B_d mixing and prospects for B_s mixing at DØ

Tulika Bose (Columbia University)

Constraining the CKM matrix

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \approx \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

Large uncertainty $\lambda \approx 0.22,\ A \approx 0.8$

Precise measurement of V_{td} ⇒
- properly constrain the CKM matrix
- yield info on CP-violating phase η

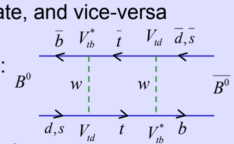
V_{td} can be measured via
- rare kaon decay $K^+ \to \pi^+ \nu \bar{\nu}$
- *mixing* in the B system

What is mixing ?

Neutral B meson transition from particle to anti-particle state, and vice-versa

Weak eigenstates ≠ mass eigenstates

Caused by higher order flavor changing weak interactions:



$\Delta m_q = m(B^o_{heavy}) - m(B^o_{light})$

$\Delta m_q \propto |V_{tb}V_{tq}|^2$

Mixing parameters $x_q = \Delta m_q/\Gamma_q$ and $y_q = \Delta\Gamma_q/\Gamma_q$ where q=d,s

First oscillations observed at ARGUS ('87) in the B_d system

⇒ signaled a large top quark mass (later verified by CDF and DØ)

$\Delta m_d \propto |V_{td}|^2 \cdot F(QCD)$ but large QCD effects dominate the extraction of V_{td}

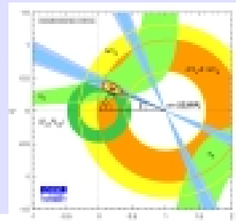
∴ consider ratio $\frac{\Delta m_s}{\Delta m_d} = \frac{M_{B_s}}{M_{B_d}} \left(\frac{\hat{B}_{B_s} f^2_{B_s}}{\hat{B}_{B_d} f^2_{B_d}}\right) \left|\frac{V_{ts}}{V_{td}}\right|^2$ from Lattice QCD

Theoretical error on the ratio expected to drop faster than that on F(QCD)

SM or NP ?

We *think* we understand the mixing of *B*'s…

A deviation from this simple diagram is a deviation from the Standard Model (New Physics)



Δm_d has been precisely measured: the world average is

$$\Delta m_d = 0.502 \pm 0.007\ ps^{-1}$$

∴ a direct measurement of Δm_s + Δm_d(current value) + V_{ts}(relatively well known) ⇒ V_{td}

Current limits say that B_s oscillates at least 30 times faster than B^0 !

Though experimentally challenging, a B_s mixing measurement will be precise.

The Tevatron *B-factory* and the new DØ

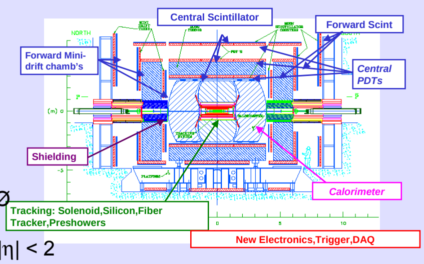
$\sigma(p\bar{p} \to b\bar{b}) \approx 150\ \mu b$ at 1.96 TeV

$\sigma(e^+e^- \to b\bar{b}) \approx 7\ nb$ at Z^0

$\sigma(e^+e^- \to b\bar{b}) \approx 1\ nb$ at $Y(4S)$

Large production cross-section

All B species, including B_s, B_c, Λ_b



Rich *B Physics* program at DØ benefits from :
- Large muon acceptance: |η| < 2
- Forward tracking coverage: |η| < 1.7 (tracking), |η| < 3 (silicon)
- Robust muon trigger

Essential ingredients of a mixing analysis

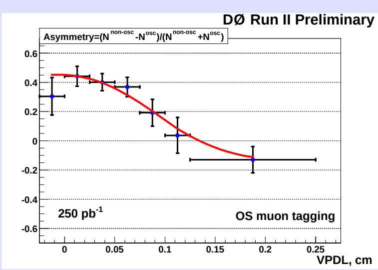
A typical oscillation analysis involves:
- Selection of final states suitable for the study
  - Tagging the meson flavor at decay time (final state)
  - Tagging the meson flavor at production time (initial state)
- Proper time reconstruction for each meson candidate

Average statistical significance $S(\Delta m, \sigma_t) = \sqrt{\frac{\varepsilon D^2 N}{2}} \sqrt{\frac{S}{S+B}} \times e^{-(\Delta m \sigma_t)^2/2}$

Flavor tagging; # of reconstructed events; signal purity; proper time resolution

B_d mixing crucial for understanding initial-state flavor tagging

B_d oscillations measured at DØ in semileptonic mode $B_d^0 \to \mu^+ D^{*-} X,\ D^{*-} \to \bar{D}^0 \pi^-,\ \bar{D}^0 \to K^+\pi^-$



Oscillations with soft-muon tagging

Identify the flavor of the other B in the event using sign of the muon it decayed to:

- same sign: one B hadron oscillated
- opposite sign: both or neither oscillated

$B^0 \to \mu^+ X$

$\bar{B}^0 \to \mu^- X$

Efficiency $\varepsilon = \frac{N_{correct} + N_{wrong}}{N_{correct} + N_{wrong} + N_{notag}}$

How often the tagging algorithm 'fires'

Dilution $D = \frac{N_{correct} - N_{wrong}}{N_{correct} + N_{wrong}}$

How often the tagging algorithm gives the correct answer

Efficiency ε = (4.8 ± 0.2) %
Dilution *D* = (46.0 ± 4.2) %

Δm_d = 0.506±0.055(stat)±0.049(syst) ps^{-1} (preliminary) 250 pb^{-1}

Oscillations with jet-charge tagging

Use "p_T weighted" sum of tracks:

$$Q_j = \frac{\sum q_i \vec{p}_i \cdot \hat{a}}{\sum \vec{p}_i \cdot \hat{a}}$$

$Q_{jet} < 0$ for *b*

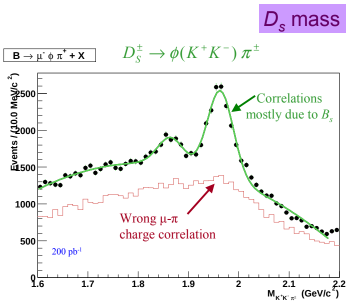
Oscillations with soft pion (same-side) tagging

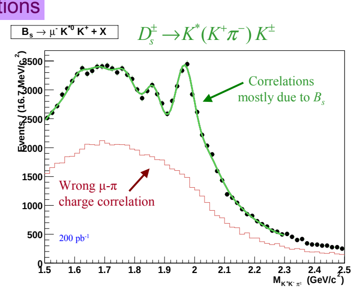
Use track with minimum p_T^{rell} wrt B momentum:

We see oscillations!
systematic errors are being worked on

B_s mixing studies at DØ: $B_s \to \mu^{\mp} D_s^{\pm} \nu\ X$

D_s mass distributions





Future prospects

$D_S^{\pm} \to \phi(K^+K^-)\pi^{\pm}$

~32 - 40 $B_s \to D_s + \mu$ events/pb^{-1} *

$D_S^{\pm} \to K^*(K^+\pi^-)K^{\pm}$

~25 - 30 $B_s \to D_s + \mu$ events/pb^{-1} *

Largest $D_s + \mu$ event yield in the world!!

Large event yields! Pushing for limit on Δm_s by end of summer

Other decay modes (hadronic B_s decay modes) are being studied.

* Cuts are being optimized for event yield and S/B