LAL 92-29
May 1992

Laboratoire de l'Accélérateur Linéaire

CHARM AND BEAUTY DECAYS IN THE ALEPH EXPERIMENT

Jacques BOUCROT

Talk given at the XXVIIth Rencontres de Moriond
"QCD and High Energy Hadronic Interactions"
Les Arcs, Savoie - France, March 22- 28, 1992

U.E.R
de
l'Université Paris-Sud

Institut National
de Physique Nucleaire
et
de Physique des Particules

Bâtiment 200 - 91405 ORSAY Cedex

LAL 92-29
May 1992

CHARM AND BEAUTY DECAYS IN THE ALEPH EXPERIMENT

J. Boucrot
Representing the ALEPH Collaboration
Laboratoire de l'Accélérateur Linéaire, IN2P3-CNRS
et Université de Paris-Sud, F-91405 Orsay Cedex, France.

Abstract

Results of the ALEPH experiment at LEP are presented on charm and beauty decays, from data taken in 1990 and 1991. Several exclusive channels of charm and beauty mesons are seen. Evidence is given for the production of beauty baryons from correlations between a high Pt lepton and a Λ^0 or a Λ_c baryon. Finally first evidence is given for the production of the strange B meson, from Ds-lepton correlations.

1. Introduction

The ALEPH detector at LEP has taken data at the Z^0 peak since September 1989. As more than 40 % of Z^0 decays come from heavy quarks, the study of hadronic Z^0 decays provides a good tool to study charm and beauty. At LEP the overall conditions for heavy flavours are very different from other e^+e machines: a large Lorentz boost is given to the heavy quarks, whereas beauty particles are almost at rest when produced at the $\Upsilon_{(4s)}$ resonance; the production yield is much more favourable at LEP than at PETRA/PEP. The results presented below have to be considered mostly as preliminary. Throughout all what follows, charge conjugate states are always implied everywhere.

2. The event sample from ALEPH and the detector properties

The data presented here have been taken with the ALEPH detector at LEP in 1990 and 1991. They correspond to an integrated luminosity of 20.5 pb^{-1}, with 456,000 reconstructed hadronic decays of the Z^0. For Heavy flavour physics, the ALEPH detector[1] has several nice features which enable a rather complete study of hadronic or semileptonic decays of heavy flavours:

- a good lepton identification with an efficiency above 50 %;
- K_s^0 and Λ^0 particles are reconstructed through their charged decays ($\pi^+\pi^-$ and proton π^- respectively) with an efficiency above 40 %;
- Protons, charged kaons and charged pions can be separated reasonably well up to 10 GeV/c using the dE/dx measurement from the TPC;
- Neutral pions are reconstructed inside hadronic jets with an efficiency around 30 %, due to the excellent spatial resolution of the electromagnetic calorimeter;
- From 1991 onwards, the presence of a silicon vertex detector enables much better fits for the tracks going into its acceptance: it also allows a clear separation of secondary vertices from beauty particle decays.

3. Results on charmed mesons (production and decay)

All the following results concerning charmed mesons are updates of the analysis given in reference 2, in which only data from 1990 were analyzed. The methods and details of the event selection are exactly the same, the data sample being extended to include 1991 data.

3.1 D^* signal with $D^* \to D^0\pi^-$ and $D^0 \to K^-\pi^+$

The signal can be seen in figure 1 and is very clean. It gives a total of 1090 D* candidates, among which only 198 ± 2 events may be estimated to come from the combinatorial background.

This very good signal/background ratio enables to perform a clean analysis of the D* production rate, using the x_E spectrum, where:

$$x_E = E(D^*)/E(Beam)$$

is the fractional D* energy.

We use a discriminant analysis method to disentangle the D* production from c quarks from the D* produced by b quarks.

