The Observation of the Beauty Baryon Λ_b in the Decay Channel $\Lambda_b \rightarrow J/\psi\ \Lambda$ at the CERN Proton-Antiproton Collider

UA1 Collaboration
Presented by Andreas Morsch
Institut für Reine und Angewandte Kernphysik
Kiel, Germany

ABSTRACT

We summarize the recently published observation of a ~ 5σ signal for the beauty baryon Λ_b in the decay channel $\Lambda_b \rightarrow J/\psi\ \Lambda$ [1] and present the measured p_t-spectrum of the Λ_b candidates.

1. INTRODUCTION

The CERN proton-antiproton collider represents a copious source of $b\bar{b}$ - events. They are tagged with the UA1 detector in their semileptonic decay modes. The total $b\bar{b}$ cross section measured by UA1 at $\sqrt{s}$ = 630 GeV is ~20 μb and the measured p_t-spectrum is in excellent agreement with 3rd order QCD calculations [2].

Beauty decays of the form $B \rightarrow J/\psi\ X$, which have an inclusive branching ratio of ~ 1% [3], are especially suited for tagging and reconstructing beauty particles [4]. An earlier UA1 analysis has demonstrated that about 1/3 of the J/ψ 's originate from beauty decays [5].

To search for the beauty baryon Λ_b we have chosen the decay mode $\Lambda_b \rightarrow J/\psi\Lambda$. The Λ particle can be easily tagged through its long decay lenghth. A detailed description of this analysis has already been published [1]. Here we present the main features and results of the analysis. A discussion of the distribution $m(p\pi)$ vs $m(J/\psi,p\pi)$ and the p_t-spectrum of the Λ_b candidates has been added.

A description of the UA1 detector can be found in reference [6].

2. DATA SELECTION

Without entering into the details of the identification and selection procedures we list the **kinematical cuts** imposed on our data sample:

$$p_t(J/\psi) > 5\ \text{GeV}/c \text{ and } |y|(J/\psi) < 2$$

$$p_t(\Lambda) > 0.5\ \text{GeV}/c,$$

$$p_t(J/\psi,\Lambda) > 6\ \text{GeV}/c \text{ and } |y|(J/\psi,\Lambda) < 2,$$

where p_t denotes the transverse momentum and y the rapidity.

$$\Delta R^2(\Lambda, J/\psi) < 5$$

with $\Delta R^2 = \Delta\Phi^2 + \Delta\eta^2$, where Φ is the azimuthal angle around the beam direction, η the pseudorapidity and Δ denotes the difference between the Λ and J/ψ direction.

The $p_t(J/\psi)$ cut is motivated by the effective 2 GeV/c cut imposed on the muons by the calorimeter and and iron absorber. The cut on $p_t(\Lambda)$ reflects the fact that the Central Detector is inefficient for particles with momenta less than 0.1 GeV/c. The ΔR^2 cut rejects particles from the jet opposite to the J/ψ direction.

For the analysis we use as the $J/\psi \rightarrow \mu^+\mu^-$ signal region the interval $2.8 < m_{\mu\mu} < 3.4$ GeV/c^2 corresponding to $\pm 2\sigma$ of our mass resolution. The neighbouring intervals $2 < m_{\mu\mu} < 2.7$ and $3.5 < m_{\mu\mu} < 5$ GeV/c^2 are used as a pair of guard bands. The signal region contains 1596 events out of which 1372±39 are estimated to be real J/ψ's and the rest background, mainly from semileptonic b-decays. From the study of the topology of these events it was established that the J/ψ's originate mainly from two sources: 31±12 % from beauty decays and the rest from χ decays [2].

For the $\Lambda \rightarrow p\pi$ signal region we chose the interval $1.105 < m_{p\pi} < 1.125$ GeV/c^2 corresponding to 1.5 σ of the mass resolution. This interval contains for the events in the J/ψ signal region 74 Λ candidates with $\Delta R^2(\Lambda, J/\psi) < 5$. We estimate that 38±9 of these candidates are real Λ's and the rest combinatorial (pπ) background.

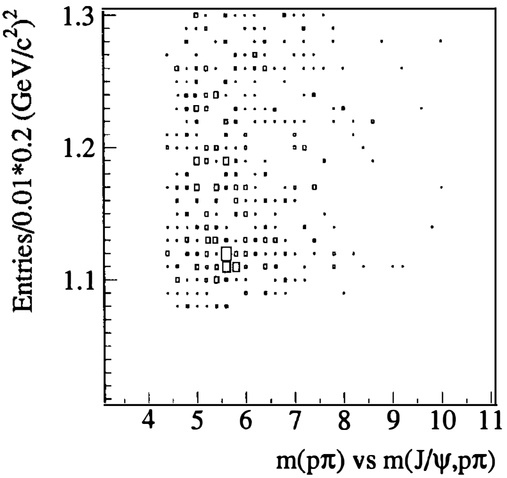


Fig. 1 *Box diagram of the two dimensional distribution m*(pπ) vs *m*(J/ψ,pπ). *The area of the boxes is proportional to the number of events.*

3. THE DECAY $\Lambda_b \rightarrow J/\psi \Lambda$

In order to yield an optimal mass resolution, we calculate from our data the effective mass difference *m*(J/ψ,Λ) - *m*(pπ). For plotting the mass spectra we add to the mass difference the PDG value of the J/ψ mass.

