Baryon and antibaryon production in hadron-hadron and hadron-nucleus interactions

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Cascade baryon and anti-baryon yields have been measured in $p+p$ and $p+A$ collisions. After extraction of the projectile component in $p+A$ interactions close similarities with $A+A$ collisions concerning the nuclear enhancement factors are observed. In addition the importance of effects related to projectile isospin and to net baryon stopping is pointed out.

1. Introduction

The NA49 experiment is unique in measuring $\Xi^-$ and $\Xi^+$ production over the full range of hadronic interactions, from $p+p$ collisions via centrality controlled $p+Pb$ to central $Pb+Pb$ reactions. This offers interesting possibilities of comparison, in particular concerning the nuclear enhancement factors in $p+A$ and $A+A$ collisions. The extraction of these factors is straightforward for the symmetric $p+p$ and $Pb+Pb$ interactions, however the interpretation of central rapidity yields from $p+A$ collision poses certain problems of normalization or, rather, separation of projectile and target contributions. In addition, the effects of projectile and target isospin and of net baryon stopping have to be properly addressed.

2. A two component picture of hadronic interactions

Invoking the absence of charge and flavor exchange at SPS energies one may postulate hadronic factorization in the sense of splitting particle production into two independent components, one from the target and one from the projectile, fig.\textsuperscript{1}. This picture has been verified \cite{1} for net proton production both for $p+p$ and $p+Pb$ interactions, using pion beams. It has been shown that particle densities in $p+Pb$ collisions at central rapidity are built up from a target part which is proportional to the number of projectile collisions, $\nu$, and a projectile part which carries the imprint of the hadron which has undergone $\nu$ collisions. The presence of nuclear enhancement in $p+A$ collisions can accordingly be analyzed along two different lines: either this enhancement $E$ is equally distributed to target and projectile components ("wounded nucleon" model),

$$
\left( \frac{dn}{dX_F} \right)_{X_F=0}^{P+A} = \left[ \frac{\nu \cdot \alpha}{2} \cdot E(\nu) + \frac{1}{2} \cdot E(\nu) \right] \cdot \left( \frac{dn}{dX_F} \right)_{X_F=0}^{P+P} (1)
$$

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or it is fully credited to the projectile contribution,

$$\left( \frac{dn}{dX_F} \right)_{X_F=0}^{p+A} = \left[ \frac{\nu \cdot \alpha}{2} + \frac{1}{2} \cdot E(\nu) \right] \cdot \left( \frac{dn}{dX_F} \right)_{X_F=0}^{p+p}$$

(2)

The latter possibility has been shown to be valid by NA49 at least for net protons [1]. Alpha is an isospin factor as discussed below.

3. Cascade enhancements

Using the measured $\Xi$ and $\bar{\Xi}$ cross sections [2, 3] the extracted enhancement factors turn out to be largely different following the two prescriptions, as shown in fig. 2 for $\alpha = 1$. Clearly, the projectile enhancement obtained from method (2) in $p + A$ collisions is very similar to the one seen in $Pb + Pb$ reactions whereas method (1), due to the overriding target contribution, yields little or no overall enhancement in $p + A$ collisions. A noteworthy feature of fig. 2 is the sizeable difference in enhancement between $\Xi^-$ and $\Xi^+$ which amounts to about a factor of two.

4. Isospin effects

Since heavy nuclei contain about 60% neutrons, eventual differences in particle yields between neutron and proton fragmentation have to be carefully taken into account. It has been shown [1, 4] that for anti-protons for example there is a 50% yield difference between neutron and proton induced elementary interactions. This difference has been traced to an important component of asymmetric baryon pair production (e.g. $n\bar{p}$ or $p\bar{n}$) which strongly depends on projectile isospin. In the absence of measurements of $\Xi$ production from neutrons, it seems reasonable to assume that similar pair production mechanisms hold for $\Xi \Xi^0$ production. Given the charge structure of the isospin triplet of $\Xi \Xi^0$ states,

$$\Xi^- \Xi^0 \quad \Xi^- \Xi^+ \quad \Xi^0 \Xi^0 \quad \Xi^0 \Xi^+$$

a decrease in $\Xi^+$ and an increase of $\Xi^-$ production is to be expected when switching from proton to neutron projectiles. Taking account of the 40/60% mixture of protons and neutrons in $Pb$ nuclei and assuming the same asymmetry factor as measured for $S = 0$.
Figure 2. Enhancement factor for $\Xi^-$ and $\Xi^+$ at midrapidity calculated with two different assumptions (see text). The stars indicate enhancement factors in $p + A$ reactions calculated from equation 1.

Figure 3. Isospin corrected enhancement factor for $\Xi^-$ and $\Xi^+$ at midrapidity calculated from equation 2.
baryons this results in an effective isospin factor $\alpha = 1.3$ for $\Xi^-$ and $0.77$ for $\Xi^+$. The isospin corrected enhancement factors (see equation 2) are shown in fig. 3. Apparently the similarity between $p + A$ and $Pb + Pb$ interactions is preserved and the large asymmetry between $\Xi^-$ and $\Xi^+$ enhancements, fig. 2, is strongly reduced.

5. Net baryon stopping

The transfer of net baryon number from forward to central region in multiple collision processes ("stopping") may play an important role in the interpretation of central baryon densities. The net proton yield from the projectile e.g. increases by a factor of about 3 at central rapidity when comparing $p + p$ and central $p + Pb$ interactions [2] (see fig. 4). For $\Xi^-$ production, corresponding studies would imply the measurement of complete $x_F$ distributions in pion and proton induced collisions. Such measurements are not available. Nevertheless one may conjecture that — given the steeper $x_F$ dependence of $\Xi^-$ as compared to $p$ — the "enhancement" of net $\Xi^-$ at $x_F = 0$ in multiple collision processes should be smaller. The experimental situation concerning net $\Xi^-$ production is given in fig. 5 which shows the enhancement factors as function of $\nu$. One may conclude that — compared to $\Xi^+$ — the relative increase is of order 1.5 which might well originate from net $\Xi^-$ stopping.

REFERENCES

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