We get the following results:

a) $P(b \to D^*)/P(c \to D^*) = 0.87 \pm 0.15$ (stat) ± 0.01 (syst). This value is now measured, whereas in reference 2 it was fixed to 0.95 with some model-dependence.

b) $\epsilon_c = (53^{+13}_{-11}) \pm 5)10^{-3}$ which is the coefficient of the Peterson fragmentation function for the charm quark.

c) $BR(c \to D^*) \cdot BR(D^{*+} \to D^0\pi^+) \cdot (BR(D^0 \to K^-\pi^+) = 6.3 \pm 0.2$ (stat) ± 0.4(syst))10^{-3}.

In the last result, it can be seen that one is already dominated by the systematic error.

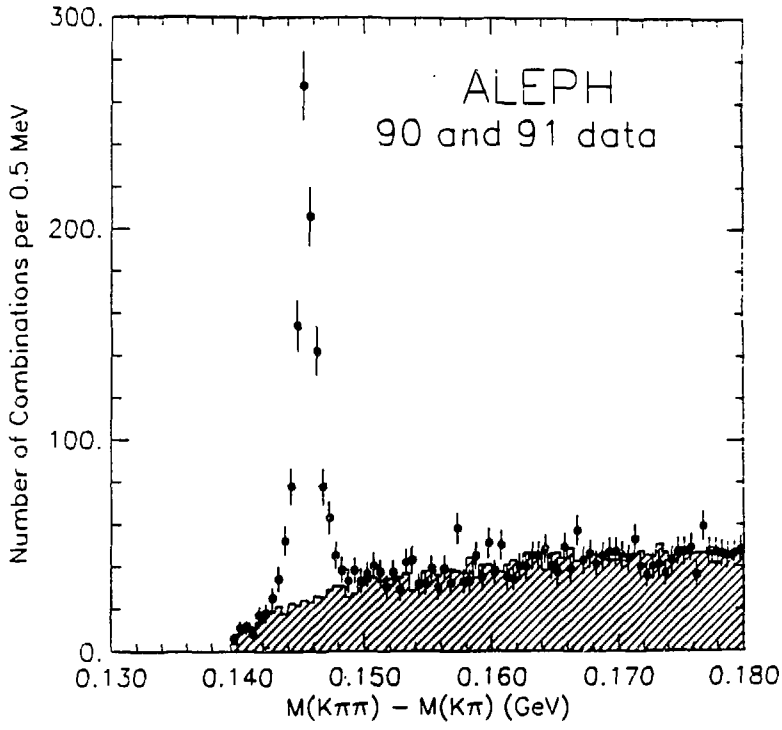

Figure 1: D^* signal: Mass difference distribution M (K ππ) - (M (K π) for $xE(K\pi\pi) > 0.25$. The kπ invariant mass is required to be between 1.835 and 1.895 GeV/c^2 (D^0 mass region) . The hatched area is the combinatorial background.

3.2 Other decay channels of charmed mesons

Clear signal have been seen for D in the $K^-\pi^+\pi^+$ channel, D^0 in the $K^0_s\pi^+\pi^-$ and $K^-\pi^+\pi^0$ channels. Inclusive signals are seen on top of a huge combinatorial background (Fig. 2a) which disappears almost completely if the D meson is asked to come from a D* when this is possible; for instance a clean signal is obtained in the channel $D \to K^-\pi^+\pi^0$ for D^0 coming from a D* (Fig. 2b).

This is the first charm decay with a π^0 in the final state to be seen in a LEP experiment. The substantial number of events allows to determine the branching ratio:

$$BR(D^0 \to K^-\pi^+\pi^0) = (14 \pm 3)\%$$

fully compatible with the world average of $(11.9 \pm 1.2)\%$[3].

These signals give a good motivation to search for other decays involving neutrals in ALEPH, especially in a near future for decays of the Ds meson.

