B_s Mixing, $\Delta\Gamma_s$ & CP Violation

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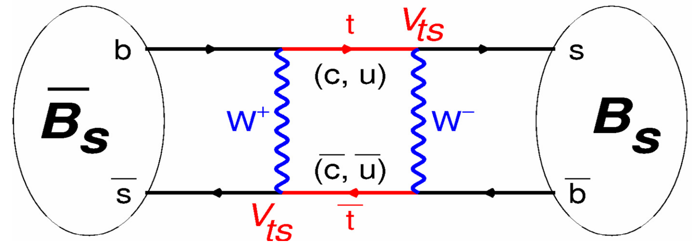
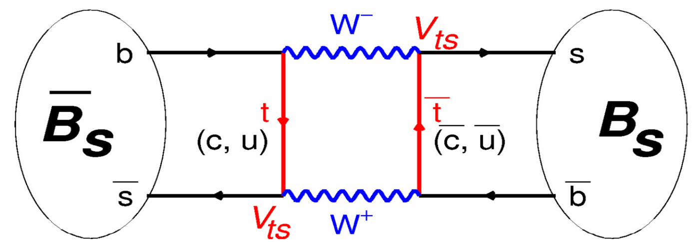
Synopsis

- Theoretical Introduction
- Neutral B_s Meson System:
  - ✓ B_s Oscillation Frequency
  - ✓ Lifetime Difference and CP Violation Phase in $B_s \to J/\Psi\ \Phi$
  - ✓ Charge Asymmetry in B_s Semileptonic Decays
- Charge Asymmetry in $B^+ \to J/\Psi\ K^+$
- Summary

Neutral B_s System





Flavor eigenstates:

$$|B_s\rangle = (\overline{b}s); \quad |\overline{B}_s\rangle = (b\overline{s})$$

Pure B_s and $\overline{B}_s$ at production:

$$i\frac{\partial}{\partial t}\begin{pmatrix}|B_s^0(t)\rangle \\ |\overline{B}_s^0(t)\rangle\end{pmatrix} = \left(M - i\frac{\Gamma}{2}\right)\begin{pmatrix}|B_s^0(t)\rangle \\ |\overline{B}_s^0(t)\rangle\end{pmatrix}$$

Mass eigeinstates are ($|p|^2+|q|^2=1$):

$$|B_H(t)\rangle = p|B_s(t)\rangle + q|\overline{B}_s(t)\rangle; \qquad |B_L(t)\rangle = p|B_s(t)\rangle - q|\overline{B}_s(t)\rangle$$

$\Rightarrow$ Different Masses:

$\Delta m_s = M_H - M_L \approx 2|M_{12}|$ defines the Mixing Oscillation Frequency

$\Rightarrow$ Different Lifetimes:

$\Delta\Gamma_s = \Gamma_L - \Gamma_H \approx 2|\Gamma_{12}|\cos\Phi_s,$

CPV:

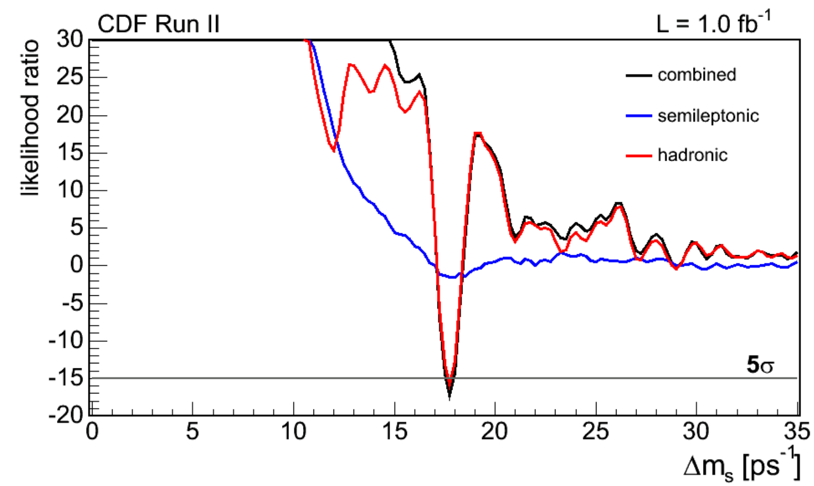
$\Phi_s^{SM} = \arg\left(-\frac{M_{12}}{\Gamma_{12}}\right) \approx 4\text{x}10^{-3}\text{rad}$

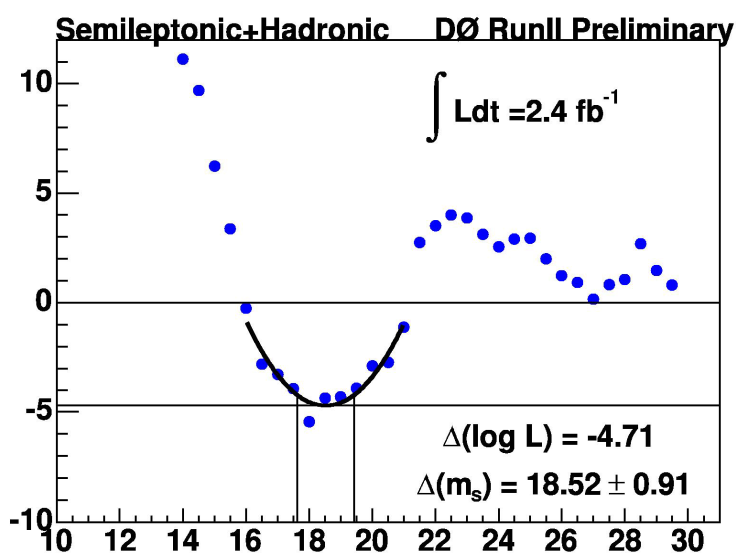
Small Phase expected in SM

B_s Mixing Oscillation

CDF: World First Observation (5σ)

- Integrated Luminosity: 1 fb^{-1}
- $\frac{\Delta m_s}{\Delta m_d} = \frac{m_{Bs}}{m_{Bd}} \xi^2 \frac{|V_{ts}|^2}{|V_{td}|^2}$, $\xi = 1.210^{+0.047}_{-0.035}$ (lattice QCD)
- $\Delta m_s = 17.77 \pm 0.10(\text{stat}) \pm 0.07 ps^{-1}$
- $\frac{|V_{td}|}{|V_{ts}|} = 0.2060 \pm 0.0007(\text{exp})^{+0.0081}_{-0.0060}(\text{theor})$





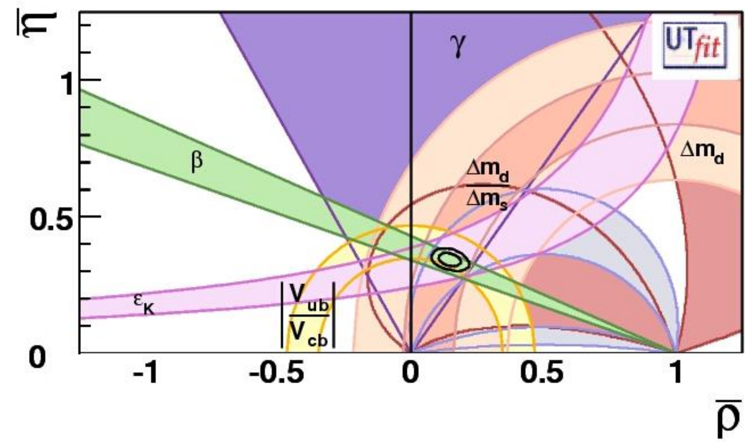
DØ: Evidence (3σ)

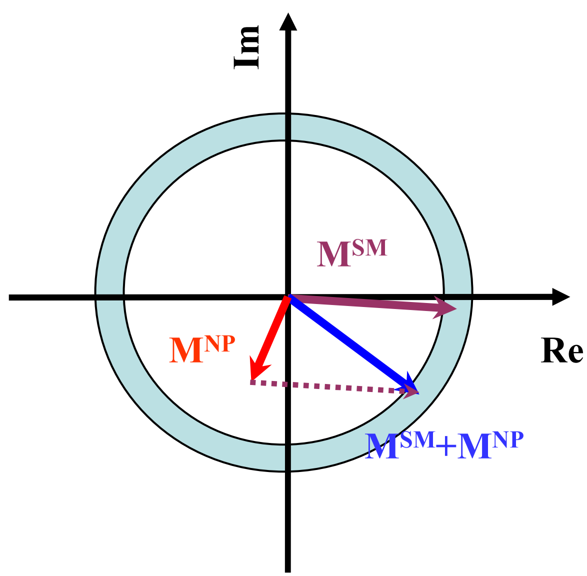
- Integrated Luminosity: 2.4 fb^{-1}
- First DØ measurement using a hadronic mode
- $\Delta m_s = 18.52 \pm 0.91 ps^{-1}$
- Consistent with CDF result

