B Physics at CDF and DØ

Wendy Taylor

YORK UNIVERSITÉ UNIVERSITY

for the CDF and DØ Collaborations

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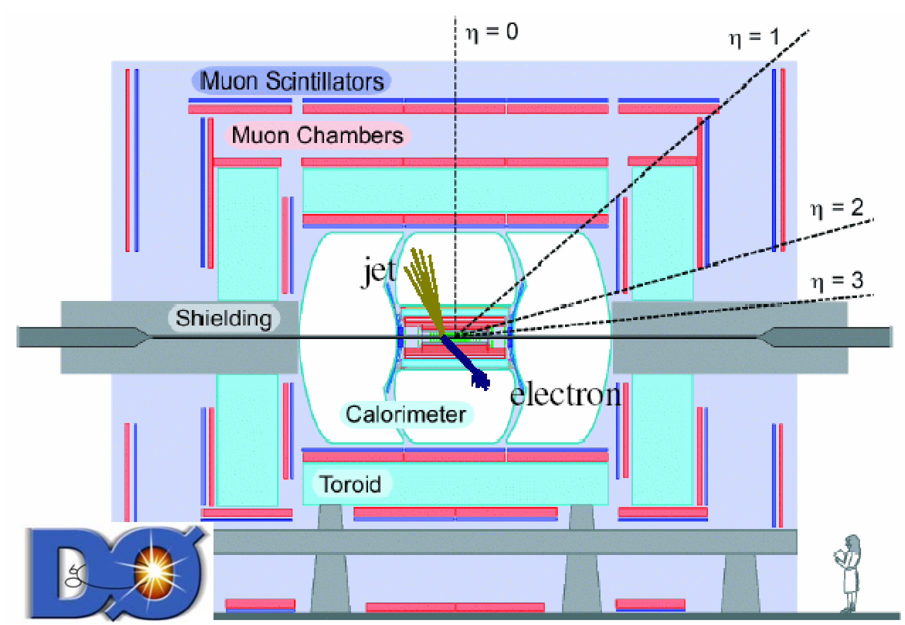
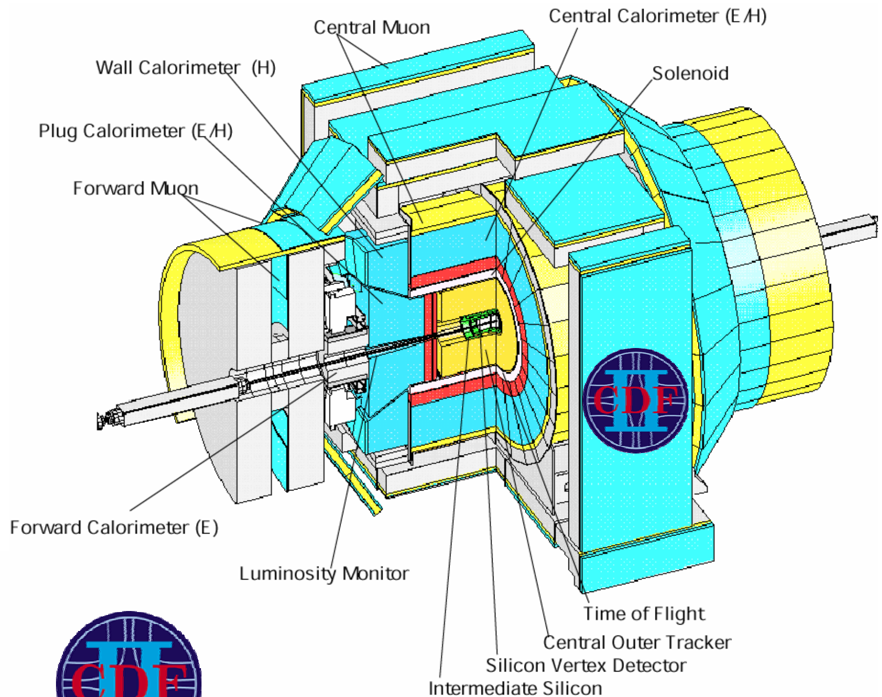
Detectors

- Excellent muon and tracking coverage ⇒ high yields
  - Extended muon system $|\eta|<2.0$
  - Tracking up to $|\eta|<3.0$

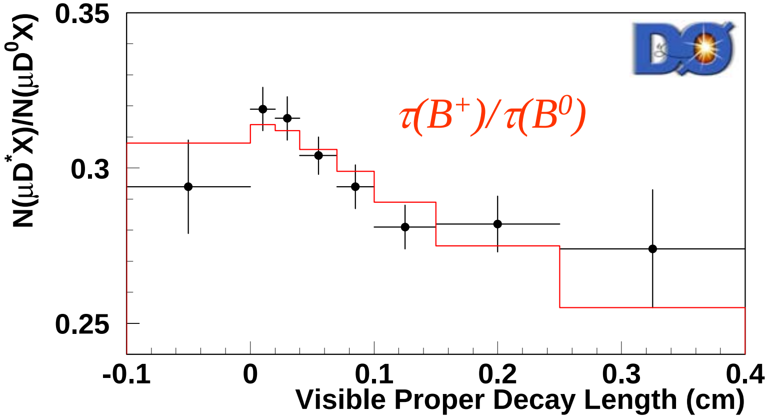




- Excellent mass resolution
- Particle ID: *p*, *K* and π by *dE/dx* and TOF
- Hadronic trigger able to trigger on two-track objects at L1
- Impact parameter trigger at L2

Lifetime Measurements

- Precision measurements constrain inputs to theoretical calculations utilizing non-perturbative techniques
- Theoretical and experimental uncertainties are reduced for ratios of lifetimes



Measure-ment	Channel	PDG	CDF Result	DØ Result
$\tau(B^+)/\tau(B^0)$	$B^+ \to J/\psi\ K^+$ $B^0 \to J/\psi\ K^{*0}$	1.086±0.017	1.080 ± 0.042	
$\tau(B^+)/\tau(B^0)$	$B \to D^*(2010)^- \mu^+ X$ $B \to \overline{D}^0 \mu^+ X$	1.086±0.017		$1.080 \pm 0.016 \pm 0.014$
$\tau(B_s)$	$B_s^0 \to J/\psi\ \varphi$	1.461± 0.057 ps	$1.369 \pm 0.100^{+0.008}_{-0.010}\ ps$	$1.444^{+0.098}_{-0.090} \pm 0.020\ ps$
$\tau(\Lambda_b)$	$\Lambda_b^0 \to J/\psi\ \Lambda^0$	1.229±0.080 ps	$1.25 \pm 0.26 \pm 0.10\ ps$	$1.22^{+0.22}_{-0.18} \pm 0.04\ ps$

