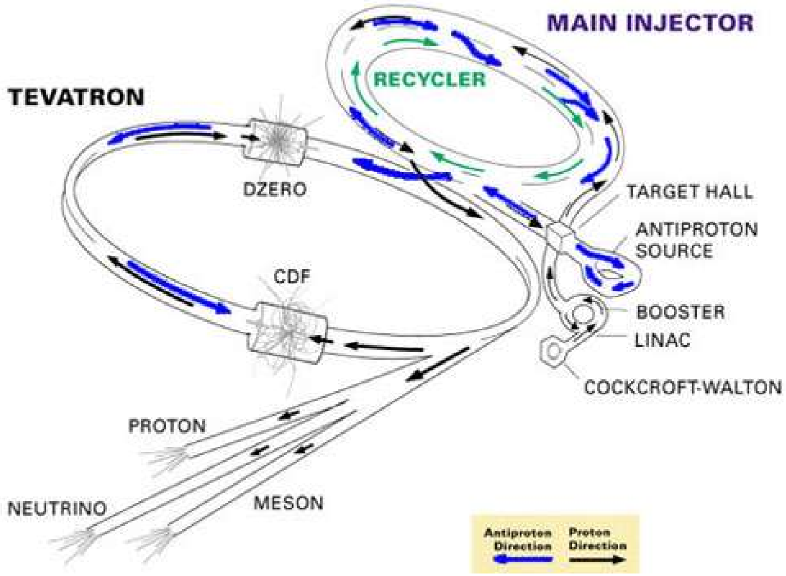
Current CDF *B* Physics Results

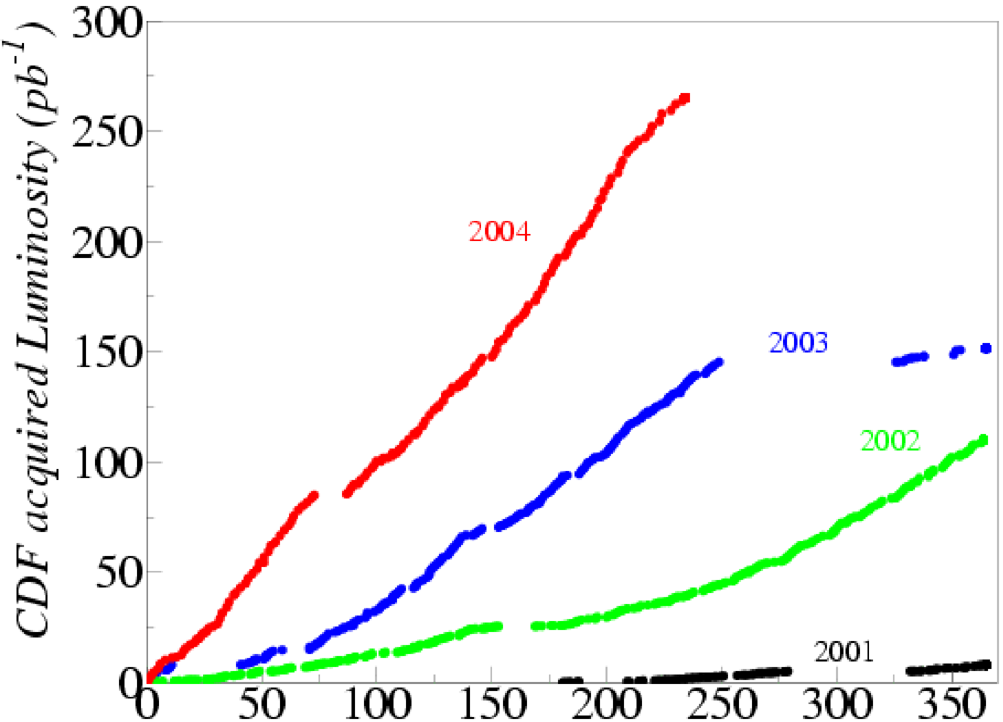
- CDF Detector
- Lifetimes, Polarization and $\Delta\Gamma_{Bs}$
- Mixing
- Charmless *B* Decay: Branching Ratios and A_{CP}
- *X* Physics
- FCNC Decay $B_s \rightarrow \mu\mu$
- Conclusion

Matthew Herndon, October 7th, 2004
Johns Hopkins University
for the CDF Collaboration
SLAC Seminar

CDF and the Tevatron

- 1.96TeV ppbar collider
  - Performance substantially improving each year
  - Record peak luminosity in 2004: $1 \times 10^{32} sec^{-1} cm^{-2}$, 2x peak in 2003
  - Expect 2x in 2005, 4-9fb^{-1} by 2009

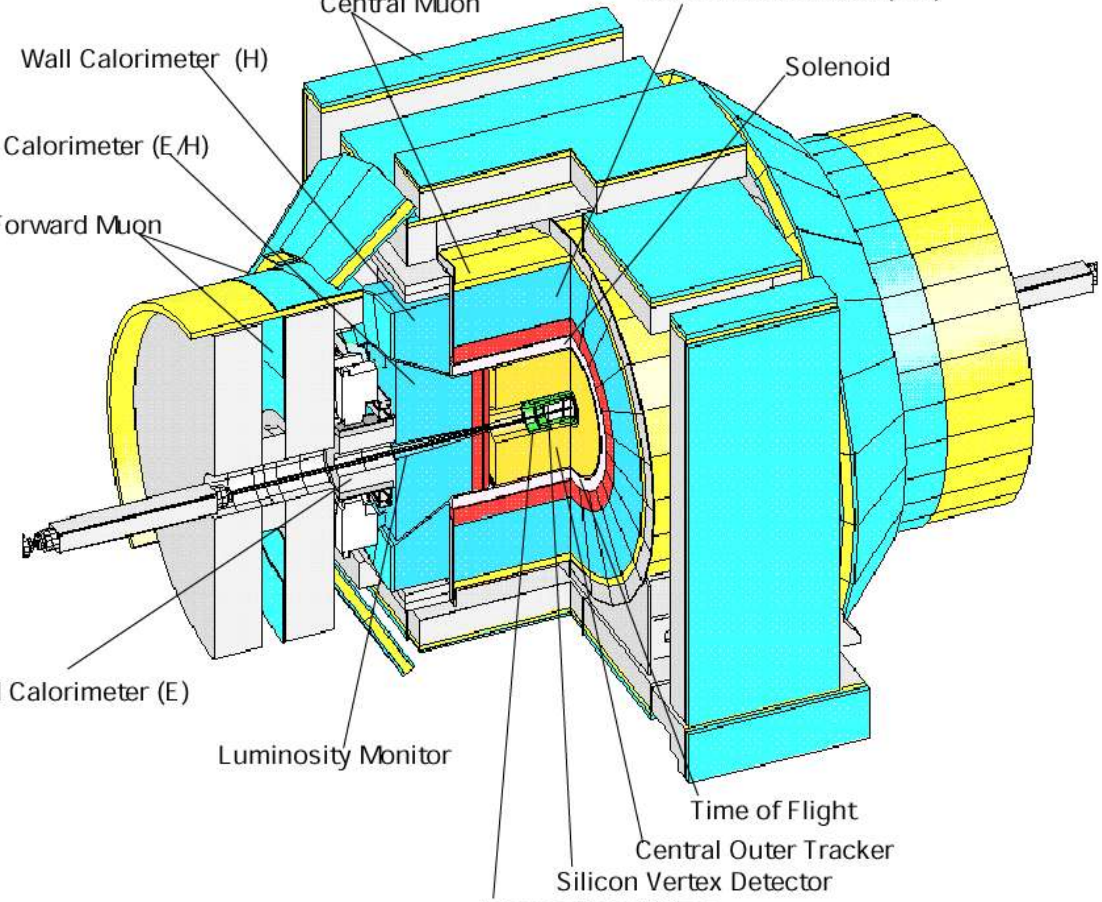




- CDF Integrated Luminosity
  - ~500pb^{-1} to tape
  - 360pb^{-1} with good run requirements
    - All critical systems operating including silicon
  - Analysis presented here use from 170pb^{-1} to 260pb^{-1}
  - Acquiring new data quickly in 2004

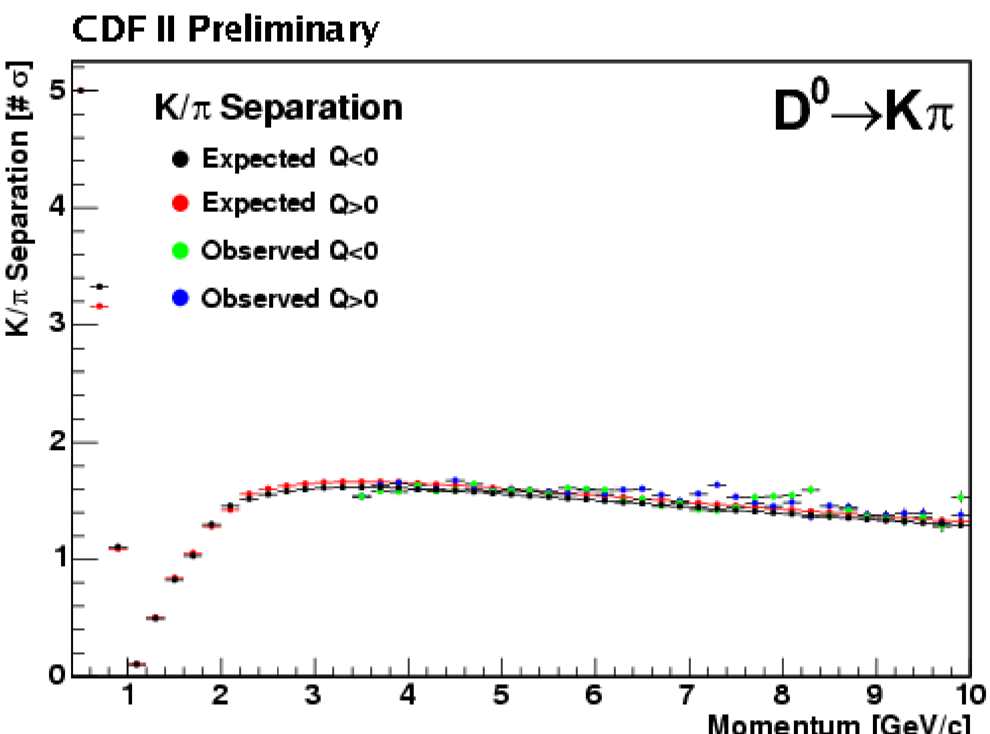
CDF Detector

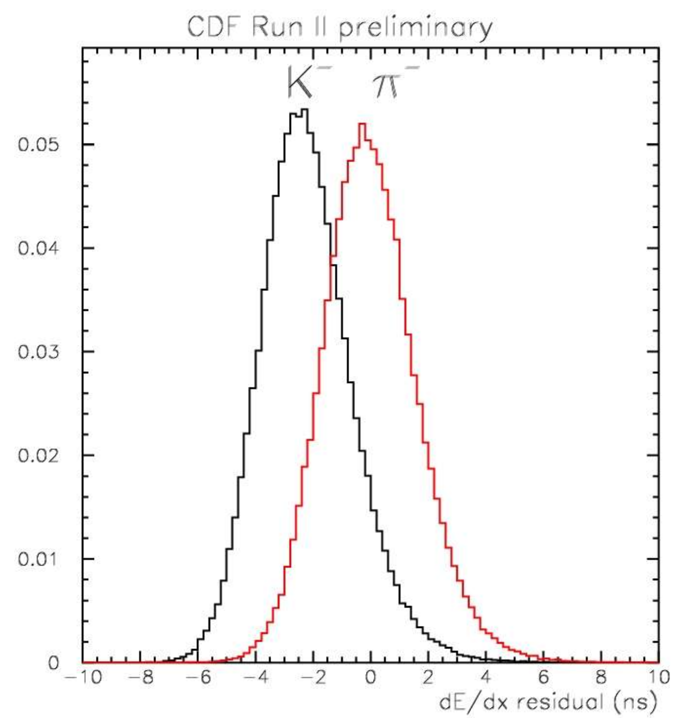
- Silicon Tracker **EXCELLENT TRACKING**
  - $|\eta|<2$, 90cm long, r_{L00} =1.3 - 1.6cm
- Drift Chamber(COT)
  - 96 layers between 44 and 132cm
- Expanded muon coverage
  - $|\eta|<1.5$
- PID
  - p, K and π by dE/dx and TOF



Detector Performance

- Careful calibration of detector response is necessary for conducting precision measurements with small systematic errors
  - Develop large samples for calibrating detector response
  - 3.1M J/ψ, 400K ψ(2S), and 18K Upsilon(1S) samples for tracking momentum scale and energy loss calibration
  - 500K D* tagged $D^0 \rightarrow K\pi$ events for dE/dx and TOF calibration: Note the low tails in dE/dx residual distribution



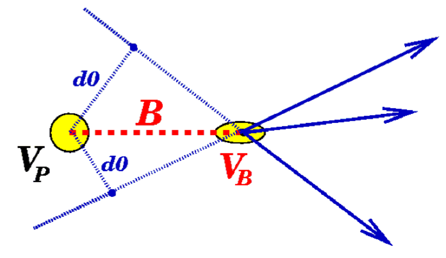


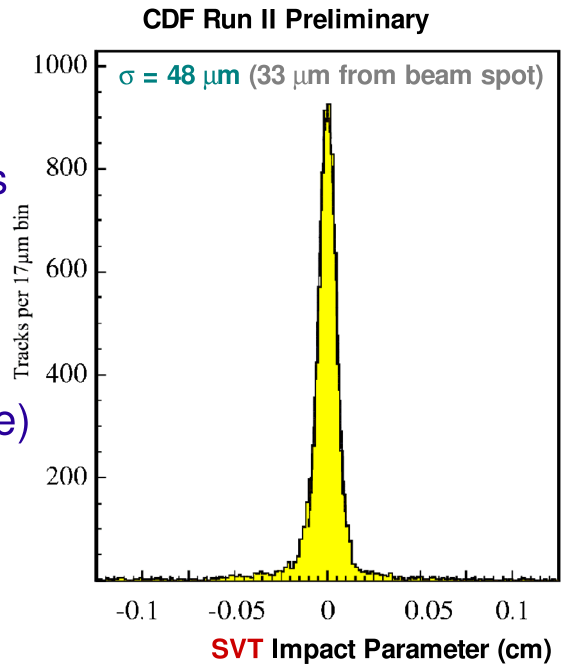
B Physics & *B* Triggers

- Large production rates
  - σ(*ppbar* → *bX*, |*y*| < 1.0, p_T(B) > 6.0GeV/c) = ~30μb or ~10μb
- Heavy *b* states produced
  - B_0, B^+, B_s, B_c, Λ_b, Ξ_b
- Backgrounds are also 3 orders of magnitude higher
  - Inelastic cross section ~100 mb
  - Challenge is to pick one *B* decay from ~10^3 other QCD events
- Di-muon trigger
  - $p_T(\mu)$ > 1.5 GeV/c
  - *B* yields 2x Run I (lowered p_T threshold, increased acceptance)
- Lepton + displaced-track trigger(SVT)
  - $p_T(\mu,e)$ > 4 GeV/c, 120 μm < d_0 < 1mm, p_T > 2 GeV/c
  - *B* yields 3x Run I(with SVT – new for Run 2)
- Two track vertex trigger
  - p_T > 2 GeV/c, 120 μm < d_0 < 1mm, L_{xy} > 200μm, Σ p_T > 5.5 GeV/c

