Same Side Flavor Tagging and B^0 Mixing at CDF

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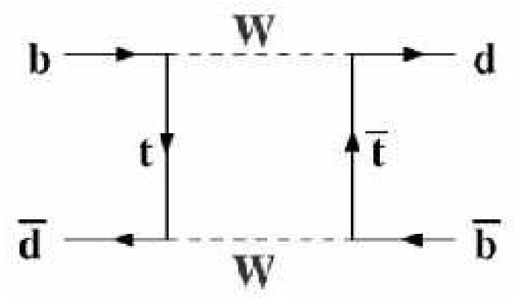
- Mixing and Flavor Tagging
- Same Side Tagging
- Exclusive B meson reconstruction
- Tagging measurements on B^+ modes
- Oscillation measurement on B^0 modes
- Prospects

Mixing and Flavor Tagging

Particle – anti-particle oscillation (mixing) occurs in a neutral B system

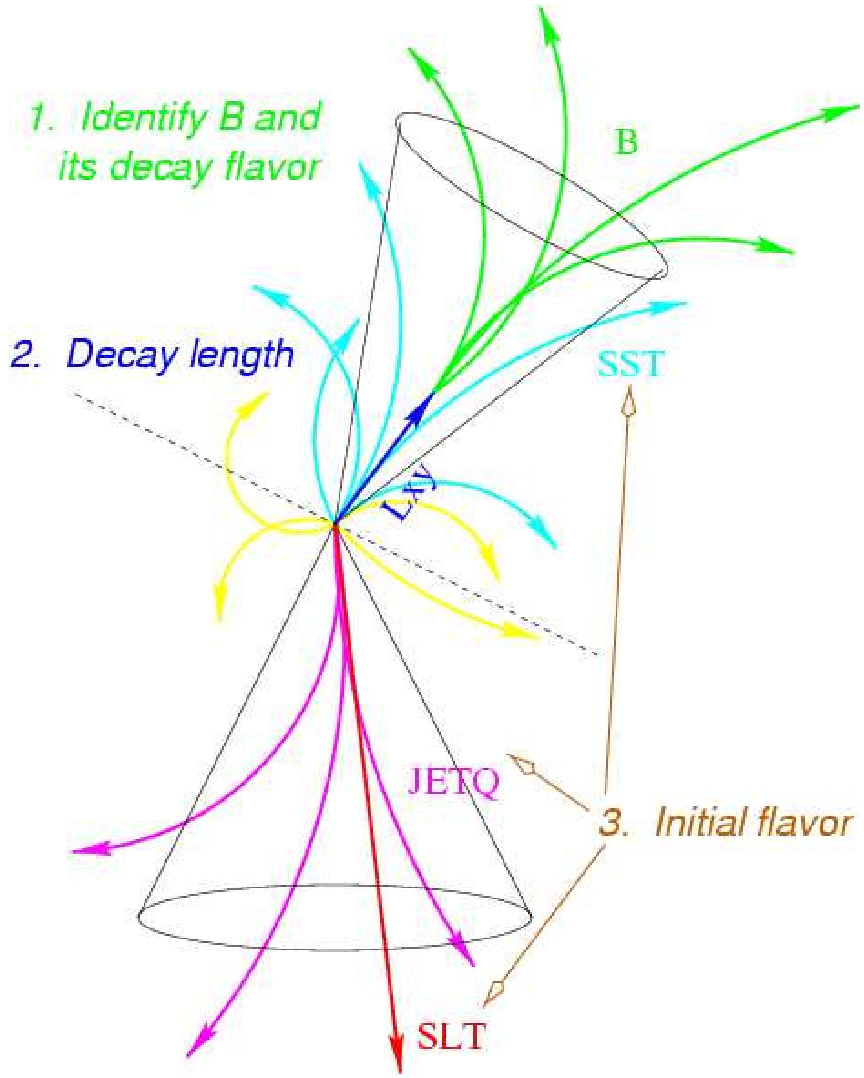


$$P(t)_{B^0 \to \bar{B}^0} = \frac{1}{2} e^{-t/\tau} (1 - cos \Delta m t)$$

- ⋆ B^0: $\Delta m_d = 0.502 \pm 0.007 \; ps^{-1}$ (PDG)
- ⋆ B_s^0: Δm_s not yet measured

