V.Balagura R.Chistov M.Danilov V.Eiges R. Mizuk

The possibility to observe B_s^0 oscillations at HERA-B

- Motivation, status, prospects
- HERA-B capabilities
  - Hadron-lepton trigger
  - Number of events
  - Backgrounds
  - Time resolution
  - x_s reach

HERA-B Seminar 4.08.99

Motivation

Measurement of B_s^0 oscillations is a crucial part of testing unitarity of CKM matrix when combined with existing precise measurement of B_d^0 oscillations.

$$\frac{\Delta m_s}{\Delta m_d} = \frac{m_{B_s^0}}{m_{B_d^0}} \frac{|V_{ts}|}{|V_{td}|} \frac{f^2_{B_s^0}\, B_{B_s^0}}{f^2_{B_d^0}\, B_{B_d^0}}$$

General aspects

Signature of oscillations:

$$\frac{N_{unmixed}(t) - N_{mix}(t)}{N_{unmixed}(t) + N_{mix}(t)} = D \cdot \cos \frac{\mathrm{x}_s}{\tau_{B_s}} t$$

$$\mathrm{x}_s = \Delta m_s \cdot \tau_{B_s} \;, \qquad D = D_{tag} \cdot \exp(-\frac{(\mathrm{x}_s\, \sigma_t)^2}{2\,\tau^2_{B_s}})$$

$$t = m_{B_s} \cdot \frac{L}{p} \;, \qquad \delta t = \frac{m}{p} \delta L \oplus t \cdot \frac{\delta p}{p}$$

Status of B_s^0 oscillations search

OPAL	$\Delta m_s > 5.2ps^{-1}$
ALEPH	$\Delta m_s > 9.6ps^{-1}$
CDF	$\Delta m_s > 5.8ps^{-1}$
DELPHI	$\Delta m_s > 6.5ps^{-1}$

OPAL : uses $l - l/Q_{hem}$
(B_s^0 purity 10%, $\sigma_t < 0.3ps$)

ALEPH : combines results from
$l - l/Q_{hem}$ or K in the same side ,
$D_s\, l - l/Q_{hem}$ or K in the same side
($B_s^0 \to D_s^{(*)} l\nu$, B_s^0 purity $= 60\%$, $\sigma_t = 0.22ps$),
$D_s\, h - l/Q_{hem}$ or K in the same side
(B_s^0 purity $= 22\%$, $\frac{\delta p}{p} \sim 0.1$).

CDF : uses $\phi\, l - l$
($B_s^0 \to D_s l\nu \to (\phi h X) l\nu$, B_s^0 purity 61%, $\frac{\delta p}{p} = 0.14$)

DELPHI : combines results from
$D_s\, l - Q_{hem}$,
$l - Q_{hem}$ and
$l - l$.