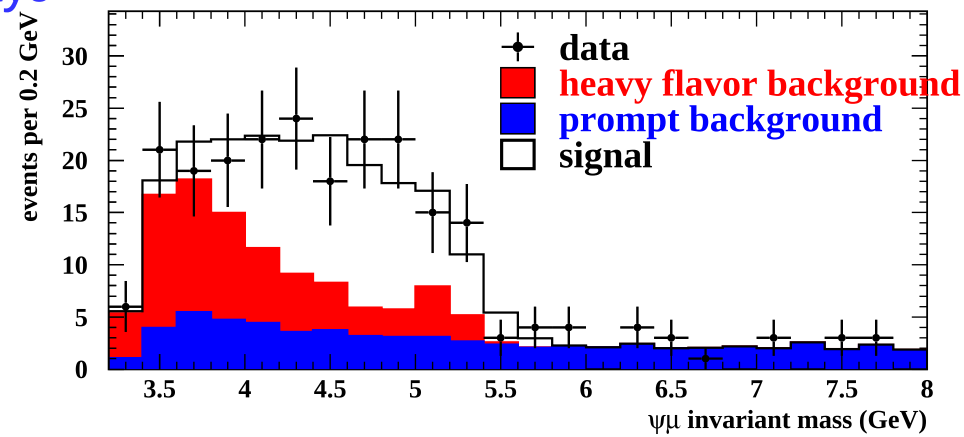
B_c Mass and Lifetime at DØ

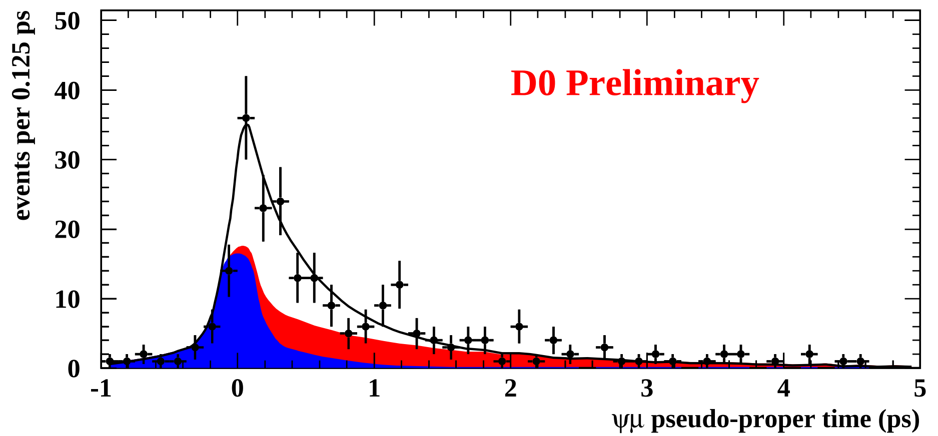
- Trigger on $J/\psi \to \mu^+\mu^-$ decays in 210 pb^{-1} of DØ data
- Reconstruct $B_c^+ \to J/\psi\mu^+ X$ decays
- 231 candidates, signal of 95±12±11 events
- Unbinned likelihood fit gives

$$m = 5.95 \pm 0.14 \pm 0.34\ GeV/c^2$$

- Average correction factor determined from Monte Carlo to account for the missing momentum of the neutrino gives

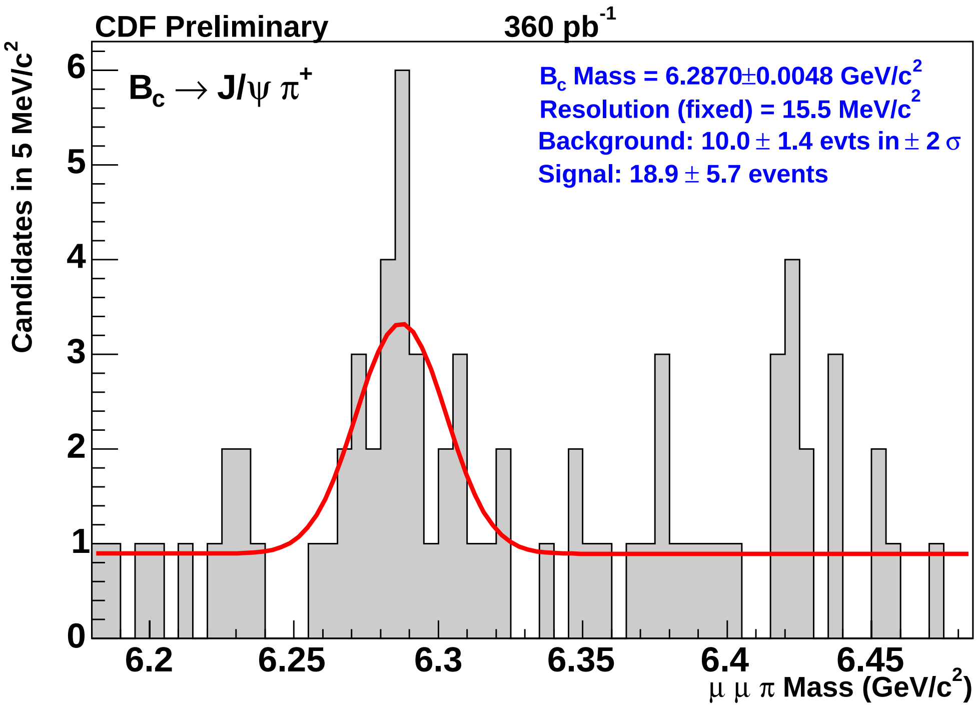
$$\tau = 0.448^{+0.123}_{-0.096} \pm 0.121 ps$$





B_c Mass at CDF

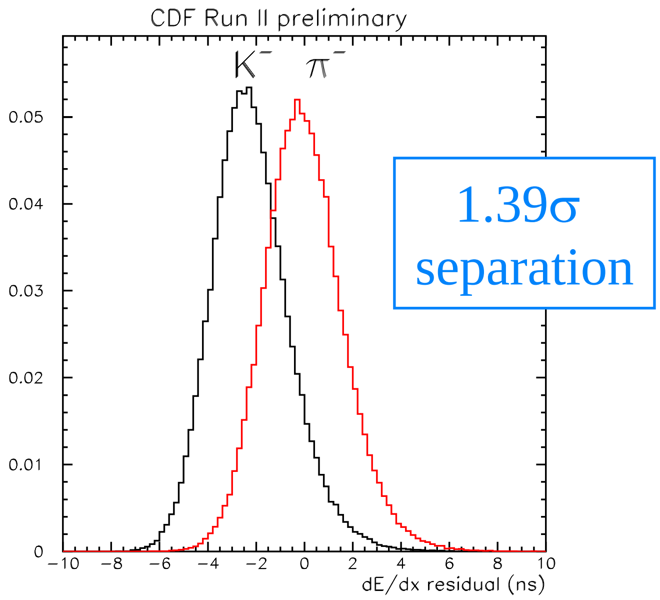
- Reconstruct $B_c^{\pm} \to J/\psi\pi^{\pm}$ decays 360 pb^{-1} of CDF data
- Layer 00 used for this analysis
- Expected signal rate is order of magnitude smaller than the semileptonic mode
- 19 signal event over a background of 10 events expected yields