Mixing measurement requires determination of B-flavor (b or $\bar{b}$) at production time:

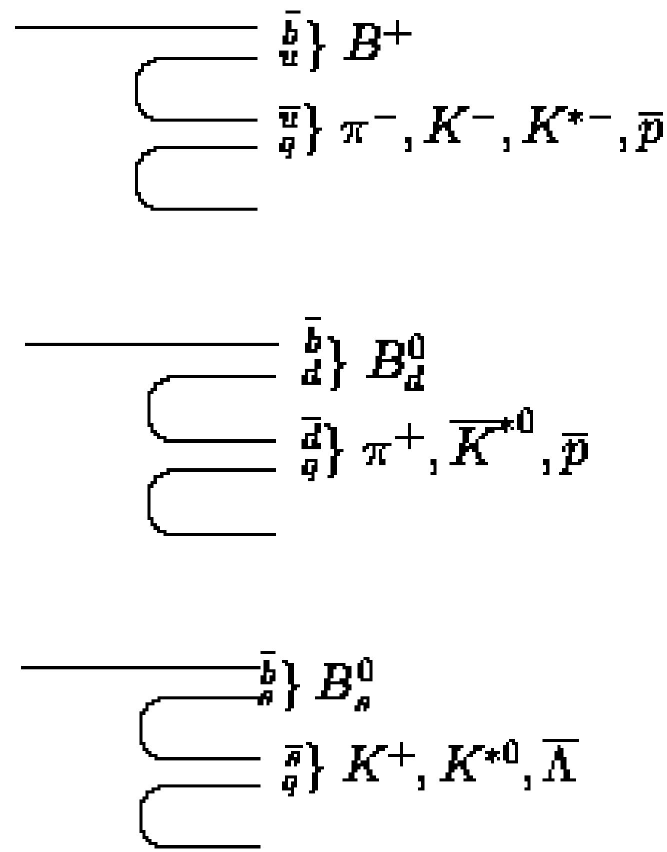
flavor tagging



Fragmentation Track Correlations

SST is based on flavor-charge correlations
between B meson and:

- pion from $B^{**} \to B\pi$ decays
- leading fragmentation track



SST works differently for each B species:

- $B^+ (B^-)$ are accompanied by **negative (positive) pions**

  $B^0 (\bar{B}^0)$ are accompanied by **positive (negative) pions**

  $B_s^0 (\bar{B}_s^0)$ are accompanied by **positive (negative) kaons**

- **mistagging probability larger for B^0 due to neutral K**

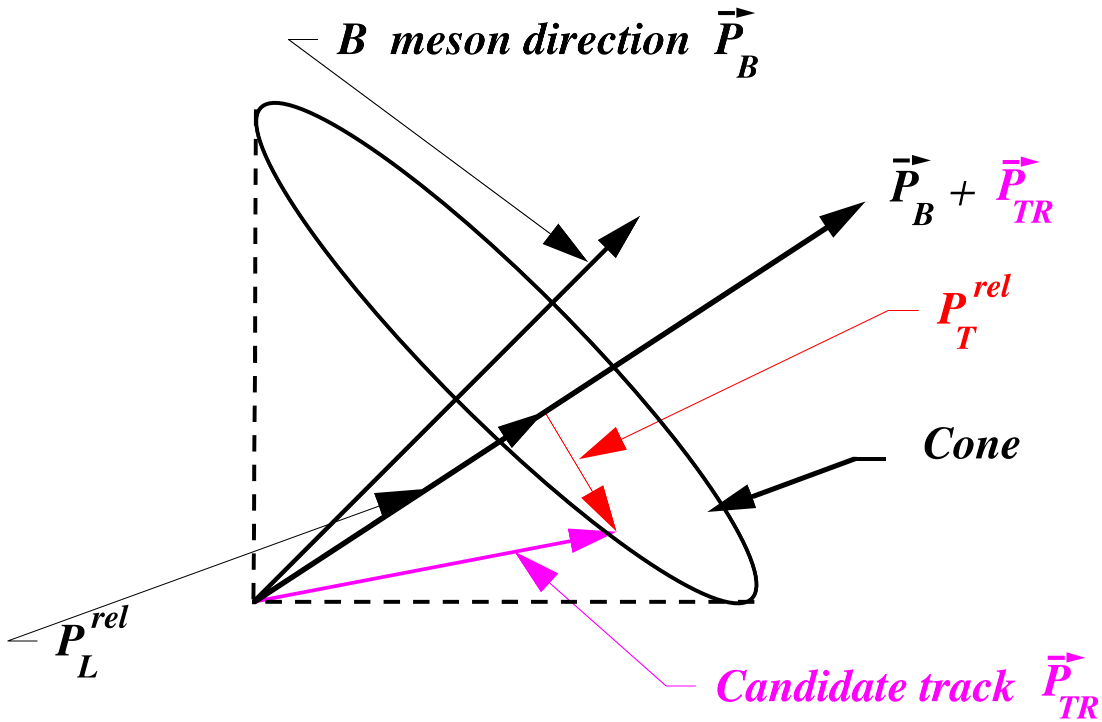
  [best performace for B_s^0 requires particle identification]

