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The Leading-Baryon Effect in Λ_b^0 Production in Proton-Proton Interactions at $\sqrt{s} = 62$ GeV.

M. BASILE, G. BONVICINI, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALI, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI

CERN - Geneva, Switzerland
Istituto di Fisica dell'Università - Bologna, Italia
Istituto Nazionale di Fisica Nucleare - Sezione di Bologna, Italia
Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali di Frascati, Italia
Istituto di Fisica dell'Università - Perugia, Italia

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Summary. — The measurement of the longitudinal-momentum production distribution of the « beauty »-flavoured baryon Λ_b^0, in the reaction $pp \to e^+ + \Lambda_b^0 +$ 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 $\overline{\Lambda_s^0}$ production is also given.

1. – Introduction.

We have recently reported evidence (1) 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.

(1) M. BASILE, G. BONVICINI, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALI, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Lett. Nuovo Cimento*, **31**, 97 (1981).

The reaction investigated was

$$
\begin{array}{ll}
 & \mathrm{pp} \to \Lambda_b^0 + \bar{\mathrm{M}}_b + \text{anything} \\
 & \qquad\qquad\quad \hookrightarrow \mathrm{e}^+ + \text{anything} \\
(1) & \qquad\quad \hookrightarrow \mathrm{pD}^0\pi^- \\
 & \qquad\qquad\quad \hookrightarrow \mathrm{K}^-\pi^+
\end{array}
$$

2. – Experimental set-up and analysis of the 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 (« $\mathrm{d}E/\mathrm{d}x$ » 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 elsewhere [2].

The analysis [1] was performed in order to search for the associated production of a Λ_b^0 decaying into $\mathrm{pD}^0\pi^-$, plus an « antibeauty »-flavoured state decaying semi-leptonically 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^-).

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[2] R. Bouclier, R. C. A. Brown, E. Chesi, L. Dumps, H. G. Fischer, P. G. Innocenti, G. Maurin, A. Minten, L. Naumann, F. Piuz and O. Ullaland: *Nucl. Instrum. Methods*, **125**, 19 (1975); M. Basile, G. Cara Romeo, L. Cifarelli, A. Contin, G. D'Ali, P. Giusti, T. Massam, F. Palmonari, G. Sartorelli, G. Valenti and A. Zichichi: *Nucl. Instrum. Methods*, **163**, 93 (1979); M. Basile, G. Cara Romeo, L. Cifarelli, A. Contin, G. D'Ali, P. Di Cesare, B. Esposito, L. Favale, P. Giusti, T. Massam, F. Palmonari, G. Sartorelli, G. Valenti and A. Zichichi: *Nucl. Instrum. Methods*, **179**, 477 (1981); H. Frehse, F. Lapique, M. Panter and F. Piuz: *Nucl. Instrum. Methods*, **156**, 87 (1978); H. Frehse, M. Heiden, M. Panter and G. Piuz: *Nucl. Instrum. Methods*, **156**, 97 (1978).

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

$$\alpha = 0.87 \pm 1.26 . \tag{2}$$

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

We have already reported (3) 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 $\overline{\Lambda_s^0}$ (4). The quantities

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(3) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALI, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Lett. Nuovo Cimento*, **30**, 487 (1981).

(4) S. ERHAN, W. LOCKMAN, T. MEYER, J. RANDER, P. SCHLEIN, R. WEBB and J. ZSEMBERY: *Phys. Lett. B*, **85**, 447 (1979).

reported are the following ratios:

$$\left(\frac{\Delta N}{\Delta|x_{\mathrm{L}}|}\right)_{\Lambda_{\mathrm{b}}^0} \Big/ \left(\frac{\Delta N}{\Delta|x_{\mathrm{L}}|}\right)_{\Lambda_{\mathrm{c}}^+} = R_{\mathrm{b/c}}$$

$$\left(\frac{\Delta N}{\Delta|x_{\mathrm{L}}|}\right)_{\Lambda_{\mathrm{b}}^0} \Big/ \left(\frac{\Delta N}{\Delta|x_{\mathrm{L}}|}\right)_{\Lambda_{\mathrm{s}}^0} = R_{\mathrm{b/s}}\,,$$

$$\left(\frac{\Delta N}{\Delta|x_{\mathrm{L}}|}\right)_{\Lambda_{\mathrm{b}}^0} \Big/ \left(\frac{\Delta N}{\Delta|x_{\mathrm{L}}|}\right)_{\overline{\Lambda_{\mathrm{s}}^0}} = R_{\mathrm{b}\bar{\mathrm{s}}}\,,$$