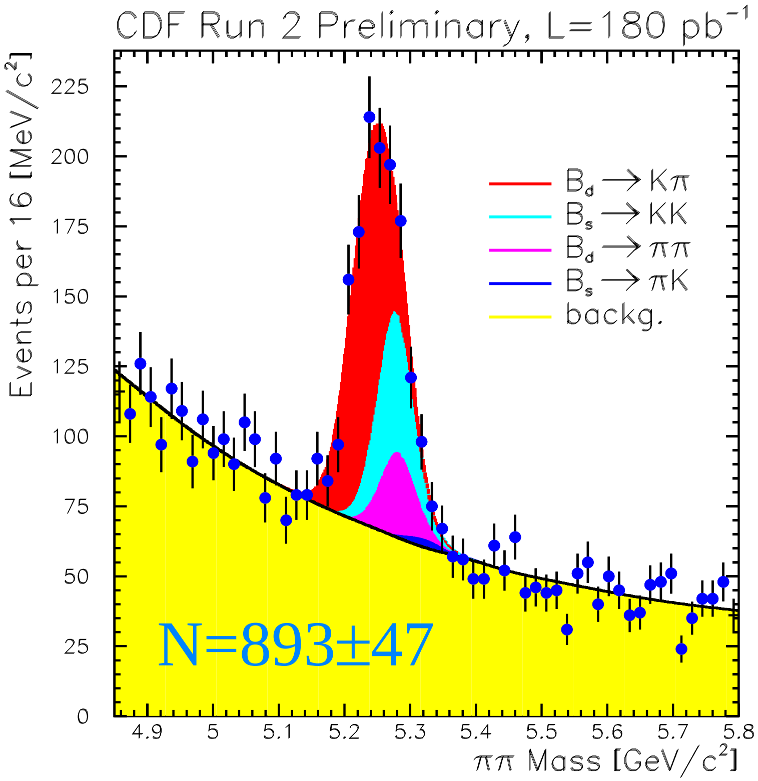


$$m = 6.2870 \pm 0.0048 \pm 0.0011\ GeV/c^2$$

Charmless B Decays $B \to hh$ at CDF

- Charmless 2-body *B* decays $B \to h^+h'^-$, $h,h'=K,\pi$ collected by hadronic *B* trigger
  - selects track pairs that exit a displaced vertex
- Use *dE/dx* in drift chamber to separate pions and kaons





$B \to hh$ Branching Fractions at CDF

$$\frac{BR(B_d \to \pi^{\pm}\pi^{\mp})}{BR(B_d \to K^{\pm}\pi^{\mp})} = 0.24 \pm 0.06(stat) \pm 0.05(syst)$$

First Measurement

$$\frac{f_s \cdot BR(B_s \to K^{\pm}K^{\mp})}{f_d \cdot BR(B_d \to K^{\pm}\pi^{\mp})} = 0.50 \pm 0.08(stat) \pm 0.07(syst)$$

$$\frac{f_d \cdot BR(B_d \to \pi^{\pm}\pi^{\mp})}{f_s \cdot BR(B_s \to K^{\pm}K^{\mp})} = 0.48 \pm 0.12(stat) \pm 0.07(syst)$$

$$\frac{BR(B_s \to \pi^{\pm}\pi^{\mp})}{BR(B_s \to K^{\pm}K^{\mp})} < 0.10 @ 90\% C.L.$$

$$\frac{BR(B_d \to K^{\pm}K^{\mp})}{BR(B_d \to K^{\pm}\pi^{\mp})} < 0.17 @ 90\% C.L.$$

$$\frac{f_s \cdot BR(B_s \to K^{\pm}\pi^{\mp})}{f_d \cdot BR(B_d \to K^{\pm}\pi^{\mp})} = 0.11 @ 90\% C.L.$$

CP Violation in Charmless Two-Body B Decays $B \to hh$ at CDF

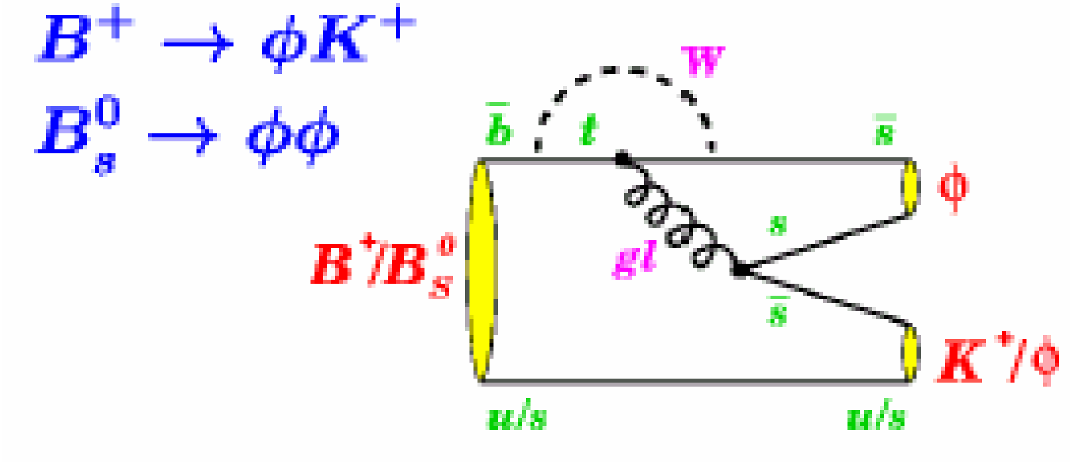
- Direct CP asymmetry

$$A_{CP} = \frac{N(\overline{B}_d^0 \to K^- \pi^+) - N(B_d^0 \to K^+ \pi^-)}{N(\overline{B}_d \to K^- \pi^+) + N(B_d \to K^+ \pi^-)}$$

