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Observation of $D_s^+ \to \overline{K^{*0}}K^{*+}$

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1 Introduction

Reconstruction of the decay modes of the D_s^+ are of interest in the study of $B_s^0 - \overline{B_s^0}$ mixing and measurements of the B_s^0 lifetime [1, 2]. The branching ratio $D_s^+ \to \overline{K^{*0}}K^{*+}$ has been measured to be $1.8 \pm 0.5 \times \mathrm{Br}(D_s^+ \to \phi\pi^+)$[3, 4]; after accounting for the decays of the D_s^+ daughters, the rate relative to the popular $\phi\pi^+$ mode is

$$\frac{\mathrm{Br}(D_s^+ \to \overline{K^{*0}}\, K^{*+}\,)\mathrm{Br}(\overline{K^{*0}} \to K^-\pi^+)\mathrm{Br}(K^{*+} \to K^0\pi^+)\mathrm{Br}(K^0 \to K_s^0 \to \pi^+\pi^-)}{\mathrm{Br}(D_s^+ \to \phi\pi^+)\mathrm{Br}(\phi \to K^+K^-)} = 0.6 \pm 0.2$$

Although $D_s^+ \to \overline{K^{*0}}K^{*+}$ will suffer from the K_s^0 reconstruction efficiency, it will have a mass resolution as good as the $\phi\pi^+$ mode and should not be affected by reflections because of the constraints imposed by the intermediate resonances, $\overline{K^{*0}}$ and K^{*+} .

2 Selection criteria

Approximately 1.64 million hadronic Z decays with the VDET operational were selected from the 1991, 1992 and 1993 MINIs. K_s^0 candidates with a momentum greater than 2.0 GeV were selected from the YV0V bank if their mass was within 3 standard deviations of a momentum-dependent "K_s^0" mass[5] and neither daughter was consistent with coming from the primary vertex(χ^2(QV0CHK) > 32). Remaining candidates were required to be successfully refit using YTOP and their mass was set to the known K_s^0 mass(QVSETM). Rejection of K_s^0 consistent with Λs or photon conversions was *not* performed. The resulting K_s^0 were combined with a K^- candidate and two π^+ candidates.

The K^- candidate criteria:

- $P(K^-) > 2.0$ GeV, and
- $\chi_K + \chi_\pi < 1$ (if dE/dx information was available), $\chi_i \equiv \frac{I_{meas} - I_{i,exp}}{\sigma_{i,exp}}$

The π^+ candidate criteria:

- $P(\pi^+) > 0.5$ GeV, and
- $|\chi_\pi| < 2$(if dE/dx information was available).

Acceptable $\overline{K^{*0}}$ and K^{*+} candidates satisfied

1. $|M(K_s^0\pi_1^+) - M(K^{*+})| < 50$ MeV and $|M(K^-\pi_2^+) - M(\overline{K^{*0}})| < 50$ MeV, or
   $|M(K_s^0\pi_2^+) - M(K^{*+})| < 50$ MeV and $|M(K^-\pi_1^+) - M(\overline{K^{*0}})| < 50$ MeV,
2. $X(\overline{K^{*0}}) > 0.045$, and
3. $X(K^{*+}) > 0.045$.

Only one combination is kept if both assignments of π_1^+ and π_2^+ are compatible with cut 1 above.

Finally, D_s^+ candidates were formed from $\overline{K^{*0}}$ and K^{*+} candidates which satisfied

- $X(D_s^+) > 0.15$, and
- Prob(D_s^+ vertex) > 0.0001.

3 Results

Two mass distributions are shown in Figure 1. The upper plot contains a sample enhanced in $b \rightarrow D_s^+$ with the requirement that the projected decay length of the D_s^+ must be at least 2 standard deviations in front of the primary vertex. There is a clear signal of 124^{+31}_{-29} events with a fitted mass of $1969.9^{+1.9}_{-2.1}$ MeV/c^2 and a resolution of $7.0^{+2.0}_{-3.7}$ MeV/c^2 which is consistent with expectations from Monte Carlo simulation. The lower plot contains a sample enhanced in $c \rightarrow D_s^+$ with the requirements that $X(D_s^+) > 0.40$ and $\frac{\vec{V}\cdot\vec{P}}{|\vec{V}||\vec{P}|} > 0.99$, where $\vec{V}$ is a vector from the primary to the D_s^+ vertex and $\vec{P}$ is the D_s^+ momentum. There are 51^{+20}_{-15} events in the peak with a fitted mass of $1970.9^{+2.2}_{-3.1}$ MeV/c^2 and a resolution of $6.1^{+3.9}_{-3.0}$ MeV/c^2 .