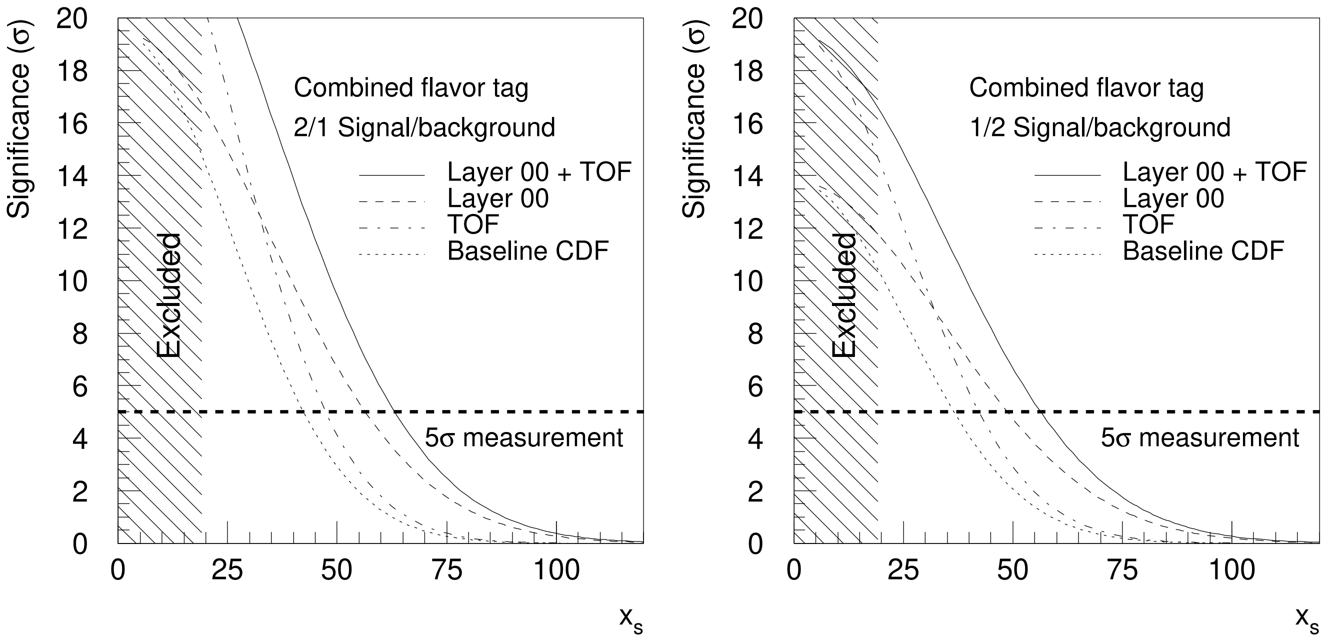
Prospects of B_s^0 oscillations search

Because Δm_s is now known to be large, its measurement will require fully reconstructed B_s^0 decays in order to achieve the necessary momentum resolution.

CDF developed an all-hadronic B decay trigger for RUN II.

Mode	A	B	C
$B_s^0 \to D_s^- \pi^+ \ (D_s^- \to \phi\pi^-)$	10600	8400	7200
$B_s^0 \to D_s^- \pi^+ \pi^- \pi^+$	12800	10400	8100
$B_s^0 \to D_s^{*-} \pi^+$	9400	7400	5800

$\sigma_t = 0.045 ps$



Hadron-Lepton Trigger at HERA-B

FLT	$\bullet P_T(e,\mu) \quad > 1.4, 1.0$ GeV/c $\bullet P_T(track) > 1.8$ GeV/c $\rightarrow 10MHz/500 = 20kHz$
SLT	• tracks refit using vertex detector • hadron, lepton not from main VX $\rightarrow 20kHz/50 = 0.4kHz$

If IR will be smaller than 40 MHz one can gain extra statistics using lower pretrigger cuts. (IR = 40 MHz was optimized for J/ψ trigger).

Dilution of the lepton tag with $p_T > 1.2GeV/c$:

$$D = 0.60$$

(for $p_T > 0.8GeV/c$ $D = 0.49$)

B_s^0 mixing with $B_s^0 \to D_s^- \pi^+ (3\pi^\pm)$

	$B_s^0 \to D_s^- \pi^+$	$B_s^0 \to D_s^- 3\pi^\pm$
Physics :		
$\sigma_{b\bar{b}} / \sigma_{inel.}$	10^{-6}	10^{-6}
$b\bar{b} \to B_s^0 (\bar{B}_s^0)$	0.16	0.16
$B_s^0 \to D_s^- \pi^+ (3\pi^\pm)$	$3.0 \cdot 10^{-3}$	$8.0 \cdot 10^{-3}$
$D_s^+ \to \phi\pi^+ \to K^+ K^- \pi^+$	0.018	0.018
$\phi 3\pi^\pm \to K^+ K^- 3\pi^\pm$	0.006	0.006
$K^+ \bar{K}^{*0} \to K^+ K^- \pi^+$	0.022	0.022
$K^+ K_S$	—	0.012
$K^{*+} \bar{K}^{*0} \to K_S \pi^+ K^- \pi^+$	0.009	0.009
$(K^+ K^- \pi^+)_{nonres.}$	0.009	0.009
Total D_s^+ branching fraction	0.064	0.076
Trigger :		
$p_T(\mu) > 1.0 GeV/c$		
$p_T(e) > 1.4 GeV/c$	0.077	0.077
$p_T(had) > 1.8 GeV/c$	0.61	0.22
Geometrical acceptance	0.77	0.57
Tracks and vertices reconstruction	0.71	0.67
$VX(B_s) > 3$mm	0.6	0.6
$VX(D_s) > 4.5$mm	0.9	0.9
Impact param.$(e\ ,\ \mu) > 100 \mu m$	0.7	0.7
Summary	$3.0 \cdot 10^{-13}$	$2.4 \cdot 10^{-13}$
N events / year	120	94

