STATE OF HEAVY FLAVOR

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Denver, CO

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Flavor Physics Program at Tevatron Has Been Tremendously Successful!

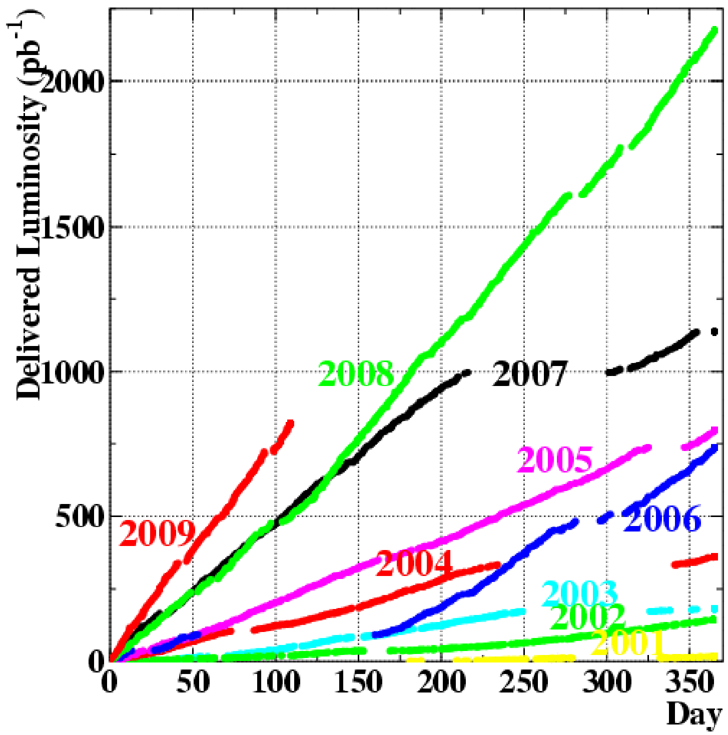
- Complements excellent programs of BABAR and Belle experiments at the B-factories
  - e^+e^- colliders produce B's at the $\Upsilon(4S)$ and $\Upsilon(5S)$
- Many unique measurements made at Tevatron
  - Observation of B_s mixing
  - CP violation in $B_s \to J/\psi\varphi$
  - Discovery of b-baryons
- Several measurements in B^0 and B^+ systems are approaching sensitivity of BABAR and Belle
  - e.g. lifetimes, direct CPV

A Special Time for TeV(atron)

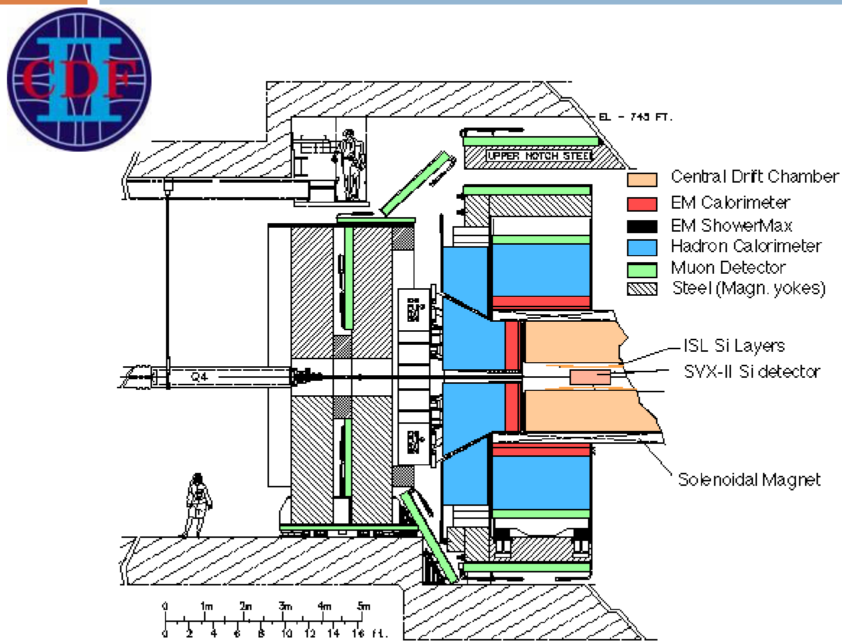
- Tevatron can contribute uniquely to flavor physics for the next few years
  - Transition between first run of B factories, LHC experiments
- Consider Tevatron flavor physics program present and future
  - Highlight recent results (from 2008 & 2009)
  - Anticipate results to come
    - Significant statistics can be added to many existing measurements before the end of Run II!

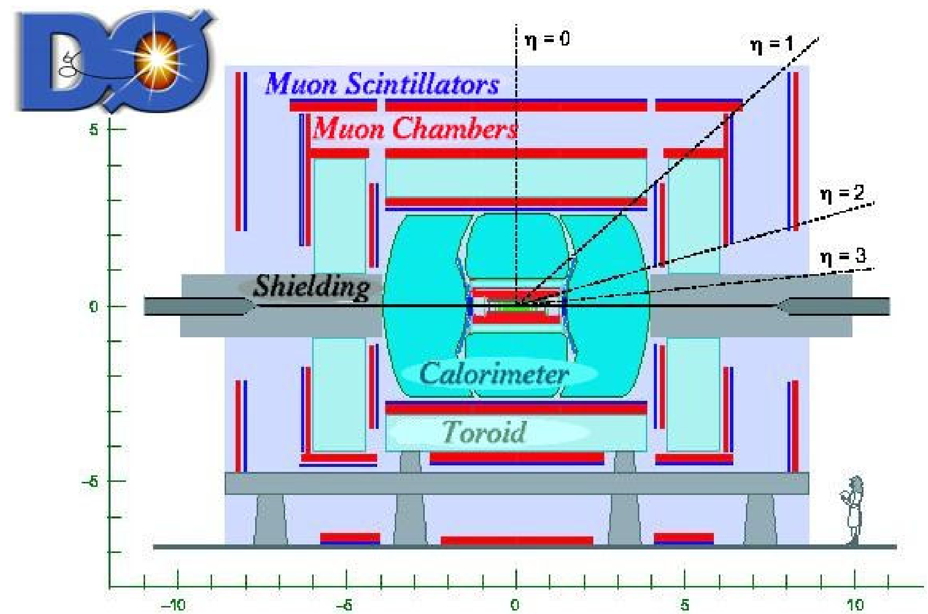
Tevatron Performance Has Been Excellent!

- Delivered > 6 fb^{-1} of integrated luminosity
  - CDF and D0 experiments have collected >5 fb^{-1} each
- Expect ~9 fb^{-1} delivered integrated luminosity through 2010



CDF and D0 Detectors Have Different Strengths in Detecting B Hadrons





Strong tracking system, ability to trigger on displaced tracks
⇒ Good mass resolution, high statistics in non-leptonic decays

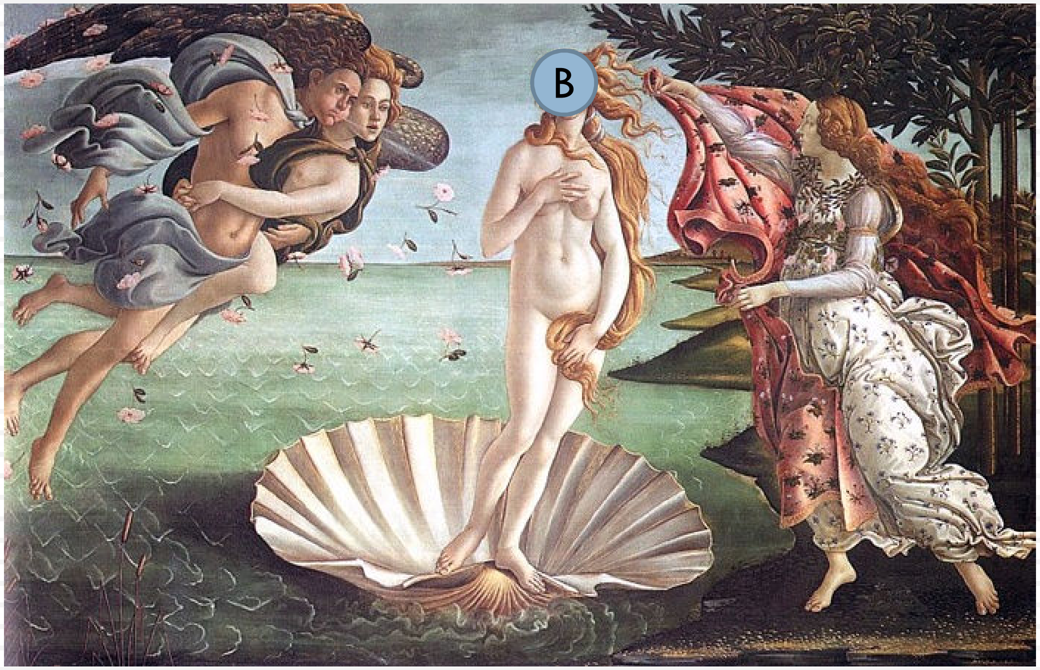
Excellent calorimetry, muon id, reverse direction of B field
⇒ Large samples of semi-leptonic and forward decays, good direct CPV res.

Main Categories of Flavor Physics Results Discussed Today

- Production
  - Birth of B hadrons
- Lifetimes
  - Death of B hadrons
- CP Violation & Rare Decays
  - The curious things in between

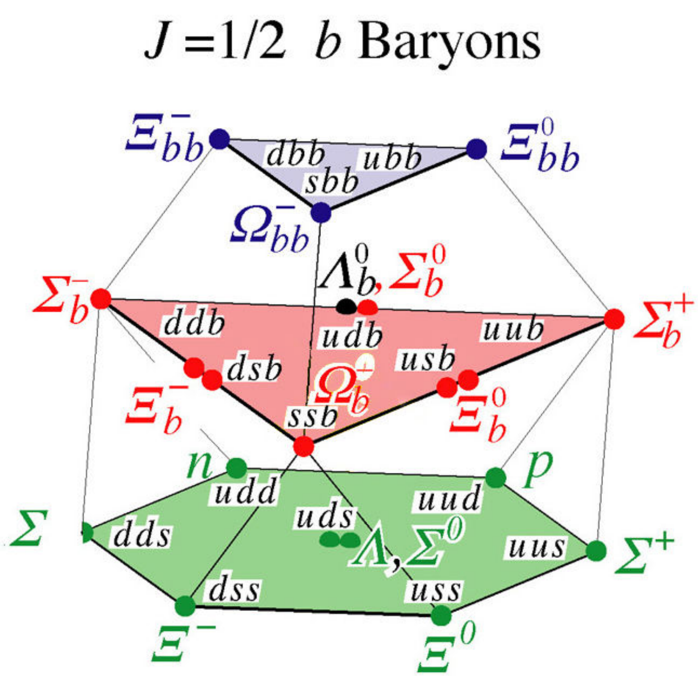
Production

Sandro Botticelli
The Birth of Venus
c. 1482-1486



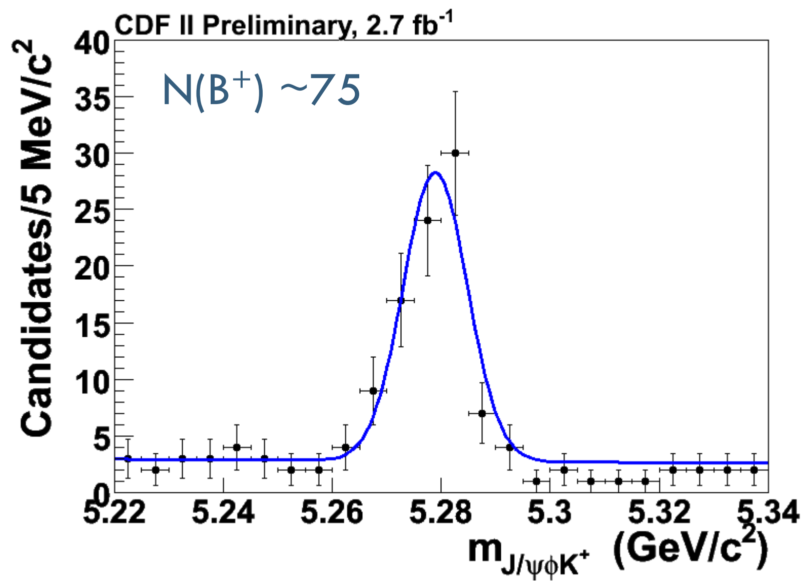
Search for New Particles and Measure Production Rates of Known Particles

- Look for things that we think should be there and also for things that shouldn't
  - Can find some surprises
    - e.g. X, Y, Z charm states
  - Many b-baryons have not been observed until Run II!
    - Observed $\Sigma_b^{\pm}$ (2006), Ξ_b^- (2007) and recently Ω_b^- (2008)
  - Measure production rates and cross-sections
    - Rel. fragmentation fractions, $\sigma(B^+)$, $\sigma(B_c^+)\times BR(B_c^+)/\sigma(B^+)\times BR(B^+)$



Evidence for New Y(4140) State

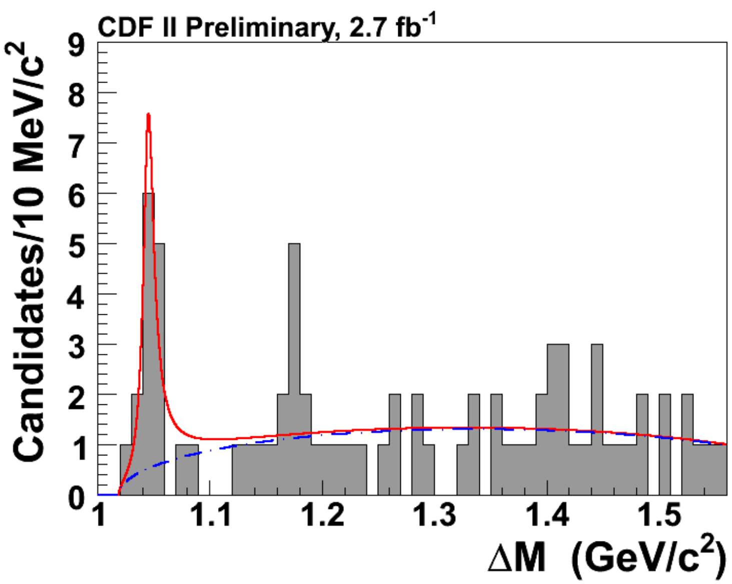
- Find evidence for new state Y(4140) in 2.7 fb^{-1} of int. lumi.
  - Observed in $B^+ \to Y(4140)K^+$ $Y(4140) \to J/\psi\varphi$
    - $J/\psi \to \mu^+\mu^-$
    - $\varphi \to K^+K^-$
- Builds on previous discoveries of charm-like states at Belle/BaBar
    - e.g. X(3872), Y(3930)
    - D*D molecule? 4-quark state?



$B^+ \to J/\psi\varphi K^+$

arXiv:0903.2229, submitted to PRL

Observe 3.8σ Significant Excess



$\Delta M = M(\mu^+\mu^-K^+K^-) - M(\mu^+\mu^-)$

$\Rightarrow$within $\pm3\sigma$ of $m(B^+)$

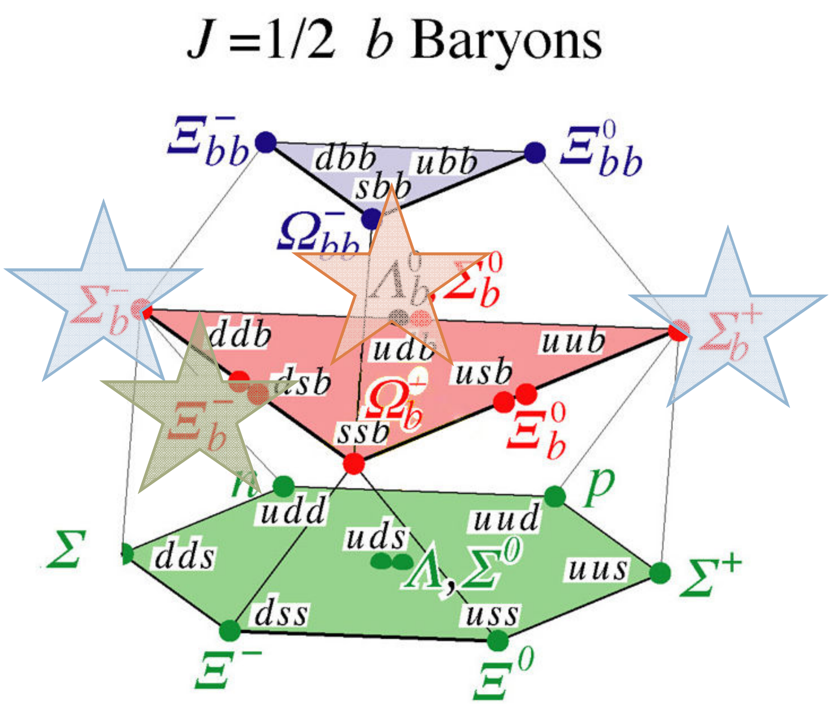
- Observe 14±5 events
  - Calculate significance to be 3.8σ
- Near $J/\psi\varphi$ threshold
  - Similar to $Y(3930) \rightarrow J/\psi\omega$

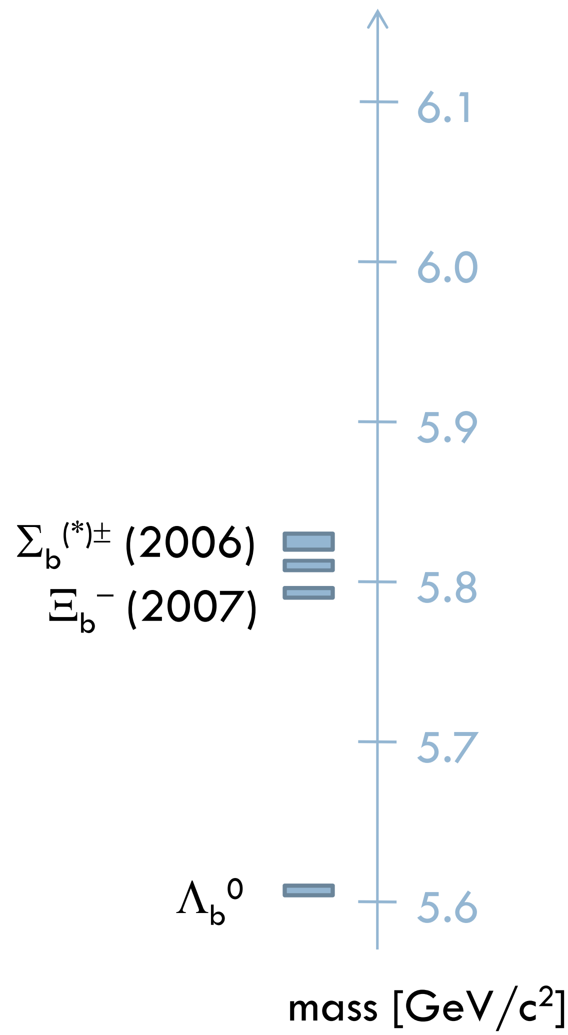
Assuming S-wave Breit-Wigner

$m = 4143.0 \pm 2.9$ (stat) ± 1.2 (syst) MeV/c^2

$\Gamma = 11.7\,^{+8.3}_{-5.0}$ (stat) $\pm$ 3.7 (syst) MeV/c^2

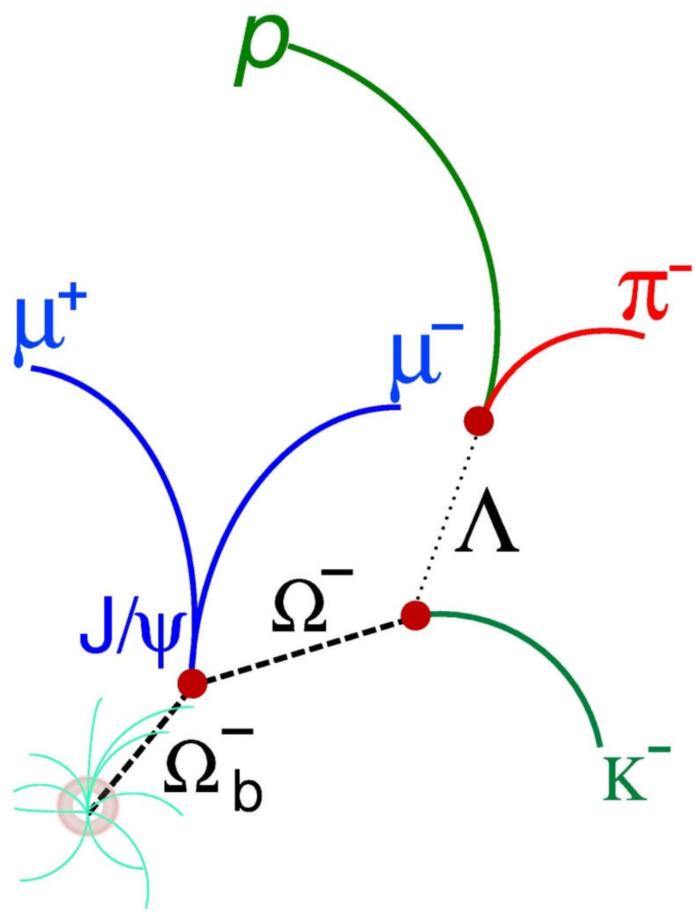
Many b-baryons Have Been Observed Since the Beginning of Run II!





