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An observation of semileptonic B_s decays in the decay mode $D_s^- \to K^0 K^-$

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Abstract

The decay $D_s^- \to K^0K^-$ has been searched for in a sample of more than 1.1 million Z^0 hadronic decays registered in 1990, 1991 and 1992 in ALEPH. A signal of about 85 events is seen. From this signal a preliminary value for the branching ratio of the D_s^- meson in this channel has been estimated. In addition about 7 D_s mesons correlated with a lepton are seen as a first sign of the B_s meson decay mode : $B_s \to D_s \ell \nu$

1 D_s^- search.

The decay mode $D_s^- \to K^0K^-$ does not have a very large branching ratio [1] but one can expect to obtain a rather clean signal thanks to the chain $K_s^0 \to \pi^+\pi^-$. Furthermore in view of studying the B_s^- meson one should try to accumulate as many decay modes of the D_s meson as possible. The $D_s^- \to K^0K^-$ decay mode benefits from the use of the large ALEPH TPC for the signature of the K meson using the dE/dx information and for the reconstruction of the decay $K^0 \to \pi^+\pi^-$.

In this note we present a preliminary measurement of the D_s^- branching ratio into K^0K^- where the K^0 is a K_s^0 which decays into $\pi^+\pi^-$, as well as a first observation of $D_s^-\ell^+$ correlations.

To evaluate the efficiency of this analysis we have generated 3000 Monte Carlo $c\bar{c}$ and $b\bar{b}$ events where at least one D_s per event decays as described above. In addition, to evaluate the possible contamination due to the decay $D^- \to K^0\pi^-$ we have also generated and fully reconstructed 3000 $c\bar{c}$ and 3000 $b\bar{b}$ events containing at least one $D^- \to K^0\pi^-$ per event. The cuts used in the analysis are the following :

- a charged track is selected with a momentum greater than 1 GeV/c and with a dE/dx compatible with the one from a K within $\pm 2\sigma$,
- the K_s^0 is selected with the YRMIST package [3]. Since the K^0 is a spin 0 particle, $|\cos\theta^*_{K^0}| \leq 0.8$ is required to reduce the combinatorial background which is peaked at $|\cos\theta^*_{K^0}| = 1$. $\theta^*_{K^0}$ is the angle between one of the two πs and the boost in the center of mass of the K^0.
- the K_s^0 and the K are combined to form the D_s^- candidate. The cosine of the angle between the K and the boost in the D_s^- rest frame should be less than 0.85 because the D_s^- is also a spin 0 particle.
- finally, to reduce the combinatorial background, the D_s^- momentum is required to be greater than 15 GeV/c. No vertexing is used in this analysis.

The resulting K^0 K mass spectrum is shown in Figure 1. From a gaussian fit and a second order polynomial for the background we obtain 158 ± 35 events in the peak. One finds a mass of 1964 ± 3 MeV and a width of 11 ± 3 MeV slightly lower than the measured D_s^- mass (1968.8 ± 0.7 MeV) [1]. The efficiencies obtained from the dedicated $b\bar{b}$ and $c\bar{c}$ Monte Carlo are (Figure 2) :

$$\varepsilon_{D_s}^{c\bar{c}} = 14.6 \pm 0.6\%$$

$$\varepsilon_{D_s}^{b\bar{b}} = 8.2 \pm 0.4\%$$

For this Monte Carlo study the charged tracks (both pions from the K_s^0 and the charged kaon) are matched with the Monte Carlo truth tracks which originated from a D_s^- .

But one should wonder about the D^- decaying into $K^0\pi^-$. This branching ratio (2.6 ± 0.4 %) [1] is of the same order of magnitude as $D_s^- \rightarrow K^0K^-$ but there are many more D^- mesons than D_s^- mesons. We have used Monte Carlo events to evaluate this possible contamination. Applying the D_s^- analysis on these Monte Carlo events which contain at least one $D^- \rightarrow K^0\pi^-$ we have found the mass plots of Figure 3 where the charged tracks (both pions from the K_s^0 and the other pion) are matched with the true Monte Carlo D^-. The efficiencies (the errors are statistical only) are determined counting the number of events in a mass range of $M_{D_s} \pm 2\sigma$ where M_{D_s} and σ are obtained from the plots of Figure 2.