Backgrounds for $B_s^0 \to D_s^- \pi^+ (3\pi^\pm)$

	min. bias	$c\,\bar{c}$
Physics :		
$\sigma_{cc}/\sigma_{inel.}$	—	10^3
$c\bar{c} \to D_s^+(D_s^-)$	—	5
Total D_s^+ branching fraction	—	14
Trigger :		
$p_T(\mu) > 1.0 GeV/c$		
$p_T(e) > 1.4 GeV/c$	$20\ \times 10^2$	$20\ \times 5$
$p_T(had) > 1.8 GeV/c$	40	40
$VX(B_s) >$ 3mm	10^4	10^3
$VX(D_s) >$ 4.5mm	10^2	2
Impact param.$(e\,,\ \mu) > 100\mu m$	10	3
Impact param.(B_s)	10	10
$M(B_s)$ cut	20	20
Summary	$1.6\ \cdot 10^{14}$	$3.4\ \cdot 10^{14}$

$$\frac{signal}{min.bias} \sim 10^2 \qquad \frac{signal}{c\bar{c}} \sim 2 \cdot 10^2$$

$B^0 \to D^- \pi^+$, D^- misidentified as D_s^-

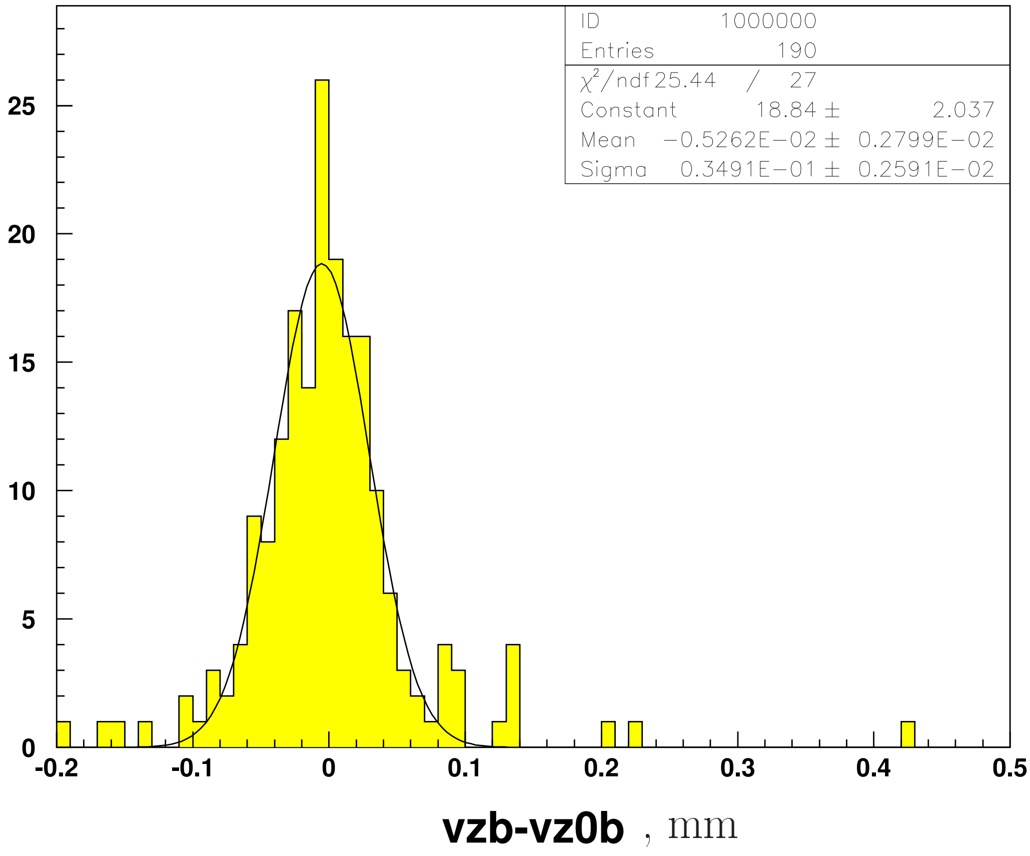
- suppressed by particle ID and $M(B_s)$ cut

