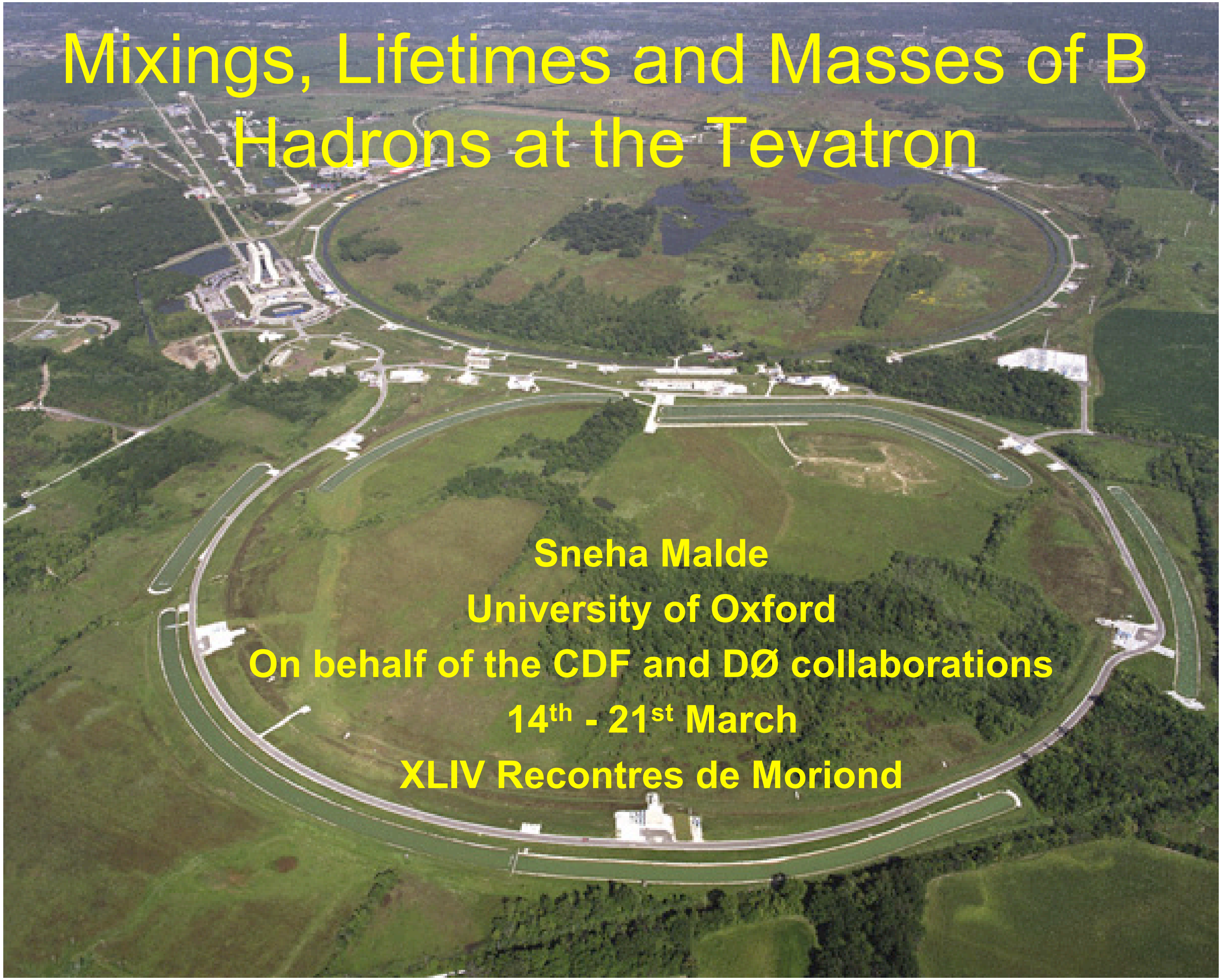
Mixings, Lifetimes and Masses of B Hadrons at the Tevatron



Sneha Malde

University of Oxford

On behalf of the CDF and DØ collaborations

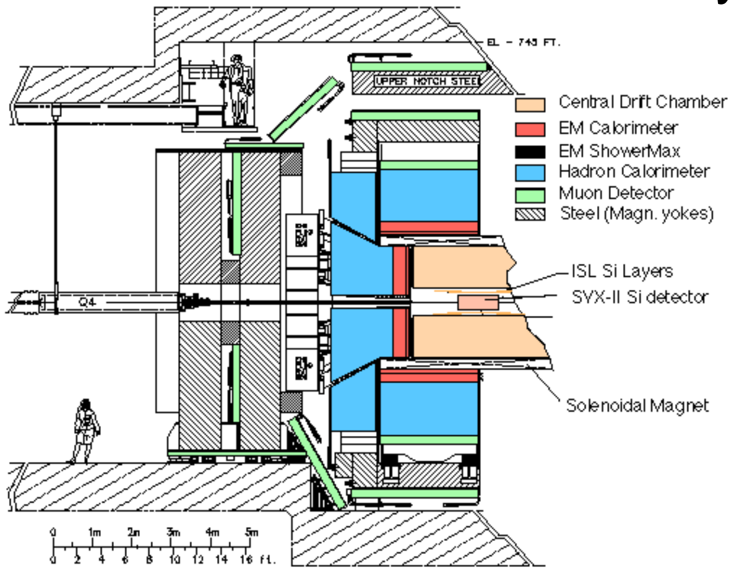
14th - 21st March

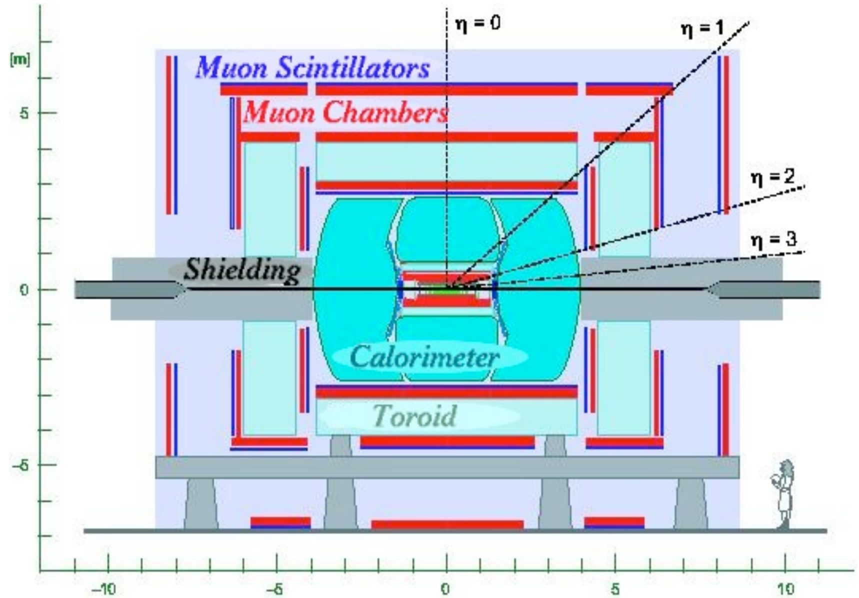
XLIV Recontres de Moriond

Strengths of the Detectors

Largest samples of $B_{s,}$ $B_{c,}$ B-baryons at the Tevatron

>5fb^{-1} recorded to date. Analyses today from 1.0 - 2.8 fb^{-1}





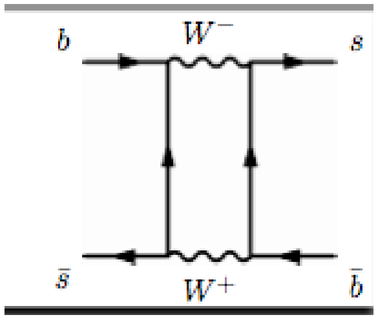
Excellent tracking and mass resolution.

Ability to trigger on displaced tracks ➔ Large sample of hadronic decays

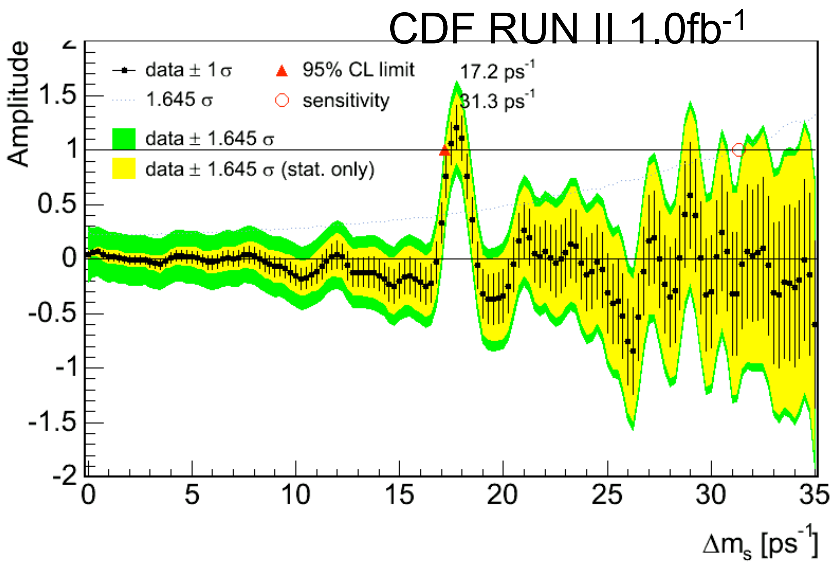
Excellent Muon Id and tracking coverage➔ Large samples of semileptonic decays

