Hyperon Production Asymmetries in 500 GeV/c Pion Nucleus Interactions

by

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ABSTRACT

We present a preliminary study from Fermilab experiment E791 of $\Lambda^0/\overline{\Lambda}^0$, Ξ^-/Ξ^+ and Ω^-/Ω^+ production asymmetries from π^- nucleus interactions at 500 Gev/c .The production asymmetries for these particles are studied as a function of x_F and p_T^2. We observed an asymmetry in the target fragmentation region for Λ^0's larger than that for Ξ's, suggesting diquark effects. The asymmetry for Ω's is significatively smaller than for the other two hyperons consistent with the fact that Ω's do not share valence quarks with either the pion or the target particle. In the beam fragmentation region, the asymmetry tends to 0.1 for both Λ^0's and Ξ's. The asymmetries vs p_T^2 are approximately constant for the three strange baryons under study.

Key-words: Strange baryons; Baryon production; Baryon asymmetries.

Leading particle effects in charm hadron production, which are manifest as an enhancement in the production rate of particles which share valence quarks over that of particles with no valence quarks in common with the initial hadrons, have been extensively studied in the recent years from both the experimental and theoretical point of view. The same type of leading effects are expected to occur in light hadron production. Indeed, there is some evidence of asymmetries in $\Lambda^0/\overline{\Lambda}^0$ production in π^-Cu interactions at 230 GeV/c [1] and in $\Lambda^0/\overline{\Lambda}^0$ and Ξ^-/Ξ^+ production in 250 GeV/c π^-p interactions [2]. Some additional evidence for $\Lambda^0/\overline{\Lambda}^0$ asymmetry can be found in Ref. 3, but in general light hadron production asymmetries in π^-p interactions are not systematically studied.

As a byproduct of our charm program in Fermilab Experiment E791 we collected a large sample of $\Lambda^0/\overline{\Lambda}^0$, Ξ^-/Ξ^+ and Ω^-/Ω^+ which was used to measure the particle/anti-particle production asymmetries reported in this paper. The x_F range covered by our experiment is $-0.12 \leq x_F \leq 0.12$ allowing for the study of baryon/anti-baryon production asymmetries in the target ($x_F < 0$) and beam ($x_F > 0$) fragmentation regions. *A priori*, strong differences are expected for the asymmetries observed in each region where there is a different content of valence quarks in the produced particles relative to the anti-particles with respect to the target and beam hadrons. Thus a growing asymmetry with $|x_F|$ is expected in $\Lambda^0/\overline{\Lambda}^0$ production in the target fragmentation region. A smaller or no asymmetry is expected in the beam fragmentation region, in which both Λ^0 and $\overline{\Lambda}^0$ share one valence quark with the pion. For Ξ^-/Ξ^+ production a growing asymmetry with $|x_F|$ is expected in both regions since the Ξ^- shares one valence quark with the π^- as well as with the target particles (p and n) whereas the Ξ^+ share none. A zero asymmetry is expected for Ω^-/Ω^+ which have no valence quarks in common with either the target or the beam.

In the E791 experiment, data were recorded from 500 GeV/c π^- interactions in five thin foils (one platinum and four diamond) separated by gaps of 1.34 to 1.39 cm. The E791 spectrometer [4] is an upgrade of apparatus used in Fermilab charm experiments E516, E691 and E769. It is a large-acceptance, two-magnet spectrometer with eight planes of multiwire proportional chambers (MPWPC) and six planes of silicon microstrip detectors (SMD) for beam tracking. Downstream of the target are a 17-plane SMD system for track and vertex reconstruction, 35 drift chamber planes, two MWPC's, two multicell threshold Cherenkov counters, electromagnetic and hadronic calorimeters and a muon detector. An important element of the experiment was its extremely fast data acquisition system [5] which was combined with a very open trigger to record a data sample of 20 x 10^9 interactions.

