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Search for $\Lambda_b \to \Lambda_c A_1$

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Abstract

In a data sample of 3.3 million hadronic Z decays collected with the ALEPH detector from 1991 to 1994, a search has been performed for the exclusive decay of Λ_b into Λ_c A_1, with the Λ_c decaying into $pK\pi$ and the A_1 into $\rho^0\pi$. Tight cuts had to be applied to get rid of the important combinatorial background. Only one candidate survives these cuts. The possible background sources are discussed.

1 Introduction

In a previous search [1, 2], evidence for exclusive Λ_b decays in the channel $\Lambda_c\pi$ has been found, based on four events in three different decay channels of the Λ_c ($pK\pi$, K^0_sp, $\Lambda 3\pi$), over a very small estimated background.

Due to isopin arguments, as well as by analogy with the B or τ decays, one can expect a higher branching ratio for the $\Lambda_c A_1$ channel than for the $\Lambda_c\pi$. However, the combinatorial background is expected to be more important.

In the present note we present the results of this search, the strategy for event selection and the background estimation.

2 Event Selection

The exclusive decay $\Lambda_b \to \Lambda_c A_1$ involves six charged tracks. As already said, the background to this channel is expected to be quite high. There are basically three sources of background: *udsc* events, true $b\bar{b}$ events where the Λ_b candidate was reconstructed with one or more fragmentation tracks (combinatorial background), and finally, reflection background for which the Λ_b candidate is in reality any other B hadron. Of all these sources of background the easiest to control is the reflection background.

In this section we will describe our selection procedure, which is aimed at reducing the *udsc* and combinatorial background to the lowest possible level, while still preserving an acceptable efficiency.

2.1 Kinematics and Particle Identification

The Λ_c is reconstructed in the decay mode $pK^-\pi^+$ (and its charge conjugate) with the following cuts:

- at least two of the three tracks must have at least 1 VDET hit;
- the momentum of the proton candidate must be greater than 2 GeV/c, that of the kaon candidate greater than 1 GeV/c and for the pion candidate the momentum must be greater than 0.5 GeV/c;
- for the proton candidate a valid dE/dx measurement is required. The measured ionisation must lie within 3σ of the proton hypothesis and be incompatible with the pion hypothesis at the level of 2σ. For the kaon and pion candidates, dE/dx, when available, must lie within 3σ of the corresponding mass hypothesis;
- the Λ_c candidate must have a momentum greater than 6 GeV/c;
- we apply a cut of $\pm 15\ MeV/c^2$ on the Λ_c candidate mass. Figure 1 shows the reconstructed Λ_c mass from Monte Carlo. The width of the distribution is 6 MeV/c^2, however, it has been shown using data from the Λ_c lepton correlations that the error on the Λ_c mass is underestimated in the Monte Carlo by a factor ≈ 1.25. Hence our cut at $\pm 1.25 \times 2\sigma$.