$$= -0.04 \pm 0.08(stat) \pm 0.01(syst)$$

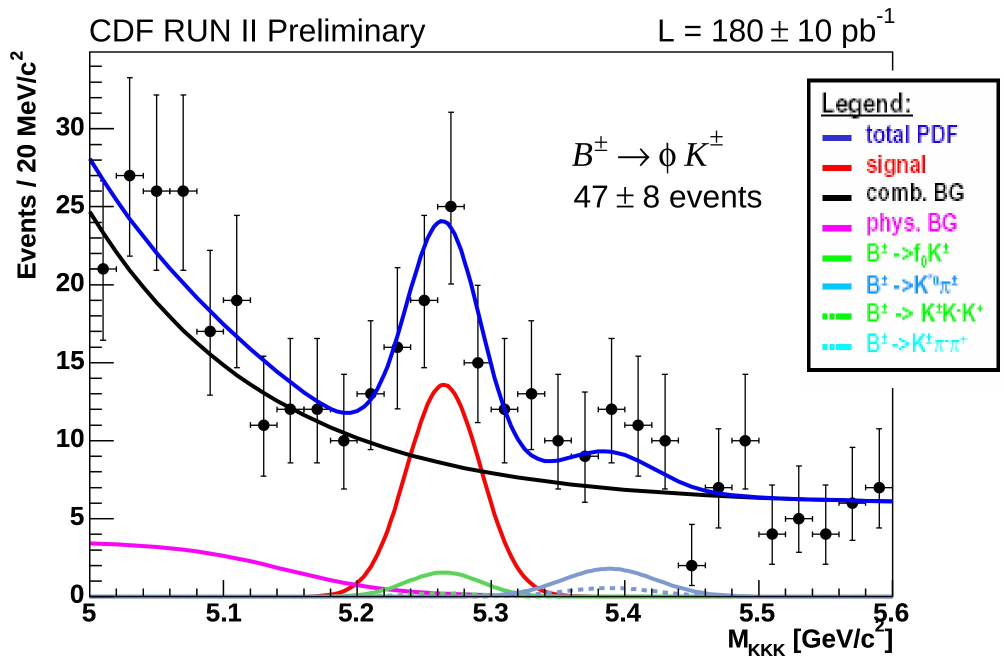
Charmless B Decays $B_{d,s} \to \varphi X$ at CDF

- Gluonic penguin-dominated decay followed by $\varphi \to K^+K^-$



- Many beyond-the-SM theories predict new CP-violating phases resulting from heavy particles in the penguin loops

Charmless B Decay $B^{\pm}\to\varphi K^{\pm}$ at CDF



- Branching ratio measured relative to $B^{\pm}\to J/\psi K^{\pm}$ (some uncertainties cancel)

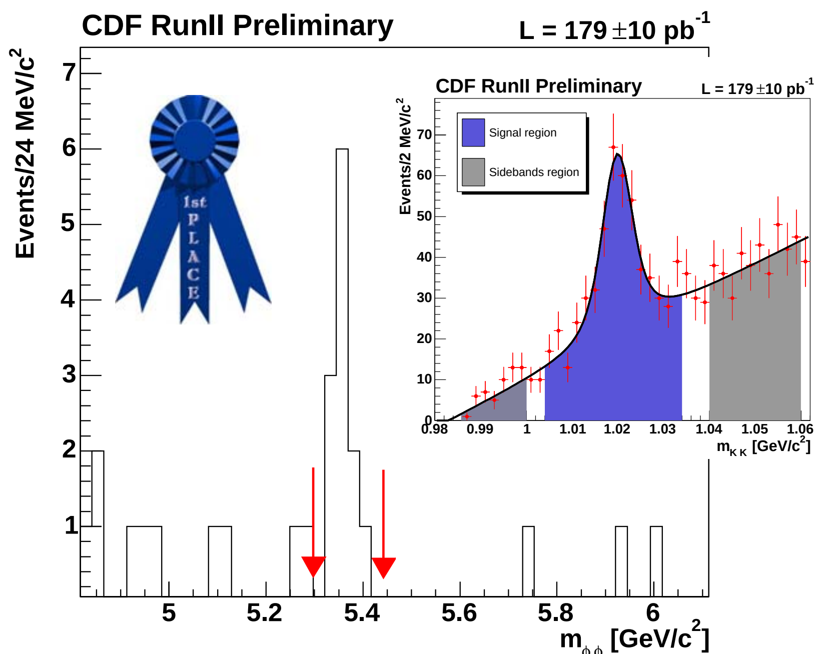
$$BR(B^{\pm} \to \varphi K^{\pm}) = (7.2 \pm 1.3(stat) \pm 0.7(syst)) \times 10^{-6}$$

- HF averaging group $\Rightarrow$ $BR=(9.0 \pm 0.6)\times 10^{-6}$

$$A_{CP} = \frac{\Gamma(B^- \to \phi K^-) - \Gamma(B^+ \to \phi K^+)}{\Gamma(B^- \to \phi K^-) + \Gamma(B^+ \to \phi K^+)} = -0.07 \pm 0.17(stat) \pm 0.06(syst)$$

Observation of $B_s \to \varphi\ \varphi$ at CDF

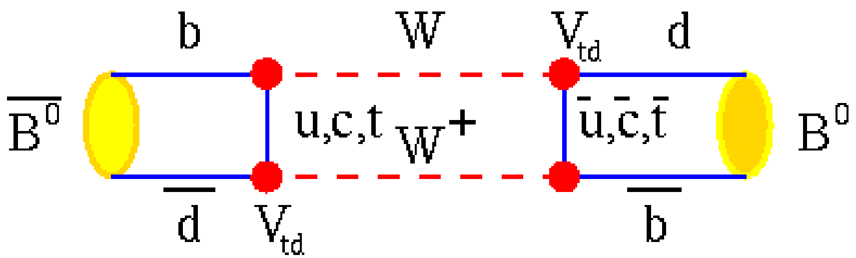
- Use $B_s \to J/\psi\ \varphi$ as a normalization mode to avoid uncertainties due to the B_d and B_s fragmentation fractions
- 12 events in signal region, 2 background events expected
  - Combinatorics and reflections from $B_d \to \varphi K^{*0}$
- 4.8σ signal
- First evidence for this decay mode

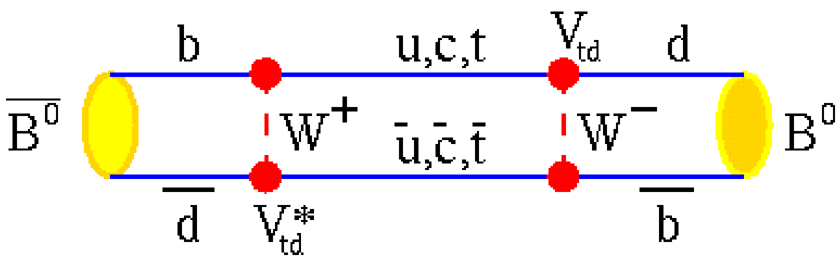


- $$BR(B_s^0 \to \varphi\varphi) = (1.4 \pm 0.6(stat) \pm 0.2(syst) \pm 0.5(BR)) \times 10^{-5}$$
  - SM predicts $BR(B_s^0 \to \varphi\varphi) = (2.5 - 5.0) \times 10^{-5}$

