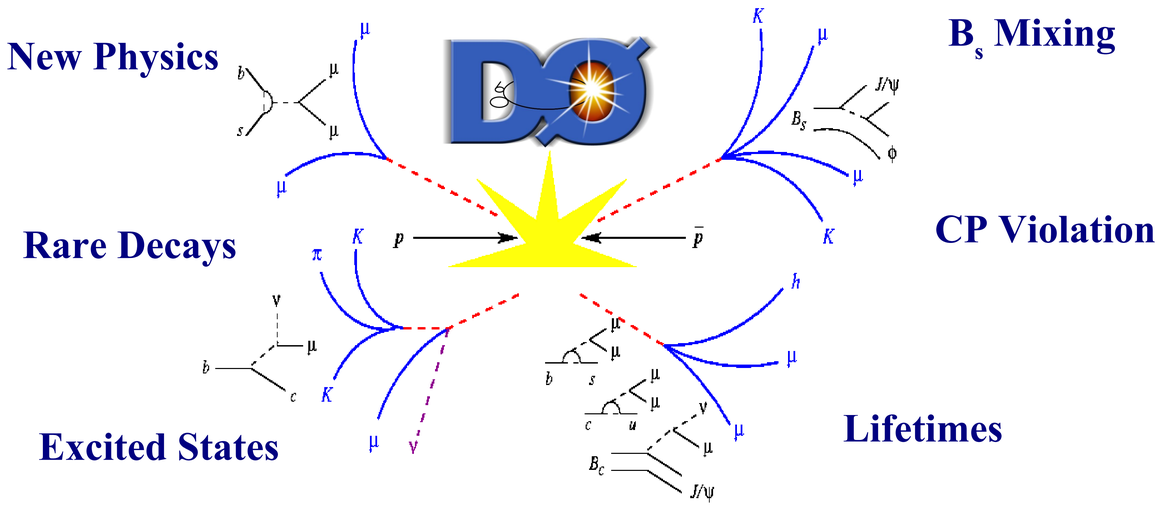
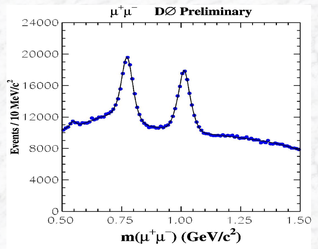
B Physics Results at DØ with 1 fb^{-1}