CP Violation in B_s System

- B_s mixing oscillation observed by **CDF**:
  - ✓ $\Delta m_s = M_H - M_L \approx 2|M_{12}|$ is well measured
  - ✓ Precisely determines $|M_{12}|$ in good agreement with the Standard Model

$\boxed{\Delta m_s = 17.77 \pm 0.10 \text{ (stat)} \pm 0.07 \text{ ps}^{-1}}$





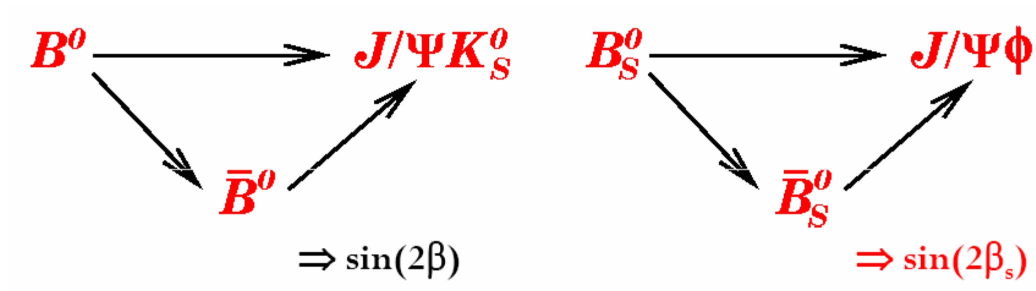
- Phase of the mixing amplitude is instead poorly determined
- Both are needed to constrain New Physics:

$$\boxed{M_{12} = |M_{12}| e^{i\Phi M} = |M_{12}| e^{-i2\beta s}}$$

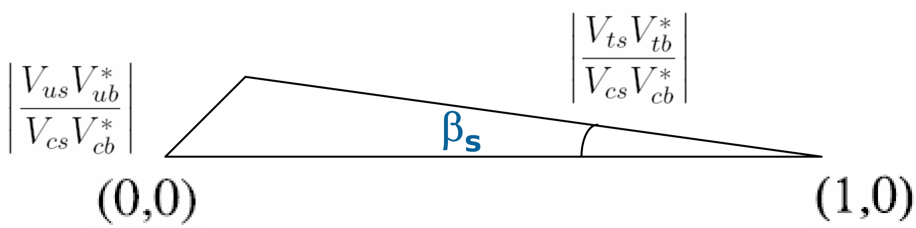
Large value of CP Violation phase Φ_M is a clear sign of New Physics!

$\not{CP}$ in $B_s \to J/\Psi\ \Phi$ Decays

- CP Violation arises from the interference between mixing and decay:



- Unitarity Triangle in B_s System:



$$\boxed{V_{us}V^*_{ub} + V_{cs}V^*_{cb} + V_{ts}V^*_{tb} = 0}$$

- CP violation phase β_s in SM is predicted to be very small:

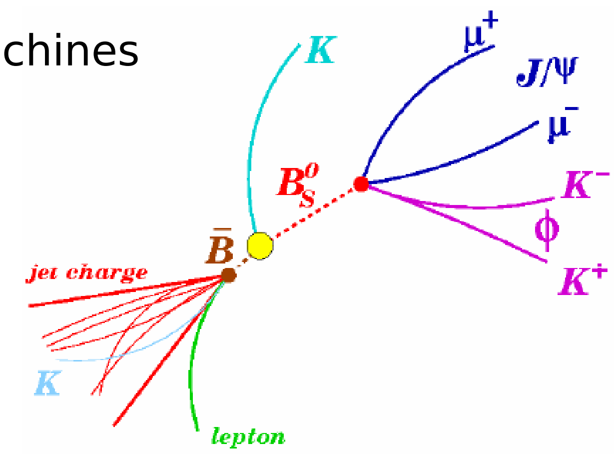
$$2\beta_s^{SM} = 2\arg(-V_{ts}V^*_{tb} / V_{cs}V^*_{cb}) \approx 0.04 \pm 0.01 \quad \text{rad}$$

- Same New Physics affects the CPV phases as $\boxed{2\beta_s = 2\beta_s^{SM} - \Phi_s^{NP} \qquad \Phi_s = \Phi_s^{SM} + \Phi_s^{NP}}$

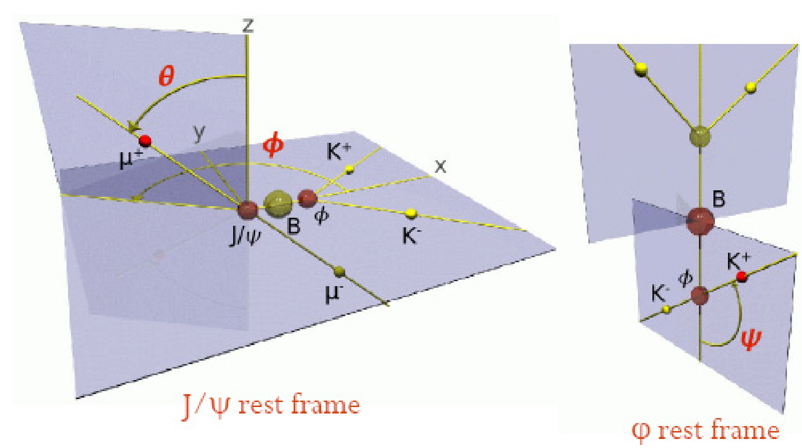
- If NP phase Φ_s^{NP} dominates $\Rightarrow$ $2\beta_s = -\Phi_s$

Phenomenology of $B_s \to J/\Psi\ \Phi$

- Nice experimental signature for B physics at hadron machines



- Decays into an <u>admixture</u> of CP even (~75%) and CP odd (~25%)
- $CP|B_{L,H}\rangle \cong \pm|B_{L,H}\rangle \Rightarrow$ Mass and CP states are very close
- C-even ⇒ <u>Different Parity</u> ⇒ Separate CP contributions
- $B_s \to J/\Psi\Phi$ decays leads to three different angular momentum final states:
  - ✓ L=0 (S-wave), L=2 (D-wave) ⇒ P-even
  - ✓ L=1 (P-wave) ⇒ P-odd



- <u>Angular Analysis</u> to separate the different parity contributions
- Transversity Basis $\vec{w} = (\theta,\ \Phi,\ \psi)$
- Sensitivity to $\Delta\Gamma_s$ and CP-Violation phase $2\beta_s$

  (also in untagged sample due to CP-even/CP-odd interference)

Signal PDF for $B_s \to J/\Psi\ \Phi$

General decay rate formula:

$$\frac{d^4P(t,\vec{w})}{dtd\vec{w}} \propto |A_0|^2\, T_+ f_1(\vec{w}) + |A_{||}|^2\, T_+ f_2(\vec{w}) + |A_\perp|^2\, T_- f_3(\vec{w}) + |A_{||}||A_\perp|\, U_+ f_4(\vec{w}) + |A_0||A_{||}|\cos(\delta_{||}) T_+ f_5(\vec{w}) + |A_0||A_\perp|\, V_+ f_6(\vec{w})$$

$$T_\pm = e^{-\Gamma t} \times [\cosh(\Delta\Gamma t/2) \mp \cos(2\beta_s)\sinh(\Delta\Gamma t/2) \mp \eta \sin(2\beta_s)\sin(\Delta m_s t)],\ \eta = +1(-1) \text{ for } P(\bar{P})$$

$$U_\pm = \pm e^{-\Gamma t} \times [\sin(\delta_\perp - \delta_{||})\cos(\Delta m_s t) - \cos(\delta_\perp - \delta_{||})\cos(2\beta_s)\sin(\Delta m_s t) \pm \cos(\delta_\perp - \delta_{||})\sin(2\beta_s)\sinh(\Delta\Gamma t/2)]$$

$$V_\pm = \pm e^{-\Gamma t} \times [\sin(\delta_\perp)\cos(\Delta m_s t) - \cos(\delta_\perp)\cos(2\beta_s)\sin(\Delta m_s t) \pm \cos(\delta_\perp)\sin(2\beta_s)\sinh(\Delta\Gamma t/2)]$$

- B_s decays into mixture of CP eigeinstates: interference terms in general decay rate formula
- In the Transversity basis the vector meson polarization w.r.t the direction of motion is:

✓ Longitudinal $\Rightarrow A_0$ [CP even]
✓ Transverse and parallel to each other $\Rightarrow A_{||}$ [CP even]
✓ Transverse and perpendicular to each other $\Rightarrow A_\perp$ [CP odd]

- Strong phases:

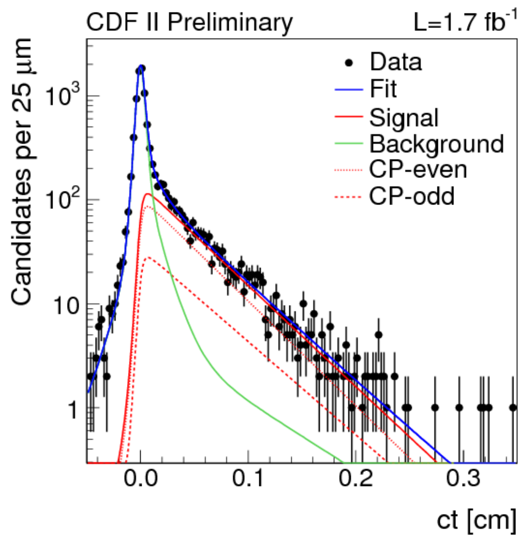
✓ $\delta_{||} \equiv \arg(A_{||}^* A_0)$
✓ $\delta_\perp \equiv \arg(A_\perp^* A_0)$

- Terms with Δm_s dependence flip sign for initial B_s flavor
- Untagged analysis are insensitive to $\Delta\Gamma_s$ and β_s signs $\Rightarrow$ 4-fold ambiguity

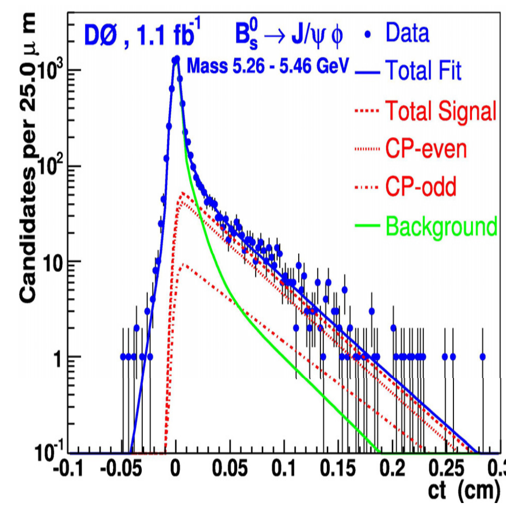
B_s Lifetime and Decay Width

- Sizeable $\Delta\Gamma_s \Rightarrow$ CP-even and CP-odd contributions of the signal can be distinguished
- Results assuming no CP violation $\Rightarrow \beta_s = 0$

CDF: ~2500 signal events (1.7 fb^{-1})



DØ: ~1040 signal events (1.1 fb^{-1})



World Best $\Delta\Gamma_s$ Measurements (arXiv: 0712.2348)

Lifetime: $\tau_s = 1.52 \pm 0.04(\text{stat}) \pm 0.02(\text{syst})$ ps

Decay Width: $\Delta\Gamma_s = 0.08 \pm 0.06(\text{stat}) \pm 0.01(\text{syst})\ \text{ps}^{-1}$

PRL 98, 121801 (2007)

$\tau_s = 1.52 \pm 0.08(\text{stat})^{+0.01}_{-0.03}(\text{syst})$ ps

$\Delta\Gamma_s = 0.12^{+0.08}_{-0.12}(\text{stat}) \pm 0.02(\text{syst})\ \text{ps}^{-1}$

- $B^0 \to J/\Psi\, K^{*0}$: CDF validates treatment of detector acceptance!
  $\Rightarrow$ Results compatible and competitive with B Factories (back-up slides)

$\not{C}\not{P}$ in Untagged $B_s \to J/\Psi\ \Phi$

- Allowing CP violation phase β_s to float in the fitter
- Symmetry in the likelihood 4-fold ambiguity
- **DØ** quotes a point estimate:

$$\Rightarrow \boxed{\begin{array}{l}\Phi_s = -2\beta_s = -0.79 \pm 0.56\ (\text{stat})^{+0.14}_{-0.01}\ (\text{syst})\ \text{rad} \\ \Delta\Gamma_s = 0.17 \pm 0.09\ (\text{stat}) \pm 0.02\ (\text{syst})\ \text{ps}^{-1}\end{array}}$$

- **CDF** observes irregular likelihood and biases in fit
  - $\Rightarrow$ Feldman-Cousins confidence region: SM probability p_{value}=22% (1.2σ)

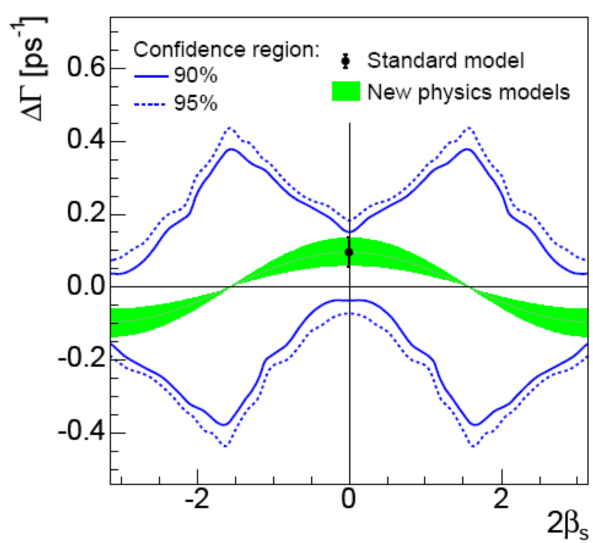
Standard Model expectations:

(arXiv:hep-ph/0612167)

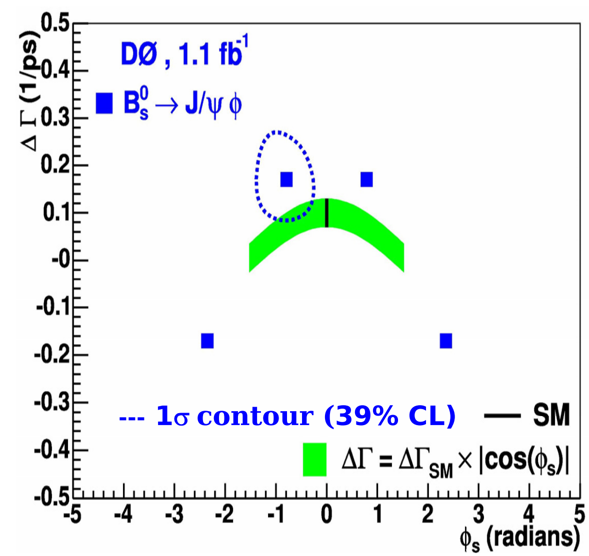
$\Delta\Gamma_s = 0.096 \pm 0.039\ \text{ps}^{-1}$

$2\beta_s = 0.04 \pm 0.01$ rad

arXiv:0712.2348



PRL 98, 121801 (2007)



Flavor Tagging Effect

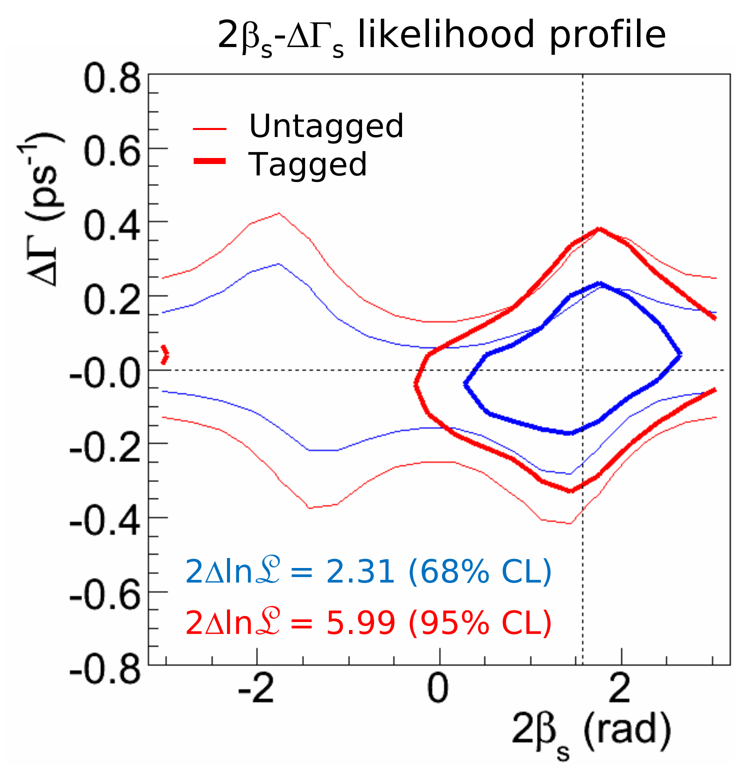
- Tagging improves sensitivity to CP violation phase β_s
- Exact symmetry present in signal probability distribution
- Two minima in the likelihood

$$
\begin{aligned}
2\beta_s &\leftrightarrow \pi - 2\beta_s \\
\Delta\Gamma_s &\leftrightarrow -\Delta\Gamma_s \\
\delta_{||} &\leftrightarrow \pi - \delta_{||} \\
\delta_{\perp} &\leftrightarrow \pi - \delta_{\perp}
\end{aligned}
$$