$B_s \to D_s\pi$ (3π) time resolution

Vertex resolution: $\sigma_z \approx 350\mu m$ $(300\mu m)$
$\oplus 150\mu m$ (main vertex resolution)
$= 380\mu m$ $(335\mu m)$

- ideal pattern recognition
- no mass constraints

Time resolution: $\sigma_t = 0.053$ ps (0.048 ps)

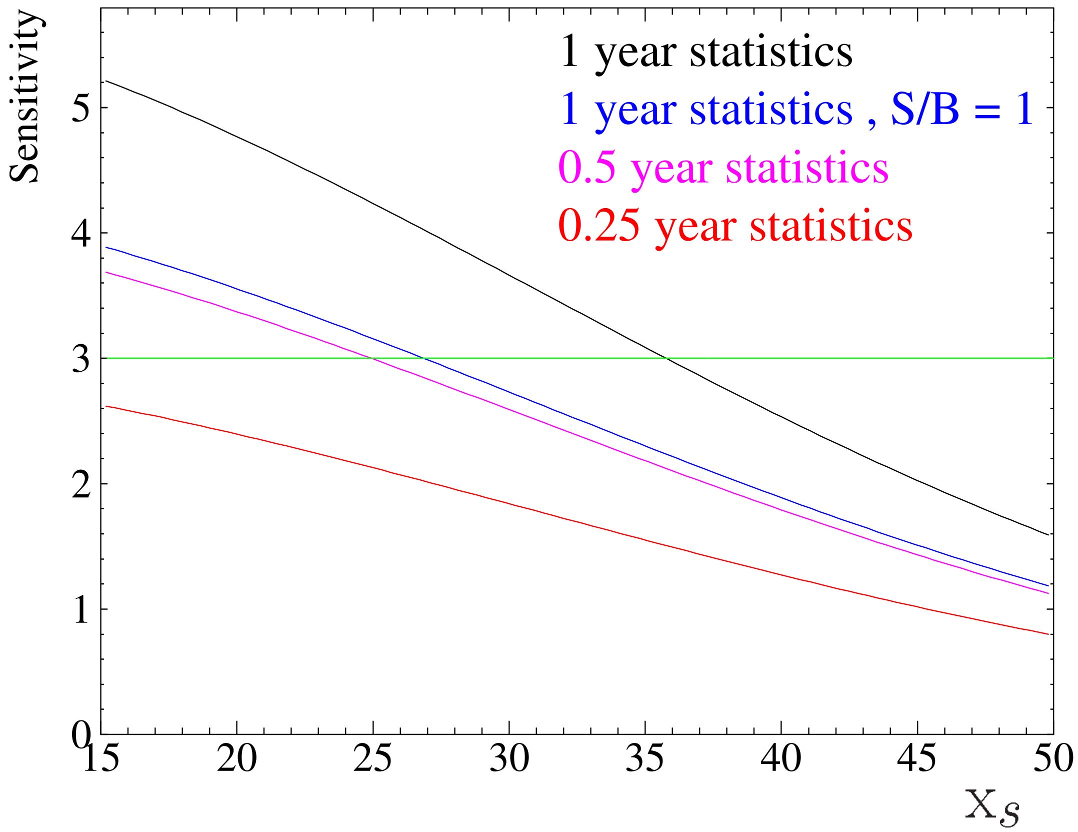


$\mathbf{x}_s$ reach

$$\text{Significance} = \sqrt{\frac{n}{2}}\, f_s\, P\, e^{-\frac{1}{2}(\mathrm{x}_s\,\sigma_t/\tau_{B_s})^2}$$

(H.-G. Moser, A.Roussarie, NIM A384 (1997) 491.)

