Recent Heavy Flavour Physics results from the Tevatron

Fermilab Users Meeting June 3 2010

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On behalf of the CDF and D0 collaborations

Overview of this presentation:

Preliminary:

Why Heavy flavours ? Why at hadron colliders ?

Physics Results & Prospects:

Testing our tools: lifetime measurements (quick)

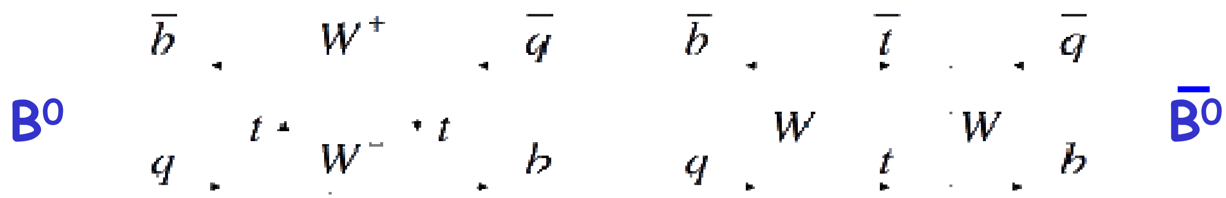
Looking for New Physics in rare decays…

Looking for New Physics in CP violation (CPV)

Conclusion and Summary

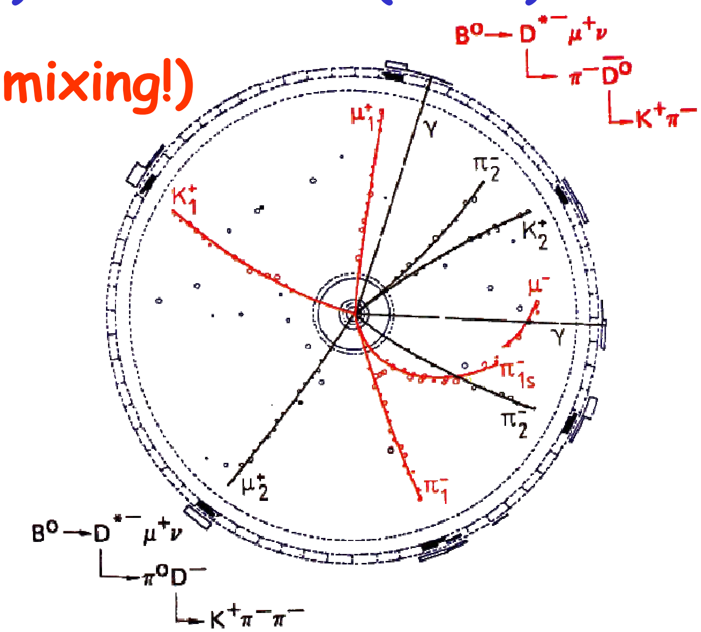
Why Heavy Flavour Physics ?

Second order weak transitions with contributions from W, Z and t are places where new physics is likely to contribute at similar scales (100s of GeV/c^2) giving a sensitivity complementary to direct searches for New Physics (NP)



<u>Example</u>: 1^{st} observation of B mixing at UA(1) and ARGUS (1987)

$b\bar{b}$ produced $\rightarrow \mu^+\mu^-$ (no mixing) $\mu^\pm\mu^\pm$ (like sign: mixing!)
(flavour tagging using leptons)



$$r = \frac{N(B^0B^0) + N(\bar{B}^0\bar{B}^0)}{N(B^0\bar{B}^0)} = 0.21 \pm 0.08$$

Implies m_t > 50 GeV/c^2
(8 years before top discovery)
several other 2^{nd} order processes with similar discovery potential…

PLB186,247 (1987) UA(1) PLB192, 245 (1987) ARGUS

Why Beauty at the Hadron-Hadron Colliders ?

$\sigma(b\bar{b})$ at $\Upsilon(4S)$ = 1nb (B-factories) at Z0 = 7nb (LEP)

$\sigma(b\bar{b})$ at $p\bar{p}$ (1.96TeV/c^2)=30μb (Tevatron Experiments)

However inelastic σ is $10^3 \times \sigma(b\bar{b})$ (huge backgrounds)

-Select b-data online, key: right detector & triggers

-Rewards: all B-hadrons $B^{\pm}$, B^0, B_s, $B_c^{\pm}$, Λ_b, Ω_b, Ξ_b, Σ_b

(all observed at CDF and D0, wider reach than B-factories)

Need Clever Online B Selection to beat background (Triggers):

Use leptons from e.g.

$B_s \to D_s^+ \mu^- \nu$ (single-lepton) (CDF & D0)

$B \to J/\psi X \to \mu^+\mu^-$:CDF & D0 (di-lepton) (CDF & D0)

Use long B lifetimes large impact parameter (IP)

of daughter tracks trigger: purely hadronic decays of b and c

eg $\phi \to K^+K^-$ (for $B_s \to \phi\phi$) (CDF)

Tevatron is performing better than ever before

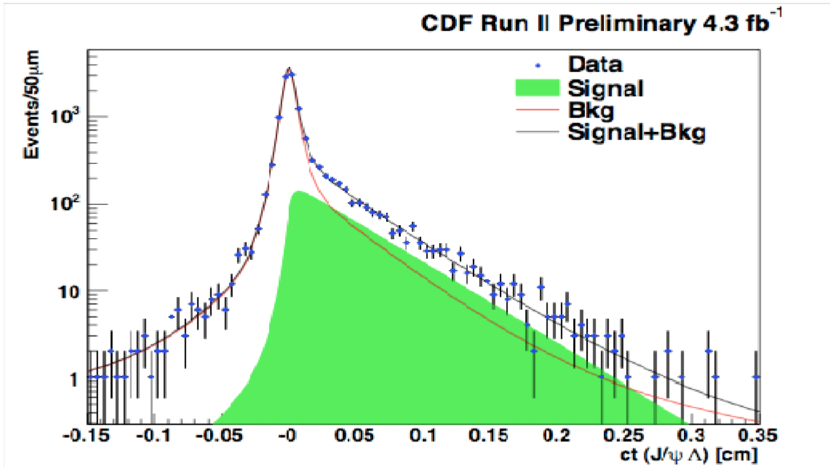
CDF and D0 are mature experiments with complementary strengths with

- roughly ~14fb^{-1} to tape
- some hints of possible new physics..
- Expect 20fb^{-1} to tape by end FYI 2011 Exciting times continue…

Testing our tools B Hadron lifetimes from fully reconstructed decays with J/Ψs in the final state…(CDF)

Test experimental lifetime resolution and theory calculations: crucial input into other analysis (not for New Physics(NP))

$B^+ \to J/\Psi\ K^+$	45000 ± 230
$B^0 \to J/\Psi\ K^*$	16860 ±140
$B^0 \to J/\Psi\ K_s$	12070 ±120
$\Lambda_b \to J/\Psi\ \Lambda$	1710+50

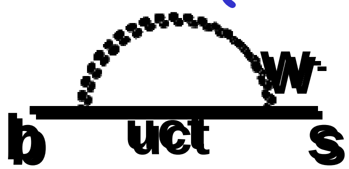


Displaced vertices and fully reconstructed decays used to measure some of the world's best lifetime measurements and ratios:

$\tau(\Lambda^0_b)$ = 1.537±0.045 (stat) ±0.014 (syst) ps
$\tau(\Lambda^0_b)/\tau(B0)$ =1.020±0.030(stat)±0.008(syst)
τ(B+)= 1.639 ± 0.009(stat)± 0.009 (syst) ps
τ(B0)= 1.507 ± 0.010(stat)± 0.008 (syst) ps)
τ(B+)/τ(B0)= 1.088 ± 0.009(stat)± 0.004 (syst)
We can make precision measurements… & HQE is a reliable framework…

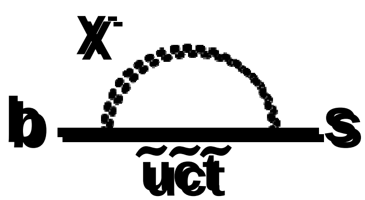
Searching for New Physics: Rare B decays
Decays with $b \rightarrow s\ \mu^+\mu^-$ transitions

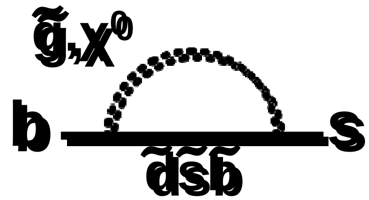
The $b \rightarrow s$ transition (BR $O(10^{-6})$) proceeds though second order processes



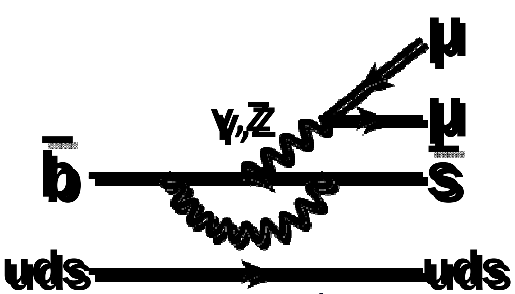
in SM (no tree level)

…however new physics processes could also contribute:

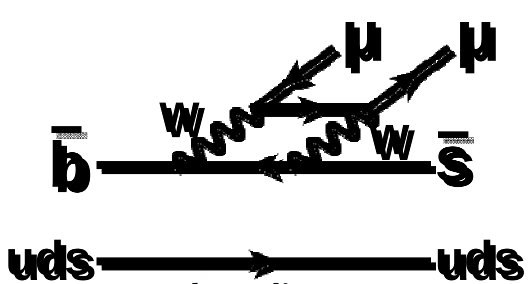




Theory allows the construction of variables (eg Forward backward asymmetries) that are extremely sensitive to NP



EW penguins

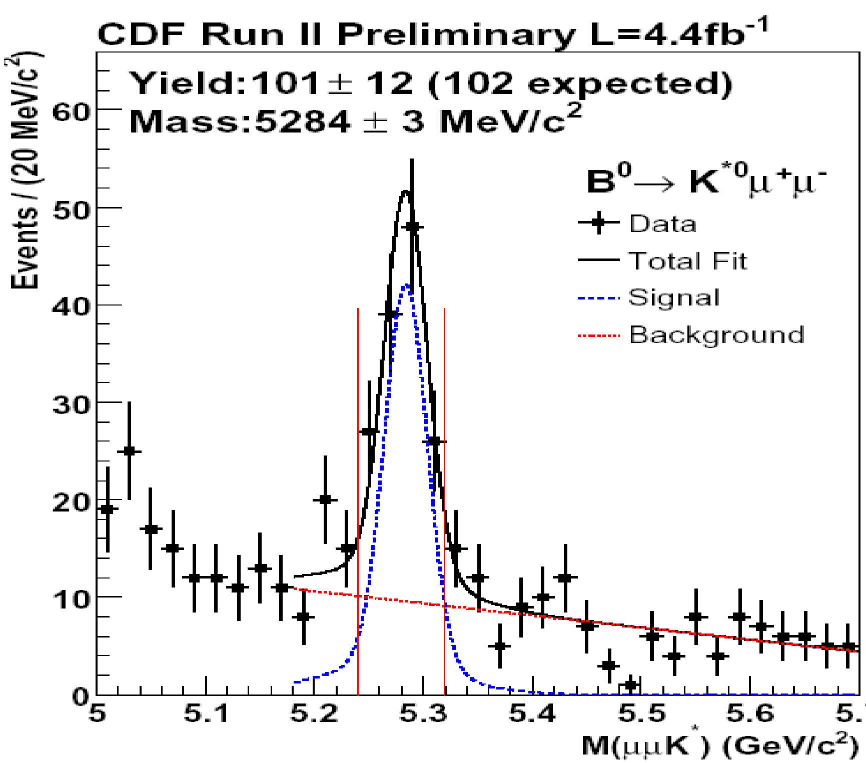


W box diagram

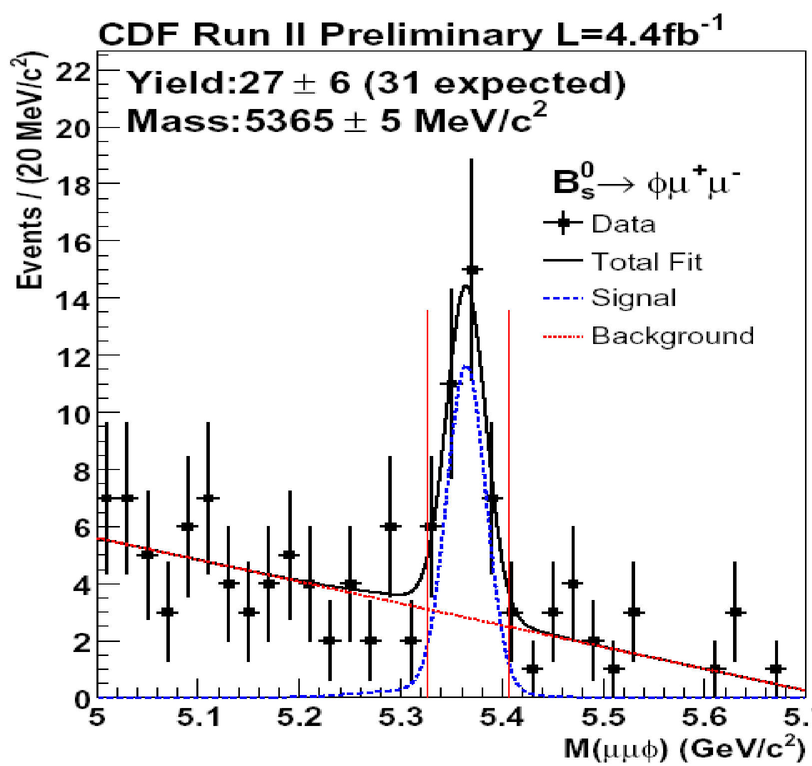
Searching for New Physics: Rare B decays results from processes with $b \to s\mu^+\mu^-$ transitions (CDF)

Analysis strategy: select events with dimuon trigger
- exclude charmonium
- likelihood based muon selection
- neural net based selection

$B0 \to K^*\mu+\mu-$ @ 9.5σ



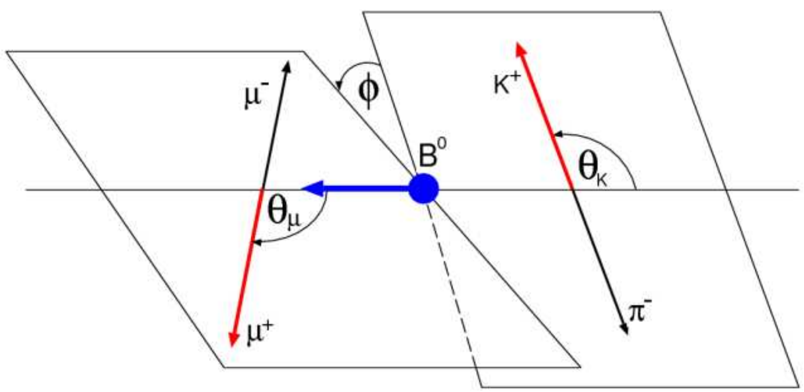
$B_s \to \varphi\, \mu^+\mu^-$ @ 6.3 σ (1^{st} observation)

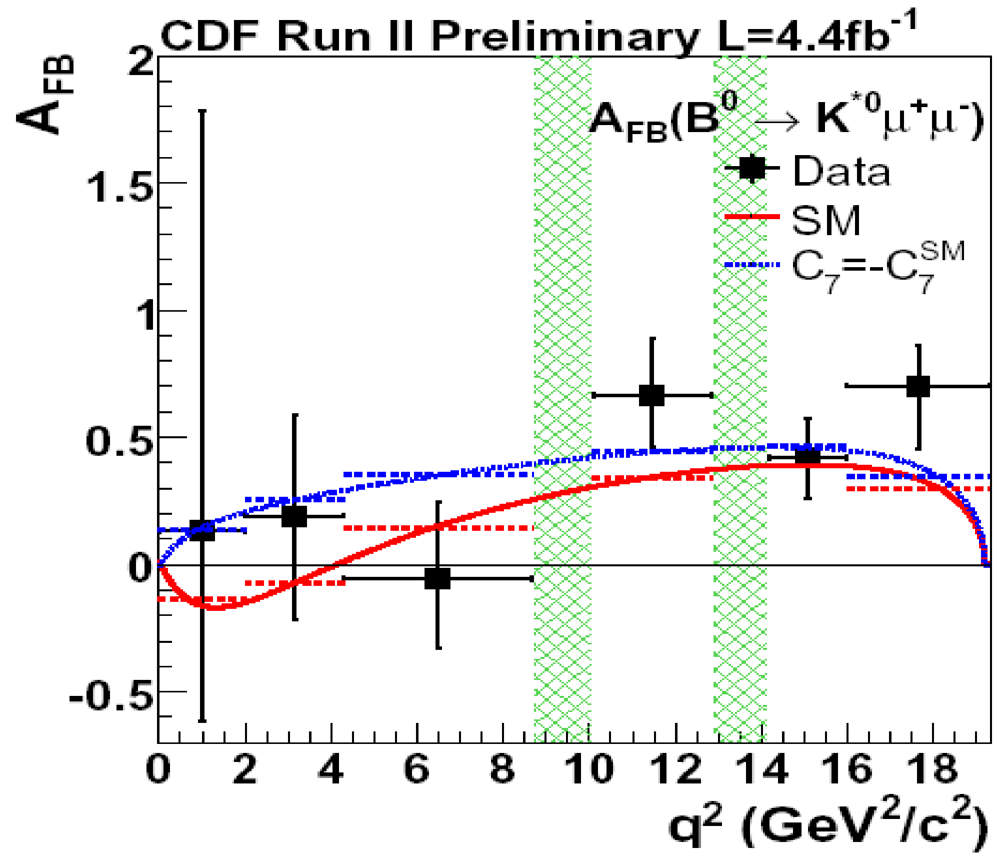


Searching for New Physics: Rare B decays forward backward asymmetry vs q^2 (CDF)

$B^0 \to K^* \mu^+ \mu^-$

Measure A_{fb} in μ^+ helicity angle as a function of q^2





$$\frac{1}{\Gamma}\frac{d\Gamma(B^0 \to K^{*0}\mu^+\mu^-)}{d\cos\theta_\mu} = \frac{3}{4}\mathrm{F_L}(1-\cos^2\theta_\mu) + \frac{3}{8}(1-\mathrm{F_L})(1+\cos^2\theta_\mu) + \mathrm{A_{FB}}\cos\theta_\mu$$

Precision comparable with B factories, more than double data expected by end of FYI 2011, blue is SUSY red is SM

CDF Public Note 10047. Expect to add more modes. Double statistics.

Searching for New Physics: Rare B decays $B_s \rightarrow \mu^+\mu^-$: Latest results from D0 6.1 fb^{-1}

SM prediction :

A.J.Buras, hep-ph/0904.4917:

- $BR(B_s \rightarrow \mu^+\mu^-) = (3.6 \pm 0.3) \times 10^{-9}$

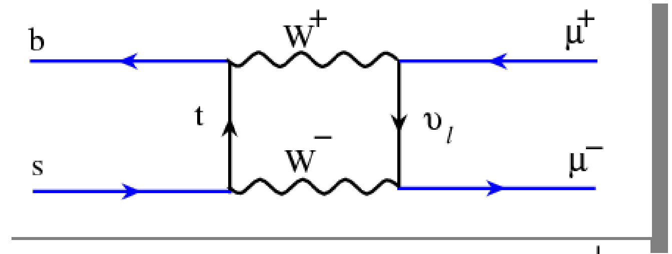
Can be enhanced by

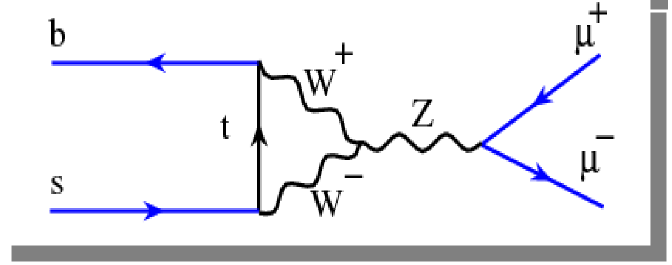
- MSSM ($BR(B \rightarrow \mu^+\mu^-) \propto \tan^6\beta$)
- GUT SO(10)
- SUSY R-parity violating models
- Non-minimal flavor violating model

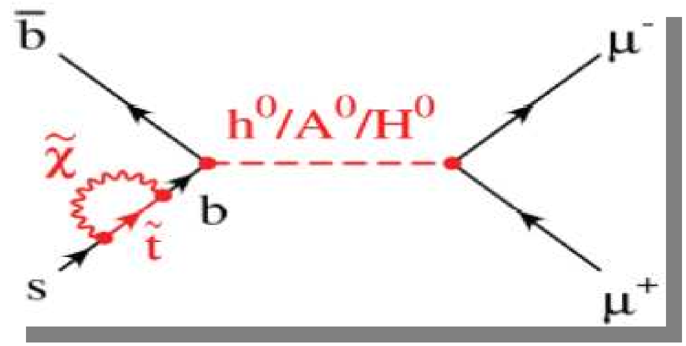
Various BSM scenarios can enhance BR 100 fold..

