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Search for rare B decays : $B\rightarrow \pi^+\pi^-$, $B\rightarrow K^+\pi^-$ and $B\rightarrow K^+ K^-$

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Abstract

The decays $B\rightarrow \pi^+\pi^-$, $B\rightarrow K^+\pi^-$ and $B\rightarrow K^+ K^-$ have been searched for in a sample of more than 1 million Z^0 hadronic decays registered in 1991 and 1992 in ALEPH. No signal has been observed and limits have been set.

1 Analysis.

Three of the simplest charmless neutral B decays are thought to be due to penguin diagrams or V_{bu} transitions as can be seen in Figure 1. The $\pi\pi$ and K π modes have been already studied by ARGUS [1] and CLEO [2] whereas the K K mode is new as it comes from the decay of a B_s^0 meson. Recently the first evidence for the $B_d \to \pi^+\pi^-$ and $B_d \to K^+\pi^-$ have been reported by CLEO the value for the branching ratio is $(2.4^{+0.8}_{-0.7} \pm 0.3)10^{-5}$ [3].

For all the three channels the following cuts are applied :

- A b-Tag is performed using the QVSRCH algorithm [4] the sum of the tags for the two hemispheres has to be greater than 8.
- Two charged tracks of opposite sign and more than 2 GeV/c of momentum are selected, each of them should have at least one VDET hit in order to assure a high quality for the vertexing.
- The two tracks are identified by dE/dx using $\chi_i = \frac{(I_{meas} - I_{exp_i})}{\sigma_i}$ for i=π or i=K. The dE/dx information is required to be present with $|\chi_i| \leq 2$
- These two tracks are vertexed to form a B candidate whose momentum must be greater than 25 GeV/c.
- The B vertex probability has to be greater than 1 %, the decay length significance (l/σ) has to be at least equal to 1 and finally the cosine of the angle between the momentum of the B meson and the direction from the primary vertex to the B vertex has to be greater than 0.95.

In order to estimate the efficiencies two Monte-Carlo samples have been used : $B_d^0 \to \pi^+\pi^-$ and $B_s^0 \to K^-\pi^+$. The summary of the directly measured efficiencies can be found in Table 1. The efficienciy for $B_s^0 \to K^-\pi^+$ is assumed to be the same as $B_d^0 \to K^-\pi^+$. In order to treat the case of the $B_s^0 \to K^-K^+$ decay mode as we do not have Monte-Carlo events we assume that $\varepsilon(B_s^0 \to K^-K^+)$ in the K^+ K^- analysis is equal to $\varepsilon(B_b^0 \to \pi^-\pi^+)$ in the $\pi^+\pi^-$ analysis ($\varepsilon_{KK\ analysis}^{KK\ channel} = \varepsilon_{\pi\pi\ analysis}^{\pi\pi\ channel}, \varepsilon_{\pi\pi\ analysis}^{KK\ channel} = \varepsilon_{KK\ analysis}^{\pi\pi\ channel}$ etc ...)

A search has been performed for these three decays in the ALEPH data of 1991 and 1992, in a sample of about 1.02 millions of hadronic Z^0 decays.

2 Results.

From the mass resolution determined from the simulation, two windows can be defined for the B_d^0 and the B_s^0 mesons : M_{B_d} = 5279 MeV and σ = 60 MeV and M_{B_s} = 5369 MeV from the ALEPH measurement [5] and σ = 60 MeV from our dedicated Monte-Carlo. From these values two windows can be defined from about 5100 MeV to 5460 MeV and from 5190 MeV to 5550 MeV. As both mesons can contribute to the studied decay modes we have decided to use only one window from 5100 MeV to 5550 MeV to count the number of signal events (NO background substraction being done). This signal region is indicated on the invariant mass distributions by an arrow.

2.1 The invariant mass distributions.

The $\pi\pi$ invariant mass plot in shown in Figure 2-a. There are two events in the signal region. The K π invariant mass plot in shown in Figure 2-b. There is only one event in the signal region and this event is one of the two of the $\pi\pi$ channel. The K K invariant mass plot in shown in Figure 2-c and there is no event in the signal region. The run and event numbers for these events are given in Table 2. These two events have been visually scanned and no obvious problems was found.