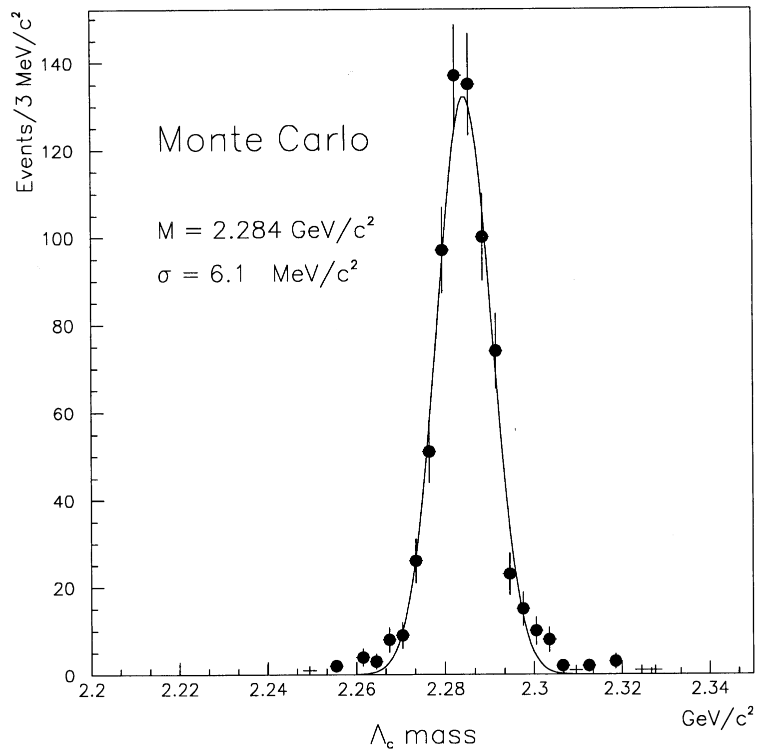

Figure 1: **Monte Carlo mass distribution of the reconstructed Λ_c**

- all three tracks are requested to be incompatible with a lepton hypothesis, according to the standard ALEPH criteria for electron and muon identification [3].

The A_1 is reconstructed with three charged tracks, two of which at least must have one or more VDET hits. The momentum of each track must be greater than .5 GeV/c, and the specific ionisation, when available, must be compatible with the pion hypothesis within 3 standard deviations. The momentum of the three-pion system must be greater than 6 GeV/c, and the following mass cuts are applied :

- the mass of the three-pion system must be lie within ± 400 MeV/c^2 of the A_1 mass;
- the mass of at least one of the $\pi^+\pi^-$ combinations must lie within ± 150 MeV/c^2 of the ρ^0 mass.

The Λ_b candidate is formed with Λ_c and A_1 candidates of opposite charges and has to have a momentum greater than 30 GeV/c. The absolute value of the cosine of the decay angle of the Λ_c in the center of mass of the Λ_b has to be less than 0.8. The expected distribution of this variable is flat, whereas the background peaks at 1.

Figure 2 shows the Monte Carlo momentum distribution of the Λ_b and its two decay products Λ_c and A_1. After applying these cuts one obtains an efficiency of 8.4% for the signal.

2.2 Topological Selection

The QIPBTAG algorithm [4] is used to reject *udsc* events. We demand that the event probability be less than 0.01. Figure 3 presents the mass distribution of the Λ_c A_1 system as obtained from the data after all the above mentioned cuts.