Selecting the Same Side Tag

The identification of the flavor of a neutral B meson can make use of hadrons produced nearby in phase space. **M.Gronau, J.Rosner, Phys.Rev. D49 (1994) 254-264**

Candidate tracks:

- close to the B meson $\Delta R \equiv \sqrt{\Delta\eta^2 + \Delta\phi^2} < 0.7$
- $P_T > 350$ MeV/c
- originating from Primary Vertex ($|d_0/\sigma| < 3$)



Tag track selection:

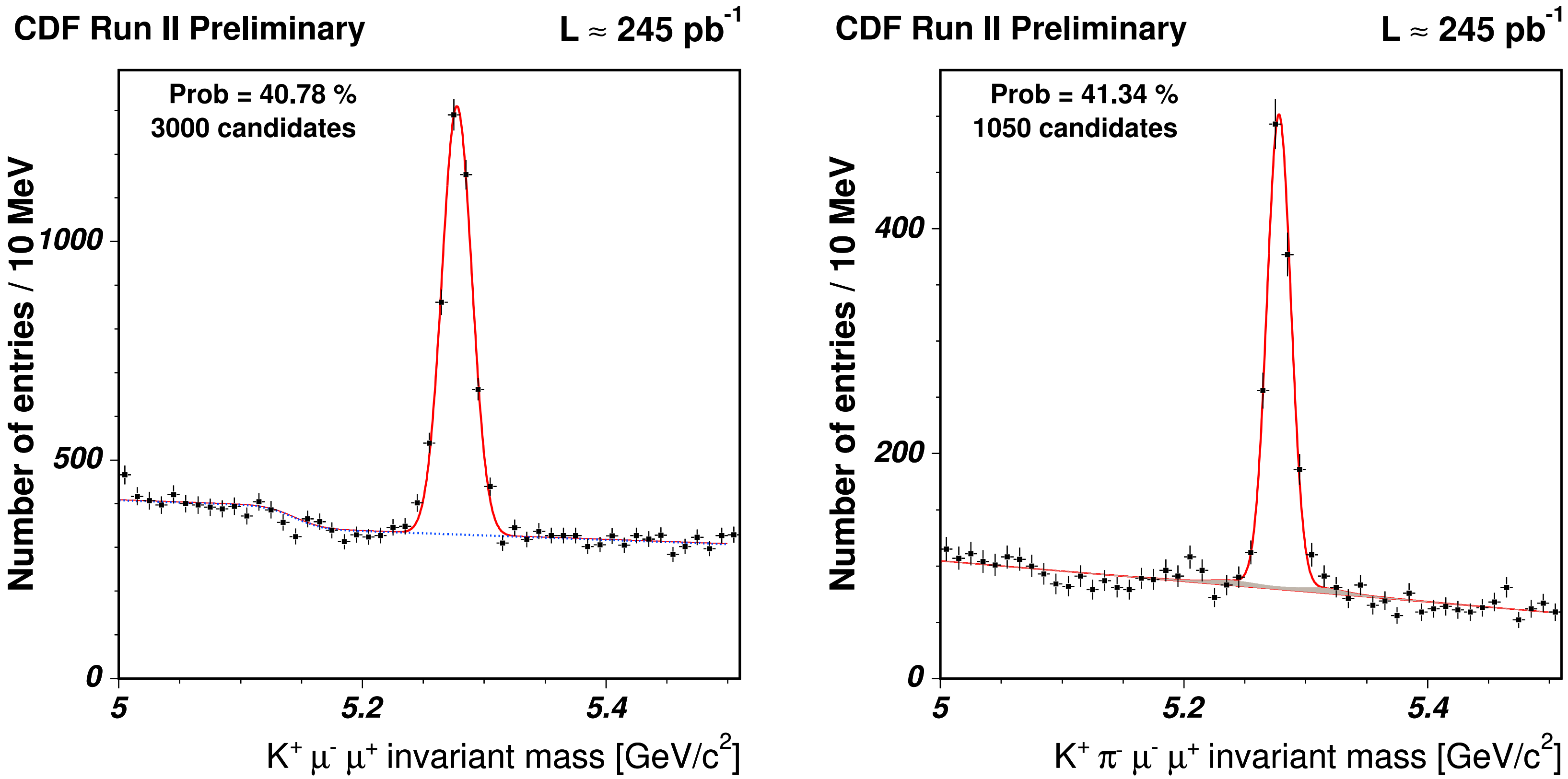
- track with minimum P_T^{rel} relative to $\vec{P}_B + \vec{P}_{track}$ direction