- Check β_s-$\Delta\Gamma_s$ likelihood profile with Toy MC to understand tagging effect

- Likelihood: with tagging, gain sensitivity to both $|\cos(2\beta_s)|$ and $\sin(2\beta_s)$, rather than only $|\cos(2\beta_s)|$ and $|\sin(2\beta_s)|$ (note absolute value)

- $\beta_s \leftrightarrow -\beta_s$ is no longer a likelihood symmetry:
  - $\Rightarrow$ 4-fold ambiguity reduced to <u>2-fold</u>
  - $\Rightarrow$ allowed region for β_s is reduced to half



$\not{CP}$ in Tagged $B_s \to J/\Psi\,\Phi$

- <u>First tagged analysis</u> of $B_s \to J/\Psi\Phi$ decay

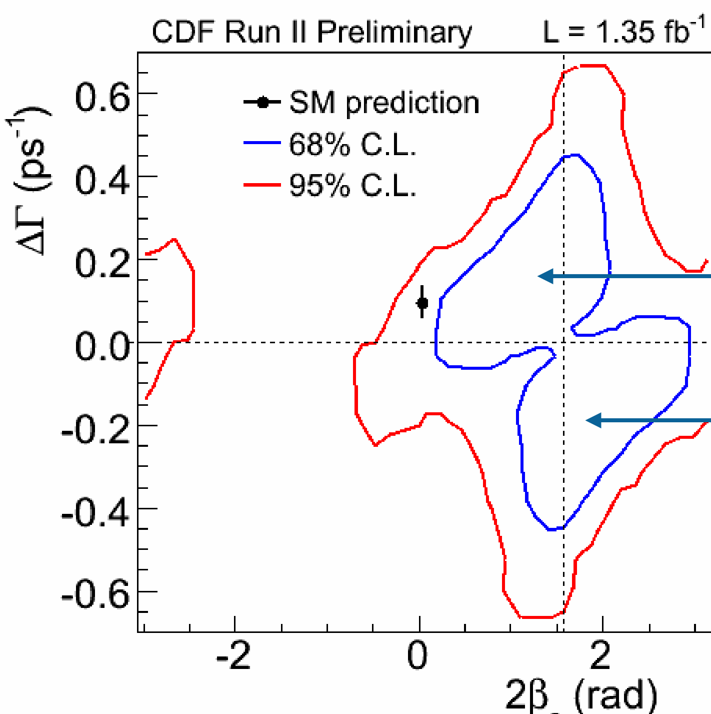
arXiv: 0712.2397

- **CDF:** ~2000 B_s events with 1.35 fb^{-1}
- Tagging power $\Rightarrow$ OST: $\varepsilon=(96 \pm 1)\%$ $\langle D \rangle = (11 \pm 2)\%$
  $\Rightarrow$ SST: $\varepsilon=(50 \pm 1)\%$ $\langle D \rangle = (27 \pm 4)\%$
- Irregular likelihood does not allow quoting point estimate:
  ✓ Feldman-Cousins likelihood ratio ordering

Standard Model expectations:
(arXiv:hep-ph/0612167)

$\Delta\Gamma_s=0.096 \pm 0.039\ ps^{-1}$
$2\beta_s = 0.04 \pm 0.01$ rad

Standard Model
$p_{value} = 15\%\ (1.5\sigma)$



strong phases can separate the two minima

$cos(\delta_\perp) < 0$
$cos(\delta_\perp - \delta_{||}) > 0$

$cos(\delta_\perp) > 0$
$cos(\delta_\perp - \delta_{||}) < 0$

$\not{C}\not{P}$ in Tagged $B_s \rightarrow J/\Psi\ \Phi$

1-dim Feldman-Cousins procedure on CP violation phase β_s

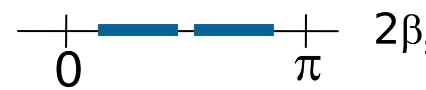
1. Without External Constraints:

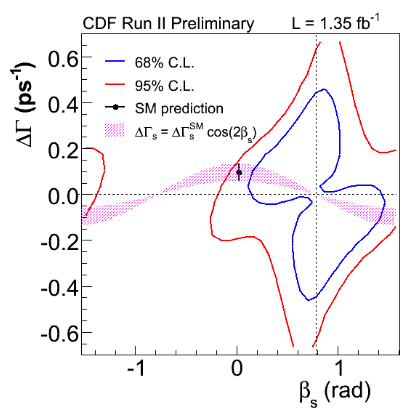
   $2\beta_s$ in [0.32, 2.82] at the 68% C.L.

2. $\Delta\Gamma_s$ is theoretically constrained:

   • Input $\Delta\Gamma_s = 2|\Gamma_{12}|\cos\Phi_s \approx 2|\Gamma_{12}|\cos(2\beta_s)$: ($\Gamma_{12}$=0.048±0.018):

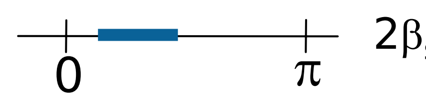
   $2\beta_s$ in [0.24, 1.36] U [1.78, 2.90] at 68% C.L.





3. Strong phases from $B_d \rightarrow J/\Psi\ K^{*0}$ [PRD 71, 032005 (2005)], B_s lifetime from B_d [PDG] and $\Delta\Gamma_s \approx 2|\Gamma_{12}|\cos(2\beta_s)$:

   $2\beta_s$ in [0.40, 1.20] at 68% C.L.



$\cancel{CP}$ in Tagged $B_s \to J/\Psi\ \Phi$

- <u>Tagged analysis</u> of $B_s \to J/\Psi\Phi$ decay from **DØ**
- **<u>DØ</u>:** ~2000 B_s events with 2.8 fb^{-1}
- Combined Tagging Power $\Rightarrow \varepsilon D^2 = (4.68 \pm 0.54)\%$
- Quoting point estimate:

arXiv: 0802.2255

$$\tau_s = 1.52 \pm 0.06\ (\text{stat}) \pm 0.01\ (\text{syst})\ \text{ps}$$

$$\Delta\Gamma_s = 0.19 \pm 0.07\ (\text{stat})^{+0.02}_{-0.01}\ (\text{syst})\ \text{ps}^{-1}$$

$$\Phi_s = -2\beta_s = -0.57^{+0.24}_{-0.30}\ (\text{stat})^{+0.07}_{-0.02}\ (\text{syst})\ \text{rad}$$

<u>FIT</u> <u>inputs</u>:

Δm_s fixed to 17.77 ps^{-1} ← **CDF**

Gaussian constraint on Strong phases:

$\delta_\perp - \delta_{||} = -0.46 \pm (\pi/5)$

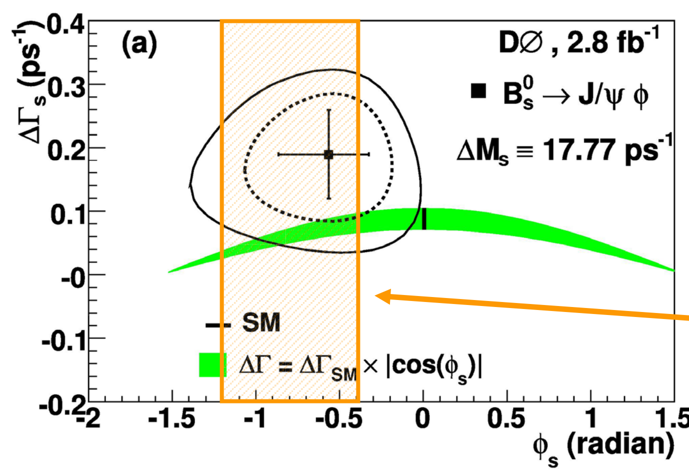
$\delta_\perp = +2.92 \pm (\pi/5)$ ← **B Factories**

