DØnote 5027-Conf

First Direct Observation of B_{s2}^{*0} meson

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The B_{s2}^{*0} meson represents an excited state of a $(b\bar{s})$ system. This note reports the first direct observation of B_{s2}^{*0} meson using a data sample with an integrated luminosity of 1 fb^{-1} produced in $p\overline{p}$ collisions at $\sqrt{s}$ = 1.96 TeV and collected by the DØ experiment at the Tevatron collider during the 2002-2005. The mass of the B_{s2}^{*0} meson is found to be 5839.1 ± 1.4 (stat) $\pm$ 1.5 (syst) MeV/c^2.

Preliminary Results for Winter 2006 Conferences

I. INTRODUCTION

The spectroscopy of B-mesons is still in its infancy. Only the stable $J^P = 0^-$ ground states B^+, B_d^0, B_s^0 and the excited 1^- state B^* have been observed [1]. Previous studies of excited $(b\bar{s})$ states have been carried out using inclusive samples with limited precision and ambiguous interpretation [2].

The properties of $(b\bar{s})$ excited states, and the comparison with the properties of the $(b\bar{u})$, $(b\,\bar{d})$ systems provide good tests of various models of quark bound states and are important for their continuing development. These models predict the existence of four P states in the $(b\bar{s})$ system, two wide resonances (B_{s0}^* and B_{s1}^*) and two narrow resonances (B_{s1} and B_{s2}^*) [3]. The wide resonances decay via S wave processes and therefore have a width of a few hundred MeV. Such states are difficult to distinguish from the combinatoric backgrounds. The narrow resonances decay via D-wave processes ($L = 2$) and should have a width of approximately 10 MeV/c^2 [3]. If the mass of the B_{sJ} $(J = 1, 2)$ is large enough then the main decay channel should be $B^{(*)}K$ as the $B_s\pi$ is forbidden by isospin conservation.

This note presents the observation of the process $B_{s2}^{*0} \to B^+K^-$ using a data sample with an integrated luminosity of 1 fb^{-1} produced in $p\overline{p}$ collisions at $\sqrt{s}$ = 1.96 TeV and collected by the DØ experiment at the Tevatron Collider during 2002-2005.

II. DATA SAMPLE

The DØ detector is described in detail elsewhere [4]. The B^+ is reconstructed in the exclusive decay [5] $B^+ \to J/\psi K^+$ where $J/\psi \to \mu^+\mu^-$. The procedure for selecting a B^+ sample is described in [6]. A total of 16219 ± 180 B^+ events were reconstructed.

To reconstruct a B_{sJ} each B^+ was combined with an additional charged particle. The charged particle was required to have hits in the silicon tracker and in the central fiber tracker [4], $p_T > 0.6$ GeV/c, and the opposite charge to the B^+. Since the B_{sJ} is expected to decay immediately after production, the additional particle was required to originate from the primary interaction vertex by requiring that its combined significance $S_{PV} < 6$, where $S_{PV}^2 = (d_{ax}/\sigma_{ax})^2 + (d_{st}/\sigma_{st})^2$, where d_{ax}, d_{st} are the axial and stereo impact parameters with respect to the primary vertex, and σ_{ax}, σ_{st} denotes the resolution. The charged particle was assigned the mass of the kaon.

The mass difference $\Delta M = M(B^+K^-) - M(B^+) - M(K^-)$ was then computed (see Fig. 1). A mass peak is clearly visible at 66 MeV/c^2. The ΔM distribution is then fitted with a third order polynomial representing the combinatoric background and a Gaussian representing the signal. The parameters describing the background and the signal were allowed to vary in the fit. The resulting signal parameters are

$$\begin{aligned} N &= 135 \pm 31\text{(stat)}, \\ \Delta M &= 66.4 \pm 1.4 \text{ (stat) MeV}/c^2, \\ \sigma &= 4.7 \pm 1.5 \text{ (stat) MeV}/c^2, \end{aligned} \tag{1}$$

where N is the total number of signal events, and σ is the width of the peak. The parameter uncertainties are statistical and are obtained from the fitting procedure. If the distribution is only fitted by the background function the total χ^2 increases by ≈36, which corresponds to a signal significance exceeding 5 standard deviations. This result can be interpreted as the process $B_{s2}^{*0} \to B^+K^-$. By using the PDG values for the masses of the B^+ and K^-, the mass of B_{s2}^{*0} is found to be:

$$M(B_{s2}^{*0}) = 5839.1 \pm 1.4 \text{ MeV}/c^2\text{(stat)} \tag{2}$$

The B_{s2}^{*0} meson should also decay via $B_{s2}^{*0} \to B^{*+}K^-$. The mass difference between the B^{*+} and B^+ is $M(B^{*+}) - M(B) = 45.78 \pm 0.35$ MeV/c^2 and the B^{*+} decays to $B^{*+} \to B\gamma$. Therefore the decay $B_{s2}^{*0} \to B^{*+}K^-$ should produce a signal with $\Delta M \simeq M(B_{s2}^{*0}) - M(B^{*+}) - M(K^-) \simeq 20$ MeV/c^2. However, the orbital momentum $L = 2$ and the small mass difference result in a strong suppression of the $B_{s2}^{*0} \to B^{*+}K^-$ process, explaining the absence of this decay in the observed mass spectrum (Fig. 1).

To estimate the experimental resolution of the signal, the decay $B_{s2}^{*0} \to B^+K^-$ was simulated using the standard DØ software and reconstructed using the same algorithms as the data. The mass difference resolution of the simulated events was found to be 4.6 ± 0.2 MeV/c^2. The width of the signal observed in the data is consistent with the experimental resolution, indicating that the B_{s2}^{*0} has a small width. It is likely that the narrow width can be explained by the small amount of phase space available for the $B_{s2}^{*0} \to B^+K^-$ decay.

The B_{s1}^0 meson can only decay via the process $B_{s1}^0 \to B^{*+}K^-$. The mass splitting between B_2^* and B_1 mesons in the $\bar{b}d$ quark system, studied in our paper [6] was found to be $M(B_2^*) - M(B_1) = 25.2 \pm 3.2$ MeV/c^2. Taking into account that the quark model predicts the same mass splitting in the $\bar{b}s$ quark system [3] and using $\Delta M(B_{s2}^{*0})$ (Eq. 2), the mass of B_{s1}^0 should be $M(B_{s1}^0) \simeq 5814$ MeV/c^2. In this case the decay $B_{s1}^0 \to B^{*+}K^-$ would be forbidden since $M(B_{s1}^0) < M(B^{*+}) + M(K^-)$. This is a possible explanation for not observing the decays of the B_{s1}^0 meson in the ΔM spectrum.