Decay Reconstruction: J/ψ channels

Two exclusive decay modes from J/ψ trigger sample:

$$B^+ \rightarrow J/\psi \quad K^+ \qquad\qquad B^0 \rightarrow J/\psi \quad K^{*0}$$

$$\hookrightarrow \mu^+\mu^- \qquad\qquad \hookrightarrow \mu^+\mu^- \quad \hookrightarrow K^+\pi^-$$

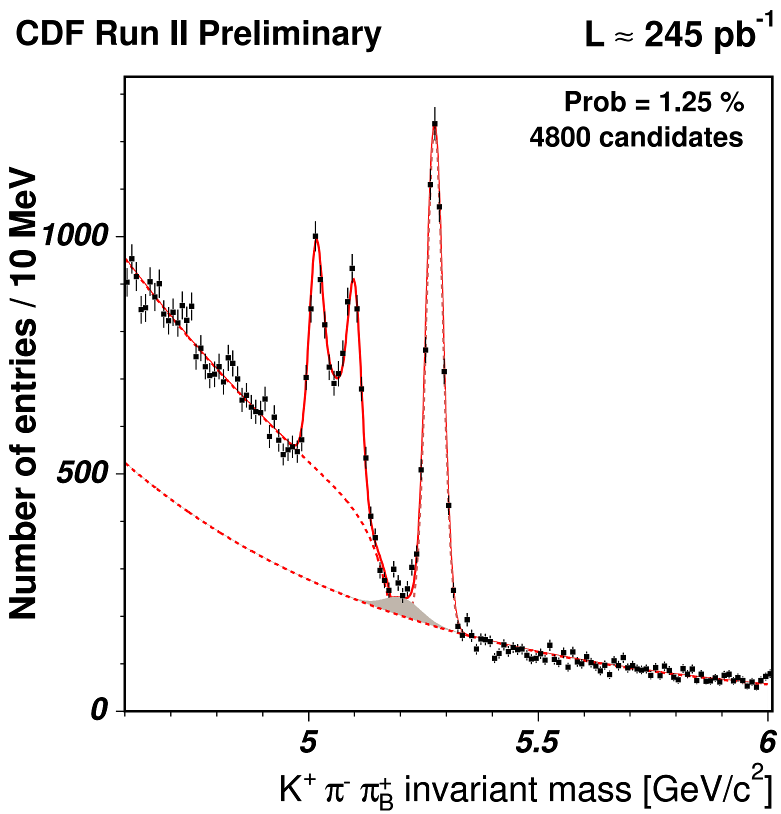


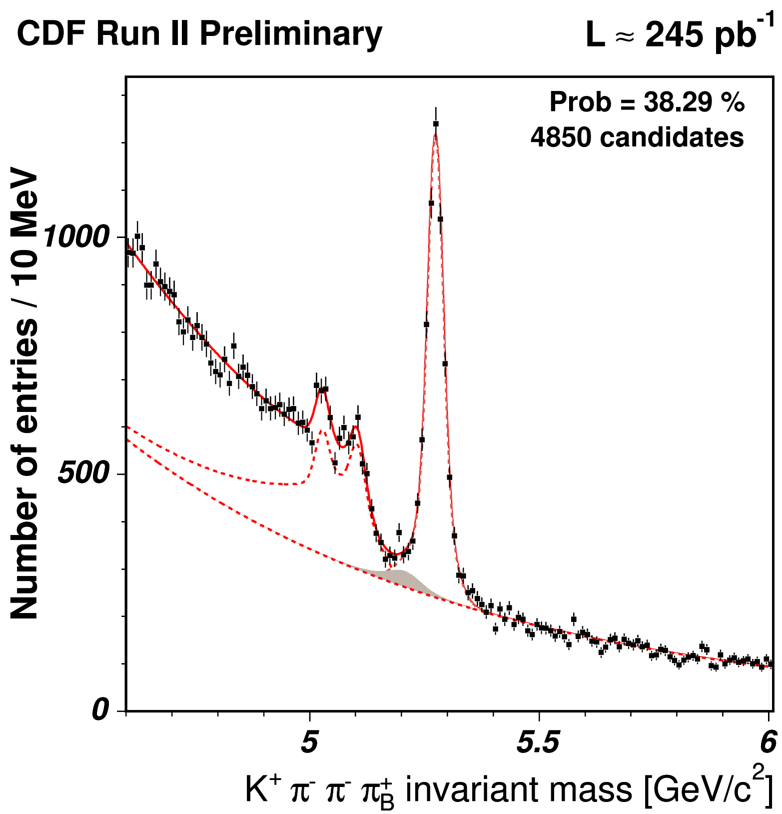
Decay Reconstruction: $D\pi$ channels

Two exclusive decay modes from displaced-vertex trigger sample:

$$B^+ \rightarrow \bar{D}^0\pi^+ \qquad B^0 \rightarrow D^-\pi^+$$

$$\hookrightarrow K^+\pi^- \qquad \hookrightarrow K^+\pi^-\pi^-$$





Measuring the Tagger Properties