Mark Williams – Lancaster University

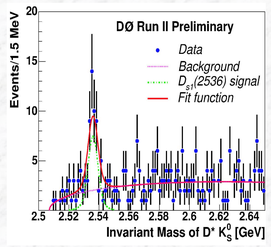


B Reconstruction

Program designed around excellent single and dimuon triggers



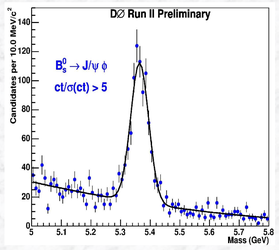
Dimuon Mass Spectrum



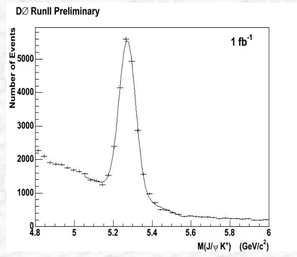
$B_s \to D_s^{**} \mu\nu X$

Large semileptonic samples ideal for mixing and lifetime studies

Large dimuon samples ideal for *B* to charmonium and rare decay searches



$B_s \to J/\psi\ \varphi$

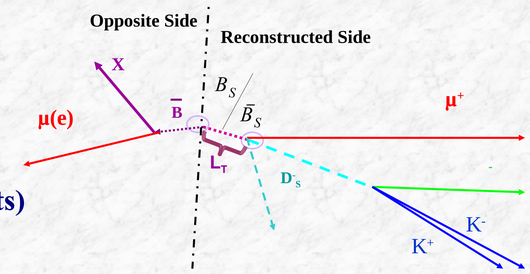


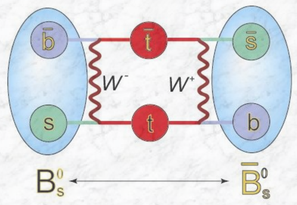
$B^{\pm} \to J/\psi\ K^{\pm}$

B_s Mixing Measurement

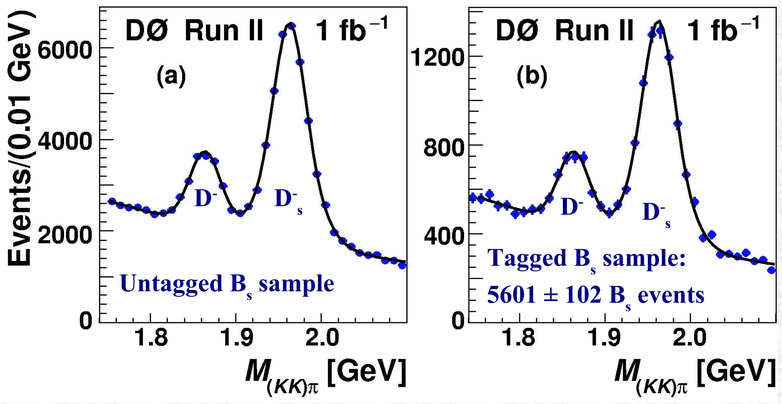
Observation of B_s mixing requires measurement of:

- Flavor of B_s^0 at production (opposite-side tagging)
- Flavor of B_s^0 at decay (from charge of B_s decay products)
- Proper lifetime of B_s meson





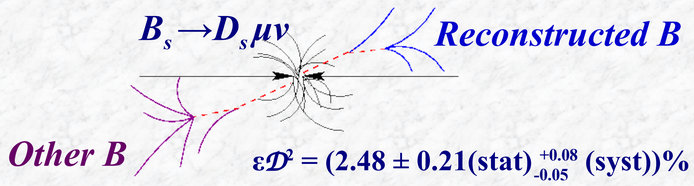
B_s mixing Box diagram in the Standard Model



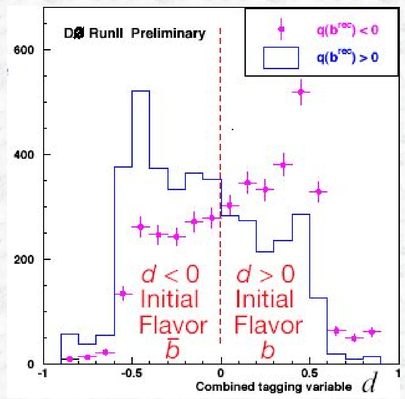
$M(K^+K^-\pi^-)$ invariant mass spectrum for B_s samples

Tagging the production Flavor

The flavor of the reconstructed *B* is determined at production by examining inclusive properties of the rest of the event. A *combined tag* uses multiple discriminating variables to distinguish between quark flavor on *opposite-side* to reconstructed b quark.



$\varepsilon\mathcal{D}^2 = (2.48 \pm 0.21(\text{stat})^{+0.08}_{-0.05}(\text{syst}))\%$