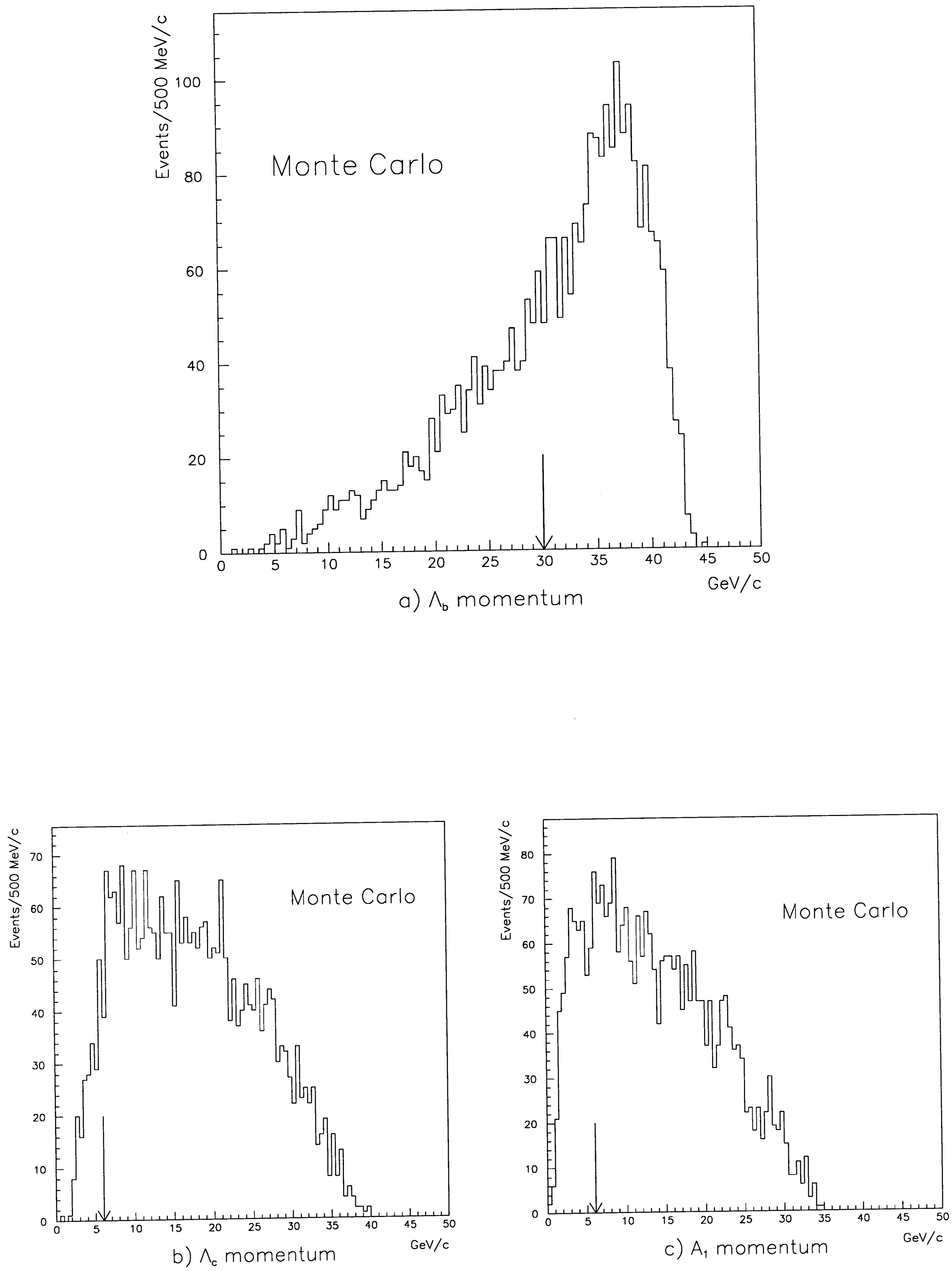

Figure 2: Monte Carlo momentum distributions: (a) Λ_b (b) Λ_c (c) A_1

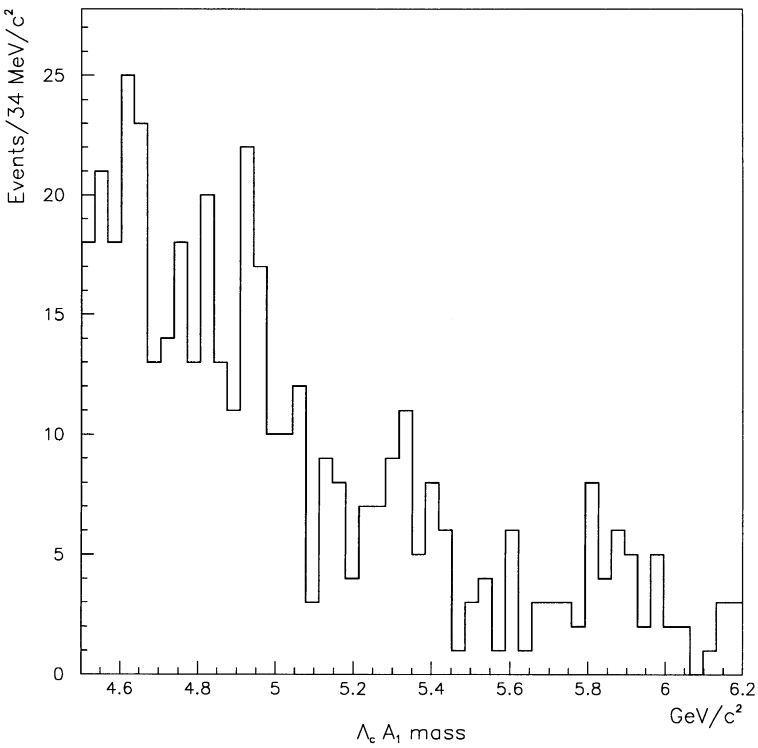

Figure 3: **Mass of the reconstructed Λ_c A_1 system**

The Λ_c vertex is reconstructed with the three charged tracks. The Λ_b vertex is reconstructed with the three pions from the A_1 candidate together with the line of fligth of the Λ_c. The fit of the Λ_c and Λ_b vertices is requested to have a χ^2 probability greater than 0.01.