$$\varepsilon_D^{c\bar{c}} = 5.1 \pm 0.4\%$$

$$\varepsilon_D^{b\bar{b}} = 2.0 \pm 0.2\%$$

These numbers are relatively high with respect to the efficiencies of the $D_s^- \rightarrow K^0K^-$ channel. They can be reduced by a very strict requirement on the dE/dx information on the kaon candidate. Two different cuts have been tried :

If one requires that the dE/dx information for the K is such that $\chi_K \leq 0$ where $\chi_K = (I^{meas} - I_K^{exp})/\sigma$, one gets :

$$\varepsilon_D^{c\bar{c}} = 0.5 \pm 0.1\%$$

$$\varepsilon_D^{b\bar{b}} = 0.2 \pm 0.1\%$$

and

$$\varepsilon_{D_s}^{c\bar{c}} = 7.0 \pm 0.5\%$$

$$\varepsilon_{D_s}^{b\bar{b}} = 4.3 \pm 0.4\%$$

If one requires that the dE/dx information for the kaon candidate is not compatible with a π within 2σ one obtains :

$$\varepsilon_D^{c\bar{c}} = 0.2 \pm 0.1\%$$

$$\varepsilon_D^{b\bar{b}} = 0.1 \pm 0.1\%$$

and

$$\varepsilon_{D_s}^{c\bar{c}} = 5.1 \pm 0.4\%$$

$$\varepsilon_{D_s}^{b\bar{b}} = 3.3 \pm 0.3\%$$

At this level one could consider that the contamination of the $D^- \rightarrow K^0\pi^-$ channel is small enough to be substracted from the $D_s^- \rightarrow K^0K^-$ peak without introducing any systematic error. Using $\chi_K \leq 0$ we obtain the mass plot shown in Figure 4. The mass is found to be 1967 ± 4 MeV and the width 13 ± 3 MeV in agreement with the D_s mass and width expected from the Monte Carlo. We found 84 ± 23 events. For these two new dE/dx cuts one must substract the events due to the $D^- \to K^0\pi^-$ contamination. These two numbers of events are obtained via the following formula :

$$\begin{aligned} N_{D\to K^0\pi} = & \; 2N_{q\bar{q}} \times BR_{D\to K^0\pi} \times P_{K^0\to K^0_s} \times BR_{K^0_s\to\pi^+\pi^-} \\ \times & \; (\varepsilon_D^{c\bar{c}} \times P_{q\to c} \times P_{c\to D} + \varepsilon_D^{b\bar{b}} \times P_{q\to b} \times P_{b\to B} \times P_{B\to D}) \end{aligned}$$

where all the values used in this formula are given in Table 1. This leads to the numbers given in Table 2. The corresponding value for the $D_s^- \to K^0K^-$ branching ratio is computed using the formula :

$$\begin{aligned} N_{D_s\to K^0K} = & \; 2N_{q\bar{q}} \times BR_{D_s\to K^0K} \times P_{K^0\to K^0_s} \times BR_{K^0_s\to\pi^+\pi^-} \\ \times & \; (\varepsilon_{D_s}^{c\bar{c}} \times P_{q\to c} \times P_{c\to D_s} \\ & + \varepsilon_{D_s}^{b\bar{b}} \times P_{q\to b} \times (P_{b\to B_s} \times P_{B_s\to D_s} + P_{b\to B} \times P_{B\to D_s})) \end{aligned}$$

with the values of Table 1.

One gets the results given in Table 2 for the branching ratio values the first error is statistical, the second one is due to the limited number of Monte Carlo events used to estimate our efficiency and the third one stands for our lack of knowledge of b and c branching ratios (see Table 1).

2 D_s^- lepton combinations.

One can also try to correlate the D_s^- meson with a lepton in order to observe the presence of a B_s^- meson using the decay mode $B_s \to D_s \ell\nu$. The D_s^- selection is as described above (with $\chi_K \leq 0$) but the D_s^- momentum cut is reduced from 15 GeV/c to 8 GeV/c . A lepton is combined with the D_s^- candidates using the lepton selection described in reference [2]. The D_s^- mass is computed using YTOP [4] to refit the K^0, the D_s^- and the B_s^- vertices. A very loose cut on each vertex is applyed ($\chi^2_V \leq 100$) Plotting the right sign ($D_s^+\ell^-$ or $D_s^-\ell^+$) and the wrong sign ($D_s^-\ell^-$ or $D_s^+\ell^+$) combinations (Figure 5) an excess of events is seen at the D_s^- mass for the right sign. One also observes an excess at a higher mass (around 2.1 GeV). This excess may be due to the reflexion of $\Lambda_b \to \Lambda_c \ell\nu$ with $\Lambda_c \to K^0$ p and where the proton is called a kaon. This hypothesis is supported by the K^0_s proton mass plot for the right sign and wrong sign combinations for which an excess at the nominal Λ_c mass (2285 MeV) is observed on Figure 6. To supress this background, a cut of ± 30 MeV around the Λ_c mass (which corresponds, according to the Monte Carlo, to a $\pm 3\sigma$ cut) for the K^0 p mass is applied. The resulting K^0 K mass plot is shown on Figure 7. An excess of about 7 events above a background of 2 events is seen for the right sign combinations ($D_s^+\ell^-$ or $D_s^-\ell^+$) where we expect about 6 $D_s^-\ell^+$ and 1 $D^-\ell^+$ with large uncertainties. With a good 1993 run we should find a significant signal in this channel.

References

[1] Particle Data Group, Phys. Lett. 239B (1990), VII 116.

[2] Observation of the Semileptonic Decays of B_s and Λ_b Hadrons at LEP, Aleph Coll. CERN-PPE/92-73.

[3] B. Rensch, YRMIST, ALEPH 90-108.

[4] M. Fernandez-Bosman, J. Lauber, G. Lutz and W. Männer, The new YTOP package for ALEPH, ALEPH 91-005.

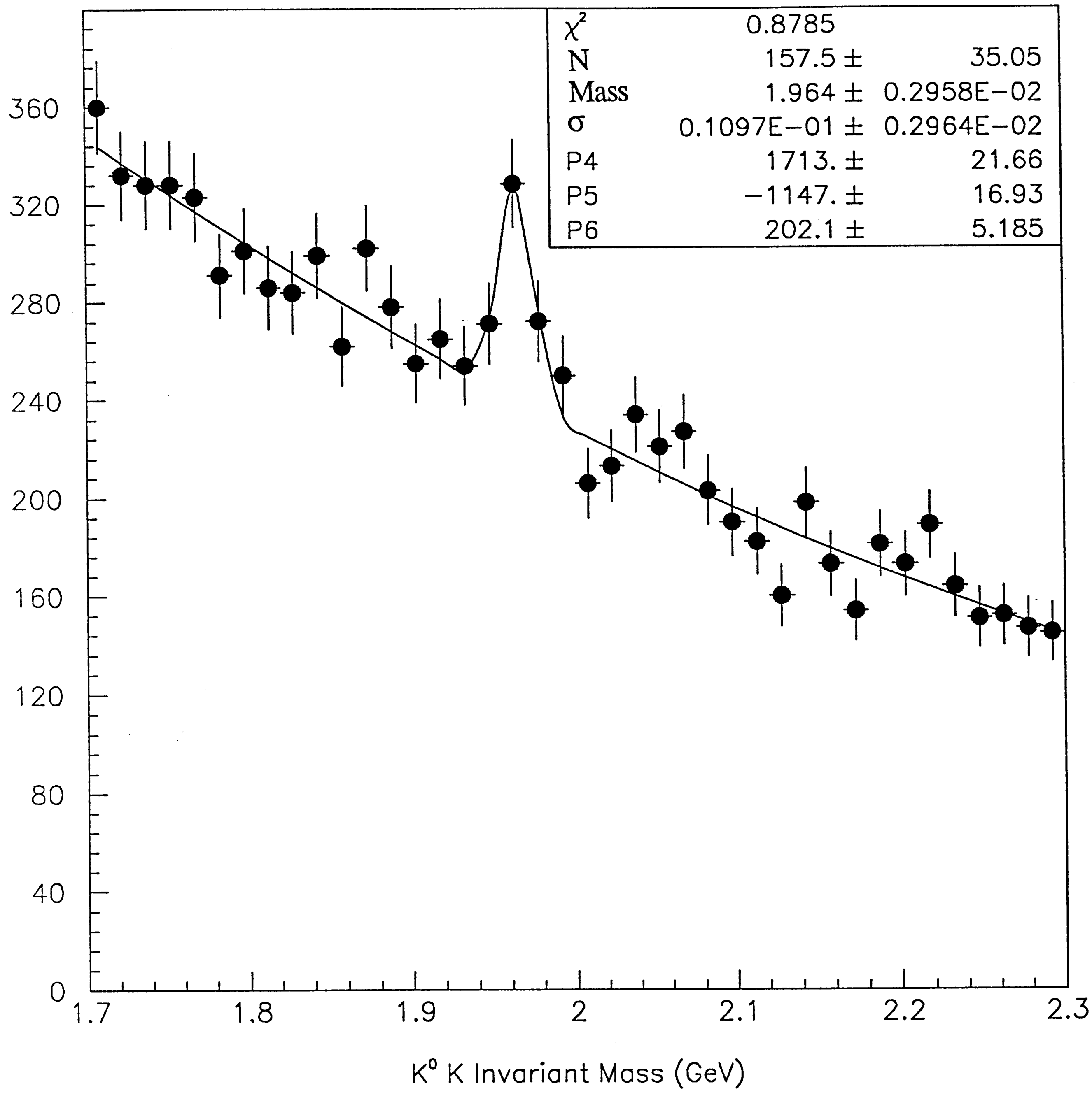

Figure 1 : The K candidate is identified as a kaon.

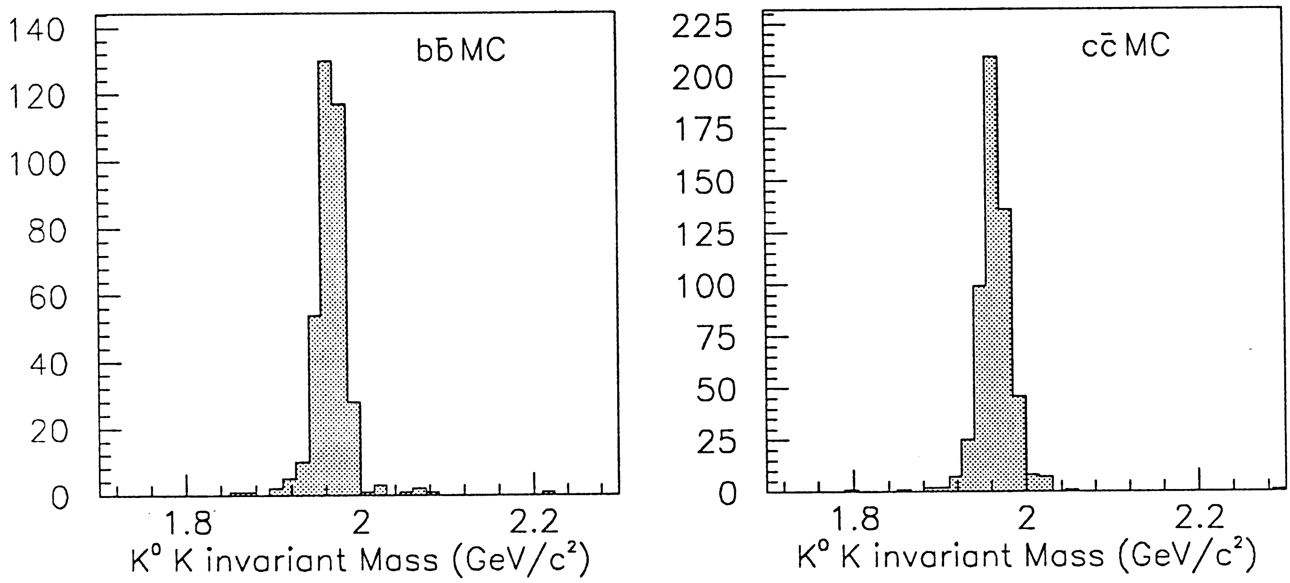

Figure 2: $D_s^- \rightarrow K^0 K^-$ Monte Carlo

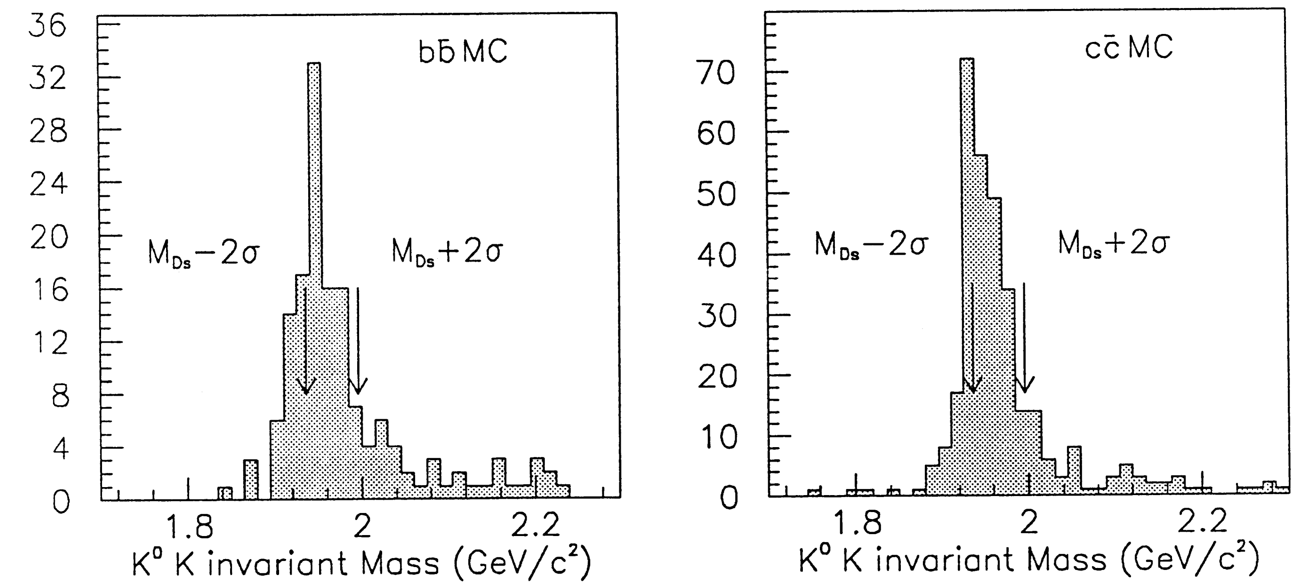

Figure 3: $D^- \rightarrow K^0 \pi^-$ Monte Carlo

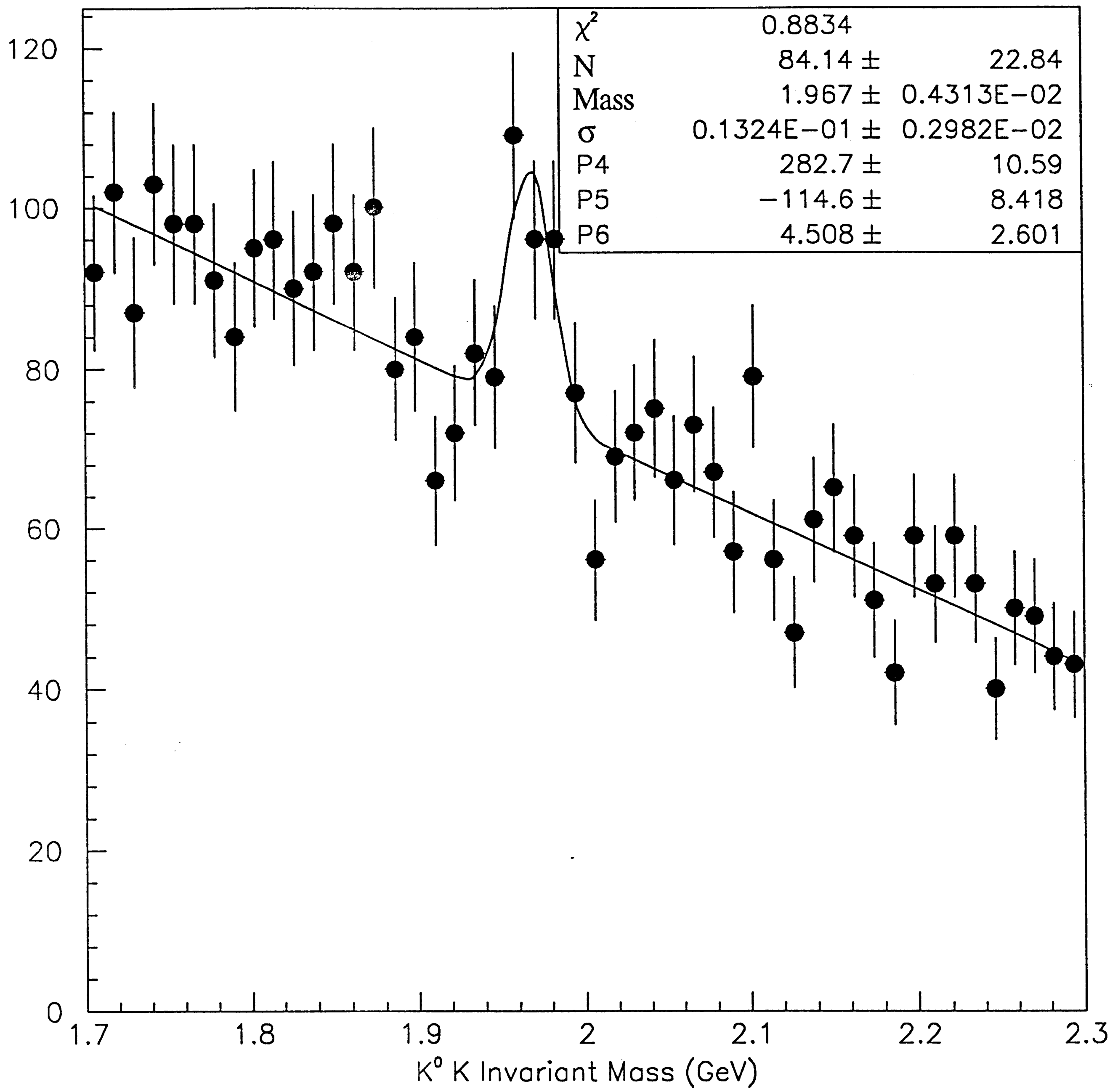

Figure 4 : For the K candidate χ_K is required to be negative to eliminate the π contamination.

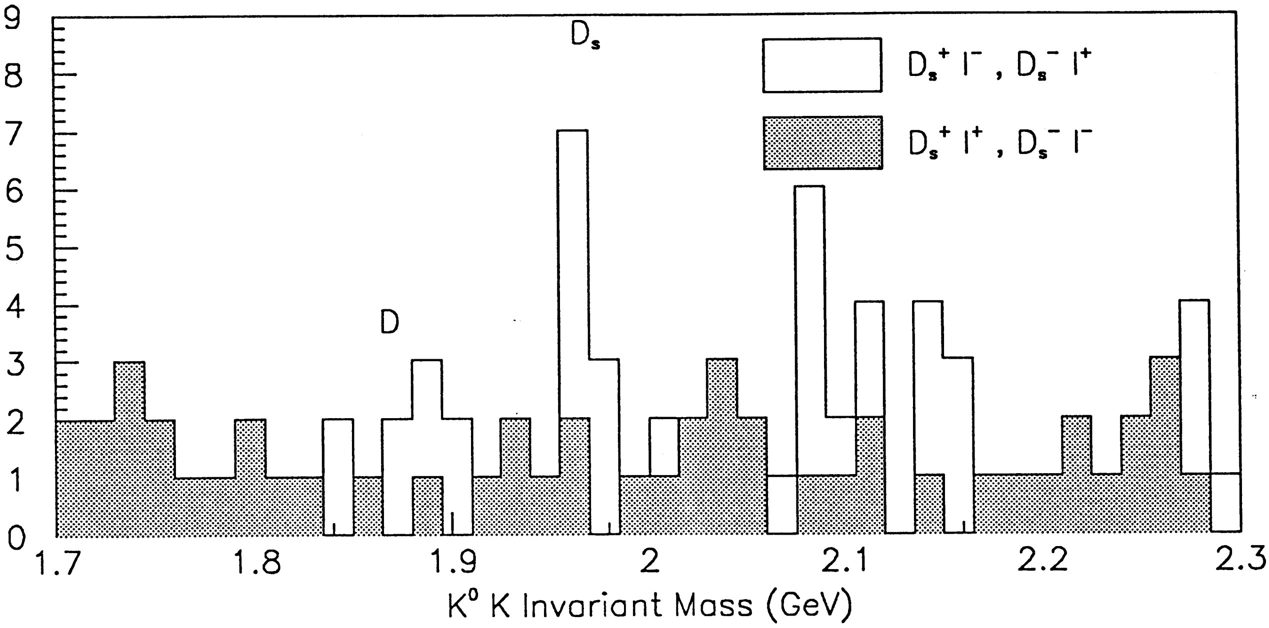

Figure 5 D_s– lepton correlations

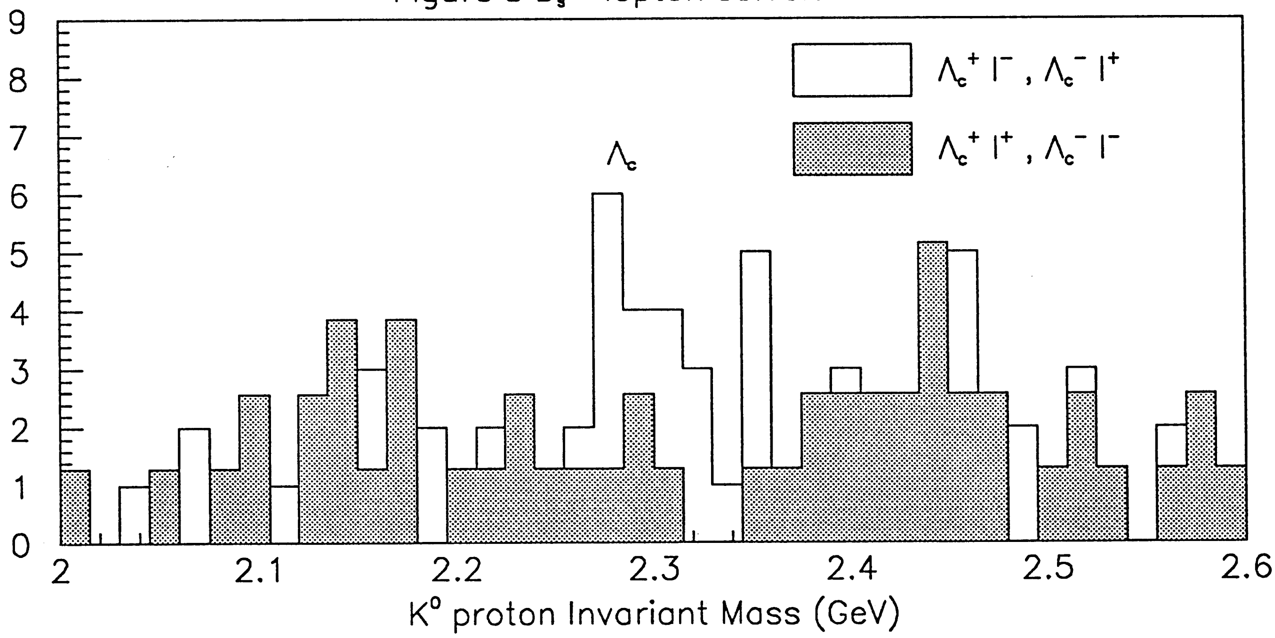

Figure 6 Λ_c– lepton correlations

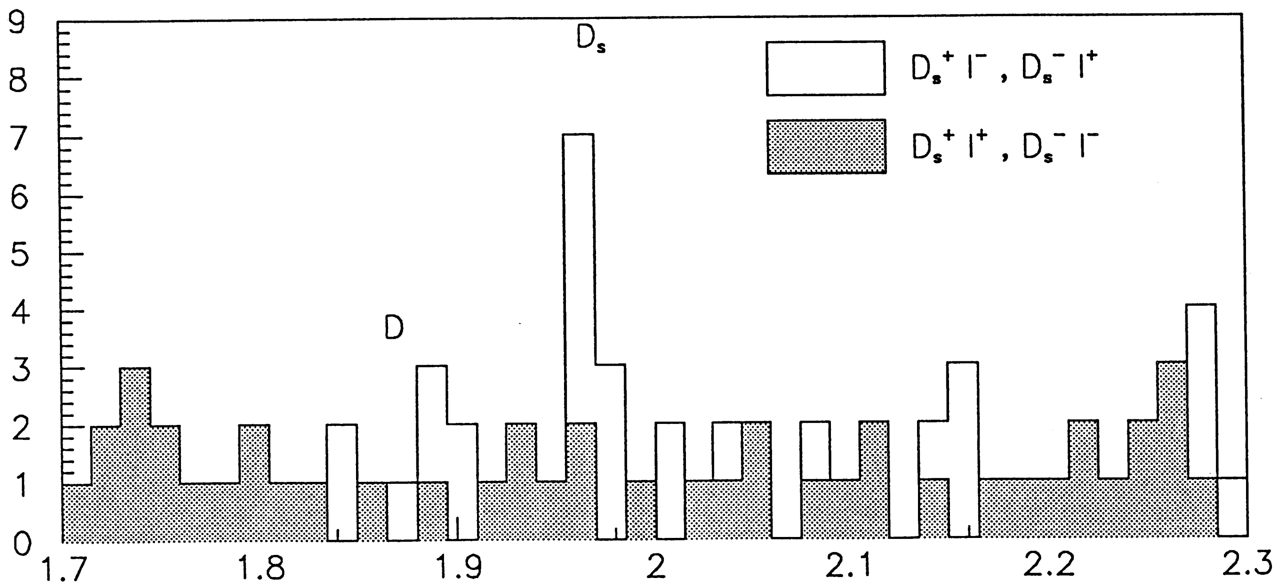

Figure 7 D_s– lepton correlations Λ_c excluded

$N_{q\bar{q}}$	1,214,949
$P_{q\to c}$	18.1 $\pm$ 3.0 %
$P_{q\to b}$	21.8 $\pm$ 1.4 %
$P_{c\to D_s}$	15 $\pm$ 3 %
$P_{c\to D}$	75 $\pm$ 10 %
$P_{b\to B_s}$	15 $\pm$ 3 %
$P_{b\to B}$	75 $\pm$ 10 %
$P_{B\to D}$	80 $\pm$ 10 %
$P_{B_s\to D_s}$	80 $\pm$ 10 %
$P_{B\to D_s}$	11.5 $\pm$ 2.8 %
$P_{K^0\to K_s^0}$	50 %
$BR_{D^-\to K^0\pi^-}$	2.6 $\pm$ 0.4 %
$BR_{K_s^0\to\pi^+\pi^-}$	68.61 $\pm$ 0.28 %

Table 1: Values used for the computation of the number of events due to the reflexion of $D^- \to K^0\pi^-$ and for the absolute $D_s^- \to K^0K^-$ branching ratio.

dE/dx cut	$N_{D\to K^0\pi}$	$N_{D_s\to K^0K}$	$BR_{D_s\to K^0K}$
$\chi_K \leq 0$	19.9 ± 14.0	64.2 ± 26.8	$2.1 \pm 0.9 \pm 0.1 \pm 0.3\%$
"K and NOT π"	8.5 ± 5.6	56.7 ± 19.7	$2.4 \pm 0.8 \pm 0.1 \pm 0.4\%$

Table 2: Two different sets of dE/dx cuts can be used to compute the $D_s^- \to K^0K^-$ branching ratio.