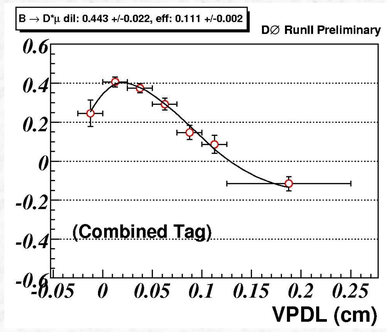
Combined Tagging Variable

$\varepsilon = N_{tag} / N_{total}$

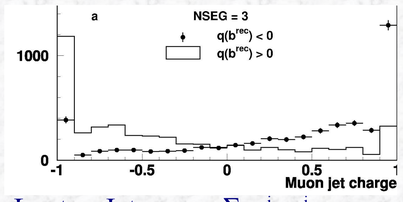
$\eta = N_{correct} / N_{tag}$

$\mathcal{D} = 2\eta - 1$

Tagging performance determined using B_d mixing



Asymmetry vs. VPDL



Lepton Jet Charge: $Q^l_J = \dfrac{\Sigma_i q^i p_T^i}{\Sigma_i p_T^i}$

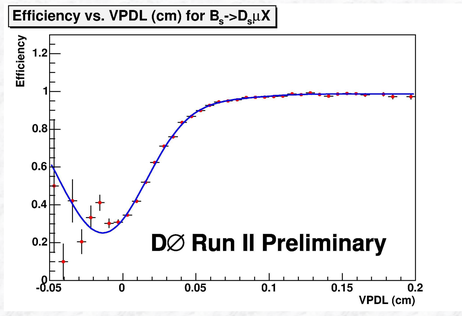
Determining the Proper Lifetime

Proper lifetime: $c\tau(B_s) = x^M . K$

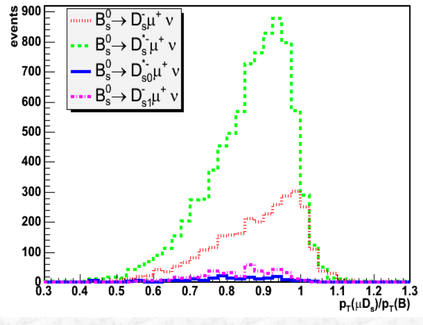
where x^M is the *visible proper decay length* (VPDL)

K is the correction (K-) factor, determined from Monte Carlo simulation, which corrects for the effects of the neutrino and other lost or non-reconstructed particles:

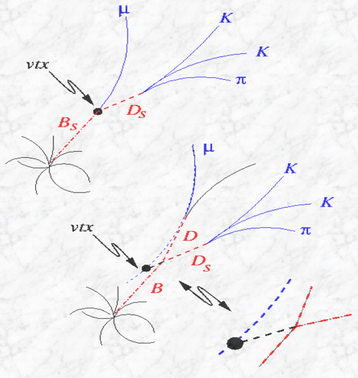
$K = p_T(\mu^+ D_s^-) / p_T(B_s)$



Efficiency vs. VPDL

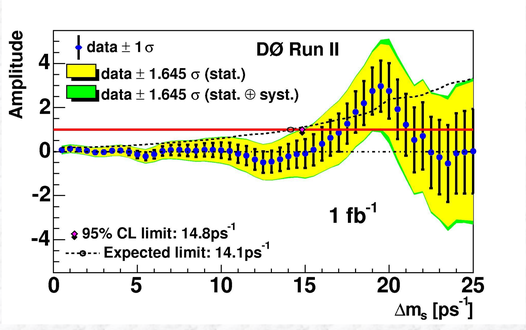


K-factor distribution for different sources



VPDL determined by reconstructing secondary vertices in the transverse plane

First two-sided bound on B_s mixing parameter Δm_s



Amplitude scan over Δm_s range.

The amplitude should be zero (within uncertainties) for incorrect values of Δm_s and then peak at 1 (within uncertainties) for the correct value of Δm_s.

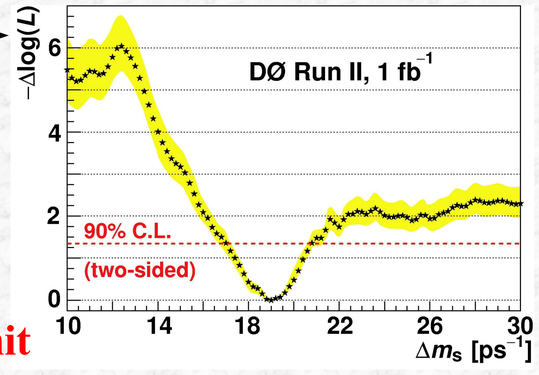
$\Rightarrow \Delta m_s > 14.8\ \text{ps}^{-1}$ (95% CL)

Likelihood Scan

Fixing the amplitude A = 1, and looking for a minimum in the Likelihood curve:

Preferred value: $\Delta m_s = 19\ \text{ps}^{-1}$

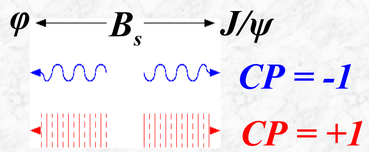
90% CL: $17\ \text{ps}^{-1} < \Delta m_s < 21\ \text{ps}^{-1}$