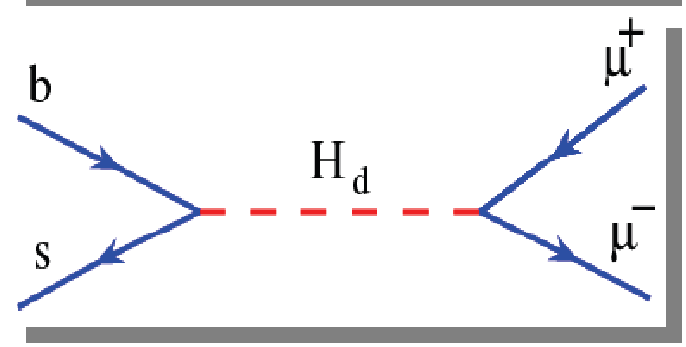
SM signal is beyond the detectors sensitivity at Tevatron

- Any observation of $B_{s,d} \rightarrow \mu^+\mu^-$ would imply new physics
- A tree level NP processes can also contribute





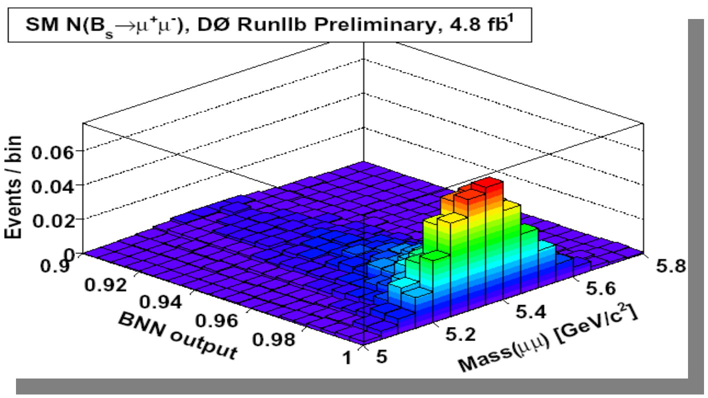


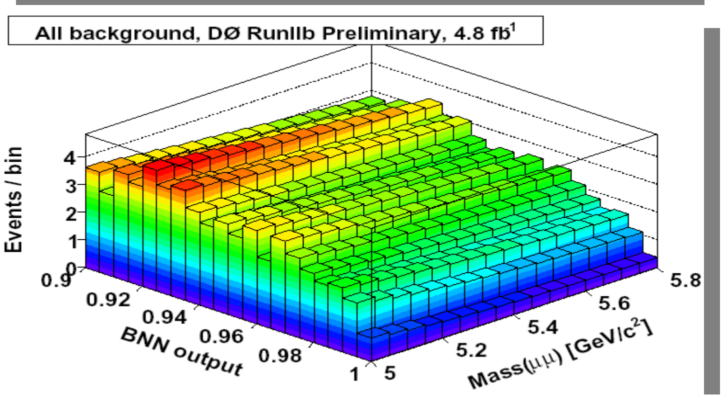


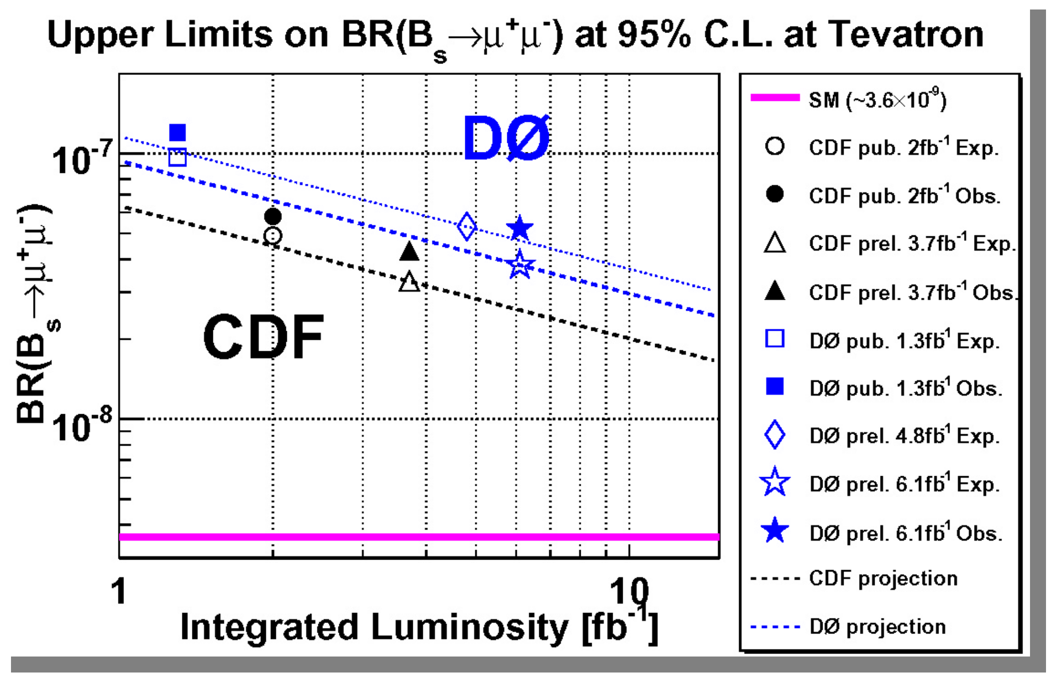
Searching for New Physics: Rare B decays $B_s \to \mu^+\mu^-$ latest results from D0 6.1 fb^{-1}

- Analysis strategy: select events from muon trigger with appropriate mass range, apply muon quality cuts and account for fakes from K, π, p
- Calculate and subtract peaking backgrounds eg $B \to K^+K^-$
- Optimize Neural Net on signal MC and sideband background
- Count in each bin of NN and $\mu\mu$ mass (2D) and combine limits

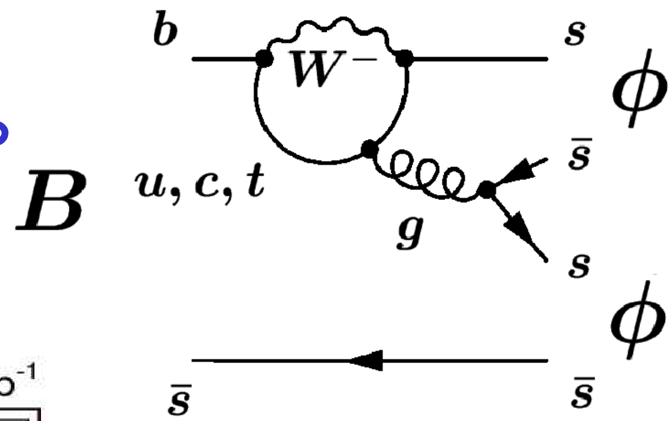
Result: $Br(B_s \to \mu^+\mu^-) < 5.2 \times 10^{-8}$ at 95% CL



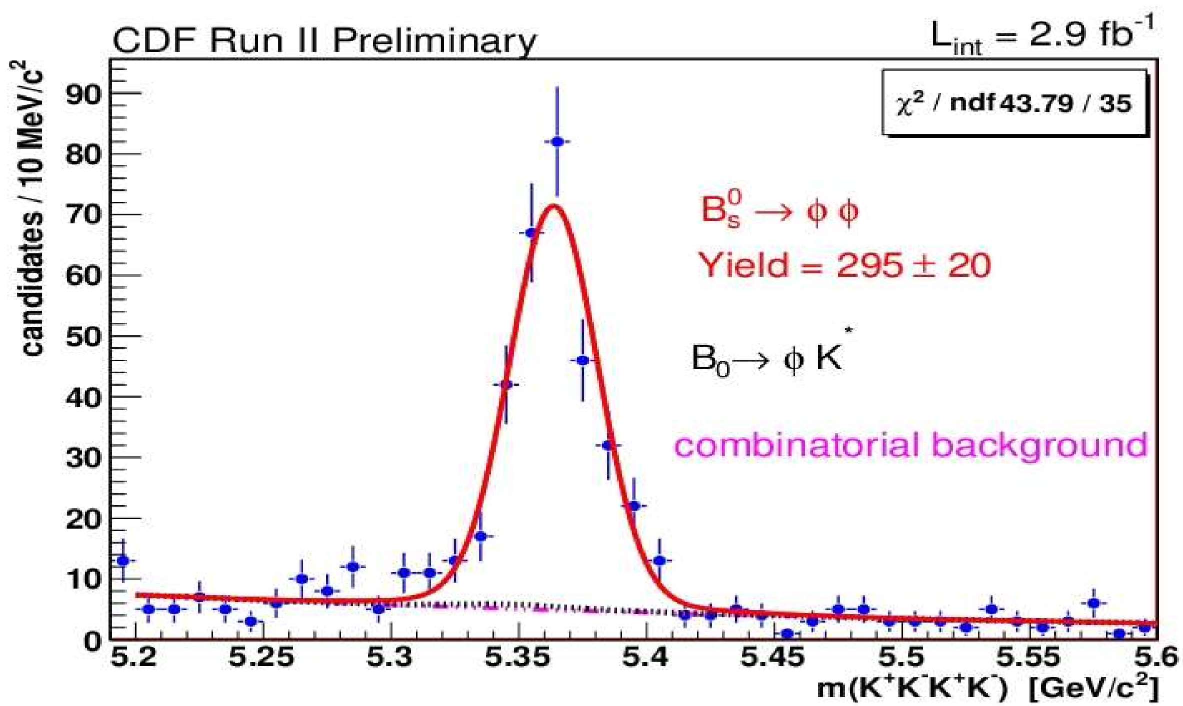




Searching for new physics $B_s \to \phi\phi$:Branching ratio and polarization (CDF)



$B \to \phi\phi$ decays via second order weak decay
- -Polarization amplitudes are sensitive to NP
- -The CKM content of this decay allows CP violating phase β_s measurement (future)



Using 295 $B_s \to \phi\phi$ using 2.9 fb^{-1} of high IP trigger data before polarization study we do branching ratio measurement:

BR($Bs \to \varphi\varphi$)=(2.4± 0.21(stat) ± (syst) ± 0.82(BR)) x10^{-5} SM

Searching for new physics in rare decays: $B_s \to \phi\phi$ polarization results 2.9fb^{-1}

This is a B→VV decay, vector meson polarizations are either:

- ⊥ to each other: $A_\perp \sim H^+ + H^-$ (transverse)
- ∥ parallel to each other: $A_\parallel \sim H^+ - H^-$ (also transverse)
- $A^0 = H^0$ (longitudinal)

SM weak interactions and QCD : A_0, $H_0 \sim$ factor of m_V/m_B >transverse confirmed in B→ρρ at the B-factories

but not in b→s transition decays eg B →φK* makes it important to check $B_s \to \phi\phi$ ("polarization puzzle") (Tevatron exclusive)

$$
\begin{aligned}
|A_0|^2 &= 0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst}) \\
|A_\parallel|^2 &= 0.287 \pm 0.043(\text{stat}) \pm 0.011(\text{syst}) \\
|A_\perp|^2 &= 0.365 \pm 0.044(\text{stat}) \pm 0.027(\text{syst}) \\
\cos\delta_\parallel &= -0.91^{+0.15(\text{stat})+0.09(\text{syst})}_{-0.13(\text{stat})-0.09(\text{syst})}
\end{aligned}
$$

longitudinal (f_L)	transverse (f_T)
$0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst})$	$0.652 \pm 0.041(\text{stat}) \pm 0.021(\text{syst})$

Polarization puzzle continues ! both SM and NP have explanations
Expect halved stat. uncertainties end FYI 2011

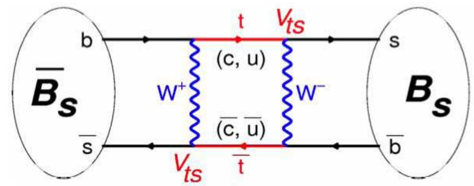
CDF Public Note 10064

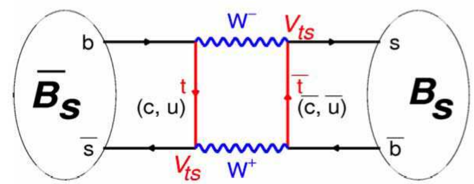
Searching for New Physics: sin $2\beta_s$ from CP violation in $B_s \to J/\psi\varphi$ decays

B mesons are born as flavour eigenstates

$$|B_s^0\rangle = (\bar{b}s)$$
$$|\bar{B}_s^0\rangle = (b\bar{s})$$

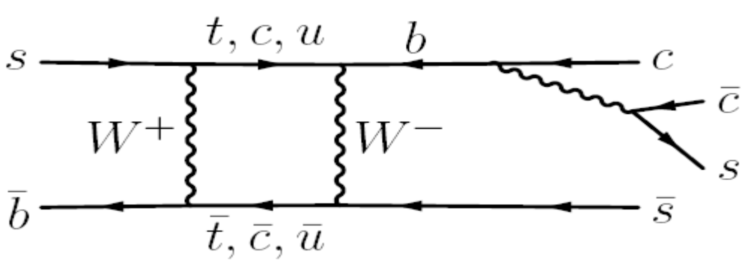
they mix

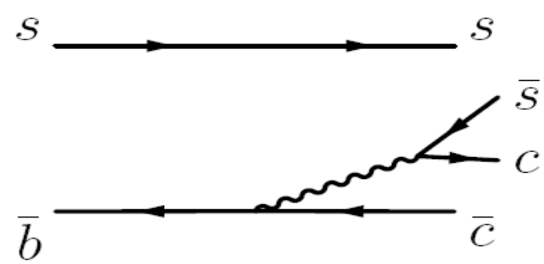




…evolve as H and L mass eigenstates with widths Γ_L, Γ_H masses M_H M_L
…observables are width and mass difference
$\Delta\Gamma_s=\Gamma_H-\Gamma_L$, $\Delta M_s=M_H-M_L$ (observed in B_s oscillations)

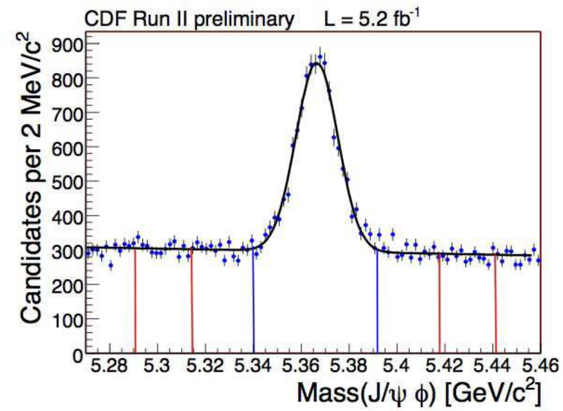
CP violation in $B_s \to J/\psi\varphi$ decays occurs due to interference between tree and mixed decays





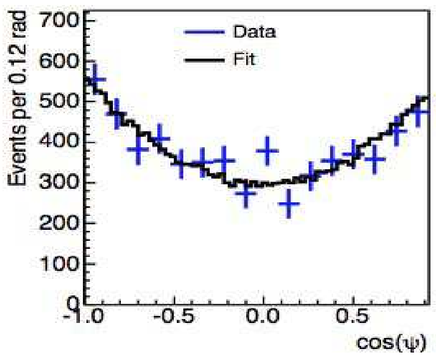
If the B's flavour is known at birth and the CP^+, CP^- content of the final state is separated the time evolution will contain a term
$\approx \pm\sin(\Delta M_s t)\sin(2\beta_s)$ where $\beta_s^{SM}=\arg(-V_{ts}V_{tb}^*/V_{cs}V_{bc}^*) \sim 0.02$
If NP contributes we'd measure $2\beta_s = 2\beta_s^{SM} - \phi_s^{NP} \sim -\phi_s^{NP}$ (if large NP)
Important to check SM prediction.

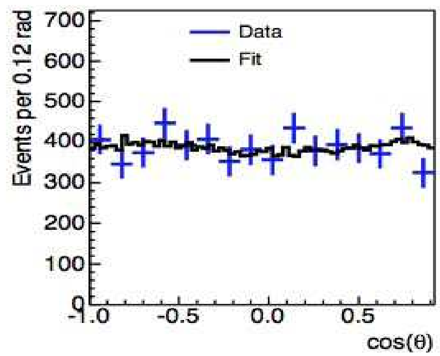
Searching for New Physics: sin 2β_s from CP violation in $B_s \to J/\psi\varphi$ decays: using 5.2fb^{-1} (CDF)

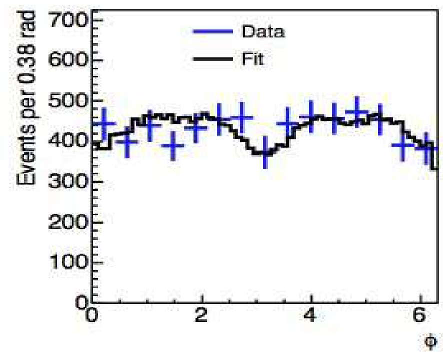


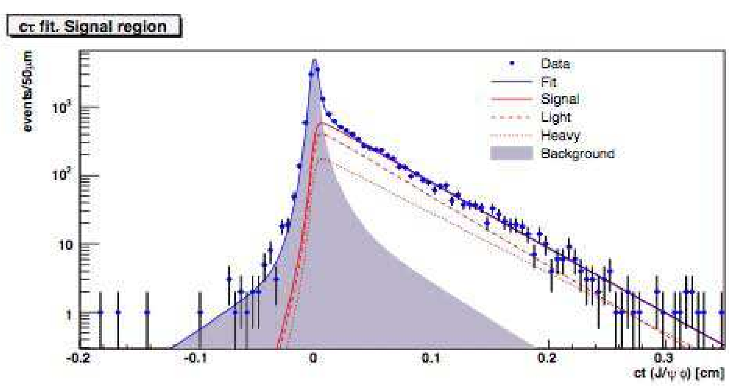
Analysis overview:

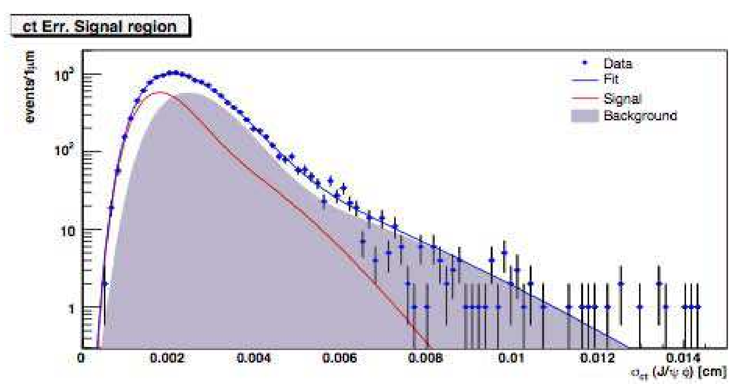
~6500 $B_s \to J/\psi\varphi$ $J/\psi \to \mu^+\mu^-$ $\phi \to K^+K^-$, neural net selection. Fit in time, mass, angles (separate the final state into CP+ CP- components)











next step determine $\bar{B}_s$ or B_s flavour at birth...

