

Towards CP-violation results from $D\bar{0}$

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Received: 1 October 2003 / Accepted: 15 October 2003 /

Published Online: 22 October 2003 – © Springer-Verlag / Società Italiana di Fisica 2003

Abstract. We have made a preliminary study of a dimuon sample corresponding to 114 pb^{-1} of data taken in Run II at the Tevatron. From this sample we have selected $157 \pm 20 B_d \rightarrow J/\psi K_S^0$ and $133 \pm 17 B_s \rightarrow J/\psi \phi$ decays. In a subset of the data we have measured the B^\pm lifetime in the $J/\psi K^\pm$ channel to be $1.76 \pm 0.24 \text{ ps}$. We have implemented a jet-charge initial-flavor tag as well as a soft-muon tag, and we have measured the respective tagging powers to be $(2.4 \pm 1.7)\%$ and $(3.3 \pm 1.8)\%$. Our conclusion from these studies is that we have made good progress towards understanding all ingredients required to make CP violation measurements in the B_d and B_s systems.

1 Introduction

The rate of $b\bar{b}$ production at the Tevatron is of the order of 10^{10} $b\bar{b}$ pairs per year at a currently typical instantaneous luminosity of $4 \cdot 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$. In combination with the b -quark fragmentation into all B hadron species, this allows for a broad range of B physics measurements. In the context of CP violation, measurements of different CKM angles and various mixing measurements are possible.

Generally, the measurement of a CP violating effect requires the determination of different decay amplitudes. Defining the decay amplitude of a B hadron B to a final state f , as a function of the B 's proper time t to be $\mathcal{A}(B \rightarrow f)(t)$, and the decay amplitude of its CP conjugate partner \bar{B} to the same final state to be $\mathcal{A}(\bar{B} \rightarrow f)(t)$. The CP asymmetry in these decays, $A_{CP}(t)$, can now be defined as:

$$A_{CP}(t) = \frac{\mathcal{A}(B \rightarrow f)(t) - \mathcal{A}(\bar{B} \rightarrow f)(t)}{\mathcal{A}(B \rightarrow f)(t) + \mathcal{A}(\bar{B} \rightarrow f)(t)} \quad (1)$$

This equation makes clear that for a CP violation measurement, after the selection of the events containing B-hadron decays, a few ingredients are required. First, the proper time t of the decaying hadron must be measured. This requires accurate vertexing and good p_T measurement. Secondly, one has to determine whether the decaying hadron contained a b quark or a \bar{b} quark. This procedure is called initial-flavor tagging.

Here we will demonstrate that we are able to select B hadron decays, and that we have the techniques in hand to make CP violation measurements. In addition an outlook for mixing measurements will be presented.

2 Data sample

For the results presented here, we have used a sample of 114 pb^{-1} , collected with a dimuon trigger from September 2002 until the end of June 2003. Figure 1 shows the dimuon mass spectrum with a J/ψ peak. The fit yields 151,174 J/ψ 's. Note that this yield has been obtained with fairly tight cuts however, and up to twice the number shown here could be obtained with looser cuts. Note that the measured mass is slightly below the PDG value of 3.097 GeV, indicating that the calibration of the magnetic field and energy loss in the tracker has not yet been finalized. In the mass spectrum, the ψ' resonance is also visible, with 4100 events in the ψ' peak.

A J/ψ trigger at the Tevatron is a good trigger to collect B hadrons, since 15-20% of the J/ψ 's are expected to come from B hadron decays. The J/ψ trigger efficiency suffers however from an implicit momentum cut on the muons of approximately 3 GeV in the L1 muon trigger. This issue is expected to be resolved with the Level-1 Central Track Trigger, which has been installed and is currently being commissioned.

According to the current baseline Tevatron plan, our dataset is expected to expand to 2 fb^{-1} by the end of 2005.

3 Event selection for CKM angle measurements

Measurement of the angle β from the largest unitarity triangle is possible by studying the decay $B_d \rightarrow J/\psi K_S^0$. We have reconstructed this decay, with the J/ψ decaying to two muons and the K_S^0 to two charged pions. The reconstructed mass spectrum is shown in Fig. 2. We reconstruct $157 \pm 20 B_d$'s in this preliminary study.

Measurement of the angle β_s , from a complementary unitarity triangle, is possible in the decay $B_s \rightarrow J/\psi \phi$.