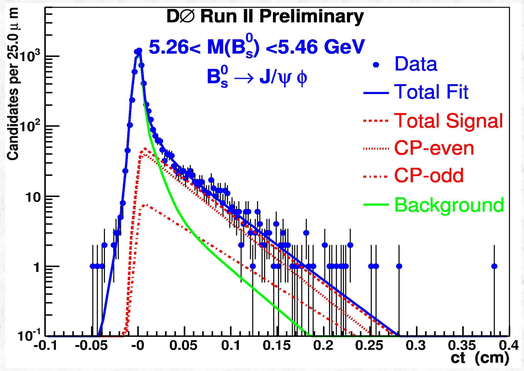
First Direct Two-Sided Limit

CP Eigenstate Width Difference $\Delta\Gamma$

In the decay $B_s \to J/\psi\ \varphi$, the angular momentum along the decay axis must add to zero. Two possibilities:



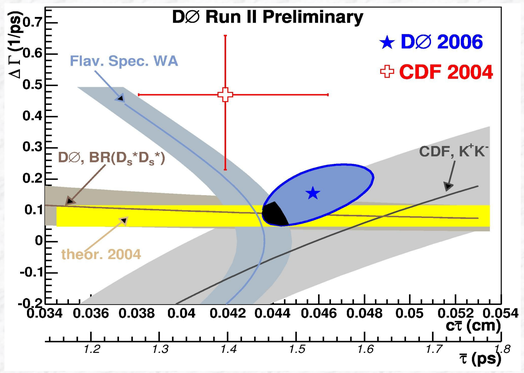
Both eigenstates are accessible and the two lifetimes can be extracted using an angular analysis



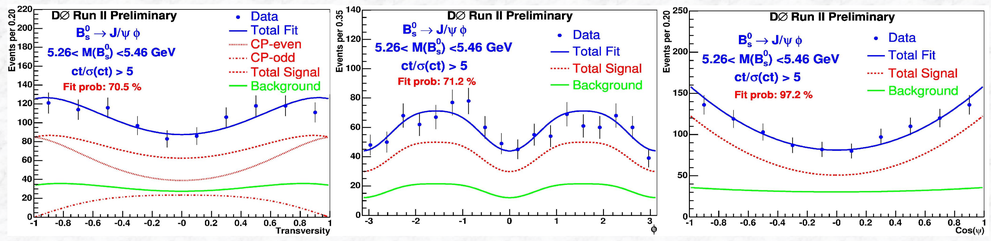
Lifetime fit for CP eigenstates

$\Delta\Gamma_s = 0.15 \pm 0.10\ ^{+0.03}_{-0.04}\ ps^{-1}$

$\tau(B_s) = 1.53 \pm 0.08\ ^{+0.01}_{-0.04}$ ps



Measurement consistent with WA and theory

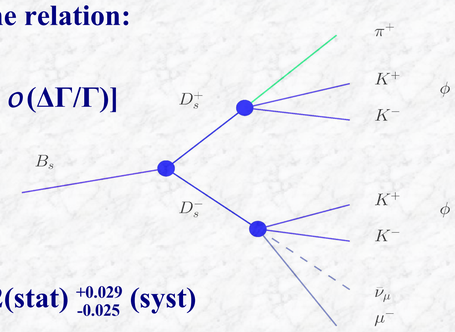


CP Eigenstate discriminating variables

$\Delta\Gamma_s$ can also be estimated from the relation:

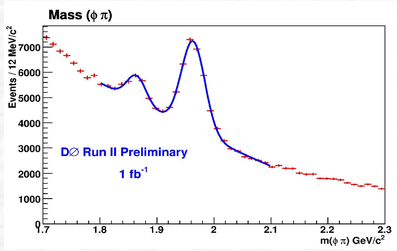
$$2Br(B_s^0 \to D_s^{(*)}D_s^{(*)}) \approx \frac{\Delta\Gamma_{CP}}{\Gamma}[1 + o(\Delta\Gamma/\Gamma)]$$

Where $\Delta\Gamma_{CP} = \Delta\Gamma_s / \cos\varphi$

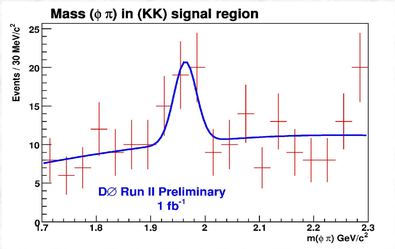


$$Br(B_s^0 \to D_s^{(*)}D_s^{(*)}) = 0.071 \pm 0.032(stat)\ ^{+0.029}_{-0.025}\ (syst)$$

$$\Rightarrow \frac{\Delta\Gamma_{CP}}{\Gamma}(B_s) = 0.142 \pm 0.064(stat)\ ^{+0.058}_{-0.050}\ (syst)\quad (SM = 0.12 \pm 0.06)$$



