New CDF *B* Physics Results

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

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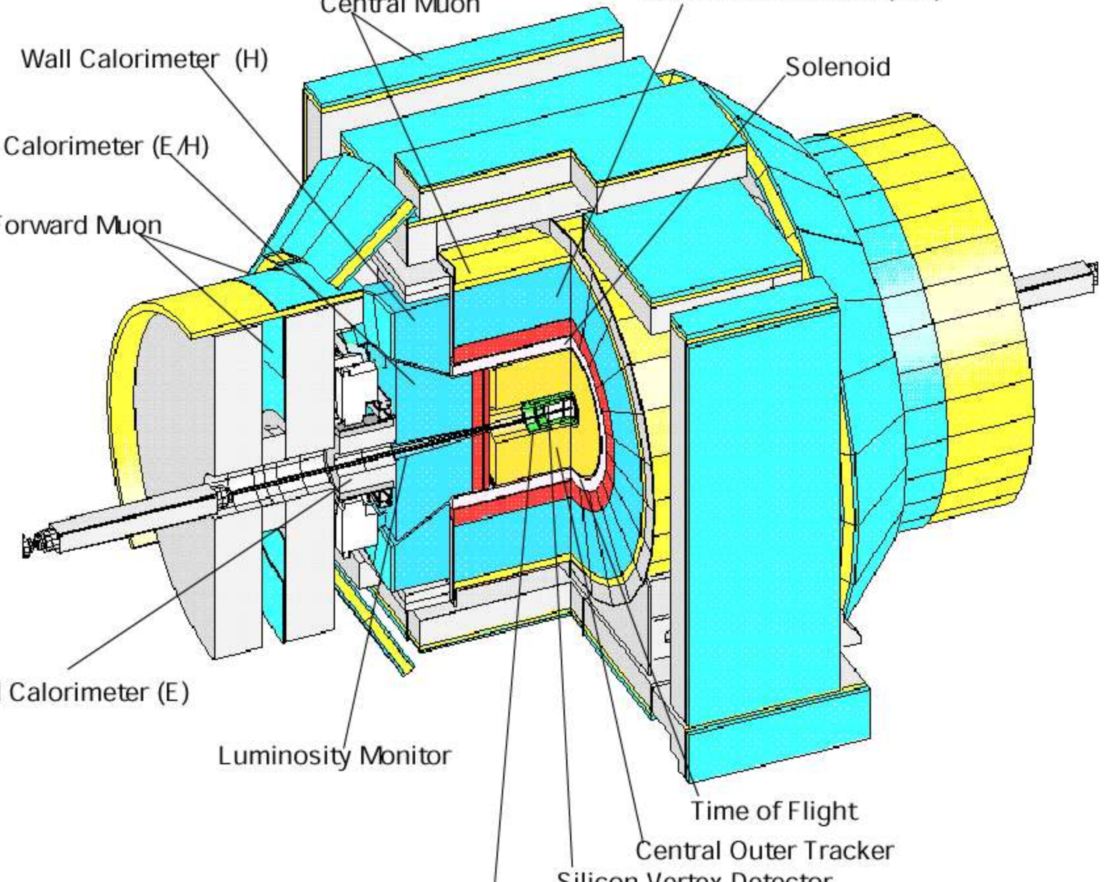
Tevatron Connection 2004

CDF Detector

- Silicon
  - |η|<2, less coverage gaps, 90cm long
- Drift Chamber(COT)
  - 96 layers between 44 and 132cm

EXCELLENT TRACKING

- Expanded muon coverage
  - |η|<1.5
- PID
  - p, K and π by dE/dx and TOF



B Physics & B Triggers

- Huge production rates
  - $\sigma(ppbar \rightarrow bX, |y| < 0.6) = 17.6 \pm 0.4$ (stat.) ± 2.5 (syst.) μb
- Heavy b states produced
  - $B_0, B^+, B_s, B_c, \Lambda_b, \Xi_b$
- Backgrounds are also 3 orders of magnitude higher
  - Inelastic cross section ~100 mb
  - Challenge is to pick one B decay from ~10^3 QCD events

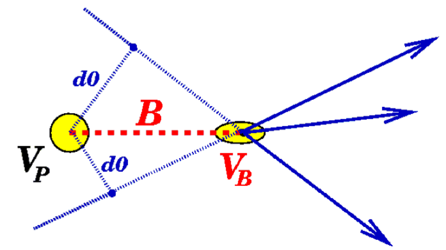
TRIGGERS ARE CRITICAL

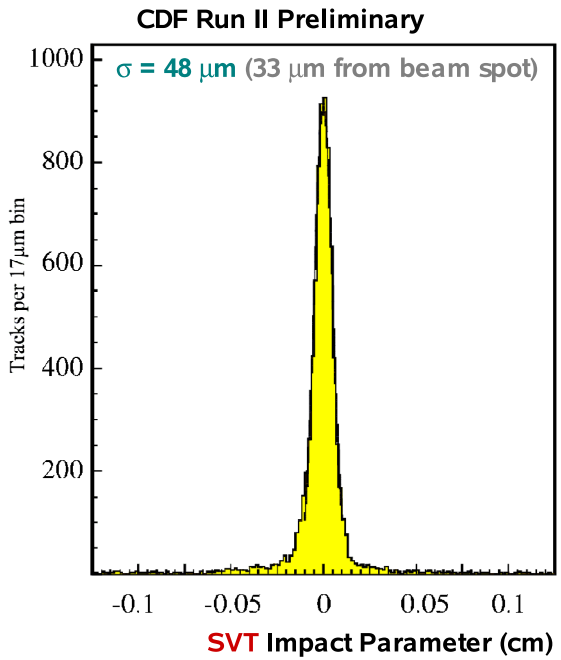
- Di-muon trigger
  - $pT(\mu) > 1.5$ GeV/c
  - B yields 2x Run I (lowered pT threshold, increased acceptance)