TRIGGERS ARE CRITICAL

SENSITIVITY TO NEW HADRONIC MODES



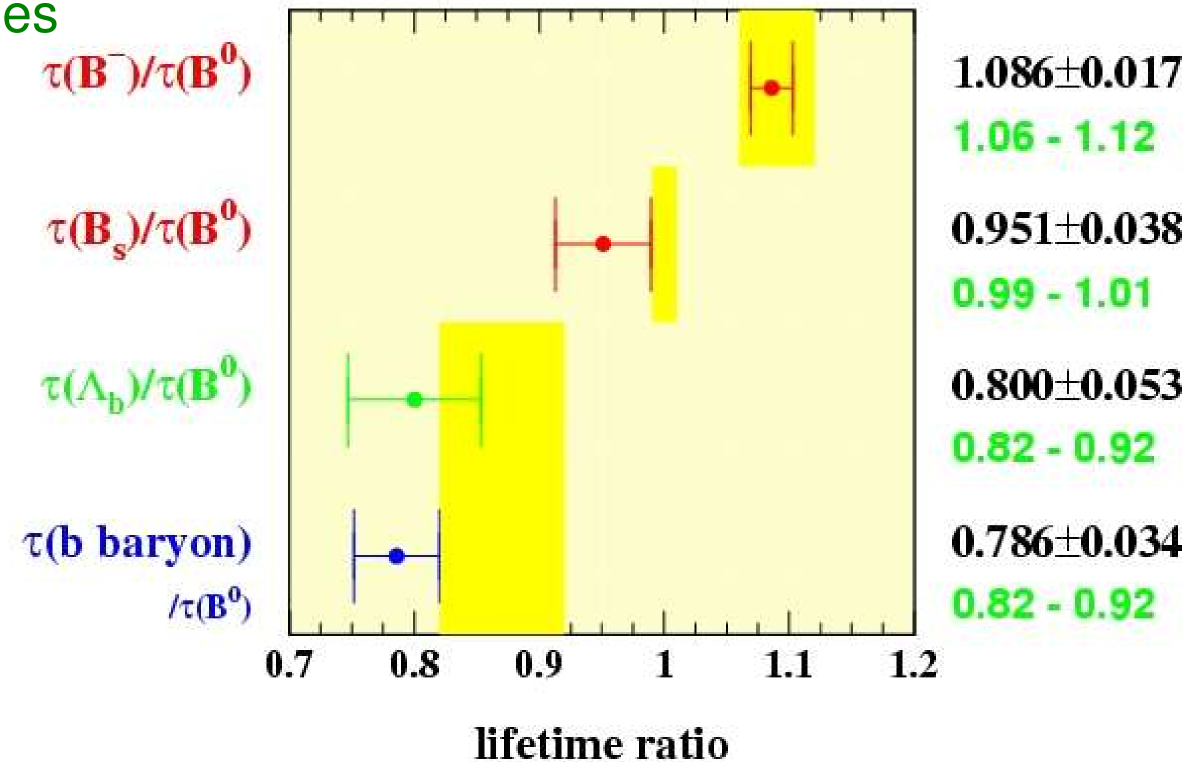


Lifetimes Motivation

- Lifetime ratios
  - Test of heavy quark expansion
  - Current results agree with theory within 1σ with large experimental errors
  - Calculate ratios from the results of the individual lifetime measurements
- Of particular interest are the ratios with the B_s and Λ_b which are not produced at the B factories

$$\frac{\tau_{B^+}}{\tau_{B_0}}, \frac{\tau_{B_s}}{\tau_{B^0}}$$

Presented Here

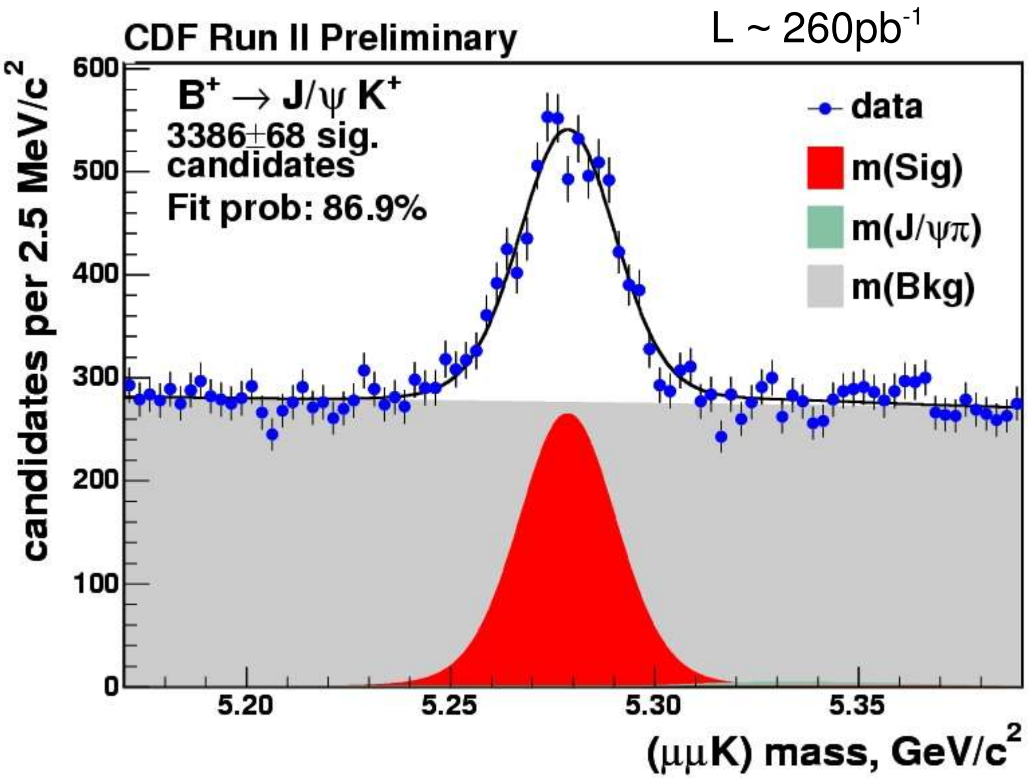


F. Gabbiani et. al. Hep-ph/0407004

Lifetimes Analysis

Decay	$p_T(B)$ GeV/c²	$p_T(K/\phi)$ GeV/c²	$Pr(\chi^2)$	K/ϕ mass MeV/c²	B mass MeV/c²
$B^+ \to J/\psi K^+$	> 5.5	> 1.6	$> 10^{-3}$	–	5170 – 5390
$B_d \to J/\psi K^{*0}$	> 6.0	> 2.6	$> 10^{-4}$	$M_{PDG}(K^{*0}) \pm 50.0$	5170 – 5390
$B_s \to J/\psi \phi$	> 5.0	> 1.5	$> 10^{-5}$	$M_{PDG}(\phi) \pm 6.5$	5220 – 5520

- Quality cuts
  - Tight silicon track quality and vertex cuts used to reduce the number of mis-measured events
- Simultaneous fit to the mass and lifetime
  - Exponential lifetime convoluted with a Gaussian for the signal
  - Prompt Gaussian background(used to extract lifetime resolution)
  - 3 exponential tails for long lived or mis-measured background



Lifetimes Results

- Ratios

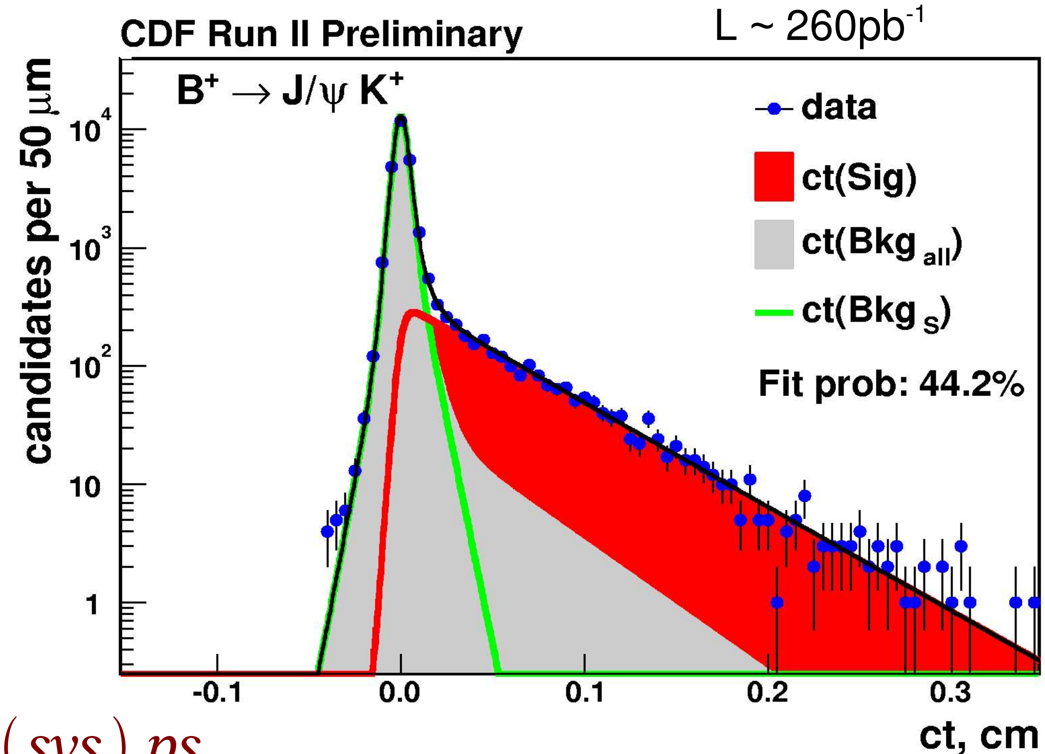
$$\tau_{B^+}/\tau_{B^0}=1.080\pm0.042(tot)$$

$$\tau_{B_s}/\tau_{B^0}=0.890\pm0.072(tot)$$

HFAG Heavy flavor averaging group

B^+/B^0:1.086 ± 0.017

B_s/B^0: 0.951 ± 0.038



- Lifetimes

$$\tau_{B^+}=1.662\pm0.033(stat)\pm0.008(sys)\ ps$$

$$\tau_{B^0}=1.539\pm0.051(stat)\pm0.008(sys)\ ps$$

$$\tau_{B_s}=1.369\pm0.100(stat)^{+0.008}_{-0.010}(sys)\ ps$$

B^+: 1.671 ± 0.018ps

B^0: 1.536 ± 0.014ps

B_s: 1.461 ± 0.057ps

- Almost no negative tails in the lifetime distribution

New Λ_b measurement soon using similar technique

$$\tau_{\Lambda_b}=1.25\pm0.26(stat)\pm0.10(sys)\ ps$$

Λ_b: 1.23 ± 0.08ps

$\Delta\Gamma_{B_s}$ Motivation

- Understanding the CP Composition of B_s decays(look for new physics)
  - $B_s \rightarrow J/\psi\phi$ Pseudoscalar → Vector Vector
  - CP eigenstates: $B_{s,light}$ CP Even and $B_{s,heavy}$ CP Odd
  - Two states have different angular decay distributions
  - The CP Even and Odd states are expected to have short and long lifetimes respectively
  - Need to understand the CP composition to interpret the lifetime measurement
- Allows an indirect Δm_s measurement in decays where both CP components are present
  - If Δm_s is very large this becomes one of the only ways to measure Δm_s

$$SM : \frac{\Delta\Gamma_{B_s}}{\Delta m_s} = 3.9^{+0.8}_{-1.5} \times 10^{-3}$$ FERMILAB-Pub-01, 197

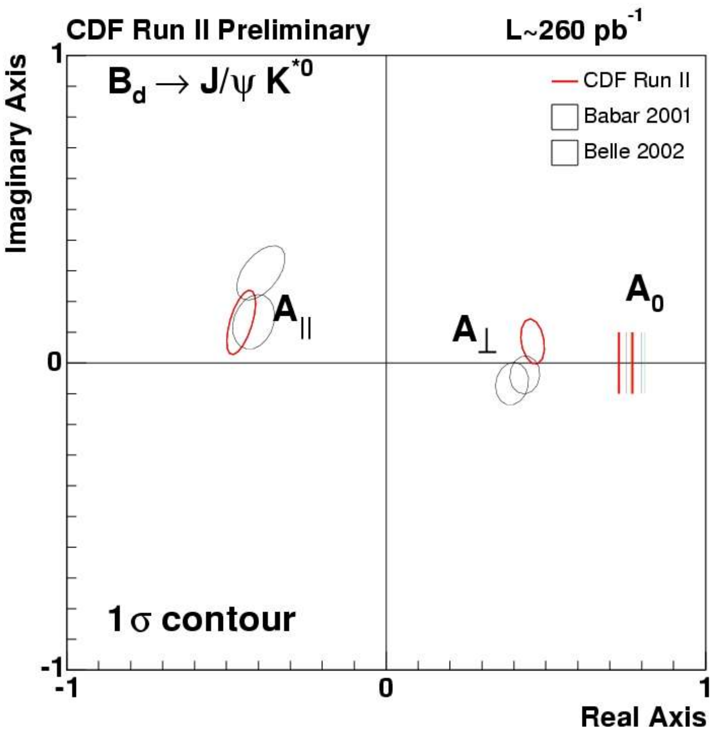
- Time dependent analysis of the decay amplitudes to extract: $\frac{\Delta\Gamma_{B_s}}{\Gamma_{B_s}}$
  - Simultaneous fit to lifetime and transversity amplitudes
  - Cross check technique with $B^0 \rightarrow J/\psi K^{*0}$

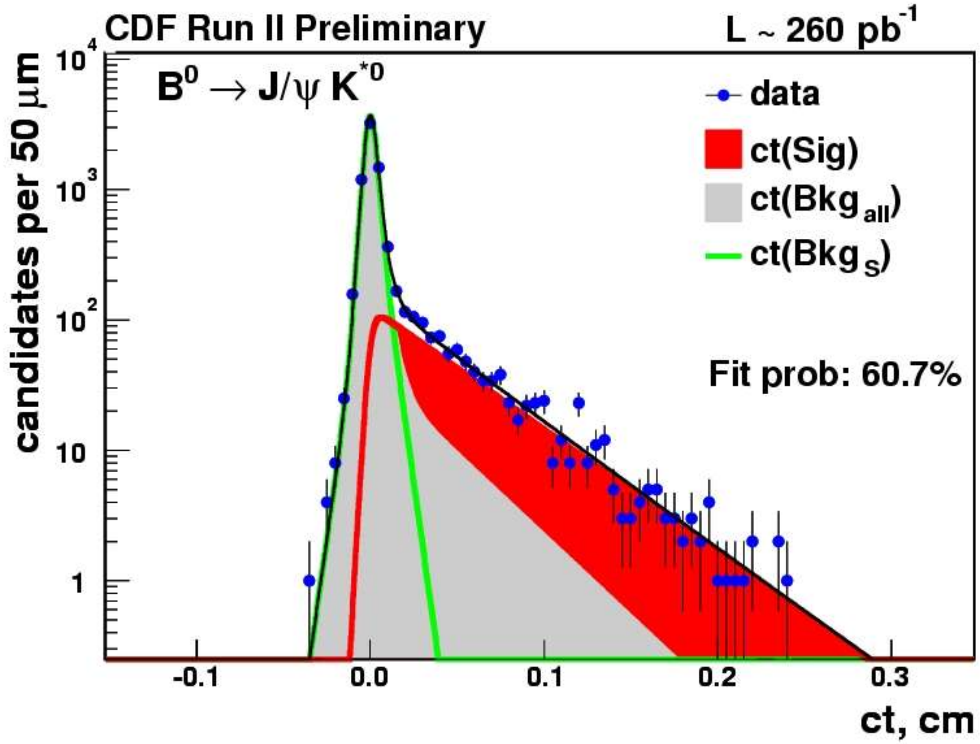
B^0 Results

B^0 lifetime and transversity angle results consistent with B factory results

HFAG:

B^0: 1.536 ± 0.014ps





$$A_0 = 0.750 \pm 0.017 \pm 0.012$$

$$A_\parallel = (0.0473 \pm 0.034 \pm 0.006)\, e^{(2.86 \pm 0.22 \pm 0.07)i}$$

$$|A_{perp}| = (0.464 \pm 0.035 \pm 0.007)\, e^{(0.15 \pm 0.15 \pm 0.04)i}$$

$$\tau_{B^0} = 1.54 \pm 0.05 \pm 0.02\ ps$$

$\Delta\Gamma_{B_s}$ Results

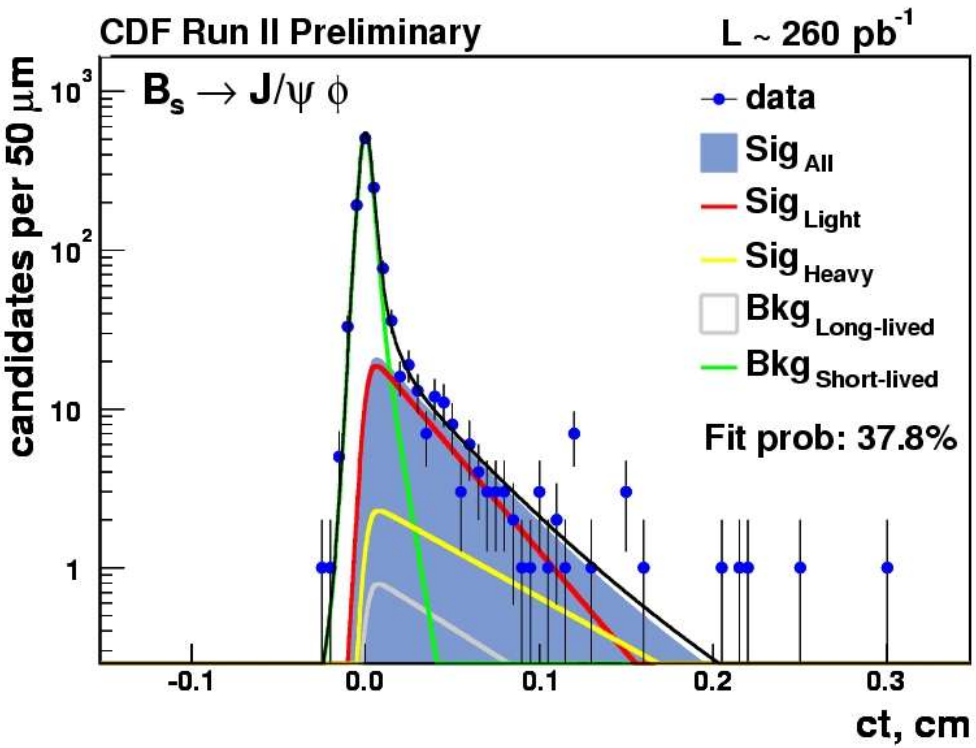
$$A_0 = 0.783 \pm 0.038 \pm 0.007$$

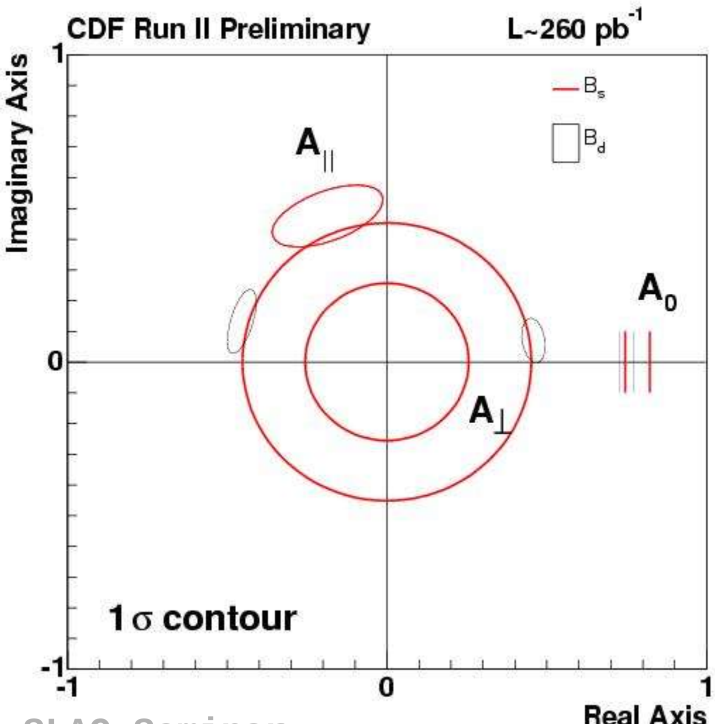
$$A_\parallel = (0.539 \pm 0.070 \pm 0.013)\, e^{(1.91 \pm 0.36 \pm 0}$$

$$|A_{perp}| = 0.308 \pm 0.087 \pm 0.003$$

$$\tau_{B_s L} = 1.13^{+0.13}_{-0.09} \pm 0.02\ ps$$

$$\tau_{B_s H} = 2.38^{+0.56}_{-0.43} \pm 0.03\ ps$$





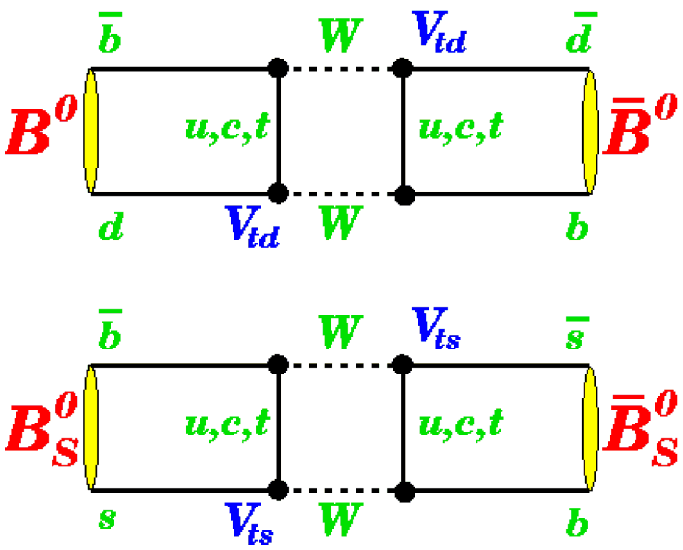
$$\Delta\Gamma_{B_s} / \Gamma_{B_s} = 0.71^{+0.24}_{-0.28} \pm 0.01$$

5.7(3.9)σ from $\Delta\Gamma_{B_s}/\Gamma_{B_s} = 0(0.12)$

$$\Delta m_s = 125^{+69}_{-55}\ ps^{-1}$$

Using SM/Theory ratio

B Mixing Motivation

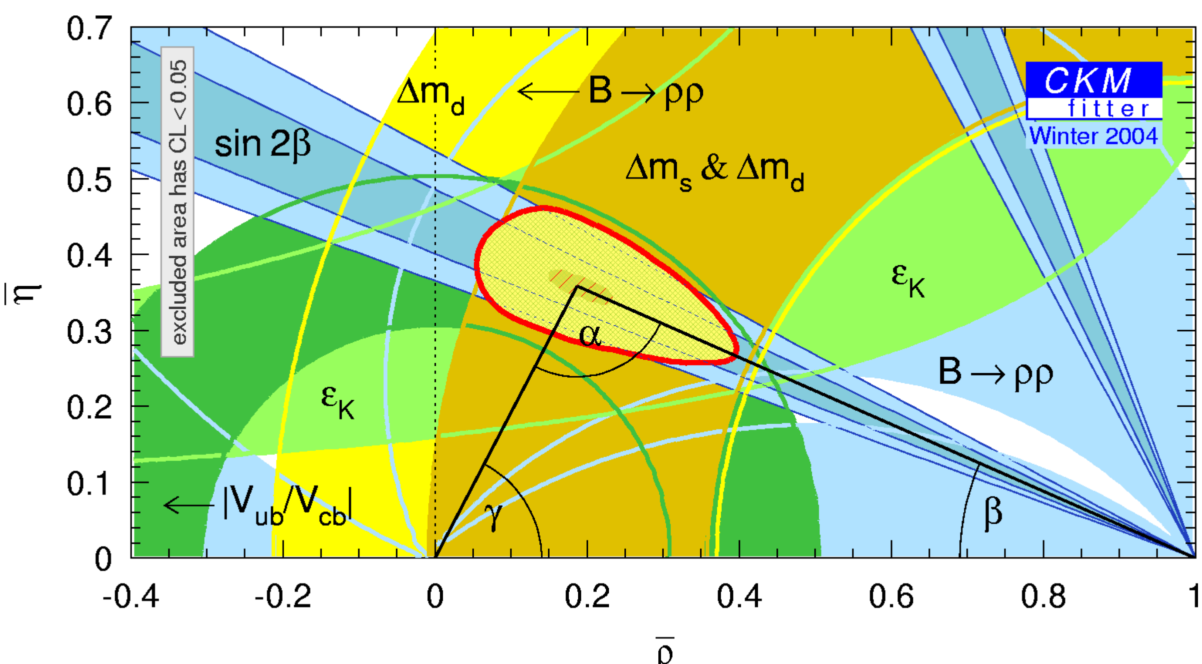


- B_d oscillations are sensitive to $|V_{td}|$
- Compromised by hadronic uncertainties
- Most cancel in B_d/B_s oscillation ratio

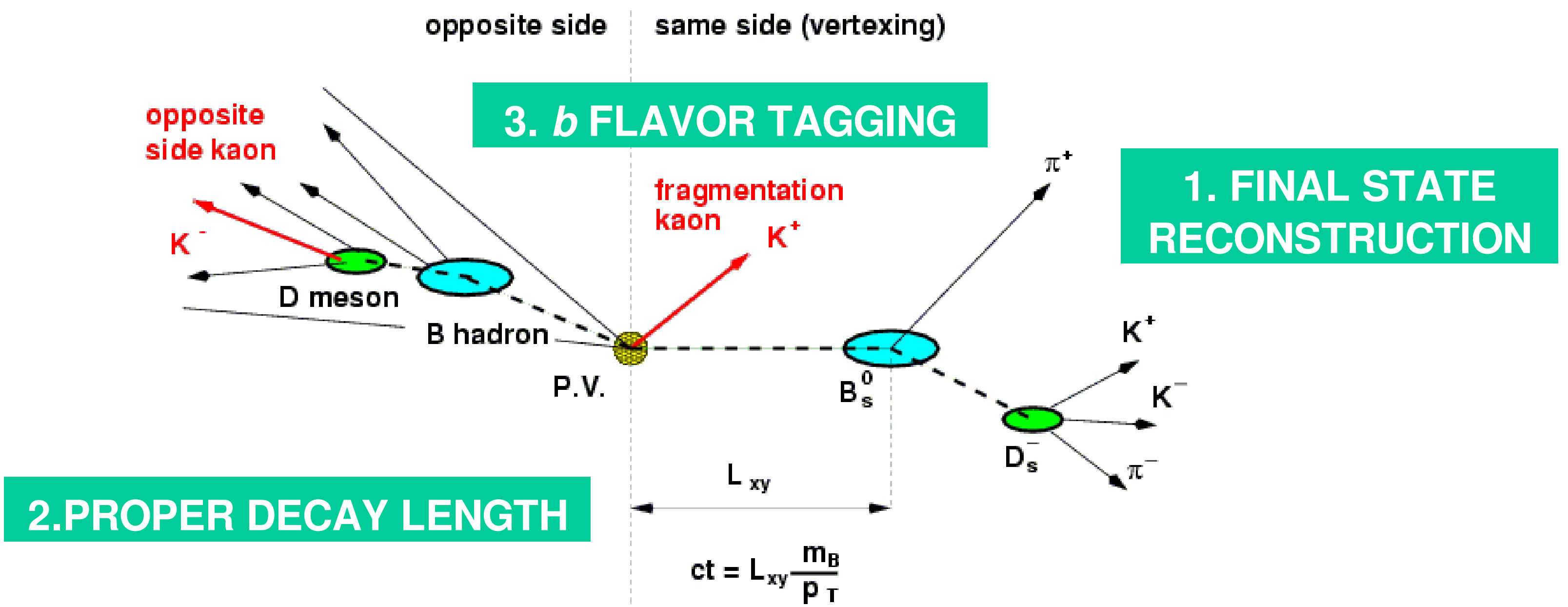
$$\frac{|V_{td}|}{|V_{ts}|} = 1.01\xi\sqrt{\frac{\Delta m_d}{\Delta m_s}}$$

from LATTICE

- New physics may affect $\Delta m_s/\Delta m_d$
  - New physics particles in the loop can lift the GIM supression of the diagram
- Δm_s prerequisite for a time-dependent B_s CP violation measurement



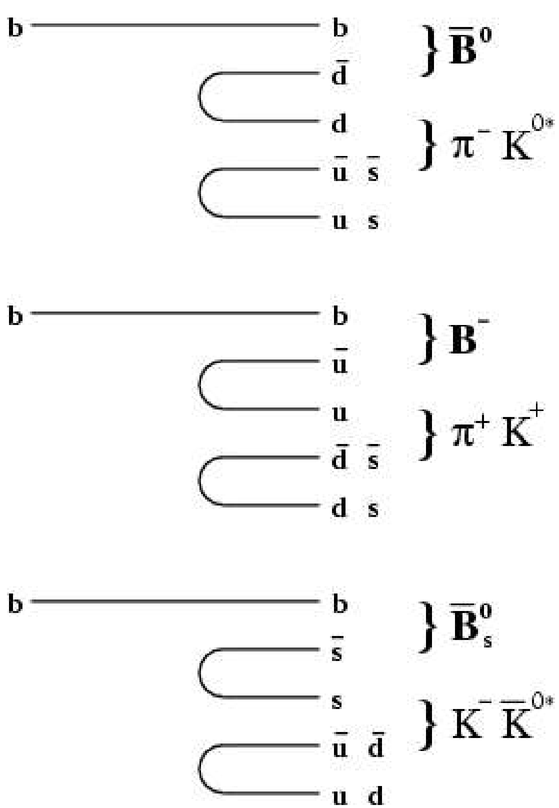
B Mixing Ingredients



- 3 primary ingredients
- Reconstruction of B Mesons: fully and in and semileptonic modes
  - Statistical power dependent on the number of events reconstructed
- Proper time resolution
  - Sensitivity depends exponentially on the square of the proper time resolution
- Flavor Taggers
  - Need to quantify the performance of each type of tagger

B Mixing Flavor Taggers

- Can be topologically separated into same and oposite side taggers
  - Same side track(SST): Fragmentation track correlated with produced B flavor
  - Opposite-Side is based on properties of the non-reconstructed *b:* Soft muon(SMT)/ electron(SET) and jet charge(JQT)
- Tagging effectiveness εD^2: shows statistical power of the tagger
  - Efficiency ε: fraction of tagged events
  - Dilution D: 2P - 1 with P the correct answer probability
- Sample dependency of the same side tagger
  - Tagged with particles produced in hadronization
  - Intrinsically different for B^0, B^- and B_s
  - Also B^0 and B^- have B** decays with the correct charge correlation.
  - Kaon same side tagger useful for B_s tagging
  - Same side B_s tagger performance can't be measured from data if setting a limit – must be understood in MC(detailed data/MC comparisons)