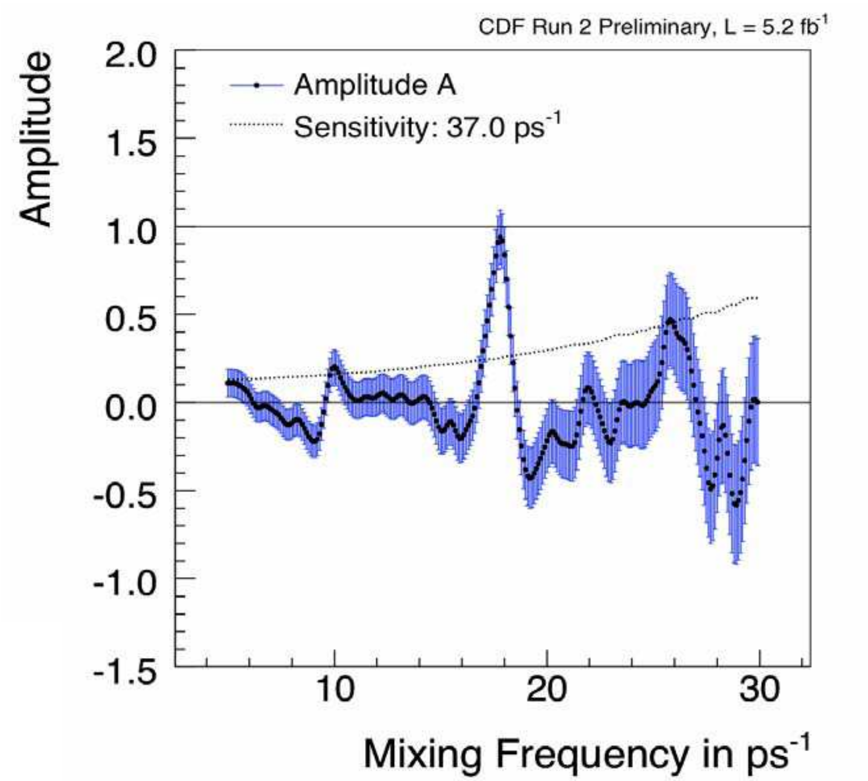
Searching for New Physics: sin $2\beta_s$ from CP violation in $B_s \to J/\psi\varphi$ decays: update from 5.2 fb^{-1}

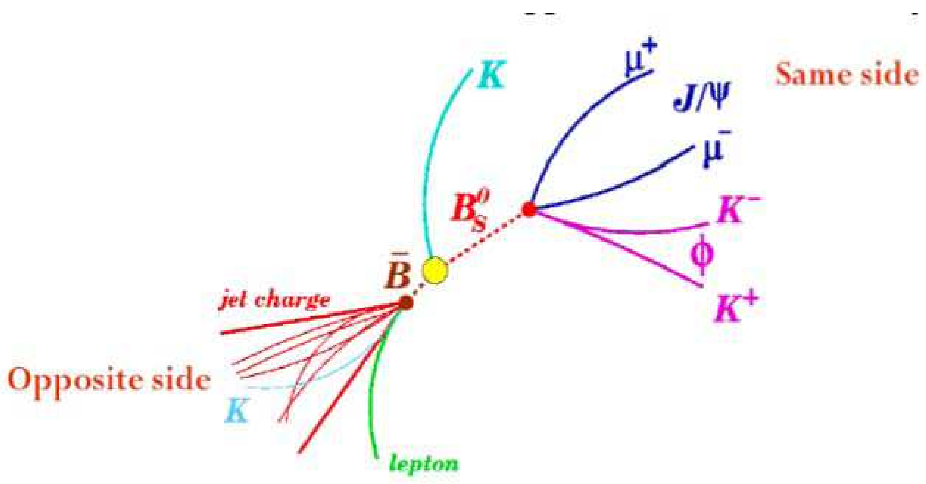
Analysis overview (cont'd)

Flavour tagging is calibrated on data using several modes :

$A = 0.94 \pm 0.15$ (stat) ± 0.13 (syst)
$\Delta M_s = 17.79 \pm 0.07 ps^{-1}$ (stat only)
$\varepsilon A^2 D^2 \sim 3.2 \pm 1.4$ %

Crucial test for Bs flavour tagging
Determination and an input into fit…





First time since 2006 that Bs mixing has been revisited

Searching for New Physics: sin $2\beta_s$ from CP violation in $B_s \to J/\psi\varphi$ decays: update from 5.2 fb^{-1} (CDF)

Results:

First we fix β_s to its SM value of ~ 0
and perform an fit to obtain :

$$\tau_s = 1.53 \pm 0.025 \text{ (stat.) } \pm 0.012 \text{ (syst.) ps}$$

$$\Delta\Gamma = 0.075 \pm 0.035 \text{ (stat.) } \pm 0.01 \text{ (syst.) } ps^{-1}$$

$$|A_{\parallel}(0)|^2 = 0.231 \pm 0.014 \text{ (stat) } \pm 0.015 \text{ (syst.)}$$

$$|A_0(0)|^2 = 0.524 \pm 0.013 \text{ (stat) } \pm 0.015 \text{ (syst.)}$$

$$\phi_\perp = 2.95 \pm 0.64 \text{ (stat) } \pm 0.07 \text{ (syst.)}$$

where we have obtained the worlds
most precise measurement of B_s lifetime

Current PDG world average
B_s lifetime $\tau_s = 1.47^{+0.026}_{-0.027}$ ps

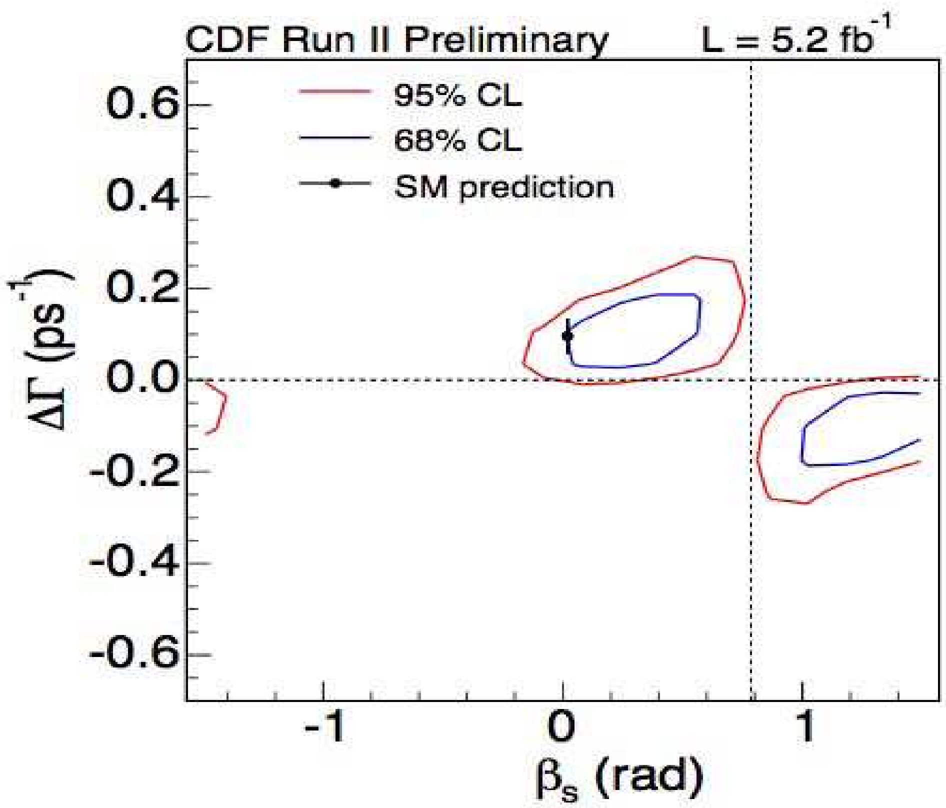
Searching for New Physics: sin 2β_s from CP violation in $B_s \rightarrow J/\psi\varphi$ decays: update from 5.2 fb^{-1} (CDF)

Results:

Likelihood contours in $\Delta\Gamma_s$-β_s space

red line 2σ

blue contour 1σ



The SM point has a p-value of 44%
SM is ~1σ away

We expect to have at least twice the data by end FYI 2011
…we expect more precise measurements in the coming years

Searching for New Physics: CP violation, anomalous charge asymmetry from (D0) : CP violation in mixing

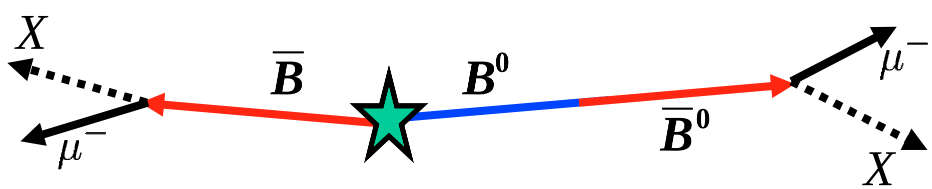
b and $\bar{b}$ quarks are produced in equal numbers in $p\bar{p}$ collisions-50% will hadronize into a neutral B (B^0 or B_s)

1.3% of the time both B hadrons will decay to a muon (BR) with $\bar{B} \to \mu^-$ & $B \to \mu^+$

Two like signed muons from B-$\bar{B}$ pair guarantees oscillation has taken place (box diagram)

Furthermore if N(++)≠N(--) CP violation has in mixing has occurred

The SM predicts $A^b_{sl} \equiv \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}}$ to be small $A^b_{sl} = (-2.3^{+0.5}_{-0.6}) \times 10^{-4}$



This asymmetry has contributions from B_s and B^0 (q=d,s ϕ_q is the CP violating phase on the right)

$$a^q_{sl} = \frac{\Delta\Gamma_q}{\Delta M_q} \tan(\phi_q)$$

A. Lenz, U. Nierste, hep-ph/0612167

Searching for New Physics: CP violation in mixing D0 measurement of A_{sl}

Analysis:

Raw di-muon and inclusive single muon asymmetries are measured in data:

$$A \equiv \frac{N^{++} - N^{--}}{N^{++} + N^{--}} \qquad a \equiv \frac{n^{+} - n^{-}}{n^{+} + n^{-}}$$

-Dilutions for both due to non B sources of muons these are determined from simulation

-Contributions to asymmetry from K π and p are determined using data and simulation: fractions faking a muon f, F asymmetry:a, A

$a_{bkg} = f_K a_K + f_\pi a_\pi + f_p a_p + (1-f_{bkg})\delta$

$A_{bkg} = F_K A_K + F_\pi A_\pi + F_p A_p + (2-F_{bkg})\Delta$

…and the δ, and Δ are muon reconstruction charge asymmetries

Asymmetry from Kaons is the largest.

Muon reconstruction asymmetry is small due to regular magnetic field polarity reversal

Searching for New Physics: CP violation in mixing
D0 measurement of A_{sl}

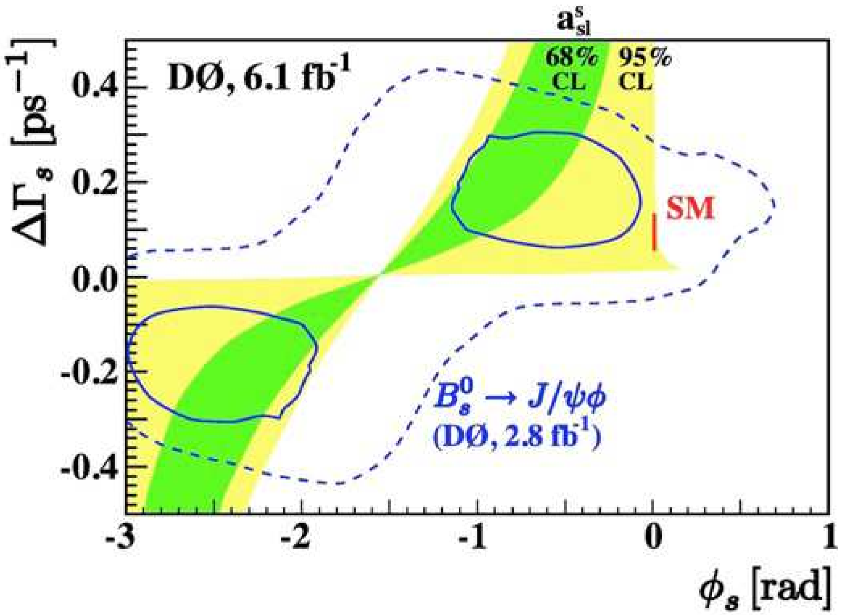
Final Result: A^b_{sl} = (- 0.957 ± 0.251 (stat) ± 0.146 (syst)) %

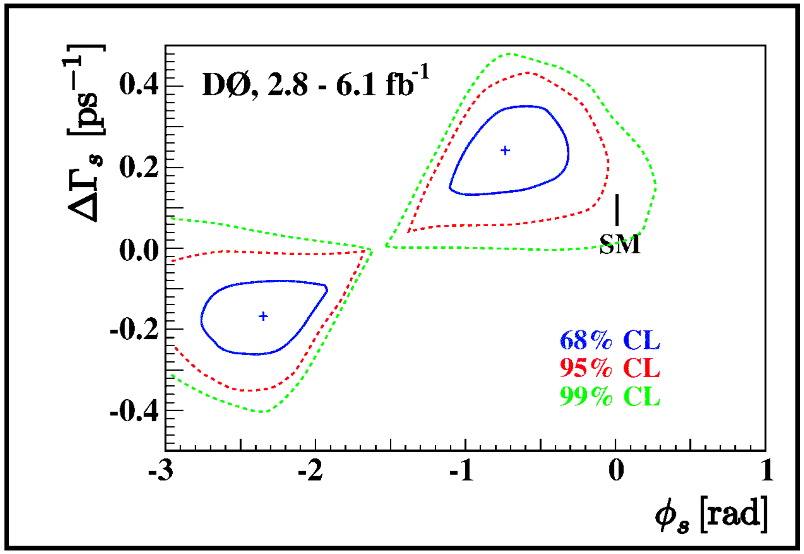
~3.2 σ away from SM

A^b_{sl} has contributions from both B_s and B^0, the relative abundance is known, also one can take a^d_{sl} from the B-factories

which gives a^s_{sl}=(-1.46 ± 0.75)% this can in turn be translated

into a constraint on $\Delta\Gamma_s$ ϕ_s from $B_s \rightarrow J/\psi\varphi$ decays





Excludes SM ϕ_s at >95% CL when combined with D0 $J/\psi\varphi$ analysis

arXiv:1005.2757 hep-ex

Conclusions:

-CDF & D0 are increasing their sensitivity to many B decays where NP could contribute, pushing the SM boundaries, some rather tantalizing hints…

-The most data of any analysis 6.1 fb^{-1}: the D0 measurement of A_{sl}

-We should have ~10 fb^{-1} per experiment by end 2011 which corresponds to at least a doubling of statistics in several modes

-Has been a very successful innings: CDF and D0 have produced ~100 flavour physics publications with 10 topcite 100, and 16 topcite 50..

-and its not over…

Backup Slides

Searching for New Physics: CP violation in mixing
D0 measurement of A_{sl}

-The $J/\psi\varphi \rightarrow \mu^+\mu^-$ is used to determine δ=(-0.076 ± 0.028)% and Δ= (-0.068 ± 0.023)% small due to regular magnet polarity reversal

-Find $K^* \rightarrow K^+\pi^-$ $\varphi \rightarrow K^+K^-$ measure mis-identification as muon and calculate asymmetry.

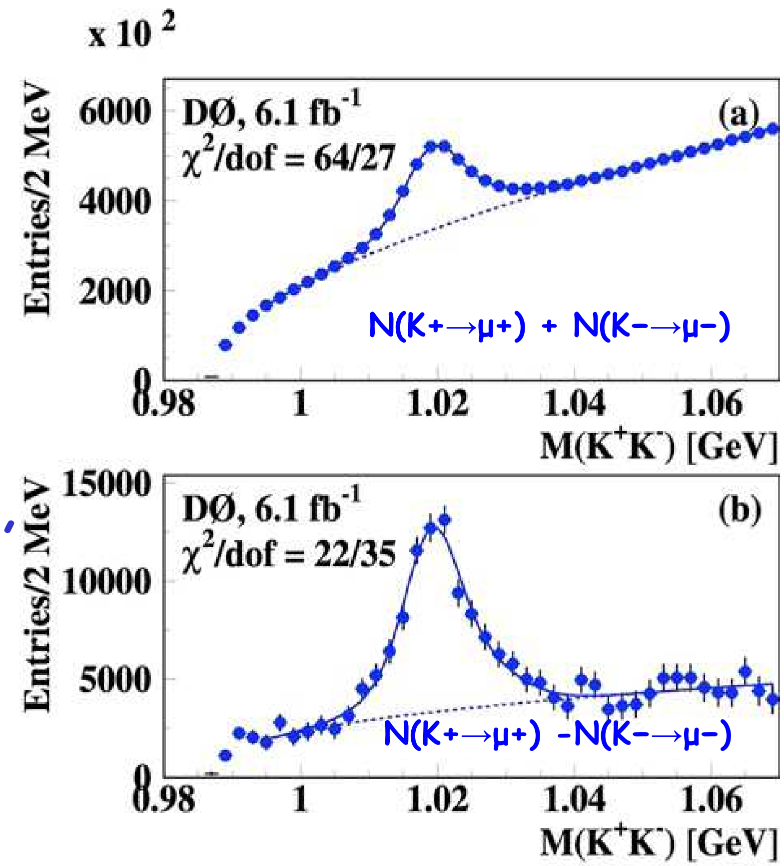
-Measure K^*, K_s in each sample

-Use isospin to determine number of f_K, F_K

Use $\Lambda \rightarrow p\pi$ and $K_s \rightarrow \pi^+\pi^-$ for a_p, a_π A_p, A_π

Use simulation to measure n_p/n_k n_π/n_k

Background in *A*, a is strongly correlated, and a is background dominated: use this fact to constrain Backround in *A*



Searching for New Physics: CP violation in mixing D0 measurement of A_{sl}

Analysis:

Raw di-muon and inclusive single muon asymmetries are measured in data:

$$A \equiv \frac{N^{++} - N^{--}}{N^{++} + N^{--}} \qquad a \equiv \frac{n^{+} - n^{-}}{n^{+} + n^{-}}$$

$A = KA^{b}_{sl} + A_{bkg}$ and $a = ka^{b}_{sl} + a_{bkg}$

-Factors K and k express dilution due to other sources of muons: and are determined from simulation (a is background dominated)

-The terms A_{bkg} and a_{bkg} contain the fractions (f,F) of K,π,p misidentified as μ & associated contribution to asymmetries (a,A):

$a_{bkg} = f_K a_K + f_\pi a_\pi + f_p a_p + (1-f_{bkg})\delta$

$A_{bkg} = F_K A_K + F_\pi A_\pi + F_p A_p + (2-F_{bkg})\Delta$

…and the δ, and Δ are muon reconstruction charge asymmetries

A_k, a_k are the largest since: cross section of K^+ vs K^- with matter in the detector thus: positive asymmetry from decays in flight of $K^+ \rightarrow$ is measured in data.