Due to the Λ_b lifetime and to the high momentum cut we apply, it is possible to constrain the decay length to some hundred microns. As the error on the reconstructed vertex obtained with the Λ_c line of flight and the A_1 tracks is of the order of 130 μ, a cut on the decay length weighted by its error is imposed:

$$L_{\Lambda_b} \ / \ \sigma \ (L_{\Lambda_b}) > 4.$$

On the other hand, the error on the vertex of the Λ_c is bigger ($\approx$ 250 μ), hence a looser cut is applied:

$$L_{\Lambda_c} \ / \ \sigma \ (L_{\Lambda_c}) > 2.$$

Finally, to insure the right order of the successive decays (Λ_b followed by the Λ_c) it is requested that :

$$L_{\Lambda_c} \text{ - } L_{\Lambda_b} > 0.$$

After the topological cuts have been applied, the selection efficiency drops to 3.7%. Figure 4 presents the mass distribution of the Λ_c A_1 system after these topological cuts.

3 Background Studies

Assuming that the topological selection criteria eliminate most of the *udsc* events and a large part of the combinatorial background one has to take care of the effects due either to reflections coming from the B and B_s decays, or to other heavy b baryons and topologies where a baryon is emitted early in the quark fragmentation.

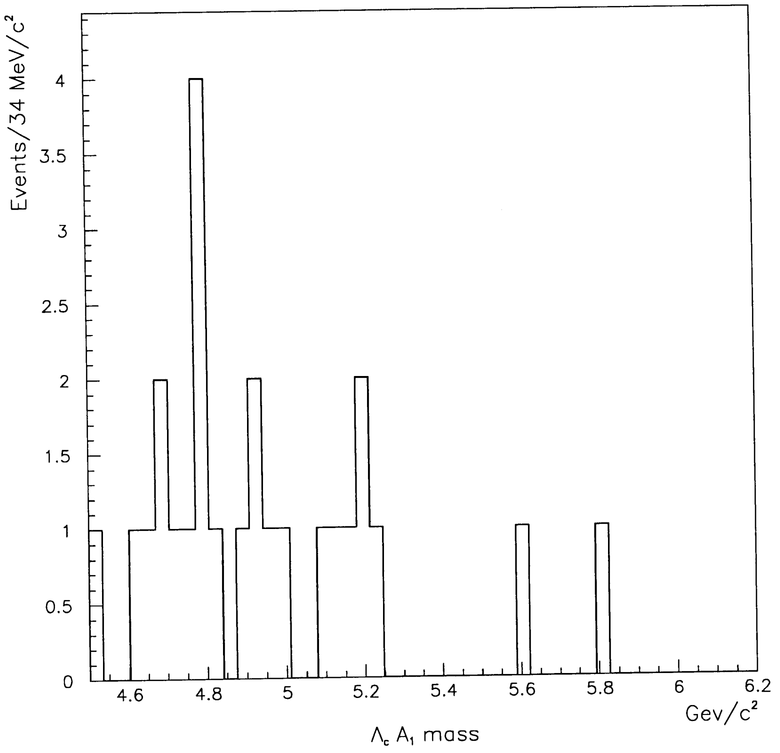

Figure 4: Mass of the reconstructed Λ_c A_1 system after the topological cuts

3.1 Reflection Background Studies

Special Monte Carlo studies have been done to evaluate the reflection background. For the B decays, the following processes have been generated:

- $B \to DA_1$ or D^*A_1 (with $D^* \to D\pi$),

  the D decaying in any modes known to the Monte Carlo generator, for an equivalent of 3.3 million hadronic Z decays, which corresponds to our data sample.