Each B candidate is assigned to one of 3 classes:

- Right Sign (RS), if production flavor = decay flavor
- Wrong Sign (WS), if production flavor $\neq$ decay flavor
- Not Tagged (NT), if no tag track is found

Definition of tagger properties:

- Efficiency:

$$\epsilon = \frac{N_{tagged}}{N_{total}} = \frac{N_{RS} + N_{WS}}{N_{RS} + N_{WS} + N_{NT}}$$

- Dilution:

$$D = 1 - 2P_{mistag} = \frac{N_{RS} - N_{WS}}{N_{RS} + N_{WS}}$$

- Tagging Power: ϵD^2 (mixing significance $\sim \sqrt{N\ \epsilon D^2}$)

Sample is further subdivided in bins of p_T and ct of the B meson

Tagging Efficiency

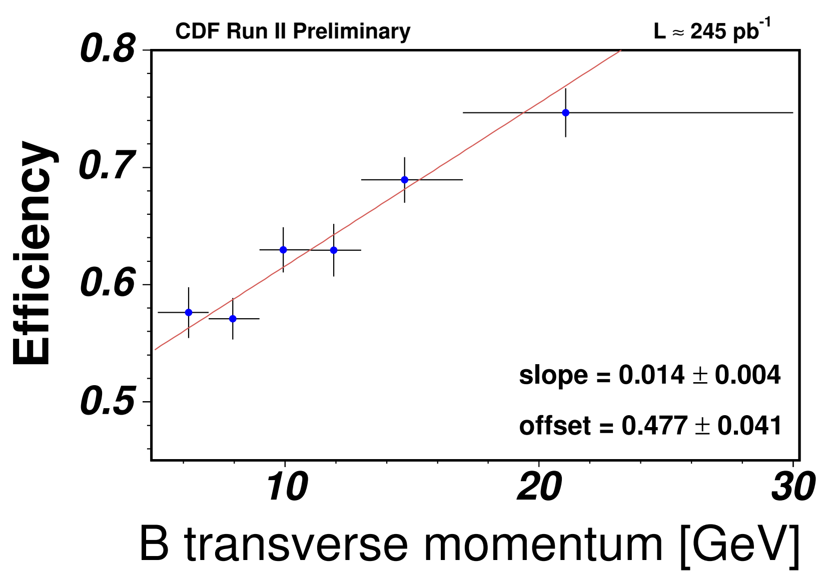
Overall efficiency:

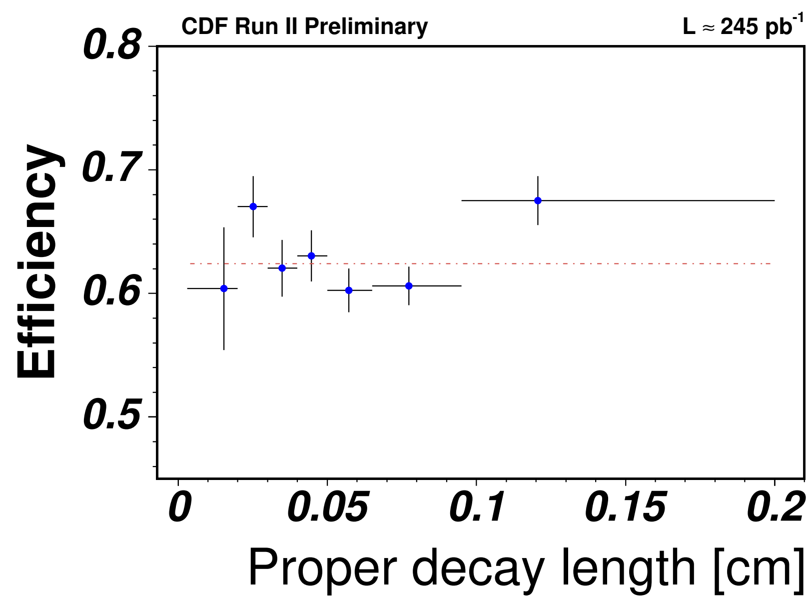
$B^+ \to J/\psi K^+$	63.5±1.2%
$B^+ \to \bar{D}^0\pi^+$	62.4±0.8%
$B^0 \to J/\psi K^{*0}$	59.9±1.8%
$B^0 \to D^-\pi^+$	63.9±1.0%

Efficiency dependence:

- on P_T: linear rise
- on proper decay length: flat
- similar for all 4 modes

(examples below for $B^+ \to \bar{D}^0\pi^+$)





Asymmetry for Charged Modes

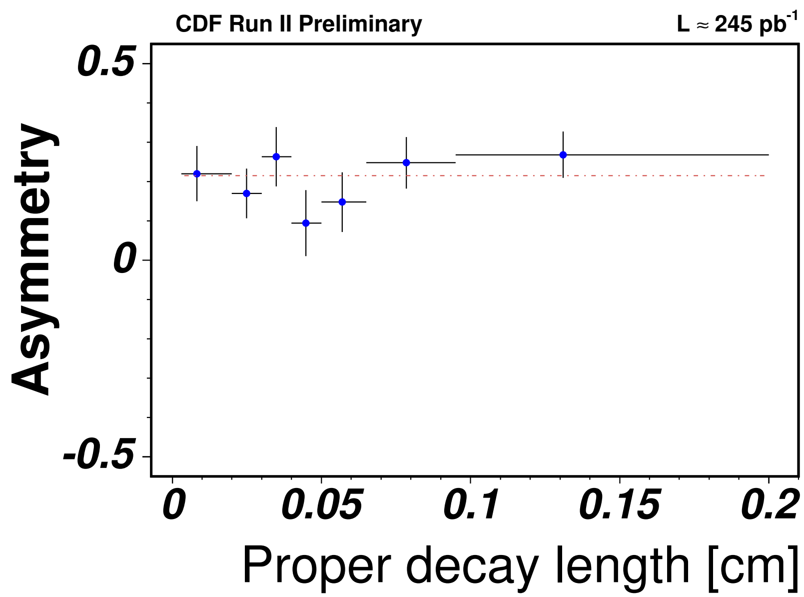
Asymmetry is ct independent

No mixing for charged B!