B Mixing   Tagging results

- SMT: Find events with Opposite Side $B \to \mu X$
  - Opposite Side μ charge gives **SMT** decision
  - Uses likelihood method to combine information, EM/HAD energy, stub matching quantities
  - Qualities
    - High Purity, Low efficiency
  - Combined $\sum \varepsilon D^2$ for subsamples(muon subdetector and p_T^{rel} bins)
  - $\sum \varepsilon D^2$ evaluated in lepton + SVT data

$\varepsilon D^2 = 0.698 \pm 0.042$ (stat.)%

- JQT: Jet charge of OS b
  - Weighted average Q of jet tracks
  - Qualities
    - Moderate purity, High efficiency
    - Other jets a problem
  - Combined $\sum \varepsilon D^2$ for subsamples(with w/o vertex tag or displaced tracks and JQ bins)

$\varepsilon D^2 = 0.715 \pm 0.027$ (stat.)%

- SST: Look for fragmentation track that is charge correlated with the produced *B*
  - Consider track close to *B*: In cone and lowest p_T^{rel}

$\varepsilon D^2 = 2.33(1.0) \pm 0.34(0.35)$ (stat.)%, $B^+(B^0)$

B Mixing m_d(in fully reconstructed modes)

$$B^0 \to J/\psi\, K^{*0}$$

$$J/\psi \to \mu^+ \mu^-,\ K^{*0} \to K^+ \pi^-$$

$$B^0 \to D^{-(*)} \pi^+ (\pi^+ \pi^-),$$

$$D^- \to K^+ \pi^- \pi^-,$$

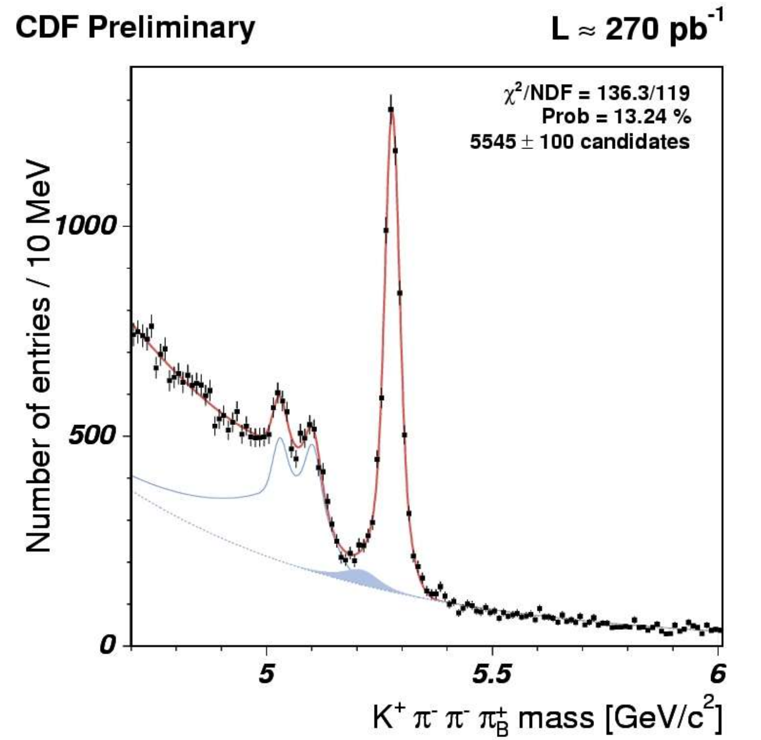
$$D^{-*} \to D^0 \pi^-,\ D^0 \to K^- \pi^+ (\pi^+ \pi^-)$$

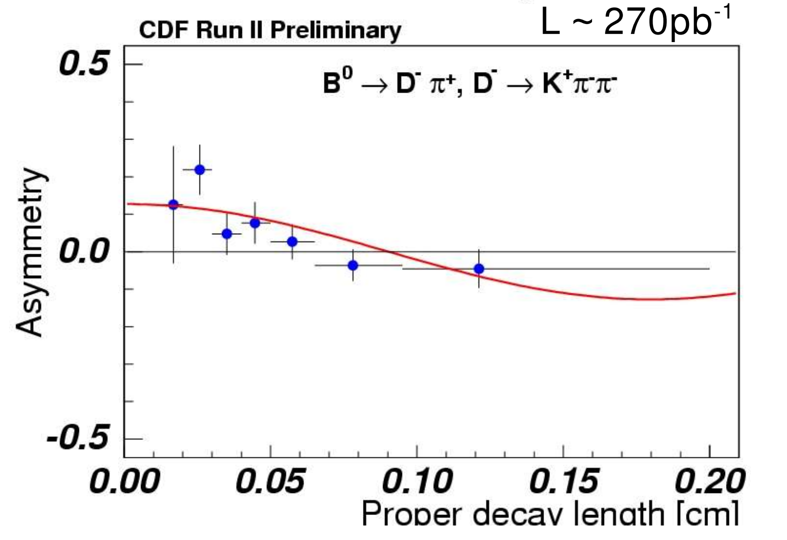
- 7 total modes
- Measure Δm_d and SST performance
  - Combine channels
  - Binned asymmetry fit for Δm_d using a convolution of physical time dependence, $\cos(\Delta m_d t)$, and the Gaussian proper time resolution.

$$\Delta m_d = 0.526 \pm 0.056 (stat) \pm 0.005 (sys)\ ps^{-1}$$

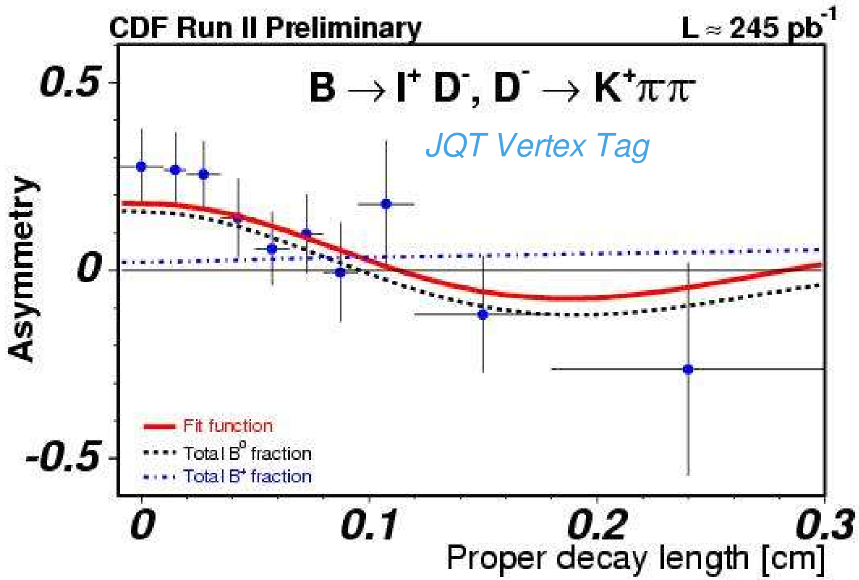
HFAG: $0.502 \pm 0.007 ps^{-1}$

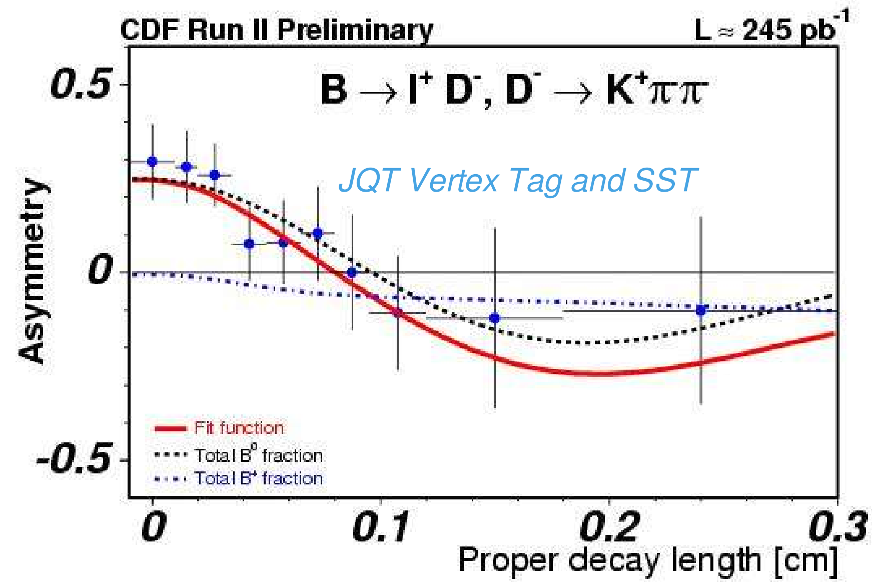
$$\epsilon D^2 = 1.0 \pm 0.35 (stat) \pm 0.06 (sys) \%$$

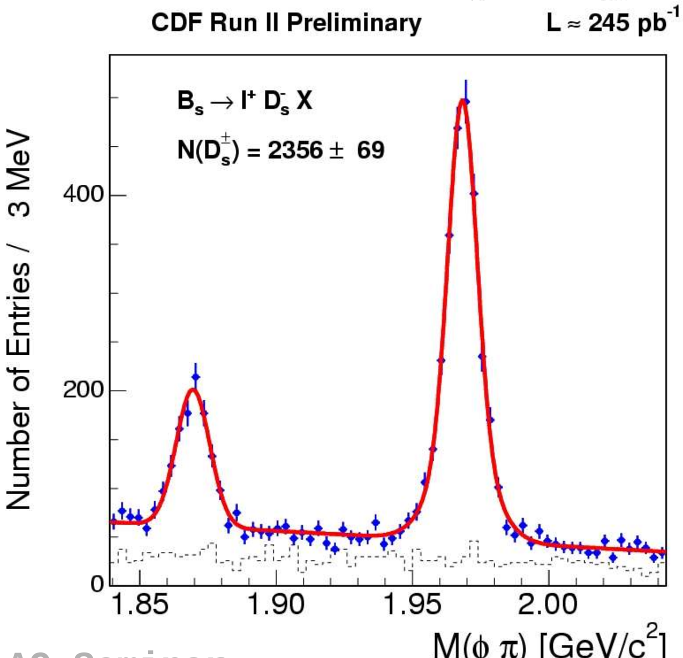




B Mixing m_d(in semileptonic modes)







- Measure Δm_d and SST, SMT, JQT performance (SMT and JQT unbinned)

$$\Delta m_d = 0.536 \pm 0.037(stat)$$
$$\pm 0.009(sc) \pm 0.015(sys)\, ps^{-1}$$

HFAG: 0.502 ± 0.007ps^{-1}

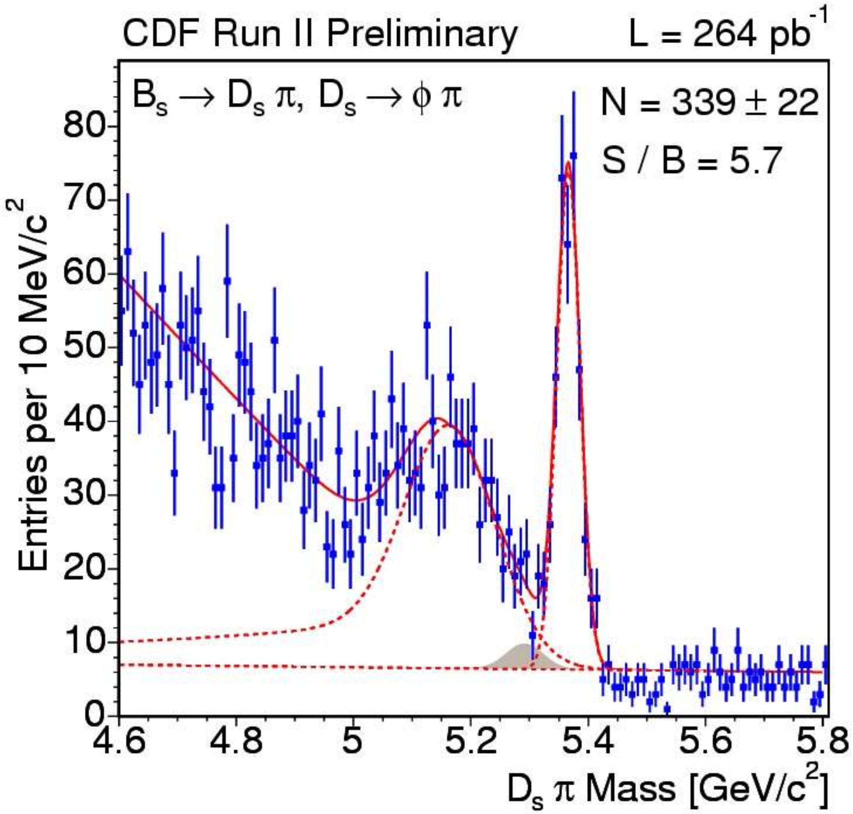
$$SST : \epsilon D^2 = 1.04 \pm 0.24(stat)\%$$
$$SMT : \epsilon D^2 = 0.32 \pm 0.05(stat)\%$$
$$JQT : \epsilon D^2 = 0.49 \pm 0.07(stat)\%$$

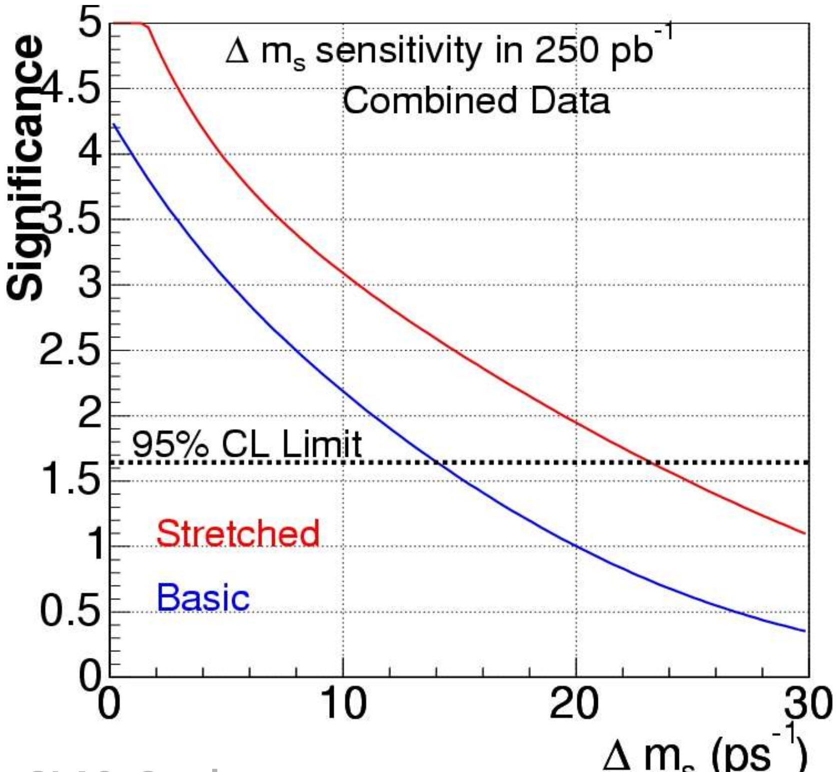
B_s Mixing   Limit Sensitivity

- Use semileptonic and hadronic decays
  - Combination improves the reach

$$B_s \to D_s^- \pi^+ (\pi^+ \pi^-), \quad B_s \to l^+ D_s^- X,$$
$$D_s^- \to \phi \pi^-, 3\pi, K^* K$$