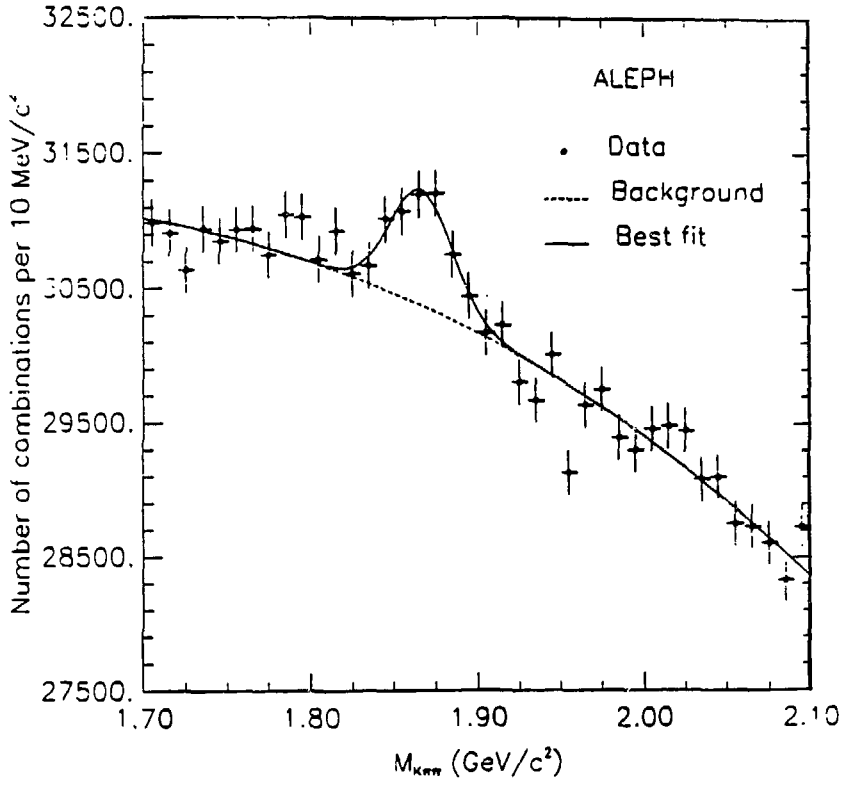

Figure 2a: The D^+ signal: $K^-\pi^+\pi^+$ invariant mass distribution for $xE > 0.25$.

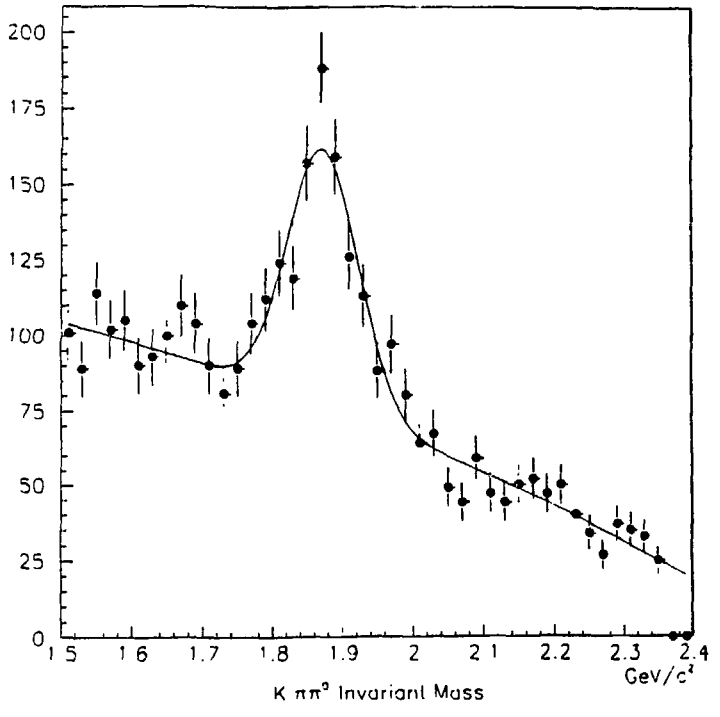

Figure 2b: The $D^0 \to K^-\pi^+\pi^0$ signal, for a mass difference $m(D^*) - m(D^0)$ in the range 0.144 to 0.147 GeV.

Determination of the $V/(V+P)$ ratio:

As described in reference 2, this ratio gives the proportion of D* mesons produced from a vector meson in the hadronization of a c quark. Using the new data and the new channels described above, we find:

$$Pv = \frac{V}{V+P} = 0.55 \pm 0.06$$

where V[p] is the probability of producing a charmed vector [pseudoscalar] meson in the hadronization of a c quark.