$B_{d,s}$ Mixing

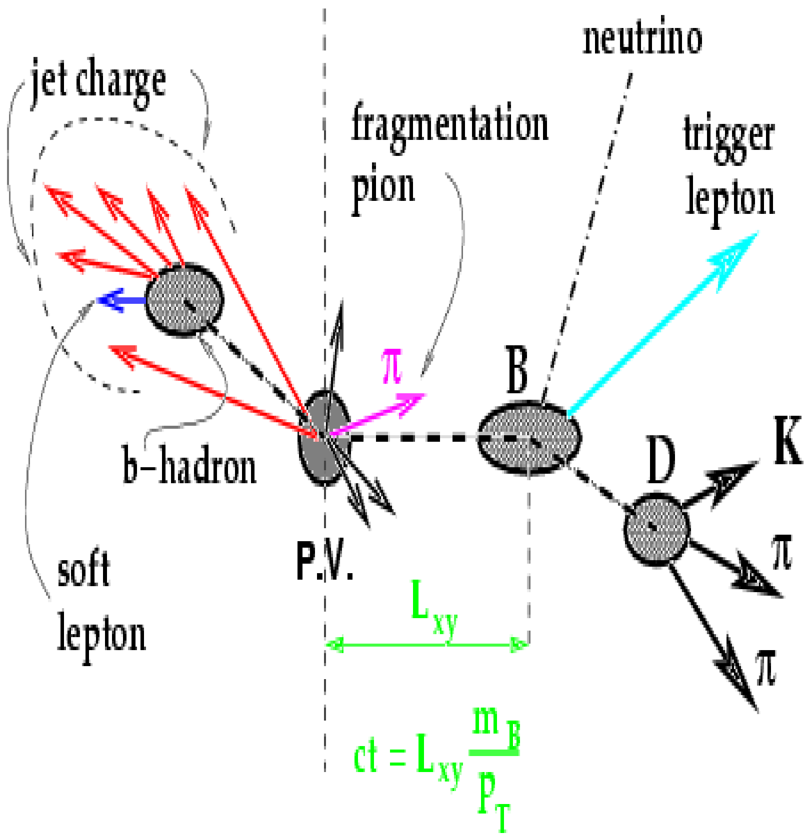
- $B_{d,s}$ mass and flavour eigenstates differ, allowing flavour states to mix





  - Eigenstates have mass difference $\Delta m_q = m_H - m_L > 0$
  - Eigenstates have width (lifetime) difference $\Delta\Gamma_q = \Gamma_L - \Gamma_H > 0$
- Want to measure $\dfrac{\Delta m_s}{\Delta m_d} = \dfrac{M(B_s)}{M(B_d)} \cdot \dfrac{\hat{B}(B_s) f^2(B_s)}{\hat{B}(B_d) f^2(B_d)} \cdot \left|\dfrac{V_{ts}}{V_{td}}\right|^2$
- Extract mass difference Δm_q from oscillation frequency

B_d Mixing

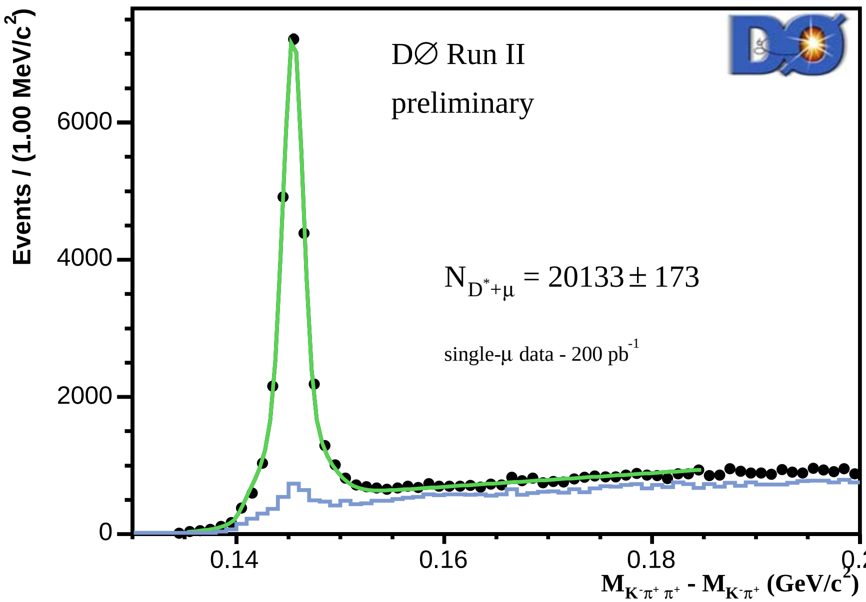


- Need to tag the production flavour of the *b* quark to know if meson mixed or not
  - Soft muon tagging
    - Low efficiency but high accuracy (*dilution*)
  - Jet-charge tagging
    - High efficiency but poor dilution
  - Same-side pion tagging
    - High efficiency but poor dilution

B_d Mixing at DØ

- Reconstruct $B_d^0 \to D^*(2010)^- \mu^+ X$ decays in 200 pb^{-1} of DØ data
- Use $B_d^0 \to \overline{D}^0 \mu^+ X$ decays for tagging studies
- Divide the data into 2 samples
  - Events that can be tagged by the soft muon tagger
  - The remaining events, which are subjected to the combined jet-charge and same-side tagger
    - Events with conflicting initial state flavour are rejected

