STRANGE PARTICLE PRODUCTION IN NUCLEAR COLLISIONS AT CERN-NA49

D. BARNA for the NA49 Collaboration
Central Research Institute for Physics, Konkoly-Thege út 29-33, H-1121, Budapest, Hungary

In order to quantify isospin effects in the comparison of elementary to nuclear collisions, p-p and n-p interactions have been studied in the NA49 experiment in addition to p-Pb and Pb-Pb reactions. Together with first measurements of cascade hyperon and Ω production in p-p collisions, isospin-corrected $K/π$ ratios and cascade yields are discussed. The $\Omega^+ / \Omega^−$ ratio in p-p collisions is found to be less than 0.5 with 95% confidence level.

1 Introduction

NA49 is a general purpose large acceptance hadron spectrometer. It’s main tracking devices are 4 large volume TPCs, which make particle identification possible. The experiment has collected data on a wide range of hadronic interactions (p-p, d-p, $π$-p, p-Pb, $π$-Pb, Pb-Pb). These data are used to make a systematic study and understand the complex A-A interactions.

2 Isospin Effects on the $K$ and $π$ Production

In order to trace the signatures of new physics, heavy ion collisions are usually compared to elementary (p-p or p-A) collisions. Beyond the possible ‘interesting’ differences there is a ‘trivial’ difference however: heavy ions are composed of neutrons and protons (for Pb the mixture is 60% n, 40% p). In order to study differences between proton and neutron fragmentation, NA49 has collected data with a deuteron beam incident upon a proton target with $p_{\text{beam}}=158$ GeV/nucleon. By tagging on a spectator proton with $p \approx 158$ GeV one can select neutron-proton collisions.

![Figure 1: Pion (left) and kaon (right) invariant $p_T$ distributions in p-p and n-p collisions (preliminary)](image-url)
Charged kaon and pion yields were determined via dE/dx measurements. Figure 1 shows the transverse momentum distributions in p-p and n-p collisions in the projectile (n or p) hemisphere at fixed Feynman-x. The flip of positive and negative pions and the unchanged kaon yields, when replacing the proton projectile by a neutron projectile, are clearly visible. Consequently the $R^+ = K^+/\pi^+$ ratio is higher, the $R^- = K^-/\pi^-$ ratio is lower in n than in p fragmentation (fig. 2a). A properly weighted average (40%p + 60%n fragmentation) is used then to estimate the magnitude of isospin effects in Pb-Pb collisions. Figures 2b) and c.) show the $R^\pm_{pPb, PbPb}/R^\pm_{pp}$ double ratios as a function of Feynman-x, after the elimination of the isospin effect from the Pb-Pb results. Note that above $x_F = 0$ the p-Pb and Pb-Pb results agree within errors. The deviation close to $x_F = 0$ is due to the target feed-over: target nucleons in p-Pb and Pb-Pb behave differently. They suffer 1 (in p-Pb) or several collisions (in Pb-Pb).

3 Strange Baryon Production

3.1 Strangeness Enhancement

Strange and multistrange baryons are reconstructed via their weak decay, using two independent reconstruction methods. The acceptance extends over a wide rapidity range ($\pm 1$ unit around midrapidity), and covers the full $p_T$ range. Rapidity distributions of $\Lambda$, $\Xi$, $\Xi$ and $\bar{\Xi}$ particles in p+p collisions are shown in figure 3. The $\Lambda$ ($\bar{\Lambda}$) results have been feeddown-corrected with respect to the $\Xi^-, \Xi^0 \rightarrow \Lambda$ ($\Xi^+, \Xi^0 \rightarrow \bar{\Lambda}$) channel. For this the measured $\Xi^-$ and $\Xi^+$ yields were used. The $\Xi^0$ ($\bar{\Xi}^0$) yields were estimated as $\Xi^0 = 1.5 \cdot \Xi^-$ and $\Xi^0 = 0.66 \cdot \Xi^+$.

Strangeness enhancement in heavy ion collisions is often defined as the increase of the
strangeness/number-of-participants ratio compared to p-p collisions. Strangeness enhancement can be attributed to the presence of the Quark Gluon Plasma, or the higher number of collisions suffered by an average participant. Assuming the latter, p-A data can be used to make a study of enhancement as a function of the number of collisions $\nu$.