Standard Model expectations:

(arXiv:hep-ph/0612167)

$2\beta_s = 0.04 \pm 0.01$ rad

Standard Model p_{value} = 6.6%



90% C.L. <u>contours:</u>

$-1.20 < 2\beta_s < 0.06$ rad

$0.06 < \Delta\Gamma_s < 0.30\ ps^{-1}$

<u>CDF 68% CL:</u>

Constraining lifetime, strong phases and Γ_{12}

Charge Asymmetry

- CP Violation in <u>mixing</u>
- if $\Delta m_s / \bar{\Gamma}_s >> 1 \Rightarrow$ $\boxed{A_{SL}^s = \frac{\Delta\Gamma_s}{\Delta m_s} \tan\Phi_s}$
- Combine these results with $B_s \to J/\Psi\Phi$ measurements to constrain phase β_s
- **CDF:** 1.6 fb^{-1} of data collected (di-muon charge asymmetry):

$$\boxed{A_{SL}^s = 0.020 \pm 0.021\ (stat) \pm 0.016\ (syst) \pm 0.009\ (inputs)}$$

(http://www-cdf.fnal.gov/physics/new/bottom/070816.blessed-acp-bsemil/)

- **D∅:** 1.0 fb^{-1} of data collected (di-muon charge asymmetry):

$$\boxed{A_{SL}^s = -0.0064 \pm 0.0101\ (stat + syst)}$$

PRD 74, 092001 (2006)

- **D∅:** 1.3 fb^{-1} of data collected (B_s semileptonic decays):

$$\boxed{A_{SL}^s = [2.45 \pm 1.93\ (stat) \pm 0.35\ (syst)] \times 10^{-2}}$$

PRL 98, 151801 (2007)

Constraints on β_s

New Physics in B_s mixing: **UTfit Group** (http://www.utfit.org/)

$$\frac{\langle B_s | H_{eff}^{full} | \bar{B}_s \rangle}{\langle B_s | H_{eff}^{SM} | \bar{B}_s \rangle} = \boxed{C_{Bs}} e^{2i \boxed{\Phi_{Bs}}}$$

$\Delta m_s = C_{Bs} * \Delta m_s^{SM}$: Lattice-QCD dominated uncertainty

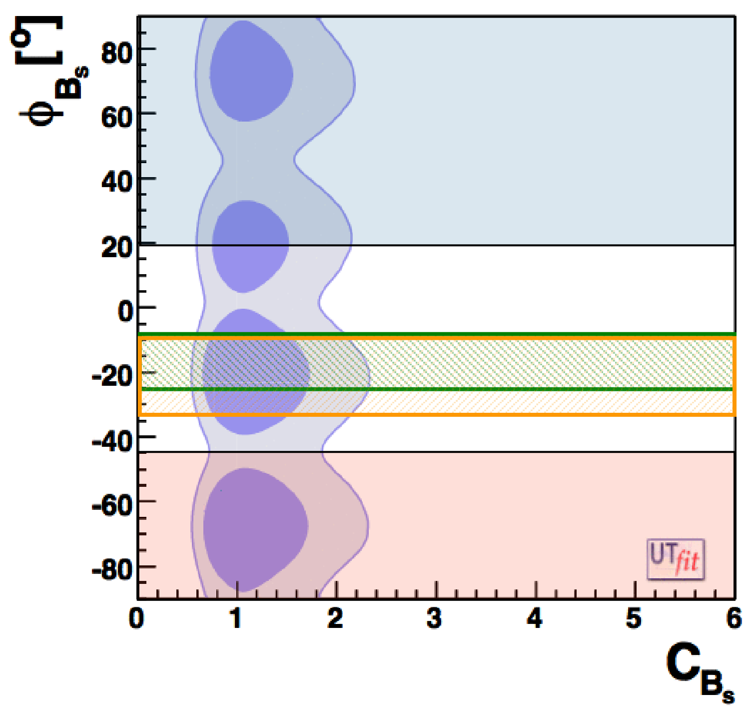
$\beta_s = \beta_s^{SM} - \Phi_{Bs}$: Experimentally dominated uncertainty

CDF input:

Tagged $B_s \to J/\Psi\, \Phi$ analysis reduces ambiguities

B Factories input:

Assuming SU(3) symmetry negative $\Delta\Gamma_s$ solution excluded



DØ Result:

$2\beta_s = +0.57^{+0.30}_{-0.24}$

CDF 68% CL:

Constraining lifetime, strong phases and Γ_{12}

UT_{fit} inputs:

Δm_s measurement (CDF)

Lifetime τ_s (CDF and DØ)

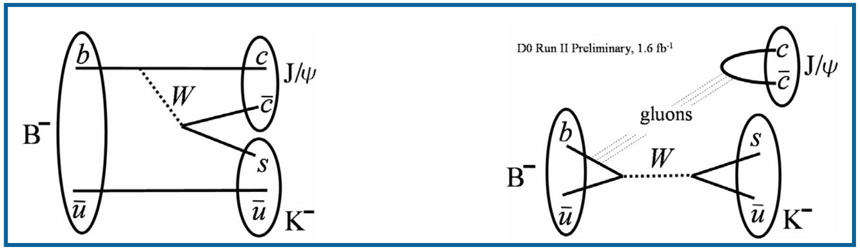
$\Delta\Gamma_s$ (CDF on 200 pb^{-1})

$\Delta\Gamma_s$ and Φ_s (DØ on 1.1 fb^{-1})

Semileptonic A_{SL} (DØ)

Direct $\not{C}\not{P}$ in $B^+ \to J/\Psi\ K^+$

- Charge asymmetry $A_{CP}(B^\pm \to J/\Psi(1S)\ K^\pm) = \dfrac{N(B^- \to J/\Psi\ K^-) - N(B^+ \to J/\Psi\ K^+)}{N(B^- \to J/\Psi\ K^-) + N(B^+ \to J/\Psi\ K^+)}$
- Direct CP violation due to interference between direct and annihilation amplitudes:



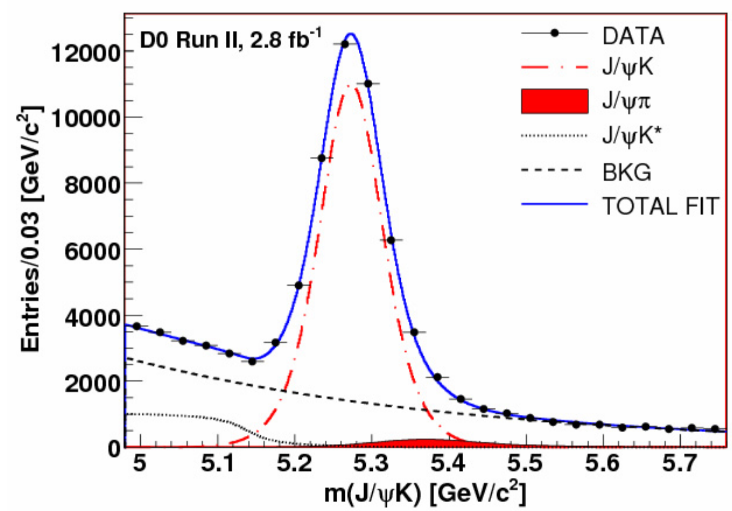
In SM $A_{CP}(B^\pm \to J/\Psi\ K^\pm)$ predicted to be of the level of **1%**

- **DØ:** ~40K signal events on 2.8 fb^{-1}

  $A_{CP} = +0.0075 \pm 0.0061\ (stat) \pm 0.0027\ (syst)$

- Consistent with the PDG-2007 world average
  $A_{CP}(B^\pm \to J/\Psi\ K^\pm) = 0.015 \pm 0.017$

- Factor 2 better precision



- Most stringent bound on NP model predicting large $A_{CP}(B^+ \to J/\Psi\ K^+)$ arXiv:0802.3299
- $A_{CP}(B^+ \to J/\Psi\ \pi^+) = -0.09 \pm 0.08\ (stat) \pm 0.03\ (syst)$

Conclusions

- Tevatron has a very active program in B Physics, with relevance to the B_s sector

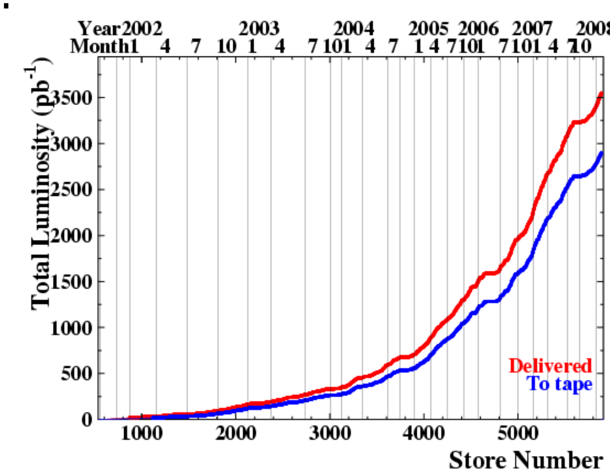
- Complementary and competitive with B Factories

- CDF and D∅ search for CP violation effects:
  - ✓ Direct CP violation ($B^+ \rightarrow J/\Psi K^+$)
  - ✓ CP Violation in Mixing: precise A_{SL}^{S} measurement
  - ✓ CP Violation in the interference between mixing and decay: FIRST $\sin(2\beta_s)$ measurement

- Interesting $\sin(2\beta_s)$ fluctuation at Tevatron experiments:
  - ✓ Exclude large negative values
  - ✓ Both experiments, CDF and D∅
  - ✓ In the same direction of A_{SL}

- Almost 3.5 fb^{-1} of data delivered

- New results with larger dataset coming soon!