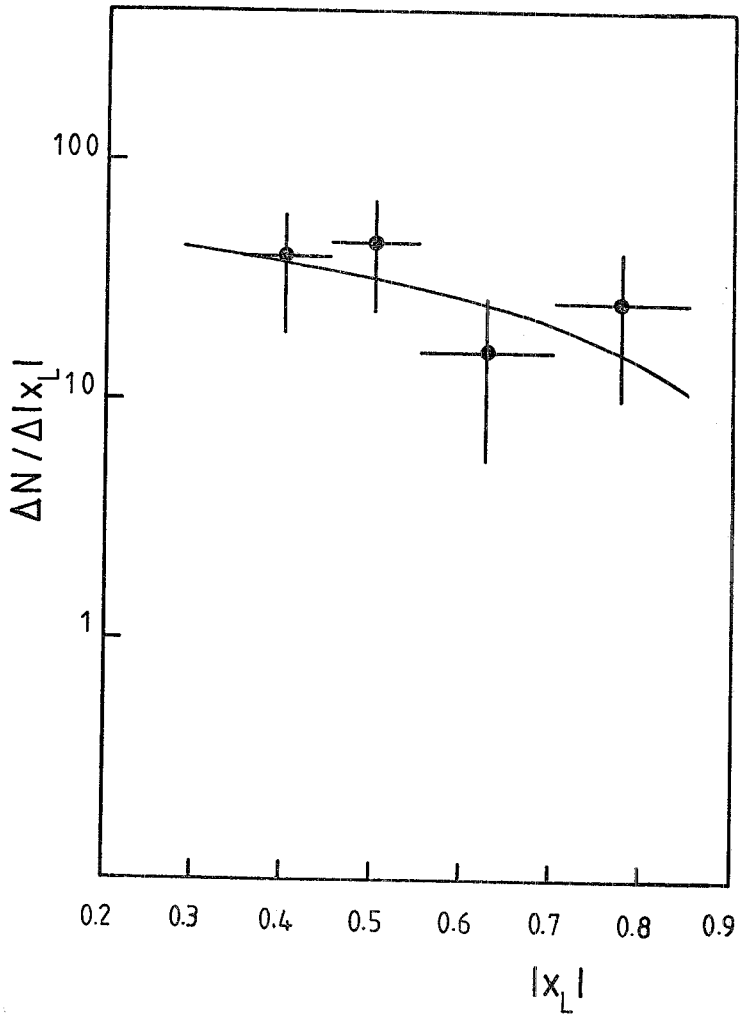

Fig. 1. – Experimental $|x_{\mathrm{L}}|$ distribution of Λ_{b}^0 events. The full line is the best fit.

as a function of $|x_{\mathrm{L}}|$. As the main point is the shape of these quantities *vs.* $|x_{\mathrm{L}}|$, only arbitrary units are reported in the ordinate.

