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Bs Mixing at the Tevatron

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The measurement of the $B_s$mixing oscillation frequency, Δm_s, has been the main goal for both experiments CDF and D0 which are running at the Tevatron collider. With 1 fb^{-1}of data collected during the last four years D0 set a lower and upper limit on this frequency, $17 < \Delta m_s < 21$ ps^{-1}. CDF measured Δm_s with a precision better than 2% and the probability that the data could randomly fluctuate to mimic such a signature is 0.2%

1. Introduction

The Tevatron collider at Fermilab, operating at $\sqrt{1.96}$ TeV is a good B meson physics laboratory, where the properties of these particles can be studied with high precision thanks to the high b production cross section and the presence of all b-hadrons species. The usage of specialized triggers based on leptons or tracks significantly displaced from primary vertex [1] allows the selection of one B meson event out of 1000 QCD events. Both CDF and D0 are multipurpose 4π coverage detectors [2,3] featuring with high resolution tracking in a magnetic field, which is one of the key element for the mixing measurement as it will be discussed later.

Particle-antiparticle oscillation is described in the Standard Model [4] by Δm and $\Delta\Gamma$, mass and lifetime difference of the two mass eigenstates, B_q^H and B_q^L. In the B_d system Δm_d is measured to be $\Delta m_d = (0.505 \pm 0.005)$ ps^{-1} [5] while in the B_s system the world average limit is $\Delta m_s > 14.4$ ps^{-1} [5], which makes the measurement really challenging.

Experimentally the oscillation manifest itself in an asymmetry which depends on the time:

$$A(t) = \frac{N_{unmix}(t) - N_{mix}(t)}{N_{unmix}(t) + N_{mix}(t)} = cos\Delta m_s t \qquad (1)$$

In practice, it is necessary to identify the B meson flavor at the production and decay time and to determine the proper time at which the decay occurred to separate mixed from unmixed events as function of proper time. The B meson flavor at the decay time is obtained by exclusive reconstruction of final state. Large B_s samples with a good signal-to-noise ratio are needed to be sensitive to high mixing frequency.

The proper decay time, $t = L_T m_B/p_T c$, obtained from the transverse decay length L_T and the transverse momentum , p_T, has to be determined with high resolution in order to resolve high mixing frequencies. This implies an high precision tracking detector to measure the decay length and magnetic filed to evaluate the momentum.

The b flavor at the production time is evaluated with the so-called flavor tagging, which has a probability $\mathcal{P}_{tag}$ to tag correctly the b flavor, giving a dilution, $\mathcal{D} = 2\mathcal{P}_{tag}$- 1. This reduce the measured asymmetry:

$$A^{meas}(t) = \mathcal{D}A(t) = \mathcal{D}cos\Delta m_s t \qquad (2)$$

and for this reason many efforts have been put in optimizing algorithms to achieve the highest $\mathcal{D}$.

The analysis will proceed through the following steps:

- Reconstruct the B_s decays;
- Measure the proper decay time;
- Identify the b flavor at the production time.

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2. B_s decay modes reconstructions

CDF exploits its trigger on tracks significantly displaced from primary vertex [1] to select fully reconstructed and semileptonic B_s decays. In the first case $B_s \to D_s^- \pi^+$ and $B_s \to D_s^- \pi^+ \pi^- \pi^+$ while in the second $B_s \to D_s^- l^+ X$ and in both $D_s^- \to \phi\pi^-$, $D_s^- \to K^{*0} K^-$ and $D_s^- \to \pi^+\pi^-\pi^-$. Figure 1 shows the invariant mass for fully recon-

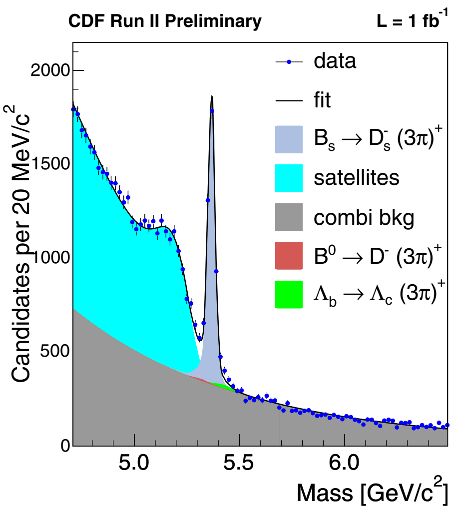

Figure 1. CDF: Invariant Mass for $B_s \to D_s^- \pi^+$ and $B_s \to D_s^- 3\pi^+$. The main signal is shown together with the contribution of partially reconstructed B decays.

structed decay modes, only events with masses greater than 5.3 GeV/c^2 are then used in the final fit in order to remove the contribution of partially reconstructed B while events with masses greater than 5.5 GeV/c^2 are taken to parametrize the combinatorial background contributions. CDF has 3,600 signal events of hadronic B_s decays and 37,000 semileptonic B_s decays.

D0 search for $B_s \to \mu^+ D_s^- X$ with $D_s^- \to \phi\pi^-$ in a sample of data collected with the muon trigger. In a cone around the muon a D_s is reconstructed first searching for a $\phi \to K^+K^-$ and then attaching a pion to it. In figure 2 is shown the invariant mass of the D_s for event that satisfy the reconstruction requirements, corresponding to a total number of 27,000 events.

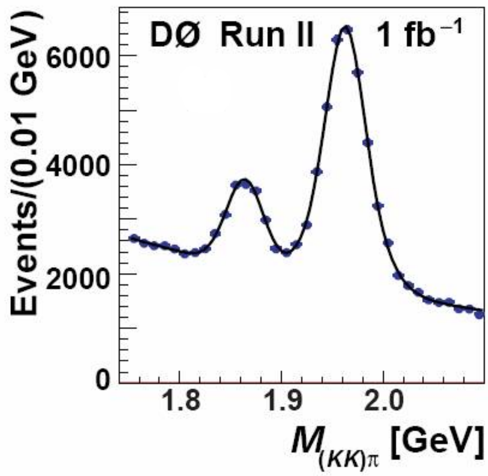

Figure 2. D0: $(K^+K^-)\pi^-$ invariant mass distribution for the untagged sample. The curve is the fit result used to evaluate the number of events.

3. Decay Length Reconstruction and Resolution

The proper decay time

$$t = \frac{L_T m_B}{p_T c}$$

is obtained directly from reconstructed quantities except m_B which is the B meson mass [5]. The transverse decay length, L_T, is defined as the displacement in the transverse plane from the primary event vertex to the reconstructed B meson decay vertex projected onto the B meson transverse momentum, $p_T(B)$. For semileptonic modes the undetected neutrino and other not-reconstructed particles like pions and photons,