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Search for exclusive decays of the Λ_b^0 baryon to $\Lambda_c^+\pi^-$ and $\Lambda_c^+ a_1^-$

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Abstract

A search for fully reconstructed Λ_b^0 baryons is performed in the colour-allowed decay channels $\Lambda_b^0 \to \Lambda_c^+\pi^-/a_1^-$, with subsequent decays $\Lambda_c^+ \to pK^-\pi^+$ or pK_S^0 or $\Lambda^0\pi^+$, and $a_1^- \to \rho^0\pi^-$, $\rho^0 \to \pi^+\pi^-$ (and their charge-conjugate states). The analysis is based on about 3.4×10^6 hadronic Z^0 decays collected in 1991–95 by the DELPHI detector at LEP. It relies on efficient particle identification and precise track and vertex reconstruction.

One $\bar{\Lambda}_b^0$ candidate is seen in the $\bar{\Lambda}_c^-\pi^+$ decay channel (with $\bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$). Three Λ_b^0 or $\bar{\Lambda}_b^0$ candidates are found in the $\Lambda_c^\pm a_1^\mp$ channel (one of each with $\Lambda_c^+ \to pK^-\pi^+$, $\bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$ and $\bar{\Lambda}_c^- \to \bar{p}K_S^0$). The estimated backgrounds of the two channels are 0.26 and 0.79 events, respectively.

From these four candidates the weighted mean Λ_b^0 mass is determined to be $(5610 \pm 24_{stat} \pm 16_{syst})$ MeV/c^2.

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1 Introduction

The existence of the lightest baryon with a b quark has been predominantly established in the colour-suppressed decay channel $\Lambda_b^0 \to J/\psi \Lambda^0$ [1, 2, 3]. It was first reported in $p\bar{p}$ collisions [1] with a mass of $(5640 \pm 50 \pm 30)$ MeV/c^2; CDF [2] determined the mass to be $(5621 \pm 4 \pm 3)$ MeV/c^2. At LEP, a recent DELPHI analysis [3] found two decays and measured a mass of $(5612.1 \pm 21.2 \pm 6.0)$ MeV/c^2.

Decays of the Λ_b^0 baryon in the colour-allowed $\Lambda_c^+\pi^-/a_1^-$ channels[1] have been observed by two experiments at LEP: a DELPHI analysis [4], based on 1991–1994 data before re-processing, found three $\Lambda_c^+\pi^-$ and one $\Lambda_c^+ a_1^-$ decays with a mass of $(5668 \pm 16 \pm 8)$ MeV/c^2; whereas an ALEPH analysis [5] observed four $\Lambda_b^0 \to \Lambda_c^+\pi^-$ decays with a mass of $(5614 \pm 21 \pm 4)$ MeV/c^2.

The weighted mean mass cited by PDG'2000 [6] of (5624 ± 9) MeV/c^2 is well within the range of 5600–5660 MeV/c^2 predicted by heavy quark effective theory [7], lattice QCD calculations [8], and potential models [9].

The analysis presented in this note is performed on re-processed[2] DELPHI data collected around the Z^0 mass peak in the years 1991–1995; the re-processing being based on more efficient track search, better precision of track reconstruction, and improved hadron identification by the RICH detectors. With improvements in proton and kaon identification and microvertex detector precision, this study aims at an update of the old DELPHI measurement [4] of the Λ_b^0 mass which is 2.2σ above the world average value [6]. The following decay channels are investigated:

$\Lambda_b^0 \to \Lambda_c^+\pi^-$	(1)	with subsequent	$\Lambda_c^+ \to pK^-\pi^+$	(a)
$\Lambda_b^0 \to \Lambda_c^+ a_1^-$	(2)		$\Lambda_c^+ \to pK_S^0$	(b)
			$\Lambda_c^+ \to \Lambda^0\pi^+$	(c)

and $K_S^0 \to \pi^+\pi^-$, $\Lambda^0 \to p\pi^-$, $a_1^- \to \rho^0\pi^-$, $\rho^0 \to \pi^+\pi^-$ decays (and c.c.).

Reconstruction starts with $\Lambda_c^+ \to pK^-\pi^+$, $\Lambda_c^+ \to pK_S^0$ (with $K_S^0 \to \pi^+\pi^-$), $\Lambda_c^+ \to \Lambda^0\pi^+$ (with $\Lambda^0 \to p\pi^-$) and $a_1^- \to \rho^0\pi^-$ (with $\rho^0 \to \pi^+\pi^-$) decay candidates. The Λ_c^+ candidates are combined with either a single charged pion or a combination of 3 charged pions making a charged a_1 to search for Λ_b^0 candidates.

The procedure for selecting Z^0 hadronic events is described in Section 2. This is followed in Section 3 by a description of selection criteria for Λ_c^+ candidates, including primary and secondary vertex reconstruction. Selection criteria for Λ_b^0, including kinematics fitting to the $\Lambda_b^0 \to \Lambda_c^+\pi^-/a_1^-$ topologies, and some additional tighter selection criteria to suppress background are described in Section 4. Section 5 presents the results obtained from the kinematically fitted data. Our conclusions are given in Section 6.

2 Selection Criteria for Hadronic Events

A detailed description of the components of the DELPHI detector and the simulation and reconstruction software can be found in [10, 11, 12]. Charged particles in each event were required to have

[1] the charge-conjugate (c.c.) states, in particular $\bar{\Lambda}_b^0 \to \bar{\Lambda}_c^-\pi^+/a_1^+$ are always implicitly considered.

[2] except for the 1991 data which have not been submitted to re-processing; however, none of these survived the selection criteria.