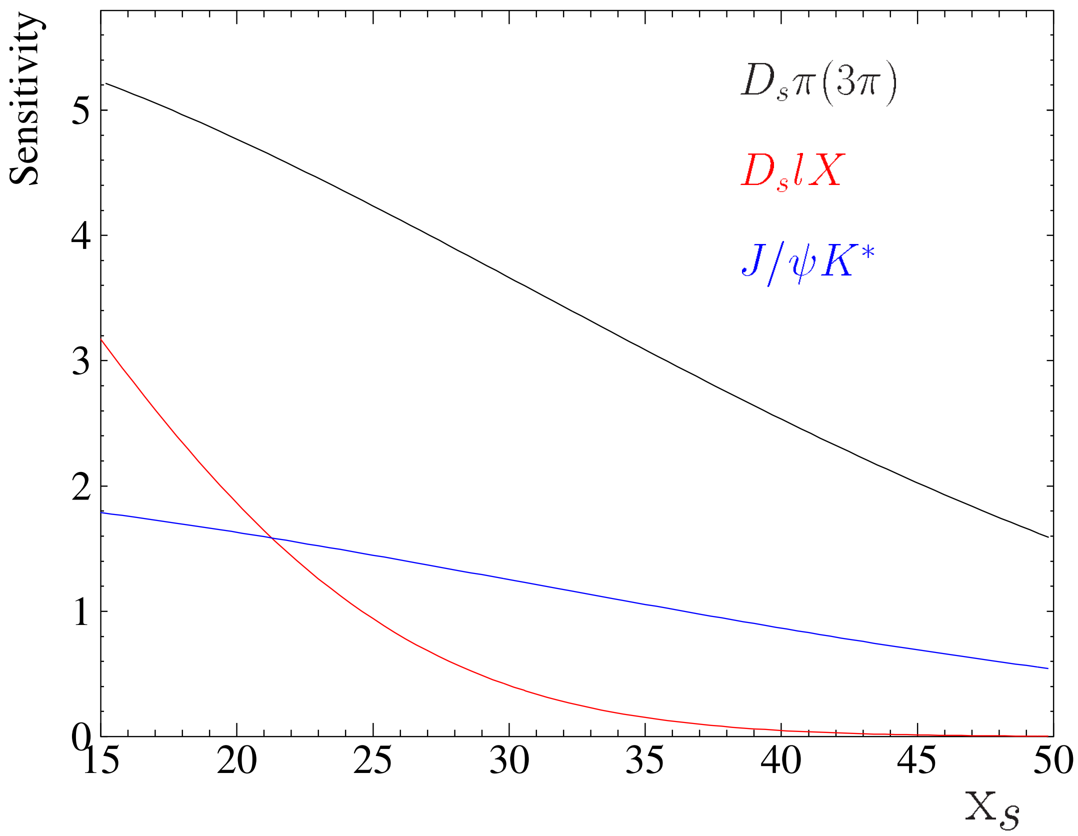
	$D_s^- \pi^+ (3\pi^\pm)$
n: events/year	214
f_s: signal fraction	0.9
P: tagging power	0.60
σ_t, ps	0.053 (0.048)