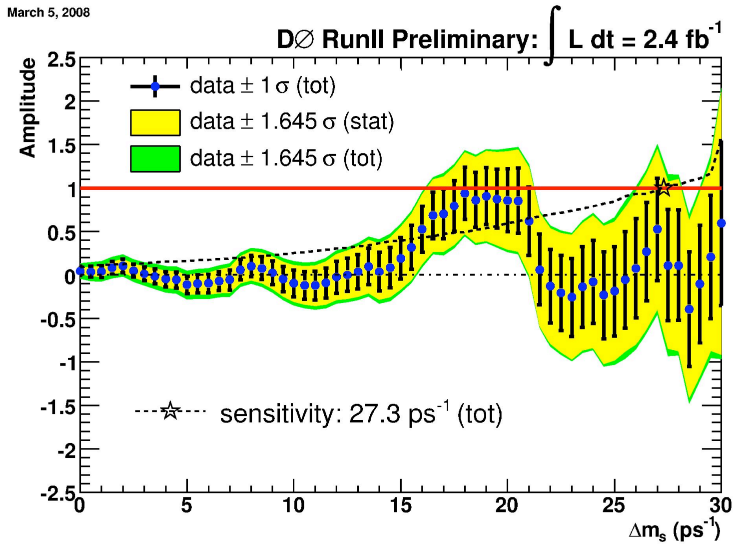
Regular magnet inversion➔ smaller systematics in charge sensitive measurements

B_s Mixing



- Flavor eigenstates ≠ mass eigenstates
- Δm_s, the mixing frequency $\Delta\Gamma$, the width difference





Δm_s=17.77±0.10(stat)±0.07 (syst) ps^{-1}

5.4σ statistical significance

Δm_s=18.53±0.93(stat)±0.30(syst) ps^{-1}

2.9σ statistical significance

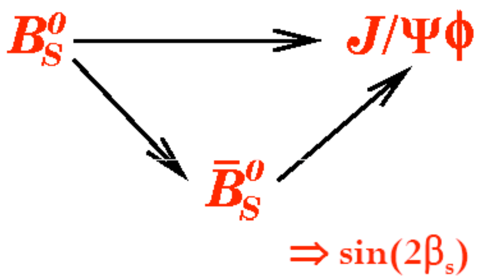
PRL **97** 242003

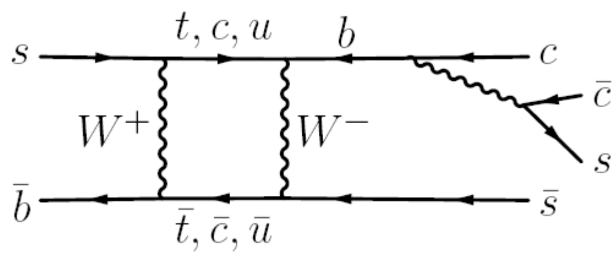
www-d0.fnal.gov/Run2Physics/WWW/results/prelim/B/B54

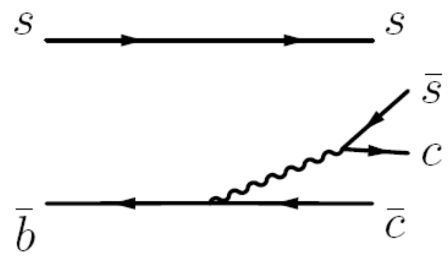
B_s Mixing and Interference

Mixing frequency established ➔ use $B_s \rightarrow J/\Psi\phi$ to look for new physics

- B_s mass eigenstate ~pure CP eigenstates in SM (ϕ_s~0)
- $B_s \rightarrow J/\psi\phi$: CP of final state given by angular momentum L
- L=0, 2 ➔ CP even, L=1 ➔CP odd

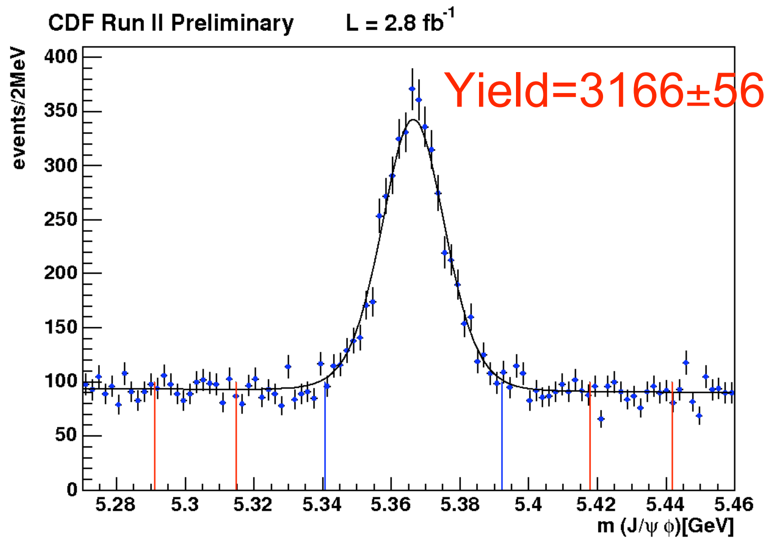


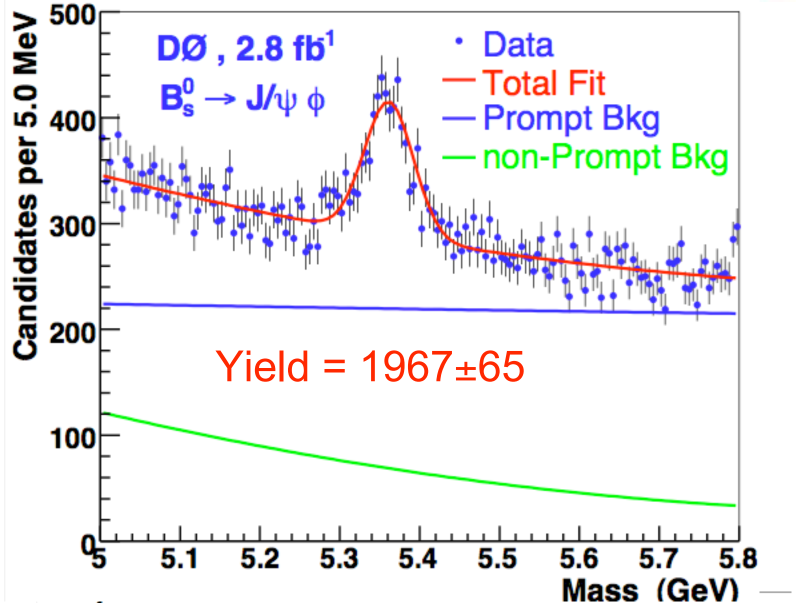


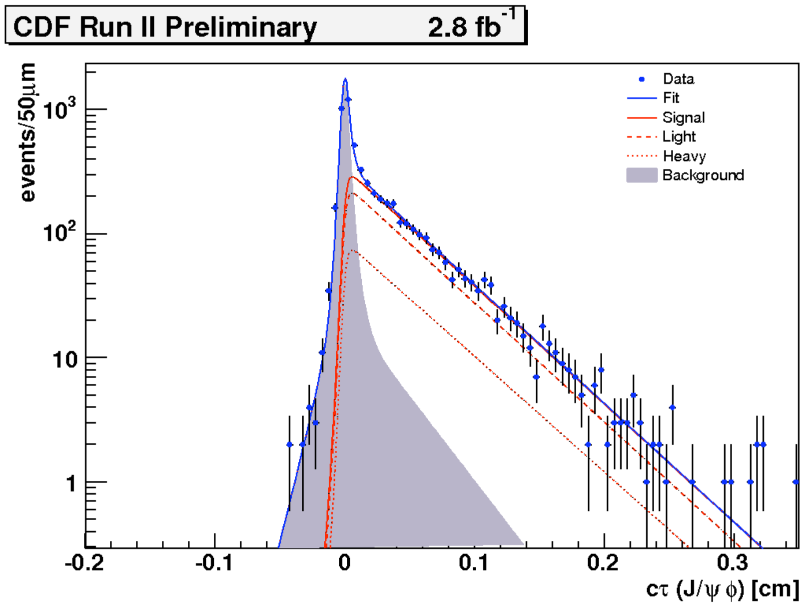


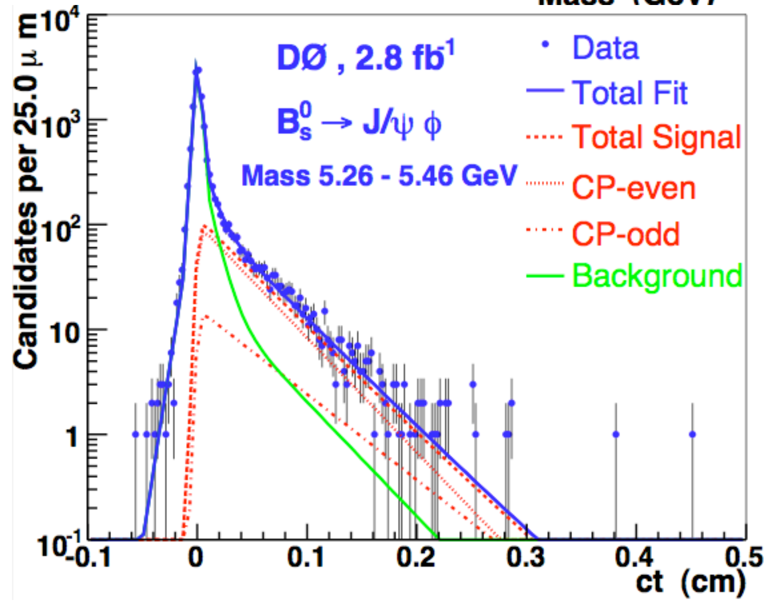
- Interference of both decay paths involves CP violating phase β_s
- β_s ~ 0.02 in standard model➔ Large observed β_s = New physics
- Analyse decay rate as a function of time, decay angles and initial B_s flavor
- Extract lifetime, $\Delta\Gamma$, β_s from unbinned likelihood fit