- $B \to DA_1$ or D^*A_1 (with $D^* \to D\pi$),

  the D decaying into $K\pi\pi$, with a statistics equivalent to ten times the data sample.

No candidates survive the cut :

$$| \mathrm{M}(\text{“}p\text{”}K\pi) \text{ - } \mathrm{M}_D | > 21 \; MeV/c^2$$

where the π mass hypothesis was used for the proton candidate.

For the B_s decay, which is obviously the most dangerous source of background, the following processes have been generated:

- $B_s \to D_sA_1$

  the D_s decaying in any modes known to the Monte Carlo generator, for an equivalent of two times the data sample.

- $B_s \to D_sA_1$

  with the D_s decaying into $KK\pi$ modes ($\Phi\pi$, K^*K), for an equivalent of twenty times the data sample.

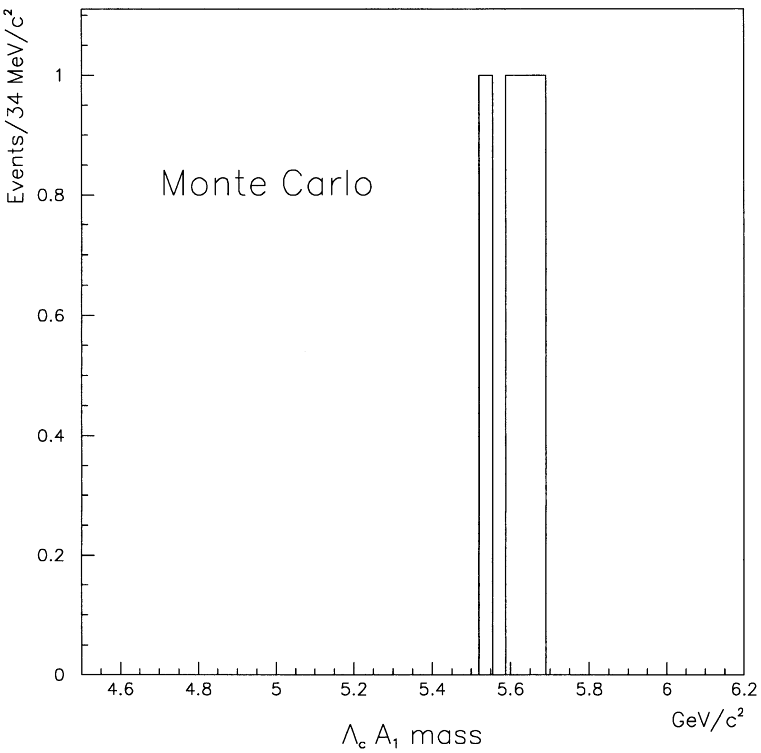

Figure 5: **Mass distribution of true $B_s \to D_s A_1$, reconstructed as $\Lambda_b \to \Lambda_c A_1$ with proton mass hypothesis for one kaon from the D_s.**

After applying the cut:

$$| \mathrm{M}(\text{"}p\text{"}K\pi) - \mathrm{M}_{D_s} | > 21 \; MeV/c^2$$

where the K mass hypothesis was used for the proton candidate, no candidate survives. Figure 5 illustrates the contribution of this background before the last mass cuts.

Given the large statistics used, we estimate the reflection background to be < 0.3 @ 95% confidence level.

The final mass distribution of the $\Lambda_c A_1$ system after the cuts for possible reflections is shown in Figure 6 (a). The final efficiency attained is 2.8%.

3.2 Other Background Studies

In addition to the reflection effects, one also expects background from other b baryon decays, such as Σ_b. To get an estimate for this, the general $b\bar{b}$ Monte Carlo was used. Obviously, even in the latest Jetset generator, all the decays of interest are not accurately simulated. Therefore our study can only provide a rough estimate for this source of background.