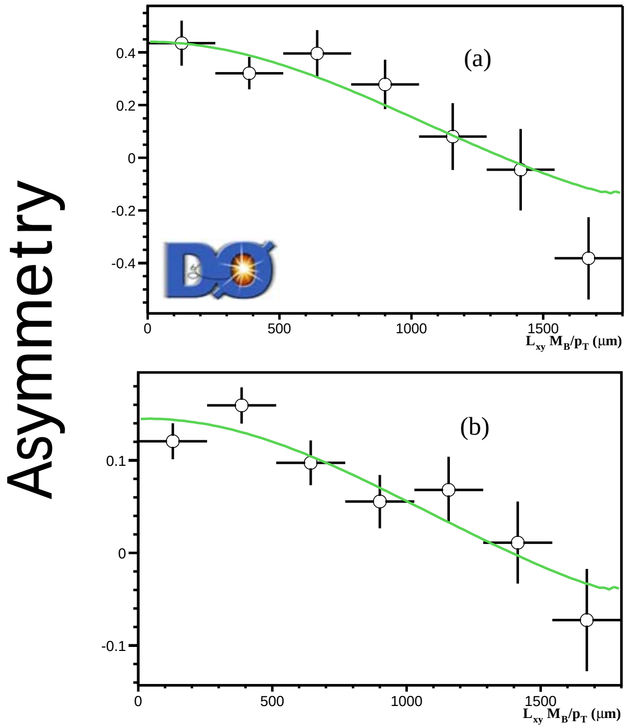
$$B_d^0 \to D^*(2010)^- \mu^+ X$$
$$\hookrightarrow \overline{D}^0 \pi^-$$



- CDF used $B \to D^{(*)} l^+ X$ decays in 245 pb^{-1} of CDF data

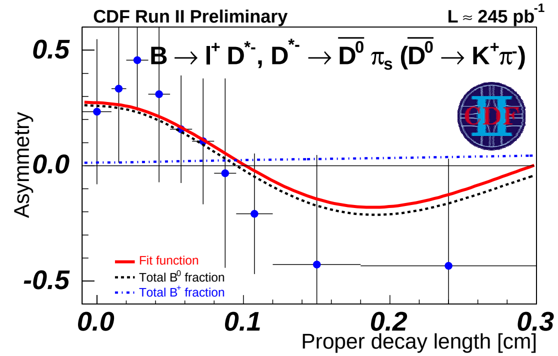
B_d Mixing

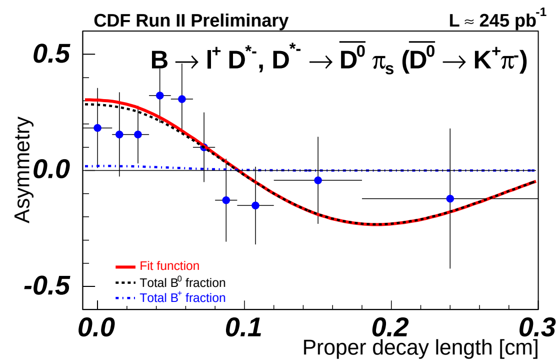
- Count the number of mixed and unmixed events in each decay length bin and plot asymmetry vs transverse pseudo-proper decay length



Soft muon tagger

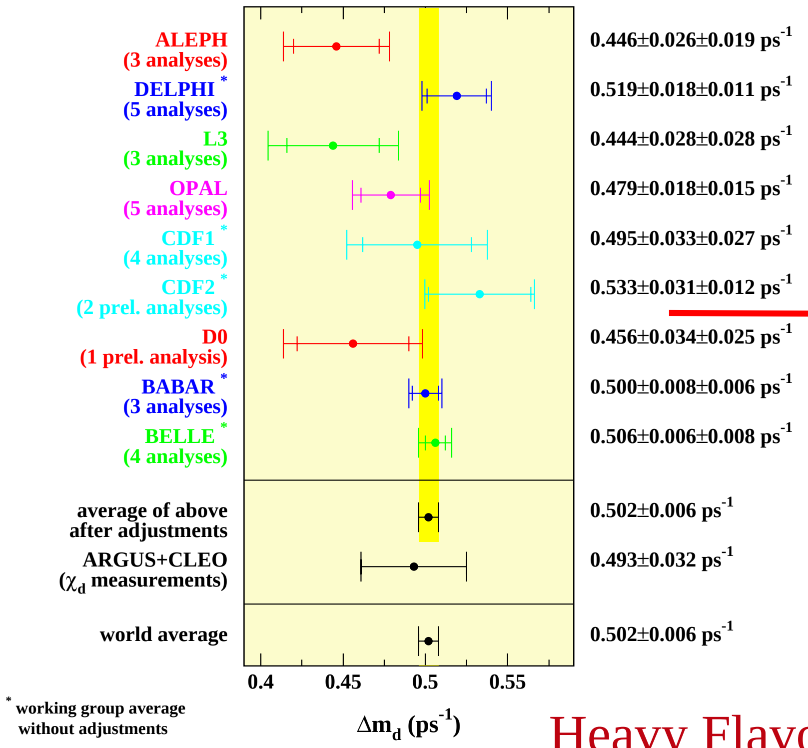
Combined same-side and jet-charge tagger

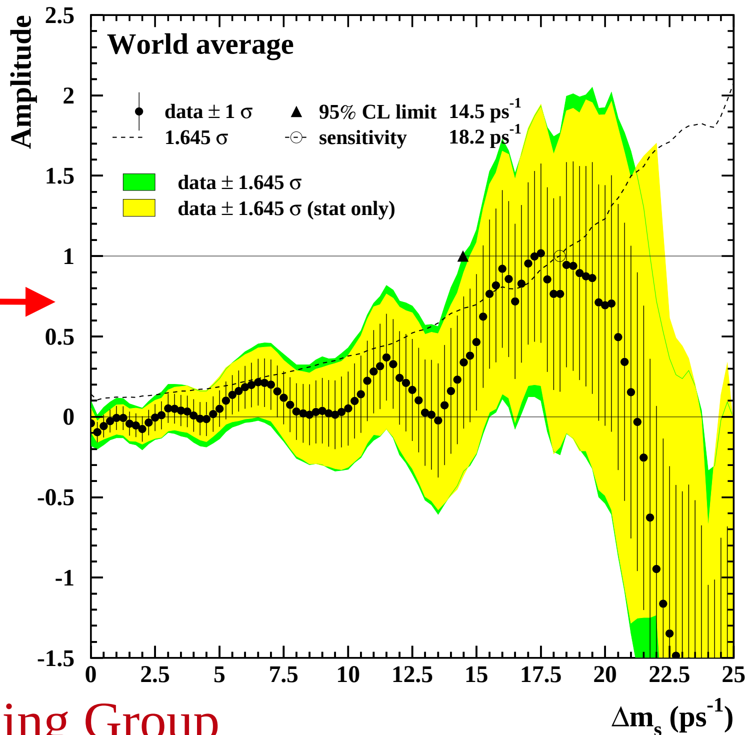




DØ Δm_d Result	CDF Δm_d Result	PDG Δm_d
$0.456 \pm 0.034 \pm 0.025\, ps^{-1}$	$0.536 \pm 0.037 \pm 0.015$ $\pm 0.009(sc)\, ps^{-1}$	$0.502 \pm 0.007\, ps^{-1}$