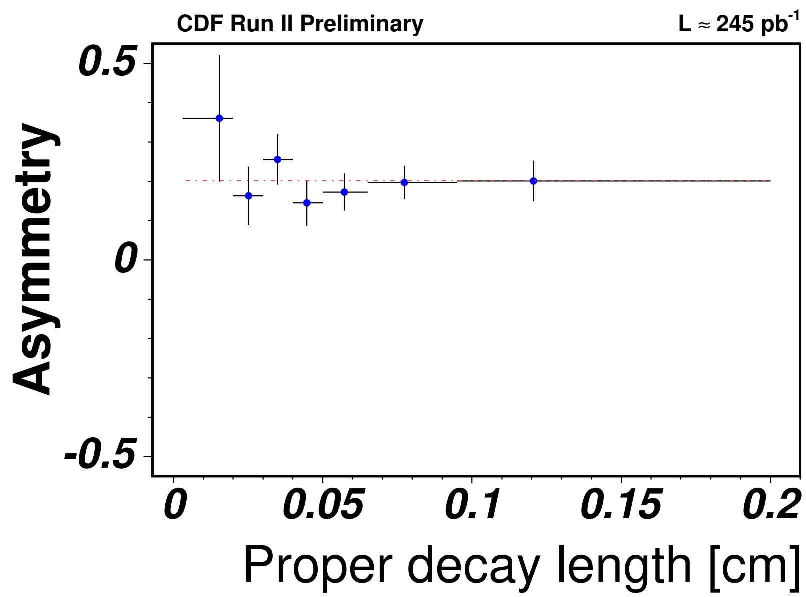
Dilution is equal to average asymmetry

$B^+ \to J/\psi K^+$ D=22.2±3.4%

$B^+ \to \bar{D}^0\pi^+$ D=20.2±2.4%



$B^+ \to J/\psi K^+$



$B^+ \to \bar{D}^0\pi^+$

Neutral Asymmetry and Fit Method

B^0 mixes: expect asymmetry oscillation in ct

With an exact proper decay time measurement:

$$A^{meas}(t) \equiv \frac{N_{RS}(t) - N_{WS}(t)}{N_{RS}(t) + N_{WS}(t)} = D \cos \Delta m_d t$$

Finite resolution in proper decay time measurement:

$$A^{meas}(t) = \frac{G(ct; ct', \sigma_{ct}) \otimes [e^{-t'/\tau} D \cos \Delta m_d t]}{G(ct; ct', \sigma_{ct}) \otimes e^{-t'/\tau}}$$

[convolution with a Gaussian introduces detector resolution in ct]