Searching for new physics $B_s \to \phi\phi$: Branching ratio

-Data collected by high impact parameter trigger: 2.9 fb^{-1}
- Branching ratio measured relative to the known $B_s \to J/\Psi\Phi$ decay
- $\varepsilon^{J/\Psi} / \varepsilon^{\Phi\Phi}$ reconstruction efficiency ratio from simulation
- Increase efficiency: require 1 muon is identified by muon chamber and determine ε_μ^{TOT} muon efficiency from data by counting J/Ψ
-Backgrounds from $B^0 \to \varphi K^{*0} \to K^+K^-K^+\pi^-$, $B^0_s \to K^{*0}\,\overline{K}^{*0} \to K^+\pi^-K^-\pi^+$ are then accounted for
-The ratio of branching ratios is then calculated:

$$\frac{\mathcal{B}(B_s^0 \to \phi\phi)}{\mathcal{B}(B_s^0 \to J/\psi\ \phi)} = \frac{N_{\phi\phi}}{N_{J/\psi\phi}} \cdot \frac{\mathcal{B}(J/\psi \to \mu\mu)}{\mathcal{B}(\phi \to K^+K^-)} \cdot \frac{\varepsilon_{TOT}^{J/\psi\phi}}{\varepsilon_{TOT}^{\phi\phi}} \cdot \varepsilon_\mu^{TOT}$$

Final results:
$$\frac{\mathcal{B}(B_s^0 \to \phi\phi)}{\mathcal{B}(B_s^0 \to J/\psi\phi)} = [1.78 \pm 0.14(stat) \pm 0.20(syst)] \cdot 10^{-2}$$

$$\mathcal{B}(B_s^0 \to \phi\phi) = [2.40 \pm 0.21(stat) \pm 0.27(syst) \pm 0.82(BR)] \cdot 10^{-5}$$

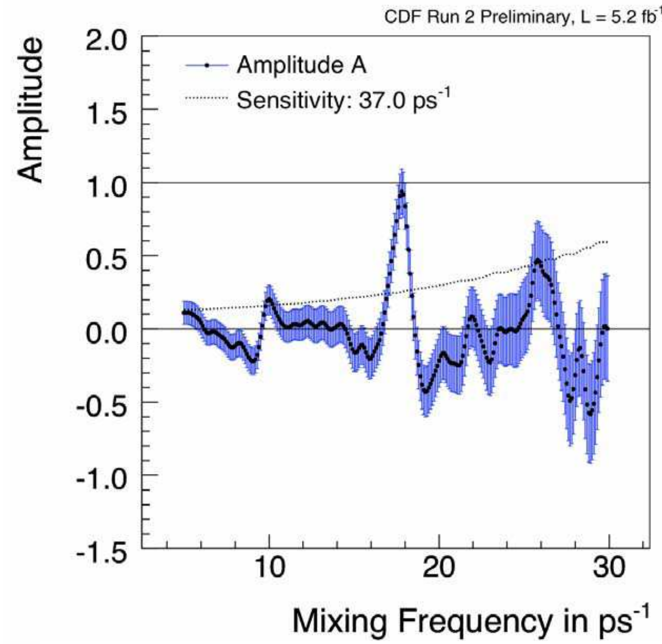
systematics dominated by polarization modeling in MC

Comparsion with theory:

	$\mathcal{B}(B_s^0 \to \phi\phi) \cdot 10^5$
QCDF(1) [13]	$2.18 \pm 0.11\ ^{+3.04}_{-1.70}$
QCDF(2) [13]	$1.95 \pm 0.10\ ^{+1.31}_{-0.80}$
pCDF [14]	$3.53\ ^{+0.83}_{-0.69}\ ^{+1.67}_{-1.02}$

[13] M. Beneke, J. Rohrer and D. Yang, Nucl. Phys. B **774**, 64 (2007) [arXiv:hep-ph/0612290].
[14] A. Ali, G. Kramer, Y. Li, C. D. Lu, Y. L. Shen, W. Wang and Y. M. Wang, Phys. Rev. D **76**, 074018 (2007) [arXiv:hep-ph/0703162].

Searching for New Physics: sin $2\beta_s$ from CP violation in $B_s \to J/\psi\varphi$ decays: update from 5.2 fb^{-1}



Analysis overview (cont'd)

Flavour tagging is calibrated on data using several modes :

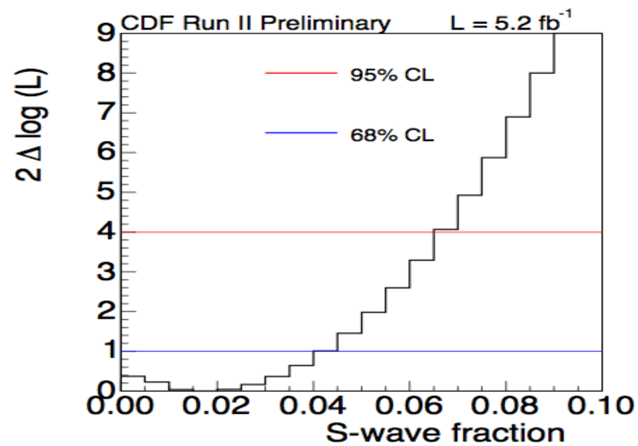
$A = 0.94 \pm 0.15$ (stat) ± 0.13 (syst)

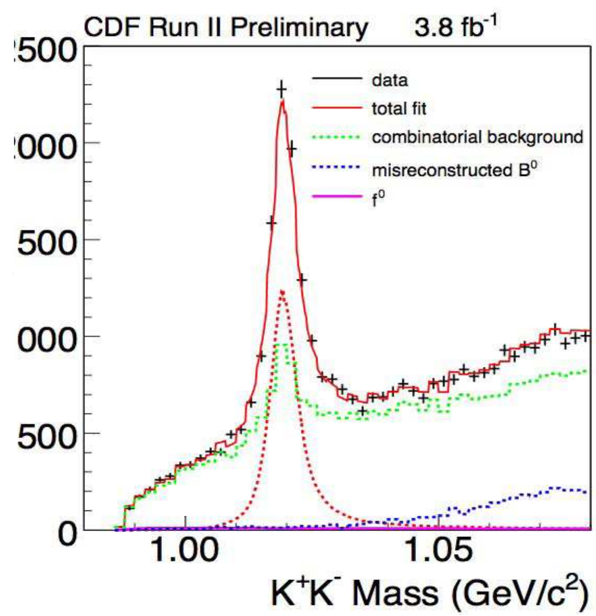
$\Delta M_s = 17.79 \pm 0.07 ps^{-1}$ (stat only)

$\varepsilon A^2 D^2 \sim 3.2 \pm 1.4$ %

Update:

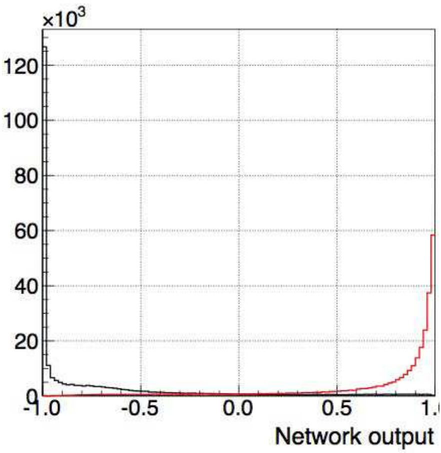
Included the angular and lifetime variables from a potential non-resonant K^+K^- in likelihood: determine < 6.7% at 95% CL





KK mass is not used in the fit we display it as a sanity check

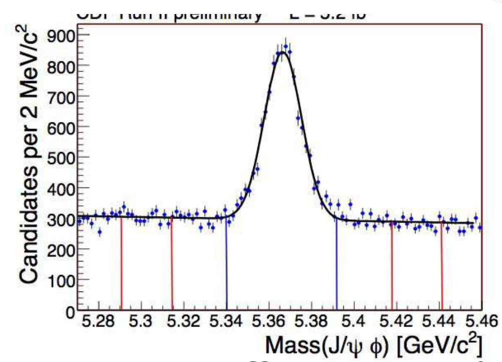
Searching for New Physics: sin $2\beta_s$ from CP violation in $B_s \rightarrow J/\psi\varphi$ decays: update from 5.2fb^{-1} (CDF)



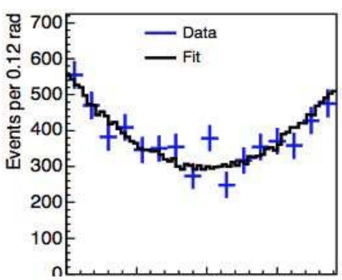
Analysis overview: Essential ingredients

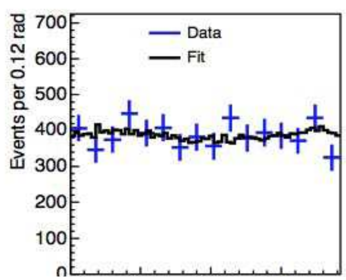
Select Bs→J/ψφ using di-muon trigger

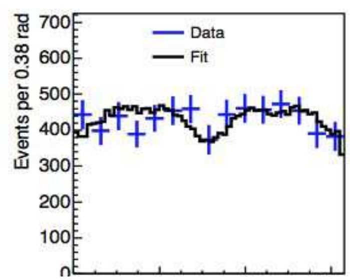
J/ψ→$\mu^+\mu^-$ ϕ→K^+K^- Using neural net selection

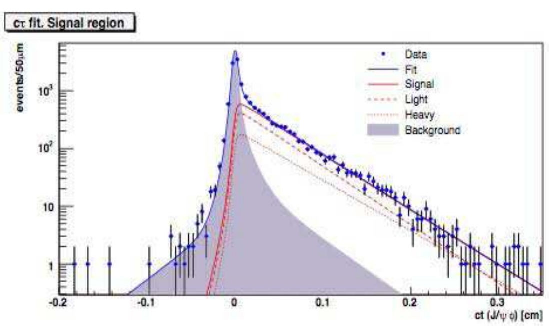


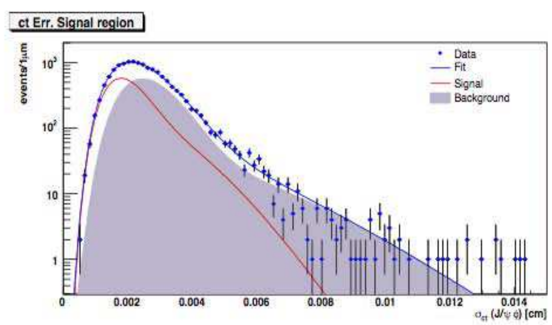
Fit in time, mass, angular variables (transversity) separate the final VV state into CP even and odd components

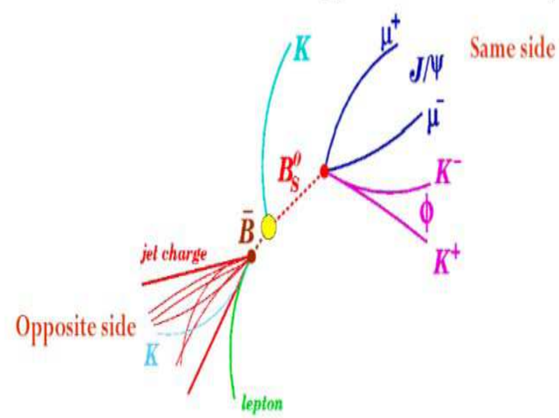












Tagging is performed to separate Bs from $\overline{\text{Bs}}$

Searching for New Physics: sin $2\beta_s$ from CP violation in $B_s \to J/\psi\varphi$ decays: latest update from 5.2 fb^{-1} (CDF)

To search for CPV we use $B_s \to J/\psi\varphi$ with $J/\psi \to \mu^+\mu^-$ $\varphi \to K^+K^-$ angular variables (transversity) allow separability of the CP eigenstates

If flavour of the $B_s(\overline{B}_s)$ is tagged at birth the final state evolution in time contains a term $\approx \sin(\Delta M_s t)\sin(2\beta_s)$ with opposite sign for $\overline{B}_s$ vs B_s rates to final CP state: embodying CP violation

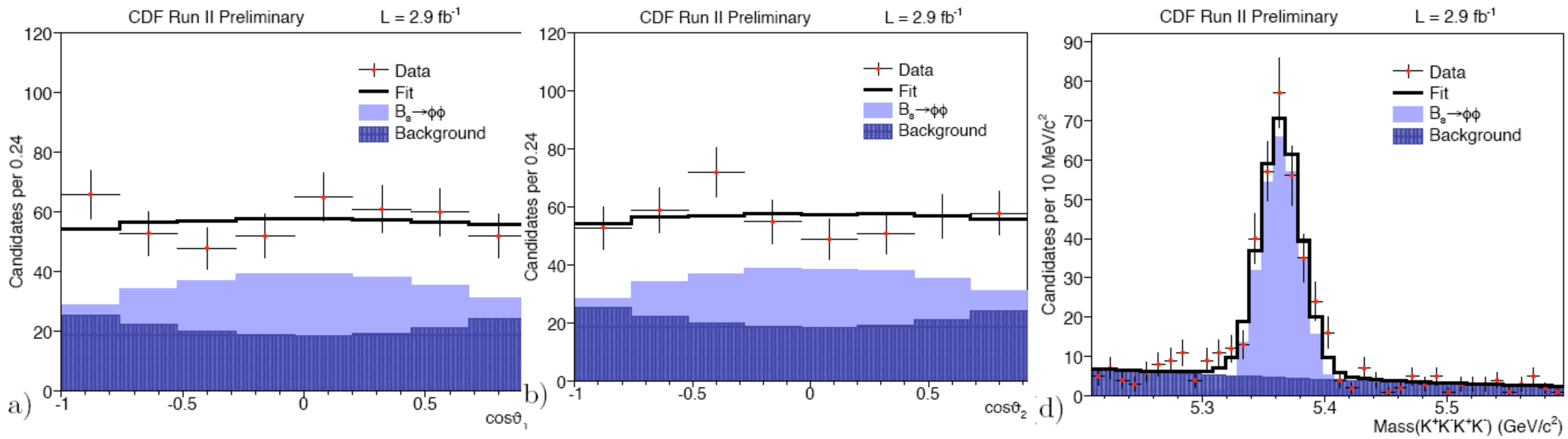
In the SM $\beta_s = \arg(-V_{ts}V_{tb}^*/V_{cs}V_{bc}^*)$ (close to 0)
In case of NP : $2\beta_s = 2\beta_s^{sm} - \phi_s^{np}$ (if β_s is sizeable we have NP)

Analysis:
B_s Mixing parameter ΔM_s is measured : input into the analysis

We measure $\Delta\Gamma_s = \Gamma_L - \Gamma_H$ the angular amplitudes $A_\perp$ (CP-), $A_\parallel$, A_0 (CP+) the average B_s lifetime τ_s, mass M_s, and $\phi_\perp = \arg(A_\perp A_0^*)$ and β_s.

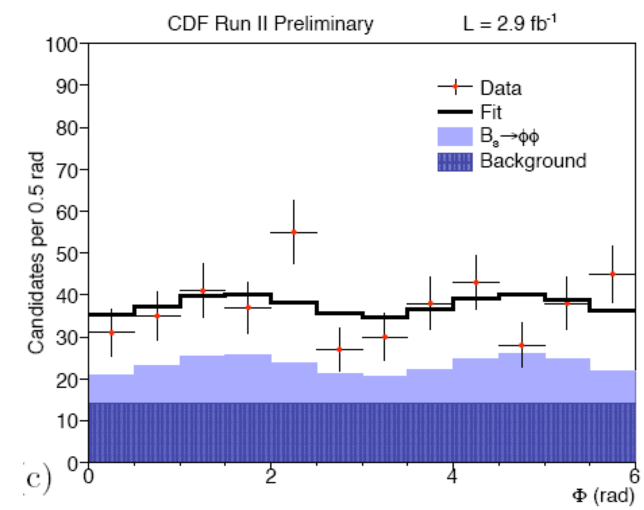
If flavour tagging is not done β_s is not measured, the remaining the observables are of interest & are measured this way as well

Searching for new physics in rare decays: Bs $\to\phi\phi$ polarization results 2.9fb^{-1}

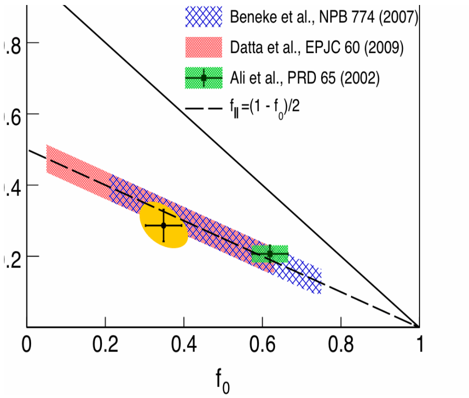


$$|A_0|^2 = 0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst})$$
$$|A_{\parallel}|^2 = 0.287 \pm 0.043(\text{stat}) \pm 0.011(\text{syst})$$
$$|A_{\perp}|^2 = 0.365 \pm 0.044(\text{stat}) \pm 0.027(\text{syst})$$
$$\cos\delta_{\parallel} = -0.91^{+0.15(\text{stat})+0.09(\text{syst})}_{-0.13(\text{stat})-0.09(\text{syst})}$$

longitudinal (f_L)	transverse (f_T)
$0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst})$	$0.652 \pm 0.041(\text{stat}) \pm 0.021(\text{syst})$



A_0 does not dominate: Polarization puzzle continues.
<u>Both SM and NP have explanations.</u>
Expect halved statistical errors with 10 fb^{-1} by end of 2011



new physics $B_s \rightarrow \phi\phi$: Polarization (CDF)

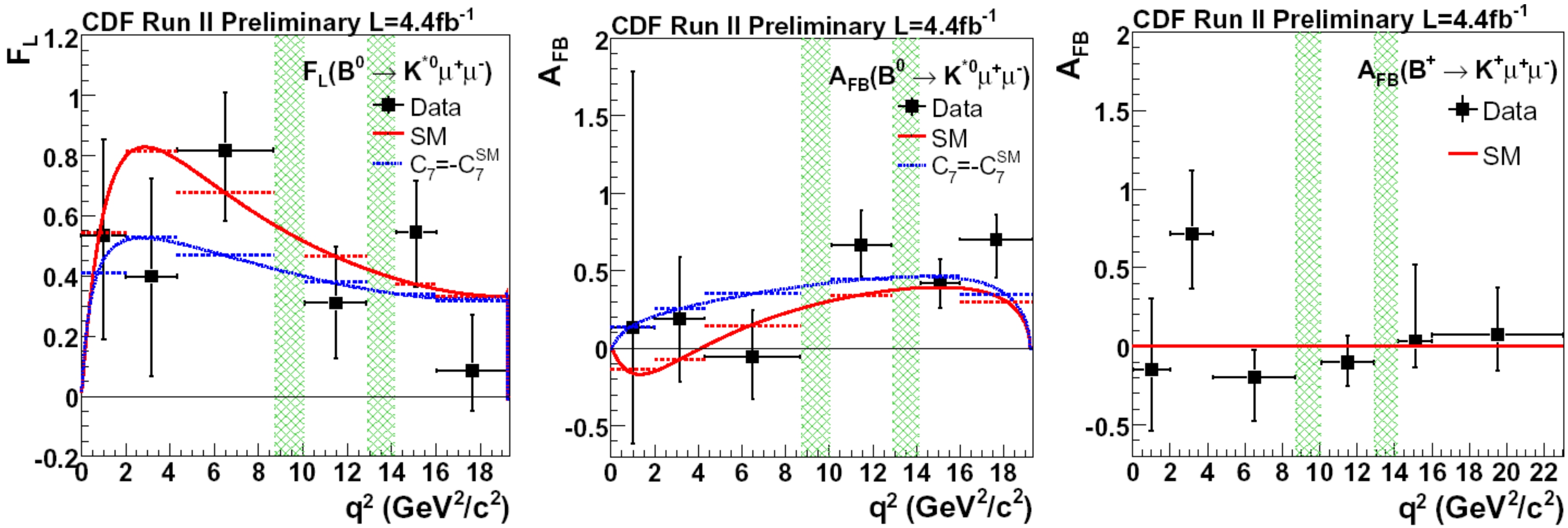
e has two vector mesons ($B \rightarrow VV$)
ons can be described in two basis:
each ϕ can have helicity +1(H^+), 0(H^0), -1(H^-)
sis: ϕ polarizations along flight are either:

- transverse, perpendicular to each other: $A_\perp \sim H^+ + H^-$
- transverse, parallel to each other: $A_\parallel \sim H^+ - H^-$
- longitudinal ($A_0 = H^0$)

SM (Weak V-A & helicity conservation in QCD) predicts (A^0, H^0) should dominate in $B \rightarrow VV$ decays, while transverse component is suppressed by m_V/m_B, this is confirmed in $B \rightarrow \rho\rho$ at the B-factories but not in decays containing an s quark eg. $B \rightarrow \phi K^*$-from B-factories (polarization puzzle): Another place to check is $B_s \rightarrow \phi\phi$ (unique to the Tevatron)

-Angles defined using K^+ in each ϕ rest frame and the decay planes of the ϕs
-Bose symmetrisation for $\phi\phi$ final state accounted for
-CP content means $B_{s,long}$ or $B_{s,short}$ lifetimes have to be accounted for
-CP violating phase is assumed to be 0.