Observation of Ω_b^- Baryon

- Announced by D0 on Aug. 29, 2008
- Observation made with 1.3 fb^{-1} of data
  - Builds on previous observation of Ξ_b^-



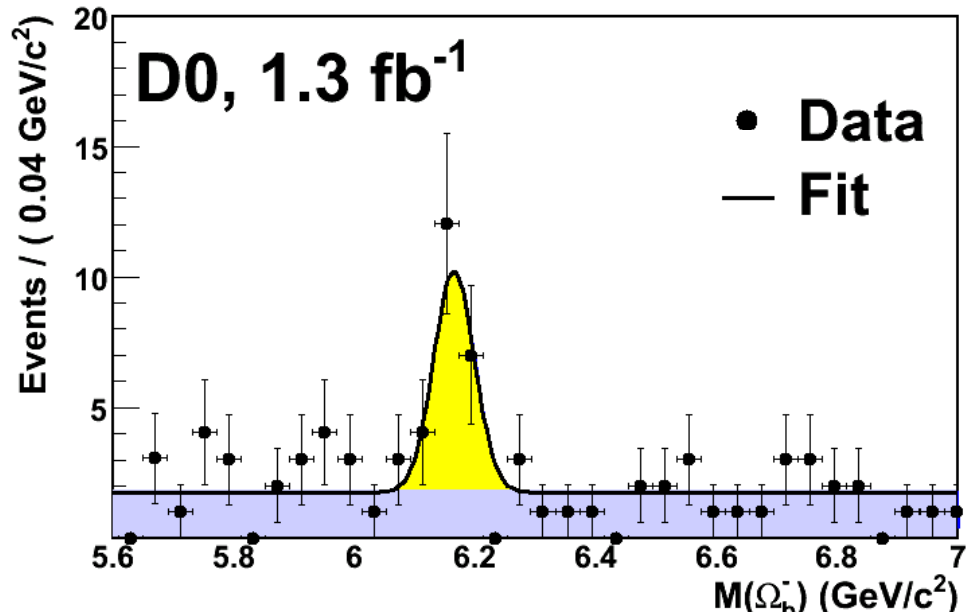
Phys. Rev. Lett. 101, 232002 (2008).

Observe Significant Ω_b^- Signal

- Observe 17.8 ± 4.9 (stat) ± 0.8 (syst) events
  - m = 6.165 ± 0.010(stat) ± 0.013 (syst) GeV/c^2

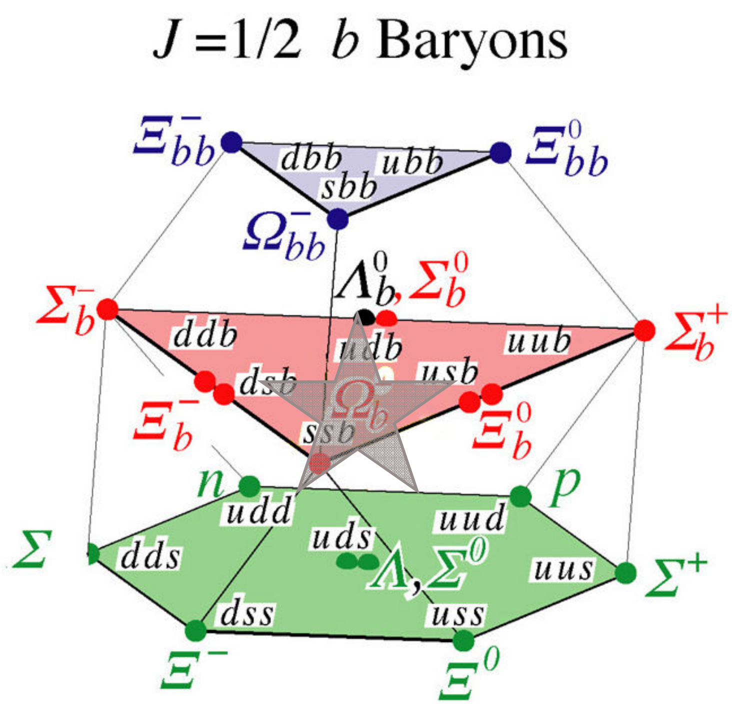
Expect 5.94–6.12 GeV/c^2 from theory

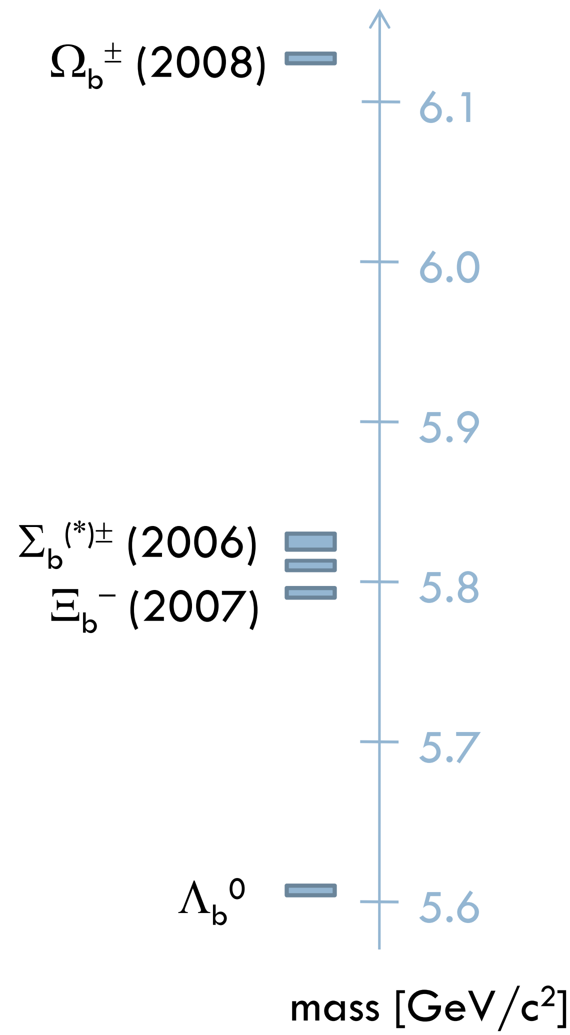
Calculate significance of 5.4σ



$$\frac{f(b\to\Omega_b^-)Br(\Omega_b^-\to J/\psi\,\Omega^-)}{f(b\to\Xi_b^-)Br(\Xi_b^-\to J/\psi\,\Xi^-)} = 0.80\pm0.32(stat)^{+0.14}_{-0.22}(syst)$$

Have Observed Most Single b-baryons!





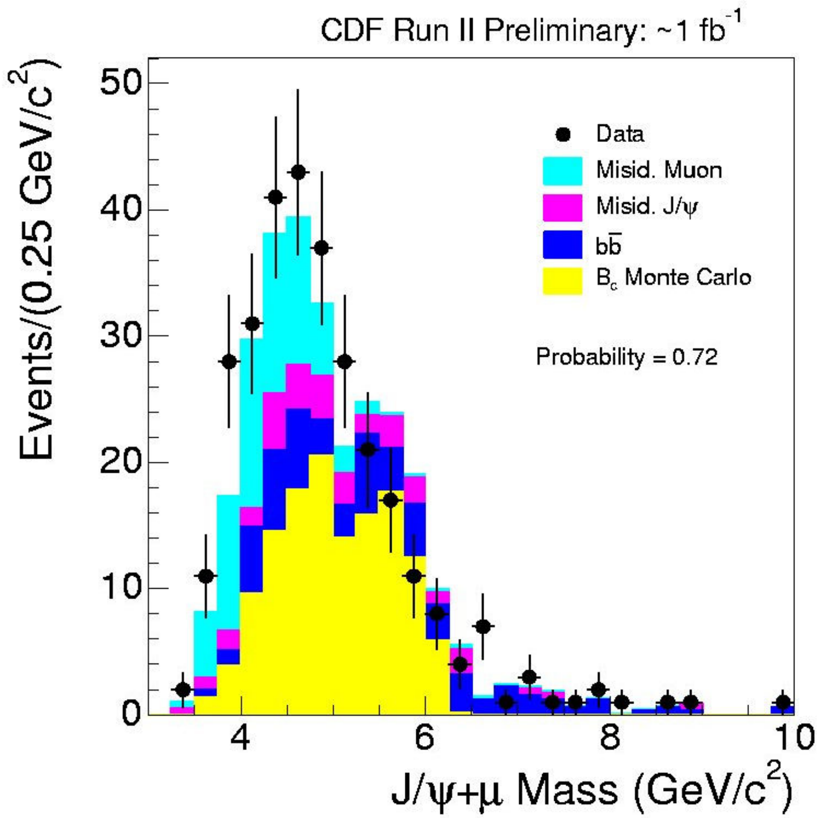
Have yet to observe double b-baryon states!

Measurement of Relative B_c^+ Cross Section Updated to 1 fb^{-1}

- Measure

$$\frac{\sigma(B_c^+)\times \mathcal{B}(B_c^+ \to J/\psi\mu^+\nu)}{\sigma(B^+)\times \mathcal{B}(B^+ \to J/\psi K^+)}$$

  - Need to model B^+, B_c^+ p_T spectrum to calculate relative efficiency between decays



Find Good Agreement with Previous B_c^+ Cross-section Measurement

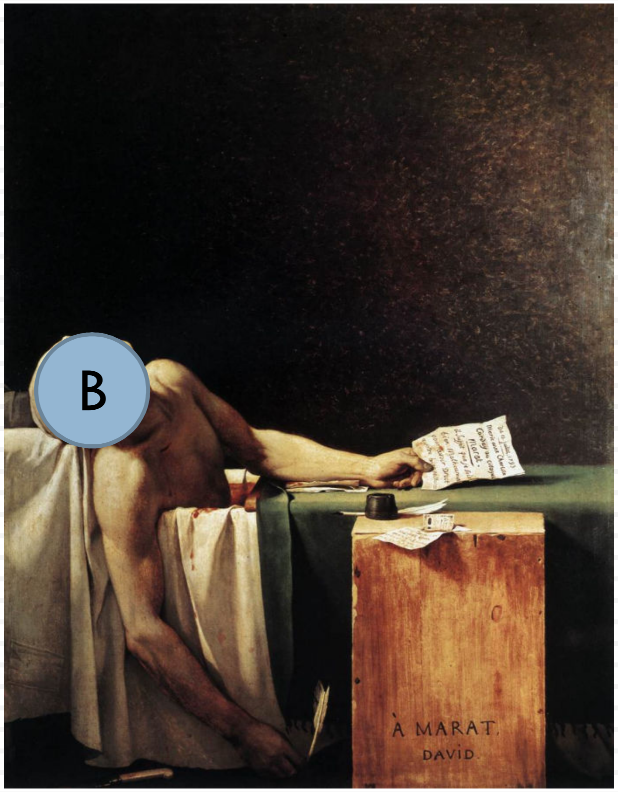
Final results	$p_T(B) > 4$ GeV/c	$p_T(B) > 6$ GeV/c
$N(B_c^+ \to J/\psi + \mu^+ + \nu)$	117.6 ± 17.2 (stat) $^{+8.3}_{-6.4}$ (sys)	107.1 ± 16.7 (stat) $^{+7.9}_{-6.1}$ (sys)
$N(B^+ \to J/\psi + K^+)$	2333 ± 55 (stat)	2299 ± 53 (stat)
ϵ_{rel}	5.867 ± 0.068 (stat) $^{+0.554}_{-0.450}$ (sys) ± 0.720 (spectrum)	4.872 ± 0.060 (stat) $^{+0.420}_{-0.278}$ (sys) ± 0.298 (spectrum)
$\frac{\sigma(B_c^+) * BR(B_c^+ \to J/\psi + \mu^+ + \nu)}{\sigma(B^+) * BR(B^+ \to J/\psi + K^+)}$	0.295 ± 0.040 (stat) $^{+0.033}_{-0.026}$ (sys) ± 0.036 (spectrum)	0.227 ± 0.033 (stat) $^{+0.024}_{-0.017}$ (sys) ± 0.014 (spectrum)

- Agrees well with previous results
  - Systematic uncertainty is significantly improved

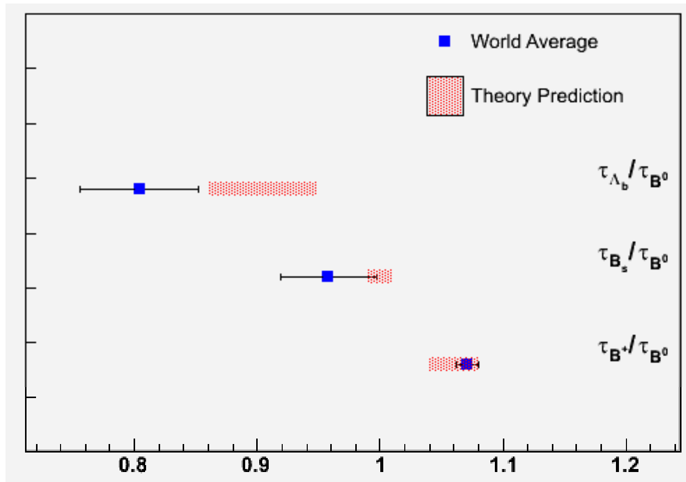
Result	pT(B)	R
$B_c^+ \to J/\psi e^+ \nu X$ (Run II, 360 pb^{-1})	>6 GeV/c	0.245 ± 0.045 (st) ± 0.066 (sys) $^{+0.080}_{-0.032}$ (lt)
$B_c^+ \to J/\psi \mu^+ \nu X$ (Run II, 360 pb^{-1})	>4 GeV/c	0.282 ± 0.038 (st) ± 0.035 (y) ± 0.065 (a)

Lifetimes

Jacques-Louis David
Death of Marat
c. 1793



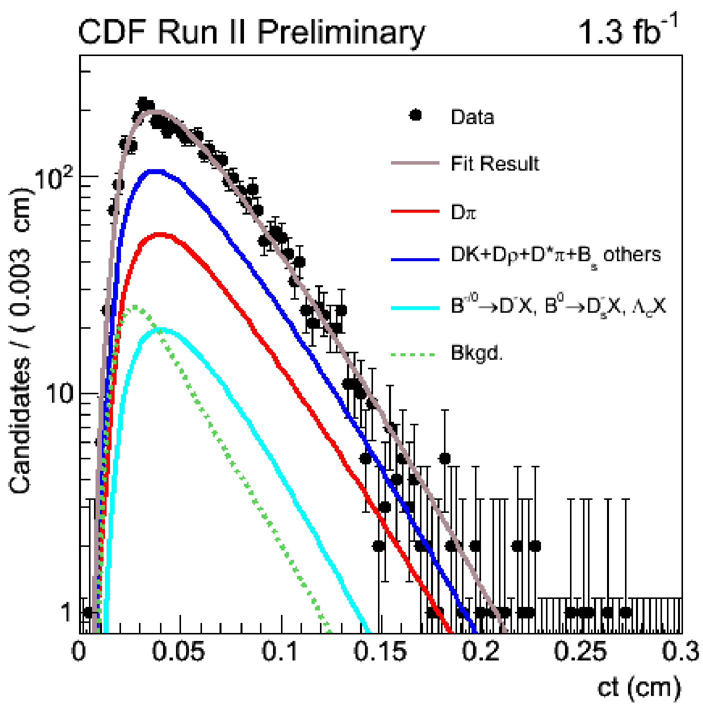
Why Measure Lifetimes?

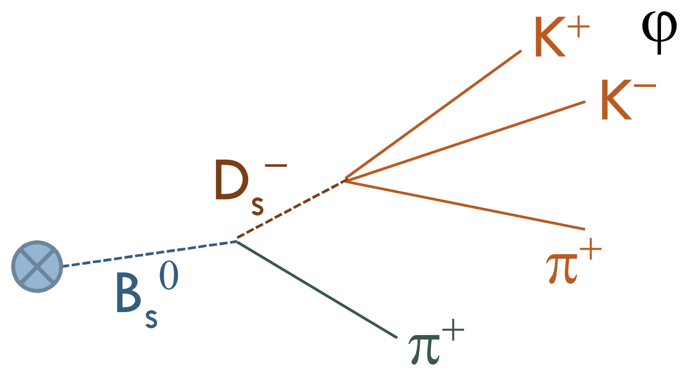


Heavy Flavor Averaging Group (HFAG) - 2006

- Test HQE predictions
  - Have previously seen 1-2σ discrepancies between lifetime predictions and measurements in B_s^0, Λ_b^0
    - Expect $\tau(B^+) > \tau(B^0) \approx \tau(B_s^0) > \tau(\Lambda_b^0) \gg \tau(B_c^+)$
- Because they're there?
  - Fundamental quantity, give complete picture of B's
  - Useful for other measurements (e.g. b-tagging)

B_s^0 Lifetime Now Agrees with HQE





Partially reco. decays double statistics!