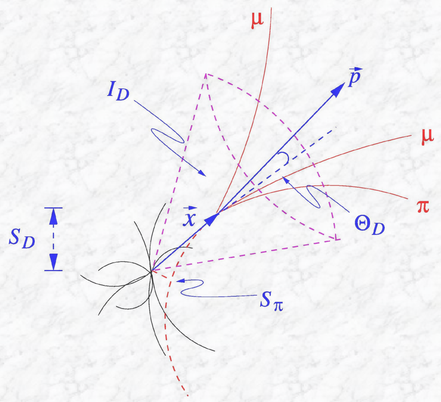
$N(\mu D_s) = 15225 \pm 310$



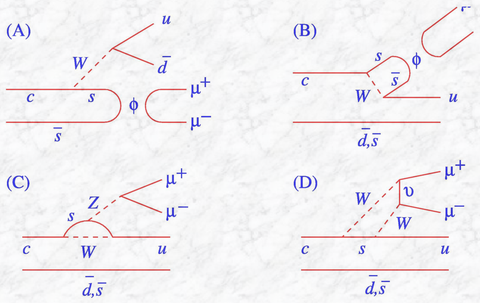
$N(\mu\varphi D_s) = 19.34 \pm 7.85$

Rare Decays and Background Suppression

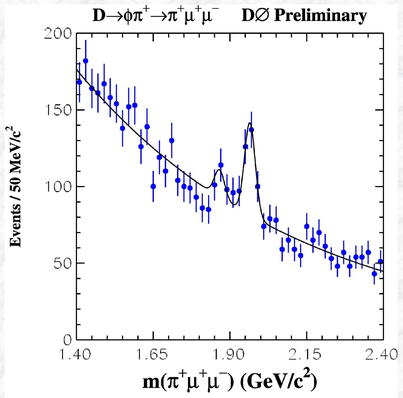
Backgrounds are reduced using flight length, kinematic and topological variables.



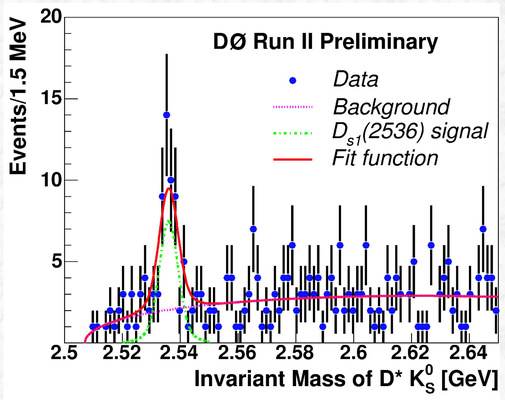
Representation of Background Suppression Variables



Feynman diagrams for FCNC Processes



$D^+_{(s)} \to \varphi\pi^+ \to \pi^+\mu\mu$ distribution



Observation of $B_s^0 \to D_{s1}^-(2536)\mu\nu X$

$N(D_{s1}(2536)) = 43.8 \pm 8.3$

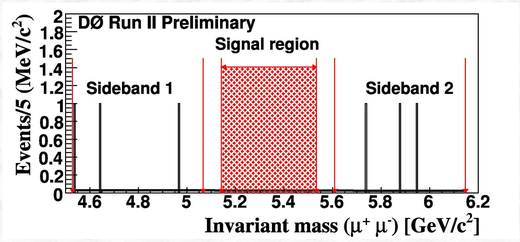
5.2σ significance

Semi-leptonic B decay to an excited charm meson is sensitive to heavy quark effective theory (HQET) corrections. Observations and measurements of such decays are important for theoretical comparisons.

Searching for rare decays, such as the FCNC process $D^+_{(s)} \to \varphi\pi^+ \to \pi^+\mu\mu$ allows limits to be set on new phenomena. For continuum production:

$\mathcal{B}(D^+ \to \pi^+\mu\mu) < 4.7 \times 10^{-6}$ 90% CL

Long-distance contributions via intermediate strong resonances can be observed and measured in the $\pi^+\mu\mu$ mass distribution for $M(\mu\mu) \approx M(\varphi)$.