This new value is more precise than the previous one obtained in reference 2, but it is even less compatible with the value Pv = 0.75 expected from naive spin counting. However, the above analysis doesn't take into account the production of D* mesons through D** tensor mesons, which is known to be not negligible and which seriously modifies the predictions.

4. Observation of beauty decays with a J/ψ meson

4.1 Inclusive J/ψ signal

Searching for J/ψ mesons is of special interest since at LEP it is estimated that 97 % of J/ψ come from decays of B mesons. J/ψ mesons are detected through their decays into lepton pairs (e^+e^- and $\mu^+\mu^-$). A clear signal is seen in both channels (Fig. 3). Taking events within a mass window of 2.95 - 3.2 GeV/c^2, and after correcting for the final state radiation one obtains the inclusive branching fraction of Z^0 into J/ψ:

$$BR(Z^0 \rightarrow J/\psi + X) = (3.34 \pm 0.37\ (\text{stat}) \pm 0.29\ (\text{syst}))10^{-3}$$

and, assuming that all J/ψ come from B decays:

$$BR(B \rightarrow J/\psi + X) = (1.09 \pm 0.12\ (\text{stat}) \pm 0.09\ (\text{syst}))\%$$

where the new branching fraction of J/ψ into lepton pairs has been used[4].

$$BR(J/\psi \rightarrow \ell^+\ell^-) = (5.91 \pm 0.11)\%$$

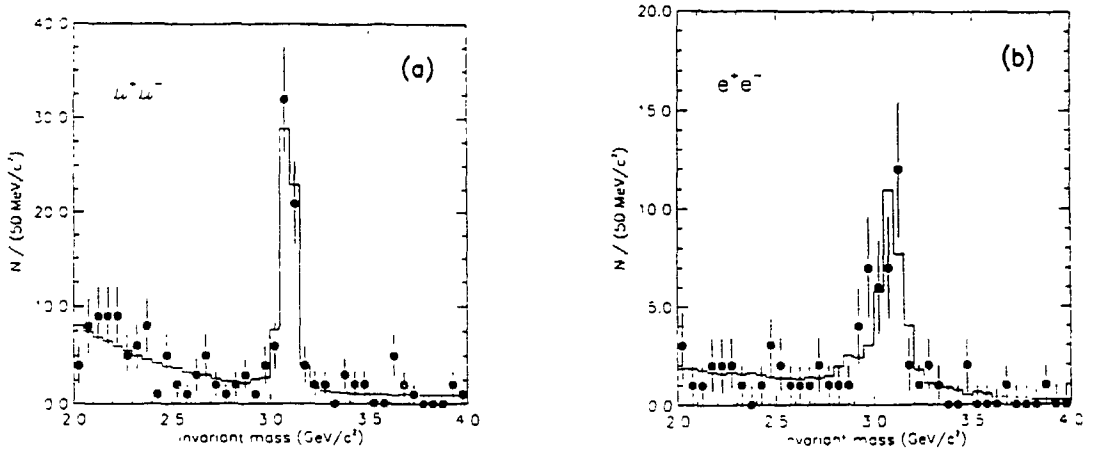

Figure 3: The J/ψ signal in the $\mu^+\mu^-$ channel (Fig. 3a, 62 J/ψ candidates) and in the e^+e^- channel (Fig. 3b, 38 J/ψ candidates).