The analysis procedure was applied to 650 000 $b\bar{b}$ events corresponding to 3.3 million hadronic Z decays. As one can see from Figure 7 (a), there are four events with a mass above 5.2 Gev/c^2. Two of them have a surprisingly high mass, around 5.9 Gev/c^2. One of these events comes from the decay of a Σ_b into $\Lambda_b\pi$ followed by $\Lambda_b \to \Lambda_c\rho$. The Λ_c is correctly reconstructed, but a fake A_1 candidate is built with the ρ and the pion from the Σ_b decay. The second event is built with a fragmentation proton of 4 GeV/c together with tracks coming from a $B \to DA_1$ decay. The A_1 is well reconstructed and the Λ_c candidate is formed with the proton and tracks coming from the D decay.

The data can also be used to estimate the background by comparing the *right sign* and *wrong sign* combinations of Λ_c and A_1. This method is however

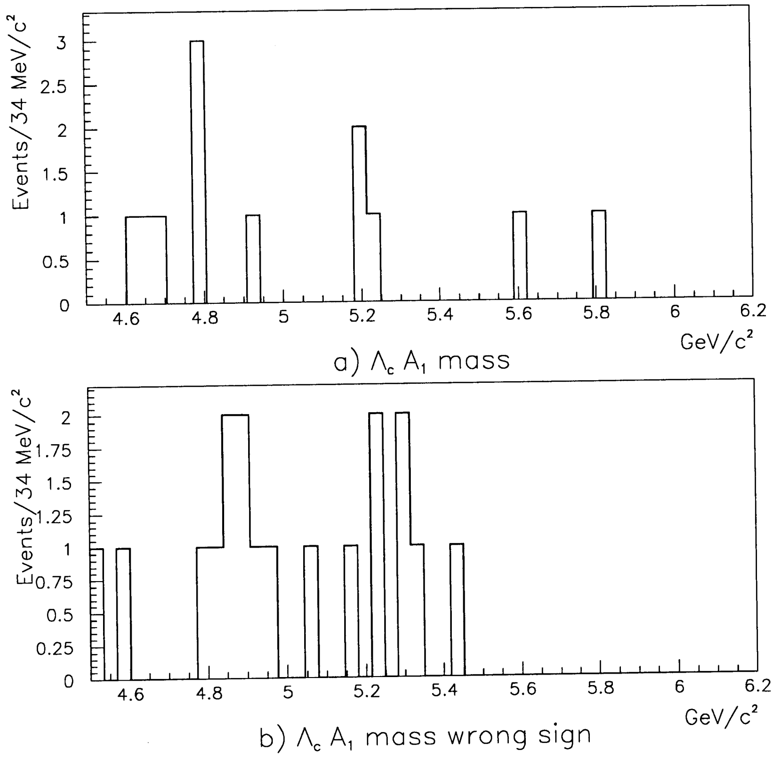

Figure 6: Mass distribution for Λ_b candidates in the data: (a) *right sign* combinations (b) *wrong sign* combinations.

statistically limited since one has to ask, in the case of *wrong sign* combinations, for a doubly charged system of six particles in one hemisphere and with a very high momentum sum. *Wrong sign* combinations are shown in Figures 6 and 7 (b), for the data sample and the $b\bar{b}$ Monte Carlo respectively.

It is clear, from this study that the reflection background can be controlled to a satisfactory level, but the combinatorial background coming from heavy b baryons or from rare primary fragmentation gives an irreducible contribution in the high mass range and in the high momentum range.