Midrapidity yields are contributed to by both the target ($T$) and the projectile ($P$). In the symmetric p-p collisions both contributions are therefore $T_{pp} = P_{pp} = \frac{1}{2} \cdot \frac{dN}{dy}|_{y=0}^{y=0}$. In the asymmetric p-A collisions no enhancement per nucleon is assumed on the target side (since each target nucleon suffers only 1 collision). The target contribution ($T_{pA}$) is therefore assumed to be the target contribution derived from the p-p results ($T_{pp}$), scaled by the number of colliding target nuclei ($\nu$). All the enhancement ($E_{\nu}$) is attributed to the projectile, suffering $\nu$ collisions:

$$
\frac{dN}{dy}|_{y=0}^{y=0} \quad pA = \nu \cdot \frac{1}{2} \frac{dN}{dy}|_{y=0}^{y=0} + E_{\nu} \cdot \frac{1}{2} \frac{dN}{dy}|_{pp}^{y=0}.
$$

The enhancement in the symmetric A-A collisions is defined as

$$
\frac{dN}{dy}|_{y=0}^{y=0} \quad AA = E_{\nu} \cdot N_W \cdot \frac{1}{2} \frac{dN}{dy}|_{pp}^{y=0},
$$

where the $N_W$ is the number of wounded nucleons. Panels (a) and (c) of figure 4 show the enhancement $E_{\nu}$ for $\Xi^-$ and $\Xi^+$ in p-Be, p-Pb and Pb-Pb collisions as a function of $\nu$ (which is the average number of collisions suffered by the projectile for p-A collisions, and by an average nucleon for A-A collisions). Enhancement factors for $\Xi^-$ are larger than for $\Xi^+$. The enhancement factors for both the baryon and the antibaryon are of the same order in p-Pb and Pb-Pb collisions.

Since $\Xi$ production from a neutron or a proton can be different, isospin effects can also play a role in strangeness enhancement. In order to take this into account, we redefined strangeness enhancement, with this isospin effect detached:

$$
\frac{dN}{dy}|_{y=0}^{y=0} \quad pA = \nu \cdot \alpha \cdot \frac{1}{2} \frac{dN}{dy}|_{pp}^{y=0} + E_{\nu} \cdot \frac{1}{2} \frac{dN}{dy}|_{pp}^{y=0}
$$

$$
\frac{dN}{dy}|_{y=0}^{y=0} \quad AA = E_{\nu} \cdot \frac{N_W}{2} \cdot \alpha \cdot \frac{dN}{dy}|_{pp}^{y=0},
$$

where the $\alpha$ factor accounts for the increase or decrease of the $\Xi$ yield due to the proton-neutron composition of the lead nucleus. This could be derived by comparing an appropriately weighted average of $\Xi$ yields from proton (40%) and neutron (60%) induced reactions to the $\Xi$ yield in proton-induced reactions. Our limited statistics of n+p data did not allow a measurement of $\Xi$ production, therefore the $\alpha$ factor for $\Xi^-$ and $\Xi^+$ could only be estimated: we used the factors measured for proton and antiproton: $\alpha_{\Xi^-} = \alpha_P = 1.3$ and $\alpha_{\Xi^+} = \alpha_p = 0.7$. The enhancements as defined in equations (1) and (2) are shown in the panels (b) and (d) of figure 4 for $\Xi^-$ and $\Xi^+$.
respectively. After taking into account the isospin effects the enhancement factors for $\Xi^-$ and $\Xi^+$ approached each other, and p-Pb and Pb-Pb results are still of the same order.

3.2 $\Omega$ Production in p-p Collisions

$\Omega^-$ signals have been observed in p-p collisions for the first time. Panels (a) and (b) of figure 5 show the $\Omega^-$ and $\Omega^+$ mass spectra in p-p collisions; panel (c) shows the $\Omega^- + \Omega^+$ mass spectrum in Pb-Pb collisions. From the absence of the $\Omega^+$ signal in p-p events we estimate the $\Omega^+/\Omega^-$ ratio to be less than 0.5 with a confidence level of 95%.

4 Conclusions

Results obtained from p-p and n-p collisions indicate a sizeable isospin-dependence of the $K/\pi$ ratio. Using these data to eliminate isospin effects from Pb-Pb results the $K/\pi$ ratio in Pb-Pb and p-p collisions in the forward hemisphere agree within errors.

The final $\Xi$ and feeddown-corrected $\Lambda$ results in p-p and Pb-Pb collisions at the NA49 experiment are obtained. The $\Xi$-enhancements at midrapidity in p-A and A-A collisions with respect to p-p collisions are of the same order. An increased statistics should make the measurement of $\Lambda$ and $\Xi$ particles in n-p collisions possible in the near future. In the present study the isospin effect on $\Xi$ production in p-Pb and Pb-Pb collisions was estimated using the factors determined for protons and antiprotons from p-p and n-p collisions. Isospin-corrected enhancement factors of $\Xi^-$ and $\Xi^+$ approach each other.

An $\Omega^-$ signal has been observed in p-p collisions for the first time. The $\Omega^+/\Omega^-$ ratio is estimated to be less than 0.5 with a confidence level of 95%. $\Omega$ production has also been observed in Pb-Pb collisions in NA49.

Acknowledgements

This work was partially supported by the Hungarian Scientific Research Fund (OTKA) under the contracts F034707 and T0032293.

References

1. S. V. Afanasiev et al., Nucl. Instrum. Methods A430, 210 (1999)
2. F. Antinori et al., Nucl. Phys. A661, 130c (1999)
3. S.V. Afanasiev et al., hep-ex/0202037
4. S. V. Afanasev et al., “Progress report and beam request for 2002”, CERN-SPSC-2002-008