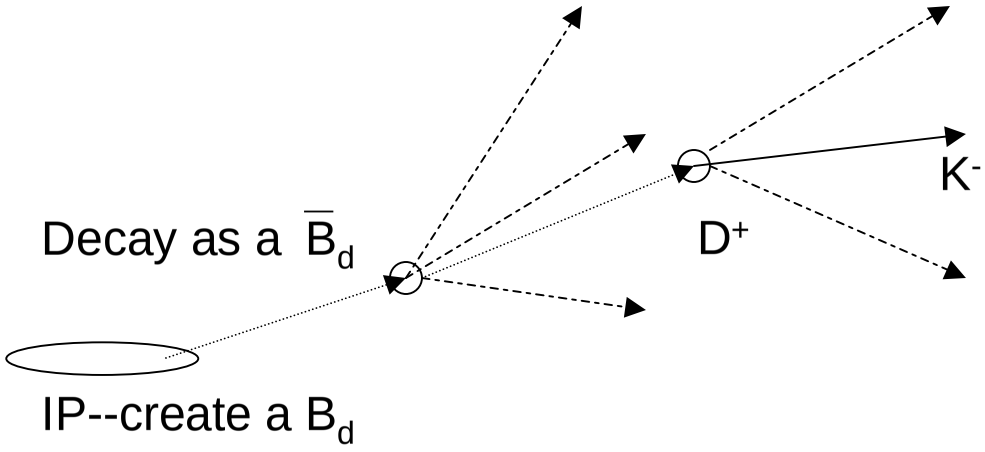
A Measurement of the Time Dependence of B_d - $\overline{B}_d$ Mixing with Kaon Tagging

Jodi L. Wittlin, UMass
representing
The SLD Collaboration

- Introduction
- Likelihood Parameterization
- Results

B_d Mixing with a Kaon tag



Final State Tag:

$B_d \rightarrow D^-/\ \overline{D}^0 \rightarrow K^+$

$\overline{B}_d \rightarrow D^+/D^0 \rightarrow K^-$

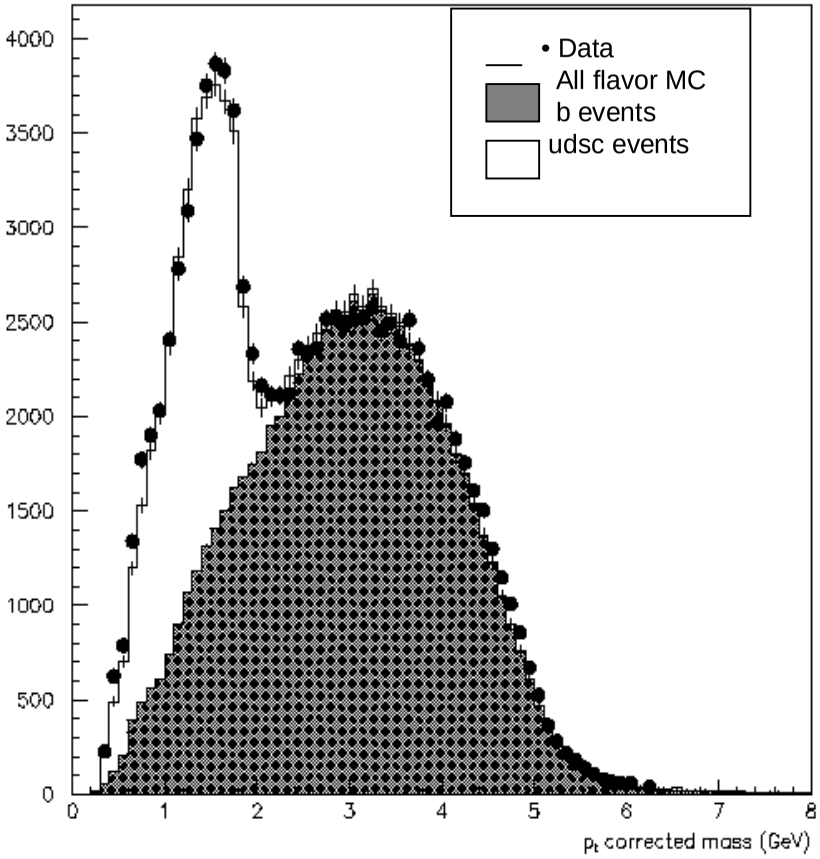
Steps to Making a Mixing Measurement:

- Use SLD Combined Initial State Tag
- Final state uses the charge of the kaon.

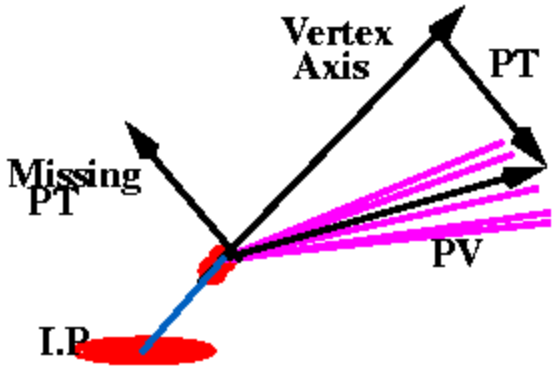
  B_d Right Sign Fraction: (82±5)% (Argus)

  Would result in a large systematic: Fit to this instead!
- Reconstruct B decay vertex and determine proper time

Topological *B* Event Selection



- Compute M_{raw} mass of tracks in secondary vtx (assign m_π)
- Exploit additional mass information from kinematics :

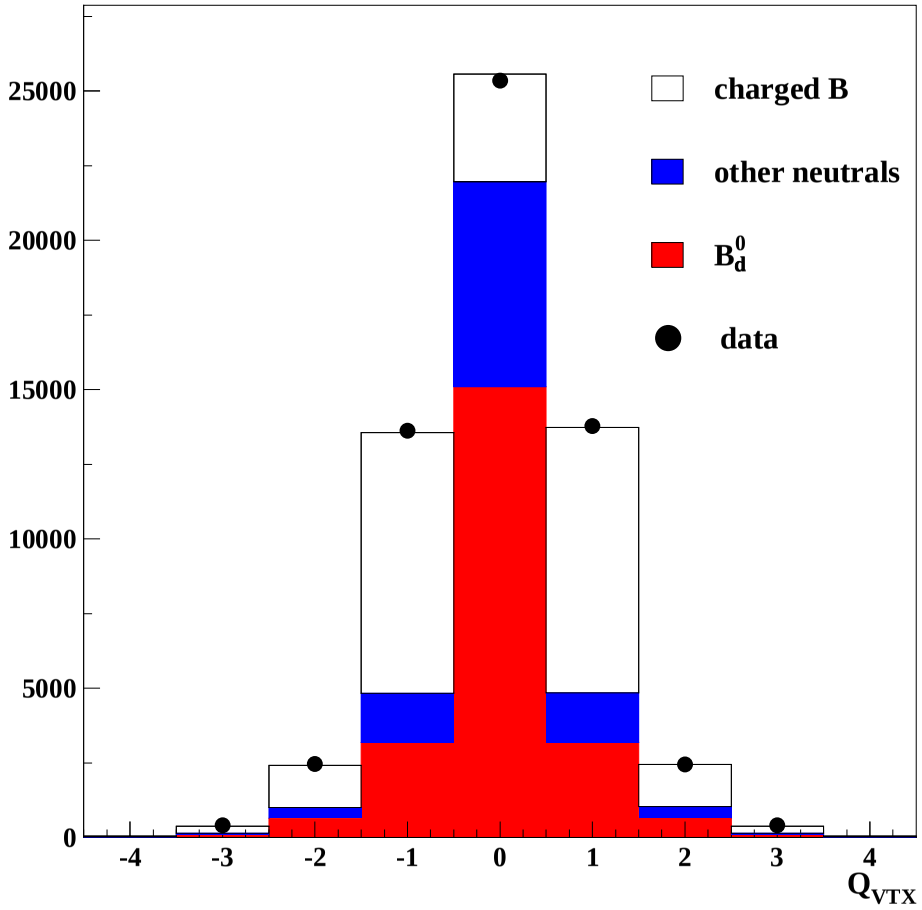


⇒ Define P_T-corrected mass:

$$M = \sqrt{M_{raw}^2 + P_T^2} + P_T$$

Results with cut at m_{pt}= 2 Gev:
98.3% Purity
55.3% Efficient

Analysis Event Selection



- Select neutral vertices
- High B_d Fraction:

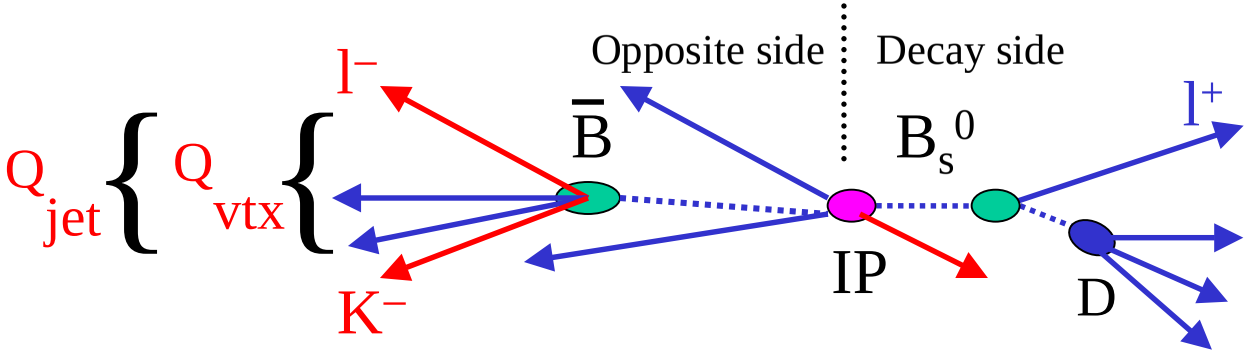
  B_d = 0.607

  B_u = 0.146

  B_s = 0.170

  Baryons = 0.067

SLD Initial State Tagging



- Polarized Forward-Backward Asymmetry (SLD only)

  Left- (right-) polarized e^- tags forward hemisphere quark as b ($\bar{b}$)

- Opposite Side Tags

  Jet Charge $\Sigma_{tracks}\, Q_i\, |p_i \cdot T|^\kappa$

  Secondary vtx charge Q_{vtx}

  Kaon charge $b \rightarrow c \rightarrow s$ (i.e. K^-)

  Lepton charge $b \rightarrow l^-$

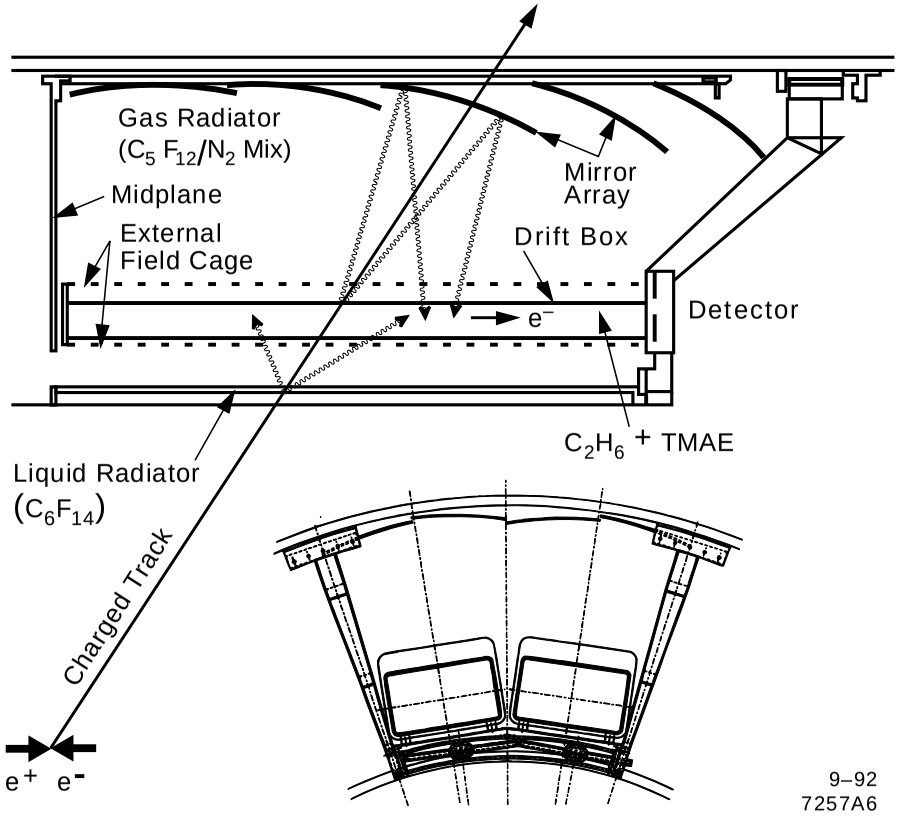
  Dipole charge $\delta q = (Q_D - Q_B)$ ($\delta q > 0$ for b quark)