$c\tau(B_s^0) = 455 \pm 12$ (stat.) $\pm$ 7 (syst.) μm

Compatible with HQE predictions that $c\tau(B^0) \approx c\tau(B_s^0)$

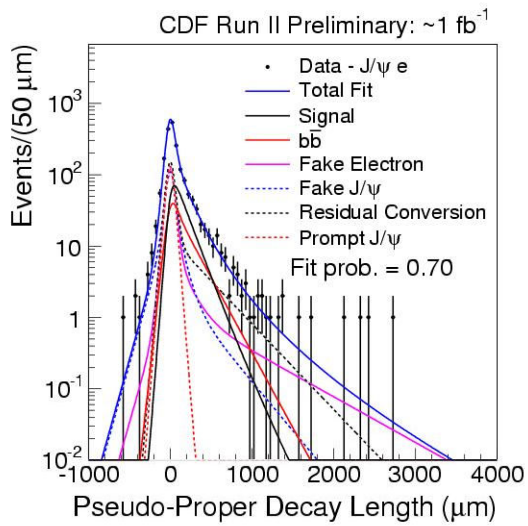
($c\tau(B^0)$ = 458.7 ± 2.7, PDG 2008)

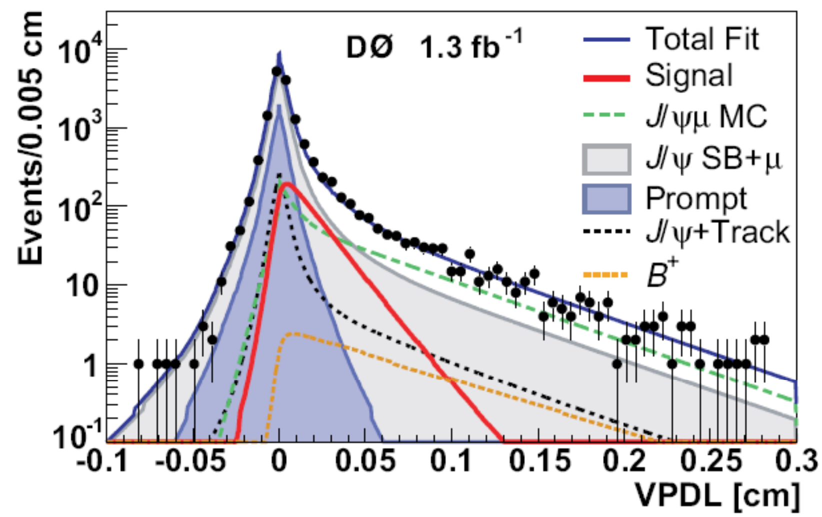
- Data collected with displaced track trigger

  ⇒ must correct for trigger bias (use Monte Carlo)

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

B_c^+ Lifetime Agrees with Theoretical Predictions



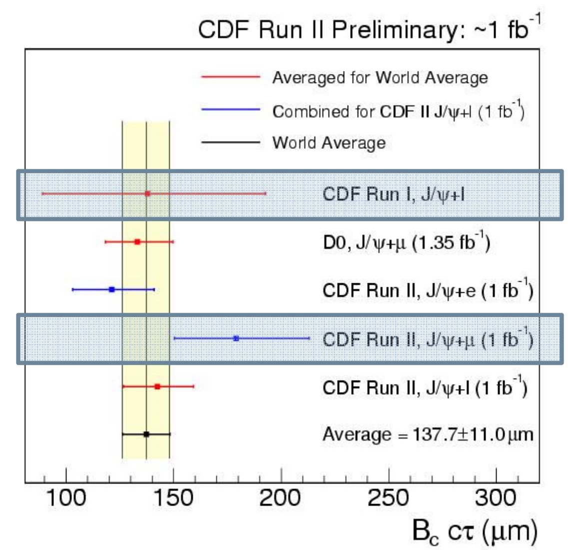


www-cdf.fnal.gov/physics/new/bottom/080327.blessed-BC_LT_SemiLeptonic/

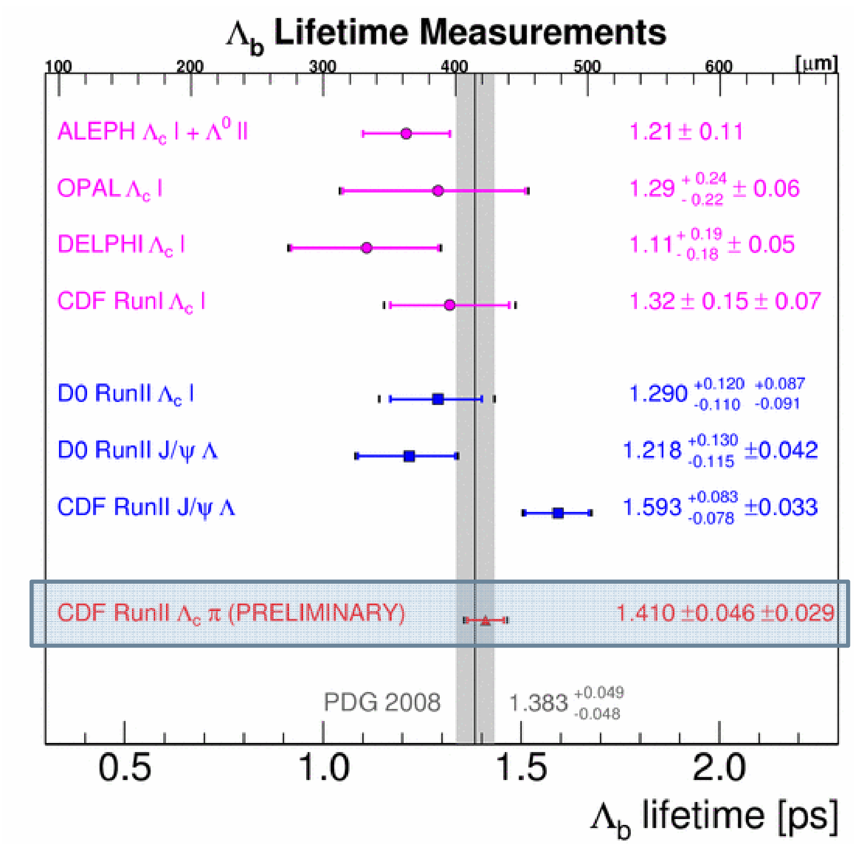
CDF: $c\tau(B_c^+) = 142 \pm 15$ (stat) $\pm\ 6$ (syst) μm

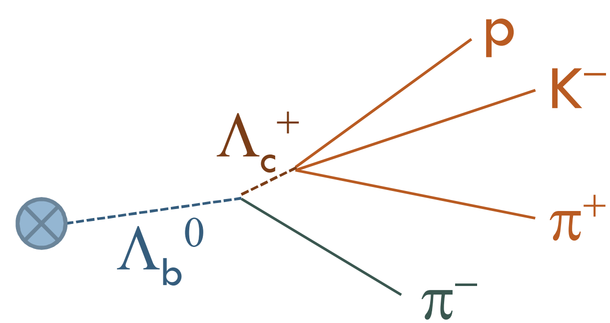
D0: $c\tau(B_c^+) = 134.3 \pm 11$ (stat) $\pm\ 10$ (syst) μm

Phys. Rev. Lett. 102, 092001 (2009)



Λ_b^0 Lifetime Question Closer to Resolution





$c\tau(\Lambda_b^0) = 420 \pm 14\ (\text{stat}) \pm 9\ (\text{syst})\ \mu\text{m},$

$c\tau(\Lambda_b^0)\ / c\tau(B^0) = 0.92 \pm 0.04$

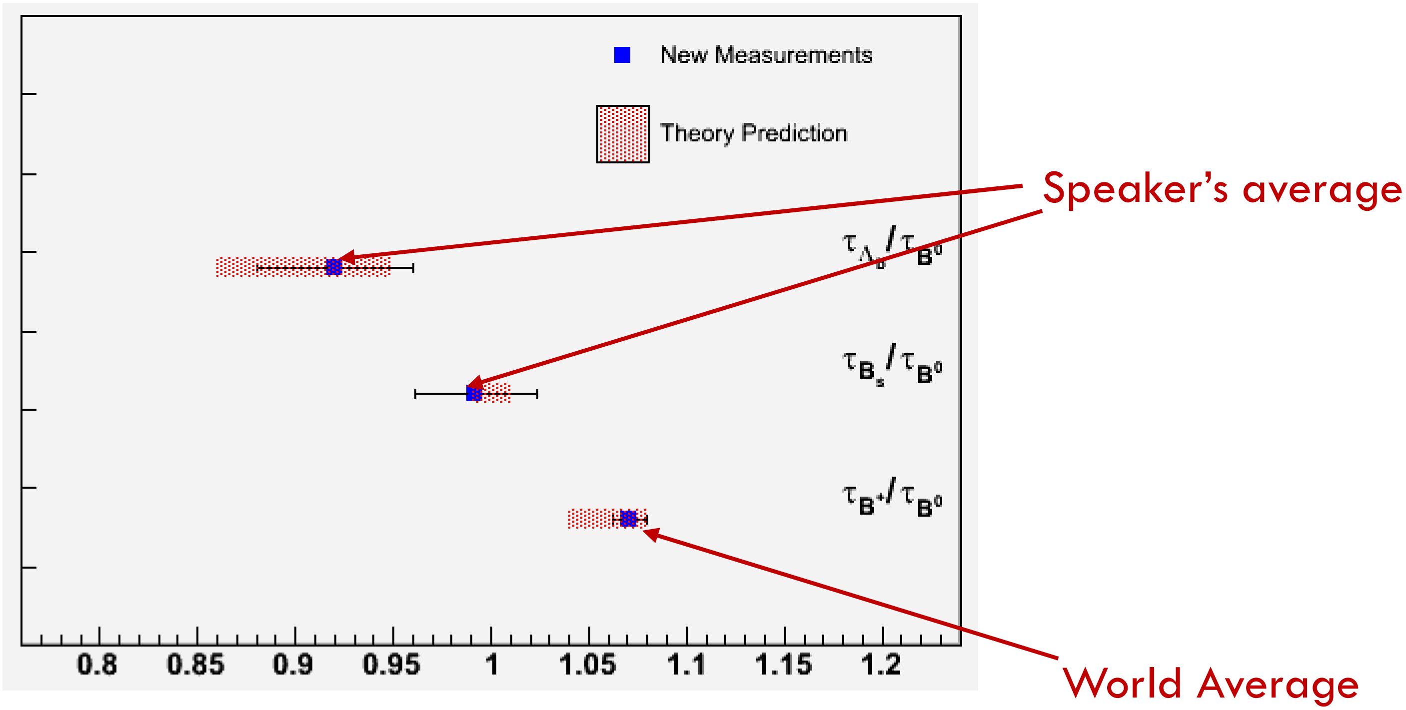
↑ PDG 2008

- Measure lifetime in displaced track sample

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

New Measurements Are in Good Agreement with Predicted Lifetimes

New measurements of lifetime are in good agreement with theoretical predictions!



CP Violation & Rare Decays

Francisco Goya
The Third of May 1808
1814

CP Violation

- CP violation is the non-conservation of charge and parity quantum numbers

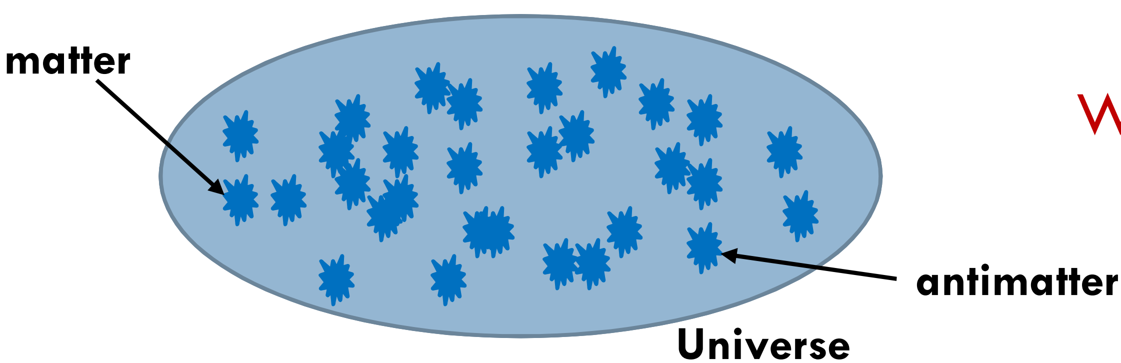
Rate of

$\neq$

Rate of

Known Amount of CP Violation is Unable to Explain Matter-Antimatter Asymmetry

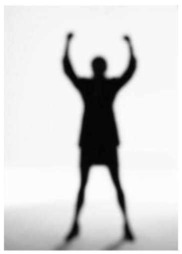
- Present sources of CP violation can't account for the amount of matter we observe in the universe!
- Important to search for new sources of CP violation in places we don't expect
  - Can indicate presence of new particles or forces
    - Maybe with much higher masses than we can observe directly at LHC!



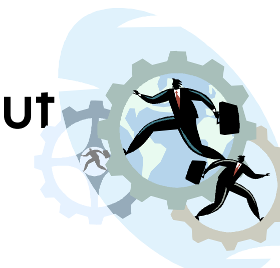
Where's the anti-matter?

There Are Three Types of CP Violation That Can Be Investigated

- Decay of hadrons $\leftrightarrow$ direct CPV
  - Only type of CPV for charged mesons



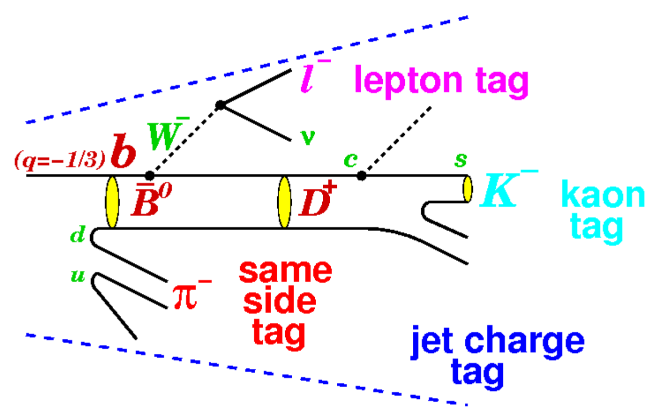
- Mixing of neutral mesons $\leftrightarrow$ indirect CPV
  - Semi-leptonic decays of neutral meson



- Interference between decays with and without mixing
  - $B^0 \rightarrow J/\psi\ K_s^0 \Rightarrow \sin 2\beta$
  - $B_s^0 \rightarrow J/\psi\varphi \Rightarrow \sin 2\beta_s$

Measured precisely by BABAR and Belle

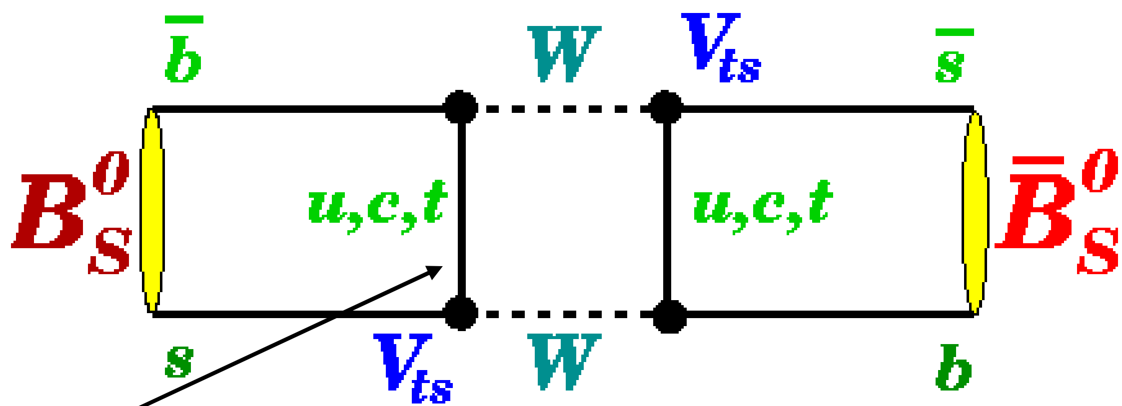
Use flavor tagging for more powerful measurement of CP phases!



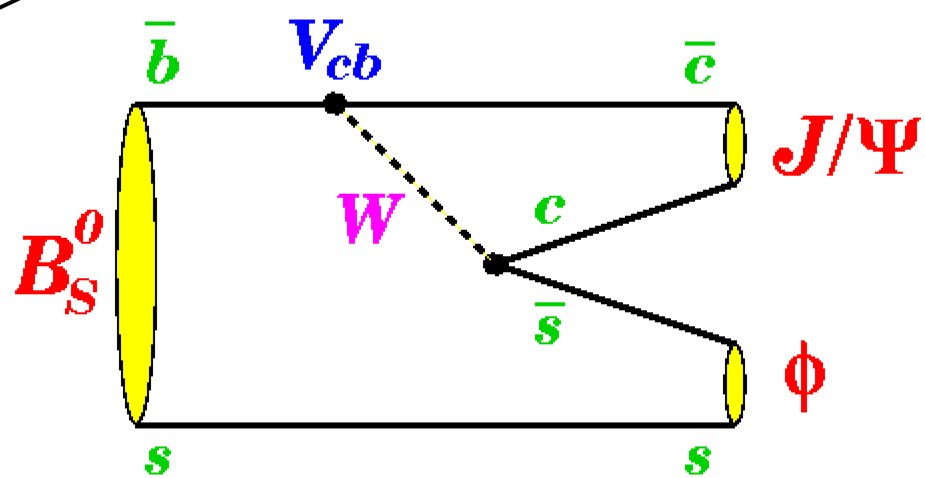
Mixing and Decay in B_s^0

Mixing between particle and anti-particle occurs through the loop processes

Oscillations are very fast- ~3 trillion times per second!



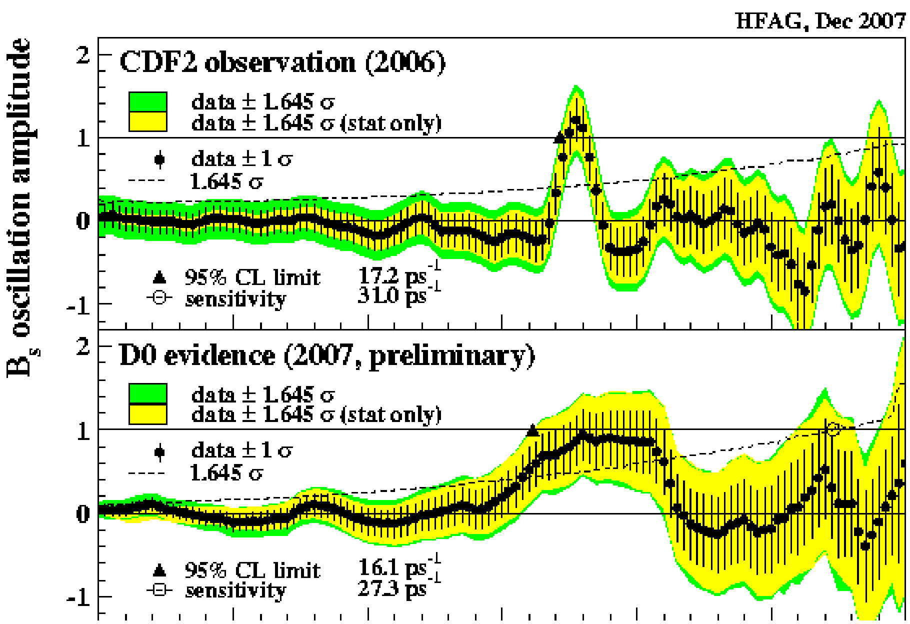
New particles can contribute to box diagram!