HIGH LUMI: TRIGGER RATES VERY HIGH

- Lepton + displaced-track trigger
  - $pT(\mu,e) > 4$ GeV/c, 120 μm $< d_0 <$ 1mm, $pT > 2$ GeV/c
  - B yields 3x Run I
- Two displaced-tracks trigger
  - $p_T > 2$ GeV/c, 120 μm $< d_0 <$ 1mm, $\Sigma p_T > 5.5$ GeV/c

SENSITIVITY TO NEW HADRONIC MODES

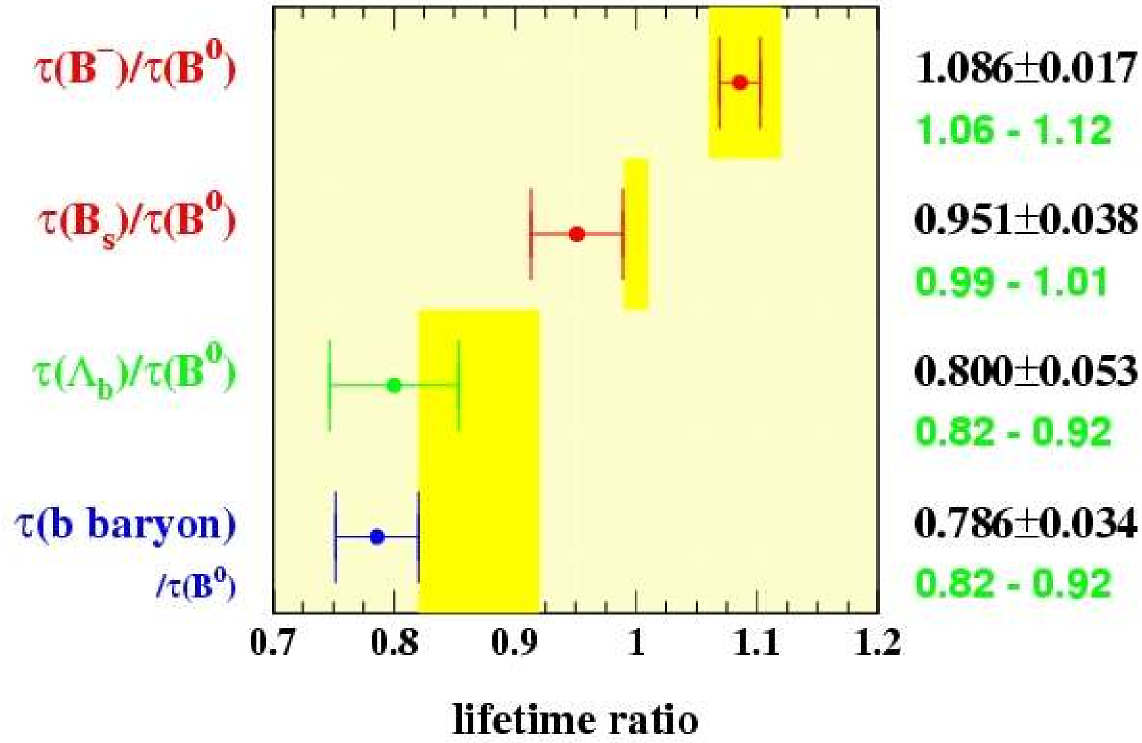




Lifetimes and $\Delta\Gamma_{B_s}$ Motivation

- Lifetime ratios
  - Test of HQET
  - From simple lifetime measurement

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



- Lifetime difference
  - $B_s \to J/\psi\phi$ Pseudoscalar → Vector Vector
  - $B_{s,light}$ CP Even and $B_{s,heavy}$ CP Odd : Polarized
  - What was the mix of light and heavy in previous measurements?
  - indirect Δm_s measurement

$$\frac{\Delta\Gamma_{B_s}}{\Gamma_{B_s}}$$

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

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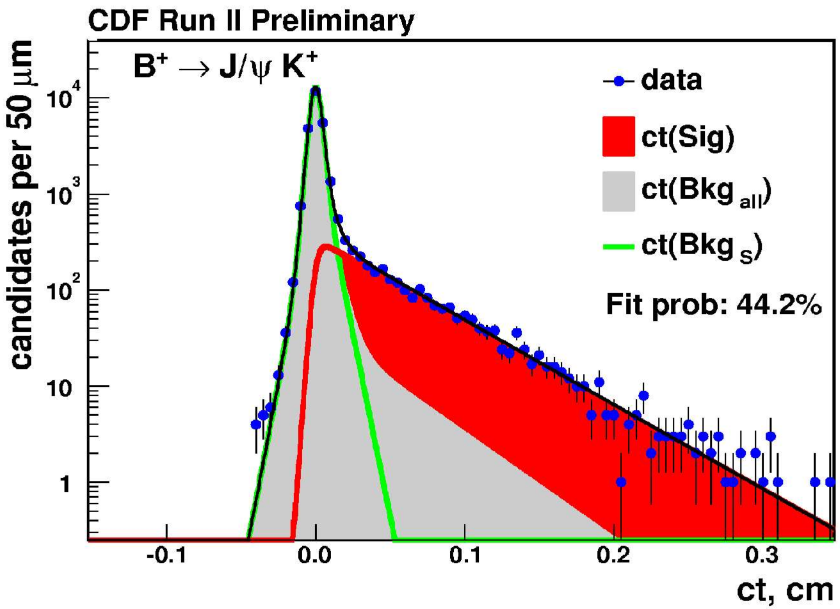
Lifetimes