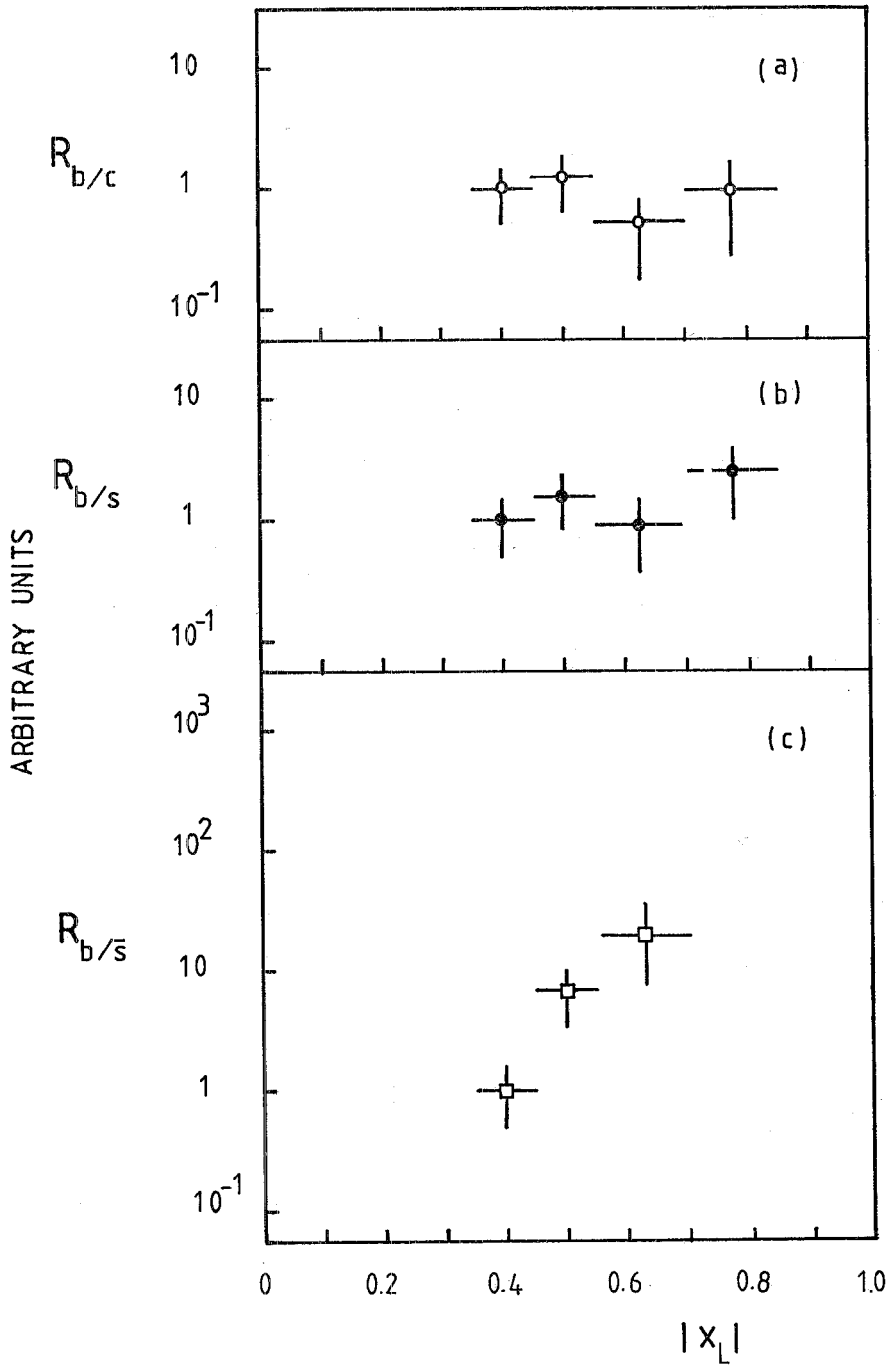

Fig. 2. – Comparison of the production distributions, *vs.* $|x_L|$, of Λ_b^0 with respect to Λ_c^+ (*a*), Λ_s^0 (*b*) and $\overline{\Lambda_s^0}$ (*c*).

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:

$$[(ud)u] \equiv p\,, \quad [(ud)s] \equiv \Lambda_s^0\,, \quad [(ud)c] \equiv \Lambda_c^+\,, \quad [(ud)b] \equiv \Lambda_b^0\,.$$

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 elsewhere [5] a world analysis of hadronic interactions, where the leading-hadron phenomenon is shown to have a universal nature.

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[5] M. Basile, G. Cara Romeo, L. Cifarelli, A. Contin, G. D'Ali, P. Di Cesare, B. Esposito, P. Giusti, T. Massam, R. Nania, F. Palmonari, V. Rossi, G. Sartorelli, M. Spinetti, G. Susinno, G. Valenti, L. Votano and A. Zichichi: *The leading-particle effects in hadron physics*, preprint CERN-EP/81-86 (August 1981), submitted to *Nuovo Cimento*.

● RIASSUNTO

La misura della distribuzione del momento longitudinale del barione con « beauty », Λ_b^0, prodotto nella reazione $pp \to e^+ + \Lambda_b^0 +$ anything all'energia $\sqrt{s} = 62$ GeV, mostra evidenza per l'esistenza di un effetto di « leading baryon » nella produzione di Λ_b^0. I dati sono inoltre confrontati con dati sulla produzione di Λ_c^+, Λ_s^0 e $\overline{\Lambda_s^0}$.

Эффект лидирующего бариона при рождении Λ_b^0 в протон-протонных взаимодействиях при $\sqrt{s} = 62$ ГэВ.

Резюме (*). — Результаты измерений распределения продольного импульса при рождении бариона Λ_b^0 в реакции $pp \to e^+ + \Lambda_b^0 +$ что-нибудь при $\sqrt{s} = 62$ ГэВ обнаруживают заметное влияние лидирующего бариона при рождении Λ_b^0. Проводится сравнение с данными по Λ_c^+, Λ_s^0 и $\overline{\Lambda_s^0}$ рождению.

(*) *Переведено редакцией.*