- Semileptonic: 2400, hadronic: 725 events





- CDF Baseline: $\Delta m_s = 14\ ps^{-1}$
  - $\epsilon D^2 = 1.6\%, \sigma_t = 67\ fs$
- CDF Stretched $\Delta m_s = 23\ ps^{-1}$
  - $\epsilon D^2 = 2.6\%, \sigma_t = 47\ fs$
  - Using primary vertex, L00 and Kaon tag

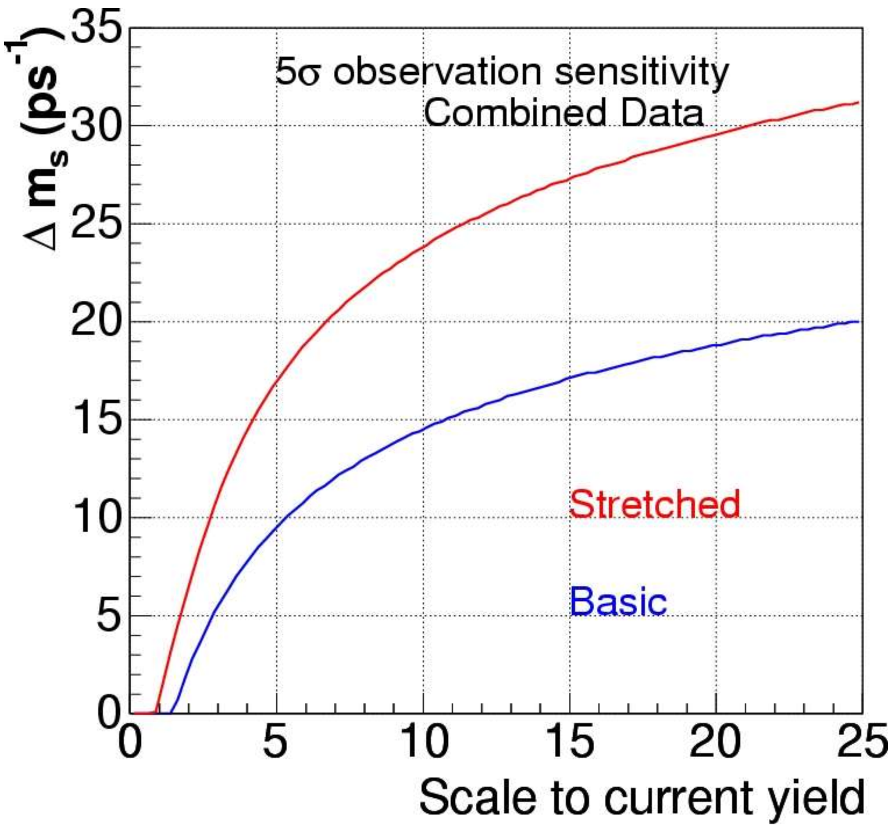
B_s Mixing Projected Reach

- 5σ significance observation
  - CDF Stretched:

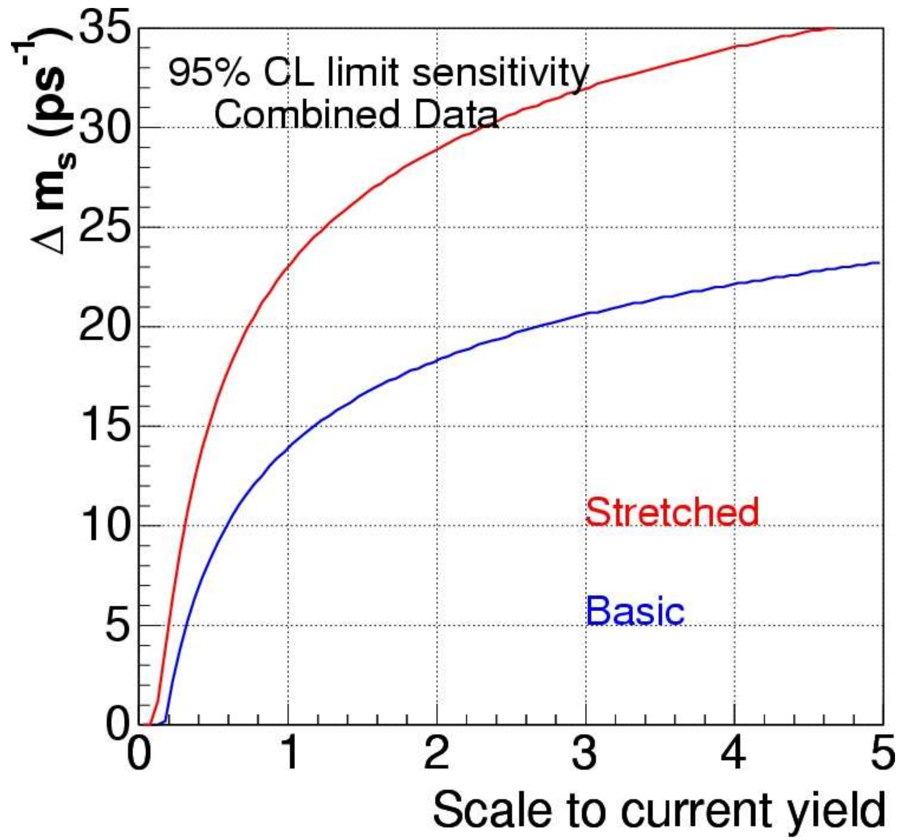
$$\epsilon D^2 = 2.6\%,\ \sigma_t = 47\ fs$$

$$\Delta m_s = 19\ ps^{-1},\ \text{with}\ \sim 6\times\ \text{more events}$$

$$\Delta m_s = 24\ ps^{-1},\ \text{with}\ \sim 10\times\ \text{more events}$$

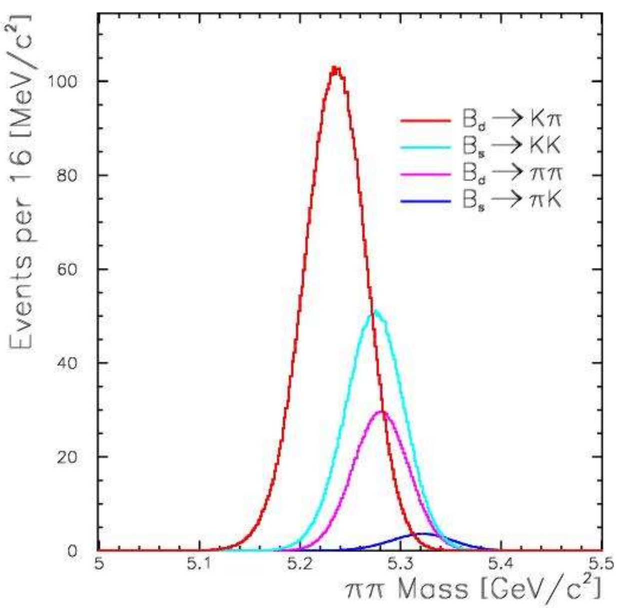


Yield with 250pb^{-1}



Charmless B Decays Motivation

- 3 sources of CP Asymmetries: A_{CP}
  - A_{CP} in mixing: neutral mesons oscillate with different phases - mass eigenstates are different from CP eigenstates
  - A_{CP} in decay(Direct A_{CP}): Decay amplitudes of CP eigenstates not equal
  - A_{CP} from the interference between decays with and without mixing
- Many charmless B decay modes are sensitive to A_{CP}
  - $B^+ \rightarrow \phi K^+$: Direct A_{CP}
    - A_{CP} rate expected to be small: Probe of new physics
  - $B_s \rightarrow \phi\phi$: Mixing and direct A_{cp}
    - Vector Vector decay never observed before
    - also small A_{CP} rate
  - $B_{s,d} \rightarrow hh$ ($h = K, \pi$): Direct or mixing and direct A_{cp}
    - B_s only accessible at the Tevatron



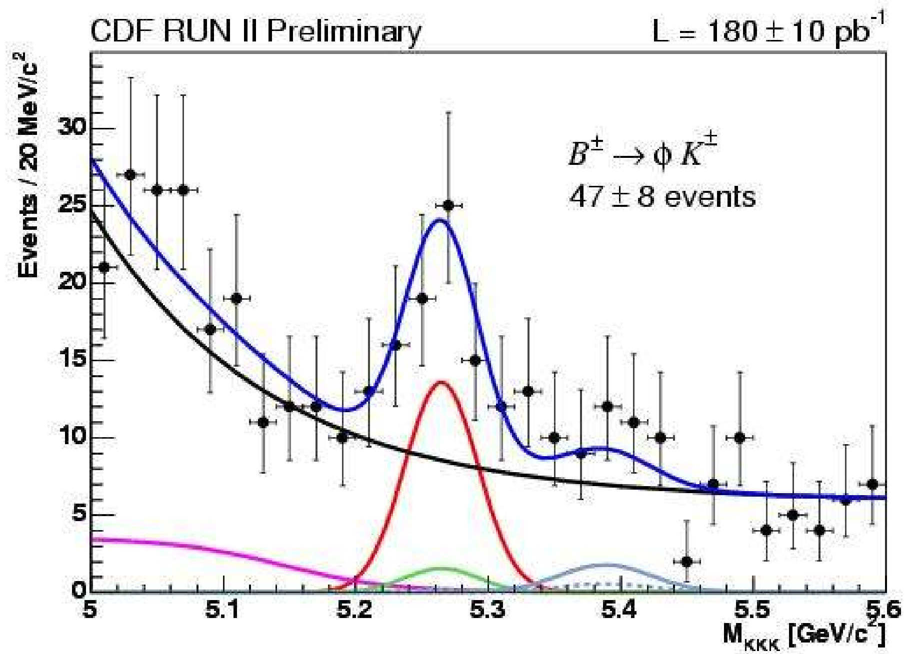
- Branching fractions of rare modes also interesting

Charmless *B* Decays

$B^+ \rightarrow \phi K^+$ Results

$$B^+ \rightarrow \phi K^+, \phi \rightarrow K^+ K^-$$

- Analysis Cuts
  - ϕ mass cut, pT > 1.3 GeV/c(third track)
  - $p_{TB} > 4.0$, $|d_{0B}|<100$ m, $L_{xy} > 350$m
  - Isolation, vertex and track quality
  - Results from likelihood fit to masses, dE/dx and helicity



- Results:

$$A_{CP}(B^+ \rightarrow \phi K^+) = -0.07 \pm 0.17(stat)^{+0.06}_{-0.05}(sys)$$

Babar result: $A_{CP} = 0.054 \pm 0.056(stat) \pm 0.012(sys)$

hep-ex/0408072

$$BF(B^+ \rightarrow \phi K^+) = (7.2 \pm 1.3(stat) \pm 0.7(sys)) \times 10^{-6}$$

HFAG: $(9.0 \pm 0.7) \times 10^{-6}$

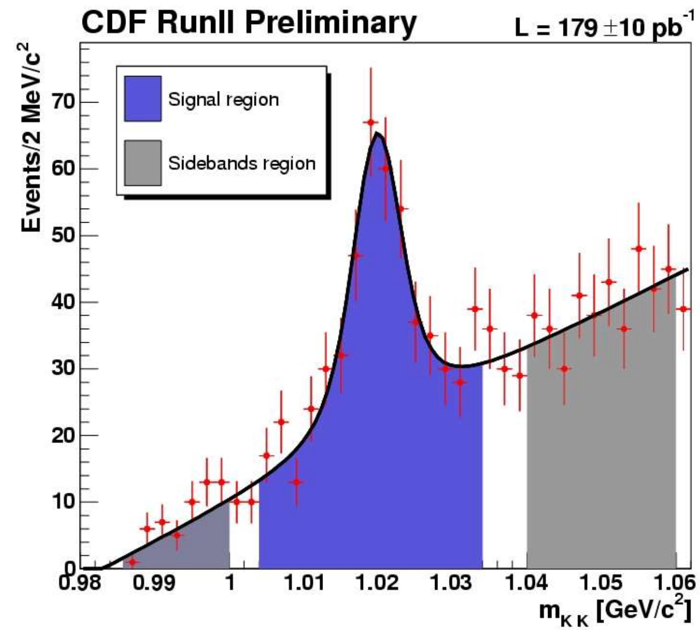
- Signal
- Backgrounds
  - Combinatorial
  - Partially reconstructed *B* decays
  - $B \rightarrow f_0 K$
  - $B \rightarrow K^{*0}\pi$, $K\pi\pi$ (Cyan)

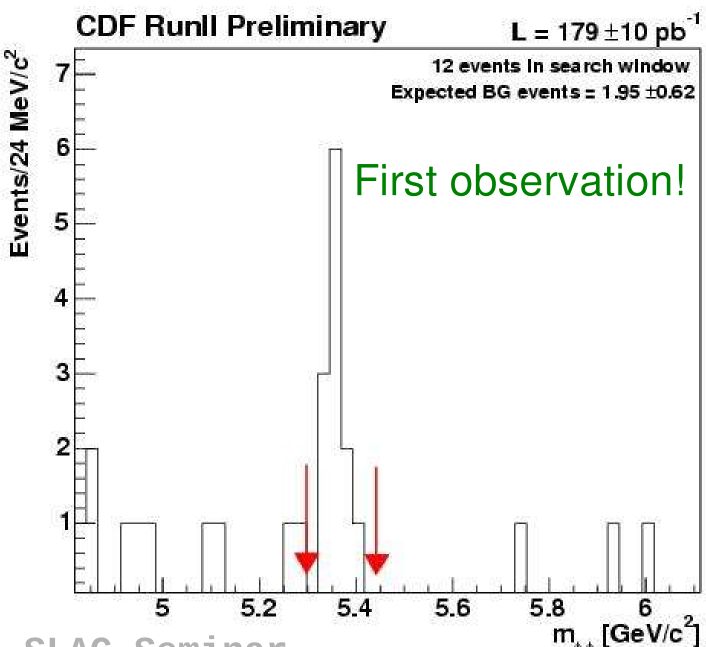
Charmless *B* Decays

$B_s \rightarrow \phi\phi$ Results

$$B_s \rightarrow \phi\,\phi\,,\ \phi \rightarrow K^+ K^-$$

- Analysis Cuts
  - Optimized using blind analysis technique
  - Optimization performed on signal MC events and ϕ sidebands
  - ϕ mass cut, p_T > 2.5GeV/c
  - $|d_{0B}|$<80 m, L_{xy} > 350 m





$$BF\,(B_s \rightarrow \phi\,\phi) =$$
$$1.4 \pm 0.6\,(stat) \pm 0.2\,(sys) \pm 0.5\,(norm) \times 10^{-5}$$