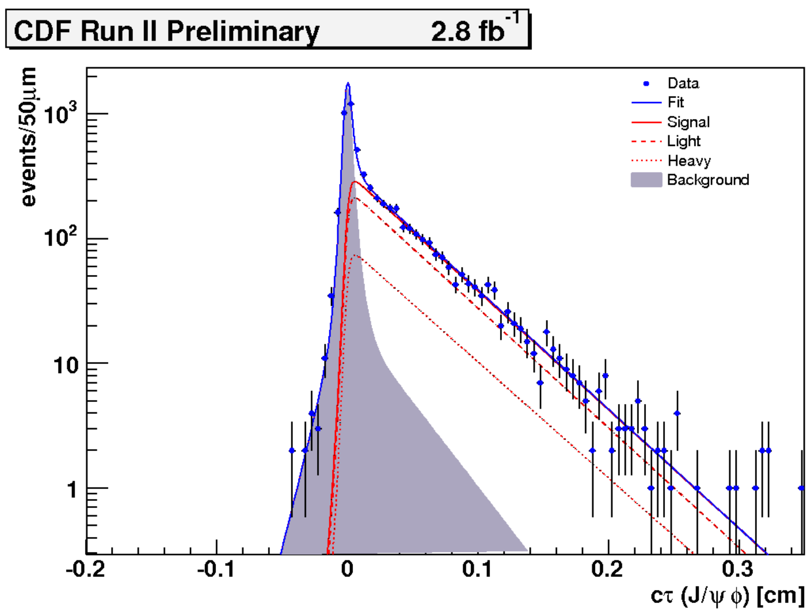


Mixing and Decay in B_s^0

Mixing of B_s^0 mesons is governed by Schrodinger eqn.

$$i\frac{d}{dt}\begin{pmatrix}|B_s^0(t)\rangle \\ |\bar{B}_s^0(t)\rangle\end{pmatrix} = \left(\mathbf{M} - \frac{i}{2}\mathbf{\Gamma}\right)\begin{pmatrix}|B_s^0(t)\rangle \\ |\bar{B}_s^0(t)\rangle\end{pmatrix} \Rightarrow \begin{aligned}|B_s^H\rangle &= p\,|B_s^0\rangle - q\,|\bar{B}_s^0\rangle \\ |B_s^L\rangle &= p\,|B_s^0\rangle + q\,|\bar{B}_s^0\rangle\end{aligned}$$





$\Delta m_s = m_H - m_L \approx 2|M_{12}|$ [ps^{-1}]

$\Delta\Gamma_s = \Gamma_L - \Gamma_H \approx 2|\Gamma_{12}|\cos(\varphi_s)$

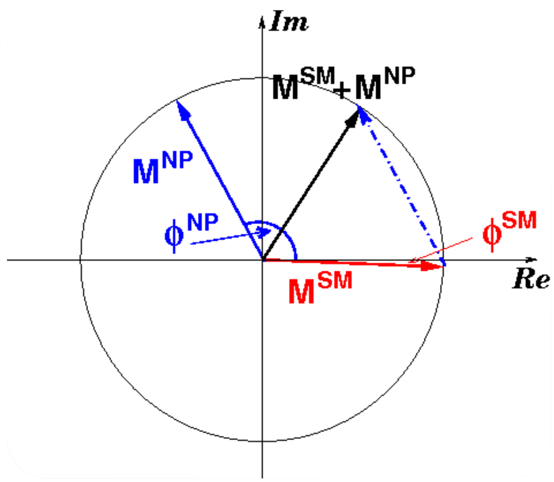
$\varphi_s = \arg(-M_{12}/\Gamma_{12}) \sim 0.004$ in SM

$B_s^0 \rightarrow J/\psi\varphi$ Decays Are A Good Place to Look for New Physics

- Decays of $B_s^0 \rightarrow J/\psi\varphi$ gives access to CP violating phase predicted to be nearly zero in Standard Model

$$\beta_s^{J/\psi\varphi} = \arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right) \sim 0.02$$

- Large phase in $b \rightarrow s$ transition could lead to significant non-zero CP phase

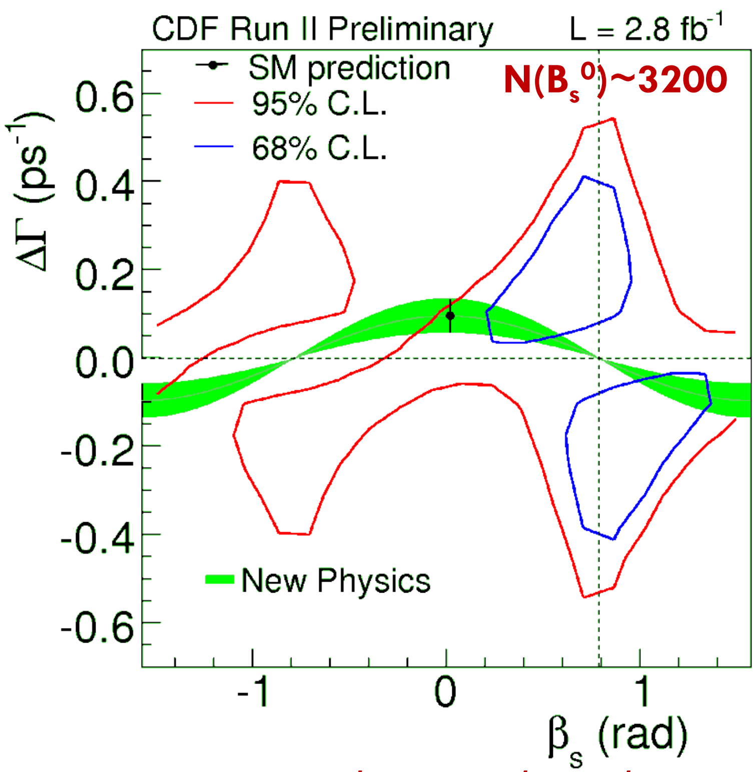


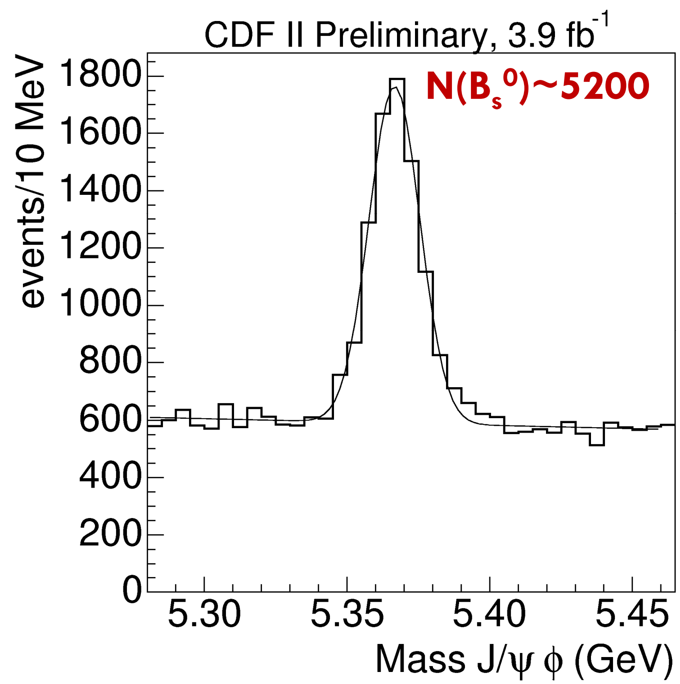
New physics could produce large CP phase!

G. Hou et al suggest that t' quark w/mass $\sim 300\ \mathrm{GeV}/c^2 - 1\ \mathrm{TeV}/c^2$ would give $\beta_s \sim 0.5$

CDF Observes Discrepancy with SM in Flavor-Tagged $B_s^0 \rightarrow J/\psi\varphi$

- Find 1.8σ (p-value = 7%) discrepancy with SM prediction for $\beta_s^{J/\psi\varphi} = 0.02$, $\Delta\Gamma_s = 0.096$
  - Expect further improvement in statistical precision shortly!

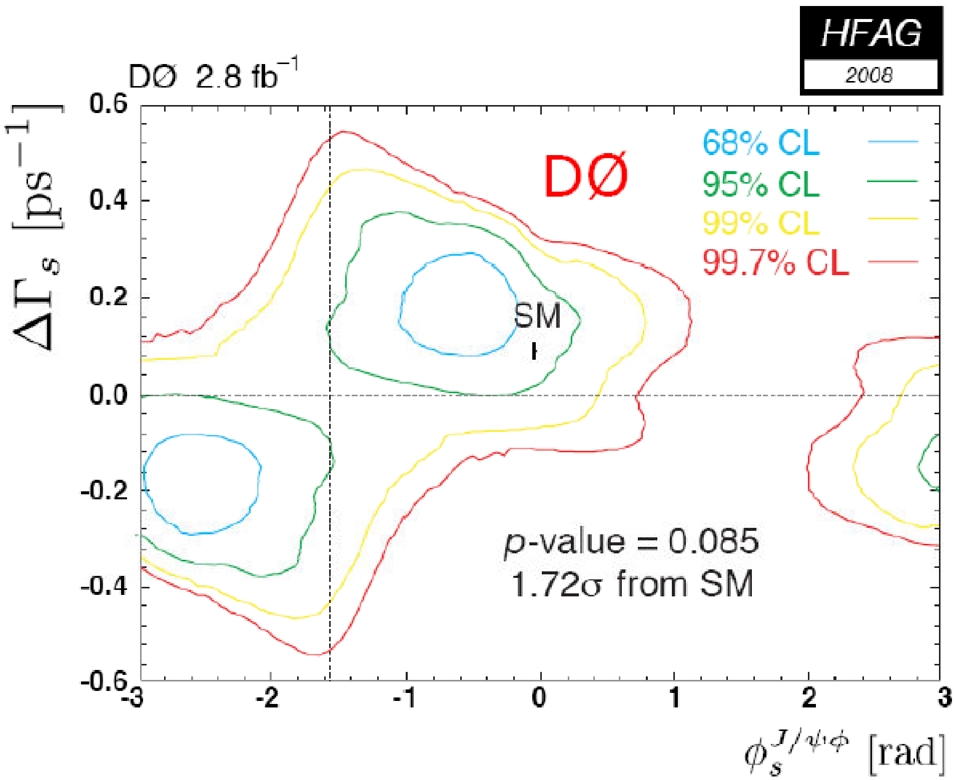




www-cdf.fnal.gov/physics/new/bottom/080724.blessed-tagged_BsJPsiPhi_update_prelim/

Similar Discrepancy Observed by D0 in Flavor-Tagged $B_s^0 \to J/\psi\varphi$

- D0 result very similar to CDF's!
  - Discrepancy w/SM is 1.7σ, p-value = 0.085



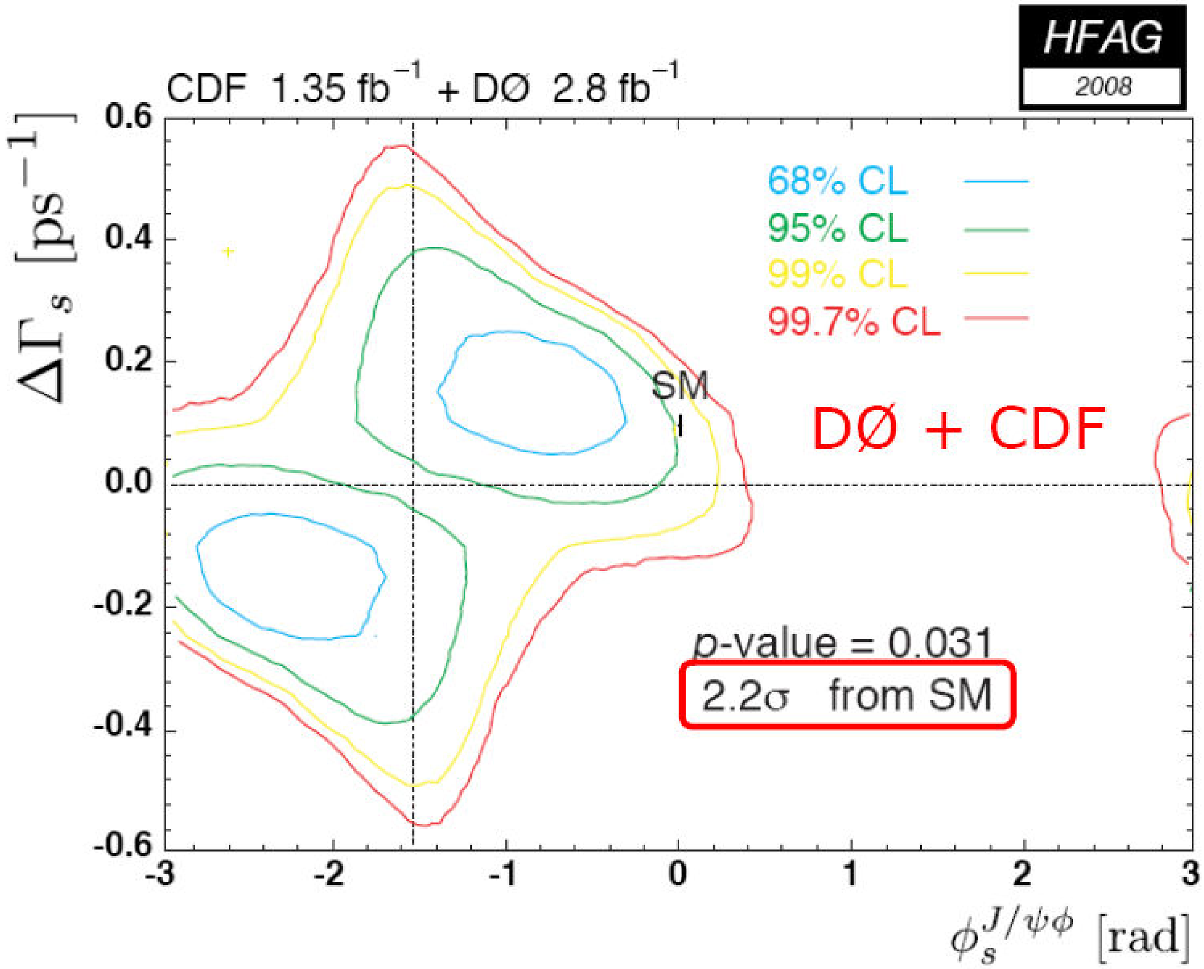
arXiv:0808.1297v1

Trend is identical, $\varphi_s^{J/\psi\varphi} \equiv -2\beta_s$

D0 finds agreement in strong phase between $B_s^0 \to J/\psi\varphi$ (assuming $\varphi_s^{J/\psi\varphi} = 0$) and $B^0 \to J/\psi\ K^{*0}$

$\Rightarrow$ Use phases in $B^0 \to J/\psi\ K^{*0}$ to choose one of two solutions?

More Significant Discrepancy in Combined $B_s^0 \to J/\psi\varphi$ Result

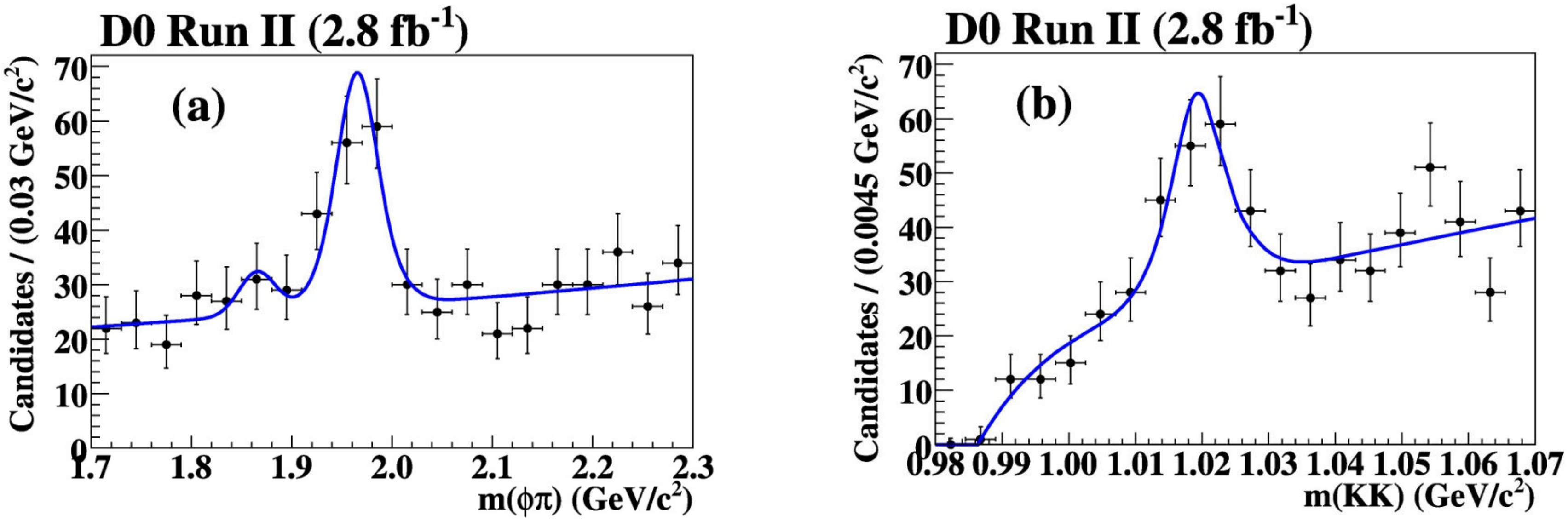


arXiv:0808.1297v1

New CDF result not included in combination!

Expect updates to both CDF and D0 results soon!

$\mathcal{B}(B_s^0 \rightarrow D^{(*)}{}_s^+ D^{(*)}{}_s^-)$ Also Gives Access to CP-even Width Difference



- Measure branching ratio to determine $\Delta\Gamma_s^{CP}$ (2.8 fb^{-1})
  - Search for one $D_s \rightarrow \varphi\pi$, other to $D_s \rightarrow \varphi\mu\nu$

$$2\mathcal{B}(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}) \cong \Delta\Gamma_s^{CP} \left[\frac{\frac{1}{1-2x_f} + \cos\varphi_s}{2\Gamma_L} + \frac{\frac{1}{1-2x_f} - \cos\varphi_s}{2\Gamma_H} \right]$$

$\Delta\Gamma_s^{CP}/\Gamma_s$ Measured in $B_s^0 \rightarrow D^{(*)+}_s D^{(*)-}_s$ Consistent with World Average

- Measure

$$\mathcal{B}(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}) = 0.035 \pm 0.010(stat) \pm 0.008(syst) \pm 0.007(\mathcal{B})$$

with 3.2σ significance (p-value = 0.0012)

Assuming x_f=0 and φ_s = 0

$$\frac{\Delta\Gamma_s^{CP}}{\Gamma_s} \cong \frac{2\mathcal{B}(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)})}{1-\mathcal{B}(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)})} = 0.072 \pm 0.021(stat) \pm 0.022(syst)$$

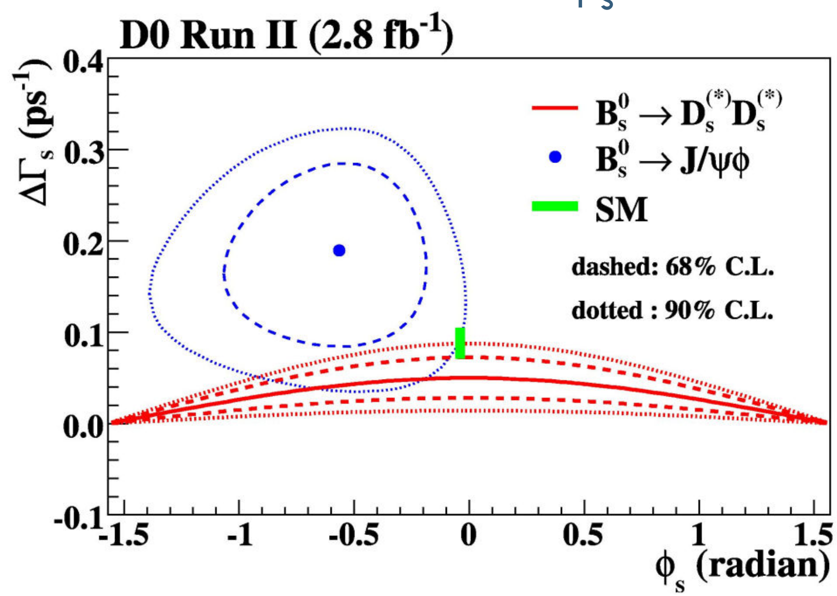
Consistent with WA (2007)

$\Delta\Gamma/\Gamma = 0.096^{+0.048}_{-0.053}$

Phys. Rev. Lett. 102, 091801 (2009)

Assuming x_f=0 and

$\Delta\Gamma = \Delta\Gamma^{CP}\cos\varphi_s$

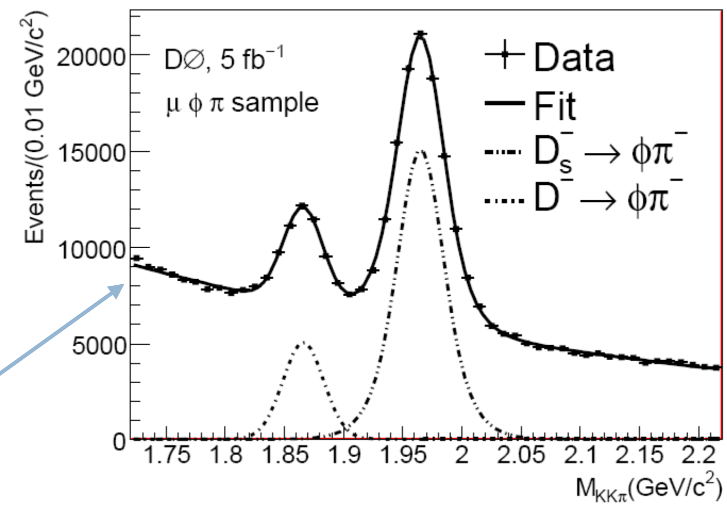


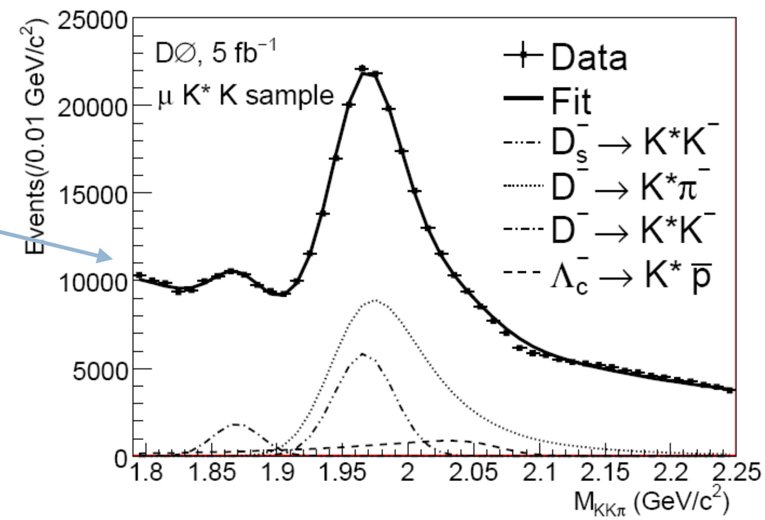
Updated Measurement of B_s^0 Semileptonic Asymmetry

- Measure flavor-specific asymmetry, a^s_{fs}, in 5 fb^{-1}
  - Time-dependent
  - Flavor-tagged
- Reconstruct $B_s^0 \rightarrow \mu^+ D_s^- X$
  - $D_s^- \rightarrow \varphi\pi^- \rightarrow (K^-K^+)\pi^-$
  - $D_s^- \rightarrow K^{*0}K^-$

$$a^s_{fs} = \frac{\Gamma_{\bar{B}_s^0(t)\rightarrow f} - \Gamma_{B_s^0(t)\rightarrow \bar{f}}}{\Gamma_{\bar{B}_s^0(t)\rightarrow f} + \Gamma_{B_s^0(t)\rightarrow \bar{f}}}$$

arXiv:0904.3907





Measurement Improves Uncertainty by Factor of 2!