Searching for New Physics: Rare B decays branching ratio dependence on A_{FB} and F_L

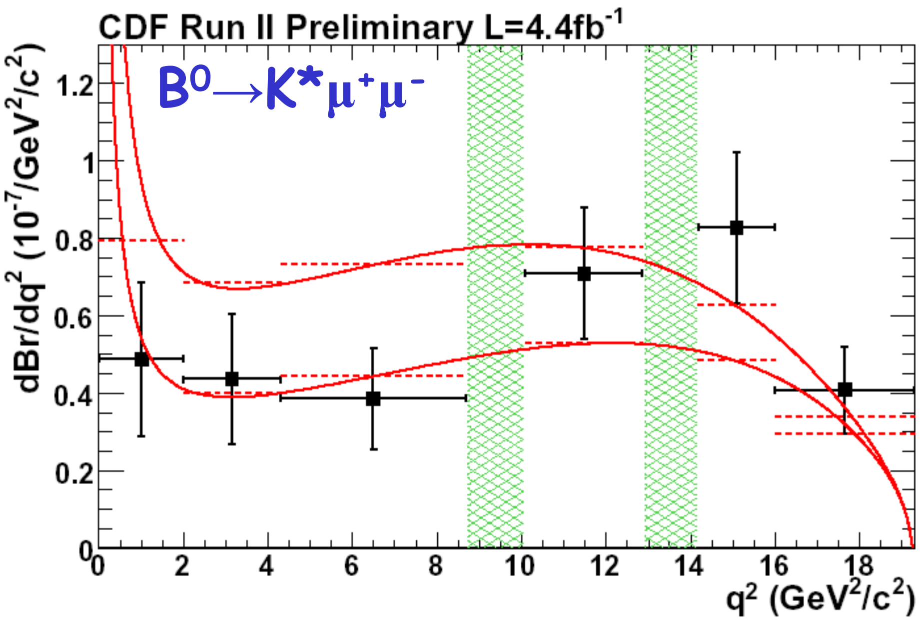


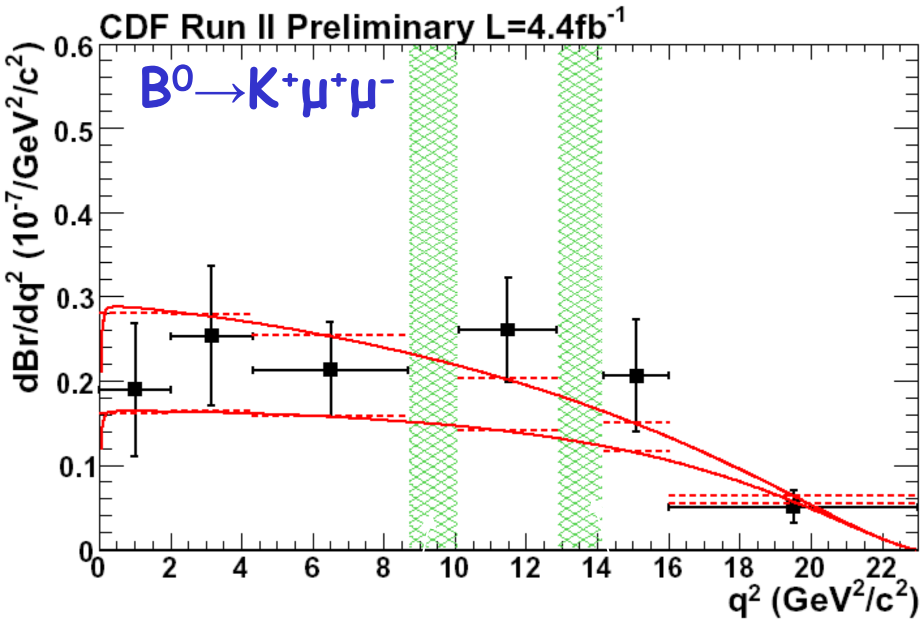
$$\frac{1}{\Gamma}\frac{d\Gamma(B^0 \to K^{*0}\mu^+\mu^-)}{d\cos\theta_K} = \frac{3}{2}\mathrm{F_L}\cos^2\theta_{\mathrm{K}} + \frac{3}{4}(1-\mathrm{F_L})(1-\cos^2\theta_{\mathrm{K}})$$

$$\frac{1}{\Gamma}\frac{d\Gamma(B^0 \to K^{*0}\mu^+\mu^-)}{d\cos\theta_\mu} = \frac{3}{4}\mathrm{F_L}(1-\cos^2\theta_\mu) + \frac{3}{8}(1-\mathrm{F_L})(1+\cos^2\theta_\mu) + \mathrm{A_{FB}}\cos\theta_\mu$$

Red lines indicate SM prediction, Data in black, data are consistent with SM prediction…first ever measurement at a hadron collider- consistent with B-factories

Searching for New Physics: Rare B decays branching ratio dependence on q^2 (CDF)





Green bands indicate J/ψ and ψ(2S) veto

Red lines indicate SM prediction

Data in black

Data are consistent with SM prediction… (4.4 fb^{-1})

expect to more than double data set by end 2011

Searching for New Physics: Rare B decays branching ratios and related analyses

First thing: measure just the branching ratios:
Ratio of BR to J/ψ h and then use PDG:

$BR(B^0 \to K^* \mu^+\mu^-) = (0.38 \pm 0.05(stat.) \pm 0.03(syst.)) \times 10^{-6}$
$BR(B^+ \to K^+ \mu^+\mu^-) = (1.06 \pm 0.14(stat.) \pm 0.09(syst.)) \times 10^{-6}$
$BR(B_s \to \varphi\, \mu^+\mu^-) = (1.44 \pm 0.33(stat.) \pm 0.46(syst.)) \times 10^{-6}$

All consistent with BELLE and BaBar and SM predictions
$BR(Bs \to \varphi\ \mu+\mu-)$ is a Tevatron exclusive

We can also examine the dependence of BR with respect to variables for consistency with SM predictions, the variables are:

- $q^2 = M^2(\mu^+\mu^-)$ invariant mass squared of muon pair
- A_{FB} = forward backward asymmetry (using helicity angle between μ^+ and B, θ_μ)
- F_L = longitudinal polarization (using angle beween kaon flight and –B flight in K* rest frame, θ_K)

Searching for New Physics: Rare B decays results from processes with $b \to s\mu^+\mu^-$ transitions

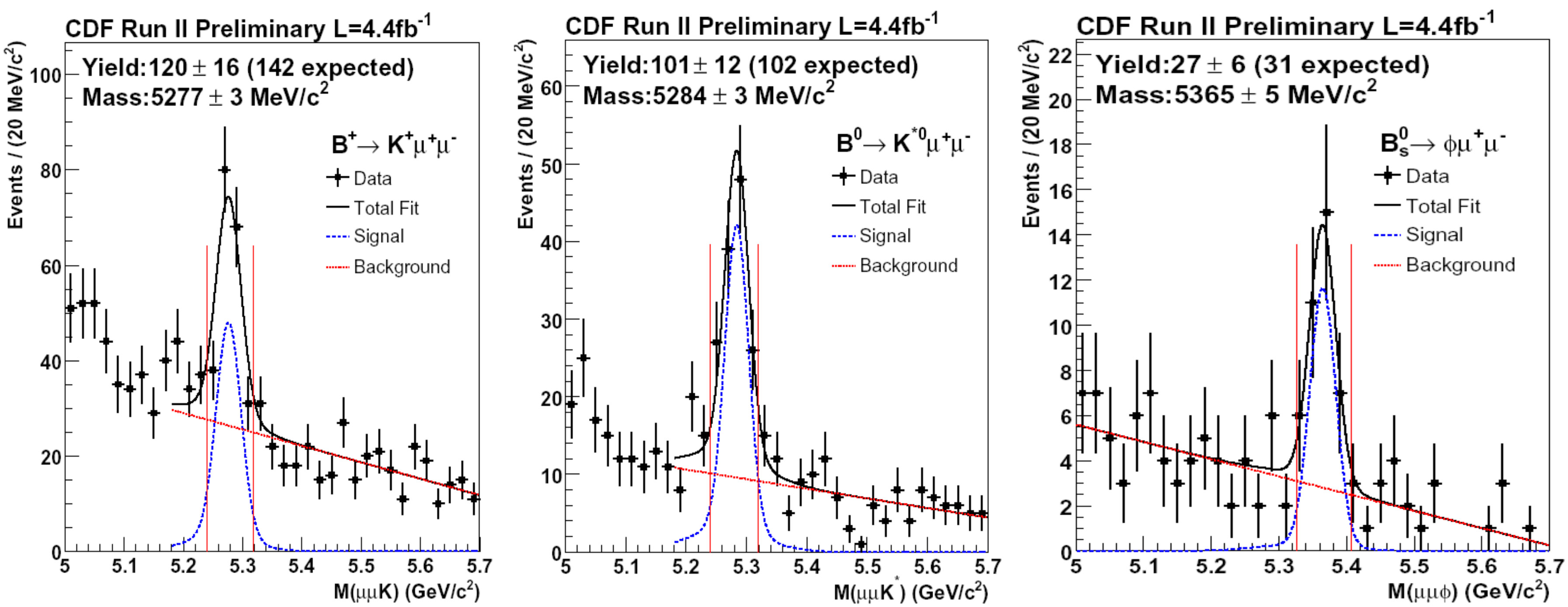
Analysis strategy: select events with dimuon trigger
- exclude charmonium
- likelihood based muon selection
- neural net based selection

Decays found:

$B^0 \to K^*\mu^+\mu^-$ @ 9.5σ, $B^+ \to K^+\mu^+\mu^-$ @8.7σ and

$B_s \to \varphi\, \mu^+\mu^-$ @ 6.3 σ 1st observation !

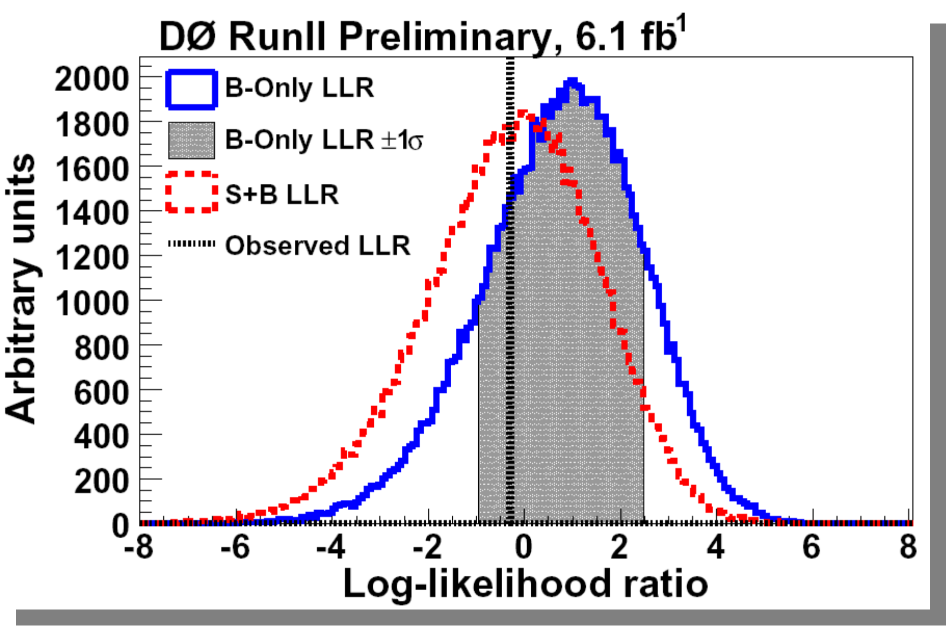
Yields from 4.4 fb-1 data sample at CDF

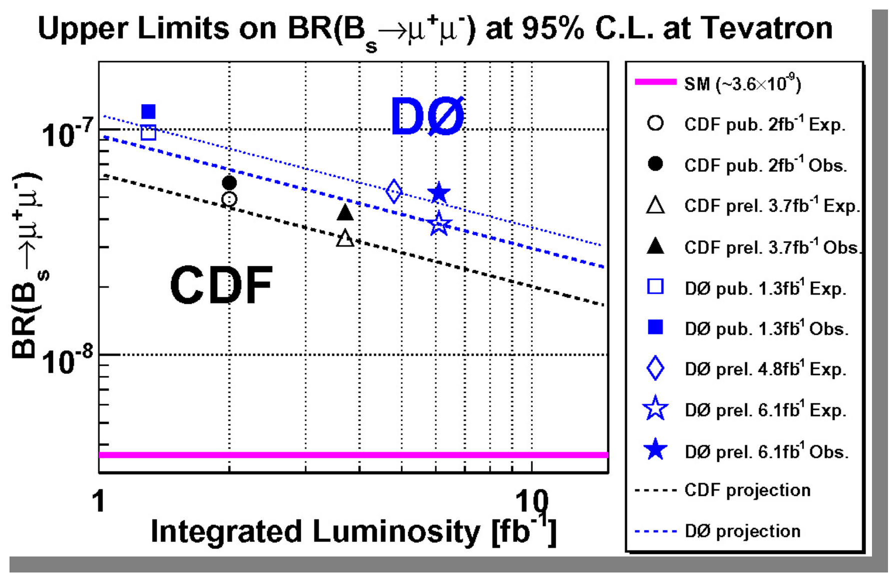


Searching for New Phyiscs: Rare B decays
$B_s \to \mu^+\mu^-$ Latest results from D0 6.1 fb^{-1}

- Analysis strategy: select events from muon trigger with appropriate mass range, apply muon quality cuts and account for fakes from K, π, p
- Feed vertexing, lifetime, p_T, fragmentation information into Neural Net

Result: $Br(B_s \to \mu^+\mu^-) < 5.2\times 10^{-8}$ at 95% CL

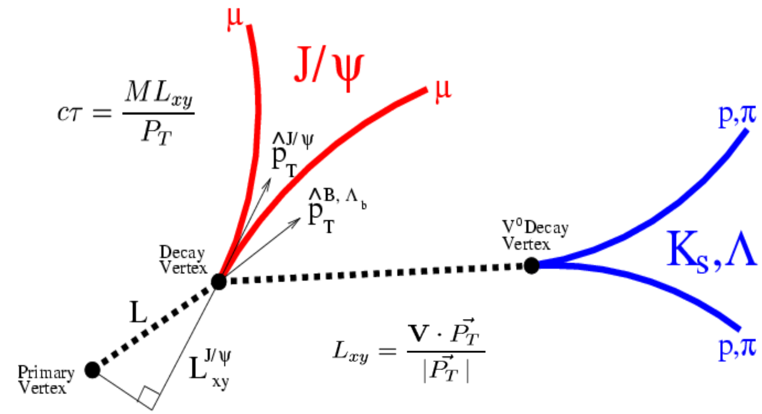




B Hadron lifetimes from fully reconstructed decays with J/Ψs in the final state…

J/ψ→μμ decays are used to find large samples of B decays

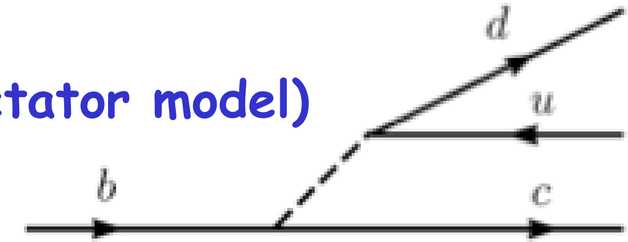
$B^+ \rightarrow J/\Psi\ K^+$	45000 ± 230
$B^0 \rightarrow J/\Psi\ K^*$	16860 ±140
$B^0 \rightarrow J/\Psi\ K_s$	12070 ±120
$\Lambda_b \rightarrow J/\Psi\ \Lambda$	1710+50



Displaced vertices and fully reconstructed decays used to measure some of the world's best lifetime measurements and ratios:

$\tau(\Lambda^0_b)$ = 1.537±0.045 (stat) ±0.014 (syst) ps
$\tau(\Lambda^0_b)/\tau(B0)$ =1.020±0.030(stat)±0.008(syst)
τ(B+)= 1.639 ± 0.009(stat)± 0.009 (syst) ps
τ(B0)= 1.507 ± 0.010(stat)± 0.008 (syst) ps)
τ(B+)/τ(B0)= 1.088 ± 0.009(stat)± 0.004 (syst)
We can make precision measurements… & HQE is a reliable framework…

Confidence in our methods: B Hadron lifetime measurements

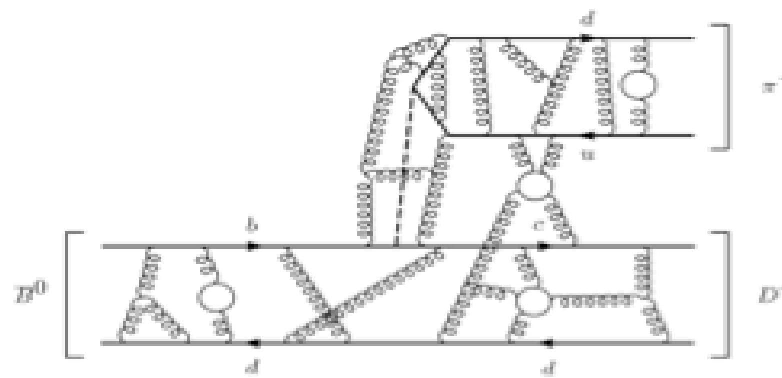


Naively all B hadrons have the same lifetime (spectator model)

Difference due to light quark interactions

Prediction from Heavy Quark Expansion (HQE)

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



Ratio Predictions from HQE:

$\tau(B^+) = 1.063 \pm 0.027\ \tau(B_d)$

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

Precision lifetime measurements are important for understanding interactions of quarks inside hadrons and so are check of HQE

HQE is used to calculate width off diagonal elements of the neutral B mixing matrix (for example) Γ_{12} and hence predict several phenomena

-Checks of HQE are very crucial as its predictions allow us to identify NP

-Lifetime measurements allow a test of our capabilities to make precision measurements relevant for NP (oscillation, width differences)

A.Lenz arXiv:0802.0977

Searching for new physics $B_s \to \phi\phi$: Polarization

$Bs \to \phi\phi$ final state has two vector mesons

Angular distributions can be described by:

Helicity basis: each V meson can have helicity +1(H+), 0(H0),-1(H-)

Transversity basis V meson polarizations either:

- transverse, perpendicular to each other: $A^{\perp}$ ~ H+ + H-
- parallel to each other: $A\|$ ~ H+ - H-
- longitudinal (A0 = H0)

V-A nature of weak interactions and helicity conservation in QCD predict that (*A0/H0*) should dominate in $B \to VV$ decays, while transverse component is suppressed by m_V/m_B, this is seen in $B \to \rho\rho$ at the B-factories but not in decays containing an s quark eg. $B \to \phi K^*$ makes it important to check $B_s \to \phi\phi$ ("polarization puzzle")

-Angular variables are polar angles of K^+ in each ϕ_1 ϕ_2 rest frames (θ_1,θ_2) and the angle Φ between ϕ_1 ϕ_2 decay plane. Strong phase =

-Identities 1,2 are alternated randomly for Bose symmetrisation.

-CP content means each angular function is associated with either $B_{s,long}$ or $B_{s,short}$ lifetime, these are integrated over

-CP violating phase is assumed to be 0.