Backup Slides

CKM Matrix

In Standard Model Mixing and CP Violation effects are described within the CKM mechanism:

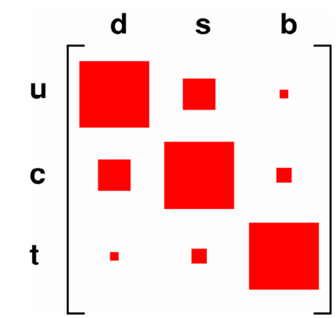
$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

- Unitarity condition for CKM matrix: $V^{\dagger}V=1$
- Expanded in terms of $\lambda=\sin(\theta_c)\sim 0.23$
- Phase η responsible for CP Violation

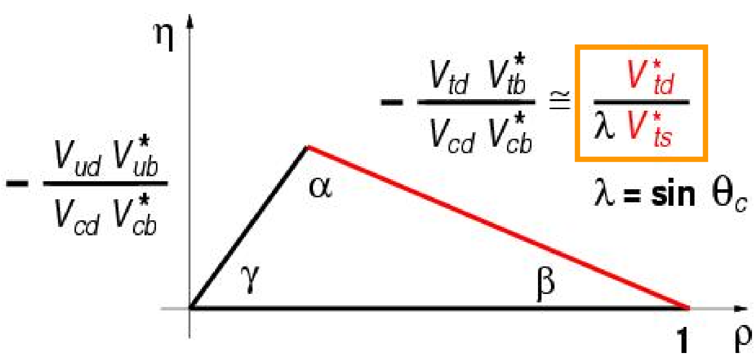
$$V_{CKM} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2-\frac{1}{8}\lambda^4 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda+\frac{1}{2}A^2\lambda^5[1-2(\rho+i\eta)] & 1-\frac{1}{2}\lambda^2-\frac{1}{8}\lambda^4(1+4A^2) & A\lambda^2 \\ \boxed{A\lambda^3[1-(1-\frac{1}{2}\lambda^2)(\rho-i\eta)]} & \boxed{-A\lambda^2+\frac{1}{2}A\lambda^4[1-2(\rho+i\eta)]} & 1-\frac{1}{2}A^2\lambda^4 \end{pmatrix} + O(\lambda^6)$$

Large CPV

Suppressed CPV



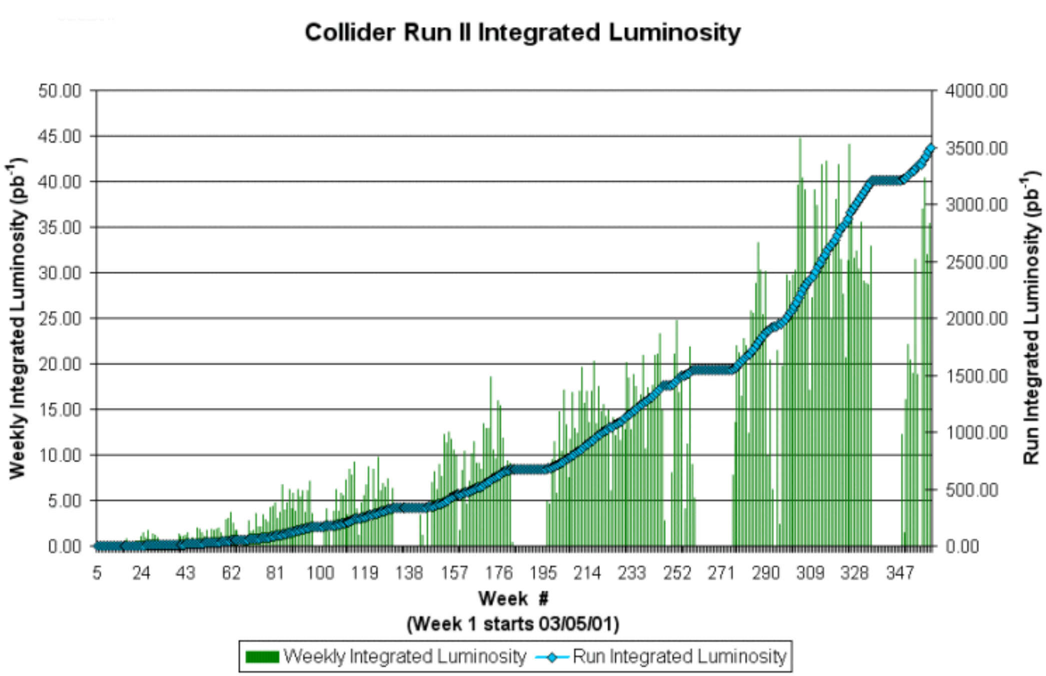
- Unitarity Triangle:

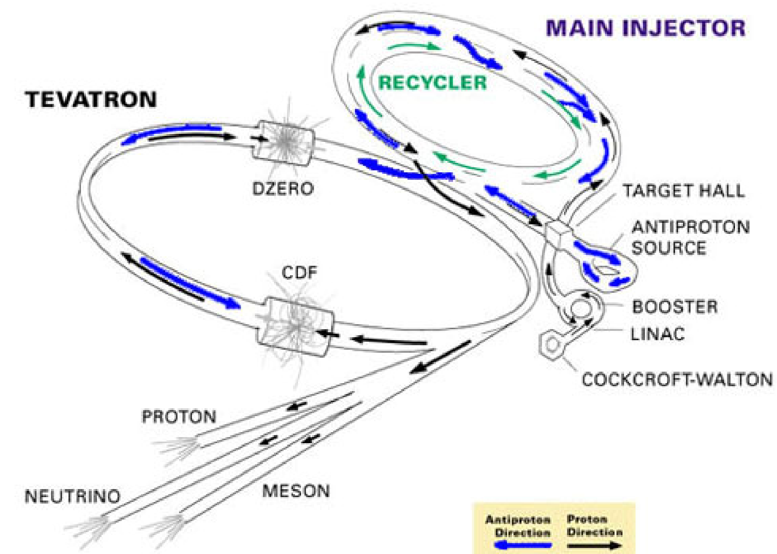


- $\boxed{V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0}$
- Standard Model does <u>not</u> predict values
- <u>Experimental Input is crucial</u>

The Tevatron

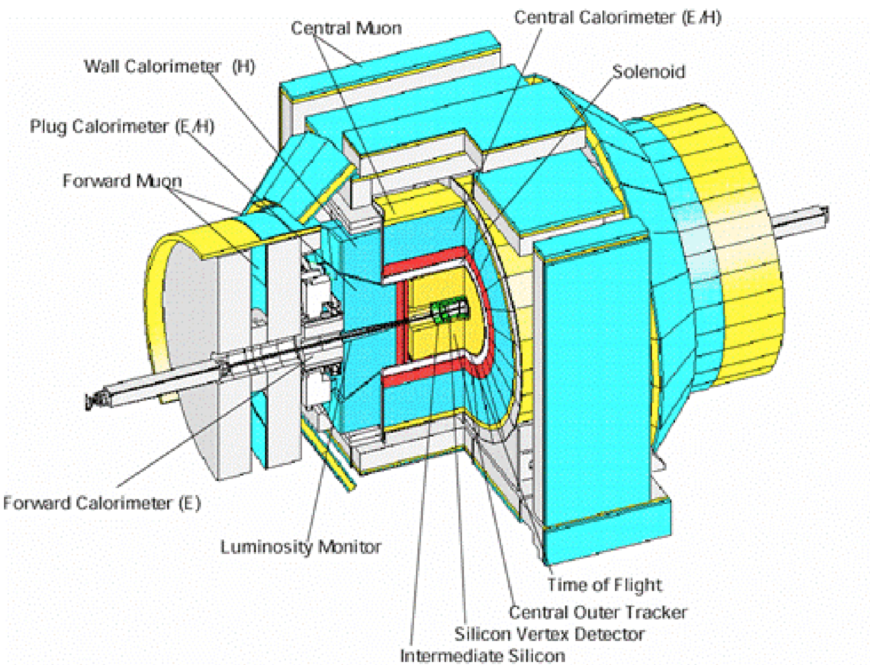
- $p\bar{p}$ collisions at 1.96 TeV
- Excellent Performance
- Peak Initial Luminosity: 3 x 10^{32} cm^{-2} s^{-1}
- Challenge for Detectors, Triggers and Reconstructions