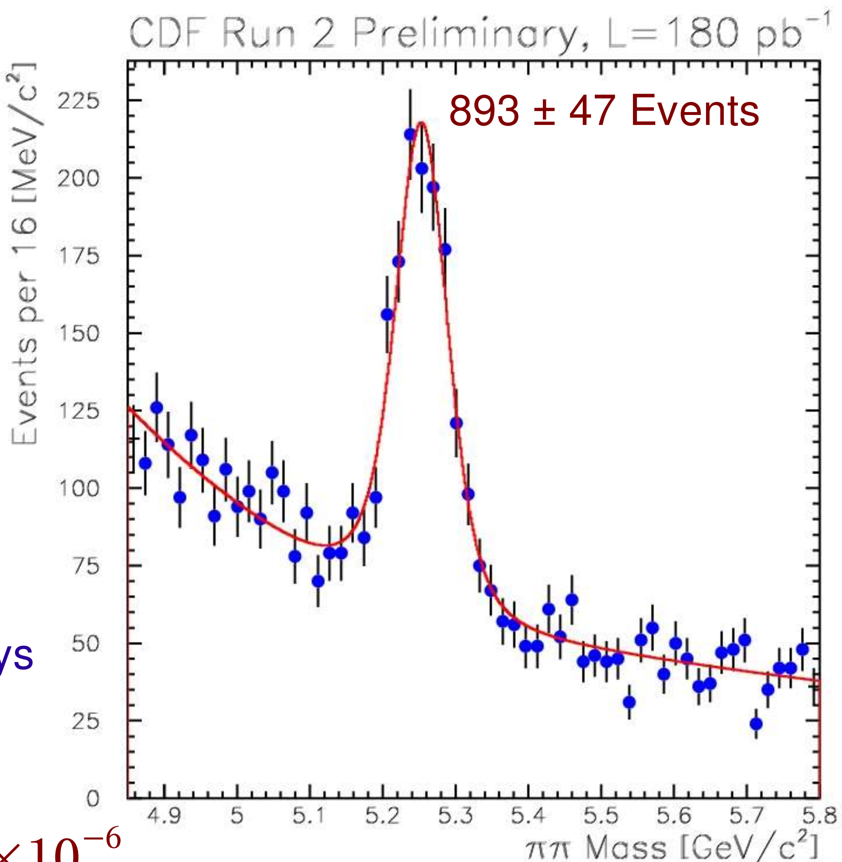
Th: QCD factorization: 3.68×10^{-5}

Th: NF factorization: 1.79×10^{-5}

Hep-ph/0309136, Li, Lu and Yang

Charmless *B* Decays $B \to hh$

- $B_{s,d} \to hh\ (h = K, \pi)$
- Unbinned likelihood fit
  - $M_{\pi\pi}$, dE/dx, charge-momentum imbalance
  - Excellent mass resolution and high statistics samples for dE/dx calibration allow for small systematic errors



- Branching ratios and A_{CP}(next page)
- BF/Limits on rare two body decays:
  - Not as sensitive as the B factories for B_d decays
  - Only Tevatron has sensitivity for B_s modes

$$BF(B_s \to K^{\pm} K^{\mp}) = 34.3 \pm 5.5(stat) \pm 5.9(sys) \times 10^{-6}$$

$$BF(B_s \to K^{\pm} \pi^{\mp}) < 7.6 \times 10^{-6} \text{@90\%CL}$$

$$BF(B_d \to K^{\pm} K^{\mp}) < 3.1 \times 10^{-6} \text{@90\%CL}$$

$$HFAG: < 0.6 \times 10^{-6} \text{@90\%CL}$$

$$BF(B_s \to \pi^{\pm} \pi^{\mp}) < 3.4 \times 10^{-6} \text{@90\%CL}$$

Charmless B Decays $B \to hh$

- Branching ratios:

$$\frac{BF(B^0 \to \pi^\pm \pi^\mp)}{BF(B^0 \to K^\pm \pi^\mp)} = 0.24 \pm 0.06(stat) \pm 0.04(sys)$$

HFAG: 0.25 ± 0.02

$$\frac{f_d \cdot BF(B^0 \to \pi^\pm \pi^\mp)}{f_s \cdot BF(B_s \to K^\pm K^\mp)} = 0.48 \pm 0.12(stat) \pm 0.07(sys)$$

$$\frac{f_s \cdot BF(B_s \to K^\pm K^\mp)}{f_d \cdot BF(B^0 \to K^\pm \pi^\mp)} = 0.50 \pm 0.08(stat) \pm 0.09(sys)$$

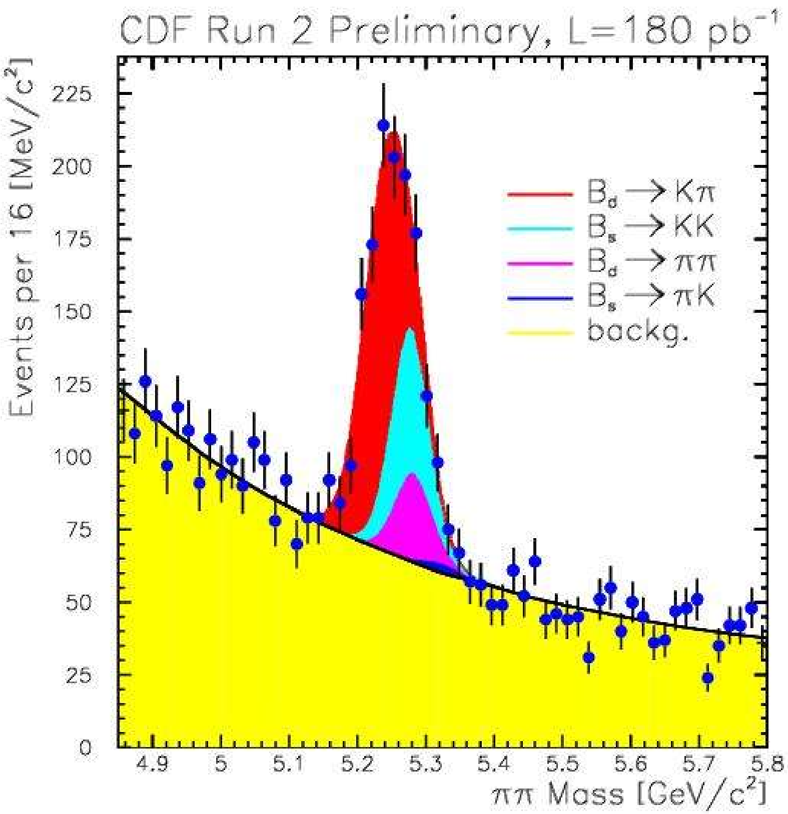
$$A_{CP}(B^0 \to K^\pm \pi^\mp) = -0.04 \pm 0.08(stat) \pm 0.006(sys)$$

Babar result: $A_{CP} = -0.133 \pm 0.030(stat) \pm 0.009(sys)$

4.2 σ hep-ex/0407057

Belle result: $A_{CP} = -0.101 \pm 0.025(stat) \pm 0.005(sys)$

3.9 σ hep-ex/0408100



B^0 ππ	134	15%
B^0 Kπ	509	57%
$B_s \to KK$	**232**	**26%**
B_s Kπ	18	2%

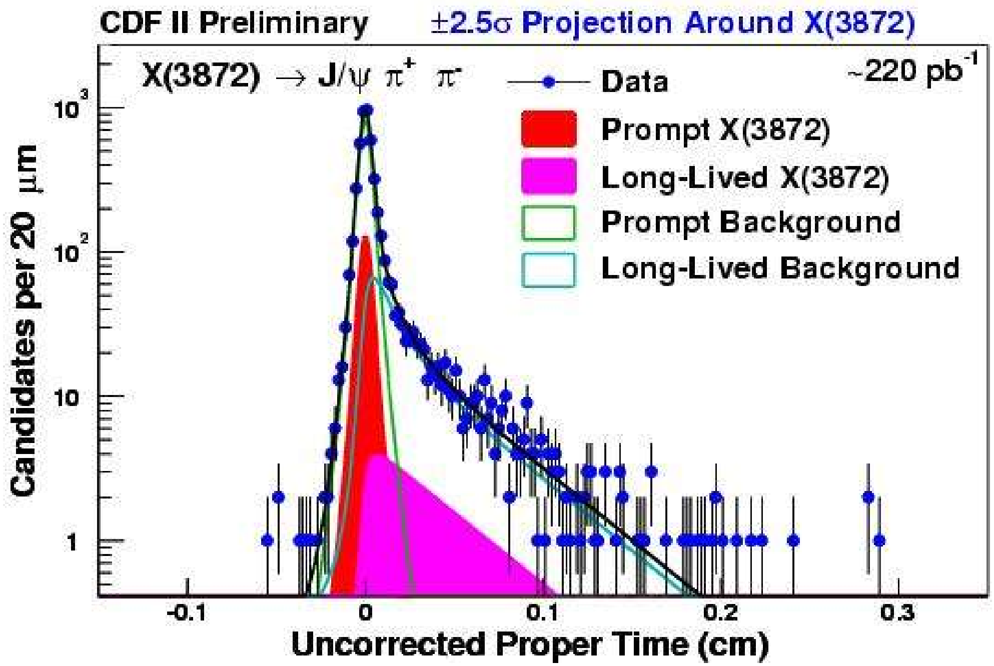
X Physics *B* Fraction

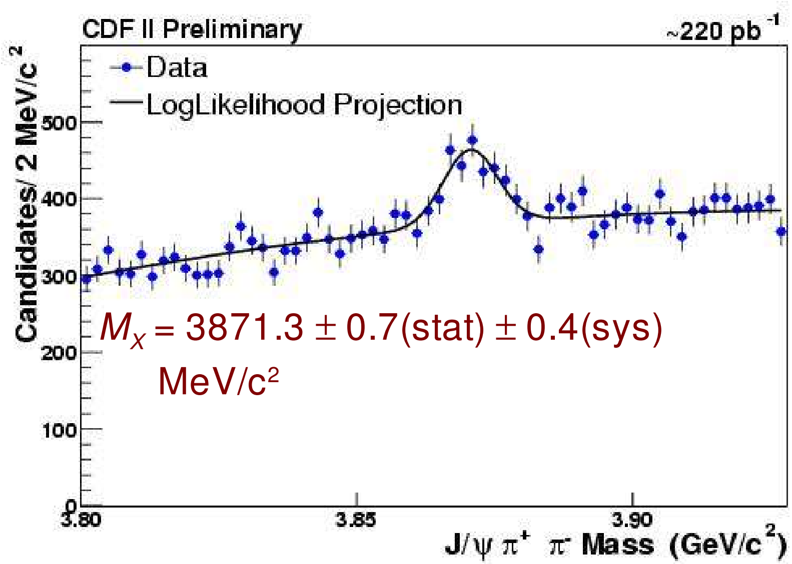
$X \rightarrow J/\psi\,\pi^+\pi^-,\ J/\psi \rightarrow \mu^+\mu^-$

- Motivation
  - *X* observed by Belle in $B^+ \rightarrow XK^+$
  - Production source in ppbar unknown
  - Measurement of prompt production fraction might indicate whether the *X* i a charmonium state
- Analysis Cuts
  - J/ψ mass window, $P_{T\pi}$ > 400MeV/c
  - Track and vertex quality cuts
- Perform likelihood fit to the proper time distribution
  - X "lifetime" relationship to the B lifetime not treated explicitly
  - Measure long lived fraction:

$$X : 16.1 \pm 4.9(stat) \pm 2.0(sys)\,\%$$

$$\psi(2S) : 28.3 \pm 1.0(stat) \pm 0.7(sys)\,\%$$

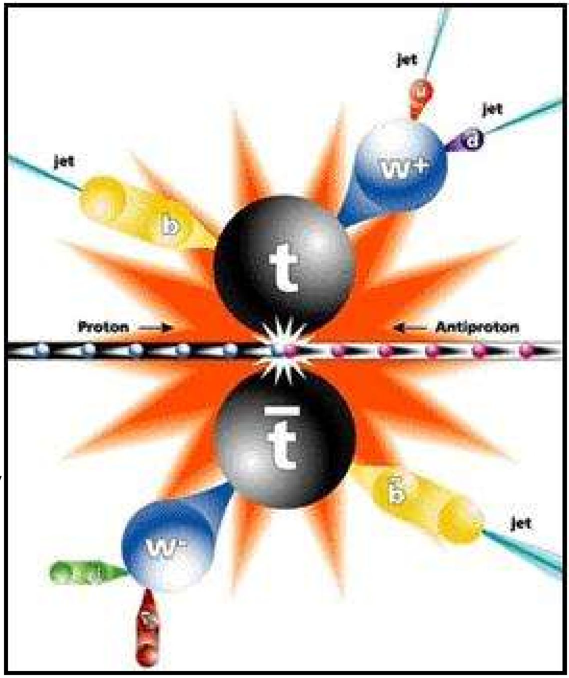




$M_X = 3871.3 \pm 0.7(stat) \pm 0.4(sys)$ MeV/c²

Indirect Searches

- How do you search for new physics at a collider?
  - Direct searches for production of new particles
    - Annihilation of two particles – available energy can contribute to formation of one or a pair of new particles
    - Example: the top quark
  - Indirect searches for evidence of new particles
    - Within a complex decay new particles can occur virtually
- In addition to being at the energy frontier the Tevatron is at data volume frontier
  - Collecting so many physics events that we can search for some very unusual things
- Where to look
  - Many weak decay rates are very low probability
  - Can look for contributions to decay rates from other low probability processes – Non Standard Model



A unique window of opportunity to find new physics before the LHC

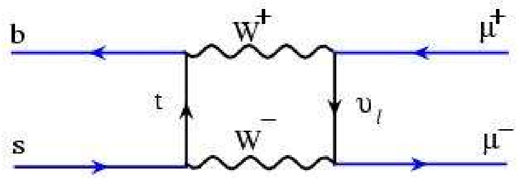
$B_s \to \mu\mu$: Beyond the SM

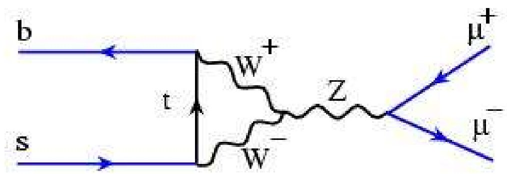
- Look at decays that are suppressed in the Standard Model: $B_{s(d)} \to \mu^+\mu^-$
  - Flavor changing neutral currents(FCNC) to leptons
    - No tree level decay in SM
    - Loop level transitions allowed though suppressed
    - CKM , GIM and helicity(m_l/m_b) suppressed
    - SM: $BF(B_{s(d)} \to \mu^+\mu^-) = 3.5\times10^{-9}(1.0\times10^{-10})$

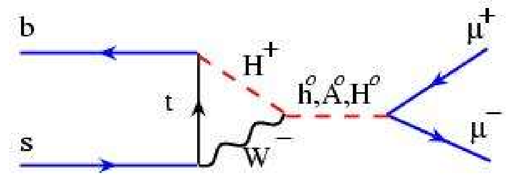
      G. Buchalla, A. Buras, Nucl. Phys. B398,285
- New physics possibilities
  - Loop and tree level decays
  - Tree: Flavor violating models or R-Parity violating SUSY
  - Loop: MSSM: mSugra, Higgs Doublet
    - 3 orders of magnitude enhancement

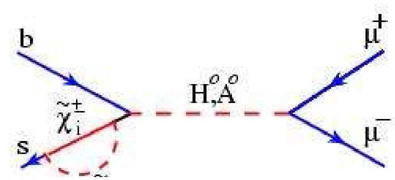
      Babu and Kolda, Phys. Rev. Lett. 84, 228
    - Rate $\propto\tan^6\beta$: can set lower limit if decay observed

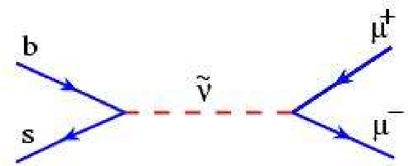
      G. Kane et al., Hep-ph/0310042
  - One of the best indirect search channels at the Tevatron