4.2 Fully reconstructed B decays involving a J/ψ

In figure 4, we show the invariant mass distribution of events obtained by combining J/ψ mesons with charged or neutral kaons belonging to the same jet. The J/ψ were selected with a momentum greater than 10 GeV/c to be less sensitive to the combinatorial background. A signal of 10 events is seen at the B mass; from the 6 events with a charged kaon one can deduce:

$$BR(B \rightarrow J/\psi + K^+) = (0.26 \pm 0.11\ (\text{stat}) \pm 0.06\ (\text{syst}))\%$$

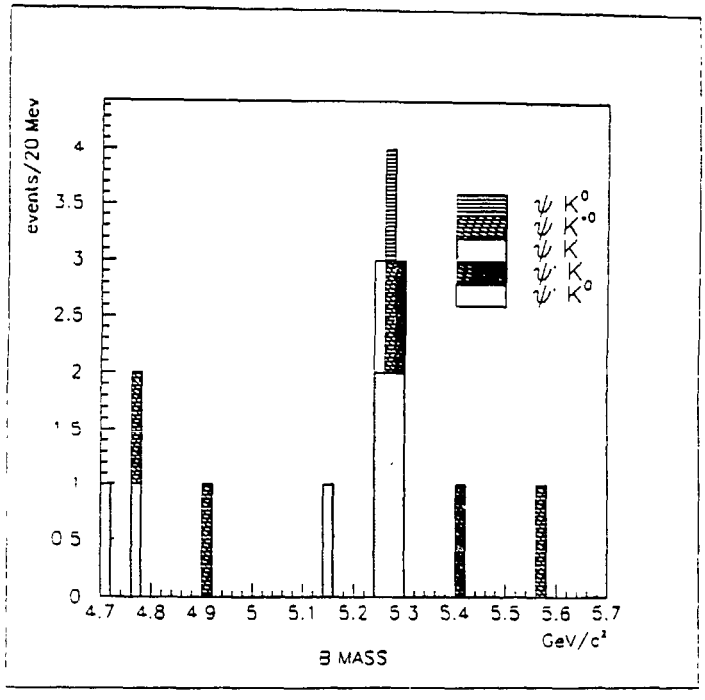

Figure 4: Summed mass distribution for exclusive B meson decays with a J/ψ or ψ' and a K or K^*.

4.3 Search for $\Lambda_b \rightarrow J/\psi + \Lambda^0$

The UA1 experiment[5] has observed recently a signal of the Λ_b baryon decaying into a J/ψ and a Λ^0 with a branching fraction:

$$BR(\Lambda_b \rightarrow J/\psi + \Lambda^0) = (1.8 \pm 1.1)\%$$

and a mass $M(\Lambda_b) = 5640 \pm 50$ MeV/c^2. We have searched for $J/\psi/\Lambda^0$ correlations inside the same jet, and found no candidate around the mass given by UA1. We can deduce an upper limit B. R. $(\Lambda_b \rightarrow J/\psi + \Lambda^0) < 1.15\%$ at 90% C. L. which is compatible with the UA1 measurement. More data are clearly needed !

5. Evidence for the production of Λ_b baryons in Z^0 decays

In all what follows, the symbol "Λ_b" is put as a generic name for all baryons carrying the beauty quantum number, which may be either the "true" Λ_b or another baryon cascading to the Λ_b in its decay chain.

5.1 Evidence for the Λ_b through Λ^0 - lepton correlations

This is only an update of what has been already published in reference 6 for the data of 1990. The analysis has been simply extended to the data of 1991 which give now an excess of 117 ± 18 events of $\Lambda^0 1-$ combinations with respect to Λ^0 $1+$ ones (Fig. 5). These events are interpreted as semi-leptonic decays of the Λ_b baryon giving a Λ_c baryon and lepton, the Λ_c giving afterwards a Λ^0 in its decay products. From the above excess of events, one finds the product branching ratio:

$$BR(b \to \Lambda_b) \,.\, BR(\Lambda_b \to \Lambda_c^+ \ell^- \nu) \,.\, BR(\Lambda_c^+ \to \Lambda^0 X) = (0.75 \pm 0.11\ (\text{stat}) \pm 0.18\ (\text{syst}))\%$$

