THE LEADING-BARYON EFFECT IN Λ_b^0 PRODUCTION
IN PROTON-PROTON INTERACTIONS AT $\sqrt{s} = 62$ GeV

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ABSTRACT

The measurement of the longitudinal momentum production distribution of the "beauty"-flavoured baryon Λ_b^0 , in the reaction $pp \rightarrow e^+ + \Lambda_b^0 + \text{anything}$ at $\sqrt{s} = 62$ GeV, shows clear evidence for a leading-baryon effect in Λ_b^0 production. A comparison with the data on Λ_c^+ , Λ_s^0 , and $\bar{\Lambda}_s^0$ production is also given.

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1. INTRODUCTION

We have recently reported evidence¹⁾ for open "beauty" production in high-energy proton-proton interactions at $\sqrt{s} = 62$ GeV total c.m. energy.

The purpose of the present paper is to report on a study to establish the way in which this new particle is produced. The relevant variable is $|x_L| = 2|p_L|/\sqrt{s}$, where p_L is the longitudinal momentum in the (pp) c.m. system and $\sqrt{s}$ is the total c.m. energy, already quoted.

The reaction investigated was:

$$pp \rightarrow \Lambda_b^0 + \overline{M}_b + \text{anything}$$
$$\begin{array}{l} \downarrow \\ \quad \downarrow e^+ + \text{anything} \\ \downarrow pD^0\pi^- \\ \quad \downarrow K^-\pi^+ \end{array} \tag{1}$$

2. EXPERIMENTAL SET-UP AND ANALYSIS OF DATA

The experiment was performed at the CERN Intersecting Storage Rings (ISR) using the Split-Field Magnet (SFM) facility.

The main feature of the experimental set-up was the positron "trigger", in the 90° region with respect to the incoming beams. It was based on Čerenkov counters and electromagnetic shower detectors (EMSDs) at the hardware level to reject the charged hadron background; and on a MWPC with analog read-out ("dE/dx" chamber) at the software level, to reject the neutral hadrons and gamma background.

The MWPC system, associated with the SFM, provided the momentum analysis of the charged secondaries.

Some particle identification was performed using a large-area time-of-flight (TOF) system.

A detailed description of the various elements of the apparatus can be found elsewhere²⁾).

The analysis¹⁾ was performed in order to search for the associated production of a Λ_b^0 decaying into $pD^0\pi^-$, plus an "antibeauty"-flavoured state decaying semileptonically into a positive electron.

The events were selected to have: i) a positron with transverse momentum greater than 800 MeV/c; ii) a positive particle with $|x_L|$ greater than 0.32 (proton); iii) a negative and a positive particle (K^- and π^+ , respectively), with invariant mass in the D^0 charmed meson region; iv) a negative particle (π^-).

The $[p(K^-\pi^+)_{D^0}\pi^-]$ combinations were required to have a rapidity $|y| > 1.4$.

Moreover, the "anything" in reaction (1) was required to have at least four charged particles, one of them being opposite to the triggering positron. For more details we refer the reader to Ref. 1.

In the $[p(K^-\pi^+)_{D^0}\pi^-]$ invariant mass spectrum, a clear signal was seen and it was interpreted as Λ_b^0 . The events in the invariant mass spectrum were divided into two classes: those inside the Λ_b^0 "peak" (IN), and the others 150 MeV below and 150 MeV above the "peak" (OUT). For these events the quantity $|x_L| = |\sum (p_L)_i| / \frac{1}{2} \sqrt{s}$ (where "i" extends to the four particles p, K^- , π^+ , π^-) was calculated.

Each particle had a momentum uncertainty below 30%.

The $|x_L|$ production distribution of the events in the Λ_b^0 peak (IN) was thus determined. The same $|x_L|$ distribution was worked out for the control region (OUT), as specified above.

The $\Delta N / \Delta |x_L|$ distributions for the IN and the OUT regions have been corrected for the apparatus acceptance, using single-track acceptance tables obtained via Monte Carlo simulation programs.

The OUT distribution was normalized to the number of background combinations under the peak.

3. RESULTS

Figure 1 shows the $|x_L|$ distribution of the Λ_b^0 , obtained by subtracting the OUT distribution from the IN one. The full line is the best fit to experimental data, taking, as functional dependence for the $|x_L|$ production distribution

$$\Delta N / \Delta |x_L| \propto (1 - |x_L|)^\alpha .$$

The result of the best fit is

$$\alpha = 0.87 \pm 1.26 . \quad (2)$$

The value of this exponent is clear evidence that the Λ_b^0 is produced following a "leading" mechanism.

We have already reported³⁾ evidence for the same effect in Λ_c^+ charmed baryon production in (pp) collisions at the same energy. In Fig. 2 we compare the production distributions of Λ_b^0 , with Λ_c^+ , Λ_s^0 , and $\bar{\Lambda}_s^0$ ⁴⁾. The quantities reported are the following ratios:

$$\left(\frac{\Delta N}{\Delta |x_L|} \right)_{\Lambda_b^0} / \left(\frac{\Delta N}{\Delta |x_L|} \right)_{\Lambda_c^+} = R_{b/c} ,$$

$$\left(\frac{\Delta N}{\Delta |x_L|} \right)_{\Lambda_b^0} / \left(\frac{\Delta N}{\Delta |x_L|} \right)_{\Lambda_s^0} = R_{b/s} ,$$

$$\left(\frac{\Delta N}{\Delta |x_L|} \right)_{\Lambda_b^0} / \left(\frac{\Delta N}{\Delta |x_L|} \right)_{\bar{\Lambda}_s^0} = R_{b/\bar{s}} ,$$

as a function of $|x_L|$. As the main point is the shape of these quantities versus $|x_L|$, only arbitrary units are reported in the ordinate.

The sharp increase in the ratio $R_{b/\bar{s}}$ together with the flatness of the ratios $R_{b/s}$ and $R_{b/c}$, clearly indicates that similar leading-baryon effects are present in Λ_b^0 , Λ_c^+ , and Λ_s^0 production mechanisms. This can be understood as follows.

The differently flavoured baryonic states, Λ_s^0 , Λ_c^+ , and Λ_b^0 , carry two of the original quarks of the incident proton, as illustrated below:

$$[(ud)u] \equiv p$$

$$[(ud)s] \equiv \Lambda_s^0$$

$$[(ud)c] \equiv \Lambda_c^+$$

$$[(ud)b] \equiv \Lambda_b^0 .$$

Despite the large mass difference between the strange (s), the charm (c), and the beauty (b) quarks, the production of these differently flavoured baryonic states shows the same "leading" effect.

This is not a peculiar property which shows up only in these processes. We report elsewhere⁵⁾ a world analysis of hadronic interactions, where the leading hadron phenomenon is shown to have a universal nature.

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Figure captions

- Fig. 1 : Experimental $|x_L|$ distribution of Λ_b^0 events. The full line is the best fit.
- Fig. 2 : Comparison of the production distributions, versus $|x_L|$, of Λ_b^0 with respect to Λ_c^+ (a), Λ_s^0 (b), and $\overline{\Lambda}_s^0$ (c).

Fig. 1

Fig. 2