Extract oscillation frequency Δm_d and dilution D from $A(ct)$ fit

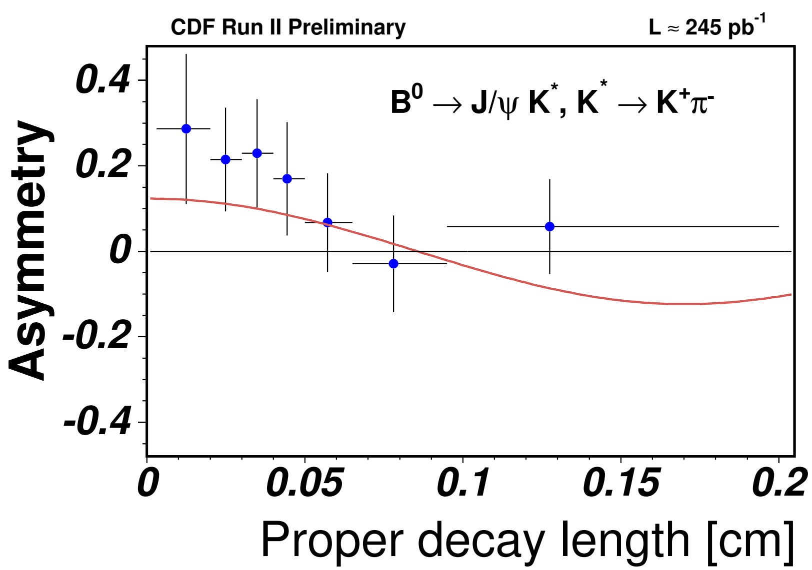
Asymmetry Fit Results

Fit simultaneously the two B^0 decay modes

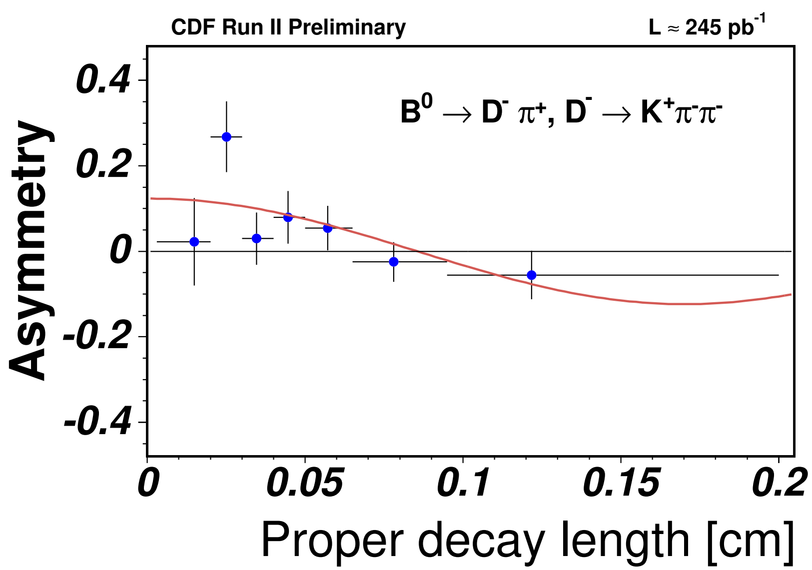
- χ^2 combined fit
- function at mean ct for each bin compared to data

$$\Delta m_d = 0.55 \pm 0.10_{stat} \pm 0.01_{syst}\ ps^{-1}$$

$$D = 12.4 \pm 3.3_{\ stat} \pm 1.2_{\ syst}\ \%$$



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



$B^0 \to D^-\pi^+$

Conclusions

With $245\ pb^{-1}$ the Same Side Tagging technique has been studied in four fully reconstructed charged and neutral B meson decays

$$D(B^{\pm}) = 21.2 \pm 2.0_{stat.}\ \% \qquad D(B^0) = 12.4 \pm 3.3_{stat} \pm 1.2_{syst}\ \%$$

$$\epsilon D^2(B^{\pm}) = 2.8 \pm 0.5_{stat}\ \% \qquad \epsilon D^2(B^0) = 1.0\ \pm 0.5_{stat} \pm 0.2_{syst}\ \%$$

$$\Delta m_d = 0.55 \pm 0.10_{stat} \pm 0.01_{syst}\ ps^{-1}$$

SST *(to follow)*

- **tune SST to Run II conditions**
  - $\neq$ trigger $\rightarrow \neq$ cuts
  - understand SST in MC
- **particle ID for SST-Kaon**

Mixing *(to follow)*

- **include more decays**
  - semileptonic, other exclusive
- **include opposite side taggers**
- **better vertexing**

Important steps on the way to B_s mixing measurement!

Backup

Systematic Errors

The assumed ct resolution in the asymmetry fit:

- $\sigma_{ct} = 0 \Rightarrow$ simple cosine function
- $\sigma_{ct} = 120\mu m$ (default $70\mu m$)

Fitting mass spectra to obtain RS, WS, NT yields:

- change mass fit range
- compare fit method with sideband subtraction

Charge asymmetry effects:

- the efficiency for tag pions depends on charge
- trigger+reconstruction efficiency different for $B^0/\bar{B}^0$

Specific per channel:

- $J/\psi K^{*0}$ - effect of the K^{*0} swap
- $D^-\pi^+$ - two (default) vs one Gaussian for the signal

Source	$\Delta m_d(ps^{-1})$	$D(\%)$	$\epsilon D^2(\%)$
Mass fitting	0.008	0.56	0.09
ct resolution	0.009	0.04	0.01
Charge asymmetry	—	1.0	0.18
Specific per channel	0.004	0.09	0.02
Total	0.01	1.2	0.2