- Extract asymmetry with un-binned maximum likelihood fit

$$\Gamma_{B_s^0 \to \bar{f}} = N_f \left|\bar{A}_{\bar{f}}\right|^2 \frac{1}{2}\left(1 - a_{fs}^s\right) e^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) - \cos(\Delta m_s t)\right]$$

$$\Gamma_{\bar{B}_s^0 \to f} = N_f \left|\bar{A}_{\bar{f}}\right|^2 \frac{1}{2}\left(1 + a_{fs}^s\right) e^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) - \cos(\Delta m_s t)\right]$$

- Find

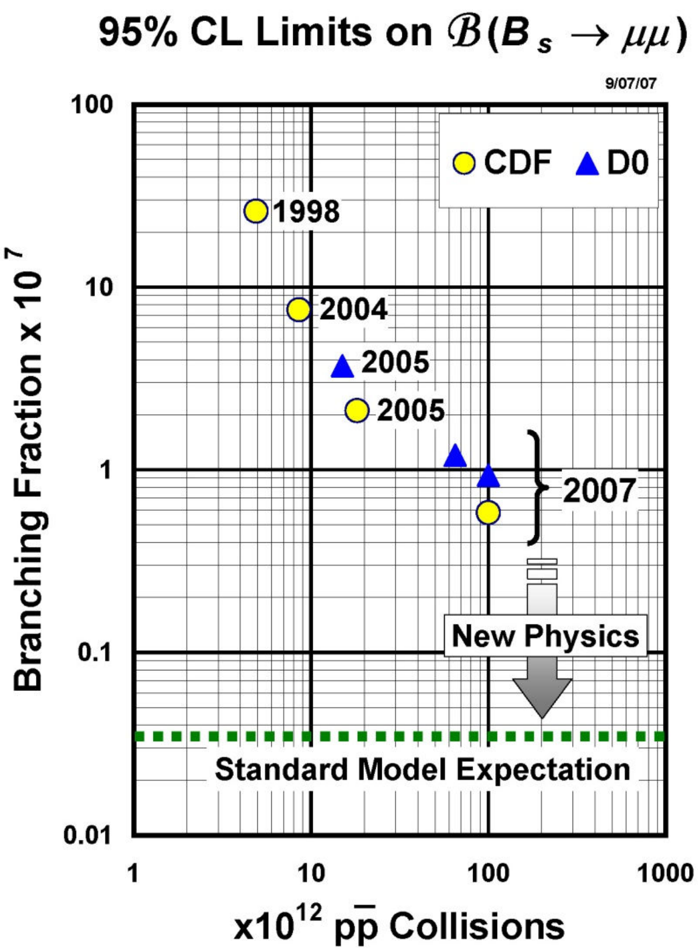
$$a_{fs}^s = \left[-1.7 \pm 9.1(stat)\,^{+1.2}_{-2.3}(syst)\right] \times 10^{-3}$$

Uncertainties improved by factor of 2 over previous direct measurement!

Standard model prediction: $a^s_{fs} = (0.021 \pm 0.006) \times 10^{-3}$

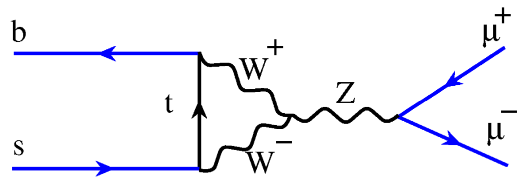
Rare Decays Help Search for Flavor Changing Neutral Currents

- Search for processes like
  - $B^0 \rightarrow \mu^+\mu^-$, $B_s^0 \rightarrow \mu^+\mu^-$
  - $D^0 \rightarrow \mu^+\mu^-$
- Standard Model processes are extremely rare
  - $\mathcal{B} \sim 10^{-9}\text{-}10^{-13}$
- New physics (e.g. SUSY) predicts new sources of FCNC
- Some processes are forbidden in SM
  - $B^0, B_s^0 \rightarrow e^+\mu^-$
    $\Rightarrow$ leptoquarks

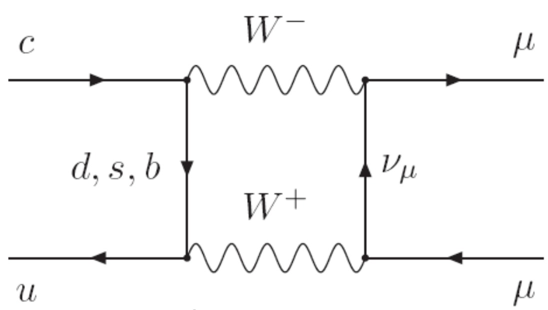


Examples of Rare Decay Processes

- SM processes

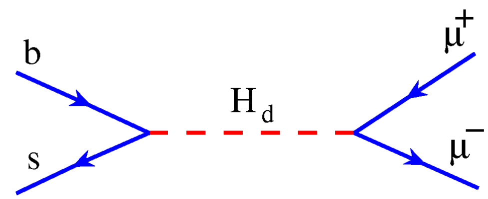


$B_s^0 \rightarrow \mu^+\mu^-$

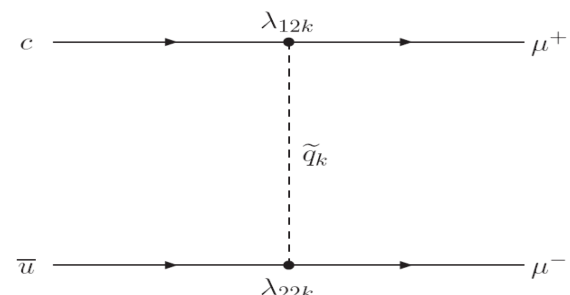


$D^0 \rightarrow \mu^+\mu^-$

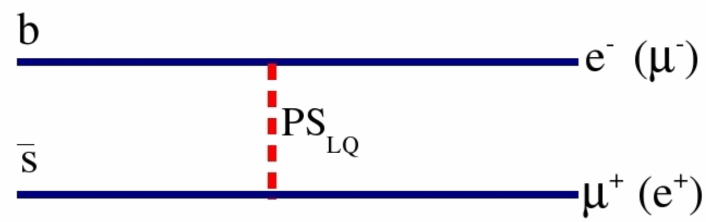
- New physics processes



$B_s^0 \rightarrow \mu^+\mu^-$



$D^0 \rightarrow \mu^+\mu^-$



B_s ---> μ e

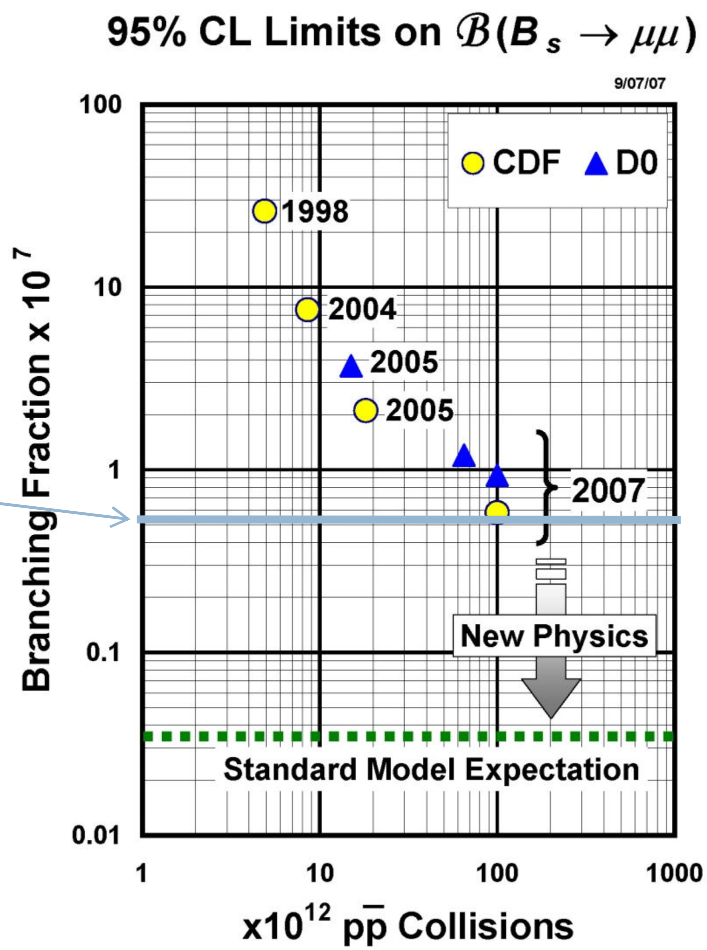
$B_{(s)}^0 \to \mu^+\mu^-$ Branching Ratios Approaching SM Predictions!

- $B_s^0 \to \mu^+\mu^-$ @ 95% CL
  - CDF (2 fb^{-1}):

    $\mathcal{B} < 5.8\times10^{-8}$
  - D0 (5 fb^{-1}) **expected:**

    $\mathcal{B} < 5.3\times10^{-8}$
- $B^0 \to \mu^+\mu^-$ @ 95% CL
  - CDF (2 fb^{-1}):

    $\mathcal{B} < 1.8 \times10^{-8}$



Other Rare Decays Are Limiting New Physics Parameter Space

- $B_s^0 \to e^+\mu^-$ @ 95% CL
  - CDF (2 fb^{-1}):

    $\mathcal{B} < 2.6\times10^{-7}$
- $B^0 \to e^+\mu^-$ @ 95% CL
  - CDF (2 fb^{-1}):

    $\mathcal{B} < 7.9\times10^{-8}$

$\Rightarrow$ $m(LQ, B_s^0) > 44.6$ TeV
$m(LQ, B^0) > 55.7$ TeV

- $D^0 \to \mu^+\mu^-$ @ 95% CL
  - CDF (360 pb^{-1}):

    $\mathcal{B} < 5.3\times10^{-7}$

Predicted rate $\sim10^{-13}$

Looking to the Future

Neo Rauch
The Next Move
2007

Many Interesting New and Updated Measurements to Come!

- Updates to CP violation measurements
  - Expect 2-4x higher yield depending on measurement
  - More flavor-tagged CP violation results
- Updated lifetimes with higher statistics
  - Updated $B \to J/\psi X$ lifetimes with 2x more data
    - Will give most precise B^+, Λ_b^0 lifetimes to date
- Observation of new states?

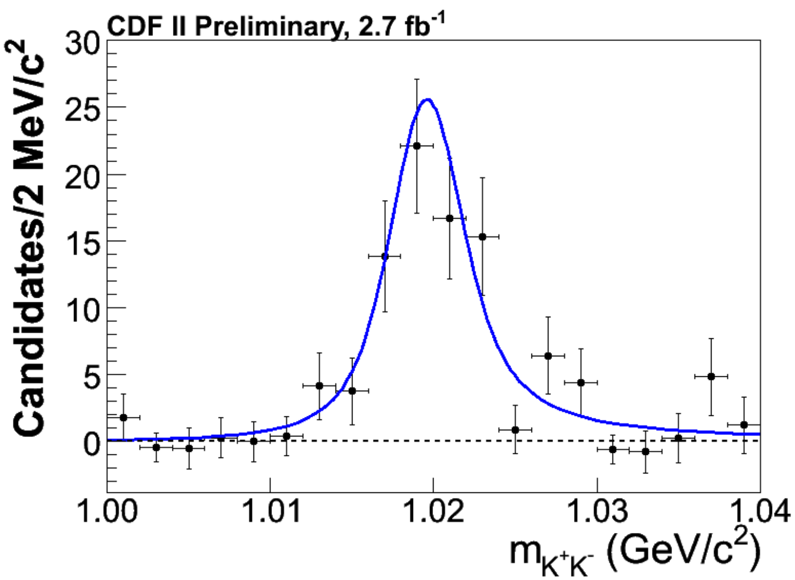
Valuable Contributions to Study of Bottom and Charm Hadrons Made at Tevatron

- Exciting time for flavor physics at the Tevatron!
  - Many significant contributions to knowledge of B hadrons has been made
  - Expect many interesting, important updates in the next few years!

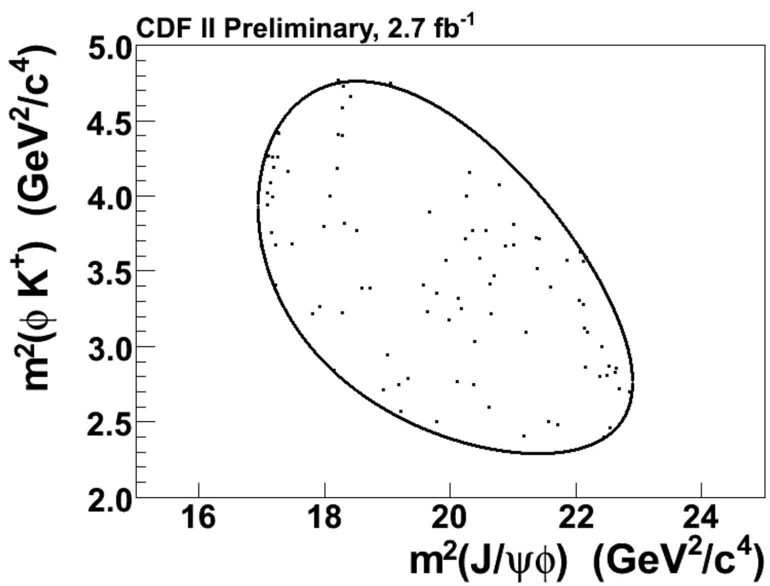
Back-up

Y(4140) Selection

- Optimize $S/\sqrt{(S+B)}$
  - $L_{xy}(B^+) > 500\ \mu m$
  - Log likelihood ratio of kaon > 0.2
- Observe clear sideband subtracted φ signal
  - Fit with P-wave relativistic Breit-Wigner
- Require events to have K^+K^- mass consistent with φ
  - $|m(K^+K^-) - m(\varphi)| < 7\ MeV/c^2$



Y(4140) Events Are Evenly Distributed in Phase Space



- See uniform distribution in Dalitz decays
  - All events are within kinematically allowed region determined from MC simulation

Investigate Properties of X(3872)

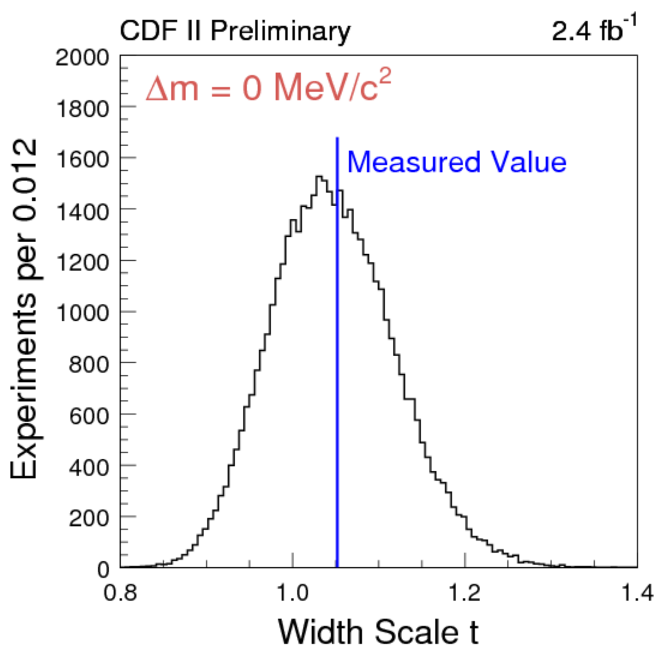
- First observed by Belle collaboration in 2003
- Observed in decay $X(3872) \to J/\psi\pi^+\pi^-$
  - Nature of particle is still unknown
    - D*D "molecule"? 4-quark state?
- Search for mass splitting, measure absolute mass
  - Observation of mass splitting offers evidence of tetra-quark
  - No mass splitting makes absolute mass interesting
    - Checks possibility of bound-state D*D

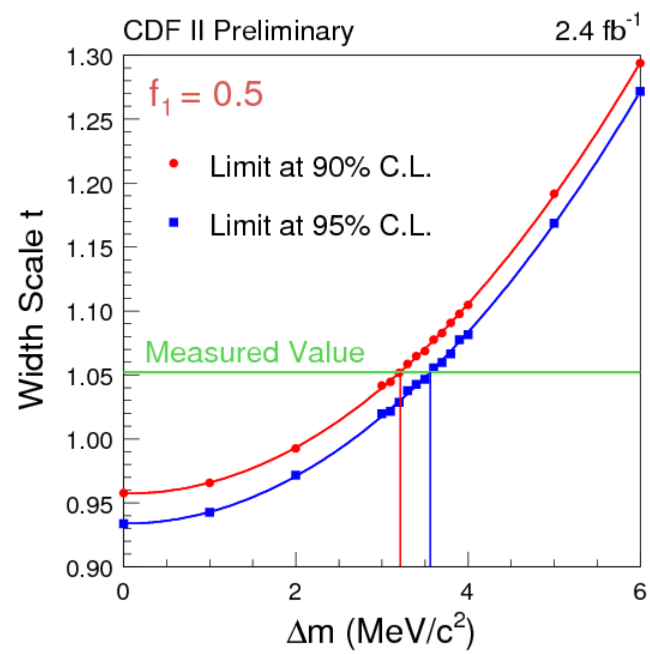
www-cdf.fnal.gov/physics/new/bottom/080724.blessed-X-Mass/