$B_s \rightarrow J/\Psi\phi$

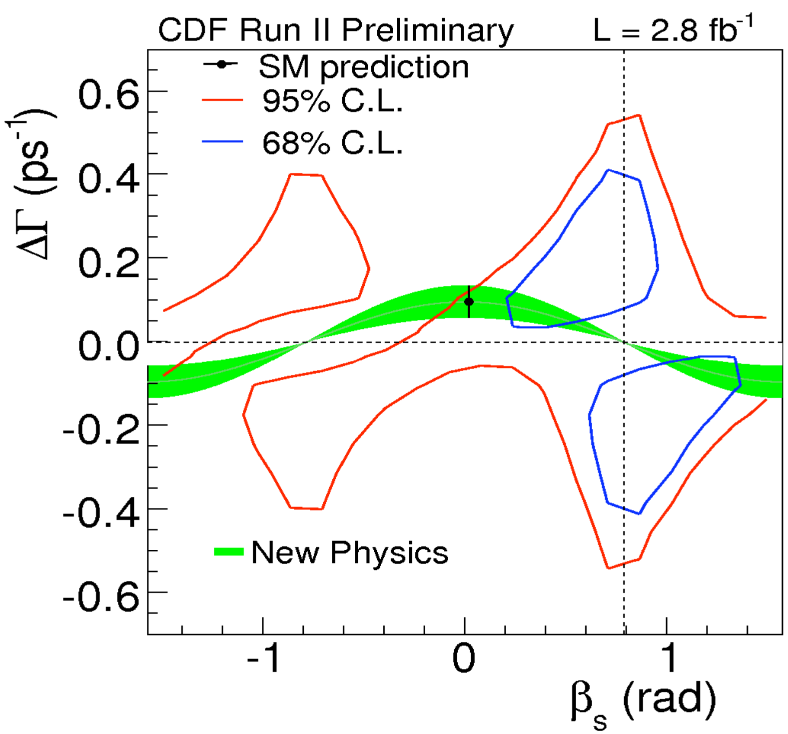


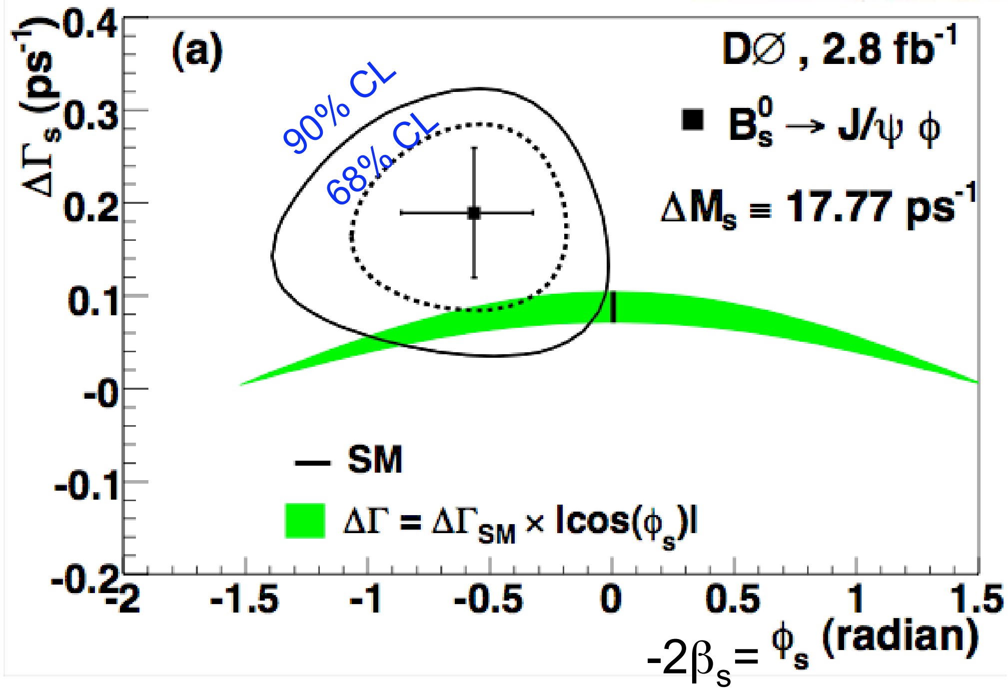






$\Delta\Gamma$ & β_s





Confidence intervals for β_s $\Delta\Gamma$ as errors non Gaussian

Probability of consistency with SM=7.0% ~1.8σ

PRL **100** 161802 (1.4fb^{-1} result)

Strong phases constrained by B factory $B_0 \rightarrow J/\Psi K^*$ measurement➔ one minimum

Probability of consistency with SM=6.6%

PRL **101** 241801

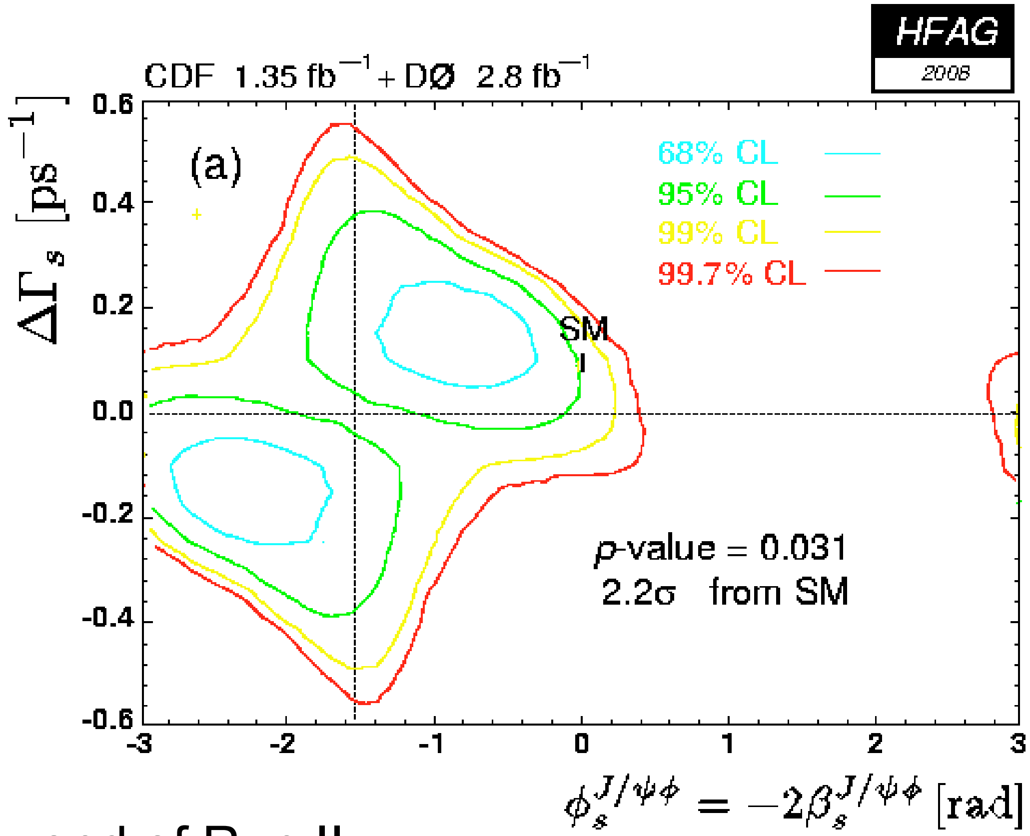
www-cdf.fnal.gov/physics/new/bottom/080724.blessed-tagged_BsJPsiPhi_update_prelim/

CDF & DØ combination

Similar deviations observed at CDF and DØ

Combination only for 1.35fb^{-1} (CDF)[1.5σ inconsistency observed] + 2.8fb^{-1} DØ

2.2σ deviation from SM



One to watch

Can expect:

More data - at least 8fb^{-1} of data by end of Run II

- use of data collected by other triggers

Improvement/Addition of tagging information

a_{sl}^{s} in semileptonic B_s Decays

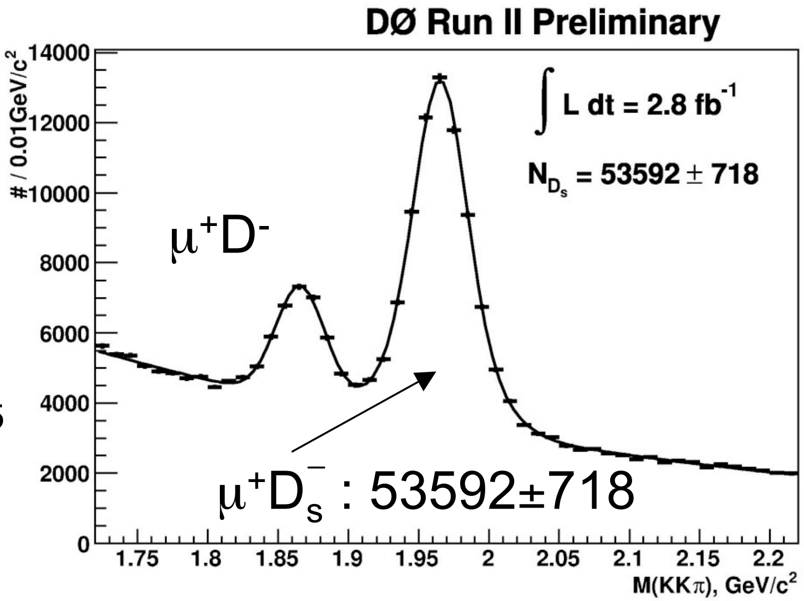
Can provide additional constraints to ϕ_s

Measurement of charge asymmetry using time-dependent analysis of:

$$B_s \rightarrow D_s^- \mu^+ \upsilon X \left(D_s^- \rightarrow \phi\pi^-, \phi \rightarrow K^+ K^- \right)$$

$$a_{sl}^{s} = \frac{\Delta\Gamma}{\Delta m_s} \tan(\phi_s)$$

Fix $\Delta m_s = 17.77 ps^{-1}$



a_{sl}^{s} in SM expected small $(\sim 2.06 \pm 0.57) \times 10^{-5}$

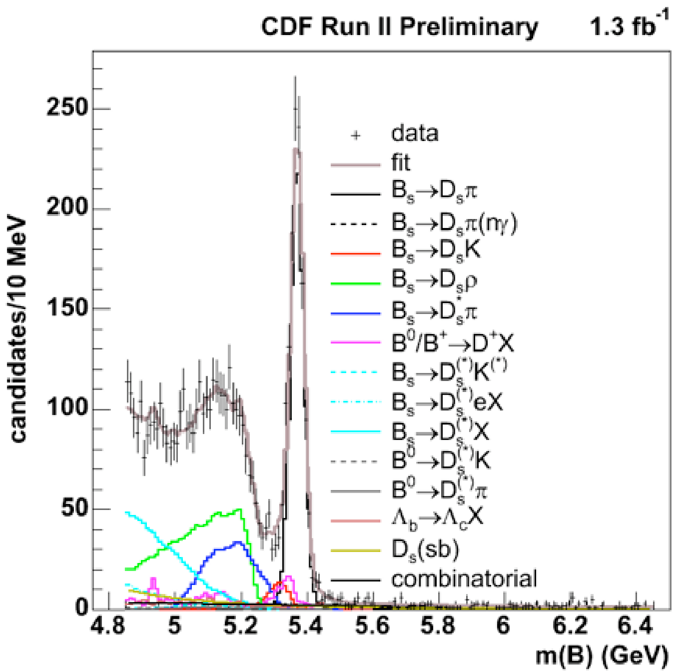
$a_{sl}^{s} = -0.0024 \pm 0.0117^{+0.0015}_{-0.0024}$

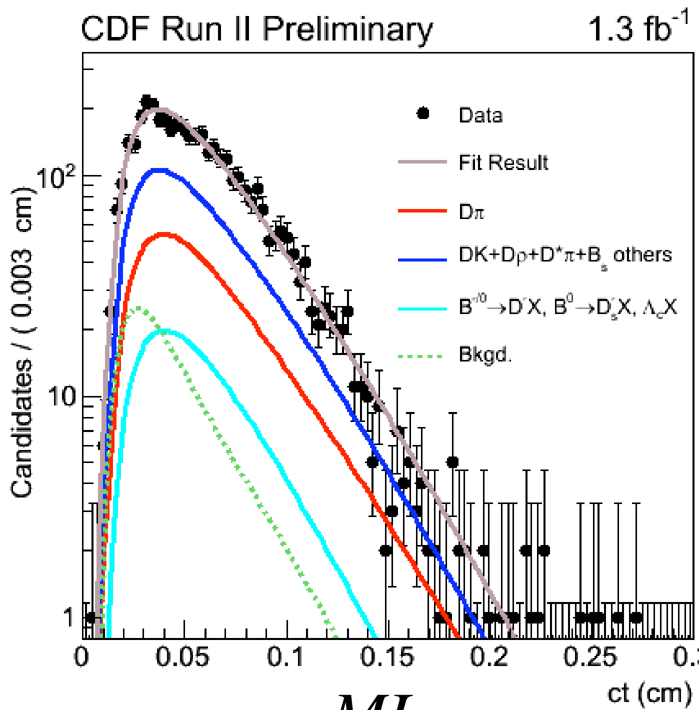
Most precise measurement to date

www-d0.fnal.gov/Run2Physics/WWW/results/prelim/B/B55

B_s Lifetime

Better measurement of $\tau(B_s)$ can also be used to constrain NP in B_s mixing





- Take advantage of yield of partially reconstructed B_s decays
- 1100 fully reconstructed $B_s \to D_s\pi$
- 2200 partial reconstructed $B_s \to D_s^*\pi$, $B_s \to D_s\,\rho$

$$ct = \frac{ML_{xy}}{P_T}$$

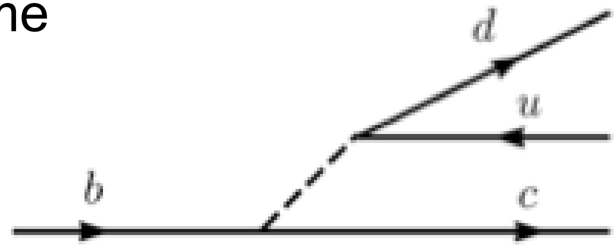
$c\tau = 455.0 \pm 12.2 \pm 8.2\ \mu\mathrm{m}$

Consistent with $\tau(B_s) \sim \tau(B_d)$

www-cdf.fnal.gov/physics/new/bottom/080207.blessed-bs-lifetime/

Lifetimes of B Hadrons

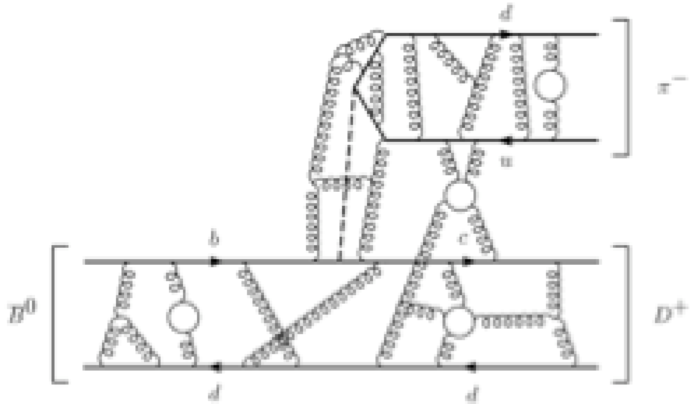
Spectator model: all B hadrons have the same lifetime



Difference from light quark interactions

Expected Hierarchy:

$\tau(B_u) > \tau\ (B_d) \sim \tau(B_s) > \tau(\Lambda_b) >> \tau(B_c)$



Ratio Predictions (HQE):

$\tau(B^+) = 1.06 \pm 0.02\ \tau(B_d)$

$\tau(B_s) = 1.00 \pm 0.01\ \tau(B_d)$

$\tau(\Lambda_b) = 0.88 \pm 0.05\ \tau(B_d)$

Eur Phys J, C33 S895 (2004)

Previously, in B_s, Λ_b have seen 1-2σ discrepancies

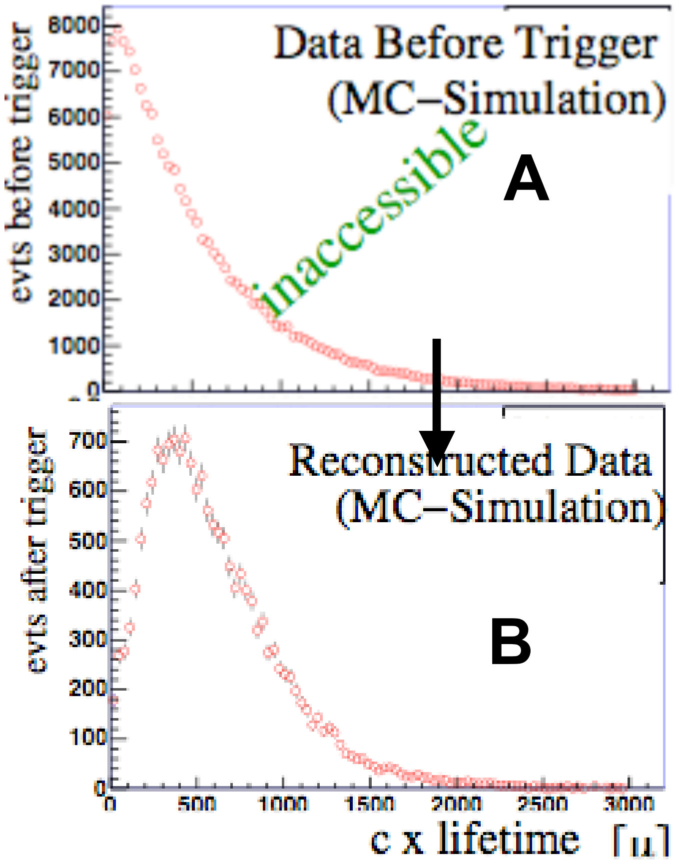
$\tau(B_c) = 0.55 \pm 0.15$ ps

PDG $\tau(B_d)$: 1.530 ±0.009 ps

arXiv:hep-ph/0308214

Lifetime measurements and the CDF track trigger

- Large Branching ratios to hadronic final states
- Use a Two Track Trigger with primary requirements:
  - -Two tracks with 120μm<impact parameter<1000 μm
  - - L_{xy} >200 μm
- Effectively triggers on displaced vertices➔high B Hadron yields
- Lifetime distribution biased