Analysis and results

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

- Fraction of signal events: 1 parameter
- Mass: Gaus + pol 1: 3 parameters
- Proper decay length
  - Delta function conv with Gaus. + 4 exp conv with gaus.(signal and 3 tails): 8 parameters.
- Unbinned maximum likelihood
  - 1+3+8 = 12 parameters



$$\tau_{B^+} = 1.662 \pm 0.033(stat) \pm 0.008(sys)\ ps$$

$$\tau_{B^0} = 1.539 \pm 0.051(stat) \pm 0.008(sys)\ ps$$

$$\tau_{B_s} = 1.369 \pm 0.100(stat)^{+0.008}_{-0.010}(sys)\ ps$$

$$\tau_{B^+}/\tau_{B^0} = 1.080 \pm 0.042(tot)$$

$$\tau_{B_s}/\tau_{B^0} = 0.890 \pm 0.072(tot)$$

HFAG B_s: 1.461 ± 0.057ps

B^+: 1.671 ± 0.018ps
B^0: 1.536 ± 0.014ps

B^+/B^0:1.086 ± 0.017
B_s/B^0: 0.951 ± 0.038

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

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

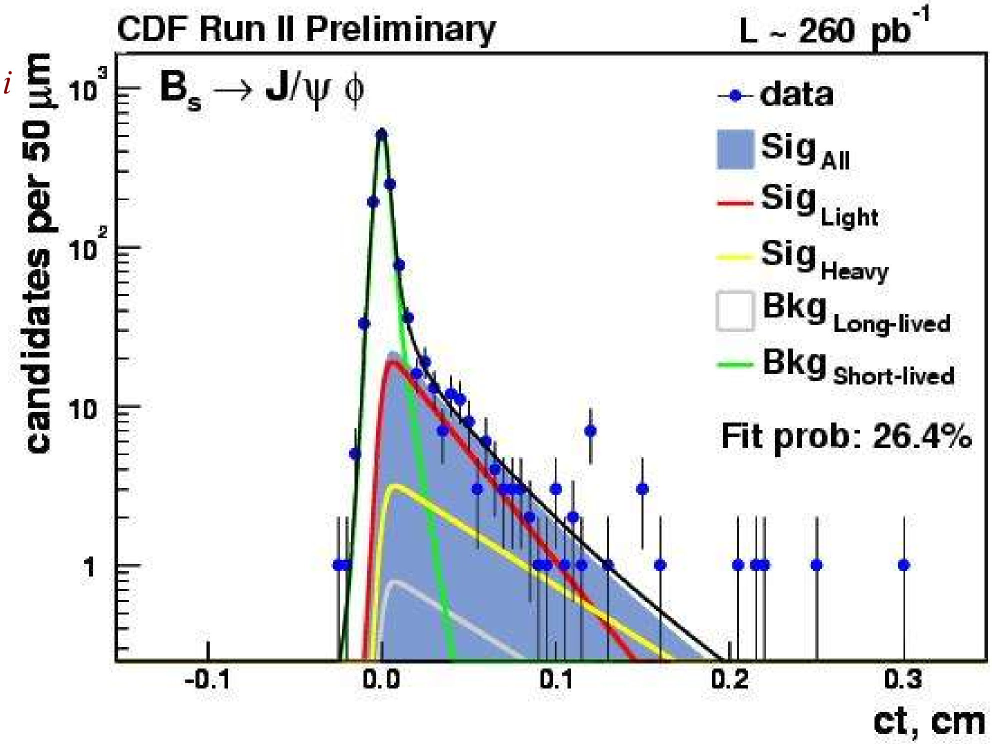
$$A_\parallel = (0.510 \pm 0.082 \pm 0.013)\, e^{(1.94 \pm 0.36 \pm 0.03)i}$$

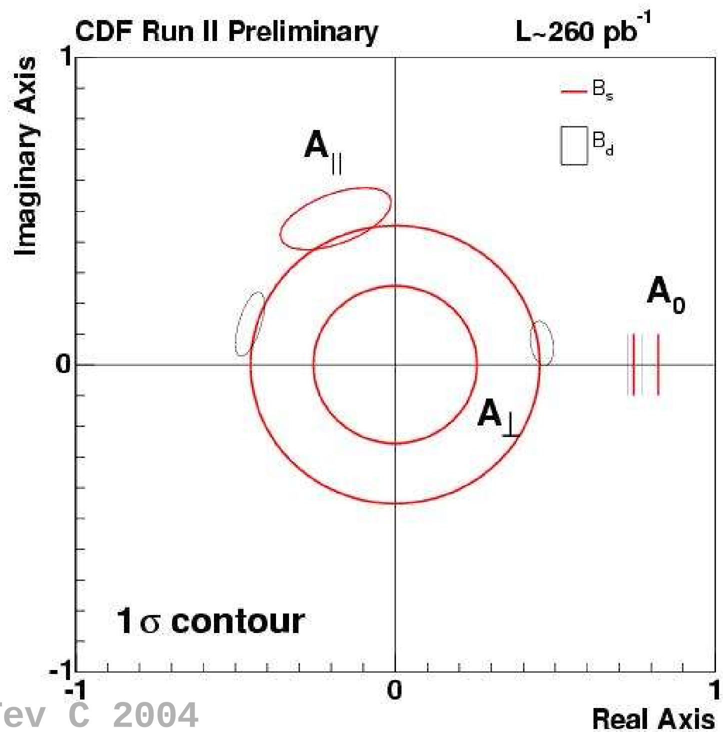
$$|A_{perp}| = 0.354 \pm 0.098 \pm 0.003$$

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

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

$\Delta m_s = 125^{+69}_{-55}\ ps^{-1}$ Using SM/Theory ratio





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

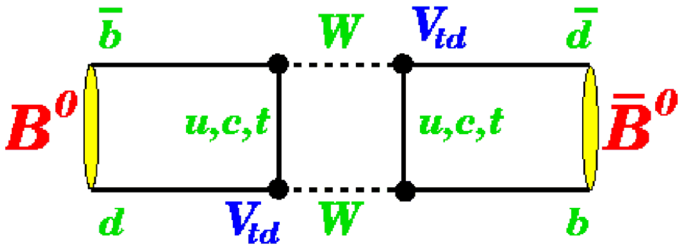
$$A_\parallel = (0.0473 \pm 0.034 \pm 0.006)\, e^{(2.86 \pm 0.22 \pm 0.07)i}$$