The $D_s^+ \rightarrow \overline{K^{*0}}K^{*+}$ candidates were also combined with a standard lepton and the unlike– and like–sign spectra are shown in Figure 2. Additional cuts for these spectra:

1. The lepton and at least 2 of the 3 charged D_s^+ daughters must have at least one VDET hit in both the $r\phi$ and z views,
2. The D_s^+ decay length must be positive,
3. The D_s^+ ,lepton vertex probability must be greater than 0.0001,
4. $3.0 < M(D_s^+, \text{lepton}) < 5.5$ GeV/c^2 and
5. The QIPBTAG *uds* probability for the opposite hemisphere must be less than 10% or the QVSRCH B–tag of the opposite hemisphere must be greater than 4.

Cuts 1,2 and 5 were inspired by similar cuts in [1]. The resulting efficiency is $4.0 \pm 0.2\%$ as determined from 9000 special Monte Carlo events where the B_s^0 is forced to decay semi–leptonically, the D_s^+ to $\overline{K^{*0}}K^{*+}$ and the D_s^+ daughters to the desired charged final states. The quoted efficiency takes into account a very small ($0.05 \pm 0.02\%$) amount of double counting which occurs when a fragmentation π is used instead of a π from $\overline{K^{*0}}$ or K^{*+} . The peak in Figure 2 contains $7.7^{+3.9}_{-3.2}$ unlike–sign events, a $\approx 2.2\sigma$ effect, at a fitted mass of 1971.6 ± 3.6MeV/c^2 with the width of the gaussian fixed at 7 MeV/c^2. If the origin of this peak entirely due to $B_s^0 \rightarrow D_s^- l^+ \nu X$ then the product branching ratio $Br(\overline{b} \rightarrow B_s^0)Br(B_s^0 \rightarrow D_s^- l^+ \nu X) = 0.035^{+0.018}_{-0.015} \pm 0.012$ where the first error is statistical and the second is due to the uncertainty on $Br(D_s^+ \rightarrow \overline{K^{*0}}K^{*+})$. This result is consistent with [6].

4 Acknowledgements

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References

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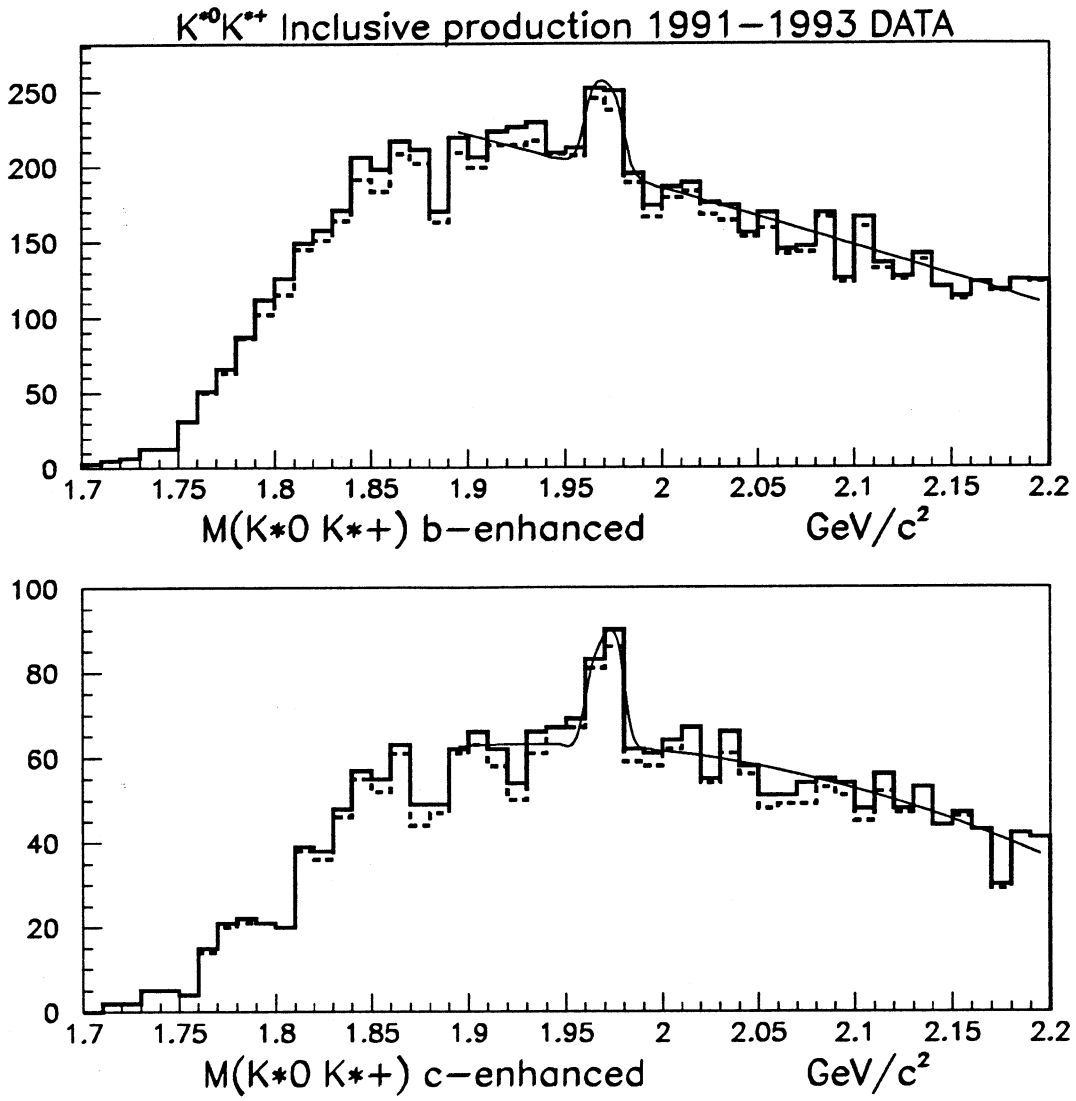