Fig. 1 shows in form of a box diagram the two dimensional distribution *m*(pπ) *vs m*(J/ψ,pπ). We observe a clear excess off events centered at the Λ mass and *m*(Λ,J/ψ) = 5.6 GeV/c^2. Fig. 2a shows the distribution in *m*(J/ψ, Λ)-*m*(J/ψ) for the Λ signal region quoted above. We perform a fit to the spectrum using a gaussian function and a background distribution obtained from a Monte Carlo (ISAJET) simulation. The resulting fit, superimposed in fig. 2a as a solid line, describes well the background and the signal. The fit yields (16 ±5) Λ_b events. The fitted width of the Gaussian is σ_m = (110 ±40) MeV/c^2 consistent with the expected measurement error of (80 ± 20) MeV/c^2. The fitted mass of the Λ_b is :

$$m\,(\Lambda_b) = 5640 \pm 50 \pm 30 \text{ MeV}/c^2\,,$$

where the first error is statistical and the second one the systematic. The measured mass is consistent with theoretical expectations which range from 5580 to 5640 MeV/c^2 [7]. The number of background events determined in the region $m(\Lambda_b) \pm 2\sigma_m$ is 9±1 and hence the statistical significance of our signal amounts to ~5 σ.

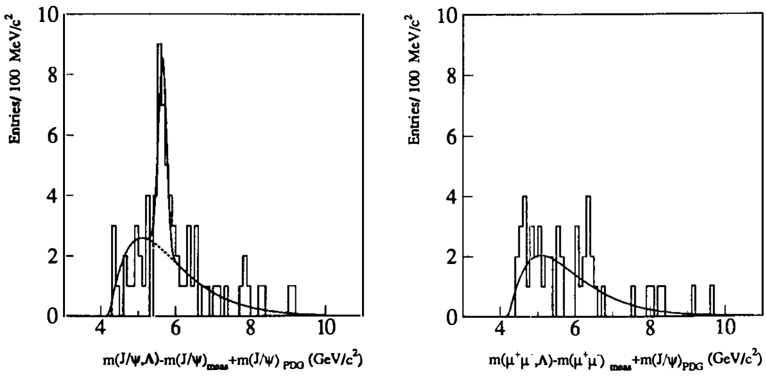
Fig. 2b shows the mass spectrum which we obtain if the same analysis as above is performed for the J/ψ guard bands. No peak is observed and the Monte Carlo distribution (solid line) is in good agreement with the data.

Using our efficiency and acceptance calculations [1] the observed 16±5 Λ_b events transform into a Λ_b production fraction times branching ratio:

$$f_{\Lambda_b} \bullet Br(\Lambda_b \rightarrow J/\psi\,\Lambda) = (1.8 \pm 1.1)\,10^{-3}$$

and assuming a production fraction of 10% we obtain:

$$Br(\Lambda_b \rightarrow J/\psi\,\Lambda) = (1.8 \pm 1.1)\,10^{-2}.$$



(a) (b)

Fig2 **(a)** *The invariant mass distribution in m*(J/ψ Λ)-*m*(J/ψ)+*m*(J/ψ)PDG. *A fit to the spectrum using a Gaussian function and the result of the Monte Carlo simulation for the background shape is shown as a solid line.* **(b)** *The corresponding distribution for the* J/ψ *guard bands. The solid line is the result of a Monte Carlo simulation.*

4. p_t - SPECTRA

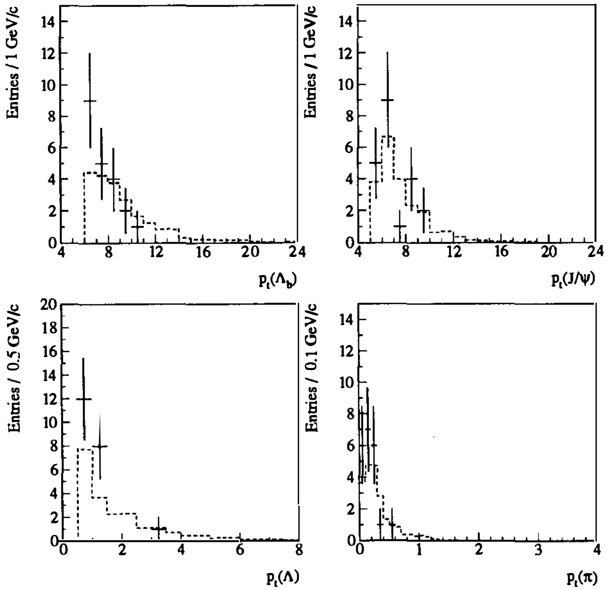


Fig. 3 *The measured p_t distributions of Λ_b, J/ψ, Λ and π's for events from the Λ_b signal region are compared to the Monte Carlo expectations (dashed lines).*

In fig. 3, we show the p_t distributions for the Λ_b, J/ψ, Λ and π candidates from the decay chain $\Lambda_b \to J/\psi\, \Lambda$; $\Lambda \to p\pi$ using the Λ_b signal region $5.5 < m(J/\psi,\Lambda) < 5.8$ GeV/c^2. They are compared with the result of the ISAJET Monte Carlo simulation for the Λ_b production and decay and backgrounds comprising particle misidentification, semileptonic beauty decays and fragmentation.

Comparing data with Monte Carlo, we observe an excess of events at the lower ends of the spectra. The $p_t(\pi)$ spectrum shows that 90 % of the pions have transverse momenta less than 300 MeV/c and our signal profits from the fact that the UA1 Central Detector has a sizeable acceptance for low momentum tracks.

We should point out that before we conclude on the observed p_t spectra we must have a careful look on the implementation of Λ_b production and decay in ISAJET. Furthermore, we have to take into account possible systematic influences from p_t-dependent acceptances, polarization effects and alternative Λ_b production mechanisms.

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