Two solutions

1. Use MC to determine average efficiency [B_s and Λ_b]
2. Use simulation free method [B^+]

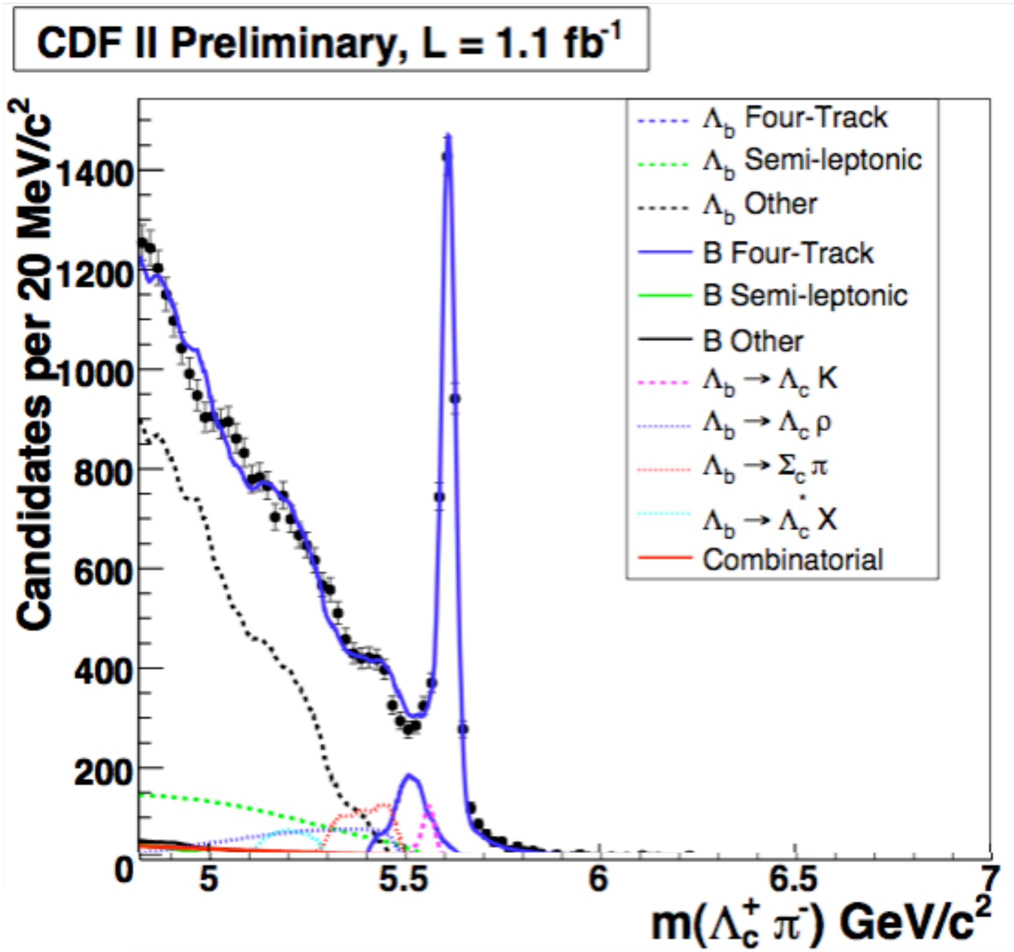
Λ_b yield

$\Lambda_b \rightarrow \Lambda_c \pi$

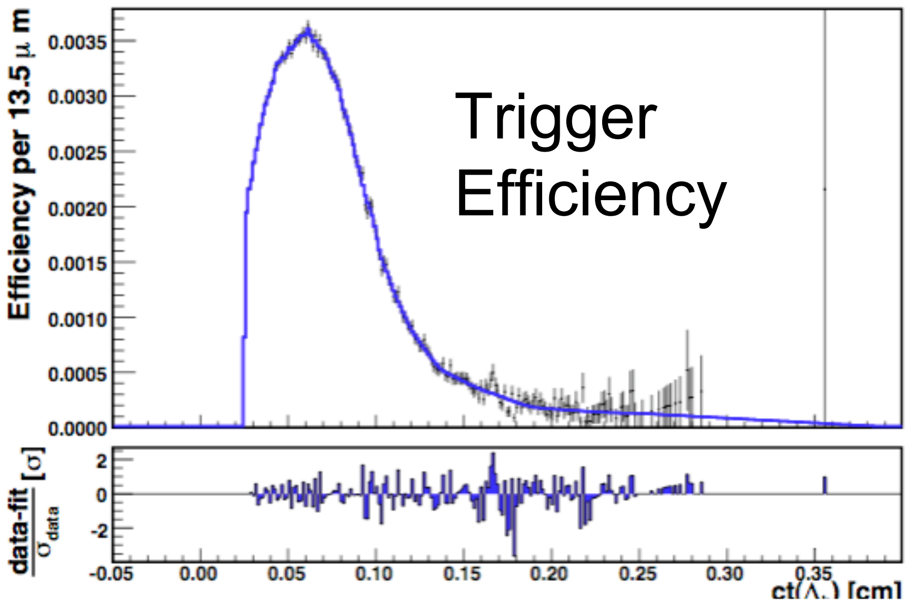
Large Signal yield

Sample composition determined from mass fit

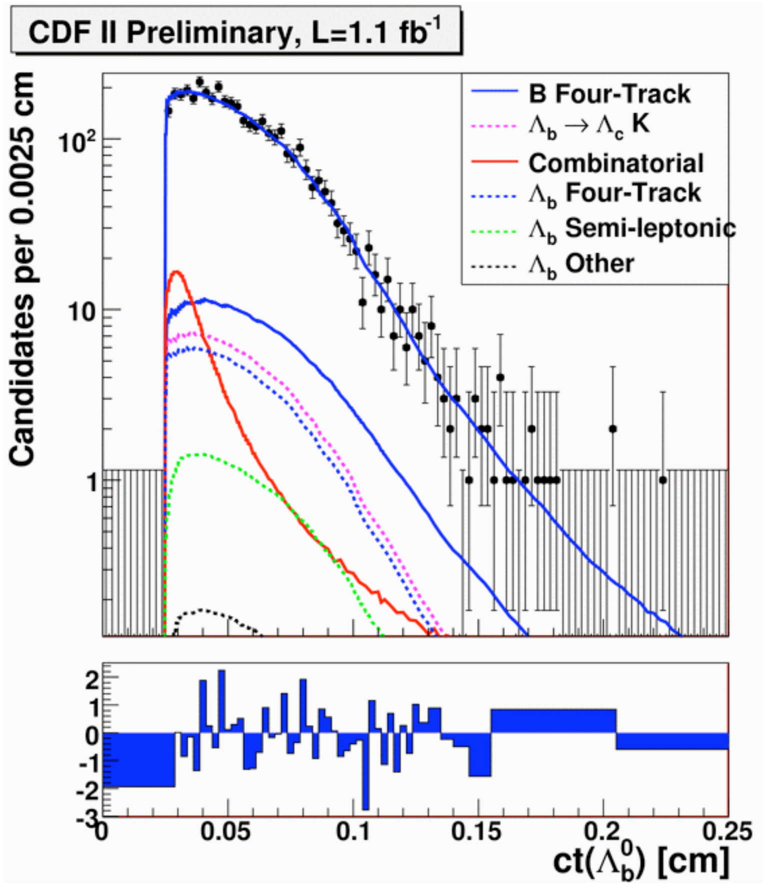
Signal: 2927±58



$\tau(\Lambda_b)$ using MC to model the trigger efficiency



Fit exponential convoluted with trigger efficiency and detector resolution.