No Mass Splitting Observed in X(3872)

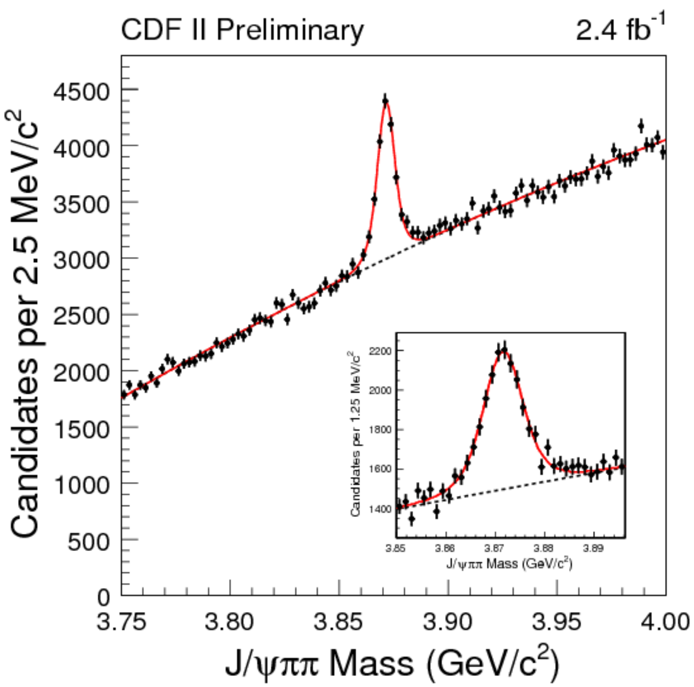
- Fit mass with Breit-Wigner convolved with resolution
  - Result consistent with no mass splitting
  - Assign upper limit CL

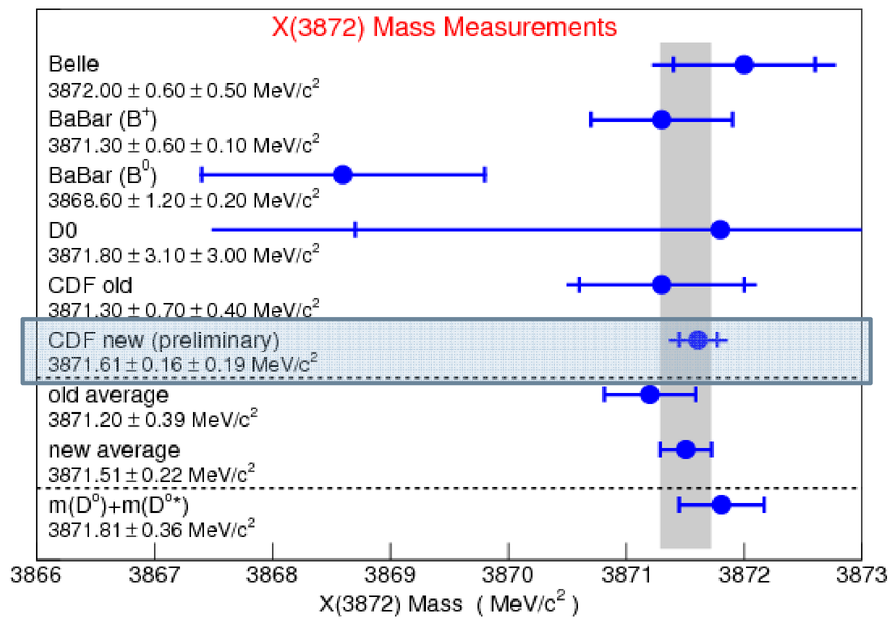
$\Delta m(X(3872)) < 3.2\ (3.6)\ \mathrm{MeV}/c^2$ at 90% (95%) C.L.





Most Precise Measurement of X(3872) Mass





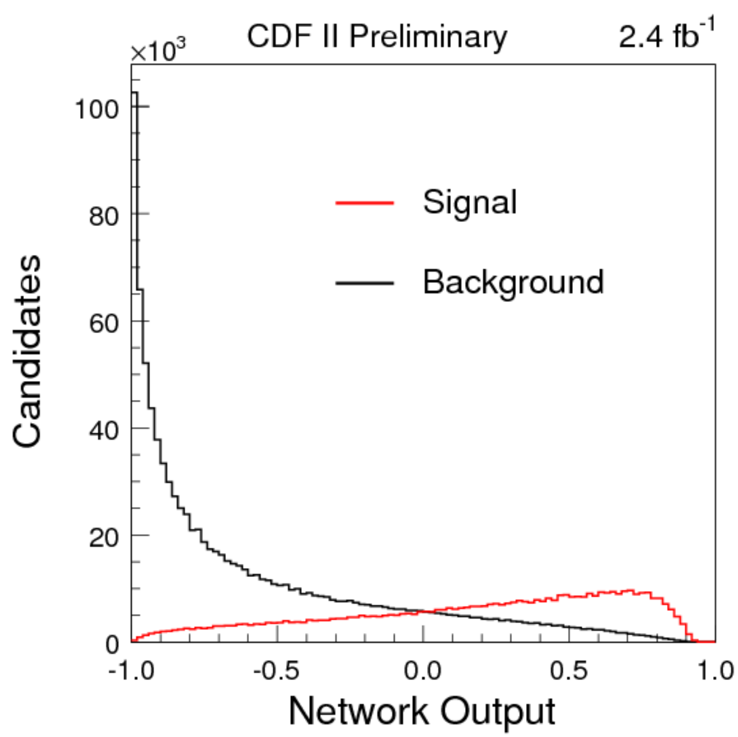
m(X(3872)) = 3871.61 +- 0.16 (stat) +- 0.19 (syst) MeV/c^2

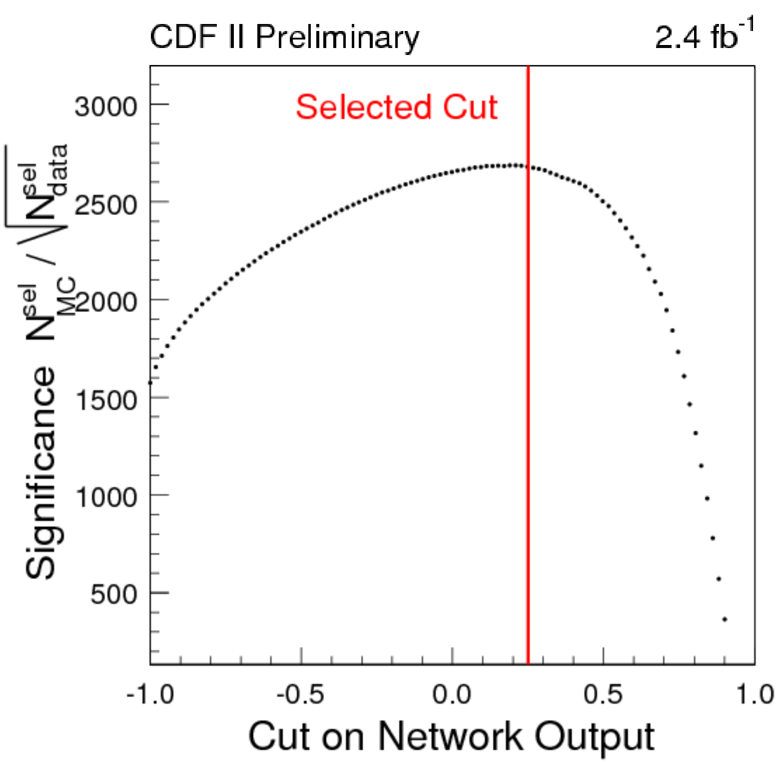
Measured mass is below D*D threshold, although uncertainties are within threshold

$\Rightarrow$ D*D bound state is still a possibility

Selection of X(3872)

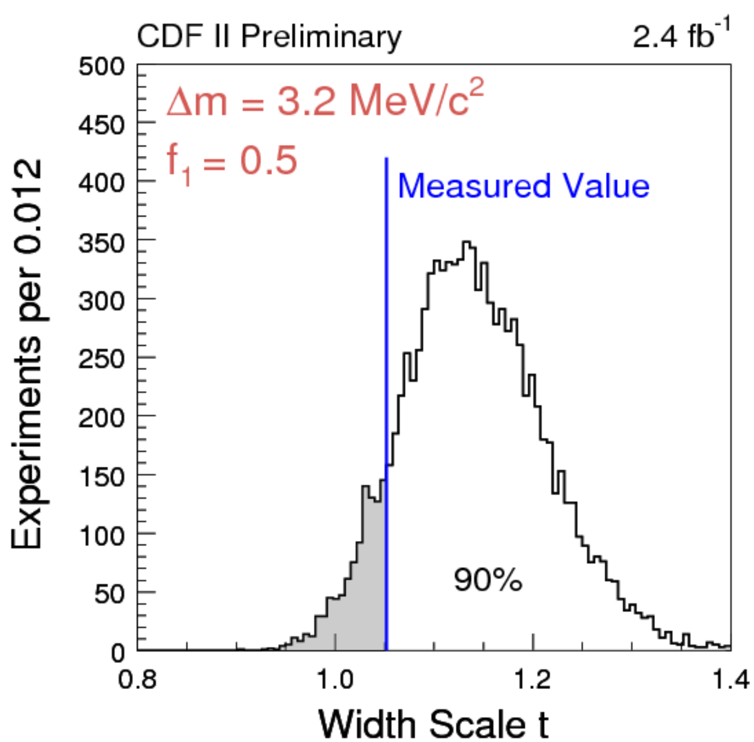
- Use ANN to select events
  - Optimize selection on Monte Carlo (signal) and mass sidebands (background)

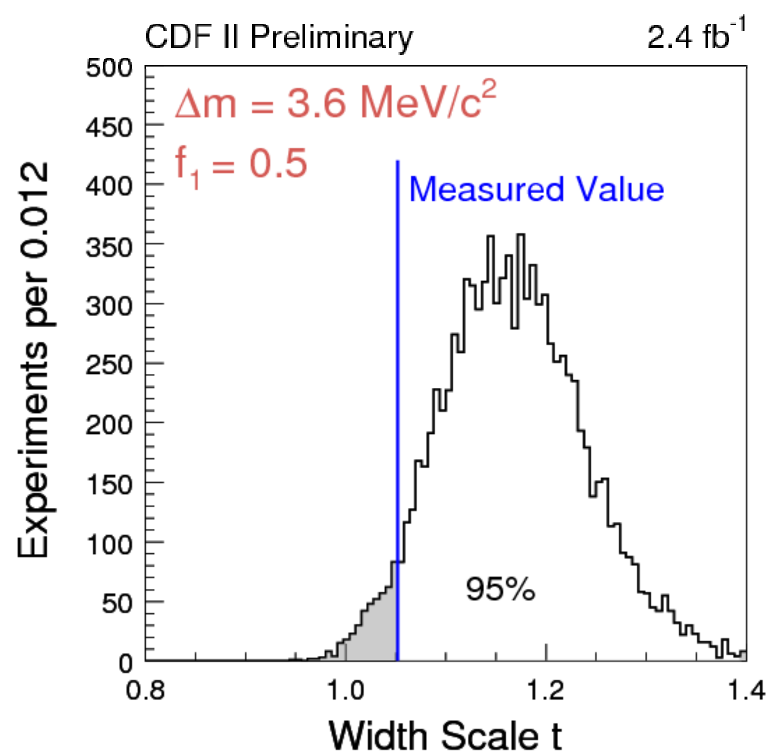




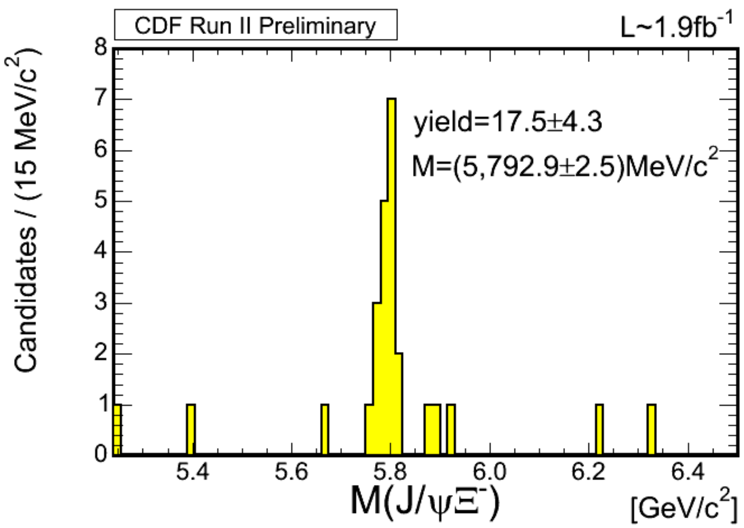
Mass Splitting of X(3872)

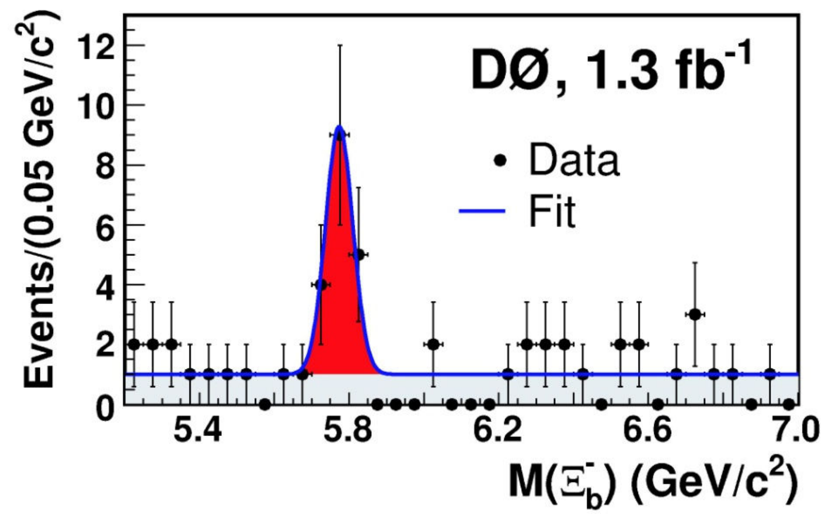
- Model resolution with Monte Carlo simulation
  - Width scale floats freely in fit



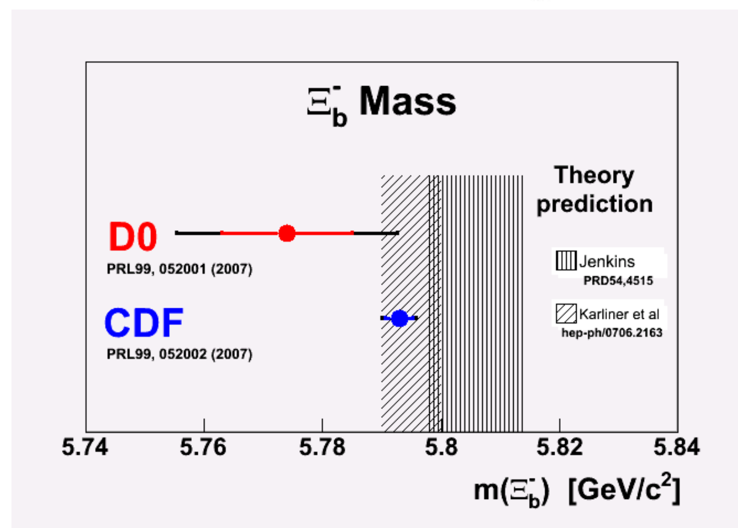


Previous Observation of Ξ_b^-



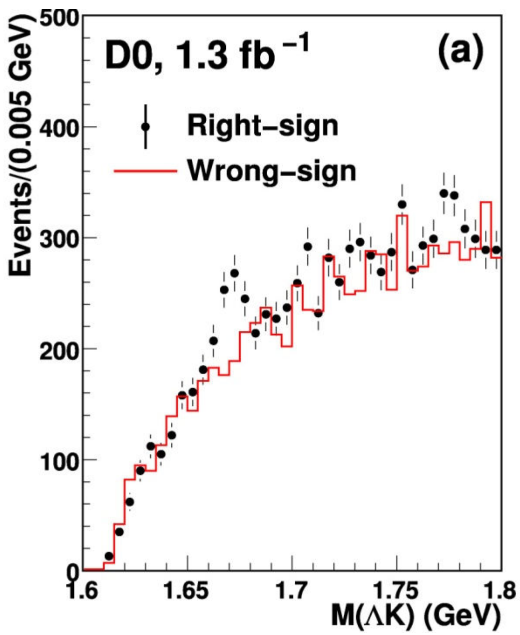


- In 2007, both CDF and D0 observed the Ξ_b^- and made a precise determination of its mass
  - $\Xi_b^- \rightarrow J/\psi\Xi^- \rightarrow [\mu^+\mu^-][\Lambda^0\pi^-]$, $\Lambda^0 \rightarrow p\pi^-$

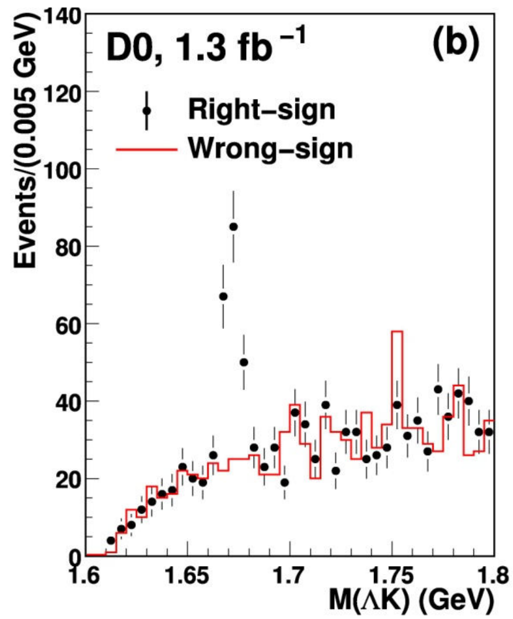


Ω^- Reconstruction Improved with Special Selection Techniques

- Use boosted decision tree (BDT) to improve identification of Ω^- signal



Before BDT



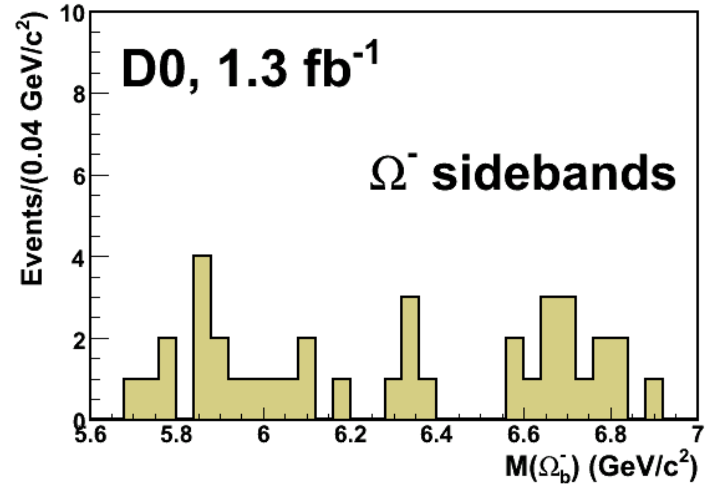
After BDT

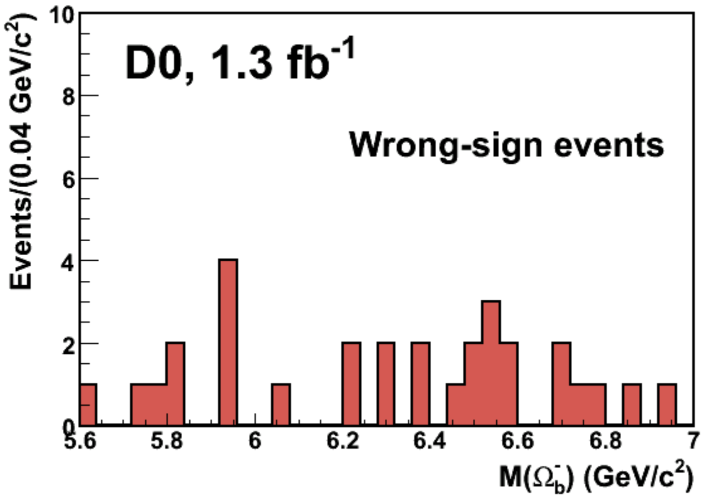
Veto $\Xi^- \to \Lambda^0 \pi^-$

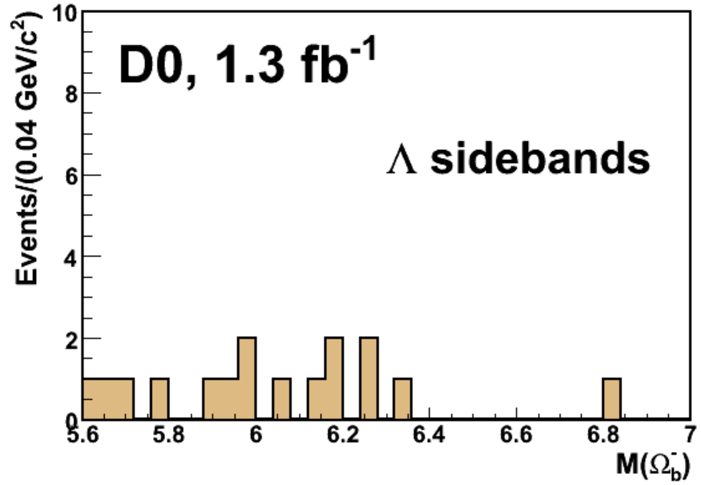
Re-process data with higher IP req. to increase Ξ^-/Ω^- acceptance!