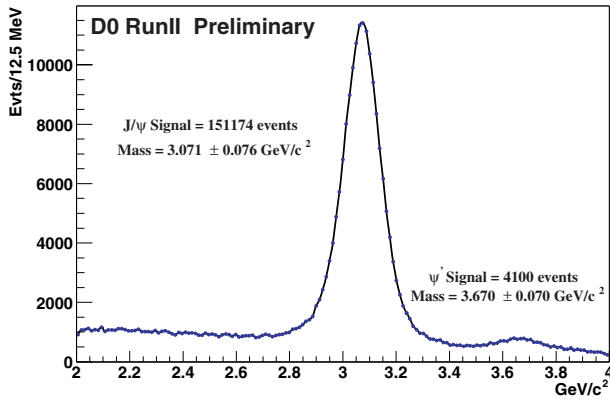


Fig. 1. Dimuon mass spectrum showing the J/ψ and ψ' resonances

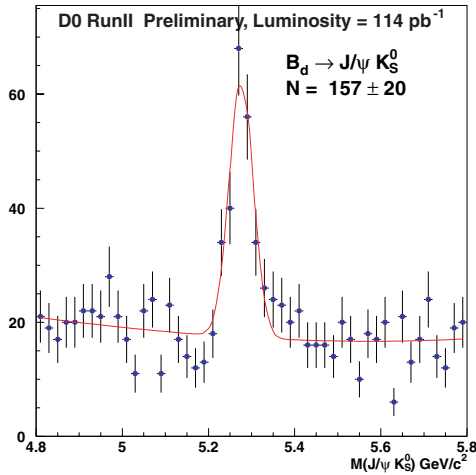


Fig. 2. B_d mass spectrum, showing 157 ± 20 candidates

The angle β_s is defined as $\beta_s \equiv \arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right)$. The CP asymmetry in this decay, as defined in equation 1, is expected to be small, at the level of a few percent. But if measurable, it is directly proportional to the Wolfenstein parameter η : $\beta_s = \lambda^2\eta$, and the parameter λ is accurately known. Otherwise, if the CP asymmetry is found to be large, this is an unambiguous sign of new physics.

The mass distribution for this channel is shown in Fig. 3. The fit to the signal peak and background yields $133 \pm 17 B_s$ candidates.

4 B^\pm lifetime

To demonstrate the ability to measure the proper decay time of B hadrons, we present here a preliminary measurement of the B^\pm lifetime in the decay channel to $J/\psi K^\pm$ using 47 pb^{-1} of Run II data. We select B^\pm candidates by combining a J/ψ candidate with one track that is assigned the charged kaon mass. In our full dataset of 114 pb^{-1} , a sample of $1235 \pm 52 B^\pm$ is reconstructed (see Fig. 4).

To determine the B^\pm lifetime, the lifetime distribution of the background under the mass peak is first determined. We do this by fitting the lifetime of candidates from

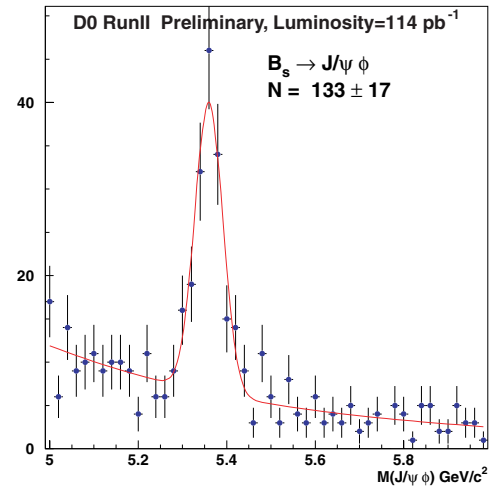


Fig. 3. B_s mass spectrum in the $J/\psi\phi$ channel, showing $133 \pm 17 B_s$ candidates

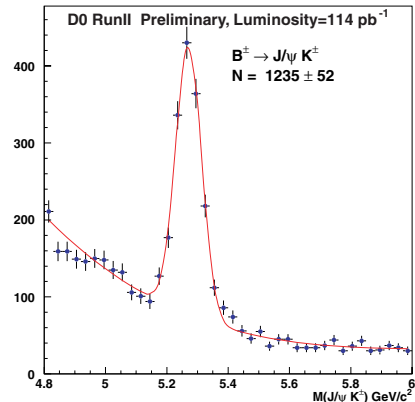


Fig. 4. Mass spectrum showing $1235 \pm 52 B^\pm$ candidates

two sideband regions bracketing the B^\pm peak in the mass spectrum. The background fit shape is a Gaussian centered at zero to represent the zero-lifetime combinatorial background, and an exponential convoluted with a Gaussian to accommodate long-lived background such as other types of B hadrons. To fit the signal, we have used an exponential convoluted with a Gaussian as well. The fits are shown in Fig. 5. The preliminary result of this measurement is $1.76 \pm 0.24 \text{ ps}$. The error given here is statistical only, but within this error, the result is compatible with the PDG value. With the completed trigger and the predicted expansion of our dataset, we expect this error to fall below the error on the PDG value of 0.018 ps . This analysis has been updated recently using the entire dataset of 114 pb^{-1} , and the errors have already been reduced accordingly.

5 Initial-flavor tagging

We are currently making use of two initial-flavor tagging procedures: a jet-charge tag and a soft-muon tag.