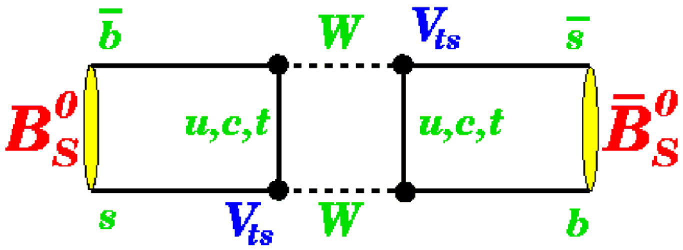
$$|A_{perp}| = (0.464 \pm 0.035 \pm 0.007)\, e^{(0.15 \pm 0.15 \pm 0.04)i}$$

$$\tau_{B_d} = 1.54 \pm 0.05 \pm 0.02\ ps$$

B^0 results consistent with B factory results

B Mixing Motivation



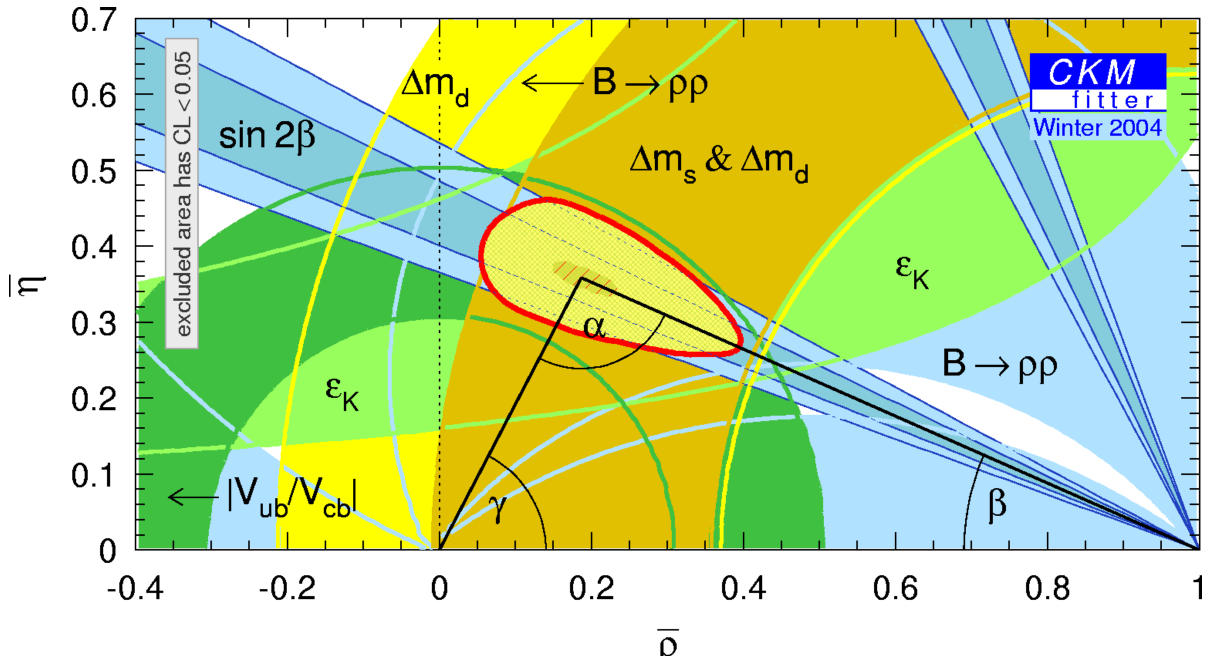


- B_d oscillations are sensitive to $|V_{td}|$
- Compromised by hadronic uncertainties
- Most cancel in B_d/B_s oscillation ratio

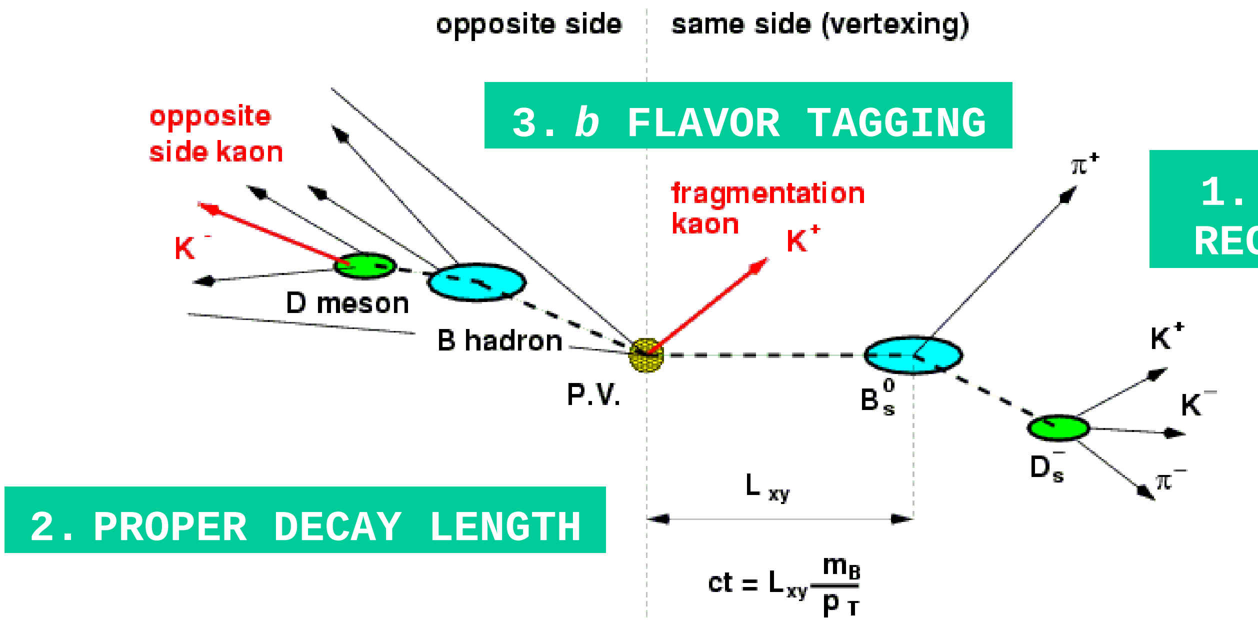
$$\frac{|V_{td}|}{|V_{ts}|} = 1.01\xi\sqrt{\frac{\Delta m_d}{\Delta m_s}}$$

from LATTICE

- New physics may affect $\Delta m_s/\Delta m_d$
- Δm_s prerequisite for time-dependent B_s CP violation measurement



