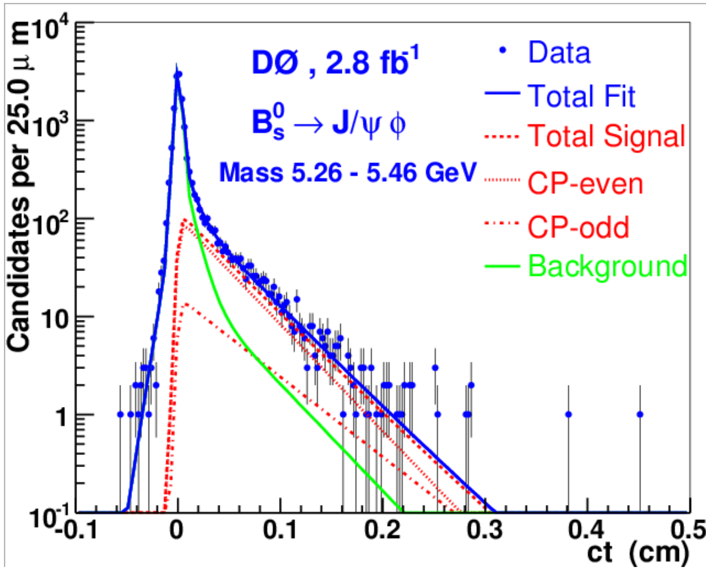
Lifetimes $B_s \to J/\psi\phi$

Average lifetime of B_s , $\bar{B}_s$ system can be measured from $B_s \to J/\psi\phi$

Average lifetime $\tau_s = 1/\Gamma_s$, where $\Gamma_s = (\Gamma_{even} + \Gamma_{odd})/2 \approx (\Gamma_H + \Gamma_L)/2$







CDF measurement using 1.7 fb^{-1} data

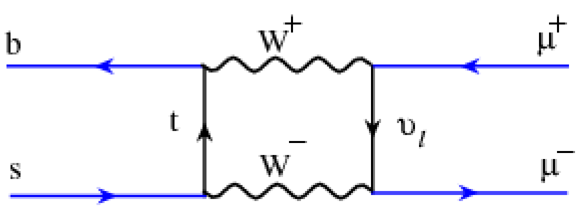
$\tau(B_s)$ = 1.52±0.04 ±0.02 ps

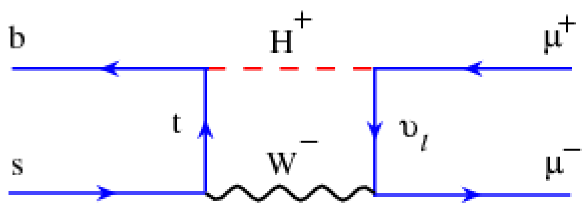
D0 measurement using 2.8 fb^{-1} data

$\tau(B_s)$ = 1.52±0.05 ±0.01 ps

Search for $B_{s(d)} \rightarrow \mu\mu$

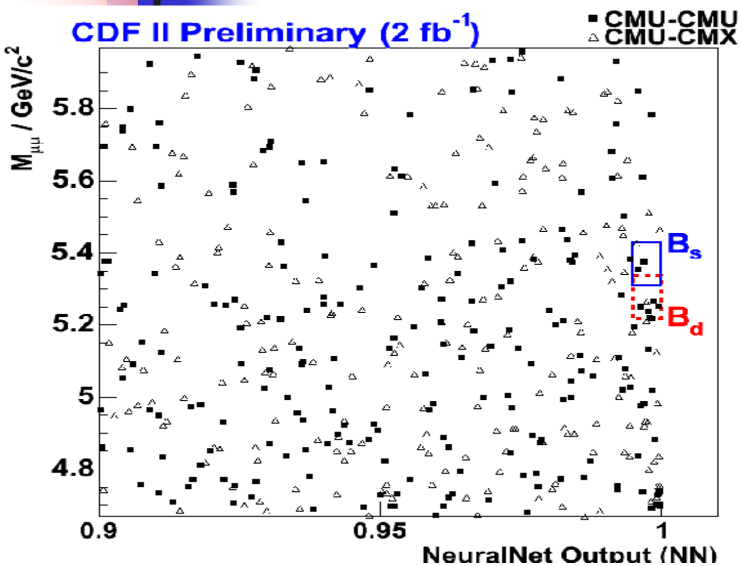
- **At tree level decays of $B_{s(d)} \rightarrow \mu\mu$ proceed through FCNC, and is prohibited**
- **Decays in standard model through higher order diagrams have very low rate**
- **Standard model prediction for**
- **Br ($B_s \rightarrow \mu\mu$) = (3.42 ±0.54). 10^{-9} (A.J Buras, Phys Lett. B 115 (2003)**
- **Br ($B_d \rightarrow \mu\mu$) is further suppressed by CKM factor $(V_{ts}/V_{td})^2$**





- **Any event at Tevatron would signal new physics**
- **In MSSM the enhancement of signal is proportional to $\tan^6\beta$**
- **$B^{\pm} \rightarrow J/\psi K^{\pm}$ is used as the normalization channel by both CDF and D0**

