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OBSERVATION OF SEMILEPTONIC B DECAYS INTO ORBITALLY EXCITED D FINAL STATES

Sudhir Malik*

Center for Applied Physics Studies, Louisiana Tech University, Ruston, Louisiana 71272, USA

For the DØ Collaboration

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Using 250 pb^{-1} of data collected with the DØ detector in Run II of the Tevatron, the two narrow ($L = 1$) states, $D_1(2420)$ and $D_2^*(2460)$ have been observed in semileptonic decays of B mesons. Results on the $D^{*+}\ \pi^-$ decay mode are presented including a measurement of the branching fraction of B mesons to these states.

Keywords: Tevatron; Semileptonic decay; B-mesons

1. Introduction

The DØ detector [1] is designed to study collisions from protons and antiprotons circulating in the Fermilab Tevatron. After its first data taking from 1992 – 1996, called Run I, the DØ Detector underwent a major upgrade [2]. The current data taking of the detector is called Run II and is defined by an increase in the center-of-mass energy from 1.8 TeV to 1.96 TeV and increased luminosity. This combined with a high precision tracking capability and robust triggering offers an ideal environment for the study of B-physics processes such as B hadron decay modes, semileptonic B decays, B hadron lifetimes and flavour oscillations. The major elements of the upgrade include a new Silicon Microstrip Tracker (SMT) placed closest to the interaction point and a new Scintillating Central Fiber Tracker (CFT) detector. The SMT and CFT together form the central tracking system and lie inside a 2 Tesla solenoid, which is also new addition for Run II. The forward muon system has been completely replaced in order to accommodate higher event rates. There are three levels of triggering and a new data acquisition system. We have measured the branching fraction of the semileptonic decay of B meson [3] into the narrow states, $D_1(2420)$ and $D_2^*(2460)$. Along with the wide states, D_0^* and $D_1^{'}$, they form the orbitally excited states of the D meson and are referred to as D^{**} mesons [4]. Conservation of parity and angular momentum restricts the final states that are

*Center for Applied Physics Studies, Louisiana Tech University, Ruston, Louisiana 71272, USA ; E-mail: malik@fnal.gov

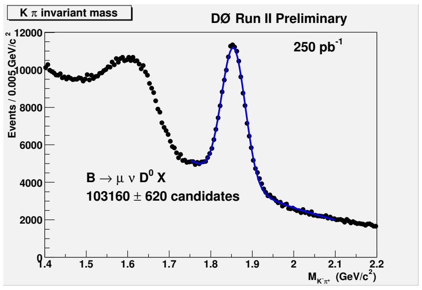

Fig. 1. The invariant mass of the $K\pi$ system for $\mu^+K^+\pi^-$

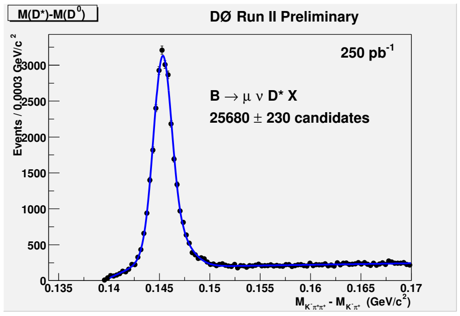

Fig. 2. The mass difference $M(D^0\pi) - M(D^0)$ for events with $1.75 < M(D^0) < 1.95$ GeV/c^2

allowed in the decays of these four D^{**} mesons. The states that decay via a D-wave are expected to be narrow ($20 \div 30\ MeV/c^2$) while the states that decay via S-wave are expected to be wide (several hundred MeV/c^2). $D_1(2420)$ and $D_2^*(2460)$ decay through a D-wave and are, therefore, expected to be narrow. The narrow states have been observed before by the BELLE [5] and BABAR [6] experiments.

2. Selection of Events

We have used information only from the muon and the tracking system and the majority of events selected satisfied single muon trigger requirements. The D^{**} mesons were looked for in the decays for $B \to \mu\nu\ D^*\ X$ as resonances in the D^{*+} π^- invariant mass spectrum. The D mesons were then required to decay into $D^{*+} \to D^0\ \pi^+$ and $D^0 \to \mathrm{K}^-\ \pi^+$. The muons from the B decay were required to have hits in more than one muon chamber, have an associated track in the central tracking with hits both in SMT and CFT and also have a pseudorapidity $|\eta| < 1$, total momentum $p^\mu > 3\ GeV/c$ and a transverse momentum $p_T^\mu > 2\ GeV/c$. Using the DURHAM clustering algorithm [7] all charged particles in an event were clustered into jets. The D^0 candidate was constructed from two particles having an opposite charge in the same jet as the reconstructed muon. They were required to have hits in both SMT and CFT as well as $p_T > 0.7\ GeV/c$ and $|\eta| < 2$. They also had a common D-vertex with $\chi^2_D < 9$. The tracks of muon and D^0 candidate were required to form a common B vertex with fit $\chi^2_B < 9$. The mass spectrum of $(K\pi)$ system after all these selections is shown in Fig.1. The events falling into the $K\pi$ invariant mass window between $1.75 - 1.95\ GeV/c^2$ were referred to as μ^+D^0 candidates. The curve in Fig.1 shows the result of the fit of the $K^+\pi^-$ mass distribution with a gaussian and a polynomial background. The left peak refers to the partially reconstructed decay $D \to K^+\ \pi^-\ X$. For μ^+D^0 candidates, we looked for an additional pion (π^*) with charge opposite to the charge of muon and with $p_T > 0.18\ GeV/c$. The mass difference $\Delta M = M(D^0\pi) - M(D^0)$ for all such pions when $1.75 < M(D^0) < 1.95$