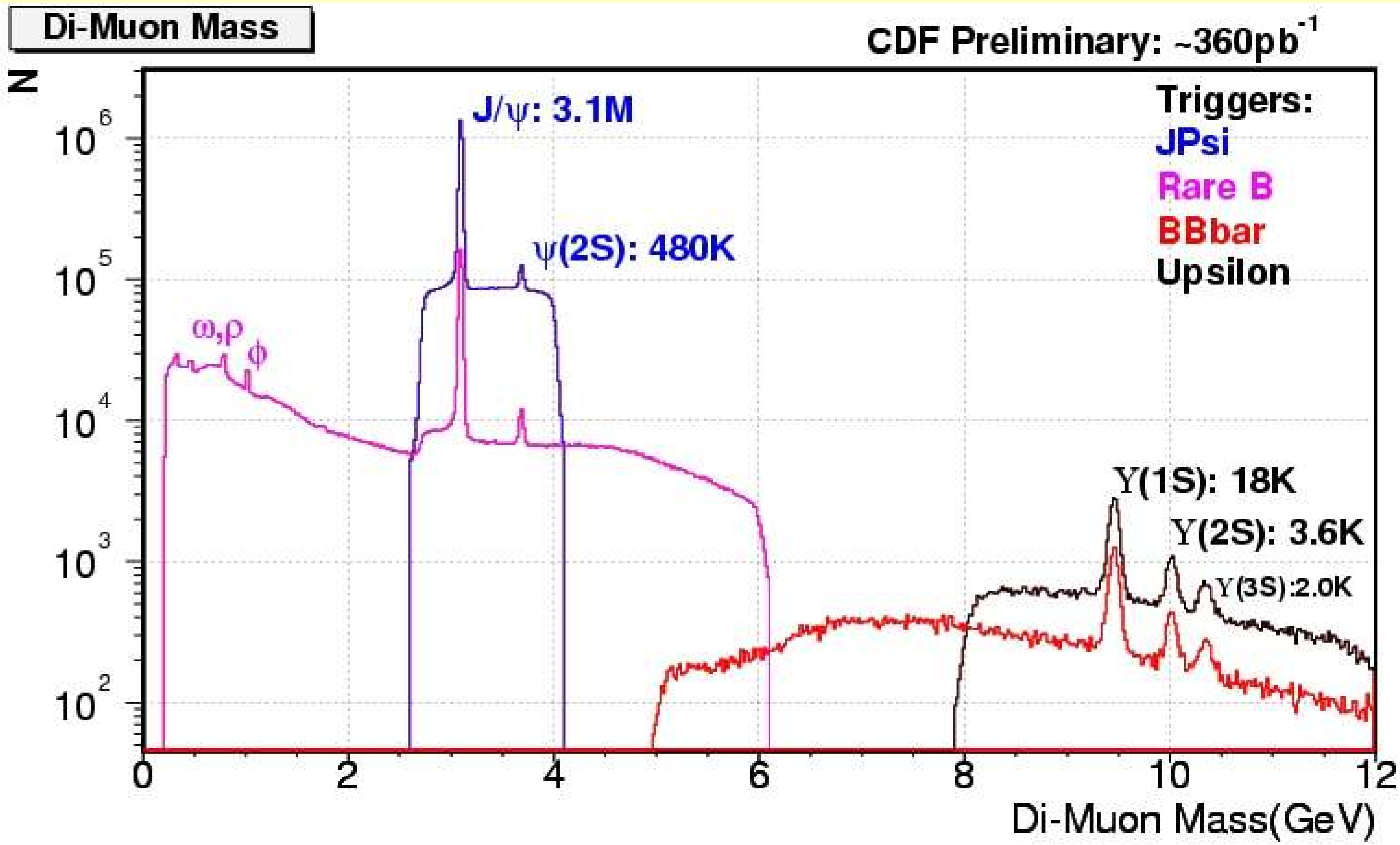








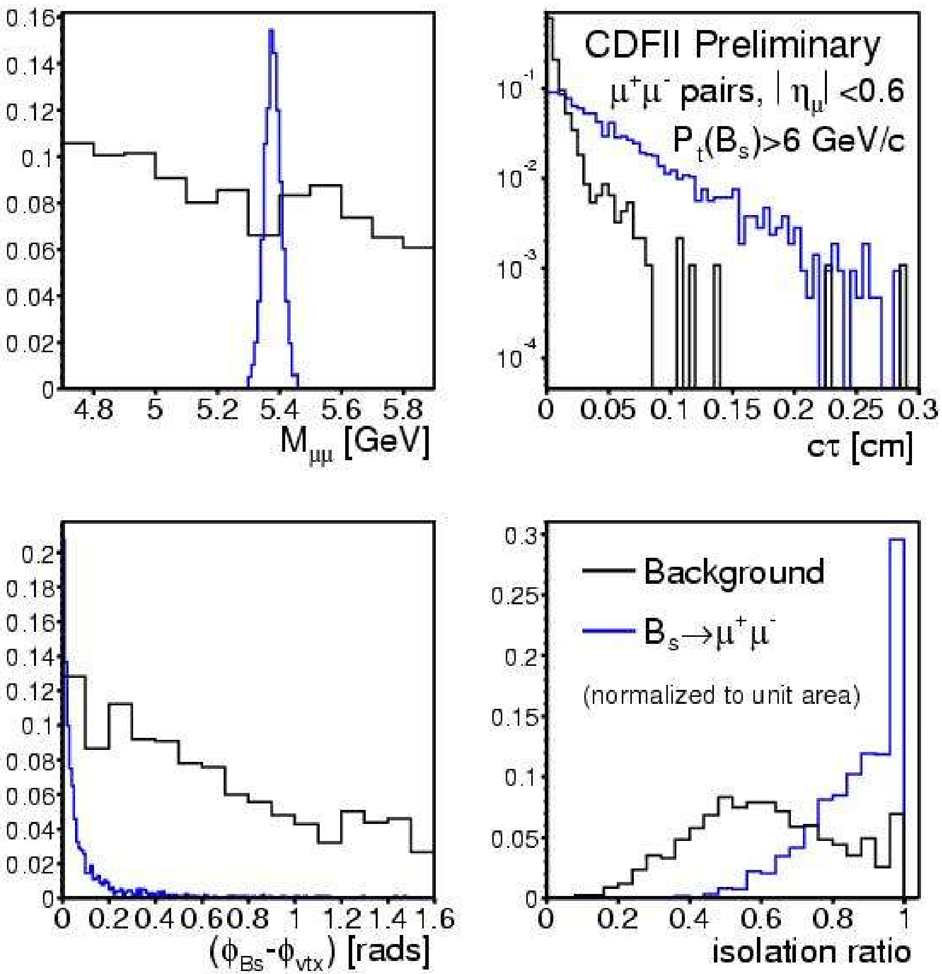
$B_s \rightarrow \mu\mu$: Experimental Challenge



- Primary problem is large background at hadron colliders
  - Analysis cuts must effectively reduce the large background around $m_{Bs} = 5.37 GeV/c^2$ to find a possible handful of events
- Key elements of the analysis are determining the efficiency and rejection of discriminating variables and estimating the background level

$B_{s(d)} \rightarrow \mu^+\mu^-$ Analysis

- Used blind analysis technique



- 4 primary discriminating variables
  - Mass M : choose 3σ window: $\sigma = 27 MeV/c^2$
  - $c\tau$: $L_{xy} \times M/p_{TB} > 200\mu m$
  - $\Delta\Phi$: $|\phi_B - \phi_{vtx}| < 0.10rad$
  - Isolation: $p_{TB}/(\ \Sigma trk + p_{TB}) > 0.65$
- Optimization
  - Use simulated signal and data sidebands
  - Independent sets of cuts were factorized for optimization
    - Improves efficiency and background estimates
  - Background estimates were checked in same sign lepton and $-c\tau$ samples

$B_{s(d)} \rightarrow \mu^+\mu^-$ Results

- CDF $B_{s(d)} \rightarrow \mu^+\mu^-$ results
  - $\alpha \times \varepsilon = 2.03 \pm 0.21\%$
  - Expected background

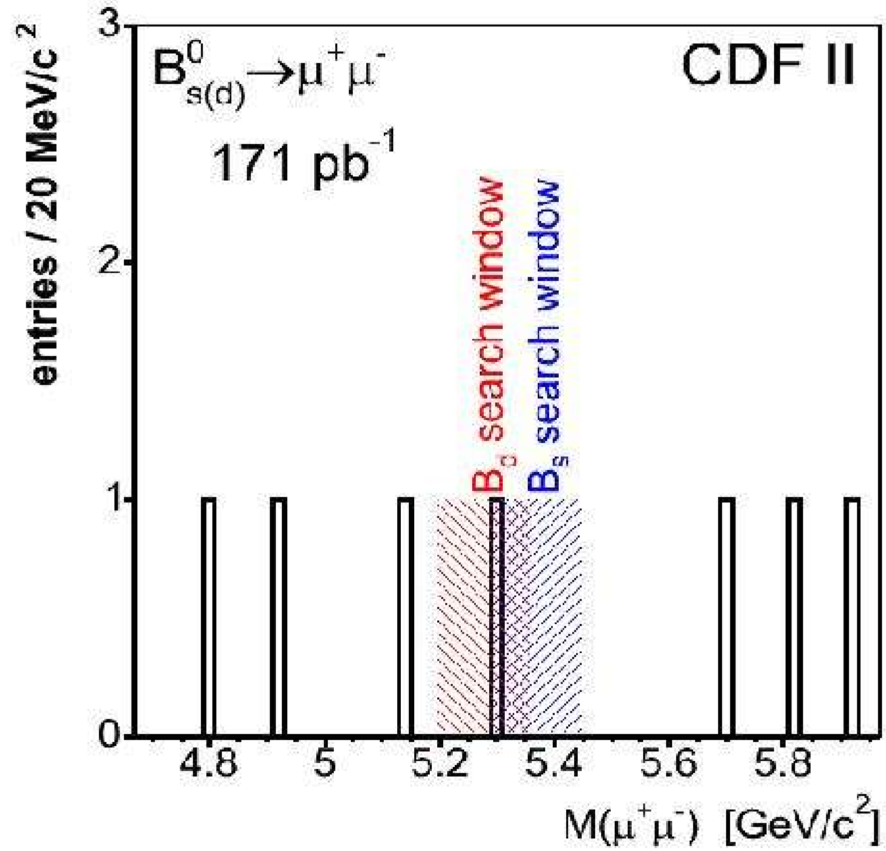
    $B_{s(d)}$: $1.05 \pm 0.30(1.07 \pm 0.31)$
  - Observe 1 common event in 3σ $B_{s(d)}$ mass window which yields a limit of

$$BF(B_s \rightarrow \mu^+\mu^-) < 5.8\times10^{-7}\ 90\%\ \mathrm{CL}$$

$$BF(B_d \rightarrow \mu^+\mu^-) < 1.5\times10^{-7}\ 90\%\ \mathrm{CL}$$

(4x more B_d produced than B_s)

D. Acosta et al., PRL 93, 032001 2004



- Less than 1/3 of previous CDF limit: 20.0×10^{-7} 90% CL
- Most recent BaBar B_d results: 8.3×10^{-8}
  - Tevatron should be competitive in all $B \rightarrow \mu^+\mu^- X$ modes

$B_s \to \mu\mu$: Physics Reach

D0 $B_s \to \mu^+\mu^-$ result: 240pb^{-1}

$$BF(B_s \to \mu^+\mu^-) < 3.8\times10^{-7}\ 90\%\ \mathrm{CL}$$

CDF $B_{(s,d)} \to \mu^+\mu^-$ results: 171pb^{-1}

$$BF(B_s \to \mu^+\mu^-) < 5.8\times10^{-7}\ 90\%\ \mathrm{CL}$$

Combined: Bayesian approach with a flat prior. Systematic error on fs correlated. Combination by M. Herndon

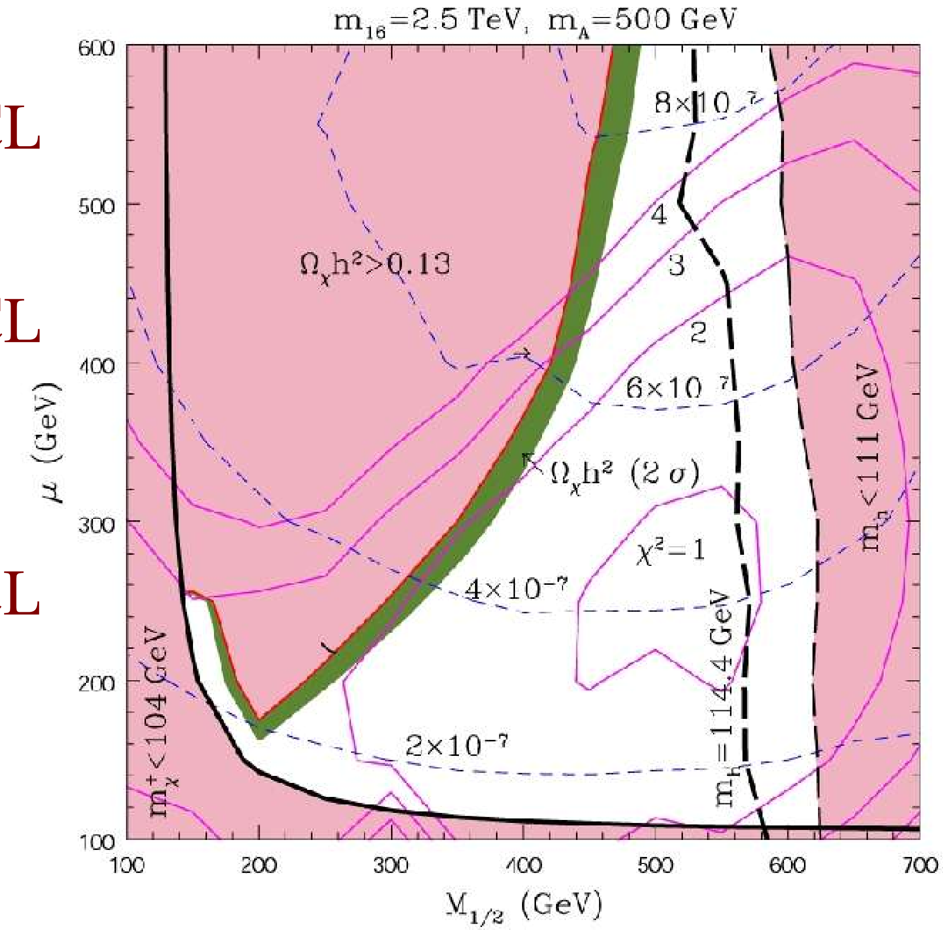
$$BF(B_s \to \mu^+\mu^-) < 2.7\times10^{-7}\ 90\%\ \mathrm{CL}$$

SM predictions

BF($B_{s(d)} \to \mu^+\mu^-$) 3.5×10^{-9} (1.0×10^{-10})

- No sensitivity for SM decay rate

- BSM predictions Limiting many models
- Example SUSY S0(10)
  - Allows for massive neutrino
  - Accounts for relic density of cold dark matter