Cross-Checks of Ω_b^- Signal (1)

- Check WS events and mass sidebands for spurious excesses
  - None observed!

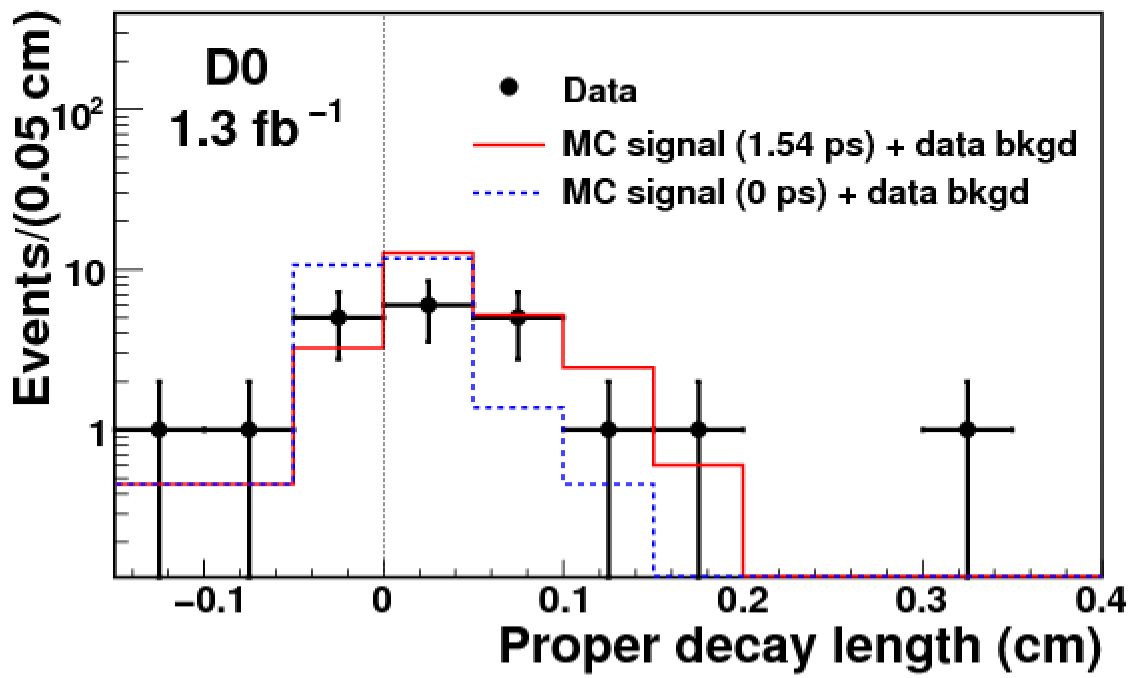




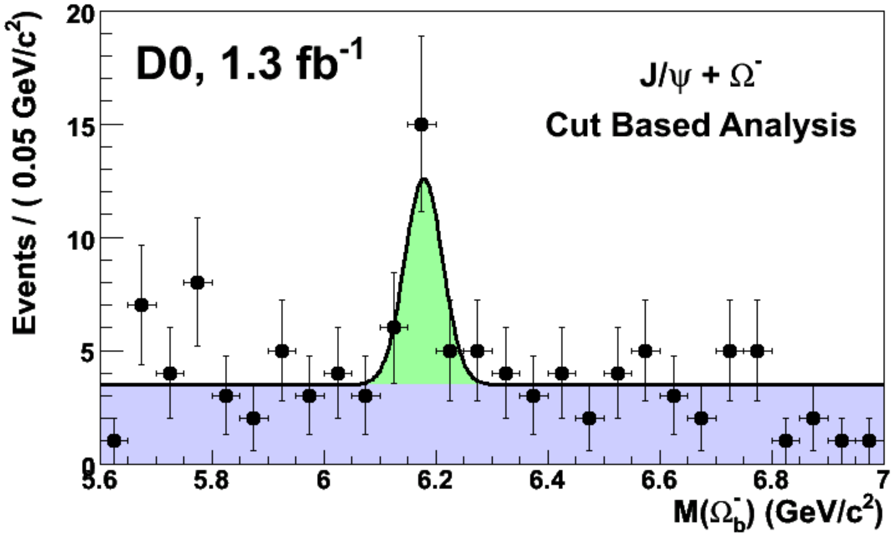


Cross-Checks of Ω_b^- Signal (2)

- Check lifetime distribution of Ω_b^- candidate events
  - Consistent with B hadron lifetime



Cut-based Analysis of Ω_b^-



- Alternatively, try using simpler cut-based analysis
  - Find 15.7 ± 5.3 (stat) events
  - $m = 6.177 \pm 0.015$ GeV/c^2
  - Signal significance is 3.9σ

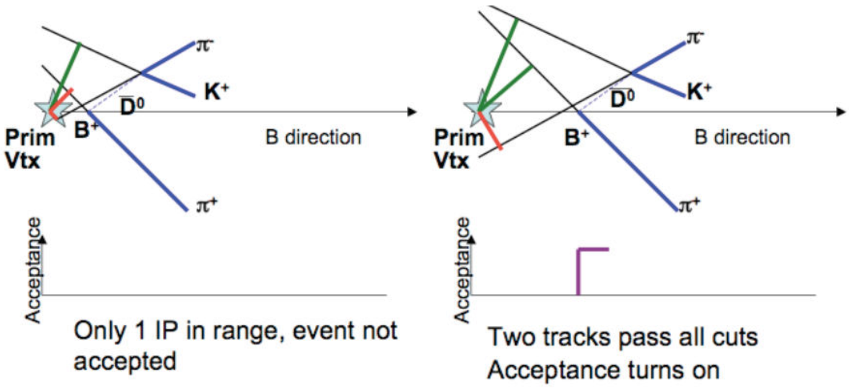
Ω_b^- Significance Calculation

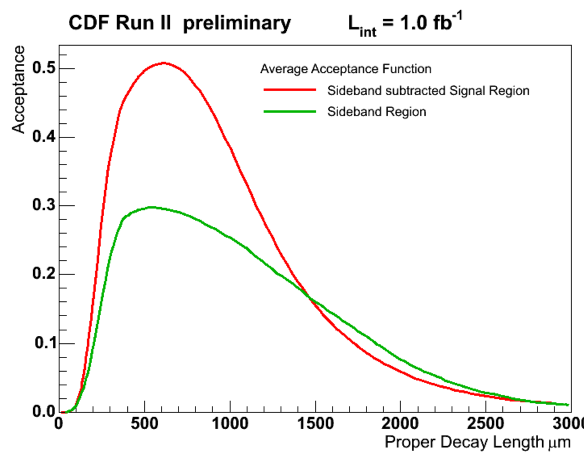
- Evaluate significance from likelihood ratio of background only hypothesis (L_B) to signal + background hypothesis (L_{S+B})

$$\sqrt{-2\Delta \ln L} = \sqrt{-2\ln\left(\frac{L_B}{L_{S+B}}\right)}$$

New Technique Used to Measure B^+ Lifetime

- Measured in displaced track sample
  - Novel method for correcting for trigger bias without using Monte Carlo





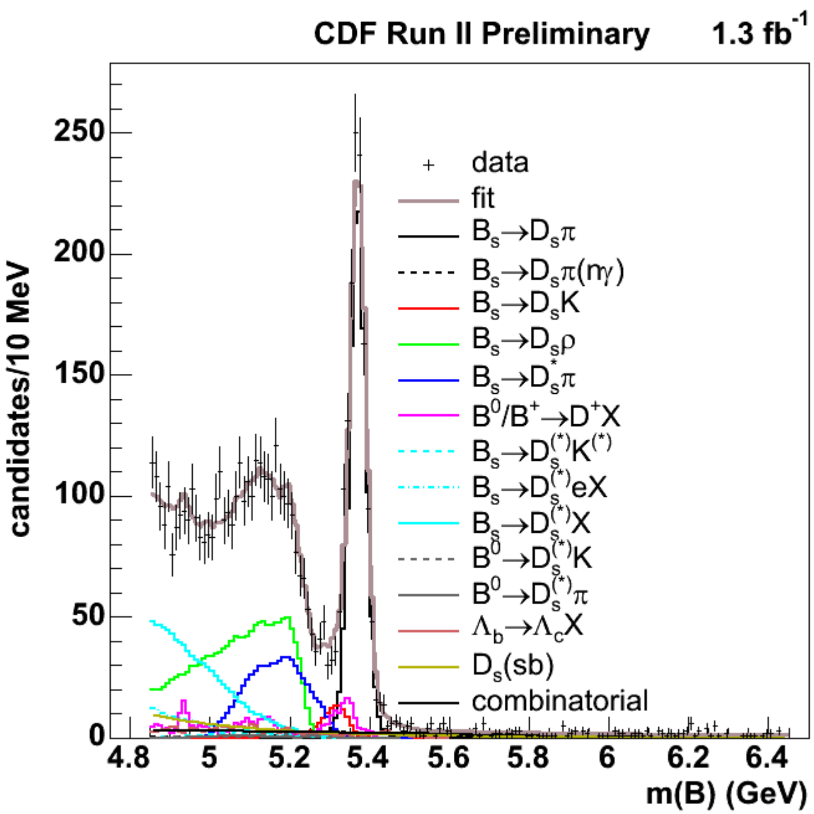
Use acceptance function to correct for trigger bias on event-by-event basis

$c\tau(B^+) = 498.2 \pm 6.8$ (stat.) $\pm$ 4.5 (syst.) μm,

($c\tau(B^+) = 491.1 \pm 3.3$ μm, PDG 2008)

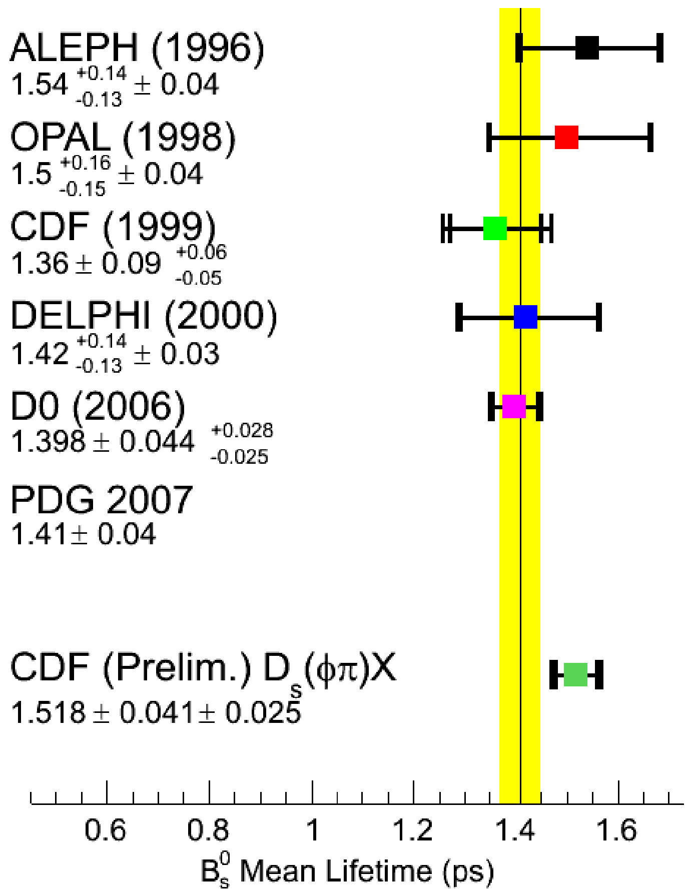
www-cdf.fnal.gov/physics/new/bottom/080612.blessed-MCfree_Blifetime/

B_s^0 Mass Fit in Lifetime Measurement



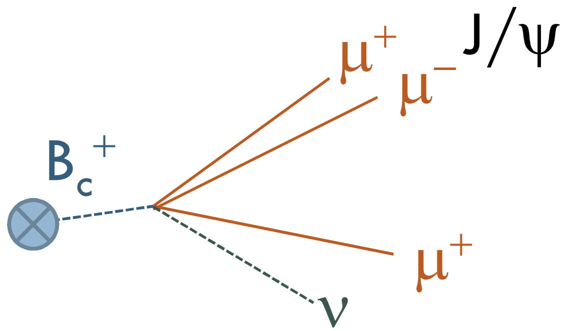
- Perform simultaneous unbinned maximum likelihood fit to mass and lifetime
  - Use partially reconstucted decays to double statistics
    - e.g. $B_s^0 \to D_s^- \rho^+ (\to \pi^0 \pi^+)$
  - ~2200 B_s^0 candidates

Comparison of B_s^0 Lifetime with Prev. Results



- B_s^0 lifetime is higher than recently measured B_s^0 lifetimes in flavor-specific decay modes
  - Expect 50% of Γ_L, Γ_H in flavor-specific modes

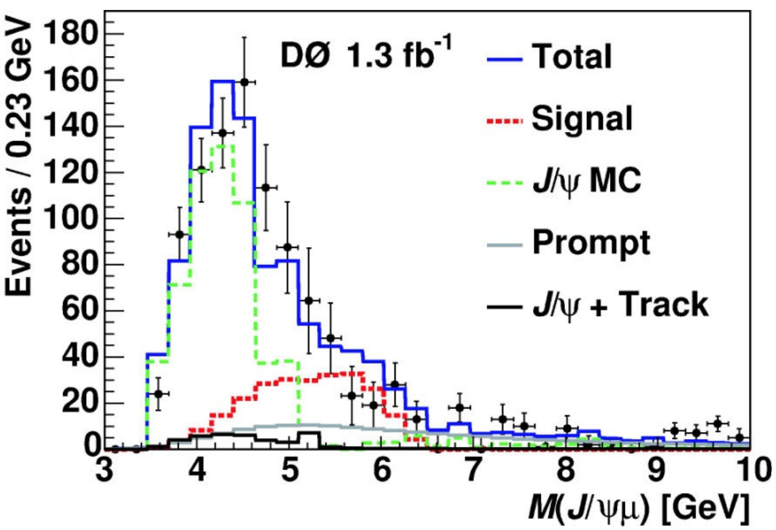
B_c^+ Lifetime Agrees with Theoretical Predictions

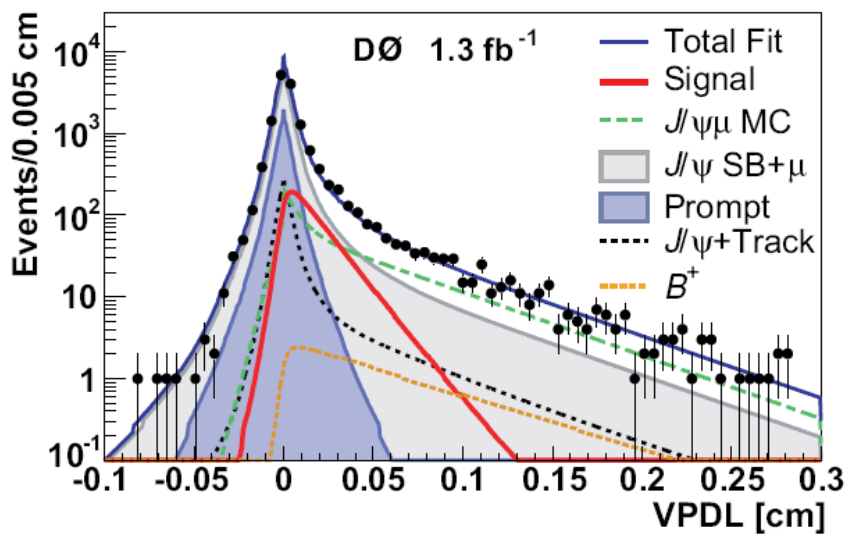


arXiv:0805.2614, submitted to PRL

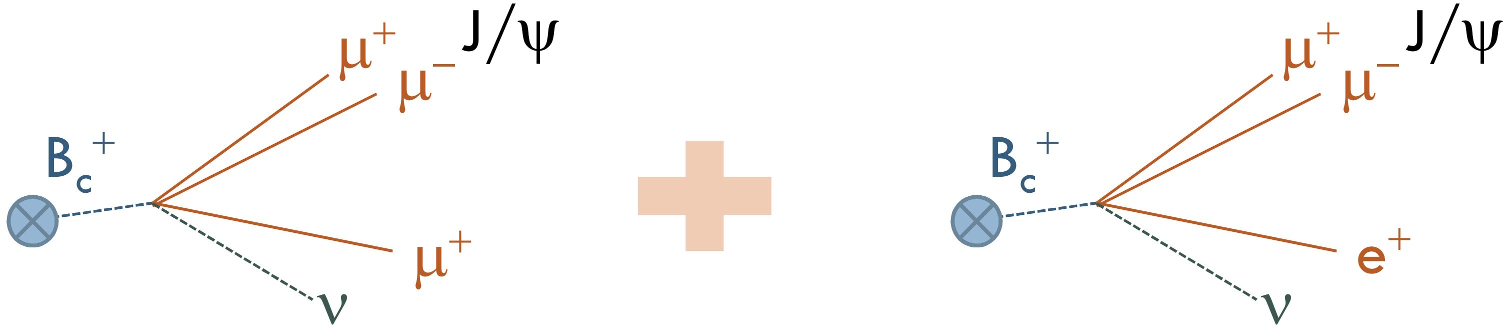
- Simultaneously fit mass and lifetime

$c\tau(B_c^+) = 134.3 \pm 11\ (\text{stat}) \pm 10\ (\text{syst})\ \mu\text{m}$



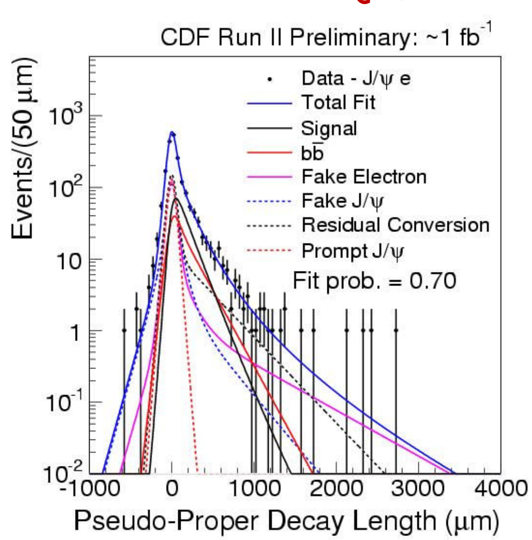


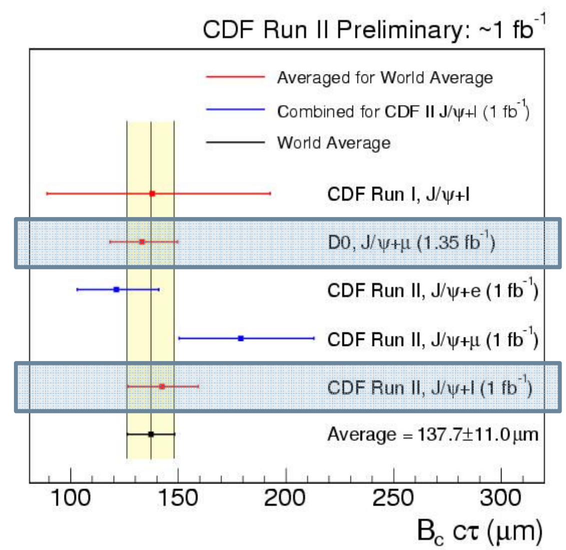
B_c^+ Lifetime Agrees with Theoretical Predictions and D0