4 Results

As one can see from Figure 6 (a), there is only one candidate around the expected mass. The properties of this candidate are:

$$\Lambda_b \text{ momentum}: 36.6\ GeV/c$$

$$\Lambda_b \text{ mass}: (5.607 \pm 0.014)\ GeV/c^2$$

$$\Lambda_c \text{ momentum}: 30.7\ GeV/c$$

$$\Lambda_c \text{ mass}: (2.271 \pm 0.009)\ GeV/c^2$$

$$A_1 \text{ mass}: 1.07\ GeV/c^2$$

$$\rho \text{ mass}: 0.833\ GeV/c^2$$

$$\Lambda_b \text{ decay length: } 2.14 \text{ mm } (\sigma = 130\ \mu)$$

$$\Lambda_c \text{ decay length: } 2.19 \text{ mm } (\sigma = 220\ \mu)$$

Figure 8 presents the display of this event (Run 28230 Evt 8815). As in the $b\bar{b}$ Monte Carlo, we find in the data sample a candidate at high mass, 5.806 GeV/c^2, with a momentum of 34.6 GeV/c.

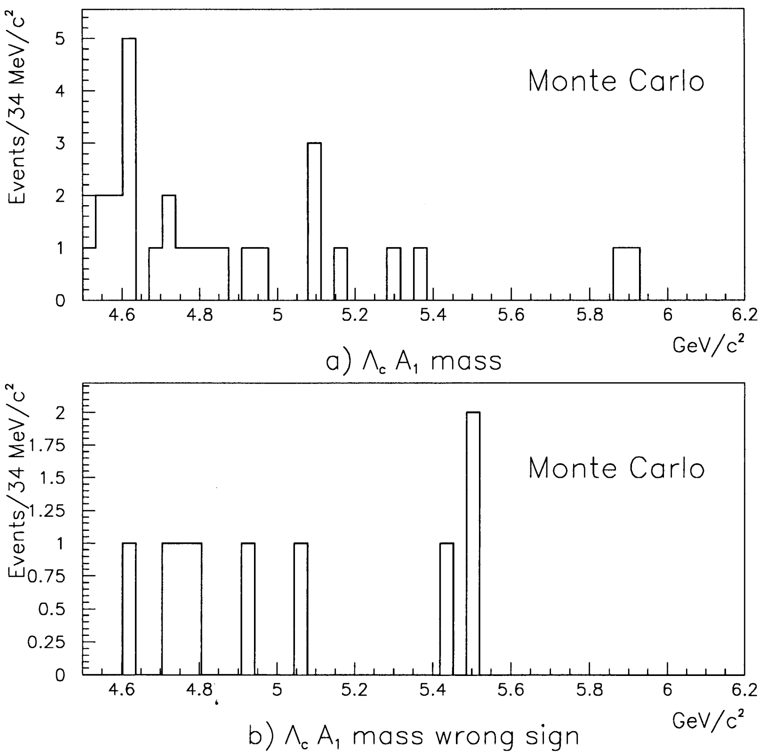

Figure 7: Mass distribution for Λ_b candidates in $b\bar{b}$ Monte Carlo: (a) *right sign* combinations (b) *wrong sign* combinations.

5 Conclusions

Using all the data accumulated by ALEPH from 1991 to 1994, we have searched for exclusive Λ_b decays in the channel $\Lambda_b \to \Lambda_c A_1$ with the subsequent decays $\Lambda_c \to pK\pi$ and $A_1 \to \rho^0\pi$.

The high combinatorial background leads to severe cuts, which considerably reduce the selection efficiency. One candidate satisfies our selection criteria. The reflection background from B and B_s decays can be controlled, however there remains an irreducible background arising from unknown decays of heavy states.

Unfortunately the statistics which will be obtained this year will not be sufficient to hope for a significant improvement.