Λ^0's were studied via their $p\pi^-$ decay mode. The distance of closest approach between the proton and π^- tracks must be less that 0.7 cm to be considered as candidates for Λ^0 decay and the candidate Λ^0 should have an invariant mass between 1.101 and 1.127 GeV/c^2. In addition, the ratio of the momentum of the proton to the pion is required to be larger than 2.5. The reconstructed Λ^0 decay vertex formed by the two tracks is required to be downstream of the last target. In order to avoid Λ^0's coming from Ξ decay,

candidates must have an impact parameter with respect to the primary vertex less than 0.3 cm for Λ^0's decaying within the first 20 cm and 0.4 cm for Λ^0's decaying downstream of 20 cm from the target. The reconstructed mass distribution of the obtained sample was fitted using a binned maximum likelihood with a Gaussian plus a linear background. We obtained $2{,}571{,}662 \pm 3{,}057$ Λ^0's and $1{,}668{,}950 \pm 2{,}627$ $\overline{\Lambda}^0$'s, from approximately 6% of the total data sample recorded in the experiment.

Ξ's are selected via the decay mode $\Xi \rightarrow \Lambda^0 \pi$ and at the same time Ω's are selected in the channel $\Omega \rightarrow \Lambda^0 K$. Starting with candidate Λ^0's we add a third track as a possible pion/kaon daughter. The cuts applied to the Λ^0 are the same quoted above except for the impact parameter cut, which is not applied in this case, and the third track must meet the following requirements: the track cannot be one of those that made the Λ^0, the invariant mass of the candidate Ξ (calculated from the mass of the Λ^0 and the net momentum of the two decays tracks plus the third track) must be between 1.290 and 1.350 GeV/c^2 for Ξ's and 1.642 and 1.702 GeV/c^2 for the Ω's. In addition, Ξ's and Ω's decaying upstream of the SMD and downstream of the Λ^0 are not allowed and the efficiency of SMD's for the candidate hyperon track must be larger than 0.75. An additional cut is applied for the third track: the Cherenkov probability of this track be a kaon mut be larger than 0.13 if its momentum is smaller than 40 GeV/c and larger than 0.018 if its momentum is larger than 40 GeV/c. As with the lambda sample, we fitted the cascade and omega samples using maximum likelihood with a Gaussian plus a linear background. From approximately 2/3 of the total E791 data sample we found $570{,}535 \pm 1{,}386$ Ξ^-; $401{,}156 \pm 1{,}166$ Ξ^+; $7{,}401 \pm 132$ Ω^- and $6{,}598 \pm 97$ Ω^+ after background substraction.

For each x_F and p_T^2 bin we define an asymmetry parameter A as

$$A\left(B/\overline{B}\right) \equiv \frac{N_B - N_{\overline{B}}}{N_B + N_{\overline{B}}} , \tag{1}$$

where N_B ($N_{\overline{B}}$) is the number of baryons (anti-baryons) in the bin. Monte Carlo studies done with PYTHIA [6] for Λ^0 and $\overline{\Lambda}^0$ have shown that efficiencies for both particle and anti-particle are the same therefore no corrections are nedeed in this case. For Ξ's and Ω's we are finishing the process of MC generation in order to study efficiency. The obtained asymmetries are shown as functions of x_F and p_T^2 in Fig. 1 for $\Lambda^0/\overline{\Lambda}^0$, Ξ^-/Ξ^+ and Ω^-/Ω^+. The total asymmetries measured in the interval $-0.12 \leq x_F \leq 0.12$ and in the backward and forward x_F regions are shown in Table 1.

In the backward x_F region we observe an asymmetry growing with $|x_F|$ for both Λ^0's and Ξ's and an approximately constant and small asymetry for Ω's. As can be seen in the figures, the asymmetry in the backward region is higher as more valence quarks are shared between the produced particle and protons and neutrons in the target. The higher asymmetry observed for the Λ^0's may be due to the ud diquark shared by the produced Λ^0 and the protons and neutrons in the target. In the forward region the asymmetry for both Λ^0's and Ξ's is approximately constant. For the Ξ^-/Ξ^+ the observed asymmetry is compatible with the fact that the Ξ^- shares one valence quark with the incident π^- whereas the Ξ^+ has no valence quarks in common with the π^-, so some leading effect must be present.

Table 1: Hyperon asymmetries. Only statistical errors are shown.

	$-0.12 \leq x_F \leq 0.12$	$-0.12 < x_F < 0$	$0 \leq x_F < 0.12$
$A(\Lambda^0/\overline{\Lambda}^0)$	0.213 ± 0.001	0.246 ± 0.001	0.138 ± 0.002
$A(\Xi^-/\Xi^+)$	0.174 ± 0.002	0.186 ± 0.002	0.131 ± 0.004
$A(\Omega^-/\Omega^+)$	0.057 ± 0.012	0.058 ± 0.015	0.056 ± 0.017

The asymmetry measured for the $\Lambda^0/\overline{\Lambda}^0$ in the forward region can not be explained by a leading-particle effect because both Λ^0 and $\overline{\Lambda}^0$ have one valence quark in common with the pion.

For the three strange baryons we observe an approximately flat asymmetry, of the order of 0.2 for Λ's and Ξ's and very small for Ω's, in the complete p_T^2 interval studied.

Acknowledgments

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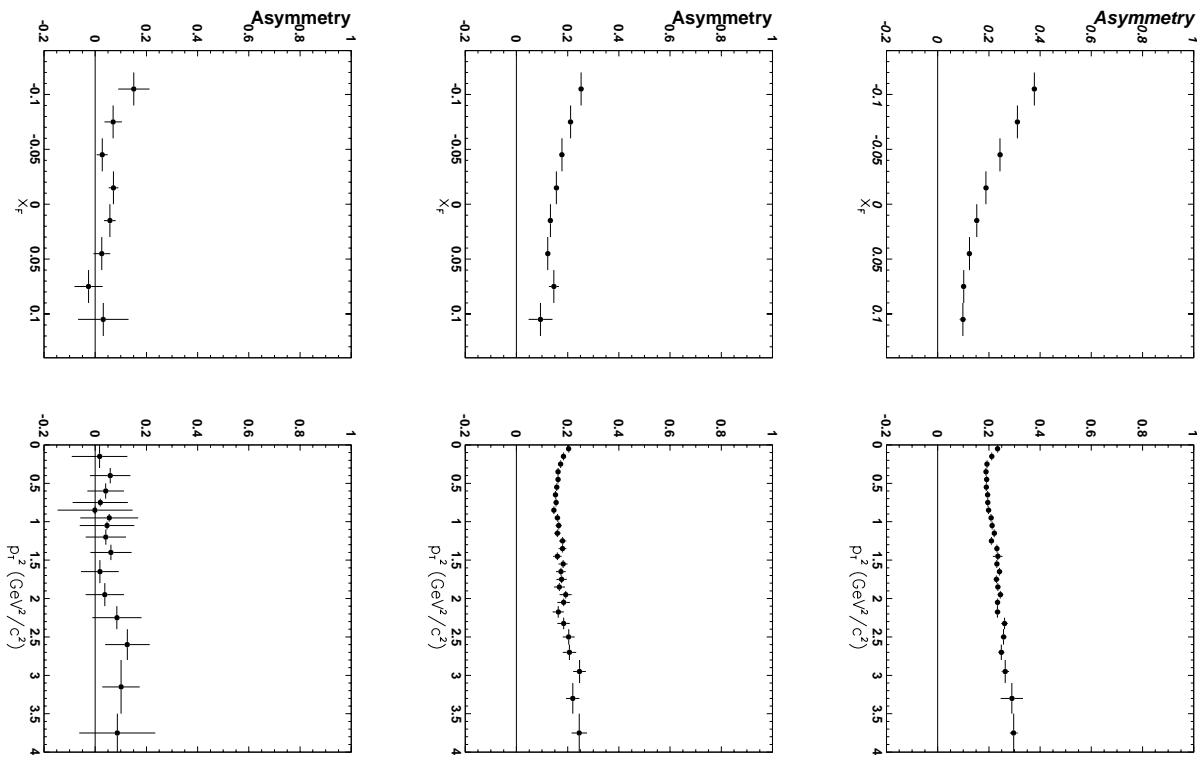
Figure 1: Preliminary results for 6% of the E791 data for Λ and 2/3 for Ξ and Ω. Statistical errors only. $\Lambda^0/\overline{\Lambda}^0$ (top), $\Xi^-/\overline{\Xi}^+$ (middle) and $\Omega^-/\overline{\Omega}^+$ (bottom) asymmetries $vs.$ x_F (left) and p_T^2 (right).