B Mixing Ingredients



- Efficiency $\varepsilon \equiv$ fraction of tagged events
- Dilution $D \equiv 2P - 1$ with P the correct answer probability
- Tagging effectiveness εD^2 shows statistical power of the tagger
- Flavor taggers can be topologically separated
  - Same-Side is sample dependent : Same side track(SST)
  - Opposite-Side is based on properties of the non-reconstructed *b:* Soft muon (SMT)/electron(SET) and jet charge(JQT)

B Mixing Tagging results

- SMT: Find events with Opposite Side $B \to \mu X$
  - Opposite Side μ charge gives **SMT** decision
  - Qualities
    - High Purity, Low efficiency

εD^2 = 0.698 ± 0.042 (stat.)%, lSVT

  - Uses likelihood method to combine information, EM/HAD energy and stub matching quantities
  - Combined $\sum\varepsilon D^2$ for subsamples(muon subdetector and p_T^{rel} bins)
  - $\sum\varepsilon D^2$ evaluated in lepton + SVT data
- JQT: Jet charge of OS b

will update for ICHEP

  - Weighted average Q of jet tracks
  - Qualities
    - Moderate purity, High efficiency
    - Other jets a problem

εD^2 = 0.419 ± 0.024 (stat.)%, eSVT

  - Combined $\sum\varepsilon D^2$ for subsamples(with and without vertex tag and for JQ bins)
- SST: Look for fragmentation track that is charge correlated with the produced B

εD^2 = 2.0(1.0) ± 0.5 (stat.)%, $B^+(B^0)$

  - Consider track close to B: In cone and lowest p_T^{rel}

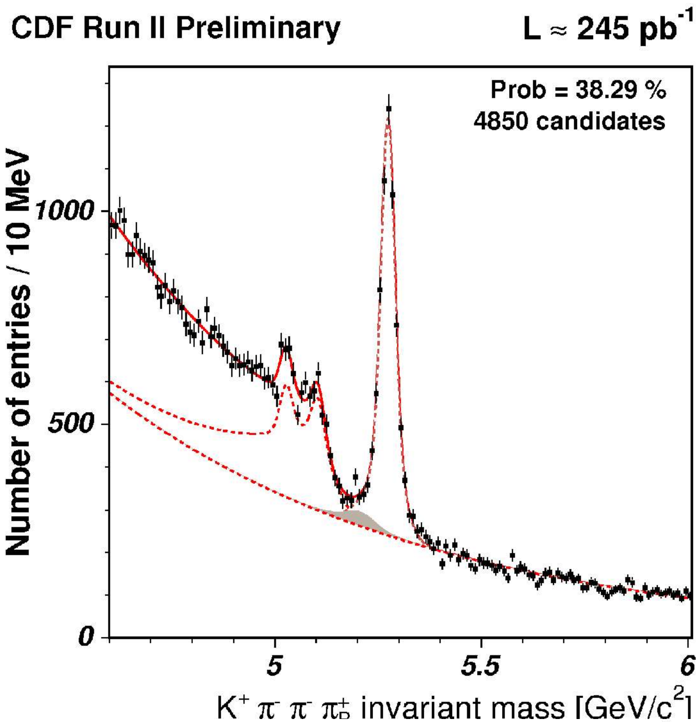
B Mixing Δm_d(in fully reconstructed modes)

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

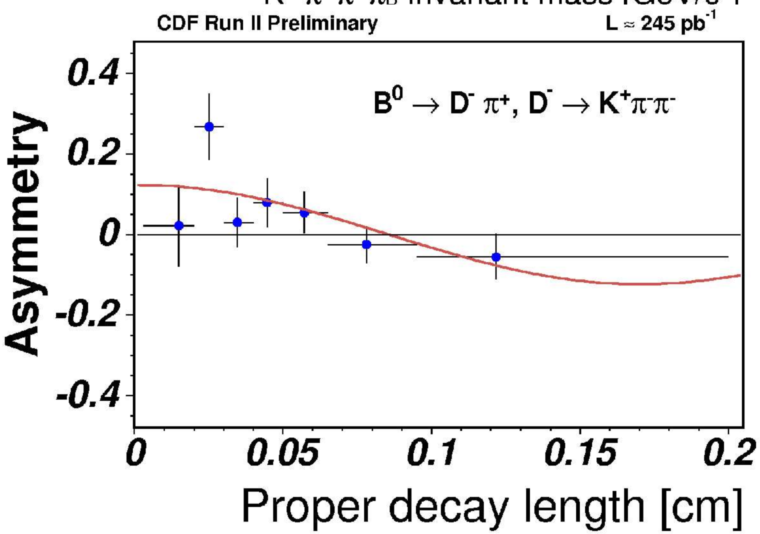
- Minimum quality cuts applied to preserve signal
  - Mass cuts for J/ψ and K^{*0}
  - $p_{TB} > 6.5$, $p_{TK} > 2.5$ GeV/c, $L_{xy} > 100\mu m$