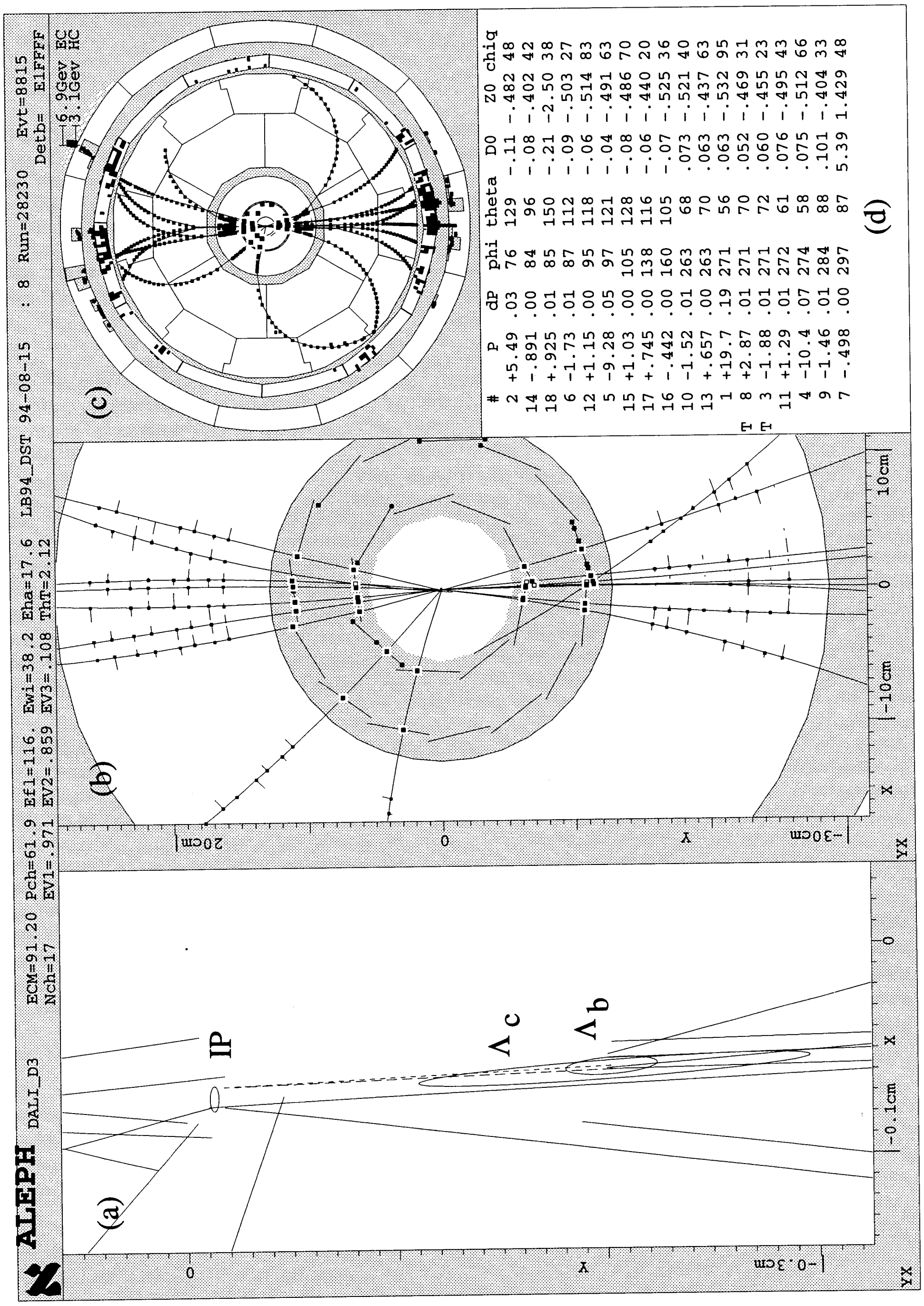

Figure 8: A reconstructed Λ_b (a) A close-up view of the interaction region: the Λ_c is reconstructed with tracks 1 (p), 4 (K) and 13 (π). The A_1 candidate is reconstructed with tracks 3, 8 and 9. The ellipses represent 2σ contours. (b) An $r\phi$ view showing the VDET and ITC hits. (c) Fisheye $r\phi$ view. (d) List of charged tracks.

References

[1] Giovanni Musolino et al. "Λ_b exclusive decay"
ALEPH 95-49, March 1995

[2] John Walsh, "Exclusive *B* Decays at LEP"
Moriond Conference, March 1995

[3] D. Buskulic *et al.*, Nucl. Instr. Meth. **A436** (1994) 461

[4] David Brown and Markus Frank "Tagging *b*-hadrons using track impact parameters"
ALEPH 92-135, August 1992