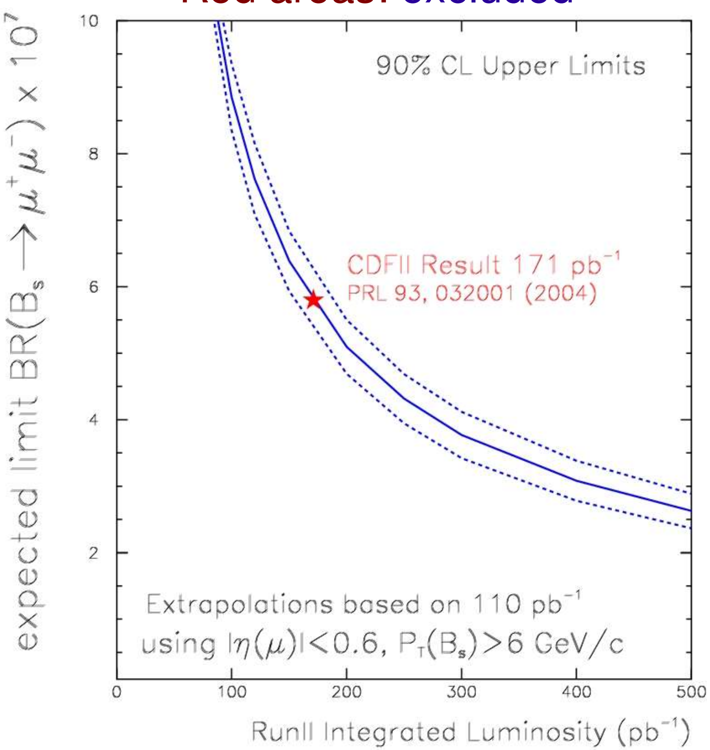
BF $B_s \to \mu^+\mu^-$: Dashed blue

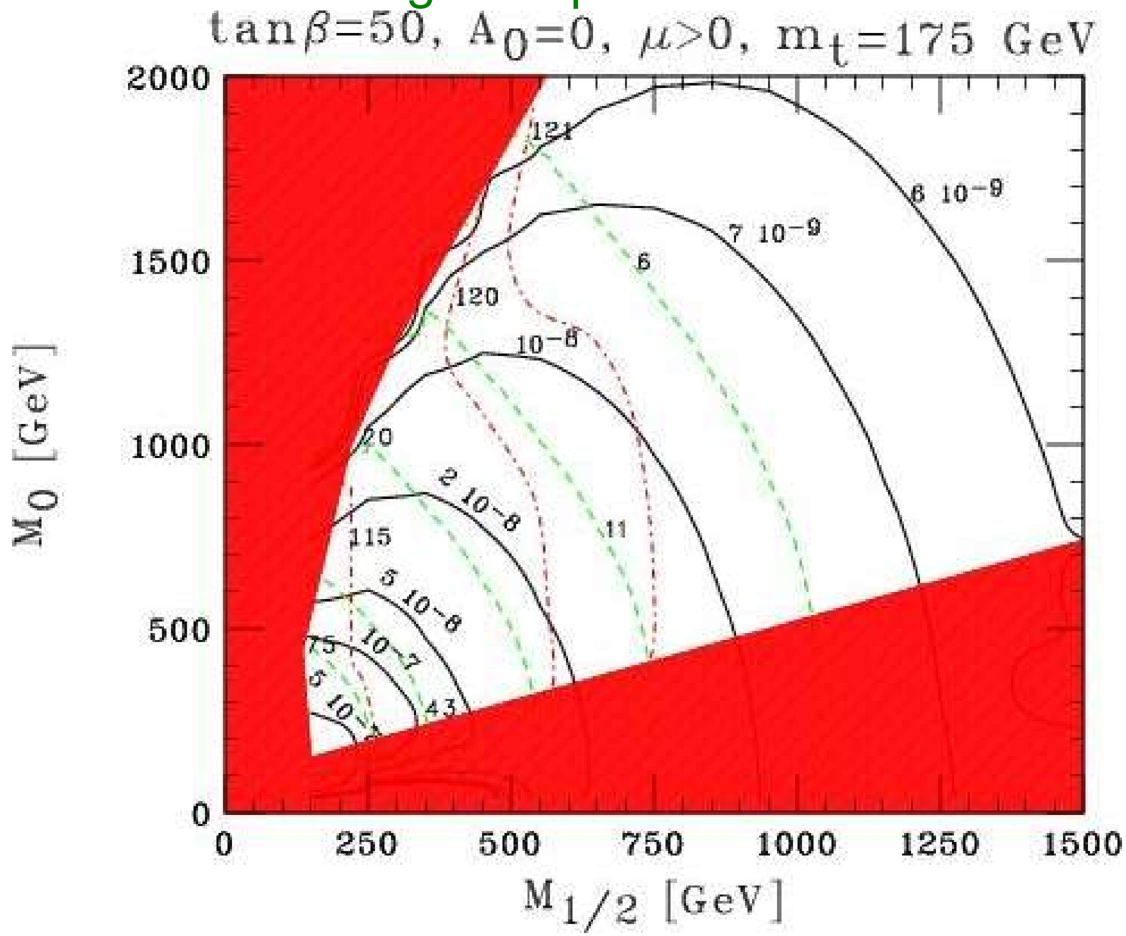
Excludes scenarios where M_A is light and tanβ ~ 50: M_A > 450GeV/c^2

R. Dermisek hep-ph/0304101,2003

$B_s \to \mu\mu$: Physics Reach

- In addition to limiting S0(10) models – starting to impact standard MSSM scenarios: mSugra
  - Solid black: $BF(B_s \to \mu^+\mu^-)$
  - Dashed green: $a_\mu = (g\text{-}2)_\mu/2$
  - Dashed red: Light Higgs Mass
  - Red areas: excluded





Limit starting to intersect 115GeV Higgs contour

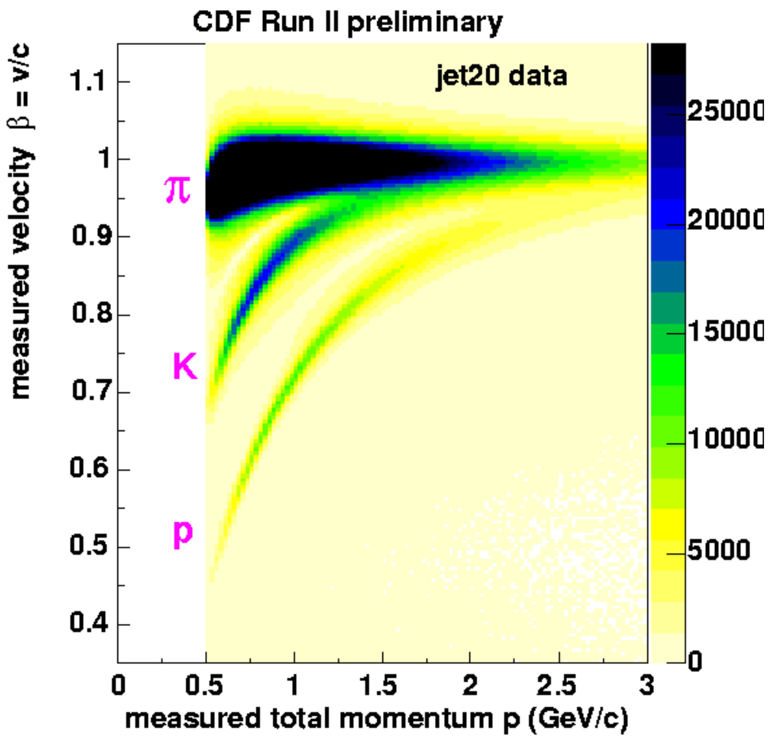
Should be able to considerably increase sensitivity this year (360pb^{-1} data taken)

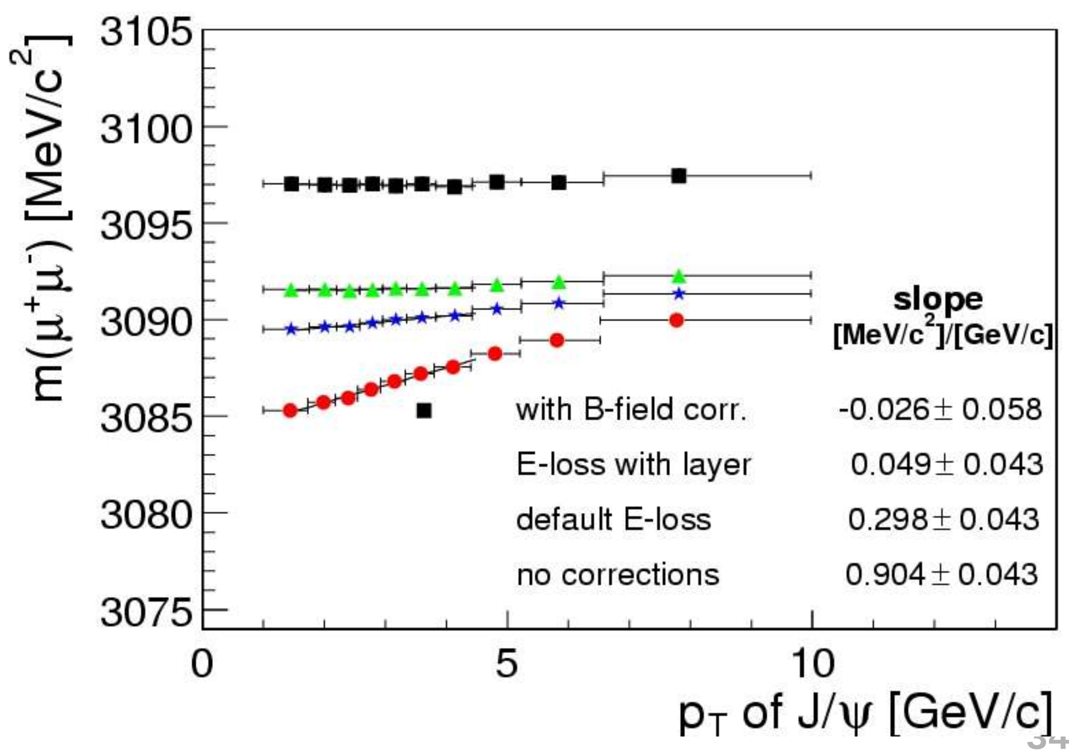
Conclusions

- CDF and the Tevatron have many interesting new measurements
  - Large $\Delta\Gamma_{Bs}$ in $B_s \to J/\psi\phi$
  - First CDF Run 2 Δm_d
  - A_{cp} in $B_{s,d} \to hh$
  - First studies of properties of *X* production at a hadron collider
  - Limits on branching fraction of the FCNC Decay $B_s \to \mu\mu$
- Many of these analysis are still statistics limited
  - Tevatron performance has been quite good in 2004
  - CDF has more data on tape and expects to eventually have 4-9fb^{-1}
  - All these analysis will see considerable improvements in sensitivity
- Still more to come!
  - Bs mixing: All pieces are in progress and many tested in the Δm_d measurement
  - More accurate Λ_b measurements: mass, lifetime, decay branching fractions
  - B_c measurements: Mass in fully reconstructed mode and other measurements...

Detector Performance: Backup

- Careful calibration of detector response is necessary for conducting precision measurements with small systematic errors
  - Develop large samples for calibrating detector response
  - 3.1M J/ , 400K ψ(2S), and 18K Upsilon(1S) samples for tracking momentum scale and energy loss calibration
  - 500K D* tagged $D^0 \rightarrow K\pi$ events for dE/dx and TOF calibration





$\Delta\Gamma_{B_s}$ Results Backup

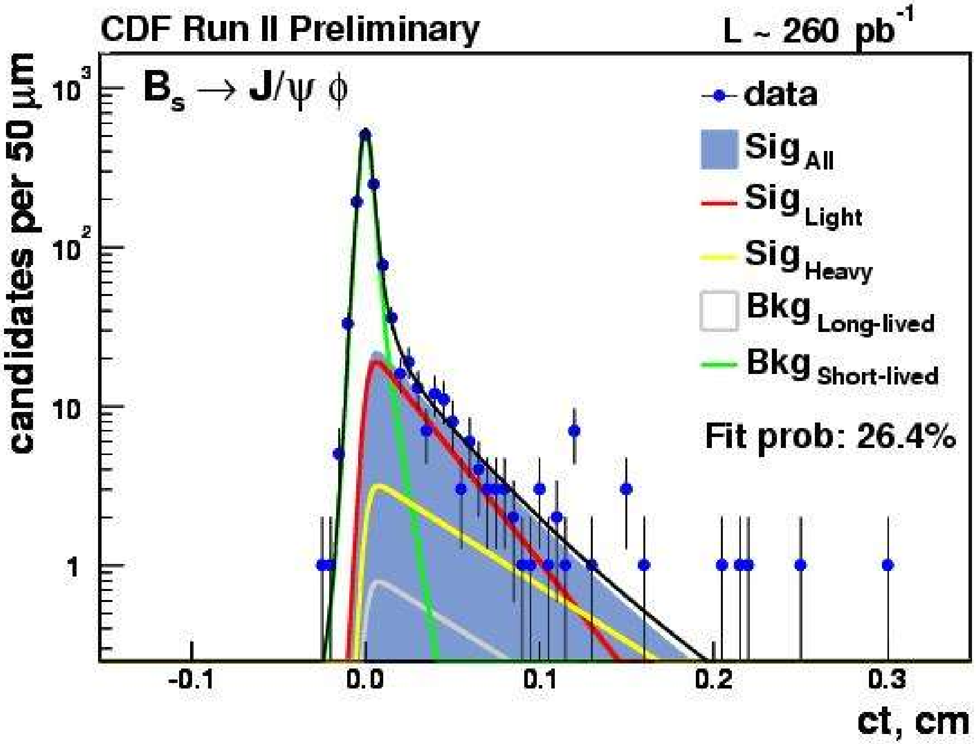
$$A_0 = 0.784 \pm 0.039 \pm 0.007$$

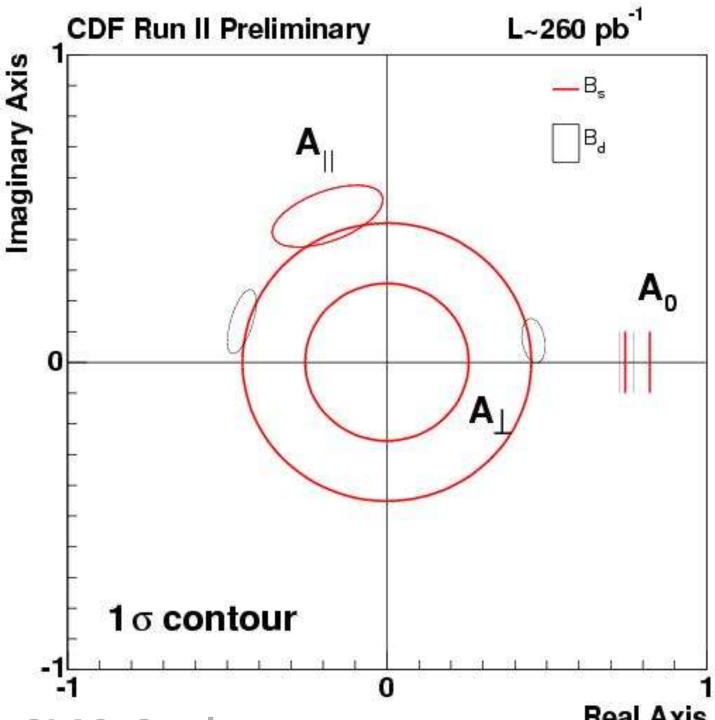
$$A_\parallel = (0.510 \pm 0.082 \pm 0.013)\, e^{(1.94 \pm 0.36 \pm 0.03)\, i}$$

$$|A_{perp}| = 0.354 \pm 0.098 \pm 0.003$$

$$\tau_{B_s L} = 1.05^{+0.16}_{-0.13} \pm 0.02\, ps$$

$$\tau_{B_s H} = 2.07^{+0.58}_{-0.46} \pm 0.03\, ps$$





$$\Delta\Gamma_{B_s}/\Gamma_{B_s} = 0.65^{+0.25}_{-0.33} \pm 0.01$$

2.5(2.0)σ from $\Delta\Gamma_{B_s}/\Gamma_{B_s} = 0(0.12)$

No constraint :

$$\tau_s = 2\tau_H \tau_L / (\tau_H + \tau_L)$$