The jet-charge tag is an opposite-side tag, making use of the fact that most b quark production is through $b\bar{b}$

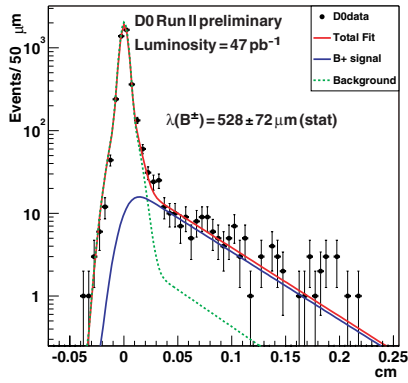


Fig. 5. Lifetime fit to B^\pm candidates in the mass peak region

Table 1. Results from jet-charge and soft-muon initial-flavor tags using a $B^\pm \rightarrow J/\psi K^\pm$ sample from 47 pb^{-1} of data. Errors indicated are statistical only

	jet-charge tag	soft-muon tag
efficiency ϵ [%]	55.1 ± 4.1	8.2 ± 2.2
dilution D [%]	21.0 ± 10.6	63.9 ± 30.1
tagging power ϵD^2 [%]	2.4 ± 1.7	3.3 ± 1.8

pair production. The jet-charge tag selects tracks in a φ -window opposite the fully reconstructed B hadron, whose flavor we are attempting to determine. The selected tracks are used to calculate the jet charge Q , according to $Q = \sum_i (p_{T,i} \cdot q_i) / \sum_i p_{T,i}$. Events with $|Q| > 0.2$ are considered “tagged”.

The soft-muon tag can be used for both B hadrons in the event, but the requirement is that the b quark decays semileptonically through $b \rightarrow \mu \nu_\mu q$, with q being c or u . The charge of the muon can be used to deduce flavor of the B hadron.

It is convenient to present tagging results in terms of efficiency and dilution. The efficiency ϵ represents the applicability of the tag: $\epsilon = (N_{\text{right}} + N_{\text{wrong}}) / N_{\text{all}}$, with N_{right} and N_{wrong} the number of right and wrong tags respectively, and N_{all} the number of B’s to be tagged. The dilution factor D accounts for the fact that some tags are wrong: $D = (N_{\text{right}} - N_{\text{wrong}}) / (N_{\text{right}} + N_{\text{wrong}})$. We define the tagging power of a tag (ϵD^2). This number is of interest because the error on the result of a measurement involving tagging does not scale with the number of signal events N_{all} , but rather with $(\epsilon D^2 \cdot N_{\text{all}})$.

The preliminary results for both tags, obtained from a sample of $B^\pm \rightarrow J/\psi K^\pm$ decays from 47 pb^{-1} of data, are shown in table 1. The tagging power ϵD^2 is $(2.4 \pm 1.7)\%$ for the jet charge tag and $(3.3 \pm 1.8)\%$ for the soft muon tag. This performance is in rough agreement with expectations before the run. The numbers have recently been updated using the entire dataset of 114 pb^{-1} , and more work is ongoing to improve further.

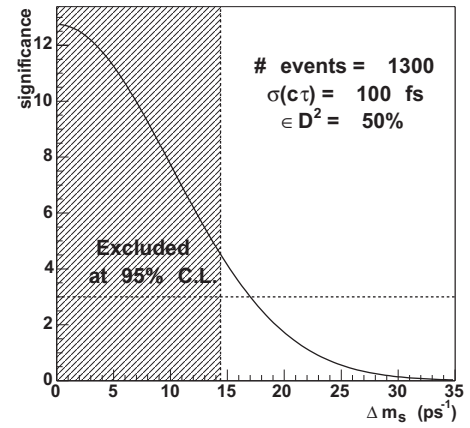


Fig. 6. Expected Δm_s significance, using 2 fb^{-1} of data and a proper time resolution of 100 fs

6 B_s mixing

DØ will attempt to measure the B_s mixing parameter Δm_s , the mass difference between the mass eigenstates, in different channels.

We have studied the hadronic B_s decay mode to $D_s^{(*)} \pi$. We expect to reconstruct between 1300 and 1900 events in this channel in 2 fb^{-1} of data. Figure 6 shows the expected significance, when a proper time resolution of 100 fs is assumed as suggested by MC, with an event yield of 1300. The area below $\Delta m_s = 14.4 \text{ ps}^{-1}$ has been excluded by the CDF, LEP and SLD experiments at 95% confidence level. Our conclusion is that even with pessimistic assumptions, DØ can make a significant contribution to the knowledge of B_s mixing using this channel. The key to improving the Δm_s reach of DØ lies in the proper time resolution. If the resolution could be improved to 75 fs, a 3σ measurement of Δm_s in this channel could be made up to 23 ps^{-1} .

The semileptonic decay to $D_s^{(*)} \ell \nu$ is also under investigation. It is expected that less integrated luminosity will be required to make a measurement in this channel, but a lower reach is expected due to poorer proper time resolution, since the escaping neutrino makes for a less accurate determination of the p_T of the B_s .

7 Conclusions

We have studied B hadrons in a dimuon sample, corresponding to 114 pb^{-1} of data taken by DØ in Run II of the Tevatron. The results of these studies demonstrate that the first techniques required to make CP violation measurements are defined and have reasonable performance. We are therefore confident that DØ will make precise CP violation measurements in the B_d and B_s systems during Run II of the Tevatron.