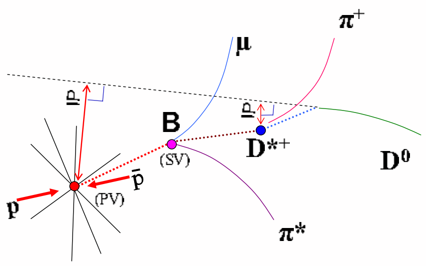

Fig. 3. Schematic of the decay of B vertex

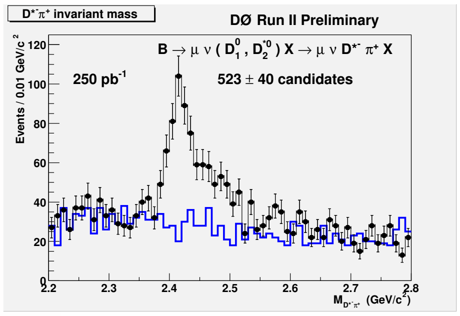

Fig. 4. The invariant mass of $M(D^{*-}\pi^+)$

GeV/c^2 is shown in Fig. 2. The peak in the figure corresponds to the production of μ^+D^{**}. The total number of D^* candidates in the peak were defined as number of signal events in the range $0.142 - 0.149\ GeV/c^2$. The signal and the background have been modelled by a sum of two gaussian functions and by the sum of exponential and first-order polynomial functions, respectively.

D^{**} were selected by combining D^* with the additional pion. The pion candidate had charge opposite to the charge of the D^* candidate and $p^T > 0.3\ GeV/c$. Fig. 3 shows a schematic of the B meson decay topology. The ratio of Impact Parameter (IP), in the XY plane for primary vertex (PV) and secondary vertex (SV) was required to be greater than 4. To reconstruct B candidates all the tracks were required to have number of SMT and CFT hits greater than 1 and 5, respectively. χ^2 of B vertex had to be < 25. The D^{**} invariant mass passing all these cuts is shown in Fig. 4. The points correspond to the $D^*\pi$ combinations with opposite charge and the histogram corresponds to the same charge combinations. The mass peak in the region between 2.4 and 2.5 GeV/c^2 can be interpreted as two merged narrow D^{**} states, $D_1(2420)$ and $D_2^*(2460)$.

3. Results

The branching rate for the D^{**} was determined by using for normalisation the known values of the branching rates for D^*, $Br(B \to \mu\nu D^* X) = (2.75\ \pm0.19)\%$ and $Br(D^{*+} \to D^0\pi^+) = (67.7\ \pm0.5)\%$ [4].

$$Br(B \to \mu\nu(D_1^0(2420), D_2^{*0}(2460))X) \cdot Br(D_1^0(2420), D_2^{*0}(2460) \to D^{*+}\pi^-) = \\ Br(B \to \mu\nu D^* X).\frac{N_{D^{**}}^{data}}{N_{D^*}^{data}} \cdot \frac{1}{\epsilon^* \cdot Br(D^{*+} \to D^0\pi^+)} \cdot \frac{1}{\epsilon_{gen}^*}. \quad (1)$$

In Eq. 1 $N_{D^{**}}^{data}$ and $N_{D^*}^{data}$ are the numbers of D^{**} and D^* candidates, respectively, ϵ^* is the relative efficiency to construct D^{**} with respect to the reconstructed D^* meson and ϵ_{gen}^* is the efficiency correction factor accounting for different efficiency for D^{**} and D^* at the generator level. The efficiencies ϵ^*=(34.7 ±2.9)% and ϵ_{gen}^*=(85.0

$\pm 2.0)\%$ were determined by the standard DØ procedure for Monte Carlo simulations: an event generator interfaced with PYTHIA and followed by full GEANT modelling of the detector response and event reconstruction [8]. Using the inputs as defined above we obtain

$$Br(B \to \mu\nu(D_1^0(2420), D_2^{*0}(2460))X) \cdot Br(D_1^0(2420), D_2^{*0}(2460) \to D^{*+}\pi^-) = (0.280 \pm 0.021(stat) \pm 0.088(syst))\%. \quad (2)$$

where the statistical error corresponds to the error on the total number of D^{**} in the mass peak. The systematic errors for the D^{**} branching rate are shown in Table 1. We have thus measured for the first time the component of $B \to \mu^\nu D^{*+}\pi^- X$ process going through the narrow D^{**} states.

Table 1. Systematic Errors

Source	Br absolute error	Br relative error
D^* branching rates	0.020%	7%
MC statistics	0.023%	8%
Normalization to D^*/D^0	0.023%	8%
$P_t^{\pi^{**}}$ dependence	0.052%	19%
Possible contribution from wide resonance	0.039%	14%
Possible interference effects of D_1^0 and D_2^{*0}	0.040%	14%
Different modelling of D^*/D^0 fit	0.010%	4%
Trigger bias	0.020%	7%
Total systematic error	**0.088%**	**32%**

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