$c\tau = 422.8 \pm 13.3 \pm 8.8\ \mu m$

Systematic error dominated by MC modeling of trigger efficiency and decay

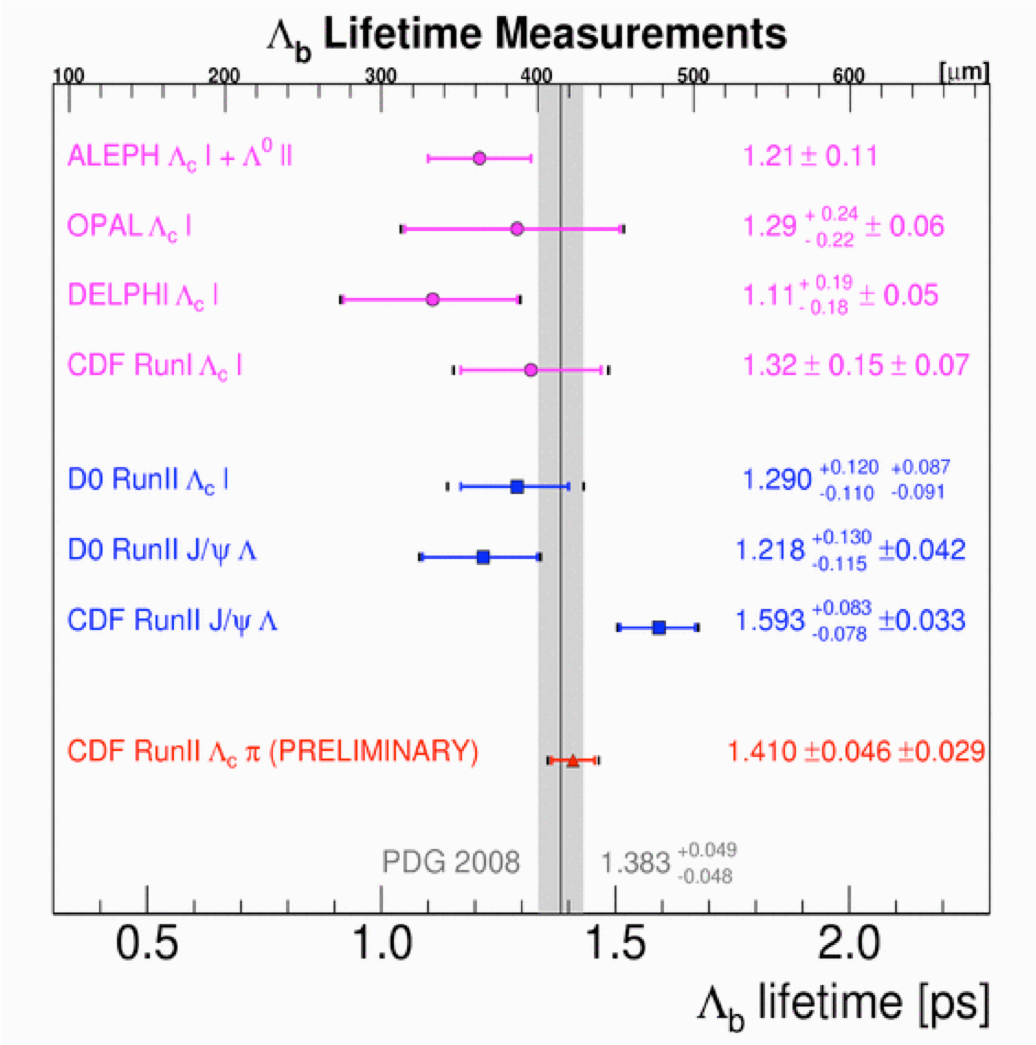
www-cdf.fnal.gov/physics/new/bottom/080703.blessed-lblcpi-ct/

Λ_b Lifetime Comparisons

- New measurement consistent with all previous measurements
- Agreement with theory prediction: $\tau(\Lambda_b)=0.88\pm0.05\ \tau(B^0)$

$\tau(\Lambda_b)=0.922\pm0.039\ \tau(B^0)$

- Utilise x4 increase in data for more precise measurements.



Simulation Free approach

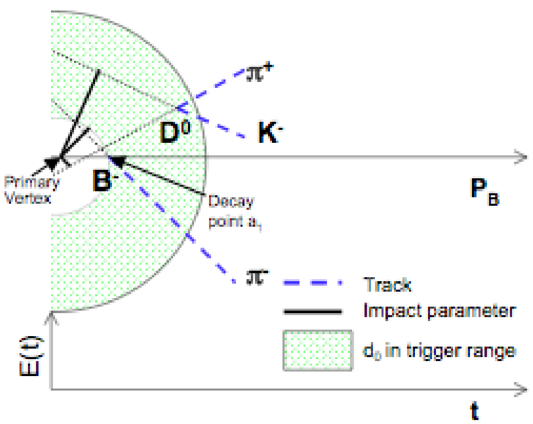
•Using MC to determine trigger efficiency ➔ dominates systematic error

•MC dependent method : systematic uncertainty ~ 8-9 μm

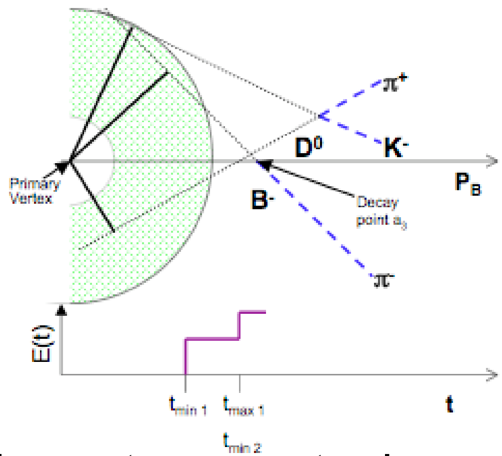
•Developed new, simulation free approach to bias correction

•Takes only kinematic information from data: Calculates the probability the trigger accepts the event at any decay point

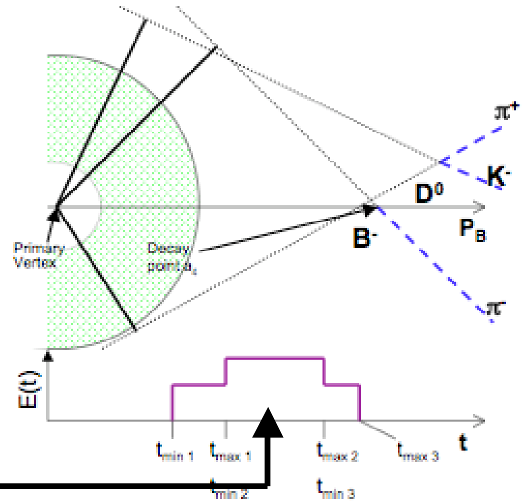
•Calculates "Event-by-Event" Efficiency function



Impact parameters too small



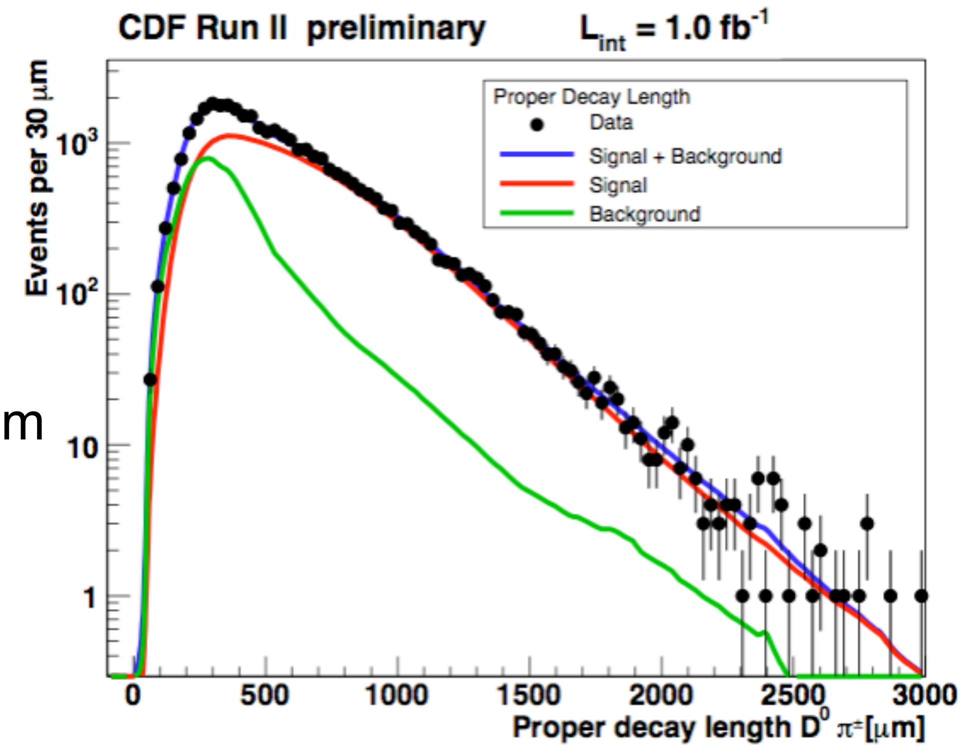
Impact parameter in trigger range



Impact parameters too large

$\tau(B^+)$ using Simulation Free approach

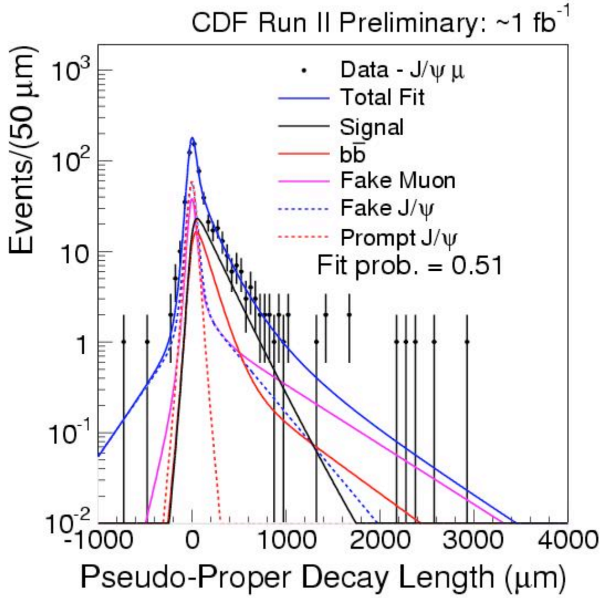
- Tested on $B^- \rightarrow D^0\pi$ (Yield ~ 24,000)
- Result consistent with PDG 491±3 μm
- Systematic uncertainty 4.5 μm c.f ~9 μm for MC dependent approach
- New method + more data ➔ high precision results for Λ_b and B_s