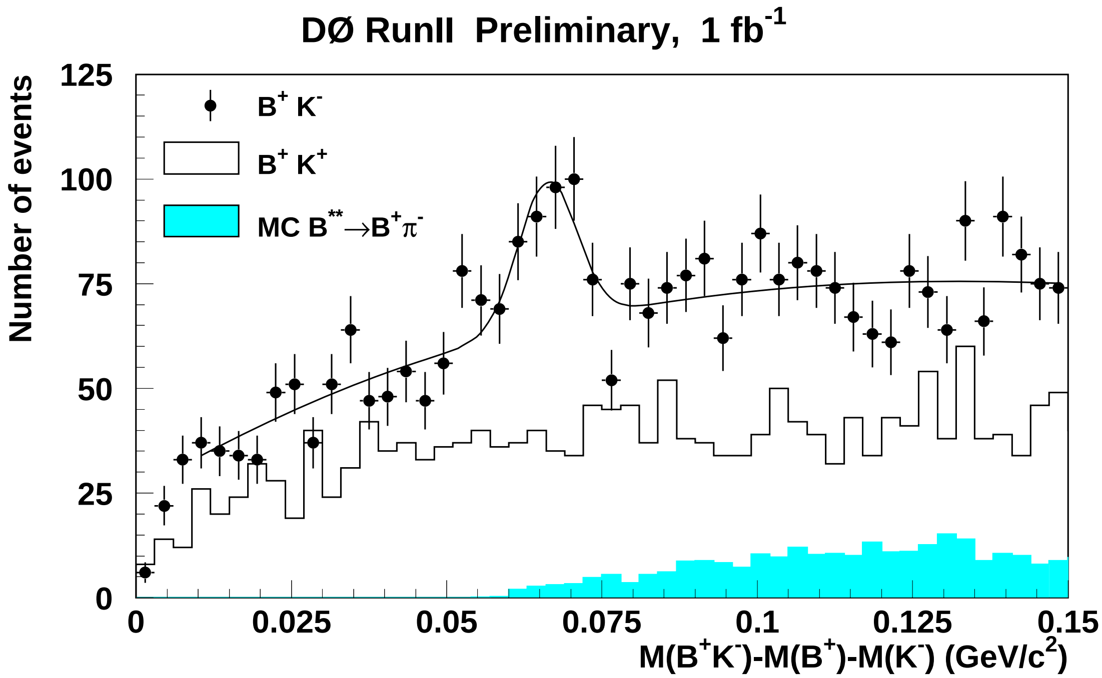

FIG. 1: The mass difference $\Delta M = M(B^+K^-) - M(B^+) - M(K^-)$. The smooth curve shows the fit of a third order polynomial representing the combinatoric background and a Gaussian representing the signal. The histogram shows the mass difference for B^+K^+ events. The solid histogram shows the MC distribution of the decay $B^{**} \to B^{(*)}\pi$ where the π is misidentified as a kaon.

III. SYSTEMATIC ERRORS AND CONSISTENCY CHECKS

The influence of different sources of systematic uncertainty were estimated by varying the background parameterization, and by varying the fitting range and the bin width of the ΔM distribution. For all these variations the change of parameters did not exceed the statistical uncertainty (Eq. 1). The measured position of B hadrons is shifted by ~ 6 MeV/c^2 relative to the world average value due to an uncertainty in the DØ momentum scale. The mass difference ΔM was corrected by the ratio of the measured and PDG masses of B^+ meson. The resulting correction is 0.1 MeV$/c^2$. A conservative estimate of the uncertainty was obtained by setting it equal to the size of the correction. The selection cut on p_T of the kaon was varied between 0.5 and 0.8 GeV and the results were consistent within the statistical error. Conservatively, the full variation was also included as the systematic uncertainty. The total systematic uncertainty for the B_{s2}^{*0} mass was found to be 1.5 MeV$/c^2$. The contribution of different sources into the systematic error is given in Table I.

TABLE I: Systematic uncertainties in the B_{s2}^{*0} mass.

source	$\delta M(B_{s2}^{*0})$ (MeV/c^2)
Fitting Procedure	1.0
Cut on p_T of kaon	1.1
Momentum scale	0.1
Total	1.5

The excited B^{**} mesons studied in [6] could produce a peak in the (B^+K^-) mass spectrum, since the type of the charged particle combined with B^+ is not identified. To study this effect, the decays $B^{**} \to B^{(*)}\pi$ with parameters similar to that measured in [6] were generated and reconstructed in the same way as our B^+K^- sample. The resulting $M(B^+K^-)$ mass distribution, where the pion was assigned the mass of kaon, is shown as a filled histogram in Fig. 1 . The simulated distribution was normalized to the measured yield of B^{**} mesons. It can be seen that the background due to B^{**} decays produces a wide distribution which does not affect the reconstruction of the narrow B_{s2}^{*0} signal.

The mass distribution in data of the B^+K^+ system (the incorrect charge for the B_{s2}^{*0}) gives an estimate of a combinatoric background for the B^+K^- system (Fig. 1). No resonant structure is visible.

IV. CONCLUSIONS

In conclusion, the B_{s2}^{*0} meson has been observed for the first time with an exclusive decay $B_{s2}^{*0} \to B^+K^-$ with the statistical significance exceeding 5 standard deviations. Its mass was found to be:

$$M(B_{s2}^{*0}) = 5839.1 \pm 1.4 \text{ (stat)} \pm 1.5 \text{ (syst) MeV}/c^2. \quad (3)$$

The combined DØ results on the excited B mesons in $(\bar{b}d)$ and $(\bar{b}s)$ system, and the quark model predictions [3] imply the absence or strong suppression of the decay $B_{s1}^0 \to B^{*+}K^-$.

[1] S.Eidelman *et al.* (Particle Data Group), Phys. Lett. **B592**, 1 (2004).
[2] R.Akers *et al.* Z. Phys. **C66**, 19 (1995).
[3] M. Di Pierro and E. Eichten, Phys. Rev. D **64** (2001) 114004 [arXiv:hep-ph/0104208].
[4] V.M. Abazov *et al.* (DØ collaboration), “The Upgraded DØ Detector”, arxiv: hep-physics/0507191
[5] Charge conjugated states are always implied.
[6] DØ Collaboration, “Study of excited B mesons”, DØ Note 5026.