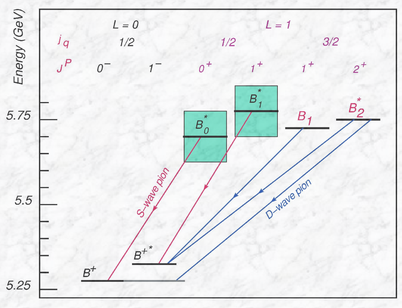
$\langle\mathcal{B}(B_s^0 \to \mu\mu)\rangle < 1.9(2.3) \times 10^{-6}$ 90(95)% CL

Simulated Monte Carlo data is used in conjunction with 'sideband' mass regions to allow objective statistical analysis of small signal samples.

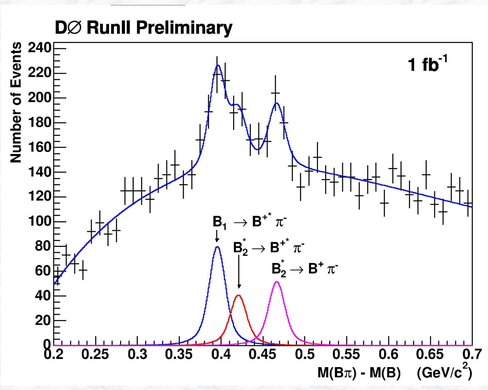
Excited States – b Quark Spectroscopy

Observation of excited states in the (bd) and (bs) quark systems, and measurement of the particle parameters, gives values which can be compared with theory. Masses, widths and branching ratios then allow different QCD models to be compared with experimental data.

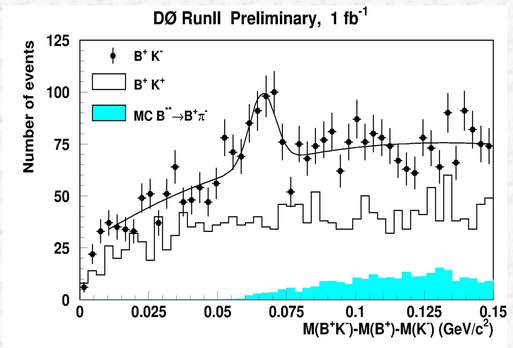
Comparison of (bd) and (bs) systems gives insight into generational symmetry in nature.



Energy level Diagram



(bd) quark system Excited states



(bs) quark system Excited states

Why only one peak in (bs) system?

CP Violation parameter of B^0 mixing

CPV in Mixing can be obtained by measuring the asymmetry of the same sign muon pairs coming from direct B decays:

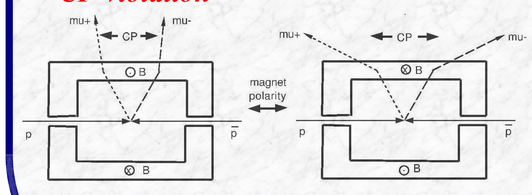
$$A_{SL} = \frac{N(b\bar{b} \to l^+l^+X) - N(b\bar{b} \to l^-l^-X)}{N(b\bar{b} \to l^+l^+X) + N(b\bar{b} \to l^-l^-X)}$$

Difficulty of this measurement is in separating the asymmetry from detector effects. The muon sample is divided into 8 groups, depending on their charge (q), direction (γ = +1(-1) for forward(backward) muons), and the toroid polarity (β).

$$n_q^{\beta\gamma} = \tfrac{1}{4} N \varepsilon^{\beta}(1+qA)(1+q\gamma A_{fb})(1+q\beta A_{q\beta})(1+\gamma A_{det})(1+q\beta\gamma A_{ro})(1+\beta\gamma A_{\beta\gamma})$$

Physics Asymmetry due to CP-violation

Detector asymmetries (beam direction, toroid polarity, 'left-right' asymmetry, 'range-out' asymmetry)



$$A_{SL} = -0.0044 \pm 0.0040(stat) \pm 0.0028(syst)$$

$$\frac{Re(\varepsilon_{B0})}{1+|\varepsilon_{B0}|^2} = -0.0011 \pm 0.0010(stat) \pm 0.0007(syst)$$

Even more precise than WA!