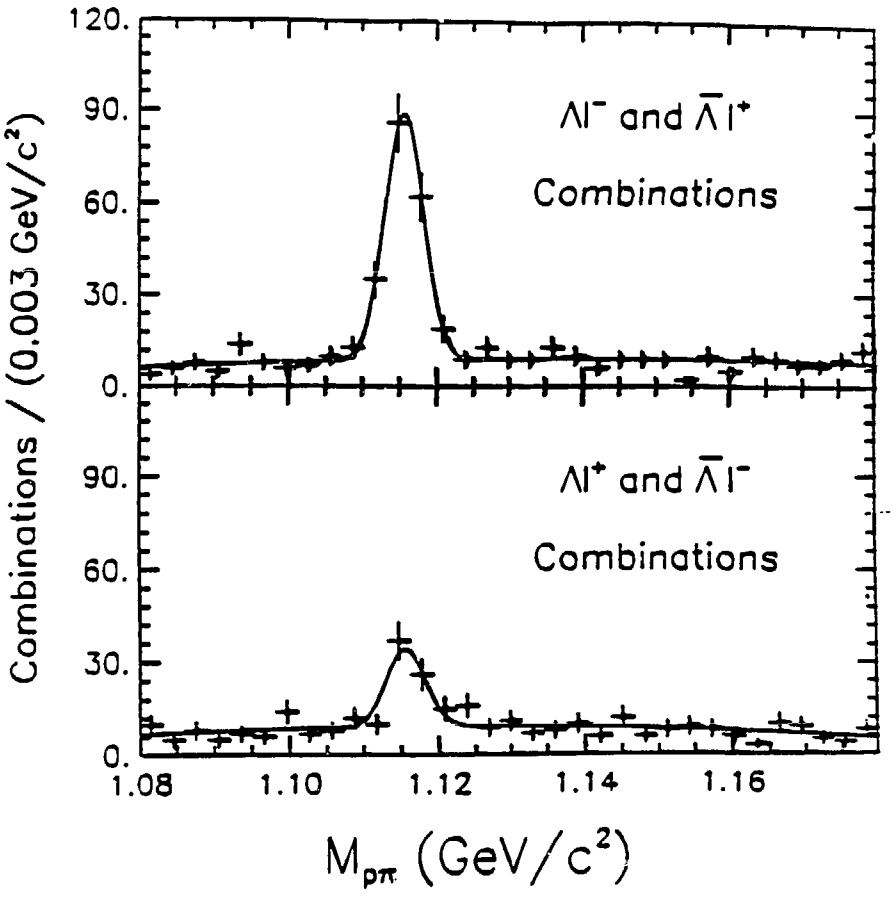

Figure 5: Proton-pion invariant mass for events with Λ- lepton correlations selected according to the cut described in reference 6.

5.2 Evidence for the Λ_b through Λ_c - Lepton correlations

Another check for the existence of the Λ_b can be done from correlations between a fully reconstructed Λ_c baryon, and a high Pt lepton in the same jet. We have chosen to

reconstruct the Λ_c baryon from its decay $\Lambda_c^+ \rightarrow p\, K^-\pi^+$ in spite of the large combinatorial background for this three-body decay, because it is the most abundant identified Λ_c decay and also because in ALEPH the proton can be identified through the dE/dx signature in the TPC.

There are several other physical processes which can give a Λ_c - lepton correlation inside the same jet, two of them being rare decays of non-strange B mesons. From Monte-Carlo studies, one can show that this physical background can be removed by rejecting events with M(Λ_c^+–lepton <= 3.5 GeV/c^2. To remove the combinatorial background, it is required that the three particles from the Λ_c decay come from a common vertex, clearly separated from the main event vertex.

After all cuts and substraction of known backgrounds, one is left with a signal of 21 ± 5.3 events (Fig. 6), for a reconstruction efficiency of $(8 \pm 1)\%$. This gives another, independent indication for the production of Λ_b baryons in Z^0 decays with the following product branching ratio:

$$BR(b \rightarrow \Lambda_b)\ .\ BR(\Lambda_b \rightarrow \Lambda_c^+ \ell^- X\nu) = (3.2 \pm 0.8\ (\text{stat}) \pm 1\ (\text{syst}))\%$$