Figure 1: The $\overline{K^{*0}}K^{*+}$ mass spectra for a b–enhanced(c–enhanced) D_s^+ sample in the upper(lower) plot. The dashed lines represent the spectra when the assignment of π_1^+ and π_2^+ are unambiguous. The results of the fits are given in the text.

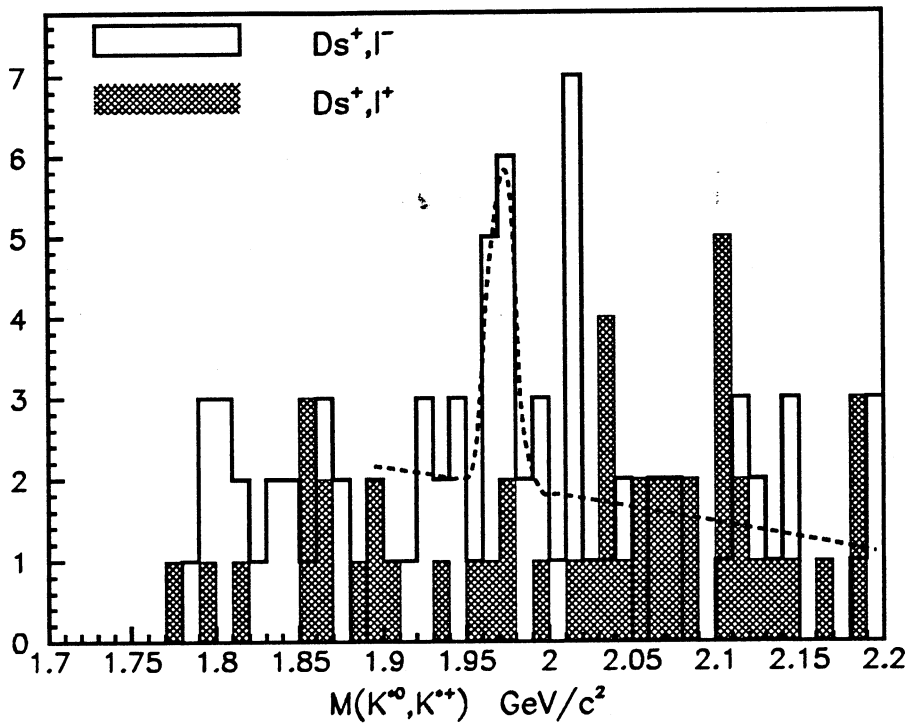

Figure 2: The $\overline{K^{*0}}K^{*+}$ mass spectra correlated with a lepton. See text for details of the fit.