B_d Mixing → B_s Mixing





Heavy Flavour Averaging Group

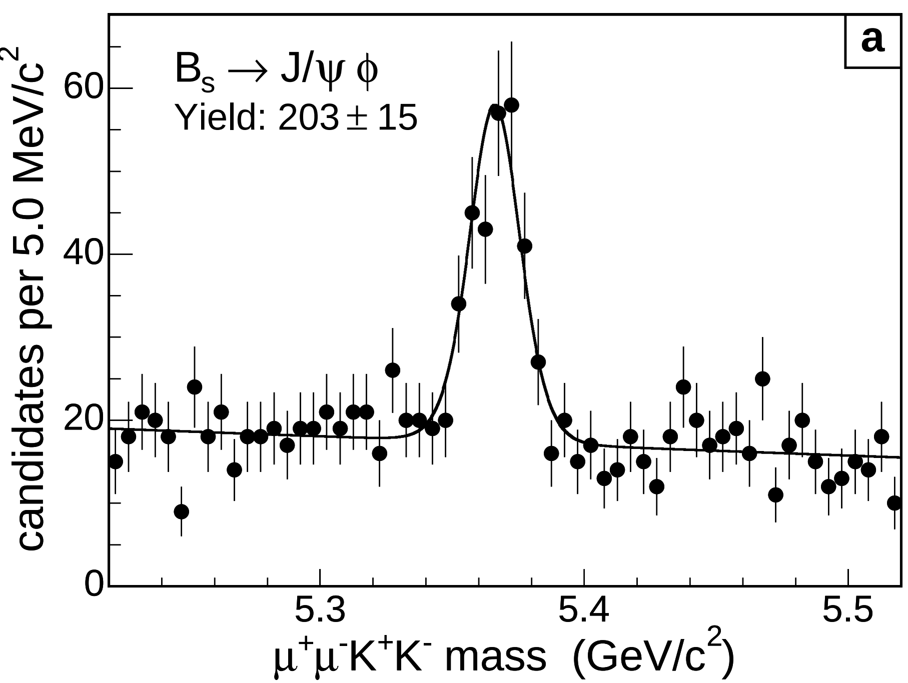
- Current 95% C.L. limit on Δm_s: 14.4 ps^{-1}
- Standard Model says $14.2<\Delta m_s<28.1$ ps^{-1} at 95% C.L.

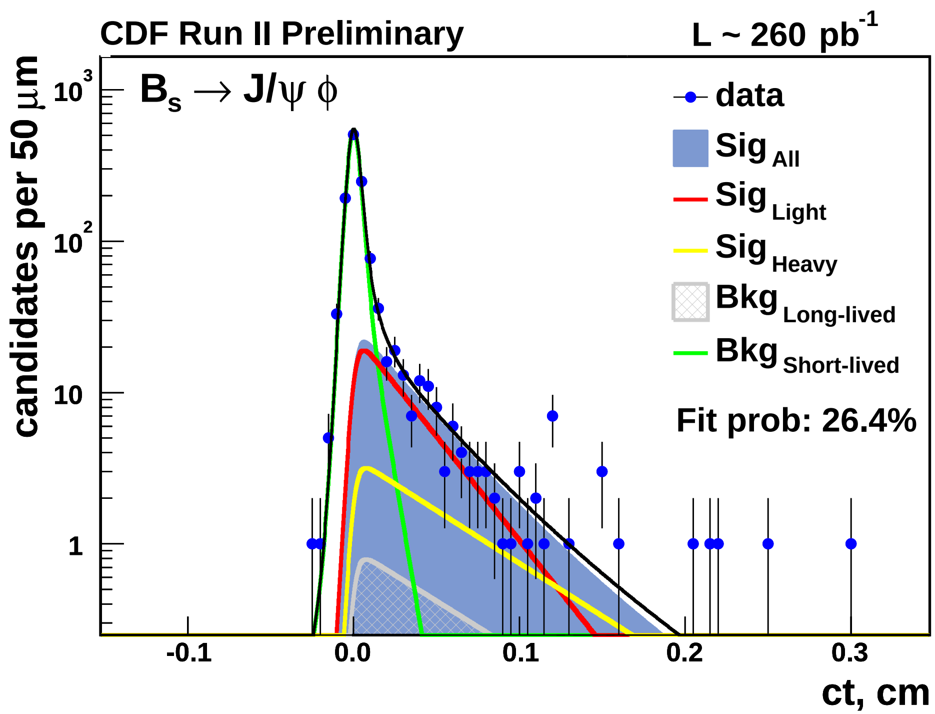
$\Delta\Gamma(B_s)$ at CDF

- $\Delta\Gamma_d/\Gamma_d$ expected to be very small but $\Delta\Gamma_s/\Gamma_s$ could be sizeable
- Mass eigenstates are expected to be nearly-CP eigenstates
- Light-mass eigenstate expected to be CP-even with larger decay width than heavier mass eigenstate
- Measure decay widths directly from the relative contributions of CP-even and CP-odd decays to the observed angular distributions as a function of decay time

$\Delta\Gamma(B_s)$ at CDF

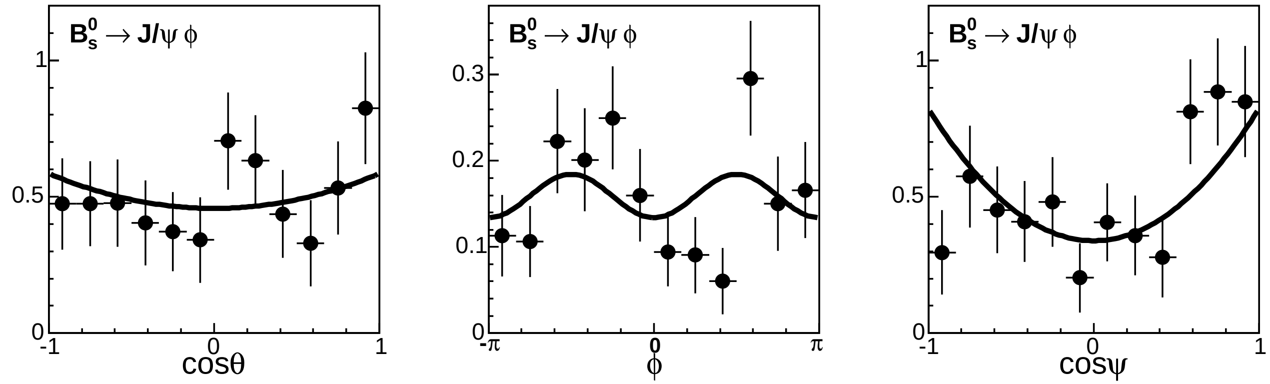
- Reconstruct $B_s^0 \to J/\psi\ \varphi$ followed by $J/\psi \to \mu^+\mu^-$ and $\varphi \to K^+K^-$ in 260pb^{-1} of CDF data