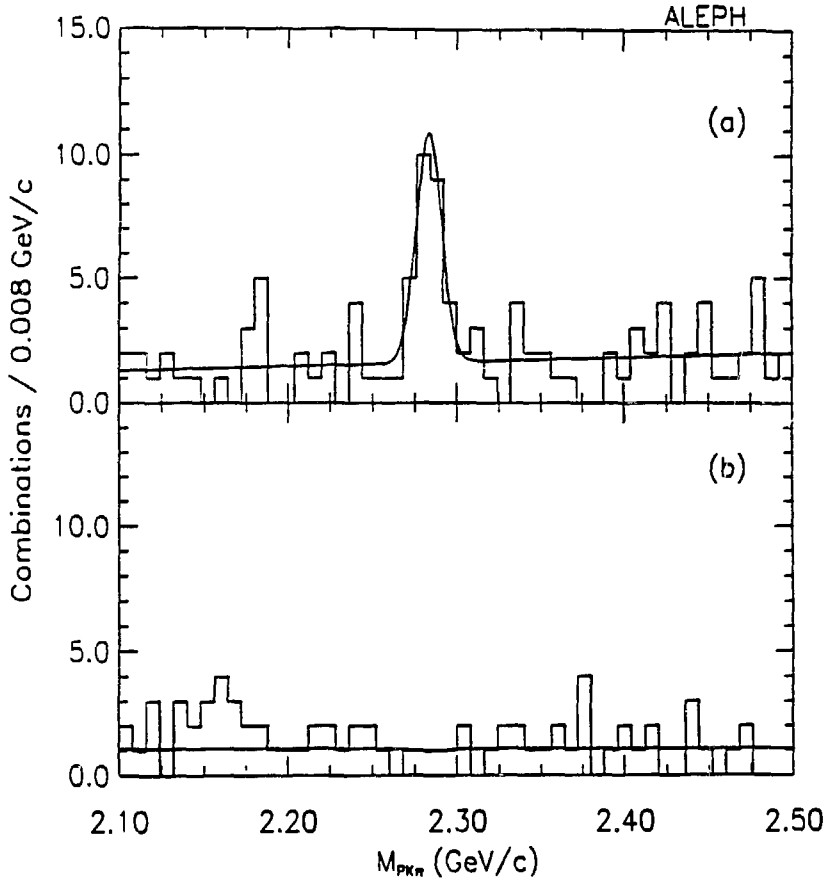

Figure 6: Search for Λ_b:
Proton $K^-\pi^+$ invariant mass for events with Λ_c - lepton correlations:
a) Λ_c^+ 1- correlations: the Lambdac signal is found at the right mass (2.283 +/- 0.002 GeV/c^2)
b) wrong sign correlations Λ_c^+ 1+: no signal seen.

6. Evidence for the strange B meson through Ds-lepton correlations

The same kind of correlations which has given evidence for the existence of the Λ_b baryon can be used for the strange neutral B meson, Bs. This meson is expected to decay most of the time into the strange charmed meson Ds. Therefore its existence can be checked in semileptonic decays involving a Ds, in Ds - lepton correlations within the same jet. The easiest way to detect the Ds is through the decay chain:

$$D_s^+ \rightarrow \varphi\pi^+(BR + 2.7 \pm 0.7)\% \text{ and } \varphi \rightarrow K^+K^-(B.R. = 50\%)$$

To minimize the physical background coming from rare decays of non-strange B mesons giving a Ds-lepton correlation, a cut on the Ds - lepton invariant mass has been used: we keep only events with M(Ds-lepton) > 3 GeV/c^2.

This leads to signal of 12 ± 5 events, as can be seen in figure 7, giving a branching product ratio:

$$BR(b \rightarrow B_s^0)\ .\ BR(B_s^0 \rightarrow D_s^- \ell^+ X\nu) + (3.9 \pm 1.2\ (\text{stat}) \pm 1.1\ (\text{syst}))\%$$