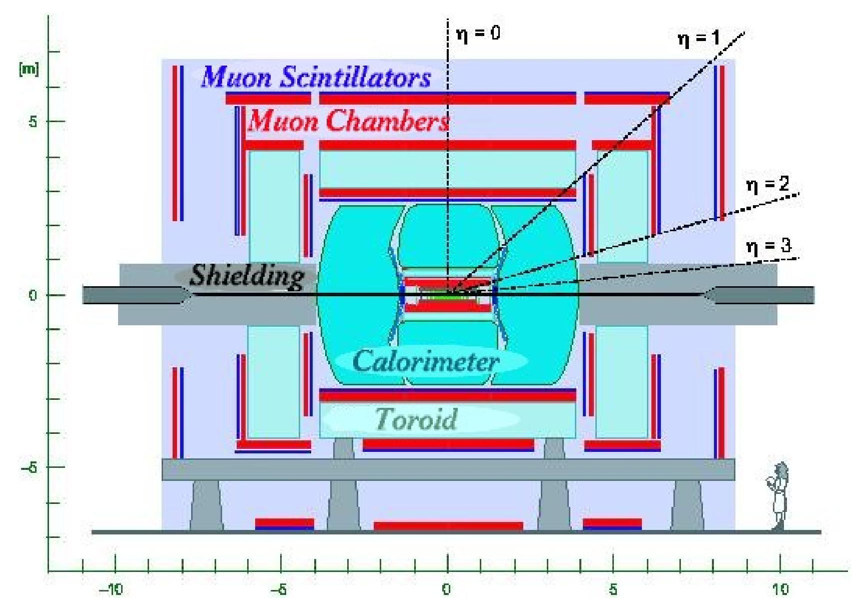
- B physics benefits from more data
- The analyses presented in this talk span from 1.0 to 2.8 fb^{-1}
- Currently on tape ~3 fb^{-1}

Tevatron Detectors



CDF II Detector

- Tracker: - Silicon Vertex Detector
  - Drift Chambers
- **Excellent Momentum Resolution**
- **Particle ID**: TOF and dE/dx
- Triggered Muon Coverage $|\eta| < 1.0$

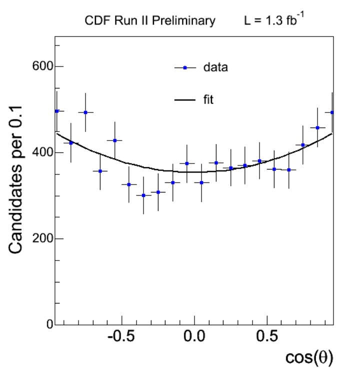


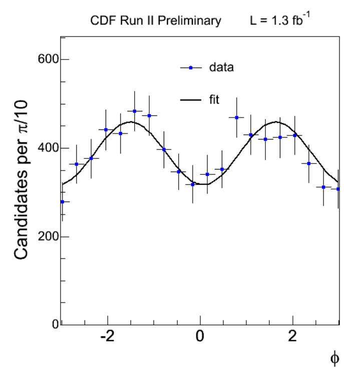
D∅ Detector

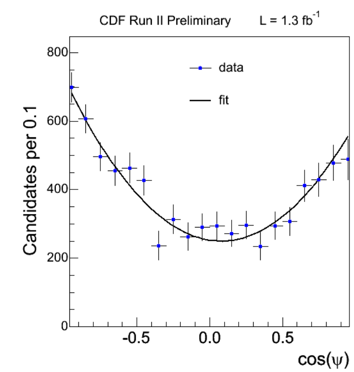
- **New L00** installed in 2006!
- Solenoid: 2T, weekly reversed polarity
- Excellent Calorimetry and electron ID
- **Triggered Muon Coverage** $|\eta| < 2.2$

Transversity Analysis: $B^0 \to J/\Psi\ K^{*0}$

- Measurements of amplitudes and strong phases using transversity basis
- Validation sample for the angular analysis on $B_s \to J/\Psi\ \Phi$
- **CDF:** ~7800 signal events on 1.35 fb^{-1}





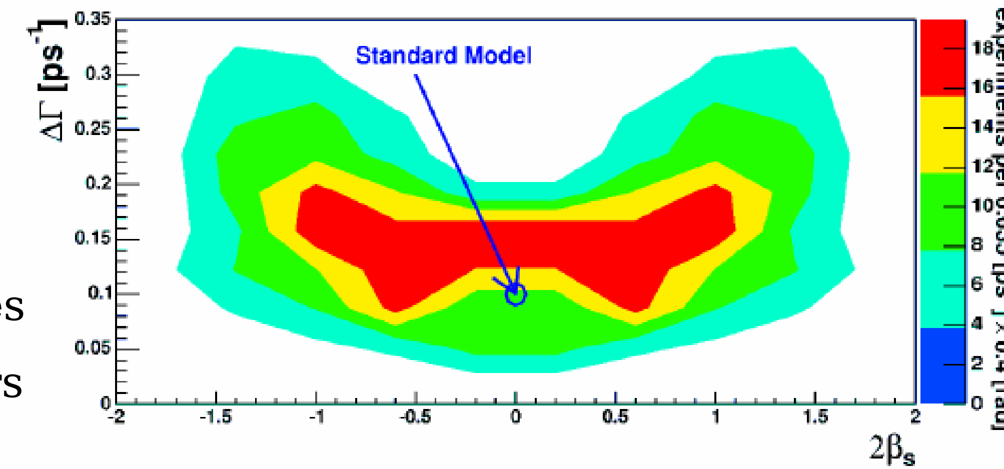


- Correct treatment of detector acceptance
- Results comparable and competitive with BaBar [Phys. Rev. D 76, 031102,(2007)]

Parameter	CDF	BaBar
$\|A_0\|^2$	0.569 ± 0.009 ± 0.009	0.556 ± 0.009 ± 0.010
$\|A_{\|\|}\|^2$	0.211 ± 0.012 ± 0.006	0.211 ± 0.010 ± 0.006
$\delta_{\|\|}-\delta_0$	-2.96 ± 0.08 ± 0.03	-2.93 ± 0.08 ± 0.04
$\delta_{\perp}-\delta_0$	2.97 ± 0.06 ± 0.01	2.91 ± 0.05 ± 0.03

Untagged Analysis: Bias

- Biases
- Non-Gaussian estimates in pseudo-experiments
- Strong dependence on true values for biases on some fit parameters



Fits on simulated samples generated with SM inputs for $\Delta\Gamma_s$ and β_s

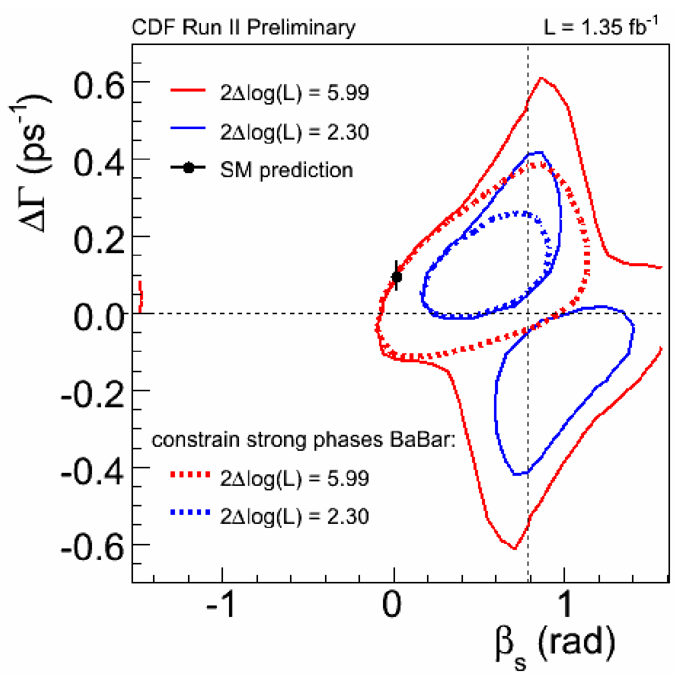
$\Rightarrow$ Dependence on one parameter in the likelihood vanishes for some values of other parameters: Likelihood looses degrees of freedom

e.g., if $\Delta\Gamma=0$, $\delta_\perp$ is undetermined: $\cos(\delta_\perp)\sin(2\beta_s)\sinh(\Delta\Gamma_s t/2)$