Tevatron is performing like never before

Initial Luminosities routinely above 350E10^{30}cm^{2}s-1

Performance:

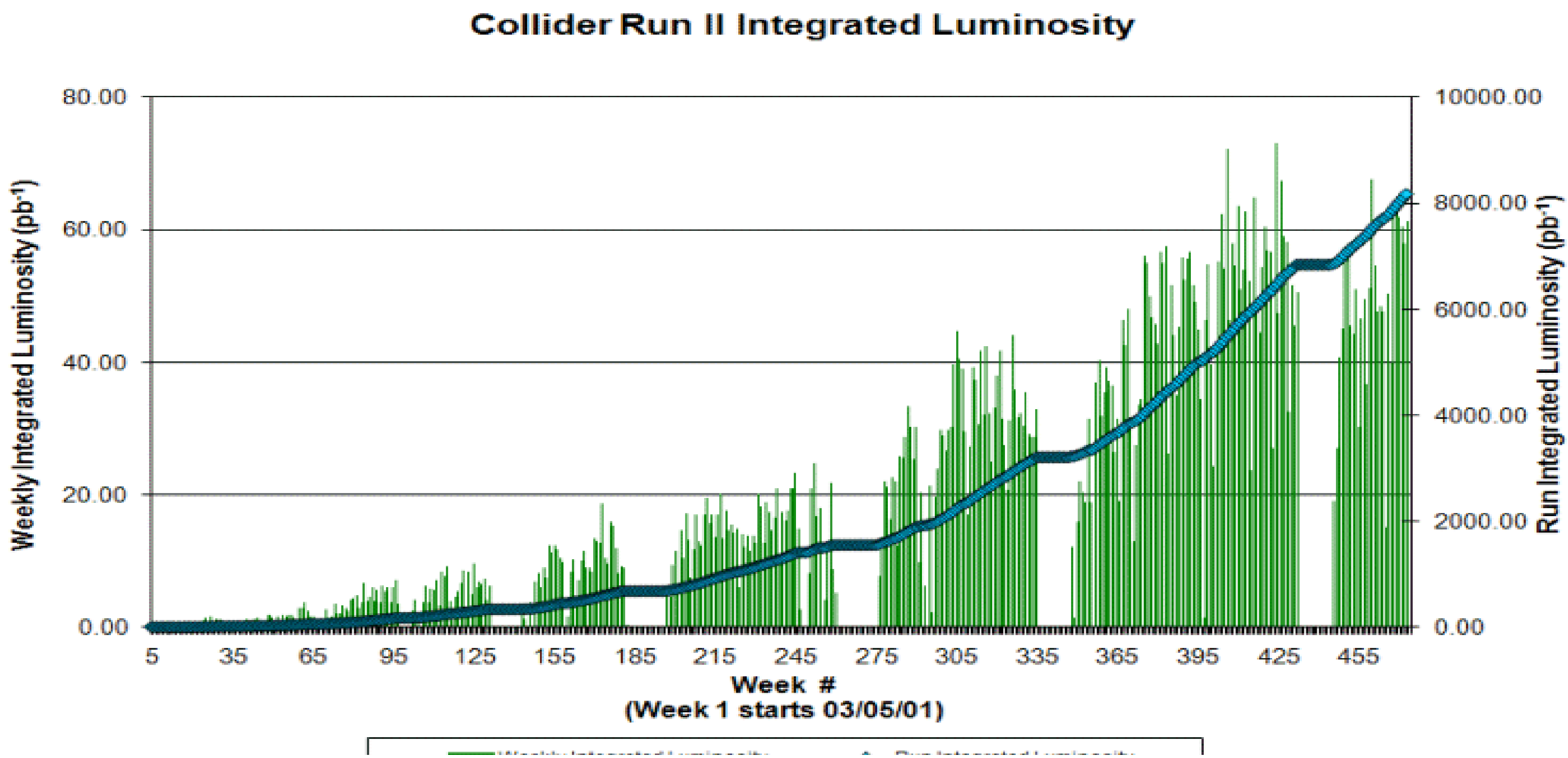
-Collision rate: 396 ns

- Bunches: 36x36

-Center of Mass energy: 1.96 TeV/c^{2}

~14 fb-1 on tape at CDF & D0
Taking > 50 pb-1 per week…
Expect > 18 fb-1 at run end in 2011

Results in this talk:
CDF analyses ~4-6 fb^{-1}
DØ analyses ~4-6 fb^{-1}



Searching for New Physics: CP violation in mixing D0 measurement of A_{sl}

Raw di-muon and inclusive single muon asymmetries are measured in data:

$$A \equiv \frac{N^{++} - N^{--}}{N^{++} + N^{--}} \qquad a \equiv \frac{n^+ - n^-}{n^+ + n^-}$$

Factors K and k express dilution due to other sources of muons: $A = KA^b_{sl} + A_{bkg}$ and $a = ka^b_{sl} + a_{bkg}$ and are determined from simulation, $K=0.342\pm0.023$, $k=0.041\pm0.003$ (a is background dominated)

The terms A_{bkg} and a_{bkg} contain the fractions (f,F) of K,π,p misidentified as μ associated charge asymmetries (a,A):

$$a_{bkg} = f_K a_K + f_\pi a_\pi + f_p a_p + (1-f_{bkg})\delta$$

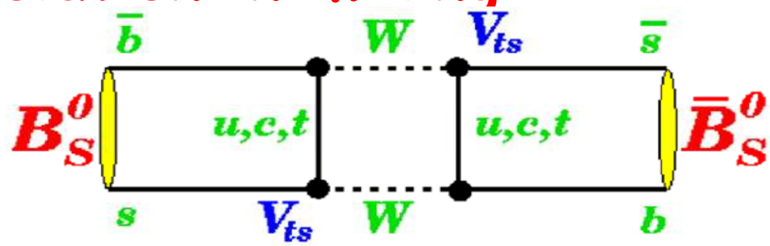
$$A_{bkg} = F_K A_K + F_\pi A_\pi + F_p A_p + (2-F_{bkg})\Delta$$

…and the δ, and Δ are muon reconstruction charge asymmetries

A_k,a_k are the largest since: cross section of K^+ vs K^- with matter in the detector thus: positive asymmetry from decays in flight of $K^+ \rightarrow$ is measured in data.

Searching for New Physics: CP violation, anomalous charge asymmetry from D0 : CP violation in mixing

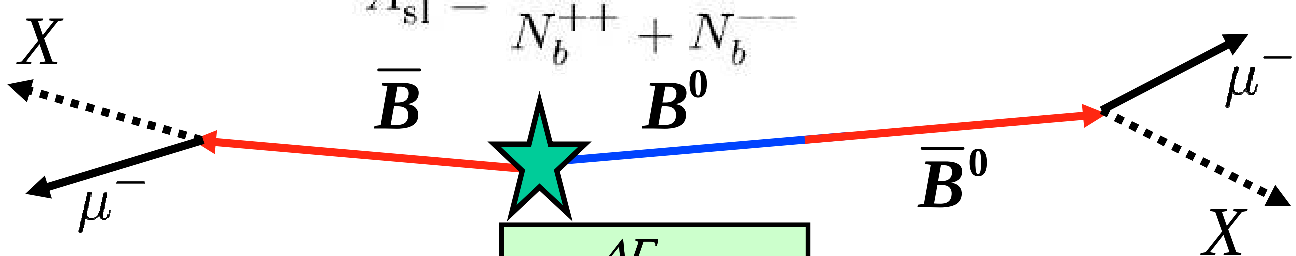
Mixing of B^0, B_s mesons proceeds via the box diagram, extra SM particles can also contribute



The asymmetry : $a^b_{\rm sl} \equiv \dfrac{\Gamma(\bar{B} \to \mu^+ X) - \Gamma(B \to \mu^- X)}{\Gamma(\bar{B} \to \mu^+ X) + \Gamma(B \to \mu^- X)} = A^b_{\rm sl}$

Can be extracted from like signed dimuon pairs using tagged semileptonic B-decays. One muon tags the flavour Of the semileptonically decaying neutral B, such a like signed pair means that one of the neutral B mesons has mixed

$$A^b_{\rm sl} \equiv \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}}$$



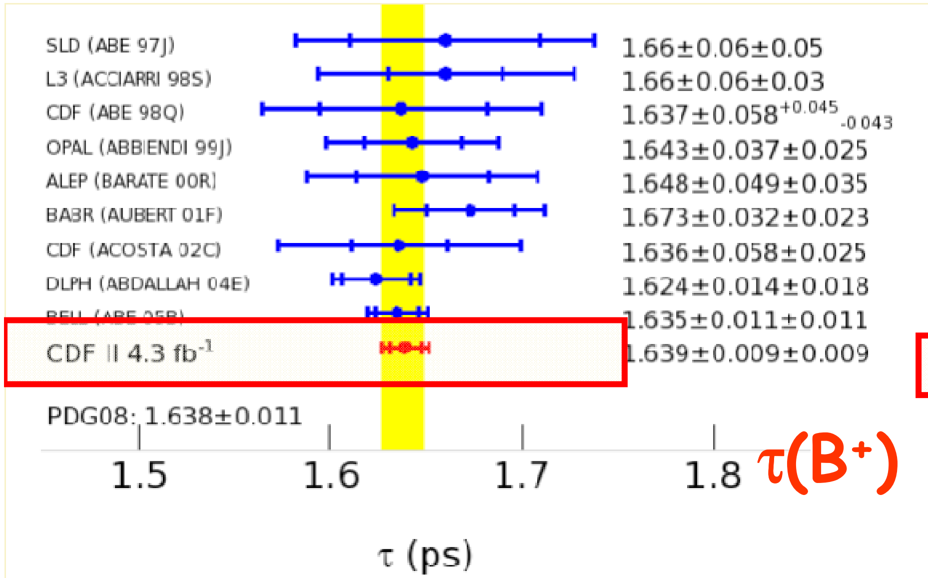
This asymmetry is equal to $a^q_{sl} = \dfrac{\Delta\Gamma_q}{\Delta M_q}\tan(\phi_q)$

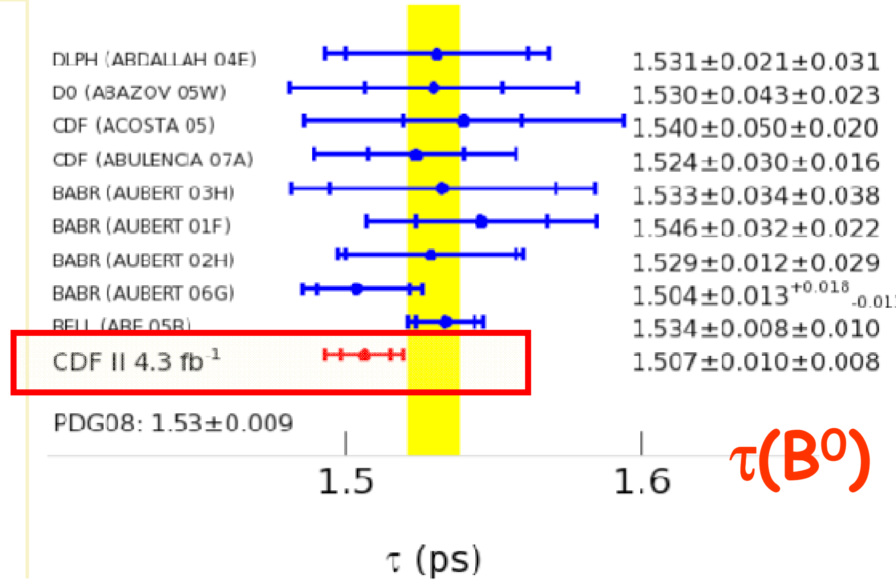
where q=d,s ϕ_q is the CP violating phase

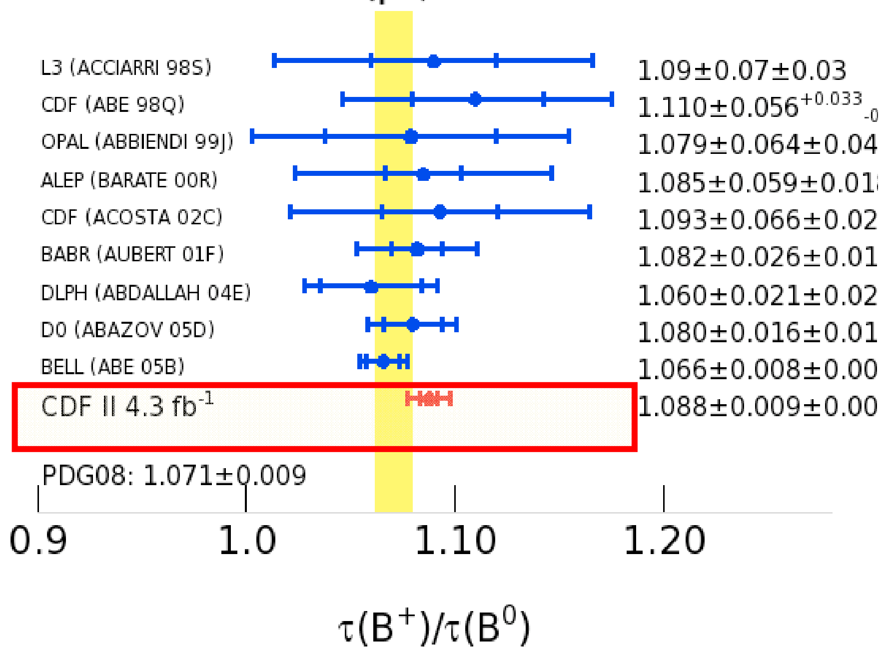
In the standard model this is calculated to be: $A^b_{sl} = (-2.3^{+0.5}_{-0.6}) \times 10^{-4}$

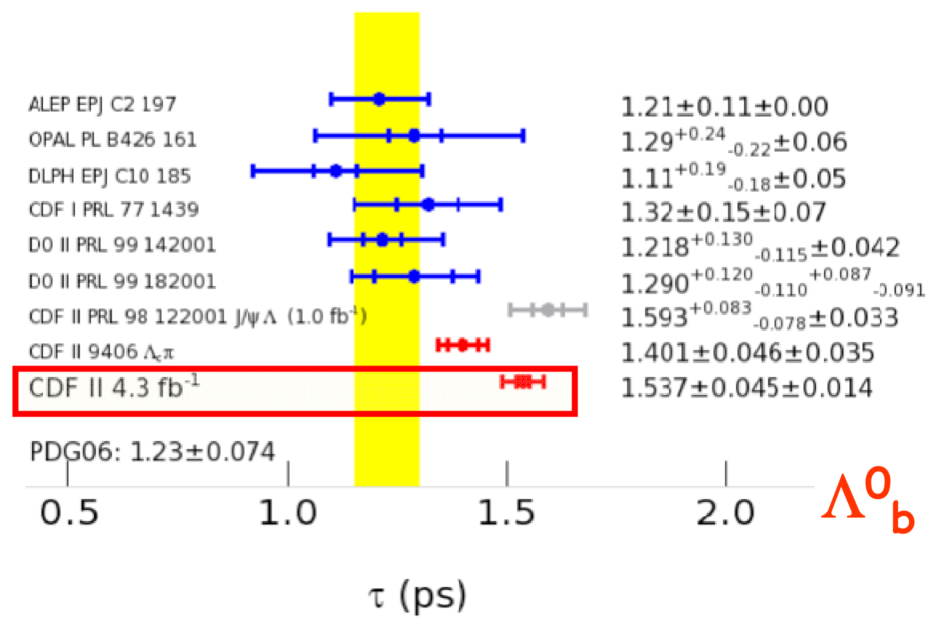
A. Lenz, U. Nierste, hep-ph/0612167

B hadron lifetime: All results summary









Searching for New Physics: CP violation in mixing D0 measurement of A_{sl}

Raw di-muon and inclusive single muon asymmetries are measured in data:

$$A \equiv \frac{N^{++} - N^{--}}{N^{++} + N^{--}} \qquad a \equiv \frac{n^{+} - n^{-}}{n^{+} + n^{-}}$$

Factors K and k express dilution due to other sources of muons: $A = KA^{b}_{sl} + A_{bkg}$ and $a = ka^{b}_{sl} + a_{bkg}$ and are determined from simulation, K=0.342±0.023, k=0.041±0.003 (a is background dominated)

The terms A_{bkg} and a_{bkg} contain the fractions (f,F) of K,π,p misidentified as μ associated charge asymmetries (a,A):

$$a_{bkg} = f_K a_K + f_\pi a_\pi + f_p a_p + (1-f_{bkg})\delta$$

$$A_{bkg} = F_K A_K + F_\pi A_\pi + F_p A_p + (2-F_{bkg})\Delta$$

…and the δ, and Δ are muon reconstruction charge asymmetries

A_k, a_k are the largest since: cross section of K^+ vs K^- with matter in the detector thus: positive asymmetry from decays in flight of $K^+ \rightarrow$ is measured in data.

B hadron lifetime: All results

World's most precise Λ^0_b lifetime measurement

With 4.3 fb^{-1} the Λ^0_b lifetime remains higher than previous measurements.

Measured Ratio: $\tau(\Lambda^0_b)/\tau(B^0)$ =1.020±0.030(stat)±0.008(syst)

Theory: $\tau(\Lambda^0_b)/\tau(B^0)$ =0.88±0.05 (A.Lenz, arXiv:0802.0977)

Some theories favour higher ratio 0.9-1.0 (I.I Bigi,hep-ph/0001003)

World's most precise measurement of $\tau(B^+)$, $\tau(B^0)$ & ratio $\tau(B^+)/\tau(B^0)$
$\tau(B^+)$= 1.639 ± 0.009(stat)± 0.009 (syst) ps
($\tau(B^0)$= 1.507 ± 0.010(stat)± 0.008 (syst) ps)
$\tau(B^+)/\tau(B^0)$= 1.088 ± 0.009(stat)± 0.004 (syst)

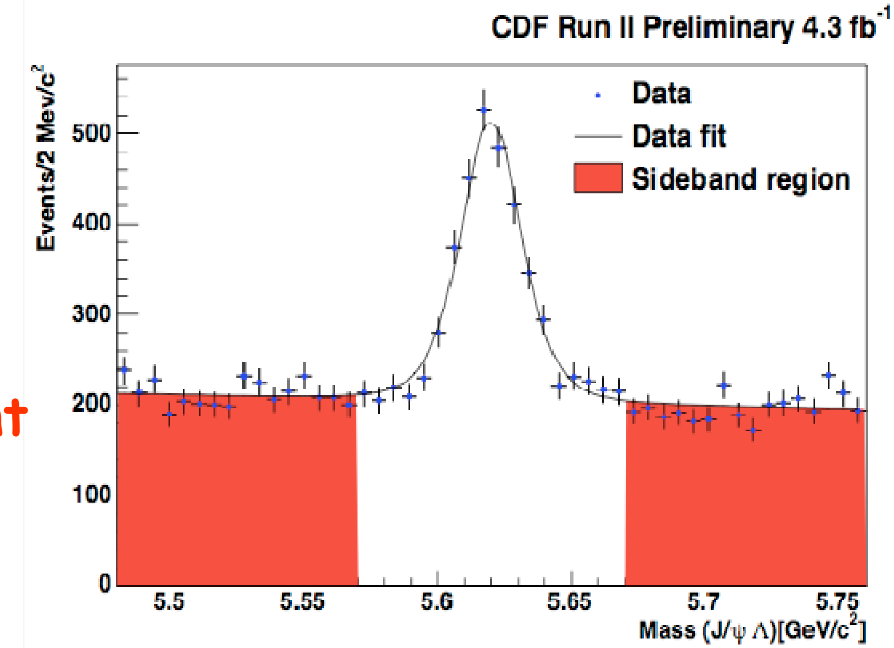
In agreement with theoretical prediction:

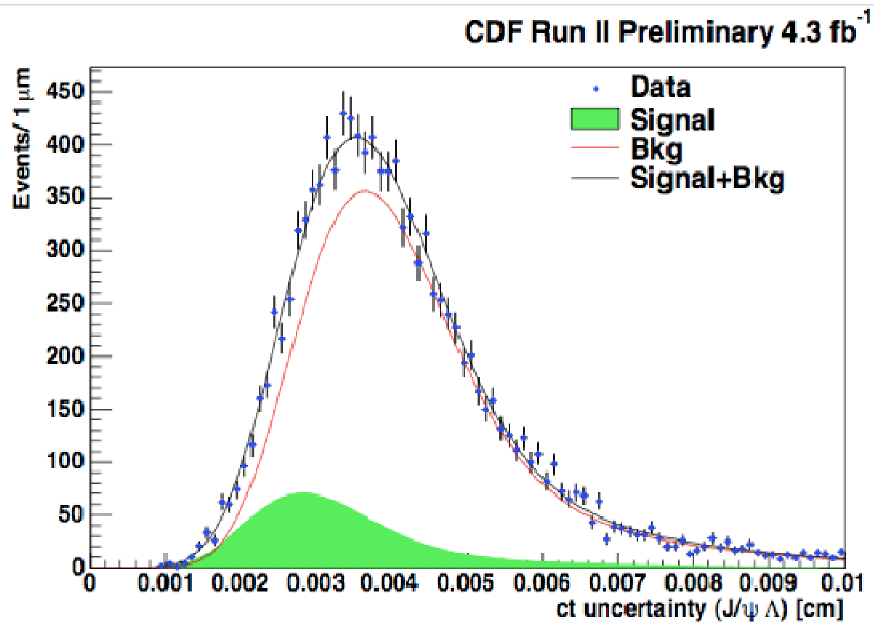
$\tau(B^+)/\tau(B^0)$ =(1.063±0.027) (theory)

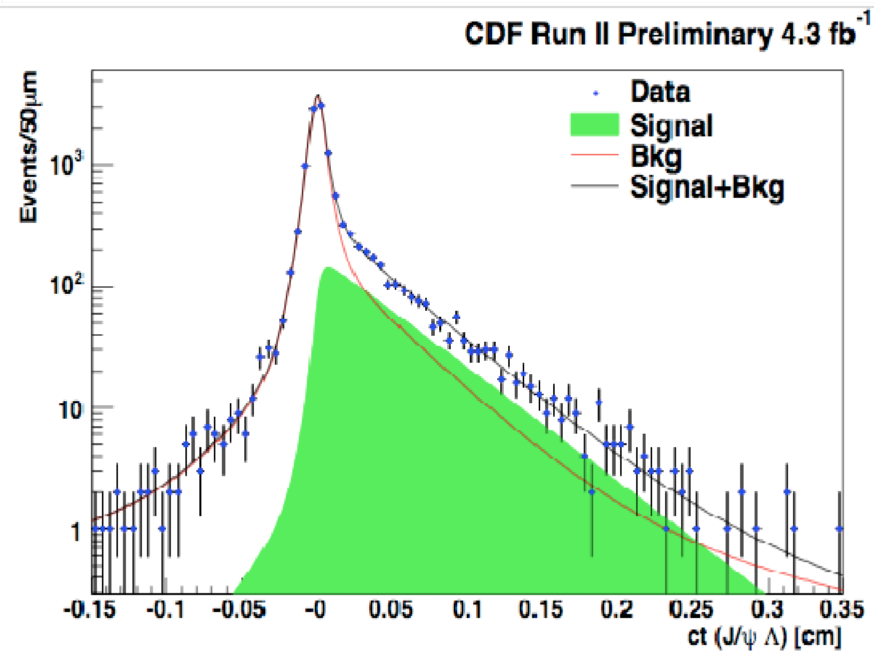
B hadron lifetimes: Λ^0_b Fit Projections

$\tau(\Lambda^0_b)$ = 1.537±0.045±0.014 ps
(first uncertainty is statistical second systematic)

This is the world's best measurement of the Λ_b lifetime







The CDF & D0 Detectors in Run-II

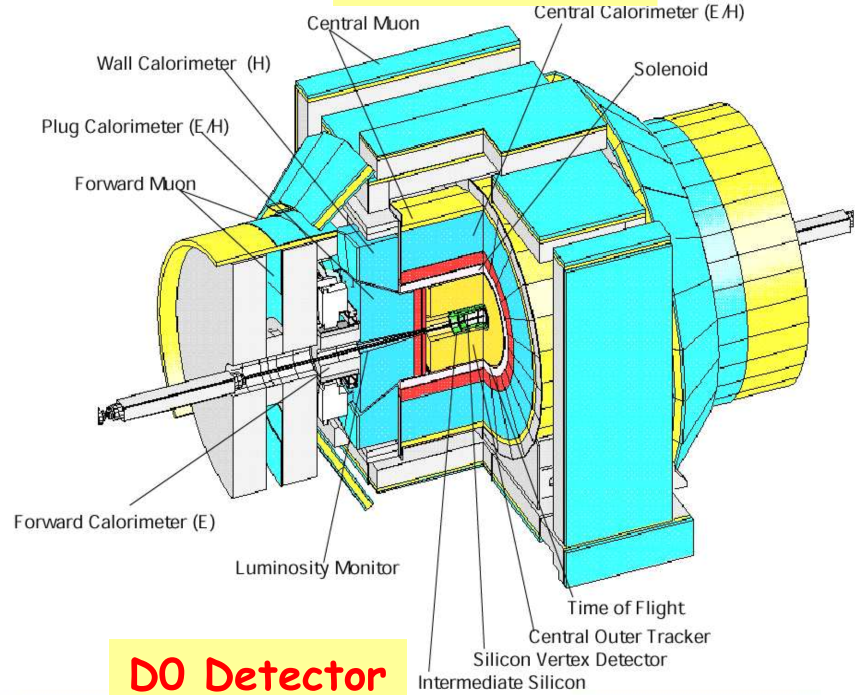
CDF & D0 Detectors are both Multi-purpose with:

- -Axial Solenoid
- -Inner Silicon micovertex detectors
- -Outer trackers
- -Calorimetry
- -Muon ID
- -Muon Triggering
- -High IP Track triggering

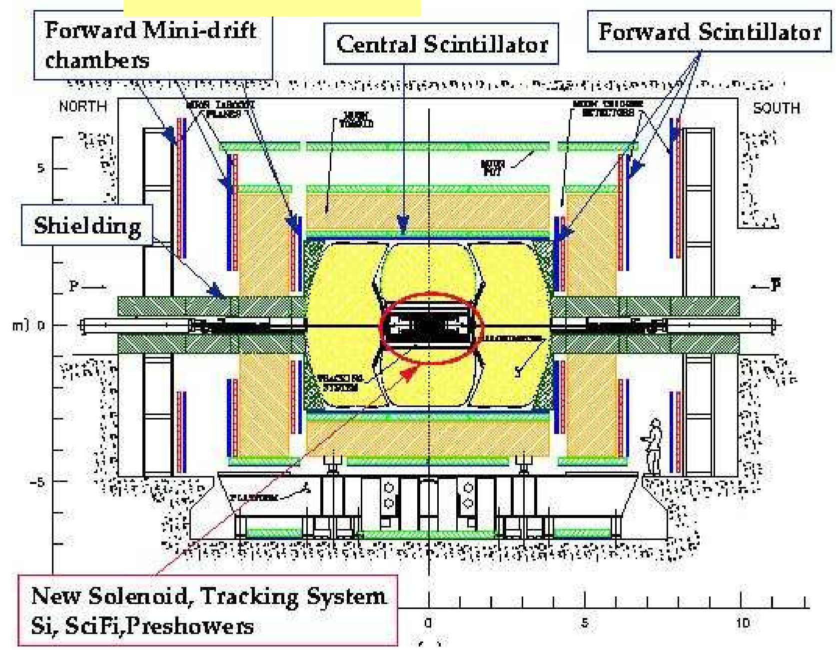
D0: Better calorimetry, better muon & tracking coverage. Figures of merit ?

CDF: Better momentum measurement, also can select high IP tracks, some Hadron ID with dE/dX, TOF
Figures of merit ?

CDF Detector



D0 Detector



Bs -> ϕϕ polarization variables

- Polarization measurement performed
  - without attempting to identify B_s flavor at production (un-tagged analysis) and
  - assuming CP violation phase $\Phi_s = 0$

- Decay rate

$$\frac{d^4\Lambda(\vec{\omega},t)}{dt\,d\vec{\omega}} = \frac{9}{32\pi}\sum_{i=1}^{6} K_i(t) f_i(\vec{\omega})$$

in helicity basis:

$$f_1(\vec{\omega}) = 4\cos^2\vartheta_1\cos^2\vartheta_2$$
$$f_2(\vec{\omega}) = \sin^2\vartheta_1\sin^2\vartheta_2(1+\cos 2\Phi)$$
$$f_3(\vec{\omega}) = \sin^2\vartheta_1\sin^2\vartheta_2(1-\cos 2\Phi)$$
$$f_4(\vec{\omega}) = -2\sin^2\vartheta_1\sin^2\vartheta_2\sin 2\Phi$$
$$f_5(\vec{\omega}) = \sqrt{2}\sin 2\vartheta_1\sin 2\vartheta_2\cos\Phi$$
$$f_6(\vec{\omega}) = -\sqrt{2}\sin 2\vartheta_1\sin 2\vartheta_2\sin\Phi$$

- After time integration:

$$g_s^{(\omega)} = \frac{d^3\Lambda(\vec{\omega})}{d\vec{\omega}} = \frac{9}{32\pi}\frac{1}{\tilde{W}}\left[\tilde{\mathcal{F}}_e(\vec{\omega}) + \tilde{\mathcal{F}}_o(\vec{\omega})\right]$$

where:

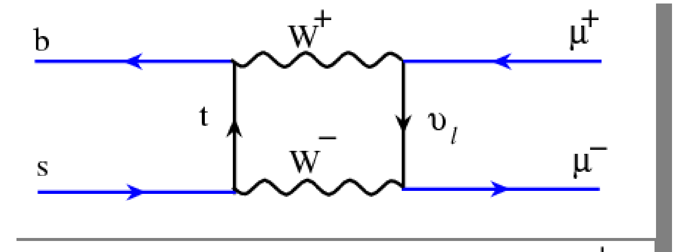
$$\tilde{\mathcal{F}}_e = \frac{2}{\Gamma_L}\left[|A_0|^2 f_1(\vec{\omega}) + |A_\parallel|^2 f_2(\vec{\omega}) + |A_0||A_\parallel|\cos\delta_\parallel f_5(\vec{\omega})\right]$$
$$\tilde{\mathcal{F}}_o = \frac{2}{\Gamma_H}|A_\perp|^2 f_3(\vec{\omega})$$
$$\tilde{W} = \frac{|A_0|^2 + |A_\parallel|^2}{\Gamma_L} + \frac{|A_\perp|^2}{\Gamma_H}$$

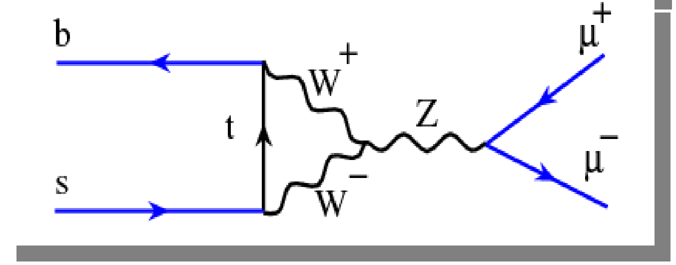
$$\delta_\parallel = \arg(A_0^\star A_\parallel)$$
$$\delta_\perp = \arg(A_0^\star A_\perp)$$

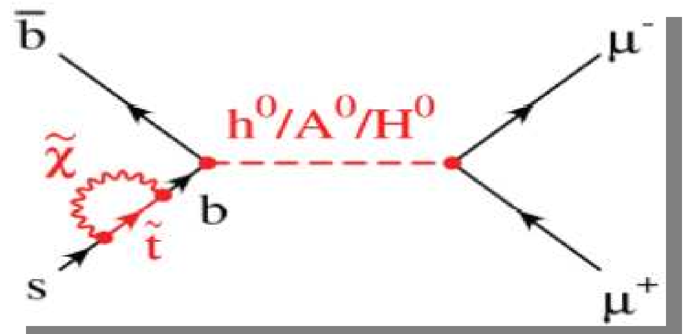
OBSERVABLES

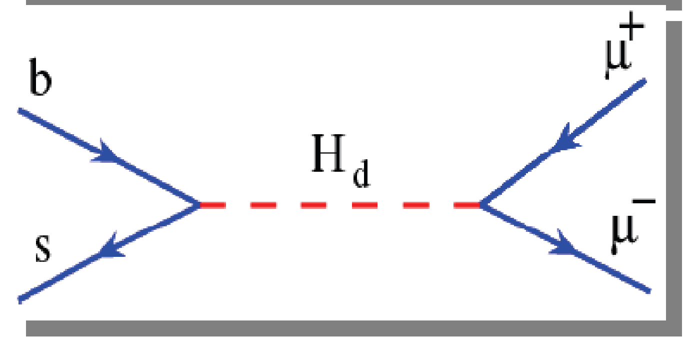
$B \rightarrow \mu^+\mu^-$

- SM prediction :
  A.J.Buras, hep-ph/0904.4917:
  - $BR(B_s \rightarrow \mu^+\mu^-) = (3.6 \pm 0.3) \times 10^{-9}$
  - $BR(B^0 \rightarrow \mu^+\mu^-) = (1.1 \pm 0.1) \times 10^{-10}$
    suppressed by $|V_{td}/V_{ts}|^2$
- Can be enhanced by
  - **MSSM** ($BR(B \rightarrow \mu^+\mu^-) \propto \tan^6 \beta$)
  - **GUT SO(10)**
  - **SUSY R-parity violating models**
  - **Non-minimal flavor violating model**
- SM signal is beyond the detectors' sensitivity at Tevatron
  - Current observation of $B \rightarrow \mu^+\mu^-$ would imply new physics









Bs phiphi branching ratio

$$N_{\phi\phi} = 295 \pm 20(\text{stat}) \pm 12(\text{syst})$$
$$N_{J/\psi\phi} = 1766 \pm 48(\text{stat}) \pm 41(\text{syst})$$

$$\frac{\mathcal{B}(B_s^0 \to \phi\phi)}{\mathcal{B}(B_s^0 \to J/\psi\phi)} = [1.78 \pm 0.14(stat) \pm 0.20(syst)] \cdot 10^{-2}$$

$$\mathcal{B}(B_s^0 \to \phi\phi) = [2.40 \pm 0.21(stat) \pm 0.27(syst) \pm 0.82(BR)] \cdot 10^{-5}$$

- Signal yields:

Systematic uncertainties

	$B_s^0 \to \phi\phi$	$B_s^0 \to J/\psi\phi$
	$\Delta N_{\phi\phi}/N_{\phi\phi}$	$\Delta N_{J/\psi\phi}/N_{J/\psi\phi}$
fit range	3%	-
signal parametrization	3%	2%
background subtraction: error on BRs	1%	1%
	$\Delta\varepsilon_{\phi\phi}/\varepsilon_{\phi\phi}$	$\Delta\varepsilon_{J/\psi\phi}/\varepsilon_{J/\psi\phi}$
polarization in MC	7%	6%
	$\Delta\varepsilon_{\phi\phi}/\varepsilon_{J/\psi\phi}$	
XFT particle dep.	4%	
p_T re-weight	0.9%	
	$\Delta\varepsilon_{\mu}/\varepsilon_{\mu}$	
η parametrization & correlation	0.9%	

Comparison with theoretical calculations:

	$\mathcal{B}(B_s^0 \to \phi\phi) \cdot 10^5$
QCDF(1) [13]	$2.18 \pm 0.11\,^{+3.04}_{-1.70}$
QCDF(2) [13]	$1.95 \pm 0.10\,^{+1.31}_{-0.80}$
pCDF [14]	$3.53\,^{+0.83}_{-0.69}\,^{+1.67}_{-1.02}$

[13] M. Beneke, J. Rohrer and D. Yang, Nucl. Phys. B **774**, 64 (2007) [arXiv:hep-ph/0612290].
[14] A. Ali, G. Kramer, Y. Li, C. D. Lu, Y. L. Shen, W. Wang and Y. M. Wang, Phys. Rev. D **76**, 074018 (2007) [arXiv:hep-ph/0703162].

Backgrounds to φφBranching ratio. from Gavril 2.9 fb-1

- *B* decays mis-reconstructed as $B_s \rightarrow \Phi\Phi$ when a pion is mis-identified as a kaon:

$$B^0 \rightarrow \phi K^{*0} \rightarrow K^+K^-K^+\pi^-$$
$$B^0_s \rightarrow \overline{K}^{*0} K^{*0} \rightarrow K^-\pi^+K^+\pi^-$$

- Estimated as:

$$N(B^0 \rightarrow \phi K^*) = \frac{f_d}{f_s}\frac{\mathcal{B}(B^0 \rightarrow \phi K^{*0})}{\mathcal{B}(B^0_s \rightarrow J/\psi\phi)}\frac{\mathcal{B}(K^{*0} \rightarrow K^+\pi^-)}{\mathcal{B}(J/\psi \rightarrow \mu\mu)}\frac{\varepsilon^{\phi K^*}(\phi\phi)}{\varepsilon^{J/\psi\phi}}N(B^0_s \rightarrow J/\psi\phi)$$

$$N(B^0_s \rightarrow \overline{K^{*0}}K^{*0}) = \frac{\mathcal{B}(B^0_s \rightarrow \overline{K^{*0}}K^*)}{\mathcal{B}(B^0_s \rightarrow J/\psi\phi)}\frac{\mathcal{B}(K^{*0} \rightarrow K^+\pi^-)}{\mathcal{B}(J/\psi \rightarrow \mu\mu)}\frac{\mathcal{B}(K^{*0} \rightarrow K^+\pi^-)}{\mathcal{B}(\phi \rightarrow K^+K^-)}\frac{\varepsilon^{\overline{K^*}K^*}(\phi\phi)}{\varepsilon^{J/\psi\phi}} \cdot N(B^0_s \rightarrow J/\psi\phi)$$

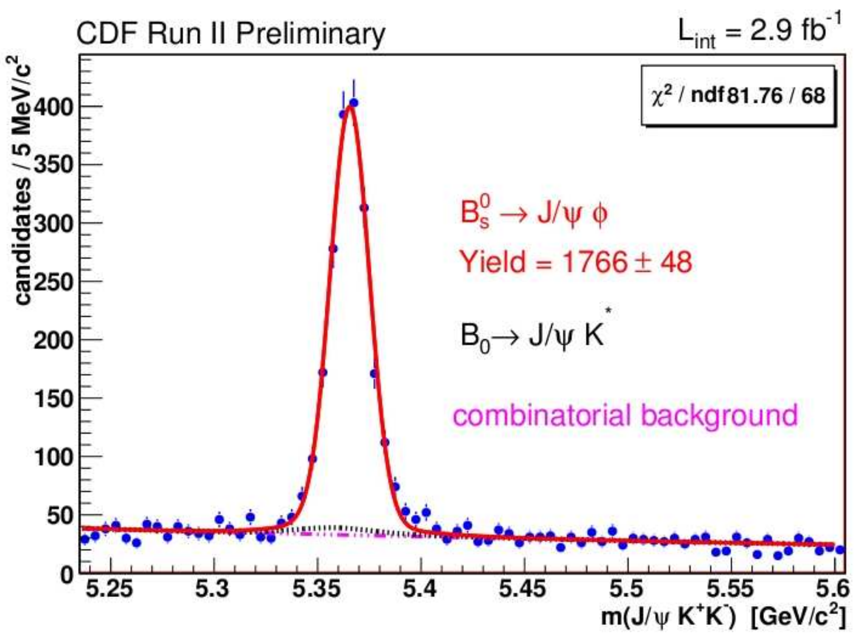
reflection	$\varepsilon(\phi\phi)$	number of events
$B^0_s \rightarrow \bar{K}^{*0}K^{*0}$	$\sim 10^{-6}$	0
$B^0 \rightarrow \phi K^{*0}$	$(0.0134 \pm 0.0002)\%$	8 ± 3