- measured momentum (p) greater than 200 MeV/c,
- $\frac{\delta p}{p} < 1$ (with δp being the error on p),
- impact parameter transverse to the beam < 2.5 cm, and
- impact parameter along the beam < 5.0 cm.

Events with 7 or more charged particles and a total charged energy greater than 12 GeV were selected as "hadronic Z^0 decays". For charged particle identification, information from the Ring Imaging Cherenkov (RICH) detectors and the ionization loss rate ($\frac{dE}{dx}$) measured in the Time Projection Chamber (TPC) were used.

The search was performed on those 3.4345×10^6 events passing the hadronic event selection in the 1991–1995 real data. In addition, the following sets of fully reconstructed Monte Carlo event samples were also analysed:

- A general $Z^0 \to q\overline{q}$ "background MC sample" generated by the parton shower model [13], and submitted to the full detector simulation [11] and event reconstruction [12] while taking into account variations of the detector geometry, calibration, alignment and analysis software over the 1991 to 1995 data taking periods.

  A total of 10.436×10^6 events passing the hadronic selection criteria, and excluding those which contain the "signal decay channels" under investigation, were used to determine the background. The normalization to real data is done separately for the five sub-samples representing the different years of data taking.

- Five "signal Monte Carlo samples" for the decay channels under investigation[3],
  - 6019 events (5868 of which passing the hadronic selection criteria) with decays $\Lambda_b^0 \to \Lambda_c^+ \pi^-$ and $\Lambda_c^+ \to pK^-\pi^+$;
  - 5981 (5834) events with decays $\Lambda_b^0 \to \Lambda_c^+ \pi^-$ and $\Lambda_c^+ \to pK_S^0$;
  - 4000 (3886) events with decays $\Lambda_b^0 \to \Lambda_c^+ \pi^-$ and $\Lambda_c^+ \to \Lambda^0 \pi^+$;
  - 1474 (1452) events with decays $\Lambda_b^0 \to \Lambda_c^+ a_1^-$ and $\Lambda_c^+ \to pK^-\pi^+$;
  - 1526 (1500) events with decays $\Lambda_b^0 \to \Lambda_c^+ a_1^-$ and $\Lambda_c^+ \to pK_S^0$,

  in order to determine the efficiencies of observing a signal in each of these decay channels (see Section 5). The Λ_b^0 mass and mean decay lifetime used in generating the 5 signal MC samples were 5624.0 MeV/c^2 and 1.29 ps, respectively.

3 Selection of Λ_c^+ Candidates

3.1 Track Quality and Kinematic Selection Criteria

Events passing the hadronic Z^0 decay selections were further subjected to "b-tagging selection" [14] by requiring the jet lifetime probability constructed from positively signed impact parameters of tracks included in a jet and corresponding to the probability of a given group of tracks being compatible with the primary vertex to be below 1%.

[3]no signal MC data were available for the channel with $\Lambda_b^0 \to \Lambda_c^+ a_1^-$ and $\Lambda_c^+ \to \Lambda^0 \pi^+$.

For each event, the thrust axis was determined using all charged particles passing the cuts described above, the reconstructed K^0 and Λ^0 and the photons (energy depositions in the electromagnetic calorimeters not associated to charged particles). The plane perpendicular to the thrust axis split the event into two hemispheres.

In each hemisphere, charged tracks identified as protons, kaons or "pions" (the latter including charged particles not consistent with being identified as heavy ones), and neutral 2-prong decays (V^0s) were tried for appropriate charge sign combinations of $pK^-\pi^+$, pK^0_S and $\Lambda^0\pi^+$ to search for Λ_c^+ candidates. The following charged particles which are important for a precise reconstruction of the Λ_c^+ decay vertex,

- at least 2 out of the 3 tracks in $pK^-\pi^+$,
- the p track in pK^0_S, and
- the π^+ track in $\Lambda^0\pi^+$,

were required to have a minimum number of associated hits in the 3-layer microvertex detector (MVD): at least 2 measurements in $R\Phi$ when the MVD had only single-sided plaquettes (1991–93), or at least 1 measurement in $R\Phi$ and 1 in z when two layers had double-sided plaquettes (1994–95).

Then, a combination was accepted as a "good Λ_c^+ candidate" if

- its effective mass was between 2245 and 2325 MeV/c^2,
- the error on this mass was less than 50 MeV/c^2, and
- the Λ_c^+ momentum was greater than 7 GeV/c.

3.2 Primary and Λ_c^+ Vertex Reconstruction

Events with a "good Λ_c^+ candidate" were subjected to geometric vertex fitting in order to increase the purity of the selected sample.

The primary vertex reconstruction was based on a track sample of all charged particles (except those from the Λ_c^+ decay), provided that they had sufficient associated hits in the MVD (see above, Subsection 3.1).

The primary vertex fit was performed by a robust two-fold iterative procedure. It started with all selected tracks and included the known beam interaction profile with its errors as a "virtual measurement".

The contribution from any participating track to the fit's χ^2 was tested to be less than 3.5 when fitting only in the $R-\Phi$ plane (1991–93 data), or less than 5.25 when fitting in three dimensions (1994–95 data). If some were greater than the critical value, the track with the largest χ^2 contribution was removed, and the fit redone. This first iteration ended either when the maximum χ^2 contribution was below the critical value, or when only one track remained. In the latter case the event was rejected.

Otherwise, if the total χ^2 probability of the resulting vertex fit was less than 0.1%, the track with the largest contribution to the fit's χ^2 was removed and the vertex fit redone. This second iteration ended sucessfully when the vertex fit had a total χ^2 probability greater than 0.1% with at least two tracks remaining. Otherwise, the event was rejected.

About 4% of the events had no successful primary vertex fit and thus were discarded from further analysis.