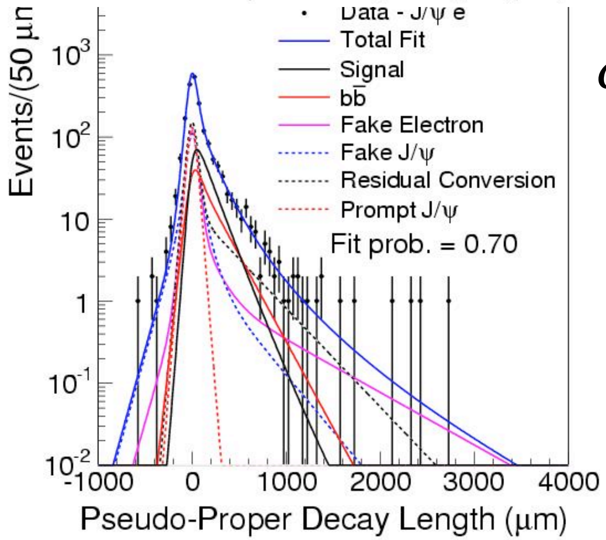


$c\tau$=498.2±6.8±4.5 μm

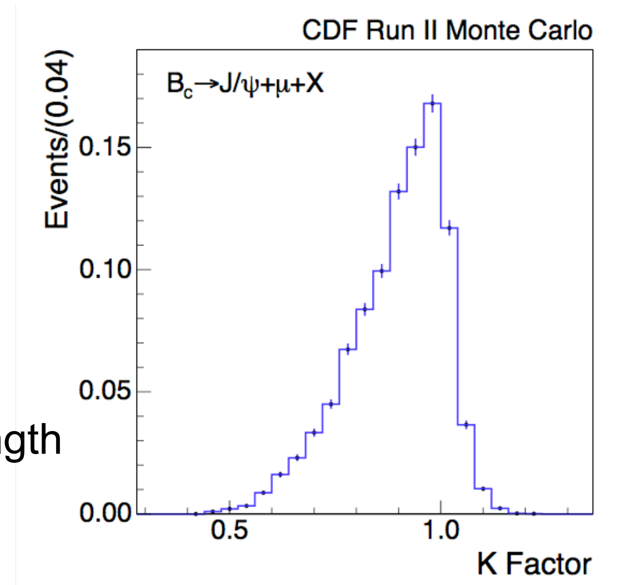
www-cdf.fnal.gov/physics/new/bottom/080612.blessed-MCfree_Blifetime/

B_c Lifetime





- Semileptonic channels can also be used for lifetime measurement
- $B_c \to J/\Psi\ \ell\ X$
- Analyse both e and µ channels
- Account for missing momentum with K factor derived from MC



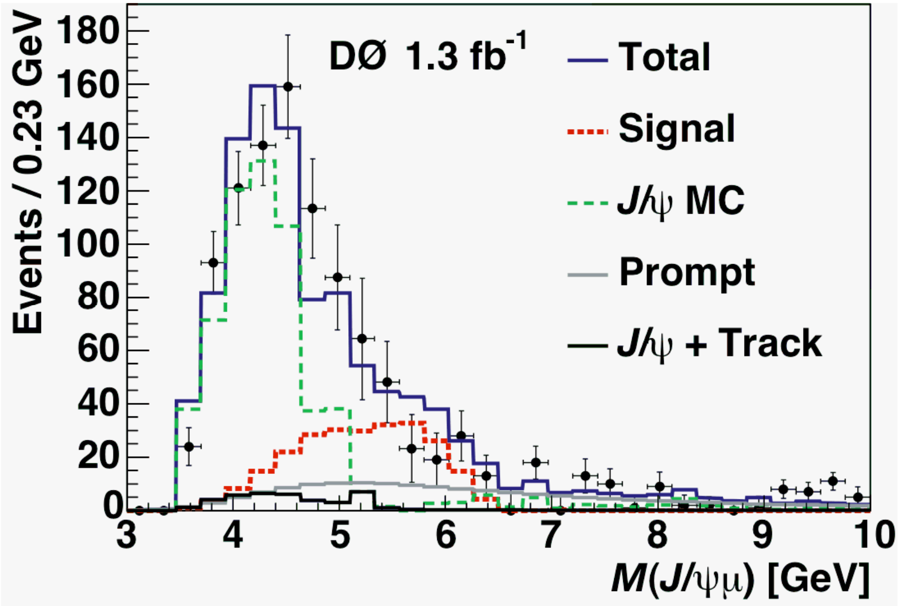
$$ct^* = \frac{ct}{K} = \frac{mL_{xy}(J/\Psi l)}{P_T(J/\Psi l)}$$

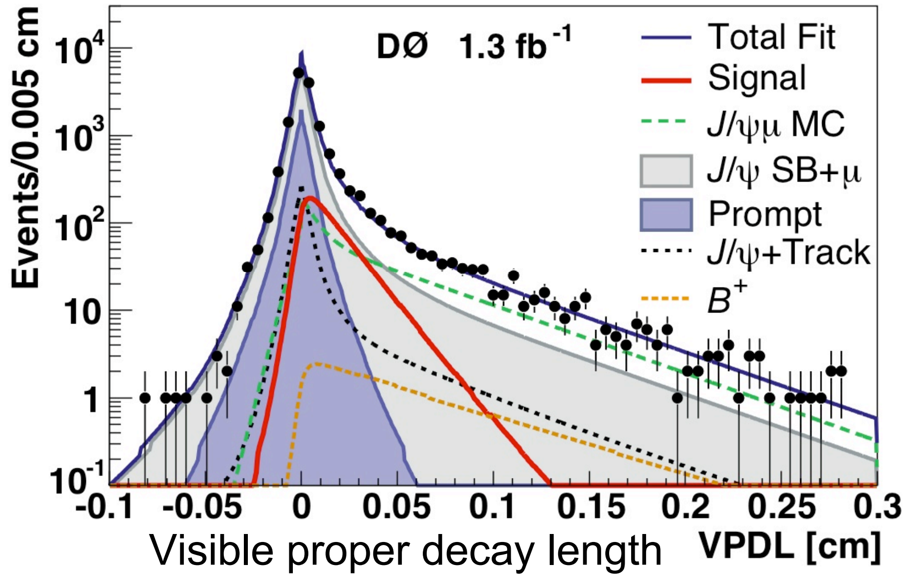
ct^*=pseudo proper decay length

CDF : $c\tau = 142.5^{+15.8}_{-14.8} \pm 5.5\ \mu m$

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

$B_c \rightarrow J/\Psi\mu$ X lifetime





DØ : $c\tau = 134.3^{+11.4}_{-10.8} \pm 9.6\ \mu m$

Simultaneous fit to mass and lifetime - Most precise measurement to date

PRL **102** 092001

Results from CDF & DØ consistent with each other and theory (165±45) μm

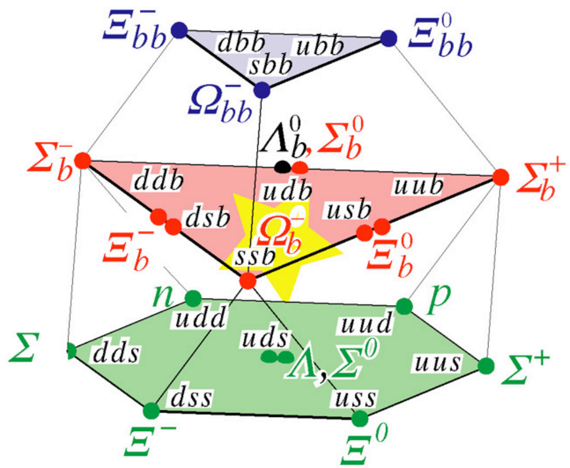
Ω_b search

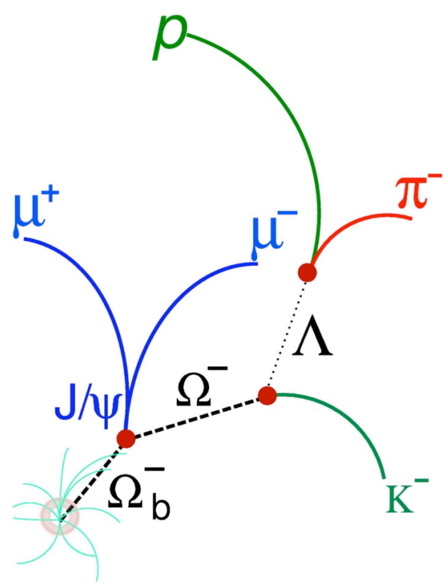
Tevatron has seen the observation of new b-baryons:

$\Sigma_b^{\pm}$ (2006), Ξ_b^- (2007), Ω_b^- (2008)

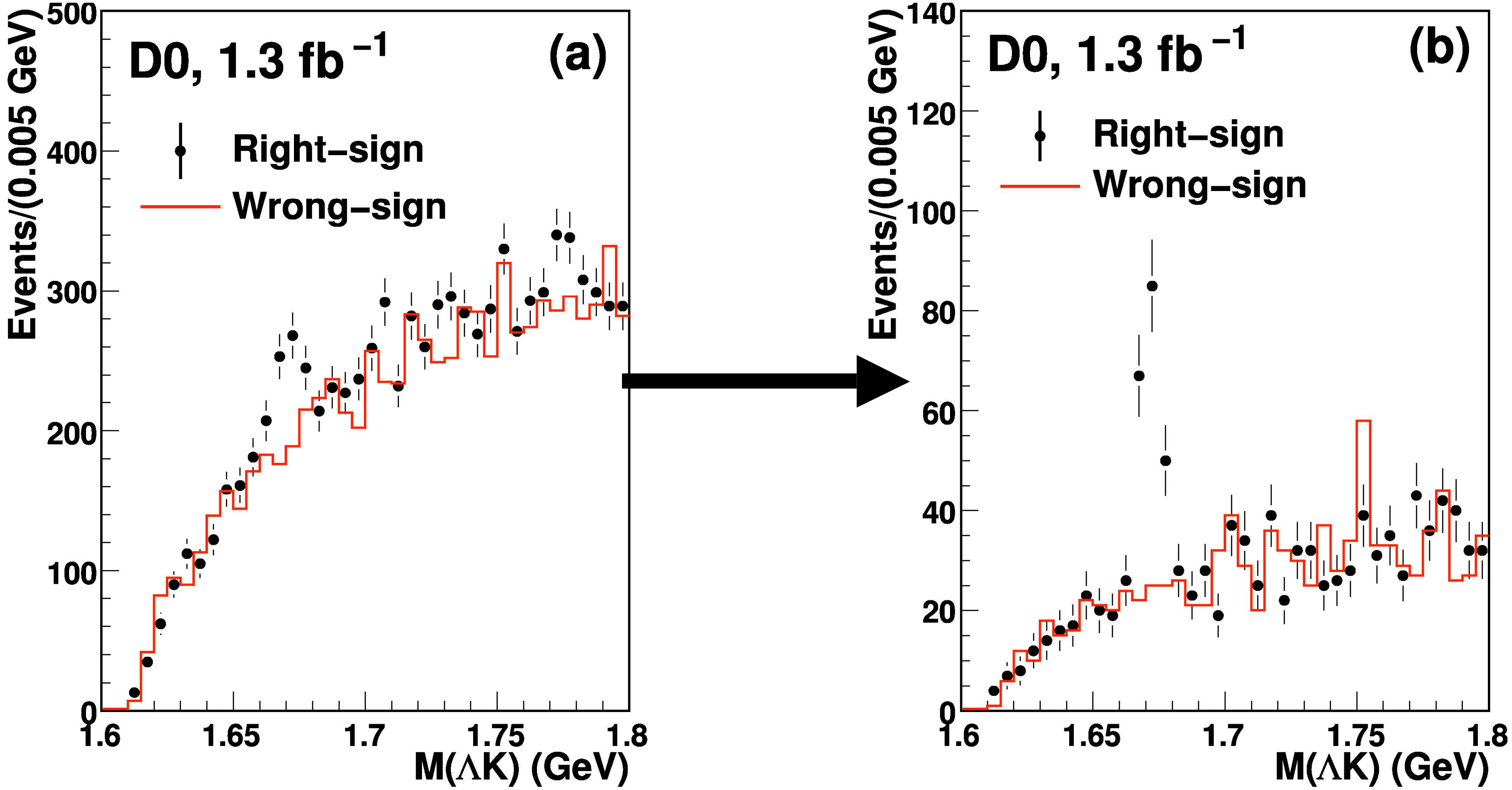
- DØ search for $\Omega_b \rightarrow J/\Psi\Omega^-$
- Builds on the Ξ_b^- discovery
- Data reprocessed allowing tracks with large impact parameter to be found. Increases yield of Ω

J =1/2 b Baryons





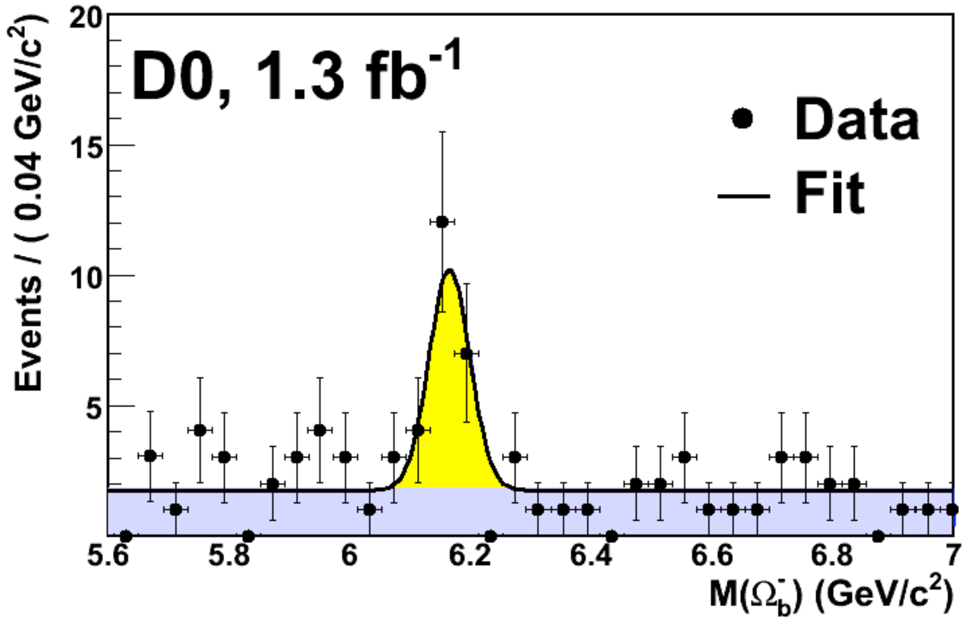
Ω^- signal



- Boosted decision tree improves $\Omega^- \rightarrow \Lambda K$ signal
- Inputs are particle momenta, vertices, track qualities

Ω_b^- Mass

- Observe 5.4σ significance
- N= 17.8±4.9±0.8



- Theoretical predictions:
- Mass Ω_b = 5.94 - 6.12 GeV
- Some predictions uncertainties ~ 50 MeV

Mass Ω_b = 6.165±0.010±0.013 GeV

$$R = \frac{f\left(b \to \Omega_b^-\right) Br\left(\Omega_b^- \to J/\Psi \Omega^-\right)}{f\left(b \to \Xi_b^-\right) Br\left(\Xi_b^- \to J/\Psi \Xi^-\right)}$$

$R = 0.80 \pm 0.32^{+0.14}_{-0.22}$

PRD **77** 014031, PRD **77** 034012

PRL **101** 232002

Prospects

- This talk features analyses using 1.0-2.8fb^{-1} of data
  - Already have many world's best mass and lifetime measurements.
  - Only place capable of exploring CPV in B_s mixing
- Tevatron continues to deliver more data: ~5 fb^{-1} recorded

Can expect:

- Improved mass determinations for new B baryons
- More precise lifetime measurements
- Signatures of new physics?

Backup

Φs and βs are <u>not</u> the same

β_s = arg [- $V_{tb}V^*_{ts}/V_{cb}V^*_{cs}$] ~ 2.2^o (SM)

phase of $b \rightarrow ccs$ transition that accounts for decay and mixing+decay.

Φ_s = arg[-M_{12}/Γ_{12}] ~ 0.24^o (SM)

arg[M_{12}]=arg$(V_{tb}V_{ts}^*)^2$ matrix element that connects matter to antimatter through oscillation.

arg[Γ_{12}] = arg[$(V_{cb}V^*_{cs})^2 + V_{cb}V^*_{cs}V_{ub}V^*_{us} + (V_{ub}V^*_{us})^2$] width of matter and antimatter into common final states.

Both SM values are experimentally unaccessible by current experiments (assumed zero). If NP occurs in mixing:

$\Phi_s = \Phi_s^{SM} + \Phi_s^{NP}$

$2\beta s = 2\beta_s^{SM} - \Phi_s^{NP}$

➔ standard approximation: $\Phi_s = -2\beta_s$

$\tau(B_s) \sim \tau(B_d)$?

PDG 07: $\tau(B_s) = 0.939 \pm 0.021\ \tau(B_d)$

$\tau(B_s)$ measurements from
$B_s \rightarrow J/\Psi\phi$ also higher than PDG 07

DØ : $\tau = 1.52 \pm 0.05 \pm 0.01$ ps

CDF: $\tau = 1.53 \pm 0.04 \pm 0.01$ ps

These recent measurements consistent with $\tau(B_s) \sim \tau(B_d)$