$$B^0 \to D^-\pi^+_B,\, \pi^-,\, D^- \to K^+\pi^-\pi^-$$

  - $p_{T\pi B} > 1.6$, $|d_{0B}| < 80\mu m$, $L_{xy} > 300\mu m$



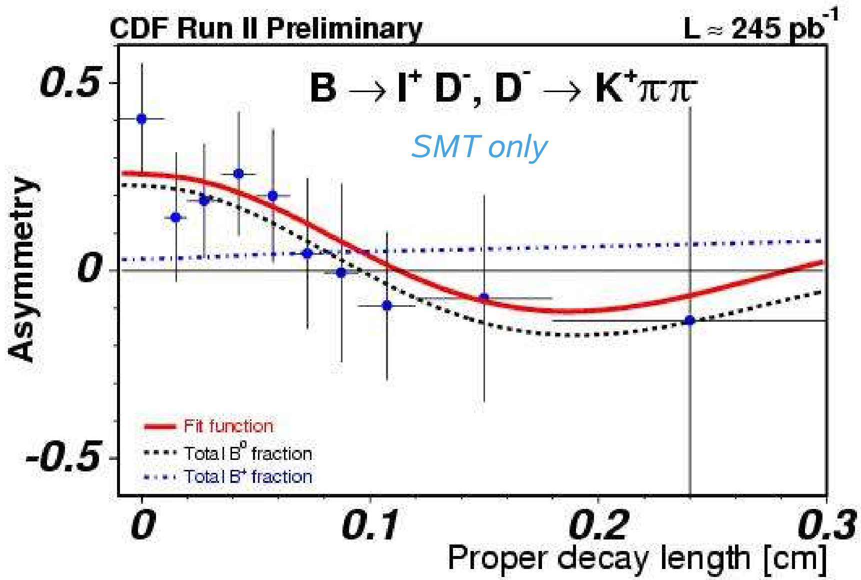
- Measure Δm_d and SST performance
  - Combine channels
  - Fit for Δm_d using a convolution of physical time dependence, $\cos(\Delta m_d t)$, and the Gaussian proper time resolution
  - Update for ICHEP: More statistics and channels

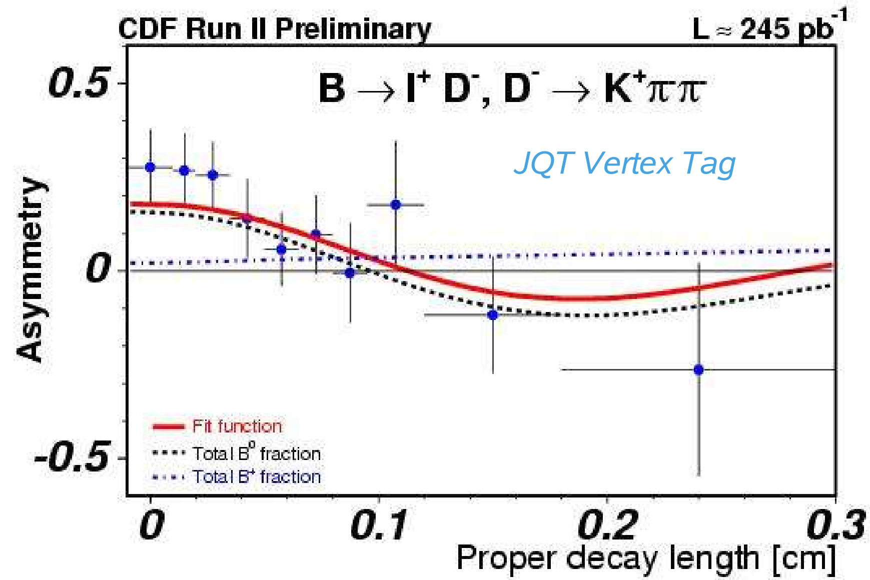


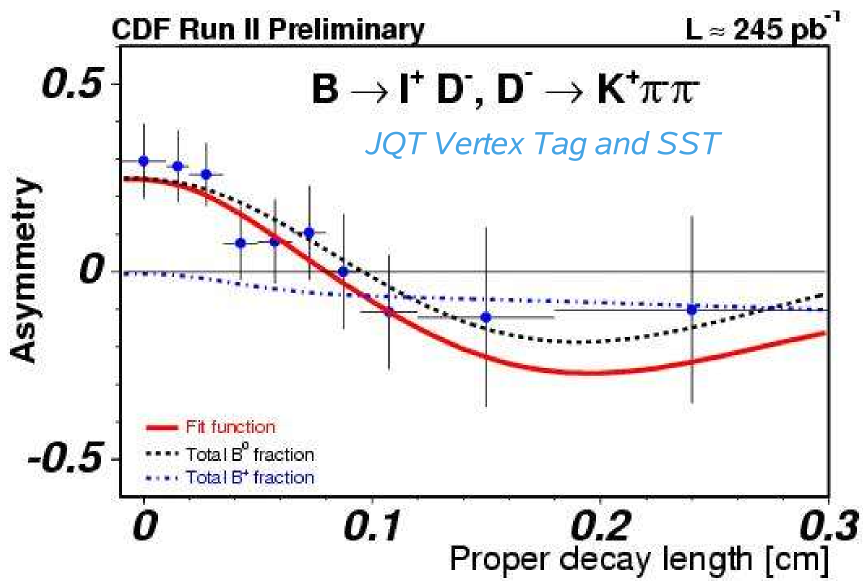
$$\Delta m_d = 0.55 \pm 0.10\ (\text{stat.}) \pm 0.01\ (\text{syst.})\ ps^{-1}$$

$$\varepsilon D^2 = 1.0 \pm 0.5\ (\text{stat.}) \pm 0.2\ (\text{syst.})\ \%$$

B Mixing Δm_d(in semileptonic modes)







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

$\Delta m_d = 0.536 \pm 0.037(\text{stat})$

$\pm 0.009(\text{sc}) \pm 0.015(\text{sys})\ \text{ps}^{-1}$

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

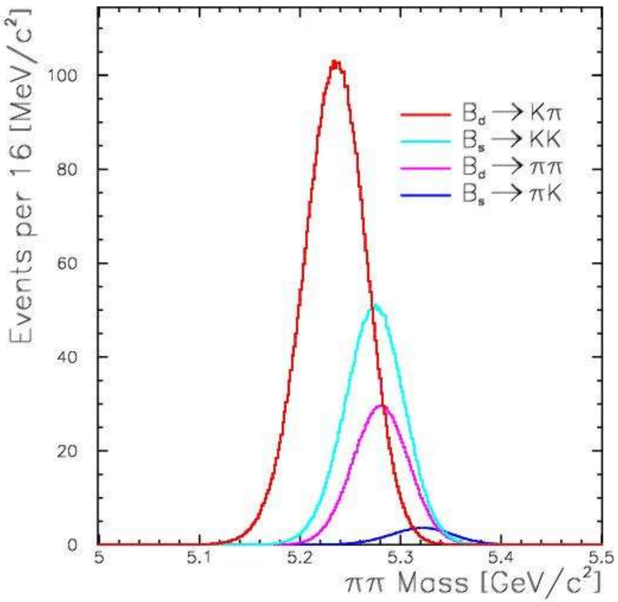
SST: $\varepsilon D^2 = 1.04 \pm 0.24$ (stat)%