Search for $B_{s(d)} \rightarrow \mu\mu$



arXiv: 0712.1708

- CDF used 2fb-1 of luminosity
- Neural net variable ν_N is concocted using

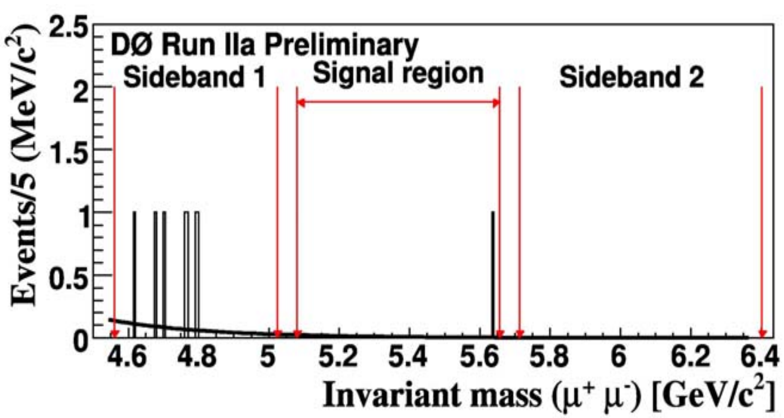
Proper decay time λ, λ/σ_{λ}, 3D opening angle between dimuon and displacement vector between primary vertex and dimuon vertex, B candidate track isolation

- 95% (90%) C.L. limits

$Br(B_s \rightarrow \mu^+\mu^-) < 5.8\ 10^{-8}\ (4.7\times 10^{-8})$

World's Best

$Br(B_d \rightarrow \mu^+\mu^-) < 1.8\ 10^{-8}\ (1.5\times 10^{-8})$



D0 also used 2fb-1 of data.

A likelihood ratio (LHR) is constructed using 6 variables: Muon pair isolation, Decay length significance, pointing angle, B impact parameter, Minimum muon impact parameter, vertex χ^2 probability.

- 95% (90%) C.L. limits

$Br(B_s \rightarrow \mu^+\mu^-) < 9.3\ X\ 10^{-8}\ (7.5\ x\ 10^{-8})$

FCNC D decays

FCNC decays of D mesons in Standard Model is highly suppressed, Br < 10^{-9}

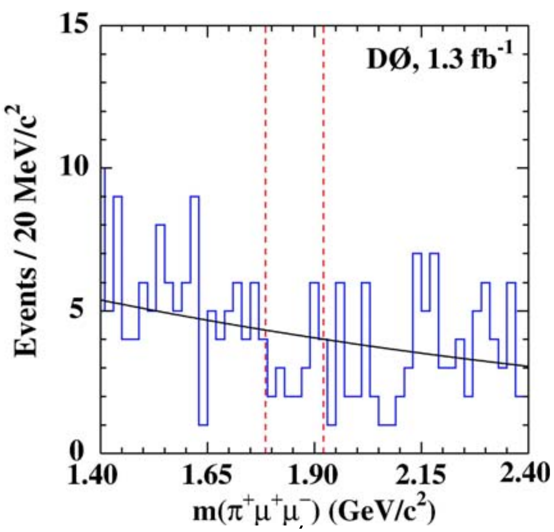
D0 reports a search using 1.3 fb-1 data

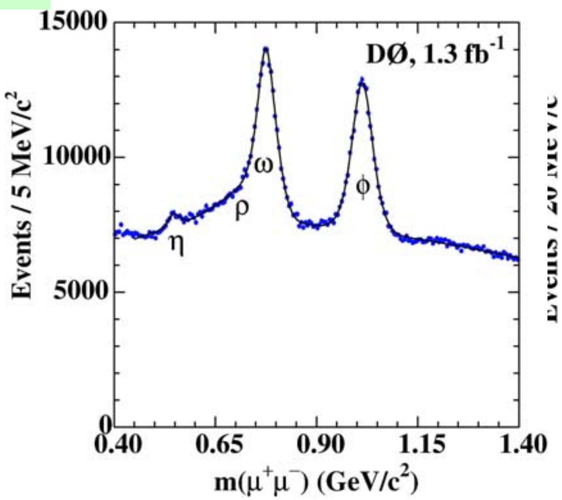
First show D_s, D $\rightarrow \varphi\pi \rightarrow \mu^+\mu^-\pi$

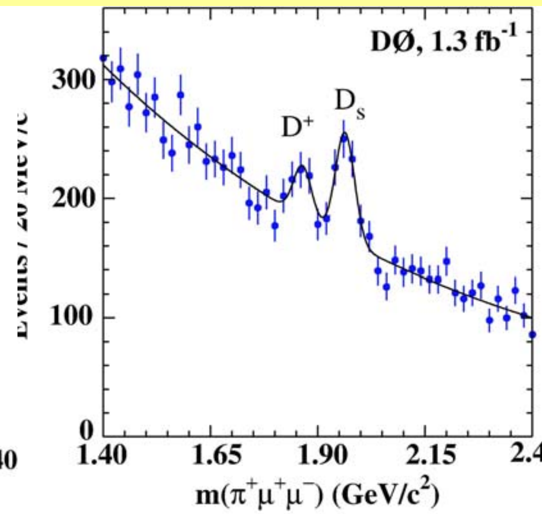
254±36 D_s^+ and 115 ± 31 D+ candidates, significance of 8 sd

Search for continuum decay D→πμμ

Look for $M_{\mu\mu}$ < 1.8 GeV excluding 0.96-1.06 GeV







Signal events 19, Background 25.8±4.6

Exclude Br ($D^+ \rightarrow \pi\mu\mu$) < 6.1 10-6 (3.9x10-6) at 90% (95%) CL

Conclusions

- **Tevatron is running well, and already collected over 3 fb^{-1} of luminosity / experiment**
- **Many new improved lifetime measurements reported, some interesting anomalies seen**
- **Uncertainties still mostly dominated by statistics, will be reduced by more data.**
- **Prospects for improved reach for new physics in rare decays**
- **Stringent limits obtained for very important FCNC rare decays**
- **Expect to at least double our dataset by the end of the Tevatron running**

So watch out for updates on existing results, and new results in coming years