2.2 Limits for the $\pi\pi$ and the K π analyses.

From these numbers one can derive limits for the spectator and the penguin diagrams assuming that only these two diagrams contribute. For an analysis a one can write :

$$\begin{aligned} N^a = \; & 2N_{q\bar{q}} \times P_{q\to b} \times (BR_{spect} \times (\varepsilon^a_{K\pi} \times P_{b\to B_s} + \varepsilon^a_{\pi\pi} \times P_{b\to B_d}) \\ & + BR_{peng} \times (\varepsilon^a_{KK} \times P_{b\to B_s} + \varepsilon^a_{K\pi} \times P_{b\to B_d})) \end{aligned}$$

in the following we use : $P_{q\to b}$ = 22%, $P_{b\to B_s}$ = 12%, $P_{b\to B_d}$ = 40% and $N_{q\bar{q}} = 1.02 \times 10^6$.

For the $\pi\pi$ analysis two events are seen (Figure 2-a) which leads to $N^{\pi\pi} \leq 5.32$ at 90% CL. Taking into account the efficiencies obtained from the Monte-Carlo samples and assuming that these two events are due to spectator diagrams one gets :

$$BR_{spect} \leq 9.7 \times 10^{-5} \text{ at } 90\% \; CL$$

and in a similar way one can compute :

$$BR_{peng} \leq 1.5 \times 10^{-4} \text{ at } 90\% \; CL$$

For the Kπ analysis one event is seen (Figure 2-b) which leads to $N^{K\pi} \leq 3.89$ at 90% CL and one obtains :

$$BR_{spect} \leq 7.3 \times 10^{-5} \text{ at } 90\% \; CL$$

and

$$BR_{peng} \leq 6.6 \times 10^{-5} \text{ at } 90\% \ CL$$

2.3 Limits for the K K analysis.

As no limit has been set before for this mode the procedure differs slightly from the previous one. Assuming that :

$$N^{KK} = 2N_{q\bar{q}} \times P_{q\to b} \times P_{b\to B_s} \times BR(B_s \to KK) \times \varepsilon_{KK}^{KK}$$

No event being observed (Figure 2-c) one gets :

$$BR(B_s \to K\ K) \leq 1.7 \times 10^{-4} \text{ at } 90\% \ CL$$

This decay mode is mainly due to the penguin diagram because of the V_{us} suppression in the spectator diagram.

3 Analysis without dE/dx information.

3.1 Analysis

The analysis is essentially the same except that no dE/dx information is required. Applying this analysis on our two Monte-Carlo sample we get the same efficiency of 33% (as expected !) for the $B_s^0 \to K^-\pi^+$ and the $B_d^0 \to \pi^+\pi^-$ modes.

3.2 Results and limits.

Applying these selection criteria on the data the invariant mass plot of Figure 3 is obtained. Two events fall in the window from 5115 MeV to 5545 MeV. These events are, of course, the two found by the previous analyses.

As explained in the previous section, the two events can be used to set limits for the spectator and the penguin diagrams separately and one gets :

$$BR_{spect} \leq 7.5 \times 10^{-5} \text{ at } 90\% \ CL$$

and

$$BR_{peng} \leq 7.5 \times 10^{-5} \text{ at } 90\% \ CL$$

If one assumes that the two events are due only to one decay mode (eg $B_s^0 \to K^-K^+$) the limit on the individual branching ratio is :

$$BR_{indiv} \leq 3 \times 10^{-4} \text{ at } 90\% \ CL$$

in agreement with what was obtained using the K K analysis.

4 Conclusion.

In conclusion the limits found by this analysis are in agreement with the values obtained by the CLEO collaboration for the $B_d^0 \to \pi^+\pi^-$ and the $B_d^0 \to K^-\pi^+$ decays modes. However, at LEP, limits can be obtained for the B_s^0 meson and our limit can be compared with the ones presented by the DELPHI collaboration at the summer conferences [6].