SMT: $\varepsilon D^2 = 0.32 \pm 0.05$ (stat)%

JQT: $\varepsilon D^2 = 0.49 \pm 0.07$ (stat)%

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



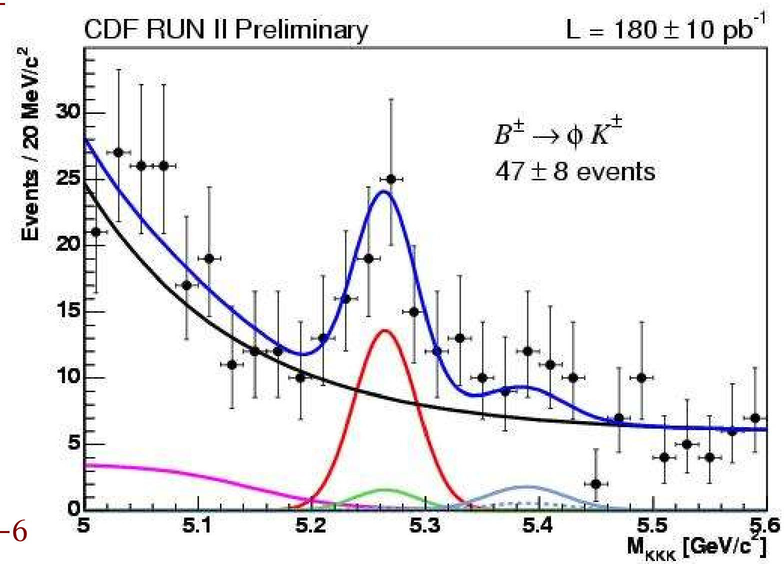
Charmless B Decays results

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

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

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

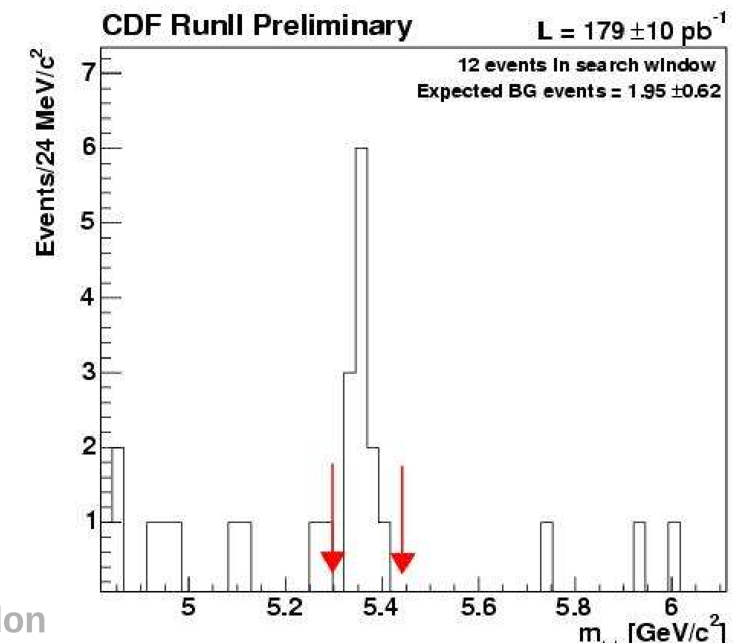
HFAG: $(9.0 \pm 0.7) \times 10^{-6}$



- Analysis Cuts $B_s \to \phi \phi , \phi \to K^+ K^-$
  - Optimized using blind analysis technique
  - ϕ mass cut, $p_{T\phi}$ > 2.5GeV/c
  - $|d_{0B}|$<80μm, L_{xy} > 350μm

$$BR(B_s \to \phi \phi) =$$

$$1.4 \pm 0.6(stat) \pm 0.2(sys) \pm 0.5(norm) \times 10^{-5}$$



Charmless B Decays $B \to hh$

- Cuts optimized to maximize $\frac{S}{\sqrt{S+B}}$
- Unbinned likelihood fit
  - $M_{\pi\pi}$, dE/dx, charge-momentum imbalance

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

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

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

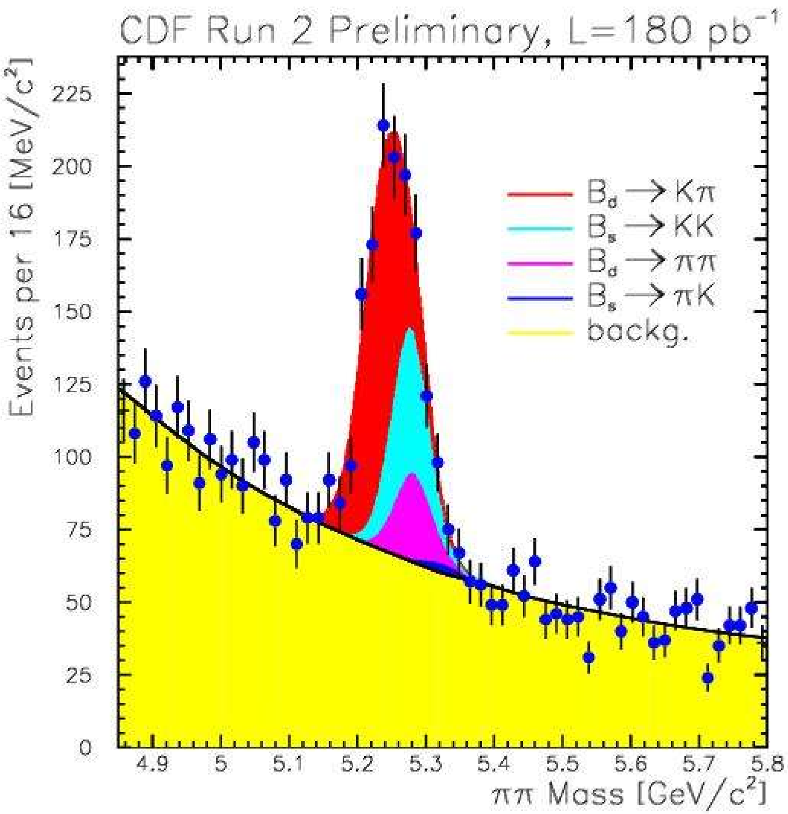
$$BR(B_s \to K^\pm \pi^\mp) < 7.6 \times 10^{-6}$$