ΔΓ(B_s) at CDF

- Plot the "transversity" angular distributions for the mass-sideband-subtracted signal events
- First time-dependent angular analysis of $B_s^0 \to J/\psi\ \varphi$ decays



- Unbinned likelihood fit to mass, proper decay length and transversity angles to get

$$\Delta\Gamma_s = (0.47^{+0.19}_{-0.24} \pm 0.01)\, ps^{-1} \qquad \frac{\Delta\Gamma_s}{\Gamma_s} = (65^{+25}_{-33} \pm 1)\%$$

- SM expectation: $\frac{\Delta\Gamma_s}{\Gamma_s} = (12 \pm 5)\%$

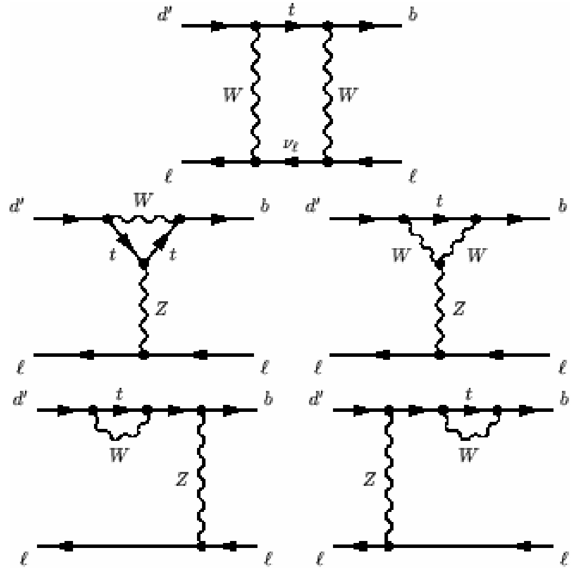
Rare Decays: $B_{d,s} \rightarrow \mu^+ \mu^-$

- Flavour-Changing Neutral Current process forbidden at tree level in the SM
- SM expectation:

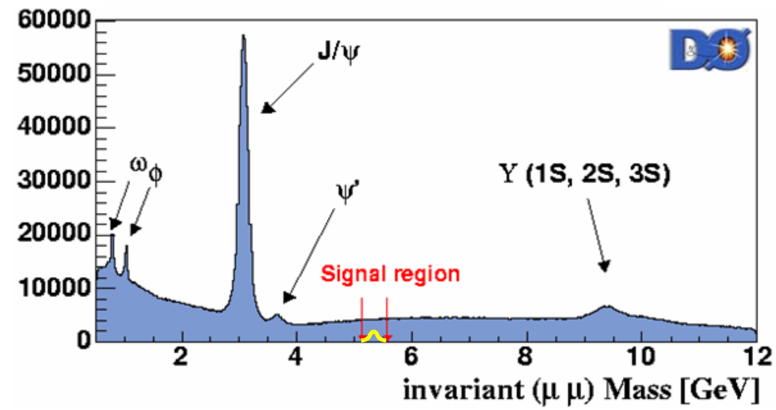
$$BR(B_s^0 \rightarrow \mu^+ \mu^-) < (3.42 \pm 0.54) \times 10^{-9}$$

- B_d decay further suppressed:

$$\left| \frac{V_{td}}{V_{ts}} \right| = (4.0 \pm 0.8) \times 10^{-2}$$

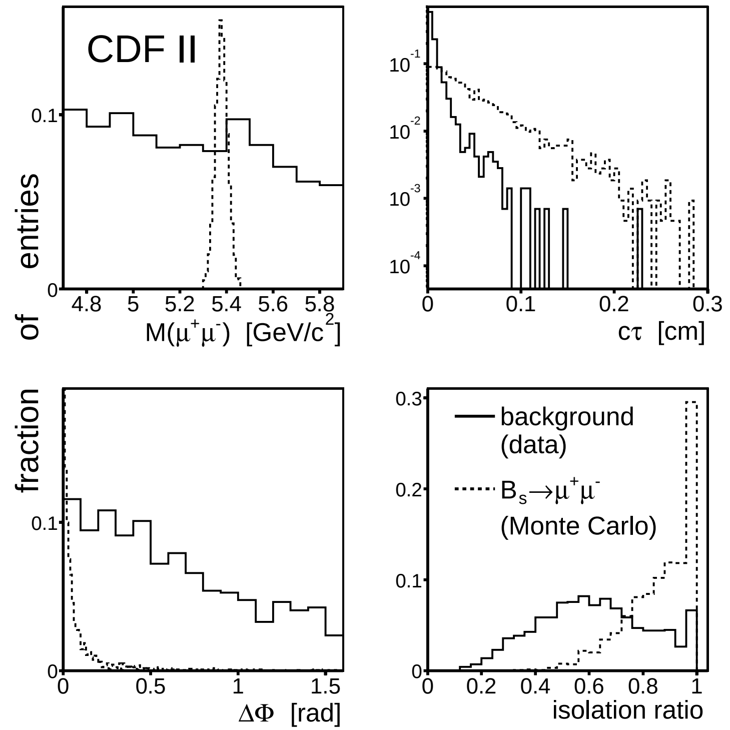


- Observation of a significantly larger BR would indicate physics beyond the Standard Model
  - Minimal Supersymmetric Standard Model
  - Type-II 2-Higgs-doublet model
  - Minimal supergravity models



Rare Decays: $B_{d,s} \to \mu^+ \mu^-$

- Background sources include
  - Fakes
  - $q\bar{q} \to \mu^+ \mu^-$
  - Sequential semi-leptonic $b \to c$ decay
  - Double semileptonic decay $b \to \mu^- X, \bar{b} \to \mu^+ X'$
- CDF published results using 171 pb^{-1}
  - One background event expected in each mass window; one event with mass consistent with both mass windows survived
  - $BR(B_s^0 \to \mu^+ \mu^-) < 7.5 \times 10^{-7}$ at 95% C.L
  - $BR(B_d^0 \to \mu^+ \mu^-) < 1.9 \times 10^{-7}$ at 95% C.L



- DØ used 240 pb^{-1}
  - 4 events observed in signal region consistent with 3.7±1.1 background events
  - $BR(B_s^0 \to \mu^+ \mu^-) \leq 5.0 \times 10^{-7}$ at 95% C.L.

Summary

- Both CDF and DØ are operating well
- Each has unique features important for successful B physics analyses
- Too many results to present in a 25 minute talk
- B Physics program at the Tevatron is broad and varied and complementary to that of the B factories
- More exciting results to come!