For the secondary vertex reconstruction, a geometric vertex fit was performed for $(pK^-\pi^+)$, (pK^0_S), or $(\Lambda^0\pi^+)$. This vertex, hence the Λ_c^+ candidate, was accepted if it had

- a total χ^2 fit probability greater than 0.1%,
- a spatial separation from the primary vertex larger than its error, and
- an angle in space between the Λ_c^+ momentum and its reconstructed line of flight of less than 90^0.

4 Selection of Λ_b^0 Candidates

Events having successfully passed this stage of analysis were searched for Λ_b^0 candidates. All charged pions within the same hemisphere as the Λ_c^+ were tried singly and in triplets of appropriate charge sign combinations for association with the Λ_c^+ vertex.

The single pion in case of $\Lambda_c^+\pi^-$, or at least 2 out of 3 pions in case of $\Lambda_c^+(3\pi)^-$ combinations were required to have the minimum number of associated hits in the MVD, as defined in Subsection 3.1.

Then, a combination was accepted as a "good Λ_b^0 candidate" if

- its effective mass was between 5400 and 5900 MeV/c^2,
- the error on this mass was less than 100 MeV/c^2,
- the p and K^- from Λ_c^+ decay (as well as the p from Λ^0 decay) were identified using stringent identification criteria[4],
- the Λ_b momentum was greater than 25 GeV/c, and
- $L/\delta L > 3$ (with L being the fitted Λ_b^0 decay length, and δL being its error).

For the case of $\Lambda_c^+(3\pi)^-$ combinations, it was further required that

- the $(3\pi)^-$ effective mass was between 800 and and 1600 MeV/c^2 (consistent with the a_1^-), and
- at least one $\pi^+\pi^-$ pair had an effective mass between 500 and 1040 MeV/c^2 (consistent with the ρ^0).

These "good Λ_b^0 candidates" were subjected to a full topological kinematics fit [15] of $\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-$ or $\Lambda_b^0 \rightarrow \Lambda_c^+ a_1^-$ decays, with added constraints of the known Λ_c^+ mass and mean lifetime [6]. After kinematics fitting, events were accepted if

- the fit's χ^2 probability was greater than 1%,
- the angle in space between the Λ_b^0 momentum and its fitted line of flight was less than 15^0, and
- $\tau/\delta\tau > 3$ (with τ being the fitted Λ_b^0 lifetime, and $\delta\tau$ being its error).

[4] tagged as at least "standard" heavy [14]; in case of an ambiguity the more strongly favoured identification was accepted.

5 Results

These are obtained from the kinematically fitted data of Λ_b^0 candidates which have survived the final cuts, and were still within a mass window between 5400 and 5900 MeV/c^2 (see above, Section 4).

Subsection 5.1 presents results from Signal Monte Carlo events, Subsection 5.2 those from Background Monte Carlo and Real Data events. Measurement of the Λ_b^0 mass is presented in Subsection 5.3. Finally, a critical comparison with the earlier DELPHI result [4] is discussed in Subsection 5.4.

5.1 Signal Monte Carlo and Efficiencies

The mass distributions of kinematically fitted $(\Lambda_c^+\pi^-)$ or $(\Lambda_c^+a_1^-)$ are shown in Figures 1.a–e for the five samples of Signal Monte Carlo events, and in Figure 1.f for all samples combined and superposed with a double Gaussian fit.

For each of the Signal MC samples the mass distribution (Figs 1.a–e) was subjected to a maximum likelihood fit, with each event being weighted by the uncertainty on its mass measurement (as given by the kinematics fit). In a background-free situation the ML fit involves maximising the likelihood function

$$\mathcal{L}(M_0, x) \;=\; \prod_{i=1}^{N} \frac{1}{\sqrt{2\pi}\; x\sigma_i}\, \mathbf{e}^{-\frac{(m_i - M_0)^2}{2(x\sigma_i)^2}} \;,$$

for 2 parameters: M_0 (the central value of the ML fitted mass) and x (a global scale factor on the mass uncertainty), while m_i and σ_i are the kinematically fitted mass values and their errors for each individual event. The values determined for the central mass of each sample were found to be consistent with 5624.0 MeV/c^2, i.e. the mass value used by the event generation (see Section 2).

For the combined Signal MC sample the kinematically fitted mass distribution (Fig 1.f), after having been subjected to the maximum likelihood fit, yielded a central mass value $M_0 = 5625.2 \pm 0.2$ MeV/c^2 and a global uncertainty scale factor $x = 1.24 \pm 0.07$. This scale factor being greater than 1 is a strong indication of a large variation in the individual errors from event to event. This is clearly visible in Fig 1.f where the effect of the fit appears as the sum of two Gaussians – one narrow and one broad – with the same central mass value.

The reconstruction efficiencies ε of the 5 Signal MC samples (corresponding to 5 decay channels) were determined to be

$$\begin{aligned}
\varepsilon(\Lambda_b^0\to\Lambda_c^+\pi^-, \Lambda_c^+\to pK^-\pi^+) &= (3.46 \pm 0.24)\% \\
\varepsilon(\Lambda_b^0\to\Lambda_c^+\pi^-, \Lambda_c^+\to pK_S^0) &= (1.40 \pm 0.15)\% \\
\varepsilon(\Lambda_b^0\to\Lambda_c^+a_1^-, \Lambda_c^+\to pK^-\pi^+) &= (1.76 \pm 0.33)\% \\
\varepsilon(\Lambda_b^0\to\Lambda_c^+a_1^-, \Lambda_c^+\to pK_S^0) &= (0.92 \pm 0.25)\% \\
\varepsilon(\Lambda_b^0\to\Lambda_c^+\pi^-, \Lambda_c^+\to\Lambda^0\pi^+) &= (0.66 \pm 0.21)\%
\end{aligned}$$

These efficiencies are rather small; they are a consequence of the tight selection criteria (see Sections 3 and 4) which have been necessary to minimize the background.

5.2 Background Monte Carlo and Real Data

The mass distributions of kinematically fitted $(\Lambda_c^+\pi^-)$ or $(\Lambda_c^+a_1^-)$ of all decay channels are shown in Fig 2.a for Background Monte Carlo events, in Fig 2.b for Real Data events, and in Fig 2.c for Real Data superposed on the normalized[5] Background MC.

The numbers of surviving Background MC events and Real data events within the broad mass window of 5400 to 5900 MeV/c^2 are 17 (unnormalized) and 5, respectively. They belong to the decay channels listed in Table 1.

Table 1: Number of Events after Final Cuts

Decay channel	Bckgd MC	Real Data
(1.a) $\Lambda_b^0 \to \Lambda_c^+\pi^-, \Lambda_c^+ \to pK^-\pi^+$	4	1
(2.a) $\Lambda_b^0 \to \Lambda_c^+a_1^-, \Lambda_c^+ \to pK^-\pi^+$	12	3
(2.b) $\Lambda_b^0 \to \Lambda_c^+a_1^-, \Lambda_c^+ \to pK_S^0$	0	1
other channels	1	0

The $(\Lambda_c^+\pi^-)$ distributions of $\Lambda_b^0 \to \Lambda_c^+\pi^-$ with $\Lambda_c^+ \to pK^-\pi^+$ are shown in Figure 3, and the $(\Lambda_c^+a_1^-)$ distributions of $\Lambda_b^0 \to \Lambda_c^+a_1^-$ with $\Lambda_c^+ \to pK^-\pi^+$ and $\Lambda_c^+ \to pK_S^0$ in Figure 4: for Background Monte Carlo events in Figs 3/4.a, for Real Data events in Figs 3/4.b and for Real Data superposed on the normalized Background MC in Figs 3/4.c.

Regarding only the decay channels with surviving Real Data events, there are 16 (unnormalized) Background MC events which are evenly distributed over the broad mass interval of 500 MeV/c^2 width (see Figures 3.a and 4.a).

Of the Real Data events, however, 4 out of 5 accumulate within a narrow mass interval between 5560 and 5660 MeV/c^2 (see Figures 3.b and 4.b). The remaining four real Λ_b^0 candidates are listed in Table 2. All have been collected in the years 1992–94.

The normalized backgrounds within the narrow mass interval of 100 MeV/c^2 width are calculated to be 0.26 (for $\Lambda_b^0 \to \Lambda_c^+\pi^-$) and 0.79 (for $\Lambda_b^0 \to \Lambda_c^+a_1^-$), respectively.

The background-subtracted number of real Λ_b^0 candidates observed in all investigated decay channels is thus 3.0 ± 2.0 events.

5.3 New Measurement of the Λ_b^0 Mass

Some properties of the four $\Lambda_b^0/\bar{\Lambda}_b^0$ candidates[6], as obtained from their individual kinematics fits, are given in Table 2.

The mass errors have been increased by the uncertainty scale factor $x = 1.24$ determined from the Signal MC (see above, Subsection 5.1). The four Λ_b^0 candidates were subjected to a maximum likelihood fit, with each event being weighted by its scaled-up mass error, by maximising the likelihood function

$$\mathcal{L}(M_0) \;=\; \prod_{i=1}^{4} \frac{1}{\sqrt{2\pi}\; x\sigma_i}\; \mathrm{e}^{-\frac{(m_i - M_0)^2}{2(x\sigma_i)^2}} \quad ,$$

[5] the normalization is done separately for each year of data taking, thus allowing for year-by-year variations of the experimental conditions (see Section 2).

[6] the Λ_b^0 and $\bar{\Lambda}_b^0$ states are exceptionally distinguished here.

Table 2: Properties of the $\Lambda_b^0/\bar{\Lambda}_b^0$ Candidates

Λ_b^0 Decay	$\Lambda_c^{\pm}$ Decay	Mass (MeV/c^2)	Decay time (ps)	Mom. (GeV/c)	Fit prob.
$\bar{\Lambda}_c^- \pi^+$	$\bar{p}K^+\pi^-$	5584.1 ± 99.1	0.938 ± 0.117	30.8	0.365
$\Lambda_c^+ a_1^-$	$pK^-\pi^+$	5568.6 ± 58.3	0.564 ± 0.141	32.9	0.474
$\bar{\Lambda}_c^- a_1^+$	$\bar{p}K^+\pi^-$	5607.4 ± 40.7	0.430 ± 0.080	34.7	0.374
$\bar{\Lambda}_c^- a_1^+$	$\bar{p}K_S^0$	5630.9 ± 36.6	1.933 ± 0.161	30.9	0.034

for the parameter M_0. m_i and $x\sigma_i$ are the kinematically fitted mass values and their scaled-up errors for each individual event.

The central value determined from this ML fit is $M_0 = (5610 \pm 24)$ MeV/c^2. The error given is a statistical one.

Dominant contributions to the systematic error on the Λ_b^0 mass are provided by:

- The uncertainty in the mass scale due to a systematic mass shift and the uncertainty in mass determination. This is manifest also in the Signal MC data. Separate Gaussian fits to the kinematically fitted mass distributions of the three decay channels of interest (Figures 1.a, 1.c and 1.d) yield a peak which is shifted by ΔM from the generated value of 5624.0 MeV/c^2, and a width σ which is broadened by the scale factor x obtained from a ML fit to this individual channel. Then, quadratically adding ΔM and (σ/x) for each channel, and calculating a weighted mean (relative weights = 1:2:1) yields a Λ_b^0 mass error of 15.84 MeV/c^2.

- The error on the NMR magnetic field measurements in the detector. Using a scale factor of 0.9967 between the measured and nominal field, as indicated by NMR measurements, changes the Λ_b^0 mass by 2.2 MeV/c^2 [3].

Combining quadratically the two contributions from above, the final systematic error on the Λ_b^0 mass is determined to be 15.94 MeV/c^2.

The weighted mean mass of the Λ_b^0 baryon, as measured in this analysis from 4 event candidates, is $(5610 \pm 24_{stat} \pm 16_{syst})$ MeV/c^2.

5.4 Comparison with the Old Measurement

This new mass measurement is 58 MeV/c^2 (1.7σ) lower than the value reported earlier by DELPHI [4], which was based on data before re-processing and had found 4 candidates: three in the $\Lambda_c^+\pi^-$ and one in the $\Lambda_c^+ a_1^-$ decay channel.

When trying to follow the fate of those candidates in our new analysis we must keep in mind that the re-processing was done by new procedures for track search, therefore an exact identification of the "old" tracks is in general not possible. Moreover, better precision of track reconstruction contributed to modified kinematic parameters, and new procedures for proton and kaon identification by the RICH detectors have an impact on the results of our Λ_c^+ and Λ_b^0 selection.

The status of each of the old candidates, as listed in Table 1 of Ref [4], when subjected to the current analysis is reported below:

- **1^{st} candidate $(pK^-\pi^+)\pi^-$**

  This event has been discarded because of its b-tagging primary vertex probability of $9.5\% > 1\%$, the cut value (see Subsection 3.1). All relevant tracks can be identified when the event is analyzed despite this selection failure. The identification of the negative kaon, however, is downgraded to "loose". Moreover, the Λ_b^0 has $L/\delta L = 1.01$ before the kinematics fit and $\tau/\delta\tau = 0.46$ after it (see Section 4). This candidate fails selection on many grounds and is therefore discarded.

- **2^{nd} candidate $(pK^-\pi^+)\pi^-$**

  This event also has a b-tagging primary vertex probability $> 1\%$ (8.6%). Ignoring this cut, all relevant tracks are again identifiable, but the particle identification has completely changed: the proton is now identified as a "loose K^+" and the negative kaon as a "tight $\bar{p}$". Moreover, the Λ_c^+ has $L/\delta L = 0.34$ before the kinematics fit (see Subsection 3.2), and the Λ_b^0 has $\tau/\delta\tau = 1.30$ after it (see Section 4). Again there are strong reasons for discarding this candidate.

- **3^{rd} candidate $(pK^-\pi^+)\pi^-$**

  This event passed succesfully all but one selection criteria, and all relevant tracks are appropriately identified. However, the positive pion is now identified as a "tight p". Apart from this failure, the candidate would have been accepted, though with a lower fitted mass (see Table 3).

- **4^{th} candidate $(\bar{p}K^+\pi^-)a_1^+$**

  This event survived all selection criteria of the present analysis and is the 3^{rd} entry in Table 2 (see above, Subsection 5.3), but has now a significantly lower fitted mass (see Table 3).

In Table 3 the kinematically fitted Λ_b^0 masses, as re-calculated above[7], are compared with the values cited in the old analysis [4].

Table 3: Comparison of the Fitted Λ_b^0 Masses

Old #	Mass (MeV/c^2) cited in [4]	Mass (MeV/c^2) re-calculated	Fate of candidate
1	5662 ± 43	5641.9 ± 42.6	discarded
2	5676 ± 33	5660.6 ± 33.9	discarded
3	5623 ± 31	5607.7 ± 36.5	discarded
4	5693 ± 24	5607.4 ± 32.8	accepted

As can be seen, all masses are systematically shifted towards lower values. This is due to better alignment of the MVD and better track reconstruction. The effect is most remarkable for the old candidate #3 (which only marginally failed) and #4 (which survived), and is a strong support for the new Λ_b^0 mass measurement.

[7]the errors are without the uncertainty scale factor $x = 1.24$ (see Subsection 5.3).

6 Conclusions

A search for fully reconstructed Λ_b^0 baryons, performed in the decay channels

$\Lambda_b^0 \to \Lambda_c^+ \pi^-$	(1)	with subsequent	$\Lambda_c^+ \to p K^- \pi^+$	(a)
$\Lambda_b^0 \to \Lambda_c^+ a_1^-$	(2)		$\Lambda_c^+ \to p K_S^0$	(b)
			$\Lambda_c^+ \to \Lambda^0 \pi^+$	(c)

and $K_S^0 \to \pi^+\pi^-$, $\Lambda^0 \to p\pi^-$, $a_1^- \to \rho^0\pi^-$, $\rho^0 \to \pi^+\pi^-$ decays (and their charge-conjugate), has found 4 candidates: one $\bar{\Lambda}_b^0$ in the channel (1.a), two (one Λ_b^0 and one $\bar{\Lambda}_b^0$) in the channel (2.a), and one $\bar{\Lambda}_b^0$ in the channel (2.b). No candidates have been found in the $\Lambda_c^+ \to \Lambda^0\pi^+$ decay mode (c).

The estimated backgrounds for the channels (1) and (2) are 0.26 and 0.79 events, respectively. After background subtraction, the number of candidates observed in all investigated channels is estimated to be 3.0 ± 2.0 events.

The weighted mean Λ_b^0 mass of these four candidates is $(5610 \pm 24_{stat} \pm 16_{syst})$ MeV/c^2. It is consistent with the world average value of (5624 ± 9) MeV/c^2 from PDG'2000 [6].