$$Th: (7-10) \times 10^{-6}$$

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

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

4.2 σ hep-ex/0407057

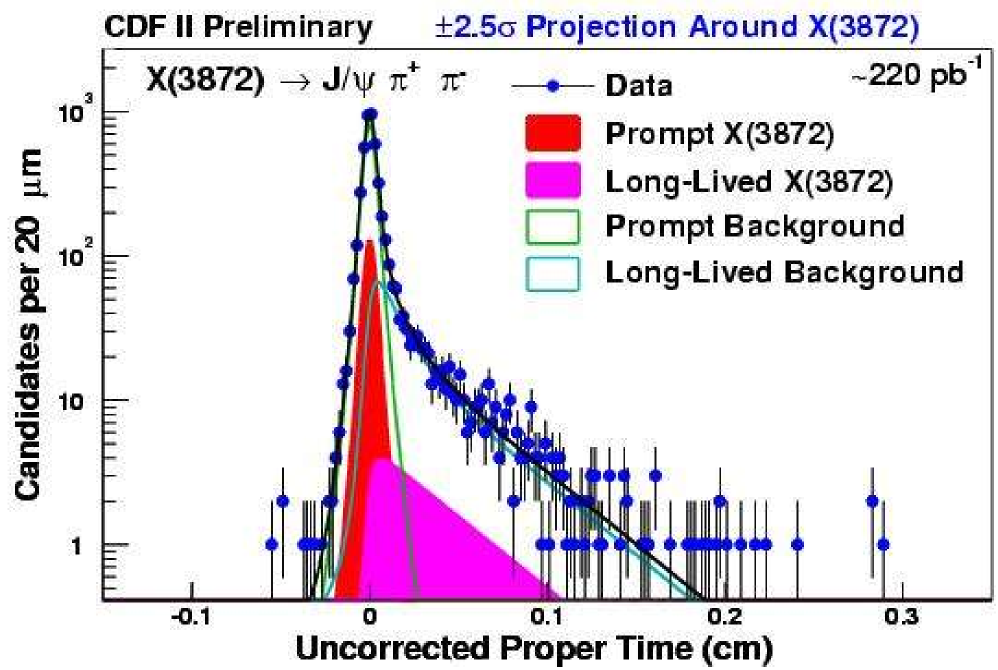


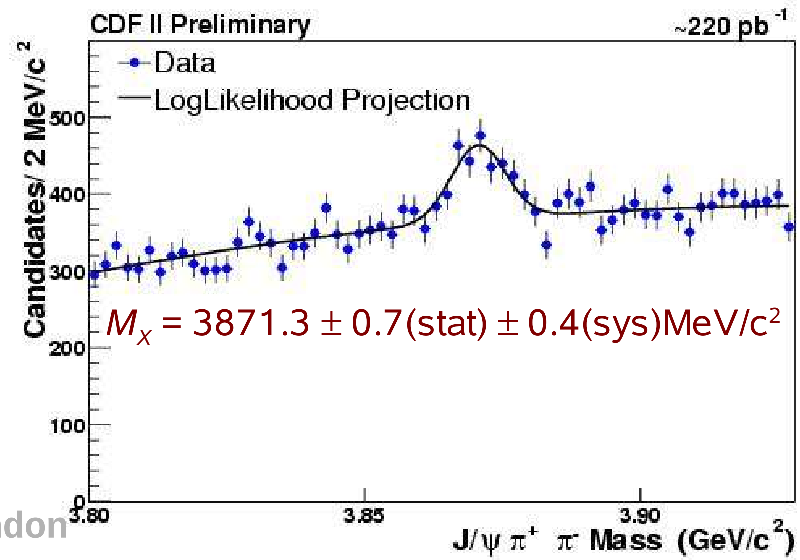
$B^0 \to \pi\pi$	134	15%
$B^0 \to K\pi$	509	57%
$B_s \to KK$	**232**	**26%**
$B_s \to K\pi$	18	2%

X Physics B fraction

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

- Motivation
  - *X* observed by Belle in $B^+ \to XK^+$
  - Production source in ppbar unknown
  - Measurement of prompt production fraction might indicate whether the *X* is 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
  - Only measuring long lived fraction
  - ψ(2S) ll fraction: $28.3 \pm 1.0 \pm 0.7\%$





$$X \text{ ll frac: } 16.1 \pm 4.9(stat) \pm 2.0(sys)\%$$

Conclusions

- Lifetimes, Polarization and $\Delta\Gamma_{Bs}$
  - *B* lifetimes competitive with PDG
  - B_0 polarization consistent with B factories
  - Measure large $\Delta\Gamma_{Bs}$
- Mixing
  - Measure B_d oscillation compatible with B factories
  - Large number of taggers tested and being used
- Charmless B Decays Branching Ratios and A_{CP}
  - See new vector vector mode $B \rightarrow \phi\phi$
  - No evidence of asymmetries
- *X* Physics
  - Fraction of long lived *X* similar to charmonium states
  - *X* needs more study