$\rightarrow$ Tags combined in most analyses + event-by-event mistag probabilities

Mistag rates $w \sim 0.22 - 0.25$

SLD Kaon Identification

Using the Cherenkov Ring Imaging Detector



Excellent Kaon Identification:
81% Purity
40% Efficiency

π-K separation

0.5 < p < 4 GeV/c: liquid radiator

2.5 < p < 30 GeV/c: gas radiator

$\pi \rightarrow$K MisID:

- rate calibrated with $K^0 \rightarrow \pi^+ \pi^-$ Data
- rate varies from 2.5-10% as a function of momentum

Monte Carlo Fit Information

Decay Length Resolution

σ_c = 79.3 μm

σ_t = 421.4 μm

Double Gaussian fit, 67% core

Relative Boost Resolution

σ_c = 6.77%

σ_t = 20.9%

Double Gaussian fit, 55% core

B Kaon Right Sign Fractions:

B_d = 0.797

B_u = 0.776

B_s = 0.497

Baryons = 0.614

2-D Unbinned Likelihood Fit in Monte Carlo:

$\Delta m_d = 0.487 \pm 0.016$ ps^{-1} B_d RSF = 0.802 ± 0.010

The SLD Monte Carlo is generated with $\Delta m_d = 0.484$ ps^{-1}.

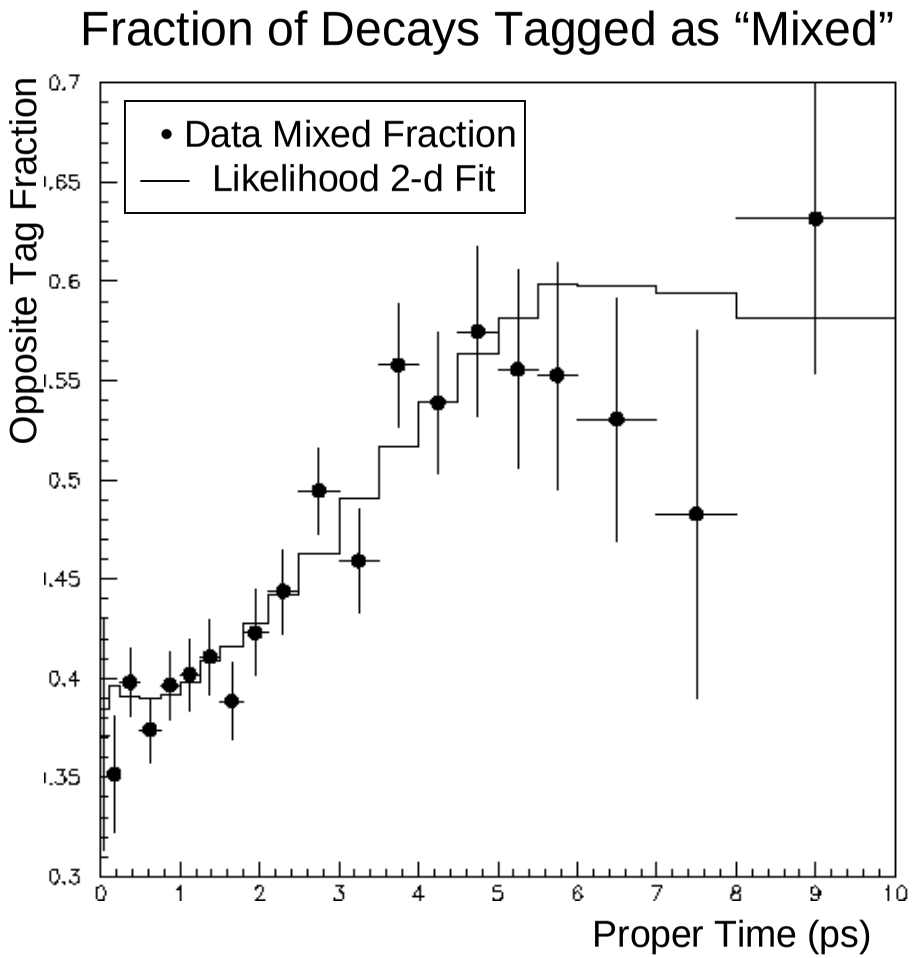
Likelihood Fit Results-Data

$\Delta m_d = 0.545 \pm 0.034\ ps^{-1}$

B_d RSF = 0.814 ± 0.023

number of vertices: 7844

(1996-1998 Data)



The world average for Δm_d as of Moriond 2001 is $0.484 \pm 0.010\ ps^{-1}$.

Systematic Errors

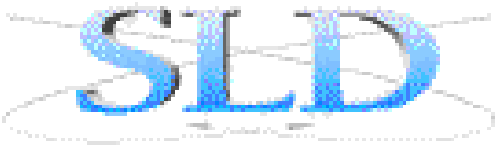
Source	$\sigma(\Delta m_d)$ (ps^{-1})
B_u Lifetime (1.64 $\pm$ 0.027)	$\pm$0.001
B_d Lifetime (1.55 $\pm$ 0.024)	$\pm$0.002
Baryon Lifetime (1.22 $\pm$ 0.052)	$\pm$0.001
B_u Fraction (.146 $\pm$ 0.010)	$\pm$0.005
B_d Fraction (.607 $\pm$ 0.010)	$\pm$0.003
B_s Fraction (.170 $\pm$ 0.012)	$\pm$0.002
Baryon Fraction (.067 $\pm$ 0.017)	$\pm$0.002
Udsc Fraction (.012 $\pm$ .006)	$\pm$0.001
B_u RSF (.776 $\pm$ 0.05)	**$\pm$0.012**
Baryon RSF (.614 $\pm$ 0.05)	$\pm$0.007
Δm_s (10 + 10 ps^{-1})	$\pm$0.001
Boost Resolution ($\pm$ 20%)	**$\pm$0.018**
Decay Length Resolution ($\pm$ 20%)	$\pm$0.001
Tracking Resolution (Correction On/Off)	$\pm$0.005
Track Efficiency (Correction On/Off)	$\pm$0.004
$\pi^{\pm}$ Misidentification (Calibration Statistics)	$\pm$0.003
Initial State Tagging ($\pm$ 0.02)	$\pm$0.005

Summary

- This is the only B_d mixing measurement using a kaon for the final state tag.
- Previous SLD all-analysis average:
  $\Delta m_d = 0.526 \pm 0.043\ (stat) \pm 0.031\ (syst)\ ps^{-1}$ (1993-95 Data)

  Preliminary Kaon tag result:

  $\Delta m_d = 0.545 \pm 0.034\ (stat) \pm 0.025\ (syst)\ ps^{-1}$ (1996-98 Data)



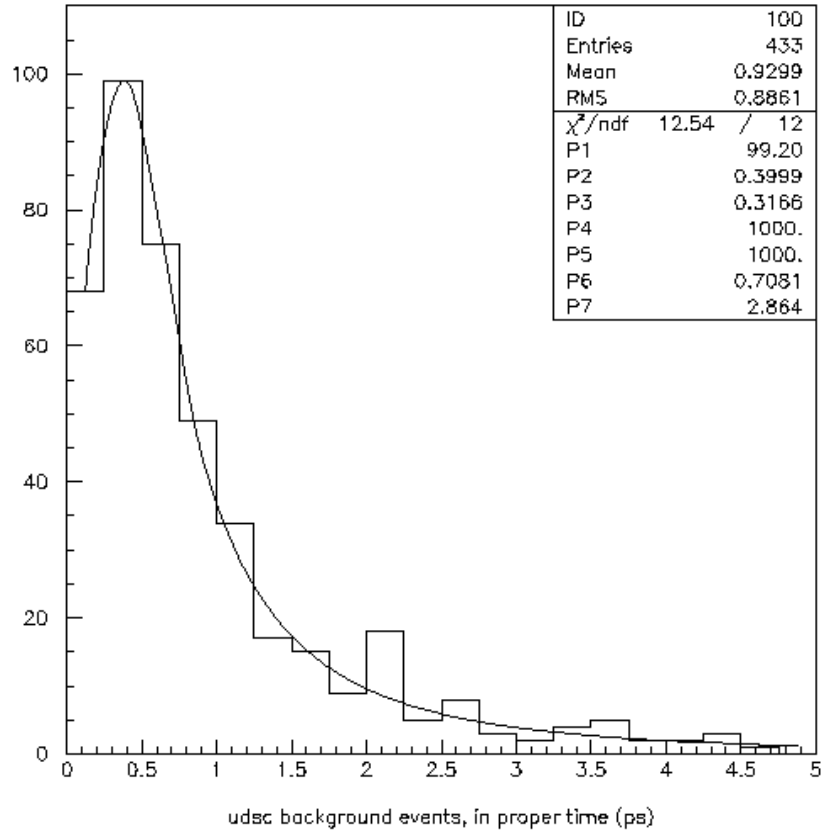
Background Parameterization

The ***udsc background*** is parameterized using a ***gaussian with power law tails***:

$$l_1 \le x \le l_2 : f(x) = p_1 e^{-0.5\left(\frac{x-p_2}{p_3}\right)^2}$$

$$x \le l_1 : f(x) = p_1 \frac{e^{p_5 \ln\left(\frac{p_3 p_5}{p_4}\right)} e^{-0.5p_4^2}}{e^{p_5 \ln\left(p_2 + \frac{p_3 p_5}{p_4} - p_3 p_4 - x\right)}}$$

$$x \ge l_2 : f(x) = p_1 \frac{e^{p_7 \ln\left(\frac{p_3 p_7}{p_6}\right)} e^{-0.5p_6^2}}{e^{p_5 \ln\left(\frac{p_3 p_7}{p_6} - p_3 p_6 - p_2 + x\right)}}$$



Where the p_i represent the fit parameters, and

$l_1 = p_2 - p_3 p_4$, $l_2 = p_2 + p_6 p$

Unbinned Log-Likelihood Fit to Δm_d

For a single event, the probability to mix is:

$$f_{Bd} P_{mix,Bd} + f_{Bs} P_{mix,Bs} + f_{Bu} P_{mix,Bu} + f_{Baryon} P_{mix,Baryons} + f_{udsc} P_{mix,udsc}$$

Where the individual terms are as follows:

$$P_{mix,Bd} = \frac{\Gamma_{Bd}}{2} e^{-\Gamma_{Bd} t} (1 - (1 - 2R_{Bd} - 2i + 4R_{Bd} i) \cos(\Delta m_d t))$$

$$P_{mix,Bu} = \Gamma_{Bu} e^{-\Gamma_{Bu} t} (R_{Bu} + i - 2R_{Bu} i)$$

- B_s is analogous to B_d, and the Baryons to B_u. The parameterization of the detector resolution and efficiencies and the background term are described on the next slides.

- $\boldsymbol{f_{(b)}}$ is the fraction of that B type (parameterized in MC); ***i*** is the initial state right sign probability; ***t*** is the proper time and is parameterized in the fit by an integral over the resolution and efficiency of the detector.

- $\boldsymbol{R_{(b)}}$ is the kaon right sign fraction for that B type, parameterized from MC.