References

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	$B_d \to \pi\pi$	$B_s \to K\pi$
$\pi\pi$ analysis	25 $\pm$1%	18 $\pm$1%
$K\pi$ analysis	22 $\pm$1%	26 $\pm$2%
KK analysis	8 $\pm$1%	14 $\pm$1%

Table 1: Summary of the efficiencies measured on our dedicated Monte-Carlo samples.

	Run	Event	M_B (MeV)
$\pi\pi$ analysis	13366	1385	5334
$\pi\pi$ analysis	16385	5247	5191
$K\pi$ analysis	16385	5247	5226

Table 2: Run and event numbers for the events falling in the signal region.

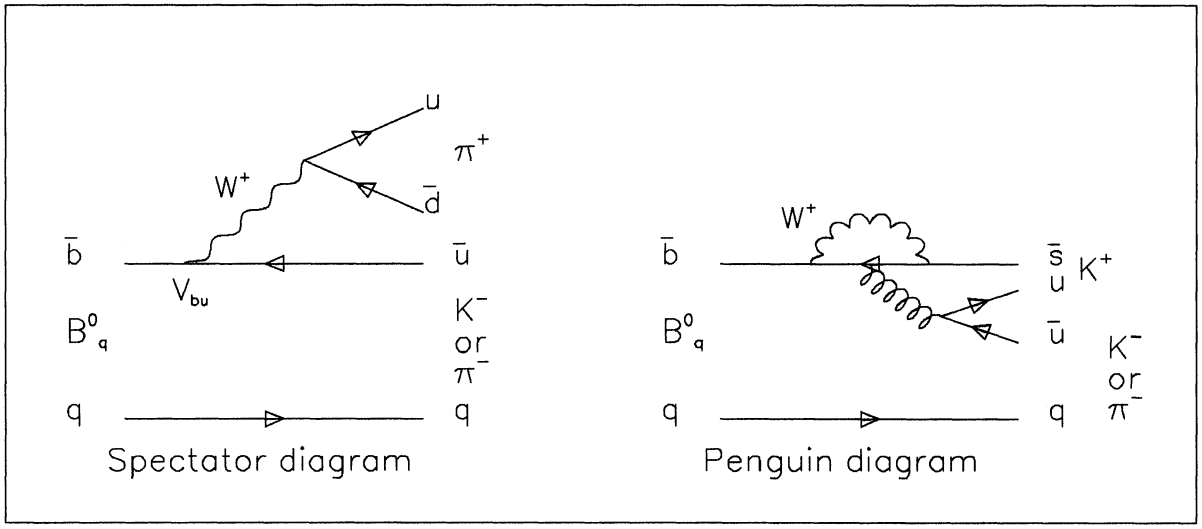

Figure 1

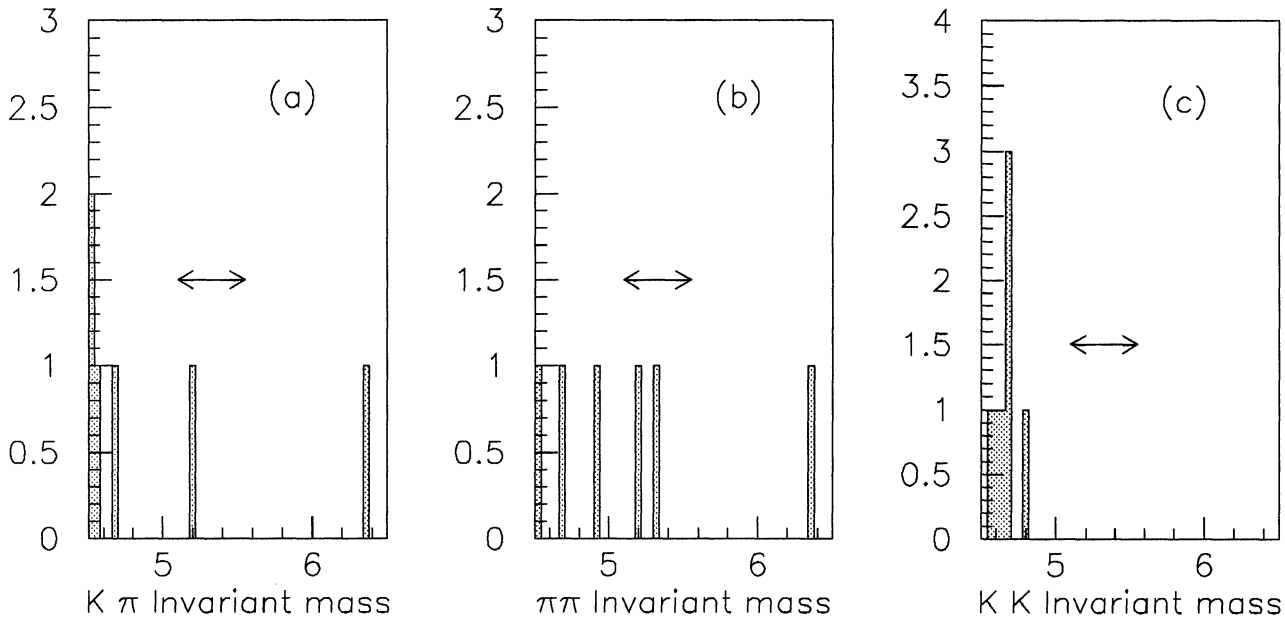

Figure 2 results from the K π the $\pi\pi$ and the K K analyses

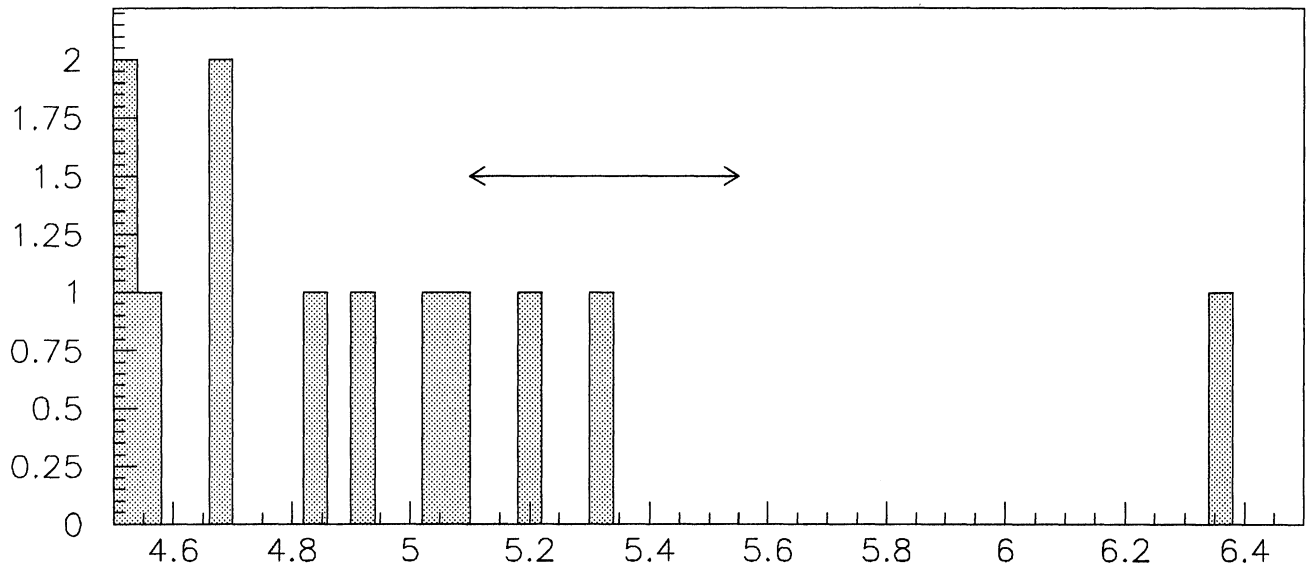

Figure 3 results from the analysis without dEdx