- Fit e, μ channels separately, combine $\mathcal{L}$ afterwards

$$c\tau(B_c^+) = 142 \pm 15\ (\text{stat}) \pm 6\ (\text{syst})\ \mu m$$



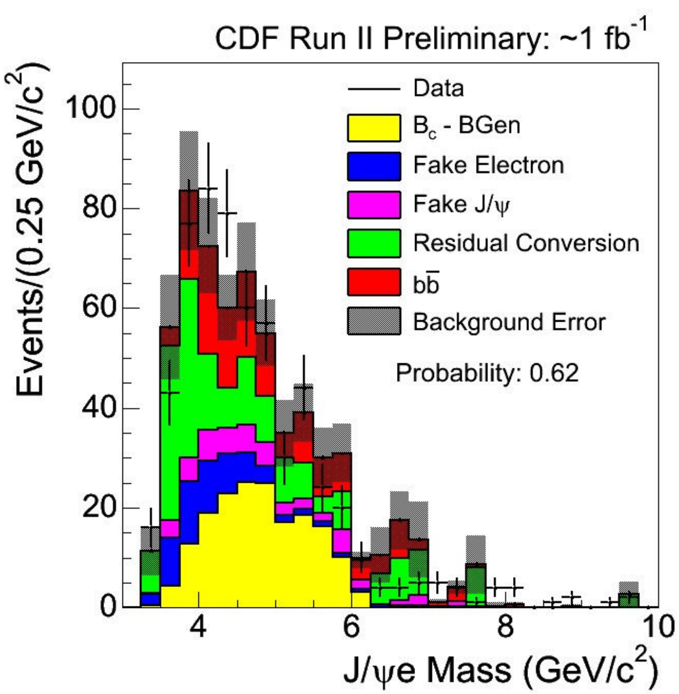


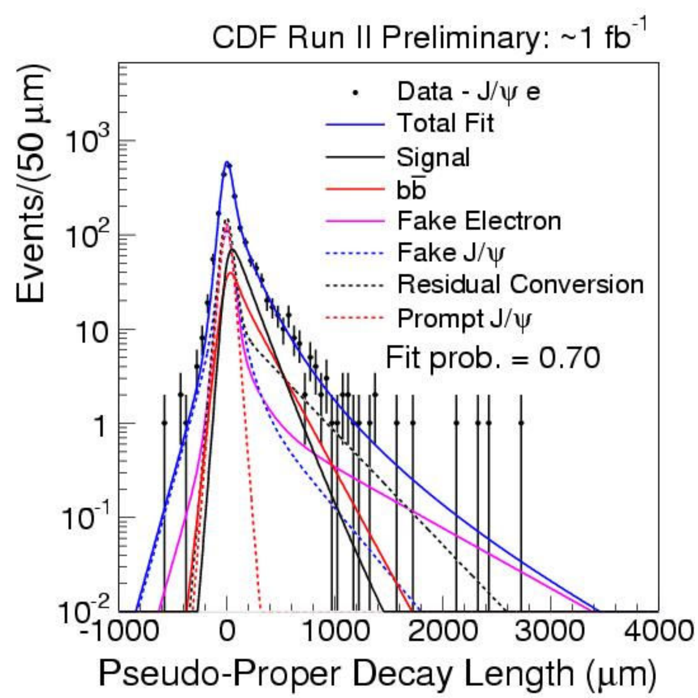
www-cdf.fnal.gov/physics/new/bottom/080327.blessed-BC_LT_SemiLeptonic/

Measurement of $B_c^+ \to J/\psi e^+ X$ Lifetime

- Fit lifetime only, use mass as cross-check
  - Determine all background shapes and normalizations from data if possible, MC otherwise $\Rightarrow$ constrain in fit

$$c\tau(B_c^+ \to J/\psi e^+ X) = 122^{+18}_{-16}\,(\text{stat})\ \mu m$$

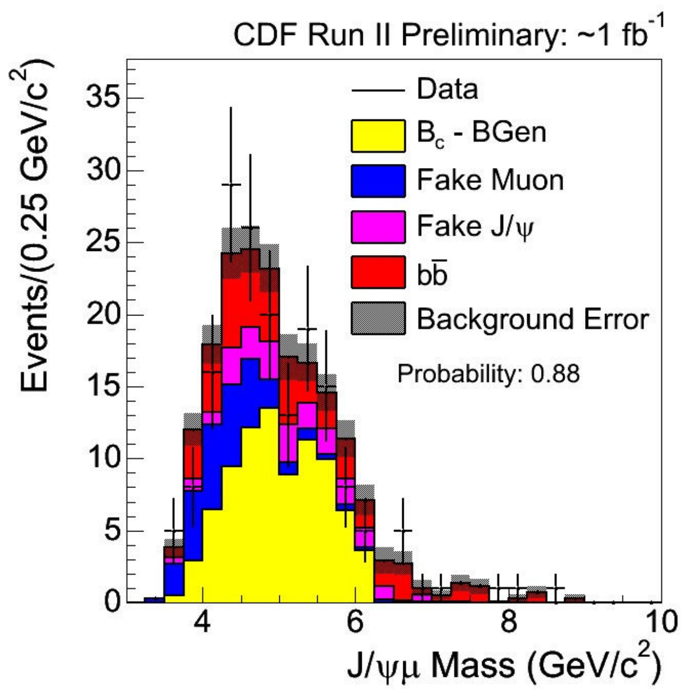


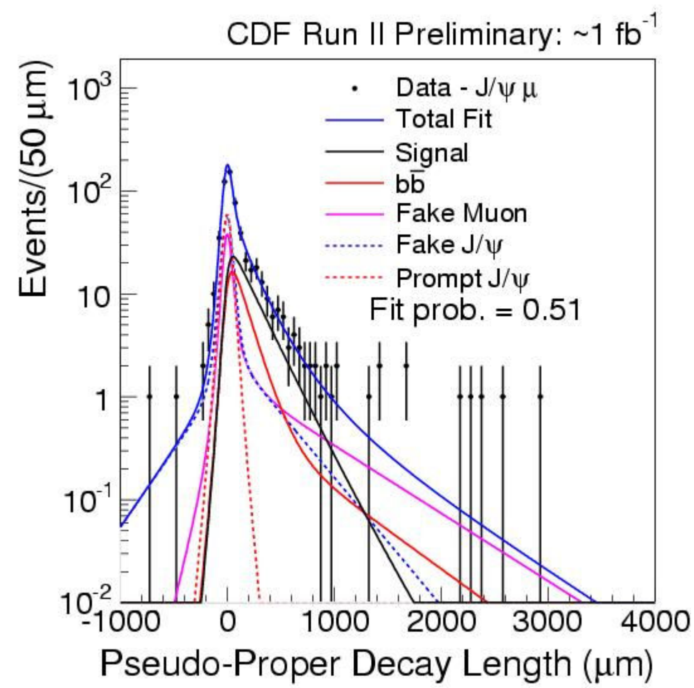


Measurement of $B_c^+ \rightarrow J/\psi\mu^+X$ Lifetime

- Fit lifetime only, use mass as cross-check
  - Determine all background shapes and normalizations from data if possible, MC otherwise $\Rightarrow$ constrain in fit

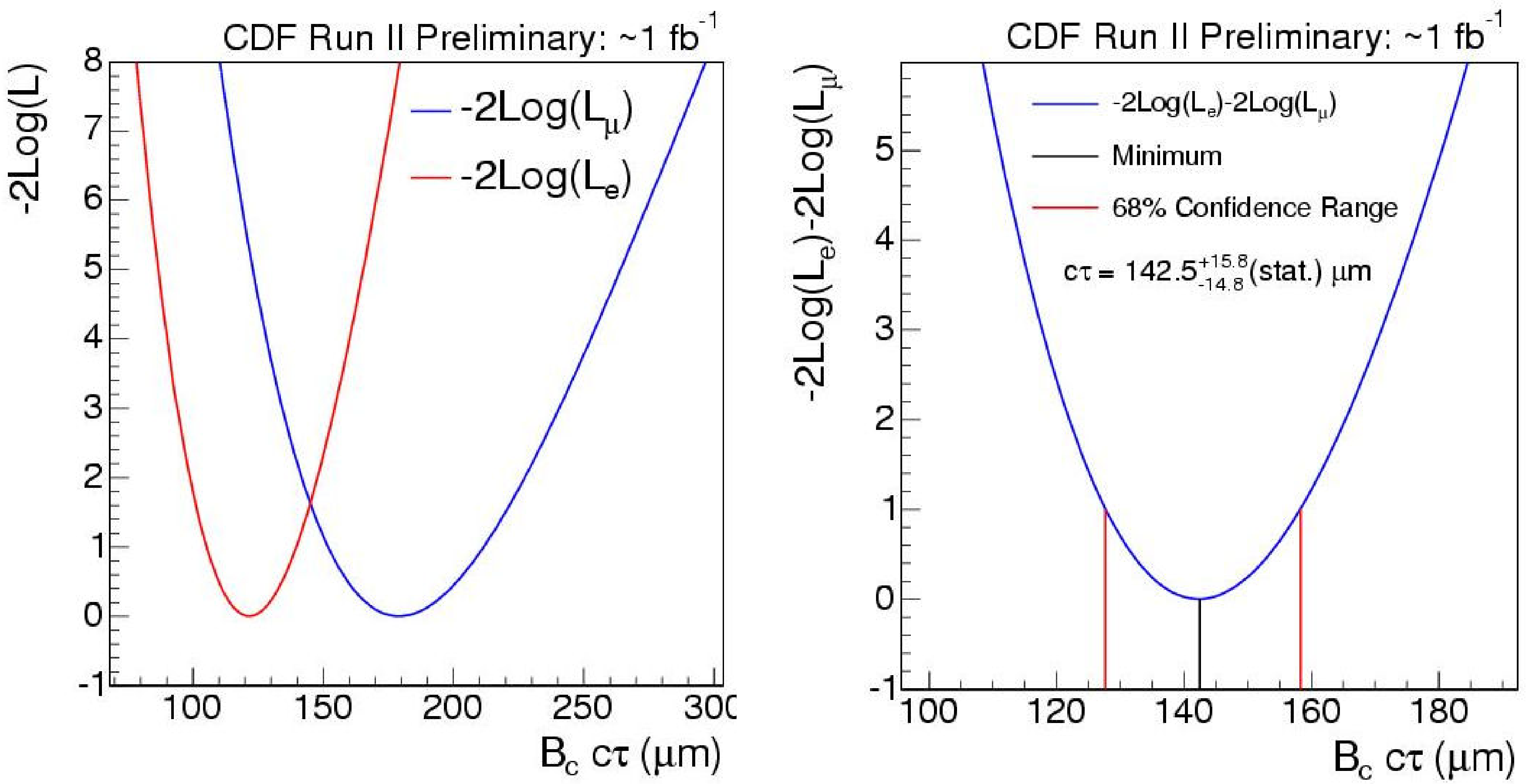
$$c\tau(B_c^+ \rightarrow J/\psi\mu^+X) = 179^{+33}_{-27}\,(\text{stat})\ \mu\text{m}$$





Combination of Semilep. B_c^+ Lifetimes

- Combine $-2\ln L_e$, $-2\ln L_\mu$

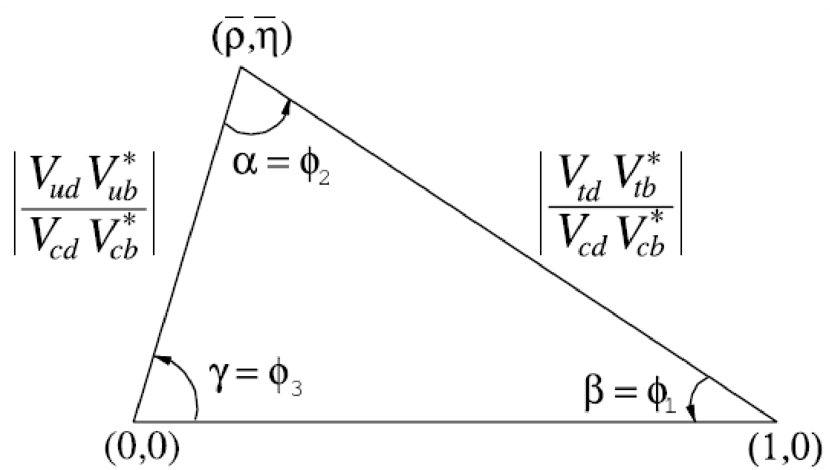


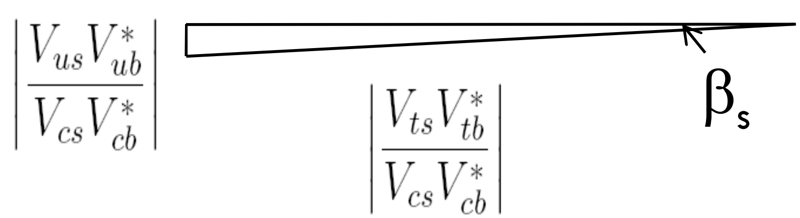
Unitarity Relations in B^0/B_s^0

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

$$V_{us}V_{ub}^* + V_{cs}V_{cb}^* + V_{ts}V_{tb}^* = 0$$

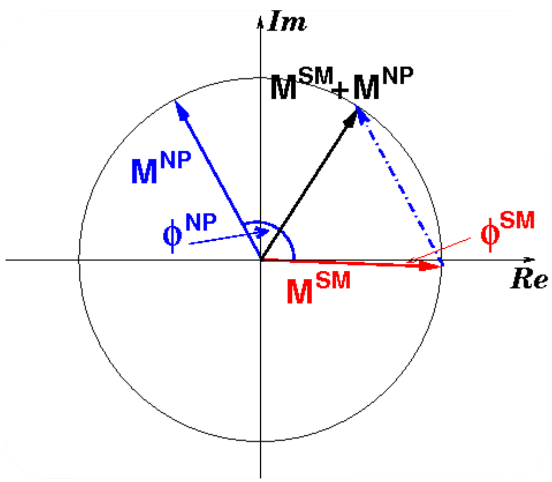




New Physics in B_s^0 Decays

- $B_s^0 - \overline{B}_s^0$ oscillations observed by CDF
  - Mixing frequency Δm_s now very well-measured
  - Precisely determines $|M_{12}|$ - in good agreement w/SM pred.
- Phase of mixing amplitude is still very poorly determined!

$M_{12} = |M_{12}| e^{i\varphi_m}$,
where $\varphi_m = \arg(V_{tb} V_{ts}^*)^2$



New physics could produce large CP phase!

$\Delta\Gamma/\Gamma$ Measured in $B_s^0 \to D^{(*)+}_s D^{(*)-}_s$ Consistent with World Average

- Measure branching ratio to determine $\Delta\Gamma$ (2.8 fb^{-1})
  - Search for one $D_s \to \varphi\pi$, other to $D_s \to \varphi\mu\nu$

Under certain theoretical assumptions, $B_s^0 \to D^{(*)+}_s D^{(*)-}_s$ is nearly CP even

$$2Br(B_s \to D_s^{(*)} D_s^{(*)}) \simeq \Delta\Gamma_s^{CP} \left[\frac{1+\cos\phi_s}{2\Gamma_L} + \frac{1-\cos\phi_s}{2\Gamma_H}\right]$$

Find

$$Br(B_s^0 \to D_s^{(*)} D_s^{(*)}) = 0.042 \pm 0.015(\mathrm{stat}) \pm 0.017(\mathrm{syst})$$

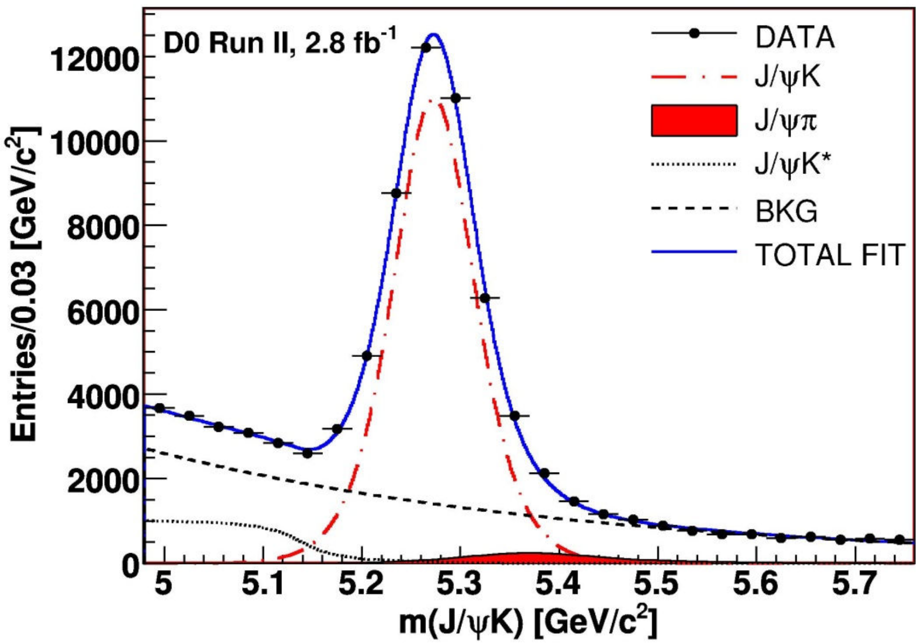
Assuming SM, $\varphi_s = 0$, $\Delta\Gamma^{CP} = \Delta\Gamma$

$$\frac{\Delta\Gamma_s}{\Gamma_s} = 0.088 \pm 0.030(\mathrm{stat}) \pm 0.036(\mathrm{syst})$$

Consistent with WA (2007) $\Delta\Gamma/\Gamma = 0.096^{+0.048}_{-0.053}$

www-d0.fnal.gov/Run2Physics/WWW/results/prelim/B/B53/

New Measurement of Direct CPV in $B^+ \to J/\psi K^+ (\pi^+)$



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- SM predicts $A_{CP}(B^+ \to J/\psi K^+) \sim 0.003$
  - NP might produce asymmetries up to ~0.01

$$A_{CP}(B^+ \to J/\psi K^+(\pi^+)) = \frac{N(B^- \to J/\psi K^-(\pi^-)) - N(B^+ \to J/\psi K^+(\pi^+))}{N(B^- \to J/\psi K^-(\pi^-)) + N(B^+ \to J/\psi K^+(\pi^+))}$$

$A_{CP}(B^+ \to J/\psi K^+) = +0.0075 \pm 0.0061\ \text{(stat)} \pm 0.0027\ \text{(syst)}$

$A_{CP}(B^+ \to J/\psi \pi^+) = -0.09 \pm 0.08\ \text{(stat)} \pm 0.03\ \text{(syst)}$