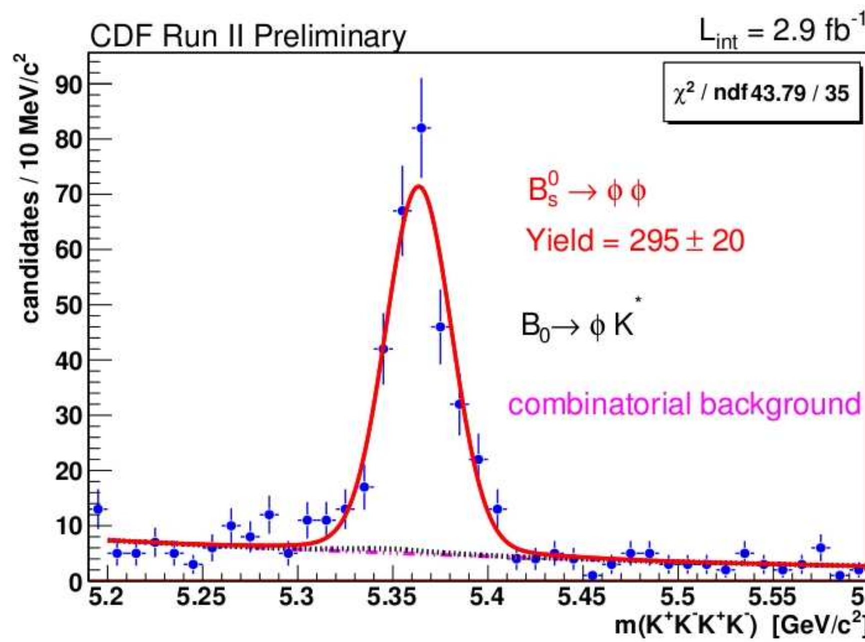
- $B^0 \rightarrow J/\Psi\, K^{*0}$ decays mis-reconstructed as $B_s \rightarrow J/\Psi\Phi$ decays

$$f_{J/\psi K^{*0}} = \frac{f_d}{f_s}\frac{\mathcal{B}(B^0 \rightarrow J/\psi K^{*0})}{\mathcal{B}(B^0_s \rightarrow J/\psi\phi)}\frac{\mathcal{B}(K^{*0} \rightarrow K^+\pi^-)}{\mathcal{B}(\phi \rightarrow K^+K^-)}\frac{\varepsilon^{J/\psi K^{*0}}(J/\psi\phi)}{\varepsilon^{J/\psi\phi}} = 0.0419 \pm 0.0093$$

Bs to phi phi yields and cuts

- Reconstruct *Φ[→KK]Φ[→KK] and Φ[→KK]J/Ψ[→μμ]* final states
- Signal selection based on optimized requirements on kinematic and topological quantities





$B_s \to J/\Psi\Phi$ selection

Variable	Cut
L_{xy}	$> 290\ \mu m$
P_T^{ϕ}	> 1.36 GeV/c
$P_T^{J/\psi}$	> 2.0 GeV/c
χ^2_{xy}	< 18
$d_0{}^B$	$< 65\ \mu m$
confirmation of ≥ 1 muon	

$B_s \to \Phi\Phi$ selection

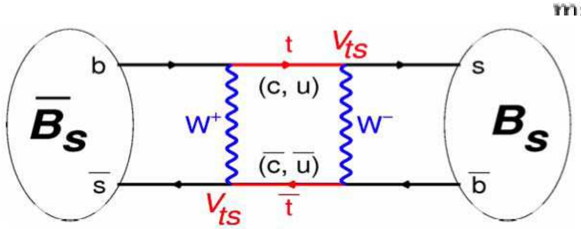
Variable	Cut
L_{xy}	$> 330\ \mu m$
$P_T^{K\ min}$	> 0.7 GeV/c
$d0^{\phi}_{max}$	$> 85\ \mu m$
χ^2_{xy}	< 17
$d_0{}^B$	$< 65\ \mu m$

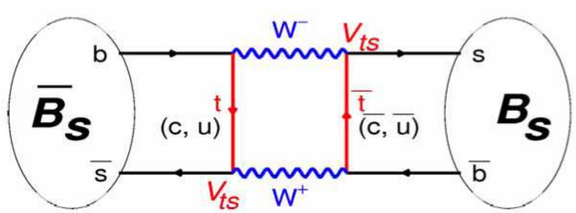
Box diagram likelihood..

$$\mathcal{L}_i = f_s \cdot P_s(m) \cdot T(t,\psi,\theta,\phi) \cdot P_s(\sigma_t) + (1-f_s) \cdot P_b(m) \cdot P_b(t,\sigma_t) \cdot P_b(\sigma_t) \cdot P_b(\psi) \cdot P_b(\theta) \cdot P_b(\phi)$$

$$\rho_B(\theta,\phi,\psi,t,\mu) = \frac{9}{16\pi} \left| \left[\sqrt{1-F_s}\, h(\mu) \mathbf{A}(t) + e^{i\delta_s} \sqrt{F_s} \frac{g(\mu)}{\sqrt{3}} \mathbf{B}(t) \right] \times \hat{n} \right|^2$$

$$i\frac{d}{dt}\begin{pmatrix} B_s^0(t) \\ \overline{B}_s^0(t) \end{pmatrix} = H \begin{pmatrix} B_s^0(t) \\ \overline{B}_s^0(t) \end{pmatrix} \equiv \Bigg[\underbrace{\begin{pmatrix} M_0 & M_{12} \\ M_{12}^* & M_0 \end{pmatrix}}_{\text{mass matrix}} - \frac{i}{2} \underbrace{\begin{pmatrix} \Gamma_0 & \Gamma_{12} \\ \Gamma_{12}^* & \Gamma_0 \end{pmatrix}}_{\text{decay matrix}} \Bigg] \begin{pmatrix} B_s^0(t) \\ \overline{B}_s^0(t) \end{pmatrix}$$





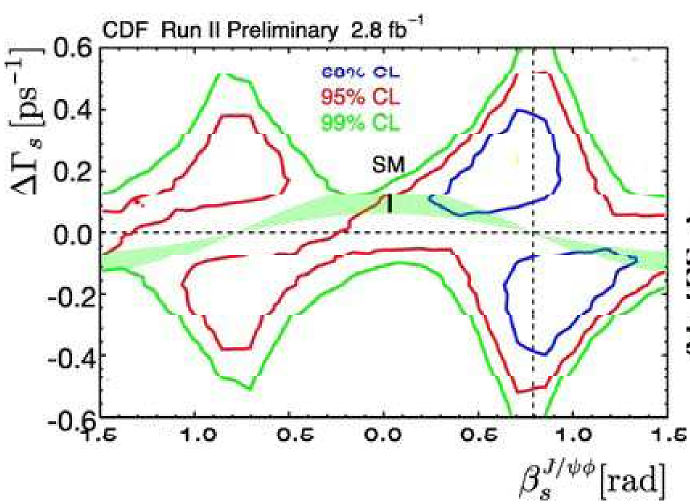
Different masses -> mixing frequency: $\Delta m_s = m_H - m_L \approx 2|M_{12}|$

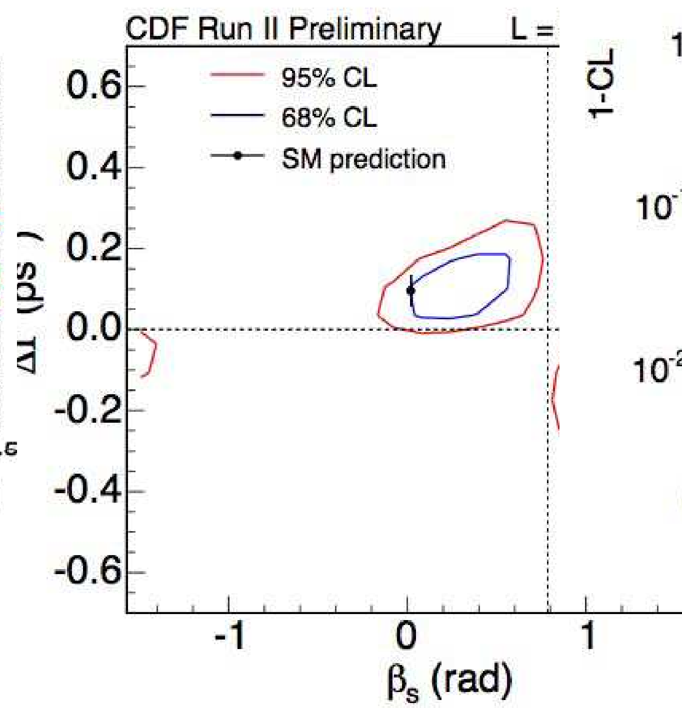
-> phase: $\varphi_s^{SM} = \arg(-M_{12}/\Gamma_{12}) \sim 0.004$

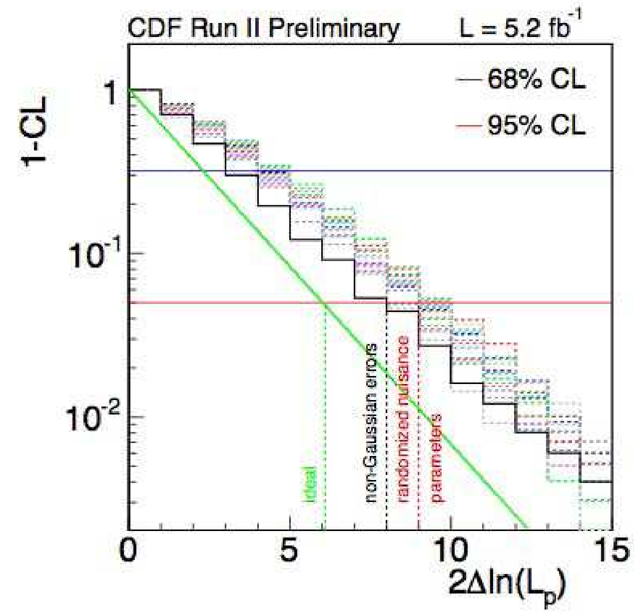
Different decay widths: $\Delta\Gamma = \Gamma_L - \Gamma_H \approx 2|\Gamma_{12}| \cos(2\varphi_s^{SM})$

$$
\begin{aligned}
c\tau_s &= 458.6 \pm 7.5\ (\text{stat.}) \pm 3.6\ (\text{syst.})\ \mu\text{m} \\
\Delta\Gamma &= 0.075 \pm 0.035\ (\text{stat.}) \pm 0.01\ (\text{syst.})\ ps^{-1} \\
|A_{\parallel}(0)|^2 &= 0.231 \pm 0.014\ (\text{stat}) \pm 0.015\ (\text{syst.}) \\
|A_0(0)|^2 &= 0.524 \pm 0.013\ (\text{stat}) \pm 0.015\ (\text{syst.}) \\
\phi_{\perp} &= 2.95 \pm 0.64\ (\text{stat}) \pm 0.07\ (\text{syst.})
\end{aligned}
$$

$$c\tau_s = 1.47^{+0.26}_{-0.27}\ \text{ps}$$

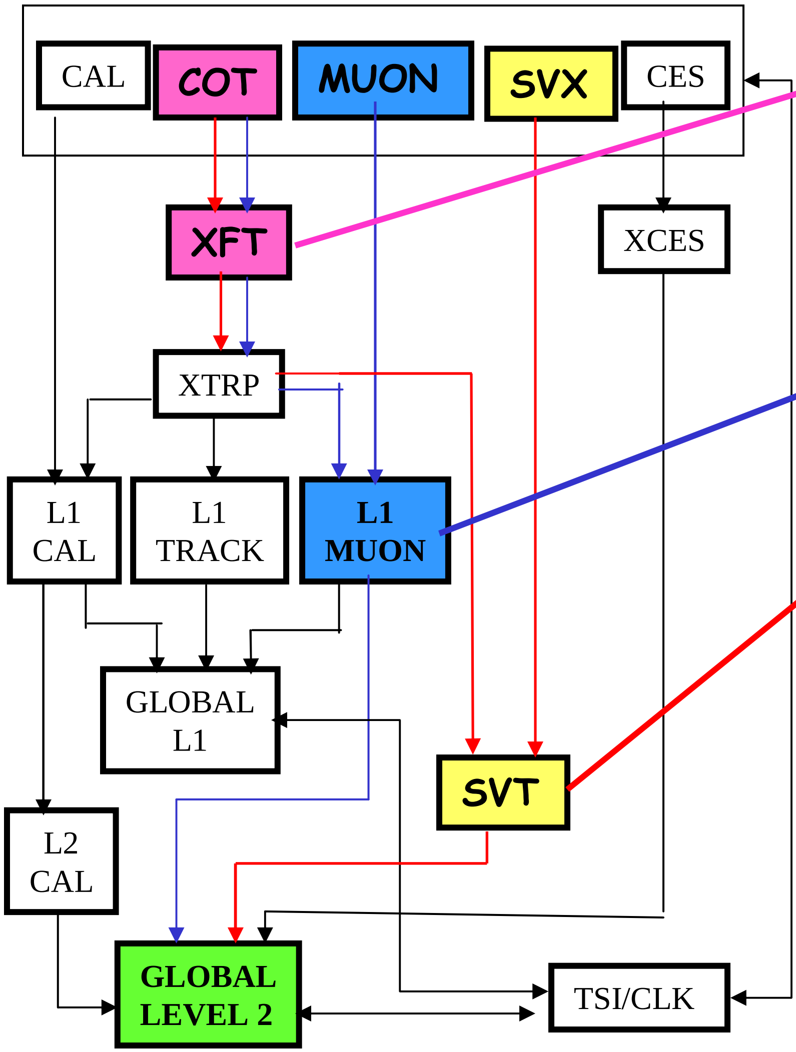






CDF II Trigger System

3 levels : 5 MHz ($p\bar{p}$ rate) → 50 Hz (disk/tape storage rate)
almost no dead time (< 10%)



XFT: "EXtremely Fast Tracker"

2D COT track reconstruction at Level 1

- P_T res. $\Delta p_T/p^2_T$ = 2% (GeV^{-1})
- azimuthal angle res. $\Delta\phi$ = 8 mrad

Matched to L1 ele. and muons

⇒ **enhanced J/ψ samples**

SVT: "Silicon Vertex Tracker"

precise 2D Silicon+XFT tracking at Level 2

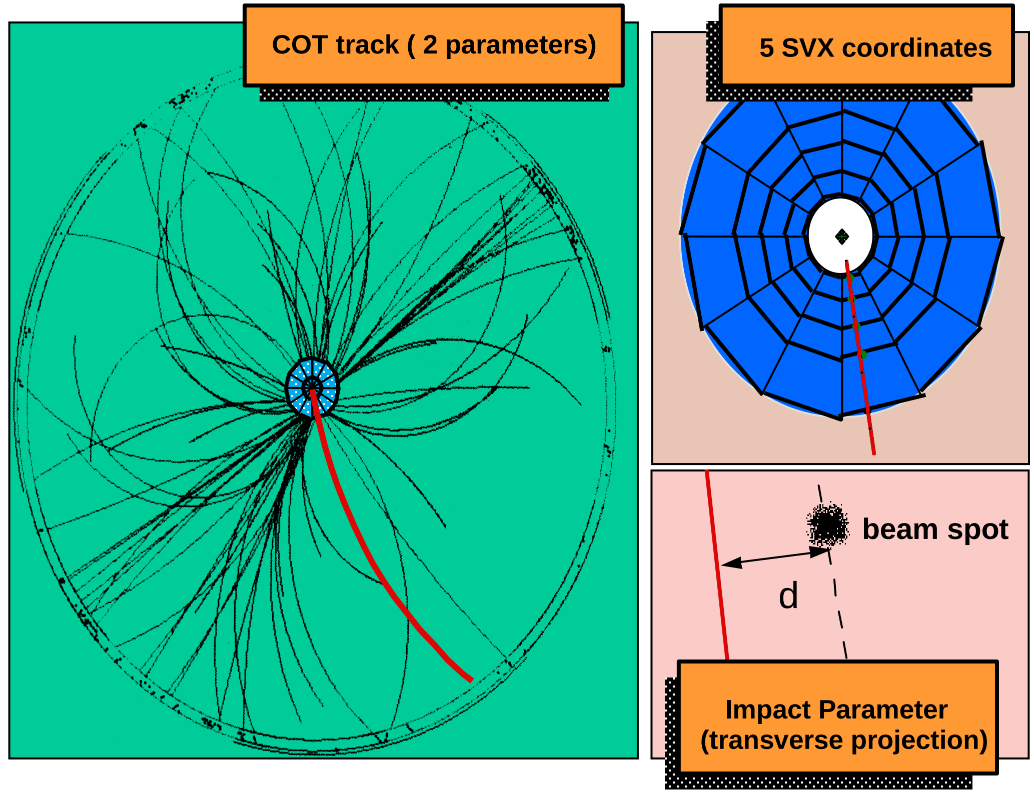
- impact parameter res. σ_d = 35 μm
  Offline accuracy !!

CDF II can trigger on secondary vertices !!

⇒ **Select large B,D samples !!**

SVT: Triggering on impact parameters

~150 VME boards



- Combines COT tracks (from XFT) with Silicon Hits (via pattern matching)
- Fits track parameters in the transverse plane (d, ϕ, P_T) <u>with offline res.</u>
- All this in ~15μs !
- Allows triggering on displaced impact parameters/vertices
- CDF becomes a beauty/charm factory

B triggers: conventional

$\sigma(b\bar{b}) / \sigma(p\bar{p}) \approx 10^{-3}$ ⇒ Need specialized triggers

CDF Run1, lepton-based triggers:

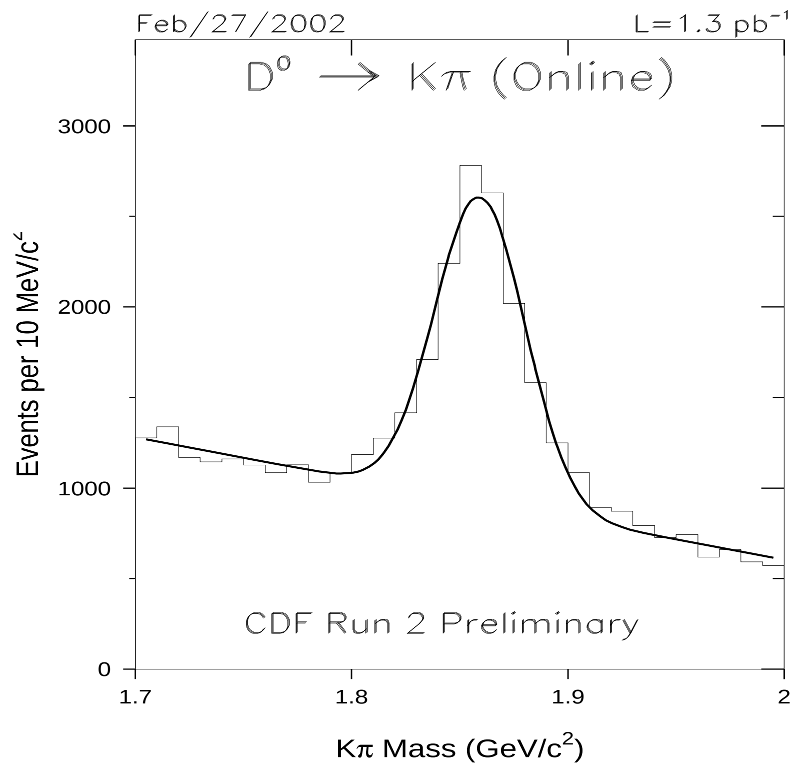
- Di-leptons ($\mu\mu$, $P_T \geq 2$ GeV/c): $B \rightarrow J/\psi\ X$, $J/\psi \rightarrow \mu\mu$
- Single high P_T lepton (≥ 8 GeV/c): $B \rightarrow l\ \nu\ D\ X$

Suffer of low BR and not fully rec. final state

Nevertheless, many important measurements by CDF 1:
B^0_d mixing, sin(2β), B lifetimes, B_c observation, …

Now enhanced, thanks to XFT (precise tracking at L1) **:**

- Reduced ($2 \rightarrow 1.5$ GeV/c) and more effective P_T thresholds
- Increased muon and electron coverage
- Also $J/\psi \rightarrow ee$


Feb/27/2002
L=1.3 pb^{-1}
$D^0 \longrightarrow K\pi$ (Online)
3000
2000
1000
0
Events per 10 MeV/c^2
CDF Run 2 Preliminary
1.7
1.8
1.9
2
$K\pi$ Mass (GeV/c^2)

ERROR: undefined
OFFENDING COMMAND:

STACK: