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Production of Ξ_c^0 and Ξ_b in Z decays and lifetime measurement of Ξ_b.

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The charmed strange baryon Ξ_c^0 was searched for in the decay channel $\Xi_c^0 \to \Xi^- \pi^+$, and the beauty strange baryon Ξ_b in the inclusive channel $\Xi_b \to \Xi^- \ell^- \bar{\nu} X$, using the 3.5 million hadronic Z events collected by the DELPHI experiment in the years 1992–1995. The Ξ^- was reconstructed through the decay $\Xi^- \to \Lambda\pi^-$, using a constrained fit method for cascade decays. An iterative discriminant analysis was used for the Ξ_c^0 and Ξ_b selection. The production rates were measured to be $f_{\Xi_c^0} \times \mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+) = (4.7 \pm 1.4(stat.) \pm 1.1(syst.)) \times 10^{-4}$ per hadronic Z decay, and $\mathrm{BR}(b \to \Xi_b) \times \mathrm{BR}(\Xi_b \to \Xi^- \ell^- X) = (3.0 \pm 1.0(stat.) \pm 0.3(syst.)) \times 10^{-4}$ for each lepton species (electron or muon). The lifetime of the Ξ_b baryon was measured to be $\tau_{\Xi_b} = 1.45^{+0.55}_{-0.43}(stat.) \pm 0.13(syst.)$ ps. A combination with the previous DELPHI lifetime measurement gives $\tau_{\Xi_b} = 1.48^{+0.40}_{-0.31}(stat.) \pm 0.12(syst.)$ ps.

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1. Introduction

In this talk two heavy baryon analyses are presented. A first measurement of the production at the Z resonance of the charm strange baryon Ξ_c^0 is presented[1], using the exclusive decay channel $\Xi_c^0 \to \Xi^- \pi^+$. As a cross-check, the $\Xi(1530)^0$ resonance is reconstructed, through the decay channel $\Xi(1530)^0 \to \Xi^- \pi^+$. A measurement of the production and lifetime of the strange b-baryon Ξ_b is also presented, using the semileptonic decay channel, $\Xi_b \to \Xi^- \ell^- \bar{\nu} X$. [2] The Ξ_b baryon will decay to $X_c X \ell^- \bar{\nu}$ followed by $X_c \to \Xi^- X'$, where X_c is a charmed baryon which yields a Ξ^- hyperon. Due to the limited space only a brief summary can be given here. Full details can be found in [1]. Detailed descriptions of the DELPHI detector and its performance can be found in [2].

2. Production rate of the Ξ_c^0 and $\Xi(1530)^0$ baryons.

The charmed strange baryon Ξ_c^0 was searched for in the exclusive decay channel $\Xi_c^0 \to \Xi^- \pi^+$, where the Ξ^- was reconstructed through $\Xi^- \to \Lambda \pi^-$. All V^0 candidates, i.e. all pairs of oppositely charged particles, were considered Λ candidates. Only very soft Λ-cuts were used. The Λ candidate was combined with a pion candidate of appropriate charge, to form a Ξ^- candidate. If the invariant mass $M(\Lambda\pi)$ was less than 2.0 GeV$/c^2$ a constrained multivertex fit method [3] was applied to reconstruct Ξ^-. Each Ξ^- candidate was combined with yet another pion, which was required to have opposite charge to that of the π from the Λ decay, and not be tagged as a lepton. The ($\Xi^- \pi^+$)'s were used in two different analyses, Ξ_c^0 was reconstructed in the mass intervall $2.2 <$ M($\Xi^- \pi^+$)< 2.75, and $\Xi(1530)^0$ was reconstructed in the mass intervall M($\Xi^- \pi^+$)< 1.6. An iterative discriminant analysis, using a non-linear combination of variables [4], was applied for the Ξ_c^0 and the $\Xi(1530)^0$ selection. Two separate sets of simulated events was needed for each analysis, the training sample which was used to find the discriminant that gave maximum signal to background separation, and the analysis sample which was used to determine the efficiency. The Ξ_c^0 discriminant analysis applied to the Monte Carlo analysis sample, resulted in (498$\pm$28) Ξ_c^0 events, and a mass of $M(\Xi_c^0) = 2471 \pm 1$ MeV/c^2, in good agreement with the number of Ξ_c^0 events in the sample (494), and the simulated mass of 2473.0 MeV/c^2. The result obtained from applying the same analysis to the DELPHI 92–95 data sample is shown in Figure 1. The corresponding result for the $\Xi(1530)^0$ analysis is shown in Figure 2. An extended unbinned maximum likelihood fit, with a Gaussian function used to parametrize the signal, and a first order polynomial for the background, gave (45$\pm$13) Ξ_c^0 events, with a mass of 2460$\pm$8 MeV/c^2. The dominating systematic uncertainty came from the uncertainty in the c and b efficiencies, as well as the relative production of Ξ_c^0 in $c\bar{c}$ and $b\bar{b}$ events. The production rate per hadronic Z^0 decay was measured to be $f_{\Xi_c^0} \times \mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+) = (4.7 \pm 1.4(stat.) \pm 1.1(syst.)) \times 10^{-4}$. The $\Xi(1530)^0$ analysis was used as a crosscheck of the method. In the $\Xi(1530)^0$ analysis 599$\pm$57 events were found and the measured $\Xi(1530)^0$ production rate per hadronic Z^0 decay was $f_{\Xi(1530)^0} \times \mathrm{BR}(\Xi(1530)^0 \to \Xi^- \pi^+) = (4.5 \pm 0.5(stat.) \pm 0.6(syst.)) \times 10^{-3}$, in agreement with previous results [5, 6].

[1] Charge conjugated states are implied throughout this paper, unless otherwise stated.

[2] Here Ξ_b is used as a notation for the strange b-baryon states Ξ_b^- and Ξ_b^0.

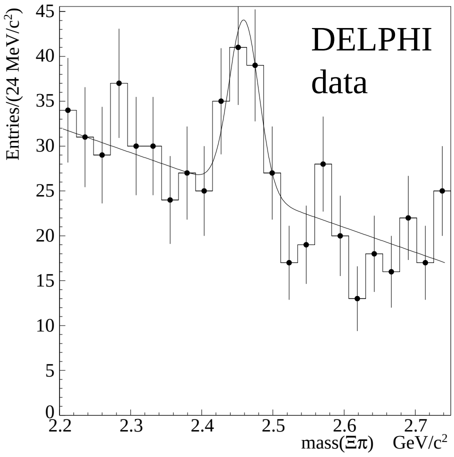

Figure 1: The resulting $\Xi^-\pi^+$ mass spectrum in the Ξ_c^0 mass intervall for the 92–95 data sample.

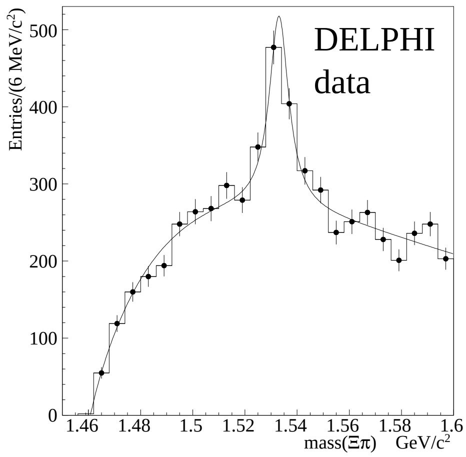

Figure 2: The resulting $\Xi^-\pi^+$ mass spectrum in the $\Xi(1530)^0$ mass intervall for the 92–95 data sample.

3. Production and lifetime of the Ξ_b baryon.

In the semileptonic decays of heavy hadrons the flavor of the spectator system of the initial state is transmitted to the final state. This property can be used to study Ξ_b baryons from the observation of $\Xi^\mp$ production accompanied by a lepton of same sign. The occurence of $\Xi^\mp-\ell^\mp$ pairs of same sign ('right sign') is then compared to that of opposite sign pairs, $\Xi^\mp-\ell^\pm$ ('wrong sign'). The Ξ^- was reconstructed in the same way as in the Ξ_c^0 analysis. If the constrained multivertex fit was succesful, the Ξ^- candidate was combined with a lepton candidate. Since the expected production rate of the Ξ_b is very small, loose cuts were applied on the Ξ^- and Λ candidates. The discriminant analysis method described above was used for the final Ξ_b selection. When applied to the Monte Carlo analysis sample, the discriminant method resulted in 34.2±5.9 right sign events, and 11.3±3.5 wrong sign events. The number of true Ξ_b events in the right sign Ξ mass peak was 25.6. The same analysis was applied to the DELPHI 92-95 data sample and the resulting invariant $(\Lambda\pi)$ mass distributions are shown in Figure 3. An extended unbinned maximum likelihood fit to the two distributions, with a gaussian for the Ξ-peak and a zero degree polynomial for the background, resulted in 28.3±5.8 right sign events, and 7.6±3.3 wrong sign events. The number of background events in the right sign Ξ mass peak was estimated from that in the wrong sign mass peak, which resulted in 20.7 ± 6.7 Ξ_b events found in the data. The dominating systematic uncertainty was the uncertainty of the contribution of Λ_b to the background. The measured Ξ_b production rate was $\mathrm{BR}(b\to\Xi_b)\times\mathrm{BR}(\Xi_b\to\Xi^-\ell^-X)=(3.0\pm1.0(stat.)\pm0.3(syst.))\times10^{-4}$ per lepton species, averaged for electrons and muons and assuming that the two channels have an equal contribution. The final sample of right sign events was also used to measure the Ξ_b lifetime. The secondary vertex from the Ξ_b semileptonic decay was obtained by use of the BSAURUS package [7], where it is calculated using tracks with a high probability to have originated from the decay chain of a weakly decaying b-hadron state. The sign of the decay length was determined by the direction of the $\Xi\ell$ momentum vector: the distance is positive if the secondary vertex is found beyond the primary vertex in this direction. The lifetime was determined by an unbinned maximum-likelihood fit to

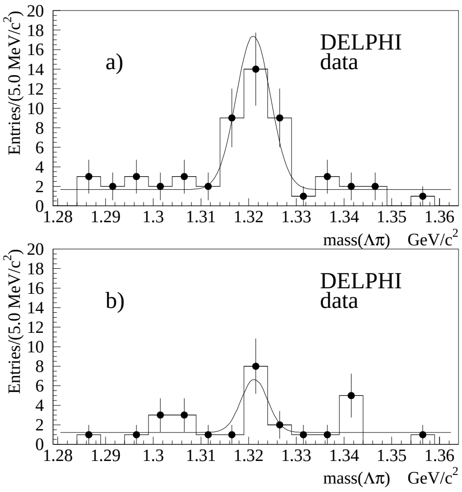

Figure 3: The resulting $(\Lambda\pi)$ mass distributions, of the 92–95 data sample.a) Right Sign events, b) Wrong Sign events.

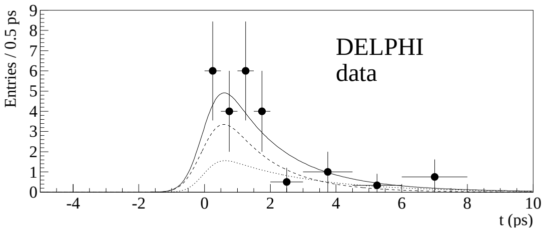

Figure 4: The result of the lifetime fit to the selected Ξ_b events in the data sample. The dotted curve is for the background, and the dashed line corresponds to the signal. The full line is the total.

the proper time distribution. The background was taken as the wrong-sign combinations plus the right-sign combinations outside the mass peak. Both signal and background lifetimes were fitted simultaneously. After the secondary vertex fit 29 events in the right-sign mass peak remained, the statistical overlap of one event with the previous DELPHI lifetime measurement was removed and the result of the lifetime fit on the DELPHI data is presented in Figure 4. The dominating systematic uncertainty came from the uncertainty on the Ξ_b purity. The Ξ_b lifetime was measured to be $\tau_{\Xi_b} = 1.45^{+0.55}_{-0.43}(stat.) \pm 0.13(syst.)$ ps. The measurement is in agreement with the previous measurements done by DELPHI and ALEPH [8]. A combination of the two DELPHI lifetime measurements gives $\tau_{\Xi_b} = 1.48^{+0.40}_{-0.31}(stat.) \pm 0.12(syst.)$ ps, using the method outlined in [9]. The systematics are uncorrelated.

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