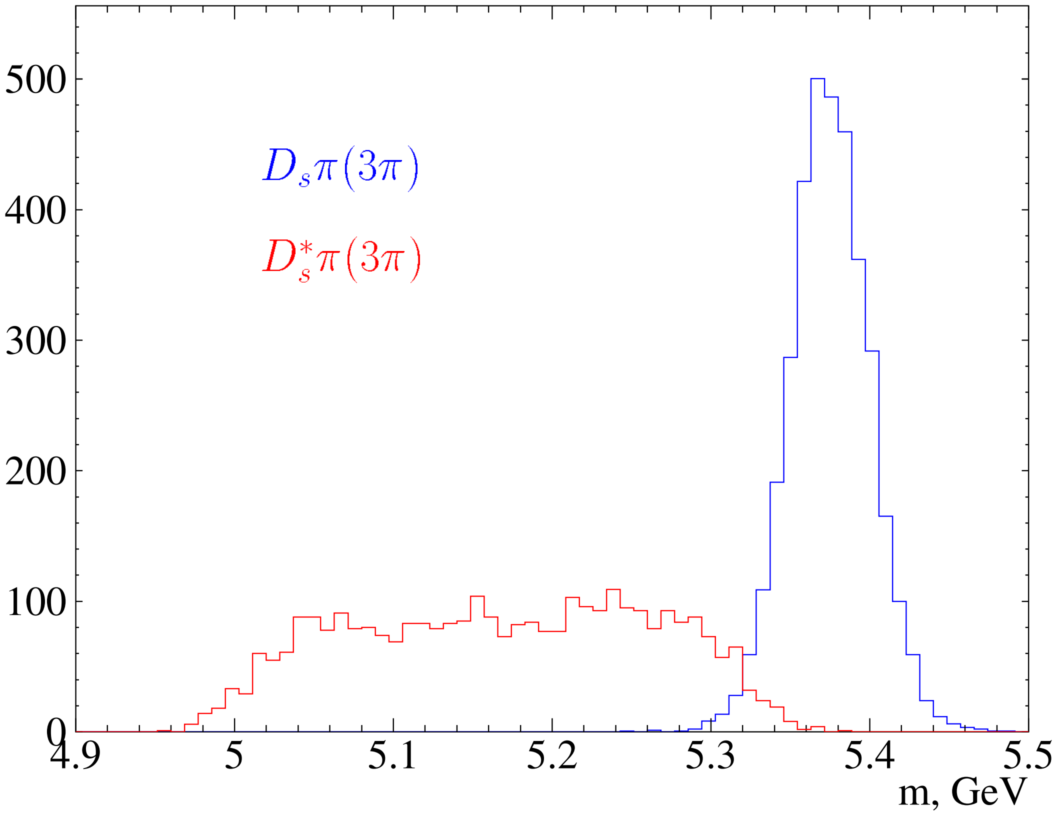
$\mathbf{x}_s$ reach

Comparison $D_s\pi(3\pi)$ with $D_s lX$ and $J/\psi K^*$ modes

	$D_s^-\pi^+(3\pi^\pm)$	$D_s lX$	$J/\psi K^*$
n: events/year	214	900	100
f_s: signal fraction	0.9	0.35	0.9
P: tagging power	0.60	0.5	0.3
σ_t, ps	0.053 (0.048)	0.12	0.045



B_s^0 **mixing with** $B_s^0 \to D_s^{*-}\pi^+(3\pi^\pm)$



$$\frac{BR(B_s^0 \to D_s^{*-}\pi^+)}{BR(B_s^0 \to D_s^-\pi^+)} = 0.92 \quad \Longrightarrow \quad 110 \text{ ev.}$$

$$\frac{BR(B_s^0 \to D_s^{*-}3\pi^\pm)}{BR(B_s^0 \to D_s^-3\pi^\pm)} = 0.81 \quad \Longrightarrow \quad 76 \text{ ev.}$$

$$\vec{p}_{D_s^*} \approx 1.07 \cdot \vec{p}_{D_s}$$

$$\frac{\delta p_{B_s}}{p_{B_s}} = 2.6 \cdot 10^{-2} \quad \Longrightarrow \quad \sigma_t = 0.066ps$$

$\mathbf{x}_s$ reach

	$D_s^{*-}\pi^+(3\pi^\pm)$	$D_s^-\pi^+(3\pi^\pm)$
n: events/year	187	214
f_s: signal fraction	0.9	0.9
P: tagging power	0.60	0.60
σ_t, ps	0.066	0.050