Moreover, it is in excellent agreement with other measurements at LEP: $(5614 \pm 21 \pm 4)$ MeV/c^2 from ALEPH [5] in the $\Lambda_c^+\pi^-$ channel, and $(5612.1 \pm 21.2 \pm 6.0)$ MeV/c^2 recently determined by DELPHI [3] in the $J/\psi\Lambda^0$ channel.

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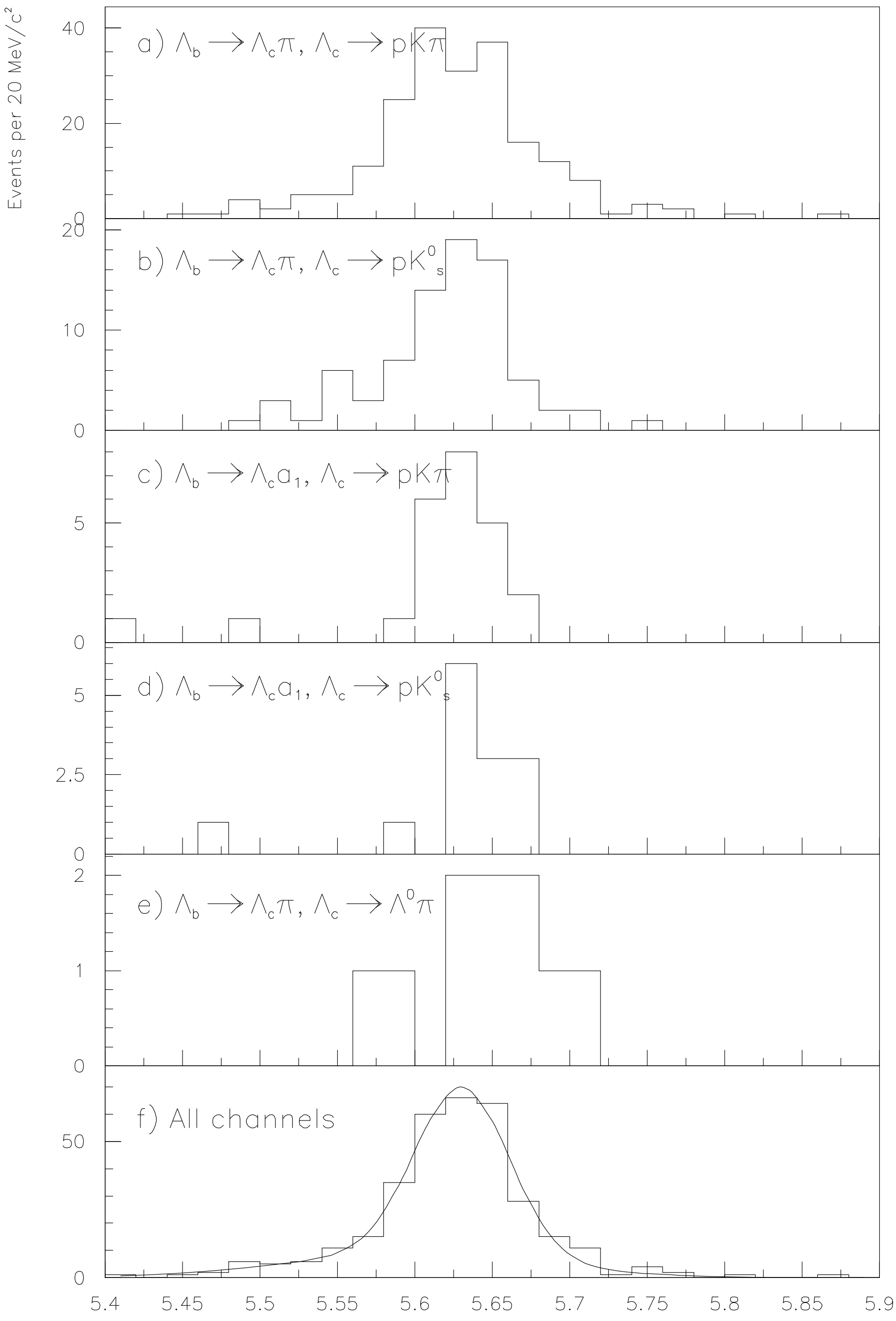

Figure 1: Kinematically fitted Λ_b^0 mass distributions of Signal Monte Carlo data: (a–e) separately for each decay channel, (f) for all channels combined and superposed with a double Gaussian fit.