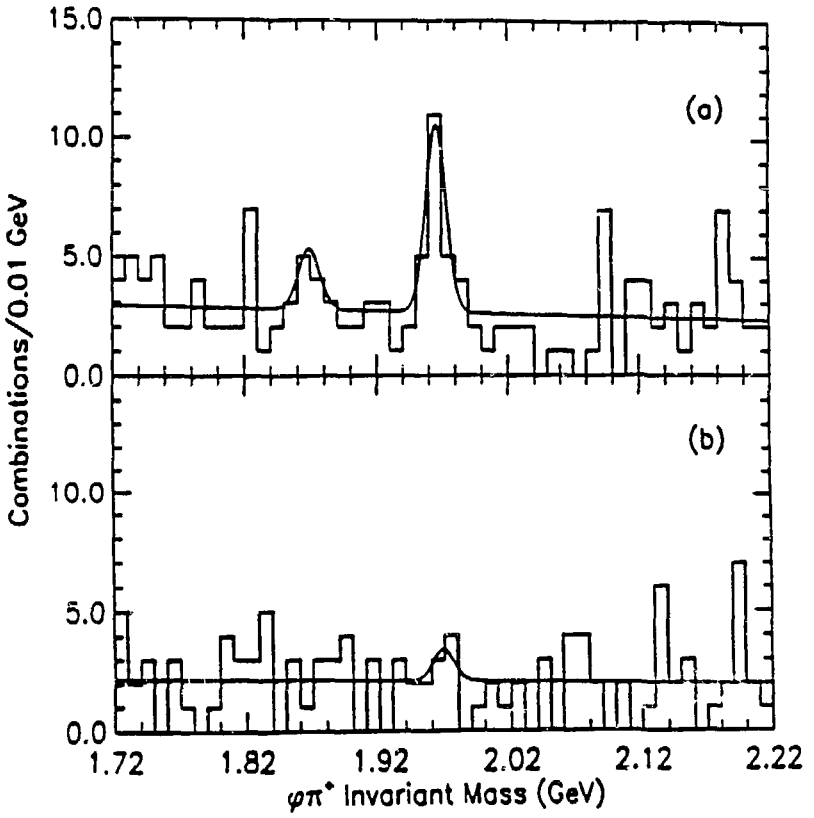

Figure 7: Search for $B^0 s$:
$\varphi\pi$ invariant mass for events with Ds - lepton correlations:
a) Ds^+ lepton - correlations: the Ds^+ signal is found at the right mass (1.966 +/- 0.003 GeV/c^2)
b) wrong sign correlations D_s^+ lepton +: no signal seen.

Nota:

Since the presentation done at Moriond, a further study of this channel using the decay $Ds^+ \to K^*0\ K^+$ with $K^*0 \to K^+\pi^-$ has been performed, giving exactly the same number of Ds - lepton candidates, substantially increasing the significance of the signal. It should be pointed out that the DELPHI experiment has also a signal[7] in the same channels.

Conclusion

From the analysis of almost half a million Z^0 decays regist-red in the ALEPH detector at LEP, we have been able to give interesting results on the production and decay of charm and beauty particles seen in ALEPH. The good performances of the detector allow to reconstruct cleanly the decays of charmed mesons, even using neutrals like K^0_s or π^0. Exclusive decays of B mesons involving a J/ψ are clearly seen. The evidence for the production of the Λ_b baryon Z^0 decays is now convicing, coming from two independant channels. Finally, the first footprints of the strange B meson are also seen in Ds - lepton correlations.

A lot of new results are clearly to be expected with more statistics, which will hopefully come with 1992 data.

Acknowledgments

This note is a report on the work of many people within the ALEPH collaboration. The author wishes to thank A. Bonissent, P. Colas, M-H Schune and V. Sharma for their help and for many stimulating discussions on the results presented here.

References

[1] D. Decamp et al., Nucl. Instr. and Meth. A294 (1990) 121.

[2] D. Decamp et al., Phys. Lett. B266 (1991) 218.

[3] Particle Data Group, Review of Particle Properties, Phys. Lett. B239 (1990).

[4] Mark III Collaboration Phys. Rev. Lett. 68 (1992) 282.

[5] UA1 Collaboration CERN-PPE/91-202.

[6] D. Decamp et al. Phys. Lett. B278 (1992) 209.

[7] P. Charpentier (DELPHI Collaboration), these proceedings.