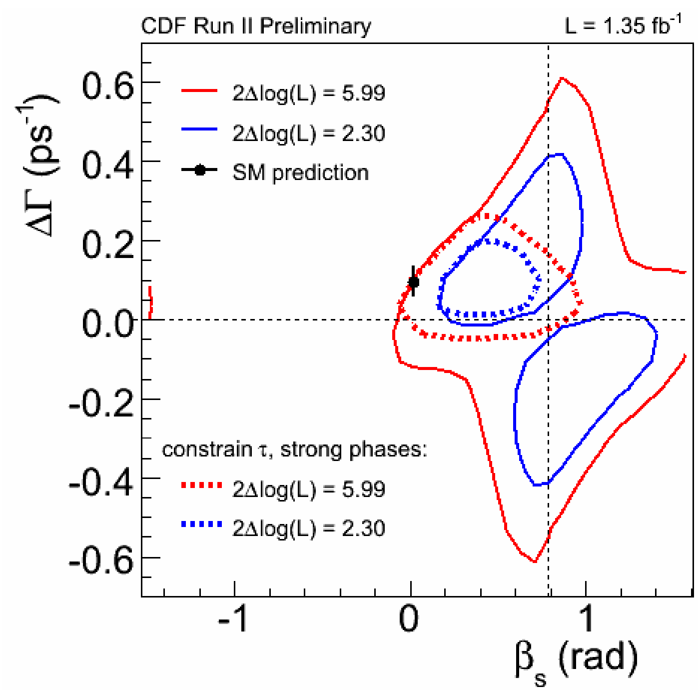
Constraints on Tagged $B_s \to J/\Psi\ \Phi$

- SU(3) flavor symmetry suggests that B_s and B^0 have similar lifetimes and strong phases
- Likelihood profiles with external constraints from B factories
- Underestimated confidence regions when using $2\Delta\ln\mathscr{L} = 2.31$ (5.99) to approximate 68% (95%) C.L. regions

constrain strong phases



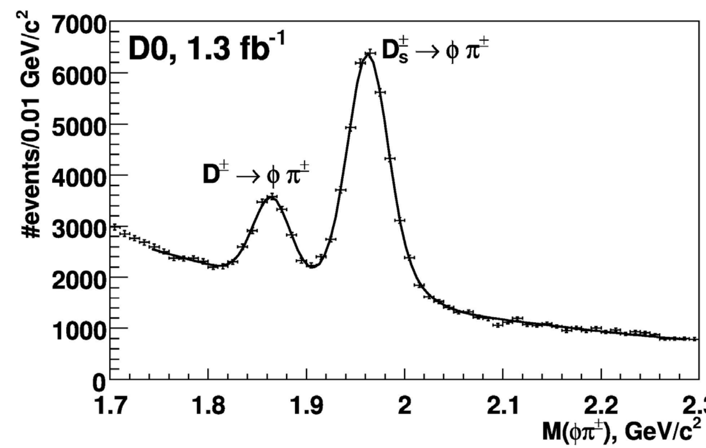
constrain lifetime and strong phases



⇒ External constraints on strong phases remove residual 2-fold ambiguity

Charge Asymmetry (I)

- Semileptonic decay $B_s \to \mu+ D_s^- \nu X$, $D_s^- \to \phi\,\pi^-$, $\phi \to K^+K$: $A_{SL}^{s,unt} = \dfrac{N(\mu^+D_s^-) - N(\mu^-D_s^+)}{N(\mu^+D_s^-) + N(\mu^-D_s^+)}$
- if $\Delta m_s / \overline{\Gamma}_s >> 1 \Rightarrow$ $\boxed{A_{SL}^{s,unt} = \dfrac{\Delta\Gamma_s}{\Delta m_s}\tan\Phi_s}$
- Sensitivity to phase Φ_s : NP does not take much to modify the SM prediction $\Phi_s^{SM} = \arg(-M_{12}/\Gamma_{12}) \approx 4x10^{-3}$rad
- If NP dominates $2\beta_s = -\Phi_s^{NP}$
- Can combine this result with the measurement from $B_s \to J/\Psi\Phi$ to constrain the phase β_s
- **DØ:** ~27k signal events (1.3 fb^{-1})



$A_{SL}^{s,unt} = [1.23 \pm 0.97(stat) \pm 0.17(syst)] \times 10^{-2}$

PRL 98, 151801 (2007)

- Detector asymmetries highly reduced by DØ regular change of magnet polarity
- Additional statistics and new decay modes will improve the result

Charge Asymmetry (II)

- Inclusive dimuon charge asymmetry $A_{SL}^{\mu\mu} = \dfrac{N(b\bar{b} \to \mu^+\mu^+X) - N(b\bar{b} \to \mu^-\mu^-X)}{N(b\bar{b} \to \mu^+\mu^+X) + N(b\bar{b} \to \mu^-\mu^-X)}$
- **D∅:** 1.0 fb^{-1} of data collected by Tevatron

$$A_{SL}^{\mu\mu} = -0.0023 \pm 0.0011\ (\text{stat}) \pm 0.0008\ (\text{syst})$$

$$A_{SL}^{\mu\mu} = \frac{1}{4}\left(A_{SL}^{d} + \frac{f_s Z_s}{f_d Z_d} A_{SL}^{s}\right)$$

$$Z_q = \frac{1}{1-[\Gamma_q/(2\Gamma_q)]^2} - \frac{1}{1+(\Delta m_q/\Gamma_q)^2}$$

f_q is the production rate of B_q mesons in the hadronization of the *b* quark

Related to A_{SL}^{s} : additional constraint on β_s

- Using world averages for f_q, the semileptonic asymmetry for B_d from B factories and the measured parameters Δm_q and $\Delta\Gamma_q$:

$$A_{SL}^{s} = -0.0064 \pm 0.0101\ (\text{stat} + \text{syst})$$

PRD 74, 092001 (2006)

- **CDF:** 1.6 fb^{-1} of data collected by Tevatron

$$A_{SL}^{s} = 0.020 \pm 0.021\ (\text{stat}) \pm 0.016\ (\text{syst}) \pm 0.009\ (\text{inputs})$$

(http://www-cdf.fnal.gov/physics/new/bottom/070816.blessed-acp-bsemil/)

Magnet Polarity Inversion

- D∅ performs a regular change of magnet polarity:
  - ✓ Reduce artificial asymmetry in the detector
  - ✓ Systematics effects in charge asymmentry analyses cancel out

- Methodology described in Phys. Rev. D 74, 092001 (2006):

  1. Divide the sample in 8 subsamples corresponding to all possible combination of toroid polarity $\beta=\pm1$, pseudorapidity sign of the system considered $\gamma=\pm1$ and charge of the muon particle $q=\pm1$

  2. Solve the system of equations:

$$\boxed{n_q^{\beta\gamma} = \frac{1}{4} N \varepsilon^{\beta} (1+qA)(1+q\gamma A_{fb})(1+\gamma A_{det}) \times (1+q\beta\gamma A_{ro})(1+q\beta A_{q\beta})(1+\beta\gamma A_{\beta\gamma})}$$

- ε^{β} is the fraction of integrated luminosity with toroid polarity β ($\varepsilon^{+}+\varepsilon^{-}=1$)
- **A** is the integrated charge asymmetry to be measured
- $\mathbf{A_{fb}}$ is the forward-backward asymmetry
- $\mathbf{A_{det}}$ is the detector asymmetry for particles emitted in fwd and bwd directions
- $\mathbf{A_{ro}}$ is the range out asymmetry: muons acceptance changes if muons bends towards or bend away the beam line
- $\mathbf{A_{q\beta}}$ is the detector asymmetry which accounts for muons reconstruction efficiency when toroid polarity is reversed
- $\mathbf{A_{\beta\gamma}}$ is the detector related asymmetry fwd-bwd remaining after toroid polarity flip
- **N** is the total number of events