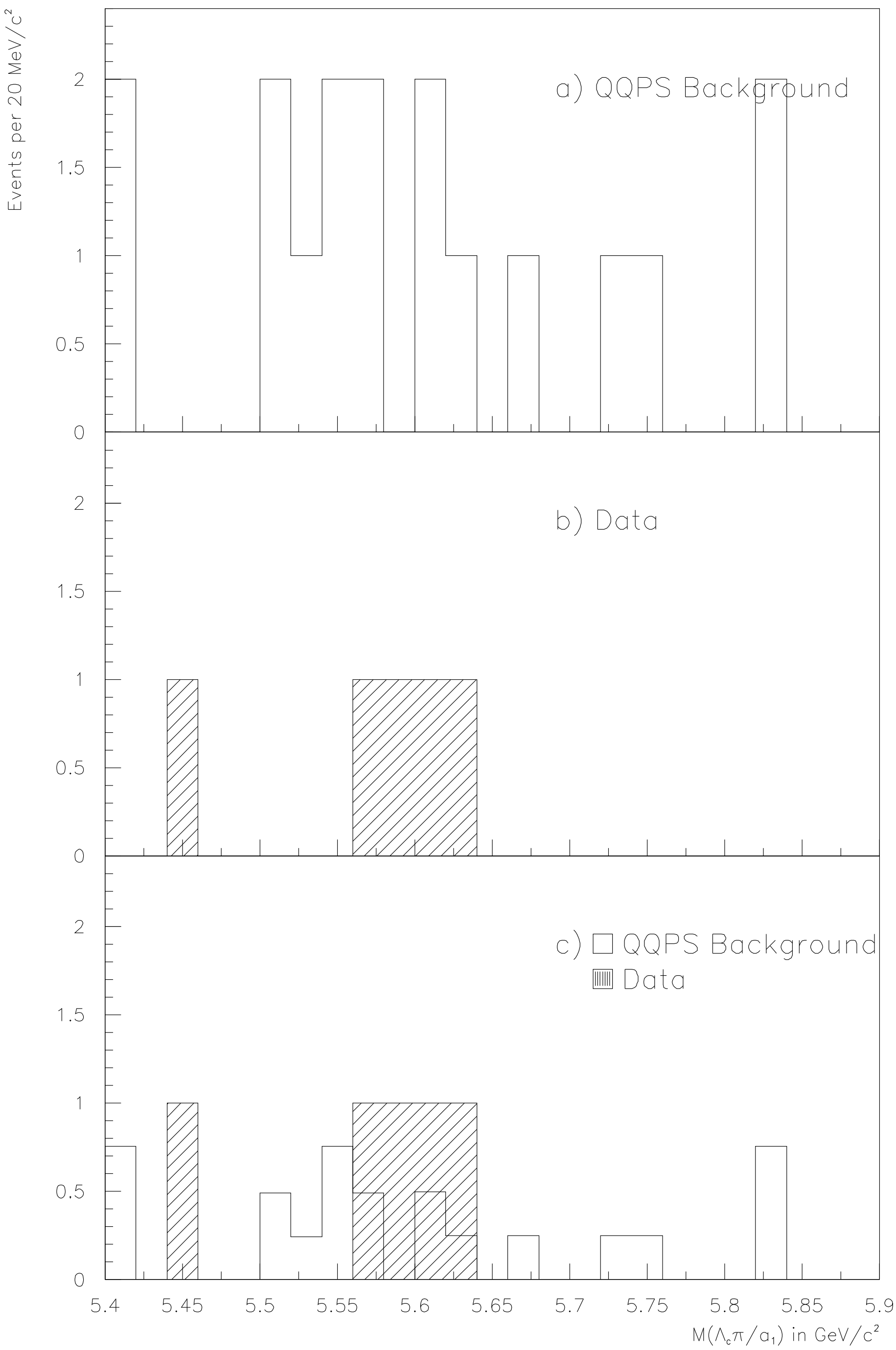

Figure 2: Kinematically fitted Λ_b^0 mass distributions for all decay channels of (a) Background Monte Carlo data, (b) Real Data, (c) Real Data (hatched) superposed on the normalized Background MC.

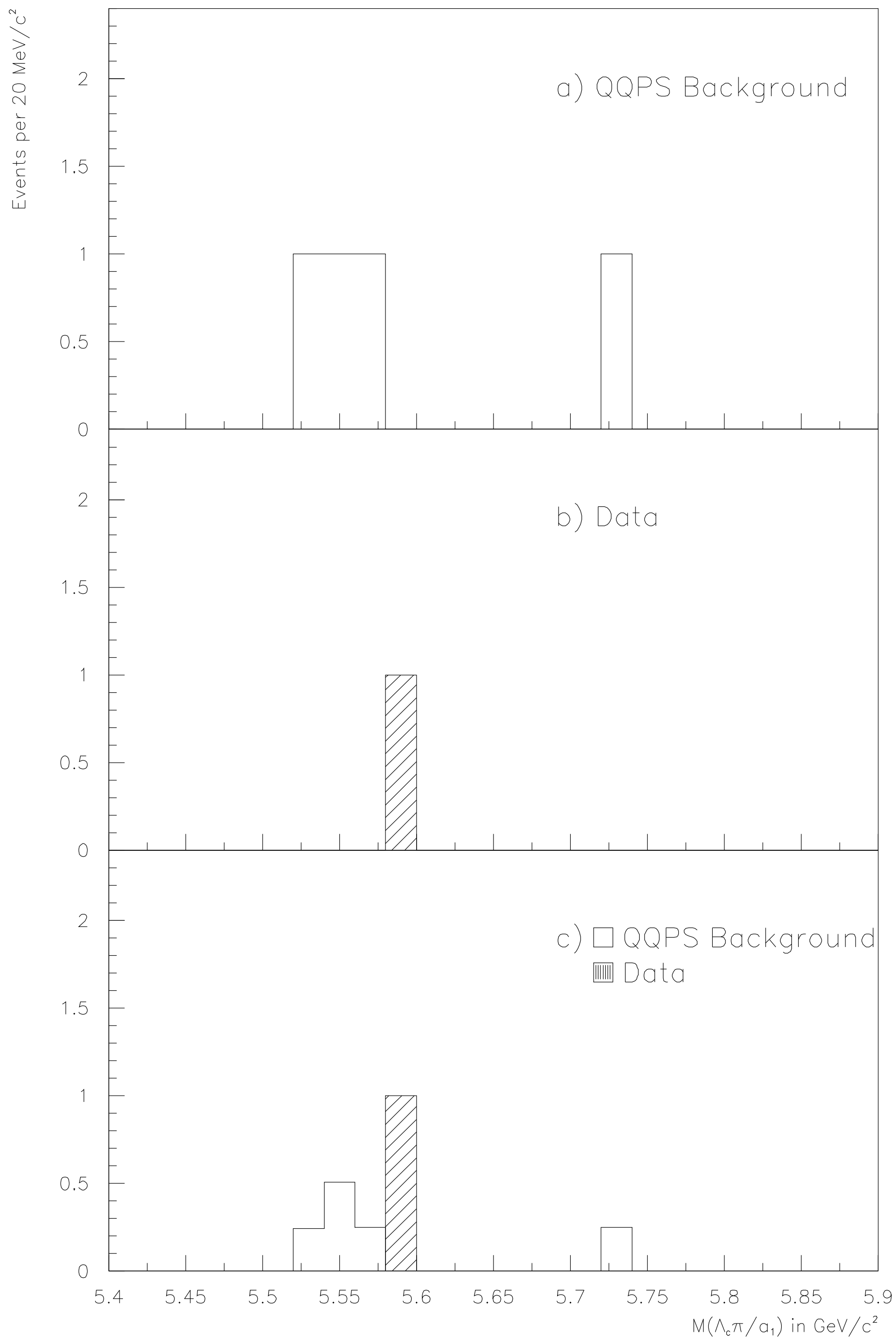

Figure 3: Kinematically fitted Λ_b^0 mass distributions for the decay channel $(pK^-\pi^+)\pi^-$ of (a) Background Monte Carlo data, (b) Real Data, (c) Real Data (hatched) superposed on the normalized Background MC.

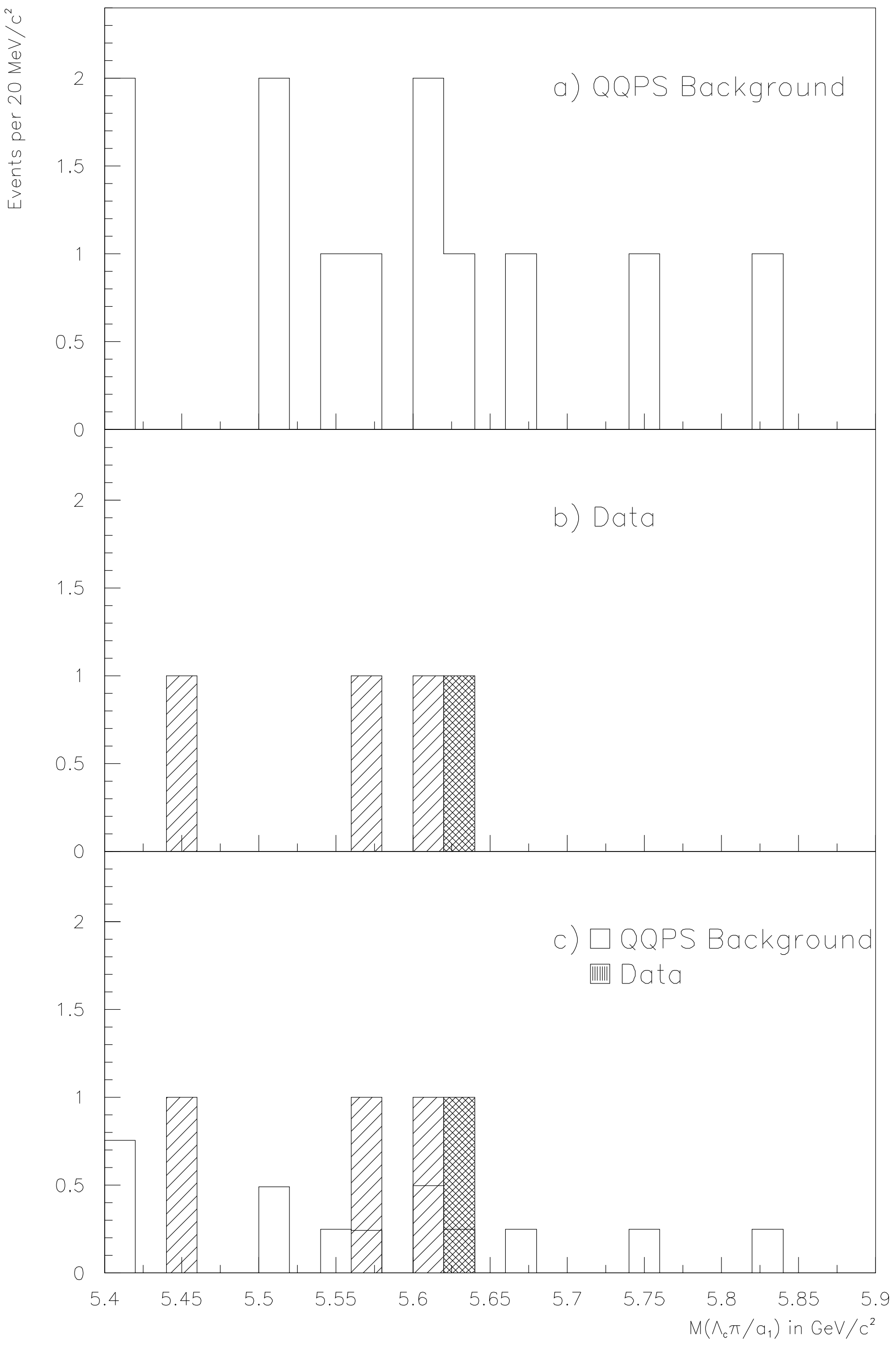

Figure 4: Kinematically fitted Λ_b^0 mass distributions for the decay channels $(pK^-\pi^+)a_1^-$ and $(pK_S^0)a_1^-$ of (a) Background Monte Carlo data (only $pK^-\pi^+$ contributing), (b) Real Data (singly and doubly hatched for $pK^-\pi^+$ and pK_S^0, respectively), (c) Real Data (hatched as above) superposed on the normalized Background MC.